UNITED STATES AIR FORCE
ABBREVIATED AIRCRAFT ACCIDENT
INVESTIGATION BOARD REPORT

MQ-9A, T/N 13-4230

12TH EXPEDITIONARY SPECIAL OPERATIONS SQUADRON
27TH SPECIAL OPERATIONS WING
CANNON AIR FORCE BASE, NEW MEXICO

LOCATION: UNITED STATES AFRICA COMMAND
AREA OF RESPONSIBILITY

DATE OF ACCIDENT: 01 MARCH 2023

BOARD PRESIDENT: COLONEL JOHN D. GALLOWAY

This investigation is an abbreviated accident investigation, conducted pursuant to Chapter 12 of Air Force Instruction 51-307

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR COMBAT COMMAND

OFFICE OF THE DEPUTY COMMANDER
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AUG 2 0 2024

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 01 March 2023 mishap in the U.S. Africa Command Area of Responsibility, involving an MQ-9A, T/N 13-4230, and operated by the 12th Expeditionary Special Operations Squadron, complies with applicable regulatory and statutory guidance, and is hereby approved.

MICHAEL G. KOSCHESKI
Lieutenant General, USAF
Deputy Commander

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION

MQ-9A, T/N 13-4230
UNITED STATES AFRICA COMMAND AREA OF RESPONSIBILITY
01 MARCH 2023

On 01 March 2023, an unmanned MQ-9A, tail number (T/N) 13-4230, experienced a system malfunction during a manually piloted landing attempt resulting in collision with terrain in the United States Africa Command Area of Responsibility (AOR). The mishap aircraft (MA) was operated in the AOR by the Launch and Recovery Element (LRE) comprised of the mishap pilot (MP) and the mishap sensor operator. The mishap resulted in no reported damage to civilian property, no injuries, and no fatalities. The loss of government property was valued at $16,711,554.

Prior to the sequence of events leading up to the mishap, the MA had completed an uneventful mission under the control of the Mission Control Element (MCE) with all systems normal. Transfer of control to the LRE for normal recovery and landing was uneventful. The LRE navigated the MA to the airfield traffic pattern, attempted an automatic landing, which was aborted for a known altitude error at this airfield, and reentered the traffic pattern for a normal, manually piloted approach and landing. As the MA initiated a descending right turn from base leg to final, engine indications on the Head-Up-Display (HUD) stagnated and a warning was displayed indicating that the electrical engine control system had transitioned to backup mode. The MA airspeed and altitude decreased significantly as the MA descent rate rapidly increased. While assessing the situation, the MP slowly increased throttle command while continuing the final turn. Thirty seconds passed from initial failure indications to full throttle command and subsequent, near-simultaneous impact with terrain well short of the runway threshold occurred.

The Abbreviated Accident Investigation Board President (AAIB BP) found, by a preponderance of the evidence, that the cause of the mishap was the ill-timed electrical short in the primary communications bus caused by pre-existing cable connection damage coupled with the MP's delay in executing an immediate stall recovery, wings level, with maximum power. Further, the AAIB BP found, by a preponderance of the evidence that the following three factors substantially contributed to the mishap: 1) maintenance technical orders and procedures did not appear to require routine inspection and/or replacement of this particular cable connector; 2) training and procedures regarding the implications of the electrical engine control system backup mode, particularly at low altitude, were insufficient; and 3) training in appropriate stall recovery procedures, primarily while in manual flight mode, was lacking.

"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 by the United States or by any person referred to in those conclusions or statements."

SUMMARY OF FACTS AND STATEMENT OF OPINION
MQ-9A, T/N 13-4230
UNITED STATES AFRICA COMMAND AREA OF RESPONSIBILITY
01 MARCH 2023

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ACRONYMS AND ABBREVIATIONS

12 ESOS	12th Expeditionary Special Operations Squadron
27 SOW	27 Special Operations Wing
1st Lt	1st Lieutenant
A1C	Airman First Class
AAIB	Abbreviated Accident InvestigationBoard
AB	Air Base
ACC	Air Combat Command
ADCS	Aircraft Digital Control System
AETC	Air Education and Training Command
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFI	Air Force Instruction
AFMAN	Air Force Manual
AFM	Air Force Member
AFRICOM	U.S. Africa Command
AFSAS	Air Force Safety Automated System
AFSOC	Air Force Special Operations Command
AFTO	Air Force Technical Order
AGL	Above Ground Level
AKC	Advanced Killchain
AoA	Angle of Attack
AOR	Area of Responsibility
Approx.	Approximately
ASC	Aeronautical Systems Center
ATD	Advance Technology Demonstrations
ATKS	Attack Squadron
ATLC	Automatic Takeoff and Landing Capability
AV	Aviation
AVT	Aviation Technician
AWI	Alcohol-Water Injection
BJMs	Battery Junction Modules
BP	Board President
BSA	Basic Surface Attack
BPO	Basic Post-flight Operation
CC	Commander
CCDL	Cross-Channel Datalink
Ch.	Chapter
Capt	Captain
Cmbt	Combat
Col	Colonel
CT	Computerized Tomography
CUI	Controlled Unclassified Information
DAFI	Department of the Air Force Instruction
DAFSC	Duty Air Force Specialty Code
Dist to TD	distance to touchdown
DLP	Datalink Processor
DO	Director of Operation
DoD	Department of Defense
DSN	Defense Service Network
EGT	Exhaust Gas Temperature
ENG	Engineer
ER	Extended Range
FAC	Forward Air Controller
FCAs	Flight Computer Assemblies
FDP	Flight Duty Period
ft	Feet
Flt	Flight
Flt CC	Flight Commander
FW	Fighter Wing
GA-ASI	General Atomics-Aeronautical Systems, Inc.
GCS	Ground Control Station
GDT	Ground Data Terminal
Gen	General
GLS	Ground Landing System
GMT	Ground Moving Target
HDD	Head-Down Display
HFACS	Human Factors Analysis & Classification System
HIPAA	Health Insurance Portability and Accountability Act
HMU	Hot Mock-Up
HOTAS	Hands on Throttle and Stick
hr	hour
HUD	Head-Up-Display
HQ	Headquarters
IAW	In Accordance With
ICT	Integrated Combat Turn
IMDS	Integrated Maintenance Data System

