UNITED STATES AIR FORCE ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

MQ-9A, T/N 08-4051

214th ATTACK GROUP
162d WING
DAVIS-MONTHAN AIR FORCE BASE, ARIZONA

LOCATION: UNITED STATES AFRICA COMMAND AREA OF RESPONSIBILITY

DATE OF ACCIDENT: 24 JUNE 2020

BOARD PRESIDENT: COLONEL PATRIC COGGIN

Abbreviated Accident Investigation, conducted pursuant to Chapter 12 of Air Force Instruction 51-307

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR COMBAT COMMAND
JOINT BASE LANGLEY-EUSTIS VA

OFFICE OF THE DEPUTY COMMANDER
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ACTION OF THE CONVENING AUTHORITY

The report of the abbreviated accident investigation board conducted under the provisions of Air Force Instruction 51-307, *Aerospace and Ground Accident Investigations*, that investigated the 24 June 2020 mishap involving an MQ-9A, T/N 08-4051, operated by the 214th Attack Squadron, complies with applicable regulatory and statutory guidance, and on that basis it is approved.

WEGGEMAN.CHRISTOPHER.P. Digitally signed by WEGGEMAN.CHRISTOPHER.P Date: 2021.05.24 09:49:47 -04'00'

CHRISTOPHER P. WEGGEMAN
Lieutenant General, USAF
Deputy Commander

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION

MQ-9A, T/N 08-4051
UNITED STATES AFRICA COMMAND AREA OF RESPONSIBILITY
24 JUNE 2020

On 24 June 2020, at 0933 Zulu time (Z), the mishap aircraft (MA), an MQ-9A, tail number (T/N) 08-4051, crashed in an undisclosed location within the United States Africa Command (US AFRICOM) Area of Responsibility (AOR). Assigned to the 162d Wing, Arizona Air National Guard, the MA was operated by the 214th Attack Squadron Mission Control Element (MCE) located at Davis-Monthan AFB, Arizona, at the time of the mishap. The location of the crashed MA was confirmed, but the wreckage was not recovered. The loss of Government Property was valued at $11,290,000. There was no reported damage to civilian property, injuries, or fatalities.

At approximately 0640Z, the Mishap Ground Control Station (MGCS) started to display warnings that the fuel level in the header tank was low. The Mishap Pilot (MP) and Mishap Sensor Operator (MSO) began to accomplish procedures to clear this fault. Soon thereafter, the MP noted through fuel calculations that the measured fuel was well short of expected levels. The MP enlisted the assistance of the Mishap Mission Crew Commander (MMCC) to help diagnose the problem. As the MP and MMCC worked the problem, the MSO used the primary camera to visually sweep the MA. During that sweep, the MSO found that the MA was severely leaking fuel from the fuselage.

At 0723Z, the crew started to return to base at maximum airspeed. Without knowing exactly where in the fuel system the leak was occurring, the MP concluded that if the leak was not affecting the aft tank and header tank, then a safe recovery was theoretically possible. After further analysis, the crew realized that the fuel leak was catastrophic. The MP and MMCC, coordinating with Combined Air Operations Center (CAOC) Remotely Piloted Aircraft Liaison Officer (RPA LNO), started to plan to crash the aircraft.

The CAOC directed MMCC and MP to crash the aircraft, and to do so in a way that would minimize chances of a successful recovery effort. Fuel exhausted at 0914Z. The MP then controlled the glide of the aircraft to optimize the impact point. As the aircraft lost altitude, the MP increased the airspeed of the MA through the crash, which occurred at 0933Z.

The Abbreviated Accident Investigation Board (AAIB) President found, by a preponderance of the evidence, the cause of the mishap was a fuel leak from the Forward Electric Fuel Heater that caused fuel exhaustion before the aircraft could be safely returned to the Launch and Recovery Element. Further, the AAIB President found, by a preponderance of the evidence, that each of the following factors substantially contributed to the mishap; (1) Delinquent Time Compliance Technical Order (TCTO) to correct a known MQ-9 deficiency (2) the design of the fuel leak detection system, and (3) lack of guidance and tolerances for the MQ-9 fuel system.

SUMMARY OF FACTS AND STATEMENT OF OPINION
MQ-9A, T/N 08-4051
24 JUNE 2020

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

1st Lt	First Lieutenant
15 AF	15th Air Force
214 ATKS	214 Attack Squadron
AAIB	Abbreviated Accident Investigation Board
ACC	Air Combat Command
AF	Air Force
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFI	Air Force Instruction
AFMAN	Air Force Manual
ANG	Air National Guard
AOA	Angle of Attack
AOR	Area of Responsibility
AZANG	Arizona Air National Guard
CAG	Commander's Action Group
CAOC	Combined Air Operations Center
CAPs	Critical Action Procedures
Capt	Captain
CCA	Control Console Assembly
CCSM	Control Console Serial Module
Col	Colonel
COMM	Communications
DET 3	Detachment 3
DoD	Department of Defense
EFH	Electric Fuel Heater
EP	Emergency Procedure
ER	Exceptional Release
FCIF	Flight Crew Information File
GA-ASI	General Atomics Aeronautical Systems, Inc.
GCS	Ground Control Station
GCSCT	Ground Control System Communications Technician
HDD	Heads Down Display
HFACS	Human Factors Analysis and Classification System
HUD	Heads-Up Display
IAW	In Accordance With
IP	Instructor Pilot
ISR	Intelligence, Surveillance, and Reconnaissance
KIAS	Knots-Indicated Air Speed
kts	Knots
L	Local Time
LCD	Liquid-Crystal Display
LNO	Liaison Officer
LRE	Launch and Recovery Element
LRU	Line Replaceable Unit
Lt Col	Lieutenant Colonel
Lt Gen	Lieutenant General
MA	Mishap Aircraft
Maj	Major
MAJCOM	Major Command
MC	Mishap Crew
MCC	Mission Crew Commander
MCE	Mission Control Element
MFW	Multi-Functional Workstation
mIRC	Mardam-Bey Internet Relay Chat
MGCS	Mishap Ground Control Station
MMCC	Mishap Mission Crew Commander
MP	Mishap Pilot
MP1	Mishap Pilot One
MP2	Mishap Pilot Two
MSgt	Master Sergeant
MSL	Mean Sea Level
MSNCC	Mission Commander
MSO	Mishap Sensor Operator
MSO1	Mishap Sensor Operator One
MSO2	Mishap Sensor Operator Two
MTS	Multi-Spectral Targeting System
NM	Nautical Miles
NOTAMs	Notices to Airmen
ORM	Operational Risk Management
OS	Operations Supervisor
Ops Tempo	Operations Tempo
PAROC	Persistent Attack and Reconnaissance Operations Center
PCBs	Printed Circuit Boards
PCL	Point and Click Loiter
PEX	Patriot Excalibur
PMI	Periodic/Preventative Maintenance Inspection
PR	Pre Flight
PS	Production Superintendent
PST	Pacific Standard Time

