ACTION OF THE CONVENING AUTHORITY

The report of the accident investigation board, conducted under the provisions of AFI 51-503, that investigated the 11 August 2015 mishap near Grafenwoehr, Germany, involving F-16CM, T/N 91-0366, assigned to the 480 Fighter Squadron, 52 Fighter Wing, Spangdahlem Air Base, Germany complies with applicable regulatory and statutory guidance and on that basis is approved.

TIMOTHY M. ZADALIS
Major General, USAF

UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

F-16CM, T/N 91-0366

480TH FIGHTER SQUADRON
52ND FIGHTER WING
SPANGDAHLEM AIR BASE, GERMANY

LOCATION: NEAR GRAFENWOEHR, GERMANY

DATE OF ACCIDENT: 11 AUGUST 2015

BOARD PRESIDENT: COLONEL JILL A. LONG

Conducted IAW Air Force Instruction 51-503

United States Air Force Accident Investigation Board Report

Class A, F-16CM, Spangdahlem Air Base, Germany

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

F-16CM, T/N 91-0366
NEAR GRAFENWOEHR, GERMANY
11 AUGUST 2015

On 11 August 2015, an F-16CM tail number 91-0366, assigned to the 52nd Fighter Wing, Spangdahlem Air Base, Germany experienced an unrecoverable engine malfunction while on a local training mission near Grafenwoehr, Germany resulting in pilot ejection and a total loss of the aircraft. After approximately 29 minutes of flight, the mishap pilot experienced a loss of thrust. Five attempts were made by the mishap pilot to restart the failed engine. Prior to ejection the mishap pilot maneuvered the aircraft away from populated areas; ejecting at 156 knots calibrated air speed and approximately 400 feet above ground level. The mishap pilot sustained minor injuries. Search and Recovery efforts were facilitated by local German nationals, the German Bundeswehr, and the US Army. The mishap aircraft was destroyed upon impact; the loss was valued at $39,796,422.00. Damage to non-US government property consisted of damage to trees, shrubbery, soil, and crops.

The Accident Investigation Board President determined, by a preponderance of evidence, that the cause of the mishap was a structural failure of the bearing cage within the lower governor ballhead bearing. This structural failure caused the main engine control to malfunction, which prohibited fuel flow to the engine. The lack of fuel flow prevented engine restart and resulted in a complete loss of thrust, requiring the mishap pilot to eject from the mishap aircraft.

United States Air Force Accident Investigation Board Report

Class A, F-16CM, Spangdahlem Air Base, Germany

SUMMARY OF FACTS AND STATEMENT OF OPINION
F-16CM, T/N 91-0366
11 AUGUST 2015

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

-1Cl	Dash 1 checklist
3 AF	3rd Air Force
52 FW	52nd Fighter Wing
52 OG	52nd Operations Group
480 FS	480th Fighter Squadron
480 OSS	480th Operations Support Squadron
AAR	After Action Report
AB	Air Base or Afterburner
AC	Alternating Current
ACBT	Air Combat Training
ACES II	Advanced Concept Ejection Seat II
AETC	Air Education and Training Command
AF	Air Force
AFB	Air Force Base
AFC	Augmentor Fuel Control
AFE	Aircrew Flight Equipment
AFI	Air Force Instruction
AFIP	Air Force Institute of Pathology
AFLCMC/LPSEBB	Air Force Life Cycle Management Center/F-110 Engineering Section
AFPAM	Air Force Pamphlet
AFAFRICA	Air Forces in Africa
AFRICOM	Africa Command
AFSAS	Air Force Safety Automated System
AFSEC	Air Force Safety Center
AFTO	Air Force Technical Order
Ag	Silver
AGL	Above Ground Level
AHLTA	Armed Forces Health Longitudinal Technology Application
AIB	Accident Investigation Board
ALO	Air Liaison Officer
AMDS	Aerospace Medicine Squadron
ARMS	Aviation Resource Management System
ATV	All-Terrain Vehicle
BSA	Basic Surface Attack
CADC	Central Air Data Computer
CAF	Combat Air Force
CAPS	Critical Action Procedures
CDP	Compressor Discharge Pressure
Capt	Captain
CAT	Critical Action Team
CAUT	Caution
CDP	Compressor Discharge Pressure
CEMS	Comprehensive Engine Management System
CIP	Core Integrated Processor
Col	Colonel
CSEL	Combat Survivor/Evader Locator
CSFDR	Crash Survivable Flight Data Recorder
CSMU	Crash Survivable Memory Unit
CT	Currency Training
Cu	Copper
DC	Direct Current
DFLCC	Digital Flight Control Computer
DFLCS	Digital Flight Control System
DFR	Digital Flight Recorder
DOB	Date of Birth
DOC	Demonstrative Operational Capability
DoD	Department of Defense
DTC	Data Transfer Cartridge
DTS	Defense Travel System
EGI	Embedded Global Positioning System/Inertial Navigation System
ELT	Emergency Location Transmitter
EDNA	Enhanced Diagnostics Air Software
EOD	Explosive Ordnance Disposal
EOF	End of Flight
EOR	End of Runway
EPE	Emergency Procedures Evaluation
EPLA	Engine Power Lever Angle
EPU	Emergency Power Unit
ER	Exceptional Release
ETAD	ICAO code for Spangdahlem
ETAR	ICAO code for Ramstein
ETIC	ICAO code for Grafenwoehr

EUCOM	European Command
FBP	Fuel Boost Pump
FCIF	Flight Crew Information File
FDP	Flight Duty Period
FDT	Fan Discharge Temperature
FL	Flight Lead
FLCS	Flight Control System
FO(D)	Foreign Object Debris or Damage
FP	Flight Profile
FS	Fighter Squadron
ft	Feet
FTIT	Fan Turbine Inlet Temperature
FTU	Formal Training Unit
FW	Fighter Wing
g/G	Gravitational Force
GCU	Generator Control Unit
G-Ex	G-Awareness Exercise
GPS	Global Positioning System
GTA	Grafenwoehr Training Area
HFACS	Human Factors Analysis and Classification Systems
Hg	Mercury
HPT	High Pressure Turbine
HUD	Heads-Up Display
IAW	In Accordance With
ICAO	International Civil Aviation Organization
IFF	Introduction to Fighter Fundamentals
IFOC	In Flight Operations Check
IFR	In Flight Rules
IMDS	Integrated Maintenance Data System
IMIS	Integrated Maintenance Information System
in.	Inches
IP	Instructor Pilot
IPI	In-Processing Inspection
IQ	Instrument Qualification
ISA	Integrated Servoactuator
ISB	Interim Safety Board
ITADS	Intelligent Trending and Diagnostics System
ITL	Individual Task List
ITP	Individual Task Plan
IUID	Item Unique Identification
JA(G)	Judge Advocate
JEIM	Jet Engine Intermediate Maintenance
JFS	Jet Fuel Starter
JHMCS	Joint Helmet Mounted Cueing System
JMTC	Joint Multinational Training Command
JOAP	Joint Oil Analysis Program
JPRC	Joint Personnel Recovery Center
JTAC	Joint Terminal Attack Controller
K	Thousand
KCAS	Knots Calibrated Airspeed
KIAS	Knots Indicated Airspeed
KIO	Knock-It-Off
KTAS	Knots True Airspeed
Kts	Knots
L	Local Time
LEF	Leading Edge Flap
LM-Aero	Lockheed Martin Aeronautics Company
LPT	Low Pressure Turbine
LPU	Life Preserver Unit
Lt Col	Lieutenant Colonel
LWD	Left Wing Down
M	Mach
MA	Mishap Aircraft
Maj	Major
MAJCOM	Major Command
MDEC	Modernized Digital Electronic Control
MEC	Main Engine Control
MEMSC	Modernized Engine Monitoring System Computer
MF	Mishap Flight
MFL	Maintenance Fault Listing
MFSOV	Main Fuel Shutoff Valve
MICT	Management Internal Control Toolset
MIL	Military
MILSEC	Military Security
MMC	Modular Mission Computer
MOA	Military Operating Area
MS	Mishap Sortie
MSL	Mean Sea Level

