PART 1.4 – FINDINGS

Introduction

1.4.1. The SI Panel has thoroughly investigated all aspects of H450 operations, training and organisation. The Panel acknowledges that a H450 operator does not require the same skills or training as the pilot of a manned aircraft and this fact should be borne in mind throughout this SI Report. While the cause of this accident was readily apparent, the Panel has found there were significant contributory factors in the H450 training system, selection procedure for UAS pilots, development of H450 pilot airmanship, captaincy skills and the experience and knowledge of the flying supervisors. During routine operations, these contributory factors were not readily apparent because the H450 system is relatively straightforward to operate and the tasking generally follows a very set pattern. When H450 operations began at Bastion Airfield, there was minimal infrastructure and low levels of manned aircraft traffic. The airfield has now evolved into one of the busiest military airfields in operation today. The H450 contributory factors identified have become far more significant as Bastion has evolved, whilst RA training has not kept pace. In the case of this accident, these factors became critical when an initially straightforward engine problem was compounded by a lack of situational awareness, limited planning, captaincy issues and human factors into a high-workload emergency situation which ended with the aircraft crashing onto Bastion Airfield, fortunately there were no injuries or fatalities.

1.4.2. Most of the identified factors were driven by the fact the H450 aviation system was an Urgent Operational Requirement (UOR), which had been implemented without an appropriate aviation infrastructure. Although it is common for UORs to be released into service without full system integration, aviation UORs are usually introduced to existing aviation systems that have an established aviation infrastructure, such as comprehensive training and currency, airmanship principles, standard operating procedures and experienced aviator supervision. However, whilst the RA has accumulated a significant amount of experience from operating various types of UAS for many years, this experience does not appear to have been nurtured and retained within the organisation; in this instance the 57 Bty command chain lacked any credible aviation experience.

1.4.3. Unless urgently addressed, the contributory factors identified by this SI are likely to continue to affect H450 operations and may contribute to a further accident or incident. Without action, there is also significant risk that these factors could be transferred to the Watchkeeper programme when it begins flying in the United Kingdom and on operations overseas.

1.4.4. **Available Evidence.** The Panel had access to the following evidence:

a. Interviews with the crew of ZK515 and other witnesses.

b. Formal statements from witnesses.

c. GCS recordings and FDR data.

d. Photography from various sources.

e. Relevant orders and documentation including flying logbooks, UA documentation, sortie planning and briefing materials.

f. Wreckage of ZK515.

g. Technical report by MilAAIB.

h. Technical report by 1710 Naval Air Squadron (NAS) Materials Integrity Group (MIG).

i. Reports provided by the Royal Air Force Centre of Aviation Medicine (RAF CAM).

j. All flight safety related material, including Aviation Safety Information Management System (ASIMS) summary.

k. Previous Board of Inquiry (BoI) and Non Statutory Investigation (NSI) reports.

l. ATC voice and radar video recordings.

m. Engine Analytic Report by Elbit Systems.

1.4.5. **Unavailable Evidence.** The Panel had access to all evidence they required.

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

a. MilAAIB.

b. RAF CAM.

c. Specialist technical support from 1710 NAS MIG.

d. Official Observer from 1 Artillery Brigade (1 Arty Bde).

e. U-TacS Training Manager for specialist advice.

TOR A - ACCIDENT CAUSE AND CONTRIBUTORY FACTORS

Investigate and, if possible, determine the cause of the accident and examine contributory factors.

1.4.7. **Accident Factors.** The Panel examined the factors according to the following definitions:[1]

a. **Cause.** Factors that led directly to the accident.

b. **Contributory.** Factors that did not directly cause the accident, but made it more likely.

c. **Aggravating.** Factors that did not cause the accident but made the final outcome worse.

d. **Other.** Factors that were none of the above but could contribute to, or cause, a future accident.

e. **Observations.** Factors that, whilst not germane to the accident and not thought likely to influence a future accident, were considered important aviation safety-related issues worthy of comment.

