UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

QRF-4C, T/N 65-0845

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

LOCATION: 16 Nautical Miles South of Tyndall Air Force Base, FL

DATE OF ACCIDENT: 13 MAY 2011

BOARD PRESIDENT: LIEUTENANT COLONEL DAVID W. ABBA

Conducted in accordance with Air Force Instruction 51-503
Abbreviated Accident Investigation pursuant to Chapter 11

EXECUTIVE SUMMARY

ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION
QRF-4C, T/N 65-0845, TYNDALL AIR FORCE BASE, FLORIDA
13 MAY 2011

On 13 May 2011, at 1751 Zulu (Z) time, the Mishap Drone (MD), a QRF-4C full-scale aerial target, tail number T/N 65-0845, drone designation AF-358, departed controlled flight and impacted the water approximately 16 nautical miles (nm) south of Tyndall Air Force Base, Florida. The MD was an asset of the 82d Aerial Targets Squadron, 53d Weapons Evaluation Group, Tyndall AFB, FL. There were no injuries, deaths, or reported non-government property damage as a result of the crash. The MD was destroyed with its loss valued at $2,801,574.00.

The MD launched from Tyndall AFB at 1748Z to support a Weapons System Evaluation Program (WSEP) live fire mission. Shortly after take-off the MD experienced a BUS TIE OPEN electrical malfunction. After leveling off at 8,000 feet Mean Sea Level (MSL), the mishap controller (MC) cycled the MD's left generator. The MD experienced flight control transients in the pitch, roll, and yaw axes resulting in a nearly inverted unusual attitude. Cycling the left generator also caused an uncommanded Automatic Flight Control System (AFCS) switch from primary to backup. The split AFCS condition resulted in the MD only responding to Backup Automatic Flight Control System (BUAFCS) commands. Several other unusual failure indications including landing gear unsafe and arresting hook down were present.

The MC selected wings level (WL) and then All-Attitude Recovery (AAR) in an attempt to recover the MD to level flight. Once AAR was commanded, the MD began an increasing G pull, peaking at 4.8Gs, while rolling right towards a wings-level attitude. This resulted in rapidly decaying airspeed and increasing angle of attack (AoA). At 17:50:48, the MD experienced an accelerated stall and departure from controlled flight. From that point until water impact, the MD remained fully stalled at 29-30 units AoA. The MD experienced several post-stall gyrations including severe wing rock and four turn direction reversals.

The Accident Investigation Board (AIB) President determined, by clear and convincing evidence, the cause of the mishap was a power disruption in the MD's alternating current (AC) electrical power system which caused both Automatic Flight Control Computers (AFCCs) to restart in flight. The AIB President found, by a preponderance of evidence, that the MD's response to the AAR command was a substantially contributing factor to the mishap. The lack of AoA limiting in BUAFCS, aggravated by additional drag from the MD's landing gear, caused an accelerated stall which led to the MD's departure from controlled flight.

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

ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION
QRF-4C, T/N 65-0845, TYNDALL AIR FORCE BASE, FLORIDA
13 MAY 2011

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COMMONLY USED ACRONYMS AND ABBREVIATIONS

ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION
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13 MAY 2011

AAIB	Abbreviated Accident Investigation Board
AAR	All-Attitude Recovery
AC	Alternating Current
ACC	Air Combat Command
ACSG	Aircraft Sustainment Group
ACSS	Aircraft Sustainment Squadron
ADI	Attitude Director Indicator
AF	Air Force
AFB	Air Force Base
AFCC	Automatic Flight Control Computer
AFCS	Automatic Flight Control System
AFI	Air Force Instruction
AFMAN	Air Force Manual
AFMC	Air Force Material Command
AFSAS	Air Force Safety Automated System
AFTO	Air Force Technical Order
AGE	Aerospace Ground Equipment
AHRS	Attitude Heading Reference System
AIB	Accident Investigation Board
AMARC	Aerospace Maintenance and Regeneration Center
AMIC	Aircraft Mishap Investigation Course
AMXS	Aircraft Maintenance Squadron
AoA	Angle of Attack
ATO	Automatic Takeoff
ATRS	Aerial Targets Squadron
BAE	British Aerospace
BUAFCS	Backup Automatic Flight Control System
C	Controller
CAMS	Core Automated Maintenance System
CG	Center of Gravity
CIV	Civilian
COMACC	Commander of Air Combat Command
CTK	Composite Tool Kit
CTS	Command Telemetry System
C/W	Complied With
DC	Deputy Commander
Det	Detachment
DFS	Drone Formation System
DIC	Discrete Commands
DITS	Discrete Telemetry Signals
DoD	Department of Defense
DPE	Drone Peculiar Equipment
DS2	Defense System Services
DSTABS	Table of Discretes
DSN	Defense Switching Network
EH	Electro-Hydraulic
ECM	Electronic Countermeasures
EM	Electro-Mechanical
FAE	Functional Area Expert
FCF	Functional Check Flight
FCS	Fixed Control Station
FL	Florida
FOIA	Freedom of Information Act
FLCB	Frequency and Load Control Box
FSAT	Full Scale Aerial Target
FTS	Flight Termination System
FWS	Fighter Weapons Squadron
G	Gravitational Force
GCI	Ground Control Intercept
GMCS	GRDCS Mobile Control Station
GRDCS	Ground Range Drone Control Station
HPO	Hourly Post-Flight
HQ	Headquarters
IMDS	Integrated Maintenance Documentation System
Kt	Knot
KIAS	Knots Indicated Airspeed
L	Local Time
LOS	Loss of Carrier
LSO	Lateral Stick Out
Mach	Speed of Sound
MC	Mishap Controller
MCC	Mission Control Center
MCO	Master Console Operator
MCS	Mobile Control Station
MD	Mishap Drone
MMC	Mission Coordinator
MSL	Mean Sea Level
msec	millisecond
NAD	No Air Data
nm	Nautical Mile
NM	New Mexico
NULLO	Not Under Live Local Operator
OI	Operating Instruction
OO-ALC	Ogden Air Logistics Center
ORM	Operational Risk Management
PAFCS	Primary Automatic Flight Control System
POR	Power On Reset
PSO	Pitch Stick Out
QA	Quality Assurance
R&R	Removed and Replaced
RCF	Range Control Facility
RDO	Range Destruct Officer
RPM	Revolutions per Minute
RTB	Return to Base

