UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

QRF-4C, T/N 69-0384

82D AERIAL TARGETS SQUADRON
53D WING
TYNDALL AIR FORCE BASE, FLORIDA

LOCATION: TYNDALL AIR FORCE BASE, FL

DATE OF ACCIDENT: 17 JULY 2013

BOARD PRESIDENT: LIEUTENANT COLONEL GARDNER J. JOYNER

Conducted in accordance with Air Force Instruction 51-503

EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION
QRF-4C T/N 69-0384, TYNDALL AIR FORCE BASE, FLORIDA
17 JULY 2013

On 17 July 2013, at approximately 13:23 Zulu (Z) time, a QRF-4C Phantom II unmanned aircraft, tail number (T/N) 69-0384, operating in autopilot, impacted the ground on the south end of runway 18 at Tyndall Air Force Base (AFB), Florida (FL), approximately 8 seconds after takeoff. The mishap aircraft (MA) was assigned to the 82d Aerial Targets Squadron (82 ATRS), 53d Weapons Evaluation Group (53 WEG), 53d Wing (53 WG), Tyndall AFB, FL. The MA, an infrared flare-dispensing pod (Mongoose 4 Pod), and 120 flares were destroyed on impact. The drone runway and its barrier also incurred significant damage and required repair. The total damage to United States (U.S.) Government property was assessed to be $4,564,536.00. There were no injuries or damage to other government or to civilian property sustained as a result of this mishap.

The Mishap Controller (MC) released the brakes on the MA at 13:22:47Z and selected the Automatic Takeoff (ATO) mode. The MC provided launch recommendations to the Drone Mission Commander (DMC) and was responsible for controlling the MA through all phases of flight. The MA began its takeoff role, increased speed to 165 knots, and lifted off the ground as the landing gear and flaps were raised. The MA lifted off the ground at 13:23:08Z and immediately demonstrated pitch issues. Upon takeoff, the MA pitched up and initially achieved its normal 12 degrees above the horizon attitude. Approximately two seconds later, the MA pitched down approximately five degrees, then rapidly pitched up to 28 degrees above the horizon—which exceeded the limits of the MA. After identifying the inappropriate pitch change, the MC determined the MA was airborne and within approximately a half second determined the appropriate emergency checklist response. At approximately the same time, the Gulf Range Drone Control Station (GRDCS) responsible for controlling the aircraft during ATO, detected a bad stabilator condition and displayed it on the MC's display. The stabilator, commonly known as an all-moving tail, provides longitudinal stability, control and stick requirements that are normally performed by a horizontal stabilizer. The MC executed the required emergency checklist items to recover the MA, using a series of push button commands beginning with the ATO and followed by the All Attitude Recovery (AAR) command. The MA subsequently entered a stall, pitched down 33 degrees and impacted the ground at 13:23:17Z. The entire flight lasted approximately 8 seconds.

The Accident Investigation Board (AIB) President found, by clear and convincing evidence, that the cause of this mishap was a defective pitch rate portion of the Attitude Heading Reference System (AHRS), otherwise known as the aircraft system that controls the up and down movement of the MA. The AHRS was responsible for the movement of the MA in all three axes—which include pitch, roll and yaw. The defective AHRS was destroyed in the crash; however, the AIB was able to determine, using the data from the GRDCS, that the AHRS sent erroneous inputs on the horizontal pitch of the MA to the Primary Automatic Flight Control Computer (PAFCC). These erroneous inputs caused the MA to pitch up and down rapidly and to enter a 28 degrees above the horizon attitude. This exceeded the stall threshold and subsequently pitched the MA down 33 degrees—causing the MA to impact the ground.

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
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COMMONLY USED ACRONYMS AND ABBREVIATIONS

ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION
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53 WEG	53d Weapons Evaluation Group
53 WG	53d Wing
82 ATRS	82d Aerial Target Squadron
83 FWS	83d Fighter Weapons Squadron
A1C	Airman First Class
AAR	All-Attitude Recovery
AB	Afterburner
A/B	Alpha and Bravo
ACC	Air Combat Command
ADI	Attitude Director Indicator
ADO	Assistant Duty Officer
AF	Air Force
AFB	Air Force Base
AFCC	Automatic Flight Control Computer
AFCS	Automatic Flight Control System
AFI	Air Force Instruction
AFIP	Air Force Institute of Pathology
AFMAN	Air Force Manual
AFMC	Air Force Materiel Command
AFSAS	Air Force Safety Automated System
AFTTP	Air Force Technical Training Manual
AFTO	Air Force Technical Order
AGE	Aerospace Ground Equipment
AGL	Above Ground Level
AH	Altitude Hold
AHRS	Attitude Heading Reference System
AIB	Accident Investigation Board
AMIC	Aircraft Mishap Investigation Course
AMXS	Aircraft Maintenance Squadron
AOA	Angle of Attack
ATC	Air Traffic Controller
ATO	Automatic Takeoff
ATRS	Aerial Targets Squadron
BAE	British Aerospace
BUAFCC	Backup Automatic Flight Control Computer
BUAFCS	Backup Automatic Flight Control System
Capt	Captain
CC	Commander
CD	Deputy Commander
CEMP	Comprehensive Emergency Management Plan
CG	Center of Gravity
CIV	Civilian
CMD/TEL	Command Control/Telemetry
COM	Communication
COMACC	Commander of Air Combat Command
CP	Chase Pilot
CTS	Command Telemetry System
D1C	Drone One Controller
DC	Deputy Commander
Det	Detachment
DFS	Drone Formation System
DMC	Drone Mission Commander
DoD	Department of Defense
DPE	Drone Peculiar Equipment
DS2	Defense System Services
DSN	Defense Switching Network
EA	Electronic Attack
EH	Electro-Hydraulic
ECM	Electronic Countermeasures
EM	Electro-Mechanical
EOC	Emergency Operations Center
EP	Emergency Procedure
EPIP	Electronic Protection Improvement Program
FAE	Functional Area Expert
FCF	Functional Check Flight
FCS	Fixed Control Station
FL	Florida
FOIA	Freedom of Information Act
FSAT	Full Scale Aerial Target
FSAT AFCS	Full Scale Aerial Target Automatic Flight Control System
FW	Fighter Wing
FWS	Fighter Weapons Squadron
G	Gravitational Force
GAB	Ground Abort
GMCS	GRDCS Mobile Control Station
GRDCS	Gulf Range Drone Control Station
GS	Government Service
HQ	Headquarters
HHI	Heading Hold Inhibit
IAW	In Accordance With
IC	Incident Commander
IMDS	Integrated Maintenance Documentation System
IO	Investigating Officer
ISB	Interim Safety Board
JMIC	Joint Military Intelligence College
JOAP	Joint Oil Analysis Program
Kt	Knot

KIAS	Knots Indicated Airspeed
L	Local Time
LA	Legal Advisor
LEU	Leading Edge Up
LED	Leading Edge Down
LTO	Landing/Takeoff
MA	Mishap Aircraft
Mach	Speed of Sound
MC	Mishap Controller
MAX	Maximum Throttle Including Full AB
MDCO	Mobile Drone Console Operator
MED	Medical Member
MHz	Megahertz
MM	Maintenance Member
MIKE	NULLO Mission Commander
MIL	Maximum Throttle Command Prior to AB
MM	Maintenance Member
MMC	Mishap Mission Coordinator
MT	Maintenance Technician
NAD	No Air Data
nm	Nautical Mile
NM	New Mexico
NOTAMS	Notice to Airmen
NULLO	Not Under Live Local Operator
NV	Nevada
OI	Operating Instruction
OPLAN	Operations Plan
ORM	Operational Risk Management
OSC	On Scene Commander
OSS	Operations Support Squadron
OWS	Operations Weather Squadron
PAC	Pitch Attitude Control
PAFCC	Primary Automatic Flight Control Computer
PAFCS	Primary Automatic Flight Control System
PC	Power Control (System)
PID	Proportional-Integral-Derivative
PM	Pilot Member
P/N	Part Number
POR	Power on Reset
PRT	Proportional Telemetry Channel
PCTO	Pitch Loop Command to Stabilator
QA	Quality Assurance
QAE	Quality Assurance Evaluator
RC	Recorder
RCF	Range Control Facility
RDO	Range Destruct Officer
RSO	Range Safety Officer
SA	Situational Awareness
SAFE	Software Acceptance Flight Evaluation
SE	Safety
SHOP	Speed Hold On Pitch
SHOT	Speed Hold on Throttle
SIB	Safety Investigation Board
S/N	Serial Number
SP	Safety Pilot
SrA	Senior Airman
SSAT	Small Scale Aerial Target
SSgt	Staff Sergeant
Stabilator	Stabilator
STBY	Standby
TAF	Terminal Area Forecast
TAFB	Tyndall Air Force Base
TANGO	NULLO Mobile Drone Console Operator
TCTO	Time Compliance Technical Order
TDY	Temporary Duty
T.O.	Technical Order
T/N	Tail Number
TRG	Training Group
U.S.	United States
USAF	United States Air Force
USAFWC	United States Air Force Warfare Center
U.S.C.	United States Code
UT	Utah
WEG	Weapons Evaluation Group
WG	Wing
WHISKEY	Master Console Operator
WL	Wings Level
WOG	Weight on Gear
WPS	Weapons Squadron
WSEP	Weapons System Evaluation Program
X-RAY	NULLO Mission Controller
YANKEE	NULLO Mission Coordinator
Z	Zulu or Greenwhich Meant Time

Variables and Data:

Θ	Theta; Pitch Attitude
Φ	Phi; Roll Attitude
Ψ	Psi; Heading
P,p	Roll Rate
Q,q	Pitch Rate
R,r	Yaw Rate
δ_s	Stabilatorilizer Deflection
Q_c	Dynamic Pressure
V_g	Ground Speed

COMMONLY USED DEFINITIONS

Automatic Flight Control Computer (AFCC): There are two AFCCs that are used during remote control flight. One AFCC is designated as the Primary Flight Control Computer (PAFCC) and the other is designated as the Backup Flight Control Computer (BAFCC). The BAFCC only operates if the PAFCC fails. These computers command and control servos and actuators of the basic Automatic Flight Control System (AFCS), as well as the equipment specific to the QRF-4C.

