UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

WC-130H, T/N 65-0968

198th Airlift Squadron
156th Airlift Wing
Muñiz Air National Guard Base, Carolina, Puerto Rico

LOCATION: 1.5 Miles Northeast of Savannah/Hilton Head International Airport, Georgia

DATE OF ACCIDENT: 2 May 2018

BOARD PRESIDENT: Brigadier General John C. Millard

Conducted in Accordance with Air Force Instruction 51-503

09 OCT 2018

ACTION OF THE CONVENING AUTHORITY

The report of the accident investigation board, conducted under the provisions of AFI 51-503, that investigated the 2 May 2018 mishap near Savannah/Hilton Head International Airport (KSAV), Georgia, involving WC-130H, tail number 65-0968, assigned to the Puerto Rico Air National Guard, 156th Airlift Wing (156 AW), located at Muñiz Air National Guard Base, Puerto Rico, complies with applicable regulatory and statutory guidance and on that basis is approved.

//SIGNED//

MARYANNE MILLER
General, USAF
Commander

United States Air Force Accident Investigation Board Report

EXECUTIVE SUMMARY

WC-130H, T/N 65-0968
1.5 Miles Northeast of Savannah/Hilton Head International Airport, Georgia
2 May 2018

On 2 May 2018, at approximately 1127 hours local time (L), the Mishap Aircraft (MA), a WC-130H, tail number 65-0968, assigned to the Puerto Rico Air National Guard, 156th Airlift Wing (156 AW), located at Muñiz Air National Guard Base, Puerto Rico, crashed approximately 1.5 miles northeast of Savannah/Hilton Head International Airport (KSAV), Georgia. All nine members aboard the MA—Mishap Pilot 1 (MP1), Mishap Pilot 2, Mishap Navigator, Mishap Flight Engineer, and Mishap Loadmaster (collectively the "Mishap Crew (MC)"), and four mission essential personnel, Mishap Airman 1, 2, 3, and 4—perished during the accident.

The MC's mission was to fly the MA to the 309th Aerospace Maintenance and Regeneration Group at Davis-Monthan Air Force Base, Arizona (commonly referred to as the "Boneyard"), for removal from service. The MA had been at KSAV for almost a month, since 9 April 2018, to undergo prescheduled fuel cell maintenance and unscheduled work on engine number one by 156 AW maintenance personnel using the facilities of the 165th Airlift Wing. During takeoff roll, engine one revolutions per minute (RPM) fluctuated and did not provide normal RPM when MP1 advanced the throttle lever into the flight range for takeoff. Approximately eight seconds prior to aircraft rotation, engine one RPM and torque significantly decayed, which substantially lowered thrust. The fluctuation on roll and significant performance decay went unrecognized by the MC until rotation, when MP1 commented on aircraft control challenges and the MA veered left and nearly departed the runway into the grass before it achieved flight. The MA departed KSAV at approximately 1125L.

As the MC retracted the landing gear, they identified the engine one RPM and torque malfunction and MP1 called for engine shutdown. However, the MC failed to complete the *Takeoff Continued After Engine Failure* procedure, the *Engine Shutdown* procedure, and the *After Takeoff* checklist as directed by the Flight Manual, and the MA's flaps remained at 50 percent. Additionally, MP1 banked left into the inoperative engine, continued to climb, and varied left and right rudder inputs. At an altitude of approximately 900 feet mean sea level and 131 knots indicated air speed, MP1 input over nine degrees of left rudder, the MA skidded left, the left wing stalled, and the MA departed controlled flight and impacted the terrain on Georgia State Highway 21.

The board president found, by a preponderance of the evidence, the cause of the mishap was MP1's improper application of left rudder, which resulted in a subsequent skid below three-engine minimum controllable airspeed, a left-wing stall, and the MA's departure from controlled flight. Additionally, the board president found, by a preponderance of the evidence, the MC's failure to adequately prepare for emergency actions, the MC's failure to reject the takeoff, the MC's failure to properly execute appropriate after takeoff and engine shutdown checklists and procedures, and the Mishap Maintainers' failure to properly diagnose and repair engine number one substantially contributed to the mishap.

SUMMARY OF FACTS AND STATEMENT OF OPINION
WC-130H, T/N 65-0968
2 May 2018

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

AC	Aircraft Commander
AF	Air Force
AFB	Air Force Base
AFI	Air Force Instruction
AFMES	Armed Forces Medical Examiner System
AFPET	Air Force Petroleum Agency
AFSC	Air Force Specialty Code
AFTO	Air Force Technical Order
AGL	Above Ground Level
AIB	Accident Investigation Board
AMARG	Aerospace Maintenance and Regeneration Group
AMC	Air Mobility Command
AMXS	Aircraft Maintenance Squadron
ANG	Air National Guard
APU	Auxiliary Power Unit
ARCNet	Air Reserve Component Network
ARM	Aviation Resource Management
AS	Airlift Squadron
ATC	Air Traffic Control
BAI	Backup Aircraft Inventory
Capt	Captain
CDC	Career Development Course
CFETP	Career Field Education and Training Plan
CMF	Component Maintenance Flight
Col	Colonel
CONUS	Contiguous United States
CRM	Crew Resource Management
CRTC	Combat Readiness Training Center
CTK	Composite Tool Kit
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DIT	Data Integrity Team
DLC	Duty Limiting Condition
DNIF	Duties Not Including Flying
DoD	Department of Defense
DSG	Drill Status Guardsman
DSV	Detected Safety Violation
EL	Evaluator Loadmaster
ETIC	Estimated Time for Completion
FBI	Federal Bureau of Investigation
ft	Feet
FCF	Functional Check Flight
FDR	Flight Data Recorder
FEF	Flight Evaluation Folder
FSR	Flight Engineer Simulator Refresher
FY	Fiscal Year
g	Gravitational Force
GTC	Government Travel Card
GTC	Gas Turbine Compressor
HAIMS	Health and Artifact Image Management Solution
HFACS	Human Factors Analysis and Classification System
HSC	Home Station Check
IAW	In Accordance With
IFR	Instrument Flight Rules
IL	Instructor Loadmaster
IMDS	Integrated Maintenance Data System
in lbs	Inch Pounds
inHg	Inches Mercury
IP	Instructor Pilot
IPI	In-Process Inspection
ISO	Isochronal
ISR	Intelligence, Surveillance, and Reconnaissance
ITP	Individual Training Plan
K	Thousand
KIAS	Knots Indicated Air Speed
KSAV	Savannah/Hilton Head International Airport
kts	Knots
L	Local Time
LIMFACS	Limiting Factors
Lt Col	Lieutenant Colonel
MA	Mishap Aircraft
MA1	Mishap Airman 1
MA2	Mishap Airman 2
MA3	Mishap Airman 3
MA4	Mishap Airman 4
Maj	Major
MAJCOM	Major Command

MC	Mishap Crew
MDG	Medical Group
MEP	Mission Essential Personnel
MFE	Mishap Flight Engineer
MICAP	Mission Impaired Capability Awaiting Parts
MLM	Mishap Loadmaster
MM1	Mishap Maintainer 1
MM2	Mishap Maintainer 2
MM3	Mishap Maintainer 3
MM4	Mishap Maintainer 4
MN	Mishap Navigator
MOC	Maintenance Operations Center
MOF	Maintenance Operations Flight
MP1	Mishap Pilot 1
MP2	Mishap Pilot 2
MRM	Maintenance Resource Management
MRSP	Mobility Readiness Spare Package
MRT	Maintenance Repair Team
MSEP	Maintenance Standardization Evaluation Program
MSL	Mean Sea Level
MXS	Maintenance Squadron
NDI	Nondestructive Inspection
NGB	National Guard Bureau
NM	Nautical Miles
NMCS	Non-Mission Capable Supply
NOTAM	Notice to Airmen
OG	Operations Group
Ops Tempo	Operations Tempo
ORM	Operational Risk Management
OSS	Operation Support Squadron
PA	Public Affairs
PAI	Primary Aircraft Inventory
PDM	Programmed Depot Maintenance
PE	Personal Evaluations
PHA	Physical Health Assessment
PMC	Partially Mission Capable
PR	Puerto Rico
PR ANG	Puerto Rico Air National Guard
PSR	Pilot Simulator Refresher
QA	Quality Assurance
QVI	Quality Visual Inspection
RGB	Reduction Gearbox
RM	Risk Management
RPM	Revolutions Per Minute
SCR	Special Certification Roster
SPR	Single Point Refueling
STP	Seasoning Training Program
TAR	Technical Assistance Request
TBA	Training Business Area
TCTO	Time Compliance Technical Order
TDV	Technical Data Violation
TIT	Turbine Inlet Temperature
T/N	Tail Number
T.O.	Technical Order
TSO	Time Since Overhaul
UCR	Unacceptable Condition Report
UTA	Unit Training Assembly
UTC	Coordinated Universal Time
UTM	Unit Training Manager
Z	Zulu
156 AS	156th Airlift Squadron
156 AW	156th Airlift Wing
156 MDG	156th Medical Group
156 MXG	156th Maintenance Group
156 OG	156th Operations Group
156 OSS	156th Operations Support Squadron
165 AW	165th Airlift Wing
198 AS	198th Airlift Squadron

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

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 8 June 2018, General Carlton D. Everhart II, Commander, Headquarters Air Mobility Command (AMC), appointed Brigadier General John C. Millard to conduct an aircraft accident investigation of the 2 May 2018 crash of a WC-130H, tail number (T/N) 65-0968, outside of the Savannah/Hilton Head International Airport, Georgia.[1] The investigation occurred at Joint Base Charleston, South Carolina, from 18 June 2018 through 16 July 2018, and included travel to Savannah, Georgia, and Muñiz Air National Guard Base, Puerto Rico. To aid in the investigation, General Everhart appointed members from the Air Force's Regular, Reserve, and Guard components: a Brigadier General Medical Member, a Lieutenant Colonel Pilot Member, a Lieutenant Colonel Maintenance Member, a Major Legal Advisor, a Senior Master Sergeant Maintenance Enlisted Member, a Master Sergeant Flight Engineer Member, a Technical Sergeant Recorder, and a Staff Sergeant Weather Member; and detailed a Chief Master Sergeant Engine Subject Matter Expert.[2]

b. Purpose

In accordance with Air Force Instruction (AFI) 51-503, *Aerospace and Ground Accident Investigations*, 14 April 2015, this Accident Investigation Board (AIB) conducted a legal investigation to inquire into all the facts and circumstances surrounding this United States Air Force aerospace accident, prepare a publicly-releasable report, and obtain and preserve all available evidence for use in litigation, claims, disciplinary action, and adverse administrative action.

2. ACCIDENT SUMMARY

On 2 May 2018, at approximately 1127 hours local time (L), the Mishap Aircraft (MA), a WC-130H, T/N 65-0968, crashed shortly after takeoff from the Savannah/Hilton Head International Airport (KSAV) in Savannah, Georgia.[3] The MA had been in Savannah since 9 April 2018 for maintenance at the facilities of the 165th Airlift Wing (165 AW) by Puerto Rico Air National Guard (PR ANG) to address five fuel cell discrepancies.[4] The time from liftoff to the mishap was approximately 90 seconds.[5] The MA was assigned to the 156th Airlift Wing (156 AW), a unit in the PR ANG.[6]

Onboard the MA were the Mishap Pilot 1 (MP1), the Mishap Pilot 2 (MP2), the Mishap Navigator (MN), the Mishap Flight Engineer (MFE), and the Mishap Load Master (MLM) (collectively the "Mishap Crew (MC)"); and four mission essential personnel, Mishap Airman 1, 2, 3, and 4 (MA1, MA2, MA3, and MA4).[7] All were members of the 156 AW and were on a mission to deliver the MA to the 309th Aerospace Maintenance and Regeneration Group (309 AMARG), at

Davis-Monthan Air Force Base (AFB), in Tucson, Arizona.[8] All nine aboard the MA died immediately upon impact.[9] There were no civilian personnel killed or injured in the mishap.[10]

3. BACKGROUND

a. Air Mobility Command (AMC)

AMC is a major command headquartered at Scott AFB, Illinois.[11] AMC provides worldwide cargo and passenger delivery, air refueling, and aeromedical evacuation. The command also transports humanitarian supplies to hurricane, flood, and earthquake victims both at home and around the world. More than 133,700 Regular, Reserve, and Guard members and Department of Defense (DoD) civilians make the command's rapid global mobility operations possible.[12]

b. Air National Guard (ANG)

The ANG mission is to provide mission-ready Airmen to the Nation and communties.[13] The ANG has two missions. The ANG's federal mission is to maintain well-trained, well-equipped units available for prompt mobilization during international armed conflict and provide assistance during national emergencies (such as natural disasters or civil disturbances). During peacetime, the combat-ready units and support units are assigned to most Air Force major commands to carry out missions compatible with training, mobilization readiness, humanitarian and contingency operations, such as Operation ENDURING FREEDOM in Afghanistan. ANG units may be activated in a number of ways as prescribed by public law. Most of the laws may be found in Title 10 of the United States Code. The ANG provides almost half of the Air Force's tactical airlift support, combat communications functions, aeromedical evacuations, and aerial refueling. In addition, the ANG has total responsibility for air defense of the entire United States.

When ANG units are not mobilized or under federal control, they report to the governor of their respective state, territory (Puerto Rico, Guam, or Virgin Islands), or the commanding general of the District of Columbia National Guard. Each of the 54 National Guard organizations is supervised by the adjutant general of the state or territory. Under state law, the ANG provides protection of life, property and preserves peace, order, and public safety. These missions are accomplished through emergency relief support during natural disasters (such as floods, earthquakes, and forest fires), search and rescue operations, support to civil defense authorities, maintenance of vital public services, and counterdrug operations.[14]

c. 156th Airlift Wing (156 AW)

The 156 AW is the primary unit of the PR ANG and is located at Muñiz Air National Guard Base, in Carolina, Puerto Rico.[15] The 156 AW flies the WC-130 Hercules, an aircraft that is capable of operating from rough, dirt strips and is the prime transport for air dropping troops and equipment into hostile areas. The mission of the 156 AW is to provide global airlift and

agile forces to execute and accomplish tasked missions, support Southern Command in theater airlift and joint military exercises, and bolster United States ties with Latin American neighbors.[16]

d. 198th Airlift Squadron (198 AS)

The 198 AS is the flying squadron of the 156 AW located at Muñiz Air National Guard Base.[17] The 198 AS is equipped with the WC-130H Hercules. The men and women of the 198 AS train to provide mobility airpower for the United States Air Force in their federal role and support for the territory of Puerto Rico when not in federal status.[18]

e. 165th Airlift Wing (165 AW)

The 165 AW is a unit of the Georgia Air National Guard based out of the Savannah/Hilton Head International Airport and is equipped with the C-130H3 Hercules aircraft.[19] The mission of the 165 AW is to provide air transport for airborne forces, their equipment, and supplies with delivery by airdrop or airland, and to provide strategic airlift of personnel, equipment, and supplies. The 165 AW is also prepared to deliver assistance during state emergencies to provide food, medical supplies, equipment, and trained personnel, not only within Georgia or the United States, but in foreign countries as well. [20] The 165 AW provided maintenance facility support to the 156 AW when needed.[21]

f. Savannah/Hilton Head International Airport (KSAV)

KSAV is a public and military use airport owned by the City of Savannah and managed by the Savannah Airport Commission.[22] The airport is located seven nautical miles northwest of the central business district of Savannah, a city in Chatham County, Georgia, and is approximately 50 feet above mean sea level (MSL).[23]

g. 309th Aerospace Maintenance and Regeneration Group (309 AMARG)

The 309 AMARG, also known as the "Boneyard," is a one-of-a-kind specialized facility within the command structure of Air Force Materiel Command and located at Davis-Monthan AFB, Arizona.[24] The 309 AMARG provides critical aerospace maintenance and regeneration capabilities for Joint and Allied/Coalition warfighters in support of global operations for a wide range of military operations.[25]

h. C-130 – Hercules

The C-130 Hercules primarily performs the tactical portion of the airlift mission.[26] The C-130 operates throughout the United States Air Force, serving with AMC, ANG, Air Force Special Operations Command, Air Combat Command, United States Air Forces in Europe, Pacific Air Forces, and Air Force Reserve Command, fulfilling a wide range of operational missions in both peace and war situations. Basic and specialized versions of the aircraft perform a diverse number of roles, including airlift support, Antarctic ice resupply, aeromedical missions, weather reconnaissance, aerial spray missions, firefighting duties for the United States Forest Service, and natural disaster relief missions.[27] The Air Force issued its original design specification in 1951, yet the remarkable C-130 remains in production.[28] The initial production model was the C-130A, with four Allison T56-A-11 or -9 turboprop engines. A total of 219 were ordered and deliveries began in December 1956. The C-130B introduced Allison T56-A-7 turboprop engines and the first of 134 entered Air Force service in May 1959. Introduced in August of 1962, the 389 C-130Es that were ordered used the same Allison T56-A-7 engine, but added two 1,290-gallon external fuel tanks and an increased maximum takeoff weight capability. June 1974 introduced the first of 308 C-130Hs with the more powerful Allison T56-A-15 turboprop engine (future updates introduced -H2 and -H3 variants). Nearly identical to the C-130E externally, the new engine brought major performance improvements to the aircraft. The latest C-130 to be produced, the C-130J, entered the inventory in February 1999. With the noticeable difference of a six-bladed composite propeller coupled to a Rolls-Royce AE2100D3 turboprop engine, the C-130J brings substantial performance improvements over all previous models. The C-130J-30, a stretch version with a 15-foot fuselage extension, increases the capabilities even more.[29]

