CANADIAN FORCES
FLIGHT SAFETY INVESTIGATION REPORT (FSIR)

FINAL REPORT

FILE NUMBER: 1010-CU161005 (DFS 2-4)
DATE OF REPORT: 18 November 2005

AIRCRAFT TYPE: CU161 SPERWER Unmanned Aerial Vehicle (UAV)
DATE/TIME: 201247Z January 2004
LOCATION: Camp JULIEN, Afghanistan
CATEGORY: "A" Category Accident

SYNOPSIS

The SPERWER Unmanned Aerial Vehicle (UAV) tail number CU161005 was being flown as a training mission to practice autopilot recoveries. This was the second flight for the vehicle's crew after a 61 day layoff. The crew were practicing vehicle recovery procedures that were initiated from counter clockwise circuits. As part of the recovery training procedure, altitude for the final approach track was being incrementally lowered on successive circuits.

Three complete circuits were flown to the overshoot without incident. On the fourth circuit, the UAV impacted the terrain while in a descending final turn to the inbound approach track.

The air vehicle (AV) suffered "A" category damage.

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1. FACTUAL INFORMATION

1.1 History of Flight

The accident occurred while conducting autopilot recovery training at the King's Palace recovery site, Camp JULIEN, Kabul. The general flight profile was counter-clockwise circuits, starting high and lowering incrementally with each circuit. The goal was to have the UAV established on the inbound approach as far back as possible to allow the UAV to adjust to the winds and allow the Air Vehicle Operator (AVO) to concentrate on tracking the recovery track.

Three circuits were flown uneventfully with successive lowering of the final track altitude. On the fourth circuit the descent command was given early to allow the AVO more time at recovery altitude to effectively track the inbound leg.

The UAV impacted high terrain in an un-cleared terrain while executing a descending final turn to the inbound approach track. The crash site was located at global positioning system (GPS) position N342559.8 and E690918.0.

1.2 Injuries to personnel

There were no injury or casualty.

1.3 Damage to Aircraft

The UAV suffered "A" category damage as a result of the crash. The vehicle's frame was fractured in several areas and there was severe damage to the wings, vertical stabilizers, nose and payload.

1.4 Collateral Damage

There was no collateral damage.

1.5 Personnel Information – Table 1

Position	**Air Vehicle Commander** (AVC)	**Mission Planner** (MP)	**Air Vehicle Operator** (AVO)	**Payload Operator** (PO)
Rank	Captain	Sergeant	Bombardier	Bombardier
Total flying Time	750 hrs	13.5 hrs	10.9 hrs	10.9
Flying hours on type	14.4 hrs	13.5 hrs	10.9 hrs	10.9
Flying hours last 30 days	5.3 hrs	5.3 hrs	5.3 hrs	5.3 hrs
Duty time last 24 hrs	8 hrs	8 hrs	8 hrs	8 hrs
Flying hours on day of occurrence	2.0 hrs	2.0 hrs	2.0 hrs	2.0 hrs

1.6 Aircraft Information

The SPERWER UAV is 3.52 meter (m) long and has a wingspan of 4.2 m. It uses a delta wing configuration and is built from a combination of glass fibre sandwich and carbon fibre materials. It is powered by a rear facing 2-stroke Rotax engine producing 64 horse power (HP) utilizing a 4 bladed pusher propeller. The front part of the UAV is dedicated to the Orientable Line-of-site Payload (OLSOP). The centre section holds the drogue and parachute system used during the recovery phase.

The maximum takeoff weight is 330 kilograms (Kgs) including 80 litres (L) of fuel and 45 Kgs of payload. The vehicle has a cruise speed of 105 knots (Kts) and has an endurance of 5 hours (hrs) under International Standard Atmospheric (ISA) conditions.

CU161005 had flown a total of 8.7 hrs (3 missions) prior to the accident.