RPA	Remotely Piloted Aircraft	STORM	Safety Tactical Operation Reliability Maintenance
RTB	Return to Base	TO	Technical Order
SAR	Search and Rescue	TCTO	Time Compliance Technical Order
SAS	Stability Augmentation System	T/N	Tail Number
SATCOM	Satellite Communications	TSgt	Technical Sergeant
SCCM	STORM Console Control Module	USAF	United States Air Force
SIB	Safety Investigation Board	U.S.C.	United States Code
SIPR	Secret Internet Protocol Router	US AFRICOM	U.S. Africa Command
SL	Sensor Lead	VITs	Variable Information Tables
SLMA	Secure Link Manager Assembly	VSI	Vertical Speed Indicator
SME	Subject Matter Expert	VVI	Vertical Velocity Indication
SO	Safety Observer	WG	Wing
SrA	Senior Airman	Z	Zulu Time
SSgt	Staff Sergeant		

The above list is derived from the Summary of Facts, the Statement of Opinion, the Index of Tab, and Witness Testimony (Tab V).

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 22 December 2020, the Deputy Commander, Air Combat Command (ACC), appointed Colonel Patric Coggin as the Abbreviated Aircraft Investigation Board (AAIB) President to investigate a mishap that occurred on 24 June 2020 involving an MQ-9A aircraft in the United States Africa Command (US AFRICOM) Area of Responsibility (AOR) (Tab Y-2 to Y-3). The AAIB was conducted in accordance with Air Force Instruction (AFI) 51-307, *Aerospace and Ground Accident Investigations*, Chapter 12, at home station and Creech Air Force Base (AFB), Nevada, from 11 January 2021 to 10 February 2021 (Tab Y-2 to Y-3). Additional board members included a Colonel (Col) Legal Advisor, and a Staff Sergeant (SSgt) Recorder (Tab Y-2 to Y-3). On 25 January 2021, a Master Sergeant (MSgt) Subject Matter Expert (SME) on the MQ-9 Fuel System was detailed to advise the board (Tab Y-4).

b. Purpose

In accordance with AFI 51-307, this AAIB conducted a legal investigation to inquire into all the facts and circumstances surrounding this Air Force aerospace accident, prepare a publicly releasable report, and obtain and preserve all available evidence for use in litigation, claims, disciplinary action, and adverse administrative action. This investigation was an abbreviated accident investigation, conducted pursuant to Chapter 12 of AFI 51-307.

2. ACCIDENT SUMMARY

On 24 June 2020, at 0933 Zulu time (Z), the mishap aircraft (MA), an MQ-9A, tail number (T/N) 08-4051, crashed in an undisclosed location within the US AFRICOM AOR (Tab A-16, R-29, V-5.2). Assigned to the 162d Wing, Arizona Air National Guard, the MA was operated by the Mission Control Element (MCE) at the 214th Attack Squadron, located at Davis-Monthan AFB, Arizona, at the time of the mishap (Tab A-16 to A-17, O-181, CC-9, CC-12). At approximately 0640Z, the Mishap Ground Control Station (MGCS) began to display warnings that the fuel level in the header tank was low (Tab R-3, V-3.1). The Mishap Pilot (MP) and Mishap Sensor Operator (MSO) began to accomplish procedures to clear this fault (Tab R-3, V-3.1). Soon thereafter, the MP noted through fuel calculations that the measured fuel was well short of expected levels (Tab R-3 to R-4, R-15, V-7.1). The MP enlisted the assistance of the Mishap Mission Crew Commander (MMCC) to help diagnose the problem (Tab R-4, R-15, V-3.1, V-4.2, V-7.1). As the MP and MMCC continued to run fuel calculations, the MSO used the primary camera to look at the MA (Tab O-182 to O-184, R-4, R-12, R-15, R-22, V-3.1, V-4.2, V-7.1). During that sweep, the MSO found that the MA was severely leaking fuel from the fuselage (Tab O-182 to O-184, R-4, R-15, R-21, V-3.1, V-4.2, V-7.1). The crew started to return to base (RTB) at maximum airspeed and declared an emergency (Tab R-4, R-13, R-15, R-27, V-4.2, V-7.1). Soon thereafter, the MGCS displayed a “Fuel: Leak Detected – Fwd” warning (Tab V-4.2, R-4). At this point, the MP and

MMCC determined there was insufficient fuel to return to base (Tab O-182 to O-184, R-4, R-13, R-15, R-21, R-27, V-3.1, V-4.2). The MP and MMCC, coordinating with Combined Air Operations Center Remotely Piloted Aircraft Liaison Officer, started to plan to crash the aircraft (Tab R-13, R-27, V-3.1, V-4.2, V-5.1). After the engine died due to lack of fuel, the MP controlled the glide of the aircraft to impact (Tab R-5, R-28, V-4.2, V-5.2, V-7.2). The location of the MA was confirmed, but the wreckage was not recovered (Tab R-29, V-5.2). The loss of Government Property was valued at $11,290,000 (Tab O-192). There was no reported damage to civilian property, injuries, or fatalities (Tab A-16).

