UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

F-16CM, T/N 90-0771

36TH FIGHTER SQUADRON
51ST FIGHTER WING
OSAN AIR BASE, REPUBLIC OF KOREA

LOCATION: HWACHON-RI, HWAYANG-MYEON, SEOCHEON, CHUNGCHEONGNAM, REPUBLIC OF KOREA
DATE OF ACCIDENT: 21 MARCH 2012
BOARD PRESIDENT: LIEUTENANT COLONEL WILLIAM R. JONES

Conducted IAW Air Force Instruction 51-503

EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION

F-16CM, T/N 90-0771
OSAN AIR BASE, REPUBLIC OF KOREA
21 MARCH 2012

On 21 March 2012, at 12:07 local Korea time an F-16CM, tail number 90-0771, experienced an engine malfunction during a routine training mission 34 nautical miles (nm) northeast of Kunsan Air Base, Republic of Korea (ROK). The engine never recovered from the malfunction. The mishap pilot (MP) ejected safely from the aircraft and was recovered by search and rescue personnel. The mishap aircraft (MA) was based at Osan AB, ROK and assigned to the 36th Fighter Squadron, 51st Operations Group, 51st Fighter Wing. The MA impacted the ground near the small town of Hwachon-ri, Hwayang-Myeon, Seocheon, Chungcheongnam, ROK; approximately 14 nm northeast of Kunsan Air Base, ROK.

The mishap sortie was uneventful until the engine malfunction. The pilot performed the appropriate emergency checklist procedures in an attempt to recover the engine, but it did not respond and continued operating in a degraded state until impact. After safely ejecting, the MP was transported to Kunsan Air Base medical clinic by the 6th Search and Rescue Group, Republic of Korea Air Force. The clinic examination revealed the MP sustained no injuries.

The MP's actions during the mishap sequence were focused, precise and appropriate. His actions or lack of actions did not contribute to the mishap. Although engine maintenance was causal, a thorough review of maintenance procedures revealed no systemic problems or adverse trends that were causal.

The AIB president found clear and convincing evidence to determine the mishap engine (ME) experienced catastrophic failure and a subsequent engine stall following the liberation of two fifth stage compressor blades. The two fifth stage compressor blades experienced higher than normal high cycle and vibration-induced fatigue. The high cycle fatigue and vibrations were caused by uneven compressor pressure in the fifth stage region. The uneven pressure was caused by an incorrectly installed stage 5 stator blade sector. The AIB president further found by a preponderance of evidence that procedural guidance substantially contributed to the mishap by failing to instruct maintenance members with suitable detail in the manner in which the error could occur as well as failing to represent the magnitude of the risk associated with the error.

Financial loss to the Air Force totaled $21,606,116.29 in lost aircraft and an additional $187,419.05 in environmental cleanup costs.

SUMMARY OF FACTS AND STATEMENT OF OPINION
F-16CM, T/N 90-0771
OSAN AIR BASE, REPUBLIC OF KOREA
21 MARCH 2012

TABLE OF CONTENTS

COMMONLY USED ACRONYMS AND ABBREVIATIONS

§	Section
7 AF	7th Air Force
36 FS	36th Fighter Squadron
51 FW	51st Fighter Wing
51 OG	51st Operations Group
AB	Air Base
ACDE	Aircrew Chemical Defense Ensemble
AF	Air Force
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFI	Air Force Instruction
AFTO	Air Force Technical Order
AGL	Above Ground Level
AIB	Accident Investigation Board
AMU	Aircraft Maintenance Unit
AMXS	Aircraft Maintenance Squadron
ATC	Air Traffic Controller
Cann	Cannibalization
CSAR	Combat Search and Rescue
CSFDR	Crash Survivable Flight Data Recorder
CSMU	Crash Survivable Memory Unit
Dash-1	A.F.T.O. 1F-16CM-1
DO	Director of Operations
DoD	Department of Defense
ELT	Emergency Locator Transmitter
EP	Emergency Procedures
EPE	Emergency Procedures Evaluation
ER	Exceptional Releases
FL	Flight Lead
FOD	Foreign Object Damage
FS	Fighter Squadron
Ft	Feet
FTIT	Fan Turbine Inlet Temperature
Ft/s	Feet per Second
FW	Fighter Wing
G	Force of Gravity
HAS	Hardened Aircraft Shelter
HFAC	Human Factors Analysis and Classification
HUD	Heads up Display
IAW	In Accordance With
IFE	In-Flight Emergency
IP	Instructor Pilot
IPI	In Process Inspection
JEIM	Jet Engine Intermediate Maintenance
JFS	Jet Fuel Starter
KCAS	Knots Calibrated Air Speed
L	Local time
lbs	Pounds
MA	Mishap Aircraft
Maj	Major
ME	Mishap Engine
MF	Mishap Flight
MFL	Mishap Flight Lead
MFL	Maintenance Fault List
MM	Mishap Mission
MOC	Maintenance Operations Control
MP	Mishap Pilot
MQT	Mission Qualification Training
MS	Mishap Sortie
MSL	Mean Sea Level
Msn	Mission
MW	Mishap Wingman
MXS	Maintenance Squadron
NDI	Nondestructive Inspection
NM	Nautical Miles
NOTAM	Notice to Airmen
OG	Operations Group
Ops O	Operations Officer
ORE	Operation Readiness Exercise
Tempo	Operations Tempo
PACAF	Pacific Air Forces
PFL	Pilot Fault List
PLF	Parachute Landing Fall
PRC	Portable Radio Communications

QVI	Quality Verification Inspection	TDY	Temporary Duty
ROK	Republic of Korea	T/N	Tail Number
RPM	Revolutions per Minute	T.O.	Technical Order
SAR	Search and Rescue	Top 3	Assigned Squadron Supervisor
SDR	Seat Data Recorder	TSgt	Technical Sergeant
SFS	Security Forces Squadron	UHF	Ultra High Frequency
SIM	Simulator	U.S.	United States
S/N	Serial Number	USAF	United States Air Force
SOF	Supervisor of Flying	VFR	Visual Flight Rules
Sortie	Flight	VHF	Very High Frequency
Stan/Eval	Standardization and Evaluation	X-INT	Alert Interdiction
TACAN	Tactical Aid to Navigation	Z	Zulu Time
TCTO	Time Compliance Technical Order		

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 5 April 2012, General Gary L. North, Commander, Pacific Air Forces (PACAF), appointed Lieutenant Colonel William R. Jones, to conduct and aircraft accident investigation of a mishap that occurred on 21 March 2012 involving an F-16CM aircraft, tail number (TN) 90-0771, at Hwachon-ri, Hwayang-Myeon, Seocheon, Chungcheongnam, ROK (Tab Y-3). The investigation was conducted at Osan, AB, ROK from 30 April 2012 through 25 May 2012. Technical advisors included the Medical Member, Legal Member, Pilot Member, Recorder, and Maintenance Member (Tab Y-5).

