ACTION OF THE CONVENING AUTHORITY

The report of the accident investigation board, conducted under the provisions of AFI 51-307, that investigated the 20 November 2024 mishap near Melrose Air Force Range, New Mexico, involving CV-22B, T/N 11-0060, assigned to the 27th Special Operations Wing, Cannon Air Force Base, New Mexico, complies with applicable regulatory and statutory guidance and on that basis is approved.

[redacted]

MICHAEL E. CONLEY
Lieutenant General, USAF
Commander

9 JAN 26

Date

UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

CV-22B, T/N 11-0060

20TH SPECIAL OPERATIONS SQUADRON
27TH SPECIAL OPERATIONS WING
CANNON AIR FORCE BASE, NEW MEXICO

LOCATION: MELROSE AIR FORCE RANGE, NEW MEXICO

DATE OF ACCIDENT: 20 NOVEMBER 2024

BOARD PRESIDENT: COLONEL BRENT A. GREER

Conducted IAW Air Force Instruction 51-307

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

CV-22B, T/N 11-0060
MELROSE AIR FORCE RANGE, NEW MEXICO
20 NOVEMBER 2024

On 20 November 2024, at 1323 Mountain Standard Time, while conducting takeoff and landing practice approaches at Wilderness Helicopter Landing Zone (HLZ) in Melrose Air Force Range (MAFR), New Mexico, the Mishap Aircraft (MA), a CV-22B, Tail Number (T/N) 11-0060 experienced left hand (LH) engine shutdown followed by a Mishap Crew (MC)-directed emergency landing (EL). The incident occurred approximately 1 Nautical Mile north of MAFR on rancher-leased New Mexico state land. The MA was assigned to the 27th Special Operations Wing at Cannon Air Force Base (AFB), New Mexico. The MC was assigned to the 20th Special Operations Squadron. The MC consisted of the Mishap Instructor Pilot (MIP), the Mishap Pilot (MP), Mishap Flight Engineer 1, and Mishap Flight Engineer 2. There was no damage to civilian property, no fatalities, no injuries, and estimated cost of damage to the MA was $2,795,884.

The MC was performing day qualification and tactical events for the MP's training. Upon takeoff from Wilderness HLZ, the MP conducted a climbing right hand turn to approximately 315 feet Above Ground Level at 113 Knots Calibrated Airspeed. The MIP contacted MAFR range control to request a return to Cannon AFB. Immediately following the call, the aircraft experienced a series of cascading warnings, cautions, and advisories, culminating in a One Engine Inoperative, LH proprotor gearbox (PRGB) failure condition. The MC expeditiously evaluated the situation, the MIP directed a landing, and the MP conducted a safe emergency approach to landing.

The Accident Investigation Board (AIB) President found by a preponderance of the evidence that the cause for the mishap is attributed to a catastrophic failure of the LH PRGB Lower Input Idler Helical Gear, P/N 901-044-105-101, S/N VL00205587 (-105) due to a material inclusion in the gear's rim-to-web radius interface. Immediately following materiel failure, an 8-tooth section of the -105 gear punctured the PRGB case causing a 12 inch by 6-inch hole, leading to loss of LH PRGB oil and oil pressure followed by an LH engine overspeed condition. The overspeed condition was caused by the no-load condition induced by the failure of the -105 gear. As designed, this overspeed caused the controlling full authority digital engine control to command a shutdown of the LH engine. As designed, engine power was then automatically transferred from the right hand PRGB to the LH PRGB for the left proprotor to provide enough lift for the MC to maintain controlled flight and conduct an EL.

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CV-22B, T/N 11-0060
MELROSE AIR FORCE RANGE, NEW MEXICO

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ACRONYMS AND ABBREVIATIONS

A Above ground level altitude
AC Aircraft Commander
ACK Acknowledgement
ADO Assistant Director of Operations
AFB Air Force Base
AFCS Automatic Flight Control System
AFE Aircrew Flight Equipment
AFI Air Force Instruction
AFMAN Air Force Manual
AFOM Air Force Operational Medicine
AFSC Air Force Specialty Code
AFSOC Air Force Special Operations Command
AFTO Air Force Technical Order
AFTTP Air Force Tactics, Techniques, and Procedures
AGL Above Ground Level
AIB Accident Investigation Board
AM Ante Meridiem
AMP Aerospace Medicine Primary
ANP Advanced Practice Nurse
AO Authenticating Official
APA Aerospace Medicine Physician Assistant
APU Auxiliary Power Unit
ASM Air Space Medicine
ATC Air Traffic Control
AVSS Active Vibration Suppression System
BLM Bureau of Land Management
C Degrees Celsius
C2 Command & Control
Capt Captain
CAS Calibrated Airspeed
CBT Cognitive behavior training
CC Commander
CDI Course Deviation Indicator
CDU Control Display Unit
CG Center of Gravity
CMR Combat Mission Ready
Col Colonel
COMAFSOC Commander, Air Force Special Operations Command
CR Congressional Review
DAF Department of the Air Force
DAFI Department of the Air Force Instruction
DEERS Defense Enrollment Eligibility Reporting System
DNIF Duties not to include flying
DO Director of Operations
DOD Department of Defense
ECL Engine Control Level
EL Emergency Landing
ELS Emergency Lubrication System
EMT Emergency Medical Technician
EP Emergency Procedures
ER Exceptional Release
ETL Effective Translational Lift
FA Flight Authorization
FADEC Full Authority Digital Engine Control
FCF Functional Check Flight
FCIF Flight Crew Information File
FCS Flight Control System
FE Flight Engineer
FPM Feet Per Minute
FPPE Focused Professional Practice Evaluation
FST Fleet Support Team
FRC Fleet Readiness Center
GWOT Global War on Terror
HCE Hard Clutch Engagement
HCM Hours per Crew Member
HFACS Human Factor Analysis and Classification System
HLZ Helicopter Landing Zone
HUD Heads-up display
IAW In Accordance With
ICDS Interconnect Drive System
ICS Intercommunications System
IFR Instrument flight rules
ILS Instrument Landing System
IMDS Integrated Maintenance Data System
IO Investigating Officer
IQA Input Quill Assembly
IQT Initial Qualification Training
IMDS Integrated Maintenance Data System
ISB Interim Safety Board
JLV Joint Longitudinal Viewer
JPO Joint Programs Office
KATS Artesia Municipal Airport
KCAS Knots Calibrated Airspeed

KCVS Cannon Air Force Base
KELP El Paso International Airport
KROW Rosell Airport
KSDM Brown Field Municipal Airport
KSEZ Sedona Airport
KSUU Travis Air Force Base
KVADR K-Series Voice and Data Recorder
LH Left Hand
Lt Col Lieutenant Colonel
LVA Low Visibility Approach
LZ Landing Zone
MA Mishap Aircraft
MAFR Melrose Air Force Range
Maj Major
MAJCOM Major Command
MC Mishap Crew
MDS Mission Design Series
METL Mission essential training list
MFD Multifunction Display
MFEl Mishap Flight Engineer 1
MFE2 Mishap Flight Engineer 2
MIP Mishap Instructor Pilot
MOA Military Operations Area
MP Mishap Pilot
MQF Master Question File
MRI Magnetic resonance imaging
MSD Medical Standards Directory
MSK Musculoskeletal
MSL Mean Sea Level
MST Mountain Standard Time
NAC Nacelle
NAVAIR Naval Air Systems Command
NCO Noncommissioned Officer
NCORP Noncommissioned Officer Retraining Program
NLT No Later than
NM Nautical Mile
Np Power Turbine Speed
NOTAMS Notices to Airmen
NOV November
NVG Night Vision Goggles
OCONUS Outside the Continental United States
OEI One Engine Inoperative
ORM Operational Risk Management
PCS Permanent Change of Station
PFD Primary Flight Display
PFT Primary Flight Training
PMA Program Manager Air
PMAI Primary Mission Aircraft Inventory
PMCR Post Mission Crew Rest
POTFF Preservation of the Force and Family
PPM Parts Per Million
PR Pre-flight Inspection
PRGB Proprotor Gearbox
Psi Pounds Per Square Inch
PT Physical Therapist
Qm Mast Torque
RANGER Range Control
RFIS Remote Frequency Indicator/Selector
RH Right Hand
RSM Removable Storage Module
RTB Return to Base
RTF Return to Fly
SDO Senior Duty Officer
SGP Surgeon General
SIB Safety Investigation Board
SII Special Interest Item
SIM Simulator
SEM Scanning Electron Microscope
SMA Special Mission Aviator
SME Subject Matter Expert
SOAMXS Special Operations Aircraft Maintenance Squadron
SOF Special Operations Forces
SOG Special Operations Group
SOMXG Special Operations Maintenance Group
SOMXS Special Operations Maintenance Squadron
SOP Standard Operating Procedures
SOS Special Operations Squadron
SOTG Special Operations Task Group
SOTU Special Operations Task Unit
SOW Special Operations Wing
SrA Senior Airman
SSgt Staff Sergeant
T/N Tail Number
TAC Tactical
TCL Thrust Control Lever

TCTO	Time Compliance Technical Order
TDY	Temporary Duty
TO	Technical Order
TOC	Tiltrotor Operations Center
TSgt	Technical Sergeant
TTO	Tactical Takeoff
TTP	Tactics, Techniques and Procedures
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
USSOCOM	United States Special Operations Command
UTC	Unit type code
VFR	Visual flight rules
VSLED	Vibration Structural Life and Engine Diagnostics
VTO	Vertical Takeoff
VVI	Vertical Velocity Indicator
WCA	Warnings, cautions, and advisories
WETPASTE	Winds, elevation, temperature, power, approach path/angle, size/surface/slope, terrain surrounding the site, egress/escape path
WG	Warm gas
WIC	USAF Weapons Instructor Course
XC	Cross-country

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 19 December 2024, Lieutenant General Michael E. Conley, Commander, Air Force Special Operations Command (COMAFSOC), appointed Colonel Brent Greer as the Accident Investigation Board (AIB) President to investigate a 20 November 2024 CV-22B Osprey aircraft accident involving one CV-22B aircraft Tail Number (T/N) 11-0060 (Tab Y-2). The AIB conducted their investigation at Cannon Air Force Base (AFB), New Mexico, and Hurlburt Field, Florida, from 27 January 2025 to 26 February 2025, in accordance with Air Force Instruction (AFI) 51-307, *Aerospace and Ground Accident Investigations,* Chapter 12, dated 18 March 2019. The following additional board members were appointed: Legal Advisor (Major), Medical Member (Captain), Pilot Member (Major), Maintenance Member (Senior Master Sergeant), and Recorder (Staff Sergeant) (Tab Y-4).

b. Purpose

In accordance with AFI 51-307, *Aerospace and Ground Accident Investigations,* this AIB 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 20 November 2024, at 13:22:57 MST, the MA experienced a rapid drop of left proprotor gearbox (LH PRGB) oil pressure (Tab DD-5 to DD-6). Between 13:22:58.016 MST and 13:23:11.328 MST (approximately 13 seconds) the MA experienced a total of 27 warnings, cautions, and advisories (WCA) (Tab DD-5 to DD-6). Ultimately, these WCAs resulted in the MA having simultaneous LH PRGB and left hand (LH) engine failure conditions (Tab BB-73 to BB-266). Following emergency actions, the MC transitioned back to normal crew duties and responsibilities for landing in an austere zone (Tab B-515 to B-519). While on final descent to the intended point of landing, the MC reported "falling through," which is an un-commanded increase in the rate of descent due to a power limited situation (Tab V-26 to V-27). At 13:24:19.7 MST, the MA right main landing gear contacted the ground at a 640 feet per minute (fpm) rate of descent (Tab DD-5 to DD-6). The rapid deceleration from contacting the ground, coupled with nacelle angle and aircraft attitude, resulted in a nose left rotation, dragging the right main landing gear and causing a rapid nose drop (Tab DD-5 to DD-6). These events caused the nose wheel to contact the ground, bounce, and rotate, inducing a "R Flapping Critical" advisory (Tab DD-5 to DD-6). The MA came to rest in slight nose and right-wing low attitude at a heading of 138-degrees (Tab DD-5 to DD-6, S-5). Upon touchdown, MFE2 was thrown from his duty station on the tail into the cabin (Tab R-40). There were no fatalities and the estimated cost of damage to the MA was $2,795,844 (Tab P-2).

