CANADIAN FORCES
FLIGHT SAFETY INVESTIGATION (FSI) REPORT

FILE NUMBER:	1010-CT155202
DATE OF REPORT:	12 June 2007
AIRCRAFT TYPE:	CT155 - Hawk
DATE/TIME:	142230Z (1630L) May 04
LOCATION:	15 Wing Moose Jaw, SK
CATEGORY:	“A” Category Accident

SYNOPSIS

The mission was part of a “conversion to type” for a post-wings student pilot (SP) in preparation for the Phase IV Fighter Lead-In Course in Cold Lake. The crew of two had completed the navigation portion of the trip and were conducting “closed patterns” at 15 Wing Moose Jaw. The Instructor Pilot (IP) had just taken over aircraft control, with the aircraft accelerating and positioned near the departure end of Runway 29 Right. At about 70 feet above ground level (AGL), 239 Knots indicated airspeed (KIAS) with the landing gear up and combat flaps selected, a bird struck the left side of the aircraft. This was immediately followed by several engine warnings and very high engine temperature indications. The IP initiated a climb to trade airspeed for altitude, confirmed that engine temperature remained high and told the student to prepare to abandon the aircraft. As the aircraft descended through 3000 feet mean sea level (MSL), (about 1000 feet AGL), and after confirming the student was ready, the IP initiated ejection. Both pilots survived the ejection, but the IP was seriously injured and the SP received minor injuries in the ejection. The aircraft crashed in a farmer’s field, about one mile north of 15 Wing, and was destroyed.

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1. FACTUAL INFORMATION

1.1 History of the Flight

The CT155 Hawk is an advanced jet fighter trainer manufactured by British Aerospace Systems (BAE). The Mk 115 variant of this aircraft is used by NATO Flying Training in Canada (NFTC). All aircraft are fitted with Martin-Baker Mk BA10LH ejection seats in a dual tandem pilot configuration. The Instructor Pilot (IP) sits in the rear position with nearly the same instrumentation and aircraft control configuration as the front seat.

Bombardier Aerospace, Military Aviation Training (BMAT) is the Prime Contractor for a consortium of civilian companies that provide all Hawk aircraft, their maintenance, simulators, shelters and many airfield functions to 15 Wing.

The mission was a navigation trip, as part of a conversion syllabus, designed to familiarize the student with the NFTC Hawk variant, prior to commencing the Phase IV Fighter Lead-In Course in Cold Lake, Alberta. The navigation portion of the trip had been completed without event and the crew was conducting some proficiency flying at 15 Wing, Moose Jaw. The IP had just taken control from the SP after conducting a touch and go. He confirmed that the SP had completed the aircraft “clean up”, selected combat flaps, and just as the aircraft approached the departure end of Runway 29R a bird was observed streaking past left of the nose. Both crewmembers heard a “thump” and felt vibrations associated with a change in engine pitch. This was followed immediately by several audio and engine caption warnings (Engine Overstress or Temperature Too High (T6NL) and Engine Control Amplifier (ECA)) and very high engine temperature indications (660^{o}C). Aircraft parameters at that time were approximately 70 feet AGL and 239 KIAS.

The IP initiated a climb to trade airspeed for altitude, confirmed that engine temperature remained high, reduced throttle to idle and told the SP to “prepare to abandon the aircraft”. Initially the “zoom” was wings level to about 3000 feet MSL (1000 feet AGL) at which point a turn to the right was initiated. The peak of the climb was nearly 3700’ MSL but airspeed was reduced to 123 KIAS and the aircraft began a slight judder as it approached the stall. The bank angle was reduced, the nose eased through the horizon and as the aircraft descended through 3000’ MSL (1000 AGL) the IP advised Moose Jaw tower of his intention to eject. After confirming the SP was ready, the IP ordered and initiated ejection. Aircraft parameters were: 2690’ MSL (690 AGL), 142 KIAS, 2000 feet per minute (FPM) descent, wings level and the pitch attitude was 14 degrees down.

Both occupants cleared the aircraft and descended under full parachutes for about 30 seconds prior to landing. The IP was seriously injured in the sequence and the SP received minor injuries. The aircraft was destroyed when it crashed in a farmer’s field about 7 seconds after the ejection, one mile north of 15 Wing.

1.2 Injuries to Personnel

	Crew	Passengers	Other
Fatalities	0	Nil	Nil
Serious	1	Nil	Nil
Minor	1	Nil	Nil

1.3 Damage to Aircraft

The aircraft, CT155202, sustained “A” category damage due to ground impact and post-crash fire. There were three main pieces in the wreckage trail: the wing section, the fuselage (with engine) section and the tail plane (with exhaust pipe) section. Damage to the aircraft was extensive and very little was salvageable.

1.4 Collateral Damage

The aircraft crashed in a cultivated field on privately owned farmland just north of 15 Wing. The ejection seats and canopy fragments also landed in the same field. The fuselage and wing sections had post-crash fires that were contained by the 15 Wing fire fighters. The burned areas associated with these fires were about 100 meters by 30 meters. The aircraft crashed with approximately 1050 pounds of fuel on board. The Salvage team removed about 250 pounds (35 gallons) of fuel from the wing section before it was transported to 15 Wing.

The Wing (Bombardier) Environmental Officer was present throughout the recovery process. A plan for establishing a baseline from surrounding soil and testing the level of contamination in affected areas was initiated. Environment Saskatchewan was consulted throughout this process and the field was cleaned and monitored in accordance with an environmental remediation plan over the following months.

1.5 Personnel Information

	IP	**Student Pilot**
Rank	Capt	Pilot Officer
Currency/Category valid	A2 - Yes	Yes
Medical Category valid	Yes	Yes
Total flying time	3639	328
Flying hours on type	834.4	96.5
Flying hours last 30 days	39.8	8.0
Duty hours last 24 hours	10	10
Flying hours on day of Occurrence	2.7	2.3

1.6 Aircraft Information

The aircraft records were checked with no anomalies noted. The aircraft had 1835 airframe hours and the engine 471.6 hours. The following items were removed from the aircraft by DFS for further investigation by Quality Engineering Test Establishment (QETE):

a. Cockpit Warning Panels Fwd – S/N 240 Rear – S/N 243
b. 8 and 10 O'clock TGT (T6 probes)
c. Air conditioning Pressure Regulating and Shut-Off Valve S/N 1091
d. Inducer Shut-Off Valve S/N 1021
e. Engine S/N 7823
f. Angle of Attack Vane S/N EY1155
g. Fuel Control Unit S/N B593
h. Engine Cam Box P/N AX56720 Not Serialized
i. DAU components:
    (1) Power Supply Unit P/N 1590-PSU-1000
    (2) 960MC/1553B/2MB SRAM P/N 1590-CPU-0000
    (3) Memory Controller Module P/N 1590-MEM-1000
    (4) Power Filter Unit P/N 1590-PSF-1000
    (5) PCB Assembly, Motherboard P/N 1590-MBD-0000
    (6) PCB Assembly, Engine Interface Unit P/N 1590-HWK-1322
    (7) Data Transfer Cartridge assembly S/N 0162

1.7 Meteorological Information

Post-accident meteorological record examination revealed there were no AIRMETS, SIGMETS or WX WARNINGS issued for the area.

METAR

CYMJ 142000Z 30009G18KT 15SM SCT067TCU BKN092 11/M03 A3007 RMK TCU3AC4 SLP202

CYMJ 142100Z 31010G15KT 15SM BKN065TCU BKN100 11/M03 A3005 RMK TCU6AC2 SLP196

CYMJ 142200Z 29014G20KT 15SM BKN074TCU BKN095 11/M04 A3004 RMK TCU6AC1 SLP192

TAF

CYMJ 141730Z 141801 30010KT P6SM BKN060 BECMG 2224 24010KT

Actual weather observation taken after accident:

142229Z 28013KT M79 BKN 91 BKN 15SM 12/M4 A3004 TCU7AC2

1.8 Aids to Navigation

No navigation facilities were involved in the aircraft emergency sequence.