MXG	Maintenance Group
NATO	North Atlantic Treaty Organization
ND	Nose Down
NHBB	New Hampshire Ball Bearings
NM	Nautical Miles
NOTAMs	Notices to Airmen
OG	Operations Group
OH	Overhaul
OJT	On the Job Training
OPR	Officer Performance Report
Ops Tempo	Operations Tempo
ORM	Operational Risk Management
OSC	On Scene Commander
OSS	Operation Support Squadron
PA	Public Affairs
PACS	Production Acceptance Certification Standards
PCS	Permanent Change of Station
PDG	Programmable Display Generator
PE	Personnel Evaluations
PEX	Patriot Excalibur
PHA	Periodic Health Assessment
PLF	Parachute Landing Fall
PMEL	Precision Measurement Equipment Laboratory
PMP	Packaged Maintenance Plan
PR	Pre Flight
PSI	Pounds Per Square Inch
QA	Quality Assurance
QIMSS	Quality Information Management Standard System
QVI	Quality Verification Inspections
RCO	Range Control Officer
RPM	Revolutions Per Minute
RTB	Return-To-Base
RWD	Right Wing Down
SA	Situational Awareness
SAR	Search and Rescue
SAT	Surface Attack Tactics
SAU	Signal Acquisition Unit
SDR	Seat Data Recorder
SEAD	Suppression of Enemy Air Defenses
SEFE	Standardization Evaluation Flight Examiner
SEPT	Simulator Emergency Procedures Training
SIB	Safety Investigation Board
SII	Special Interest Item
SME	Subject Matter Expert
SOF	Supervisor of Flying
SS	System Status
TCTO	Time Compliance Technical Order
TER	Triple Ejector Rack
TDY	Temporary Duty Assignment
TGP	Targeting Pod
T/N	Tail Number
TO (T.O.)	Technical Order
TOD	Technical Order Data
TOP-3	Operations Supervisor
UAV	Unmanned Aerial Vehicle
UHF	Ultra High Frequency
UPT	Undergraduate Pilot Training
USAFE	United States Air Forces in Europe
USAFRICOM	United States Africa Command
USEUCOM	United State European Command
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOC	Volatile Organic Compound
VSV	Variable Stator Vane
VVI	Vertical Velocity Indication
WCD	Work Control Document
Z	Zulu

The above list was compiled from the Summary of Facts, Statement of Opinion, Index of Tabs, and attached tabs.

PSEUDONYMS

ADCC1	Assistant Dedicated Crew Chief 1
ADCC2	Assistant Dedicated Crew Chief 2
ADCC3	Assistant Dedicated Crew Chief 3
ADCC4	Assistant Dedicated Crew Chief 4
ADCC5	Assistant Dedicated Crew Chief 5
AFE MBR	Aircrew Flight Equipment Member
AMDS/CC	Aerospace Medicine Squadron Commander
AMXS/CC	Aircraft Maintenance Squadron Commander
Army General Engineer	
Assistant Superintendent	
AT1	Avionics Technician 1
AT2	Avionics Technician 2
AT3	Avionics Technician 3
AT4	Avionics Technician 4
Bioenvironmental Engineer	
Command and Control	
Co-Worker	
DCC1	Dedicated Crew Chief 1
DCC2	Dedicated Crew Chief 2
DCC3	Dedicated Crew Chief 3
DCC4	Dedicated Crew Chief 4
DCC5	Dedicated Crew Chief 5
DCC6	Dedicated Crew Chief 6
DW1	Depot Worker 1
DW2	Depot Worker 2
DW3	Depot Worker 3
DW4	Depot Worker 4
DW5	Depot Worker 5
DW6	Depot Worker 6
DW7	Depot Worker 7
DW8	Depot Worker 8
DW9	Depot Worker 9
DW10	Depot Worker 10
DW11	Depot Worker 11
DW12	Depot Worker 12
DW13	Depot Worker 13
DW14	Depot Worker 14
DW15	Depot Worker 15
DW16	Depot Worker 16
DW17	Depot Worker 17
DW-Unknown 1	Depot Worker-Unknown 1
DW-Unknown 2	Depot Worker-Unknown 2
E&E1	Electrical & Environmental Technician 1
E&E2	Electrical & Environmental Technician 2
EM1	Engine Mechanic 1
EM2	Engine Mechanic 2
EM3	Engine Mechanic 3
Expediter	
FO	Fuel Operator
FSRT	Fuel Systems Repair Technician
GE AE	General Electric Aviation Engineer
Intel Briefer	
ISB IO1	ISB Investigating Officer 1
ISB IO2	ISB Investigating Officer 2
ISB PM1	ISB Pilot Member 1
ISB PM2	ISB Pilot Member 2
LA	Legal Advisor
MC	Mishap Commander
MDO	Mishap Director of Operations
Mechanic 1	
Mechanic 2	
MED MBR	Medical Member
MFP1	Mishap Flight Pilot 1
MFP3	Mishap Flight Pilot 3
MFP4	Mishap Flight Pilot 4
MOSC1	Mishap On Scene Commander 1
MOSC2	Mishap On Scene Commander 2
MP	Mishap Pilot
MSOF	Mishap Supervisor of Flying

MX MBR	Maintenance Member
MXG QA	Maintenance Group Quality Assurance
NHBB Manager	
Notifier 1	
Notifier 2	
OGD	Operations Group Deputy
PM	Pilot Member
Pro Sup	Production Superintendent
RC	Range Controller
REC	Recorder
SIB AFE	SIB Aircrew Flight Equipment Member
SIB AFLCMC/EBHJ Advisor	
SIB AFLCMC/LPSEBB Advisor 1	
SIB AFLCMC/LPSEBB Advisor 2	
SIB AFRL/RXSA Advisor	SIB Air Force Research Laboratory Materials Integrity Branch Advisor
SIB AFSEC Advisor	SIB Air Force Safety Center Advisor
SIB AFSEC MAAF ADVISOR1	SIB Safety Center Mishap Analysis & Animation Facility Advisor 1
SIB AFSEC MAAF ADVISOR2	SIB Safety Center Mishap Analysis & Animation Facility Advisor 2
SIB AFSEC REP1	SIB Air Force Safety Center Representative 1
SIB AFSEC REP2	SIB Air Force Safety Center Representative 2
SIB BP	SIB Board President
SIB GE Advisor	SIB General Electric Advisor
SIB GL	SIB German Liaison
SIB HF	SIB Human Factors Member
SIB IO	SIB Investigating Officer
SIB LM Advisor 1	SIB Lockheed Martin Advisor 1
SIB LM Advisor 2	SIB Lockheed Martin Advisor 2
SIB MEDO	SIB Medical Officer
SIB MO	SIB Maintenance Officer
SIB PM	SIB Pilot Member
SIB REC1	SIB Recorder 1
SIB REC2	SIB Recorder 2
SME1	Subject Matter Expert 1
SME2	Subject Matter Expert 2
Superintendent	
W&B	Weight and Balance Authority
WG REP	Woodward Governor Representative
Wingman 1	
Wingman 2	
Wingman 3	
Witness 1	
Witness 2	
Witness 3	
Witness 4	
Witness 5	
Witness 6	
Witness 7	
Witness 8	
Witness 9	
Witness 10	
Witness Verifier	
WS1	Weapons Specialist 1
WS2	Weapons Specialist 2
WS3	Weapons Specialist 3
WS4	Weapons Specialist 4
WS5	Weapons Specialist 5
WS6	Weapons Specialist 6
WS7	Weapons Specialist 7
WS8	Weapons Specialist 8
WS9	Weapons Specialist 9
WS10	Weapons Specialist 10
WS11	Weapons Specialist 11
WS12	Weapons Specialist 12
WS13	Weapons Specialist 13
WS14	Weapons Specialist 14
WS15	Weapons Specialist 15
WS REP	Wing Safety Representative

The above list was compiled from the Summary of Facts, Statement of Opinion, Index of Tabs, and attached tabs.

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 4 December 2015, Major General Timothy M. Zadalis, Vice Commander, United States Air Forces in Europe-Air Forces Africa (USAFE-AFAFRICA), appointed Colonel Jill A. Long to conduct an aircraft accident investigation of the F-16CM aircraft mishap, tail number 91-0366, which occurred on 11 August 2015 near Grafenwoehr, Germany (Tab Y-3 to Y-5). The aircraft accident investigation was conducted in accordance with Air Force Instruction (AFI) 51-503, *Aerospace and Ground Accident Investigations*, and was convened at Spangdahlem Air Base (AB), Germany from 5 January 2016 through 18 February 2016 (Tab Y-3 and Y-8). The following board members were also appointed: Lieutenant Colonel Medical Member, Captain Pilot Member, Captain Legal Advisor, Senior Master Sergeant Maintenance Member, Master Sergeant Aircrew Flight Equipment (AFE) Member, and a Staff Sergeant Recorder (Tab Y-3). The USAFE-AFAFRICA Staff Judge Advocate appointed an F-16 Engine Propulsion Subject Matter Expert (SME) and a Main Engine Control SME on 13 January 2016 (Tab Y-6).

b. Purpose

In accordance with AFI 51-503, *Aerospace and Ground Accident Investigations*, this accident investigation board conducted a legal investigation to inquire into all the facts and circumstances surrounding this Air Force aerospace accident, prepare a publicly releasable report, and obtain and preserve all available evidence for use in litigation, claims, disciplinary action, and adverse administrative action.

