UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

MQ-1B, T/N 07-3182

3rd Special Operations Squadron
27th Special Operations Wing
Cannon Air Force Base, New Mexico

LOCATION: Kandahar Airfield, Afghanistan

DATE OF ACCIDENT: 5 May 2011

BOARD PRESIDENT: Lt Col Thomas M. Joss

Conducted IAW Air Force Instruction 51-503

EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION
MQ-1B PREDATOR, T/N 07-3182
KANDAHAR AIRFIELD, AFGHANISTAN
5 May 2011

On 5 May 2011, at 0916 Zulu time (Z), the mishap remotely piloted aircraft (MRPA), an MQ-1B Predator, tail number 07-3182, crashed approximately 0.5 nautical miles (nm) northeast of Kandahar Air Field (KAF), Afghanistan.

The MRPA was an asset of the 3rd Special Operations Squadron, 27th Special Operations Wing, Cannon Air Force Base, New Mexico. At the time of the mishap, the MRPA was flown by a launch and recovery element (LRE) crew from the 62nd Expeditionary Reconnaissance Squadron, 451st Air Expeditionary Wing, KAF, Afghanistan. The home unit of the mishap pilot (MP) is the 18th Reconnaissance Squadron, 432nd Air Expeditionary Wing, Creech Air Force Base, Nevada. The mishap sensor (MSO) is a member of the Texas Air National Guard whose home unit is the 111th Reconnaissance Squadron, 147th Reconnaissance Wing, Ellington Field, Texas. There were no injuries, deaths, or reported non-governmental property damage as a result of the crash. The $4.2 million MRPA was destroyed and the airfield perimeter fence was slightly damaged.

After normal pre-flight checks and taxi, the MRPA departed KAF in support of Operation ENDURING FREEDOM. Four hours and 48 minutes after takeoff, the mission crew observed high turbocharger oil temperature and conducted the engine overheat checklist, however the temperature did not return to normal. The crew initiated a return to KAF and approximately 15 minutes later after observing additional anomalous engine indications, declared an emergency. The MRPA was handed off to the MP and MSO at 15,200 ft above field elevation (AFE) approximately 10 miles from KAF. The MP descended the MRPA over the runway while conducting normal and emergency checklists. At approximately 7,600 ft AFE and 8 minutes prior to the crash, the engine failed. The crew did not recognize the engine failure at this time. The MP began the final orbit 2,100 ft above the flight manual recommended altitude for an engine-out recovery. The MP flew an extended pattern while maintaining a higher than recommended airspeed. On final approach, 0.8 miles from the runway, the crew recognized the MRPA was too low on the approach and the MP moved the throttle to full power with no response from the engine. The MRPA impacted the top of the perimeter fence and crashed inside the base perimeter.

The Accident Investigation Board (AIB) President determined by clear and convincing evidence that there were two causes of the mishap. First, failure of the engine cooling system resulted in engine failure. Second, the MP failed to properly execute a successful engine-out recovery, causing the aircraft to crash prior to the runway. In addition, the AIB President determined by the preponderance of the evidence that a leak at the coolant feed elbow on the number one engine cylinder was a substantially contributing factor to the mishap.

Under 10 U.S.C. 2254(d), any opinion of the accident investigators as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report, if any, may not be considered as evidence in any civil or criminal proceeding arising from the accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.

SUMMARY OF FACTS AND STATEMENT OF OPINION
AIRCRAFT ACCIDENT INVESTIGATION
MQ-1B PREDATOR, T/N 07-3182
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5 MAY 2011

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COMMONLY USED ACRONYMS AND ABBREVIATIONS

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ACC	Air Combat Command
AEW	Air Expeditionary Wing
AFB	Air Force Base
AFE	Above Field Elevation
AFI	Air Force Instruction
AFMES	Armed Forces Medical Examiner System
AFSOC	Air Force Special Operations Command
AFTO	Air Force Technical Order
AGL	Above Ground Level
AGM	Air to Ground Missile
AIB	Accident Investigation Board
AMXS	Aircraft Maintenance Squadron
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATO	Air Tasking Order
BFS	Battlespace Flight Services
CAP	Commander's Awareness Program
CHT	Cylinder Head Temperature
DO	Director of Operations
DoD	Department of Defense
ECT	Engine Coolant Temperature
EGT	Exhaust Gas Temperatures
ERS	Expeditionary Reconnaissance Squadron
FDP	Flight Duty Period
FL	Florida
FPM	Feet per Minute
GA	General Atomics
GCS	Ground Control Station
GLS	Global Positioning System Landing System
GPS	Global Positioning System
HDD	Heads down Display
HFACS	Human Factors Analysis and Classification System
HUD	Heads up Display
IAW	In Accordance With
IMDS	Integrated Maintenance Data System
ISR	Intelligence, Surveillance and Reconnaissance
KAF	Kandahar Airfield

KIAS	Knots Indicated Airspeed
LLC	Limited Liability Company
LR	Launch and Recovery
LRE	Launch and Recovery Element
MAP	Manifold Air Pressure
MC	Mishap Crew
MCE	Mission Control Element
MEF	Mission Execution Forecast
MCEP	Mission Control Element Pilot
MCES	Mission Control Element Sensor Operator
mIRC	Internet Relay Chat
MP	Mishap Pilot
MRPA	Mishap Remotely Piloted Aircraft
MSL	Mean Sea Level
MSO	Mishap Sensor Operator
MXG	Maintenance Group
nm	Nautical Miles
NM	New Mexico
NV	Nevada
NOTAMs	Notices to Airmen
OEF	Operation ENDURING FREEDOM
OG	Operations Group
ORF	Operation Read File
OSS	Operations Support Squadron
PSI	Pounds per Square Inch
RPA	Remotely Piloted Aircraft
RPM	Revolutions per Minute
RS	Reconnaissance Squadron
RTB	Return to Base
RW	Reconnaissance Wing
SO	Sensor Operator
SOF	Special Operations Forces
SOS	Special Operations Squadron
SOW	Special Operations Wing
TAC C2	Tactical Command and Control Agency
TCIs	Time Change Items
TCTO	Time Compliance Technical Order
T.O.	Technical Order
TX	Texas
UAS	Unmanned Aerial Systems
US	United States
USAF	United States Air Force
USAFCENT	United States Air Forces Central
UPT	Undergraduate Pilot Training
WG	Wing
Z	Zulu Time

SUMMARY OF FACTS
AIRCRAFT ACCIDENT INVESTIGATION
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5 MAY 2011

1. AUTHORITY AND PURPOSE

a. Authority

On 16 June 2011, Major General Otis G. Mannon, Vice Commander, Air Force Special Operations Command (AFSOC), United States Air Force (USAF), convened an Accident Investigation Board (AIB) in accordance with (IAW) Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*, to investigate the 5 May 2011 crash of an MQ-1B Predator aircraft, tail number (T/N) 07-3182, Kandahar Airfield (KAF), Afghanistan. The following USAF personnel served in the AIB:

Lieutenant Colonel Thomas M. Joss	Board President
Captain (Redacted)	Legal Advisor
Captain (Redacted)	Pilot Member
Major (Redacted)	Medical Member
Major (Redacted)	Maintenance Member
Staff Sergeant (Redacted)	Recorder

b. Purpose

This is a legal investigation convened to inquire into the facts surrounding the aircraft mishap, to prepare a publicly-releasable report, and to gather and preserve all available evidence for use in litigation, claims, disciplinary actions, administrative proceedings, and for other purposes. This report is available for public dissemination under the Freedom of Information Act, Title 5, United States Code, Section 552.

2. ACCIDENT SUMMARY

On 5 May 2011, at 0916 Zulu time (Z), the mishap remotely piloted aircraft (MRPA), an MQ-1B Predator, tail number 07-3182, crashed approximately 0.5 nautical miles (nm) northeast of Kandahar Airfield (KAF), Afghanistan. The MRPA was an asset of the 3rd Special Operations Squadron (3 SOS), 27th Special Operations Wing (27 SOW), Cannon Air Force Base, NM. At the time of the mishap, the MRPA was flown by a launch and recovery element (LRE) crew from the 62nd Expeditionary Reconnaissance Squadron (62 ERS), 451st Air Expeditionary Wing (451 AEW), KAF, Afghanistan. The home unit for the mishap pilot (MP) is the 18th Reconnaissance Squadron (18 RS), 432nd Wing (432 WG), Creech AFB, NV. The mishap sensor operator (MSO) is a member of the Texas Air National Guard whose home unit is the 111st Reconnaissance Squadron (111 RS), 147th Reconnaissance Wing (147 RW), Ellington Field, TX. There were no injuries, deaths, or reported non-governmental property damage as a result of the crash. The $4.2 million MRPA was destroyed and the airfield perimeter fence was slightly damaged.

