UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

F-16CM, T/N 94-0043

77TH FIGHTER SQUADRON
20TH FIGHTER WING
SHAW AIR FORCE BASE, SOUTH CAROLINA

LOCATION: Shaw Air Force Base, South Carolina

DATE OF ACCIDENT: 30 June 2020

BOARD PRESIDENT: Major General Randal K. Efferson

Conducted IAW Air Force Instruction 51-307

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR COMBAT COMMAND
JOINT BASE LANGLEY-EUSTIS VA

OFFICE OF THE COMMANDER
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JOINT BASE LANGLEY-EUSTIS VA 23665-2788

OCT 18 2020

ACTION OF THE CONVENING AUTHORITY

The report of the accident investigation board conducted under the provisions of Air Force Instruction 51-307, *Aerospace and Ground Accident Investigations*, that investigated the 30 June 2020 fatal mishap involving an F-16CM, T/N 94-0043, 20th Fighter Wing, complies with applicable regulatory and statutory guidance, and on that basis it is approved.

MARK D. KELLY
General, USAF
Commander

On 3 Nov 20, the Board President concurred with a non-material change to the report, specifically removing an incorrect reference.

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

F-16CM, T/N 94-0043
Shaw Air Force Base, South Carolina
30 June 2020

On 30 June 2020, the mishap pilot (MP), flying F-16CM tail number (T/N) 94-0043, assigned to the 77th Fighter Squadron, 20th Fighter Wing, Shaw Air Force Base (AFB), South Carolina, engaged in a night mission qualification training (MQT) flight near Shaw AFB. During the recovery and landing phase of the mission, at approximately 2226 local time (L), the mishap aircraft's (MA) landing gear was damaged in an initial landing attempt at Shaw AFB. In a subsequent landing attempt, at approximately 2259L, the MA departed the runway and the MP was fatally injured during an unsuccessful ejection.

The mishap flight was planned as a 4-ship night MQT suppression of enemy air defenses mission with pre-strike air-to-air refueling from a KC-135. The first three F-16s of the mishap flight, which included the mishap flight lead, mishap wingman, and mishap element lead (MEL) refueled without incident. However, the MP was unable to refuel, requiring the MEL and MP to return to Shaw AFB. During the final phase of landing on runway 22R, the MA struck the localizer antenna array short of the runway threshold, severely damaging the left main landing gear. After briefly touching down in the underrun, the MP executed a go-around and alerted the MEL and air traffic control personnel of the situation. Following more than twenty minutes of discussion between the supervisor of flying (SOF), the MEL, and MP it was decided to attempt an approach-end cable arrestment on runway 04L. During the maneuver, the MA's tail hook did not catch the cable and the left wing fell to the runway, dragging the MA to the left. The MP ejected from the MA, but the ejection seat malfunctioned and the parachute did not deploy. The MP was fatally injured and the MA was destroyed.

The Accident Investigation Board (AIB) President found by a preponderance of evidence the cause of the mishap was the MP's failure to correctly interpret the approach lighting system and identify the runway threshold during his first landing attempt, which resulted in severely damaged landing gear. Additionally, the AIB President found by a preponderance of evidence two factors substantially contributed to the mishap: (a) the SOF chose not to consult the aircraft manufacturer, which resulted in the decision to attempt a cable arrestment in lieu of a controlled ejection and (b) a series of ejection seat malfunctions occurred, which resulted in the MP impacting the ground while still in the ejection seat.

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

SUMMARY OF FACTS AND STATEMENT OF OPINION
F-16CM, T/N 94-0043
SHAW AIR FORCE BASE, SOUTH CAROLINA
30 JUNE 2020

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

04L	4 Left
20 FW	20th Fighter Wing
20 OG	20th Operations Group
22R	22 Right
77 FS	77th Fighter Squadron
9 AF	9th Air Force
AAR	Air-to-Air Refueling
ACC	Air Combat Command
ACES	Advanced Concept Ejection Seat
AFB	Air Force Base
AFI	Air Force Instruction
AFLCMC	Air Force Life Cycle Management Center
AFMAN	Air Force Manual
AFRL	Air Force Research Laboratory
AFTO	Air Force Technical Order
AFPET	Air Force Petroleum
AGL	Above Ground Level
AIB	Accident Investigation Board
AIM	Air Intercept Missile
ALS	Approach Lighting System
AFLSF-1	ALS Flashing Lights 1
AOA	Angle of Attack
ATC	Air Traffic Control
B-course	Basic Course
CB	Circuit Breaker
CH	Conference Hotel
COVID	Corona Virus Disease
CPR	Cardiopulmonary Resuscitation
CSFDR	Crash Survivable Flight Data Recorder
DA	Decision of Altitude
DO	Director of Operations
DoD	Department of Defense
DRS	Digital Recovery Sequencer
EED	Electro-Explosive Device
EMPDH	Emergency Manual Parachute Deployment Handle
EMS	Emergency Medical Services
EMT	Emergency Medical Technician
EP	Emergency Procedures
G-Forces	Gravitational Forces
HFACS	Human Factors Analysis and Classification System
HUD	Heads-Up Display
IAW	In Accordance With
IFE	In-Flight Emergency
IFF	Introduction to Fighter Fundamentals
ILS	Instrument Landing System
IMDS	Integrated Maintenance Data System
IP	Instructor Pilot
IQT	Initial Qualification Training
knots	nautical miles per hour
L	Local Time
LM	Lockheed Martin
MA	Mishap Aircraft
MASS	Modernized ACES II Seat Sequencer
MEL	Mishap Element Lead
MF	Mishap Flight
MFL	Mishap Flight Lead
MLG	Main Landing Gear
MOA	Military Operating Area
MP	Mishap Pilot
MQT	Mission Qualification Training
MS	Mishap Seat
MSL	Mean Sea Level
MWG	Mission Wingman
NLG	Nose Landing Gear
nm	nautical mile
NOTAM	Notice to Airmen
NWS	Nosewheel Steering
OGBH	Operations Group Brickholder
OG/CC	Operations Group Commander
ORM	Operational Risk Management
PAPI	Precision Approach Path Indicator
PM	Power Module
PR/BPO	Preflight/Basic Post Flight
QRC	Quick Reaction Checklist
RM	Risk Management
SC	South Carolina
SEAD	Suppression of Enemy Air Defenses
SEFE	Standards and Evaluation Flight Examiner
SOF	Supervisor of Flying
SQ/CC	Squadron Commander

SM	Statute Miles	T/N	Tail Number
T/C	Time Change	Top 3	Operations Supervisor
TCTO	Time Compliance Technical Order	UPT	Undergraduate Pilot Training
TDR	Trajectory Divergence Rocket	US	United States
TH	Thru-Flight	USAF	United States Air Force

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 2 July 2020, General James M. Holmes, the Commander of Air Combat Command, appointed Major General Randal K. Efferson to conduct an aircraft accident investigation of the 30 June 2020 mishap of a F-16CM aircraft at Shaw Air Force Base (AFB), South Carolina (SC) (Tab Y-2 to Y-3). On 10 August 2020, the Accident Investigation Board (AIB) convened at Shaw AFB. A Legal Advisor (Major), Medical Member (Captain), Pilot Member (Captain), Maintenance Member (Master Sergeant), and a Recorder (Staff Sergeant) were also appointed to the board (Tab Y-2 to Y-4). The AIB was conducted in accordance with (IAW) Air Force Instruction (AFI) 51-307, *Aerospace and Ground Accident Investigations*, dated 18 March 2019, (incorporating through Air Force Guidance Memorandum, dated 26 February 2020), and AFI 51-307, *Air Combat Command Supplement, Aerospace and Ground Accident Investigations*, dated 18 March 2019.

b. Purpose

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

2. ACCIDENT SUMMARY

On 30 June 2020, the mishap pilot (MP), flying F-16CM tail number (T/N) 94-0043, assigned to the 77th Fighter Squadron, 20th Fighter Wing, Shaw AFB, SC, engaged in a night mission qualification training (MQT) flight near Shaw AFB (Tabs J-17, K-3, and K-6). During the recovery and landing phase of the mission, at approximately 2226 local time (L), the mishap aircraft's (MA) landing gear was damaged in an initial landing attempt at Shaw AFB (Tab J-17). In a subsequent landing attempt, at approximately 2259L, the MA departed the runway and was destroyed (Tabs J-17). The MP was fatally injured during an unsuccessful ejection (Tabs J-17 and X-2).

3. BACKGROUND

a. Air Combat Command (ACC)

Headquartered at Joint Base Langley-Eustis, Virginia, ACC is one of ten major commands in the United States Air Force (USAF) (Tab CC-2). ACC organizes, trains, and equips Airmen who fight in and from multiple domains to control the air, space, and cyberspace (Tab CC-2). As the lead command for fighter, command and control, intelligence, surveillance and reconnaissance, personnel recovery, persistent attack and reconnaissance, electronic warfare, and cyber operations, ACC is responsible for providing combat air, space, and cyber power and the combat support that assures mission success to America's warfighting commands (Tab CC-2).

b. 9th Air Force (9 AF)

Headquartered at Shaw AFB, SC, 9 AF is a Numbered Air Force under ACC (Tab CC-3). It is responsible for organizing, training, and equipping Airmen to meet the demands of today's expeditionary tasking while preparing for tomorrow's challenges (Tab CC-3). Additionally, it is responsible for ensuring the agile combat support of nine wings and two direct reporting units in the Southeastern United States (US), ensuring the operational readiness of more than 395 aircraft and 26,000 active duty and civilian members (Tab CC-3 and CC-5).

c. 20th Fighter Wing (20 FW)

Located at Shaw AFB, SC, the 20 FW operates the largest F-16 combat wing in the United States Air Force (USAF), and the only defense suppression wing in the continental United States (Tab CC-11). The wing is equipped with more than eighty Lockheed Martin F-16CM Falcons (a.k.a. "Viper") and is capable of meeting all operational requirements worldwide (Tab CC-11). The 20 FW consists of more than 6,000 active-duty Airmen, 1,000 Soldiers, 13,000 family members and more than 700 civilian employees (Tab CC- 9).

d. 20th Operations Group (20 OG)

Located at Shaw AFB, SC, the 20 OG employs more than seventy F-16CM fighter aircraft in conventional and anti-radiation suppression/destruction of enemy air defenses, strategic attack, counter air, air interdiction, close air support and combat search-and-rescue missions (Tab CC-12). The 20 OG has personnel assigned to the 20th Operations Support Squadron, the 55th Fighter Squadron, 77th Fighter Squadron a.k.a. Gamblers, and 79th Fighter Squadron (Tab CC-12).

e. 77th Fighter Squadron (77 FS) a.k.a. "Gamblers"

Located at Shaw AFB, SC, the 77 FS is equipped with the F-16CM and specializes in air defense suppression (Tab CC-12). The 77 FS maintains a mission ready, multi-role capability to mobilize, deploy and tactically employ forces worldwide for any contingency in support of U.S. national objectives (Tab CC-12).

f. F-16 Fighting Falcon a.k.a. "Viper"

The F-16 Viper is a multirole fighter jet constructed by Lockheed Martin Corp (Tab CC-14). The Viper's intrinsic maneuverability, advanced avionics and communication suites, and weapons diversity, allow it to operate a full spectrum of mission sets; from defensive counter-air to offensive missions (Tab CC-13). The Viper's versatility, low operating cost, and adaptability have kept it at the forefront of America's military power (Tab CC-13). The Viper is over 49 feet long and 16 feet high (Tab CC-14). The Viper can reach speeds up to 1,500 miles per hour, with a ceiling of above 50,000 feet and has a range up to 2,000 miles (Tab CC-14).

g. Flying Operations Supervision Structure

The basic supervision structure for USAF flying operations consists of the Operations Group Commander (OG/CC) or their designee, the Supervisor of Flying (SOF), and the Operations Supervisor (Top 3) (Tab BB-4). The OG/CC will be available to the SOF or Top 3 for consultation during flying operations (Tab BB-4). The OG/CC will ensure locally developed checklists outline procedures for normal and emergency situations (Tab BB-5). The SOF is a group-level position and is a direct representative of the OG/CC (Tab BB-6). The SOF is the focal point for command and control of flight operations, and ensures that In-Flight Emergency (IFE) recovery plans and weather related mission changes reflect sound airmanship, follow established guidance, and adhere to sound operational risk management (ORM) principles (Tab BB-6). The SOF directs appropriate actions to correct/prevent unsafe situations by using all resources to include radios, telephone hot lines, and all wing-flying operations on the ground or in the air (Tab BB-6). The Top 3 will be available to assist the SOF and aircrew, be the liaison between Operations and Maintenance during the execution of the flying schedule, and debrief the Squadron Commander (SQ/CC) and/or Director of Operations (DO) of any aircraft involved in an unusual situation, IFE, weather divert, or other events (Tab BB-7).

4. SEQUENCE OF EVENTS

a. Mission

On 30 June 2020, the mishap flight (MF) was a 4-ship of F-16CMs, and consisted of call sign Meat 41 as the Mishap Flight Lead (MFL), Meat 42 as the Mishap Wingman (MWG), Meat 43 as the Mishap Element Lead (MEL), and Meat 44 as the MP (Tab K-3 and K-6).

The mission was an MQT sortie planned to take off from Shaw AFB, fly to the Bulldog Military Operating Area (MOA) approximately 110 nautical miles (nm) southwest of Shaw AFB, execute air-to-air refueling (AAR) with a KC-135 Stratotanker, conduct Suppression of Enemy Air Defenses (SEAD) training, and return to Shaw AFB (Tabs K-3, Z-8, and FF-6). Due to the MP's inability to AAR, he was unable to perform SEAD training, which was the primary training focus of the mission (Tab AA-29 and AA-31).

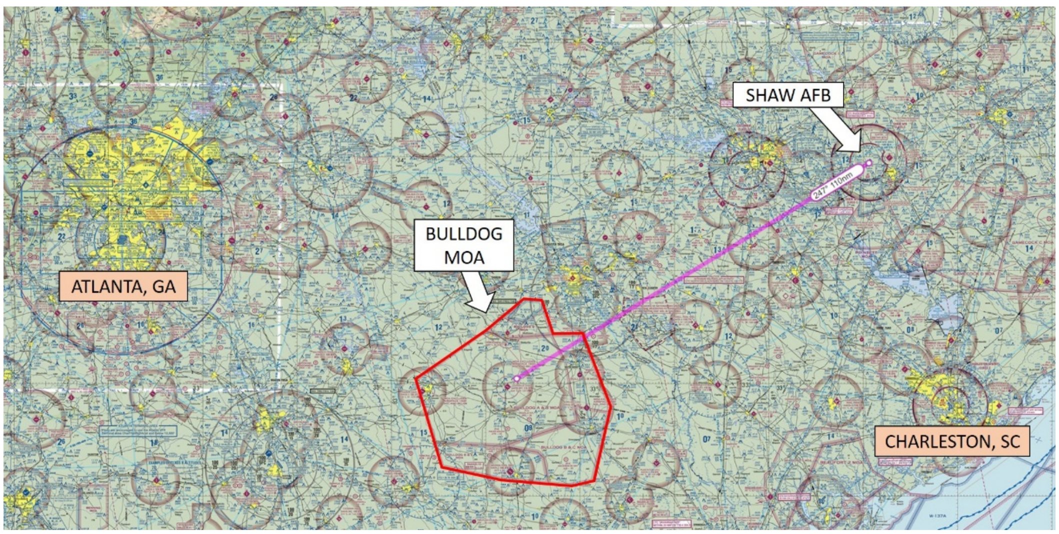

Figure 1: Mishap Flight Operating Area (Tab Z-8)

b. Planning

The mission was the MP's first SEAD training sortie and first attempt to conduct AAR (Tabs G-1046 and T-6). Prior to the pre-flight brief, the MFL reviewed various tactics, techniques, and procedures with the MP (Tab R-48).

