UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

F-16CM, T/N 96-0085

55TH FIGHTER SQUADRON
20TH FIGHTER WING
SHAW AIR FORCE BASE, SOUTH CAROLINA

LOCATION: MONCKS CORNER, SOUTH CAROLINA

DATE OF ACCIDENT: 7 JULY 2015

BOARD PRESIDENT:

MAJOR GENERAL SCOTT A. KINDSVATER

Conducted IAW Air Force Instruction 51-503

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

OFFICE OF THE COMMANDER
205 DODD BOULEVARD SUITE 200
JOINT BASE LANGLEY-EUSTIS VA 23665-2788

9 NOV 2016

ACTION OF THE CONVENING AUTHORITY

The Report of the Accident Investigation Board, conducted under the provisions of AFI 51-503, that investigated the 7 July 2015 mishap, at Moncks Corner, South Carolina, involving an F-16CM, T/N 96-0085, assigned to the 55th Fighter Squadron, Shaw AFB, SC, and a civilian aircraft (Cessna), complies with applicable regulatory and statutory guidance; on that basis it is approved.

//Signed//

HERBERT J. CARLISLE
General, USAF
Commander

EXECUTIVE SUMMARY
AIRCRAFT ACCIDENT INVESTIGATION

F-16CM, T/N 96-0085
MONCKS CORNER, SOUTH CAROLINA
7 JULY 2015

On 7 July 2015, at approximately 11:00:55 hours local time (L), near Moncks Corner, South Carolina (SC), Mishap Aircraft 1 (MA1), a F-16CM, Tail Number 96-0085, assigned to the 55th Fighter Squadron, 20th Fighter Wing, Shaw Air Force Base, SC, collided with Mishap Aircraft 2 (MA2), a Cessna 150M, registration N3601V, originating from Berkeley County Airport, SC. Neither pilot nor passenger of MA2 survived the collision. Falling debris damaged two private travel trailers near the collision site. Due to separation of the engine exhaust module during impact, MA1 did not have sufficient thrust to maintain altitude, forcing MA1 Pilot (MP1) to eject. MP1 landed with minor injuries. MA1 impacted an uninhabited forest about 9 miles south of the collision. Both MA1 and MA2 were destroyed. The estimated government loss was $29,161,541.52.

MA1 was enroute from Myrtle Beach, SC, to Charleston, SC, when MA2 departed Berkeley County Airport, near Charleston, enroute to Myrtle Beach. MA1 was flying at 1600 feet as directed by the Mishap Air Traffic Controller (MC) at Charleston Air Traffic Control. The Cessna pilot, MA2 Pilot (MP2), was not in contact with MC, and was not required to be, but was visible on MC's radar. At 11:00:16L, MC first advised MP1 of MA2 with *"traffic, 12 o'clock, 2 miles, opposite direction, one thousand two hundred indicated, type unknown*" (another aircraft is at your 12 o'clock position, 2 miles away, flying towards your aircraft at 1200 feet, aircraft type unknown). MP1 had no previous expectation of a potential traffic conflict. At 11:00:25L, MC instructed MP1 to turn left to 180 degrees (south) if MP1 did not see MA2 but MP1 did not hear the left turn advisory. MP1 looked, but did not see MA2 and asked MC to confirm the distance. At 11:00:33, MC told MP1 "*if you don't have that traffic in sight, turn left heading 180 immediately*." MP1 acknowledged the instruction and had completed 30 degrees of a left turn before MA1 collided with MA2 at 11:00:55L.

The Board President (BP) found by a preponderance of the evidence there are two causes of this mishap: (1) MC issued a radar vector directing MP1 to immediately turn left to 180 degrees (south) placing the MA1 and MA2 on a collision course; and (2) MP1 and MP2 were not able to see and avoid each other in time to prevent collision. The BP found, by a preponderance of the evidence, the following factors substantially contributed to the mishap: (1) MC directed MA1 to fly on a course and at an altitude that would increase potential for conflicts by passing in close proximity to the departure routes of an uncontrolled airfield; (2) MP1 and MP2 did not use available systems which may have increased situational awareness; and (3) MC did not provide MP1 with traffic information in time for MP1 to identify the conflict before MC issued the immediate left turn instruction.

SUMMARY OF FACTS AND STATEMENT OF OPINION
F-16CM, T/N 96-0085
7 July 2015

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

’	Feet
20 FW	20th Fighter Wing
437 AW	437th Airlift Wing
55 FS	55th Fighter Squadron
77 FS	77th Fighter Squadron
9 AF	Ninth Air Force
AAR	Air to Air Refueling
AB	After Burner
ACC	Air Combat Command
ACMI	Air Combat Maneuvering Instrumentation
ADO	Assistant Director of Operations
AEF	Air Expeditionary Force
AF	Air Force
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFI	Air Force Instruction
AFPAM	Air Force Pamphlet
AFTO	Air Force Technical Order
AFTTP	AF Tactics, Techniques, Procedures
AGL	Above Ground Level
AIB	Accident Investigation Board
ALIC	Aircraft Launcher Interface Computer
AIM	Aeronautical Information Manual
AMU	Aircraft Maintenance Unit
AMXS	Aircraft Maintenance Squadron
AOS	Angle of Side-Slip
AP	Area Planning
ATC	Air Traffic Control
ATIS	Automatic Terminal Information System
ATP	Advanced Targeting Pod
Aux	Auxiliary
BAT	Battery
BFM	Basic Fighter Maneuvers
BIT	Built in Test
BPO	Basic Post Flight
CAP	Critical Action Proced ure
Capt	Captain
CAMS	Core Automated Maintenance System
CATCA	Chief ATC Automation
CATM	Captive Air Training Missile
CC	Commander
CFR	Codified Federal Regulations
CMR	Combat Mission Ready
Col	Colonel
Comms	Communications
CSFDR	Crash Survivable Flight Data Recorder
CSMU	Crash Survivable Memory Unit
DO	Director of Operations
DoD/DD	Department of Defense
DSN	Defense Switched Network
DU	Display Unit
ECM	Electronic Counter Measure
ECS	Environmental Control System
EGT	Exhaust Gas Temperature
EMS	Emergency Medical Services
Eng	Engine
EPU	Emergency Power Unit
ER	Exceptional Release
FAA	Federal Aviation Administration
FBO	Fixed Base Operator
FCF	Functional Check Flight
FLCS	Flight Control System
FRT	Field Response Team
FS	Fighter Squadron
FTIT	Fan Turbine Inlet Temperature
G	Gravitational Force
HARM	High Speed Anti-Radiation Missile
HATR	Hazardous Air Traffic Report
HFACS	Human Factors Analysis and Classification System
HTS	HARM Targeting System
HUD	Head-Up Display
IAW	In Accordance With
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMDS	Integrated Maintenance Data System
JBCHS	Joint Base Charleston
JOAP	Joint Oil Analysis Program
KCHS	Charleston AFB/International Airport
KMKS	Berkeley County Airport
KMYR	Myrtle Beach International Airport

L	Local Time
LAO	Local Area Orientation
LOA	Letter of Agreement
Lt	Lieutenant
Lt Col	Lieutenant Colonel
LVDT	Linear Variable Drive Transducer
MA1	Mishap Aircraft
MA2	Mishap Aircraft 2
Maj	Major
MACA	Mid-Air Collision Avoidance
MC	Mishap Air Traffic Controller
MCD	Magnetic Chip Detector
MDEC	Modernized Digital Engine Control
MESL	Minimum Equipment System List
MIDS	Multifunctional Information Distribution System
MM	Maintenance Member
MOO	Maintenance Operations Officer
MOA	Military Operating Area
MP1	Mishap Pilot 1
MP2	Mishap Pilot 2
MPS	Mishap Passenger
MQT	Mission Qualification Training
MSL	Mean Sea Level
MTR	Military Training Route
MXO	Maintenance Operations
MXG	Maintenance Group
MXS	Maintenance Squadron
NAS	National Airspace System
NAV	Navigation
NMC	Non-Mission Capable
NOTAM	Notice to Airman
NTSB	National Transportation Safety Board
OA1	Unrelated Aircraft
OCF	Operational Check Flight
OG	Operations Group
OGV	Operations Group-Standards and Evaluations Office
OIC	Officer in Charge
ops	Operations
Ops Sup	Operations Supervisor
Ops Tempo	Operations Tempo
ORM	Operational Risk Management
PCS	Permanent Change of Station
PHA	Physical Health Assessment
PLF	Parachute Landing Fall
Pro-Supr	Production Supervisor
BP	Board President
PSI	Pounds Per Square Inch
QA	Quality Assurance
QAI	Quality Assurance Inspector
RADOME	Radar Dome
RAP	Ready Aircrew Program
SA	Situational Awareness
SAR	Search and Rescue
SDR	Seat Data Recorder
SEF	Flight Safety
SII	Special Interest Item
SIB	Safety Investigation Board
SFO	Simulated Flame-Out Approach
SIB	Safety Investigation Board
SIM	Simulator
SMSgt	Senior Master Sergeant
SOF	Supervisor of Flying
Spec	Specialist
SrA	Senior Airman
SSgt	Staff Sergeant
SUPR	Supervisor
TO	Technical Order
T/N	Tail Number
TDY	Temporary Duty
TACAN	Tactical Air Navigation System
TCAS	Traffic Collision Avoidance System
TCTO	Time Compliance Technical Order
US	United States
USAF	United States Air Force
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
Vol	Volume
Z	Zulu

