UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

MQ-9 REAPER, T/N 09-4066

138TH ATTACK SQUADRON
174TH ATTACK WING
HANCOCK FIELD AIR NATIONAL GUARD BASE

LOCATION: LAKE ONTARIO, NEW YORK

DATE OF ACCIDENT: 12 NOVEMBER 2013

BOARD PRESIDENT: COLONEL DANA A. HESSHEIMER

CONDUCTED IAW AIR FORCE INSTRUCTION 51-503

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

OFFICE OF THE VICE COMMANDER
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19 MAY 2014

ACTION OF THE CONVENING AUTHORITY

The Report of the Accident Investigation Board, conducted under the provisions of AFI 51-503, that investigated the 12 November 2013 mishap near Fort Drum, New York, involving an MQ-9 Reaper, T/N 09-4066, assigned to the 138th Attack Squadron, 174th Attack Wing, Hancock Field Air National Guard Base, New York, complies with applicable regulatory and statutory guidance; on that basis it is approved.

LORI J. ROBINSON
Lieutenant General, USAF
Vice Commander

EXECUTIVE SUMMARY
AIRCRAFT ACCIDENT INVESTIGATION
MQ-9 REAPER, T/N 09-4066
LAKE ONTARIO, NEW YORK
12 NOVEMBER 2013

On 12 November 2013, at approximately 13:01 local time (L), the mishap aircraft (MA), an MQ-9 Reaper, tail number 09-4066, assigned to the 138th Attack Squadron, 174th Attack Wing, Hancock Field Air National Guard Base, New York (NY), impacted Lake Ontario, NY, approximately 35 miles southwest of Fort Drum, NY. There were no injuries to any military members or civilians. The MA was destroyed upon impact, with loss of government property valued at $10,622,210. There was no damage to private property.

The MA departed Wheeler-Sack Army Airfield, NY, at 10:42L on 12 November 2013 for the Oswego Military Operating Area to conduct a training mission. The mishap crew (MC), consisting of a Mishap Pilot (MP) and Mishap Sensor Operator, was the launch and recovery element (LRE) for the mission. The MC accomplished an uneventful takeoff. At 10:52L, the mission control element (MCE) gained control of the MA from the LRE without incident. About two hours into the mission, the MCE noticed a series of warnings on the head down displays indicating the MA's embedded global positioning system/inertial navigation system a/k/a (EGI) unit #1 had failed. The MCE looked up the warnings in the MQ-9 flight manual and ran the Multiple Navigation Sensor Failure Checklist. The MCE made an effort to return the MA to base, but the MA went lost link and began to fly its emergency mission. Lost link occurs when there is a loss of connectivity between the aircraft and the pilot. An emergency mission is a series of waypoints arranged to bring the aircraft back to its point of origin and is automatically engaged when the aircraft goes lost link. The MA was flying on autopilot by the time it entered the emergency mission. The MCE disabled the command link because they were unable to monitor the MA. The MC entered the LRE ground control station and began to run the Gaining Handover Checklist. At 12:58:14L, the MA's EGI unit #3 failed. Following the checklist, the MP enabled the ground data terminal (GDT) transmitter causing the MA to fly on autopilot. The autopilot commanded a right turn. Invalid autopilot attitude data was transferred to the MA which caused it to continue turning right until completely inverted, and then entered a spin. At 12:59:55L, the MP disabled the GDT transmitter in an attempt to send the MA back lost link so it would recover on its own, however, the MA did not return to a lost link profile. Approximately one minute later, the MA impacted Lake Ontario and was destroyed.

The Accident Investigation Board President found by clear and convincing evidence that the failure of the MA's EGI units #1 and #3 in conjunction with a transfer of invalid attitude data to the MA's autopilot system was the cause of the mishap. The MQ-9 relies on the EGI units for valid attitude reference data. Without valid data, the MA could not discern its attitude and became uncontrollable.

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-9 REAPER, T/N 09-4066
12 NOVEMBER 2013

TABLE OF CONTENTS

COMMONLY USED ACRONYMS AND ABBREVIATIONS

138 ATKS	138th Attack Squadron
174 ATKW	174th Attack Wing
174 FTU	174th Formal Training Unit
174 MXG	174th Maintenance Group
AAF	Army Airfield
ACC	Air Combat Command
ACU	Antenna Control Unit
ADCS	Aircraft Digital Control System
AF	Air Force
AFB	Air Force Base
AFI	Air Force Instruction
AFTO	Air Force Technical Order
AGL	Above Ground Level
AIB	Accident Investigation Board
ANG	Air National Guard
ANGB	Air National Guard Base
ATC	Air Traffic Control
Capt	Captain
Col	Colonel
Dash One	MQ-9 Flight Manual
DoD	Department of Defense
EADS	Eastern Air Defense Sector
EGI	Embedded Global Positioning System Inertial Navigation System
FCA	Flight Computer Assembly
FCIF	Flight Crew Information File
FTU	Formal Training Unit
GA-ASI	General Atomics-Aeronautical Systems Incorporated
GCS	Ground Control Station
GDT	Ground Data Terminal
GLS	GPS Landing System
GPS	Global Positioning System
HDD	Head Down Display
HUD	Head up Display
IAW	In Accordance With
IMDS	Integrated Maintenance Data System
INS	Inertial Navigation System
INTEL	Intelligence
IQT	Initial Qualification Training
L	Local
LAT	Latitude
LONG	Longitude
LRE	Launch and Recovery Element
LOS	Line of Sight
Lt Col	Lieutenant Colonel
MA	Mishap Aircraft
Maj	Major
MAJCOM	Major Command
MC	Mishap Crew
MCE	Mission Control Element
MOA	Military Operating Area
MP	Mishap Pilot
MSgt	Master Sergeant
MSL	Mean Sea Level
MSO	Mishap Sensor Operator
MSOF	Mishap Supervisor of Flying
MXG	Maintenance Group
Nav	Navigator
nm	nautical miles
N	North
NY	New York
NYANG	New York Air National Guard
OFP	Operational Flight Program
Ops Sup	Operations Supervisor
Ops Tempo	Operations Tempo
ORM	Operational Risk Management
P1	Pilot 1
P2	Pilot 2
PSO	Pilot/Sensor Operator
RCM	Redundant Control Module
RPA	Remotely Piloted Aircraft
SATCOM	Satellite Communications
sm	Statute Miles
SMSgt	Senior Master Sergeant
SO1	Sensor Operator 1
SO2	Sensor Operator2
SSgt	Staff Sergeant
TBA	Training Business Area
TCTO	Time Compliance Technical Order
TO	Technical Order
T/N	Tail Number
USAF	United States Air Force
W	West
Z	Zulu