At approximately 1825L, the MFL conducted the flight brief in accordance with 20 OG Standards, Air Force Manual (AFMAN) 11-2F-16, Volume 3, *F-16 Operations Procedures*, dated 4 February 2020, and Air Force Instruction (AFI) 11-202, Volume 3, *General Flight Rules*, dated 19 March 2020 (Tabs K-6, K-9 to K-23, R-48 to R-49, BB-23 to BB-24, BB-26 and BB-95). The MFL discussed mission objectives, ORM measures, current and forecasted weather, notices to airmen (NOTAMs), emergency procedures (EPs), special interest items, and the mission materials (Tabs K-6, K-9 to K-23, R-48 to R-49, BB-23 to BB-24, BB-26, and BB-95 to BB-96). The weather forecast included thunderstorms, rain, and a layer of broken clouds from 13,000 to 17,000 feet mean sea level (MSL) (Tab F-2 to F-14). Due to the forecasted weather conditions, the MFL directed the MF to use a Bingo, or predetermined recovery fuel state, which would allow aircraft to divert to Robins AFB, Georgia if required (Tabs R-60 and V-7.6). During the flight brief, the MFL emphasized techniques for keeping situational awareness and how to AAR at night (Tab R-45 and R-48 to R-49). The flight brief lasted approximately fifteen minutes longer than planned due to sortie complexity and the amount of instruction required (Tab R-45).

The Air Force's risk management (RM) system is a decision-making process to systematically evaluate possible courses of action, identify risks and benefits, and determine the best courses of action for a given situation (Tab BB-74). All commanders are expected to identify and clearly establish specific risk acceptance authority levels and thresholds for elevating risk acceptance decisions for operations and activities (Tab BB-75). These levels can vary depending upon specific operations or activities, units, personnel involved, etc. (Tab BB-75). The intent is to ensure that as risk levels increase, risk acceptance and associated Go or No-Go decisions are elevated to obtain appropriate commander or supervisory oversight and approval (Tab BB-75).

The MFL used the 20 OG RM worksheet to assess the overall risk of the mission, and determined the risk to be in the moderate range due to a number of factors, including night AAR, thunderstorms in the area, a wet runway, and it being the first time for the MWG and MP to fly a SEAD mission (Tab K-5). The 77 FS/DO approved the flight's RM level, and the morning Top 3 authorized the flight (Tabs K-5, T-2, and V-15.8). The MFL miscalculated the level of risk for the mission, neglecting to include the risk values for "Landing After 2200L", "Instrument Meteorological Conditions Enroute/in the Working Area", and "Greater than 5 Days Since the Last Flight" for both the MP and MWG (Tabs F-8, G-1045, G-1065, and K-5 to K-6). Additionally, two risk categories (Upgrade/MQT and Never Flown Mission Type) were included in the total score, but actually applied to both the MP and MWG separately, and their individual contributions to the total score should have been doubled based on guidance at the bottom of the form (Tab K-5). These changes would have increased the Risk Management score from 30 to 51, and would have required approval from the Operations Group Commander or his designee (Tab K-5).

c. Preflight

During ground operations, the MFL was impressed with the MP's preparedness and timeliness despite the intricacy of the required setup procedures for the weapons and systems (Tab R-49 to R-50). The MF took off on time (Tab R-46).

d. Summary of Flight

At 2101L, the MF departed Shaw AFB and joined with a KC-135, call sign Turbo 27, for AAR in the Bulldog MOA (Tabs AA-7 to AA-10 and FF-6). Refueling was delayed while Turbo 27 exited a dense layer of clouds and relocated to a different altitude block (Tabs V-7.6 and AA-13 to AA-16). The MFL and MEL refueled without incident, and the MWG, on his second-ever AAR attempt and first at night, was able to receive fuel, but bobbled somewhat, required approximately ten minutes (twice the time of the MP and MEL) and was not able to completely fill his tanks, ending the AAR approximately 1,000 pounds below the planned offload (Tabs V-7.16, V-11.3, and AA-18 to AA-22). The MP's AAR attempt, however, ended after being unable to meet the intense formation requirements to receive fuel (Tabs V-11.3 and AA-29). Following his unsuccessful AAR attempt, the MP is heard expressing frustration over the cockpit voice recorder (Tab AA-17 to AA-29). After being unable to receive fuel, the MEL and MP were required to return to Shaw AFB (Tab AA-29).

During the return to Shaw AFB, the MP is heard once again expressing frustration at having to return to base early, and struggles to maintain proper formation spacing and airspeed while trailing the MEL (Tabs AA-40 and FF-2). Approximately 16 nm from Shaw AFB, the MEL communicated, in a lighthearted tone, "that was not the way to start your tanking experience," and then follows more sincerely with "that was really challenging" (Tabs AA-41 and V-11.4). In response, the MP exhaled and said, "no excuse" (Tab AA-41).

e. Summary of Accident

Shaw AFB is equipped with an Instrument Landing System (ILS) approach to runways 22R and 04L (Tab AA-72). An ILS consists of two electronic beams which work together to steer approaching aircraft to the runway through clouds and other weather (Tabs BB-130 to BB-131 and CC-15). The localizer beam guides aircraft laterally along the runway extended centerline, and the glideslope beam guides aircraft vertically to a point approximately 1,000 feet beyond the runway threshold (Tabs AA-72, BB-131, and CC-15). The localizer also broadcasts a specific Morse code signal which aircraft can listen to in order to confirm the system is functioning and they are receiving the signal properly (Tabs AA-72, BB-130, and CC-15). On the night of the mishap, the runway 22R ILS components were operating normally with no faults detected, reported, or logged, and the MP successfully tuned, identified, and monitored the ILS signal (Tabs V-2.2 and FF-3). The final approach portion of the ILS to runway 22R begins 4.3 nm from the end of the runway (Tab AA-72). At that point, the procedure directs a 2.82-degree descent until transitioning to the runway visual environment for landing or arriving at the Decision Altitude (DA) of 440 feet MSL (Tab AA-72).

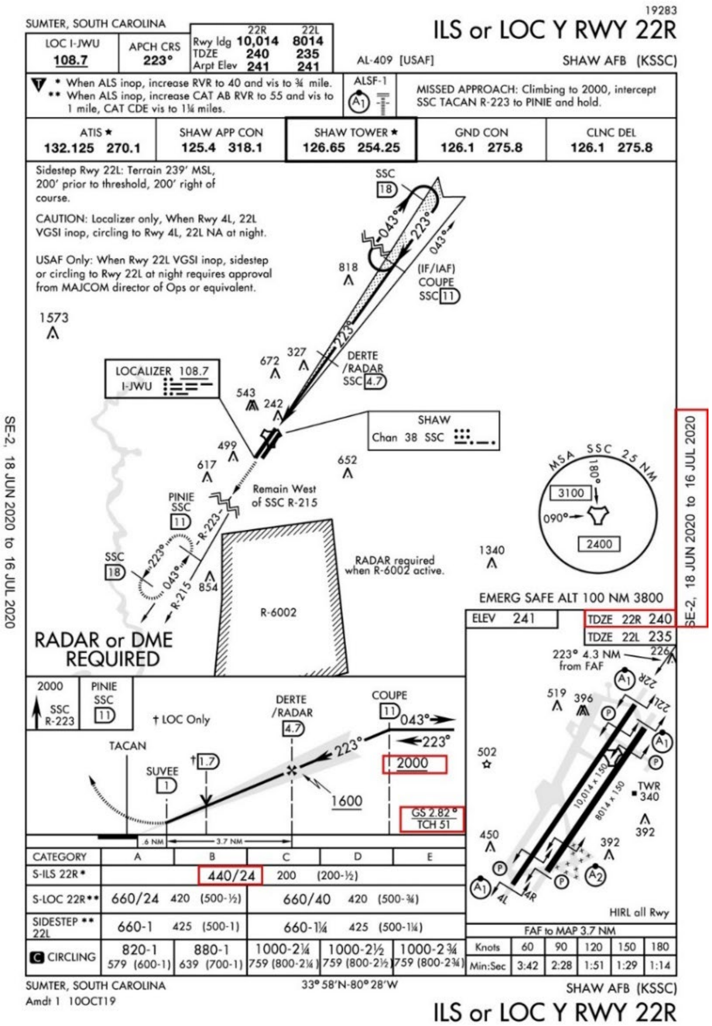

Figure 2: ILS Y 22R procedure (Tab AA-72)

At 2224L, the MP was trailing the MEL by 2.5 nm and established on the localizer's lateral guidance (Tab FF-2). At that time, the MP was at 2,000 feet MSL, and below the clouds (Tab FF-2). He did not reenter the clouds throughout the remainder of the approach (Tabs AA-72 and FF-2). Eighteen seconds after intercepting and descending on the glideslope, the MP radioed that his gear were down, and the Air Traffic Control (ATC) tower acknowledged and issued the MP a clearance to land (Tabs N-4 and FF-2). Prior to transitioning to visual landing cues, the MP executed an ILS approach to runway 22R with minor deviations and corrections (Tab FF-2).

Two minutes after lowering the landing gear, at an altitude of 620 feet above and 1.8 nm from the runway, the MP transitioned from ILS electronic guidance to the visual cues of the runway environment for a visual landing (Tab FF-3).

Runway 22R at Shaw AFB is equipped with a precision approach path indicator (PAPI) and an approach lighting system (ALS) with sequenced flashing lights 1 (ALSF-1) (Tab AA-72). Along with other lighting elements, this system includes a line of green lights along the threshold of the runway (Threshold Lights) and a line of white lights oriented the same direction, approximately

1,000 feet prior to the threshold (1000 FT Light Bar), see figure 3 (Tab Z-4). On runway 22R, there is an array of localizer antennas approximately 82 inches tall located 76 feet in front of the 1000 FT Light Bar (1,076 feet before the runway threshold) (Tabs V-2.3, Z-5, and FF-5). All runway lights were in good working order on the night of the mishap, they were inspected one hour prior to the mishap, and there were no pilot requests to change ALS intensity settings (Tabs V-7.6 to V-7.7, V-13.3, V-13.6, and AA-70).

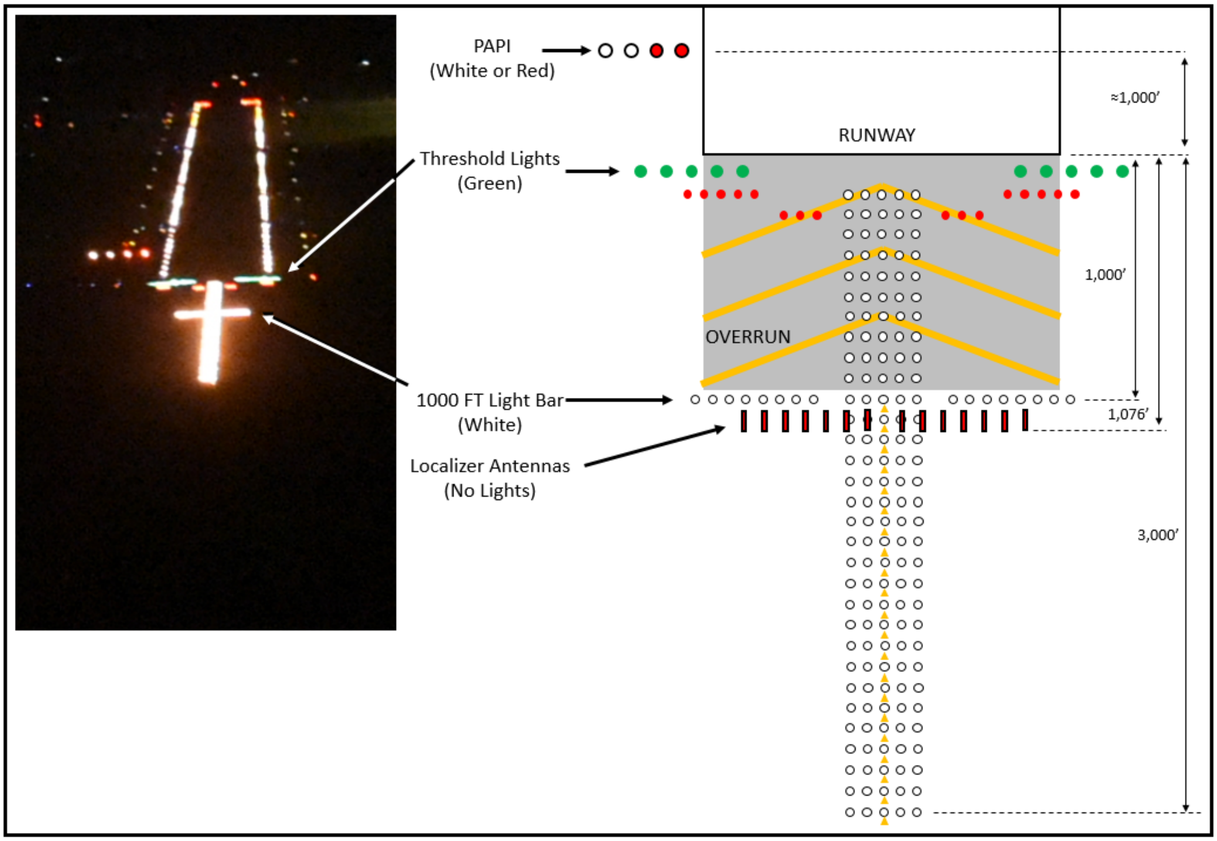

Figure 3: Runway 22R Approach-End Lighting Environment (Tab Z-4)

Approximately 1.8 nm from the runway, the MP was established on course with both the localizer and glide slope signals (Tab FF-3). At that point, the MP steepened his descent from the 2.82-degree electronic ILS glideslope to a 4.5-degree descent in order to intercept a 2.5-degree approach using visual cues to land (Tab FF-3). This maneuver is typical, but a pilot should set their aimpoint on or just beyond the green threshold lights, and the MP erroneously set his aimpoint to land at the 1000 FT Light Bar, which is 1,000 feet short of the runway threshold (Tabs BB-100 to BB-101 and FF-3). At approximately 1.8 nm from the runway, the PAPI lights are clearly visible in the MA's Heads-Up Display (HUD) (Tab FF-3). As the MP flew toward the 1000 FT Light Bar, the vertical ILS guidance indicated that he was well below the glide path, and the visual guidance of the PAPIs would have also indicated the MP was well below glide path (Tabs BB-100 and FF-3). The MP did not "declutter" his HUD display, which left aircraft symbology superimposed over the runway environment, and would have made the landing slightly more challenging (Tabs BB-101 and FF-3). The remainder of the MP's approach was stable (attitude, airspeed, and angle of attack were all normal) (Tabs BB-98 to BB-101 and FF-3).

