UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

F-16C T/N 87-0306

121ST FIGHTER SQUADRON
113TH WING
JOINT BASE ANDREWS, MARYLAND

LOCATION: CLINTON, MD

DATE OF ACCIDENT: 5 APRIL 2017

BOARD PRESIDENT: COLONEL DAVID V. COCHRAN

Conducted IAW Air Force Instruction 51-503

[Volume One of Two]

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

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19 OCT 2017

ACTION OF THE CONVENING AUTHORITY

The Report of the Accident Investigation Board, conducted under the provisions of AFI 51-503, that investigated the 5 April 2017 mishap involving F-16C, T/N 87-0306, 121st Fighter Squadron, 113th Wing, Joint Base Andrews, Maryland, complies with applicable regulatory and statutory guidance; on that basis it is approved.

//Signed//

JOHN K. MCMULLEN
Major General, USAF
Deputy Commander

United States Air Force Accident Investigation Board Report

F-16C Mishap, Clinton, MD

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

F-16C, T/N 87-0306
CLINTON, MD
5 APRIL 2017

On 5 April 2017, at 09:13 hours local time (L), an F-16C impacted the ground southwest of Joint Base Andrews (JBA), in Clinton, Maryland (MD). The mishap pilot (MP) safely ejected and did not sustain any injuries. The mishap aircraft (MA) tail number 87-0306 and the MP are assigned to the 113th Wing, 121st Fighter Squadron, JBA, MD. The MA, valued at $22,198,075, was destroyed. The MA's two external fuel tanks were jettisoned prior to MP ejection and impacted private property located east of the Potomac River shoreline and approximately 1,750 feet south of National Harbor, MD. The MA impacted a wooded area 3.4 nautical miles southwest of JBA. There were no personnel injured on the ground. The area upon which the MA and external fuel tanks landed was disturbed by the respective impacts, resulting fireball (from the MA), and associated fluids and debris. The environmental clean-up cost was $856,777.

The mishap occurred as part of a four aircraft F-16 formation on departure from JBA. The flight was planned as a basic surface attack training mission to be conducted at Fort Indiantown Gap (Restricted Area: R-5802), Pennsylvania. The MA was the number two aircraft in the formation. During the departure, the MA experienced an uncommanded engine acceleration, followed by a loss of thrust. The uncontrollable engine resulted in an engine core overspeed, over temperature, fire and engine failure. The distance to the nearest suitable recovery airfield was beyond MA glide capabilities, negating any chance of safely recovering the MA. The MP successfully executed a controlled ejection at 09:16:55 L, after maneuvering the disabled MA over a non-residential area.

JBA first responders arrived on scene at the MP's location at 09:26 L. The MP was evacuated by the 1st Helicopter Squadron (1 HS), which was conducting a local training mission with a flight surgeon onboard. The 1 HS transported the MP to JBA for further evaluation by medical personnel at Malcom Grow Medical Center.

The Accident Investigation Board President found by a preponderance of evidence the cause of this mishap was the incorrect assembly of the main engine control (MEC) differential pressure pilot valve, which was missing a required 600-degree retaining ring and the anti-rotation pin. The misassembled differential pressure pilot valve caused the MEC to malfunction and to incorrectly meter abnormally high fuel flow to the engine. The uncontrolled engine operation caused severe engine overspeed, severe engine over-temperature, and engine fire, which resulted in a catastrophic engine failure. A substantially contributing factor to the mishap was the 552d Commodities Maintenance Squadron, MEC Overhaul Shop, Oklahoma City, Air Logistics Complex, lack of an adequate procedural requirement for MEC parts accountability.

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
F-16C, T/N 87-0306
5 APRIL 2017

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

1 HS	1st Helicopter Squadron
113 WG	113th Wing
121 FS	121st Fighter Squadron
201 MSS	201st Mission Support Squadron
7 AOA	7 Degrees Angle of Attack
9 AF	9th Air Force
ΔP	Differential Pressure
AB	Afterburner
AC	Aircraft
ACA	Aerospace Control Alert
ACC	Air Combat Command
ACM	Air Combat Maneuvers
ACT	Aerospace and Commercial Technologies
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFLCMC	Air Force Life Cycle Management Center
AFMES	Armed Forces Medical Examiner System
AFSC	Air Force Specialty Code
AGL	Above Ground Level
AGR	Active-Guard Reserve
AIB	Accident Investigation Board
AMXS	Aircraft Maintenance Squadron
AOA	Angle of Attack
ARC	Air Reserve Component
ARTS	Air Reserve Technicians
ASIMS	Aeromedical Services Information Management System
AT	Annual Training
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATO	Air Tasking Order
Aux	auxiliary
Avg	Average
BDU	Bomb Drop Unit
BFM	Basic Fighter Maneuvers
BSA	Basic Surface Attack
CAF	Combat Air Forces
CAMS	Consolidated Aircraft Maintenance System
CANN	Cannibalization
CAP	Critical Action Procedure
CAT	Crisis Action Team
CBT	Computer Based Training
CDU	Center Display Unit
CE	Civil Engineering
CEM	Chief Enlisted Manager
CFCC	Commercial Fire Control Computer
CDN	Combustor Discharge Nozzle
CMMXS/MXDPAA	Commodities Maintenance Squadron, MEC Overhaul Shop
CMMXG	Commodities Maintenance Group
CMR	Combat Mission Ready
CND	Could Not Duplicate
COM	Communication
Comm	Communications
CPU	Central Processing Unit
CRM	Crew Resource Management
CSAR	Combat Search and Rescue
CSFDR	Crash Survivable Flight Data Recorder
CSMU	Crash Survivable Memory Unit
CT	Continuation Training
CTK	Consolidated Tool Kit
DC	District of Columbia
DCA	Ronald Reagan National Airport
DEC	Digital Electronic Control
DIFMS	Due In From Maintenance
DETCO	Detachment Commander
DNIF	Duty Not Involving Flying
DO	Director of Operations
DP	Differential Pressure
DPH	Director of Psychological Health
DR	Deficiency Report
DSG	Drill Status Guardsman
DSV	Direct Safety Violation
EGT	Exhaust Gas Temperature
EMSC	Engine Monitoring System Computer
EOR	End of Runway
EP	Emergency Procedure
EPA	Environmental Protection Agency
EPE	Emergency Procedures Evaluation
EPR	Enlisted Performance Report
EPU	Emergency Power Unit

ETIC	Estimated Time in Commission
FCC	Flight Control Computer
FCIF	Flight Crew Information File
FDT	Fan Discharge Temperature
FEVER	Fluids, EGT, Vibration, Erratic Roughness
FI	Fault Isolation
FLUG	Flight Lead Upgrade
FMC	Flight Management Computer
FO	Flame-Out Landing
FOD	Foreign Object Debris
FTIT	Fan Turbine Inlet Temperature
FWIC	Fighter Weapons Instructor Course
G	Gravity
GABS	Ground Aborts
GE	General Electric
HFACS	Human Factors Analysis Classification Systems
HMIT	Helmet Mounted Integrated Targeting
HPT	High Pressure Turbine
HRO	Human Resources Office
HUD	Heads Up display
HYB	Hybrid
HYD	Hydraulic
IDO	Installation Deployment Officer
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
IG	Inspector General
IMDS	Integrated Maintenance Data System
In. Hg	Inches of Mercury
IP	Instructor Pilot
IPUG	Instructor Pilot Upgrade
ISA	International Standard Atmosphere
ISB	Interim Safety Board
JBA	Joint Base Andrews
JFS	Jet Fuel Starter
JST	Job Standard
K	Thousand
KCAS	Knots Calibrated Air Speed
KEAS	Knots Equivalent Air Speed
KTS	Knots
LAO	Local Area Orientation
LCAP	Logistics Compliance Assessment Program
LOA	Letter of Admonishment
LOC	Letter of Counseling
LOR	Letter of Reprimand
LPT	Low Pressure Turbine
LRS	Logistics Readiness Squadron
LRU	Line Replaceable Unit
MA	Mishap Aircraft
MAMC	Mishap Aircraft Maintenance Crew
MC	Master Caution
MDEC	Modernized Digital Electronic Control
MEC	Main Engine Control
MESL	Minimum Essential Subsystem List
MF	Mishap Flight
MFL	Maintenance Fault List
MICAP	Mission Capability
MICT	Management Internal Control Toolset
MIL	Military Power Setting
MIS	Maintenance Information System
MND	Maintenance Non-Delivery
MOA	Military Operations Area
MOC	Minimum Obstruction Clearance
MOCC	Maintenance Operations Control Center
MOD	Modular
MOF	Maintenance Operations Flight
MOO	Maintenance Operations Officer
MP	Mishap Pilot
MQT	Mission Qualification Training
MSEP	Maintenance Standardization and Evaluation Program
MSG	Mission Support Group
MSL	Mean Sea Level
MX	Maintenance
MXG	Maintenance Group
MXS	Maintenance Squadron
N1	Fan Speed
N2	Engine Core
NCR	National Capitol Region
NF	Fan Shaft
NMC	Non-Mission Capable
NORAD	North American Aerospace Defense Command
NOTAM	Notices to Airman
OC-ALC	Oklahoma City – Air Logistics Complex
OG	Operations Group
OGV	Standardization and Evaluation
OIC	Officer in Charge
OPR	Officer Performance Report
OPS	Operations
OPS O	Operations Officer
Org	Organization
ORM	Operational Risk Management

