‘Act in Haste, Repent at Leisure’ An Overview of Operational Incidents Involving UAVs in Afghanistan

Chris. W. Johnson

Department of Computing Science, University of Glasgow, Scotland, UK, Johnson@dcs.gla.ac.uk

Keywords: UAV, UAS; accident analysis; military safety.

Abstract

Unmanned Airborne Vehicles (UAVs) provide significant operational benefits to many different military organisations. At present, however, most systems lack the reliability of conventional air support. This imposes considerable demands on the teams that must operate and maintain UAVs. It also creates considerable risks for the units that must retrieve these vehicles and for local populations during offensive and peace keeping operations. The lack of reliability further increases the workload on investigatory agencies, which must identify the causes of failure in increasingly complex airborne and ground-based systems. It is, therefore, important that we identify the lessons that can be learned from previous UAV mishaps. The following pages review the four most serious incidents involving Tactical UAVs (TUAVs) used by the Canadian Defence Forces during Operation ATHENA (August 2003-November 2005). The military demands of operations around Kabul created an urgent requirement for UAV support. However, the decision to rush the deployment of these systems contributed to technical and organisational risks that threatened safety and created the preconditions where mishaps were likely to occur.

1. Introduction

Operation ATHENA began in August 2003, when Canadian forces returned to support the International Stabilisation Force (ISAF) around Kabul, Afghanistan. Over five successive, six month rotations, troops conducted foot patrols and surveillance in cooperation with other ISAF units. Their aim was to provide a visible military presence, improve the intelligence and situation awareness of local organisations and, in turn, support the Afghan National Assembly. This deployment ended in November 2005 with the withdrawal of the Canadian squadron from ISAF. Their base at Camp Julien was closed and the focus of operations was transferred to the Kandahar region.

The demands placed on Canadian forces during ATHENA made it an ideal testing ground for the deployment of UAVs. There was a clear operational need to provide ground forces with tactical and operational information. The diverse and changing demands on ISAF units made it difficult to coordinate the deployment of conventional air resources. In August 2003, the Canadian defence minister, therefore, announced the acquisition of an Unmanned Airborne System (UAS) consisting of four UAVs, two control stations and support facilities; “In military terms, UAVs will decrease the risk to troops in Afghanistan. The security threat is a big concern for all Canadians, especially those serving in Kabul, and I want to ensure that they have the necessary equipment for the operation. As well, Canada will be fulfilling a commitment made in 2002, to NATO, to obtain a UAV capability by 2004”.

As we shall see, however, the initial enthusiasm for the deployment of UASs was soon tempered by the organisational, technical and environmental demands that ATHENA placed on the equipment and its crews. The first group of UAVs were purchased as an ‘unforecast operational requirement’. It has been claimed that the entire process from tender to deployment took only seventeen weeks in late 2003. The Canadian Forces Director of Flight Safety subsequently remarked ‘the high risks associated with deploying a new system directly into the extreme operational environment of Kabul, Afghanistan had been identified prior to the deployment. The overriding operational requirement for this capability in theatre resulted in the acceptance of this risk’ [1].

The Sperwer UAS chosen for the ATHENA operation was built by a French company and had five primary components: 1. the air vehicle based on a delta-wing design and a push propeller; 2. the Orientable Line-of-Site payload that provided the imagery; 3. the ground control station (GCS) that operated the UAV; 4. The communications links that linked data between the GCS, the UAV and outside agencies, and 5. the ground support elements including a catapult launching system, maintenance resources etc. Recovery involved the deployment of a parachute and a number of airbags. The maximum take-off weight of these UAVs was 330 kgs with a 45 kg payload. The Sperwer has a wing-span off just less than seven meters and a top speed of around 80 knots.

The Ground Control System has three working positions: the Mission Planner coordinates current and future operations and reports to outside agencies; the Air Vehicle Operator controls and monitors the vehicle; the Payload Operator performs similar functions for the imaging equipment. The Mission Planner and Air Vehicle Operator workstations are identical and provide additional redundancy in the case of failure. In addition to the three working positions originally supported by the Sperwer design, the ATHENA deployment also made use of an Air Vehicle Commander. This was, typically, an air force pilot or navigator. The commander did not have a control position but was responsible for monitoring the GCS screens of the Mission Planner and Air Vehicle Operator. This use of four-person rather than three-person crews was developed to meet concerns about Canadian military 'airworthiness requirements' during the deployment [2].

