

AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT



F-16C+, S/N 87-0242

**176TH FIGHTER SQUADRON
115TH FIGHTER WING
TRUAX FIELD, WISCONSIN**



ACCIDENT LOCATION: NEW CHESTER, WISCONSIN

DATE OF ACCIDENT: 7 JUNE 2011

BOARD PRESIDENT: LT COL DAVID B. FAULK

Conducted IAW Air Force Instruction 51-503

EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION BOARD

**F-16C+, SN 87-0242
TRUAX FIELD, WISCONSIN
7 JUNE 2011**

On 7 June 2011, at 1316 local time, an F-16C+, serial number 87-0242, impacted the ground approximately 57 nautical miles northwest of Truax Field, Wisconsin. The Mishap Aircraft (MA) and Mishap Pilot (MP), assigned to the 176th Fighter Squadron, 115th Fighter Wing, Truax Field, Wisconsin, were participating in a training mission when the MA experienced a sudden loss of thrust approximately one hour and twenty-three minutes after takeoff. The MP was unable to achieve a successful engine restart. The MP ejected safely and sustained only minor scratches and bruises. The MA impacted near an unoccupied private residence and both were completely destroyed. There were no civilian injuries. The MA was valued at \$25,691,100.30.

The mishap mission was briefed as a continuation training basic fighter maneuver mission which involved simulated air-to-air "dogfights" between the MP and the mishap wingman, each in their own F-16 aircraft. As the mishap flight prepared to return to base, the MA experienced a sudden loss of thrust. The MP had cockpit indications of an engine failure and immediately began a turn to the nearest suitable runway while simultaneously initiating air start procedures to recover the engine. The MP jettisoned his empty external fuel tanks to reduce drag once clear of a populated area below the MA. The MP continued to attempt to recover the engine by executing air start procedures until the MA descended to the recommended minimum controlled ejection altitude. The engine never fully recovered and the MP initiated a successful ejection at 1,500 feet above the ground. The MA impacted the ground with the engine stabilized at a sub-idle RPM of approximately 50%. Distance to the nearest recovery field was beyond the MA's glide capabilities, thus negating any chance of safely recovering the MA.

The Accident Investigation Board (AIB) President found clear and convincing evidence the cause of the mishap was a failure of the power take-off shaft forward main bearing assembly within the Accessory Gearbox (AGB). Additionally, the AIB President found clear and convincing evidence the failure was caused by inadequate lubrication of the bearing assembly due to a complete or partial blockage of the AGB oil supply line with debris.

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 OPINION
F-16C+, SN 87-0242
115 Fighter Wing
Truax Field, WI
7 June 2011

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COMMONLY USED ACRONYMS & ABBREVIATIONS

1V1 – 1 versus 1	FW – Fighter Wing
AB – Afterburner	GE – General Electric
ACCEL – Acceleration	HFACS – Human Factors Analysis and Classification System
ACES II – Advanced Concept Ejection Seat II	HPT – High Pressure Turbine
ACMI – Air Combat Maneuvering Instrumentation	IGV - Inlet Guide Vane
ADG – Accessory Drive Gearbox	IMDS – Integrated Maintenance Data System
AFI – Air Force Instruction	INS – Inertial Navigation System
AFOSH – Air Force Occupational Safety and Health	IP – Instructor Pilot
AFMES - Armed Forces Medical Examiner System	JFS – Jet Fuel Starter
AFSC – Air Force Specialty Code	JOAP – Joint Oil Analysis Program
AFTO – Air Force Technical Order	KIAS – Knots Indicated Airspeed
AGB - Accessory Gearbox	L – Local TimeLA – Low Alloy
AGL – Above Ground Level	LAU – Launcher Assembly Unit
AIB – Accident Investigation Board	LM Aero – Lockheed Martin Aeronautics
AIM – Air Intercept Missile	LPT – Low Pressure Turbine
AMU – Aircraft Maintenance Unit	LRU – Line Replaceable Unit
BD – Battle Damage	MA – Mishap Aircraft
BFM – Basic Fighter Maneuver	MCD – Master Chip Detector
CAMS – Core Automated Maintenance System	ME – Mishap Engine
CAPS – Critical Action Procedures	MEC - Main Engine Control
CATM – Captive Air Training Missile	MFD – Multi Function Display
CRU-60 – Crew Regulator Unit	MFL – Mishap Flight
CSFDR - Crash Survivable Flight Data Recorder	MIL – Military
CSMU - Crash Survivable Memory Unit	MM - Millimeter
D.C. – District of Columbia	MOA – Military Operating Area
DECEL - Deceleration	MP – Mishap Pilot
DEC – Digital Engine Control	MSL – Mean Sea Level
DoD – Department of Defense	MW – Mishap Wingman
EGT – Exhaust Gas Temperature	NDI – Non Destructive Inspection
EOT – Engine Operating Time	NM – Nautical Miles
EPLA - Engine power level angle	NOTAM – Notice to Airman
EPU - Emergency Power Unit	OC-ALC – Oklahoma City-Air Logistics Center
FCIF – Flight Crew Information File	ORM – Operational Risk Management
FPI – Fluorescent Penetrate Inspection	PA - Pilot Advisor
FS – Fighter Squadron	PHA – Periodic Health Assessment
FTIT - Fan Inlet Turbine Temperature	PLA – Power Lever Angle
	POS – Process Order Supplement
	PRI - Primary
	PSI – Pounds per Square Inch

PTO – Power Take Off
QA – Quality Assurance
QVI – Quality Verification Inspection
RPM – Rotations Per Minute
SARCAP – Search and Rescue Combat air
Patrol
SEC – Secondary
SEM/EDX - Scanning Electron
Microscope/Energy Dispersive
X-Ray)
SFO – Simulated Flameout Overhead
SIM - Simulator
SLEP – Service Life Extension Program

S/N – Serial Number
SOF – Supervisor of Flight
SPINS – Special Instructions
SUPER – Supervisor
TACS – Total Accumulated Cycles
TBD – To Be Determined
TCTO – Time Compliance Technical Order
TDY – Temporary Duty
T.O. – Technical Order
VSV – Variable Stator Vane
WCD – Work Control Document

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 AND PURPOSE

a. Authority

On 8 August 2011, Lieutenant General William J. Rew, Vice Commander, Air Combat Command (ACC), convened an Accident Investigation Board (AIB) in accordance with Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*, to investigate the 7 June 2011 mishap involving an F-16C+ aircraft, serial number (S/N) 87-0242, which crashed 57 nautical miles north by northwest of Truax Field, Wisconsin (Tab Y-3). Lieutenant Colonel David B. Faulk, 4th Operation Group, Seymour Johnson AFB, NC, was appointed AIB President. There was also a Pilot Advisor, Maintenance Advisor, Propulsion Functional Area Expert, Medical Advisor, Legal Advisor, and Recorder appointed to the AIB. This investigation was conducted at Truax Field, Wisconsin from 15 August 2011 through 5 September 2011.

b. Purpose

This is a legal investigation convened to inquire into the facts surrounding the aircraft or aerospace accident, to prepare a publicly-releasable report, and to gather and preserve all available evidence for use in litigation, claims, disciplinary actions, administrative proceedings, and for other purposes.

2. ACCIDENT SUMMARY

On 7 June 2011, an F-16C+ piloted by the Mishap Pilot (MP) of the 176th Fighter Squadron (176 FS), Wisconsin Air National Guard, Madison, Wisconsin, experienced a sudden loss of thrust during the flight back to his home airfield (Tab N-3). The Mishap Aircraft (MA) was approximately 35 miles east of Volk Airfield, Wisconsin (Tab N-3, N-6). The MP was unable to successfully restart the engine and subsequently ejected at 1,500 feet Above Ground Level (AGL) (Tab V-1.9). The MA impacted an unoccupied residence in rural Adams County, Wisconsin destroying both the \$25 million dollar aircraft and the residence (Tab P-4, P-5). There were no casualties or civilian injuries.

3. BACKGROUND

a. Air National Guard



The Air National Guard is administered by the National Guard Bureau, a joint bureau of the departments of the Army and Air Force, located in the Pentagon, Washington, D.C. It is one of the seven Reserve components of the United States armed forces that augment the active components in the performance of their missions. The Air National Guard has both a federal and state mission. The dual mission, a provision of the U. S. Constitution, results in each

guardsman holding membership in the National Guard of his or her state and in the National Guard of the United States (Tab DD-22).

b. 115th Fighter Wing



Located in Madison, Wisconsin, the 115th Fighter Wing's (115 FW) federal mission is to staff and train flying and support units to augment Air Combat Command general purpose fighter forces to effectively and rapidly project F-16 combat power anywhere in the world to perform wartime or peacetime missions as well as operations other than war. 115 FW will maintain mobilization readiness and conduct training in support of Total Force capabilities as directed by gaining commands. The State mission is to provide trained and equipped units to protect life and property and to preserve peace, order, and public safety as directed by the Governor of Wisconsin (Tab DD-5).

c. 176th Fighter Squadron



The 176 FS is stationed at Madison Dane County Regional – Truax Field, and flies the Block 30 F-16C+ Fighting Falcon powered by a single F110-GE-100 afterburning turbofan engine capable of producing approximately 27,000 pounds of thrust (Tab DD-9). The 176 FS primary training missions include counter air, strategic attack, interdiction, and close air support (Tab DD-3).