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

DEFINITIONS

Above Ground Level	An altitude measured with respect to the underlying ground surface.
BUS	The primary information handler between the flight computers and the triple EGI units
Embedded Global Positioning System/ Inertial Navigation System	Unit that provides the aircraft with level platform data for the attitude system.
Emergency Mission	A series of waypoints the aircraft automatically flies when it goes lost link arranged to bring the aircraft back to its point of origin.
Flight Computer Assembly	A single board computer capable of controlling the aircraft and receiving sensor data.
Ground Control Station	The "cockpit" for the MQ-9. It houses the pilot/sensor operator workstations for aircraft control, multifunction workstations, and auxiliary information displays.
Ground Data Terminal Transmitter	The C-band (portion of electromagnetic spectrum) GDT that maintains the C-band line of sight radio frequency datalink with the aircraft.
Ku-Band	Data link system used to get the aircraft from the airfield environment to the mission operating area.
Launch and Recovery Element	The organizational element comprised of personnel and equipment required to prepare, inspect, service, and arm the individual aircraft for the mission as well as launch, perform system check-out, recover, and land the aircraft.
Lost Link	Lost link occurs when there is loss of connectivity between the aircraft and pilot.
Mean Sea Level	An altitude measured with respect to the aircraft's distance above the ocean.

Military Operating Area	Airspace established to segregate certain non-hazardous military activities from non-military air traffic.
Mission Control Element	The organizational element comprised of personnel and equipment required to assume control of aircraft launched by the LRE through the handover process.
Redundant Control Module	The heart of the aircraft digital control system.
Technical Order	Publication that explains procedures for aircraft operations and maintenance.
Telemetry	Electronic data, such as pitch, roll, yaw, latitude, and longitude.

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 18 December 2013, Lieutenant General Lori J. Robinson, Vice Commander, Air Combat Command (ACC), appointed Colonel Dana A. Hessheimer to conduct an aircraft accident investigation of the 12 November 2013 mishap of an MQ-9 Reaper aircraft, tail number (T/N) 09-4066, in Lake Ontario, New York (NY) (Tabs Y-3 through Y-4, DD-22). The aircraft accident investigation was conducted in accordance with (IAW) Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*, 26 May 2010, at Hancock Field Air National Guard Base (ANGB), NY, from 24 February 2014 through 24 March 2014. The following board members were also appointed: Pilot Member (Major), Legal Advisor (Captain), Medical Member (Captain), Maintenance Member (Master Sergeant), and Recorder (Master Sergeant) (Tab Y-5).

b. Purpose

This is a legal investigation convened to inquire into the facts surrounding the aircraft or aerospace accident, to prepare a publicly-releasable report, and to gather and preserve all available evidence for use in litigation, claims, disciplinary actions, administrative proceedings, and for other purposes.

2. ACCIDENT SUMMARY

On 12 November 2013, the mishap aircraft (MA), an MQ-9 Reaper, T/N 09-4066, assigned to the 174th Attack Wing (174 ATKW), Hancock Field ANGB, NY, departed controlled flight and became unrecoverable during a training mission (Tab Q-5 through Q-6). At approximately 13:01 local (L) time, the MA impacted Lake Ontario, NY, approximately 35 nautical miles (nm) southwest of Wheeler-Sack Army Airfield (AAF), NY (Tab AA-8). The mishap crew (MC), which consisted of a Mishap Pilot (MP) and a Mishap Sensor Operator (MSO), was the launch and recovery element (LRE) for the mission (Tab V-5.3, V-7.3). The mission control element (MCE), which consisted of Pilot 1 (P1), Pilot 2 (P2), Sensor Operator 1 (SO1), and Sensor Operator 2 (SO2), was conducting a mission execution ride for P2 (Tab V-6.3). The MCE was combining intelligence, surveillance, and reconnaissance scenarios with close air support training scenarios (Tab V-6.3). During the training, the MA went lost link and began to fly its pre-programmed emergency mission (Tab V-3.4). The MA went lost link because its embedded global positioning system (GPS)/inertial navigation system (INS) or (EGI) unit #1 failed (Tab BB-45). The MP gained control of the MA for about one to two seconds by enabling the ground data terminal (GDT) transmitter (Tab V-5.9). The MA made a right-banked autopilot command turn, became completely inverted, and then entered a spin (Tabs V-7 through V-8, AA-8). The MP disabled the GDT transmitter in an attempt to send the MA back lost link so it could recover on its own (Tab V-5.10 through V-5.11). Approximately one minute later, the MA impacted Lake Ontario (Tab AA-8). It was destroyed upon impact, with loss of government property valued at $10,622,210 (Tabs P-4, Q-6). No military members or civilians were injured during the mishap (Tab X-5). There was no damage to private property (Tab P-3).

3. BACKGROUND

The MA and MC were assigned to the 138th Attack Squadron (138 ATKS), 174 ATKW, Air National Guard (ANG), ACC, and stationed at Hancock Field ANGB, NY (Tabs Q-6, V-5.2, V-8.2).

a. Air Combat Command

ACC is the primary force provider of combat airpower to America's warfighting commands (Tab CC-3). To support global implementation of national security strategy, ACC operates fighter, bomber, reconnaissance, battle-management, and electronic-combat aircraft (Tab CC-3). It also provides command, control, communications and intelligence systems and conducts global information operations (Tab CC-3).

b. Air National Guard

The ANG has both a federal and state mission (Tab CC-5). The federal mission is to maintain well-trained units available for prompt mobilization during war and provide assistance during national emergencies (such as natural disasters or civil disturbances) (Tab CC-5). When ANG units are not mobilized or under federal control, they report to the governor of their respective state, territory or the commanding general of the District of Columbia National Guard (Tab CC-5).

c. New York Air National Guard

The New York Air National Guard (NYANG) is a diverse organization with a total strength of more than 6,000 people (Tab CC-12). The NYANG is ready to deploy at the direction of the Governor to protect life and liberty, and preserve peace, order, and public safety (Tab CC-12). State missions, which are funded by the state, include disaster relief in times of earthquakes, hurricane, floods, and forest fires; search and rescue; protection of vital public services; and general support to civil authorities (Tab CC-12).

