Ministry of Defence

Ministry of Defence
Main Building
Whitehall
London SW1A 2HB
United Kingdom

Ref: FOI2019/06856

E-mail: [redacted]

[redacted]

10 Jul 2019

Dear [redacted],

Thank you for your email of 12 June requesting the following information:

> "I am looking to obtain any report made, or other information available discussing, the loss of Watchkeeper drone WK050.
> I understand it crashed near Aberporth, in Ceredigion, last June."

I am treating your correspondence as a request for information under the Freedom of Information Act 2000 (FOIA).

A search for the information has now been completed within the Ministry of Defence, and I can confirm that information in scope of your request is held.

The information you have requested can be found attached but some of the information falls within the scope of the absolute exemptions provided for at sections 40 (Personal Data), and qualified exemptions provided for at, 27 (International Relations) and 43 (Commercial Interests) of the FOIA and has been redacted accordingly.

Section 40(2) has been applied to some of the information in order to protect personal information as governed by the Data Protection Act 1998. Section 40 is an absolute exemption and there is therefore no requirement to consider the public interest in making a decision to withhold the information.

Section 27 and 43 are qualified exemptions and are subject to public interest testing which means that the information requested can only be withheld if the public interest in doing so outweighs the public interest in disclosure.

Section 27(1)(a) has been applied because some of the information has the potential to adversely affect relations with our allies. The balance of the public interest test concluded that whilst release would increase public understanding and confidence in the relation the United Kingdom has with other international states in its assistance with operations the balance of the public interest lay in withholding this information you desire. I have considered it necessary to apply the lower level of prejudice against release of "would be likely to".

Section 43 (Commercial Guidance) has also been applied because some of the information has been provided by a MOD Contractor and to disclose technical details of their system and processes would harm their commercial interests. The outcome of the balance of the public interest test concluded that whilst release would promote openness and transparency, greater public interest lay in withholding this information given that the public interest is best served in not releasing information that would be a disadvantage or impact on the commercial interests of MOD suppliers. I have set the level of prejudice against the release of the exempted information at the higher level of 'would' rather than 'would be likely to'.

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Yours sincerely,

DSA Secretariat

OFFICIAL - SENSITIVE

Defence
Safety
Authority

Safety Investigation Report

Watchkeeper WK050 ACCIDENT - NSI

13 June 2018

Defence Accident
Investigation Branch

Defence Accident Investigation Branch

Enhancing safety through investigation

The role of the DAIB is to conduct independent safety investigation of accidents and serious incidents to determine causal factors and make targeted recommendations in order to prevent accidents and enhance safety, whilst preserving operational capability.

The primary aim of an accident investigation shall be the prevention of future accidents. It shall not be the purpose of a safety investigation to determine liability nor to apportion blame.

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Report Title:	Watchkeeper WK050, West Wales Airport - NSI
Reference:	**DAIB/18/016**
Issue:	1
Date:	Feb 19
Authors:	Maj [redacted] (Ops) and WO1 [redacted] (Eng)
Reviewed by:	Hd DAIB
Approved by:	DG DSA

Probability Expressions.

The use of probability expressions in this Non-Statutory Inquiry (NSI) follows DAIB SOP 514 "Probabilistic Language" (Figure 1). The purpose of introducing probability expressions is to facilitate standardised communication of uncertainty in DSA Accident and Incident reporting.

The choice of expression remained a matter of judgement by the Investigation Team and provided an indication of meaning based on common usage and understanding. The terminology should therefore be thought of in terms of relative meaning within the report rather than a precise measurement of probability.

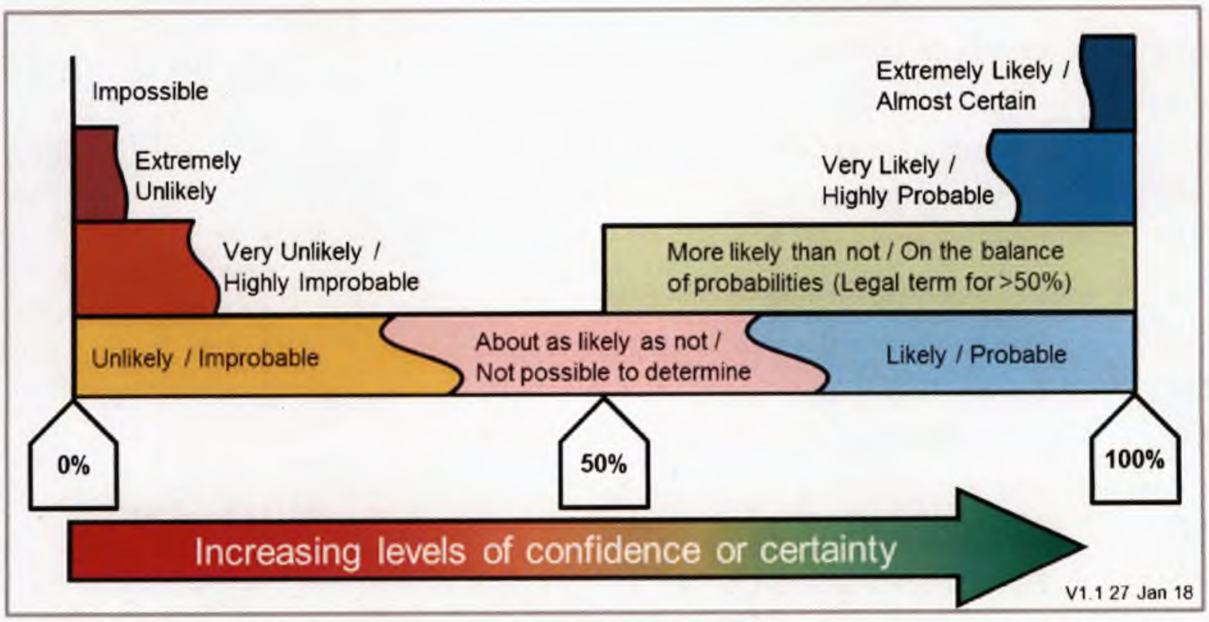

Figure 1: Probability expressions used in this Non-Statutory Inquiry.

Glossary

AI	Aircrew Instructor
AGL	Above Ground Level
AIB	Ascension Island Base
ALARP	As Low As Reasonably Practicable
AM(CAw)	Accountable Manager (Continuous Airworthiness)
AM(MF)	Accountable Manger (Military Flying)
AMSL	Above Mean Sea Level
ASMS	Air Safety Management System
ATC	Air Traffic Control
ATOLS	Automatic Take-off & Landing System
AV	Air Vehicle
AVDC	Air Vehicle Display Computer
AVGAS	Aviation Gasoline
BDN	Boscombe Down
BFS	Before Flight Service
CAME	Continuing Airworthiness Management Exposition
CAMO	Continuing Airworthiness Management Organisation
CAPH	Continuing Airworthiness Post Holder
CCTV	Closed Circuit Television
CFAOS	Contractor Flying Approved Organisation Scheme
CFOE	Contractor Flying Organisation Exposition
C of S	Change of Serviceability
DA	Design Authority
DAIB	Defence Accident Investigation Branch
DG DSA	Director General Defence Safety Authority
DDH	Delivery Duty Holder
DME	Design Modification Engineering
Eng	Engineer
EOP	Electro-Optic Payload
EPT	Emergency Procedure Trainer
ESL	Elbit Systems Limited
ES2	Equipment Standard 2
FELA	Flight Execution Log Author
FMV	Full Motion Video
FOB	Flying Order Book
FOO	Flight Operations Organisation

FRC	Flight Reference Card
FSC	Flight Servicing Certificate
FTT	Full Task Trainer
GBU	Ground Beacon Unit
GCS	Ground Control Station
GDT	Ground Data Terminal
GMTI	Ground Moving Target Indication
GRU	Ground Radar Unit
GTOLS	GPS Take-off & Landing System
HF	Human Factors
IETP	Interactive Electronic Technical Publication
IO	Investigating Officer
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
JARTS	Joint Aircraft Recovery & Transportation Squadron
L&R	Launch and Recovery
LLR	Lost Link Route
LRU	Line Replacement Unit
LSTO	Land Status Timeout
m	Metres
MAA	Military Aviation Authority
MAA-RA	Military Aviation Authority-Regulatory Articles
MFL	Maintenance Fault Logs
MLG	Main Landing Gear
MFTP	Military Flight Test Permit
MPTF	Military Permit To Fly
NAS	Naval Air Squadron
NLG	Nose Landing Gear
NSI	Non-Statutory Inquiry
OCU	Operational Conversion Unit
ODH	Operating Duty Holder
OFT	Operational Field Trial
OPS	Operators
P1	Pilot 1
P2	Pilot 2
PATE	Portable Aircraft Test Equipment
PCM	Post-Crash Management
PCMO	Prime Contractor Management Organisation

PCMIO	Post-Crash Management Incident Officer
POL	Petrol Oils & Lubricants
RA	Royal Artillery
RAFCAM	RAF Centre of Aviation Medicine
RoD	Rate of Decent
RtE	Risk to Equipment
RtL	Risk to Life
RTS	Release to Service
RW	Runway
SA	Situational Awareness
SAR	Synthetic Aperture Radar
SME	Subject Matter Expert
SM	Safety Manager
SMP	Safety Management Plan
SMS	Safety Management System
SOP	Standard Operating Procedure
STEP	Sequentially Timed Events Plotting
SQEP	Suitably Qualified and Experienced Person
TD	Touch Down
T&E	Test and Evaluation
TH2	Threshold 2
TRHA	Trials Risk Hazard Analysis
UAS	Unmanned Air System
UAST	Unmanned Air System Team
UTTC	Unmanned Air Systems Trials & Training Centre
UTacS	UAV Tactical System Ltd
VMSC	Vehicle Management System Computer
WCA	Warnings Cautions & Advisories
WGS	World Geodetic System
WK	Watchkeeper
WOT	Wide Open Throttle
WTF	Watchkeeper Training Facility
WWA	West Wales Airport

1 Executive Summary

At 1652 on 13 Jun 18, Watchkeeper 050 (WK050) crashed just outside the western boundary of West Wales Airport (WWA) whilst conducting WK Equipment Standard 2 (ES2) Flight 750. The crash followed an unsuccessful attempt to land during an Army Captaincy Development Flight commanded by a UAV Tactical System Ltd (UTacS) Aircrew Instructor (AI). The accident resulted in WK050 AV being assessed as Category 5[1]. The Defence Accident Investigation Branch (DAIB) deployed 3 investigators to carry out the initial triage investigation. The Director General Defence Safety Authority (DG DSA), upon review of the triage report, decided that DAIB would carry out a Non-Statutory Inquiry (NSI).

The NSI team confirmed that as WK050 approached Runway (RW) 25 to land, it landed long of the Touch Down (TD) point just to the right of the centreline; it immediately deviated to the right during the landing roll. Vehicle Management System Computer (VMSC) analysis showed that WK050 failed to register ground contact during the ground touch window and auto-aborted for Land Status Time Out (LSTO) as it approached the edge of the RW. The Air Vehicle (AV) continued to deviate to the right as the engine powered up, rotating when both Main Landing Gear (MLG) wheels were on the grass. The AV climbed away to the righthand side of RW25 over the grass. These circumstances had not been encountered in the previous 749 WK flights. Pilot 1 (P1) manually aborted the landing 4 seconds after the AV had auto-aborted and 2 seconds later he pressed engine cut. The AV was at approximately 40ft Above Ground Level (AGL) with a Wide-Open Throttle (WOT) and a positive rate of climb when the engine was cut. After engine cut the AV attempted to intercept the Lost Link Route (LLR) and in doing so it glided over a road (B4333) before impacting a tree, approximately 900m from the TD point (Figure 3). The NSI team were able to confirm that the AV system was fully serviceable at the time of the accident. Had no action been taken, the AV would have completed its automatic go-around from which it could have been commanded to conduct a further approach.

When initially assessing the sequence of events leading to the accident the NSI team considered the trigger for P1 to press engine cut. The NSI team confirmed that although the crosswind and RW slope were within limits, LSTO and the disengagement of the asymmetric flight compensation loop (BETA loop) were functions of the VMSC design, when all 4 factors were combined they resulted in an extreme drift to the right. Consequently, the AV left the tarmac and went onto the grass. The NSI team's analysis indicated that the AV's deviation onto the grass was the trigger for P1 to press engine cut. The NSI team concluded that the AV deviation was one of 2 **causal factors** that led to the engine being cut.

The NSI team considered how the Ground Control Station (GCS) crew lost Situational Awareness (SA) of what mode of flight the AV was in. The team found that the influence of the Full Motion Video (FMV) distracted the crew from monitoring the flight modes of the AV and led to a false belief that the AV had landed. The WK simulators were unable to replicate: LSTO, the AV departing the RW or FMV. The Flight Reference Card (FRC) drills lacked some essential procedures that may have helped the pilots[2], however the cards called for engine cut if the AV was not maintaining the

[1] The aircraft is considered beyond economic repair
[2] To check the flight mode of the AV before engine cut

centreline. Other than P1 and Pilot 2 (P2), there were 3 other personnel in the GCS resulting in a more complicated and confusing working environment. The NSI team concluded that due to the totally unique situation encountered, P1 had lost SA of the flight mode of the AV. Moreover, so had all the other members of the GCS crew as they were unable to give clear instructions to P1 to stop his action or provide an alternative option. The NSI team concluded that the loss of SA by the GCS crew was the second **causal factor** and the engine cut was **the cause** of the accident.

To address the findings of this NSI, 13 Safety Recommendations have been made to: The Head of the Unmanned Air System Team (UAST), Accountable Manger (Military Flying) (AM(MF)) and Army Aviation Standards with the aim of reducing the likelihood of reoccurrence of this type of accident.

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2 Factual Information

2.1 Introduction

Throughout this report all times are LOCAL. The following information has been established from witness statements and physical evidence gathered during this investigation.

At 1652 on Wed 13 Jun 18 WK050 crashed just outside the western boundary of WWA whilst conducting WK ES2 Flight 750. The crash followed an unsuccessful attempt to land during an Army Captaincy Development Flight commanded by a UTacS AI.

DAIB deployed 3 investigators[3] to carry out an initial triage investigation into this accident. The aim of the triage deployment was to conduct a fact-finding investigation to assist the DG DSA in determining the most appropriate post accident course of action and to secure vulnerable and perishable evidence. The Engineer (Eng) investigators attended the crash site and viewed the associated equipment on the airfield. The Operations (Ops) investigator collected the impounded documents, witness statements and interviewed the crew. He also collected flight data, the download of the FMV and the GCS audio. Based on the triage report[4] the DG DSA decided that an NSI conducted by the DAIB was the most appropriate method to investigate this accident.

2.2 WK Capability Overview

WK is a system comprised of an unmanned AV fitted with sensors, connected via data-links to a GCS. WK is designed to deliver a flexible, 24-hour, low visibility (including poor weather) Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) capability. WK is employed primarily within the land environment and contributes to information superiority.

2.2.1 WK Procurement Overview

In 2005, Thales was awarded the contract for the development, manufacture, and initial support phases of the WK programme. Thales was able to undertake the development flying of WK aircraft as they had been approved by the Military Aviation Authority (MAA) under the Contractor Flying Approved Organisation Scheme (CFAOS) and its predecessor scheme(s). The system was originally intended to reach Initial Operating Capability by Jun 10 and Full Operating Capability in 2013. In Sep 13, the MAA provided a Statement of Type Design Assurance for WK, confirming its airworthiness.

2.2.2 WK Programme Organisation

Thales is the Prime Contractor Management Organisation (PCMO) and Design Authority (DA) for the WK system. As PCMO, Thales leads an industry team consisting of Cubic Corporation (data-links), Elbit Systems Limited (ESL) (UA air vehicles), Marshall SV (ground station shelters and ground vehicles), Altran (programme safety), and UAV Engines Ltd (AV engines). UTacS is a joint venture company that was created by Thales and ESL to enable technology transfer, manufacture, and UK support. UTacS also provide crews and maintenance personnel for WK air operations at WWA.

[3] 1x Ops and 2x Eng
[4] Evidence reference - DAIB/18/016/131

2.2.3 Thales Flight Operation Organisation

WK air operations have been conducted at WWA since Apr 10 under the Thales Flight Operations Organisation (FOO). Primarily a Test and Evaluation (T&E) organisation, Thales created the FOO which would provide the overarching organisation and an equivalent Duty Holder chain along with the operations personnel supported by UTacS. UTacS provide both the Maintenance Organisation and a Design and Production Organisation, providing both the engineering support and the design production support. Thales also provide an equivalent to the military Delivery Duty Holder (DDH) construct through the AM(MF). All flying at WWA was conducted under a Military Flight Test Permit (MFTP) that outlines what flying was permissible at WWA, and if there are any special conditions imposed on the flying activity.

The FOO was set up to undertake flight operations of the WK AV on behalf of the Defence Equipment and Support UAST for the British Army. The FOO had several post holders who were legally responsible and were named individuals within the management structure of the MAA approved CFAOS.

