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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR COMBAT COMMAND
LANGLEY AIR FORCE BASE, VIRGINIA

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OFFICE OF THE SECRETARY
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OFFICE OF THE COMMANDER
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6 FEB 2002

MEMORANDUM FOR ACC/JA

SUBJECT: AFI 51-503, Accident Investigation Board Report, F-16CG, S/N 88-0533, 4th Fighter Squadron, 388th Fighter Wing, Hill AFB, Utah, 17 October 2001

I have reviewed the Accident Investigation Board Report regarding the F-16CG that aborted during take-off at Hill AFB, UT on 17 October 2001. The report, prepared by Lieutenant Colonel Walker H. Bowman, complies with the requirements of AFI 51-503. This report is approved.

HAL M. HORNBURG
General, USAF
Commander

Attachment:
Accident Investigation Board Report

NUCLEAR REGULATORY COMMISSION

Docket No. _____ Official Exh. No. 9.8
In the matter of _____

Staff _____ IDENTIFIED _____
Applicant ✓ RECEIVED ✓
Intervenor _____ REJECTED _____
Other _____ WITHDRAWN _____
DATE 5-14-02 Witness _____
Clerk _____

Global Power For America

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SECY-02

EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION

F-16CG, S/N 88-0533

HILL AIR FORCE BASE, UTAH

17 OCTOBER 2001

On 17 October 2001, at 2116 Mountain Time, 0416 Universal Coordinated Time, an F-16CG, serial number 88-0533, departed the right side of Runway 32 after an aborted takeoff. The mishap aircraft (MA), assigned to the 388th Fighter Wing, 4th Fighter Squadron, at Hill Air Force Base, Utah, was part of a night, two aircraft ("two-ship") flight lead upgrade mission. There were no civilian injuries and only minor injuries sustained by the mishap pilot (MP). The F-16 sustained over $10,000,000 in damage.

During the takeoff roll the nose tire of the MA failed catastrophically. Analysis of the tire remains concluded the most likely cause was striking an object on the runway at high speed. As the nose tire disintegrated, it severed several critical wires on the nose gear assembly and damaged another vital component, rendering the nosewheel steering inoperative. This significantly reduced the MP's ability to steer the F-16. The MP noted an explosion, a column of flame on the left side of the canopy, and some deceleration and elected to abort the takeoff. He correctly applied abort procedures in an effort to stop the MA.

Approximately eleven seconds after initiating the abort the MA veered to the right but the MP was unable to maintain directional control. When it became evident the aircraft would depart the runway the MP successfully ejected. The MA continued off the prepared surface, across an unused taxiway, and came to a full stop after catching the right wingtip in the soft ground.

The primary cause of the mishap, supported by clear and convincing evidence, was a phenomenon known as reverse castering. After the tire failed the nosewheel ground down to a smaller radius. The new geometry forced the point of contact between the wheel and the runway to move forward of the nose landing gear strut axis, causing the nose wheel to caster in the direction opposite the direction the MP was attempting to move the aircraft. In this case the pilot was applying controls to return the MA to the left, which forced the nosewheel further to the right. As the aircraft slowed and the rudder became less effective, the MP lost sufficient authority from differential braking to counteract the effect of reverse castering.

The MP made every reasonable effort to maintain control of his aircraft, but the combination of the loss of nosewheel steering and the forces generated by the reverse castering exceeded his ability to keep the MA on the runway. The F-16 is inherently unstable on an unprepared surface at high speed; therefore the MP's decision to eject was prudent and proper.

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

SUMMARY OF FACTS AND STATEMENT OF OPINION

F-16CG ACCIDENT

17 OCTOBER 2001

TABLE OF CONTENTS

COMMONLY USED ACRONYMS & ABBREVIATION

AB	Afterburner
ACC	Air Combat Command
ACES II	Advanced Concept Ejection Seat
AFB	Air Force Base
AFI	Air Force Instruction
AFIP	Air Force Institute of Pathology
AGL	Above Ground Level
AIB	Accident Investigation Board
AMD	Acceleration Measuring Device
AOA	Angle of Attack
BAO	Boeing Aerospace Organization
CAMS	Core Automated Maintenance System
CAP	Critical Action Procedures
CSMU	Crash Survivable Memory Unit
DELTA-P'S	Differential Pressure
DSN	Defense Service Network
ECM	Electronic Countermeasures
ECP	Entry Control Point
EOR	End of Runway
EP	Emergency Procedure
EPE	Emergency Procedures Evaluation
EPU	Emergency Power Unit
ER	Exceptional Release
FEF	Flight Evaluation Folder
FLIR	Forward Looking Infrared
FLUG	Flight Lead Upgrade
FOD	Foreign Object Damage
FW	Fighter Wing
HUD	Head Up Display
INS	Instrument Navigation System
JFS	Jet Fuel Starter
L	Local Time
LANTIRN	Low Altitude Navigation and Targeting Infrared for Night
MA	Mishap Aircraft
MAU	Miscellaneous Armament Unit
MF	Mishap Flight
MOA	Military Operations Area
MP	Mishap Pilot
MQT	Mission Qualification Training
MRL	Missile Launch Rail
MSL	Mean Sea Level
MW	Mishap Wingman
NLG	Nose Landing Gear
NOTAM	Notice to Airmen
NVG	Night Vision Goggles
NWS	Nosewheel Steering
OPS	Operation Group
PQDR	Product Deficiency Quality Report
RTB	Return to Base
S/N	Serial Number
SA	Situational Awareness
SAT	Surface Attacks Tactics
SAU	Signal Acquisition Unit
SEFE	Standardization/Evaluation Flight Examiner
SEPT	Selected Emergency Procedure Flight
SIB	Safety Investigation Board
SOF	Supervisor of Flying
TCTO	Time Critical Technical Order
TOT	Time on Target
USAF	United States Air Force
WOW	Weight on Wheels
Z	Zulu or Greenwich Meridian Time (GMT)

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

SUMMARY OF FACTS

1. AUTHORITY, PURPOSE, AND CIRCUMSTANCES

a. Authority:

On 6 November 2001, Lieutenant General Donald G. Cook, Commander of Air Combat Command (ACC), appointed Lieutenant Colonel Walker H. Bowman to conduct an aircraft accident investigation of the 17 October 2001 crash of an F-16CG aircraft, serial number 88-0533, on Hill Air Force Base, Utah, in accordance with Air Force Instruction (AFI) 51-503, *Aircraft, Missile, Nuclear, and Space Accident Investigations*. The investigation was conducted at Hill Air Force Base (AFB), Utah, from 21 November 2001 through 14 December 2001. Technical advisors were Major LeRoy C. White (Medical), Captain Darren M. Willis (Pilot), Captain David R. Short (Maintenance), and Captain Mark J. Nackman (Legal), as ordered by Special Order M-02.4, dated 6 November 2001 (Tab Y-3). Technical Sergeant Mischelle Meleg acted as transcriptionist and provided administrative support.

b. Purpose:

This aircraft accident investigation was convened under AFI 51-503. The primary purpose is to gather and preserve evidence for claims, litigation, disciplinary, and administrative actions. In addition to setting forth factual information concerning the accident, the board president is also required to state his opinion as to the cause of the accident or the existence of factors, if any, that substantially contributed to the accident. This investigation is separate and apart from the safety investigation, which is conducted pursuant to AFI 91-204, *Safety Investigations and Reports*, for the purpose of mishap prevention. This report is available for public dissemination under the Freedom of Information Act (5 United States Code (U.S.C.) §552) and the Air Force Supplement to Department of Defense Regulation 5400.7, *Department of Defense Freedom of Information Act Program.*

c. Circumstances.