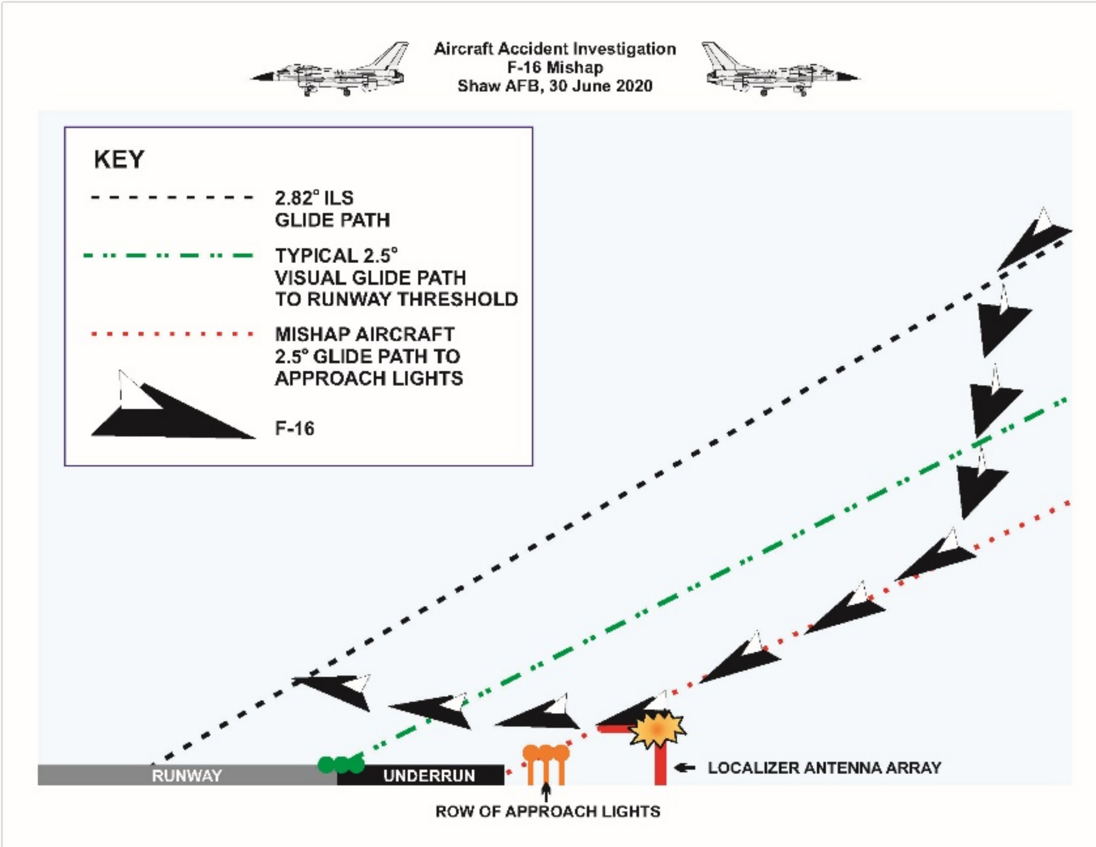

Figure 4: ILS glidepath, Intended glidepath, and MP glidepath (Tab Z-3)

At 2226:49L, as the MP began his flare to land, still aiming 1,000 feet before the threshold, the MA's left and right main landing gear (MLG) impacted the two inner-most localizer antennas while traveling at 165 knots (Tabs J-20 to J-21, J-42, and FF-3 to FF-4). The impact damaged the left MLG, rotated the wheel perpendicular to the direction of travel, split hydraulic lines creating a System B hydraulic failure, and severed the left drag brace's front mount from the aircraft body and left it hanging by the rear mount, which was still attached to the wheel (Tabs J-21, J-43, and AA-45). After impacting the localizer antennas, the MP initiated a go-around, but the MA briefly touched down in the underrun, remaining on the ground for approximately 330 feet, and lifting back into the air approximately 470 feet prior to the beginning of runway 22R (Tab J-21).

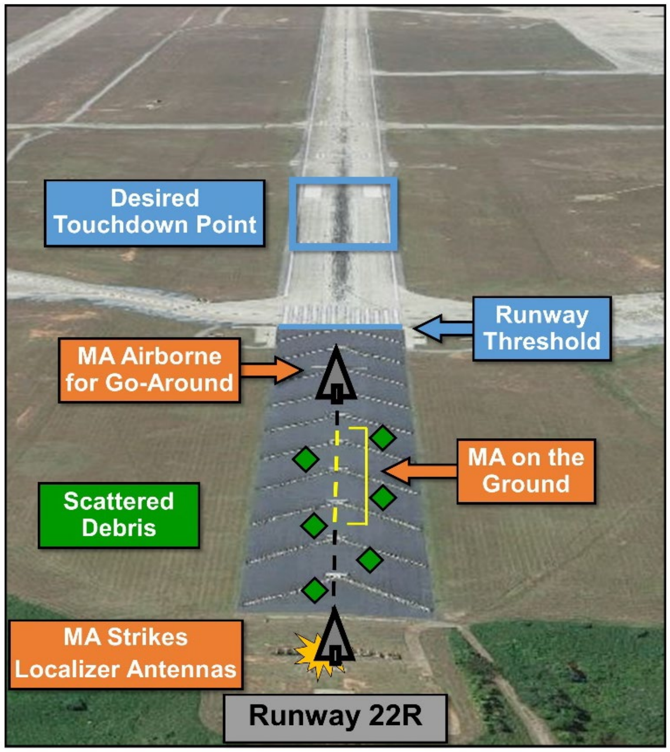

Figure 5: Mishap Aircraft initial landing (Tab Z-2)

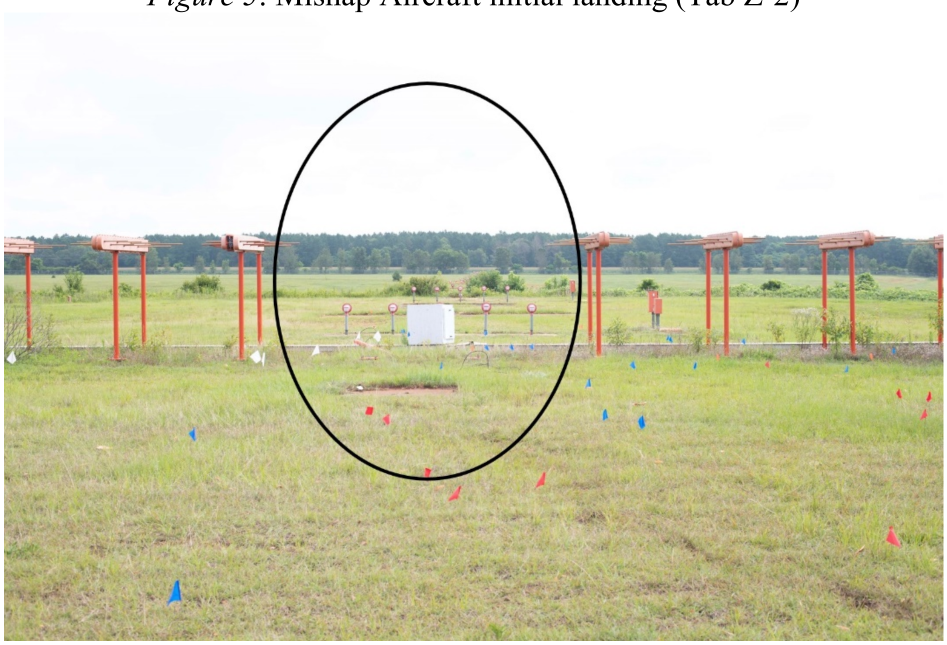

Figure 6: Two missing localizer antennas at the approach end of runway 22R (Tab Z-7)

At 2227:30L, fifty seconds after impact with the localizer antennas, the MP radioed the MEL, who had executed a low approach and was flying in the airspace near Shaw AFB, that he had "Landed short, [had] a hydraulic pressure light, and the gear [were] stuck down" (Tab AA-45). Twenty seconds later, the MP declared an IFE to the ATC tower and stated he had thirty minutes of fuel remaining as the MEL rejoined to inspect the MA's damage (Tabs AA-45 to AA-46 and FF-4).

At 2231L, based on the MA's System B hydraulic failure, the MP and MEL began reviewing the SINGLE HYDRAULIC FAILURE checklist in the F-16CM Flight Manual (Tab AA-46 to AA-48). At 2232:03L, all three of the MA's landing gear safe indications ("3 green") went away, and never returned (Tab FF-4). At 2232:33L, the MP and MEL contacted the SOF (Tab FF-4). While visually inspecting the MA, the MEL reported to the MP and SOF that the MA's left MLG was "broken, and [was] hanging" with the front drag brace at a 90 degree angle, but the right MLG and nose landing gear (NLG) appeared normal (Tab AA-49 to AA-50). Based on the MEL's observations, the MEL, MP, and SOF transitioned to the LANDING WITH LG UNSAFE/UP checklist in the F-16CM Flight Manual (Tabs V-13.9 to V-13.10 and AA-51).

As the SOF began the LANDING WITH LG UNSAFE/UP checklist, he stated the checklist directs the pilot to refer to EJECTION "if conditions are not favorable" before proceeding to the rest of the checklist, which concludes with an approach-end cable arrestment (Tab AA-51 to AA-69). The checklist notes potential factors that may be considered favorable or unfavorable, such as the airfield facilities, hook engagement limits, the crosswind component, and the runway and overrun conditions; however, no factors were ever discussed between the SOF, MEL, and MP (Tabs V-13.6, V-14.3, V-14.7, V-15.6, V-17.3 to V17.4, AA-51 to AA-69, and BB-127).

While reviewing the LANDING WITH LG UNSAFE/UP checklist, MEL confirmed once again that the right MLG and NLG appeared to be down and locked, despite the MP reporting that his safe indications had gone away (Tab AA-50 and AA-66). In addition to the "3-green" lights extinguishing, the MA's landing light was inoperative and the angle of attack (AOA) bracket in the HUD disappeared (Tabs AA-68 to AA-69 and FF-4). Post-mishap analysis confirms all these indications are consistent with a short circuit in the left main landing gear uplock/downlock circuit breaker, which was later found to be tripped (Tab J-44).

From 2234L to 2242L, the SOF, MEL, and MP discussed the courses of action (Tab AA-50 to AA-57). During the discussion, the MP asked on two separate occasions if the LANDING WITH LG UNSAFE/UP checklist was applicable based on the state of the MA's left MLG and the presence of steps in the checklist the group knew should not be accomplished (Tab AA-54 to AA-55). On each occasion, the SOF did not directly answer the MP's question, and, after the second time the MP questioned the checklist usage, the MEL reviewed the checklist once more and stated that he believed the checklist was appropriate because the MA's NLG appeared down and locked, which the MEL understood to mean the MA was in a "landable" configuration, and the group continued to execute the cable arrestment option in the LANDING WITH LG UNSAFE/UP checklist (Tab AA-53 to AA-55 and AA-60). From 2242L to 2248L, the MEL and SOF emphasized on four occasions the importance of a go-around following a failed engagement, and the SOF reminded the MP that a ground ejection may be required prior to the aircraft departing the runway (Tab AA-51 to AA-69).

The F-16 is equipped with an arresting gear system, which allows the pilot to engage ("catch") a steel cable placed across a runway using a hook (Tab BB-112 to BB-113 and BB-124). When a cable is located at the beginning of a runway, it is called an "approach-end" cable, and when a cable is located at the end of a runway, it is called a "departure-end" cable (Tabs BB-124 and FF-6). Procedures dictating how and when to engage a cable vary widely based on the type of emergency, phase of flight, and available cable geometry, but approach-end cables during landing emergencies are generally specified for use during situations when the integrity of the landing gear is in question (Tabs BB-124, BB-127, and FF-5). For any cable engagement, it is essential that the pilot engage the cable perpendicularly and as near to the center as possible (Tabs BB-124 and FF-5).

Figure 7: Runway 04L approach cable (Tab Z-10).

Figure 8: Example of an F-16CM engaging a cable (Tab Z-9).

For the F-16CM, the Lockheed Martin Aeronautics Company – Fort Worth (LM) is available for IFE technical assistance through a procedure called Conference Hotel (CH) (Tab V-6.2). For IFE technical assistance discussions, customer personnel (usually the SOF) may contact LM 24 hours a day (Tab V-6.2). During normal local business hours, the telephone is answered by LM F-16 Flight Safety personnel directly (Tab V-6.2). After normal local business hours, the telephone is answered by LM Security personnel, who will immediately attempt to connect the caller with one of the F-16 Flight Safety engineers (Tab V-6.2). Each Flight Safety engineer keeps an additional call list of specific systems experts and company test pilots, and has additional conferencing capability on their home phones (Tab V-6.2). This after-hours service is provided as a courtesy by LM, with no assurance of always being able to reach someone after normal Flight Safety office duty hours (typically 0730 to 1730 local Fort Worth, Texas time) (Tab V-6.2).

From 2228 to 2247L, while in the ATC tower and supporting the MP, the SOF coordinated the immediate return of all other 20 FW aircraft, discussed the nature of the MA's damage and possible courses of action with the TOP3, advised the OGBH ("Brickholder", the OG Commander's direct representative when the OG/CC is not available) of the plan to land the MA on 04L, and directed the change of the active runway from 22R to 04L (Tab V-13.5 and V-13.12). The runway change was necessary to make the single cable available function as an approach-end cable (AA-53). During this time, the SOF gave his quick reaction checklist (QRC) to SOF2 (an upgrading SOF in the ATC tower) to "back him up" in case he missed anything (Tab V-13.4 to V-13.5, V-13.11 to V-13.13, and V-14.3). The F-16CM flight manual states, "because of the number of possible malfunctions, specific procedures for every situation are not feasible (Tab BB-126). If time and conditions permit…technical assistance should be requested" (Tab BB-126). Further, the SOF QRC directs the SOF to "consider" a CH as part of the AIRCRAFT EMERGENCY CHECKLIST (Tab BB-65). The SOF and SOF2 had discussed CH procedures earlier in the evening, but did not discuss them during the mishap (Tab V13.4, V-14.3 and V-14.7). SOF2 thought about the merits of executing a CH, but did not verbalize it (Tab V13.5, V14.3, and V-14.7). The SOF chose not to execute a CH with LM because he believed LANDING WITH LG UNSAFE/UP was the appropriate checklist, provided adequate direction for the situation, and that CHs are for situations not covered in a checklist, depending on the amount of time available (Tab V-13.4 to V-13.6).

