

UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT



F-16C, T/N 86-0317

176TH FIGHTER SQUADRON
115TH FIGHTER WING
TRUAX FIELD AIR NATIONAL GUARD BASE, WISCONSIN



LOCATION: HIAWATHA NATIONAL FOREST, MICHIGAN

DATE OF ACCIDENT: 8 DECEMBER 2020

BOARD PRESIDENT: BRIGADIER GENERAL DAVID W. SMITH

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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29 APR 2021

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 8 December 2020 fatal mishap involving an F-16C, T/N 86-0317, 115th Fighter Wing, complies with applicable regulatory and statutory guidance, and on that basis it is approved.

MARK D. KELLY
General, USAF
Commander

A handwritten signature in black ink, appearing to be "D", written next to the typed name and title.

People First... Mission Always...

**EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION**

**F-16C, T/N 86-0317
HIAWATHA NATIONAL FOREST, MICHIGAN
8 DECEMBER 2020**

On the night of 8 December 2020, at approximately 19:17 local time (L), the mishap aircraft (MA), an F-16C, tail number (T/N) 86-0317, crashed into a wooded area in the Hiawatha National Forest in Michigan. The mishap pilot (MP) was operating out of the 115th Fighter Wing, Truax Field Air National Guard Base, Wisconsin (WI) while conducting a practice Aerospace Control Alert (ACA) mission. Upon impact, the mishap resulted in fatal injuries to the MP and destruction of the MA.

The mishap flight was planned as a 2-ship night practice ACA mission, to include an air-to-air intercept supported by the WI Civil Air Patrol (CAP) as a Track of Interest. Due to weather conditions in Green Bay, the small CAP aircraft cancelled the intercept portion of the flight and the mishap sortie launched as a 2-ship practice scramble on a back-up instrument profile. Shortly after takeoff, upon terminating the practice scramble, the MP observed a global positioning system (GPS) degradation due to the absence of satellite tracking data. The MP elected to perform an inflight alignment of the inertial navigation system (INS). While troubleshooting the GPS no track and during the inflight alignment, the mishap element performed a lead swap. Shortly after a positive change in roles, the MA entered weather conditions, and the MP lost visual contact with the mishap wingman (MW). The MP and MW established de-confliction via vertical and horizontal means. Subsequently, the MA went into a series of heading, altitude, and attitude changes. Estimated outer boundaries of the flight envelope included 90 degrees nose low attitude, 135 degrees of right bank, and 600 knots airspeed, culminating with an extreme attitude that terminated with controlled flight into terrain. There was no attempt to eject by the MP.

The Accident Investigation Board President found, by a preponderance of the evidence, the cause of the mishap was the MP's failure to effectively recover from spatial disorientation. Further, the combination of night, weather conditions, the use of NVGs, low illumination, the MA's altitude, attitude and airspeed, as well as the MP's breakdown in visual scan of the available primary and standby instrumentation impacted the MP's ability to recognize, confirm, and recover from the unusual attitude created by the spatially disorienting event. The Board President also found, by a preponderance of the evidence, two substantially contributing factors: fixation and a degraded GPS satellite tracking system.

“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-16C, T/N 86-0317
HIAWATHA NATIONAL FOREST, MICHIGAN
8 DECEMBER 2020

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ACRONYMS AND ABBREVIATIONS

115 FW	115th Fighter Wing	HFACS	Human Factors Analysis and Classification System
176 FS	176th Fighter Squadron	HUD	Heads-Up Display
A/A TACAN	Air-to-Air Tactical	IAW	In Accordance With
	Air Navigation System	IFA	Inflight Alignment
ACA	Aerospace Control Alert	IMDS	Integrated Maintenance Data System
ACC	Air Combat Command	INS	Inertial Navigation System
ADI	Attitude Direction Indicator	kts	Knots
AFE	Aircrew Flight Equipment	L	Local Time
AFI	Air Force Instruction	LIS	Line-In-The-Sky
AFMAN	Air Force Manual	MA	Mishap Aircraft
AFSEC	Air Force Safety Center	MF	Mishap Flight
AFTO	Air Force Technical Order	MFL	Maintenance Fault List
AGL	Above Ground Level	MI	Michigan
AIB	Accident Investigation Board	MP	Mishap Pilot
ALOW	Adjustable Altitude Low	MSL	Mean Sea Level
ANGB	Air National Guard Base	MW	Mishap Wingman
AOA	Angle Of Attack	NATO	North Atlantic Treaty Organization
ARMS	Aviation Resource Management System	NM	Nautical Miles
ATAGS	Advanced Tactical Anti-G System	NTRK	No Track
CAP	Civil Air Patrol	NVG	Night Vision Goggles
CARA	Combined Altitude Radar Altimeter	ORM	Operational Risk Management
CDM	Climb Dive Marker	PFD	Primary Flight Display
CDU	Center Display Unit	PHA	Physical Health Assessment
CSMU	Crash Survivable Memory Unit	PR	Pre-Flight
DoD	Department of Defense	RWR	Radar Warning Receiver
DVR	Digital Video Recorder	SADL	Situation Awareness Data Link
EADS	Eastern Air Defense Sector	SAR	Search and Rescue
EGI	Embedded GPS/INS	SME	Subject Matter Expert
FPM	Flight Path Marker	T/N	Tail Number
ft	Feet	TCTO	Time Compliance Technical Order
G	Gravitational Force-Equivalent	TO	Technical Order
GAAF	Ground Avoidance Advisory Function	TOI	Track Of Interest
GCAS	Ground Collision Avoidance System	WAI	Walk-Around Inspections
GPS	Global Positioning System	WI	Wisconsin

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

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 11 December 2020, General Mark D. Kelly, Commander of Air Combat Command (ACC), appointed Brigadier General David W. Smith to conduct an Accident Investigation Board (AIB) for the 8 December 2020 mishap involving an F-16C aircraft, tail number (T/N) 86-0317, which was assigned to the 176th Fighter Squadron, 115th Fighter Wing, Truax Field Air National Guard Base (ANGB), Wisconsin (WI) (Tabs FF-6 to FF-7). The investigation occurred at Truax Field ANGB, WI from 3 February 2021 through 26 February 2021. Additionally, General Kelly appointed the following board members to assist in the investigation: a Major legal advisor, a Major medical member, a Captain pilot member, a Chief Master Sergeant maintenance member, a Master Sergeant maintenance member, and a Staff Sergeant recorder (Tabs FF-4 to FF-5). Three (3) subject matter experts were appointed: a Lieutenant Colonel F-16 systems lead, a Captain physiologist, and a DoD civilian F-16 aerospace engineer (Tabs FF-8 to FF-10).

b. Purpose

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

2. ACCIDENT SUMMARY

On the night of 8 December 2020, at approximately 19:17:37 local time (L), the mishap aircraft (MA), an F-16C aircraft, T/N 86-0317, crashed into a wooded area in the Hiawatha National Forest in Michigan (MI) (Tab M-7). The mishap pilot (MP) was operating out of the 176th Fighter Squadron, 115th Fighter Wing, Truax Field ANGB, WI while conducting a practice Aerospace Control Alert (ACA) mission (Tab K-4). Upon impact, the mishap resulted in fatal injuries to the MP (Tabs S-3 to S-10 and Y-55). The MA was destroyed, and no damage to non-Department of Defense (DoD) property occurred (Tabs O-2 and S-3 to S-10).

The mishap flight (MF) was planned as a 2-ship night practice ACA mission, to include an air-to-air intercept supported by the WI Civil Air Patrol (CAP) as a Track of Interest (TOI) (Tab R-270). Due to weather conditions in Green Bay and the small Cessna aircraft used by CAP, the CAP aircraft cancelled the intercept portion of the sortie and the MF launched as a 2-ship practice scramble on a back-up instrument profile (Tabs R-269 and U-5). Shortly after takeoff, upon completing the practice scramble, the MP observed a global positioning system (GPS) degradation due to the absence of satellite tracking data (Tab T-40). The MP elected to perform an inflight alignment (IFA) of the inertial navigation system (INS) (Tab T-40). While troubleshooting the GPS no track (NTRK) and during the IFA, the MF performed a lead swap (Tab T-40). Shortly

after a positive change in roles, the MA entered broken clouds and lost visual contact with the mishap wingman (MW) (Tab T-40). The MP and MW established de-confliction via vertical and horizontal means (Tab T-40). Subsequently, the MA went into a series of heading, altitude, and attitude changes (Tab T-40). Estimated outer boundaries of the flight envelope included 90 degrees nose low attitude, 135 degrees of right bank, and 600 knots (kts) airspeed, culminating with an extreme attitude that terminated with controlled flight into terrain (Tab T-42). There was no attempt to eject by the MP (Tab J-14).

3. BACKGROUND

a. Air Combat Command (ACC)

ACC is one of ten major commands in the United States Air Force (Tab CC-2). To support global implementation of national security strategy, ACC operates fighter, reconnaissance, battle-management and electronic combat aircraft (Tab CC-2). It also provides command, control, communications and intelligence systems and conducts global information operations (Tab CC-2). The command operates more than 1,000 aircraft, 35 wings, 12 bases, and has more than 300 worldwide operating locations with 95,270 total force active-duty and civilian personnel (Tab CC-2).



b. 115th Fighter Wing (115 FW)

The 115 FW has two distinct missions (Tab CC-6). The Federal mission is to staff and train flying and support units to augment ACC fighter forces to effectively and rapidly project F-16 combat power anywhere in the world to perform wartime or peacetime missions as well as operations other than war (Tab CC-6). The State mission is to provide trained and equipped units to protect life and property and to preserve peace, order, and public safety as directed by the Governor of Wisconsin (Tab CC-6).



c. 176th Fighter Squadron (176 FS)

The 176 FS organized at Truax Field in 1948 (Tab CC-9). In 1992, the unit re-designated under the newly formed ACC, and it began converting to the F-16 aircraft (Tab CC-9). The unit began supporting the Global War on Terrorism on 11 September 2001 (Tab CC-10). The unit was tasked to provide homeland defense under the operational command of the North American Aerospace Defense Command (Tab CC-10). From 2004 to 2008, the unit supported Operation Iraqi Freedom, Operation Jump Start, and Hurricane Katrina relief (Tab CC-10).



d. F-16 – Fighting Falcon

The F-16, Fighting Falcon, is a compact, multi-role fighter aircraft (Tab CC-11). The aircraft is highly maneuverable and has proven itself in air-to-air combat and air-to-surface attack (Tab CC-11). In an air combat role, the F-16's maneuverability and combat radius exceed that of all potential threat fighter aircraft (Tab CC-11). Since 11 September 2001, the F-16 has been a major component of the combat forces committed to the war on terrorism, flying thousands of sorties in support of Operation Noble Eagle (Homeland Defense), Operation Enduring Freedom in Afghanistan, and Operation Iraqi Freedom (Tab CC-12).



4. SEQUENCE OF EVENTS

a. Mission

The MF consisted of two (2) pilots, the MP and MW, each flying an F-16C aircraft (Tab K-4). Initially, the MF mission consisted of an ACA practice scramble with CAP providing support as a TOI (Tab R-269). CAP cancelled the planned flight because local weather conditions were not suitable for the small Cessna CAP aircraft (Tabs R-270 and U-5). The MF adjusted the mission plans, to include a practice scramble with a routine backup instrument profile (Tabs K-2 and R-271). The instrument profile included practice approaches at Sawyer International Airport, MI and Chippewa Valley Regional Airport, WI (Tabs K-2 and R-271).