OSC	On Scene Commander
P1	Pilot 1
P3	Pilot 3
P4	Pilot 4
PAA	Primary Assigned Aircraft
PAC	Production Acceptance Certification
PACAF	Pacific Air Forces
PAX	Passenger
PCDS	Personal Computer Debrief System
PDU	Power Display Unit
PEX	Patriot Excalibur (software)
PHA	Periodic Health Assessment
PLA	Power Level Angle
PLF	Parachute Landing Fall
PMC	Partially Mission Capable
POC	Point of Contact
PPH	Pounds Per Hour
PR	Preflight Inspection
PS&D	Plans, Scheduling and Documentation
PWIG	Product Improvement Working Group
QA	Quality Assurance
QDR	Quality Deficiency Report
QE	Quality Evaluation
R2'd	Removed and Replaced
RAP	Ready Aircrew Program
RPM	Revolutions Per Minute
RSD	Regularly Scheduled Drill
RSU	Runway Supervisory Unit
RTM	Tasking Memorandum
SA	Situational Awareness
SAPR	Sexual Assault Prevention Response
SAR	Search and Rescue
SARCAP	Search and Rescue Combat Air Patrol
SCU-9	Software Capability Upgrade 9
SDC	Signal Data Converter
SEC	Secondary Mode
SEPT	Supplementary Emergency Procedure Training
SFO	Simulated Flame-Out Landing
SIB	Safety Investigation Board
SID	Standard Instrument Departure
SII	Special Interest Item
SIM	Simulator
SM	Statute Mile
SME	Subject Matter Expert
SMS	Stores Management System
SOF	Supervisor of Flying
SPEC	Specifications
SPINS	Special Instructions
SSI	Safety Special Interest
STAB	Horizontal Stabilizer
Stan-Eval	Standardization and Evaluation
SORTS	Status of Resources and Training System
SUP	Supplement
T4B	Pyrometer
TAC	Tactical
TACV	Total Accumulated Cycles Since Overhaul
TAD	Tactical Awareness Display
TAR	Training Accomplishment Report
TBA	Training Business Area
TBC	Thermal Barrier Coating
TCMAX	Tool Control Max
TCTO	Time Compliance Technical Order
TFI	Total Force Integration
TO	Technical Order
TOD	Time of Day
TSP	Theatre Security Package
UH-1	Helicopter Type Designator
UHF	Ultra High Frequency
UTA	Unit Training Assembly
UTC	Unit Type Code
VFR	Visual Flight Rules
VHF	Very High Frequency
VSV	Variable Stator Vane
WoW	Weight on Wheels

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

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 19 May 2017, the Vice Commander, Air Combat Command (ACC), appointed Colonel David V. Cochran to conduct an aircraft accident investigation of the 5 April 2017 mishap of an F-16C Block 30 aircraft, in Clinton, Maryland (MD) (Tab Y-2). On 19 May 2017, the Accident Investigation Board (AIB) convened at Joint Base Andrews (JBA), MD. A maintenance member (Lieutenant Colonel), legal advisor (Major), pilot member (Captain), medical member (Lieutenant Colonel), and a recorder (Staff Sergeant) were appointed to the board (Tab Y-2). Subject Matter Experts (SME) in maintenance documentation (Senior Master Sergeant), the General Electric (GE) F110-GE-100C engine (Civilian Employee), and F110-GE-100C main engine control (MEC) (Civilian Employee) were appointed on 5, 6, and 19 June 2017 respectively (Tabs Y-6 to Y-8). The Convening Order was amended on 13 June 2017, to appoint the maintenance SME as the maintenance member (Tab Y-4). The AIB was conducted in accordance with Air Force Instruction (AFI) 51-503, *Aerospace and Ground Accident Investigations*, dated 14 April 2015, and AFI 51-503, *ACC Supplement, Aerospace and Ground Accident Investigations*, dated 28 January 2016.

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 5 April 2017, an F-16C+ Block 30 tail number (T/N) 87-0306 assigned to the 121st Fighter Squadron (121 FS), 113th Wing (113 WG), JBA, MD, departed JBA as number two of a four aircraft formation on a day, basic surface attack (BSA) training mission (Tabs J-34 and AA-4). Shortly after takeoff, the mishap aircraft (MA) experienced abnormal engine response, with apparent high thrust inconsistent with commanded throttle positions (Tab J-34, J-39 to J-43). This progressed to an engine core (N2) overspeed and an in-flight engine failure (Tab J-39 to J-43). The MA then experienced a severe in-flight engine fire that extended 20 to 30 feet aft of the aircraft, which was extinguished approximately 35 seconds later (Tabs N-2 to N-3 and R-21 to R-24). The mishap pilot (MP) ejected at 1,950 feet mean sea level (MSL) (Tabs H-8, J-34, N-3, and V-1.9). The MP suffered no injuries from the ejection and the MA was destroyed on impact (Tabs J-34, Q-6.1.3, and V-11.1). There were no military or civilian casualties as a result of the mishap (Tab X-7). The loss to the government was $22,198,075 (Tab P-2). Environmental clean-up costs are $856,777.06 (Tab EE-2).

3. BACKGROUND

a. Air Combat Command

ACC is the primary force provider of combat airpower to America's warfighting commands (Tab CC-2). To support global implementation of national security strategy, ACC operates fighter, bomber, reconnaissance, battle-management, and electronic-combat aircraft (Tab CC-2). It also provides command, control, communications and intelligence systems, and conducts global information operations (Tab CC-2). ACC's mission is to support global implementation of national security strategy (Tab CC-2). ACC operates over 1,300 aircraft across 34 wings and 19 bases, comprising over 94,000 active duty and civilian personnel (Tab CC-2).

b. 113th Wing

The 113 WG executes one of the most diverse flying missions in the Air National Guard (Tab CC-7). The 113 WG provides exceptional lift to enable global engagement of national leaders, provide resilient fighters and support forces capable of rapid global employment and support to the District of Columbia and local communities (Tab CC-7). The 113 WG is composed of 1,300 personnel, including both full-time and drill-status members, contractors, and state employees (Tab CC-7).

c. 121st Fighter Squadron

The 121 FS flies the F-16C Fighting Falcon, and provides 24/7 alert fighter defense of the National Capital Region while simultaneously providing a worldwide deployable fighter capability to meet expeditionary fighter requirements (Tab CC-8).

d. F-16 Fighting Falcon

The F-16 Fighting Falcon is a compact multi-role fighter aircraft (Tab CC-10). It is highly maneuverable and has proven itself in air-to-air combat and air-to-surface attack (Tab CC-10). It provides a relatively low-cost, high performance weapon system and air demonstration capabilities for the United States and allied nations (Tab CC-10).

4. SEQUENCE OF EVENTS

a. Mission

The mishap pilot (MP) was number two of a four aircraft (4-ship) formation departing JBA, MD on 05 April 2017, for a continuation training BSA mission to Fort Indiantown Gap range (R5802) (Tabs R-6, AA-4, BB-12, and BB-19). The flight planned to accomplish simulated basic unguided bomb attacks followed by low angle strafe attacks with training ammunition in the aircraft gun (Tabs R-6, R-52, and AA-4). The 121 FS Director of Operations (DO), the senior duty officer in charge of squadron operations, authorized the mission in accordance with (IAW) the F-16 Block 25-42 Ready Aircrew Program Tasking Memorandum (Tabs K-3 and BB-20).

b. Planning

Pilot 1 (P1) and Pilot 3 (P3) began mission planning for the sortie the day prior IAW Air Force Tactics, Techniques, and Procedures (AFTTP) 3-3.F-16, *Combat Aircraft Fundamentals F-16*, and finalized planning the morning of the mishap, to include filling out a range line-up card and a range coordination sheet (Tabs R-5, R-52, and BB-22 to BB-25). P1 prepared a briefing room with these materials to brief the formation on the mission specifics (Tab R-5). A mass brief was given by the Supervisor of Flying (SOF), which was attended by the 121 FS DO and the mishap flight (MF) (Tab R-5, R-52). At the mass brief; the current and forecasted weather; as well as the Notices to Airmen (NOTAMS) at JBA, Fort Indiantown Gap (R5802), and local divert airfields were briefed (Tabs F-2 to F-9 and AA-7 to AA-16). Following the mass brief, P1 briefed the MF on the mission specific details using a personal briefing guide (Tab R-6).

c. Preflight

The MF finished their flight brief uneventfully and proceeded to the operations desk for their step brief, where the SOF provided the up to date weather and NOTAMS (Tab R-7). P1 filled out the requested flight plan, which was sent to base operations for filing (Tab K-2). An Operational Risk Management (ORM) worksheet was completed and the risk was assessed as low for the flight (Tab AA-3). The aircraft assigned for P1, MP, and P3 were F-16C models configured with two 370 gallon wing fuel tanks, 240 rounds of training ammunition in the gun, 30 chaff cartridges, and 45 flares, while Pilot 4's (P4) aircraft was an F-16D two-seat variant with a single external 300-gallon centerline fuel tank (Tabs R-52 and AA-4). After receiving the weather and NOTAMS update, the MF stepped to their aircraft for preflight and engine start (Tab R-7 and R-52 to R-53).

