UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

F-16CM, S/N 93-0554

55th EXPEDITIONARY FIGHTER SQUADRON
332d AIR EXPEDTIONARY WING
BALAD AIR BASE, IRAQ

LOCATION: BALAD AIR BASE, IRAQ

DATE OF ACCIDENT: 12 NOVEMBER 2008

BOARD PRESIDENT: LT COLONEL ROGER A. QUINTO

Conducted IAW Air Force Instruction 51-503

EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION

F-16CM, S/N 93-0554
BALAD AIR BASE, IRAQ
12 NOVEMBER 2008

On 12 November 2008, at 0531L, an F-16CM aircraft, serial number (S/N) 93-0554, on takeoff roll and during initiation of afterburner, experienced a catastrophic engine failure and aircraft fire. The Mishap Aircraft (MA) was deployed from the 20th Fighter Wing and assigned to the 55th Expeditionary Fighter Squadron, 332d Air Expeditionary Wing, Balad Air Base, Iraq. The MA was part of a two-ship close air support mission in support of Operation IRAQI FREEDOM.

During takeoff roll, the Mishap Pilot (MP) selected MIL power and observed normal aircraft operations and flight instrument indications. Shortly after selecting afterburner, the MP heard a loud pop, saw a bright light directly behind the cockpit and experienced an immediate loss of thrust. The MP initiated the appropriate critical action procedures and aborted the takeoff. The aircraft departed the runway near the approach end barrier at 1,800 feet and continued traveling forward and to the right. After traveling an additional 900 feet, the nose landing gear collapsed and the MA came to complete stop. After the MA came to a complete stop, the MP safely ground egressed from the MA and sustained no injuries.

After the MP's safe egress, fire engulfed the MA and some of the loaded munitions discharged. The MA was destroyed as the result of the fire, sustaining a total loss of approximately $28.8 million. The fire was extinguished without injury to personnel or damage to equipment. The mishap caused no damage to private or other military property.

The AIB President found by clear and convincing evidence that the cause of this mishap was a catastrophic failure of the engine's second stage fan disk. An undetected subsurface crack in the second stage fan disk caused a portion of the fan disk to break free shortly after the MP selected afterburner. There are no required inspections that would have detected the subsurface crack. Pieces of the fan disk and other engine fragments pierced the aircraft fuel cell and severed hydraulic lines, causing loss of control and the fire that destroyed the aircraft.

SUMMARY OF FACTS AND STATEMENT OF OPINION
F-16CM, S/N 93-0554
12 November 2008

TABLE OF CONTENTS

COMMONLY USED ACRONYMS AND ABBREVIATIONS

°	Degree
§	Section
AB	After Burner or Air Base
AEF	Air Expeditionary Force
AEW	Air Expeditionary Wing
AF	Air Force
AFB	Air Force Base
AFI	Air Force Instruction
AFPAM	Air Force Pamphlet
AFRL	Air Force Research Laboratory
AFSC	Air Force Specialty Code
AFTO	Air Force Technical Order
AIB	Aircraft Investigation Board
AIM-9	Air Intercept Missile
AMU	Aircraft Maintenance Unit
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AMXS	Aircraft Maintenance Squadron
AOR	Area of Responsibility
C	Celsius
C2	Command and Control
CAMS	Computer Automated Maintenance System
CAP	Critical Action Procedures
Capt	Captain
CAS	Close Air Support
CSFDR	Crash Survivable Flight Data Recorder
CEMS	Comprehensive Engine Management System
CMS	Component Maintenance Squadron
COMMS	Communications
CSAR	Combat Search and Rescue
DCA	Defensive Counter-Air
DSN	Defense Switch Network
DTS	Data Transfer System
ECI	Eddy Current Inspection
EMSC	Engine Monitoring System Computer
EOR	End of Runway
EOT	Engine Operating Time
EP	Emergency Procedures
EPE	Emergency Procedures Evaluation
EPU	Emergency Power Unit
FDP	Flight Duty Period
FL	Flight Lead
FM	Flight Manual
FO	Foreign Object
FOD	Foreign Object Damage
Freq	Frequency
FS	Fighter Squadron
FTIT	Fan Turbine Inlet Temperature
FW	Fighter Wing
GBU	Guided Bomb Unit
GE	General Electric
GRC	Global Research Center
GSU	Ground Station Unit
HUD	Heads up Display
IFT	In Flight Time
IMDS	Integrated Maintenance Data System
JEIM	Jet Engine Intermediate Maintenance
JFS	Jet Fuel Starter
JG	Job Guide
L	local
LRU	Line Replacement Unit
Lt Col	Lieutenant Colonel
MA	Mishap Aircraft
Maj	Major
MAJCOM	Major Command
MAU	Munitions Adapter Unit
Max	Maximum
ME	Mishap Engine
MFL	Mishap Flight Lead
MFSOV	Main Fuel Shut Off Valve
MIL or MIL POWER	Military Power
Mil	Milli-Inch
MOC	Maintenance Operations Control
MP	Mishap Pilot
NCO	Noncommissioned Officer
NCOIC	Noncommissioned Officer in Charge
NDI	Non-destructive Inspection
NOTAMS	Notices to Airmen
OC-ALC	Oklahoma City Air Logistics Center
OG	Operations Group
OIM	Orientation Imaging
Ops Tempo	Operations Tempo
OPT	Oil Pressure Transmitter
OSC	On-Scene Commander
PA	Public Affairs
RPM	Revolutions Per Minute
SAU	Signal Analysis Unit
SC	South Carolina
SELO	Standardization Evaluation Liaison Officer
SEM	Scanning Electron Microscope
SIMS	Simulations
S/N	Serial Number
SMSgt	Senior Master Sergeant
SOF	Supervisor of Flying
Sortie	Flight
Stan Eval	Standardization and Evaluation
TAC	Total Accumulated Cycles
TBA	Training Business Area
TCTO	Time Compliance Technical Order
TDY	Temporary Duty