3. BACKGROUND

a. Air Force Special Operations Command

The Air Force Special Operations Command's (AFSOC's) core missions include battlefield air operations, agile combat support, aviation foreign internal defense, information operations and military support operations, precision strike, specialized air mobility, command and control, and intelligence surveillance and reconnaissance operations, and specialized mobility (Tab CC-3). The organization is made up of six active-duty wings, one Reserve wing, two National Guard wings, and several direct reporting units (Tab CC-3).

b. 27th Special Operations Wing

The 27 SOW's core missions include close air support, agile combat support, information operations, precision strike, forward presence and engagement, intelligence surveillance and reconnaissance operations, and specialized mobility (Tab CC-5). The wing is made up of an air staff, a mission support group, 26 squadrons, five aircraft maintenance units, and several wing staff and support agencies (Tab CC-5). As the owning unit at Cannon AFB, New Mexico, the 27 SOW also supports several tenet units on the base (Tab CC-5).

c. 27th Special Operations A3 Directorate

The 27th Special Operations A3 Directorate [formerly 27 Special Operations Group (SOG)], located at Cannon AFB, New Mexico, accomplishes global special operations taskings as an Air Force component member of the United States Special Operations Command (USSOCOM) (Tab CC-7). The 27 SOW A3 conducts infiltration, exfiltration, combat support, tilt-rotor operations, helicopter aerial refueling, close air support, unmanned aerial vehicle operations, non-standard aviation, and other special missions (Tab CC-7). The directorate leads the deployment, employment, training, and planning for 27 SOW operational and operational support squadrons (Tab CC-7).

d. 27th Special Operations A4 Directorate

The 27th Special Operations A4 Directorate [formerly 27 Special Operations Maintenance Group (SOMXG)] is responsible for all flight lines, back shop, and ammunition maintenance in support of the 27 SOW mission (Tab CC-9). The 27 SOW A4 conducts quality maintenance for five mission design series aircraft across four squadrons, seven defense contractor groups, and 1,400 Air Commando maintainers (Tab CC-9). The directorate manages over 90 facilities and provides oversight of civilian maintenance on contractor-maintained aircraft (Tab CC-9).

e. 20th Special Operations Squadron

The 20 SOS assigned to the 27 SOW A3, Cannon AFB, New Mexico, provides flexible vertical lift for USSOCOM (Tab CC-11).

f. 20th Special Operations Aircraft Maintenance Squadron

The 20th Special Operations Aircraft Maintenance Squadron (SOAMXS) executes global Special Operations maintenance taskings as an Air Force component member of USSOCOM (Tab CC-13). The 20 SOAMXS organizes, trains, and equips personnel to conduct maintenance and sustainment of CV-22B Osprey tilt-rotor aircraft and the MQ-9 Reaper remotely piloted aircraft (Tab CC-13).

g. CV-22B Osprey

The CV-22B Osprey is a tilt-rotor aircraft that combines the vertical takeoff, hover, and vertical landing qualities of a helicopter with the long-range, fuel efficiency and speed characteristics of a turboprop aircraft through the use of its rotating nacelles, measured in degrees from 0 horizontal and 96 full aft (Tab CC-15). The mission of the CV-22B is to conduct long-range infiltration, exfiltration, and resupply missions for Special Operations Forces (SOF) (Tab B-464). The CV-22B can take off with its nacelles near vertical (90-degree position) to perform a vertical takeoff (VTO) or with nacelles slightly forward (80-degree position) to accelerate forward while climbing to affect a faster departure, known as an 80 Tactical Takeoff (TTO) (Tab B-737 to B-739). "Power" developed by the CV-22B proprotor system to produce lift and thrust comes from the torque applied to the proprotor mast and is measured as percent mast torque (Qm) (Tab B-65). The MA was accepted into the Air Force inventory on 27 August 2013 and arrived at Cannon AFB on 2 December 2022 (Tab DD-3 to DD-4). The MA had recorded a total of approximately 2810 flight hours over its lifetime prior to the mishap sortie (Tab).

4. SEQUENCE OF EVENTS

a. Mission

The MA, callsign HAVOC 51, was a single ship aircraft performing day qualification and tactical events as part of the CV-22B Osprey RTF syllabus for the MP (Tab R-13). The CV-22B Osprey RTF syllabus is the AFSOC-approved training following standdowns resulting from previous mishaps (Tab BB-267 to BB-272). The planned first sortie consisted of instrument approaches at Roswell Airport (KROW), transition maneuvers at Artesia Municipal Airport (KATS), landing approaches and hover at Alien HLZ located on Bureau of Land Management-owned land near Roswell, New Mexico, landing approaches at Wilderness HLZ on MAFR, and refuel at Cannon AFB (KCVS) (Tab K-45 to K-47). The planned second sortie consisted of a crew swap with the MP disembarking the aircraft and the MC emplaning a new copilot to complete a unit indoctrination flight. The second planned sortie was not accomplished due to the mishap (Tabs K-45 to K-47, V-24). The flight authorization for HAVOC 51 was created, reviewed, and signed by the 20 SOS Assistant Director of Operations (ADO) one day prior to the mishap (Tab K-2). The 20 SOS ADO is 1 of 4 members in the 20 SOS authorized to serve as an Authenticating Official (AO) for flight authorizations. (Tab BB-21). The AO reviewed crew composition, qualifications, recent flying time, and currencies before signing the flight authorization. No deficiencies in flight authorization practices were noted following the mishap (Tab K-2).

b. Planning

Mission planning was performed by HAVOC 51 crew members on 20 November 2024 in accordance with Air Force Tactics, Techniques, and Procedures (AFTTP) 3-3.CV-22 (Tab R-12 to R-13). The MC arrived at the squadron between 0630 and 0700 MST on the day of the mishap for a 0700 MST show time (Tab R-6, R-12, R-34, and R-39). To document risk analysis, the MC utilized the 20 SOS Operational Risk Management (ORM) worksheet. The ORM worksheet considers multiple planning factors and risk assessment considerations to include mission, environment, troops, mission complexity, and others that affect the perceived risk of the mission (Tab K-5 to K-6). Risks are assessed separately as either low, medium, high, or extreme, which are then aggregated to indicate the overall risk assessment for the mission (Tab K-6). The MIP completed the ORM worksheet for HAVOC 51 and marked all areas as low except for *Troops* which was marked as medium (Tab K-6). *Crew Proficiency, Fatigue, and Repetitive Profile* was self-identified by individual MC members as the top risks for the mission (Tab K-6). Risk-mitigating factors for the identified highest risks were annotated on the ORM worksheet (Tab K-6). *Crew Proficiency* was to be mitigated by having a high time (crew experience and crew recency) instructor pilot and two instructor flight engineers on board (Tab K-6). *Fatigue* was to be mitigated by the planned simple flight profile in daytime visual flight rule (VFR) conditions and utilization of caffeine (Tab K-6). *Repetitive profile* was to be mitigated by varying the type of training (i.e., instruments, transition maneuvers, or remotes) and locations (Tab K-6). The back of the ORM worksheet contains sections to document waivers and squadron specific items that require approval (Tab K-5). It also identifies crew members who are scheduled to perform evaluations, recurrency training, upgrades, or certification training, and documents the AO's overall assessment of the risk and potential benefit of the mission (Tab K-5). Under squadron specific items, *80 TTO/VTO* approval was requested and approved (Tab K-5). MP was identified as having a recurrency flight in accordance with (IAW) with the RTF syllabus under MIP instruction (Tab K-5). The MIP assessed the overall risk for the mission to be at the high end of "low" and the ORM worksheet was signed by the MIP (Tab K-5). There is no evidence that suggests the risks identified were causal or contributory to the mishap, nor were additional hazards found to be unidentified on the MC's ORM worksheet or through MC testimony.

The mission briefing was led at the 20 SOS by the copilots, including the MP, for their respective portions of the sortie (Tab R-13). The brief was completed in accordance with the Air Force Manual (AFMAN)11-2CV-22V3CL-1 "General Aircrew Briefing" and included forecast weather, Notices to Airmen (NOTAM), route of flight, mission priorities and timelines, and ORM (Tab K-2 to K-56, R-13). Following the mission briefing, the MIP briefed the crew on general crew duties and responsibilities which covered crew coordination and emergency procedures (Tab V-22 to V-23). At the conclusion of the crew brief the MIP briefed the AO on the mission (Tab R-13). The MIP identified the risks using the 20 SOS ORM worksheet and the AO reviewed the crew currencies, qualifications, composition and assessed the overall risk of the mission (Tab K-5). Maintenance problems with the primary CV-22B aircraft scheduled for the sortie required the MC step to a spare aircraft, which was the MA (Tab R-13 to R-14). Due to the maintenance issues, the crew received a "crew ready" from maintenance for the MA at approximately 1030 MST and elected to step to the aircraft as a crew to complete the preflight (Tab R-13 to R-14).

c. Preflight

The MC arrived at the aircraft approximately 30 minutes prior to scheduled takeoff. Due to the late "crew ready" notice, the MIP delegated the exterior, interior, forms review, walk around, and all ground operations tasks to the MC in accordance with the applicable checklists (Tab R-6, R-14). The MC experienced no significant abnormalities during preflight checklists (Tab R-14). The MC started the MA's engines at 10:53 MST, taxied via Romeo and Charlie taxiways for a Charlie taxiway departure on Runway 22 (Tab N-52 to N-54).

d. Summary of Accident

The MC conducted a rolling takeoff on Cannon AFB Runway 22 at 13:13:33 MST completing all applicable checklists and associated procedures (Tab N-54). Following the departure the MC completed instrument approach training at KROW, transition maneuvers at KATS, remote landing practice at Alien HLZ prior to transitioning to MAFR for additional austere HLZ landings and hover training at Wilderness HLZ (Tab V-31). Of note, while completing landing at KATS the crew identified a fuel imbalance between the left and right forward sponson tanks (Tab V-32). The MC took appropriate action in accordance with the applicable checklist and regulations to address the fuel imbalance (Tab V-32). All other events were in accordance with applicable guidelines and regulations, were uneventful, and not relevant to this mishap. (Tabs DD-5 to DD-6, N-5 to N-37, and V-32).

As the MC was wheels down in Wilderness HLZ on MAFR after the first no hover landing, the MIP led a discussion with the MC about training and time remaining prior to their scheduled refuel time at Cannon AFB (Tab V-24). After a brief discussion the MC crew elected to discontinue training at Wilderness HLZ to ensure they could make their scheduled refuel time and complete the crew swap with the additional copilot (Tab V-24). At 13:22:15 MST the MA departed from Wilderness HLZ via an 80 TTO (Tab N-38). As the MP called for landing gear retraction, the MC discussed a strong strange smell, which they described as a skunk or burnt marijuana (Tab N-38). Interviews with the MC show there were no additional indicators (i.e. additional visual, audio, olfactory, or vibrations) or MA provided parametric data (i.e. vibrations, WCA, loss of pressure, visual, or audio) to draw correlation between the scent and the mishap (Tabs DD-5 to DD-6, N-38, and V-21 to V-68).

At 13:22:57 MST, the MA was established in a standard rate right hand turn passing through a heading of 007-degrees, at 315 feet above ground level (AGL), 60-degree nacelle angle, and 113 knots calibrated airspeed (KCAS) (Tab DD-5 to DD-6). At this moment, the LH PRGB oil pressure rapidly dropped from a steady state pressure of 81 psi to 33.5 psi in 1.67 seconds (TabsDD-5 to DD-6). At 13:22:58.25 MST, the MC received simultaneous indications of a LH Engine Power Turbine Speed (Np) at 112% and "LH PRGB Press Low" caution (Tab DD-5 to DD-6). At 13:22:59.25 MST the LH engine Np was at 119%, resulting in a Full Authority Digital Engine

Control (FADEC)-directed engine shutdown. At 13:22:59.547 MST the MA reported "LH Engine Fail" warning (Tab DD-5 to DD-6). Simultaneously, the entire MC reported feeling a minor shudder in the MA like when the Active Vibration Suppression System (AVSS) is cycled on and off (Tab V-25). At 13:22:59.75 MST the LH PRGB oil pressure gauge indicated 0 psi, then at 13:23:00.016 MST a "LH PRGB Fail" warning posted (Tab DD-5 to DD-6). These near simultaneous failures triggered the voice warning tone system (Tab DD-5 to DD-6).

The CV-22B Osprey voice warning system is designed to provide a voice warning tone to the crew which is prompted by 19 conditions (Tab BB-55). The first four warnings categories are prioritized 1) LH or RH Engine Fire, 2) LH, RH, or Mid Wing Fire, 3) LH or RH Engine Failure, and 4) LH or RH PRGB failure (Tab BB-55). Warnings cannot be cleared by crew acknowledgement as cautions and advisories can (Tab BB-55). An ongoing voice warning message will continue to be announced to completion (Tab BB-55). In the event of multiple, concurrent, or overlapping system warning conditions, subsequent voice warnings are suppressed for a period of five seconds after any warning occurrence (Tab BB-55). During the voice suppression period, the occurrence of subsequent warnings is signaled by an audible warning tone (Tab BB-55). The tone is a sweep from 700-1700 Hertz in 1 second and sounds like a "WHOOP," With one sweep, or "WHOOP," per subsequent warning tone (Tab DD-5 to DD-6). The MA only had one "WHOOP," denoting a total of two voice warnings for the "ENGINE FAILURE, ENGINE FAILURE" and "GEARBOX FAILURE, PROPROTOR GEARBOX" (Tab DD-5 to DD-6). The voice warning "ENGINE FAILURE, ENGINE FAILURE" was the only voice warning reported by the MC (Tabs N-38, R-17, R-25, R-30, and R-40).

The MA indicated 27 WCAs in a 13 second period between 13:22:58.016 MST and 13:23:11.328 MST (Tab DD-5 to DD-6). It is assessed that the MC did not have the time to fully analyze the situation but reached the logical conclusion to land due to the frequency and amount of WCAs.

Of these WCAs, the MA had six conditions that required landing (Tab BB-73 to Tab BB-266). In chronological order they were "LH PRGB PRESS LOW" (land as soon as practical), "LH PRGB PRESS LOST" (land as soon as possible), "L ENG FAIL" (land as soon as practical), "PRGB" fail (land as soon as possible or with secondary indications, land immediately), "LH PRGB CHIPS" (land as soon as possible or with secondary indications, land immediately), and "L NAC BLOWER FAIL" (land as soon as possible or with secondary indications, land as soon as possible) (Tab BB-73 to Tab BB-266). Upon the first indication, MFE1 said "Press Low, land" (Tab N-38).

