UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

B-2A, T/N 90-0041

393d BOMB SQUADRON
509th BOMB WING
WHITEMAN AIR FORCE BASE, MISSOURI

LOCATION: WHITEMAN AIR FORCE BASE, MISSOURI

DATE OF ACCIDENT: 10 DECEMBER 2022

BOARD PRESIDENT: COLONEL JESSE W. LAMARAND

Conducted IAW Air Force Instruction 51-307

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE GLOBAL STRIKE COMMAND

JUL 30 2025

ACTION OF THE CONVENING AUTHORITY

The report of the accident investigation board, conducted under the provisions of AFI 51-307, that investigated the 10 December 2022 mishap near Whiteman AFB, MO, involving a B-2, T/N 90-0041, assigned to the 509th Bomb Wing, substantially complies with the applicable regulatory and statutory guidance and on that basis is approved.

THOMAS A. BUSSIERE
General, USAF
Commander

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

B-2A, T/N 90-0041
WHITEMAN AFB, MISSOURI
10 DECEMBER 2022

On 10 December 2022 at approximately 1429 Central Standard Time (CST), Mishap Aircraft (MA) B-2A tail number 90-0041, assigned to the 509th Bomb Wing, experienced a landing gear failure that resulted in an aircraft mishap.

Earlier that day, at approximately 0700 CST, the MA launched from Whiteman Air Force Base (AFB), Missouri as an airborne spare on a mission to Joint Base Pearl Harbor-Hickam (JBPHH), Hawaii. The mission's objective was to fly one aircraft to JBPHH. The mission planning, maintenance, aircraft servicing, maintenance preflight inspections, aircrew preflight inspections, engine start, taxi, and takeoff were uneventful. Upon arriving at the enroute decision point, the MA was directed to return to Whiteman AFB, as planned.

The MA's return to Whiteman AFB was uneventful until the approach to landing on Runway 01. On the final approach, the Mishap Crew (MC) extended the landing gear and received a primary hydraulic system caution followed by a backup hydraulic system caution, indicating the system had begun to leak. During the sequence to extend the landing gear, the Left Main Landing Gear (LMLG) and Nose Landing Gear (NLG) extended fully. However, the Right Main Landing Gear (RMLG) did not extend. The MC then performed a successful emergency gear extension, which resulted in all three landing gears (LMLG, RMLG, and NLG) indicating down and locked.

Upon touchdown, at approximately 1429 CST, the LMLG collapsed. As the MA continued down the runway, the left wing dragged several thousand feet, rupturing the left fuel surge tank under the wing and causing a fire that spread to the left outboard fuel tank. The MA came to a stop with the left wing extended into the grass infield and the fuel in the left surge tank feeding a left-wing fire. The MC safely egressed the MA. Firefighters battled the fire as the left fuel surge tank and then the left outboard fuel tank exploded, destroying the left wing. The emergency terminated at 2051 CST. There were no injuries. The MA incurred over an estimated $300 million in damage to the LMLG and outer left wing. There was approximately $27,500 in damage to the airfield.

The Accident Investigation Board (AIB) President found by a preponderance of evidence that the mishap was caused by a truck position sequence valve hydraulic CryoFit ® coupling failure. Additionally, the AIB President found two substantially contributing factors: (1) Main Landing Gear (MLG) design vulnerabilities caused the lock link assembly to move out of the required overcenter (locked) position during an emergency gear extension; and (2) the delay in using Aqueous Film Forming Foam (AFFF) to quickly extinguish the fire allowed the fire to spread, causing more external damage.

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 by the United States or by any person referred to in those conclusions or statements.

SUMMARY OF FACTS AND STATEMENT OF OPINION
B-2A, T/N 90-0041
WHITEMAN AFB, MISSOURI
10 DECEMBER 2022

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFFF	Aqueous Film Forming Foam
AFGSC	Air Force Global Strike Command
AFI	Air Force Instruction
AFMAN	Air Force Manual
AFPET	Air Force Petroleum Agency
AFRL	Air Force Research Laboratory
AFRL/RX	Air Force Research Laboratory's Materials and Manufacturing Directorate
AFTO	Air Force Technical Order
AGE	Aerospace Ground Equipment
AGL	Above Ground Level
AIB	Accident Investigation Board
AMOPS	Airfield Management Operations
AR	Aerial Refueling
ARFF	Aircraft Rescue and Fire Fighting
ARTCC	Air Route Traffic Control Center
BS	Bomb Squadron
BW	Bomb Wing
CSMU	Crash Survivable Memory Unit
CST	Central Standard Time
CT	Computed Topography
DAFI	Department of the Air Force Instruction
DEP	Data Entry Panel
DME	Distance Measuring Equipment
DoD	Department of Defense
EP	Emergency Procedure
ER	Exceptional Release
FCC	Flight Control Computer
FCIF	Flight Crew Information File
ft	Feet
g	Gravitational Force Equivalent
HFACS	Human Factors Analysis and Classification System
HPO	Hourly Post Flight
IAP	Initial Approach Point
IAW	In Accordance With
IFE	In-Flight Emergency
ILS	Instrument Landing System
IMDS	Integrated Maintenance Data System
IP	Instructor Pilot
JBPHH	Joint Base Pearl Harbor-Hickam
KCAS	Knots Calibrated Airspeed
KSZL	Whiteman AFB Airport Code
LMLG	Left Main Landing Gear
MA	Mishap Aircraft
MC	Mishap Crew
MCC	Mishap CryoFit ® Coupling
MDU	Multipurpose Display Unit
MLG	Main Landing Gear
MO	Missouri
MP	Mishap Pilot
MP1	Mishap Pilot 1
MP2	Mishap Pilot 2
MPH	Miles Per Hour
MS	Mishap Sortie
MSL	Mean Sea Level
MX	Maintenance
NLG	Nose Landing Gear
NM	Nautical Mile
NOTAM	Notices to Air Mission
OGP	Onboard Ground Processor
PCAS	Primary Crash Alert System
PDM	Programmed Depot Maintenance
PF	Pilot Flying
PNF	Pilot Not Flying
PRP	Personnel Reliability Program
psi	Pounds per Square Inch
PSLU	Proximity Sensor Logic Unit
RADAR	Radio Detection and Ranging
RMLG	Right Main Landing Gear
RWY	Runway
SOF	Supervisor of Flying
SPO	System Program Office
TCTO	Time Compliance Technical Order
T/N	Tail Number
TO	Technical Order
TPA	Truck Position Actuator
USAF	United States Air Force
WAFBI	Whiteman AFB Instruction
WSO	Weapon System Operator
WOW	Weight on Wheels
ZKC	Kansas City ARTCC

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 20 January 2023, General Thomas A. Bussiere, Commander, Air Force Global Strike Command (AFGSC), appointed Colonel Jesse W. Lamarand to conduct an Accident Investigation Board (AIB) for a mishap that occurred on 10 December 2022 involving a B-2A Spirit aircraft, tail number (T/N) 90-0041, at Whiteman Air Force Base (AFB), Missouri (MO) (Tab Y-3 to Y-4). The investigation was conducted in accordance with (IAW) Air Force Instruction (AFI) 51-307, *Aerospace and Ground Accident Investigations*, from 1 February 2023 to 23 June 2024. The board members included a Pilot Member (Major), two Legal Advisors (Majors), two Maintenance Members (one Senior Master Sergeant and one Master Sergeant), and three Recorders (two Technical Sergeants and one Staff Sergeant) (Tab Y-3 to Y-14). A Human Factors specialist (Major), B-2 Engineering specialist (Civilian), B-2 Safety Engineering specialist (Civilian), B-2 Hydraulic Equipment specialist (Master Sergeant), B-2 Landing Gear specialist (Civilian), Firefighting specialist (Civilian), and Licensed Medical Practitioner (Captain) were appointed as Subject Matter Experts (Tab Y-15 to Y-27).

b. Purpose

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

2. ACCIDENT SUMMARY

On 10 December 2022 at 1429 Central Standard Time (CST), the Mishap Aircraft (MA) B-2A, T/N 90-0041, callsign DEATH 12, assigned to the 509th Bomb Wing (509 BW), Whiteman AFB, MO, landed at Whiteman AFB and experienced an aircraft mishap (Tab N-4 to N-5). After declaring an in-flight emergency due to a hydraulic system failure related to the Main Landing Gear (MLG), the Mishap Crew (MC), consisting of Mishap Pilot 1 (MP1) and Mishap Pilot 2 (MP2), performed an emergency landing gear extension and landed the aircraft, but the Left Main Landing Gear (LMLG) collapsed immediately after landing (Tab CC-81). The left wing struck the runway and was dragged several thousand feet (ft) as the MC attempted to stop the MA (Tab N-5 to N-8). The MA came to a stop in the grass infield with the left wingtip on fire (Tabs N-5 to N-8 and V-12.4). The fire, fed from the left surge fuel tank, caused the left surge fuel tank to explode, then spread to the left outboard fuel tank, which exploded shortly afterwards (Tabs R-186 to R-187, and V-12.4). There were no fatalities or injuries. The left wing and LMLG were damaged to the extent of over an estimated $300 million (Tab CC-81). The runway was damaged to the extent of approximately $27,500 (Tab CC-32).

3. BACKGROUND

a. Air Force Global Strike Command (AFGSC)

AFGSC is a U.S. Air Force major command with headquarters at Barksdale AFB, Louisiana. The command provides strategic deterrence, global strike capabilities, and combat support to combatant commands around the globe. Comprised of more than 33,700 Airmen and civilians, AFGSC is responsible for the nation's three intercontinental ballistic missile wings, the Air Force's entire bomber force, including B-1, B-2, and B-52 Bomb Wings, Air Force Nuclear Command, Control, and Communications systems, and operational and maintenance support to organizations within the nuclear enterprise (Tab CC-3 to CC-5).

b. 509th Bomb Wing (509 BW)

The 509 BW operates and maintains the B-2A Spirit, Stealth Bomber, in Total Force Integration with the Air National Guard's 131st Bomb Wing (131 BW). The Wing's mission is to "Execute Nuclear Operations and Global Strike...Anytime, Anywhere!" The 509 BW is also host to six tenant units at Whiteman AFB: The Air Force Reserve 442d Fighter Wing, Missouri Army National Guard 1st Battalion 135th Aviation Unit, 72d Test and Evaluation Squadron, 325th Weapons Squadron, Office of Special Investigations Detachment 811, and 20th Attack Squadron (Tab CC-7 to CC-9).

c. 131st Bomb Wing (131 BW)

The 131 BW, located at Whiteman AFB, also operates and maintains the B-2A, in Total Force Integration with the 509 BW. The Wing's primary operational mission is to provide full-spectrum, expeditionary B-2A global strike and combat support capabilities. A unit of the Missouri Air National Guard, the 131 BW is also responsible for performing combat and emergency duty in support of federal and state missions (Tab CC-11).

d. 393d Bomb Squadron (393 BS)

The 393 BS trains and equips pilots to fly the B-2A Spirit in combat (Tab CC-13). Consituted as the 393d Bombardment Squadron on 28 February 1944, the 393 BS is one of the most storied bomb squadrons in the Air Force. It has been home to B-17s, B-29s, B-47s, B-50s, B-52s, and FB-111s. Its most famous missions happened on 6 and 9 August 1945 when the 393d took off from North Field on Tinian Island carrying the first operational atomic bombs in the belly of the B-29. Today, 393 BS is a bastion of strategic deterrence and provides worldwide combat capability in support of nuclear and conventional taskings (Tab CC-13 to CC-17 and CC-23).

e. B-2A Spirit

(1) Bomber Overview. The B-2A Spirit is a multi-role bomber capable of delivering both conventional and nuclear munitions. The B-2A brings massive firepower to bear, anywhere on the globe through previously impenetrable defenses. The B-2A provides the penetrating flexibility and effectiveness inherent in manned bombers. Its low-observable characteristics give it the unique ability to penetrate an enemy's sophisticated defenses and threaten its most valued, and heavily defended targets. Its capability to penetrate air defenses and threaten effective retaliation provides a strong, effective deterrent and combat force well into the 21st century (Tab CC-15 to CC-16).

(2) Aircraft Relevant Systems. The following systems are relevant to this mishap.

(a) Hydraulic System

The hydraulic power system has two parts: a main system with several sub-systems, and a monitoring system that indicates status and health. The main subsystems include pumps, hydraulic fluid reservoirs, filters, heat exchangers, and accumulators (Tab CC-81). Hydraulic power is provided by redundant, independent, high pressure hydraulic subsystems. Each subsystem is powered by variable delivery, pressure-compensated hydraulic pump assemblies capable of producing sufficient flow. A self-pressurizing reservoir provides and maintains pump inlet fluid under low return pressure to the pumps (Tab CC-81). The monitoring system transmits hydraulic fluid level, temperature, and pressure data to the flight control system and to the controls and displays system for status reporting, data comparison, and data recording (Tab CC-81).