After normal pre-flight checks and taxi, the MRPA departed KAF in support of Operation ENDURING FREEDOM (OEF). Four hours and 48 minutes after takeoff, after observing indications of high turbocharger oil temperature, the mission crew conducted the engine overheat checklist, however the temperature did not return to normal. The mission crew initiated a return to KAF and approximately 15 minutes later, the pilot declared an emergency after observing low oil pressure and high oil, engine and cylinder head temperatures. The MRPA was handed off to the LRE crew at 15,200 ft above field elevation (AFE) approximately 10 nm from the airfield. The MP descended the MRPA in a right hand orbit over the runway, while conducting descent, low oil pressure, high engine oil temperature and engine overheat checklists. At approximately 7,600 ft AFE and 8 minutes prior to the crash, the engine failed. Post accident analysis indicates that at some point during the recovery, leaking oil from the left side of the engine ignited on the overheated engine, but the fire was contained to the engine bay and was not detected by the crew. The aircraft is not equipped with a fire detection system. On the final right-hand orbit, the MRPA crossed the threshold of runway 23 at 4,300 ft AFE, 2,100 ft above the flight manual recommend altitude for an engine-out recovery with a windmilling propeller. The MP flew the MRPA to a point 1.8 miles from the runway 23 threshold before turning back towards the runway at 1,300 ft AFE. The MP maintained 70-80 knots with an average descent rate of 1075 ft per minute (FPM). The MP then turned the MRPA to an approximate heading of 170° and overshot the runway centerline by 1350 feet at 1.5 nm from the threshold and 900 feet AFE, as indicated by the GPS landing system cross track indicator on the heads up display (HUD). The MP acquired the runway and turned to a heading of 242°. On final, 0.8 miles from the runway, the crew noted the MRPA was low and slow. The MP moved the throttle to full power, with no response from the engine. The MRPA continued to descend while the pilot slowed the MRPA to 57 knots. The MRPA impacted the top of the perimeter fence and crashed inside the base perimeter.

3. BACKGROUND

The MRPA was an asset of the 3 SOS, 27 SOW, Cannon AFB, NM. The 27 SOW is part of AFSOC, headquartered at Hurlburt Field, FL.

At the time of the mishap, the MRPA was controlled by the LRE crew operating out of KAF, Afghanistan and assigned to the 62 ERS. The 62 ERS is a unit within the 451 AEW. The 451 AEW is operationally assigned to the US Air Forces Central (USAFCENT). The MP's home unit is the 18 RS, 432 WG, Creech AFB, NV. The MSO's home unit is the 111 RS, 147 RW, Ellington Field Joint Reserve Base, TX.

Note: Because AFSOC remotely piloted aircraft operate from a deployed location, employment of AFSOC deployed MQ-1B aircraft by mixed crews (AFSOC & Air Combat Command (ACC)) occurs regularly.

a. Air Force Special Operations Command

AFSOC is headquartered at Hurlburt Field, FL, and is one of ten major Air Force commands. It provides Air Force special operations forces for worldwide deployment and assignment to regional unified commanders. The command's Special Operations Forces (SOF) are composed of highly trained, rapidly deployable Airmen conducting global special operations missions, such as precision application of firepower, intelligence, surveillance and reconnaissance (ISR), infiltration, ex-filtration, resupply and refueling of SOF operational elements.

b. 27th Special Operations Wing

The 27 SOW located at Cannon AFB, NM, is one of two Air Force active duty special operations wings and falls under AFSOC. The primary mission of the 27 SOW is to plan and execute specialized and contingency operations using advanced aircraft, tactics, and air refueling techniques to infiltrate, ex-filtrate, and resupply SOF and provide ISR and close air support for SOF operations.

c. 3rd Special Operations Squadron

The 3 SOS belongs to the 27 SOW and accomplishes global special operations tasking as a member of the Air Force component of United States Special Operations Command. It directly supports theater commanders by providing precision weapons employment and persistent ISR. It also plans, prepares, and executes MQ-1B Predator missions supporting special operations forces.

d. Air Combat Command

ACC is the primary forces provider of combat airpower to America's warfighting commands. To support global implementation of national security strategy, ACC operates fighter, bomber, reconnaissance, battle-management, and electronic-combat aircraft. It also provides command, control, communications and intelligence systems, and conducts global information operations.

e. 432d Wing

The 432 WG flies and maintains the MQ-1B Predator and MQ-9 Reaper aircraft to support United States and Coalition war-fighters. The 432 WG conducts RPA initial qualification training for aircrew, intelligence, weather, and maintenance personnel. The 432 WG oversees operations of the 432d Operations Group (432 OG), 432 MXG, 11th Reconnaissance Squadron (RS), 15 RS, 17 RS, 18 RS, 30 RS, 42 Attack Squadron, 432 AMXS, 432d

Maintenance Squadron, and the 432d Operations Support Squadron (OSS).

f. 15th Reconnaissance Squadron

The 15 RS is one of the first armed Remotely Piloted Aircraft (RPA) squadrons. The squadron provides combatant commanders with persistent ISR, full-motion video, and precision weapons employment. Global operations architecture supports continuous MQ-1B Predator employment providing real-time actionable intelligence, strike, interdiction, close air support, and special missions to deployed war fighters.

g. 18th Reconnaissance Squadron

The 18 RS provides combatant commanders with persistent ISR, full-motion video, and precision weapons employment. Global operations architecture supports continuous MQ-1B Predator employment providing real-time actionable intelligence, strike, interdiction, close air support, and special missions to deployed war fighters.

h. 451st Air Expeditionary Wing

The 451 AEW provides a persistent and powerful airpower presence in the Afghanistan area of operations, to include tactical airlift, close air support, intelligence, surveillance and reconnaissance, command and control, airborne data link, combat search and rescue, casualty evacuation and aeromedical evacuation capabilities whenever and wherever needed.

i. 62nd Expeditionary Reconnaissance Squadron

The 62 ERS consists of operators that are responsible for launch and recovery of Predator aircraft at Kandahar Airfield, Afghanistan.

j. 147th Reconnaissance Wing

The 147 RW is a unit of the Texas Air National Guard that provides two 24/7 MQ-1B Predator Unmanned Aerial Systems (UAS) combat support sorties which provide theater and nation-level leadership with critical real time ISR and Air to Ground Missile (AGM) precision strike capability.

k. 111th Reconnaissance Squadron

The 111 RS is a MQ-1B flying squadron attached to the 147th RW located at Ellington Field, Texas and is a member of the Texas Air National Guard.

l. MQ-1B Predator System

The MQ-1B Predator aircraft is a medium-altitude, long endurance, remotely piloted aircraft. Its primary mission is interdiction and conducting armed reconnaissance against critical time-sensitive targets.

4. SEQUENCE OF EVENTS

a. Mission

The mishap sortie was an armed ISR mission flown in support of OEF and was authorized by a classified Air Tasking Order (ATO).

The MCE crew's responsibility for operating the MRPA was to execute the ISR mission, whereas mishap crew's (MC) responsibility, as the LRE, was limited to launch and recovery (LR) only. After the MCE initiated an early Return to Base (RTB) due to engine problems, the control was then transitioned from MCE to LRE for landing.

b. Planning

The MC reported for duty at approximately 2330Z on 4 May 2011. The MC received a daily mass briefing covering daily operational issues. (Tab V-32). The MC was informed they would be recovering an emergency aircraft experiencing an engine overheat. Based on this information, the MC read through the engine overheat procedures in Chapter 3 of the MQ-1B Flight Manual in order to prepare for taking the MRPA, while the MCE crew flying the MRPA positioned the aircraft for handover. (Tab R-3).

The Mission Execution Forecast (MEF) for KAF, after 0800Z on 5 May, listed scattered clouds at 12,000 ft above ground level (AGL), visibility of 4800 meters, blowing dust, temperature 31°C or 88°F, pressure altitude of 3,485 ft and winds coming from a 260° direction at 15 gusting to 25 knots. This wind resulted in a crosswind component of 12 knots. The satellite picture showed no significant cloud buildup over the airfield. (Tab F-2,4) Applicable Notices to Airmen (NOTAMs) for KAF cautioned that runway rubber removal may delay arrivals and departures; however, such delays did not affect preflight or the terminal phase of flight just prior to the mishap. (Tab K-6)

c. Preflight

The MC was not involved with the ground operations and launch for the MRPA. Another LR crew took that responsibility and executed the preflight. (Tab DD-3). NOTAMs and weather were not significant enough to alter normal operations for launch. (Tabs F-2,4, K-6). Filing a flight plan was not necessary due to the MRPA's mission being tied to an approved ATO.