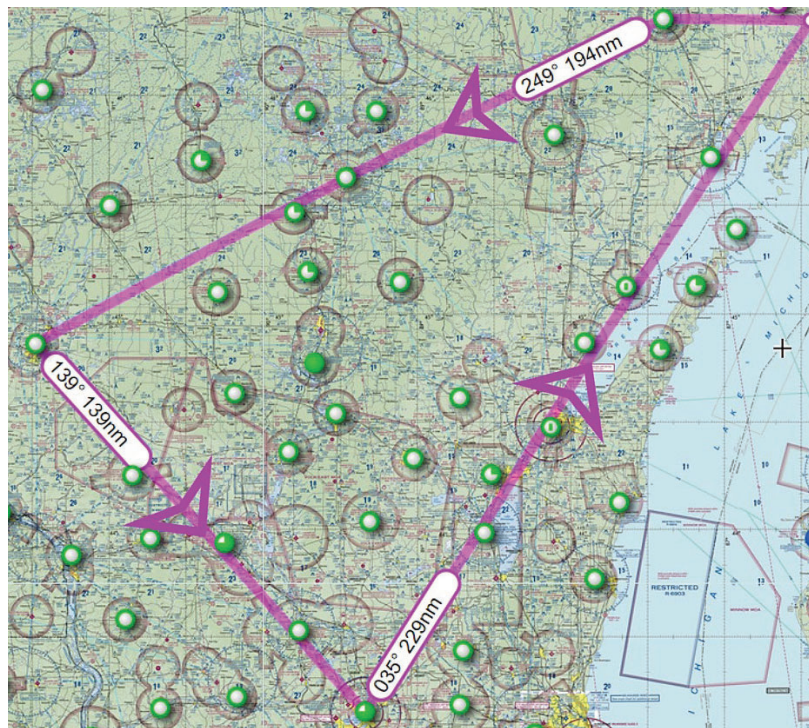


Figure 1: Mishap Flight Operating Area (Tabs K-2, R-271, and T-18)

b. Planning

The MP arrived at the alert facility on the day of the mishap and received the changeover brief at 12:25L (Tab R-268). The MP and MW completed the MF's operational risk management (ORM) form and also signed the Aviation Resource Management System (ARMS) Fighter Flight Authorization form (Tabs K-3 to K-4). ORM for the flight fell into the "Elevated Risk" notification level according to the 115 FW ACA deliberate risk management worksheet, which evaluates risk based on mission, environment, and person (pilot) categories (Tab K-4). At 17:00L, the MP conducted a flight briefing with the MW using the standard briefing guide, commonly utilized within the squadron (Tab R-272). The briefing covered the specifics of the flight, to include arming, the weather conditions, and the planned approaches (Tabs R-272 to R-275).

c. Preflight

The MP and MW donned flight equipment, to include advanced technology anti-G suits (ATAGS) and anti-exposure suits (Tab R-274). The MP and MW carried night vision goggles (NVG) in addition to their Scorpion helmets during the MF (Tabs R-273 to R-282). Figure 2 (below) depicts the MF's flight equipment arrangement (Tab X-19).



Figure 2: MF's Flight Equipment Configuration (Tab X-19)

Prior to the MF, the MP and MW briefed the expected weather conditions and later confirmed the forecast with the tower (Tabs R-268 to R-270 and U-5). The MA was put on alert status, indicating the MA had been deemed ready following the completion of 'Hot Preflight Procedures' (Tabs R-269 and U-3 to U-5). IAW ACA squadron standards, the MP and MW completed power on checks following the changeover brief to prepare the aircraft for the MF (Tabs R-269 and U-3 to U-5).

d. Summary of Accident

During ground operations following an uneventful start, the MP and MW attempted a stored heading alignment IAW alert mission procedures (Tab U-4). At 18:36L, the MW asked the MP if the MP got a flashing RDY (ready) notice, indicating the Embedded GPS/INS (EGI) was fully aligned (Tab T-40). The MP did not get a flashing RDY (Tab T-40). The MW had the same issue, which led the MW to also perform a normal alignment (Tabs R-275 and T-40). Following the 4 minutes required to achieve a full, normal alignment, the MP transmitted “I’m aligned, how are you?” to the MW, verifying the MP deemed the MA’s EGI properly aligned and ready for flight (Tab T-40). The MP then called ready for taxi at 18:42L IAW with their mission planned practice scramble on Runway 36 at Truax Field (Tab T-40). At 18:45L, tower air controllers cleared the MF for takeoff (Tab T-40).

Both MF aircraft were airborne at 18:46L with no known issues (Tab T-40). Approximately 2 minutes after takeoff, at 18:48L, local air controllers cleared the MF to fly on a heading of 030 degrees and to maintain a block altitude of 10,000 to 12,000 ft MSL, equating to approximately 9,000-11,000 ft above ground level (AGL) (Tab T-40). The MP subsequently transmitted to the Eastern Air Defense Sector (EADS), “[MP] terminate”, to which EADS replied, “[MP], [EADS], copy terminate”, effectively completing the practice scramble portion of the mission, which allowed the MF to continue on the planned backup instrument mission (Tab T-40).

At 18:49L, the MP mentioned for the first time the MA’s GPS was not tracking any satellites (Tab T-40). The MP asked the MW to voice corrections should the MA drift off course (Tab T-40). 5 minutes after departure, at 18:51L, the MP donned NVGs (Tab T-40).

At 18:57L, the MP stated, with the MF in good weather and about 150 miles to go until their next turn point, the MP was going to try an IFA (Tab T-40). The MP then stated, if the MP encountered any issues, they would pass the MW the lead and the MP would fly using the standby attitude display indicator (ADI) and maintain a trail position (Tab T-40). About one minute later, at 18:58:32L, the MW lost the MP on Situation Awareness Data Link (SADL), which is consistent with the MA’s INS being turned off (Tab T-40). At 18:58:40L, the MP confirmed the MA’s INS was off and the MP was using the standby ADI for attitude awareness (Tab T-40). Based off radio communications between the MP and MW, the MP confirmed the MA was in the middle of conducting the IFA at 18:58:56L (Tab T-40).

At 19:04L, about 25 nautical miles (NM) northeast of Green Bay, the MW commented on how dark of a night it was especially near the Upper Peninsula of MI, consistent with the low illumination forecast and a 13:58L moonset (Tabs F-8 and T-40). Approximately 7 minutes after selecting IFA, at 19:05L, the MP told the MW there was no improvement with the EGI (Tab T-40). Additionally, the MP stated the standby ADI was functional and, in the center display unit (CDU), the primary flight instrument data present was attitude, airspeed, and altitude indicators (Tabs T-40 to T-41). The MP also mentioned there was no attitude information or flight path marker (FPM) in the heads-up display (HUD) (Tab T-41). Furthermore, the MA was still not tracking any satellites (Tab T-41).

At 19:11:33L, the MP passed flight lead responsibilities to the MW and confirmed available flight instruments in the primary flight display (PFD), including the horizontal situation indicator,

attitude, airspeed and altitude indicators, angle of attack (AOA), aircraft pitch reference, and radar altitude (Tab T-41). However, the MP did not have the climb/dive marker (CDM) displayed in the PFD and, in the HUD, the MP did not have a FPM, attitude bars, or a horizon line available for reference (Tab T-41). Additionally, the MP mentioned having a 1553 fail in the CDU (Tab T-41).

At 19:13:30L, while performing the lead change, the MW established altitude de-confliction by calling on the radio that the MW will maintain 11,500 ft MSL (Tab T-41). To which, the MP responded the MP was established 10,500 ft MSL and below (Tab T-41). While still performing the lead change, at 19:14:16L, the MP confirmed the MA's GPS was not tracking any satellites (Tab T-41). The MP transmitted on the radio "I'm turning [the INS] off and going to try it a couple more times" as the MF flew to Sawyer International Airport (Tab T-41). At 19:15:00L, the MF completed the lead change and setup the Air-to-Air Tactical Air Navigation System (A/A TACAN), tying the two jets positions together (Tab T-41). At that time, the MP and MW were approximately 3 NM apart as indicated by the MW's HUD (Tab T-41).

With A/A TACAN indicating 4.0 NM, at 19:16:30L, the MW said on the radio, "looks like I'm getting into the weather.... Are you able to keep track of me?" (Tab T-41). The MP responded the MP was "blind" at 10,000 ft MSL, a term indicating the MP lost visual contact of the MW (Tab T-41). The MW subsequently received a radar spike indication from the radar warning receiver (RWR), consistent with the MP having a radar lock on the MW (Tabs R-282 and T-41). While the MP was still blind, the distance between the MP and MW increased to 5.0 NM on the A/A TACAN (Tab T-41). At 19:17:05L, the MP asked if the MW was making a left hand turn (Tab T-41). The MW responded "I'm not quite yet, I was going to press a little further forward" (Tab T-41). In parallel with the MW's response, spike indications on the MW's RWR ceased and the distance on the A/A TACAN steadily increased (Tab T-41). The last radio communication received from the MP was vague and non-specific (Tab T-41). Radar recreation shows the MA continued in a right hand turn up to 135 degrees bank, a maximum dive angle of approximately 90 degrees nose low, and a maximum airspeed of over 600 kts (Tab T-41). The modeled flight path resembles a "split S" type maneuver (Tab T-42). A/A TACAN showed 8.3 NM at the estimated time of impact, 12 seconds after the MP's last communication (Tab T-41).

e. Impact

The MA impacted the ground in Hiawatha National Forest at 19:17:37L (Tab T-42). The MP did not attempt to eject (Tab J-14). At the time of impact, the MA was approximately 58 degrees nose low, with over 20 degrees of right bank, heading 205 degrees, and traveling over 600 kts (Tabs T-21 to T-38 and T-42). The MA terminated with controlled flight into terrain (Tabs J-14 and T-27). Controlled flight into terrain is described as unintentional flight into the ground and typically the pilot is unaware of the impending impact (Tab J-14). Subject matter expert (SME) analysis revealed the MA's nose and right wing tip both struck the ground, leaving recognizable cratering (Tab T-25). Tree shearing at the mishap site verified the steep AOA and heading at impact (Tabs T-21 to T-38). The impact destroyed the MA, and the MP suffered fatal injuries (Tabs J-14 and O-2 to O-3).

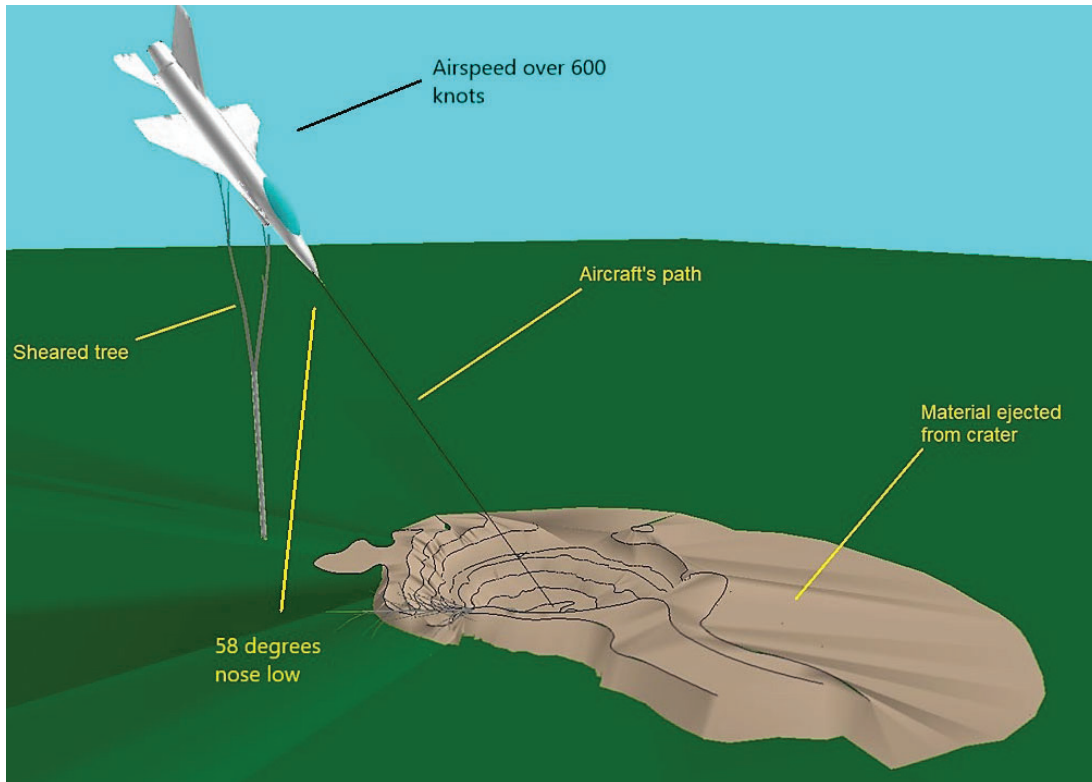


Figure 3: Recreation of MA at Impact (Tab T-27)

f. Egress and Aircrew Flight Equipment (AFE)

The MP did not initiate an ejection sequence (Tab J-14). Review of the MA's and MP's egress equipment showed no abnormalities (Tabs J-13 to J-15).

g. Search and Rescue (SAR)

At 19:17:25L, the MP made his last communication with the MW (Tab T-42). 12 seconds later, the MW lost the ability to track the MA's radar data (Tab R-283). The MW attempted to make contact with the MP multiple times with no response (Tab R-283). The MW returned to the MA's last known coordinates to search for an impact site and found a possible conical impact surrounded by heat signals in a wooded area of Hiawatha National Forest (Tabs R-283 to R-286). Several F-16s and helicopter platforms in the region also arrived on station to engage in search efforts (Tabs R-242 to R-243 and S-12). At 19:55L, the Air Force Search and Rescue Coordination Center initiated rescue procedures (Tab T-6). 5 minutes later, the Delta County Sheriff's Department, MI, began their rescue effort (Tab T-6). At 21:21L, Michigan State Police arrived at the last known coordinates for the MA (Tab T-6). At 21:35L, the U.S. Coast Guard obtained a visual on MA debris (Tab T-5). The Delta County Sheriff's Department secured the scene at 22:30L (Tab T-5). At 23:13L, an RC-26 aircraft and crew prepared to depart for the mishap site (Tab T-5). At 00:24L, the RC-26 began performing sweeps of the area (Tab T-5). No personnel observed any emergency locator transmissions (Tabs T-3 to T-8). On 10 December 2020 at 06:06L, the 115 FW Commander declared the MP deceased and initiated next-of-kin notification based on the results of recovery efforts conducted at the mishap site (Tab T-2).

