UNITED STATES AIR FORCE ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

MQ-9A, T/N 08-4035

42d ATTACK SQUADRON
432d WING
CREECH AIR FORCE BASE, NEVADA

LOCATION: UNITED STATES CENTRAL COMMAND AREA OF RESPONSIBILITY

DATE OF ACCIDENT: 10 APRIL 2019

BOARD PRESIDENT: COLONEL TODD C. SPRISTER

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

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION

MQ-9A, T/N 08-4035
UNITED STATES CENTRAL COMMAND AREA OF RESPONSIBILITY
10 APRIL 2019

On 10 April 2019, at about 0200 Zulu time (Z), the mishap aircraft (MA), an MQ-9A, tail number (T/N) 08-4035, departed controlled flight and impacted the terrain in an undisclosed location within the United States Central Command (US CENTCOM) Area of Responsibility (AOR). Assigned to the 432d Wing, Creech Air Force Base (AFB), Nevada, the MA was operated by the 42d Attack Squadron Mission Control Element (MCE) located at Creech AFB, Nevada, at the time of the mishap. The MA wreckage was located and destroyed. The loss of Government Property was valued at $11,319,416. There was no reported damage to civilian property, injuries, or fatalities.

At about 0156Z, several control inputs from the mishap Ground Control Station (MGCS) to the MA changed simultaneously. Among these commands was an input to close the fuel shut-off valve and feather the propeller. Over the next minute, the MA's engine torque, oil pressure, and propeller speed decreased, as the engine shutdown. In accordance with the emergency procedures checklist, the mishap crew (MC), consisting of the mishap pilot (MP) and mishap sensor operator (MSO), performed engine failure procedures. Since the MA continued to receive erroneous commands, which kept the fuel shut-off valve closed for the remainder of the mishap flight, the engine remained shut down and could not be restarted.

The MGCS sent erroneous pitch, roll, and yaw commands, but the MA initially ignored them because autopilot hold modes were enabled. When hold modes were disabled to permit emergency checklist accomplishment, the MA began executing the erroneous pitch, roll, yaw stick, and rudder commands from the MGCS. The MC performed emergency checklist procedures to prevent loss of control, but they were unable to recover the MA. The rapid changes in MA attitude resulting from the erroneous control inputs caused intermittent departures from controlled flight and a permanent loss of datalink. Subsequently, the MA impacted the ground at an undisclosed location within the USCENTCOM AOR and the MA wreckage was destroyed.

The Abbreviated Accident Investigation Board (AAIB) President found, by a preponderance of the evidence, the cause of the mishap was a loose, flat metallic washer on the Control Console Serial Module (CCSM) that created an electrical short between several pins, resulting in erroneous control inputs being transmitted to the MA. Further, the AAIB President found, by a preponderance of the evidence, that each of the following factors substantially contributed to the mishap; (1) the design of the Control Console Assembly (CCA), which contains inadequately restrained metallic hardware, and (2) limitations in software fault logic.

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.

SUMMARY OF FACTS AND STATEMENT OF OPINION
MQ-9A, T/N 08-4035
10 APRIL 2019

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ACRONYMS AND ABBREVIATIONS

1st Lt	First Lieutenant
12 AF	12th Air Force
42 ACMS	42d Aircraft Communications Maintenance Squadron
42 ATKS	42d Attack Squadron
432 WG	432d Wing
ACC	Air Combat Command
AF	Air Force
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFI	Air Force Instruction
AFSOUTH	Air Forces Southern
AAIB	Abbreviated Accident Investigation Board
AOA	Angle of Attack
AOR	Area of Responsibility
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
EP	Emergency Procedure
ER	Exceptional Release
FCIF	Flight Crew Information File
FOD	Foreign Object Debris
GA-ASI	General Atomics Aeronautical Systems, Inc.
GCS	Ground Control Station
GCSCT	Ground Control System Communications Technician
HDD	Heads Down Display
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
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
MCE	Mission Control Element
MFW	Multi-Functional Workstation
mIRC	Mardam-Bey Internet Relay Chat
MGCS	Mishap Ground Control Station
MP	Mishap Pilot
MP1	Mishap Pilot One
MP2	Mishap Pilot Two
MSL	Mean Sea Level
MSO	Mishap Sensor Operator
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
PSO1	Pilot/Sensor Operator Position 1
PSO2	Pilot/Sensor Operator Position 2
PST	Pacific Standard Time
RPA	Remotely Piloted Aircraft
SAR	Search and Rescue
SAS	Stability Augmentation System
SATCOM	Satellite Communications
SCCM	STORM Console Control Module
SIB	Safety Investigation Board

SIPR	Secret Internet Protocol Router
SL	Sensor Lead
SLMA	Secure Link Manager Assembly
SME	Subject Matter Expert
SO	Safety Observer
SrA	Senior Airman
SSgt	Staff Sergeant
STORM	Safety Tactical Operation Reliability Maintenance
TO	Technical Order
TCTO	Time Compliance Technical Order
T/N	Tail Number
TSgt	Technical Sergeant
USAF	United States Air Force
U.S.C.	United States Code
US CENTCOM	U.S. Central Command
VIT	Variable Information Table
VSI	Vertical Speed Indicator
VVI	Vertical Velocity Indication
Z	Zulu Time

