aircraft Captain stated to his crew that he was "*visual with the wire*" indicating that he was aware of its location. Furthermore, during an earlier approach (3rd sortie) into Qargha HLS, which was 330 m adjacent to another PTDS, both crews mentioned the PTDS and used it to assist with their estimation of wind direction. Exhibit 33 Exhibit 189 Exhibit 34

1.4.193 The Panel therefore considered that, in all likelihood, the crews were very aware of the PTDS but, due to the frequency of and predictable nature of approaches into SOC, and the use of ground features to provide procedural clearance of the PTDS, it was not routinely mentioned.

1.4.194 **Hazard mitigation.** Puma crews were provided with the Rotary Wing Aircrew Moving Map Wires Alerting System (RWAMMWAS)[87]. This was a standalone tablet computer that displayed information about the location of pre-loaded hazards (wires, masts etc) on a moving map and visually alerted the crew of their proximity. RWAMMWAS was not used by either crew on 11 Oct 15, this will be examined further in paragraph 1.4.341. Exhibit 132 Witness 3

Tether visibility prior to impact

1.4.195 In the 13 sec prior to striking the tether A22 was within 0.28 nm (530 m) of the PTDS and was turning right at circa 20° AOB. As a result the aerostat would have been outside of the Captain's field of view and therefore could not have been used to indicate the hazard. Identification of the base station as a means of locating the tether would have required the Captain to be consciously looking for the required ground features. There was no evidence to suggest that this was the case and in the Panel's opinion he was most probably looking for A21. Therefore, the only visible cues that were likely to have been within the Captain's field of view were the tether and the flags. Exhibit 35 Exhibit 129 Exhibit 72

1.4.196 The stated purpose of the flags was to increase visibility to aircrew and not to provide a method of sighting the tether. When avoiding action was initiated the aircraft was at circa 430 ft AGL, with the nearest flags approximately 30 ft below and 170 ft above the aircraft. There was no evidence to indicate whether or not these flags were seen. Exhibit 127 Exhibit 35 Exhibit 126

1.4.197 Conversely, analysis of the CVFDR indicated that as A21 commenced the orbit to the south east of HQRS the Captain stated that he was visual with the wire; this was at a range of approximately 0.29 nm (550 m) and 20 sec prior to A22 striking the tether. The relative positions of the aircraft and the tether is shown at Figure 1.4.20. Exhibit 10

[87] In use with the Puma Force since Q2 2014.

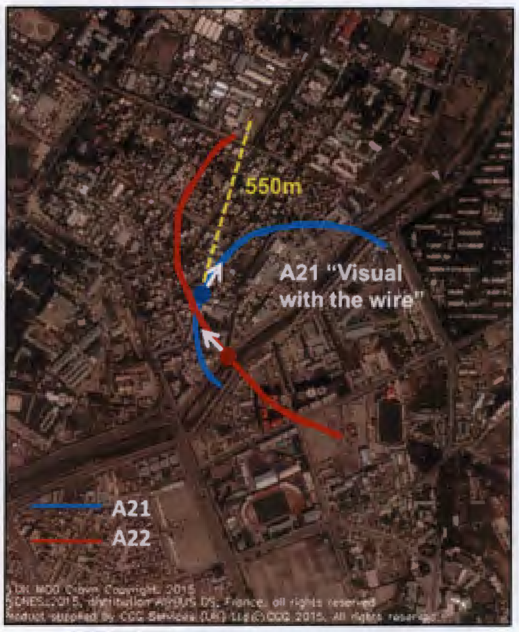

Figure 1.4.20 - Relative positions of aircraft and tether when A21's Captain stated that he was visual with the wire

1.4.198 In the opinion of the HF specialist, for an item to be detected visual attention must be focused accordingly. Although there was no evidence to confirm where A22's Captain had focused his attention, he had stated that he (as the HP) had lost the leader and based on the experience of the Panel would more likely than not have prioritised regaining visual contact with A21. There was no evidence to suggest that any of A22's crew were attempting to locate the PTDS tether or were concerned by its proximity. Exhibit 72

1.4.199 Whilst the Danger Area provided effective procedural deconfliction, the HLS was on its boundary resulting in aircraft operating unavoidably close to the hazard. The Panel observed that despite the markings the tether was difficult to see. The Panel felt that in the event of the Danger Area being compromised the markings may not have been sufficient to alert aircrew to the presence of the tether.

1.4.200 The Panel concluded that in the immediate seconds before the aircraft impacted the tether the crew of A22 were neither considering nor looking for it, and therefore the markings were **Not a Factor** in the accident. However, in the Panel's opinion the location of HQRS, the proximity of the PTDS to SOC, the volume of helicopter movements, constrained approach/departure routes and urban environment combined to create a situation that further reduced the ability of aircrew to identify the tether. As a result the Panel considered the tether marking on the HQRS PTDS to be an **Other Factor**.

Recommendation

1.4.201 PJHQ COS(OPS) should engage with NATO HQ RESOLUTE SUPPORT to review the markings on the HQRS PTDS in order to improve visibility of the hazard.

Accident sortie, pre-tether strike – summary

1.4.202 The Panel concluded that although there was an inadvertent crossover in passenger to aircraft allocation, and no safety brief was conducted, these factors did not contribute to the cause of the accident. Likewise, although irregularities in the recording of aircraft W&M and calculations of CofG were evident, the Panel retrospectively concluded that the aircraft was within RTS limits and that CofG was **Not a Factor**.

1.4.203 Other than difficulty in establishing radio communications with SOC Ops, the departure and transit to SOC was uneventful; the airspace was quiet with no other aircraft operating in the area. The meteorological conditions at the HLS were benign and had no impact on the sortie. The presence of individuals conducting sport on part of the HLS resulted in the formation executing a go around.

1.4.204 As the formation flew 'downwind' after the go round, there was a difference in perceptions between the 2 crews as to whether the HLS was being cleared and whether a further approach would be conducted immediately; neither crew communicated their perceptions to the other aircraft. As there was no urgent requirement to land, the formation leader elected to conduct an orbit; this intent was not passed to A22. The Panel recognised that the use of radio calls to clarify intentions is an airmanship consideration, however when noting the relatively simple nature of the go-around and the absence of any other aircraft in the area, the Panel considered that the lack of a radio call was reasonable.

1.4.205 In the Panel's opinion it was more likely than not that during the latter part of the conversation regarding ground features both of A22's pilots' attention was primarily focused on one particular building to the left of the aircraft. During a period of approximately 5 sec, the differences in AOB between the 2 aircraft was such that the lead aircraft moved rapidly away to the right which resulted in A22's loss of visual contact with it. Had visual contact with A21 been retained, it is more likely than not that A22 would have followed into the orbit. The Panel determined that the loss of visual contact with the lead aircraft was a **Contributory Factor** in the accident.

1.4.206 Having lost sight of the lead aircraft and in the immediate seconds before tether strike, the Panel formed the opinion that the attention of the Co-pilot and Crewman was on the HLS, whilst the attention of the Captain may have been on looking for the lead aircraft. Consequently the crew may have had a reduced ability to maintain situation awareness and recall the hazard. The Panel concluded that the lack of situation awareness regarding the PTDS was a **Contributory Factor** in the accident.

1.4.207 The Panel considered that on the balance of probability, the crews were aware of the PTDS but, due to the frequency of, and predictable nature of approaches into SOC and the use of ground features to provide procedural clearance of the PTDS, it was not routinely mentioned.

1.4.208 In the 13 sec prior to striking the tether A22 was within 0.28 nm (530 m) of the PTDS and was turning right at circa 20° AOB. As a result the aerostat would have been outside of the Captain's field of view and therefore could not have been used to indicate the hazard. In the Panel's opinion he was most probably looking for A21 and would not have utilised the ground station to indicate the location of the tether. Therefore, the only visible cues of the hazard that were likely to have been available to the Captain were the tether and the flags, both of which were difficult to see.

1.4.209 Whilst the Danger Area provided effective procedural deconfliction, the HLS was on its boundary resulting in aircraft operating unavoidably close to the hazard. The Panel felt that in the event of the Danger Area being compromised the markings may not have been sufficient to alert aircrew to the presence of the tether.

Tether strike

Avoiding action and tether strike

1.4.210 CVFDR data indicated that the aircraft commenced a rapid roll to the left within the second before tether strike. In initiating the manoeuvre the aircraft Captain applied nearly full left cyclic and full left yaw[88] pedal resulting in the aircraft rolling through circa 47° (18° right AOB to 29° left AOB) in less than a second. Exhibit 35 Exhibit 185

1.4.211 Witnesses reported that the Main Rotor Blades (MRBs) contacted the tether on the right hand side of the aircraft. However, due to the damage sustained by the 4 MRBs during impact with the ground no physical evidence could be gathered to indicate at what point along the blades contact occurred. When viewed from above. as shown in Figure 1.4.21, the Puma's MRBs turned in a clockwise direction and were retreating[89] when they contacted the tether. Exhibit 21 Exhibit 32

[88] The yaw pedals varied the pitch on the TRB and thus controlled heading and balance.
[89] A rotor blade moving in the opposite direction to forward flight is referred to a 'retreating blade', a blade moving in the same direction as the aircraft is an 'advancing blade'. In forward flight the advancing blade has a higher airspeed than a retreating blade.

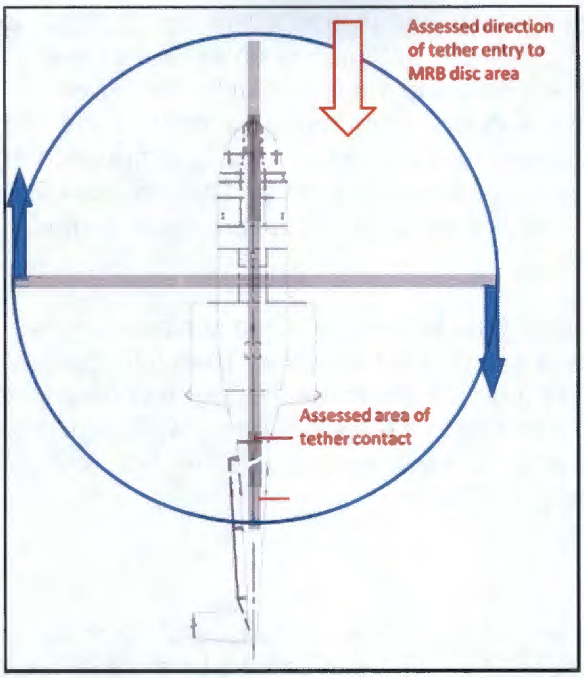

Figure 1.4.21 - Puma HC Mk2 main rotor disc viewed from above

1.4.212 The Panel assessed that a MRB drew the tether onto the right of the tail cone and as it crossed the aircraft's longitudinal axis tension on the tether increased. The Panel judged that the tension would have been further increased by the momentum of the advancing MRB and this caused the tether to part; the PTDS technical specifications stated that the tether was designed to break at a strain of 18,000 pounds (tension). Analysis by 1710 NAS described the failure of the tether as a tension failure due to pulling or stretching, rather than as a result of an instant guillotine-type failure. The end of the tether below the point of failure is shown in Figure 1.4.22.

Exhibit 124
Exhibit 19
Exhibit 32

Figure 1.4.22 - PTDS tether at point of failure

1.4.213 Within a second of the aircraft commencing the roll and as it passed 21° - 28° left AOB, the CVFDR background area microphone[90] recorded a noise which sounded to the Panel like a sharp 'thwack'. The only passenger who recalled the

Exhibit 34
Witness 2

[90] The area microphone was located above and to the right of the left hand seat pilot's head and recorded ambient noise in the aircraft.

Defence Safety Authority

accident sequence described hearing a *'pop'* and feeling a *'jerk'* through the aircraft. Based on the noise from the area microphone and ground based witnesses[91] hearing the noise at the same time as observing the tether strike, the Panel concluded that this was the point at which the tether impacted the tail cone and failed. When the evidence was analysed, and noting the rapidity of the occurrence, it was not possible to confirm the exact sequence of events. Therefore the Panel considered that the tether's impact with the airframe and failure were in effect coincident.

Exhibit 21
Exhibit 23
Exhibit 133

1.4.214 Witness marks indicated that the tether came into contact with the airframe on both sides of the tail cone and on the top of the TRDS fairings; having damaged the TRDS fairing, the tether interacted with the TRDS. Technical analysis carried out by 1710 NAS was unable to determine what damage was caused to the TRDS at that time. Damage to the tether below the point of failure was analysed and was consistent with damage on the airframe.

Exhibit 32

Damage to right side of aircraft

1.4.215 On the right side of the tail cone, there was evidence of a linear dent to the outer aircraft skin; this was assessed to have been caused by the initial impact of the tether. Figure 1.4.23 shows the right side of an undamaged tail cone and the damage sustained to XW229.

Exhibit 32

Figure 1.4.23 - Images showing right side of an undamaged tail cone and post tether impact damage to XW229

1.4.216 A series of rub marks were identified that commenced at the assessed initial impact point and continued rearwards for approximately 0.44 m, finishing below a join between fairings covering the TRDS. Figures 1.4.24 and 1.4.25 show impact and rub marks on the tail cone. The marks were considered to have been caused by the tether, held taught against the tail cone skin whilst the aircraft continued to move forward, 'skipping' over rivets on the aircraft's surface. Although the right side of the aircraft was damaged on impact with the ground, the rub marks were evident inside folded areas of the airframe structure (crash damage) indicating that they occurred prior to ground impact.

Exhibit 32

[91] Witnesses were all within the HQRS compound.

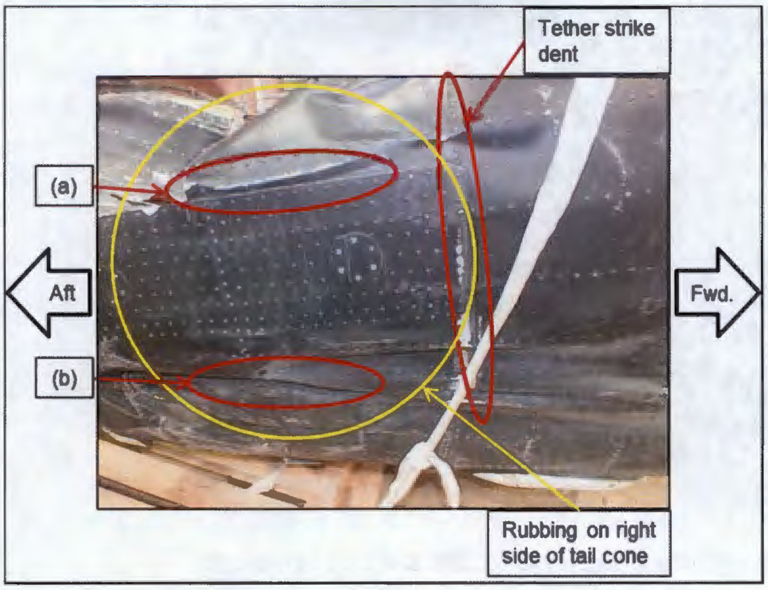

Figure 1.4.24 - Impact and rub marks on right side of tail cone

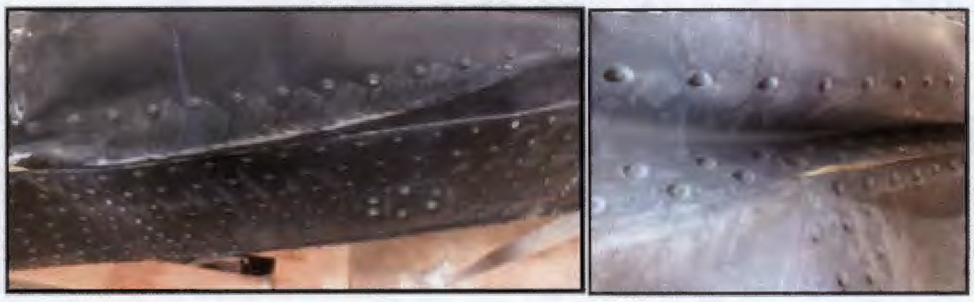

Figure 1.4.25 - Areas (a) & (b) of Figure 1.4.24 showing rub marks on right side of tail cone

Damage to left side of aircraft

1.4.217 An impact mark/dent was identified on the left side of the tail cone, aligned with the join in the TRDS fairings; this is shown in Figure 1.4.26. The Panel concluded that having failed, and under tension from the base station, with the aircraft moving forward at 82 kts, the tether 'whipped' down the left side of the tail cone and impacted the aircraft's High Frequency Radio antenna and was then pulled back over the airframe; a section of the antenna was recovered from within the PTDS compound. The location of the High Frequency antenna on the aircraft is shown in Figure 1.4.27. Forensic examination of the fracture surfaces of the antenna identified black material, which was chemically consistent with the outer coating of the PTDS tether. This indicated that the antenna was broken by the tether as it came into contact with the left side of the tail cone.