SA	Situational Awareness
SAFE	Systems Acceptance Flight Evaluation
SHOT	Speed Hold on Throttle
SIB	Safety Investigation Board
S/N	Serial Number
SSAT	Small Scale Aerial Target
Stab	Stabilator
SPO	Systems Program Office
TCI	Time Change Item
TCTO	Time Compliance Technical Order
TDY	Temporary Duty
TO	Technical Order
TM	Telemetry
T/N	Tail Number
T/R	Transformer/Rectifier
TRG	Training Group
TSD	Trade Corps Systems Division (now BAE)
TVI	Transponder Vehicle Interface
UHF	Ultra High Frequency
USAF	United States Air Force
USAFWC	United States Air Force Warfare Center
U.S.C.	United States Code
VDOPS	Vector Doppler Scoring
WD	Wire Diagram
WEG	Weapons Evaluation Group
WG	Wing
WL	Wings Level
WPS	Weapons Squadron
WSEP	Weapon System Evaluation Program
Z	Zulu or Greenwich Mean Time

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

SUMMARY OF FACTS

ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION
QRF-4C, T/N 65-0845, TYNDALL AIR FORCE BASE, FLORIDA
13 MAY 2011

1. AUTHORITY AND PURPOSE

a. Authority

On 27 June 2011, Lieutenant General William J. Rew, Vice Commander, Air Combat Command (ACC), United States Air Force (USAF), convened an Abbreviated Accident Investigation Board (AAIB) pursuant to Chapter 11 of Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*, to investigate the 13 May 2011 crash of a QRF-4C aircraft, tail number (T/N) 65-0845, near Tyndall Air Force Base (AFB), Florida (FL) (Tab Y-3). The following USAF personnel served on the AIB:

Lieutenant Colonel David W. Abba	Board President
Captain (Redacted)	Legal Advisor
Staff Sergeant (Redacted)	Recorder
Mr. (Redacted)	Engineer Functional Area Expert (FAE)
Master Sergeant (Redacted)	Maintenance FAE

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 13 May 2011, at 1751 Zulu time (Z), a QRF-4C full-scale aerial target, T/N 65-0845, drone designation AF-358, hereinafter referred to as the Mishap Drone (MD), departed controlled flight and impacted the water approximately 16 nautical miles (nm) south of Tyndall AFB, FL (Tab K1; Tab M-3; M-5). The MD was an asset of the 82d Aerial Targets Squadron (82 ATRS), 53d Weapons Evaluation Group (53 WEG), Tyndall AFB, FL. At the time of the mishap, the MD was en route to the W-151 overwater airspace to support a Weapons System Evaluation Program (WSEP) live fire mission (Tab K1). Shortly after take-off, the MD experienced an electrical malfunction (Tab M3, Attachment M-1). The mishap controller (MC) climbed the aircraft to 8,000 feet Mean Sea Level (MSL) and then accomplished required checklist steps in an attempt to clear the malfunction (Tab M3, Attachment M-1; Tab N-3; Tab V-1.1; V-3.1–V-5.1; Tab BB-7). After the MD's left generator was cycled off, then on, the MD entered an unusual attitude (Tab M3, Attachment M-1; Tab R-3–R-6; R-9–R-10; R-21–R-22; Tab V-1.1; V-4.1; V-5.1). Attempts to recover the MD to level flight were unsuccessful and the MD eventually departed controlled flight (Tab M3, Attachment M-1). The MD experienced several post-stall gyrations

before impacting the water clear of any surface traffic (Tab M3, Attachment M-1; Tab R-6). The MD was destroyed with its loss valued at $2,801,574.00 (Tab P-3, Attachment P-1).

3. BACKGROUND

The MD was an asset of the 82 ATRS, 53 WEG, 53d Wing (53 WG), USAF Warfare Center, ACC, Tyndall AFB, FL (Tab A-4; Tab D2, Attachment D-1).

a. Air Combat Command

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

b. United States Air Force Warfare Center

The USAF Warfare Center exists to provide well-trained and well-equipped combat forces ready to deploy into a combat arena to conduct integrated combat operations. From training schools and venues to testing and tactics development programs, USAF Warfare Center provides a means to equip the force with superb academic training, proven technology, the most current tactics, and a unique opportunity to practice integrated force employment. The USAF Warfare Center mission statement and specified tasks are central to fulfilling our role in supporting the U.S. Air Force's mission to fly, fight and win the nation's wars in air, space and cyberspace (Tab CC-7).

c. 53d Wing

The 53 WG, located at Eglin Air Force Base, FL, serves as the focal point for the Combat Air Forces in electronic warfare, armament and avionics, chemical defense, reconnaissance, and aircrew training devices. The wing reports to the USAF Warfare Center at Nellis AFB, Nevada, a direct reporting unit to Headquarters ACC. The wing is also responsible for development, test and evaluation of advanced weapons and tactics to perfect the lethality, survivability and sustainability of our nation's combat forces (Tab CC-9).

d. 53d Weapons Evaluation Group

The 53rd WEG, headquartered at Tyndall AFB, FL is comprised of five squadrons and two detachments: 53rd Test Support Squadron, 81st Range Control Squadron, 82 ATRS, and 83d Fighter Weapons Squadron (FWS),

all located at Tyndall; 86 FWS, located at Eglin; Det. 1, 82 ATRS, located at Holloman AFB, New Mexico (NM); and Det. 1, 86 FWS located at Hill AFB, Utah. The group conducts the Air Force air-to-air WSEP, known as Combat Archer, and the Air Force air-to-ground WSEP, known as Combat Hammer. It also supports Weapons Instructor Course air-to-air formal training syllabi. Unit personnel provide all USAF aerial target support for Department of Defense (DoD) users in the gulf ranges and full-scale targets for Title 10 testing on White Sands Missile Range near Holloman (Tab CC-14–CC-15).

e. 82d Aerial Targets Squadron

The 82d Aerial Targets Squadron operates approximately 50 full-scale QF-4 aircraft and 45 BQM-167 subscale targets to provide manned and unmanned aerial targets support for numerous USAF and DoD-directed programs. The squadron maintains three 120-foot drone recovery vessels and two smaller vessels to recover aerial targets and support range safety, patrol and salvage operations. Squadron members also operate the Air Force's only two E-9A airborne platform/telemetry relay aircraft that provide ocean surface surveillance and relay missile/target telemetry of missiles fired in over-the horizon profiles on the Gulf Range. The squadron executes an annual budget of $16 million to support three operations and maintenance contracts and more than 150 contract personnel (Tab CC-15).

f. QF-4 Full Scale Aerial Target System

The supersonic QF-4 is a reusable full-scale target drone modified from the F-4 Phantom. The QF-4 provides a realistic full-scale target for air-to-air weapons system evaluation, development and testing at Tyndall Air Force Base, FL and Holloman AFB, NM (Tab CC-17, CC-19).

