UNITED STATES AIR FORCE
ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

F-16CG, T/N 89-2035

555TH FIGHTER SQUADRON
31ST FIGHTER WING
AVIANO AIR BASE, ITALY

LOCATION: AVIANO AIR BASE, ITALY

DATE OF ACCIDENT: 2 MARCH 2022

BOARD PRESIDENT: COLONEL DAVID J. GORDON

This investigation is an abbreviated accident investigation, conducted pursuant to Chapter 12 of AFI 51-307.

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

F16CG, T/N 89-2035
AVIANO AB, ITALY
2 MARCH 2022

On 2 March 2022, at 11:24:56 local time (L), the mishap aircraft (MA), a United States Air Force (USAF) F-16CG Fighting Falcon, Tail Number (T/N) 89-2035, call sign VIPER 21, assigned to the 555th Fighter Squadron (FS), "the Triple Nickel," 31st Fighter Wing (FW), Aviano Air Base (AB), Italy, experienced wheel separation of the left main landing gear (MLG) from the aircraft during takeoff at Aviano AB. The separation of the left wheel caused the Mishap Pilot (MP) to execute a gear-up landing bringing the MA to rest on its belly at 13:41:26L.

At 11:24:45L, the MA initiated takeoff from runway 05 at Aviano AB as lead of two F-16CGs to execute an air tasking order (ATO) mission. MP experienced abnormal flight indications through the takeoff sequence, including illumination of the anti-skid light, which caused him to terminate the originally planned departure in order to allow Mishap Wingman (MW) to conduct an aerial inspection of the MA for damage. MW's inspection of the left MLG and communications from Aviano Tower Air Traffic Control (ATC) initially indicated that the MA suffered a blown left MLG tire on takeoff. During the next hour and forty-five minutes, Security Forces personnel discovered the separated wheel on the airfield. MW and the Aviano AB Air Traffic Control (ATC) separately confirmed the MA lost the left MLG wheel entirely. Upon recommendation of Aviano AB supervising personnel and a flight safety engineer, MP executed a gear-up landing to safely recover the MA.

At 13:40:59L, the MA landed gear-up on runway 05 and continued to skid along the runway until it came to rest at 13:41:26L. MP was uninjured and exited the MA safely as emergency vehicles responded. The MA suffered significant damage to its ventral fins and electronic countermeasures (ECM) pod from sliding along the runway with its MLG retracted. The estimated cost to repair the MA is $6.1 million.

The Abbreviated Accident Investigation Board (AAIB) President found, by a preponderance of the evidence, the cause of the mishap was the failure of the MA's left outboard MLG wheel bearing. The excessive heat and friction created by the failed wheel bearing caused softening and deformation of the bearing cone. Rotational forces of the spinning wheel led to undesired rotation of the cone around the fixed axle. Friction between the stationary spacer and rotating bearing cone friction-weld the bearing cone to the spacer. Once fused, shear forces fractured the anti-rotational tab on the spacer and allowed the spacer to rotate in the counter-clockwise direction. Friction between the rotating spacer and wheel nut sheared the locking tab on the wheel nut, which loosened the wheel nut during the takeoff sequence. Once the wheel separated from the aircraft, the only course of action to safely recover the aircraft was to land with the landing gear retracted.

SUMMARY OF FACTS AND STATEMENT OF OPINION

F-16CG, T/N 89-2035
AVIANO AIR BASE, ITALY
2 MARCH 2022

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ACRONYMS AND ABBREVIATIONS

A1C	Airman First Class
AAIB	Abbreviated Accident Investigation Board
AB	Air Base
AB	after burner
AFAFRICA	United States Air Force Africa
AFB	Air Force Base
AFE	aircrew flight equipment
AFI	Air Force Instruction
AFMAN	Air Force Manual
AFPET	Air Force Petroleum Office
AFRL	Air Force Research Laboratory
AFSAS	Air Force Safety Automated System
AFSEC	Air Force Safety Center
AFTO	Air Force Technical Order
AGE	aerospace ground equipment
AGL	above ground level
AIB	Accident Investigation Board
AMMOS	Morning Mishap Operations Supervisor
AMU	Aircraft Maintenance Unit
AMXS	Aircraft Maintenance Squadron
AOC	Air Operations Center
ATC	Air Traffic Control
ATO	air tasking order
AUX	auxiliary
BP	Board President
Capt	Captain
CC	Commander
CD	Deputy Commander
CE	Civil Engineer
CES	Civil Engineer Squadron
CMSgt	Chief Master Sergeant
Col	Colonel
COSO	Combat-Oriented Supply Operations
DoD	Department of Defense
DRMO	Defense Reutilization Management Office
ECM	electronic countermeasures
EDS	X-ray spectroscopy
EOR	end of runway
EPU	emergency power unit
ER	exceptional release
ESR	engineering support request
FL	Flight Lead
FOD	foreign object debris
FS	Fighter Squadron
FSE	Mishap Flight Safety Engineer
ft	feet
FW	Fighter Wing
HFACS	Human Factors Analysis and Classification System
ICP	inductively coupled plasma
ID	inner diameter
IFE	in-flight emergency
IFR	Instrument Flight Rules
IMDS	Integrated Maintenance Data System
INBD	inboard
IP	Instructor Pilot
IPI	in-place inspection
ISB	Interim Safety Board
ISBFS	Interim Safety Board Flight Surgeon
ISBMXM	Interim Safety Board Maintenance Member
ITAF	Italian Air Force
HUD	heads-up display
L	local time
LA	Legal Advisor
LG	landing gear
Lt Col	Lieutenant Colonel
LM	Lockheed Martin
MA	Mishap Aircraft
MADDOG	Mishap Mission Director
Maj	Major
MC	Mission Commander
MD	Mission Director
MECSIP	Mechanical Equipment and Subsystems Integrity Program
MED	Medical Subject Matter Expert
MFO	Monitoring Facility Operator
MHA	mental health assessment
MLG	main landing gear
MM	Mishap Maintainer
MOC	Maintenance Operations Center
MOS	Mishap Operations Supervisor/Top 3
MP	Mishap Pilot

MSEP	Maintenance Standardization and Evaluation Program
MSF	Mishap Security Forces Witness
MSgt	Master Sergeant
MSL	mean sea level
MSOF	Mishap Supervisor of Flying
MXG	Maintenance Group
MXS	Maintenance Squadron
MXM	Maintenance Member
MW	Mishap Wingman
NCO	noncommissioned officer
NDA	nondisclosure agreement
NITE	Nitrogen
NM	nautical mile
NOTAM	Notice to Airmen
OD	outer diameter
OG	Operations Group
ORM	operational risk management
OSS	Operations Support Squadron
OTBD	outboard
OTI	one-time inspection
PAHA	Personnel Alert Holding Area
PHA	public health assessment
PM	Pilot Member
PR	personnel recovery
PRD	pilot-reported discrepancy
PR/BPO	Preflight/Basic Post-flight
psi	pounds per square inch
QA	Quality Assurance
REC	Recorder
RQS	Rescue Squadron
RULER	Remaining Useful Life Evaluation Routine
RXSA	Air Force Research Laboratory Materials Integrity Branch
SADO	Senior Air Defense Officer
SAR	search and rescue
SEM	scanning electron microscope
SF	Security Forces
SIB	Safety Investigation Board
SIBAFSEC	Safety Investigation Board Air Force Safety Center Member
SIBFS	Safety Investigation Board Flight Surgeon
SIBHFM	Safety Investigation Board Human Factors Member
SIBIO	Safety Investigation Board Investigating Officer
SIBMXM	Safety Investigation Board Maintenance Member
SIBP	Safety Investigation Board President
SIBPM	Safety Investigation Board Pilot Member
SIBREC	Safety Investigation Board Recorder
SMSgt	Senior Master Sergeant
SN	serial number
SOF	Supervisor of Flying
SrA	Senior Airman
SSgt	Staff Sergeant
SUP	Superintendent
TA	Transient Alert
TCTO	Time Compliance Technical Order
T/N	tail number
T.O.	technical order
TO	technical order
TSgt	Technical Sergeant
U.S.	United States
USAF	United States Air Force
USAFE	United States Air Force in Europe
USEUCOM	United States European Command
VFR	Visual Flight Rules
VR1	Viper One
VR2	Viper Two
WAI	walk-around inspection
WOC	Wing Operations Center
WOCMXM	Wing Operations Center Maintenance Member
Z	Zulu time

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 3 April 2022, Lieutenant General Steven L. Basham, Deputy Commander, United States Air Forces in Europe (USAFE) and Air Forces Africa (AFAFRICA), appointed Colonel David J. Gordon to conduct an abbreviated aircraft accident investigation board (AAIB) for the 2 March 2022 mishap involving an F-16CG aircraft, tail number (T/N) 89-2035, which occurred in flight near Aviano Air Base (AB), Italy (Tab Y-3 to Y-4). The investigation is an abbreviated accident investigation, conducted pursuant to Chapter 12 of Air Force Instruction (AFI) 51-307, *Aerospace and Ground Accident Investigations*, and the USAFE-AFAFRICA supplement, at Ramstein AB, Germany, from 11 April 2022 to 4 May 2022. Additional board members were a Major (Maj) Legal Advisor (LA), Captain (Capt) Pilot Member (PM), Master Sergeant (MSgt) Maintenance Member (MXM), and MSgt Recorder (REC) (Tab Y-3 to Y-4 and Y-6 to Y-7). A Lieutenant Colonel (Lt Col) Medical Subject Matter Expert (MED) was also appointed (Tab Y-6 to Y-7).

b. Purpose

In accordance with AFI 51-307, this AAIB conducted a legal investigation to inquire into all the facts and circumstances surrounding this Air Force aerospace accident, prepare a publicly releasable report, and obtain and preserve all available evidence for use in litigation, claims, disciplinary action, and adverse administrative action.

2. ACCIDENT SUMMARY

On 2 March 2022, at 11:24:45 local time (L), the mishap aircraft (MA), an F-16CG, T/N 89-2035, call sign VIPER 21, took off from Aviano AB, Italy, for an air tasking order (ATO) sortie (Tabs R-37 and V-1.2). The MA was assigned to the 555th Fighter Squadron (FS), "Triple Nickel," 31st Fighter Wing (FW), Aviano Air Base (AB), Italy (Tab D-3). During takeoff, MP experienced abnormal indications, including the illumination of the anti-skid light and a yaw to the left (Tab V-1.3). Unbeknownst to MP, the wheel on the left main landing gear (MLG) separated from the MA as it became airborne (Tabs R-45, R-48 to R-51, and V-1.3 to V-1.4). As a result of these abnormal indications, MP canceled the planned route and instructed the Mishap Wingman (MW) to inspect the MA landing gear for damage (Tab V-1.4 to V-1.5). MW and MP initially suspected a blown tire on takeoff, however, airfield personnel, MW, and MP later determined the left MLG wheel was no longer attached to the MA (Tabs R-41, V-1.5, and V-1.7). Upon recommendation of Aviano AB supervision and the flight safety engineer (FSE), MP executed a gear-up landing to safely recover the MA (Tabs R-35, R-39, R-41, and V-1.8 to V-1.9). At 13:40:59L, the MA landed gear-up on runway 05 and continued to skid along the runway until it came to rest at 13:41:26L (Tabs R-39, R-35, R-41, and V-1.8 to V-1.9). MP was uninjured and exited the MA safely as emergency vehicles responded. Preliminary estimates put the cost of repairing the MA at a minimum of $5.3 million, though further evaluation determined a final cost of $6.1 million (Tabs P-3 to P-4 and FF-3 to FF-7).