During pre-flight, the MP noted only one anomaly annotated within the MA Air Force Technical Order (AFTO) 781 series maintenance documentation forms, which was a head-up display (HUD) rate sensor unit with no gun symbology discrepancy, that the MP planned to operationally check later in the flight (Tab V-1.3).

d. Summary of Accident

The MF taxied to the arming area and then continued to runway 01 left (RWY01L) uneventfully (Tab R-7). There were no abnormal indications observed by the MP or other members of the MF during taxiing (Tabs R-53 and V-1.3). On the taxi to RWY01L from the arming area, P1 received an update to the weather at JBA via the automatic terminal information service (ATIS) Bravo, which stated winds were 330 (northwest) at 7 knots, 10 statute miles (SM) of visibility, skies clear, and an altimeter setting of 29.91 inches of mercury (in. Hg) (Tab R-19).

P1 took off at approximately 09:12 L and began to follow the standard instrument departure procedures for the Camp Springs 1 departure out of JBA (Tabs K-2, N-2, and R-7 to R-8). The MP waited 20 seconds IAW P1's brief before selecting max afterburner (AB) and beginning the takeoff roll (Tabs R-8 and V-1.3). The MA crash survivable flight data recorder (CSFDR) recorded a takeoff time of 09:13:12 L for the MA with the engine operating normally in AB (Tabs J-39, R-53, and V-1.3). Approximately four seconds after weight off wheels for the MA, the engine monitoring system computer (EMSC) recorded engine faults which indicated the MA's engine had transitioned to a hybrid (HYB) mode of operation, experienced a pyrometer (T4B) over temperature, and a fan shaft (NF) overspeed (Tabs J-39, J-47, and BB-28). The F110-GE-100C engine HYB mode of operation is activated when the digital electronic control (DEC) detects certain failures with the engine (Tab BB-27). In HYB mode, the main engine control (MEC) provides main engine fuel flow scheduling and metering, and variable stator vane (VSV) control (Tab BB-27). The reported faults caused a master caution (MC) light to display, with an associated engine fault caution light (Tab J-47). The MP remembered seeing the MC at some point on the departure and recalled only seeing an avionics caution light and the Identification Friend or Foe caution light on the caution panel (Tab V-1.3). MP acknowledged the MC and warning lights by depressing the MC light, but was not concerned at this time because of his knowledge of the HUD rate sensory unit discrepancy (TAB V-1.3). The MP moved the throttle from AB to its military power setting approaching 300 knots calibrated air speed (KCAS) and continued with the departure, making a left turn to heading 270 (west) with no perceived indications of engine abnormalities (Tabs J-40, R-53 to R-54, and V-1.3).

While on the 270 heading (west), the MP recalled feeling the engine accelerate as if in AB, inconsistent with the current throttle setting, and observed the airspeed increasing through 420 KCAS (Tabs J-40 and V-1.4). During this time, the EMSC recorded abnormally high fuel flow of 16,320 pounds per hour (PPH), also inconsistent with the current throttle setting (Tab J-40). At 09:14:17 L, the EMSC recorded a fan speed (N1) overspeed of 110.50% revolutions per minute (RPM), which initiated an engine core roll back to 61.5% RPM, a sub-idle condition (Tab J-41). The MP recognized the engine RPM roll back, felt a loss of thrust and made a radio call to P1 stating, "Lead, my engine's giving out" (Tabs N-2, R-8, R-54, and V-1.4). The MP executed critical action procedures for a low altitude engine failure by jettisoning the external wing fuel tanks to decrease weight and increase glide distance, while beginning a left turn south towards JBA (Tabs N-2, R-9 to R-10, R-55, and V-1.6). The external wing fuel tanks landed approximately one half-mile south of National Harbor, MD, in two separate locations (Tabs N-3 and Z-3). One landed in a residential area between two houses and the other landed in a wooded area; neither tank hit anything (Tabs N-3 and Z-3).

P1 acknowledged MP's radio call and directed P3, who was approximately two miles behind the MA, to rejoin and chase the MP (Tabs N-2, R-8, and R-54). The 121 FS standard is to "chase up the line," meaning with a 4-ship, if the lead aircraft has a problem on takeoff or departure number 2 assists (Tab R-30 to R-31). If number 2 has a problem, number 3 assists (Tab R-30 to R-31). The MP was approximately eight to nine nautical miles from JBA, at approximately 6,520 feet MSL, at the time of reporting the engine problem to P1 (Tab J-41). The 121 FS does not use Ronald Reagan Washington National Airport as an emergency divert for engine flame-out situations due to the longest runway length being only 7,170 feet (Tabs R-9, R-16, R-64, R-81, and V-1.7). The MF pilots stated that, in a simulated flame-out landing or flame-out landing situation, attempting to land on runways less than 8,000 feet without aircraft arresting gear provides insufficient distance to safely stop the aircraft (Tabs R-16, R-64, and V-1.7).

As P3 began to rejoin with the MP, P1 and P3 both noticed a large, bright orange flame extending 20 to 30 feet aft of the MA (Tab R-8 to R-9, R-21, R-54, and R-57 to R-59). P3 notified the MP "you've got a fire" and the MA EMSC recorded an exhaust gas temperature, displayed to the pilot as fan turbine inlet temperature, of 1,290 degrees Celsius (Tabs N-2 and J-42). The MP had no other indications inside the cockpit that the MA's engine was on fire (V-1.8). P1 then declared an emergency with Air Traffic Control and began to deviate from the flight clearance to assist P3 and the MP (Tab N-2 to N-3). The MP now had compounding emergencies of a low altitude engine failure and an engine fire as the airspeed decreased through approximately 196 KCAS at an altitude of 5,800 feet MSL (Tabs J-42 and V-1.9).

At 09:15:35 L, the MP placed the throttle to the cut-off position in response to the engine fire reported by P3, extinguishing the engine fire (Tabs J-42, N-3, and V-1.9). After realizing his current energy state was not adequate to safely recover the aircraft back to JBA, the MP radioed the MF and stated, "My engine's off, I'm at 180 knots and 4,800 feet. Do you think I can make it?" (Tabs N-3, R-55, and V-1.9). P3 immediately responded with "No" (Tabs N-3 and R-55).

The MP described shifting mindsets from a flame-out landing to a controlled ejection, with the intent to point the MA away from populated areas to avoid collateral damage (Tab V-1.9). The MP observed an open field nearby, and began to maneuver the MA towards the field (Tabs R-10 and V-1.9 to V-1.11). The MA was still maneuverable because the emergency power unit (EPU) provided hydraulic pressure to the flight controls after the throttle was moved to cutoff position (Tab J-55). The EPU automatically activates when both main and standby generators fail or when both hydraulic system pressures fall below 1000 pounds per square inch (Tab J-55).

At 09:16:44 L, the MP radioed the MF stating, "I'm not going to make it. I'm at 2,000 feet, I'm punching," notifying the MF that the MP would be ejecting from the aircraft (Tabs N-3 and V-1.11). The MP ejected from the MA at 09:16:55 L at 1,950 feet MSL, followed by the MA pitching downward to a nose down, wings level attitude, and impacting the ground at 09:17:06 L, three minutes and 54 seconds after takeoff (Tabs H-8 and J-42).

e. Impact

The MP ejected at 09:16:55 L, at 1,950 feet MSL and approximately five nautical miles southwest of JBA (Tabs H-8, J-3, and J-42). The MA impacted a wooded area in Clinton, MD, 3.4 nautical miles from JBA (Figure 1), with a descent angle of about 60 degrees nose low (Tabs J-35, S-2, and Z-3). Due to the steep impact angle, the radome, cockpit, and forward fuselage sections of the aircraft folded beneath the engine and aft fuselage (Figure 2) (Tab J-35 and S-2). The right wing was in two pieces and the left wing was mostly intact (Tab J-5). The aft fuselage, vertical tail, left horizontal stabilizer and engine were in one piece (Tab J-5). There was evidence of a post impact fire found on numerous locations of the aircraft and surrounding area (Tabs N-5 and J-36). The impact crater was approximately 25 feet long and 25 feet wide, and the debris field was oblong in shape, approximately 500 feet long and 200 feet wide (Tab J-36).

Figure 1 – Aerial view of crash site (Tab S-2)

Figure 2 – Ground level view of MA crater site (Tab S-2)

The MP jettisoned both external wing fuel tanks, which landed approximately one half-mile south of National Harbor; one landed in a residential area between two houses (Figure 3), and the other landed in a wooded area (Figure 4) (Tabs N-3, Z-3, Z-6, and Z-14).

Figure 3 – Wing external fuel tank impact site 1 (Tab Z-6)

Figure 4 – Wing external fuel tank impact site 2 (Tab Z-14)

f. Egress and Aircrew Flight Equipment (AFE)

After assessing that the MA was not going to make it back to JBA, the MP successfully ejected at 1,950 feet MSL and 155 KCAS, landing in a field nearby the MA impact site with no injuries (Tabs H-8, R-10, V-1.11, and X-7). At that altitude and airspeed, the Advanced Concept Ejection Seat II digital recovery sequencer selected a Mode 1 ejection sequence (Tab H-8). Mode 1 operation is for ejections with speeds less than 250 knots equivalent air speed at sea level and for altitudes from zero to 15,000 feet MSL (H-3). The aircraft canopy, ejection seat and aircraft wreckage were recovered and moved to a hanger on JBA where the egress system was evaluated (H-5). Analysis identified no anomalies, discrepancies, or noncurrent inspections with the egress system or aircrew flight equipment and all equipment functioned properly and according to specifications (Tabs H-5 to H-8 and DD-1 to DD-47).

g. Search and Rescue (SAR)

The MP ejected at 09:16:55 L, and the MA impacted the ground 10 seconds later (Tab J-42 to J-43). The initial on-scene commander search and rescue role was P1, circling above the MA impact site below 6,000 feet MSL, with P3 and P4 circling above the site in the altitude block 7,000 feet MSL to 8,000 feet MSL providing support (Tabs N-4, R-10 to R-11, R-55, and AA-5). Once the MP was on the ground, five eyewitness civilians approached the MP to offer assistance, and then P3 made radio contact with the MP to get an assessment of any injuries (Tabs R-12, R-56, and V-1.11). At 09:17:14 L, P1 notified the 121 FS SOF of the MP ejection and location of the MA impact (Tab N-3). P1 observed a Park Police helicopter land near where the MP came down in the parachute one to three minutes after the MP was on the ground (Tabs N-5 and R-12). Three to four personnel came out of this helicopter to meet the MP, and helped to collect the MP's parachute and other AFE gear (Tab R-12).