3. BACKGROUND

a. Air Combat Command (ACC)

ACC is a major command of the United States Air Force (USAF) and the primary force provider of combat airpower to America's warfighting commands, established to support global implementation of national security strategy (Tab CC-2). ACC operates fighter, bomber, reconnaissance, battle management and electronic warfare aircraft (Tab CC-2). It also provides command, control, communications and intelligence systems, and conducts global information operations (Tab CC-2). ACC numbered air forces provide the air component to United States Central, Southern and Northern Commands, with Headquarters ACC serving as the air component to Joint Forces Commands (Tab CC-2 to CC-4). ACC also augments forces to United States European, Pacific, Africa-based and Strategic Commands (Tab CC-2).

b. Fifteenth Air Force (15 AF)

Fifteenth Air Force (AF) trains Airmen to deliver combat airpower worldwide and provides a light, lean, and agile Air Force, Joint, or Combined Task Force Headquarters (Tab CC-7). Fifteenth AF is responsible for ensuring the agile combat support capabilities of 13 wings and three direct reporting units, preparing Airmen for the dynamic requirements of air, space and cyberspace of the future (Tab CC-7). These units encompass about 600 aircraft and more than 45,000 active duty and civilian members. Fifteenth AF is also responsible for the operational readiness of 16 National Guard and Air Force Reserve Units (Tab CC-7).

c. 162d Wing (162 WG)

The 162d Wing is one of the largest Air National Guard wings in the country (Tab CC-10). The wing serves the United States and allied nations by providing the finest fighter training programs in the world, securing our nation's skies and providing global intelligence surveillance and reconnaissance precision attack in support of joint force missions around the world (Tab CC-10). When 162d Wing Guardsmen are not mobilized or under federal control, they report to the governor of Arizona and are led by the adjutant general of the state. Under state law, the wing provides protection of life and property and preserves peace, order, and public safety (Tab CC-10).

d. 214th Attack Group (214 ATKG)

The 214th Attack Group employs the MQ-9 Reaper through remote split operations from Davis-Monthan Air Force Base, Arizona and from Ft. Huachuca in Sierra Vista, Arizona (Tab CC-13). The 214th, also known as "The Black Sheep," flies daily combat missions, providing troops on the ground with around the clock intelligence, surveillance, reconnaissance and precision attack and local domestic Incident Assessment and Awareness flights over the United States in support of national and state objectives (Tab CC-13). The unit is also prepared to support local agencies and fulfill state mission requirements (Tab CC-13).

e. MQ-9A Reaper

The MQ-9A Reaper is an armed, multi-mission, medium altitude, long endurance remotely piloted aircraft (RPA) employed secondarily as an intelligence collection asset and primarily against dynamic execution targets (Tab CC-15). The MQ-9A's capabilities, including its significant loiter time, wide-range sensors, multi-mode communications suite, and precision weapons, make it uniquely qualified to conduct irregular, time-sensitive warfare operations in support of combatant commander objectives (Tab CC-15). Reapers can perform the following missions and tasks: intelligence, surveillance and reconnaissance (ISR), close air support, combat search and rescue, precision strike, buddy-lase, convoy/raid overwatch, route clearance, target development, and terminal air guidance (Tab CC-15).

4. SEQUENCE OF EVENTS

a. Mission

On 24 June 2020, the Mishap Aircraft (MA) was conducting an operational mission at an undisclosed location within the United States Africa Command (US AFRICOM) Area of Responsibility (AOR) (Tab A-16, A-17).

b. Planning

The Mishap Crew (MC) believed the flight authorizations and paperwork for the MA and MGCS were in order (Tab V-3.1, R-12, K-1, K-5). They received all the required weather and operations briefs prior to launch, and the handover from the previous crew to the MC was uneventful. (Tab V-3.1, R-12, F-2, F-3).

c. Preflight

MA and MGCS preflight checks were conducted without incident (Tab D-217 to D-251, D-374 to D-545, R-24, V-8.1, V-9.1).

d. Summary of Accident

On 23 June 2020, at approximately 1905Z, the MA took off under control of the launch and recovery element (LRE), and it was handed off to the mission control element (MCE) at approximately 1914Z without incident (Tab K-3). The MA flew normally for more than 14 hours (Tab V-2.1 to V-2.2, K-3). The MC indicated that the MA was performing nominally and responding to commands (Tab R-7 to R-8, R-10, V-2.1 to V-2.2). The crew swapped out for a normal change of work shift (Tab R-3, V-2.1, V-3.1, V-6.1, V-7.1). The Mishap Pilot (MP) swapped out at 0630Z and completed an ops check, which was normal (Tab R-3, V-3.1). All fuel system indications appeared normal before the crew swap out. (Tab R-10).