2.2.4 WK Military Flying

On 28 Feb 14 the WK platform was issued with its Initial Release to Service and the Royal Artillery (RA) commenced flying operations at Boscombe Down (BDN). The DDH for Military WK Flying was Commander Watchkeeper Force and the Operating Duty Holder (ODH) was Commander Joint Helicopter Command. In Aug 14, Operational Conversion Unit (OCU) build standard WK was deployed to Afghanistan in support of Operation HERRICK, whilst Thales continued to conduct T&E flying to develop the ES2 aircraft under the FOO at WWA. In Mar 15, on return from Afghanistan the Army re-commenced WK flying operations from BDN and flying continued until 2 Nov 15. A programme was then put in place for the RA to fly WK at Ascension Island Base (AIB), to allow military personnel to convert onto the OCU build standard WK allocated to the Army.

The AIB training took place using a mix of military, Thales and UTacS instructors. It allowed the Army to build a cohort of qualified and experienced WK Aircrew, Instructors and Launch & Recovery (L&R) crews. This training concluded at AIB on 30 Mar 17. Expectation was for a rapid transition to the ES2 WK. The ES2 Operational Field Trial (OFT) was due to be flown in Apr 17 with an RTS following its completion. After the loss of WK042, 3 Feb 17, and WK043, 24 Mar 17 additional assurance requirements, technical issues and a poor flying rate pushed the ES2 OFT to Jul, and then onto Sep-Oct 17, causing further delay of the RTS.

With the delay to ES2, consideration was given to a return to flying on OCU build standard WK at BDN. However, the Delegated Release to Service Authority indicated that the OCU RTS would be rescinded if this took place. The degradation of the RW surface at AIB closed the airbridge preventing a further WK deployment being an option. Since 30 Mar 17 the only WK flying has been WK ES2 from WWA under the Thales MFTP.

2.2.5 Pre-accident Events

The RA crew for Flight 750 had completed Conversion to Mark (OCU to ES2) and were back at WWA to complete Captaincy Development Training. Captaincy Development Training consisted of 6 flights, 3 in each role P1/P2. The accident sortie was flight 4 of 6. On 13 Jun the crew arrived at WWA in time for the daily 0815 brief and meteorological forecast. The plan was for the crew to fly 2 flights that day, switching their roles between flights. A different AI would command each flight.

The plan for the first flight was for the RA crew to fly approximately 1:15hrs to 1:30hrs before handing over and crewing out to the second flight's AI and spare pilot who required 55mins of flying for their own currency. The RA crew would have lunch before returning to crew back in for the flight's recovery and landing. The RA crew briefed and authorised before walking to the GCS and the first flight took off at 1100. The flight was completed without incident, the only point of note being the low cloud base[5]. The landing was without issue, but the crew noticed that the crosswinds had been strengthening towards the end of the flight. Post-flight the crew were debriefed by the AI and then went straight into the brief and authorisation for the second flight.

The RA crew switched roles for the second flight, P2 becoming P1 and vice versa. The standard sortie brief process was run by P1. The Flight Execution Log Author[6] (FELA) briefed the specification of the AV and the AI[7] briefed the objectives of the sortie, what he expected from the crew, emphasising that they should take ownership and lead it. The authorisation process included the checking of everyone's qualifications and signatures on the authorisation sheet. A total of 5 crew were to be present in the GCS: P1, P2, AI, FELA and spare pilot.

The crew walked and crewed into the GCS, all pre-flight checks were carried out in accordance with FRCs and engine start was requested. There was a small delay to the departure as the crosswinds were close to the AV's limits. The RA crew consulted the wind component table for crosswind landing/take-off within the FRCs. The entire crew monitored the winds more closely than normal. Once the crew had set off for the GCS the authoriser went to the WWA control tower for the take-off. He received a meteorological update and was content that the crosswinds would stay within limits for the sortie duration and this was relayed to the crew.

P1 conducted the pre-take-off brief, covering his intended actions-on before and after AV rotation[8]. He would abort the take-off if there were any warnings and cautions before decision speed, subsequently monitoring the AV for keeping to the centreline and cutting the engine if it veered. After rotation any warnings and cautions would be dealt with once airborne either in the circuit or over the sea. His intention was to conduct one circuit, to check the metrological conditions, before transiting to the operating area. After a final check of the wind by the RA crew the AV took off at 1459 from RW25 at WWA. Post take-off the authoriser returned to his office.

During the circuit at WWA the cloud scan was carried out, using the Electro-Optic Payload (EOP). The cloud base was suitable for the transit to the operating area, Danger Area 201 which was over the sea. Initially the AV was instructed to climb to 1800ft Above Mean Sea Level (AMSL), the cloud was still above the AV, so it was further climbed to 2000ft AMSL. Once established in the area the RA crew went through the sortie's objectives as briefed, including Ground Moving Target Indication (GMTI) and Synthetic Aperture Radar (SAR) tasks. Everything was normal with the AV during the flight. The wind was monitored closely throughout the flight with the aid of a laptop logged onto the WWA online meteorological station. P1 noted that the crosswinds at WWA were gusting up to 15kts and decided to return to base earlier than originally planned. This was due to

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[5] Between 1000ft and 1500ft AMSL

[6] Accountable to the AV Cdr for ensuring the Execution Log is kept, to record the pre-flight, flight and post flight activities during non-trials flight events

[7] AV Commander

[8] Decision speed

the adverse wind conditions and anticipation of several go-arounds; this decision was communicated to the L&R team.

2.2.6 Accident Events

P1 initiated the recovery and pre-landing checks in accordance with the FRCs. These checks were highlighted yellow denoting that they were to be conducted on a 'challenge and response' basis. As part of the pre-landing checks P1 initiated the AV landing sequence and conducted the landing brief. In the brief P1 asked P2 to monitor the Warnings Cautions Advisories (WCA) for the landing and he stated that there would be no intentional aborts but if anything was out of the ordinary they would abort the landing.

The AV intercepted the Automatic Take-off and Landing System[9] (ATOLS) and reported the stages of the landing sequence. P1 monitored the AV's progress via the Air Vehicle Display Computer (AVDC), reading out to the crew each stage as it appeared on his screen. P2 monitored the WCA and EOP generated FMV to check initially that the RW was clear and in the latter stages that the AV was staying on the RW centreline.

Everything was normal with the AV during the final approach to RW25. The AV was visibly crabbing to the left, due to the crosswind component but was tracking the RW centreline. P2 stowed the EOP in preparation for TD[10]. P1 verbalised semi-flare[11] and de-crab[12]. After de-crab the AV started drifting right, verbalised by P2. Air Traffic Control (ATC) reported touchdown. The AV landed long of the TD point, just to the right of the centreline; it immediately deviated to the right during the landing roll, reported by ATC. The AV failed to register ground contact and auto-aborted for LSTO as it approached the edge of the RW. The AV continued to deviate as its engine powered up, rotating when both MLG wheels were on the grass (figure 2). P2 reported the AV was on the grass and said the emergency code words to abort the landing. Expletives from the AI and P1 followed. P1 verbalised abort and engine cut immediately followed by the spare pilot saying cut engine. P1 manually aborted the landing 4 seconds after the AV had auto-aborted, 2 seconds later he pressed engine cut twice in quick succession. The AV was climbing away to the righthand side of RW25 over the grass and at approximately 40ft AGL with a WOT and a positive rate of climb when the engine was cut. The AV attempted to gain its LLR, in doing so it glided over the road (B4333) before impacting a tree at approximately 1652.

[9] The AV flies itself, guided down by the ATOLS and completes the landing autonomously
[10] At approximately 30ft the camera was rotated to the rear but remained on
[11] 7m AGL
[12] 6m AGL

Figure 2: Image from rear-facing EOP as AV departed the RW (seen top right).

2.2.7 Post-accident Events

A Mayday call was transmitted on the tower frequency by the GCS crew at 1652 and WWA ATC activated the crash alarm. The Post-Crash Management Incident Officer (PCMIO) contacted the tower to establish the location of the crash. An incident centre was stood up within the offices at WWA and the Post-Crash Management (PCM) plan was activated. An Incident Officer centrally coordinated and controlled PCM activities and communications.

Figure 3: The AV deviation track (red & yellow) and accident location.

The AV crashed just outside the airfield boundary past the threshold of RW07 (Figure 3). Due to its proximity to the airfield the PCMIO and a WK Eng deployed to the site. The AV had glided over the B4333 and impacted a large tree just the other side of the road from the airfield. There were no injuries or fatalities and the AV was categorised as CAT 5. The PCMIO arrived at the crash site shortly after 1655 and met an eyewitness who had called the emergency services. An initial cordon of 40m radius around the crash site was setup but subsequently reduced to 15m radius once an initial debris assessment had been carried out.

The wreckage was spread over an area of approximately 10m by 10m and the AV had come to rest with its propeller on the ground at the base of the tree. The fuselage structure was broken in 2 aft of the wing section and the forward section was lying upside down on the ground. Much of the wreckage had been contained by the branches with the remainder lying at the base of the tree.

The DAIB were notified within 15 minutes of the accident by the Incident Officer. The Police and Fire Brigade arrived shortly after the PCMIO and the Police visited the landowner. The PCMIO oversaw the disconnection of the AV's battery and provided advice to the Fire Brigade on potential hazardous substances. Due to the ruptured fuel and oil tanks with the loss of approximately 32kgs of fuel[13] and 9.5kgs of oil[14] the Fire Brigade dowsed the wreckage with foam. They waited an hour before handing the site over to the PCMIO and departed at 1830, the Police had left 30 minutes earlier.

The Incident Officer worked through the internal and external lines of communication, impounding documentation for WK050 and the GCS, collecting initial statements from the GCS crew, the L&R crew and ATC. He confirmed that the DAIB accident investigators were en-route but would not arrive on site until early the next day. A Serious Occurrence Notification was raised on the Air Safety Information Management System followed by a Defence Aviation Safety Occurrence Report for the accident.

A small guard force was established to keep watch throughout the night until the DAIB accident investigators arrived at approximately 0800. The guard force, provided by individuals from Thales Unmanned Air Systems Trials and Training Centre (UTTC) WWA, were assisted by the deputy RAF Regional Liaison Officer from RAF Valley. The guard force remained on site throughout and assisted DAIB and the Joint Aircraft Recovery and Transportation Squadron (JARTS). The Defence Infrastructure Organisation representative for mid Wales briefed the landowner on the recovery process.

The JARTS team arrived at 1345 on 14 Jun. With the ongoing triage investigation, they were advised recovery would not start until the morning of 15 Jun. During the JARTS initial site survey the state of the tree and some of its branches were identified as a potential issue for Health and Safety during the recovery phase. A local tree surgeon was contracted to make the tree safe. Recovery started on the morning of 15 Jun after the tree surgeon had declared the tree safe for work to continue. The wreckage was removed, for subsequent recovery to BDN and the site was handed back to the land owner at 1600 on 15 Jun.

2.3 System Operating Requirements

Before WK can be operated the RW to be used must be surveyed and marked, in accordance with parameters laid down in the Interactive Electronic Technical Publication (IETP). The intended RW requires several points both on and off the RW to be surveyed[15] dependent upon whether the strip is single, bi-directional and the overall RW length. The survey points need to be measured to a high accuracy, one point is surveyed absolute to an accuracy of less than 3m and the remaining

[13] AVGAS
[14] Mobile Pegasus 1
[15] Ground Radar Unit (GRU), Ground Beacon Unit (GBU), Threshold 1, Touchdown point, Threshold 2 and Under-run point

points surveyed relative to an accuracy of 1m[16]. The WK AV can be operated on existing tarmac prepared RWs or on semi-prepared RWs.

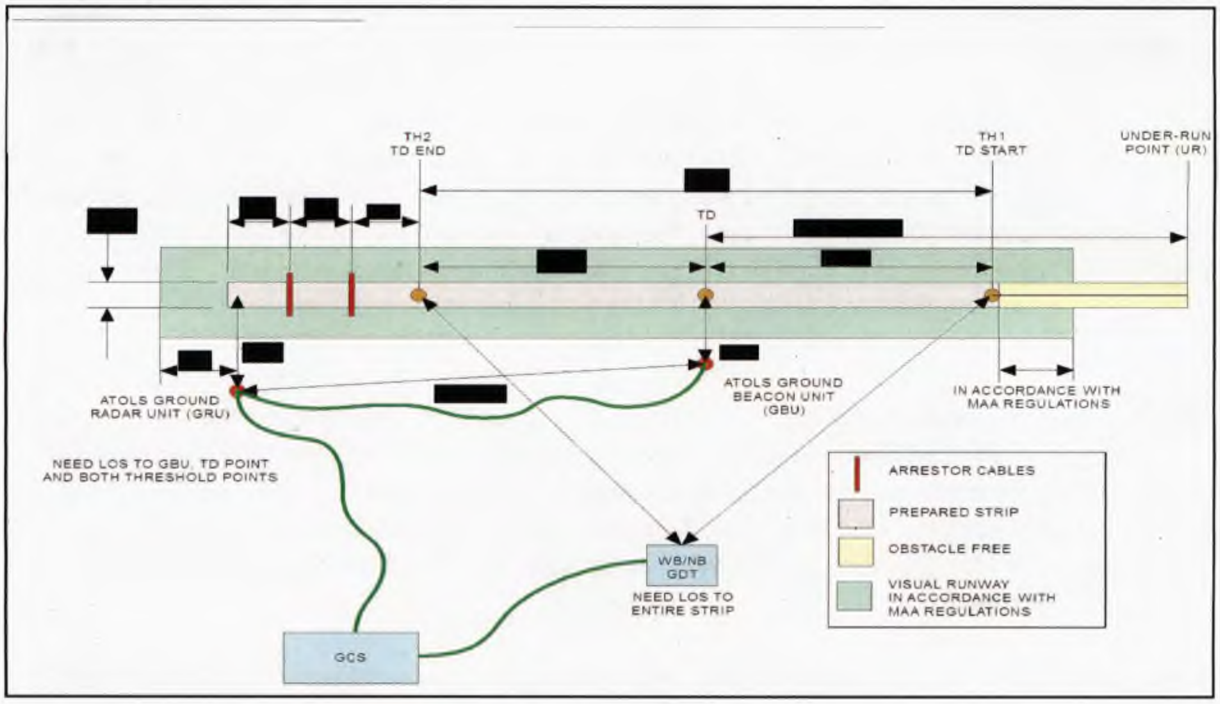

Figure 4: Airstrip parameters.

Figure 4 and Table 1 give the parameters that must be followed when conducting a RW site survey. The location of the individual parts of the ATOLS must be sited using the following parameters:

- [redacted]

[16] Evidence reference - DAIB/18/016/108
[17] Maximum length of grass [redacted]mm

[redacted].

Condition	Requirement
Length	Minimum [redacted]
Width	[redacted]
Approach/Departure clearance	[redacted] (both ends)
Maximum acceptable slope along the RW	[redacted]
Maximum acceptable slope across the RW (centre to edge)	[redacted]
Orientation	Position to stay within wind and gust limitations
Maximum height of step	[redacted]
Maximum height of bump	[redacted]
Maximum depth of hollow	[redacted]
Grass RWs	[redacted]
Permissible surfaces	[redacted]

Table 1: Semi-prepared RW parameters.

Figure 5 depicts the survey of WWA RW25 showing elevation, slope, and the locations of Threshold 1 and 2 and the TD point. The RW was surveyed at 25m intervals along its length.

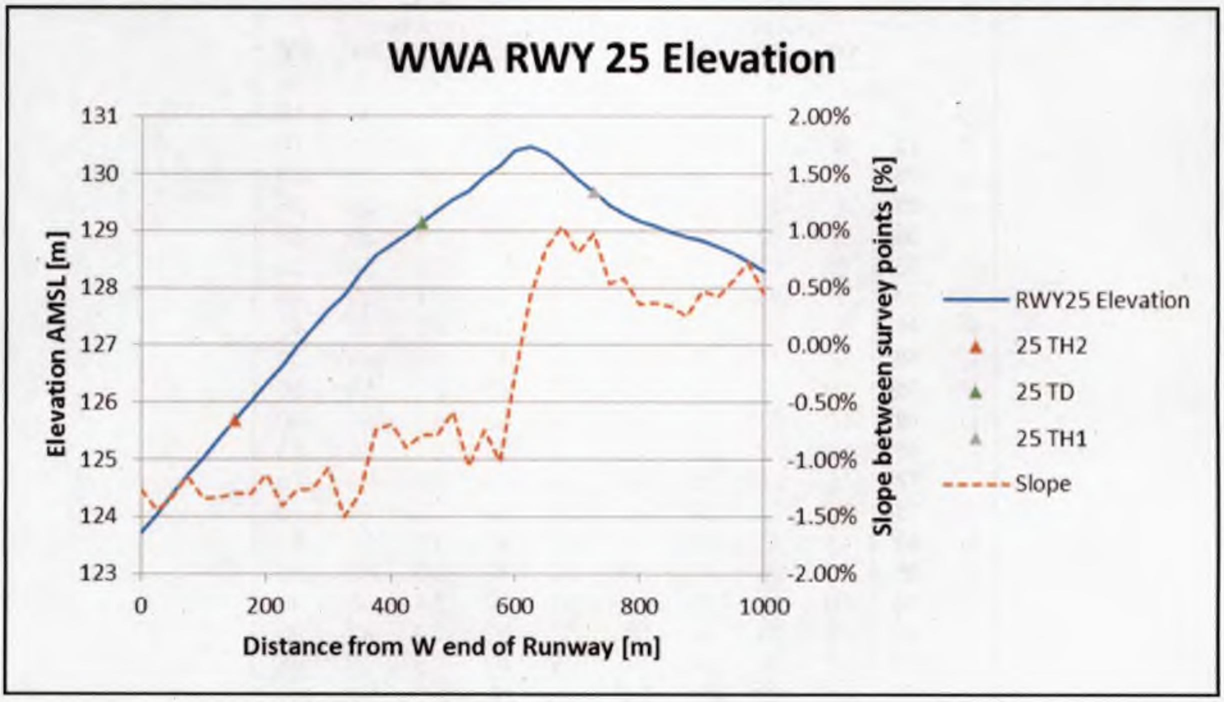

Figure 5: WWA RW25 elevation and slope.