The LR crew in charge of launching the MRPA examined the aircraft and executed launch procedures in accordance with the aircraft checklist and flight manual. Engine start procedures were uneventful with all engine sensors indicating within normal operating limits. However during preflight, after engine start, the MRPA's engine was inadvertently shutdown due to losing link with the Ground Control Station (GCS). The crew re-executed the checklists for a second engine start, and all indications were within normal operating limits after a successful start. At 0331Z the LR crew launched the MRPA and handed it off to the MCE uneventfully. (Tab DD-3).

d. Summary of Accident

From takeoff to 0700Z, aircraft anomalies were neither detected nor reported. At 0700Z, the MCE pilot (MCEP) and the MCE sensor operator (MCES) from the 15 RS replaced a previous MCE crew due to shift change. The MRPA was located northeast of KAF at 19,000 ft MSL under the control of a tactical command and control agency (TAC C2). At approximately 0715Z, the MCEP observed a rise in turbocharger oil temperature to the cautionary or yellow range. The MCEP elected to continue the mission and closely monitored the turbocharger oil temperature. At 0730Z, the turbocharger oil temperature read in the cautionary high range for approximately 5 seconds. Again, the MCEP continued to monitor the temperature. At approximately 0815Z, turbocharger oil temperature read cautionary high range for greater than a minute. At this point, the MCEP called for the engine overheat checklist and referenced the aircraft flight manual. The crew accomplished the checklist and turned on the engine cooling fan. The MCEP directed his MCES to scan the tail of the MRPA to detect anything out of the ordinary, but the crew found nothing. The turbocharger oil temperature increased again, with a sustained range of cautionary high range. At this point, the MCEP referenced the flight manual, which directed RTB. (Tabs N-11, R-15,18,19)

At 0823Z, the MCEP notified the LRE via internet relay chat (mIRC) of the MRPA's high turbocharger oil temperature and relayed their intent to RTB. (Tab N-15) The MCEP also notified the TAC C2 of their intentions to RTB and started coordinating with KAF air traffic control (ATC) for a sector of airspace for handover. The MCEP requested 19,000 ft mean sea level (MSL) north of the field, and ATC approved the MCEP to stay at the requested altitude beyond 10 nm north of the field. Immediately after acknowledging the approval, the MCE crew observed on the heads down display (HDD) that turbocharger oil temperature and engine oil temperature were all reading high, out of normal operating limits. Engine oil pressure and cylinder head temperature (CHT) were reading out of limits low. (Tab R-18).

At 0832Z, the MCEP declared an in-flight emergency with ATC after observing the abnormal engine indications. The approach controller acknowledged the call and directed the MCEP to fly a 120° heading in order to place the MRPA near the final approach corridor for landing. The MCEP immediately realized the 120° heading would take the MRPA away from the airfield, notified the controller and flew a heading direct to KAF. The MRPA was unable to maintain 19,000 ft MSL and descended 400 ft to maintain 18,600 ft MSL. The MCEP requested, and ATC approved, a block altitude of 18,000 to 19,000 ft MSL. During this coordination, the MCE crew executed the engine overheat checklists and normal checklists required for a handover to a LRE crew. At 0843Z, the MCE crew handed the MRPA to the LRE. (Tab N-14, R-19).

The LRE crew assumed control of the MRPA, and executed gaining handover checklists at 0843Z. (Tab N-2, 6) At this time, the MRPA was at 15,200 ft above field elevation (AFE) and approximately 10 nm north of KAF. The MP flew the MRPA towards the airfield at the aircraft performance manual best range speed of 67 knots indicated airspeed (KIAS) for the aircraft weight of 2,350 lbs. (Tabs N-6, BB-29) At 0845Z, the crew executed the engine overheat checklist. At 0846Z, the MC recorded the following automatic terminal information service (ATIS) for KAF: Runway in use was 23, winds 300° at 5 knots, skies clear of clouds, visibility greater than 9000 meters, temperature 31°C, dew point 1°C, altimeter 29.86 inches of mercury. (Tab DD-5).

The MRPA continued to the airfield while maintaining 15,200 ft AFE until 0850Z, when the MP coordinated with KAF ATC to conduct a right circling descent near the approach corridor of runway 23. Initially, the MP requested a circling descent directly over the field, but ATC requested that he circle over the final approach corridor in order to allow the MP to conduct a straight-in final after descent. The MP accepted ATC's recommendation and circled down to 6,600 ft AFE. ATC asked the MP if their engine had failed. The MP responded, "We still have control of the engine, but engine failure is imminent, we would like to stay higher if possible." Shortly after this, ATC made a radio call for all aircraft in the airspace: "…OK gentlemen emergency inbound I'm gonna need to put everyone in holding, let's do this. [Callsign] proceed to [holding point], maintain one zero thousand need you to climb back up to 10 and hold at [holding point]." (Tab N-7). During this call, the MP moved the throttle to idle and started a descent at 70 KIAS. The MP stayed between 2 and 5 nm from the airfield over the approach corridor.

At 0852Z, the MP and MSO both turned on and configured their GPS Landing System (GLS). As the MRPA passed through 13,900 ft AFE, at 0854Z, the MC attempted to analyze the engine indications with a maintenance person who had entered the GCS. The MC explained that, prior to assuming control, the MCE crew turned the engine cooling fan on, but some of the engine temperatures increased beyond limits, causing them to turn off the fan. At 0858Z, after getting approval from the MP, the MSO used the sensor ball to visually inspect the aft portion of the MRPA, but no abnormalities were observed. (Tab N-7,8).

At the same time, 0854Z, ATC notified the MC that traffic would not be a factor and instructed the MC to proceed over KAF rather than orbit above the approach corridor. The MP flew the MRPA to an orbit over runway 23. (Tab N-8).

As the MRPA descended through 11,400 ft AFE, at 0900Z, the MSO reported to the MP that the CHTs were "getting better", oil temperature was steady, and exhaust gas temperatures (EGT) were starting to drop toward the lower limit. Approximately 2 minutes later, the MP reported that the turbocharger oil temperature started to decrease, CHTs started to increase yet remained low, oil temperature remained high, and oil pressure was low. The MP called for the low oil pressure, high oil temperature, and engine overheat checklists, but directed the MSO to start with the low oil pressure checklist. The MC did the necessary steps to complete all checklists. Once the MC determined they had covered all applicable checklists, the MSO had the engine failure checklist ready to allow for quick reference should the engine fail. (Tab N-8).

At 0908Z, while the MRPA descended past 7,600 ft AFE, the MP said the following to the MSO, "Alright so we have the gear up, we're going to keep it up until we know we definitely have the runway made, not going to put it down, we don't want to put anymore strain on the engine, and we are just going to keep circling, on 360 is about..." (Tab N-9). The MSO interrupted the MP at this point, commenting that the EGTs were about to fail. The MP acknowledged his comment, but continued his briefing. Then the MSO said, "It might be because you're at idle. EGTs. Shouldn't be that low though, right? Is that the lowest it has dropped?" The MP replied "Coolants coming up. See if I can get the coolants to come up with more power. Looks like these things are getting better." The MSO responded that EGTs were not improving; the oil pressure stayed low, engine oil and CHT stayed high. The turbocharger oil temperature was also high, but started to decrease. (Tab N-9). Post-crash analysis of the engine data log indicates the engine failed at 0908Z. (Tab U-156,163). Although the engine failed, the propeller was windmilling. Because the propeller was windmilling, some engine indications remained normal. However, the EGTs dropped to a point that indicated engine failure. The MC failed to recognize the engine had failed. (Tabs N-9,10, U-163).

At 0909Z, ATC was coordinating with another aircraft regarding holding delay. The pilot in the other aircraft reported that he was at minimum fuel with 30 minutes of fuel remaining. At this time, as the MRPA descended past 6,900 ft AFE, ATC said, "OK, is there any way that you can increase that rate of descent 'cause these guys are getting a little tight on fuel for me?" The MP responded, "We can do that." ATC then stated, "I need your best rate all the way down." (Tab DD-5). The MP extended the landing gear and increased the airspeed to 80 KIAS. This resulted in a descent rate of approximately 900-1400 ft per minute (FPM) compared to approximately 300-600 FPM before complying with ATC's request. The MP made the comment, "Nine thousand five hundred. Get the speed up here; definitely want to get down here before these guys run out of fuel, that's for sure." (Tab N-9). Using the sensor ball, the MC visually inspected the gear and confirmed that it was down and locked. The MC executed all normal checklists necessary for landing.