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

The mishap aircraft (MA) departed Osan AB, ROK at 11:29 Korea time on 21 March 2012, to conduct an unopposed X-INT (alert interdiction) training mission (Tab V-1.2). The mission sortie (MS) was uneventful for the first 37 minutes of the sortie (Tab J-33). While the mishap pilot (MP) was maneuvering the MA for a simulated attack, the MA experienced a catastrophic engine failure (Tab V-1.17). The MP was unable to regain usable thrust after several recovery attempts (Tab J-31). The MP safely ejected 5 minutes and 42 seconds after the compressor stall and was recovered by the 6th Search and Rescue Squadron operating out of Chong-Ju AB (Tab EE-16). The MP was transported via HH-60 to Kunsan AB medical clinic for examination (Tab V-1.34). The MP sustained no injuries (Tab V-1.27). The MA was destroyed upon impact (Tab J-31). Financial loss to the Air Force totaled $21,606,116.29 (Tab P-2). The MA impacted the ground in a rice field; environmental cleanup costs are estimated at $187,419.05 (Tab EE-12). Media coverage of the mishap was moderate. Public Affairs for 51 FW made the initial press release at 14:03L on the day of the mishap (Tab DD-3).

3. BACKGROUND

The MA was assigned to the 36 FS (Tab K-10). The 36 FS is a squadron within the 51 OG. The 51 OG is, in turn, part of the 51 FW and 7 AF. 7 AF is a Numbered Air Force within PACAF.

a. Pacific Air Forces (PACAF)

PACAF's primary mission is to provide ready air and space power to promote U.S. interests in the Asia-Pacific region during peacetime, through crisis, and in war (Tab CC-7). PACAF's area of responsibility extends from the west coast of the United States to the east coast of Africa and from the Arctic to the Antarctic, more than 100 million square miles (Tab CC-7). The area is home to nearly two billion people who live in 44 countries (Tab CC-7). PACAF maintains a forward presence to help ensure stability in the region (Tab CC-7).

The command has approximately 300 fighter and attack aircraft and 45,000 military and civilian personnel serving in nine major locations and numerous smaller facilities, primarily in Hawaii, Alaska, Japan, Guam and South Korea (Tab CC-7).

b. 7th Air Force (7 AF)

7 AF is the United States Air Force's oldest numbered air force. The Army Air Corps first activated 7 AF on 1 November 1940, as the Hawaiian Air Force, to control the growing number of air units arriving in the Territory of Hawaii that year (Tab CC-11). Since then, 7 AF took on many roles within PACAF's area of responsibility (Tab CC-11).

On 8 September 1986, 7 AF activated at Osan AB, ROK, and assumed the mission of maintaining the fragile armistice on the Korean peninsula previously performed by the 314th Air Division (Tab CC-11). Organizations assigned to 7 AF include the 51st and 8th Fighter Wings (Tab CC-19). Since then, both as U.S. Air Forces Korea, under the joint U.S. Forces Korea and the U.S. Air Force component to the United States and Republic of Korea Combined Forces Command's Air Component Command, 7 AF has been an integral part of deterring North Korea aggression (Tab CC-11).

c. 51st Fighter Wing (51 FW)

The 51 FW, headquartered at Osan AB, ROK, is the most forward deployed wing in the world, providing combat ready forces for close air support, air strike control, counter air, interdiction, theater airlift, and communications in the defense of the Republic of Korea (Tab CC-13). The wing executes military operations to bed down, maintain` and employ follow-on forces for the combined arms base that includes three major flying tenants and large multiservice fighting units. (Tab CC-13).

d. 51st Operations Group (51 OG)

51 OG was first established as 51st Pursuit Group (Interceptor) on 20 November 1940, and trained in the United States for fighter operations (Tab CC-15). After the Pearl Harbor attack of 7 December 1941, 51 OG served as part of the defense force for the west coast. Over the years, it moved to several countries, including India, China, Japan, eventually being located at Osan AB, ROK (Tab CC-15).

After the Korean armistice in July 1953, the group remained on alert, flew patrol missions, and participated in air defense exercises (Tab CC-16). Since 1990, 51 OG trained and participated in a series of exercises to maintain combat readiness for the air defense of South Korea (Tab CC-16). In February 1992, the group was redesignated as 51 OG.

e. 36th Fighter Squadron (36 FS)

The 36 FS is a combat ready F-16CM squadron with the capability to conduct air interdiction, close air support and counter-air missions in both day and night conditions. During its distinguished 90-year history, the 36 FS has flown 21 different types of aircraft, received 22 unit citations and accumulated 24 service and campaign streamers (Tab CC-17).

f. The F-16 Fighting Falcon

The F-16 Fighting Falcon 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. Since Sept. 11, 2001, the F-16 has been a major component of the combat forces flying thousands of sorties in support of operations Noble Eagle (Homeland Defense), Enduring Freedom in Afghanistan and Iraqi Freedom (Tab CC-3).

4. SEQUENCE OF EVENTS

a. Mission

The mishap sortie (MS) was scheduled as a 2-ship Alert Interdiction (X-INT) mission in support of an Operational Readiness Exercise (ORE) on 21 March 2012 (Tabs J-31, K-18, V-1.3). The two aircraft in the mishap flight (MF) were piloted by the Mishap Pilot (MP) as the flight lead and the Mishap Wingman (MW) (Tab K-18, V-1.3). The flight was properly scheduled, authorized, and released in accordance with AFI 11-401, paragraph 1.8 under the authority of the 51 FW and the 36 FS (Tabs K-11, K-12, K-18).

b. Planning

The MP and MW coordinated the day prior on 20 March 2012. Items discussed were simulated munitions for the two sorties and the mechanics of operating the Sniper targeting pod (Tab V-1.6). The MP and MW arrived at the squadron at 04:15L for a non-standard brief time due to exercise operations (Tabs V-1.4, V-1.7, and V-1.35). After accomplishing exercise driven squadron in processing actions (sign in, issue weapons, file accountability card, etc), both the MP and MW donned their appropriate Aircrew Flight Equipment (AFE) (Tab V-1.4). The MP received their mission planning materials for both flights (Tab V-1.5). The mission materials were produced by the mission planning cell and were adequate for both missions (Tab V-1.5). Both the MP and MW attended a mass briefing conducted by the Squadron Director of Operations (Tab V-1.7). (Notices to Airmen) NOTAMs and weather were adequately briefed and neither were a factor on the MS (Tab F-52 to F-82, and Tab K-21 to K-22). The MP accomplished the flight briefing for two missions utilizing squadron briefing materials required by AFI 11-2F-16 Volume 3 paragraph 2.8 (Tabs V-1.7, V-1.4). The flight briefing focused heavily on the differences between flying a routine local training sortie and flying during an exercise (Tabs V-1.6, V-1.8). The briefing was thorough and complete, covering all required briefing items (Tabs V-1.7).

c. Preflight

The MP and MW donned their Aircrew Chemical Defense Ensemble (ACDE) in accordance with the current Mission Oriented Protective Posture level 4 and received a step brief from the Top-3 Supervisor (Tab V-1.8). The mishap aircraft (MA) was parked in a hardened aircraft shelter (HAS) (Tab V-1.9). The pre-flight inspection was normal with no aircraft abnormalities noted (Tab V-1.9). Engine start, taxi, and take-off were normal (Tab V1.10 to V1.11).

d. Summary of Accident

The MF's first mission of the day was uneventful and was not a factor in the mishap (Tabs V-1.8 to V-1.9). After the first mission, the MP and the MW were forced to maintain their position in their respective HAS with the doors closed due to exercise conditions (Tab V-1.9). At the first opportunity, the MP and MW met in the operations building and debriefed the first mission, re-briefed highlights and prepared for the second mission (the MS) (Tab V-1.36). The MP and the MW had approximately 10 minutes to re-brief before stepping for the MS (Tab V-1.36).