Approximately five to ten minutes after the MP ejected, 2 UH-1 helicopters from the 1st Helicopter Squadron (1HS), JBA, arrived on scene with one landing next to the Park Police helicopter and the other remaining airborne overhead (Tab R-12). The 1 HS helicopter that landed had an experienced flight surgeon on board, who performed an initial on scene injury assessment on the MP observing no injuries (Tab V-1.11 and V-11.1). The 1 HS then transported the MP to JBA where medical and fire rescue personnel transported the MP to Malcom Grow Medical Center (JBA) for further evaluation (Tabs R-12 to R-13 and V-1.11). The SOF activated the 113 WG crash network, notified the 113 WG command post, and executed their emergency checklist (Tab AA-5 to AA-6). Local and JBA emergency personnel arrived at the field where the MP landed to restrict traffic from the surrounding roads and secure the site, while the fire department arrived at the MA impact site to extinguish the post-impact fire (Tabs R-13 and AA-6).

h. Recovery of Remains

Not Applicable.

5. MAINTENANCE

a. Forms Documentation

AFTO Form 781 series collectively provide a maintenance, inspection, service, configuration, status, and flight record for the particular aerospace vehicles for which they are maintained (Tab BB-5). The Integrated Maintenance Data System (IMDS) is a comprehensive database used to track maintenance actions, flight activity, and to schedule future maintenance (Tab BB-6).

Review of applicable AFTO 781 forms revealed two overdue radar threat warning system inspections (180 day and 12 month), neither of which were factors in the mishap (Tabs D-8 and BB-7 to BB-10). Review of IMDS data for the MA covering a 30-day period prior to the mishap revealed maintenance documentation was properly accomplished under applicable maintenance directives (Tab U-5 to U-22).

Review of Time Compliance Technical Orders (TCTOs) indicated none were required at the time of the mishap (Tab U-34). Historical records showed all TCTOs were accomplished IAW applicable guidance (Tabs D-35 to D-41 and U-34). Records indicated the mishap engine (ME), serial number (S/N) 509307, went through a modernized digital engine control (MDEC) upgrade to comply with TCTO 2J-F110-838 on 31 March 2017, and had accumulated 0.0 flight hours prior to the mishap (Tabs D-25 and U-3 to U-4).

Prior to the mishap, the MA had accumulated 6183.0 flight hours (Tabs D-3 and U-3 to U-4). The ME was installed in the MA on 20 June 2016; it accumulated an engine operating time of 7608.7 hours and total accumulated cycles since overhaul of 3617 (Tab J-3).

b. Inspections

The pre-flight inspection (PR) mandates a visual examination of the aerospace vehicle and operationally checking certain systems and components to ensure there are no serious defects or malfunctions (Tab BB-3). Phase inspection (PH) is a thorough inspection of the entire aerospace vehicle (Tab BB-3). The total airframe operating time of the MA at takeoff of the mishap sortie was 6183.0 hours (Tabs D-3 and U-3 to U-4). The MA had flown 30.0 hours since PH, which was completed on 10 May 2016 (Tab D-2). The last PR inspection occurred on 4 April 2017, at 21:30L with no relevant discrepancies noted (Tab D-3, D-5, and D-32 to D-34).

There is no evidence to suggest inspections were a factor in the mishap.

c. Maintenance Procedures

The 552d Commodities Maintenance Squadron, MEC Overhaul Shop (CMMXS/MXDPAA) at Oklahoma City – Air Logistics Complex (OC-ALC), was responsible for the overhaul of mishap MEC S/N WYG62971 (MA MEC), and conducted on-site operational testing prior to returning it to service (Tab D-47 to D-137). The 552d CMMXS/MXDPAA OC-ALC is a DOD contracted entity that provides post-manufacturer overhaul support for the MEC used on the GE F110-100C engine used in the MA (Tabs D-47 to D-137 and U-33).

The MEC overhaul process employed by the 552d CMMXS/MXDPAA at OC-ALC consists of complete disassembly, solvent wash, and inspection of parts for serviceability (Tab D-47 to D-67). Upon completion of inspection and appropriate parts replacement, the MEC is reassembled and sent for on-site testing to validate operational integrity (Tab D-47 to D-137). After overhaul, MA MEC underwent routine operational testing on 31 January 2017, and failed to meet performance standards (Tab D-68 to D-69 and D-136). After failure of its first operational test, the MA MEC was inspected and found to have a fuel cam spline misaligned (Tab D-69 and D-136). The error was corrected and MA MEC was retested on 16 February 2017 (Tab D-99 to D-111 and D-137). During the second operational test, MA MEC once again failed to meet performance standards and was rejected with comments "check FDT [fan discharge temperature] spring and VSV [variable stator vane]; VSV not repeating" (Tab D-111 to D-136). MA MEC returned to the overhaul shop for re-inspection and repair; the FDT spring was serviceable, the governor servo valve was changed due to a broken tang, and O-ring foreign object debris (FOD) in the VSV was documented (Tab D-124 to D-126 and D-137). The MA MEC was operationally tested for a third time on 8 March 2017, and deemed serviceable (Tabs D-111 to D-123, D-127 to D-135, and U-33). Testing was conducted utilizing a static test stand with no induced vibration, this type of testing is used to verify the functionality and validate operational integrity of the MEC without simulating the actual stresses or loads associated with an operational flight (Tabs V-3.5 and U-33). Ultimately, the MA MEC passed final testing as intended, despite having missing parts (Tabs J-83 to J-86 and U-33).

The 113th Maintenance Squadron (MXS) Engine Shop received the overhauled MA MEC from the supply system on 3 April 2017, and MA MEC was installed on ME S/N 509307 and passed an operational engine run test on 4 April 2017 (Tabs D-13, D-23, and J-4).

d. Maintenance Personnel and Supervision

The 113th Aircraft Maintenance Squadron (AMXS) personnel performed all required inspections, documentation, and servicing for MA prior to flight (Tab D-3 to D-41). A detailed review of maintenance activities and documentation revealed no major documentation errors (Tabs D3 to D-41 and U-3 to U-4). Personnel involved with MA preparation for the flight had adequate training, experience, and expertise to perform their assigned tasks (Tab T-3 to T-58).

There is no evidence to suggest that 113th AMXS maintenance personnel and supervision were a factor in this mishap.

The 552d CMMXS/MXDPAA at OC-ALC conducted the overhaul of MA MEC (Tabs D-47 to D-137 and U-33). Technicians receive about six months of on-the-job training and are required to perform three zero-defect MEC overhauls before obtaining their certification (Tab V-2.8, V-3.6 to V-3.7, V-4.15 to V-4.16, V-5.5, and V-5.10). Certification training is recorded in employee Production Acceptance Certifications (Tabs T-59 to T-66 and V-2.8 to V-2.9). All personnel in the overhaul process were trained and qualified to perform assigned tasks (Tab T-59 to T-66).

e. Fuel, Hydraulic, and Oil Inspection Analyses

Samples of both the fuel truck and oil carts were taken prior to the mishap sortie on 5 April 2017 (Tab U-29 to U-32). Fuel samples from the R-11 fuel truck serial number 05L166 were tested locally and found to be within specified limits (Tab U-32). Oil samples were taken from two separate oil carts, field S/N 1 and field S/N 3, both of which were tested at the 113th MXS non-destructive inspection laboratory and found to be within specified limits (Tab U-30 to U-31). Post mishap fuel and oil samples were taken from the MA and oil servicing carts for analysis at the Air Force Petroleum Office located at Wright-Patterson AFB, Ohio, and found to have no detectable volatile contamination (Tab U-23 to U-28).

There is no evidence to suggest fuel or oil contamination were factors in the mishap.

f. Unscheduled Maintenance

During ME operational checks following MDEC upgrade, engine faults were discovered that required the MEC to be changed (Tab D-27). MEC S/N WYG45153 was removed and replaced with MA MEC on 4 April 2017 (Tab D-27). Following the installation of MA MEC all maintenance follow on actions, engine runs and leak checks were completed with no defects (Tab D-13, D-31, and D-32). MA was returned to service on the night of 4 April 2017 (Tab D-3 and D-13).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

The MA was destroyed on impact (Tab J-34). Due to the steep impact angle, the radome, cockpit, and forward fuselage sections of the aircraft folded beneath the engine and aft fuselage (Tab J-35). The right wing was in two pieces and the left wing was mostly intact (Tab J-5). The aft fuselage, vertical tail, left horizontal stabilizer and the engine (Figure 5) were in one piece (Tab J-5).

