PART 1.4 – ANALYSIS AND FINDINGS

METHODOLOGY

METHODOLOGY

Definitions

1.4.1 The following definitions were used to classify the various factors which were pertinent to the accident.

1.4.2 Once an accident factor had been determined it was then assigned to one of the following categories:

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

b. **Contributory Factor**. Factors which made the accident more likely to happen.

c. **Aggravating Factor**. Factors which made the outcome worse.

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

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

Human Factor (HF) Modelling

1.4.3 A structured approach was taken to review the Human Factors (HF) aspects of the accident. Specialist advice was provided by the Royal Air Force Centre for Aviation Medicine (RAF CAM) to ensure that HF aspects were suitably considered. This advice was provided based on the Accident Route Matrix (ARM) approach[1]. The ARM was developed by RAF CAM based on the systematic and validated framework of the Human Factors Analysis Classification System (HFACS[2], which is itself based on James Reason's Swiss Cheese Model[3]), and experience of providing HF advice to over 50 accident and incident investigations.

1.4.4 Due to its grounding in the HFACS and Swiss Cheese Models, the HF approach used in the SI considered the broad range of HF contributors to aviation accidents including organisational factors, the nature of the supervision and tasks undertaken, the equipment used, the operating environment, as well as individual actions and the condition of operators involved in the accident. The HF issues that were identified were categorised according to the definitions outlined below so that a consistent approach was used across the SI.

1.4.5 **Individual Acts**. The Panel has made some fact-based statements aimed at categorising individual acts that were potentially unsafe, with the aim of identifying specific types of actions so that a correct assessment can be made of human performance issues related to the accident. While a number of different types of acts can be identified in human error literature, two definitions (taken from Reason, 1990) relevant to this SI are:

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[1] Harris, S. (2011). Human factors investigation methodology. International Symposium on Aviation Psychology. Available from: http://www.wright.edu/isap/

[2] Wiegmann, D.A. and Shappell, S.A. (2003). A Human Error Approach to Aviation Accident Analysis: The Human Factors Analysis and Classification System. Aldershot, UK: Ashgate.

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

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

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

Available Evidence

1.4.6 Evidence available to the Panel was limited due to: the impact damage; subsequent fire; and operational constraints during the wreckage recovery. There were no survivors or eye witnesses to the accident.

1.4.7 **Witness Statements**. The Panel interviewed 27 people during the course of the investigation, and recorded statements were taken. Witnesses included:

a. The Crew of Lynx 2 (crewed by the Sqn OC and Sqn 2iC)

b. The Passenger from Lynx 2

c. The in-Theatre Chain of Command

d. The Air Det Ops Officer/PCMIO

e. The UK Chain of Command

f. Training staff from the Sqn

g. Sqn crews

h. Senior Engineering Officer (SEngO) of the home-base Unit

i. A former Lynx Det Aircraft Engineering Officer

j. A former Lynx Det Avionics Class 1 technician

1.4.8 **Cockpit Voice Recorder (CVR)**. There was no Flight Data Recorder[4] (FDR) fitted to this aircraft. The Cockpit Voice Recorder (CVR) was recovered from the accident site in reasonable condition and captured voice data covering the period from take-off to accident.

1.4.9 **Aircraft Wreckage**. The aircraft wreckage recovered equated to less than half of the original aircraft. Nevertheless, many of the major components such as: engines; electronic engine control units; main, intermediate and tail rotor gearboxes; most of the tail cone; and main rotor head unit were included within the recovered items and able to be analysed. The Panel first viewed the wreckage in a secure hangar at KAF, prior to its preparation for transportation back to the UK for technical analysis.

1.4.10 **Photographic Imagery**. Photographic imagery included: photographs taken from Lynx 2 whilst orbiting the crash site after the accident; aerial footage taken from a Tornado aircraft; Thermal Imaging from Reaper aircraft; numerous photographs taken on

[4] A Flight Data Recorder (FDR) is an electronic recording device placed in an aircraft for the purpose of facilitating the investigation of aviation accidents and incidents. The FDR is an independent device, that preserves the recent history of the flight, through the recording of dozens of parameters, including flying control inputs and aircraft operating systems, collected several times per second.

the ground by recovery teams (Airborne Response Force and the UK and US Post Crash Management (PCM) teams); and Sea King helicopter over flight with the SI Panel on board.

1.4.11 **Relevant 'Orders'**. Relevant UK Military 'Orders', including:

a. MAA Regulatory Articles

b. Joint Helicopter Command (JHC) Flying Order Book

c. Joint Aviation Group (JAG) Flying Order Book

d. Air Det Flying Order Book

e. Air Det Capability Directive

f. Key personnel Terms of Reference (TOR)

g. JHC Directive

h. JHC Operational Shooting Policy (OSP)

i. JHC Command Instructions

1.4.12 **Flying Related Documentation**. Flying-related documentation including: authorisation sheets; flying Log Books; Flying Record Folders (FRF); Aircrew Continuation Training Record Folders (CTRF); various sortie planning and briefing materials; Lynx Force Standard Operating procedures; Lynx Force Aircrew Training Manual; Lynx AH Mk 9A Aircrew Manual; Sqn Training Directive.

1.4.13 **Aircraft Technical and Engineering Documentation**. Aircraft technical and engineering documentation, including: ZF540 aircraft MOD Form 700[5] (MF 700), GOLDesp[6], unit Quality Assurance (QA) reports, engineering authorisations and training record folders.

1.4.14 **Flight Simulator Sorties**. The Panel was able to draw evidence from flying two separate sorties in the Thales Eagle Lynx simulator based at the Army Aviation Centre, Middle Wallop.

1.4.15 **Radar Data**. The TopSky Radar System data was taken from the KAF Air Traffic Control (ATC) recording tapes. The data was converted by the UK National Air Traffic Services (NATS) into Latitude and Longitude coordinates with associated height information. These coordinates were used by QinetiQ to provide the pictorial representations contained in this Report. The Latitude and Longitude coordinates have been adjusted by -0.0028 degrees Latitude and +0.007944 degrees Longitude to account for inaccuracies found in the Radar data. The SI Panel considers the corrected Radar data provides a close representation of the aircraft track, which has been verified by Lynx 2 Ac Comd. Further details outlining the genesis of the Radar data is contained in Exhibit 251.

[5] MOD Form 700 is an omnibus title given to a collection of MOD Forms in the 700 numerical series. These forms provide a complete technical history of the in-service use of the aircraft and a current statement of its condition.
[6] GOLDesp is a computer database used to capture all aircraft technical information, to include all MOD Form 700 records.

1.4.16 **ATC Transcripts**. Limited ATC transcript data has been provided via email but a full recording of the sortie duration was not available.

1.4.17 **Terrain Modelling**. Defence Intelligence Fusion Centre (DIFC)[7], part of the Joint Forces Intelligence Group (JFIG), generated a detailed terrain model of the accident location.

1.4.18 **Air Safety Material**. Access to all Air Safety related material, including previous occurrence reports extracted from Air Safety Information Management System (ASIMS)[8] and Defence Air Safety Occurrence Reports (DASORs)[9].

1.4.19 **Specialist Reports**. The Panel received the following Specialist Reports:

a. Military Air Accident Investigation Branch (MilAAIB) Technical Assessment Report, drawing from a number of experienced and competent independent organisations and Industry experts.

b. RAF CAM provided: a HF Specialist Report; Survival Equipment (SE) Engineering Documentation Report; and Aviation Pathology Report.

c. 1710 Naval Air Squadron (NAS) provided a wide range of scientific and engineering expert reports, including: Spectral (frequency) Analysis of the CVR and Drive Failure Report; Fuel, Oil and Lubricants Analysis Report; detailed analysis of the Pilot's Quick Release Fitting.

Services

1.4.20 Personnel and agencies which provided assistance to the Panel included:

a. Military Air Accident Investigation Branch (MilAAIB), Farnborough

b. Royal Air Force Centre for Aviation Medicine (RAF CAM), RAF Henlow

c. 1710 Naval Air Squadron (NAS), Gosport, Hampshire

d. Lynx Project Team (PT), Yeovil, Somerset

e. Rolls-Royce ASI, Indianapolis, USA

f. Honeywell ASI, Phoenix, USA

g. OEM, Triumph Engine Control Systems (TECS), USA

h. AgustaWestland Ltd, Yeovil, Somerset

i. THALES Aircrew Training Services, Middle Wallop

j. QinetiQ, Boscombe Down, Wiltshire

k. National Air Traffic Services (NATS), Swanwick

[7] Formerly known as the Defence Geospatial Intelligence Fusion Centre (DGIFC).
[8] ASIMS is a web-based tool to support the reporting, management and analysis of Defence air safety occurrences, investigations and recommendations.
[9] All Air Safety occurrences and failures of safety controls are to be reported on a DASOR, and then recorded in ASIMS.

l. Aircraft Accidents Investigation Branch (AAIB), Farnborough

m. Institute of Naval Medicine (INM), Gosport, Hampshire

n. Rotary Wing Test and Evaluation Squadron (RWTES), Boscombe Down

o. Defence Intelligence Fusion Centre (DIFC), RAF Wyton

ACCIDENT SITE ANALYSIS

1.4.21 This accident site analysis has been conducted from photography and imagery provided by airborne and ground based assets on the day of the accident, and interviews with a number of coalition and unit personnel who attended the accident site. The Panel has also drawn upon the Military Air Accident Investigation Branch (MilAAIB) Technical Engineering Report (Annex A) and from information gained from flying over the accident site on 3 May 2014, which included a number of slow passes with video footage recorded from a high resolution, externally mounted camera. Annex A Exhibit 118

1.4.22 Lynx AH Mk 9A aircraft are not fitted with a Flight Data Recorder (FDR), and therefore the Panel lacked empirical evidence of aircraft attitude, control positions and other key parameters, thus making it difficult to establish exactly what happened in the final moments of the flight.

1.4.23 Figure 1 is one of the first aerial photos of the accident site, taken by the crew of Lynx 2. For the purpose of this analysis, the accident site has been divided into three illustrative[10] zones:

a. Zone One – Initial Impact Area.

b. Zone Two – Fuel Burnt Debris Trail.

c. Zone Three – Final Resting Position.

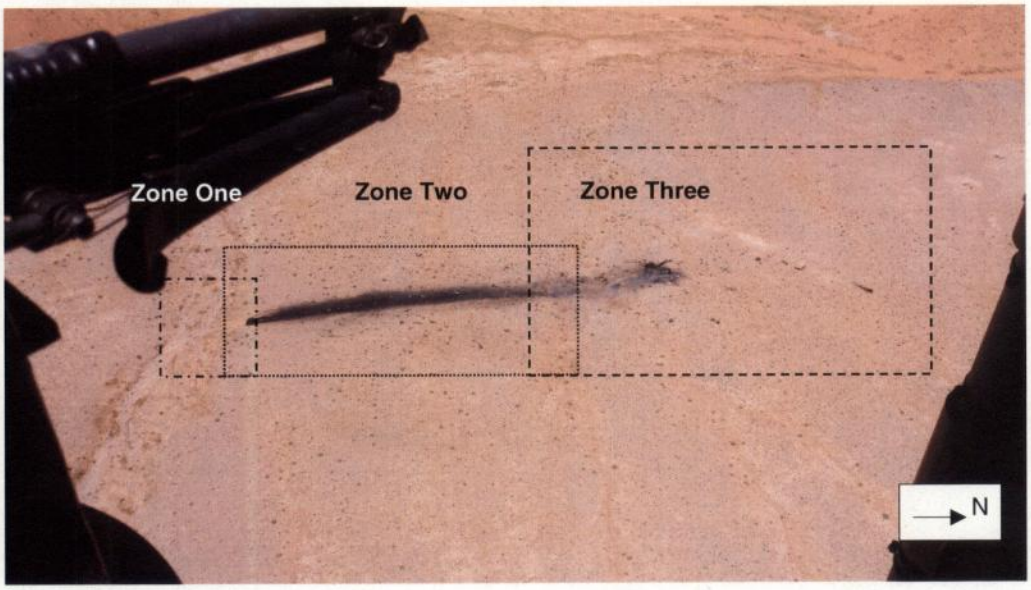

Figure 1 – Aerial Photo of Accident Site Taken By Lynx 2

1.4.24 **Zone One – Initial Impact Area**. The initial point of impact was on the upward face of a dried-up water course. Three clear impact marks were documented by the UK Post Crash Management (PCM) team, and were assessed by the MilAAIB to be from the left, right and nose wheel undercarriages (Figures 2, 3 and 4). The central impact mark Exhibit 140 Annex A

[10] These illustrative zones are not accurate and purely to ease the flow of analysis.

also included components[11] from under the aircraft tail. Figure 5 shows the location of these components on the aircraft. Annex A

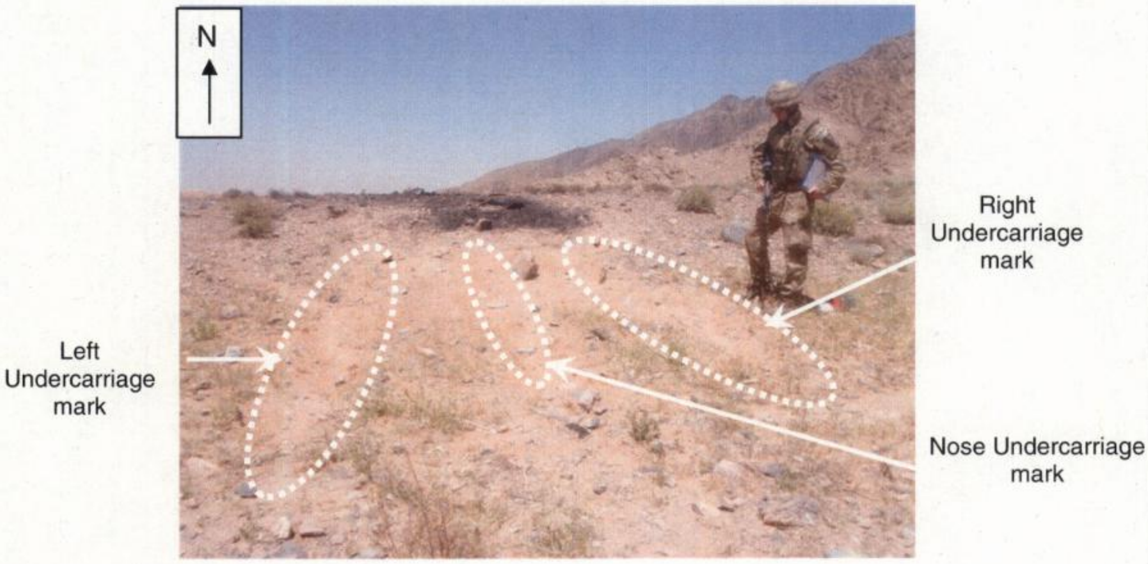

Figure 2 – Three Impact Marks; Photo Taken Slightly Offset, Looking North

Figure 3 – Impact on Upward Face of Dried-up Water Course; Looking North-West

Figure 4 – Impact on Upward Face of Dried-up Water Course; Looking South-East

[11] Shattered glass from the infra-red jamming device, upper end of the ARC 231 radio antenna and lower plate of Talon radio antenna.

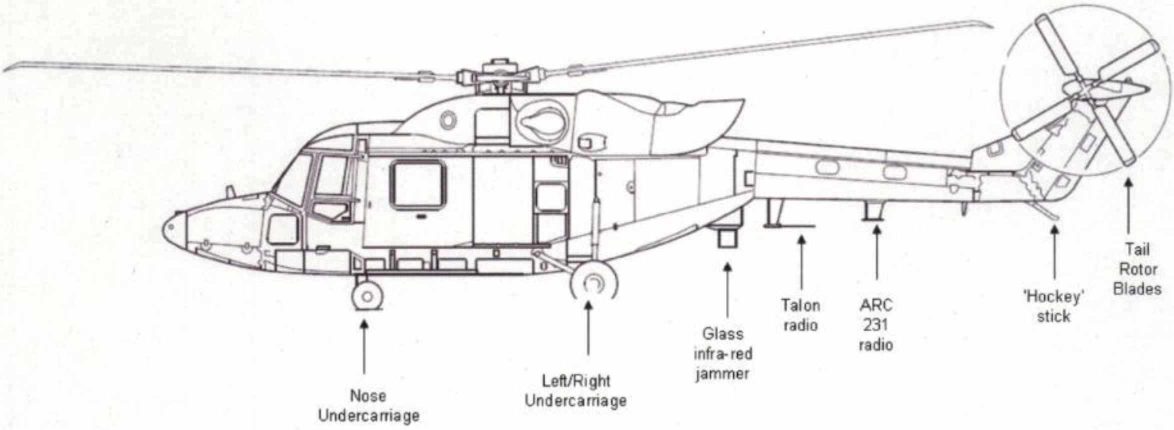

Figure 5 – Location of Components on Lynx[12].

1.4.25 The aircraft tail skid (colloquially known as the 'hockey stick' (Figure 5)) was not recovered[13] and there was a small piece of Tail Rotor Blade (TRB) photographed in the initial impact area. The underside of the tail cone displayed numerous longitudinal scorings and the lower surface had lost its rigidity and structural integrity. These facts supported the prognosis that the tail cone impacted the ground, concurrently with or immediately post initial impact and was dragged behind the aircraft. Annex A Annex A

1.4.26 The initial impact marks were evenly distributed and prior to a straight fuel burnt debris field and enabled the Panel to conclude that the aircraft impacted the ground in a wings-level[14] attitude, with minimal drift and with downward force[15]. It is at this point that the MilAAIB concluded the aircraft lost all structural integrity[16]. A section of TRB was also found 45 metres behind the initial impact point (behind the direction of travel) consistent with it being projected rearwards by its own rotational velocity, enabling the Panel to conclude that tail rotor drive was also likely lost on immediate impact with the ground. Annex A Exhibit 157

1.4.27 **Zone Two – Fuel Burnt Debris Trail**. The wreckage had sufficient momentum to travel 75 metres along the ground, providing the Panel with compelling evidence of a high speed impact. In addition to the speed, the aircraft must have impacted the ground in a 'shallow' nose-up attitude, as the debris field remained largely together[17] throughout the accident sequence until the final resting place. Based on all the evidence available, the Panel assessed that the most likely nose-up attitude on impact was approximately five degrees (illustrated in Figure 6), but without the fitment of an FDR this could not be determined conclusively. Exhibit 56 Annex A

[12] Note the illustrative drawing does not have the correct Talon radio antenna profile, but the position would be 'in place of' the radio indicated.
[13] Although the hockey stick-to-tail mounting bolt was still attached to the tail.
[14] The term 'wings-level' is a common term used in fixed-wing and rotary-wing aviation to indicate that the aircraft was in a level attitude, i.e. not banking left or right.
[15] From an undetermined Rate of Descent.
[16] The AgustaWestland Assistant Chief Project Engineer states that "In general the airframe structure has been designed statically for a global 10 G load".
[17] A nose-down attitude at impact would have resulted in a much smaller compressed debris field; conversely a high nose-up attitude at impact would have resulted in a much more spread out debris field.

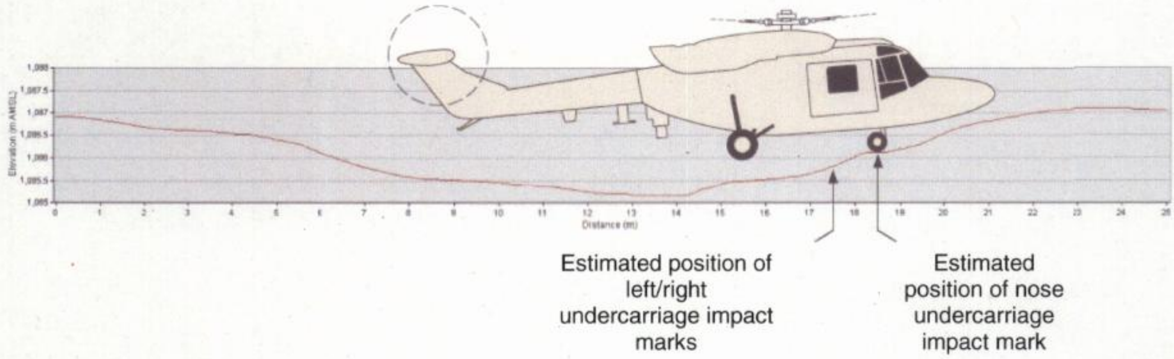

Exhibit 183

Figure 6 – Terrain Modelling Indicating Five Degree Nose-Up on Impact

1.4.28 Evidence suggested the initial impact was of sufficient force to rupture the two main fuel tanks (located to the rear of the main cabin, immediately behind the rear crew seats), the left and right collector tanks and the forward tank (Figure 7). Fuel from the ruptured tanks was most likely diffused either as a mist or as fluid, and immediately vaporised and ignited[18]. The origin of the ignition source was not determined.

Annex A

Annex A

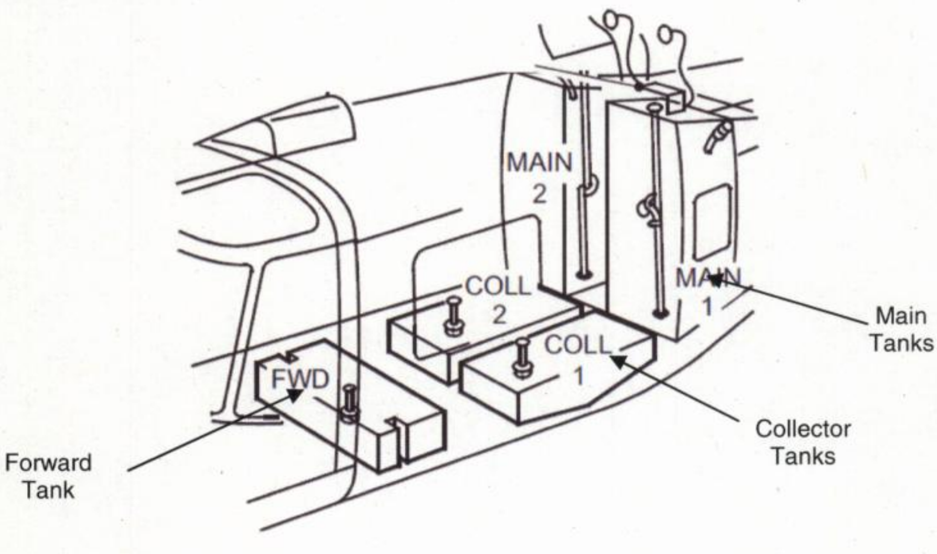

Figure 7 – Location Of Fuel Tanks

1.4.29 The left and right collector tank bases were located immediately after the start of the fuel burnt debris trail, and burning on both sides of the collector tank bases indicated ignition of the fuel vapours was immediate. It is very unlikely that there was an explosion as the vegetation immediately along the edge of the fuel burnt trail did not appear to have been scorched or burnt.