Subsequently, the MC observed the L ENG FAIL and PRGB red text boxes on all the multi-function displays (MFD), confirmed LH PRGB oil pressure lost, and confirmed LH engine shutdown via primary and secondary flight displays (Tab V-25 to V-26). The MP began an immediate descent and left turn into the wind (Tab V-26). Additionally, the MIP and MP rapidly analyzed surface conditions, slope, hazards, and obstacles to select a suitable landing location (Tab DD-5 to DD-6). The MIP and MFE1 identified and evaluated aircraft systems to bolster the MC's collective understanding of the aircraft state, including critical failure states and requirements to land immediately (Tab V-26). MFE1 completed the checklist requirements for landing including gear actuation and landing approach calls. Simultaneously, MFE2 completed a visual scan of the LH engine nacelle to check for smoke, fluid leaks, or damage and reported nothing unusual (Tab V-65). Following emergency actions, the MC transitioned back to normal crew duties and responsibilities for landing in an austere zone with the potential of low visibility approach (Tab B-515 to Tab B-519).

e. Landing

The MA had a significant reduction in power available due to the OEI condition, resulting in a 28% power deficit (81% Mast torque (Qm) required and 53% Qm available) for the conditions experienced at the time of the mishap (Tab B-90 and B-376). In an OEI condition, the 1-CV-22(C)B-1 recommends a roll-on landing (Tab BB-73 to BB-266). Due to the land immediately situation, the MC was unable to return to a prepared surface and had two landing options: a normal approach to landing or marginal power roll on landing. A marginal power roll-on landing as defined in the AFTTP 3-3. CV-22 is a maneuver requiring the crew to maintain a faster air speed closer to the ground than normal to minimize the power required (Tab B-746). A marginal power roll-on landing per the AFTTP 3-3.CV-22 is more like an airplane landing than a helicopter landing. The marginal power roll-on landing is a challenging maneuver that requires skillful timing to dissipate forward speed and minimize the rate of descent. This maneuver, if not skillfully timed, has the potential to result in a forward velocity and/or rate of descent exceeding the 1-CV-22(C)B-1 Operational Limits (Tab B-519 and BB-63). MC interviews revealed that the MC analyzed power margins and complexity of both landing maneuvers prior to electing to complete a normal approach (Tab V-21 to V-43). The MP decided to fly a normal approach and managed the power, closure rate, and vertical velocity for a vertical landing to an unprepared surface (Tab DD-5 to DD-6). The final landing location of the MA was an austere cattle pasture 0.93 nautical miles north of Wilderness HLZ with a slight downward sloping aircraft left to right gradient (Tab V-28).

The MP flew a stabilized approach with minimal power application, not exceeding 300 feet per minute rate of descent, while staying above effective translational lift (ETL) air speed. Employing this technique increased rotor efficiency and reduced the power required for forward flight (Tab DD-5 to DD-6). The MP established the MA on short final to the intended point of landing on a 151-degrees heading, 88-degree nacelles, 34 knots ground speed, and at 100 feet AGL (Tab DD-5 to DD-6) began slowing below ETL. The MA sensors indicated winds on short final were 203-degrees at 10 knots (Tab DD-5 to DD-6). At approximately 40 feet AGL the MC reported "falling through," which is an un-commanded increase in the rate of descent due to a power limited situation (Tab V-27). Below 50 KCAS, the CV-22B Osprey Automatic Flight Control System (AFCS) transitions from coordinated flight to heading hold mode for the directional control logic, resulting in automated rudder inputs to hold current aircraft heading (Tab BB-58 to BB-59). ETL for the CV-22B Osprey is approximately 40 KCAS. The change in AFCS directional control logic ensured the MA held the 155-degree heading instead of allowing the nose to turn into the wind (Tabs BB-59 and DD-5 to DD-6). The drag induced by crosswind controls from the AFCS combined with slowing below ETL too high exacerbated the power deficiency causing the "fall through" (Tab DD-5 to DD-6).

From the "fall through" at 40 feet AGL to 20 feet AGL, the MP increased power. At 20 feet AGL, the MP called "power's all in," followed by an MFE2 "slow your forward" call. (Tabs DD-5 to DD-6, N-39, and V-27). The MP then commanded the nacelles full aft to 96-degrees (Tab DD-5 to DD-6). At 13:24:19.7 MST the MA right main landing gear contacted the ground at a 640 foot per minute (fpm) rate of descent, 96-degree nacelle angle, 5-degree nose high attitude, 6-7 knot forward ground speed, and on a 151-degree heading (Tabs DD-5 to DD-6). The MA landed below the maximum allowable rate of descent (720 fpm) for its gross weight in accordance with the 1-CV-22(C)B-1 (Tabs BB-63 and DD-5 to DD-6). The forward velocity of the MA exceeded the recommended touchdown speed and rate of descent for a Low Visibility Approach (LVA) in accordance with the AFTTP 3-3.CV-22 (Tab B-514). The optimal LVA approach tactics, techniques, and procedures (TTP) assumes both engines are operating (Tab B-514). The rapid deceleration from contacting the ground, coupled with nacelle angle and aircraft attitude, resulted in a nose left rotation, dragging the right main landing gear, causing a rapid nose drop (Tab DD-5 to DD-6). These events caused the nose wheel to contact the ground, bounce, and rotate, inducing a "R Flapping Critical" advisory (Tab DD-5 to DD-6). The MA came to rest in a slight nose and right-wing low attitude at a heading of 138-degrees (Tab DD-5 to DD-6). Upon touchdown, MFE2 was thrown from his duty station on the tail into the cabin (Tab V-64).

Figure 4-1. MA Right Main Landing Gear Imprint (Tab S-2)

Figure 4-2. MA Nose Gear (Tab S-3)

Figure 4-3. MA Nose Gear ditch (Tab S-4)

Figure 4-3. MA Final landing orientation (Tab S-5).

f. Egress and Aircrew Flight Equipment (AFE)

The MC did not conduct an emergency shutdown (Tab V-26 to V-27). After landing, they assessed the situation to be stable with no immediate or continued danger (Tab V-27). The MC elected to conduct a modified normal shutdown remaining on the auxiliary power unit (APU) to keep electrical power, perform maintenance downloads, and communicate with range personnel (Tab V-27 to V-28). The MC expedited the normal shutdown sequence by omitting the engine cooldown procedure and nacelles to 78 degrees procedure per the normal shutdown checklist (Tab BB-75). Given the totality of the circumstances, this checklist deviation was not a factor in this mishap. Upon completing the shutdown and transmission of their status and location to MAFR range control the MC egressed the aircraft via the aft cabin ramp (Tab N-43). Further, AFE maintainability, serviceability, and inspections were not a factor in this mishap (Tab H-2 to H-21).

g. Search and Rescue (SAR)

The MC followed the local procedures for Cannon AFB and MAFR, in accordance with FCIF (Flight Crew Information File) 27 SOG 23-021 (Tabs BB-53, N-51). At 13:31:32 MST the MC contracted MAFR Range control utilizing the CV-22 line of sight radios and provided the MC position and no crew injuries. At 13:33:31 MST Ranger coordinated the overhead visual surveillance of the MA utilizing an MQ-9 Predator (Tab N-42). By 13:36:24 MST MFE2 completed a visual inspection of the aircraft, and the MIP has contacted the 20 SOS operations desk to relay the situation and status of the crew (Tab N-43). At 13:54:34 MST Melrose range control informs Cannon Approach no emergency response is required from Cannon AFB, because Melrose range emergency personnel are responding to the event (Tab N-48). Within approximately thirty minutes of landing first responders arrived on scene to include the fire captain and the crew was medically assessed (Tab V-64). Post medical assessment, via EMTs, at the MA the MC the recommendation was no ER required, and the MC would be transported to the Cannon AFB clinic (Tab R-52).

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Technical Orders (TO)

Air Force TOs provide instructions for the operation and maintenance of AF military systems and end items (Tab BB-3). TOs include all manuals developed or acquired for organic operation, maintenance, inspection, modification, or management of centrally acquired and managed AF systems and end items (Tab BB-2). Prior to starting any task, all applicable TOs must be reviewed for familiarization with the latest procedures (Tab BB-4). Time Compliance Technical Orders (TCTOs) are TOs used by maintenance personnel to process system changes which must be completed within a specified period and/or specified date (Tab BB-5).

b. Aerospace Equipment Forms Documentation

(1) General Information

AF CV-22B aircraft utilize the Air Force Technical Order (AFTO) 781 series forms and the computerized database Integrated Maintenance Data System (IMDS) to document all maintenance and inspection actions (Tab BB-10). These mechanisms collectively provide a maintenance, inspection, service, configuration, status and flight record for the aerospace vehicles and trainers for which they are maintained (Tab BB-10).

a. AFTO Form 781H, Aerospace Vehicle Flight Status and Maintenance

The AFTO Form 781H is used to document maintenance status, servicing information, and provide a ready reference of aircraft status (Tab BB-17). The form also indicates the status and history of inspections (Tab BB-17).

b. AFTO Form 781A, Maintenance Discrepancy and Work Document

The AFTO Form 781A is used to document each discrepancy identified by aircrew or maintenance personnel (Tab BB-16). Symbols are used on maintenance documents to make important notations instantly apparent, they indicate condition, fitness for flight or operation, servicing, inspection, and maintenance status of the aircraft (Tab BB-13).

i. Red X "X"

The Red X indicates the aircraft is considered unsafe or unserviceable, non-airworthy, or unknown status of accountability of a special inspection/time change item has been identified and will not be flown or used until the unsatisfactory condition is corrected and the symbol is cleared (Tab BB-13 to BB-14).

ii. Red Dash "—"

The Red Dash indicates the condition of the aircraft or equipment is unknown (Tab BB-14 to BB-15). The Red Dash is also used to document operational checks, cure checks, Functional Check Flight (FCF) and when inspections are due IAW applicable aircraft specific -6 TOs (Tab BB-14).

iii. Red Diagonal "/"

The Red Diagonal indicates a discrepancy exists on the equipment but is not sufficiently urgent or dangerous enough to warrant its grounding discontinued use (Tab BB-15).

c. AFTO Form 781K, Aerospace Vehicle Inspection, Engine Data, Calendar Inspection, and Delayed Discrepancy Document

The AFTO Form 781K is used to document period, major or phase inspections, engine data, calendar or hourly inspection schedule items, and delayed discrepancies (Tab BB-19). Delayed discrepancies are those that will be completed later, upon receipt of parts, or at the next maintenance convenience and do not affect the safety of flight or use of equipment (Tab BB-19).

(1) Active Forms

Active AFTO Form 781 series forms are those currently in use by maintenance personnel to accurately report aircraft condition, any recent repairs, and report airworthiness (Tab BB-12). Open discrepancies are those that have not been corrected (Tab BB-16). The active AFTO Form 781 series binder accompanying the MA on the day of the mishap contained zero open Red X discrepancies, 10 open Red Dash discrepancies, and 50 open Red Diagonal discrepancies, with most of the Red Diagonals placed in the AFTO Form 781K as delayed discrepancies (Tab D-9 to D-20 and D-71 to D-79). There were no open discrepancies affecting the safety of flight or airworthiness of the aircraft (Tab D-9 to D-20 and D-71 to D-79). The status of the day was a Red Dash (Tab D-7). Maintenance personnel completed a TCTO inspection on the LH Nacelle the night prior to the day of mishap (Tab D-15 to D-19). The inspection was a visual inspection of the routing of a wire harness along the PRGB Input Quill, no damage to the PRGB prior to the time of the mishap was identified (Tab D-15 to D-19 and U-26 to U-28).

(2) Inactive Forms

Inactive AFTO Form 781 series forms are those that are retained for historical purposes, known as the aircraft historical jacket file (Tab BB-12). When active forms are moved to the historical file, all active/open discrepancies are carried forward to the active forms (Tab BB-16). Historical forms dating back to 12 September 2024 were reviewed (Tabs DD-3 to DD-4). Historical forms dated 24 September 2024 through 4 October 2024 were missing from the historical file and documented via a "27 Wing Plans and Scheduling Missing Aircraft Forms Letter" and were not able to be reviewed (Tab DD-3 to DD-4). There was no maintenance activities during the period reviewed identified that could have contributed to or been causal to the mishap (Tab DD-3 to DD-4). The last maintenance activity performed on the LH PRGB occurred on 18 October 2024 and was a 70-hour scheduled maintenance to remove and inspect the PRGB debris sensors and collectors for debris/chips. No debris/chips were found during this inspection and all applicable TOs were followed (Tab DD-3 to DD-4).

d. Aerospace Vehicle Inspections

Inspection intervals required for AF aerospace vehicles are prescribed in specific mission design series (MDS) -6 TOs (Tab BB-7). The CV-22B MDS uses the Phase concept for inspection intervals (Tab BB-20). Major inspections are completed on an accumulated flight hour basis, the CV-22B Phase inspection occurs every 280 flight hours (Tab BB-20).

(a) Pre-Flight Inspections

The Pre-Flight Inspection (PR) is a flight preparedness inspection done in accordance with the MDS specific -6 TO or maintenance manual and includes visually examining the aerospace vehicle and operationally checking certain systems and components to ensure there are no serious defects or malfunctions (Tab BB-7 to BB-8). The PR validity period is 72 hours (Tab BB-7). The PR on the MA was accomplished on 19 November 2024 at 2245 MST and no serious defects or malfunctions were identified (Tab D-6). The fuel system was de-serviced to the scheduled amount to the day's flight and the right-hand main landing gear strut was serviced (Tab D-7 and D-20). Neither of these two servicing actions were contributary or casual to the mishap (Tab D-7 and D-20). All inspection and servicing actions were completed IAW all applicable TOs (Tab D-7 and D-20).

(b) Hourly Inspections

Hourly Inspections are those designated by applicable MDS -6 TOs or maintenance manuals that are to be completed or evaluated at a specified hourly period (Tab BB-9). The Phase inspection is cumulative for the life of the aircraft and is completed IAW with specified MDS TOs or maintenance manuals (Tab BB-9). The last Phase inspection completed on the MA was completed at 2721.4 accumulated flight hours (Tab D-70).

e. Maintenance Procedures

Prior to the launch of any aircraft, maintenance actions and procedures are accomplished and documented, to include servicing, PR, exceptional release (ER), and verification of inspections (Tab BB-18). The ER serves as a certification that the authorized individual who enters their minimum signature has reviewed the active forms, and IMDS, to ensure the aerospace vehicle is safe for flight (Tab BB-18). Prior to flight on the day of the mishap, all pre-flight maintenance activities were accomplished IAW prescribed TOs and the ER was signed by an authorized individual (Tab D-6).

f. Maintenance Personnel

On the day of the mishap, there were eight (8) maintenance personnel actively involved with launch operations (Tab V-2 to V-20). All launch actions were performed in accordance all applicable TOs and/or maintenance manuals (Tab D-2 to D-115).All maintenance actions involved with the generation and launch of the MA were normal and IAW with all applicable TOs and revealed no information that could be contributary or causal to the mishap (Tab V-2 to V-20). A review of all individual military training records was conducted and all personnel who performed maintenance actions on the MA were properly trained on all tasks (Tab DD-3 to DD-4). All actions were performed IAW applicable TOs and no pre-mishap damage or abnormalities were identified (Tab V-2 to V-20). Additionally, MX members took photographs of the area to confirm correct wire routing, the lower section of the LH PRGB and Input Quill Assembly (IQA) are visible with no abnormalities noted (Figures 5-1, 5-2, 5-3; Tab U-26 to U-28). Following the mishap, blood samples were taken from maintenance personnel and no members tested positive for improper substances (Tab C-3 to C-24).