The MF took off at 11:30L (02:30Z) (Tab EE-19). Takeoff and departure were uneventful (Tab V-1.11). The MF checked in with the Command and Control agency for clearance into Military Operating Area 2. The MF flew along the airspace's western border to de-conflict from another flight that was exiting the airspace (Tab V-1.11). The MP then assumed the role of the Strike Coordination and Reconnaissance – Commander (SCAR-C) (Tabs V-1.5, V-1.11, Tab V-1.16). The MF performed a G-awareness maneuver, systems checks and began training in the scenario (Tab V-1.11). Two flights checked-in and the MP directed them to conduct SCAR in other airspace (Tabs V-1.15 to V-1.16).

At approximately 12:07L, the MP heard a loud bang followed by subsequently quieter bangs and noticed rapidly decreasing Revolutions per Minute (RPM) and Fan Turbine Inlet Temperature (FTIT) (Tabs EE-19, N-6, V-1.17 to V-1.19) (note: CSFDR recorded rapidly increasing FTIT) (Tab J-33). The MP retarded the throttle to Idle, initiated a "Knock-it-Off" radio transmission, and pointed the aircraft toward Kunsan AB which was the nearest suitable emergency airfield (Tab V-1.19). The MA was approximately 34 nm from Kunsan AB at 16,280 ft mean sea level (MSL) and 412 knots calibrated airspeed KCAS (Tabs N-6, S-12). The MP completed the emergency procedure checklist items for an engine stall and airstart (Tabs J-33 to J-35, V-1.19 to V-1.23). The MP made several unsuccessful attempts to restart the engine (Tabs J-31, J-33 to J35, V-1.19 to V-1.23). The MP made one radio transmission to Command and Control declaring an emergency and that he was proceeding direct to Kunsan and told Command and Control to standby on all other transmissions (Tab N-6). Another flight of F-16s asked if any assistance was needed and the MP also told them "standby" (Tab N-6). The MP jettisoned the wing tanks approximately 5 minutes after the initial malfunction approximately 17 NM from Kunsan and 3,900 ft MSL (Tabs EE-19, J-35, N-7, V-1.25). Shortly thereafter, the MP prepared for ejection and subsequently initiated ejection at approximately 12:13L (03:13Z) (Tabs EE-19, J-35, V-1.26).

e. Impact

Aircraft T/N 90-0771 impacted the terrain at approximately 12:14L approximately 14 nm northeast of Kunsan AB (Tab H-2, EE-19). The impact site was a semi-dry rice field consisting of wet clay and was approximately 570 ft by 360 ft oriented towards the northwest and located on the south side of a river (Tab H-9, N-48). Analysis and testimony indicate the MA impacted level terrain at low speed, right wing low approximately 75 degrees bank, at an impact angle of approximately 20 degrees nose low (Tabs J-31, V-1.27). The wreckage was mainly buried or remained at the impact site (J-31). However, the radome, forward fuselage, and other debris were thrown forward in a wedge shaped area out to approximately 500 ft from the impact site (Tab J-31).

f. Egress and Aircrew Flight Equipment (AFE)

The ejection sequence was initiated at 12:13L within the performance envelope and at an altitude of approximately 1,600 ft MSL or 1,572 ft AGL and a speed of 196 KCAS resulting in a successful Mode I ejection (Tabs H-2, H-8, J-35, N-7). The escape system functioned as designed. No inspection currencies were expired (Tabs U-154, EE-19). The MP did not have time to complete the post-ejection checklist as his focus was on steering away from the river and landing on dry land (Tab V-1.27). However, the MP did check his parachute canopy and raise his visor (Tab V-1.27). After noting a good canopy and steering toward the river bank the MP prepared for landing (V-1.27). The MP landed on the north bank of the river in a flat field (N3603.2993 E12650.1281) at approximately 12:15L (Tabs N-9, N-47, V-1.27, EE-19). After accessing his condition, the MP used the portable radio communications (PRC)-112 radio to establish contact with the MW and initiate the recovery (Tab V-1.28). When he attempted to transmit voice on GUARD frequency, he heard the Emergency Locator Transmitter (ELT) beacon transmitting. The MP turned off his ELT beacon (Tab V-1.30).

g. Search and Rescue (SAR)

The MP disconnected from his life support equipment and spread his parachute out fully to act as a visual reference to airborne assets (V-1.28). The MP initially made contact with the other F-16 flight at 12:17L after two transmissions on GUARD for "any radio" to meet him on Ultra-high Frequency (UHF) 282.8 (Tabs N-12, V-1.28). After confirming he was physically unharmed, the MP directed the airborne assets to visually acquire his location on the north side of the river (Tabs N-11, V-1.28,). Meanwhile, the Crash Phone activated at Kunsan AB at approximately 12:17L (Tab N-19). The MP had to keep civilian bystanders and reporters from getting too close to any of the wreckage around him while the Korean Police were on-scene at the aircraft impact site 4,500 ft away to the west-northwest with an established cordon (Tabs N-49, S-11, V-1.32). One HH-60 and one HH-47 launched from Chong-Ju, 6th Search and Rescue Group, 17th Fighter Wing at approximately 12:45L (Tab EE-16, EE-19, V-13.1). ROK ground-based civilian rescue services were the first on-scene and performed initial medical checks on the MP (TabV-12.1). Shortly thereafter the Republic of Korea Air Force (ROKAF) SAR package, consisting of one HH-60 and one HH-47, arrived (Tab V-1.31, EE-16). There were no reported delays from the ROKAF scrambling the SAR package and the delivery of the pilot to Kunsan Tab EE-15). The MP departed the site at 12:45L via the HH-60 and arrived at Kunsan AB for medical examinations at 13:04L (Tabs EE-19, N-50, N-36). There were no difficulties reported for the rescue operation (Tab EE-15). There were no issues reported between the SAR package and the On-Scene Commander, a flight of A-10 aircraft overhead (Tab EE-15). From the first indication of an engine malfunction to the pilot arriving at Kunsan approximately 57 minutes elapsed.

h. Recovery of Remains

Not Applicable.

5. MAINTENANCE

a. Maintenance Documentation

Maintenance documentation is divided into two separate sections, Aircraft Maintenance Documentation and Engine Maintenance Documentation. Aircraft Maintenance Documentation provides information and data on the Mishap Aircraft (MA) T/N 90-0771 and includes the engine, when installed in the MA. Engine Maintenance Documentation provides information and data on the Mishap Engine (ME) while it is not installed in the MA.