2. ACCIDENT SUMMARY

On 11 August 2015, at approximately 0731 Zulu (Z), the mishap aircraft, a Block 50 F-16CM, tail number 91-0366, assigned to the 480th Fighter Squadron (480 FS), 52nd Operations Group (52 OG), 52nd Fighter Wing (52 FW), Spangdahlem AB, Germany, crashed on a training mission in a wooded area near Grafenwoehr, Germany (Tabs J-2, J-8, N-3, S-2 to S-4, and V-5.4). The mishap flight included: the flight lead - mishap flight pilot 1 (MFP1), mishap pilot (MP), mishap flight pilot 3 (MFP3), and mishap flight pilot 4 (MFP4) (Tabs K-2 to K-3, V-1.1, V-1.3, V-3.1, V-3.3, V-4.1, V-5.1, and V-5.4). The pilots, referred to by the pseudonyms of MFP1, MP, MFP3, and MFP4, are also designated by the following mission callsigns, respectively: ROCKY 01, ROCKY 02, ROCKY 03, and ROCKY 04. The flight took off as a four-ship at 0659Z to conduct a Basic Surface Attack mission in the airspace designated as EDR-136 near Grafenwoehr, Germany (Tabs R-10, V-3.3, and V-5.5). Upon entering the airspace, ROCKY 01 initiated a standard G-Exercise (G-Ex) maneuver (Tab V-3.3). During the first 90 degree turn of the maneuver, MP/ROCKY 02 noticed a loss of thrust and engine indications commensurate with an engine malfunction (Tab V-1.3). MP/ROCKY 02 immediately initiated a "Knock-It-Off" radio call at 0729:13Z (Tabs N-2 and V-1.3). ROCKY 01 initiated the required response procedures ending with MP/ROCKY 02 stating "2's got a major engine malfunction, I'm losing RPM now" (Tabs N-2 and V-1.3). MP/ROCKY 02 immediately sought a divert airfield while accomplishing the critical action procedures for the emergency (Tab V-1.4). The other mishap flight members assisted MP/ROCKY 02 by providing general direction to the nearest airfield and maintaining situational awareness for the flight (Tab V-4.3 and V-5.9). After realizing the mishap aircraft's engine would not restart, MP/ROCKY 02 turned the mishap aircraft in a direction to avoid damage to personnel and property on the ground (Tab V-1.4 and V-4.4). MP/ROCKY 02 ejected, sustaining only minor injuries (Tabs V-1.14 and X-4). The mishap aircraft was destroyed upon impact; the loss was valued at $39,796,422.00 (Tab P-4). Damage to non-US government property consisted of damage to trees, shrubbery, soil, and crops (Tabs S-4 to S-6, S-9 to S-10, V-38.4 to V-38.7, V-39.5 to V-39.7, and V-40.4 to V-40.6).

3. BACKGROUND

a. United States Air Forces in Europe-United States Air Forces Africa (USAFE-AFAFRICA)

With headquarters at Ramstein AB, Germany, USAFE-AFAFRICA is a major command of the United States Air Force and is the air component for two Department of Defense unified combatant commands: the US European Command (USEUCOM), which is responsible for US military relations with the North Atlantic Treaty Organization (NATO) and 51 countries on two continents; and the US Africa Command (USAFRICOM), which is responsible for building defense capabilities, responding to crises, and deterring and defeating transnational threats in order to advance US interests and promote security, stability, and prosperity in Africa (Tab CC-3 to CC-4 and CC-7). USAFE-AFAFRICA executes the Air Force, USEUCOM, and USAFRICOM missions with forward-based infrastructure and airpower to conduct and enable both global and theater operations. Combined USEUCOM and USAFRICOM cover more than 15 million square miles, encompass 104 independent states, and possess more than one-fifth of the world's population (Tab CC-3).

b. Third Air Force (3 AF)

Third AF is USAFE-AFAFRICA's component numbered air force, which provides airpower to USEUCOM and USAFRICOM. Based at Ramstein AB, Germany, 3 AF directs all USAFE-AFAFRICA forces engaged in contingency and wartime operations in the USEUCOM and USAFRICOM areas of responsibility. Along with its headquarters operations directorate, 3 AF is comprised of 10 wings, two groups, and an Air Operations Center (Tab CC-8).

c. 52nd Fighter Wing (52 FW)

The 52 FW maintains, deploys, and employs F-16 aircraft and TPS-75 radar systems in support of NATO and national defense directives. The wing supports the Supreme Allied Commander Europe with mission-ready personnel and systems providing expeditionary air power for suppression of enemy air defenses, close air support, air interdiction, counter-air, air strike control, strategic attack, combat search and rescue, and theater airspace control. The wing also supports contingencies and operations other than war when required (Tab CC-10).

d. 52nd Operations Group (52 OG)

The 52 OG consists of the 480th Fighter Squadron (480 FS), the 606th Air Control Squadron, and the 480th Operations Support Squadron (480 OSS). The 480 FS operates both C and D model F-16 (C/D) Fighting Falcon aircraft (Tab CC-12).

e. 480th Fighter Squadron (480 FS)

The 480 FS operates the Block 50, F-16CM Fighting Falcon, which is informally referred to as the Viper. As USAFE's only F-16 Block 50 squadron, the 480 FS provides the Supreme Headquarters Allied Forces Europe and USAFE commanders with dedicated suppression of enemy air defense, air interdiction, counter-air, and close air support capability (Tab CC-14).

f. F-16 Fighting Falcon

The F-16 Fighting Falcon is a highly maneuverable, multi-role fighter aircraft. It has proven itself in the air-to-air combat and air-to-surface attack roles and provides a "relatively low-cost, high-performance weapon system" for the US and allied nations (Tab CC-15 to CC-17).

4. SEQUENCE OF EVENTS

a. Mission

ROCKY flight, a flight of four F-16s assigned to the 480 FS, was scheduled to fly a Basic Surface Attack mission on 11 August 2015 to the Grafenwoehr Training Area (GTA) range, EDR-136 (Tabs K-2 and V-5.5). Each F-16 aircraft in ROCKY flight was configured for the air-to-surface mission with six lightweight practice bombs, BDU-33s, loaded on Triple Ejector Racks (TERs) (Tab K-4 and K-7). While on the range the mission is observed by a range control officer (Tab V-8.1). The range control officer on-duty the day of the mishap is referred to by the pseudonym "Range Controller" (Tab V-8.1).

b. Planning

On the morning of 11 August 2015, ROCKY flight attended a mass brief at 0500Z with GURU 01 flight, a flight of two F-16s scheduled for the same range complex twenty minutes after ROCKY flight (Tabs R-20, R-29, and V-6.1). The mass brief included information pertaining to weather, aircraft status, airspace, range issues, Notices to Airmen (NOTAMS), and divert airfield information (Tab V-6.1 and V-17.1). The weather forecast indicated visual flight rules (VFR) conditions at both Spangdahlem AB and GTA range (Tab F-12). The on-duty Operations Supervisor, or TOP-3, conducted the mass brief and did not note anything unusual the day of the mishap (Tab V-17.1 to V-17.2).

At approximately 0520Z, the mass brief concluded and ROCKY 01 began briefing the roles and responsibilities for their four-ship mission (Tab R-20). ROCKY 01 briefed all the required items to safely conduct the mission (Tab R-20). At 0540Z, ROCKY flight finished their brief and donned their flight equipment (Tab R-20). ROCKY flight submitted an Operational Risk Management (ORM) sheet identifying potential risks associated with flying operations (Tabs V- 17.1, V-18.3, and AA-5). The Operations Supervisor reviewed the ORM sheet and did not note anything which required higher authority approval or that precluded safe flying operations (Tabs V-17.1 and AA-5).

c. Preflight

MP/ROCKY 02 did not notice anything abnormal during his preflight inspection of the mishap aircraft and engine start was uneventful (Tab V-1.3 and V-1.10). During ground operations the pilot originally designated in the number two position of the formation, MFP4, found a maintenance issue with his assigned aircraft and moved to a spare becoming ROCKY 04 (Tab V-1.3, V-5.4, and V-5.5). MP/ROCKY 02, who was originally designated ROCKY 04, was renumbered and assigned the ROCKY 02 position (Tabs R-6, V-1.3, V-5.4, and V-5.5). Three F-16s in ROCKY flight taxied to the End of Runway (EOR) for final checks: ROCKY 01, ROCKY 02, and ROCKY 03 (Tabs R-6, V-1.3, and V- 5.5). ROCKY 04 joined the formation at the EOR, enabling ROCKY flight to depart as a four-ship of F-16s (Tabs R-6, V-1.3, and V- 5.5).

d. Summary of Accident

ROCKY flight took off from Spangdahlem AB at 0659Z on 11 August 2015 (Tab R-10). The airfield status was designated by the on-duty mishap supervisor of flying, as VFR with Ramstein as the divert airfield (Tab V-31.1). The observed weather included calm winds with unrestricted visibility (Tab F-12). Takeoff, departure, and navigation to the airspace were uneventful (Tab V-1.3 and V-4.3). The GTA range is approximately 200 miles from Spangdahlem AB (Tab V-1.3). In order to enter the range airspace and get below a few scattered clouds, ROCKY flight descended from cruise altitude to approximately 5,000 feet mean sea level (MSL) (Tabs F-12 and R-6).

Upon entering the range airspace, ROCKY flight members switched from München Center frequency to the Range Controller’s frequency, and began check-in procedures (Tab V-1.10). The Range Controller reported environmental conditions for the GTA range as: light and variable winds, unrestricted visibility, altimeter 29.99 [inches mercury, in. Hg], and no hazards associated with the airspace (Tab V-8.1).