The MA, T/N 65-0968, rolled off the assembly line in 1965 as a standard C-130E.[30] Sometime in the early 1970's, it was converted to a WC-130H for use in weather reconnaissance (the "W" designation indicates the weather modifications).[31] The engines were also upgraded from the T56-A-7 to the T56-A-15 at that time (which changed the "E" designation to "H").[32] Previous assignments include the 53d Weather Reconnaissance Squadron at Keesler AFB, Mississippi; the 53d Airlift Squadron at Little Rock AFB, Arkansas; and the 105th Airlift Squadron, Tennessee ANG, Nashville, Tennessee. At the time of the mishap, it was assigned to and operated by the 156 AW.[33]

i. C-130 Aircraft Assigned to the Puerto Rico Air National Guard (PR ANG)

Toward the end of Fiscal Year (FY) 2012, the PR ANG had six Air Combat Command-gained, primary aircraft C-130Es assigned to the 156 AW.[34] At that time, the C-130Es were scheduled to retire due to overall fleet reductions.[35] During this period, the PR ANG supported the United

States Southern Command and augmented CORONET OAK, a mission in South America to provide theater airlift, disaster relief, and embassy support.[36]

In the FY 2012 Presidential Budget, the Air Force coordinated with the National Guard Bureau (NGB) to internally-source six C-130 backfills for the PR ANG to replace the C-130Es.[37] NGB proposed a transfer of six WC-130H aircraft from the Tennessee ANG to the PR ANG, and, on 12 June 2012, the NGB assigned the MA to the 156 AW.[38] In the FY 2013 Presidential Budget, the PR ANG converted to an AMC-gained unit, but continued support to the CORONET OAK mission with airlift capability.[39] During this transition, the WC-130H aircraft were not included in long-term fleet totals or major modifications, and the PR ANG never assumed a fully qualified combat delivery role.[40]

The FY 2016 Presidential Budget initially divested the six WC-130H aircraft from the PR ANG and provided direction to move the 156 AW to the RC-26, a manned Intelligence, Surveillance, and Reconnaissance (ISR) platform.[41] However, this direction did not prove viable, as there was no requirement for a manned ISR mission in the United States Northern Command Theater.[42] As a result, the WC-130H aircraft were extended.[43]

The FY 2019 Presidential Budget reduced the number of Primary Aircraft Inventory (PAI) of the 13 ANG C-130H equipped wings from eight to seven.[44] The purpose was to provide sufficient Backup Aircraft Inventory (BAI) to account for the depot possessed aircraft.[45] BAI assigned aircraft are aircraft above the PAI to allow scheduled and unscheduled depot level maintenance, modifications, inspections and repairs, and certain other mitigating circumstances without reduction of aircraft available for a wing's assigned mission, which is based on PAI.[46] In effect, this provided more flexibility for the C-130H fleet.[47]

However, NGB, with Headquarters Air Force coordination, determined that the transfer of six (of those 13) C-130H2 aircraft to the PR ANG (to replace their six WC-130H aircraft slated to retire) could still be accomplished while leaving sufficient BAI aircraft for the fleet.[48] Until these six aircraft arrive in Puerto Rico, NGB approved the use of two "loaner" aircraft from contiguous United States (CONUS) ANG C-130H units for PR ANG to maintain operator and maintainer currency and qualifications.[49] The first "loaner" C-130H2 arrived in Puerto Rico on 27 April 2018.[50]

4. SEQUENCE OF EVENTS

a. Mission

The planned mission on 2 May 2018 was a ferry flight of the MA, under ANG authority, from KSAV to Davis-Monthan AFB for induction into 309 AMARG.[51] The MA had been at KSAV for almost a month, since 9 April 2018, undergoing prescheduled fuel cell maintenance and work on engine one by 156th Maintenance Group (156 MXG), PR ANG, personnel.[52] On 30 April 2018, the MC, the four Mishap Airmen, and a second crew flew from Puerto Rico to Savannah on T/N 65-0984, another 156 AW aircraft.[53] On 1 May 2018, the MC flew a stateside mission with T/N 65-0984 to drop off the second crew at the Nashville International Airport in Tennessee, to pick up T/N 64-4866, another 156 AW aircraft undergoing off-site maintenance.[54] The second

crew flew T/N 64-4866 to Lawson Army Airfield, Fort Benning, Georgia, to become a static trainer.[55] The MC then picked up the second crew at Lawson Army Airfield in T/N 65-0984 and flew back to KSAV on 1 May 2018, to remain overnight.[56]

b. Planning

The MC planned their mission in accordance with AFI 11-2C-130, Volume 3, *C-130 Operations Procedures*, 23 April 2012.[57]

c. Preflight

The MC gathered all appropriate Notices to Airmen (NOTAMS) and weather briefings, and filed their flight plan.[58] Nothing of note occurred prior to the MC arriving at the aircraft.[59]

d. Summary of Accident

The engine start-up and taxi were normal.[60] The MC accomplished all checklists from *Before Starting Engines* through *Line Up* in accordance with the Flight Manual.[61] However, MP1 did not brief emergency actions on the day of the mishap during the *Before Takeoff* checklist.[62] According to the *Before Takeoff* checklist, a crew must brief all applicable items prior to each takeoff.[63] The data briefed typically includes the takeoff and landing data (i.e., airspeeds and runway requirements), coordinated action(s) during emergencies (including aborted takeoff and emergency return/fuel dumping), and departure procedures (e.g., navigation aids used, hazardous terrain/obstacles, etc.).[64] A crew can conduct the briefing before initiating the *Before Takeoff* checklist.[65]

As captured by the cockpit voice recorder (CVR), the MC did conduct the crew briefing during the *Before Takeoff* checklist.[66] The MN briefed specific departure procedures for KSAV and MP1 briefed takeoff and landing data and procedures for Instrument Flight Rules (IFR) departure clearance.[67] However, MP1 stated, "everything else remains the same," indicating that emergency action procedures briefed during a previous flight still applied.[68] The Flight Manual does indicate that a crew only needs to brief changed data for multiple takeoffs or landings.[69] However, the C-130 community generally recognizes "multiple takeoffs or landings" to denote within the same day or sortie, not separate days as was the situation with the MC.[70] The MC then taxied the MA uneventfully to Runway 10 for an IFR departure.[71]

MP1 sat in the left seat pilot position and was the primary pilot of the aircraft.[72] The left seat pilot is typically the senior pilot and the Aircraft Commander.[73] During takeoff, the left seat pilot controls the nose wheel steering with his left hand (a small steering wheel to the left of the yoke used to steer the aircraft on the ground), the throttles with his right hand, and the rudder and brake pedals with his feet (see Figure 1).[74]

Figure 1 - WC-130H (T/N 65-0983) Flight Deck (Tab Z-9)

MP2 sat in the right seat pilot position (often referred to as the copilot).[75] The right seat pilot controls the yoke (ailerons and the elevator) with his right hand until the left seat pilot states "pilot's aircraft" (indicating the left seat pilot has moved his left hand from the nose wheel steering to the yoke and assumed control of the yoke).[76] This usually occurs when the rudder becomes effective at 50 to 80 knots.[77] The right seat pilot will also back up the left seat pilot's throttle application with his left hand, to ensure the engines are not over torqued, and be ready to assume control of the aircraft if required.[78] At charted takeoff speed (the speed at which the aircraft can maintain safe flight), the right seat pilot will state, "GO," indicating the aircraft is at a safe speed to fly.[79]

Upon takeoff clearance from KSAV Air Traffic Control (ATC), the MC performed a rolling takeoff, as briefed, rather than a static takeoff.[80] During a static takeoff performed by the left seat pilot, the aircraft comes to a complete stop, the left seat pilot applies the brakes, the left seat pilot powers up the engines, then he releases the brakes and the aircraft begins to move forward.[81] An advantage of the static takeoff is it allows the aircrew to check engine performance briefly prior to beginning the takeoff sequence.[82] Whereas a rolling takeoff requires the aircrew to perform several duties at once and makes it more difficult to assess engine performance prior to flight.[83] The Flight Manual does not specifically address conditions or situations to conduct a static takeoff; however, there is a commonly known practice to perform a static takeoff on the first flight of the

day to confirm engine and aircraft performance.[84] This was the MA's first flight of the day and first flight since engine maintenance on 24 April 2018.[85]

As the MA rolled onto the runway, the MC completed the *Lineup* checklist.[86] MFE then verbally assisted MP1 with setting takeoff power and called "Power Set" (indicating MP1 had fully advanced the throttles to takeoff power).[87] During takeoff roll, engine one speed fluctuated between 94% and 98% revolutions per minute (RPM) and did not provide normal flight RPM (98% to 102%) when the throttle levers were advanced into the flight range for takeoff.[88] According to the Flight Manual, if an engine malfunction occurs before reaching refusal speed, the crew must stop the airplane (refusal speed is the speed at which an aircraft must lift off or risk running out of runway).[89] When MFE called, "Power Set," and engine one had not provided normal flight RPM, the MA was only at 64 knots indicated air speed (KIAS), well below the calculated refusal speed of 139 KIAS.[90] However, no member of the MC made a call to reject takeoff.[91]

Approximately eight seconds prior to aircraft rotation (when the nose rotates up and the nose wheel comes off the ground), engine one RPM and torque significantly decayed.[92] At takeoff rotation, engine one RPM had dropped to 65%, torque dropped to 1,971 inch-pounds (from a normal torque range around 18,000 inch-pounds), and engine thrust dropped significantly, essentially dropping 90% from over 4,000 horsepower to under 300.[93] This loss of engine one power was unrecognized by the crew, in particular the MFE, whose primary responsibility during takeoff is to monitor engine performance using the gauges, warning lights, and fire detection indicators.[94]

Moments before rotation, with the MA traveling at approximately 94 KIAS, MP1 applied a right rudder input just above 25-degrees (maximum rudder deflection is 35-degrees[95]) to keep the MA

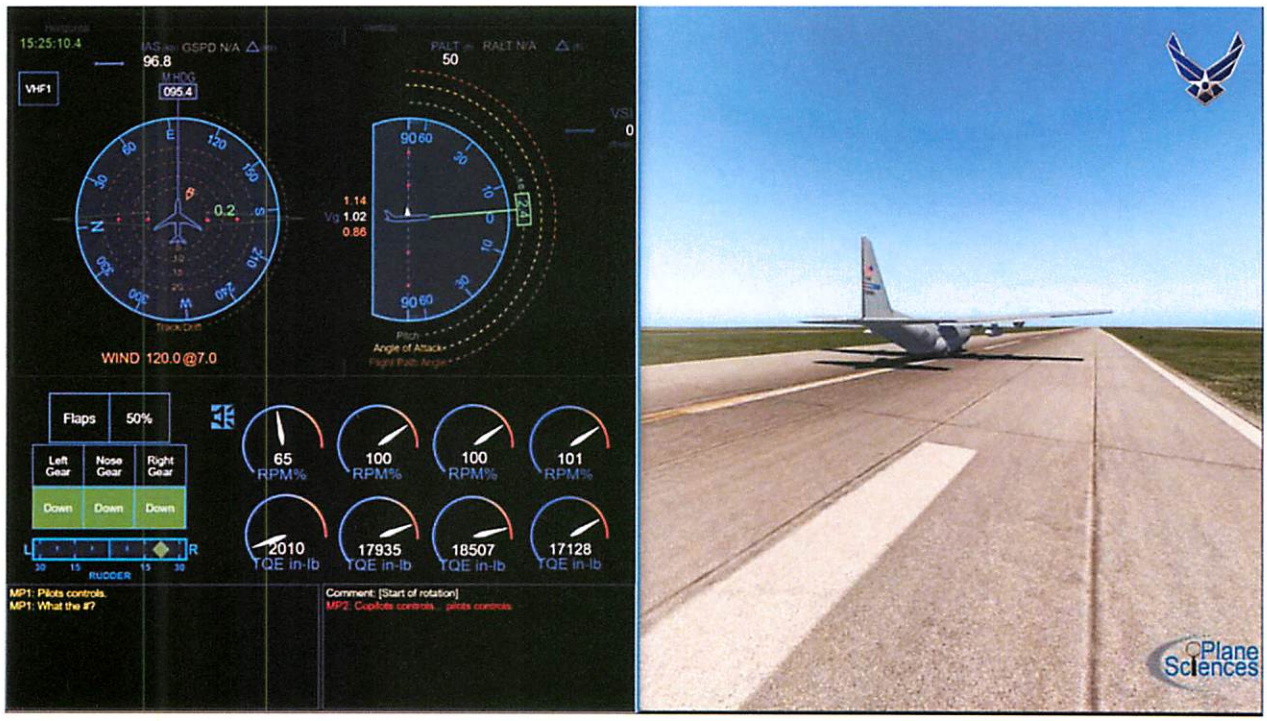

Figure 2 - MP1 Call for "Pilot's Controls" (Tab Z-66)

on the runway's centerline, indicating the MA was pulling to the left.[96] The MA rotated at approximately 95 KIAS, within the normal range for rotation (rotation speed was calculated for 99 KIAS).[97] Rotation occurs five knots below charted takeoff speed.[98]

At aircraft rotation, MP1 called for "pilot's controls," communicating he had moved his hands from nose wheel steering (which was no longer effective) to the yoke and was taking control from MP2 (see Figure 2).[99] As MP1 made the call, he verbalized something was wrong with the MA, but he was not specific.[100] As soon as the nose wheel lifted from the ground, the MA veered to

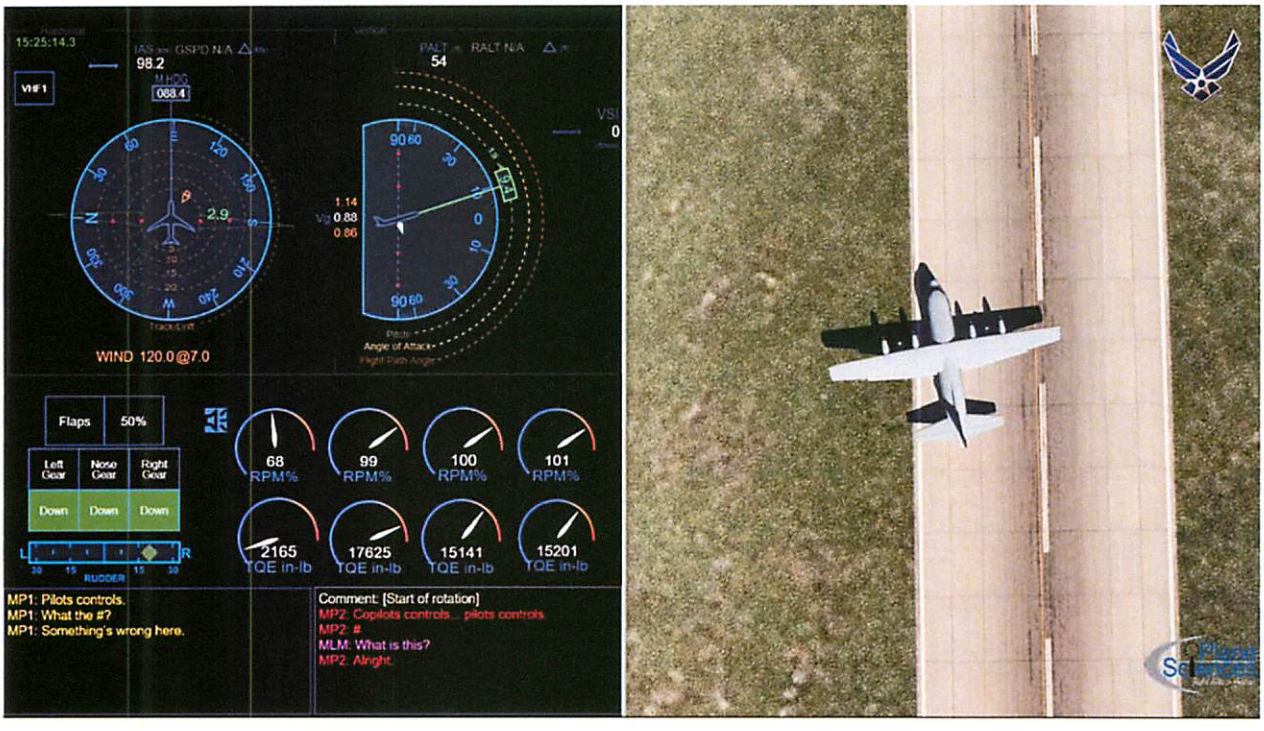

Figure 3 - MA Veered Left at Rotation (Tab Z-175)