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

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 16 December 2019, the Deputy Commander, Air Combat Command (ACC), appointed Colonel Todd C. Sprister as the Abbreviated Aircraft Investigation Board (AAIB) President to investigate a mishap that occurred on 10 April 2019 involving an MQ-9A aircraft in the United States Central Command (US CENTCOM) 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 Creech Air Force Base (AFB), Nevada, and Nellis AFB, Nevada, from 10 January 2020 to 10 February 2020 (Tab Y-2 to Y-3). Additional board members included a Captain (Capt) Legal Advisor, and a Staff Sergeant (SSgt) Recorder (Tab Y-2 to Y-3). On 17 January 2020, a Technical Sergeant (TSgt) Subject Matter Expert (SME) on Ground Control Station (GCS) Maintenance 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 10 April 2019, at about 0200 Zulu time (Z), the mishap aircraft (MA), an MQ-9A, tail number (T/N) 08-4035, departed controlled flight and impacted the ground in an undisclosed location within the US CENTCOM AOR (Tabs Q-6, Y-2, and DD-3). Assigned to the 432d Wing (432 WG), Creech AFB, Nevada, the MA was operated by the 42d Attack Squadron (42 ATKS), Mission Control Element (MCE), located at Creech AFB, Nevada, at the time of the mishap (Tabs Q-5 to Q-6, and DD-3). At about 0156Z, several control inputs from the mishap ground control station (MGCS) to the MA changed simultaneously (Tab DD-4). Among these commands were inputs to close the fuel shut-off valve and feather the propeller (Tab DD-4). As a result of these commands, the aircraft engine torque, oil pressure, and propeller speed decreased, as the engine shut down over the next minute (Tab DD-4). In accordance with the emergency procedures checklist, the mishap crew (MC), consisting of the mishap pilot (MP) and mishap sensor operator (MSO), performed engine failure procedures (Tab V-4.2, V-9.2, and V-10.7). Since the MA continued to receive erroneous commands, which kept the fuel shut-off valve closed for the remainder of the mishap flight, the engine remained shut down and could not be restarted (Tab DD-3). The MGCS sent erroneous pitch, roll, and yaw commands, but the MA initially ignored them because autopilot hold modes were enabled (Tab DD-3). When the MP disabled hold modes to permit checklist accomplishment, the MA began executing the erroneous pitch, roll, yaw stick, and rudder commands from the MGCS (Tab DD-3 to DD-6). The MC performed emergency checklist procedures to prevent loss of control, but they were unable to recover the MA (Tab V-7.2, V-8.2, V-9.2, V-10.8, and V-10.16). The rapid changes in MA attitude, resulting from the erroneous control inputs, caused intermittent departures from controlled flight and the permanent loss of datalink (Tab DD-3 to DD-6). Following impact, the MA's wreckage was located and destroyed (Tabs Q-7 and DD-3). The loss of Government property was valued at $11,319,416 (Tab Q-11 to Q-12). There were no reported fatalities, injuries, or damage to civilian property (Tab Q-11 to Q-12).

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 aircraft (Tab CC-2). It also provides command, control, communications and intelligence systems, and conducts global information operations (Tab CC-2). As a force provider and Combat Air Forces lead agent, ACC organizes, trains, equips and maintains combat-ready forces for rapid deployment and employment while ensuring strategic air defense forces are ready to meet the challenges of peacetime air sovereignty and wartime air defense (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). ACC also augments forces to United States European, Pacific, Africa-based and Strategic Commands (Tab CC-2).

b. Twelfth Air Force (12 AF)

12 AF, or Air Forces Southern (AFSOUTH), controls ACC's conventional fighter and bomber forces based in the western United States and serves as the air component for United States Southern Command (Tab CC-3). 12 AF is responsible for United States air and space operations in Central America, South America and the Caribbean, and its subordinate commands operate more than 800 aircraft with more than 64,000 uniformed and civilian Airmen (Tab CC-3 and CC-7).

c. 432d Wing (432 WG)

The 432 WG consists of combat-ready Airmen who fly and maintain the MQ-1 Predator and MQ-9 Reaper remotely piloted aircraft (RPA) in direct support of the United States total force components and combatant commanders (Tab CC-12). 432 WG also trains aircrew, intelligence, weather, and maintenance personnel for RPA operations (Tab CC-12). The RPA systems provide real-time intelligence, surveillance, and reconnaissance (ISR), as well as precision attack against fixed and time-critical targets (Tab CC-12).

d. 42d Attack Squadron (42 ATKS)