ROCKY 01 directed his flight members to change their avionics from navigation mode to employment mode and to increase airspeed to 400 knots for the G-Ex (Tabs N-2, R-3, and V-5.5). The G-Ex is a required maneuver anytime five G's or more are anticipated during the mission, to test equipment under G-loading and prepare the pilot for higher G-loading later in the mission (Tabs V-5.5 and BB-9). The G-Ex consists of one 90 degree turn using four to five Gs, then a subsequent 90 degree turn up to the maximum allowable G-loading per the aircraft configuration (Tabs V-5.5 and BB-9).

ROCKY flight was flying in an offset container formation in order to conduct the G-Ex; MP/ROCKY 02 was in a line abreast position on the left side of ROCKY 01 (Tab V-4.6). At 0729:00Z ROCKY 01 called over the radio "For G warm up, 90 Left," which commanded ROCKY flight to begin the maneuver (Tab N-2). MP/ROCKY 02 advanced the throttle to Military (MIL) power, rolled his wings to an 80 degree bank angle, and then immediately noticed a loss of thrust as he was slung forward in the seat (Tab V-1.3 and V-1.8). MP/ROCKY 02 looked at the engine instruments and confirmed that the engine was operating below normal limits and was not responding to throttle position (Tab V-1.3). MP/ROCKY 02 initiated a "Knock-It-Off" call at 0729:13Z (Tab N-2). The Knock-It-Off procedure was executed by all flight members (Tab V-1.3 to V-1.4 and V-4.3 to V-4.4). ROCKY 01 acknowledged responsibility for deconfliction with the radio call "Rocky 2, Press" at 0729:26Z (Tabs N-2, V-3.3, and V-3.8). MP/ROCKY 02 radioed to flight members that his aircraft was experiencing "a major engine malfunction" and was losing Revolutions Per Minute (RPM) at 0729:30Z (Tab N-2).

ROCKY flight members promptly provided MP/ROCKY 02 with the heading to the nearest emergency divert airfield and notified the Range Controller of the emergency, specifically an engine malfunction with intentions of departing the airspace to the northwest (Tabs N-2, V-1.4, V-4.3, and V-5.9). ROCKY 01 collapsed to an emergency chase formation on the mishap aircraft in order to relay any visual anomalies (Tab V-3.3 and V-4.3). At that time, ROCKY 01 did not see anything abnormal with the mishap aircraft (Tab V-3.6 to V-3.7).

MP/ROCKY 02 immediately accomplished the critical action procedures for low thrust at low altitude; initiating two airstart attempts, with no signs of engine recovery (Tabs J-7, V-1.3, and V-1.4). MP/ROCKY 02 jettisoned fuel tanks at 0729:50Z (Tab J-7). ROCKY 03 notified the Range Controller of the jettisoned fuel tanks and directed ROCKY 04 to obtain coordinates for the jettisoned fuel tanks impact point (Tabs R-21, V-4.4, and V-5.9). MP/ROCKY 02 actuated the Jet Fuel Starter (JFS) at 0730:01Z and reported a "significant increase in thrust" at 0730:23Z (Tabs J-7 and V-1.4). MP/ROCKY 02 thought the mishap aircraft engine had recovered to normal operation (Tab V-1.4). Another loss of thrust occurred a few seconds later, which was confirmed by data displayed on the engine instruments (Tabs J-7 and V-1.3 to V-1.4). ROCKY flight members assisted MP/ROCKY 02 by confirming he had accomplished the restart procedures (Tab V-1.4). MP/ROCKY 02 initiated two more airstart attempts experiencing one more occurrence of a potential engine restart followed immediately by another engine malfunction (Tab J-7). At 0731:21Z MP/ROCKY 02 attempted a fifth, and final, unsuccessful airstart procedure (Tab J-7).

MP/ROCKY 02 determined an ejection was necessary but recognized that the mishap aircraft's flight path would place populated areas at risk (Tab V-1.4 and V-4.4). MP/ROCKY 02 maneuvered his aircraft to ensure the impact would avoid all populated areas (Tab V-1.4). Once the aircraft's flight path was satisfactory, MP/ROCKY 02 began to climb and slow for ejection (Tab V-1.4 and V-1.15). Once the ejection posture was obtained, the ejection sequence was initiated at 0731:40Z with an airspeed of 156 knots and approximately 400 feet above ground level (AGL) (Tabs J-7 and V-1.4). ROCKY 03 witnessed the ejection and notified the Range Controller that MP/ROCKY 02 had a good parachute and there was a downed aircraft (Tabs N-3 and V-4.4). ROCKY flight passed coordinates to the Range Controller, N 49-48.12 E011-38.30, to initiate Search and Recovery procedures (Tabs R-18, R-35, V-8.1, and V-8.3). The remaining ROCKY flight members requested that the Range Controller notify emergency crews while they orbited over the crash site and established communication with MP/ROCKY 02 on the ground, confirming he had no serious injuries (Tab V-4.4).

e. Impact

The mishap aircraft crash site was approximately 190 nautical miles east of Spangdahlem AB in a wooded area (Tab H-21). According the Range Controller, the crash site was located at coordinates N 49-48.12 E011-38.30 Elevation 1392 feet (Tab R-35). The mishap aircraft initially impacted trees at an attitude of 8 degrees nose low, approximately wings level, with a descending 22 degree flight path, and heading approximately 266 degrees true (Tab H-21). The debris stretched approximately 400 feet long and 200 feet wide along the mishap aircraft flight path (Tab J-3). The wings had separated from the mishap aircraft but were intact (Tab H-21). The aft fuselage, vertical tail, right horizontal tail, and engine were intact (Tab H-21). The mishap aircraft forward of the engine was broken into small pieces (Tab J-2). The canopy was located approximately 1,200 feet east of the crash site and the parachute was located approximately 1,590 feet east of the crash site (Tabs H-21 and J-3).

f. Egress and Aircrew Flight Equipment (AFE)

The ejection parameters were 156 knots calibrated airspeed (KCAS) and 2,200 barometric altitude (approximately 400 feet AGL) (Tab J-2). Based on these parameters, MP/ROCKY 02's Advanced Concept Ejection Seat II (ACES II) functioned properly using Mode 1 operation with no anomalies noted (Tab H-2 to H-8). MP/ROCKY 02 followed ejection procedures in accordance with training instructions (Tabs V-1.13 and BB-19 to BB-39). Upon checking for successful parachute operation, MP/ROCKY 02 identified and successfully corrected crossed risers (Tab V-1.13). Subsequently, MP/ROCKY 02 was able to verify a fully inflated canopy, the seat kit had deployed, and the life raft had inflated (Tab V-1.13). MP/ROCKY 02 lifted his visor, removed his mask, and prepared for a parachute landing fall position (Tab V-1.13). A German citizen assisted MP/ROCKY 02 with successfully securing all aircrew flight equipment (Tab V-1.14 to V-1.15). The equipment worn by MP/ROCKY 02 was recovered from the crash site (Tab H-19). All inspections were current and performed by qualified AFE technicians (Tab H-19). Minor documentation errors were noted on the drogue parachute and the ACES II Survival Kit which did not affect proper operations or deployment (Tab H-19 to H-20).

A post-crash analysis was performed on all equipment (Tab H-19). The Joint Helmet Mounted

Cueing System (JHMCS) helmet was cracked on the left side (Tab H-19). The ACES II Survival Kit internal components were unused and found to be serviceable (Tab H-19). The attached life raft was found deflated but showed the bottle had operated properly (Tabs H-19 and V-1.13). The Air Ace Survival Vest was fitted with the Combat Survival/Evader Locater (CSEL) radio, which MP/ROCKY 02 confirmed operated properly by transmitting on frequency 282.8 (Tabs H-19 and V-1.13).

g. Search and Rescue (SAR)

The crash occurred at approximately 0731Z (Tabs J-8 and N-3). Approximately two to three minutes after ejection, MP/ROCKY 02 was able to establish communications with ROCKY 03 on the guard frequency using his CSEL radio (Tab V-1.13 to V-1.14). MP/ROCKY 02 informed ROCKY 03 that no serious injuries were sustained during the ejection (Tab V-1.13 to V-1.14). The crash site coordinates were relayed by the mishap flight to the Range Controller, who then informed the 52 FW Commander that he would coordinate with fire, police, environmental, and both the US Army and German Bundeswehr [military] (Tab R-35). First responders arrived on scene within minutes of initial notification (Tab V-1.14 and V-4.4). MP/ROCKY 02 was transported by German ground ambulance to Bayreuth Hospital (Tab R-35).