Figure 4 - MA Position at Takeoff (Tab Z-16 and Z-20)

the left and nearly departed the runway into the grass before the MA achieved flight at approximately 1125L (see Figures 3 and 4).[101]

Once airborne, MP1 banked right to maintain runway centerline (see Figures 5 and 6).[102] This bank angle away from engine one, toward the right, was also in compliance with the Flight Manual, which directs a 5-degree bank angle away from a failed engine if an outboard engine fails near minimum controllable speed during takeoff or inflight.[103] KSAV ATC noted the unusual banking of the MA and contacted the MC.[104] The MC responded and indicated they had a mechanical malfunction.[105]

Figure 5 - MP1 Banking Right After Takeoff (Tab Z-18 and Z-22)

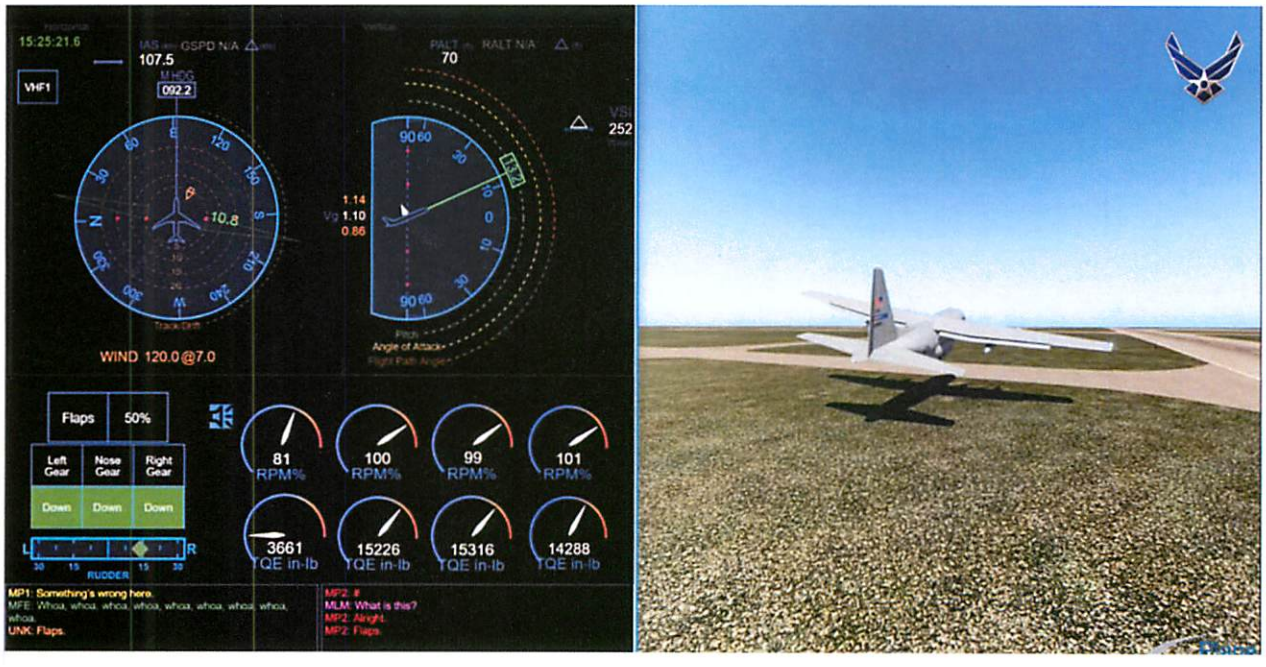

Figure 6 - MP1 Bank Right After Takeoff (Tab Z-75)

When an engine failure occurs during takeoff, the Flight Manual directs an aircrew in the *Takeoff Continued After Engine Failure* procedure to: (1) maintain directional control with flight controls

and engine power as necessary; (2) when safely airborne and certain the airplane will not touch down, raise the landing gear while accelerating to flap retraction speed; (3) after the landing gear is up, and airspeed permits, commence flap retraction (with a warning about the importance to obtain two-engine air minimum control speed as soon as possible after takeoff and prior to positioning the flap lever to less than 15 percent); and (4) after the landing gear and flaps are up, continue as a normal takeoff, accelerating to three-engine climb speed.[106] Seconds after becoming airborne, during the bank right, a MC member made an incorrect call for "flaps," and MP2 repeated it.[107] However, MP1 instructed the flaps to stay at 50 percent and called for MP2 to raise the landing gear.[108] MP1 never followed up with a subsequent direction to commence flap retraction.[109]

Approximately 15 seconds into flight, engine one regained partial power in the range of 94% to 95% RPM.[110] In response to MP2 questioning what happened, MP1 indicated that they lost engine one, and he, MN, and the MFE all questioned if it was in fact engine one.[111] MFE stated that they had not lost engine one, but it had low power.[112] However, just as the landing gear finished the transition up, engine one RPM and torque decayed once again, losing significant engine thrust.[113] At 380 feet MSL, MP1 called for engine one shutdown.[114] According to the Flight Manual, if an engine experiences uncontrollable power (among other engine conditions) in flight or on the ground and the corrective action specified in the Flight Manual does not alleviate the condition, engine shutdown will be at the pilot's discretion, depending on flight conditions and the situation.[115] When it is necessary to continue operation of an engine experiencing uncontrollable power in the interest of safety of the airplane and crew, the Flight Manual alerts the crew to operate the engine with extreme caution, and at the minimum power required.[116] Thus, the decision to shut down engine one complied with the Flight Manual.[117]

At approximately 430 feet MSL, MP1 banked left into the inoperative engine, rather than continuing acceleration to a three-engine climb speed.[118] Approximately 50 seconds after departure and near 600 feet MSL, the MC successfully shutdown engine one and feathered the propeller (the process of rotating the propeller blades to reduce drag).[119] However, the MC failed to follow the *Engine Shutdown* procedure as stated in the Flight Manual, which would have

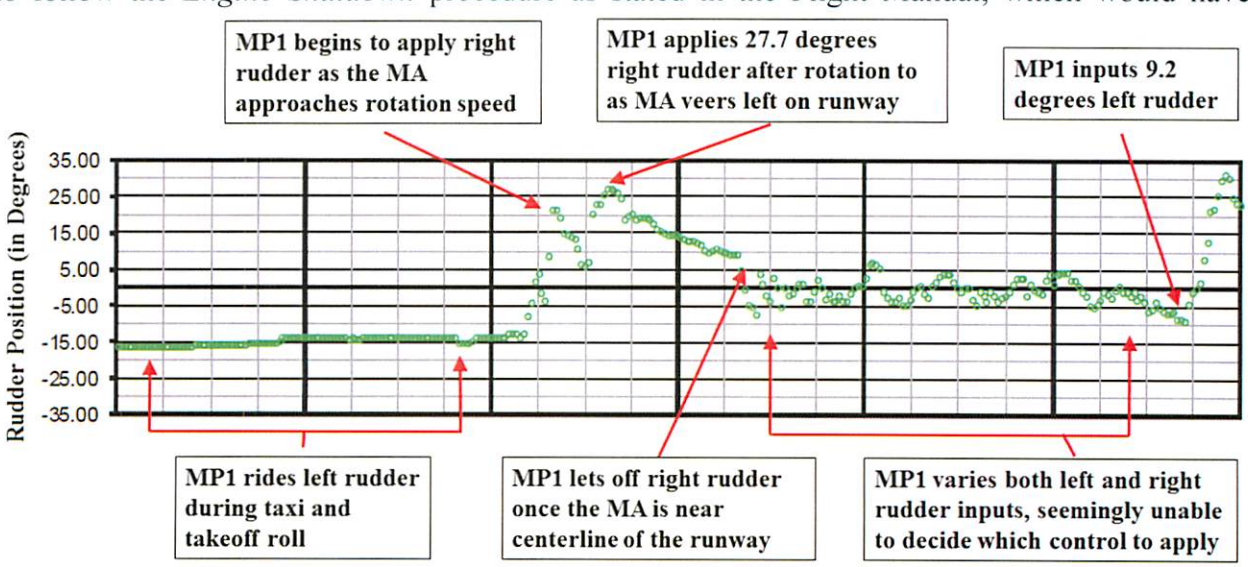

Figure 7 - Rudder Position Directed by MP1 (Tab Z-32)

required MP2 to state the flap setting after moving the condition lever to feather and after pulling the fire handle.[120] The MC also did not complete the *Takeoff Continued After Engine Failure* procedure by commencing flap retraction after raising the landing gear.[121] Additionally, the MC did not follow the standard *After Takeoff* checklist, which would have also prompted MP1 to call for flap retraction and focus the MP1 on attaining an appropriate airspeed.[122] Rather, the MA's flaps remained at 50 percent.[123] Raising the flaps up would have decreased drag and allowed the MA to accelerate, provided more authority to the MA's control surfaces, and allowed for better control of the MA.[124]

MP1 continued to climb and turn left toward engine one.[125] Throughout the turn, MP1 varied both left and right rudder inputs (see Figure 7).[126] According to the Flight Manual, when one engine is inoperative, the listed minimum control speeds require maximum available rudder deflection, limited by 180 pounds (lbs) pedal force, or maximum rudder surface deflection, whichever occurs first.[127] In addition, a 5-degree adverse bank angle (into the inoperative engine) requires a speed increase of 20 KIAS above the minimum control speed at 80,000 pounds and 37 KIAS at 140,000 pounds.[128] Thus, the Flight Manual states that a crew should avoid banked turns into an inoperative engine because of this effect.[129]

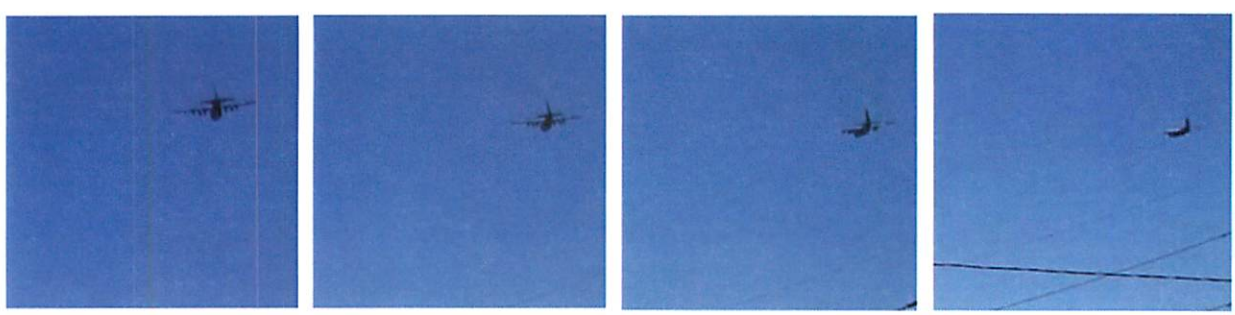

Figure 8 - MA in an Uncoordinated Left Turn (Tab Z-26 to Z-29)

At a takeoff gross weight of 125,622 lbs,[130] the MA's flap retraction speed was 124 KIAS, the two-engine minimum control speed was 148 KIAS, and the calculated three-engine climb speed was 158 KIAS.[131] There are no known minimum calculated airspeed estimates for 10-degree adverse bank angles (into an inoperative engine).[132] However, based on an expansion of data, the minimum estimated airspeed for a 10-degree adverse bank angle would have required 166 KIAS to maintain proper control of the MA.[133] With a 5-degree bank angle away from the inoperative engine (to the right), the calculated three-engine minimum control speed would have been 106 KIAS.[134]

As MP1 continued to climb and turn left, the MC never retracted the MA's flaps, the MA never achieved three-engine climb speed (the maximum speed obtained was 131 KIAS), and the MA's adverse bank angle exceeded 10-degrees (see Figure 8).[135] Although this banked turn into the failed engine was well below the minimum air speed needed for proper control of the aircraft, the MA did still have enough airspeed to maintain flight.[136] However, as the MA reached approximately 900 feet MSL and banked up to 19-degrees left, MP1 increasingly input left rudder over nine degrees in the direction of the inoperative engine, contrary to the directives of the Flight Manual (see Figure 9).[137] As soon as he reached nine degrees, the MA skidded left (i.e, the right

side of the aircraft was in front of the left side), the left wing lost lift and stalled, and the MA departed controlled flight.[138]

Figure 9 - MA Just Before Departure from Controlled Flight (Tab Z-135)

e. Impact

The MA obtained a maximum of 52.2 degrees nose-low attitude, did a left hand barrel roll, and crashed on a northerly heading.[139] The MA impacted the ground less than two minutes after takeoff, at approximately 1127L, on Georgia State Highway 21, East-North East of KSAV, approximately 1.5 miles from the airport.[140] The MC and Mishap Airmen all died instantly upon impact.[141]

Figure 10 - MA Crash Site on Georgia State Highway 21 (Tab S-3)

f. Egress and Aircrew Flight Equipment

The MC had no opportunity to egress while airborne and the MA was destroyed upon impact.[142] The WC-130H is not equipped with any type of crew ejection system.[143]

g. Search and Rescue

KSAV ATC notified the airport's Crash-Fire Rescue immediately after the mishap and units arrived to the scene shortly after receiving the call.[144] Chatham County Emergency Response (911) received a call at 1127L and responded to the scene at 1129L.[145] The Port Wentworth Fire Department received a call at 1129L and arrived on scene at 1134L.[146] After extinguishing the fire, emergency workers searched for survivors, but found the nine individuals on the MA deceased.[147]

h. Recovery of Remains

Local law enforcement officials secured the mishap site in accordance with local disaster response plans.[148] Joint Base Charleston and the members of the 628th Air Base Wing supported the recovery efforts, along with the 165 AW.[149] The recovery team identified the physical remains of the MC and the Mishap Airmen, recovered them with full military honors at the site, and released them to Armed Forces Medical Examiner System (AFMES).[150] AFMES transported the remains to Dover AFB, Delaware, for autopsy and toxicology evaluation by the Armed Forces Medical Examiner.[151]

5. MAINTENANCE

a. Forms Documentation

The Air Force records maintenance actions on Air Force Technical Order (AFTO) 781 forms. Air Force units keep active AFTO 781 forms in a binder onboard an aircraft, while older AFTO 781 forms, retained for historical and archival purposes, are stored at the aircraft's home station in an aircraft jacket file.[152] In addition, maintainers enter AFTO 781 data into a computerized maintenance information system referred to as the Integrated Maintenance Data System (IMDS) or G081 database.[153] When one Air Force organization transfers aerospace equipment to another, the losing organization must forward current and historical documents no later than the same day of the transfer, usually by sending the physical documents onboard the aerospace asset.[154]

Since the MA was being transferred to 309 AMARG, the active and historical AFTO 781 forms were onboard the MA at the time of the mishap.[155] Due to the nature of the mishap and ensuing high-intensity fire, recovery teams only found fragments of forms that were unreadable and unrelated to the mishap.[156] As a result, investigators were unable to recover any portion of active maintenance forms for the MA.[157] However, a review of the 12-month history of the MA's IMDS/G081 records and Time Compliance Technical Orders (TCTOs) revealed no indications of non-compliance.[158]

b. Inspections

An Air Force WC-130H undergoes progressive inspections at intervals to ensure the airworthiness of the aircraft.[159] These inspections include minor Home Station Checks (HSC), major Isochronal (ISO) inspections, and in-depth Programmed Depot Maintenance (PDM) inspections requiring skills, equipment, and/or facilities not normally present at operating locations.[160] The most recent HSC for the MA was on 11 August 2017, with the next HSC due

on 8 May 2018.[161] The most recent ISO inspection was also on 11 August 2017, with the next ISO inspection due on 2 February 2019.[162] The most recent PDM was on 2 March 2013, with the next PDM due on 2 March 2018.[163] However, there was an approved Technical Assistance Request (TAR) deferring the next PDM until 31 May 2018.[164]