1.9 Communications

The crew was using standard tower radio frequencies during the emergency and transmitted the ejection intent to the tower before the ejection was initiated. The CT155 has no aircraft mounted bailout tone and relies exclusively on the functioning of the Personal Locator Beacon (PLB). There were two other CT155 aircraft in the Moose Jaw circuit at the time of the ejection. Neither crew heard any emergency tones. The Moose Jaw Instrument Flight Rules Control Centre (IFRCC) did receive a distress tone momentarily. The SAR satellites (monitored by RCC/CMCC - Trenton) did not receive the emergency PLB broadcast on 406 MHz until 150040Z May 04, over two hours after the accident at 2230Z.

1.10 Aerodrome/Alighting Area Information

15 Wing Moose Jaw is primarily a training base for NFTC. It is also the home base of the Canadian Forces Air Demonstration Squadron, “The Snowbirds”. The airport has tower, ground and arrival/departure controllers, a WD1 (CFFC) weather office, full Crash and Fire Response (CFR) response and Automated Terminal Information System (ATIS).

15 Wing primarily has two parallel runways, 29/11 Left and Right. The main runway is 29R/11L (the inner) (8320x150 asphalt), which is used for departures and arrivals and as the primary runway for the CT155 (Hawk). The outer runway, 29L/11R (7280x150 asphalt), is the primary runway for the CT156 (Harvard II) during visual meteorological conditions (VMC). The inner runway (29R/11L) is serviced by PAR, VORTAC, ILS, NDB and PAPI, whereas the outer is used for VMC operations. A third runway, 21/03 (3400x100 asphalt) is used primarily as a taxiway or for emergency situations. At the time of the accident all services were operational.

1.11 Flight Recorders

This aircraft type is not equipped with a Cockpit Voice Recorder/Flight Data Recorder (CVR/FDR) but does have “Head-Up Display” (HUD) videotape, a Data Acquisition Unit (DAU) and a Data Transfer Cartridge (DTC).

The HUD tape is used for post-mission replay. It was recovered in its case, packaged and shipped to the National Research Council (NRC) Flight Recorder Playback Centre (FRPC). The FRPC recovered, rewound and reformatted this tape. The tape contained the full mission with only minor degradation in the last 30 seconds of flight. The tape contained voice and aircraft parameters, including footage of the bird, and the ejection sequence, including the ground impact.

The HUD recording includes voice tracks from the crew and radios. After an accident, this voice track is treated as a CVR with its associated privileges, in accordance with the Canadian Transportation Accident Investigation and Safety Board (CTAISB) Act and the A-GA-135-001/AA-001, Flight Safety for the Canadian Forces.

The DAU records some aircraft and engine parameters, but this device is not crashworthy. The DAU was destroyed in the impact sequence.

The DTC is a portable solid-state memory unit that carries mission planning information from the ground flight-planning computer to the aircraft. During flight, the DTC stores various navigation and weapons parameters plus information on system failures. The unit is not crashworthy and if the aircraft crashes, the crash switches will cause the DTC to be erased. NFTC representatives are currently looking into the steps required to remove this function on the Hawk fleet. Information could then potentially be available to an accident investigation where the DTC is not damaged.

1.12 Wreckage and Impact Information

A large impact scar, extending about 12 meters by 5 meters and up to ½ meter deep, was noted at the point of impact. This impact scar contained most of the centre line fuel tank and consequently the majority of composite materials of the aircraft were located in this area. This scar indicated where the aircraft hit the ground left wing first and in a nose low attitude. The HUD video confirmed the aircraft orientation on ground impact to be 22 degrees of left bank and minus 14 degrees of pitch.

The extent of the full wreckage trail, without the ejection seats, Aviation Life Support Equipment (ALSE) and canopy fragments was about 200 metres long by 40 meters wide. There were three main pieces in the trail: the wing section, the fuselage (with engine) section and the tail plane (with exhaust pipe) section. The fuselage and wing sections suffered post-impact fires, but the 15 Wing fire fighters contained these fires.

Some of the equipment fitted to the CT155 consisted of hazardous materials. The 15 Wing salvage team had prepared a list of these hazards and presented the list of potential problems to the investigation team at the initial in-briefing. This list and actual disposition included:

Beta Lights - Hazard - Radioactive gas, if fractured, 30 minutes required to clear radioactive gas. Disposition - Front and rear seat lights were complete, found still in the aircraft and recovered by salvage team for proper disposal – 18 May 04.

Centreline Fuel Tank - Hazard - Carbon Fibre (burnt Carbon fibres create toxic substances). Disposition – fragmented on impact but not burned, the majority of the remnants were collected by salvage team – 18 May 04.

Inflated Tires - Hazard – Potential catastrophic explosive failure during recovery operations. Disposition – all three tires deflated by salvage team - 18 May 04.

Inflated Oleos - Hazard – Potential catastrophic failure of inflated vessel. Disposition – nose oleo destroyed on impact and main oleos deflated by salvage team - 18 May 04.

Emergency Flap and Gear Squibs - Hazard – Explosive charge as the initiator for blow down gas release. Disposition – found by salvage team and disposed of in proper container - 18 May 04.

Charged Accumulators - Hazard – Potential failure of inflated vessel. Disposition – confirmed deflated by salvage team - 18 May 04.

O2 Bottles -Hazard – Potential failure of bottle (pressurized vessel) and/or feeding fire – Disposition - confirmed depleted by salvage team - 18 May 2004.

Batteries - Hazard – Corrosive materials. Disposition – both batteries totally destroyed and plates scattered throughout crash site. Pieces recovered by salvage team – 17-18 May 04.

Seat and canopy charges - Hazard – Explosive charges. Disposition - All charges made safe by Aerospace Engineering Test Establishment (AETE) Escape Systems team 17 May 04.

Initial engine examination on scene revealed that there appeared to be soft foreign object damage (FOD) on the front stage of the Low Speed Compressor and the damage likely occurred at high RPM. Removal of the high-pressure bleed valves in the field yielded more materials consistent with bird remains.

Both ejection seats with survival packs, many pieces of shattered canopy, both parachutes and all ALSE were located within 400 meters up track of the wreckage trail.

1.13 Medical

The IP was seriously injured during the ejection sequence and the SP received minor injuries. Both crew were transported to the Moose Jaw Union Hospital via a 15 Wing Ambulance as part of the Emergency Response. Later, the IP was transferred by local Emergency Medical Services (EMS) to the Royal University Hospital in Saskatoon. The SP was released a few hours after the accident.

Toxicology samples were taken from the crew in accordance with orders by the responding Flight Surgeon at the local hospital and sent to the Armed Forces Institute of Pathology (AFIP) in Washington for analysis. Toxicology results were negative.

1.14 Fire, Explosives Devices, and Munitions

1.14.1 Fire

There was a post-impact fire involving the aircraft and the surrounding farmer's field with most of the fire in proximity to the wing and fuselage sections. The burned areas were confined to about 100X30 meters because the 15 Wing emergency fire response was effective in containing the fire. Both major firefighting vehicles (x2) and hand held extinguishers were used in these efforts. The fuel for the post-impact fire was mostly the aviation fuel from the wing section.

1.14.2 Explosive Devices (Ejection Seats and Components)

Other than the Emergency Flap and Gear Squibs used to initiate emergency selection of these aircraft systems, all explosive devices in this aircraft are associated with the Ejection System. The 15 Wing Immediate Response team from NFTC reported to the accident site and was directed by the On Scene Controller Emergency Response (OSCER) to "safety and de-arm the seats." The technician installed pins in the two seats and removed breaches from the explosive devices. AETE Escape System specialists finished de-arming the seats three days after the accident.

The CT155 canopy system uses Miniature Detonating Cord (MDC) to fracture the canopy during ejection. MDC is a lead sheathed detonating cord covered with a hard plastic layer, which is designed to fracture the canopy into small pieces prior to the seats being ejected from the aircraft. However, this system splatters very small but sharp particles throughout the cockpit area when it detonates, along with molten metal from the lead sheathed cord.