Converting F-4s to QF-4s is a multi-step process. This process begins by removing the aircraft from long-term storage at the Aerospace Maintenance and Regeneration Center (AMARC) at Davis-Monthan AFB, Arizona. Once the F-4 is cleared for flight, it is flown to a BAE conversion facility in Mojave, California to be modified as a remote controlled target. After conversion, it is flown to Tyndall AFB, Florida where it performs a manned Systems Acceptance Flight Evaluation (SAFE) flight. A successful SAFE is required for acceptance as a drone aircraft. Once the aircraft is accepted, it is categorized as "unrestricted" or "restricted" depending upon the amount of service life remaining in the airframe. Unrestricted QF-4s are flown manned to support the WEG mission and to supplement controller training. Restricted aircraft are placed in line for operational support as unmanned target aircraft. These aircraft are

"de-manned," which consists mainly of removing most life support systems, and otherwise converted to a final state for unmanned operations. When flying unmanned, QF-4s are referred to as NULLO, or Not Under Live Local Operator, aircraft (Tab CC-19–CC-20).

At Tyndall AFB, QF-4s (both QF-4E and QRF-4C) are flown remotely using the Gulf Range Drone Control System (GRDCS). GRDCS software sends command messages to the Aircraft Flight Control Computers (AFCC) every 100 milliseconds via the Gulf Range antenna chain. GRDCS also receives Automatic Flight Control Computer (AFCC) telemetry data and other drone operating parameters of interest. GRDCS commands to control the drone are relayed from the controller's ground station. These commands can be initiated by manual controls or a series

Drone Controller's Ground Station

of pre-determined responses to push-button inputs. Manual commands are passed when the controller operates a control stick to fly the drone similar to a manned aircraft. Push-button commands can be used to initiate automatic sequences (Automatic Take-Off, preplanned maneuvers in the airspace, etc.) or to establish certain desired operating parameters (like lowering the landing gear). Some push-button commands bypass cockpit switches such as the landing gear and arresting hook. For example, drones are launched with these switches in the down position but the NULLO panel allows the controller to raise and lower the gear and hook remotely. Drone position, control, and performance data is displayed to the controller on two screens. The left display in the Figure above shows an overhead view of the drone's position on a map, attitude indicator (ADI), compass, and various control and performance parameters. The right display shows downlinked instrument panel information similar to what a pilot would see in a manned aircraft. This display includes an ADI, engine instruments, and performance data such as altitude, airspeed, and angle of attack (AoA). The top of the right screen above is used to

display both normal and abnormal operating conditions of the drone (Tab M; Tab R; Tab V; Tab BB; Tab CC; Tab EE).

The QRF-4C flight control system consists of the primary RF-4C flight control system augmented by several elements of drone-peculiar equipment. GRDCS uplink and download data messages are passed via one of two controller-selectable Control Telemetry Systems (CTS). Uplink commands are received by the Transponder Vehicle Interface (TVI) which translates and distributes commands to either the Primary or Backup Automatic Flight Control System (PAFCS or BUAFCS). Each AFCS is comprised of an Automatic Flight Control Computer (AFCC), sensors, servos, and actuators. The PAFCS and BUAFCS are largely interchangeable with minor exceptions. The PAFCS receives processed air data information (airspeed, altitude) via the Central Air Data Computer while the BUAFCS relies upon raw air data sensors including pitot and static pressure. In the QRF-4C only, both PAFCS and BUAFCS receive platform attitude and rate information from a dual Attitude Heading Reference System (AHRS). The AFCS in command, either the primary or backup, sends surface position commands to the electro-mechanical (EM) and/or electro-hydraulic (EH) servos. The pitch path uses EM or EH servos depending on controller selection. The roll and yaw paths use a mix of the EM and EH servos and the throttle path uses the EM servos only. Several feedback control loops are implemented in the AFCS to control pitch/roll attitude, pitch/roll/yaw rates, altitude, airspeed, and Gs. The drone's response to uplink commands is sent to the ground control system via the downlink path of the CTS. In summary, the drone provides the controller, via the GRDCS datalink, control of such parameters as altitude, airspeed, pitch, bank, flight control surface commanded and actual position. The normal operating mode of the system is PAFCS. The system will only switch to BUAFCS when manually commanded by the controller or automatically in the event of PAFCC failure or extended processing of stale AFCC data. The PAFCS provides AoA limiting protection for drone maneuvers but does not provide G limiting. BUAFCS provides G limiting but no AoA limiting (Tab M; Tab R; Tab V; Tab BB; Tab CC; Tab EE).

The Emergency Procedures section of the QRF-4C flight manual does not contain a procedure to recover a drone from an out of control situation but does have an unusual attitude recovery procedure. While it is impossible to define precisely the difference between an unusual attitude and out of control, the flight manual states that out of control conditions are typically associated with high AoA. Additionally, the manned flight manual says that a sustained out of control condition may follow a departure from controlled flight. These departures are characterized by uncontrolled motions about any or all axes (pitch, roll, and yaw) and are only preventable or recoverable by controlling the aircraft's AoA. The potential causes of a NULLO unusual attitude listed in the flight manual imply low AoA conditions. Commanding All-Attitude Recovery (AAR) is a critical step in the Unusual Attitude Recovery checklist. In AAR, the drone determines its spatial attitude and executes a pre-determined recovery maneuver appropriate to its attitude and altitude. The checklist cautions that AAR is not designed to recover a drone from an out of control condition (Tab BB-5–BB-6).

4. SEQUENCE OF EVENTS

a. Mission

The mishap sortie was scheduled as a full-scale aerial target (FSAT) in support of an 83 FWS WSEP live fire mission (Tab K-4).

b. Planning

The MC performed mission planning to support the live fire mission. Elements included pre-launch, take-off, mission profile, and recovery (Tab F; Tab K2, Attachment K-1).

c. Preflight

The MC showed for duty at approximately 0730L (1230Z) on 13 May 2011. The first brief (WSEP Agency Brief) began on time at 1430Z, three hours prior to the scheduled NULLO take-off time of 1730Z (Tab K1, Attachment K-1). The NULLO brief began on time at 1530Z, and the final GRDCS coordination brief was accomplished prior to NULLO engine start (Tab K1, Attachment K-1). All briefs covered all pertinent items and reviewed critical action responses to emergency situations. The MC and other members of the drone control team accomplished all required checklists prior to MD launch (Tab R-5). Minor issues with WSEP shooter aircraft resulted in a delayed MD launch at 1748Z (Tab M3, Attachment M-1; Tab R-9).

d. Summary of Accident

At 1748Z, the MC performed a normal fixed control station (FCS) Auto Control Launch of the MD (Tab R-5). Rhino 69, the chase pilot (CP), rejoined on the MD shortly after take-off (Tab R-6; R-21-R-22; Tab V-3.1). At 17:49:18Z, the MC's console display indicated BUS TIE OPEN[1] which was communicated to Rhino 69 at 17:49:23Z via a radio call, "got a bus tie open" (Tab N-3; Tab R-15; Tab V-3.1). At 17:49:43Z, the MC stated, "we're going to wait until we get into the airspace until we start actuating buttons" (Tab N-3).