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

A thorough review was conducted of the mishap aircraft's active Air Force Technical Order (AFTO) 781 series forms; no discrepancies were noted (Tab D-3 to D-17). There were seven open Time Compliance Technical Orders (TCTOs) in the active forms, none of which restricted the mishap aircraft from flying operations (Tab D-15 to D-17). Additionally, there was no overdue hourly or calendar scheduled maintenance (Tab D-13 to D-14). Integrated Maintenance Data System (IMDS) historical records for the 90 days prior to the mishap were also reviewed and revealed no previous maintenance discrepancies that could be correlated to the mishap (Tab U-16). The work package cover sheets, checklists, daily maintenance summaries, and IMDS documentation during the time the engine was in the Jet Engine Intermediate Maintenance (JEIM) shop showed all appropriate maintenance had been accomplished (Tab U-4 to U-5 and U-16).

b. Inspections

The total airframe operating time prior to the mishap was 6,469.2 hours (Tab D-11). The mishap engine was a F110-GE-129 engine, serial number GE0E538149, and was installed into the mishap aircraft on 5 September 2014 (Tab J-38 to J-39). The mishap engine had 3,456.6 hours total engine operating time and 271.6 flight hours remaining before its next scheduled 400 hour engine phase inspection (Tab D-11 and D-13). Phase inspections are regularly scheduled maintenance inspections performed at a 400 flight-hour interval on this mission design series aircraft (Tab BB-43).

Prior to being placed in the mishap aircraft on 5 September 2014, the mishap engine had 11 TCTOs completed, one time change component was replaced, and four additional scheduled inspections accomplished (Tab U-4 to U-5). After overhaul, a thorough test of the engine was conducted and revealed no abnormalities (Tab U-6).

On 20 April 2015, the following maintenance actions were accomplished: an 800-hour engine exhaust nozzle inspection, a 100-hour engine borescope inspection, a 25-hour joint oil analysis program (JOAP) sample test, and two engine TCTOs, with no abnormalities noted in the documentation (Tab U-14 to U-16).

On 10 August 2015, maintenance personnel performed a combined preflight/basic postflight inspection on the mishap aircraft (Tab D-3). This type of inspection is valid for 72 hours and was valid at the time of the mishap mission (Tab BB-41). The on-duty Production Superintendent signed the Exceptional Release to release the aircraft from maintenance to the pilot (Tabs D-3 and V-16.1). This release certifies that the active maintenance forms were reviewed and the aircraft was safe for flight (Tab BB-18).

The last maintenance technicians to inspect the aircraft prior to takeoff were the end of runway (EOR) crew (Tab BB-42). The EOR crew is responsible for removing the safety pins from any munitions loaded on the aircraft and checking for any obvious discrepancies, such as open doors and panels or incorrect hydraulic systems pressure; the EOR crewmembers stated they did not note anything abnormal about the mishap aircraft (Tab V-13.1 and V-15.1).

c. Maintenance Procedures

Summaries of the Main Engine Control's (MEC) work control documents, dating 29 August 2013 to 17 December 2013, and the MEC Test to Overhaul to Test Notes, dating 27 June 2013 to 10 December 2013, were reviewed (Tab J-80 to J-84). During that time, an overhaul of the component was accomplished along with TCTOs 6J3-4-120-504 and 6J3-4-120-505 by personnel assigned to the 552nd Commodities Maintenance Squadron, 76th Commodities Maintenance Group, 76th Maintenance Wing at the Oklahoma City Air Logistics Complex at Tinker AFB, Oklahoma (Tab J-80 to J-96). During the overhaul process, there were five instances where the MEC failed test/calibration procedures and was returned for further maintenance (Tab J-80 to J-84). It was noted by maintenance and test personnel at the facility at Tinker AFB that test failures are not uncommon; however, multiple failures for the same fault are rare (Tabs V-24.2, V-26.1, V-33.2, and GG-11). Additionally, when the necessary maintenance corrections have been completed, the MEC will go through all test/calibration procedures and only be placed in service once it has successfully passed re-testing (Tab V-26.1 to V-26.2).

According to the AFLCMC/LPSEBB *MEC Overhaul and Test Shop Visit Report*, the MEC failed test/calibration on 27 June 2013 for compressor discharge pressure (CDP), on 24 July 2013 for CDP, on 15 August 2013 for CDP, on 10 September 2013 for tachometer calibration, and on

19 October 2013 for CDP (Tab J-84). Each time corrective actions were taken and subsequent testing/calibration was conducted, with the final testing and validation taking place on 17 December 2013 (Tab J-80 to J-84). After passing the final testing, the MEC was re-stamped with a new part number per TCTO 6J3-4-120-505, marked as serviceable, and returned to service (Tabs J-93 to J-96 and U-3).

The mishap engine was inducted into the JEIM facility on 29 January 2014 (Tab U-4). On 11 July 2014, the overhauled MEC was installed on the mishap engine (Tab J-76).

Starting on 30 July 2014, the mishap engine went through post-maintenance engine run and operational checks; all appropriate inspections and checks were completed with no anomalies noted (Tab U-6 and U-16). Following operational testing the engine was preserved for storage and sent to the spare engine line on 1 August 2014 (Tab U-16). On 8 August 2014, a non-serially tracked line was replaced and the engine was sent to the test cell section to accomplish a follow up leak check (Tab U-16). All necessary leak checks were accomplished and no defects were noted. The engine was preserved and returned to the spare engine line on 8 August 2014 (Tab U-16).

On 5 September 2014, the engine was installed on the mishap aircraft (Tab J-39). The engine was later removed in order to facilitate other maintenance [not associated with the engine] on 29 January 2015 and again on 30 April 2015; after each subsequent reinstallation no engine defects were noted (Tab U-16).

d. Maintenance Personnel and Supervision

Interviews conducted with maintenance personnel indicated all preflight activities were normal and no anomalies with personnel or aircraft were noted (Tab V-9.1, V-11.1, V-12.1, V-13.1, V-14.1, V-15.1, and V-16.1). Training records were reviewed for all maintenance personnel who serviced and maintained the mishap aircraft, as well as the JEIM members who installed the mishap MEC, and all were fully qualified (Tab T-3 to T-23 and T-130 to T-190).

Training records for the MEC depot maintenance facility workers and test members at Tinker AFB, Oklahoma who overhauled the mishap MEC were reviewed and all personnel were qualified (Tabs G-56 to G-59 and T-191 to T-208). Training procedures at the maintenance facility were reported as conducted “on-the-job” (Tab V-27.1 and V-33.1). The maintenance facility’s quality assurance program at Tinker AFB includes documented bi-annual personnel evaluations and random quality assurance verification inspections (Tab V-26.2 and V-30.1). Some personnel from the maintenance facility interviewed reported appropriate resources and training were available to perform their assigned duties (Tab V-24.1, V-27.1, V-28.1, V-32.1, V-33.1, and V-34.1). However, one worker interviewed reported several problems with available resources, including old test stands that would frequently break and consistently leak, old and bent tools, and inaccurate gauges used to calibrate the tachometer and speed (Tab V-26.1).

e. Fuel, Hydraulic, and Oil Inspection Analyses

Fuel samples were taken and tested post-mishap from all equipment used to refuel the mishap aircraft including the fuel truck, the upper hydrant system fill stand, and the aircraft (Tab U-7 to

U-13). All samples were within technical data limits and free from contamination (Tab U-7 to U-13).

The post-impact fire prevented analysis of aircraft oil samples; however, all oil servicing equipment was sampled and within technical limits (Tab U-14). A review was conducted of the mishap aircraft's records to include: the AFTO 781, the Non Destructive Inspection Records, and the associated records on teardown and inspection of the engine; there was no evidence of excessive contaminants, oil consumption, or other negative trends associated with the mishap engine (Tabs J-38 to J-71 and U-14).

f. Unscheduled Maintenance

A review of all maintenance actions performed on the mishap engine that were not the result of a scheduled inspection revealed two instances of such unscheduled maintenance accomplished on the mishap engine (Tab J-41). The first took place on 22 October 2014, when the augmentor fuel control (AFC) was replaced due to an aircraft maintenance fault listing (MFL) 082 "Sig AFC" and MFL 018 "Aug Inhib" (Tab J-41, J-73, and J-75). The second instance took place on 8 December 2014, when the engine T4B pyrometer was replaced due to a MFL 013 "Trend Fault" (Tab J-41 and J-73). Neither maintenance action was associated with the main engine control.

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

According to post-flight analysis, the mishap aircraft was destroyed upon impacting the ground (Tab J-2). The aircraft crashed into a heavily wooded area on a slight uphill slope, resulting in a small debris field approximately 400 feet by 200 feet at its widest points (Tab J-2 to J-3). The aircraft forward of the engine was severely broken apart, with pieces ranging in size from a few inches to a few feet (Tab J-2). The aft portion of the fuselage, vertical tail (with the rudder still attached), right horizontal tail, and engine were in one piece, although the lower portion was severely damaged by the impact and post-impact fire (Tab J-2 and J-19). Both aircraft wings separated from the aircraft (Tab J-2). "The left wing of the aircraft hit several trees during the descent" (Tab J-2). The left wing was found with the left leading edge flaps still attached; however, the left flaperon was detached from the left wing (Tab J-2 and J-19). The right wing was found with the right leading edge flaps and right flaperon still attached (Tab J-2 and J-19). The left horizontal tail separated from the rest of the aircraft's empennage but was found lying next to the aircraft (Tab J-19). The Digital Flight Control System Accumulator was found intact in the tail section and was not removed (Tab J-24). The MP's main parachute was located approximately 1,590 feet from the site of aircraft impact (Tabs H-21 and J-3). The canopy was found generally intact with two longitudinal cracks in the transparency and several smaller cracks in the canopy frame, approximately 1,200 feet from the aircraft (Tab J-3).