d. 174th Attack Wing

The 174 ATKW is a unit of the NYANG located in Syracuse, NY, adjacent to Hancock International Airport (Tab CC-13). The wing has both a federal and state mission (Tab CC-13). The federal mission is to provide qualified Airmen and weapon systems engaging in global air, space and cyberspace operations, as well as support homeland defense and joint operations (Tab

CC-13). The state mission is to support civil authorities at the direction of the Governor in times of crisis (Tab CC-13). The 174 ATKW flies the state-of-the-art MQ-9 Reaper (Tab CC-13).

e. 138th Attack Squadron

The 138 ATKS is a unit of the NYANG 174 ATKW located at Hancock Field ANGB, Syracuse, NY (Tab CC-13). On 9 September 2012, the 138th Fighter Squadron was renamed the 138 ATKS (Tab CC-14). The 138 ATKS was the first post World War II ANG flying unit in NY (Tab CC-14). The 138 ATKS has a long history of providing close air support (Tab CC-14).

f. MQ-9 Reaper

The MQ-9 Reaper is an armed, multi-mission, medium altitude, long-endurance remotely piloted aircraft (RPA) that is employed primarily as an intelligence-collection asset and secondarily against dynamic execution targets (Tab CC-16). 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-16).

MQ-9s also perform the following missions and tasks: intelligence, surveillance, reconnaissance, close air support, combat search and rescue, precison strike, buddy-laser, convoy/raid overwatch, route clearance, target development, and terminal air guidance (Tab CC-16). The MQ-9's capabilities make it uniquely qualified to conduct irregular warfare operations in support of combatant commander objectives (Tab CC-16).

The LRE is comprised of the personnel and equipment required to prepare, inspect, service, and arm the individual aircraft for the mission as well as launch, perform system check-out, recover, and land the aircraft (Tab BB-91). An LRE is typically forward-deployed relative to the mission control element (Tab BB-91).

The MCE is comprised of the personnel and equipment required to assume control of aircraft launched by LREs through the handover process (Tab BB-92). The MCE executes the assigned missions and returns the aircraft to LRE control for recovery (Tab BB-92). The MCE includes RPA control stations as well as the communications links to the squadron operations center (Tab BB-92).

g. Embedded Global Positioning System/Inertial Navigation System (EGI)

The attitude, air data, and navigation system for the MQ-9 utilizes three H-764 EGI units and various air data sensors to provide flight data to the aircraft (Tab BB-44). Each EGI unit has accelerometers and a gyro that sense linear accelerations (i.e., speeding-up) and angular rates (rolling or turning) in relation to the three perpendicular axes (yaw, pitch, and roll) of the aircraft (Tab BB-44). The triplex EGI systems provide a level of redundancy against an EGI failure by allowing all three EGI units to communicate with all three flight computers using a 1553 bus (Tab BB-89). Despite the redundancy, a failure of EGI unit #1 may result in a lost link condition since Ku-band antenna requires EGI unit #1 for level platform data (Tab BB-89). Lost link is a loss of connectivity between the aircraft and the pilot (Tab AA-7). The EGI unit functions by determining initial position data with the GPS unit (Tab BB-50). The INS then fills in data between GPS updates (Tab BB-50). This blended GPS/INS data allows an increased positional accuracy (Tab BB-50).

4. SEQUENCE OF EVENTS

a. Mission

The mishap mission was a mission execution pre-check ride for P2 (Tab V-6.3). The MCE was combining intelligence, surveillance, and reconnaissance scenarios with close air support training scenarios (Tab V-6.3). The MC was tasked with launching and recovering the MA (Tab V-5.3, V-7.3). The 174th Formal Training Unit (FTU) Commander, who was acting as the operations supervisor for the mission, properly authorized the mission on 12 November 2013 (Tabs K-3, V-4.3).

b. Planning

The MC received a standard pre-mission mass briefing at Hancock Field ANGB at 07:00L on the morning of the mishap (Tab V-5.3 through V-5.4, V-7.3). The pre-mission briefing included a review of airspace, weather, operational resource management, crew resource management, close air support, and training scenarios (Tab V-6.4). MP, MSO, Mishap Supervisor of Flying (MSOF), P2, SO2, P1, and SO1 attended the mass brief (Tab V-4.5, V-5.3, V-7.3). The briefing officer was Operations Supervisor (Ops Sup); no additional supervisory personnel were in attendance (Tab V-4.5, V-8.4). A briefing guide was utilized during the brief, and standard procedures were used during mission planning (Tab V-4.5, V-6.4). Mission planning was adequate IAW AFI 11-202, Volume 3, *General Flight Rules*, 22 October 2010, ACC Supplement, 28 November 2012, paragraph 2.7, and AFI 11-2MQ-1 & 9, Volume 3, *MQ-1 and MQ-9 Operations Procedures*, 1 November 2012, paragraph 2.1.

c. Preflight

The MC departed Hancock Field ANGB at approximately 07:30L after the pre-mission brief and drove to Wheeler-Sack AAF where the MA was located (Tab V-5.3 through V-5.4, V-7.3). MSOF reviewed the aircraft forms, which showed the MA was fully mission-capable (Tab V-3.3). MSOF also completed a walk-around inspection of the MA, while MP ran through ground operations checks at the ground control station (GCS) (Tab V-3.7). There were no equipment anomalies (Tab V-7.7). Nothing of significance was noted in the flight plan and Notices to Airmen for the mission (Tab K-2, K-14 through K-18).

d. Summary of Accident

The MA departed Wheeler-Sack AAF at 10:42L (Tab AA-6). The takeoff and handover of the MA from the LRE to the MCE were uneventful (Tab V-7.7). The MCE gained control of the MA at approximately 10:52L, and P2 climbed to 22,000 feet mean sea level (MSL) (Tab DD-5). P2 accomplished an aircraft operations check; all systems were within normal parameters (Tab V-6.8).

For approximately two hours, P2 flew the MA within the confines of the Oswego Military Operating Area (MOA) (Tab V-6.6). During the flight, the MA remained between 20 and 40 nm away from the GDT at Wheeler-Sack AAF (Tab DD-5). Although the MCE encountered some clouds about 5,000 feet above the surface, the crew conducted the training in otherwise clear airspace (Tabs V-4.3).