The MDC detonation in this ejection sequence resulted in burns to all exposed skin on the crew, and the particulates penetrated flying suits and undergarments, resulting in minor burns in some clothed areas.

1.14.3 Munitions

No munitions were carried on this aircraft.

1.15 Survival Aspects

1.15.1 Ejection Sequence

Early in the emergency, the IP ordered the SP student to prepare to abandon the aircraft. As the aircraft was descending through approximately 800 AGL, the command "Eject, eject, eject" was given and the IP initiated the ejection from the rear seat. Both pilots were ejected from the aircraft and landed up track of the aircraft impact in a farmer's field.

The HUD tape analysis indicated about 49 seconds elapsed from bird impact to ejection initiation. Ejection parameters were 2690 MSL (about 690' AGL), 142 KIAS, 2000 FPM down, wings level, and minus 14 degrees pitch.

1.15.2 Emergency Response

The crash was about 1 mile from the airfield and the aircraft was seen to go down from the tower; therefore, there was no national SAR aircraft response. Fire- fighters, ambulance and Ground Search and Rescue (GSAR) were dispatched immediately and were on the scene about 3 to 4 minutes after the pilots' parachutes hit the ground. There was no civilian EMS response, because there was no notification of local authorities through the 911 emergency telephone service.

A pilot flying in the area heard the ejection call over the radio, but did not hear an ejection tone. After arriving at the crash site, the 15 Wing fire department began to secure the area with the help of the Military Police (MP) while the Med Techs from the ambulance began to assess and treat the mishap pilots. OSCER arrived on scene at about the same time. A GSAR team member and a local Registered Nurse (the spouse of a Canadian Forces (CF) member on base) assisted the Med Techs in their assessment and initial stabilization of the injured pilots. The Wing Surgeon arrived on scene about five to ten minutes later, due to emergency team transport problems.

The IP was secured to a spinal board and subsequently loaded into the ambulance. Because he was in significant pain due to injuries, pain medication was given intravenously. Both crewmembers were transported to the Moose Jaw Union Hospital emergency department. Without a 911 call, the local hospital was not prepared to receive the injured crewmembers. Further, there was minor confusion about the location of the emergency entrance, since there had been a recent change that was not communicated to the 15 Wing Emergency Response Team.

The required specialist surgeon was not available in Moose Jaw, and no beds were available in Regina, so the IP was transferred to Saskatoon.

1.16 Test and Research Activities

The engine was removed from the crash site and transported to 15 Wing for further examination. "Black light" was used to attempt to highlight protein from bird remains on various parts of the engine. Speckles were found on the intake spinner, and portions of the 1st stage compressor blades. Further, the T6 probe showed signs of protein, but initially the angle of attack (AOA) probe did not. Of note, synthetic oil highlighted very well using this light and was present in this area.

The igniter plugs (x2) were removed for borescope viewing. Because this portion of the engine lacked rotational ability a very limited viewing area was available to this inspection. Small hard FOD damage to the high-pressure (HP) compressor was noted. Other external components were stripped from the engine for examination.

The 7 o'clock TGT (T6 probe) was removed from the aircraft and given to Rolls Royce for shipment to the UK to aid in their attempt to determine the bird species.

The engine was shipped to QETE labs for teardown and analysis. The engine Original Equipment Manufacturer (OEM), Rolls Royce, had both a field service representative (FSR) available for consultation and an OEM representative was present at the teardown.

1.17 Organizational and Management Information

1.17.1 Wildlife Issues

SERCO, one of the companies in the NFTC consortium, is responsible for the wildlife control for the 15 Wing airfield. When ATC assess that birds are a hazard, a wildlife control officer is called to scare the birds away using distress call recordings or other bird scare tactics.

1.18 Useful or Effective Investigation Techniques

The investigation team used "black light" to look for evidence of bird remains (and the "tell tale" proteins after a bird strike) inside the engine intakes and components. This was effective, but a portable "black light" source was not available in the field. Consequently, the team could not conduct this examination until the aircraft was recovered into a Hangar at 15 Wing.

2. ANALYSIS

2.1 General

The investigation gathered a great quantity of first hand information from interviews with the two surviving aircrew. The HUD tape from the mishap flight clearly shows the bird that entered the left hand intake after the touch and go, and records the communications of the pilots up to the subsequent ejection. Pilot actions are not depicted but flight parameters are displayed on the tape.

2.2 The Aircraft

The pilots did not detect any unserviceabilities with CT155202 prior to the accident. The aircraft technical documentation and maintenance work were completed in accordance with orders by qualified personnel.

2.3 The Birdstrike

The HUD tape from the mission shows a bird come into view, slightly above and to the right of the nose of the aircraft, after the post-take off check was completed and tower clearance was obtained for a closed pattern. In less than two seconds it passes slightly left of, and below the windscreen when the aircraft is at 239 KIAS and 70 feet AGL. Investigation found small amounts of bird remains on the intake spinner, the T6 probe and first stage compressor blades. As well a bird wing was recovered from runway 29R near the departure end. Analysis of DNA from the wreckage as well as the wing determined the bird species to be a Franklin's Gull, a small to medium sized wetland gull with a wingspan of 33 to 38cm and a weight of approximately 280 grams.

Examination of the AOA probe revealed impact damage. The probe was bent and the cylindrical portion crushed. Closer examination of the vane slots under a microscope revealed down-like filaments that resembled the feathers from the bird remains. These filaments were found under a layer of dirt that accumulated during impact with the terrain.

The Hawk Mk 115 is powered by the Adour Mk 871 turbofan engine with a 2-stage low-pressure compressor and a 5-stage high-pressure compressor. Examination of the low-pressure section showed soft FOD impact damage on up to four compressor blades, one isolated and three adjacent blades of the first stage compressor. (Photo 1) There was no indication that any of the first stage compressor blades were damaged enough for pieces to break off and to travel through the engine.

After initial investigation at the crash site and at 15 Wing Moose Jaw, the engine and various components were sent to QETE for further detailed inspection and disassembly. Representatives from Rolls-Royce were requested to participate in the engine tear down because of their specialised knowledge and the requirement for specialised equipment.

QETE analysis determined that the four damaged compressor blades had been drawn forward of their normal rotational plane at the position where the bird originally impacted. This bending was caused by the compressor trying to move a substance heavier than air rearwards through the compressor. There was also distortion to the airfoil for over 50% of the length of the four blades. The majority of the bird remains were directed through the bypass duct of the engine after passing through the low-pressure compressor. The remaining stages of the compressor section showed hard FOD damage that was most probably caused as the engine impacted the ground at low RPM. QETE concluded that the damage caused to the blades of the first stage compressor prevented the production of stable airflow that was necessary to firstly clear the stalled engine and then allow for a successful restart.

The Hawk features a Central Warning System (CWS) that indicates faults in the aircraft system by audio warnings accompanied by warning lights and/or annunciator panel lights. Annunciator panel lights are red for warnings and amber for cautions. Red warnings are accompanied by two chirps of a lyrebird tone followed by a voice message said twice.

The aircraft had been cleared for the closed pattern and the pilot had selected combat flaps for the manoeuvre when the bird came into sight. Both crewmembers heard a “thump” and felt vibrations associated with a change in engine pitch and loss of thrust. This was followed immediately by several audio (lyrebird) and engine warnings (T6NL and ECA) and very high engine temperature indications (660^{o}C).

“T6NL” warning is activated when there is an engine overstress or when the Turbine Gas Temperature (TGT) is too high. It would also be activated if the ECA failed to control TGT or the low-pressure compressor shaft speed (NL).

“ECA” caution activates if there is a failure of an ECA channel, NL or TGT limits are exceeded or NL is greater than 88.5% with TGT less than 260^{o}C.

The indications after the bird strike were all symptomatic of a compressor stall.

2.4 Aircrew Response

The aircrew were exposed to an engine malfunction in the worst possible regime of flight: low altitude and low airspeed. Two tasks had to be dealt with nearly simultaneously, and in short order: interpret the emergency then decide whether to stay with the aircraft or eject. In general, deciding to stay with the aircraft gives more time to interpret information and attempt to rectify the emergency; but, should a relight be unsuccessful, altitude for the ejection has been sacrificed. The eject decision is often time critical, and a delay of even seconds can mean the difference between life and death.