At 0912Z, according to the HUD video, the MRPA was over the runway at 4412 ft AFE, 78 KIAS, descending at 1330 FPM. After approximately 14 seconds, the MP commanded a right turn to start the engine-out pattern for landing. A standard engine-out pattern is depicted in the flight manual. (Tab BB-30). Once passing 3,600 ft AFE, ATC directed the MC to call KAF tower. After initial contact with tower, tower reported winds coming from 280° at 7 knots and cleared the MC to land on runway 23. The MC acknowledged the call and continued their descent. (Tab N-9).

Based on HUD video, the MP flew a downwind leg that was 1.6 miles from the runway while descending through 3392 ft AFE. At 0914Z, after turning right to 096°, the MP depressed the Landing Configuration button in order to disengage all autopilot hold modes. The MP continued to a point 1.8 miles from the threshold before beginning a gradual turn back towards the runway. At this point, the MRPA was at 1,320 ft AFE with an average descent rate of approximately 1,075 FPM and an average airspeed of 75 KIAS.

At 0915Z, the MP made three additional right turns to a heading of 175°. At this point, the MRPA descended past 1,002 ft AFE at 73 KIAS and was 1.6 nm from the runway threshold.

Approximately 8 seconds later, while maintaining 175°, the MP turned the MRPA to an approximate heading of 170° and overshot the runway centerline by 1350 ft at 1.5 miles from the threshold and 900 ft AFE. At 1 mile from the threshold, the MSO commented "little low…slow". (Tab N-10). The MP moved the throttle from the idle position to maximum power with no response from the failed engine. (Tab U-157). The pilot began slowing the MRPA to 57 knots. The engine RPM slowly decreased and the manifold air pressure (MAP) slowly increased. The RPM fell below the minimum for the alternators to provide electrical power as indicated by the appearance of the battery indicator on the upper left-hand corner of the HUD. At 0916Z, the MRPA crashed 0.5 nm short of the runway. (Tab S-3).

Engineers for GA, the MPRA's manufacturer, conducted a post-mishap analysis of the engine. They asserted that the MRPA's engine caught fire some time during the recovery, but could not determine when the engine fire occurred. (Tab U-164).

e. Impact

At 0916Z, 0.5 miles from the runway, the MRPA clipped the top of the airfield perimeter fence then impacted the ground. The MRPA was carrying one AGM-114 Hellfire missile and a wing pod. One second prior to impact, the MRPA's gear was down, airspeed was 62 KIAS, pitch was 4° nose up, descent rate was 712 FPM, and heading was 239°. See Tab S for crash photographs.

f. Life Support Equipment, Egress and Survival

Not applicable.

g. Search and Rescue

Not applicable.

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

(1) General Definitions

Each Air Force aircraft and GCS has its own set of written and electronic maintenance records used to document routine scheduled, as well as unscheduled (e.g., flight or ground reported discrepancies) maintenance. These maintenance actions are documented in writing in the Air Force Technical Order (AFTO) 781 forms and the electronically based Integrated Maintenance Data System (IMDS). In addition to capturing historical data, these documents provide an avenue to more effectively troubleshoot and resolve new or recurring maintenance discrepancies.

Time Compliance Technical Orders (TCTO) are system changes, usually parts upgrades, with a specific required completion date. A TCTO may also direct inspections or adjustments to equipment of parts already attached to the aircraft or ground support items. TCTOs may be immediate, urgent or routine, based on the severity of the issue. Time change items (TCIs) are routine maintenance actions in which components are removed and replaced for overhaul at a given number of flight hours.

(2) General Documentation Reviewed

Maintenance activities for the MRPA and the LRE GCS, serial number 6109 were performed by Battlespace Flight Services, LLC (BFS), a contracted maintenance support company. A thorough review of IMDS documentation was conducted. This review reflected maintenance conducted 90 days prior to the mishap. The 90-day aircraft maintenance history revealed one recurring maintenance problem. On 27 April 2011, the aircraft would not produce the required manifold air pressure (MAP). As a result, maintenance personnel replaced the manifold charge temperature sensors. On 28 April 2011, the turbocharger failed to produce the required MAP again and the turbocharger was replaced. From 29 April to 4 May 2011, three engine runs and two flights were accomplished with no recurrences of the MAP discrepancy. The MAP discrepancy was not a factor in the accident. Also of note, the aircraft had a CHT split discrepancy on 1 May 2011. Contract maintainers drained the engine coolant system and changed the engine coolant temperature (ECT) sensor. Excluding routine servicing, this was the last maintenance accomplished on the engine coolant system.

A review of the AFTO 781 series forms was conducted and four documentation errors were found. On 30 April 2011, following an ECT sensor replacement, an engine coolant pressure check was required but there is no documentation this task was completed. Without proper documentation, there is no evidence that the engine coolant pressure check was accomplished. There were no other engine coolant pressure checks required or accomplished prior to the mishap. It was not possible to determine if this error contributed to the accident. The other three errors did not contribute to the accident. (Tab D-28). A thorough review of all TCTOs, TCIs and special inspections was accomplished and none were overdue at the time of the mishap. There were four delayed discrepancies annotated in the 781Ks and none of these were a factor in the mishap. (Tab U-5).

b. Inspections

(1) Mishap Aircraft

All scheduled inspections were accomplished within scheduled time limits to include the preflight. There were no overdue aircraft TCTOs. The next scheduled aircraft inspection was a 60-hour inspection for the aircraft engine. The last 150-hour airframe phase inspection was accomplished on 24 April 2011, with 70 hours remaining until the next phase inspection. Scheduled inspections on the MRPA were not a factor in this mishap. (Tab U-5).

(2) Mishap GCS

Aeronautical Service Center/WII Detachment 3 performed an analysis using data logs of the MCE and LRE GCSs. The logs from the flight were reviewed with emphasis on determining if the GCSs were functioning correctly. The analysis indicated the MRPA was following pilot commands and the data link did not experience any significant signal loss during the return to base. Based on the engineering analysis, both GCSs were returned to service. (Tab U-11). Scheduled inspections on the MCE and LRE GCSs were not a factor in this mishap.

(3) Mishap Engine

The Predator RPA requires engine inspections every 60, 360 and 720 flight hours. All scheduled engine inspections were completed on time and there were no overdue inspections or modifications. The engine had not flown since the last scheduled 60-hour engine inspection. The engine was installed on 21 April 2011 with 719 hours previously flown on another aircraft. At the time of the mishap, the engine had flown for 851 of its 1,080-hour operational life. The scheduled inspections on the engine were not a factor in this mishap. (U-5).

c. Maintenance Procedures

Based on a review of 90 days of aircraft maintenance history, 3 weeks of aircraft forms, 13 training records, and 8 witness interviews, it is evident BFS has a highly qualified work force. However, seven of eight BFS employees interviewed acknowledged an unauthorized method used to drain the engine coolant fluid. Technical Order (T.O.) 1Q-1(M)B-2-72-50-1 directs draining of the coolant system via the coolant drain screw on the bottom of the water pump. (Tab BB-24). The AIB determined through witness interviews that it is common practice to drain the engine coolant system by disconnecting the line attached to the coolant feed elbow at cylinder one or two. (Tab V-96,103,109,114,123) All other maintenance procedures investigated were completed in accordance with applicable T.O. and Air Force Instructions (AFIs). It could not be determined if the unauthorized maintenance procedure of draining the engine coolant system was a factor in this mishap. Maintenance procedures for the GCSs were not a factor in this mishap.

d. Maintenance Personnel and Supervision

A review of BFS training records and the special certification roster indicate all relevant employees were trained, experienced, and/or certified to complete the assigned task. Aircraft maintenance records and statements provided by BFS indicated all maintenance activities were normal with the following exceptions: 1) an unauthorized method of draining the engine coolant system was preferred and commonly practiced. (Tabs V-96,103,109-110,114-115,123,133, BB-24); 2) a required engine coolant system pressure check was required but not documented. (Tab D-28). All individual training records reviewed and interviews conducted indicated maintenance personnel involved were trained and qualified. Although an unauthorized method for draining the engine coolant system and lack of documentation of a required engine coolant pressure check was discovered, it could not be determined that maintenance personnel and supervision were a factor in the mishap.