(1) Aircraft Maintenance Documentation

A thorough review of the Aircraft Maintenance Documentation and most recently pulled (filed) Air Force Technical Order (AFTO) 781 series MA forms was conducted (Tab U-153). There were no open discrepancies that would have prevented the MA from flying. Additionally, no overdue inspections, time changes, or Time Compliance Technical Orders (TCTO) were required at the time of the mishap. AFTO 781 Series Forms dating back to November 2011 were thoroughly reviewed and revealed the following:

On 17 February 2012, the ME (Serial No. GE0E509610) was installed on the MA and passed all operational and leak checks (Tab U-22). The ME remained in the MA until the date of the mishap, 21 March 2012 (Tab D-15).

From the time the ME was installed in the MA until the mishap, the ME flew 40.9 hours and 30 missions (Tab U-4, D-5). Six engine discrepancies were noted, but none contributed to the mishap (Tab U-153, U-154).

(2) Engine Maintenance Documentation

The ME was originally installed in F-16CM T/N 89-2020, assigned to the 36th Fighter Squadron, Osan AB, Republic of Korea (ROK) (Tab U-51). The engine was removed due to fifth stage compressor damage attributed to steel bead media that was used to remove interior paint in the hardened aircraft shelters (HAS) and painted lines in and around the airfield (Tab EE-3, V-5.4, V-3.13). A receiving inspection was completed at the Jet Engine Intermediate Maintenance (JEIM) facility on 28 February 2011, which included a borescope inspection of the compressor (Tab U-64). Damage to the third, fourth, fifth, eighth, and ninth stage compressor blades was noted (Tab U-59, U-60). The upper and lower, forward and aft compressor stator cases were removed to repair and replace damaged blades. While the cases were removed, repair and replacement of the stator vanes was accomplished, in particular, one on the rear compressor case, not specified on 1 June 2011, two fifth stage stator sectors on 24 March 2011 and at least one seventh stage stator on 28 March 2011. (Tabs U-73, U-74, U-101) The ME work package does show that a review was accomplished by Flight Chief 1 on these tasks. Once all required repairs were complete, installation of the lower forward compressor case was accomplished on 1 June 2011, and the upper forward compressor case was accomplished on 2 June 2011 (Tab U-75). A Quality Verification Inspection (QVI) of the compressor stator case assemblies was accomplished 6 June 2011, and a borescope of the engine was accomplished along with preparations for engine testing on 22 June 2011 (Tabs U-75, U-79). On 27 June 2011, the engine was wrapped for shipment to Misawa AB, Japan where Test Cell run would be performed. The F110-GE-100 JEIM Engine Test Preparation Work Sheet was finalized on 28 June 2011 (Tabs U-80, U-145).

Technical Order guidance for compressor stator vane assemblies stage 4 and 5, and liner stage 5 - installation, clearly direct, "Vane assemblies shall be installed correctly. It is possible to install vane assembly incorrectly (180 degrees out on vane sector working against airflow)" (Tab U-154). In reference to the parts order log, two 5th stage compressor stator vane sectors were ordered and received, and in the ME work package it states that two 5th stage compressor stator vane sectors were installed (Tabs U-74, U-101, U-132).

Documentation shows that there was an In Process Inspection (IPI) accomplished prior to installation of the upper forward stator case (Tab U-84). Interviews disclosed that a stator vane sector fell out of the upper compressor stator case during the installation process (Tab V-8.12). Records do not indicate that a stator sector fell out nor do they indicate that it was subsequently reinstalled. Furthermore, the records do not indicate that a second IPI was accomplished during the reinstallation. Of those interviewed, none identified which stator had fallen out. Either during the initial stator case tear down, stator case maintenance, or stator case reassembly, two stator vanes were installed incorrectly into the upper stator vane case. One of which was installed 180 degrees out.

For Test Cell runs the ME was shipped to Misawa AB, Japan due to Osan's Test Facility being nonoperational. Three borescope inspections were accomplished while the ME was at Misawa revealing only minor dents determined to be within limits (Tab U-154). A receiving inspection was accomplished on 23 June 2011. Prior to the test run on 2 Aug 2011 an initial borescope inspection was accomplished (Tab U-154). The ME was tested on 4 August 2011, but encountered issues with the Augmenter and had to be downloaded for component replacement (Tab U-154). A second borescope was accomplished on 7 Aug 2011 in preparation for another engine run that was complied with on 10 Aug 2011 (Tab U-154). The final borescope took place after the ME passed all operational and leak checks and the ME was placed in a serviceable spare status on 7 September 2011 (Tab D-47). Due to the proximity of 5th stage stator sector in position E (one o'clock position when looking forward through the aft end of the engine), and the borescope port S21 at the six thirty position, technicians would not see a vane sector installed 180 degrees out when performing borescope procedures (Tab U-154).

On 17 February 2012, the ME was installed on the MA and remained there until 21 March 2012, the date of the mishap (Tab U-21, D-15).

b. Maintenance Personnel and Supervision

(1) Flightline Maintenance Personnel and Supervision

According to MA maintenance documentation, the aircraft was properly serviced and inspected prior to flight (Tab D-6, D-10, D-11). Individual training records confirmed that the individuals in the servicing, inspecting and launching of the aircraft were all qualified and certified in the tasks they performed. The technician who performed the last engine inlet inspection prior to the mishap reported no discrepancies during the inspection. Maintenance supervision reported all aspects of the launch for the MS as trouble free, and there were no indications that the aircraft had any problems. There was no evidence that flightline maintenance personnel or supervision contributed to the mishap (Tab R-12, R-48, D-5 thru D-24).

(2) Engine Maintenance Personnel and Supervision

The Accident Investigation Board interviewed four maintenance personnel involved in the build-up process of the ME. The findings are based on interviews and other related evidence.

Training records reflect that Flight Chief 1 was qualified to accomplish the task of removing, installing and inspecting the forward compressor case (Tab G-147). Interviews reflect that Flight Chief 1 had only one year of practical experience working the F110-GE-100 engine (Tab V-5.5). Flight Chief 1 also stated that Maintainer 1, Maintainer 3, and Maintainer 4 were relied upon heavily to accomplish the majority of the build up process because they were more experienced (Tab V-5.9, V-5.14). When questioned about the replacement of stator vane sectors, it was confirmed that they had replaced some, but due to the length of time that had passed, Flight Chief 1 could not recall which one were replaced. Flight Chief 1 testified that she knew the potential to install a vane sector 180 degrees out existed but had never personally seen one in that configuration (Tab V-5.16). Flight Chief 1 also testified to hearing that it is possible for a stator sector to fall out during reassembly of the engine, but did not specify if this happened to the ME (Tab V-5.15).