Hawk pilots fly with a checklist made available to them. In CF aviation, the checklist is an adjunct to the Aircraft Operating Instructions (AOIs); the AOIs contain the details and background knowledge necessary to use the checklist. The Hawk checklist is divided into four chapters, Normal Operating Procedures, Operating Limits and Performance, Emergency Operating Procedures and Non-Critical Emergencies. The Emergency Operating Instructions contain the following:

TIME CRITICAL EMERGENCIES

- Maintain Aircraft Control
- Analyze the Situation
- Take Immediate Action

SUSPECTED ENGINE MALFUNCTION

- Zoom	IF POSSIBLE, WINGS LEVEL
- Throttle	CURRENT POSITION

- Analyze, CONSIDER EJECTION

If decision is made to continue, proceed with the appropriate emergency response

ENGINE MECHANICAL FAILURE

- Throttle	OFF
- Fuel Pump Switch	OFF
- LP Cock	OFF

- Do Not Try to Relight

EJECT or FORCE LAND

The crew in this case knew they had hit a bird, followed by a power loss, rumblings and vibrations, as well as CWS alerts. These symptoms could be construed as an engine mechanical failure, and the above items actioned. However, the checklist also contains the following procedure for a TGT/NL Overlimit Warning;

<u>T6NL OR T6NL & ECA</u>

Note TGT, IF T6NL ONLY,

-Throttle IDLE

If T6NL and ECA

- Throttle 80% AND CHECK TGT IS WITHIN LIMITS

If TGT too high or blank, remains over limit or surge suspected,

- Engine Surge Drill PERFORM

TGT is Normal

DO NOT EXCEED 90% rpm or 95% below 20,000 FEET

Land As Soon as Possible

Since the CWS displayed T6NL and ECA, accompanied by audio T6NL alerts, the crew could have followed this checklist procedure. The pilot stated that he brought the throttle to idle after confirming the engine temperature remained high. According to the checklist procedure, the throttle should have been retarded only after the TGT was noted in the absence of an ECA caution. With T6NL *and* ECA indications, the throttle should have been reduced to 80%. But even at idle the high TGT persisted. Setting 80% may have allowed the TGT to stabilize, or possibly might have allowed the crew to determine if any residual thrust was available. According to the AOIs, if thrust is available the engine is not surged. In this situation this information would not have mattered, as the crew did not have the required time available to assess if any thrust was available and if so, was it adequate to maintain flight.

The TGT remaining high would have led the crew to perform a surge drill. The surge drill requires three action items (including bringing the throttle to idle) followed by a six second pause to monitor TGT. If the TGT stays high after 6 seconds, the surge drill directs that an Immediate Relight be attempted. At low altitude and low speed there is not the necessary time to follow these steps.

The AOIs prescribe an Immediate Relight in the event of a flameout. For all other engine malfunctions, an Immediate Relight is not prescribed unless a Surge Drill is first carried out and is unsuccessful.

The Time Critical Emergencies section of the AOIs states: “The engine malfunction (especially at low level) may leave very little time for diagnosis and recovery action, particularly if the cause is a bird strike or FOD ingestion.” In some cases the appropriate response to a loss of thrust is to lift the aircraft’s nose and eject. An emergency brief is introduced in the ground school syllabus of Phase III flying training, which is to be verbalized by the pilot in command before take-off. This brief applies to initial and subsequent take-offs, and should include critical emergencies on the take-off roll or soon after becoming airborne. One example given on course is "Airborne, gear up, less than 300kts –maintain climb, assess emergency, confirmed engine problem or total hydraulics – eject." No other guidance with respect to a minimum altitude or airspeed required before engine recovery attempts may be initiated is given to NFTC Hawk pilots. Given the complexities of the immediate actions required for engine malfunctions, the time these procedures take and the low levels of experience student pilots have, it is assessed that a more defined standard operating procedure for low-level ejection is required.

The IP pulled the aircraft up in an aggressive, 24 degree wings level zoom to a height of 1190 AGL, before initiating a turn of up to 45 degrees angle of bank to the right. The aircraft continued to climb in the turn obtaining an apex height of 1610 AGL and airspeed as low as 123 KIAS.

The aircraft captain told his SP to prepare to eject prior to reaching the top of the zoom. He had decided they were ejecting by that point in time. He stated to the investigators that he had previously experienced a bird-strike, which caused an engine failure in a CF-18, in which the indications were identical to the vibrations and noise following this incident. The IP did not expect a successful relight, but thought he had directed the SP to attempt a relight procedure in the small amount of time he had gained with the zoom.

The SP had been told to prepare to eject and had tossed his checklist onto the glare shield in preparation. The Standard Operating Procedure in use by the air force where the SP initially flew the Hawk aircraft is to eject upon engine failure if the speed is less than 330 KIAS in the low level environment. With regard to an emergency engine out landing, the Canadian AOIs state "a successful turn-back is possible from approximately 330 KIAS and 1000' AGL if the manoeuvre is executed promptly and flown correctly." As stated earlier, the bird was struck at 70' AGL when the aircraft was travelling at 239 KIAS.

Several anomalies were noted when different operators within the CT155 community were queried as to the ideal behaviour expected under the circumstances of a low and slow (below 300 KIAS) engine malfunction. Several responses were postulated, which suggest that a training and standards deficiency may have existed.

Some terminology/phraseology used in the emergency was not understood within the crew. Although the language for both crewmembers was English, cultural differences resulted in a lack of precise and timely communication between the crew in a time critical situation.

The IP believed he had instructed the SP to commence an Immediate Relight but investigation revealed that the terminology used by the IP did not clearly describe what he wanted. Although the IP thought he directed the SP to conduct an Immediate Relight, the IP actually used the terminology for a CT-114 Tutor relight procedure. The Canadian Forces used the Tutor aircraft for basic and advanced jet training for over 30 years, and the IP had trained and instructed on that aircraft. While the IP wanted the SP to move the throttle to the “OFF” position in accordance with the Immediate Relight procedure, this was not done. Both pilots thought the other had that responsibility. The SP later stated he had been confused by some of the IP’s comments, specifically to “go around the horn.” (This refers to the action required to move the Tutor throttle outboard to the Cut-Off position.) The SP assumed the IP had attempted an Immediate Relight, so when he heard the instruction to try a start from the front he realized he did not have the necessary time or airspeed (165 to 250 KIAS) to conduct an Assisted Relight procedure.

Although there was some confusion amongst the crew, this was not causal to this accident as there was insufficient time to complete a relight. It is interesting to note that, if the throttle had been positioned to “OFF”, the DC Generator would have been off-loaded and the HUD footage would have ceased. The consequences this would have had for the investigation, particularly if the ejections had been non-survivable, point to the need for CVR/FDR capability in this aircraft.

2.5 The Zoom Technique

The AOIs and the Manual of Flying Training do not give an optimum zoom angle or “G” technique required to most efficiently transfer airspeed for altitude. They do provide optimum glide speed as 5.5 units AOA in a clean configuration, or about 185-190 KIAS giving maximum lift over drag. The pilot in this case brought the nose up rapidly to 24 degrees. As a result of the aggressive pull up, the aircraft quickly decelerated through 190 KIAS during the zoom and decreased to as low as 123 KIAS. In this incident it is assessed that the bird damaged the AOA system; the AOA read-out terminates on the HUD tape at the precise moment the bird passes from view. Damage was also evident on the AOA probe itself. Therefore the IP did not have the AOA indicator to set optimum angle and would have to rely on indicated airspeed.