At 12:46:25L, the MA's EGI unit #1 failed and began sending erroneous telemetry data (i.e., pitch, roll, yaw, latitude, longitude) to flight computer assembly (FCA) #1 (Tab DD-5). The EGI units provide aircraft position data by receiving signals from navigation satellites (Tab BB-50). An FCA is a single board computer capable of controlling the aircraft and receiving sensor data (Tab BB-42). Two seconds after EGI unit #1 failed, a number of warnings and cautions appeared on the head down displays (HDDs) for both members of the MCE (Tabs V-4.6, DD-5). The red "WARN" head up display (HUD) message was also present (See Figure 1) (Tab AA-3). Additionally, the artificial horizon line turned from green to red on the LRE GCS HUD (See Figure 2) (Tab AA-4).

The MCE looked up the warnings in Technical Order (T.O.) 1Q-9 (M)(A)-1, *Flight Manual MQ-9A Aircraft*, 6 June 2013, and began to run the Multiple Navigation Sensor Failure Checklist (Tab V-6.6). Additionally, P2 re-sent the emergency mission to the MA (Tabs V-6.6, AA-7). An emergency mission is a series of waypoints arranged to bring the aircraft back to its point of origin; it is automatically engaged if the aircraft goes lost link (Tab BB-35 to BB-36).

Figure 1. MCE GCS HUD (Tab AA-3)

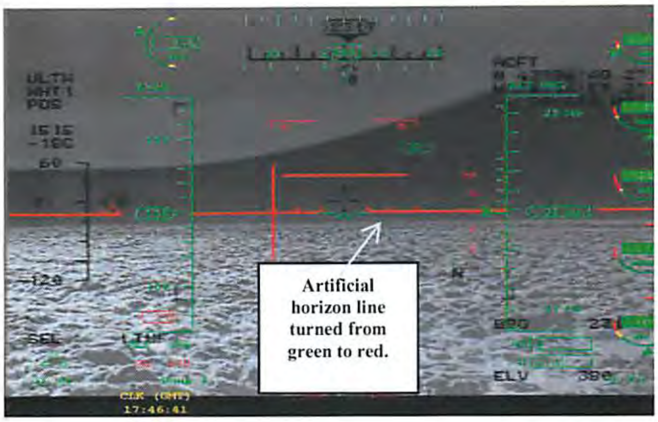

Figure 2. LRE GCS HUD (Tab AA-4)

At 12:47:24L, P2 turned the MA to the right in an attempt to return back to the base (Tab N-7). As the MA turned to the right, the MA's satellite communications (SATCOM) dish antenna stopped updating because it was receiving stagnant or erroneous data from EGI unit #1 (Tab DD-5 through DD-6). At 12:47:29L, the MA lost SATCOM command link and went lost link (Tab AA-7). The MA was in pre-programmed mode or flying on autopilot (Tab V-3.5). The MCE disabled the command link to avoid sending transmissions to the MA while it was lost link (Tab V-4.7). After the command link was disabled, the MCE was no longer able to monitor the MA (Tab V-4.7). The MA flew its emergency mission profile for approximately 11 minutes (Tab DD-6). SATCOM return link was not re-established (Tab DD-6).

P1 called Ops Sup who informed the MC that the MA had gone lost link (Tab V-5.7, V-6.6). The MC entered the LRE GCS and began to run the Gaining Handover Checklist at approximately 12:54L (Tabs V-7.8, AA-7). At 12:58:14L, EGI unit #3 failed and began sending erroneous telemetry data to FCA #3 (Tab DD-6). No additional cautions or warnings were generated (Tab DD-6). At 12:58:30L, IAW the Gaining Handover Checklist, MP enabled the GDT transmitter and gained control of the MA (Tabs V-5.9, AA-24). Approximately one to two seconds later, the MA began a pre-programmed autopilot command turn to the right (Tabs V-7.3, AA-8). It continued to turn to the right until completely inverted (Tab AA-8). Then it entered a right-hand spin (See Figure 3) (Tabs V-7.4, AA-8). MP stated "I can't recover it" (Tab AA-8).

Figure 3. LRE HUD Snapshot of Spin (Tab AA-5)

Despite the fact that the MA was lost link, the MC was able to continue to monitor its activity via a video feed (Tab V-5.7). At 12:58:49L, the video and telemetry showed the MA at 18,800 feet MSL, with a descent rate of 5,000 feet per minute, still spinning to the right (Tab AA-8). At 12:59:55L, MP disabled the GDT transmitter in an attempt to send the MA back lost link so it could recover on its own (Tabs V-5.10 through V-5.11, AA-24). The MA did not regain its lost link profile (Tab V-7.4). The last air traffic control contact with the MA occurred at approximately 13:00:36L while the MA was at 3,200 feet MSL (Tab AA-8). At approximately 13:01L, the MA impacted Lake Ontario (Tab AA-8).

A timeline was created from GCS data logger files and post mishap technical reports (Tab DD-3 through DD-13). Key points from the timeline are summarized in Figure 4 below.

Local Time	Event
10:42:00	The MA departs Wheeler-Sack AAF.
10:52:00	MCE accepts control of the MA and begins training.
12:46:25	EGI unit #1 fails.
12:47:29	The MCE crew loses link with the MA. The MA begins executing its emergency mission.
12:58:14	EGI unit #3 fails.
12:58:30	MP enables GDT transmitter.
12:58:34	The MA begins right-hand roll and spins to the right. Video and telemetry data from this point on is intermittent until impact time.
13:01:00	Approximate impact time.

Figure 4. Summary of Mishap Timeline in L Time (Tabs AA-6 through AA-8, DD-5 through DD-13)

e. Impact

The MA impacted Lake Ontario at approximately 13:01L (Tab AA-8). The point of impact was latitude 43.44.16 North (N), longitude 076.22.07 West (W), approximately 35 nm to the southwest of Wheeler-Sack AAF (See Figure 5) (Tabs AA-8, DD-22). The MA was completely inverted and spinning at the time of impact (Tab AA-8). It was destroyed upon impact, and the majority of its parts was not recovered (Tabs Q-6, AA-8).