Figure 5-1. View of Outboard LH PRGB Looking UP (Tab U-26)

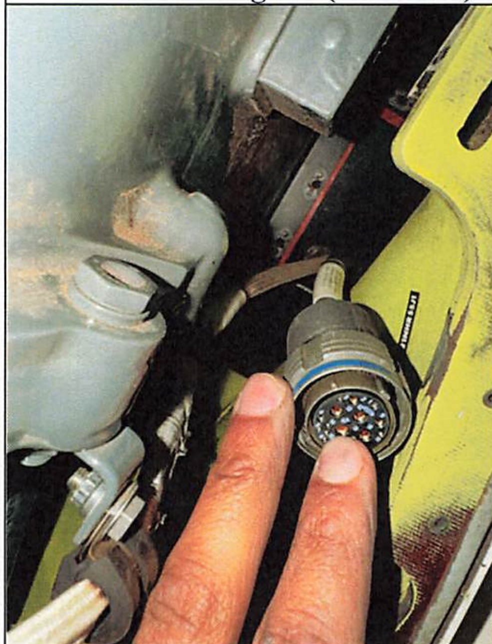
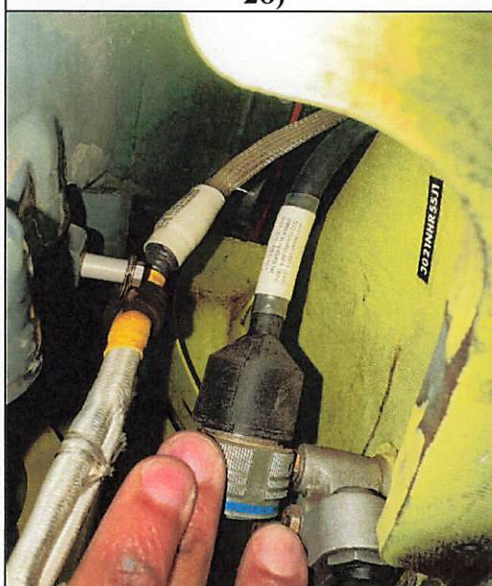


Figure 5-2. View of Outboard LH PRGB Looking Inboard (Tab U-27)

Figure 5-3. View of Outboard LH PRGB Looking Up and Aft (Tab U-28)



g. Fuel, Hydraulic Fluid, and Oil Analysis

(1) Fuel

Post-mishap, fuel samples were taken from the MA's individual fuels tanks, the last fuel truck used to service the aircraft and the fuel storage tank 396 and sent to the Air Force Petroleum Office laboratory at Wright-Patterson, Ohio for testing (Tab J-225 to J-240). All samples except the Left Forward Sponson and storage tank 396 tested within limits and free of contamination (Tab J-225 to J-240). The samples from the Left Forward Sponson tank and fuel storage tank 396 exhibited evidence of visible sediment in the sample (Tab J-233 to J-234). There is no evidence to suggest this sediment was contributory or causal to the mishap.

(2) Hydraulic Fluid

Post-mishap, hydraulic fluid samples were taken from the MA's 3 hydraulic systems and sent to the Air Force Petroleum Office laboratory at Wright-Patterson, Ohio for testing (Tab J-241 to J-243). All 3 samples failed specification requirements for presence of water and neutralization number (Tab J-241 to J-243). The #1 Hydraulic system sample tested at 126-parts per million (ppm) water content, exceeding the 100-ppm maximum and .14 (mg KOH/g) neutralization number, exceeding the .10 (mg KOH/g) maximum (Tab J-241). The #2 Hydraulic system sample tested at 130-ppm water content, exceeding the 100-ppm maximum and .13 (mg KOH/g) neutralization number, exceeding the .10 (mg KOH/g) maximum (Tab J-242). The #3 Hydraulic system sample tested at 131-ppm water content, exceeding the 100-ppm maximum and .15 (mg KOH/g) neutralization number, exceeding the .10 (mg KOH/g) maximum (Tab J-243). It was noted in the laboratory testing for all 3 samples that there was insufficient quantity provided in each sample to complete all testing requirements (Tab J-241 to J-243). There is no evidence to suggest the failed test results of the hydraulic fluid were contributary or casual to the mishap.

(3) Engine Oil

Post-mishap oil samples were taken from both the left and right engines and sent to the Air Force Petroleum Office laboratory at Wright-Patterson, Ohio for testing (Tab J-211 to J-214). Both samples tested within limits and were free of contamination (Tab J-211 to J-214).

(4) Midwing Gearbox

Post-mishap, an oil sample was taken from the midwing gearbox and sent to the Air Force Petroleum Office laboratory at Wright-Patterson, Ohio for testing (Tab J-215 to J-216). The sample failed the specification requirement for trace metal content for the presence of silicon in the sample, testing 53-ppm, exceeding the 10-ppm limit (Tab J-215 to J-216). There is no evidence to suggest the failed test results were contributary or casual to the mishap.

(5) Tilt Axis Gearbox

Post-mishap, oil samples were taken from both the left and right tilt axis gearboxes and sent to the Air Force Petroleum Office laboratory at Wright-Patterson, Ohio for testing (Tab J-221 to J-224). The left tilt axis gearbox sample failed the specification requirement for trace metal content for the presence of titanium in the sample, testing 3-ppm, exceeding the 2-ppm limit (Tab J-221 to J-222). The right tilt axis gearbox failed the specification requirement for viscosity, testing 5.50-mm^2/s, exceeding the 5.40-mm^2/s maximum (Tab J-223 to J-224). It was noted in the laboratory testing for both samples that there was insufficient quantity provided in each sample to complete all testing requirements (Tab J-221 to J-224). There is no evidence to suggest the failed test results were contributary or casual to the mishap.

(6) Proprotor Gearbox

Post-mishap, oil samples were taken from both the left and right PRGBs and sent to the Air Force Petroleum Office laboratory at Wright-Patterson, Ohio for testing (Tab J-217 to J-220). The right PRGB sample tested within limits and was free of contamination (Tab J-219 to J-220). The left PRGB sample failed the specification requirement for trace metal content for the presence of Aluminum, testing 3-ppm, exceeding the 2-ppm maximum and the presence of Iron, testing 4-ppm, exceeding the 2-ppm maximum (Tab J-217 to J-218). It is most likely the presence of both trace metals is from debris processing in the PRGB during the mishap and not from prior contamination.

h. Unscheduled Maintenance

The last scheduled maintenance inspection was accomplished on 7 November 2023 (Tab U-63). Between the 280-hour Phase D inspection and the day of the mishap, aircrew reported 6 discrepancies resulting in unscheduled maintenance (Tab U-22). Each of the discrepancies were reported during debrief and documented in the aircraft AFTO 781 series forms and in IMDS (Tab U-22). Maintenance personnel performed maintenance on each discrepancy and cleared each one after performing all required operational checks or the discrepancy remained open as it did not affect safety of flight or airworthiness (Tabs D-2 to D-115, U-2 to U-17). In the preceding 60 days prior to the mishap there was only 1 aircrew reported discrepancy that resulted in unscheduled maintenance on the LH PRGB, a crew reported LH PRGB pressure loss intermittently on 24 Oct 2024 (Tab U-14). Maintenance personnel replaced the LH PRGB oil pressure transducer, all applicable TOs were followed, and operations and cure checks complied with (Tab U-14). A 12-month history of all maintenance records for the LH PRGB, LH IQA, and LH Engine were reviewed (Tab U-2 to U-12). There were 2 documented maintenance actions performed prior to the mishap: During the TCTO 1183 PRGB debris inspection performed on 5 March 2024, debris was found on the LH PRGB #3 Debris Sensor, #3 Strainer, and #4 Strainer and the previous identified oil pressure transducer replacement (Tab U-2 to U-12). The debris were collected and shipped to the Naval Air Warfare Center Weapons Division, China Lake, CA for analysis (Tab U-20 to U-21). Additional checks for further debris were conducted on 14 April 2024; no debris was identified at that time (Tab U-4). Final analysis determined the material was manufacturing debris and returned the PRGB to service on 29 April 2024 (Tab U-19). All follow-on maintenance checks were completed IAW all applicable TOs and/or maintenance manuals (Tab U-2 to U-12). A review of the MA's performance for the 60-day period prior to the mishap revealed the MA flew 10 of 10 scheduled sorties, of which 7 of 10 sorties flown landed with zero to minor discrepancies and accumulated 38.9 flight hours (Tab U-22). A review of the V-22 Virtual Technical Assistance and Maintenance Program, the program used to request FST engineering assistance, for the past 12 months indicated a total of 12 technical assistance requests were submitted (Tab U-23 to U-25). Of those, 12 were answered and maintenance completed with no defects (Tab U-23 to U-25). Two remain open for various reasons but do not affect the safety of flight or airworthiness (Tab U-23 to U-25).

6. AIRFRAME

a. Historical Analysis

It is important to understand some of the history of X-53 steel, its use on various components in the V-22 Osprey and documented cases of material failure due to material inclusions. A material inclusion is a foreign or unwanted substance, particle, of defect trapped within a material during its formation or processing, which can negatively impact its properties. X-53 steel is used on the V-22 to manufacture several drive system components to include the helical drive gears in the PRGBs (Tab J-104). X-53 steel, at the time of the MA's installed component manufacture, is refined using a "double-melt" process that includes vacuum induction melting followed by vacuum arc remelting (Tab J-204). It is during the refining process that microscopic material inclusions can form inside the steel (Tab J-204). It should be noted that there are presently no processes in existence that produce materials totally free from inclusions, and each remelt step after the initial removes or refines non-metallic inclusions from the material (J-204).

A Program Manager Air-275 (PMA-275) System Safety Formal Risk Assessment dated 28 March 2014 identified impurities in the gear raw material that can result in stress concentration resulting in cracks in the gear structure (Tab J-103 to J-124). Cracks in gears can result in pieces breaking off and damaging other gearbox components or can result in failure of the gear to perform its function, potentially leading to loss of gearbox function (Tab J-104). The material in reference is X-53 Steel (Tab J-104). Prior to the document release, there were 6 documented cases of gear cracks from impurity inclusions in the material, with 3 resulting in chip indications (Tab J-106). The document identifies the criticality of the various X-53 components based on normal, OEI, and Blue Water (over bodies of water) operations (Tab J-115). The -105 Helical Input Idler Gear is identified as NOT CRITICAL for normal operations as failure still allows for the opposite engine to drive the PRGB and CRITICAL only for failure of opposite engine during OEI operation and during Blue Water operations where failure could possibly lead to collateral damage to gearbox case causing loss of lubrication (Tab J-115). A Preliminary System Safety Risk Assessment dated 1 October 2020, distributed by PMA-275, discussed the X-53 inclusion failure for a -105 Helical Input Idler Gear for a LH PRGB (Tab J-66). As of publication, there were an additional 7 documented gear failures from inclusions in the X-53 steel (Tab J-68). Additionally, 10 of the 13 documented gear failures resulted in chips (Tab J-69). Of the 13 total documented instances of gear failure, only 1 was the -105 Helical Input Idler Gear on a LH PRGB during a Green Run (test run on a stand-alone platform) (Tab J-69). The document did not change the overall risk assessment for the -105 Helical Input Idler Gear; however, it added verbiage that the gear is critical to drive the PRGB oil pump -110 gear, during OEI scenarios, and during Blue Water operations (Tab J-77). The 31 January 2024 V-22 System Safety Risk Assessment discussed single point failures within the PRGB that could cause catastrophic failure. (Tab J-82 to J-102). Additionally, a non-chip producing failure mode of a crack or hole in the PRGB case set which could result in rapid loss of oil and the seizure of gears and failure to transfer power to the proprotor system was noted (Tab J-90). Per the 2024 risk assessment, all documented inclusions were too small to be detected by the currently approved ultrasonic inspection technique (Tab J-109). A type of inclusion failure called Gear Web/Rim failure was defined as a flaw in the non-carburized area of the rim or web of the gear and can occur if a flaw of significant size (undefined) is located anywhere in these areas (Tab J-102). This high-cycle, or fast rotating, fatigue issue will be catastrophic since complete loss of drive will occur when a crack separates the gear rim or web from the shaft section (Tab J-102). This failure mode may not generate any chips prior to loss of drive (Tab J-102). Gear Web/Rim failure was highlighted as the greatest risk of catastrophic gearbox failure due to the loss of function and the lack of early detection in the form of chips (Tab J-102).