3. BACKGROUND

a. United States Air Forces in Europe (USAFE)

USAFE is the air component for United States (U.S.) European Command (USEUCOM) and executes the Air Force and USEUCOM missions with forward-based airpower and infrastructure to conduct and enable theater and global operations (Tab CC-3). USAFE, along with its subordinate command Air Forces Africa (AFAFRICA), directs air operations in a theater spanning three continents, containing 104 independent states (Tab CC-3). The command is composed of more than 35,000 active duty, Air Force Reserve, Air National Guard, and civilian employees, with assets including about 217 fighter, attack, rotary wing, tanker, and transport aircraft, as well as a full complement of conventional weapons (Tab CC-4).

b. 31st Fighter Wing (31 FW)

31 FW, located at Aviano AB, Italy, is a USAFE Air Force wing with a mission to deter through safe, secure, effective operations (Tab CC-5). 31 FW maintains two F-16 fighter squadrons capable of conducting offensive and defensive air combat operations (Tab CC-5). 31 FW is the only U.S. fighter wing south of the Alps, which makes it critical to operations in the North Atlantic Treaty Organization (NATO) southern region (Tab CC-5).

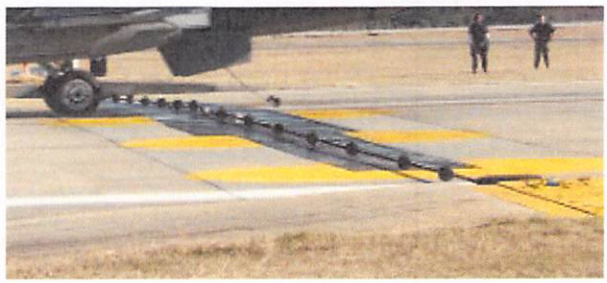
c. 555th Fighter Squadron (555 FS)

555 FS, or "Triple Nickel," is one of two F-16 fighter squadrons located at Aviano AB, Italy, providing combat airpower on demand to U.S. and NATO Combatant Commanders, as well as the National Command Authority, in order to meet National Security objectives (Tab CC-7). It also performs air and space control and force application roles of counter-air, strategic attack, and counter-land, including interdiction and close-air support, with 21 F-16Cs employing state of the art munitions in support of the joint, NATO, and combined operations (Tab CC-7).

d. F-16 Fighting Falcon

The F-16 Fighting Falcon is a compact, multi-role fighter aircraft that is highly maneuverable and capable in air-to-air combat and air-to-surface attack, providing a relatively low-cost, high-performance weapon system for the U.S. and allied nations (Tab CC-9). In an air combat role, the F-16's maneuverability and combat radius exceed that of all potential threat fighter aircraft, while in an air-to-surface role, the F-16 can fly more than 500 miles, deliver its weapons with superior accuracy, defend itself against enemy aircraft, and return to its starting point (Tab CC-9).

e. Airfield Emergency Arrestment Cable System



The aircraft arresting system consists of a hydraulic braking system connected to a steel cable that runs perpendicular across the runway (Tabs BB-27 to BB-30 and CC-12 to CC-13). If a fighter aircraft has an in-flight emergency in which it may not brake safely under its own power, the cable is stretched across the runway and, upon landing, the tail hook of the aircraft will catch the cable (Tab CC-12 to CC-16). When the aircraft pulls on the cable, it engages the hydraulic braking system (Tab CC-12 and CC-13). The harder the cable is pulled, the harder the brakes are applied, which allows the aircraft to be slowed down in a safe and controlled manner (Tab CC-12 and CC-13). Aviano AB has multiple locations for arrestment cables on runway 05 that can be raised or lowered (Tab Z-19 and Z-21). This process may also be referenced as "stringing" or "de-stringing" the cables (Tab R-37 and R-39). Aircraft arresting cables are part of the aircraft arresting system that span the runway surface and are engaged by the aircraft arresting hook (Tab BB-30).

f. Tail Hook

The F-16C is equipped with a tail hook for use in an emergency that will affect landing distance or directional control upon landing (Tab CC-14). The aircraft uses the hook to engage an arrestment cable that is installed perpendicular to the runway (Tab CC-12). In the "down" position, the hook is held in place through pneumatic pressure, ensuring it engages the cable (Tab CC-15).

g. Gear-Up Landing

In the event of damaged or malfunctioning landing gear, the F-16C can execute a gear-up landing in which the pilot will retract the landing gear and land the aircraft on its "belly," the external fuel tanks, or electronic countermeasures (ECM) pod, if installed (Tab R-39).

h. Go-Around

A go-around is an instruction from Air Traffic Control (ATC) for a pilot to abandon his or her approach to landing (Tab BB-32). Unless otherwise advised by ATC, a Visual Flight Rules (VFR) aircraft or an aircraft conducting a visual approach should overfly the runway while climbing to traffic pattern altitude and enter the traffic pattern via the crosswind leg of the runway (Tab BB-32).

i. Low Approach

A low approach is an approach over an airport or runway following an instrument approach or a VFR approach, including the go-around maneuver, where the pilot intentionally does not make contact with the runway (Tab BB-33).

j. CONFERENCE HOTEL

The initiation of a CONFERENCE HOTEL telephone conference makes aircraft specialists accessible to the Supervisor of Flying (SOF) or Operations Superintendent (Ops Sup/Top 3) and aircrew, 24-hours a day and 7-days a week, when in-flight situations pose system-related questions that cannot be answered at the local level (Tab BB-9). CONFERENCE HOTEL procedures put the Operations Group (OG) Commander (CC), SOF, or Ops Sup/Top 3 directly in contact with a representative from the Air Force Life Cycle Management Center (AFLCMC), the Wright-Patterson program office, or the contractor (Tab BB-9). The AFLCMC representatives are the most knowledgeable maintenance and engineering personnel for each weapons system and, as such, aircrews are urged to take advantage of this expertise and initiate a CONFERENCE HOTEL telephonically for additional assistance on board the aircraft (Tab BB-9).

k. Fighter Squadron Supervision

The supervision structure for flying operations in the Fighter Squadron (FS) typically includes an OG/CC, a SOF, and an Ops Sup/Top 3 (Tab BB-4). The FS falls under the OG and the SOF is the direct representative of the OG/CC (Tab BB-4). The SOF also ensures in-flight emergency (IFE) recovery plans and weather-related mission changes reflect sound airmanship, follow established practices, and adhere to sound operational risk management (ORM) principles (Tab BB-4 to BB-5). During an emergency or abnormal situation, the SOF provides aircrew with guidance, and timely advice and assistance to determine the correct course of action (Tab BB-4 to BB-5). The role of the Ops Sup/Top 3 is to execute the daily flying schedule and coordinate any mission changes as needed (Tab BB-5 to BB-6). Additionally, the Ops Sup/Top 3 assists the SOF and aircrew, is the primary liaison between operations and maintenance sections, and ensures all pilots are current and qualified to fly the briefed mission (Tab BB-5 to BB-6). The Ops Sup/Top 3 reviews pilots' ORM assessments and briefs aircrew on airfield status, scheduled and available airspace, weather, local hazards, and any additional items defined by unit supplements at the "Step Brief" (Tab BB-5 to BB-6). The Step Brief is where the Ops Sup/Top 3 conducts the final check of aircrew qualifications and communicates the above information to the aircrew (Tab BB-5 to BB-6).

l. Anti-Skid Caution Light

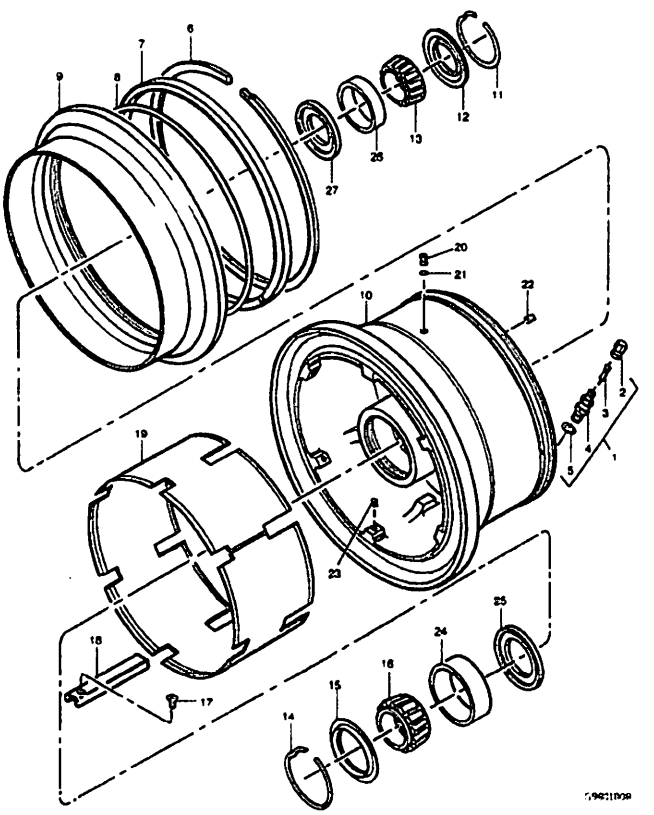
Illumination of the anti-skid caution light indicates an aircraft failure affecting brake performance (Tab BB-17). A flashing light represents a complete loss of braking capability on either or both sides, while a steady light represents the loss of a wheel speed sensor signal (Tab BB-17). In this mode, braking effectiveness will decrease while stopping distance increases (Tab BB-17).

m. Wheel Assembly Breakdown

The process of disassembling the wheel includes the removal of the inflation valve, tire, retaining ring, lock ring, preformed packing, bearing cones, seal assemblies, and thermal relief plug assembly (Tab DD-3). As the wheel assemblies contain two halves, the wheel is placed into a bead breaker assembly to help break the tire beads away from the wheel flanges (Tab DD-3). This device allows access to the retaining ring, locking ring, and preformed packing for ease of removal (Tab DD-3). Inboard and outboard bearing cones are removed from their respective positions on the wheel assembly, which is accomplished by removing the retaining ring, seal, and bearing cone (Tab DD-3).