The recovered wreckage was returned to Spangdahlem Air Base (Tab J-48 and Q-2). The Crash Survivable Flight Data Recorder (CSFDR) and the Digital Flight Control Computer (DFLCC), commonly referred to as the Seat Data Recorder (SDR), were recovered and sent for analysis (Tab J-6, J-12, and J-13).

The Digital Flight Recorder (DFR), Modular Mission Computer (MMC), and Programmable Display Generator (PDG) were recovered but the extent of the damage prevented recovery of data from these systems. Therefore, the stored information on these devices was not available for analysis (Tab J-19).

The Signal Acquisition Unit (SAU), Data Transfer Cartridge (DTC), Generator Control Unit (GCU), and Emergency Power Unit (EPU) were not recovered (Tab J-12, J-19, and J-25).

The Main Engine Control (MEC), Modernized Digital Engine Control (MDEC), and Modernized Engine Monitoring System Computer (MEMSC) were recovered and sent to the original equipment manufacturers for analysis (Tab J-68). The Jet Fuel Starter (JFS) was recovered and examined by Lockheed Martin (Tab J-21). Two fuel samples were taken from the aircraft wreckage and sent to the Air Force Petroleum Agency for analysis (Tab U-7 to U-10).

b. Evaluation and Analysis

(1) Recorded Data

Based on analysis of the data retrieved from the CSFDR and the SDR, the mishap aircraft was operating normally from takeoff to a flight time of approximately 29 minutes (Tab J-17). Various fault indications and stale source data from the Embedded Global Positioning System/Inertial Navigation System (EGI), indicated a loss of 115-volt Alternating Current (AC) Bus No. 1 power to the Central Air Data Computer (CADC), 28-volt Direct Current (DC) Emergency DC Bus No. 1 power to the EGI and Emergency DC Bus No. 2 power to the Store Enhancement Relay 2756K2 (Tab J-17). As stated in *Lockheed Martin Aeronautical Company Report of F-16C 91-0366 Mishap Investigation,* Summary of SDR Data:

> Indications of a loss of electrical power without Integrated Servoactuator (ISA) faults indicated the engine was operating in a sub-idle range. Electrical power was restored to the CADC and EGI within approximately 2.5 seconds, which is the typical delay for starting the emergency power unit and for the emergency generator to come on line. Pilot ejection occurred between the last recording of the mishap flight (MF) at 0:31:30 and the next scheduled recording at 0:31:45. The flight control system was functioning through the time of pilot-initiated ejection (Tab J-17).

A recording anomaly in the CSFDR data was observed in the throttle signal. The recorded values were consistently low by between 15-18 degrees (Tab J-11 to J-12). This anomaly was consistent with previous occasions where this was noted and it was determined that the throttle potentiometer had been mis-rigged (Tab J-11). This signal; however, "only goes to the CSFDR and it does not affect engine performance" (Tab J-11).

(2) Flight Control Surfaces

According to Lockheed Martin Aeronautics Company, "all flight control surfaces were found at the crash site" (Tab J-19). An examination of the flight control surfaces included: the leading edge flaps; speedbrakes; and the ISAs for the right and left flaperons, the right and left horizontal tail, and the rudder (Tab J-19 to J-20). Lockheed Martin concluded that all flight controls were functioning properly at the time of the mishap and the speedbrakes were closed at the time of ground impact (Tab J-19 to J-20 and J-25 to J-26).

(3) Landing Gear

The CSFDR and DFLCC indicated that the landing gear handle was in the up position (Tab J-25). "The landing gear actuators were in the up position and landing gear door actuators were in the closed position, indicating the landing gear was in the up position" (Tab J-25).

(4) Fuel System

The CSFDR recorded a fuel quantity of 8,192 pounds at 0729:12.63Z, shortly after the engine roll back (Tab J-22). "Fuel flow just prior to engine roll back was 10,688 pounds per hour" (Tab J-22). After roll back, "fuel flow was in the idle to sub-idle range with the exception of the two engine restarts" (Tab J-22). The Master Fuel Switch was "on" and the Main Fuel Shutoff Valve (MFSOV) was in the "fully open" position (Tab J-22 to J-23). Analysis determined fuel flow system to the main engine control was normal until the time of impact (Tabs J-25 and GG-5).

(5) Hydraulic System

The System A hydraulic reservoir was filled to approximately 44% of volume and the System B hydraulic reservoir was filled to approximately 61% of volume, which is considered to be a normal fill level (Tab J-24). Both the CSFDR and the SDR data indicated that both hydraulic systems were operating properly (Tab J-24 and J-26).

(6) Electrical Systems

The CSFDR and DFLCC data showed that the electrical system was operating properly at the time of impact (Tab J-24).

(7) Emergency Power System (EPU)

The EPU was not recovered; however, the CSFDR data was intact and indicated that the EPU was operating normally (Tab J-25).

(8) Propulsion Interface

The engine was returned to Spangdahlem Air Base and disassembled for inspection (Tabs J-48 and Q-2). It was determined that both system A and B hydraulic pumps maintained approximately 1700 psi (Tab J-20). The CSFDR recorded an "Engine Flameout" MFL at 0729:11.62Z and approximately 38 seconds later, the "HYD A/Eng Oil LOW discrete" was set due to low oil pressure (Tab J-20). The JFS compressor and JFS brake accumulators were examined. The examination determined that there was no evidence of pre-impact damage (Tab J-21 to J-22 and J-25).

(9) Engine

The following items were inspected by the Air Force Life Cycle Management Center/F-110 Engineering Section (AFLCMC/LPSEBB) and were found to have no pre-impact damage: fan, compressor, combustor, high pressure turbine (HPT), low pressure turbine (LPT), augmentor/exhaust nozzle, main engine bearings, accessory gear box, fuel tubes and manifolds, air tubes and manifolds, oil tubes and manifolds, as well as various engine accessories specifically listed in Tab J-70 (Tab J-49 to J-71).

The following engine accessories were either not found or were unidentifiable: the fuel boost pump (FBP), the fuel/oil cooler, and the oil level/temperature sensor (Tab J-70). The electrical cables associated with the engine were severely damaged; therefore, no determination as to pre-impact condition could be assessed (Tab J-70).

(a) Modernized Digital Engine Control (MDEC)

According to AFLCMC/LPSEBB, The MDEC was “distorted and fused with slag from other engine accessories and airframe components due to the post-impact fire” (Tab J-68). The MDEC housing burned through in multiple places, exposing the internal circuit cards (Tab J-68). The MDEC was sent to the original equipment manufacturer, Honeywell International, Inc., in order to attempt recovery of the data; however, due to extensive fire damage no data was recovered (Tab J-68).

(b) Modernized Engine Monitoring System Computer (MEMSC)

According AFLCMC/LPSEBB, the MEMSC was “distorted, burned through and the circuit cards were damaged due to impact and the post-impact fire” (Tab J-69). The MEMSC was sent to the original equipment manufacturer, Hamilton Sundstrand, to attempt recovery of the data; however, due to extensive fire damage no data was recovered (Tab J-69).

(c) Main Engine Control (MEC)

Due to post-impact fire, the MEC was distorted and fused with slag from other engine accessories and airframe components (Tab J-67 to J-68). The MEC was also burned through, exposing internal MEC components (Tab J-68). The MEC was sent to the original equipment manufacturer, Woodward Governor, Inc., for teardown and analysis (Tab J-68).

General Electric Aviation and Woodward Governor, Inc. conducted analysis and teardown of the MEC, using standard disassembly techniques whenever possible (Tab J-132). Due to the degree of post-impact fire damage, the majority of the teardown involved non-standard techniques including cutoff wheels and pry bars (Tab J-132). The hydroclone filter assembly was found to be heavily damaged by the impact and post-impact fire (Tab J-132 to J-133). The hydroclone filter assembly and overspeed trip set screw showed either no-abnormalities/damage or the abnormalities/damage were determined to be unrelated to component failure (Tab J-68 and J-133). The overspeed trip set screw was “still engaged” and CFSDR data shows the overspeed trip mechanism was functioning per design before impact (Tabs J-43 to J-47, J-68, and GG-9).

The MEC is a sophisticated hydro-mechanical computer (Tab GG-6). The MEC is bolted to the engine gearbox and is rotated by an input shaft from the gearbox (Tab GG-6). The MEC senses core speed in the tachometer system, using the rotating input shaft connected to the gearbox. When the sensed speed from this input shaft exceeds 113%, the overspeed mechanism will activate, shutting off fuel flow to the engine combustor (Tab GG-6). The overspeed trip mechanism is designed to initiate at 113% RPM and reset when the core speed drops below 55% RPM (Tab GG-5 and GG-9). However, according to the CSFDR data the MEC was sending the 113% RPM signal to the overspeed trip mechanism when the actual RPM reached 102% causing the engine to roll back to approximately 35% RPM (Tabs J-43 to J-46 and GG-9). These erroneous signals were caused by contamination found on the flyweight within the tachometer assembly of the tachometer ballhead (Tab GG-9). These flyweights rotate from the input shaft, providing centrifugal force, which moves the pilot valves – ultimately leading to a three-dimensional fuel cam, which the main engine control computer uses to set fuel flow and to trigger the overspeed trip (Tab GG-6). The flyweights in the tachometer system operate within a precisely calculated system based on centrifugal force; any material changes in the mass of the flyweights will upset this system (Tab GG-9). The additional mass on the flyweight caused the MEC to sense an RPM higher than actual, which triggered early activation of the overspeed trip mechanism (Tab GG-9).

