UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

F-16CM, T/N 92-3907

55th FIGHTER SQUADRON
20th FIGHTER WING
SHAW AIR FORCE BASE, SOUTH CAROLINA

LOCATION: OSAN AIR BASE, REPUBLIC OF KOREA

DATE OF ACCIDENT: 16 JULY 2013

BOARD PRESIDENT: LIEUTENANT COLONEL WILLIAM R. JONES

Conducted IAW Air Force Instruction 51-503

Volume One of Two

EXECUTIVE SUMMARY
AIRCRAFT ACCIDENT INVESTIGATION

F-16CM T/N 92-3907
Osan Air Base, Republic of Korea
16 July 2013

On 16 July 2013, at approximately 18:07 hours local time (L), the mishap aircraft (MA), an F-16CM, tail number 92-3907 assigned to the 55th Fighter Squadron, 20th Fighter Wing, Shaw Air Force Base, South Carolina, after a routine training mission at Osan Air Base, Republic of Korea, skidded off the runway and crashed after a normal approach and landing. At 0.75 seconds after touchdown, the right main landing gear (RMLG) collapsed. As a result, the MA's right station 6 external fuel tank contacted the runway surface along with the MA's station 8 air intercept missile (AIM) -9. The MA drifted right on its nose landing gear (NLG), left main landing gear (LMLG), station 6 external fuel tank and station 8 AIM-9 until it skidded off the runway 5 seconds later, approximately 9 seconds after touchdown, 2,000 feet from its touchdown point. Two seconds after the MA skidded off the runway, the NLG collapsed and the MA's nose dug into the ground, and the MA flipped and rolled. The MA came to rest in the grass to the right of the runway 16 seconds after touchdown and 3,000 feet from the touchdown point. The MA was destroyed. The mishap pilot (MP) incurred a minor back injury during the mishap. The MP egressed the aircraft and fire recovery personnel recovered him for medical care. There was no damage to private property. Estimated government loss is $33,483,954.56.

The Accident Investigation Board (AIB) President found, by clear and convincing evidence, the cause of this mishap was the collapse of the right main landing gear by the unlocking of the toggle and link assembly in the right main landing gear drag brace assembly.

Additionally, the AIB president found, by a preponderance of evidence that each of the following factors substantially contributed to the mishap: (1) the installation of an incorrect pivot pin that connected the upper drag brace assembly to the main drag brace assembly and (2) natural resonant vibrations of the drag brace assembly, when combined with the vibrations created by wheel spin up and spring back phenomena unlocked the toggle and link drag brace assembly, thereby unlocking the RMLG. The RMLG collapsed as the weight of the aircraft settled onto it. Specifically, during normal operations, the toggle and link assembly may move towards an unlocked position. The probability of achieving an unlocked condition increases under certain conditions. Several of these conditions existed during the mishap: an incorrect drag brace assembly pin (connects the upper drag brace with the drag brace assembly) was installed, high vertical velocity during touchdown, normal wheel spin up and spring back of the landing gear, and compression loads on the landing gear. Each of these conditions had a cumulative effect on moving the RMLG toggle and link assembly far enough to reach an unlocked condition. As the weight of the aircraft settled onto the RMLG, the unlocked drag brace assembly collapsed, which in turn allowed the entire RMLG to collapse.

SUMMARY OF FACTS AND STATEMENT OF OPINION
F-16CM, T/N 92-3907
16 July 2013

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ACRONYMS AND ABBREVIATIONS

1v1	One Versus One
20 FW	20th Fighter Wing
55 FS	55th Fighter Squadron
9 AF	9th Air Force
AB	Air Base
ACC	Air Combat Command
AF	Air Force
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFI	Air Force Instruction
AFPAM	Air Force Pamphlet
AFTO	Air Force Technical Order
AGL	Above Ground Level
AIB	Accident Investigation Board
AIM	Air Intercept Missile
AMU	Aircraft Maintenance Unit
AMXS	Aircraft Maintenance Squadron
AOA	Angle of Attack
AR	Aero Repair
ATO	Air Tasking Order
ATP	Advanced Targeting Pod
Aux	Auxiliary
BFM	Basic Fighter Maneuvers
BPO	Basic Post Flight
Capt	Captain
CATM	Captive Air Training Missile
CCIP	Common Configuration Implementation Program
CIP	Core Integrated Processor
CMR	Combat Mission Ready
CMS	Component Maintenance Squadron
Col	Colonel
Comms	Communications
CSFDR	Crash Survivable Flight Data Recorder
CSMU	Crash Survivable Memory Unit
CT	Continuation Training
CTK	Composite Toolkit
DoD	Department of Defense
DU	Display Unit
DVR	Digital Video Recorder
ECM	Electronic Counter Measure
ECS	Environmental Control System
EMS	Equipment Maintenance Squadron
EPS	Emergency Power System
EPU	Emergency Power Unit
FL	Flight Lead
FLCS	Flight Control System
FPM	Feet Per Minute
fps	Feet Per Second
FS	Fighter Squadron
ft	Feet
g	Gravitational Force
HARM	High Speed Anti-Radiation Missile
HAS	Hardened Aircraft Shelter
HFACS	Human Factors Analysis and Classification System
HMCS	Helmet Mounted Cueing System
HTS	HARM Targeting System
HUD	Heads-Up Display
Hz	Hertz
IAW	In Accordance With
IMDS	Integrated Maintenance Data System
IMIS	Integrated Maintenance Information System
IPB	Illustrated Parts Breakdown
IVSC	Integrated Vehicle Subsystem Controller
JBER	Joint Base Elmendorf-Richardson
JDAM	Joint Direct Attack Munitions
JHMCS	Joint Helmet Mounted Cueing System
K	Thousand
KCAS	Knots Calibrated Airspeed
KGS	Knots Ground Speed
KTAS	Knots True Airspeed
kts	Knots
L	Local Time
LG	Landing Gear
LMLG	Left Main Landing Gear
Lt Col	Lieutenant Colonel
LWD	Left Wing Down
MA	Mishap Aircraft
Main Gen	Main Generator
MARSA	Military Assumes Responsibility for Separation of Aircraft
MF	Mishap Flight
MFL	Maintenance Fault List
MIC	Micrometer
MLG	Main Landing Gear
MM1	Maintenance Member 1
MM2	Maintenance Member 2
MM3	Maintenance Member 3
MM4	Maintenance Member 4
MOA	Military Operating Area
MP	Mishap Pilot
MQT	Mission Qualification Training
MS	Mishap Sortie
MSL	Mean Sea Level
MXO	Maintenance Operations
MXS	Maintenance Squadron
NLG	Nose Landing Gear
NOTAM	Notice to Airman
NWS	Nose Wheel Steering
Ops Sup	Operations Supervisor
Ops Tempo	Operations Tempo
ORM	Operational Risk Management
PACAF	Pacific Air Forces
PEX	Patriot Excalibur
PHA	Physical Health Assessment
PMG	Permanent Magnet Generator
Pres	Board President
PSI	Pounds Per Square Inch

QA	Quality Assurance
QAI	Quality Assurance Inspector
QVI	Quality Verification Inspection
RADOME	Radar Dome
RAP	Ready Aircrew Program
RMLG	Right Main Landing Gear
ROK	Republic of Korea
ROKAF	Republic of Korea Air Force
RTB	Return To Base
RWD	Right Wing Down
SAR	Search and Rescue
SAT	Surface Attack Tactics
SEAD	Suppression of Enemy Air Defenses
SII	Special Interest Item
SIM	Simulator
SMSgt	Senior Master Sergeant
SOF	Supervisor of Flying
SSgt	Staff Sergeant
T.O.	Technical Order
T/N	Tail Number
TCTO	Time Compliance Technical Order
TI	Tactical Intercepts
TOD	Technical Order Data
TSP	Theater Security Package
USAF	United States Air Force
VFR	Visual Flight Rules
VVI	Vertical Velocity Indicator
WOW	Weight on Wheels
Z	Zulu

The above list is derived 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 6 August 2013, Lieutenant General Lori J. Robinson, Vice Commander, Air Combat Command (ACC), United States Air Force (USAF), appointed Lieutenant Colonel William R. Jones as the Accident Investigation Board (AIB) President to conduct an aircraft accident investigation of a mishap that occurred on 16 July 2013 involving an F-16CM, Fighting Falcon aircraft at Osan Air Base (AB), Republic of Korea (ROK) (Tab Y-8). The aircraft accident investigation was conducted in accordance with Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*, at Osan AB, ROK, from 26 August 2013 through 13 September 2013. Board members included a Pilot Member, Flight Doctor, Legal Advisor, Maintenance Member, and Recorder (Tab Y-3).