The wheel assembly components are cleaned by hand with approved solvents and cleaning agents (Tab DD-3). Components are then dried by compressed air or by hand with a cloth (Tab DD-3). Once the cleaning process is complete, the inspection process begins (Tab DD-3).

TO 4W1-3-5-2



1	INFLATION VALVE	10	WHEEL BASE ASSEMBLY	19	HEAT SHIELD
2	CAP 16, BEARING CONE	11	OUTER RETAINING RING	20	THERMAL RELIEF PLUG (3)
3	VALVE CORE	12	OUTER SEAL ASSEMBLY	21	PREFORMED PACKING (3)
4	VALVE STEM	13	BEARING CONE	22	INSERT (3)
5	PREFORMED PACKING	14	INNER RETAINING RING	23	INSERT (6)
6	RETAINING RING	15	INNER SEAL ASSEMBLY	24	BEARING CUP, INNER
7	LOCKING	16	BEARING CONE	25	GREASE RETAINER INNER
8	PREFORMED PACKING	17	MACHINE SCREW (6)	26	BEARING CUP, OUTER
9	SIDE RIM	18	DRIVE INSERT (6)	27	GREASE RETAINER, OUTER

All wheel components are inspected to ensure their integrity is within prescribed limits (Tab DD-3). If discrepancies are identified with a component, it is replaced or, depending on the severity, sent to depot for repair (Tab DD-3). Once the bearing cones are inspected, they are repacked with grease and prepped for installation onto the wheel assembly (Tab DD-3).

After inspection, the wheel assembly is ready to be rebuilt through a process mirroring the disassembly (Tab DD-4). The bead breaker is used to ease installation of preformed packing, retaining ring, and lock ring to mate the two halves together (Tab DD-4). The new tire is dampened with soapy water to help with installation onto the wheel assembly (Tab DD-4). Prior to bearing cone installation, bearing part numbers are verified to ensure proper bearings are installed to alleviate improper bearing installation in the inboard or outboard positions (Tab DD-4). Both inboard and outboard bearing cones are installed in their respective positions with the seal and lock ring holding them in position (Tab DD-4). A special tool is used for the outboard bearing to ensure there is no gap between the bearing seal and the bearing cone assembly (Tab DD-4). Once these checks are complete, barrier paper is applied to the outboard side of both bearings to prevent foreign objects from entering the bearing (Tab DD-4). On the bearing paper, the inspector will

annotate that the bearing part numbers were verified and the gap check was completed (Tab DD-4). Finally, the tire is filled with nitrogen to approximately 325 pounds per square inch (psi) and allowed to sit for 12 to 24 hours to ensure the tire is not leaking (Tab DD-4). Once the leak check is complete, the wheel assembly is taken to the Aircraft Maintenance Units (AMUs) or base warehouse where it is stored until installation (Tab DD-4).

4. SEQUENCE OF EVENTS

a. Mission

The Mishap Sortie (MS), VIPER 21 flight, was scheduled in accordance with an air tasking order (ATO) for a mission that required two F-16CG aircraft to depart Aviano AB, conduct operations for approximately four hours, and return to Aviano AB for landing (Tabs K-3, R-37, V-1.2, and V-1.10). The original planned duration of the sortie required the flight to aerial refuel three times: en route, during patrol, and prior to returning to Aviano AB (Tab V-1.10). The MS included Mishap Pilot (MP) as the Flight Lead flying the Mishap Aircraft (MA), VIPER 21, tail number (T/N) 89-2035, with Mishap Wingman (MW) flying VIPER 22 (Tabs G-32, G-59, and K-3).

b. Planning

MP and MW flew similar missions in the weeks leading to the mishap and were familiar with the flight profile (Tab G-34 and G-59). MP and MW completed flight planning and briefing prior to the MS in accordance with Air Force Manual (AFMAN) 11-2F-16 Volume 3, *F-16—Operations Procedures* (Tabs BB-11 to BB-13 and V-1.2). Prior to the flight, MP completed an operational risk management (ORM) assessment worksheet for the flight and submitted it to the squadron Ops Sup/Top 3 (Tab K-7). The worksheet assessed mission risk to be "moderate" requiring Ops Sup/Top 3 approval, which he granted (Tab K-7). MP checked the forecasted weather and reviewed the Notices to Airmen (NOTAMs) for any airfield issues, but none were listed (Tabs F-3 to F-4, O-3 to O-5, V-1.2, and V-10.2).

c. Preflight

On 2 March 2022, the day of the MS, following mission planning, MP and MW picked up their flight equipment from the aircrew flight equipment (AFE) section, received a final briefing from the Ops Sup/Top 3, and proceeded to the flight line (Tab V-1.2 and V-10.2). Upon arriving at the MA, MP reviewed the aircraft forms, conducted a pre-flight inspection, and started the aircraft in accordance with Technical Order (T.O.) 1F-16CM-1CL-1 (Tab V-1.3). MP did not notice any issues from ground operations through taxi of the MA (Tab V-1.3).

The MS was the MA's first scheduled flight of the day (Tab D-4). MP did not observe any irregularities on the MA, including the left MLG, during pre-flight inspection (Tab V-1.3). Maintenance personnel responded to a concern raised by MP regarding his communications equipment and resolved it without further issue (Tab R-63). Additional maintainers completed required end of runway (EOR) checks and did not identify any anomalies prior to clearing MP and the MA for takeoff (Tab R-65).

d. Summary of Accident

Figure 1 (Tab Z-6)
The MA on an unknown date prior to the mishap at Aviano AB, Italy

Aircraft taxi for the MS occurred uneventfully (Tab V-1.3 and V-10.2). At 11:23:37L, the Aviano AB Air Traffic Control (ATC) Tower cleared the MA onto the runway (Tab N-3). At 11:24:33L, while taxiing on to the runway, Tower cleared the MA for takeoff from runway 05 (Tab N-3). MP directed his formation to change their primary radio to the departure frequency and at approximately 11:24:45L, MP started the takeoff roll aligned on the centerline of the runway (Tab N-3). During acceleration of the MA, MP noticed an illuminated anti-skid caution light, which indicated an issue with the aircraft braking system (Tabs V-1.3 and BB-17). At approximately this time, the left MLG wheel outboard bearing failed, beginning a chain reaction of part failures inside the left MLG wheel (Tab EE-4 and EE-11).

Approaching 90 knots, failure of the outboard bearing caused subsequent torque on the axle nut, forcing failure of the axle nut anti-rotation tab (Tabs L-3 to L-4, EE-4, and EE-10 to EE-11). Failure of the anti-rotation tab caused the axle nut to back off the axle, leaving the wheel unsecured (Tab EE-4 and EE-10 to EE-11). Unsecured, the wheel began to separate from the axle and landing gear assembly (Tab EE-9). Coincident with the initial separation, at 11:24:56L, as the aircraft passed 90.1 knots, the MA's data system recorded a fault with the wheel speed sensor (Fault #76), which indicated an "Open circuit in the left wheel speed transducer wiring, seen by both [left brake] channels (1/Primary and 2/Backup)" (Tab L-3 to L-4). Simultaneously, MP experienced a yaw, or pull, to the left that caused the nose of the aircraft to point three degrees from centerline (Tabs N-3 and V-1.3). MP assessed the yaw was equivalent to a slight crosswind and, at 11:24:59L, while exceeding 130 knots, MP fully corrected the yaw and the MA ran parallel to the runway centerline, offset to the left by approximately one "[F-16] ship length" (Tabs N-3 and V-

1.3). MP observed the anti-skid light turn off between 125 and 145 knots (Tab V-1.4). MP observed normal acceleration and aircraft performance for the remainder of the takeoff roll (Tab V-1.3 to V-1.4). At 11:25:02L, the MP raised the nose as the aircraft passed 165 knots and lifted off at approximately 175 knots at 11:25:03L (Tab N-3). Coincident with MP initiating lift off, the left MLG wheel completely separated, causing the MA to settle onto the left brake assembly (Tabs S-7, Z-8, Z-11, Z-18, and EE-9). As the MA lifted away from the ground, the left MLG wheel continued to roll down the runway, eventually veering right towards the Personnel Alert Holding Area (PAHA) (Tab Z-17).

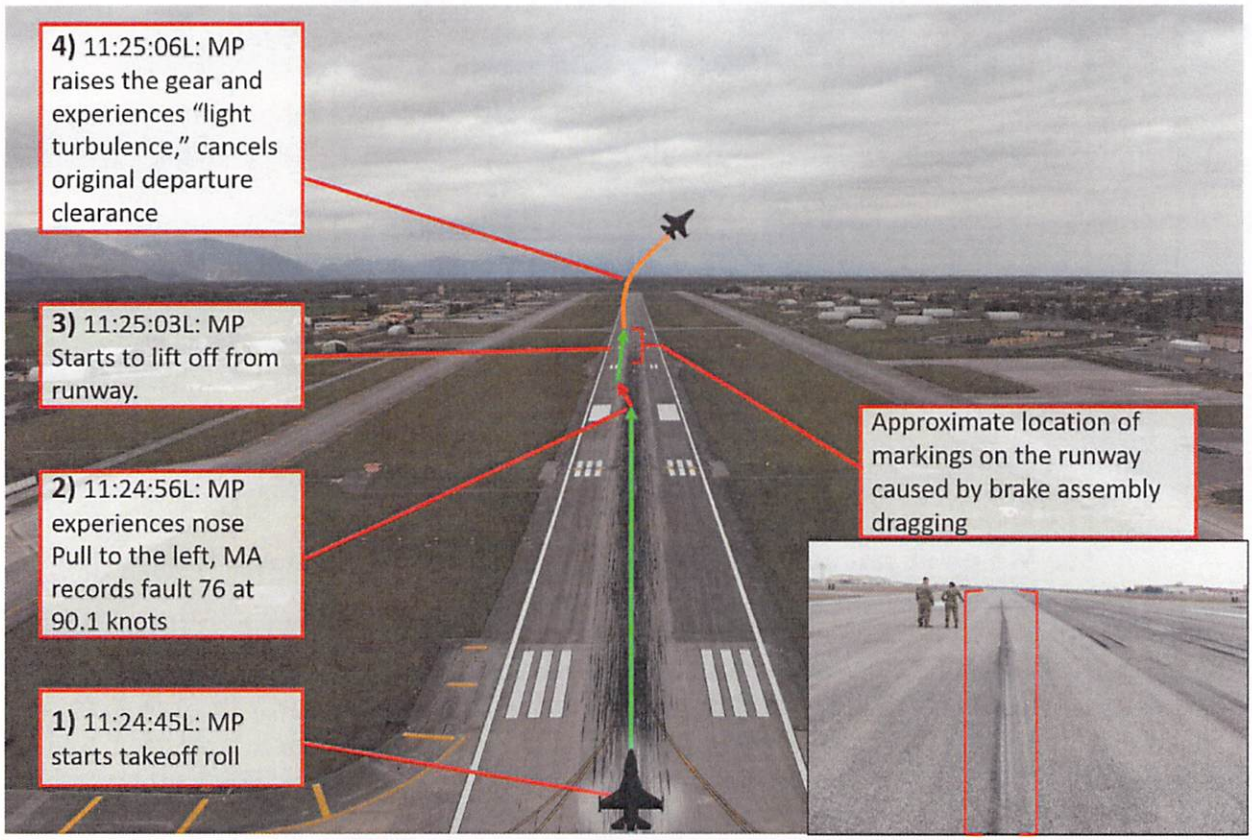


Figure 2 (Tabs L-3 to L-4, N-3, V-1.4 to V-1.5, and Z-6)
The MA's takeoff sequence and runway damage

MP raised the MLG handle as the MA accelerated past 210 knots (Tab V-1.4). As the MLG retracted between 210 to 260 knots, the MP observed "turbulent air" inconsistent with weather conditions (Tabs F-3 to F-4 and V-1.4). Based on observations, MP assessed the turbulence was "likely caused by some type of unusual asymmetry in the gear coming up" (Tab V-1.4). MP continued to climb to approximately 4,000 feet mean sea level (MSL) and accelerate to 360 knots while simultaneously initiating a right-hand turn to the east (Tabs N-3 and V-1.4). MW took off without issue approximately 15 to 20 seconds after MP and rejoined the MA (Tab V-1.5 and V-10.3). MW did not notice anything abnormal about MP's taxi, takeoff, or initial departure (Tab V-10.2).