The system does not normally exchange fluid between the primary and backup hydraulic systems (Tab CC-81). However, the Switching Valves may allow fluid to be transferred when switched from the primary system to the backup system (Tab CC-81).

The hydraulic system plumbing uses titanium tubing, and CryoFit ® fittings are used for many of the tubing joints (Tab CC-81). Externally, a CryoFit ® coupling is a cylindrical sleeve that fits around the outside of the two lines which it is joining. Internally, a CryoFit ® coupling has knurling (i.e., small ridges) to add tensile strength to the joint. CryoFit ® couplings need to be submerged in liquid nitrogen prior to installation. While in liquid nitrogen, the coupling is mechanically expanded by pulling a tapered mandrel through the center bore. The coupling will maintain the expanded size while in the liquid nitrogen. This is known as the expanded condition. The coupling is then fitted over the titanium hydraulic lines, as seen in Figure 1 below (Tab CC-81).

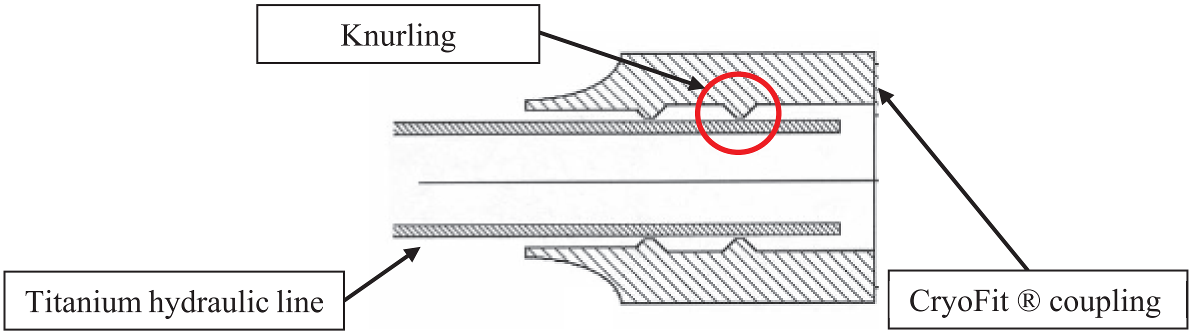

Figure 1: CryoFit ® Coupling Cross Section in Expanded Condition (Tab CC-81)

When the CryoFit ® coupling is returned to room temperature, it returns to its originally machined dimensions (Tab CC-81). Coupling shrinking is resisted by the titanium of the hydraulic line or T-fitting (Tab CC-81). A fluid-tight seal is formed when the machined teeth inside the CryoFit ® coupling "bite" into the hydraulic line or T-fitting as the coupling warms. This creates a "pooch," which resists tension pullout loads, as seen in Figure 2 below (Tab CC-81).

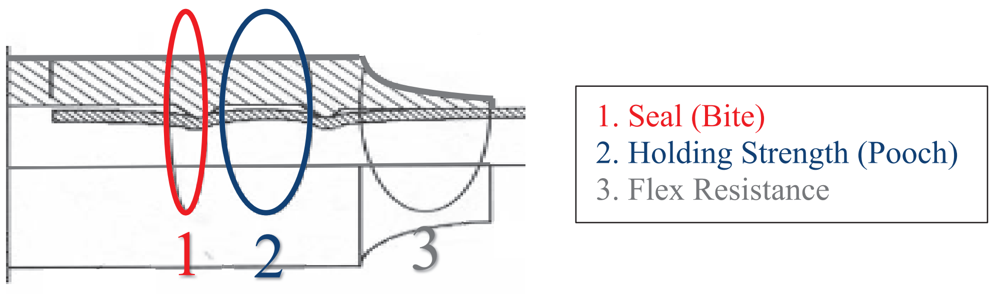

Figure 2: CryoFit ® Coupling Cross Section in Relaxed Condition (Tab CC-81)

(b) Landing Gear

The landing gear system supports the aircraft on the ground during towing, taxi, takeoff, and landing. The system consists of a conventional tricycle configuration using a steerable, dual-wheel Nose Landing Gear (NLG), a RMLG, and a LMLG, each with a four-wheel truck. The NLG retracts in the aft (i.e., rearward) direction, and the MLG retract forward. The landing gear system extends through two independent means: normal and emergency (Tab CC-81 to CC-82).

The landing gear is controlled electronically but actuated hydraulically (Tab CC-81 to CC-82). During normal operations, the landing gear is extended and retracted by positioning the Landing Gear Handle. Emergency extension is controlled by positioning the Landing Gear Emergency Lowering Switch (Tab CC-81 to CC-82). The landing gear collectively operate on one of two hydraulic systems to extend and retract the gear. Flight Control Computers (FCCs), in conjunction with the Proximity Sensor Logic Units (PSLUs), control hydraulic pressure source selection.

Normal extension is powered by the primary hydraulic system and alternately powered by the backup system under conditions discussed below (Tab CC-81 to CC-82).

MLG components include the Truck Beam, Shock Strut, Upper and Lower Drag Braces, and the Lock Link Assembly, which is comprised of the Upper and Lower Lock Links, Lock Springs, and the MLG Lock Actuator and the Truck Position Actuator (TPA) as seen in Figure 3 below. MLG extension and retraction is initiated by the Landing Gear Control Handle or the Landing Gear Emergency Lowering Switch. Extension and retraction are monitored and controlled by the FCCs, PSLUs, and proximity sensors, which are actuated by the hydraulic system (Tab CC-81 to CC-82).

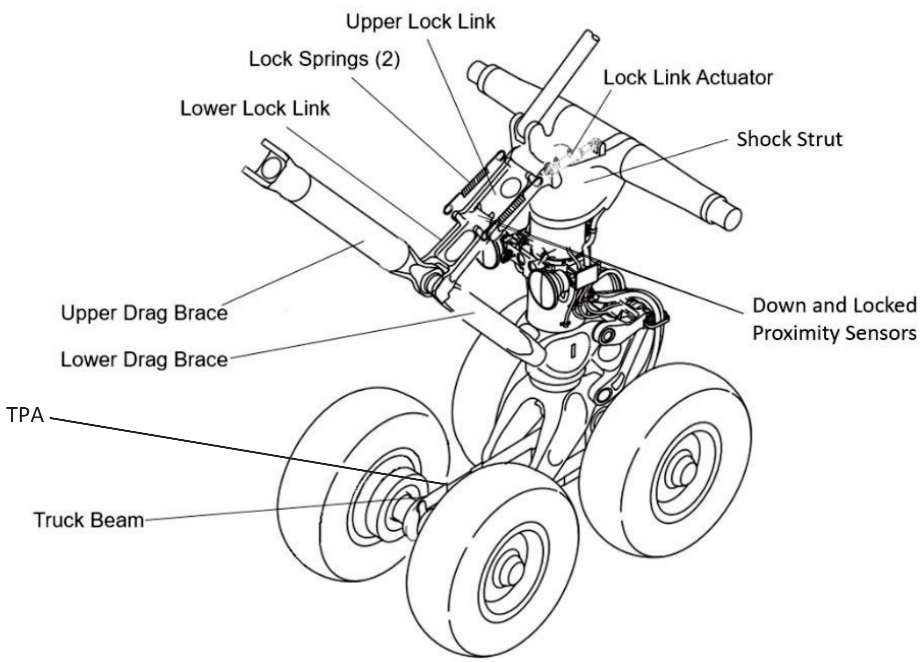

Figure 3: First view of MLG Components (Tab CC-82)

The PSLUs manage the gear extension by issuing driver commands, which reposition valves throughout the landing gear subsystem. The LMLG and RMLG drivers are separate from each other and transfer independent of each other according to the progress each gear is making during the extension event (Tab CC-81 to CC-82).

(i) Normal Extension

The normal MLG extension starts when the landing gear handle is moved to the down position in the cockpit. The following steps occur in a normal extension (Tab CC-82 to CC-83):

1. **MLG Switching Valve shuttles to primary**. This pressurizes the hydraulic circuit that feeds the valves and actuators involved in gear extension.
2. **MLG doors hydraulically open**.
3. **MLG unlocks and extends**.
4. **Truck positioner actuator extends and pivots the beam to landing configuration**.

5. **Force is applied to the lock link assembly via the MLG Lock Actuator**. This holds the Lock Link Assembly and MLG in the down and locked position.

The normal MLG extension is complete when the MLG Lock Link Assembly rotates to the overcentered position and associated proximity switches indicate "Target NEAR" (Tab CC-82 to CC-83). The truck beam pivots to its mechanical stop, positioning the MLG wheels in a toe-down configuration for landing (Tab CC-82 to CC-83).

The PSLUs have timers for each step of the landing gear extension and retraction sequence (Tab CC-82 to CC-83). If any of the steps exceed its timer, the primary and alternate PSLUs will alternately issue commands to execute sequenced actions up to three times before halting the landing gear operation.

Restrictors are placed throughout the landing gear system to control actuator speed operation. They are located next to the MLG Lock Actuators, TPAs, and MLG Retract Actuators (Tab CC-82 to CC-83).

Once the landing gear is extended normally, the MLG is held down and locked by gravity, air load, landing gear geometric design, the Lock Link Assembly being held locked/overcenter by the MLG Lock Springs, and a MLG Lock Actuator applying force, as seen in Figure 4 below (Tab CC-82 to CC-83).

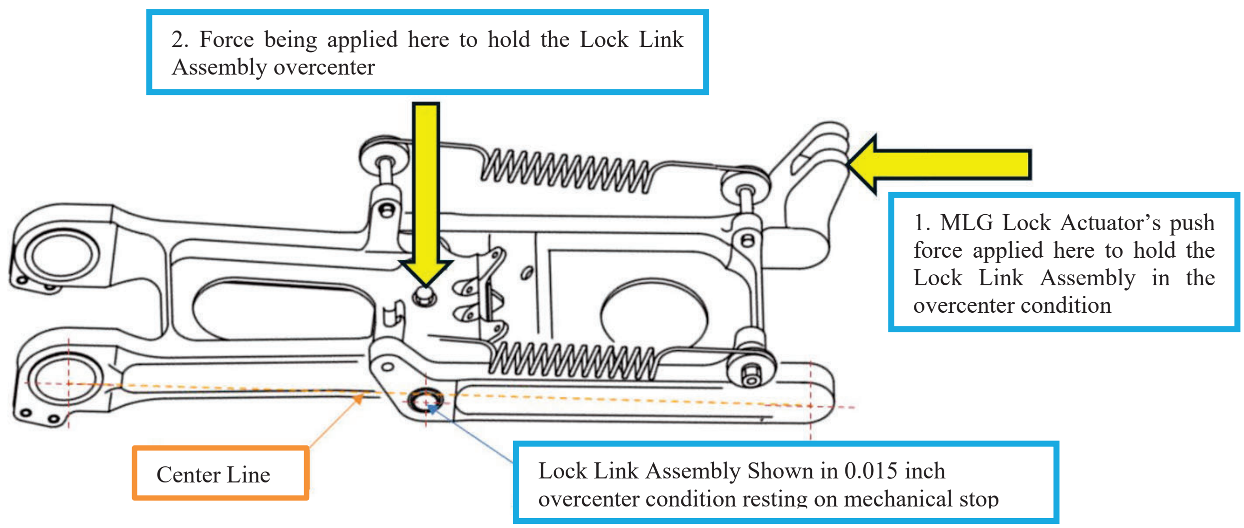

Figure 4: MLG Lock Link Assembly pictured with an orange dashed center line to highlight the degree of overcenter required for the gear to be safe in the down and locked configuration. The yellow arrows indicate the location and direction of the force applied. The overcenter position also exists in the up and locked position (Tab CC-83).

(ii) Emergency Extension

Should both primary hydraulic and backup hydraulic systems fail, a separate emergency extend system is available to extend the NLG and stored pressure is available to extend both MLG (Tab CC-83).

The emergency gear extension is complete when MLG Lock Link Assembly rotates to the overcentered position and associated proximity switches indicate "Target NEAR." Down and locked is reported to the PSLUs by the same two proximity sensors on the Lock Link Assembly as in a normal gear extension (Tab CC-83). After the MLG is extended by gravity and air loads it is held down and locked by the MLG Lock Springs (Tab CC-83). A major difference between the normal and emergency gear extensions is that active force from the MLG Lock Actuator is not holding the MLG Lock Assembly overcenter following an emergency extension (Tab CC-83). Instead, the MLG are held down and locked only by the two springs, which exert approximately 100 pounds each (200 pounds total) of force into the MLG Lock Link Assembly on which they are mounted (Tab CC-83).