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 16 July 2013, at approximately 18:07 hours local time (L), an F-16CM, tail number 92-3907, the mishap aircraft (MA), assigned to the 55th Fighter Squadron, 20th Fighter Wing, Shaw Air Force Base, South Carolina, departed runway 27 after a normal approach and landing (Tab J-2, Tab Q-7, Tab CC-10). At 0.75 seconds after touchdown, the right main landing gear (RMLG) collapsed (Tab J-2). As a result, the MA's right station 6 external fuel tank contacted the runway surface along with the MA's station 8 air intercept missile (AIM) -9 (Tab J-2). The MA drifted right on its nose landing gear (NLG), left main landing gear (LMLG), station 6 external fuel tank and station 8 AIM-9 until it departed the runway five seconds later, approximately nine seconds after touchdown, 2,000 feet from its touchdown point (Tab J-2). Two seconds after the MA departed the runway, the NLG collapsed and the MA's nose dug into the ground, after which, the MA flipped and rolled (Tab J-2). The MA came to rest in the grass to the right of the runway 16 seconds after touchdown and 3,000 feet from the touchdown point (Tab J-2). The MA was destroyed (Tab P-3). The mishap pilot (MP) incurred a minor back injury during the mishap (Tab J-2). The MP egressed the aircraft and fire recovery personnel recovered him for medical care (Tab J-2, Tab V-1.21). There was no damage to private property (Tab P-3). Estimated government loss is $33,483,954.56 (Tab P-3).

3. BACKGROUND

The MA belonged to the 55 FS, 20 FW, 9th Air Force (9 AF), Air Combat Command (ACC) stationed at Shaw AFB, South Carolina (Tab CC-3 through Tab CC-4, Tab K-7, Tab Q-8).

a. Air Combat Command (ACC)

ACC is the primary force provider of combat airpower to America's warfighting commands. Supporting the global implementation of national security strategy, ACC operates fighter, bomber, reconnaissance, battle-management, and electronic-combat aircraft. It also provides command, control, communications and intelligence systems, and conducts global information operations. ACC numbered air forces provide the air component to U.S. Central, Southern, and Northern Commands. ACC also augments forces in U.S. European, Pacific, and Strategic Command (Tab CC-3).

b. 9th Air Force (9 AF)

The 9th AF organizes, trains, and equips Air Combat Command air component forces based throughout the Southeastern United States. Ninth Air Force comprises eight active-duty wings and two direct reporting units with more than 480 aircraft and 28,000 active-duty and civilian personnel. Ninth Air Force is also responsible for the operational readiness of 14 Air Reserve Component Wings (Tab CC-5).

c. 20th Fighter Wing (20 FW)

The 20 FW provides combat ready airpower and Airman, to meet any challenge, anytime, anywhere. The wing is capable of meeting all operational requirements worldwide, maintains a state of combat readiness and operates as the host unit at Shaw AFB by providing facilities, personnel, and material (Tab CC-8).

d. 55th Fighter Squadron (55 FS)

The 55 FS can trace its roots back to 1917 when it first formed as the 55th Aero Squadron at Kelly Field, Texas. The "Fighting Fifty-fifth" saw combat during World War I, World War II, and Operations DESERT STORM, NORTHERN WATCH, and SOUTHERN WATCH. In its distinguished 96-year history, the 55 FS has flown 12 different types of aircraft (Tab CC-10).

e. 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 is a high performance weapon system used by the United States and allied nations. Since 1979, the F-16 has been a major component of the combat forces flying tens of thousands of sorties in support of various combat operations worldwide (Tab CC-12).

4. SEQUENCE OF EVENTS

a. Mission

The mishap sortie (MS) was scheduled and authorized by the Squadron Operations Supervisor (Tab K-7). The MA was the wingman in a two-ship flight of F-16s, designated Dice 21 flight (Tab V-1.7). The MS was part of a routine two-ship training mission flown on the afternoon of 16 July 2013 (Tab K-3, Tab K-11). The MS was planned and briefed as a surface attack tactics (SAT) mission in the central complex airspace in the Republic of Korea with a planned backup mission of tactical intercepts (TI) and basic fighter maneuvers (BFM) (Tab K-3, Tab K-4, Tab K-7, Tab K-11, Tab V-1.13). Dice 21 flight executed their planned backup mission of TI and BFM (Tab V-1.13). The MP's call sign was Dice 22 (Tab K-11).

b. Planning

Mission planning and briefing for the MS was conducted IAW standard procedures per AFI 11-2F-16, Volume 3, *F-16 Operations Procedures*, AFI 11-2F-16, Volume 3, Shaw AFB Supp, *F-16 Operations Procedures*, and the 20th Fighter Wing Standards (Tab DD-38). The day of the MS, all flight members involved in the MS attended a mass brief conducted by the fully qualified Squadron Operations Supervisor (Tab V-1.7, Tab K-19 through Tab K-35). The mass brief covered forecasted weather conditions, notices to airmen (NOTAMs), aircraft configuration, divert airfields, emergency procedures, and operational risk management (ORM) pertaining to each of the flights (Tab K-19 through Tab K-35). The coordination briefing and flight briefing were uneventful (Tab V-1.5).

c. Preflight

After donning their aircrew flight equipment, the mishap flight (MF) proceeded to the operations desk and received a step briefing from the Squadron Operations Supervisor (Tab V-1.8, Tab DD-38). The MF then proceeded to their assigned aircraft and performed preflight operations (Tab V-1.8). The MP stepped to the spare aircraft due to minor malfunctions with the originally assigned aircraft (Tab V-1.8). Preflight operations of the MA were uneventful (Tab V-1.9). The aircraft configuration was two external wing fuel tanks, two AIM-120 captive air training missiles (CATMs), one AIM-9 CATM, empty weapons pylons, a HARM targeting system (HTS) pod, a Sniper Advanced Targeting Pod, an AN/ALQ-184 electronic counter measures

pod, and a unarmed gun (Tab P-3, Tab P-4). There were no live weapons on the aircraft (Tab K-9).

d. Summary of Accident

Ground operations and aircraft taxi were normal (Tab V-1.8 through Tab V-1.9). There were no indications of any aircraft anomalies or malfunctions during pre-flight, ground operations, and aircraft taxi (Tab V-1.8 through Tab V-1.9). The MA took off at 17:02L (Tab DD-39). There was no evidence of anything abnormal about the takeoff, departure, or airspace entry. Furthermore, the MP testified that the landing gear retraction sequence and system B hydraulics were all normal during the takeoff phase (Tab V-1.6, Tab V1.11). Analysis of the crash survivable flight data record (CSFDR) data confirms the takeoff was normal (Tab J-7).

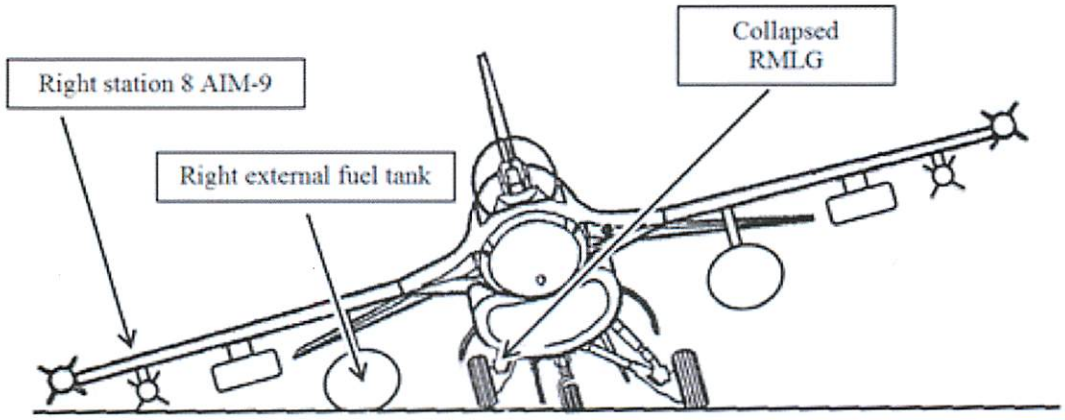
At 17:08L, the MF entered their designated training airspace (Tab J-7, Tab DD-39). The MF performed uneventful 1 versus 1 tactical intercepts and basic fighter maneuvers (3,000 ft setups) (Tab V-1.12). At 17:52L, upon training completion and while leaving the airspace, the MP turned off the aircraft's onboard video recording system (Tab DD-39, Tab V-1.17).