While MW took off and climbed from the runway, Mishap Security Forces Witness 1 (MSF1) and Mishap Security Forces Witness 2 (MSF2) were posted at the PAHA, Building 1446,

approximately 500 feet east of Bravo and Bravo 3 taxiway intersections (Tab R-48 and R-53). Almost immediately after hearing both jets from the MS takeoff, MSF1 and MSF2 heard a loud "thump" between their post and the East Aircraft Gate of Tower Loop (Tab R-48 to R-49 and R-53). Looking in the direction of the noise, MSF1 and MSF2 observed a knocked over concrete barrier and a tire approximately 50 to 80 feet in the air (Tab R-48 to R-49 and R-53). The tire landed near the East Aircraft Gate and continued to roll until settling on taxiway B3 (Tabs R-48 to R-49, R-53, and Z-17). MSF2 contacted the base security center to stop any aircraft movement on the field and report what happened (Tab R-48 to R-49 and R-53). Approximately five minutes later, airfield management personnel arrived in a truck to collect the tire (Tab R-48 to R-49 and R-53). MSF1 noted the inside of the wheel was "sharp" and it "appeared to be stripped or cross-threaded" (Tab R-48 to R-49).

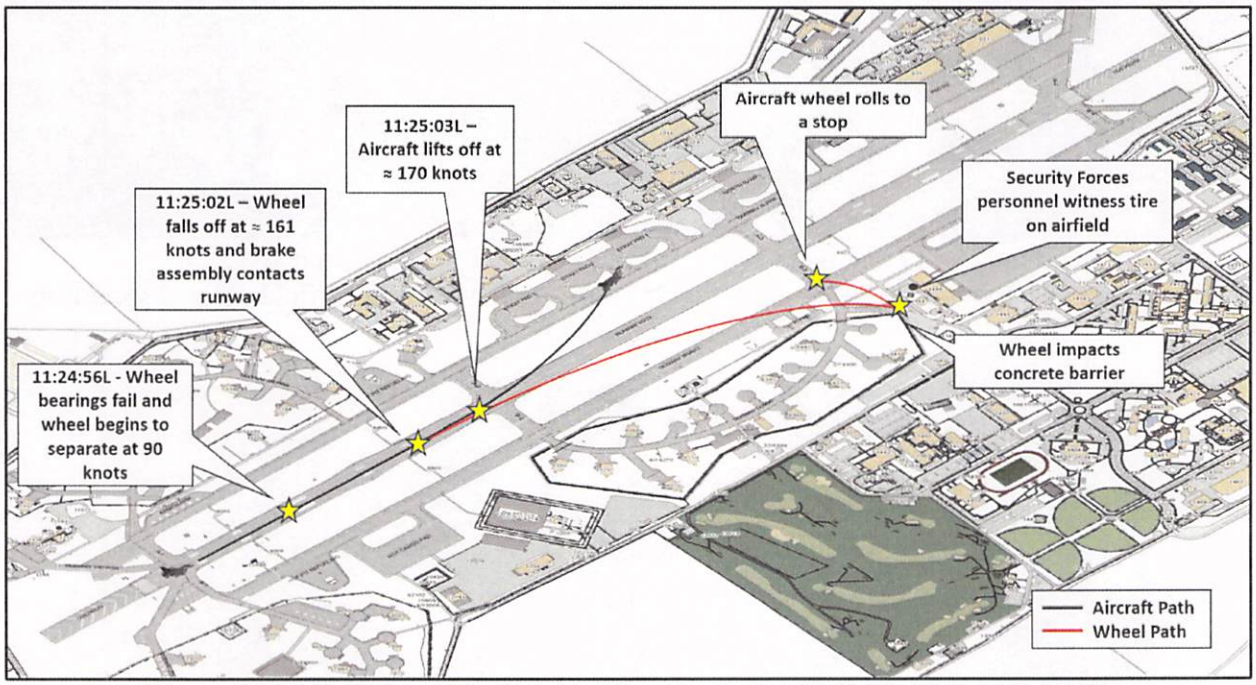


Figure 3 (Tabs L-3 to L5, N-3, R-48 to R-49, R-51, R-53, Z-6, and Z-17)
Approximate positions of the dislocated wheel from the MA during takeoff

As the MA approached 4,000 feet, MP contacted Departure ATC and requested to delay proceeding on his flight plan in order to conduct a check of his aircraft (Tab V-1.4 to V-1.5). MP requested termination of the departure "based on the anti-skid light, the slight yaw, and the possible asymmetric gear retraction" (Tab V-1.4). ATC approved cancellation of the original departure clearance and gave permission to proceed directly to PAYES, which is an aerial location approximately 11 nautical miles (NM) south of Aviano AB (Tab V-1.4 to V-1.5). MP continued directly to PAYES and directed MW to a close observation position, decelerated, and lowered the gear approximately five miles from PAYES (Tab V-1.4 and V-10.3). MP intended to lower the MLG, have MW inspect that the MLG lowered properly, then raise the gear, and continue on the planned sortie to the east (Tab V-1.4). At PAYES, MW conducted a close inspection of the MA and passed over the auxiliary (AUX) radio frequency to MP, the MA had a blown tire with almost all the rubber gone (Tab V-1.5 and V-10.3). Within seconds of receiving this information, MP received a radio call from Departure ATC, which relayed that Tower ATC personnel noted a puff

of smoke during his takeoff roll and they suspected the MA likely had a blown tire (Tab V-1.5 and V-10.3).

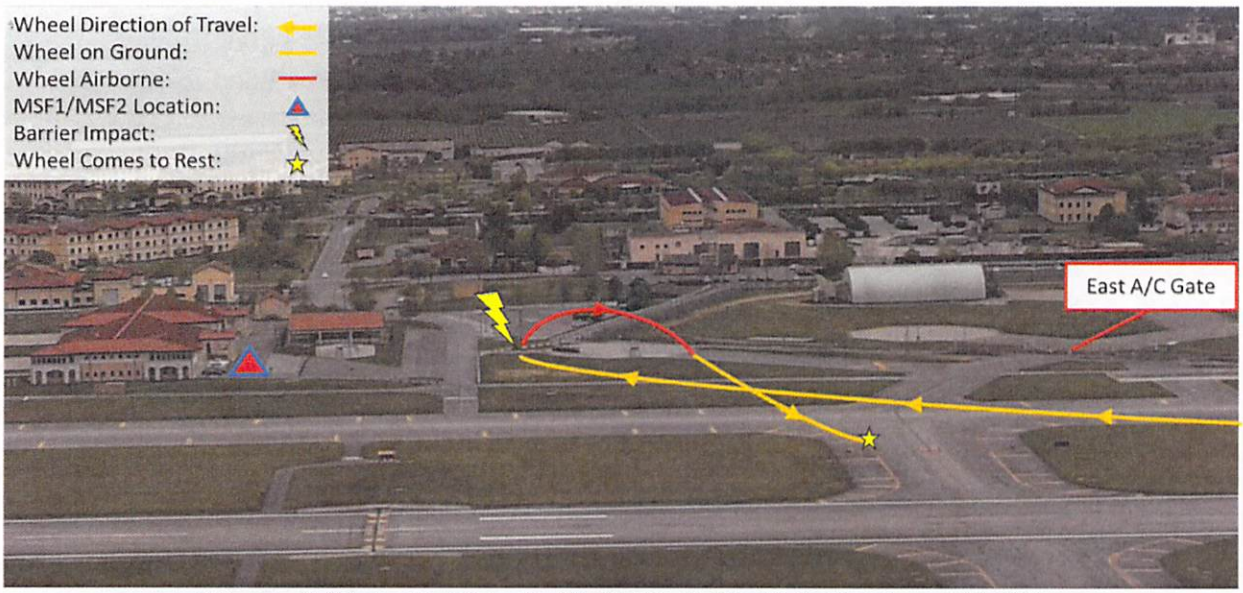


Figure 4 (Tabs R-48 to R-49, R-51, R-53, Z-6, Z-17, and Z-19)
Second perspective of the MA's wheel as it bounced around the airfield after dislocating from the MA

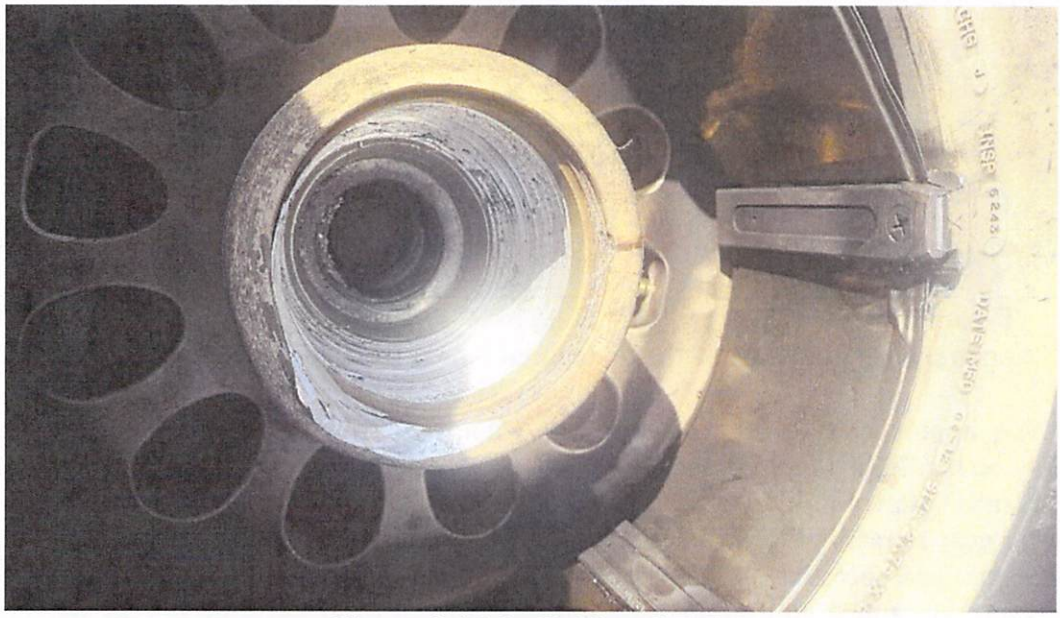


Figure 5 (Tabs R-38 and Z-7)
The wheel from the MA as it appeared at the time of recovery from the airfield