Approved by C-130 aircraft systems program office engineers, a TAR provides guidance on repairs typically beyond field-level repair capability, provides flight authority for aircraft beyond required repair schedules, authorizes use of a specific part/commodity with defects or deviations beyond Technical Orders (T.O.) limits, and/or provides authorization for limited use of non-listed substitutes (supplies, components, support equipment, etc.).[165] A review of all TARs from 2015 to the mishap found all accomplished in accordance with applicable guidance, to include TARs to extend the PDM due date and for a flight from Puerto Rico to KSAV for fuel maintenance.[166] Furthermore, all TCTOs complied with applicable guidance and no TCTOs restricted the MA from flying.[167]

c. Engine Operation

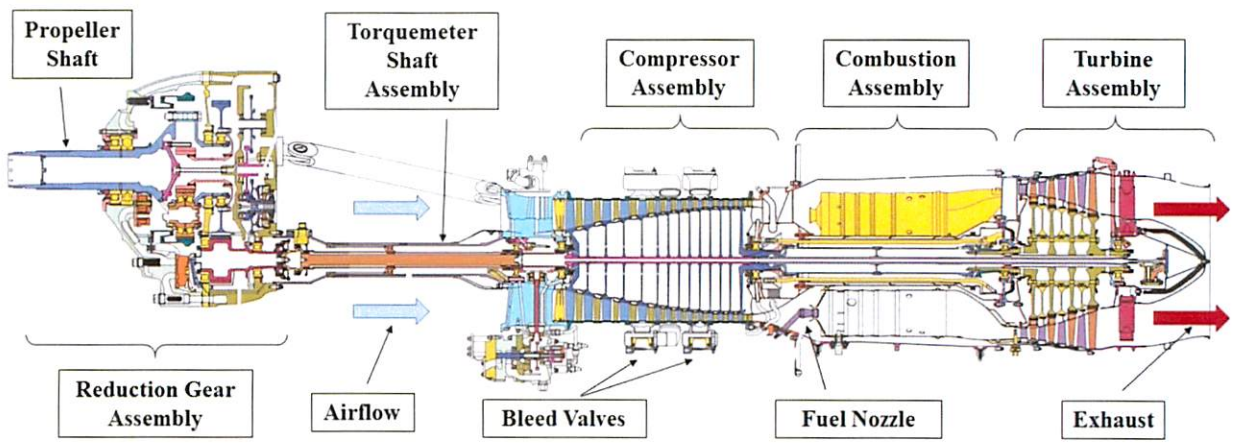

Figure 11 - T-56A-15 Engine (Tabs J-4 and Z-33)

Four T56-A-15 turboprop engines powered the MA.[168] A turboprop engine is a turbine engine that drives a propeller through a reduction gear.[169] The exhaust gases drive a power turbine connected by a shaft that drives the reduction gear assembly.[170] Reduction gearing is necessary in turboprop engines because optimum propeller performance is achieved at much slower speeds than the turbine engine's operating RPM.[171] For example, on the T56-A-15 engine, the turbine spins at approximately 13,820 RPM at power, while the propeller shaft turns at around 1,020 RPM.[172] At low-speed ground idle, the T56-A-15 operates between 69% and 75.5% RPM. At high-speed ground idle, it operates between 96.2% and 99% RPM.[173] However, during all flight conditions, it is designed to operate at 100%.[174] By operating at 100% in all flight conditions, the engine can deliver a great amount of power and torque even at low speeds, making the turboprop engine ideally suited for cargo aircraft carrying heavier payloads.[175]

Once the power levers on the aircraft (commonly referred to as the throttles) are advanced beyond ground idle and into flight idle, they no longer control turbine engine speed, as the turbine and propeller are operating at 100%.[176] Rather, movements in the power levers change the turbine

inlet temperature (TIT) by adjusting the amount of fuel pumped into the engine combustion chamber. An increase in the TIT means an increase in energy provided to the turbine, which in turn sends it to the propeller as torque.[177]

To accommodate this increase in torque, the propeller blade angle adjusts as necessary, based on flight conditions, to maintain 100% RPM. For example, at takeoff while an aircraft is climbing, the blade angle is lowered, taking a smaller bite of air.[178] When the aircraft levels out at cruise altitude, the blade angle increases, taking a larger bite of air. This constant adjustment ensures the engine is always operating at 100%, regardless of aircraft attitude (i.e., the orientation of the aircraft) or flight speed commanded by the pilot. Since the propeller blade angle is constantly changing during flight, a complex device is required to adjust blade angle automatically. This complex device is called the valve housing assembly (see Figure 12).[179]

There are several operational considerations common to all types of turbine engines. One of them is called a compressor stall. This occurs when there is an imbalance between inlet air velocity and rotational speed of the compressor, which interrupts smooth airflow and creates turbulence. This turbulence slows down airflow through the compressor and can stagnate or even reverse direction. To avoid compressor stalls, the compressor section contains valves that open to bleed air from the system when the demand for air is low.[180] In a T56-A-15 engine, these valves are open at low-speed ground idle since the engine is not running above 94%.[181] During flight operation these valves are closed, but will open below 94% RPM to prevent a compressor stall.[182] This generally will only happen in extreme flight attitudes, e.g., when airflow is not flowing straight into the inlet, which is unusual for a C-130.[183] It can also occur during flight if a malfunction causes engine performance to drop below 94% RPM.[184]

A significant concern with dispatching an aircraft engine operating at a low governing speed is the proximity of that speed to the speed at which the bleed valves open.[185] If the engine speed drops to a value that causes the bleed valves to open, engine power can be substantially reduced.[186] An engine with low efficiency may shutdown completely if bleed valves open and recovery does not occur quickly.[187]

When engine speed on the T56-A-15 does not perform at 100% RPM, Air Force maintainers are required to troubleshoot the issue.[188] In many cases, the remedy is a slight adjustment to the engine's valve housing assembly, which can be performed by unit level maintainers. To adjust the valve housing, an Air Force maintainer adjusts the mechanical governor, which has a click type adjustment, with a basic screwdriver (see Figure 12).[189] Each click adjustment changes engine speed by approximately 0.25%.[190] Clockwise rotation increases engine

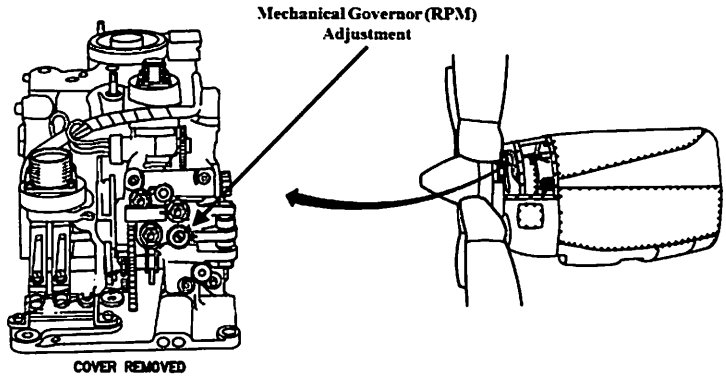

Figure 12 - Location of Valve Housing Assembly on Engine and RPM Adjustment (Tabs DD-69 and Z-33)

speed and counterclockwise rotation decreases engine speed.[191] A calibrated precision tachometer must be used to validate this adjustment.[192]

When an adjustment to the mechanical governor does not resolve the performance issue, an Air Force maintainer is not permitted to disassemble the valve housing at the unit level.[193] Rather, the aircraft must not be dispatched and the maintainers must remove the valve housing assembly and replace it with a new or refurbished component. Only an overhaul facility equipped with specialized equipment can repair or refurbish a failed valve housing.[194]

d. Maintenance Procedures

On 9 April 2018, the MA flew from Puerto Rico to Savannah, Georgia, for scheduled in-tank fuel cell maintenance.[195] Although the MA was scheduled for removal from service at some point in the future, it was intended to return to Puerto Rico after the fuel cell maintenance was complete.[196] The decision to fly the MA to the 309 AMARG from Savannah was not made until after it arrived in Savannah.[197] Typically, a C-130 unit conducts in-tank fuel cell maintenance in a dedicated fuel cell hangar at home station.[198] In-tank fuel cell maintenance requires the use of a hangar to reduce the chance of contaminants entering the aircraft fuel system (since the fuel tanks are open and exposed), to provide a controlled breathing environment for the maintenance technicians, and to provide greater fire suppression capability in the event of a fire.[199] Due to damage from Hurricane Maria in September 2017 and disrepair of the 156 AW's main aircraft hangar, the 156 AW coordinated with the 165 AW for use of their facilities at KSAV to conduct the fuel cell maintenance.[200]

On the ferry flight from Puerto Rico to Savannah, the flight crew operating the MA experienced an RPM issue with engine one, and reported the incident for troubleshooting and repair.[201] The crew explained in the write up that engine one's RPM dropped to 96% when the crew switched the synchrophaser master switch off during final approach (a step taken as the aircraft is on approach for landing).[202] However, as explained in the write up, the ferry crew believed the RPM corrected to normal parameters when they switched on the propeller governor control to mechanical governing.[203] Upon landing in Savannah, the ferry flight crew chief notified the 156 MXG in Puerto Rico of the discrepancy in engine RPMs, and the 165 AW shop supervisor loaded the write up into the IMDS/G081 system, which also informed the 156 AW that the MA had an engine discrepancy.[204]

From 10 April 2018 to 23 April 2018, the MA underwent fuel cell maintenance at Savannah to correct five separate problems.[205] A complete review of the records for the fuel cell maintenance performed showed all maintenance actions and documentation accomplished in accordance with standard practices and applicable T.O.s.[206] Fuel samples were taken from the MA post-fuel cell maintenance, and post-mishap from the fuel storage facility and fuel truck.[207] All samples met material test requirements and were within limits.[208] There is no indication the fuel cell maintenance was a factor in the mishap.

On 23 April 2018, two propulsion specialists from the 156 MXG, Mishap Maintainer 1 (MM1) and Mishap Maintainer 2 (MM2), arrived at KSAV to perform post-fuel cell maintenance engine runs and, because of the RPM issue on the 9 April 2018 ferry flight, to troubleshoot and repair the engine one RPM malfunction.[209] On 24 April 2018, MM1 and MM2, with the assistance of two

156 MXG crew chiefs, Mishap Maintainer 3 (MM3) and Mishap Maintainer 4 (MM4) (collectively the four are referred to as the "Mishap Maintainers"), performed two separate engine runs on the MA.[210]

According to the maintenance T.O., the first step when conducting a C-130 engine maintenance run to troubleshoot an engine RPM discrepancy is to connect a precision tachometer (commonly referred to as an "Accu-Tach").[211] Often, propulsion specialists will travel with a precision tachometer from their home unit, if one is available.[212] MM1 and MM2 were unable to do so because the 156 AW only had one working precision tachometer and when MM1 and MM2 departed Puerto Rico for Savannah, it was away from station traveling with T/N 65-0984.[213] At some point during the engine runs (possibly after the first engine run), the Mishap Maintainers did check out a precision tachometer from the 165 AW Composite Took Kit (CTK) program inventory (see Figure 13).[214]

Figure 13 - 165th Airlift Wing Composite Tool Kit Program Precision Tachometer (Tab Z-4)

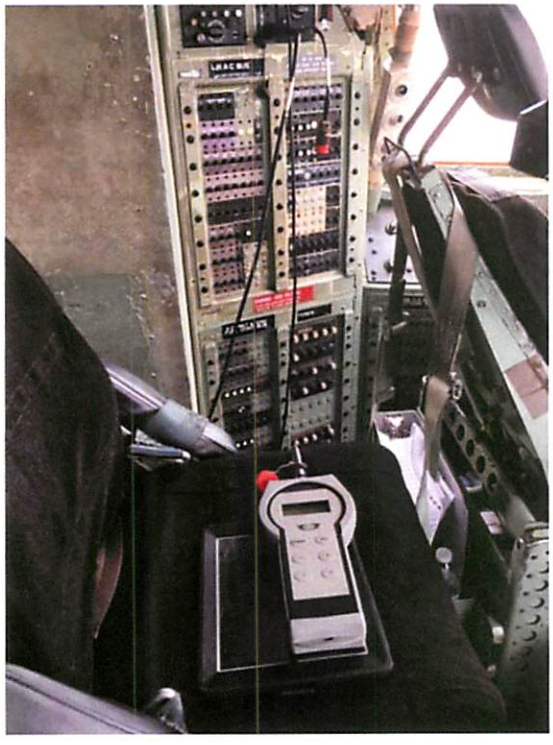

Figure 14 - 165 AW Precision Tachometer Plugged into WC-130H T/N 65-0984 (Tab Z-8)

The model supplied by the 165 AW CTK was a different model than the version normally used by the Mishap Maintainers in Puerto Rico.[215] As a result, the Mishap Maintainers were unable to get this version to connect to the MA because the plugs were a different configuration.[216] The maintainers were unaware the precision tachometer supplied by the 165 AW contained an adapter plug that allowed the device to plug into the MA (see Figure 14).[217] The first step of the T.O. required connecting the precision tachometer and, thus, the Mishap Maintainers should not have continued the engine runs, as they had not completed the first step.[218] However, without using a precision tachometer, the Mishap Maintainers proceeded with the engine runs.[219]

During the first engine run, MM1 and MM2 attempted to duplicate the discrepancy and solution noted by the 9 April flight crew.[220] They were able to duplicate the discrepancy, but not the solution reported by the flight crew.[221] Regardless of the engine governing selection, neither MM1 nor MM2 observed the engine achieve an RPM greater than 96%.[222] The MA's Digital Flight Data Recorder (DFDR) confirms this observation (the

DFDR records engine performance, among other data, independent of cockpit flight instruments).[223] The first troubleshooting method MM1 and MM2 took was to check the RPM tachometer gauge associated with the malfunctioning engine to ensure it was operating correctly.[224] This is done by removing the gauge and replacing it with a new one, and C-130 maintainers commonly do this by swapping it with another tachometer gauge on the aircraft.[225] Per T.O. guidance, this should only happen after the engine is shutdown to avoid damage to the gauge.[226] Believing that swapping the gauges while the engines were running was appropriate, the Mishap Maintainers swapped the engine one tachometer gauge with the engine two gauge, but the replaced gauge still indicated 96% RPM on engine one.[227]

Figure 15 - WC-130H T/N 65-0984 Engine Performance Gauges (Torque, RPM, and Temperature) (Tab Z-13)

After verifying the indicator gauge was not malfunctioning, the Mishap Maintainers terminated the first engine run, reviewed the applicable T.O., and exited the MA to adjust the engine-one valve housing.[228] MM2 made a 12-click clockwise adjustment up with the aim of increasing the engine RPM up to 99%.[229] As the expected effect of each clockwise click is a .25% increase in RPM, the anticipated effect of the adjustment was an increase of 3% in RPM.[230]

According to post-mishap interviews, during a second maintenance engine run, the Mishap Maintainers observed engine one produce 99% RPM.[231] However, this is not supported by the DFDR, which indicates engine one never reached sustained RPM above 96.8% and had significant oscillations between 95% and 98%.[232] In addition, based on the gauge swap during the first engine run, there is no indication the gauge was malfunctioning. When performing an engine run, the T.O. requires a range of 99.8% to 100.02% RPM, as displayed on a precision tachometer, to verify an engine is operating properly at 100%.[233] The T.O. also provides a range of 98% to 102%, as displayed on the aircraft gauge, but the intent is to use that wider gauge range as verification when using the precision tachometer (i.e., by first achieving the required RPM on the precision tachometer and then looking at the instrument gauge to confirm).[234]

During the engine runs and without the use of a precision tachometer, MM1 and MM2 knew that 100% RPM was the speed the engine should operate at, but believed 99% was sufficient to conclude their maintenance because of the wider gauge range provided in the T.O.[235] Thus, the Mishap Maintainers never corrected the engine one discrepancy and did not resolve the RPM issue,

not just because they stopped at what they believed was a sufficient engine speed of 99% RPM, but because, in actuality, the engine only made it to 96.8% sustained speed during the runs, as recorded by the DFDR.[236] Both MM3 and MM4 were present during the runs and followed their specific checklist items for their roles as either brake operator or ground observer; however, neither actively participated in the troubleshooting of the engine discrepancy.[237]

The final minutes of the second engine run were captured on the MA's CVR.[238] This is because the CVR in a C-130 records on a 30-minute loop.[239] On this recording, MM1 stated his intention for the maintenance team to give the valve housing an additional four-click adjustment up and then call the maintenance complete without performing another engine run.[240] However, after the conclusion of the engine run, MM1 and MM2 discussed the need for an additional adjustment.[241] They concluded that an additional four clicks would get the engine RPM to 100%, but doing so would require an additional engine run because any adjustment made to an engine requires a run to verify the results.[242] Rather than obtaining 100%, MM1 and MM2 felt that 99% was acceptable and that no additional adjustments were necessary.[243] The DFDR confirms the Mishap Maintainers did not attempt a third engine run.[244] None of the Mishap Maintainers understood the significance of the MA's engine discrepancy or the importance of using a precision tachometer and considered the discrepancy somewhat common.[245] MM1 signed off the engine discrepancy as repaired in accordance with the T.O.[246]