T/N	Tail Number	USAF	United States Air Force
T.O.	Technical Order	VFR	Visual Flight Rules
TSgt	Technical Sergeant	Z	Zulu or Greenwich Mean Time
U.S.	United States		

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

SUMMARY OF FACTS

1. AUTHORITY, PURPOSE, AND CIRCUMSTANCES

a. Authority

On 23 December 2008, Major General R. Michael Warden, Vice Commander, Air Combat Command (ACC) appointed Lieutenant Colonel Roger A. Quinto to conduct an aircraft accident investigation of the 12 November 2008 crash of an F-16CM aircraft, serial number (S/N) 93-0554 at Balad Air Base (AB), Iraq. The investigation occurred at Shaw Air Force Base (AFB), South Carolina (SC), from 5 January 2009 through 23 January 2009. Board Members were Lieutenant Colonel Leonid M. Katkovsky (Medical), Captain Paul E. Welling (Legal), Senior Master Sergeant Reginald D. Franks (Maintenance) and Technical Sergeant James M. Watson (Recorder) (Tab Y-3).

b. Purpose

This aircraft accident investigation was convened under Air Force Instruction (AFI) 51-503. The primary purpose is to gather and preserve evidence for claims, litigation, and disciplinary and administrative actions. In addition to setting forth factual information concerning the accident, the board president is also required to state his opinion as to the cause of the accident or the existence of factors, if any, that substantially contributed to the accident. The report is available for public dissemination under the Freedom of Information Act.

c. Circumstances

The accident investigation board (AIB) was convened to investigate the Class A accident involving an F-16CM aircraft, S/N 93-0554, assigned to the 55th Expeditionary Fighter Squadron (EFS), Balad AB, Iraq, which was destroyed on 12 November 2008.

2. ACCIDENT SUMMARY

The Mishap Aircraft (MA) experienced an engine fire on takeoff roll and during initiation of afterburner. Captain Joseph R. Ashcroft, the Mishap Pilot (MP) aborted the takeoff and the MA departed the prepared surface at approximately 1,800 feet on the right side of the runway. After traveling an additional 900 feet, the nose landing gear collapsed and the MA came to complete stop (Tab Z-6). The MP emergency ground egressed the aircraft safely and suffered no injuries (Tab V-1.5 thru V-1.6). The MA was engulfed by the fire and destroyed with loss valued at $28,852,748.66 (Tab P-3). There were no injuries or damage to private or government property (Tab P-4). Media interest was minimal.

3. BACKGROUND

The MA aircraft was an asset of the 20th Fighter Wing (20 FW), Shaw AFB, SC, and was deployed to Balad AB, Iraq, and assigned to the 55 EFS in the 332d Air Expeditionary Wing (332 AEW). The 20 FW at Shaw AFB, SC, maintains approximately 80 F-16 fighter aircraft in conventional and anti-radiation suppression of enemy air defense, strategic attack, counter air, air interdiction, joint maritime operations and combat search and rescue missions. The 55th Fighter Squadron (55 FS) is a component of the 20 FW. The wing and its subordinate units are all components of ACC.

The MA was deployed to the 332 AEW. The 332 AEW is the most forward deployed Air Force wing in Operation IRAQI FREEDOM (OIF). It is comprised of nine groups, including four geographically separated units--the 407th Air Expeditionary Group (AEG), 447 AEG, 438 AEG and 506 AEG located respectively at Ali, Sather, Al Asad, and Kirkuk Air Bases. The wing operates three F-16 fighter squadrons, a Predator Unmanned Aerial Vehicle squadron, a C-130 squadron, a combat search and rescue squadron (HH-60s) and an A-10 Thunderbolt II squadron.

The 332 AEW consists of over 8,000 personnel, including 1,800 Airmen of the 732 AEG, which provides oversight for Airmen who are operationally assigned to U.S. Army units at over 60 forward operating locations throughout Iraq.