The above list is derived 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 4 August 2015, General Herbert J. Carlisle, Commander, Air Combat Command (ACC), appointed Brigadier General Scott A. Kindsvater (since promoted to Major General) to conduct an aircraft accident investigation of a mishap that occurred on 7 July 2015 involving a F-16 aircraft near Charleston, South Carolina (SC) (Tab Y-2). The aircraft accident investigation was conducted in accordance with (IAW) Air Force Instruction (AFI) 51-503, *Aerospace and Ground Accident Investigations*, at Shaw Air Force Base (AFB), SC, from 17 August 2015 through 18 September 2015 and from 10 April 2016 to 15 April 2016 (Tab Y-2). Accident Investigation Board (AIB) members were a Legal Advisor Member (Colonel), a Pilot Member (Major), a Maintenance Member (Major), a Flight Surgeon Medical Member (Captain), an Operations Member (Chief Master Sergeant), and a Recorder Member (Technical Sergeant) (Tab Y-2). The following Subject Matter Experts were appointed: Physiologist (Captain) and Airfield Operations (Chief Master Sergeant) (Tab Y-4 to Y-5).

b. Purpose

IAW AFI 51-503, 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 administration action.

2. ACCIDENT SUMMARY

On 7 July 2015, at approximately 11:00:55 hours local time (L), during an Operational Check Flight (OCF), Mishap Aircraft 1 (MA1), a F-16CM, tail number 96-0085, assigned to the 55th Fighter Squadron (55 FS), 20th Fighter Wing (20 FW), Shaw AFB, SC, and flown by a member of the same unit, collided with Mishap Aircraft 2 (MA2), a Cessna 150M, registration N3601V, originating from Berkeley County Airport, SC (KMKS) (Tabs, D-2, H-2, K-4, Q-5 to Q-6, S-7, V-1.3, V-1.13, Z-9, AA-5 and GG-3). MA2 was destroyed; neither MA2 pilot (MP2) nor passenger survived the collision (Tabs Q-5, X-4 to X-7). During the collision, the engine exhaust module separated from MA1 and MA1 did not have sufficient thrust to maintain altitude, forcing MA1 Pilot (MP1) to eject approximately 2 minutes 30 seconds later at about 300' above ground level (AGL) (Tabs H-8, R-3 to R-4, U-28, V-1.13V-8.2). MP1 landed with minor injuries (Tab Q-5, X-3). MA1 impacted an uninhabited forest approximately 9 miles south of the collision and was destroyed; the loss to the government was $29,161,541.52 (Tabs H-2, P-3, S-4, Z-8, and Z-10). Falling debris damaged two private travel trailers (Tabs P-2 and S-5). There was significant media interest in this mishap (Tab FF-2).

3. BACKGROUND

MA1 belonged to, and MP1 was assigned to, the 55 FS, 20 FW, Ninth Air Force (9 AF), ACC, and stationed at Shaw AFB, SC (Tabs K-4, T-6, U-2, and CC-2 to CC-3 and CC-11).

a. Air Combat Command

ACC is the primary force provider of combat airpower to America's warfighting commands (Tab CC-2). Supporting the global implementation of national security strategy, ACC operates fighter, bomber, 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). ACC numbered air forces provide the air component to U.S. Central, Southern, and Northern Commands (Tab CC-2). ACC also augments forces in U.S. European, Pacific, and Strategic Command (Tab CC-2).

b. Ninth Air Force

The 9 AF organizes, trains, and equips Airmen to meet the demands of today's expeditionary taskings while preparing for tomorrow's challenges (Tab CC-3, CC-6) 9 AF comprises eight active-duty wings and three direct reporting units with more than 400 aircraft and 29,000 active-duty and civilian personnel (Tab CC-3). 9 AF is also responsible for the operational readiness of 16 National Guard and Air Force Reserve units (Tab CC-3).

c. 20th Fighter Wing

The 20 FW provides combat ready airpower and Airman to meet any challenge, anytime, anywhere (Tab CC-8). The wing is capable of meeting all operational requirements worldwide, maintains a state of combat readiness and operates as the host unit at Shaw AFB by providing facilities, personnel, and material (Tab CC-8).

d. 55th Fighter Squadron

The 55 FS can trace its roots to 1917 when it formed as the 55th Aero Squadron at Kelly Field, Texas (Tab CC-11). The "Fighting Fifty-Fifth" saw combat in World War I, World War II, and Operations DESERT STORM, NORTHERN and SOUTHERN WATCH, IRAQI FREEDOM and ENDURING FREEDOM. In its distinguished 96-year history, the 55 FS has flown 12 different types of aircraft (Tab CC-11 & CC-12).

e. F-16 Fighting Falcon

The F-16 Fighting Falcon is a compact, highly maneuverable, multi-role fighter aircraft (Tab CC-13). It has proven itself in air-to-air combat and air-to-surface attack (Tab CC-13). It is a high performance weapon system used by the United States and allied nations (Tab CC-13). Since 1979, the F-16 has been a major component of the combat forces flying tens of thousands of sorties in support of various combat operations worldwide (Tab CC-3).

4. SEQUENCE OF EVENTS

a. Mission

MA1 was on a single aircraft OCF mission on 7 July 2015 to verify corrective maintenance (Tabs, R-41, V-1.3 to V-1.6, and AA-3). MA1 originated at Shaw AFB and accomplished the mission via an instrument procedures training flight (Tabs K-2, V-1.3, and V-2.2). MP1 intended to conduct practice approaches at Myrtle Beach International Airport, SC (KMYR) and Joint Base Charleston/International Airport, SC (KCHS) prior to returning to Shaw (Tabs K-2, R-3, V-1.4; and Figure 1). The 55 FS Assistant Director of Operations was standing Top-3, the senior duty officer in charge of the operations for the squadron, and authorized the mission (Tabs R-34 to R-35, V-2.2, V-2.3, and AA-3).