ISB	Interim Safety Board
INF	Interface processor board
IP	Instructor Pilot
ISO	Information Systems Officer
JA	Judge Advocate
KC	Killchain
KIAS	Knots Indicated Airspeed
KT	Knots
LA	Legal Advisor
lbs	Pounds
LR	Launch and Recovery
LRA	Launch and Recovery Academics
LRE	Launch and Recovery Element
LRUs	Line Replaceable Units
LST CHMB	Last Altitude Chamber Training
LST PHYS	Last Flight Physical
MA	Mishap Aircraft
Maj	Major
MAJCOM	Major Command
MC	Mishap Crew
MCE	Mission Control Element
MDS	Mission Design Series
Mech	Mechanic
MGCS	Mishap Ground Control Station
MLG	Main Landing Gear
MP	Mishap Pilot
MSNP	Mission Pilot
MSL	Mean Sea Level
MSO	Mishap Sensor Operator
MSO	Mission Sensor Operator
MXS	Maintenance Squadron
MXS MBR	Maintenance Member
NJA1	Network Junction Assembly 1
NO	Number
NOTAMS	Notice to Airmen
NSTR	Nothing Significant to Report
OAT	Outside Air Temperature
OCONUS	Outside the Continental U.S.
OG	Operational Groups
OPTEMPO	Operational Tempo
ORM	Operational Risk Management
PA	Pressure Altitude
PCR	Publication Change Request
PHA	Periodic Health Assessment
PIC	Pilot-in-Command
PII	Personally Identifiable Information
PLT	Pilot
PM	Pilot Member
P/N	Part Number
PPE	Personal Protective Equipment
PPDMs	Payload Power Distribution Modules
PR	Preflight
PS	Production Supervisor
PTP	Product Test Procedure
QT	Quick-Turn
Qty	Quantity
RCM	Redundant Control Module
Rec	Recorder
RNET	Response Network
RPA	Remotely Piloted Aircraft
RTAFB	Royal Thai Air Force Base
RTB	Return to Base
SAR	Search and Rescue
SCRs	Software Change Requests
SEO	Simulated Engine Out
SIB	Safety Investigation Board
SIO	Single Investigating Officer
SJA	Staff Judge Advocate
SLR	Satcom Launch and Recovery
SO	Sensor Operator
SOF	Special Operations Forces
SOP	Standard Operating Procedure
SOS	Special Operations Squadron
SOW	Special Operations Wing
SR	System Release
SrA	Senior Airman
SSAN	Social Security Account Number
SU	Student Pilot
TCTO	Time Compliance Technical Order
TEMPO CONDS	Temporary Conditions
TH	Thru-flight
TR	Transition
TSgt	Technical Sergeant
TM	Technical Manual
T/N	Tail Number
TO	Technical Order
TX	Transition Course
UARB	UAV Asynchronous RS-422 BUS
UAV	Unmanned Aerial Vehicle
UP	Unqualified Pilot
USAF	United States Air Force

U.S.C.	United States Code
USO	Unqualified Sensor Operator
VITs	Variable Information Table
VIS SM	Visibility in Statute Miles
VOIP	Voice Over Internet Protocol
VOSIP	Voice Over Secure Internet Protocol
VOT	Vote Processor
VV	Vertical Velocity
WG	Wing
WSPM	Wheel Signal Processing Module
WX	Weather
X-WIND	Crosswind

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 08 November 2023, the Air Combat Command (ACC) Deputy Commander appointed a board president to conduct an Abbreviated Accident Investigation Board (AAIB) for the mishap that occurred on 01 March 2023 involving an MQ-9A in the United States Africa Command Area of Responsibility (Tabs Y-3 and CC-18). The appointment letter was later amended on 29 November 2023, to appoint Colonel John Galloway Jr. as Board President (BP) (Tab Y-5). Other board members included a Captain (Capt) Legal Advisor, a 1st Lieutenant (1st Lt) Pilot Member, a Technical Sergeant (TSgt) Maintenance Member, and a Senior Airman (SrA) Recorder (Tab Y-5). The AAIB conducted its investigation in accordance with Air Force Instruction (AFI) 51-307, *Aerospace and Ground Accident Investigations*, Chapter 12, remotely from 29 January 2024 to 23 April 2024 (Tab Y-5).

b. Purpose

In accordance with AFI 51-307, *Aerospace and Ground Accident Investigations*, 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.

2. ACCIDENT SUMMARY

On 01 March 2023, an unmanned MQ-9A, tail number (T/N) 13-4230, experienced a system malfunction during a manually piloted landing attempt resulting in collision with terrain in the United States Africa Command Area of Responsibility (AOR) (Tabs R-4, R-8, Y-3, CC-18, and DD-10. The mishap aircraft (MA) was operated in the AOR by the Launch and Recovery Element (LRE) comprised of the mishap pilot (MP) and the mishap sensor operator (MSO) assigned to the 12th Expeditionary Special Operations Squadron (Tabs K-5 to K-6, R-4, and CC-18). The mishap resulted in no reported damage to civilian property, no injuries, and no fatalities (Tab P-3). The loss of government property was valued at $16,711,554 (Tab P-3).