At approximately 0640Z, the Mishap Ground Control Station (MGCS) began to display warnings that the fuel level in the header tank was low (Tab R-3, V-3.1). The MP and Mishap Sensor Operator (MSO) began to accomplish procedures to clear this fault (Tab R-3, V-3.1). The MP stated that he had experienced this situation before when the aircraft tried to pull fuel from an empty tank (Tab R-3). The MP then noticed the aircraft was trying to pull fuel from the empty left wing tank, so the MP commanded fuel to be drawn from the forward tank, which cleared the warning (Tab R-3). Both wing tank readings were zero but the calculated fuel level was approximately 240 pounds (Tab R-3). The MP tried locking out the left wing tank (Tab R-3). A few minutes later, there were warnings that the fuel level in the header tank was low again (Tab R-3). The MP commanded fuel be drawn from forward tank again and the warning cleared (Tab R-3). This cycle occurred three or four times (Tab R-3). The MP locked out both wing tanks and noticed that the auto mode kept trying to pull the fuel from the wing tanks (Tab R-3). The MP switched the fuel mode to manual and selected the forward tank to get the header tank back up to normal (Tab R-3).

At around 0650Z, the MP noted through fuel calculations that the measured fuel was well short of expected levels (Tab R-3 to R-4, R-15, V-7.1). The MP enlisted the assistance of the Mishap Mission Crew Commander (MMCC) to help diagnose the problem (Tab R-4, R-15, V-3.1, V-4.2, V-7.1). As the MP and MMCC continued to run fuel calculations, the MSO used the primary camera to look at the MA (Tab R-4, R-12, R-15, R-21, V-3.1, V-4.2, V-7.1). During that sweep, the MSO found that the MA was severely leaking fuel from the fuselage (Tab R-4, R-15, R-21, V-3.1, V-4.2, V-7.1). At 0723Z, the crew started to return to base (RTB) at maximum airspeed and declared an emergency (Tab R-4, R-13, R-15, R-27, V-4.2, V-7.1).

After starting RTB, the crew continued fuel calculations (Tab R-4, R-13). Without knowing exactly where in the fuel system the leak was occurring, the MP initially concluded that a safe recovery was possible (Tab R-4, R-13, R-21, R-27, V-3.1). However, it became clear that the leak was severe and was not stopping (Tab R-4, R-13, V-3.1, V-4.2). The MP and MMCC determined they could not make it back to the airfield (Tab R-4, R-13, R-15, R-21, R-27, V-3.1, V-4.2). The MP and MMCC, coordinating with Air Operations Center (AOC) Remotely Piloted Aircraft Liaison Officer, started to plan to crash the aircraft (Tab R-13, R-27, V-3.1, V-4.2, V-5.1).

The CAOC directed the MMCC and MP to crash the aircraft, and to do so in a way that would minimize chances of a successful recovery effort (Tab R-5, R-13, R-15, R-27, V-3.1, V-4.2, V-5.1 to 5.2, V-7.2). All of the fuel depleted, and at 0914Z the engine failed due to fuel exhaustion (Tab R-28, V-7.2). The MP controlled the glide of the aircraft to impact (Tab R-5, V-4.2, V-5.2). As the aircraft lost altitude, the MP increased the airspeed of the MA through the crash, which occurred at 0933Z (Tab R-16, R-29, V-7.2). The final moments of the glide, crash and images of the debris were captured on video by another airborne asset (Tab R-13, R-29, V-5.2).

e. Impact

The MA impacted in an undisclosed location in the US AFRICOM AOR (Tab A-16, R-29, V-5.2). The MA's wreckage was not recovered (Tab R-29).

f. Egress and Aircrew Flight Equipment (AFE)

Not applicable.

g. Search and Rescue (SAR)

Not applicable.

h. Recovery of Remains

Not Applicable.

5. MAINTENANCE

No evidence indicated the maintenance of the Mishap Ground Control Station (MGCS) (forms documentation; inspections; maintenance procedures; maintenance personnel and supervision; fuel, hydraulic, oil, and oxygen inspection analysis; or unscheduled maintenance) was a factor in the mishap (Tab D-217 to D-251, D-1528 to D-1543).

The following information pertains to the maintenance of the Mishap Aircraft (MA):

a. Forms Documentation

A review of the maintenance records for the MA leading up to the mishap revealed no relevant discrepancies or issues, and showed no overdue Time Compliance Technical Orders (TCTO) (Tab D-217 to D-251, D-1528 to D-1543). All preflight inspections and release procedures were completed (Tab D-217 to D-251, D-1528 to D-1543).

b. Inspections

All MA maintenance inspections were current and complied with by relevant authorities (Tab D-217 to D-251, D-1528 to D-1543). The most recent 400-hr inspection was completed on 18 June 2020 (Tab D-217 to D-251). All recorded details of the inspection were reviewed and no issues were identified (Tab D-217 to D-251, D-1528 to D-1543).

c. Maintenance Procedures

Maintenance personnel conducted all maintenance procedures in accordance with applicable Technical Orders (TOs) and guidance (Tab D-217 to D-251, D-1528 to D-1543).

d. Maintenance Personnel and Supervision

A review of applicable records on maintenance personnel and supervision revealed no issues (Tab D-217 to D-251, D-1528 to D-1543). No evidence indicated the training, qualifications, and supervision of the maintenance personnel were a factor in this mishap (Tab D-217 to D-251, D-1528 to D-1543).

e. Fuel, Hydraulic, Oil, and Oxygen Inspection Analyses

A review of the maintenance records for the MA leading up to the mishap day revealed no relevant discrepancies or issues, and showed no fuel or oil issues (Hydraulic/Oxygen is N/A for the MQ-9) (Tab D-217 to D-251, D-1528 to D-1543).

f. Unscheduled Maintenance

Maintenance documentation revealed only minor unscheduled maintenance was performed on the MA since completion of the last scheduled 200/400/800 hour inspection (Tab D 217-251). These corrective actions included repair of the Angle of Attack probe and actions to improve the clarity of one of the nose cameras (Tab D-217 to D-251). There was no evidence of any unscheduled maintenance on the fuel system (Tab D-217 to D-251).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

(1) MQ-9 Fuel Delivery System

The fuel system of the MQ-9 consists of seven internal tanks and up to two external tanks (Tab EE-4). The internal tanks consist of two tanks in each wing, a forward fuselage tank, an aft fuselage tank, and a header tank (Tab EE-4). The outer tank in each wing gravity feeds to the inner wing tank (Tab EE-4). The inner wing tanks, the fuselage tanks and any external tanks are fed to the header tank by jet pumps and solenoids (Tab EE-4). All fuel fed to the engine comes directly from the header tank (Tab EE-4).