At 17:50:25 the MD was established at 8,000 feet MSL, heading approximately 193 degrees, and 354 knots indicated airspeed (KIAS) (Tab M3, Attachment M-1). The MD was operating in PAFCS with Speed Hold on Throttle (SHOT), which maintains a constant airspeed, and Altitude Hold (AH) enabled (Tab M3, Attachment M-1). Rhino 69 was in a chase position approximately 3,000 feet to the MD's right, slightly aft of the MD's 3 o'clock position (Tab R-

[1] The BUS TIE OPEN light indicates the relay that ties the aircraft's left and right alternating current (AC) generator bus systems is open. The purpose of the relay switch is to allow one generator to assume the electrical load for the entire aircraft in the event of a power loss or disruption from the other generator. The BUS TIE OPEN indicates the left and right generators are out of synch in either phase or frequency. These conditions may be corrected by cycling a generator off, then on. Corrective action for the RF-4C is to cycle the right generator first. The checklist for the QRF-4C and QF-4E says to cycle the left generator first. While not explicit in technical data, witness testimony indicates the rationale for this change is that the most critical drone peculiar equipment (DPE) is tied to the right AC bus (Tab V-6.1; Tab BB-7).

22). After conducting a UHF radio check, the MC cycled the MD's left generator off at 17:50:34 (Tab M3, Attachment M-1; Tab N-3; Tab V-1.1). GRDCS data indicates the BUS TIE OPEN light went out 300 milliseconds (msec) later (Tab M3, Attachment M-1). At 17:50:37, the MC turned the left generator back on (Tab M3, Attachment M-1; Tab V-1.1). Both generator switch actuations were accompanied by radio calls to inform Rhino 69 what the MC was doing (Tab M3, Attachment M-1; Tab N-3).

When the left generator was cycled back on, GRDCS shows a momentary loss (approximately 400 msec) of MD multiplexed downlink telemetry (Tab M3, Attachment M-1). Console data indicates the CTS was functioning normally during this time and no audible loss of carrier (LOC) tone was present (Tab M3, Attachment M-1; Tab V-1.2). Throughout the remainder of the mishap sequence, the MD continued to downlink discrete telemetry signals (DITS) indicating acknowledgment of commanded changes to operating modes and states (Tab M3, Attachment M-1; Tab M4, Attachment M-2; Tab M5, Attachment M-3; Tab V-1.1; V-2.1).

Within one second of cycling the left generator back on, the MD experienced non-MC-commanded transients in the pitch, roll, and yaw axes (Tab M3, Attachment M-1; Tab M4, Attachment M-2; Tab M5, Attachment M-3; Tab EE-5–EE-6). A recreation of the mishap sequence–constructed from GRCDS telemetry data–shows several small, rapid yaw movements followed by a 1.8G pitch up to approximately 5 degrees nose high, then a left roll to 122 degrees of bank (Tab S3). GRCDS also shows that both MD throttles moved to the flight IDLE position (Tab M3, Attachment M-1; Tab M4, Attachment M-2; Tab M5, Attachment M-3). At 17:50:39, CP stated, "big roll left, big roll left. Roll right and pull out. Roll right and pull out" (Tab N-3).

The MC's ground control station displayed several abnormal indications when this maneuver occurred (Tab M3, Attachment M-1; Tab M4, Attachment M-2). The MD experienced an automatic AFCS switch from primary to backup with an accompanying switch to EM Servos only (Tab M3, Attachment M-1; Tab M4, Attachment M-2; Tab EE-3–EE-5). This resulted in a split AFCS condition which means the controller is attempting to control the MD via primary AFCS but the drone is responding to BUAFCS commands (Tab M3, Attachment M-1; Tab M4, Attachment M-2; EE-33–EE-6). Additional caution lights displayed included AUX AIR DOOR FAIL, GEAR UNSAFE, PRIMARY AFCS FAILED, UTIL HYDR SYS FAIL, and TAIL HOOK DOWN (Tab M3, Attachment M-1, Tab M4, Attachment M-2). The validity of the gear and hook messages was verified by a cell phone photograph taken by the rear cockpit occupant of the chase aircraft (Tab S-5; Tab V-3.1). The photograph shows the landing gear and arresting hook in transit between the up-and-locked and full down positions (Tab S-5).

At 17:50:39, the MC selected wings level (WL) via console push-button (Tab M3, Attachment M-1). The MD acknowledged this command according to GRDCS data but no flight control movement or motion toward wings level flight was observed by the MC (Tab M3, Attachment M-1; Tab V-1.1). Telemetry also shows a pitch stick out (PSO) of detent condition, meaning the MC moved the control stick either forward or aft (Tab M3, Attachment M-1; Tab R-4). After the initial pitch up and left roll, the MD paused briefly in a near-inverted attitude with the nose beginning to fall through the horizon (Tab M3, Attachment M-1; Tab V-1.1).

At 17:50:41, the MC initiated All-Attitude Recovery (AAR) in accordance with the Unusual

Attitude Recovery checklist (Tab M3, Attachment M-1; Tab V-1.1, 2.1; Tab BB-6). The MD began an increasing G pull, peaking at 4.8Gs, in a right roll towards a wings-level attitude (Tab M3, Attachment M-1; Tab M4, Attachment M-2). This resulted in rapidly decaying airspeed and increasing AoA (Tab M3, Attachment M-1; Tab M4, Attachment M-2). At 17:50:48, the MD experienced an accelerated stall and departure from controlled flight which was characterized by a rapid left yaw rate (Tab M3, Attachment M-1; Tab M4, Attachment M-2). One second later the CP communicated, "drone's inverted in left hand spin" (Tab N-3).

From 17:50:49 until water impact at 17:51:21, the MD remained fully stalled at the display maximum 29-30 units AoA with one momentary excursion to 15 units AoA (Tab M3, Attachment M-1; Tab M4, Attachment M-2). Airspeed remained below 200 KIAS for most of this time (Tab M3, Attachment M-1; Tab M4, Attachment M-2). The MD never entered a developed spin but instead experienced several post-stall gyrations including severe wing rock and four turn direction reversals exhibiting rapid roll and yaw rates (Tab M3, Attachment M-1; Tab S3; Tab EE-6).