1.4.8. **Cause.** The cause of the accident was **engine failure**. Oil starvation resulted in overheating which led to engine failure. (TOR D)

Exhibits 1 & 2

1.4.9. **Contributory Factors.** The Panel has identified 13 factors that made the accident more likely to happen:

a. **Omission of the QRH landing brief by the UAS-c.** During ZK515's recovery to Bastion Airfield the landing brief was not conducted between the UAS-c, crew, EP and FSR. (TOR E)

Witness 1, 9, 10
Exhibit 3

b. **Failure of the crew to read back ATC clearance.** ATC cleared ZK515 to make an approach to runway P01.[2] The crew did not read back this clearance and ATC did not confirm the crew's intentions as laid down in CAP 413-Radiotelephony Manual. (TOR E)

Exhibit 4

c. **Approach to the wrong runway.** The first landing attempt was made to runway P19 when the landing runway in use for H450 operations at the time was P01. The UA could not have landed safely from this approach as the arrestor cables were already set for P01. (TOR E)

Witness 1, 7, 9, 10

d. **GTOLS error.** Unfamiliarity with GTOLS procedures following a **(S26)** led to the crew loading an incorrect flight plan parameter for the P19 GTOLS landing. This incorrect parameter resulted in the UA self aborting the GTOLS approach. The go-around and climb placed more strain on an already overheating engine. (TOR E)

Exhibits 5, 6, 7
Annex A
Witness 3, 6, 9, 10

[1] Aviation Safety Information Management System (ASIMS) User Guide, V3.1.
[2] Runway 'Papa' is the parallel taxiway to the main Bastion 01/19 runway, but is used by H450 for launch and recovery.

e. **Supervision by the Senior Operator.** The 57 Bty SO was present in the GCS during the crew's recovery of ZK515 in order to oversee correct GTOLS procedures were carried out, yet the crew still made a number of errors which were not picked up by the SO. The UAS-c and UAS-p both assumed the lack of intervention by the SO during the developing emergency situation was tacit approval that their actions were correct. (TOR F)	Witness 12, 9, 10, 17 Witness 9, 10 Exhibit 7
f. **Senior Operator fatigue.** Due to inadequate and broken sleep patterns for the week prior to the accident the Panel believes the SO was suffering from the effects of cumulative fatigue which is likely to have affected his actions during the accident events. (TOR H)	Witness 12 Exhibit 7
g. **Senior Operator GTOLS currency.** The SO had not personally conducted any GTOLS procedures for over 2 years prior to overseeing the **(S26)** . This included failing to conduct the minimum number of GTOLS take-off and landings (TOLs) required by the 1 Arty Bde and Theatre UAS Flying Order Books (FOB) for Theatre Qualification (ThQ). The Panel believes the SO was therefore not sufficiently current on the system to conduct this task. (TOR E)	Witness 12 Exhibit 8
h. **Breakdown of 2-man checks.** The mandated 2-man check procedures were not adhered to during the high workload situation. (TOR E)	Witness 9, 10 Exhibit 9
i. **Crew airmanship during the high workload situation.** The Panel has assessed that the crew's airmanship (UAS-p, UAS-c and MxC), although initially good, deteriorated as the situation worsened, which ultimately led to a number of errors being made. The Panel has investigated the experience and training of the crew and subsequently believes their actions were as good as could be expected. (TOR E)	See TOR E for detailed evidence
j. **UAS-c captaincy.** The UAS-c's captaincy skills were initially good, but quickly deteriorated as the situation developed and workload increased. The UAS-c took on the responsibility to deal with the situation by herself, rather than delegating and prioritising. Given the UAS-c's experience and lack of any training for the role, the Panel believes the UAS-c acted to the best of her ability. (TOR E)	See TOR E for detailed evidence Witness 10
k. **Impact of work-in-progress.** WIP on the southern end of Papa taxiway had, on the morning of the accident, moved much closer to the active part of the taxiway used for H450 operations. Whilst some consideration of its impact had been made by the Battery Commander (BC) and Senior Air Traffic Controller (SATCO), the full impact was not fully understood by the UAS-p, UAS-c, the SO, the Authorising Officer (AO) or the supervisory chain. (TOR G)	Witness 9, 10, 12, 13, 14, 17 Exhibit 7
l. **The H450 flight authorisation process lacks rigour.** The H450 flight authorisation follows a set process. Due to the extremely limited aviation experience of the non-H450 qualified AOs, they rely heavily on trusting their H450 pilots. The AO had not checked that the crew understood what the impact of the WIP was; the failure to check understanding led to confusion amongst the crew when ZK515	Witness 13, 14, 17