176 FS has several military operating areas (MOAs) where F-16s conduct air-to-air and air-to-ground training missions. These areas include the Volk, Falls, and Minnow MOAs for air-to-air training and the Hardwood Range (Restricted Area 6904) for practicing air-to-ground deliveries with inert bombs. All of these airspaces are located approximately 40NM north of Madison, Wisconsin. Pilots practice visual and instrument approaches at Volk Airfield inside of the Volk West MOA (Tab AA-3).

d. F-16 Fighting Falcon

The F-16 Fighting Falcon (Figure 1) is a compact, multi-role fighter aircraft. It is highly maneuverable and has proven itself in air-to-air combat and air-to-surface attack. It provides a relatively low-cost, high-performance weapon system for the United States and allied nations (Tab DD-9).

In an air combat role, the F-16's maneuverability and combat radius (distance it can fly to enter air combat, stay, fight and return) exceed that of all potential threat fighter aircraft. It can locate targets in all weather conditions and detect low flying aircraft in radar ground clutter. In an air-to-surface role, the F-16 can fly more than 500 miles (860 kilometers), deliver its weapons with superior accuracy, defend itself against enemy aircraft, and return to its starting point. An all-weather capability allows it to accurately deliver ordnance during non-visual bombing conditions (Tab DD-9).



Figure 1: F-16C+

In designing the F-16, advanced aerospace science and proven reliable systems from other aircraft such as the F-15 and F-111 were selected. These were combined to simplify the airplane and reduce its size, purchase price, maintenance costs and weight. The light weight of the fuselage is achieved without reducing its strength. With a full load of internal fuel, the F-16 can withstand up to nine G's -- nine times the force of gravity -- which exceeds the capability of other current fighter aircraft (Tab DD-9).

4. SEQUENCE OF EVENTS

a. Mission

ROCK 31 flight, a two-ship formation of F-16C+ aircraft, was scheduled as a continuation training-basic fighter maneuver (BFM) mission which involved simulated air-to-air “dogfights” between the MP and the Mishap Wingman (MW) (Tab K-11). ROCK 31 was flown by the MP, who was a current and qualified F-16 instructor pilot (IP) and was acting as the flight lead. ROCK 32 was flown by the MW, who was a current and qualified F-16 IP and was acting as the wingman (Tab G-3). Planned mission tasks included a single-ship takeoff, Simulated Flameout Overhead (SFO) at Volk Airfield, BFM engagements in accordance with Special Instructions (SPINS), culminating with a return to Truax Field for a normal overhead pattern to a full-stop landing (Tabs V-1.5, K-5). The mission was authorized by the 176 FS Squadron Supervisor, also known as Top-3, in charge of daily operations in accordance with AFI 11-401 (Tab K-7).

b. Planning

The mission planning was conducted in accordance with 115 FW Standards. The MP arrived at the squadron at approximately 1030L, half an hour prior to the mission briefing, prepared the mission data card, reviewed the weather conditions, Notices to Airmen (NOTAMS), and Operational Risk Management form (ORM) (Tabs F-3, K-3, K-5, K-11, V-1.4 through V-1.5). The MP started the briefing on time and utilized the standard briefing guide located in the 115 FW In-Flight Guide, pages B-1 through B-3 (Tab V-1.5). The MP concluded the briefing 40 minutes later to allow for an early “step” (Tab V-1.5). “Step” refers to the time the pilot will depart the squadron to allow time for sufficient preflight of the aircraft and follow-on ground operations. The MP discussed all required items for takeoff, departure, recovery, safety of flight,

and the tactical portions of the flight (Tab V-1.5). Both flight members were prepared for the mission and fully understood the mission profile and tasks (Tab V-1.5).

c. Preflight

The MP and MW attempted to “step” early, but because the aircraft was not crew-ready, they were required to wait until scheduled “step” time. They received a “step” brief from the Top-3 at the operations desk (Tabs V-1.5, and AA-5 through AA-10). During the “step” brief, the Top-3 confirmed the current runway in use, briefed any weather or NOTAM changes that occurred the previous two hours, discussed any operations or supervisory concerns about the day’s training missions, reviewed each pilot’s ORM, and passed along any other administrative information that might have been pertinent to the pilots (Tabs R-9, R-10, and AA-5 through AA-10). The MP and MW departed the squadron at approximately 1105L (Tab K-5, V-1.5). After arriving at the aircraft, the MP performed a thorough preflight of his aircraft and found nothing unusual (Tab V-1.5). The MP started his aircraft on time at 1120L, completed his preflight checks, and was ready to taxi to the runway at 1135L (Tabs K-5, V-1.5).

d. Summary of Accident

The Mishap Flight’s (MF) taxi to the end of runway was uneventful (Tab V-1.5). At 1150L, the MF performed single-ship military power takeoffs. Military power is the maximum power setting for the engine without selecting afterburner. The MF proceeded on a standard departure path north direct to Volk airfield utilizing standard coordination procedures with the Air Traffic Control (ATC) agencies (Tabs V-1.5). There were no communications or navigational difficulties. At Volk airfield, the MF performed multiple SFO practice approaches to burn down fuel and gain valuable training in a simulated engine out situation (Tab V-1.5). The SFO practice approaches and subsequent navigation to the Volk East MOA were uneventful. The MF completed standard checks upon entering the airspace in preparation for BFM engagements (Tab V-1.5). The MF then performed 4 BFM engagements as briefed. No significant weather was encountered (Tab V-1.6, F-3).

After completion of the BFM engagements, the MF rejoined as a 2-ship to perform a battle damage check (Tab V-1.5). During a battle damage check, each aircraft visually inspects the other aircraft to ensure there was no damage during the aggressive maneuvering. The MF was established at an altitude of 9,000 feet mean sea level (MSL), 300 knots indicated airspeed (KIAS) on a southerly heading (Tab V-1.6). As the MP crossed underneath the MW’s aircraft, the MP experienced a sudden loss of thrust and he heard the engine begin to “wind down” (Tab V-1.6). Pilot testimony coupled with Crash Survivable Flight Data Recorder (CSFDR), Seat Data Recorder (SDR), and Crash Survivable Memory Unit (CSMU) data indicate the following actions were taken after the MP recognized abnormal engine response (Tab V-1.6). At 1313L, the MP observed the engine revolutions per minute (RPM) indicator drop rapidly to 0% (Tab V-1.7, J-25). The MP’s displayed engine temperature, also known as fan turbine inlet temperature (FTIT), and oil pressure instruments also wound down but at a slower rate (Tab V-1.7, J-25). Simultaneously, the main and standby generator lights illuminated and the associated electrical systems in the aircraft turned off (Tabs J-25, V-1.7). One to two seconds later, the MP heard the

emergency power unit (EPU) activate, which provided emergency hydraulic pressure and emergency electrical power for flight (Tabs J-25, V-1.7).

The MP stated he was able to see both Truax Field and Volk Airfield, but assessed Volk Airfield as being the nearest suitable runway (Tab V-1.7). The MP then initiated a right hand turn to the west and proceeded direct to Volk Airfield (Tab V-1.7). At 13:13:12L, the MP transmitted over the auxiliary radio to the MW, “knock it off, knock it off”...13:13:17L, “ROCK 31, knock it off”...13:13:27L “just lost my engine” (Tab N-3, V-1.7). The MW looked over his right shoulder and saw the MA in a right hand turn and flew his aircraft to a chase position, approximately 6,000 feet aft and slightly high, to provide assistance (Tab V-2.3). While proceeding direct toward Volk Airfield, the MP began a slow descent to maintain 250 KIAS in accordance with Air start Procedures (Tab V-1.8). The MP then correctly performed multiple air start attempts, however, the engine did not successfully restart (Tab V-1.8, 1.9). During the airstart process, the MP momentarily delayed releasing his empty external fuel tanks until clear of a small residential area and then released them at 13:13:31L to reduce drag on the aircraft (Tab V-1.8, N-3). The expended fuel tanks landed in an unpopulated area and were later recovered by the local Sheriff’s department (Tab N-23). No injuries or property damage were reported as a result.