4. SEQUENCE OF EVENTS

a. Mission

The Mishap Sortie (MS) was scheduled as a daytime, two-ship formation, aircraft commander upgrade training sortie from Whiteman AFB, MO, and the primary mission for the formation was to fly one aircraft to JBPHH, Hawaii (Tabs K-4, V-1.3, and V-2.3). The MA was an airborne back-up to ensure primary mission completion (Tab V-2.3). The planned mission profile included a formation departure, simulated weapons activity, and aerial refueling prior to a formation break-up (Tab V-1.3). After the formation break-up, if the MA was not required to assume the primary mission, then the MC would return to Whiteman AFB, MO for an approach and landing by MP2 (Tab V-1.3). MP1 was in the left seat and MP2 was in the right seat (Tabs K-4, V-1.3, and V-2.3).

The two-ship formation, for which the MS was the second aircraft, was the only planned flight formation at Whiteman AFB on 10 December 2022 and was approved via normal scheduling processes (Tab K-4, K-10 to K-14, and K-21).

b. Planning

Mission planning took place on 9 December 2022 (Tab V-1.19). The formation lead, in the primary aircraft, led the mission planning, which included creating the route, developing the tactical scenario, and briefing the plan to the formation using standardized briefing computer aids and the Whiteman AFB inflight guide (Tab V-1.19 to V-1.24). The mission was thoroughly briefed to both crews (Tab V-1.20). MP2 conducted the crew brief for the MS (Tab V-1.21). The MC completed mission planning and departed Whiteman AFB at approximately 1500 CST on 9 December and entered crew rest (Tab V-1.19 and V-2.22).

c. Preflight

The MC arrived at approximately 0430 CST on 10 December 2022 at the Combined Operations Building (Tab V-1.19 to V-1.20 and V-2.3). The MC picked up and inspected their aircrew flight equipment (AFE) (Tab V-2.3 and V-7.3). They received a verbal brief and printed copy of the weather brief including takeoff weather for Whiteman AFB, enroute weather, weather on the aerial refueling track, and landing weather for JBPHH and Whiteman AFB (Tabs V-19.3 and W-3 to W-15). The MC filed their flight plans with Airfield Management Operations (AMOPS) and received a printed copy of the Notices to Air Missions (NOTAM) for JBPHH, Whiteman AFB, and enroute divert airfields (Tab K-6 to K-20).

The MC received a step brief from the operations supervisor (the 393 BS Commander) including aircraft assignments and status (Tabs V-1.22, V-19.3, and AA-9 to AA-25). Following the brief, the MC proceeded to the flightline (Tab V-1.23). MP1 performed a preflight walk-around inspection of the MA, and no anomalies were noted (Tab V-1.11 to V-1.12). The MC started the MA, and no unplanned maintenance was required during start-up (Tab V-2.3 to V.2-4 and V-2.24).

d. Summary of Accident

Taxi, takeoff, and departure were uneventful (Tab V-1.20 to V-1.21, V-10.4, and V-19.3). Approaching the decision point, the formation lead determined their aircraft was mission capable and directed the MC to split from the formation and return to Whiteman AFB as planned (Tab V-1.3 and V-2.4). The tanker aircraft was delayed, so the MC elected to bypass aerial refueling training, which was not required for mission success (Tab V-1.3, V-1.9, and V-2.4 to V-2.5). The flight to the Whiteman AFB local area was uneventful (Tab V-1.3 and V-1.10). Prior to the landing gear extension, the only malfunction the MC noted was a minor, unassociated mission system malfunction (Tab V-2.5, V-2.15, and V-2.24).

At approximately 1423 CST on 10 December 2022, the MC was cleared for the Instrument Landing System (ILS) approach to Runway (RWY) 01 at Whiteman AFB by Kansas City Air Route Traffic Control Center (ARTCC) (ZKC) (Tabs V-1.3, V-2.5, and N-3 to N-4). MP2 was piloting the MA and performing Pilot Flying (PF) duties. MP1 was performing Pilot Not Flying (PNF) duties, such as performing checklist procedures (Tab V-1.3 and V-2.4 to V-2.6).

At 1424:30 CST, MP1 placed the landing gear handle to the down position at approximately 200 Knots Calibrated Airspeed (KCAS), below the B-2A's prescribed gear limit speed (Tabs V-1.3 to V-1.4, V-2.6, and CC-83 to CC-85). Placing the landing gear handle down transmits electrical control signals to hydraulically actuate the gear extension sequence (Tab CC-83 to CC-85). Prior to lowering the landing gear handle, all indications were optimal, and the landing gear extension sequence began normally. The LMLG, RMLG, and NLG doors unlocked as designed (Tab CC-83 to CC-85). However, as the sequence valve hydraulic lines were pressurized in preparation for actuating the RMLG Unlock Actuator, the Truck Position Sequence Valve CryoFit ® coupling (i.e., Mishap CryoFit ® Coupling (MCC)), failed as depicted in Figure 5 below (Tab CC-83 to CC-85).

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Figure 5: Failed MCC in RMLG Wheel Well (Tab S-14)

The MCC failure expelled the 1/2-inch diameter MCC from its compatible T-fitting, preventing hydraulic pressure from reaching the RMLG sequence valve circuit, which would have unlocked the RMLG. This failure created an opening in the MLG hydraulic circuit, causing hydraulic fluid to be pumped overboard rapidly (Tab CC-83 to CC-85). This loss caused an immediate drop in pressure in the primary hydraulic system (Tab CC-83 to CC-85).

At 1424:33 CST, the Master Caution light illuminated, and a primary hydraulic system caution appeared on the Multipurpose Display Unit (MDU) status display (Tab CC-83 to CC-85). At 1424:33 CST, the FCCs recognized the pressure drop in the primary system and electrically moved the MLG Switching Valve to the backup system, as designed (Tab CC-83 to CC-85). MP1 selected a hydraulic display on an MDU and saw that both hydraulic pumps for the primary system had failed (Tab V-1.4). As the backup system attempted to pressurize the lines to the RMLG Unlock Sequence Valve, it began expelling fluid overboard through the opening in the MLG hydraulic circuit caused by the MCC (Tab CC-83 to CC-85).

Two seconds later, at 1424:35 CST, the FCCs recognized the pressure drop in the backup hydraulic system and moved the MLG Switching Valve back to the primary system (Tab CC-83 to CC-85). This expelled even more fluid from the primary system (Tab CC-83 to CC-85). Three seconds later, at 1424:40 CST, the FCCs recognized the pressure drop in the primary system and moved the MLG Switching Valve back to the backup system (Tab CC-83 to CC-85).

By 1424:49 CST, the FCCs had moved the MLG Switching Valve between the primary and backup systems six additional times to initiate the RMLG Unlock Sequence Valve and subsequent components, but none of the attempts were successful at unlocking the RMLG (Tab CC-83 to CC-85). As the switching valve was alternating between systems, hydraulic fluid expelled from the associated reservoir, and the resulting pressure was well below standard operating pressure (Tab CC-83 to CC-85). A backup hydraulic system caution appeared after the FCCs switched to the backup system for the final time (Tab CC-83 to CC-85).

Because the NLG and LMLG actuators had integrity in their circuits downstream of their Switching Valves, the NLG and LMLG extended at a normal rate, and all proper steps of their extension sequence occurred (Tab CC-83 to CC-85). At that time, the PSLUs stopped transmitting commands to the LMLG and NLG as they had completed their extension (Tab CC-83 to CC-85). The PSLUs were still alternating and sending commands to the RMLG as described above in the normal gear extension theory of operations (Tab CC-83 to CC-85). The RMLG door began to open since the RMLG door actuators are positioned upstream of the MCC failure and therefore had sufficient hydraulic pressure to open the RMLG door (Tab CC-83 to CC-85). However, the RMLG door did not open fully, but partially opened and closed erratically due to the FCC cycling the MLG Switching Valve to compensate for the opening in the hydraulic line caused by the MCC failure (Tab CC-83 to CC-85). The RMLG did not extend because the MCC failed between the Switching Valve and the RMLG Lock Actuator, preventing the requisite pressure to unlock the gear (Tab CC-83 to CC-85). Only the NLG and LMLG extended, which is an asymmetric landing gear configuration (Tab CC-83 to CC-85).

Around 30 seconds after placing the landing gear handle down, at approximately 1425:00 CST, the MC performed an emergency gear extension to achieve a safe landing gear configuration (Tabs V-1.4 and CC-83 to CC-85). The MA was in approximately two degrees of left bank and in a two-degree nose-low descent when MP1 performed the emergency gear extension (Tabs V-2.6 to V-2.7, V-2.15, and CC-83 to CC-85). The Landing Gear Emergency Lowering Switch electrically commanded the landing gear system to isolate from both the primary and backup hydraulic systems by shuttling the Emergency Bypass Valve from a normal to an emergency configuration. It also commanded the MLG Emergency Accumulator to release the MLG by retracting the Emergency Unlock Actuator in both MLG wheel wells (Tab CC-83 to CC-85). The RMLG began extending (Tab CC-83 to CC-85).

Approximately 12 seconds after the RMLG began extending, around 1425:12 CST, the MA indicated that the RMLG was down and locked via the MDU status display and the landing gear indicator lights around the landing gear handle (Tabs V-1.4 to V-1.5 and CC-83 to CC-85). All three gear indicated down and locked at this time (Tab CC-83 to CC-85).

At approximately 1426:03 CST the MC made radio contact with the Whiteman AFB tower controller (Tab N-4). Upon initial contact, the MC declared an In-Flight Emergency (IFE) for a hydraulic failure and stated their intention to land straight ahead on Whiteman AFB RWY 01 (Tab N-4). The tower controller acknowledged the IFE and issued the MC clearance to land on RWY 01 (Tab N-4). The tower controller immediately activated the Primary Crash Alert System (PCAS), which called the Whiteman AFB Aircraft Rescue and Fire Fighting (ARFF) department, command post, AMOPS, and ambulance services (Tab N-4 to N-5).

MC completed normal checklists and performed a safety check (Tab V-1.4 and V-2.13). MP1 also completed the items prescribed by the Hydraulic System Failure and Landing Gear Fails to Extend/Emergency Extension emergency procedures (EP) checklist (Tab V-1.7). MP2 continued to fly the MA on approach to RWY 01, and the final two minutes of approach had stable airspeed and glidepath (Tab CC-83 to CC-85). The MA aircraft broke out of the clouds at approximately

600-800 ft Above Ground Level (AGL), well above the minimum ceiling required for the Instrument Landing System (ILS) approach (Tabs V-1.3, V-2.6, V-19.4, and CC-51).

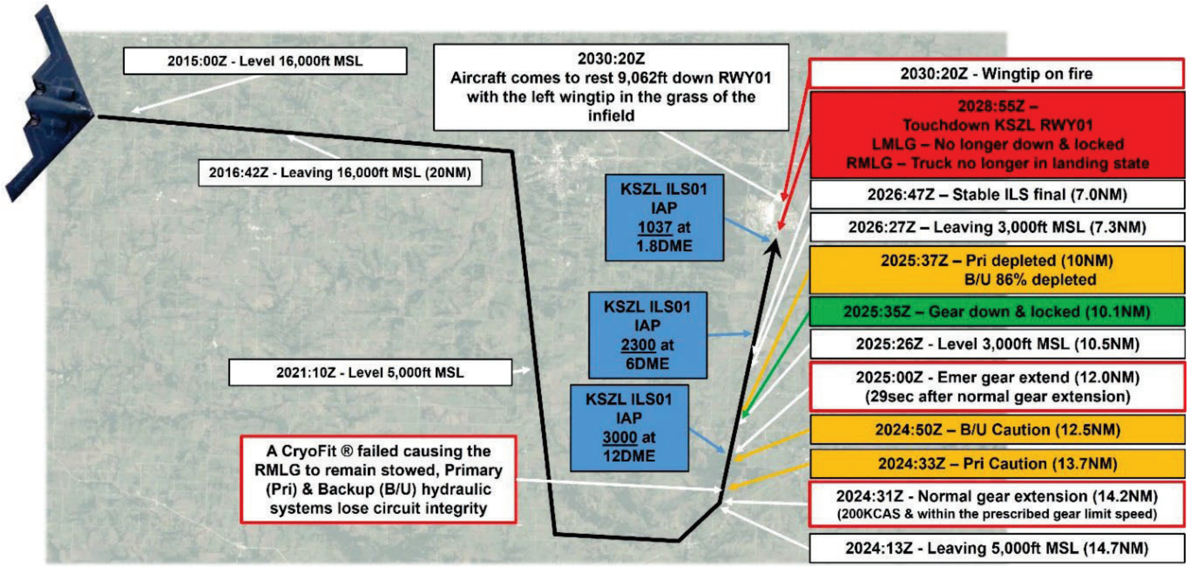

Figure 6: MA's Flight Path with Sequence of Events (Tab CC-85)

e. Impact

At approximately 1429:01 CST, MP2 landed the MA on both the LMLG and RMLG around the "captain's bars," which are 1,000 ft down Whiteman AFB RWY 01, on centerline (Tabs V-1.5 and Tab CC-85). Upon landing, the aircraft had the following approximate conditions: 120 knots true air speed, 0.971 Gravitational Force Equivalent (g), 2.5 degrees of pitch, 4 degrees of angle of attack, and 0.5 degrees of right roll (Tab CC-85). The NLG touchdown was uneventful, and a hard landing was not recorded (Tab CC-85).