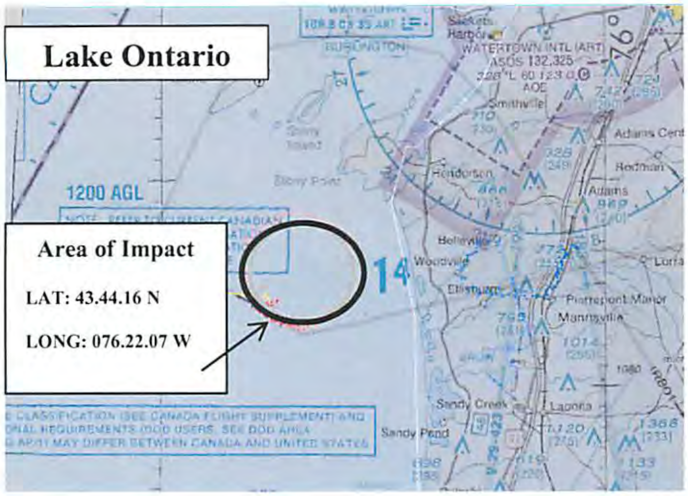

Figure 5. Last Known Position of MA, Lake Ontario (Tab DD-22)

f. Egress and Aircrew Flight Equipment

Not applicable.

g. Search and Rescue

Not applicable.

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

(1) General Definitions

(a) Recurring Discrepancy

IAW AFI 21-101, *Aircraft and Equipment Maintenance Management*, 26 July 2010, Attachment 1, a recurring discrepancy is one that occurs on the second through fourth sortie or attempted sortie after corrective action has been taken and the system or sub-system indicates the same malfunction when operated (AFI 21-101, Attachment 1).

(b) Aircraft 781 Series Forms

The Air Force Technical Order (AFTO) 781 series forms collectively provide a maintenance, inspection, service, configuration, status, and flight record for the particular aerospace vehicles and trainers for which they are maintained (Tab BB-5). Supervisors will ensure current forms are being used and entries on these forms are accurate (Tab BB-5). Prior to flight, the aircrew will review the AFTO Form 781 series forms for aerospace vehicle status (Tab BB-5). Prior to maintenance, technicians will review the AFTO Form 781 series forms (Tab BB-5).

(c) Time Compliance Technical Order

A Time Compliance Technical Order (TCTO) is the authorized method of directing and providing instructions for modifying military systems and end items or performing one-time inspections (Tab BB-7). TCTOs are categorized as Immediate Action, Urgent Action, Routine Action, Routine Safety Action and Record (Tab BB-7). The category determines the compliance period (Tab BB-7).

(2) Review of Documentation

A review of active and historical AFTO Form 781 series forms showed there was one open entry in the AFTO Form 781A (Tab D-49). According to the guidance in T.O. 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures*, 15 June 2013, paragraph 4.4, this red diagonal entry was not of a serious nature that would endanger safe operation of the MA (Tab BB-4). The MA's historical files for 34 months prior to the mishap were reviewed (Tab U-7). This review included an evaluation of the MA's TCTO status, AFTO Forms 95, major inspection packages, and archived data in the Integrated Maintenance Data System (IMDS) (Tab U-7). At the time of the mishap, the MA was current on all relevant TCTOs and did not have any recurring maintenance problems (Tab U-7 through U-8). The MA had 446.2 total flight hours (Tab D-2). No evidence was found to suggest any information noted in the aircraft forms for the MA was a factor in the mishap.

b. Inspections

The MA's inspections were documented, up to date, and completed satisfactorily (Tabs D-2, D-55, U-8). The last preflight inspection was accomplished on 12 November 2013 at 09:00L, and no discrepancies were noted (Tab D-46). The MA's last major inspection was a 200/400-hour airframe inspection performed on 24 September 2013, 49 days prior to the mishap (Tab D-2). There is no evidence to suggest the 200/400-hour airframe inspection or the preflight inspection was a factor in the mishap.

c. Maintenance Procedures

All proper maintenance procedures were followed, and only minor documentation errors were found (Tab U-8). Qualified technicians from the 174th Maintenance Group (174 MXG) completed maintenance for the MA (Tabs T-5 through T-95, T-99 through T-101, U-9). There is no evidence to suggest maintenance procedures contributed to the mishap.

d. Maintenance Personnel and Supervision

Aircraft maintenance records indicated all maintenance actions and supervisory actions regarding the MA were completed IAW technical guidance (Tab U-8 through U-9). IAW AFI 36-2232, *Maintenance Training*, 22 February 2006, information contained in maintenance personnel training records (AF Forms 623) is tracked electronically in the Training Business Area (TBA) system (AFI 36-2232, Chapter 4, paragraph 4.1). Individual TBA records and the 174 MXG Special Certification Roster indicated all 174 MXG personnel were trained, experienced, and certified to complete their assigned tasks (Tabs T-5 through T-95, T-99 through T-101, U-9). There is no evidence to suggest maintenance personnel or supervision was a factor in the mishap.

e. Fuel, Hydraulic and Oil Inspection Analyses

Due to the destruction of the MA upon impact, there were no post flight fuel or oil samples available for testing (Tab U-8). IAW T.O. 42B-1-1, *Quality Control of Fuel and Lubricants*, 13 August 2012, a fuel sample from the pre-accident fuel storage tank and fuel truck that last serviced the MA was submitted to the Air Force Petroleum Agency Laboratory for testing (Tabs U-3 through U-4, BB-22 through BB-23). Gas chromatographic analysis indicated both fuel samples were typical JP-8 fuel with no contamination (Tab U-4).

f. Unscheduled Maintenance

Unscheduled maintenance is any maintenance action taken that is not the result of a scheduled inspection and normally is the result of a pilot-reported discrepancy or condition discovered by ground crew (Tab U-8). There were two separate but similar discrepancies related to previous failures of EGI units onboard the MA (Tabs D-25, D-36, U-7 through U-8). On 28 October 2013, the MA returned to base after its EGI unit #1 stopped communicating with the Ku satellite (Tabs D-25, V-1.3). On 6 November 2013, the MA returned to base after its EGI unit #2 failed (Tabs D-36, V-1.3). The MA did not stop communicating with the Ku satellite during this incident (Tab U-7 through U-8). On both occasions, the EGI units were removed and replaced by maintenance personnel (Tabs D-25, D-36, V-1.3 through V-1.4).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

The majority of the MA, including the EGI units onboard the MA at the time of the mishap, was not recovered from Lake Ontario (Tab AA-8). Approximately three days after the mishap, a few components (miscellaneous composite fuselage and control surface pieces) washed ashore (See Figure 7) (Tabs Z-3, AA-8). Figure 6 details the locations where these components were recovered (Tab S-4). There is no evidence to suggest the recovered parts contributed to the mishap.