Automatic Flight Control System (AFCS): The AFCS is the automated system that controls the aircraft during unmanned missions without the assistance of a person. The QRF-4C has a Primary Automatic Flight Control System (PAFCS) and a Backup Automatic Flight Control System (BAFCS). The BAFCS only operates if the PAFCS fails.

Attitude Heading Reference System (AHRS): The AHRS provides pitch rate and attitude data, specifically the angle of the airplane in the air, to the AFCC. The AFCC uses the information provided by the AHRS to provide commands to the aircraft.

Automatic Takeoff (ATO): ATO is a computer system used to guide the aircraft from brakes release to rotation without the assistance of a person.

Gulf Range Drone Control System (GRDCS): A ground-based computer system used to track and control unmanned aerial targets in support of weapons testing and evaluation for the U.S. air Force.

Not Under Live Local Operator (NULLO): This means that the aircraft is flown and controlled through takeoff, and if necessary landing, by the Drone Formation System (DFS) ground control. The aircraft is unmanned.

Stabilator: The stabilator, commonly known as an all-moving tail, provides longitudinal stability, control and stick requirements usually performed by a horizontal stabilizer.

Time Compliance Technical Orders (TCTO): Publications issued to accomplish one time changes to, or to impart precautionary instructions or inspections on, aircraft or related equipment.

SUMMARY OF FACTS

AIRCRAFT ACCIDENT INVESTIGATION
QRF-4C, T/N 69-0384, TYNDALL AIR FORCE BASE, FLORIDA
17 JULY 2013

1. AUTHORITY AND PURPOSE

a. Authority

On 21 August 2013 Lieutenant General Lori J. Robinson, Vice Commander, Air Combat Command (ACC), United States Air Force (USAF), convened an Accident Investigation Board (AIB) pursuant to Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations* to investigate the 17 July 2013 crash of a QRF-4C Phantom II unmanned aircraft, tail number (T/N) 69-0384, at Tyndall Air Force Base (AFB), Florida (FL) (Tabs Y-1.1 through Tab Y-1.2). The AIB was comprised of: the Board President; a Legal Advisor; a Recorder; a Pilot Member; a Medical Member; a Maintenance Member; and two Functional Area Experts (Tabs Y-1.1 through Y-2.1).

b. Purpose

In accordance with AFI 51-503, paragraph 8.7.8.1.2, this is a legal investigation convened to inquire into the facts surrounding the aircraft 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 17 July 2013, at approximately 13:23 Zulu (Z) time, a QRF-4C Phantom II aircraft, T/N 69-0384, operating in Automatic Takeoff (ATO) mode, impacted the ground on the south end of drone runway 18 at Tyndall AFB, FL approximately 8 seconds after takeoff (Tabs L-1 Attachments L-1.1 through L-1.4; Tabs S-1 through Tab S-7). The mishap aircraft (MA) was assigned to the 82d Aerial Targets Squadron (82 ATRS), 53d Weapons Evaluation Group (53 WEG), 53d Wing (53 WG), Tyndall AFB, FL (Tab CC-4.2). The MA, an infrared flare-dispensing pod (Mongoose 4 Pod) and 120 flares were destroyed on impact (Tab P-4). The runway and its barrier also incurred significant damage and required repair (Tab P-4). The total damage to United States (U.S.) Government property was assessed to be $4,564,536.00 (Tab P-4). There were no injuries or damage to other government or to civilian property as a result of this mishap (Tab P-3).

3. BACKGROUND

The MA was an asset of the 82 ATRS, 53 WEG, 53 WG, United States Air Force Warfare Center (USAFWC), ACC, Tyndall AFB, FL (Tabs CC-1.1 through Tab CC-4.1).

a. Air Combat Command (ACC)

ACC, with headquarters at Joint Base Langley-Eustis, Virginia, is a major command created 1 June 1992, by combining its predecessors Strategic Air Command and Tactical Air Command (Tab CC-1.1). ACC is the primary provider of air combat forces to America's warfighting commanders (Tab CC-1.1). To support global implementation of national security strategy, ACC operates fighter, bomber, reconnaissance, battle-management and electronic-combat aircraft (Tab CC-1.1). It also provides command, control, communications and intelligence systems, and conducts global information operations (Tab CC-1.1). As a force provider, 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-1.1).

b. United States Air Force Warfare Center (USAFWC)

The USAFWC, located at Nellis AFB, Nevada (NV), reports directly to ACC (Tab CC-2.1). The USAFWC exists to ensure deployed forces are well trained and well equipped to conduct integrated combat operations (Tab CC-2.1). From the testing and tactics development programs to the training schools and venues, USAFWC provides Airmen with proven and tested technology, the most current tactics, superb academic training and a unique opportunity to practice integrated force employment (Tab CC-2.1). The USAFWC vision, mission and priorities are central to supporting ACC's mission to fly, fight, and win – integrating capabilities across air, space, and cyberspace to deliver precise coercive effects in defense of the U.S. and its global interests (Tab CC-2.1).

c. 53d Wing (53 WG)

The 53 WG, located at Eglin AFB, FL, serves as the focal point for the Combat Air Forces in electronic warfare, armament and avionics, chemical defense, reconnaissance and aircrew training devices (Tab CC-3.1). The wing is responsible for operational testing and evaluation of new equipment and systems proposed for use by these forces (Tab CC-3.1). The 53 WG, comprised of four groups, numbers more than 2,200 military and civilians at 22 various locations throughout the U.S. (Tab CC-3.1). The wing reports to the USAFWC at Nellis AFB, NV, a direct reporting unit to ACC (Tab CC-3.1).

d. 53d Weapons Evaluation Group (53 WEG)

The 53 WEG is an ACC tenant organization that reports to the 53 WG, Eglin AFB, FL (Tab CC-4.1). The 53 WEG is comprised of five squadrons and two detachments: the 53d Test Support Squadron; the 81st Range Control Squadron; the 82 ATRS and 83d Fighter Weapons Squadron (83 FWS), located at Tyndall AFB, FL; the 86th Fighter Weapons Squadron, located at Eglin AFB, FL; Detachment (Det) 1, 82 ATRS, located at Holloman AFB, New Mexico (NM); and Det 1, 86 FWS, located at Hill AFB, Utah (UT) (Tab CC-4.1). The group conducts the Air Force's air-to-air Weapons System Evaluation Program (WSEP), known as Combat Archer, and the Air Force's air-to-ground WSEP, known as Combat Hammer (Tab CC-4.1). It also supports Weapons Instructor Course air-to air formal training syllabi (Tab CC-4.1). Unit personnel provide all Air Force aerial target support for Department of Defense (DoD) users in the Gulf Ranges and full-scale targets for Title 10 testing at White Sands Missile Range, Holloman AFB, NM (Tab CC-4.1).

e. 82d Aerial Targets Squadron (82 ATRS)

The 82 ATRS at Tyndall AFB, FL and Holloman AFB, NM operates the DoD's only full-scale aerial target program, maintaining an inventory of 50 modified QF-4 Phantom II aircraft for this purpose (Tab CC-4.2). It also provides BQM-167 subscale aerial targets to Gulf Range customers at Tyndall AFB, FL (Tab CC-4.2). Full and subscale aerial targets are provided to Air Force, Navy, and Army customers for development and operational tests (Tab CC-4.2). Squadron members also operate the Air Force's only two DeHavilland E-9A "Widget" airborne surveillance/telemetry relay aircraft (Tab CC-4.2). These aircraft provide ocean surface surveillance and relay missile and target telemetry for over-the-horizon coverage of the Gulf Range and also support over-land telemetry missions for WSEP at Holloman AFB, NM, and the Utah Test and Training Range near Hill AFB, UT (Tab CC-4.2).

f. QF-4 Full Scale Aerial Target System

The supersonic QF-4 is a reusable full-scale target aircraft modified from the F-4 Phantom II (Tab CC-6.1). The QF-4 program attained initial operational capability in 1997 (Tab CC-6.1). The Air Force adopted the Navy's F-4C, under the initial designation of "F-110A Spectre," and retained the Navy Phantom name when it went into service in 1963 (Tab CC-8.2). Although the Air Force had some resistance to acquiring a Navy fighter aircraft, after adopting the Phantom the Air Force quickly became enthusiastic about the type (Tab CC-8.3). Shortly after ordering their first production Phantom fighters, the service decided to acquire a reconnaissance variant to replace their current McDonnell RF-101 Voodoo (Tab CC-8.3). The "recce" (pronounced "rekky") Phantom was originally designated the "RF-110A," but was re-designated "RF-4C" in September 1962 (Tab CC-8.3). Phantom aircraft later converted into high-performance target drones and are collectively referred to as "QF-4s" regardless of the distinct aircraft variant (Tab CC-8.6).

The QF-4 provides a realistic full-scale target for air-to-air weapons system evaluation, development and testing at Tyndall AFB, FL, and Holloman AFB, NM (Tab CC-6.1). The QF-4 is a remotely controlled target, which simulates enemy aircraft maneuvers (Tab CC-6.1). The drone can be flown by remote control or with a safety pilot to monitor its performance (Tab CC-6.1). The aircraft is flown unmanned when missiles are fired at it, and only in specific overwater airspace authorized for unmanned flight (Tab CC-6.1). When flown unmanned, an explosive device is placed in the QF-4 to destroy the aircraft if necessary (Tab CC-6.1).