e. Fuel, Coolant and Oil Inspection Analysis

The documented forms confirmed correct levels of fluids in the MRPA at takeoff (Tab U-4). Maintenance personnel properly serviced fuel, coolant and oil levels IAW technical data. An oil sample was submitted to Wright-Patterson AFB for analysis (Tab J-3). The scan was that of a typical SR-5 lube with no anomalous volatile contamination (Tab U-160). Fuel and coolant samples were unavailable for analysis. There was no evidence that improper servicing or contaminated fuel, coolant or engine oil was a factor in the mishap.

f. Unscheduled Maintenance

A review of the unscheduled maintenance actions revealed the following discrepancies and corrective actions:

5 May 2011 – Left brake requires adjustment; left break adjusted

This maintenance was not a factor in the mishap

3 May 2011 – Multiple gimbal disconnect errors; recycled power

This maintenance was not a factor in the mishap

2 May 2011 – (Redacted) inoperable; this system is not required for flight and not repaired

This maintenance was not a factor in the mishap

2 May 2011 – Cowl flap servo bushing worn; replaced cowl flap servo arm

This maintenance was not a factor in the mishap

1 May 2011 – Cylinder head temperature split; replaced engine coolant temperature sensor

Draining of the engine coolant system is required when replacing the ECT sensor IAW T.O. 1Q-1(M)B-2-72JG-20-1. (Tab BB-3). T.O. 1Q-1(M)B-2-72-50-1 directs draining of the coolant system via the coolant drain screw on the bottom of the water pump. (Tab BB-24). On 1 May 2011, a BFS employee drained the engine coolant system by disconnecting an engine coolant line instead of the coolant drain screw; however, the BFS employee could not remember which line he disconnected. (Tab V-122,123). An engine coolant pressure check was required IAW T.O. 1Q-1(M)B-2-72-50-1 following the draining of the engine coolant system and was not documented in aircraft forms. (Tabs D-28, BB-22). Without proper documentation, there is no evidence that the engine coolant pressure check was accomplished. There were no other engine coolant pressure checks required or accomplished prior to the accident.

6. AIRCRAFT AND AIRFRAME

Condition of System

(1) Engine

The MRPA experienced an engine failure due to an engine coolant leak and subsequent engine overheat. All cylinder heads experienced deformation due to the overheat condition and cylinder number one head was no longer flush with the head cover in the lower aft corner. The resulting gap allowed a small amount of oil to leak out and ignite, resulting in a fire damage that caused damage to cylinder one and three side of the engine. The intake and exhaust valves of the cylinders showed evidence of warping. The coolant leak location could not be definitively determined due to fire damage.

Engineering Evaluations, Analysis, and Reports

(2) Engine Teardown Analysis

The engine was disassembled by powerplant technicians at a GA test facility in El Mirage, CA. The engine teardown indicated that the engine experienced significant overheating. There was evidence that all four cylinder heads, intake valves, exhaust valves and piston heads had deformed. The heat required to deform these components was the result of an inability of the engine to be adequately cooled by the coolant and oil systems. GA analysis determined the fire that occurred on the cylinder one and three side of the engine was most likely a result of the engine overheating. (Tab U-159).

According to the GA report, the seals on the coolant return elbows were brittle and some were cracked. The torque stripe on the screws that mated the coolant return elbows to the cylinder heads was black. The torque strip on the flange for the air intake, a few inches away, remained yellow. These factors are evidence of excessive heat on coolant system components. (Tab U-159).

During manufacturer post-accident analysis, the coolant system was pressurized and the coolant feed lines to cylinder one and two were observed to leak at normal operating pressure where the coolant feed elbow mated to the lower side of the cylinder heads. Although the specific location of a coolant leak was not definitively identified during the engine teardown, the GA analysis determined the leak most likely occurred where the coolant feed elbows were inserted into cylinder one or two. Furthermore, GA determined it is more likely the coolant leaked from the cylinder one coolant feed elbow since heat damage to cylinder one was greater. The coolant feed elbows were glued into the bottom of the cylinder heads with a Loctite-like compound. The manufacturer determined it is possible that one of the connections became compromised due to a weak bond or maintenance actions. It is also possible that the mishap overheat condition and subsequent fire compromised the seal; however, cylinder three and four did not leak during the pressure check and were exposed to the same overheat condition. (Tab U-164,165).

During GA analysis, the crank case was pressurized to normal operating pressure and the cylinder one head cover leaked air from the lower aft corner. A gap between the head cover and the cylinder head was visible due to warping of the cylinder head. There was evidence that the engine was exposed to fire on the cylinder one and three side. The fire damage appeared to be the result of an oil fire. According to GA analysis, the oil most likely leaked from the deformed cylinder one head that was no longer flush with the cylinder head cover. A spark would not have been required to ignite the leaking oil, due to the high heat of the engine. (Tab U-164).

A leak-down check was performed by GA on all cylinders. Cylinders one through four had 18%, 14%, 12%, and 8% leakage, respectively. The valves in some cylinder heads were visibly warped and unable to completely seal, as tested by pouring alcohol in the top and examining the underside. After the engine overheated and the valves warped, cylinder combustion was free to escape. GA determined that this is the most likely cause of the engine-out condition. Cylinder one had the most leakage of any cylinder. The valves on cylinder one were also the most affected by the fire as the oil from cylinder one was the source of fuel. (Tab U-160,165).

The pistons and piston rings did not show any significant signs of damage. The lifters were clean and there was no evidence of debris in the lifter bore. The engine had not seized and was able to be turned by hand before disassembly. The fact that there were no significant mechanical failures is an indication that the engine did not experience a lack of oil or poor lubrication. According to GA analysis, insufficient oil volume or a blockage of the oil system would have resulted in an engine temperature increase due to friction and the effects of the increased friction would have been evident during the teardown. (Tab U-163,164).

The coolant reservoir was pressurized and no leaks were detected. The coolant reservoir cap released at the correct pressure. (Tab U-160).

(3) Data Logger Analyses

There were several anomalous oil and coolant-related parameters during the final 30 minutes of the MCE datalogs. The signals that first indicated a trend from the norm during the flight were coolant temperature, oil temperature, and oil pressure. (Tab U-161).

The coolant temperature began to oscillate, with the coolant temperature decreases correlating to the engine fan electrical current and cowl flap opening. The coolant temperature had been maintaining approximately 175°F, but began to range from ~110° F to ~210° F. The widely fluctuating coolant temperature values, which corresponded to the increasing CHT values indicated that there was insufficient coolant in the coolant system. As the cowl opened and the engine fan was enabled, the coolant temperature sensor indicated a dramatic response. GA determined this was most likely due to the coolant thermal mass having been lost and the coolant sensor measuring air temperature in the coolant system. (Tab U-161).

The oil temperature increased from 245° F to ~325° F. The temperature was increasing in a sawtooth-like pattern once the temperature exceeded ~250°. The oil temperature increased along with the manifold charge temperature increase and did not appear to be dramatically influenced by cowl flap or engine fan activity, which, according to GA, indicates oil was still present in the system. (Tab U-161).

The oil pressure decreased from 49 psi to ~25 psi. The oil pressure is measured after the oil passes through the engine block and immediately before it flows to the turbocharger. The low oil pressure values were an indication of low oil pressure at any point along the oil path between the reservoir and the turbocharger. According to GA, the low oil pressure was most likely the result of increased oil temperature. (Tab U-161).

The oil level began to increase at the end of the MCE datalogs and had risen to 100% prior to the handover to the LRE. After the engine stopped firing, the oil pump continued to operate, as it was mechanically driven by the windmilling propeller, and the oil level sensor again reported a decrease. The fact that the oil level sensor reported an increase to 100% and subsequent decrease indicates that the oil path was not obstructed and a significant loss of oil had not occurred. (Tab U-161).

The CHT sensor reported a 200° F increase to ~390° F, which correlated to a period when the coolant temperature was widely fluctuating (+/-100 deg F). As the CHT value increased to ~300 deg F, the oil pressure decreased quickly and the oil level increased to 100%. After the CHT sensor reported a value of ~390 deg F, the reported temperature instantly decreased to below 0° F, which, according to GA, indicates the sensor failed. (Tab U-162).

While the oil system provided lubrication and cooling for the engine, the engine bay cooling fan and cowl flap also provided cooling for the engine. The engine fan and cowl flap were operated automatically. According to GA, they appeared to be effectively reducing the coolant temperature reading and were not contributing factors in the anomaly. (Tab U-161).