[18] WWA RW25 was 30m wide

The winds at the time of the accident are shown in the Table 2. They were recorded roughly every 10 seconds by the meteorological facility at the airfield.

Time	Wind Direction	Wind Speed Kts	Time	Wind Direction	Wind Speed Kts
1648:32	198	20	1651:08	217	14
:42	192	17	:18	209	12
:53	206	17	:29	213	11
1649:03	203	17	:39	214	11
:14	205	17	:50	206	16
:24	200	15	1652:00	194	14
:34	212	14	:11	205	17
:45	213	13	:21	197	17
:55	220	17	:32	207	15
1650:06	200	14	:42	194	15
:16	217	16	:53	205	15
:26	213	14	1653:03	220	15
:37	200	13	:13	207	14
:47	209	17	:24	215	15
:58	221	15	:34	209	15

Table 2: The recorded winds at WWA on 13 Jun at the time of the accident.

WIND COMPONENT TABLE
FOR CROSSWIND COMPONENT
ANGLE BETWEEN WIND DIRECTION AND RUNWAY HEADING

		10°	20°	30°	40°	50°	60°	70°	80°	90°
	5	1	2	2	3	4	4	4	5	5
W	10	2	3	5	6	7	8	9	9	10
I	15	3	5	7	9	11	13	14	14	15
N	20	3	7	10	13	15	17	18	19	20
D	25	5	8	12	16	19	22	23	24	25
	30	5	10	15	19	23	26	28	29	30
	35	6	12	17	22	26	30	32	34	35
S	40	7	14	20	25	30	35	37	39	40
P	45	8	15	22	29	34	39	42	44	45
E	50	9	17	25	32	38	43	47	49	50
E	55	10	19	27	35	42	48	52	54	55
D	60	10	20	30	38	46	52	56	59	60
	65	11	22	32	42	50	56	61	64	65
	70	12	24	35	45	54	60	66	69	70
K	75	13	26	37	48	57	64	70	73	75
N	80	14	27	40	51	60	69	75	78	80
O	85	15	29	43	55	64	73	80	83	85
T	90	16	31	45	58	68	77	84	88	90
S	95	16	33	48	61	72	82	89	93	95
	100	17	34	50	64	75	86	93	98	100
		80°	70°	60°	50°	40°	30°	20°	10°	0°

ANGLE BETWEEN WIND DIRECTION AND RUNWAY HEADING
FOR HEADWIND COMPONENT

Table 3: Wind Component Table from the FRCs.

2.4 Equipment Details

2.4.1 System Overview

WK is an Unmanned Air System (UAS), which provides a network enabled ISTAR capability. The WK consists of several separate system components and support equipment that enable pre-flight preparation, launch, operation, and recovery of the AV, controlled from a GCS. There are also associated ground elements to enable transportation, storage, and maintenance.

2.4.2 Air Vehicle

The AV is the airborne element of the WK ISTAR capability. Externally it comprises a cylindrical fuselage, main wing, V-Tails, rear-mounted engine and propeller, a tricycle undercarriage and an EOP and a Radar payload (Figure 6).

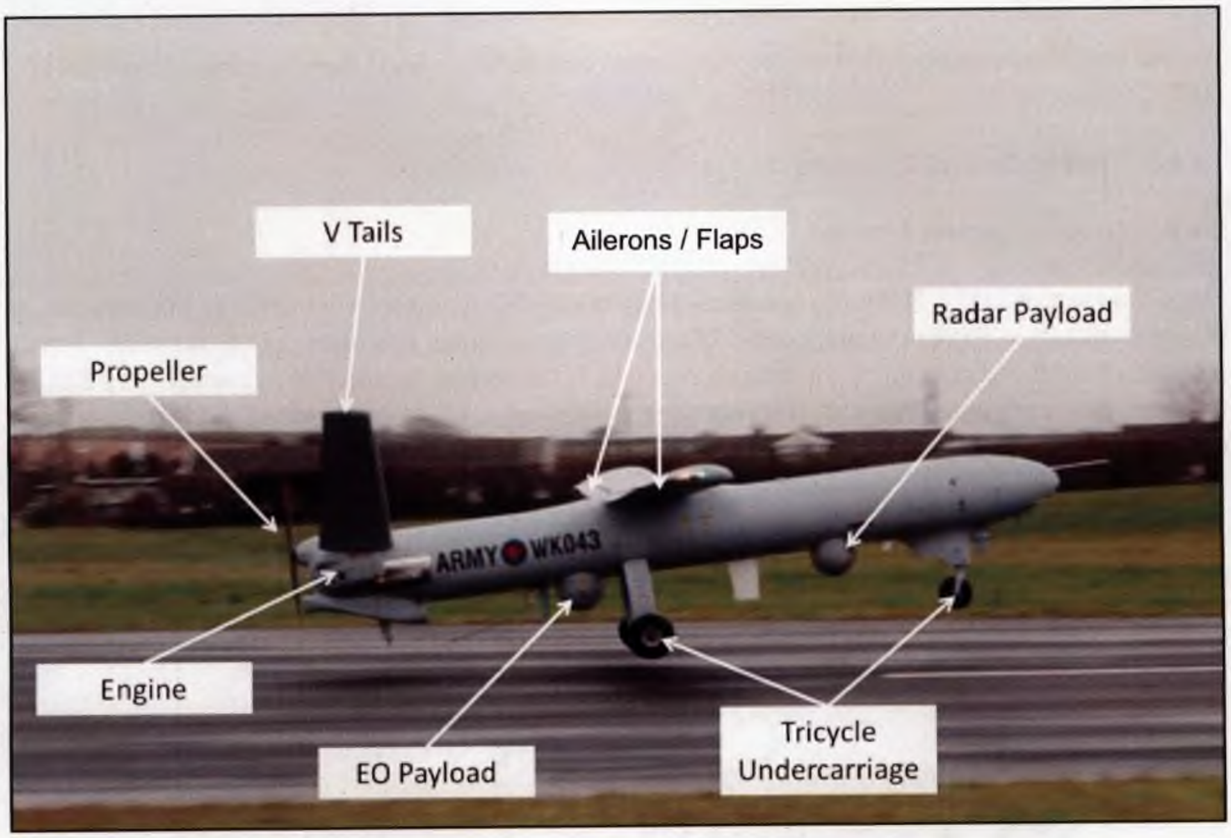

Figure 6: Watchkeeper ES2 AV.

The AV has a length of 6.50m, a wingspan of 10.95m and an overall height of 2.18m. It has a maximum all up mass of 500kg. Further details of the AV are as follows:

2.4.2.1 Fuselage

The fuselage is a carbon composite monocoque design. Most of the avionic components are packaged inside the fuselage, with the payloads, undercarriage and antennae protruding outside.

2.4.2.2 Undercarriage

The AV has a non-retractable tricycle undercarriage and can take-off and land on paved and semi-prepared airstrips. It has a steerable nose landing gear assembly. There are no wheel brakes; on landing, the AV is halted by a fixed arrestor hook system.

2.4.2.3 Propulsion, Fuel, Lubrication and Cooling System

The AV is powered by a Wankel rotary engine, produced by UAV Engines Ltd in the UK, which runs on Aviation Gasoline (AVGAS) and drives a pusher type propeller. The fuel system comprises an integral fuel tank and collector tank designed to ensure that the engine will not run dry at low fuel levels or whilst manoeuvring. The engine is water cooled and has a total loss oil system, using Mobil Pegasus 1 oil, which is indirectly heated by the coolant system.

2.4.2.4 Payloads

The AV has 2 payload bays and the following loads can be fitted: EOP, dummy payload and SAR / GMTI System.

2.4.3 Ground Control Elements

2.4.3.1 Ground Control Station

The GCS (Figure 7) is a 20ft long, specifically designed, ISO-type container used by the crew for planning missions, command and control of the AV and its sensor payloads during missions. It is a self-contained unit containing the main computing infrastructure for the WK system (Figure 8). It provides the operators with a safe working environment, which is air-conditioned, and temperature controlled during operation. Each GCS can accommodate 5 crew members.

Figure 7: GCS.

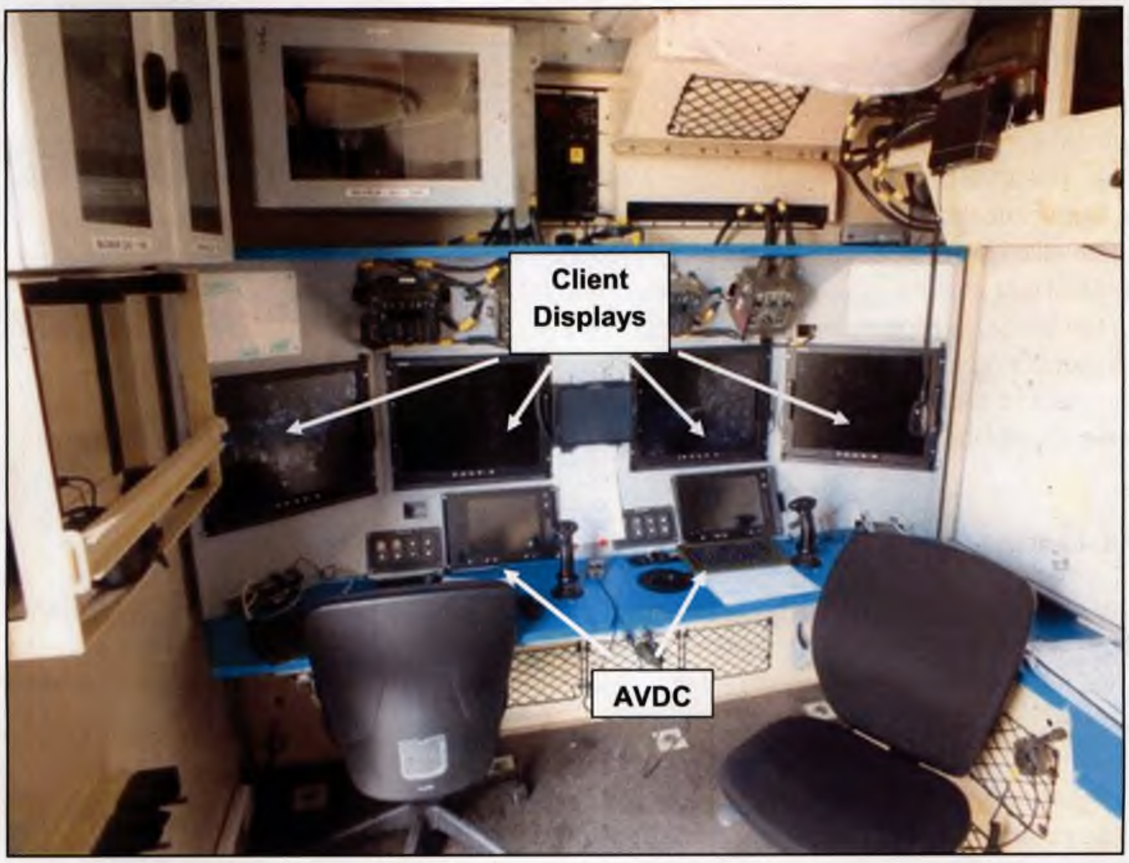

Figure 8: Interior of the GCS.

2.4.3.2 Automatic Take-off and Landing System

ATOLS is a system which allows the AV to perform automatic take-offs and landings. It comprises of a GRU and a GBU next to the RW at accurately surveyed points and an Airborne Beacon Unit in the AV itself. Based on initial position data passed from the GCS, it tracks the position of the AV and provides steering information to the vehicle via the GCS and data-links using the GBU as a surveyed reference to enable accurate target positioning. In the event of a failure or malfunction of the ATOLS, the AV can still perform an ATOL using the GPS Take-off and Landing System (GTOLS). The VMSC will select the more accurate of ATOLS or GTOLS during the landing phase.

2.4.4 Portable Aircraft Test Equipment (PATE)

The PATE is ground support and test equipment used to perform pre and post flight servicing to confirm that the AV is fit to fly and is also used for fault finding and maintenance. It connects to the AV through an umbilical cable and connectors on the side of the AV. The PATE also provides the electrical engine start facility and the air blower for cooling the AV whilst on the ground. It is recognised that the PATE influences other functions, such as flight controls and propulsion, however this is only when the AV is connected to the PATE via the umbilical for conducting the pre-flight checks.

2.4.5 Flight Control

Flight control of the AV is achieved through the VMSC monitoring the various inputs from the aircraft sensors and sending signals to actuators controlling the ailerons, flaps, V-tail, and engine throttle. The VMSC controls all aspects of AV flight dynamics, power, propulsion, and navigation. It is a flight critical system that contains the entire flight control software. Its primary role is to calculate all changes in atmospherics and aerodynamics to maintain the AV in a safe and controlled flight attitude by applying the correct control surface error corrections. The software within the VMSC is programmed to control power switching, redundancy, failure management and status monitoring for all Line Replacement Units (LRUs). The VMSC contains all the logic, algorithms and coding designed to calculate flight paths, loiters, take-offs and landings, glide slopes and predicted landing points and utilises the integral Flight Control Software to achieve this.

2.4.6 Landing Logic

The AV enters its landing phase once a 'land' command has been received from the GCS, and the VMSC has completed its landing validity checks. The land command is generated after the AV pilot has pressed the soft key on the AVDC. Prior to proceeding into the landing mode, the VMSC will confirm the following:

- The take-off landing site exists.
- The commanded landing route contains the minimum number of points.
- RW is within a defined take-off landing area.
- RW direction is aligned with the landing route.
- RW position is within tolerance with respect to the landing route.

If the landing validity checks fail, the VMSC will remain in its current mode and not proceed with landing. If the validity checks by the VMSC are correctly verified, the AV flies to the nearest waypoint on the landing route and then follows the route to the Connect Point. At the Connect Point the VMSC changes the flight mode to Automatic Landing and declares Intercept Mode. The laser altimeters are switched on and the VMSC transitions from using barometric altitude to the World Geodetic System (WGS84) reference. The following stages may be reported during the landing cycle, depending upon where the AV is within its landing cycle:

- Intercept.
- Approach.
- Under-run.
- Threshold.
- Semi-flare.
- De-crab.
- Ground Contact.
- Jump.
- Free roll.
- Cable stop.

Once the AV has achieved the 3-degree glide slope, 'Approach' is declared. The AV will continue to navigate its way towards the final approach point. The VMSC will then disable the Flight

Envelope Protection manoeuvre and attempt to line up with the RW. 'Under run', 'Crossing' and 'Threshold crossing' are declared as these points are reached during the AV's final approach.

The VMSC uses the laser altimeters to calculate a one-off bias correction with respect to the WGS84 reference altitude to provide absolute height above the RW and, if both laser altitudes are valid, uses an average of both readings. If this is unsuccessful, the VMSC will use the reading from the valid laser altimeter.

When the AV is [redacted] AGL, a semi-flare manoeuvre is performed, reducing the glide slope from [redacted] degrees to [redacted] degrees. At [redacted] AGL the AV is de-crabbed to align with the RW. At [redacted] AGL the VMSC opens the 'Ground touch window' for [redacted] seconds to sense for ground contact. If a bounce is detected following ground touch, the VMSC repeats the semi-flare and de-crab, unless the vertical velocity is too high, in which case the landing is aborted.

Once on the ground the VMSC declares 'Ground contact' based on a landing algorithm. This enables the Nose Landing Gear (NLG) to steer the AV to the centreline. 0.5 Seconds after 'Ground contact' the VMSC initiates a pitch-down command. 'Free roll' is declared after a further 0.5 seconds and the engine is commanded to idle. The AV is in 'Free roll' and will no longer get airborne either automatically or manually. The V-tail and NLG are both used to maintain the AV on the centre line until it is captured by the arrestor cable. 'Cable stop' is declared once captured, using the ground speed of the AV as a trigger. If Threshold 2 (TH2) plus 100m is passed, cable overrun is declared after 2 seconds, and the engine is automatically cut. If the VMSC fails to detect 'Ground contact' during the 'Ground touch' window it will automatically abort the landing, declare a 'LSTO', open the throttle fully and conduct a go-around. Figure 9 shows the logic applied in a normal landing cycle.