Annex A

Annex A

1.4.30 **Zone Three – Final Resting Position**. The main body of the wreckage traversed a second and then third dried-up water course in close succession (Figure 8), during which contact with the ground was momentarily lost and, in the absence of tail rotor

[18] A blackened trail as seen in this accident can only be achieved by the burning of vaporised fuel.

drive, enabled the weakened structure to go into a clockwise rotation (when viewed from above) to counteract the Main Rotor Head (MRH) motion. Annex A

Second and third dried-up water course in close succession

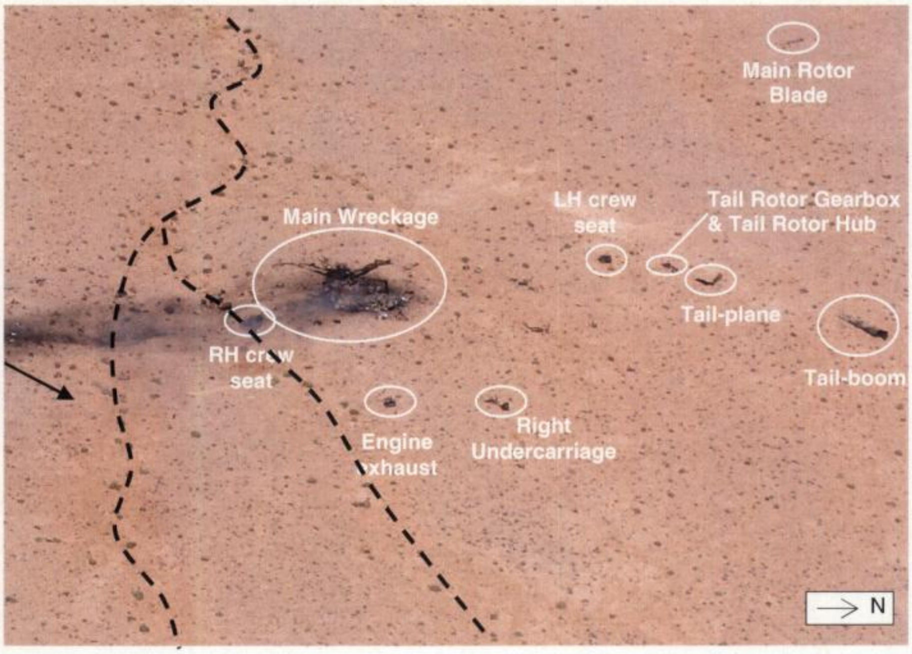

Figure 8 – Dried-Up Water Courses Before Final Resting Position

1.4.31 The clockwise rotation resulted in a further breakdown of the weakened structure. The Main Rotor Gearbox (MRGB) was found upright within the main wreckage but approximately 180 degrees out of orientation with the direction of travel; both engines were found sheared from the MRGB but also located within the main wreckage. Annex A

1.4.32 The MRH was found upright in the main wreckage with signs of heat exposure and heavy sooting (Figure 9) but there were no obvious signs of impact damage. This enabled the Panel to conclude that the MRH did not tumble throughout the accident sequence, providing further evidence that the aircraft was in a wings-level attitude and in controlled flight on initial impact. A large section of one Composite Main Rotor Blade (CMRB) was located approximately 40 metres forward and 20 metres to the left of the main wreckage site (Figure 8), suggesting the MRH was rotating during the accident sequence. Annex A Annex A

Figure 9 – Main Rotor Head (MRH)

1.4.33 The right-hand cockpit seat was found to the rear and right of the main wreckage, and the left-hand cockpit seat was found forward of the main wreckage (Figure 8); analysed in greater detail at 1.4.453. Annex A

1.4.34 The tail cone was found significantly forward and to the right of the main wreckage, broken into three main sections[19] (Figure 8). The MilAAIB concluded that the tail cone, although severely weakened on initial impact, remained attached to the main wreckage throughout the accident sequence[20] until the rotational phase. The Panel believed the rotational phase was strong enough to throw the tail cone forwards and photographic evidence suggested it may have tumbled as it landed, hence breaking into the three sections in close proximity to one another (Figure 10). Annex A

[19] Tail Rotor Gearbox (TRGB), Tail cone and Tailplane.
[20] Heavy sooting was on the leading edge of the tail strake and the forward end of the sheared tail cone also displayed light sooting.

Figure 10 – Tail Cone Forwards and Right of the Main Wreckage

1.4.35 Upon coming to rest, the main wreckage was engulfed in an intense fire which continued to burn for several hours post-accident, destroying a significant amount of aircraft structure. The upper cabin and cockpit structure, transmission deck, the rear equipment bay and fuel tank bays had been completely burnt away. The majority of the cockpit and cabin instruments, switches, controls and equipment had been burnt beyond immediate recognition; none were of analytical use. Annex A Annex A

1.4.36 **Accident Site Analysis Summary**. From the accident site analysis, the Panel concluded that the aircraft impacted the ground at speed, in a wings-level, nose-up attitude, in what appeared to be controlled flight.

DETERMINING THE CAUSE OF THE ACCIDENT

Context (and Limitations)

1.4.37 Evidence available to the Panel was limited. There were no eye witnesses or survivors, and the wreckage recovered equated to less than half of the original aircraft due to damage sustained in the impact and subsequent fire. Further, due to the damage sustained in the post-accident fire, some of the wreckage was unable to provide any beneficial technical analysis. The aircraft was not fitted with an FDR, so the Panel were unable to accurately determine the flying control inputs in the final stages of flight. However, a Cockpit Voice Recorder (CVR)[21] was fitted and recovered in reasonable condition and captured the majority of the flight; this has proved to be the main source of evidence when determining the cause.

1.4.38 Due to the accident location and the potential hostile threat, recovery of the wreckage was required during daylight hours on the day of the accident. This provided a 7 hour window to conduct all PCM activity. The Panel was therefore unable to view the wreckage in-situ.

1.4.39 Upon arrival at KAF, MilAAIB accident investigators and the Panel were able to view the wreckage in a secure hangar. The Panel was also able to view the accident location during an over flight but, due to the potential hostile threat, were unable to 'walk the site'.

1.4.40 The Panel considered the following factors which may have caused the accident:

a. Technical Aspects

(1) Lynx 1 Maintenance History

(2) Lynx Det Engineering Standards and Practices

(3) Technical Failure/Malfunction

(4) Flight Data Recorder Observations

b. Hostile Action

c. Pilot Incapacitation

d. Deliberate Act

e. Weather

f. Aircraft Performance

g. Aircraft Handling Characteristics

h. Flying Control Issues

i. Controlled Flight Into Terrain

[21] Capturing the recent history of the sounds in the cockpit, including the conversation of the pilots and ambient noise.

Technical Aspects

Lynx 1 Maintenance History

[Note: for the purpose of the maintenance history section of this Report, Lynx 1 will be referred to as ZF540.]

1.4.41 **Lynx AH Mk 9A History**. In December 2008 the Ministry of Defence (MOD) endorsed an Urgent Operational Requirement[22] (UOR) to re-engine existing Lynx AH Mk 9 aircraft with LHTEC CTS800-4N engines to provide increased performance for operations in Afghanistan. The Release to Service (RTS), including an 'Extended Forward Flight Envelope', was underpinned by clearance trials which were conducted by QinetiQ, Boscombe Down, UK. The upgraded aircraft was designated the Lynx AH Mk 9A, and the conversion programme (design and build) was undertaken by AgustaWestland (AW) Helicopters Ltd in Yeovil, Somerset, UK. AW is the Lynx aircraft Design Organisation, supporting the aircraft airworthiness and ongoing design improvements. AW holds a valid Design Approval Organisation Scheme (DAOS) Certificate, having demonstrated and met the MAA criteria for certification.

Exhibit 34
Exhibit 95
Exhibit 92
Exhibit 79

1.4.42 **Conversion to Lynx AH Mk 9A Standard**. AW certified the conversion of ZF540 to Lynx AH Mk 9A standard by endorsing the Build Standard Certificate on 5 December 2011. The Panel has no airworthiness concerns over the conversion of ZF540.

Exhibit 37

1.4.43 **Recent History**. Since 2011, ZF540 had operated almost exclusively in desert conditions. During this time the aircraft was subjected to a reduced (more frequent) servicing periodicity and received additional desert maintenance activities. ZF540 was also subject to regular Quality Assurance (QA) checks, and was deemed by the Unit as in '*good material condition*' as it entered its last Depth Maintenance package. The Panel has no airworthiness concerns over the recent history of ZF540 before it entered its last Depth Maintenance.

Exhibit 38

1.4.44 **Last Depth Maintenance**. ZF540 entered its last Depth maintenance, a Depth Level 2[23], on 22 March 2013 at Vector Aerospace Helicopters Services (VAHS). VAHS are an approved and certified Military Maintenance Organisation contracted by the Lynx PT to conduct Lynx Depth maintenance. ZF540 completed its Depth maintenance on 27 September 2013 and was received back by the Air Det in KAF on 22 October 2013, again in *'good condition'.* The Panel has no airworthiness concerns regarding ZF540's last Depth maintenance.

Exhibit 39
Exhibit 40
Exhibit 80
Exhibit 41

1.4.45 **Maintenance Overview from October 2013 to April 2014**. The MilAAIB engineering team conducted a data integrity check of all maintenance activity conducted from ZF540 last Depth maintenance in October 2013 until April 2014; the Panel noted that the results showed no trends or concerns over the serviceability of ZF540.

Exhibit 81

1.4.46 **Detailed Audit of Maintenance from January 2014 to Accident**. An independent quality assurance (QA) audit of ZF540 last 96 flying hours of maintenance activity (covering the period from January 2014 to the accident) was carried out by Royal Naval Air Station (RNAS) Yeovilton Quality Assurance Cell. This detailed inspection

Exhibit 82

[22] UOR number A01438.
[23] Depth Level 2 (D2) takes place every 1200 flying hrs of the aircraft's life. All rotables are removed (Main Rotor Gearbox, Drive Shafts, Tail Rotor Gearbox, Servo jacks etc), the aircraft is stripped of the majority of panels, interior fittings, soundproofing and electrical equipment. The aircraft is surveyed in every area for structural condition and electrical integrity, and all faults rectified. The final stage is a comprehensive ground test and flight test.

included review of all aircraft technical and engineering documentation, including: ZF540 aircraft MOD Form 700, electronic records (known as GOLDesp), unit Quality Assurance (QA) reports, engineering authorisations and training record folders. The audit report indicated that the engineers of the Lynx Det were a professional unit, comprising very capable technicians who had intimate professional knowledge of the Lynx AH Mk 9A and the specific modification standard of the aircraft in KAF. The audit indentified that the content of the engineering paperwork was minimalist, often documenting the fault with no evidence of fault finding procedures. The Panel noted this is not a breach of regulations. There were a number of minor errors found during the paperwork QA audit, but these errors were not out of the ordinary and were typical of those often highlighted during any engineering unit's QA audit. The Panel found no evidence that would have been a factor in the accident.

Annex A

1.4.47 **Authorisations**. Records of Engineering Authorisations (REAs) were given by the Wing Senior Engineering Officer (SEngO), and followed a formal process to prove competence and training completed during the 'Unit Arrival Induction Package'. The Panel found that the REAs for Sqn engineering personnel engaged in maintenance activity of ZF540 were largely correct, albeit with the occasional signature missing, with evidence of competence located in training record folders. To enable the Sqn's enduring detachment to the Air Det, engineering personnel were augmented by four personnel from 7 Air Assault Battalion (Bn) REME. The SEngO controlled the issue of REAs to these augmentees, which involved them visiting the Wing for a period of familiarisation training with the Lynx AH Mk 9A to prove their training and competence prior to deployment. However, in January 2014, four personnel from 7 Battalion deployed directly to KAF without following this process. Nevertheless, on arrival in Theatre, they met with the Det Aircraft Engineering Officer (AEO) and were subjected to interview and competency assessment prior to award of their REAs. The Panel concluded that, although the REA process was not as robust as it could have been for augmentees, this was not a factor in the accident.

Witness 25
Exhibit 83
Witness 25
Witness 25
Witness 26
Witness 27

1.4.48 **Previous Unscheduled Maintenance Activity**. Nine days prior to the accident ZF540 required unscheduled maintenance activity after the crew noticed a hydraulic leak whilst conducting their post flight walk round at Camp Bastion. An engineering team was despatched from KAF to conduct fault diagnosis and the leak was identified as coming from a crack in the Number 2 hydraulic system pressure filter housing. The housing was replaced and independent checks carried out, including check for absence of leaks. The QA audit found all documented work correctly identified and signed; this included the filter housing replacement, the independent inspection and the required follow-ups. All the required sections of the independent check were itemised and signed, confirming serviceability of the aircraft. The engineering maintenance crew then flew back to KAF in ZF540 on completion of the work. The aircraft had flown a further 12 hours, without issue, since the hydraulic leak at Camp Bastion, and had been subjected to a further 8 uneventful Daily Flight Servicing (DFS[24]) checks and 2 uneventful Technical Flight Servicing (TFS[25]) checks. The Panel concluded that the unscheduled maintenance at Camp Bastion was rectified correctly and the aircraft was fully serviceable and airworthy on completion of the work.

Witness 2
Exhibit 42
Witness 26
Annex A
Witness 26
Annex A
Witness 26
Exhibit 43
Exhibit 44

[24] A DFS is the servicing that is required to prepare the aircraft for flight(s) during the next 24 hrs and is valid from the commencement of the servicing within the TFS period. A DFS checks and replenishes all consumables, as well as preparing the aircraft's documentation or the next period of flying. The first 24 hrs following a TFS does not require a DFS to be carried out, as a TFS incorporates the initial DFS.

[25] The TFS establishes the baseline for all servicing checks in the next flight servicing cycle. A TFS is valid for a set period, provided it is not invalidated by any other maintenance work carried out during the period. The aim of the TFS is to examine the aircraft and documentation, check and replenish all consumables and prepare the aircraft for the next period of flying. The TFS remains valid from the commencement of the servicing for a period stipulated in the Support Policy Statement (SPS) along with details of any backstop; for example 7 days or 25 flying hrs.

1.4.49 **Previous Day's Maintenance Activity**. ZF540 had an uneventful TFS conducted the night prior to the accident, which was signed off on 25 April 2014 at 23:59 hrs. The TFS is a full and detailed flight servicing, conducted in accordance with the aircraft Flight Servicing Manual and is valid for 25 flying hours or 7 calendar days (which ever is the soonest). The Panel has no concern over the TFS. Exhibit 45

1.4.50 **Lynx 1 Maintenance History Summary**. The Panel concluded that the maintenance history for ZF540 was correct and in accordance with extant regulations. Lynx 1 was deemed to be fully serviceable (in the MF700) prior to the accident sortie. The Panel also noted that the REA process was not as robust as it could have been. Exhibit 46

1.4.51 **The Panel recommends that the JHC Assistant Director Operational Support (the ODH Chief Aircraft Engineer) should ensure that the process for the award of 'Record of Engineering Authorisation' to engineering augmentees (to include competency assessment and training) is robust and followed.**

Lynx Det Engineering Standards and Practices

1.4.52 The Air Det had been based at KAF permanently since October 2011, and as such Lynx line operations and Lynx engineering facilities were well established. The Panel's impression of the Lynx hangar was that good engineering standards and practices were in place with a clean, organised, safe working environment which was largely dust and dirt free. Exhibit 75

1.4.53 The Panel was able to witness a Lynx AH Mk 9A 'B3' maintenance activity (the largest and most intrusive of inspection maintenance regimes conducted on an aircraft in Theatre, carried out every 300 aircraft flying hours). The aircraft had been stripped back to enable detailed inspection of all areas. The Panel observed that the aircraft was maintained to a high standard, behind and under panels were clean, and there were no signs of corrosion or wear; evidence that the more frequent maintenance activities necessary for Theatre operations were keeping the aircraft in a good airworthy condition.

1.4.54 The Panel saw no evidence to indicate that Lynx 1 would have been maintained any differently from the other two Lynx AH Mk 9A operated by the Air Det in Theatre. The Panel is of the opinion that Lynx 1 was equally well maintained prior to departing HOTEL ramp for its final sortie.

1.4.55 The Air Det had an enduring requirement for two of the three Lynx in KAF to be serviceable with 6 flying hours available at all times. The Panel was informed by the Air Det Comd that if the Det AEO was unable to meet this requirement (due to unscheduled maintenance or scheduled maintenance that required deeper engineering activity, or delays in receiving replacement items from the UK) a discussion would take place (routinely during weekly Deputy Heads of Departments meetings but also informally as required at HOTEL ramp) and an acceptable way forward determined. Exhibit 47

1.4.56 The Panel observed a professional engineering unit, tightly managed and controlled, with a good appreciation of their role in maintaining aircraft airworthiness. The Panel reviewed recent External Quality Audit reports, Internal Quality Reports and Self Audits, and found the Lynx detachment engineers to be operating at a high standard, backed up by comments from the Principal Air Engineer[26] (PAE - based at Camp Bastion)

[26] PAE provided engineering advice, oversight and assurance to the Engineering Detachments in KAF, and was directly responsible to JHC for the airworthiness of all JHC deployed assets.

and the Senior Air Engineer[27] (SAE - based at HOTEL ramp in KAF) during the Lynx Det Airworthiness Audit 22 February 2014; the Report stated *'An excellent and unsurprising airworthiness audit…of a very high standard.'* Exhibit 76 Exhibit 77 Exhibit 78

1.4.57 **Lynx Det Engineering Standards and Practices Summary**. The Panel had no concerns over the engineering standards and practices of the Sqn, and had no reason to doubt the airworthiness of the aircraft before it departed from KAF on the day of the accident.

Technical Failure/Malfunction

1.4.58 **First Layer of Evidence**. The first layer of evidence to determine if Lynx 1 suffered technical failure/malfunction was the CVR. Throughout the 32 min 53 secs recording, which includes the whole flight from aircraft take-off to the accident, there were no comments or concerns from the aircrew over the handling or performance of the aircraft, nor any comment or concern over the aircraft systems. There was no warning tone[28] generated by the Central Warning System (CWS) which would indicate an occurrence of a hazardous situation that requires immediate corrective action[29] by the crew. The crew did not transmit an emergency distress (MAYDAY) call. Exhibit 1 Annex A Exhibit 1

1.4.59 **Secondary/Tertiary Layers of Evidence**. The wreckage recovered included most of the major rotables[30] which have been subjected to detailed analysis by MilAAIB and Industry experts for signs of technical failure/malfunction (Figure 11). Annex A

Figure 11 – Major Rotables Recovered for Technical Assessment

1.4.60 In parallel to the detailed assessment of the major rotables, technical analysis

[27] SAE provided engineering advice and oversight, via day-to-day interface with the respective engineering detachments in KAF, to ensure that engineering standards and practices were maintained to the highest standard.
[28] A warning tone is generated by the Central Warning System (CWS) in conjunction with a red Master Warning Light (MWL) on the Central Warning Panel (CWP).
[29] Immediate Actions must be carried out immediately after the failure is positively identified in order that safe flight is not jeopardised. Immediate Actions must be committed to memory for instant use. In slower time, the drill should be confirmed from the Flight Reference Cards (FRCs).
[30] Main Rotor Head (MRH), Main Rotor Gear Box (MRGB), Intermediate Gear Box (IGB), Tail Rotor Gear Box (TRGB) and both engines.

of fluid samples taken from the aircraft's major systems (including fuel, hydraulic and gearbox oils) have also been conducted. The results of chemical and physical analysis did not highlight any evidence to suggest that the quality of the fuel or lubricating oils were abnormal and there was no evidence that component failure had occurred. Exhibit 254

1.4.61 The MilAAIB Technical Report provided the Panel with a full and detailed descriptions of all technical findings; a précis of fuel and major systems is provided below:

a. **Fuel**. The refuel bowser used to fuel Lynx 1 prior to its last sortie was quarantined in KAF after the accident. Fuel samples were taken and sent to 1710 NAS for analysis. Samples were found to be normal. The Panel concluded that **fuel contamination was not a factor in the accident.** Exhibit 254

b. **Engines**. Both LHTEC T800-CTS engines were recovered from the accident site and escorted by MilAAIB accident investigators to a specialist teardown laboratory in the USA for formal assessment. The engines had suffered from severe impact and heat damage, but neither engine displayed any evidence of technical failure. Analysis determined that one engine was rotating at speed at the moment of impact[31] and one engine was still being supplied fuel throughout the accident sequence. The only concern raised during the detailed inspection were eight missing nuts from a shim[32] pack in the Number 1 engine[33]. The engine manufacturer immediately instigated an investigation into their manufacturing processes and the effect the missing nuts and loose shim would have on engine performance. The engine manufacturer concluded that the missing nuts would have no impact on engine performance and there was no safety concern[34]. They went on to confirm that the engine had *'good'* Power Performance Indication (PPI) figures and had been at a relatively consistent level for the operating life of the engine. The Panel's own investigation of the PPI figures also confirmed that Lynx 1 engines had consistently high PPI figures necessary for operations in Afghanistan[35]. The Panel note that Lynx 1 also had better PPI figures than Lynx 2. The Panel concluded that both engines were operating normally when the aircraft impacted the ground and therefore **engine failure/malfunction was not a factor in the accident**. Annex A Annex A Annex A Annex A Annex A

c. **Engine Electronic Control Units (EECUs)**. The engines are equipped with Full Authority Digital Engine Control (FADEC), comprising two EECUs per engine, with the primary purpose to control the fuel flow to the engines to deliver the power required to maintain the rotor speed. Three of the four EECUs were recovered from the accident site and, despite not being crash survivable in design, data was recovered for Industry analysis. The EECU data indicates that the engines were operating normally prior to impact and recorded a high collective demand (to 96% of collective travel) placed immediately prior to impact; the engines had responded to the demand. Annex A Annex A Annex A

[31] There was evidence of sooting and desert debris internally throughout the engine, but particularly prior to the combustion casing.
[32] Shims (thin washers) are used to ensure that the components of the engine are tightly mated by removing any 'play' that might of been introduced a result of the manufacturing process. They also prevent the mating surfaces adversely wearing.
[33] The shim pack, located between the pre-swirl assembly and the combustion chamber, should be held in place by eight nuts. The threads of the studs from the combustion chamber that provide the mounting for the shim and the nuts to tighten onto, showed no signs of thread wear. The studs exhibited signs of exposure to heat and normal engine operating debris, consistent with other components located in that location. The shim showed signs of light rubbing which had polished its flat surface.
[34] The shim had only suffered light rubbing likely to have caused by vibration within its position. The shim was located between two components and would not have been able to free itself and cause a failure of the engine.
[35] Higher PPI figures were required for operations in Afghanistan due to the heat and altitude of the country (ie: the best performing engines were fit to aircraft operating in Afghanistan).

d. **Main Rotor Gearbox (MRGB)**. The MRGB was on reduced 25 flying hour[36] oil sampling as a precaution[37]. This had been recommended by subject matter experts[38] after a previous oil sample had been tested and found to have a higher than expected metal debris content. The MRGB was recovered from the accident site and, although the paint was blistered and heavily sooted, the casing remained intact and did not display any signs of deformation from prolonged heat exposure. This was most likely due to it coming to rest slightly in front of the main wreckage and hence was not seated within the core of the post-crash fire. After the accident, and prior to detailed teardown by Industry experts, the MRGB could still be rotated by hand (via the MRH) confirming the gearing drives to the engines, tail rotor, auxiliary gearbox, electric generators, and hydraulic pumps were correctly aligned and rotating as expected. Post teardown, expert analysis confirmed all assemblies were intact and free to rotate; there was no evidence of technical failure. The Panel concluded that **MRGB failure/malfunction was not a factor in the accident.**

Annex A
Exhibit 254
Annex A
Annex A

e. **Intermediate Gearbox (IGB)**. The IGB was recovered with external impact damage; all four attachment bolts to the aircraft structure had sheared. The IGB cooling fan vanes had all sheared identically indicating that the drive shaft was still rotating on impact. A small sample of oil was recovered from the IGB and was confirmed to have Lynx IGB oil type properties, and displayed no evidence of significant degradation in the overall quality. The Panel also note that failure of the IGB would have resulted in loss of tail rotor drive and there was no evidence of this either from the crew on CVR or from the characteristics of the wreckage trail. The Panel concluded that **IGB failure/malfunction was not a factor in the accident.**