4. SEQUENCE OF EVENTS

a. Mission

The Mishap Flight Lead (MFL) and the MP were scheduled for a 2-ship Close Air Support (CAS) mission as directed by the Air Tasking Order (ATO) with a 0225 Zulu (Z) (0525L) takeoff (Tab V-1.3, V-2.3). Taskings are provided by the Combined Air and Space Operations Center (CAOC) in support of OIF.

b. Planning

Mission planning was adequate and in accordance with standards. The MFL provided the mission briefing in accordance with 20 FW Pilot Guide. Both pilot members had flown similar missions in the past and noted nothing unusual during the briefing (Tab V-1.3, V-2.3).

c. Preflight

The MP stepped to his aircraft and initiated normal preflight routine. Review of aircraft forms revealed no discrepancies or issues. The MP noted no discrepancies during walk around and visual inspection of aircraft. Launch procedures were uneventful with no delays or maintenance problems. The MA started and taxied to the end of runway (EOR) inspection area with no issues. EOR inspection and arming of the MA was normal, and it proceeded to Runway Three-Zero Right prior to takeoff initiation (Tab V-1.4 thru V-1.5, V-1.7 thru V-1.8, Z-7).

d. Flight

The MFL successfully completed an afterburner takeoff (Tab V-2.5). The MP then taxied into position and selected MIL power as part of the takeoff procedures; all indications were normal (Tab V-1.4 thru V-1.5, Z-7). The MP then moved the throttle to afterburner. Approximately one second later, the MP heard a loud pop, noticed a bright light directly behind him, and the MA experienced an immediate loss of thrust (Tab V-1.5 thru V-1.6). As the MA continued down the runway with a slight veer to the right, the MP executed Critical Action Procedures (CAP) (Tab V-1.5 thru V-1.6, V-1.9). The MP moved the throttle to IDLE but had no braking or nose wheel steering response (Tab V-1.5). The MP then attempted to catch the approach end barrier with his tail hook but was unsuccessful (Tab V-1.5). At approximately 1,800 feet the MA departed the runway, the MP shutoff the throttle and performed Engine Fire on Ground CAP (Tab V-1.5). After traveling another 900 feet, the nose gear collapsed and the MA came to a complete stop (Tab V-1.6). The MP performed emergency ground egress procedures and climbed out the left side of the MA. As fire engulfed the MA, some of the loaded munitions discharged, and the MP evacuated to safety until he met up with emergency response crews near taxiway Delta (Tab V-1.5 thru V-1.6, V-1.9, Z-7).

e. Impact

All wreckage from the fire and subsequent cleanup was contained on Balad AB, Iraq. There was no evidence of environmental harm or damage to civilian property (Tab P-4).

f. Life Support Equipment, Egress, and Survival

Life Support, Egress, and Survival Equipment was inspected prior to the mishap in accordance with Technical Order (T.O.) guidance and was found to be serviceable. It was not used in this mishap (Tab H-2).

g. Search and Rescue

Search and rescue were not employed due to the nature of this mishap. The MP egressed the cockpit, evacuated the mishap site and ultimately boarded an ambulance near taxiway Delta (Tab V-1.6). There were no fatalities in this mishap.

5. MAINTENANCE

A thorough review of maintenance documentation, procedures and inspections was performed and no discrepancies or irregularities were identified.

a. Forms Documentation

(1) Summary: The AIB reviewed the following sources and no discrepancies or irregularities were identified: active aircraft forms; aircraft legacy forms (pulled forms); engine legacy forms (in-shop work packages); Aircraft Maintenance Unit (AMU) engine specialist logs; and Comprehensive Engine Management System (CEMS) and Integrated Maintenance Data System records (IMDS) (Tab D-1 thru D-41, U-1 thru U-43).

(2) Aircraft Major Maintenance: The mishap engine (ME) S/N E538304 was installed on 19 Oct 2008 following a series of faults with a previously installed engine (Tab U-22 thru U-25, U-32).

(3) Engine major maintenance: The ME was last received by Jet Engine Intermediate Maintenance (JEIM) on 24 August 2008 for high pressure turbine blade distress. In addition to repairing the distress condition, the engine mechanics also accomplished the required component time change of the augmenter fuel control. No time compliance technical orders (TCTO) were accomplished. This engine underwent final inspection on 22 September 2008, shipped from Shaw AFB, SC, to Balad AB, Iraq on 08 October 2008, and was installed on the MA 19 October 2008. No evidence was found to show that these actions contributed to the mishap (Tab U-34 thru U-41).

(4) Recurring Maintenance Problems: None.

(5) Open Write-ups: MA AFTO Form 781A had an open write-up for post-flight Joint Oil Analysis Program (JOAP) sample due. No evidence was found to show this open write-up contributed to the mishap (Tab D-11).

(6) Aircraft and Engine AFTO Form 781K Write-ups: MA AFTO Form 781K identified seven delayed discrepancies, with the aircraft wash identified as the only overdue inspection. This is normal due to lack of wash rack facilities at the mishap location. No other overdue or grounding discrepancies were identified (Tab D-20 thru D-23). No evidence was found to show that these scheduled inspection items identified on the AFTO Form 781K were a factor in this mishap and there were no overdue engine inspections identified on ME AFTO Form 781K (Tab D-24 thru D-25).

(7) Preflight Operational Checks: The MA AFTO Form 781A for the day prior to and day of the mishap showed MA operational checks, preflight servicing checks and inspections, to include intake and exhaust inspections, were completed in accordance with applicable T.O.s. In addition, exceptional releases were properly documented on the AFTO Form 781H, releasing the aircraft for flight. No evidence was found to show preflight maintenance actions were a factor in this mishap (Tab D-8, D-11 thru D-12).

b. Inspections

(1) Aircraft: The last 400-hour phase inspection was completed in accordance with applicable T.O.s on 29 August 2008 at 3,780.1 aircraft hours. The MA had flown for 306.0 hours since last 400-hour phase inspection (Tab D-20).