The MW directed the MP to continue west towards Volk Airfield, which was 37 nautical miles away (Tab V-2.5, N-3). The MA was not within gliding distance to any airfields suitable for F-16s and MP slowed the MA to 210 KIAS to create more time for a potential engine restart (V-1.8). At 13:13:59L, the MP engaged the Jet Fuel Starter (JFS), a smaller auxiliary engine, to assist the engine restart (Tab V-1.8, J-26). After the MP started the JFS, the MW observed a yellow flame briefly ignite in the exhaust nozzle and then quickly disappear (Tab V-2.4). At 13:14:42L, the MP reported observing the engine stabilized at 50% RPM, indicating a “hung start”, and made a radio transmission, “RPMs heading up...about 50, looks like I may get it back” (Tab V-1.8, N-3). A “hung start” situation occurs when the RPM indication stabilizes at a sub-idle RPM during the start sequence rather than increasing to the normal idle RPM. At 13:15:06L, the MP attempted to reset the engine control in accordance with his emergency checklist to recover the hung start without success (Tab V-1.9, J-26). While the MP was performing the checklist items, the MW asked the MP for his altitude to ensure the proper safe ejection altitude was still met (Tab N-3). MP responded with “alt 3,000 feet AGL” (above ground level), which is 1,000 feet above the minimum recommended ejection altitude during controlled flight (Tab N-3). After multiple failed air start attempts, the MA had descended to the minimum controlled ejection altitude and the MP initiated a successful ejection at approximately 1,500 feet AGL with no significant injuries at 13:15:38L (Tab V-1.9, H-7, N-4).

e. Impact

The MA impacted the ground on privately owned land at approximately 1316L (Figure 2), 57 nautical miles northwest (345 degrees True) of Truax Field and was completely destroyed (Tabs S-1 through S-10, H-3). Coordinates were North 43 50’ 51.5”, West 89 37’ 13.7” (Tab S-3). The wreckage field was fan shaped with the majority of wreckage 280-355 degrees True from the crater out to a distance of approximately 820 feet (Tab S-4).

At impact, the MA was configured with a centerline pylon, one Launcher Assembly Unit (LAU)-129 missile rail and one Captive Air Training Missile (CATM)-120 on station one, one LAU-129 missile rail and one Air Combat Maneuvering Instrumentation (ACMI) Pod on station two, one LAU-129 missile launcher rail and Air Intercept Missile (AIM)-9X practice missile on station eight, one LAU-129 missile launcher rail and one CATM-120 on station nine, two flare modules, and one chaff module (Tabs D-8, K-13 through K-15, P-3).



Figure 2: Impact Site

The MA impact crater (Figure 3) was approximately 9 feet deep and 30 feet in diameter (Tab P-5). The wreckage distribution and condition indicated that the MA was slightly right wing low, approximately 80-90 degrees nose down, and at 285 KIAS on a northwesterly heading at impact (Tab P-5). Following impact, the MA pivoted forward symmetrically about the nose, coming to rest inverted (Tab P-5). Both wings, and the horizontal stabs and vertical tail were separated from the fuselage (Tab P-5). The horizontal stabs remained in the impact crater, the wings were adjacent to the crater and the vertical tail was 117 feet beyond the crater (Tab P-5). Most of the remaining objects from the aircraft dispersed in a fan pattern out to 821 feet from the point of impact covering approximately 6 acres in a 45 degree arc (Tab P-5). Upon impact, fire enveloped the MA and a vacant double wide mobile home (Tab P-5). The vacant double wide mobile home structure was completely destroyed (Tab P-5).



Figure 3: Impact Crater

f. Egress and Aircrew Flight Equipment

The pilot initiated a successful Mode I ejection within the performance envelope of the ACES II ejection system (Tabs H-3, H-4, V-1.9). Mode 1 is the low airspeed (less than 250 KIAS), low altitude (below 15,000 Feet) mode of the ejection seat and is the preferred ejection mode (Tab H-4). During ejection, the MP experienced twisted risers but was able to successfully clear them with no issues (Tab V-1.9). All required life support and survival equipment inspections were current (Tabs CC-3 through CC-21). The MP was wearing the appropriate life support equipment for a daytime BFM mission (Tab V-1.9).

g. Search and Rescue

The MP safely parachuted into a field approximately 500 yards south east from the impact site (Tab V-1.10-11). The MA impacted the ground at 1316L, 57 nautical miles northwest of Truax Field, Wisconsin (Tab S-3). The MW reported MP's status to Volk Approach at 1317L and began coordination for emergency response vehicles (Tab N-9). At 13:18:10L, the MW attempted radio contact with the MP on guard frequency, but was unsuccessful (Tab N-10). The MP attempted to pass information with his hand held survival radio via Volk Approach to the MW (Tab V-1.10). At 1319L, the MW visually acquired the MP, recorded his location

coordinates, and confirmed movement on the ground by watching the MP pack up his parachute (Tab V-2.6). At 1320L, the MW returned to Truax Field and passed the MP location coordinates to the SOF (Tab V-2.6).

At 1324L, the 115 FW Command Post (CP) was notified of pilot ejection in the Volk MOA and began completing the aircraft accident/incident checklist (Tab N-21 through N-24). The MP was picked up by a civilian couple driving nearby and driven to the impact site (Tab V-1.10 through V-1.11). The MP borrowed a cell phone and called back to the SOF to report condition and help establish security at impact site (Tab V-1.11). The MP was examined by paramedics and found to have a minor laceration to the chin (Tab V-1.11). At 1344L, the CP received a report that the MP had been recovered (Tab N-22). At 1415L, the New Chester fire department responded to the accident and reported two structures on fire in the impact area (Tab N-22). At 1501L, the rescue was complete and transitioned to incident cleanup and initial safety board (Tab N-23). The CP submitted initial lost aircraft report at 1513L (Tab N-23). The CP closed the incident checklist at 1156L on the following day (Tab N-18).

There were no significant delays or difficulties during the recovery process.

h. Simulator Analysis of Mishap Engagement

The AIB did not conduct a re-enactment of the mishap maneuver due to the inability of simulators to reproduce this specific malfunction.

5. MAINTENANCE

a. Forms Documentation

Each individual Air Force aircraft has records that are kept on Air Force Technical Order (AFTO) Form 781s, and in a database known as Core Automated Maintenance System (CAMS) or more inclusive Integrated Maintenance Data System (IMDS) (Tab D-5). The AFTO Form 781 documentation for Aircraft 87-0242 was reviewed against the IMDS with regards to relevant maintenance performed prior to the mishap and all entries were complete and accurate (Tabs D-1 through D-16). Unit level engine intermediate build documentation was also reviewed to include S/N and time change items (Tabs D-17 through D-41). All records reviewed were complete and accurate.

Time Compliance Technical Orders (TCTO) are inspections or maintenance procedures that are required to be completed by specific dates or flight hours. AFTO Form 781s and IMDS track and record compliance times and dates. No TCTOs restricted the MA from flying. Historical records showed all TCTOs were accomplished in accordance with applicable guidance (Tab D-5). Records indicated the ME went through a "C-Mod" conversion which included a Service Life Extension Program (SLEP) for the F110-100. The "C-Mod", or C-Model, modifies the ME from a B-Model engine to a C-Model engine, which included an overhauled AGB (Tabs D-5, O-3, J-4).

Prior to the mishap, the MA accumulated 5294.2 flight hours (Tab D-6). The ME, installed in the MA on 2 June 2011, accumulated an Engine Operating Time (EOT) of 5912.2 hours (Tab J-4). The ME accumulated 5.2 hours of EOT since SLEP (Tab J-4). The MA had only flown one sortie with the ME since SLEP modification for a total of 1.4 flight hours prior to the mishap (Tab D-6).

b. Inspections

A document review was performed that included validation of written entries in the AFTO Form 781s to IMDS (Tab D-5). MA scheduled inspections included a 100 hour engine fuel shutoff valve actuator inspection and a 60 day anti-gravity suit hose leak and pull check (Tab D-11). The day of the mishap showed one scheduled inspection for the ME after the first flight of the day for a Master Chip Detector (MCD) visual inspection (Tab D-9). The MCD is a magnetic device attached to the engine that collects metal chip fragments from the engine oil supply. A SEM/EDX (Scanning Electron Microscope/Energy Dispersive X-Ray) machine is used to scan the MCD sample and determine what type and quantity of particular metals are in a given sample. SEM/EDX analysis returned with a "Level 1 Warning for 9310/4340" (Tab D-10). Certain engine components are constructed of 9310/4340, a low alloy steel (Tab U-3). The appropriate troubleshooting was initiated and found to be within limits for return to service (Tab D-10 and Tab J-4, U-3). Routine inspections included preflight, postflight, and thruflight which were performed according to schedule (D-6).

c. Maintenance Procedures

Maintenance procedures were reviewed. Oklahoma City – Air Logistics Center (OC-ALC), conducted an overhaul on AGB S/N 00WIA91830 (Tab U-7 through 9). The overhaul was completed on 25 March 2010 (Tab U-9). The overhaul process included teardown, chemical cleaning, and glass-bead media, or "sand", blasting of the housing with number 13 glass-bead (Tab V-9.3). The overhaul included inspection and replacement, if required, of the two and three piece bearings and 100 percent replacement of all solid bearings (Tab V-11.5). Once the AGB overhaul was complete, it was prepared for shipment by covering all ports (Tab V-5.4). The 115th JEIM shop received the overhauled AGB from the supply system on the 23 April 2010 (Tab U-9). No internal maintenance of the AGB was conducted at Truax Field (Tab V-3.4).