Two electric fuel pumps, arranged in parallel, pressurize the solenoids and jet pumps for the entire fuel system (Tab EE-4). These fuel pumps are located between the header tank and the forward electric fuel heater (Tab EE 4 to EE-5). After pumped fuel leaves the forward electric fuel heater, it is filtered and delivered to the engine after passing through the jet pump manifold and mass flow sensor (Tab EE-4 to EE-5). The engine has an engine-driven fuel pump, but it is only capable of pulling fuel from the header tank (Tab EE-4 to EE-5). The engine-driven fuel pump will not pressurize the solenoids or manifolds and therefore will not pump any additional fuel into the header tank (Tab EE-4 to EE-5).

(2) MQ-9 Fuel Monitoring

The MQ-9 provides information on the fuel system to aircrew with variable information tables (VITs) (Tab EE-2). VITs are tables that list categories and values of information in a textual format

(Tab EE-2). Depending on the type and layout of the ground control system, the aircrew can have two or more VITs displayed at any one time, with the aircrew choosing which VITs to display (Tab EE-2).

In the VITs, fuel quantity is displayed for each tank, displaying a "calculated" value and a "measured" value (Tab EE-2). The only exception is the header tank for which the system displays only a "measured" value (Tab EE-2). The system also displays total calculated fuel for the aircraft, which is calculated through fuel burn data (Tab EE-2). There is no total measured fuel quantity provided to aircrew (Tab EE-2 to EE-3). Calculated fuel is based on fuel burn as reported from the mass flow sensor while measured fuel is based on sensors in each fuel tank (Tab EE-2 to EE-3).

Pilots testified that they knew of no guidance on which set of numbers to trust more, and defaulted to using the more conservative numbers (Tab V-2.2, V3.1-3.2). The MP further testified that low header tank warnings are common, especially as a tank is close to empty (Tab V-4.1).

None of the pilots who testified had a hard limit of when to suspect a fuel system problem as the fuel numbers began to diverge (Tab V-2.2, V3.1-3.2). Pilots also testified that they normally do not add up the measured fuel, which they have to do manually, until late in the sortie (Tab V-2.2, V-3.1).

(3) MQ-9 Fuel Leak Detect System

The MQ-9 Ground Control Station will alert aircrew of a possible leak when any one fuel tank has a difference of 200-250 pounds of fuel between calculated fuel and measured fuel (Tab EE-2 to EE-3). The variance between the 200 pounds and 250 pounds depends on the particular tank on the aircraft (Tab EE-2 to EE-3). There is no limit or programmed alert to aircrew of a difference between totalized calculated and measured fuel on the aircraft (Tab EE-2 to EE-3). Pilots testified that they expected to see a fuel leak detected warning for all major fuel leak scenarios (Tab V-2.2, V-3.2).

b. Evaluation and Analysis from GA-ASI

As there was no wreckage to analyze, General Atomics-Aeronautical Systems, Inc. (GA-ASI) was only able to conduct analysis of data logger information (Tab J-12 to J-13). The analysis of the MGCS data logs "indicates a fuel leak between the airframe fuel pumps and mass flow meter" (Tab J-13). Additionally, GA-ASI reported that there was a "[p]ossible leak at the forward fuel heater" and that there was a "[h]istory of fuel heater cracks at weld leading to fuel leaks" (Tab J-13). The GA-ASI analysis also compared data logger information from the MA to known instances of fuel leaks from the forward electric fuel heaters, with all categories of data having a "similar" data plot (Tab J-15). Additionally, the payload video showed fuel possibly exiting the right wing root (Tab J-5). This would be possible if fuel sprayed up into the wing spar area, which is possible with a fuel heater leak (Tab J-5). Lastly, a "[s]lightly decreasing jet pump manifold pressure… suggests a leak downstream of airframe fuel pumps" (Tab J-13).

A GA-ASI report verified fuel leak rates of previously reported failed forward electric fuel heaters (Tab J-6). Leak rates ranged from approximately 50 – 400 pounds per hour (Tab J-6). The rate of fuel leak for this accident was consistent with previous confirmed EFH failures (Tab J-6).

The first EFH issue was identified on a failure that occurred on 21 October 2019 (Tab EE-6). This was reported to AFLCMC/DET 3 on 6 November 2019 through a Category (CAT) 1 Deficiency Report (Tab EE-6). Furthermore, from March through May of 2020, GA-ASI Engineers continued to investigate the weld seams on the fuel heaters (Tab EE-6). Revisions A-F of the EFHs utilize Butt-welds, which are problematic in achieving proper melt-through and are therefore more susceptible to fatigue (Tab EE-6). Further revisions clarified the inspection criteria for welding by incorporating a radiographic inspection to verify welds (Tab EE-6). Revision H incorporated a fillet-weld, which would improve the manufacturability and the yield of the fuel heater (Tab EE-6).