(2) Engine: The last 200-hour engine phase inspection was completed on 24 August 2008. The last 100-hour engine inspection was completed the day prior to the mishap on 11 November 2008. Both inspections were properly complied with in accordance with applicable T.O.s (Tab D-24).

(3) Foreign Object (FO) Inspections: F-16 aircraft deployed to Balad AB, Iraq, have higher foreign object damage (FOD) rates when compared to home station. A 120-day review identified zero FOD events at home station compared to 11 FOD events recorded at Balad AB. Of those 11 events at Balad AB, 5 were caused by stones and all events caused negligible damage (Tab U-44). The MA crew chief performed an intake and exhaust inspection of the ME as part of the preflight inspection. The MP and the MA crew chief performed aircraft parking location and immediate taxi area FO inspections prior to engine start (Tab V-1.7, V-4.4). There is no evidence FOD contributed to the mishap.

c. Maintenance Procedures

A review of the maintenance indicates AMU and propulsion flight maintenance actions were conducted in accordance with applicable T.O.s and procedures (Tab U-10 thru U-20, U-34 thru U-41). There is no evidence that maintenance procedures contributed to this mishap.

d. Maintenance Personnel and Supervision

A review of maintenance personnel training records revealed no contributing factors to this mishap. There is no evidence maintenance personnel or supervision contributed to this mishap (Tab U-43).

e. Fuel, Hydraulic, and Oil Inspection Analysis

Oil samples collected from the ME tested with high levels of copper and silicon. These increased levels of wear metals were the result of the mishap and were not causal to the mishap. Oil and hydraulic samples collected from the MA and ME servicing equipment tested normal and were not factors in the mishap. There was no fuel from the MA available for testing (Tab D-29 thru D-38).

f. Unscheduled Maintenance

No unscheduled maintenance was performed on the MA after the last scheduled maintenance event (preflight inspection) (Tab D-11 thru D-12).

6. AIRCRAFT AND AIRFRAME, MISSILE, OR SPACE VEHICLE, SYSTEMS

a. Condition of Systems

(1) Aircraft and Systems: The structural damage of the aircraft was severe and occurred as a result of the fire caused by the engine failure. The aircraft was consumed by fire. The debris field shows the majority of debris exited the right side of the aircraft at the start of the mishap, with aircraft and engine components scattered across the airfield (Tab Z-6). Crash survivable flight data recorder (CSFDR) and engine systems recording components analysis indicate all systems operated normally (Tab CC-13 thru CC-16). There were no abnormal system indications prior to the mishap (Tab V-1.5, V-1.9).

Second stage disk components were recovered in the aircraft, in the engine, and on the airfield (Tab Z-6). There was a large hole on the right side of the MA where a liberated piece of the second stage fan disk exited after failure (Tab S-7 thru S-8, Z-3 thru Z-5). After liberation, the engine debris ruptured the fan case and continued outward rupturing the main engine fuel feed line and damaging the main fuel shutoff valve (MFSOV) (Tab R-38 thru R-52, Z-3 thru Z-4).

Engine's Second Stage Fan Disk Following Removal

Liberated Portion of Second Stage Fan Disk

The exit path also damaged hydraulic components causing a loss of hydraulic fluid and pressure and loss of aircraft braking ability (Tab R-38 thru R-52, V-1.5). The aircraft experienced a loss in nose wheel steering as a result of the loss of power (Tab V-1.5). Continuing outward, the debris punctured the fuel cell before contacting and damaging the trailing edge of the right wing and puncturing the right external fuel tank (Tab R-38 thru R-52, S-7, Z-3 thru Z-4). The nose wheel landing gear collapse was caused by the MA's exit from the prepared surface after steering loss (Tab V-1.6). The liberated piece of the second stage fan disk was found in the post mishap debris field approximately 150 feet from the mishap origin (Tab S-8, Z-6).

(2) Engine History: The ME, a F110-GE-129 engine, is manufactured by General Electric (GE) and is primarily maintained at the field level by aerospace propulsion personnel assigned to the AMU and to the 20th Component Maintenance Squadron (CMS) Propulsion Flight. Most propulsion flight repairs are done in the Jet Engine Intermediate Maintenance Section (JEIM). Detailed engine records are contained in CEMS and IMDS.

The ME had accumulated 4,886.1 hours Engine Operating Time (EOT), 3,154.9 In Flight Time (IFT) hours and 6,297 Total Accumulated Cycles (TAC) since new at the time of the mishap (Tab U-33). The engine was removed from another aircraft on 23 August 2008 to replace all of the high pressure turbine blades (Tab D-39, U-34 thru U-41). The ME was taken to JEIM on 24 August 2008 and turned into a serviceable spare on 22 September 2008 (Tab U-22). The spared engine was shipped to Balad AB, Iraq, on 08 October 2008 and installed on the MA on 19 October 2008 with 4,762.3 EOT, 3,064.8 IFT, and 6,204 TACs (Tab U-32).