Maintainer 1 was an Apprentice while assigned to the 51 MXS, Osan AB, Korea, and his only training prior to this assignment was technical school. His training records do not reflect that he was qualified to accomplish maintenance on the forward compressor case assembly (Tab G-117). The ME work package (maintenance records) shows he replaced two fifth stage upper forward compressor case stator vane sectors on 24 March 2011, but the records do not specify which two (Tab U-74). Parts ordered for the ME indicate the ordered sectors were for positions B, C, D or E (Tab U-132, U-154). The engine work package also indicates that Maintainer 1 was not involved in the upper forward compressor case installation. During testimony, Maintainer 1 had no knowledge of a stator sector falling out during engine reassembly.

Maintainer 3 was a journeyman technician while assigned to 51 MXS, Osan AB, Korea, and had previous experience working on the F110-GE-100 engine (Tab V-8.3). His training records do not indicate that he was qualified to perform inspections, assembly, removal, or installation of the forward compressor cases during the period in which this work was performed on the ME (Tab G-129). Maintainer 3 was involved in the installation of the upper forward compressor case. During his interview, he reported remembering that a stator vane sector fell out and hit Maintainer 5 in the chest (Tab V-8.12). Due to the length of time that had passed, Maintainer 3 could not recall the details of vane sector's reinstallation (Tab V-8.14). He also indicated that Flight Chief 1 and another maintainer were present and believes they too saw the stator sector fall out during installation of the case but was unclear on that fact (Tab V-8.15). The position and stage number from which the sector fell out could not be determined from the interview.

Maintainer 5 reported that he had very little F110-GE-100 engine maintenance experience (Tab V-7.5). His training records were not available to verify his qualifications during the ME's maintenance timeframe. His records only reflect his current qualifications at his follow-on assignment (Tab V-7.3). Maintainer 5's training on the F110-GE-100 engine was accomplished via On-the-Job Training (OJT) (Tab V-7.6). Maintainer 5 did report that he had seen a vane sector come out but during the interview claimed it was during removal of the case and not installation (Tab V-7.12). Maintainer 5 could not verify which stage the vane came from or even if it came from the ME (Tab V-7.12).

(3) Engine, Fuel, Oil, and Hydraulic Inspection Analysis

Fuel samples were taken from the fuel truck that serviced the aircraft. These samples met specifications (Tab D-57). Oil and Hydraulic fluid was taken from the servicing carts that were used to service the MA and passed local testing (Tab D-57). Liquid oxygen used to service the MA was also tested with passing results (Tab D-57). The tool kit and laptop used during the launch sequence were inventoried and found to be all accounted for (Tab D-57).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS.

a. Structures and Systems

Analysis of the ME and testimony from the MP clearly indicate that there was a serious malfunction of the engine that was causal to the mishap (Tabs J-29, V-1.17 to V-1.19). Analysis of the MA indicates that all other systems were operating correctly and within limits (Tab J-38). At the time of the mishap, electrical power was available, both hydraulic systems were pressurized, the flight control system and the EPU both operated normally and the JFS operated properly (Tab J-38).

The engine was recovered and analyzed (Tab J-21). Examination of the ME revealed that two stator vane sectors were incorrectly installed. More so, one of the sectors was installed 180 degrees out (Tab J-25). The incorrectly installed stator vane sector (part number 2038M65G02) was installed in the wrong position as well as 180 degrees out (Tab J-25). In a statement from the Osan Air Force Engineering Services Technical representative, he stated that such an installation would create a "pressure pulse." This in turn would generate increased low amplitude, high frequency vibrations on the compressor rotor blades as they traveled through the affected area (Tab U-153). The increased vibrations could cause compressor blades to fail (Tabs J-26, J-46). Metallurgical analysis shows that two blades separated first. The liberation of these two blades caused a compressor stall that liberated two more compressor blades (Tab J-46). The four liberated compressor blades subsequently destroyed the high-pressure compressor (Tabs J-29). All damage outside of the compressor section was secondary as a result of the impact (Tab J-29). The Osan Jet Engine Intermediate Maintenance shop's analysis of the engine is listed below.

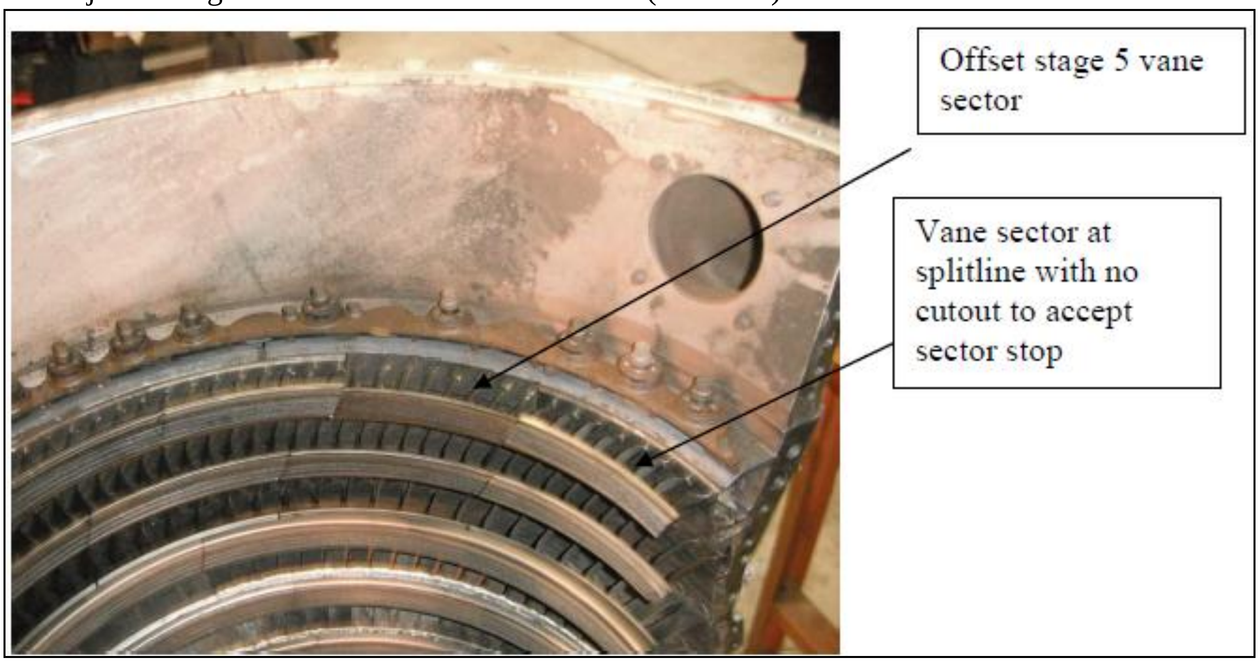
b. Evaluation and Analysis of Engine GE0E509610

(1) Fan Section

The front frame and fan rotor exhibited distortion and bending consistent with impact (Tab J-22). The fan stator case showed severe damage on the fan stator vanes consistent with blade damage and impact damage (Tab J-22).