The return to base phase of the mission from airspace exit until landing was normal and the MP reported nothing out of the ordinary (Tab V-1.13). Although the crash survivable flight data recorder (CSFDR) overwrote stored data during this portion of the flight, it would have stored and saved any "special event" data if any anomalies or aircraft malfunctions had occurred (Tab J-16). The CSFDR recorded no "special event" data during this portion of the mission thus corroborating the MP's testimony that airspace exit and return to base were normal and uneventful up until the landing phase of the mission (Tab J-7, Tab V-1.13).

At approximately 18:06L the MP lowered the landing gear handle (Tab J-8, Tab DD-39). The landing gear extended normally and cockpit indications showed all three landing gear in the down and locked position (Tab V-1.14). This was confirmed by an analysis of the CSFDR data (Tab J-8). Furthermore, the Supervisor of Flying, located in the control tower, observed the MA's three extended landing gear (Tab R-3).

At 18:07L, the MA aircraft touched down (Tab J-8). The touchdown parameters were 8.0 feet per second (fps) (8 fps was recorded however the recorded precision is +/- 4 fps therefore actual vertical velocity range is between 4 fps and 12 fps), 12.7 degrees angle of attack (AOA), 1.5 times the force of gravity (g), throttle at idle, 156 knots calibrated airspeed (KCAS), 159 knots ground speed (KGS), and 600 ft down the runway (Tab J-2, Tab J-7). These parameters are all within the range of a normal landing (Tab J-39). Approximately 0.75 seconds later, the MA's right main landing gear collapsed (Tab J-36). Immediately, the MA's takeoff/landing configuration warning light illuminated, the pilot's heads up display flashed "WARN," and the voice message system stated "Warning Warning" (Tab J-8, Tab V-1.14). The MP quickly applied left roll control inputs and briefly kept the right wing off the runway (Tab J-2). Two seconds later, the MA's right external fuel tank contacted the runway (Tab J-2). One second later, at 147 KGS, the MA's station 8 AIM-9 missile contacted the runway (Tab J-2). With the increased drag on the right side of the MA, it skidded to the right side of the runway (Tab V-1.15). The aircraft continued moving forward and skidding right on its nose landing gear, left

main landing gear, and the right external fuel tank until it departed the runway nine seconds after touchdown and approximately 3,200 ft down the runway at 128 KGS (Tab J-2).

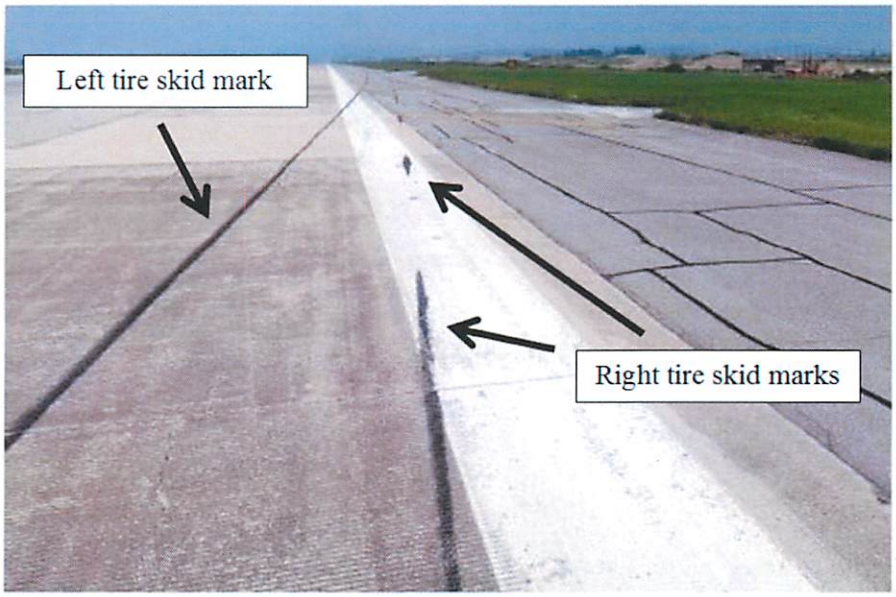


Tab Z-7

The MA's nose gear collapsed two seconds after departing the runway (Tab J-2). Three seconds later, the MA's nose dug into the ground at 70 KGS, followed by a flip and subsequent roll (Tab J-2). The MA came to rest in the grass, right of the runway, 16 seconds after touchdown and 3,600 ft from the end of the runway (Tab J-2). The aircraft was a total loss (Tab P-3). The MP egressed the MA and was driven to a medical facility for examination and treatment of a minor back injury (Tab J-2, Tab V-1.21 through V-1.22).

e. Impact

The MA skidded to a complete stop 3,000 ft from touchdown and 3,600 ft from the approach end of the runway (Tab J-2, Tab S-7). The initial touchdown point could not be confirmed visually due numerous touchdown skid marks on the runway and was therefore estimated using data from the CSFDR (Tab J-10). The first clear mishap-related marks on the runway were caused by the right external fuel tank and the station 8 AIM-9 missile fins scraping on the runway, starting at a point just past the first arrestment cable, approximately 1,400 feet from the approach end of the runway (Tab J-10). Starting approximately 1,700 feet from the approach end of the runway, there were skid marks of various lengths and shapes caused by the RMLG tire (Tab J-10). Because the RMLG collapsed, it was able to move up and down freely as it skipped along the surface of the runway, thus creating a series of short skid marks (Tab J-51). There was a continuous skid mark caused by the left main tire starting approximately 2,000 ft from the approach end of the runway and extending to the point where the MA departed the runway (Tab J-10). There was no damage to private property (Tab P-2).



Tab J-11

f. Egress and Aircrew Flight Equipment (AFE)

The MP did not eject (Tab H-2). After the MA departed the runway and came to a stop, the MP executed emergency ground egress procedures and evacuated the MA after disconnecting all aircrew flight equipment and seat connections (Tab H-2). No parts of the MP's uniform, restraint devices, or aircrew flight equipment created any egress problems (Tab H-2). The MP's aircrew flight equipment was fully functional, had a current inspection, and was in normal condition (DD-36).

g. Search and Rescue (SAR)

Not applicable.

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

The 20th Maintenance Group, 20th Aircraft Maintenance Squadron, 55th Aircraft Maintenance Unit maintained the aircraft forms for the MA. All maintenance was documented on Air Force Technical Order (AFTO) 781 forms and the Integrated Maintenance Data System (IMDS). The purpose of the AFTO 781 series forms is to document various maintenance actions (Tab U-16). They are maintained in a binder specifically assigned to each aircraft (Tab U-16). The IMDS is an automated database of aircraft discrepancies, maintenance repair actions and flying history (Tab U-16).

The MA had 5,489.2 total flight hours at the time of the mishap (Tab D-3). The engine, a General Electric F-110-GE-129, serial number GE0E538223B, had 6,420.0 hours total operating time with 834 Jet Fuel Starter starts (Tab D-2, Tab D-13). A detailed review of AFTO Form 781 series aircraft maintenance forms revealed no discrepancies indicating engine, mechanical, flight control anomalies, structural or electrical failure on the MA (Tab D-5 through Tab D-10). The IMDS historical records 30 days prior to MA's deployment to Osan and 60 days prior to the mishap were used to validate and confirm all form entries (Tab D-34 through Tab D-108). A review of the historical records confirmed Time Compliance Technical Orders (TCTO) compliance did not contribute to the mishap (Tab D-16 through Tab D-19).