Analysis downloads and the work order logs were also reviewed. The engine build work order logs showed AGB S/N 00WIA91830 was initially installed on the mishap engine (ME) S/N 509-540 on 23 January 2011 with an engine operating time (EOT) of 5907.0 hours (Tab J-4). The AGB was removed from the ME on 24 January 2011 to conduct a search for a piece of missing safety wire dropped during engine maintenance (Tab U-13). The AGB was re-installed on 10 February 2011 and the engine buildup was completed on 2 May 2011 (Tab J-4). On 4 May 2011, the ME's acceptance test was completed (Tab J-4). The ME was installed into the MA on 23 May 2011 with an EOT of 5909.1 hours (Tab J-4). On 24 May 2011, ME interface checks produced a fault that required the replacement of the Main Engine Control (MEC), which required the ME to be removed from the MA (Tab J-4). The ME was re-installed 1 June 2011 (Tab J-4). The ME was operationally checked which produced a fault that required a Digital

Engine Control (DEC) replacement on 4 June 2011 (Tab J-4). The ME was operationally checked again on 6 June 2011 with no defects noted with an EOT of 5910.8 hours (Tab J-4).

Maintenance on the MA was performed in accordance with all applicable T.O.s (Tab O-3). The ME completed a SLEP (Tab D-5). In addition to the SLEP, T.O. 2J-F110-818 included the installation of a "Depot level" overhauled AGB, S/N 00WIA91830 (Tab O-3). Maintenance documentation was complete and all required inspections were performed (Tab J-4).

d. Maintenance Personnel and Supervision

The 548th Production Services Squadron (PMXS) at OC-ALC conducted the overhaul of AGB S/N 00WIA91830. All personnel in the overhaul process were trained and qualified. Supervision provided over maintenance personnel was appropriate.

The Maintenance Advisor assessed pre-mission maintenance for the MA was performed by the 115th Aircraft Maintenance Squadron. All maintenance activities were normal and all personnel involved in the preflight, servicing, inspecting, and launch of the MA were qualified and proficient in their duties. A Quality Verification Inspections (QVI) was conducted on personnel who had performed the C-MOD upgrade on the ME. The QVI was given a "pass" rating with no discrepancies noted. The unit Special Certification Roster (SCR) was reviewed to ensure maintenance personnel were qualified for servicing, inspecting, troubleshooting and releasing the aircraft for flight. Maintenance training records (AF Forms 623 & 797) were reviewed and revealed no training deficiencies.

e. Fuel, Hydraulic, & Oil Inspection Analyses

All fuel, oil, oxygen & hydraulic fluid samples from servicing equipment were tested for purity. All analysis met standards (Tab D-43).

The NDI section performs two tests: JOAP (Joint Oil Analysis Program) Atomic Emission Spectrometry and SEM/EDX. JOAP records for the first sortie were reviewed. The results were well within limits (Tab J-21).

Post-mishap, the MCD housing was recovered with the MCD still installed, but both tubes fractured on the sides of the housing. Visual inspection of the MCD revealed only a small amount of "fuzz" particles (Tab J-21). Engine teardown debris contaminated the exposed MCD, so an accurate SEM/EDX analysis was not possible. However, the MCD sample from the first sortie was available and re-ran on both the Jetscan and Aspex SEM/EDX units (Figure 4). Neither analysis yielded warnings above Level 1, nor were there any M50 metal chips found by either unit (Tab J-21). The AGB bearings, along with other engine components, are constructed from M50 material (Tab U-3). These results are in the normal range for an engine recently having undergone significant maintenance (Tab J-21, D-10).

Unit	Analysis Date	Parameter	9310/4340							Inco	Ag	LA	Cr	NI	Unclass.	Total
			M50	M50NI	4340	17/4	410	347	A286							
Jetscan	6/7/2011	Max Area			118	29						11		10	612	N/A
		Total Area			232	29						22		10	749	1042
		# Particles			10	1						2		1	10	24
Jetscan	6/17/2011	Max Area			144							11		18	557	N/A
		Total Area			344							22		54	802	1222
		# Particles			9							2		5	8	24
Aspex	6/17/2011	Max Area			446	38		19				35		17	59	N/A
		Total Area			875	70		19				69		42	148	1223
		# Particles			13	2		1				4		3	5	28

SEM/EDX Analyses of Sortie #1 MCD

Figure 4: SEM/EDX Analysis Results (Tab J-21)

f. Unscheduled Maintenance

The most recent unscheduled maintenance performed on the MA was after the first flight of the day on 6 June 2011. The engine required an MCD check after the first flight, which was analyzed as an MCD Level 1 warning for 9310/4340 material (Tab D-10). The aircraft was grounded until troubleshooting could ensure the analysis was within limits for the second flight of the day. The only other maintenance performed between flights was to tighten a screw on the T2, turbine temperature, sensor on the engine housing which had no impact on the mishap (Tabs D-9, D-10).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Condition of Systems

The MA was destroyed in the crash (Tab J-4, J-5). The impact crater was approximately 9 feet deep and 30 feet in diameter (Tab P-5). The two main sections of the engine were contained within the impact crater but were heavily fragmented and exposed to the post impact fire. The recoverable parts were brought back to Truax Field for investigation by personnel from OC-ALC and GE Aviation (Tabs J-4, J-5). Engine analysis showed primarily “rotational impact damage” to the dynamic components of the ME indicating engine rotation prior to impact (Tab J-11 and J-13). The loss of engine driven accessories prior to impact focused the investigation on the AGB (Tab J-25 through J-27).

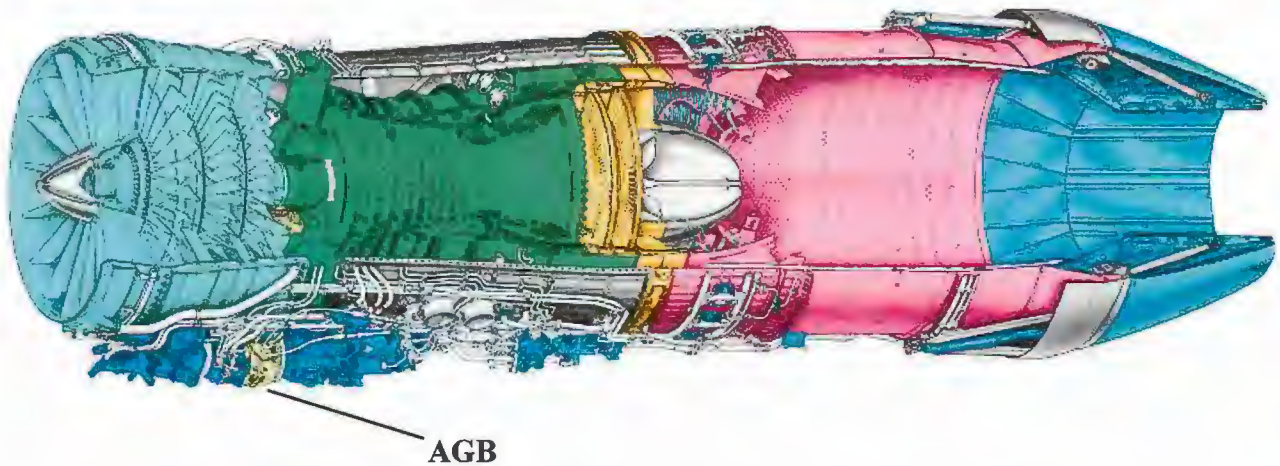


Figure 5: F110-100 Engine Cross-Section

(1) Accessory Gear Box

The AGB assembly attaches to the bottom of the inlet/fan assembly of the engine (Figure 5). The following is a summarized description of the AGB assembly connections as published in T.O. 1F-16C-2-80GS-00-1-WA-1. Power to drive the AGB is extracted from the compressor stubshaft. The power is transmitted to right angled gears in the mid sump of the compressor section of the engine. The radial drive shaft (Figure 6) carries the power from the mid sump through frame shaft to a second pair of right angled bevel gears within the AGB. The bevel gears transmit power to the drive train of the AGB. The AGB has mount pads for the AC generator, augmenter fuel pump, fuel boost pump, main fuel pump, MEC, lube and scavenge pump, and power takeoff (PTO) shaft, all of which are powered through the gear assembly within the AGB. The AGB radial drive shaft and attached bevel gear is the only mechanical connection between the engine and engine driven accessories on the AGB.