Exhibit 32
Exhibit 92
Exhibit 134
Exhibit 32

Defence Safety Authority

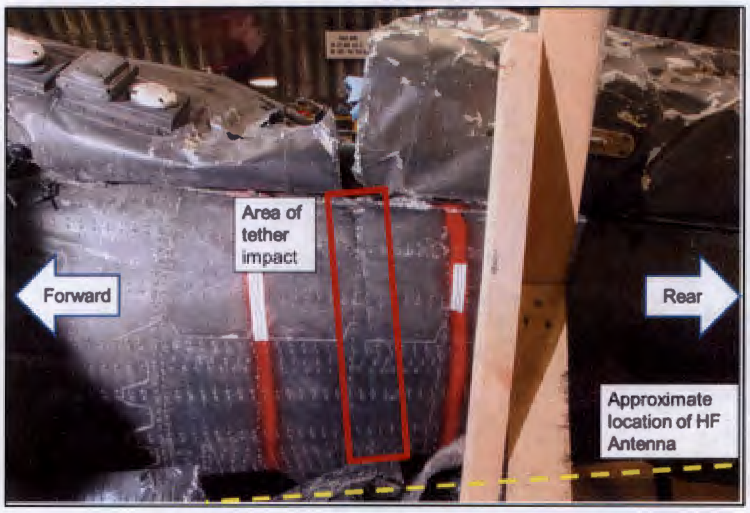

Figure 1.4.26 - Impact damage to left side of tail cone

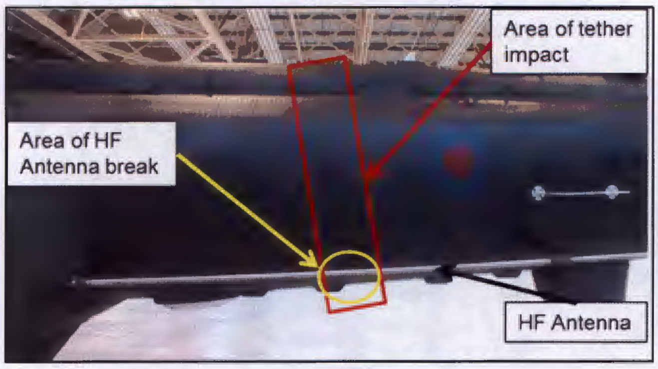

Figure 1.4.27 - Location of HF antenna

Interaction with TRDS

1.4.218 During the rapid sequence of the tether moving rearwards along the tail, being 'pulled' over the tail cone by the MRBs, 'whipping' down following failure and falling to the ground[92], evidence indicated that it passed between the forward and centre TRDS fairings causing the edges to buckle inwards as shown in Figure 1.4.28. The gap between undamaged TRDS fairings can vary between 2 mm and 4 mm. In the Panel's opinion, and considering that the diameter of the tether was 14.7 mm, it is more likely than not that the gap was sufficient to allow the tether, under tension, to breach the TRDS fairing.

Exhibit 17
Exhibit 19
Exhibit 126
Exhibit 32

[92] When the tether fell away from the aircraft it landed adjacent to the PTDS base station.

Defence Safety Authority

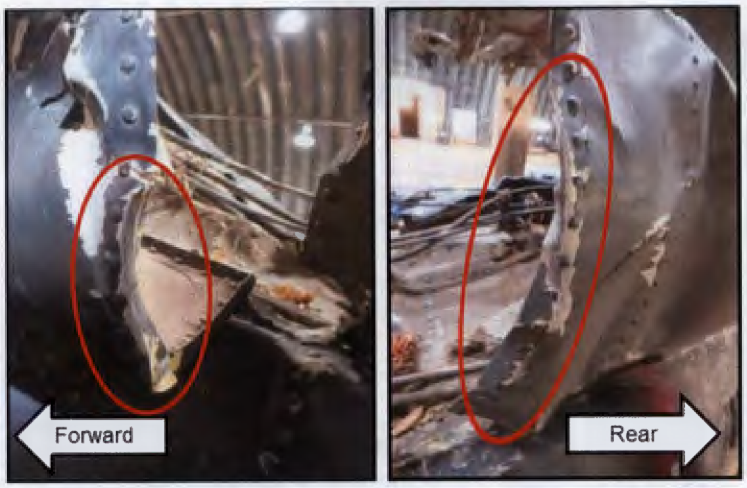

Figure 1.4.28 - TRDS fairing gap showing damaged edges assessed to be caused by the tether

1.4.219 Forensic examination of traces of blue paint found on the section of PTDS tether immediately below its break, confirmed that it was chemically consistent with paint used on the No 5 TRDS indicating that the tether interacted with the TRDS. Images of damaged tether sections where blue paint was identified are shown in Figure 1.4.29. Exhibit 32

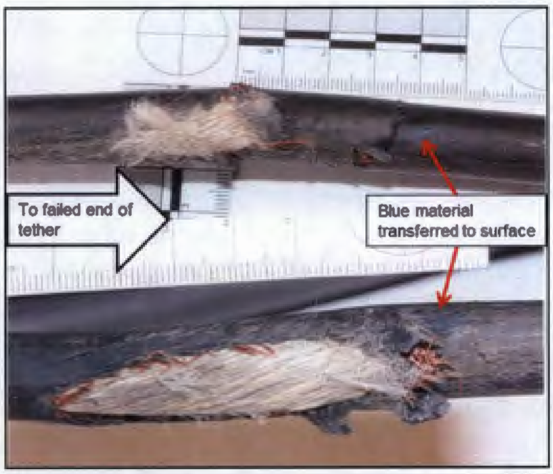

Figure 1.4.29 - Images of damaged tether sections where blue paint was identified

Effect on TRDS

1.4.220 Forensic examination of the aircraft structure immediately beneath the TRDS, and in the vicinity of the gap between TRDS fairings, identified several rivets that had been scuffed and showed traces of blue paint that was chemically consistent with paint from the No 5 TRDS. In addition, the TRDS had physical evidence of parallel score marks that were consistent with the damaged rivets, which is shown in Figure 1.4.30. Technical analysis assessed that the nature of the score marks indicated that the shaft was rotating when it came into contact with the rivets. Exhibit 32

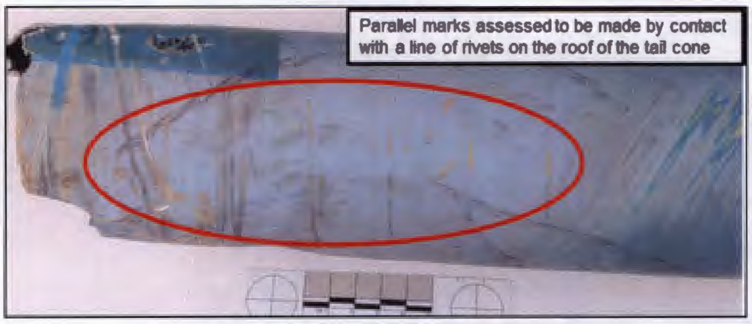

Figure 1.4.30 - No 5 TRDS showing parallel scoring from rivets

1.4.221 Technical specialists considered that the interaction between the shaft and aircraft structure occurred before the impact with the ground when the shaft, drive train and surrounding area were distorted. In order for the transfer of paint to occur, technical analysis concluded that the tether displaced the drive shaft downwards, and distorted the associated mountings, to such an extent that it contacted the aircraft structure, and hence rivets. The distance between an undamaged drive shaft and the aircraft structure is circa 8.3 cm. Exhibit 32

1.4.222 CVFDR data indicated that coincident with the tether strike the aircraft experienced a momentary vertical loading of 40 g. The Panel judged that whilst this may have been a spurious recording, it is likely to have been the moment that the tether applied downward force on the TRDS. Exhibit 185 Exhibit 135

1.4.223 After significant examination of the wreckage there was no physical evidence to indicate that the tether continued any further rearwards and made contact with the tail fin, Tail Rotor Gearbox or Tail Rotor. Exhibit 32

1.4.224 Analysis of the CVFDR indicates that for the 17 sec following tether strike the aircraft responded to pilot inputs suggesting there was no catastrophic failure of any system at the time of impact. The sequence of events concerning the tether interaction with the aircraft was almost instantaneous and cannot be categorically determined. The Panel were unable to determine the nature of the damage that the TRDS sustained but assessed that it was such that the shaft was weakened to the extent that it subsequently catastrophically failed. Exhibit 32 Exhibit 135

1.4.225 The Panel concluded that the damage caused to the TRDS by the PTDS tether strike was a **Causal Factor** in the accident.

Aircraft systems

1.4.226 **Auto-Pilot related cautions.** CVFDR data indicated that immediately after avoiding action was initiated several warnings and cautions were displayed in the cockpit along with the associated Automatic Voice Alert Device (AVAD)[93] cue. Each warning and caution is discussed below:

[93] Automatic Voice Alert Device – an electronically generated voice that provides audio messages designed to warn the crew of certain critical events. It provides audio warnings for low heights, engine fire(s), master warnings and master cautions.

a. **TRIM[94].** The first caution to illuminate was a 'TRIM' caption on the Auto-Pilot Caution Panel (ACP) and was accompanied by an amber[95] 'AP' (Auto-Pilot) caption[96] on the Central Warning Panel (CWP). CVFDR technical analysis by Airbus Helicopters and Defence AIB Engineering Investigators considered that the pilot's rapid control inputs were likely to have caused the 'TRIM' caption due to the Automatic Flight Control System (AFCS) detecting an anomaly[97]. The caption extinguished after one sec which was coincident with slower cyclic inputs. Exhibit 34 Exhibit 32

b. **Attitude and Heading Reference System Discrepancy (AHRS Disc)[98].** Within a second of the 'TRIM' caption an 'AHRS Disc' caution illuminated indicating a discrepancy between the 2 AHRSs. Technical analysis provided 2 possible explanations for the AHRS caution; the aggressive manoeuvre or the momentary force of the tether impact. As a result the AFCS considered the attitude information to be unreliable and illuminated the caption. Exhibit 34 Exhibit 32

c. **Second TRIM caption.** The CVFDR showed that after the initial significant left cyclic input (avoiding action) there was a right cyclic application as the HP tried to counter the left roll being induced by the left yaw pedal input[99]. As with the initial 'TRIM' caption, the rapid movements of the cyclic were the likely cause of the further 'TRIM' caption. Exhibit 135 Exhibit 34 Exhibit 32

d. **Collective Link (Coll Link)[100].** During the avoiding manoeuvre, the CVFDR showed a rapid raising/lowering of the collective lever and a 'Coll Link' caution. Technical analysis considered this to have been a result of the AFCS monitoring system detecting a variance with pre-programmed tolerances. Exhibit 34 Exhibit 32

1.4.227 The AP related cautions illuminated immediately after the initiation of avoiding action and were almost coincident with the tether strike[101]. Technical analysis assessed that all cautions resulted from the rate of flying control movement or the tether strike and not system technical failures. The analysis stated that the various cautions and degradations resulted in a loss of automated attitude control[102] but the retention of stability assistance[103] from the avoiding manoeuvre to the AP reset. In the Panel's opinion, and considering the technical analysis, the AFCS degradations were unlikely to have had a detrimental effect on the pilot's ability to fly the aircraft but the various AP cautions and caption may have attracted his attention. Exhibit 34 Exhibit 32

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[94] An electro-mechanical system which assisted the pilot by providing stabilisation and allowed the AFCS to move the flying controls as directed by the pilot.
[95] Cautions were displayed as amber captions with an accompanying audio alert of "Master Caution". Warnings were displayed as red captions with an accompanying audio alert of "Master Warning". Master Warnings were afforded a higher priority than Master Cautions and as a result should simultaneous malfunctions occur the warning alert would be heard.
[96] Any ACP caution would generate an AP caption on the CWP.
[97] The basic autopilot incorporates internal monitoring circuits that enable failures to be detected, and control to be automatically handed to serviceable components in a manner that assures uninterrupted safe handling.
[98] The AHRS is a set of gyros providing pitch, roll and yaw references for the aircraft. The Puma HC Mk2 has two separate AHRS.
[99] Roll is a secondary effect of yaw.
[100] The Collective Link enables the AFCS to use the collective lever during its operation.
[101] The AP was providing attitude hold and stabilisation as opposed to 'hands off' automatic control functions, ie it was not being used to control heading, height or speed.
[102] Attitude retention mode – the AFCS holds the pilot set attitude.
[103] Stability Augmentation System mode – the AFCS provides stability but the pilot holds the attitude, known as SAS mode.

1.4.228 **Main Gear Box Pressure (MGBP) caption.** The red MGBP caption[104] illuminated for approximately one second in conjunction with the 'Master Warning' caption and audio warning. The CVFDR indicated that coincident with the tether impact the aircraft sustained a momentary 40 g loading through the vertical axis. Additionally, during the avoiding manoeuvre the collective lever was lowered rapidly from approximately 75% torque to circa 45%; such a sudden control input may have resulted in a short reduction in normal acceleration (g force). As there were no other indications associated with a failure of the MRGB, and post-accident inspections confirmed the integrity of the oil system, the Panel concluded that the MGBP caption resulted from movement of oil in the MRGB caused by the aircraft's momentary change in vertical acceleration.	Exhibit 34 Exhibit 92 Exhibit 32
1.4.229 **Pilot assimilation of system indications.** In the Panel's opinion the initiation of avoiding action, and momentary increase in vertical g loading, caused the initial warnings and cautions but did not result in any significant degradation to the associated systems; the AFCS continued to provide stability throughout. HF analysis stated that, immediately after tether strike, the crew experienced a high level of workload which took up a significant proportion of their mental resources. This may have reduced their capacity to gather information, make effective decisions and implement actions. The Panel considered that the volume of visual and audio information presented to the pilots, during a matter of seconds, was potentially confusing and did not resemble any single recognisable emergency listed in the Puma HC Mk2 Flight Reference Cards.	Exhibit 32 Exhibit 72 Exhibit 136
Pilot actions	
1.4.230 Although the aircraft Captain initiated the avoiding manoeuvre, 2 sec after the tether strike the Co-pilot declared *'I've control'* to which the Captain stated *'you have control'*, an unambiguous handover of the controls was conducted. Thereafter the Co-pilot remained the HP.	Exhibit 33 Exhibit 189 Exhibit 35
1.4.231 When considering the severity of the avoiding manoeuvre, the associated noise of the tether impacting the airframe and failing, and the 40 g loading through the aircraft the Panel concluded that it was understandable and appropriate that the more experienced pilot took control. The Co-pilot was a Training Captain and was trained to intervene if a situation had the potential to become dangerous.	Exhibit 84 Exhibit 137
1.4.232 After handing over control the aircraft Captain transmitted a Mayday call on the inter-aircraft frequency. One sec later the HP directed that a Mayday call be made; during interviews aircrew stated that they varied the radio volumes depending on their role (HP or NHP). Therefore, the Co-Pilot may not have heard the Captain's Mayday call due to differing volume settings. In the Panel's opinion, the fact that both pilots decided that a Mayday call was appropriate indicated that they recognised the severity of the situation.	Exhibit 33 Exhibit 189 Exhibit 35 Witness 3 Witness 4 Witness 5
1.4.233 HF analysis indicated that the management of the high workload experienced immediately after tether strike was made more difficult due to the	Exhibit 72

[104] MGBP caption illuminated when MGB oil pressure dropped below 0.8 Bar.

Defence Safety Authority

sudden change from a non-demanding flight profile. In the opinion of the Panel, the HP's contextual framework changed from not flying the aircraft whilst discussing the HLS, to experiencing an un-alerted rapid roll to the left and taking control in an emergency situation. Exhibit 35

1.4.234 Immediately following the handover of control, 6 sec after the initiation of avoiding action, the aircraft attitude was 19° nose down, 34° left wing low and skidding to the left at a yaw rate of 22°/sec. Having considered the sudden attitude changes, the Panel concluded that the aircraft was in an abnormal flight profile. Exhibit 35

1.4.235 RWTES Test Pilot analysis of the control inputs following the avoiding manoeuvre showed that the left yaw pedal application was held at, or near to, maximum deflection for approximately 10 sec. This caused the aircraft to yaw left and then, due to the aerodynamic effect, intensified the left roll. To counter the roll a progressive right cyclic input was made and held, initially with the full left yaw pedal, at approximately 60% of available cyclic range. The roll attitude was maintained at approximately 30° left wing low for 16 sec post tether strike and a nose down pitch attitude developed reaching a maximum of 25° nose down, but averaging 10° nose down, with a slight aft cyclic held throughout. Exhibit 135

1.4.236 A22 sustained significant left yaw/right skid which resulted in unreliable airspeed indications; the Panel assessed that the HP was presented with conflicting information of low airspeed despite a nose down attitude, excesses of pitch and roll and several warning captions. The significant rates of yaw were in excess of those that either pilot were likely to have previously experienced and were beyond the aircraft's RTS clearance[105]. Exhibit 35 Exhibit 185 Exhibit 95

1.4.237 In the Panel's opinion, and noting the information available to the HP, it is most likely that his priority would have been to achieve a stable, known, flight condition before any diagnosis of the situation could be conducted[106].

Puma HC Mk2 simulator analysis

1.4.238 The Puma HC Mk2 Dynamic Mission Simulator (DMS) is a synthetic, full motion simulator which is capable of replicating the aircraft in the majority of scenarios and environments. The Panel, in conjunction with Defence AIB Investigators and a RWTES Test Pilot, replicated closely A22's flight profile and control inputs in the Puma HC Mk2 DMS. Exhibit 15

1.4.239 The Panel were unable to conclude why the HP made no early discernable effort to address the significant yaw but the Test Pilot reported that the sustained yaw pedal position did not feel as unusual as it was expected to be. In the Panel's experience it is likely that a HP would want the roll to reduce before making any further control inputs. Such actions could be considered rational and when replicated in the DMS the Panel concluded that they would have been appropriate. Exhibit 135 Exhibit 138

[105] The RTS states "*Flight in the forward flight envelope (>40 kts CAS) with intentional sideslip is prohibited*".
[106] Aircrew were taught to follow the WADFIR pneumonic: Warn the crew, Achieve safe flight, Diagnosis, Flight reference cards, Intentions and Radio call.