Engines two, three, and four were all operating normally during the engine runs.[247] There is no indication that these engines were a factor in the mishap. There is also no indication that swapping the MA's gauges while the engines were running was a factor in the mishap.

e. Maintenance Personnel and Supervision

Training records for all available 156 MXG personnel who conducted maintenance actions on the MA were reviewed and, according to the training records, all maintenance was performed by qualified personnel.[248] The review only discovered one documentation error in the training records.[249] MM2's training records maintained within the Training Business Area (TBA) did not contain the appropriate work center Job Qualification Standard stating she was aircraft engine run qualified.[250] This training is required to operate the engines on an aircraft.[251] However, MM2 is listed on the 156 MXG's Special Certification Roster as being engine run qualified.[252] This minor documentation error did not have an impact on the work performed on the MA and was not a factor in the mishap.[253]

(1) Mishap Maintainer 1 (MM1)

MM1 has 15 years of Air Force experience as an Aerospace Propulsion Technician (AFSC 2A671H) and is assigned to the 156 MXS.[254] He is a full time technician.[255] He was awarded his Craftsman skill level (7-level) on 31 May 2011.[256] He has been engine run qualified since 4 April 2014.[257] MM1 was the engine run supervisor sitting in the flight engineer position for the two maintenance runs on 24 April 2018.[258]

(2) Mishap Maintainer 2 (MM2)

MM2 has five years of Air Force experience as an Aerospace Propulsion Technician (AFSC 2A651H).[259] She spent three years at Peterson AFB, Colorado, prior to her assignment to the 156th Maintenance Squadron (156 MXS).[260] She was hired as a full time technician in July 2016.[261] She was her awarded Journeyman skill level (5-level) in December 2014.[262] She was signed off on engine operational checks in June 2014.[263] MM2 was sitting in the left pilot seat for the two maintenance runs on 24 April 2018, and was the main operator of the engines.[264]

(3) Mishap Maintainer 3 (MM3)

MM3 has 15 years of Air Force experience as a Crew Chief (AFSC 2A551B) in the 156 MXG.[265] He is a traditional Guardsman who was awarded his Journeyman skill level (5-level) on 29 February 2012 and, according to the Training Business Area (TBA) records system, he accomplished all necessary tasks to be awarded a Craftsman skill level (7-level) on 30 August 2017.[266] MM3 was the ground observer for the first maintenance run and was the brake operator in the right pilot seat for the second maintenance run on 24 April 2018.[267] He was also the member who signed out the precision tachometer for MM1 and MM2 from the 165 AW.[268]

(4) Mishap Maintainer 4 (MM4)

MM4 has 32 years of Army and Air Force experience.[269] He served 12 years in the Army Reserve.[270] He has been a Crew Chief in the 156 MXG for 20 years (AFSC 2A571).[271] He is a traditional Guardsman who received a recommendation for his Craftsman skill level (7-level) on 15 March 2010.[272] MM4 sat in the brake operator for the first maintenance run and was the ground observer for the second maintenance run on 24 April 2018.[273]

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

The Air Force Petroleum Agency (AFPET) at Wright-Patterson AFB, Ohio, analyzed the hydraulic fluid and engine oil of the MA, but was unable to complete testing due to the limited hydraulic fluid and engine oil recovered.[274] However, there is no evidence to indicate hydraulic fluid and engine oil were factors in the mishap.

AFPET analyzed fuel samples from the fuel holding tanks and fuel delivery truck at KSAV and determined the fuel met material test requirements.[275] No fuel samples were recovered from the MA due to the ensuing fire, which consumed all remaining fuel.[276] There is no evidence to indicate the MA's fuel was a factor in the mishap.

AFPET also analyzed an oxygen sample taken from the KSAV storage tank and determined it met T.O. requirements.[277] There is no evidence to indicate the MA's oxygen was a factor in the mishap.

g. Unscheduled Maintenance

All active aircraft forms and the jacket file were inside the MA at the time of the mishap and were destroyed by the resultant fire.[278] A comprehensive review of the IMDS/G081 records history and available forms for the prior 12-months, with the exception of the engine one RPM

discrepancy, revealed there is no evidence to suggest any other unscheduled maintenance was a factor in the mishap.[279]

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

The MA was a total loss, therefore limited aircraft systems were recovered post-impact.[280] The tail section was largely intact, to include vertical and horizontal assemblies and rudder and elevator flight control surfaces.[281] The recovered aircraft parts were thoroughly analyzed and there is no indication of any structure or systems failure on the MA, with the exception of engine one.[282]

There were several data recording anomalies, but there is no evidence to indicate they were factors in the mishap.[283] The DFDR data contained three errors: vertical acceleration on the ground recorded approximately 1.4g's (rather than 1.0g), flap setting recording 72% when flaps were set to 50%, and rudder position occasionally reported positions up to -70 degrees when the maximum rudder deflection of the aircraft is 35 degrees.[284] The MA's DFDR had not been downloaded and checked since 18 December 2010, when the MA was assigned to the Tennessee ANG, rather than every 540 days as required by the T.O.[285] While these errors did exist, technical engineers were able to eliminate actual mechanical errors during analysis of the structures and systems.[286]

b. Evaluation and Analysis

(1) Engine One Malfunction

Engines[287]:

Aircraft Position	Engine S/N	Reduction Gearbox (RGB) S/N	RGB TSO (hours)	Compressor Module S/N	Compressor TSO (hours)	Turbine Module S/N	Turbine Rotor S/N	Turbine Rotor TSO (hours)
1	AD00109984	AG029043	3987.9	AD0C5N0020	35.4	AD0T502200	A13642	1385.4
2	AD00111562	AG025674	2367.5	AD0C509452	800.5	AD0T511562	A15188	800.5
3	AD00112090	AG025807	2640.5	AD0C502453	35.4	AD0T511340	A13889	3125.4
4	AD00109285	AG027624	441.5	AD0C502109	441.5	AD0T513213	A6361M	441.5

For the mishap flight, engine three was started first, then engine four, engine two, and finally engine one (per standard startup procedure).[288] Soon after startup, engine two and three were set to low-speed ground idle and engine one and four were set to high-speed ground idle.[289] At high-speed ground idle, engine one's speed was approximately 96.5% RPM, while engine four (the opposite outboard) was at 98% RPM. The normal operating range for high-speed ground idle is 96.2% to 99% RPM. The elapsed time between engine start and takeoff was typical, with no engine run-ups or Ground Power Assurance Checks before takeoff.[290] As the MC increased the throttles in preparation for takeoff, engines two, three, and four responded normally at 99% to 101% RPM, with a slight overshoot at the top of the transient (which is normal).[291] However, engine one did not respond as expected and became more unstable as the throttle increased, with engine speed fluctuating between 94% and 98% RPM.[292]

This speed instability continued until shortly before aircraft rotation, when at just below 94%, engine speed and power rapidly dropped.[293] A rapid drop in engine power below 94% speed is consistent with the compressor bleed valves opening. At aircraft rotation, engine one speed and power bottomed at approximately 65.2% and 1971 in-lbs torque. This torque drop is equivalent to a drop in engine power from nearly 4,000 horsepower to under 300. As the MA started to climb, engine one recovered to takeoff power and 99% RPM, resulting in a 20% overshoot in power for the given throttle setting. Engine one power then reduced to typical levels although engine speed remained somewhat unstable and less than 100%. After approximately 12 seconds of semi-stable operation, engine one power and speed again dropped significantly and became more unstable.[294] After another 12 seconds of unstable operation, the MC shut down engine one and commanded the propeller to feather (see Figure 16).[295]

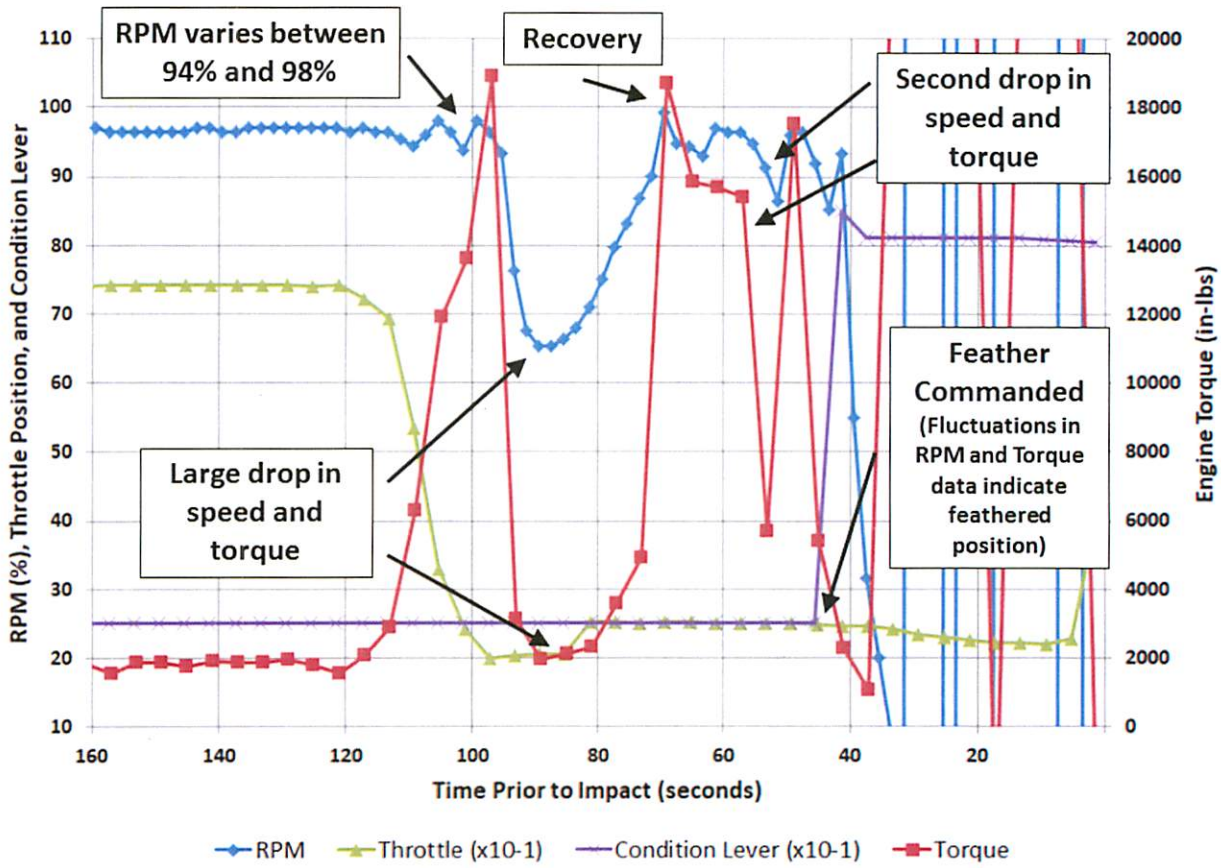

Figure 16 - Engine One Parameters (Tabs J-113 and Z-34)

Review of the DFDR revealed evidence of deviations in engine one speed in flights prior to the mishap.[296] In the second to last flight, engine one did not achieve 100% speed at takeoff, operating at approximately 98.5%. In contrast, engine four, which was controlled to the same condition as engine one, did achieve 100%. Soon after takeoff and with the engine at takeoff power, engine speed did recover. The cause for the speed recovery is unclear within the data available.[297]

A similar pattern occurred during landing in the second to last flight, where engine one speed dropped ahead of the other engines.[298] Engine one operated at 100.3% speed for long periods of time, before it reduced to approximately 99% (1% lower than engine four speed), and then dropped

to 97% with no reduction in throttle. Engine four speed was at 100% until the throttle was reduced, when it dropped to 98%. Engine one speed remained about 1% lower. There was a brief moment when engine one speed exceeded 100% that roughly aligned with touchdown, although the cause is unknown.[299] The fifth to last flight is the last flight engine one did not exhibit any speed anomalies during takeoff, as recorded by the DFDR.[300]

A comprehensive review of the engine one hardware did not identify an engine specific condition that could explain the abnormal operational behavior of the number one engine/propulsion system.[301] However, a low governing RPM, as identified in the DFDR, affects a valve housing assembly's ability to decrease propeller blade angles and correct under-speed conditions.[302] Thus, the decrease in engine speed identified on engine one is consistent with a valve housing assembly's failure to correct propeller and ultimately engine under-speed. Due to extensive damage to the engine one valve housing assembly, there is no way to determine from the remnants what precisely failed. However, based on engine one behavior in various modes of operation (as noted on the DFDR), the actions taken by the Mishap Maintainers, and analysis of all engine one components ruling out everything except the valve housing, the most likely reason for the engine one malfunction was a failure of the valve housing assembly.

(2) Engine One, Propeller, and Valve Housing Assembly History

A review of maintenance records for engine one and the propeller assembly dating back to 2006 show normal wear and tear and nothing to indicate that any component was a factor in the mishap, other than the engine one RPM discrepancy and the engine one valve housing.[303]

The record for the engine-one valve housing assembly begins on 12 August 1999, indicating it was a new component as of that date.[304] It was last overhauled on 27 July 2000, with a reason code of "fluctuates, unstable, or erratic." Additionally, there are two write-ups regarding similar RPM problems. One on 7 September 2005, with a reason code of "fluctuates, unstable, or erratic." At that time, the Time Since Overhaul (TSO) was recorded as 1,595.7 hours. A second occurred on 2 April 2007 with as reason code of "surges/fluctuates." At that time, the TSO was recorded as 509.0 hours. There is no record of the valve housing assembly going to a field-level or depot-level repair shop for the documented RPM problems; rather, records only indicate the component was removed and later installed on different propellers. [305]

On 17 July 2015, it was installed on engine one of the MA.[306] Since that date, there are no reported discrepancies (other than on 9 April 2018) and no maintenance was performed (other than on 24 April 2018). The TSO was recorded as 1,456.7 hours on 17 July 2015. However, the actual operating time is indeterminate because of the inconsistent TSO reporting. The TSO was reported over time as 1,595.7 to 509.0 to 1,456.7 hours. The above RPM write-ups are similar to the valve housing assembly discrepancy observed leading up to the mishap. [307]

7. WEATHER

a. Forecast Weather

Prior to their flight, the 26th Operational Weather Squadron provided a weather briefing to the MC.[308] This weather forecast predicted few clouds at 25,000 feet MSL and 10 statute miles

visibility, with no significant weather, variable winds at 3 knots, temperature of 20 degrees Celsius (68 degrees Fahrenheit), and an altimeter setting of 30.36 inches of mercury (inHg).[309] There were no active watches, warnings, or advisories in effect.[310]

b. Observed Weather

Observed weather prior to the mishap was taken at 1053L at KSAV.[311] The observed weather contained few clouds at 3,500 and 25,000 feet MSL, variable winds from 6 knots, visibility of 10 statute miles, with no significant weather, temperature of 24 degrees Celsius (75.2 degrees Fahrenheit), and an altimeter setting of 30.35 inHg.[312]

A special weather observation was issued approximately six minutes following aircraft impact reporting few clouds at 3,500 and 25,000 feet MSL, winds from the northeast at 8 knots, visibility of 10 statute miles, with no significant weather, temperature of 26 degrees Celsius (78.8 degrees Fahrenheit), and an altimeter setting of 30.35 inHg.[313]

There is no indication that weather was a factor in the mishap.

c. Space Environment

Not applicable.

d. Operations

Based on the forecast and actual observations, the weather was within operational limitations.[314]

8. CREW QUALIFICATIONS

A WC-130H utilizes a crew of five people: the Pilot (MP1), the Copilot (MP2), the Flight Engineer (MFE), the Navigator (MN), and the Loadmaster (MLM).[315] During the mishap flight, four additional Airmen were onboard as mission essential personnel, accompanying the MA to Davis-Monthan AFB to assist with the MA's induction into 309 AMARG.[316]

a. Mishap Pilot (MP1)

MP1 was a current and qualified Aircraft Commander (AC) with 1246.8 total WC-130H hours, 165.0 hours in the C-130H, and 2070.53 hours in the C-130E aircraft.[317] He was initially qualified as a Pilot on 27 August 2004.[318] He upgraded to AC on 1 January 2016.[319] He was certified as an Instructor Pilot (IP) and as a Functional Check Flight (FCF) Pilot on 12 September 2016.[320] Additionally, he was certified as a Flight Examiner on 12 January 2018.[321] His last flight evaluation was 3 December 2017.[322]

Qualification dates are based off of available AF Form 4324s, *Aircraft Assessment/Aircrew Qualification Worksheets*, as the Aviation Resource Management (ARM) data appears to be inaccurate.[323] According to ARMs data, MP1 was certified as an AC, IP, and FCF Pilot on 1 January 2016. Several other certifications carry the same date as well. A request was made to the 156th Operations Group (156 OG) ARMs office for any AF Form 4324s for MP1.