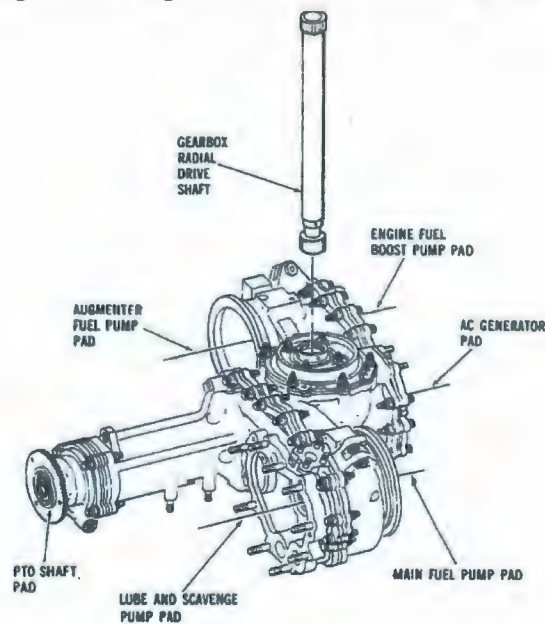


Figure 6: AGB Assembly

F-16C+, S/N 87-0242, 7 June 2011

Post-mishap analysis was performed by General Electric Aviation and Tinker OC-ALC Engineers (Tab J-23). The recovered parts were analyzed at the 115th JEIM shop (Tab J-3). Engineering analysis determined that the PTO shaft forward ball bearings were reduced in size allowing PTO shaft movement (Tab J-82). The PTO shaft movement ultimately resulted in disengagement of the mating bevels gears (Figure 7) within the AGB (Tab J-16).



Figure 7: PTO Bevel Gear Teeth



Figure 8: PTO Shaft Bevel Gear

(2) Engine

The subsequent lateral movement of the internal PTO shaft resulted in disengagement of the internal bevel gears, separating the AGB and all AGB driven accessories from the main engine (Tab J-16). Because of the disengagement from the main engine and the internal AGB resistance, the AGB decelerated rapidly (Tab V-8.5). The on-board diagnostic computer indicated that the ME experienced an almost instantaneous rollback of indicated engine RPM to 0% RPM within two seconds (Tab L-12 @ time 3630, Tab V-8.6). Engineers determined that a jet engine is not capable of these deceleration rates (Tab J-22). Cockpit engine RPM indication, also known as N2 or engine core speed, is extracted from the rotational speed of the internal AGB PTO shaft which is now disconnected from the main engine. Therefore, the MP is provided a false 0% engine RPM indication (Tab V-8.14).

All AGB driven accessories, which include the main fuel pump, AC generator, MEC and oil pump, decelerated and ceased functioning as the AGB decelerated (Tab V-8.9). The ME began to decelerate primarily due to fuel starvation as the main fuel pump was no longer capable of pumping fuel to the ME (Tab L-12 @ time 3635). Simultaneously, the EPU activated providing emergency power for flight controls and emergency electrical power (Tab J-25).

The MP executed emergency procedures and engaged the JFS which is connected to the AGB by a PTO shaft (Figure 9) (Tab J-26, V-1.8). With the AGB decoupled from the engine, the JFS had

a significant reduction in dynamic load and rotated the AGB and all AGB driven accessories to a false indicated 50% engine RPM % in 3 - 4 seconds (Tab L-12 @ time 3690, V-8.14). All AGB driven accessories began functioning and were then being powered solely by the JFS (Tab L-12 @ time 3690, V-8.15).

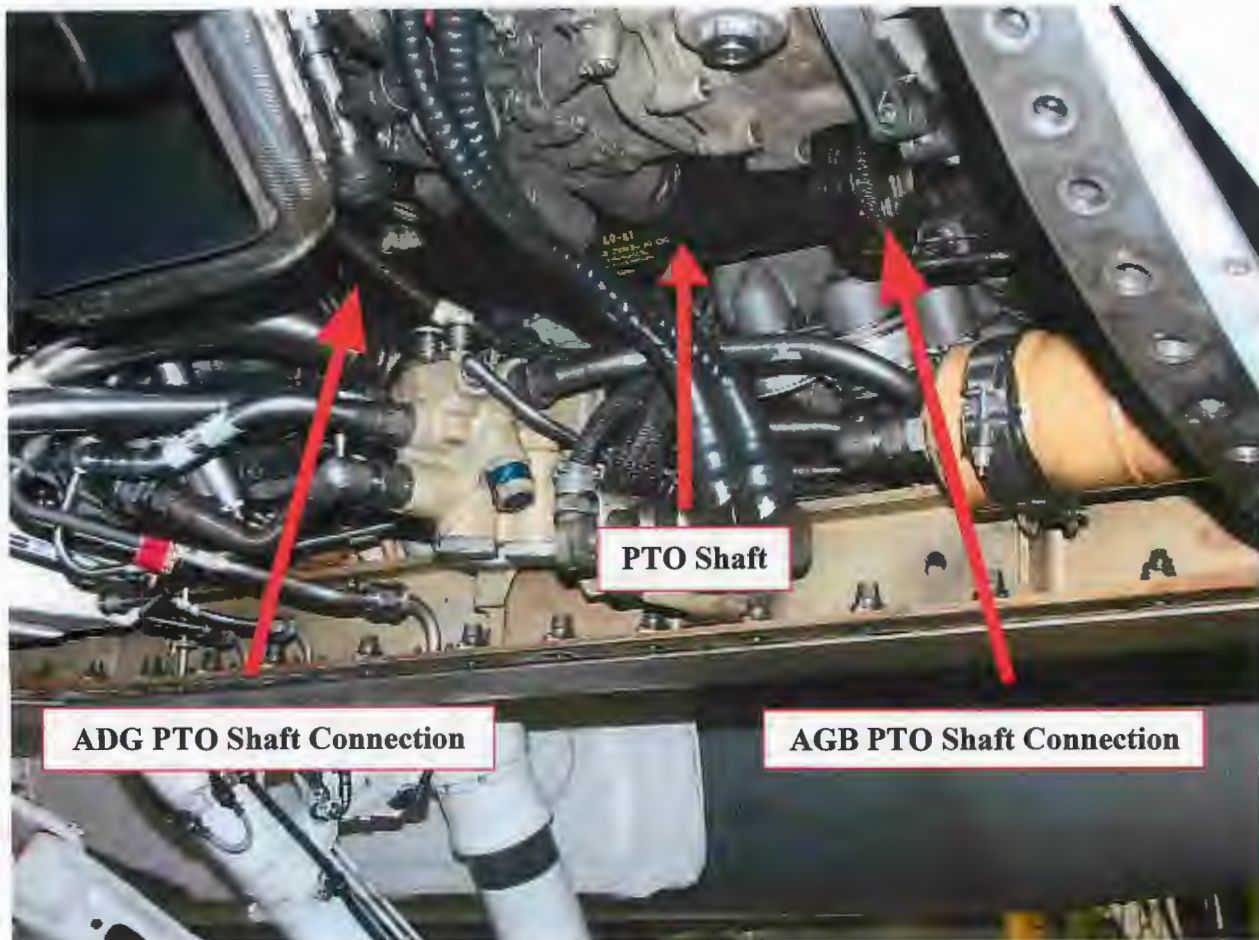


Figure 9: ADG to AGB connection (Tab Z-4)

The MEC was energized and was provided the same false 50% engine RPM (V-8.14). The MEC had engine control authority which scheduled fuel flow and repositioned IGVs and VSVs to the 50% engine RPM position (Tab J-22, V-8.15). IGVs and VSVs “shape” the airflow through the engine. IGVs control the angle at which airflow enters the face of the engine while VSVs control the angle at which airflow enters the internal compressor blades of the engine. The ME began to restart, but was unable to achieve a full recovery due to the MEC not sensing an appropriate engine RPM acceleration during the engine start phase (Tab V-8.17). The MEC was still provided with a constant false 50% engine RPM from the JFS powered AGB (V-8.14). This resulted in an apparent “hung start” (Tab V-8.17). IGVs and VSVs remained at a 50% engine RPM position which provided a reduced airflow through the engine, however, the MEC continued to increase fuel flow to meet pilot throttle position which was at military power (Tab V-8.16, 8.17). This resulted in the engine exceeding temperature operating limits just prior to

impact (Tab L-12 @ time 3895). The ME impacted the ground with actual engine speed of 50% RPM (Tab J-22).

b. Testing

Engine analysis was performed by OC-ALC/GKGBBB Aeronautical Engineers. Lockheed Martin Aeronautics Company (LM AERO) Flight Safety Engineers performed the Crash Survivable Memory Unit (CSMU) and the Seat Data Recorder (SDR) download analysis. The engine metallurgical investigation was performed by General Electric (GE).