The accident board was convened to investigate the 17 October 2001 Class A mishap involving an F-16CG aircraft, S/N 88-0533, assigned to the 4th Fighter Squadron, 388th Fighter Wing, Hill AFB, Utah.

2. ACCIDENT SUMMARY

The mishap aircraft (MA), F-16CG, S/N 88-0533, departed the right side of the runway following an aborted takeoff for a night Flight Lead Upgrade (FLUG) sortie on 17 October 2001. (Tabs B-3 through B-5). The mishap pilot (MP), Captain (Capt) Casey J. Tidgewell ejected safely. The MP received minor bruises, contusions, and a fracture of his left little finger. The MA suffered over $10,000,000 in damage. There was minimal damage to other government

property; one runway light was damaged. There was no damage to civilian property and there were no civilian casualties or injuries. Media interest was minimal (Tab CC-41).

3. BACKGROUND

The 388th Fighter Wing, stationed at Hill AFB, Utah, maintains three F-16CG squadrons and six supporting units capable of day, night, and all-weather combat operations worldwide through the use of precision guided weapons with the Low Altitude Navigation and Targeting InfraRed for Night (LANTIRN) pods. The 4th Fighter Squadron is a component of the 388th Fighter Group, within the 388th Fighter Wing. The wing and its subordinate units are all components of ACC (Tab CC-45).

4. SEQUENCE OF EVENTS

a. Mission:

The mishap flight (MF) consisted of a formation of two F-16 aircraft (commonly referred to as a "two ship") flown by pilots and aircraft assigned to the 4th Fighter Squadron. The two-ship flight lead was Capt Tidgewell, the MP, whose radio call sign for the mission was "JEDI 1". The mishap wingman (MW) was Lieutenant Colonel (Lt Col) Robert Craig, whose radio call sign for the mission was "JEDI 2". The MW also acted as the instructor pilot observing the MP's upgrade sortie and had final authority over the conduct of the flight. As the 4th Fighter Squadron Operations Officer, Lt Col Craig was Capt Tidgewell's supervisor and second in command of the squadron, with oversight of the squadron's pilots and flight operations. He was the authorizing official for this sortie. (Tab K-11)

The MF was scheduled to fly two separate night sorties. The missions were to fulfill the requirements of FLUG 7, a 2-ship flight lead upgrade for the MP, consisting primarily of night surface attack tactics (SAT) with opposing Red Air fighters. The first sortie for the night was a non-Night Vision Goggles (NVG) tactics ride and the second sortie planned to include employment of NVG tactics. The mission objectives, as described in the 388th Fighter Wing Syllabus, were for the MP to demonstrate proficiency in briefing, executing the missions, debriefing, and drawing lessons learned in an opposed night SAT. Specific tasks were to find and destroy an assigned target through valid attacks employing Paveway III laser-guided munitions, conduct effective air and surface threat reactions, maintain and maximize mutual support between the flight members, and practice clear, concise communications (Tab K-23).

Between sorties, the MF planned to refuel in the hot pits. Normally, F-16s are refueled in their parking spots on the ramp by a fuel truck after the pilot has left the aircraft. In this case, however, the MF planned to refuel with their engines running in the hot pits. The hot pits enable the pilots to take on fuel and then taxi to the runway for their next sortie with minimum delay. The practice not only expedites preparing the aircraft for the next flight, but also simulates combat practices during surge operations where a large number of sorties are required. Hot pit refueling is a standard practice at most fighter bases in the US Air Force.

b. Planning:

The accident board reviewed all available mission-planning materials and the preflight briefing for the two-ship flight (Tab K-29). JEDI 1 thoroughly planned both missions and conducted a standard preflight briefing in accordance with 4th Fighter Squadron standards and AFI 11-2F16, Volume 3, *F-16 Operations Procedures* (Tab V-1.3). The 4th Fighter Squadron covers emergency procedures, required by AFI 11-2F16, Volume 3, in accordance with a printed schedule (Tab O-75) at a mass briefing attended by all of the scheduled pilots and conducted by the TOP 3. The TOP 3 is a senior, experienced pilot who has immediate responsibility for his shift's flying operations, flying schedule, and pilots.

c. Preflight:

The local area Notices to Airmen (NOTAMs) of 17 October 2001 did not contain any information that affected the planned mission or the accident (Tab K-17). NOTAMs provide short-notice or temporary information to aviators concerning hazards or special restrictions affecting flight activities.

JEDI 1's preflight inspection was in accordance with Technical Order (T.O.) 1F-16CG-CL-1, *Flight Crew Checklist*, and did not reveal any problems with the MA. A T.O. is a manual explaining the operation of an aircraft or system. Examples are the flying manual for the F-16 or the electrical wiring diagrams for various subsystems. JEDI 1 recalled that the nose tire might have had some cord showing, but that it appeared in overall good condition (Tab V-1.5). Only one of the ground crew recalled that the MA may have had some cord showing on the nose tire. None recalled red cord showing on the nose tire (Tabs V-8.1, 10.1, 11.1, 12.1, 13.1, 14.1, 15.1, 16.1). Aircraft tires are designed with multiple cloth cords molded into the rubber beneath the outer tread. As the tire wears down and tread is removed more cords are revealed, indicating level of wear. The last cord, normally the fifth and red cord, indicates the tire wear limit. F-16 crew chiefs normally change out the tire before the red cord is exposed (Tab V-16.2). Remaining ground operations were uneventful and standard.