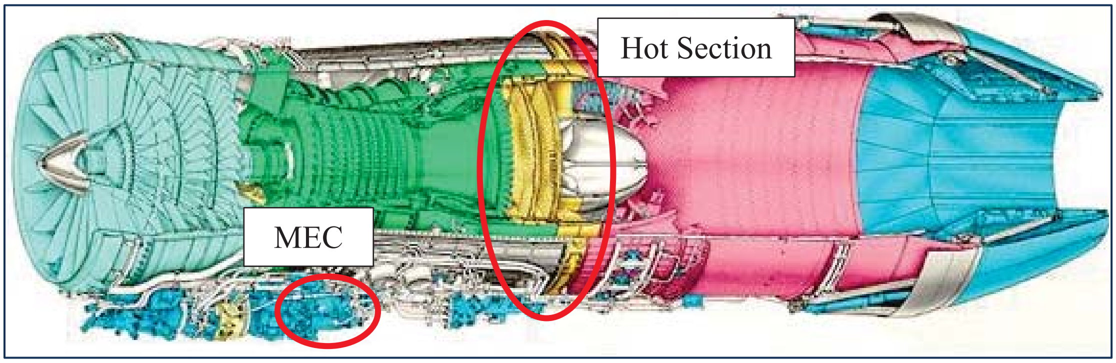

Figure 5: F110-GE-100C Engine Cross Section Overview (Tab J-6)

The engine remained relatively intact with exception of the front frame, which sheared off along with most of the struts (Tab J-7). The controls and accessories were still attached to the gearbox, with the exception of the hydraulic pump (Tab J-8). The fuel boost pump and augmenter fuel pump were badly damaged and sheared from the gearbox, but remained attached to the engine via tubing (Tab J-8). The MDEC also remained attached to the lower fan duct with one mount bolt and tubing holding it in place (Tab J-8). The MEC and main fuel pump remained mounted to the gearbox housing with the v-band clamp still secured (Tab J-8). The MDEC, MEC, and main fuel pump had relatively minor structural damage, as seen in Figure 6 and Figure 7 (Tab J-8).

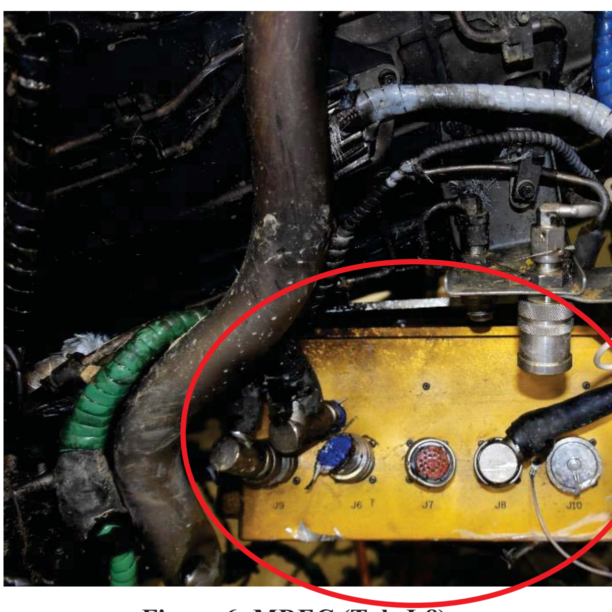

Figure 6: MDEC (Tab J-8)

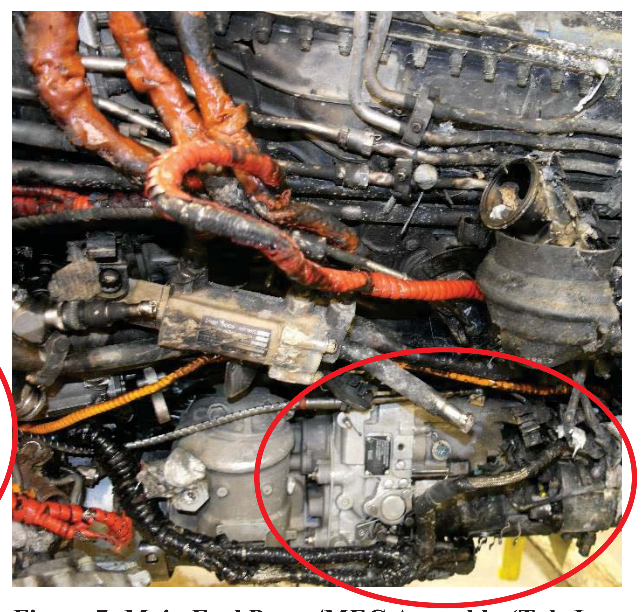

Figure 7: Main Fuel Pump/MEC Assembly (Tab J-9)

b. Engine Teardown Observations

i. Fan Section

Most of the front frame assembly was not recovered from the mishap site or was unrecognizable (Tab J-9). The outer cases of the fan stators had only minor damage (Tab J-10). No buckling, denting, or cracking was observed (Tab J-10). Seals on all three stages showed signs of severe rub (Tab J-10). All fan blades remained installed on their respective fan disks and, with the exception of Stage 1 blades, showed relatively minor damage (Tab J-10).

ii. High Pressure Compressor Section (HPC)

All fan frame struts were fractured to some extent as a result of the impact (Tab J-12). The Outer Fan Ducts showed moderate axial and radial buckling damage due to impact (Tab J-12). The ducts had several perforations, all of which were consistent with impact-related damage (Tab J-12). The forward compressor stator case had minor external damage (Tab J-12). The actuation rings were intact and properly connected to all of the vane arms and there were no observations of bent or improperly installed vane arms in the actuation rings or the connecting links (Tab J-12). The rear compressor stator case showed no major external damage (Tab J-13). All vane sectors were intact with very little FOD or domestic object damage (DOD) (Tab J-13). All airfoils from the high-pressure compressor rotor were intact and showed little to no FOD or DOD (Tab J-14).

iii. Hot Section

The low pressure turbine (LPT) rotor was unable to be removed (Tab J-15). Therefore, the condition of the combustor, high-pressure turbine (HPT) nozzles, HPT blades, LPT nozzles (Stage 1 and leading edge of Stage 2), and LPT Stage 1 blades could only be documented by borescope (Tab J-15). The combustor discharge nozzle case was structurally intact with no evidence of external/internal penetration or burn through (Tab J-15). The combustor liners showed evidence of thermal distress, exhibited by visual burn marks and thermal barrier coating spallation (Tab J-15). This condition was relatively consistent throughout the entire combustion chamber (Tab J-15). The HPT nozzles were all intact with no signs of significant damage (Tab J-16). No evidence of excessive cracking, spalling, or deterioration was noted (Tab J-16). All HPT blades were present and intact; however, they exhibited extensive deterioration, especially near the blade tips (Tab J-17). Severe spalling of the aluminide coating was observed on all surfaces of the blades, as seen on Figure 8 (Tab J-17).

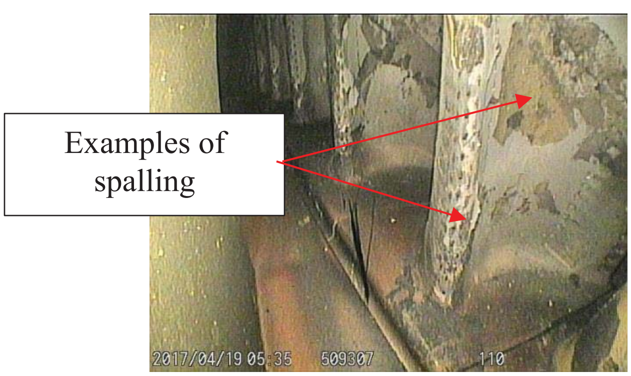

Figure 8: HPT Blades Leading Edge and Platform (Tab J-17)

Deterioration of the tips extended radially inward past the blade tip caps, exposing the hollow interior of the blade (Figure 9) (Tab J-18 to J-19).

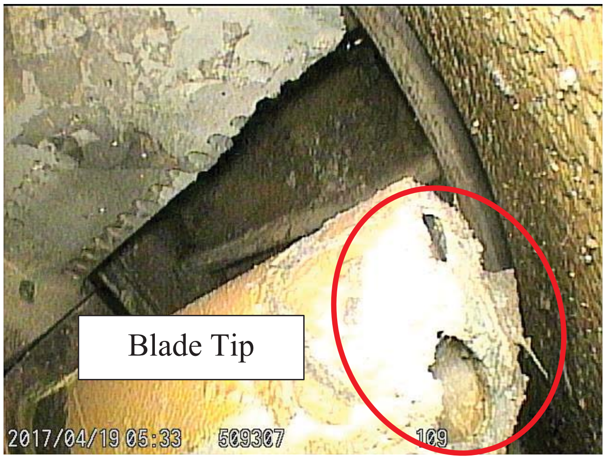

Figure 9: HPT Blade Tips (Tab J-19)

The HPT shroud segments showed severe signs of oxidation, discoloration, and metal splatter (Tab J-19). It was also noted that the shrouds showed no signs of excessive wear, which would be indicative of a hard rub (Tab J-19).