The Failure Analysis and Corrective Action Report, stemming from an exhibit received by AFLCMC/DET 3 on 14 November 2019 further stated that, "The butt-type welds (Fuel Heater Body Revision F or earlier) required full weld penetration. Fatigue cracks formed at stress concentrations due to lack of weld penetration and propagated due to normal fuel pressure changes. The cracks discovered were large enough to allow substantial fuel to leak out of the assembly" (Tab J-11).

Two days after the mishap, GA-ASI released an alert bulletin on 26 June 2020 that directed all operators of the MQ-9 to bypass the electric fuel heater (Tab J-4, EE-7). This alert bulletin stated: "**CONSEQUENCE:** Failure to comply with this Alert Bulletin may result in fuel leaks during operations and loss of aircraft" (Tab J-4).

c. History of Corrective Actions to USAF MQ-9s

The MQ-9 Program Office initially identified the Forward Electric Fuel Heater (EFH) leak issue on 6 Nov 2019, more than six months before the mishap (Tab EE-6). The program office allotted General Atomics-Aeronautical Systems, Inc. (GA-ASI) 60 days to produce a Failure Analysis and Corrective Action Report in response to a near loss of a MQ-9 due to a fuel leak from the forward EFH that occurred in November 2019 (Tab EE-6).

The MQ-9 community submitted six CAT 1 Deficiency Reports for EFH issues in the same month of the initial Failure Analysis and Corrective Action Report (Tab EE-6). At that time, AFLCMC/DET 3 suggested that the field submit additional deficiency reports and to submit an urgent technical order change request (Tab EE-6). In the nine months leading up to this mishap, there were eight total EFH leak incidents reported (Tab J-8).

For the six months following the initial release of the Failure Analysis and Corrective Action Report, GA-ASI engineers continued to investigate the welds on the problematic EFH (Tab EE-6).

Two days after the mishap, GA-ASI produced an Alert Bulletin (AB2349), in which GA-ASI recommended bypassing the EFH entirely (Tab J-4, EE-7). The report detailed how the EFH is not required for safe operation of the MQ-9 (Tab EE-7).

GA-ASI began developing a Safety Time Compliance Technical Order (TCTO) to bypass the EFH on the MQ-9 fleet in July 2020, nine months after the first CAT 1 deficiency report (Tab EE-7). GA-ASI completed the TCTO in August of 2020 (Tab EE-7). An Air Force Form 1067, modification proposal, states that the proposed TCTO would cost approximately $37,000 for the entire USAF fleet of MQ-9s (Tab J-17).

The MQ-9 program office did not release the Safety TCTO to the field until December 2020, as they awaited for additional technical order data from GA-ASI (Tab EE-7).

7. WEATHER

a. Forecast Weather

The weather briefed prior to the mishap flight indicated a forecast for isolated showers and thunderstorms in the United States Africa Command (US AFRICOM) Area of Responsibility (AOR) with unlimited visibility (Tab F-2 to F-4). Clouds were forecasted to be scattered from 16000 through 18000 feet (Tab F-2 to F-4). Winds aloft were forecast variable at 10 knots or less (Tab F-2 to F-4). There was no other significant weather forecasted at the time of the mishap (Tab F-2 to F-4).

b. Observed Weather

Observed weather was worse than forecast (Tab R-7 to R-8). Clouds were observed to be broken to overcast, with showers in the AOR (Tab R-7 to R-8). There is no evidence, however, that weather played a part in the cause of the accident (Tab R-7 to R-8).

c. Space Environment

Not applicable.

d. Operations

Not applicable.

8. CREW QUALIFICATIONS

a. Mishap Pilot (MP)

The MP was current and qualified to accomplish the mission in the MQ-9A at the time of the mishap (Tab L-2 to L-7, L-268 to L-283). The MP had 467.0 hours of MQ-9A flight time and 75.2 hours of MQ-9A simulator time around the time of the mishap (Tab L-270 to L-271). Recent flight hours were as follows (L-268):

	Flight Hours	Flight Sorties
Last 30 Days	25.1	6

Last 60 Days	41.5	10
Last 90 Days	81.2	21

b. Mishap Sensor Operator (MSO)

The MSO was current and qualified to accomplish the mission in the MQ-9A at the time of the mishap (Tab L-183 to L-189, L-309 to L-323). Of note, it had been 18 months since the MSO's last periodic evaluation, but due to waivers in place due to COVID-19, the MSO was still current and qualified (Tab L-183 to L-189). The MSO had 939.7 hours of MQ-9A flight time and 7.3 hours of MQ-9A simulator time around the time of the mishap (Tab L-311). Recent flight hours were as follows (Tab L-309):

	Flight Hours	Flight Sorties
Last 30 Days	16.7	5
Last 60 Days	46.0	13
Last 90 Days	69.0	21

9. MEDICAL

a. Qualifications

The aircrew and maintenance personnel were physically and medically qualified for the mission (Tab G-2 to G-132).

b. Health

No evidence was found to suggest the health of the aircrew or maintenance personnel was a factor in this mishap (Tab G-2 to G-132).

c. Pathology/Toxicology

The medical clinic collected blood and urine samples from the mishap crew after the mishap (Tab FF-2 to FF-7). Toxicology was not a factor in this mishap (Tab FF-2 to FF-7).

d. Lifestyle

There is no evidence to suggest lifestyle was a factor in the mishap (Tab R-30 to R-93).

e. Crew Rest and Crew Duty Time

Prior to performing in-flight duties, aircrew members must have proper rest, as defined in AFMAN 11-202, Volume 3, *Flight Operations*. AFMAN 11-202, Volume 3 Paragraph 3.1 defines normal crew rest as a minimum of 12-hour non-duty period before the designated flight duty period begins, and crew rest is defined as free time, and includes time for meals, transportation, and the opportunity to sleep. The mishap crew verified they had received the proper crew rest by signing the pre-flight authorization (Tab K-5).