The QF-4 is equipped to carry electronic and infrared countermeasures to fully evaluate fighters and weapons flown and fired against it (Tab CC-6.1). Full-scale unmanned aircraft are flown by computer using the Gulf Range Drone Control System (GRDCS) (Tab CC-6.1). As a safety precaution, a chase plane trails the unmanned aircraft during critical periods of flight (Tab CC-6.1). The GRDCS allows the aircraft to complete automatic takeoffs, landings, and formation flights (V-1.7).

On the day of the mishap, the mission was a Full Scale Aerial Target (FSAT) Not Under Live Local Operator (NULLO) and the following positions and responsibilities were as follows:

(1) The GRDCS Drone Controller (position of the MC), call sign: X-RAY

The X-RAY is the Primary NULLO controller, responsible for planning and briefing the NULLO mission, overall execution of the preflight checks, and coordinating the transfer of the MA drone control with the GRDCS Mobile Control System (GMCS) controllers (Tab BB-3.2). Additionally, the X-RAY provides launch recommendations to the Drone Mission Commander (DMC) and is responsible for controlling the QF-4 through all phases of flight including the execution of emergency checklist procedures in the event of a malfunction or emergency during an FSAT mission (Tab BB-3.2). During NULLO missions, the X-RAY is not authorized to manually control the takeoff of the aircraft (Tab BB-3.13). Instead, the YANKEE, TANGO, and Chase Pilot (CP) assist the X-RAY in monitoring the ATO sequence performed by the GRDCS (Tab BB-3.13). On the day of the mishap, X-Ray 2 was the Mishap Controller (MC).

(2) Assistant GRDCS Drone Controller (position of the MMC), call sign: YANKEE

Each X-RAY works with a secondary NULLO Controller, responsible for backing up X-RAY during preflight checks, monitoring the aircraft's performance throughout all phases of flight, and assisting with emergency checklist procedures in the event of a FSAT malfunction or emergency (Tab BB-3.3). YANKEE 2 was the Mishap Mission Coordinator (MMC).

(3) The Drone Mission Commander (position of the DMC), call sign: MIKE

The MIKE is responsible for reviewing the mission objectives and ensuring the mission is accomplished as briefed (Tab BB-2.3). Additionally, the MIKE maintains authority to terminate the mission to ensure real time safety and operations control of the aircraft (Tab BB-2.3). The MIKE is ultimately responsible for the conduct of the mission, even when the drone is under the TANGO's control (Tab BB-2.3). Further, the MIKE can direct the termination of the aircraft if he/she sees fit (Tab BB-2.3). Every unmanned FSAT must have a DMC in place at the GRDCS facility (Tab BB-2.2).

(4) Mobile Drone Console Operator (position of the MDCO), call sign: TANGO

The TANGO is the pilot controller responsible for conducting a pre-flight inspection on the aircraft, and serves as an additional back-up for the X-RAYs from a mobile van during the aircraft ground checks prior to launch (Tab V-6.1). Specifically, the TANGO accomplishes the NULLO preflight checklist in accordance with the 53 WEG Local Checklist 101 (V-3.13). Additionally, the TANGO visually monitors ATO during FSAT NULLO missions, and calls pre-takeoff steering action including "slowly converging," "two good burners," and "good airspeed" (Tab BB-3.3; Tab BB-3.13).

(5) Chase Pilot (position of the CP)

The Chase Pilot (CP) is an additional manned F-4, whose duties include chasing the aircraft out to the air space, and if the aircraft receives battle damage during missions, determining whether the aircraft can safely return to base (Tab V-5.1). Additionally, the CP provides a "Boat Report" by aligning themselves with the runway the aircraft takes off from, flying out 1,000 feet above ground level (AGL) at 300 knots to ten miles aligned with the runway, and announcing any boats in the water within three miles east or west of the runway to ensure the aircraft avoids the boat positions during takeoff (Tab V-5.2). The CP is also responsible for flying parallel to the runway alongside each aircraft during the ATO to ensure the aircraft is proceeding successfully to the designated airspace (Tab V-5.1).

4. SEQUENCE OF EVENTS

a. Mission

The sortie, Mission Number 3284, was scheduled as a FSAT NULLO in support of an 83 FWS Weapons System Evaluation Program (WSEP) and Electronic Protection Improvement Program (EPIP) (Tab V-3.3; Tab EE1.1 through Tab EE-1.3). It was a live fire mission configured with an infrared flare-dispensing pod (Mongoose 4 Pod) and 120 flares (Tab EE-1.1 through Tab EE-1.3). The 53 WEG Deputy Commander properly authorized the mission. (Tabs K-2 through Tab K-7). The mission was planned as a two-ship formation in support of WSEP and EPIP (Tab AA-1.1*)*. Both unmanned aircraft were prepared in accordance with (IAW) the preflight checklist (Tab V-1.4).

b. Planning

The briefing for the mission was conducted in two segments and was IAW AFI 11-2F/QF-4, Volume 3, *F/QF-4 Operations and Procedures*, 1 July 2000, Chapter 2; 82 ATRS Operating Instruction (OI) 11-5; *Flying Operations*, 9 January 2006; and *82 ATRS Standards*, September 2012, Paragraph 4 (Tab V-3.8; Tab BB-3).

The first segment was held at 09:15Z on 17 July 2013 and was led by a project engineer from the 83 FWS and the Drone One Controller (D1C). They reviewed the profiles, communications, and safety requirements of the mission (Tabs K-2 through Tab K-5; Tab V-3.7).

The second segment, also known as the NULLO mission brief, which the D1C conducted at 10:00Z in the drone operations building, covered weather, unmanned aircraft preparations, Notice to Airmen (NOTAMs), launch procedures, and details on how the unmanned aircraft profiles were to be flown as well as the aircraft operating areas (Tabs K-2 through Tab K-13; Tab V-3.3). Also covered were chase procedures for launching and recovering both drones (Tabs K-2 through Tab K-13; Tab AA-1.1 through Tab AA-1.5). The 82d ATRS standards require pilots and controllers to attend NULLO mission briefs, and recommend that the DMC attend (Tab BB-3.3 through Tab BB-3.4). In this case, the DMC did attend (Tab V-3.3).

c. Preflight

On 17 July 2013, the FSAT NULLO mission included the launch of two QRF-4C drones controlled by two separate GRDCS Drone Controllers known as X-RAY 1 and X-RAY 2 (MC) (V-1.3). Additionally, the MMC, the MDCO and the CP arrived for preflight checks (K-2; Tab V-2.3).

All aircrew received the NOTAMS from the Defense Internet NOTAM Service (Tab K-8; Tab V-3.10). The CP departed for his aircraft at 10:23Z, and the MC and MMC proceeded to the GRDCS facility at 10:15Z (Tabs V-3.3 to V-3.4). Both unmanned aircraft passed their preflight checklists (Tab V-1.4).

d. Summary of Accident

On 17 July 2013, the first unmanned aircraft launched normally at approximately 13:22Z (Tab S-8; Tab V-3.4). The MA drone launched second in order (Tab V-1.4). Prior to the MA launch, the MC reviewed the ATO information displayed on the GRDCS control panel which displayed no malfunctions (Tab V-1.8) The MC released the brakes on the MA at 13:22:47Z and selected ATO mode which the MA remained in from the time of brake release until impact (Tabs L-1, Attachments 1 through 4; Tab S-8).

The MA began its takeoff role, increased speed to 165 knots, and lifted off the ground as the landing gear and flaps were raised (Tabs L-1, Attachments 1 through 4; Tab S-8). The MC observed the performance of the aircraft on two screens linked to a control console (Tab V-1.5). The MA lifted off the ground at 13:23:08Z and immediately demonstrated pitch issues during takeoff (Tabs L-1, Attachments 1 through 4; Tab S-8). Upon takeoff, the MA pitched up and initially achieved its normal 12 degrees above the horizon attitude (Tabs L-1, Attachments 1 through 4; Tab S-8; Tab V-1.5). Approximately two seconds later, the MC noticed the MA pitched down approximately five degrees then rapidly pitched up to 28 degrees above the horizon, which exceeded the limits of the MA (Tabs L-1, Attachments 1 through 4; Tab S-8; Tab V-1.5).

The MC noted three distinct changes in the pitch of the MA on the GRDCS control panel from the time of lift off to impact (Tab V-1.5). After identifying the inappropriate pitch changes, the MC determined the MA was airborne, which means the MA was in the flying phase of flight rather than the takeoff phase of flight, and within approximately a half second determined the appropriate emergency checklist response (Tab V-1.6). At approximately that same time, the GRDCS responsible for controlling the aircraft during ATO, detected a bad stabilator condition and displayed it on the MC's display (Tabs L-1, Attachments 1 through 4). The stabilator, commonly known as an all-moving tail, provides longitudinal stability, control and stick requirements usually performed by a horizontal stabilizer. The MC did not see the message because the MC was executing the required emergency checklist items to recover the MA using a series of push button commands, beginning with the ATO and followed by the All Attitude Recovery (AAR) command (Figure 4; Tabs L-1 Attachments 1 through 4, Tab V-2.7). The MC determined that the typical boldface procedure, or expected emergency checklist item of selecting the All-Attitude Recovery (AAR) that would attempt to recover the MA based on the attitude, altitude and airspeed of the MA, was inappropriate given the low altitude of the aircraft (Tab V-1.6). The AAR was not designed to recover a stalled aircraft. Attempts to recover it was not ideal at the low altitude because it would have lowered the nose of the aircraft in an attempt to gain airspeed and recover the MA, forcing the aircraft into the ground (Tab V-3.12). Instead, the MC pressed the ATO button on the GRDCS control panel in an attempt to increase the afterburners forcing the MA to the 12 degrees above the horizon take-off attitude, and then pressed the AAR button (Tab V-1.5; Tab V-3.12). The MA subsequently entered a stall, pitched down 33 degrees and impacted the ground at 13:23:17Z (Tabs L-1, Attachments 1 through 4; Tab S-8). The entire chain of events lasted approximately 8 seconds (Tabs L-1, Attachments 1 through 4; Tab S-8).

e. Impact

When the MA impacted the runway at 13:23:17Z nose first, it exploded and was destroyed (Tabs L-1, Attachments 1 through 4; Tab S-2 through Tab S-7).

f. Egress and Aircrew Flight Equipment (AFE)

Not applicable.

g. Search and Rescue (SAR)

Not applicable.