The engine ignition system was energized at all times, indicating no ignition anomalies. (Tab U-157).

The MRPA was responding to pilot input prior to and during the period of anomalous oil and coolant system performance, and the datalink did not experience any significant signal loss during the return to base. (Tab U-165).

7. WEATHER

a. Forecast Weather

The MEF for KAF, after 0800Z on 5 May 2011 listed scattered clouds at 12,000 ft AGL, visibility of 4800 meters, blowing dust, temperature at 31°C or 88°F, pressure altitude of 3,485 ft, and winds coming from a 260° direction at 15 gusting to 25 knots, with a crosswind component of 12 knots. The satellite picture showed no significant cloud buildup over the airfield. (Tab F-2,4).

b. Observed Weather

Automatic Terminal Information Service (ATIS) for KAF: Runway in use was 23, winds came from 300° at 5 knots, skies were clear of clouds, visibility was greater than 9000 meters, temperature was 31°C, dew point was 1°C, and altimeter setting was 29.86 in. Hg. (Tab DD-5).

KAF tower report of the winds: 280° at 7 knots. (Tab N-9).

8. CREW QUALIFICATIONS

a. Mishap Pilot

(1) Training

The MP has been a qualified pilot of the MQ-1B since 9 July 2010. The MP qualified for LR on 31 March 2011. The summary of the MP's initial training for the MQ-1B revealed the MP's performance as below average during the flying portion, average during the simulator portion, and above average during the academic portion of training. The MP struggled with basic aircraft handling, airspace management, and task prioritization. (Tab G-9).

During his LR training, the MP was placed on the Commander's Awareness Program (CAP) status because he failed two simulator events and one flying event. In this case, CAP emphasized more instructor continuity and steady training. The MP struggled with emergency procedures analysis and execution. Also, his training reports indicated that he struggled with speeding up his instrument crosscheck. A Training Review Board was convened regarding MP's performance after failing an additional LR flying event. The MP's 18 RS commander attended this board. The board decided to give the MP one extra simulator training session and one flight training event. Moreover, even though the MP struggled through the course, leadership documented that he displayed a great attitude and a motivation to improve. (Tab G-106).

Despite his training deficiencies, the MP passed his evaluations, both his initial and LR qualification. Therefore, he was considered a qualified MQ-1B pilot and cleared to fly unsupervised. (Tab G-4,5).

(2) Experience

The MP's aeronautical rating is Pilot. Based on his 385.7 total hours, the MP was considered an inexperienced pilot. The MP had no prior major weapon system experience. His first assignment following undergraduate pilot training (UPT) was flying the MQ-1B at Creech AFB, NV. The MP's flight time during the last 90 days prior to the mishap is as follows: (Tab G-12).

Flight Period	Total Hours	Days Flown
Last 30 days	9.5	7
Last 60 days	30.1	17
Last 90 days	51.1	27

(3) Currency

The MP was current to fly a LR sortie on the day of the mishap. He appropriately signed off all relevant grounding items prior to the sortie. (Tab K-4). The MP accomplished the necessary flying events to maintain LR currency IAW AFI 11-2MQ-1, Volume 1, *MQ-1 Aircrew Training*, 21 January 2010. (Tab T-3,4)

b. Mishap Sensor

(1) Training

The MSO has been a qualified sensor operator on the MQ-1B since 15 July 2009. He qualified as an LR sensor operator on 1 March 2011. After completing initial qualification for the MQ-1B, the MSO's training summary indicated that his performance was average during the mission phase, average during the transition phase, and above average during the academic phase. LR instructors considered the MSO's LR training progression to be average. The MSO didn't display any alarming deficiencies throughout his LR training. The MSO passed his initial qualification, annual, and LR evaluations. (Tab G-31,32).

(2) Experience

The MSO flew a total of 676.5 hours prior to the mishap. Thus, the MSO was considered an experienced sensor operator. The MSO's flight time during the last 90 days prior to the mishap is as follows: (Tab G-38).

Flight Period	Total Hours	Days Flown
Last 30 days	39.1	23
Last 60 days	43.1	25
Last 90 days	49.3	29

(3) Currency

The MSO was current to fly an LR sortie on the day of the mishap. He appropriately signed off all relevant grounding items prior to the sortie. (Tab K-4) The MSO accomplished the necessary flying events to maintain LR currency in accordance with AFI 11-2MQ-1, Volume 1. (Tab T- 5-16)

9. MEDICAL

Qualifications

At the time of the mishap, the MC was medically qualified for flight duty. (Tab CC-3)

Health

A review was accomplished of the Armed Forces Health Longitudinal Technology Application, the Department of Defense electronic medical record system. Preventive Health Assessments were current for the MC. A review of the MC's post accident medical examination records was conducted and the results appeared non-related to the accident. The MC's 72-hour and 14-day histories and the MSO's testimony revealed no erratic sleep patterns, unusual eating habits, or significant stressors. (Tabs V-39,40, CC-3).

Pathology

Immediately following the mishap, toxicology testing was ordered by command for MC. Blood and urine samples were submitted to the Armed Forces Medical Examiner System (AFMES) for toxicological analysis. This testing included ethanol levels in the blood and urine. (Tab CC-3).

No ethanol was detected for the MC. (Tab CC-3).

AFMES performed a urine screen for amphetamine, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates and phencyclidine by immunoassay (or chromatography).

None of these drugs were detected. (Tab CC-3).

Lifestyle

There is no evidence that unusual habits, behavior, or stress on the part of the aircrew members contributed to this accident.

Crew Rest and Crew Duty Time

Air Force Instructions require pilots to have proper "crew rest," as defined in AFI 11-202, Volume 3, *General Flight Rules*, 22 October 2010, prior to performing in-flight duties. AFI 11-202 defines normal crew rest as a minimum 12-hour no-duty period before the designated flight duty period (FDP) begins. During this time, an aircrew member may participate in meals, transportation or rest as long as he or she has the opportunity for at least eight hours of uninterrupted sleep.

Crew rest and duty time were not factors in this mishap.

10. OPERATIONS AND SUPERVISION

a. Operations Tempo

During the day of the mishap, operations tempo for both MP and MSO was higher than normal for the 62 ERS. The MC completed four launches and one landing prior to the mishap on 5 May. Additionally, another LRE crew was handling an emergency aircraft. Therefore, two LRE crews, including the MC, were handling emergencies, and the Director of Operations (DO) flew a MQ-9 LR event during the time of the mishap. (Tab V-66, 68).

b. Supervision

For daily LR operations, an Ops Sup, accountable to the DO, oversees the execution of LR events and coordinates with appropriate higher agencies regarding any deviations to the LR schedule. There was an Ops Sup on shift during the mishap. However, the Ops Sup was in the process of doing a shift change. The incoming Ops Sup was on shift for approximately five minutes before she was made aware that the MC was flying an emergency aircraft with an impending engine failure. By the time the Ops Sup entered the GCS occupied by the MC, the MRPA was gliding on the final approach phase of flight. As a result, the Ops Sup arrived too late to be of any assistance. Moreover, the DO was flying at the time of the mishap. (Tab V-66, 67).