Line of sight communications is required between the GCS and the UAV. Once 'line of sight' is lost, the UAV returns to a pre-programmed flight sequence for up to 15 minutes. The intention is to provide an opportunity for ground teams to re-establish communications. However, if no further contact is made then the vehicle will initiate recovery through the deployment of the parachute.

2. First ATHENA Case Study: November 2003

The first major incident involving one of the Sperwer's led to category 'A' damage: the aircraft is destroyed, declared missing or sustains damage beyond economic repair'. This mishap occurred while the weapon system was still undergoing in-theatre certification against the tight deadlines imposed for deployment [1]. On the day of the accident, the in-flight section of the test had been completed without difficulty. The AVO issued commands to start recovery. During this process, the engine is shut down. This triggers the opening of the parachute door. This releases a compressed spring which deploys a drogue chute into the air stream. The force on the drogue extracts the main chute, which in turn triggers the inflation of air bags under the nose and each wing.

At the time of this incident, winds around Camp Julien were measured at 3m/sec. This was sufficient to create 'standing eddies' in the lee of the Queen's Castle hill which overlooked the landing area. These eddies caused an instantaneous climb of 12m in half a second as the UAV passed through them. The forces created by the climb exceeded the escape velocity of the drogue-spring mechanism. In consequence, the main chute did not deploy and the airbag sequence was not triggered. Instead, the UAV maintained a 7-degree nose-high pitch as the on-board computers waited for parachute deployment. Airspeed fell to the point where the UAV entered a glide mode as it passed over the Queens Palace and line of sight communications were lost.

Figure 1 uses Events and Causal Factors (ECF) charting to provide an overview of the immediate events leading to the first case study incident, these are denoted by rectangles and the parentheses denote page numbers where supporting evidence is provided in the official report [1]. This notation is one of several techniques that might have been used to support our work. The decision to use ECF is justified by the large amount of training material and previous case studies that have been developed to support the application of this accident analysis technique, since its inception within the US Department of Energy during the 1980s [3].

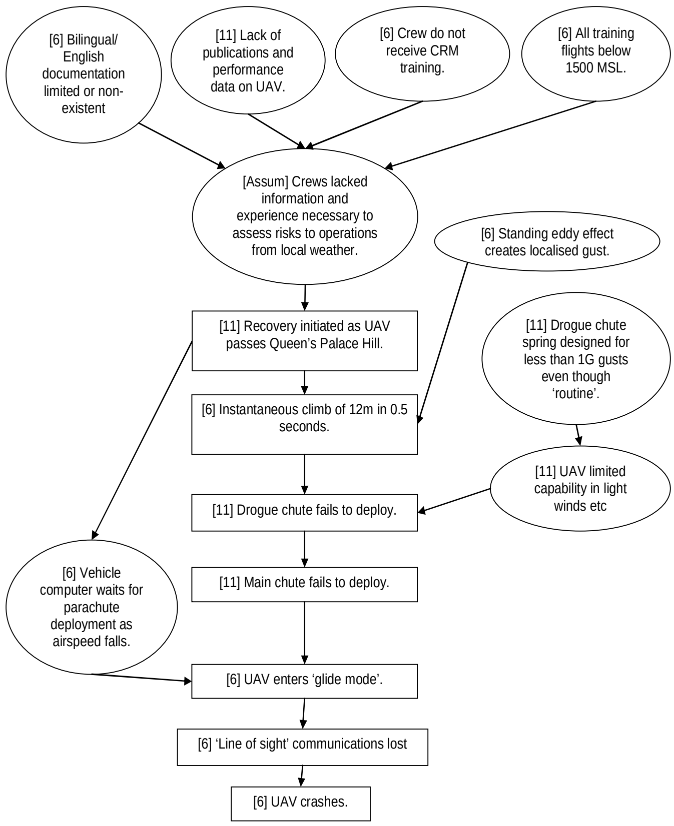

Figure 1 —November 2003 UAV Incident

As can be seen, the operators failed to consider that the release springs on the drogue chute would be insufficient to trigger the main parachute. This, in turn, led to the loss of control as the UAV passed beyond 'line of sight' in glide mode. A number of contributory factors, denoted by ellipses, combined to make these events more likely. The lack of bilingual reference material, of training flights over 1,500MSL and of Crew Resource Management techniques all combined to prevent the operators from accurately assessing the risks from local meteorological conditions.