returned unexpectedly with a problem. This confusion introduced more pressure into an already high workload situation. (TOR F)	
m. **Situational awareness of GCS crew.** There is a multi-layered communications network between the GCS and external players such as the EP, ATC, Operations Room, REME and Lydian FSR. Rather than aiding the crew, the Panel believes this network contributed towards hampering the crew's situational awareness. (TOR E)	Exhibits 7, 10 Witness 1, 9, 10, 11, 17
1.4.10. **Aggravating Factors.** The Panel identified 2 factors that were considered to have made the final outcome of the accident worse:	
a. **GTOLS go-around route abbreviation.** Following the UA's GTOLS self abort, the crew used a Fly to Coordinate (FTC) command to direct the UA straight back to **(S26)** Hold[3] **(S26)** , rather than letting the UA complete the pre-determined GTOLS go-around route. This action caused the UA to perform a non-authorised manoeuvre at low altitude. (TOR E)	Witness 9, 10, 12 Exhibit 11
b. **Failure of the UA to route towards an ELS.** Following the FTC command, as the UA routed back to **(S26)** hold it was not within glide range of a selected ELS.[4] The crew had not uploaded an ELS within glide range as they were rapidly preparing for a second GTOLS approach, this time to P01. When the engine failed the UA was no-longer in GTOLS mode but had no ELS within glide range; the logic in this situation directs the UA to adopt the No-Comms route which is pre-determined to be along a safe ground track should an engine failure occur. Way Point 6 (WP6) happened to be closest when the engine failed and the UA routed towards it in a glide descent. However, this particular No-Comms route had been designed with a 'Critical Altitude' restriction of **(S26)** . Without power a climb **(S26)** proved impossible and the UA glided in a left-hand turn around WP6 until it crashed. This is the cause of the turn towards the airfield that the crew were not expecting and the reason the UA impacted on the airfield and not outside the boundary. (TOR E)	Witness 9, 10, 36 Exhibits 12 & 13 Annex A Exhibit 12 & 13
1.4.11. **Other Factors.** The Panel identified 3 other factors that could make a future accident more likely:	
a. Difference in understanding of the emergency situation between the H450 crew and ATC. The crew believed they were in an emergency situation, but only communicated to ATC via Radio Telephony (RT) that they were returning early due to "a problem". (TOR E)	Witness 2, 9, 10
b. As the H450 UAS-c role did not receive any extra training, nor did it have any prerequisite flying experience, this is likely to have negated the mitigation provided by a typical captaincy role, such as experience and authority during unexpected scenarios.	See TOR E for detailed evidence

[3] This action was contrary to direction not to intervene with a UA whilst in GTOLS mode below 1000ft agl.
[4] As per the GTOLS system design, during a GTOLS procedure the ELS are deliberately placed outside glide range to force the UA to follow the GTOLS route in the event of an engine failure.
[5] Restriction: **(S26)**

c. The 57 Bty UAS-c had not received any guidance on an appropriate decision making process to assess an unusual or complex risk to H450 operations.	See TOR F for detailed evidence

1.4.12. **Observations.** The Panel made 7 observations:

a. It did not appear that the SO was considered to be part of the operating crew whilst conducting his supervisory function. As such, he was not included in the flight authorisation sheets and his flying logbook and pilot record folder were not quarantined following the accident.	See TOR F for detailed evidence
b. Airmanship development of H450 crews is limited by two factors: the truncated training pipeline does not adequately equip students with the foundations of airmanship; and the periods of intense training interspersed by periods of zero flying (live or simulated) does not adequately allow consolidation of knowledge or development of experience.	See TOR E for detailed evidence
c. Inconsistent guidance has been provided from the command chain to the UASS-c concerning when and whether it is acceptable to breach the H450 Release To Service (RTS) limitations. This inconsistent guidance has led to the perception amongst some personnel that it is acceptable to breach weather limitations on recovery in order to preserve operational capability.	See TOR F for detailed evidence
d. There appears to be a lack of policy regarding professional counselling and assessment of an individual's mental state following an accident, particularly when determining if the individual is fit to resume flying operations.	See TOR K for detailed evidence
e. There are no specific selection criteria for H450 pilots, such as a unique General Trainability Index (GTI) score or aptitude tests, and there have never been any specific criteria determined for ab-initio pilots.	See TOR L for detailed evidence
f. A crucial opportunity to implement key actions that could have prevented or lessened the impact of this accident was missed due to a lack of importance placed on the June 11 RAF CAM Human Factors (HF) report.	See TOR L for detailed evidence
g. An opportunity now exists for a separate study into the Watchkeeper programme to ensure the factors in this Service Inquiry are not transferred from H450 to Watchkeeper operations.	See TOR L for detailed evidence