b. Structures and Systems

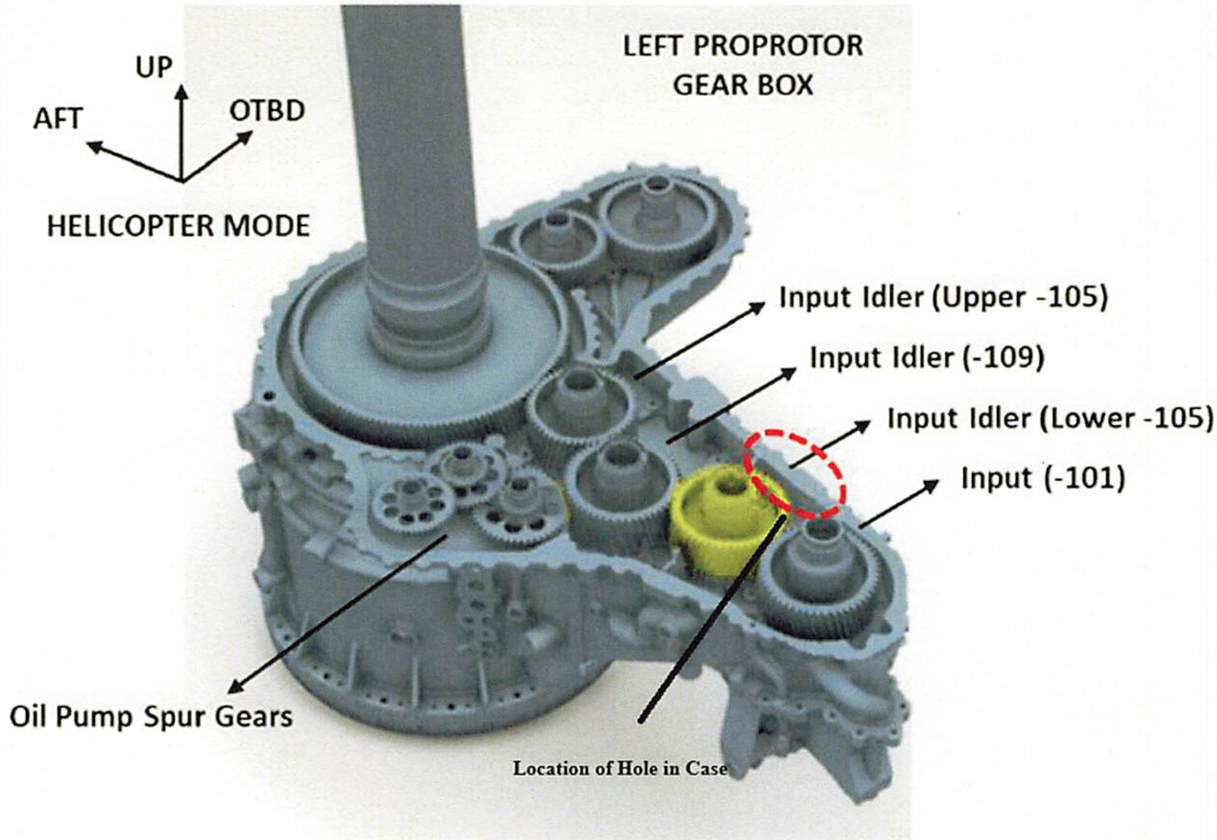
The MA's LH PRGB and LH IQA were damaged in this mishap (Tab J-33 to J-65, J-162 to J-202, and U-29 to U-62). The MA's LH PRGB, LH IQA, and LH Engine were removed and sent for engineering analysis (Tabs J-2 to J-65, J-162 to J-202, and U-29 to U-62).

The V-22 utilizes a chip detection system to identify and alert the crew when the presence of foreign metallic debris in the PRGB is detected (Tab J-86). Chips are any metallic or conductive debris that may be present in the system. The chip detection system consists of 3 automatic burn-off type debris sensors (chip detectors) and 4 chip collectors (magnetic plugs) (Tab J-86). When metallic or conductive material collect on the debris sensors, the automatic burn off function engages and the system attempts to burn the debris off the sensors, and the crew is alerted with a "PRGB CHIP BURN" advisory (Tab J-87). In the event there are 3 consecutive failed attempts to burn off the debris, the crew receives a "PRGB CHIPS" caution (Tab J-87). If the debris is successfully removed from the sensor, the system resets and another caution or advisory may post, there is no limit to the number of times a "PRGB CHIP BURN" advisory may post and all 3 of the debris sensors can post advisories at any time (Tab J-87).

1. V-22 Drive System Engineering Investigation

The MA's LH PRGB and IQA were removed and sent to Fleet Readiness Center (FRC) East for engineering investigation by the Fleet Support Team (FST) (Tab J-33 to J-65). The engineering investigation determined the following: The LH engine failure and LH PRGB chip indications that caused an EL to be executed for CV-22B T/N 11-0060 on 20 November 2024, were the result of a failure initiated at a material inclusion in the Lower Input Idler Helical Gear, P/N 901-044-105-101, S/N VL00205587, within LH PRGB S/N A-101 (Tab J-59).

Figure 6-1. Diagram of LH PRGB (Tab J-36)



Upon investigation of the LH PRGB, the following damage was identified (Tab J-39 to J-49). A hole in the LH PRGB case measuring approximately 12 inches by 6 inches on the outboard side of the helical section (Tab J-39). The PRGB cover internal surfaces exhibited significant damage and material loss in the vicinity of the failed -105 Lower Input Idler Helical Gear (Tab J-43). The shroud that covers the input helical gears was bent and mangled (Tab J-43). An 8-tooth piece of the -105 Lower Input Idler Helical Gear was found in the LH center body inlet assembly. (Tab J-40). The remaining 43-tooth section of the -105 Lower Input Idler Helical Gear was deformed into a "J" shape and wedged in the hole in the helical section of the PRGB (Tab J-39). The -105 Upper Input Idler Helical Gear exhibited minor tooth damage and evidence of debris processing (Tab J-48). The -109 Input Idler Helical Gear exhibited significant tooth damage, chipping, cracking, and material loss (Tab J-45). All four primary oil lubrication jets adjacent to the failed -105 Upper Input Idler Helical Gear exhibit damage (Tab J-43). Evidence of milling damage and material loss on the internal LH PRGB case under the bore of the Oil Pump Drive Roller Bearing was found (Tab J-43). The -101 Input Helical Gear exhibited minor tooth damage and chipping (Tab J-47). The - 113 Bull Gear exhibits minor evidence of debris processing (Tab J-48). The Oil Pump Drive Spur and Helical Gear exhibited evidence of grinding/milling and material loss (Tab J-49).

Figure 6.2. Photo of LH PRGB Damage While Still on MA (Tab S-6)

Figure 6-3. LH PRGB Outboard Case Damage with Wedged -150 Gear Segment (Tab J-39)

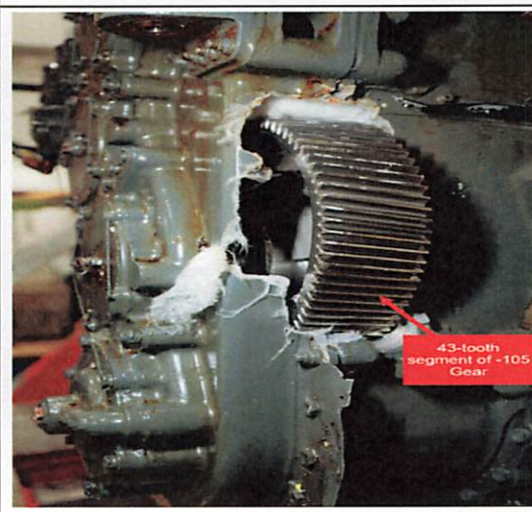


Figure 6-4. Photo of LH PRGB Outboard Case Damage (Tab J-42)

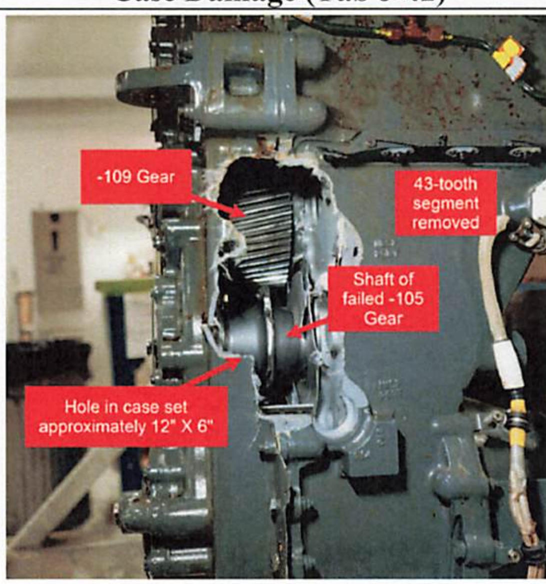


Figure 6-5. Photo of LH PRGB Helical Drive Section Damage (Tab J-44)

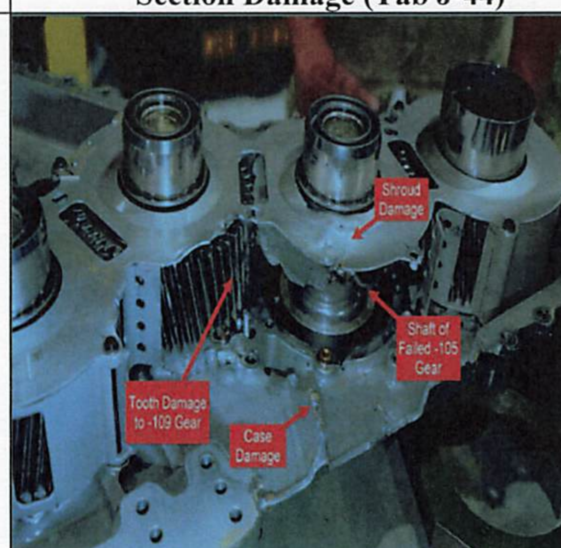


Figure 6-6. Photo of LH PRGB -105 Lower Input Idler Helical Gear Damage (Tab J-53)

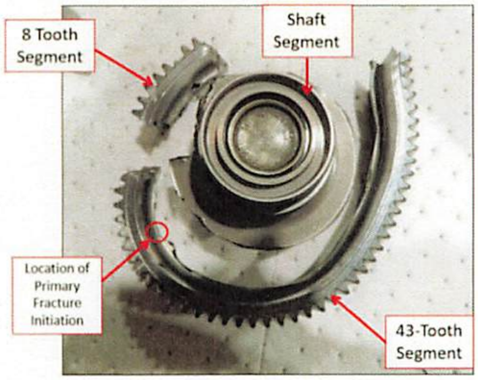


Figure 6-7. Photo of LH PRGB -105 Upper Input Idler Helical Gear Damage (Tab J-48)

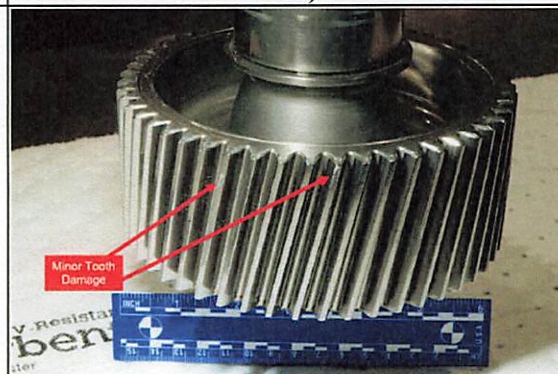


Figure 6-8. Photo of -109 Input Idler Helical Gear Damage (Tab J-47)

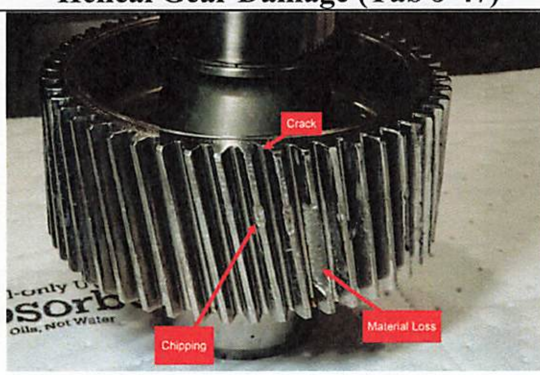


Figure 6-9. Photo of -101 Input Helical Gear Damage (Tab J-47)

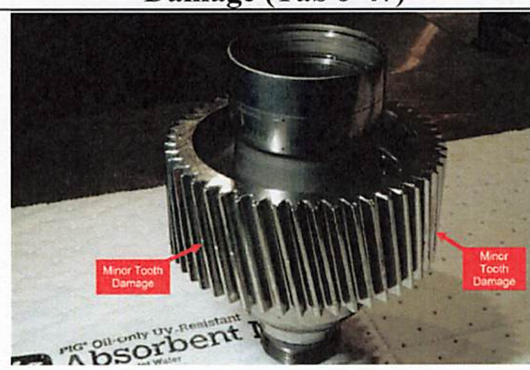


Figure 6-10. Photo of -113 Bull Gear Damage (Tab J-48)

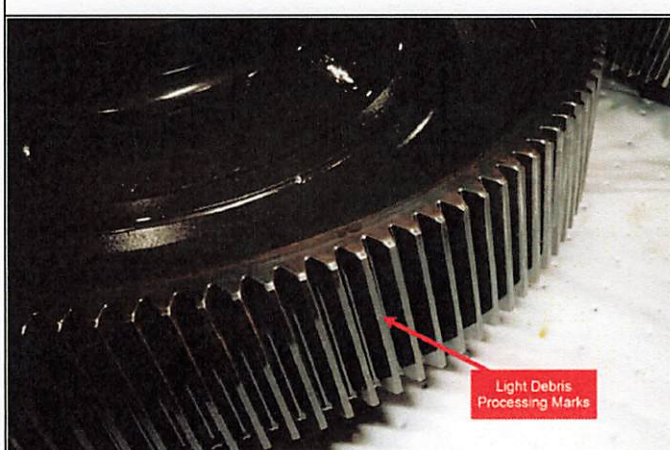


Figure 6-11. Photo of Oil Pump Drive Spur and Helical Gear Damage (Tab J-49)