1.7 Meteorological Information

Kabul Terminal Area Forecast

OAKB 200340Z 200606 VRB03KT 3000 BR BKN1000 BECMG 0709 5000 HZ TEMPO 0306 2000 SN BKN030 OVC080

OAKB 200940Z 201212 VRB05KT 9999 SCT100 BKN200 BECMG 1315 3000 BR TEMPO 1812 5000 RASN BKN030 OVC080 TEMPO 0306 1000 BR

METARS

211050Z 06004KT 9999 FEW050 BKN200 9/-4 Q1018 NOSIG

211150Z 32004KT 9999 BKN050 BKN200 8/-6 Q1017 NOSIG

211250Z 31003KT 9999 BKN050 BKN200 6/-4 Q1017 NOSIG

211350Z 0000KT 8000 SCT050 SCT080 BKN200 5/-3 Q1017

1.8 Aid to Navigation

Not applicable.

1.9 Communications

Due to a line of sight requirement between the vehicle and the ground control station (GCS), communication with and control of the air vehicle was maintained until just prior to impact.

1.10 Aerodrome Information

The King's Palace recovery area is located to the North of Camp JULIEN outside the camp perimeter.

1.11 Flight Recorders

The UAV was neither equipped with nor required to have any type of flight recording device. All mission and flight data is recorded by the GCS when the UAV is within line of sight parameters.

1.12 Wreckage and Impact Information

The UAV impacted the side of a hill in an un-cleared terrain while in a left bank, shallow angle, descending turn, at a speed of 52 meters per second (52m/s) (approximatively 105 kts). The UAV came to rest several meters from the crest of the hill. Parts and debris from the initial impact point to the final resting point were strewn down hill from the crash path. The hill incline exceeded 45 degrees. Most of the UAV wreckage remained within the immediate impact area. The debris field was limited to pieces of fuselage, electronics and airframe panels.

1.13 Medical

Not applicable.

1.14 Fire, Explosives Devices, and Munitions

Not applicable.

1.15 Survival Aspects

Not applicable.

1.15.1 Crash Survivability

Not applicable.

1.15.2 Life Support Equipment

Not applicable.

1.15.3 Emergency Transmitters

Not applicable.

1.16 Test and Research Activities

Not applicable.

1.17 Organisational and Management Information

A crew of four located in a GCS controls the air vehicle remotely via a communications link. The crew consisted of a Mission Planner (MP), an Air Vehicle Operator (AVO), a Payload Operator (PO) and an Air Vehicle Commander (AVC). The MP position was held by a senior non-commission member (NCM). His responsibilities included but are not limited to: updating the tactical situation, placing and updating overlays on the map background showing mission related information, displaying the UAV current position, defining warnings (i.e. airspace control restriction or a flight path restriction) and computing estimated time and fuel for missions. The AVO was responsible for but not limited to: controlling of the UAV while in flight, monitoring its control as it flies its pre-programmed mission, its re-routeing, if required, and supervising its flight path by means of alarms and warnings. The PO controlled the payload camera and performs duties assigned by the AVC. The AVO and the PO were Bombardiers / Corporals (Cpls). The AVC was an Air Force pilot/navigator who had overall responsibility for the mission. The AVC did not actually have a control position in the GCS. He monitored the screens of both the MP and AVO from behind these positions.

This crew construct used during Op Athena was inconsistent with the original design of the CU161 Sperwer. This UAV was designed to be operated by a crew of three and the Op Athena crew construct was implemented to meet CF operational airworthiness requirements.

2. ANALYSIS

2.1 General

The accident crew received their training from the Original Equipment Manufacturer (OEM), at its facilities in Monluçons, France. The training included simulator and hands on training, for the MP, AVO and PO but not the AVC. 1 Canadian Air Division (1 Cdn Air Div) deemed the hands on training of the AVC very necessary, however due to the late involvement of the division in the programme and the short notice given to have the AVC's qualified prior to deployment, there was insufficient time to conduct the required training. Therefore the AVC, the aircrew member of the flight crew, did not receive hands on simulator training, as his role was overall direction of the crew. He was not directly involved in the operation of the AV. However, the AVC of this particular crew felt that hands on experience was necessary and he spent time during his lunch hour to gain this experience.