JEDI 1's aircraft was configured correctly for the planned air-to-ground mission with targeting and navigation pods and two wing fuel tanks. JEDI 2's aircraft was delivered in an air-to-air configuration, without the pods and with only a centerline fuel tank. JEDI 2 determined that the sortie could be flown and the pilots changed the flight profile to accommodate JEDI 2's aircraft configuration. Specifically, JEDI 2 had to fly his departure from Hill AFB using his radar to lock onto and track JEDI 1 (commonly called "radar trail departure") instead of using the Forward Looking Infrared (FLIR) camera in the targeting pod (commonly called "FLIR trail departure") as originally planned. Neither change to the profile was considered significant. JEDI 2 testified that JEDI 1 handled the unexpected change to the profile with ease (Tab V-2.2).

d. Flight and Summary of Accident:

The first sortie was uneventful and flown in accordance with the briefing. JEDI 1 experienced no difficulties with nosewheel steering or braking up to the point where the nose tire failed (Tab V-1.5-1.6).

After landing from the first sortie, the MF de-armed their weapons and taxied to the hot pits where a ground crew inspected their aircraft prior to refueling. A separate crew refueled each aircraft. Refueling was uneventful. The flight then taxied to the arming area for Runway 32. None of the ground crews interviewed specifically remember working on the MA, but all stated none of the jets they serviced that evening had tire or gear problems (Tabs V-8.1, 10.1, 11.1, 12.1, 13.1, 14.1, 15.1, 16.1).

The de-arm, hot pit, and arming crews are required by T.O 1F-16CG-6WC-1 and T.O. 1F-16CG-2-12JG-00-1 to conduct a visual inspection of the Nose Landing Gear (NLG) (Tab BB-3). However, due to the danger area surrounding the F-16s intake (Tab BB-3), they position themselves no farther forward than the aft end of the NLG well. This allows a reasonable view of the aft part of the nose tire. After the aircraft pulls into the arming area and the ground crew does an initial visual inspection, they direct the pilot to move forward several feet, exposing the segment of the tires that were previously hidden. All ground crews stated they had adequate illumination from their supplied flashlights (Tabs V-8.1, 10.1, 11.1, 12.1, 13.1, 14.1, 15.1, 16.1).

At approximately 9:13 P.M. local time (or 2113L in military time, which adds 12 to the hour for P.M. times), JEDI 1 contacted HILL Tower and reported they were ready for takeoff. They experienced a two-minute delay due to opposite direction departures and landings. At 2115L HILL Tower cleared them on to the runway, but not for takeoff (Tab V-1.8). JEDI 1's configuration and weight required him to perform his takeoff with full afterburner. JEDI 2, significantly lighter in weight, planned his takeoff without afterburner, following 20 seconds behind JEDI 1 (Tabs V-2.3, N-3).

JEDI 1 stopped on the runway, in accordance with his instructions from HILL Tower (Tab V-1.8). At 2116L he received takeoff clearance and advanced his throttle to military power, which provides full engine thrust without afterburner. He released his brakes and advanced the throttle to full afterburner (Tabs V-1.7, V-1.8). Afterburner light and acceleration were normal (Tabs V-1.7, V-1.8). In the afterburner section, located at the aft part of the engine, spray nozzles dump a large amount of fuel into a chamber. The fuel is ignited and the burning gas escapes the engine at high velocity. This provides a great deal of extra thrust for the F-16 and enables a heavy aircraft to takeoff within the available runway.

At approximately 1,400 feet down Runway 32, at 126 knots (a measure of speed), JEDI 1 reported he heard a very loud explosion, saw a column of flame by the left side of his canopy, and experienced a slight deceleration (Tab V-1.9). JEDI 1 testified that the deceleration was not severe, as can be experienced when the afterburner ceases during takeoff (Tab V-1.9, V-1.10, V-1.11). JEDI 1 concluded that he had an engine problem and elected to abort the takeoff (Tab

V-1.9). At 1,400 feet, the chart at Tab J-23 (also summarized in Table 1) shows a small disturbance in the aircraft's longitudinal Gs. Longitudinal G's measure acceleration along the fore-aft axis of the aircraft.

The Michelin Company, which manufactured the tire, examined the remains at their facility. They determined the most likely cause of the tire failure was due to an impact with a foreign object (FOD) at some point on the runway (Tab CC-47 to CC-81). The survey at Tab R-3 shows two small pieces of concrete at approximately the same point on the runway where the tire failed, but the board was unable to conclusively link the two.

The runway is cleaned by specialized sweeper trucks on a regular basis and at the request of base operations. The Chief of Base Operations walked along the runway after the mishap, and found the area where the tire initially failed free of FOD. Hill AFB's FOD prevention program is exemplary (Tab O-3 to O-55 and Tab V-21.1).

Rubber marks were found in the intake of the MA and the 388th Fighter Wing engine shop discovered remains of the nose tire in the engine after teardown (Tab CC-17). The Digital Engine Control (DEC) will record engine parameters if an engine disturbance is encountered; however, no such fault was recorded. Although an engine compressor stall with associated explosion and flame out the intake are not out of the question, there is no firm evidence that the pilot witnessed the results of the engine ingesting parts of the tire. The explosion and flame were most likely due to the rapid disintegration of the nose tire and the contact of the high-speed metal nose wheel with the runway (Tab V-1.9).

Three seconds later, at 1,850 feet and 150 knots, the first nose tire remains were left on the runway. Grooves from the nose wheel were cut into the runway starting at 2,600 feet, at the end of the nose tire debris field (Tab R-3).

JEDI 1 reduced his throttle to idle at 2,250 feet and 162 knots, approximately four seconds after the recorded disturbance, pulled back on the stick to increase weight on the main gear, and opened the speed brakes in an effort to slow the aircraft. All actions were in accordance with T.O. 1F-16CG-1, *Flight Manual,* also known as the "Dash 1" (Tabs V-1.9, BB-3).

Hill AFB's runway is 13,500 feet long; aborted takeoffs normally do not require immediate braking. A more appropriate technique is to let the aircraft coast to a slower speed before applying brakes. JEDI 1 applied moderate to heavy symmetrical braking at 4,350 feet and 132 knots. Approximately 5,000 feet down the runway (120 knots) the aircraft started to veer right (Tabs R-3, V-1.9 to V-1.13). Without nosewheel steering and with a blown nose tire, the aircraft will naturally drift to the right, a result of NLG design characteristics. JEDI 1 selected nosewheel steering via the select button on the control stick, but does not remember seeing the NWS light on the AR Status/NWS Indicator on the glareshield, nor did he recall actively looking for the light. The MP testified he had reduced the brightness of those indicators in preparation for the NVG sortie (Tab V-1.14). He does not recall a CAUTION in the Heads Up Display (HUD), or an audible warning at any time during the abort (Tab V-1.14). When the F-16

experiences certain types of malfunctions, a recorded voice calls out "WARNING" (along with the effected system) to alert the pilot. At the same time, the HUD (a piece of reflective glass located in front of the pilot which displays flight information) flashes "CAUTION". The warning systems are designed to highlight malfunctions that might not be immediately apparent to the pilot, especially in a busy environment.