The MA flew 23 times in the 60 days prior to the mishap (Tab U-10). Three Code III discrepancies, or discrepancies that render the aircraft non-mission capable, occurred within 60 days of the mishap, but did not involve any systems pertaining to the mishap and are considered irrelevant to this investigation (Tab U-5, Tab U-3).

b. Inspections

Phase inspections are regularly scheduled maintenance performed on Air Force aircraft at specific flying hour intervals (Tab U-16). The F-16CM has a 400-hour phase inspection cycle per T.O. 1F-16CM-6 (Tab U-16). The last phase inspection for the MA began on 2 August 2012 and ended on 14 August 2012 (D-108). The MA had 210.8 hours remaining before its next 400-hr phase inspection (Tab D-2, Tab D-14).

The MA's crew chief conducted a basic post-flight/pre-flight inspection at 14:30L on 15 July 2013, approximately 27.5 hours before the MS, and noted no significant discrepancies (Tab D-3). IAW T.O. 0020-1, this type of inspection is good for 72 hours and was still valid on the day of the mishap (Tab U-16).

The maintenance documentation reflected all scheduled maintenance was satisfactorily accomplished in accordance with applicable maintenance directives and did not contribute to the mishap (Tab D1 through Tab D4).

The landing gear requires a 200-hr main landing gear drag brace assembly wear check per T.O. 1F-16CM-6 (Tab U-16). The MA had 105.5 hours remaining before its next 200-hr inspection (Tab D-14).

c. Maintenance Procedures

A review of AFTO 781 and IMDS records indicated maintenance practices and procedures were in compliance with T.O.s and Air Force Instructions (AFIs) (Tab U-16).

d. Maintenance Personnel and Supervision

A thorough review of individual military training records, to include the Air Force (AF) Form 623, AF Form 797, Staff progress reports and certifications, on all personnel who performed maintenance on the MA indicated maintenance personnel were well trained on all tasks executed on the MA (Tab G-23, Tab U-16, Tab DD-19). Maintenance Supervisors were engaged in daily

maintenance activities and actively involved in the repair and launch of aircraft (Tab D-1 through Tab D-4). Maintenance personal indicated all preflight activities were normal and all personnel involved in the preflight and launch of the MA were experienced and qualified (Tab V-1.70, Tab DD-19).

e. Fuel, Hydraulic, and Oil Inspection Analyses

Laboratory tests determined JP-8 aviation turbine fuel taken post-accident from servicing equipment were within limits and free of contamination (Tab DD-34). In addition, a thorough review of the MA engine's historical AFTO 781 file and associated maintenance forms did not indicate any negative trends with the MA's engine (Tab DD-34 through Tab DD-35). No evidence was found that servicing equipment contributed to the mishap.

f. Unscheduled Maintenance

A review of the MA's performance since it completed its phase inspection on 14 Aug 2012 revealed 117 of 134 sorties flown landed with only minor maintenance issues. (Tab U-5). Unscheduled maintenance jobs open in the AFTO 781s were minor and did not contribute to the mishap (Tab D-5 through Tab D-10).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

MP testimony and data obtained from the aircraft wreckage following structures and systems operated normally, with exceptions noted:

- Flight controls (Tab J-14, Tab V-1.11).
- Avionics/communications: The MP did have trouble with the aircraft's auxiliary radio (Tab J-14, Tab V-1.13). This had no impact on the mishap.
- Hydraulic system (Tab J-14, Tab V-1.10).
- Fuel system (Tab J-14, Tab V-1.14).
- Electrical system (Tab J-13, Tab V-1.10).
- Life support and egress (Tab J).
- Oil system (Tab J-14, Tab V-1.14).
- Engine system (Tabs J-14, Tab V-1.14).

A review of the MA's CSFDR data conducted by the Lockheed Martin Company confirmed all MA systems were operating normally up until touchdown (Tab J-4, Tab J-14). The CSFDR also contains a record of Maintenance Fault Lists (MFLs) that occur during flight. Engineers

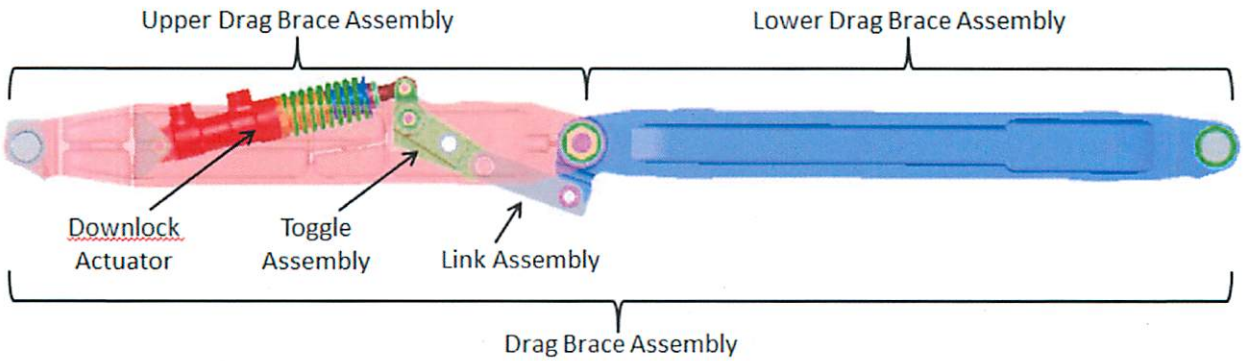
reviewed the MLFs and determined there were no discrepancies listed that would contribute to the mishap (Tab J-31).

b. Relevant Structure: Landing Gear

The landing gear (LG) system is a conventional fuselage-mounted, retractable, tricycle-type system (Tab U-18). The gear arrangement provides ground stability and control during taxi, takeoff, and landing (Tab U-18). Hydraulic system B supplies pressure for normal LG extension and retraction, LG door opening/closing, wheel braking, and nose wheel steering (NWS) (Tab U-18). The main landing gear (MLG) free falls into the extended position once the MLG doors fully open (Tab U-18). All normal LG functions are electrically controlled from the cockpit via the landing gear handle (Tab U-18). Emergency gear extension is mechanically controlled by stored pneumatic pressure (Tab U-18). Oleo-pneumatic shock struts on the nose and main landing gear absorb the landing energy (Tab U-18). Each MLG wheel has a multiple disc brake system (Tab U-18). An arresting hook is provided for emergency arrestment in the event of brake failure (Tab U-18).

The main landing gear drag brace assembly is a major structrual load bearing member of the landing gear (Tab J-39). It holds the landing gear in the extended position during taxi, take-off, and landing (Tab J-39). The drag brace attaches to the fuselage in the main wheel well and to the tension strut assembly at the lower end of the LG (Tab J-39). The drag brace is made up of five major components: the upper drag brace, the lower drag brace, link, toggle, and the downlock actuator (Tab U-18). The upper and lower drag brace are structrual members. When the drag brace is extended, it is locked into position by the link, toggle and downlock actuator (Tab J-39). The downlock actuator is a spring loaded hydraulic actuator that uses spring force to keep the link and toggle in an over center locked position and uses hydraulic pressure to release the lock for landing gear retraction (Tab J-39).

After lowering the gear, the downlock actuator holds the toggle/link assembly in the over center locked position using spring forces only (Tab J-40). Hydraulic pressure is only used to unlock the toggle/link assembly during gear retraction (Tab J-40). CSFDR analysis indicates no hydraulic pressure was supplied to the downlock actuator (resulting in an unlocked toggle/link assembly) (Tab J-40). This in turn indicates that the landing gear handle remained in the down and locked position during the landing phase (Tab J-40).