In order to understand the reasons why these factors complicated the operation of the UAV, it is necessary to consider the longer term, organisational causes behind this mishap. Figure 2 extends the analysis of the previous ECF diagram to denote the mistaken assumption that UAV operations pose significantly less risks than conventional aviation and, consequently, require a much lower skill set. This assumption, in turn, explains the rapid procurement of a UAV capability to support the Canadian involvement in ISAF as well as the need to meet the NATO commitment to acquire UASs. The rapid acquisition created considerable time constraints that contributed to the operational risks of deployment. The weapons systems were deployed without comprehensive test and acceptance programmes. Similarly, the crews lacked the training and documentation identified as contributory factors in Figure 1.

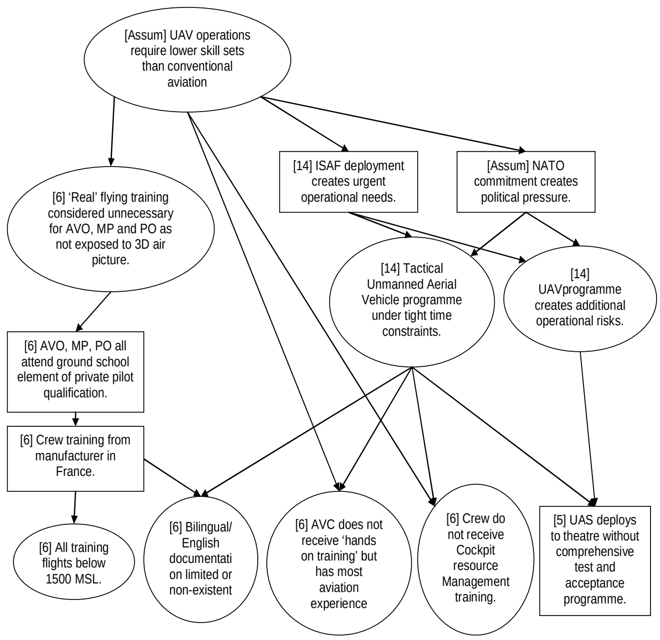

Figure 2 —Latent Factors in November 2003 Incident

4. Second ATHENA Case Study: January 2004

The second major incident also resulted in Category A damage [2]. The crew were conducting their second flight after a 61 day layoff. They were practicing a range of recovery procedures at successively lower altitudes. The aim was to initiate the procedure earlier and earlier in the approach to provide additional time to track the in-bound leg of the flight. On the fourth circuit, the UAV hit terrain while descending in a final turn onto the in-bound approach. Figure 3 again provides an overview of the events leading to the loss of the UAV. As can be seen, the lack of Standard Operating Procedures, a Standard Manoeuvre Manual, crew standard procedures, standard crew terminology etc exacerbated the crews' lack of experience in the operational environment. These factors combined to create the context in which the crew decided to further reduce the approach altitude on the fourth circuit. The lack of SOPs also explains why the Payload Operator had skewed their camera at 90 degrees to acquire the recovery area so that they had less opportunity to identify any potential collision with the mountain.

Figure 3 also shows that further opportunities to identify the potential collision were lost by the decision to set the automated altitude warning at 200 rather than 300m AGL. This reduced the number of spurious alarms that were generated during routine flights in this mountainous terrain. However, it also delayed the automated alarm so that the crew only received the warning a very short time before any potential collision. The large number of spurious alarms may also explain why the crew habitually ignored the aural warning associated with the altitude alarm.

The crews' apparent lack of situation awareness was exacerbated by the Airborne Vehicle Operator's decision to display engine monitoring information on their workstation rather than the altitude screen that might have provided additional cues to the potential danger from rising terrain. This decision can, in turn, be explained by the way in which the manufacturer's documentation stressed the need for the AVO to continually monitor engine parameters, for example to ensure correct fuel mixtures. However, this engine monitoring information was of limited value during this recovery stage of the flight.