1.4.240 The Panel considered two other possibilities that could explain the sustained application of left yaw pedal:

a. **Tail Rotor control restriction.** There was no CVFDR evidence to indicate that the aircraft suffered a Tail Rotor Control restriction. The HP made three inputs with the right yaw pedal and each produced a corresponding TR output. Exhibit 33 Exhibit 189 Exhibit 35

b. **Unintentional Yaw Pedal Input by NHP.** The Panel considered the possibility that the Captain maintained his application of left yaw pedal after the handover of control. However, for the Co-pilot to have made three yaw inputs, with corresponding TR output, he must have been able to move the yaw pedals. The Panel formed the opinion that had the Captain sustained his yaw pedal application, the Co-pilot would have found it difficult to make any input due to the opposing force.

The Panel could not prove or disprove either possibility due to an absence of supporting evidence. However, the Panel considered that as the aircraft responded to the pilot's control inputs it was, on the balance of probabilities, unlikely that either had an effect on the flight profile.

1.4.241 **Lateral Control Authority.** In evaluating the pilots' actions the Panel considered the potential for A22 to have experienced a loss of Lateral Control Authority (LCA). As referred to in paragraph 1.4.90, a Puma HC Mk2 originally encountered a loss of LCA in low speed turning flight and approach profiles, in the airspeed region of 30-40 knots, during which the aircraft developed a rate of roll to the left which could not be overcome using right lateral cyclic alone. Two Test Pilots, the CO of RWTES and one with actual experience of loss of LCA, analysed the CVFDR data and in their expert opinion A22's flight profile did not at any point show the same undemanded, divergent roll to the left that characterised the loss of LCA. Correspondingly, full right cyclic was not used until post TRDS failure which, with an aircraft diverging in a left roll, would be a pilot's immediate, instinctive response. The data indicated that the aircrew did not lose control of the aircraft prior to the TRDS failure. The Panel concluded that loss of LCA was **Not a Factor** in the accident. Exhibit 135 Exhibit 139

1.4.242 **Auto-Pilot (AP) engagement.** Twelve sec after tether strike, and with the aircraft's attitude at 24° left AOB, 23° nose down and with a left yaw rate of 8°/sec, the HP asked for the AP to be '*put back in*'. The aircraft Captain deselected and re-engaged the AP declaring it back in 4 sec later. Exhibit 33 Exhibit 189 Exhibit 35

1.4.243 Technical analysis confirmed that despite the presence of a warning caption the AP was functioning, albeit in a degraded manner as discussed earlier in paragraph 1.4.227. The AP and related cautions cleared when the system was reset which demonstrated their continued serviceability. Exhibit 135 Exhibit 32

1.4.244 In requesting the AP to be put back in, the Panel were of the opinion that the HP may have been aware of the AP related cautions and considered the AP to be disengaged. The Panel found no other evidence as to why the HP made the request for the AP.

1.4.245 **Right yaw pedal application.** In taking avoiding action the aircraft Captain applied full left yaw pedal, the application of which dominated for the 18 sec Exhibit 35 Exhibit 185 from the initial manoeuvre to the Co-pilot's verbal recognition of a TRDS failure. Following the avoiding action the HP[107] made 3 applications of right yaw pedal:

a. After 2 sec, for approximately 1.5 sec following which full left pedal was resumed.

b. After 11 sec, for 2 sec which returned the yaw pedals to an approximately central position.

c. After 15 sec (following a further 1 sec of left application). This was during the AP re-engagement process.

Analysis of the CVFDR indicated that the aircraft responded to the first 2 applications of right yaw pedal. During the third application the rate of left yaw increased for 2 sec before reducing for 1.5 sec following which it increased. Seventeen and a half sec after the initiation of avoiding action, and with right yaw pedal applied, the rate of yaw to the left increased rapidly. The HP applied full right yaw pedal but the aircraft continued to yaw left.

1.4.246 Coincident with the rapid increase of left yaw the output speeds of both engines (Nf) and the speed of the Main Rotor (Nr) transiently increased, this would result from the instantaneous removal of power to the Tail Rotor. The Panel concluded that this was the moment that the TRDS failed. Exhibit 185

Crewman comment regarding MRBs

1.4.247 Seventeen and a half sec after the avoiding action the crewman commented on the state of the MRB's, assuring the rest of the crew that they were in good condition; this was the first statement he had made since avoiding action was initiated. From the Panel's experience, his comment may have been as a result of a deduction that the aircraft had struck an object. Exhibit 33 Exhibit 189

1.4.248 In the Panel's opinion and experience, and noting the focus of the pilots on flying the aircraft, his comment would have been a timely input in their diagnosis of the emergency. His statement corresponded with the commencement of the rapid yaw to the left.

TRDS failure

1.4.249 One and a half sec after the aircraft started yawing more rapidly to the left the HP exclaimed '*shit*'. Concurrent to the HP's comment the aircraft Captain transmitted a 'Mayday' call on the inter-aircraft radio frequency; the Panel believe that both pilots may have recognised the critical change in the situation at the same time. At this point the aircraft's attitude was approximately 20° left AOB, 8° nose down, rate of yaw increasing through 60°/sec, CAS between 35 and 46 kts, and height 200 ft AGL. Exhibit 33 Exhibit 189 Exhibit 35

1.4.250 The CVFDR recorded that there were 3 calls for '*throttles*'[108], one of which was inadvertently transmitted on the inter-aircraft frequency. Up to this point, Exhibit 33 Exhibit 189

[107] The first application was made by the aircraft Captain thereafter by the Co-pilot.

since impacting the tether, there had been no discussion or diagnosis as to the nature of the situation that they were dealing with. A call for 'throttles' is synonymous with the actions required when reacting to a TRDS failure; as a result the Panel concluded that the crew simultaneously recognised the nature of the emergency. Exhibit 35

1.4.251 As the aircraft started yawing rapidly, the orientation of the roll reversed from left to right reaching 80° right AOB before it reduced to 50°. Similarly the pitch attitude reached 40° nose down before reversing to 40° nose up due to the airframe turning around the rotor axis. For the final 5 seconds of CVFDR data the yaw rate varied between 40° and 60°/sec. Both the airspeed indicators dropped to 0 kts within 3.5 sec and the aircraft began a rapid near vertical descent. Video footage of the final seconds of flight shows the aircraft in an extreme nose down attitude rapidly yawing to the left. All available evidence led the Panel to conclude that during this phase, the HP was unable to exercise any control of the aircraft. Exhibit 22, Exhibit 185, Exhibit 32

Aircrew actions following TRDS failure

1.4.252 The Puma HC Mk 2 Flight Reference Cards immediate actions for a TRDS failure state: *'Enter autorotation and if possible achieve 80 kts'*. The aircraft did not enter autorotation and the collective lever was maintained at approximately the 70% position; at the point that CVFDR data ends the collective was at 80%. The continued application of collective lever would have exacerbated the torque reaction until both engines were shut down, after which it would have caused the Nr to decay rapidly. CVFDR data showed that No. 1 engine was shut down within 4 sec of the HP's exclamation of '*shit*', but data recording finished before the No. 2 engine was shut down. The Panel assessed that the No. 2 engine was shut down before the aircraft impacted the ground. The MRBs stopped within one rotation and CCTV footage of the site showed no evidence of the engine continuing to run. This was confirmed in the Defence AIB Technical Report and a report by Turbomeca, the engine manufacturer. Exhibit 136, Exhibit 185, Exhibit 32, Exhibit 33, Exhibit 189, Exhibit 2, Exhibit 32

1.4.253 At the moment of TRDS failure A22 was 200 ft over a densely populated area; the majority of the buildings were 2-3 storey with a 9 storey building at the northern end of SOC. The aircraft had descended circa 200 ft during the previous 17 sec whilst yawing, pitching and rolling; all with airspeed reducing. In the Panel's opinion, with all of these inputs, it would have been counter-intuitive for the HP to fully lower the collective lever in an attempt to enter autorotation. Exhibit 35, Exhibit 141

1.4.254 The continued application of collective lever, once the engines had been shut down, resulted in rapid Nr decay which in turn caused an increase in the aircraft's rate of descent. When the CVFDR data ended[109] the Nr had decayed through 90%. The estimated vertical speed on impact was 4100 ft/min (21 m/sec). Exhibit 32, Exhibit 185, Exhibit 32

1.4.255 During the DMS assessment of A22's flight the Rotary Wing Test Pilot flew a series of profiles to determine the handling characteristics post the TRDS failure. From these simulated flight profiles the Panel concluded that from the height, speed and attitude that the TRDS failed, as at paragraph 1.4.249, a successful engines off landing was unachievable. The Panel considered that even if Exhibit 138

[108] 'Throttles' is a call for the engines to be shut down and is an immediate action that would be carried out in dealing with a TRDS failure.
[109] CVFDR data capture ended between 0 and 0.25 sec before impact due to the sampling rate of the aircraft.

the aircraft had immediately entered autorotation and the engines been shut down instantaneously the outcome would not have changed. In the Panel's opinion, and noting the extreme changes of aircraft attitude, the crew's handling of the TRDS failure was **Not a Factor**.

1.4.256 **Brace position**. There was no evidence that the crew directed passengers to adopt a brace position. The time from the HP's recognition of the emergency to the aircraft impacting the ground was 5.5 sec during which time the aircraft experienced significant and rapid attitude changes and the crew were responding to the emergency. In the Panel's opinion it was therefore unlikely that a warning would have been considered. Furthermore, and when bearing in mind the nature of the impact, it was unlikely that the adoption of a brace position would have changed the outcome. Exhibit 35 Exhibit 33 Exhibit 189 Exhibit 6

Technical analysis

1.4.257 As the HP applied right pedal, the torque through the TRDS increased. Simultaneously, the aircraft failed to respond to the pilot's pedal inputs and the rate of yaw to the left increased; this was symptomatic of a catastrophic failure of Tail Rotor drive. Exhibit 185 Exhibit 135 Exhibit 32

1.4.258 Technical investigation identified a catastrophic torsional failure of the No 5 TRDS directly in line with the TRDS fairing gap through which the tether is assessed to have passed. Figure 1.4.31 shows an undamaged No 5 TRDS; Figure 1.4.32 shows the torsional failure. Exhibit 32

Figure 1.4.31 - Undamaged No 5 TRDS (not XW229)

Defence
Safety
Authority

Figure 1.4.32 - Catastrophic torsional failure of No 5 TRDS

1.4.259 Although there were other breaks in the TRDSs, they had significantly reduced torsional fracture surfaces and on the balance of evidence were likely to have occurred as the aircraft impacted the ground. Figure 1.4.33 is a diagrammatic representation of the tail rotor drive chain showing fracture points. Exhibit 32

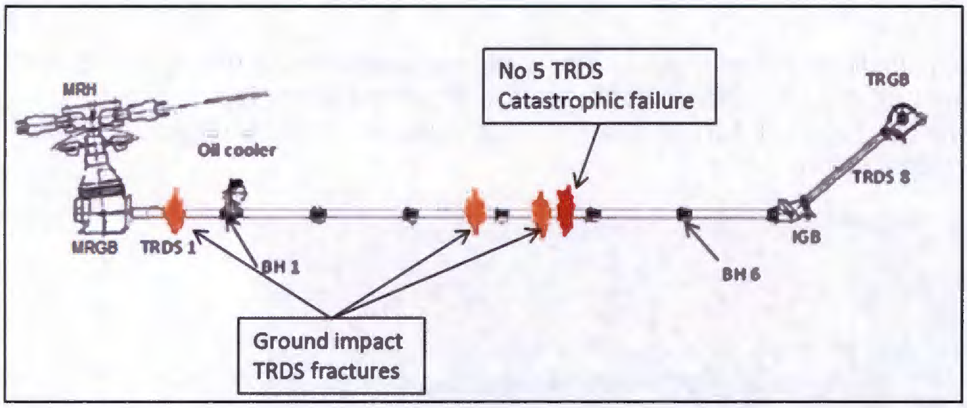


Figure 1.4.33 - Diagram showing location of TRDS fractures

1.4.260 On inspection, the bearings and flexible couplings on either side of the No 5 TRDS were damaged and displaced towards the catastrophic failure point, Figure 1.4.34. It was not possible to positively determine whether this damage was caused by tether strike, TRDS failure or ground impact. However, due to the significant downwards displacement required of the TRDS to interact with the structure immediately beneath it, paragraph 1.4.220, some of this damage is highly likely to have occurred at the time of tether strike and subsequently been exacerbated by the failure of the TRDS and ground impact. Exhibit 32

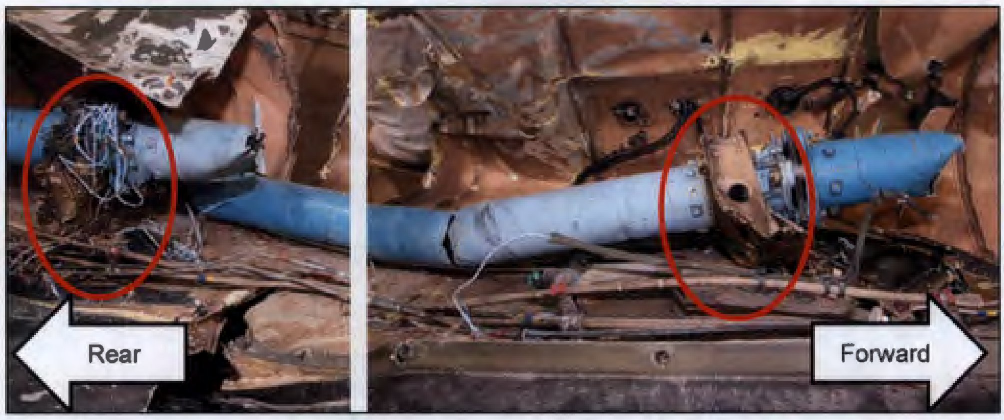


Figure 1.4.34 - TRDS Bearings and flexible coupling damage

1.4.261 The catastrophic failure of the No 5 TRDS would have led to a rapid loss of power to the Tail Rotor and reduction of the associated thrust. Whilst the Tail Rotor controls continued to function in response to HP inputs, the effect would have rapidly diminished as the Tail Rotor speed reduced; a witness statement described the Tail Rotor as stationary prior to the aircraft impacting the ground. This was reinforced by the post impact inspection of TRBs that only showed evidence of direct impact damage; no rotational damage or ground marks were evident.

Exhibit 135
Exhibit 21
Witness 19
Exhibit 32

Impact with the ground

1.4.262 In the last second before impact the aircraft's attitude was approximately 34° nose up and right wing low; the last CVFDR data recorded a right AOB between 45° and 59° with a decreasing trend[110]. CCTV showed that the MRBs hit the branches of an adjacent tree and the edge of a 2 storey building; the Panel assessed that they did little to arrest the rate of descent. Damage to the building caused by the MRBs is shown in Figure 1.4.35. Furthermore, when considering the weight of the aircraft, speed of descent and decaying Nr, the Panel judged that the aircraft's contact with the tree did not cause it to rotate further to the right.

Exhibit 32
Exhibit 185
Exhibit 2

[110] This was approximately 0.5 sec before impact. The numerical discrepancy was due to the technical processing of the AHRS systems.