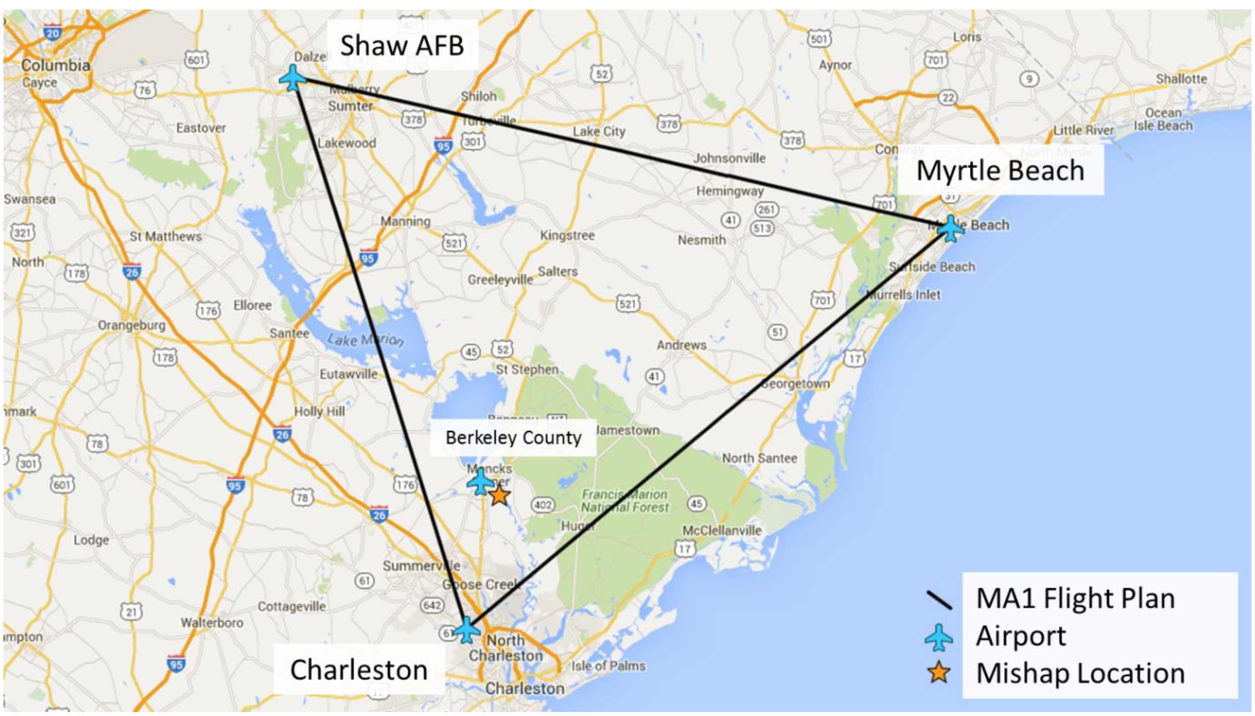


Figure 1: Overview of MA1 Flight Plan (Tab K-2). Map is from Google Earth. Lines do not represent actual flight path shown on MC's radar in Tab Z-17.

b. Planning

Mission planning was accomplished using standard procedures for a local flight IAW the *20 FW Pilot Aid*, AFI 11-202v3, *General Flight Rules*, and AFI 11-2F-16v3, *F-16 Operations Procedures* (Tabs V-1.4 to V-1.6, V-2.3, BB-2, BB-113). As a single aircraft mission, MP1 conducted an individual flight brief by reviewing a personal briefing guide (Tab V-1.5). There were no interruptions or hindrances to the planning process (Tab V-1.4).

c. Preflight

Maintenance Quality Assurance personnel briefed MP1 concerning MA1's maintenance history (Tabs V-1.6, V-2.3, V-6.2). Maintenance did not have any specific requirements for the OCF (Tabs U-28, V-1.6, and V-6.2). Prior to the step brief, MP1 donned appropriate Aircrew Flight Equipment (AFE) and collected other required flying gear (Tab V-1.6). Top-3 provided MP1 a standard Top-3 brief covering all required items for flight such as Notices to Airmen and weather (Tab V-1.6, V-2.3). MP1 then proceeded to MA1, which was equipped with a standard air-to-ground training configuration (Tabs P-3, and V-1.6 to V-1.7).

MP1 completed a Department of Defense Form (DD) 175 flight plan and gave it to the Top-3 to file (Tab V-1.4 . V-2.3, and R-36). After engine start, MA1's Link-16 system was inoperable (Tab V-1.6). Link-16 is a tactical data exchange network that allows for military aircraft and ground systems to share real time data such as radar surveillance tracks (Tab V-1.6 to V-1.7). The Link-16 system is primarily of benefit for multi-aircraft combat operations, and not required for single aircraft training flights in the U.S. (Tabs T-8, V-1.7 and BB-30). All other engine start procedures were uneventful (Tab R-47 to R48, V-1.6 to V-1.7, V-2.3, and V-7.2).

d. Summary of Accident

Taxi and takeoff were uneventful (Tab R-47 to R-48, V-1.7 and V-2.3). MA1 departed Shaw AFB at approximately 10:24L (14:24Z) (Tab AA-2). MA1 completed practice approaches at KMYR as planned, then proceeded towards KCHS (Tabs K-2 and V-1.7 to V-1.8). MP1 contacted the KCHS Mishap Air Traffic Controller (MC) when MA1 was approximately 45 miles northeast of KCHS at an altitude of 6000' Mean Sea Level (MSL) (Tabs N-3, V-1.10, and Z-17, GG-3). MP1 requested heading and altitude directions (vectors) for an instrument approach to KCHS Runway 15 (Tab N-3). MC directed MA1 to a 260 degree heading (west-southwest) at 10:52L and then to descend to 1600' MSL at approximately 10:55L, when MA1 was approximately 35 miles northeast of KCHS (Tabs GG-3, N-3 to N-4, V-1.10, Z-17, and GG-5). MC was also controlling other aircraft at the time, which MC characterized as "light" and "routine" (Tabs N-3, Z-17, and GG-5). There were no conflicts or other aircraft along MA1's route of flight for the next 2 to 3 minutes after MA1 began descending to 1600' MSL (Tabs V-1.10 and Z-17).

At approximately 10:57L, MA2 departed KMKS from Runway 23 and first appeared on MC's radar at 200' MSL (Tabs Z-17, GG-3 to GG-5). MA1 was approximately 16 miles to the east of MA2 (Tab Z-17). MA2 began a steady climb (increase in altitude) of about 400' per minute on an approximate heading of 200 degrees (south-southwest) (Tab Z-17). About 33 seconds later and at approximately 400' MSL, MA2 turned to a heading of roughly 090 degrees (east) and continued climbing (Tab Z-17). MC observed MA2 depart on radar but had no radio contact with MP2 (Tabs

N-5, Z-17, and GG-3 to GG-5). Evidence does not indicate that MP2 filed a flight plan or requested basic radar services from MC (often referred to as "flight following") (Tabs N-3 to N-5, Z-17, GG-5, BB-128 to 130, and BB-152). MC assumed MA2 was going to remain near KMKS at or below 1000' to practice landings (Tab GG-3). According to MC, pattern work aircraft rarely exceeded 1000' at KMKS (Tab GG-3).

Table 1 below contains both altitudes and communications from MC to aircraft MC was controlling, until approximately 1 minute before collision, when MA2 was at 1000' MSL (Tabs GG-3, N-3 to N-5, and Z-17).

Time (L)	Event
10:52	MA1 made initial contact with MC with a reported altitude of 6000' MSL MC issued MA1 a heading of 260 degrees to KCHS Runway 15 final approach course
10:54	MC confirmed MA1's flight profile, issued follow-on instructions
10:55	MC issued MA1 a decent to 1600' MSL
10:56	Unrelated Aircraft 1 (OA1) contacts MC 35 miles west of KCHS Runway 15
10:57:18	First radar indication of MA1 at 1600' MSL
10:57:40	*MA2 at 200' MSL, immediately southwest of KMKS; First radar indication of MA2* MA1 roughly 16 miles east of MA2 at 1600' MSL
10:57:50	*MA2 at 300' MSL* MC instructed Unrelated Aircraft 2 to Charleston Executive Airport
10:57:59	MC transferred Unrelated Aircraft 3 to tower
10:58:08	MC contacted by Unrelated Aircraft 4, 45 miles northeast of KCHS
10:58:13	*MA2 at 400' MSL. MA2 started a left turn, heading 180*
10:58:22	*MA2 at 500' MSL*
10:58:36	*MA2 at 600' MSL now tracking towards the east* MA1 roughly 12 miles east of KMKS at 1600' MSL
10:58:50	*MA2 at 700' MSL*
10:59:08	*MA2 at 800' MSL*
10:59:18	*MA2 at 900' MSL*
10:59:27	MC issued an altitude descent to a OA1 20 miles west of KCHS
10:59:31	*MA2 at 1000' MSL* MA1 at 1600' MSL, roughly 7 miles northeast of MA2's position
10:59:39	MC contacted by Unrelated Aircraft 5, requesting an altitude descent

Table 1 Note: MA2 altitudes in *blue italic* are from radar indications.

For 2 minutes and 25 seconds after MA2 first appeared on MC's radar, MA1 continued on the 260 degrees heading at 1600' MSL as directed by MC (Tabs N-3 to N-5, V-1.10, and Z-17). MP1 had completed all applicable approach-to-field checks required to perform an approach and landing, and MP1 was visually clearing his flight path and searching for aircraft while monitoring aircraft instruments (Tab V-1.10). MC was controlling other aircraft during that time, and did not provide any information to MP1 concerning potential traffic conflicts with MA2 (Tabs N-3 to N-5, and V-1.10). Radar data indicates the first conflict alert occurred from 10:59:59L through 11:01:01L, but MC did not recall seeing or hearing the conflict alert (Tab GG-3).

An overview of the ground tracks of both aircraft is in Figure 2 below (Tabs M-2, N-3 to N-5, and Z-17).