The UAV training flights conducted by the flight crew in France were all for flights below 1500 feet above mean sea level (MSL). Additionally, simulation training was conducted in low-lying, flat terrain. The actual conditions faced by the same flight crew in Kabul were flights well in excess of 6000 feet MSL in mountainous terrain where the actual density altitude parameters were at the extreme edge of the UAV flight envelope. Therefore, the vehicle flight crews were not well prepared for the actual conditions in which they were expected to operate.

2.2 Standards

At the time of the accident, there was no set standard of operations between the different flight crews. There was no Standard Operating Procedures (SOP's), no Standard Manoeuvre Manual (SMM), no standard crew procedures and no standard crew terminology used. Each flight crew had adapted the OEM training to create unique, although similar, methods of operating the UAV.

2.3 UAV Operations

The PO operates the payload (sensing equipment) during the mission. His role was clearly defined for the mission but not for recovery operations. This particular flight crew used the PO and his video cameras as part of the recovery procedure. During the recovery phase the PO was using the camera to try and acquire the landing area. At the time of the accident the camera was slewed to the left approximately 90 degrees in anticipation of picking up the landing site. He was the first to notice that the terrain (mountain top) was above the flight path of the UAV. There was insufficient time to action his warning prior to ground impact. Had the camera been positioned straight ahead to provide a pilot's perspective to the AVO and the AVC, sufficient visual warning may have been provided to initiate alternative action and avoid the accident. This would have been an additional tool to enhance Situational Awareness (SA).

The AVO has a choice of screens that he can select to monitor the various parameters of flight and engine operation. The OEM training teaches the importance of monitoring the engine parameters so that the engine can be operated at peak efficiency and power. Failure to adjust the fuel mixture during the flight can result in either a seized engine, if the mixture is too lean, or fouled plugs if the mixture is too rich. During the operational portion of the flight, this is an extremely important screen to monitor. Hence, that screen was being monitored at the time of the occurrence. However, for the recovery phase, reduced power requirements and the short duration mean that monitoring the engine is less important. This is especially so if the mixture is set to full rich.

The Altitude screen provides a visual display of the projected flight path for a one-minute period forward of the UAV. It includes a line indicating the terrain below, which also extends for one-minute forward of the UAV. If there is an intersection of these lines within the one minute time frame depicted, it is literally indicating a point on the ground where the UAV will impact the ground. A UAV in descent or in rising terrain are situations that would show a ground impact unless avoidance measures were taken. Additionally, there is an altitude selectable line, which can be set to various altitudes above ground. This line can be used as a safety altitude to visually show a preset safety buffer. This line follows the contours of the terrain. Associated with this line is an audible tone, which is activated when the UAV is below the safety line. This tone can be manually cancelled or automatically ceases when the UAV’s flight is again above the safety line.

This safety line was set to 200 m above ground level (AGL) for the accident flight. Around the Kabul area, this altitude setting provided little time to react to a possible ground impact situation. The terrain gradient variation in this mountainous regions and the reduced climb performance of the UAV at high altitudes suggest that a safety line setting of 300 m AGL would have been more appropriate.

The UAV flight crew also had the habit of not responding to the warning tone when flight below the preset 200 m AGL sounded. The tone sounded so frequently during a flight that it became a nuisance and hence was disregarded. The altitude screen, which was not selected, would have provided an additional level of visual cue that flight into terrain was imminent.

A horizontal depiction of the area was provided to the flight crew on their screens. It was a map of the area, which included populated areas, man made and natural features, and contours of the terrain. On this map, it was possible to overlay the pre-planed mission profile including waypoints and the recovery track. This planned track profile was available to the crew as they practiced their recovery set-ups.

As the trip progressed, the crew elected to begin descent earlier. It was on the fourth approach that the UAV was flown into the terrain. On this approach, the UAV was still inside the planned path and therefore closer to the mountain peak and operating below the 200 m AGL safety height. The descent was initiated earlier than previous patterns to allow the AVO more time to correct for winds at approach altitude. The driving factor behind the decision to begin descent earlier was to allow proper time for Hybrid Navigation System (HNS) wind convergence. The objective of the crew was to recover in autonomous mode. However, this meant that the descent was initiated prior to passage of the mountain peak. In hindsight, flying the pre-planned route with safety altitudes and descent points would have minimized the risk of controlled flight into terrain.