Annex A
Exhibit 254
Exhibit 1

f. **Tail Rotor Gearbox (TRGB)**. The TRGB was recovered with impact damage; all eight attachment bolts to the aircraft structure had sheared. Analysis of the damage by MilAAIB concluded the TRGB was rotating as it came away from the wreckage. If the TRGB had failed, the crew would have lost tail rotor drive and, as noted above in the accident site analysis, there was no evidence that this was the case. The Panel concluded that **TRGB failure/malfunction was not a factor in the accident.**

Annex A
Annex A
Exhibit 1

g. **Tail Rotor Drive Shaft (TRDS)**. Lynx aircraft are fitted with five Tail Rotor Drive Shafts (TRDS) that transmit rotational drive from the main transmission (the MRGB) to the aircraft tail (see Figure 12). The Number Four (No 4) TRDS was the only shaft recovered; it had been torn apart (in torsion) and remained attached to the IGB. The failure is consistent with a rapid deceleration of tail rotor drive when the TRBs struck the ground. A circumferential mark was observed and subsequently matched to a point of impact with the tail structure[39]. The torsional ripping of the drive shaft and circumferential mark indicate that the TRDS was being driven at the moment of impact and the damage was a result of the impact and subsequent break-up of the tail cone section. Electronic records prove the aircraft was at the correct latest modification standard[40]. The Panel also noted that TRDS

Annex A
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Exhibit 160

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[36] The normal periodicity sample rate is every 75 hrs.
[37] Reduced sampling is not unusual, applied in recognition of the criticality of the components that could be affected and the potential for the wear to become progressive and degenerative. This would be indicated by an increase in the quality, size and thickness of debris being produced and found in the oil samples.
[38] 1710 NAS
[39] There is a step under the No 4 TRDS just forward of the IGB cowling which matches the position of the mark.
[40] Post a Danish Lynx accident in 2011 (where a TRDS failed) all marks of Lynx were required to be fit with a modified standard of TRDS.

failure/malfunction would have resulted in loss of tail rotor drive and the aircraft would have yawed before impacting the ground, leading to a different accident site profile. The Panel concluded that **TRDS failure/malfunction was not a factor in the accident.**

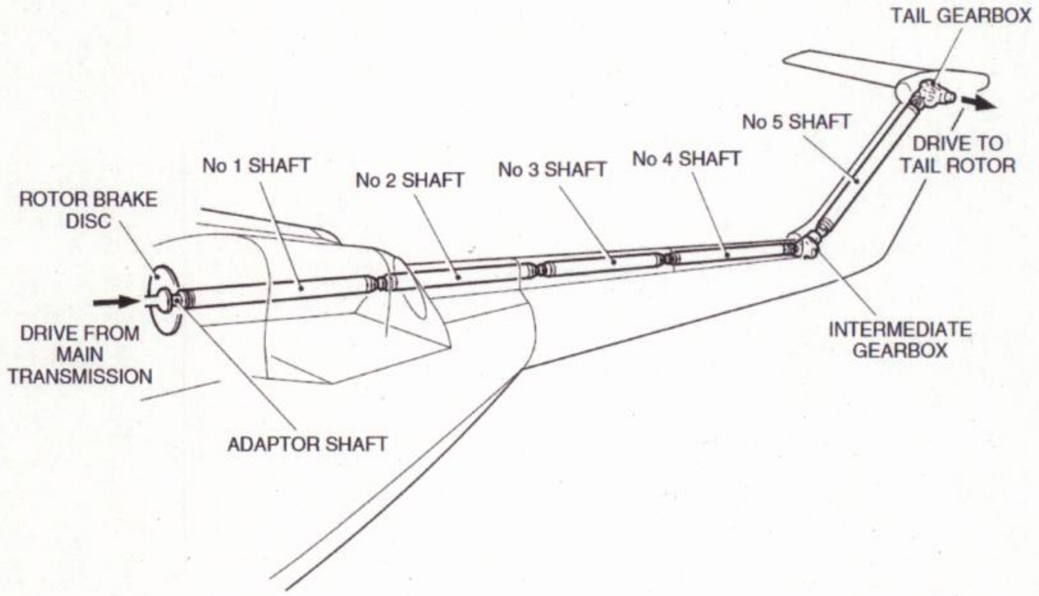

Figure 12 – Five Tail Rotor Drive Shafts (TRDS)

h. **Main Rotor Head (MRH)**. There were no signs of damage to the upper sections of the MRH, indicating the aircraft did not roll or tumble during the accident sequence, and the four CMRB were still attached. The MRH could be turned by hand (smoothly and with ease) post the accident. The Panel concluded that **MRH failure/malfunction was not a factor in the accident.** Annex A Annex A

i **Composite Main Rotor Blades (CMRB)**. The four CMRB were still attached to the MRH. Two out of the four CMRB were bent midway down the blade length due to the forces of impact and the subsequent exposure to heat. Evidence from the distribution of CMRB debris would indicate that the MRH continued to rotate with considerable velocity along the debris trail. Annex A Annex A

j. **Main Rotor Actuators (MRAs)**. The aircraft's three Main Rotor Actuators (MRAs), which transmit flying control inputs to the MRH, were removed from the MRGB and escorted, by MilAAIB accident investigators, for formal assessment by industry experts. Due to the MRAs suffering impact damage and heat exposure, it was difficult to draw a conclusion from the technical analysis. However, the Panel noted that the MRA flying control input levers (internal to the MRAs) could be moved post-accident. Additionally, analysis of two hydraulic fluid samples taken from within two of the MRAs provided evidence that both Number 1 and Number 2 hydraulic systems (that feed the MRAs) contained the correct oil specification. The Panel noted that a failure or malfunction of an MRA is a significant event for the crew, and is recognised as an undemanded control input which may result in severe attitude changes and control in pitch, roll or collective being lost. The CVR does not indicate any undemanded control input being experienced by the crew. The Panel concluded that **MRA failure/malfunction was not a factor** Annex A Annex A Annex A

in the accident.

1.4.62 **Quality of CVR Recording**. The CVR was located in the rear of the aircraft (Figure 13). The Panel noted that, whilst the CVR was recovered in reasonable condition, the CVR ended abruptly on what is believed to be the initial impact due to the magnetic tape's driveshaft breaking. The impact loading required to cause this failure is covered at 1.4.446.

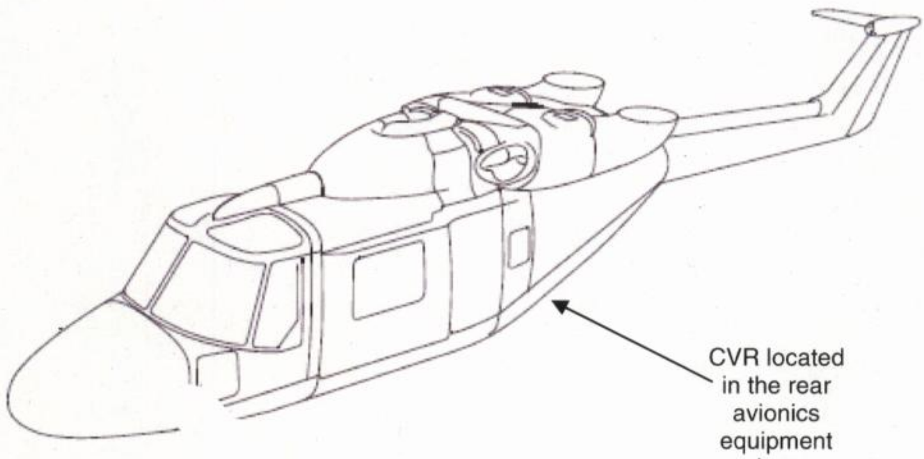

Figure 13 – Location of CVR on Lynx AH Mk 9A

1.4.63 The CVR was configured to record three audio channels: two aircrew channels and a cockpit area microphone channel. It also included a rotor RPM monitoring channel. Annex A
Whilst 32 min 53 secs of audible aircrew dialogue has been recorded, expert[41] analysis found that the rotor RPM recording was inaccurate most likely due to the variations in the tape recording speed. Annex A
There are a number of factors that can cause variations in tape speed, including the stretching of the magnetic tape from environmental conditions and vibrations generated by the helicopter. Exhibit 241
The Panel noted the CVR was mounted on fixed wing aircraft anti-vibration mounts and not, as would be expected, on rotary wing anti-vibration mounts. The fitment of a solid state CVR would eradicate most of the problems mentioned above and provide an accurate recording of rotor RPM data in the event of any future accidents. Annex A

1.4.64 **Technical Failure/Malfunction Summary**. CVR and expert analysis of recovered aircraft components, confirmed by the MilAAIB Technical Report, provided evidence to indicate that **technical failure/malfunction was not a factor in the accident.**

1.4.65 **The Panel recommends that the Lynx Project Team Leader should fit a solid state CVR to Lynx AH Mk 9A aircraft to overcome the problems associated with the current magnetic tape CVR.**

Flight Data Recorder (FDR) Observations

1.4.66 The Panel noted that Military Defence Standard (Def Stan) 00-970 regarding the fitment of FDR is in the process of being updated[42] to make it both clearer and better

[41] 1710 NAS and QinetiQ.
[42] MAA Technical Director letter 'Puma XW211 Service inquiry Recommendation – Fitment of Flight Data Recorders' dated 18 Dec 14.

reflective of current civilian regulation. The Def Stan requires air systems new to the Military Register to be fitted with an FDR, but does not mandate retrospective FDR fitment to current in-service aircraft. Exhibit 147

1.4.67 The Panel also noted that the MAA Director (Technical) had recently considered the merits of mandating the retrospective fitment of FDRs, and wrote to all Aviation Operational Duty Holders (ODHs - see 1.4.235), having concluded that: Exhibit 147

a. The costs and complexity of fitting digital recording equipment into legacy aircraft would be significant and quite probably fail the test of gross proportionality in a Cost-Benefit Analysis.

b. Fitment of such capability would clearly improve understanding of causal factors in accidents, provide valuable lessons and enhance Air Safety.

c. Benefits in terms of improved airworthiness, availability and reduction in Risk to Life could be felt down-stream, in the form of accident avoidance.

Therefore, MAA Director (Technical) encouraged ODHs to review the FDR capability of their in-service aircraft and, if the opportunity arose, to consider improving this as part of a sustainment or upgrade programme. Exhibit 147

1.4.68 The Panel noted that the Lynx PT had recently conducted a Cost-Benefit Analysis for the provision of an Accident Data Recorder (ADR[43]) to all Lynx Fleets. The analysis highlighted a number of options but the recommended option for Lynx AH Mk 9A was to 'Do Nothing' based on the cost of the modification being significantly financially disproportionate to any Risk to Life mitigation benefit that could be achieved. This recommendation had been considered and accepted by Navy Command for Lynx HMA[44] Mk 8, and JHC for Lynx AH Mk 7. However, whilst JHC indicated that they were 'content' not to proceed with the fitment of FDR to the Lynx AH Mk 9A, the Panel could not find any explicit acceptance of this option by JHC. Exhibit 148 Exhibit 149

1.4.69 **FDR Observations Summary**. The Panel concluded that retrospective fitment of FDRs to current in-service aircraft is not mandated; further, ODHs had been 'encouraged' rather than mandated to review their in-Service platform FDR capability. For Lynx, a Cost-Benefit Analysis of retrospective FDR fitment had taken place, which recommended the 'Do Nothing' option; however, the Panel could not find any formal evidence to confirm that JHC had accepted this recommendation for Lynx AH Mk 9A. Exhibit 149

1.4.70 **The Panel recommends that Commander JHC should, as ODH, formally respond to the Lynx Project Team recommendation of 'Do Nothing' regarding retrospective fitment of FDR to the Lynx AH Mk 9A.**

1.4.71 **The Panel recommends that DG MAA should mandate FDR fitment, through regulation, to all current in-service aircraft (to the requirements detailed in Def Stan 00-970) from which ODHs are required to apply for a waiver (if deemed necessary, having completed a Cost-Benefit Analysis).**

Hostile Action

1.4.72 The Panel considered a number of factors which may indicate whether hostile action was a factor in the accident. These include: local area background and recce before the accident; post accident observations; ballistic damage to the aircraft; CVR

[43] ADR is old terminology now replaced with FDR.
[44] Helicopter Maritime Attack.

analysis; accident site analysis; injury to the crew; and post accident propaganda.

1.4.73 **Local Area Background**. The area known as Texas Helo range was frequently used for Air to Ground Gunnery practice by a number of coalition aircraft. Although largely uninhabited, there was a scattering of small Bedouin-style camps, consisting of a few local national people and their livestock, along the western side of the valley in amongst the sand dunes. It is believed that many of these people made their living from collecting the 'brass' from expended ammunition cartridges, and then selling it Witness 3
on as scrap metal. For this reason, they had always been considered tolerant of Coalition Forces and, anecdotally, had repelled the Taliban as a threat to the locals' livelihood. The Witness 6
rocky mountain area along the eastern side of the valley was uninhabited. The nearest village was approximately three km east of the accident location, in the low ground to the east of the mountains. The District Governor confirmed in a media statement that the area Exhibit 74
was remote, unpopulated by insurgents and very safe.

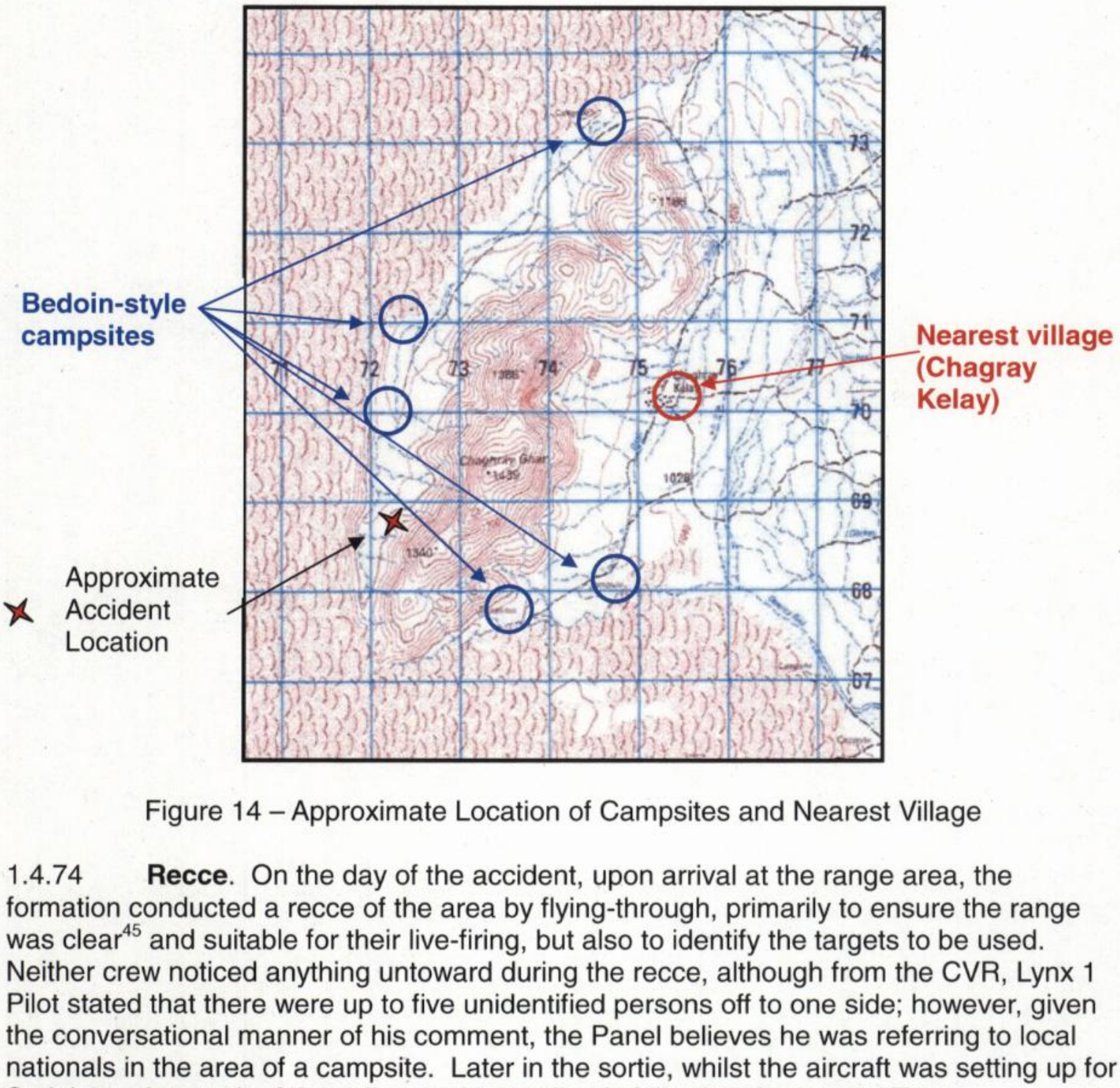

Figure 14 – Approximate Location of Campsites and Nearest Village

1.4.74 **Recce**. On the day of the accident, upon arrival at the range area, the formation conducted a recce of the area by flying-through, primarily to ensure the range was clear[45] and suitable for their live-firing, but also to identify the targets to be used. Witness 3
Neither crew noticed anything untoward during the recce, although from the CVR, Lynx 1 Exhibit 1
Pilot stated that there were up to five unidentified persons off to one side; however, given the conversational manner of his comment, the Panel believes he was referring to local nationals in the area of a campsite. Later in the sortie, whilst the aircraft was setting up for Serial 4 to the south of the valley, and immediately following the second Tac Climb/Descent, the Ac Comd is heard to say "*Sneaky little bastards*". It is not known to Exhibit 1
who or what he is referring; however, the statement is again made in a more

[45] i.e. not in use and suitable for live-firing without risk of damage to property or injury to people/livestock on the ground.

conversational rather than alarmist manner, and the Panel therefore believes he may have been referring to local national movement on the ground, potentially brass collectors. Other than these two comments, there was nothing of note captured on the CVR which would indicate that the crew had any concerns over the potential for hostile activity. The Ac Comd of Lynx 2 confirmed this during interview. Witness 3

1.4.75 **Post Accident Observations**. Upon realising that Lynx 1 had been involved in an accident, the crew of Lynx 2 were immediately concerned as to the possibility of enemy action. As they flew to the overhead of the accident site, they were vigilant in looking for any indications of a hostile act. A motorcycle was seen by Lynx 2 at the northern end of the Range heading towards one of the camp sites, but was some distance away and not considered to have been threatening. After spending some time orbiting overhead the accident site, during which time they made initial radio distress calls to KAF ATC, Lynx 2, whilst remaining mindful of potential enemy activity, elected to land. They stayed on the ground for approximately seven mins before taking off and remaining in the area for approximately one further hour, when their low fuel state necessitated a return to KAF. A number of coalition rotary, ISTAR and Fast Jet aircraft also remained in the area following the accident and throughout the Post Occurrence Management and wreckage recovery. Throughout, there were no signs of any hostile activity. Witness 3 Witness 2 Exhibit 68

1.4.76 **Ballistic Damage to the Aircraft**. For ballistic damage[46] to have caused this accident, one of the major components would have needed to have been hit, which in-turn would have led to a technical malfunction leading to a forced landing or crash scenario. Accepting that not all of the aircraft was available to be inspected due to impact damage and post-accident fire, the majority of the major components were recovered and have been confirmed as working normally at the time of the accident.

1.4.77 **CVR Analysis**. Had the aircraft been subject to attack from larger calibre weapons, such as Heavy Machine Gun (HMG), this would have been apparent on the CVR and there would likely have been evidence in the wreckage. Further, had a hand-held Infra Red (IR) Missile targeted the aircraft, the Missile Approach Warning System (MAWS) should have detected the incoming threat, sounded an alarm and the aircraft Defensive Aids Suite could have deployed decoy flares to address the threat[47]. Nevertheless, the damage sustained by the aircraft is not consistent with that which might be incurred from an IR missile, nor is there any indication on the CVR of either the sound of a missile impacting or passing close by the aircraft. Exhibit 1

1.4.78 **Accident Site Analysis**. Finally, the Panel believes the crash profile to be more indicative of an aircraft in controlled flight. Had the aircraft been out of control due to a technical malfunction or impact from enemy fire, the Panel considered that the accident site would likely have seen a greater spread of the wreckage. Annex A

1.4.79 **Injury to the Crew**. The RAF CAM Aviation Pathology Report provides no evidence that the crew or passengers had suffered any injury as a result of hostile action; specifically, there was no evidence to suggest they had been hit by small arms fire. Annex C

1.4.80 **Propaganda**. The MOD Directorate of Defence Communications has confirmed that in incidents such as this, the Taliban (or relevant extremist group) will invariably try and claim responsibility. Following the accident, a Taliban spokesman claimed in a telephone interview that their militia had used a '*secret new weapon*' to target the aircraft and that a lot of ISAF soldiers were killed. The same spokesman also sent a Exhibit 102

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[46] Damage incurred from a high speed flying projectile, such as a bullet or missile.

[47] Automatic dispense would occur if the release was set to automatic. However, the CVR indicates that the flares had been set to 'Manual' release after take off, and there is no mention of switching to 'Automatic' release on the CVR. Had they been set to manual, flares would not have been released automatically but the alarm would still sound.

text message to a journalist, claiming '*the mujahedin hit the…helicopter with a rocket, and 12 soldiers on board were killed*'. It is known by the Panel that the aircraft was not hit by a rocket, as this would have caused a technical malfunction and there would have been evidence of ballistic damage to the major components recovered from the wreckage. Further, there would have been audio recording of the impact on the CVR, along with a potential crew acknowledgement of the impact. Other than this isolated piece of propaganda, there were no other claims to suggest the accident was a result of enemy action.

1.4.81 **Hostile Action Summary**. Given the local area background, the recce, Lynx 2's observations after the accident, the lack of evidence of ballistic impact damage to the aircraft or crew, the limited propaganda in the aftermath and the lack of crew acknowledgement on the CVR that they were being targeted, the Panel concluded that **Hostile Action was not a factor in the accident.**

Pilot Incapacitation

1.4.82 The Panel considered whether the Pilot was rendered incapable of controlling the aircraft in the final stages of flight prior to the accident. Evidence from the CVR identifies that the Pilot was in handling control of the aircraft during the final seven minutes of flight. The Pilot's last recorded words were "*Clear left?*" 16.5 secs before the CVR ends. Exhibit 1
During the remaining 16 secs, the only voice heard on the CVR is the Ac Comd who hums periodically before shouting "*Pull up*" 3 times approximately one second before the recording ends. The Panel considered the following:

a. The Panel believes the Pilot actively controlled the aircraft into the final descent. Further, CVR analysis provides evidence of the aircraft manoeuvring during the descent (covered further at 1.4.148), believed to be when the aircraft rolled out of the left-hand turn approximately five secs before impact and was being flared with cyclic input up until two secs before impact. Accident site analysis also indicates the aircraft impacted the ground in a wings-level, nose-up attitude, consistent with the aircraft being levelled out at the bottom of a descent. The Panel concluded that this indicates that the Pilot was conscious two secs before impact. Exhibit 1 Annex A

b. There is no acknowledgment from either the Ac Comd or the Aviation crewman (Acmn) of any concern over the way the aircraft was being handled during the descent, or that there was potentially something wrong with the Pilot. The Panel considered that the Ac Comd, in particular, would have been highly likely to have noticed anything amiss with the Pilot, given their close proximity (and side-by-side seating) in the cockpit. The Panel believes that this indicates that all appeared normal within the cockpit until the Ac Comd shouts "*Pull up*" approximately one second before impact. Additionally, the Panel believes that the fact that the Ac Comd uses "*pull up*" rather than "*I have control*" indicates that the Ac Comd believed the Pilot to be conscious and in flying control of the aircraft. Exhibit 1 Exhibit 1

c. Analysis of the EECUs indicated that there was a very large and rapid power demand placed upon the engines in the final second of the flight, coincident with the Ac Comd shouting "*Pull up*". The Panel considered that the power demand was as a result of a rapid collective input in an attempt to arrest the Rate of Descent (RoD) and avoid impact with the ground (covered further at 1.4.150). The Panel could not ascertain who made this collective input, and accept that it could have been made by either the Pilot or Ac Comd. Annex A

d. The absence of communication between the Pilot and the Ac Comd for 16 secs was not uncommon during the sortie and the Panel does not consider this out of the ordinary during routine military flights. The Panel considered the lack of communications could have been either:

(1) Indicative of a high workload, either due to the demands of the profile or due to recognition of the impending hazard and taking actions to recover. However, the Panel felt this was unlikely, due to: the good weather and flying conditions; familiar area and terrain; this being considered a relatively benign area; and having already successfully completed 5 serials into the same area. The crew of Lynx 2 confirmed that they did not find the sortie particularly demanding. Witness 2

(2) Indicative that the Pilot was comfortable with the flying demands and had not recognised the impending hazard. The Panel felt this to be more likely, as periods without speech were not unusual for the sortie. Annex C

1.4.83 **Pathology Report**. The Pathology Report and subsequent scrutiny of medical records do not provide any evidence to suggest the Pilot was incapacitated or likely to become incapacitated during the flight.