If a CH had been initiated at the time of the mishap, the call would have been answered by the LM Security Control Center and an F-16 Flight Safety Engineer would have been called (Tab V-6.2). At the time of the mishap, three of the four Flight Safety Engineers who support F-16 CH calls were available (Tab V-6.2). Flight Safety Engineers from LM explained, after the mishap, that the LANDING WITH LG UNSAFE/UP checklist only applies if a landing gear fails to extend normally, not when it is damaged or hanging (Tab V-6.2). The engineers also stated there is no checklist in the F-16CM flight manual for this particular situation, and the outcome of an attempted cable arrestment would be unknown (Tab V-6.3). They are aware of two previous instances of damaged landing gear similar to the MA's, and in both instances an ejection was performed instead of attempting a cable arrestment (Tab V-6.3).

At 2246:45L, the MP lowered his hook in level flight at 222 knots, and the MEL reported the MA's hook appeared to be extended normally (Tabs AA-59 and FF-4). At 2247L, the SOF radioed that he had coordinated the plan with the TOP3 and OGBH (Tab AA-60). For the next five minutes, the MP, MEL, and SOF discussed approach-end cable arrestment procedures, including the location of the cable, desired landing attitude and location, the importance of a go-around if the cable is not engaged, and the imperative of an ejection in the event the left wing contacted the ground (Tab AA-60 to AA-65). Because of the damage to the left main landing gear, it would not have been able to support the weight of the MA (Tab J-43). The F-16CM flight manual directs a go-around in the event of a missed cable engagement and warns that a "ground loop" (very dangerous event) may occur if the wing is allowed to contact the ground when the gear fails to support the aircraft (Tab FF-6).

Due to damage caused to the 04L localizer antennas by the MA (located at the beginning of runway 22R), vertical guidance was not available, and the MP executed a visual approach to 04L (Tabs V-2.4 and AA-67).

At 2253L, the MP began a turn toward the airfield to land and reported he had 1,500 pounds of fuel (Tab AA-65). The MEL reminded the MP he had sufficient fuel for another attempt, if required (Tab AA-65).

At 2253:52L, as the MP maneuvered for his final approach, the MEL asked the MP to confirm that his right MLG and his NLG were both still indicating as down-and-locked, and the MP responded that he had "no green lights" (Tabs AA-66 and FF-4). After referencing the LANDING WITH LG UNSAFE/UP checklist once again, the SOF recommended that despite all gear indicating unsafe, the MP continue with the approach-end cable arrestment because the gear appeared down-and-locked and it was unlikely they had become unlocked while airborne (Tab AA-67). The landing gear lights not illuminating despite being down-and-locked is consistent with a short circuit in the left MLG, keeping them locked in the down position (Tab J-44).

At 2256:19L, the MP reported the airfield in sight, and sixteen seconds later, the MP received clearance to land on runway 04L (Tab FF-4). At 2257:26L, the MP began a visual descent and radioed that his AOA bracket was not displayed in his HUD, consistent with the left MLG short circuit (Tabs J-44, AA-68, and FF-4). The MEL counseled the MP to use the other AOA indicator, by his left leg (Tab AA-68). At 2258:25L, with the MA in sight from the ATC tower, the SOF reported that the MA's landing light was not illuminated, which would make the touchdown darker than usual (Tabs V-13.11, AA-69, and FF-5). The landing light not illuminating is also consistent with the left MLG short circuit (Tab J-44).

f. Impact

At 2259:26L, the MA touched down approximately 730 feet prior to the approach-end cable on runway 04L with the hook lowered, throttle in idle, and approximately four degrees of left roll (Tabs L-10, J-17, J-28 to J-29, J-50, J-56 and FF-5 to FF-6). The lower portion of the hook assembly, just prior to the hook itself, impacted the cable, but the engagement was unsuccessful (Tabs J-26, J-48, and Z-12). There are several potential reasons an aircraft can miss a cable engagement, and engineers identified and analyzed nine possible reasons following the mishap (Tab J-48 to J-51). The possible reasons include the runway condition; the MA's installed parts, settings, and pressures; known aircraft system anomalies; and the geometric relationship between the hook and the cable at contact (Tab J-48 to J-51). Most of these reasons affect the hook in known ways, and the fact the cable impacted the hook shank five inches above the hook itself precludes most of these reasons (Tab J-48 to J-51). The remaining three possible reasons all involve changing the geometry between the hook and the cable at contact (Tab J-48 to J-51). The three remaining reasons are:

(1) The hook is intended to be able to pivot upon contact with the cable, and a shear bolt exists to hold the hook in place until contacting the cable (Tab J-49 to J-50). In some instances, the bolt

may break prematurely, allowing the hook to pivot to one side before contacting the cable, which would in turn cause the hook to not contact the cable directly perpendicular (Tab J-49 to J-50). The F-16CM flight manual includes a caution to lower the hook while wings level to prevent failure of the bolt, which the MP did properly, but the bolt may have sheared before touchdown, as the aircraft approached the cable, or during the subsequent crash (Tabs J-49 to J-50 and FF-4).

(2) The hook requires some distance between landing on the runway and contacting the cable to stabilize along the ground and "present" itself to the cable (Tab J-50 to J-51). While the MA touched down in excess of the recommended distance, the crash survivable flight data recorder (CSFDR) reported several cycles of the right MLG carrying the weight of the MA, indicating that the aircraft was possibly not stabilized as it approached the cable (Tabs J-50 to J-51 and L-10).

(3) The damaged left MLG may have disturbed the cable as it passed over it in such a way that the hook was no longer properly positioned to engage it (Tab J-51). Data is unavailable to model the likely effects on the cable since there are no known approach-end cable arrestments with damaged and hanging main landing gear components (Tab J-51).

Figure 9: Cable impact marks on hook shank (Tab Z-12)

At 4.5 seconds after touchdown, after traveling approximately 1,108 feet and at 138 knots ground speed, the MA rolled to 14 degrees left bank, indicating the left main gear had failed to support the weight of the aircraft and the left wing had contacted the runway, and the MP commanded full right roll (Tabs J-27 to J-28, J-32, J-43, L-10, and FF-6). Over the next 1.5 seconds, the MA began to drift to the left, and the MP momentarily commanded full nose up while increasing the throttle to afterburner (Tabs J-32 to J-33 and FF-6). The MP then stopped providing flight control inputs to the MA as he activated his ejection seat (Tabs J-33 and FF-6).

The MA continued veering to the left, departed the runway into the grass infield, flipped nose-over-tail, and came to rest upside-down in a large parking apron area (Tab J-23 to J-24).

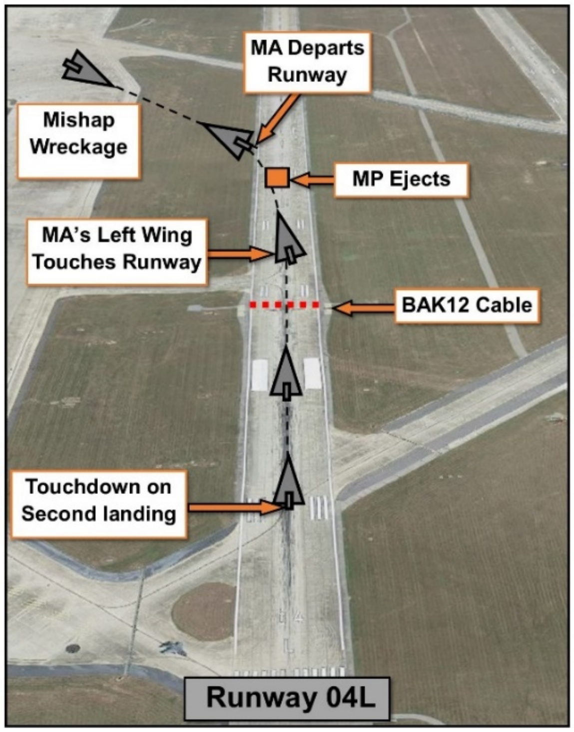

Figure 10: MA ground track on second landing (Tab Z-6)

g. Egress and Aircrew Flight Equipment (AFE)

The F-16CM is equipped with an Advanced Concept Ejection Seat (ACES) II ejection seat, and both the F-16CM flight manual and ACES II ejection seat academic material state that "the ejection seat and parachute are capable of successful ejection for all landing gear failure scenarios (and corresponding aircraft attitudes) with ground speeds up to 200 knots" (Tabs BB-117 and EE-46). The MP commanded ejection while experiencing a landing gear failure at 129 knots ground speed (Tabs J-33, BB-117, and FF-5).

At 2259:33L, approximately 751 feet past the cable, the MP pulled the ejection handle, initiating the ejection sequence at 129 knots ground speed, with the nose at 8 degrees nose high and in a 16-degree left bank (Tabs J-33, BB-116, and FF-6). Based on the airspeed and altitude of the ejection, the mishap seat (MS) should have initiated a Mode 1 ejection (Tab J-3).

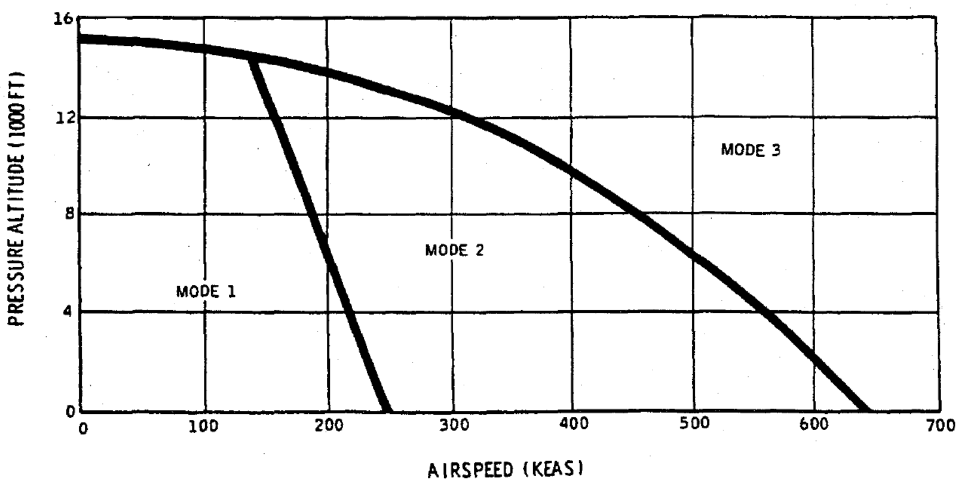

Figure 11: Ejection mode envelopes (Tab BB-93)

During a nominal ejection, pulling the ejection handle retracts the shoulder harness straps and locks the inertia reel (similar to how a car seatbelt locks when you brake hard), fires initiators to jettison the canopy, and ignites two rockets to remove the canopy (Tab BB-116). Once the canopy has left the aircraft, two ejection seat initiators are activated, and a rocket catapult propels the seat from the aircraft (Tab BB-116). As the seat exits the aircraft, the Digital Recovery Sequencer (DRS) is activated, which is responsible for providing seat stabilization, pilot/seat separation, and parachute deployment (Tab J-3). For a Mode 1 ejection, the seat's drogue chute is not used, expediting the deployment and inflation of the personnel parachute (Tabs J-3, BB-92 to BB-93, BB-116, and BB-118).

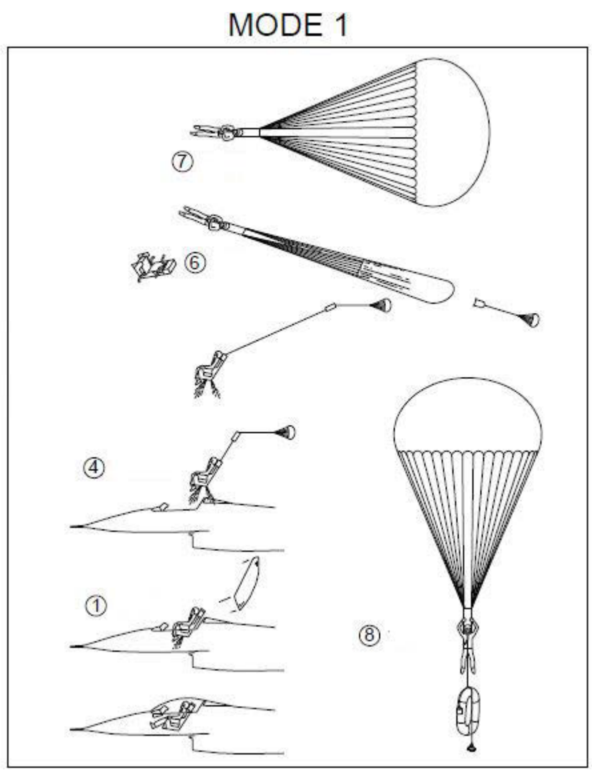

Figure 12: Mode 1 Ejection Sequence (Tab BB-119)

When the MP initiated ejection, the sequence proceeded as expected until the MS left the aircraft, at which point a critical failure of the DRS occurred, resulting in its failure to sequence or control all subsequent actions (Tab J-8 to J-10). Six of seven pyrotechnic devices in the seat should have activated during the MP's ejection; however, the DRS failure resulted in none of them activating, and the subsequent failure of the stabilization gyro, trajectory divergence rocket motor, the harness release thruster, two drogue chute severance cutters, and primary parachute deployment cartridge (Tab J-8 to J-10). The failure of the DRS to initiate multiple devices resulted in the MP remaining in the MS and following a parabolic flight path until impacting the ground (Tabs J-8 to J-10 and EE-8).

When the MS impacted the ground, its structure failed, and the bottom of the seat was liberated from the back of the seat (Tab J-10). The liberation of the bottom of the seat sufficiently pulled a cable attached from the back of the seat to the emergency manual parachute deployment handle (EMPDH) located in the bottom of the seat, releasing the MP from the seat and firing the secondary parachute deployment cartridge, which led to his subsequent entanglement in the parachute riser cords while the parachute itself remained packed in its container (Tab J-10, V-5.4, and V-5.7).