Several comparisons of angular zoom and time to apex were conducted in the FTD (flight simulator) to assess the effectiveness of the aircraft zoom profile. The results are thought to be fairly representative of real aircraft performance. The higher angle profiles, beyond 15 degrees of pitch up, suffered from a “roller-coaster effect”, in that the aircraft decelerated through 190 KIAS airspeed before the pilot could establish the 190 KIAS glide attitude. This is partially due to the requirement to anticipate the 190 KIAS by pushing on the controls to establish the glide attitude before attaining the glide airspeed. By comparison, the 190 KIAS/5.5-unit AOA descent rate is approximately 1100 FPM (basic aircraft configuration), whereas the accident descent rate at about 140 KIAS was 2000 FPM. The FTD data showed that a less aggressive zoom yields a lower apex altitude, but more time available prior to arrival at apex, and less danger of a descent rate greater than optimal glide post-apex. The AOIs state, “when circumstances permit, a zoom manoeuvre will make it easier to escape.” In all ejections, it is favourable to have an upward vector as opposed to a rate of descent. Therefore, a less aggressive zoom resulting in a lower apex means more time prior to the onset of a descent rate.

The IP did a wings level pull up initially, but entered a steep turn approaching the apex, sacrificing altitude by using the lift vector to turn the aircraft. His statements later revealed he did not realize how much of a turn he had completed. He further stated he did not initiate the turn consciously in an effort to turn back but may have been subconsciously completing the next step in the procedure he had been cleared for, the closed pattern to the right.

2.6 Latent Factors

The CT155 Hawk front seat throttle has an IDLE/OFF FINGER-LIFT LEVER located at the base of the throttle. Lifting it withdraws the idle stop permitting the throttle to be moved from idle to cut-off. The rear cockpit is similar but the IDLE/OFF FINGER-LIFT LEVER has a longer lever providing mechanical advantage. This in turn is interconnected by a Teleflex control cable to the idle stop in the front cockpit. At the time of the accident, shutting down the aircraft using the rear seat throttle to cut-off created a servicing requirement to inspect this cable. This generated a disincentive to use the rear seat throttle for shutdowns. The rear seat does not exist in the FTD, so pilots are not exposed to the different FINGER-LIFT LEVER configuration in simulator sessions. These factors may have lead the instructor to feel less familiar with the rear-seat actions required for the Immediate Relight and more disposed to delegate the task to the front seat pilot.

2.7 Ejection Sequence Analysis

The IP sustained serious injuries during the ejection and subsequent parachute landing. The SP sustained minor injuries. All of the injuries can be attributed to the ejection sequence, parachute landing and associated equipment or systems.

2.7.1 Ejection Seat Performance:

Back Seat Ejection: After warning the front seat pilot, the IP initiated the ejection. The canopy fracturing system activated and the seat was propelled out of the aircraft. Post-crash analysis showed evidence of some minor interference between the pilot’s lower left G-suit pocket and the aircraft. After the seat was propelled out of the aircraft, the parachute inflated allowing the IP to descend under a full canopy for about 30 seconds.

Front Seat Ejection: The front seat was command ejected from the rear seat of the aircraft. The SP pushed himself against the back of the seat and grasped the seat-firing handle but did not pull it. The MDC of the canopy fracturing system detonated into the cockpit splattering the aircrew with molten metal, MDC sheathing and canopy fragments. The seat was propelled out of the aircraft without identifiable interference with the cockpit. The parachute deployed and the SP descended under a full parachute canopy.

Ejection Injuries: Both pilots suffered burns from contact with molten MDC material during the ejection. The IP suffered injuries during the catapult phase. His statements later revealed he had looked down to see the seat-firing handle prior to pulling it and recalled that the control stick was well forward. These two factors are assessed as indicating he was in a head down and slightly hunched position at the time the seat fired. He immediately felt a sharp pain as the seat was propelled up the rails. After parachute opening, he attempted to relieve pressure/pain during the descent by lifting himself with the risers. This had the effect of rotating his parachute through 360 degrees as it descended and slightly increasing his descent rate. No attempt was made to deploy the Parachute Survival Pack (PSP). He also suffered serious injuries on landing. The non-deployed PSP and high descent rate contributed to these ground impact injuries. Based on the injuries sustained during the ejection sequence, this ejection is classified as 'unsuccessful / survivable'. The SP was able to deploy his PSP prior to ground impact, although it took three attempts. This aircrew member suffered minor injuries as a result of the ejection sequence. This ejection was classified as 'successful'.

Automatic PSP Deployment: Some Hawk aircraft variants utilize a device that will deploy the PSP even if the pilot is injured or incapacitated. (Martin Baker's Automatic Deployment Unit, ADU.) In this accident such a device might have mitigated the pilot's landing injuries.   A concern with the ADU is that its installation would add weight to the seat, which would have to be accommodated by removing weight from the PSP or a reduction in maximum pilot weight.

Harness Powered Retraction Unit (HPRU) Operation: The HPRU is designed to pull the seat occupant back into the seat in the event that the proper body position has not been adopted in advance of the ejection initiation. The HPRU is activated by hot gas generated by the charge at the firing handle and is activated immediately after the ejection handle is pulled. Data on the qualification of the HPRU provided by the OEM shows that the HPRU must fully retract within 0.20 seconds from activation. The hot gases that activate the HPRU also initiate the catapult, which propels the seat up the rails. Because hot gases from the same source initiate the HPRU and the catapult, their operations are nearly simultaneous for the back seat occupant. In a commanded ejection, the front seat catapult activation is delayed 0.3 seconds to prevent both seats from being ejected at exactly the same time. The time it takes for the seat to travel up the rails is less than 0.15 seconds – less time than the haul back time of the restraint/occupant under the operation of the HPRU.   In this case the occupant was leaning forward slightly at the time of ejection initiation, and suffered injuries as a result. It is assessed that the HPRU did not ensure the occupant was pulled into a proper posture prior to the onset of the catapult forces.   However, in order to ensure the HPRU has performed its operation before the catapult forces are applied it would be necessary to delay the catapult operation by approximately

0.2 seconds from seat initiation. This would have a detrimental effect on the overall performance of the Escape System in adverse conditions.

2.7.2 G-suit Publication Storage

There is no practical publications storage in the CT155 Hawk. This problem was documented in AETE Report 00/15 25 July 2001. This situation forces the aircrew to use the lower leg pockets on their G-suits for storage of publications required during flights. The narrow rudder channels on the Hawk aircraft makes using the G-suit lower pockets problematic. The AETE report recommended that “the minimum publication carriage requirement be determined and that a provision for stowage of these items be provided.” A solution has not yet been incorporated into the CT155 Hawk. In this case, the IP did have publications in his G-suit pockets and there was evidence that the lower left G-suit pocket was ripped during the ejection from the cockpit.

2.7.3 Aircrew Weight

The CT155 AOIs state that the maximum crew boarding weight “equipped” shall not exceed 239.0 lbs. This includes helmet, mask, boots, clothing, LPSV and publications. Based on equipment weighed, during the on site investigation, along with input from medical files, it is assessed that the IP had a boarding weight of 249 lbs +5 lbs/-0 lbs, which represent at least 10 lbs over the maximum OEM boarding weight IAW the AOIs. The AOIs include the following warning:

“The risk of injury will increase under certain ejection conditions involving aircrew weights outside the certified limits.”

Bombardier has requested and received Martin-Baker support for a Seat Weight Extension Program that is in its initial stages.

2.7.4 GQ1000 Parachute Descent Rate

The GQ1000 17-foot aeroconical parachute installed in the CT155 Hawk has a history with regard to high descent rates and subsequent landing injuries, which is consistent with the serious injuries sustained by the IP. The GQ1000 is reliable and fast opening but its characteristics produce high total velocities near its maximum suspended weights. It is noteworthy that the maximum suspended weight for GQ1000 parachute in the CF188 Hornet is 300 lbs and the injured crewmember was well below this weight (estimated suspended weight of 284 lbs +5 lbs/-0 lbs.) The aircrew were both within the suspended weight limit determined by DTA, for the GQ1000, despite the IP being 10 lbs over the CT155 Hawk boarding weight. When the IP’s parachute was recovered the steering lines were still in the stowed location. This indicates he had not steered the parachute with the lines, therefore it is impossible to estimate the effect of wind on ground speed at landing. The IP stated that he could not see, or find the steering lines. His statements indicate he did attempt to manoeuvre the parachute and relieve the strain on his back by pulling on the right hand riser. Based on data provided by the OEM, his descent rate and total velocity in zerowind conditions were estimated to be 26 feet per second (fps) and 36 fps respectively, beyond the limits of 24 fps and 30 fps stated in MIL-S-18471F(AS), General Specification for System, Aircrew Automated Escape, Ejection Type, 1 May 74.