The provided AF Form 4324 shows the AC, IP, and FCF Pilot qualifications, along with several others, dated 12 September 2016, and has no effective date or Commander signature on the form. A review of MP1's Flight Evaluation Folder (FEF) show no downgrades or decertifications. MP1's AF Form 8, *Certificate of Aircrew*, also shows him to have been an IP as early as November 2013.[324]

MP1's flight time for the 90 days prior to the mishap was[325]:

	Hours	Sorties
30 days	2.7	1
60 days	16.0	6
90 days	16.0	6

MP1 was current on Crew Resource Management (CRM) and simulator refresher training related to inflight emergencies.[326] MP1 last accomplished the training on 8 March 2017, which included[327]:

(1) G230 CRM Refresher Academics (this is an annual requirement – once per calendar year). This course meets the requirements for CRM, and covers various military and commercial aviation mishap and lessons learned from these mishaps with regards to CRM.
(2) G240 CRM Simulator (this is an annual requirement – once per calendar year). Provides a practical application of classroom-presented CRM refresher concepts through CRM simulator training addressing human factors issues in a realistic mission scenario.
(3) G250 Pilot Simulator Refresher and Flight Engineer Simulator Refresher Courses (this is an annual requirement – once per calendar year). Items that are covered in this course include performance characteristic of the C-130 for three-engine take-off and other asymmetric aerodynamic conditions. Discussions on both ground and air minimum control speeds, stall aerodynamics and low speed flying characters of the C-130. Simulator profiles will normally include various scenarios where the crew has an engine failure at a different point during the take-off roll including at or just prior to rotation speed.

MP1 was a C-130 Mobility Evaluator Pilot assigned to the 198 AS and served honorably for 18 years.[328] Known for his leadership and professional skills, MP1 was the Chief of Squadron Training and a Flight Commander. His Squadron Commander wrote that MP1 was his number one Instructor Pilot and Flight Commander. As Chief of Aircrew Training, he managed program goals and objectives, leading aircrew to unprecedented heights, and as a Flight Commander, he sought career progression for six officers and nine enlisted service members through implementation of effective coaching and mentorship. Regarded by many as the best pilot in the unit, MP1 most notably commanded Hurricane Irma relief effort flights, providing direct support to the evacuation of hundreds of civilians from the neighboring island of St. Maarten. In addition, he volunteered for multiple rotations in support of Operation CORONET OAK, where he expertly executed a total of 287 flying hours and 128 sorties. MP1's skills earned him top choice to command the flight demonstration team on board a WC-130H aircraft during the 2016 Puerto Rico International Airshow.[329]

b. Mishap Pilot (MP2)

MP2 was a current and qualified Copilot with 7.7 total WC-130H hours and 9.8 hours in the C-130H aircraft.[330] He was initially qualified as a Copilot on 8 September 2017, and his last flight evaluation was 9 January 2018.[331] Additionally, he was previously qualified as a C-130 Loadmaster with 1653.2 hours in the C-130E and the WC-130H aircraft.[332]

MP2's flight time for the 90 days prior to the mishap was[333]:

	Hours	Sorties
30 days	4.6	3
60 days	4.6	3
90 days	4.6	3

MP2 was current on CRM and simulator refresher training related to inflight emergencies.[334] MP2 last accomplished the training on 15 March 2018, which included G230, G240, and G250.[335] MP2 also received praise from an instructor during flight training regarding his performance during takeoff reject scenarios.[336] On 2 November 2017, the instructor wrote on an Aircrew Training Progress Report after the takeoff reject training that MP2 was a sharp pilot who seemed to be ahead of his peers; that MP2's aborts, engine failure after takeoff, and propeller failure after takeoff procedures were great; that all areas of the training were pretty darn good, with no areas for improvement; and that he was well above average.[337]

MP2 was a C-130 Mobility Pilot assigned to 198 AS.[338] He began his honorable military career as an Aircraft Loadmaster for 14 years before he earned his commission as an officer and served another two years. He attended the Specialized Undergraduate Pilot Training Course where he graduated within the top five percent of his class. At the C-130 Formal Training Unit, MP2 earned high marks on his evaluation, an Excellent overall, and one instructor commented that MP2 was well above average and ahead of his peers. Prior to his commission and pilot training completion, MP2 performed duties to include C-130 Combat Deliveries, Guard Lifts, Mission Ready Airlifts, Air Expeditionary Force Steady-State Flying, Joint Airborne Air Transportability Training, Shadow Harvest, Channel Augmentation, and deployed in support of Operations CORONET OAK, ENDURING FREEDOM, and SEMINOLE PAVON. He was known by many in the squadron for his positive attitude and professionalism in support of his Nation's defense.[339]

c. Mishap Navigator (MN)

MN was a current and qualified Navigator with 841.3 total WC-130H hours, 196.8 hours in the C-130H, and 1359.4 hours in the C-130E aircraft.[340] He was initially qualified as a Navigator on 26 October 2007.[341] Additionally, he was certified as an Instructor Navigator on 1 January 2016 and a Flight Examiner on 3 March 2017.[342] His last flight evaluation was 4 May 2017.[343]

MN's flight time for the 90 days prior to the mishap was[344]:

	Hours	Sorties
30 days	16.5	6
60 days	27.7	11
90 days	30.2	12

MN was a Master Navigator and Evaluator assigned to 156th Operations Support Squadron (156 OSS) and served honorably for 23 years.[345] Known by many for his consistent "Service Before Self" attitude, tireless spirit, and volunteerism in his community, he began his Air Force service as a Life Support Journeyman and then as Chief of Weapons and Tactics. MN managed all C-130 tactics and procedures for the wing's aircrew and was a major contributor for missions with Air Mobility and Combat Commands in Joint Airborne Air Transportability Training and Special Assignment Airlift Missions. MN also deployed in support of Operations JOINT ENTERPRISE, JOINT FORGE, CORONET OAK, SEMINOLE PAVON, ENDURING FREEDOM, and FREEDOM'S SENTINEL. His Squadron Commander wrote that MN was his number one officer of six in the squadron and selected him as the 156 OG Senior Navigator. As Senior Navigator, MN enabled 116 sorties and over 298 flying hours directly participating in humanitarian assistance for the disaster relief efforts in Puerto Rico and neighboring islands during Hurricanes Irma and Maria to transport over 700 neighboring citizens and lifesaving cargo.[346]

d. Mishap Flight Engineer (MFE)

MFE was a current and qualified Flight Engineer with 170.6 total WC-130H hours and 18.5 hours in the C-130H aircraft.[347] He was initially qualified on 24 March 2017 and his last flight evaluation was on 25 July 2017.[348]

MFE's flight time for the 90 days prior to the mishap was[349]:

	Hours	Sorties
30 days	6.1	2
60 days	12.8	5
90 days	17.9	7

MFE was current on CRM and simulator refresher training related to inflight emergencies.[350] MFE last accomplished the training on 23 March 2017, which included G230, G240, and G250.[351]

MFE was a C-130 Flight Engineer Craftsman assigned to the 198 AS and honorably served for over 17 years.[352] As a previous Aircraft Maintenance Technician, he was the first to be selected from a pool of highly qualified candidates to attend the Flight Engineer Training Course, where he earned the Distinguished Graduate recognition. In the 198 AS, he was known for his academics and earned two Community College of the Air Force Degrees in Aircraft Maintenance Technology and Aviation Operations. MFE was a major contributor for missions in the Air Mobility and Air Combat Commands supporting Operation ENDURING FREEDOM.[353] In addition, his exceptional professional skills were instrumental in the airdrop of the Canadian Parachute Demonstration Team for the Salute to Veterans Airshow and he directly participated in

humanitarian assistance during the disaster relief efforts in Puerto Rico and adjacent Caribbean islands during Hurricanes Irma and Maria.[354]

e. Mishap Loadmaster (MLM)

MLM was a current and qualified Loadmaster with 444.9 total WC-130H hours, 6.6 hours in the C-130H2, 2382.9 hours in the C-130E, and 91.2 hours in the C-130H.[355] He was initially qualified on 31 December 1998.[356] He was certified as an Instructor Loadmaster (IL) on 1 January 2016 and Flight Examiner on 13 June 2012.[357] His last flight evaluation was on 11 May 2017.[358]

Qualification dates are based off available AF Form 4324s, *Aircraft Assessment/Aircrew Qualification Worksheets*, as the ARMs data appears to be inaccurate.[359] MLM's Individual Training Summaries show his IL and Flight Examiner Loadmaster (EL) qualifications dated 1 January 2016.[360] The AF Form 4324 provided by the 156 OG ARMs office shows MLM's EL certification on 13 June 2012. According to the 156 OG ARMs office, they have no additional AF Form 4324s for the MLM, so there is no way to verify when he received his IL certification. The MLM's AF Form 8, *Certificate of Aircrew Qualification*, also shows him to have been an IL as early as December 2011. Additionally, MLM's FEF shows no indication that MLM was ever decertified from any higher-level qualifications (IL or EL).[361]

MLM's flight time for the 90 days prior to the mishap was[362]:

	Hours	Sorties
30 days	4.2	2
60 days	9.4	4
90 days	11.9	5

MLM was a C-130 Instructor and Evaluator Loadmaster assigned to 198 AS.[363] He served honorably for 31 years and accumulated more than 2,900 flying hours. MLM began his career as a Materiel Management Journeyman and then cross-trained to become an Aircraft Loadmaster Craftsman. Ultimately, he achieved one of the highest aircrew positions as the Standardization Evaluation Loadmaster Superintendent. Innovation was his hallmark, as MLM coordinated the implementation of the unit's Electronic Flight Bag program and ensured on time unit compliance with the newly established publication program. His aviation skills further guaranteed mission success with the 35th Expeditionary Airlift Squadron and 198 AS for C-130 Combat Deliveries, Air Expeditionary Force Steady-State Flying, Senior Scout, Joint Airborne Air Transportability Training, and in support of Operations CORONET OAK, SEMINOLE PAVON, and ENDURING FREEDOM.[364]

f. Mishap Airman 1 (MA1)

MA1 was a Maintenance Management Analyst assigned to the 156th Maintenance Operations Flight and served honorably for 21 years.[365] He recently graduated from the Maintenance Analysis technical course where he earned Distinguished Graduate honors. His commander wrote that MA1 was a stellar performer in every aspect and displayed outstanding leadership. He was an avid volunteer in the unit and helped raise the morale of the 75-member maintenance group. MA1 deployed to Afghanistan in support of Operation ENDURING FREEDOM and served in

multiple rotations in support of CORONET OAK as a Metals Technology Specialist and Aircraft Maintenance Management Production Controller. In addition, MA1 was responsible for training over 100 members in the Data Integrity Team Program to ensure all data input into the maintenance information systems were accurately reported. Additionally, as a Maintenance Operations Center controller, MA1 actively controlled the arrival and departure of over 100 sorties to ensure the successful operation of over 320 flying hours for the wing.[366]

g. Mishap Airman 2 (MA2)

MA2 was an Aerospace Maintenance Craftsman assigned to the 156th Aircraft Maintenance Squadron and served honorably for 16 years.[367] His squadron leadership commented that MA2 was a great performer in every aspect of his duties and displayed outstanding leadership and airmanship skills. During his tenure, he oversaw the CTK program with a 90% inspection rate and managed over $100,000 to establish a base gymnasium. MA2's knowledge and skill were vital and he became a major contributor for missions with 12th Air Force, 35th and 38th Expeditionary Airlift Squadrons, 156th Aircraft Generation Squadron, and 169th Reconnaissance Squadron for Air Expeditionary Force Steady-State Flying, Senior Scout, Joint Airborne Air Transportability Training, and he supported Operations CORONET OAK, JOINT FORGE, LION PAVON, and ENDURING FREEDOM. In addition, he was selected as Flight Chief for the President and Vice-President visits and participated in 15 humanitarian relief effort missions during Hurricanes Irma and Maria to transport neighboring citizens and lifesaving cargo.[368]

h. Mishap Airman 3 (MA3)

MA3 was an Aircrew Flight Equipment Craftsman assigned to the 156 OSS and served honorably for 22 years.[369] Highly regarded in his career field, MA3 was the subject matter expert for the State Partnership Program and led the Aircrew Flight Equipment Team with the Dominican Air Force at San Isidro Air Base, advising each squadron pilot in techniques for associated equipment and fitting proper gear. In addition, MA3 always sought ways to better the community. He spearheaded the first Joint Water Survival Training for the Puerto Rico Police Department, the Salinas Municipal Police and Mayor's Office, and the State Civil Defense Service to provide real world experience and situational awareness. He assisted in humanitarian assistance through disaster relief efforts during Hurricanes Irma and Maria and provided direct logistical and transportation liaison between the wing and the 714th Water Purification Unit, Camp Santiago Army Base, Salinas, Puerto Rico. Furthermore, as shop supervisor, he led the section into a successful 2016 Capstone Inspection ensuring 100% compliance.[370]

i. Mishap Airman 4 (MA4)

MA4 was an Aircrew Flight Equipment Journeyman assigned to the 156 OSS.[371] His performance and dedication to his country were outstanding as he served honorably for three years. MA4's commitment to education shined when he earned the Distinguished Graduate award for outstanding academic achievement while attending technical training. Moreover, he guaranteed mission effectiveness for his unit with the preparation and delivery of necessary flight equipment to aircrews. MA4's specialized skills, leadership, and participation were major contributors for missions with AMC to deploy in support of Operation CORONET OAK. In addition, he lived the Air Force core values, specifically "Service Before Self," when he volunteered to participate in

the humanitarian assistance and disaster relief efforts in Puerto Rico and neighboring Caribbean islands during Hurricanes Irma and Maria to help evacuate over 700 American citizens and transport critical lifesaving cargo.[372]

9. MEDICAL

a. Qualifications

At the time of the mishap, all of the MC had current annual physical flight examinations and were medically qualified for worldwide flight duty without restrictions.[373] The MFE had a valid AF 469, *Duty Limiting Conditions Report*, documenting a condition that was deemed not to be disqualifying from Flight Duties.[374]

b. Health

No current health or dental issues were identified through review of the medical records and interviews with the medical staff at the 156th Medical Group (156 MDG).[375] The Flight Surgeon who performed the annual flight physical for MP1 did not reveal any cause for concern.[376]

c. Pathology

The remains of all the personnel on board the MA were recovered at the mishap site and sent to the Armed Forces Medical Examiner at Dover AFB, Delaware.[377] The remains were positively identified through pre- and post-mortem DNA, dental records, footprint, and fingerprint analysis, or a combination of these methods.[378] The cause of death was multiple injuries due to aviation mishap in each case and the manner of death was "Accident" in each case.[379]

d. Toxicology

The remains of all personnel were tested for drugs, volatiles, carbon monoxide, and cyanide.[380] No screened drugs of abuse were detected in any of the tested specimens.[381] No volatiles were detected in any of the remains, and any ethanol present was determined to be consistent with the circumstances of the crash.[382] Cyanide and carbon monoxide were present only in minute quantities and are associated with the post-crash fire.[383]

e. Lifestyle

There is no evidence to suggest lifestyle was a factor in the mishap.[384]

f. Crew Rest and Crew Duty Time

Interviews were conducted with members of the 156 AW who were present in Savannah the night before the accident, to include at least one member who spoke with MP1 at breakfast on the morning of the mishap.[385] According to multiple witnesses, the MC was released from duty at approximately 1730L the night before the mishap, and the MC checked into a downtown Savannah hotel for overnight billeting.[386] Several members of the 156 AW reported seeing the MC at dinner prior to 2100L, but there are no confirmed sightings of the MC after that time.[387] MP1 was seen

at breakfast in the hotel the morning of the mishap, and the Chief of Standardization and Evaluation spoke with him briefly and noted nothing unusual during the encounter.[388] MP1 did not show any outward signs of distress, nor did he appear to be physically ill.[389] Review of the 165 AW main gate video shows the MC arriving on time for the mission with the appearance of a seemingly normal crew day on the road.[390]

10. OPERATIONS AND SUPERVISION

a. Operations

The 156 AW operated on a stable schedule at the time of the mishap; however, there was a certain degree of apathy and low morale within the 156 AW.[391] This largely stemmed from a lack of cohesive mission for a wing that flies non-combat coded aircraft.[392] Another factor for poor morale was aircraft availability, which affected crew proficiency and forced the 156 AW to seek other means to keep aircrew current and qualified.[393] Additionally, manpower shortfalls have left the unit with prolonged vacancies in hiring adequate replacements.[394]