(2) Compressor Section

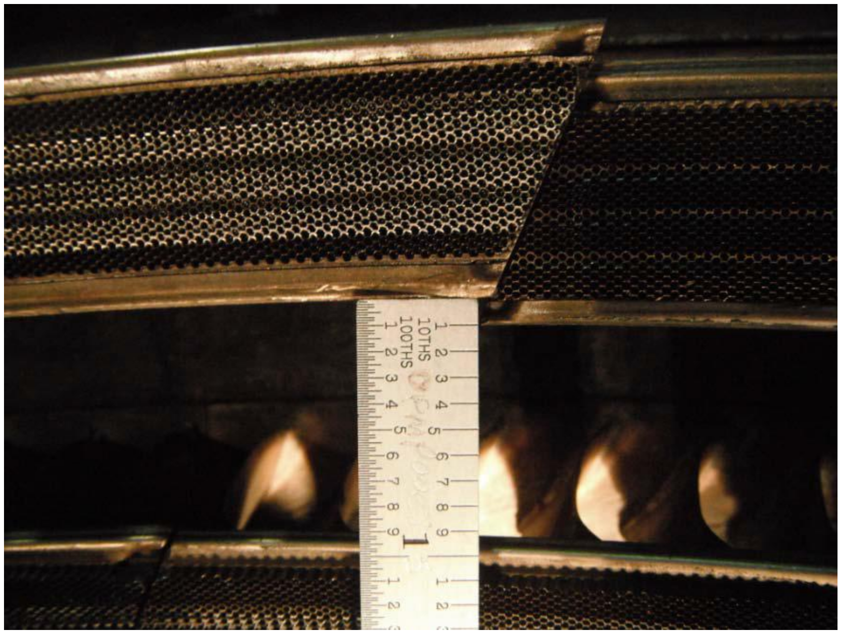
The lower and upper outer fan ducts were moderately damaged with buckling and holes due to the impact (Tab J-23). The exterior of the forward stator case assembly exhibited no signs of damage (Tab J-24). Stage 1 vane sectors had damage to the leading edge on several vanes with no trailing edge damage (Tab J-24). Stage 2 sector vanes had minor nicks on both the leading and trailing edges (Tab J-24). Stage three vanes showed heavy damage on the leading edges and minor damage on the trailing edges (Tab J-25). Stage 4 vane sectors exhibited much more damage on the trailing edges than the damage noted on the stages forward of stage 4 (Tab J-25). Uniform damage was identified in the form of large tears and nicks along the outer diameter of the stage 4 vane sectors (Tab J-25). One of the stage 5 vane sectors was found offset from the two adjacent stage 5 vane sectors as shown below (Tab J-25).



Forward case with two incorrectly installed stator vane sectors (Tab J-25)

The offset stage 5 vane sector was turned 180 degrees in the radial direction, that is to say it was found installed 180 degrees out from its designed position. The offset sector has a cutout to accept the anti-rotation stop whereas the vane sector installed at the 3 o'clock splitline did not have a cutout for this stop (Tab J-25). This indicates that not only was the vane sector installed 180 degrees out but the positions of these two stator vane sectors were incorrect.

The incorrectly installed sector extended forward approximately 0.1 inch into the stage 5 compressor blade area as shown below (Tab J-25).


Offset vane sector extending forward 0.1 inch (Tab J-26)

All stage 5 vanes showed significant damage on both the leading and trailing edges (Tab J-26).

The aft compressor case showed severe damage on both leading and trailing edges (Tab J-26). For the compressor rotor, stages 1-4 were all intact with damage on the leading and trailing edges (Tab J-26). Stage 5 blades of the compressor rotor showed extreme damage and four stage 5 blades were liberated (Tab J-26). Metallurgical examination revealed that all four blades fractured in fatigue with features consistent with low-alternating stress, high-cycle fatigue (Tab J-46). Of the four liberated blades, two were liberated based on the vibration-induced loading while the other two were liberated based on the subsequent stall (Tab J-46). The first two blades to liberate were shown to have a crack initiating from a small impact at the leading and trailing edges (Tab J-46). This is consistent with the bead damage that the ME was originally removed for and routed to JEIM for repair (Tab U-51). Inconsistent pressure within the compressor section resulting in pressure pulsing would be one of the effects of an improperly installed stator vane sector in stage 5 (Tab U-153).

Correctly Installed Stator Vane Sector

Incorrectly Installed Stator Vane Sector

Compressor blades in stages 6 to 9 were heavily damaged with a total of 27 liberated blades all resulting from an overload condition (Tab J-27).

(3) Hot Section

The high-pressure turbine (HPT) shroud and rotor showed no damage. The low pressure turbine (LPT) rotor was sheared via a torsional failure mode indicative of the fan rotor stopping while the LPT continued spinning during impact. This is consistent with impact damage (Tab J-27).

(4) Main Engine Bearings

All bearings appeared to have been adequately lubricated at the time of impact. The #2 bearing area was damaged from the impact (Tab J-28).

(5) Augmenter and Exhaust Nozzle

The augmenter and the nozzle were severely buckled due to impact damage. Bluing was seen on the augmenter and nozzle (Tab J-28).

7. WEATHER

a. Forecast Weather

The forecast weather at Osan AB for the flying period from scheduled takeoff to scheduled landing was: winds 270 degrees at 7 knots, 7 miles visibility, few clouds at 20,000 ft, and an altimeter setting of 30.18 inches of mercury (Tab F-55).

b. Observed Weather

Observed weather for Kunsan AB at the time of the mishap was: winds 290 degrees at 8 knots, 10 miles visibility, sky clear, and an altimeter setting of 30.30 inches of mercury (Tab F-18). The observed weather at the time of the mishap closely resembled the forecast weather.

8. CREW QUALIFICATIONS

The MP is an experienced Senior Pilot with over 1,200 hours in the F-16 and over 1,500 total hours (Tab G-8). The MP arrived to Osan AB from Hill AFB after completing the Weapons Instructor Course (WIC) (Tabs G-17, EE-20). The MP completed an abbreviated Mission Qualification (MQT) upgrade which also served as his Instructor Pilot certification (Tab G-17). The MP met 30-day lookback and did not meet 90-day lookback on the day of the mishap (Tab G-9). This was due to a time of transition after WIC graduation and Permanent Change of Station (PCS) to Osan (Tab EE-20). The MP was current and qualified in the F-16CM at the time of the mishap (Tab G-5).

Recent flight time (Tab G-9):

	Hours	Sorties
30 Days	**18.6**	**17**
60 Days	**18.6**	**17**
90 Days	**18.6**	**17**

9. MEDICAL

a. Qualifications - Mishap Pilot

The Mishap Pilot (MP) was medically qualified to perform flying duties at the time of the mishap. The MP's annual Preventative Health Assessment (PHA) was current and his Air Force Form 1042 was current. Furthermore, the MP had no physical or medical restrictions and was worldwide qualified prior to the mishap (Tab X-3).