10. OPERATIONS AND SUPERVISION

a. Operations

There was no evidence found that suggests operations tempo contributed to the mishap (Tab V-2.1, V-3.1, V-4.1, V-5.1, V-6.1 V-7.1, V-8.1, V-9.1).

b. Supervision

There was no evidence found that suggests the Operations Supervision contributed to the mishap (Tab V-2.1 to V-3.1).

11. HUMAN FACTORS ANALYSIS

The AAIB considered all human factors as prescribed in the Department of Defense (DoD) Human Factors Analysis and Classification System (HFACS), Version 7.0, to determine if those human factors that directly related to the mishap (Tab BB-2 to BB-3). Based on the evidence, human factors did not play a factor in this mishap (Tab BB-2 to BB-3).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 51-307, *Aerospace and Ground Accident Investigations*, 18 March 2019

(2) AFI 51-307, Air Combat Command Supplement, *Aerospace and Ground Accident Investigations*, 3 December 2019

(3) AFI 91-204, *Safety Investigations and Reports*, 27 April 2018

(4) AFMAN 11-202, Volume 3, *Flight Operations*, 10 June 2020

(5) Human Factors Analysis and Classification System, Version 7.0

NOTICE: All directives and publications listed above are available digitally on the Air Force Departmental Publishing Office website at: http://www.e-publishing.af.mil.

b. Other Directives and Publications Relevant to the Mishap

None

c. Known or Suspected Deviations from Directives or Publications

There is no evidence to suggest that any directive or publication deviations occurred during this mishap.

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29 April 2021

PATRIC COGGIN, Colonel, USAF
President, Abbreviated Accident Investigation Board

STATEMENT OF OPINION

MQ-9A, T/N 08-4051
UNITED STATES AFRICA COMMAND AREA OF RESPONSIBILITY
24 JUNE 2020

Under 10 U.S.C. § 2254(d) the opinion of the accident investigator 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

On 24 June 2020, at 0933 Zulu time (Z), the mishap aircraft (MA), an MQ-9A, tail number (T/N) 08-4051, crashed in an undisclosed location within the United States Africa Command (US AFRICOM) Area of Responsibility (AOR). Assigned to the 162d Wing, Arizona Air National Guard, the MA was operated by the 214th Attack Squadron Mission Control Element (MCE) located at Davis-Monthan AFB, Arizona, at the time of the mishap. The location of the crashed MA was confirmed, but the wreckage was not recovered. The loss of Government Property was valued at $11,290,000. There was no reported damage to civilian property, injuries, or fatalities.

At about 0640Z, the Mishap Ground Control Station (MGCS) started to display warnings that the fuel level in the header tank was low. The Mishap Pilot (MP) and Mishap Sensor Operator (MSO) began to accomplish procedures to clear this fault. Soon thereafter, the MP noted through fuel calculations that the measured fuel was well short of expected levels. The MP enlisted the assistance of the Mishap Mission Crew Commander (MMCC) to help diagnose the problem. As the MP and MMCC worked the problem, the MSO used the primary camera to visually sweep the MA. During that sweep, the MSO found that the MA was severely leaking fuel from the fuselage.

At 0723Z, the crew started to return to base (RTB) at maximum airspeed. Soon after the RTB began, the MGCS displayed a detected fuel leak warning. During the recovery, the crew continued fuel calculations. Without knowing exactly where in the fuel system the leak was occurring, the MP concluded that if the leak was not affecting all tanks, then a safe recovery was theoretically possible. However, soon it was clear that the leak was between the header tank and the engine, and the MP and MMCC, coordinating with Combined Air Operations Center (CAOC) Remotely Piloted Aircraft Liaison Officer (RPA LNO), started to plan to crash the aircraft.

The CAOC directed the MMCC and MP to crash the aircraft, and to do so in a way that would minimize chances of any successful recovery effort. After the engine shut down due to fuel exhaustion, the MP controlled the glide of the aircraft to optimize the impact point. As the aircraft lost altitude, the MP increased the airspeed of the MA through the crash, which occurred at 0933Z. The final moments of the glide, crash and images of debris were captured on video by another airborne asset.

2. CAUSE

I found, by a preponderance of the evidence, the cause of the mishap was a fuel leak from the Forward Electric Fuel Heater that caused fuel exhaustion before the aircraft could be safely returned to the Launch and Recovery Element.

a. Fuel Leak from Forward Electric Fuel Heater

The testimonial evidence of the aircrew and other Airmen who were watching the live video feed from the aircraft, clearly demonstrates that a serious fuel leak occurred. The evidence from the data loggers reinforces this conclusion. The difference between measured fuel and calculated fuel occurred in all fuel tanks, which indicates that there was not a problem in any one tank. Had the leak been between the mass flow meter and the engine, fuel flow indications would have drastically increased and the leaked fuel would have been included in the calculated fuel numbers from the aircraft. As the header is the last place fuel is measured before passing through mass flow meter, this clearly indicates that the fuel leak occurred between the header tank and the mass flow meter.

The Forward Electric Fuel Heater (EFH) is located between the header tank and the mass flow meter. In the nine months leading up to this accident, there were seven confirmed fuel leaks from the Forward EFH in the MQ-9 fleet. Additionally, the location of the fuel leaking out of the fuselage and the slight change in fuel pressure in the jet manifold further indicates that the source of the fuel leak was the Forward Electric Fuel Heater.