Post installation, the only major engine maintenance accomplished was a 100-hour cycle borescope inspection on 11 November 2008. The 100-hour inspection consisted of a borescope of the high pressure turbine (HPT) and the forward and aft turbine frame fairings and a visual inspection of the oil pressure transmitter (OPT) (Tab D-24). No defects were noted at the time of the inspection (Tab U-14 and U-21).

(3) Second stage fan disk history: The second stage fan disk is attached as part of the engine fan rotor assembly, consisting of three stages. The disk was manufactured in 1993 and was previously installed in another fan rotor assembly (Tab U-3 thru U-8). The fan rotor remained in another engine until it was removed for a 4000 TAC interval inspection in 2000 and returned to the engine depot. It underwent cleaning and inspections which included visual, dimensional and eddy current inspections (ECI) (Tab U-5 and U-9).

The ECI is a non-destructive inspection (NDI) that obtains information on a number of material variables such as type, hardness, heat treat conditions, thickness, cracks, etc. (Tab U-9). During the ECI of the second stage fan disk in 2000, one rejectable flaw was found. It was then re-prepped, inspected, and it passed the next ECI. The initial rejectable flaw was not in the same location as the disk failure origin for this mishap (Tab U-5).

The only NDI inspection of the second stage fan disk is accomplished during fan rotor overhaul when the disk is accessible. This area is not accessible when the engine is installed. A visual only surface inspection can be accomplished when the engine is uninstalled and the fan casing is removed. ECI inspections can only detect cracks at or near the surface of the material (Tab U-9).

The ECI would not have been able to detect the subsurface crack in the second stage fan disk that led to this mishap because the crack was too far beneath the surface (Tab U-9).

The second stage disk was installed on fan rotor S/N GWNDK354 on 21 November 2000 (Tab U-3). This fan rotor was installed in the ME at Spangdahlem AB, Germany, on 10 November 2002 as part of a 4,000 TAC interval inspection (Tab U-26). The ME was turned into a serviceable spare from that inspection on 14 January 2003 (Tab U-26 thru U-27). A review of subsequent maintenance performed shows the ME was installed and removed on different aircraft for various maintenance required, and the fan rotor was removed once to facilitate bearing replacement. The second stage disk was not removed (Tab U-28).

The ME was installed on the MA on 19 October 2008 and operated normally until the mishap (Tab U-22 thru U-25, CC-13 thru CC-16). Engine start, taxi, idle power, and military power operations were normal (Tab V-1.4 thru V-1.5). Analysis of the engine operation during this timeframe shows the fan operating normally (Tab CC-13 thru CC-16).

The mishap occurred when afterburner power was selected for takeoff (Tab V-1.5). The second stage fan disk failure caused the liberation of a section measuring approximately 12.5 inches and multiple fan rotor blade and stator components (Tab J-47).

b. Testing and Teardown Analysis

(1) The CSFDR system houses the Signal Acquisition Unit (SAU) containing nonvolatile memory. The SAU was removed and delivered to the Air Force Safety Center (AFSC) at Kirtland AFB, New Mexico for download analysis. The aircraft also contained an Engine Monitoring System Computer (EMSC) which was also delivered to the AFSC for analysis. The download analysis showed all aircraft systems operating normally up until the time of the mishap (Tab CC-13 thru CC-16).

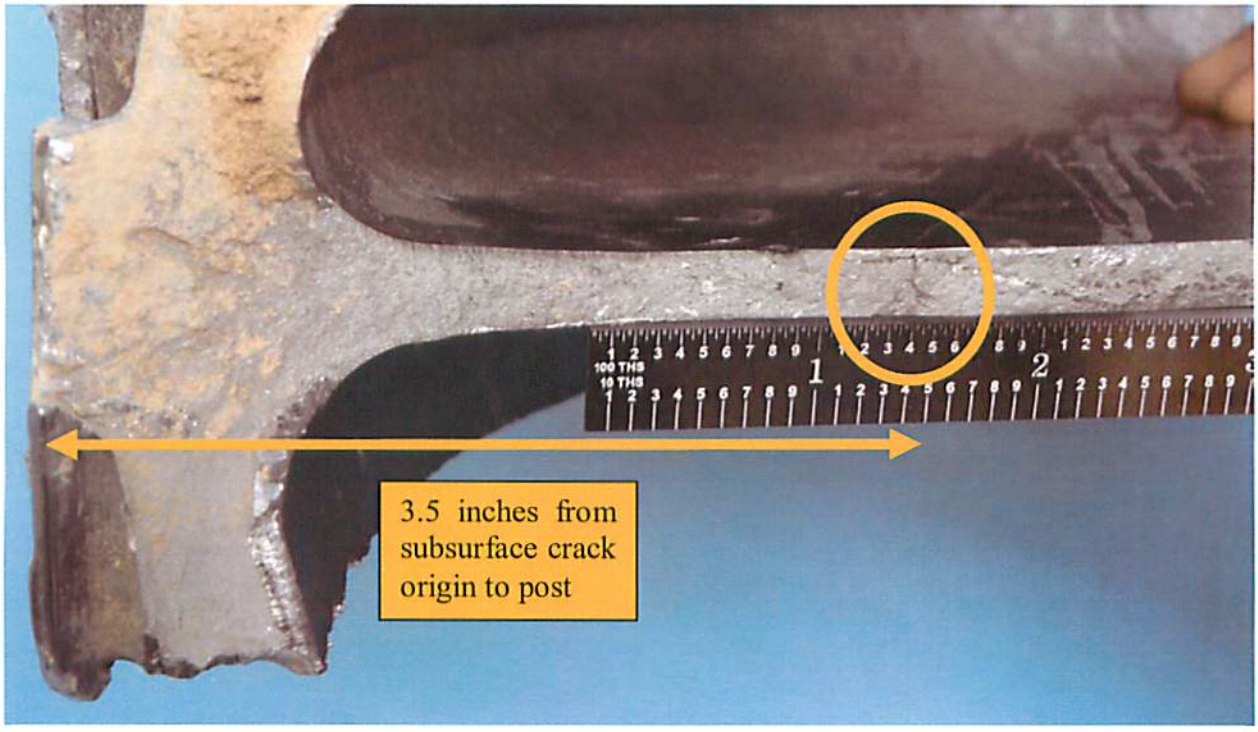
(2) There was no evidence that the bird feathers found in the debris field were contributory in this mishap. Evidence did not support a possible bird strike. Analysis of the feathers revealed they were from two different species. The feathers were identified as a common skylark which weighs approximately 1.5 ounces and a dove (biological family Columbidae) which weighs approximately 4-6 ounces. The feathers were found complete and in good physical condition. They were unsoiled and not mangled indicating they had not been ingested in the ME (Tab CC-3 thru CC-11).