The ACES II ejection seat is equipped with an EMPDH (Tab BB-115 to BB-117 and BB-123). This handle is integrated into the seat, and remains next to the pilot's right thigh throughout the deployment sequence until pilot/seat separation (Tab BB-115 to BB-117 and BB-123). At any point prior to pilot/seat separation, the pilot can pull the EMPDH to activate a secondary system, which will deploy the recovery parachute and release the pilot from the seat (Tab BB-116 to BB-117 and BB-123). The F-16CM flight manual warns that the EMPDH "should only be used if the automatic sequence has failed," "pilot/seat separation in modes 1 and 2 should occur rapidly," and "if the pilot has time to realize seat separation has not taken place, a failure has probably occurred and manual seat separation should be performed" (Tab BB-115 to BB-117 and BB-123).

In a typical ejection, as the seat is accelerated upward above the aircraft, a pilot will experience 9-14 Gs of acceleration force, and is therefore unable to pull the EMPDH until after the rocket motors have stopped (Tab EE-6). G-force is the force of gravity or acceleration on a body (Tab X-7 to X-8) If a pilot were required to use the EMPDH, there would be a delay of approximately 2.0-2.5 seconds once the handle was pulled until the parachute is fully deployed, inflated, and has reduced the pilot's sink rate to a safe level (Tabs EE-11 to E-12 and FF-6 to FF-7).

The MS's trajectory resulted in it being airborne for a total of 6.27 seconds (Tab EE-10). Air Force Research Laboratory (AFRL) analysis concluded that the MP had a total of 3.475 seconds from when the MS left the aircraft to pull the EMPDH and achieve a successful parachute deployment (Tab EE-10 and EE-12). If the MP had executed a controlled ejection based on the locally developed controlled ejection procedures, which direct a controlled ejection between 2,000-3,000 feet AGL, he would have had between 13.9 and 18.3 seconds to pull the EMPDH (Tabs Z-14 and EE-12 to EE-15). Neither of these time windows take into account other factors that would have made pulling the EMPDH more challenging, including the initial incapacitation from G-force during the launch, darkness (makes seeing the ground difficult), and a seat without stabilization would be rotating and rolling in multiple axes (Tabs J-4 to J-5, X-6, EE-5, and EE-16). Due to these factors, any additional available time to recognize the seat's failure would be critical to overcoming the DRS failure (Tab X-6).

An ejection sequencing failure also occurred in 2014, when an experienced F-16C IP in the Tulsa Air National Guard, with over 2,600 flight hours, experienced a similar DRS failure during an uncontrolled ejection near Moline, Kansas (Tab GG-3, GG-21, and GG-30). In that ejection, the DRS successfully sent firing signals to stabilize the ejection seat, but neither pilot/seat separation nor parachute deployment occurred (Tab GG-20 to GG-21). The pilot ejected at 7,500 feet AGL (Tab GG-21). During that pilot's daytime, fair weather ejection, with far more experience and training than the MP, it required approximately 4 seconds for him to recognize the failure had occurred and pull the EMPDH in order to deploy the parachute and land with minor injuries (Tab GG-3, GG-21, and GG-30).

h. Search and Rescue (SAR)

At 2239L, Shaw AFB Fire Department received notification via crash net radio communications of an IFE and immediately dispatched fire trucks, crash response vehicles, barrier maintenance, and ambulances to the flight line in preparation and staging (Tabs N-25 to N-27, R-6, and V-4.11). At 2255L, the ATC tower made notification that the MA was the next aircraft to land (Tab N-31). Approximately four minutes later, shortly after touch down, the MP ejected (Tabs N-31, V-4.11, and V-4.16). The MA then departed the runway and began burning (Tab N-31). Fire trucks immediately proceeded to the crash site and began extinguishing flames on and around the MA (Tab N-31). Simultaneously, Emergency Medical Technicians (EMT) began searching for the MP in and around the flightline (Tabs N-31 and V-4.11). At 2302L, Shaw Emergency Management Services (EMS) requested Sumter County EMS provide additional support (Tabs N-32 and R-6).

At approximately 2310L, firefighters located the MP in the flightline infield grass (Tab V-5.6). Emergency personnel had difficulty locating the MP because of his unknown ejection trajectory, unlit runway infield, the infield's tall grass, and the MP's green flight suit (Tab V-4.4). Immediate assessment by firefighters revealed the MP was unconscious, pulseless, and not breathing (Tab V-5.4). The MP was also found wrapped in parachute cord (Tab V-4.3). In response, Cardiopulmonary Resuscitation (CPR) was initiated (Tab V-5.4). Approximately one minute later, paramedics arrived and rendered further medical care, including cervical spine stabilization, application of cardiac monitor pads, and ventilation support with a bag valve mask (Tab V-4.11, N-38, V-5.6). The cardiac monitor indicated a lack of cardiac activity (Tab V-4.13 to V-4.14). Prior to transfer to the ambulance, firefighters cut the MP free from the parachute cords (Tab V-5.7). Once in the ambulance, firefighters and paramedics continued CPR and further evaluated the MP (Tab V-4.13 to V-4.14 and V-5.5).

i. Recovery of Remains

During their in-depth trauma survey, the paramedics observed extensive cranial injuries and multi-system trauma, which necessitated immediate consultation with the on-call-physician at Prisma Health Toumey Hospital, located in Sumter, SC (Tab V-4.12 and V-5.5). Based on the severity of MP's injuries, as described by the onsite paramedics, the on-call physician ordered the cessation of life-saving measures at approximately 2358L (Tabs V-4.12, V-5.5, and X-2).

5. MAINTENANCE

a. Forms Documentation

The Air Force Technical Order (AFTO) 781 series of forms collectively provides maintenance, inspection, service, configuration, status, and flight record of the particular aerospace vehicle for which they are maintained (Tab BB-79 to BB-80). The AFTO 781 forms, in conjunction with the Integrated Maintenance Data System (IMDS), provide a comprehensive database used to track and record maintenance actions and inspection histories on each individual Air Force aircraft (Tab BB-79 to BB-80). A comprehensive review of the active AFTO 781 forms and IMDS historical records for the 30 days preceding the mishap revealed no recurring maintenance problems (Tabs D-2 to D-79 and U-40 to U-68).

b. Time Compliance Technical Order (TCTO 11P2-3-502)

There were two related maintenance issues with the MA and the first was that Time Compliance Technical Order (TCTO) 11P2-3-502 (Installation of Shorting Plug on the DRS Electronic Module) was not completed on the MA prior to the mishap (Tabs J-13 and U-82). The shorting plug was designed to prevent noise bias issues observed in channel three of the three-channel system on the DRS (Tabs J-13 and V-18.1 to V-18.2). Two of the three channels must be in agreement for the DRS to function properly (Tabs J-13 and V-18.1 to V-18.2). DRS failure due to channel three noise bias issues have been observed in approximately 9% of all live ejections and sled tests (Tab J-13). TCTO 11P2-3-502 was issued on 20 January 2016 and was to be accomplished during the next scheduled 36-month ejection seat inspection (Tab U-99). The first opportunity to accomplish this TCTO was on 28 August 2017, but was not accomplished due to a lack of available parts (Tab U-99). The TCTO requirement was automatically deferred to the next 36-month seat inspection, which was 28 August 2020 (Tab U-99).

c. Digital Recovery Sequencer (DRS) Shelf/Service Life

The MA's second maintenance issue was regarding the DRS 10-year shelf/service life which expired as of 28 February 2019; however, the DRS received three temporary shelf/service life extensions approved by the Air Force Life Cycle Management Center (AFLCMC) (Tab U-69 to U-73 and U-77). The first extension was approved on 4 February 2019 due to a lack of available parts, which provided a shelf/service life extension through 30 September 2019 (Tab U-87 to U-92). The second extension was approved on 26 September 2019 due to a lack of available parts, which provided a shelf/service life extension through 30 June 2020 (Tab U-93 to U-98). Once parts became available, the third and final extension was approved on 27 May 2020 for maintenance consolidation efforts, which provided a shelf/service life extension through 31 July 2020 (Tab U-69 to U-73). The MA's DRS was scheduled to be replaced with an upgraded seat sequencer, Modernized ACES II Seat Sequencer (MASS), while the MA was scheduled down for cannibalization maintenance from 8 July 2020 to 21 August 2020 (Tab U-69 to U-73). Installation of the new MASS would negate the required compliance with TCTO 11P2-3-502 (U-81).

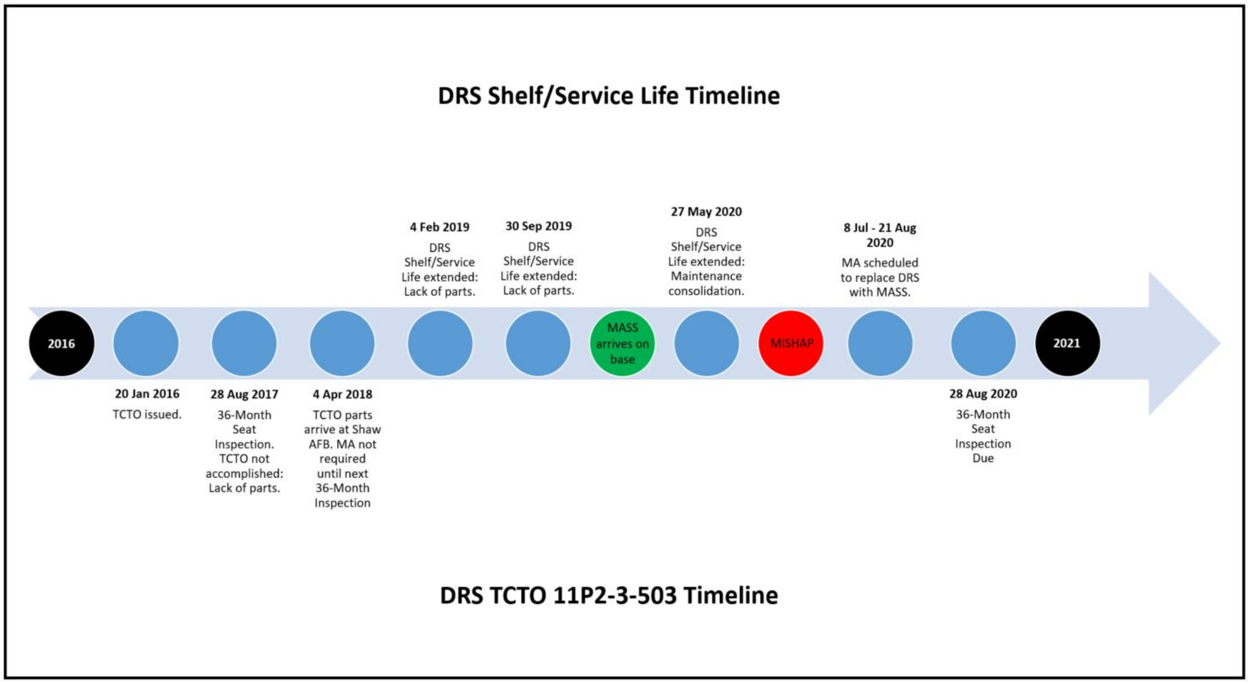

Figure 13: DRS Timeline (Tabs U-69 to 73, U-77 to U-79, U-82, U-87 to U-98, U-99, and Z-15)

d. Inspections

The combined Pre-Flight/Basic Post Flight (PR/BPO) inspection is accomplished at the end of the specified flying period or prior to the first flight of the next specified flying period (Tab BB-78). The PR/BPO inspection consists of checking the aircraft condition by performing a visual examination and operational checks of certain components, areas or systems to ensure no defects exist that would be detrimental to flight (Tab BB-77 to BB-78). The Thru-Flight (TH) inspection is a between flights inspection and will be accomplished after each flight, when another flight is scheduled during the same flying period (Tab BB-77 to BB-78). The TH inspection consists of checking the aircraft for flight continuance suitability by performing a visual examination of certain components, areas or systems to ensure no defects exist which would be detrimental to further flight (Tab BB-77 to BB-78). F-16 phase inspections are accomplished upon accrual of 400 flying hours and is an extensive inspection of the entire aircraft (Tabs D-68 and BB-78).

The last PR/BPO inspection occurred on 29 June 2020 at 0030L with no discrepancies noted (Tab D-38 and D-49). A TH inspection occurred on 30 June 2020 at 1830L with no discrepancies noted (Tab D-56 and D-63). The total aircraft flying hours of the MA at takeoff of the mishap sortie was 6,149.7 hours (Tab D-56). Since its last phase inspection on 12 February 2020, the MA flew 64.8 hours (Tabs D-56, D-68 and U-83). Prior to the mishap, all inspections were satisfactorily completed (Tabs D-2 to D-79 and U-40 to U-68).

e. Maintenance Procedures

A thorough review of the MA's active and historical maintenance records revealed all maintenance actions complied with standard approved maintenance practices, procedures, and technical orders (Tabs D-2 to D-79 and U-2 to U-68). On 5 February 2020, during its last phase inspection, the ejection seat Trajectory Divergence Rocket (TDR) was replaced for a scheduled time change (Tab U-84). There is no evidence to suggest the TDR replacement was a factor in this mishap (Tab J-2 to J-13).

f. Maintenance Personnel and Supervision

Maintenance personnel from the 20 FW performed all required inspections, documentation, and servicing for the MA prior to flight (Tab D-55 to D-74). A detailed review of maintenance activities and documentation revealed no errors (Tab D-55 to D-74). Personnel involved with the MA's preparation for flight had proper and adequate training, experience, certification, and supervision to perform their assigned tasks (Tab DD-2 to DD-446).

g. Fuel, Hydraulic, and Oil Inspection Analyses

The Air Force Petroleum (AFPET) Office at Wright-Patterson AFB, Ohio tested the provided post-mishap engine oil and hydraulic fluid samples (Tab D-133 to D-134). The oil and hydraulic sample fluid quantity was insufficient to complete all the test requirements (Tab D-133 to D-134). The AFPET Office at Cape Canaveral Air Force Station, Florida tested the provided post-mishap fuel sample (Tab U-76). The fuel sample test was not completed due to contamination of Aqueous Film Forming Foam from post-mishap fire extinguishing efforts (Tab U-76). However, an Oil Analysis Program sample was taken from the MA engine prior to the mishap on 29 June 2020 and tested within acceptable levels by the Non-Destructive Inspection lab at Shaw AFB (Tab U-74 to U-75).

h. Unscheduled Maintenance

Unscheduled maintenance is any maintenance action taken that is not the result of a scheduled inspection and normally is the result of a pilot-reported discrepancy during flight operations or a condition discovered by ground personnel during ground operations (Tab U-99). A review of the MA's active and historical maintenance records revealed twelve unscheduled maintenance events during the 120 days preceding the mishap, none of which are related to the mishap (Tab U-2 to U-68). The twelve unscheduled maintenance events were as follows:

From 1 March 2020 to 31 March 2020, unscheduled maintenance actions included replacement of external wing fuel tank, sniper pod video downlink lower antenna, System A hydraulic reservoir accumulator, right MLG tire, and canopy transparency (Tab U-2 to U-14).