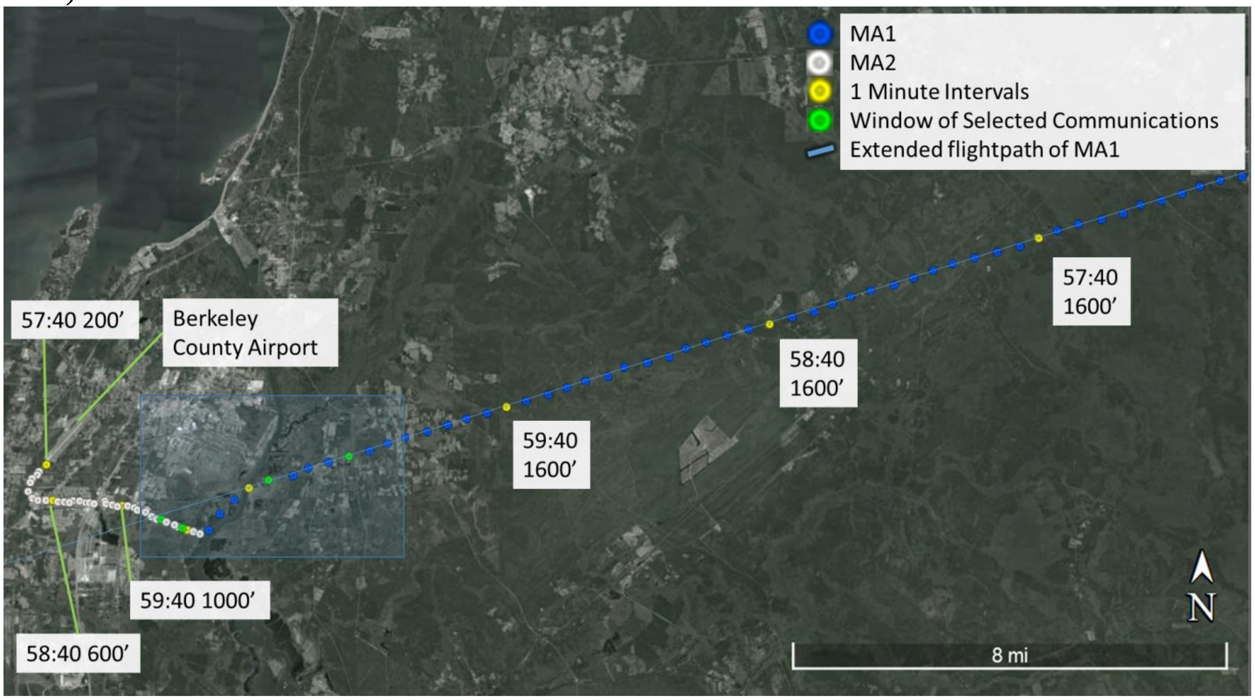


Figure 2: Overview of Air Traffic Control Radar Plots (Tabs M-2, N-3 to N-5, and Z-17). Each 1-minute interval starting with the first appearance of MA2 is yellow. Figure 3 expands the shaded rectangle. The locations of MA1 and MA2 during selected communications in Table 1 are green. Note: Figure 2 is not a depiction of actual MC radar displays.

At 11:00:16L, shortly after MA2 passed through 1200' MSL, MC stated, "[MA1], traffic, twelve o'clock, two miles, opposite direction, one thousand two hundred indicated, type unknown" (Tabs N-6, R-3, and Z-17). MP1 acknowledged receiving the transmission from MC (Tab N-6). This was MP1's first indication of MA2's presence and first knowledge of a potential traffic conflict (Tab V-1.11). MP1 prioritized visually scanning the airspace, but was unable to locate MA2 visually (Tab V-1.11 to V-1.12).

At 11:00:25L, MC transmitted "[MA1], turn left heading 180 if you don't have that traffic in sight" (Tab N-6). MP1 did not recall hearing this radio transmission and did not acknowledge the turn instruction (Tabs N-6, V-1.11, and V-1.14). Four seconds after MC finished the transmission, at 11:00:31L, MP1 asked MC to confirm the traffic was 2 miles away because MP1 recalled having radar indications for an aircraft 20 miles away (Tabs N-6, R-5, V-1.2 and V-1.14). At the same time, MA2 was still traveling east and climbing through 1300' MSL (Tab Z-17). At 11:00:33L, MC transmitted "[MA1] if you don't have that traffic in sight, turn left heading 180 immediately" (Tab N-6). MC believed a left turn was "faster than a turn to the north and would de-conflict a potential merging target quicker" (Tab GG-3 and GG-5). MC believed "fighters could turn on a dime" (Tab GG-3 and GG-5). The turn instruction directed MP1 to expeditiously begin a standard rate, 30-degree bank turn (Tab V-1.11 to V-1.12, V-1.15, and BB-141).

Figure 3 below shows an expanded version of the ground tracks from Figure 2 with overlaid communications.

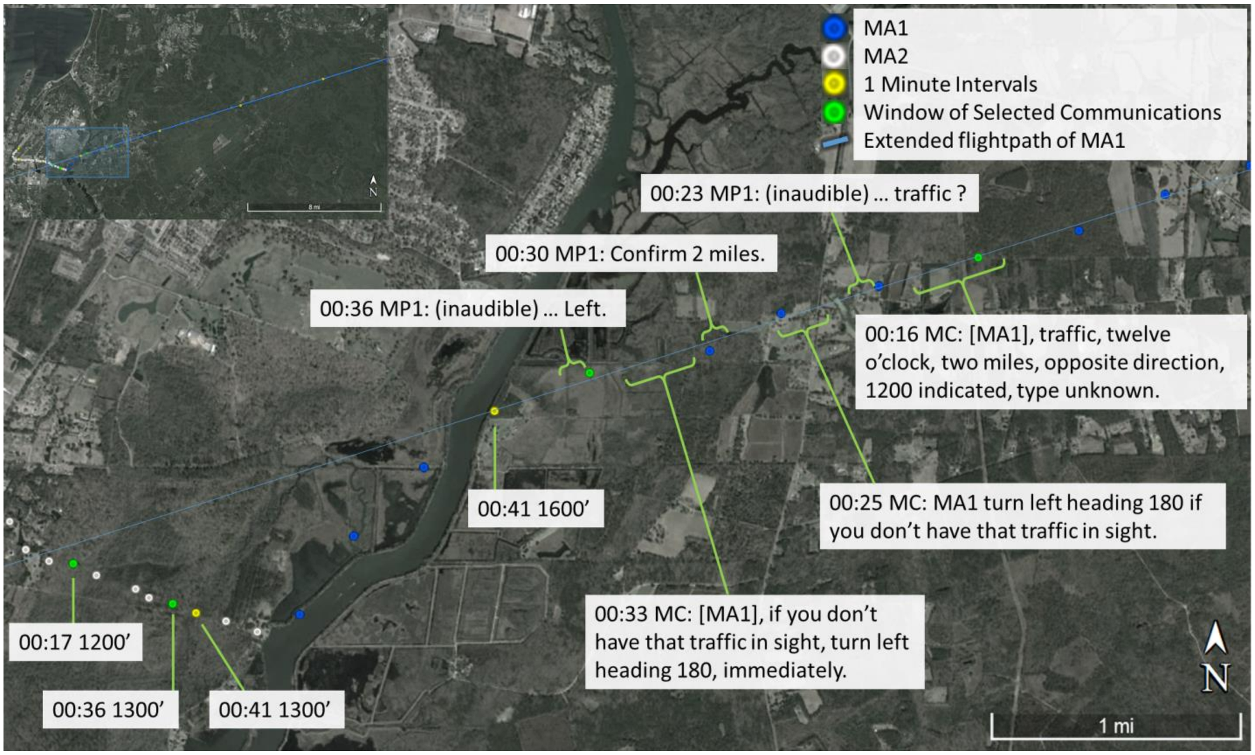


Figure 3: Expanded View of Air Traffic Control Radar Plots with Overlaid Communications (Tabs M-2, N-3, and Z-17). The brackets approximate the distance traveled by MA1 during the radio communications. During the depicted communications, MA2 was south of the blue line representing MA1's extended flight path (260 degrees) and traveling further south away from MA1's path (Tabs M-2, N-3, and Z-17). Not a depiction of actual radar displays.

MP1 acknowledged MC's instruction after MC's transmission ended and immediately began a standard rate, 30-degree bank, autopilot turn towards 180 degrees (south) (Tabs N-6, V-1.11, V-1.12, V-1.15, and Z-17). According to radar data, MA1 descended approximately 100' in the autopilot turn as MA2 continued to climb through 1300' MSL (Tab Z-17). During this turn, MP1 continued to look for MA2 in the direction of turn and underneath his aircraft (Tab V-1.12, V-1.14). MA1 had completed 30 degrees of turn toward the south when MC transmitted, at 11:00:52L, "[MA1], traffic passing below you, one thousand four hundred (Tabs N-6 and Z-17). At 11:00:55L, MA1 and MA2 merged on radar (Tab Z-17).