Prior to the sequence of events leading up to the mishap, the MA had completed an uneventful mission under the control of the Mission Control Element (MCE) with all systems normal (Tabs R-8, V-3.22 to V-3.23, and DD-11). Transfer of control to the LRE for normal recovery and landing was uneventful (Tabs R-4, R-8, and CC-18). The LRE navigated the MA to the airfield traffic pattern, attempted an automatic landing, which was aborted for a known altitude error at this airfield, and reentered the traffic pattern for a normal, manually piloted approach and landing

(Tabs R-4 and DD-11). As the MA initiated a descending right turn from base leg to final, engine indications on the Head-Up-Display (HUD) stagnated and a warning was displayed indicating that the electrical engine control system had transitioned to backup mode (Tabs R-4 and DD-13). The MA's airspeed and altitude decreased significantly as the MA descent rate rapidly increased (Tabs DD-13, DD-25 to DD-26). While assessing the situation, the MP slowly increased throttle command while continuing the final turn (Tabs DD-26). Thirty seconds passed from initial failure indications to full throttle command and subsequent, near-simultaneous impact with terrain well short of the runway threshold (Tabs CC-18, DD-10, and DD-13).

Subsequent analysis of the MA's data logs, HUD video, and hardware identified a broken cable connection that caused an electrical short in a primary communications bus and the Dual Aircraft Control Network (Tab DD-15 to DD-16 and DD-30). This resulted in the stagnated engine and Angle of Attack (AoA), outside air temperature, engine telemetry provided by the Electronic Engine Control System, etc. indications which forced the electrical engine control system into backup mode and circumvented normal stall warning indications (Tab DD-16, DD-21, DD-22, and DD-30). Additionally, there was pre-existing cable connection damage caused by a damaged cable connector, bent grounding fingers, and missing bayonet pins (Tab DD-30).

This system failure was replicated in the MQ-9 simulator, as close to mishap conditions as possible, with two different, unsuspecting crews (Tab DD-27 and DD-28). In each case, the electrical engine control system transition to backup mode caused airspeed to decrease below stall and descent rate to increase (Tab DD-33). In both simulations, without foreknowledge, each pilot failed to recover the stalled aircraft and the aircraft impacted terrain. It is unlikely that anyone without foreknowledge of the impending system failure would have successfully recovered the MA (Tab DD-27).

3. BACKGROUND

The MA was owned by the 432d Wing and is organized under Air Combat Command (Tab CC-18). The MP and MSO were assigned to the 12th Expeditionary Special Operations Squadron, a forward deployed extension of the 12th Special Operations Squadron, 27th Special Operations Wing (27 SOS) (Tabs K-6, CC-12 and CC-18). The 27 SOS is organized under the Air Force Special Operations Command (Tab CC-4).

a. Air Combat Command (ACC)

Headquartered at Joint Base Langley-Eustis, Virginia, ACC is one of ten major commands (MAJCOMs) in the United States Air Force (Tab CC-15). ACC is the primary provider of combat air forces to America's warfighting commanders (Tab CC-15). ACC organizes, trains, and equips Airmen who fight in and from multiple domains to control the air, space, and cyberspace (CC-15). As the lead command for fighter, command and control, intelligence, surveillance and reconnaissance, personnel recovery, persistent attack and reconnaissance, electronic warfare, and cyber operations, ACC is responsible for providing combat, air, space, and cyber power and the combat support that assures mission success to America's warfighting commands (Tab CC-15).

b. 432d Wing (432 WG)

The 432 WG is located at Creech Air Force Base (AFB), Nevada (Tab CC-16 to CC-17). The 432 WG is the U.S. Air Force's first unmanned (and later remotely piloted) aircraft systems wing (Tab CC-16 to CC-17). The wing's mission is to conduct unmanned precision attack and intelligence, surveillance, and reconnaissance combat missions in support of overseas contingency operations (Tab CC-17).

c. Air Force Special Operations Command (AFSOC)

AFSOC, headquartered at Hulburt Field, Florida, is also one of the ten MAJCOMs in the United States Air Force and the Air Force component of U.S. Special Operations Command (Tab CC-3). Established on May 22, 1990, AFSOC has served as the primary provider of Air Force special operations forces for worldwide deployment and assignment to regional unified commands (Tab CC-3). The command's forces composed of highly trained, rapidly deployable Airmen, conducting global special operation missions ranging from precision application of firepower to infiltration, exfiltration, resupply and refueling of Special Operations Forces (SOF) operational elements (Tab CC-3). The command's core missions include battlefield air operations; agile combat support; aviation foreign internal defense; information operations/military support operations; precision strike; specialized air mobility; command and control; and intelligence, surveillance, and reconnaissance (Tab CC-3).

d. 27th Special Operations Wing (27 SOW)

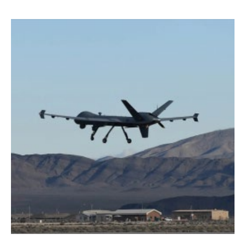
The 27 SOW is located at Cannon AFB, New Mexico and is organized under AFSOC (Tab CC-4 to CC-5). The wing's mission is to develop, sustain and employ professional Air Commandos to execute specialized airpower and combat support to achieve the nation's security objectives (Tab CC-5).

e. 12th Expeditionary Special Operations Squadron (12 ESOS)

The 12 ESOS is the forward deployed extension of the 12th Special Operations Squadron (12 SOS) (Tab CC-12). The 12 SOS was re-activated on February 12, 2015, and is located at Cannon AFB, New Mexico (Tab CC-12 to CC-13). The 12 ESOS conducts forward deployed launch and recovery operations supporting Remotely Piloted Aircraft (RPA) (Tab CC-6 and CC-11 to CC-12).

f. MQ-9A Reaper

The MQ-9A Reaper is an armed, multi-mission, medium-altitude, long-endurance remotely piloted aircraft that is employed primarily against dynamic execution targets and secondarily as an intelligence-collection asset



(Tab CC-9). Given its significant loiter time, wide-range sensors, multi-mode communications suite, and precision weapons, it provides a unique capability to perform strike, coordination, and reconnaissance against high-value, fleeting, and time-sensitive targets (Tab CC-9). Reapers can also perform the following missions and tasks: intelligence, surveillance and reconnaissance, close air support, combat search and rescue, precision strike, buddy-lase, convoy and raid overwatch, target development, and terminal air guidance (Tab CC-9). The MQ-9A's capabilities make it uniquely qualified to conduct irregular warfare operations in support of combatant commander objectives (Tab CC-9).