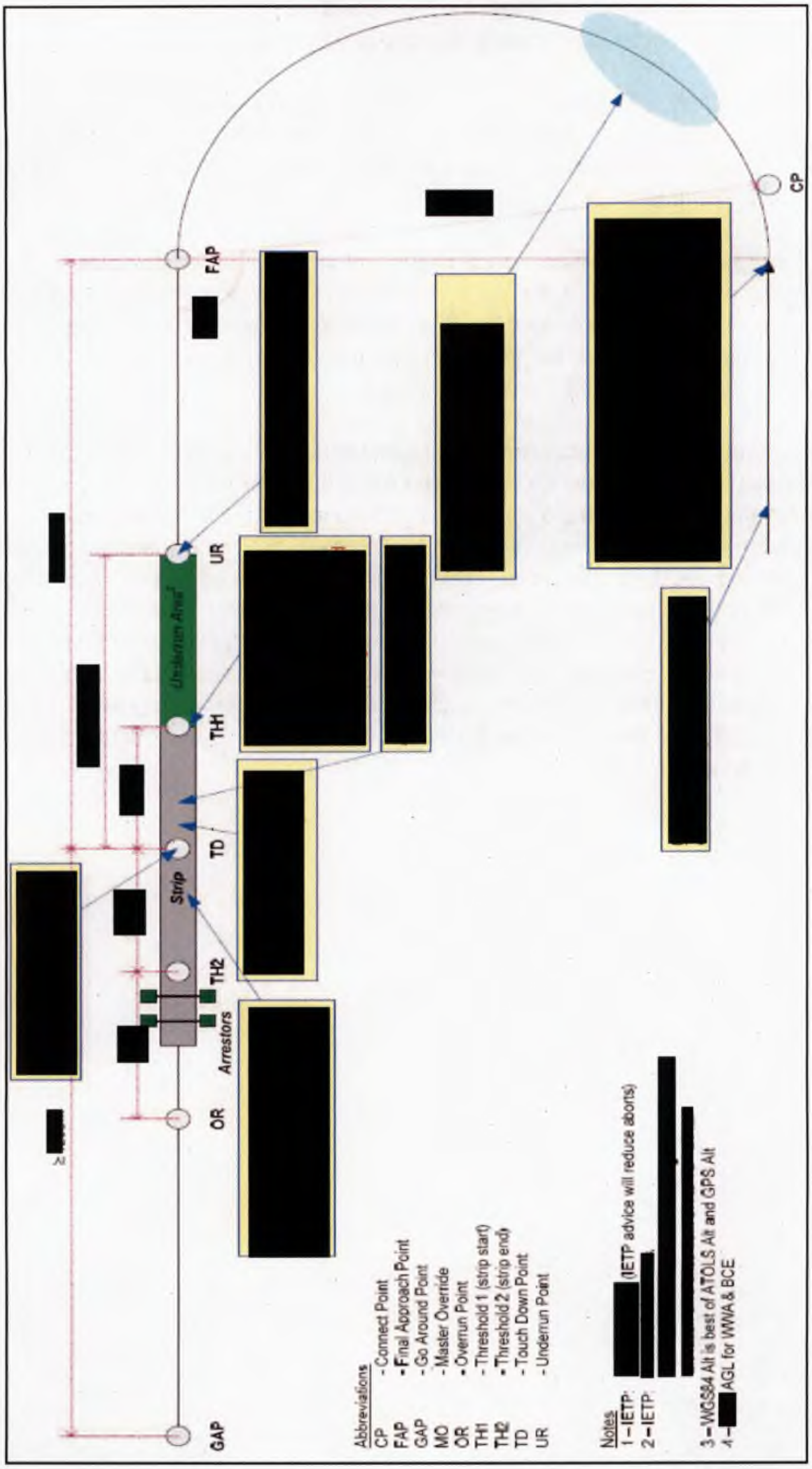

Figure 9: Normal ATOLS landing logic.

2.5 Accident and Other Data Recorders

The WK ES2 did not have an accident Flight Data Recorder capability; there had been no requirement in the original ES2 build specification to include such a device in the design. The main data source for the WK050 accident investigation was heavily based on the VMSC and GCS data recording facilities. The VMSC was removed from the wreckage in excellent condition with no sign of damage to the outer casing. In consultation with Thales engineers, it was agreed that an attempt to extract the data from the VMSC should be made, however due to the concerns associated with wiping the data from the unit, the proposed data extraction process was tested on another unit first to provide assurance. The PATE at WWA was utilised to extract the VMSC data and recover the flight telemetry plan recordings. The data from the VMSC was inserted into an Excel spreadsheet where it could be used to review the sequence of events and produce a timeline.

The GCS had a digital voice recording system which records, as separate channels, the mic, left ear and right ear audio for the positions occupied by the GCS crew. The NSI team recovered the audio recordings for all 5 crew positions in the GCS and this included external radio communications between the ATC and GCS crew.

The NSI team collected Close Circuit Television (CCTV) footage[19] of WK050 attempting to go-around post its aborted landing. The CCTV camera was installed on a hangar located at the mid-point of RW25. RW25 had been previously extended in length and the existing hanger obscured the view of ATC staff. The CCTV camera installed on the hangar roof, steered by an ATC operator, provided full visibility of RW25 via a monitor located in ATC.

The EOP fitted to the AV contained a solid-state camera capable of providing real-time, video-rate digital imagery, and lower rate, still digital imagery. The camera has a continuous optical zoom lens fitted. The imagery obtained is transmitted to the GCS where it is displayed on the client displays and recorded[20] for training and investigative purposes. During the final stages of landing, at 30ft AGL, the EOP is rotated aft to protect the lens.

Newquay Airport in Cornwall provided radar data[21] for the time-period between 1630L to 1700L on 13 Jun 18. The data produced was a standalone recording of the radar plot showing the last 30 minutes of Flight 750.

2.6 Wreckage and Impact Information

The AV directly impacted a large tree before coming to rest with its propeller on the ground at the base of the tree (Figure 10). The tree had sustained impact damage and several branches had become detached or broken as the AV fell to the ground.

[19] Evidence reference - DAIB/18/016/050
[20] Evidence reference - DAIB/18/016/049
[21] Evidence reference - DAIB/18/016/033

Figure 10: Impact damage to large tree.

The fuselage structure was broken in 2 aft of the wing section and the forward section was lying upside down on the ground (Figure 11). The right-hand wing had become detached from the main fuselage and was resting vertically to the ground. The aileron and flap control surfaces were detached from the right wing and were resting in branches next to the wing. Much of the wreckage had been contained by the branches with the remainder lying at the base of the tree resting on the ground. Several small fuselage and nose cone fragments had shattered due to impact damage and were scattered around the base of the tree within a 5m radius.

Despite extensive damage to the main fuselage assembly, the LRUs contained within the AV were secure in situ and appeared to be in a good physical condition, however their serviceability status was unknown. The EOP and radar were secured within the main fuselage and appeared to be in a good state of repair. The AV's fuel tank was ruptured and completely empty of fuel. The oil tank was damaged and did not contain any oil.

Figure 11: WK050 wreckage at base of large tree.

2.7 Test and Research

Fuel and oil samples were taken from the AV at the crash site (Table 4). As both fuel and oil tanks had been ruptured, the samples had to be taken from internal pipelines using standard DAIB crash kit sampling equipment in accordance with branch engineering standards and practices. 1710 Naval Air Squadron (NAS) were tasked by the NSI team with assessing aviation gasoline, a lubricating oil sample and fuel from the bowser that had been used to refuel the AV.

DAIB Ref.	Sample Point	Fluid Type	Sample Date
DAIB 18/016/5001	Watchkeeper 050 Oil Pipe	Mobil Pegasus 1	14/06/2018
DAIB/018/016/5002	Watchkeeper 050 Fuel System Pipeline and Fuel Tank	AVGAS 100LL	15/06/2018
DAIB/18/16/5003	West Wales Airport Sample Tin (Bowser Sample 1)	AVGAS 100LL	07/06/2018
DAIB/18/016/5003	West Wales Airport Sample Tin (Bowser Sample 2)	AVGAS 100LL	07/06/2018

Table 4: Fuel and oil samples submitted to 1710 NAS for testing.

The NLG and 2 MLG tyre pressures were checked by UTacS Engs at the accident site using UTacS servicing equipment.

2.8 Documentation

During the triage investigation, the team gathered the relevant documentation associated with the WK System. Where it was likely that a specific piece of equipment may have been required to be returned into service at the earliest opportunity, a copy rather than the master was collected. As it was almost certain that the AV was beyond economical repair, the Master F700 log book was collected for further analysis. Due to the Human Factors (HF) nature of the accident the NSI team felt it was unnecessary to heavily scrutinise the WK System's documentation. The NSI team did however review the maintenance documentation and where errors were discovered they were investigated. The following documentation was gathered:

- WK050 F700 Master Copy
- GCS WB00013 Log Book (certified true copy)
- Ground Data Terminal (GDT) Set 2 Log Book (copy)
- ATOLS Set 3 Log Book (copy)

3 Analysis and Findings

3.1 Introduction

The following section of this report details the analysis of the evidence available to the NSI team.

3.1.1 Available Evidence

The NSI team visited WWA to observe the accident site, conduct interviews and to fully understand the activity at the UTTC. The team had 2 meetings at the Thales offices in Crawley including a teleconference with Elbit in [redacted]. Three visits were conducted to the Watchkeeper Training Facility (WTF) at Larkhill which included interviews and simulator familiarisation. Considerable correspondence occurred throughout the investigation between the NSI team and Thales as well as focused questions to Elbit. All correspondence with Elbit was via Thales.

All evidence received and used during the investigation was recorded in the evidence log. Available evidence included:

- Statements from or interviews with:
  - Authoriser.
  - WWA ATC.
  - AI.
  - P1.
  - P2.
  - FELA.
  - Spare Pilot.
  - L&R Crew.
  - UTacS Engs.
- An HF report produced by RAF Centre of Aviation Medicine (RAFCAM).
- Thales produced HF report.
- Fuel and oil test results produced by 1710 NAS.
- QinetiQ produced Graphical Data Analysis System Presentation.
- Elbit flight data investigation report.
- Thales WK documentation set.
- DSA MAA Regulatory Articles (MAA-RA).

3.2 Methodology

The NSI team used several investigatory methodologies at different times throughout the investigation. This was done so that the most appropriate methodology could be matched to the stage of the investigation. The methodologies used were: The 5 Whys, Sequentially Timed Events Plotting (STEP) and the HF Analysis and Classification System. The 5 Whys was used to determine the root cause of the problem by repeating the question 'Why', each answer formed the basis of the next question. STEP was used to draw together the different events during the accident into one coherent timeline to aid analysis. The HF Analysis and Classification System enabled the NSI team to investigate, analyse and classify the HF aspects of the accident.

3.3 Accident Factors

The factors that played a part in the accident are categorised as; causal, contributory, aggravating, other and observations.

3.3.1 Causal Factors

Causal Factors are defined as factors which, in isolation or in combination with other factors and contextual details, led directly to the accident.

3.3.2 Contributory Factors

Contributory Factors are defined as factors which made the accident more likely.

3.3.3 Aggravating Factors

Aggravating Factors are defined as factors which made the accident outcome worse.

3.3.4 Other Factors

Other Factors are defined as factors which were none of the above but were noteworthy in that it may cause or contribute to future accidents.

3.3.5 Observations

Observations are defined as factors that were not relevant to the accident but worthy of consideration to promote better working practices.

3.4 Main Lines of Inquiry

The NSI team, when initially attempting to understand the cause of the accident, used the 5 Whys and STEP to identify the necessary lines of inquiry. The teams Terms of Reference outlined additional areas to be investigated. These lines of inquiry were regularly reviewed and updated throughout the investigation. The main lines of inquiry have been distilled into 5 main topic headings which will be considered in this section:

- AV Deviation.
- System Serviceability.
- Events within the GCS.
- Training, Currency, Competencies, Qualifications and Supervision.
- Policy and Regulation.

The 5 topics listed above are further broken down into sub-sections and cover all areas outlined within the NSI's Terms of Reference.

3.5 Chronology of Events

The NSI team produced a timeline that would be the baseline throughout the investigation. Following Elbit's flight data investigation the NSI team were supplied with the VMSC derived timeline (Table 5). This timeline was accepted by both Thales and the NSI team as the most appropriate and accurate to work from.

Time	Event
15:59:15	Airborne
16:50:08	Auto Landing
16:50:08	Intercept Land
16:50:10	Approach Land
16:51:31	Under-run Cross
16:51:50	Theshold1 Cross
16:51:57	7m
16:51:57	Semi-Flare Land
16:51:58	Decrab
16:52:03	1m (6.3secs after 7m)
16:52:04	0.69m (1.0sec after 1m)
16:52:06	ATOLS Landing Aborted
16:52:06	Land Status Timeout
16:52:06	Initial Climb Take-off
16:52:06	Auto Take-off
16:52:07	0.73m (3.1secs after 0.69m)
16:52:10	ATOLS Manual Abort Command
16:52:12	Manual Engine Cut Command x2
16:52:15	Engine tacho low RPM
16:52:15	Engine tacho fail
16:52:15	VMSC comms with Engine fail
16:52:18	Last valid altitude
16:52:28	Impact

Table 5: The VMSC derived timeline.

3.6 AV Deviation

When initially assessing the sequence of events leading to the accident the NSI team considered the trigger for P1 to press engine cut. Witness interviews and Thales data[22] suggested that multiple landings had been to the right of the centreline, particularly prevalent on RW25 and even when the crosswind had been from the right. However, in the previous 749 flights a WK had never left the RW. Analysis of the GCS audio recording and witness testaments indicated that the trigger was when the AV was reported to be on the grass. Following their data investigation Elbit stated that the VMSC had worked as designed. The NSI team therefore focussed on why the AV deviated onto the grass.

3.6.1 Wind

The wind speed and direction at the time of the landing, 1652L, can be seen in Table 2. The AV crosswind limit[23] was stated in the FRCs as '15kts max'. AV crews were trained to assess the crosswind component using the 'Wind Component Table For Crosswind Component' (Table 3).

[22] Evidence reference - DAIB/18/016/085
[23] Evidence reference - DAIB/18/016/043

Using the known wind and the wind component table the NSI team calculated that the wind was within limits throughout the landing. The team noted that although the maximum permissible crosswind speed for the AV was only 15kts, the table's wind speed was marked in increments of 5kts and went up to 100kts. This made interpolation essential and getting accurate figures difficult. The NSI team determined that although within limits the crosswind, on occasion was close to the limit. During finals the AV maintained RW track but was visibly crabbing to the left, into wind. From 150ft AGL the AV was crabbing between 15 and 10 degrees[24] left of RW heading. The AV was reacting to the windy conditions and its heading fluctuated frequently up to 10 degrees. The team deduced that the AV was working hard to maintain track and that the wind was having a notable effect on the AV. With a weight of just 450kg at the time of the accident, a length of 6.50m, a wingspan of 10.95m and an overall height of 2.18m the AV was light with a large surface area; it was also slow and therefore susceptible to drift.

At 6m AGL the AV 'de-crabbed' and turned towards the RW heading. Immediately after de-crab the AV started drifting right. The wind effect, seen before de-crab, was still affecting the AV post de-crab however the AV was no longer crabbing into wind so would have begun to drift right as a result. The NSI team concluded that the crosswind was a **contributory factor** in the AV deviation. The team considered that the wind component table design was inappropriate for the WK flight envelope and could have been better, therefore concluded it was an **other factor**.

Safety Recommendation – The Head of the Unmanned Air System Team should review the current Air Vehicle crosswind limitations to determine whether they remain fit for purpose.

Safety Recommendation – Army Aviation Standards should revise the Wind Component Table within the Flight Reference Cards to better reflect the Air Vehicle flight envelope.

3.6.2 Runway Slope

The data from the slope survey of RW25 can be seen in Figure 5. It conforms to the slope limitations, laid down in the IETP[25], not to exceed 2% and exceeds the 20m width requirement by 10m. The part of RW25 used for the ATOLS slopes downhill in the direction of travel. The NSI team considered whether the slope could have influenced the AV deviation.

During a normal landing the AV would 'semi-flare' at 7m AGL, modifying its glideslope from 3 to 1.5 degrees, reducing its Rate of Descent (RoD). Between the TD point and TH2 the RW sloped down from between 0.5% and 1.50%. The AV landed long of the TD point. With the RW dropping away as the AV attempted to land it would have had the effect of reducing the AV's RoD relative to the RW. This would have prolonged the time to touchdown from the semi-flare and would have allowed influences, such as crosswind, to act on the AV for longer, resulting in a greater deviation towards the edge of the RW. Furthermore, it would have resulted in a more gentle touchdown. The NSI team considered the suitability of the entire length of RW25 for the ATOLS. Figure 5 shows that the Eastern end of the RW slopes up hill and would have had the effect of increasing the AV's RoD on landing. However, the requirement for the ATOLS to have line of sight between

[24] Evidence reference - DAIB/18/016/112
[25] Evidence reference - DAIB/18/016/108

component equipment may preclude this area without equipment modification. In the opinion of the NSI team a greater period airborne, resulting from the RW slope, would have allowed influences such as crosswind to act on the AV for longer. The NSI team concluded that the RW slope was a **contributory factor** in the AV deviation.

Safety Recommendation – The Head of the Unmanned Air System Team should review the current Air Vehicle runway slope limitations to determine whether they are fit for purpose.