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

At the time of the mishap, the MA had accumulated 5,291.7 flight hours (Tab U-2.1).

a. Forms Documentation

Air Force Technical Order (AFTO) 781 series forms, Intermediate Maintenance Data System (IMDS), and Time Compliance Technical Orders (TCTO) document aircraft maintenance and provide a record of inspections, servicing, configuring, status and flight records related to a specific aircraft (Tab U-1.1). There were documentation errors for the removal and replacement of the Backup Automatic Flight Control Computer (BUAFCC), which is the backup computer that commands the unmanned aircraft should the primary fail to work, in both the IMDS and the

AFTO Form 781A; however, there is no evidence that forms documentation discrepancies were a factor in this mishap (Tab U-1.1).

b. Inspections

Phase inspections are scheduled maintenance inspections performed on Air Force aircraft at specific flying hour intervals. The QRF-4C requires a 600-hour phase inspection cycle to inspect the aircraft components and airframe for damage, structural integrity and correct system operations (Tab D-2).

The total operating hours of the dual engines installed on the MA were 676.2 hours for engine one and 1326.6 hours for engine two since the last required 600-hour inspection conducted on 30 November 2011 (Tab D-2). The engines were last installed in the MA on 22 December 2012, and all inspections on the 781A in the AFTO Forms binder were current (Tab D-2; Tab U-1.1).

Technical Order (TO) 1F-4(Q)C-2-96GS-00-1, *Pre-Mission Test Procedures: USAF Series of QF-4E, QF-4G and QRF-4C Aircraft*, Revision No. 3, dated 6 March 2009, directed the Pre-Mission Test (PMT) and alignment and adjustment procedures for the MA otherwise known as a "wiggles" test (Tab U-7.1). The operations tempo and mission requirements of the WSEG program allowed extensive dwell time for the MA not common within other Air Force airframes (Tab V-1.7). However, the MA was started every month and a wiggles test was performed on the MA (Tabs D-1 through Tab D-4; Tab V-1.7). Additionally, a wiggles test was performed on the MA prior to takeoff with no error messages (Tab V-6.1).

c. Maintenance Procedures

A review of the MA's AFTO 781 series forms, IMDS, and TCTO records revealed all maintenance actions on the MA were accomplished with standard approved maintenance procedures and technical orders (Tabs D-2 through D-3; Tab U-1.1).

d. Maintenance Personnel and Supervision

Local maintenance activities for the QRF-C aircraft at Tyndall AFB, FL were performed by Defense System Services (DS2), a contracted maintenance support company supervised by the 53 WEG (Tab V-4.4). Each DS2 maintenance members and technicians were required to complete a "one time" Comprehensive and Performance examination that does not require annual recertification (Tab U-6.2). A review of the NULLO training certifications of all DS2 personnel who conducted any activity on the MA showed they were qualified and proficient in their duties with one exception (Tab U-1.1; Tab U-6.1-6.6). However, there is no evidence that the one non-compliant maintenance member was causal or contributing to the mishap (Tab U-6.3). Additionally, there is no evidence that supervision was a factor in this mishap.

e. Fuel, Hydraulic, and Oil Inspection Analyses

Collection of fuel and oil samples was not possible due to the condition of the MA (Tab S-2 through S-8). However, there is no evidence that fuel, hydraulic, or oil were factors in this mishap.

f. Unscheduled Maintenance

The mishap sortie was the MA's first FSAT NULLO flight after its conversion to a QRF-4C aircraft (Tab D-2; Tab EE-1.3). The most recent unscheduled maintenance performed on the MA was on 15 July 2013 (Tab D-3). A 60-day wiggle PMT was performed and a Drag Chute was removed in accordance with TO 1F4C-2-2CLY that was discovered and corrected by qualified maintenance personnel (Tab U-1.1; Tabs U-6.1 through Tab U-6.6). The 60-day wiggle PMT was inspected by an unqualified DS2 employee; however, there is no evidence that the inspection by the unqualified DS2 employee was contributing or causal to the mishap (Tab U-1.1; Tabs U-6.1 through Tab U-6.6).

Additionally, unscheduled maintenance occurred on different portions of the Automatic Flight Control System (AFCS) (Tab U-1.1). On 2 May 2011, DS2 removed and replaced the Pitch Gyro (Tab U-5.2). On 24 June 2011, DS2 replaced the Automatic Flight Control System (AFCS) Control Amplifier (Tab U-5.2). Both inspections were conducted prior to the MA's last successful flight on 22 December 2012 (D-2). Finally, the AFTO 781A from 10 July 2013 notes the BUAFCC required replacement; however this replacement was not contributing or causal to the accident because the MA was not operating under the BUAFCC at the time of the mishap (Tab DD-1). There is no evidence that unscheduled maintenance procedures were relevant to the mishap.

6. AIRFRAME SYSTEMS

a. Structures and Systems

(1) Gulf Range Drone Control System (GRDCS)

The GRDCS is a ground-based, highly automated computer system operated and maintained by the 46th Range Control Squadron, Eglin AFB, FL, used to track and control unmanned aerial targets in support of weapons testing and evaluation for the U.S. Air Force (Tab BB-12.2). The current version of the GRDCS was used to track and control the MA (Tab BB-12.2). The MC could give commands to the MA in one of two ways: (1) manually, utilizing the GRDCS Operating Console, or (2) by directing the FSAT Automatic Flight Control System (FSAT AFCS) to automatically operate the MA by utilizing a series of pre-determined commands, (Figure 1; Tab BB-3.2; Tabs Z-1.1 through Tab Z-1.10).

Manual commands were transmitted by the MC using a control stick to fly the drone similar to a manned aircraft (Figure 2; Tab Z-1.4).

The MC was responsible for controlling the MA through all phases of flight including the execution of emergency checklist procedures in the event of a malfunction or emergency during FSAT missions; however, the MC was not authorized, by regulation, to manually control the takeoff of the MA during NULLO missions (Tab BB-3.2; Tab BB-3.13). Instead, the GRDCS provided automatic control of the MA through the Drone Formation System (DFS) providing navigation, guidance and control messages addressed to the MA (Tab BB-5.2 through Tab BB-5.3). Remote control of the MA was possible because of drone-peculiar aircraft systems which processed the messages for execution through the FSAT AFCS. (Tab BB-5.3). Messages from the FSAT continuously informed the ground station on the status of the MA (Tab BB-5.3).

Figure 1: GRDCS Operating Console (Tab Z-1.1)

Figure 2: GRDCS Control Stick (Tab Z-1.4)

The MA position, control and performance data were displayed on three controller screens (Figure 3; Tabs Z-1.2 through Tab Z-1.3). The left display showed an overhead view of the drone's position on a map, the attitude director indicator, compass, and various control and performance parameters (Figure 3, Tab Z-1.3).

Figure 3: GRDCS Map Display (Tab Z-1.3)

During ATO, the right display provided information to the MC that replicated what the MC would see if the MC was in the MA cockpit (Figure 4; Tab V-1.8; Tab Z-1.3). Additionally, five boxes at the top of the right screen were used to display both normal and abnormal operating conditions of the unmanned aircraft (Figure 4; Tab Z-1.2 through Tab Z-1.3).

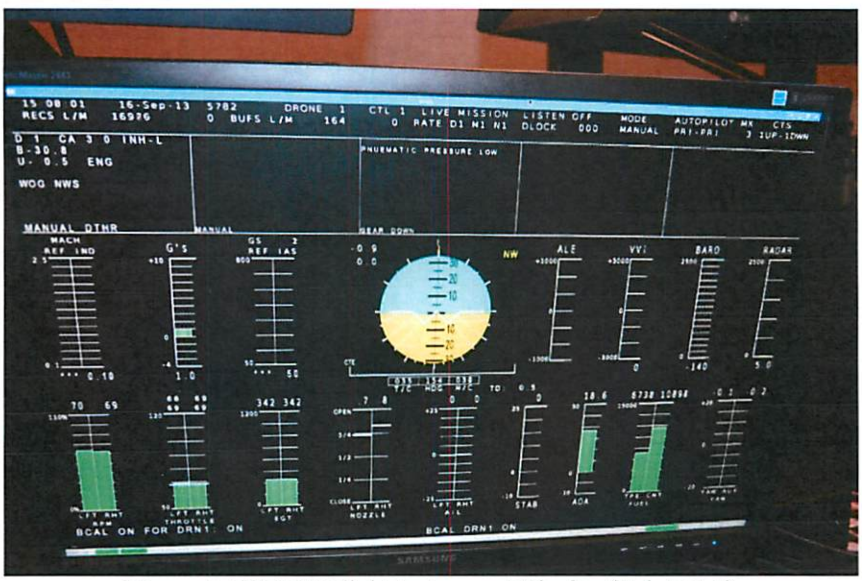

Figure 4: GRDCS Flight Instrument Display (Tab Z-1.3)

Initially, through pre-programmed commands, the GRDCS pushed the throttles to 80% power to start the MA moving (Tab DD-1.2). Once the ATO sequence began, the MA reached a speed sufficient for takeoff at approximately 160 Knots Indicated Air Speed (KIAS) (Tab DD-1.2). After the MA started to lift off the runway, it pitched up to an expected angle of 12 degrees above the horizon to get the MA airborne (Tab DD-1.2). Typically, the MA would have continued at a 12 degrees pitch until it reached approximately 2000 feet AGL (Tab DD-1.2).