From 1 May 2020 to 31 May 2020, unscheduled maintenance actions included bleeding the NLG strut and replacement of the left MLG and NLG tires (Tab U-29 to U-39).

From 1 June 2020 to 30 June 2020, unscheduled maintenance actions included replacement of the water separator coalescer, countermeasure dispenser, ground refuel receptacle, and station seven forward coaxial switch (Tab U-40 to U-68).

6. AIRFRAME SYSTEMS

a. Structures and Systems

The MA exited the left side of runway 04L approximately 1,400 feet beyond the arresting cable (Tab J-17). After exiting the runway, the MA traveled approximately 600 feet before hitting a grass berm (Tab J-23). The MA became airborne momentarily until coming to a rest inverted on taxiway Alpha with its final heading reversed almost 180 degrees from its direction of travel (Tab J-23). After the MA came to a rest, there was evidence of fire damage to the top side of the MA, with limited heat damage on the lower half of the aircraft (Tab J-25). Several stores and aircraft structural components separated from the MA after contacting the berm, including the nose wheel, right speedbrake, left MLG, right horizontal tail, electronic countermeasure pod, Air Intercept Missile (AIM)-9X, AIM-120s, and forward section of the 370-gallon wing tank from station 6 (Tab J-24). The ejection seat and parachute were located near where the MA aircraft hit the berm (Tab J-24).

b. Evaluation and Analysis

1. MA Landing Gear

The aircraft is equipped with a fuselage mounted, tricycle landing gear system consisting of a single-wheel NLG and two single-wheel MLGs (Tab BB-106). Normal retraction and extension of the landing gear system is electrically controlled and hydraulically actuated (Tab BB-106).

Both MLG tires and axles made contact with the ILS antennas during the MP's first approach (Tab J-42). Parts recovered in the underrun of runway 22R included broken pieces from the left MLG retract actuator, left MLG drag brace assembly, and left MLG drag brace pin housing mounted to the keel beam (Tab J-43). The left MLG tire contacted the underrun surface during the first approach and left abnormal marks consistent with damaged landing gear (Tab J-43). After the mishap, the left MLG was separated from the MA and the right MLG was still attached in the normal down position (Tab J-23 to J-24).

2. MA Hydraulic System

The main hydraulic power is generated and distributed by two independent systems designated as System A Hydraulics and System B Hydraulics (Tab BB-105). Both systems provide 3,100 pounds per square inch of hydraulic pressure for operation of aircraft systems (Tab BB-105). System A and System B provide redundant power for operation of the primary flight control functions and the wing leading edge flaps (Tab BB-105). In addition, System B provides power to the landing gear, nosewheel steering (NWS), wheel brakes, jet fuel starter, air refueling system, and gun system (Tab BB-105).

The left MLG wheel well has two System B hydraulic lines that are attached near the top of the drag brace (Tab J-41). When the drag brace attach fitting failed and the drag brace broke free, both System B hydraulic lines broke resulting in a rapid depletion of System B hydraulic pressure (Tab J-41). Loss of system B hydraulic pressure occurred immediately after the first approach

(Tab J-42). According to the digital flight control system data, the flight controls were operating in the non-redundant mode, indicating full operation of System A hydraulics (Tab J-41).

3. MA Electrical System

The aircraft electrical system is equipped with circuit breakers (CB) as a protective device that will trip when the electrical current is too high (Tab BB-109 to BB-110). An open CB indicates the breaker has failed or an abnormal electrical overload has occurred (Tab BB-109 to BB-110).

Engineering analysis suspects that the damaged left MLG caused a short in the downlock switch, which tripped the landing gear uplock/downlock CB (Tab J-44). Opening of this CB causes all wheels down lights "3-green" to remain off (Tab J-44). Another result of this CB opening is that the landing gear will go into hydraulic isolation mode immediately after the gear handle is raised and the gear will not retract (Tab J-44). Other effects associated with this CB opening are no AOA bracket in the HUD, speedbrakes are not limited to 43 degrees, landing/taxi light is inoperative, and NWS is inoperative (Tab J-44). A post-mishap examination of MA indicated the landing gear uplock/downlock CB was tripped (Tab J-44).

4. MA Arresting Gear

The arresting gear system provides a means of stopping the aircraft on the runway during an emergency landing by hook engagement with a barrier cable (Tab BB-106). The system is electrically controlled from the cockpit and pneumatically powered to unlock and extend (Tab BB-112). The arresting gear utilizes a hook alignment shear bolt to minimize lateral movement and to maintain hook center alignment before cable engagement (Tab BB-112 to BB-113).

The MA's hook shank showed evidence of making contact with the arresting cable, yet the hook toe did not catch the cable (Tabs J-47 and Z-12). Marks on the MA hook shank indicated that the cable did not hit the hook squarely (Tab J-51). The MA's hook shear bolt was sheared when examined in the wreckage (Tab J-49). It could not be determined if the shear bolt sheared before or after the missed cable engagement (Tab J-49).

5. MA Crew Escape System

The crew escape system provides a fully automatic escape from the aircraft with a means for recovery (Tab BB-107). There are two principal system functions, canopy jettison and crew ejection/recovery (Tab BB-107). For emergency egress, the ejection seat is equipped with firing controls, propulsion, pitch control, environmental sensing, emergency oxygen, harness release, drogue and recovery parachutes, recovery sequencing, and a survival kit (Tab BB-107). The ejection seat is also equipped with an EMPDH, which serves as a back-up to the primary system in the event the DRS fails to automatically sequence the ejection event (Tab J-11).

The MA's ejection seat sustained severe damage upon impact with the ground (Tab J-6). The bottom portion of the ejection seat separated from the back portion, but remained attached by various hoses and cables (Tab J-6). The DRS electronic module was recovered from the ejection seat and was determined that it did not automatically sequence recovery of the MP after the ejection event occurred (Tab J-8). This determination was supported by evaluation of seven individual electro-explosive devices (EEDs) which were recovered in the LIVE-unfired condition (Tab J-8). Six of these EEDs should have fired in the ejection event (Tab J-8). A visual inspection of the DRS power supply batteries indicated sufficient temperature to power the DRS (Tab J-9). Analysis from AFRL revealed that the MA's DRS had failures in two of the three channels (Tabs EE-17 to EE-34 and V-18.1 to V-18.2). Channel two failed due to a critical error at power-on and channel three failed due to a signal noise issue (Tabs EE-17 to EE-34 and V-18.1 to V-18.2). Based on the AFRL analysis, the AFLCMC Cartridge Actuated Devices/Propellant Actuated Devices office assessed that the noise present in channel three should have been cancelled out if TCTO 11P2-3-503 was accomplished (Tabs EE-16 to EE-33 and V-18.1 to V-18.2). Without that noise, channels one and three should have been able to communicate, and the ejection seat would have functioned properly (Tabs EE-17 to EE-34 and V-18.1 to V-18.2). Post-mishap inspection revealed the EMPDH was in the seated position (Tab J-10 to J-11). However, the emergency power system and secondary parachute deployment cartridge EED were observed in the fired condition, which would normally be the result of pulling the EMPDH (Tab J-11). This indicates, although the EMPDH was in the seated position, there was sufficient force upon ground impact to effectively pull the EMPDH cable and initiate recovery parachute deployment (Tab J-11).

7. WEATHER

a. Forecast Weather

On the night of the mishap, the forecast for Shaw AFB had winds out of the northwest at nine knots, few clouds at 4,000 feet above the ground (AGL), scattered clouds at 13,000 feet AGL, broken clouds at 20,000 feet AGL and good visibility (Tab F-3).

b. Observed Weather

The observed weather at the time of the mishap, as reported at Shaw AFB, was winds from the southeast at four knots, scattered clouds at 14,000 feet AGL, and broken clouds at 17,000 feet AGL (Tab F-14). Visibility was in excess of ten statute miles (SM) (Tab F-14). The MFL reported similar weather to the official observation, and added that there was lightning in the area, but a clear area over and around the base (Tab V-7.6 to V-7.7). Additionally, runway conditions were wet (Tab AA-68).

c. Space Environment

Not applicable.

d. Operations

The MP was operating within prescribed weather requirements for pilot minimums (Tabs T-4 and BB-30).

8. CREW QUALIFICATIONS

a. Mishap Pilot

The MP was a current and qualified F-16 pilot undergoing MQT (Tab G-1043 and G-1053). The MP had completed Undergraduate Pilot Training (UPT), Introduction to Fighter Fundamentals (IFF), and the Initial Qualification Training (IQT) in the F-16 (Tab G-59, G-400, G-1054, and G-1058). He was a Distinguished Graduate from UPT and earned the Top Gun Award during IFF (Tab G-400 and G-1058). During IQT, the MP was lauded for his work ethic, EP performance, and time management, and with an overall rating of "average" (Tab G-59, G-400, G-1054, and G-1058). During his MQT training program, the MP was graded as "slightly above average" flying performance, with normal syllabus progression (Tab T-7 to T-11).

The MP completed IQT with 72.0 hours, and at the time of the mishap, the MP had 97.5 hours in the F-16 (Tab G-61 and G-1037). Prior to the mishap, the MP had flown twelve night flights in the F-16, including two at Shaw AFB (Tab G-60 to G-399 and G-1044 to G-1045). His two previous night flights had been with the same IP, who, after reviewing his HUD footage, did not have any concerns about his ability to land at night (Tab V-1.3 to V-1.5). He was a weather category four pilot, permitting him to fly instrument approaches with weather better than 700 feet AGL and a visibility of 2 SM or greater (Tabs T-4 and BB-29 to BB-30).

On the night of the mishap, the MP's recent flight time in the F-16CM was as follows: (Tab G-1037)

MP	Hours	Sorties
Last 30 Days	8.6	7
Last 60 Days	12.8	11
Last 90 Days	14.8	13

Since arriving to Shaw AFB on 13 January 2020, the MP had flown twenty flights at Shaw AFB (Tabs G-1044 to G-1045 and T-5). Due to Shaw AFB Corona Virus Disease (COVID) mitigation measures and adverse weather earlier in the upgrade program, the MP had only completed six upgrade events (Tab T-6). The impact of the COVID mitigation measures is evidenced by the MP flying only two hours and two sorties from 60-90 days prior to the mishap (Tab G-1044 to G-1045).

The MP had flown two night sorties in the eight days preceding the mishap, with the most recent flight on 24 June 2020 (Tabs G-1045 and V-1.3). He was current in Night Landings, Precision Approaches, and EP training, but had never attempted AAR prior to the night of the mishap (Tab G-1046 to G-1047 and G-1080).

b. Mishap Element Lead

The MEL was a proficient, qualified and current Instructor Pilot (IP) and was current in AAR and Night Sortie (Tab G-40 to G-41).

c. Supervisor of Flying (SOF)

The SOF was current and qualified to perform SOF duties, and was an F-16 Standardization and Evaluation Flight Examiner (Tabs G-1079, K-35, T-12 and BB-12).

d. Other Pilots

There were no other currency or qualification issues relevant to this investigation.

9. MEDICAL

a. Mishap Pilot

1. Qualifications

At the time of the mishap, the MP was medically qualified for flying duty and required no aeromedical waivers (Tab X-3).

2. Health

The MP received his most recent periodic health assessment on 3 October 2019, and revealed no disqualifying medical conditions (Tab X-3).

3. Pathology

The South Carolina Law Enforcement Division, Forensic Services Laboratory, tested a sample of the MP's blood, and its report indicated the MP's blood was "negative" for ethanol, methanol, acetone, isopropanol, amphetamine, barbiturates, benzodiazepines I, benzodiazepines II, cannabinoids, cocaine metabolites, dextromethorphan, fentanyl, generic opioids, meprobamate, methadone, methamphetamine, opiates, oxycodone I, oxycodone II, phencyclidine, tramadol, tricyclic antidepressants, and zolpidem (Tab X-4). The MP sustained severe injuries on impact with the ground, which resulted in his immediate death (Tab X-4).

4. Lifestyle

There is no evidence to suggest lifestyle factors were a factor in the mishap (Tabs K-5 and X-3).

5. Crew Rest and Crew Duty Time

Due to the nature of the mishap, no 72-hour and 7-day histories were available to fully evaluate activities, behaviors, sleep and nutritional habits, however, review of the preflight ORM worksheet and witness interviews, indicate no concerning factors (Tabs K-5, V-7.18, and V-16.3).

b. Other Crew Members

1. Qualifications

Seven pilots, in addition to the MP, were involved in the mishap flight (OGBH, SOF1, SOF2, TOP3, MEL, MFL, MWG) (Tab X-5). At the time of the mishap, the members were medically qualified for duty and required no aeromedical waivers nor had disqualifying conditions (Tab X-5).

2. Health

The medical review of the records for the seven pilots, revealed no evidence of medical conditions or medications that could have contributed to the mishap (Tab X-5).

3. Pathology

On review of the toxicology reports from the Defense Health Agency, Forensic Toxicology Lab, Dover AFB, Delaware the results were "None Detected" for drugs of abuse panel, ethanol, methanol, isopropanol and acetone for SOF1, SOF2, TOP3, MEL, MFL, MWG, however the OGBH was not tested (Tab X-5).

4. Lifestyle

There is no evidence to suggest lifestyle factors were a factor in the mishap (Tab X-5).

5. Crew Rest and Crew Duty Time

A review of the 72-hour and 7-day histories revealed no evidence that abnormalities existed to have contributed to the mishap (Tab X-5).

10. OPERATIONS AND SUPERVISION

a. Operations

As a COVID mitigation strategy, the 77 FS reduced flying operations in February 2020, and then further reduced to minimal flying in March and April 2020 (Tabs R-42 to R-61 and V-17.9 to V-17.10). Prior to the mishap and in response to a number of pilots failing to comply with established operating parameters and procedures during a return to normal operations, the 77 FS initiated a "Back to Basics" initiative (Tabs R-42 to R-61, R-70 to R-71, R-138, V-1.2 to V-1.3, V-7.3 to V-7.4, V-7.19, V-7.40 to V-7.41, V-9.4, V-11.9, V-12.6, and V-16.5 to V-16.6). Since it was believed by 77 FS leadership that the loss of proficiency was a result of reduced flying operations over multiple months, the initiative required fundamental F-16CM flying skills to be included in each flight brief and debrief (Tab V-1.2 to V-1.3 and V-11.9).

b. Supervision

USAF directives require that MQT students not execute events, such as AAR, at night until they have demonstrated proficiency in "similar events" during the day unless they are scheduled to attempt the events in a dual-cockpit aircraft with an IP (Tab BB-21). The MP was not able to accomplish AAR during IQT, and it was documented on his Air Education and Training Command Form 904 upon leaving the basic course (Tab G-1080). This limitation was not incorporated as a consideration or possible limitation to syllabus events in the 20 OG syllabus (Tabs V-9.3 and BB-31 to BB-62). 77 FS leadership was aware the MP had not accomplished AAR before the sortie, but was not aware of the restriction on night events, and the limitation was violated when the MP attempted to AAR the night of the mishap (Tabs V-7.5, V-7.16, V-7.37, V-7.41, V-8.3, V-10.3, V-11.2 to V-11.3, V-12.3, V-15.7, V-16.4 to V-16.5, and BB-21).