From 17:50:49 on, the MC made several additional recovery attempts using AAR, WL, and PSO (Tab M3, Attachment M-1; Tab V-1.1–V-1.2). All recovery attempts were unsuccessful (Tab V-1.1; V-2.1; V-3.1; V-4.1; V-5.1). The YANKEE (mission coordinator), the ECHO (mobile drone console operator) and CP testified they thought the MD was on the verge of recovery several times due to reduced roll rates and a pitch tendency toward level flight (Tab V-1.1; Tab R-15; R-22; Tab V-4.1). Telemetry confirms those visual observations but shows the drone with significant periodic residual yaw rate and AoA "pegged" at the maximum 29-30 units for the remaining 32 seconds until water impact (Tab M3, Attachment M-1; Tab M4, Attachment M-2). The MD was not destroyed by the flight termination system (FTS) prior to impact (Tab V-4.2).

e. Impact

The MD impacted the water approximately 16 nm south of Tyndall Air Force Base, Florida (Tab M-5). A visual inspection by CP indicated the surface was clear of boat traffic and that the closest boat was approximately 4 nm east-southeast of the impact site (Tab M-5; Tab R-3; R-6). The MD was completely destroyed upon impact and the only wreckage recovered from the crash site was the MD's electronic countermeasures (ECM) Pod (Tab P-3, Attachment P-1; Tab Q-3; Tab S-3).

f. Egress and Aircrew Flight Equipment

Not applicable.

g. Search and Rescue

Not applicable.

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

At the time of the mishap, the aircraft had accumulated 5,655.0 flight hours (Tab D-3). Two service life extensions were requested and approved, ultimately extending the MD's unmanned service life to 5,677.3 hours (Tab D2, Attachment D-1). At the time of the mishap, the MD had 22.3 flight hours remaining in its service life and the mishap sortie was the MD's first NULLO flight (Tab D2, Attachment D-1).

a. Forms Documentation

(1) General Definitions

Detailed maintenance documents are kept on every Air Force aircraft. Hard copy forms documenting scheduled and unscheduled maintenance are maintained via Air Force Technical Order (AFTO) 781-series forms. Electronic records are maintained in the Integrated Maintenance Documentation System (IMDS). Prior to the year 2000, electronic maintenance records were stored in the Core Automated Maintenance System (CAMS). Time Compliance Technical Orders (TCTO) are system changes, usually parts upgrades, with a specified completion date. A TCTO may also direct inspections or adjustments to equipment of parts already attached to the aircraft or ground support item. TCTOs are categorized as immediate, urgent, or routine. Time change items are routine maintenance actions in which components are removed and replaced for overhaul at a given number of flight hours (Tab D2, Attachment D-1).

(2) General Documentation Reviewed

All available maintenance records, including regeneration at AMARC and drone conversion by BAE, were reviewed to determine the airworthiness of the MD (Tab V-7.1). Local maintenance activities for QF-4 aircraft are performed by Defense Support Services, LLC (DS2), a contracted maintenance support company (Tab D-7). A thorough review of IMDS, CAMS, and AFTO 781 series forms documentation was conducted (Tab V-7.1). On 10 February 1991, an aircrew reported discrepancy indicates a BUS TIE OPEN light illuminated shortly after take-off (Tab V-7.1). The complete narrative and any maintenance corrective actions were lost when CAMS data was transferred to IMDS (Tab V-7.1). While this discrepancy was noted 20 years ago, the MD accumulated less than 29 flight hours between the discrepancy and the mishap (Tab D2, Attachment D-1). In the absence of definitive maintenance documentation, the status of maintenance corrective actions prior to AMARC transfer is unknown. The AIB was unable to rule out the possibility that the same underlying condition that caused the BUS TIE OPEN light in 1991 caused the initial indication prior to this mishap (Tab V-7.1). Therefore, the AIB was unable to discount that a repeat discrepancy was a contributing factor to this mishap.

The 90-day aircraft maintenance history revealed nine flight control related discrepancies between 9 February 2011 and 21 April 2011 (Tab V-7.1). All maintenance corrective actions were accomplished and documented properly (Tab D2, Attachment D-1; Tab V-7.1).

b. Inspections

All scheduled inspections were accomplished within scheduled time limits, and there were no overdue TCTOs, time change items, or special inspections at the time of the mishap. No inspection discrepancies relevant to this mishap were found in the reviewed maintenance documentation (Tab D2, Attachment D-1; Tab V-7.1).

c. Maintenance Procedures

Maintenance procedures on the MD were completed in accordance with applicable Technical Orders and Air Force Instructions. No maintenance procedures discrepancies relevant to this mishap were found in the reviewed maintenance documentation (Tab V-7.1).

d. Maintenance Personnel and Supervision

Aircraft maintenance records indicated all preflight maintenance and supervisory activities were normal. A thorough review of the training records provided and special certification rosters of the DS2 contractors who performed maintenance on the mishap drone was accomplished. Several individual training records were found to have minor documentation errors but all maintenance personnel were trained and qualified. No maintenance personnel or supervision discrepancies relevant to this mishap were found (Tab G-10; Tab V-7.1).

e. Fuel, Hydraulic and Oil Inspection Analyses

Collection of fuel and oil samples was not possible due to the impact location of the MD. The aircraft forms indicate the aircraft was serviced prior to launch. Interviews indicate maintenance personnel properly serviced fuel tanks and oil reservoirs in accordance with technical data. No fuel, hydraulic, or oil maintenance discrepancies relevant to this mishap were found (Tab D2, Attachment D-1; Tab V-7.1).

f. Unscheduled Maintenance

A review of unscheduled maintenance actions revealed maintenance was performed and documented correctly. No unscheduled maintenance discrepancies relevant to this mishap were found in the maintenance documentation (Tab D2, Attachment D-1; Tab G-10; Tab V-7.1).

6. AIRFRAME SYSTEMS

a. Structures and Systems

The AIB reviewed recorded GRDCS telemetry streams, GRDCS QF-4 simulation data, underwater video of the wreckage, and one still photograph taken from the rear cockpit of the chase aircraft (Tab M3, Attachment M-1; Tab S3; S-5). According to GRDCS data, all aircraft systems were operating correctly prior to launch (Tab M3, Attachment M-1). As the aircraft was destroyed upon water impact, post-mishap analysis of the left generator, frequency and load control box (FLCB), bus tie relay, or electrical distribution system was not possible.

b. Telemetry Analysis

Analysis of available drone telemetry data, both GRDCS uplink and downlink data, was conducted to assess the MD's receipt of flight control commands, processing and application of those commands, and resultant MD flight path (Tab M3, Attachment M-1; Tab M4, Attachment M-2). GRDCS data indicates a normal drone flight until the BUS TIE OPEN indication annunciated (Tab M4, Attachment M-2). All uplink and downlink messages were present with minor exceptions lasting a maximum of a few hundred msec (Tab M4, Attachment M-2). Temporary loss of data link communications for a 100 msec cycle is not abnormal in a GRDCS-like system. None of the data link interruptions lasted long enough to trigger an LOC tone and screen captures from the mission console show near-continuous and reliable data link availability (Tab M-5).