1.4.84 **Pilot Incapacitation Summary**. Without the aid of a FDR, the Panel is unable to conclude exactly what flying control input either the Pilot or Ac Comd made during the final descent. However, despite the lack of any spoken words by the Pilot in the last 16 secs of flight, analysis of the CVR and EECUs, coupled with the accident site analysis, indicates to the Panel that the aircraft was being actively controlled by the Pilot until at least two secs before impact. The Panel was not able to completely discount the Pilot becoming suddenly incapacitated two secs before impact, as the Ac Comd may have made the final collective input in response to the impending collision. However, the Pathology Report offers no evidence that this was the case, and there was no acknowledgement by the crew that anything was amiss. The Panel therefore concluded that **Pilot Incapacitation was highly unlikely to be a factor in the accident.**

Deliberate Act

1.4.85 The Panel considered the possibility that one or more of the crew or passengers acted in a deliberate manner to cause the accident.

1.4.86 **Medical Records**. There is no evidence in the crew medical records to suggest any of the crew were suffering from stress influenced medical conditions. Exhibit 103

Exhibit 104

1.4.87 **State of Mind**. There is no indication from any of the Air Det personnel interviewed in the immediate aftermath that any of the crew or passengers from Lynx 1 appeared tense or nervous in the days preceding the flight. Similarly, none of the interviews indicated any hint of ill-feeling or malevolence between the crew members, or inclination to self-harm. Further, the Panel was allowed access to a number of messages between the Pilot and his family from the evening preceding the accident, and assessed the dialogue to be upbeat throughout. Exhibit 105 Exhibit 13

1.4.88 **Accident Site**. The aircraft attitude at impact suggests the aircraft was being manoeuvred to level out or climb at the bottom of the descent and not being deliberately flown into the ground (manoeuvring in the descent also covered at 1.4.148 and 1.4.149). Annex A

1.4.89 **CVR**. There is no dialogue on the CVR to indicate any of the crew or passengers acted in a deliberate manner to cause the accident. The overwhelming impression gained from the CVR is that the crew and passengers were content and enjoying the sortie, with good verbal interaction between the Pilot and the Ac Comd throughout. During the post-accident interviews, the Panel noted a general consensus that (prior to the accident) the Air Det's morale was high. Exhibit 1

1.4.90 **Deliberate Act Summary**. The Panel found no motive or evidence to suggest that the accident was a result of a Deliberate Act by any of the crew or passengers. As such, the Panel concluded that **a Deliberate Act was not a factor in the accident.**

Weather

1.4.91 The Panel considered whether the meteorological conditions on 26 April 2014 experienced by the crew of Lynx 1 in the area were a factor in the accident.

1.4.92 **METAR**. A Meteorological Airfield Report (METAR) is the observed weather conditions experienced at an airfield, and is usually issued hourly. The METAR issued by the KAF[48] Meteorological Office at 0607Z (1037 hrs local – approximately 6 mins after the accident) was as follows: Exhibit 190

'OAKN 260607Z VRB03KT 9999 SKC 25/09 Q1019 RMK A3009 DA5221 BLU' Exhibit 48

The METAR is decoded as follows:

Ser (a)	METAR text (b)	Decode (c)	Remarks (d)
1.	OAKN 260607Z	Issued at Kandahar Airfield on 26 April (2014) at 0607 Zulu	Zulu time is also known as Greenwich Mean Time (GMT) and is the time at the zero meridian (Greenwich, UK)
2.	VRB03KT	Wind variable at 3 knots	
3.	9999	Visibility greater than 10 kilometres	
4.	SKC	Sky Clear	No Cloud
5.	25/09	Air temperature +25 degrees / Dew Point temperature +9 degrees	Dew point is the temperature at which a sample of air would become saturated with water if cooled at a constant pressure
6.	Q1009	QNH 1019	Observed pressure of the airfield elevation, corrected for air temperature and reduced to mean sea level. Figure given in hectopascal (hPa)
7.	RMK A3009	Remark: Pressure Altitude 30.09 Inches of Mercury	As above; figure given in Inches of Mercury (inHg)
8.	DA5221	Density Altitude 5221 feet	This Density Altitude was calculated by the US Meteorological forecaster and differs from the UK calculation which indicates the Density Altitude was 5023 feet.
9.	BLU	Colour code Blue	Colour code Blue means that if clouds were present, they would be greater than 2500 feet above the airfield and the visibility would be greater than 8000 meters

Exhibit 191

Exhibit 197

Exhibit 93

Table 1 – KAF METAR Decode

1.4.93 **TAF**. A Terminal Airfield Forecast (TAF) gives a forecast of weather conditions and significant changes expected during a specified period (often 9 hours) at an airfield. The TAF issued by the by KAF Met Office at 0505Z (0935 hrs local, approximately one hour before the accident) was as follows: Exhibit 190

[48] Texas Helo Range did not have a dedicated METAR or TAF. Due to the proximity of KAF (>12 nautical miles), the METAR is considered to be an accurate reflection of the weather experienced in the area and was the only product available to the crews during the outbrief prior to the sortie.

'OAKN 260505Z 2606/2706 27010KT 9999 SKC PROB40 TEMPO 2606/2614 25012G22KT BECMG 2616/2618 VRB05KT SCT280' Exhibit 49

The TAF is decoded as follows:

Ser (a)	TAF text (b)	Decode (c)	Remarks (d)
1.	OAKN 260505Z	Issued at Kandahar Airfield on 26 April (2014) at 0505 Zulu	Zulu time is also known as Greenwich Mean Time (GMT) and is the time at the zero meridian (Greenwich, UK)
2.	2606 / 2706	Valid between 0600 Zulu on 26 April and 0600 Zulu on 27 April (2014)	
3.	27010KT	Wind from 270 degrees at 10 knots	
4.	9999	Visibility greater than 10 kilometres	
5.	SKC	Sky Clear	No Cloud
6.	PROB40	40% probability	PROB40 is used when the predicted weather is between 30% to less than 50% range, thus a probability of 40%
7.	TEMPO 2606/2614	Temporarily between 0600 and 1400 Zulu on 26 April (2014)	TEMPO is used for any conditions in wind, visibility, weather, or sky condition which are expected to last for generally less than an hour at a time (occasional), and are expected to occur during less than half the time period.
8.	25012G22KT	Wind from 250 at 12 knots gusting to 22 knots	
9.	BECMG 2616/2618	Becoming between 1600 and 1800 Zulu	BECMG is used when a gradual change in conditions is expected over a longer time period, usually two hours
10.	VRB05KT	Wind variable at 05 knots	
11.	SCT280	Cloud scattered at 28000 feet	

Exhibit 190
Exhibit 190
Exhibit 190

Table 2 – KAF METAR Decode

1.4.94 **Temperature**. The outside air temperature at the time of the accident was approximately +25 degrees centigrade, one of the hottest days experienced so far that month; however, this was still comfortably within the level the crews would anticipate as they had, in the Panel's opinion, become acclimatised to over the preceding weeks. The temperature was also well within the normal operating temperature limits for the Lynx Mk 9A[49]. Exhibit 92

1.4.95 **Wind**. The TAF predicted 15 knot (kts) winds gusting up to 22 kts at some time between 1000 and 1800 hrs. Evidence from the crew of Lynx 2 and the pattern of scorch marks at the accident site indicate the prevailing wind at the accident site was northerly and with a strength of between 0 – 5 kts. The Panel considered that, if the wind had been stronger and more easterly, there may have been potential turbulence caused by the rocky high ground to the east. However, the light northerly wind present on the 26 April 14 was likely to have followed the line of the valley and, if anything, would have provided an element of up-draught as the aircraft entered the valley. Further, there is no mention of concern over the wind strength or direction on the CVR, nor from statements from the crew of Lynx 2 or any of the rotary wing assets who flew to the accident site in the immediate aftermath of the accident; indeed, many elected to land in a 'downwind' configuration due to the good flying conditions and the light or negligible effect of the northerly wind[50].

Witness 3
Exhibit 207
Exhibit 1

1.4.96 **Weather Phenomena**. There is no evidence on the CVR data or in the Lynx 2 or other rotary crew statements to indicate anything unusual with the ambient weather

[49] Minus 26 degrees to + 50 degrees centigrade (or ISA +35 degrees, which equated to 43 degrees centigrade at the accident site).
[50] AP 3456 (the RAF Manual of Flying) states '*Approach and landing down-wind should only be made when there is no alternative; in a strong tailwind this may mean that the helicopter has an effective backward airspeed which is potentially dangerous because of impaired directional control and reduced aft cyclic control*'.

conditions, or that any localised weather phenomena[51] were experienced in the area on the day of the accident. Exhibit 1

1.4.97 **Weather Summary**. The Panel considered the weather on the 26 April 14 as very good conditions for the sortie. Indeed, the crew of Lynx 1 described the conditions as '*epic*'. The weather was significantly better than the prescribed minima in the JHC Flying Order Book. The Panel concluded that the **weather was not a factor in the accident**. Exhibit 1 Exhibit 134

Aircraft Performance

1.4.98 The Panel calculated the aircraft performance figures, based on the conditions of the day, to ascertain whether the aircraft was operating within the aircraft flight envelope and limitations as specified in the Operating Data Manual (ODM), RTS and Aircrew Manual. Exhibit 91 Exhibit 92

1.4.99 **Maximum All Up Mass (MAUM)**. The performance of an aircraft is influenced by its All Up Mass (AUM). The RTS states the MAUM for the Lynx Mk 9A is 5330 kgs. The Panel calculated that Lynx 1 weighed approximately 5268 kgs at take off. The Panel noted this weight was close to the MAUM but was consistent with the aircraft weight the crew would have experienced on numerous previous sorties in Theatre. The Panel concluded that the aircraft was operating within the RTS MAUM limit and therefore **the aircraft AUM was not a factor in the accident**. Exhibit 206 Exhibit 92 Exhibit 93

1.4.100 **Centre of Gravity (CG)**. The performance of an aircraft is also influenced by the position of the CG. Operation of an incorrectly loaded aircraft, in which the AUM or position of the CG is outside the design limits, can lead to difficulty in handling, reduce performance, and impose increased loads on the aircraft structure and dynamic components. The Panel calculated the CG for Lynx 1 and concluded that the aircraft was operating within limits; therefore **the aircraft CG was not a factor in the accident**. Exhibit 92 Exhibit 91 Exhibit 93

1.4.101 **Maximum Permitted Airspeed**. The maximum permitted Indicated Airspeed (IAS) for Lynx 1 was 120 kts because the airframe was fitted with a CSW system and the cabin doors were open[52]. Radar data indicates that there were instances when Lynx 1 flew at a Ground Speed (GS)[53] greater than 120 kts; the Panel observed that these instances were coincident with the downwind leg of the live-firing serials, when the aircraft had a tailwind component and hence will have been travelling faster over the ground (GS) than was being indicated in the cockpit (IAS). Witness statements from the crew of Lynx 2 do not indicate any evidence of Lynx 1 exceeding IAS limitations. Although the Panel were unable to accurately determine the IAS of the aircraft throughout the sortie due to a lack of FDR, the Panel found no evidence to suggest the maximum permitted IAS was exceeded. The Panel therefore concluded that **aircraft airspeed was not a factor in the accident**. Exhibit 92 Exhibit 55 Witness 3

1.4.102 **Maximum Permitted Angle of Bank (AOB)**. The maximum permitted AOB for Lynx 1 during flight was 30 degrees immediately after take-off, increasing to 45 degrees once the MAUM had reduced below 5125 kgs (approximately 28 mins into the flight). There is no evidence on the CVR or from the statements from the crew of Lynx 2 to suggest Lynx 1 was flown outside of the maximum AOB during the sortie. The Panel concluded that there was no evidence to indicate that the aircraft was handled outside of the maximum permitted AOB limits and therefore **AOB was not a factor in the accident**. Exhibit 91

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[51] For example, the weather conditions were not consistent with those required to produce either wet or dry microbursts (a localised column of sinking air).
[52] IAS is the speed indicated on the cockpit instruments.
[53] GS is the actual speed of the aircraft over the ground, when considering the combined effect of the IAS and wind.

1.4.103 **Calculating Aircraft Performance Data**. The RTS and the ODM contains the data which covers the maximum range of ambient conditions and aircraft performance that can be reasonably expected. In each area of performance (e.g. hover performance and performance in forward flight), the effects of altitude, temperature, mass and other parameters relating to that phase of flight are presented. In order to calculate the majority of the performance data, the crews are required to calculate the Pressure Altitude (PA) and Density Altitude (DA) first. Exhibit 91 Exhibit 92

1.4.104 **Pressure and Density Altitude**. Aircraft performance is directly related to PA and DA. The density of the atmosphere will depend on the ambient pressure and temperatures. The Panel calculated the PA and DA on the day in order to calculate the performance data pertinent to the sortie. The PA at the Bowling Alley was 3362 ft and the DA at the Bowling Alley was 5402 ft; the maximum altitude allowed for the aircraft is 12,000 ft PA and DA. The Panel considered both the PA and DA were comfortably within the maximum altitude allowed and therefore **the PA and DA were not a factor in the accident**. Exhibit 221 Exhibit 93 Exhibit 92

1.4.105 **Thrust Margin (TM) Available**. Part of the performance figures calculated by the crew prior to flight is the Thrust Margin (TM). TM is an expression of the power available over and above that required to perform a free air hover in nil wind. Lynx Force Standard Operating Procedure (SOP) 21 ('Operating in Desert and Dusty Conditions') states that a 5% TM[54] is a recognised bench mark when conducting Vehicle Interdiction (VI) in the desert. The Panel calculated that Lynx 1: Exhibit 112

a. Had an approximate 2% TM at take-off. Exhibit 93

b. The TM had increased to approximately 6% at the time of impact (as the AUM had decreased due to fuel burn). Exhibit 93

The Panel considers the aircraft had less than 5% TM for the majority of the VI serials. However, SOP 21 does allow for the reduction in the TM dependent upon the experience of the crew and states that it is ultimately the Ac Comd's decision as to what TM they elect to use (0% TM being the minimum). Further, TM is particularly pertinent when operating in the hover, and it is known that the aircraft had forward speed at the time of the accident. When considered alongside the fact that the TM at time of impact was greater than the minimum suggested when operating in the desert, the Panel concluded that **the TM available was not a factor in the accident**. Exhibit 112

1.4.106 **Air Det Lynx Aircrew Produced Performance Table**. On a monthly basis, the Lynx Det aircrew produced a generic performance table which was used to calculate aircraft performance figures prior to flight[55]. The generic performance table calculations were based on worst-case performance data expected for the month, extrapolated from the aircraft ODM. SOP 21 states that it is imperative that crews '*can interpolate and manipulate the graphs in the Lynx ODM; this will allow Thrust Margins to be adjusted on the hoof*'. The Air Det Lynx Aircrew produced performance table was carried by crews within the aircraft so that the aircrew could refer to, and update performance figures during flight. The Panel cross-checked the performance figures against the ODM and found them to be pessimistic (and therefore safer) in all cases. The Panel therefore concluded that, whilst not an authorised or approved means of producing the expected performance figures, **the Lynx Det generic performance table was not a factor in the accident**. Exhibit 94 Exhibit 112

[54] A 5% TM means the aircraft is capable of performing a free air hover in nil wind and still maintain the hover if the AUM was increased by 5%.
[55] The one used by the crews had been produced at the beginning of April 2014.

1.4.107 **Aircraft Performance Summary**. The Panel concluded that the aircraft was operating within the RTS, MAUM, CG, airspeed, AOB and performance limits. The Panel concluded that **Aircraft Performance was not a factor in the accident.**

1.4.108 **The Panel recommends that Army Aviation Standards should assess the Lynx Det Aircrew produced generic performance table in order to ascertain if it should be formally introduced as an approved product for Lynx AH Mk 9A crews to use as a planning aid.**

Aircraft Handling Characteristics

1.4.109 The Panel considered whether Lynx handling characteristics were a factor in the accident, specifically: aircraft stability in high Density Altitudes; engine governing of the rotor RPM; and anecdotal evidence of aircraft handling characteristics.

1.4.110 **Aircraft Stability**. In April 2010, QinetiQ conducted a qualitative aircraft and engine handling assessment in order to gather data in support of the Lynx AH Mk 9A Aircraft Release Recommendations (ARR) for high altitude operation and an extended forward flight envelope. The ARR assessment noted that the Lynx AH Mk 9A: Exhibit 95

> *'Exhibited good handling qualities for high density altitude operation[56] with the Automatic Flight Control System (AFCS) engaged, although spiral stability[57] was weaker in turns than at lower altitudes. With AFCS disengaged, the aircraft required significant out of turn cyclic to recover to level flight from turns to the right and a Warning has been recommended for manoeuvring flight at high density altitude'.*

1.4.111 **Automatic Flight Control System (AFCS)**. The Panel noted the AFCS is normally engaged during flight, and is only disengaged for specific training purposes, or if called for when dealing with an AFCS-related malfunction. The Panel noted that the Lynx AH Mk 9A AFCS provides flying control stabilisation in the pitch, roll, yaw and vertical axis; further, when the AFCS is disengaged, full control of the aircraft is retained but pilot workload will increase as the controls become very responsive. The Panel found no evidence on the CVR to indicate that the crew had disengaged the AFCS deliberately or accidently at anytime during flight. The Panel concluded that the AFCS was not disengaged during flight. AFCS malfunctions are further discussed at 1.4.121 b. Exhibit 127

1.4.112 **Spiral Instability**. The Panel sought expert advice from Rotary Wing Test and Evaluation Squadron (RWTES) and AgustaWestland Test Pilots on the potential effects of spiral instability. During discussions, they confirmed that spiral instability is common amongst helicopters and may adversely affect handling qualities, such that it becomes more difficult to target and maintain a particular AOB; however, it does not lead to a loss of control or departure from controlled flight. The Panel also considered that the accident site and debris field does not suggest Lynx 1 was in a diving turn at the time of impact. Equally, the CVR offers no indication the aircraft was experiencing any adverse handling issues. The Panel therefore concluded that **Spiral Instability was not a factor in the accident**. Annex A

1.4.113 **Rotor Response**. The Panel considered if the aircraft rotor response, namely

[56] The ARR trials were conducted up to 11,000 ft Density Altitude; the Bowling Alley DA was 5402 ft.

[57] Spiral Stability (AP3456) is described as the lateral stability of an aircraft when AOB is applied. Specifically, whether the aircraft has a tendency to correct itself and roll wings-level (stability) or whether the AOB causes the aircraft to yaw into the airflow, overcoming the correcting effect, increasing the AOB and leading the aircraft into a turn of steadily increasing steepness (instability).

engine governing of the rotor RPM, was a factor in the accident. The default rotor RPM datum is governed (set) by the EECUs at 104%[58] during flight; however, normal operating limits are considered to be between 101.5 – 106.5%[59]. The Panel noted that the Lynx AH Mk 9A ARR stated that *'Large and rapid (power) demands from minimum pitch may result in excessive transient rotor droop.'* Rotor droop is a term used to describe a reduction in the rotor RPM which occurs when there is insufficient power to maintain the rotor RPM at the governed datum[60]. Although the CVR was not able to provide an accurate rotor RPM reading (see 1.4.63), the EECU data[61] indicates the aircraft did experience a rotor droop (to 97.93%) immediately prior to impact, consistent with the large and rapid power demand as the collective was raised, coincident with the Ac Comd shouting *"Pull up"*. There is also a small and momentary increase in rotor RPM approximately five secs before the CVR ends, which the Panel believes to be consistent with flying control inputs at that stage of flight[62] (covered further at 1.4.148). The Panel concluded that **the rotor response was consistent with the flying control inputs, and therefore was not considered to be a factor in the accident**. Exhibit 111 Exhibit 95 Exhibit 96 Annex A Exhibit 1

1.4.114 **Anecdotal Evidence of Handling Characteristics**. During the course of the SI, the Panel was made aware of four separate anecdotal incidents from Lynx AH Mk 9A aircrew (outside of the Sqn) that highlighted potentially dangerous handling characteristics associated with the Lynx AH Mk 9A aircraft. The aircrew involved did not formally report these incidents at the time by Defence Aviation Safety Occurrence Report (DASOR) or any other means; further, the Panel searched the Lynx AH Mk 9A DASOR archive and could find no reports similar to these anecdotal experiences. Nevertheless, the Panel investigated further to determine whether these were relevant to the accident. The Panel received a written description from two of the pilots and discussed the remaining incidents with the other two pilots. To précis: Exhibit 236 Exhibit 98 Exhibit 99

a. Three of the four pilots reported their aircraft responding sluggishly to corrective cyclic and collective input during turns with high power settings and high ambient temperatures. These pilots also suggested their incidents felt like their aircraft were experiencing a control restriction, but found no evidence afterwards to indicate such.

b. The fourth pilot described his incident as running out of power at high AUM and high Density Altitude and being unable to arrest the RoD (the aircraft eventually responded and flew safely away from the landing site).

1.4.115 The Panel consulted the AgustaWestland and RWTES Test Pilots who offered no obvious reason or known phenomena which would cause incidents similar to those described in the anecdotal evidence. The Panel was therefore unable to determine exactly what happened during the anecdotal incidents; however, possible causes may have been: Exhibit 97

a. The aircraft being flown outside of the RTS/Flight Envelope (either excessive AOB or above the Density/Pressure Altitude limitations).

b. Perception difference between normal UK flying and hot & high

[58] 104% equates to a 331 rotor RPM.
[59] It is common for the rotor RPM to momentarily change during flight due to the changes in forces acting on the rotor blades during manoeuvres and flying control input.
[60] The Panel note that minor and transient rotor RPM fluctuations above and below the governed datum of 104% are a regular occurrence during flight
[61] The EECUs do not record all data throughout flight, but recording is triggered when pre-determined airframe and engine-monitored parameters are exceeded; rotor RPM is one of these parameters.
[62] Cyclic input whilst rolling wings-level and/or flaring the aircraft.

conditions (a change to the muscle memory required to do similar activities but in different conditions).

c. Some form of momentary control restriction due to snagging from within the cockpit.