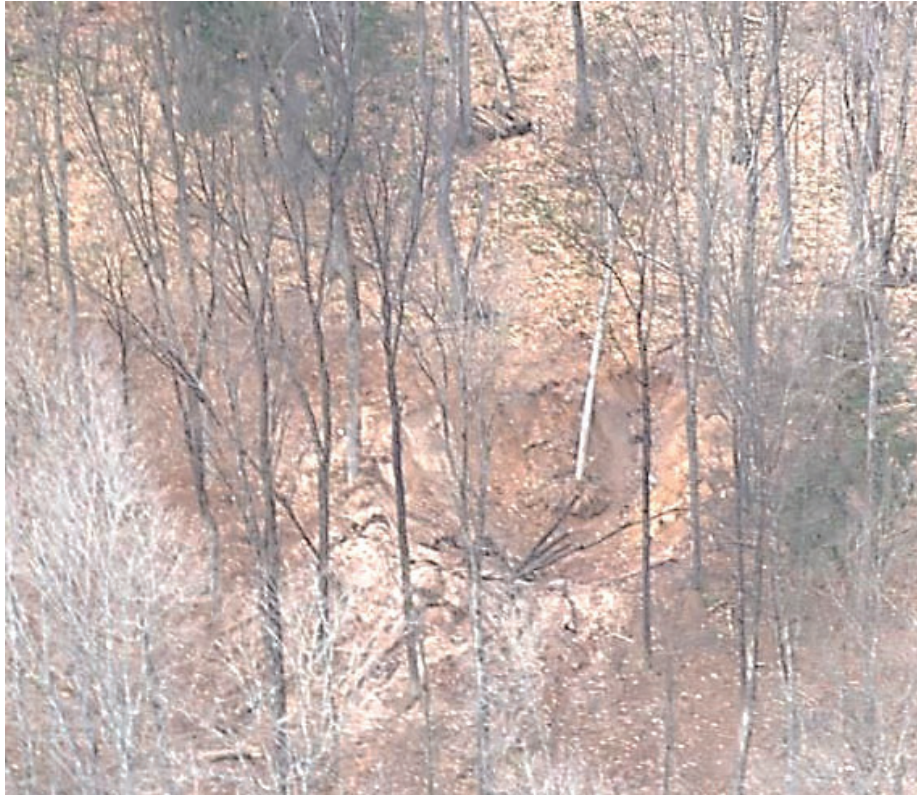


Figure 4: Overhead View of Mishap Site (Tab S-6)

h. Recovery of Remains

Rescue and recovery teams from the 115 FW departed for the mishap site at 00:41L on 9 December 2020 (Tab T-5). The teams arrived on scene and began conducting continuous search, rescue, and recovery efforts into the following day (Tabs T-5 to T-6). The teams secured and collected the MP's remains and returned them to Truax Field (Tabs T-2 to T-7).

5. MAINTENANCE

a. Forms Documentation

Air Force Technical Order (AFTO) 781 series forms collectively document maintenance actions, inspections, servicing, configuration, status, and flight activities for the maintained aircraft (Tab DD-2). The Integrated Maintenance Data System (IMDS) automates aircraft history, aircraft scheduling, and aircrew debriefing processes and provides a common interface for entering base level maintenance data into other standard logistics systems (Tab DD-2). In most cases, data is entered to update the database as a result of some activity taking place in the maintenance environment (Tab DD-3). Review of active 781 series forms and IMDS for the 60 days preceding the mishap revealed no overdue inspections or open Time Compliance Technical Orders (TCTOs) that would affect MA flight operations (Tabs D-29 to D-34 and DD-53 to DD-138).

b. Inspections

The Pre-Flight (PR) Inspection and Basic Post-Flight Inspection include visually examining the aerospace vehicle and operationally checking certain systems and components “to ensure no serious defects or malfunctions” exist (Tab DD-4). Phase inspections are a thorough inspection of the entire aerospace vehicle (Tab DD-5). Walk-Around Inspections (WAI) are an abbreviated PR Inspection and are completed as required prior to launch IAW the applicable Technical Orders (TO) (Tab DD-4).

Review of the active AFTO 781 forms and IMDS revealed no overdue inspections or overdue TCTOs that would ground the MA from flight operations (Tabs D-29 to D-34). The total airframe operating time of the MA at takeoff was 7,795.0 hours (Tab D-28). The MA had flown 193.4 hours since its last phase inspection, which was completed on 14 October 2019 (Tabs D-28 and DD-7). The last PR inspection occurred on 6 December 2020 at 11:00L with no discrepancies noted (Tabs DD-7 to DD-8). A WAI occurred on 8 December 2020 at approximately 14:00L with no discrepancies noted (Tabs D-45 and DD-8). Prior to the mishap, the MA had no relevant reportable maintenance issues and inspections were satisfactorily completed (Tabs D-27 and DD-6 to DD-7).

c. Maintenance Procedures

A review of the MA’s active and historical AFTO 781 series forms and IMDS revealed all maintenance actions complied with standard approved maintenance procedures and TOs (Tabs D-24 to D-34).

d. Maintenance Personnel and Supervision

Maintenance personnel from the 115 FW performed all required inspections, documentation, and servicing for the MA prior to flight (Tabs DD-51 to DD-56). A detailed review of maintenance activities and documentation revealed no errors (Tabs DD-51 to DD-56). Personnel involved with the MA’s preparation for flight had proper and adequate training, experience, certification, and supervision to perform their assigned tasks (Tabs EE-2 to EE-130).

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

Due to the nature of the impact, all fluid samples from the MA were destroyed and not testable (Tab O-4). According to the Air Force Petroleum Office Joint Oil Analysis Program, samples from the associated servicing carts were normal and no unusual volatiles were noted in the spectrum (Tabs DD-10 to DD-43). There is no evidence to indicate oil, fuel, or hydraulic fluid contamination was a contributing factor to the mishap (Tab O-4).

f. Unscheduled Maintenance

Unscheduled maintenance is any maintenance accomplished between scheduled maintenance and scheduled inspections, excluding TCTO accomplishment (Tab DD-6). A review of the MA’s active and historical maintenance records revealed 2 unscheduled maintenance events during the 90 days preceding the mishap (Tabs DD-53 to DD-138). There is no evidence to indicate they contributed to the mishap (Tabs DD-53 to DD-138). From 14 September 2020 to

16 September 2020, unscheduled maintenance actions included replacement of 3 coaxial connectors and the EGI Line Replaceable Unit (Tabs D-5 to D-7). From 6 October 2020 to 7 October 2020, unscheduled maintenance actions included replacement of the EGI (Tabs D-18 to D-20). The maintenance member, who performed the unscheduled actions, verified the MA received tracking from 5 GPS satellites and loaded almanac data (Tabs U-16 to U-17). After this maintenance, the MA flew 6 uneventful (Code 1) sorties (Tab DD-139).

6. AIRFRAME SYSTEMS

a. Structures and Systems

Impact with the ground at Hiawatha National Park caused total destruction of the MA (Tabs S-6 and T-42). Initial investigators recovered fragmented parts and secured them for analysis (Tabs J-2 to J-14).

b. Evaluation and Analysis

(1) Crash Survivable Memory Unit (CSMU)

The MA's CSMU was designed to record and store flight data during catastrophic events (Tab T-14). Investigators recovered the CSMU from the mishap site (Tab T-14). Analysis of the CSMU by Lockheed-Martin and the Air Force Safety Center (AFSEC) provided minimal parametric data on the MA due to impact damage to the unit (Tabs L-2 to L-56 and T-14). Using a combination of parametric data and radar data from three ground-based radar sites, AFSEC built a viable recreation of the MA's flight path (Tabs T-14 and T-42). Sixty-six (66) radar data lines provided a consistent base for the recreation (Tabs L-2 to L-56 and T-14). The MA's last radar data point was at 3,600 ft MSL (Tabs L-2 to L-56). A contractor aviation accident investigator provided crater and impact analysis and validated the flight path recreation (Tabs T-21 to T-38).

(2) Heads-Up Display (HUD)/Digital Video Recorder (DVR)

The MA's HUD/DVR data was unrecoverable, preventing a complete analysis of the MA's cockpit displays at the time of the mishap event (Tab S-6). Investigators secured the MW's HUD/DVR data, which were used to provide communications, visual conditions, and important flight data for analysis (Tabs T-40 to T-42).

(3) EGI System and Primary Flight Instruments

On the ground, while performing preflight checks, the MP reported having a sufficiently aligned EGI system (Tab T-40). Without the MP's HUD/DVR data, it cannot be determined whether the MA was tracking satellites during ground operations (Tab T-41). However, if an aircraft is stationary and at a level attitude, GPS is not required for the INS to achieve a full and accurate alignment (Tab T-15). Figures 5 and 6 (below) illustrate a fully aligned system with satellites tracking (Tab T-16). A fully aligned system without satellites tracking would appear the same, with the exception of the '4 E 3 03' symbology in the lower left corner of the HUD (Tabs T-15 to T-16).



Figure 5: Simulated Fully Capable HUD (Tab T-16)



Figure 6: Simulated Fully Capable PFD (Tab T-16)

Once airborne, the MP stated the MA was not tracking any GPS satellites and the MP would attempt an IFA (Tab T-40). Assuming a full performance alignment of 0.8 NM/hour drift rate, GPS satellite tracking is not required for safe flight; although, INS drift may lead to navigation errors over time (Tab BB-16). Several possible reasons exist for difficulty in tracking GPS satellites or not tracking GPS satellites at all (Tabs T-15 to T-16). Those reasons include erroneous alignment coordinates over 1 NM or outdated/corrupted almanac data (Tabs T-15 to T-16). SME consultation and inflight testing confirmed a system date error does not affect EGI satellite tracking ability (Tabs T-15 to T-16). Almanac data is current for up to 6 months (Tabs T-15 to T-16). Without the MA's recorded system data, the cause of the MA's inability to track GPS satellites cannot be determined (Tabs T-15 to T-16). However, the MP's communications revealed the MA's GPS was not tracking satellites throughout the duration of the MF (Tabs T-40 to T-41).