2.7.5 Simplified Combined Harness (SCH) Issues

The CT155 Hawk uses a Gen 2 SCH that is designed to be the seat harness for normal operations and the parachute harness when the crewmember uses the ejection system. The Gen 2 SCH suspension generates a triangular void above the aircrew member's shoulders, the same as in the Gen 1 SCH, when the harness is used in the parachute mode. The void is generated after seat/pilot separation in the ejection sequence and it has been determined that this suspension system can generate fatal head/neck forces in high-speed ejections (as was observed on CF188732), a phenomenon known as "riser-slap". The GQ1000 aeroconical parachute is known for its rapid deployment; however, this introduces high opening loads. The IP noted the void and used it in an attempt to relieve pain, by pulling on his harness to reduce his weight in the harness pressure points. The void was between 4 and 5 inches off his shoulders. If correct strapping in procedures are followed, this void is only 1 to 3 inches. The strap in procedure is a 15-step process outlined in the AOIs. The AOIs contain a warning stating "To minimise the risk of personal injury during ejection it is essential that strapping-in is done correctly and meticulously as described."

Despite the low speed nature of the ejection, there were indications on his ALSE and from his physical injuries that there was an interaction between the SCH and the IP's neck and helmet. His Life Preserver Survival Vest (LPSV) had signs of harness contact and was slightly damaged. As well, his SCH had a broken bungee cross strap on the left side.

The CT155 Hawk Operational Airworthiness Authority (OAA) has conducted a Risk Assessment to address this hazard. (Record of Risk Assessment, Rev 2, 13 May 04, - A1 Training.) This RARM determined that a Medium risk exists, but by factoring in the predicted ejection rates the risk is reduced to Low.

2.7.6 Other ALSE Damage

Both helmets and visors showed signs of pitting, scratches and residue deposits. (Photo 2) As well, the blast cover of one Beaufort Mk30LC LPSV was perforated rendering the floatation bladder, stored within the carrier, unserviceable. Several puncture holes were in the right lobe and one was in the left lobe, causing air loss at a rate that would require constant manual inflation for the LPSV to retain floatation. A preliminary investigation, carried out by DRDC Toronto and AETE Escape Systems, revealed two large penetrations (one on each side) of the LPSV protective cover (carrier). QETE was tasked to identify what caused the damage. The carrier is constructed of three layers of material that are folded over and held closed with a zipper and hook and pile fasteners. The bladder is encased and protected on all sides by the three layers. Although a large quantity of MDC splatter contacted the outer layer of the LPSV carrier (both left and right hand lobes), the middle or second layer of material appeared to have arrested the progression of the splatter. It is considered likely that sharp objects, such as those generated by the fragmentation of the canopy during the ejection sequence, caused the holes in the LPSV bladder assembly. QETE determined that the design of the carrier was able to protect the LPSV bladder from MDC splatter; however, the carrier is not capable of protecting the LPSV bladder from sharp projectiles such as those generated by the fragmentation of the canopy during the ejection sequence. Adding more protective layers to the carrier is not realistic, as the LPSV would become too bulky and restrictive for the operators. Also, a small canopy fragment (about the size of a thumb nail) was found behind one pilot's O2 mask. This fragment was likely responsible for a facial cut to this crewmember. This injury was sustained despite the fact that this crewmember had one visor deployed.

BMAT uses an electronic record keeping system for recording all maintenance on NFTC aircraft, aircraft parts and ALSE equipment. The records for the SP's ALSE equipment were incomplete, as there was no record of any equipment being issued to him. Therefore the investigation team was unable to analyse the maintenance history of the SP's ALSE.

2.7.7 Personal Locator Beacon Performance

The PLB broadcast and the emergency radio functions used in the CT155 Hawk are designed to be transmitted by a PSP mounted device (radio with integral antenna) that is activated by separation of the aircrew from the seat. Despite successful separation for both pilots, it appears the PLBs did not perform adequately. A PLB tone was heard and recorded by IFRCC for approximately 2 seconds immediately after ejection and was picked up by SARSAT approximately 2 hours later. The CT155 Hawk has no aircraft mounted bailout tone and relies exclusively on the functioning of the PLBs. It is believed the composite shell of the PSP shields the PLB antenna, attenuating the signal. The manufacturer's instructions clearly indicated that the antenna must be deployed for proper functioning of the PLB. The PLB Operating Manual stated "*to ensure the best propagation of the distress signal it is necessary to deploy the antenna by turning it through 180 degrees into an upright position and then extending the telescopic section.*" The PLB is not packed in the PSP with the antenna deployed, but rather the antenna is held in a stowed position. Consequently, the signal could not be received with sufficient strength unless the aircrew had manually deployed the antenna once on the ground.

While not a factor in this accident, the necessity to manually deploy the antenna, to ensure adequate locator signal strength, could prevent a timely rescue and medical response, especially when an aircrew is injured or incapacitated.

2.8 Wildlife Program

15 Wing has an active Bird and Mammal Control program delivered by contracted support through Bombardier Industries. A wildlife control officer regularly patrols the airfield, locates and eliminates any nuisance animals. The wildlife plan is comprehensive and appears to address all reasonable aspects of controlling birds and other animals within the boundaries of the airport, but its scope is confined to the airfield. Moose Jaw reported 22 local bird-strikes in 2002, 39 in 2003 and 21 in 2004. Results of these collisions varied from no damage to the loss of the aircraft in this case. The bird scare tactics used in 15 Wing seem to be ineffective against gulls, since they only appear to make the birds curious and cause them to circle the area. Gulls that linger on the airfield are the major bird risk at 15 Wing. It is believed that the habitat of these gulls is 17 nm southwest of the airfield (Old Wives Lake area). These birds make regular transits, through the airfield area, to the landfill site to the northeast of the City of Moose Jaw.

An analysis of the tower logs over the past 4 years revealed that, during the period between August and October, the airfield was under a “Heavy Local Bird” state an average of 5 hours and 42 minutes per month. Conducting further studies in the vicinity of the Moose Jaw airfield to further understand the bird risk would help to refine the bird threat mitigation plan. 15 Wing and 1 Canadian Air Division (1 Cdn Air Div) have submitted a Wildlife Survey Request to that end.

2.9 Initial Recovery of Wreckage

2.9.1 Securing the Seats

During the post-occurrence reaction by 15 Wing, the Immediate Response Team from NFTC reported to the accident site and was directed by OSCER to “safety and de-arm the seats”. The Response Team technicians assigned responsibility for the escape systems went back to the flight line and retrieved the appropriate tools and an explosive can. The technicians then pinned the seats and started to remove the breaches from most of the seat explosive devices. The technicians noted that there was a lot of pressure on the breach firing units and in some cases they shot out.

Residual pressure in the lines and breaches can pose a serious hazard to personnel, particularly for those not specifically trained to deal with this hazard. In addition, the expelled gas from these cartridges is caustic and respirators should be worn at all times. The technicians were not aware of these hazards and were not wearing appropriate Personal Protective Equipment during these de-arming activities.

The Investigation Team Escape System (ES) personnel from AETE were not aware of the steps taken by the crash recovery personnel and did not discover what had been done until seat de-arming activities were undertaken three days after the accident. The ES personnel did not request, nor were they provided, a copy of the OSCER’s activity log or a briefing on the status of the ES components

AETE ES personnel thought that the CT155 Hawk escape system was similar enough to the CF188 Hornet system that specific training on the NFTC aircraft was unnecessary. However, during the post-accident activities AETE ES personnel required assistance from NFTC personnel, as the AETE ES team was not sufficiently familiar with the Hawk's ejection systems.