USAF directives require that MQT students not execute events, such as SEAD, at night until they have demonstrated proficiency in "similar events" during the day, unless they are scheduled to attempt the events in a dual-cockpit aircraft with an IP (Tab BB-21). The MP had not accomplished any SEAD events, nor any events "similar" to SEAD, prior to the mishap (Tab T-6). The MP, therefore was not allowed to execute the SEAD mission that was planned and scheduled (Tabs T-6 and BB-21). Furthermore, the 20 OG syllabus specifically authorizes any training sortie during an upgrade to be accomplished at night, and goes on to specify possible adjustments to the syllabus in the case that all primary mission training sorties are accomplished at night, in violation of the MQT limitation discussed above (Tab BB-21 and BB-35). 77 FS leadership was aware the MP had not accomplished SEAD before the sortie, but was not aware of the restriction on night events, and the limitation was violated when the MP was scheduled for a SEAD training sortie the night of the mishap (Tabs V-7.5, V-7.16, V-7.37, V-7.41, V-8.3, V-10.3, V-11.2 to V-11.3, V-12.3, V-15.7, V-16.4 to V-16.5, and BB-21).

USAF directives state that upgrading SOFs must complete a SOF shift under the supervision of an "experienced" SOF, as determined by the local unit supplement (Tab BB-11 to BB-12). The Shaw AFB supplement fails to identify what qualifies as an "experienced" SOF, and in day-to-day operations, any SOF is allowed to supervise upgrading SOFs (Tabs V-8.7 and BB-17 to BB-18).

USAF directives require each unit to specify who is certified to upgrade SOFs in their own supplement to the AF directive (Tab BB-10 to BB-11). At this time, the Shaw AFB supplement does not specify who is permitted to upgrade SOFs, and in practice, any SOF is allowed to (Tabs V-8.7 and BB-16 to BB-18).

USAF directives state that OG/CCs will ensure that SOF training includes a "thorough review" of CH procedures (Tab BB-11). The SOF upgrade program at Shaw AFB includes fourteen separate tasks in addition to two supervised SOF shifts (Tab BB-18). During the upgrade, SOFs are only exposed to the CH procedure briefly, in two ways. 1) One of those fourteen tasks is a review of "Local Guidance" which includes, among other things, the SOF QRC, where CH is one of 37 referenced responses. 2) Another of those fourteen tasks includes a SOF test with thirty questions, where two questions briefly discuss the procedure (Tab BB-18, BB-63, and BB-69 to BB-72). The upgrade does not require a practice call, nor is there a required periodic test of the system (Tabs V-8.8 and BB-17 to BB-18)

11. HUMAN FACTORS ANALYSIS

a. Introduction

The AIB considered all factors presented in the Department of Defense Human Factors Analysis and Classification System 7.0 (HFACS) (Tab BB-82 to BB-90). This list includes potential human factors that play a role in aircraft mishaps and identifies potential areas of further assessment during an investigation (Tab BB-83). Having this systematic approach enables investigation boards to better classify variables that could affect human performance. The taxonomy classifies potential factors into either active failures or latent failures. Active failures are actions (or inactions) by the individual that are causative or contributory to the mishap. Latent failures are conditions that exist within a supervisory or organizational level. The four identified factors listed below represent human factors that contributed to the mishap (Tab BB-83 to BB-90).

b. AE103 Procedure Not Followed Correctly

HFACS code AE103 is a factor when a procedure is performed incorrectly or accomplished in the wrong sequence (Tab BB-87).

At approximately 1.8 nm from the runway threshold, the MP incorrectly steepened his descent angle from 2.82 degrees to 4.5 degrees until reaching a 2.5-degree approach directed at the 1000 FT Light Bar of the ALS (Tab FF-3).

c. PE101 Environmental Conditions Affecting Vision

HFACS code PE101 is a factor that includes obscured windows; weather, fog, haze, darkness; smoke, etc.; brownout/whiteout (dust, snow, water, ash or other particulates); or when exposure to windblast affects the individual's ability to perform required duties (Tab BB-88).

The mission, including MP's first time conducting AAR, was at night (Tabs BB-21 and G-1080).

d. PC106 Distraction

HFACS code PC106 is a factor when the individual has an interruption of attention and/or inappropriate redirection of attention by an environmental cue or mental process (Tab BB-89).

The MP, twice, verbally expressed frustration with himself as heard on the MA's cockpit voice recording regarding AAR failure (Tabs AA-26 and AA-40). The first time was during the AAR attempt, and the second while descending for the final approach to Shaw AFB (Tab AA-26 and AA-41). In addition, the MEL made supportive comments during the flight back to Shaw AFB, because he knew the MP was disappointed they were returning home early (Tab AA-41). The first comment was a lighthearted comment, "That was not the way to start your tanking experience. That was really challenging" (Tab AA-41). The MP answered these comments by saying, "no excuse" (Tab AA-41).

e. SI001 Supervisory/Command Oversight Inadequate:

HFACS code SI001 is a factor when the availability, competency, quality or timeliness of leadership, supervision or oversight does not meet task demands. Inappropriate supervisory pressures are also captured under this code (Tab BB-90).

USAF directives dictate that MQT student will accomplish tasks, such as AAR, in the day prior to accomplishing similar events at night (Tab BB-21). The MP had not accomplished day AAR prior to being scheduled for night AAR (Tab G-1080).

Additionally, the SOF's decision to not call the aircraft manufacturer through CH procedures for technical assistance, resulted in a decision to attempt an approach-end cable arrestment with less than favorable conditions in lieu of a controlled ejection (Tab AA-53, AA-55, AA-57, AA-61, and AA-66 to AA-67).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 51-307, *Aerospace and Ground Investigations*, dated 18 March 2019 (Incorporating Air Force Guidance Memorandum 2020-01, dated 26 February 2020)
(2) AFI 11-418, *Operations Supervision*, dated 28 February 2020
(3) AFMAN 11-2F-16, Volume 1, *F-16 Aircrew Training*, dated 17 June 2019
(4) AFMAN 11-2F-16, Volume 3, *F-16 Operations Procedures*, dated 4 February 2020

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

b. Other Directives and Publications Relevant to the Mishap

1. AFI 90-802, *Risk Management*, dated 1 April 2019
2. AFI 11-202, Volume 3, Air Combat Command (ACC) Supplement, *General Flight Rules*, dated 10 August 2016
3. 20th Operations Group (OG) Operating Instructions (OI) 11-2F16, Volume 1, *F-16 Pilot Training*, dated 22 April 2020

c. Known or Suspected Deviations from Directives or Publications

1. AFMAN 11-2F-16, Volume 1, *F-16 Aircrew Training*, dated 17 June 2019, paragraph 3.2.2.3. Although MQT students are to demonstrate proficiency and currency in day events prior to training in similar events at night, the MP was scheduled for AAR and SEAD training at night before attempting those events during the day. (Tabs V-7.5, V-7.16, V-7.37, V-7.41, V-8.3, V-10.3, V-11.2 to V-11.3, V-12.3, V-15.7, V-16.4 to V-16.5, and BB-21)

2. AFI 11-418, *Operations Supervision*, dated 28 February 2020, paragraph 5.4.5. Although unit commanders are required to define who is certified to upgrade other aircrew members to SOF in the unit supplement to AFI 11-418, the Shaw AFB

supplement does not specify who is permitted to upgrade SOFs (Tabs V-8.7 and BB-16 to BB-18).

3. AFI 11-418, *Operations Supervision*, dated 28 February 2020, paragraph 5.5.4. Although the unit supplement to AFI 11-418 is to define a "current and experienced SOF" for the purposes of upgrading other SOFs, the Shaw AFB supplement does not define or specify who is a current or experienced SOF (Tabs V-8.7 and BB-17 to BB-18).

16 OCTOBER 2020

RANDAL K. EFFERSON
Major General, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

F-16CM, T/N 94-0043
Shaw Air Force Base, South Carolina
30 June 2020

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 30 June 2020, the mishap pilot (MP, Meat 44), flying F-16CM tail number (T/N) 94-0043, assigned to the 77th Fighter Squadron (77 FS), 20th Fighter Wing (20 FW), Shaw Air Force Base (AFB), South Carolina, engaged in a night Mission Qualification Training (MQT) flight near Shaw AFB. During the recovery and landing phase of the mission, at approximately 2226 local time (L), the mishap aircraft's (MA) landing gear was damaged in an initial landing attempt at Shaw AFB. In a subsequent landing attempt, at approximately 2259L, the MA departed the runway after an unsuccessful emergency cable arrestment and the MP was fatally injured during an unsuccessful ejection.

The mishap flight was planned as a 4-ship night MQT suppression of enemy air defenses mission with pre-strike air-to-air refueling (AAR) from a KC-135 Stratotanker. The first three F-16s of the mishap flight, which included the mishap flight lead (MFL), mishap wingman (MWG), and mishap element lead (MEL) refueled without incident, but the MP was unsuccessful. Therefore, the MEL and MP returned to Shaw AFB due to the MA's lower fuel state and flew the instrument recovery procedure for runway 22R. During the final phase of landing the MA struck the localizer antenna array short of the runway threshold, severely damaging the left main landing gear and hydraulic system. After briefly touching down in the underrun, the MP executed a go-around and alerted the MEL and air traffic control (ATC) personnel of the situation.

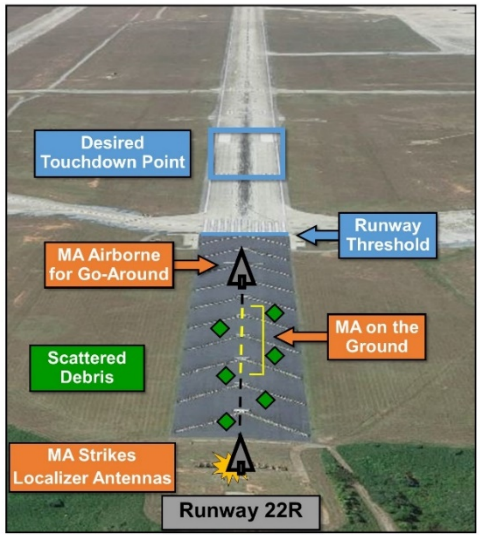

Figure 1: Mishap Aircraft Initial Landing

An approach-end cable arrestment on runway 04L was attempted following more than twenty minutes of discussion. During the maneuver, the MA tail hook did not catch the cable and the left wing fell to the runway, dragging the aircraft to the left. The MP initiated an ejection, but the ejection seat malfunctioned and the parachute did not deploy. The MP was fatally injured and the MA was destroyed.

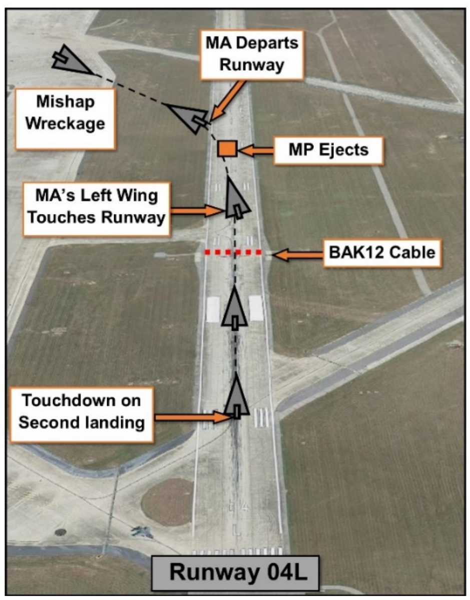

Figure 2: Mishap Aircraft on second landing

I find by a preponderance of evidence the cause of the mishap was the MP's failure to correctly interpret the approach lighting system (ALS) and identify the runway threshold during his first landing attempt, which resulted in severely damaged landing gear. Additionally, I find by a preponderance of evidence two factors substantially contributed to the mishap: (a) the SOF chose not to consult the aircraft manufacturer, which resulted in the decision to attempt a cable arrestment in lieu of a controlled ejection and (b) a series of ejection seat malfunctions occurred, which resulted in the MP impacting the ground while still in the ejection seat.

I developed my opinion by carefully considering the standard of proof for a preponderance of evidence and the requirements for causes and substantially contributing factors. I analyzed available flight data, the Lockheed Martin crash report, witness testimony, engineering analysis, Air Force technical orders, regulations, and guidance.

2. CAUSE

I find by a preponderance of evidence the cause of the mishap was the MP's failure to correctly interpret the ALS and identify the runway threshold during his first landing attempt, which resulted in severely damaged landing gear. Evidence also indicates the MP was not fully engaged on the challenges of flying a night instrument approach due to his unsuccessful attempt to conduct his first ever AAR at night, which is not allowed by Air Force regulations.

On the night of the mishap, all airfield systems were in good working order, to include the procedure known as the Instrument Landing System (ILS) Y 22R, all approach lights, runway identification lights, and the precision approach path indicator (PAPI) lighting system. Based on the cloud ceiling being above 3,000 feet above ground level (AGL) and visibility greater than 10 statute miles (sm), the MA was in visual meteorological conditions during the entire approach. The MP successfully followed the ILS Y 22R, to a point where the MA was on course, on glide path, and the ALS was visible in the MA's Heads-Up Display (HUD). In this case, the ALS and PAPI were identifiable in the HUD at approximately 2 nm. From this point, the MP flew a normal approach, but he mistook the 1000 FT Light Bar for the runway threshold lights, resulting in the MA striking the ILS antennas located 1,076 feet before the runway threshold. Immediately after striking the antennas, the MP executed a go-around and relayed to the MEL and ATC personnel that he "landed short."