The GRDCS data stream provided sufficiently valid data to enable the AIB to draw conclusions regarding the cause of this mishap (Tab M3, Attachment M-1; Tab M4, Attachment M-2; Tab M5, Attachment M-3).

c. Simulation Results

The AIB conducted a console simulation with a current and qualified controller (X-RAY) and WHISKEY to assess drone response to generator power cycles and execute a variety of AARs in PAFCS and BUAFCS. In every case, AAR recovered the drone from the same unusual attitude experienced by the MD. Timely X-RAY responses to simulated emergency conditions recovered the drone every time. One drone was lost in simulation due to the X-RAY intentionally ignoring status messages and not accomplishing boldface checklist items (per AIB direction) in an attempt to induce an out of control drone. Simulator fidelity was a limiting factor in this analysis as the simulator was unable to replicate the exact emergency condition experienced by the MD. Additionally, there is no way to simulate improper drone response to console commands. For example, cycling the generators always results in a "clean" power cycle; therefore, proper checklist execution should always result in drone recovery. Sufficient data was gleaned to indicate that cycling the left generator to clear a BUS TIE OPEN condition, under normal drone operating conditions, should not result in an unusual attitude (Tab EE).

d. Engine Run Results

The AIB conducted an engine run with a QRF-4C in a weight-off-wheels condition replicating flight conditions at the beginning of the mishap (8,000 feet MSL and 350 KIAS). The primary objective of the engine run was to replicate the MD's response to cycling the left generator. With the QRF-4C in PAFCS, the left generator was cycled off, then on, 10 times. In each case, the power cycle was smooth, resulting in zero impact to the AFCSs. The same findings were seen with the drone is BUAFCS. Every time the generator was cycled back on, the ground console displayed a momentary BUS TIE OPEN as the FLCB synchronized the generators prior to closing the bus tie and resuming normal operation. Once the generators are synchronized in phase and frequency and the buses are tied, the BUS TIE OPEN light goes out. The engine run confirmed that cycling the generator should not cause abnormal AFCC behavior provided the system is functioning normally. Additionally, the console should display a momentary BUS TIE OPEN when the generator is turned back on. With weight on gear, the AFCCs require 6-8

seconds to complete a reboot process. During the engine run, with weight off gear, ground personnel power cycled power to the AFCCs three times and each time the AFCC reboot time was less than 2 seconds. This indicates that airborne POR (Power on Reset) time is significantly less than when the aircraft is on the ground (Tab EE).

Of the three AFCS circuit breaker resets, one reset produced a split AFCS condition. As in the mishap, the console was in PAFCS but the drone was in BUAFCS. Valuable information was learned while the drone was in this state. First, longitudinal control stick commands had zero impact on horizontal stabilator scheduling. The GRDCS station indicated no pitch command was transmitted to the drone but PSO was illuminated on the console during stick movement and uplinked in the command stream. Neither the ground crew nor available console video showed any stabilator movement when PSO was initiated. Second, lateral stick command responses were similar to longitudinal stick commands except 1 degree of aileron deflection was commanded (of an available 30 degrees). Again, the launch crew observed no flight control surface movement but the ground console displayed LSO. Third, a WL command had no effect on the drone. The drone was stationary in ½ degree of bank. The WL command did not cause any flight control movement. Finally, the drone responded to an AAR command by commanding aileron in an attempt to zeroize the ½ degree bank angle. The drone applied increasing aileron until the maximum deflection of 30 degrees was reached. This indicates the drone responded to the AAR command even though a split AFCS condition existed (Tab EE).

7. WEATHER

a. Forecast Weather

Valid from 1615-2030Z: Winds from 220 degrees at 10 knots (kts), gust 15 kts, visibility 7 statute miles, clouds scattered at 4000 feet, broken at 20,000 feet, altimeter setting 29.85 (Tab F-6).

b. Observed Weather

At 1755Z: Tyndall weather reported winds from 230 degrees at 9 kts, gust 17 kts, visibility 10 statute miles, clouds few at 11,000 feet, scattered at 14,000 feet and 17,000 feet and broken at 20,000 feet, altimeter setting 29.91 Temperature 28 degrees Celsius. Dewpoint: 22 degrees Celsius. (Tab F-3). Weather was not relevant to this mishap.

c. Operations

Operations were conducted within prescribed operational weather limitations.

8. CREW QUALIFICATIONS

a. Mishap Controller

(1) Training

The MC is a civilian QF-4 pilot with extensive prior active duty and contractor flying experience. The MC requalified in the QF-4 on 28 Feb 2006, regained instructor qualification on 16 October 2006, and was certified as a flight evaluator on 16 November 2006. The MC qualified in the QRF-4C on 14 January 2007. The MC's last combined Instrument/Qualification/Mission/Rear Cockpit SPOT evaluation was completed on 18 November 2010, with an expiration date of April 2012. The MC was qualified to perform all assigned mission tasks on 13 May 2011 (Tab G-2; G-19; Tab V-9.1).

(2) Experience

The MC has approximately 3375 hours total flying time in the F-4D/E/G, RF-4C, F-16C/D, E-9, and QF-4 aircraft. The MC retired from active duty with 2511.2 total hours. E-9 and contract F-4 experience was derived from contractor-maintained databases since contractor flight hours may not be tracked in Air Force flight records. Tyndall AFB contract QF-4 pilots transitioned to Department of the Air Force civilians in January 2010. Since that time, the MC has flown 124.3 hours in the QF-4E and QRF-4C. NULLO flight control time is not maintained in formal Air Force records. Local database entries indicate the MC has controlled at least 63 NULLO missions since April 2006. The MC was current in all mission tasks on 13 May 2011. While no formal 30/60/90 NULLO records are maintained, the MC's training summary indicates five NULLO missions accomplished since the current training period began on 1 Oct 2010. The MC's manned flight summary for the 90 days prior to the mishap is as follows: (Tab G-3; G-5; Tab V-9.1)

MC	Hours	Sorties
Last 30 Days	7.6	7
Last 60 Days	14.9	13
Last 90 Days	23.6	21

b. Drone Mission Crew

While the MC, or X-RAY, controls the drone, several other personnel are directly involved with drone mission execution. The drone mission commander (MIKE) is responsible for the overall conduct of the mission. The safety observer (SAFETY) maintains awareness on overall safety considerations including location of boats and non-participating aircraft. The mission coordinator (YANKEE) is the primary backup for the X-RAY and provides assistance during emergencies. Technicians (WHISKEY and SHOTGUN) provide real-time GRDCS status updates. Several personnel assist from the mobile GRDCS van at the drone launch facility. The ECHO and ROMEO perform functions similar to the X-RAY and YANKEE in the event of drone launch issues. They are also the primary recovery team in the event of drone controllability issues. Additional WHISKEY support is available via the mobile team (Tab R-14; R-16–R-20; Tab V-2.1; V-4.1–V4.2; V-5.1).