(2) Primary Automatic Flight Control Computer (PAFCC) and Back Up Automatic Flight Control Computer (BUAFCC)

The MA had two Automatic Flight Control Computers (AFCC) on board (Tab BB-9.2). The AFCCs are used during remote control flight (Tab-BB 9.2). One is designated as the primary computer (PAFCC) and the other is designated as the backup computer (BUAFCC) (Tab BB-9.2). Through a highly automated computer system using pre-programmed flight commands, these computers commanded and controlled the MA (Tab BB–9.2). The PAFCC served as the brain of the MA during all stages of flight controlling the actions of the unmanned aircraft through a series of commands after receiving and processing information received from multiple components (Tabs L-1, Attachments 1 through 4; Tab S-8. The PAFCC and BUAFCC are the same except the BUAFCC does not operate unless the PAFCC malfunctions (Tab BB–9.2). The PAFCC was in control of the MA during the mishap (Tab DD-1.1). The PAFCC and BUAFCC were intact; however they were not tested (Tab Z-3.1.1; Tab Z-3.1.2).

(3) Stabilator Power Control Cylinder

The MA AFCC provided control inputs to the Stabilator Power Control Cylinder which is commonly known as an all-moving tail, provides longitudinal stability, control and stick requirements usually performed by a horizontal stabilizer (Tab BB–9.2). The Stabilator Power Control Cylinder suffered extensive damage during the mishap. (Tab Z-4.1.1; Z-4.1.2; Z-4.2.3; Z-4.2.4; Z-4.3.5).

(4) Attitude Heading Reference System (AHRS) Units

The MA had two Attitude Heading Reference Systems (AHRS) manufactured by Northrup Grumman (Tab BB–9.2). The AHRS provided heading, pitch, and roll data and rate data to the primary and backup AFCC (Tab BB-9.2; BB-7.3). Both AHRS units were destroyed on impact (Tab FF-1.1). The AHRS provides pitch rate and attitude data, specifically the angle of the plane in the air, to the AFCC (Tab DD-1.3). Once the AFCC receives the pitch rate and attitude data from the AHRS, the AFCC uses that information to provide commands to the aircraft (Tab DD-1.3). Specifically, the commands from the AFCC directed the stabilator to move the aircraft nose up towards the horizon or down towards the ground (Tab DD-1.3).

b. Evaluation and Analysis

The AIB evaluated the following aircraft systems in order to determine the cause of the mishap. An analysis of the MA's data logs and recovered hardware determined the following:

(1) Analysis of GRDCS

A detailed review of the GRDCS data was conducted for the MA, and the information as compared to the GRDCS data for the first unmanned aircraft that took off without incident (Tab DD-1.1). An analysis of the GRDCS data showed that the information transmitted and received by the GRDCS directly correlated with the actions of the MA (Tab DD-1.4).

The GRDCS program identified oscillations in the aircraft during the MA's takeoff role as demonstrated in Figure 5 (Tab DD-1.2).

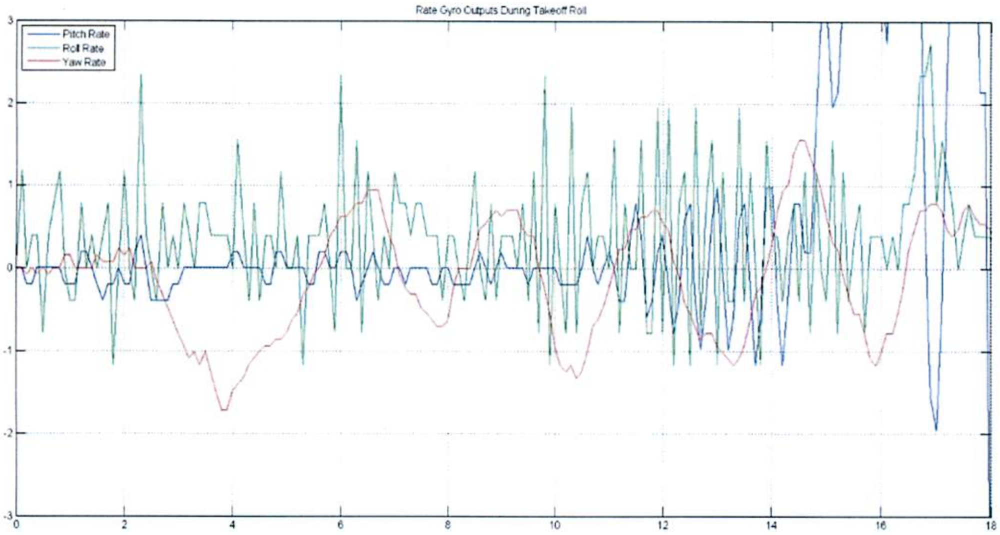

Figure 5: Oscillations of the MA during Takeoff Roll Downloaded by the GRDCS (Tab DD-1.7)

Additionally, these oscillations were not present during the takeoff role of the first unmanned aircraft that successfully launched shown in Figure 6 (Tab DD-1.2).

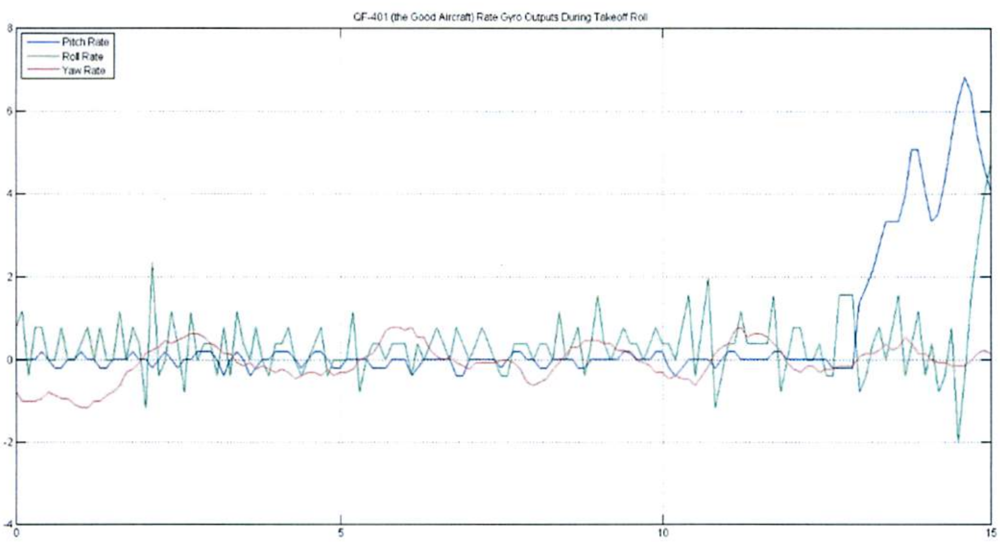

Figure 6: Oscillations of Drone 1 during Takeoff Roll Downloaded by the GRDCS (Tab JJ-1.12)

Further analysis demonstrates the GRDCS was not a factor in this mishap. Specifically, after the "BRAKES OFF" command on the MA, the GRDCS sensed a "BAD HEADING GYRO" meaning the aircraft was not steering down the center of the runway properly (Tab DD-1.2). However, the GRDCS correctly switched the MA to a backup system that corrected the path of the MA on the runway (Tab DD-1.2). At the appropriate time in the takeoff roll, the MC pushed the ATO button on the ground-operating console required for takeoff of the MA (Tab DD-1.2). The GRDCS subsequently received the command, entered ATO mode, and increased the power on the MA for takeoff (Tab DD-1.2). As the MA continued down the runway the AFCS did not receive any pitch commands from the GRDCS that would provide the GRDCS the opportunity to provide an erroneous command (Tab DD-1.4). However, the GRDCS program did identify the AFCS received data from the AHRS and the Stabilator Power Control Cylinder, and generated a pitch command from the data received by the components to the MA (Tab DD-1.4).

(2) Analysis of the PAFCC and BAFCC

A detailed review of the PAFCC data that was downlinked to the GRDCS was conducted (Tab DD-1). The BAFCC was not evaluated as the MA was operating only under the PAFCC at the time of the mishap (Tab DD-1). The PAFCC served as the brain of the MA during all stages of flight, controlling the actions of the unmanned aircraft through a series of commands after receiving and processing information received from multiple components. Specifically, the AHRS provides pitch information to the PAFCC which subsequently provides commands to the Stabilator Power Control Cylinder, also known as the Stabilator Electric-Hydraulic (EH) actuator (Tab DD-1.10). The PAFCC relies on the pitch information provided by the AHRS to appropriately command the Stabilator Power Control Cynlider to extend or retract the stabilator control shaft, or move the aircraft up and down (Tab DD-1.3). This cycle is known as the "Pitch Attitude Control Loop" (Tab DD-1.3).

As demonstrated in Figure 7, the GRDCS data indicates the PAFCC computed and outputted the Stabilator EH commands correctly based on the inputs to the AHRS (Tab DD-1.5).