Figure 1.4.35 - Damage caused by MRBs

1.4.263 The aircraft impacted the ground between buildings within the HQRS compound with no forward and only minimal lateral momentum. The location of the aircraft is shown in Figure 1.4.36 with images of the aircraft between buildings shown in Figure 1.4.37. Exhibit 2

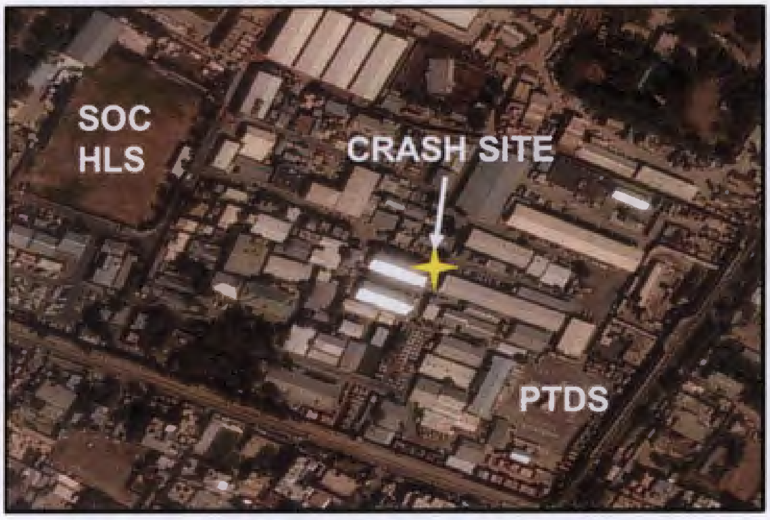


Figure 1.4.36 - Location of XW229 crash between HQRS buildings

Figure 1.4.37 - Images of XW229 between buildings in HQRS

1.4.264 After impact the aircraft was orientated on its right side; the airframe suffered extensive disruption during the accident sequence which was subsequently worsened by the rescue activities, this is shown in Figure 1.4.38. Exhibit 32

Figure 1.4.38 - Distortion to XW229's airframe

1.4.265 The ground was flat and a mix of hard packed earth and concrete. The tail struck first followed by the right rear wheel and then main fuselage. The force of impact ruptured the fuel bladder under the cabin floor and forced the right rear undercarriage and ballistic flooring into the cabin causing significant loss of survivable space. Figure 1.4.39 shows the inside of the aircraft cabin when viewed from above. Exhibit 32

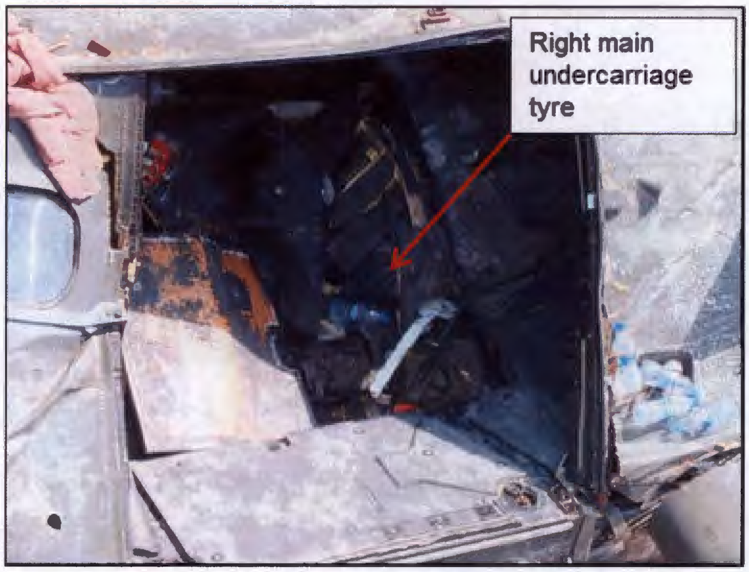


Figure 1.4.39 - View into aircraft cabin from above

Tether strike – summary

1.4.266 The Panel concluded that a MRB drew the tether onto the right of the tail cone. As it then crossed over the tail, tension on the tether increased to such an extent that it failed. Having failed, and under tension from the base station, the tether 'whipped' down the left side of the tail cone and was then pulled back over the airframe. During this sequence the tether passed between two TRDS fairings and displaced the TRDS downward to interact with the aircraft structure. Coincident with the tether strike the aircraft experienced a momentary vertical loading of 40 g; the Panel judged that this is likely to have been the moment that the tether applied downward force on the TRDS. For the 17 sec following tether strike the aircraft responded to pilot inputs suggesting there was no catastrophic failure of any system at the time of tether impact. The Panel were unable to determine the nature of the damage that the TRDS sustained but assessed that it was such that the shaft was weakened to the extent that it subsequently catastrophically failed.

1.4.267 Several warnings and cautions were displayed in the cockpit along with their associated audio cues. In the Panel's opinion the initiation of avoiding action, and momentary increase in vertical g loading, caused their initiation but did not result in any significant degradation of the associated systems. The Panel considered that the volume of visual and audio information presented to the pilots, during a matter of seconds, was potentially confusing.

1.4.268 Following the avoiding action, A22 sustained a significant left yaw/right skid which resulted in unreliable airspeed indications; the HP was presented with conflicting information of low airspeed despite a nose down attitude, excesses of pitch and roll and several warning captions. The significant rates of yaw were in excess of those that were likely to have been previously experienced and were beyond the aircraft's RTS clearance.

1.4.269 The application of full left yaw pedal dominated for 18 sec from the initial avoiding manoeuvre until the TRDS failure was recognised. During this time 3 applications of right yaw pedal were made; the aircraft responded to the first 2 but during the third the rate of left yaw increased rapidly and Nf and Nr speeds transiently increased; the Panel concluded that this was the moment that the TRDS failed.

1.4.270 As the aircraft started yawing more rapidly it was at 200 ft AGL and experienced significant and rapid attitude changes. The pilots responded to the emergency and both engines were shut down; however the aircraft did not enter autorotation. The continued application of collective lever resulted in rapid Nr decay which in turn caused an increase in the aircraft's rate of descent. The Panel considered that even if the aircraft had immediately entered autorotation and the engines been shut down instantaneously, the outcome would not have changed. The Panel concluded that from the height, speed and attitude that the TRDS failed, a successful engines off landing was unachievable.

1.4.271 A torsional failure of the No 5 TRDS was identified directly in line with the gap in the fairing covers through which the tether was assessed to have passed. The bearings and flexible couplings on either side of the shaft were damaged and displaced towards the catastrophic failure point. It was not possible to positively determine whether this damage was caused by the tether strike. However, due to the significant downwards displacement required of the TRDS to interact with the structure immediately beneath it, some of this damage most probably occurred at the time of tether strike. The Panel concluded that the damage caused to the TRDS by the PTDS tether strike was the **Causal Factor** of the accident.

Post-accident

1.4.272 There was no immediate post-crash fire and a considerable number of personnel provided assistance to the aircraft occupants, the first of which was on scene within 15 sec with 10 more in attendance within a minute. Numerous hand held fire extinguishers were discharged to mitigate the risk of fire due to leaking fuel; A22 had approximately 350 kg of fuel on board at the time of the accident. CCTV footage showed fuel pooling on the ground within a minute of the impact; rescuers reported working in ankle deep puddles throughout much of the rescue. Rescue activities continued for approximately 1.5 hrs before all the casualties had been extracted. Exhibit 2 Exhibit 25 Exhibit 6

1.4.273 At the time of the incident HQRS was a densely populated site with many multi-storey buildings and limited open space; by impacting the road the crash was confined by blast walls and buildings yet remained accessible. The crash site was secure, removing the requirement for dedicated FP; rescue activity was conducted in a benign threat environment. The rapid medical and rescue response resulted in early application of medical care and swift extraction of all on board personnel. Exhibit 26 Exhibit 141 Exhibit 6

1.4.274 In the Panel's opinion, by impacting on a road rather than on a building, the potential for multiple casualties on the ground was, fortuitously, not realised.

Location of crew and passengers

1.4.275 Both pilots were strapped into their seats and the crewman was recovered from the cabin floor between the doors attached to his despatcher harness. The passengers were all within the seats as described at the point of Exhibit 25 Exhibit 6 Exhibit 26 loading, but had to be cut free from the wreckage due to the significant loss of survivable space.

Rescue

1.4.276 None of the crew or passengers were able to conduct their own egress either having been trapped within the wreckage or rendered incapable by the force of the impact. Two principle egress points were immediately available to rescuers: the open left cabin door and the left cockpit door (once it had been removed). The left cockpit door was not used to extract anyone from the aircraft. The substantial deformation of the cabin structure and resultant entrapment of passengers forced rescuers to cut an extraction route through the tail cone of the aircraft. Figure 1.4.40 shows the 3 areas used to extract the aircraft's occupants. Exhibit 6

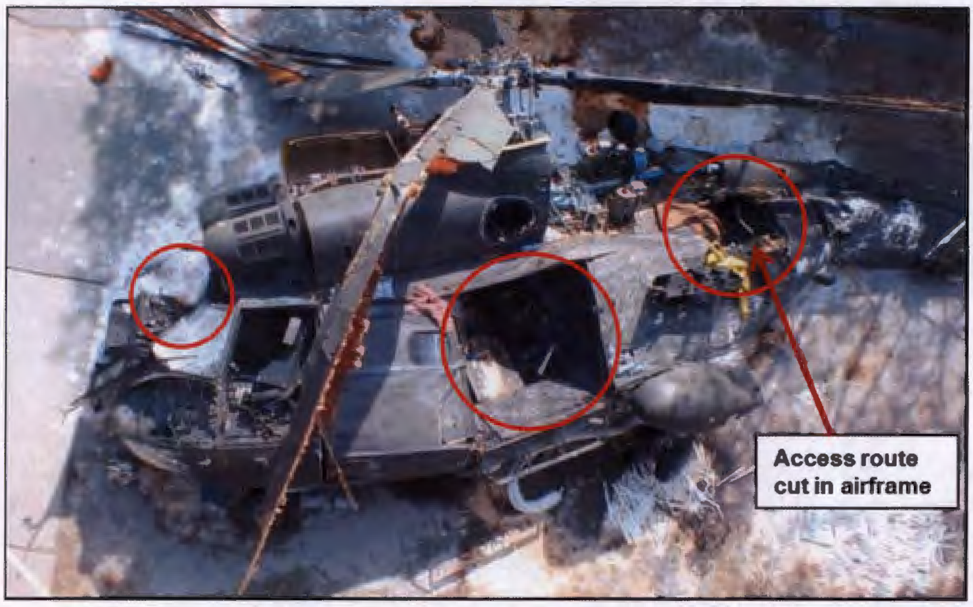


Figure 1.4.40 - Extraction routes for XW229's occupants

1.4.277 The crewman was immediately visible to the rescuers through the cabin door. The rescuers cut his despatcher harness before lifting him out of the cabin 2 mins 15 sec after impact; he was placed on a stretcher and transferred to the Role 1[111] medical facility based at HQRS. Exhibit 6

1.4.278 The aircraft Captain (in the right hand cockpit seat) was accessed by rescuers manually pulling the cockpit windscreen and supporting superstructure out of the way, Figure 1.4.41. He was released without reported difficulty and extracted from the aircraft after 5 mins 52 sec. He was placed on a stretcher and given immediate first aid before being removed to the Role 1 medical facility. Exhibit 6

[111] Role 1 medical support provides routine primary health care, specialised first aid, triage, resuscitation and stabilisation.

Figure 1.4.41 - Displacement of cockpit structure

1.4.279 The Co-pilot (in the left hand cockpit seat) was initially accessed by rescuers through the left hand cockpit door which was removed 49 sec after impact. He was extracted from the cockpit after 10 mins and 48 sec via the same route as the aircraft Captain and transferred to Role 1 medical facility. Exhibit 6

1.4.280 Passengers were extracted via the left hand cabin doorway or through the hole cut in the tail area. Figure 1.4.42 shows seating positions and exit routes. Table 1.4.8 summarises passenger extraction times. Exhibit 6

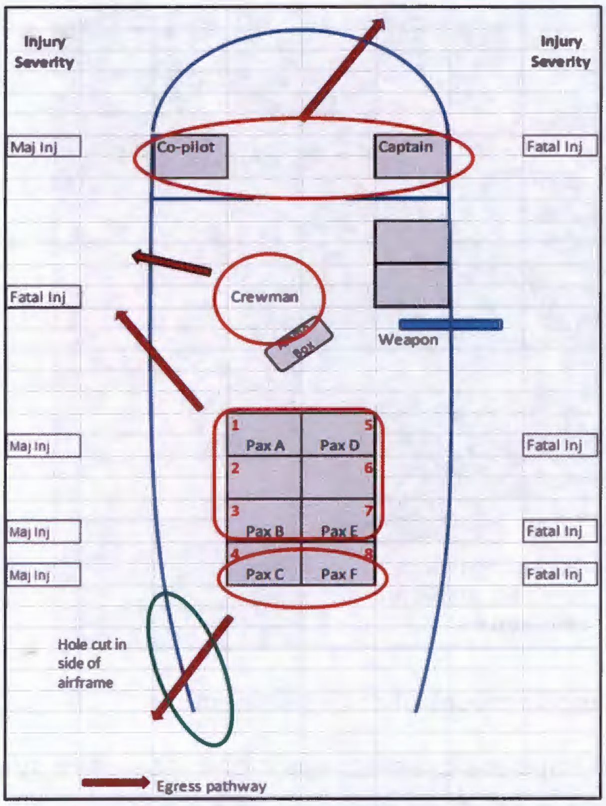


Figure 1.4.42 - XW229 Crew and passenger seating and exit routes

Individual	Time	Exit Point
Passenger A	11 mins 24 sec	Cabin Doorway
Passenger B	15 mins 25 sec	Cabin Doorway
Passenger D	23 mins 54 sec	Cabin Doorway
Passenger C	90 mins	Hole in tail area
Passenger F	94 mins 10 sec	Hole in tail area
Passenger E	98 mins 31 sec	Cabin Doorway

Note: Times are from aircraft impact with ground.

Table 1.4.8 - Summary of passenger extraction times and exit points

1.4.281 Coordination of the on-site rescue was initially limited, small groups worked independently to free the aircraft's occupants. However this evolved toward a well-coordinated rescue headed by a handful of individuals with First Person on Scene medical qualifications. The pooling of fuel and secondary vapour hazard added to the imperative for quick extraction. Medical supplies eg first aid packs, stretchers and neck collars, were immediately available from emergency medical packs located in adjacent buildings, from the HQRS medical facility and from personal supplies. Exhibit 6

1.4.282 The Panel concluded that the speed and magnitude of the rescue effort ensured that crew and passengers were extracted as quickly as possible in the circumstances. For the survivors, this reduced the risk of secondary injury effects eg increased blood loss, fuel burns. Exhibit 6

Medical facilities

1.4.283 **Role 1 - HQRS.** Initial medical evacuation was to Role 1, located 150 m from the crash site. The first casualty was seen 5 mins after the accident and last casualties were evacuated by helicopter 3 hrs 40 mins later. 42 rescuers were treated post-accident for fuel inhalation and irritant dermatitis; 2 required evacuation to Role 3 for overnight observation. Exhibit 6

1.4.284 **Role 2 - HKIA.** Role 2[112] was a 5 min flight by helicopter. Role 2 provided advanced resuscitation, limited diagnostics and damage limitation surgery; 2 surgical teams were available on the day and treated both pilots and Passenger B. As Role 2 had limited facilities, both pilots and Passenger B were subsequently moved to Role 3[113], at Bagram Air Base. Exhibit 6

1.4.285 **Role 3 - Bagram Air Base.** Role 3 was 11 minutes flying time north of HKIA, and was a well-equipped hospital offering definitive surgery including neurosurgery, longer term bedding down and limited rehabilitation. All aircrew and passengers from XW229 ultimately passed through Role 3 either for treatment or mortuary services. Those needing long term rehabilitation and specialist treatments were evacuated by Strategic Aeromedical Evacuation to Landstuhl Regional Medical Centre, Germany or the Queen Elizabeth Hospital, Birmingham, UK. Exhibit 6

1.4.286 The Panel concluded that the immediate access to the Role 1 medical facility and subsequent rapid transfer to the Role 2 and Role 3 facilities was instrumental in the effective treatment of the survivors.

Survivable space

1.4.287 Survivable space in the cockpit was well preserved, probably due to the nose up attitude at impact, although the central instrument console was displaced to the right. Some energy absorption was evident from the collapse of the nose wheel and deformation of structures below the cockpit flooring. Exhibit 6

1.4.288 The survivable space within the cabin was significantly reduced. The magnitude of impact forced the right main undercarriage and ballistic flooring into the cabin space. Concurrently the inertia of the MGB and Main Rotor Head buckled the cabin ceiling. Normally the height of the Puma cabin varied between 1.45 – 1.53 m along the centre line of the rear cabin; post-accident this was severely reduced leaving cabin volume at an estimated 1/3 of the pre-accident state. Exhibit 6

1.4.289 Figure 1.4.43 shows the cabin volume of a Puma HC Mk2. Figure 1.4.44 is a diagrammatical representation of the reduction of cabin volume in the area of the first passenger seats (Figure 1.4.42 seats 1&5). Figure 1.4.45 shows the reduction of XW229's cabin volume post-accident.

[112] Role 2 medical support provides an intermediate capability for the reception and triage of casualties, as well as being able to perform resuscitation and treatment of shock to a higher technical level than Role 1. Role 2 capabilities routinely include Damage Control Surgery and may include a limited holding facility for the short term holding of casualties until they can be returned to duty or evacuated.
[113] Role 3 medical support provides deployed hospitalisation and the elements required to support it, including a mission-tailored variety of clinical specialties such as primary surgery and diagnostic support. Role 3 is designed to provide secondary care within the restrictions of the Theatre Holding Policy.