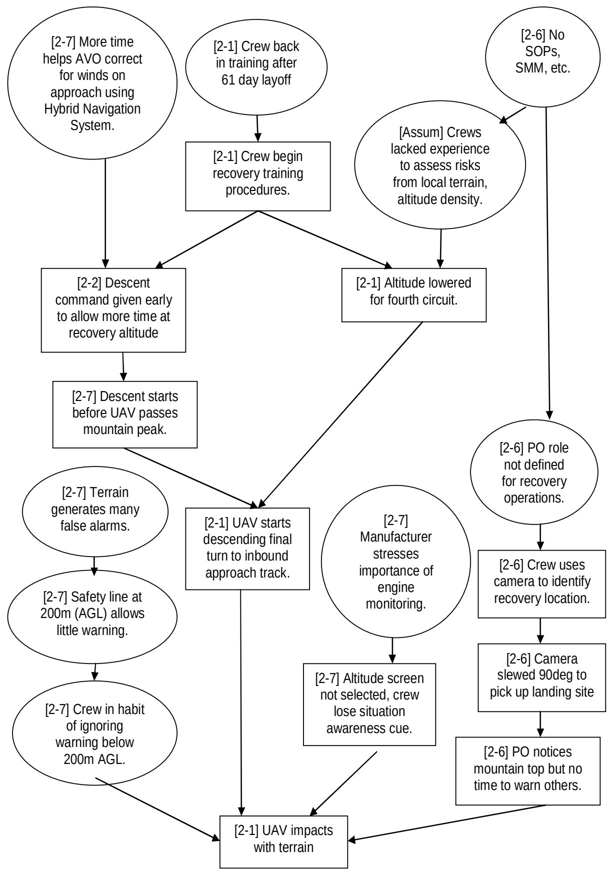

Figure 3 —January 2004 UAV Incident

Figure 4 considers the longer term causes of this second 'category A' accident. The tight operational deadlines associated with the Sperwer deployment prevented the development of specific SOPs and associated procedural support. The simulator time and other forms of training before operations focused on low-lying flat ground that was very different from the conditions encountered around Kabul. This may, in turn, explain why the crew failed to recognise the risks of a collision with terrain and why did not focus on the altitude screen during the fourth recovery circuit.

Figures 2 and 4 show that the operational requirements for ATHENA contributed to both incidents. Once in the field, it can be extremely difficult to address the many operational problems that are created by the rapid deployment of complex military systems. These problems are compounded by the lack of necessary doctrine, either in the form of Standard Operating Procedures for a particular region or in the form of supporting techniques such as Crew Resource Management.

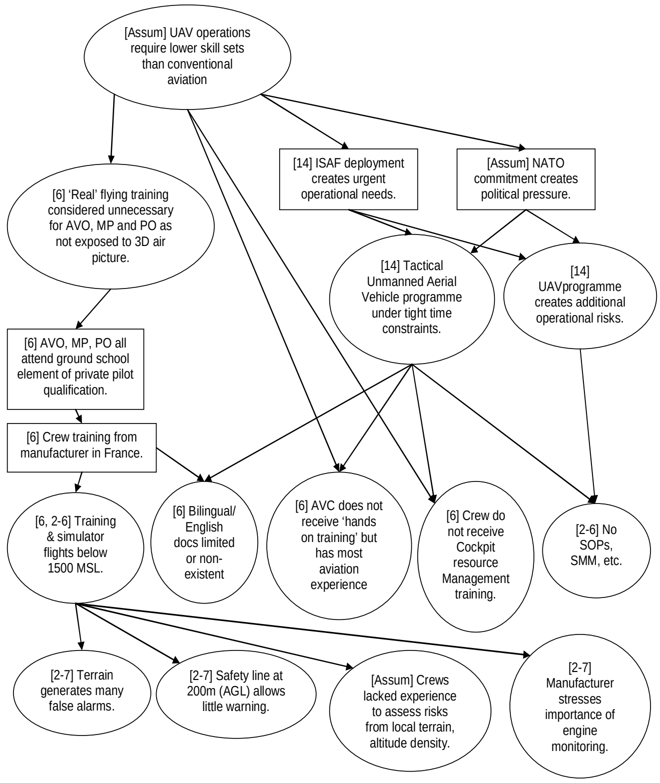

Figure 4 — Latent Factors in January 2004 Incident

5. Third ATHENA Case Study: March 2004

The third mishap led to a category 'B' incident; the aircraft sustained damage to major components requiring the vehicle to be shipped to a 3rd line repair facility but where the overall structural damage is assessed to be within economical repair [4]. This occurred during a training exercise to familiarise a new crew. Shortly after take-off the UAV entered a shallow descent into a populated suburb of Kabul. The AVC noticed that the UAV was producing insufficient thrust to sustain flight and so ordered an emergency recovery before the vehicle reached Kabul. However, the parachute deployed at too low an altitude for it to fully slow the vehicle before impact with the ground. Figure 5 illustrates the complex set of circumstances that lies behind this high-level summary of the incident. Insufficient power was produced by the UAV because the number 1 cylinder carburettor's fuel mixture was too rich. This, in turn, was due to a lean mixture preset screw being advanced beyond the recommended ¾ turn, probably during routine maintenance.