The 42 ATKS provides combat support to multiple AORs (Tab CC-13 to CC-14). The squadron, through its use of the MQ-9 Reaper, provides combatant commanders uninterrupted persistent attack and reconnaissance capabilities (Tab CC-13). From training to operational—bombers to remotely piloted aircraft, the Panthers of the 42 ATKS have been a key part of the United States airpower for the past 100 years (Tab CC-13). In November of 2006, the 42nd was called upon as the 42nd ATKS to serve as the first MQ-9 Reaper unit at Creech AFB (Tab CC-14). The new mission harkened back to the squadron's legacy of training young aviators before transferring into an attack role leading cutting-edge remotely piloted aircraft technology (Tab CC-14). They played a major role in deployed operations by providing persistent attack and reconnaissance (Tab CC-14).

e. MQ-9A Reaper

The MQ-9A Reaper is an armed, multi-mission, medium altitude, long endurance 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 to CC-16). Reapers can perform the following missions and tasks: 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-16).

4. SEQUENCE OF EVENTS

a. Mission

On 10 April 2019, the MA was conducting an operational mission at an undisclosed location within the US CENTCOM AOR (Tabs Q-6, V-9.2, V-10.4 to V-10.5, and Y-2).

b. Planning

The MC believed the flight authorizations and paperwork for the MA and MGCS were in order (Tab V-10.5). They received all the required weather and operations briefs prior to launch (Tab V-8.2, V-9.1, and V-10.4).

c. Preflight

MA and MGCS preflight checks were conducted without incident (Tab V-8.2, V-9.1, and V-10.4 to V-10.5).

d. Summary of Accident

On 9 April 2019, at approximately 2023Z, 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 2042Z without incident (Tabs V-2.1, DD-3, and DD-4). The MA flew normally for more than five hours (Tabs V-2.1 to V-2.2, V-3.2, V-9.2, V-10.7, DD-3, and DD-4). The MC indicated that the MA was performing nominally and responding to commands up until the time of the mishap (Tab V-2.1 to V-2.2, V-9.2, and V-10.7).

The MA was on station during an operational mission, in a point and click loiter (PCL) (Tab V-10.7). Shortly before 0200Z, a heads up display (HUD) warning indicated “Check Condition Lever” (Tab V-9.2 and V-10.7). The MP checked the condition lever, noting that it was in the full forward position (Tab V-7.3, V-9.2, V-10.7, and V-10.11). The MP also received “Check Condition Lever” and “Engine Out Detected” warnings in the heads down display (HDD) (Tab V-9.2 and V-10.7). The MC began conducting the critical action procedures (CAPs) for an engine failure (Tab V-4.2, V-9.2, and V-10.7). As part of the CAPs, the MP established a glide, selected a landing site, and pulled the condition lever aft (Tab V-7.3, V-8.2 to V-8.3, V-9.2, V-10.7, and V-10.12). In the course of following the CAPs, the MP took the MA off of the PCL (Tab V-10.7, V-10.10, and V-10.13). This left the MA on airspeed and altitude holds, yet it allowed the MP left and right control with the stick (Tab V-10.7, V-10.10, and V-10.13). The MP stated he set a left hand turn with the stick to bring the MA back to the airfield (Tab V-10.8 and V-10.10). However, the MA turned right (Tab V-10.8). The MP then initiated the CAPs to prevent loss of control. (Tab V-4.2, V-7.2, V-8.2, V-9.2, and V-10.8). The MP then began to configure the MA for landing, turning off all hold modes and allowing the MP to manually control the MA via the stick and throttle quadrant (Tab V-4.3, V-7.2, V-7.4, V-8.3, V-9.3, V-10.8, V-10.14, and V-10.15). At this point, the multi-spectral targeting system (MTS) returned to position mode, facing the front of the MA (Tab V-4.2, V-7.2, V-9.2, V-9.3, V-10.8, and V-10.15 to V-10.16). The MC was unable to regain control of the MA through the loss of control prevent checklist CAPs (Tab V-7.2, V-8.2, V-9.2, V-10.8, and V-10.16).

The MSO called the Operations Supervisor (OS) for a safety observer as the MC continued to gain control of the MA (Tab V-4.2, V-7.2, V-9.3, V-10.8, and V-10.16). The OS, Safety Observer (SO), and Sensor Lead (SL), entered the MGCS (Tab V-4.2, V-7.2, V-8.2, V-9.3, V-10.8, and V-10.16).

The MC noted that the front of the MA was pointing upwards (nosing up), and the MA was stalling, rolling, and losing link (Tab V-4.2, V-7.2, V-8.2, V-9.2, and V-10.8). During the loss of link, the MC received a black screen and the MC had no control over the MA (Tab V-10.8). The MA continued to nose up, stall, and lose link (Tab V-4.2, V-7.2, V-9.2, and V-10.8). Ultimately, the MA lost link for the last time, and a negative 5,000-foot vertical velocity indicator (VVI) was displayed (Tab V-10.8). The MC completed all steps in the loss of control prevent and engine failure checklists (Tab V-4.2, V-10.8, and V-10.18). Additionally, the MC referenced the forced landing procedures, in the event they were able to regain link with the MA (Tab V-10.8 and V-10.18). Shortly thereafter, the MP received a message from the air traffic controller, via Mardam-Bey Internet Relay Chat (mIRC), indicating the MA had crashed (Tabs V-10.8 and CC-19).

e. Impact

The MA impacted the ground in an undisclosed location in the US CENTCOM AOR (Tabs Q-7, Y-2, and DD-3). The MA's wreckage was located and destroyed (Tabs Q-7 and DD-3).