(1) OC-ALC/GKGBBB (Tinker AFB)

Analysis of the AGB described the PTO bearing cage damage as a “dull burnt appearance” (Tab J-16). The bearing cage houses the solid ball bearings. The ball bearings were not recovered (Tab J-16). The bearing cage was cracked between the cage pockets (Figure 10), but still intact (Tab J-16). Several pockets on the cage of the ball bearing had raised lips in the direction of rotation indicating bearing decay (Tab J-16). Metal deposits were visible on the surfaces of the cage and the inner and outer races (Figure 11) (Tab J-16). The bearing failure resulted in loss of axial support and the subsequent forward shifting of the PTO shaft during engine operation, allowing the disengagement of the mating bevel gears within the AGB (Tab J-16).



Figure 10: Ball Bearing Cage (Tab J-17)



Figure 11: Metal Deposits (Tab J-17)

The PTO shaft bevel gear (Figure 13) had damage to the top lands of the gear teeth, described as a jagged finish and notable material missing that increases at the center of the teeth (Tab J-15). The forward bevel gear had heat discoloration from contact with the 37-tooth spur gear (Tab J-17). The forward half of the spur gear teeth also showed heat damage (Figure 12) (Tab J-17). The PTO Spur Gear teeth also had a groove worn into the forward face (Tab J-17). The PTO

shaft bevel gear damage was consistent with improper alignment of the PTO shaft during engine operation prior to impact (Tab J-18).



Figure 12: PTO Spur Gear Teeth (Tab J-18)



Figure 13: Bevel Gear Teeth (Tab J-19)

The High Pressure Turbine (HPT) damage to the vanes displayed evidence of some metal splatter and/or slurry accumulation (Figure 14) (Tab J-10). The source of the molten metal is most likely from rotating HPT components damaged late in the mishap sortie by high temperature (Tab J-13). Engineers indicated that the MEC would continue to supply fuel to the engine despite sub-idle positioning of the IGVs and VSVs resulting in exceeding engine operating limits (Tab L-12 @ time 3790, V-8.17).



Figure 14: High Pressure Turbine (Tab J-12)

(2) General Electric (GE)

GE evaluated the AGB components and the HPT Forward Outer Seal (FOS). During analysis of the AGB forward ball bearing assembly, GE reported round indentations on the back side of the inner ring (Figure 21) (the inner portion of the ball bearing cage), consistent with the ball bearings having been present at the time of impact and liberated during the post impact breakup (Tab J-37). The outer ring raceway had indentations consistent with debris roll-over damage (Tab J-37). The overall cage, both inner and outer ring, lost most of the silver plating and the base metal was hardened, consistent with high temperature exposure (Figure 15) (Tab J-37).

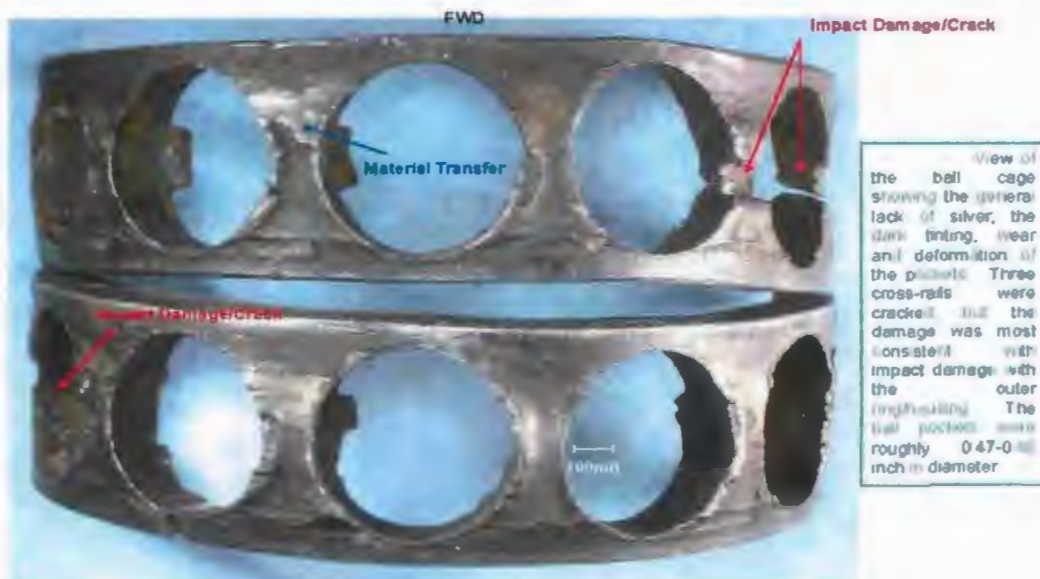


Figure 15: Ball Bearing Cage (Tab J-78)

The adjacent roller bearing cage, the bearing forward of the ball bearing, was intact with silver present, but the rollers and raceway showed surface indentations consistent with debris roll-over damage from the adjacent ball bearing (Figure 16) (Tabs J-37, J-39, J-67). The rollers were tinted, consistent with elevated temperature exposure as well (Tabs J-37, J-39, J-67).



Figure 16: Roller Bearings with Indentations (Tab J-67)

Analysis of filtered debris from the oil supply passage showed that in addition to particles consistent with dirt, sand, and AGB housing material were many particles that had size, shape, and compositional spectra similar to glass-bead media utilized in the AGB overhaul process (Figure 17) (Tabs J-37, J-102).



Figure 17: Glass-Bead Media (Tab J-103)

In addition, a piece of white debris consistent with Teflon[®] was found that was approximately 223 millimeters long by 44 millimeters thick and 82 millimeters wide (Figure 18) (Tab J-37 and J-102).



Figure 18: Teflon[®] Piece Close-Up (Tab J-102)

As illustrated in Figure 19, the recovered Teflon[®] debris is small enough to travel freely through the 100 millimeter diameter oil supply line. However, the Teflon[®] debris was unable to exit through the 36 millimeter diameter oil supply nozzle as show in figure 20. The Teflon[®] debris is of unknown origin. Engineers testified that the Teflon[®] debris in combination with glass-bead media would be sufficient to clog the oil supply line (Tab V-8.4)



Figure 19: Teflon[®] at Supply Line (Tab Z-5)



Figure 20: Teflon[®] at Nozzle (Tab Z-6)

GE summarizes their report with the following statement: “The quick bearing degradation time, the lack of observed M50 chips, and the intact cage are characteristics most consistent with having been produced by inadequate lubrication. The intact cage that was found outside of the outer ring assembly and the rounded indentations on the aft side of the ball inner ring were consistent with some/all of the balls having been reduced in size (Figure 21). The loss of ball/inner ring material, the rub damage in adjacent parts, and the fracturing of the bevel gear teeth tips, are all consistent with damage produced by loss of the ball bearing that allowed the shaft to move forward and eventually disengage from the bevel gear” (Tab J-37).

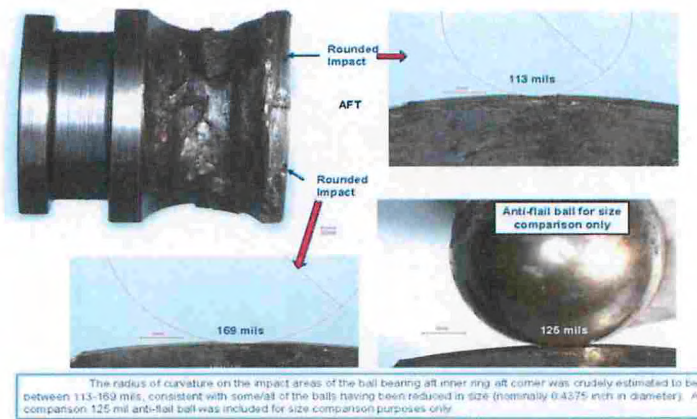


Figure 21: Ball Bearing Impact Comparison (Tab J-82)

(3) Lockheed Martin (LM Aero)

The Crash Survivable Memory Unit (CSMU) (Tab J-24), Seat Data Recorder (SDR) (Tab J-24), Maintenance Fault List (MFL) (Tab J-27) and Flight Control System (FLCS) (Tab J-27) downloads were reviewed for general operation of aircraft systems. All systems were reported as operating normally with the exception of the Global Positioning System (GPS) which did not operate in “Back Up” mode as designed (Tab J-29). This was not a contributing factor to the mishap.