1.4.116 Neither the CVR nor accident site debris profile provide any evidence that Lynx 1 crew experienced any handling characteristics similar to those described in the anecdotal evidence. The Panel concluded that the **anecdotal incidents of handling characteristics provided nothing of relevance to this Inquiry and were therefore discounted as a possible factor.**

1.4.117 **Aircraft Handling Characteristics Summary**. The Panel can find no evidence of hazardous, generic-to-helicopters or Lynx-specific handling characteristics which may have been a factor in this accident. Therefore, the Panel concluded that **Aircraft Handling Characteristics were not a factor in the accident.**

Flying Control Issues

1.4.118 The flying control inputs made throughout the flight are unknown due to the lack of an FDR. The crew had already flown five race-track circuits, including two tactical climbs and descents, without incident. Further, the CVR offers no evidence of any issue with the flying controls or crew concerns over the handling characteristics of the aircraft. The accident site analysis also indicates the aircraft impacted the ground in a controlled flight configuration (wings-level, heading straight and in a nose-up attitude). The Panel therefore concluded that, had there been a flying control issue, it could only have manifested itself in the final secs of flight. Exhibit 1 Annex A

1.4.119 The Panel sought to analyse all possible flying control issues, and considered: Flying Control Severance; In-Flight Emergency Malfunction; and Control Jam/Restriction in Flight.

1.4.120 **Flying Control Severance**. The majority of flying controls were either destroyed during the aircraft break up and post-accident fire or were not recovered from the accident site. As such, the ability to technically analyse flying controls was limited. However, EECU data recorded in the last second of aircraft flight reveals that the Pilot demanded 96% collective immediately prior to impact, and that the engines had responded to the demand. The Panel believes that, as this was coincident with the Ac Comd shouting "*Pull up*" immediately prior to impact, this provided evidence that the collective flying control was operating as expected. The Panel also believes the aircraft attitude at impact provides some evidence that the cyclic flying control was operating as expected. Annex A

1.4.121 **In-Flight Emergency Control Malfunction**. Lynx AH Mk 9A Flight Reference Cards (FRCs) give direction on actions to be taken by the crew in the event of an emergency. The Lynx AH Mk 9A is also fitted with a Central Warning Panel (CWP) which will illuminate as follows: a Red Caption (and associated audio warning) for a flight critical emergency requiring immediate actions by the crew; and a Yellow Caption (without an audio warning) to indicate a potentially hazardous or impending hazardous condition which requires attention but not necessarily requiring immediate pilot intervention. The CWP was recovered with the wreckage, but severely fire damaged and as such unable to be Exhibit 88 Exhibit 1 analysed[63]. However, as there was no audio warning captured on the CVR, the Panel was able discount the majority of flight critical emergencies. The Panel considered the following emergencies, as referred to in the FRCs, as to whether they may have had an effect on the aircraft:

a. **Hydraulics Main Rotor Actuator (MRA) Main Servo Failure**. In the event of an MRA Main Servo failure, the aircraft would experience a severe, undemanded attitude change, with associated loss of control in pitch, roll or collective. The immediate actions for this are to oppose any attitude change using sufficient force (approximately 14 kg) to shear a piece of steel locking wire and maintain manual control. The Panel replicated this emergency in the simulator, and was easily able to overcome the force required and maintain the aircraft in controlled flight; however, the Panel considered the Pilot (or crew) would have commented on this, as the symptoms were very noticeable. Finally, the MRAs were also recovered and subject to detailed analysis by the manufacturer, confirming that there was no evidence of a pre-accident malfunction. The Panel therefore **discounted MRA Main Servo Failure as a Factor in the accident**. Exhibit 89 Annex A

b. **Automated Flying Control System (AFCS) Emergencies**. Most AFCS malfunctions would involve a Yellow Caption but no audio warning. The Panel considered whether a Caption may have been illuminated prior to impact, but gone unnoticed[64] by the crew. An AFCS malfunction usually involves a disturbance in the flying controls, which the Panel believes would have been noticed and commented on by the Pilot. Further, all AFCS malfunctions are able to be overcome with positive control by the Pilot (which occurred throughout this sortie). There is one malfunction which may have led to a collective lever jam, namely a failure in the Collective Parallel Actuator Gearing; however, this restriction can be overcome by applying appropriate force to break a shear pin (11 to 18 kg). Whilst the Panel cannot completely discount the possibility of a Collective Parallel Actuator Gearing failure in the final secs of flight, the Panel concluded that this was unlikely do to the lack of any acknowledgement by the crew that anything was amiss, and the very large collective demand in the final second of flight. Exhibit 90

1.4.122 **Control Jam/Restriction in Flight**. The Panel considered the following:

a. **Stiff Collective**. Lynx 1 was on a reduced desert maintenance regime (more frequent) for operations in desert environments to prevent the build up of sand, dirt and debris that could result in a stiff 'grinding' operation of the collective lever. The aircraft was deemed to be in *'good material condition'*. The CVR gives no indication of either the Pilot or Ac Comd experiencing a problem or stiff operation of their flying controls and five previous circuits had been flown without issue. Exhibit 38 Exhibit 1

b. **Collective Jam**. There has been one reported case, from a foreign Lynx operator, of a collective lever that jammed in flight. On review of the foreign investigation, the Lynx PT found it '*difficult to reconcile the findings (of the investigation) with the event*' but stated '*The report concludes that the cause of the arising was a combination of excessive wear and incorrect shimming* Exhibit 86

[63] The CWP consists of a number of caution and warning lights, and post accident investigation can sometimes identify if a light bulb filament was on (or off) at the moment of an accident.
[64] It was a bright and sunny day, and if the CWP illumination setting was not bright enough it is plausible that the crew may not have noticed a yellow CWP caption, particularly given no audio tone is generated for a yellow caption.

coupled to poor husbandry.' The Panel noted that the Lynx collective lever flying control is a common item across the Super Lynx 300 fleet, AW 159 fleet and Lynx 100 fleet, totalling over 200 aircraft throughout numerous countries of operation, and this is the only known reported case of a collective lever jam in flight. The CVR offers no indication of either aircrew experiencing a jam in collective flying control and the EECU provides evidence of a large collective demand immediately prior to the accident. Exhibit 110 Exhibit 1

c. **Loose Article**. The Panel witnessed the stowage of equipment inside a Lynx aircraft in KAF, and had no reason to believe procedures had been changed as a result of the accident. The aircraft was tidy and secure, and engineering aircraft husbandry standards were good, resulting in the likelihood of a loose article in the very final stages of the flight being remote. Ultimately, although considered unlikely (due to aircraft attitude at impact and the large power demand), it is unknown whether a loose article caused a flying Control Jam/Restriction just prior to impact.

d. **Snagging Hazards**. The CVR gives no indication of either aircrew experiencing a flying controls snagging hazard from their clothing/equipment. The Panel requested an independent DASOR review for snagging hazards which could have resulted in a flying Control Jam/Restriction. The searched covered all Lynx AH Mk 7, 9 and 9A fleets, and dated back to 01 January 2012. From a total of 876 DASOR, only two were generated to report a flying Control Restriction, both have been discounted[65] by the Panel as possible factors in this accident. Exhibit 1 Exhibit 87

1.4.123 **Flying Control Issues Summary**. Without a FDR, the Panel lacked the empirical evidence required to conclusively discount a flying control issue in the very final stages of flight. However, given the lack of evidence that the crew had any concerns over the aircraft handling characteristics, coupled with the accident site analysis and EECU data, the Panel concluded **it was highly unlikely that Flying Control Issues were a factor in the accident.**

Controlled Flight Into Terrain

1.4.124 It is evident from the CVR and the Radar trace that from take-off until the final moments, the flight proceeded as intended; the crew had no difficulty achieving the flight path that they required during the transit out to the range and during the preceding five serials at the range. Exhibit 1

1.4.125 It is clear from the CVR discussions in the final minute that the Crew intended to cut in early, over the highest part of the escarpment and then turn and descend into the valley to run northwards back up the range towards the target area. During the final 16 secs of flight, the aircraft was below the Radar horizon coverage but the aircraft did indeed make a left-hand turn and descended from a height of approximately 400ft above ground level (AGL) into the centre of the valley. There is no indication on the CVR that the flight path during the descent was anything other than that required by the Crew. Exhibit 55 Exhibit 1

1.4.126 During the last few secs of flight captured on the CVR, the Ac Comd can be heard humming a tune. The Ac Comd then shouted "*Pull up*" three times approximately one second before impact, followed by the Radar Altimeter (RADALT) audio warning sounding immediately prior to impact. The Pilot was the handling pilot at the time of the

[65] Both involved carry-on equipment coming into contact with the flying controls, neither of which were being used on this flight.

accident and, from the Ac Comd's 'Pull up' instruction (rather than 'I have control' or some other warning or expletive), the Panel concluded that the Ac Comd perceived that the Pilot was fully in control of the aircraft. Exhibit 1

1.4.127 Analysis of the accident site and the aircraft wreckage indicated that the aircraft attitude at impact (wings-level, nose up and with minimal yaw) was consistent with an attempt to recover the aircraft from the descent, and was not consistent with a loss of control. Analysis of the engines and EECU provided clear evidence of high power being demanded and delivered, further indication of an attempt to recover from the descent.

1.4.128 **Controlled Flight Into Terrain Summary**. The Panel concluded that there was strong evidence that the aircraft was in a controlled flying state throughout the sortie up to and including the final descent into the valley, along with clear evidence of an attempt to recover the aircraft from the descent. The Panel concluded that there were strong indications that there was no loss of control and no evidence to contradict the possibility that the accident was an example of Controlled Flight Into Terrain (CFIT).

Determining the Cause of the Accident – Conclusion

1.4.129 Following analysis of the available evidence, the Panel was able to discount: Technical Failure; Hostile Action; Deliberate Act; Weather; Aircraft Performance and Aircraft Handling Characteristics as potential causes of the accident. The Panel was unable to completely discount Pilot Incapacitation or Flying Control Issues as a potential cause (in part due to a lack of FDR), but considered both to be highly unlikely due to: the evidence from the CVR; the aircraft attitude at impact; and the large power demand in the very final stage of flight. The Panel considered these to be strong indications that the aircraft was under control and the Panel could find no evidence to contradict this.

1.4.130 The Panel concluded that the aircraft was serviceable and functioning as expected until the accident. The Crew made no acknowledgement that anything was amiss until immediately prior to impact, at which point the Panel believes recovery action was initiated by either the Pilot or Ac Comd. The Panel therefore concluded that **the accident was a CFIT event, caused by the aircraft being established in a descent from which it was not fully recovered prior to impact with the ground**.

FACTORS LEADING TO THE ACCIDENT

1.4.131 With the accident identified as a CFIT event caused by the aircraft being established in a descent from which it was not fully recovered prior to impact with the ground, the Panel considered what Factors might have Contributory (i.e. made the accident more likely to happen). Factors considered were:

a. Final Circuit

(1) Reposition

(2) Descent Profile

(3) Recovery Profile

b. RADALT

c. Distraction and Attention Focus

d. Spatial Disorientation and Reduced Situation Awareness

e. Fatigue

f. Time Pressure

g. Planning

h. Briefing

i. Authorisation

j. Duty Holder Construct

k. Air Det Supervision

l. Sortie Aims

m. Airmanship

Final Circuit

1.4.132 The Panel analysed the Final Circuit to determine if there were any factors which might have contributed to the accident. The Panel assessed that the Final Circuit had 3 distinct parts, namely: the Reposition; the Descent Profile; and the Recovery Profile.

Reposition

1.4.133 Figure 15 identifies the aircraft track during the final circuit reposition taken from the Radar data. The Panel considered the reposition included:

a. **Cross Wind**. Once the aircraft had completed the live-firing aspect of the previous Serial (5), the Handling Pilot initiated a climbing left hand turn onto a westerly heading to climb over the escarpment and establish the aircraft Exhibit 55 over the Red Desert.

b. **Down Wind**. Once the aircraft was west of the Bowling Alley[66], the Handling Pilot initiated a left hand turn onto a southerly heading and continued to fly over the Red Desert towards the southern end of the Bowling Alley. Exhibit 55

c. **Base Leg**. Once towards the southern end of the Bowling Alley, the Handling Pilot initiated a left hand turn onto an easterly heading and flew over the Red Desert escarpment towards the centre of the Bowling Alley. Exhibit 55

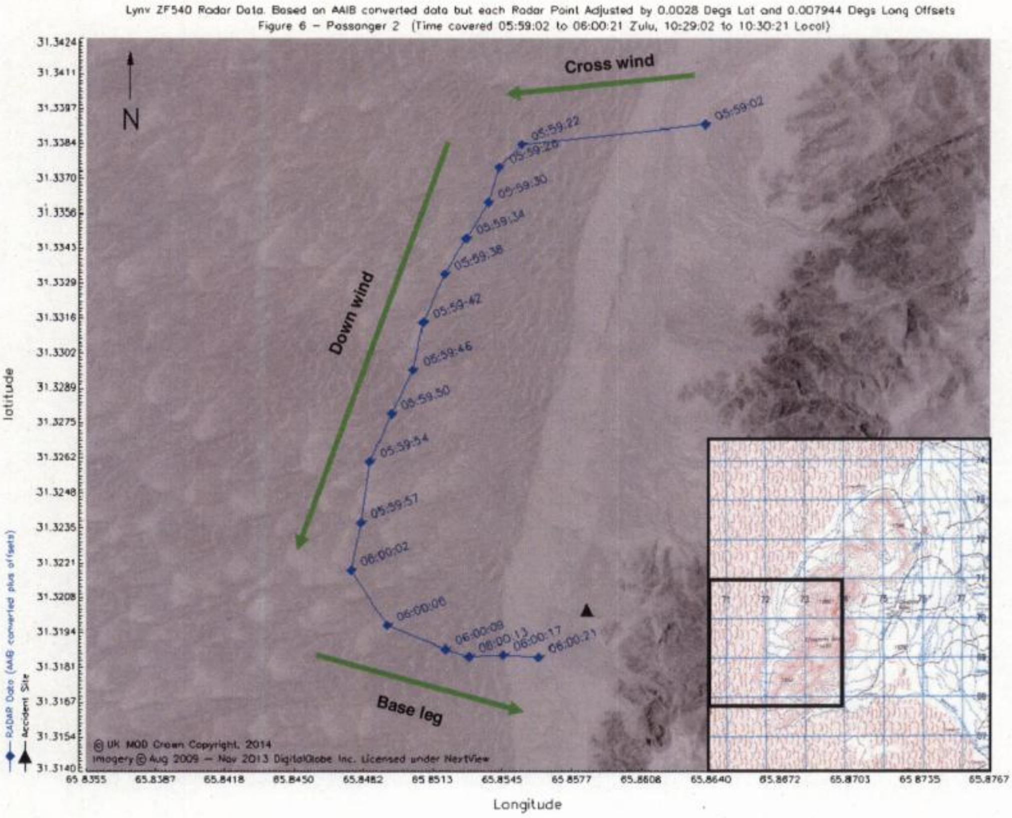

Figure 15 – The Final Circuit

1.4.134 **'*Voyager Flashbacks*' Statement**. The CVR indicates that Lynx 1 completed a tactical climb and descent on Serials 2 and 4. The Pilot flew the first and the Ac Comd flew the second. Both tactical climbs and descents were flown over the Red Desert to the south of the Bowling Alley. The Radar data indicates Lynx 1 climbed to a height of approximately 1700 and 2000 ft AGL respectively. The Radar trace does not identify what height Lynx 1 descended to during the tactical descents. Evidence from Lynx 2 crew statements does not indicate any concern with the recovery heights and the profiles in general. During the second tactical descent (Serial 4), the CVR recorded laughter and one of the passengers, believed to be Passenger A, stating "*Voyager flash backs*". The Panel considered that during the second tactical descent the aircraft was likely to have experienced an element of low 'G' loading[67], giving the crew and passengers the

Exhibit 1

Exhibit 55
Witness 2

[66] See Narrative of Events Part 1.3.59 for a description of the Bowling Alley.
[67] A load factor of 1 G represents an aircraft in straight and level flight. The Mk 9A Aircrew Manual states that 'During low-G manoeuvres (such as rapidly pushing the nose forward or trying to fly the aircraft following the terrain contours), the manoeuvre must be restrained at the moment the onset of low-G (i.e. below 1 G) is sensed. The pilot should not apply negative-G in flight (i.e. below 0 G) because such application is likely to result in damage to or malfunctions of the aircraft and engine systems. Low-G is apparent at approximately 0.5 G (i.e. similar to that experienced on fairly rapid entry into autorotation).'

momentary feeling of weightlessness. The Panel believes the statement made by Passenger A to "*Voyager flash backs*" is likely to refer to an incident associated with an RAF trooping flight (a Voyager A330 aircraft) en route to Afghanistan in early 2014 which lost a significant amount of height in a short period of time (resulting in a low 'G' experience), rendering all on board momentarily weightless. It is known that Passenger A was onboard that specific RAF Voyager A330. Exhibit 136 Exhibit 84

1.4.135 **'*Floaty*' Statement**. During the downwind leg of Serial 6, the Pilot asked the Acmn if everyone was strapped in before stating "*bit of err, bit of floaty*". Immediately after this the Ac Comd responded with "*We'll tip in early…save some flying time*". The Panel believes the reference to '*floaty*' might indicate that the Pilot intended to induce a floating sensation (a low 'G' manoeuvre) during the descent into the Bowling Alley on Serial 6. The Panel considered the Ac Comd's response was ambiguous. It may have indicated a tacit acknowledgment of the Pilot's intention to induce a floating sensation; equally, the Ac Comd's response may indicate he was re-focusing the Pilot, in effect dismissing the Pilot's "*floaty*" statement. Exhibit 115 Exhibit 1

1.4.136 **Previous Base Legs**. The Radar data indicates that the Base Legs for all the previous live-firing serials (2 to 5) were flown further to the south. The Panel considered the Base Leg used on Serial 6 led the aircraft to cross the Red Desert escarpment and enter the Bowling Alley at a point further north than previously used. The Panel assessed this may have offered slightly different visual cues to the Pilot although the Panel noted the crew would already have been very familiar with the area. Exhibit 55 Exhibit 106

1.4.137 **Serial 6 Bowling Alley Entry Point**. The Bowling Alley entry point used on Serial 6 crossed the Red Desert escarpment at the highest point which is approximately 3980 ft Above Mean Sea Level (amsl). The aircraft crossed the escarpment at approximately 4050[68] ft amsl (70 ft above the escarpment). The Bowling Alley valley floor at the accident site is approximately 3550 ft amsl. The Radar data indicated the aircraft was starting to descend as it passed the escarpment (Figure 16). Exhibit 55

1.4.138 **Last Known Radar Position**. The Panel's assessment of the last known Radar position[69] of Lynx 1 indicated the aircraft was between 0.2 to 0.5 nm from the impact point, heading 093 degrees (approximately 70 degrees off the final impact heading) at 3950 ft amsl (approximately 400 ft above the impact point) and travelling at around 112 kts GS. The Panel considered the last Radar position indicates the aircraft was nearer the centre of the Bowling Alley (i.e. further north), and higher, than on any of the previous descent entry points. The Panel assessed this may have presented the Pilot with a slightly different set of entry parameters and visual cues for the descent into the Bowling Alley than those experienced on previous serials.

[68] The aircraft altitude has been taken from the KAF Radar data. The Radar data is represented in 100 ft increments. The Panel are unable to determine at which height in 100 ft the Radar data will revert to the next increment. Therefore, the accuracy of all the altitude data is +/- 50 ft.
[69] N31.19.13 (Latitude) E65.51.23 (Longitude).

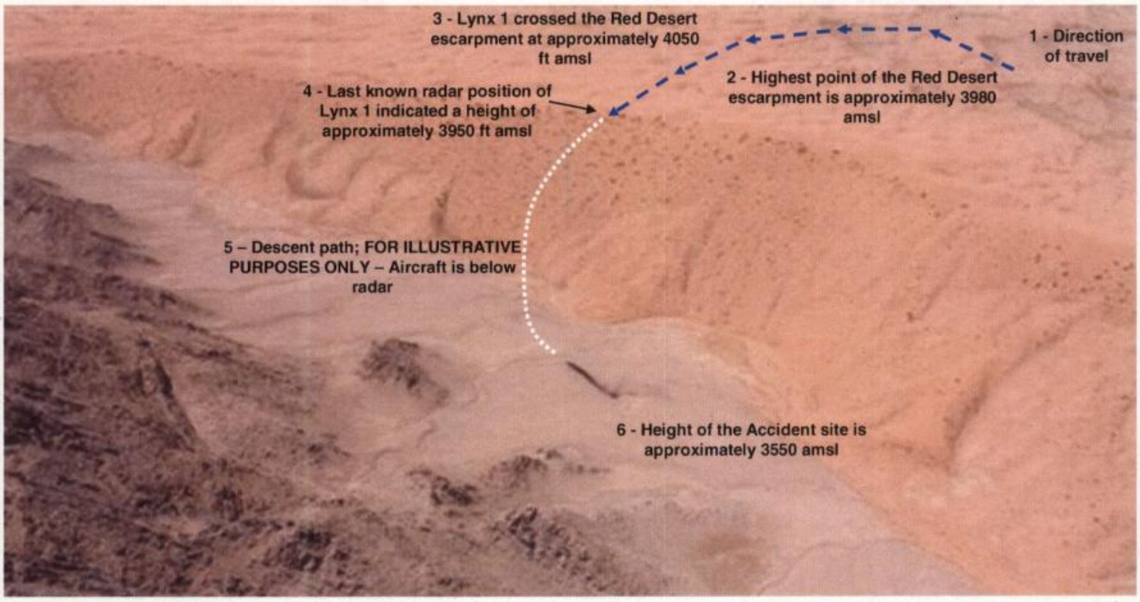

Figure 16 – For Illustrative Purposes Only, Lynx 1 Descent Path

1.4.139 **CVR and Radar Data Overlay**. The Panel was unable to fuse the timings on the CVR with the timings on the Radar data with 100% accuracy. However, the Panel has assessed all the data available and consider the last known Radar position was approximately 16 secs before the CVR recording ends.

1.4.140 **Reposition Summary**. The Panel considered that the track taken during the Reposition was similar to the previous five serials, albeit the base leg was further north. Hence, the pilot may have experienced different visual cues. However, the Panel considered the crew would have been very familiar with the Bowling Alley at this stage in the flight and able to choose a Base Leg at any point or height and subsequently fly an appropriate descent into the Bowling Alley. Therefore, the Panel considered **the Reposition was not a factor in the accident.**

Descent Profile

1.4.141 The Panel considered the likely Descent Profile used to determine if it was a factor in the accident.

1.4.142 **Low 'G' Entry**. The Panel assessed that the "*floaty*" statement made by the Pilot during the Downwind Leg of Serial 6 indicated the Pilot may have intended to fly a low 'G' entry into the Descent Profile. The low 'G' entry would require either a significant nose down attitude (pushing forward the cyclic stick) or very quick reduction in power to the engines (lowering the collective lever) or a combination of the two. The Panel considered that if a significant nose down attitude was selected, consistent with a tactical descent profile of 20 to 25 degrees nose-down, then it would have resulted in a higher than normal airspeed and RoD than the Panel would reasonably expect for a standard descent into the Bowling Alley from a similar position. The Panel considered that if the collective lever was lowered significantly then it would have resulted in a higher than normal RoD but the airspeed would not necessarily increase unless it was combined with a nose down attitude. The Panel is unable to conclude whether the Pilot actually initiated a low 'G' entry into the Descent Profile. There is no evidence on the CVR to indicate that any of the crew or passengers felt that the entry parameters were excessive. Similarly, during the descent, there is no conversation in the cockpit and all that can be heard is the

Exhibit 115
Exhibit 1
Exhibit 127
Exhibit 1

Ac Comd humming.