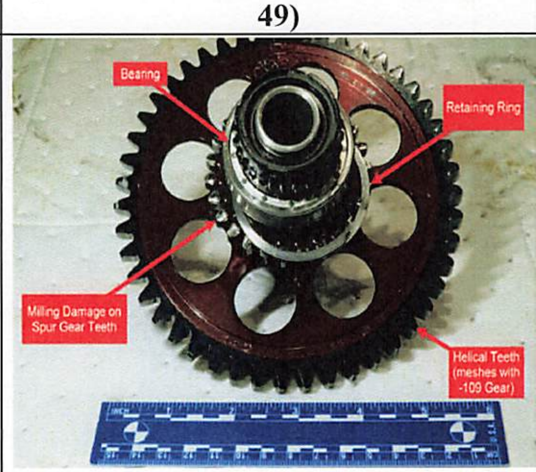


Figure 6.12. Photo of Debris found in LH Centerbody Inlet (Tab S-7)

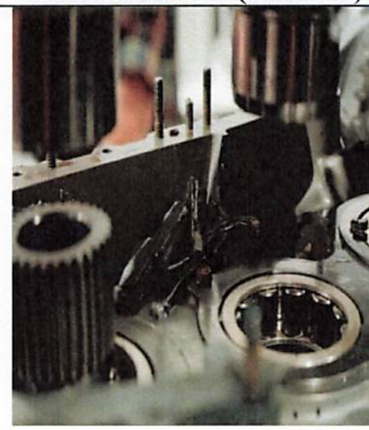


Figure 6.13. Photo of Debris in LH PRGB Helical Section (Tab S-8)

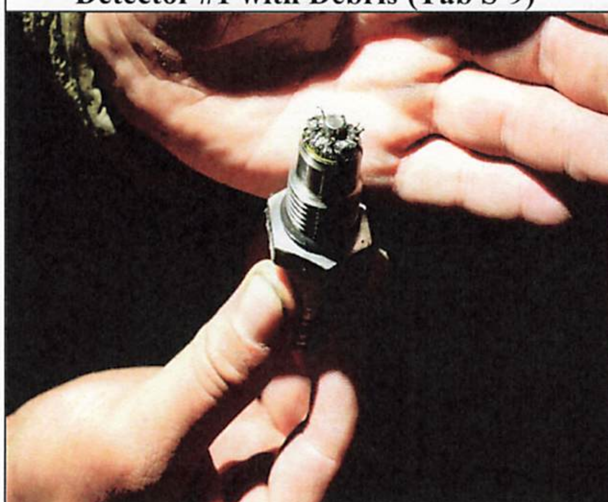


Figure 6.14. Photo of LH PRGB Chip Detector #1 with Debris (Tab S-9)

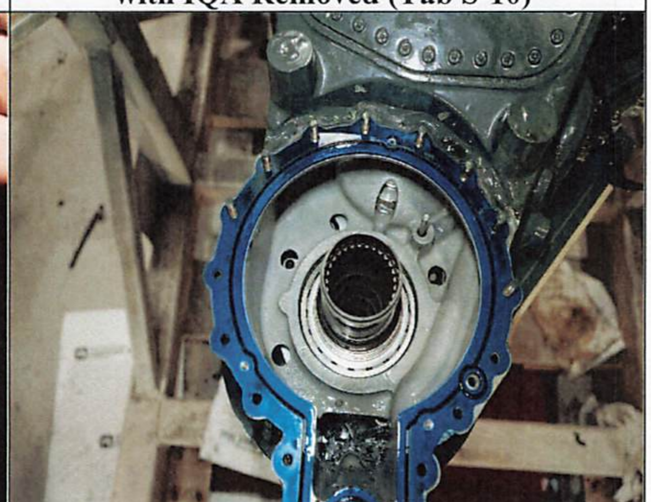


Figure 6.15. Photo of Debris in LH PRGB with IQA Removed (Tab S-10)

The LH IQA, P/N 901-044-055-103, S/N A-102, was disassembled from the LH PRGB and inspected (Tab J-50). The clutch inner race exhibited evidence of minor scuffing/smearing and material transfer forward of the engine side sprag track (Tab J-50). The PRGB side sprag track exhibit normal wear (Tab J-50). The engine side sprag retainer assembly on 3 sprags exhibited significant scuffing/scoring and material loss on the forward edges (Tab J-50). the PRGB side sprag retainer assembly exhibited normal wear (Tab J-50). The Clutch outer race exhibited normal wear (Tab J-50).

Figure 6-16. Photo of LH IQA Clutch Sprag Track Damage (Tab J-50)

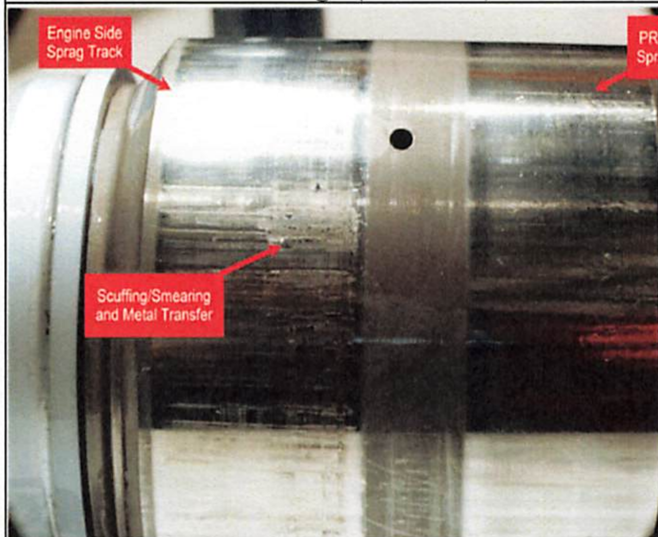
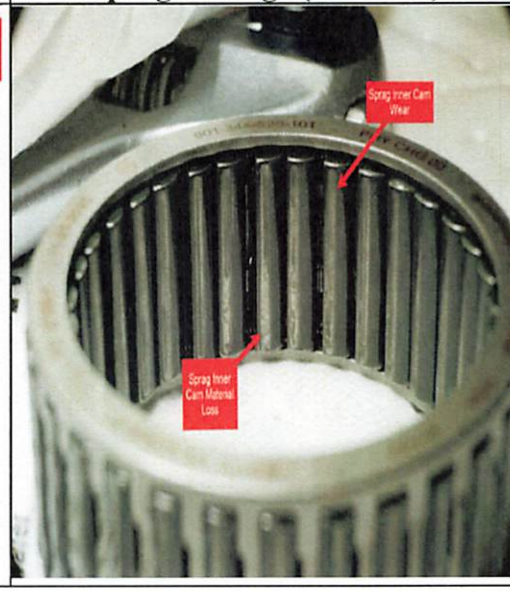


Figure 6-17. Photo of LH IQA Clutch Sprag Damage (Tab J-51)



Fracture analysis of the failed -105 Input Idler Helical Gear pieces identified multiple locations with evidence of fatigue crack origination (Tab J-52). Analysis revealed one fatigue origination on the 43-tooth segment web to rim interface with corresponding evidence of fatigue on the gear shaft segment at the associated location (Tab J-52). This was determined to be the primary crack initiation site (Tab J-52). The crack propagated from the origin circumferentially both clockwise and counterclockwise around the gear (Tab J-52). A segment of the gear shaft was sectioned by FRC East to have the fatigue origin evaluated under Scanning Electron Microscope (SEM) (Tab J-54). The SEM chemical analysis identified the presence of a non-metallic inclusion consisting of aluminum, calcium, and oxygen measuring 0.055 inches long by 0.011 inches wide (Tab J-54). A material certification and process review of the raw material supplier for the failed -105 gear determined the X-53 bar stock conformed to all material specifications at the time of production and inspection (Tab J-59).

Figure 6-18. Diagram of -105 Input Idler Helical Gear Web and Rim (Tab J-142)

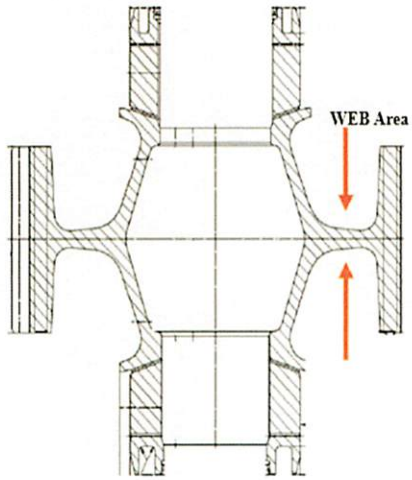
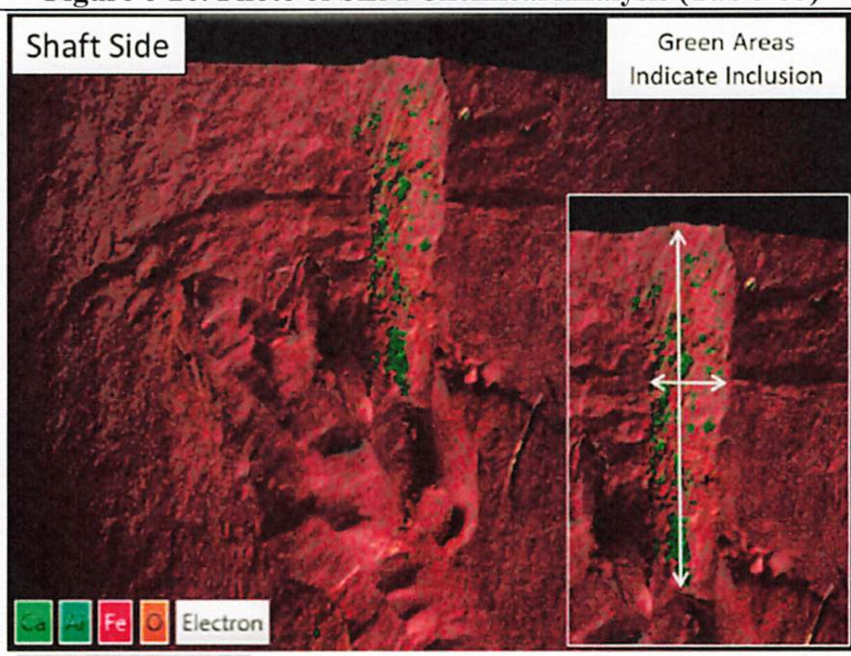


Figure 6-19. Photo of Inclusion Found in -105 Input Idler Helical Gear (Tab J-56)

Figure 6-20. Photo of SEM Chemical Analysis (Tab J-55)



The LH PRGB was overhauled at Bell's Repair and Overhaul Center where both -105 Input Idler Helical Gears and the -101 Input Helical Gear were installed new (Tab J-34 to J-35). The total accumulated flight time at the time of mishap for the aforementioned gears was 93.8 hours (Tab J-35).

2. V-22 Engine Engineering Investigation

The MA's LH Engine, P/N 23060102, S/N CAE130511, was removed and sent to Rolls-Royce Excellence Building, Indianapolis, IN for Engineering Investigation (Tab J-3). No significant findings were identified on external inspection (Tab J-5). Chips identified on engine magnetic indicating plug were within limits and no damage on any bearings during teardown were identified (Tab J-8). Internal inspection revealed no significant damage to any components beyond normal wear (Tab J-8).

c. Data Analysis & Evaluation

Post-mishap, the MA's K-Series Voice and Data Recorder (KVADR), all 4 FADEC units, and Vibration/Structural Life and Engine Diagnostics (VSLED) unit were removed and analyzed (Tab DD-3 to DD-4). Analysis verified that no missing data or relevant faults were present, however the data from the KVADR was mislabeled as having occurred on 7 April 2019 (Tab DD-3 to DD-4). A thorough review of data from all sources confirms the data recovered from the KVADR is from the date of the mishap, 20 November 2024 (Tab DD-3 to DD-4). All data reviewed indicates normal systems operation prior to the moment the mishap occurred (Tab DD-3 to DD-4). A review of recovered MA data along with engineering investigation results and MC testimonies supports that the following events occurred in flight on 20 November 2024. All times referenced are in Mountain Standard time: At 13:22:16.656 the MA's data recorder indicated weight off wheels (Tab DD-3 to DD-4). Between 13:22:16.656 and 13:22:58.016 the -105 Lower Helical Input Idler Gear succumbed to fatigue cracking from a non-metallic inclusion that originated in the web to rim interface of the gear, causing the gear to separate from its shaft, sending pieces of debris into the helical section of the gearbox and rapidly ejecting an 8-tooth fragment into the outboard side of the PRGB helical section cover and breaking a 12 inch by 6 inch hole in the PRGB case (Tab DD-3 to DD-4, J-42). The hole caused a rapid loss of oil pressure in the PRGB. Simultaneously, the rapid destruction of the -105 Lower Helical Input Idler Gear caused damage to the drive gear of the LH PRGB oil pump and at 13:22:58.016 the MC was notified of a LH PRGB Oil Press Low caution (Tab DD-3 to DD-4). The failed -105 Lower Helical Input Idler Gear caused a no-load condition on the LH engine resulting in a turbine overspeed condition which was recorded at 13:22:58.297 (Tab DD-3 to DD-4). The LH engine overspeed was detected by the controlling FADEC B, which upon detection, transferred control to FADEC A at 13:22:58:469 (Tab DD-3 to DD-4). FADEC A confirmed the overspeed condition and was unable to lower the engine speed due to the no-load condition and commanded the engine to shut down at 13:22:59:547 (Tab DD-3 to DD-4). Several additional faults associated with the LH engine sudden overspeed and rapid shutdown were recorded by the data recorders (Tab DD-3 to DD-4). The RH engine began to drive the LH PRGB through the Interconnect Drive System (ICDS) as evidenced by an increase in RH engine measured gas temperature (Tab DD-3 to DD-4). In response to the loss of oil pressure in the LH PRGB, the Emergency Lubrication System (ELS) engaged and began pumping emergency oil into the LH PRGB at 20:23:01.344 (Tab DD-3 to DD-4). Due to the hole in the helical section of the PRGB case, pressure was unable to be reestablished, and further LH PRGB pressure lost indications were given to the MC and recorded at 13:23:01.547 (Tab DD-3 to DD-4). As debris from the failed -105 Lower Helical Input Idler Gear were processed by the remaining gears in the helical drive section, they migrated to the #1 PRGB debris sensor and provided the MC indication of "LH PRGB Chips" at 13:23:04.516 (Tab DD-3 to DD-4). An excessive amount of debris material collected on the #1 debris sensor causing a "Chip Detector Fail" and a "LH PRGB Detector 1 Fail" at 13:12:05.344 (Tab DD-3 to DD-4). At 13:23:07.344 the LH engine overspeed coupled with the rapid slow down after shutdown caused a resonance in the Nacelle Blower system, causing the blower shaft to shear and "L NAC Blower Fail" notification (Tab DD-3 to DD-4). FADEC A attempted to restart the LH Engine at 13:24:21.078 but was unsuccessful (Tab DD-3 to DD-4). The flight recorder logged several indications during the MA landing (Tab DD-3 to DD-4). Upon landing, the MC crew commanded the engines to shut down at 13:25:40.031 (Tab DD-3 to DD-4). The ELS posted an "Emer Lube Oil Sys Fail," "Emer Lube System Fail," and "Emergency Lube Oil Res Low Oil Sens" to the flight data recorder at 13:51:58.734 (Tab DD-3 to DD-4). These indications are evidence that pressure in the LH PRGB could not be reestablished due to the hole in the helical section of the case, despite the ELS continuing to pump oil into the PRGB for the duration of the mishap. The ELS continued to run until it was empty and until the MA landed and shutdown (Tab DD-3 to DD-4).