(3) The 20 CMS JEIM section performed the teardown of the ME. During the initial teardown, all five engine bearings were removed. The bearings appeared to have been lubricated and balanced at the time of the mishap and observed damage was consistent with catastrophic engine failure (Tab J-36 thru J-41). Failure of the second stage fan disk led to an unrestrained liberation of some fan section components. The resulting failure of the fan rotor led to engine failure. The ME suffered irreparable internal and external damage (Tab J-1 thru J-41). Both the liberated and non-liberated portions of the second stage fan disk were delivered to the GE Infrastructure section for analysis (Tab Q-8).

c. Second Stage Fan Disk Analysis

(1) Analysis: Analysis of the second stage disk was primarily conducted by three agencies working jointly at the GE facility in Evandale, Ohio. Personnel performing testing and analysis of the second stage disk were from GE, the Metallurgical Analysis section from the Air Force Research Laboratory (AFRL) at Wright-Patterson Air Force Base and the Material Integrity Branch from the Oklahoma City Air Logistics Center (OC-ALC). Testing and analyses were performed using different methods including, but not limited to, visual inspections, chemical treatment, and electronic equipment (Tab J-44 thru J-293). Due to lack of some specific equipment, some orientation imaging (OIM) work was done by the Global Research Center (GRC) in Schenectady, NY (Tab J-255).

(2) Metallurgy: The stereomicroscopic examination of the liberated segment revealed a subsurface crack origin (Tab J-63, J-224, J-246). The second stage fan disk is not solid cast; it is a web design with a diameter of approximately 23 inches and weighs approximately 60 pounds (Tab U-45). The total web area thickness measured at 0.287 inches and met drawing requirements (Tab J-63). The fail point origin occurred at approximately 0.159 inches below the surface (Tab J-265). A subsurface crack developed approximately 3.5 inches inboard of the disk posts in the web and would have been approximately 3.3 inches long at the time of the mishap (Tab J-222, J-246). An abrupt transition from faceted fracture to fatigue was observed; however, there is no way to pinpoint a timeline from the fracture to fail point (Tab J-64).



Extracted from 14 January 2009 General Electric Manufacturing Report

An approximate 12.5 inch sectional arc of the second stage disk was liberated (Tab J-47). The speed and trajectory associated with this liberation led to the inside-to-out rupturing of the case,

initial damage and failure to several in-line parts and engine and aircraft structure. The AFRL was unable to match this incident with any other previous like-item failure surface (Tab J-223). Subsequent area damage and parts failures came as a result of the catastrophic engine failure and aircraft fire (Tab J-43).

Analysis was done at the macro and micro levels. Blue etch anodizing was utilized as an NDI. An Axiovert stereomicroscope was used and identified that the overall microstructure of the disk showed no abnormalities that would have been cause for rejection at the time the second stage fan disk was fabricated (Tab J-221).

Additional fractography was done using a scanning electron microscope (SEM). The SEM identified evidence of several brittle cleavage fractures, fatigue crack growth, and ductile overload all in the same vicinity (Tab J-222). Additional SEM analysis identified the origin of the anomaly; the Material Integrity Branch from OC-ALC theorized it may have been created during the manufacturing process (Tab J-246). However, observed regions of the second stage disk were found to be metallurgically consistent with 1990 manufacturing standards, and all inspections indicate the material was normal (Tab J-224, J-223).