1.4.143 **Expected Height at the Bottom of the Descent**. There is no evidence on the CVR to indicate to what height above the ground the Pilot intended to fly down to in the Bowling Alley on Serial 6. The Panel noted that during the preceding Serial (5), the Ac Comd told the Pilot to fly at 60 kts and 200 ft. The Panel also noted that during the Vehicle Interdiction Serials (2, 3 and 4), the Ac Comd of Lynx 2 suggested both aircraft (Lynx 1 and Lynx 2) descended to straight and level flight between 60 to 70 ft AGL in the Bowling Alley before climbing to 200 ft AGL to conduct the CSW firing. The CVR indicates that these profiles were flown by the Ac Comd. The Panel is unable to determine what height the Pilot anticipated descending to during Serial 6. The Panel considered that if the Pilot intended to descend and subsequently recover the aircraft to fly straight and level at 200 ft AGL then it would be likely that the Ac Comd would make a comment as the aircraft continued to descend below 200 ft AGL; no such comment is audible on the CVR. The Panel considered it more likely that the Pilot was intending to descend and subsequently recover the aircraft to straight and level flight at 50 ft AGL commensurate with the previously flown recoveries during the descents on Serials 2, 3 and 4. Even though the Pilot had not flown the descents during Serials 2, 3 and 4, the Panel considered the profile would have been comfortably within the Pilot's capabilities. Exhibit 1 Witness 3 Exhibit 1

1.4.144 **Simulator Reconstructions**. The Panel conducted 2 separate simulator trials on the Thales Eagle Lynx Simulator at Middle Wallop to try and ascertain the most likely descent methods[70]. The first sortie was flown by a Test Pilot from the Rotary Wing Test and Evaluation Sqn (RWTES). The second sortie was flown by the Panel Aircrew member. Whilst the Panel acknowledges that the simulator is not a precise replication of the Lynx AH Mk 9A performance, the RWTES Test Pilot stated that the simulator modelled the handling characteristics closely and was representative of the aircraft's stability and control for the set parameters. The Panel noted the following generic observations during both simulator sorties: Exhibit 108

a. The Descent Profile would have been visually judged, so that the crew were unlikely to descend with reference to their cockpit instruments.

b. A nose-down attitude between 15 to 25 degrees during the descent led to a significant increase in RoD in a relatively short amount of time (approximately 2000 to 4000 feet per minute (fpm) possible within 5 secs)[71].

c. During high RoD, the Test Pilot naturally raised the collective (increasing power to the engines) and selected a nose-up attitude (with the cyclic) at the bottom of the descent to avoid the ground. He suggested this was inherent 'muscle memory' to helicopter pilots. He also stated how difficult it was to deliberately fly the simulator to impact with the ground as all visual cues led the pilot to automatically reduce the RoD towards the bottom of the descent.

1.4.145 **Aircraft Manoeuvring during the Descent Profile**. The Panel considered that the aircraft descended approximately 400 ft and completed a 70[72] degree left-hand turn from the last assessed Radar position during the final 16 secs of flight. Simulator reconstructions confirmed that the final manoeuvre would most likely have been a combined left turn and descent, as there was insufficient time to conduct the manoeuvres Exhibit 55 Exhibit 1 Exhibit 108

[70] An exact replication was impossible due to the lack of an FDR providing empirical data on the flying control inputs.
[71] The Panel note that the Standard Operating Procedure (SOP) for a tactical descent is for the crew to select a 20 – 25 degree nose-down attitude to achieve a RoD up to 4000 fpm.
[72] The last assessed Radar location indicates the aircraft was on an Easterly heading of 093 degrees. The impact location and debris field indicate the aircraft crashed on a heading of 025 degrees.

sequentially. The Panel is unable to conclude if the Pilot initiated the descent and turn at precisely the same time but believe the two must have been started in close succession. The Panel considered the following:

a. **Airspeed**. The Panel was unable to determine the aircraft speed during the descent, although the last known GS taken from the Radar data indicates the aircraft was travelling at 112 kts immediately prior to the turn and descent. If the Pilot initiated a nose down entry into the descent, to create a low 'G' sensation, then the speed could have increased. The Panel considered the estimated speed during the descent was between 100 to 120 kts. Exhibit 55

b. **Angle of Bank (AoB)**. The Panel was unable to determine the AoB used during the descent. The Panel calculated that to complete the descent and turn in 16 secs at 110 kts would require an average AoB of 26 degrees. The Panel is unable to determine exactly how many secs it took to complete the turn, although analysis of the accident site indicates that on impact, the aircraft was wings-level, with minimal lateral component (i.e. heading straight). This suggests the turn was already complete a few seconds prior to impact. Lynx 2 Ac Comd also indicated that the usual AoB utilised when entering the range was between 30 to 40 degrees. The Panel noted that 35 degrees AoB would have completed the turn in approximately 11 secs, and therefore concluded that an AoB between 30 to 40 degrees was the most likely to have been utilised during the descent. Exhibit 35 Annex A Witness 3

c. **Rate of Descent (RoD)**. The Panel was unable to determine the actual RoD attained during the descent. The Panel calculated that to descend 400 ft in 16 secs would require an average RoD of 1500 fpm. Therefore, allowing for the entry into the descent, and flying control recovery inputs made in the final secs, the aircraft must have exceeded 1500 fpm RoD during the descent. Further, CVR analysis of the RADALT audio warning indicates that the RoD was at least 2000 fpm (see 1.4.152). The Panel used the simulator sorties to identify the maximum realistic RoD achievable during the descent, and noted that a RoD of 2500 fpm could quickly be attained; however, any further increase in RoD proved counter-intuitive to initiate and difficult to recover from within 400 ft. Exceeding 2500 fpm also felt uncomfortable to the crew and challenging for the Pilot to manage whilst controlling the rotor RPM. Spectral (frequency) analysis of the CVR does not indicate any notable increase in rotor RPM during the descent between 16 to 5 secs before impact. Although inconclusive, the lack of increase in rotor RPM suggests the Pilot was easily able to control the RoD. The Panel therefore considered 2000 fpm as the minimum and 2500 fpm as the maximum realistic RoD during the descent. In addition, given that the aircraft had commenced the manoeuvre from the highest point, and therefore had a greater height to lose than on previous serials, the Panel concluded that the RoD was higher on this Serial than that experienced previously. Exhibit 35 Exhibit 1 Exhibit 108 Exhibit 96

1.4.146 **Descent Profile Summary**. The Panel assessed that the Pilot may have intended to fly a low 'G' entry into the descent due to his "*floaty*" statement recorded on the CVR immediately prior to the descent although the Panel is unable to conclude if a low 'G' entry was actually flown. The Panel assess the most likely manoeuvre flown by the Pilot during the Descent Profile was a simultaneous descent and turn, with an airspeed between 100 to 120 kts, using 30 to 40 degrees AoB and between 2000 to 2500 fpm RoD (a greater RoD than experienced on previous serials). The Panel assessed that the Pilot intended to descend into the valley and recover to straight and level flight at 50 ft AGL, consistent with Serials 2, 3 and 4. The CVR provides no evidence that the aircraft was being handled unduly dynamically or that the crew or passengers felt the Descent Profile as potentially dangerous until the Ac Comd's final statement. Nevertheless, the Panel considered that the RoD was higher than those experienced on previous serials. The Panel therefore concluded that **the Descent Profile, specifically that the RoD was higher than those experienced on previous serials, was a Possible Contributory Factor in the accident.**

Recovery Profile

1.4.147 The Panel analysed the Recovery Profile to determine if this could be a factor in the accident. The Lynx Aircrew Training Manual[73] states the recovery from a standard descent should be initiated with Power (collective lever), then Attitude (cyclic stick) then Trim (using the cyclic stick trim). The Manual emphasises that recovery from a more dynamic descent (rapid descent) should be led with a collective input swiftly followed with rearward cyclic input[74]. The Panel noted during the two simulator sorties that even with an aircraft close to MAUM, in a 5500 ft Density Altitude environment, the Lynx AH Mk 9A was very responsive to a collective-led recovery. The Panel assessed that any significant power increase applied by the Pilot would have quickly started to arrest the RoD. In order to analyse the Recovery Profile, the Panel considered two generic methods of arresting the RoD as follows: Exhibit 127 Exhibit 108

a. **Cyclic-Led Recovery**. A cyclic-led recovery involves the Pilot applying rear cyclic to raise the nose of the aircraft. If the aircraft is already in a high power setting (the collective lever is raised), the aircraft would fly similar to a fixed-wing aircraft. If the aircraft is in a low power setting (the collective lever is lowered), the aircraft would 'flare'[75], reducing both airspeed and RoD[76], and may cause an increase in rotor RPM. Without an FDR, the Panel is unable to conclude what the power setting was during the descent.

b. **Collective-Led Recovery**. A collective-led recovery involves the Pilot raising the collective lever to apply more pitch to all main rotor blades. This will result in more lift generated which will reduce the RoD whilst largely maintaining the forward airspeed. This technique is the more common method used (and as described in the Lynx Aircrew Training Manual) and is much more effective at reducing the RoD than a cyclic-led recovery[77].

1.4.148 **Increased Rotor RPM Five Secs Before Impact**. The spectral analysis of the CVR indicates a momentary rise in the rotor RPM[78] approximately five secs before impact. Advice from the RWTES Test Pilot suggested the momentary rise in rotor RPM is consistent with the expected aircraft's response to the Pilot either manoeuvring the aircraft to a wings-level attitude (i.e. rolling right out of the left-hand turn), or possibly 'flaring' the aircraft, or a combination of both. The Panel noted that the Lynx AH Mk 9A EECUs govern rotor RPM very tightly around the set datum. However, it is possible to induce a rotor RPM Exhibit 96 Exhibit 151

[73] The Panel acknowledge that the Lynx Aircrew Training Manual is aimed at students learning to fly the aircraft.
[74] The Panel consider that more experienced crews will be able to recover from a descent leading with either the collective or cyclic once they become familiar with the aircraft, operating environment and inputs required to control the rotor RPM.
[75] AP 3456 states 'to execute a flare the cyclic stick is moved in the opposite direction to that in which the helicopter is moving. The harshness of the flare depends upon how far the stick is moved. The flare will produce a number of effects: Thrust Reversal (decelerating the aircraft), increase in Total Rotor Thrust (aircraft will want to climb) and increase in rotor RPM (unless contained).'
[76] The Panel are unable to determine what power setting was on the collective lever during the descent. This power setting would affect the rate of flare and ability of the aircraft to reduce the RoD.
[77] The Panel note that there is a collective to cyclic interface which induces an automatic, progressively fore-and-aft pitch change when collective pitch is applied. The interlink automatically applies a nose down input when the collective lever is raised. The Panel consider the effect of this interlink is negligible to the Pilot.
[78] A momentary rise of 1.7% in Rotor RPM for 2 to 3 secs when compared to the mean Rotor RPM over the preceding minute.

rise by flaring the aircraft when at a low power setting. This rotor RPM rise can be pre-empted by raising the collective lever. The Panel noted that the rise in rotor RPM was not excessive which suggests to the Panel that the Pilot may have made small inputs on the collective lever. The Panel considered that Lynx 1 had, in effect, caught up with Lynx 2 during the circuit, with separation down to 600 metres or less. The Ac Comd told the Pilot that the separation with Lynx 2 was *"a good distance there"*. The Pilot may therefore have been using a greater degree of flare in order to slow the aircraft down and maintain horizontal separation from Lynx 2 ahead (which was believed to be in the final stages of firing at the targets in low-speed flight), whilst also preparing the aircraft for the forthcoming passenger firing serial. The Panel was unable to accurately determine the cause of the rise in rotor RPM five secs before impact but assessed that it may indicate the Pilot was leading with a cyclic-led recovery with potentially small inputs on the collective, insufficient to arrest the RoD but enough to contain an excessive increase in the rotor RPM. Exhibit 100 Exhibit 1

1.4.149 **Increased Rotor Noise Four to Two Secs Before Impact**. Analysis of the CVR indicates an increase in aircraft rotor noise between four and two secs before impact. Increases in helicopter rotor noise, at the blade passing frequency, is characteristic of all helicopters during certain regimes of flight. The Panel considered the increase in rotor noise is likely to have occurred as a result of the aircraft 'flaring'. The Panel considered that a 'flare' is likely to have decelerated the aircraft from an estimated speed of between 100 to 120 kts, but to what extent is unknown. Accident site analysis is unable to conclude an impact speed but suggests the aircraft was still travelling with significant forward speed. The Panel also considered that a 'flare' would reduce the RoD, although the degree of effectiveness is dependant upon the collective power setting when the 'flare' is initiated. The Panel assessed that the continued rotor noise audible on the CVR until 2 secs before impact suggests the collective power setting was still low and that the collective lever was not raised significantly between four and two secs before impact; a RoD therefore remained. The Panel concluded that the increased rotor noise suggests the Pilot was attempting to reduce airspeed and arrest the RoD with a cyclic-led recovery with potentially small inputs on the collective, insufficient to arrest the RoD but enough to contain an excessive increase in the rotor RPM. Exhibit 1 Annex A

1.4.150 **EECU Data Less Than One Second Before Impact**. The data from the EECUs indicated that the collective lever was raised to make a large power demand to the engines less than one second before impact. Technical analysis provided by the MilAAIB indicated that the large collective input was 96% of the total range of the collective (the analysis is unable to determine the actual torque applied). The Panel considered that aircrew would only apply such a large power demand in an emergency situation as the likely representative torque would exceed the normal aircraft operating limits[79]. The EECU data also indicated a droop in the rotor RPM to 97.93%. The MilAAIB Technical Report considered this rotor RPM consistent with such an immediate and large collective input. The Panel considered the data recorded on the EECUs indicated the crew were taking emergency action to avoid impact with the ground. The Panel also noted: Annex A Annex A

a. The EECU data recorded less than the last second of flight and could not provide an indication of when the collective was first raised. Accident site analysis indicated the aircraft still had a RoD at impact and, as such, the Panel assessed that the Pilot had not started to arrest the RoD with collective any earlier than two secs before impact. Annex A

b. It is possible that the Ac Comd would have tried to make an input to the

[79] The normal twin-engine torque limitation during flight is 115%; the transient (i.e. momentary) limit is 130%.

flying controls by raising the collective in an attempt to arrest the RoD when he recognised the situation and shouted "*Pull up*", approximately one second before impact.

1.4.151 **CVR One to 0.5 Secs Before Impact**. The Panel considered that the Ac Comd's last statement approximately one second before impact suggests the aircraft was still descending with a high RoD. The RADALT audio warning, which can be heard alarming approximately 0.5 secs before impact, supports this. Exhibit 1

1.4.152 **RoD Determined by the RADALT Audio Warning**. The Panel was unable to precisely determine the RoD of the aircraft once the RADALT audio warning sounds 0.5 second before impact. This is due to a finite time lag between the RADALT receiving and computing the data and then transmitting the data to the audio warning. The accuracy of the RADALT will also be affected by the attitude of the aircraft. However, the Panel assessed the RADALT audio warning indicates the aircraft RoD approximately 0.5 secs before impact may have been closer to the maximum realistic RoD of 2500 fpm[80].

1.4.153 **Time Required to Arrest the RoD**. The Panel attempted to identify how quickly the aircraft could recover from a 2000 fpm RoD at 110 kts[81]. The Panel noted that a collective-led recovery using 110% torque required two to three secs to achieve straight and level flight, whereas a cyclic-led recovery typically required three to four secs to achieve straight and level flight, although this depended upon collective power setting applied. Further, an 'emergency' collective-led recovery from 2000 fpm RoD using 130% torque (maximum transient limitation), or even greater, would require one to two seconds to arrest the RoD and recover to straight and level flight. Exhibit 108 Exhibit 252

1.4.154 **Height Required to Arrest the RoD**[82]. The Panel attempted to identify what was the minimum height AGL the aircraft required to arrest a 2000 fpm RoD to avoid impact. The Panel noted that a collective-led recovery using 110% torque required 75 ft to recover, whereas a cyclic-led recovery typically required 150 ft to recover, albeit this depended on the collective power setting applied. The 'emergency' collective-led recovery from 2000 fpm RoD using 130% torque would require between 40 and 50 ft to arrest the RoD and recover to straight and level flight. Therefore, recovery action would need to have been initiated by 50 ft. Exhibit 108 Exhibit 252

1.4.155 **Obscured Forward Visual Cues**. The Panel considered that if the Pilot led the recovery of the RoD with the cyclic, then the aircraft nose would pitch-up and could affect some of the forward visual cues (also covered at 1.4.186 e). The Panel noted that AgustaWestland set a Design Eye Point, which is the point at which the optimal Field Of View is available to the pilot. Pilots can adjust the height of their seat to 6 different settings. The Panel was unable to determine which one of the 6 settings Lynx 1 Pilot (or Ac Comd) had selected and are therefore unable to ascertain the Field Of View available. Field Of View data provided by RWTES highlights that the Pilot's vision is obscured directly below and immediately in front of the nose of the aircraft due to the aircraft design. The Panel considered that the higher the pitch-up angle by Lynx 1, the greater the forward obscuration effect would be. The Panel noted that the Lynx Aircrew Training Manual identifies that all forward visual references are obscured when selecting 17 degrees or more pitch-up angle from straight and level flight. From the accident site analysis, the Exhibit 101 Exhibit 111 Exhibit 101 Exhibit 127

[80] The RADALT audio warning suggests the aircraft was descending through 25 ft AGL approximately 0.5 second before impact. Allowing for a finite delay between the trigger and audio warning, the aircraft could have been at 25 ft somewhere between 0.5 and 0.75 secs before impact. The difference between the two gives a possible RoD between 2000 – 3000 fpm. The Panel have previously concluded that the likely maximum RoD during the descent was 2500 fpm. Therefore, the RADALT indicates the aircraft may have been descending between 2000 – 2500 fpm when the audio warning sounds.
[81] The Panel used 2000 fpm and 110 kts as estimated parameters for the calculations.
[82] Based on simulator reconstructions and Subject Matter Expert advice.

Panel assess that the aircraft had a nose-up attitude of around 5 degrees at impact, although the Panel was unable to determine if this angle was greater or lesser in the few secs leading up to the accident. The Panel concluded that forward visual cues may have been reduced or obscured due to the aircraft pitch-up angle.

1.4.156 **Recovery Profile Summary**. The Panel concluded that the evidence from the spectral analysis of the CVR indicated the Pilot was either manoeuvring the aircraft into a wings-level attitude or starting to 'flare' the aircraft (or a combination of both) approximately five secs before impact. The Panel assessed the increased rotor noise heard on the CVR indicates the Pilot was 'flaring' the aircraft with the cyclic stick approximately four to two secs before impact. The Panel assessed that the likely collective power setting during this 'flare' was low, which resulted in a continued high RoD, but the Panel considered the Pilot may have made minor collective inputs, insufficient to arrest a RoD but enough to contain any excessive rotor RPM.

1.4.157 During the 'flare', the forward visual cues may have become obscured, but to what extent is unknown. The Panel considered that the Pilot applied no significant input into the collective lever 5 – 2 secs before impact and was attempting to reduce airspeed and arrest the RoD with a cyclic-led recovery. EECU data indicates that just less than one second before impact, a large power demand was made (raising the collective lever) which the Panel believed to be 'emergency' collective recovery action, coincident with the Ac Comd shouting "Pull up". However, in order to arrest a 2000 fpm RoD at 110 kts and avoid impact with the ground, an 'emergency' collective-led recovery would need to have been initiated by 50 ft AGL, or between one to two secs prior to impact[83].

1.4.158 The Panel concluded that recovery action was underway; however, **the RoD was not arrested in sufficient time or with sufficient height to prevent impact with the ground and therefore the Recovery Profile was a Contributory Factor in the accident**.

RADALT

1.4.159 The Lynx is fitted with an APN 198 RADALT which provides an accurate indication of the aircraft's height[84] above the ground. This reading is repeated on indicator gauges, fitted to each pilots' instrument panel. The RADALT audio warning 'bug' can be set independently by each pilot rotating the knob on his RADALT gauge; however the audio warning will only sound as the aircraft descends through the higher 'bugged' setting. There is also a Low Height Warning light on the gauge which is triggered as the aircraft descends through the bug setting, although this is not immediately apparent during day flying (the light is more prominent during night flying). The audio warning can be silenced by either pilot pressing the 'AUDIO DISABLE' button, which is situated towards the centre of the instrument panel (see Figure 17). Once the audio warning has been cancelled it will not sound again as the aircraft descends through the lower bug setting, with the system effectively 're-arming' as the aircraft climbs back above the higher bug setting. Exhibit 111

[83] At 2000 fpm RoD, an aircraft will descend 33.3 ft per second.
[84] Up to 5000ft AGL and 45 degrees AOB.