According to TO 1F-16C-1, an IFA may not be possible with a GPS accuracy worse than HIGH/50 (Tab BB-3). In addition, TO 1F-16C-34-1-1 explains a lack of GPS satellite reception extends the time required for an IFA (Tab BB-17). TO 1F-16C-34-1-1 also warns an IFA "is not possible and should not be attempted" without GPS aid (Tab BB-17). In a note under the EGI Failure checklist in TO 1F-16C-1CL-1, GPS information is required for an IFA and, with a GPS NTRK condition, an IFA should not be initiated (Tab BB-6). However, the MP did not experience an EGI failure and would not be directed to the EGI failure checklist (Tab T-41). Although TO 1F-16C-1CL-1 does contain an IFA checklist, the checklist does not include a note referencing the GPS satellite tracking requirement for an IFA (Tab BB-5). TO 1F-16C-1CL-1 was the only TO available for the MP to quickly reference in flight (Tabs BB-2 to BB-18).

The first step to perform an IFA is to place the INS knob in the "OFF" position for 10 seconds (Tab BB-2). Next, while established in straight, level, and unaccelerated flight, the INS knob is placed in "INFLT ALIGN" (Tab BB-2). Figure 7 (below) shows the OFF and INFLT ALIGN positions on the INS knob (Tab X-13).

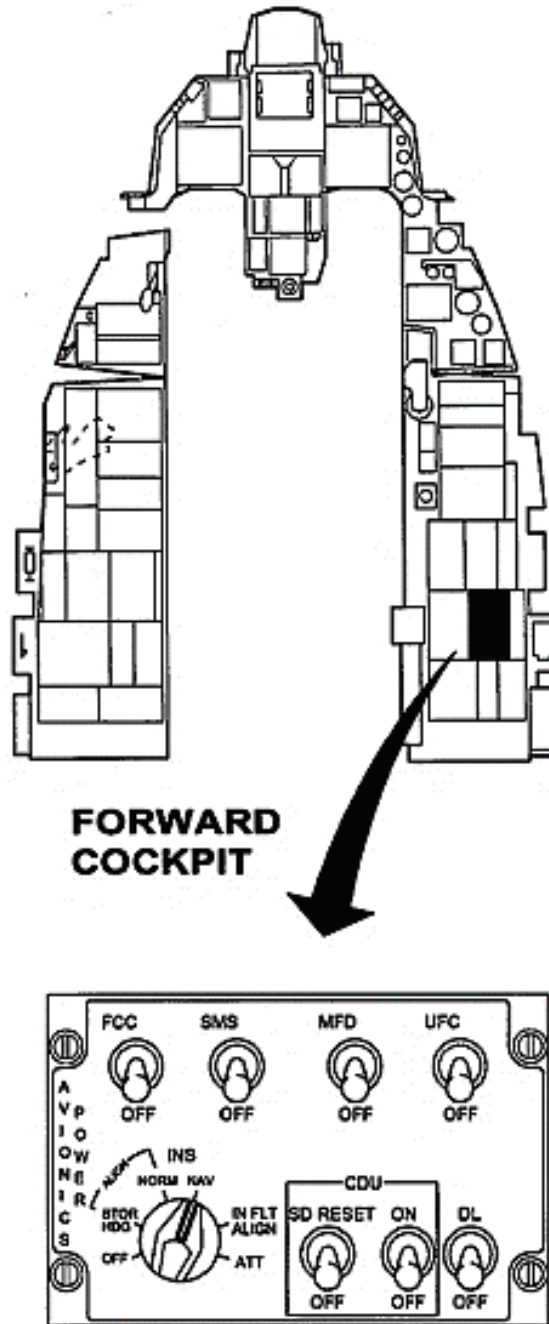


Figure 7: Visual Depiction of INS Switch (Tab X-13)

Due to the destruction of the MA, it cannot be determined how long the MP left the INS knob in OFF and how that would affect the IFA (Tabs T-16 to T-17). Communications confirm, after placing the INS knob to INFLT ALIGN, the MP observed attitude, airspeed, and altitude indications in the PFD (Tab T-41). The MP also confirmed the HUD had no FPM or attitude

indications (Tab T-41). The destruction of the MA prevented an assessment of how long it took the MP to regain primary flight instruments in the PFD (Tab T-41).

Flight testing demonstrates, with good GPS satellite tracking, it takes approximately 10 seconds to regain attitude information (Tab T-43). Regaining attitude information in the PFD normally occurs in conjunction with regaining attitude information in the HUD (Tab T-43). Available evidence and SME consultation could not establish why the MP did not have attitude information displayed in the HUD (Tab T-43). However, the MA experienced a 1553 failure in the CDU, which could be attributed to a digital data transfer malfunction in the HUD and CDU (Tab T-43). The 1553 bus is what carries digital data from the EGI to the CDU (Tab T-43). Lack of available evidence could not determine how this failure would affect the MA's flight displays (Tab T-43).

After selecting IFA, straight, level, unaccelerated flight is necessary to assist the inertial platform leveling process (Tab BB-17). The INS assumes the aircraft is straight and level during the process; therefore, any roll or pitch induced while aligning will result in inaccurate and/or unreliable attitude information in the PFD and HUD (Tabs T-16 to T-17). Testing has shown, after an IFA with GPS tracking satellites, attitude indications appear on the PFD after 10 seconds (Tab T-43). Salvaged evidence, flight simulations, and SME consultation could not establish how a lack of GPS satellite tracking data would affect the MA's PFD (Tab T-43). However, if the EGI transitioned to an attitude mode alignment due to the lack of a valid GPS solution, it is possible the MP would regain attitude information after 10 seconds (Tab T-43). Flight testing has not been conducted to establish what indications would appear in the PFD and HUD when attempting an IFA without GPS satellite tracking (Tab T-43).

While attempting the IFA, in radio communications, the MP discussed trying to change the GPS reception mode from "YMODE" to "MIXED" (Tab T-41 and Figure 7). When in YMODE, the EGI navigation solution uses only encrypted, precision satellite signals (Tab BB-14). While in MIXED, the EGI navigation solution uses course and/or precision satellite signals (Tab BB-14). MIXED may be less precise, but the GPS will utilize more GPS satellites in an attempt to provide a navigation solution (Tab BB-14). The switch from YMODE to MIXED resets the GPS and reinitiates satellite acquisition (Tab BB-15). Switching from YMODE to MIXED requires the Mode-Select button on the integrated control panel to be depressed (Tab BB-14). After, the GPS RESET field and the selected reception mode are highlighted (Tab BB-14). Available evidence could not determine if the MP applied the correct steps to switch modes or what mode the GPS was in prior to the mishap (Tab T-41).

The EGI system was not recovered intact, leaving it unknown what position the MA's INS switch was placed in during the mishap event (Tab T-41). Figure 8 (below) provides a simulation of the cockpit displays when the INS is in the INFLT ALIGN position prior to a completed alignment (Tabs T-15 to T-19). Figure 9 (below) provides a simulation of the cockpit displays when the INS is in the OFF position (Tabs T-17 to T-18). In either switch position (OFF or INFLT ALIGN), primary flight data available to the MP is reduced (Tab T-17).

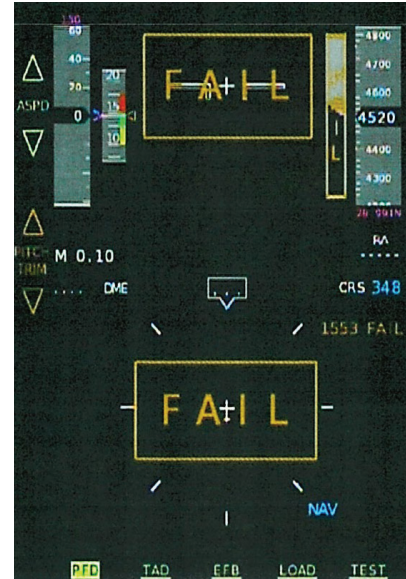
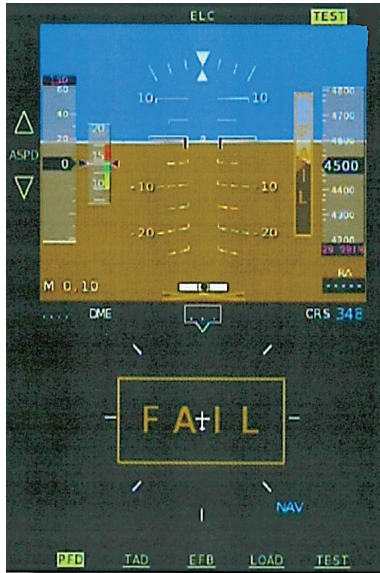


Figure 8: Simulated PFD and HUD in INS INFLT ALIGN Position with GPS NTRK (Tab T-17)

Figure 9: Simulated PFD and HUD in INS OFF Position (Tab T-18)

Following analysis, SME consultation, and flight testing, incorrect GPS system date and the lack of GPS cryptovariable keys were ruled out as possible causes for the MA's inability to track GPS satellites (Tabs T-16 to T-18). Flight testing discovered several F-16C Block 30 aircraft had been flying for at least 3 months with incorrect GPS system dates and did not have issues with GPS satellite tracking (Tabs T-16 to T-18). SME consultation also confirmed a lack of GPS keys would not affect satellite tracking regardless of the GPS reception mode, YMODE or MIXED (Tabs T-16 to T-18). A GPS in YMODE, without GPS keys, will track satellites, albeit with poor horizontal and vertical navigation accuracy (Tabs BB-14). A GPS in MIXED will track satellites with high horizontal and vertical navigation accuracy regardless of GPS keys (Tabs BB-14 to BB-15). The MP's radio communications revealed the only maintenance fault lists (MFL) present were EGI 082 and EGI 083 (Tab T-42). These MFLs indicate horizontal and vertical navigation accuracy was less than a pilot adjustable amount (Tab T-42). The absence of any other MFLs rule out maintenance malfunctions as a possible cause for a GPS NTRK (Tabs T-42 to T-43).

(4) Dive Recovery Analysis

Recreation of the mishap event showed the MA at one point in a 45 degree descent at 7,500 ft MSL and 550 kts (Tab T-42). According to TO 1F-16C-1, *Dive Recovery Chart*, had the MP recognized the unusual attitude and immediately initiated a wings level, 7G pull to the horizon in idle thrust and speedbrakes fully extended, the MP would have recovered in approximately 2,000 ft (Tab BB-4).

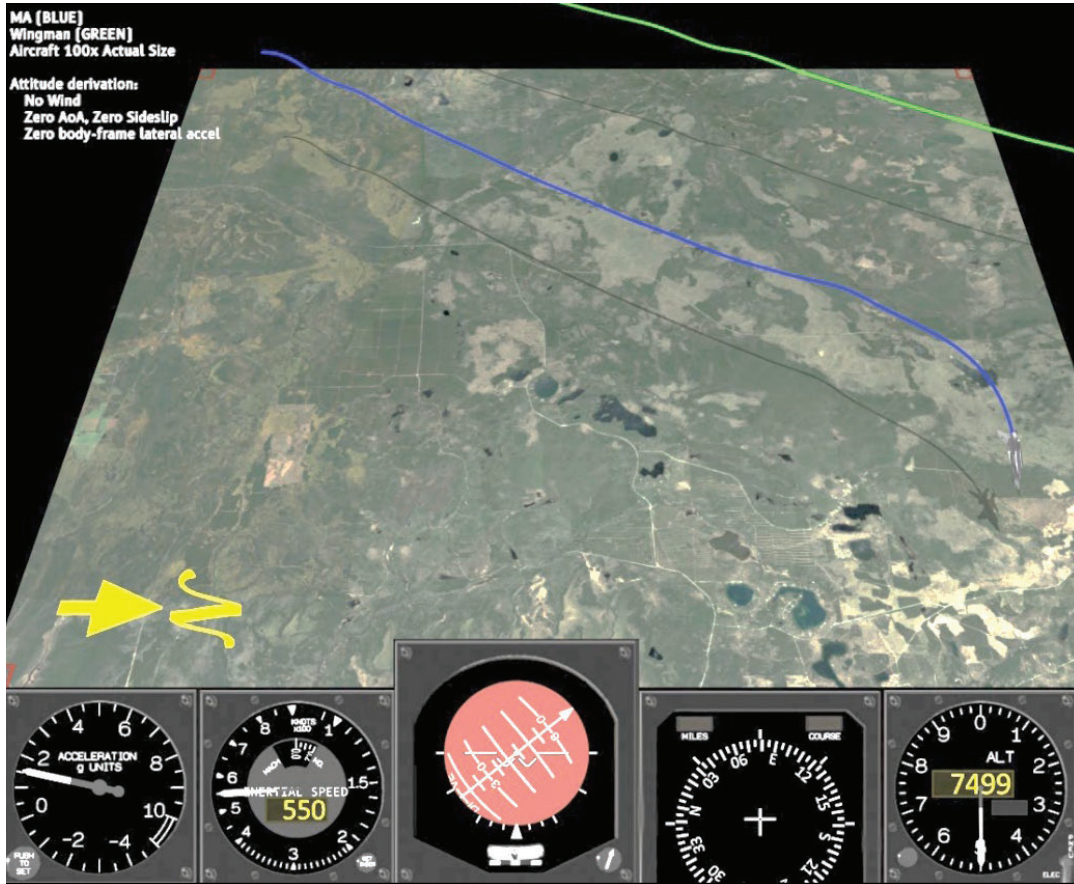


Figure 10: Simulated Flight Path (Tab T-42)

Recreation shows the MP pulling an estimated maximum of 4Gs (Tab T-42). Under the previously stated conditions, the MP's exertion of 4Gs would have increased the altitude lost in the recovery to approximately 3,500 to 4,000 ft (Tab BB-4). Due to a lack of recoverable evidence, the MP's thrust and speedbrake settings are unknown throughout the mishap event (Tab T-42). However, at speeds above 350 kts, thrust settings above idle will generally increase the altitude required to recover (Tab BB-26). Additionally, recreation shows the MA continued in an increasingly steeper dive, up to about 90 degrees, and the MA's airspeed increased to over 600 kts (Tab T-42). These conditions would exponentially increase the altitude lost during an attempted recovery (Tab BB-4).