1.4.13. **Elimination of other possible causes.** The Panel considered a range of possible accident causes and each one was eliminated when either evidence was gathered that disproved the theory or alternatively no evidence was apparent that it had been a factor. The other causes considered were:

a. **Enemy Action.** There is no evidence that enemy action played any part in this accident.	Exhibit 2

b. **Malicious Intent.** Following the interviews, the Panel determined that no person involved in the accident contributed to its outcome through malicious intent. At no time was a crew-initiated signal sent from the GCS to the UA commanding it to stop the engine.	Witness 1, 9, 10, 11, 12, 14, 17 Exhibits 2, 12
c. **Un-commanded GCS input.** At no time was an un-commanded signal sent from the GCS to the UA to stop the engine. The engine stopped due to oil starvation.	Exhibit 2
d. **Environmental Conditions.** There were no environmental conditions or meteorological activity to adversely affect operation of the UA during the accident sequence.	Exhibit 14
e. **Technical failure (other than engine failure).** With the exception of the oil supply system, there is no evidence that any part of the UA or system was unserviceable that may have contributed to the accident.	Exhibit 2
f. **Mid air collision.** No evidence exists of a mid-air collision. ATC had sterilised the airspace around the airfield for the approach of ZK515.	Exhibit 2 Witness 2

TOR B – DUTIES

Ascertain whether service personnel involved were acting in the course of their duties

1.4.14. The Panel believes that all personnel were acting in the course of their duties.

TOR C – POLICIES, ORDERS AND INSTRUCTIONS

Examine what policies, orders and instructions were applicable and whether they were complied with

1.4.15. **Flying.** 1 Arty Bde has a comprehensive set of policies, orders and instructions that are disseminated to the sub-units with the aim of ensuring safe and well regulated flying activities. With the evolution of Military Aviation Authority (MAA) guidance and the MAA Regulatory Publications (MRP), the Bde has worked hard to ensure their document set has kept pace; the Panel were impressed by the level of maturity of the documents, particularly the 1 Arty Bde Flying Order Book (FOB). Knowledge of the policies, orders and instructions is generally very good; however, the Panel discovered the exceptions that are detailed as follows:

a. At the time of deployment, the SO was a qualified MxC and was appointed Bty SO shortly prior to deployment. However, his UAS-c Trained, Qualified, Competent and Current (TQC2) status had expired as he had not flown H450 for 2 years or maintained simulator currency and therefore did not hold a valid Certificate of Competence. Given the evidence available, the Panel has found that the SO did not hold the required competencies of a H450 UAS-c on the Theatre UAS Bty. Further detail provided within TOR E.

Witness: 12
Exhibit 8

b. Further to sub-paragraph a above, the SO did not complete any GTOLS events as part of his ThQ package, which is in contravention of the requirements of the 1 Arty Bde FOB and Theatre FOB. As the SO was subsequently tasked to oversee the **(S26)** , the Panel has found that he was not current or competent in GTOLS at the time of the accident. As such, the SO did not comply with MAA Regulatory Article 1002 – Competent Persons. More detail is provided in TOR E.

Exhibit 8
Witness 12
Exhibits 118, 119
Witness 12, 17
Exhibit 5
Exhibit 154

c. The GTOLS Observer did not hold the appropriate rank of Lance Bombardier and had not completed the requisite training for the role.[6] More detail is provided within TOR E.

Exhibit 21

d. The SO's supervisory function during the GTOLS events of the sortie was not recorded in the flight authorisation sheets or in the mission back brief. This has been covered in detail in TOR F.

Exhibit 51

1.4.16. The Panel discovered one instruction that was not complied with, that became an **aggravating factor** in this accident. GTOLS is used to take off and land the UA without an EP and is designed so that, should an engine failure or loss of communications occur, the UA will follow a pre-determined route along a safe ground track. The GTOLS handover notes, written as instructions by the OSC for 57 Bty to adhere to during their tour contained a Bastion Airfield specific restriction for the safe operation of GTOLS:

Witness 9, 10, 12

"UAS-p and UAS-c are not to intervene with the GTOLS process below 1000 ft in the event of an abort".

Exhibit 11

The rationale for this instruction is that if an engine fails below 1000' agl during a

[6] In accordance with 1 Arty Bde FOB Issue 5 Dated 1 Nov 2009. Training requirements have been updated in Issue 6 Dated 30 Jun 11.

GTOLS procedure there will not be sufficient glide potential to recover the UA to an ELS, but if left alone it will come down somewhere along the predetermined GTOLS safe ground track. In the case of this accident, the UA self aborted the GTOLS approach due to an incorrect entry parameter within the GTOLS setup. Following this self-abort, when the UA was at approximately 500' agl, the crew used an FTC command to direct the UA straight to **(S26)** Hold instead of leaving it to run its course in accordance with the instruction within the handover notes. This FTC command placed the UA in a position approaching **(S26)** hold without an associated in range ELS. If the restriction had been followed, the UA would have crashed along the safe ground track on the GTOLS route following the engine failure.