Safety Recommendation – The Accountable Manger (Military Flying) should consider relocating the Automatic Take-off & Landing System on runway 25 West Wales Airport to an area that has less slope.

3.6.3 Land Status Time Out

At 1m AGL the 'ground touch' window opens for 2.8 seconds. During this window the VMSC is primed to detect a predetermined change in vertical acceleration to declare 'ground contact'. If the VMSC fails to detect 'ground contact' during the 'ground touch' window it will automatically abort the landing, declare a 'LSTO', open the throttle fully and conduct a go-around. On Flight 750 the AV did not detect a landing during the ground touch window and automatically aborted the landing. The NSI team considered why this might have happened and whether it could have affected the AV deviation.

The VMSC contained a landing algorithm using a change in vertical acceleration and pitch rate to determine a landing. The touchdown of the AV was insufficient to register as a landing. The investigation revealed that LSTO go-arounds happen from time to time but were rare. If 'ground contact' had been detected the NLG would have been enabled, steering the AV to the centreline and away from the edge of the RW. The slope of RW25 would have reduced the AV's rate of descent relative to the RW and made the possibility of a LSTO more likely than a flat RW. By not registering ground contact the AV remained flying[26] for the maximum possible duration, 2.8 seconds after the opening of the ground touch window. This allowed external influences to continue acting on the AV for the maximum possible duration.

Whilst the system's landing logic performed as designed, the NSI team concluded that the AV not detecting 'ground contact' and instead declaring LSTO compounded the deviation right and was a **contributory factor** in the accident sequence.

3.6.4 BETA Loop

In all autonomous flight modes, except de-crab and acceleration phases[27], the BETA control loop is engaged. The loop generates yaw and roll commands to eliminate asymmetry including engine torque reaction, this is known as BETA error and is calculated by the VMSC. It is assumed that AVs are not symmetrical. The direction of rotation of the AV's propeller leads to a torque reaction

[26] The AV may have been in contact with the ground for part of this period
[27] Take-off and Go-around up to 50ft AGL

to the right (positive yaw). Data analysis[28] has shown that yaw and roll commands in straight and level flight were present to eliminate BETA error. When the de-crab phase starts at 6m AGL the BETA control loop is disengaged, and the yaw loop is engaged. [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Safety Recommendation – The Head of the Unmanned Air System Team should improve the Air Vehicle's landing accuracy, within its flight envelope, in order to ensure the effect of combining all landing factors does not lead to a runway excursion.

[28] Evidence reference - DAIB/18/016/077

3.7 System Serviceability

3.7.1 Fuel

The flight servicing certificate[29] within the F700 had a recorded fuel state of 37kg of AVGAS 100. The flight data from the VMSC indicates that at the time of the accident the AV had accumulated approximately 1hr of flying and had 32 kg of AVGAS 100 remaining. The fuel burn rates[30] for a WK ES2 are listed in the IETP as follows:

- 2.5 kg/hr when in idle.
- 6 kg/hr in cruise.
- 12 kg/hr when climbing.

The triage accident investigation team collected fuel samples from the AV's internal pipelines and from the fuel bowser that refuelled WK050. The collected fuel samples were sent to 1710 NAS for further testing and analysis. 1710 NAS confirmed that the physical properties of the fuel samples from WK050 and the fuel bowser were consistent with AVGAS 100 and further chemical assessment did not highlight any significant degradation or adulteration with another Petrol Oil and Lubricants (POL) type product. The AV had sufficient fuel quantity that was not contaminated at the time of the accident. The NSI team concluded that the AV's fuel was **not a factor** in this accident.

3.7.2 Oil

The Leading Particulars in the WK F700[31] stated that the AV should contain 9.5 kg of Mobil Pegasus 1 oil in its lubricating system and the Flight Servicing Certificate (FSC) for WK050 on 13 Jun 18 had a recorded oil quantity of 10 kg. When questioned, the DA[32] stated that the oil tank capacity is 11 kg, however the PATE is only capable of reporting a maximum weight of 10.3 kg. The DA could not provide any information on where the 9.5 kg figure in the Leading Particulars originated from. The NSI team **observed** that the oil quantity figures in the WK F700 contradicted each other and could cause confusion to the user, however they did not consider it to be contributory to the accident.

A sample of Mobil Pegasus 1 oil was collected by the triage team from the internal lubrication system pipelines. The 1710 NAS assessment correspondence[33] confirmed that the physical properties of the Mobil Pegasus 1 oil sample were assessed as consistent with previous Mobil Pegasus 1 oil samples tested by them. Further chemical assessment of the oil sample did not highlight any significant degradation or adulteration with another POL type product. The AV had sufficient oil quantity that was not contaminated at the time of the accident. The NSI team concluded that the AV's oil was **not a factor** in this accident.

3.7.3 AV Fault Logs

The VMSC was removed from WK050 by UTacS Engs and was downloaded[34] using the PATE at WWA. An annotated version of the VMSC fault log[35] was produced. This provided a history of

[29] WK050 F700 Flight Servicing Certificate Sheet Jun 09
[30] Evidence reference - DAIB/18/016/187
[31] QMS-F0185 Issue 4.0 Leading Particulars Watchkeeper
[32] Evidence reference - DAIB/18/016/217
[33] Evidence reference - DAIB/18/016/106
[34] Evidence reference - DAIB/18/016/031

faults being declared and cleared from Flight 750. The NSI team were able to conclude[36] that the AV was fully serviceable during the attempted landing of Flight 750, with no significant faults shown in the Maintenance Fault Log (MFL) or PATE Fault Log. The NSI team concluded that the AV's serviceability was **not a factor** in this accident.

Figure 12: Main wheel tyre pressure check.

3.7.4 AV Undercarriage

All tyre pressures were checked in accordance with the IETP[37] during the triage investigation. The NSI team were able to confirm that the all tyre pressures were correct and therefore would not have affected the landing (Figure 12). The NLG was in the locked position and slightly misaligned. The misalignment was consistent with impact damage with the tree and there was no evidence to suspect the serviceability of the AV's undercarriage during the attempted landing. The NSI team concluded that the AV's undercarriage was **not a factor** in this accident.

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[35] Evidence reference - DAIB/18/016/210
[36] Evidence reference - DAIB/18/016/133
[37] MLG: WATCHKEEP0MK1-RPA-CB2-41-00-0000-311A-A & NLG: WATCHKEEP0MK1-RPA-CB2-43-00-0000-311A-A

3.7.5 GCS, ATOLS and GDT Serviceability

The recorded GCS data was collected by the triage team and passed to the WK DA for further analysis[38]. The DA provided a data analysis spreadsheet[39] listing all the alerts recorded by the GCS client server for the GDT, ATOLS and GCS during Flight 750. The NSI team was able to confirm that there were no unusual alerts seen during Flight 750 and that the GCS, GDT and ATOLS were serviceable at the time of the accident. The NSI team concluded that the serviceability of the GCS, ATOLS and GDT were **not a factor** in this accident.

3.7.6 PATE Serviceability

The PATE is primarily used for the Before Flight Service (BFS), it can also be used to download flight and system data post-flight[40]. PATE Serial No: HP38AB was used for the BFS for Flight 750 on 13 Jun 18.

Analysis of the PATE logs confirmed that they contained no unexpected issues or discrepancies with the MFL from the VMSC or the GCS reports post-acquisition. From this it can be inferred that the PATE was working correctly, effectively acting as a Human Computer Interface between the VMSC and engineer in the lead-up to the flight. The NSI team concluded that the serviceability of the PATE was **not a factor** in this accident.

3.7.7 AV Log Book (F700)

WK050 was registered on the UK Military Register on 06 Jul 16. The AV was found to have an in-date Engine Ground Running Certificate and Flight Authorisation Certificate issued by the Defence Quality Assurance Field Force. The AV airframe had accrued 97.44 flying hours and this was recorded in the F700[41].

The BFS and supplementary servicing for WK050 had been certified as carried out in the FSC and supplementary FSC respectively. WK050 had no open entries in the Change of Serviceability (C of S) log on 13 Jun 18. The limitations and acceptable deferred faults for WK050 were correctly recorded in the appropriate log. All scheduled maintenance activities were in date and correctly recorded on the forecast sheet.

The NSI team concluded that the AV's serviceability had been correctly recorded and certified in the F700 and that the AV Log Book was **not a factor** in the accident.

3.7.8 GCS Log Book

The GCS designated with serial number WB00013 was in use on 13 Jun 18 for controlling WK050, Flight 750. The GCS had a scheduled maintenance routine detailed in the IETP and all maintenance activities carried out on the GCS were recorded and certified in the GCS log book[42] for GCS WB00013. The BFS and supplementary servicing for GCS WB00013 had been certified as carried out in the 'GCS/GE Operations/Flight' page on 13 Jun 18.

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[38] Evidence reference - DAIB/18/016/030
[39] Evidence reference - DAIB/18/016/020
[40] Evidence reference - DAIB/18/016/026
[41] Evidence reference - DAIB/18/016/039
[42] Evidence reference - DAIB/18/016/041

GCS WB00013 had no open entries in the C of S log on 12 Jun 18. C of S log sheet number 134 and 135 contained certified entries and were physically inserted into the GCS log book, however the NSI team **observed** that these sheets were not recorded in the register of controlled forms. This minor administrative error is considered by the NSI team not to have affected the accident. The team concluded that the recorded data in the GCS log book was **not a factor** in this accident.

3.7.9 ATOLS Log Book

ATOLS set 3[43] was in use on 13 Jun 18 for Flight 750 and had no open entries in the C of S log. The BFS and supplementary servicing for ATOLS set 3 had been certified as carried out in the 'GCS/GE Operations/Flight' page Jun 07 on 13 Jun 18. The NSI team **observed** that certain scheduled maintenance tasks had been incorrectly forecasted in the scheduled maintenance forecast sheet for ATOLS Set 3, although these were in date at the time of the accident. This minor administrative error is considered by the team not to have affected the accident. The team concluded that the recorded data in the ATOLS's log book was **not a factor** in this accident.

3.7.10 GDT Log Book

GDT set 2[44] was in use on 13 Jun 18 for Flight 750 and had no open entries in the C of S log. The BFS and supplementary servicing for GDT set 2 had been certified as carried out in the 'GCS/GE Operational/Flight' page Jun 07 on 13 Jun 18. The team **observed** that item 2 in the supplementary flight servicing register to carry out alternative checks on the GDT fibre optic cable had not been signed for in the supplementary FSC. This is likely to have been a minor administrative oversight and would not affect the serviceability of the GDT. The team concluded that the recorded data in the GDT log book was **not a factor** in this accident.

3.7.11 PATE Log Book

The C of S log for the PATE had a certified entry for the self-test carried out on 05 Jun 18. There were no further recorded logs available for the self-test. The team **observed** that the PATE should be tested every week[45] and therefore an entry in the C of S log for a PATE self-test on 12 Jun 18 should have been recorded and certified. Despite this discrepancy, the DA maintain that had there been a significant issue with the PATE, they would have expected to see either a failure of the BFS or additional fault reports to be visible in the VMSC MFL, or issues with the AV once acquired by the GCS. The NSI team confirmed that as none of these occurred it was extremely likely that the PATE was fully serviceable for the BFS and pre-flight procedure. The NSI team concluded that the recorded data in the PATE log book was **not a factor** in this accident.

3.7.12 Serviceability Conclusion

Through data download analysis from the VMSC and the GCS client server, the NSI team confirmed AV system serviceability with no significant fault codes apparent in the equipment logs. The AV system was certified serviceable in the relevant log book and the administrative errors **observed** were considered by the team as minor. The NSI team concluded that the serviceability of the AV system was **not a factor** in the accident.

[43] Evidence reference - DAIB/18/016/069
[44] Evidence reference - DAIB/18/016/068
[45] Evidence reference - DAIB/18/016/200

3.8 Events Within the GCS

The crew comprised 5 personnel all of whom were in the GCS at the time of the accident. The crew composition can be seen in Table 6. The NSI team had access to the GCS audio recording[46] for the entire accident sortie. Analysis of the GCS audio recording, visits to WWA and the WTF simulators and witness interviews provided an insight into the environment and events within the GCS at the time of the accident.

Position Held	Organisation
P1	RA
P2	RA
AI / Aircraft Commander	UTacS
Spare Pilot	UTacS
FELA	Thales

Table 6: WK050 crew composition.

3.8.1 Sortie Planning and Briefing

The NSI team considered whether the planning, preparation and briefing were suitable for the activity undertaken. WK pre-flight out-briefs are to be conducted in accordance with Annex A 'Out-Brief Checklist'[47] to the Thales Watchkeeper Flying Order Book (FOB). The annex specifies that before the out-brief the flight authoriser is to conduct a documentation check to include the competence matrix and the currency tracker. The brief starts with findings from the documentation check and continues with weather, mission brief, other and finishes with signing the authorisation sheets. A take-off brief is also a mandatory requirement and is to be conducted in accordance with the 'Take Off and Landing Brief v2 for ES2'[48].

The crew attended the 0815 meteorological brief, planned, briefed, and flew the day's earlier sortie. The accident sortie was planned and briefed at 1430 with the entire crew in attendance, it included an updated met brief. Crew testament was that the brief was conducted in accordance with Annex A, to the Thales Watchkeeper FOB. As a Captaincy Development Flight, the AI was assessing P1's brief using the AV Commander Assessment check list. The team considered that P1, under assessment by the AI, would have used Annex A and covered all aspects of the brief. It was also the second brief of the day that they had all conducted. The NSI team were able to listen to the take-off brief using the GCS recording and confirmed it was in accordance with the 'Take-off and Landing Brief v2 for ES2'.

It was the assessment of the NSI team that the planning and briefing were suitable for the activity and were therefore **not a factor** in the accident.

3.8.2 GCS Manning

The crew layout within the GCS can be seen in Figure 13. The Thales FOB[49] states the maximum number of occupants permitted in a GCS is 6. The IETP states that the GCS is designed for 5 operators. The role of the spare pilot was outlined in the Trials Risks Hazard Analysis (TRHA) for

[46] Evidence reference - DAIB/18/016/024
[47] Evidence reference - DAIB/18/016/161
[48] Evidence reference - DAIB/18/016/155
[49] Evidence reference - DAIB/18/016/161

Army ES2 Live Flying Training[50]. The TRHA stated that '*All training flights for RA AV pilots will be conducted with a qualified WK AI instructing and a qualified FOO AV pilot providing additional safety oversight. The additional FOO AV pilot adds flexibility to the training flight and allows the AI to concentrate on training / assessing the 2 RA AV pilots.*' The role of all other crew members was laid down in the Thales UK Ltd Flight Operations Organisation Terms of Reference (People)[51]. The NSI team considered whether the number of individuals in the GCS and their roles contributed to the accident.

The GCS is a small working environment and interview evidence indicated that there were more people in the GCS than was typical. RA pilots are accustomed to training with up to 3 people in the GCS: P1, P2 and AI. The larger crew made the GCS feel cramped and increased the amount of chatter[52]. This fact may have impeded the ability of the FELA to obtain the information, from the pilots' screens, that his role required. On several occasions this information was verbally requested, increasing the amount of talking on the intercom. Both pilots commented that the amount of talking added to their workload[53]. They said it was difficult, at times, due to the quality of the audio in the headsets and the numbers of crew to distinguish voices and to know whether they were giving instructions or information.

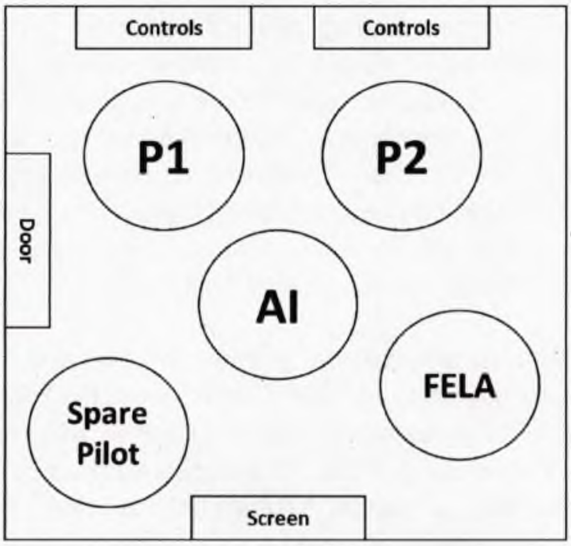


Figure 13: The crew layout within the GCS.

The spare pilot was only qualified as P2 and had not been current P1 since Jul 16. The NSI team considered this to detract from the role set out within the TRHA as he was only qualified to monitor P2. The benefit of his presence was likely outweighed by the negative factors of an extra person and possible confusion caused by his role in the GCS. The team also noted that the role of the spare pilot was not laid down in the Thales UK Ltd Flight Operations Organisation Terms of Reference (People) unlike all the other crew roles. The team recognised it could have been difficult for the pilots to differentiate who said a command during a high-pressure situation as 3 of the crew were sat behind them and only one of them was the aircraft commander. This is likely to have had a detrimental impact on the command and control within the GCS.

[50] Evidence reference - DAIB/18/016/114
[51] Evidence reference - DAIB/18/016/123
[52] Witness interviews
[53] Evidence reference - DAIB/18/016/109

The NSI team concluded that the combined effects of the manning level and the role of the spare pilot created a more difficult working environment than was necessary within the GCS and was a **contributory factor** in the accident.