7. WEATHER

a. Forecast Weather

The 27th Special Operations Support Squadron Weather Flight provided the mission execution forecast on 20 November 2024 at 0300 MST (Tab F-2). Weather at Cannon AFB was forecast at departure to have surface winds variable at 6 knots with a temperature of 12-degrees Celsius (C) and visibility was expected to be at least 7 statute miles with no minimum ceiling (Tab F-2). Weather at MAFR was forecast for the period of operations to have surface winds from 220-degrees at 10 knots with gusts to 20 knots and a temperature of 07-degrees C and visibility was expected to be at least 7 statute miles with no minimum ceiling (Tab F-3). Area moderate low-level turbulence from 10,000 to 18,000 feet in Northeast New Mexico was forecast, however the flight profile avoided this region and was not a factor (Tab F-5).

b. Observed Weather

Observed weather at the time of the mishap was similar to the forecast. Weather for the departure was observed at Cannon AFB to have winds from 190-degrees at 11 knots with a temperature of 10-degrees C and visibility was unlimited with skies clear of clouds (Tab F-71). The weather observation at 1255MST prior to the mishap, MAFR surface observations measured the winds from 200-degrees at 12 knots with gust to 17 knots and a temperature of 11-degrees C with unlimited visibility and skies clear of clouds (Tab F-70). The MAFR weather observation at 1355MST measured surface winds at 210-degrees and 13 knots with unlimited visibility and skies clear of clouds (Tab F-70). The MA measured and recorded the winds on MAFR prior to the mishap to be from 178-degrees at 11 knots and a temperature of 11-degrees C; these measurements were taken at 300 feet AGL in conversion mode at 60-degrees nacelle angle (Tab DD-5 to DD-6).

c. Space Environment

Not appliable

d. Operations

Based on the forecast and actual observations made by ground stations, the weather was within operational limits for the crew, aircraft, airfield, and the training area (Tab F-2, F-70 to F-71). Actual weather observations reported by the MA onboard system had higher temperatures and weaker than expected winds (Tab DD-5 to DD-6). Prior to takeoff, the MC calculated the OEI conditions for airplane and conversion mode utilizing the takeoff temperature and MA gross weight (Tab K-43). The briefed OEI conditions for conversion mode, which is defined as 60-degree nacelle angle per 1-V-22(C)B-1-1, were a service ceiling of 4,800 feet mean sea level (MSL) at a speed of 79 KCAS (Tab K-43). The briefed OEI conditions at takeoff would have allowed the crew to complete a climb from Cannon AFB field elevation to 500 feet AGL. Post mishap the investigating pilot Subject Matter Expert (SME) calculated power available, power required, and conversion OEI conditions for the time of the mishap utilizing the MA gross weight of 41,374 pounds, outside air temperature of 10-degrees C, and a pressure altitude of 4000 feet MSL (Tab DD-5 to DD-6). The investigating pilot SME-derived power calculations and single engine ceiling are denoted in Figure 7-1 below.

Figure 7-1. Pilot SME Power Calculations

Type	Calculated Value	Reference
CONV OIE service ceiling	8,100 feet MSL/ 3700 feet AGL	Tab B-395
Power Available: Both engines operating	114% Qm	Tab B-79
Power Required: Hover Mast Torque Required (104% Nr, Wheel height ≥ 50 ft)	81% Qm	Tab B-90
Power Available: Single engine operating	53% Qm	Tab B-376

8. CREW QUALIFICATIONS

There was no evidence indicating that crew qualifications, training, or experience were a factor in this mishap.

a. Mishap Instructor Pilot – Pilot in the Right Pilot Seat

MIP was a current and qualified CV-22B pilot with 1063.9 hours of military flying time prior to the mishap (Tabs G-Disc 2, K-2). MIP was initially qualified as a CV-22B pilot on 4 February 2021 and qualified as an Instructor Pilot on 28 August 2024 (Tab DD-5 to DD-6). MIP had 617.6 total hours in the CV-22B aircraft: 9.0 instructor hours, 335.9 primary hours, 217.6 secondary hours, and 55.1 other hours (Tab DD-5 to DD-6). MIP had 271.6 total hours in the CV-22B simulator: 3.0 Instructor hours, 176.6 primary hours, 90 secondary hours, and 2.0 other hours (Tab DD-5 to DD-6).

MIP's flight time for the 90 days prior to the mishap are shown in Table 8-1.

Table 8-1. MIP 14 Day, 30 Day, 60 Day, and 90 Day Flight Hours (Tab K-13 to K-18)			
	Total Hours	CV-22B	CV-22B Simulator
Last 14	25.5	25.5	0.0
Last 30	33.5	33.5	0.0
Last 60	46.1	46.1	0.0
Last 90	46.1	46.1	0.0

b. Mishap Pilot – Pilot in the Left Pilot Seat

MP was a current and qualified CV-22B pilot, apart from being non-current for mission evaluation, basic sortie, and instrument approach, with 893.8 hours of military flying time prior to the mishap (Tabs DD-5 to DD-6, K-2). MP was initially qualified as a CV-22B pilot on 18 May 2021 (Tab DD-5 to DD-6). MP had 413.9 hours in the CV-22B Aircraft; 236.0 primary hours, 135.1 secondary hours, and 42.8 other hours (Tab DD-5 to DD-6). MP had 295.6 total hours in the CV-22B simulator: 196.0 primary hours, 97.0 secondary hours, and 2.6 other hours (Tab DD-5 to DD-6).

MP's flight time for the 90 days prior to the mishap are shown in Table 8-2.

Table 8-2. MP 14 Day, 30 Day, 60 Day, and 90 Day Flight Hours (Tab K-13 to K-18)			
	Total Hours	CV-22B	CV-22B Simulator
Last 14	0.0	0.0	0.0
Last 30	0.0	0.0	0.0
Last 60	0.0	0.0	0.0
Last 90	18.0	2.5	15.5

c. Mishap Flight Engineer 1 – Flight Engineer in Cockpit

MFE1 was a current and qualified Instructor CV-22B flight engineer, apart from being non-current for Day shipboard operations, Night Vision Goggle (NVG) shipboard operations, night water hoist, and FCF open book test, with 1050.9 hours of military flying time prior to the mishap (Tabs DD-5 to DD-6, K-2). MFE1 was initially qualified as a CV-22B flight engineer on 20 May 2020 and qualified as an Instructor Flight Engineer on 26 September 2024 (Tab DD-4 to DD-5). MFE1 had 853.5 hours in the CV-22B Aircraft; 785.8 primary hours, 1.4 secondary hours, and 66.3 other hours (Tab DD-5 to DD-6). MFE1 had 307.4 total hours in the CV-22B simulator: 281.6 primary hours, 3.5 secondary hours, and 22 other hours (Tab DD-5 to DD-6).

MFE1's flight time for 90 days prior to the mishap are shown in Table 8-3.

Table 8-3. MFE1 14 Day, 30 Day, 60 Day, and 90 Day Flight Hours (Tab K-13 to K-18)			
	Total Hours	CV-22B	CV-22B Simulator
Last 14	3.0	0.0	3.0
Last 30	3.0	0.0	3.0
Last 60	3.0	0.0	3.0
Last 90	3.0	3.0	3.0

d. Mishap Flight Engineer 2 – Flight Engineer Tail Scanner

MFE2 was a current and qualified Evaluator CV-22B flight engineer, with 1006 hours of military flying time prior to the mishap (Tabs DD-5 to DD-6 and Tab K-2). MFE2 was initially qualified as a CV-22B flight engineer on 13 June 2019 and qualified as an Evaluator Flight Engineer on 7 October 2024 (Tab DD-5 to DD-6). MFE2 had 988 hours in the CV-22B Aircraft; 883.9 primary hours, 1.3 secondary hours, 53.3 Instructor hours, 2.3 evaluator hours, and 47.2 other hours (Tab DD-5 to DD-6). MFE2 had 277.4 total hours in the CV-22B simulator: 245.3 primary hours, 5.1 secondary hours, 18.7 instructor hours, and 8.3 other hours (Tab DD-5 to DD-6).

MFE2's flight time for 90 days prior to the mishap are shown in Table 8-4.

Table 8-4. MFE2 14 Day, 30 Day, 60 Day, and 90 Day Flight Hours (Tab K-13 to K-18)			
	Total Hours	CV-22B	CV-22B Simulator
Last 14	18.0	10.0	8.0
Last 30	46.3	38.3	8.0
Last 60	83.2	75.2	8.0
Last 90	104.6	90.6	14.0

9. MEDICAL

a. Qualifications

The entire MC were medically qualified and appropriately certified for flight duty without restrictions or duty limitations at time of mishap (Tab AA-3 to AA-4). Additionally, all MC were current for annual Preventative Health Assessments, to include flight physicals, and none were on Duties Not Including Flying (DNIF) status (Tab AA-3 to AA-4).

b. Health

All available medical records were reviewed extensively (Tab AA-3 to AA-4). No members of the MC had duty limitations or restrictions that would have precluded involvement in the mission (Tab AA-3 to AA-4). The MC was in good health without performance-limiting conditions, diseases, illnesses, injuries, or use of non-authorized medication prior to the mishap (Tab AA-3 to AA-4). A review of MP's medical record uncovered a history of intermittent headaches (Tab Y-3). Those headaches did not meet criteria for a specific headache syndrome (Tab AA-3). Nor were they of a severe or incapacitating nature, therefore they were deemed not disqualifying from flying duties

(Tabs BB-349, AA-3). Furthermore, the use of the over-the-counter medicine Excedrin, a combined medication consisting of individually authorized ingredients aspirin, paracetamol, and caffeine, was deemed not disqualifying from flying duties (Tabs BB-25, AA-3).

c. Pathology

The Defense Health Agency performed a Forensic Toxicology Examination, in accordance with Department of the Air Force Instruction (DAFI) 91-204, paragraph 2.6.4, of the blood and urine of the MC and mishap maintainers (Tab B-1067 to B-1068). All specimens were analyzed for the presence of drugs of abuse, ethanol, in addition to carboxyhemoglobin solely for the MC specimens (Tab C-3 to C-24). The results for the MC and mishap maintenance personnel were negative for all assayed substances (Tab C-3 to C-24).

d. Lifestyle

There is no evidence to suggest lifestyle factors were a factor in the mishap based on 72 hour and 7-day history forms review (Tabs R-56 to R-107, AA-3 to AA-4).

e. Crew Rest and Crew Duty Time

Commanders will ensure aircrew members are provided a 12-hour rest period prior to performing flight duties in accordance with AFMAN 11-202, Volume 3, AFSOC Supplement, *Flying Operations*, 4 April 2023. Crew rest is free time and includes time for meals, transportation, and an opportunity for at minimum 8 hours of uninterrupted sleep. The 72-hour and 7-day histories of the MC indicate that each of the crew members scheduled for duties had the opportunity for at least 8 hours of uninterrupted sleep consistent with current crew rest regulations (Tab R-56 to R-107). There is no evidence to suggest that inadequate crew rest contributed to this mishap (Tab V-32).