Most airplane brakes are located on the aft (or main) landing gear. Each brake is actuated by depressing the top of the associated rudder pedal. For example, depressing the left brake pedal actuates the left main landing gear brake, which turns the aircraft to the left. Differential braking occurs when the pilot depresses one brake more than the other in an attempt to turn the aircraft.

The Brake Chart (Tab J-45 and summarized in Table 1) shows that JEDI 1 applied significant differential braking from 4,900 feet till the aircraft departed the runway. Prior to the skid, although the MP was applying maximum effort to the left brake, the anti-skid system prevented the wheel from locking up and depositing rubber on the runway (Tab R-3). Shortly after applying this differential braking, the photograph at Tab Z-5 shows the path of the MA reversing direction to the right and a pronounced nose-left skid. As the aircraft went into a left skid, the tires broke free of the surface and slid, instead of rolled, across the runway (Tab R-3). The skid left a thin layer of molten rubber between the surface of the tire and the runway, lowering the coefficient of friction. This action significantly reduced the effect of differential braking, much like a car skidding on ice. Five hundred feet later, the nosewheel rims were ground down do the hub (Tab R-3).

JEDI 1 testified the aircraft tracked straight down the runway for several seconds, but as he slowed the F-16 swerved left, then right, slightly left again, then back to the right (Tab V-1.9). Photographs confirm this path (Tabs Z-5 to Z-13); however, the grooves cut by the nose wheel in the asphalt do not show the 30 to 45 degree course changes JEDI 1 reported (Tab V-1.9). The skid marks left by the main tires show definite signs of swerving or "fishtailing" after 5,500 feet, which would explain some of JEDI 1's observations (Tab V-1.11). Measurements taken from the photographs at Tab Z-9, Figure 5, show the MA skidded 15 to 30 degrees counter-clockwise (nose left) of the path the aircraft was traveling. There were no skid marks from the main tires up to this point, indicating that the anti-skid braking system was working properly.

JEDI 1 stated he felt as though his inputs to rudder, braking, and nosewheel steering were ineffective and that he was "along for the ride" (Tabs V-1.9 to V-1.13). He was familiar with the Dash 1 warnings about reverse castering, but he did not recall or consider them during the abort (Tabs V-1.17, V-1.18).

Normally, the point of contact between the nose tire and the runway is behind, or trails the axis of the NLG strut and the tire moves in the direction of turn. Reverse castering occurs when the point of contact between the wheel and the runway moves forward of the NLG strut axis (Tab CC-9). During reverse castering, the nose wheel casters in the opposite direction the pilot is attempting to move the aircraft, similar to a shopping cart with a bad wheel (Tab CC-9). In this

case, the nose tire separated from the aircraft and the nose wheel ground down to a smaller radius creating the geometry that resulted in reverse castering (Tab CC-9).

As the MA neared the painted stripe at the right side of the runway at what he perceived to be a 30 to 45 degree angle, JEDI 1 elected to eject (Tabs R-3, V-1.9). Two to three seconds later he left the aircraft at 6,400 feet and 75 knots, at the same time the MA departed the prepared surface (Tab R-3).

The Supervisor of Flying (SOF), tower personnel, JEDI 2, and ROGUE 1 (another F-16 waiting for takeoff) were all witnesses to the accident (Tabs V-2.1, V-3.1, V-4.1, V-17.1, V-18.1, V-19.1, V-20.1). Their testimony as to the basic events was generally the same and was considered useful. However, due to their perspective under night conditions, their sense of distance and speed was considered unreliable. They were unable to provide the level of detail one would expect had the accident occurred during daylight hours.

e. Recorded Data:

The Signal Acquisition Unit (SAU) onboard the F-16 recorded baseline data during the takeoff roll and provided reliable, accurate details for speed, distance, throttle setting, and longitudinal G's (Tabs J-21, J-23).

The following Table summarizes significant events as recorded by the SAU. It also includes the events as depicted on the accident survey (Tab R-3), marked with an asterisk (*). Time starts from throttle advancement on the runway.

Event	Time (SAU data)	Delta (sec)	Speed (ft/sec)	Speed (knots)	Distance (ft)	Left Brake Output	Right Brake Output
Throttle Up	181:00	0	0	0	0	85	85
Concrete Chips *	181:07	7	200	120	1250	0	0
Disturbance	181:08	8	210	126	1350	0	0
Tire Field Starts *	181:11	11	250	150	1850	0	0
Throttle Back	181:12	12	270	162	2250	0	0
Tire Field Ends *	181:13	13	285	171	2600	0	0
Rim Scrape Starts *	181:13	13	285	171	2650	0	0
Decelerate	181:14	14	285	171	2750	12	30

Metal Wire *	181:14	14	275	165	2900	12	30
Small Veer to Right *	181:20	20	220	132	4350	61	55
Wheel Rim Remnants *	181:23	23	200	120	4900	73	18
Large Veer to Right *	181:23	23	200	120	5000	73	18
Hub Scrape Starts *	181:26	26	175	105	5550	73	30
Depart Runway	181:32	32	125	75	6400	85	24

TABLE 1

The wheel brake output is measured in standardized units, and is included to show the relative level of effort the MP exerted on the brakes during the abort.

The first event was a small disturbance in the longitudinal G's at 1400 feet. JEDI 1 reduced his throttle to idle approximately four seconds afterwards, a reasonable amount of time for recognition, analysis, and action. The aircraft continued to accelerate for 2 seconds, as described in T.O. 1F-16CG-1, *Flight Manual.* The SAU data does not indicate aircraft movement to the left or right, but the survey and photographs (Tab R-3) show slight movement to the left as the MA traveled down Runway 32, then a significant veer to the right at 5,000 feet. At Tab J-23, the data shows marked increase in longitudinal G's at 6,400 feet, indicating runway departure. The survey shows the jet leaving the runway surface at 6,400 feet, corresponding precisely with the SAU data.

The Crash Survivable Memory Unit (CSMU) normally starts recording after the main generator comes on line after engine start or when the aircraft senses weight off the main gear as measured by the right main gear's Weight on Wheels (WOW) switch, and stops 90 seconds after landing. As the MA had already flown one sortie and the electrical power was not interrupted, the CSMU was inactive and did not start recording again till it sensed that the aircraft was airborne (in this case a small bounce after leaving the runway).

The Canopy Unlock channel shows a change from locked to unlocked, indicating the point where the ejection occurred. This data indicates the ejection occurred at the same point where the F-16 left the runway (Tab J-13).

f. Impact:

The aircraft came to rest approximately 6,900 feet down Runway 32, 100 feet from the east edge of the runway, at coordinates N41 07.5 W111 58.3 (Tab R-3). After departing the prepared surface at 6,400 feet, the MA rolled across an unused taxiway, then pulled to the left as it entered

the soft soil. Photograph Z-11 (Tab Z-15) distinctly shows the path of the MA after it crossed the taxiway. During this pull to the left, the MA tipped to the right (approximately 75 degrees), and caught the right wingtip and right wing fuel tank. This action pulled the MA hard to the right where it came to rest, the nose wheel hub embedded in the soil. The final 500 feet of the MA's ground track after it departed the runway, as depicted by the CSMU data in Tab J-13, is summarized in Table 2 (Also, Tab R-3).