Activation of the overspeed trip mechanism ceases all fuel flow to the engine combustor (Tab GG-12). The energy released from the combustion of the fuel with air produces high energy combustion gases, which can then be accelerated in the exhaust nozzle to produce engine thrust (Tab GG-12). This complete cessation of fuel flow made airstart attempts impossible, as the engine requires fuel to start and operate (Tab GG-12). Once the core speed dropped below 55%, the overspeed mechanism would reset, allowing fuel flow to the engine once again (Tab GG-12). However, selecting an EPLA setting above idle would cause the engine to accelerate to the point where the overspeed trip would once again prematurely activate, shutting off the fuel to the engine again (Tab GG-12). This sequence of events would make airstarts ultimately unsuccessful, as the engine would repeatedly shut off unless left at an idle setting (Tab GG-12). The engine, at idle, only produces minimal thrust by design, and keeping the engine at idle would not produce enough thrust to sustain flight (Tab GG-12).

The governor ballhead assembly was removed and inspected (Tab J-133). The governor ballhead assembly contains a matched set of duplex bearings which allow the governor ballhead to rotate, and are referred to as an "upper," or inboard, and "lower," or outboard, bearing (Tab GG-8). The outboard-side (lower) governor ballhead bearing cage was found to be fractured and liberated from the bearing (Tab J-133 to J-134). Personnel at the Woodward Metallurgical Lab visually inspected a one-inch sector of the lower governor ballhead bearing cage and did not find any evidence of fatigue (Tab J-134). The fracture surface was so heavily smeared that the exact nature of the fracture could not be determined (Tab GG-8). During inspection of the governor ballhead bearings, the ‘V’ markings were found to indicate the bearings were installed in the correct orientation (Tab J-135). The governor ballhead bearing cages are a two-piece design (Tab GG-8). The governor ballhead inboard (upper) side of the lower governor bearing cage was found to be loose between the two bearings, resulting in wear marks on the cage (Tab J-135 to J-136). The tachometer assembly was removed and inspected, along with the flyweight location, and contact damage to the snap ring and laminate shims of the unit were found (Tab J-137). The tachometer ballhead was sent to Woodward Metallurgical Lab for further evaluation, where a light metal spray of copper (Cu) and silver (Ag) was found on the inside diameter of the flyweight (Tab J-137). The tachometer ballhead bearing and flyweights were disassembled for further evaluation (Tab J-138). During this evaluation, a witness mark and a metal particle were found on the underside of the tachometer ballhead flyweight (Tab J-138 to J-139). This metal particle was consistent with the governor ballhead bearing cage material or shim lamination material (Tabs J-139). The tachometer ballhead bearing was inspected under further magnification and a small piece of material was found loose in the bearing (Tab J-139). This small piece of material was removed for analysis by the Woodward Metallurgical Lab and was found to match the recovered piece of the bearing cage from the failed lower governor ballhead bearing (Tab J-139).

The MEC uses internal fuel pressures to perform internal functions (Tab GG-9). These internal fuel pressures are used through the MEC (Tab GG-9). This requires internal passages within the MEC to port these fuel pressures to the various areas of the MEC that utilize the internal fuel pressures for proper MEC function, in addition to a lubrication function (Tab GG-9). The governor system and tachometer system interact directly with each other via these MEC internal fuel pressures (Tab GG-9).

According to the Air Force Research Laboratory's *F-16 Main Engine Control (MEC) Bearing Failure (Failure Analysis) Report*, they concluded that "failure of the lower [governor ballhead] bearing retainer (cage) [within the lower ballhead bearing cage] occurred before ground impact" (Tabs J-105 and GG-8) and that migration of the retainer cage fragment through a gear to a different location would not occur during an impact event (Tab J-105).

AFLCMC/LPSEBB's *Engine Investigation Report* concluded the engine RPM was at sub-idle at the time of impact; the engine was not responding to commanded throttle setting at time of impact; no pre-impact turbomachinery distress was observed during engine teardown; and the abnormal engine response observed is consistent with failure of the MEC overspeed trip system (Tab J-71).

(10) Escape System

The CSFDR recorded the beginning of the pilot-initiated ejection sequence at 0731:40.13Z (Tab J-25). See section 4.f. above for details.

7. WEATHER

a. Forecast Weather

Forecast weather conditions for takeoff and landing at Spangdahlem AB on 11 August 2015 met visual meteorological conditions (VMC) (Tab F-12). Based on this forecast the, mishap supervisor of flying declared the status at Spangdahlem AB as VFR with Ramstein AB designated as the alternate (Tabs R-27 and V-31.1). Winds at Spangdahlem AB were expected to be calm, less than 10 knots, out of the northwest with no significant weather and unrestricted visibility (Tab F-12). The forecast weather from 1,000 feet up to 40,000 feet in the EDR-136 airspace was expected to have a few clouds from 7,000 feet to 9,000 feet with light winds out of the west trending to the southeast (Tab F-6 and F-12). All applicable divert bases were forecasted to be VMC (Tab F-8). No turbulence, icing, thunderstorms, or any other hazards were forecasted (Tab F-12).

b. Observed Weather

Checking into the airspace on 11 August 2015, MP observed unrestricted visibility with "scattered to light clouds" above his flight level (Tab V-1.5). Surface winds were light and variable in EDR-136 with clear visibility and an altimeter setting of 29.99 in. Hg (Tab V-8.1). Before and after the mishap, observed conditions were calm to light winds out of the northwest with unrestricted visibility, clear skies, and no significant weather (Tab F-12). Additionally, no rapid changes in pressure or any other hazards were observed (Tab F-12).

c. Space Environment

Not applicable.

d. Operations

The mishap flight conducted the mission within the prescribed operational weather limitations in accordance with paragraph 5.3.1 of AFI 11-214, *Air Operations Rules and Procedures* (Tab BB-10).

8. CREW QUALIFICATIONS

All members of ROCKY flight were current and qualified four-ship flight leads (Tabs G-2 and V-17.1). MP, MFP3, and MFP4 were experienced per requirements found in paragraph 6.2, AFI 11-2F-16, Volume 1, *Flying Operations, F-16-Pilot Training* (Tabs G-2 and BB-4). Additionally, MFP3 and MFP4 were current and qualified instructor pilots, with MFP3 being a graduate of the Weapons Instructor Course (Tabs G-2, V-4.2 to V-4.3, and V-5.2). MFP4 was Chief of Standards and Evaluations and a current and qualified flight examiner (Tabs G-2 and V-5.2 to V-5.3). The Operations Supervisor considered the overall experience level of members in ROCKY flight to be "high" (Tab V-17.1 to V-17.2).

MP had a total of 675.0 flight hours, was an experienced four-ship flight lead, and was qualified as a Supervisor of Flying (Tab G-2 and G-5). On the day of the mishap, MP had completed all required training, pilot read files, monthly critical action procedures, and was up-to-date in all currencies for the type of mission assigned (Tab G-48 to G-54). MP completed an instrument qualification evaluation on 26 November 2014, a no-notice mission evaluation on 12 June 2014, and was certified as a qualified combat-mission pilot with no discrepancies noted during either evaluation (Tab G-23 to G-26).