Figure 6. Debris Locations (Tab S-4)

Figure 7. Components Recovered From the MA (Tab Z-3)

(1) Embedded Global Positioning System/ Inertial Navigation System

The three EGI units onboard the MA were manufactured by Honeywell Aerospace (Tab U-8). The EGI units provide aircraft level platform data for the attitude data system (Tab BB-44). Each EGI unit has accelerometers and a gyro that sense linear accelerations (i.e., speeding-up) and angular rates (rolling or turning) in relation to the three perpendicular axes (yaw, pitch, and roll) of the aircraft (Tab BB-44). Each EGI unit transmits its attitude data to its assigned FCA via a 1553 bus (Tab BB-44). An FCA is a single board computer capable of independently controlling the aircraft and receiving sensor data (Tab BB-42). Each of the flight computers receives attitude data from its paired EGI unit (Tab B-44). The 1553 bus is the primary information handler between the flight computers and the triple EGI units (See Figure 8) (Tab BB-44).

Attitude, Air Data, and Navigation System

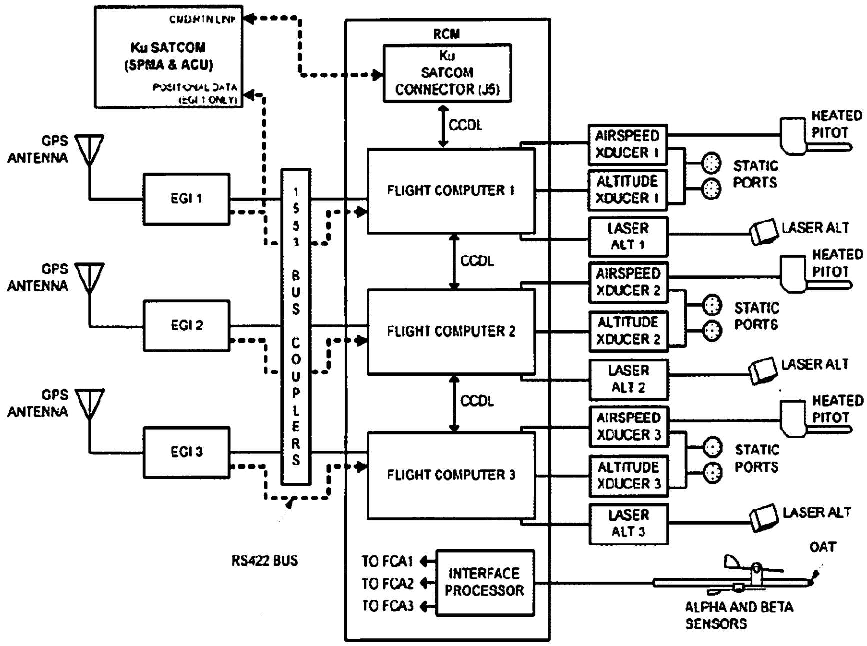

Figure 8. MQ-9 Attitude, Air Data, and Navigation System (Tab BB-44)

The triplex EGI systems provide a level of redundancy against an EGI failure by allowing all three EGI units to communicate with all three flight computers (Tab BB-89). Despite the redundancy, a failure of EGI unit #1 may result in a lost link condition since Ku-band antenna requires EGI unit #1 for level platform data (Tab BB-89). In other words, the Ku SATCOM will not be able to aim properly (Tab BB-45). The three EGI units also provide aircraft position data by receiving signals from the navigation satellites (Tab BB-45). The INS fills in the data between GPS updates from the navigation satellites (Tab BB-50). This blended GPS/INS data allows an increased positional accuracy (Tab BB-50).

(2) Redundant Control Module

The redundant control module (RCM) is the heart of the aircraft's digital control system, and the autopilot is an integral part of the RCM (Tab BB-28, BB-42). One of the functions of the RCM is to control the MA's autopilot command generation and distribution (Tab BB-42). In essence, the RCM takes attitude data from the EGI units and sends control commands to the components or autopilot system (Tab BB-42, BB-58). Put simply, the RCM is the brain of the MQ-9 aircraft digital control system, generating valid data using the EGI units to give autopilot control commands (Tab AA-25). If an individual EGI malfunctions, an FCA can use EGI data from another FCA to provide input to the RCM (Tab BB-44). In theory, in the case of two EGI unit failures, the RCM should select "good" or valid quality data from another sensor, which prevents the use of invalid data from EGI units to generate autopilot commands (Tabs AA-25, BB-42). In the case of the MA, after the MA's EGI unit #1 failed, the RCM continued to provide valid output using the remaining functioning EGI units #2 and #3 (Tab AA-25). When EGI #3 failed, the RCM should have stopped the selection process and selected data from the remaining functioning EGI unit #2 (Tab AA-25). However, the RCM did not use EGI #2's input, instead, it set all autopilot values to 0. The MA was unable to determine its attitude because of the invalid input to the control system from the RCM.

b. Evaluation and Analysis

As stated above, the EGI units onboard the MA were not analyzed because they were not recovered from Lake Ontario (Tab AA-8). Air Force Life Cycle Management Center, Detachment 3, conducted testing on the both the MCE GCS and LRE GCS used on the mishap date (Tab J-2 through J-4). Testing determined both GCSs and associated hardware were operating normally (Tab J-4).

7. WEATHER

a. Forecast Weather

On the day of the mishap, the forecasted weather for takeoff of the MA at Wheeler-Sack AAF was overcast skies at 2,400 feet MSL, visibility of 7 statute miles (sm) and winds out of the northeast at 10 knots gusting to 18 knots (Tab F-2 to F-5). The forecasted surface temperature was 30 degrees Fahrenheit and freezing at ground level (Tab F-5 to F-6). The altimeter setting was 30.13 inches of mercury (Tab F-2).