The CSMU data indicates the aircraft traveled approximately 500 feet after it departed the runway, corresponding well with the physical evidence and the survey at Tab R-3.

Event	Time (sec)	Delta (sec)	Speed (ft/sec)	Speed (knots)	Bank (degrees)	Heading (degrees)
MA departs runway	181:32	32	125	75	0	340
	181:33	33	102	61	5 Left	350
Veer to left in soft soil	181:34	34	95	57	0	340
	181:35	35	85	51	0	330
Right wing starts to drop	181:36	36	60	36	10 Right	320
Significant drop in speed	181:37	37	30	18	15 Right	300
	181:38	38	5	3	70 Right	250
MA starts pulls back to north after right wingtip catches	181:39	39	3	2	75 Right	260
MA continues pull to the right	181:40	40	0	0	50 Right	300
Aircraft settles	181:41	41	10	6	10 Left	300
Aircraft stops	181:42	42	3	2	0	300

TABLE 2

Pieces of the aircraft were broken off after the MA left the prepared surface, but the majority of the damage occurred when the right wingtip caught in the soil. The captive AIM 9 (a heat seeking air-to-air missile without an operational rocket motor) was torn off and destroyed, the

right wingtip was heavily damaged, and the right fuel tank was partially torn from the MA and destroyed. The FLIR, LANTIRN, and Electronic Countermeasures (ECM) pods were heavily damaged (Tab M).

g. Life Support Equipment, Egress and Survival:

JEDI 1 ejected at approximately 70 knots, wings level. The ejection and landing were normal, although JEDI 1 experienced some minor injuries. The MP has an excellent recollection of the details of the ejection (Tab V-1.9).

JEDI 1 felt one swing in the parachute, landed firmly on the right side of the runway, and released his parachute fittings. He collected his survival gear and placed it in the inflated survival raft. The parachute was blown down the runway by the wind and he did not recover it. He walked away from the crash site so as not to be a hazard to the emergency vehicles. The MP was passed by several trucks, then was picked up by a member of the fire department and taken to the ambulance at the crash site (Tab V-1.10).

The left M53 initiator in the ACES II ejection seat failed, however seat redundancy completed the ejection sequence. The M53 initiators are part of the chain of explosive devices in the ejection seat. One of the two ballistic hoses that provide gas pressure to actuate the CKU-5/B/A rocket catapult, which in turn ejects the seat and aircrew from the aircraft, was severely damaged when the M53 initiator failed. A Product Quality Deficiency Report (PQDR) was submitted on the faulty initiator (Tab I-3).

Additionally, the battery for the AN/URT-33 beacon failed to provide power for the beacon upon ejection. The beacon, which only actuates after an ejection, generates an intermittent tone on radio frequency 243.0 megahertz that can guide rescue crews to a downed crewmember. A PQDR on the battery was also submitted. (Tab I-9)

h. Search and Rescue:

All crews responded from the Hill Air Force Base Fire Department for the accident. The first call, received through the primary crash net, was received at 2118L and the first vehicles were on scene within a minute. Three minutes after arriving on scene, Crash 5 (a fire truck enroute to the crash site) made contact with the pilot walking on the runway. At 2122L, the fire department extinguished several small fires burning around the aircraft. Around 2125L, the rescue crews followed steps to shut down the aircraft. After pinning the Emergency Power Unit (EPU), fire department personnel moved to the fuel shut-off switch located on the right side, aft-end of the aircraft, but were unable to shut down the engine as they followed outdated publications that did not include a time critical tech order (TCTO), T.O. 105 E-9, directing an additional electrical cable be disconnected in addition to actuating the fuel shut-off switch. They then followed procedures for a manual shut down by climbing a ladder into the cockpit and placing the throttle to off. At approximately 2146L, the fire department foamed the brakes to reduce the chance of

subsequent fires due to the extreme temperatures. All follow-on actions taken on the part of the fire department were according to established procedures (Tab CC-21, 33).

The MP was taken by ambulance to Davis Hospital, located five miles south of Hill AFB in Layton, Utah, for observation, and released (Tab X-5).

5. MAINTENANCE

a. Forms Documentation:

All existing Aircraft AFTO 781 series, the aircraft forms documenting ongoing maintenance, were reviewed for accuracy and completeness. This information, along with the information from the Core Automated Maintenance System (CAMS), was reviewed to determine condition of the aircraft prior to the mishap (Tab H).

A CAM is a computerized central maintenance record system used by maintenance personnel for documentation in addition to the Aircraft AFTO 781s.

The MA flew 90 sorties and 117.4 hours from 2 July 2001, the completion of its 300-hour phase inspection, through 17 October 2001, the date of the accident. Of these sorties, 53 were mission capable code 1 (no maintenance discrepancies discovered during the flight), 22 were mission capable code 2 (minor discrepancies), 15 were mission capable code 3 (grounding discrepancies), and four were ground aborts (pilot returned the aircraft to maintenance before attempting flight) (Tab H-3).

Daily aircraft servicing was correctly documented on this aircraft (Tab U-5).

There were no historical records that revealed recurring maintenance problems.

b. Inspections:

All daily inspections of the aircraft were performed, documented, and satisfactorily completed in accordance with technical data.

The MA had seven open TCTOs (Tabs H-17, H-19). The first called for a 600-hour inspection of the hydraulic/JFS lines that are located in the engine bay. This inspection was deferred to the AFTO 781K until the next time the engine is removed. The second was an inspection of digital flight control computer supports, rack, and proper electrical bonding. This TCTO has not been accomplished yet. Grounding date for this TCTO is 30 June 2003. The third was a modification of wing assemblies and this was held in abeyance. The fourth was the installation of ring laser gyro inertial navigation unit; currently kit parts are on order for this TCTO. The fifth was a modification to integrate aircrew eye/respiratory protection. Kit parts are currently on order. The sixth was the removal and replacement of canopy release male fitting on UWARS configured ACES II recovery parachute assemblies. This was also held in abeyance. The final

TCTO was an inspection for proper clearance between wiring harness and crew station support and this has not been complied with yet. Grounding date for this is 31 July 2004 (Tab H-19).

There was a local one time inspection required on all F-16 aircraft for chafing/pinching and proper routing of NLG WOW harness. This one time inspection on this aircraft was performed on 21 September 2001 with no defects noted.