Stereo photographs were taken of the disk mating fracture surface (Tab J-251). Energy dispersive spectrometer scans showed no anomalous chemicals (Tab J-253). Based on the submitted overall metallurgical reports, analyses identified subsurface cracks in the web material with no clear indication of the exact time of origin (Tab J-65, J-224, J-246). In summary, the metallurgical analysis could not identify a root cause for this subsurface crack.

7. WEATHER

a. Forecast Weather

The MFL and MP received a standard SECRET online weather brief prior to stepping to fly (Tab F-3).

b. Observed Weather.

Observed weather was low winds and few and scattered clouds (Tab F-4). Visibility was clear and weather was not factor in the mishap (Tab V-1.3 thru V-1.4, V-2.3).

c. Conclusion

There was no evidence weather contributed to the mishap.

8. CREW QUALIFICATIONS

The MP is a current and fully qualified F-16 pilot (Tab V-1.3, G-16 thru G-20). The MP had a total of 440.0 flight time (Tab G-4). The MP had a total of 408.4 hours in the F-16 (Tab G-4). His last flight prior to the mishap was the day prior on 11 November 2008 (Tab G-5). There is no evidence that crew qualifications were a factor in this mishap.

9. MEDICAL

a. Qualifications

The medical and dental records for the MP were thoroughly reviewed by the AIB. He was medically qualified for flying duties at the time of mishap and was not on waiver.

b. Health

Thorough review of medical and dental records of the MP and key maintainers involved with the MA revealed no health problems. There is no evidence the health of the MP and key maintainers contributed to this mishap.

c. Toxicology

Post-mishap toxicology testing was conducted by Armed Forces Institute of Pathology and revealed no abnormalities.

d. Lifestyle

There is no evidence that any lifestyle factors, including unusual habits, behavior, or stresses of the MP or maintenance crew servicing the ME prior to the sortie, contributed to this mishap.

e. Crew Rest and Crew Duty Time

Pilots are required to have proper "crew rest," as defined in AFI 11-202, Volume 3, *General Flight Rules*, 16 February 2005, prior to performing in-flight duties. AFI 11-202 defines normal crew rest as a minimum 12-hour non-duty period before the designated flight duty period (FDP) begins. MP was in compliance with crew rest and duty time requirements.

10. OPERATIONS AND SUPERVISION

a. Operations

Operations tempo was described as normal for Balad AB, Iraq. There is no evidence that operations tempo was a factor in the mishap (Tab V-3.3, V-4.3).

b. Supervision

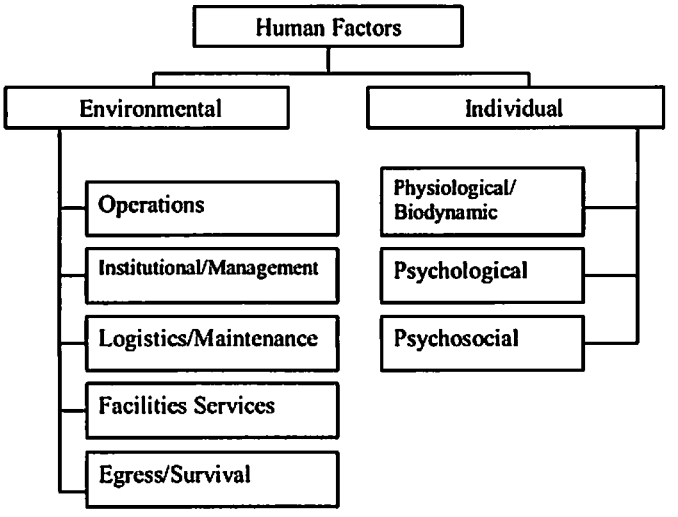
The MFL was a qualified instructor pilot and had worked and previously flown with the MP. Mission planning and briefing was uneventful (Tab V-1.3, V-2.3). There is no evidence that supervision was a factor in the mishap.

11. HUMAN FACTORS

A human factor is any environmental factor or individual psychological factor a human being experiences that contributes to or influences his performance during a task. In the Life Science

Report Program, human factors are broken down into two categories: environmental and individual. The environmental factors cover not only the physical environment to which mishap aircrew members are exposed, but also the organizational and personal environments. In turn, the mishap crew, operator or pilot reacts to the environment to which they are exposed. The second category of the individual factors covers physiological/biodynamic, psychosocial and psychological factors. The human factors analysis logic tree looks as follows:

HUMAN FACTORS ANALYSIS LOGIC TREE



Air Force Pamphlet (AFPAM) 91-211, USAF Guide to Aviation Safety Investigation, 23 July 2001, Attachment 8 contains a comprehensive list of human factors that may contribute to a mishap. The AIB carefully reviewed the potential human factors in light of known facts about the mishap. There is no evidence that human factors substantially contributed to this mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Primary Operations Directives and Publications