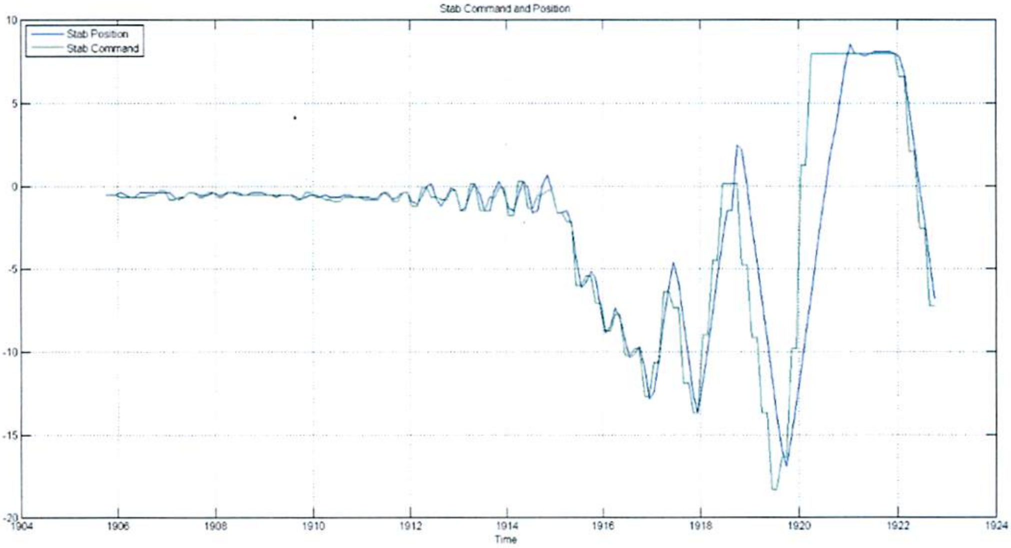

Figure 7: GRDCS Tracking of MA PAFCC Stabilator Electro-Hydraulic (EH) Command and Position (Tab DD-1.10)

Based on this analysis, there is no evidence to indicate that the PAFCC or BAFCC were factors in this mishap.

(3) Analysis of the Stabilator Power Control Cylinder

An analysis was conducted on the Stabilator Power Control Cylinder by the United States Air Force Materiel Command (AFMC) (Tab DD-2.3). The evaluation tested the following components and determined the following:

(a) Auxiliary Ram

The auxiliary ram is housed inside the primary cylinder which was melted through as a result of the MA impacting the ground and catching on fire (Tab Z-4.1 through Tab Z-4.3; Tab DD-2.4). The rod was deformed due to the high temperatures it was exposed to (Tab Z-4.1 through Tab Z-4.3; Tab DD-2.4). Every seal in the assembly was non-existent due to the heat of the fire following the crash (Tab Z-4.1 through Tab Z-4.3; Tab DD-2.4). Therefore, it was impossible to estimate the hydraulic seal integrity before the mishap occurred (Tab Z-4.1 through Tab Z-4.3; Tab DD-2.4).

(b) Servo Flapper Valve

The servo was not included in the part remains; therefore the flapper valve was unable to be evaluated (Tab DD-2.4). However, the damage to the power control cylinder and attached manifold was so extensive, the evaluators determined it was doubtful the testing of the valve would be feasible (Tab DD-2.4).

(c) Main Ram and Auxiliary Ram Feedbacks

The potentiometer/transducer was still intact inside the tandem ram rod (Tab Z-4.1 through Tab Z-4.3; Tab DD-2.4). However, the functionality of the part was compromised by the fire (Tab Z-4.1 through Tab Z-4.3; Tab DD-2.4). All internal wiring was destroyed making testing impossible (Tab Z-4.1 through Tab Z-4.3; Tab DD-2.4).

(d) Additional Findings

Research indicated the Stabilator Power Control Cylinder's rod end involved in the MA was completely intact, and was not a factor in this mishap (Tab DD-2.5). The post-crash position of the cylinder (and therefore the stabilator position) was determined based upon the positioning of the piston rod within the cylinder assembly (Tab DD-2.5). The analysis conducted by AFMC found no evidence that would suggest that the Stabilator Power Control Cylinder failed prior to crash (Tab DD-2.9). The positioning of the Stabilator Power Control Cylinder on the MA is characteristic of a normal takeoff (Tab DD-2.9). Therefore, there is no evidence to suggest the Stabilator Power Control Cylinder was a factor in this mishap (Tab DD-1.5; Tab DD-2.9).

(4) Analysis of the AHRS Units

The primary and backup AHRS units were destroyed in the mishap and unable to be tested (Tab S-1 through S-10; Tab FF-1.1). However, an analysis of GRDCS data in Figures 8 and 9 demonstrates the proper pitch attitude of the aircraft was sent to the AFCC and downlinked to GRDCS so the software internal to the AHRS was operational during the mishap. (Tab DD-1.5).

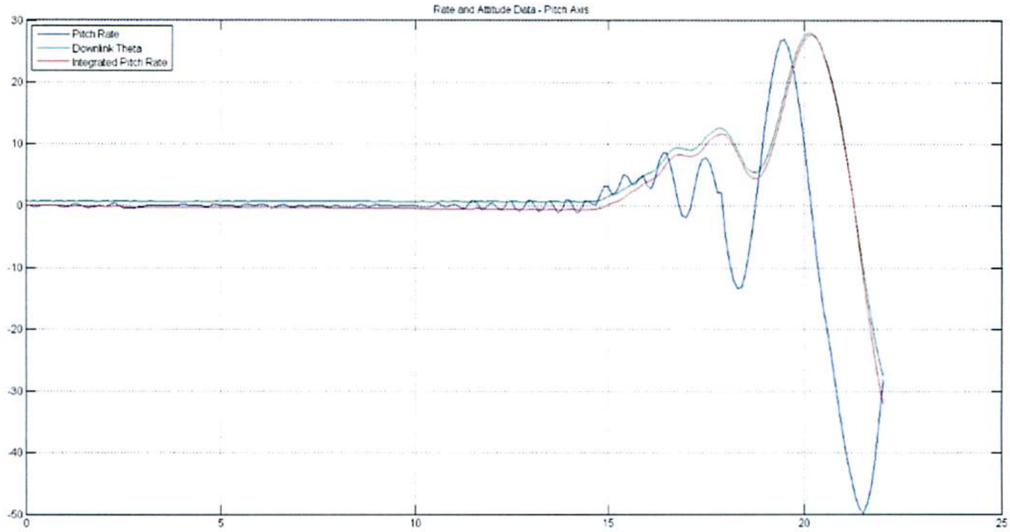

Figure 8: MA Pitch Rate and Attitude Data (Tab JJ-1.8)

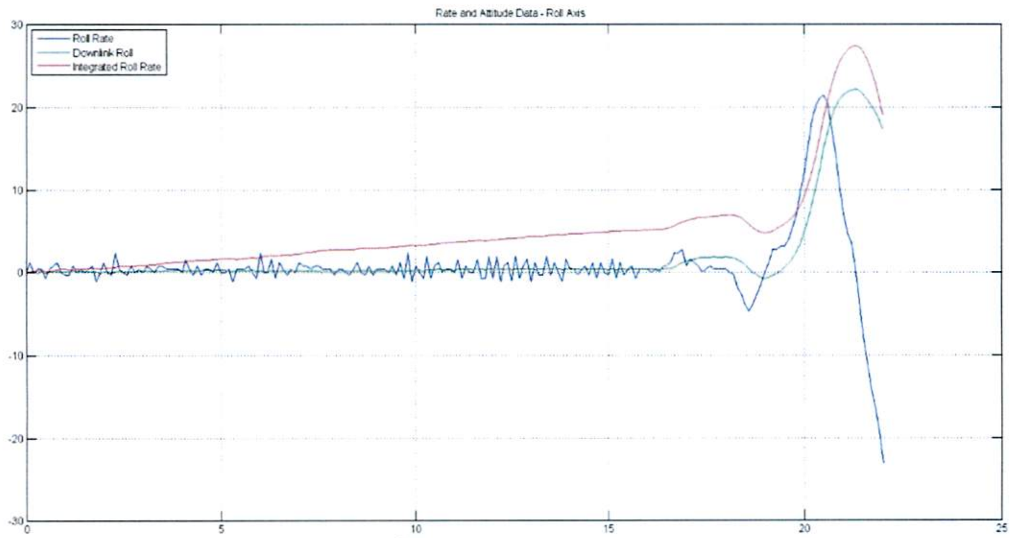

Figure 9: MA Roll Rate and Attitude Data (Tab JJ-1.8)

The rate feedback system can appear to be working normally but lacks the bandwidth necessary to provide stability in an attitude control system (Tab DD-1.6). Generally speaking, this means that the AHRS system may appear to be operating correctly based on normal observation even when the system itself is not receiving enough power to appropriately process the information it is responsible for receiving and sending to the AFSC (Tab DD-1.6). This degradation can cause the AHRS to receive and send incorrect pitch attitude to the AFSC and cause an inappropriate response from the AFSC when controlling the aircraft (Tab DD-1.6).

The stabilator command is comprised of two feedbacks and a command (Tab DD-3.1). The basic structure is shown in Figure 10. The AFCC commands came from the summation of controller uplink commands and AFCC auto sequence commands (Tab DD-3.1). In this particular case, the uplink command was 0.0 and the ATO auto sequence command was 12 degrees (Tab DD-3.1).