Figure 1.4.43 - Puma HC Mk2 Cabin space

Exhibit 6

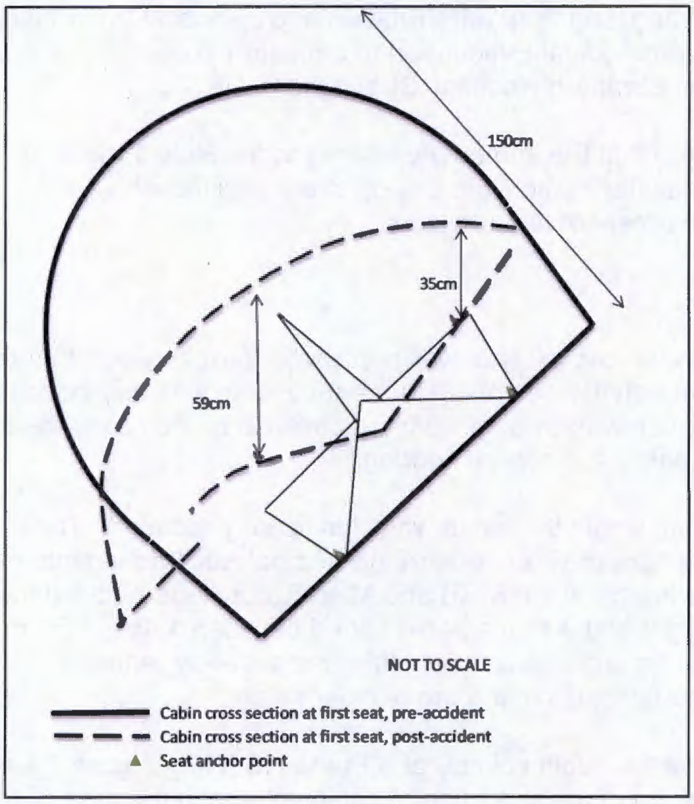


Figure 1.4.44 - Diagrammatic representation of decrease in cabin volume in area of first passenger seats viewed towards rear of aircraft

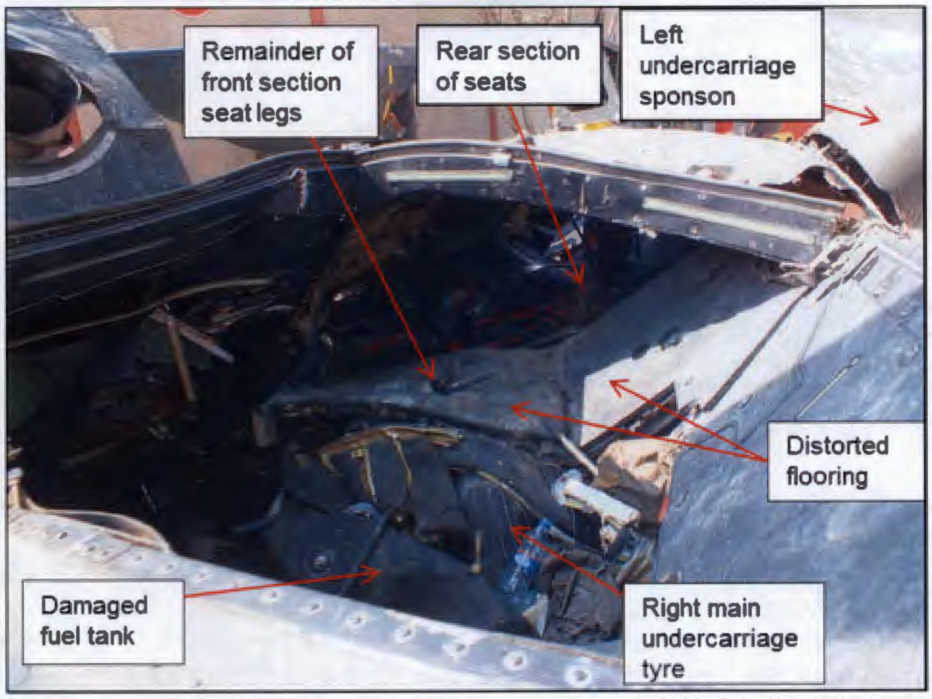


Figure 1.4.45 - View of XW229's cabin post-accident

1.4.290 The reduction in cabin volume was the most significant cause of passenger injury. Additionally the orientation of the aircraft and the buckling of the floor collapsed the right side passenger seats causing significant crush injuries to the occupants. The 3 passenger fatalities were all sat on the right of the aircraft; the passengers on the left all survived with varying degrees of injury. Exhibit 6

1.4.291 The Panel concluded that the loss of survivable space was the single most important factor in determining passenger survivability. The orientation of the aircraft at the moment of impact aggravated the injuries to occupants on the right of the aircraft and mitigated the effect to those on the left of the aircraft.

Cockpit seats

1.4.292 Cockpit seats were fitted with a Ballistic Protection Seat Liner as part of the TES fit. The basic non-armoured seats were originally qualified by the manufacturer to support and restrain a 77 kg man under relatively modest impact forces (+6 Gx, +/-3 Gy, +6 Gz, -2.25 Gz); further testing[114] in 2014 re-qualified this to 133.1 kg in all directions except Gx. As a result the seat was cleared for occupants with a dressed mass of up to 100 kg in the RTS. A representation of the G loading axis is in Figure 1.4.46. Exhibit 142 Exhibit 6

[114] Testing conducted by Zodiac Seat France and Airbus Helicopters.

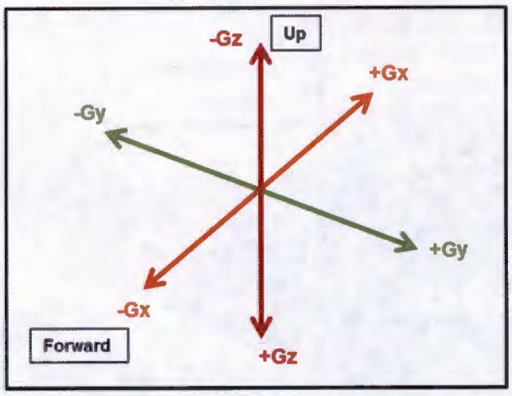


Figure 1.4.46 - Axis of G loading

1.4.293 The ballistic liner consisted of 4 separate plates which were mounted on the existing seat to form the 'armoured seat'. Armoured seats were originally approved in Dec 14 (RTS AL10) as Clearance with Limited Evidence (CLE) 016. CLE 016 was uplifted to full clearance in Apr 15 after further test evidence was provided. The RTS clearance included a statement that occupants with a dressed mass greater than 84.8 kg may be of increased risk of injury in the event of a heavy landing[115]. Op TORAL aircrew were required to wear additional equipment[116] which weighed in excess of 20 kg; the estimated weight of A22's pilots when equipped and in the aircraft, were 98 kg and 97 kg. The Panel observed that a significant proportion of Puma pilots, when deployed on operations, would exceed 84.8 kg, however the DDH had limited the use of the armoured seat to Op TORAL only, thus minimising the exposure and bounding the associated risk. Exhibit 92 Exhibit 143 Exhibit 95 Exhibit 6 Exhibit 143

1.4.294 The predominant force at impact was a combination of +Gz and -Gy. Both seats exceeded qualified design parameters with the average impact g of A22 calculated as 15 g; design qualification forces were 6 g in Gz and +/-3 g in Gy. Peak g was approximately 30 g. Exhibit 6

1.4.295 Both seats remained firmly attached to the cockpit floor and underlying beams; the harness systems showed no evidence of stress or malfunction. Both seats showed some rotation to the right under -Gy force and the lateral ballistic seat liner on the left hand seat had partially separated. Exhibit 6

1.4.296 The Panel acknowledged that the impact forces considerably exceeded the design standard and, as a result, formed the opinion that the cockpit seats performed well.

Passenger seats

1.4.297 Passenger seating was constructed from tubular steel connected by a series of welds and hinge joints. A canvas seat and back support was held taut by lacing below the seat area. The main seating in the centre of the cabin was formed by 2 units of 4 (2 seats back to back) and is shown in Figure 1.4.47. The seats were Exhibit 32 Exhibit 6

[115] P2G PT did not have a definition of a heavy landing. It was down to pilots to advise the engineers if they thought a landing was outside 'normal' parameters.
[116] Body Armour Load Carriage System (BALCS) included survival equipment.

Defence Safety Authority

secured to the floor using locking pins.

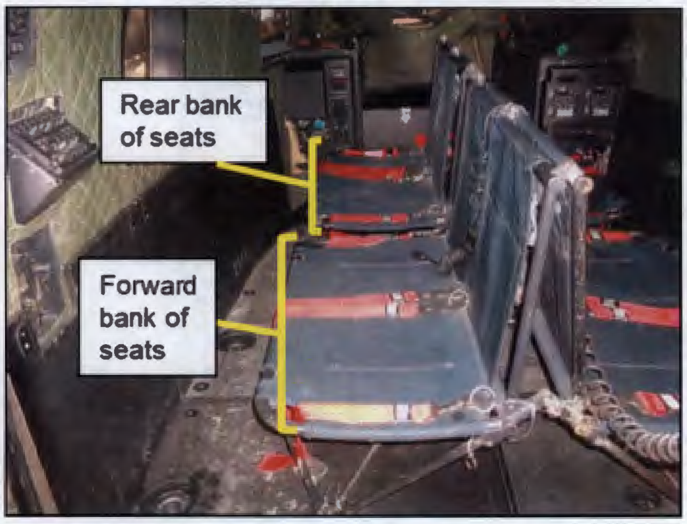


Figure 1.4.47 - Rear seating configuration

1.4.298 The seat was qualified in 1996 to withstand 6 g +Gx, 3 g +/-Gy and 6 g +Gz with a passenger weighing 80 kg and wearing an additional 20 kg of equipment. The seats were not upgraded during the Puma LEP with the requirement being for a seat that was at least as capable as the Puma HC Mk1. Exhibit 6

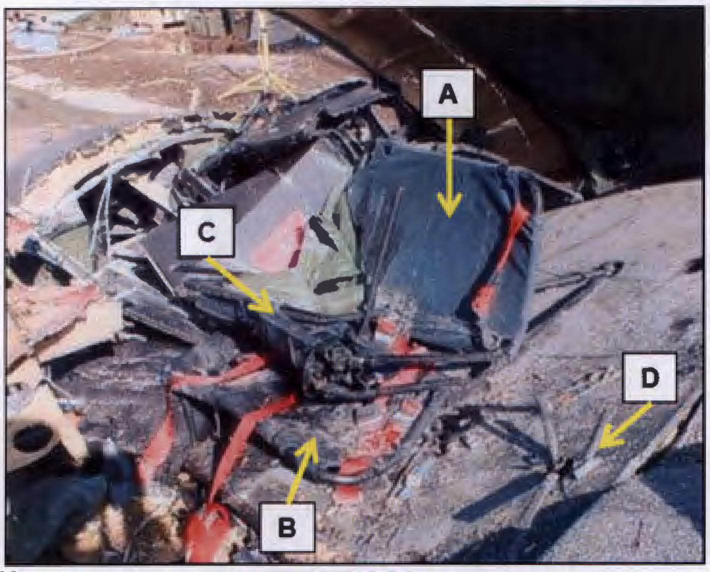
1.4.299 The JHC CI 19 stated a planning weight of 115 kg for a soldier in Assault Order[117]; this figure was used by the crews to calculate aircraft weight and performance. Weights of the passengers are unknown but it is probable that with the requirement for protective armour, helmets and the carriage of weapons, the loading on the rear 4 seats, which were all occupied, was exceeded. Exhibit 101 Exhibit 6

1.4.300 A22 experienced impact forces which were higher than the qualified tolerances. The tubular supports showed some deformation and welds were dislocated but much of this may be attributable to the deformation of the floor. Exhibit 6

1.4.301 Seats mounted on the left hand side generally maintained good shape and form but to the detriment of those seated on the right side of the aircraft whose seats folded between the rising floor and the weight of passengers seated above them when the aircraft came to a halt. Figure 1.4.48 shows the rear bank of passenger seats during the aircraft recovery. Floor fittings were all intact save one where the floor had given way. All harness attachment points, harness straps and buckles remained intact although the 'male' buckle element for seat 7 was bent but could still be released. Exhibit 6

[117] Assault Order consists of the essential weapons, ammunition, personal protective equipment and other items required for operations and patrols of a limited duration.

Defence Safety Authority



Key:
A. Left side seat pan.
B. Right side seat pan.
C. Back support.
D. Forward seat bank attachment.

Figure 1.4.48 – Rear bank of seats viewed front to rear during aircraft recovery

1.4.302 The Panel concluded that although the design parameters of the seats were exceeded (velocity of impact and resultant g loading meant the aircraft was subject to between 15 and 30 g), the seats performed well with regard to their structural integrity.

1.4.303 Two passengers sustained injuries that the Aeromedical Report considered were most likely caused by the troop seat. Passenger B's injuries were consistent with a forced hyperextension ie backward flexion of an unsupported neck. The rear ballistic plate (30 cm (height) x 25 cm (width)) of passenger C's personnel protective equipment revealed multiple fractures (Figure 1.4.49) which would have transmitted sufficient force to cause the related injuries. It is probable that the plate was fractured when Passenger C struck the bar at the top of the troop seats; the horizontal fracture mark broadly aligned with the top of the seat. Exhibit 6

Figure 1.4.49 - Fracture Damage to Passenger C's rear ballistic protection

1.4.304 The back of the passenger seat is a canvas panel secured to a horizontal bar at a seated height of 43 cm; a seated passenger, supported across the upper back, who experiences a significant +Gx force will inevitably experience forced neck extension. Injuries were more likely with head mounted mass such as a ballistic helmet and whilst wearing body armour with ballistic plates as these factors would have increased the moment and concentrated the fulcrum around the neck area. The position of the troop seat's upper support in relation to a passenger's back is shown in Figure 1.4.50. Exhibit 6

Figure 1.4.50 - Position of troop seat upper support

1.4.305 Aeromedical specialist analysis considered that the rigidity and prominence of the tubular bar on the seat back accentuated point loading forces Exhibit 6 across the passengers' backs with a commensurate risk of injury. There was also no means of head support in the event of a significant passenger rearward inertial force, as experienced by passengers seated on the left side of the aircraft.

1.4.306 The Panel concluded that the central bank of troop seats' horizontal support bar and lack of head support were an **Aggravating Factor** in the accident.

Recommendation

1.4.307 The Puma Project Team Leader should instigate improvements to the Puma HC Mk2 central troop seat upper body support.

Improved passenger seating

1.4.308 A study of occupant crash safety in rear cabins of UK military aircraft in 2015 recommended wall mounted, energy attenuating seats with 4 point harnesses as a potential safety enhancement for Puma HC Mk2. The Military Aviation Authority (MAA) also recommended a review of platform risk registers regarding crew and passenger seat design following the release of the Puma HC Mk1 XW211 Service Inquiry in 2014. The recommendation was addressed by the Puma DDH in Jun 15 who concluded that the current risk was both tolerable and As Low As Reasonably Practicable.

Exhibit 144
Exhibit 145
Exhibit 146
Exhibit 6

1.4.309 The Panel concluded that whilst recommendations for energy attenuating seats and use of a 4 point harness is in-line with survivability principles it is unlikely that either would have changed the fatality rate for this accident as the buckling of the cabin floor and loss of survivable space were the defining factors.

1.4.310 However, since the seat was qualified 20 years ago the weight of troops (plus their equipment) has increased; for planning purposes JHC assumed that a soldier in Assault Order weighs 115 kg, 15 kg beyond the weight assessed in 1996. Whilst this accident exceeded the certified g limits for the seats, the Panel considered that the associated information was dated, and therefore there is no accurate understanding of the expected g tolerance for passengers in current equipment.

Exhibit 101
Exhibit 6

Recommendation

1.4.311 The Puma Project Team Leader should re-qualify the passenger seat with representative current troop weights.

Crewman restraint

1.4.312 The crewman was not seated at the time of the accident and therefore was only restrained by a despatcher harness. Although crewmen were directed to have access to a seat for use in an emergency, the Panel assessed that the nature of the aircraft's rapid attitude changes, and the time to impact, made it unrealistic for A22's crewman to become secured in a seat.

Exhibit 6
Exhibit 147

1.4.313 At the moment the aircraft struck the tether, the Panel assessed that it was appropriate for the crewman to be using a despatcher harness; the formation was positioning to land and his duties required him to be able to move about the cabin and operate the crew served weapon.

1.4.314 For the 17 sec following the tether strike the Panel judged that as the crew were unclear as to the nature of the emergency and whether a landing would immediately ensue, it was appropriate for the crewman to remain on the harness. Following the catastrophic failure of the TRDS and during the 6 sec to impact the Panel assessed that the crewman did not have time to secure himself in a seat.

Post-Crash Management

1.4.315 **Context.** The APG contained generic Post Crash Management (PCM) procedures for RS aviation units. Irrespective of NATO requirements the responsibility for a UK PCM plan rested with the unit. The TAD had two dedicated emergency procedure plans: Op CABRIS for a downed aircraft within the confines of HKIA and Op ICARUS for an incident outside of the airfield boundary. Due to the operational context, a crash or downed aircraft incident occurring away from HKIA [redacted] Within the TAD the Detachment Commander, or the Operations Officer[118], would assume the role of the Incident Commander and the TAD Detachment Support Group (DSG) Commander would assume the role of Post Crash Management Incident Officer (PCMIO). The TAD had exercised Op ICARUS during the changeover of aircrew in late Sep. A post exercise report noted several minor issues which were addressed by the TAD. Exhibit 18 Exhibit 148 Exhibit 149 Exhibit 150 Exhibit 150 Exhibit 151 Witness 7

1.4.316 **Execution.** A22 crashed inside the secure confines of HQRS and whilst the TAD Ops room initiated Op ICARUS within a minute of the accident, it was quickly apparent that personnel within HQRS were best placed to lead the onsite activity. TAD Ops staff completed the appropriate elements of Op ICARUS while maintaining close liaison with HQRS and HQ COMBRITFOR. By coincidence, on 11 Oct two UK aviation staff officers were conducting a handover and happened to be at HQRS close to the crash site. Although neither were PCMIOs, they had a PCM Aide Memoire with them and provided immediate advice to COMBRITFOR staff. Exhibit 26 Witness 7 Witness 17

1.4.317 **PCMIO.** An RAF officer based at HQRS was nominated as the PCMIO by the senior British airman (Deputy NATO Air Commander). The individual was qualified, had been in theatre for 3 months and had existing relationships with many of the enablers within HQRS which assisted him in executing his PCMIO duties. During the recovery phase the TAD offered to deploy their nominated PCMIO to the crash site but HQ COMBRITFOR were content that the situation was under control. Exhibit 26 Witness 7

1.4.318 The Panel concluded that although the TAD had a coherent PCM plan, the use of a PCMIO who was based at HQRS and familiar with its resources ensured that PCM was highly effective and efficient.