There were two write-ups associated with safety of flight (Red Xs) that were signed off in the AFTO 781s but not signed off in CAMS. One was for the Inertial Navigation System and the second was for BPO/Preflight inspection (Tab H-17).

There was one open write-up for a non-safety of flight discrepancy (Red Diagonal) for station 3 and 7 requiring installation of panels as annotated in the 781As (Tab H-17).

There was one write-up that was open as an inspection, non-safety of flight, (Red Dash) for the engine's 1st stage blade #14, which had a deformation. This write-up was signed off in the 781As as within technical order limits but not signed off in CAMS or signed off in the 781 Engine K (Tab H-19, U-7).

There was a 1200-hour landing gear inspection that was completed during the aircraft's last phase. The post dock was signed off on 9 July 2001. There were no major problems associated with this inspection (Tab H-19).

These maintenance actions were not related to the mishap.

c. Maintenance Procedures:

Daily servicing, to include checking the tire pressure, was accomplished on this aircraft in accordance with proper technical order procedures (Tab U-5).

These maintenance actions were not related to the mishap.

d. Maintenance Personnel and Supervision:

The board focused on four specific maintenance areas; preflight/servicing, exceptional release (ER), thru-flight, and end of runway (EOR) checks. First area was the preflight and servicing of the aircraft prior to the first sortie of the day. The preflight was conducted and signed off in accordance with technical data. The nose wheel tire pressure was signed off as 300 psi, also in accordance with technical data. The second area was the ER. The ER is a procedure used to verify that there are no safety of flight write-ups in the Aircraft AFTO 781 Forms. There were two ER's in the aircraft forms. The first ER was signed off by the production superintendent after the station 3 and 7 write-up but before the intake inspection due for the thru-flight (Tab U-5). There were no safety of flight open write-ups at that time. The second ER was signed off by the aircrew. This was the last documentation in the active AFTO 781A form after the write-up for the first stage fan blade (Tab U-5). Again, all safety of flight write-ups were

signed off. The third area was the thru-flight that was conducted between the second and third sortie, which was also completed in accordance with technical data. There were no defects noted (Tab U-5). The final area was the EOR check. Ground crews followed the proper work cards and there were no problems annotated.

The maintenance personnel involved in these four inspections were qualified and proper documentation was made for their qualifications. Special certification rosters were reviewed along with individual training records. During interviews, individuals said they felt that they have received adequate training and were confident in their abilities to perform their job. Finally, there was adequate supervision in place to monitor activities (Tab V-8.1, 9.1, 10.1, 11.1, 12.1, 13.1, 14.1, 15.1, 16.1)

These maintenance actions were not related to the mishap.

e. Fuel, Hydraulic and Oil Inspection Analysis:

The Interim Safety Board and Safety Investigation Board took fluid samples after the mishap for evaluation of fuel, oil, and hydraulic systems and the results were turned over to the Accident Investigation Board. The fuel result was within technical order limits. The oil result was also within technical order limits. The first hydraulic fluid result from the Hydraulic A-System (Primary) was outside technical order limits, but a second evaluation of the fluid was within limits. The first hydraulic fluid result that was evaluated from the Hydraulic B-system (Utility) was outside technical order limits, but there was not enough fluid left over for a second evaluation (Tab U-3).

The test failures were not related to the mishap.

f. Unscheduled Maintenance:

There was a pilot reported discrepancy for a "severe nose wheel shimmy on landing between approximately 30 and 70 knots" on 16 August 20001. Standard troubleshooting was performed in accordance with the proper fault isolation technical order. The torque link arm assembly, nose landing gear tire (Tab CC-3), nose wheel spacer, the nose landing gear collar, and nose wheel torque arm bushings were found out of limits and adjusted in accordance with T.O. guidance. (Tab H-9). This unscheduled maintenance was not related to the mishap.

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

a. Condition of Systems:

The MA's airframe, although suffering substantial damage during the mishap, was relatively complete. The composite material of the radome delaminated and splintered. The navigation, targeting, and electronic counter measure pods were heavily damaged. The cockpit was intact

minus the ejection seat and canopy. The left horizontal stabilizer was delaminated but the top and bottom remained together. There was no damage noted to the right horizontal stabilizer. The left wing remained intact with no damage. The 370-gallon fuel tank on station 6, the captive AIM-9 on station 8, and the Launcher Armament Unit (which holds air-to-air missiles) on station 9 (wing tip), which are all on the right wing, were destroyed. Each of the main wheels and tires suffered heat damage from extensive skidding (Tab CC-15). The NLG tire disintegrated and separated from the nosewheel. The torque links and lower portion of the NLG assembly were heavily scratched when the nose tire shredded. There were metal wires from the nose tire bead embedded inside the NLG WOW wiring harness and the NLG feedback potentiometer wiring harness. The forward portion of the NLG door and the nose gear door retract actuator were pulled away from the aircraft. The aft portion of the NLG door was still attached to the MA at the aft hinge. There was a substantial amount of dirt and debris on the inside of the nose landing gear well, bottom of the right wing, and right main landing gear. The engine suffered severe foreign object damage (FOD) after the aircraft departed the paved surface (Tab CC-17). The engine continued running after the MP ejected and was shut down by the fire department.

Several F-16 systems are activated or de-activated when the airplane becomes airborne. The aircraft senses weight off or on wheels by switches positioned on the landing gear. The NLG WOW switch, connected by wires to the aircraft systems and computers, is simply a plunger that moves in and out of it's casing. The switch is bolted through the upper NLG torque link, and presses against the NLG strut assembly when the torque link rotates downward after the strut extends during takeoff. The nosewheel steering system, actuated by the pilot with a switch on the control stick, is automatically de-activated during takeoff when the nose of the airplane rises and the NLG strut extends.

Investigation of the NLG WOW switch and wiring harness revealed three severed wires. The wires were tested for electrical continuity from the first cannon plug disconnect (P532 located on the top of the NLG well) to the WOW switch. One of those wires acts as a spare and does not carry any signals. The other two wires carry a signal to the steering control box to indicate when the WOW switch senses weight off wheels. When these wires were severed, the relay in the WOW switch automatically switched to it's fail-safe position, the "airborne mode", and rendered the MA's nose wheel steering system inoperative (Tab CC-3, 5, 13).

The F-16's nosewheel steers left and right when the system is turned on and the pilot pushes in the corresponding rudder pedal. A feedback potentiometer is located on the NLG upper assembly to provide the nosewheel steering control unit with the actual left/right position of the nosewheel. The potentiometer, connected to aircraft systems through a wiring harness, is a metal tube fixed to the NLG. The tube contains a rod; one end is tied to the rotating portion of the NLG and the other end moves in and out of the potentiometer case. A variable resistor inside the case senses the position of the rod, which corresponds to the position of the nosewheel.