4. SEQUENCE OF EVENTS

a. Mission

On 01 March 2023, an unmanned MQ-9A, TN 13-4230, under control of the Mission Control Element (MCE), was returning to base after successfully completing an operational mission in support of United States Africa Command AOR (Tabs R-4, R-6, R-8, Y-3, CC-18 and DD-10). During the operational mission, no unusual aircraft handling issues or engine indications were observed (Tabs R-4, R-8, V-3.23, and DD-10). Handover to the LRE was uneventful (Tab R-4 and R-8). The mission of the LRE was to recover and land the MA at the forward deployed location (Tab R-4 and R-8). The LRE was in control for the final 23 minutes of the flight, including the mishap sequence (Tabs R-8 and DD-11). The mishap crew (MC) consisted of the MP and MSO (Tab K-5 to K-6). The mission orders were authorized by the 12 ESOS Director of Operations (K-5).

b. Planning

The MC accomplished all applicable planning steps and procedures to conduct launch and recovery operations on 01 March 2023 (Tab R-6). There is no evidence indicating a lack of proper planning to be a factor in this mishap.

c. Preflight

All applicable checklist steps and procedures were accomplished correctly to prepare the mishap ground control station (MGCS) and the MA for flight (Tab D-4 to D-39 and DD-29). No evidence indicates that preflight procedures were a factor in this mishap.

d. Summary of Accident

Prior to the mishap, the MC completed all descent, recovery, and pre-landing checklists and navigated the MA to the airfield traffic pattern (Tabs R-4 and DD-11). The MC set up for and attempted an automatic landing which was aborted for a known altitude error at this airfield (Tabs R-4 and DD-10. The MA reentered the traffic pattern for a normal, manually-piloted approach and landing starting at prescribed pattern altitude, on downwind and beginning a descending right-hand turn to base (Tabs R-4, DD-10, DD-25 to DD-33, and Figure 1). While descending on base leg, the MP initiated a descending right turn from base leg to final. (Tabs R-4, DD-10 to DD-11, and DD-13). A critical component of the MA's primary communications bus failed due to pre-existing damage to a key cable connection (Tabs R-4, DD-15 to DD-16, and

DD-21). This failure caused engine indications in the HUD to stagnate and forced the electrical engine control system into backup mode (Tabs R-4 and DD-10, and DD-26). While the MP assessed the situation presented by this compound emergency, the MA airspeed decreased below stall speed as the descent rate rapidly increased (Tabs R-4, DD-10, and DD-25 to DD-26). The MP initially increased the throttle just above that setting required to maintain level flight under normal conditions while continuing the final turn (Tabs DD-10 and DD-15 to DD-26). The MP commanded full throttle followed by loss of datalink a few seconds later, resulting in impact with terrain well short of the runway threshold (Tabs DD-10 and DD-25 to DD-26).

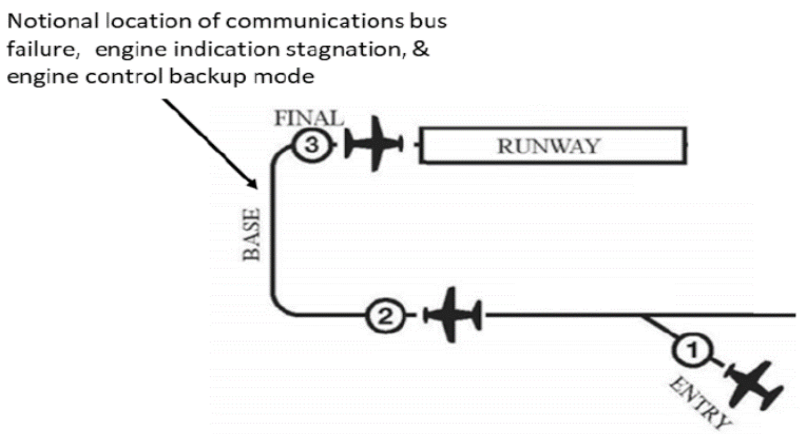


Figure 1. Components of a Traffic Pattern (Tab DD-38)

e. Impact

The MA impacted terrain well short of the intended landing runway (Tab DD-10). Upon impact, full throttle had been commanded, the MA was in a slight right bank, and in a stall (Tab DD-10 and DD-25 to DD-26).

f. Egress and Aircrew Flight Equipment (AFE)

Not applicable.

g. Search and Rescue (SAR)

Not applicable.

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

A review of the Air Force Technical Order (AFTO) 781 series forms maintenance records was conducted for the MA (Tabs D-3 to D-23). Records showed no outstanding discrepancies or related overdue Time Compliance Technical Orders (TCTOs) (Tab D-l9 and D-20). All preflight inspections and release procedures were followed (Tab D-291).

b. Inspections

At the time of the mishap, the MA was not overdue for any inspections (Tabs D-3 to D-23). All maintenance inspections were current and complied with relevant authorities (Tab DD-31). AFTO Form 781H, dated 28 February 2023, indicated maintenance personnel inspected the MA prior to its last flight (Tab DD-31).

Integrated Maintenance Data System (IMDS) records also indicated that Major Periodic Inspections; 400 Hour Airframe Inspection, 400 Hour Engine Inspection, 200 Hour Airframe Inspection and 200 Hour Engine Inspection were complied with on 17 February 2023 (Tab DD-31).

c. Maintenance Procedures

Maintenance personnel conducted all maintenance procedures in accordance with applicable Technical Orders (TOs) and guidance (Tab D-31). No evidence indicates that the maintenance procedures executed were a factor in this mishap (Tab D-31).

d. Maintenance Personnel and Supervision

No evidence indicates that the training, qualifications, and supervision of the maintenance personnel were a factor in this mishap (Tab DD-31).