Exhibit 11
Annex A
Annex A

1.4.17. **Engineering.** All engineering activity is carried out in accordance with the MAP-01. The Battery Fitter Section has a comprehensive set of deployed Air Engineering Standing Orders (AESOs), and the Record of Engineering Authorisations (REAs) were complete and in date in accordance with MAP 01 Ch 4.3. The Panel found that these policies were being complied with and that the Quality Assurance (QA) checks were being carried out regularly in accordance with the theatre deployed AESOs.

Exhibit 141
Exhibit 48

1.4.18. **Post Crash Management.** The PCM was carried out in accordance with the MAA Manual of Post Crash Management and MilAAIB orders and followed the Theatre UAS Bty PCM procedure, **(S26)** . 57 Bty implemented a very effective post crash management plan after the incident and they have been complimented by other agencies regarding their professionalism during this phase.

Exhibit 66, 67
Witness 16,19, 26

TOR D – AIRCRAFT SERVICEABILITY AND RELEVANT EQUIPMENT

Determine the state of serviceability of the aircraft and relevant equipment

Documentation

1.4.19. Prior to the flight the UA was certified as serviceable by the REME
with 31 hours available before the next servicing was due. The MOD Form
700C had no open entries and no limitations in the MOD Form 703. The MOD
Form 704 (Acceptable Deferred Faults) contained one deferred fault, which the — Exhibit 145
Panel does not consider relevant to the incident.[7]

1.4.20. The SI Panel has discovered a number of minor errors in the MOD
Form 700. There was a Project Team (PT) concession in the Form 704D that — Exhibit 142
should have been cancelled on 31 Jan 09 and should have been discovered — Exhibit 91
during the quality assurance checks carried out in accordance with the in theatre
AESOs.[8] This error was not a factor in the accident. — Exhibit 48

1.4.21. The MOD Form 737A (Oil Replenishment Record) had a missing
entry for the flight prior to the accident which should have been entered by the
REME engineers as part of the flight servicing. It is the responsibility of the — Exhibit 49
technician carrying out the flight servicing to ensure the Form 737A has been
completed, but it is not mandated as part of the Form 700 co-ordinating — Exhibit 50
signature. According to the Form 705 'levels certificate' which had been
completed and the evidence from the crash site, it was apparent that the oil must
have been replenished for this particular flight. The omission of the Form 737A
entry is not considered a contributory factor in this accident, but it did make it
impossible for the Panel to accurately determine the oil usage rate during the
flights immediately prior to the crash. This information would have been
particularly useful when trying to ascertain whether the engine oil pipe had been
reducing the flow to the engine over a period of time. The information on the
Form 737A is not currently utilised for the monitoring of engine health and the — Exhibit 2
Panel believe that it could provide a method of highlighting whether an engine
requires further inspection to ensure that airworthiness is maintained.

Ground Control Station

1.4.22. The GCS was serviceable, although one of the EP's communication
headset was reported to have been unserviceable after ZK515's take off. The — Exhibit 143
same headset had been entered into the MOD Form 700 as unserviceable 4
days before the crash, checked by REME and found to be serviceable, despite a — Witness
higher than normal background noise. This is not considered to be a — 1,8,10,19,22
contributory factor since only one headset is required to operate the system,
while the other is used for training and as a redundancy. — Witness 51

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[7] The MOD Form 704 Entry was for a distorted access panel.
[8] Quality Assurance 2 check should be carried out every 7 days on the 700 and as part of the QA1 every six months. In accordance with Air Engineering Standing Orders (AESO).

Engine Strip and Diagnosis

1.4.23. Post accident, the UA was examined by the SI engineer and the MilAAIB engineering investigator; the aircraft contained both fuel and oil at the time of engine failure and the engine assembly was intact with the propeller still attached. The engine mounting assembly showed signs of significant damage so the decision was made to remove the engine for transit back to the UK. The H450 oil system is shown below: Exhibit 2