In an extreme unusual attitude with complete flight instruments available to the pilot in the PFD, two chevrons appear on the PFD to provide the pilot another visual cue the aircraft is in a steep

climb or dive (Tabs BB-10 to BB-11). Additionally, a dashed horizon line is presented at the edges of the PFD to aid the pilot in recovering toward the horizon (Tab T-15). This is in contrast to the standby ADI, which is the basic instrument always available to the MP (Tabs T-16 to T-17). What was displayed to the MP in the PFD at the time of the mishap cannot be established (Tab T-43). Nonetheless, if attitude information was displayed to the MP, the chevrons would have appeared in an indicated steep dive (Tab T-15). Prior to the mishap event and confirmed through radio communications, the MP verified the standby ADI was available (Tab T-40). Figure 11 (below) depicts a PFD and standby ADI in a steep dive, similar to what the MP may have encountered if the INS was in the INFLT ALIGN position with attitude information present in the PFD (Tabs T-15 and T-20). Figure 12 (below) depicts a PFD and standby ADI in a steep dive, similar to what the MP would have encountered if the INS was in the OFF position (Tabs T-18 and T-20).

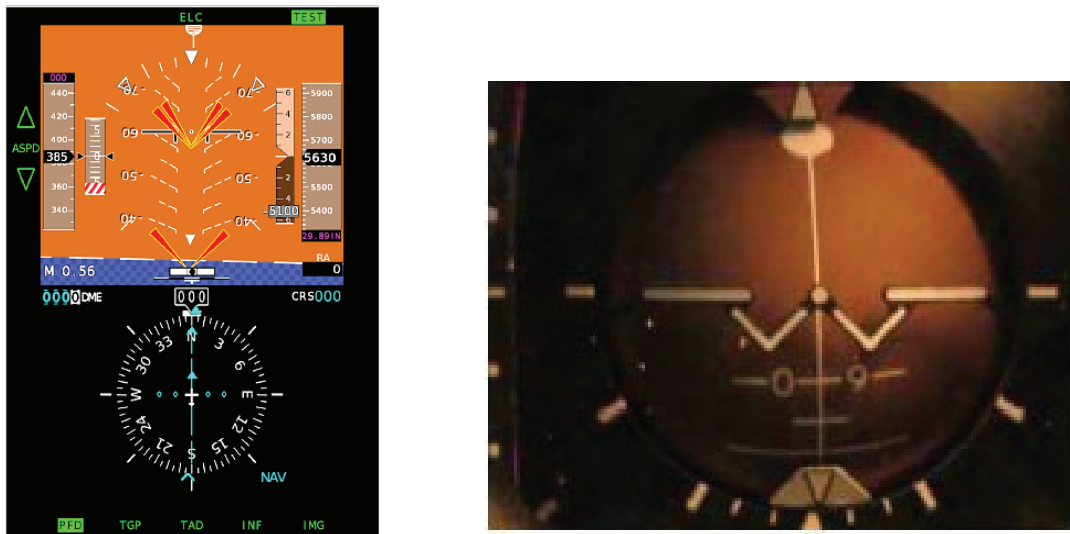


Figure 11: PFD and Standby ADI in Steep Dive with INS INFLT ALIGN (Tabs T-15 and T-20)

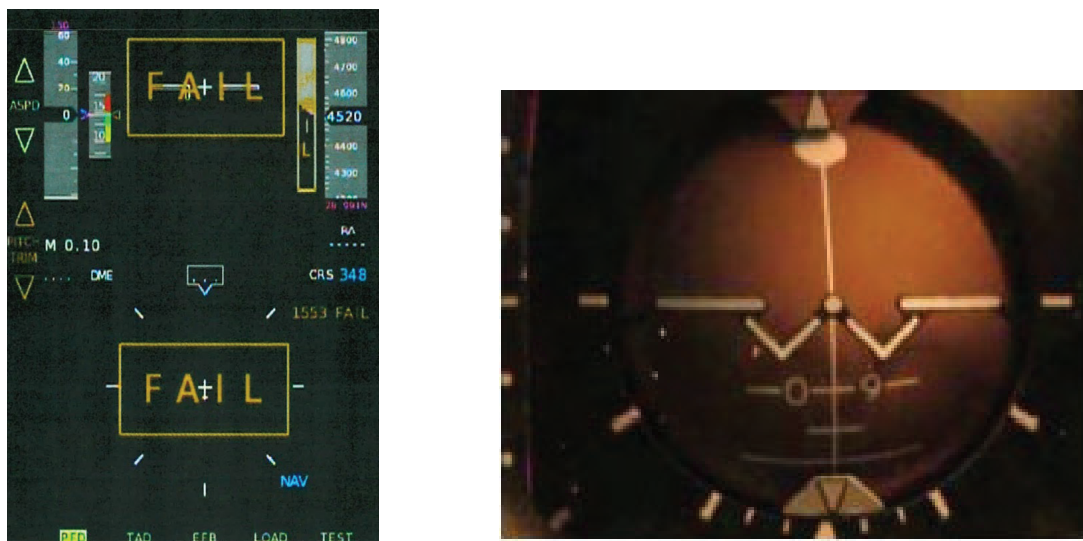


Figure 12: PFD and Standby ADI in Steep Dive with INS OFF (Tabs T-18 and T-20)

(5) Ground Avoidance Advisory Analysis

To prevent controlled flight into terrain, the F-16C is equipped with a ground avoidance advisory function (GAAF) (Tab BB-19). The system provides advisory cues both visually and aurally when the aircraft AGL altitude is less than or equal to the predicted altitude lost during a 4G pull-up plus a clearance buffer (Tab BB-19). Moreover, the ground advisory utilizes combined altitude radar altimeter (CARA) data as long as the aircraft is within the CARA ground track envelope (Tab BB-21). The radar altimeter is located on the bottom of the F-16C, and in extreme attitudes the radar altimeter readings are outside of the ground track envelope (Tab BB-21). Based on the recreation, the MA was outside of the CARA envelope throughout the mishap event up until impact (Tabs T-42 and BB-13). As such, the MP would not receive a GAAF advisory cue (Tab BB-21). Figure 13 (below) provides CARA ground tracking capabilities (Tab BB-13).

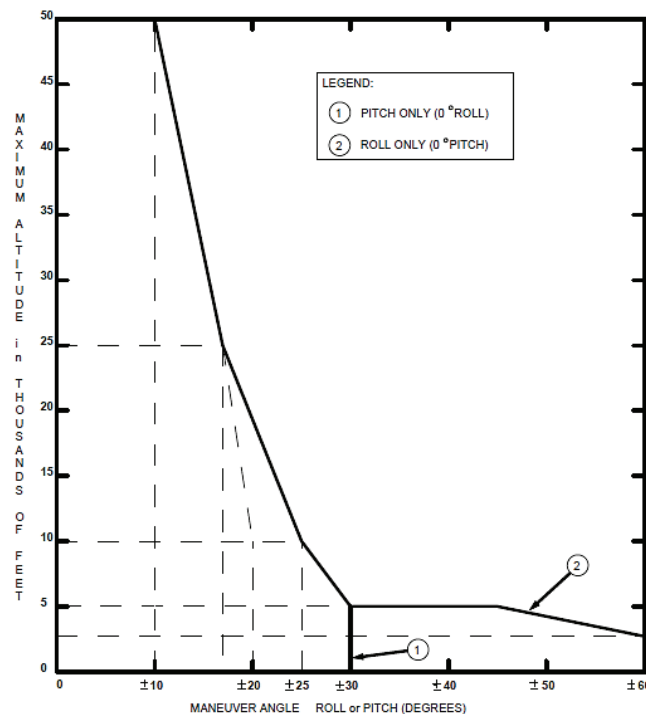


Figure 13: CARA Tracking Capabilities (Tab BB-13)

In addition to the GAAF, some F-16C Block 30s are equipped with a ground collision avoidance system (GCAS) to prevent controlled flight into terrain (Tab BB-19). The MA was not equipped with the GCAS function (Tab T-43).

A pilot adjustable altitude low (ALOW) advisory cue is provided any time the aircraft descends below the entered AGL altitude (Tabs BB-21 to BB-22). Available evidence is insufficient to determine what ALOW setting the MP entered (Tab T-43). The ALOW advisory cue utilizes CARA data, and the MA would need to be within the CARA ground track envelope for the ALOW advisory to be provided (Tab BB-21). The MA was outside of the CARA ground track envelope, and the MP would not have received an ALOW advisory cue (Tabs BB-13 and BB-21).

Independent of CARA operation is a pilot adjustable line-in-the-sky (LIS), which also provides an aural altitude advisory (Tab BB-24). A LIS advisory is generated anytime the aircraft descends below the barometric altitude entered by the pilot (Tab BB-24). Had the MP entered a LIS value below the MA's altitude prior to the mishap event, the MP would receive an altitude advisory (Tab BB-24). Available evidence is insufficient to determine what LIS value the MP entered (Tabs T-41 to T-43).

7. WEATHER

a. Weather Forecast

The forecast for Truax Field on 8 December 2020 predicted winds out of the southwest at 8-10 kts with broken clouds at 11,000 ft MSL (Tab F-2). Illumination conditions were predicted as moderate at Truax Field, but the airspace surrounding Hiawatha National Forest forecasted low illumination conditions (Tab F-2).

b. Observed Weather

On the day of the mishap, sunset at Truax Field ANGB, WI occurred at 17:39L (Tab F-13). Moonset occurred at 13:58L (Tab F-13). At the time of the MF's takeoff, winds were out of the southwest at 9 kts with broken clouds at 10,000 to 19,000 ft MSL and scattered clouds at 19,000 to 26,000 ft MSL (Tab F-2). Truax Field also experienced 10 statute miles of visibility (Tab F-12). The local temperature was 33 degrees Fahrenheit (Tab F-13).

Prior to reaching the Hiawatha National Forest area, the MF observed dark conditions (Tab R-295). The MW stated the darkness of the surrounding water, namely Lake Michigan and Lake Superior, could create visual illusions (Tab U-7). The MW recalled minimal cultural lighting in the area and stated the trees in the wooded areas absorbed most cultural lighting (Tab U-5).

Illumination conditions at Hiawatha National Forest were low (Tab F-8). Further, the areas surrounding Hiawatha National Forest experienced moderate rain and light snow (Tab F-7). Figure 14 (below) shows the precipitation in the areas surrounding the mishap site (Tab F-7).