On touchdown, the LMLG Lock Link Assembly failed to stay locked in the overcenter position, causing the LMLG to collapse under the aircraft's weight (Tab CC-85). As shown in Figure 7, approximately 3,750 ft down the runway, the aircraft's weight transferred to the LMLG door due to the LMLG collapsing and folding into the LMLG wheel well (Tabs S-4 to S-6, S-11, S-13, V-3.7, and Z-23).

MP2 perceived the RMLG was in the air (Tab V-2.9). MP1 took control of the MA from MP2, noticed a heavy drag to the left, used full deflection of the right rudder to keep the MA on the runway, and "st[ood] up out of [the] seat to give it everything [he] had on the right brake" (Tab V-1.5 to V-1.6). As noted in Figure 7, approximately 7,000 ft down the runway, the left wingtip and left rudder assembly began dragging through the unprepared surface west of RWY 01 (Tab Z-23).

Approximately 8,750 ft down the runway, as shown in Figure 7, the left wingtip and rudder assembly were dragged across taxiway Bravo (Tab Z-23). The concrete surface of Taxiway Bravo eroded the left wingtip to such a degree that the fuel tank within the wing ruptured and caused a fire to ignite on taxiway Bravo (Tabs N-5 and V-12.6).

At 1430:20 CST, the MA came to rest 9,062 ft down the runway, with the left wingtip in the unprepared surface to the west of the runway and both the LMLG and RMLG on the runway surface, as seen in Figures 7 and 8 below (Tabs S-3 and Z-23). A trail of fuel-fed fire extended behind the left wingtip, as seen in Figure 8 below, but was not observed from the cockpit (Tabs S-3, V-1.6, and V-2.10).

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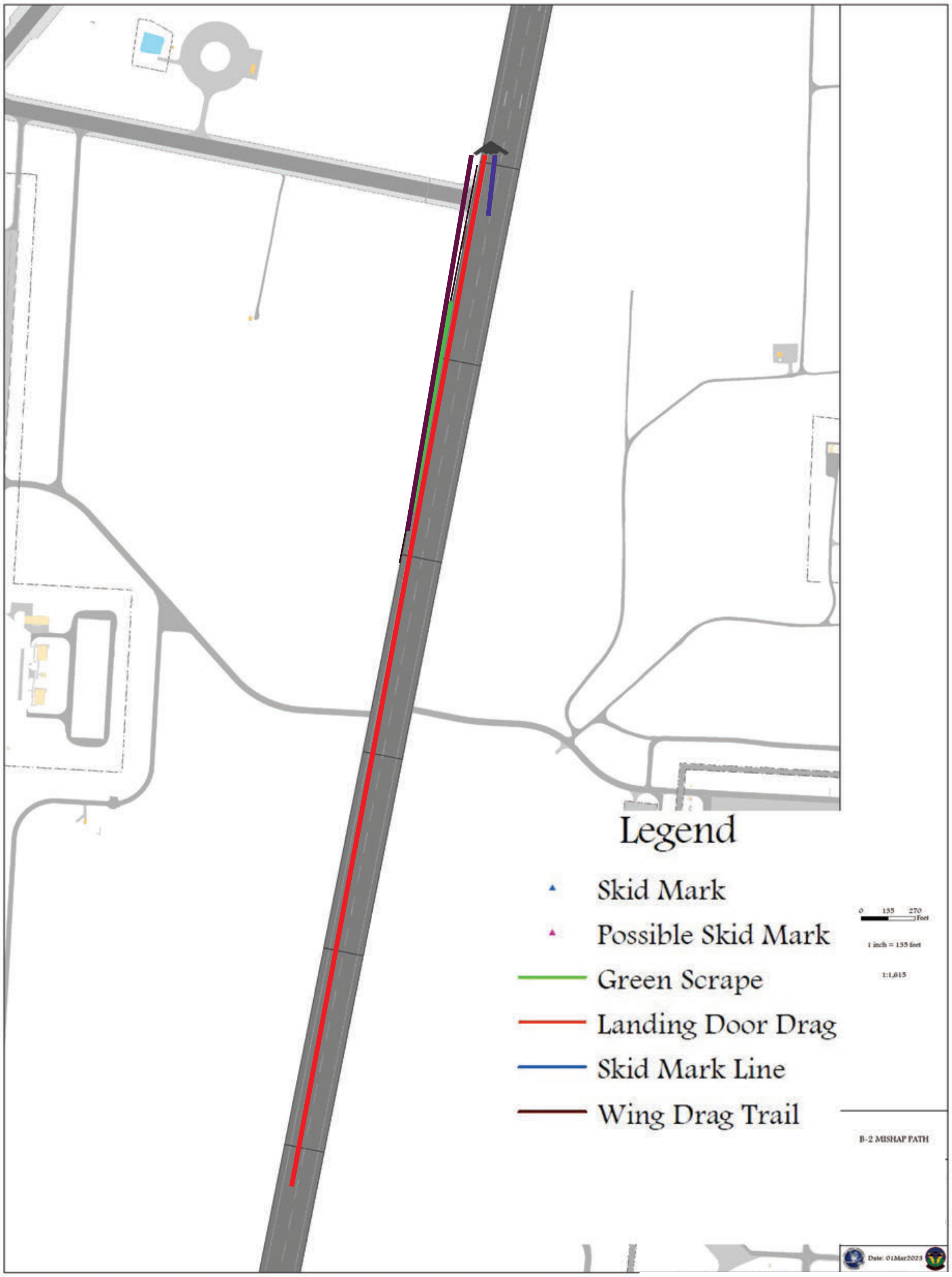

Figure 7: Runway Diagram Depicting Drag and Fire Damage (Tab Z-23)

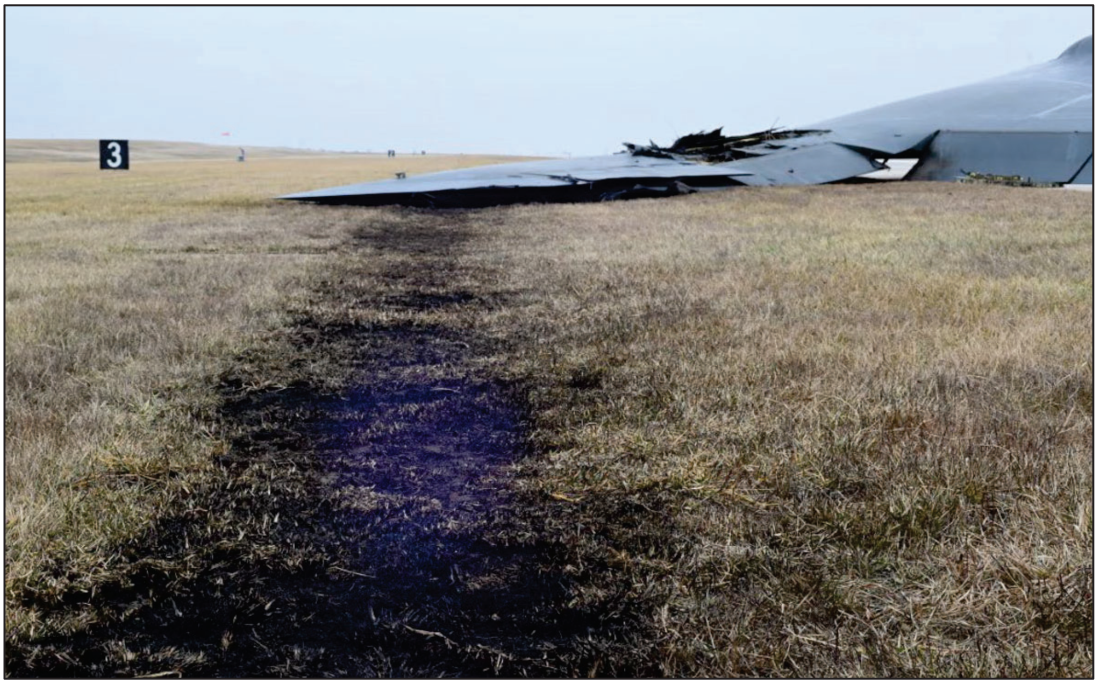

Figure 8: Photograph of Drag and Fire Damage (Tab S-3)

f. Egress and Aircrew Flight Equipment

The MC shut down the MA IAW with the Ground Egress emergency procedures checklist (Tab V-1.6). The MC was able to electrically command the crew entry door open, but the ladder could not fully extend because the MA was listing to the left (Tab V-1.6 and V-2.10). The MC found they could still safely egress by shimmying through the crew entry ladder (Tab V-1.6 and V-2.10). Neither the ejection seats nor the emergency hatch jettison was employed nor were they a factor in the mishap (Tab V-1.6 and V-2.10).

g. Search and Rescue

The MC egressed the area of the mishap to the northwest where they were met by maintenance personnel who escorted them to an ambulance (Tab V-5.4 to V-5.5). The MC did not suffer any injuries (Tab V-7.4 and V-19.5). The Whiteman AFB fire department, 509th Civil Engineer Squadron, responded with an incident command truck (Chief 2) and two ARFF trucks (Crash 4 and Crash 14) (Tabs R-186 and V-12.4). Crash 4 and 14 were each capable of fighting fire with either water or Aqueous Film Forming Foam (AFFF) (Tab V-12.4 to V-12.5 and V-22.4 to V-22.6). Fire attack began with water approximately three minutes and 16 seconds after the MA landed (Tab CC-69).

Upon arrival, the incident commander identified the source of the fire as fuel leaking from under the left wing (Tab V-12.5). The incident commander directed the two ARFF trucks to attack the fire using water only rather than using AFFF, believing Air Force policy only allowed use of AFFF as a last resort (Tabs R-186 to R-187, V-12.5, and V-12.7). However, although AFFF use has been restricted for non-firefighting purposes, there was no prohibition or "last-resort" policy in place during the time of the mishap that restricted the ability to use AFFF during emergencies such as the mishap (Tab BB-8.1).

Approximately three minutes and 28 seconds after beginning to fight the fire, and because the fire appeared fuel related, the incident commander authorized the two ARFF vehicles to use AFFF (Tabs V-12.5 and CC-69). AFFF is a more effective fire suppressant than water when used to fight flammable liquid fires (Tab V-14.8). It "has two separate mechanisms that combine to aid in the extinguishment of a flammable liquid fire; a water/surfactant film that forms on the fuel surface and a foam blanket (i.e., matrix of bubbles) and both serve to seal-in the flammable vapors resulting in extinguishment (i.e., shutting off the fuel vapors that are burning above the fuel surface." (Tab BB-5.2). After employing the AFFF for approximately 15 minutes, the external fire appeared to be suppressed (not extinguished but substantially diminished) (Tab V-14.6).

Once the external fire was suppressed, the incident commander authorized the crew to begin using handheld hoses (i.e., handlines) to fight the fire more aggressively and closer to the internal source (Tabs R-186 and V-14.5). At approximately 1500 CST, as firefighters approached the MA with their handlines, the MA's left surge fuel tank exploded (Tab V-12.4). The ARFF vehicles re-attacked the fire with AFFF until the fire appeared "knocked down" again (Tab V-12.6).

At approximately 1510 CST, as the firefighters again approached the MA with handlines to get closer to the source of the fire, the left outboard fuel tank of the MA exploded (Tab V-14.5). This second, larger explosion sent a roughly six-foot section of the aircraft skin through the air, narrowly missing the firefighters, and rained down debris around the mishap site (Tab V-14.5). The crew was then able to attack the internal fire since the hole in the top of the wing gave direct access (Tab R-186). At approximately 1530 CST, one hour after the fire began, it was completely extinguished (Tab V-12.5). No firefighting personnel were injured during their response (Tab CC-71).