The potentiometer was pulled downward out of its normal position; with some minor abrasion noted on the top of the rubber casing (Tab Z-35). The position rod in the feedback potentiometer was bent downward about 45 degrees, which prevented it from providing mechanical feedback to

the variable resistor inside the body of the potentiometer which in turn sent the signal to the steering control box (Tab Z-35, Z-33). The feedback potentiometer wiring harness has two cannon plugs (J1 and J2) that connect to the feedback potentiometer and at the first disconnect (P531 located in the upper NLG well). The wiring harness contained four wires that were cut. Severing these wires resulted in a loss of signal to the relay driver module inside the steering control box, which by design turns off the nosewheel steering system (Tab CC-7 and CC-11).

All severed wires showed clean cuts to the insulation and copper indicating they were slashed instead of crushed or pulled apart in tension (Tab Z-33, 37).

b. Testing.

The Michelin Company, which manufactured the tire, examined the remains at their facility. They determined the most likely cause of the tire failure was due to an impact with a foreign object (FOD) at some point on the runway (Tab CC-47 to CC-81). The survey at Tab R-3 shows two small pieces of concrete at approximately the same point on the runway where the tire failed, but the board was unable to conclusively link the two.

The main landing gear tires were sent to Building 1216, OO-ALC/LILE on Hill AFB. Analysis of both tires showed evidence of overheating from excessive skidding,-and that the left tire had cuts in the tread region that extended into the belt package. The overheating damage to the left tire was more severe. The cuts in the left tire were not deep enough to cause catastrophic failure. Neither tire showed evidence of flat-spotting associated with locking of the main landing gear brakes; thus the MA's anti-skid system was functioning properly. Both tires performed in accordance with design requirements and did not contribute adversely to the accident (Tab CC-15).

7. WEATHER

a. Forecast Weather:

Forecast weather starting at 2100L (received at 1855L) on 17 October 2001 was for winds from 330 degrees at 10 knots gusting to 15 knots, visibility of seven miles, broken clouds at 10,000 feet, 15,000 feet, and 20,000 feet. The forecast included light to moderate turbulence in clear air from surface to 5,000 feet Above Ground Level (AGL). A temporary condition of winds from 320 at 12 knots gusting to 25 knots was later cancelled (Tab W-5).

b. Observed Weather:

At 2055L, the reported weather indicated winds from 310 degrees at 7 knots, few clouds at 10,000 feet, broken clouds at 14,000 to 20,000 feet, temperature at 15 C, dewpoint at 3 C, altimeter setting of 30.09, pressure altitude was 4,633 feet MSL. At 2119L, the reported weather indicated winds from 320 degrees at 7 knots, few clouds at 10,000 feet, broken clouds at 14,000

to 20,000 feet, temperature at 14 C, dewpoint at 2 C, altimeter setting of 30.10, pressure altitude was 4,624 feet MSL (Tab W-3).

c. Space Environment:

Not applicable.

d. Conclusions:

The weather at the time of the accident was well within the operational limits of both the airplane and the MP. Night operations contributed to a lack of visual acuity for the pilot and the ground crews, but did not affect the final outcome.

8. CREW QUALIFICATIONS

a. Mishap Pilot:

Upon completion of the F-16 initial qualification course at Luke Air Force Base the MP entered follow-on training, again at Luke AFB. He progressed well throughout the course. During Mission Qualification Training (MQT) at Hill AFB the MP continued his strong performance with no problems noted and above average progression. The MP entered night vision goggle training eight months after completion of MQT, again with no problems noted and strong performance. The MP's 2-ship flight lead upgrade training was characterized by strong flight leadership and performance. The MP was in the process of becoming a four-ship flight lead at the time of the incident; this sortie was unaccomplished from his two-ship flight lead upgrade. As the chart below shows, the MP was flying at a pace above the minimum required. All of the MP's peers and supervisors characterized him as an above average pilot and officer (Tabs V-2.7, V-5.4).

Recent flight time is as follows (Tab G-7):

	Hours	Sorties	Minimum Sorties Required
30 days	22.3	12	10
60 days	39.5	25	N/A
90 days	63.3	39	29

Table 3

9. MEDICAL

a. Qualifications:

The MP's medical records were reviewed. At the time of the mishap, the MP was fully medically qualified with a current physical exam and AF Form 1042, Medical Recommendation for Flying or Special Operational Duty, on file (Tab X-3). The MP was in excellent health on the day of the mishap. He was not on a waiver for any medical condition or medication use.

b. Health:

The MP sustained minor injuries from the mishap, including abrasions on his right shin, both knees and nose, as well as a fracture of the tip of left hand's little finger (Tab X-5).

Testimony of the MP and a thorough review of his medical records reveal that his health was neither a cause nor a contributing factor to the mishap. The only apparent physical consequences of the mishap were the abrasions and finger fracture (Tab X-5).

There is no evidence that any medical condition contributed to this mishap.

c. Toxicology:

Toxicology was performed at the Air Force Institute of Pathology (AFIP) and at the Davis Hospital. A review of the AFIP lab results shows that the urine was negative for the presence of amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates and phencyclidine (Tab X-9). Blood and urine screening for alcohol was also done and was negative (Tab X-9). The blood carbon monoxide level was well within the normal range (Tab X-9). Emergency Department blood studies detected a Tylenol level of 5.6 (normal range 5-20) in the MP's blood (Tab X-11). MP took two 500-milligram caplets at 1430 for a slight headache. This is permissible and not disqualifying in accordance with AFI 48-123, attachment 7.32.3.2.

There is no evidence this contributed to the mishap.

d. Lifestyle:

The MP's and key maintainers' records were reviewed and the individuals interviewed. There is no evidence that unusual habits, behavior, or stress on the part of the mishap pilot or key maintainer contributed to the mishap (Tabs V-1.1, 8.1, 10.1, 11.1, 12.1, 13.1, 14.1, 15.1, 16.1).

e. Crew Rest and Crew Duty Time:

The MP complied with crew rest and duty day requirements on the day of the mishap (Tab V-1.2).

10. OPERATIONS AND SUPERVISION

a. Operations:

At the time of the accident, the squadron was conducting operations in two separate locations. Thirteen of the squadron's pilots were deployed overseas for Exercise BRIGHT STAR. The squadron also had pilots deployed within the United States in support of Operation NOBLE EAGLE. All but the BRIGHT STAR participants returned to the squadron by 14 October 2001. During the week of the accident, the 4th Fighter Squadron was conducting daily surge flight operations. During a surge, the squadron may fly up to 52 sorties per day, whereas during normal flight operations, 22 sorties a day is the norm. The operations tempo was considered normal for the squadron at the time of the accident.

At the time of the incident, the squadron had 31 pilots assigned in combat mission ready (CMR) status. A high experience level also existed in the squadron with 65 percent of the pilots experienced and 35% non-experienced.

b. Supervision:

The oversight and supervision for the mission was high. The MP's wingman was the 4th Fighter Squadron's Operations Officer, a highly experienced F-16 instructor pilot.