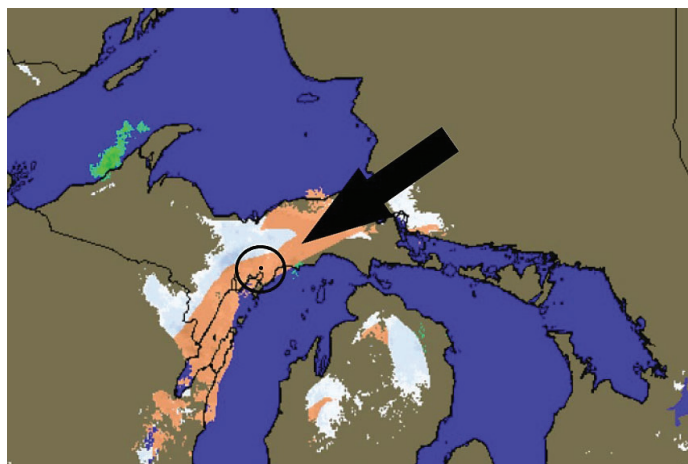


Figure 14: Local Precipitation at 18:20L (Tab F-7)

c. Space Environment

Not applicable.

d. Operations

The MF operated within prescribed weather requirements for pilot minimums (Tab F-2).

8. CREW QUALIFICATIONS

a. Mishap Pilot (MP)

The MP was a current and qualified ACA F-16 pilot (Tab G-2). In 2013, the MP graduated from the Euro-NATO Joint Jet Pilot Training Program at Sheppard Air Force Base, Texas (Tab T-8). Later, in 2014, the MP completed Introduction to Fighter Fundamentals (Tab T-8). In September 2015, the MP finished F-16 mission qualification training (Tab G-3). In March 2018, the MP completed the flight lead upgrade in the F-16 (Tab G-26). In total, the MP logged more than 1,300 flying hours in rated aircraft and more than 1,000 flying hours in the F-16C (Tab G-4). Additionally, the MP flew over 240 combat hours and over 300 night hours (Tab T-43).

At the time of takeoff, the MP’s recent flight time in the F-16C was as follows (Tab G-4):

	Hours	Sorties
Last 30 Days	10.3	6
Last 60 Days	13.0	8
Last 90 Days	26.5	18

b. Mishap Wingman (MW)

The MW was a proficient, current, and qualified ACA F-16C pilot (Tab G-2).

9. MEDICAL

a. Qualifications

The MP was medically qualified to perform flight duties at the time of the mishap (Tab Y-55). The MP’s most recent annual Preventative Health Assessment (PHA) was performed on 28 February 2020 (Tab Y-55). A review of the Aeromedical Information and Medical Waiver Tracking System database demonstrated a current and valid indefinite Flying Class Two waiver approved by Joint Force Headquarters – Air National Guard on 8 February 2015 (Tab Y-55). The MP was current on all required medical examinations and immunizations with a current DD2992, *Medical Recommendation for Flying or Special Operational Duty*, valid through 7 May 2021 (Tab Y-55). Review of all other medical records reflected no recent performance-limiting illness prior to the mishap (Tab Y-55).

b. Health

A review of the MP's medical records, ORM worksheet from the day of the mishap, and interviews with coworkers showed the MP was in his normal state of health, performance, attitude, and energy (Tabs R-273 to R-282 and Y-55). A review of the Aeromedical Services Information Management System did not reveal any illnesses or duty limiting conditions at the time of the mishap (Tab Y-55). There is no evidence to suggest the MP's health was a factor in this mishap (Tab Y-55).

c. Pathology

The MP's remains were received and examined by the Armed Forces Medical Examiner at Dover Air Force Base, Delaware (Tab Y-55). There was positive identification by ante-mortem and post-mortem DNA comparisons (Tab Y-55). The cause of death was multiple injuries (Tab Y-55). There was no evidence of illicit drugs or medications detected in post-mortem toxicology evaluation (Tab Y-55).

All maintenance personnel associated with the mishap provided samples for toxicology testing (Tab Y-55). All toxicology samples were negative for drugs of abuse by immunoassay or gas chromatography/full scan-mass spectrometry (Tab Y-55). There is no evidence to suggest illegal substances or medications were a factor in the mishap (Tab Y-55).

d. Lifestyle

72-hour and 14-day histories, medical charts, and interviews with the MW and maintenance crewmembers revealed no lifestyle factors relevant to the mishap (Tab Y-55). History for the MP was collected through interviews with the MW and maintenance members (Tabs R-273 to R-282). There is no evidence to suggest lifestyle factors were a factor in the mishap (Tab Y-55).

e. Crew Rest and Crew Duty Time

Air Force pilots are required to have proper crew rest, as defined by Air Force Manual (AFMAN) 11-202, Volume 3, *Flight Operations*, Chapter 3, prior to performing inflight duties (Tab Y-55). Crew rest consists of a minimum 12-hour non-duty period before the designated flight duty period starts (Tab Y-55). During this time, aircrew may participate in meals, transportation, or rest, which allows for the opportunity for at least 8 hours of continuous sleep (Tab Y-55). The ACA facility is a designated crew rest facility, which allows personnel a space to accomplish crew rest while on alert duty (Tab Y-55). According to the MW, the MP complied with crew rest and duty time requirements (Tabs R-273 to R-282). At the time of the mishap, the MP was within the 10-hour flight duty period described by AFMAN 11-202, Volume 3 (Tabs R-273 to R-282).

10. OPERATIONS AND SUPERVISION

a. Operations

The operations tempo was normal at the time of the mishap (Tab U-11). The unit had been working the weekend prior as part of their monthly drill and had just started night flying for the week the day prior to the mishap (Tab U-12). 8 December 2020 was the MP's first night and alert flight since 19 November 2020 (Tabs G-15 to G-23). The MP's last flight was a daytime continuation

training flight on 3 December 2020 (Tabs G-15 to G-23). Additionally, the MP had emergency procedures training in the simulator on 4 December 2020 (Tabs G-15 to G-23). The day prior to the mishap the MP was supervisor of flying for that day’s flying events (Tabs G-15 to G-23). On 8 December 2020, the MP arrived at the ACA facility at 12:25L and received a changeover briefing (Tab R-268). Power on checks of the alert aircraft were completed by the MP and MW with no issues (Tab R-272). Later that day, the MP briefed the MW on the planned practice mission IAW the squadron ACA standards (Tab R-272).

b. Supervision

The ORM process in the squadron identified the risk for the mission as elevated (Tab K-4). The MF recognized the low illumination and cloud layer as a risk and, in turn, planned their mission to be below the weather for the duration of the flight (Tab K-4). In addition, the preflight brief and ORM assessment worksheet addressed the use of anti-exposure suits for flight over water less than 60 degree Fahrenheit (Tab K-4).

11. HUMAN FACTORS ANALYSIS

a. Introduction

The AIB considered all human factors as prescribed in the Department of Defense Human Factors Analysis and Classification System 7.0 (DoD HFACS 7.0), which lists potential human factors that can play a role in an aircraft mishap and identifies potential areas of assessment during an accident investigation (Tab Y-5).

DoD HFACS 7.0 are divided into four parts: acts, preconditions, supervision, and organizational influences (Tab Y-6). Four human factors were identified as relevant to the mishap: (1) Environmental Conditions Affecting Vision; (2) Instrumentation & Warning System Issues; (3) Breakdown in Visual Scan; and (4) Spatial Disorientation (Tabs Y-4 to Y-26).

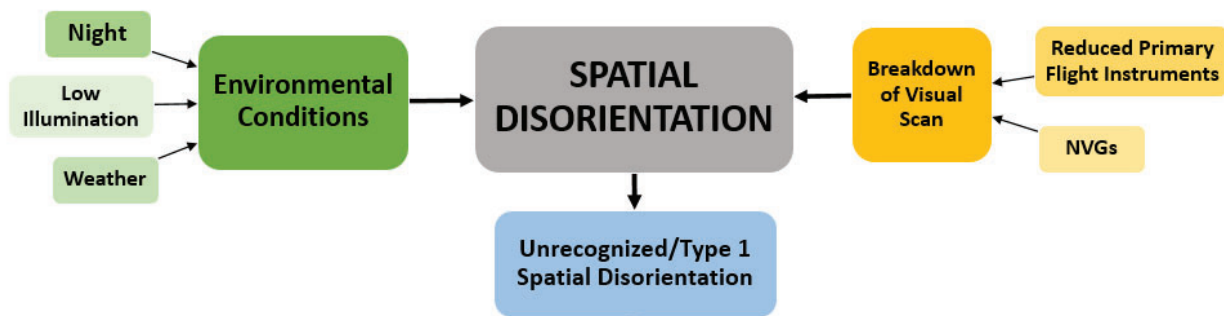


Figure 15: Human Factors Breakdown (Tab Y-57)

b. Applicable Factors

(1) Environmental Conditions Affecting Vision – DoD HFACS PE101

Environmental conditions affecting vision 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 the required duties (Tab Y-12).

Visual references provide the most important sensory input to the brain and its ability to maintain spatial orientation during flight (Tab Y-61). These references provide information about distance, speed, depth, and orientation (Tab Y-61).

Vision can be divided into two types, focal and ambient vision (Tab Y-53). The distinction between the two types is important in determining spatial orientation during flight (Tab Y-53). With good visibility and a clearly defined horizon, the pilot employs the peripheral visual system for spatial orientation (Tab Y-53). The peripheral visual system requires little conscious processing to effectively perform (Tab Y-53). At night, with degraded visual conditions, a pilot determines aircraft orientation through the use of primary and standby flight instruments (Tab Y-54). The use of these instruments requires focal vision (Tab Y-54).

Focal vision is not the natural spatial orientation mechanism and requires increased cognitive processing if external visual cues are not available (Tab Y-54). Factors that decrease these external visual cues include night conditions, the presence of weather, the absence of moon illumination, and cultural lighting (Tab Y-12). If visual contact with a horizon is lost, the vestibular system, or "seat of the pants" feeling, becomes unreliable and can result in sensory illusions unless overridden by visual input from primary or standby instruments (Tab Y-29). This makes reliance on instrumentation absolute, to override the inherent, normal sensory illusions of motion, orientation, and acceleration (Tabs Y-29 to Y-30).

The weather forecast for Truax Field included a broken cloud layer at 11,000 ft MSL (Tab F-2). Meanwhile, the airspace surrounding Hiawatha National Forest was forecast for broken clouds from 10,000 to 19,000 ft MSL and low illumination (Tabs F-2 to F-8). As the MF flowed to the northeast toward Sawyer International Airport, the MW reported a lack of cultural lighting, aside from a small group of homes to the southeast (Tab U-5). To the north and northeast, the surrounding geography, including lakes and surrounding forest, provided little to no graphic contrast to aid in horizon differentiation (Tabs T-41 to T-42). Cultural lighting conditions also created no visible horizon to the north or northwest (Tab Y-33). Additionally, the moon was under the horizon, removing moon illumination as a source of available light to assist in visual acuity of a true horizon (Tab F-13). As the flight continued northeast, the MW entered weather conditions (Tab T-41). Shortly thereafter, the MP lost visual contact with the MW due to the weather as confirmed by the radio call of "blind" at 10,000 ft MSL (Tab T-41). At that time, the MF was located near Hiawatha National Forest, which had broken clouds from 10,000 to 19,000 ft MSL (Tab F-2).

The combination of night conditions, a lack of moon illumination, cultural lighting, and entering a cloud layer caused degradation of visual references available for flight (Tabs F-2 to F-12). As

the MP flew northeast, likely unable to identify a true horizon with NVGs, the MP had to rely solely on available instruments for orientation to an artificial horizon (Tab T-42). The MP had decreased data available in the primary instruments (CDU and HUD), which required using standby instruments to determine the MA's actual orientation (Tab T-42). Therefore, spatial disorientation was more likely to occur with these conditions (Tab Y-16).

(2) Instrumentation & Warning System Issues – DoD HFACS PE202

Instrumentation and warning system issues is a factor when instrument design, reliability, lighting, location, symbology, size, display systems, auditory or tactile situational awareness, or warning systems create an unsafe situation (Tab Y-13).