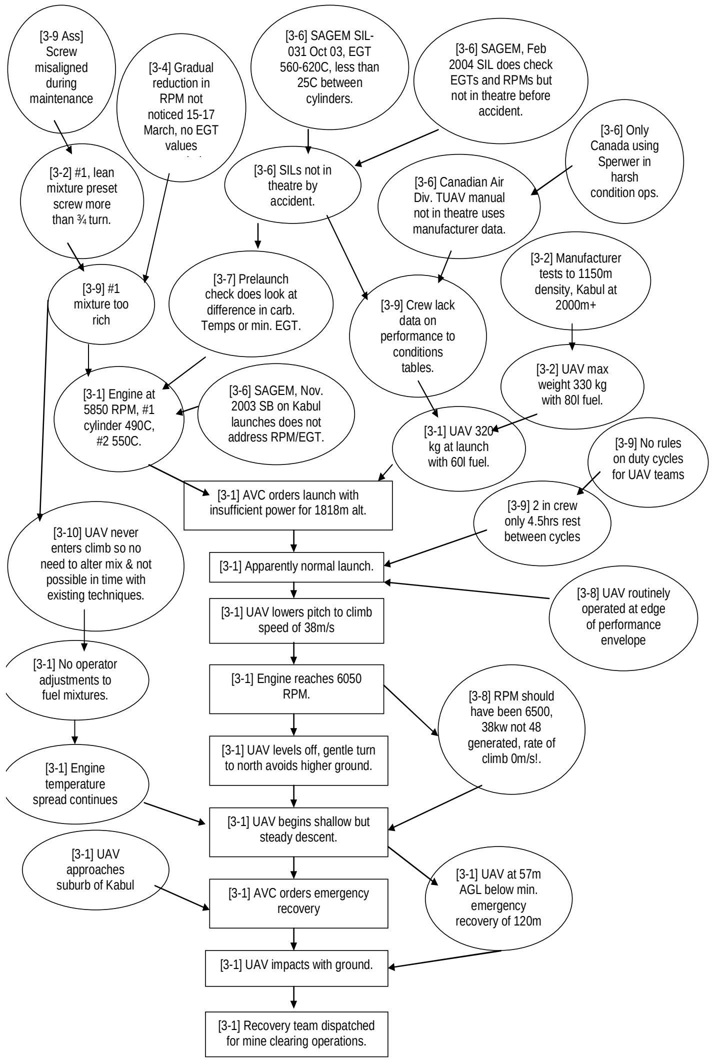

Figure 5 —March 2004 UAV Incident

The incorrect setting for the lean mixture preset led to a gradual fall in power during subsequent flights between 15th and 17th March. This reduction was not noticed by the operating and maintenance teams partly because they did not usually record differences in the Engine Gas Temperatures between the cylinders. Such differences can be used to diagnose potential problems in the engine settings. The manufacturer recommended that these values should be analysed in a Service Information Letter (SILs). However, this document had not been received in theatre by the time of the accident. The manufacturer's service bulletins that did describe launch profiles for the Kabul area did not specifically consider these engine management issues in detail.

The relatively harsh operating conditions meant that the UAV was routinely being launched on the edge of its performance profile but the crews lacked the necessary documentation to judge whether the UAS could meet the prevailing environmental conditions. Even if they had been provided with this data, the lack of doctrine governing sleep and duty rotations for TUAV crews may have prevented the effective use of guidance material; two of the crew had only had 4.5 hours between two duty periods. As can be seen on the left side of the ECF in Figure 5, the UAV never entered the climb phase that might have provided the crew with the opportunity to alter the fuel mixture. However, there was insufficient time for them to complete any adjustments in the short interval before the crash and it is uncertain whether the available techniques could have been used to resolve the fuel mixture problems before the collision.

As with the previous two incidents, most of the causal factors can be linked back to the decision to deploy the Sperwer TUAV at relatively short notice. The manufacturer had no time to work with the operational teams in the Kabul area. Hence there was a lack of appropriate performance data and associated operational doctrine. These problems were compounded by the difficulty of distributing the limited available information in theatre before the incident took place. Without the time necessary to prepare and disseminate these additional sources of information, it is little surprise that operational staff could not accurately assess the mission risks that were posed by their operating environment.