1.4.319 **SOC crash plan.** At the time of the accident NATO did not have a dedicated aircraft crash plan for SOC, there was an Immediate Action drill for general emergencies for the whole HQRS site, but nothing specifically designed for an aircraft incident. In the Panel's opinion, noting the role of HQRS and its Exhibit 153

[118] As the Det Comd was one of 6 pilots there was a high probability that he would be flying in the formation so the Operations Officer shared the role.

operational and administrative functions, it was understandable that there was no specific aircraft crash plan for the main site. However, with circa 10,000 helicopter movements a year the Panel assessed that a specific aircraft crash plan for SOC would have been advisable. The Panel were informed that an aircraft crash plan had been implemented by Jul 16.

Site safety

1.4.320 Once the casualties were removed the site was cleared of rescue personnel and cordoned. During the period 11 - 14 Oct 15 the cordon was maintained by the HQRS Guard Force with an additional permanent UK military presence[119] to ensure national standards of evidence preservation. Controlled access ensured the accident site was undisturbed[120] until Defence AIB Investigators arrived. Exhibit 26

1.4.321 With TAD assistance the aircraft's defensive flares were removed and while electrical (battery) power was switched off, the battery could not be isolated due to airframe disruption. This resulted in a continuing risk of fire due to the presence of residual fuel and the possibility of an electrically generated ignition; HQRS Fire crews maintained a presence until the Joint Aircraft Recovery & Transportation Squadron (JARTS) team had recovered the wreckage. Crew and passenger weapons and personal effects were collected and secured at HQRS. Exhibit 26 Exhibit 154

1.4.322 In the days following the accident, the PCMIO sought guidance from the Defence AIB in the UK and began collecting and collating evidence. Statements were requested from those who had witnessed the incident or assisted in the aftermath. Concurrently, a member of the Royal Military Police went to the TAD to ensure all necessary items had been impounded in accordance with Op ICARUS. Exhibit 26

1.4.323 As A22 was a UK aircraft, the UK assumed the lead for the post-crash accident investigation in accordance with NATO STANAG 3531. However, the multi-national aspect of the accident and its location within a NATO base required close liaison between the PCMIO, HQ COMBRITFOR and representatives from the other nations that had had personnel killed or injured. Of those nations, only the US requested an observer to be included in the Defence AIB team once they arrived in Theatre. Exhibit 155 Exhibit 26

1.4.324 The Defence AIB team arrived on 14 Oct and took control of the site. A small team of TAD engineers under the direction of the Defence AIB assisted with the recovery of the CVFDR and other data memory sources from the aircraft. Aeromedical and HF specialists arrived on 15 Oct. Members of the investigation team conducted interviews with a number of first responders. Exhibit 26

1.4.325 **Trauma risk management.** A UK Trauma Risk Management (TriM) practitioner was appointed from the outset and held voluntary sessions for those involved in the incident both at HQRS and HKIA; several non-UK first responders attended the sessions and remarked on the benefit of their inclusion. Exhibit 26

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[119] Initially a Royal Military Police JNCO followed by members of the resident Infantry Battalion.
[120] Other than essential safety related activity.

Aircraft recovery

1.4.326 On completion of Defence AIB evidence gathering on 19 Oct 15, JARTS prepared, under the guidance of Defence AIB investigators, the wreckage for transportation. Due to transport limitations, access to the crash site and FP considerations for road movement, the wreckage had to be significantly disrupted to facilitate transportation. The wreckage was moved by road over 2 nights on 20 and 21 Oct 15 to a secure hangar at HKIA(N). It was subsequently recovered via RAF Strategic Air Transport to RAF Brize Norton and moved to a MOD site on 3 Nov 15 for detailed investigation. Exhibit 26 Exhibit 30

Site recovery

1.4.327 Damage to HQRS infrastructure was limited to minor MRB strikes on an accommodation building's roof, an air conditioning unit and a tree. There was some contamination of the HQRS drainage system due to fuel spillage and the extensive use of fire suppressing agents during the immediate response. Exhibit 32

1.4.328 NATO engaged a local contractor to excavate the crash site, remove and dispose of hazardous material and carry out reconstruction. NATO was subsequently advised that the area had been cleaned and returned to its original state at a cost of US $100,000. Exhibit 156

1.4.329 The Panel considered the overall PCM response and follow up activity to have been effective and well executed.

Aircraft category

1.4.330 XW229 was categorised as CAT 5 (Scrap). Exhibit 157

Cost to Defence

1.4.331 The cost to Defence of the loss of XW229 and its associated TES equipment is £18.5M. Exhibit 158

Post-accident – summary

1.4.332 After impact the aircraft was orientated on its right side; the airframe suffered extensive disruption during the accident sequence which was exacerbated by rescue activities. None of the aircraft occupants were able to conduct their own egress having being either trapped within the wreckage or incapacitated by the force of the impact. The substantial deformation of the cabin structure, and resultant entrapment of passengers, forced rescuers to cut an additional extraction route through the tail cone of the aircraft. The Panel considered that the speed and magnitude of the rescue effort ensured that crew and passengers were extracted as quickly as possible in the circumstances.

1.4.333 The Panel concluded that the loss of survivable space was the single most important factor in determining passenger survivability. The orientation of the aircraft at the moment of impact aggravated the injuries to occupants on the right of the aircraft and mitigated the effect to those on the left of the aircraft.

1.4.334 The Panel concluded that although the design parameters of the seats were exceeded, the seats performed well with regard to their structural integrity. However, two passengers sustained injuries that were most likely caused by interaction with the troop seat. In the Panel's opinion, the combination of the horizontal bar securing the vertical panel of the seat and the orientation of the aircraft on impact accentuated forces across the passengers' backs. There was also no means of head support in the event of a significant passenger rearward inertial force. The Panel concluded that the central bank of troop seats' horizontal support bar and lack of head support were an **Aggravating Factor** in the accident.

1.4.335 Although there was no dedicated aircraft crash plan for SOC, the Panel assessed when considering the high volume of helicopter movements one would have been advisable. The Panel were informed that an aircraft crash plan had been implemented by Jul 16. Nevertheless the Panel assessed that Post Crash Management activities were effective.

Organisation

Air Safety Management

1.4.336 JHC had a functioning Air Safety Management System which required the Puma DDH to produce a subordinate Air Safety Management Plan (ASMP) providing Force-level air safety management processes. Both documents provided direction and guidance for the identification of hazards, management of air safety risks and mitigation activity. A Unified Air Safety Risk Register was maintained by Comd JHC (the ODH) which covered all credible Risk to Life (RtL) within the Command; a sub-section of the Unified Air Safety Risk Register was dedicated to the Puma. Exhibit 159 Exhibit 148 Exhibit 160

1.4.337 The RAF Benson ASMP directed a separate RAF Benson Consolidated Risk Register to collate all risks not just air safety risks; 'collision with an obstacle' was captured, with associated mitigations in both risk registers. Variations were apparent due to the Unified Air Safety Risk Register dealing with generic risks and the Consolidated Risk Register focussing on Puma risks. Puma mitigations for 'collision with an obstacle' and applicability to the TAD are at Table 1.4.9. Exhibit 161

Mitigation	Applicability to TAD Operations
Maps	Up to date, carried in the aircraft but not used due to familiarity with AO
Defensive Flying	Crews flew at approximately 500 ft AGL above most obstructions in city and maintained a reduced airspeed
RWAMMWAS	Database out of date on 11 Oct. Not carried in the aircraft for tasks over city due to familiarity with AO

Table 1.4.9 - Collision with an Obstacle - Puma mitigations

1.4.338 **Command Instruction 14.** X Flt's Statement of Deploying Aircrew Capability made specific mention of the expected hazards and the mitigations to be employed. The document stated '*wire strike*' but expanded the scope to include '*masts or other vertical obstructions*'. The only mitigation stated was 'training/defensive flying'. The Panel considered that within the 'training' element the Exhibit 47 Witness 24

TQ process ensured that newly deployed crews were made aware of the PTDS locations[121] and had been shown safe approaches into the main HLSs.

Exhibit 61

1.4.339 **Maps.** Maps were carried in TAD aircraft but were not routinely used in the Kabul area; the constrained nature and familiarity of the AO negated their use. They were used for sorties away from the city.

Witness 12
Witness 3

1.4.340 **Defensive flying.** The Panel could not find a definitive description of defensive flying, although it was referred to in Puma SOP 22 – Low Flying. In effect, and when considering a witness testimony that discussed defensive flying, the Panel considered that it was flying the aircraft in a manner that provided space, time, opportunity and built situation awareness to react to an unexpected situation. Around Kabul TAD crews flew at a height that was above the majority of obstructions and at a speed commensurate with the restricted operating area. In the Panel's opinion, and given the operational constraints, the Puma Force were flying in accordance with the principles of defensive flying as described by witnesses.

Exhibit 163
Witness 9
Witness 25
Witness 3
Witness 24

Rotary Wing Aircrew Moving Map Wire Alerting System (RWAMMWAS).

1.4.341 RWAMMWAS was a 7 inch touch-screen tablet that displayed information about the location of known wires/obstructions on a moving map showing the aircraft position and was utilised within the Puma Force[122]. Usually carried by the left hand seat occupant on a kneeboard on the right leg, it flashed to alert the crew if they were approaching an obstruction/wires hazard. The system generated a visual alert when the aircraft was at the same height or below and within 3 nm of a hazard, and a visual warning occurred when within 1 nm[123]; when within the warning area the tablet would flash continuously. The system would only alert to hazards within 30° either side of the aircraft's heading. There was no audio warning to crew members; to identify warnings the operator had to look directly at the tablet.

Exhibit 165
Witness 9
Witness 25
Witness 16
Exhibit 163
Exhibit 164
Witness 9
Witness 24
Witness 3
Witness 22

1.4.342 There were mixed opinions regarding the effectiveness of RWAMMWAS on Op TORAL. It was considered useful for low level transits away from the city, but ineffective in the familiar environment of the Kabul cluster. A mid-air collision was regarded to be a greater risk and crews stated that they preferred to maintain a good lookout rather than looking down into the cockpit.

Witness 27
Witness 25
Witness 26
Witness 3
Witness 24
Witness 9

1.4.343 Interviewees stated that with the number of vertical obstructions within the Kabul area, the tablet would have been alerting constantly minimising its utility. When considering the PTDS at HQRS, RWAMMWAS would alert immediately after departing HKIA as the direct line distance was 2.5 nm. Furthermore, crews stated they were aware of the significant hazards such as the HQRS PTDS.

Witness 25
Witness 26
Witness 3
Witness 4
Witness 5

1.4.344 The combination of the volume of hazards, requirement to look into the cockpit to register warnings and familiarity with the confined AO around the city, resulted in TAD crews electing not to use RWAMMWAS for sorties over the city.

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121 Crews were required to sign as having read the Afghan AIP, the APG and the TAD Aircrew Handbook – all contained PTDS details.
122 It was also utilised in other JHC aircraft.
123 GECO User Guide, Module 5 Mission Data lists default settings for the warning and alert areas. JHC CI 07 RWAMMWAS states that the settings should not be changed from the default.

1.4.345 Hazard information contained within the RWAMMWAS tablets was pre-loaded and updated on a routine basis. Updates were provided by the Aeronautical Information Distribution Unit (AIDU) in the form of an Aeronautical Information Regulation and Control (AIRAC) update card[124] which was sent directly to the TAD. However, many temporary hazards, such as cranes and kites, would not be represented on the database. AIDU sent the AIRAC 1508 update on 2 Sep 15 to the TAD, but it did not arrive. On 16 Sep 15 TAD Operations issued Aircrew Information 15/52 which declared RWAMMWAS documents to be out of date. The Panel could not ascertain why the update card did not arrive. The next AIRAC update to arrive at the TAD was on 15 Oct 15 – this was AIRAC 1509 which was sent by the AIDU on 7 Oct 15. The Panel formed the opinion that even if the RWAMMWAS tablets had been updated they would not have been used by the crews on 11 Oct 15. Exhibit 164 Exhibit 166 Witness 24 Exhibit 167 Exhibit 13 Exhibit 167

1.4.346 Although the DDH accepted that it was not being used, the change in mitigation was not communicated to the ODH. However, the ODH had stated previously that he was content for DDHs to ultimately decide whether to use RWAMMWAS or not. Another JHC DDH had directed his crews not to use the tablet due to concerns regarding the tendency for aircrew to look inside the aircraft too much. The Panel concluded that the decision by TAD crews not to use RWAMMWAS on sorties over the city was justified and understandable. Witness 24 Exhibit 168 Exhibit 160

1.4.347 Having considered the available evidence, including the size of the Kabul area and the crews' familiarity with it, the Panel concluded that the lack of use of RWAMMWAS was **Not a Factor** in the accident.

Use of Helmet Mounted Displays (HMD) as mitigation against Controlled Flight Into Terrain and impact with unseen obstacle.

1.4.348 The Panel were made aware of the use of HMD[125] within the Puma Force as mitigation against Controlled Flight Into Terrain and impact with unseen obstacles. The Day Head-Up Display (DHUD) consisted of a monocle attached to a pilot's helmet which could be rotated down in front of a pilot's eye to provide relevant flight data[126]. During interviews the Panel was informed of the mixed use of HMD in theatre. Several witnesses reported using the DHUD at the beginning of their detachment but discarded it after a short period because it produced a pink/purple tinge through the monocle under conditions frequently encountered over the city[127], and the plastic support obstructed their lookout. Witnesses considered these issues to be potential distractions. Another witness found it difficult to see the information on the screen amongst the cluttered background of the city. Conversely, A21's Captain had initially not used it but was using it more frequently as he became more comfortable with the urban environment. The crew of A22 were carrying DHUD on the aircraft but were not using it[128]. Exhibit 169 Exhibit 92 Witness 3 Witness 25 Witness 26 Witness 4 Witness 3 Exhibit 187

1.4.349 The Panel formed the opinion that whilst the DHUD would have allowed pilots to lookout more, rather than looking in at the flight instruments as frequently, it was unlikely to have prevented A22 from impacting the PTDS tether as the DHUD

[124] Aeronautical Information Regulation and Control – a 28 day cycle of updates to aeronautical documents.
[125] HMD consists of DHUD and Display Night Vision Goggles (DNVG).
[126] Selectable parameters included Airspeed, Altitude, Heading, Attitude, Radar Altitude, Vertical Speed and Torque.
[127] Cluttered background with minimal contrast.
[128] Two sets of DHUD were found in the wreckage still inside the protective cases. Crewmen did not use DHUD.

would not have provided any additional information relating to the PTDS location or the lead aircraft's position.

1.4.350 **Direction for use.** The RAF Benson FOB was amended on 10 Sep 15 and introduced direction for the use of RWAMMWAS and HMD but the Panel could not determine if the order applied worldwide or only when operating from RAF Benson. The amendment stated: Exhibit 171 Witness 24

a. RWAMMWAS.

(1) *P2315.200.1 Use of RWAMMWAS below 500 ft AGL. IAW JHC CI J5007, RWAMMWAS should be used on all sorties planned to operate below 500 ft AGL to aid situational awareness (it is not to be used as the primary navigation source). RWAMMWAS is not a Go/No-go item of equipment. If crews plan to operate without the equipment then the captain and the authoriser are to consider and brief the increased risk. Should the RWAMMWAS fail during flight or there is doubt about the validity of its GPS accuracy then the aircraft captain is to consider the change in risk mitigation upon the sortie and adjust the sortie profile if appropriate.*

(2) *P2315.200.2 Use of RWAMMWAS above 500 ft AGL. RWAMMWAS may be used above 500 ft AGL to aid situational awareness.*

b. DHUD. *P2315.300.2 DHUD. DHUD should be considered for use on all day sorties unless IF*[129] *is being conducted for the duration of the sortie. If either member of the front seat crew plan to operate without DHUD, the captain and the authoriser are to consider and brief the impact on the risk for the sortie. DHUD is not a Go/No-go item of equipment but if the DHUD fails, the aircraft captain is to consider the change in risk mitigation upon the sortie and adjust the sortie profile if appropriate.*

1.4.351 As TAD crews flew around Kabul at approximately 500 ft AGL, paragraph 1.4.110, their operational profile was on the boundary of the direction regarding the use of RWAMMWAS. In the Panel's opinion the direction could therefore be interpreted in either way dependant on circumstances at the time.

1.4.352 The FOB guidance relating to DHUD was contrary to that contained in Puma HC Mk2 SOP 24 – 'Helmet Mounted Display' AL5 dated 04 Oct 14 which stated *"HMD, if available, is to be used on all day and night VFR sorties"*. This direction appeared to remove the Captain's discretion to not use the equipment after discussing further mitigation with the Duty Authoriser[130]. Exhibit 170

1.4.353 The Panel **observed** that the direction for the use of RWAMMWAS and DHUD was ambiguous.

[129] Instrument Flying.
[130] Puma 2 SOP 24 was amended in late 2015 after DASOR\15\11846 raised the issue. At the time of the accident HMD was to be used on all day and night VFR sorties.