The MP was an experienced instrument pilot with 566.7 hours of instrument flight time and 286.6 hours of NVG flight time (Tab G-4). The MP was current and qualified at instrument and night flying, with and without the aid of NVGs (Tab G-4).

The F-16 ADI, a primary flight instrument, gives the pilot an indication of the aircraft's orientation in relation to the horizon (Tab T-41). The MP was unable to rely solely on this primary instrument (Tabs T-40 to T-42). The standby ADI located in the forward field of view of the pilot would be the MP's most reliable flight instrument (Tab T-41). Visibility of the standby ADI can be difficult when using NVGs (Tab Y-41). Cockpit lighting is normally turned down as low as possible and the HUD is turned up for greatest visual precision, still allowing for a clear view of standby instruments (Tab Y-41). The viewing of these instruments "under" NVGs is affected by natural dark adaptation (Tab Y-27). Dark adaptation is the process during which the human eye becomes more sensitive to vision in dark environments (Tab Y-27). This adaptation takes about 6 to 8 minutes (Tab Y-27). The MP donned NVGs 5 minutes after takeoff (Tab T-40). The status of the MP's cockpit lighting is unknown, but the MP never indicated any issues with the cockpit lighting environment (Tab T-42). Available cockpit lighting would support natural dark adaptation to view the standby ADI under NVGs (Tab T-42).

AN/ANVS-9G-TG (F4949 series) NVGs used in the mishap sortie have a 40-degree field of view (Tab Y-3). The human eye is able to perceive almost 180 degrees of vision, with the aid of peripheral vision (Tab Y-54). In order to view flight instruments, other aircraft, and the horizon, the loss of peripheral vision with NVGs requires increased movement of the head and neck (Tab Y-42). This motion can cause conflicting stimuli within the vestibular organs, leading to an erroneous perception of orientation, motion, or acceleration, which can create vestibular illusions leading to spatial disorientation (Tab Y-45).

On the night of the mishap, the degraded primary flight data available to the MP created an increased dependence on standby instruments for aircraft orientation (Tab T-42). An IFA requires switch changes on the avionics power panel (Tab T-42). This panel is located to the right and slightly behind the pilot (Tab X-13). To maintain visual contact with the MW, who was located to the left and forward of line abreast, the MP's head and neck would need to rotate through a range of approximately 90 to 180 degrees to perform switch changes and cross-check the standby ADI (Tab X-13). The degradation in primary flight instrumentation combined with completing an IFA may have caused the MP to become unaware of a change in altitude, attitude, and airspeed, creating the conditions for an unusual attitude (Tab T-42).

(3) Breakdown in Visual Scan – DoD HFACS AE105

A breakdown in visual scan occurs when the individual fails to effectively execute visual scan patterns, including properly cross-checking instruments for accuracy and reliability with known reliable indications or instruments (Tab Y-9).

An appropriate visual scan includes a cross-check of the environment outside of the aircraft and the aircraft flight instruments (Tabs Y-48 to Y-49). The combined information provides the pilot with situational awareness of the aircraft's attitude and orientation (Tab Y-48). A good instrument cross-check and control of the aircraft by reference to reliable flight instruments is an integral part of Air Force pilot training (Tab Y-56). The training aims at preventing pilots from succumbing to the effects of spatial disorientation (Tab Y-56). The MP was a current and qualified instrument pilot (Tab G-4).

Due to the reduced primary flight data, the most reliable attitude information available to the MP was the standby ADI (Tab T-42). With the additional task of performing an IFA while maintaining and subsequently attempting to re-establish visual contact with the MW, the MP was likely unable to maintain appropriate visual scan with this reliable flight instrument (Tab T-42). This breakdown in visual scan preconditioned the MP to experience spatial disorientation (Tab Y-48). In addition, the environment outside the cockpit was severely degraded and the use of NVGs restricted the MP's field of view, further reducing the MP's available visual cues to aid in aircraft attitude and orientation (Tab T-42).

(4) Spatial Disorientation – DoD HFACS PC508

Spatial disorientation is a failure to correctly sense a position, motion, or attitude of the aircraft or of oneself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical (Tab Y-28). It is a factor when perceptual confusion or an illusion is induced through one or more of the following senses: visual, vestibular, auditory, tactile, proprioception, or kinesthetic (Tab Y-16). Spatial disorientation may be recognized or unrecognized and result in partial or total incapacitation (Tab Y-31).

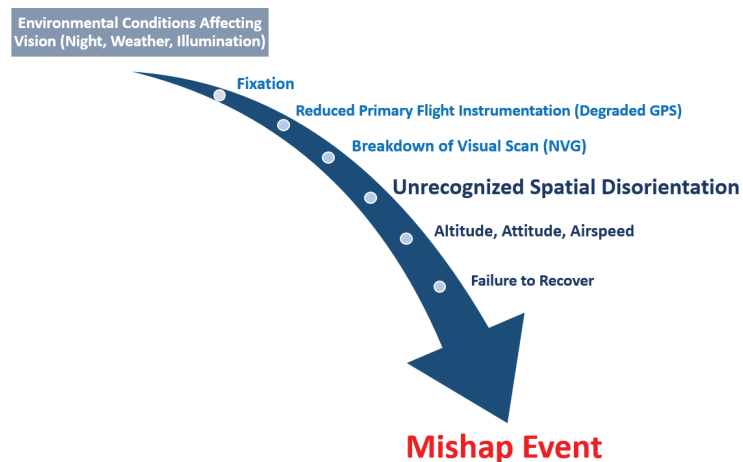


Figure 16: Human Factor Chain (Tab Y-58)

The possibility of becoming spatially disoriented is hard-wired into all humans (Tab Y-45). It is the proper functioning of our spatial orientation system, which provides the illusion leading to spatial disorientation (Tabs Y-30 to Y-31). This spatial orientation system consists of visual inputs, proprioceptive information about body position from muscles, joints, and tendons (“seat of the pants”), and acceleration inputs from the vestibular system (Tabs Y-45 to Y-48). The vestibular system consists of three semi-circular canals to detect rotational movements and the otolith organs to sense translational acceleration (Tabs Y-37 to Y-40). Because humans have learned to trust this system, it is difficult to override and accept that the actual orientation is not what is perceived (Tab Y-45). Despite the capability, accuracy, reliability, and flexibility of modern flight displays, pilots can feel themselves questioning what the aircraft instruments are telling them, simply because the “seat of their pants” or gut feeling is saying something else (Tab Y-29).

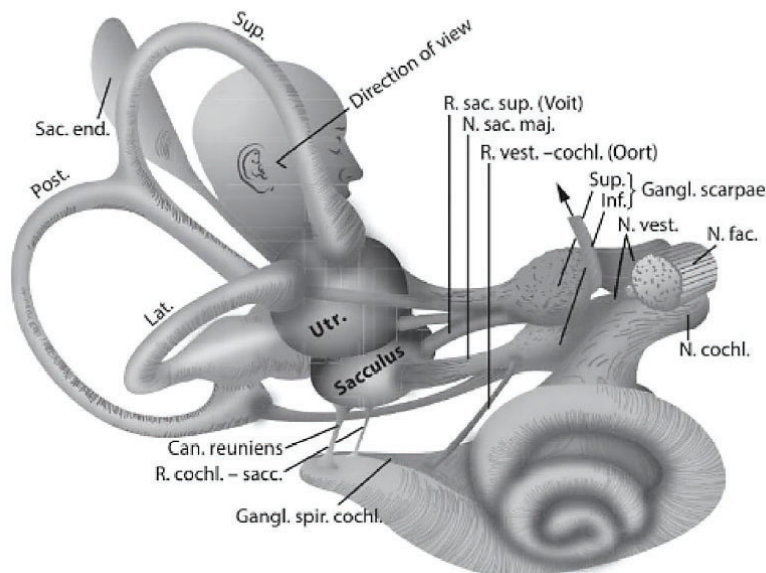


Figure 17: The Human Inner Ear (Tab Y-37)

After losing visual contact with the MW, the MP queried the MW asking “are you making a left hand turn now?” (Tab T-41). At that point in time, the MW was in straight and level flight (Tab T-41). Next, the MP entered in a subthreshold or unrecognized series of turns, one of which the MP initially perceived as the MW moving away in a perceived left turn (Tab T-41). Simultaneously, the MP’s unrecognized right turn would initially be correctly perceived by the cupulae of the semicircular canals, but when overridden by visual cues, an unrecognized vestibular illusion would be created (Tabs T-41 and Y-37 to Y-40). As the turn continues, the sensation of angular motion subsides in the cupulae and the otolith organs return to their neutral positions, creating a sensation of straight and level flight within this organ (Tabs Y-37 to Y-40). When a pilot attempts to recover from this turn, usually following a cross-check of flight instruments, the rotation is slowed or stopped, and the canal-cupula-endolymph system deflects the cupulae in the direction opposite to their initial deflection (Tabs Y-38 to Y-39). The second deflection causes a sensation of spinning in the opposite direction of the initial turn, to the left (Tab T-41). If the MP

had succumb to this false sense of rotation, the MP would feel as though the MA was turning to the left and make more severe corrections into a right bank to achieve what is perceived as straight and level flight (Tab Y-46). This sensory illusion is termed the graveyard spiral illusion (Tabs Y-47 to Y-48).

The graveyard illusion is often times exacerbated by the control-reversal error, another sensory, or non-visual illusion (Tab Y-46). This results from the misinterpretation of the gyro-display horizon of the standby ADI (Tab Y-52). The error is caused by confusing the moving horizon bar of the ADI and the fixed airplane symbol (Tab Y-52). During perceptual and cognitive confusion, as experienced during spatial disorientation, there is a tendency to control the part of the display that is moving (Tab Y-52). For example, to fly the artificial horizon back to level by moving the control stick to the right, the MP would increase the MA's bank and tighten the turn into a near-vertical spiral dive (Tabs Y-47 to Y-48).

In addition to these sensory illusions, the MP likely experienced a visual illusion (a false horizon), further preconditioning the outcome of spatial disorientation (Tab Y-50). Pilots rely heavily on visual cues during flight, rather than nonvisual orientation signals (Tab Y-50). This is termed visual field dependence (Tab Y-50). The MP's exposure to this greater potential for visual field dependence and visual illusion, in conjunction with entering worsening weather, increased darkness of the outside environment, vestibular illusions, degraded instruments, and fixation may have led to a breakdown of visual scan culminating in unrecognized spatial disorientation (Tab Y-16).

The MP's actions are consistent with an individual experiencing unrecognized spatial disorientation (Type 1) (Tab Y-16).

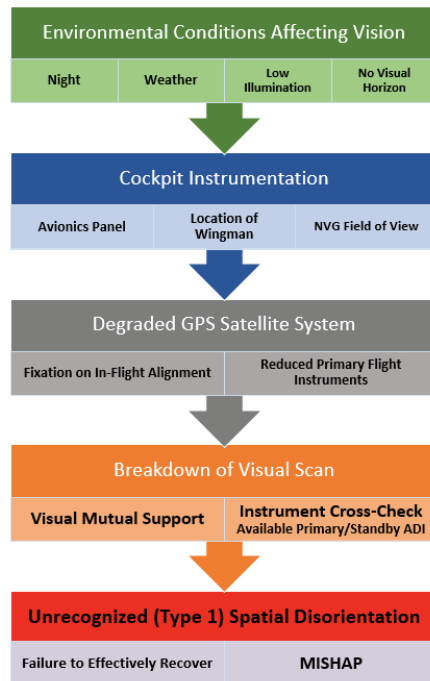


Figure 18: Mishap Critical Point Progression (Tab Y-56)

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

- (1) AFI 51-307, *Aerospace and Ground Accident Investigations*, 18 March 2019 (updated per AFI 51-307_AFGM2020-01, 26 February 2020)
- (2) AFI 51-307 ACC Supplement, *Aerospace and Ground Accident Investigations*, 3 December 2019
- (3) AFI 91-204, *Safety Investigations and Hazard Reporting*, 27 April 2018 (updated per AFI 91-204_AFGM2020-01, 7 July 2020)
- (4) AFMAN 11-202, Volume 3, *Flight Operations*, 10 June 2020 (updated per AFMAN11-202V3_AFGM2020-01, 10 September 2020)
- (5) AFI 11-301, Volume 1, *Aircrew Flight Equipment (AFE) Program*, 10 October 2017

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

None.

c. Known or Suspected Deviations from Directives or Publications

None.