Engineers also examined JFS hardware and determined the JFS was operating at impact (Tab J-29). During the examination, the JFS accumulators were cut open to examine evidence of piston position at impact (Tab J-29). Once opened, a shop rag was discovered in the pneumatic end of the accumulator (Tab J-29). There is no evidence that the shop rag had any impact on JFS operation (Tab J-29).

7. WEATHER

a. Forecast Weather

Madison/Dane County Regional - Truax Field: At brief time, 1105L, weather for takeoff at Truax Airfield was forecast to be few clouds at 25,000 feet. Visibility was forecast to be

unrestricted, greater than 10 NM. Winds were projected to be from the west at 12 knots with gusts to 24 knots. Surface temperature was forecast to be 77 degrees Fahrenheit (Tab F-3).

Volk/Falls Military Operating Areas: At brief time, 1105L, weather for the flying airspace was forecast to be sky clear. Visibility was forecast to be 7 NM, and isolated thunderstorms reported north of route. The wind at 10,000 feet AGL was from the west at 30 knots (Tab F-6).

b. Observed Weather

Madison/Dane County Regional - Truax Field: The morning observation taken at 0453L, reported winds out of the southwest at 4 knots, no clouds, and 6 NM visibility with haze (Tab F-3). The MP stated the skies were clear, with light haze (Tab V-1.6).

c. Space Environment

Not applicable.

d. Operations

Operations were being conducted in accordance with applicable directives. The weather was not a factor in the conduct of the mission or the mishap.

8. CREW QUALIFICATIONS

The MP is a current and qualified F-16 IP and has the required flying continuity (Table 1) (Tabs G-3 through G-5, G-10, G-13). The mishap mission was the MP's first mission for the week. The MP had a total of 3915.0 flight hours with 3090.8 hours in the F-16. (Tabs G-7, G-15) The MP was current on his Flight Crew Information File (FCIF) and had a current Critical Action Procedures (CAPS) test on file (Tabs G-19 through G-21). The MP was current on all required ground training except for Laser Safety (G-23 through G-32). The MP was approximately 2 months overdue on Laser Safety Training in accordance with AFOSH 48-139 (Tabs G-25). This training event was non-grounding and did not prevent the MP from flying or have an impact on the mission.

	Hours	Missions
30 days	5.8	5
60 days	7.4	8
90 days	19.1	15

Table 1: MIP 30/60/90 Day History

9. MEDICAL

a. Qualifications

At the time of the mishap, the MP was fully medically qualified for flight duty without any medical restrictions. The AF Form 1042, Medical Recommendation for Flying or Special Operational Duty, and annual Preventative Health Assessment (PHA) were current (Tab EE-3). The MP's most recent flight physical determined he was medically qualified for flight duties and qualified for worldwide military duty (Tab EE-3). Physical and medical qualifications were not factors in the mishap.

b. Health

Medical record review indicated the MP was in good health and had no recent performance limiting illnesses prior to the mishap. On the day of the mishap, the MP's health was self-described as "great" (TAB V-1.12). In addition, the MP suffered no significant injuries from the incident (TAB X-3).

c. Pathology/Toxicology

No pathological samples were taken and no pathological reports were given.

Immediately following the mishap, toxicology testing was performed on all personnel involved in the flight and the launch of the MA. Blood and urine samples were submitted to the Armed Forces Medical Examiner System (AFMES) in Rockville, Maryland for toxicological analysis. This testing included carbon monoxide and ethanol levels in the blood and drug testing of the urine (Tab EE-4).

Carboxyhemoglobin saturations of zero to three percent are expected for non-smokers and three to ten percent for smokers. Saturations above ten percent are considered elevated and are confirmed by gas chromatography. The carboxyhemoglobin saturation in the blood for the MP was one percent (normal), as determined by spectrophotometry (Tab EE-4). Testing was also performed on associated maintenance crew members. The AIB Medical Advisor confirmed all results were normal.

AFMES examined the blood for the presence of ethanol at a cutoff of twenty milligrams per deciliter. AFMES detected no ethanol in the MP's blood (Tab EE-4). The AIB Medical Advisor confirmed all ethanol results were also negative for the associated maintenance crew members.

Furthermore, AFMES screened the MP's and maintenance crew members' urine for amphetamine, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates and phencyclidine by immunoassay or chromatography. AFMES detected none of these drugs in the MP (Tab EE-4). Associated maintenance members were negative as well except for one member who was positive for diazepam, for which he had a valid prescription (Tab EE-5 through 6).

d. Lifestyle

There is no evidence that unusual habits, behavior or stress on the part of the MP or maintenance crew members contributed to this accident. Witness testimonies, as well as review of 72-hour histories of the MP and pertinent maintenance crew members, revealed no lifestyle factors, including unusual habits, behaviors or stressors which were causal or substantially contributory to the mishap (TAB EE-7 through 14).

e. Crew Rest and Crew Duty Time

Air Force Instructions require pilots have proper "crew rest," as defined in AFI 11-202, Volume 3, General Flight Rules, dated 22 October 2010, prior to performing in-flight duties. AFI 11-202V3 defines normal crew rest as a minimum 12-hour non-duty period before the designated flight duty period (FDP) begins. During this time, an aircrew member may participate in meals, transportation or rest as long as he or she has the opportunity for at least eight hours of uninterrupted sleep.

A review of the duty cycles of the MP leading up to the mishap indicated that he had adequate crew rest. The MP stated he was well rested and had no complaints or illnesses. The MP complied with the crew rest and duty day requirements on the day of the mishap. MP fatigue was not indicated and is not a factor in this mishap. The MP stated he did not suffer from stress, pressure, fatigue or lack of rest prior to or during the mishap sortie (Tab V-1.12).

10. OPERATIONS AND SUPERVISION

a. Operations

At the time of the mishap, the 176 FS had a decreased operations tempo at Truax Field (Tab K-11). Half of the squadron was deployed to Iceland for an exercise (Tab K-11, R-5). There were no other tasking that would have increased the workload or operations tempo for the remaining pilots (Tab K-11). The experience level in the mishap flight was high because both pilots were experienced instructors, as listed on the squadron letter of qualifications (Tab G-3).

b. Supervision

The supervision of all 176 FS flying operations on the day of the mishap, including the mishap formation, was normal (Tab K-7). The mishap flight had all proper and required authorization, supervision, and documentation for the sortie scheduled during the flying period (Tab K-7, R-10). The MW coordinated with the SOF to execute a timely search and rescue response (Tab R-5). The SOF on duty executed the correct checklists and properly informed the command post of the mishap thus including all applicable supervision (Tab R-5, N-22).

11. HUMAN FACTORS ANALYSIS

a. Overview

A human factor is any environmental factor or individual psychological factor a human being experiences that contributes to or influences performance during a task. There are many potential human factors which need to be assessed for relevancy during a mishap investigation. The AIB considered all human factors as prescribed in AFI 91-204, Attachment 5, the Department of Defense Human Factors Analysis and Classification System (DoD HFACS) to determine those that were potentially causal or contributory to the mishap.

b. Significant Human Factors

SI004 Supervision – Policy is a factor when policy or guidance or lack of a policy or guidance leads to an unsafe situation.