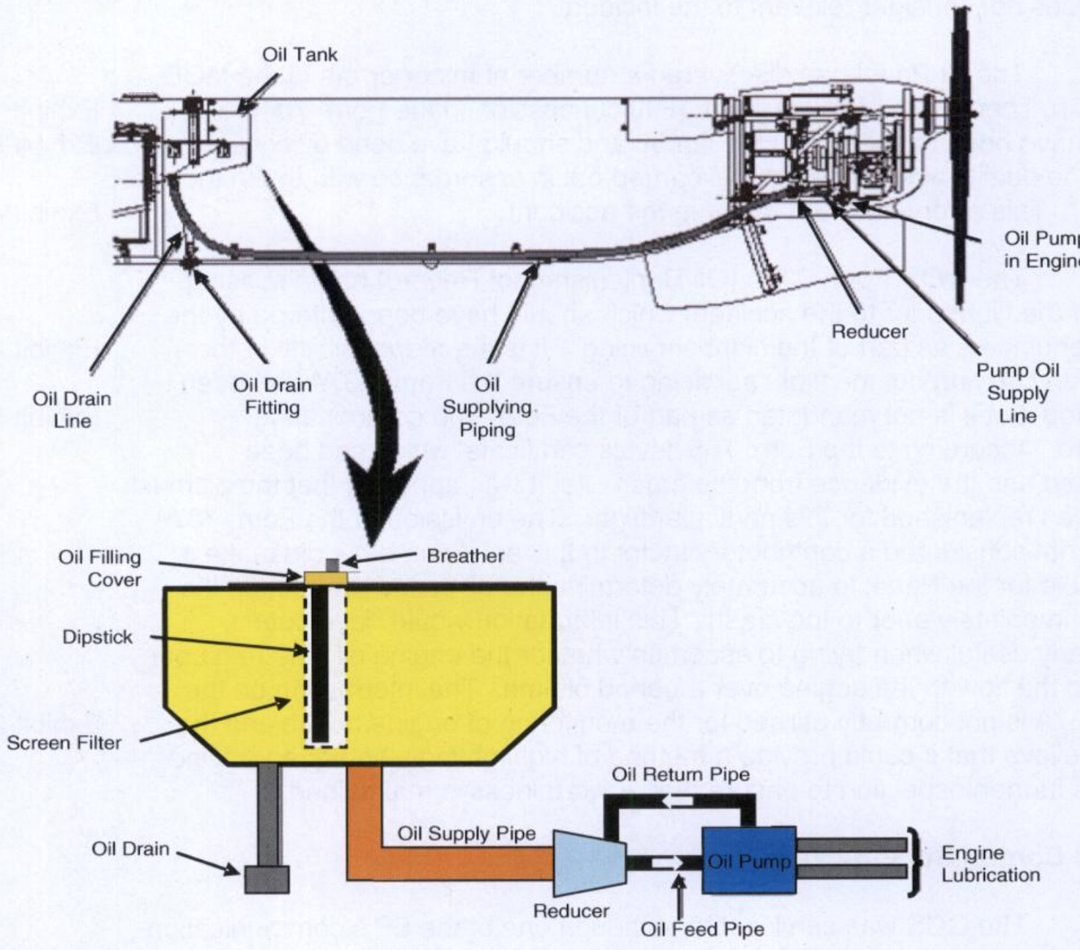

Figure 5 - Oil System Diagram

1.4.24. During the engine removal, the aircraft technician Sergeant who was assisting the MilAAIB investigator, noticed a thick brown congealed substance, which appeared to block the oil feed pipe. The early detection of this phenomenon enabled a fleet-wide check to ensure the serviceability of the other aircraft in theatre. This was particularly relevant as these oil pipes had been subject to a recent engine modification. No further anomalies were found in this area on the other UAs. The area where the blockage was discovered is shown in figure 6 and 7. Exhibit 52