A thorough review of qualifications, currencies, and experience for the remainder of the drone mission crew was conducted. All members were current and qualified in their particular specialties on 13 May 2011 (Tab G; Tab V-9.1).

9. MEDICAL

a. Qualifications

At the time of the mishap, the MC was medically qualified for flight duty (Tab V-8.1).

b. Health

The MC's medical records were reviewed by a qualified flight surgeon. The MC's Federal Aviation Administration Medical Certification was current. A review of the 72 hour and 14 day histories revealed no contributing factors (Tab V-8.1).

c. Pathology

Toxicology testing was ordered for the MC immediately following the mishap. Blood and urine samples were submitted to the Armed Forces Institute of Pathology for analysis. No prohibited substances were detected (Tab V-8.1).

d. Lifestyle

There is no evidence that unusual habits, behavior, or stress on the part of the aircrew members contributed to this accident.

e. Crew Rest and Crew Duty Time

Air Force Instruction 11-202, Volume 3, *General Flight Rules*, 22 October 2010, requires aircrew have proper "crew rest" prior to performing flight duties. Normal crew rest is defined as a minimum 12-hour no-duty period before the designated flight duty period begins. During this time, aircrew members may participate in meals, transportation or rest as long as they have the opportunity for at least eight hours of uninterrupted sleep. There is no evidence that crew rest or duty time were factors in this mishap.

10. OPERATIONS AND SUPERVISION

a. Operations

Interviews and the 82 ATRS flight schedule indicate the operations tempo for the 82 ATRS and the MC was average and sustainable. (Tab K1, Attachment K-1). There is no evidence to suggest that operations tempo was a factor to this mishap.

b. Supervision

Tyndall AFB drone operations are executed under the control of the 82 ATRS as delegated by the 53 WEG Commander. The mission commander (MIKE) on the day of the mishap was the 53 WEG Deputy Commander (Tab K1, Attachment K-1). All members of the drone control team

were actively engaged in the mission and there is no evidence to suggest that a lack of supervision contributed to this mishap.

11. HUMAN FACTORS

The AIB reviewed the DoD Human Factors Analysis and Classification System to analyze the impact of human factors on this mishap. After reviewing the facts from the investigation, witness testimony, one ground console simulation, and one engine run, PE202, Instrumentation and Sensory Feedback Systems, was found to be a factor.

Under normal circumstances, the QF-4 ground console enables adequate controller input and feedback for all mission tasks. Controller workload is eased by automated functionality including speed and altitude hold. While somewhat cumbersome, console displays provide the X-RAY sufficient information to control the drone, particularly with support from the YANKEE.

In emergency situations, however, the ground console does not adequately communicate flight-critical cautions and warnings. Pertinent data is scattered across both screens requiring the controller to look in several locations to find and process relevant information. The only indication of a split AFCS condition is a small text window that displays "PRI B/U" in yellow font which is the same size as other typically mundane information such as the status of the CTS links. This text is positioned at the top right of the controller's display outside the primary visual scan pattern. Without an obvious warning or caution light, message, or tone, it is unlikely either the X-RAY or the YANKEE would recognize the split AFCS condition while both are focused on the ADI and executing the checklist procedure for an unusual attitude. Additionally, there is no positive feedback to the controller that PAFCS has been selected. In fact, only negative feedback exists. PAFCS selection is confirmed by the absence of an illuminated backup AFCS light on the console. The lack of consolidated flight-critical data and an effective mechanism to capture the controller's attention were factors in this mishap.

In situations in which physical control of the drone is in doubt, the console provides inadequate feedback to the controller. Visual sensory cues are limited to a computer-generated ADI, auditory cues are limited to voice communication from the chase aircraft, and the control stick and other buttons on the console provide no tactile feedback. This forces the console operator to build a mental picture of what is physically happening to the airplane in flight. Several witnesses mentioned that the MD appeared on the verge of recovery several times during this mishap. Recreations of the ADI indeed show the drone approaching wings level and 20 degrees nose low at those times. In the flatter segments of the MD's post-stall gyrations, the apparent wings level times are accompanied by yaw rates which are not perceptible on the ADI. Yaw indications are only found on a tape-type display which shows yaw as a +/- value and not left or right. There are similar interpretation issues for AoA. While the MD appeared nearly wings level, the AoA was nearly constant at 29-30 units with a vertical velocity of -12,000 feet per minute for the last 32 seconds of the mishap. It is highly unlikely that the drone would have recovered from a high AoA stall in the available altitude using AAR. The absence of visual, auditory, and physical flight cues were factors in this mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Directives and Publications

*AFI 11-202, Volume 3, *General Flight Rules*, 22 October 2010
*AFI 11-202, Volume 3, ACC Supplement 1, *General Flight Rules*, 27 February 2007, Incorporating Change 1, 28 April 2008
*AFI 11-2F/QF-4, Volume 3, *F/QF-4 Operations Procedures*, 1 July 2000.
*AFI 11-401, *Aviation Management*, 10 December 2010
*AFI 11-418, *Operations Supervision*, 21 October 2005, incorporating Change 1, 20 March 2007
*AFI 21-101, *Aircraft and Equipment Maintenance Management*, 26 July 2010
*AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010
*AFI 91-204, *Safety Investigations and Reports*, 24 September 2008
GRDCS/DFCS Requirements
QF-4 Control Algorithm Description document
T.O. 00-20-1, Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures, 30 April 2003, incorporating Change 4, 1 September 2006
T.O. 1F-4(Q)E-1
T.O. 1F-4(R)C-1
T.O. 1F-4(R)C-2-13
TSD-0009 revision J
TSD-0017 revision T
TSD-0075 revision P
TSD-0076 revision J
WD 200072 revision V
WD 201413 revision G

*Available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**

b. Known or Suspected Deviations from Directives or Publications

Not applicable.

13. ADDITIONAL AREAS OF CONCERN

None.

AUG 0 4 2011

DAVID W. ABBA, Lt Col, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION
QRF-4C, T/N 65-0845, TYNDALL AIR FORCE BASE, FLORIDA
13 MAY 2011

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 cause of the mishap was a power disruption in the mishap drone's (MD) alternating current (AC) electrical power system which caused both Automatic Flight Control Computers (AFCC) to restart in flight. The simultaneous loss of both AFCCs caused the MD to temporarily enter an uncontrolled state with neither Automatic Flight Control System (AFCS) controlling the drone, resulting in an unusual attitude. I find, by a preponderance of evidence, that the MD's response to the All-Attitude Recovery (AAR) command was a substantially contributing factor to this mishap. The lack of angle of attack (AoA) limiting in backup AFCS (BUAFCS), aggravated by additional drag from the MD's landing gear, caused an accelerated stall. The MD departed controlled flight and experienced several post-stall gyrations prior to its destruction upon water impact. The Board found no evidence that the mishap controller (MC) or other operations or maintenance personnel contributed in any way to the loss of the MD.