2.4 Additional Flight Safety Concerns

There were a number of additional issues that, although not directly causal to the accident, are of significant concern.

The OEM ability to provide instruction in English was minimal. At the time of this accident most documentation was in French only. The publications have since been translated into English. In addition, training aids were not available and CF instructional technique was not used.

Human Performance in Military Aviation (HPMA), formerly known as Crew resource management (CRM), has the objective of enhancing the crew's ability to operate as a cohesive unit and therefore enhance operational effectiveness. Such training was not provided to the flight crews prior to their deployment at Kabul. Some of the crews did discuss HPMA/CRM as part of individual crew training but no formal program was in place. This type of training is mandatory for aircrew and ground crews in the Air Force and is provided through the 1 Canadian Air Division (1 Cdn Air Div) HPMA course. It is assessed that HPMA training would be very beneficial for UAV crews.

The UAV operation is conducted in three-dimensional airspace and requires a high degree of crew situational awareness (SA) and coordination. Prior to actual operations, the Land Force personnel were provided some training to familiarize them with the concept of “Air Picture”, i.e. movement in three dimensions over time. The AVO, MP and PO all attended Transport Canada (TC) private pilot ground school as part of their training. However, this training did not include actual flight time in an aircraft or flight simulation training that would have helped to develop this "Air Picture" concept. This type of training would have exposed the crews to the importance of maintaining SA and a valid air picture at all times.

Lack of flying standards during training meant that there was no validation of the training provided to the Canadian flight crews. For example, there was no recourse available if it was determined that proficiency was lacking. There was no defined standard for those who graduated from the course.

3. CONCLUSIONS

3.1 Findings

3.1.1 The AVC did not receive formal ‘hands on’ training to actually operate the UAV.

3.1.2 The simulation training provided by the OEM did not reflect the operational environmental parameters in Kabul.

3.1.3 The PO and his equipment were not being used effectively during the approach and recovery phase.

3.1.4 The AVO and MP had the engine parameters screen selected on their monitors.

3.1.5 The safety warnings were set to 200 m AGL, which did not provide sufficient time to take alternative action when considering the factors of the mountainous terrain and UAV climb rate.

3.1.6 The audible altitude alert was routinely disregarded.

3.1.7 The pre-planned, track overlays were not flown.

3.1.8 The OEM has a limited capability to provide instruction in English.

3.1.9 No aircrew HPMA/CRM training had been provided to the flight crews.

3.1.10 The AVO, MP and PO received hands on training at the OEM facilities. They also attended civilian Private Pilot Ground School as part of their training. However, this training did not give them all the skills necessary to operate in three-dimensional airspace.

3.1.11 The OEM did not validate the training given to the Canadian flight crews.

3.1.12 There were no SOPs and no SMM’s for the operation of the UAV.

3.2 Cause

The UAV flight crew flew the CU161005 into terrain because their attention was channelized on the approach and set up for landing. Their concentration on the approach resulted in their missing the visual and auditory warnings that occurred prior to the controlled flight into terrain.

3.3 Contributing factors

3.3.1 The UAV flight crews were not trained sufficiently to operate in three-dimensional airspace. They did not experience operating the TUAV in mountainous terrain prior to arrival in theatre.

3.3.2 The UAV flight crew lacked HPMA Training.

4. SAFETY ACTION

4.1 Safety Action Taken

4.1.1 Following this occurrence, the Unit Standards Officer has developed SOPs to ensure better crew co-ordination takes place during the approach and landing phases as well as any time the vehicle is operated in the low level environment.

4.1.2 The altitude alert /data page was displayed and monitored by at least one member of the crew during the approach phase.

4.1.3 The minimum altitude at which the low altitude (aural) warning should be set to 300 m AGL in the Kabul area of operations (mountainous region).

4.1.4 All altitude audible and / or visual alerts will be actioned, by a member of the crew.

4.1.5 The TUAV capability was re-assigned to 1 Cdn Air Division following the return of the Sperwer to Canada from Op Athena. As a result, the drafting of documentation for training and currency standards are being developed and evaluated to ensure training is complete and validated. This will include the creation of qualifications standards, training plans and proficiency requirements. Furthermore, a UAV Standards Evaluation Team (UAVSET) will be created to ensure the standards function is provided for all CF UAV operations.