In addition to the ARFF vehicles that responded to the incident, Crash 5 also attempted to respond but would not start (Tab R-186). Although Crash 5 was signed off as operational the day of the mishap, later evaluation determined its coolant was low, preventing it from starting (Tab CC-73 to CC-74). Crash 5 was the only ARFF vehicle equipped with an articulating arm and penetrating nozzle (Tab V-12.7). Penetrating nozzles are used to pierce the skin of aircraft to apply firefighting agent inside confined spaces, such as fuel tanks and cargo areas (Tab V-12.7).

Technical Order (TO 00-105E-9) provides firefighting guidance to U.S. Air Force firefighters but does not address penetrating the B-2 aircraft for any type of fire (Tab CC-69). Nevertheless, the Whiteman AFB Fire and Emergency Services lesson plan for firefighters addresses "Aircraft Skin Penetration Points & Fire Access Locations" in cases of engine fires and weapons bay fires (Tab CC-76). The lesson plan does not, however, address penetrating the B-2 in cases of wing or fuel tank fires, as were present in the mishap (Tab CC-76).

Despite the lack of piercing guidance for wing or fuel tank fires, the incident commander testified, "[m]ost likely, after the first explosion, we would've probably used the piercing nozzle to penetrate the left wing…because it…it was most likely an internal fire in a confined space that we couldn't get to." (Tab V-12.9). Because there is no guidance on using the penetrating nozzle in cases like the mishap, it is unknown how the firefighters would have attempted to penetrate the B-2 skin if they had the nozzle (Tab CC-70). It is also unknown what, if any, effect such penetration would have had on firefighting efforts (Tab CC-70).

After Crash 5 failed to start, its crew subsequently responded in a fourth ARFF vehicle (Crash 3) (Tab R-186). The incident commander initially tasked Crash 3 with assessing the MC and escorting them to the ambulance (Tab R-186). Then, after the first explosion, the incident commander directed Crash 3 to take over firefighting from Crash 14, and Crash 14 was resupplied with water (Tab R-186 to R-187). However, Crash 3 suffered a pump failure and was not able to attack the fire (Tab R-187). Despite this failure, Crash 4 and Crash 14 were able to suppress the external fire enough for handlines to be used, and it was during these handline operations that the second explosion occurred, allowing access to the internal fire (Tabs R-187 and V-14.5). The extent that Crash 3's failure may have contributed to the mishap is unknown (Tab CC-69). However, two facts reduce the likelihood that it contributed to the damage: First, the crew was able to suppress the external fire without Crash 3; second, the explosions were caused by the internal fire, which none of the trucks were able to address (Tab CC-69). After the internal fire was exposed by the second explosion, Crash 4 and Crash 14 were able to extinguish the fire (Tab R-187).

h. Recovery of Remains

This section is not applicable.

5. MAINTENANCE

a. Forms Documentation

The MA's Air Force Technical Order (AFTO) Forms 781 and Jacket Files were examined and reviewed, and no discrepancies were noted (Tab CC-85). The MA's Time Compliance Technical Orders (TCTOs) were current, and no TCTOs were overdue at the time of the mishap (Tab U-3). Historical records did not reveal any relevant or recurring maintenance problems or discrepancies (Tab CC-85).

b. Inspections

The MA's required pre-flight inspection was completed and annotated on an AFTO Form 781H on 9 December 2022 at approximately 0700 CST by maintenance personnel who completed the MA's Exceptional Release (ER) review and documentation (Tab D-5). The only discrepancy noted was that the 15-day power battery functional check was due on 2 December 2022 (Tab D-3). No further discrepancies were identified (Tabs D-5 and V-6.5).

Other scheduled inspections on the MA included the Hourly Post Flight (HPO) and 1,000-hour Phase inspection, both of which were signed off as completed as of 8 December 2022 (Tab D-28). The MA's last scheduled Periodic Depot Maintenance (PDM) was completed in March 2017 with the next PDM due on 1 March 2026 (Tab D-3). On the day of the mishap, all required inspections were complete (Tab D-5 and D-28).

c. Maintenance Procedures

Pre-flight maintenance procedures and servicing were completed and annotated on MA forms and complied with maintenance technical orders (Tabs D-5 to D-6 and V-6.5). During preflight, the maintenance crew serviced the hydraulic systems of the MA and documented service with an informational note (Tab V-17.4 to V-17.11).

d. Maintenance Personnel and Supervision

Supervisors and maintainers who performed maintenance on the MA at Whiteman AFB, MO were assigned to the 509 BW and the 131 BW (Tab U-5). All members had adequate training, experience, and supervision (Tab U-5). No reported limitations or discrepancies were discovered in any of these three areas (Tab U-5).

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

Hydraulic fluid samples were pulled from the MA and the hydraulic Aerospace Ground Equipment (AGE) that was used to service the MA hydraulic systems during preflight inspection (Tab J-11 to J-14 and J-17). After the mishap, the fluid was tested for contamination, color, viscosity, acidity, pour point, flash point, and water content (Tab J-11 to J-14 and J-17). The results from each of the systems were then compared to the specification requirements of new hydraulic fluid (Tab J-11 to J-14 and J-17). The report states that "Material fails specification requirements and is not satisfactory for Air Force use...The limits stated on this report are for new, unused fluid and are listed for reference purposes only." (Tab J-11 to J-14 and J-17). Because the tested fluid was not in the state for which the specification requirement was written (i.e., new and unused), the "pass/fail" results are informational only and do not indicate that the fluid was deficient or contributed to the mishap, especially since the hydraulic pressures were within all normal operating limits during the mishap sortie (Tab CC-85).

f. Unscheduled Maintenance

A Data Entry Panel (DEP) update to reflect the MA's current weight and balance was the only unscheduled maintenance task performed on the aircraft prior to takeoff (Tab V-5.15 and V-6.5). Maintenance personnel completed the DEP update prior to the mission (Tab V-6.4).

6. AIRFRAME SYSTEMS

a. Structures and Systems

External areas on the MA which were damaged include the aircraft skin under the left wing, aircraft skin on top of left wing, left rudder, mid elevon, outboard elevon, retractable left wingtip light, MCC on a RMLG hydraulic line, LMLG door, LMLG door actuators, and LMLG door mounts (Tabs P-3, S-3 to S-6, and S-11 to S-14).

Internal damage areas in the MA include major structural damage to the internal left wing, left surge fuel tank, and left outboard fuel tank (Tab CC-85). It is currently estimated that repairs would cost over $300 million (Tab CC-81).

(1) Aircraft Skin Under and on Top of Left Wing / Retractable Left Wingtip Light

After the MA landed and the LMLG collapsed, the left-wing began dragging across an unprepared surface west of Whiteman AFB RWY 01 and across the concrete of taxiway Bravo (Tab S-3 to S-7). This caused significant damage to the aircraft skin under the left wing (Tab S-3). It also caused the retractable left wingtip light to detach from the wing (Tab CC-85). The top of the left wing also suffered damage due an explosion of the left outboard fuel tank (Tabs S-3 and V-5.5).

(2) Left Rudder / Mid and Outboard Elevons

The left rudder also experienced significant damage when the left wing began dragging across the unprepared surface west of RWY 01 and across the concrete of taxiway Bravo (Tab S-3 to S-7). The concrete of taxiway Bravo scraped the under skin enough to rupture and penetrate the left surge fuel tank, causing it to ignite (Tabs S-8 to S-9, V-5.5, V-10.5, and V-12.4 to V-12.5). This caused structural and fire damage to outboard and mid elevons (Tab S-3).

(3) Left Outboard Fuel Tank / Left Surge Fuel Tank

As the left wingtip was being dragged, the concrete of taxiway Bravo wore down the under skin enough to rupture the left surge fuel tank, igniting it (Tabs S-8 to S-9, V-5.5, and V-10.5). This fire caused a small explosion from the left surge fuel tank (Tabs S-8 to S-9, V-5.5, V-10.5, and V-12.4 to V-12.5). The fire spread to the left outboard fuel tank, which caused a larger second explosion from the top of the left wing as seen in Figure 8 above (Tabs S-3, V-12.4 to V-12.5, and V-12.9).

(4) LMLG Door / Mounts / Door actuators

The LMLG door was damaged when it was dragged across the runway after the LMLG collapsed upon landing (Tab S-11). After the MA came to rest, the weight of the left side of the aircraft bent the door outwards towards the left wingtip (Tab S-4 to S-6, S-11, and S-13). This broke the forward door mount and forward door actuator and bent and damaged the aft door actuator, as seen in Figure 9 below (Tab S-11).

Figure 9: Damage to LMLG Door (Tab S-11)

(5) RMLG MCC

Failure of the RMLG MCC occurred inflight immediately after the MC placed the Landing Gear Handle Down, sending pressurized hydraulic fluid overboard and depleting the primary and backup hydraulic systems as the PSLUs commanded the switching valves to utilize each system (Tab CC-86).

b. Analysis and Evaluation

(1) Analysis of LMLG Lock Link Assembly, Proximity Sensors, and PSLUs

Lock Link Assembly visual inspection revealed no damage (Tab BB-3.2). The proximity sensors installed on the Lock Link Assembly were tested without any change from how they were installed during the MS (Tab CC-86). The assembly was incrementally lowered into a locked/overcenter position (Tab CC-86). At each step, the distance between the proximity sensor and its target and the state reported to the PSLUs (i.e., locked or unlocked) was recorded (Tab CC-86). This test was then repeated with the proximity sensors connected to the opposite PSLU (Tab CC-86).

This testing sought to confirm two items (Tab CC-86). First, that the proximity sensors met the specification for the allowable distance at which they must report a change from an unlocked to a locked state, and vice versa (Tab CC-86). Second, that the PSLUs accurately reported the status from the proximity sensor (Tab CC-86). In all configurations, the proximity sensors met specifications, and the PSLUs accurately reported the status of the Lock Link Assembly (Tab CC-86).

(2) Analysis of MCC

Visual inspection, Computed Topography (CT), and scanning electron microscopy were used to analyze the MCC (Tab CC-86). These techniques revealed no notable surface or internal flaws nor any evidence of microcracking (Tab CC-86). However, witness (i.e., drag) marks on the exterior of the T-fitting were observed using scanning electron microscopy (Tab CC-86). The witness marks were continuous in nature, relatively linear, and present around the entire circumference with similar frequency, as seen in Figure 10 below (Tab CC-86). There was no evidence of multiple starts or stops, which suggests that the expulsion likely occurred during a single event (Tab CC-86).

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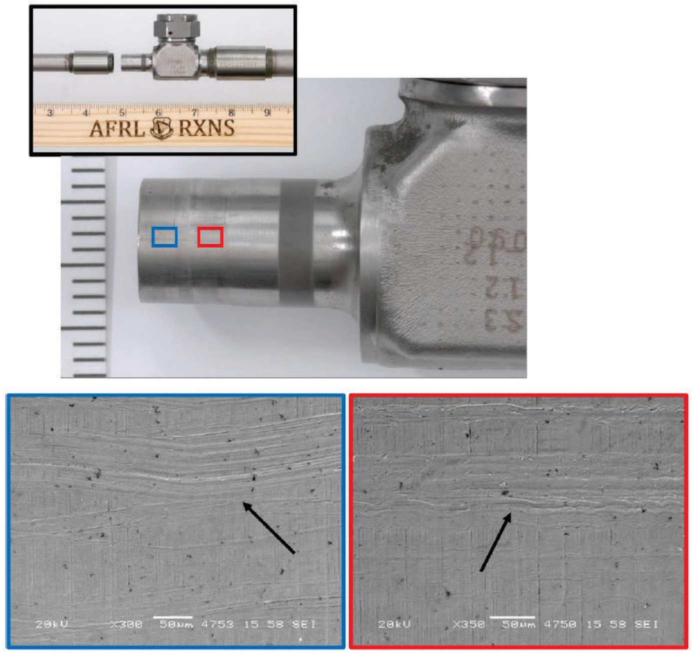


Figure 10: Witness Marks on the T-Fitting after MCC Expulsion (Tab CC-86)

A section of the MCC and a second uninstalled CryoFit ® coupling underwent microstructure and compositional comparison testing (Tab CC-86). The testing noted differences in the microstructure of the MCC relative to a new CryoFit ® coupling; however, the cause and significance of the difference is unknown (Tab CC-86).

(3) Analysis of MLG Lock Springs

Analysis by the Air Force Research Laboratory (AFRL) determined that each of MLG Lock Springs from the LMLG and RMLG of the MA met all mandatory design specifications (Tab CC-87). Each MLG Lock Spring met the specification, and no abnormalities were noted (Tab CC-87

(4) Analysis of the Mishap (Overview)

The CryoFit ® coupling failure initiated the sequence of events that concluded with the LMLG failure upon touchdown (Tab S-14). The LMLG Lock Link Assembly System failed to hold the LMLG in the overcenter position during landing after an emergency gear extension following a loss of hydraulic system pressure in the MLG system (Tab CC-87 to CC-88).