In the previous days before the mishap, the MC did fly from Puerto Rico to Savannah on 30 April 2018, and flew a stateside mission on 1 May 2018.[395] However, the missions were not complex and there was sufficient time for crew rest and recovery.[396]

b. Supervision

There does appear to be a safety culture in the 156 OG, as crews use their best judgment when faced with safety related issues on aircraft, and get very little or no pushback from leadership if a crew feels unsafe to fly.[397] With regard to flight safety, the use of the whole crew concept, CRM, and Operational Risk Management are present within the 156 OG.[398] Supervision was fully aware of the mission plans and had no concerns with the MC flying the MA to the 309 AMARG.[399] The commander of the 156 OG considered the MA to be one of the better aircraft in the 156 AW and believed the MA was good to go with a strong crew to get it to the 309 AMARG.[400]

11. HUMAN FACTORS ANALYSIS

a. Introduction

The DoD Human Factors Analysis and Classification System (HFACS) lists potential human factors that can play a role in mishaps and is designed for an investigation board to accurately record all aspects of human performance associated with individuals and the mishap or event. The discussion below lists the human factors directly involved in this mishap.[401]

b. Organizational Culture Allows for Unsafe Task/Mission

Organizational culture is a factor when explicit or implicit actions, statements or attitudes of unit leadership set unit or organizational values (culture) that allow an environment where unsafe task or mission demands or pressures exist.[402]

During the course of the investigation, several recurring factors emerged with regard to the health and low morale of the 156 AW. These factors were captured in statements, testimony, and discussions during the visit and tour of the Muñiz Air National Guard Base.[403] While several of the items are common in any organization (manning challenges for example), the number, the repetition, and the combination of all the factors, highlighted up and down the chain of command at the 156 AW, may be indicative of a climate and culture of complacency. This climate could have shaped the attitudes and actions of the Mishap Maintainers to disregard T.O. guidance, the team's attitude that 99% RPM was good enough as the "aircraft is going to the boneyard anyway" (as captured on the CVR), and not realizing the significance of T.O. violations.[404] It may have also been a factor with the MC's apparent complacency during takeoff roll, failure to brief emergency actions adequately, and failure to monitor the MA's performance, specifically the performance of engine one after maintenance work for a recent discrepancy.[405]

Many of the Airmen interviewed commented on the low morale and overall health of the Wing. The factors cited as leading to low morale include:

1. Having the oldest C-130's in the USAF and the belief the 156 AW is an afterthought in Air Force planning.[406]
2. 156 AW aircraft are not combat-coded; thus, members do not see themselves as participants in the Total Force.[407]
3. Airmen have no direct connection to a Mission other than maintaining current and qualified aircrews.[408] Of the senior leadership that were available for interview, including the 156 OG Commander, 198 AS Commander, and the 156 MXS commander, none of them could accurately describe the mission of the unit.[409] The Wing Commander and Vice Wing Commander were not present on the days the AIB conducted interviews in Puerto Rico.
4. The overall age and condition of the facilities at Muñiz Air National Guard Base and the lack of initiative or urgency to repair, replace, or fix the structural damage to several buildings from Hurricane Maria in September 2017. The damage caused a significant loss of workspace and subsequent lack of maintenance and repair facilities.[410]
5. The difficulty with obtaining spare parts from CONUS, leading to long repair times and lower mission capable rates for their aircraft.[411]
6. Manning challenges. Wing members repeatedly stated how the low morale was affecting their operations and causing manpower shortfalls because many people left the unit, which caused with prolonged vacancies while hiring adequate replacements.[412]
7. Rather than being a source of pride and excellence, the concept of a Citizen Airman was twisted into an excuse of, "I am just a TR" (Traditional Reservist).[413]
8. The AIB identified several problems with internal processes:
   a. In the Operations Group, processes appear to be broken, evident with ARMs and corresponding Training AF Form 4324s.[414] There were several discrepancies noted in the MC's AF Form 4324s provided to the AIB. These discrepancies range from the forms being incomplete to forms completely missing.[415] Additionally, there are discrepancies where ARMs documents and AF Form 4324s have dates that are not aligned.[416]
   b. The 156 MDG recently had MP1 listed as DNIF (Duties Not Including Flying) for 270 days, although he continued operational flying. Additionally, the 156 MDG

began loading medical records from the MC into Health and Artifact Image Management Solution (HAIMS) database on the day of the mishap, something that should not have taken place once the mishap occurred.[417]

c. Although training records indicate members were qualified, 156 MXG members were lacking in requisite job skill knowledge, risk assessment, and error management. Most of the members of the maintenance team who were interviewed could not say whether they had attended Maintenance Resource Management training and/or were not sure what the training included.[418] Additionally, the Propulsion Shop Lead did not know the difference between back shop manuals and on-aircraft manuals, neither MM1 nor MM2 realized there were troubleshooting guides in the on-aircraft manuals and relied on a back-shop manual,[419] and MM3 could not define his role and responsibilities during a maintenance engine run.[420]

c. Motivation

Motivation is a factor when an individual's motivation to accomplish a task/mission is excessive, weak, indecisive or when personal goals supersede the organization's goals.[421]

The Mishap Maintainers (MM1, MM2, MM3, and MM4) showed a distinct lack of motivation to ensure engine one was operationally ready for flight.[422] Rather than use the appropriate equipment for the job by learning how to plug the 165 AW's precision tachometer into the MA, they simply relied on the aircraft gauges although the T.O. required use of the precision tachometer. Additionally, they decided that 99% RPM was "good enough" and chose not to make additional valve housing adjustments or conduct additional troubleshooting to ensure the engine was operating at 100%.[423]

d. Violation - Lack of Discipline

Extreme Violation or Lack of Discipline is a factor when an individual, crew or team intentionally violates procedures or policies without cause or need. These violations are unusual or isolated to specific individuals rather than larger groups. There is no evidence of these violations being condoned by leadership. These violations may also be referred to as "exceptional violations."[424]

The Mishap Maintainers violated T.O.s when conducting their engine test runs on 24 April 2018.[425] Connecting a precision tachometer to the aircraft is the first step on the T.O. checklist and essential to obtaining precise readings while analyzing engine performance during an engine run.[426] In failing to use the precision tachometer, the Mishap Maintainers did not get an accurate reading from engine one during the second engine run and believed they had raised the engine speed to 99% RPM, when the engine had actually only gone as high as 96.8%.[427] Failing to use the precision tachometer also led the Mishap Maintainers to misuse the T.O.'s guidance regarding correct engine performance.[428] According to the T.O., when adjustments to the engine governing components are performed correctly, the precision tachometer will indicate between 99.8% and 100.2% RPM, while the engine tachometer gauge will indicate 98% to 102% RPM or within 1% of the precision tachometer.[429] Without the precision tachometer, the Mishap Maintainers disregarded the required precision results, and believed that 99% (which is within 1% of the 99.8% required on the precision tachometer) was acceptable and terminated the run.[430]

In addition, the Mishap Maintainers violated an additional T.O. by improperly swapping the RPM tachometer gauges during the first engine run by not first shutting down the engines.[431] However, this violation was not a factor in the mishap as there is no indication that swapping the gauges while the engines were running did any damage to the gauges.

e. Checklist Not Followed Correctly

This is a factor when an individual (or group), either through an act of commission or omission, makes a checklist error or fails to run an appropriate checklist.[432]

As captured by the CVR, the MC did conduct the crew briefing during the *Before Takeoff* checklist.[433] The MN briefed specific departure procedures for KSAV and MP1 briefed takeoff and landing data and procedures for IFR departure clearance.[434] However, MP1 stated, "everything else remains the same," indicating that emergency action procedures briefed during a previous flight still applied.[435] The Flight Manual does indicate that a crew only needs to brief changed data for multiple takeoffs or landings, but "multiple takeoffs or landings" is generally understood to be within the same day or sortie, not separate days as was the situation with the MC.[436] In addition, the Flight Manual does allow a crew brief to occur before the checklist. Thus, it is possible MP1 briefed emergency action procedures before the CVR began recording the on-board conversation. However, this is highly unlikely. MP1 did not brief emergency procedures to the MC according to the checklist in the event of an engine shutdown.[437]

Additionally, the MC did not follow the standard *After Takeoff* checklist, which would have prompted MP1 to call for flap retraction and focused the MP1 on attaining an appropriate airspeed.[438] Rather, the MA's flaps remained at 50 percent.[439] Raising the flaps up would have decreased drag and allowed the MA to accelerate, provided more authority to the MA's control surfaces, and allowed for better control of the MA.[440]

f. Breakdown in Visual Scan

Breakdown in Visual Scan is a factor when an individual fails to effectively execute visual scan patterns.[441]

At approximately eight seconds prior to aircraft rotation, the engine one RPM and torque began to significantly decay and dropped to 65% RPM and 1,971 in-lbs torque at the moment of rotation.[442] MFE failed to execute his learned and practiced visual scan patterns to recognize the loss of power and call for a reject of the takeoff.[443] In addition, the MC failed to adequately cross-monitor MFE, as MP1, MP2, and MN failed to scan engine one performance during the takeoff roll.[444]

g. Procedure Not Followed Correctly

Procedure Not Followed Correctly is a factor when a procedure is performed incorrectly or accomplished in the wrong sequence.[445]

When an engine fails during takeoff, the Flight Manual provides procedures an aircrew should follow—the *Takeoff Continued After Engine Failure* procedure and the *Engine Shutdown* procedure.[446] The MC did not complete the *Takeoff Continued After Engine Failure* procedure by

commencing flap retraction after raising the landing gear and continuing as a normal takeoff by accelerating to three-engine climb speed.[447] Additionally, the MC failed to follow the *Engine Shutdown* procedure as stated in the Flight Manual, which would have required MP2 to call out flap settings after moving the condition lever to feather and after pulling the fire handle.[448] Raising the flaps up would have decreased drag and allowed the MA to accelerate, provided more authority to the MA control surfaces, and allowed for better control of the MA.[449]

h. Lack of Assertiveness and Rank/Position Intimidation

Lack of Assertiveness is a factor when an individual fails to state critical information or solutions with appropriate persistence and/or confidence.[450]

Rank/Position Intimidation is a factor when the differences in rank of the team or crew caused task performance capabilities to be degraded. Also, conditions where formal or informal authority gradient is too steep or too flat across a crew or team and this condition degrades collective or individual performance.[451]

As the MA turned into the feathered engine, MP2 verbalized the hazard in time to correct the situation with his call, "Turning into number one, crew."[452] MP1 never acknowledges the call of MP2.[453] This call by MP2 appears to be an attempt by MP2 to state critical information, i.e., that the MA should not be turning towards the inoperative outboard engine. However, MP2 who performed well in the simulator during flight training on this type of emergency, said nothing further, did not run any of the proper checklists or procedures, and did not suggest or direct any solutions, e.g., keeping the nose low, applying right rudder, etc.[454]

MP1 was an instructor/evaluator pilot and many 156 AW members thought of him as one of the best pilots in the organization.[455] MP2 and MFE were new to their crew positions with significantly less operational flying time than MP1.[456] This may have led to a lack of communication and assertiveness from the less experienced crewmembers to address MP1's difficulties in managing the emergency.[457]

i. Fixation

Fixation is a factor when an individual is focusing all conscious attention on a limited number of environmental cues to the exclusion of others.[458]

MP1 made the decision to return to the airfield almost immediately upon takeoff once the engine problem was recognized.[459] MP1 directed the engine one shutdown, and then repeated the phrase, "Coming Back" five times over the next 25 to 30 seconds without giving other meaningful direction to the MC other than "Brace" just prior to impact.[460] In addition, MP1 never directed the completion of the *Engine Shutdown* procedure, the *Takeoff Continued After Engine Failure* procedure, or the *After Takeoff* checklist.[461]

j. Confusion

Confusion is a factor when an individual is unable to maintain a cohesive and orderly awareness of events and required actions, and experiences a state characterized by bewilderment, lack of clear thinking, or perceptual disorientation.[462]

The MC was initially unaware of the engine one failure until MP1 commented on his challenges controlling the MA as he began to rotate off the runway.[463] MP1 recognized and informed the crew they had lost thrust on engine one.[464] However, 15 seconds into the flight, engine one RPM increased, and the MC was unsure of the actual emergency until the engine failed again.[465] The momentary increase in engine one power may have confused the MC.[466]

In addition, MP1 had several external verbal inputs that may have added to his confusion and distracted his attention away from handling the emergency appropriately.[467] Immediately after rotation of the MA, as the MC began to troubleshoot and identify the malfunction, two MC members made the call for "flaps."[468] The flaps were at the takeoff position and should have remained there until the landing gear was fully retracted.[469] MP1 had to correct the verbal call for flap retraction stating, "No, leave them there," adding to his confusion.[470] Further, KSAV ATC's radio call asking if the MC required assistance also may have distracted MP1's attention away from flying the aircraft.[471]

Although the motivation for MP1's left rudder input just before the MA's departure from controlled flight is unknown, a possible explanation is a neurocognitive stimulus response selection in a state of confusion.[472] MP1, in this situation—faced with a left side engine failure, indicators on the left side of the control panel, and a sight picture of the runway threshold of Runway 19 outside the left window—applied left rudder toward the stimulus contrary to the Flight Manual.[473]

k. Overcontrolled/Undercontrolled Aircraft

Overcontrolled/Undercontrolled Aircraft is a factor when an individual responds inappropriately to conditions by either over- or undercontrolling the aircraft. The error may be a result of preconditions or a temporary failure of coordination.[474]

In the last minute of the mishap flight, MP1 applied and varied both left and right rudder pressure multiple times, then reversed and sustained the pressure to the left rudder.[475] This left rudder input led to an increasing left skid of the MA.[476] This final rudder input coincides with the MA stall and subsequent left roll when the MA departed controlled flight.[477]

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 11-2C-130 Volume 1, *C-130 Aircrew Training*, 21 August 2012 (AFGM2018-01, 27 March 2018)
(2) AFI 11-2C-130, Volume 2, *C-130 Aircrew Evaluation Criteria*, 25 July 2014
(3) AFI 11-2C-130, Volume 3, *C-130 Operations Procedures*, 23 April 2012

(4) AFI 11-290, *Cockpit/Crew Resource Management*, 15 October 2012
(5) AFI 11-290, *Cockpit/Crew Resource Management*, 15 October 2012 (AMC Supplement, 4 December 2014)
(6) AFI 21-101, *Aircraft and Equipment Maintenance Management*, 21 May 2015
(7) AFI 21-101, *Aircraft and Equipment Maintenance Management*, 21 May 2015 (AMC Supplement, 9 February 2016)
(8) AFI 21-101, *Aircraft and Equipment Maintenance Management*, 21 May 2015 (ANG Supplement, 4 March 2016) (ANGGM 2017-01, 3 November 2017)
(9) AFI 48-123, *Medical Examinations and Standards*, 5 November 2013 (AFGM2018-02, 28 January 2018)
(10) AFI 48-149, *Flight and Operational Medicine Program (FOMP)*, 12 November 2014 (Certified Current, 18 December 2015)

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

b. Other Directives and Publications Relevant to the Mishap

(1) TO 1C-130A-6WC-15, *Minor and Major Isochronal Inspection USAF Series All C-130 Aircraft Except C-130J Aircraft*, 1 April 2013 (Chg 9, 15 December 2017)
(2) TO 1C-130-1-4, *Partial Flight Manual USAF Series C-130 Aircraft with Self Contained Navigation System*, 17 March 2012 (Chg 3, 15 April 2017)
(3) TO 1C-130E(H)-1, *Flight Manual USAF Series C-130E, C-130H, EC-130E, and WC-130H*, 21 August 2009 (Change 2, 21 December 2011)
(4) TO 1C-130H-1-1, *Flight Manual USAF Series C-130 Airplanes Equipped with T56-A-15 Engines*, 1 June 2014
(5) TO 1C-130H-6CF-1, *Acceptance and Functional Check Flight Manual USAF Series AC-130W, C-130H, EC-130H, HC-130N/P, LC-130H, MC-130P and WC-130H*, 26 July 2016
(6) TO 1C-130H-2-31JG-30-1-1, *Indicating and Recording USAF Series AC-130U/W, C-130E/H, EC-130H, HC-130(H)N, HC-130N/P, LC-130H, MC-130H/P, and WC-130H Aircraft*, 15 May 2002 (Chg 24, 15 July 2017)
(7) TO 1C-130H-2-61FI-00-1, *Propellers USAF Series All C-130 Aircraft*, 1 February 2002 (Chg 14, 15 February 2018)
(8) TO 1C-130H-2-61JG-10-1, *Propellers Propeller Assembly USAF Series All C-130 Aircraft*, 10 December 1990 (Chg 47, 15 March 2018)
(9) TO 1C-130H-2-61GS-00-1, *General System Organizational Maintenance Propellers USAF Series All C-130 Aircraft*, 10 December 1990 (Chg 13, 1 January 2018)
(10) TO 1C-130H-2-71JG-00-1, *Power Plant Operating Limits and Checklists USAF Series All C-130 Aircraft*, 30 June 1999 (Chg 45, 1 November 2017)
(11) TO 1C-130H-2-71JG-00-3, *Power Plant Engine Health Management (EHM) Handbook USAF Series All C-130 Aircraft*, 15 August 2011 (Chg 10, 15 November 2017)
(12) TO 1C-130H-2-77JG-00-1, *Power Plant Engine Indicating USAF Series All C-130 Aircraft*, 10 August 1993 (Chg 23, 15 March 2018)
(13) TO 2J-T56-56, *Technical Manual Work Package Intermediate Maintenance Turboprop Engine Models T56-A-7B, T56-A-15, T56-A-15A*, 15 April 2018

(14) C-130H Simulator Training, *C-130H Pilot/Flight Engineer Simulator Refresher Training Instructor Guide, PF/RT-0-70-01, Confidence Maneuvers*, 15 June 2017 (Chg 1)
(15) C-130H Simulator Training, *C-130H Pilot/Flight Engineer Simulator Refresher Training Student Materials, PF/RT-0-70-01, Confidence Maneuvers*, 15 June 2017 (Chg 1)

c. Known or Suspected Deviations from Directives or Publications

None other than those previously discussed.