Supervision – Policy was found to be contributory in this mishap. T.O. 2J-F110-3-4 SWP 00517, *Depot Maintenance Manual, Cleaning and Stripping*, states “Cover all ports, cavities, and tube ends, when applicable, to prevent abrasives from entering areas where an accumulation would be difficult to detect or remove” (Tab BB-4). The “when applicable” guidance required the cleaning technician to determine when it was applicable to “cover all ports, cavities, and tube ends”, if at all, and also required the technician to determine where “an accumulation would be difficult to detect or remove.” A witness testified that he “never found it necessary to mask any ports” (Tab V-9.7). This ambiguous policy resulted in undetected glass-bead media remaining in the AGB assembly and was determined to be contributing factor in this mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Primary Operations Directives and Publications

- 1) AFI11-2F-16V1, Flying Operations, F-16 Pilot Training
- 2) AFI11-2F-16V2, Flying Operations, F-16 Aircrew Evaluation Criteria
- 3) AFI11-2F-16V3, Flying Operations, F-16 Operations Procedures
- 4) T.O. 1F-16C-1S-4, USAF Series F-16C/D Blocks 25, 30, and 32 Aircraft Flight Manual
- 5) T.O. 1F-16C-1-CL-1, USAF Series F-16C/D Blocks 25, 30, and 32 In-flight Checklist
- 6) T.O. 14D1-2-1, Operational Personnel Parachutes
- 7) T.O. 1F-16C-34-1, USAF Series F-16C/D Blocks 25, 30, and 32 Aircraft Avionics Manual
- 8) AFI11-301 V1, Aircrew Flight Equipment Program
- 9) AFI11-301 V1, ACC Sup 1, ACC Aircrew Flight Equipment Program
- 10) AFI51-503, Aerospace Accident Investigations

b. Maintenance Directives and Publications

- 1) T.O. 2J-F110-3-1, Depot Maintenance Instruction General 1
- 2) T.O. 2J-F110-3-4, Dry abrasive grit blast cleaning
- 3) T.O. 2J-F110-3-6, Maintenance Instruction Depot Turbofan
- 4) T.O. 2J-F110-3-11, Depot Maintenance Instruction Gearboxes
- 5) T.O. 2J-F110-6-6, Gearboxes
- 6) T.O. 2J-F110-6-12, Engine testing
- 7) T.O. 2J-F110-6-13, Troubleshooting
- 8) T.O. 2J-F110-6-14, External Tubing/cabling/clamping
- 9) T.O. 2J-F110-13-4, Maintenance Instructions Depot Level Cleaning and stripping
- 10) T.O. 1F-16C-2-70FI-00-11-1, Maintenance Engine monitoring
- 11) T.O. 1F-16C-2-70JG-10-11-WA-1, Engine removal and installation
- 12) T.O. 1F-16C-2-80GS-00-1-WA-1, Maintenance Engine Starting & Accessory Drive Gearbox System
- 13) T.O. 1F-16C-2-12JG-00-1, Servicing
- 14) T.O. 1F-16C-2-3SJG-00-1, Oxygen System
- 15) T.O. 1F-16C-2-76JG-00-12, Engine Power Controls (DEC Change)
- 16) T.O. 2J-F110-818, Modification of aircraft engine model F110-GE-100B to F110-GE-100C (SLEP)

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

13. NEWS MEDIA INVOLVEMENT

Personnel assigned to the 115 FW Public Affairs Office responded to media interests and issued two initial press releases. The first was published on the day of the mishap, 7 June 2011, announcing the safe recovery of the pilot (Tab DD-1). The second press release, dated 8 June 2011, gave an update on the health of the pilot and details of the crash site (Tab DD-2). In response to 25 media requests on the day of the mishap, the Wisconsin Air National Guard Public Affairs Office held a press conference releasing essentially the same information discussed in the first press release. Local media entities published print stories, internet, witness interviews and video footage of the crash site beginning the day of the mishap (Tab DD-3 through DD-5). Coverage of the mishap tapered off in the week following the mishap. The last documented print story was 23 June 2011 reflecting the 115 FW being returned to active flying status as of 14 June 2011 (TAB DD-5). No further inquiries or publicity have since been received or generated.

14. ADDITIONAL AREAS OF CONCERN

There are no additional areas of concern.

15. SIGNATURE AND DATE

6 September 2011

DAVID B. FAULK, Lt Col, USAF
President, Accident Investigation Board

AIRCRAFT ACCIDENT INVESTIGATION BOARD
F-16C, S/N 87-0242
TRUAX FIELD AIR NATIONAL GUARD BASE, WISCONSIN
7 JUNE 2011

STATEMENT OF OPINION

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 an aircraft 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 this mishap was caused by a catastrophic engine Accessory Gearbox (AGB) failure due to rapid disintegration of the Power Take-Off (PTO) shaft forward ball bearing assembly. The bearing failure caused a loss of axial support of the PTO shaft and allowed the PTO shaft to move forward which disengaged the mating bevel gears within the AGB. The AGB was no longer powered by the radial drive shaft from the main engine and all AGB accessories ceased functioning which resulted in engine failure. The Mishap Pilot (MP) properly applied the Critical Action Procedures (CAPs) for Air Start Procedure, but was unable to achieve a successful engine restart. Distance to the nearest recovery field was beyond the Mishap Aircraft's (MA) glide capabilities, negating any chance of safely recovering the MA.

Additionally, I find by clear and convincing evidence that the rapid PTO shaft forward ball bearing disintegration was caused by inadequate lubrication of the bearing assembly due to a partial or complete blockage of the AGB oil supply line. The two primary factors leading to inadequate lubrication of the bearing assembly were Teflon[®] debris in the AGB oil supply line and contamination of the AGB oil supply by glass-bead media.

2. DISCUSSION OF OPINION:

a. Sequence of Events:

On 7 June 2011, at 1316 hours Central Standard Time, an F-16C+, serial number 87-0242, crashed approximately 57 nautical miles northwest of Madison, Wisconsin, in a rural area near New Chester, Wisconsin. The F-16, assigned to the 115th Fighter Wing, Truax Field, Wisconsin, was part of a two-ship continuation training mission. The MP, assigned to the 176th Fighter Squadron, ejected safely. There were no significant injuries to the MP, however, the MA impacted the ground near an unoccupied private residence and both were completely destroyed. There were no civilian injuries or deaths.

The mishap mission was briefed as a continuation training basic fighter maneuver mission involving simulated air-to-air "dogfights" between the MP and the Mishap Wingman (MW),

each in their own F-16 aircraft. The sortie was uneventful until one hour and twenty-three minutes after takeoff, as the mishap flight prepared to return to base. Without warning, the MA experienced a sudden loss of thrust, and the MP had cockpit indications of an engine failure. The MP immediately began a turn to the nearest suitable runway and simultaneously initiated air start procedures to recover the engine. The MP jettisoned his empty external fuel tanks to reduce drag once clear of a populated area below the MA. The MP engaged the jet fuel starter and noticed the engine RPM indicator had increased to 50% and holding. The MP assessed the engine to be in a hung start situation which occurs when the RPM indication stabilizes at a sub-idle RPM during the start sequence rather than increasing to the normal idle RPM. The MP continued to attempt to recover the ME by executing air start procedures until the MA descended to an altitude of approximately 1,500 feet above the ground. The engine never fully recovered and the MP initiated a successful ejection. The MA impacted the ground with the engine stabilized at approximately 50% RPM.

Distance to the nearest recovery field was beyond the MA's glide capabilities, thus negating any chance of safely recovering the MA. Post-impact examination of the recovered wreckage indicated the MA was structurally intact and all aircraft systems, except the engine, were operating within normal operational parameters prior to ground impact.

b. Causal Factors

Post-mishap teardown and metallurgical analyses of the PTO shaft forward ball bearing assembly found clear and convincing evidence that the rapid disintegration and subsequent failure of the ball bearing assembly was due to inadequate lubrication. Additional analyses of the AGB found clear and convincing evidence that inadequate lubrication was due to a complete or partial blockage of the AGB oil supply line which provided critical lubrication and cooling to the PTO shaft ball bearing assembly.

The two primary factors leading to inadequate lubrication of the bearing assembly were: (1) Teflon[®] debris recovered from the oil supply line within the AGB, and (2) contamination of the AGB oil supply by glass-bead media similar to that used in the cleaning process at depot during the AGB overhaul process.

The Teflon[®] debris recovered from the AGB oil supply line was approximately 223 millimeters long by 82 millimeters wide by 44 millimeters thick. The oil supply line is approximately 100 millimeters in diameter and the oil supply nozzle is approximately 36 millimeters in diameter. The size and shape of the Teflon[®] debris allowed it to travel freely through the oil supply line, but was unable to exit through the oil supply nozzle. This created a partial or complete blockage of the AGB oil supply line at the supply nozzle. The Teflon[®] debris is of unknown origin.

Analysis of the glass-bead media recovered from the AGB oil supply determined the media to be chemically and optically similar to the glass-bead media used at depot in the overhaul and cleaning of the AGB assembly. Oklahoma City - Air Logistics Center Aerospace Engineers cited that the glass-bead media in the AGB housing would accumulate in the oil supply line behind the Teflon[®] debris and further aggravated the blockage.

3. CONCLUSION:

I find by clear and convincing evidence that this accident was caused by a catastrophic engine AGB failure due to rapid PTO shaft forward ball bearing disintegration allowing the PTO shaft to move forward and disengage from the mating bevel gears during engine operation resulting in engine failure. Additionally, I find by clear and convincing evidence that the cause of the PTO shaft forward ball bearing disintegration was inadequate lubrication of the bearing assembly as a result of a partial or complete blockage of the AGB oil supply line.

6 September 2011

DAVID B. FAULK, Lt Col, USAF
President, Accident Investigation Board

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