LPT Stage 1 nozzle segments were all intact with significant damage noted (Tab J-19). The vanes exhibited signs of deterioration and metal splatter from upstream hardware (Tab J-19). There was also evidence of metal flow on the leading edge of the nozzle vanes as shown in Figure 10 (Tab J-19 to J-20). The trailing edges showed severe deterioration, spalling, and metal splatter (Tab J-19). All damage on the LPT Stage 1 is indicative of an over temperature condition (Tab J-19).

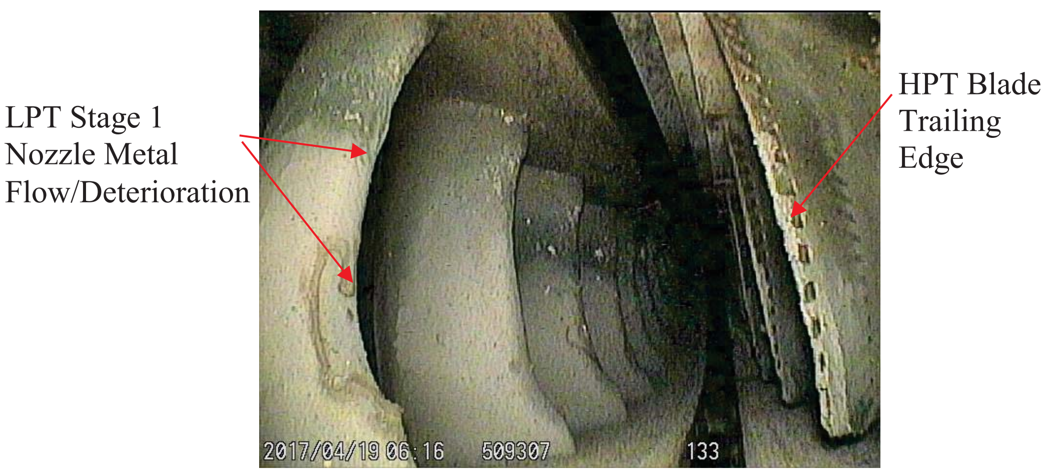

Figure 10: LPT Stage 1 Nozzle Leading Edge deterioration (Tab J-20)

Severe signs of metal splatter was observed on all surfaces of the LPT Stage 1 blades (Tab J-20). Coating loss was observed on all areas of the blades, indicating an over temperature condition (Tab J-20). The trailing edge of the LPT Stage 1 blades also showed signs of severe deterioration and heat distress (Tab J-20). The honeycomb seals of the LPT nozzle shrouds showed signs of melting and/or solidified molten metal covering the surface (Tab J-20). Similar to LPT Stage 1 blades and nozzle, the LPT Stage 2 Nozzle showed evidence of severe heat distress with missing coating and erosion seen on all surfaces (Tab J-21). All of the LPT Stage 2 blades, as shown in Figures 11 and 12, were missing approximately one-half to one-third of the blade from the blade midpoint, radially outboard to the blade tip (Tab J-22 to J-23). Metal splatter and coating loss was also observed (Tab J-22). The Stage 2 nozzle shrouds also showed evidence of severe rubbing (Tab J-22).

Figure 11: LPT Stage 2 Blades (Tab J-22)

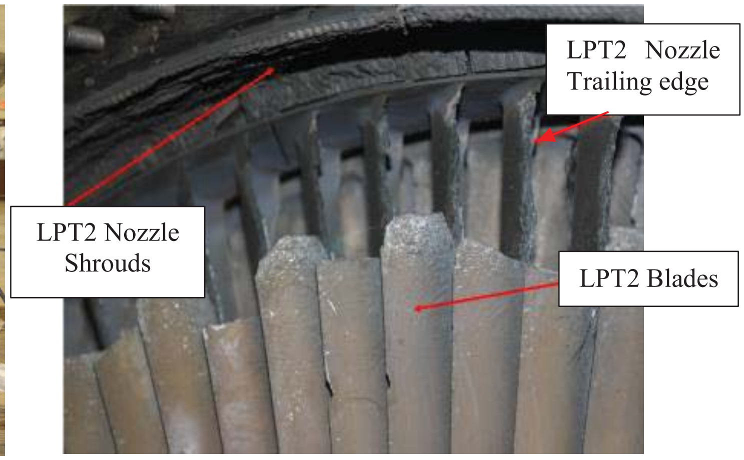

Figure 12: LPT Stage 2 Blade Distress (Tab J-23)

The turbine frame assembly showed signs of buckling due to the impact (Tab J-23). All struts remained structurally intact with only minor damage (Tab J-23). The #5 bearing housing had only minor damage (Tab J-23).

iv. Augmenter/ Exhaust Section

The augmenter duct exhibited buckling at the 12 o'clock position (Tab J-24). All fan/core local spray bars were present, although some outer tubes of the fan/core spray bar were noted to be missing/fractured (Tab J-24). The exhaust manifolds and local fuel manifolds were also severely damaged (Tab J-24). The exhaust nozzle assembly was extensively damaged and buckled (Tab J-25). No evidence of a burn through was observed (Tab J-24 to J-25).

c. Engine Teardown Summary

Exterior portions of the engine demonstrated damage from the impact of the crash and post-impact fire (Tab J-26). The combustor section displayed moderate signs of heat distress (Tab J-26). Aft of the combustor section there was confirmation of a severe over temperature condition as evidenced by the deterioration of the HPT/LPT blades and HPT/ LPT nozzles (Tab J-26).

d. MEC Teardown Observations

The MEC was shipped to GE Aviation, who then transported it to Woodward Governor in Rockford, Illinois, where Woodward personnel performed a teardown investigation (Tab J-81). The teardown was observed by a GE investigator and an AFLCMC representative (Tab J-81).

The mode select valve depth checked at 0.626 inch (Tab J-83). A depth of 0.580 inch or deeper indicates HYB mode (Tab J-83).

Upon removal of the manifold plate gaskoseal, a backing ring was found between the gaskoseal and the pilot valve plate (Figure 13) (Tab J-83 to J-84). The backing ring appeared to be of a Teflon or nylon material, and not included on the parts list for this MEC (Tab J-83). The backing ring was noted to be .015-inch thick and 5/16-inch in diameter (Tab J-83).

Figure 13: Foreign Object backing ring (Tab J-84)

The pressuring valve transfer tube was found to contain a Viton seal rather than a fluorosilicone seal as specified in tech data (Figure 14) (Tab J-86).

Figure 14: Pressurizing valve transfer tube – Black ring is Viton (Tab J-86)

The differential pressure (ΔP) pilot valve was removed and it was observed that the 600-degree spiral retaining ring, which normally secures the internal bushing and anti-rotation pin, was missing (Tab J-84). The anti-rotation pin was also missing (Tab J-84). The bushing was displaced aft approximately 0.300 inch and was noted to be contacting the dashpot of the ΔP valve and the dashpot was entirely outside the valve sleeve (Figure 15) (Tab J-84 to J-85). The contact between the bushing and the dashpot was such that score marks were clearly visible on the forward end of the dashpot and aft end of the bushing (Figure 16) (Tab J-85). Figure 17 shows exemplars of the missing parts (Tab FF-14).

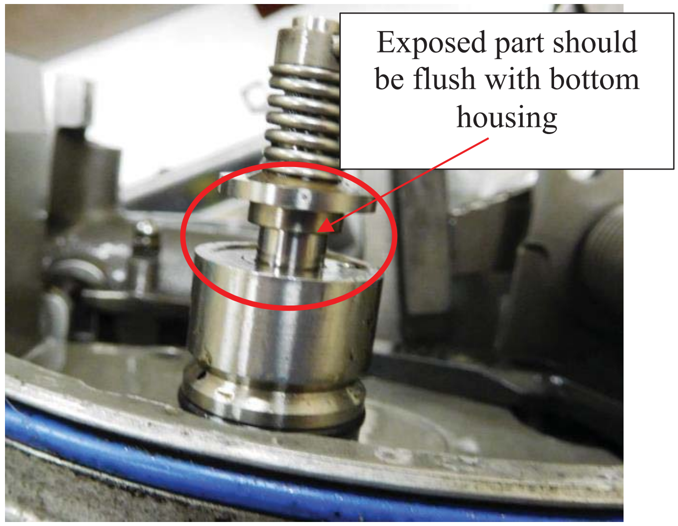

Figure 15: ΔP Pilot valve dashpot extended aft (up in photo) and contacted by the ΔP bushing (Tab J-85)

Figure 16: Bushing removed (left) Dashpot (right) – note relative score marks and spiral ring witness on bushing circumference (Tab J-85)

Figure 17: Exemplar photo of missing retaining ring and anti-rotation pin (Tab FF-14)

e. MEC Teardown Summary

The mode select valve depth indicating HYB mode confirms the ME transferred to HYB mode, which the crash survivable memory unit recorded four seconds after take-off (Tab J- 83 and J-47).

The backing ring was found in a position that could have prevented full internal sealing of the gaskoseal against the manifold plate (Tab J-83). Additionally, Viton seals are more prone to loss of sealing in extremely cold temperatures, and as a result, fluorosilicone is utilized in the MEC (Tab FF-12). However, there is no evidence to suggest that the backing ring or the Viton seals were a factor in the mishap.