Modeling of the mishap from the viewpoint of a nominal pilot indicates MA1 and MA2's designs and structures obstructed both MP1 and MP2's ability to see the other aircraft during significant periods of time (Figures 7, Figure 8, Figure 9, Tab Z-19 to Z-20; further discussion in Section 13 below). MP1 saw MA2 less than 500' away, less than a second before the collision, and applied full control input (pulled "full aft stick") in an attempt to avoid collision (Tab V-1.12 to V-1.13). MA1 did not have sufficient maneuverability to avoid MA2 and the two aircraft impacted (Tab V-1.13). MP2 and passenger did not survive this impact (Tab X-4 to X-7). The collision separated the engine exhaust module and other parts from the underside of MA1, which fell to the southwest below the impact location of MA1 (Tabs V-1.13, U-28, V-8.2, Z-2, Z-8, and Z-10). MP1 looked back and saw MA2 spiraling towards the ground (Tab V-1.13). The main portion of MA2 descended into a tree line on the west side of the Cooper River (Tab Z-10). MP1 attempted to turn back to provide assistance but did not have sufficient thrust due to separation of the exhaust module (Tab V-1.13 and V-8.2).

Table 1: Timeline of Communications on MC's Frequency (Tabs N-6 to N-7, T-8, Z-17, GG-3). [Note: Tab N contains typographical error regarding 11:00:16 communication]

Start Time (L)	End Time (L)	Speaker	Communication
10:59:48	10:50:51	MC	Information Tango is current at Charleston, the altimeter is 3016
10:59:55	*MA2 at 1100' MSL and tracking east southeast*		
10:59:59	*Data indicates Traffic Conflict Alert occurred at MC's radar position*		
11:00:07	11:00:10	MC	[OA1], a good rate of descent to 3000
11:00:09	*MA2 at 1200' MSL*		
11:00:11	11:00:13	OA1	[OA1], expedite descent to 3000
11:00:16	11:00:21	MC	**[MA1], traffic, twelve o'clock, two miles, opposite direction, one thousand two hundred indicated, type unknown**
11:00:24	11:00:24	MP1	**(inaudible) …**
11:00:25	11:00:27	MC	**[MA1] turn left heading 180 if you don't have that traffic in sight**
11:00:31	11:00:31	MP1	**Confirm 2 miles?**
11:00:32	*MA2 at 1300' MSL*		
11:00:33	11:00:35	MC	**[MA1], if you don't have that traffic in sight, turn left heading 180, immediately**
11:00:36	11:00:37	MP1	**(inaudible) … [MA1]**
11:00:45	*MA2 at 1400' MSL*		
11:00:52	11:00:55	MC	**[MA1] traffic passing below you, one thousand four hundred**
11:00:57	11:00:58	MP1	**[MA1] … (inaudible)**
11:01:03	11:01:06	MP1	**[MA1], that, uh, aircraft is a (inaudible)**
11:01:08	11:01:10	MC	**[MA1], uh, unable to read you, say again**
11:01:19	11:01:20	MP1	**[MA1], Mayday, Mayday, Mayday**
11:01:22	11:01:23	MC	**[MA1], Charleston …**
11:01:39	11:01:41	MC	[OA1] Turn right heading zero niner zero
11:01:42	11:01:44	MP1	**[MA1] is …** [interrupted by OA1]
11:01:44	11:01:45	OA1	… (inaudible) … Confirm for [OA1]?
11:01:45	11:01:46	MC	**[MA1], Charleston**

MA2 altitudes in *blue italic* are from radar indications. MC and MA1 communications are **bold**. Communications on Figure 3 between MA1 and MC are **bold green**.

Seconds after the collision, MP1 made an inaudible transmission and MC asked MP1 to "say again" (Tabs N-6 and Z-17). Eight seconds later, MP1 transmitted "Mayday, Mayday, Mayday" (Tabs N-6 and Z-17). MP1 began Critical Action Procedures ("Steps") in an attempt to land MA1 safely (Tab V-1.13). Heading southeast at the time, MP1 selected maximum power ("full afterburner") and jettisoned external stores and equipment, which landed on the east side of the river (Tabs V-1.13 and Z-10). MP1 turned towards KCHS (Tab V-1.13). Unable to produce enough thrust to continue flying, MA1 continued south in a steady descent over the next 2-3 minutes, dropping off the radar while passing through 300' MSL (Tabs V-1.13, Z-10, and Z-17).

e. Impact

MP1 ejected at approximately 11:03L, about 300' AGL (Tab H-8). MA1 was in a shallow decent and impacted an uninhabited forested area approximately 10 miles south of Moncks Corner, SC (Tabs H-4, Z-8, and Z-10). The majority of MA1 broke apart as it tumbled across the forest floor (Tab H-4). A post-crash fire further damaged parts of the wreckage (Tabs H-4 and S-4). The debris field, covered with medium-to-large fragments from MA1, measured approximately 200 yards long by 100 yards wide (Tabs H-4 , Z-2, and Z-8).

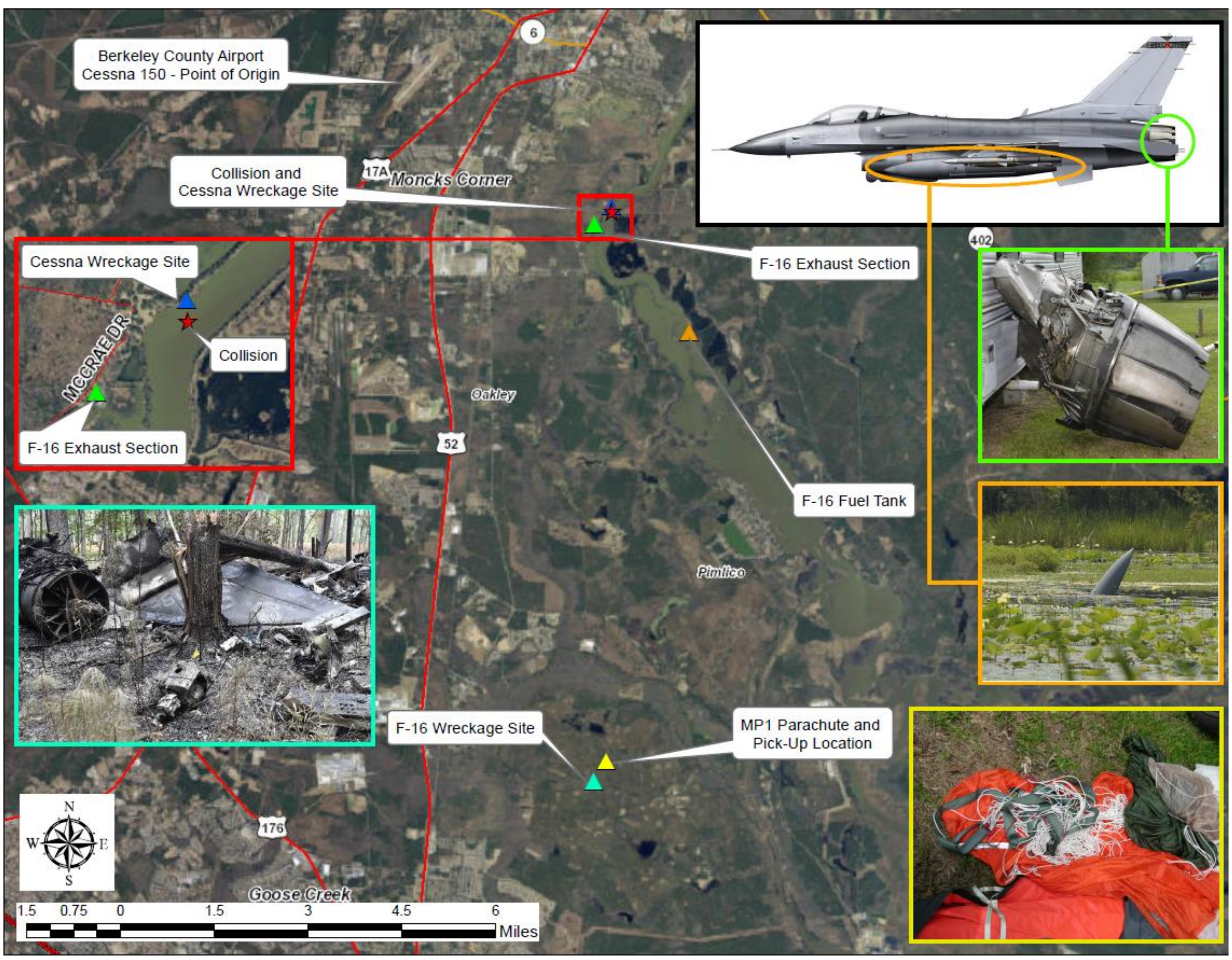


Figure 4: Post Impact Overview (Tabs H-2, Z-2, Z-8, Z-10, and Z-17)

f. Egress and Aircrew Flight Equipment (AFE)