After the MCC failure, the following events occurred which created the final conditions wherein the LMLG was unable to maintain the overcenter position upon touchdown:

1. The CryoFit ® coupling failure caused the RMLG Sequence Valve Circuit to lose the hydraulic pressure required to unlock the RMLG from the stowed position driving the MC to emergency extend the RMLG (Tabs S-14 and CC-87 to CC-88).

2. Although the LMLG was initially down and locked in the overcenter position with normal hydraulic system pressure applied, when the MC selected the Emergency Extension, the

design of the MLG components when the Emergency Bypass Valve shuttles to the emergency position caused the normal high-pressure to rapidly drop to a low-pressure and resulted in the LMLG Lock Actuator retracting and causing the Lock Link Assembly to relax from its original overcenter position (Tab Z-25 to Z-26).

3. During touchdown, the MLG is designed so that the truck beam pivots roughly 15 degrees causing the TPA to compress two inches (Tab CC-87 to CC-88). While the TPA is compressing, the fluid is circulating internally; however, fluid is forced out due to the different dimensions and characteristics of the two sides of the actuator (Tab CC-87 to CC-88). The touchdown cycle lasts approximately 1/15th of a second (Tab CC-87 to CC-88). The rapid TPA compression creates a transient hydraulic pressure pulse that propagates through the return circuit (Tab CC-87 to CC-88). The fluid's path of least resistance is via the destow return hydraulic line, through the MLG sequence valves, the MLG Switching Valve, and directly to the reservoir (Tab CC-87 to CC-88). The pulse also propagates to both ports of the Lock Actuator causing a retraction due to design specifications of the port restrictors, thus creating an unlocking force on the Lock Link Assembly (Tab CC-87 to CC-88). This retraction force overcomes the strength of the downlock springs (Tabs BB-4.2 and CC-87 to CC-88). Once slightly retracted, the Lock Link Assembly is no longer able to maintain an overcenter, locked position throughout landing (Tab Z-25 to Z-26).

The following section will analyze the above conditions in further detail in chronological order:

(5) Analysis of key landing gear and hydraulic sequence of events following MCC failure

(a) Normal gear extension to an asymmetric condition that required an emergency gear extension

The LMLG extended normally to the down and locked position (Tab CC-88). The RMLG remained stowed due to the MCC's failure that created an open pressure line in the sequence valve circuit resulting in no hydraulic pressure available in the sequence valve circuit to unlock the RMLG Lock Actuator (Tab CC-88). The primary and backup hydraulic systems continued expelling hydraulic fluid as the MLG Switching Valves cycled in their attempts to lower the RMLG until the Landing Gear Emergency Lowering Switch was engaged (Tab CC-88). This asymmetric (only two landing gear down and locked) configuration drove the MC to emergency extend the RMLG to a down and locked position (Tabs V-1.4, V-2.7, and CC-88).

(b) Rapid pressure drop caused lock link assembly to lose integrity (unlock)

A sequence of two events resulted in the LMLG losing integrity. First was a rapid pressure drop. When the Landing Gear Emergency Lowering Switch was set to the emergency extend position (down), the Emergency Bypass Valves closed, then blocked the high-pressure to the MLG sequence valves and redirected that pressure to the low-pressure return circuit (Tab CC-88). This action allowed trapped fluid to flow freely within the circuit, preventing the MLG components hydraulic lockup, and allowed the stowed RMLG to fall from the wheel well to the down and locked position (Tab CC-88).

The Emergency Bypass Valve closing and blocking the high pressure to the LMLG sequence valves caused the Lock Actuator to retract an unknown distance in the unlock direction, breaking the integrity of the LMLG Lock Link Assembly which had held the LMLG down (Tab Z-25 to Z-27). Despite the slight retraction, the LMLG Locked Proximity Sensors remained within a gap tolerance and continued to report as down and locked to the MA's MDU Status Page and Landing Gear Panel that indicated the LMLG was down and green (i.e., safely locked in the landing position) (Tabs V-1.4 to V-1.5, V-1.8, V-2.8 to V-2.9, and CC-88).

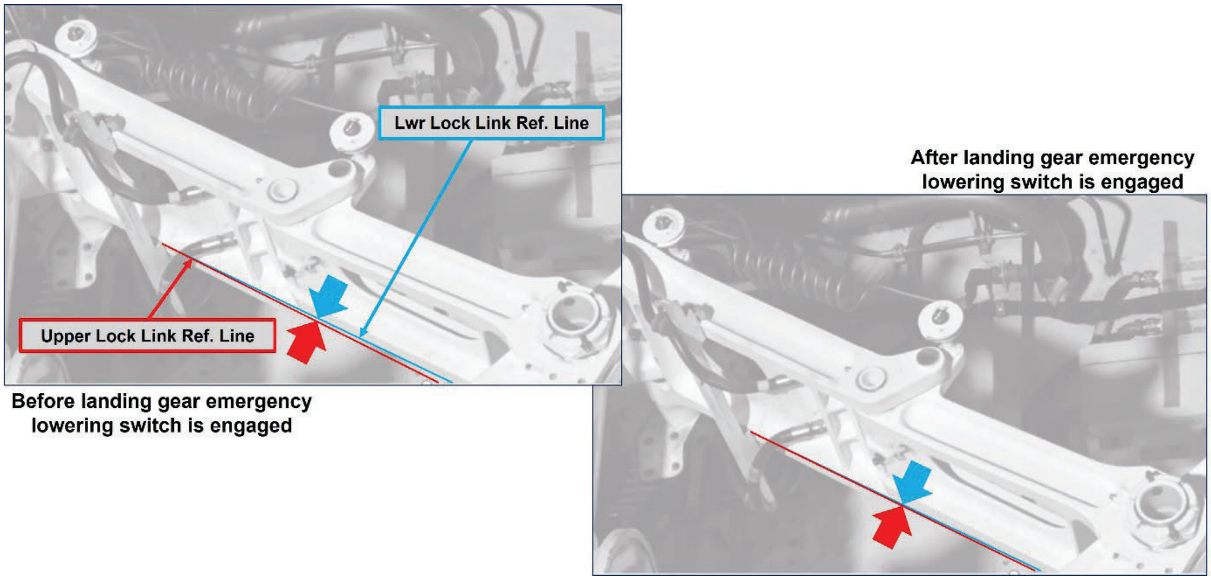


Figure 11: The light blue line is a reference line highlighting the lower edge of the Lower Lock Link and remains in a fixed position. The red line is referencing the bottom edge of the upper Lock Link. The red line moves closer to the light blue line in the second frame immediately following the Emergency Lowering Switch. These screenshots from the video of testing conducted during the AIB that demonstrate that the MLG Lock Actuator retracted an unknown distance, moving the Lock Link Assembly from its overcenter position, causing a loss of integrity because the MA's LMLG was already down and locked when the pressure was removed by the Emergency Bypass Valve (Tab Z-27).

(c) MLG locked proximity sensors indicated down and locked to the MC after emergency extension even though the LMLG was not fully down and locked

The MLG Lock Link Assembly will indicate down and locked or up and locked when the lock links are overcenter and resting on a mechanical stop. Although the MLG Lock Link Assembly may no longer have integrity when resting on its mechanical stop, if the distance between the sensor and the target falls within the rig tolerance (seen in Figure 12, below), the proximity sensors still report "target NEAR" (i.e., locked) (Tab CC-88). This tolerance allowed the MA's LMLG Lock Link Assembly to lack integrity but still indicate down and green (i.e., safely locked in the landing position) on the MDU Status Page and Landing Gear Panel (Tab CC-88).

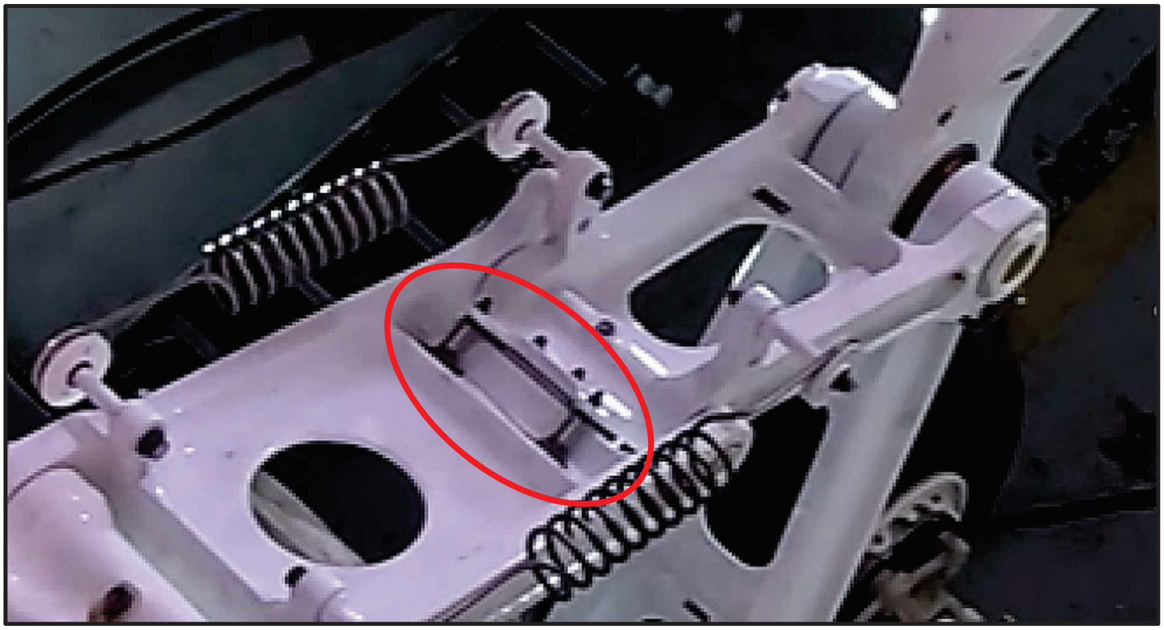


Figure 12: MLG Primary and Alternate Locked Proximity Sensors (Tab Z-25 to Z-26)

(d) Unlock sequence valves and truck position sequence valves moved to a neutral position

When the high pressure was removed from the sequence valves' pressure port, it drove the valves' internal shuttle valves to a neutral state by design (Tab CC-88). This sequence valves' neutral position allowed a hydraulic pressure pulse and fluid flow to pass through the valves with little to no resistance (Tab CC-88).

(e) LMLG TPA created an unintended pressure pulse to the LMLG Lock Actuator, which further broke its integrity

The second event that caused further lack of integrity of the LMLG was an unintended TPA pressure pulse upon landing. The TPA compressed approximately two inches under the weight of the aircraft upon landing (Tab CC-88 to CC-89). During this compression, there are additional restrictors and check valves which enable and control internal hydraulic fluid flow within the actuator (Tab CC-88 to CC-89). Hydraulic fluid inside the TPA is forced out of the return port and into the common return circuit due to the different dimensions and characteristics of the two sides of the actuator (Tab CC-88 to CC-89). The pulse from the TPA impacts the MLG Lock Actuator which is connected to this common return circuit through the MLG sequence valves when they shuttle to a neutral configuration (Tab CC-88 to CC-89). A higher pressure fluid inside the TPA during compression was released into the common return circuit due to the internal relief valves specification (Tab CC-88 to CC-89). The fluid flowed rapidly into the return circuit and back to the system reservoir (Tab CC-88 to CC-89).