6. Fourth ATHENA Case Study: June 2004

The final incident reported during the Canadian UAS deployment in support of ISAF resulted in category ‘C’ damage; ‘the aircraft must be flown to a contractor or depot facility for repairs, repairs are carried out by a mobile repair party, or a major component has to be replaced’ [5]. During this incident, the crew lost communication with the UAV while it was some 15 kilometres from the recovery zone. Attempts to restore communication failed and the UAV went into an autonomous recovery mode, landing in a residential area.

Figure 6 maps out the events and contributory factors that led to the mishap. The bottom left of the diagram charts the events surrounding the initial loss of ‘line of sight’ control. The UAV descended to 3000m ASL and a mountain ridge interrupted signal transmission. Subsequent events record how communications were regained once the crew had implemented their emergency checklist and the vehicle had entered into autonomous recovery mode. However, the second interruption was not due to the loss of communications. The Sperwer was operating at 3,350m ASL, well above the required line of sight. Subsequent analysis revealed that there was a 55 amp spike immediately before a voltage drop in the on-board systems. This loss in voltage is similar to that experienced during an engine shut-down but the avionics seemed to indicate that power was still being generated by the UAV.

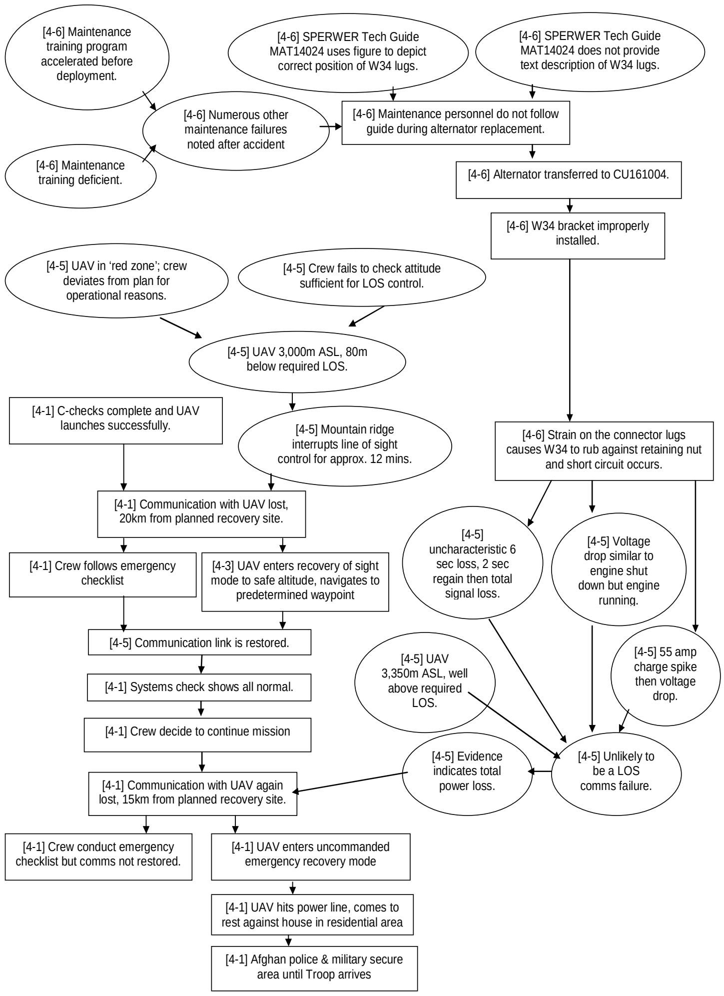

Figure 6 —June 2004 UAV Incident

The series of events and contributory factors at the top of Figure 6 illustrates the possible causes of the electrical anomalies that affected the UAV. The subsequent investigation found numerous faults in the vehicle, one of these included the improper installation of the bracket that helped to retain the W34 alternator cable. This, in turn, left the cable free to rub against a retaining nut and hence create the short circuit that would have interrupted electrical power to the UAV.

The manufacturer’s guidance material provides a detailed diagram to illustrate the ‘correct’ installation of these components. This documentation together with the evidence of other maintenance problems, suggested that there were ‘systemic problems’ in the field maintenance of TUAV’s during ATHENA. These problems can be traced back to the operational demands that were created by the decision to deploy the UAS’ within extremely tight timescales. There is evidence that maintenance training was 'rushed' when the UAV infrastructure was being exposed to unforgiving operational environments.