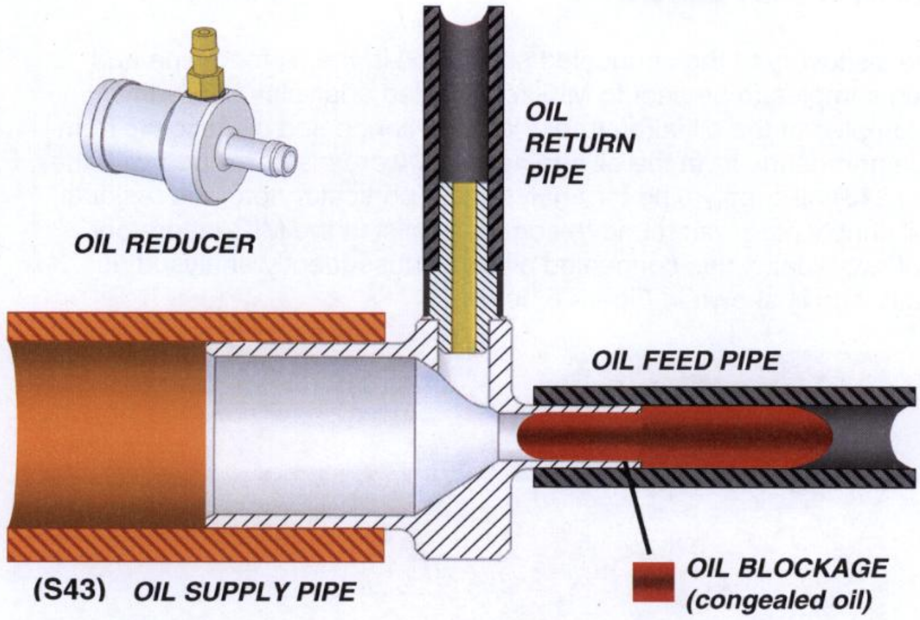

Figure 6 - Oil reducer Diagram

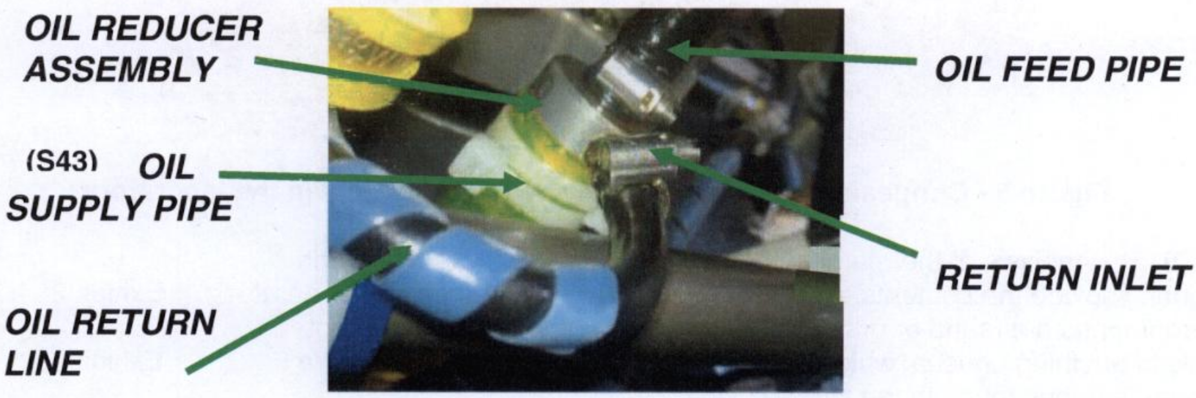

Figure 7 - Oil reducer assembly

1.4.25. Further examination of the airframe highlighted the discovery of significant debris found in the 250 micron oil strainer which makes up part of the oil tank. A sample of the debris was sent to 1710 NAS MIG and the UAS PT were informed. Exhibit 2

1.4.26. Following transport of the engine to the Design Authority (DA) in Israel, Elbit Systems, a comprehensive engine strip and examination was carried out with the MilAAIB engineering investigator and SI engineer in attendance. Elbit's diagnosis is that the engine failed due to oil starvation, the most probable cause being a blockage due to congealed oil just forward of the oil pipe reducer fitting. Following this expert advice, the Panel determined that oil starvation was the **cause** of the engine failure; further investigation was required to understand what had caused the oil starvation. Exhibit 2 Exhibit 1

Materials Integrity Group Analysis

1.4.27. The discovery of the congealed substance in the oil feed pipe and reducer enabled samples to be sent to MIG for detailed analysis. MIG were supplied with samples of the oil taken from the tank, congealed oil deposits from the oil feed pipe and debris from the oil strainer. MIG were also provided with the large diameter **(S43)** oil supply pipe for analysis. Of particular note, the residual oil within the oil supply pipe was found to congeal whilst in the MIG laboratory over a period of two weeks; this congealed oil was subsequently analysed as part of the inquiry and is shown in Figure 8 below. Exhibit: 53, 54