Safety Recommendation – The Accountable Manger (Military Flying) should conduct a review of the current manning and command arrangements within the Ground Control Station to determine if they are fit for purpose.

3.8.3 Loss of SA

The AV landed long of the TD point just to the right of the centreline; it immediately deviated to the right during the landing roll. It failed to register ground contact during the ground touch window and auto-aborted for LSTO as it approached the edge of the RW. The AV continued to deviate as it powered up, rotating when both MLG wheels were on the grass. The AV climbed away to the righthand side of RW25 over the grass. These circumstances had not been encountered in the previous 749 WK ES2 flights. P1 manually aborted the landing 4 seconds after the AV had auto-aborted, 2 seconds later he pressed engine cut twice in quick succession. The AV was at approximately 40ft AGL with a WOT and a positive rate of climb at the time engine cut was pressed, an irreversible event. The NSI team sort to understand why P1 pressed the engine cut.

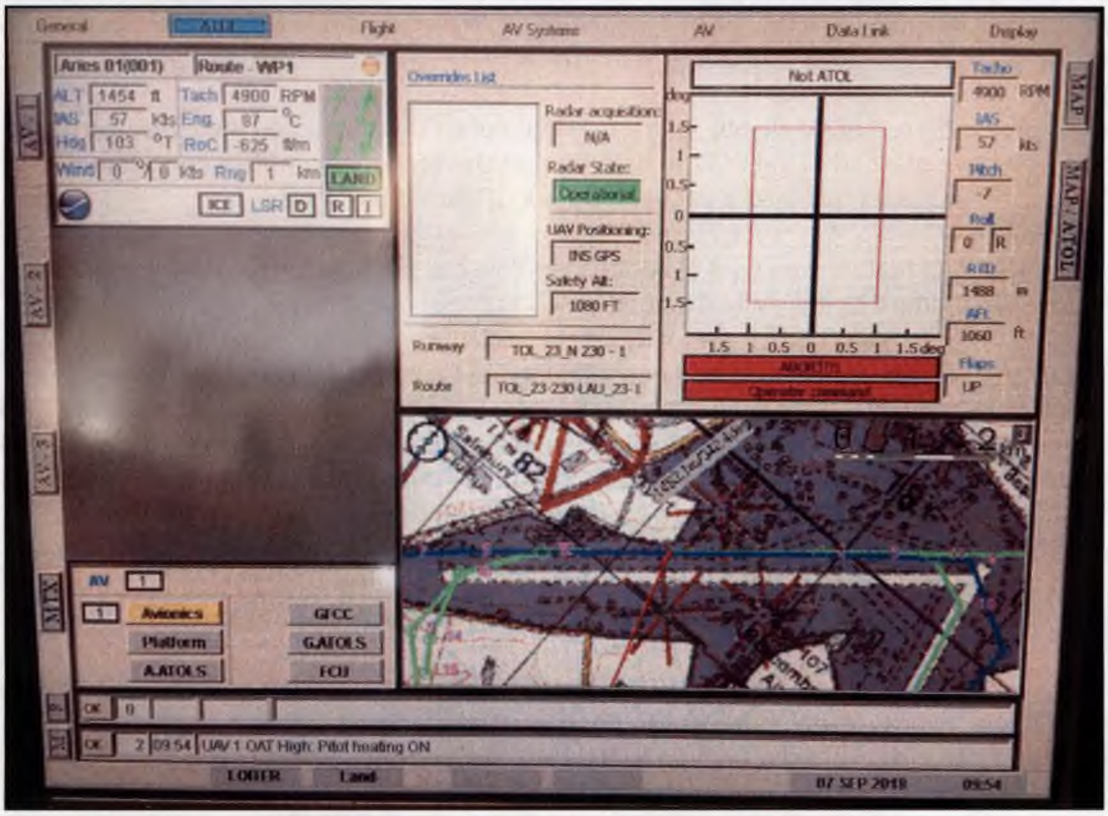


Figure 14: The red ATOLS abort caption on the AVDC.

Had no action been taken, the AV would have completed its automatic go-around from which it could have been commanded to conduct a further approach. At 30ft AGL on the approach the EOP had been stowed, rotating through approximately 180 degrees to protect the lenses; however, the FMV remained on and displayed in the GCS. The AV flight modes had been displayed throughout the incident on the AVDC and Client Displays within the GCS (Figure 8). The ATOLS abort caption on the AVDC (Figure 14) was illuminated red from LSTO and would have remained on until 50ft AGL during the go-around. However, there was no audio alert associated with this caption and it provided minimal visible indication. The NSI team considered the AVDC to be a poor user interface. A pilot's SA can be heavily affected by poor user interfaces so careful design is key[54]. The NSI team concluded that this minimal visible indication could have easily been missed in a situation of high workload and stress.

The NSI team considered the events inside the GCS sequentially:

- The landing initially progressed normally, P1 was reading out the changing flight modes as they appeared on his AVDC and P2 was monitoring the EOP derived FMV and WCA displayed on his client screen.

- P2 stowed the EOP at approximately 30ft AGL.

- Shortly after, P1 read out de-crab and P2 called that the AV was slightly left (incorrectly), which P1 repeated. De-crab was the last flight mode read out.

- ATC transmitted the AV's touchdown. Although correct, this transmission may have created an incorrect mental model that the AV had landed. The AV had in fact failed to detect ground contact.

- P2 corrected his call of AV slightly left by calling it right. This correction may have confused P1 who might have glanced at the FMV to gain SA and clarification. The team considered P2's error to be a slip, a perceptual failure caused by the EOP facing rearwards.

- ATC transmitted that AV was right of centreline. This call possibly further reinforcing the incorrect mental model that the AV had landed.

- P2 called AV on the grass. This had never happened in the previous 749 flights of ES2 and put the crew into a totally unique situation. The team considered this to be the moment when P1's attention was drawn away from the AVDC (his instrument scan) if it had not been earlier. The FMV showed a screen full of grass and the NSI team considered this to be highly compelling for the crew, far more so than the AVDC display (Figure 14). As the EOP was facing to the rear and located behind the MLG (Figure 6) even when the AV rotated and began to climb the FMV was displaying grass and appeared to be close to the ground. The monochromatic surface made it difficult to distinguish that the AV was climbing until it was well off the ground.

- The AI verbalised a single expletive. The team considered this to be a genuine exclamation of shock due to the unique situation. However, it provided no guidance to the students under instruction and had the potential to rapidly raise anxiety levels among the crew.

- P2 called the emergency code words for 'stop the launch or approach sequence' as laid down in the Thales FOB. The team considered this to be the appropriate response to the developing situation.

- P1 verbalised an expletive, abort, and engine cut. This was immediately followed by the spare pilot saying cut engine. Neither P1 nor P2 could identify which of the 2 pilots behind them

[54] Evidence reference - DAIB/18/016/193

had said cut engine[55]. The NSI team could not determine whether P1's call was a question or a statement of intent or if the spare pilot's words were interpreted as an answer or command. The NSI team considered that the influence of the FMV at this stage was total, providing a compelling picture that the AV had landed and departed the RW. The ATC touchdown call may have reinforced this belief. The most appropriate FRC drill, Yellow 27 Reverse (Figure 16), ATOL Emergency Drills states: '*If UA not maintaining centreline axis: Engine cut……..Command*'.

Had the AV detected the landing during the ground touch window the NLG steering would have been enabled, the engine RPM would have reduced to idle and the V-Tails deflected to a constant nose down attitude[56]. The AV would have been in free roll and no longer capable of getting airborne either automatically or manually.

The NSI team considered other influences on P1's decision to press engine cut. There was evidence from crew interviews of a misconception of the severity of Risk to Life (RtL) and Risk to Equipment (RtE) associated with the AV departing the RW. The layout of the ATOLS has limited equipment close to the RW (Figure 4). Level with the TD point is the GBU, and beyond the arrestor system is the GRU. No personnel are routinely near the ATOLS during a landing and access to the area is controlled by ATC.

System knowledge of the post ground contact sequence, especially 'engine to idle', was not well known and may have perpetuated the risk misconception. WK OCU grass landing trials[57] in Jul 13 demonstrated that the AV lost speed far faster on the grass than on a paved RW. This resulted in very low cable engagement speeds and in one case the AV stopped before the arrestor cable even with engine at idle. The risk misconception lead to a belief that the engine cut command had to be activated swiftly. This belief was further reinforced by the pre-landing checks requiring P1 to locate the ATOL abort key. It was taught that pilots should place their hand near the abort and engine cut buttons prior to landing. The nature of the sortie, assessment of P1 as a possible AV captain and the briefing by the AI that P1 should take ownership of the flight was assessed by the team. The team considered this may have contributed to P1 taking swift emergency action without seeking approval from the AI.

The NSI team concluded that due to the totally unique situation encountered, the highly influential effect of the FMV and the breakdown of the instrument scan P1 had lost SA of the AV flight mode before he pressed engine cut. Moreover, so had all the other members of the GCS crew as they were unable to give clear instructions to P1 to stop his action or provide an alternative option. The NSI team concluded that the loss of SA by the GCS crew was a **causal factor** and P1 pressing the engine cut was **the cause** of the accident.

Safety Recommendation – The Accountable Manger (Military Flying) should review the use of the Full Motion Video during the landing phase below 30ft Above Ground Level, to ensure that it does not distract the crew from monitoring the Air Vehicle Data Computer and Client Screen.

Safety Recommendation – The Accountable Manger (Military Flying) should

[55] Evidence reference - DAIB/18/016/109

[56] It is highly likely that had the AV detected ground contact it would have remained on the RW

[57] Evidence reference - DAIB/18/016/218

standardise pilot instrument scanning techniques to ensure that situational awareness is maintained during approach to landing.

Safety Recommendation – The Head of the Unmanned Air System Team should improve the prominence of the Ground Control Station's Warning Cautions and Advisories display in order to provide better awareness of the Air Vehicle's condition to the crew.

3.9 Training, Currency, Competencies, Qualifications, and Supervision

The NSI team investigated those areas of training, currency, competencies, qualifications, and supervision relevant to the individuals and activities being undertaken at the time of the accident.

3.9.1 Training

The NSI team considered the emergency training undertaken by the crew. WK crews are taught the principles of '2-man drills' (identify and confirm) and WAADFIR[58]. WAADRIR is a mnemonic for crews dealing with emergencies. 2-man drills (identify and confirm) is a process whereby one member identifies, indicates, and verbalises a control and awaits confirmation from the other before activating it. WAADFIR is as follows:

- Warn Crew.
- Acknowledge Alert.
- Achieve Safe Flight.
- Diagnose.
- FRCs.
- Intensions.
- Radios.

Throughout training crews are taught that at any time if the AI says 'my aircraft' the crew are to stop their actions and await direction. The NSI team found no evidence to suggest that during the accident sequence either the WAADFIR mnemonic, 2-man drills, or the command 'my aircraft' were used. Had they been, the pause generated may well have allowed time for the crew to realise the AV had auto aborted and was conducting a go-around.

RA crews have access to 2 different types of simulator, Emergency Procedure Trainer (EPT) and Full Task Trainer (FTT). There is one EPT and 3 FTTs all located at the WTF, Larkhill, all are non-deployable. The EPT has 61 fully modelled emergencies and the FTT has 10. There are 760 failures and alerts on the WK system. The EPT was originally designed as a test rig but was converted to become the EPT. Neither simulator can generate: LSTO, the AV departing the RW or an FMV feed. The simulators are available 0800-1700 Mon-Fri and for 2 weeks per year their availability can be extended to 0800-2000.

There were only 5 qualified RA instructors in the Army at the time of the accident. There were 4 instructors at the WTF, none of whom had flown the live AV since Oct 17, the remaining instructor was at Army Aviation Standards.

[58] With and additional A for Acknowledge Alert

During module 4 of the WK course, students have 10 simulator trips, 3 in the FTT and 7 in the EPT. These sorties were designed to be blended training, alternating between live flying and the simulator. However, the simulators single location, 180 miles from WWA, precluded the possibility of blended training during module 4 of the initial course or at any other time. Often there were delays between completing the simulator phase and starting the live flying. This resulted in suboptimal training for the students. If the WK simulators had been deployable, consideration may have been given to deploy one to WWA. The added benefit of a deployable simulator would be that if training returns to AIB or a similar location a simulator could accompany the deployment.

The hours of availability and the limited pool of instructors were considered an impediment to best practice. With more instructor's available better utilisation could be made of the simulators. However even with greater instructor numbers the NSI team's analysis indicated the current simulator hours available would be insufficient for a Regiments worth of pilots.

The inability to generate LSTO, the AV departing the RW and an FMV feed resulted in this accident being completely unreplicable in the simulator environment. This made it a unique scenario for the crew as they were without suitable training and knowledge on how to react.

The team concluded that with more capable and representative simulators, with a greater number of failures and alerts modelled, the likelihood of another unique situation arising would be reduced. Additionally, the necessity to fly live could be decreased. The NSI team concluded that the insufficient and ineffective simulators were a **contributory factor**. The NSI team concluded that the lack of application of the emergency mnemonic WAADFIR, 2-man drills and the 'my aircraft' command was a **contributory factor**.

Safety Recommendation – The Head of the Unmanned Air System Team should conduct a review of simulator capability to ensure that it accurately reflects the operation of the Air Vehicle.

Safety Recommendation – The Head of the Unmanned Air System Team should conduct a review of simulator availability to determine if simulator provision is fit for purpose.

Safety Recommendation – The Accountable Manger (Military Flying) should introduce measures in order to improve crew emergency response to unforeseen events.

3.9.2 Currency, Qualifications and Supervision

The NSI team considered the currency of the crew against the requirements of the Thales FOB detailed in Table 7. The duration of a currency earning flight was not specified within the FOB however flight content was stated as:

- Data checking and upload.

- Engine start.
- Take-off.
- Departure to operating area.
- Establish Wide Band Data Link track.
- Reversionary flight control.
- Recover from operating area.
- One approach.
- Land and shutdown.

Role	Flight Currency
P1	One flight within the previous 31 days flying as AV-P1
P2	One flight within the previous 60 days flying as AV-P2
AV Cdr	One flight within the previous 60 days as UAV Cdr
AI	No flight currency requirement, but annual check must be in date
FELA	No currency requirement

Table 7: Flight currency extract from Thales FOB.

The Thales FOB[59] stated that:

- Simulator currency is monthly but with no more than 45 days between simulator flights.
- If an AV pilot has not flown as P1 or P2 in the previous 6 months he must undertake a bespoke refresher flying under the instruction of a qualified AI.

The RA crew were not in possession of a Thales Certificate of Competence (CoC), issued by the Flight Operations Post Holder following satisfactory completion of Conversion to Role. For the purposes of the Captaincy Development Training they were considered as students and could only fly under AI supervision, therefore negating the necessity for refresher training. Prior to starting the Captaincy Development Training P1 and P2 had not flown the AV live for 4 months and 7 months respectively. P1 and P2 had flown 2hrs and 2.15hrs respectively at the end of May in the simulator (Table 8).

	Hrs Previous 30 days		Hrs Previous 6 months		Hrs Previous 12 months	
	Flying	**Simulator**	**Flying**	**Simulator**	**Flying**	**Simulator**
P1	4.50	2.00	10.30	11.55	15.25	27.50
P2	4.50	2.15	4.50	19.15	21.20	37.55
AI	5.55	2.00	7.10	9.30	19.20	13.30
Spare Pilot	12.30	1.35	25.35	9.30	62.25	17.45
AI Instruction	*17.35*	*3.15*	*20*	*9.55*	*42.30*	*31.50*

Table 8: Crew currency.

The AI was in possession of a CoC and a Central Flying School certificate to instruct. AI instructional hours did not count towards currency. The AI had conducted a P1/P2 currency regain on 3 May 18, had not flown during Apr, flew once in Mar to conduct a P1 currency regain, did not fly in Feb, and had a competence check in Jan. The AI's instructor competence check was not due until 7 Sep 18. The spare pilot was only qualified as P2 and had not been current P1 since Jul 16.

[59] Evidence reference - DAIB/18/016/161

The NSI team considered whether the crew's currencies were factors in the accident. The team noted that although the AI was qualified and current at the time of the accident he had struggled to maintain currency during the preceding period. His flying rate was low (Table 8) and his extended periods of non-flying were noted. The team believed it likely that the AI's flying rate would have had a detrimental effect on his competency.

By treating the RA crew as students, the necessity to conduct the mandatory refresher training was avoided. The team considered this less than optimal as the crew were being asked to act as aircraft commanders and make the necessary decisions without any recent live flying experience to draw upon. The team noted P1 and P2's simulator sorties in May but assessed this as unsuitable mitigation for their lack of live flying during the preceding months.

The team considered whether the supervision applied during the planning of the crew composition was a factor in the accident and if the possible implications of this crew configuration were foreseeable. The team concluded that it was not foreseeable and therefore supervision was **not a factor**.

The NSI team considered whether the crew's flying rates and currencies were a factor in the accident. The team concluded that the flying rates and currencies were a **contributory factor** in the accident.