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

No evidence indicates that the fuel, hydraulic, oil, and oxygen were a factor in this mishap (Tab D-7 and DD-31).

f. Unscheduled Maintenance

Prior to the mishap and unbeknownst to the 12 ESOS, the cable and cable module were broken. (Tab DD-31). Within 90 days of the mishap, no unscheduled maintenance was conducted on the broken mishap cable or broken mishap cable module (Tab DD-31).

On 30 June 2021, the left and right MLG retract actuator cables, the left and right brake cables, and the WSPM cables were replaced as part of a broader block upgrade to the MA (Tab DD-14). On 12 August 2022, the MA experienced a hard landing, which required the landing gear to be replaced along with the retract drivers and brake servos (Tab DD-23). Available evidence does not indicate that the mishap cable was inspected following the hard landing (Tab DD-23). The hard landing event may have had effects that later related to the mishap, but no failure mode could be conclusively traced back to the hard landing (Tab DD-23).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

(1) Electronic Engine Control System

In Backup mode, engine commands (throttle lever angle, and condition lever position) are transmitted from the Flight Computer Assemblies (FCA) to the power servo and stop/feather servo via the UARB transmit network (Tab DD-20). Engine solenoids are de-energized such that spring-loaded valves set engine speed and allow engine power to be controlled directly by the power servo (Tab DD-20). Engine feedback data is sent from the EFIU to the FCAs via the UARB response network (Tab DD-20). In Backup mode, engine control switches to open-loop power (Tab DD-20). In open-loop power, engine torque is not used in a control loop to adjust power production (Tab DD-20). The throttle will change the amount of fuel going into the engine, but there will not be any automatic adjustments made to achieve a specific torque output (Tab DD-20). Pilot awareness of indicated torque and/or aircraft attitude is the only method by which engine power production is monitored during open-loop power mode (Tab DD-20).

(2) Aircraft Digital Control System (ADCS)

The ADCS is the master control system for the aircraft and uses the control module and a dual aircraft control network subsystem (Tab DD-17 to DD-18 and DD-35). Once a command is initiated by the GCS, those commands are received via the Redundant Control Module and then routed throughout the aircraft using the two paths of the subsystem concurrently (Tab DD-17 to DD-18 and DD-35). After a command-completion signal is received by the subsystem, it is routed through either of the two paths (dependent on which one was selected by the aircrew) to the control module and ultimately back to the GCS where those commands are updated on the HUD (Tab DD-17 to DD-18 and DD-35).

(3) Aircraft Stall Warning System

With stall protection disabled, as in the mishap sequence, the aircraft still provides cautions and warnings of impending stall (Tab J-6 to J-7). Warning messages are displayed in the GCS Head-Down Display (HDD) when AoA approaches and exceeds normal operating range (Tab J-6 to J-7). When exceeding normal AoA range, the warning message is accompanied by an audible tone (Tab J-6 to J-7). The MQ-9 technical order provides detailed stall recovery procedures which amounts to lowering the nose to decrease AoA, increasing power, and maximizing lift by rolling wings level (Tab J-6 to J-7). Additionally, the system is designed to display a message in the HDD when the aircraft is approaching stall speed or has a low coefficient of lift (Tab J-6 to J-7). This message is unaccompanied by any audible tone (Tab DD-32). Available evidence could not confirm if the MGCS displayed these stall warning messages; however, the mishap video did confirm a lack of audible stall warning tones (Tab DD-32). Multiple caution statements in the MQ-9 technical order caution pilots to be careful not to exceed engine temperature limits (Tab J-8 to J-9 and DD-33). Review of training syllabi and testimony by and conversations with pilots trained in launch and recovery operations revealed that the prevailing training method for stall recovery procedures was a deskside or "table-top" conversation regarding expected indications and appropriate crew actions (Tab DD-28 and DD-33). An immediate, near-instantaneous stall recovery, wings level, with maximum power is likely the only pilot action that could have prevented this mishap (Tab DD-28).

b. Evaluation and Analysis

The Electronic Engine Control System component was tested for operation post-mishap by GA-ASI and showed no anomalies (Tab DD-16). Component exterior surfaces appeared to be in an undamaged condition upon receipt by GA-ASI (Tab DD-15 and DD-35).

System mock testing consisted of all available aircraft avionics and most actuator servos that were electronically analogous to the MA (Tabs DD-10). Landing gear retract drivers and brake servo hardware from the MA were not included in the mock system testing, as they were not sent for testing (Tabs DD- 23).

The inability to duplicate the exact mishap indications during system testing with the mishap hardware prompted further investigation into the conditions required to match the faults presented (Tab DD-21).

The sensing module, a component of the dual aircraft control network, was connected to the suspected mishap cable (Tab DD-15 and DD-35). The sensing module was received with external damage of a broken mounting leg (Tab DD-15 and DD-35). Disassembly and internal inspection of the sensing module showed no signs of water intrusion, corrosion, or component failure (Tab DD-15 and DD-35).

A Computerized Tomography (CT) scan was taken off the broken mishap cable end connector to evaluate the bent grounding fingers in the connector (Tab DD-15). The CT results allowed for identification and evaluation of all grounding fingers that surround the circumference of the connector (Tab DD-15).

The landing gear retract drivers and brake servos are other possible locations of the short-circuit failure that were impacted by the hard landing on 12 August 2022 (Tab DD-23). The hard landing event may have had effects that later related to the mishap, but no failure mode could be conclusively traced back to the hard landing (DD-23).

System testing of the dual network with GA-ASI's Hot Mock-Up (HMU) (a test setup containing most aircraft avionics), indicated that a short circuit within the network circuitry was most likely the cause of the network failure (Tab DD-10). The mishap data log signature was duplicated by inducing a short circuit on this branch (Tab DD-10 to DD-11). Other short-circuit locations and failure modes were investigated, but the mishap data log signature was not duplicated (DD-11).