Although no safety concerns were encountered during de-arming activities, extra time and assistance were required with the unique sub-systems of the CT155 Hawk.

2.9.2 Handling of Fluid Samples

During the emergency response, because Bombardier uses the Alberta Research Council (ARC) laboratories for routine testing purposes under contract by 15 Wing, fuel and fluid samples were gathered and shipped to ARC for analysis. QETE is the primary authority for Canadian Forces technical investigative analysis. Normal post-accident fluid examination is handled through QETE to cover all the unique testing required for such an occurrence. Consequently, QETE 3-4 Petroleum, Oils and Lubricants (POL) section was required to talk with an ARC representative to coordinate the required testing of the fluids. For aviation related analysis, non-CF laboratories will be used only on the authority of DFS, to ensure that QETE will coordinate with the agency and ensure that all test requirements are met.

2.10 Miniature Detonating Cord Safety Measures

The CT155 Hawk canopy system uses MDC to fracture the canopy during ejection, ground rescue assistance or for emergency egress. MDC had not been used on any canopy system employed in Canada until the introduction of the CT155 Hawk and the CT156 Harvard II aircraft. This occurrence was the first aircraft loss in Canada involving MDC to shatter the canopy. There are several safety concerns associated with these systems. The CT155 Hawk AOIs clearly indicate that:

"To avoid MDC injury, both ground crew and aircrew must take precautions as follows:

a. Warn ground crew to shelter under the wing when the canopy is about to be closed;
b. Confirm with the pilot in the other cockpit that the canopy and MDC are clear of obstructions; and
c. Ensure that both pilots have their visors down and their eyes tightly closed before closing and locking the canopy."

Observations made on the flight line indicated that several ground crew and aircrew were not taking these precautions during CT155 Hawk operations. It is assessed that the dangers posed by MDC were not appreciated or fully understood.

Dual layer clothing will also reduce skin injuries caused by MDC splatter. 1 Cdn Air Div Orders state that “Personnel engaged in flying operations shall adhere to the dual layered clothing principle of fire protection. Wing Commanders/Unit Commanding Officers shall promulgate an order(s) on the wearing of dual clothing layers, with due consideration to heat stress depending on local environmental and climatic conditions.”

One pilot was not wearing dual layer clothing (long undergarments). He had the sleeves of his flight suit partially rolled up his forearms and the cuffs of his flight gloves rolled down, exposing the skin of his forearms and wrists. The gloves were extremely well worn, were used without liners, and the right glove had the fingertips cut off. In this instance, these deficiencies contributed to the burn injuries associated with the use of MDC.

3. CONCLUSIONS

3.1 Findings

3.1.1. CT155202 was serviceable at the time of the bird-strike. (2.2)

3.1.2. The crew was qualified and current to perform the mission. (1.5)

3.1.3 The pilot at the controls was the instructor pilot in the rear seat. (1.1)

3.1.4 The aircraft had been cleared for a closed pattern following a touch and go, when it struck a bird off the departure end of the runway. (2.3)

3.1.5. The bird hit the AOA probe, then separated into multiple pieces that entered the left hand engine intake and were ingested by the engine, causing serious FOD damage. (2.3)

3.1.6. The bird strike was immediately followed by a loss of thrust accompanied by T6NL and ECA warnings, as well as high engine temperature indications and vibrations. (2.3)

3.1.7. The IP initially zoomed the aircraft wings level and advised the SP to prepare to abandon the aircraft. (2.4)

3.1.8 The aircraft did not have sufficient airspeed and/or altitude to perform a successful turn-back. (2.4)

3.1.9. Approaching the apex of the zoom the aircraft turned right through approximately 150 degrees as airspeed bled to 123 KIAS. (2.4)

3.1.10. There are no recommended minimum parameters (airspeed and altitude) to achieve to establish safe low altitude engine diagnosis and recovery actions. (2.4)

3.1.11. Because of confusion in communicating the IP’s intent, an Immediate Relight attempt was not conducted. (2.4)

3.1.12. The IP warned the SP about imminent ejection and command ejected both seats 49 seconds after the bird strike. (2.7.1)

3.1.13. The ejections were carried out within the published envelope. (1.15.1)

3.1.14. The SP sustained minor injuries during the ejection sequence. (2.7.1)

3.1.15. The IP was not in an optimal body position at the time of ejection initiation. The HPRU did not force the IP into a suitable body position before the catapult forces were applied. (2.7.1)

3.1.16. The IP sustained serious injuries during the ejection phase as well as serious injuries at ground impact. (2.7.1)

3.1.17 The non-deployed PSP and high descent rate contributed to the IP's serious ground impact injuries. (2.7.1)

3.1.18. The IP was approximately 10 lbs over the maximum OEM specified crew boarding weight equipped. (2.7.3)

3.1.19. The aircraft was destroyed upon ground impact. (1.3)

3.1.20. The HUD tape was recovered and made playable by NRC. The tape contained voice and aircraft parameters up until the moment of ground impact. (1.11)

3.1.21. The CT155 Hawk does not have adequate IFR publications storage space. (2.7.2)

3.1.22. The LPSV carrier is not capable of protecting the LPSV bladder from sharp projectiles such as those generated by the fragmentation of the canopy during the ejection sequence. (2.7.6)

3.1.23. The GQ1000 aeroconical parachute used in the CT155 Hawk places the aircrew at a higher risk of injury if the aircrew's weight is in the higher limits of the certified weight envelope. (2.7.4)

3.1.24. There was evidence that "riser slap," (impact between the Gen 2 SCH suspension system and a pilot's head and neck), occurred upon parachute opening. (2.7.5)

3.1.25. The size of the observed triangular void in the SCH will be larger if correct strapping in procedures are not followed. Proper strap-in will result in a 1-3 inch void.

3.1.26. Aircraft flying in the vicinity of the ejections did not receive any emergency PLB signals or tones. (1.9)

3.1.27. The vicinity of 15 Wing is home to large populations of various bird species. Gulls transiting the airfield daily pose a serious threat to aviation during the summer months. (2.8)

3.1.28. During the immediate response, 15 Wing (NFTC) Response Team technicians responsible for ES unknowingly performed unsafe work on the ejection seats. (2.9.1)

3.1.29. AETE ES personnel had not undertaken CT155 Hawk specific training. (2.9.1)

3.1.30. AETE ES personnel were not informed of what work had been undertaken on the ejection seats prior to their arrival on scene. (2.9.1)

3.1.31. POL samples were sent to ARC vice QETE for analysis. (2.9.2)

3.1.32. At the time of the accident, several ground crew and aircrew were not taking the prescribed precautions with respect to MDC during CT155 Hawk operations. (2.10)

3.1.33. Interviews conducted with 15 Wing and 419 Sqn pilots of 4 Wing, revealed a lack of consensus regarding the appropriate immediate reactions required when confronted with the cockpit indications detailed in section 2.4.

3.1.34. One of the aircrew was not wearing dual layered flying clothing. (2.10)

3.1.35. After the One-Bell alarm, the Wing fire fighters, ambulance and GSAR immediately departed for the crash site. No vehicle remained to transport the Wing Surgeon. (1.15.2)

3.1.36. The pain medication administered to one injured pilot at the accident site completely depleted the stock carried on the ambulance. (1.15.2)

3.1.37. The local hospital was not warned of arriving trauma patients because no 911 emergency telephone call was made. (1.15.2)

3.1.38. BMAT was unable to provide maintenance documentation of the SP's ALSE for the investigation's analysis. (2.7.6)

3.2 Cause

CT155202 struck a Franklin's Gull, which was ingested in the engine causing an immediate and severe loss of thrust during a critical phase of flight.

4. PREVENTATIVE MEASURES

4.1 Preventative Measures Taken

4.1.1 The investigation team briefed the 15 Wing Comd, 2 CFFTS Comd, NFTC management and their staffs on the preliminary findings of the investigation on 21 May 04. All of the Preventative Measures Required (section 4.2 except 4.2.7) were covered so that immediate action could be undertaken.