The missing 600-degree spiral retaining ring and anti-rotation pin allowed the internal bushing to migrate aft and contact the dashpot of the ΔP valve (see Figure 15) (Tab J-84 to J-85). The dashpot was entirely outside of the valve sleeve and exposed to case reference pressure versus metered fuel pressure (Tab J-84). Due to pressure fluctuations, the ΔP valve could not achieve a null state and pressure was ported to the bypass valve driving it toward the closed position, resulting in uncontrolled (high) fuel flow to the engine (Tab FF-11 to FF-12). The uncontrolled high fuel flow resulted in the engine T4B over temperature, NF overspeed and ultimately uncontrolled engine operation (Tabs J-47 and FF-12 to FF-13). The fuel valve housing was taken to the real-time x-ray facility and checked for the missing spiral retaining ring and anti-rotation pin (Tab J-86). The retaining ring and pin were not detected within the housing during this check (Tab J-86).

The MA MEC contained backing ring FOD, an incorrect Vitron seal, and the absence of both the 600-degree retaining ring and anti-rotation pin (Tab J-83 to J-86). T.O. 6J3-4-131-3, paragraph 3.1.d – 3.1.g, requires parts accountability and emphasizes the critical importance of such procedures (Tab BB-31). T.O. 6J3-4-131-3 does not specify a methodology for parts accountability (Tab BB-31). The MEC overhaul work control documents (WCD) provide an auditable account of the work accomplished IAW the TOs; however they do not address or require inventory of parts post disassembly or prior to assembly of MECs (Tabs D-47 to D-135 and FF-8). During disassembly of the MEC, technicians determine whether parts require replacement or if they can be reused; replacement parts are ordered as needed (Tab V-2.7 and V-4.3 to 4.7). Replacement part kit packages were observed to have excess parts; in addition, spare parts were also retained from previous MEC overhauls, resulting in no definitive way to determine that all required MEC parts were used during assembly (Tab FF-8).

7. WEATHER

a. Forecast Weather

On 5 April 2017, the 15th Operational Weather Squadron provided the weather forecast to the MF (Tab F-2). The forecast for JBA was winds from 320 (northwest) at 9 knots, unlimited visibility, skies clear and a temperature of 16 degrees Celsius (Tab F-3).

b. Observed Weather

JBA ATIS updated the MF during taxi to RWY01L, stating winds were 330 (northwest) at 7 knots, 10 statute miles of visibility, skies clear, and an altimeter setting of 29.91 in. Hg (Tab R-19). The JBA observed weather at MF takeoff was winds from 320 (northwest) at 8 knots, 10 statute miles of visibility, skies clear and an altimeter setting of 29.93 in. Hg (Tab F-11). The post-mishap weather was reported as winds from 320 (northwest) at 9 knots, 10 SM visibility, skies clear and altimeter setting of 29.93 in. Hg (Tab F-11).

c. Space Environment

Not Applicable.

d. Operations

There is no evidence to suggest that MF was operating outside its prescribed weather limits.

8. CREW QUALIFICATIONS

a. Mishap Pilot

The MP was a current and qualified combat mission ready wingman as outlined in AFI 11-2F-16V1 with 239.7 total flying hours in the F-16 (Tabs G-9 to G-10 and BB-12 to BB-13). MP's last instrument check ride was 17 January 2017, and last mission check ride was 05 October 2016 (Tab G-28). None of the MP's post-pilot training check rides contained discrepancies or downgrades (Tab G-28).

Table 1: MP 30-60-90 day Flying History as of the day of mishap (Tab G-11)

MP	Hours	Sorties
Last 30 Days	3.9	3
Last 60 Days	6.2	5
Last 90 Days	19.5	15

9. MEDICAL

a. Qualifications

MP was medically qualified for flying duties without limitations at the time of the mishap (Tab X-5). MP's Aeromedical Services Information Management System was reviewed, verifying the MP held a current DD Form 2992, *Medical Recommendation for Flying or Special Operational Duty*, with no duty limiting conditions found (Tab X-5). MP had no medical waivers in the Aeromedical Information Management Waiver Tracking System (Tab X-3).

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

b. Health

The MP was in good health at the time of the mishap (Tab X-5). A review of MP's medical and dental records, 72-hour and 7-day history, ORM worksheet on the day of the mishap, personal account, and the Aeromedical Services Information Management System reports, did not reveal any illnesses or duty limiting conditions at the time of the mishap (Tabs X-5, V-1.13, and AA-3). MP did not suffer any injuries during the ejection sequence or during landing under parachute (Tabs V-11.1 and X-5 to X-7).

There is no evidence to suggest the MP's health was a factor in the mishap.

c. Toxicology

In accordance with AFMAN 91-223, *Aviation Safety Investigations and Reports* and AFI 91-204, *Safety Investigations and Reports*, blood and urine samples were collected from the MP and mishap aircraft maintenance crew (MAMC) and submitted to the Armed Forces Medical Examiner System (AFMES), Division of Forensic Toxicology, 115 Purple Heart Drive, Dover Air Force Base, Delaware, for toxicological analysis (Tab X-5). These tests identify carbon monoxide and ethanol levels in blood and detect the presence of drugs (amphetamine, barbiturates, benzodiazepines, cannabinoids, cocaine, opioids, phencyclidine, and sympathomimetic amines) in urine (Tab X-5).

i. Mishap Pilot

Blood samples for MP were found to be within normal limits for carbon monoxide levels and were negative for ethanol (Tab X-5). Urine drug screen testing for MP was negative for amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates, phencyclidine, and sympathomimetic amines by immunoassay or gas chromatography/full scan-mass spectrometry (Tab X-5).

ii. Mishap Aircraft Maintenance Crewmembers

Blood testing for all MAMC were negative for ethanol (Tab X-5). Urine drug screen testing for all MAMC was negative for amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates, phencyclidine, and sympathomimetic amines by immunoassay or gas chromatography/full scan-mass spectrometry (Tab X-6).

There is no evidence to suggest that toxicology was a factor in the mishap.

d. Lifestyle

Medical records, personal testimony, 72-hour and 7-day histories, and ORM worksheet for the MP were reviewed (Tabs X-5 and AA-3). Medical records, personal testimony, and 72-hour and 7-day histories of MAMC were also reviewed (Tab X-6). 552d CMMXS/MXDPAA technicians did not report any problems with work hours or external stressors (Tab V-4.6, V-5.10 to V-5.11).

There is no evidence to suggest that lifestyle factors were a factor in the mishap.

e. Crew Rest and Crew Duty Time

AFI 11-202V3, *General Flight Rules*, ACC Supplement, dated 28 November 2012, prescribes mandatory crew rest and maximum flight duty periods for all personnel who operate USAF aircraft. Based on the information provided from the 72-hour and 7-day histories, crew rest was adequate for the MP and IAW published guidance (Tab X-5).

10. OPERATIONS AND SUPERVISION

a. Operations

At the time of the mishap, the 121 FS had decreased flying operations at JBA, due to recently returning from a deployment and having aircraft still deployed down range (Tab R-17 to R-18). However, the 113th MXG was constrained due to limited availability of aircraft (Tab R-109 to R-112). The planned number of aircraft for the morning of the mishap was six, which was then reduced to four aircraft for maintenance non-deliverables (Tabs K-3, R-18, and AA-4). The MF consisted of three experienced instructor pilots, and the MP, who was an inexperienced but currently qualified wingman (Tab G-3, G-9, G-15, and G-21).

b. Supervision

The supervision of the 121 FS flying operation on the day of the mishap was IAW directives (Tab K-3). The MF had all required authorization, supervision, and documentation for the scheduled sortie (Tab K-2 to K-3). After the MP ejected, P1 coordinated with the SOF with minor radio difficulty, to begin search and rescue response (Tabs N-3 and R-29 to R-30). The SOF on duty executed the correct emergency checklists and informed the 113 WG command post of the incident (Tab AA-5).

There is no evidence to suggest that supervision was a factor in the mishap.

11. HUMAN FACTORS ANALYSIS

a. Introduction

AFI 91-204, *Safety Investigations and Reports*, 12 February 2014, as amended 19 January 2017, Attachment 6, contains the Department of Defense (DoD) Human Factors Analysis and Classification System (HFACS), which lists potential human factors that can play a role in aircraft mishaps. Policy and process issues are factors if a process negatively influences performance and results in an unsafe situation (Tab BB-33). The human factor listed below was determined to be relevant to the determination of cause or substantially contributing factors to the mishap.

b. OP003 Provided Inadequate Procedural Guidance or Publications

Provided inadequate procedural guidance or publications is a factor when written direction, checklists, graphic depictions, tables, charts or other published guidance is inadequate, misleading or inappropriate (Tab BB-33).