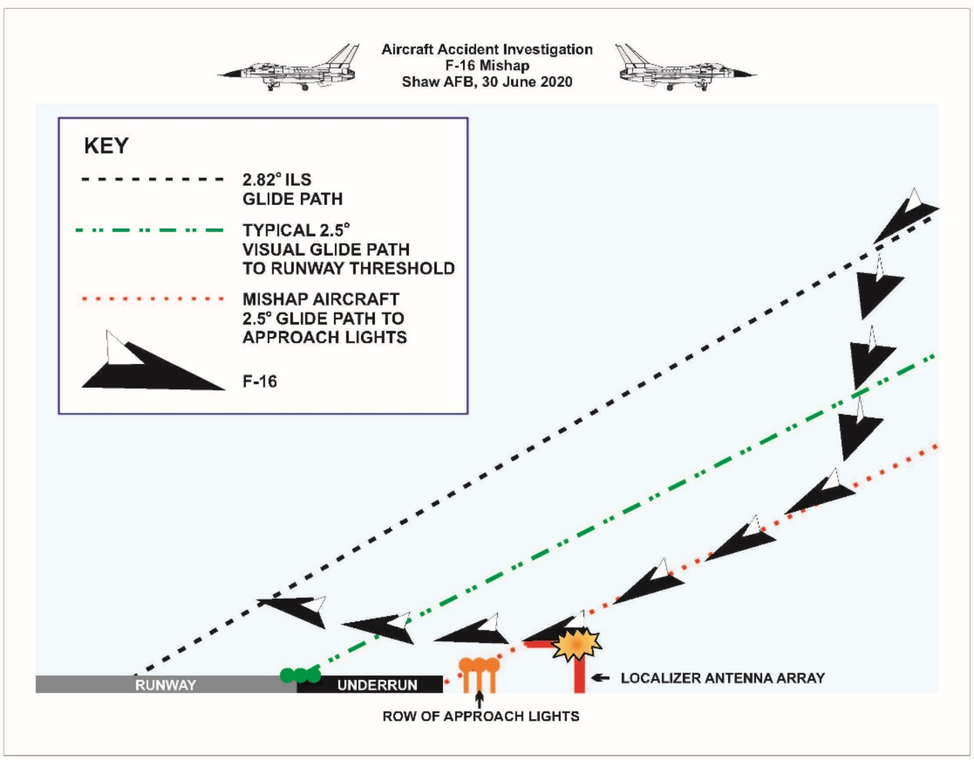

Figure 3: ILS glidepath, Intended glidepath, and MP glidepath

Prior to the mishap, all instructor pilot (IP) interactions with the MP during his MQT program yielded positive opinions and his training progression was normal. The MP was familiar with the approach lighting at Shaw AFB, having flown two night missions during the week prior to the mishap. The same IP flew both previous night missions and, after reviewing cockpit video in debriefing, had no concerns about the MP's landing technique.

I believe the MP was distracted and dwelling on his earlier unsuccessful AAR attempt, which may have contributed to misinterpreting runway visual cues. On the night of the mishap, the direct impact of the MP's unsuccessful AAR was two aircraft returning home early, meaning the entire mission was ineffective for training purposes. The MP was a distinguished graduate from undergraduate pilot training and had a solid performance record. I believe he did his absolute best during his first ever AAR attempt, and was disappointed with his performance. The MP twice verbally expressed frustration with himself, as heard on the MA's cockpit voice recording. The first time was during his AAR attempt and again while descending for the final approach to Shaw AFB. In addition, the MEL made two supportive comments on the way back to Shaw AFB because he knew the MP was disappointed they were returning home early. The first was a lighthearted comment, "that was not the way to start your tanking experience," followed by "that was really challenging." The MP responded to these comments in a lighthearted tone by saying, "no excuse." These comments were made eight minutes before damage to the MA occurred, so the AAR failure was still in the forefront of the MP's thoughts.

AAR is a precision formation event that must be learned and practiced to gain and maintain proficiency. The MFL and the MEL were both experienced and proficient IPs, and only took a few minutes each to receive their planned offload of fuel. However, the MWG was inexperienced, with this being only his second time to AAR and first time at night. The MWG took approximately ten minutes, had several bobbles that resulted in disconnecting from the tanker, and his experience ended after receiving less than the planned amount of fuel, but was able to continue the mission. The MP also took ten minutes, but was not able to stabilize the MA in relation to the tanker long enough to refuel before being forced to return to base. This was the MP's first time trying to AAR and it was at night, complicating an already difficult task. However, the MP completed the B-course without AAR experience, pushing the responsibility to the 20 FW. The deficiency is documented in the MP's Air Education Training Command Form 904 training record. To account for the increased demands and pilot workload that flying at night causes, Air Force Instructions mandate that proficiency in missions/events such as SEAD and AAR must be demonstrated in the daytime before attempting them at night. Air Force Instructions do allow for a first event at night, but only if it is conducted in a dual-control aircraft with an IP aboard the same aircraft. Even though the 77 FS leadership was aware this was the MP's first attempt at SEAD and AAR, they were unaware of the restrictions imposed by Air Force Instructions. The MFL and 77 FS leadership displayed an additional lack of awareness and attention to detail in assessing overall mission risks when filling out the 20 OG risk management worksheet that is required for all flights. The miscalculation resulted in assessing the mission at a lower risk level than it actually was, which allowed the 77 FS commander to be the approval authority. In reality, the approval authority should have been the 20 OG commander, which may have provided a final opportunity to question why the MP was scheduled for a mission he was not ready for or authorized to fly.

It is my opinion the MP mistook the approach lights for the runway threshold lights due to preoccupation with his earlier failure to accomplish AAR and SEAD training. Unfortunately, the MP should have never been scheduled to fly this mission at night.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

I find by a preponderance of evidence two factors substantially contributed to the mishap: (a) the SOF chose not to consult the aircraft manufacturer, which resulted in the decision to attempt a cable arrestment in lieu of a controlled ejection and (b) a series of ejection seat malfunctions occurred, which resulted in the MP impacting the ground while still in the ejection seat.

a. SOF decision to not call the aircraft manufacturer

I believe the SOF's decision to not call the aircraft manufacturer for technical assistance directly resulted in a decision to attempt an approach-end cable arrestment with less than favorable conditions in lieu of a controlled ejection. Specifically, the Air Force, in coordination with Lockheed Martin (LM), provides a dedicated hotline that an F-16 SOF, at any location around the world, can call for technical assistance when experiencing an in-flight emergency (IFE), which may not be specifically addressed in the pilot checklist. The program is known as the Conference Hotel (CH) procedure and was available at the time of the mishap. Following initial damage, the MA had more than thirty minutes of fuel remaining to troubleshoot the problem, so I assess there was time available to seek CH assistance. The critical items of the emergency were identified approximately six minutes after the initial damage occurred. The MA had a broken left main landing gear and system B hydraulic failure. Within two minutes, the SOF verbalized the two possible courses of action (COAs), which were to consider a controlled ejection or attempt an approach-end cable arrestment. The conditions that would favor one COA over the other COA were not discussed and the possibility of a controlled ejection was not mentioned again.

In accordance with Air Force instructions, the SOF is the focal point for command and control of flight operations. The Operations Group Commander (OG/CC) decision authority is delegated to the SOF to accomplish the mission. As the OG/CC's representative, the SOF ensures that IFE recovery plans and weather-related mission changes reflect sound airmanship, follow established guidance, and adhere to sound operational risk management principles (i.e., Does it make sense?). The SOF directs appropriate actions to correct/prevent unsafe situations. This includes the use of all resources to include radios, telephone hot lines, and all wing-flying operations on the ground or in the air. During an IFE or an abnormal situation, the SOF provides aircrews with guidance, timely advice and assistance to determine a correct COA.

During the mishap, the SOF had immediate access to a quick reaction checklist (QRC) that contains a reminder to consider the CH program as part of the emergency response and a procedure for conducting the call. This information is also in Air Force instructions, which mandate that all SOFs are to conduct a thorough review of CH procedures during their SOF upgrade training. The SOF was familiar with CH procedures, and reviewed them with an upgrading SOF earlier in his shift. However, he did not think a CH consult was needed on the night of the mishap, because the situation matched the F-16CM flight manual checklist for Landing with a Landing Gear Unsafe/Up. It should be noted that there is a generic discussion in the F-16CM flight manual addressing landing gear malfunctions. Specifically, it states, “Because of the number of possible malfunctions, specific procedures for every situation are not feasible. If time and conditions permit, ground supervisory and technical assistance should be requested.” Air Force instructions give the SOF authority to direct actions and request assistance from anyone required. Multiple personnel were available during flying operations to include the OG/CC or designee, the 77 FS Operations Supervisor (Top 3), and the upgrading SOF who was sitting next to the SOF in the control tower. All of these individuals were qualified F-16 pilots and briefed on details of the IFE, and they could have been asked to initiate a CH phone call. The upgrading SOF later stated he thought about the merits of executing a CH, but he did not verbalize it.

After the mishap, flight safety engineers from LM stated the mishap scenario did not match the Landing with Landing Gear Unsafe/Up checklist. The flight safety engineers explained that the pilot checklist for Unsafe/Up Landing Gear only applies if a landing gear fails to extend normally, and not when it is damaged or hanging. Had a CH been initiated, a LM flight safety engineer would have provided readily available information on two previous mishaps where F-16s experienced almost identical damage to the left main landing gear and associated hydraulic system. Both situations occurred in the daytime and resulted in a decision to execute a controlled ejection in lieu of attempting an approach-end cable arrestment. In both cases it was assessed that damaged and hanging landing gear could potentially interfere with or greatly reduce the chances of a successful cable engagement. Therefore, the LM flight safety engineers said that in this scenario it is unknown whether an F-16 with similar damage to the MA can safely engage an approach-end arresting cable.

If the SOF, MEL, and MP had this knowledge, I believe they would have made the decision to execute a controlled ejection in the locally designated area. I base this on the belief that the aforementioned historical data would have been combined with the fact that this was at night, the MP was inexperienced, and had just landed short during a normal landing.

b. Ejection seat malfunction

The MP was fatally injured during an ejection due to a failure in the digital recovery sequencer (DRS), which resulted in the MP impacting the ground while still in the ejection seat. It is my opinion that a lack of available parts resulted in delayed implementation of the TCTO designed specifically to address a known problem in the ACES II ejection seat, which occurred during this ejection.

The F-16 is equipped with the advanced concept ejection seat (ACES II) and is capable of providing aircrew with an escape option utilizing three modes of operation. The mode is automatically selected when the pilot initiates an ejection, depending on aircraft speed and altitude. Mode 1 operation is for relatively low speeds and altitudes. Modes 2 and 3 are for progressively higher altitudes and/or airspeeds. The MP initiated an ejection on the runway, in approximately 16 degrees of left bank and 129 nautical miles per hour (knots), resulting in a Mode 1 ejection sequence. Post-mishap analysis confirmed that these parameters are within the performance envelope for the ACES II and should have resulted in a successful ejection sequence.

The ACES II uses a series of initiators and gas pressure to retract and hold the pilot in a proper posture, jettison the cockpit canopy, and fire the ejection seat catapult rocket. The catapult rocket further provides gas pressure to activate a power module (PM), consisting of thermal batteries, which provide electrical current to power the DRS. While the ejection seat is exiting the aircraft and as the bottom of the seat nears the top of the guide rails, a sequence start switch activates, beginning an internal DRS timing circuit that triggers follow on actions. Flight information then determines the ejection mode and the DRS should send signals to fire a series of up to seven pyrotechnic devices. During the MP's Mode 1 ejection, six pyrotechnic devices should have fired, yielding a parachute in less than two seconds, but the devices did not fire.

Preliminary analysis indicates that the thermal batteries providing power to the DRS reached sufficient temperature, but no DRS initiated events occurred. DRS actuated pyrotechnics sequence actions are required to stabilize the seat during ejection, deploy the recovery parachute, and separate the crewmember from the seat. Post-accident analysis also showed that the lower portion of the ejection seat liberated during ground impact, effectively pulling the emergency manual parachute deployment handle (EMPDH). At this point, the MP was released from the seat and the recovery parachute began deployment. According to ejection seat performance simulations, it may have been possible but highly unlikely, that the MP would have had 3.4 seconds after ejection to recognize the failure, pull the EMPDH, and deploy the parachute. The theoretical 3.4 seconds would have been further reduced because a pilot normally experiences between 9-14 times the force of gravity (G-force) during an ejection event, which results in a brief period of incapacitation and disorientation. Therefore, the MP theoretically had 1-2 seconds for action.

A somewhat similar DRS failure occurred on 20 October 2014, when a Tulsa Air National Guard F-16C pilot ejected near Moline, Kansas. In that mishap, the DRS successfully sent firing signals to stabilize the ejection seat, but neither pilot/seat separation or parachute deployment occurred. The pilot ejected at 7,500 feet AGL, was able to recognize the failure, and pull the EMPDH, thus separating him from the seat and deploying his parachute. The Tulsa pilot was highly experienced, ejected in an uncontrolled situation during daylight hours, took four seconds to recognize the failure, and survived with minor injuries. Following the 2014 DRS failure, a time compliance technical order (TCTO) 11P2-3-502, *Installation of the Shorting Plug on the DRS Electronic Module*, was issued on 20 January 2016. The shorting plug was designed to prevent noise bias issues observed in channel three of a three-channel system. Two channels are required to be in agreement for the DRS to function properly. Channel three noise bias issues have been observed in approximately 9% of all live ejections and sled tests. TCTO instructions allowed for installation of the shorting plug during regularly scheduled 36-month maintenance/inspections.

Following issuance of the 2016 shorting plug TCTO the first opportunity for installation on the MA was in August 2017. This was the regularly scheduled 36-month ejection seat maintenance/inspection, but TCTO shorting plug parts were not available, so the next installation date was moved three years to August 2020. In addition, the ten-year shelf/service life of the DRS installed in the MA expired in February 2019, but received three temporary service life extensions, extending it to 31 July 2020. All extensions were coordinated and approved by the Air Force Life Cycle Management Center. There was a small window of opportunity to replace the MA DRS in May 2020 with a newer system, which replaces the DRS and does not require a TCTO shorting plug. The newer system, known as the Modernized ACES II Seat Sequencer (MASS), became available in May 2020, but in order to consolidate maintenance actions, a request was granted to move the MASS installation to the July-August 2020 timeframe. Engineers have assessed that the

MA's DRS had critical failures in both channel two and three. Therefore, ejection seat engineers have confirmed that earlier installation of the TCTO should have prevented the channel three noise issue, allowing channel one and three to communicate normally, so the ejection seat would have functioned properly.

When considering the overall decision to attempt a cable engagement or execute a controlled ejection from 2,000-3,000 feet AGL, any ejection event would have forced the MP to overcome a malfunctioning ejection seat. However, ejecting between 2,000-3,000 feet AGL, per local procedures, would have given the MP 13-18 seconds to identify the malfunction and potentially pull the EMPDH. The F-16CM flight manual contains a warning that states if the pilot has time to realize that seat separation has not taken place, a failure has probably occurred and manual seat separation should be performed.

In my opinion, a lack of available parts resulted in delayed implementation of the TCTO designed specifically to address the ejection seat failure, which occurred during this mishap.

4. CONCLUSION

I find by a preponderance of evidence the cause of the mishap was the MP's failure to correctly interpret the ALS and identify the runway threshold during his first landing attempt, which resulted in severely damaged landing gear. Additionally, I find by a preponderance of evidence two factors substantially contributed to the mishap: (a) the SOF chose not to consult the aircraft manufacturer, which resulted in the decision to attempt a cable arrestment in lieu of a controlled ejection and (b) a series of ejection seat malfunctions occurred, which resulted in the MP impacting the ground while still in the ejection seat.

16 OCTOBER 2020

RANDAL K. EFFERSON
Major General, USAF
President, Accident Investigation Board

INDEX OF TABS