HQRS Air Safety Management

1.4.354 In order to mitigate a number of Flight Safety risks eg airspace congestion and HLS coordination, the Deputy NATO Air Commander (Afghanistan) (D-NAC(A))[131] established the 'HQRS Safety and Standardisation Council'. Although the group lacked formal authority[132], it was inclusive of all rotary wing operators and attempted to improve safety within the AO by corralling the disparate range of operators. Meetings were held every 2 – 3 months; associated minutes indicated an expanding membership and progress with the issues raised. Witness 19 Exhibit 172 Exhibit 110 Exhibit 111 Exhibit 173 Exhibit 174 Exhibit 176 Exhibit 76

1.4.355 Having considered witness evidence, the Panel observed the forum to have been successful in drawing the disparate rotary wing operators together; it enabled a collective awareness of extant and emerging issues and attempted to improve the overall safety of rotary wing operations. Nevertheless, the ability to authoritatively enforce compliance with agreed mitigations was limited. Aviation operators under NATO Command could be directed to comply with new directions, however, the compliance of non-NATO operators relied on influence, acceptance and goodwill. Witness 19

1.4.356 In the Panel's opinion the provision of an empowered Flight Safety organisation would be beneficial in the delivery of operational output and improve safety within the Kabul cluster, and therefore considered it an **Other Factor**.

Recommendation

1.4.357 PJHQ COS(OPS) should engage with NATO HQ RESOLUTE SUPPORT to establish an empowered Flight Safety Authority to manage and implement air safety related activities across all helicopter operators in the Kabul area.

Airspace

1.4.358 **Transitional context.** Since the completion of NATO combat operations the operational focus had shifted to advising and assisting the Afghan Government. Accordingly, Afghan airspace was transitioning from operational battlespace to a sovereign, civilian, coordinated airspace. A national Aeronautical Information Publication (AIP) had been produced which was a predominantly civilian document that also captured the remaining military requirements. By invitation[133], the Combined Forces Air Component Commander was the Airspace Control Authority for Afghanistan. Kabul ATC controlled the wider Kabul area which included the majority of the TAD's AO; airspace deconfliction was achieved through AIP mandated procedures, ATC instructions and the use of a common frequency. Exhibit 184 Exhibit 18

Airspace coordination

1.4.359 The TAD had access to the Airspace Control Order and the Air Tasking Order; however they did not use them routinely for coordination and tasking. Helicopter coordination in the Kabul area was achieved through height deconfliction Witness 7

[131] D-NAC(A) was based in Kabul and was the senior British airman in country.
[132] D-NAC(A)'s responsibility was for aviation assets above the coordination level 3500 ft AGL.
[133] The Afghan Ministry of Transportation and Civil Aviation was responsible for coordinating with other agencies for the implementation of policy covering ICAO matters. They invited the CFACC to be the ACA.

(stated in the APG) and mandated interaction with Kabul ATC. TAD Operations were aware that they were included in the documents and that they were not tasked by them; TAD tasking came from the US Aviation Task Force in Bagram. TAD callsigns were contained within the Air Tasking Order. Exhibit 18

1.4.360 The APG prescribed RS Command policies and procedures for aircraft operations, aircrew requirements and flight rules. It applied to all RS Command rotary wing aviation assets, including civilian and contracted organisations, operating below the coordinating altitude[134]. Included within the APG was direction for crews to read applicable sections of the Afghanistan AIP. Exhibit 18

1.4.361 The APG referred to No-Fly areas and Restricted Operating Zones (ROZs) whereas the Afghan AIP referred to Danger Areas, Special Use Airspace (SUA), Restricted Areas, ROZs and Prohibited Areas. As an example, SUA, Prohibited and ROZ were all used in a single sentence in relation to the Presidential Palace. The Panel noted that the use of multiple airspace descriptors in relation to one specific site had the potential to cause confusion and possibly denude the significance of the restriction. Several interviewees stated 'ROZ' when discussing general airspace restrictions that were designated as Danger Areas and the Panel formed the opinion that the acronym 'ROZ' and the phrase 'Danger Area' had potentially become synonymous. Exhibit 18 Exhibit 12 Witness 12 Witness 3 Witness 4 Witness 26 Witness 25

1.4.362 With specific relation to the protective airspace around PTDSs this may explain why TAD crews would enter what was articulated in the AIP as a Danger Area (Special Use Airspace – NO FLY) which was prohibited to military aircraft. TAD aircraft routinely landed at a HLS within a PTDS Danger Area, and in the case of SOC on the boundary of the HQRS PTDS Danger Area. The Panel could not find an explicit clearance for the crews to enter these areas. The Panel formed the opinion that if the airspace was perceived as a ROZ, then TAD crews would be more likely to deem it acceptable to enter, if tasked to do so, as part of their mission. Exhibit 14 Exhibit 107

1.4.363 In the Panel's opinion there was potential for confusion between what would be understood as 'operational' terminology eg ROZ, and peace time descriptors eg Danger Area. Misunderstanding of the status of an airspace restriction has the potential to be a significant safety hazard and therefore the Panel considered it to be an **Other Factor**.

Recommendations

1.4.364 Puma HC Mk2 DDH should ensure that crews understand the differences between operational and civilian airspace restrictions.

1.4.365 PJHQ COS(OPS) should, through NATO HQ RESOLUTE SUPPORT, clearly articulate in appropriate publications the status of military and civilian airspace restrictions within Afghanistan.

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[134] The coordinating altitude was 3500 ft AGL. It was the main method for deconfliction between rotary wing and fixed wing aircraft operations. Rotary wing operations stopped at 3000 ft AGL in order to provide a 'buffer'.

Volume of aviation related documentation

1.4.366 The Human Factors specialist report highlighted the volume of procedures that may be relevant to a particular task. For example rules and regulations relating to flying on Op TORAL were drawn from a hierarchy of documents included (not in order): Exhibit 72

a. Military Regulatory Publications.

b. Release to Service. Exhibit 95

c. JHC Flying Order Book. Exhibit 48

d. JHC Command Instructions. Exhibit 78

e. Training and Standardisation Instructions. Exhibit 60

f. Benson Flying Order Book. Exhibit 147

g. TAD Flying Order Book. Exhibit 61

h. Puma HC Mk2 Standard Operating Procedures. Exhibit 79

i. Puma HC Mk2 Aircrew Flying Guide. Exhibit 15

j. Aeronautical Information Publication. Exhibit 12

k. RS Aviation Procedures Guide. Exhibit 18

Many were subject to frequent amendments. Similarly, technical documentation was published and amended[135] in both electronic and hard copy formats. Furthermore, and as a result of the incremental expansion, the RTS was also frequently amended[136].

1.4.367 More specifically, procedures related to formation flying were found within 6 documents:

a. JHC Flying Order Book. Exhibit 48

b. Puma HC Mk2 Aircrew Flying Guide. Exhibit 15

c. Allied Tactical Publication 49137. Exhibit 178

d. Puma HC Mk2 Standard Operating Procedures. Exhibit 79

e. JHC Command Instruction. Exhibit 78

[135] Electronic updates were routinely published by Airbus Helicopters (UK) at 6 monthly intervals.
[136] RTS AL0 was issued in Sep 13 and was amended to AL17 over the next 25 months to the time of the accident.
[137] Use of Helicopters in Land Operations Doctrine.

f. JHC Mission Reference Cards. Exhibit 186

The requirement to brief emergency procedures for loss of visual contact was a single line within one of these documents. Therefore, in the Panel's opinion, it was possible for an omission to occur. Furthermore, details relating to the HQRS PTDS Danger Area were located in the Afghan AIP and the APG although the positions were in different formats (longitude/latitude and grid reference). Exhibit 78 Exhibit 18 Exhibit 107

1.4.368 The necessity to be aware of the contents of a large volume of publications is a common feature of aviation. However, the Panel **observed** that where information was spread across multiple documents, and where there were inconsistencies between documents, it was unsurprising that errors in understanding or application occurred.

Puma Force

1.4.369 **Commitment level.** The Puma Force had two tasks – Op TORAL and National Standby; in addition, the Force's training priorities were PDT, instructor training and aircrew conversions. The competing requirements for the number of available airframes were prioritised in line with the direction in Support Helicopter TASIs. Witnesses differed in their opinions of the situation with some stating that they had enough aircraft to meet their planned outputs while others contested that the Force had insufficient numbers of aircraft available to meet the requirements. JHC staff acknowledged that commitments would be reduced if required. Witness 24 Exhibit 41 Witness 24 Witness 15 Witness 21

Aircraft availability

1.4.370 While all Puma HC Mk2s had been delivered to the RAF, some were required to undergo further updates[138], some were unavailable due to scheduled maintenance, some were unserviceable due to a lack of spare parts and one was permanently attributed to trials. As a result availability at Sqn level varied on a daily basis. Exhibit 152 Exhibit 40

1.4.371 Aircraft availability was in some instances constrained by a lack of spares. Although the Puma HC Mk2 had numerous new components, a significant proportion of Puma HC Mk1 components remained. It was stated to the Panel that some repair contracts had caused delays to the delivery of spares which had led to aircraft remaining unserviceable for longer periods than expected. In addition, aircraft undergoing routine maintenance frequently had components removed in order to generate serviceable aircraft[139] thus increasing the engineering task. In order to generate more flying hours from the available aircraft scheduled maintenance was frequently extended[140]. Witness 28 Witness 29 Witness 15

1.4.372 However, due to the limited number of serviceable aircraft at any one time, the overall Annual Flying Task[141] was under-flown, meaning that the Force was not attaining its target flying hour rate, partially because of aircraft availability. Witness 29 Witness 30

[138] A standardisation update conducted by Airbus Helicopters concurrent with depth maintenance.
[139] The process is known as cannabilisation and is inefficient in terms of man hours.
[140] Aircraft were routinely extended to their maximum of 25% additional flying hours i.e. extended beyond a 400 hr servicing requirement to fly 500 hrs.
[141] The AFT was the anticipated number of aircraft hours required for the year's task.

Witnesses differed in their opinions as to whether there was pressure to achieve the Annual Flying Task. Throughout FY15/16 Puma serviceability failed to meet the overall target requirement, but as Figure 1.4.51 shows the situation was improving towards the end of the period.

Exhibit 43

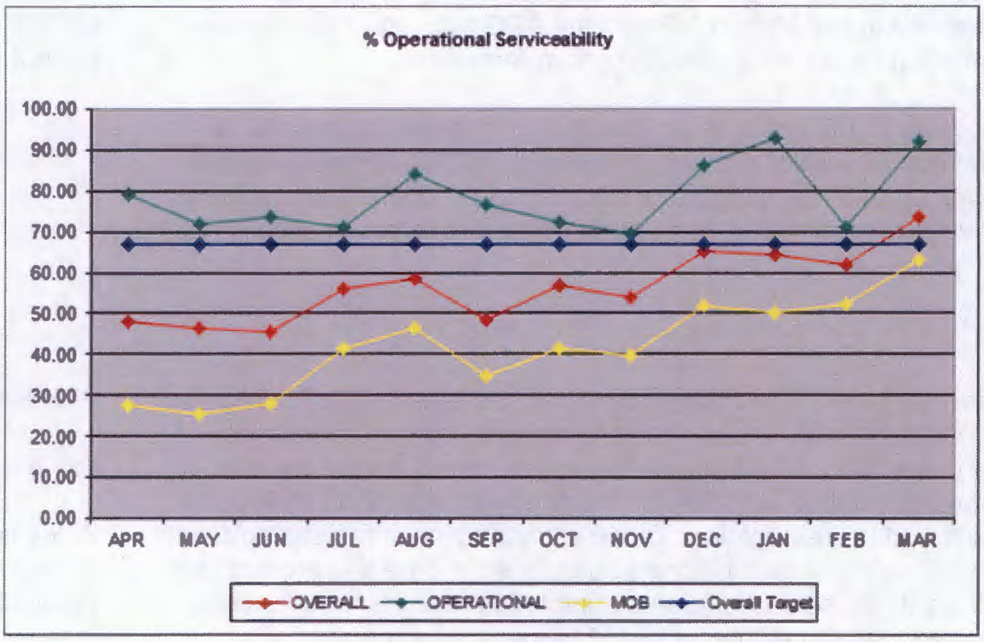

Figure 1.4.51 - Puma HC Mk2 overall, operational and MOB serviceability FY15/16

Manning levels

1.4.373 **Engineering manpower.** The ability to generate serviceable aircraft relied on engineers[142] being available; however witnesses stated that more were required to meet the demands being placed on the Puma Force. Conversely, the Panel was advised that there were sufficient personnel for the current level of commitments but insufficient to meet future requirements. The Panel concluded that, whilst opinions differed on the timeframe regarding shortages in engineering manpower, the consistency of the sentiment suggested that a lack of suitably qualified and experience personnel may have a detrimental effect across the Puma Force.

Witness 28
Witness 15
Witness 29

1.4.374 **Crewman manning levels.** In Dec 15, the available Puma Force crewmen were distributed between 3 Sqns[143]. The Panel were advised that although the Puma Force was in growth, it would take time to generate the required crews and there were insufficient crewmen to meet all of the Force's commitments resulting in individuals moving between flights for PDT and deployments. In the Panel's opinion this had the potential to undermine the Fight-by-Flight concept and impact on individual harmony and unit cohesion.

Witness 22

[142] Most specifically suitably qualified and experienced personnel of the correct trade and rank.
[143] 33 Sqn, 230 Sqn and 28 (R) Sqn.

Other considerations

1.4.375 **Maturity of the Aircraft Document Set (ADS).** Concerns were raised relating to incomplete aircraft maintenance documentation. The issue was acknowledged and captured as an air safety risk, with mitigation established until errors[144] were corrected. By way of example, the Panel noted a range of issues relating to Weight and Moment documentation during the Inquiry which are discussed in paragraph 1.4.105.

Witness 15
Witness 28

1.4.376 **Incremental RTS.** In order to allow aircrew training and Force development, the RTS was delivered incrementally and expanded as clearances[145] became available; there was considerable engagement between the DDH and Project Team Leader in managing this approach. However this methodology resulted in frequent changes to documentation[146], with the potential for errors or misunderstanding to occur.

Witness 20

1.4.377 **High altitude operations.** The Aircraft Test and Evaluation Centre[147] was tasked by the Puma Project Team to provide independent technical evaluation of the Puma HC Mk2 when operated to Airbus Helicopters' Centre of Gravity limits. Further trials were conducted in Colorado during mid-2015 to assess the high altitude, low speed operation of the Puma HC Mk2. During an interview it was noted that frontline crews had questioned the logic of deploying to a hot and high environment before hot and high trials had been conducted. However, the aircraft had an extant clearance under a European Aviation Safety Agency recognised aircraft design standard[148] and the aircraft was cleared to operate throughout the planned Op TORAL flight envelope. The trials resulted in recommendations for RTS expansion and updated previous advice. In the Panel's opinion, the frontline crews' concerns were most likely due to misperceptions relating to the purpose of the trial as opposed to operating the aircraft in 'un-trialled' conditions.

Exhibit 90
Exhibit 188
Exhibit 180
Witness 12
Witness 30
Exhibit 180

Deployment to Op TORAL

1.4.378 JHC considered that the Puma HC Mk2 was the most appropriate platform to meet the operational requirement on Op TORAL; the decision to deploy it was made in the first half of 2014, with a target date for deployment of Apr 15. JHC assessed that the aircraft would have sufficient capability at IOC[149] to meet the defined requirement. By Jul 14 detailed planning established that the Op TORAL task would require additional capabilities[150] beyond those originally required for IOC. Conversely some capabilities scheduled for IOC were not required[151] and were therefore deferred. As a result, a balance was found to ensure the aircraft were appropriately configured for deployment. Witnesses commented positively on the close interaction between the Puma Project Team and the Puma Force when managing the resultant training for new equipment and RTS amendments.

Witness 20
Witness 21
Witness 20
Witness 20

[144] Over 830 MF765s Unsatisfactory Feature Reports were raised against the technical ADS.
[145] Regimes included Day, Night VFR and IFR.
[146] As at May 16, the RTS was at AL21 having had 20 updates since Dec 13.
[147] ATEC is a partnership between QinetiQ and the Air Warfare Centre (AWC).
[148] FAR 29 - Federal Aviation Regulations 29, Airworthiness Standards Transport Rotorcraft.
[149] Three aircraft for two tasking lines worldwide and another three aircraft for another operation.
[150] [redacted]
[151] Fast roping, abseiling and Puma Auxiliary Fuel System.

1.4.379 Although the aircraft deployed soon after the declaration of IOC, JHC assessed that by the end of Mar 15 the aircraft was capable of undertaking the task and the crews were appropriately trained. Nevertheless, the physical preparation of the aircraft for Theatre continued up until the days immediately before deployment, as some TES equipment was only available at the last moment. Witness 21 Witness 28

1.4.380 Witness' opinions varied as to the levels of pressure applied to the fielding of the aircraft and the deployment dates. The declaration of IOC was a programme milestone with contractual relevance for DE&S and Airbus Helicopters, but for the operators it was the point at which meaningful capability could be deployed. Witness 20 Witness 28

1.4.381 The Panel **observed** that whilst there was no evidence of direct pressure to deploy the aircraft and train the requisite number of crews, the combined requirements has the potential to negatively impact the whole Force.