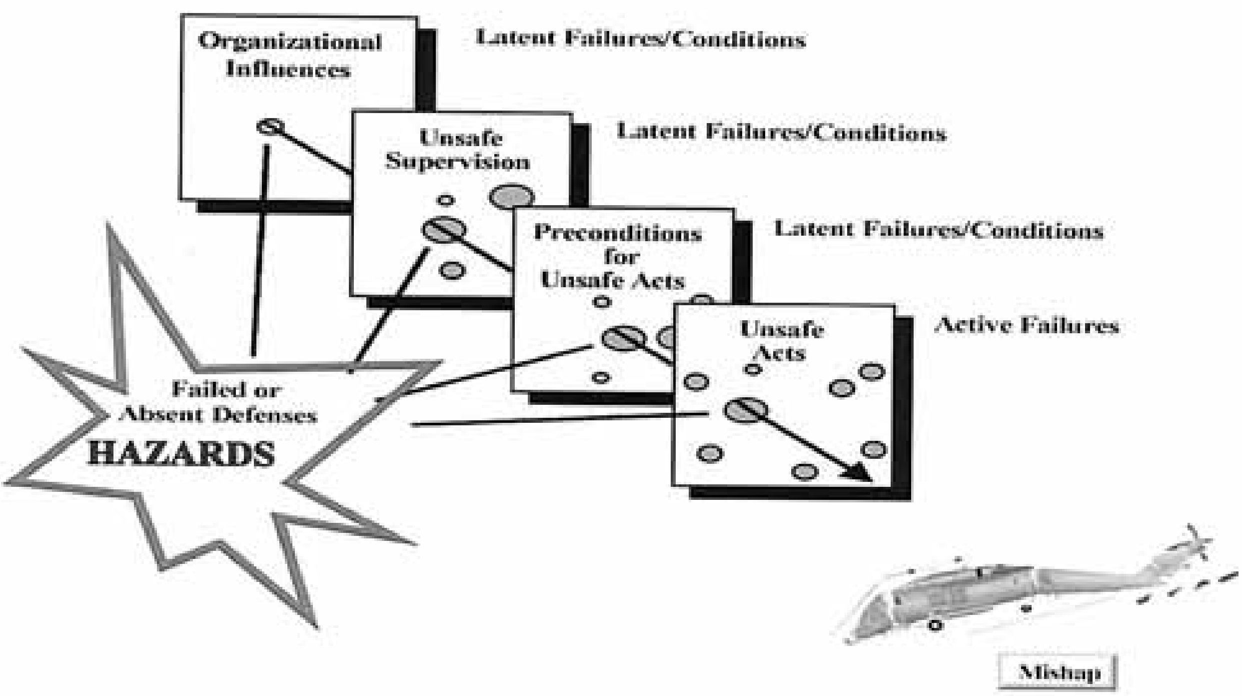
A safety observer was encouraged, but not required to be present in the GCS to assist a LRE crew during an emergency situation. On the day of the mishap, the Ops Sup would have acted as a safety observer; however, she arrived too late to help. (Tab V-67).

11.HUMAN FACTORS ANALYSIS

a. Overview

A DoD taxonomy was developed to identify hazards and risks, called the DoD Human Factors Analysis and Classification System (DOD-HFACS). DOD-HFACS describes four main tiers of failures/conditions: **1) Acts 2) Preconditions 3) Supervision and 4) Organizational Influences**.

The investigation process endeavors to detect and identify failed or absent defenses (hazards), which can be visually depicted by the "Swiss Cheese" model (adapted from Reason, 1990), as seen below:



After reviewing the facts from the investigation, including witness testimony, human factors found to be relevant to this mishap are enumerated below. Also included are the DoD-HFACS taxonomy (or "nanocodes") for reference.

Acts are those factors that are most closely tied to the mishap, and can be described as active failures or actions committed by the operator that result in human error or unsafe situation.

Errors (AExxx) are factors in a mishap when mental or physical activities of the operator fail to achieve their intended outcome as a result of skill-based, perceptual, or judgment and decision making errors leading to an unsafe situation. Errors are unintended.

Skill-Based Errors (AE1xx) are factors in a mishap when errors occur in the operator's execution of a routine, highly practiced task relating to procedure, training or proficiency and result in an unsafe a situation.

AE103 Procedural Error is a factor when a procedure is accomplished in the wrong sequence or using the wrong technique or when the wrong control or switch is used. This also captures errors in navigation, calculation or operation of automated systems.

The MP committed procedural errors and used faulty technique during descent. Based on HUD video, the MP performed a non-standard engine-out recovery, initiating the maneuver 2,100 ft above the flight manual recommended altitude. (Tab BB-30) He intentionally flew an extended pattern in an attempt to lose the extra altitude while maintaining 70-80 knots. (Tab R-13) For the weight of the aircraft in this case, the flight manual recommended airspeed for an engine-out recovery was 67 knots. (Tab BB-29) Based on HUD video, this increase in airspeed resulted in an average vertical velocity of 1,075 FPM through the last four minutes of the flight. The MP flew the MRPA to a point 1.8 miles from the runway 23 threshold before back towards the runway, extending .8 miles beyond the recommended distance from threshold. In a post-mishap statement, the pilot wrote that he extended the downwind leg in attempt to lose excess altitude. (Tab R-13) However, during the descent, the MP also maintained a high rate of descent. The combination of a high rate of descent and the extended pattern placed the MRPA in an altitude/distance scenario which precluded the possibility of an on-airfield landing absent a functioning engine.

In addition, the MP failed to use all information available to maintain situational awareness during the recovery. A tracker display is available to the pilot with various zoom levels. This display can be adjusted to depict the aircraft in relation to the flight manual recommended engine-out recovery pattern. However, no procedural requirement exists to adjust the tracker to display the pattern. In this case, the MP did not adjust the zoom level of the tracker to display the pattern, which increased workload during the engine-out recovery. (Tab V-164) This also led to a loss of situational awareness while the pilot was attempting to intercept the final approach course, which caused the overshoot of final.

Judgment and Decision Making Errors (AE2xx) are factors in a mishap when behavior or actions of the individual proceed as intended yet the chosen plan proves inadequate to achieve the desired end-state and results in an unsafe situation.

AE206 Decision-Making During Operation is a factor when the individual through faulty logic selects the wrong course of action in a time-constrained environment.

According to HUD video, the MP initiated the final orbit of the engine-out recovery 2,100 ft high, rather than maneuver the MRPA prior to the final orbit so as to arrive at the high key position at the flight manual recommended altitude for an engine-out recovery. (Tab BB-30) This decision required him to make calculations during a critical phase of flight.

Preconditions are factors in a mishap if active and/or latent preconditions, such as conditions of the operators, environmental, or personnel factors, affect practices, conditions or actions of individuals and result in human error or an unsafe situation.

Technological Environment (PE2xx) is a factor in a mishap when cockpit/vehicle/control station/workspace design factors or automation affect the actions of individuals and result in human error or an unsafe situation.

PE202 Instrumentation and Sensory Feedback Systems is a factor when instrument factors such as design, reliability, lighting, location, symbology or size are inadequate and create an unsafe situation. This includes night vision devices, HUD, off-bore-site and helmet-mounted display systems and inadequacies in auditory or tactile situational awareness or warning systems such as aural voice warnings or stick shakers.

RPA pilots and sensor operators remotely aviate and navigate the aircraft from inside a GCS and do not have auditory cues such as engine noise. The absence of this auditory cue inhibited the crew's detection of the engine failure situation. The lack of auditory input removed an auditory cue a manned aircraft crew possesses. Engine noise, in combination with instrumentation, may have significantly aided the MRPA crew's identification of the engine failure.

Condition of Individuals is a factor in a mishap if cognitive, psycho-behavioral, adverse physical state or physical/mental limitations affect practices, conditions or actions of individuals and result in human error or an unsafe situation.

Cognitive Factors (PC1xx) are factors in a mishap if cognitive or attention management conditions affect the perception or performance of individuals and result in human error or an unsafe situation.

PC104 Confusion is a factor when the individual is unable to maintain a cohesive and orderly awareness of events and required actions and experiences a state characterized by bewilderment, lack of clear thinking, or (sometimes) perceptual disorientation.

The MP was confused during the MRPA recovery, misjudging the size of the pattern and descent rate needed to successfully complete the engine-out recovery.

12.GOVERNING DIRECTIVES AND PUBLICATIONS

Primary Operations Directives and Publications

1. AFI 11-2MQ-1, Volume 1, MQ-1 Aircrew Training, 21 January 2010 available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**
2. AFI 11-2MQ-1, Volume 2, MQ-1 Crew Evaluation Criteria, 28 November 2008 available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**
3. AFI 11-2MQ-1, Volume 3, MQ-1 Operations Procedures, 29 November 2007 available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**
4. AFI 11-202, Volume 3, General Flight Rules, 22 October 2010 available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**
5. AFI 11-401, Aviation Management, 10 December 2010 available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**
6. AFI 11-418, Operations Supervision, 21 October 2005, incorporating Change 1, 20 March 2007 available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**
7. T.O. 1Q-1(M)B-1, USAF Series MQ-1B and RQ-1B Systems, 1 November 2003, incorporating Change 13, 8 April 2009
8. T.O. 1Q-1(M)B-1CL-1, USAF Series MQ-1B and RQ-1B Systems Flight Checklist, 1 November 2003, incorporating Change 15, 8 April 2009
9. AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010 available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**
10. AFI 91-204, *Safety Investigations and Reports*, 24 Sept 2008 available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**