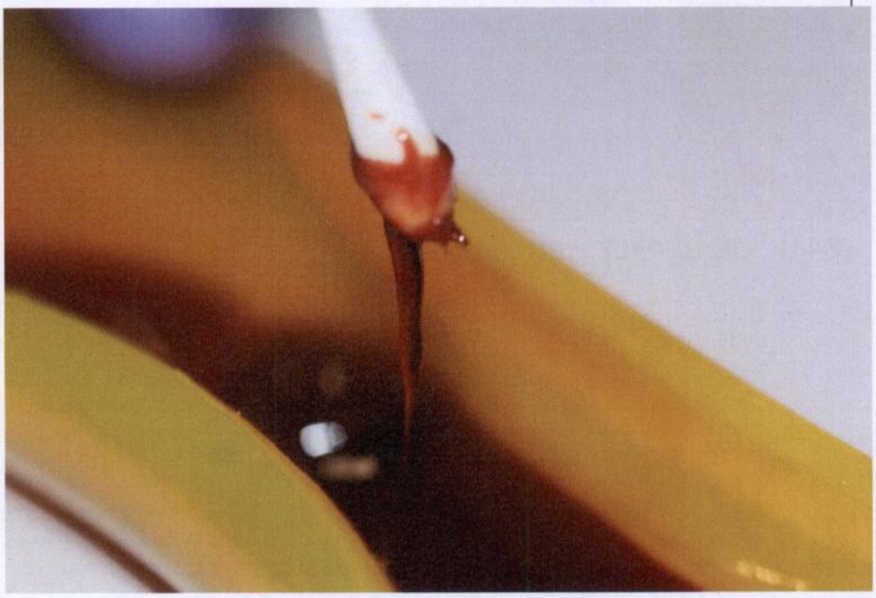

Figure 8 - Congealed oil discovered in (S43) Supply pipe in the laboratory

1.4.28. Analysis of the material found within the oil tank's 250 micron strainer, showed the contents to be predominantly fluff together with general environmental dirt (sand or grit). The examination of the strainer did not highlight anything unusual which could be attributed to the event. Figure 9 shows the debris found in the filter. Exhibit 2 Exhibit 55

Figure 9 - Debris removed from the Oil strainer

1.4.29. MIG's initial GC[9] analysis into the congealed oil samples from the oil pipe indicated that the phenomenon was highly likely to be linked to the additive packages present in the oil: i.e. the lubricant had become separated from the viscosity improving additives, resulting in a soft and tacky deposit. The 'normal' oil samples taken from ZK515's oil tank were tested for viscosity and constitution and both were found to be consistent with typical fresh Mobil Pegasus 1. Exhibit 2 Exhibit 151 Exhibit 53

1.4.30. MIG then contacted ExxonMobil, the manufacturer of the Pegasus 1 oil, in order to improve understanding of the nature of the additive packages present in the oil. Consequently, ExxonMobil tasked the Lubricants Technical Support (LTS) Laboratory in Canada to examine the samples of congealed oil taken from ZK515's oil feed pipe at the crash site and the **(S43)** pipe residue discovered in MIG's laboratory. LTS were specifically asked to identify the nature of the congealed oil found in the oil pipes and to ascertain whether this anomaly was due to oxidation by-product, additive drop-out or something else. The congealed deposits were analysed using Fourier Transform Infrared Spectroscopy, which highlighted the presence of an additional ester within the oil, which is not found in Mobil Pegasus 1. A database search for this ester indicated that it is consistent with a polyester polymer. Small pieces of the inside of the **(S43)** oil supply pipe were then sectioned and analysed by the same method. The overlay of the composition of the congealed samples and pipe sample indicates that both spectra show the presence of the same ester, suggesting the ester material in the oil is highly likely to have originated from the pipe. MIG have concluded that the congealed oil deposits were formed by chemical interaction of the engine oil with the plasticised PVC pipe. Exhibit 56 Exhibit 151

Elbit Systems Analysis

1.4.31. Running concurrently with this SI, Elbit have conducted their own investigation into the oil systems on four of their H450s flying in Israel. These UAs use the same pipe material and the same oil type as ZK515. In each oil line between the tank and the reducer, they found small quantities of a black substance which they believe to be similar to the congealed substance found in ZK515's oil pipe. Elbit took the precautionary measure of changing the oil supply pipes on all H450 to allow them to collect more information, which was communicated by Service Bulletin (SB).[10] Exhibit 57 Exhibit 58

1.4.32. Elbit's analysis into the tacky deposits found in oil pipes of their own H450 has also identified the presence of an additional ester. They have identified this ester as a PVC plasticiser additive, which they determine has diffused from the oil pipe into the oil. Elbit's theory is that this plasticiser reacted with the additive packages within the Mobil Pegasus 1 and caused the congealed tacky residue found in the pipe. The Panel was encouraged to note that Elbit's analysis, parallel with and independent of the UK work, corroborated MIG's conclusions. Exhibit 57

Miscellaneous

1.4.33. During implementation of the SB by the Theatre UAS Battery Fitter Section, debris was found in the oil tanks and filler straniers and a dark sandy debris was found to have collected in the bottom of the oil supply pipes between

[9] Gas Chromatography with a Mass Selective Detector

[10] Service Bulletin SB-450-11027 was issued to replace the oil supply line P/N 1-495-2700161 on all UK assets and return the pipe to Israel for analysis. This was converted and issued as STI-H450-3088 by the UAST.