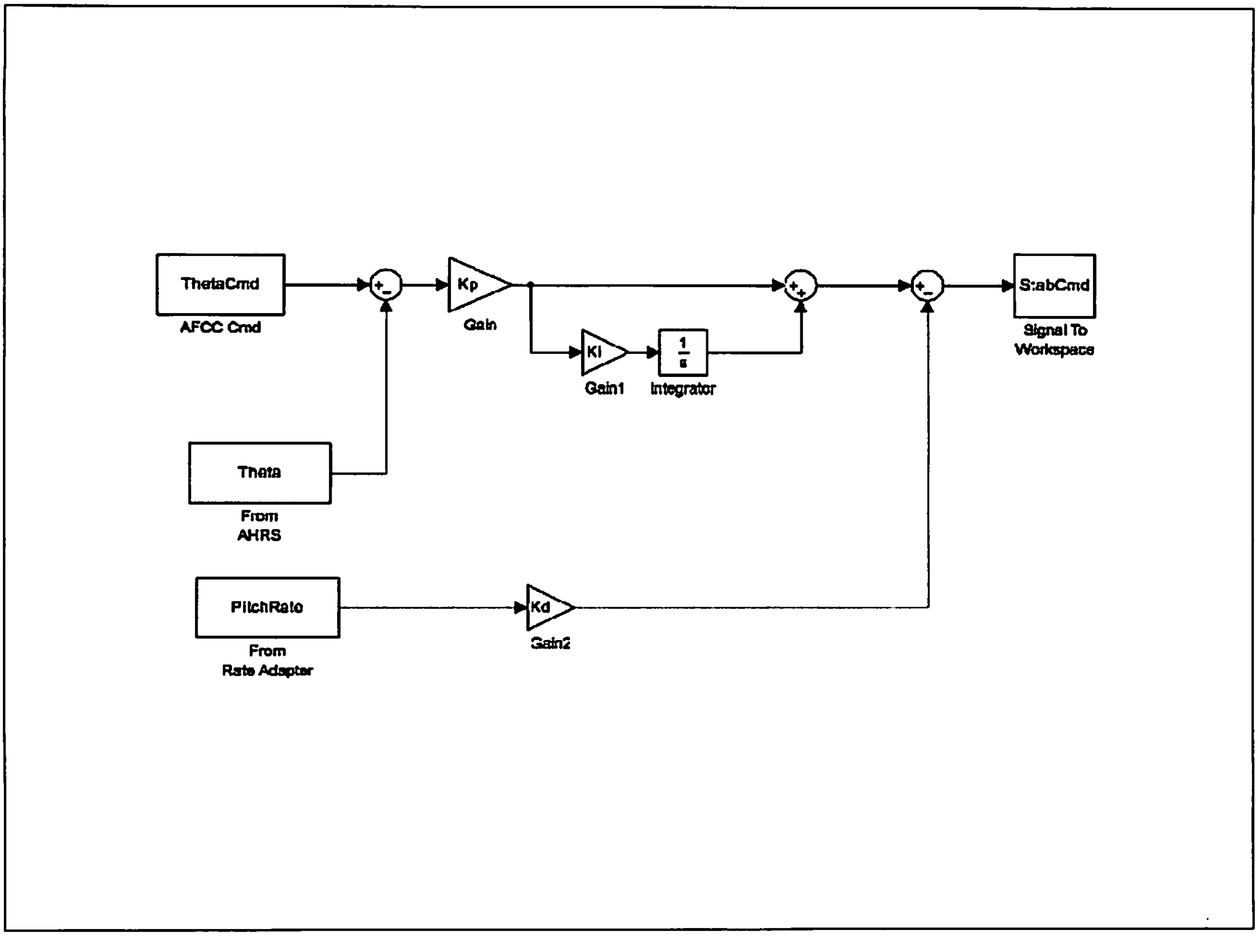

Figure 10: Stabilator Command Basic Structure (Tab JJ-3.1)

The Theta feedback is the pitch attitude feedback from the AHRS, and the Pitch Rate feedback is the AHRS pitch rate fed thru the rate adapter and then into the AFCC (Tab DD-3.2). The pitch attitude (Theta) was, in this case, simply the integral of the rate (Tab DD-3.2). The pitch attitude and the integral of the pitch attitude agree, which confirms that the software in the AHRS unit was operating correctly (Tab DD-3.2). The true pitch attitude is unknown; however, the video of the mishap demonstrates what the pitch attitude "should" be (Tab DD-3.2). In this case, the downlink data shows the MA lifted correctly to the 12 degree mark, then suddenly pitched down, then violently pitched up past the 12 degree mark, then pitched down just prior to impact, similar to the actions of the MA in the accident video recording (Tab DD-3.2. Therefore, the evaluated pitch attitude collected from the GRDCS coincides with the video feedback of the mishap (Tab DD-3.2).

In the takeoff mode of the QRF-4C, the basic loop structure of the pitch attitude control loop has a bandwidth of about 1.0 Hertz (Tab DD-3.2). Therefore, in normal operating conditions the sensors in this aircraft system have very high bandwidth compared to the control loop they are used in (Tab DD-3.2). The AHRS bandwidth should be in the 10 Hz or better range if operating correctly (Tab DD-3.2). If a sensor "loses" some of its bandwidth, the loop is destabilized (Tab DD-3.2). Since the AHRS did not fail completely, the AFCC did not subsequently fail (Tab DD-3.2). Therefore, the fact that the aircraft went unstable indicates that somewhere in the AHRS system, bandwidth was lost causing the loop to become unstable (Tab DD-3.2).

7. WEATHER

a. Forecast Weather

X-RAY 1 obtained the weather from the 325th Wing weather flight, which contained observed and predicted winds, sky conditions, and sea states (Tabs F-1 through F-4; Tab V-3.10). The Terminal Area Forecast and the weather observations were also obtained from the National Oceanographic and Atmospheric Administration internet site and the Aviation Digital Data Service site (Tab F-4; Tab K-1.4; Tab V-3.10; Tab BB-10.1). The following was the forecasted weather for Tyndall AFB on 17 July 2013 at 13:22 Z: winds 080 degrees at 7 knots; temperature 26 degrees Celsius; altimeter setting 3021; no icing, turbulence, or windshear; and 10 nautical miles visibility, sky clear (Tab F-4).

b. Observed Weather

The actual weather was as forecasted (Tabs F-6 through F-8; Tab V-3.10). The following was the actual observed weather for Tyndall AFB on 17 July 2013 at 13:22 Z: winds 098 degrees at 7 knots; temperature 27 degrees Celsius; altimeter setting 3023; no icing, turbulence, or windshear; 12 nautical miles visibility, sky clear (Tab F-6).

c. Operations

Operational systems were conducted within their prescribed operational weather limitation. There is no evidence to suggest weather was a factor in this mishap.

8. CREW QUALIFICATIONS

a. Mishap Controller (MC)

(1) Training

The MC was qualified in the QF-4 as a pilot since 27 June 2011 (Tab G-48). The MC's training record was reviewed and there were no discrepancies noted (Tab G-48). Additionally, a review of the certificate of aircrew qualification, individual training summary, and 30/60/90 flying report were completed with no discrepancies noted (Tab G-48).

(2) Experience

At the time of the mishap, the MC was current, qualified and had a total flight time of 417.7 hours as a QF-4 pilot (Tab G-3). The MC's flight time for the 30, 60, 90 days prior to the mishap were as follows (Tab G-4):

	Hours	Sorties
Last 30 Days	9.5	7
Last 60 Days	19.2	15
Last 90 Days	35.8	32

b. Mishap Mission Coordinator (MMC)

(1) Training

The MMC was qualified in the QF-4 as a pilot since 31 January 2013 (Tab G-51). The MMC's training record was reviewed and there were no discrepancies noted. Additionally, a review of the certificate of aircrew qualification, individual training summary, and 30/60/90 flying report were completed with no discrepancies noted (Tab G-51).

(2) Experience

At the time of the mishap, the MMC was current, qualified, and had a total of 74.6 hours as a QF-4 pilot (Tab G-20). The MMC's flight time for the 30, 60, 90 days prior to the mishap were as follows (Tab G-21):

	Hours	Sorties
Last 30 Days	6.1	5
Last 60 Days	12.1	9
Last 90 Days	19.2	15

c. Mobile Drone Console Operator (MDCO)

(1) Training

The MDCO was qualified in the QF-4 as a pilot since 23 January 2006 (Tab G-56). The MDCO's training record was reviewed and there were no discrepancies noted (Tab G-56). Additionally, a review of the certificate of aircrew qualification, individual training summary, and 30/60/90 flying report were completed with no discrepancies noted (Tab G-56).

(2) Experience

At the time of the mishap, the MDCO was current, qualified, and had a total of 338.6 hours as a QF-4 pilot (Tab G-32). The MDCO's flight time for the 30, 60, 90 days prior to the mishap were as follows (Tab G-41 through Tab G-43):

	Hours	Sorties

Last 30 Days	11.2	11
Last 60 Days	22.4	20
Last 90 Days	40.2	33

9. MEDICAL

a. Qualifications

At the time of the mishap, the MC, MMC and MDCO were medically qualified for flight duty (Tab T-1.1).

b. Health

The MC, MMC and MDCO's medical records were reviewed by a qualified flight surgeon (Tab T-1.1; Tab Y-1.1). The MC, MMC and MDCO's Federal Aviation Administration Medical Certifications were current (Tab T-1.1). Further, the MC, MMC and MDCO did not have health issues or concerns on the day of the mishap and 14 days prior to the mishap (Tab V-1.12; Tab V-2.8; Tab V-6.2).

c. Pathology

Toxicology testing was ordered for the MC, MMC and MDCO immediately following the mishap (Tab T-1.1). Urine samples were submitted to the Armed Forces Medical Examiner System for analysis (Tab T-1.1). No prohibited substances were detected (Tab T-1.1).

d. Lifestyle

There is no evidence that unusual habits, behavior, or stress on the part of the MC, MMC or MDCO contributed to this mishap. (Tab R-8 through Tab R-20; Tab T-1.1).

e. Crew Rest and Crew Duty Time

All aircrew are required to have proper crew rest prior to performing flying duties as outlined in AFI 11-202, Volume 3, paragraphs 9.4.5 and 9.8. Proper crew rest is defined as a minimum of a 12-hour non-duty period before the designated flight duty period begins. During this time, an aircrew member may participate in meals, transportation, or rest as long as he or she has had at least 10 hours of continuous restful activity with an opportunity for at least 8 hours of uninterrupted sleep. The MC, MMC and MDCO demonstrated no issues with receiving the proper crew rest prior to performing flying duties (Tab V-1.4; V-2.3; V-2.9, V-6.2). Additionally, the mishap occurred within the first few hours of the MC, MMC, and MDCO's duty time (V-1.3; V-2.3; V-2.9, V-6.2). There is no evidence that crew rest or duty time were factors in this mishap.