Maintenance Directives and Publications

1. AFI 21-101, Aircraft and Equipment Maintenance Management, 26 July 2010, available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**
2. T.O. 00-20-1, Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures, 30 April 2003, incorporating Change 4, 1 September 2006, available digitally on the Tinker AFB internet site at: **http://www.tinker.af.mil/technicalorders/index.asp**
3. 1Q-1(M)B-2-72JG-20-1, MQ-1B Technical Manual, Aircraft Scheduled Inspection and Maintenance Requirements, 21 January 2010

4. 1Q-1(M)B-2-72JG-20-1, MQ-1B Job Guide, Engine Reciprocating, Ignition, Indicating and Starting, 8 June 2010
5. 1Q-1(M)B-2-72JG-50-1, MQ-1B Job Guide, Engine Reciprocating, Cooling and Lubrication, 8 June 2010

Known or Suspected Deviations from Directives or Publications

(1) On 1 May 2011, a BFS employee drained the engine coolant system by disconnecting an engine coolant line instead of the coolant drain screw. (Tab V-122). T.O. 1Q-1(M)B-2-72-50-1 directs draining of the coolant system via the coolant drain screw on the bottom of the water pump. (Tab BB-24). The employee could not remember which line he disconnected to drain the system. There are coolant lines to and from the radiator and coolant lines between the water pump and the cylinder heads. Per the manufacturer, disconnecting the coolant lines attached to the cylinder heads for the purpose of draining the coolant system can weaken the bond of the elbow-to-cylinder head connection and cause a coolant leak.

(2) On 1 May 2011, the engine coolant was drained prior to installing an ECT sensor. The follow-on maintenance for draining the engine coolant IAW T.O. 1Q-1(M)B-2-72-50-1 is to perform a cooling system pressure check. (Tab BB-22). This follow-on maintenance was not documented and signed off in the AFTO 781 forms as being accomplished. Without proper documentation, there is no evidence that the engine cooling system pressure check was accomplished. If the cooling system pressure check was not accomplished, potential leaks in the engine coolant system would not be identified and corrected.

(3) Seven of eight BFS employees interviewed acknowledged an unauthorized method used to drain the engine coolant fluid. (Tab V-96,103,109-110,114-115,123,133). T.O. 1Q-1(M)B-2-72-50-1 directs draining of the coolant system via the coolant drain screw on the bottom of the water pump. (Tab BB-24). The unauthorized method drains the engine coolant system by disconnecting an engine coolant line instead of the coolant drain screw. Per the manufacturer, disconnecting the coolant lines attached to the coolant feed elbows for the purpose of draining the coolant system can weaken the bond of the elbow-to-cylinder head connection and cause a coolant leak.

13. ADDITIONAL AREAS OF CONCERN

Not applicable.

STATEMENT OF OPINION

AIRCRAFT ACCIDENT INVESTIGATION
MQ-1B PREDATOR, T/N 07-3182
KANDAHAR AIRFIELD, AFGHANISTAN
5 May 2011

Under 10 U.S.C. 2254(d), any opinion of the accident investigators as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report, if any, may not be considered as evidence in any civil or criminal proceeding arising from the accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.

1. OPINION SUMMARY

I find by clear and convincing evidence that there were two causes of the mishap. First, a coolant system failure resulted in an engine failure. Second, the mishap pilot (MP) failed to properly execute a successful engine-out recovery, causing the aircraft to crash prior to the runway. In addition, I find by a preponderance of the evidence that a leak at the coolant feed elbow on the number one cylinder substantially contributed to the mishap.

After receiving the mishap remotely piloted aircraft (MPRA), the MP flew it towards Kandahar Airfield and began a circling descent over the airfield. While descending, at 7,600 ft above field elevation (AFE), the engine failed and the propeller began windmilling. The engine failure was due to a loss of coolant and subsequent overheat. The mishap crew (MC), acting as the LRE, failed to properly analyze the engine indications as an engine failure. The MP began the final orbit over the threshold of runway 23, at 4300 ft AFE. This is 2,100 ft above the flight manual recommended altitude for an engine-out recovery with a windmilling propeller. The MP intentionally delayed the turn back towards the runway in order to lose the excess altitude while maintaining 80 knots, instead of the best glide speed of 67 knots, as directed in the flight manual for an engine-out recovery. The MP misjudged the size of the pattern required to lose the extra altitude and did not turn towards the runway until the MRPA was 1.8 miles from the threshold. At 0.8 miles from the threshold, the crew recognized the MRPA was becoming low and slow. The MP advanced the throttle to maximum, but received no response from the failed engine. The crew recognized the engine failure at this point. The MRPA continued to descend while the MP slowed the MRPA to 57 knots. The MRPA crashed 0.5 miles short of the runway.

2. DISCUSSION OF OPINION

a. Cause: Cooling System Failure Resulting in Engine Failure

I find by clear and convincing evidence that a cause of the mishap was a coolant system failure that resulted in an engine failure. A coolant leak in the MRPA led to the engine overheat. This was evidenced by engine data contained in the data log, as well as engine indications discussed by the mission and recovery crews during the flight. Post-accident analysis revealed that all cylinder heads experienced deformation due to the overheat condition and the cylinder one head was no longer flush with the head cover in the lower aft corner. The resulting gap allowed a small amount of oil to leak out and ignite, resulting in fire damage on the left side of the engine. The intake and exhaust valves of the cylinders showed evidence of warping, which resulted in the engine-out condition.

b. Cause: Pilot Error

I find by clear and convincing evidence that a cause of the mishap was the MP's failure to properly execute an engine-out recovery, causing the aircraft to crash prior to the runway. The MRPA was handed off to the MC at 15,200 ft above field elevation (AFE) approximately 10 miles from the airfield. The MP flew the MRPA to the airfield and descended over the runway while conducting normal and emergency checklists. The MP failed to maneuver the MRPA to lose excess altitude prior to beginning the final orbit over the field, which resulted in the final orbit starting 2,100 ft above the flight manual recommended altitude for an engine-out recovery. According to his post-accident statement, "I was in an energy state where I thought one more 360° turn would have put me too low, so I extended out on my final turn so I could line up on final in a safe place to land". During the last four minutes of flight, starting above the runway threshold, the MRPA's airspeed averaged 75 knots with an average descent rate of 1,075 ft per minute (FPM). This airspeed exceeded the flight manual recommended airspeed of 67 knots, which resulted in an excessive descent rate for the size of pattern being flown.

The MP misjudged the distance and descent rate required to lose the excess altitude. He extended the downwind leg so the MRPA reached a maximum distance of 1.8 miles from the threshold of runway 23 at an altitude of 1,300 ft AFE. At this point, the MRPA was approximately 90° off the inbound course to the runway. From this position and heading, given the altitude, airspeed, descent rate and distance from the runway, it was not possible to glide to the runway. The MP failed to transition to best glide speed to decrease the descent rate and extend glide distance. Because the MP did not fly an appropriate engine-out recovery for the situation, he caused the MRPA to crash short of the runway.

3. CONTRIBUTING FACTOR

Leak at the Coolant Feed Elbow on the Number One Engine Cylinder

I find by a preponderance of the evidence that a leak at the coolant feed elbow on the number one engine cylinder substantially contributed to the mishap. As a result, the MRPA experienced a cooling system failure, leading to an engine overheat which resulted in an engine failure.

The evidence suggests that a leak at the coolant feed elbow was responsible for the engine overheat. During manufacturer post-accident analysis, the coolant system was pressurized and the coolant feed lines to cylinder one and two were observed to leak at 5 psi where the coolant feed elbow mated to the lower side of the cylinder heads. For these reasons, the leak likely occurred where the coolant feed elbows were inserted into cylinder one or two. Because the heat damage to cylinder one was greater, it is more likely that the coolant leaked from that cylinder. This leak at the coolant feed elbow significantly contributed to the coolant system failure.

4. CONCLUSION

I arrived at my opinion by examining the General Atomics report, witness testimony, data logger information, HUD video and audio transcripts from the mishap flight, air traffic control transcripts, applicable technical data, and after consulting with subject matter experts. All evidence is consistent with the following two causes: (1) the engine cooling system failed, which resulted in engine failure, and (2) the mishap pilot failed to properly execute a successful engine-out recovery, causing the aircraft to crash prior to the runway. In addition, the evidence is consistent with the following substantially contributing factor: a leak at the number one cylinder coolant feed elbow led to an engine overheat and subsequent engine failure.

28 July 2011

THOMAS M. JOSS, Lt Col, USAF
President, Accident Investigation Board

Under 10 U.S.C. 2254(d), any opinion of the accident investigators as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report may not be considered as evidence in any civil or criminal proceeding arising from the accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.