4.1.2 The investigation team produced a Power Point presentation for use by the CT155 Hawk and CT156 Harvard II communities with respect to MDC and its' associated properties, dangers and recommended precautions. This presentation was distributed to the Wing Flight Safety Officers of 4 and 15 Wings for air and ground crew education.

4.1.3 The automatically activated PLB of the CT155 Hawk did not function adequately. Since this accident, BMAT has developed and installed on the aircraft an external antenna which will fall clear of the PSP after its release, ensuring adequate distress signal propagation.

4.1.4 AETE ES personnel have taken training and are now familiar and proficient on the Hawk aircraft escape sub-systems.

4.1.5 The 15 Wing Emergency Response Plan checklist has been amended to address the lack of a 911 emergency telephone call, to prepare the local hospital to receive the injured crewmembers and avoid the minor confusion about the location of the emergency entrance at the Moose Jaw Union Hospital. The 15 Wing ERP was exercised during a CRASHEX on 28 Feb 06.

4.1.6 Due to the inability to locate the maintenance documentation of the SP's ALSE, BMAT conducted a detailed internal investigation and review of procedures to determine what may have contributed to this anomaly and how it could be prevented in the future. Since this review, the system in use to track ALSE has repeatedly proven effective in the course of FS investigations.

4.1.7 The DFS investigator equipment kits now include a portable black-light for the identification of organic (bird) remains.

4.2 Preventative Measures Required

It is recommended that:

4.2.1 The OAA audit Wing Emergency Response Plans to make certain they contain a means of ensuring all required personnel are accounted for and arrive at the crash site expeditiously. The emergency response was rapid, but did not ensure all required personnel had been collected prior to departure from the Wing. In this case the Wing Surgeon had to make his own way to the scene.

4.2.2 The Aerospace Medical Authority validate the quantity of pain medication required for emergency responses and prescribe a minimum holding requirement for emergency medical response teams in case of aircraft accidents. Because a crewmember was in significant pain, pain medication was given intravenously. This depleted the entire amount of ready use stock carried on the ambulance.

4.2.3 The OAA develop a clear and concise quick response CT155 Hawk Checklist procedure to respond to engine problems at low level, within defined airspeed and altitude parameters. It is further recommended that the training for this procedure be included in the syllabus, publications and simulator training. The ideal behaviour expected under the circumstances of a low and slow engine problem must be instinctive, because time is critical and actions need to be nearly immediate. Consistency seems to be lacking: several possible responses were advanced by various CT-155 Hawk pilots during the investigation inquiries. The present checklist is complicated and not clear as to the expected reaction in response to an engine problem in the low level environment.

4.2.4 The OAA ensure aircrew and support personnel are trained annually on safety precautions associated with MDC. Compliance with, and the monitoring of, these precautions must be continued. MDC splatter following its detonation represents a serious hazard to aircrew and ground crew during the ejection sequence and on the ground. Ground crew and aircrew should follow existing safety measures to minimize potential injuries. The need for aircrew to wear dual layer flying clothing and minimize exposed skin must be stressed.

4.2.5 The TAA pursue a solution to the CT155 Hawk publication storage issue. Flight publication storage was previously identified as problematic in the CT155 Hawk, particularly due to restrictions in the lower G-suit and the confined rudder channels in this aircraft. Damage to the IP's G suit was noted in this occurrence; it was a result of this known problem.

4.2.6 The OAA ensure existing AOI weight limits are enforced. The CT155 Hawk AOI maximum crew boarding weight "equipped" is 239.0 lbs. Bombardier has requested and received Martin-Baker support for a Seat Weight Extension Program that is in its initial stages. In the interim, existing AOI weight limits must be observed.

4.2.7 The TAA seek a replacement for the GQ1000 in the CT155 Hawk. The GQ1000 aeroconical parachute has a history with regard to high descent rates and subsequent landing injuries that are consistent with the serious injury sustained by the IP. The GQ1000 is slated for replacement in the CF188 Hornet system.

4.2.8 The TAA find a replacement for the Gen Simplified Combined Harness. The CT155 Hawk Gen 2 SCH involved in this ejection demonstrated problems similar to those observed on CF188732, however, to a lesser degree. Specifically the "triangular void" was observed and damage to the ALSE and the particulars of the injuries corroborate findings of the CF188732 accident investigation, that riser slap had occurred.

4.2.9 The OAA must ensure CT155 Hawk pilots properly follow the strapping in instructions. The expansive instructions must be meticulously adhered to in order to mitigate the risk of injury following an ejection.

4.2.10 The TAA replace or modify the LPSV to ensure better puncture resistant properties. The design of the carrier was able to protect the LPSV bladder from MDC splatter; however, the carrier is not capable of protecting the LPSV bladder from sharp projectiles such as those generated by the fragmentation of the canopy during the ejection sequence.

4.2.11 The OAA conduct further studies in the vicinity of the Moose Jaw airfield to understand the bird risk with the aim of improving the bird threat mitigation plan. Birds, particularly local flocks of gulls, remain problematic in the 15 Wing area.

4.2.12 The OAA must ensure that all personnel who may work at a crash site have received the necessary training. Following this accident, safety was compromised when Response Team personnel performed work on hazardous items without the appropriate personal protective equipment, (respirators).

4.2.13 The OAA takes measures to ensure all contracted service providers are aware of the procedures to follow following an accident as detailed in the A-GA 135-001/AA-001, Flight Safety for the Canadian Forces. During the emergency response by 15 Wing, fuel and fluid samples were gathered and shipped to Alberta Research Council (ARC) laboratories for analysis, contrary to normal Canadian Forces post-accident fluid examination, which is handled through QETE labs.

4.3 Other Safety Concerns

It is recommended that a crashworthy CVR/FDR be obtained for the CT-155.

4.4 DFS Remarks

The cause of this accident is quite straightforward. Ingestion of a gull into the engine led rapidly to a situation where ejection was the only practical option. Such a hazard will always be present. The preventive measures already taken, and adoption of those further measures proposed, should mitigate the risks to the aircrew in the event that a similar ejection occurs in the future.

//ORIGINAL SIGNED BY//

C.R.Shelley
Colonel
DFS

ANNEX A: PHOTOS

Photo 1 First Stage Compressor Damage

Photo 2 **MDC Blast Damage**

ANNEX B: ABBREVIATIONS

ADU:	Automatic Deployment Unit
AETE:	Aerospace Engineering Test Establishment
AGL:	Above Ground Level
ALSE:	Aviation Life Support Equipment
AOA:	Angle of Attack
AOIs:	Aircraft Operating Instructions
ATIS:	Automated Terminal Information System
BMAT:	Bombardier Aerospace, Military Aviation Training
CFR:	Crash and Fire Response
CVR/FDR:	Cockpit Voice Recorder/Flight Data Recorder
CWS:	Central Warning System
DAU:	Data Acquisition Unit
DTA:	Director Technical Airworthiness
DTC:	Data Transfer Cartridge
ECA:	Engine Control Amplifier
EMS:	Emergency Medical Services
ES:	Escape Systems
FOD:	Foreign Object Damage
FPM:	Feet Per Minute
FTD:	Flight Simulator
GSAR:	Ground Search and Rescue
HP:	High Pressure
HUD:	Head-up Display
HPRU:	Harness Powered Retraction Unit
IFRCC:	Instrument Flight Rules Control Centre
IP:	Instructor Pilot
KIAS:	Knots Indicated Airspeed
LP:	Low Pressure
LPSV:	Life Preserver Survival Vest
MDC:	Miniature Detonating Cord
MSL:	Mean Sea Level
NFTC:	NATO Flying Training in Canada
NL:	Low Pressure Compressor shaft speed
NRC:	National Research Centre
OEM:	Original Equipment Manufacturer
OSCER:	On Scene Controller Emergency Response
POL:	Petroleum, Oils and Lubricants
PLB:	Personal Locator Beacon
PSP:	Parachute Survival Pack
QETE:	Quality Engineering Test Establishment
SCH:	Simplified Combined Harness
SP:	Student Pilot
T6NL:	Engine Overstress or Temperature Too High (Warning Light)
VMC:	Visual Meteorological Conditions