In the 90 days preceding the mishap, MP's flying history in the F-16 was summarized as:

F-16	Hours	Sorties
Last 30 Days	14.6	10
Last 60 Days	28.3	18
Last 90 Days	48.5	33

(Tab G-6)

9. MEDICAL

a. Qualifications

Based on a review of the MP's medical record, MP was medically qualified for flying duty at the time of the mishap as annotated on AF Form 1042 Medical Recommendation for Flying or Special Operational Duty dated 2 March 2015 (Tab X-3 and X-5). The most recent Periodic Health Assessment (PHA) was accomplished 2 March 2015, at which time he was medically cleared (Tab X-3). MP's last dental exam was accomplished on 29 June 2015, with a Dental Classification of 1; indicating no unresolved dental health problems (Tab X-3). MP possesses one waiver for medical conditions inconsistent with flying duty (Tab X-3). This waiver was initiated as a Flying Class One waiver and granted by Air Education and Training Command (AETC) on 14 July 2009 (Tab X-3). Upon graduation from Undergraduate Pilot Training (UPT), the waiver was changed to a Flying Class Two waiver and was renewed on 29 March 2012 by AETC and again on 16 March 2015 by USAFE with a current expiration date of 31 March 2018 (Tab X-3).

b. Health

A medical record review and an interview of MP indicate he was in excellent health prior to the mishap (Tabs V-2.1 and X-4). According to the PHA on 2 March 2015, he exercised regularly and ate a healthy diet (Tabs V-2.1 and X-4). As previously stated in section 9.a. above, MP was determined to be medically qualified for flight duty at the time of the accident (Tab X-3). A review of the post-accident medical examination record revealed only minor post-accident injuries – cervicalgia (pain in the neck); no pre-accident injuries were noted (Tab X-4). MP was treated at a local national facility, observed overnight, and released the following day (Tab X-4). The 480 FS flight surgeon returned MP to flight status on 18 August 2015 (Tab X-4).

c. Pathology

All mishap flight members and maintainers associated with the mishap aircraft provided samples for toxicology testing. All samples were negative (Tab X-3 to X-4).

d. Lifestyle

During MP's interview, no evidence was presented to suggest MP's habits, behaviors, stress-level, or lifestyle were factors the day of the mishap (Tabs V-2.1 and X-4).

e. Crew Rest and Crew Duty Time

During MP's interview, MP stated he obtained 8 to 9 hours of sleep and 13 to 14 hours of crew rest prior to reporting for duty on the day of the accident (Tab V-2.1). The amount of sleep the MP obtained and his subsequent crew rest met the requirements of paragraph 2.1, AFI 11-202, Volume 3, *General Flight Rules* (Tab BB-7).

10. OPERATIONS AND SUPERVISION

a. Operations

The 480 FS Director of Operations considered the operations tempo of the unit to be moderately-high to high at the time of the mishap (Tab V-17.1). MP had been assigned temporary duty, away from home station, a total of 119 days of the preceding 365 days (Tab G-55). MP's most recent temporary duty was 30 days in duration, ending on 5 August 2015, to a large force exercise where MP performed flight duties (Tabs G-55 and V-2.1). At the time of the mishap, the 480 FS had 45 pilots (27 assigned and 18 attached), of which 34 were experienced and 19 of the experienced pilots were also instructor pilots (Tab G-2).

b. Supervision

The 480 FS Operations Supervisor validated all aircrew were qualified to execute assigned flight duties in accordance with paragraph 4.4.5 of AFI 11-418, *Flying Operations–Operations Supervision* (Tabs G-48 and BB-45). Furthermore, a review of Certification of Aircrew Qualifications, aircrew currencies, Go/No-Go Summary, and training records confirmed all members of the mishap flight were trained and qualified to accomplish the assigned mission (Tab G-48 to G-54).

11. HUMAN FACTORS ANALYSIS

Human Factors were evaluated using the Department of Defense Human Factors Analysis and Classification System: acts, preconditions, supervision, and organizational influences (Tab BB-14 to BB-16). The AIB Medical Member reviewed the following evidence: toxicology reports and medical and dental records for all mishap flight members, including MP, and maintainers associated with the mishap aircraft; 17 72-hour and 14-day histories; and the Aeromedical Information and Medical Waiver Tracking System of MP. Additionally, the AIB Medical Member was present for MP's 72-hour and 14-day history interview before the AIB. Based on the evidence reviewed, the AIB Medical Member did not note any anomalies or evidence of adverse human factors (Tab X-3 to X-5).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

AFI 11-2F-16, Volume 1, *Flying Operations, F-16-Pilot Training*, 20 April 2015
AFI 11-202, Volume 3, *General Flight Rules*, 7 November 2014
AFI 11-214, *Air Operations Rules and Procedures*, 14 August 2012
AFI 11-418, *Flying Operations–Operations Supervision*, 14 October 2015
AFI 51-503, *Aerospace and Ground Accident Investigations*, 14 April 2015
AFI 91-204, *Safety Investigations and Reports*, 12 February 2014, *Corrective Actions Applied on 10 April 2014*

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

DoD HFACS, Version 7.0, 12 February 2014
T.O 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures*, 15 October 2015
T.O. 1F-16CJ-6-11, *Scheduled Inspection and Maintenance Requirements USAF Series F-16C and F-16D Using F110-GE-129/129B Engine Block 50*, 1 November 2013, *with Change 5, dated 1 November 2015* (partially redacted)
USAFE Code of Conduct Continuation Training Instructor Guide, *Operations Support, Emergency Parachute Training*, 1 March 2011

c. Known or Suspected Deviations from Directives or Publications

None.

4 August 2016

JILL A. LONG, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

F-16CM, T/N 91-0366
NEAR GRAFENWOEHR, GERMANY
11 AUGUST 2015

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 11 August 2015, an F-16CM tail number 91-0366, assigned to the 52nd Fighter Wing, Spangdahlem Air Base, Germany experienced an unrecoverable engine malfunction while on a local training mission near Grafenwoehr, Germany. The mishap resulted in pilot ejection and a total loss of the aircraft. After approximately 29 minutes of flight, the mishap pilot experienced a loss of thrust. Five attempts were made by the mishap pilot to restart the failed engine. Prior to ejection the mishap pilot maneuvered the aircraft away from populated areas; ejecting at 156 knots calibrated air speed and approximately 400 feet above ground level. The mishap pilot sustained minor injuries. Search and Recovery efforts were facilitated by local German nationals, the German Bundeswehr, and the US Army. The mishap aircraft was destroyed upon impact; the loss was valued at $39,796,422.00. Damage to non-US government property consisted of damage to trees, shrubbery, soil, and crops.

After analyzing technical reports, engineering evaluations, parametric data, physical evidence, Air Force Instructions, Air Force Technical Orders, maintenance reports, maintenance records, aircrew training and qualifications, statements about operations and supervision, medical reports, human factors, visual media, witness testimony, and weather reports – I find by a preponderance of evidence that the cause of the mishap was a structural failure of the bearing cage within the lower governor ballhead bearing. This structural failure caused the main engine control to malfunction, which prohibited fuel flow to the engine. The lack of fuel flow prevented engine restart and resulted in a complete loss of thrust, requiring the mishap pilot to eject from the mishap aircraft.

2. CAUSE

Data extracted from the Crash Survivable Flight Data Recorder (CSFDR) indicated that the mishap aircraft's engine was operating in a sub-idle condition at the time of ground impact. [Note: A sub-idle condition indicates the engine components are free to rotate but the engine is not producing sustainable thrust.] This sub-idle condition was caused by early activation of the overspeed trip mechanism in the main engine control unit.

Early activation was recorded by the CSFDR, which showed engine core speed "roll back" (the term roll back is used here as a steady deceleration or reduction in RPM) consistent with overspeed trip mechanism activation. The overspeed trip mechanism is designed to initiate at 113% RPM and reset when the core speed drops below 55% RPM. However, according to the CSFDR data the MEC was sending the 113% RPM signal to the overspeed trip mechanism when the actual RPM reached 102% causing the engine to roll back to approximately 35% RPM.

In accordance with the design, the main engine control senses core speed via the tachometer system which receives data via the rotating input shaft connected to the engine gearbox. Flyweights rotate from the input shaft, providing centrifugal force which moves the pilot valves – ultimately leading to a three-dimensional fuel cam which the main engine control computer uses to set fuel flow and to trigger the overspeed trip.

The flyweights in the tachometer system operate within a precisely calculated system based on centrifugal force; any material changes in the mass of the flyweights will upset this system. During metallurgical lab analysis a witness mark and a metal particle were discovered on the tachometer ballhead flyweight denoting contact with a foreign object. The lab also identified a particle of foreign material loose in the tachometer ballhead bearing. The witness mark, along with material particles, affected the flyweights' mass causing the Main Engine Control to record a higher RPM than actual; thus, commanding early activation of the overspeed trip mechanism.

Technical and engineering analysis shows that one of the duplex bearings in the main engine control governor system failed. Specifically, the governor cage located in the lower governor bearing fractured. In the analysis, it is postulated that pieces of the cage were liberated and migrated into the tachometer system. The tachometer system and the governor system interact with one another via the fuel within the main engine control system which flows from one system to the other freely for lubrication purposes as well as its primary function of providing metered fuel to the engine.

The material found in the tachometer system was analyzed by personnel at Woodward Metallurgical Lab and found to be consistent with the alloys characteristic of the lower governor ballhead bearing's fractured bearing cage. While a direct correlation could not be assigned due to the destructive nature of the bearing cage fracture, I infer that the witness mark on the tachometer ballhead flyweight and the material found on the flyweight and ballhead bearing in the tachometer system were a result of liberated particles in the lower governor ballhead bearing.

It is my opinion that the reason for failure of the bearing cage within the lower governor ballhead bearing cannot be determined due to the destructive nature of the cage fracture. There simply is not enough material evidence remaining to permit further analysis

3. CONCLUSION

I find, by a preponderance of evidence, that the cause of the mishap was a structural failure of the bearing cage in the lower governor ballhead bearing within the main engine control. This structural failure caused the main engine control to malfunction, which prohibited fuel flow to the engine.

The lack of fuel flow prevented engine restart and resulted in a complete loss of thrust, requiring the mishap pilot to eject from the mishap aircraft.

4 August 2016

JILL A. LONG, Colonel, USAF
President, Accident Investigation Board

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