7. WEATHER

a. Forecast Weather

The forecast weather from handover to mishap was fair (Tab F-3). Winds were forecast to be a light breeze with moderate visibility and clouds were forecasted to be broken (Tab F-3). A moderate temperature of 25 degrees Celsius (77 degrees Fahrenheit) was expected (Tab F-3). The only forecast hazard was light turbulence and haze (Tab F-3).

b. Observed Weather

Observed weather differed marginally with clouds broken at a different level than forecasted (Tab F-5). Additionally, winds were a gentle breeze (Tab F-5).

c. Space Environment

Not applicable.

d. Operations

Not applicable.

8. CREW QUALIFICATIONS

a. Mishap Pilot (MP)

The MP was current and qualified to conduct launch and recovery duties in the MQ-9A (Tabs DD-29 and K-4 to K-5). The MP had 210 hours of MQ-9A flight time and 152.5 hours of MQ-9A simulator time prior to the mishap (Tab G-44). Recent flight hours and days flown were as follows (Tab G-45):

	Flight Hours	Days Flown
Last 30 Days	19.7	27
Last 60 Days	34.8	52
Last 90 Days	50.1	79

b. Mishap Sensor Operator (MSO)

The MSO was current and qualified to conduct launch and recovery duties in the MQ-9A at the time of the mishap (Tabs DD-29, K-3, and K-6). The MSO had 167.3 hours of MQ-9A flight time and 121.8 hours of MQ-9A simulator time prior to the mishap (Tab G-180). Recent flight hours and days flown were as follows (Tab G-181):

	Flight Hours	Days Flown
Last 30 Days	20.1	27
Last 60 Days	40.6	56
Last 90 Days	62.3	84

9. MEDICAL

a. Qualifications

All members were medically qualified for their specific duties at the time of the mishap (Tabs DD-34).

b. Health

No evidence indicates the member’s health was a factor in the mishap (Tabs DD-34).

c. Pathology

Not applicable.

d. Lifestyle

No evidence indicates that lifestyle was a factor in the mishap (Tab DD-34).

e. Crew Rest and Crew Duty Time

At the time of the mishap, Air Force Manual (AFMAN) 11-202, Volume (V) 3, *Flight Operations*, 10 January 2022, required aircrew members have proper crew rest prior to performing any duties involving aircraft operations (Tab BB-4). Crew rest is a minimum 12-hour rest opportunity period before the flight duty period begins (Tab BB-4). “Crew rest is free time and includes time for meals, transportation, and an opportunity for at least 8 hours of uninterrupted sleep” (Tab BB-4). MC verified they received adequate crew rest before the mishap (Tab H-5 to H-31).

10. OPERATIONS AND SUPERVISION

a. Operations

The MC was only 2.5 hours into their duty day when they gained control of the MA via the LRE (Tabs R-4 and R-6). When the MA experienced the communications bus failure, the MC had been in control of the MA for less than 23 minutes (Tab DD-3). No evidence indicates that the MC’s operations tempo was a factor in the mishap (Tabs H-5 to H-31, R-17, and DD-29).

b. Supervision

No evidence indicates that supervision was a factor in the mishap (Tab DD-33).

11. HUMAN FACTORS ANALYSIS

a. Introduction

The Department of Defense Human Factors Analysis and Classification System 8.0 (DoD HFACS 8.0) breaks down human factors into potential acts, preconditions, supervisory, and organizational factors that can play a role in aircraft mishaps and identifies potential areas of assessment during an accident investigation (Tab EE-3, EE-6, EE-9, EE-20, and EE-25). Four acts, four preconditions, and one organizational factor were identified as relevant to this mishap:

b. Acts

DoD HFACS 8.0 describes acts as factors that are most closely tied to the mishap and can be described as active failures or actions committed by the operator (mishap person) that result in human error or an unsafe situation (Tab EE-6). Acts are divided into the following categories: Performance/Skill Based Errors or AE100 nanocodes, Judgment and Decision-Making Errors or AE200 nanocodes, and Known Deviations or AD000 nanocodes (Tab EE-6 to EE-9). Four acts were identified as factors in this mishap.

(1) Procedure or Checklist Not Followed Correctly (AE102) is when the mishap individual did not follow correct procedure which resulted in the near-miss or mishap (Tab EE-7). During this mishap, MP failed to follow correct stall recovery procedures, as outlined in MQ-9A TOs, by not increasing throttle as required and neutralizing ailerons (Tabs J-7 and DD-25 to DD-25 and DD-33).

(2) Over-Controlled/Under-Controlled Aircraft/Vehicle/Vessel or System (AE104) is when the mishap individual(s) inappropriately reacted to conditions by either over- or under-controlling the aircraft/vehicle/vessel/system (Tab EE-7). MP initially increased throttle to only 39% which was not enough to expeditiously arrest the stall (Tab DD-26 and DD-33).

(3) Rushed or Delayed a Necessary Action (AE107) is when the mishap individual took the correct action(s) as dictated by the situation but performed the action(s) either too quickly or too slowly, which resulted in the near-miss or mishap (Tab EE-7). MP delayed increasing throttle to 100% until ground impact was imminent (Tab DD-26).

(4) Ineffective Task Prioritization (AE202) is when the mishap individual did not effectively organize and accomplish the tasks required to manage a situation (Tab EE-8). Despite stall, MP continued right navigational turn, increasing stall speed, at the expense of arresting descent and regaining aircraft control (Tab DD-26).

c. Preconditions

DoD HFACS 8.0 defines preconditions as evidence supported conditions in a mishap if active and/or latent conditions of the individual, the operating environment, or team communications affected the performance or actions of the mishap individual and resulted in unsafe acts/active failures (Tab EE-10). Preconditions are further divided into the following categories: Mental Awareness Conditions or PC100 nanocodes, State of Mind Conditions or PC200 nanocodes, Adverse Physiological Conditions or PC300 nanocodes, Physical Environment or PE100 nanocodes, Technological Environment or PE200 nanocodes, Team

Coordination/Communication Condition or PP100 nanocodes, and Training Conditions or PT100 nanocodes (Tab EE-10 to EE-19). Four preconditions were identified as factors in this mishap.