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 MA (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 GG-2 to GG-28, and GG-56 to GG-116).

The following information pertains to the maintenance of the MGCS:

a. Forms Documentation

A review of the maintenance records for the MGCS leading up to the mishap day revealed no relevant discrepancies or issues, and showed no overdue Time Compliance Technical Orders (TCTO) (Tabs V-5.1, V-6.1, and EE-2). All preflight inspections and release procedures were followed (Tabs V-5.1 to V-5.2, V-6.1, and EE-3).

b. Inspections

All MGCS maintenance inspections were current and complied with by relevant authorities (Tab EE-2). The most recent 7-Day Inspection was performed on 3 April 2019 (Tabs DD-7 and EE-2). In addition to general external surface cleaning, this inspection includes the throttle lever positioning pin operation check and the keyboard/trackball operational check (Tabs V-5.2 and EE-2). The most recent 168-Day Inspection was performed on 24 October 2018 (167 days before the mishap) (Tabs DD-7 and EE-2). This was the last time the CCA had been opened for any maintenance (Tabs DD-7 and EE-2). No other periodic maintenance inspection (PMI) requires the CCA to be opened (Tabs V-5.2 and EE-2). The 7-Day, 28-Day, 84-Day, and 168-Day PMIs were all due on 10 April 2019, following the mishap flight (Tab EE-2).

c. Maintenance Procedures

Maintenance personnel conducted all maintenance procedures in accordance with applicable TOs and guidance (Tab EE-2).

d. Maintenance Personnel and Supervision

A review of applicable records on maintenance personnel and supervision revealed no issues (Tab EE-2). No evidence indicated the training, qualifications, and supervision of the maintenance personnel were a factor in this mishap (Tab EE-2).

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

Not applicable.

f. Unscheduled Maintenance

Maintenance documentation revealed no unscheduled maintenance was performed on the MGCS since completion of the last scheduled inspection (Tabs EE-2 and DD-7). Maintenance records indicate the Pilot/Sensor Operator Position 1 (PSO1) status screen was inoperable on 19 January 2018; therefore, the CCA was replaced (Tabs D-8 and DD-7). However, several PMIs occurred after that date, including the 168-Day Inspection on 24 October 2018 (Tabs DD-7 and EE-2).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