Cumulative risk

1.4.382 Collectively these observations were illustrative of the pressures inherent in a Force in growth that was concurrently operationally committed. Whilst all issues were managed at an appropriate level, the Panel considered that there were key pinch points with the potential to increase the safety risk across the Force. A reduction in available personnel, aircraft or spares could have a detrimental effect on output/training and potentially affect morale and reputation.

1.4.383 Likewise an increase in operational commitments may require a comparable reduction in training, compromising the longer term sustainment of the Force. The Op TORAL commitment was bounded by time; however a change in strategic direction and an extension of the task has the potential to detrimentally affect the platform's further development and increase pressure on individuals and Sqns.

1.4.384 Whilst there is no single catalyst to prompt a safety risk, the totality of the issues considered has the potential to lead to an emergent cumulative risk, and therefore, in the Panel's opinion is an **Other Factor**.

Recommendation

1.4.385 Commander JHC should review the cumulative risks associated with the development of the Puma Force whilst concurrently committed to an operational deployment.

Health Monitoring System

1.4.386 Within the LEP the Puma HC Mk2 was fitted with a Health Monitoring System (HMS). During the Inquiry Defence AIB engineering investigators sought to gain data from XW229's HMS, however Airbus Helicopters reported that no data had been recorded on the system during the accident sortie as prerequisite operating parameters had not been met. Exhibit 32

1.4.387 HMS recording parameters required the aircraft to be above 50 ft 'Radio Altitude' and between an Indicated Air Speed of 90 kts and 130 kts. When Exhibit 32 parameters were met the HMS conducted a sequence of 8 acquisition cycles, each cycle captured data on a range of components before commencing the next cycle. The 8 cycles took 2 minutes to record, and only when all had been completed did the system write the data to a memory card. A22's final sortie lasted 6 mins during which it was within recording parameters for 1 min 16 sec, as a result no data was captured. Exhibit 34

1.4.388 The majority of TAD operations were conducted within a small operating area, as noted in paragraph 1.4.189, with short transits and frequent landings. As a result the Panel assessed that the volume of recorded HMS data was therefore limited. The Panel concluded that the current HMS recording parameters would not capture some of the more demanding low speed profiles of Support Helicopter operations[152].

1.4.389 Furthermore, Airbus Helicopters revealed that whilst the HMS fitted to Puma HC Mk2 was routinely downloaded there was no capability to process and analyse the data at RAF Benson; all HMS data was sent to Airbus Helicopters. There was no established regular feedback of HMS vibration trending information to the UK MOD unless a serious safety issue was identified. Witness 29 Witness 30 Exhibit 182 Exhibit 183

1.4.390 The Panel **observed** that whilst the operation and functionality of the HMS was non-germane to the accident, the limitations of the recording parameters combined with the embryonic processing, analysis and feedback capability hindered the ability of the current HMS to contribute to vibration trending across the full range of Puma HC Mk2 flying profiles.

Recommendation

1.4.391 The Puma Project Team Leader should expand the Health Monitoring System data recording parameters to ensure the capture of the typical range of Puma HC Mk2 flying profiles.

Organisation – summary

1.4.392 The series of broader issues that were considered by the Panel were all assessed as 'Other Factors' or 'Observations' and had no direct bearing on the cause or outcome of the accident, however each subject area has the potential to contribute to a future accident.

1.4.393 The Puma Force and TAD had a robust Air Safety Management System and mitigations to known hazards were appropriate. Nevertheless, when considering the use of RWAMMWAS and the context of operations in the Kabul area, the Panel concluded that the decision by TAD crews not to use it was justified. However, ambiguity regarding direction for the use of RWAMMWAS and DHUD was observed.

1.4.394 The ability to mitigate the Flight Safety risks in the Kabul area was hindered by the lack of an empowered Flight Safety organisation that could implement actions across the range of military and non-military helicopter operators.

[152] Ie. Under slung load and confined area operations.

Furthermore, the transitional nature of operations in Afghanistan resulted in misunderstandings between operational and civilian terminology regarding airspace restrictions.

1.4.395 It was acknowledged that there are a large volume of documents with which aircrew are required to be familiar. However, the Panel observed that for the TAD, necessary information was spread between several documents and inconsistencies were evident.

1.4.396 Whilst the provision of a HMS in the Puma HC Mk2 will assist aircraft operation and maintenance, limitations of recording parameters and embryonic processing hindered its ability to contribute to vibration analysis across the full range of the aircraft's flying profiles.

Summary of Findings

Analysis and findings - conclusion

1.4.397 The Panel concluded that the accident was caused by the catastrophic failure of the TRDS following damage sustained from the PTDS tether strike.

1.4.398 The Panel assessed that a loss of situation awareness was caused by the discussion regarding ground features and resulted in the loss of visual contact with the formation leader. Subsequently, and in attempting to regain sight of the lead aircraft, there was a resultant reduction in awareness regarding the PTDS.

1.4.399 The Panel concluded that during the aircraft's interaction with the PTDS tether the TRDS was weakened to the extent that it subsequently failed as loading on the shaft was increased. Following the failure, and when considering the aircraft's height, speed and significant variations in attitude, the Panel formed the opinion that the aircraft was unrecoverable and a successful engines off landing was unachievable.

1.4.400 **Causal Factors.** The Panel identified one Causal Factor of the accident (ie that which led directly to the accident); the damage caused to the TRDS by the PTDS tether strike. 1.4.225

1.4.401 **Contributory Factors.** The Panel identified 2 Contributory Factors to the accident (ie those which made the accident more likely to happen):

a. The loss of visual contact with the formation leader. 1.4.165

b. The momentary lack of situation awareness regarding the PTDS. 1.4.166

The Panel concluded that these factors were interlinked and could not be considered in isolation, the attempt to regain sight of the formation leader directly contributed to the lack of awareness.

1.4.402 **Aggravating Factors.** The Panel identified one Aggravating Factor (ie that which made the outcome of the accident worse); the central bank of troop seats' horizontal support bar and lack of head support. 1.4.306

1.4.403 **Other Factors.** The Panel identified 13 Other Factors (ie were not factors in the accident but noteworthy in that they may cause or contribute to future accidents):

a. The lack of a brief regarding the loss of visual contact within the formation. 1.4.60

b. The volume of minor documentary errors in the MF700. 1.4.77

c. The lack of a passenger safety brief. 1.4.98

d. The uncleared presence of an ammunition container as a rest for the crewman. 1.4.101

e. Errors within the MF700 relating to W&M data and the lack of aircrew CofG calculations. 1.4.107

f. Poor air to ground communications at Soccerfield HLS resulting in late notification of aircraft arrivals. 1.4.118

g. The ground to air radio terminology used by Soccerfield Operations. 1.4.119

h. The dual use nature of Soccerfield HLS. 1.4.133

i. Distraction due to equipment discomfort. 1.4.173

j. Tether markings on the HQRS PTDS. 1.4.200

k. The lack of an empowered Flight Safety organisation to support aviation activity in the Kabul area. 1.4.356

l. Misunderstanding of the status of airspace restrictions. 1.4.363

m. There were a series of considerations within the Puma Force which individually did not prompt a safety risk but the totality of which has the potential to lead to an emergent cumulative risk. 1.4.384

1.4.404 **Observations.** The Panel made 6 Observations (ie issues that were not relevant to the accident but worthy of consideration to promote better working practises):

a. The lack of clarity regarding the requirement for Pre-Deployment Training Sortie Report Forms generated ambiguity and potentially nugatory work for training staff. 1.4.29

b. The risk of mid-air collision around Kabul remained elevated despite the use of the CTAF and provision of flying programmes from the 2 main HLS's. 1.4.49

c. Ambiguous direction to aircrew regarding the use of RWAMMWAS and DHUD. 1.4.353

d. That where information was spread across multiple documents, and where there were inconsistencies between documents, it was unsurprising that errors in understanding or application occurred.	1.4.368
e. Whilst there was no evidence of direct pressure to deploy aircraft to Op TORAL and train the requisite number of crews, the combined requirement has the potential to negatively impact the whole Puma Force.	1.4.381
f. Whilst the operation and functionality of the HMS was non-germane to the accident, the limitations of the recording parameters combined with the embryonic processing, analysis and feedback capability hindered the ability of the current HMS to contribute to vibration trending across the full range of Puma HC Mk2 flying profiles.	1.4.390

PART 1.5 – RECOMMENDATIONS

Recommendation		Analysis Reference
1.5.1	**Introduction**. The following recommendations are made in order to enhance Defence Air Safety.	
1.5.2	**PJHQ COS(OPS) should** engage with NATO HQ RESOLUTE SOUTH to:	
	a. Implement improved Rotary Wing coordination and deconfliction measures in the Kabul operating area.	1.4.50
	b. Ensure the provision of passenger safety briefings and briefing material.	1.4.99
	c. Improve the capability of air to ground communications at HQRS HLS (Soccerfield) in order to ensure the timely establishment of communications with approaching aircraft.	1.4.120
	d. Clarify Radio Telephony terminology to be used by civilian contractors and confirm the associated meaning within the HQRS Aviation Procedures Guide.	1.4.120
	e. Review the feasibility of using Soccerfield as a combined HLS and sports facility and if this is unavoidable, ensure that robust deconfliction measures are in place.	1.4.134
	f. Review the markings on the HQRS PTDS in order to improve visibility of the hazard.	1.4.201
	g. Establish an empowered Flight Safety Authority to manage and implement air safety related activities across all helicopter operators in the Kabul area.	1.4.357
	h. Clearly articulate in appropriate publications the status of military and civilian airspace restrictions within Afghanistan.	1.4.365
1.5.3.	**Commander JHC should:**	
	a. Direct the standardisation of formation briefing procedures across the JHC to ensure conformity with higher level documents.	1.4.61
	b. Review the cumulative risks associated with the development of the Puma Force whilst concurrently being committed to an operational deployment.	1.4.385
1.5.4.	**The Puma HC Mk2 DDH should:**	
	a. Clarify reporting requirements for PDT sorties.	1.4.30
	b. Ensure that the required levels of technical education are provided, and the supervision appropriate, for the accurate completion of engineering documentation.	1.4.78

Defence Safety Authority

	c. Review the Puma Force Quality Management System to ensure that the engineering QA procedures and periodicity are appropriate to identify emerging safety trends.	1.4.79
	d. In conjunction with the Puma Project Team, Release to Service Authority and Handling Squadron conduct a review of associated documentation to ensure that information appertaining to Weight and Moment and Centre of Gravity is standardised across all relevant publications.	1.4.108
	e. Conduct a review of all MF702 Series to ensure accuracy of information relating to weight and lateral and longitudinal moments.	1.4.108
	f. Conduct a review of procedures to ensure pre-flight calculation and briefing of Centre of Gravity.	1.4.108
	g. Ensure that crews understand the differences between operational and civilian airspace restrictions.	1.4.364
1.5.5.	**Puma HC Mk2 Project Team Leader should:**	
	a. Instigate a programme of measures to reduce aircrew discomfort associated with the Puma HC Mk2 armoured seat.	1.4.174
	b. Instigate improvements to the Puma HC Mk2 central troop seat upper body support.	1.4.307
	c. Re-qualify the passenger seat with representative current troop weights.	1.4.311
	d. Expand the Health Monitoring System data recording parameters to ensure the capture of the typical range of Puma HC Mk2 flying profiles.	1.4.391

PUMA XW229 – PART 1.6

1. This has been a well conducted and thorough Service Inquiry (SI) which has established the cause of this tragic accident and identified the most likely contributory factors. The basic circumstances were immediately available with multiple eyewitnesses and the Combined Voice & Flight Data Recorders (CVFDR) from both aircraft being available. What was more complex and the focus of the SI was to understand why on a straightforward movement task in ideal weather conditions, A22 collided with the Persistent Threat Detection System (PTDS) tether which led to fatal or serious injuries to the 9 personnel on board. I commend the Panel for their efforts and agree the cause, contributory, aggravating, other factors, observations and recommendations which the Panel has made. In terms of flying administration, supervision, training and currencies, this was a well conducted detachment and sortie with only minor omissions that are well covered in the main report and I will not repeat here. Indeed, I will largely confine my comments to the most significant issue in this accident which is the loss of situational awareness by the crew which led to the tether strike and then make a more general observation about tether strikes.

2. It is clear that the loss of visual contact with the lead aircraft contributed to a lack of situational awareness with the PTDS and ultimately the tether. I am persuaded, that the reason for the crew of A22 losing sight of the leader was likely their focus on ground features to the extent that the formation integrity broke down. During this short period, it appears that both pilots were fixed looking to the left of the aircraft. I do not believe that scrutiny of ground features should have been such a priority, at this stage of the flight, to the extent that both pilots lost sight of the lead aircraft. Whilst not unreasonable for the Left-Hand-Seat pilot and indeed the crewman to be looking left, in my opinion, the handling pilot, at least, should have maintained eyes on the lead aircraft. It is clear, following the pilots' discussion of ground features, that when the handling pilot's attention came back to the lead aircraft it was not where he expected it to be in that the leader had entered a right hand turn and was now out beyond A22's 3 o'clock position by about 230 m. This was not an unreasonable act by the lead crew who would have expected their wingman to follow them into the right hand turn as it was the wingman's responsibility to maintain the formation position at that time. It might have helped if the leader had called "coming right" or similar but this was not necessary and perhaps, due to the routine use of minimum communications, deemed to be inappropriate by the lead crew. I concur with the Panel that following the loss of visual by the crew of A22, their attempt to regain sight of their leader caused a loss of situational awareness with regard to the PTDS Danger Area which they inadvertently entered and unluckily struck the tether.

3. I am surprised that the crew of A22 did not make a radio call, on the formation common frequency, to A21 after losing sight of the leader. Even when considering the informal guidance on minimum communications, in my opinion the priority should have been to establish visual with the leader as the threat of a mid-air collision could have been a significant risk. Indeed, from the CVFDR, they had no sight of the lead aircraft for at least the last 13 seconds, likely more, before striking the tether which is a long time in the context of their location and what was happening, particularly as the distance between the 2 aircraft reduced to 230m at one stage. I am not suggesting that a radio call to A21 would have prevented the tether strike but it just might have helped the crew in regaining situational awareness as their leader might have been able to assist. As mentioned by the Panel in the 'other factors' section, the Puma Force (and helicopter forces more generally) should review

their Standard Operating Procedures with regard to "Loss of visual contact within the formation". I do not see this as a procedure which is reserved for larger or tactical formations only and has general utility when operating more than one aircraft.

4. Once the tether strike happened, the crew made a valiant attempt to regain control of their aircraft. After the tail-rotor failed they were poorly placed for height and speed to handle the emergency. Essentially, the crew had little control of the helicopter following the TRDS failure and it was very fortunate that the aircraft came down in the street rather than on a building. It was remarkable that anyone survived the crash and we must remember that despite the tragic outcome, 4 people did survive what was potentially an unsurvivable accident considering the helicopter hit the ground with a velocity of over 4,000 ft/min and a deceleration of between 15g and 30g. Whilst we will never know for certain, it is likely that the crew's best efforts in handling this catastrophic situation may have played a significant part in the survival of at least some of the occupants.

5. It is worth mentioning the history and failure modes of the PTDS tether following other helicopter rotor strikes. This was not the first time that a tether had been struck in Afghanistan, and other theatres, by helicopters and there are potentially 11 multi-national tether strikes on record that we know about, although detail is hard to find. This particular tether is designed to fail under a certain loading which, when struck by a rotor blade depends on a number of factors such as helicopter type, weight, speed, blade structure and whether the rotor blades were retreating or advancing. Ultimately, the tether that XW229 struck failed under torsional load (i.e. was not cut) but in doing so it caused damage to the TRDS housing and TRDS itself which was ultimately weakened to a point that it subsequently failed. I am aware that there may have been a belief amongst the detachments that a tether would fail (sever) in the case of a strike by rotor blades and this appears to have been the case during other rotor strikes. This is clearly not the case with XW229 and this accident will serve as a warning of the catastrophic consequences of accidental penetration of the PTDS Danger Area.

6. This was a straightforward sortie which the operating crew were both familiar with and well qualified for. The sortie ran well up until the point that the crew of A22 focussed their attention on ground features to the extent that they lost sight of their leader resulting in the formation integrity breaking down. In trying to regain visual, the crew lost situational awareness to the point that they entered the PTDS Danger Area and struck the tether. This was a tragic and avoidable accident, where a few seconds loss of focus on a well-known hazard had catastrophic consequences. Recommendations have been made to the Joint Helicopter Command, Defence Equipment & Support and to NATO Headquarters RESOLUTE SUPPORT (through the UK Permanent Joint Headquarters (PJHQ)) to address the issues from this SI. I am certain that the recommendations for NATO Headquarters RESOLUTE SUPPORT will make helicopter operations in this part of Afghanistan safer. These recommendations have been placed through the PJHQ for action by NATO. The DSA will hold the PJHQ to account for pursuing them to the best possible conclusion, mindful of the operational constraints. The accident serves as a salutary reminder to all aircrew of the importance of lookout, crew resource management, communication and formation discipline. Finally, I would like to commend the many rescuers, both professional and others on the scene who worked in both dangerous and difficult conditions to preserve the life of those who survived.

DG DSA