(1) Task Saturation (PC103) is when the quantity of information an individual was processing exceeded his or her mental resources in the amount of time available and resulted in a hazardous condition or unsafe act (Tab EE-10). During the mishap, MC had to process frozen AoA, engine speed, engine torque, fuel flow, and oil pressure indications; electronic engine control failure and its implications; and respond to a stall while in base turn to final (Tab DD-25 to DD-26).

(2) Terrain Feature Affected Performance (PE112) is when known yet unanticipated or unseen/unknown terrain hazards were encountered, which negatively affected performance and resulted in hazardous conditions or unsafe acts (Tab EE-16). The LRE was aware of a known altitude error at this airfield (Tabs R-4 and DD-11). When the LRE navigated the MA to the airfield traffic pattern and attempted an automatic landing, the landing was aborted (Tabs R-4 and DD-11). The LRE then needed to reenter the traffic pattern for a normal, manually piloted approach and landing (Tabs R-4 and DD-11).

(3) Instrumentation and Warning System Issues (PE202) is when workspace/cockpit instrument or warning system elements (design, reliability, lighting/backlighting, audible cues, location, symbology, size, display, etc.) negatively affected performance, which resulted in a hazardous condition or unsafe act (Tab EE-17). MC did not receive audible stall warning due to stall warnings' inherent tie to AoA (Tab J-9). Further, there is no audible warning for low airspeed (Tab J-9).

(4) Ineffective Team Resource Management (PP101) is when crew/team members failed to actively maintain an accurate and shared understanding of the evolving task, or manage their distribution of tasks, which resulted in a hazardous condition or unsafe act (Tab EE-18). MSO stated that they could have called out airspeed (Tab DD-33).

d. Organizational Influences

DoD HFACS 8.0 defines this tier of failures as an organization's communications, actions, omissions, and policies which can lead to a mishap or near miss (Tab EE-25). Organizational Influence are divided into the following categories: Organizational Climate/Culture or OC000 nanocodes; Organizational Policy, Procedures, or Process Issues or OP000 nanocodes; Resource Support Problems or OR000 nanocodes; and Training Programs or OT000 nanocodes (Tabs EE-25 to EE-30).

(1) Resident Formal School Training Program is Ineffective or Unavailable (OT001) is when resident based formal school training conducted by a formal schoolhouse under AETC (Air Education Training Command) is either incorrect, incomplete, insufficient, or unavailable for performance to standard, resulting in hazardous conditions or unsafe acts throughout subordinate units or the field/fleet (Tab EE-30). According to syllabi from both the 11th ATKS (LR Qualification Training Schoolhouse) and 6th ATKS (Initial Qualification Training Schoolhouse), stall recovery is only taught to a "tabletop" or introductory level via deskside conversation (Tabs DD-5 to DD-8, and DD-28 and DD-33).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publicly Available Directives and Publications Relevant to the Mishap

(1) Human Factors Analysis and Classification System, Version 8.0, available at https://www.safety.af.mil/Divisions/Human-Performance-Division/HFACS/

(2) AFI 51-307, *Aerospace and Ground Accident Investigations*, 18 March 2019, available at https://www.e-publishing.af.mil

(3) AFI 51-307, Air Combat Command Supplement, *Aerospace and Ground Accident Investigations*, 3 December 2019, available at https://www.e-publishing.af.mil

(4) Department of the Air Force Instruction (DAFI) 91-204, *Safety Investigations and Reports*, 10 March 2021, available at https://www.e-publishing.af.mil

(5) AFMAN 11-202, V3, *Flight Operations*, 10 January 2022, available at https://www.e-publishing.af.mil

(6) AFMAN 11-2MQ-9 V3, *Flying Operations*, 1 October 2020 (previous version), current version available at https://www.e-publishing.af.mil

b. Other Directives and Publications Relevant to the Mishap

(1) TO 1Q-1(M)A-1, *Flight Manual*, 31 Oct 2022

(2) MQ-9 Launch and Recovery Qualification and Requalification Training Course

(3) AFTTP 3-3.MQ-9, *Combat Fundamentals MQ-9, 14 April 2023*

8 August 2024

JOHN D. GALLOWAY, Colonel, USAF
President, Abbreviated Accident Investigation Board

STATEMENT OF OPINION

MQ-9A, T/N 13-4230
UNITED STATES AFRICA COMMAND AREA OF RESPONSIBILITY
01 MARCH 2023

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 01 March 2023, an unmanned MQ-9A, tail number (T/N) 13-4230, experienced a system malfunction during a manually piloted landing attempt resulting in collision with terrain in the United States Africa Command Area of Responsibility (AOR). The mishap aircraft (MA) was operated in the AOR by the Launch and Recovery Element (LRE) comprised of the mishap pilot (MP) and the mishap sensor operator (MSO). The mishap resulted in no reported damage to civilian property, no injuries, and no fatalities. The loss of government property was valued at $16,711,554.

Prior to the sequence of events leading up to the mishap, the MA had completed an uneventful mission under the control of the Mission Control Element (MCE) with all systems normal. Transfer of control to the LRE for normal recovery and landing was uneventful. The LRE navigated the MA to the airfield traffic pattern, attempted an automatic landing which was aborted for a known altitude error at this airfield, and reentered the traffic pattern for a normal, manually piloted approach and landing. As the MA initiated a descending right turn from base leg to final,engine indications on the Head-Up-Display (HUD) stagnated and a warning was displayed indicating that the electrical engine control system had transitioned to backup mode. The MA's airspeed and altitude decreased significantly as the MA descent rate rapidly increased. While assessing the situation, the MP slowly increased throttle command while continuing the final turn. Thirty seconds passed from initial failure indications to full throttle command and subsequent, near-simultaneous impact with terrain well short of the runway threshold.