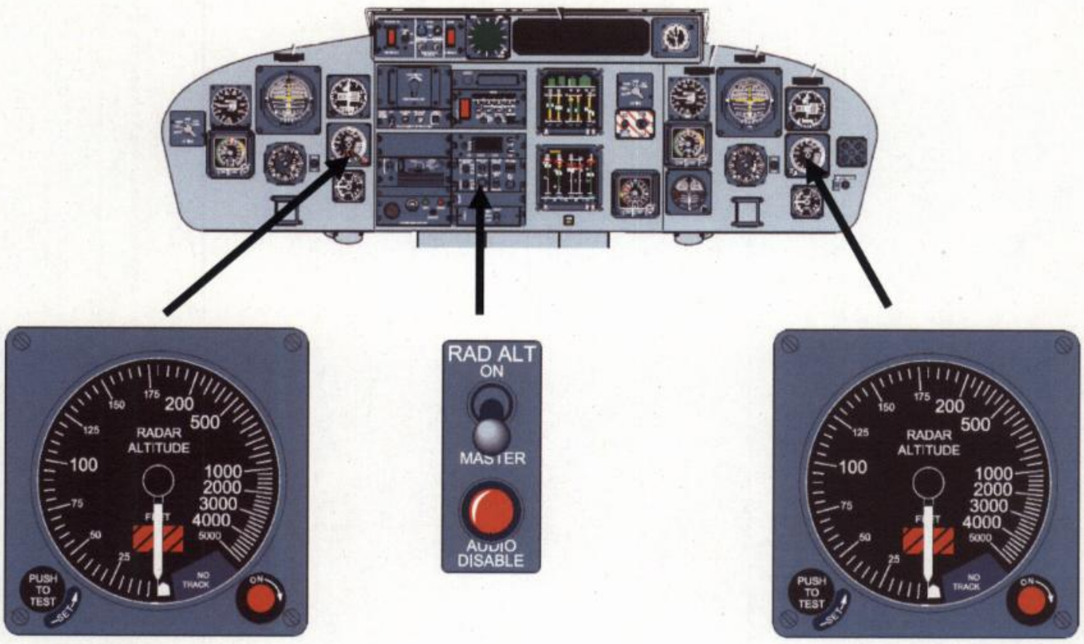

Figure 17 – RADALT Gauges and Indications

1.4.160 When low flying, the audio warning is a safety system which acts as a ground proximity warning device[85]. If the aircraft descends below the required height, the RADALT audio warning should provide the prompt for the handling pilot to apply power and/or adopt a climbing attitude in order to regain an appropriate height. The Lynx Force Standard Operating Procedure (SOP) 21 articulates the RADALT setting procedure in dusty and desert conditions. SOP 21 indicates that the HP keeps hover height set throughout the sortie whilst the NHP sets the RADALT audio warning bug to an appropriate height, commensurate with the stage of flight. Exhibit 112

1.4.161 The JHC Flying Order Book states:

> '*When low flying, the Radar Altimeter is to be used as a ground proximity warning device. When aircrew are required to operate down to the lowest authorised minima, the Aircraft Commander must ensure that the audio warning of one Radar Altimeter is set up to a maximum of 20% below the minimum authorised height.*' Exhibit 113

1.4.162 The authorised minima for this flight was 50 ft AGL and therefore the audio warning should have been set no lower than 40 ft[86]. The only time the audio warning is heard is immediately prior to impact, and evidence from the CVR indicates that the RADALT audio warning was set at 25 ft (i.e. 50% lower than the authorised minima) throughout the flight. Further: there was no discussion of RADALT heights with reference to the 'threat band'[87] during either of the Tac Climb/Descents; RADALT heights were not Exhibit 50 Exhibit 1

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[85] The Lynx AH Mk 9A Release To Service states that neither the RADALT or its associated low height audio warning system should be relied upon as the sole means of ensuring safe separation from the ground.
[86] Had the audio warning been set to 40 ft (as might reasonably be expected at this stage of flight), the Panel believe that this would not provide a timely warning to *initiate* recovery from a high RoD.
[87] The height band between which helicopters are most vulnerable to small arms-type threats; this varies, depending on the theatre.

called-out by the Non-Handling Pilot as a 'talk-down'[88] during the Tac Descents; and the audio warning bug was not re-set during any of the manoeuvres[89]. Indeed, there is very little reference to the RADALT during the 31 mins of flight captured on the CVR, limited to the following occasions:

a. Immediately after take-off, where the Ac Comd confirms that he has 25 ft set. Exhibit 1

b. 22 mins into the CVR recording (approx 20 mins into the flight), where the pilot states "*bug 50 ft*", which is acknowledged by the Ac Comd saying "*Roger*", immediately followed by the Pilot appearing to correct himself by stating "*25 ft set…roger*". Exhibit 1

c. Approximately one minute later the Pilot confirms that he has 25 feet set. Exhibit 1

d. After a further minute, during the Serial 4 VI Profile, the Pilot states "*200 feet*". As the Pilot did not say "*set*" or "*bug*" (as he had on the preceding three occasions), the Panel believes that he is referring to the indicated RADALT height rather than an Audio Warning Bug setting. Exhibit 1

1.4.163 Interviews with the other Lynx crews indicate that the RADALT setting would be expected to be adjusted several times during a sortie to reflect changes in height profiles, in order to provide a warning of ground proximity which was appropriate to that stage of flight. For example, if operating at medium level (i.e. above 2000' AGL following a tac climb), the audio bug should also be set higher in order to warn the crew should the aircraft descend below the desired/required height. Although the majority of this sortie was conducted at low level, other Lynx crews confirmed that RADALT settings should have been discussed and changed during the tac climbs/descents, as well as when flying control is handed between the Ac Comd and Pilot. Witness 21 Witness 2

1.4.164 The Panel considered why the RADALT audio warning was set to 25ft by the crew, as it did not relate to any recognised procedure. Interviews with a number of other Lynx crews, including the Sqn OC, Sqn Qualified Helicopter Instructor (QHI) and 2 pilots who had been crewed with the Ac Comd on previous Air Det detachments, confirmed that that this was not common practice; further, the Sqn OC, QHI and one of the pilots could provide no explanation as to why 25 ft would be set. However, one of the pilots who had been crewed with Lynx 1 Ac Comd on a previous detachment confirmed that Lynx 1 Ac Comd had set 25 ft on the RADALT Audio Warning throughout that detachment, regardless of the stage of flight or authorised minimum height. Witness 2 Witness 21 Witness 18 Witness 23

1.4.165 The Panel also noted that other Sqn aircrew, when questioned during interview, were not immediately familiar with the JHC Regulation regarding RADALT Audio Warning setting; however, all believed it to be either 10 or 20% below the authorised minima, and all were aware of the potential protection afforded by the RADALT audio warning, and the dangers associated with it being set too low to provide an appropriate warning of ground proximity. Further HF analysis of the RADALT setting can be found at 1.4.430. Witness 21 Witness 22 Witness 23

1.4.166 One of the RADALT gauges recovered from the wreckage has the RADALT bug set to 35 feet; however, the severity of the impact and post-crash fire may have had Annex A

[88] The Lynx Aircrew Training Manual states that during rapid descents, pilots should use the RADALT as an aid for warning of ground proximity and the need to initiate recovery action; however, it goes on to say that pilots must be taught to use external visual cues and not rely on the RADALT warning for initiating recovery action.
[89] It would be expected for the RADALT bug to be set to a maximum of 20% below the new operating height at the top of a Tac Climb.

an effect on the gauge and therefore it cannot be confirmed that this was where the audio warning was set at the point of impact.

1.4.167 **RADALT Summary**. The Panel concluded that the RADALT audio warning was set to alarm at 25 ft throughout the sortie (which was 50% below the authorised minimum height for the sortie) and the crew appeared to be making little reference to RADALT heights and bug settings. The RADALT audio warning is heard to alarm on the CVR immediately before the CVR stops, and immediately after the Ac Comd shouts *"Pull up"*.

1.4.168 The Panel acknowledges that the RADALT should not be relied upon as the sole means of ensuring safe separation from the ground. Furthermore, setting the audio warning to 40 ft (the minimum permissible for this flight in accordance with the JHC regulations) would not provide timely warning to *initiate* recovery from a high RoD. However, the RADALT system could have been used to monitor height during the descent to ensure recovery action was initiated at an appropriate level and completed by a safe margin. The Panel therefore concluded that **best use was not being made of the RADALT system and this was a Contributory Factor in the accident.**

1.4.169 The Panel concluded that**,** in accordance with the HF Modelling employed by the Panel (see 1.4.5 b), setting the RADALT audio warning at 25 feet was a **'violation'**, in that it was a deliberate and conscious departure from an established rule or procedure.

1.4.170 The Panel **observed** that, whilst there was questionable knowledge of the precise RADALT setting regulation amongst the Sqn pilots interviewed by the Panel, there was a general consensus that the maximum permitted was 20% below the authorised minima.

1.4.171 **The Panel recommends that Commander JHC should take steps to increase awareness of, and compliance with, RADALT audio warning setting procedures amongst all JHC aircrew.**

Distraction and Attention Focus

1.4.172 The RAF CAM HF Report into the accident highlights that, had the crew been distracted or fixated while descending into the range, it may have increased the likelihood of error, particularly a skill-based error. Although there was no evidence on the CVR of a specific distraction source, distraction may have arisen from a wide variety of sources. Exhibit 1
Although not possible to provide an exhaustive list, the Panel broke this down into three possible categories, namely: internal distraction (to include aspects associated with the aircraft equipment or persons onboard); external distraction; and attention focus. Annex B

1.4.173 **Internal Distraction**. The CVR offers no indication of distraction from within the cabin. The passengers were appropriately restrained in the cabin seating. There were no conversations (from either the passengers or crew) in the 16 secs preceding the accident and no sounds of equipment distraction, such as the CSW being reloaded[90] or movement of items about the cabin. In addition: Exhibit 1

a. **Radios**. There were no radio calls being made by either aircraft at the time of the accident, although air traffic chatter can be heard in the background which was not associated with the Lynx formation. However, this was not uncommon and the radio volume of these transmissions was low. There is a Exhibit 1

[90] The gun had recently been reloaded and had sufficient rounds going into the final serial.

short burst of static interference on one of the radios approximately 3 secs before impact; however, the Panel considered that this was not uncommon and would not have caused a distraction to the Pilot.

b. **Audio Warnings**. There was no evidence of a technical emergency/malfunction, and no warning tone generated from the CWP. Exhibit 1

c. **Communication Ear Plugs (CEPs)**. CEPs are an in-ear communication device, designed to provide augmented hearing protection when worn in conjunction with a flying helmet. JHC mandate the use of CEPs for aircrew, but acknowledge that aircrew can sometimes experience problems associated with the use of CEPs, such as pain and discomfort or devices becoming dislodged in flight. The Panel believes it is likely that the crew were wearing CEPs during the flight, especially the Ac Comd (covered further at 1.4.415). However, the CVR provides no evidence of any crewmember having concerns about, or experiencing difficulties with CEPs during the flight. Similarly, had the crew experienced any problems, it is extremely unlikely that they would have elected to deal with them at a critical stage of flight, i.e. during the descent. Exhibit 85 Exhibit 225 Exhibit 1

The Panel concluded that **internal distraction was not a factor in the accident**.

1.4.174 **External Distraction**. During the accident serial, other than discussion regarding separation from Lynx 2, the CVR offers no evidence of distraction from outside of the aircraft. The position of the sun was to the south and east (i.e. behind and to the right), and therefore not in the crew's eyes. There were no discussions about movements on the ground or sightings of other aircraft except when referring to Lynx 2. Due to the lack of evidence to the contrary, the Panel concluded that **external distraction was not a factor in the accident.**

1.4.175 **Attention Focus**. The CVR does, however, give an indication that the crew of Lynx 1 were focusing their attention to some degree on Lynx 2, as follows:

a. Approximately 53 secs prior to CVR tape ending, the Ac Comd directs the Pilot to *"… watch him, just tip in when you want. We'll give him a decent spacing, then go in behind him. At least sort of 5/600 meters behind him that'll be fine."* Exhibit 1

b. Approximately 25 secs prior to CVR tape ending, the Ac Comd informs the Pilot, "*Okay, our playmate should be off to our left 10 o'clock somewhere" "I'll have a look for him"*. Exhibit 1

c. Approximately 16 secs prior to CVR tape ending, the Ac Comd informs the Pilot, *"that's good distance there, we'll keep that"*. Exhibit 1

The RAF CAM HF Report highlights that when attention is focused on one aspect of the task, fewer attentional resources are available to allocate to other parts of a task. Although the crew were trained to operate in close and tactical formation with other aircraft (and had been doing so throughout this detachment), it is possible that the crew may have been fixated on, or distracted by, the proximity of Lynx 2 ahead. Lynx 2 was likely flying slowly in a CSW firing configuration; conversely, Lynx 1 commenced the descent at approximately 112 kts and the desired 600 metre separation may have been reducing (due to difficulties encountered when visually judging closure speed). Faced with this situation, the Pilot may have adopted a cyclic-led recovery so as to reduce speed and not close on the aircraft ahead. By focusing on the other aircraft during the descent, rather than Annex B attending to other visual cues, the crew's ability to develop an appropriate level of Situation Awareness (SA) during the descent would have been reduced and, as a result, there may have been a delay in detecting the risk of impact with the ground. Annex B

1.4.176 **Distraction and Attention Focus Summary**. Whilst the Panel could not find any evidence of a specific distraction source, the crew had discussed separation from the other aircraft immediately prior to the descent into the range, and the Pilot (and Ac Comd) may have focused attention on the aircraft ahead, leading to a reduced SA during the descent. The Panel concluded that **Attention Focus, specifically concentrating on the aircraft ahead, was a possible Contributory Factor in the accident.**

Spatial Disorientation and Situation Awareness

1.4.177 Spatial Disorientation (SD) is the (mis)understanding of where you are in relation to the world; formally it has been defined as 'failure to sense correctly the position, motion or attitude of his aircraft or of him/herself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical'[91]. SD is usually detected by aircrew when it is noted that the aircraft's flying instruments contradict the individual's perceived position in relation to the earth. Situation Awareness (SA) is the understanding of what is going on around you; formally it has been defined as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future'[92]. If a crew suffers from SD, then there will be a loss of SA as they will have an inaccurate view of their position in relation to the world. A loss of SA can, however, arise from a wider range of sources. By definition, loss of SA is a prerequisite for CFIT to occur. The Panel considered whether SD was a factor in the accident, and what might have affected the pilot's SA during the descent. Exhibit 117 Annex B

1.4.178 **Spatial Disorientation**. There are a number of erroneous sensations and perceptions which fall within the broad definition of SD. SD often occurs: when aircraft are flown solely with reference to the aircraft instruments and the pilot is receiving conflicting sensations as to the aircraft orientation; or as a result of limited external visual cues (e.g. when aircraft are operating in low visibility conditions); or when the pilot experiences a visual illusion arising from the features outside the aircraft. As the weather conditions were excellent, and given the nature of the sortie, it is believed that Lynx 1 was being flown with reference to the visual cues outside the cockpit, backed up by aircraft instruments when required; the final descent and turn flown into the Bowling Alley was almost certainly a visually judged profile. Exhibit 108 Exhibit 1

1.4.179 The Panel flew a one hour sortie on board two Royal Navy Sea King helicopters over the Red Desert and into the Bowling Alley one week after the accident. This sortie offered the Panel a chance to experience the visual cues present in the Bowling Alley, at a comparable time of day and in a similar profile. During the sortie, the Panel could find no obvious ground texture or features which might provide a visual illusion or affect SA. The Panel also spoke with other Air Det aircrew, none of whom thought it possible to experience SD or reduced SA at the Bowling Alley range due to the visual cues available.

1.4.180 A Subject Matter Expert (SME) review was held to review the role of SD and visual illusion during the descent and turn. The review was undertaken by two Aviation Annex B

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[91] Previc, F.H. and Ercoline, W.R. (2004). Spatial Disorientation in Aviation. American Institute of Aeronautics and Astronautics: Reston, VA.

[92] Endsley, M.C. and Garland, D.J. (2000). Situation Awareness Analysis and Measurement. Lawrence Erlbaum Associates: Mahwah, NJ.

Medicine Officers and facilitated by the RAF CAM HF Specialist and the SI Panel Aircrew Member. One of the Aviation Medicine Officers was an experienced aviation medicine practitioner from RAF CAM, the other was a USAF Exchange Officer based with RAF CAM, who also approached the USAF Flight Safety Centre to ascertain if their historic reports shared any common themes of disorientation with the accident. The review examined the evidence collected by the Panel related to SD and considered the scope for disorientation and/or visual illusion to occur. It concluded that false sensations of motion were unlikely to have contributed to the accident, although aspects of the visual environment could have affected the Crew's SA and increased the risk of misjudgement (covered further at 1.4.186).

1.4.181 The Panel considered whether the crew were using the Head Up Display (HUD) and whether this may have caused SD. HUD is a helmet mounted, high resolution, lightweight display unit that projects the aircraft flight and mission data in front of the pilot's and co-pilot's right eye (Figure 18). Whilst the Panel has been unable to ascertain if the crew were using the HUD during the sortie, it is noted that only the Pilot had signed out and received a HUD prior to the flight[93]. There are two notes[94] contained within the Lynx AH Mk 9A Aircrew Manual regarding use of the HUD, as follows:

Exhibit 111

Exhibit 119

a. When wearing the HUD, the Field of View is slightly reduced.

b. When the head is tilted laterally, or turned to the side, the visual horizon will become misaligned with the horizon symbology.

Exhibit 111

Figure 18 – Alpha 928 Helmet

1.4.182 The Panel note that the Lynx AH Mk 7 Service Deviation Report assessed the impact on the User when wearing Helmet Mounted Display (HMD - now referred to as HUD). The Report stated that the User who trialled the HMD experienced no apparent effect on their vision, with no feelings of nausea, dizziness or disorientation. The User also reported that their overall situational awareness increased whilst their workload decreased due to the provision of flight data information in front of their eye. The HMD was considered an enhancing feature whilst visual fatigue and physiological effects were graded satisfactory.

Exhibit 101

[93] The ground-crew, who were the last to see the crew and passengers of Lynx 1, were unable to confirm the use of HUD.
[94] Notes are inserted (in the Aircrew Manual) to clarify the reason for a procedure or to give information which, while not essential to the understanding of the subject, is useful to the reader.

1.4.183 HUD is further referred to in the Lynx AH Mk 7 RTS, which contains the following Warning[95]: Exhibit 120

> 'When the head is tilted laterally, or turned to the side, the visual horizon will become misaligned with the horizon symbology. This may be momentarily disorientating and can be immediately rectified by readjusting the head position or by concentrating solely on external cues.'

1.4.184 The Panel noted that this Warning does not appear in the Lynx AH Mk 9A RTS. Advice sought from RWTES suggests the Lynx AH Mk 9A RTS was compiled using read-across data from the Lynx AH Mk 7 RTS where appropriate, but updated to take into account extra trials work on the upgrade programme. For the HUD, this entailed an additional report from the RAF Centre of Aviation Medicine and a further, independent flight trial conducted by a Test Pilot. RWTES suggested that either the conclusion from the second flight trial did not match the same findings as the original Lynx AH Mk 7 HUD trial, or the disorientating effect was so momentary as to not be worthy of a Warning in the Lynx AH Mk9A RTS. However, the Panel could find no firm evidence to confirm why the Warning was not taken across to the Lynx AH Mk 9A RTS. Exhibit 92 Exhibit 97

1.4.185 Notwithstanding the warnings with regard to potential momentary disorientation when wearing the HUD, the Panel could find no evidence to suggest that the Pilot was experiencing SD due to the HUD. The Panel therefore concluded that the Pilot did not suffer from SD due to either: false perceptions of motion; a visual illusion caused by the features outside the aircraft; or from wearing the HUD.

1.4.186 **Situation Awareness**. The Panel considered whether the Crew's perception of visual cues could have affected the crew's SA. SA can be affected when visibility is impaired, and the appearance of the external visual world can be difficult to interpret when visual cues are sparse or unfamiliar, or if there is a paucity of external cues. In particular, during flight over featureless terrain (such as sand, snow, or over a waveless sea), the judgement of height is made more difficult. Height perception can also be affected when ground features are not of the expected size (such as the size of trees and shrubs, or even surface texture), or when there is a slope on the ground. The SME review concluded that aspects of the visual environment could have affected the Crew's SA and increased the risk of misjudgement. The Panel considered the following: Exhibit 156

a. **Reduced Visibility**. The Panel considered the weather conditions on the day as excellent with very good visibility, clear sky, light winds and no precipitation. The crew of Lynx 2 did not report any haze or any other obscurants to slant visibility. Similarly, the position of the sun was to the south east and not in the field of view as the aircraft descended and turned north (left) into the Bowling Alley; similarly, there were no shadows cast over the area of the descent. Lynx 1 was travelling too fast to generate 'brown out' due to recirculating dust; similarly, Lynx 2 ahead was too high to generate any recirculating dust. Reduced visibility was discounted as a factor.

b. **Ground Texture and Features**. The Panel assessed that the descent to the range would have been flown visually with the crew primarily using external visual cues such as ground texture and features, rather than their instruments, to judge RoD and height above the ground, albeit some cross-reference to instruments would be expected. Desert environments, such as

[95] Warnings are inserted (in the Aircrew Manual) only when the serious consequences of not following a certain procedure may result in the loss of aircraft and/or death or injury.

the Bowling Alley Range, have few terrain features. The Range included rocks and vegetation. However, there was little variation in the size and nature of these visual features, and there was potential for the scale of those features to be misinterpreted[96]. As a result, the visual cues to height and RoD from the valley floor may have been limited in comparison to a richer visual environment. However, the Red Desert escarpment to the west and the rocky outcrop to the east would have provided some additional visual cues to assist with perception of height and RoD.

c. **Slope of the Terrain**. The valley floor is at its highest at the southern end, with elevation reducing by approximately 50 ft over 5 kms towards the northern end. The Panel considered this slope to be negligible and unlikely to be distinguishable to the crew or to offer any illusion to the crew of Lynx 1. The previous 5 descents into the Bowling Alley (serials 1 – 5) would have given the crew of Lynx 1 a good appreciation and understanding of the limited gradient of the terrain. The slope was therefore discounted as a factor which may have affected the Crew's SA.

d. **Circuit Profile**. The Panel considered that, although the circuit profile differed from previous ones in that the base-leg was commenced earlier (and therefore required more height to be lost during the descent), the crew had been operating in the same area for approximately 20 mins, and had also operated within the valley on a previous sortie 19 days earlier. Further, the Pilot was considered by the Panel to be familiar with the operating environment, having been in Theatre for approximately 2 months. Exhibit 129

e. **Field of View**. As discussed at 1.4.155, the Panel considered that the Pilot likely led the recovery of the RoD with the cyclic, causing the aircraft nose to pitch-up and possibly obscuring some of the forward visual cues. Whilst unable to determine what, if any, obscuration of forward visual cues occurred, the Panel considered that this may have had an effect on the Pilot's SA in the final stages of the descent.

1.4.187 **Spatial Disorientation and Situation Awareness Summary**. The Panel considered it most unlikely that the crew experienced SD during the final descent and turn of the aircraft into the Bowling Alley. However, the Panel acknowledged that the terrain of the valley floor was such that the Pilot may have experienced increased difficulty in visually judging his height above the ground, and this effect may have been exacerbated by the nose-up attitude of the aircraft in the latter stages, possibly affecting his initiation of the recovery from the descent. The Panel therefore concluded that **loss of SA with respect to height and rate of closure with the ground during the descent was a Contributory Factor.**

1.4.188 **The Panel recommends that the Army Release To Service Authority should review the wording in the Lynx AH Mk 7 and Mk 9A RTSs regarding the potential for disorientation when using the HUD to ensure consistency (if appropriate).**

Fatigue

1.4.189 The Panel considered potential fatigue implications for the accident,

[96] Davis, J.R., Johnson, R., Stepenek, J. and Fogarty, J.A. (2008). Fundamentals of Aerospace Medicine, Forth Edition. Lippincott, Williams, and Wilkins. Chapter 6: Spatial Orientation in Flight.

dividing this into: Crew Fatigue (that experienced by the crew on the day); Individual Fatigue (particular to any individual on the day); and Cumulative Fatigue (looking at the longer term effects which any of the crew members may have been experiencing).

1.4.190 **Crew Fatigue**. Although MAA Regulations state that *'Aircrew must accept their share of responsibility in the avoidance of fatigue'*, the JHC Flying Order Book defines specific regulations regarding fatigue management, including mandated Crew Duty Periods (CDP), Crew Rest Periods (CRP) and maximum flying hrs within specified periods[97], as follows: Exhibit 109

a. **Crew Duty Period**. CDP is defined as the time from first reporting for duty to the time when aircraft shutdown checks have been completed. The JHC Flying Order Book states that the maximum CDP without an operational extension is 14 hrs; however, as a guide, the CDP should not normally exceed 12 hrs whenever possible. Exhibit 114

b. **Crew Rest Periods**. The JHC Flying Order Book defines CRP as the time allocated for rest, specifically that eight hrs must be available for uninterrupted sleep. Supervisors are to ensure that flight briefings/debriefings, administrative duties, and other miscellaneous tasks do not take place during the CRP. Exhibit 114

c. **Maximum Flying Hrs.** The JHC Flying Order Book stipulates the maximum flying hrs to manage fatigue, which all of the crew were within (Table 3). Exhibit 114

Fatigue Management Regulations		Lynx 1 Crew Flying Hrs			
Time	Hrs Limit		Ac Comd	Pilot	Acmn
Within any CDP	10 hrs	Preceding 24 hrs	3:30 hrs	3:30 hrs	3:30 hrs
In any 30 consecutive days	100 hrs	Preceding 30 days	38:10 hrs	56:50 hrs	57:25 hrs
In any 3 consecutive months	250 hrs	Preceding 3 Months	64:50 hrs	79:05 hrs	101:15 hrs
In any one calendar year	850 hrs	Preceding Year	287:35 hrs	234:50 hrs	242:00 hrs

Exhibit 16
Exhibit 22
Exhibit 26

Table 3 – JHC Regulated Maximum Flying Hrs vs Lynx 1 Crew Flying Hrs

1.4.191 The Panel found that CDPs and CRPs were being adhered to. Further, in the two weeks preceding the accident, the crew had been on a day cycle, flying between 40 mins and 3 hrs 30 mins per day, with only one day flying after 1900 hrs (to 2330 hrs on the 23 April, three days prior to the accident). Over this two week period, the authorisation sheets indicate that the crew flew on 11 of the 14 days, with the previous non-flying day being on the 24 April 14, two days prior to the accident. Considering the crew's recent working pattern, flying rate and adherence to CDP/CRP limits, the Panel concluded that **Crew Fatigue was not a Factor in the accident.** Exhibit 129

1.4.192 **Individual Fatigue**. On the day of the accident, it was reported that the crew rose at approximately 0800 hrs to give time for breakfast ahead of the 0900 hrs briefing.