MP attempted communications on the "single frequency approach" frequency, which allowed communications with the Mishap Operations Supervisor (MOS), Departure ATC, and MW simultaneously, but they were unable to establish clear communications due to "garbled" transmissions (Tab V-1.5 and V-10.3). MP then switched his radio to the MOS frequency as the

AUX radio frequency, so MOS could hear all communication between MP and MW and provide inputs (Tab V-1.5 to V-1.6 and V-10.3). Under the belief the MA sustained a blown tire on the left MLG, MOS contacted the Wing Operations Center (WOC) Mission Director (MADDOG) to explain the emergency and that the MA would not be able to complete the mission (Tab R-37). The WOC communicated the news of the MA emergency to the 31st Fighter Wing Commander (FW/CC) and the 31st Operations Group Commander (OG/CC), who were both present in the WOC (Tab R-37). Knowing a SOF was not on duty, OG/CC and MOS directed Mishap Supervisor of Flying (MSOF), a qualified SOF, to go to the tower and fill that role (Tab R-34 and R-37). With MADDOG informed, MOS then initiated a CONFERENCE HOTEL, which connected MOS with a Lockheed Martin Aero Flight Safety Engineer (FSE) (Tabs R-34, R-37, R-41, R-55, and V-1.6). MOS informed FSE about a potentially blown tire on the MA and started to work a solution (Tabs R-55 and V-1.6). With the addition of FSE on the CONFERENCE HOTEL, MP now had MADDOG, MOS, MSOF, and FSE for support (Tabs R-34, R-37, R-55, and V-1.6).

Figure 6 (Tab Z-7)
The MA with its landing gear extended during the mishap flight

MP continued to orbit over PAYES and, with the information known at the time, directed MW to execute a detailed inspection of the MLG to look for any leaking or damaged oil and hydraulic lines (Tab V-1.5). MW reported what he perceived as a damaged rim of the wheel, but no visible damage on the MLG (Tab V-1.5 and V-10.3). Further discussion between MP, MSOF, MOS, and FSE about the perceived blown tire led to a planned course of action in which MP will execute the steps outlined in the *Landing with a Blown Tire* checklist, culminating in an approach end cable arrestment in accordance with T.O. 1F-16CM-1CL-1 (Tabs R-34, R-37, R-41, R-44, R-55, V-1.6, and V-10.3). For normal operations on runway 05, two cables are "strung" at the departure end of the runway, which are referenced as cables 4 and 5 (Tab V-1.6). To prevent an opposite direction approach on the runway, MSOF and MOS coordinated to have cables 2 and 3 strung at the approach end of runway 05 (Tabs R-41, R-44, V-1.6, and V-10.3). Due to the proximity of cable 2 to the approach end of the runway, MP planned to execute a low approach of the runway to identify whether cable 2 or cable 3 would be best for the arrestment (Tabs R-41 and V-1.6).

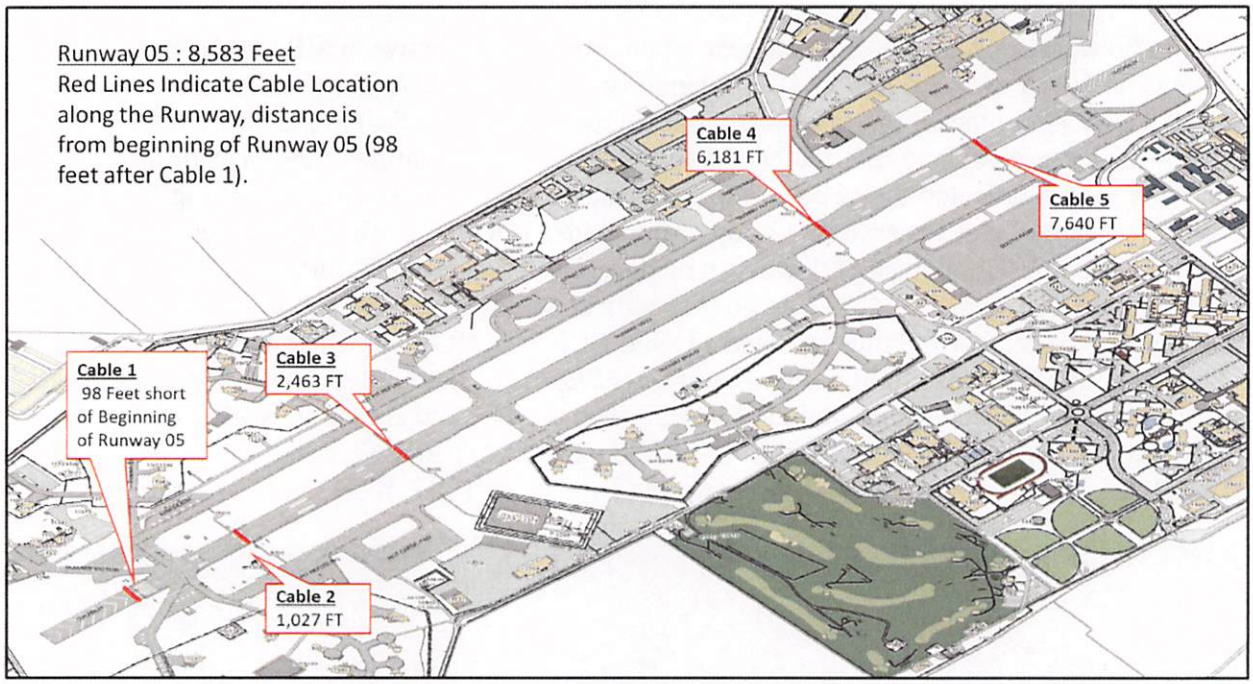


Figure 7 (Tab Z-19 and Z-21)
Cable locations on runway 05 at Aviano AB

Figure 8 (Tab Z-8)
The remaining brake assembly after the MA lost the left wheel

At approximately 13:00L, MP started a practice low approach with MW two miles behind him, intending for MW to land (Tab R-34). While MP began the practice low approach, MADDOG received a message in the WOC from the 31st Aircraft Maintenance Squadron Commander (AMXS/CC) that contained images of the recovered wheel reported by MSF1 and MSF2 (Tab R-38). MADDOG communicated this information to both MSOF and MOS to explain the MA did

not blow a tire as previously reported, but instead lost the entire wheel (Tab R-38). MSOF directed MP to execute a go-around to terminate the landing and informed him of the updated information while MSOF, MOS, and FSE developed a new plan (Tabs R-34, R-38, R-41, R-45, R-55 to R-56, V-1.7, and V-10.3). After completing the go-around, MP directed MW back to the close observation position to re-examine the left MLG and execute a close-pass by the ATC tower, which allowed Tower personnel to inspect the left MLG via binoculars (Tabs R-34, R-38, R-41, R-45, V-1.7, and V-10.3). MW and Tower personnel visually confirmed that only the brake assembly remained on the left MLG (Tabs R-34, R-38, R-41, R-45, V-1.7, and V-10.3).

Figure 9 (Tab Z-8)
The remaining brake assembly after the MA lost the left MLG as seen airborne

With the status of the left MLG confirmed, FSE recommended MP execute a gear-up, hook-up landing (Tabs R-34, R-38, R-41, R-45, R-55 to R-56, V-1.7, and V-10.3). MP successfully raised the MLG and hook and, based on the remaining levels of fuel in the MA, cleared MW to land (Tab V-1.8 and V-10.3 to V-10.4). At approximately 13:20L, MW landed his F-16 and taxied without any issues (Tab V-1.8 and V-10.3 to V-10.4). MP continued to execute the steps to prepare for a gear-up landing in accordance with T.O. 1F-16CM-1CL-1 (Tab V-1.8). As MP prepared for the gear-up landing, MSOF, MOS, and FSE discussed the effect landing on a raised cable may have on the MA in its gear-up configuration (Tabs R-34, R-38, R-41, R-45, R-55 to R-56, and V-1.8). FSE recommended landing after any raised cables due to the possibility of the external wing tanks grinding down and catching a cable on landing (Tabs R-34, R-38, R-41, R-45, R-55 to R-56, and

V-1.8). MSOF and MOS discussed if it was possible to "de-string" cables on the runway to increase the available landing distance for MP (Tabs R-34, R-38, R-41, R-45, and V-1.8). At the time, there was approximately 4,400 feet available between cables 3 and 4 (Tab V-1.8). MSOF, MOS, and OG/CC decided, based on the MA's fuel levels, there was not enough time to "de-string" the cables, so MP would have to execute a landing between cables 3 and 4 (Tabs R-34, R-38, R-41, R-45, and V-1.8). MSOF communicated the agreed-upon plan to MP, who completed all checklist items and started a 15 nautical mile final approach at approximately 13:35L to execute the gear-up landing on runway 05 (Tab V-1.8).

Figure 10 (Tab Z-9)
The MA as it prepares to land on the runway

e. Landing

Figure 11 (Tab Z-9)
The MA during landing on the runway

At 13:39L, the MA touched down on the runway past cable 3, which is located approximately 2,500 feet down the runway, via a gear-up landing (Tabs N-3 to N-4, R-35, R-39, R-41, R-46, R-56, V-1.8 to V-1.9, V-10.3, and Z-19). MP executed the approach without issue (Tabs R-35, R-39, R-41, R-46, R-56, V-1.8 to V-1.9, and V-10.3). MP shut off the engine at touchdown in

accordance with T.O. 1F-16CM-1CL-1, and continued to slide along the runway veering slightly right, using available control inputs to keep the aircraft upright and centered on the runway (Tabs N-3 to N-4 and V-1.9). The MA continued to slide down the runway until it impacted cable 4, which caused the MA to become momentarily airborne and slow down significantly (Tabs N-4 and V-1.9). The MA continued to slow to a stop and came to rest on the left external fuel tank on the right side of the runway with approximately 1,300 feet remaining (Tab V-1.9). MP accomplished an emergency ground egress of the aircraft in accordance with procedures as emergency crews responded (Tabs O-7 and V-1.9).