After assessing MA1 was going to impact the ground, MP1 successfully ejected at approximately 300' AGL, between 155 and 167 knots indicated airspeed (Tabs H-8, L-7, R-3, and V-1.2). MP1 landed with minor injuries (Tabs R-4, V-1.2, X-3). The aircraft canopy, ejection seat and associated egress system components were recovered from the mishap site and moved to on-base facilities located at Charleston, AFB and then Shaw, AFB for detailed evaluation (Tab H-5). Analysis identified no relevant anomalies, discrepancies, or noncurrent inspections with the egress system or AFE (Tab H-2 to H-11). All equipment functioned appropriately and much of the AFE gear remained in serviceable condition (Tab H-2 to H-11).

g. Search and Rescue (SAR)

Multiple civilian agencies responded to the mishap scene with the Berkeley County Emergency Medical Services (EMS) being the first to arrive at approximately 11:11L (Tab X-5). Other responding civilian agencies included the Berkeley County Coroner's Office, Berkeley County Rescue, Berkeley County Sheriff's Department, Charleston Country Rescue Squad, South Carolina Department of Natural Resources, Federal Aviation Administration, National Transportation Safety Board (NTSB), and several local fire departments (Tab X-5). KCHS tower activated the Joint Base Charleston (JBCHS) crash network, and the JBCHS Field Response Team (FRT) responded for the Air Force (Tabs DD-2, DD-3, DD-14, GG-7, and GG-11).

After ejecting, MP1 sent out a distress call (Tabs R-4 and V-1.2). A local groundskeeper, accompanied by Coast Guard personnel, made first physical contact with MP1 (Tabs R-4 and V-1.2). MP1 received care from Berkeley County EMS prior to arrival of Air Force responders (Tab DD-14). MP1 was transported to Trident Medical Center, Charleston, SC (Tabs X-3 and DD-14). MP1 was accompanied by two members of the FRT to ensure proper military procedures were followed during the hospital's evaluation (Tab DD-14). The emergency department evaluated and discharged MP1 the same day (Tabs X-3 and DD-14).

h. Recovery of Remains

The Berkeley County coroner recovered MP2 and passenger's remains (Tab X-5 and X-7). On 8 July 2015, the coroner positively identified MP2 and passenger and proceeded with the pronouncements of death (Tab X-4 and X-6). The coroner, accompanied by a chaplain, notified the next of kin of the deceased (Tab X-5 and X-7).

5. MAINTENANCE

a. Forms Documentation

Air Force Technical Order (AFTO) 781 series forms, Integrated Maintenance Data System (IMDS), and Time Compliance Technical Orders (TCTO) document aircraft maintenance and provide a record of inspections, servicing, configuration, status and flight records related to a specific aircraft (Tabs BB-31 to BB-44). A detailed review of the AFTO 781 series forms historical records for the 30 days preceding the mishap revealed no documented engine, mechanical, flight control anomalies, structural, electrical or recurring maintenance discrepancies on MA1 (Tab U-2 to U-28). In addition to the AFTO 781 series forms review, a 30-day review of IMDS historical records validated that MA1's engine, flight controls, and hydraulic components were all within prescribed inspection periods and met TCTO compliance (Tab U-2 to U-28). There is no evidence to suggest that maintenance forms documentation was a factor in this mishap.

b. Inspections

Inspections are regularly scheduled maintenance performed on Air Force aircraft at specific intervals (Tabs U-26 to U-27 and BB-31 to BB-44). The last 400-hour phase inspection for MA1 occurred on 4 June 2014 and MA1 had 162.7 hours remaining before its next 400-hour phase inspection, within the required inspection interval at the time of the mishap (Tab D-2). MA1 had 4,435.4 total flight hours at the time of the mishap (Tab D-2). The engine, a General Electric G-110-GE-129B, serial number GE0E538403, had 2,787.2 hours total operating time, with 1,199 Jet Fuel Starter starts at the time of the mishap (Tabs U-26 to U-27).

Maintenance personnel accomplished and documented all preflight and scheduled inspections IAW applicable regulations and TO's (Tab U-26). TO 00-20-1 requires an Exceptional Release (ER) before each flight (Tab BB-37). An ER is a thorough AFTO 781 series forms review conducted by authorized maintenance personnel to ensure the aircraft is safe for flight (Tab BB-37). The production superintendent verified proper completion of all required maintenance and annotated the ER in MA1's AFTO 781 series forms (Tab U-27). Maintenance personnel satisfactorily accomplished all scheduled inspections IAW applicable technical guidance. (Tab U-27). There is no evidence to suggest deficient inspection was a factor in this mishap.

c. Maintenance Procedures

A review of MA1's AFTO 781 series forms and IMDS revealed all maintenance actions complied with standard approved maintenance procedures and TOs (Tab U-27). There is no evidence to suggest maintenance procedures were a factor in the mishap (Tab U-27).

d. Maintenance Personnel and Supervision

The 20th Maintenance Group Superintendent properly released MA1 from impound (Tab U-27). The production superintendent was properly qualified to sign the ER in MA1's AFTO 781 series forms prior to the mishap flight (Tab U-27). Upon a detailed review of the maintenance documentation, all maintenance activities were normal (Tab U-27). There is no evidence to suggest maintenance personnel or supervision were factors in this mishap (Tab U-27).

e. Fuel, Hydraulic, and Oil Inspection Analyses

Following the mishap, a fuel sample was taken from fuel truck 06L-018, which supplied fuel to MA1 (Tab U-25 and U-27). The sample was tested IAW TO 42B-1-1 and all results were within specified limits (Tab U-25 and U-27). Hydraulic and oil samples were collected from the hydraulic test stands and servicing carts used to service MA1; these samples were not tested with no observed deficiencies or constraints in flight (Tab U-27).

Maintenance personnel collected a Joint Oil Analysis Program (JOAP) sample from MA1's engine oil on 29 May 2015 with 13.2 operating hours remaining until the next required sample (Tab U-24 and U-27). Maintenance personnel collected a Scanning Electron Microscope/Energy Dispersive X-Ray (Magnetic Chip Detector) sample on 11 June 2015, the last sortie flown prior to the mishap sortie (Tab U-27). Results of both tests were within specified limits (Tab U-24 and U-27).

There is no evidence to suggest fuels, hydraulics, or oils were factors in this mishap (Tab U-27).

f. Unscheduled Maintenance

The most recent relevant unscheduled maintenance performed on MA1 prior to the mishap sortie was for aircraft movement without pilot input (uncommanded flight control movement) (Tab R-40 to R-42, U-27). On 11 June 2015, MA1 returned from a flight and the pilot documented the following discrepancy in the AFTO 781 series forms: "Nose had small constant pitch and yaw movement (Nose hunting)" (Tab U-28). Maintenance personnel subsequently impounded MA1 for uncommanded flight control movement as required by applicable regulations (Tab U-28). After thorough trouble-shooting, maintenance found the moisture drain valve on the Pneumatic Servo Actuator leaking out of tolerance, the horizontal stabilators out of rig, and the rudder Integrated Servo Actuator out of tolerance (Tab U-28). Maintenance personnel completed all actions IAW applicable technical data and cleared the impoundment on 2 July 2015 (Tabs U-28 and BB-60). An OCF was scheduled to check the functionality of the flight controls for the previously documented uncommanded flight control movement (Tabs U-28, V-1.6, V-6.2, and V-7.1). MP1 found no issues with flight controls during the OCF (Tab V-1.1 to V-1.15). Data recovered from the Crash-Survivable Memory Unit (CSMU) and Seat Data Recorder (SDR) indicated no anomalies with MA1's flight controls during the OCF (Tab U-26). There is no evidence to suggest unscheduled maintenance was a factor in this mishap.