Tab J-328

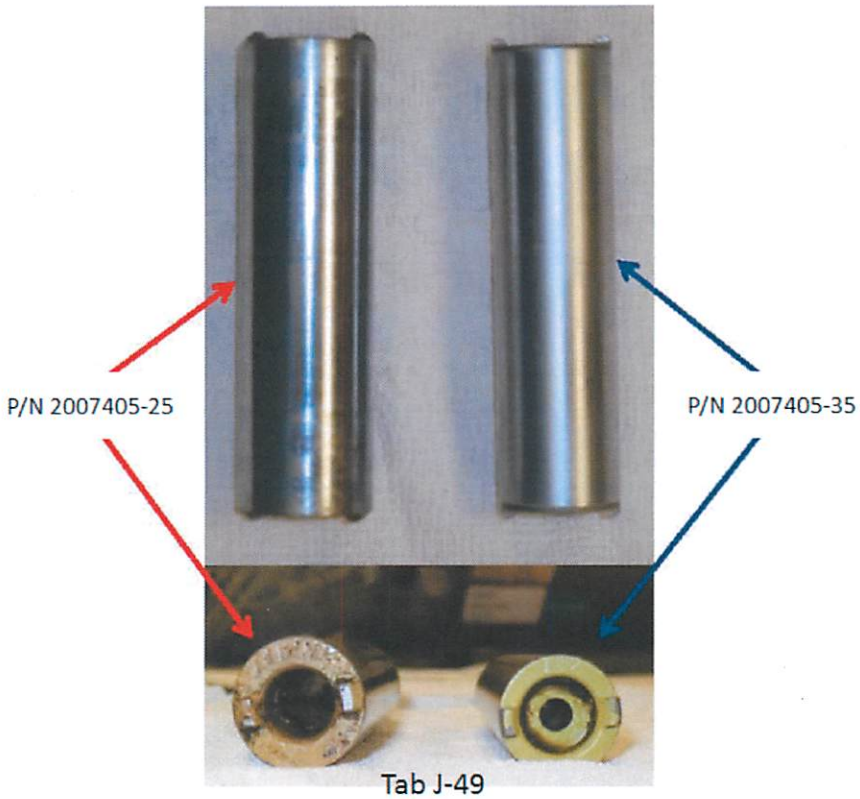
c. Evaluation and Analysis

Following the mishap, data collected from various instruments, to include the CFSDR and the Digital Flight Control Computer, was sent to F-16 Lead Systems Engineers at the depot facility at Hill AFB, Utah (Tab J-36). Analysis of this data revealed the MA touched down at 156 KCAS, 159 KGS, at approximately 26,000 lb. gross weight, 12.7 degrees AOA, approximately 8 ft (+/-4 ft) per second vertical velocity and a side load of approximately 4,600 lbs due to drift (Tab J-36). These parameters are all within the range of a normal landing and should have resulted in an uneventful landing (Tab J-36, Tab J-39).

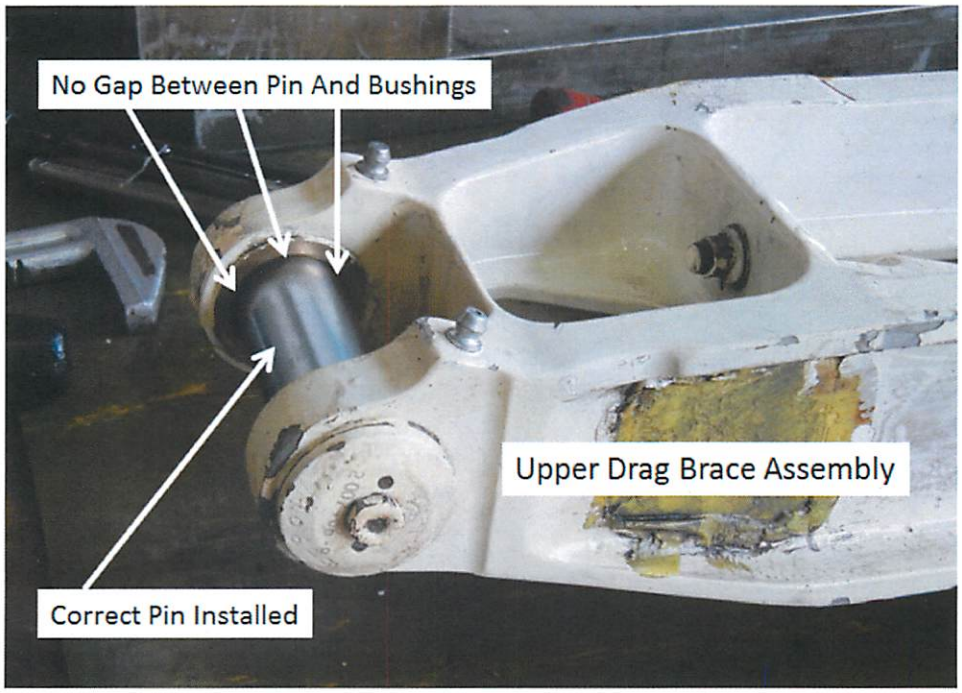
Data analysis also confirmed that as the MA's MLG touched down on the runway, there was a weight on wheels (WOW) indication provided by a sensor in the right main landing gear (Tab J-7). This WOW signal indicates the RMLG was fully extended into the down and locked position. (Tab J-39). The WOW signal disappeared 0.75 seconds later, indicating a collapse of the RMLG (Tab J-2).

The disassembled RMLG and the various components were also sent to the F-16 Lead Systems Engineers at the depot facility at Hill AFB, Utah for further analysis (Tab J-36). Examination of the MA's RMLG drag brace assembly revealed that an incorrect pivot pin connecting the upper drag brace assembly to the main drag brace assembly was installed (Tab J-38 through J39). The incorrect pivot pin (P/N 2007405-35) belongs in the nose gear drag brace assembly (Tab J-39). The incorrect installation took place during a MLG change that occurred between 30 May 12 and 2 Jun 12 (Tab D-110). The correct pin is P/N 2007405-25 (Tab J-39). The two pins are almost identical in length, weight, and external features (Tab J-38 through J-39). However, the incorrect pin's diameter is 0.1 inch less than the correct pin's diameter (Tab J-38 through J-39). The AIB assembled an upper drag brace assembly using the smaller pin (Tab U-18). It was immediately apparent that the incorrect pin could be easily installed (Tab U-18). Furthermore, it was obvious an incorrect pin would be difficult to detect if the main drag brace assembly were already attached to the aircraft and would be almost impossible to detect if the caps and cap retaining bolt were installed (Tab U-18).

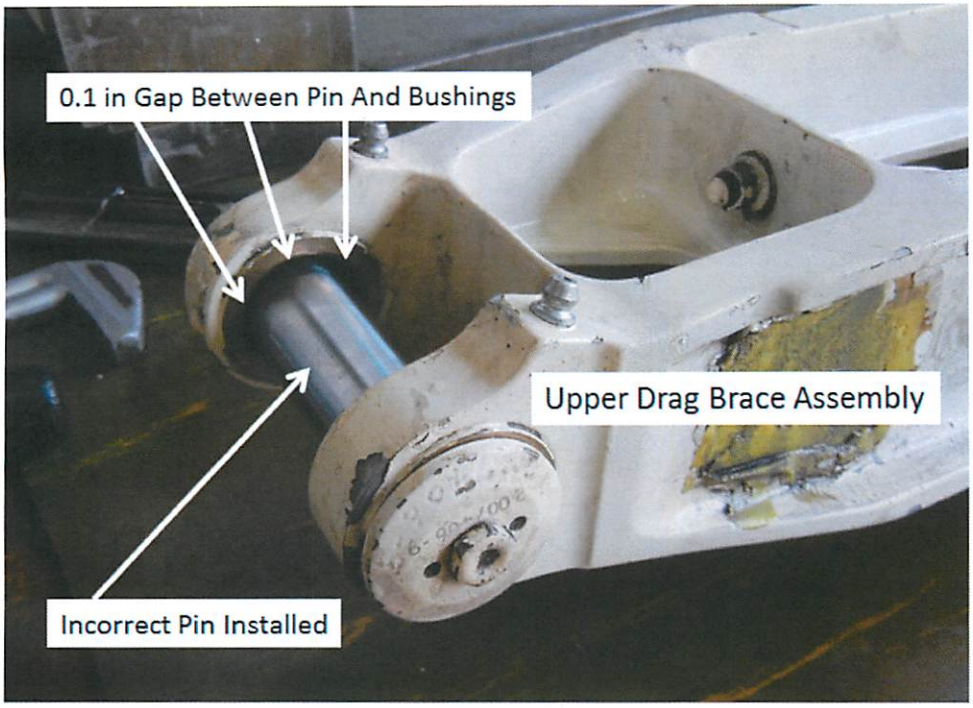
The inner bushing faces on the upper drag brace attach lugs had abnormal wear indications showing that there was significant play available to the attach lugs (Tab J-41). The upper drag brace attach lug bushings and drag pin attach lug also showed wear markings consistent with the installation of a smaller pin installed into the bushings (Tab J-38 through Tab J-39).