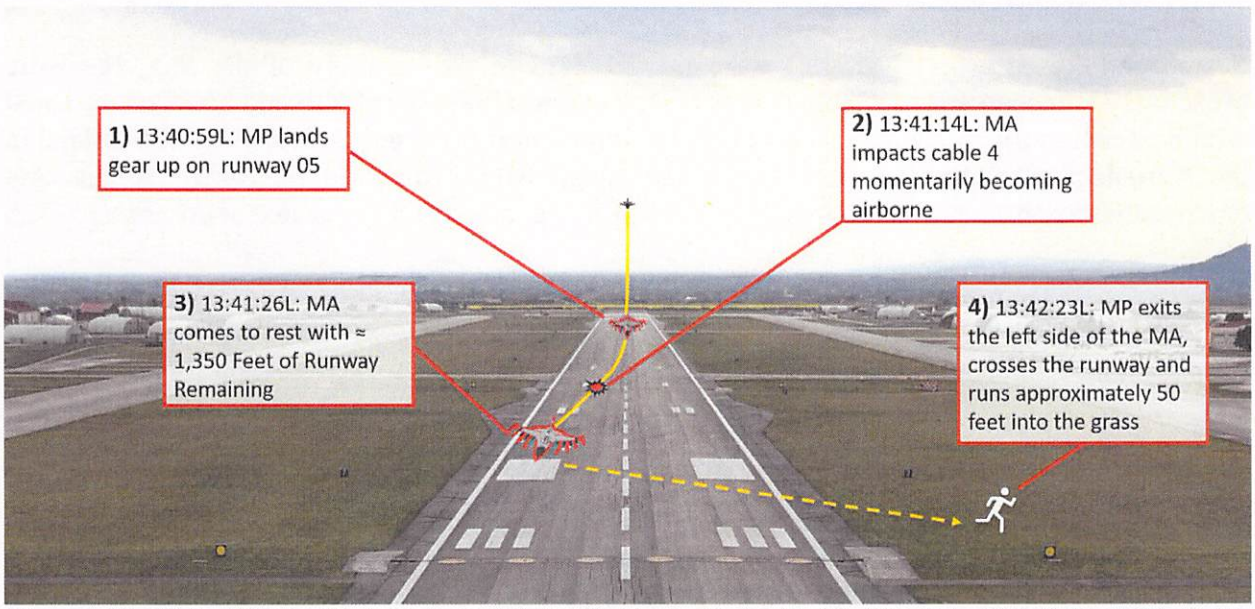


Figure 12 (Tabs N-3 to N-4, O-7, R-35, R-39, R-41, R-46, R-56, V-1.8 to V-1.9, V-10.3, Z-19, and Z-20)
The MA landing sequence

Figure 13 (Tab Z-5)
The MA after MP completed the landing and exited the cockpit

f. Egress and Aircrew Flight Equipment (AFE)

MP's AFE was properly configured, performed as expected, and there is no evidence it was a factor in the mishap (Tab V-1.2 and V-10.2).

MP accomplished an emergency ground egress from the MA without injury after the MA came to a stop (Tab V-1.9). Since the ejection seat was not utilized, it was not removed for analysis (Tab V-1.9).

g. Search and Rescue (SAR)

Search and Rescue (SAR) aircraft were not required in the recovery of the MA, but were proactively launched and available (Tabs R-34, R-41, and V-1.7). MSOF and MOS coordinated with host-nation for an alternate controlled ejection point if necessary to allow the MA to land in the Adriatic Sea, while allowing MP to land on dry land (Tab R-44 to R-45). Aviano AB emergency response units were present as the MA came to rest and responded appropriately (Tab O-7).

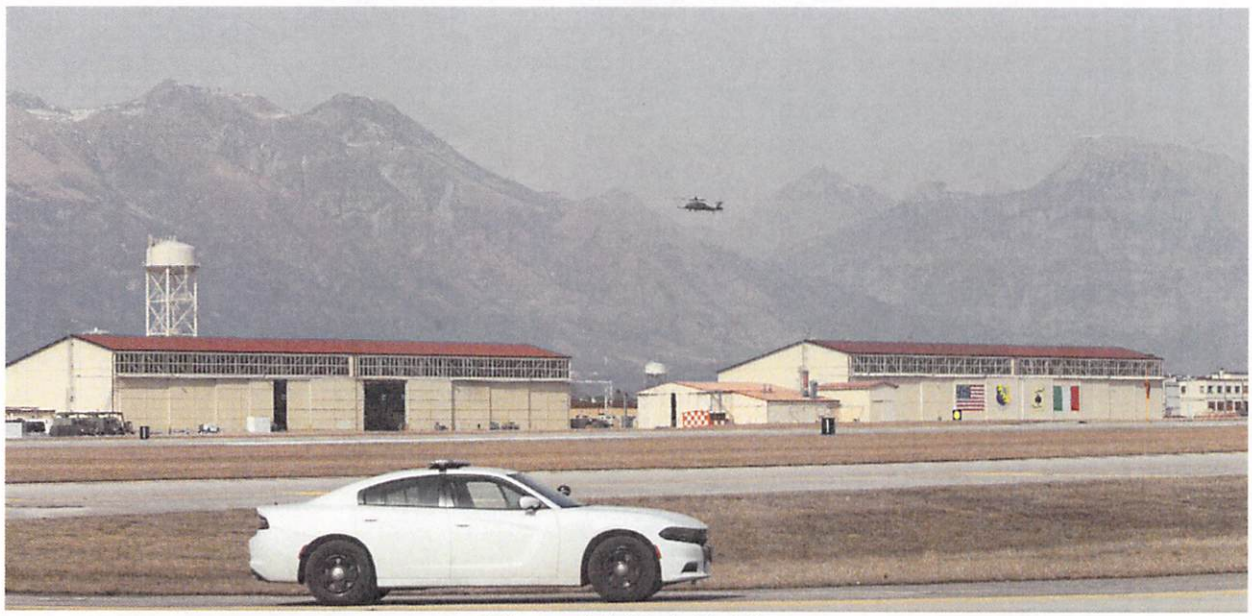


Figure 14 (Tab Z-10)
Search and rescue aircraft on scene at the mishap

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

The AAIB MXM conducted a review of the MA's maintenance documentation, including its maintenance history and Air Force Technical Order (AFTO) Forms 781. This review revealed no

discrepancies (Tab D-3 to D-27). The AFTO 781 series of forms collectively document maintenance actions, inspections, servicing, configurations, status, and flight activities (Tab D-3 to D-27). The AFTO 781 Forms, in conjunction with the Integrated Maintenance Data System (IMDS), provide a comprehensive database used to track and record maintenance actions, flight activity, and to schedule future maintenance (Tab D-3 to D-27).

A combined pre-flight/basic post-flight (PR/BPO) inspection was documented at 05:00L on 1 March 2022 with no discrepancies annotated (Tab D-4). Additionally, a walk-around inspection (WAI) was documented at 04:00L on 2 March 2022 (Tab D-4). This inspection occurs when the combined PR/BPO inspection was accomplished more than 24 hours prior to flight. Maintenance personnel completed the exceptional release (ER) documentation, clearing the MA to fly (Tab D-4 and D-11). Other maintenance records, including Time Compliance Technical Orders (TCTOs), engineering support requests (ESRs), extension letters, and historical records were reviewed with no significant findings (Tab D-3 to D-27).

b. Inspections

All MA inspections were current with previous inspections annotated, complete, and no discrepancies noted (Tab D-3 to D-27).

c. Maintenance Procedures

The combined PR/BPO inspection in conjunction with the WAI performed prior to the mishap were completed in accordance with the proper T.O. (Tab D-3 to D-27). All servicing, required inspections, and visual inspections were accomplished in their entirety and signed-off on the AFTO Form 781H with no discrepancies (Tab D-4).

d. Maintenance Personnel and Supervision

Maintenance personnel from the 31st Aircraft Maintenance Squadron (31 AMXS) and 31st Maintenance Squadron (31 MXS) performed various maintenance actions on the MA (Tab D-3 to D-27 and Tab U-3). A review of individual training records noted no discrepancies in training or certification for personnel performing maintenance of the MA (Tab T-3 to T-9). Additionally, maintenance personnel did not identify any supervisory shortfalls or hindrances that affected the quality of maintenance on the MA (Tab V-2.1 to V-2.9, V-3.1 to V-3.7, V-4.1 to V-4.4, V-5.1 to V-5.5, V-6.1 to V-6.11, V-7.1 to V-7.9, V-8.1 to V-8.3, V-9.1 to V-9.5, and V-12.1 to V-12.4).

e. Fuel, Hydraulic, Oil, and Oxygen Inspection Analyses

Hydraulic fluid samples from the MA's two hydraulic systems and lubricating oil samples from the MA's engine were sent to the Air Force Petroleum (AFPET) Office at Wright-Patterson Air Force Base (AFB), Ohio, for analysis (Tab J-3 to J-6). The AAIB reviewed the results of the analysis, which were not a factor in the mishap (Tab J-3 to J-6).

f. Unscheduled Maintenance

Unscheduled maintenance is any maintenance action taken that is not the result of a scheduled inspection (Tab D-3 to D-27). This is normally the result of a pilot-reported discrepancy (PRD)

during flight operations or a condition discovered by ground personnel during ground operations (Tab D-3 to D-27). There were no recurring or unscheduled maintenance problems with the MA that contributed to the mishap (Tab D-3 to D-27).

On 9 February 2022, maintenance members performed disassembly, cleaning, inspection, and reassembly of the MA's wheel assembly (Tab U-3). Once this process was complete and all checks verified, the wheel assembly was deemed serviceable and put into the supply inventory (Tab U-3). Aircraft maintenance members retrieved the wheel assembly for the MA from the base warehouse on 12 February 2022 (Tab U-4). After obtaining the wheel assembly from the base warehouse, it was taken to the MA and installed in accordance with the proper T.O. with no discrepancies noted (Tab D-27). The MA executed six sorties post-wheel assembly installation without incidence prior to its seventh MS (Tab U-7 to U-11).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

The MA sustained damage in the following areas, the left MLG wheel assembly, the left MLG brake assembly, the left MLG axle assembly, the left external fuel tank, the left horizontal stabilizer, the left speed brake assembly, the ECM pod, and the left and right ventral fins (Tab P-3 to P-4).

(1) Left Main Landing Gear Wheel Assembly

The mishap wheel assembly sustained significant damage to the inside of its inboard bearing hub, exterior of hub, and its six drive keys (Tabs S-9, Z-7, Z-10, EE-7, and EE-16). Once the wheel assembly separated from the MA's axle, it traveled down the active runway then crossed taxiway Bravo where it struck a concrete barrier, bounced into the air, and rolled back onto the taxiway where it came to a stop (Tabs Z-17 to Z-19).