[97] The CDP and CRP limits figures are designed for use by acclimatised and properly rested crews .

The Pilot of Lynx 1 was reported to have told his room mate (Lynx 2 Pilot, also his Sqn OC), that he had slept badly the night before, but indicated that he was fine. It is known that the Pilot had been up late on the evening prior to the accident, and had exchanged messages with his family. The last message by the Pilot was at 2215 hrs UK time (0145 hrs Afghanistan time), stating that it was late and he needed some sleep. Given that the crews rose at approximately 0800 hrs, this would have provided a maximum window of 6 hrs 15 mins for the Pilot to sleep. Witness 2 Exhibit 13

1.4.193 The RAF CAM HF Report highlights that, for the majority of people, sleeping for less than six hrs a night may result in fatigue, leading to reduced alertness and increased risk of error. That said, there are individual differences in the amount of sleep required per person. As a result, some people can cope with six hrs sleep or less per night. Anecdotally, the Pilot was someone who did not require much sleep, and regularly had circa six hrs per night. This was confirmed by the Pilot's room mate, who stated that he regularly went to sleep before the Pilot, although they tended to rise at a similar time. Annex B Exhibit 13 Witness 2

1.4.194 From the CVR, the Panel believed the that crew were in good spirits with no indication that the Pilot was suffering the effects of fatigue. The sortie content was relatively dynamic, so the Pilot's arousal levels might reasonably be expected to have been high. There is no evidence of yawning or delayed responses to discussions or questions; however, the Pilot was silent in the final 16 secs captured on the CVR, and he makes no acknowledgement of the impending impact with the ground. The Panel considered that, whilst unusual at this stage of flight, this is not the only time on the CVR to have a period of silence and was therefore not necessarily fatigue-related or indicative of reduced alertness. Exhibit 1

1.4.195 There is no evidence to indicate that the Ac Comd or Acmn experienced individual fatigue on the day. However, there is limited evidence to suggest the Pilot may have been suffering from the effects of fatigue at the time of the accident, namely that he indicated that he had slept badly. The Panel therefore concluded that **the Pilot's potential individual fatigue, due to his poor night's sleep the previous night, was a Possible Contributory Factor in the accident.** Witness 2

1.4.196 **Cumulative Fatigue**. Whilst the Sqn's Task versus Manpower Resource is covered in more detail later in this Report (1.4.404), the Panel considered whether there were any longer term effects which may have led to cumulative fatigue amongst the crew. The Panel noted that the Sqn was established for 10 crews[98] but had been resourced to only 7.5 crews for some period of time. When viewed against the Sqn's considerable operational and exercise commitments, this meant that the crews were working hard, with more frequent deployments and spending more time away from home (measured in Separated Service (SS), i.e. nights away from home). This also led to certain aircrew double-hatting, i.e. covering 2 or more roles. However, the fatigue implications of the high workload should be balanced by considering the amount of leave/stand down being taken. Exhibit 214 Exhibit 219

a. **Ac Comd**. In the past 30 months, the Ac Comd had a SS of 349 (effectively, a year of the preceding 2½ years had been spent away from home). In the 12 months preceding the accident, he had taken 40 days of leave/stand down (where five days equates to one week), totalling eight weeks. However, he had managed little time-off in the preceding six months or so, having been on deployment in Afghanistan between September-October 2013 and having spent the majority of the Christmas/New Year period holding a short-notice Standby commitment. He deployed on a three week overseas Exhibit 218 Exhibit 116

[98] i.e. 20 pilots and 10 acmn.

jungle environment Exercise in January 14 and, although he had a two week period of leave in February 2014, this was interrupted by him going to work to fly a currency sortie and attend his annual medical check. He then again deployed on overseas exercise in March 2014, this time for desert environmental training. This detachment was cut short as the Ac Comd was required to deploy to Afghanistan on operations, [redacted]. The short-notice deployment offered little opportunity for pre-detachment leave. The Panel noted that the Ac Comd had also volunteered to deploy at short-notice on his previous Air Det deployment (September – October 2013) to provide sickness cover. The Panel considered that over the previous six months the Ac Comd had been subject to considerable operational and exercise commitments whilst taking relatively little leave/stand down; the Panel therefore considered that the Ac Comd had the potential to suffer the effects of Cumulative fatigue. However, due to the relatively low workload experienced since his arrival in Theatre, the Panel concluded that there was no evidence to suggest that his potential cumulative fatigue was a factor in this accident. Exhibit 16 Witness 3 Witness 22

b. **Pilot**. In the preceding 30 months, the Pilot had a SS of 316. Since joining the Unit in October 13, the Pilot had conducted a period of role-specific flying training, before deploying on the three week overseas jungle Exercise in January 2014. The Pilot had taken 19 days of leave since October 13, six days of which were immediately prior to this operational deployment. The Panel considered that the Pilot's recent commitments, when considered against the leave taken, were such that he was unlikely to have been suffering from the effects of cumulative fatigue. Exhibit 218 Exhibit 116

c. **Acmn**. In the preceding 30 months, the Acmn had a SS of 326. In the previous six months, he had spent a month on overseas desert environment training Exercise (September to October 2013), approximately two weeks on forward-based Standby, and had deployed on the overseas jungle Exercise in January 2014 for three weeks. In the 12 months preceding the accident, he had taken 44 days of leave, nine days of which were immediately prior to this detachment. He had also taken 11 days of leave over the Christmas/New Year period, although this was interrupted by the requirement to spend two days holding a Standby commitment. The Panel considered that the Acmn's recent commitments, when considered against the leave taken, were such that he was unlikely to have been suffering from the effects of cumulative fatigue. Exhibit 218 Exhibit 26 Exhibit 116

1.4.197 The Panel concluded that the crews were working hard and spending a considerable amount of time away from home. As a result, the conditions were set such that cumulative fatigue could become a factor on the Sqn, particularly for the longer serving members of the Sqn. That said, there was also a perception that the workload was significantly higher in the UK than when on deployment. Similarly, personnel had been able to take a reasonable amount of leave and stand-down, thus providing some respite from the workload.

1.4.198 **Fatigue Summary.** The Panel could find no evidence to indicate that the crew were suffering from Crew fatigue, and the Ac Comd's potential cumulative fatigue was not considered to be a Factor in the accident. The Panel concluded that **the Pilot's potential individual fatigue, due to his poor night's sleep the previous night, was a Possible Contributory Factor.**

Time Pressure

1.4.199 The CVR indicates that the crew may have perceived some time pressure in the latter stages of the sortie, evident in the Ac Comd's radio transmissions to Lynx 2 and direction to the Pilot, as follows:

a. **Approximately Seven Mins before the accident**. Lynx 1 Ac Comd transmits to Lynx 2 "*If you're happy, going to chin-off the next serial*[99] *and go for the guys in the rear on some passing shoots, just to save hrs.*" Exhibit 1

b. **98 Secs Before the accident**. Lynx 1 Ac Comd to Lynx 1 Pilot "*We'll come back in half way down the range*". Exhibit 1

c. **62 Secs Before the accident**. "*We'll give him (Lynx 2) a decent spacing, then go in behind him. At least sort of 5 to 600 metres behind him that'll be fine. As long as he doesn't stop in the hover*". Exhibit 1

d. **30 Secs Before the accident**. "*We'll tip in early… save some flying time.*" Exhibit 1

The Panel considered that 'tipping-in early' would itself lead to time pressure, as it would reduce time available to set up for the passenger firing of the CSW. The Panel considered what other factors may may have led to a perceived time pressure.

1.4.200 **Afternoon Enablement Sortie**. There was an enablement[100] task for both crews to be conducted in the afternoon of the 26 April 2014; the crew intended to return from the training sortie, take lunch, then re-brief prior to the task. The Panel considered there was sufficient time available between the planned completion of the morning live-firing serials at the Bowling Alley (approximately 1100 hrs) and the programmed take-off time for the afternoon enablement task (1400 hrs) to ensure the crews did not feel rushed or perceive any time pressure. Witness 3

1.4.201 **B3 Scheduled Maintenance**. The Lynx Engineering Det were planning to conduct a 'B3' scheduled (600 hourly) maintenance on one of the other Lynx aircraft later that week. This work could take up to a week to complete, during which the Lynx Det would only have two aircraft to provide two task lines. Therefore, the crew may have felt some pressure to preserve available flying hrs on the remaining two aircraft. The Panel noted that it is not uncommon to conduct a B3 servicing whilst deployed. The Det Aircraft Engineering Officer and the Lynx 1 Ac Comd discussed airframe hrs immediately prior to the accident sortie. The Panel considered the discussion may have prompted the Ac Comd to try to fly the live-firing serials in the most expeditious manner possible. Witness 3 Witness 3

1.4.202 **Passenger B Allowed to Fire a Second Time**. Lynx 1 had two passengers whilst Lynx 2 only had one. Therefore, Lynx 1 could reasonably expect to take twice as long as Lynx 2 to complete passenger firing. The Panel considered the ad hoc decision by Lynx 1 Ac Comd to allow Passenger B a second chance to fire the CSW would increase the time required for both passengers on board Lynx 1 to fire. The Panel considered that this may have led to a perceived time pressure. Exhibit 1

1.4.203 **Inter-Aircraft Deconfliction**. The Panel considered that once the VI training serials were complete and the two aircraft became separated for individual CSW live firing,

[99] Transmitted after Serial 4, the "next serial" presumably referring to further training at Rocket Range, approximately 4km to the South.
[100] A routine task, usually involving the movement of personnel or freight.

the deconfliction between the aircraft became more difficult. There is evidence on the CVR that the crew of Lynx 1 was unable to see Lynx 2 for significant periods of the final two serials. The Panel noted there were no radio calls made between the aircraft during the final two serials and deconfliction was only achieved by visual confirmation and time separation. The CVR suggests Lynx 1 lost visual contact with Lynx 2 for approximately 45 secs during the downwind leg prior to Serial 6, regaining visual contact between 25 secs and 16 secs before the accident: Exhibit 1

a. **25 Secs Before the Accident**. *"Okay, our playmate (Lynx 2) should be off to our left 10 o'clock somewhere. I'll have a look for him."* Exhibit 1

b. **16 Secs Before the Accident**. *"Cool, that's a good distance there, we'll keep that."* Exhibit 1

Radar data indicates that the separation between the two aircraft reduced during the Final Circuit, as Lynx 1 had caught-up with Lynx 2. The Ac Comd may have decided to cut short the final circuit in order to ascertain Lynx 2's exact location, or as a result of the extra serials required due to the additional passenger firing requirements; nevertheless, the late sighting of Lynx 2 meant that Lynx 1 had limited time available to ensure deconfliction from the aircraft ahead. Exhibit 100

1.4.204 **Time Pressure Summary**. The Panel considered the combination of: upcoming pressure on aircraft availability; Lynx 1 having twice the number of passengers as Lynx 2; allowing Passenger B a second opportunity to fire the CSW could have led to a perceived, self-induced time pressure. This time pressure manifested itself in: a shorter pattern circuit, leading to a steeper descent profile (and therefore higher RoD) to those used on previous circuits; and potentially rapid closure with Lynx 2 who was still conducting CSW firing, causing the Pilot to focus his attention on the aircraft ahead during the descent (itself a possible contributory factor in the accident). The Panel therefore concluded that **self-induced time pressure was a Possible Contributory Factor in the accident**.

Planning

1.4.205 The Panel considered whether pre-sortie planning was a factor in the accident.

1.4.206 **Planning Requirements**. The Panel witnessed the shared planning facilities at Air Ops and considered them to be good, offering sufficient resources and tools to fulfil the crews' requirements. The Panel considered that, on any given sortie, the planning and authorisation process could reasonably expect to include:

a. Planning – in the dedicated planning rooms available

b. Crew brief – in a suitable location

c. Outbrief – in Air Ops

d. Authorisation – at a suitable location, usually Air Ops

1.4.207 **Responsibilities of the Ac Comd**. The MAA Regulatory Publication details the responsibilities of the Ac Comd and specifies that the Ac Comd should ensure that all '*necessary flight and fuel planning has been carried out*'. There is no specific policy on what should be covered during the planning for any given sortie. The Panel considered that, as a bare minimum, 'necessary' planning should cover the key aspects of the sortie, Exhibit 128 including: weather; performance; sortie aims/task; routes (including heights/headings/speeds etc); timings; passengers; deconfliction; freight; fuel; bookings; and crew responsibilities.

1.4.208 **Planning on 26 April 2014**. There was no dedicated planning conducted for the sortie on the morning of 26 April 2014. The crews met at Air Ops at 0900 hrs and immediately conducted the outbrief before driving to the flight line and taking off at 1000 hrs. The Panel balance this lack of planning with the nature of the sortie. The Panel noted that the aircrew had flown together as constituted crews for the previous three weeks and would need little time to discuss a routine sortie. Equally, the nature of the task was relatively straightforward and followed the Vehicle Interdiction (VI) SOP, which was well-rehearsed and known by the crew. Also, the Air Det carried out a full set of VI orders each week involving key personnel from across the chain of command and aircrew, in order to ensure they were prepared for short-notice tasking. The Panel considered that little discussion would have been required to cover the key features of the VI.

Witness 3
Exhibit 129

1.4.209 **Third Passenger Added**. The Panel received conflicting witness statements to indicate when the third passenger, who boarded Lynx 2, was added to the CSW sortie. (covered further at 1.4.270 b), providing further indication that aspects of the sortie planning were not as robust as they could have been. However, the Panel acknowledge the dynamic nature of aviation operations often requires short-notice changes to passengers and freight; as such, the increase from 2 to 3 passengers would have required minimal additional planning.

Exhibit 210
Exhibit 130

1.4.210 **Passenger Firing the CSW**. The Panel noted that there was no dedicated planning for, or discussion during the outbrief of, the passenger firing of the CSW. Further analysis of passenger firing of the CSW is conducted later in this Report at 1.4.281.

Exhibit 130

1.4.211 **Planning Summary**. The Panel assessed that the planning conducted by the aircrew for the VI Serials was minimal but acceptable, given that they were following well rehearsed SOP on a well known range. However, the Panel considered that the passenger firing of the CSW should have been planned and discussed during the outbrief. This would have identified the number of passengers flying and the sequence required to allow the passengers to fire, potentially removing some of the time pressure. Nevertheless, the Panel concluded that the planning for the sortie, whilst not as thorough as it might have been, did not have an impact on the outcome and therefore **planning was not a factor in the accident.**

Briefing

1.4.212 Both MAA Regulations and JHC Flying Order Book mandate that '*Briefing of aircrew before flight, and subsequent debriefing on completion of the sortie, is essential*' and should be *'conducted in a thorough and professional manner.'* Whilst no formal brief took place, the sortie contents were discussed at the outbrief which took place at 0900 hrs on the day in Air Ops, at which Lynx 1 Ac Comd ran through the checklist; all crew members and the two passengers from Lynx 1 were present at the outbrief, which was witnessed by the Deputy Air Det Comd. The Panel considered whether the outbrief met the MAA and JHC regulated requirements to brief before flight, and whether this had any bearing on the final outcome.

Exhibit 131
Exhibit 132
Witness 3
Witness 5

1.4.213 When analysing whether any briefing had been conducted in a thorough and professional manner, the Panel considered the relatively straightforward nature of the training, and the fact that the crews were constituted and therefore familiar with each other. The crews were also flying a familiar aircraft, in a familiar area, to a range where they had previously conducted a similar profile sortie 19 days earlier; further, crews conducted a full set of VI Orders on a weekly basis, to ensure they were best prepared in the event of a short notice mission. It is also known that some elements of the sortie content had been informally discussed when some of the crew, and the passenger from Lynx 2, were socialising on the evening preceding the accident. However, there was no mention of passenger firing, nor of the third passenger, during the outbrief. The Panel also found inconsistencies in the Lynx 2 Crew's understanding of the training planned to be conducted at Rocket Range. The lack of detailed briefing was further supported by some light-hearted 'banter' between the Ac Comd and Pilot in the sortie during a discussion about radios and frequencies. Similarly, upon walking to his aircraft, Lynx 2 Ac Comd expressed surprise at the passenger he would be carrying, a view shared by the Lynx 2 Acmn. In order for the brief to be considered thorough, the Panel considered that these details should have been clarified at the brief.

Exhibit 130
Exhibit 52
Exhibit 1
Witness 3
Exhibit 163

1.4.214 The Panel considered whether the level of briefing had an effect on the outcome of the accident. Despite the relatively straight-forward nature of the training and the many common features which might have negated any requirement to be covered during briefing, the Panel considered that the passenger flying and, in particular, passenger firing should have been discussed in more detail. However, at the time of the outbrief there were only 2 passengers confirmed to be flying on this sortie, which would likely have been split one per aircraft. The change in the passenger numbers only occurred once the crews arrived at Line Ops, where the extra passenger was added. Although the passenger firing had not been planned or mentioned during the outbrief, the extra passenger would effectively lead to extra firing serials for Lynx 1; however, as there was no further briefing to reflect the change, this ultimately contributed to the time-pressure previously discussed (at 1.4.211).

Exhibit 130
Witness 5

1.4.215 **Supervision of Briefings**. The JHC Flying Order Book states that '*Supervisors should conduct periodic checks of the quality and content of aircrew flight planning and briefings'.* The Deputy Air Det Comd was present for the outbrief, and could therefore be considered to be checking the quality and content of the briefing; however, the Panel concluded that the Deputy Air Det Comd was not suitably qualified or experienced to effectively complete this duty (covered later at 1.4.226, 1.4.249 e and 1.4.251). That said, both the Sqn OC and 2iC (Lynx 2 Crew) were present at the outbrief, and the Deputy Air Det Comd might reasonably expect them to have raised any concerns, if they had any, with regard to the sortie.

Exhibit 132
Witness 5

1.4.216 **Briefing Summary**. The Panel considered that crew briefing was fairly minimal, just covering the mandated outbrief requirements. It wasn't thorough because the passenger firing elements weren't covered at all, and the addition of the third passenger wasn't discussed until later (if at all); it was also a missed opportunity to clarify firing profiles and deconfliction measures. In mitigation, the Panel considered: the routine nature of the sortie; the weekly VI Orders; Lynx aircrew were operating as constituted crews; and the familiar area. However, the lack of any detailed briefing of the Passenger firing of the CSW may have contributed to the self-induced Time Pressure. Further, the crews' full intentions (passenger firing and carriage of third passenger) were not exposed to the Deputy Air Det Comd, who was the senior supervisor present and also acted as Approving Officer for the carriage of passengers. Ultimately, the briefing was not conducted in as thorough a manner as it could have been, and this was a missed opportunity for the aims of the sortie to be scrutinised and challenged. Whilst the Panel did not consider this to be a factor in this accident, the Panel felt a lack of detailed briefing could cause or contribute to future accidents. Therefore, the Panel concluded that **the lack of detailed briefing was an Other Factor.**

Authorisation

1.4.217 The Panel considered whether the sortie was appropriately authorised, and whether there had been appropriate delegation of powers of authorisation, to determine whether this was a factor in the accident.

1.4.218 Authorisation is the authority given to an ac comd to fly a particular aircraft on a specified mission or duty. The key role of the authoriser is to have awareness of potential problems and eliminate, reduce or control any hazards through risk management and implementation of suitable controls prior to authorising the flight. In order to authorise a sortie, an individual (usually but not exclusively with appropriate type qualification or experience) needs to have been delegated appropriate powers of Authorisation. MAA Regulations also state that authorisers are to have attended an appropriate training course (e.g. Flying Authoriser's Course), which carries a currency of 5 years. Exhibit 133 Exhibit 133

1.4.219 **Delegation of Powers of Authorisation**. The JHC Flying Order Book contains a list of appointments who are empowered to authorise flights and further delegate those powers within their command. One of these appointments was the Station Commander (Stn Cdr), RAF Odiham (the home-base of the Sqn); in this capacity, and with the agreement of the Delivery Duty Holder (see 1.4.236 c), he delegated powers of authorisation to appropriately qualified and experienced Sqn aircrew. Commander Joint Aviation Group (COMJAG – see Part 1.4.249 a) was also one of the appointments, and in the JAG Flying Order Book[101] he further delegated Air Det Powers of Authorisation to the Air Det Comd and *'named aircrew'* within the Air Det Comd's command. The Air Det Flying Order Book [102] contained no further delegation of Powers of Authorisation. The Panel sought to clarify how the Deputy Air Det Comd and Air Adviser[103] had been awarded Powers of Authorisation. The only evidence the Panel could find was in the JHC HQ issued Capability Directive for the Air Det, which stated that only '*Flt Leads[104], the Air Det Comd or his nominated deputy*' were to authorise mission sorties unless there were overriding operational reasons not to. The Panel was of the opinion that this order was intended to provide constraints as to who could authorise sorties, in particular *mission sorties*, rather than an express delegation of Powers of Authorisation. The Panel also noted that the Directive referred to a '*nominated deputy*' rather than specifically to either '*named aircrew*' or the appointments of Deputy Air Det Comd or Air Adviser. Exhibit 134 Exhibit 135 Exhibit 50 Exhibit 6

1.4.220 **JHC Authorisation Policy**. The JHC Flying Order Book states that it is JHC policy to have independent authorisation[105] wherever possible, and that Delivery Duty Holder/Flying Unit Commanders (see 1.4.236, 1.4.241 and 1.4.242) must question the need for any self-authorisation[106] and be satisfied that independent authorisation is not practicable. The Air Det Flying Order Book, which had been signed by the previous Air Det Comd, echoed the JHC policy by stating that all flights conducted by the Air Det were to be approved and authorised by the Air Det Comd, Deputy Air Det Comd or Air Adviser. However, it contained the following clause regarding self authorisation for missions: Exhibit 134 Exhibit 50

> *'Individual Det Comds, Flt Leads and aircraft Capts with written, delegated powers of authorisation from their Sqn OCs, may, <u>in extremis</u>, self authorise their missions once they are approved.'*

[101] Aviation Regulations pertinent to JHC aircraft operating in Afghanistan.
[102] Aviation Regulations pertinent to the Air Det.
[103] The Air Det Comd, Deputy Air Det Comd and Air Advisor made up the in-Theatre Supervisory Chain for the Air Det.
[104] Whilst the Panel could not find a definition for Flt Leads, it is taken to mean individual Det Comds or those most experienced in-role, e.g. Air Mission Commanders.
[105] i.e. When an appropriately empowered person who is external to the crew provides authorisation.
[106] i.e. When the Ac Comd authorises his own sortie.