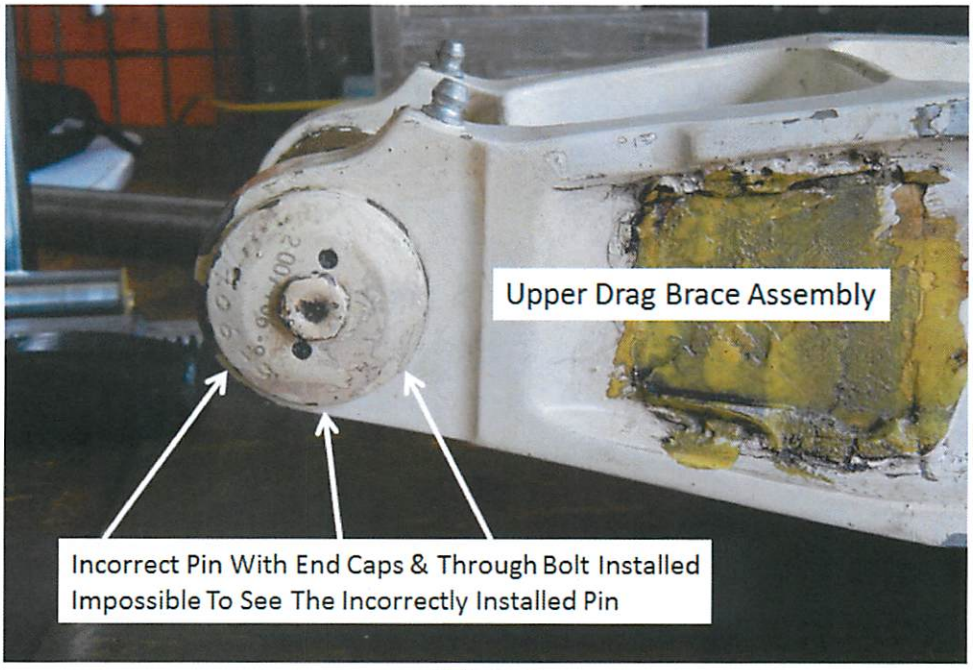
Tab J-49



Tab Z-4



Tab Z-5



Tab Z-6

At touchdown, the F-16 experiences a phenomenon known as "wheel spin up and spring back." When the wheels first contact the runway, there is a discrete amount of time required for the wheel to spin up and match the speed of the runway passing underneath (Tab J-40). This pulls the landing gear aft and then it springs forward (Tab J-40).

Flight and laboratory testing shows this phenomenon may cause the toggle/link assemblies to move towards an unlocked condition during a normal landing (Tab J-40). Other vibration factors associated with landing influence this event and may cause the link and toggle to break over center and become unlocked (Tab J-40). The spring back effect applies a simultaneous compressive load to the drag brace and allows it to collapse once the downlock has become unlocked (Tab J-40). There are seven prior (eight total including this mishap) F-16 mishaps attributed to this phenomenon (Tab J-40, Tab DD-38). Although four of the seven mishap aircraft had worn bushings in the landing gear drag brace assembly, the data still shows an unlock condition is possible when all bushings and other parameters are well within design limits (Tab J-40).

Laboratory testing shows the natural resonant frequency of a drag brace assembly to be 30 Hz (Tab J-303). However, testing further shows the frequency lowers to 20 Hz if oversized bushings are used (Tab J-303). Using a smaller pivot pin has the same effect as using oversized bushings (Tab J-40 through Tab J-41). Therefore, the MA's drag brace assembly naturally resonated at 20Hz (Tab J-303). The lower resonant 20Hz frequency increases the probability of unlocking the drag brace assembly (Tab J-41).

7. WEATHER

a. Forecast Weather

The forecast weather for Osan Air Base at takeoff and land time for the MS was scattered clouds at 3,000 ft and broken clouds at 5,000 ft with visibility at five statute miles and mist (Tab F-3). There were showers in the vicinity and southwest winds at 15 knots gusting to 25 knots (Tab F-3). The forecast weather for the Central Complex airspace (Military Operating Area or MOA 2 and MOA 15) was a scattered to broken layer from 3,000 ft to 5,000 ft with four to six statute miles of visibility and haze (Tab F-4).

b. Observed Weather

The observed weather during the MS was southwest winds at 11 knots gusting to 16 knots (Tab F-12). Clouds were broken at 5,000 ft, visibility was unrestricted, and the runway was dry (Tab F-12). This weather observation was taken at 17:55L (Tab F-12).

c. Space Environment

Not applicable.

d. Operations

The forecast and observed weather conditions were within limits IAW AFI 11-214 and AFI 11-202 Volume 3. There is no evidence to suggest the weather was a factor in this mishap.

8. CREW QUALIFICATIONS

a. Mishap Pilot

The MP was a current and qualified F-16 wingman; however, the MP was non-combat mission ready (CMR) for not flying the minimum required number of rated aircrew program (RAP) sorties (Tab G-4, Tab V-1.22 through 1.23). The MP took leave prior to deploying, therefore he did not meet the minimum number of sorties (Tab V-1.23). The MP pilot had a total of 465.7 flight hours and 282.4 flight hours in the F-16 (Tab G-3, Tab G-5). There is no evidence to suggest that crew qualifications were a factor in this mishap.

Mishap Pilot's Supplemental 30/60/90 Day Sortie History (Tab G-4)

Days	Flights	Hours
30 days	5	6.7
60 days	6	8.1
90 days	15	22.9

9. MEDICAL

a. Qualifications

(1) Mishap Pilot (MP)

The MP was medically qualified for flight and worldwide duty per review of his medical record. His most recent annual flight physical and Periodic Health Assessment (PHA) were both performed on 15 Oct 2012 (Tab DD-18). He did not possess a need for a waiver for any medical condition and displayed no physical, medical or mental limitations prior to the mishap (Tab V-1.26, Tab DD-18).

(2) Maintenance Member One (MM1)

MM1 performed and signed off the install of the right main gear assembly at Shaw AFB in May 2012 (Tab D-116). At the time of the install, he was medically qualified as well as worldwide qualified and did not possess a need for a profile (Tab V-2.32, Tab DD-18). His most recent PHA did not indicate any acute or chronic medical problems relevant to the mishap (Tab DD-18).

(3) Maintenance Member Two (MM2)

MM2 was the quality assurance inspector for the MA landing gear change (Tab V-3.6). The MM2 was medically qualified as well as worldwide qualified at the time of service on the MA (Tab DD-18). He did not possess a need for a profile and did not have any acute or chronic medical problems relevant to the mishap (Tab DD-18).

(4) Maintenance Member Three (MM3)

MM3 was present during the preflight on the day of the MS (Tab V-4.9). MM3 was medically qualified and had no medical issues that would be disqualifying for military service. MM3 had no mobility, duty, or fitness restrictions (Tab DD-18).

(5) Ground Maintenance Crewmembers

The AF ground maintenance crewmembers were medically qualified for duty at the time of the mishap (Tab DD-4 through Tab DD-18). Physical and medical qualifications were reviewed and were not factors in the mishap (Tab DD-18).

b. Health

The AIB's medical member reviewed the medical records of the MP and the ground maintenance crew members, as well as their 72 hour and14 day histories (Tab R-28, Tab DD-18). Records revealed all individuals were in good health and had no recent performance limiting illnesses prior to the mishap (Tab R-28, Tab DD-18). There was no evidence that any medical condition contributed to this mishap (Tab R-28).