10. OPERATIONS AND SUPERVISION

a. Operations

The 20 SOS is the largest CV-22B unit in AFSOC with a high operations tempo which includes an enduring deployment commitment complicated by multiple recent CV-22 mishaps and training restrictions that created challenges for preparing crews for combat deployments (Tab V-93 to V-94, V-96). Additionally, experience levels in the squadron have declined due to a combination of less experienced aviators entering the CV-22 community and an overall slowdown in deployment operations (Tab V-72 to V-73, V-80). During the months leading up to the mishap, the unit was completing its RTF efforts following a CV-22B standdown that was the result of a previous mishap (Tab V-70, V-80). MIP, MFE1, and MFE2 were all current and qualified and had completed their RTF syllabus-required events prior to the mission (Tab DD-5 to DD-6). Due to the standdown, the MP was overdue for a mission evaluation and was the primary focus to finish their RTF syllabus (Tab DD-5 to DD-6). Mission planning was performed by the MC on 20 November 2024 in accordance with AFTTP 3-3.CV-22B (Tab R-6, R-13, R-24, R-39). The MC arrived at the squadron between 0630 and 0700 MST on the day of the mishap for a 0700 MST show time (Tab R-58, R-71, R-84, and R-97).

b. Supervision

The flight authorization for HAVOC 51 was created, reviewed, and signed by the 20 SOS ADO one day prior to the mishap (Tab K-2 to K-3). The 20 SOS ADO is 1 of 4 members in the 20 SOS authorized to serve as an AO for flight authorizations (Tab BB-21). The AO reviewed crew composition, qualifications, recent flying time, and currencies before signing the flight authorization (Tab K-2). No deficiencies in flight authorization practices were noted following the mishap (Tabs DD-5 to DD-6, K-2 to K-3). The 20 SOS Commander and Director of Operations are both experienced CV-22B pilots with multiple deployments and assignments in multiple CV-22B units (Tab T-2 to T-6). AIB interviews revealed that they had concern that this event and others had created uncertainty in some 20 SOS members regarding the safety of the CV-22B airframe (Tab V-73 to V-75, V-90). Despite this, leadership assessed overall unit confidence in the aircraft as high, but aircrew (especially the Special Mission Aviator (SMA) community) were stressed due to the many changes the CV-22B community had experienced in the previous 2-3 years and the number of mishaps that had occurred in the past two years (Tab V-73 to V-74, V-81 to V-82). These changes included a reduction in SMA instructors through the Non-commissioned Officer Retraining Program (NCORP) and a "Bold Moves" initiative that restructured CV-22B aircraft and personnel numbers (Tab V-81, V-85, V-89 to V-91). Regarding mishaps, there was growing concern that materiel solutions for PRGB issues were not occurring fast enough, and that all X-53 steel components in the PRGB needed to be improved through these materiel solutions, including the triple-melt manufacturing process (Tab V-75 and V-91). In 2023 the 20 SOS experienced two mishaps in short succession. The first, at MAFR, was the result of a SMA's NVG catching on an Engine Control Lever and bringing it to "OFF" during a seat change at 100 feet AGL, causing a hard landing. The other was a taxi incident in Inyokern, CA where a taxiing CV-22B's propellors struck a stationary CV-22B's propellors. As a result of these incidents, 27 SOW and 27 SOG leadership instituted a 27 SOG and 20 SOS training standdown (Tab V-93). The standdown forced a focus on fundamentals, checklist discipline, and operational risk management (Tab V-93 to V-101). As a result of these three incidents and the requirement to return CV-22B crews to flying following the standdown, the 20 SOS focused heavily on identifying and mitigating risk (Tab V-93 to V-101). This risk awareness led to a culture of "getting the aircraft on the ground" in an emergency, especially in situations related to PRGB malfunctions or failures (Tab V-77 to V-78). It is assessed that this leadership intervention and clear guidance influenced MC decision-making during this mishap (Tab V-77 to V-78, V-93 to V-101). The combined factors of this clear guidance and the crew's understanding that a PRGB failure with secondary indications is a "land immediately" condition, improved the outcome of this mishap (Tab V-77 to V-78, V-93 to V-101).

11. HUMAN FACTORS

Human factors describe how our interaction with tools, tasks, working environments, and other people influence human performance (Tab BB-273). This report includes an analysis of the human factors that contributed to this mishap. A review of all documents, plans, MC interviews, and other witness' testimonies were entered into the Department of Defense (DoD) Human Factors Analysis and Classification System (HFACS) model to formulate a systematic, multidimensional approach to mishap analysis.

DoD HFACS is a framework of assessment that is divided into four main categories: organization influences, supervision, preconditions to unsafe acts, and unsafe acts (Tab BB-273).

a. Organizational Influences

Organizational Influences factors in a mishap if the communications, actions, omissions, or policies of upper-level management directly or indirectly affect supervisory practices, conditions or actions of the operator(s) and result in system failure, human error, or an unsafe situation (Tab BB-290 to BB-293).

(1) Human Factor 1: OP007 – Purchase or Providing Poorly Designed or Unsuitable Equipment

Purchasing or Providing Poorly Designed or Unsuitable Equipment is a factor when there are processes through which aircraft, vehicle, equipment, or logistical support acquired allows inadequacies or when design deficiencies allow inadequacies in the acquisition (Tab BB-292).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publicly Available Directives and Publications Relevant to the Mishap

(1) AFI 51-307, *Aerospace and Ground Accident Investigations*, dated 18 March 2019

(2) AFMAN 11-202, Volume 3, AFSOC Supplement, *Flying Operations*, date 4 April 2023

(3) AFMAN 11-2CV-22, Volume 3, *CV-22 Operations Procedures*, dated 13 September 2021

(4) DAFI 91-204, *Safety Investigations and Reports*, dated 10 March 2021

(5) DAFMAN 48-123, *Medical Examination and Standards*, dated 2 August 2024

(6) DODI 5000.08, *Engineering of Defense Systems*, dated 18 November 2020

(7) MIL-STD-882E, Department of Defense Standard Practice System Safety, dated 27 September 2023

(8) NAVAIRINST 5100.3F, Naval Aviation System Safety Engineering Policy, dated 5 September 2023

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) A1-V22AC-AFM-000/1V-22(C)B-1, *NATOPS Flight Manual*, CV-22 Tiltrotor, dated 15 October 2022

(2) A1-V22AC-AFM-200/1V-22(C)B-1-1, *NATOPS Flight Manual*, CV-22 Tiltrotor, dated 15 February 2021

(3) AFTTP 3-3.CV-22, *Combat Fundamentals – CV-22*, dated 9 August 2024

(4) Cannon AFBI 11-201-O, *Fixed-Wing and Vertical-Lift Aircraft Operations*, dated 16 March 2022

(5) SD-572-1-3, *Detail Specification for V-22*, modified 6 February 2020

(6) TO 00-5-1, *Air Force Technical Order System*, dated 30 August 2022

(7) TO 00-20-1, *Equipment Maintenance Inspection, Documentation, Policies and Procedures*, 6 September 2019

(8) A1-V22AB-MRC-000/TO 1V-22(C)B-6, *Time Compliance Technical Orders (TCTOs)*

c. Known or Suspected Deviations from Directives or Publications

No known or suspected deviations from directives or publications were discovered by the AIB.

[redacted]

8 OCTOBER 2025

BRENT A GREER, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

CV-22B, T/N 11-0060
MELROSE AIR FORCE RANGE, NEW MEXICO
20 NOVEMBER 2024

"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."

1. OPINION SUMMARY

On 20 November 2024, at approximately 1323 Mountain Standard Time (MST), the Mishap Aircraft (MA), CV-22B Tail Number (T/N) 11-0060, while conducting takeoff and landing practice approaches at Wilderness Helicopter Landing Zone (HLZ) on Melrose Air Force Range (MAFR), New Mexico, experienced a left hand (LH) engine shutdown followed by an emergency landing (EL). The incident occurred approximately 1 Nautical Mile (NM) north of MAFR on rancher-leased New Mexico state land. The MA was assigned to the 27th Special Operations Wing (27 SOW) at Cannon Air Force Base (AFB), New Mexico.

The mishap crew (MC), assigned to the 20th Special Operations Squadron (20 SOS), consisted of Mishap Instructor Pilot (MIP), Mishap Pilot (MP), Mishap Flight Engineer 1 (MFE1), and Mishap Flight Engineer 2 (MFE2). There was no damage to civilian property, no fatalities, and no immediate or emergency medical services were required following the incident. Two (2) MC members reported minor medical concerns following the incident, but did not require further treatment.

The MC was conducting a local training sortie as part of the 20 SOS Return to Fly (RTF) syllabus. The RTF syllabus was directed by the Air Force Special Operations Command (AFSOC) Headquarters following the CV-22B standdown caused by a previous mishap. The syllabus consisted of a "crawl-walk-run" methodology to ensure CV-22B aircrew return to flying in a deliberate and safe manner following a stand-down period of approximately six (6) months.

During the training sortie, the MC departed Cannon AFB, conducted uneventful training and practice approaches in Roswell New Mexico and Artesia New Mexico, then proceeded to MAFR for further HLZ training. Following the final landing at Wilderness HLZ in the northern portion of MAFR, the MIP elected to return to Cannon AFB to refuel the aircraft and swap the MP for another pilot who needed to conduct training as part of the RTF syllabus. Upon takeoff from Wilderness HLZ, the MP conducted a climbing right hand turn to approximately 315 feet Above Ground Level (AGL) at 113 Knots Calibrated Airspeed (KCAS). The MIP contacted MAFR range control (RANGER) to request a return to Cannon AFB. Immediately following the call to RANGER, the aircraft experienced a series of cascading failures, culminating in a "land immediately" condition.

The first abnormal indication was a rapid reduction in steady state Left Hand (LH) proprotor gearbox (PRGB) oil pressure. Over the next three seconds the aircraft experienced a rapid and complete loss of LH PRGB oil pressure resulting in a "PRGB Failure" warning. Concurrently, the MA experienced a LH Engine Power Turbine Speed (Np) overspeed which caused a Full Authority Digital Engine Control (FADEC)-directed LH Engine shutdown and voice warning "ENGINE FAILURE, ENGINE FAILURE" and an aural "WHOOP." The aural "WHOOP" annunciation indicated that the aircraft experienced multiple warning conditions simultaneously. If the indications had been separated by more than five (5) seconds, the voice aural warnings would have included a "GEARBOX FAILURE, PROPROTOR GEARBOX" annunciation, which constituted the first "land immediately" condition, which is a PRGB failure combined with secondary indications.

Immediately following these indications MFE1 directed the pilots to land the aircraft. The MP immediately initiated an EL profile by descending the MA and MFE1 lowering the landing gear. Concurrently, the MIP directed the MP to turn the MA left (south) and into the wind in preparation for the EL. After MFE1 placed landing gear handle down and as the MP was descending for EL, the MC experienced a LH PRGB CHIPS caution, which was the second "land immediately" condition. This notification was verified by MFE1 then the MC proceeded to accomplish an expedited approach to landing with MFE1, MFE2, and MP making standard distance to go, speed, and altitude calls. The MC landed the aircraft approximately one (1) NM north of MAFR at a sink rate of approximately 640 ft/min and at approximately 6-7 knots ground speed forward travel. The nosewheel bounced approximately three (3) feet to the left following initial contact with the ground. The MC evaluated the situation on the ground to determine if an emergency shutdown was required. After being off the communication system for approximately 18 seconds, MFE2 reported they were uninjured and did not observe fire or any other abnormalities with the MA. The MC then started the auxiliary power unit (APU), called RANGER to inform of the MC situation, and initiated shutdown procedures. The MA was shut down and the MC elected not to emergency egress the aircraft. The time from the initial MA malfunction indications to landing was approximately 83 seconds.

2. CAUSES

The DoD HFACS framework is applied to identify causal and/or contributory factors. Causal factors are deficiencies which, if corrected, would likely have prevented or mitigated damage and/or injury. Contributory factors are independent events or conditions that do not directly result in damage and/or injury but are integral to the progression of the mishap sequence.

I found by the preponderance of the evidence that MC responses to the emergency mitigated damage to the aircraft and injury to the crew, despite not fully understanding the cause of the problem. The initial event that led to aircraft malfunction, damage, and subsequent emergency landing procedure was a sudden lower input helical idler gear failure due to non-metallic inclusions caused by poorly designed equipment. The incident's lower input helical idler gear was conforming to specifications at the time of manufacture. Notably, per the updated 2024 guidance, the incident lower input helical idler gear was not deemed a critical single point of failure component.

While not causal, the instrumentation and warning system delayed the MC's proper analysis of the emergency. The current VOICE warning system is designed to suppress multiple VOICE warning tones for a period of five seconds. When a condition exists where multiple VOICE warning tones are present or indicated, the second unique VOICE warning tone will be suppressed and expressed as an aural sweeping tone, also known as a "WHOOP". The aircrew received the VOICE auditory warning for "ENGINE FAILURE, ENGINE FAILURE" followed by a "WHOOP" to denote "PRGB FAILURE, PRGB FAILURE" based on pre-programmed prioritization of the warnings. However, "PRGB FAILURE, PRGB FAILURE" was not annunciated. My analysis determined that the decision to prioritize engine failure over proprotor gearbox failure is incongruent with the threat posed to aircraft and crew for continued flight, which was expressly denoted in the MC interviews.

I found, by a preponderance of the evidence, the mishap was caused by a catastrophic failure of the LH PRGB Lower Input Idler Helical Gear, P/N 901-044-105-101, S/N VL00205587 (-105) due to a non-metallic material inclusion in the gear's rim-to-web radius interface. Immediately following materiel failure, an 8-tooth section of the -105 gear punctured the PRGB case causing a 12-inch by 6-inch hole, leading to the immediate loss of LH PRGB oil and oil pressure followed by a LH engine overspeed condition. It is assessed that the LH engine's momentary overspeed condition was caused by the no-load condition induced by the failure of the -105 gear. As designed, this overspeed caused the controlling FADEC to command a shutdown of the LH engine. As designed, Right Hand (RH) engine power via the Interconnect Drive System (ICDS) was then automatically transferred to the LH PRGB for the left proprotor to provide enough lift for the MC to maintain controlled flight and conduct a safe EL.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

a. A Poorly Designed -105 Gear in CV-22 Proprotor Gearbox

I find by a preponderance of the evidence the following factor substantially contributed to the mishap: poorly designed -105 gear in CV-22 Proprotor Gearbox. Since CV-22 mishaps in 2023, the JPO has proposed a plan to implement materiel solutions including X-53 triple melt for PRGB gears. The X-53 triple melt process is projected to reduce risk to individual parts and the PRGB by up to 90%.

4. CONCLUSION

I find by a preponderance of the evidence the cause of the mishap was a catastrophic failure of the LH PRGB Lower Input Idler Helical Gear, P/N 901-044-105-101, S/N VL00205587 (-105) due to a material inclusion in the gear's rim-to-web radius interface. . Additionally, I found by a preponderance of the evidence the following factors, substantially contributed to the mishap: Poorly designed -105 gear in CV-22 Proprotor Gearbox.

[redacted]

8 OCTOBER 2025

BRENT A GREER, Colonel, USAF
President, Accident Investigation Board