Safety Recommendation – The Accountable Manger (Military Flying) should review the Ground Control Station crew currency requirement, for both synthetic and live flying, to ensure maintenance of an adequate level of competence and currency. An identical recommendation has been made and will be implemented and tracked as part of Service Inquiry Watchkeeper 043, paragraph 1.4.218.

3.10 Policy and Regulation

3.10.1 MAA-RA 2501 Contractor Flying Approval Organisation Scheme

For the Thales WK flying at WWA to fully comply with MAA RA 2501[60] and to be approved as a CFAOS organisation, they submitted a formal application, which was endorsed by the MAA. This included submitting a Contractor Flying Organisation Exposition[61] (CFOE), demonstrating that the WK ES2 would be operated in accordance with the limitations stated in the Military Permit To Fly (MPTF) or MFTP[62], and ensure that the MAA were granted appropriate access to determine initial and continued MAA-RA compliance.

Thales were initially approved as a CFAOS organisation[63] on 26 Aug 15 with an updated approval issued on 28 Sep 17, which was the extant version on 13 Jun 18. There was an appointed AM(MF) who had certified through a signed corporate commitment dated 08 Dec 17 that the submitted CFOE[64] and any associated manuals correctly defined the organisation's compliance with the MAA Regulatory Publications.

[60] Evidence reference - DAIB/18/016/145
[61] Evidence reference - DAIB/18/016/122
[62] Evidence reference - DAIB/18/016/110
[63] Evidence reference - DAIB/18/016/103&104
[64] Evidence reference - DAIB/18/016/122

The NSI team concluded that Thales was an MAA approved CFAOS organisation when WK050 crashed at WWA. The CFAOS compliancy requirement had been satisfied correctly and therefore was **not a factor** in the accident.

3.10.2 MAA-RA 1024 AM(MF)

MAA-RA 1024 states '*that the AM(MF) shall act on behalf of CFAOS organisations to actively manage air safety via an Air Safety Management System (ASMS) to ensure that RtL is at least tolerable and As Low As Reasonably Practical (ALARP)*'. The MAA's defined roles and responsibilities of the AM(MF) were stated in MAA-RA 1024[65] and these were further explained within the CFOE.

At the time of the accident, Thales had appropriately selected and appointed an AM(MF) in accordance with the MAA-RAs and this selection had been endorsed by the MAA through the CFAOS application. Based on the AM(MF)'s submitted CV within the CFOE, the NSI team concluded that his level of experience and obtained qualifications to carry out this role were appropriate. The appointed AM(MF) was **not a factor** in the accident.

3.10.3 MAA-RA 5880 MPTF

MAA-RA 5880 states '*a MPTF shall be required for an air system to be operated outside the flight conditions permitted by an extant RTS or where there is no RTS*'. MAA-RA 5202[66] was withdrawn by the MAA on 25 Aug 16[67], and RA 5880[68] was initially issued on this date. This change was part of a major review of the Design Modification Engineering (DME) RA 5000 Series, a significant part of which was to develop the new RA 5800 series and retitle DME as the Type Airworthiness Engineering (TAE) RA 5000 Series. To facilitate this transition, the MAA released regulatory notice MAA/RN/2016/08[69] detailing the transitional arrangements, which should have been completed by 31 Dec 17.

On the 13 Jun 18, there was no extant RTS for the WK ES2 build standard or an extant MPTF, however the Type Airworthiness Authority had authorised a legacy MFTP in accordance with MAA-RA 5202. Thales had not completed their DME TAE transition within the allotted MAA timeframe and it had still not been completed at the time of the accident.

The NSI team concluded, despite being obsolete the use of a MFTP to operate WK ES2 is considered **not to be a factor** in the accident, however the team **observed** that this was a contravention of extant MAA regulation and will need to be resolved at the earliest opportunity.

3.10.4 MAA-RA 1016 Continuous Airworthiness Responsibilities

MAA-RA 1016 Issue 2[70] requires registered air systems to be managed by a MAA approved Continuous Airworthiness Management Organisation (CAMO). The CAMO supports the Aviation Duty Holders and Chief Air Engineers for their aircraft type. At the time of the accident, for CFAOS organisations, the MAA-RA defined an Accountable Manager (Continuous Airworthiness) (AM(CAw)) as a Suitably Qualified and Experienced Person (SQEP) individual who had corporate

[65] Evidence reference - DAIB/18/016/141
[66] Evidence reference - DAIB/18/016/176
[67] Evidence reference - DAIB/18/016/163
[68] Evidence reference - DAIB/18/016/149
[69] Evidence reference - DAIB/18/016/163
[70] Evidence reference - DAIB/18/016/140

authority for ensuring that all continuing airworthiness management activities were financed and carried out in accordance with MAA-RA 1016 Issue 2. In accordance with MAA-RA 1016 Issue 2, details of the AM(CAw) should be listed in the CFOE and in the Continuous Airworthiness Management Exposition (CAME)[71].

At the time of the accident, the Thales UK Board of Directors had nominated a SQEP to act as the AM(CAw)[72]. The Thales Head of UAS had taken up this role and this was detailed in the CFOE, but no CAME[73] had been submitted to the MAA. Thales did have an established Continuing Airworthiness Post Holder (CAPH), listed in the CFOE, who was responsible for all continuous airworthiness activity and ensuring that the AVs were maintained in accordance with MAA-RA 4050.

The NSI team concluded that Thales had appointed an appropriate AM(CAw) and CAPH, therefore they were compliant with MAA-RA 1016 Issue 2 which was extant at the time of the accident. This requirement to appoint an AM(CAw) was **not as a factor** in the accident.

MAA-RA 4050[74] states that for a '*Class II or III Remote Piloted Air System, the DDH or AM(MF) shall ensure that the airworthiness of the air system is managed by an approved CAMO*'. The Thales FOO is supported by the CAPH, AM(CAw) and DA, which in accordance with MAA-RA 1016 Issue 2 allows them to operate without a CAMO for a period of 6 months. Trials flying for WK ES2 commenced in 2013[75] at WWA but Thales had no CAMO approval from the MAA in place at the time of the accident. MA-RAA 4943 defines the purpose of the CAME, mandating the requirement for Mil CAMOs to provide a CAME that sets forth the procedures, means and methods of the CAMO. Compliance with the contents of the CAME will assure that the organisation satisfies regulatory requirements.

The NSI team confirmed that at the time of the accident Thales had approached the MAA with their implementation plan to establish a CAMO. A Form 2 application for CAMO approval to the MAA was submitted in Mar 18 and in recognition of the application and agreed schedule to develop the CAMO, the MAA had issued a CAMO approval reference number (UK.MAA.CAMO.0062)[76]. However, the NSI team discovered that the issue of this reference number did not constitute any form of interim MAA approval.

Thales had applied to the MAA for a waiver against MAA-RA 1016 Issue 2 however this had not been granted by the MAA due to a lack of clarity and information supporting the CAMO application. The NSI team considered that whilst Thales did not have a MAA certified CAMO, they had fulfilled the requirement to appoint an AM(CAw) and CAPH, and their proposed strategy to develop a CAMO had achieved MAA approval. Despite this activity, at the time of the accident, ES2 WK was operated at WWA without an approved CAMO and therefore contravened MAA-RA 4943.

The NSI team concluded that the lack of a MAA registered CAME[77] is regarded by the NSI team as a missing part in Thales' airworthiness assurance and is considered as an **other factor**.

[71] Evidence reference - DAIB/18/016/206
[72] Evidence reference - DAIB/18/016/179
[73] Evidence reference - DAIB/18/016/177
[74] Evidence reference - DAIB/18/016/189
[75] Evidence reference - DAIB/18/016/214
[76] Evidence reference - DAIB/18/016/177
[77] Evidence reference - DAIB/18/016/190

Safety Recommendation – The Accountable Manager (Military Flying) should produce a Continuing Airworthiness Management Exposition for submission to the Military Aviation Authority to comply with the Military Aviation Authority – Regulatory Article 4943. An identical recommendation has been made and will be implemented and tracked as part of Service Inquiry Watchkeeper 043, paragraph 1.4.102.

3.10.5 Air Safety Management System

MAA-RA 1200[78] stated that '*All organisations directly or indirectly involved in defence aviation shall establish and maintain an effective ASMS.*' MAA-RA 1210[79] stated that '*As the risk owner, ODHs shall always remain accountable for RtL within their Area of Responsibility.*' A TRHA[80] for Army Watchkeeper ES2 Live Flying Training aimed to bridge the gap between the more generic risk register and the specific risks associated with a trial or phase of trials. The TRHA was written in the context of live flying training for RA AV Pilots who have completed WK conversion to type at the OCU build standard. The TRHA included additional measures to mitigate against an uncontrolled AV on the ground due to incorrect take-off and landing site data.

To demonstrate their compliance, Thales had an Air Safety Management Plan (ASMP)[81] issued under the authority of the WK ES2 AM(MF) and this was the mechanism by which their air safety policy, management accountability and responsibilities were articulated. Thales had a Flight Operations Risk Register (FORR)[82] containing a record of all operational hazards. Within the FORR, an uncontrolled AV on the ground had been assessed as a Top-Level Event with 9 different threats taken into consideration. However, the FORR and TRHA did not consider the possibility for an AV diverging from the RW when operating within its design parameters and environmental limits or the potential for this to be misconstrued by the crew as an uncontrolled divergence on the ground. In the FORR's assessment of the various threats that could result in an uncontrolled AV on the ground, the NSI team assessed that the document provided suitable risk mitigation in preventing fatalities, injury to 2nd and 3rd parties, and damage to the AV.

The NSI team concluded that the WK ES2 risk assessment could not reasonably have been expected to consider the potential associated risks when the AV was operating in a serviceable condition within its design parameters. The hazard risk analysis was **not a factor** in the accident.

3.10.6 WK Operator and Maintenance Documents

Under a CFAOS, WK ES2 had not entered service and was operated under a MFTP to support its trial period. The MFTP listed the maintenance and operating documents that the WK ES2 must be operated in accordance with and this was amplified in the CFOE. Of those listed in the MFTP and CFOE, the NSI team reviewed the following documents pertinent to the investigation:

3.10.6.1 WK ES2 IETP

The IETP is an electronic document that contains a variety of technical, safety and maintenance information to support the operation of the air system. The IETP is reviewed every 6 months and

78 Evidence reference - DAIB/18/016/142
79 Evidence reference - DAIB/18/016/196
80 Evidence reference - DAIB/18/016/114
81 Evidence reference - DAIB/18/016/118
82 Evidence reference - DAIB/18/016/ 124

its release is validated by the WK ES2 DA and UAST. It includes a functional description of the equipment, servicing and maintenance procedures, common operating and maintenance faults, an illustrated parts catalogue, and operating and handling routines. Version 2 of the ES2 WK IETP was issued on 1 May 18[83] and that version was extant at the time of the accident.

The RA WK aircrew at WWA highlighted the need to the NSI team for a document that provided a system overview without going into too much technical detail. They believed that the current IETP did not satisfy this requirement[84]. The instructors at the WTF believed their students at times, found it difficult to find a generic system description within the document and were more inclined to ask an instructor for clarification rather than consult the IETP. The NSI team concluded that the IETP did not contain a basic system overview for operators to use and subsequently their overall knowledge and understanding of the AV's functionality was sub-optimal.

When requested by the NSI team to locate a specific part of the WK ES2 air system within the IETP, a nominated experienced RA instructor struggled to navigate his way around the publication and was unable to complete the task. This suggested to the team that if an experienced WK instructor could not navigate his way around the electronic document then it was highly likely that other WK aircrew personnel would also find it difficult. The NSI team concluded that the IETP was difficult to use, challenging the WK operators when attempting to locate a specific part of the WK system. The IETP is an **other** factor in the accident.

Safety Recommendation – The Head of the Unmanned Air System Team should amend the content and structure of information in the Interactive Electronic Technical Publication to enable users to access more detailed information expediently. An identical recommendation has been made and will be implemented and tracked as part of Service Inquiry Watchkeeper 043, paragraph 1.4.151.

3.10.6.2 Aircrew Manual

The purpose of an aircrew manual is to provide military operators with comprehensive descriptive and management information relating to the type of air system they are operating. This should include a description of the systems and equipment, normal and emergency handling characteristics, procedures, and limitations, to enable the aircraft to be operated effectively and safely within its specified roles. This is defined in the Defence Aircrew Documentation Specification. At the time of the accident, the WK ES2 FOO did not have an aircrew manual. MAA-RA 1310(10) defined the aircrew manual as a publication that was considered to form part of the air system document set, however it also stated that not all air systems will utilise all of the listed Aircrew Publications[85].

To understand the benefits of a dedicated aircrew manual the NSI team interviewed the WK crew. During these interviews they were unable to provide accurate and comprehensive answers when questioned, for example, about the LSTO[86]. The aircrew also stated that they believed that an aircrew manual would assist in their development, aid crews in dealing with emergencies and

[83] Evidence reference - DAIB/18/016/199
[84] Evidence reference - DAIB/18/016/87&88
[85] Evidence reference - DAIB/18/016/194
[86] Evidence reference - DAIB/18/016/087&088

enhance their understanding of system interaction. The interviewed crew members also commented on the ineffectiveness of the IETP to bridge this gap.

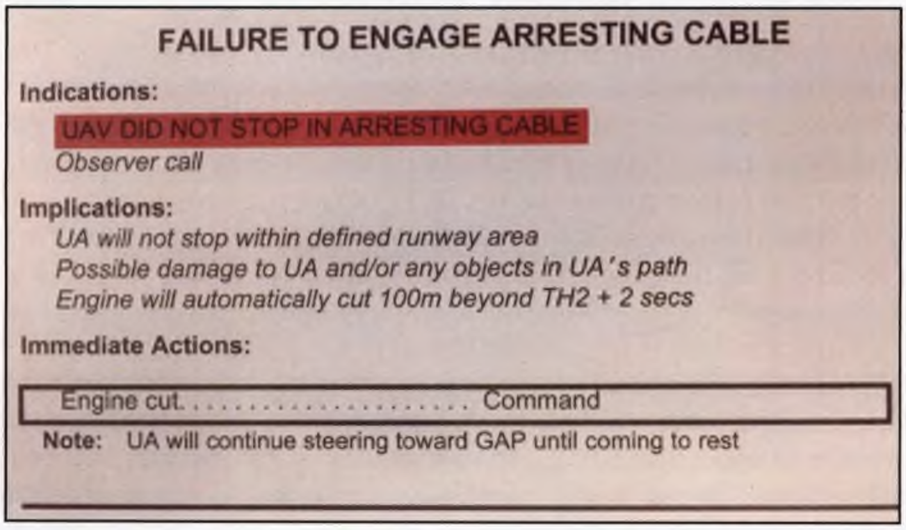
In conclusion, the NSI team believed that an aircrew manual would aid WK crews in dealing with emergencies by improving their basic system's knowledge. The absence of an aircrew manual was considered as a **contributory factor.**

Safety Recommendation – The Head of the Unmanned Air System Team should mandate the production of an Aircrew Manual to support the operation of the WK ES2. An identical recommendation has been made and will be implemented and tracked as part of Service Inquiry Watchkeeper 043, paragraph 1.4.143.

3.10.6.3 Flight Reference Cards

The control and issue of the WK ES2 FRCs was managed by the WTF Military Liaison Officer under guidance from JHC Army Aviation Standards. Upon receipt of the FRCs the FOO certified receipt and acceptance of controlling and managing them appropriately. The number of FRCs produced for WWA had been curtailed to 8 copies reflecting the pre-RTS flying activity under a CFAOS. FRC AP101B-7901-14A1, Advance Issue dated Aug 17 was the extant version of the issued FRCs. JHC Army Aviation Standards[87] confirmed that the FRCs issued were being managed and controlled in accordance with WWA policy; this was corroborated by the NSI team during their investigation.

The FRCs contained 17 Red Card Warnings, 30 Yellow Card Cautions and 15 Advisory Drills. The NSI team considered there to be 2 drills which could have relevance to this accident. Card Red 10 reverse, (Figure 15) Failure to Engage Arresting Cable and Card Yellow 27 reverse, (Figure 16) ATOL Emergency Drills. In both drills engine cut is an immediate action, highlighted in a black rectangle.