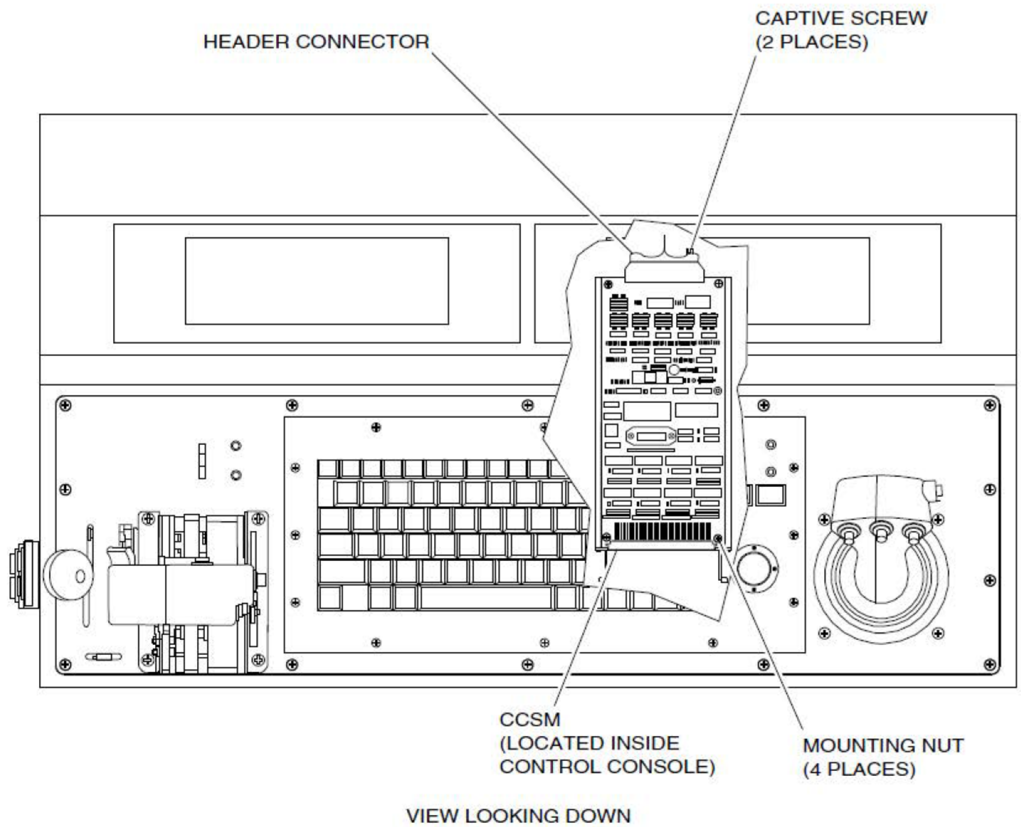
(1) MGCS PSO1 CCA

The CCA consists of the throttle quadrant assembly, keyboard/trackball assembly, and control stick assembly (Tabs V-6.2 to V-6.3, DD-7, and EE-2). These components are secured to the "lid" of the CCA (Tab EE-2). The "lid" is secured by 13 screws that are machined/threaded into the CCA itself (Tabs V-6.3 and EE-2). The Control Console Serial Module (CCSM) is located inside the CCA tray (Tabs V-5.3, V-6.3, and EE-3).

(2) MGCS PSO1 CCSM

The MGCS PSO1 CCSM board was manufactured in October 2017 (Tab DD-8). Visual inspection of the CCSM board by General Atomics Aeronautical Systems, Inc. (GA-ASI) found two loose washers and one loose nut resting on the board (Tab DD-7 to DD-8). One of the keyboard case posts located directly above the CCSM board was missing fastening hardware (Tab DD-8). These keyboard posts are part of the keyboard assembly (Tab DD-8). The heads of the screws are located under the keys of the keyboard and are not accessed during normal maintenance (Tab DD-8). The fastening hardware comes installed on the keyboard/trackball assembly Line Replaceable Unit (LRU) (Tab DD-8). The fastening hardware consists of one nut, one washer, and one locking washer (Tab EE-2). None of the fastening hardware in the MGCS is secured with dual anchoring (Tab EE-2). There is no cover protecting the CCSM or cover containing the keyboard/trackball assembly and its hardware (Tab EE-2). Each of the three pieces of loose hardware on the PSO1 CCSM board appeared to be resting on several pins (Tab DD-8). The flat washer was found between integrated circuits (Tab DD-8). The locking washer did not appear to be touching any visible leads (Tab DD-8).

Maintenance to the underside of keyboard/trackball assembly LRU is not performed by GCS technicians and is not covered in TO 1Q-1(M)B-2-2 (Tabs V6.2 to V-6.3, and EE-2). All LRUs and associated hardware are sent off to the depot for repair actions (Tab EE-2).



Control Console Serial Module

Diagram displaying typical components of a Block 15 Fixed GCS CCSM (Tab BB-4)

b. Evaluation and Analysis from GA-ASI

The CCSMs (PSO1 and PSO2), CCA (PSO1), and data logs from the MGCS were sent for technical review (inspection and testing) by the contractor manufacturer of the MGCS, GA-ASI (Tabs Q-2, Q-9, and DD-3). GA-ASI conducted analysis of the MGCS data logs and "indicated that several control inputs changed simultaneously with the loss of engine torque" (Tab DD-3). GA-ASI's technical report stated that:

> "[i]nspection and testing of the [M]GCS hardware determined that metallic Foreign Object Debris (FOD) – a flat washer, on the PSO1 CCSM board – caused an

> electrical short between several pins that convert the analog signals of the control inputs into digital, resulting in erroneous control inputs being transmitted to the [MA]. The electrical short and erratic commands were later replicated on the PSO1 CCSM board with an exemplar washer in the observed position and a test GCS" (Tab DD-3).

GA-ASI concluded that "[t]he flat washer shorted a +5 VDC signal to the analog-to-digital converter, resulting in a specific and repeatable signature in the data logs" (Tab DD-13). Furthermore, "[t]he exact duplication of the erroneous commands on the PSO1 CCSM board with the flat washer in the incident location indicated that the washer shorting pins on the CCSM board caused the erroneous commands" (Tab DD-13). "Among these commands was to close the fuel shut-off valve and feather the propeller, the equivalent of moving the condition lever to 'Feather/Off'. Because of this, during the mishap flight, the engine shut down and could not be restarted (the fuel shut-off was continually being commanded closed)" (Tab DD-3).

The GA-ASI Contractor Report to USAF Safety Investigation Board indicated that:

> "Erroneous pitch, roll, and yaw commands also occurred but were initially ignored by the [MA] because autopilot hold modes were enabled. A CCSM warning was not displayed to the [MC] because the GCS processor interpreted the erroneous commands as valid. After the hold modes were disabled, the [MA] began executing the erroneous pitch, roll, and yaw stick and rudder commands from the [M]GCS. The resulting rapid changes in [MA] altitude caused the intermittent departures from controlled flight. Although the [MA] twice recovered, the erroneous commands resulted in a third departure from controlled flight and the permanent loss of SATCOM [satellite communications] datalink" (Tab DD-3 to DD-4).