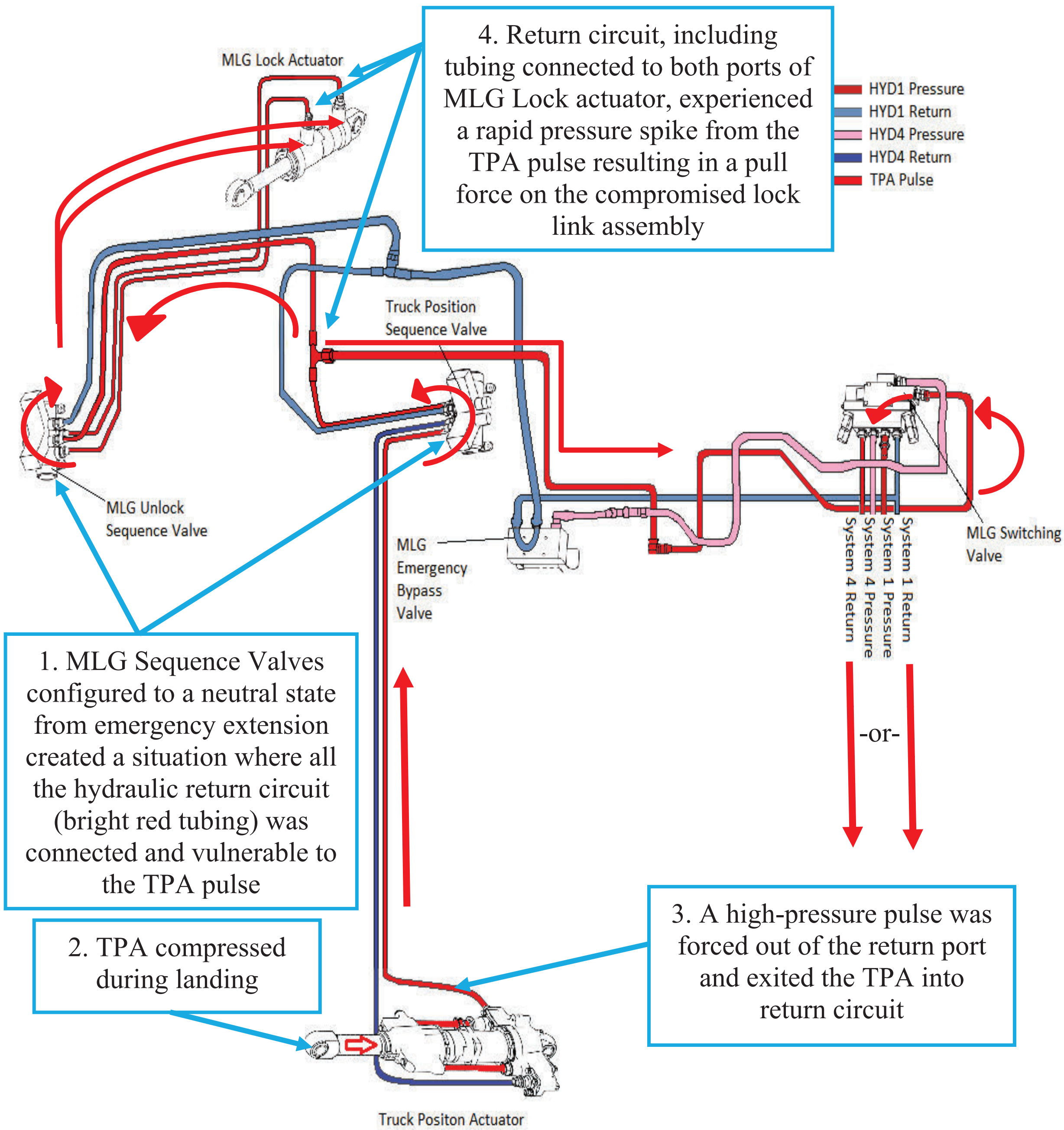
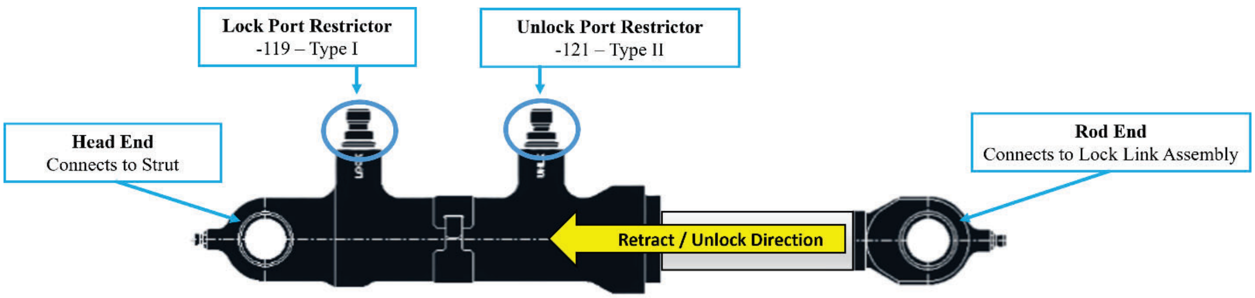


Figure 13: TPA Pulse and Common Return System Layout (Tab CC-89).

(f) LMLG Lock Actuator created a pull force on the LMLG Lock Link Assembly, collapsing the LMLG

Upon landing, the TPA pulse traveled up the common return circuit to both ports of the Lock Actuator (Tab CC-89). The Lock Actuator has restrictors installed on the lock and unlock ports, which regulate fluid flow and pressure to assist in locking and unlocking the Lock Actuator to and from the up/stowed and down/locked positions (Tab CC-89). The Lock Actuator has a Type I restrictor on the lock port and a Type II restrictor on the unlock port (Tab CC-89). The unlock Type II port is less restrictive than the lock Type I port (Tab CC-89). Upon landing, both restrictors received a simultaneous pulse, and this design created a pull force in the unlock/retraction direction (i.e., greater pressure on the rod end versus the head end of the Lock Actuator), which retracted the actuator, overcame the LMLG lock link assembly spring force, and collapsed the LMLG (Tab CC-89).



Type I Restrictor – Metered flow in 1 direction and free flow in the reverse direction
Type II Restrictor – Metered flow in both directions

Figure 14: MLG Lock Actuator highlighting the specifications of the installed restrictors (Tab CC-89).

(g) RMLG did not collapse because it was up and stowed at the time of the rapid pressure loss and therefore did not experience the loss of lock link integrity from the rapid pressure loss

Whereas the LMLG was down and locked when the emergency extension switch was engaged, causing it to lose integrity from the rapid pressure drop, the RMLG was up and stowed during the pressure drop and fell into place later by gravity and air loads (Tab CC-90). The RMLG Lock Link Assembly had integrity after lowering from the up and stowed position because it was unaffected by the rapid pressure loss (Tab CC-90). After it extended, the RMLG Lock Link Assembly was held locked/overcenter by means of the MLG Lock Springs and was resting on the mechanical stop in the overcenter position upon touchdown (Tab CC-90). Upon touchdown, the transient pulse from the TPA was present on the RMLG; however, because the RMLG Lock Link Assembly still had its integrity, this transient pulse was not sufficient to overcome the Lock Spring's force to buckle the Lock Link Assembly out of position during landing, and the RMLG did not collapse.

(6) Relevant Historical Events

There have been 25 recorded CryoFit ® coupling failures across the B-2 fleet (Tab BB-2.2). Of those 25, 10 have been in the MLG hydraulic pressure circuit (Tab BB-2.2). Of those 10, five have been the Truck Position Sequence Valve CryoFit ® coupling (Tab BB-2.3). Of those five, two resulted in a LMLG collapse upon landing (including this current mishap) (Tab BB-7.2).

During the investigation into a previous B-2A LMLG collapse, in September 2021, it was discovered that one of two MLG Lock Springs did not meet specification (Tab BB-7.2). As a result, the Air Force released a Time Compliance Technical Order (TCTO) in March of 2022 that directed replacing the four MLG Lock Springs and validate rigging on the lock link proximity sensors. (Tab CC-90). The TCTO was complied with on the MA in June of 2022 (Tab U-3). Since then, the MA recorded 33 landings, including the mishap landing (Tab U-3).

(7) 1B-2A-1 and 1B-2A-1CL-1 Emergency Procedures

If any landing gear extension malfunctions are present, then aircrew should follow the Landing Gear Fails to Extend/Emergency Extension checklist. The checklist directs aircrew to take the following actions:

1. Landing gear handle – DOWN.
2. Landing gear emergency lowering switch – DOWN.

If all landing gear extend:

3. Do not retract gear.

If all landing gear fail to extend after 90 seconds:

4. Landing gear emergency lowering switch – RESET.
5. Landing gear handle – UP.
6. Prepare for gear up landing.

(Tab CC-90)

This checklist requires emergency gear extension to occur when the wings are level (Tab CC-90). It also directs aircrew to allow one minute to elapse between placing the landing gear handle down and initiating the checklist (Tab CC-90). This checklist also contains a warning to aircrew that landing with a mixed configuration of NLG up and MLG down is not recommended (Tab CC-90). This checklist cautions that with both the primary and the backup hydraulic system pressures below 500 psi, the emergency accumulator's pressure could deplete within 15 minutes from placing the landing gear handle down (Tab CC-90). Without pressure in the hydraulic emergency brake accumulator, there would be little or no braking action available, presenting a significant risk to aircraft and aircrew when landing.

Here, the MC performed the emergency gear extension approximately 30 seconds after placing the landing gear handle down, rather than waiting one minute as directed by the checklist (Tabs V-1.4 and CC-85). Analysis showed that the hydraulic system's response, including the configuration of the physical hydraulic fluid path, the MLG unlock and TPA sequence valve, and MLG lock actuator restrictors, remained consistent regardless of the interval between the Cryofit ® failure and activation of the emergency extend switch (Tab CC-91). Analysis further showed that the aircraft was susceptible to the rapid release that compromised the LMLG and allowed a transient pulse from the TPA to reach the MLG lock actuator, regardless of how much time had elapsed (Tab CC-91).

7. WEATHER

a. Forecast Weather

The weather brief provided to the MC forecasted an overcast cloud layer beginning at 700 ft AGL, six miles of visibility, light rain, and winds from the East at three Miles Per Hour (MPH) at planned takeoff time (Tab W-7). At the planned landing time, the forecast called for an overcast cloud layer beginning at 1,000 ft AGL, seven miles of visibility, no hazardous weather, and winds from the southeast at three MPH (Tab W-15).

b. Observed Weather

Operations were conducted within prescribed weather limitations (Tab CC-67). When the MC declared an emergency with the Whiteman AFB tower controller, they were told the winds were from the northwest at 5 MPH (Tab N-4). The MC stated they were in the clouds on the ILS approach to Whiteman AFB until approximately 600-800 ft AGL (Tab V-1.3 and V-2.6). A special weather observation published at 1437 CST in response to the mishap noted winds out of the west at 5 MPH, 10 miles of visibility, and an overcast cloud layer at 1,000 ft AGL (Tab N-6).

c. Space Environment

This section is not applicable.

d. Operations

The ILS and airfield lighting was operable (Tab V-11.4).

8. CREW QUALIFICATIONS

a. MP1

MP1 was a B-2A Instructor Pilot (IP) with more than 1,100 total hours in the B-52H, T-38A, and B-2A (Tab G-6 to G-7). MP1 was a B-52H co-pilot with over 680 hours in that platform from April 2017 to July 2019 (Tab G-7). In 2019, MP1 transitioned to the B-2A program and maintained dual qualification in the T-38A and B-2A (Tab G-6). MP1 had over 100 hours in the T-38A from September 2019 to the mishap (Tab G-6). MP1 completed B-2A Initial Qualification Training (IQT) in July 2020 (Tab T-3). MP1 completed IP upgrade training in June 2022 (Tab T-3). MP1 logged over 350 hours in the B-2A, including more than 80 hours as an IP (Tab G-6).

MP1 was current and qualified for all areas of the planned sortie (Tab G-11 to G-16).

	Hours (B-2A / T-38A)	Sorties (B-2A / T-38A)
30 days	20.0 / 6.5	4 / 5
60 days	41.5 / 9.8	7 / 9
90 days	83.8 / 13.1	10 / 12

b. MP2

MP2 was a B-2A pilot with more than 800 total hours in the B-1B, T-38A, and B-2A (Tab G-24). MP2 had over 540 hours as a B-1B Weapon System Officer (WSO) from December 2016 to September 2019 (Tab G-25). In 2019, MP2 attended Specialized Undergraduate Pilot Training (Tab G-24). Upon graduation, MP2 was selected for the B-2A program and maintained a dual qualification in the T-38A and B-2A (Tab G-23). MP2 had over 100 hours in the T-38A from November 2020 to the time of the mishap (Tab G-23). MP2 completed B-2A Initial Qualification Training (IQT) in November 2021 (Tab T-22). At the time of the mishap, MP2 was enrolled in B-2A aircraft commander upgrade training (Tab V-2.4). MP2 logged over 180 hours in the B-2A (Tab G-23).

MP2 was current and qualified for all areas of the planned sortie (Tab G-30 to G-35).

	Hours (B-2A / T-38A)	Sorties (B-2A / T-38A)
30 days	20.3 / 3.0	3 / 3
60 days	20.3 / 6.3	3 / 6
90 days	24.8 / 6.3	5 / 6

9. MEDICAL

a. Qualifications

There is no evidence that the MC or relevant maintenance personnel were medically unqualified at the time of the mishap (Tabs AA-3 to AA-5 and CC-79).

b. Health

There is no evidence that the health of either MP or relevant maintenance personnel was a factor in the mishap (Tab CC-79).

c. Pathology

This section is not applicable.

d. Lifestyle

There is no evidence that lifestyle was a factor in the mishap (Tab CC-79).

e. Crew Rest and Crew Duty Time

MP1 indicated he had normal, uninterrupted crew rest, and MP2 did not note any abnormalities with his crew rest (Tab V-1.20 and V-2.22). Mission planning ended more than 12 hours prior to the start of their flight duty on 10 December 2022 (Tab V-1.17 to V-1.18, and V-2.19 to V-2.20).