Subsequent analysis of the MA's data logs, HUD video, and hardware identified a broken cable connection that caused an electrical short in a primary communications bus. This caused the stagnated engine and Angle of Attack (AOA) indications which forced the electrical engine control system into backup mode and circumvented normal stall warning indications.

2. CAUSES

I found, by a preponderance of the evidence, that the cause of the mishap was the ill-timed electrical short in the primary communications bus, caused by pre-existing cable connection damage, coupled with the MP's delay in executing an immediate stall recovery, wings level, with maximum power. Given the circumstances of this compound emergency, considering processing time, the lack of engine indications, the lack of normal stall indications, and the very low altitude above the ground, it is assessed that only an immediate maximum power stall recovery would have had a chance of recovering the aircraft.

The pre-existing cable connection damage was caused by a damaged cable connector, bent grounding fingers, and missing bayonet pins. Physical evidence verified these damaged and missing parts but could not conclusively determine when the damage occurred or the parts went missing. Post-mishap analysis indicated the damage and missing parts were likely caused by previous maintenance actions or the MA's hard landing on 12 August 2022.

The Dual Aircraft Control Network experienced an electrical short. Network condition values and stagnated HUD indications (AOA, outside air temperature, engine telemetry provided by the Electronic Engine Control System, etc.) indicated a failure on one of the dual aircraft control response networks. In response to the loss of feedback data from the Electronic Engine Control System, the control module commanded the Electronic Engine Control System to backup mode.

This primary communications bus malfunction caused stagnated engine, AoA, Outside Air Temperature, and other feedback indications. This failure also forced the electrical engine control system into backup mode. A signal downstream of the bus network was identified, and system mock testing supported that a short circuit of the signal within a network path response input was the most likely cause of the network failure. A failure on this path resulted in the same combination of nodes that had reflected intermittent valid responses and nodes that lost all valid responses. Additionally, the HUD video showed that normal stall warning indications, specifically audio warnings, were absent; this is attributed to the stagnation of AoA indications.

By forcing the electrical engine control system into backup mode, this system failure resulted in an immediate loss of thrust requiring a higher-than-normal throttle setting to achieve the thrust necessary for level-to-climbing flight. This resulted in the MA quickly slowing below stall speed and developing a high descent rate.

Review of the MA data files, witness testimonies, and mission video of the mishap showed while assessing the situation, the MP slowly increased throttle command and continued the turn to final. These actions allowed the MA to remain in a stall and prevented aircraft recovery prior to impact due to the low altitude at which the system failure occurred.

This system failure was replicated in the MQ-9 simulator, as close to mishap conditions as possible, with two different, unsuspecting crews. In each case, the electrical engine control system transition to backup mode caused airspeed to decrease below stall and descent rate to increase. In both simulations, without foreknowledge, each pilot failed to recover the stalled aircraft and the aircraft impacted terrain. It is unlikely that anyone without foreknowledge of the impending system failure would have successfully recovered the MA.

2. SUBSTANTIALLY CONTRIBUTING FACTORS

Further, I find, by a preponderance of the evidence that the following three factors substantially contributed to the mishap: 1) maintenance technical orders and procedures did not appear to require routine inspection and/or replacement of this particular cable connector; 2) training and procedures regarding the implications of the electrical engine control system backup mode, particularly at low altitude, was insufficient; and 3) training in appropriate stall recovery procedures, primarily while in manual flight mode, was lacking.

First, the 12th Expeditionary Special Operations Squadron was unaware of the damaged cable connector, bent grounding fingers, and missing bayonet pins prior to the mishap. The damage and missing parts were likely caused by previous maintenance actions after 30 June 2021 or the MA's hard landing on 12 August 2022. I found, by the preponderance of the evidence, the maintenance technical orders and procedures did not appear to require routine inspection and/or replacement of the cable connector, grounding fingers, or bayonet pins.

Second, MQ-9 crew training and procedures regarding the implications of the electrical engine control system backup mode, particularly at low altitude, is insufficient. Multiple caution statements in the MQ-9 technical order caution pilots to be careful not to exceed engine temperature limits. The technical order does not clearly communicate that engine torque is lower in backup mode for a given throttle setting; not slightly lower but significantly lower.

Third, MQ-9 pilot training in appropriate stall recovery procedures, primarily while in manual flight mode, is lacking. The MQ-9 technical order provides detailed stall recovery procedures which amounts to lowering the nose to decrease AoA, increasing power, and maximizing lift by rolling wings level. Review of training syllabi and testimony by and conversations with pilots trained in launch and recovery operations revealed that the prevailing training method for stall recovery procedures was a deskside or "table-top" conversation regarding expected indications and appropriate crew actions.

4. CONCLUSION

After reviewing aircraft data logs, maintenance records, witness testimony, technical reports, and maintenance practices, I find, by a preponderance of evidence, the cause of the mishap was the ill-timed electrical short in the primary communications bus, caused by pre-existing cable connection damage, coupled with the MP's delay in executing an immediate stall recovery, wings level, with maximum power. Given the circumstances of this compound emergency, considering processing time, the lack of engine indications, the lack of normal stall indications, and the very low altitude above the ground, I assessed that only an immediate maximum power stall recovery would have had a chance of recovering the aircraft.

Further, I find, by a preponderance of the evidence, the following three factors substantially contributed to the mishap: 1) maintenance technical orders and procedures did not appear to require routine inspection and/or replacement of this particular cable connector; 2) training and procedures regarding the implications of the electrical engine control system backup mode, particularly at low altitude, was insufficient; and 3) training in appropriate stall recovery procedures, primarily while in manual flight mode, was lacking.

8 August 2024

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