T.O. 6J3-4-131-3 requires parts accountability and emphasizes the critical importance of such procedures (Tab BB-31). T.O. 6J3-4-131-3 does not specify a methodology for parts accountability (Tab BB-31). During on-site observation of the MEC overhaul shop, it was observed that gaps exist in terms of parts accountability (Tabs FF-3 to FF-8). WCDs provide an auditable account of the work accomplished IAW the TOs; WCD numbers 110M1R and 110M5R do not require a technician stamp to document that all parts are accounted for during MEC overhaul and assembly (Tabs D-47 to D-135 and FF-8). Furthermore, there is no process to determine if all required parts have been installed after overhaul and assembly completion (Tab FF-8). It was observed that some parts remained in part trays from previous assembly kits, with no way to determine if all required parts were installed (Tab FF-8). The technician who overhauled the MA MEC, other MEC technicians and the quality assurance supervisor from the 552d CMMXS/MXDPAA, acknowledged parts accountability during MEC assembly is dependent upon individual technician efforts (Tab V-2.5, V-2.9 to V-2.11, V-3.7 to V-3.8, V-4.6 to V-4.8, and V-5.1 to 5.13).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publicly Available Directives and Publications Relevant to the Mishap

i. AFI 51-503, Aerospace and Ground Accident Investigations, dated 14 April 2015
ii. AFI 51-503, Air Combat Command Supplement Aerospace and Ground Accident Investigations, dated 28 January 2016
iii. AFI 91-204, Safety Investigations and Reports, dated 12 February 2014, incorporating corrective actions applied on 19 January 2017
iv. AFI 11-202 V3, General Flight Rules, dated 10 August 2016
v. AFI 11-2F-16 V1, Flying Operations, F-16 Pilot Training, dated 20 April 2015
vi. AFI 11-2F-16 V2, Flying Operations, F-16 Aircrew Evaluation Criteria, dated 10 December 2009, incorporating Change 1, dated 27 August 2010
vii. AFI 48-123, Medical Examinations and Standards, dated 5 November 2013, incorporating Air Force Guidance Memorandum (AFGM) 2016-01, dated 19 September 2016

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

i. F-16 Block 25-41, Ready Aircrew Program (RAP) Tasking Memorandum, Aviation Schedule 2017
ii. T.O. 00-20-1, Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures
iii. T.O. 1F-16C-1, Flight Manual USAF Series F-16C and F-16D, Blocks 25/30/32
iv. AFTTP 3-3.F16 Combat Aircraft Fundamentals
v. T.O. 1F-16C-2-70FI-00-11, Fault Isolation, Power Plant Model F110-GE-100/100B/100C
vi. T.O. 1F-16C-2-70GS-00-11, General System, Power Plant Model F110-GE 100/100B/100C
vii. T.O. 1F-16C-6-11, Scheduled Inspection and Maintenance Requirements, F110-GE-100/100B/100C Engine
viii. T.O. 6J3-4-131-3, Overhaul Main Engine Control Assembly (Used on F110-GE-100 Engine)

c. Known or Suspected Deviations from Directives or Publications

None.

//Signed//

6 OCTOBER 2017

DAVID V. COCHRAN, Colonel, WVANG
President, Accident Investigation Board

STATEMENT OF OPINION

F-16C, T/N 87-0306
Clinton, MD
5 APRIL 2017

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 5 April 2017, at 09:13 hours local time, an F-16C was destroyed by ground impact after the Mishap Pilot (MP) ejected southwest of Joint Base Andrews (JBA), Clinton, Maryland (MD). The MP safely ejected and did not sustain any injuries. There were no personnel injured on the ground. The Mishap Aircraft (MA), Tail Number 87-0306, and the MP are assigned to the 113th Wing, 121st Fighter Squadron, JBA, MD. The MA, valued at $22,198,075, was destroyed. There was minimal damage to non-Department of Defense property; the environmental clean-up cost is $856, 777.

The mishap occurred as part of a four aircraft F-16 formation on departure from JBA. The flight was planned as a basic surface attack training mission to be conducted at Fort Indiantown Gap (Restricted Area: R-5802), Pennsylvania. The MA was the number two aircraft in the formation. Shortly after takeoff, the MA experienced an uncommanded engine acceleration, followed by a loss of thrust. The uncontrollable engine resulted in an engine core overspeed, over temperature, fire and ultimately engine failure. The distance to the nearest suitable recovery airfield was beyond MA glide capabilities, negating any chance of safely recovering the MA. The MP successfully executed a controlled ejection at 09:16 L, after maneuvering the disabled MA over a non-residential area.

JBA first responders arrived on scene at the MP's location at 09:26 L. The MP was evacuated by the 1st Helicopter Squadron (1 HS), which was conducting a local training mission with a flight surgeon onboard. The 1 HS transported the MP to JBA for further evaluation by medical personnel at Malcom Grow Medical Center.

I find by a preponderance of evidence that the cause of this mishap was the incorrect assembly of the main engine control (MEC) differential pressure pilot valve, which was missing a required 600-degree retaining ring and the anti-rotation pin. The misassembled differential pressure pilot valve caused the MEC to malfunction and to incorrectly meter abnormally high fuel flow to the engine. The uncontrolled engine operation caused severe engine overspeed, severe engine over-temperature, and engine fire, which resulted in a catastrophic engine failure.

I also find by a preponderance of the evidence that a substantially contributing factor in the mishap was the lack of an adequate procedural requirement for MEC parts accountability in the 552d Commodities Maintenance Squadron, MEC Overhaul Shop (CMMXS/MXDPAA).

I developed my opinion by analyzing recorded flight data, consulting technical experts from the F-16 System Program Office, Air Force Research Laboratory, Oklahoma City-Air Logistics Complex and Lockheed Martin, interviewing maintainers of the mishap aircraft, the MP, pilots of the mishap formation flight, members of the 552d CMMXS/MXDPAA, as well as operations and maintenance supervisors. I also, reviewed Air Force directives, and technical engineering analysis involving the engine and the MEC.

2. CAUSE

I find by a preponderance of evidence that the cause of this mishap was the incorrect assembly of the MEC differential pressure pilot valve, which was missing a required 600-degree retaining ring and the anti-rotation pin. The misassembled differential pressure pilot valve caused the MEC to malfunction and to incorrectly meter abnormally high fuel flow to the engine. The uncontrolled engine operation caused severe engine overspeed, severe engine over-temperature, and engine fire, which resulted in a catastrophic engine failure.

The MEC is designed to regulate fuel flow and the variable stator vane position of the engine. The MEC senses the engine core speed and adjusts fuel flow as necessary to maintain the desired engine speed in accordance with pilot input via the throttle. The MEC contains many small washers, shims, pins, clips, and retaining rings. Omitting or improperly installing any of these items can result in malfunction of the MEC and possible loss of the aircraft. In this instance, the misassembled differential pressure pilot valve caused the MEC to incorrectly meter abnormally high fuel flow to the engine, uncontrolled by the MP throttle inputs. The uncontrolled engine operation caused severe engine overspeed, severe engine over-temperature, engine fire, and ultimately a catastrophic engine failure. The MP was able to extinguish the engine fire by placing the throttle to cut-off. However, the engine had sustained considerable damage and was unusable. At this point, the distance to the nearest suitable recovery airfield was beyond the MA glide capabilities, negating any chance of safely recovering the MA. It is commendable that the MP had the wherewithal to successfully maneuver the disabled MA over a wooded area, in an otherwise highly residential area, resulting in no injuries on the ground.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

I find by a preponderance of evidence that lack of MEC parts accountability in the 552d CMMXS/MSDPAA, substantially contributed to the mishap. During the investigation, it was evident that the 552d CMMXS/MXDPAA did not have an adequate procedural requirement for MEC parts accountability. The applicable Technical Order (T.O.) emphasizes the critical role of parts accountability; however, it does not detail the methodology to follow in implementing a parts accountability protocol.

The 552d CMMXS/MSDPAA was responsible for the overhaul and assembly of the MA engine's MEC. In my opinion, there was a lack of adequate procedural controls to ensure that only required MEC parts were provided to MEC mechanics during assembly and that no excess MEC parts were retained by mechanics after disassembly, overhaul and re-assembly. Furthermore, it is my opinion that the lack of parts accountability by itself was not responsible for the mishap, but could have potentially decreased the likelihood of omitting required MEC parts during re-assembly. However, other factors must also be considered, to include: the MEC overhaul technician determination of whether to reuse serviceable parts, the small size of the missing anti-rotation pin, task complexity, and human error. These factors led me to conclude that the misassembly of the differential pressure pilot valve could still have occurred, even if an adequate parts accountability program was in place.

In addition to the causal missing parts of the incorrectly assembled MEC differential pressure pilot valve; the MA MEC teardown and post-mishap technical analysis revealed an unidentified backing ring (or foreign object debris) and an incorrect Vitron seal within the MA MEC. Moreover, it was identified that the MEC overhaul work control documents do not address or require inventory of MEC parts post disassembly or prior to assembly of MECs. Lastly, some MEC part kits provided to mechanics were observed to have excess parts. This fact combined with the retention of excess parts from previous MEC overhauls, results in no definitive methodology to determine that all MEC parts are used during the assembly. It is critically important to ensure that all small washers, shims, pins, clips, and retaining rings are accounted for during the MEC overhaul process, in accordance with the applicable T.O. guidance. Omitting or improperly installing any of these items, as stated in the T.O., did result in failure of the MEC and aircraft loss. The 552d CMMXS/MSDPAA procedural requirements were not adequate and substantially contributed to the misassembled differential pressure pilot valve in the MA MEC.

4. CONCLUSION

I find by a preponderance of evidence that the cause of this mishap was the incorrect assembly of the MEC differential pressure pilot valve, which was missing a required 600-degree retaining ring and the anti-rotation pin. The misassembled differential pressure pilot valve caused the MEC to malfunction and to incorrectly meter abnormally high fuel flow to the engine. The uncontrolled engine operation caused severe engine overspeed, severe engine over-temperature, and engine fire, which resulted in a catastrophic engine failure. I also find by a preponderance of evidence that a substantially contributing factor in the mishap was the lack of an adequate procedural requirement for MEC parts accountability in the 552d CMMXS/MSDPAA.

//Signed//

6 OCTOBER 2017

DAVID V. COCHRAN, Colonel, WVANG
President, Accident Investigation Board

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