The MGCS is a Block 15 Fixed GCS and was built in 2008 (Tab DD-7). GA-ASI noted that "[t]he Block 30 GCS uses a Safety Tactical Operation Reliability Maintenance (STORM) console. The STORM Console Control Module (SCCM) is located behind the monitor and does not have any fastening hardware directly above it" (Tab DD-4).

Additionally, GA-ASI stated that:

> "Conformal coating was present on both the PSO1 and PSO2 CCSM boards; however, the coating near the pins … on the PSO1 board was slightly eroded, making the pins in that area more susceptible to an electrical short from contact with the FOD. Vibrations and physical manipulation of the CCA drawer may have caused the flat washer to abrade the conformal coating over time. Conformal coating is primarily intended to protect Printed Circuit Boards (PCBs) from moisture and will not withstand prolonged abrasion." (Tab DD-13).

7. WEATHER

a. Forecast Weather

The weather briefed prior to the mishap flight indicated the forecast was for scattered clouds at 15,000 feet, with unlimited visibility (Tab F-3). Winds were forecasted as variable, with the potential for crosswinds up to 6-knots (Tab F-3). Between 0100Z and 0159Z, the forecasted high was 55 degrees Fahrenheit (13 degrees Celsius) (Tab F-3). There was no other significant weather forecasted at the time of the mishap (Tab F-3).

b. Observed Weather

No significant weather was reported or observed at the time of the mishap (Tab V-10.7). The MP observed clear skies and indicated that the weather was in line with the forecast (Tab V-10.7). The MP further stated the weather did not play a factor in the conduct of the mission (Tab V-10.7).

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 (Tabs G-3 to G-5, V-8.1 to V-8.2, and V-10.5). The MP had 577.7 hours of MQ-9A flight time and 58.4 hours of MQ-9A simulator time around the time of the mishap (Tab G-6). Recent flight hours were as follows (Tab G-6):

	Flight Hours	Flight Sorties
Last 30 Days	33.7	13
Last 60 Days	44.6	18
Last 90 Days	66.9	29

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 (Tabs G-11 to G-13, V-8.1 to V-8.2, and V-9.1). The MSO had 673 hours of MQ-9A flight time and 63.8 hours of MQ-9A simulator time around the time of the mishap (Tab G-14). Recent flight hours were as follows (Tab G-14):

	Flight Hours	Flight Sorties
Last 30 Days	32.9	8
Last 60 Days	37.5	9
Last 90 Days	64.3	20

9. MEDICAL

a. Qualifications

The aircrew and maintenance personnel were physically and medically qualified for the mission. (Tabs G-7, G-15, and K-3).

b. Health

No evidence was found to suggest the health of the aircrew or maintenance personnel was a factor in this mishap (Tab V-9.1 and V-10.2 to V-10.3).

c. Pathology/Toxicology

The medical clinic collected blood and urine samples from the MC after the mishap (Tab FF-2 to FF-5). Toxicology was not a factor in this mishap (Tab FF-2 and FF-4).

d. Lifestyle

There is no evidence to suggest lifestyle was a factor in the mishap (Tab V-9.1 and V-10.2 to V-10.3).

e. Crew Rest and Crew Duty Time

Prior to performing in-flight duties, aircrew members must have proper rest, as defined in the ACC Supplement to AFI 11-202, Volume (V) 3, *General Flight Rules* (Tab BB-5 to BB-6). AFI 11-202 V3 defines normal crew rest as a minimum of 12-hour non-duty period before the designated flight duty period begins (Tab BB-6). Crew rest is defined as free time, and includes time for meals, transportation, and the opportunity to sleep (Tab BB-6).

The mishap crew verified they had received the proper crew rest by signing the pre-flight authorization (Tabs K-3, V-9.1, and V-10.2 to V10.3).

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-7.1, V-8.1, V-9.1, and V-10.2).

c. Supervision

There was no evidence found that suggests the Operations Supervision contributed to the mishap (Tab V-4.1 to V-4.8, V-7.1 to V-7.11, V-8.1 to V-8.9, V-9.3, V-10.5, V-10.8, and V-10.16).

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 those human factors that directly related to the mishap (Tab BB-7). Based on the evidence, human factors did not play a factor in this mishap.