6. AIRFRAME

Based on the interview with MP1, there were no abnormal indications prior to the mishap to suggest MA1 was operating outside of normal parameters (Tabs U-28, and V-1.1 to V-1.15). The data collected from CSMU and SDR mirrors this information (Tab U-28). Lockheed Martin engineers evaluated the data from the SDR and concluded that the electrical system, hydraulic system and flight control system were operating normally prior to the mishap (Tab U-28). There is no evidence to suggest a pre-collision condition of MA1's structures or systems was a factor in the mishap (Tab U-28).

Figure 5: Post-ground impact MA1 wreckage (Tab S-4)

The F-16CM is a single engine single seat fighter aircraft powered by a General Electric engine with afterburner (Tabs U-28). The exhaust module, which includes the nozzle, controls thrust from the engine (Tab V-8.2). The collision with MA2 separated the exhaust module from MA1 and MA1 did not have sufficient thrust to maintain altitude (Tabs V-1.13, V-8.2).

7. WEATHER

a. Forecast Weather

On the day of the mishap, the forecast for Shaw AFB at takeoff was scattered clouds at 3000’ MSL with unrestricted visibility and winds from 200 degrees (south-southwest) at 6 knots (Tab F-2). At the planned landing time at Shaw AFB, the weather forecast was scattered clouds at 4000’ MSL and 25,000’ MSL with unrestricted visibility and winds from 230 (southwest) at 9 knots (Tab F-2).

The forecast for MA1’s route of flight called for Visual Meteorological Conditions (VMC) (Tab F-2, BB-158 through BB-160, and BB-164). VMC describes weather conditions equal to or better than the minimum for flight under Visual Flight Rules (VFR) (Tab BB-123 and BB-160). Rules governing VFR flight assist pilots in meeting the responsibility to see and avoid other aircraft (Tab BB-126). Minimum flight visibility and distance from clouds required for VFR flight are contained in 14 CFR Section 91.155 (Tabs BB-122 and BB-126). The most adverse condition was a scattered layer of clouds at 2500’ MSL with unrestricted visibility (Tab F-2). There were no forecast hazards during the planned time of flight (Tab F-2). For the duration of the flight, the forecast placed the sun high in the sky, with the lowest elevation 45 degrees above the horizon (Tab F-2 to F-4).

b. Observed Weather

The observed weather at 10:56L in the vicinity (recorded at KCHS) was winds out of 220 degrees (southwest) at 7 knots (Tab F-7). Clouds were scattered at 4000’ AGL and visibility was unrestricted (Tabs F-7 and V-1.9 to V-1.10). The temperature was 86 degrees Fahrenheit, with a dew point of 72 degrees Fahrenheit (Tab F-7). The air was stable, with no pilot reports of turbulence in the state of South Carolina during mission times (Tabs F-7 to F-8 and V-1.9 to V-1.10). MC reported the altimeter at KCHS as 30.16 inches of mercury (Tabs N-6 and Z-17).

c. Space Environment

Not Applicable.

d. Operations

There is no evidence to suggest MA1 was operating outside its prescribed operational limitations.

8. CREW QUALIFICATIONS

a. Mishap Pilot 1, F-16CM

MP1 was current and qualified in the F-16CM as a Four-Ship Flight Lead who met required flying continuity training (Tabs T-5 to T-6). MP1 had 2383.6 total flying hours, including 624.2 hours in the F-16, 1055 hours in the MQ-1B, and 456.1 hours in the MQ-9 (Tab T-6 to T-7). Of this time, 1023.5 hours were combat support (Tab T-6). MP1 meets the requirements of an experienced F-16CM pilot per AFI 11-2F-16 (Tabs T-6, T-7, V-1.2). MP1’s last instrument check ride was 25 August 2014, and last mission check ride was 24 March 2015 (Tab T-8). None of MP1’s post-pilot training check rides contained discrepancies or downgrades (Tab T-8).

Table 2: MP1 30-60-90 Flying History (Tab T-8)

	Hours	Sorties
Last 30 Days	11.3	8
Last 60 Days	24.0	17
Last 90 Days	35.5	26

b. Mishap Pilot 2, Cessna

MP2 earned a single engine land certificate on 19 December 2014 (Tab G-3). Evidence indicates MP2 was a current and qualified private pilot (Tabs G-3, V-11.2, Z-6). MP2 had amassed 244.2 total flight hours (Tab Z-6). MP2’s last logged flight prior to 7 July 2015 was on 5 July 2015 (Tab Z-7).

c. Mishap Air Traffic Controller

MC was a current and qualified controller at all positions at KCHS (Tab GG-5).

There is no evidence to suggest crew qualifications were factors in this mishap.

9. MEDICAL

a. Qualifications

At the time of the mishap, MP1 was medically qualified for flight duty without any medical restrictions (Tab X-2). MP1 did not have any flying waivers on file (Tab X-2). MP1's annual Preventative Health Assessment was current as of 6 July 2015, and MP1 had no duty limiting conditions (Tab X-2). MP1 had a current DD Form 2992, *Medical Recommendation for Flying or Special Operational Duty*, valid through 2 October 2016 (Tab X-2). There is no evidence to suggest physical or medical qualifications were factors in the mishap (Tab X-2).

b. Health

MP1 was in good health at the time of the mishap (Tab X-2). A review of MP1's medical records, dental records, 72-hour and 7-day History, personal and witness testimonies, Aerospace Information Management System (ASIMS) reports, and Operational Risk Management (ORM) worksheet, dated 7 July 2015, did not reveal any illnesses or duty limiting conditions at the time of the mishap (Tab X-2). MP1 wore required vision correction during the mishap flight (Tab X-2). There is no evidence to suggest MP1's health was a factor in the mishap (Tab X-3).

c. Pathology

Toxicology results for MP1 were negative for carbon monoxide, ethanol, amphetamine, barbiturates, benzodiazepines, cannabinoids, cocaine, opioids, phencyclidine, and sympathomimetic amines (Tab X-3).

The Berkeley County Coroner's Office concluded that MP2's and passenger's cause of death was blunt trauma force secondary to plane-plane collision (Tab X-4 and X-6). The Coroner's report listed the time of the incident as 11:02L on 7 July 2015, and the times of death as 11:02L on 7 July 2015 (Tab X-4 and X-6). MP2's and passenger's remains were transported to the Medical University of South Carolina (Tab X-5 and X-7).

d. Lifestyle

Review of medical records, personal testimony, 72-hour and 7-day History, and ORM worksheet for MP1, as well as testimonies from pertinent squadron and maintenance personnel, did not reveal any remarkable lifestyle factors, including unusual habits, behavior, or stress (Tab X-3). There is no evidence to suggest MP1's lifestyle was a factor in the mishap (Tab X-3).

e. Crew Rest and Crew Duty Time

U.S. Air Force Pilots are required to have proper "crew rest," as defined by AFI 11-202v3, paragraph 2.1, prior to performing in-flight duties (Tab BB-116). AFI 11-202v3, paragraph 2.2, defines normal crew rest as a minimum 12-hour non-duty period before the designated flight duty period begins (Tab BB-116). During this time an aircrew member may participate in meals, transportation, or rest as long as he or she has the opportunity for at least eight hours of uninterrupted sleep (Tab BB-116). MP1 complied with all applicable crew rest requirements (Tabs K-6, V-1.3, V-2.3). There is no evidence to suggest crew rest or duty times were factors in the mishap (Tab X-3).

10. OPERATIONS AND SUPERVISION

a. Operations

MP1 was familiar with Shaw AFB local flying area operations, having flown with the 55 FS since October 2014 (Tabs T-4, V-1.2). Operations tempo was described as very high, as the squadron completed multiple off-station exercises and prepared for temporary duty (Tab V-1.3 and V-4.3). There is no evidence to suggest operations tempo was a factor in the mishap.

b. Supervision

The flight for MA1 was properly supervised, scheduled, authorized, and released. (Tabs V-2.2 to V-2.3 and AA-3). Top-3 ensured MP1 was current and qualified before conducting the step briefing, and was readily available at the operations desk during the mishap sortie (Tabs V-2.3 and AA-3).

The ORM level of the mishap flight was six, the lowest risk category (Tab K-6, R-37 and V-2.2). Operational Risk Management is a decision making process to systematically evaluate possible courses of action, identify risks and benefits, and determine the best course of action for any given situation (Tab BB-112). Areas of analysis included elements such as mission, environmental, and aircrew impacts (Tab K-6).

11. HUMAN FACTORS

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) (Tab BB-66 to BB-87).

b. Applicable Human Factors

The AIB identified two human factors relevant to the mishap: (1) Inaccurate Expectation and (2) Fixation.