After interviewing the MP and the relevant maintenance crewmembers and thoroughly reviewing all medical records of the MP and the maintenance crewmembers, there was no evidence that any medical conditions existed prior or contributed to the mishap (Tab DD-18). The AIB's medical member reviewed the MP's post-accident medical examination records (Tab DD-18). An emergency room physician and a qualified flight surgeon conducted post-accident physical exams on the MP and noted minor injuries (Tab V-1.21).

c. Pathology

The injuries sustained by the MP were consistent with the nature of the mishap (Tab V-1.21). The MP was able to walk away from the mishap but did require hospitalization and was later released (Tab V-1.21).

d. Toxicology

Toxicology testing was performed on the MP and 14 ground support personnel (Tab DD-3 through Tab DD-17). Blood and urine samples were submitted to the Department of Defense Armed Forces Medical Examiner System for analysis (Tab DD-3 through Tab DD-17). The testing included blood ethanol levels and urine amphetamine, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates and phencyclidine by immunoassay or chromatography (Tab DD-3 through Tab DD-17). The samples were collected post-mishap (Tab DD-3 through DD-17). All results were negative with the exception of the pilot who tested positive for opiates (Tab DD-3). The opiates were administered after the mishap for the treatment of his injuries.(Tab V-1.21, Tab DD-3, Tab DD-18).

e. Lifestyle

No lifestyle factors were found to be relevant to this mishap (Tab R-28).

f. Crew Rest and Crew Duty Time

All Air Force pilots are required to have "crew rest" IAW AFI 11-202 Volume 3, prior to performing in-flight duties (AFI 11-202V3, Chapter 9). AFI 11-202V3 states, in part, "Air Force aircrews require at least 10 hours of continuous restful activities including an opportunity for at least 8 hours of uninterrupted sleep during the 12 hours immediately prior to the Flight Duty Period (FDP)" (AFI 11-202V3, para. 9.8). It also states:

> The crew rest period is normally a minimum 12-hour non-duty period before the FDP begins. Its purpose is to ensure the aircrew member is adequately rested before performing flight or flight related duties. Crew rest is free time, which includes time for meals, transportation, and rest. Rest is defined as a condition that allows an individual the opportunity to sleep (AFI 11-202V3, para. 9.4.5).

A review of the duty cycles of the MP leading up to the mishap indicated that there was adequate crew rest (Tab K-36). The MP stated he was well rested and had no complaints or illnesses (Tab V-1.26). The MP complied with the crew rest and duty day requirements on the day of the mishap (Tab K-36). Fatigue was not indicated and is not a factor in this mishap (Tab V-1.26). The MP did not suffer from stress, pressure, fatigue or lack of rest prior to or during the MS (Tab K-36). There is no evidence to suggest that inadequate crew rest was a factor in this mishap.

10. OPERATIONS AND SUPERVISION

b. Operations

The 55th Fighter Squadron at the time of the mishap was deployed to Osan Air Base, Republic of Korea (Tab Q-7, Tab V-1.23). The squadron arrived at Osan Air Base in April 2013 (Tab V-1.23). There is no evidence to suggest that the operations tempo was anything but normal (Tab DD-38).

b. Supervision

The flight was properly supervised, scheduled, authorized, and released in accordance with AFI 11-401, para. 1.8 (Tab DD-38). The squadron Operations Supervisor conducted the mass briefing and was readily available at the operations desk during the MS (Tab DD-38). The MP's inflight publications were inspected by the AIB and were found current and up to date (Tab DD-36).

11. HUMAN FACTORS

The board evaluated human factors relevant to the mishap using the Department of Defense (DoD) Human Factors Analysis and Classification System (DoD-HFACS) guide. And are referenced in AFI 91-204, *USAF Safety Investigations and Reports*, (24 Sept 2008), Attachment 5. DoD-HFACS is a tool to understand how features of people's tools, tasks, and working

environment systemically influence human performance to provide a systemic, multidimensional approach to error analysis (AFI 91-204, Attachment 5, A5.1).

The DoD-HFACS classification taxonomy describes four main tiers of human factors that may contribute to a mishap (AFI 91-204, Attachment 5, Figure A5.3). These four divisions include Acts, Pre-Conditions, Supervision, and Organizational Influences (AFI 91-204, Attachment 5, Figure A5.3). Each category is further subdivided into related human factor subcategories (AFI 91-204, Attachment 5, Figure A5.3). 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 (AFI 91-204, Attachment 5, A5.4). The framework allows for evaluation of the unsafe acts that are directly related to the mishap through the indirect preconditions, supervision, or organizational influences that may have led to the mishap (AFI 91-204, Attachment 5, A5.4). Acts are those factors that are most closely tied to the mishap, and can be described as active failures or actions committed by the operator that result in human error or unsafe situations (AFI 91-204, Attachment 5, page 116). Preconditions are factors in a mishap if active and/or latent preconditions such as conditions of the operators, environmental or personnel factors affect practices, conditions or actions of individuals and result in human error or an unsafe situation (AFI 91-204, Attachment 5, page 119). Supervision is a factor in a mishap if the methods, decisions or policies of the supervisory chain of command directly affect practices, conditions, or actions of individual and result in human error or an unsafe situation (AFI 91-204, Attachment 5, page 133). Organizational Influences are factors in a mishap if the communications, actions, omissions or policies of upper-level management directly or indirectly affect supervisory practices, condition or actions of the operator(s) and result in system failure, human error or an unsafe situation (AFI 91-204, Attachment 5, page 136).

The Board reviewed a substantial amount of evidence during its proceedings to include, but not limited to, video recordings, witness interviews, mishap wreckage and maintenance logs (Tab DD-38). The following human factors were found to be relevant to the mishap:

Errors: *Errors are factors in a mishap when mental or physical activities of the operator fail to achieve their intended outcome as a result of skill-based, perceptual, or judgment and decision making errors, leading to an unsafe situation. Errors are unintended.* We classified Errors into three types: *Skill-Based*, *Judgment and Decision Making*, and *Misperception Errors* (AFI 91-204, Attachment 5, page 116).

Skill-based Errors: *Skill based errors are factors in a mishap when errors occur in the operator's execution of a routine, highly practiced task relating to procedure, training or proficiency and result in an unsafe a situation. Skill-based Errors are unintended behaviors.* (AFI 91-204, Attachment 5, page 116).

During MA landing gear maintenance, T.O. guidance was not followed during the installation of the right main landing gear assembly with the installation of the wrong drag brace pivot pin (T.O. 1F-16C-2-32JG-10-1,Tab J-41). This was a result of a skill-based error.

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* (AFI 91-204, Attachment 5, OP003).

Technical Order guidance for the installation of the right main landing gear assembly is ambiguous in that it does not include the part number for the linkage attachment pivot pin (T.O. 1F-16C-2-32JG-10-1). This may have contributed to a smaller pin being used during installation of the right main landing gear upper drag brace assembly (Tab J-39).

Channelized Attention: *Channelized Attention is a factor when the individual is focusing all conscious attention on a limited number of environmental cues to the exclusion of others of a subjectively equal or higher or more immediate priority, leading to an unsafe situation. May be described as a tight focus of attention that leads to the exclusion of comprehensive situational information* (AFI 91-204, Attachment 5, PC102).

The MP failed to eject in a situation that mandates ejection IAW T.O. 1F-16CM-1. This guidance states that crewmembers should eject if it appears that the aircraft will depart a prepared surface above normal taxi speed if go around is not possible. The MP's decision to not eject was not causal.

There is no evidence that pilot or maintenance members were fatigued.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010
(2) AFI 48-123, *Medical Examinations and Standards*, 29 January 2013
(3) AFI 11-2F-16 Volume 1, *F-16 Pilot Training*, 11 August 2011
(4) AFI 11-2F-16 Volume 2, *F-16 Aircrew Evaluation Criteria*, 27 August 2010
(5) AFI 11-2F-16 Volume 3, *F-16 Operations Procedures*, 18 February 2010
(6) AFI 11-2F-16 Volume 3, Shaw AFB Supplement, *F-16 Operations Procedures*, 10 October 2012
(7) AFI 11-202 Volume 1, *Aircrew Training*, 22 November 2010
(8) AFI 11-202 Volume 2, *Aircrew Standards/Evaluations Program*, 18 October 2012
(9) AFI 11-202 Volume 2, Pacific Air Forces (PACAF) Supplement, *Aircrew Standards/Evaluations Program*, 11 August 2011
(10) AFI 11-202 Volume 3, *General Flight Rules*, 22 October 2012
(11) AFI 11-214, *Air Operations Rules and Procedures*, 14 August 2012
(12) AFI 91-204, AFGM1, *Safety Investigations and Reports*, Attachment 5, 8 April 2013

NOTICE: All directives and publications listed above are available digitally on the Air Force Departmental Publishing Office website at: http://www.e-publishing.af.mil.