7. Conclusions

Unmanned Airborne Vehicles (UAVs) provide significant operational benefits to many different military organisations. At present, however, most systems lack the reliability of conventional air support. This imposes considerable demands on the teams that must operate and maintain UAVs. It also creates considerable risks for the units that must retrieve these vehicles and for local populations during offensive and peace keeping operations. The lack of reliability further increases the workload on investigatory agencies, which must identify the causes of failure in increasingly complex airborne and ground-based systems. It is, therefore, important that we identify the lessons that can be learned from previous UAV mishaps. This paper has reviewed the four most serious incidents involving Tactical UAVs (TUAVs) used by the Canadian Defence Forces during Operation ATHENA (August 2003-November 2005). The military demands of operations around Kabul created an urgent requirement for UAV support. However, the decision to rush the deployment of these systems contributed to technical and organisational risks that threatened safety and created the preconditions where mishaps were likely to occur.

The decision to rapidly deploy this complex technology created clear operational and political benefits. These benefits cannot be underestimated. However, the rapid deployment created immense logistic and technical challenges that placed both soldiers and the local population at some risk. Operational staff worked without standard operating procedures and inadequate training for the environment in which they were placed. The assumptions that governed the basic configuration of the engine was based on the conditions close to the manufacturers' facilities in France rather than those that held around Kabul. Similarly, training in Crew Resource Management and in 3-dimensional situation awareness were not offered to the initial rotations because there was a misconception that UAV operations were trivial compared to conventional aviation. With the benefit of hindsight, many of these programmes were extended to later UAS rotations.

Maintenance teams struggled to cope with the demands placed on their equipment by the hostile environments of their deployment. The loss of several of the Sperwer UAVs indicated deep rooted problems in the maintenance of these weapons systems. These failures were so widespread that they cannot simply be dismissed as the result of individual failures by negligent personnel or as a consequence of inadequate documentation for particular procedures.

It should not be surprising that the urgent deployment of complex systems is a cause of military mishaps. This paper mirrors a previous study that traced a recent rise in incidents in Iraq to the rapid deployment of night-vision equipment to units that had not been properly trained in their use, for example while driving at speed over broken terrain. This paper also builds on previous studies into the problems of military risk assessment; many of the problems during ATHENA arose because the crews failed to anticipate the hazards that arose from the operational deployment of UAVs [7]. Unless these deeper problems are addressed then it is likely that we will continue to acquire systems that endanger the lives of those who operate and support them while they are 'debugged' in the field.

References

[1] Canadian Forces Flight Safety Investigation Report (FSIR), CU161 Sperwer Unmanned Aerial Vehicle (UAV), File 1010-CU161003 (DFS 2-6), 17th November 2003, Camp Julien, Kabul, Afghanistan, 17th November 2005.

[2] Canadian Forces Flight Safety Investigation Report (FSIR), CU161 Sperwer Unmanned Aerial Vehicle (UAV), File 1010-CU161005 (DFS 2-4), January 2004, Camp Julien, Kabul, Afghanistan, 18th November 2005.

[3] C.W. Johnson, A Handbook of Accident and Incident Investigation techniques, Glasgow University Press, Glasgow, 2003.

[4] Canadian Forces Flight Safety Investigation Report (FSIR), CU161 Sperwer Unmanned Aerial Vehicle (UAV), File 1010-CU161002-1 (DFS 2-3), 20th March 2004, Camp Julien, Kabul, Afghanistan, 10th April 2007.

[5] Canadian Forces Flight Safety Investigation Report (FSIR), CU161 Sperwer Unmanned Aerial Vehicle (UAV), File 1010-CU161004 (DFS 2-3-2), 20th March 2004, Camp Julien, Kabul, Afghanistan, 20 February 2007.

[6] C.W. Johnson, The Operational Strengths and Weaknesses of Military Night Vision Equipment, Defence Management Journal - Yearbook 2004, 72-75, PCSA International, Newcastle Under Lyme, UK.

[7] C.W. Johnson, The Paradoxes of Military Risk Assessment, In A.G. Boyer and N.J. Gauthier, Proceedings of the 25th International Systems Safety Conference, Baltimore, USA, International Systems Safety Society, Unionville, VA, USA, 859-869, 0-9721385-7-9, 2007.