25 September 2018

//SIGNED//
JOHN C. MILLARD
Brigadier General, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

WC-130H, T/N 65-0968
1.5 Miles Northeast of Savannah/Hilton Head International Airport, Georgia
2 May 2018

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

1. OPINION SUMMARY

On 9 April 2018, at approximately 1525 hours local time (L), the Mishap Aircraft (MA), tail number (T/N) 65-0968, landed at Savannah/Hilton Head International Airport (KSAV). The MA was assigned to the 156th Airlift Wing (156 AW), a unit in the Puerto Rico Air National Guard (PR ANG), and was scheduled for maintenance at the facilities of the 165th Airlift Wing (165 AW) to address five fuel cell discrepancies. During the approach, the flight crew operating the MA experienced a speed (revolutions per minute (RPM)) malfunction with engine one. They landed without incident and reported the malfunction to the 156 AW. On 23 April 2018, two propulsion specialists from the 156 AW's maintenance group, Mishap Maintainer 1 (MM1) and Mishap Maintainer 2 (MM2), arrived at KSAV, and on 24 April 2018, performed post-fuel cell maintenance engine runs following the fuel cell work and to troubleshoot and repair the number one engine RPM malfunction reported by the 9 April flight crew.

On 30 April 2018, the Mishap Crew (MC) arrived at KSAV on aircraft T/N 65-0984. The MC flew a stateside mission on the same aircraft, returning to KSAV on 1 May at approximately 1720L. On 2 May 2018, the MC was scheduled to fly the MA to the 309th Aerospace Maintenance and Regeneration Group at Davis-Monthan Air Force Base, Arizona, for removal from service. During takeoff roll, engine one RPM fluctuated from 94% to 98% RPM and did not provide normal RPM (98% to 102%) when Mishap Pilot 1 (MP1) advanced the throttle lever into the flight range for takeoff. Approximately eight seconds prior to aircraft rotation, engine one RPM and torque significantly decayed. At takeoff rotation, engine one RPM had dropped to 65%, torque dropped to 1,971 inch-pounds, and engine thrust dropped significantly. The fluctuation on roll and significant performance decay were unrecognized by the MC until rotation when MP1 commented on the aircraft control challenges. Immediately upon takeoff, MP1 banked right to maintain runway centerline. The MC departed KSAV at approximately 1125L.

As the MC retracted the landing gear, the engine one RPM and torque malfunction was identified and MP1 called for engine shutdown. At approximately 430 feet MSL, the MA began to turn left. The MC successfully shutdown engine one and feathered the propeller at approximately 600 feet MSL, 50 seconds after departure. The MA's flaps improperly remained at 50 percent. MP1, fixated on returning to the airfield, continued the left turn, varying left and right rudder, and climbed to a maximum altitude and airspeed of approximately 900 feet MSL and 131 knots

indicated air speed (KIAS). When MP1 input over nine degrees of left rudder, the MA skidded left, the left wing stalled, and the aircraft departed controlled flight. The MA impacted the terrain on Georgia State Highway 21 at approximately 1127L. All nine personnel onboard perished immediately upon impact. There were no civilian personnel killed or injured in the mishap.

I find, by a preponderance of the evidence, the cause of the mishap was MP1's improper application of left rudder, which resulted in a subsequent skid below three-engine minimum controllable airspeed, a left-wing stall, and the MA's departure from controlled flight. Additionally, I find, by a preponderance of the evidence, the MC's failure to adequately prepare for emergency actions, the MC's failure to reject the takeoff, the MC's failure to properly execute appropriate after takeoff and engine shutdown checklists and procedures, and the Mishap Maintainers' failure to properly diagnose and repair engine number one substantially contributed to the mishap.

2. CAUSE

The cause of the mishap was MP1's improper application of left rudder, which resulted in a subsequent skid below three-engine minimum controllable airspeed, a left-wing stall, and the MA's departure from controlled flight.

Almost immediately upon takeoff and once the engine problem was recognized, MP1 made the decision to return to the airfield. This fixated attention is evident by his repeated use of the phrase "Coming Back" five times over 25 to 30 seconds without giving any other meaningful direction to the MC other than "Brace" just prior to impact. In addition, the confusion from the Mishap Flight Engineer (MFE) about the status of engine one, the early and unusual call for flaps by one member of the crew, the radio call from KSAV Air Traffic Control (ATC), all likely led to MP1 becoming confused himself and unsure about the proper action to take. This can be seen in MP1's varied left and right rudder inputs throughout the mishap flight, banking of the MA toward an inoperative engine, failing to gain airspeed, and failing to retract the flaps. MP2 did attempt to call attention to the left turn into the inoperative engine; however, it was not forceful enough to key MP1 into correcting the dangerous situation.

Although the MC made several errors, which placed the MA in the position of turning left toward an inoperative engine one at a bank angle greater than 10-degrees and airspeed no greater than 131 KIAS, the MA was still flyable. It was not until MP1 applied a hard left rudder input that the MA skidded and the left wing stalled. Although the motivation for MP1's left rudder input just before the MA's departure from controlled flight is unknown, a possible explanation is a neurocognitive stimulus response selection in a state of confusion. MP1, faced with a left-side engine failure, indicators on the left side of the control panel, and a sight picture of the runway threshold outside the left window, responded by applying a left rudder input in the same direction, although it was critical not to and was contrary to the Flight Manual and his training. If not for this left rudder input, the MA would not have departed controlled flight.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

I find, by a preponderance of evidence, the following four factors substantially contributed to the mishap:

a. The Mishap Crew Failed to Adequately Prepare for Emergency Actions

MP1 failed to adequately brief emergency procedures to the MC in response to the *Before Takeoff* checklist. While running the *Before Takeoff* checklist, MP1 briefed takeoff and landing data (i.e., airspeeds and runway requirements), Instrument Flight Rules departure clearance, and the Mishap Navigator (MN) briefed specific departure procedures for KSAV. However, MP1 stated, "everything else remains the same" in lieu of briefing coordinated actions during emergencies and emergency return procedures. While it is possible MP1 briefed emergency procedures prior to activation of the cockpit voice recorder (CVR) and before the checklist, it is highly unlikely and I find by the preponderance of the evidence that MP1 did not brief emergency procedures in accordance with the *Before Takeoff* checklist. The omission of the coordinated emergency actions and lack of an emergency return briefing before the mishap flight was a checklist and mission briefing error, which resulted in an unsafe situation. The information and instructions provided to the MC before the mishap flight were insufficient to discuss contingencies and strategies to cope with emergencies.

b. The Mishap Crew Failed to Reject the Takeoff

Upon takeoff clearance from KSAV ATC, the MC performed a rolling takeoff, as briefed, rather than a static takeoff. While the flight manual does not specifically address conditions or situations to conduct a static takeoff, there is a commonly known practice to perform a static takeoff on the first flight of the day to confirm engine and aircraft performance. If the MC performed a static versus rolling takeoff, there is a greater chance they would have noted the out-of-limit RPM on engine one and called for a reject. However, even with a rolling takeoff, the MC had ample time to identify the engine malfunction and reject the takeoff.

During takeoff roll, engine one RPM fluctuated between 94% and 98% RPM and did not provide normal RPM corresponding to the other three engines when the throttles were advanced into the flight range for takeoff. The MFE should have observed this issue and reported the unusual conditions to MP1 or directed a reject of the takeoff as required by the Flight Manual, which requires rejecting a takeoff if an engine malfunctions before refusal speed. At approximately eight seconds prior to MA rotation, engine one RPM and torque significantly decayed and RPM dropped to 65%, while the torque dropped to 1,971 in-lbs. Again, the MFE failed to recognize the loss of power and call for a reject of the takeoff. MFE failed to execute his learned and practiced visual scan patterns to recognize the loss of power and call for a reject of the takeoff. Moreover, the MC failed to adequately cross-monitor the MFE, as MP1, Mishap Pilot 2 (MP2), and the MN failed to scan engine one performance during the takeoff roll.

In addition to the torque and RPM gauges showing a malfunction, the aural cue of an abnormal propeller noise and yawing movement would have been significant enough for anyone on the MC to call out a problem with the MA.

Furthermore, MP1 recognized there was a malfunction with the MA at approximately 94 KIAS, just before he began to rotate the MA, and failed to reject the takeoff. As rotation speed was

calculated at 99 KIAS and refusal speed was calculated at 139 KIAS, there was enough time and runway distance remaining to stop the MA. All members of the MC failed to call "Reject" on the takeoff roll.

c. The Mishap Crew Failed to Properly Execute Appropriate After Takeoff and Engine Shutdown Checklists and Procedures

The MC failed to identify the engine one failure until MP1 commented on the challenges with controlling the MA as he began to rotate off the runway. MP1 recognized and informed the MC they had lost thrust on engine one. However, 15 seconds into flight, engine one RPM increased and the MC was unsure of the actual emergency until the engine failed again. The momentary increase in engine one power confused the MC and affected their ability to think clearly and respond to the emergency. MP1 did order the shutdown of engine one. However, during the shutdown procedure, MP1 fixated on returning to the base, failed to direct the MC into action, and allowed the MA to begin a left turn into the failed engine.

In addition, MP1 had several external verbal inputs, which may have added to his confusion and distracted his attention away from handling the emergency appropriately. Immediately after rotation of the MA, as the MC began to troubleshoot and identify the emergency, two MC members made a call for "flaps." The flaps were at the takeoff position, which was proper since the pilot flying had not yet commanded the landing gear raised. It is unknown why this call was made, but since MP1 had to correct the verbal call for flap retraction stating, "No, leave them there," it likely added to his confusion. Furthermore, KSAV ATC's radio call asking if the MC required any assistance also likely distracted MP1's attention from flying the MA.

MP1 did not direct, nor did the MC suggest, accomplishing the *Takeoff Continued After Engine Failure* procedure, *Engine Shutdown* procedure, or *After Takeoff* checklist. Had the MC accomplished any or all of the checklists, it may have refocused the crew, in particular MP1, and provided them the correct steps to take in response to an engine out emergency. For example, the *Takeoff Continued After Engine Failure* procedures would have directed MP1 to maintain directional control and engine power, accelerate to flap retraction speed (rather than turning), commence flap retraction at the proper time, obtain a two-engine minimum control airspeed as soon as possible after takeoff, and continue as a normal takeoff while accelerating to a three-engine climb speed. Had the MC completed the *Engine Shutdown* procedure, MP2 would have called out flap settings, thus focusing the crew on obtaining the proper flap retraction speed. Similarly, following the standard *After Takeoff* checklist would have also prompted MP1 to call for flap retraction at the proper time and focused the MP1 on attaining an appropriate airspeed.

As the MA turned into the inoperative engine, MP2 seemed to have recognized the hazard in time to correct the situation, with his call, "Turning toward number 1, crew." However, MP1 never acknowledged the call of MP2, which was a critical piece of information that the MA was entering into a dangerous situation. Given no response from MP1 to the call, this would have been an appropriate time for MP2 to assert himself and directly address the issue with MP1, by either working through one of the checklists or suggesting or directing other solutions, e.g., keeping the nose low, applying right rudder, etc. MP1 was an instructor/evaluator pilot and many 156 AW members thought of him as one of the best pilots in the organization. MP2 and the MFE were new to their crew positions with significantly less operational flying time than MP1. This created a

steep formal authority gradient that may have contributed to a lack of assertiveness on the part of MP2 or MFE.

The MC did not follow the appropriate procedures in the Flight Manual to address their emergency. These procedures are designed and written for these very scenarios to help flight crews maintain focus in chaotic and confusing situations. Had the MC followed the appropriate checklists and procedures, they could have easily flown out of the emergency and not placed the MA in such a dangerous flight position and vulnerable to an errant left rudder input.

d. The Mishap Maintainers Failed to Properly Diagnose and Repair Engine One

On the 9 April 2018 ferry flight from Puerto Rico to Savannah, the flight crew operating the MA experienced an RPM issue with engine one, and reported the incident for troubleshooting and repair. On 24 April 2018, the Mishap Maintainer team (consisting of two propulsion technicians and two crew chiefs from the 156th Maintenance Group) performed two separate engine runs. However, the Mishap Maintainers did not use a precision tachometer when troubleshooting the engine malfunction, a direct violation of maintenance Technical Orders (T.O.s).

Maintenance T.O.s require the use of a precision tachometer, yet it appears the Mishap Maintainers did not have the precision tachometer during the first engine run. Records indicate that Mishap Maintainer 3 did not check out a precision tachometer from the 165th Maintenance Group (165 MXG) until after the first engine run was complete. The maintenance team stated in their interviews that even though the precision tachometer was available for the second engine run, they did not use it because the precision tachometer did not have the correct plug to make it compatible with the MA. However, the precision tachometer kit did contain the necessary adapter plug for the MA. Either the maintainers did not physically open the kit or they did not know how to properly use the precision tachometer available to them.

The Mishap Maintainers' reliance solely on gauge indication for RPM data deprived them of knowing the true RPM on engine one and contributed to the uncertainty surrounding the actual performance of the engine. The Mishap Maintainers stated the maximum RPM obtained was 96% during the first maintenance run. Digital Flight Data Recorder (DFDR) data supports this. They then adjusted the mechanical governing speed in the propeller valve housing with a 12-click clockwise adjustment, with each click equating to .25% for an expected increase of 3%. Following the second engine run, the Mishap Maintainers stated that engine one produced 99% RPM. However, the DFDR data, which records digitally from the engine independent of the cockpit flight instruments (just as the precision tachometer does), showed fluctuation between 95% and 98%, and a sustained RPM of only 96.8%. The Mishap Maintainers could have discovered this had they used a precision tachometer per the T.O. In addition, had they discovered their 12-click adjustment made only a minor difference in RPM, well below the anticipated results, the Mishap Maintainers would have determined that the valve housing on engine one was malfunctioning and the MA would have been grounded until the valve housing was removed and repaired or replaced.

Although the CVR captured a portion of the second engine run and MM1 stated an intention to make an additional four-click adjustment on the valve housing, the evidence indicates an additional adjustment was not accomplished and an additional (third) engine run was not completed.

The Mishap Maintainers believed 99% was good enough as the "aircraft [was] going to the boneyard anyway," although DFDR data indicates the engine never reached sustained RPM above 96.8%. In addition, the two mishap crew chiefs did not act as members of a cohesive team with the mishap propulsion maintainers. They seemed to be oblivious to any and all maintenance actions on the MA and specifically engine one. They should have participated as part of the team and, as such, could have voiced a concern over not following T.O. guidance and/or provided an additional scan on the engine one RPM gauge.

Since the Mishap Maintainers failed to properly diagnose and repair engine one, the MA was cleared for flight with a significant malfunction in the valve housing. When engine speed dropped below 94%, the bleed valves opened as designed to prevent a compressor stall. This substantially reduced engine power and required the MC to take action to shutdown engine one. Had engine one functioned properly, the engine shutdown and inflight emergency would not have occurred.

4. CONCLUSION

After a comprehensive investigation into this mishap, I find, by a preponderance of the evidence, the cause of the mishap was MP1's improper application of left rudder, which resulted in a subsequent skid below three-engine minimum controllable airspeed, a left-wing stall, and the MA's departure from controlled flight.

Additionally, I find, by a preponderance of the evidence, the MC's failure to adequately prepare for emergency actions, the MC's failure to reject the takeoff, the MC's failure to properly execute appropriate after takeoff and engine shutdown checklists and procedures, and the Mishap Maintainers' failure to properly diagnose and repair engine number one substantially contributed to the mishap.

25 September 2018

//SIGNED//
JOHN C. MILLARD
Brigadier General, USAF
President, Accident Investigation Board

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