b. Other Directives and Publications Relevant to the Mishap

(1) AFTTP 3-3 v F-16, *Combat Aircraft Fundamentals – F-16*, 29 June 2012
(2) T.O. 1F-16CM-1, *Flight Manual F-16C/D CCIP Aircraft*, 1 August 2012
(3) T.O. 1F-16CM-1-2, *Supplemental Flight Manual*, 1 May 2013
(4) T.O. 1F-16CJ-2-32GS-00-1, *Landing Gear System*, 1 December 2012
(5) T.O. 1F-16CJ-06, *Work Unit Code Manual*, 1 August 2013
(6) T.O. 1F-16CJ-6WC-2, *Phased Inspection Workcards*, 1 October 2012
(7) T.O. 4SA6-39-4, *Main Landing Gear Drag Brace Assembly*, 10 September 2008
(8) T.O. 4AA1-9-2, *Maintenance Instructions Downlock Hydraulic Actuator*, 1 August 2003 (Change 6)
(9) T.O. 1F-16CJ-6-11-WA-1, *Scheduled Inspection and Maintenance Requirements*, 1 October 2012
(10) T.O. 1F-16CG-2-32JG-10-1, *Main Landing Gears and Doors*, 1 September 2011

NOTICE: All directives and publications listed above are not publically releasable under the *Arms Export Control Act* and the *Export Administration Act of 1979*. Please see AFI 61-204, *Disseminating Scientific and Technical Information* for further guidance.

c. Known or Suspected Deviations from Directives or Publications

T.O. 1F-16CM-1 specifically directs crewmembers to eject if the aircraft will depart a prepared surface (runway, taxiway, parking ramp, etc) (Tab DD-37). The MP did not eject (Tab V-1.18). This was not causal to the mishap.

13. ADDITIONAL AREAS OF CONCERN

T.O. Ambiguity. The main landing gear drag brace installation task in the T.O. is ambiguous because it does not specify which pin to insert but only states, "install pin" (Tab U-18). In an area as critical as landing gear maintenance, parts should be specifically referenced by part number. Example: "Install pin P/N XXXX" as opposed to a task that simply reads, "install pin."

Parts Identification. There are no identification markings on the landing gear pins examined during this mishap investigation (Tab U-17). Parts identified with their specific part number would give maintenance members the opportunity to confirm they have the correct part prior to installation.

AFTO 22 Process. Testimony from MM4 and other aspects of this AIB investigation revealed that that the AFTO 22 process (a process in which important changes are coordinated and eventually published in newer versions of the T.O.) is not widely known among less experienced maintenance personnel(Tab V-5.9). Furthermore, the AFTO 22 process is not a formal part of maintenance technical training (Tab V-5.13).It is possible that T.O. part number ambiguities were previously recognized; however an unclear AFTO 22 process may have prevented new changes that would have prevented part number ambiguities.

Landing Gear Ship Sets. The ship set is a spare landing gear set that is partially assembled, inspected, and ready for installation on the aircraft (Tab V-2.13). The ship set is used during the

six year landing gear inspection requirement (Tab V-2.13 through Tab V-2.26). It is treated as a forward supply point maintained by the individual maintenance units (Tab V-2.13 through Tab V-2.26). The AIB's investigation identified that there is no standardized guidance on how to control, manage, or label these ship sets. A poorly organized ship set increases the probability of parts being inadvertently swapped or incorrectly installed during landing gear maintenance. Photographic evidence indicated that bins used to hold ship set pins were not labeled and that these bins contain LG pins of differing types and sizes (Tab Z-3).

Although these additional areas of concern may have had an effect on events leading up to this mishap, there was insufficient evidence to indicate they caused (clear and convincing) or significantly contributed to (preponderance of the evidence) this mishap.

13 Sep 2013

WILLIAM R. JONES, Lt Col, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

F-16CM T/N 92-3907
Osan Air Base, Republic of Korea
16 July 2013

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 cause of the mishap was the collapse of the right main landing gear (RMLG) by the unlocking of the toggle and link assembly in the right main landing gear drag brace assembly. I also find by a preponderance of the evidence that each of the following factors substantially contributed to the mishap: (1) an incorrect pivot pin was installed connecting the upper drag brace assembly to the main drag brace assembly and (2) natural resonant vibrations of the drag brace assembly, when combined with the vibrations created by wheel spin up and spring back phenomena, unlocked the toggle and link drag brace assembly allowing the collapse of the RMLG as the weight of the aircraft settled onto it.

I determined the mishap aircraft's (MA) RMLG collapsed immediately after touchdown. Evidence from the scene of the mishap, including skid marks and gouges on the runway caused by the right external fuel tank and station 8 air intercept missile (AIM) -9, and data extracted from the crash survivable flight data recorder (CSFDR), indicate the right main landing gear (RMLG) collapsed while the left main landing gear (LMLG) and nose landing gear (NLG) remained in the down and locked position. This condition caused the MA to veer uncontrollably to the right. It departed the runway, flipped and rolled, and was subsequently destroyed.

Following recovery of the MA, CSFDR data was downloaded and the RMLG was dismantled and sent to engineers for further analysis. CSFDR data and multiple witness testimonies confirmed that all landing conditions were with normal design criteria and should have resulted in an uneventful landing. Furthermore, CSFDR data and post mishap cockpit inspections confirmed that the landing gear handle was in the down position, all three landing gear were in the down and locked position, and hydraulic pressures were within the normal operating ranges. Analysis of the RMLG provided no evidence to suggest that any component on the landing gear assembly was flawed or had failed during the landing. However, analysis revealed that an incorrect pin was installed in the bushings between the upper drag brace assembly and the drag brace pin assembly (a rotating bracket attached to the aircraft's bulkhead).

While the probability is extremely low, test data reveals it is possible for the RMLG drag brace assembly to collapse during a normal landing whose parameters are well within design criteria. This can occur without any warning, any cockpit indications, or any maintenance indications.

I developed my opinion using historical data, testing analysis, analysis of the mishap site, engineering analysis, witness testimony, and data from technical experts. In addition, the board analyzed an animation provided by the Mishap Analysis and Animation Facility as well as a mishap video captured by a security video camera. Lastly, three F-16 flight simulations were flown replicating the mishap sequence.

2. DISCUSSION OF OPINION

Examination of the MA's RMLG drag brace assembly revealed that an incorrect pivot pin was installed connecting the upper drag brace assembly to the main drag brace assembly. The incorrect pivot pin, part number (P/N) 2007405-35, belongs in the nose gear drag brace assembly. The incorrect installation took place during a MLG change occurring between 30 May 12 and 2 Jun 12. The correct pin is P/N 2007405-25. The different pins are almost identical in length, weight, and external features. However, the incorrect pin's diameter is 0.1 inch less than the correct pin's diameter.

The drag brace assembly, whether on a test stand, on the aircraft, or on a supply shelf, oscillates (vibrates) at its own natural resonant frequency. Testing shows the natural resonant frequency of a drag brace assembly to be 30 Hz. However, testing further shows the frequency lowers to 20 Hz if oversized bushings are used. Using a smaller pivot pin has the same effect as using oversized bushings. Therefore, the MA's drag brace assembly resonated at 20Hz. This lower frequency makes it easier to add additional vibrations from other sources. The source of the additive vibrations were those caused by the "wheel spin up and spring back" phenomenon. Normally, the aircraft frame would absorb some of this energy. However, because of the loose connection between the upper drag brace assembly and the aircraft frame (due to the smaller pivot pin) there was less oscillatory energy absorbed by the aircraft frame. Although there is no evidence showing the installation of the incorrect link pin was the cause of the unlocked condition, testing does show that an incorrect installation, as that found on the MA, increases the probability that an unlocked condition can occur.

Lower resonant oscillations coupled with vibrations from normal wheel spin up and spring back resulted in oscillations great enough to create an unlocked condition in the RMLG's drag brace assembly. That is why I find by clear and convincing evidence that the cause of the mishap was the collapse of the RMLG by the unlocking of the toggle and link assembly in the right main landing gear drag brace assembly. I also find by the preponderance of the evidence the following were substantially contributing factors: (a) an incorrect pivot pin was installed connecting the upper drag brace assembly to the main drag brace assembly; (b) natural resonant vibrations of the drag brace assembly combined with the vibrations created by wheel spin up and spring back phenomena.

13 Sep 2013

WILLIAM R. JONES, Lt Col, USAF
President, Accident Investigation Board

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