The MP did not suffer any major injury from the mishap. The MP did however feel mild neck soreness as a result of the ejection. He was initially evaluated by the responding fight surgeon of the 8th Medical Group at Kunsan AB, then referred to flight medicine at the 51st Medical Group at Osan AB. The 51st Medical Group performed X-rays of cervical, thoracic and lumbar spine and all revealed negative findings. The MP returned to flying status on 30 Mar 2012 after being thoroughly evaluated physically and mentally by flight medicine staff (Tab X-4).

b. Toxicology

Toxicology tests were conducted for MP, MW, and aircraft maintenance members. The Carbon Monoxide, ethanol and drug screening results were negative (Tab X-4).

c. Lifestyle

Review of the MP's 72 hour history did not reveal any lifestyle factors, including unusual habits, behavior or stresses which were found to be causal or substantially contributory to the mishap (Tab X-4).

d. Crew Rest and Crew Duty Times

Air Force Instructions require all aircrew to have proper "crew rest" as defined in AFI 11-202, Vol 3, General Flight Rules, prior to performing in-flight duties. AFI 11-202, Vol 3 defines normal crew rest as a minimum of a twelve-hour non-duty period before the designated flight duty period begins. During this time, an aircrew member may participate in meals, transportation, or rest as long as he or she has had at least ten hours of continuous restful activities including an opportunity for at least eight hours of uninterrupted sleep. After reviewing the 72 hour histories and MP's testimony, the MP met all AFI 11-202, Vol 3 crew rest requirements, had a normal crew rest and was afforded the opportunity for at least 8 hours of uninterrupted sleep the night prior to the mishap (Tabs V-1.4, X-4). The MP did not feel fatigued the day of the mishap (Tab X-4).

10. OPERATIONS AND SUPERVISION

a. Operations

The 36th Fighter Squadron is located in Korea and is thus a remote assignment. The squadron does not support deployed contingency operations, but focuses on the Korean Theater. Numerous exercises, Operational Readiness Inspections, Operational Readiness Exercises, and the rapid turnover associated with remote assignments increases the sorties required to support operations. On the day of the mishap, the squadron had 25 assigned pilots with an Aircrew Position Indicators (API) 6 and 8. Of the 25 total 14 were at the experienced level and 11 at the inexperienced level. Three additional pilots were in MQT status (Tab G-5). This is a total of 28 assigned pilots. Pilot and flying requirements are being effectively managed.

b. Supervision

The flight was properly scheduled, authorized, and released in accordance with AFI 11-401, paragraph 1.8 (Tabs K-11, K-12, K-18). The squadron Director of Operations served as the Top-3 Supervisor, conducted the squadron mass briefing and was readily available to the operations desk during the MS.

11. HUMAN FACTORS

The board evaluated human factors relevant to the mishap using the analysis and classification system model established by the Department of Defense (DoD) Human Factors Analysis and Classification System (HFACS) guide, implemented by Air Force Pamphlet (AFPAM) 91-204, *USAF Safety Investigations and Reports*, dated 24 September 2008 (Tab BB-1). A human factor is any environmental, technological, physiological, psychological, psychosocial, or psycho-behavioral factor a human being experiences that contributes to or influences his performance during a task. The DoD has created a framework to analyze and classify human factors and human error in mishap investigations (Tab BB-1).

The framework is divided into four main categories: Acts, Preconditions, Supervision, and Organizational Influences. Each category is further divided into related human factor subcategories. The main categories allow for a complete analysis of all levels of human error and how they may interact together to contribute to a mishap. This framework allows for evaluation from the unsafe acts that directly are related to the mishap through the indirect preconditions, supervision, or organizational influences that may have led to the mishap (Tab BB-1). The relevant factors to this mishap are discussed below.

a. Causal

(1) AE101 Inadvertent Operation: *Inadvertent Operation is a factor when individual's movements inadvertently activate or deactivate equipment, controls or switches when there is no intent to operate the control or device. This action may be noticed or unnoticed by the individual* (Tab BB-1).

The mishap was caused by an incorrectly installed stage 5 stator vane sector. Analysis determined there were three opportunities to incorrectly install the stage 5 stator vane: 1) during disassembly of the upper compressor case; 2) during installation of the stage 5 stator vane assemblies; 3) during reassembly of the upper compressor case (Tab U-64, U-74 – 75). There is no evidence to support that this mistake was made intentionally, or was noticed by any individual involved.

(2) AE103 Procedural Error: *Procedural Error is a factor when a procedure is accomplished in the wrong sequence or using the wrong technique or when the wrong control or switch is used. This also captures errors in navigation, calculation or operation of automated systems* (Tab BB-1).

According to analysis, the mishap was caused by an incorrectly installed stage 5 stator vane sector. Technical Order guidance clearly states vane assemblies shall be installed correctly (Tab U-154). At some point during engine maintenance, Technical Order guidance was not followed during the reinstallation of the stator vane sectors.

b. Contributory:

OP003 Procedural Guidance/Publications *Procedural Guidance/Publications is a factor when written direction, checklists, graphic depictions, tables, charts or other published guidance is inadequate, misleading or inappropriate and this creates an unsafe situation* (Tab BB-1).

Technical Order guidance states "Vane assemblies shall be installed correctly, it is possible to install vane assembly incorrectly (180 degree out on vane sector working against air flow)" (Tab U-154). However, the T.O. does not specifically identify how this may happen nor does it provide detailed drawings or photographs showing how a stator vane sector can be installed 180 degrees out. Furthermore, the one comment contained in the T.O. concerning the potential for incorrect stator vane sector installation is labeled as a "note" rather than a "caution" or "warning." Since this error will lead to catastrophic failure of the engine, a "note" is not adequate (Tab U-154).

c. Non-Contributory:

PC307 Fatigue - Physiological/Mental Fatigue - *Physiological/Mental is a factor when the individual's diminished physical or mental capability is due to an inadequate recovery, as a result of restricted or shortened sleep or physical or mental activity during prolonged* *wakefulness. Fatigue may additionally be described as acute, cumulative or chronic* (Tab BB-1).

MP's and MW's self reported ORM assessment worksheets indicate fatigue and less than 18 hrs of sleep over the last 3 nights (Tab K-24). Review of the mishap crew's medical records did not show any medical history of fatigue or sleeping problems (Tab X-3). Both MP and MW did not feel fatigued on the day of mishap; their flying performance during the mishap sortie did not indicate any fatigue or any degradation of performance (Tab X-4). Likewise, there was no evidence that the engine shop maintainers were either mentally or physically fatigued (Tab X-3).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

The following publications are available on the AF e-Publishing web site: http://www.e-publishing.af.mil.

a. Directives and Publications Relevant to the Mishap

(1) Air Force Policy Directive (AFPD) 11-2, Aircraft Rules and Procedures, 14 January 2005
(2) Air Force Instruction 11-202, Volume 3, General Flight Rules,
(3) Air Force Instruction 48-123 Medical Examination and Standards
(4) Air Force Instruction 11-401 Aviation Management
(5) Air Force Instruction 11-2F-16, Volume 3, F-16 Operations Procedures
(6) Air Force Instruction 11-2F-16, Volume 1, F-16 Pilot Training

b. Other Directives and Publications Relevant to the Mishap

(1) AETC Handout, *Flying Training, Introduction to Aerodynamics*, January 2002

c. Known or Suspected Deviations from Directives or Publications

Technical Order guidance was not followed during the installation of two stage 5 stator vane sectors.