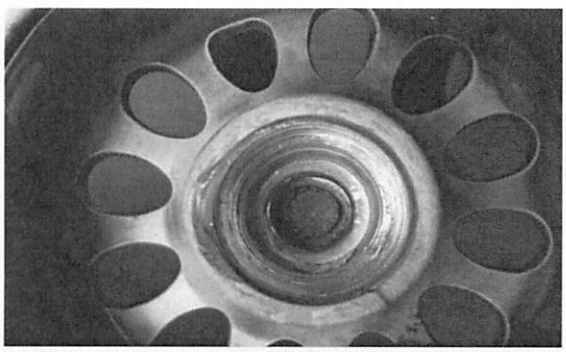


Figure 15 (Tab Z-10)
The left MLG wheel assembly pictured after the mishap

(2) Left Main Landing Gear Brake Assembly

Prior to takeoff, the wheel assembly separated from the axle assembly, resulting in the left brake assembly contacting the runway (Tabs S-7, Z-8, Z-11, Z-18, EE-9, and EE-14). As a result, the

brake assembly sustained significant material loss, resulting in a flat spot where it contacted the runway (Tabs S-7, Z-8, Z-11, Z-18, EE-9, and EE-14).

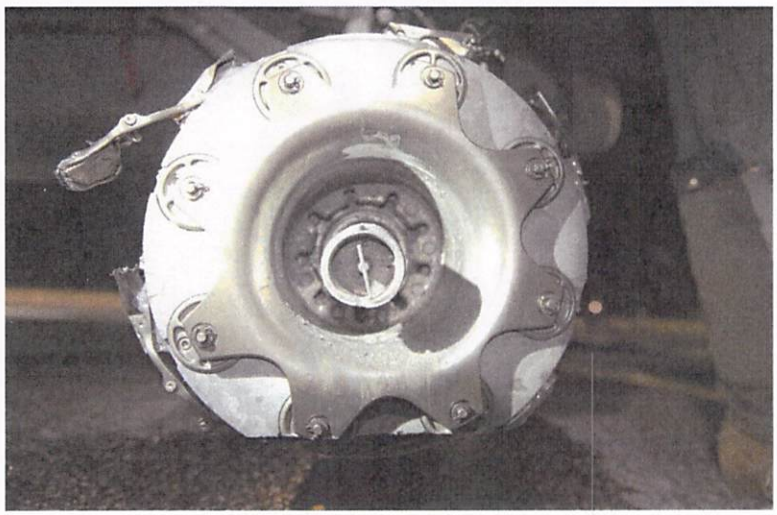


Figure 16 (Tab Z-11)
The left MLG brake assembly after the mishap

(3) Left Main Landing Gear Axle Assembly

The left main landing gear axle assembly sustained damage near the outboard bearing lower surface, as well as the axle threads (Tabs S-8, Z-11, and EE-24).

Figure 17 (Tab Z-11)
The left MLG axle after the mishap

(4) Left External Fuel Tank

As a result of the gear-up landing, the left external fuel tank sustained multiple scrapes on its lower side due to contact with the runway surface (Tab Z-12).

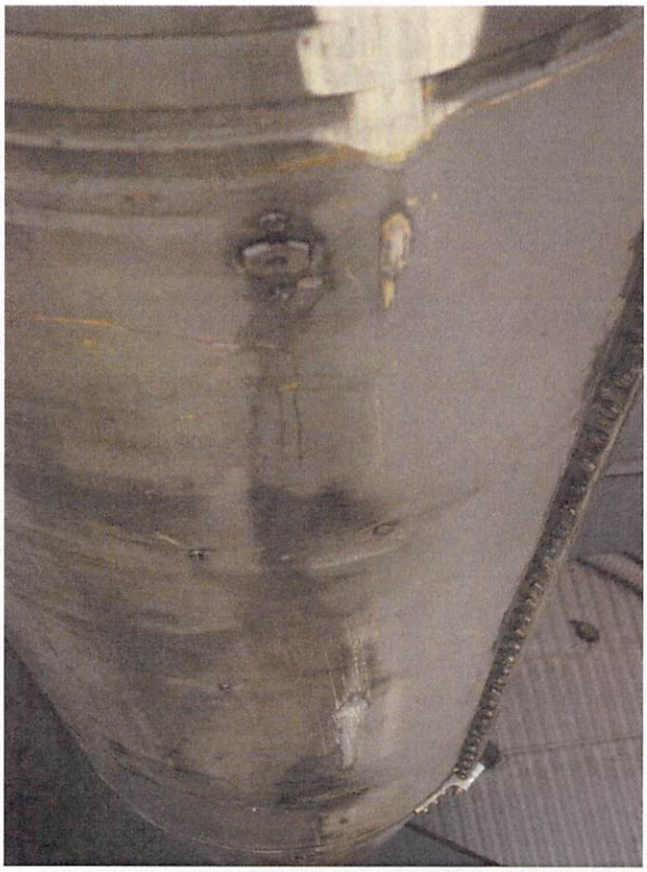


Figure 18 (Tab Z-12)
The left external fuel tank after the mishap

(5) Left Horizontal Stabilizer

When the MA came to a stop, the lower trailing edge surface of the left horizontal stabilizer contacted the runway surface (Tab Z-13).

Figure 19 (Tab Z-13)
The left horizontal stabilizer after the mishap

(6) Left Speed Brake Assembly

With the speed brakes opened to help reduce airspeed and ground speed, the left speed brake assembly lower portion contacted the runway surface resulting in the loss of material (Tabs S-6 and Z-13).

Figure 20 (Tab Z-13)
The left speed brake assembly after the mishap

(7) Electronic Countermeasures Pod

The ECM pod is located on the lower most center position of the aircraft (Tabs S-6 and Z-14). As a result of the gear-up landing, the ECM Pod supported all the aircraft weight, resulting in significant material loss and damage (Tabs S-6 and Z-14).

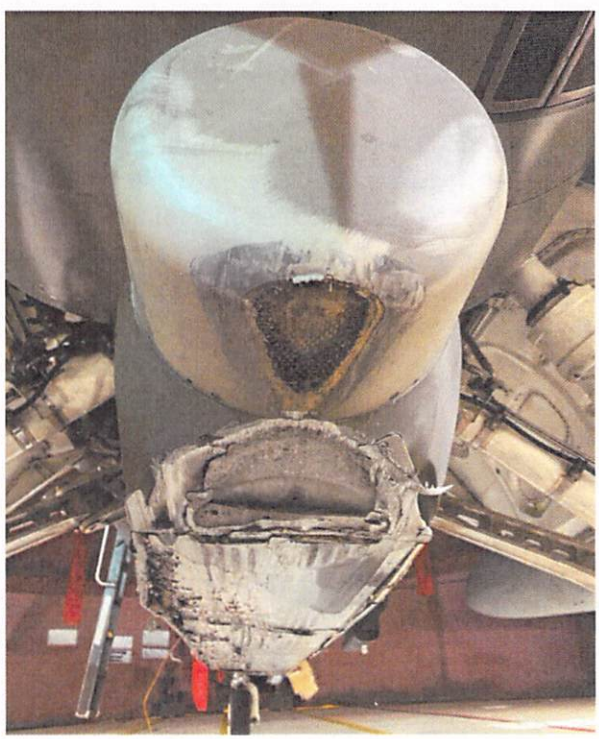


Figure 21 (Tab Z-14)
The ECM pod after the mishap

(8) Left and Right Ventral Fins

Much like the ECM Pod due to the gear-up landing, both left and right ventral fins contacted the runway surface and ground down significantly, sustaining damage and material loss (Tab Z-15).

Figure 22 (Tab Z-15)
The left and right ventral fins after the mishap

b. Evaluation and Analysis

The AAIB obtained analyses of several components, the results of which are described below.

(1) Analysis of the Left Wheel Assembly

Air Force Research Laboratory (AFRL) personnel at Wright-Patterson AFB conducted analysis of the left wheel assembly that separated from the MA during takeoff (Tabs EE-4 through EE-26). The analysis identified severe damage to the inner hub diameter with a significant amount of aluminum removed (Tab EE-7). With the hubcap removed, analysts observed flakes of metallic debris matching that of the wheel hub material (Tab EE-7). The wheel nut was loose under the hub cap with its anti-rotation tab still secured to the nut via both fasteners and safety wire, however, the feature that rotationally locks the nut to the axle was fractured, causing the wheel to come off the MA (Tab EE-7).

The outboard bearing remained inside the MA wheel assembly and was not free-spinning as is typical, but instead lodged into the bearing cup (Tab EE-7). The bearing cage was severely damaged and in two pieces with all 21 rollers present, but damaged (Tab EE-7). Additionally, the spacer, which is installed prior to the axle nut and features a key designed to rotationally lock the spacer to the axle, was found friction welded to the outboard bearing cone, with its locking key fractured, in the MA wheel assembly (Tab EE-8).

The inboard bearing cup was both visually and stereo-optically examined (Tab EE-8). Examinations identified a burr on the inside of the bearing cup, as well as a lack of residual grease

(Tab EE-8). The burr is consistent with secondary damage from the axle as the wheel came off, but no spalling, chipping, corrosion, or other similar damage was noted on the rolling surface of the cup (Tab EE-8). The analysis was inconclusive whether the lack of grease in the bearing cup was caused by heat and friction during the mishap or inadequate grease applied during installation (Tab EE-9).

(2) Analysis of the Left Axle Assembly

AFRL personnel at Wright-Patterson AFB also conducted an analysis of the left axle assembly through visual and stereo-optical examination (Tab EE-9). Discoloration was observed on the axle assembly, mostly on the bottom (Tab EE-9). Color variations within this region appeared to be oriented perpendicularly to the axle, suggesting the cones rotated on the axle (Tab EE-9).

(3) Analysis of the Left Brake Assembly

Additionally, the left brake assembly was visually examined by AFRL personnel at Wright-Patterson AFB (Tab EE-9). All damage observed on the brake assembly was consistent with secondary damage (Tab EE-9). The brake assembly was ground flat on the bottom side consistent with the weight of the aircraft on the brake when the brake assembly was damaged (Tab EE-9).

7. WEATHER

a. Forecast Weather

MP received a flight weather briefing and mission execution forecast for the departure and recovery base and the planned route of flight (Tab F-3 to F-4). The morning of the mishap, forecasted cloud ceiling and visibility for takeoff and landing was clear with a temporary forecast of visibility reduced to 4,000 meters (Tab F-3 to F-4, and W-3 to W-6). The weather forecast was not expected to change significantly over the duration of the flight (Tabs F-3 to F-4 and W-3 to W-6).

b. Observed Weather

At the time of the mishap, observed weather included winds from 210 degrees at 8 knots and clear skies with unlimited visibility (Tab W-7 to W-8). Observed weather at the time of MA landing included winds from 220 degrees at 9 knots and clear skies with unlimited visibility (Tab W-7 to W-8).

c. Space Environment

Not applicable.

d. Operations

MP operated inside prescribed operational limits with respect to weather conditions on the day of the MS (Tab G-61). MP attributed the weather conditions, mostly calm winds and clear skies, as integral in successfully landing the MA (Tab V-1.9 to V-1.10).