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) AFI 11-202, Volume 3, *General Flight Rules*, ACC Supplement, 28 November 2012

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.

d. Other Directives and Publications Relevant to the Mishap

(1) TO 1Q-1(M)B-2-2, *TECHNICAL MANUAL, ORGANIZATIONAL MAINTENANCE, MD-1A SERIES GROUND CONTROL STATION MAINTENANCE PROCEDURES*, 4 December 2018 (Updated 29 March 2019)

(2) TO 1Q-9(M)A-1-1, *FLIGHT MANUAL, APPENDIX A, PERFORMANCE DATA, USAF SERIES MQ-9A AIRCRAFT SERIAL NUMBERS 004, 006, 008, AND ABOVE,* 12 November 2018

(3) DOD HFACS, Version 7.0

e. 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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5 August 2020

TODD C. SPRISTER, Colonel, USAF
President, Abbreviated Accident Investigation Board

STATEMENT OF OPINION

MQ-9A, T/N 08-4035
UNITED STATES CENTRAL COMMAND AREA OF RESPONSIBILITY
10 APRIL 2019

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 10 April 2019, at about 0200 Zulu time (Z), the mishap aircraft (MA), an MQ-9A, tail number (T/N) 08-4035, departed controlled flight and impacted the terrain in an undisclosed location within the United States Central Command Area of Responsibility. Assigned to the 432d Wing, Creech Air Force Base (AFB), Nevada, the MA was operated by the 42d Attack Squadron Mission Control Element (MCE) located at Creech AFB, Nevada, at the time of the mishap. The MA wreckage was located and destroyed. The loss of Government Property was valued at $11,319,416. There was no reported damage to civilian property, injuries, or fatalities.

At about 0156Z, several control inputs from the mishap Ground Control Station (MGCS) to the MA changed simultaneously. Among these commands was an input to close the fuel shut-off valve and feather the propeller. Over the next minute, the MA engine torque, oil pressure, and propeller speed decreased with engine shutdown. In accordance with the emergency procedures checklist, the mishap crew (MC), consisting of the mishap pilot (MP) and mishap sensor operator (MSO), performed engine failure procedures. Since the MA continued to receive erroneous commands, which kept the fuel shut-off valve closed for the remainder of the mishap flight, the engine remained shut down and could not be restarted.

The MGCS sent erroneous pitch, roll, and yaw commands, but the MA initially ignored them because autopilot hold modes were enabled. When hold modes were disabled to permit emergency checklist accomplishment, the MA began executing the erroneous pitch, roll, yaw stick, and rudder commands from the MGCS. The MC performed emergency checklist procedures to prevent loss of control, but they were unable to recover the MA. The rapid changes in MA attitude resulting from the erroneous control inputs caused intermittent departures from controlled flight and a permanent loss of datalink. Subsequently, the MA impacted the ground at an undisclosed location within the USCENTCOM AOR and the MA wreckage was destroyed.

2. CAUSES

I find, by a preponderance of the evidence, the cause of the mishap was a loose, flat metallic washer on the Control Console Serial Module (CCSM) that created an electrical short between several pins, resulting in erroneous control inputs being transmitted to the MA.

a. Metallic Flat Washer

The specific cause of the mishap was a metallic flat washer from the underside of the keyboard/trackball assembly LRU. The General Atomics Aeronautical Systems, Inc. (GA-ASI) report indicated that the metallic flat washer fell onto the CCSM causing "an electrical short between several pins that convert analog signals of the control inputs into digital, resulting in the transmission of erroneous control inputs to the [MA]." GA-ASI's "[v]isual inspection of the CCSM board [from the MGCS] found two loose washers and one loose nut resting on the board." Correspondingly, "[o]ne of the keyboard case posts located directly above the CCSM board was missing fastening hardware." The report confirmed that "[t]hese keyboard posts are part of the keyboard assembly." Additionally GA-ASI noted that "[t]he [conformal] coating near the pins on the [pilot/sensor operator position 1] (PSO1) board was slightly eroded." The "[c]onformal coating is primarily intended to protect the printed circuit boards from moisture and will not withstand prolonged abrasion." The contractor report stated that "[v]ibrations and physical manipulation of the CCA drawer may have caused the metallic flat washer to abrade the conformal coating over time," therefore, "making the pins in that area more susceptible to an electrical short."

Review of the mishap data logs and analysis of the MGCS hardware concluded that the simultaneous change of all control console command values was caused by a washer that had fallen onto the PSO1 CCSM board. This washer shorted several pins and caused erroneous data packets to be transmitted to the aircraft. These inputs were deemed as valid and accepted by the MA resulting in engine shutdown, rapid changes in aircraft attitude leading to intermittent departures from controlled flight, and the eventual and permanent loss of datalink to the MA. The electrical short and erratic commands were later replicated by GA-ASI on the mishap PSO1 CCSM board with an exemplar washer in the observed position and a test GCS. GA-ASI reported that:

> "[t]he exact duplication of the erroneous commands on the mishap PSO1 CCSM board with the flat washer in the incident location indicated that the washer shorting pins on the CCSM board caused the erroneous commands. The flat washer shorted a +5 VDC signal to the analog-digital converter, resulting in a specific and repeatable signature in the data logs."