FAILURE TO ENGAGE ARRESTING CABLE

Indications:

UAV DID NOT STOP IN ARRESTING CABLE

Observer call

Implications:

UA will not stop within defined runway area

Possible damage to UA and/or any objects in UA's path

Engine will automatically cut 100m beyond TH2 + 2 secs

Immediate Actions:

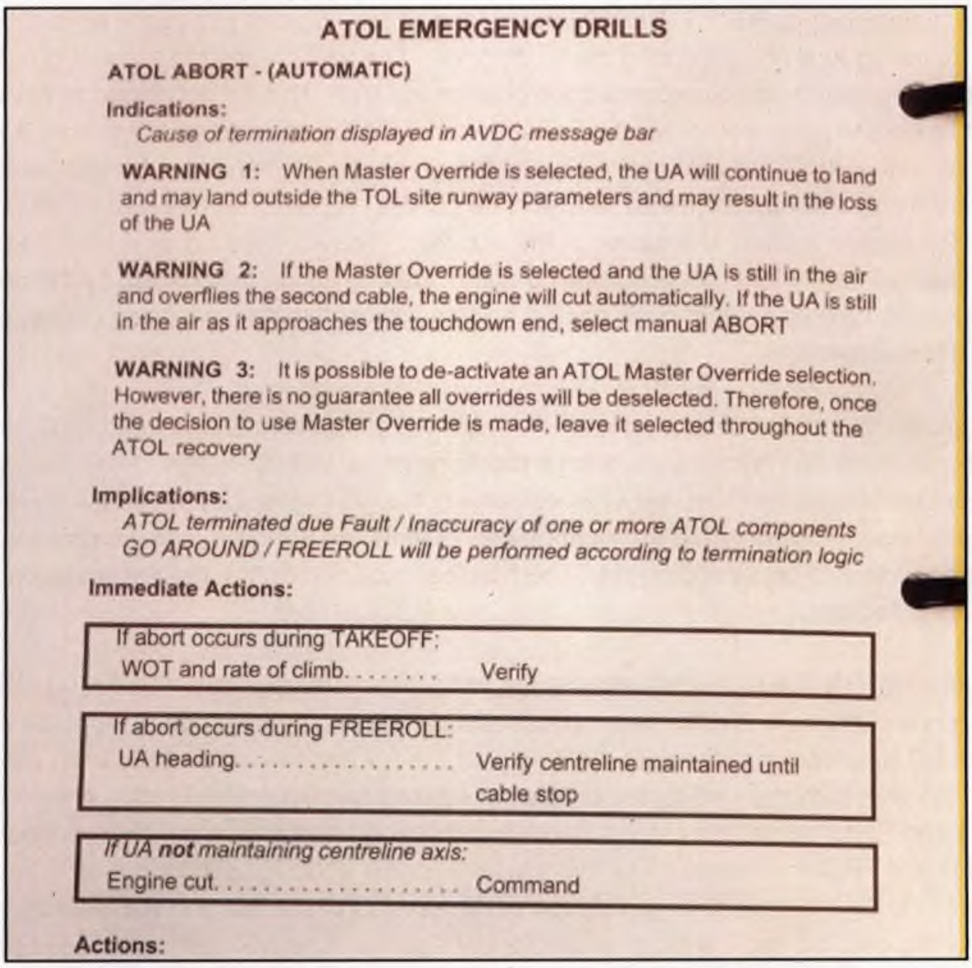
Engine cut. . . . . Command

Note: UA will continue steering toward GAP until coming to rest

Figure 15: FRC Warning Drills Red Card 10 Reverse.

87 Evidence reference - DAIB/18/016/171

The NSI team noted that the immediate actions in both cards lacked the requirement to ensure the AV was in free roll before pressing engine cut. The team considered the risk associated with selecting engine cut when airborne to be significantly higher than that associated with a delay to engine cut in case of RW excursion. The team felt engine cut should also be preceded with AV commander approval, and if the AV commander was P1 then P2 approval must be sort.



ATOL EMERGENCY DRILLS

ATOL ABORT - (AUTOMATIC)

Indications:

Cause of termination displayed in AVDC message bar

WARNING 1: When Master Override is selected, the UA will continue to land and may land outside the TOL site runway parameters and may result in the loss of the UA

WARNING 2: If the Master Override is selected and the UA is still in the air and overflies the second cable, the engine will cut automatically. If the UA is still in the air as it approaches the touchdown end, select manual ABORT

WARNING 3: It is possible to de-activate an ATOL Master Override selection. However, there is no guarantee all overrides will be deselected. Therefore, once the decision to use Master Override is made, leave it selected throughout the ATOL recovery

Implications:

ATOL terminated due Fault / Inaccuracy of one or more ATOL components
GO AROUND / FREEROLL will be performed according to termination logic

Immediate Actions:

If abort occurs during TAKEOFF:
WOT and rate of climb. . . . . Verify

If abort occurs during FREEROLL:
UA heading. . . . . Verify centreline maintained until cable stop

*If UA **not** maintaining centreline axis:*
Engine cut. Command

Actions:

Figure 16: FRC Caution Drills Yellow Card 27 Reverse.

The team considered the size and complexity of the FRCs and the working environment in which they were to be used, noting it was very different to that of an aircraft cockpit. The team questioned why a different more user-friendly approach to the WK FRCs had not been developed with the removal of the cockpit constraints. The NSI team considered the possibility of a pared down version of the FRCs with reference made to on-the-shelf files that would provide greater explanation and background.

The team concluded that the FRCs were missing vital drills preceding the engine cut which may have averted this accident and concluded that the FRCs were a **contributory factor**.

Safety Recommendation – The Accountable Manger (Military Flying) should review and improve the suitability of the Flight Reference Cards in assisting crews in dealing with emergencies.

4 Summary of Findings and Recommendations

4.1 Conclusion

After a normal approach to RW25, WK050 landed long of the TD point just to the right of the centreline; deviating further right during the landing roll. The VMSC failed to register ground contact and auto-aborted as it approached the edge of the RW. The AV continued to deviate to the right as its engine powered up, rotating when both MLG wheels were on the grass. As it climbed away to the righthand side of RW25 over the grass the P1 manually aborted the landing and when the AV was at approximately 40ft AGL he cut the engine. The NSI team concluded the pressing of the engine cut was **the cause** of the accident. The AV glided over a road and crashed into a tree, approximately 900m beyond the TD point. Had no action been taken by the crew the AV would have completed its automatic go-around from which it could have been commanded to conduct a further approach.

The NSI team found that the crosswind and RW slope were within limits and that LSTO and the disengagement of the BETA loop were normal functions of the VMSC design. However, when all 4 factors were combined they resulted in an extreme drift to the right. Consequently, despite being operated normally and within the flight envelope limits the AV went onto the grass which was the trigger for P1 to press engine cut. The NSI team concluded that the AV deviation was one of 2 **causal factors**.

The GCS crew lost SA due to the influence of the FMV, prior to engine cut. The FMV both distracted the crew from the AVDC, causing loss of awareness of what mode of flight the AV was in, and provided a compelling picture to the crew that the AV had landed and departed the RW. This loss of SA was compounded by the crew's emergency handling. Pre-landing checks and training required P1 to locate and place a hand near the abort and engine cut buttons prior to landing. This and FRC immediate action drills to 'engine cut' if the AV did not maintain centreline axis helped reinforce the crew's misconception of the severity of the RtL and RtE associated with the AV departing the RW and the requirement for swift action. The NSI team concluded that the loss of SA by the GCS crew was the second **causal factor**.

The NSI team discovered that the WK simulators were unable to replicate: LSTO, the AV departing the RW or FMV. The circumstances of the accident had not been encountered in the previous 749 WK flights making it a unique scenario for which the crew were without suitable training and knowledge on how to react.

To address the findings of this NSI, 13 Safety Recommendations have been made to: Head of the UAST, AM(MF) and Army Aviation Standards with the aim of reducing the likelihood of reoccurrence of this type of accident.

4.2 Findings

The DAIB NSI team identified the following findings, factors, and recommendations from the investigation into the loss of WK050 on 13 Jun 18 at WWA.

4.2.1 Causal Factors

The cause of the accident was:

- P1 pressing the AV's engine cut – **Para 3.8.3**.

This came about because of the influence of 2 causal factors:

- The AV deviating off the RW onto the grass – **Para 3.6.4**.
- Loss of SA by the GCS crew – **Para 3.8.3**.

4.2.2 Contributory Factors

Contributory factors include:

- The crosswind – **Para 3.6.1**.
- The runway slope – **Para 3.6.2**.
- The influence of the AV reaching Land Status Time Out – **Para 3.6.3**.
- Disengagement of the BETA loop – **Para 3.6.4**.
- GCS Manning – **Para 3.8.2**.
- Insufficient and ineffective simulators – **Para 3.9.1**.
- Lack of application of the emergency handling procedures – **Para 3.9.1**.
- Crew flying rate and currencies – **Para 3.9.2**.
- The lack of an aircrew manual – **Para 3.10.6.2**.
- FRCs – **Para 3.10.6.3**

4.2.3 Other Factors

- Wind Component Table was poor and could have been better – **Para 3.6.1**.
- Lack of an MAA registered CAME and approved CAMO – **Para 3.10.4**.
- The IETP – **Para 3.10.6.1**.

4.2.4 Observations

- Oil quantity figures in the WK050's F700 contradict each other and could cause confusion to the user – **Para 3.7.2**.

- In the GCS Log Book, the Register of Controlled Forms did not list all the inserted forms – **Para 3.7.8**.

- In the ATOLS Log Book, scheduled maintenance tasks were incorrectly forecasted – **Para 3.7.9**.

- In the GDT Log Book, the supplementary Flight Servicing Certificate had missing signatures – **Para 3.7.10**.

- In the PATE Log Book, missing entry for self-test – **Para 3.7.11**.

- Contravention of MAA/RN/2016/08 – **Para 3.10.3**.

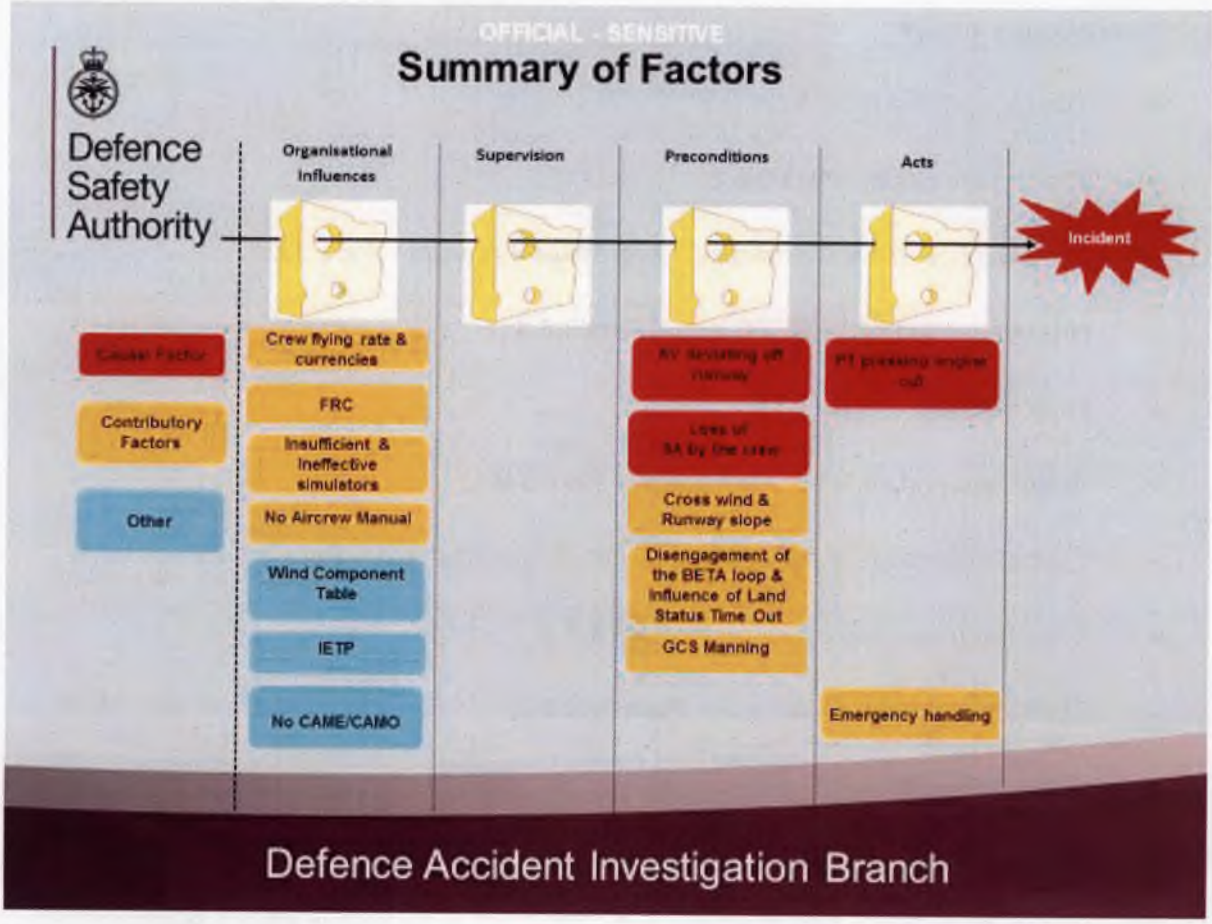


Figure 17: Summary of Factors

4.3 NSI Safety Recommendations

The following recommendations are made to prevent reoccurrence or enhance safety:

The Head UAST		Analysis Section
DAIB/18/016/01	The Head of the Unmanned Air System Team should review the current Air Vehicle crosswind limitations to determine whether they remain fit for purpose.	3.6.1

DAIB/18/016/02	The Head of the Unmanned Air System Team should review the current Air Vehicle runway slope limitations to determine whether they are fit for purpose.	3.6.2
DAIB/18/016/03	The Head of the Unmanned Air System Team should improve the Air Vehicle's landing accuracy, within its flight envelope, in order to ensure the effect of combining all landing factors does not lead to a runway excursion.	3.6.4
DAIB/18/016/04	The Head of the Unmanned Air System Team should improve the prominence of the Ground Control Station's Warning Cautions and Advisories display in order to provide better awareness of the Air Vehicle's condition to the crew.	3.8.3
DAIB/18/016/05	The Head of the Unmanned Air System Team should conduct a review of simulator capability to ensure that it accurately reflects the operation of the Air Vehicle.	3.9.1
DAIB/18/016/06	The Head of the Unmanned Air System Team should conduct a review of simulator availability to determine if simulator provision is fit for purpose.	3.9.1
The AM(MF)		
DAIB/18/016/07	The Accountable Manger (Military Flying) should consider relocating the Automatic Take-off & Landing System on runway 25 West Wales Airport to an area that has less slope.	3.6.2
DAIB/18/016/08	The Accountable Manger (Military Flying) should conduct a review of the current manning and command arrangements within the Ground Control Station to determine if they are fit for purpose.	3.8.1
DAIB/18/016/09	The Accountable Manger (Military Flying) should review the use of the Full Motion Video during the landing phase below 30ft Above Ground Level, to ensure that it does not distract the crew from monitoring the Air Vehicle Data Computer and Client Screen.	3.8.3
DAIB/18/016/10	The Accountable Manger (Military Flying) should standardise pilot instrument scanning techniques to ensure that situational awareness is maintained during approach to landing.	3.8.3
DAIB/18/016/11	The Accountable Manger (Military Flying) should introduce measures in order to improve crew emergency response to unforeseen events.	3.9.1
DAIB/18/016/12	The Accountable Manger (Military Flying) should review and improve the suitability of the Flight Reference Cards in assisting crews in dealing with emergencies.	3.10.6.3
The Army Aviation Standards		
DAIB/18/016/13	Army Aviation Standards should revise the Wind Component Table within the Flight Reference Cards to better reflect the Air Vehicle flight envelope.	3.6.1

5 Supporting Evidence

5.1 Annexes

Annex	Title	Provided by
A	Human Factors Report, WK050 WWA 13 Jun 18	RAFCAM
B	WK Human Factors SME Assessment of WK050 Incident 13/06/18	Thales
C	UTTC WK – PCM for Watchkeeper Flight 750	Thales
D	DAIB/18/016 WK050 Triage Report	DAIB
E	WK A/C Hazard Sheet (Jan 2013)	MAA
F	JARTS Report WK050 Flight 750 – 13 Jun 18	JARTS

5.2 References

All referenced documents are held on file by the DAIB.

Reference	Title	Provided by
A	Watchkeeper ES2 System Description. Thales Ref: 701-133985. Issue 3.	Thales
B	Watchkeeper Flying Order Book. Thales Ref: 701-511756, Issue 10.	Thales
C	Watchkeeper Flight Operations Organisation Training Policy & Syllabus. Thales Ref: 701-120802, Issue 2.	Thales
D	Watchkeeper Force Flying Order Book. Edition 2.1 Dated 9 Oct 17	WK Force
E	Thales UK Flight Operations Organisation Terms of Reference. Thales Ref: 701-122830, Issue 2.	Thales
F	Watchkeeper Flying Order Book. Thales Ref: 701-511756, Issue 11.	Thales

6 Distribution

6.1 Distribution:

External:

Action:

DES UAS-Hd
Thales AM(MF)
JHC-AAvnStds SO1

Information:

Navy:

Navy Fleet Commander EA
Navy Safety Director
Navy Safety Cntr-CESO RN

Army:

Army DCGS-Private Office-MA
Army LF-CESO
JHC Comd MA
WKF HQ-Comd
ArtyCen-ISTAR-CI
47RA-RHQ-CO

Air:

Air-DComOps-PSO
Air-SafetyCtre-CESO Mailbox

DES:

DES ISTAR-PDG-3-HD
DES ISTAR-BMT-SM
DES DAT Hd

DIO:

DIO CESO (Multiuser)
DIO SD Trg-HQ TrgSafety

Internal:

DSA:

DG-MA
HQ-COS
HQ-SO1 Service Inquiries
HQ-Legad
HQ-SecComms
MAA-D MA
MAA-ASIMS (MULTIUSER)

DAIB:

Hd
DepHd
Air-SO1
Air-Snr Eng