10. OPERATIONS AND SUPERVISION

a. Operations

The pace of operations at the 509 BW is predicated upon meeting strategic and operational requirements, and at the time of the mishap, the operations tempo in the 509 BW and in the 393 BS was in line with historical norms (Tab CC-67). Additionally, the upgrade timeline for pilots to progress from Aircraft Commander to Flight Lead and then to Instructor Pilot was in line with historical norms (Tab CC-67).

b. Supervision

The operations supervisor/Supervisor of Flying (SOF) were assigned to the 509 BW at Whiteman AFB (Tab CC-67). All members were qualified and had adequate training, experience, and supervision (Tab V-19.3).

11. HUMAN FACTORS

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 (Tab BB-1). One human factor was identified as contributing to the mishap:

> "**SV002 Allowing Unwritten Policies to Become Standard**: is a factor when unwritten or "unofficial" policy is perceived and followed by the individual, although it has not been formally recognized by the organization" (Tabs BB-1.15 and CC-77 to CC-78).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publicly Available Directives and Publications Relevant to the Mishap

(1) AFI 51-307, *Aerospace and Ground Accident Investigations*, 18 March 2019.
(2) Air Force Manual (AFMAN 11-202) Volume 1, *Aircrew Training*, 27 September 2019.
(3) AFMAN 11-202 Volume 3, *Flight Operations*, 10 January 2022.
(4) AFMAN 11-202 Volume 3, AFGSC Supplement, *Flight Operations*, 23 December 2021.
(5) AFMAN 11-2B-2 Volume 1, *B-2-Aircrew Training*, 20 August 2020.
(6) AFMAN 11-2B-2 Volume 3, *B-2 Operations Procedures*, 30 October 2020.
(7) Back, Gerard G., and Farley, John P. Evaluation of the Fire Protection Effectiveness of Fluorine Free Firefighting Foams. Fire Protection Research Foundation, 2020. https://www.iafc.org/docs/default-source/1safehealthshs/effectivenessofflourinefreefoam.pdf.
(8) Department of Defense (DoD). *Human Factors Analysis and Classification System (DOD HFACS) Version 7.0*. https://www.dcms.uscg.mil/Portals/10/CG-1/cg113/docs/pdf/DoD_HFACS7.0.pdf?ver=2017-02-23-152408-007.
(9) Department of the Air Force Instruction (DAFI) 32-2001, *Fire and Emergency Services (F&ES) Program*, 28 July 2022.

(10) DoD Instruction 6055.06, *DoD Fire and Emergency Services (F&ES) Program*, 3 October 2019, https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/605506p.pdf?ver=2019-10-03-065848-680.
(11) Edgar School District. *Hydraulics - How It Works*. https://www.edgar.k12.wi.us/faculty/mreinders/How%20Hydraulics%20work.pdf.
(12) U.S. Air Force. *Abbreviated Accident Investigation Board Report, B-2A, T/N 89-0129*. March 2022. https://www.afjag.af.mil/Portals/77/AIB-Reports/2021/14SEP21%20B-2%20AIB%20Report.pdf.
(13) U.S. Air Force. *Technical Implementation Guide 403-18 for NFPA 403, Standard for Aircraft Rescue and Fire-Fighting Services at Airports*. March 2018. https://media.defense.gov/2018/Aug/23/2001957748/-1/-1/1/NFPA%20403%202018%20EDITION%20TIG.PDF.
(14) University of Central Florida. *University Physics Volume 1: 14.3 Pascal's Principle and Hydraulics*. 2016. https://pressbooks.online.ucf.edu/osuniversityphysics/chapter/14-3-pascals-principle-and-hydraulics.

Notice: Unless otherwise noted, all U.S. Air Force directives and publications listed above are available digitally on the Air Force Departmental Publishing Office website at: https://www.e-publishing.af.mil.

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b. Other Directives and Publications Relevant to the Mishap

(1) Technical Order (TO) 1B-2A-1. *Flight Manual*, 10 March 2014, Change 15 - 7 January 2022.
(2) TO 1B-2A-1C-1. *Flight Crew Checklist*, 10 March 2014, Change 11 - 7 January 2022.
(3) TO 1B-2A-2-00GV-00-1. *General System On-Equipment Maintenance General Vehicle*, 30 October 2023.
(4) TO 1B-2A-2-05GS-00-1. *General System, On-Equipment Maintenance, Aircraft Ground Handling and Safety*, 21 January 2021.
(5) TO 1B-2A-2-27GS-00-2. *General System, On-Equipment Maintenance, Flight Controls*, 21 November 2021.
(6) TO 1B-2A-2-29GS-00-1. *General System, On-Equipment Maintenance, Hydraulic Power*, 31 May 2022.

(7) TO 1B-2A-2-32GS-00-1. *General System, On-Equipment Maintenance, Landing Gear*, 30 November 2022.
(8) TO 1B-2A-2-32JG-10-3. *Job Guide, On-Equipment Maintenance, Landing Gear, Main Landing Gear*, 1 November 2010.
(9) TO 1B-2A-2-40GS-00-1. *General System, On-Equipment Maintenance, System Integration*, 31 January 2023.
(10) TO 1B-2A-1093. *Replacement of Main Landing Gear Lock Springs P/N DAA3222D263-001, B-2A Aircraft*, 29 March 2022.
(11) TO 9H2-2-133-3. *Overhaul Instructions with Illustrated Parts Breakdown, Depot Maintenance, Actuator Assembly, Truck Positioner*, 13 March 2023.

c. Known or Suspected Deviations from the Directives or Publications

No known deviations from policy or directives were a factor in the mishap (Tab CC-91).

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14 July 2025

JESSE W. LAMARAND, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

B-2A, T/N 0-0041
Whiteman AFB, MO
10 December 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 referred to in those conclusions or statements.

1. OPINION SUMMARY

On 10 December 2022 at approximately 1429 Central Standard Time (CST), the Mishap Aircraft (MA) B-2A, tail number (T/N) 90-0041, assigned to the 509th Bomb Wing, Whiteman Air Force Base (AFB), Missouri, landed at Whiteman AFB and experienced an aircraft mishap.

At approximately 0700 CST that morning, Mishap Pilot (MP) 1 and MP2 launched the Mishap Aircraft (MA) as an airborne spare to back up the primary aircraft for a mission to Joint Base Pearl Harbor-Hickam (JBPHH), Hawaii. The mission objective was to fly one healthy aircraft to JBPHH. The mission planning, maintenance, aircraft servicing, maintenance preflight inspections, aircrew preflight inspections, engine start, taxi, and takeoff were uneventful. Upon arriving at the enroute decision point, the MA was directed to return to Whiteman AFB, as planned.

At approximately 1424:31 CST, while on the final approach to landing, MP1 extended the MA's landing gear within safe flight parameters and immediately experienced a primary hydraulic system leak due to a failed truck position sequence valve hydraulic Mishap CryoFit ® Coupling (MCC) in the Right Main Landing Gear (RMLG) wheel well. As a result, the primary hydraulic system experienced rapid fluid loss. Then, the Main Landing Gear (MLG) Switching Valve opened to allow the backup system to pressurize the circuit. However, because the Switching Valve was upstream of the MCC, hydraulic fluid leaked from both systems. Consequently, only the Nose Landing Gear (NLG) and Left MLG (LMLG) had enough pressure to achieve a down and locked status. Since there was not enough hydraulic pressure remaining in the hydraulic system to complete a normal landing gear extension for the LMLG, the Mishap Crew (MC) had to accomplish an Emergency Gear Extension. The MC performed an Emergency Gear Extension, and the MA indicated all landing gear were down and locked until landing.

At approximately 1428:55 CST, MP2 landed the MA approximately 1,000 feet (ft) down Whiteman AFB's runway (RWY) 01 on centerline, within safe landing parameters for airspeed, vertical velocity, and g-forces. The Onboard Ground Processor (OGP) and Crash Survivable

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Memory Unit (CSMU) data indicated the MA did not have a hard landing. However, upon landing, the LMLG collapsed. As a result of the collapse, the LMLG door and left wingtip were dragged down the runway, into the infield grass and across Taxiway B. At approximately 9,062 ft down RWY 01, the MA came to a stop with the left wing extended into the infield grass and the left surge fuel tank on fire. The MC accomplished an engine shutdown and egressed via the crew entry ladder. Firefighters responded and battled the fire for approximately 30 minutes before the left surge fuel tank exploded. Approximately 10 minutes later, the left outboard fuel tank also exploded. About 20 minutes later, at 1530 CST, firefighters extinguished the fire, almost an hour after it began. The left wing and LMLG were damaged to an estimated extent of more than $300 million. The runway was damaged to the extent of approximately $27,500.

2. CAUSE

I find by a preponderance of the evidence that the cause of this mishap was the failure of the truck position sequence valve hydraulic CryoFit ® coupling, which created a rapid hydraulic fluid loss in the primary and backup hydraulic systems, resulting in the need to perform the emergency extension. The underlying source of the failure is undetermined.

The CryoFit ® coupling joined a hydraulic line to a T-fitting, which was located downstream of the MLG Switching Valve. When the fitting broke, the MLG Switching Valve cycled between the primary and backup hydraulic systems, attempting to maintain pressure in the circuit. The resulting leak at the T-fitting bled out both systems. Since the coupling was located downstream from the Switching Valve, this resulted in fluid loss in both hydraulic systems. The fluid loss resulted in the lack of sufficient pressure to lower the RMLG. Once the MC determined the RMLG was not down and locked, the MC performed an emergency gear extension. The hydraulic fluid loss in the primary system, followed by an emergency gear extension, resulted in the hydraulic MLG Lock Actuator having insufficient hydraulic pressure to assist in holding the LMLG Lock Link Assembly in place.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

I find by a preponderance of evidence that two factors substantially contributed to the mishap.

a. MLG Design Vulnerabilities

During a normal gear extension, both the RMLG and LMLG Lock Link Assemblies are held locked by the hydraulic MLG Lock Actuator (via hydraulic pressure), Upper and Lower Lock Link integrity, gravity, air loads, and the MLG Lock Springs (via tension holding the systems' overcenter geometric rigidity together). However, in an emergency gear extension following a hydraulic failure downstream of the MLG Switching Valve, the hydraulic LMLG Lock Actuator does not have hydraulic pressure to hold the Upper and Lower Lock Links in the overcenter position. The Lock Link Assembly is instead held in place only by the assembly's compromised

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overcenter geometric rigidity, anchored by the Upper and Lower Lock Link's integrity, the MLG Lock Spring's tension, airflow, and gravity.

During the emergency gear extension following the loss of hydraulic pressure, the lock link supporting the previously down and locked LMLG moved out of the required overcenter position due to the rapid pressure drop across the Emergency Bypass Valve and the restrictors' specifications, creating a hydraulic pull on the Lock Link Assembly. This change in the lock actuator's overcenter position occurred before the aircraft landed. Then, upon contact with the runway, a hydraulic fluid pulse through the LMLG Truck Position Actuator (TPA) return circuit pulled the Lock Link Assembly further out of the overcenter position, overcoming the spring tension, which broke the LMLG integrity and caused the LMLG to collapse under the weight of the aircraft.

b. Firefighting Response

The incident commander's decision to not immediately use Aqueous Film Forming Foam (AFFF) allowed the fire to spread, causing further damage to the aircraft wing. The incident commander testified that the source of the fire was determined to be fuel leaking from the MA. However, he did not permit AFFF be used for approximately the first three minutes and 28 seconds of the fire attack because of a misunderstanding that AFFF should be used only as a last resort. This misunderstanding of Air Force policy is explained by the human factor "SV002 Allowing Unwritten Policies to Become Standard." Immediate use of AFFF would have reduced the damage to the exterior of the aircraft but would not have had any impact on the internal fire in the fuel tanks, which caused the explosions.

4. CONCLUSION

After a comprehensive investigation into this mishap, I find by a preponderance of evidence that the mishap was caused by the truck position sequence valve hydraulic CryoFit ® coupling failure. Due to the MCC failure and the resulting primary and backup hydraulic system leaks, the RMLG did not extend, and the MA's landing gear system would never have achieved a safe landing configuration without the MC performing the emergency gear extension. Additionally, there are two substantially contributing factors: (1) MLG design vulnerabilities caused the lock link assembly to move out of the required overcenter (locked) position during an emergency gear extension causing it to become vulnerable to collapse upon landing; and (2) the delay in using AFFF to quickly extinguish the fire allowed the fire to spread, causing more external damage.

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14 July 2025

JESSE W. LAMARAND, Colonel, USAF
President, Accident Investigation Board

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