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DAVID W. SMITH, Brigadier General, USAF
President
Accident Investigation Board

STATEMENT OF OPINION

F-16C, T/N 86-0317 HIAWATHA NATIONAL FOREST, MICHIGAN 8 DECEMBER 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 the night of 8 December 2020, at approximately 19:17 local time, the mishap aircraft (MA), an F-16C, tail number 86-0317, crashed into a wooded area in the Hiawatha National Forest, Michigan. The mishap pilot (MP) was operating out of the 115th Fighter Wing, Truax Field Air National Guard Base, Wisconsin (WI) while conducting a practice Aerospace Control Alert (ACA) mission. The impact fatally injured the MP and destroyed the MA.

The mishap flight was planned as a 2-ship night practice ACA mission, to include an air-to-air intercept supported by the WI Civil Air Patrol (CAP) as a Track of Interest. Due to weather conditions in Green Bay, the CAP aircraft cancelled the intercept portion of the flight and the mishap sortie launched as a 2-ship practice scramble on a back-up instrument profile. Shortly after takeoff, upon terminating the practice scramble, the MP observed a global positioning system (GPS) degradation due to the loss of satellite tracking data. The MP elected to perform an inflight alignment of the inertial navigation system (INS). While troubleshooting the GPS tracking malfunction and during the inflight alignment (INFLT ALIGN), the mishap element performed a lead swap. After a positive change in roles, the mishap element continued to diagnose the MA's available systems; at one point, the MP suggested performing a second inflight alignment. However, shortly after the lead swap, the MA entered weather conditions, at which time the MP experienced a loss of visual contact with the mishap wingman (MW). The MP and MW began to establish de-confliction via vertical and horizontal means, subsequent to which, the MA went into a series of heading, altitude, and attitude changes. Estimated outer boundaries of the flight envelope included 90 degrees nose low attitude, 135 degrees of right bank, and 600 knots airspeed, culminating with an extreme attitude, that terminated with controlled flight into terrain. There was no attempt to eject by the MP.

The total destruction of the aircraft significantly limited the ability to analyze physical evidence from the MA. Evidence including switch positions on the Avionics Power Panel, heads-up display (HUD)/digital video recorder (DVR) data, and complete crash survivable memory unit (CSMU) data was simply not available for analysis. Therefore, I had to rely on witness interviews, radar data, the MW's HUD/DVR data, as well as the communications between the MP and MW to reach an evidence-based causal conclusion.

I find, by a preponderance of the evidence, the cause of the mishap was the MP's failure to effectively recover from spatial disorientation. The combination of night, weather conditions, the use of NVGs, low illumination, the MA's altitude, attitude and airspeed, as well as the MP's breakdown in visual scan of the available primary and standby instrumentation impacted the MP's ability to recognize, confirm, and recover from the unusual attitude created by the spatially disorienting event. I also find, by a preponderance of the evidence, two substantially contributing factors: fixation and a degraded GPS satellite tracking system.

2. CAUSES

Although I did not have complete and conclusive CSMU telemetric data available, I did have accurate analysis based on data from three separate radar sources. With the available radar and limited CSMU data, I was able to observe two independent models of the MA's flight path from the start of the mishap event through ground impact. Analysis of this data indicates that after the "blind" call, the MA banked approximately 20 degrees left and 15 degrees nose high. Shortly thereafter, the MA banked right to approximately 135 degrees, reaching up to 90 degrees nose low, and culminated with roughly 600 knots airspeed, all of which conclude with an extreme unusual attitude condition at the time of impact. The analysis and facts of the final flight segment are consistent with an unrecognized spatially disorienting event.

The mishap sortie was a night mission. Although initial lighting conditions were favorable for visual horizon cues, both cultural and natural lighting deteriorated as the mishap element traveled northeast over the Hiawatha National Forest area. In addition to the increased darkness, illumination conditions also deteriorated to "low" as the flight flew to the northeast, effecting the MP's visual cues while using NVGs. The use of NVGs effected the MP's visual scan of both primary and standby flight instruments, as well as requiring movement of head position for switch changes and to maintain visual mutual support.

Subsequently, the mishap element entered into broken clouds moments before the mishap event. As a result of entering the weather conditions, the MP lost visual contact with the MW. Therefore, it is reasonable to conclude the MP had to transition to instruments during reduced visibility, nighttime, and low illumination conditions while using NVGs. Further, the evidence suggests the MA had reduced primary instrument flight data available for reference during the mishap event due to an attempted inflight alignment. Lastly, the altitude, attitude, and airspeed conditions during the mishap events severely limited the time available for the MP to effectively recover from an extreme unusual attitude condition. The MA was not equipped with a Ground Collision Avoidance System to assist in recovery.

Sufficient evidence exists to confirm the MP was performing an inflight alignment at the time of the mishap event. The evidence also suggests the MP *may* have attempted to initiate a second inflight alignment: the first step of which is to turn the INS switch on the Avionics Power Panel to OFF. Due to the destruction of the aircraft, evidence is not available to conclude the actual position of the INS switch. However, I can conclude from the available evidence that the INS knob was in the OFF *or* the INFLT ALIGN position. In either case (OFF or INFLT ALIGN), both switch positions result in the degradation of primary flight data available to the MP to perform an instrument cross-check. Therefore, the MP would have to rely on available outside visual cues

and/or a visual scan of the remaining primary and standby instruments to recognize, confirm, and recover from spatial disorientation and an unusual attitude.

Human factors analysis revealed four significant factors that contributed to the mishap event. Environmental Conditions Affecting Vision (night, low illumination, and weather) limited the MP's available visual horizon cues. Next, Instrumentation and Warning System Issues (reduced primary flight data and a narrow field of view) required head and neck movement by the MP for switch changes during visual and instrument cross-checks. Third, a Breakdown in Visual Scan of the remaining primary and standby flight instruments occurred during the mishap event. NVGs contributed to all three: Environmental Conditions Affecting Vision, Instrumentation and Warning System Issues, and Breakdown in Visual Scan. These three factors preconditioned the MP to both vestibular and visual illusions, ultimately creating the fourth significant human factor condition of unrecognized Spatial Disorientation.

I find, by a preponderance of the evidence, the cause of the mishap was the MP's failure to effectively recover from spatial disorientation. The combination of night, weather conditions, the use of NVGs, low illumination, the MA's altitude, attitude and airspeed, as well as the MP's breakdown in visual scan of the available primary and standby instrumentation impacted the MP's ability to recognize, confirm, and recover from the unusual attitude created by the spatially disorienting event.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

I also found sufficient evidence to indicate two substantially contributing factors: fixation and a degraded GPS system.

a. Fixation

Fixation is a factor in which the individual is focusing all conscious attention on a limited number of environmental cues to the exclusion of others of a subjectively equal or higher and more immediate priority, leading to an unsafe situation. This factor may be described as a tight focus of attention that leads to the exclusion of comprehensive situational awareness. The MP focused a significant amount of attention on recovering a minor system degradation. A pilot's instrument flying priorities in the simplest of terms can be broken down to: aviate, navigate, and communicate, in that order. The MP's fixation on a minor system degrade detracted from the primary task of "aviate", i.e. flying the MA "first" using the remaining available primary instruments and/or the standby attitude indicator. Therefore, I find that fixation was a substantially contributing factor to the MP's ability to recover from spatial disorientation.

b. Degraded Global Positioning Satellite System

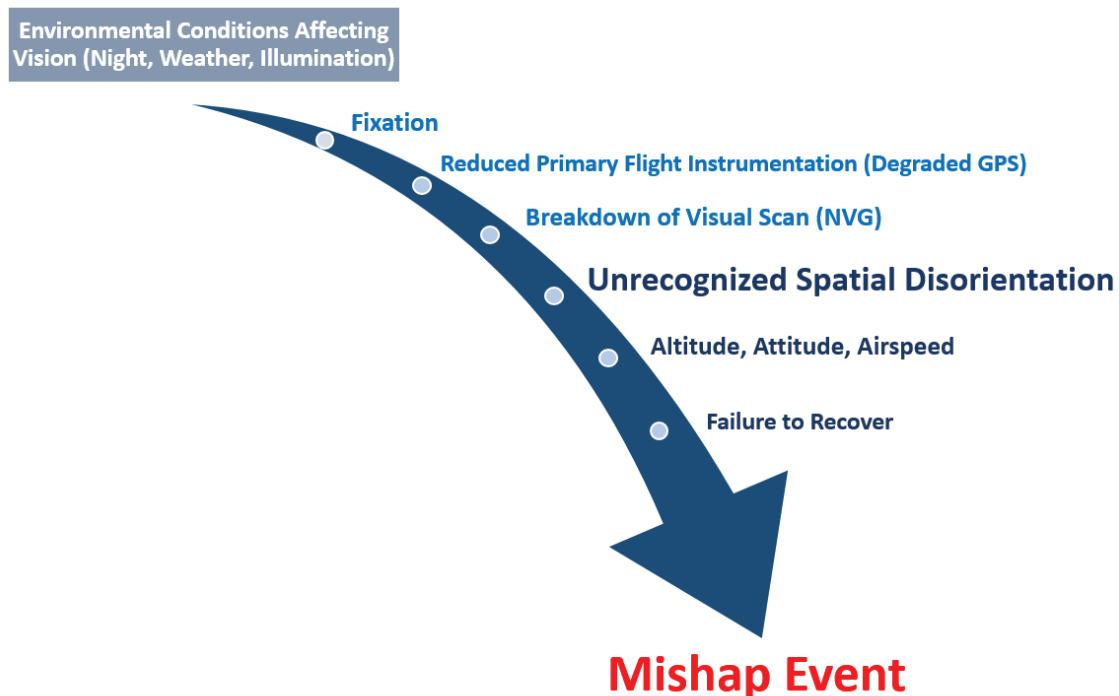
The evidence shows the MA had a degraded GPS system due to an inability to track available satellites. We also know the MP attempted to troubleshoot the GPS no track (NTRK) by performing an inflight alignment. While it is reasonable for a pilot to attempt an inflight alignment with a degraded EGI, there is no written guidance requiring an inflight alignment with a GPS NTRK. Furthermore, GPS successfully tracking satellites is not a requirement to fly an instrument profile sortie with a good INS platform. In addition, the F-16 parent Technical Orders (TO), 1F-

16C-1 and 1F-16C-34-1-1, recommend in a note an inflight alignment “should not be attempted” without the GPS successfully tracking satellites. Of note, the pilot checklist (TO 1F-16C-CL-1) “EGI INFLIGHT ALIGNMENT” does not contain this applicable note for pilot quick reference during flight. It is not reasonable to expect the MP to refer to the -1 or -34 parent documents inflight.

The MA’s GPS degrade can be attributed to two potential causes: incorrect alignment coordinates entered by the MP or outdated/corrupt almanac data. Other possibilities would have involved a maintenance malfunction, invalid cryptovariable keys, or a system date error. The latter of which were eliminated through factual investigation and subject matter expert consultation as either not applicable in this case or not influential on the MA’s GPS satellite tracking capability.

Regardless of the MP’s procedural choice or the reason for the GPS NTRK condition, the act of performing the steps of the inflight alignment (INS switch to OFF or INFLT ALIGN) resulted in the reduction of primary flight data available to the MP to reference during an instrument cross-check. This reduction in primary flight data significantly contributed to the MP’s inability to recognize, confirm, and recover from an unusual attitude. Therefore, I find the degraded GPS was a substantially contributing factor to the MP’s ability to recover from spatial disorientation.

4. CONCLUSION



I find, by a preponderance of the evidence, the cause of the mishap was the MP’s failure to effectively recover from spatial disorientation. The combination of night, weather conditions, the use of NVGs, low illumination, the MA’s altitude, attitude and airspeed, as well as the MP’s breakdown in visual scan of the available primary and standby instrumentation impacted the MP’s

ability to recognize, confirm, and recover from the unusual attitude created by the spatially disorienting event. I also find two major factors, fixation and a degraded GPS satellite tracking system, substantially contributed to the mishap.

31 March 2021

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