2. SUBSTANTIALLY CONTRIBUTING FACTOR

Further, I find, by a preponderance of the evidence, that each of the following factors substantially contributed to the mishap; (1) the design of the Control Console Assembly (CCA), which contains inadequately restrained metallic hardware, and (2) limitations in software fault logic. Software fault logic allowed the MA to accept the erroneous inputs as valid and complicated MP attempts to countermand those erroneous inputs.

a. CCA Design

Additionally, the design of the CCA was determined to be a substantially contributing factor in the mishap because it used and inadequately restrained metallic hardware above critical circuits. The CCA consists of the throttle quadrant assembly, which serves to cover the tray housing the CCSM. This cover is secured to the CCA tray by 13 screws that are machined or threaded into the CCA itself. Similarly, the keyboard/trackball assembly line replacement unit (LRU) attaches at the center of the throttle quadrant assembly and is located directly above the CCSM. Part of the LRU, the keyboard assembly uses metallic fastening hardware consisting of one nut, one washer, and one locking washer on its keyboard posts. The heads of the screws are located under the keys of the keyboard and are not accessed during normal maintenance. The fastening hardware comes pre-installed on the keyboard/trackball assembly LRU and is not secured to the posts using dual anchoring techniques. Moreover, there is currently no physical barrier preventing fastening hardware from falling into the CCA tray or onto the CCSM. The GA-ASI report indicates that unlike the MGCS, "[t]he Block 30 GCS uses a Safety Tactical Operation Reliability Maintenance (STORM) console." Furthermore, "[t]he STORM console control serial module (SCSM) is located behind the monitor and does not have any fastening hardware directly above [critical circuits]."

b. Software Fault Logic

Limitations in software fault logic were a substantially contributing factor. Although Heads-Up Display (HUD) and Heads-Down Display (HDD) warning messages related to the Condition Lever, no CCSM warnings were present because the MGCS processor interpreted the erroneous commands as valid. The CCSM continued to send what was considered valid data, despite the mismatch that existed between dynamic changes in the physical positions of the control inputs and the stagnant values displayed on the Variable Information Table (VIT). Current limitations in the software fault logic failed to recognize or reject the simultaneous, multiple, or conflicting commands as a failure within the CCSM and complicated MP attempts to countermand those erroneous inputs.

During the mishap flight on 10 April 2019, the MP used a Point and Click Loiter (PCL) to maintain position while conducting the mission. Shortly after 0156Z, several control inputs from the MGCS to the MA changed simultaneously. Since the MP was in a loiter around a point with all three autopilot hold modes enabled when the anomaly began, the erroneous stick commands, detent command, and flap position commands were ignored. However, engine speed, stop/feather, and brake commands, were accepted and acted upon by the MA. The continuous stop/feather command closed the fuel shut-off valve and feathered the propeller, the equivalent of manually moving the condition lever to "Feather/Off" on the control console. The MC initially perceived the onset of the erroneous inputs when "Check Condition Lever" appeared in the HUD. In accordance with the emergency procedures checklist, the MP verified the Condition Lever was in the full forward "Run" position. Over the next minute, the aircraft engine torque, oil pressure, and propeller speed decreased with engine shutdown and displayed "Engine Out Detected" in the HDD. In accordance with the emergency procedures checklist, the MC, performed engine failure procedures. As the MP began the critical action procedures for engine failure and exited the PCL to establish a glide and turn toward a suitable landing site, the hold modes were disabled and the MA began executing the previously ignored erroneous pitch, roll, yaw stick, and rudder commands from the MGCS. Recognizing the MA was no longer responsive to MP commands, the MC, performed loss of control prevent procedures, in accordance with the emergency procedures checklist. The resulting rapid attitude changes caused two MA stalls from which the MA recovered, but because the erroneous commands continued to be executed, the MA entered a third stall. During this third stall, the MA experienced a permanent loss of datalink and impacted the terrain at approximately 0200Z. Throughout the mishap sequence, the MP remained unable to provide the MA control inputs due to the MA acceptance of erroneous command inputs resulting from the electrical short on the CCSM. Although the MC could have elected to mute the command link or conduct a rack swap, neither are directed by published emergency procedures. In my opinion, the actions taken by the MC did not cause or contribute to this mishap and MP attempts to countermand erroneous inputs were significantly complicated by limitations in software fault logic that failed to accurately assess the validity of conflicting inputs.

3. CONCLUSION

Engineering analysis of the data logs, visual inspection of the MGCS, as well as laboratory testing by General Atomics Aerospace Systems, Inc. (GA-ASI) of the CCA and CCSM hardware involved in this mishap, prove, by a preponderance of the evidence, this mishap was caused by a loose, flat metallic washer on the Control Console Serial Module (CCSM) that created an electrical short between several pins, resulting in erroneous control inputs being transmitted to the MA. Further, I find, by a preponderance of the evidence, that each of the following factors substantially contributed to the mishap; (1) the design of the Control Console Assembly (CCA), which contains inadequately restrained metallic hardware, and (2) limitations in software fault logic. Limitations in software fault logic failed to recognize or reject the simultaneous, multiple, or conflicting commands resulting from the short as a failure within the CCSM and complicated MP attempts to countermand erroneous control inputs being transmitted to, and accepted by, the MQ-9A aircraft.

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5 August 2020

TODD C. SPRISTER, Col, USAF
President, Abbreviated Accident Investigation Board

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