13. ADDITIONAL AREAS OF CONCERN

None

23 May 2012

WILLIAM R. JONES, LT COL, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

AIRCRAFT ACCIDENT INVESTIGATION

F-16CM, T/N 90-0771
OSAN AIR BASE, REPUBLIC OF KOREA
21 MARCH 2012

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

1. OPINION SUMMARY

I find by clear and convincing evidence that the MA crashed due to the catastrophic failure and subsequent compressor stall of the mishap engine (ME). Following the failure, the ME could not produce enough thrust to sustain flight. Evidence obtained from the ME confirmed that a stage 5 stator vane sector was incorrectly installed in the ME. The incorrectly installed stator vane sector created an area of reduced pressure and unstable airflow which applied vibratory oscillations to the nearby stage 5 compressor blades resulting in excessive and accelerated fatigue and premature failure of fifth stage compressor blades 52 and 64.

I developed my opinion by analyzing factual data from historical records, guidance and directives, engineering analysis, engineering data on material excitation and fatigue, witness testimony, information provided by technical experts, prior mishaps, and photographic evidence. Additionally, I reviewed an animation provided by the Mishap Analysis and Animation Facility. I used this in conjunction with the MW's DVR to determine the mishap sequence of events. Lastly, numerous flight simulation profiles were flown duplicating the conditions that existed at the time of the mishap.

2. DISCUSSION OF OPINION

a. Cause:

Compressor blades, even when not in motion, vibrate at their own specific natural frequency. When blades are in motion inside the engine, they are subjected to even more vibrations. These vibrations impart energy on the blades commonly called "excitation." When compressor blades are excited, the amplitude of their vibration increases. In other words, their movement (twisting, stretching, and bending) increases in distance and frequency. Vibrations and other excitation sources are all compensated for within the General Electric F110 engine (model of the ME) through material design, installation methods, and airflow control. However, if unaccounted for excitation is introduced, it can lead to rapid blade fatigue and subsequent component failure. The fatigue and failure is accelerated even more if the blades are damaged (dings, nicks, etc).

Even if the damage is well within normal operating limits, the failure can still occur more rapidly.

In December 2005 and February 2009, metallic bead material was used to remove paint from the interiors of a number of hardened aircraft shelters and painted lines on the airfield. Although most of the bead material was collected when the project was completed, some of the material still lingered in and around aircraft parking areas: grassy areas, light fixtures within the shelters, and within concrete joints. Despite efforts to remove all bead material, approximately 22 engines over the next two years were removed from aircraft and sent to the engine maintenance facility for excessive nicks due to FOD (foreign object damage) caused by the metallic beads. On 23 February 2011, the ME was sent to the engine shop for nicks on the leading edges of several stage 5 compressor blades.

From 24 February 2011 through 27 June 2011, the ME was disassembled. Many of the repairs included repairing or replacing compressor blades and stator vanes sectors. During this period, stage 5 stator vane sectors E and F either were removed or fell out of the upper forward compressor casing. Both vane sectors were incorrectly installed in reverse order. More critically however, stator vane sector F was installed backwards; that is to say, it was rotated 180 degrees out of the normal position.

After maintenance was complete, the ME remained a serviceable spare until 16 February 2012 at which time the ME was installed in the MA, T/N 90-0771.

During normal operation, the compressor blades experience a relatively equal amount of pressure as they rotate. This was not the case for the stage 5 compressor blades in the ME. Because the stage 5 stator vane sector in position F was incorrectly installed, extremely high-pressure air escaped through gaps on either side of the sector. Additionally, high-pressure air escaped through gaps in the honeycomb seals at the joints between the incorrectly installed sector and the two adjacent sectors and through the third race seal on the sectors honeycomb structure. This created a much lower area of pressure in and around stator vane sector F. As the compressor blades rotated, they experienced relatively constant pressure until reaching stator vane sector F. There they experienced a rapid pressure drop followed by a rapid pressure increase as the blades continued rotating through sectors D, C, B, and so on.

As the blades transited these areas of varying pressures, they flexed back and forth very rapidly. The compressor blades will flex back and forth 10,845 to 15,328 times per minute based on engine RPM. This bending back and forth creates accelerated material fatigue; much like a metal wire will break when bent very rapidly many times over. The stage 5 blades flexed between 31.9 and 35.4 million times prior to the mishap.

In addition to fatigue due to flexing, these high frequency pressure changes created what is commonly referred to as “pressure pulses.” These pressure pulses were a source of external “excitation” applied to the blades and whose frequency was proportional to engine RPM. At typical operating RPMs, the frequency of the resultant vibrations can range from 13,556 to 19,160 pulses per second. These vibrations added to the blades’ own resonant vibrations accelerated the blades’ fatigue.

These multiple sources of accelerated blade fatigue (blast bead FOD damage, flexing, and resonant vibrations) led to premature stage 5 compressor blade failure.

Most of the stage 5 compressor blades exhibited rubbing marks on their trailing edges near the blade root. The incorrectly installed stator blade sector at position F protruded towards the stage 5 blades 0.1 inch creating slight contact between the stage 5 compressor blades and the incorrectly installed stator vane sector. These rubbed areas are also a source of accelerated blade fatigue.

Metallurgical analysis revealed that four stage 5 compressor blades separated: blades 52, 58, 59, and 64. Blades 52 and 64 separated due to the excitation and flexing described above. Blades 58 and 59 separated due to the compressor stall caused by the failure of blades 52 and 64. Because blades 52 and 64 were already damaged along their leading and trailing edges (albeit within limits), they experienced fatigue at a faster rate and thus failed first. After the four blades separated, they caused extensive internal damage and the engine was unable to produce enough thrust to sustain flight.

b. Contributing Factors.

The Note in the relevant Technical Order informs the reader that it is possible to install a vane assembly incorrectly. However, the T.O. does not provide detailed drawings or photographs showing how a stator vane sector could be installed 180 degrees out. The note also does not warn that the probable outcome of incorrect installation is catastrophic engine failure. A "note" is also not normally used to warn maintenance members of catastrophic errors; a "caution" or "warning" more accurately conveys the risk associated with violating the guidance. A "note" does not typically trigger the same level of awareness. It is probable that both Note 3's lack of precise detail in describing the error and its' status as a "note" failed to adequately instruct maintenance members in the manner in which the error could occur as well as failing to represent the magnitude of the risk associated with this error.

3. CONCLUSION

I find by clear and convincing evidence that the primary cause of the accident was an incorrectly installed stage 5 stator blade sector, brought about by an inadvertent operation and procedural error, which occurred during maintenance on the Mishap Engine. I further find by a preponderance of evidence that procedural guidance substantially contributed to the mishap by failing to instruct maintenance members with suitable detail in the manner in which the error could occur as well as failing to represent the magnitude of the risk associated with the error.

23 May 2012

WILLIAM R. JONES, LT COL, USAF
President, Accident Investigation Board

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.