2. DISCUSSION OF OPINION

Shortly after take-off, and while en route to the W-151 overwater range complex to support a Weapons System Evaluation Program (WSEP) live-fire mission, the MD experienced a BUS TIE OPEN condition. After leveling off, the MC correctly executed the BUS TIE OPEN checklist procedure, cycling the left generator off and then on.

Turning the left generator back on created a power disruption that affected both the left and right AC buses. Witness testimony, validated by the engine run conducted by the Board, indicates that when a generator is cycled back on, the bus tie relay should open momentarily until the frequency and load control box (FLCB) ensures coherent phase and frequency outputs from both generators. Depending on the amount of time required for the FLCB to establish coherency, the drone ground console should momentarily display BUS TIE OPEN, but did not in this case. All 10 generator cycles accomplished during the Board's engine run resulted in a visible BUS TIE OPEN indication on the console when the generator was turned on. Gulf Range Drone Control System (GRDCS) telemetry did not downlink that the relay ever opened. Turning the left

generator back on produced either a significant power spike or current that was asynchronous in phase or frequency with the power supplied by the right side generator. Since the left generator was immediately reconnected to both AC bus systems, this power anomaly impacted the left and right systems.

The power disruption caused both AFCCs to execute a Power on Restart. The missed downlink message and three repetitive multiplex downlink messages lasting 400 milliseconds (msec) total suggest the Primary AFCC (PAFCC) rebooted resulting in an automatic switch to BUAFCS. This timeline corresponds to the warm AFCC restart times observed by the Board during the engine run. The conclusion that the BUAFCC restarted as well is supported by a photograph taken from the rear cockpit of the chase aircraft which shows the MD's landing gear and hook in transit. QF-4s are launched with the landing gear handle and hook switch in the down position. When the operating AFCS is functioning normally, the not under live local operator (NULLO) panel ignores cockpit switch positions and uses GRDCS commands to extend and retract the landing gear. If the QF-4 "forgets" it is in drone mode due to lack of power or a functioning AFCC, it reverts to a "normal" F-4, referencing handle and switch positions. Several witnesses testified that uncommanded extension of the landing gear and hook suggests that neither AFCS was actually controlling the drone.

Although this uncontrolled condition lasted only 400 msec, it lasted long enough to induce an unusual attitude caused by uncommanded transients in the pitch, roll, and yaw axes. Additionally, the MD's throttles momentarily drove uncommanded to IDLE. Prior to the automatic AFCS switch, the MD was in Altitude Hold with Speed Hold on Throttle selected so console commands were ruled out as the cause of the transients. There is no telemetry data to prove that an automatic sequence such as escape was causal since an escape in No Pitch Change mode should have resulted in straight and level flight. This led the AIB to conclude that these transients were the result of either erroneous Attitude Heading Reference System (AHRS) inputs to the AFCC, electro-mechanical (EM) servo transients induced by the transition to BUAFCS with EM servos enabled, or bad air data inputs from the back-up air data sensors.

Once the unusual attitude developed, the MC accurately assessed the drone's spatial attitude by looking at the Attitude Director Indicator (ADI) and processing a radio call from the chase aircraft. The MC's initial response, selecting wings level (WL), appears via telemetry to have had a chance to recover the MD from the unusual attitude. The lack of sufficient visual, auditory, and vestibular cues denied the MC crucial peripheral understanding of the MD's flight dynamics. Without any ability to see or feel the MD's response to the command, the MC appropriately attempted AAR to recover the drone.

3. CONTRIBUTING FACTOR

The MD's response to the AAR command significantly contributed to the mishap by worsening an unusual attitude into an out of control condition. The automatic AFCS switch resulted in a split AFCS condition, meaning the MC was commanding the drone to fly using the PAFCS but the MD was actually operating in BUAFCS. This condition went unrecognized and uncorrected by the MC for more than 18 seconds. While this may appear excessive, it is not unreasonable that neither the MC (X-RAY) nor the YANKEE saw or processed the available information

while they were focused on regaining control of the drone. Insufficient visual or audible cues exist to indicate the MD was no longer operating in PAFCS. Selection (only) of PAFCS is confirmed by the lack of an illuminated BUAFCS selected console light. Additionally, the AIB was unable to find evidence of any checklist procedure requiring a controller to confirm congruency between the commanded and operating AFCS.

The automatic switch to BUAFCS is relevant because BUAFCS provides no AoA protection or limiting during drone maneuvers. Even though AAR was commanded in a split AFCS condition, the MD responded to the command and executed AAR exactly as programmed. Upon initiation, AAR commanded approximately 1G while the MD's roll angle was greater than 90 degrees (AAR Area 5). Once roll reduced to less than 90 degrees, AAR commands generated 4.8Gs as expected in AAR Area 7b. Without AoA limiting in BUAFCS, the excessive G commanded during AAR, aggravated by excess drag due to the uncommanded extension of the MD's landing gear, generated sufficient AoA to exceed the MD's departure resistance threshold. As AoA increased, aileron inputs commanded by AAR became less effective, causing the MD's roll rate to slow and aggravating the accelerated stall condition. Additionally, the amount of rudder applied in the direction of roll is fixed in BUAFCS (assumes 5 degrees AoA) as opposed to being proportional to AoA increases in PAFCS. At higher AoAs the rudder is more effective and efficient rolling the aircraft than are the ailerons and rudder input in BUAFCS was reduced by a factor of 5-6. Once the AoA limited the vertical tail's exposure to the relative wind, the MD's directional (yaw) stability became negative, and adverse yaw created by right roll attempts via aileron caused the MD to depart to the left.

4. CONCLUSION

I arrived at my opinion by examining GRDCS telemetry data, mishap recreations, witness testimony, functional area expert reports, console simulation, and an engine run conducted with a QRF-4C. All evidence is consistent with a significant power disruption affecting the left and right AC buses and AFCCs caused by cycling the left generator. This initiated a sequence of events which culminated in the MD departing controlled flight. Once the MD departed and entered a sustained out of control condition, there is nothing in the AAR logic that would have reduced the MD's AoA to the point it would have been recoverable. The flight manual cautions that AAR is not designed to recover the aircraft from out of control conditions. It is also noteworthy that the entire mishap sequence occurred below 10,000 feet MSL. Had this aircraft been manned, the out of control recovery procedure directs ejection if at or below 10,000 feet.

AUG 0 4 2011

DAVID W. ABBA, Lt Col, USAF
President, Accident Investigation Board