The forecasted weather for the Oswego MOA for the date and time of the mishap was overcast skies between 4,000 feet and 7,000 feet MSL, visibility of 7 sm, and flight-level winds at 20,000 feet MSL out of the west at 45 knots (Tab F-6). Light icing was forecasted between 4,000 feet and 7,000 feet MSL (Tab F-6).

b. Observed Weather

The observed weather on the day of the mishap was low scattered and broken cloud decks (Tab V-6.6). Clouds were moving in from the west (Tab V-4.6). The post mishap weather was cold with clouds from 2500 to 4300 AGL (Tabs F-10, V-8.8). There were no in-flight weather reports (Tab V-4.6).

c. Space Environment

Not applicable.

d. Operations

The mission complied with weather requirements IAW AFI 11-202, Volume 3, *General Flight Rules*, 22 October 2010, ACC Supplement, 28 November 2012, paragraph 8.11 and table 7.1, AFI 11-214, *Air Operations Rules and Procedures*, 14 August 2012, paragraph 5.3.1.1, and AFI 11-2MQ-1 & 9, Volume 3, *MQ-1 and MQ-9--Operations Procedures*, 1 November 2012, paragraph 4.2.1.2.1.

8. CREW QUALIFICATIONS

a. Mishap Pilot

MP was a fully qualified MQ-9 LRE instructor pilot and an experienced FTU instructor pilot (Tab T-3). MP was current in all flight areas IAW AFI 11-2MQ-9 Volume 1, *Flying Operations: MQ-9 Crew Training,* 3 June 2008, Table 4.1. MP completed his most recent instrument, mission, and qualification check ride in the MQ-9 on 24 October 2012 (Tab G-65). At the time of the mishap, MP had 757 total hours in the MQ-9 (Tab G-9). MP was previously qualified as an MQ-1 pilot (1,268 total hours) and KC-135 pilot (790 total hours) (Tab G-9).

Recent flight time is as follows (Tab G-5):

	Hours	Sorties
Last 30 Days	6.0	6
Last 60 Days	20.0	19
Last 90 Days	35.0	29

b. Mishap Sensor Operator

MSO was a fully qualified MQ-9 LRE sensor operator and an experienced LRE instructor sensor operator and FTU instructor sensor operator (Tab T-4, T-96 through T-98). MSO was current in all flight areas IAW AFI 11-2MQ-9 Volume 1, *Flying Operations: MQ-9 Crew Training,* 3 June 2008, Table 4.1. MSO completed his most recent mission and qualification check ride in the MQ-9 on 25 June 2013 (Tab T-96). At the time of the mishap, MSO had 1,003 total hours in the MQ-9 (Tab G-55). MSO was previously qualified as an aircraft weapons load crew chief (Tab V-7.2 through V-7.3).

Recent flight time is as follows (Tab G-16):

	Hours	Sorties
Last 30 Days	13.9	11
Last 60 Days	25.7	21
Last 90 Days	33.6	28

There is no evidence to suggest crew qualifications were a factor in this mishap.

9. MEDICAL

a. Qualifications

A review of medical records for the MC revealed both members were medically qualified for duty at the time of the mishap (Tab X-5 through X-6).

b. Health

A review of the medical records and 72-hour and 14-day histories for the MC revealed both members were in good health and had no performance-limiting condition or illness prior to the mishap (Tab X-5 through X-6).

c. Toxicology

Immediately following the mishap, the MC and all maintenance members that had contact with the MA were screened for drug and alcohol use (Tab X-3). All tests were negative (Tab X-3). There is no evidence to suggest drugs or alcohol use was a factor in the mishap (Tab X-4).

d. Lifestyle

No lifestyle factors were found to be relevant to the mishap.

e. Crew Rest and Crew Duty Time

IAW AFI 11-202 Volume 3, *General Flight Rules*, 22 October 2010, ACC Supplement, 28 November 2012, prior to performing in-flight duties, Air Force crewmembers must have proper crew rest (Tab BB-77 through BB-78). Paragraphs 9.4.5 and 9.8 of the AFI defines normal crew rest as a minimum 12-hour non-duty day period before the designated flight duty period begins, during which time an aircrew member may participate in meals, transportation, and rest, as long as he or she has the opportunity for at least eight hours of uninterrupted sleep (Tab BB-77 through BB-78). The purpose of crew rest is to ensure crewmembers are adequately rested before performing flight or flight-related duties (Tab BB-77). A review of the 72-hour and 14-day histories for the mishap crew revealed each member had adequate crew rest prior to the mishap (Tab X-5 through X-6).

There is no evidence to suggest medical issues contributed to the mishap.

10. OPERATIONS AND SUPERVISION

a. Operations

IAW AFI 11-401, 10 December 2010, ACC Supplement, *Aviation Management*, 25 March 2013, Table A2.3, the second to last letter, "E," in the members' crew position code on the Letter of Certification indicates they were experienced (Tab T-3). The 138 ATKS, including the 174 FTU, had a total of 38 assigned and attached pilots, 34 of whom were experienced flying the MQ-9 (Tab T-3). There were 42 assigned and attached sensor operators, 32 of whom were experienced crew on the MQ-9 (Tab T-4). 23 of the 38 pilots are qualified as instructors, and 18 of 42 sensor operators are qualified as instructors (Tab T-3, T-4). Both members of the MC were qualified and experienced (Tab T-3, T-4).

Using the guidelines in Air Force Pamphlet 90-803, *Risk Management Guidelines and Tools: Special Management*, 11 February 2013, paragraph 28, the operational risk management (ORM) level of the mishap mission was assessed as 26 (Tab K-23). ORM is a decision-making process used to systematically evaluate possible courses of action, identify risks and benefits, and determine the best course of action for any given situation (Air Force Pamphlet 90-803, paragraph 1.1). The ORM score was in the lowest risk or "green" category (Tab K-23). Operations Supervisor was experienced and qualified (Tab T-3). The MC described the operations tempo on the day of the mishap as normal (Tab V-5.3, V-7.4).

b. Supervision

The FTU squadron commander reviewed and authorized the mishap mission (Tabs K-3, V-4.3). The FTU squadron commander was also the Ops Sup on the day of the mishap (Tabs Q-4, V-4.3). There is no evidence to suggest that squadron operations or supervision was a factor in the mishap.