8. CREW QUALIFICATIONS

a. Mishap Pilot

At the time of the mishap, MP was current, qualified, and experienced as an F-16C Weapons Officer with 1,612.2 flight hours in the F-16C/D (Tab G-3 and G-62 to G-67). MP was qualified to accomplish the following tasks in the F-16C: Instructor Pilot (IP), Flight Lead (FL), and Mission Commander (MC) (Tab G-62 to G-67). MP's most recent flight prior to the MS was on 25 February 2022 and was a similar mission to the day of the mishap (Tab G-34). On the day of the mishap, MP's recent flight time in the F-16CG was as follows:

	Hours	Sorties
30 days	12.0	4
60 days	22.6	9
90 days	31.6	13

(Tab G-31)

b. Mishap Wingman

At the time of the mishap, MW was current and qualified as a Wingman with 303.3 flight hours in the F-16C/D (Tab G-36 and G-62 to G-67). MW was current and qualified to fly as an F-16 Wingman and was enrolled in the Flight Lead upgrade program at the time of the mishap, though the MS was not flown as a training mission (Tab G-62 to G-67). The MW's most recent flight prior to the MS was on 26 February 2022 and was a similar mission (Tab G-59 to G-60). On the day of the mishap, MW's recent flight time in the F-16C was as follows:

	Hours	Sorties
30 days	13.8	5
60 days	23.3	12
90 days	29.1	15

(Tab G-61)

9. MEDICAL

a. Qualifications

No evidence suggests MP or maintenance personnel were physically or medically unqualified at the time of the mishap (Tab DD-5). MP did not have a flying waiver for disqualifying medical conditions and possessed a current valid DD Form 2992 at the time of the mishap (Tab DD-5).

b. Health

No evidence suggests the health of MP or maintenance personnel was a factor in this mishap. All personnel had up to date physical health assessments and mental health assessments with no concerning findings (Tab DD-5).

c. Pathology

Base medical personnel performed toxicology testing on MP six days after the mishap (mishap occurred on 2 March 2022, sample obtained on 8 March 2022) with negative findings (Tab DD-5). Toxicology was not likely a factor in this mishap (Tab DD-5).

d. Lifestyle

After reviewing 72-hour and 7-day history from MP, there is no evidence to suggest lifestyle was a factor in the mishap (Tab DD-5).

e. Crew Rest and Crew Duty Time

Prior to performing flight duties, aircrew members must have proper crew rest, defined in AFMAN 11-202, Volume 3, *Flight Operations*, as a minimum of a 12-hour non-duty period before the designated flight duty period begins (Tab BB-15). Crew rest is defined as "free time" and includes time for meals, transportation, and the opportunity for at least eight hours of uninterrupted sleep (Tab BB-15). MP and MW stated they had adequate crew rest and denied fatigue played a role in the mishap (Tab V-2.11 and V-3.13).

10. OPERATIONS AND SUPERVISION

a. Operations

The operations tempo at the time of the mishap was high for MP and average for maintenance (Tab V-1.2, V-2.9, V-3.2, V-4.3, V-5.2, V-6.2, and V-7.6). MP also noted that his sleep schedule had been irregular due to the increased operations tempo (Tabs R-23 and V-1.2). Airfield equipment at Aviano AB was in working order for the planned MS and there were no identified airfield hazards or limitations (Tab O-3 to O-4). The AAIB found no evidence operations tempo or operational conditions were factors in the mishap (Tab V-1.2, V-2.9, V-3.2, V-4.3, V-5.2, V-6.2, and V-7.6).

b. Supervision

On the day of the MS, OG/CC approved a combined SOF and Ops Sup/Top 3 due to reduced flying operations criteria associated with the limited number of aircraft on the flight schedule in accordance with AFI 11-418 (Tabs V-1.3 and BB-7). Reduced flying is defined as six or less fighter aircraft operating at the same time (Tab BB-7). MOS was current and qualified as an Ops Sup, and current, qualified, and experienced as a Flight Evaluator and Instructor Pilot in the F-16CG (Tab G-62 to G-67). MOS reviewed ORM and qualifications for MP and MW and provided their step brief (Tab V-1.3). MOS handled all initial emergency actions for the MS until OG/CC appointed MSOF to assume the role of SOF (Tabs R-34, R-37, V-1.6, and V-10.3). MSOF was a current and qualified SOF and current, qualified, and experienced as a Flight Lead in the F-16CG (Tab V-1.6 and V-10.3).

MOS and MSOF coordinated as a team for the remaining duration of the MS to assist MP in recovering the MA (Tab V-1.6, and V-10.3). The AAIB found no evidence supervision was a factor in the mishap (Tab V-1.10).

11. HUMAN FACTORS ANALYSIS

The Department of Defense Human Factors Analysis and Classification System 7.0 (DoD HFACS 7.0) lists potential human factors that can play a role in aircraft mishaps and identifies potential areas of assessment during an accident investigation. The AAIB conducted an analysis of all listed human factors potentially relevant to the mishap, but there is insufficient evidence to find any causal or contributory.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 11-418, *Operations Supervision,* 22 December 2021

(2) AFMAN 11-2F-16V3, *F-16—Operations Procedures*, 4 February 2020, incorporating Change 2, 25 May 2021

(3) AFMAN 11-202V3, *Flight Operations*, 10 January 2022

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

b. Other Directives and Publications Relevant to the Mishap

(1) T.O. 4W1-3-5-2, *Landing Gear Wheel*, 20 July 2021

(2) T.O. 1F-16CG-2-32JG-40-1, *Landing Gear Wheels and Brakes*, 1 April 2018

(3) T.O. 1F-16CM-1, *F-16 Flight Manual*, 15 June 2021

(4) T.O. 1F-16CM-1CL-1 Change 5, *F-16 Flight Crew Checklist*, 15 June 2021

(5) Federal Aviation Administration, *Pilot/Controller Glossary*, 3 April 2014

(6) FC 3-260-18F, *Air Force Aircraft Arresting Systems Installation, Operation, and Maintenance,* 28 October 2016

c. Known or Suspected Deviations from Directives or Publications

Not applicable.

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17 May 2022

DAVID J. GORDON, Colonel, USAF
President, Abbreviated Accident Investigation Board

STATEMENT OF OPINION

F-16CG, T/N 89-2035
AVIANO AIR BASE, ITALY
2 MARCH 2022

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 referenced in those conclusions or statements.

1. OPINION SUMMARY

On 2 March 2022, the mishap aircraft (MA), an F-16CG, tail number (T/N) 89-2035, departed Aviano Air Base (AB), Italy, at 11:24 local time for an air tasking order (ATO) sortie in support of an aerial mission. The MA was assigned to the 555th Fighter Squadron (FS), "Triple Nickel," 31st Fighter Wing (FW), Aviano AB, Italy. During the Mishap Sortie (MS) takeoff roll, Mishap Pilot (MP) experienced abnormal indications including the illumination of the anti-skid light and a yaw to the left of the runway's centerline. As the MA became airborne, unbeknownst to MP, the wheel from the left main landing gear (MLG) separated from the MA and was found by airfield personnel on the taxiway. As a result of abnormal indications observed during the takeoff roll and landing gear retraction, MP initially suspected a blown tire on takeoff. MP canceled the planned route and instructed the Mishap Wingman (MW) to inspect the MA landing gear for damage. However, wing leadership informed MP and MW the left MLG wheel was no longer attached to the MA. Upon recommendation of Aviano AB supervision and the flight safety engineer (FSE), MP executed a gear-up landing to recover the MA. Around 13:40L, the MA landed gear-up on runway 05 and skidded along the runway until it came to rest. MP was uninjured and exited the MA safely as emergency vehicles responded. Preliminary estimates put the cost of repairing the MA at a minimum of $5.3 million, with a final evaluation cost of $6.1 million.

2. CAUSE

I find, by a preponderance of the evidence, that the cause of the mishap was the failure of the MA's left outboard MLG wheel bearing. The excessive heat and friction created by the failed wheel bearing caused softening and deformation of the bearing cone. Rotational forces of the spinning wheel led to undesired rotation of the cone around the fixed axle. Friction between the stationary spacer and rotating bearing cone was sufficient to friction-weld the bearing cone to the spacer. Once fused, shear forces fractured the anti-rotational tab on the spacer and allowed the spacer to rotate in the counter-clockwise direction. Friction between the rotating spacer and wheel nut was sufficient to shear the locking tab on the wheel nut, which allowed the wheel nut to loosen during the takeoff sequence. Once the wheel separated from the aircraft, the only course of action to safely recover the aircraft was to land with the landing gear retracted. The most significant damage sustained by the MA occurred during the gear-up landing.

The evidence indicates premature wear was caused by pre-existing damage or defect of the outboard MLG bearing, incorrect preload, contamination with debris, insufficient spacer support, or a combination thereof. The exact cause was undetermined due to secondary damage to the recovered components. Premature wear caused excessive heat and friction in the bearing assembly, which consumed the lubricating grease and exacerbated the deterioration over the course of the six takeoff and landings prior to the MS. During the takeoff roll, the wheel bearing seized and sheared the anti-rotational tabs that prevent the wheel nut from coming off. This allowed the wheel nut to unscrew from the axle and liberated the wheel from the landing gear assembly prior to the MA becoming airborne. As the aircraft became airborne, the brake assembly briefly contacted the runway and sustained damage.

This board examined all evidence related to the mishap and interviewed aircraft maintenance personnel who assembled the wheel and installed it on the aircraft. We did not identify any evidence of errors in the assembly of the wheel or MLG bearings that would cause or contribute to the failure of the wheel bearings. The correct wheel bearing part numbers were used during wheel assembly and were installed using technical order procedures. The maintainers were trained, qualified, and under appropriate supervision during the wheel assembly, which was adequately documented. The process for ensuring that bearings are adequately greased during assembly was sufficient. Three days after assembly, the wheel was installed on the MA using correct T.O. procedures, tools, and documentation. This board was unable to determine the precise cause of the bearing failure due to secondary damage of bearing components during the mishap.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

I find that there were no substantially contributing factors to the mishap.

4. CONCLUSION

After a comprehensive investigation into this mishap, I find, by a preponderance of the evidence, the cause of the mishap was the failure of the outboard wheel bearing on the left main landing gear which resulted in the wheel separating from the aircraft.

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17 May 2022

DAVID J. GORDON, Colonel, USAF
President, Abbreviated Accident Investigation Board

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