I found, by a preponderance of the evidence, the cause of the mishap was a fuel leak from the Forward Electric Fuel Heater that caused fuel exhaustion before the aircraft could be safely returned to the Launch and Recovery Element.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

Further, I found, by a preponderance of the evidence, that each of the following factors substantially contributed to the mishap; (1) delinquent Time Compliance Technical Order to correct a known MQ-9 deficiency (2) the design of the fuel leak detection system, and (3) lack of guidance and tolerances for the MQ-9 fuel system.

a. Delinquent Time Compliance Technical Order to Correct Known MQ-9 Deficiency

Delinquent corrective actions for the known deficiency of cracking/leaking Forward EFHs for the MQ-9 fleet was a substantially contributing factor. In the 15 months leading up to this accident, there were eight confirmed fuel leaks from the Forward EFH in the MQ-9 fleet.

In November 2019, in response to the near loss of an MQ-9, the MQ-9 Program Office allotted 60 days to General Atomics-Aeronautical Systems, Inc. (GA-ASI) to deliver a Failure Analysis and Corrective Action Report for the Forward EFH.

GA-ASI developed an Alert Bulletin, which was released two days after this mishap, and recommended that MQ-9 operators reroute the fuel line to bypass forward EFH. The Alert Bulletin also described how the Forward EFH was not required for safe operation of the aircraft.

It took over 13 months for USAF agencies and GA-ASI to release a TCTO (Time Compliance Technical Order) to prevent this failure from happening again. The parts and hardware required for the TCTO was estimated to cost approximately $37,000 for the entire USAF fleet of MQ-9s. If this Safety TCTO was released in under seven months (time from when the Program Office initiated the request for a Failure Analysis and Corrective Action Report from GA-ASI), instead of the actual 13 months, this accident could have been avoided.

b. Fuel Leak Detection System

The software design of the MQ-9 fuel leak detection system was determined to be a substantially contributing factor in the mishap. The fuel detection warning is designed to only detect a leak in any one fuel tank. In cases where fuel is leaking from locations other than the fuel tanks, including from the main fuel line that leads from the header tank to the engine, the fuel leak detection system may not alert the crew until after multiple hours' worth of fuel has already leaked.

Additionally, the MQ-9 flight manual has no notes, warnings or cautions that the fuel leak detection system may be ineffective in detecting leaks between the header tank and the engine. Pilots testified that they expected to see a fuel leak detection warning for most, if not all, major fuel leak scenarios.

Before the crew became aware of the leak, the total measured and calculated fuel began to diverge, indicating the beginning of the fuel leak. Had the software been designed to look at and compare total calculated fuel and total measured fuel, the MP would have been notified of the leak sooner and therefore had a better chance of successfully recovering the aircraft.

c. Lack of Guidance and Tolerances for the MQ-9 Fuel System

Lack of guidance and tolerances for the MQ-9 fuel system was a substantially contributing factor in the mishap. Generally, the MQ-9 provides all information on fuel remaining in each tank to aircrew in two separate and distinct ways: calculated fuel and measured fuel. Calculated fuel is based on fuel burn as reported from the mass flow sensor. Measured fuel is based on sensors in each fuel tank.

MQ-9 aircrew are presented two separate values for fuel remaining in each tank, which presents the aircrew with the unusual problem of having two systems for fuel awareness. Even more unusual is the fact that the only fuel totalizer displayed to aircrew takes the sum of header tank (measured) and the calculated fuel for all remaining tanks. In order for aircrew to determine total measured fuel in the aircraft, the pilot must use a calculator or white board to add the individual values for each of eight fuel tanks.

There is no published guidance in the aircraft flight manual or 11- series instructions that instructs aircrew on which "set" of numbers should be trusted more. As the totalizer uses calculated fuel, this appears to create a situation where an aircrew "trusts" the calculated numbers. There is no published guidance on what maximum allowable tolerance, or difference, is acceptable between measured and calculated fuel. During testimony, not one pilot had a hard limit of when to suspect a problem in the fuel system. When asked about how they handle differences between measured and calculated fuel, they all indicated that differences were quite normal, especially when getting closer to end of mission. During those times when they had differences in fuel numbers, the pilots simply used the lower number to be more conservative.

The MQ-9 fuel system uses calculated numbers, not measured, to direct the automatic switching of tanks. In other words, if the calculated fuel numbers show fuel remaining in a tank (even if the measured numbers show no fuel remaining in that tank), the aircraft will attempt to pull fuel from an empty tank. As the system does not or cannot measure an empty tank, nuisance header tank low warnings happen and therefore aircrew are desensitized to fuel warnings. On 24 June 2020, when the MP started dealing with the low header tank warnings, he did not think that he might have a fuel leak. Had the flight manual or 11-series guidance provided specific guidance on what the maximum tolerance is between the two sets of fuel numbers, and/or the software showed both totalized calculated and totalized measured fuel (and the delta), the MP may have recognized the fuel leak sooner and therefore had a better chance of successfully recovering the aircraft.

4. CONCLUSION

Engineering analysis of the data logs, testimony, video evidence, the history of the MQ-9 fuel system provided by GA-ASI, and information provided by a subject matter expert, prove, by a preponderance of the evidence, the cause of this accident was a fuel leak from the Forward Electric Fuel Heater that caused fuel exhaustion before the aircraft could be safely returned to the Launch and Recovery Element. Further, I find, by a preponderance of the evidence, that each of the following factors substantially contributed to the mishap: (1) Delinquent Time Compliance Technical Order to correct a known MQ-9 deficiency (2) The design of the fuel leak detection system, and (3) Lack of guidance and tolerances for the MQ-9 fuel system.

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29 April 2021

PATRIC COGGIN, Colonel, USAF
President, Abbreviated Accident Investigation Board

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