11. HUMAN FACTORS

There is no evidence to suggest human factors contributed to the mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publicly Available Directives and Publications Relevant to the Mishap

(1) AFI 11-2MQ-1 & 9, Volume 3, *MQ-1 and MQ-9--Operations Procedures*, 1 November 2012
(2) AFI 11-2MQ-9, Volume 1, *Flying Operations: MQ-9 Crew Training,* 3 June 2008, Certified Current 23 June 2010
(3) AFI 11-202, Volume 3, *General Flight Rules*, 22 October 2010, ACC Supplement, 28 November 2012
(4) AFI 11-214, *Air Operations Rules and Procedures*, 14 August 2012
(5) AFI 11-401, *Aviation Management*, 10 December 2010, ACC Supplement, 25 March 2013
(6) AFI 21-101, *Aircraft and Equipment Maintenance Management*, 26 July 2010, Incorporating Change 1, 16 August 2011
(7) AFI 36-2232, *Maintenance Training,* 22 February 2006
(8) AFI 51-503, *Aerospace Accident Investigations,* 26 May 2010
(9) AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010, ACC Supplement, 5 September 2013
(10) Air Force Pamphlet 90-803, *Risk Management Guidelines and Tools: Special Management*, 11 February 2013

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

b. Other Directives and Publications Relevant to the Mishap

(1) T.O. 00-5-1, *Air Force Technical Order System*, 15 January 2013
(2) T.O. 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures*, 15 June 2013

(3) T.O. 1Q-9(M)A-1S-40, *Flight Manual MQ-9A Aircraft*, Operational Supplement 1S-40, 6 June 2013
(4) T.O. 42B-1-1, *Quality Control of Fuels and Lubricants*, 13 August 2012
(5) *Air Force Tactics, Techniques, and Procedures* 3.3.MQ-9, 14 December 2012

c. Known or Suspected Deviations from Directives or Publications

Not applicable.

13. ADDITIONAL AREAS OF CONCERN

There were no additional areas of concern.

24 APRIL 2014

DANA A. HESSHEIMER, Col, CAANG
President, Accident Investigation Board

STATEMENT OF OPINION

MQ-9 REAPER, T/N 09-4066
LAKE ONTARIO, NEW YORK
12 NOVEMBER 2013

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

I find by clear and convincing evidence that the failure of the mishap aircraft's (MA) embedded global positioning system/inertial navigation system (EGI) units #1 and #3 in conjunction with a transfer of invalid attitude data to the MA's autopilot system was the cause of the mishap. The MQ-9 relies on the EGI units for valid attitude reference data. Without valid data, the MA could not discern its attitude and became uncontrollable.

I developed my opinion by analyzing factual data from Air Force directives and guidance, engineering analyses, witness testimony, flight data, animated simulations, and information provided by technical experts.

2. BACKGROUND

The MA departed Wheeler-Sack Army Airfield, NY, at 10:42L on 12 November 2013 for the Oswego Military Operating Area to conduct a training mission. The mishap crew (MC), consisting of a Mishap Pilot (MP) and Mishap Sensor Operator, was the launch and recovery element (LRE) for the mission. The MC accomplished an uneventful takeoff. At 10:52L, the mission control element (MCE) gained control of the MA from the LRE without incident. About two hours into the mission, the MCE noticed a series of warnings on the head down displays indicating the MA's embedded global positioning system/inertial navigation system (EGI) unit #1 had failed. The MCE looked up the warnings in the MQ-9 flight manual and ran the Multiple Navigation Sensor Failure Checklist. The MCE made an effort to return the MA to base, but the MA went lost link and began to fly its emergency mission. Lost link occurs when there is a loss of connectivity between the aircraft and the pilot. An emergency mission is a series of waypoints arranged to bring the aircraft back to its point of origin and is automatically engaged when the aircraft goes lost link. The MA was flying on autopilot by the time it entered the emergency mission. The MCE disabled the command link because they were unable to monitor the MA. The MC entered the LRE ground control station and began to run the Gaining Handover Checklist. At 12:58:14L, the MA's EGI unit #3 failed. Following the checklist, the MP enabled the ground data terminal (GDT) transmitter which caused the MA to fly on autopilot. Invalid attitude data from the failed EGI units caused the autopilot to command a right turn, and continued turning right, until the MA completely inverted, and then entered a spin. The MP lost control of the MA. At 12:59:55L, the MP disabled the GDT transmitter in an attempt to send the MA back lost link so it would recover on its own, however, the MA did not return to a lost link profile. Approximately one minute later, the MA impacted Lake Ontario and was destroyed.

3. CAUSE

The failure of the MA's EGI unit #1 caused the MA to go lost link. Shortly after EGI unit #1 failed, EGI unit #3 failed. Normally, the remaining functioning EGI unit will provide attitude reference data to the autopilot system through the redundant control module (RCM). The RCM is the heart of the aircraft digital control system. One of its functions is to control the MA's autopilot command generation and distribution by taking attitude data from the EGI units and sending control commands to the autopilot system. When operating normally, two EGI unit failures should not be problematic because the RCM should select the valid data from the functioning EGI unit. In this case, that would have been EGI unit #2. However, the RCM did not select valid data from EGI unit #2, instead, it set all autopilot values to 0, which resulted in passing erroneous attitude data to the MA. Based on the limited information and evidence received on the RCM, I was unable to conclude why the RCM did not select the data from EGI unit #2. When the MA made the right-hand turn, the autopilot did not have valid data regarding its current attitude. With invalid attitude data, the MA continued the right-hand turn until it became completely inverted and began to spin. The MA spun out of control and impacted Lake Ontario. The failure of EGI units #1 and #3 in conjunction with the transfer of no attitude data to the MA was the cause of the mishap.

Despite having two EGI unit failures on previous flights, I find no evidence that maintenance personnel, practices, or procedures substantially contributed to the mishap. The previous EGI units were replaced prior to any further flight in accordance with the technical orders and guidance.

I considered whether the flight level temperature on the date of the mishap adversely affected the MA's EGI units and substantially contributed to the mishap. Due to the fact that I was unable to determine by a preponderance of the evidence that flight level temperature was a substantially contributing factor, I did not discuss it in the AIB report.

4. CONCLUSION

I find by clear and convincing evidence that the failure of the MA's EGI units #1 and #3 in conjunction with a transfer of invalid data to the MA's autopilot system was the cause of the mishap. The MQ-9 relies on the EGI units for valid attitude data. Without valid data, the MA could not discern its attitude and became uncontrollable.

24 APRIL 2014

DANA A. HESSHEIMER, Col, CAANG
President, Accident Investigation Board

INDEX OF TABS