4.1.6 The crew construct and crew duties were recently changed to a three person flight crew system. Current Sperwer operations utilize a CF pilot (MOSID – 00183) as mission commander (formally the MP) who will be trained and certified to operate the TUAV and who holds the responsibility of “Pilot-in-Command”.

4.1.7 UAV flight crew will be provided additional operational level training prior to being deployed for operations.

4.1.8 The assigned training agency now provides instructors with better capability in English.

4.1.9 1 Wing has been tasked with establishing HPMA training for TUAV flight crews.

4.1.10 A complete review of the procedures and tactics utilized by the Sperwer TUAV is being conducted by 1 Cdn Air Div to include additional Equipment Testing and Evaluation (ET&E) and Operational Testing and Evaluation (OT&E).

In addition, the Aircraft Operating Instructions (AOI's), SMM's and SOP's are being amended and will be evaluated as part of this OT&E process.

4.2 Safety Action Recommended

4.2.1 All members of the flight crew should receive simulator training at the controls of the UAV.

4.2.2 The simulator training should reflect the actual environmental conditions that are expected in the operational theatre.

4.2.3 The assigned training agency should validate the training given to the flight crews.

4.2.4 The assigned training agency should develop a standard to which students can be compared.

4.2.5 The recovery overlays should be flown as planned.

5. DFS Comments

The CU161 Sperwer was deployed on Op Athena as a result of an urgent operational requirement to field this system very quickly. It was understood that this approach entailed significant risks and that the challenges faced by flight crews who operated the Sperwer would be significant. These personnel had to operate a new and unfamiliar technology, in an operational theatre of armed conflict. The mountainous terrain present in the area of operations and the density altitude parameters that were found on most days, compounded these challenges. Moreover, the need to generate this capability quickly resulted in a lack of time to identify the training and proficiency requirements necessary for the crews to safely operate the equipment.

A number of improvements have been made to the TUAV program in the recent past. A great number of lessons have been learned from Op Athena and crews have gained more experience with this system. In addition, the current TUAV force generation capability utilizes an approach to training, qualifications and proficiency that is more conductive to safe and efficient Sperwer operations. The improved accident and attrition statistics demonstrated by the recent Sperwer flying campaigns are reassuring.

//ORIGINAL SIGN BY//

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Annex A: Photographs

Photo 1: Final resting place

Photo 2: Nose/payload damage

Photo 3: Vertical Stabilizers

Photo 4: Right wing damage

Annex B: Abbreviations

1 Cdn Air Div	1 Canadian Air Division
AA	Aeronautics Act
AGL	Above Ground Level
AIA	Airworthiness Investigative Authority
AOI’s	Aircraft Operating Instructions
AVC	Air Vehicle Commander
AVO	Air Vehicle Operator
CF	Canadian Forces
CRM	Crew Resource Management
DFS	Director of Flight Safety
ET&E	Equipment Testing and Evaluation
FSIR	Flight Safety Investigation Report
ISA	International Standard Atmospheric
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
GCS	Ground Control Station
GPS	Global Positioning System
HNS	Hybrid Navigational System
HP	Horse Power
HPMA	Human Performance in Military Aviation
Hrs	Hours
HSI	Horizontal Situation Indicator
Kg	Kilogram
Kts	Knots
L	Litre
M	Meter
MND	Minister of National Defence
MOS	Military Occupational Structure
M/S	Meter per Second
MSL	Mean Sea Level
MP	Mission Planner
NCM	Non-Commissioned Member
NDHQ	National Defence Headquarters
OEM	Original Equipment Manufacturer
OLSOP	Orientable Line-of-Sight Payload
OT&E	Operational Testing and Evaluation
PO	Payload Operator
SA	Situational Awareness
SMM	Standard Manoeuvre Manual
SOPs	Standard Operating Procedures
TUAV	Tactical Unmanned Aerial Vehicle
UAV	Unmanned Aerial Vehicles
UAVSET	Unmanned Aerial Vehicles Standards and Evaluation Team