1. 20th Fighter Wing Pilot Guide, 15 April 2008
2. AFI 11-202, Volume 3, *General Flight Rules*, 16 February 2005
3. T.O. 1F-16CM-1-1, *Flight Manual*, 15 Jun 2008
4. AFPAM 91-211, *USAF Guide to Aviation Safety Investigation*, 23 July 2001

b. Maintenance Directives and Publications

1. AFI 21-101, *Aerospace Equipment Maintenance Management*, 29 June 2006
2. AFI 21-104, *Selective Management of Gas Turbine Engines*, 11 December 2007
3. AFI 21-124, *Oil Analysis Program*, 4 April 2003
4. T.O. 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies and Procedures*, 30 April 2003 with Change 4 dated 01 September 2006
5. T.O. 1F-16CJ-2-10JG-00-1, *Aircraft Safety*, 15 August 2007
6. T.O. 1F-16CJ-2-12JG-00-1, *Servicing*, 15 March 2007

7. T.O. 1F-16CJ-2-70FI-00-11, *Fault Isolation,* 15 March 2008
8. T.O. 1F-16CJ-2-70JG-00-1, *Engine Operation,* 15 December 2008
9. T.O. 1F-16CJ-2-70FI-00-11, *Engine Removal and Installation,* 15 December 2008
10. T.O. 1F-16CJ-6-11, *Scheduled inspection and Maintenance Requirements,* 15 June 2008
11. T.O. 2J-F110-16, *F110-GE-129 Intermediate Maintenance Manual,* Revision 39, 15 April 2008
12. T.O. 33-1-11, *Nondestructive Inspection, Turbofan Engines,* 1 June 2002 with Change 21 dated 15 April 2008

NOTICE: The AFIs listed above are available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**

c. Known or Suspected Deviations from Directives or Publications

There are no known or suspected deviations from directives or publications by crew members or others involved in the mishap mission.

13. NEWS MEDIA INVOLVEMENT

Media interest in this mishap was minimal.

14. ADDITIONAL AREAS OF CONCERN

No additional areas of concern contributed to this aircraft accident.

23 January 2009

ROGER A. QUINTO, Lt Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

F-16CM, S/N 93-0554 ACCIDENT
12 November 2008

Under 10 U.S.C. 2254(d), any opinion of the accident investigators as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report may not be considered as evidence in any civil or criminal proceeding arising from the accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.

1. OPINION SUMMARY

I find by clear and convincing evidence that the cause of this mishap was a catastrophic failure of the engine's second stage fan disk. An undetected subsurface crack in the second stage fan disk caused a portion of the fan disk to break free shortly after MP selected afterburner. There are no required inspections that would have detected the subsurface crack. Pieces of the fan disk and other engine fragments pierced the aircraft fuel cell and severed hydraulic lines, causing loss of control and the fire that destroyed the aircraft.

2. DISCUSSION OF OPINION

The MP and MA were part of an early morning 2-ship CAS mission. Up until the time the MP selected afterburner for his takeoff, the mission was uneventful and went as briefed. When the MP selected afterburner, he heard a loud pop, saw a bright light immediately behind him and experienced an immediate loss of thrust. The cause of these events was a catastrophic failure of the engine's second stage fan disk.

A portion of the second stage fan disk liberated itself, proceeded to penetrate the fan casing and the aircraft fuel cell, exited the MA, and landed approximately 150 feet on the right side of the aircraft. The liberated portion measured 12.5 inches in circumference and 7 inches radially. Additional pieces from the engine and aircraft formed a debris field to the immediate right of the aircraft.

As pieces of the engine flew out the right side of the MA, a fuel cell was punctured causing a fire. Additionally, hydraulic lines were damaged causing loss of brakes and nose wheel steering. The MA proceeded down the runway with a slight veer to the right. The MP was unable to catch the approach end barrier with the MA tailhook, and the MA departed the prepared surface at approximately 1,800 feet and continued forward for another 900 feet until the nose landing gear collapsed and the MA came to a complete stop. The MP safely ground egressed the aircraft and evacuated the area until he met up with emergency response crews.

Metallurgical evaluation of the liberated second stage fan disk and the remaining portion of the second stage fan disk determined the origin of a subsurface crack 3.5 inches inboard of the fan disk post. The crack was 3.3 inches long at the time of catastrophic failure, although there is no

way to determine how fast the crack grew from defect origin. There were no material anomalies found to explain the crack progression and all previous inspections identified the material as acceptable. The origin of the crack was subsurface and would not have been detectable with current inspections. Although borescope inspections are conducted every 100 flight hours, these inspections do not inspect the area of concern. The second stage fan disk was last inspected in 2000 during an engine overhaul. Although a different surface defect was noted and corrected in 2000, the defect was not near the point of origin of this mishap.

Of note, bird feathers were found within the debris field and the AIB investigated bird strike as a potential cause of the mishap. The Smithsonian determined the feathers to be from a skylark and a dove. In addition, the curator also determined that the bird feathers did not exhibit the normal signs of engine digestion. According to the MP, birds during early morning missions (prior to sunrise) were normally not a concern. An evaluation of foreign object damage in the preceding 120 days at Balad AB, Iraq, found no F-16 bird strikes. The AIB found no evidence that a bird strike was contributory to the catastrophic failure of the engine due to the nature and location of the failure point on the second stage fan disk as determined by metallurgical testing, the condition of the bird feathers, the small size of the birds and the general lack of bird hazards during the early morning hours.

23 January 2009

ROGER A. QUINTO, Lt Colonel, USAF
President, Accident Investigation Board

INDEX OF TABS