The supervision and leadership within the 4th Fighter Squadron is extremely strong and evident throughout all of their programs.

11. HUMAN FACTORS ANALYSIS

There is no evidence that human factors contributed to this mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Primary Operations Directives and Publications:

AFI 11-202, Vol 3, *General Flight Rules*

AFI 11-2F-16, Vol 3, *F-16 Operations Procedures*

T.O. 1F-16CG-1, *Flight Manual*

T.O. 1F-16CG-1CL-1, *Aircrew's Checklist*

b. Maintenance Directives and Publications:

AFI 21-101 *Maintenance Management of Aircraft*

ACCI 21-101 *Maintenance Management of Aircraft*

T.O. 1F-16CG-2-12JG *Organizational Maintenance Job Guide Servicing*

T.O. 1F-16CG-6WC *Combined Pre-flight/Post-flight/End-of-runway/Thru-flight/Launch and recovery/Quick Turn Around/BPO/Walk Around Before First Flight of Day Inspection Work Cards*

T.O.1F-16CG-2-32GS *Organizational Maintenance Landing Gear General System*

T.O. 1F-16CG-2-*00WD Organizational Maintenance Wiring Data Manual*

T.O. 1F-16CG-2-32FI *Organizational Maintenance Landing Fault Isolation*

T.O. 4T-1-3 *Inspection/Maintenance Instructions/Storage/Disposition of Aircraft Tires and Inner Tubes.*

c. Known or Suspected Deviations from Directives or Publications:

Mishap Pilot. No deviations from directives or publications found.

Operations Supervision. No deviations from directives or publications found.

Maintenance. No deviations from directives or publications found.

13. NEWS MEDIA INVOLVEMENT

There was an initial surge in media interest; however, the level of interest dropped after initial reports were released and time passed. A total of nine queries were made, while only two print media stories relative to the mishap appeared in local area papers (Tab CC-41, CC-43). There have been no further stories since that time.

14 December 2001

WALKER H. BOWMAN, Lt Col, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

F-16CG ACCIDENT

17 OCTOBER 2001

1. LIMITATIONS:

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

2. OPINION SUMMARY:

While taking off as the lead of a two-ship night flight lead upgrade mission, the mishap aircraft (MA), F-16C 88-0533, call sign "JEDI 1", experienced a catastrophic nose tire failure and subsequent nose wheel steering failure. The mishap pilot (MP) elected to abort the takeoff. There is clear and convincing evidence that he was unable to maintain directional control on the runway, due in large part to a phenomenon known as reverse castering. When it became evident that the aircraft would depart the runway the pilot successfully ejected. The aircraft continued through the grass, across a taxiway, and came to a full stop after catching the right wingtip. The mishap aircraft (MA) sustained heavy damage after departing the runway.

3. DISCUSSION OF OPINION:

After thorough review of all maintenance information, post-mishap failure analysis, and witness interviews, it was determined that all maintenance actions and inspections were carried out correctly and in accordance with all technical order guidance.

The nosewheel tire manufacturer inspected the remains and determined the most likely cause of the tire failure was due to an impact with a foreign object (FOD) at some point on the runway. The survey at Tab R-3 shows two small pieces of concrete were found at approximately the same point on the runway where the tire failed, but the board was unable to conclusively link the two. Hill AFB's FOD program is exemplary.

Clear and convincing evidence exists that the disintegration of the nose tire severed critical wires in the nosewheel steering potentiometer wiring harness and the Weight on Wheels (WOW) switch wiring harness, both located in the nose landing gear (NLG) well. Additionally, short pieces of the steel wire from the bead within the nose tire were embedded in the rubber casing and wires at the connections to both of these devices, shorting the circuits. The high velocity

flailing also pulled the body of the potentiometer out of its cradle, which bent the shaft of the potentiometer and rendered it useless. These failures led to the loss of the MA's nosewheel steering (NWS) system and reduced the MP's ability to steer the F-16.

From testimony of an explosion, visible flame, deceleration, and physical evidence on the runway and in the MA, it was reasonable for the MP to conclude that he had experienced an engine malfunction. Although F-16 guidance recommends takeoff for nose tire failure at high speeds, the MP did not have sufficient cues to reach that decision. Post accident inspection of the engine revealed tire, aircraft debris, dirt, rock ingestion, as well as significant damage to numerous fan and turbine blades, most of which occurred after the MA departed the prepared surface.

Normally, the point of contact between the nose tire and the runway is behind, or trails the axis of the NLG strut and the tire moves in the direction of turn. Reverse castering occurs when the point of contact between the wheel and the runway moves forward of the NLG strut axis. During reverse castering, the nose wheel casters in the opposite direction the pilot is attempting to move the aircraft, similar to a shopping cart with a bad wheel. In this case, the nose tire separated from the aircraft and the nose wheel ground down to a smaller radius creating the geometry that resulted in reverse castering.

Following the abort, the MA tracked straight down Runway 32 for approximately 2,500 feet. Due to design characteristics of the NLG assembly, the F-16 will drift to the right with a blown NLG tire and failed NWS. At 5,000 feet down the runway, as the aircraft drifted right, the MP applied left rudder, differential braking, and nosewheel steering (now inoperative) in an attempt to keep the MA from turning further right. These efforts compounded the effects of reverse castering and forced the nosewheel to caster further to the right.

As the aircraft slowed and the rudder became less effective, the MP lost sufficient authority from differential braking to counteract the effect of reverse castering. Applying the main brakes forced the nosewheel rims deeper into the asphalt, which created side loads between the sides of the grooves in the asphalt and the side of the rims, increasing force to the right. Runway, brake, and main tire analysis reveal that at 5,500 feet down the runway, the MA was in a left skid and the MP was applying maximum differential braking to the left. This skid produced a thin layer of molten rubber and reduced the frictional forces between the tire and the runway, negating the MP's efforts to slow and turn the MA.

The MP's decision to eject was appropriate as the MA was heading off the runway and he perceived a lack of control. The F-16's relatively short wheelbase can result in a rollover if it experiences too much sideslip or skid. Pilots are warned to eject if it appears the aircraft is about to depart a prepared surface.

Given his inputs, the MP correctly elected to abort his takeoff. He properly applied procedures and aircraft controls in an attempt to keep the MA on the runway, but given the lack of nosewheel steering and the strong forces generated by reverse castering it is highly unlikely any

pilot could prevent the MA from departing the runway. This type of accident is somewhat rare, but it is well documented that the F-16 will likely depart the runway in the event of a blown NLG tire and inoperative NWS.

14 December 2001

WALKER H. BOWMAN, Lt Col, USAF
President, Accident Investigation Board