10. OPERATIONS AND SUPERVISION

a. Operations

The MC flew sorties the two days prior to the mishap on 15 July 2013, for 1.4 hours and 16 July 2013, for 1.3 hours (Tabs R-10 through R-11). However, there is no indication the MC's operational tempo was a factor in this mishap. The MMC flew sorties the two days prior to the mishap on 15 July 2013, for 1.2 hours and 16 July 2013, for 1.3 hours (Tabs R-16 through R-17). While the MMC indicated his work performance had changed in the weeks preceding the mishap due to civilian furloughs, the MMC stated he did not feel stressed about the changes (Tab R-19). Therefore, there is no indication the MMC's operational tempo was a factor in the mishap.

b. Supervision

The briefing for the mission, conducted in two segments, was IAW AFI 11-2F/QF-4, Volume 3, F/QF-4 Operations and Procedures, 1 July 2000, Chapter 2; 82 ATRS Operating Instruction (OI) 11-5; Flying Operations, 9 January 2006; and 82 ATRS Standards, September 2012, Paragraph 4 (Tab V-3.8; Tab BB-3). The DMC attended and properly supervised mission planning and execution prior to the mishap (Tab K; Tab V-3.3). There is no indication that supervision was a factor in this mishap.

11. HUMAN FACTORS

There was no evidence that human factors were causal to the mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010
(2) AFI 91-204, *Safety Investigations and Reports*, 24 September 2008
(3) AFI 11-2F/QF-4, Volume 3, *F/QF-4 Operations and Procedures*, 1 July 2000

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

b. Other Directives and Publications Relevant to the Mishap

(1) T.O. 1F-4(Q) E-1, *USAF Series QF-4E and QRF-4C Aircraft*, June 2011 (Releasable portions are included in Tab BB of this report. The full T.O. is not releasable due to the Arms Export Control Act, 22 U.S.C. 2778);
(2) *System Schematics of the QF-4 Full Scale Aerial Target Program*, 19 December 2011 (Releasable portions are included in Tab BB of this report. The full T.O. is not releasable due to the Arms Export Control Act, 22 U.S.C. 2778);
(3) T.O. 1F-4(Q)C-2-00GV-00-1, *General Vehicle Description-USAF Series QF-E and QRF-4C Aircraft*, 1 July 2004 (Releasable portions are included in Tab BB of this

report. The full T.O. is not releasable due to the Arms Export Control Act, 22 U.S.C. 2778);

(4) *GRDCS System Software User's Guide*, 10 January 2013 (Releasable portions are included in Tab BB of this report. The full T.O. is not releasable due to the Arms Export Control Act, 22 U.S.C. 2778);

c. Known or Suspected Deviations from Directives or Publications

No additional suspected deviations from directives or publications.

13. ADDITIONAL AREAS OF CONCERN

The operations tempo and mission requirements of the WSEG program allowed the MA to remain on the ground unflown for an extensive amount of time which is uncommon for other Air Force aircraft. (Tab V-1.7). Despite the dwell time, the MA was started every month and a wiggles test was performed on the MA (Tabs D-1 through Tab D-4; Tab V-1.7). Additionally, a wiggles test was performed on the MA prior to takeoff with no error messages (Tab V-6.1). However, the rate feedback system can appear to be working normally but lacks the bandwidth necessary to provide stability in an attitude control system (Tab DD-1.6). Generally speaking, this means that the AHRS system may appear to be operating correctly based on normal observation even when the system itself is not receiving enough power to appropriately process the information it is responsible for receiving and sending to the AFSC (Tab DD-1.6). If the AHRS had been removed from the MA during the MA's dwell time and placed in climate control storage, the bandwidth degradation may have been avoided.

9 January 2014

GARDNER J. JOYNER, Lt Col, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

AIRCRAFT ACCIDENT INVESTIGATION
QRF-4C, T/N 69-0384, TYNDALL AIR FORCE BASE, FLORIDA
17 JULY 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

On 17 July 2013, at approximately 13:23 Zulu (Z) time, a QRF-4C Phantom II unmanned aircraft, tail number (T/N) 69-0384, operating in autopilot, impacted the ground on the south end of Runway 18 at Tyndall Air Force Base (AFB), Florida (FL), approximately 8 seconds after takeoff. The mishap aircraft (MA) was assigned to the 82d Aerial Targets Squadron (82 ATRS), 53d Weapons Evaluation Group (53 WEG), 53d Wing, Tyndall AFB, FL. The MA, an infrared flare-dispensing pod (Mongoose 4 Pod), and 120 flares were destroyed on impact. The drone runway and its barrier also incurred significant damage and required repair. The total damage to United States (U.S.) Government property was assessed to be $4,564,536.00. There were no injuries or damage to other government or to civilian property sustained as a result of the mishap.

The Accident Investigation Board (AIB) President found, by clear and convincing evidence, that the cause of this mishap was a defective pitch rate portion of the Attitude Heading Reference System (AHRS), otherwise known as the aircraft system that controls the up and down movement of the MA. The AHRS was responsible for the movement of the MA in all three axes—which include pitch, roll and yaw. The defective AHRS was destroyed in the crash; however, the AIB was able to determine, using the date from the Gulf Range Drone Control Station (GRDCS) that the AHRS sent erroneous inputs on the horizontal pitch of the MA to the Primary Automatic Flight Control Computer (PAFCC). These erroneous inputs caused the MA to pitch up and down rapidly while entering a 28 degrees above the horizon attitude. This exceeded the stall threshold and subsequently pitched the MA down 33 degrees, causing the MA to impact the ground.

After reviewing and considering all the evidence, I find by clear and convincing evidence, that the cause of the mishap was a defective pitch rate portion of the AHRS.

2. DISCUSSION OF OPINION

There were only three components that could have caused the MA to malfunction in the manner it did. Those components were the AHRS, the PAFCC, and the horizontal stabilator, all of which work together. Both the PAFCC and the horizontal stabilator were recovered in the wreckage. The horizontal stabilator was sent for technical analysis. After reviewing the evidence, specifically the GRDCS data, I concluded the PAFCC was not causal—it was thus not sent for further testing. However, I reviewed the analysis of the horizontal stabilator, along with the GRDCS reports and analysis, to conclude that both the PAFCC and the horizontal stabilator were working in accordance with the technical order at the time of the mishap. Therefore, even though the AHRS units were destroyed in the mishap and were unable to be tested, I concluded that the AHRS unit was the only piece of equipment that could have caused this mishap. Specifically, the pitch loop operation of the AHRS was unstable due to a lack of bandwidth.

I arrived at my conclusion by examining the technical reports and analysis from the horizontal stabilator, and the GRDCS data. I also used witness testimony, technical orders, and input from subject matter experts. Specifically, an analysis of the GRDCS data demonstrated that the information transmitted and received by the GRDCS correlated directly with the actions of the MA. Additionally, the GRDCS data indicated the PAFCC computed and outputted the Stabilator Electro-Hydraulic commands correctly based on the inputs to the Automatic Flight Control Computer (AFCC) Pitch Attitude Control Loop, more specifically the AHRS. Therefore, there is no evidence that the PAFCC or Backup AFCC were factors in this mishap. Finally, the positioning of the Stabilator Power Control Cylinder on the MA was characteristic of a normal takeoff.

Therefore, the remaining evidence is consistent with the finding that the defective AHRS unit gave erroneous inputs to the horizontal stabilator, via the PAFCC, causing the MA to pitch up and down rapidly. The AHRS bandwidth should have been in the 10 Hz or better range if operating correctly. The fact that the aircraft went unstable indicates that somewhere in the AHRS system, bandwidth was lost causing the pitch control loop to become unstable. In an attempt to respond to the erroneous inputs, the autopilot caused the MA to enter a 28-degree nose high attitude which exceeded the stall threshold. Because of the low altitude of the MA, there was insufficient altitude to recover from the stalled condition, and the MA impacted the drone runway approximately 8 seconds after takeoff.

Finally, I find there were no human factors that were causal to the mishap. The GRDCS is a ground-based, highly automated computer system. While the Mission Crew (MC) was responsible for controlling the MA through all phases of flight, the MC was not authorized to manually control the takeoff of the MA after brakes release. However, the MC reasonably and diligently identified the pitch changes in the aircraft and responded appropriately by executing the emergency checklist procedures in an attempt to recover the MA.

3. CONCLUSION

I find by clear and convincing evidence that the cause of the mishap was a defective pitch rate portion of the AHRS.

9 January 2014

GARDNER J. JOYNER, Lt Col, USAF
President, Accident Investigation Board

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