(1) Inaccurate Expectation (PC110)

DoD HFACS defines *Inaccurate Expectation* as a human factor when the individual expects to perceive a certain reality and those expectations are strong enough to create a false perception of the expectation (Tab BB-78).

MA1 was on a single aircraft OCF mission on 7 July 2015 to verify corrective maintenance (Tabs U-28, V-1.3 to V-1.6, and AA-3). MP1 flew to KMYR for two approaches under Instrument Flight Rules (IFR), using his instruments for navigation, then proceeded towards KCHS for more IFR approaches (Tabs K-2, V-1.3, V-1.7 to V-1.8 and V-1.10). IFR govern the procedures for conducting flight under instrument conditions, where weather does not allow use of visual references (Tab BB-155). About 10:52L, MC directed MA1, under IFR control by MC, to a heading of 260 degrees for vectors to the final approach course at KCHS (Tabs N-3, V-1.10, and Z-17). At 10:55L, MC directed MA1 to descend from 6000' to 1600' MSL (Tabs N-4 and Z-17). MP1 was alternating between 20- and 40-mile radar scans to search for traffic in the area (Tab V-1.8). Evidence does not indicate whether MA1's interrogator was set to a mode conducive for locating non-military aircraft such as MA2 (see Section 13.D. of this Report for further discussion); MP1 used "good visual scan and radar" to mitigate mid-air collision avoidance potential (Tab V-1.6 and V-1.8). At 11:00:16L, MC notified MA1, "traffic, twelve o'clock, two miles, opposite direction, one thousand two hundred indicated, type unknown" (Tabs N-6 and Z-17). Approximately 2 minutes and 35 seconds had elapsed from the time MA2 appeared on MC's radar at 200' MSL to the time MC issued an initial traffic advisory to MP1 (Tabs N-3 to N-5, V-1.10, and Z-17).

MP1 previously observed a radar return at 20 miles on MA1's radar before the initial traffic advisory was made (Tabs N-6, R-5, V-1.2, and V-1.14. At the same time, MP1 did not have radar contact with MA2, which MC reported as 2 miles away (Tabs N-6, V-1.14, and Z-17). MP1 was unable to locate MA2 visually (Tab V-1.11). MP1 did not expect to receive a traffic advisory for a conflict 2 miles away (Tab V-1.11). MP1 wanted to compare the altitude from the traffic alert with the altitude of the traffic at 20 miles (Tab V-1.14). At 11:00:31, MP1 queried back to MC, "Confirm 2 miles" (Tabs N-6, V-1.14, and Z-17).

IAW FAA Order JO 7110.65V, *Air Traffic Control* (Tab BB-138), paragraph 2-1-2, the primary purpose of the Air Traffic Control (ATC) system is to prevent a collision between aircraft operating in the system and to provide a safe, orderly and expeditious flow of traffic (Tab BB-140). During personal testimony after the mishap, MP1 stated, "a two-mile call is the closest call I've ever received" and "that was a big alert for me" (Tab V-1.11). The traffic advisory contradicted MP1's expectations (traffic at 20 miles as opposed to traffic at 2 miles) (Tabs R-5 and V-1.14). This resulted in additional time expended by MP1 to process and react to MC's traffic advisory in comparing the altitudes and asking MC to confirm the distance (Tab N-6, R-5, and V-1.14). MP1 realized the exacting situation and "aggressively" worked to visually acquire and avoid MA2 (Tab V-1.11). Individuals in time-critical situations are susceptible for skill-based inaccuracies (Tab X-9 to X-12). Therefore, when unexpected situations force individuals to rapidly process and react, there is increased potential for error (Tab X-9 to X-12).

(2) Fixation (PC102)

DoD HFACS defines *Fixation* as a human factor when the individual is focusing all conscious attention on a limited number of environmental cues to the exclusion of others (Tab BB-78).

When asked what actions were taken after receiving the initial 2-mile traffic advisory, MP1 stated (Tab V-1.11):

> I immediately tried looking left and right over the HUD [Head-Up Display], anything in my way to try and find the aircraft visually … I was still on autopilot … I really had nothing else taking my attention away from my task time. I was looking aggressively, trying to find that plane … becoming more and more anxious to find that plane.

A few seconds later, at 11:00:25L, MC transmitted, "[MA1], turn left heading 180 if you don't have that traffic in sight" (Tabs N-6 and Z-17). MP1 did not acknowledge or remember hearing that control instruction from MC (Tabs N-6, V-1.14, and Z-17). At 11:00:33L, MC transmitted, "[MA1], if you don't have that traffic in sight, turn left heading 180, immediately" (Tabs N-6 and Z-17). MP1 acknowledged the second "turn left … immediately" instruction and began a standard rate turn while simultaneously attempting to locate MA2 with visual scanning (Tabs N-6, V-1.11, and Z-17).

Visually locating a small aircraft on a collision course can be very difficult (Tabs V-1.9, V-2.3, V-3.2, V-5.1.3 to V-5.1.4, V-11.5, BB-89, BB-102, EE-9, and EE-24; Figure 6). MP1 was working on this difficult task – visually acquiring MA2 – and did not hear the first radio transmission from MC to "turn left" (Tabs N-6 and V-1.14). Undergraduate Pilot Training (UPT), IAW Air Force Manual (AFMAN) 11-248, *T-6 Primary Flying*, paragraph 1.16, details specific visual scanning techniques to clear for (visually locate) other aircraft (Tab BB-107). It is not uncommon for task fixation to occur during highly automatized or learned behavior (Tab X-9 to X-12). MP1's failure to hear MC's first instruction is consistent with task fixation (visually locating MA2) during a time-critical situation (Tab X-9 to X-12).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

c. Publically Available Directives and Publications Relevant to the Mishap

(1) AETCTTP 11-1, *Employment Fundamentals T-38C/Introduction to fighter Fundamentals (IFF)*, 4 September 2009
(2) AFI 11-2F-16 Volume 1, *F-16 Pilot Training*, 11 August 2011
(3) AFI 11-2F-16 Volume 2, *F-16 Aircrew Evaluation Criteria*, 27 August 2010
(4) AFI 11-2F-16 Volume 3, *F-16 Operations Procedures*, 18 February 2010
(5) AFI 11-2F-16 Volume 3, Shaw AFB Supplement, *F-16 Operations Procedures*, 10 October 2012
(6) AFI 11-202 Volume 1, *Aircrew Training*, 22 November 2010
(7) AFI 11-202 Volume 2, *Aircrew Standards/Evaluations Program*, 18 October 2012
(8) AFI 11-202 Volume 2, Shaw AFB Supplement, *Aircrew Standards/Evaluations Program*, 15 June 2015

(9) AFI 11-202 Volume 3, *General Flight Rules*, 7 November 2014
(10) AFI 11-202 Volume 3, ACC Supplement, *General Flight Rules*, 28 November 2012
(11) AFI 11-214, *Air Operations Rules and Procedures*, 14 August 2012
(12) AFMAN 11-217 Volume 1, *Instrument Flight Procedures*, 22 October 2010
(13) AFMAN 11-217 Volume 2, *Visual Flight procedures*, 22 October 2010
(14) AFMAN 11-248, *T-6 Primary Flying*, 19 January 2011
(15) AFMAN 11-251 Volume 1, *T-38 Flying Fundamentals*, 1 August 2013
(16) AFI 11-401, *Aviation Management*, 10 December 2010
(17) AFI 11-418, *Operations Supervision*, 1 March 2013
(18) AFI 21-101 Combat Air Forces Supplement, *Aircraft and Equipment Maintenance Management*, 11 July 2012
(19) AFI 21-124, *Oil Analysis Program*, 14 March 2013
(20) AFI 48-123, *Medical Examinations and Standards*, 29 January 2013
(21) AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010
(22) AFI 90-901, *Operational Risk Management*, 1 April 2000
(23) AFI 90-802, *Risk Management*, 11 February 2013
(24) AFI 91-204, *Safety Investigations and Reports*, 12 February 2014
(25) AFI 91-204, ACC Supp, *Safety Investigation and Reports, 16 November 2007*
(26) Aeronautical Information Manual, *Official Guide to Basic Flight Information and ATC Procedures*, 25 June 2015
(27) Code of Federal Regulations Title 14, Part 91, *General Operating and Flight Rules*
(28) Federal Aviation Administration Order 8020.16, *Air Traffic Organization Aircraft Accident and Incident Notification, Investigation, and Reporting*, 13 Sep 2015
(29) FAA Order JO 7110.65V, *Air Traffic Control*, 25 June 2015
(30) FAA *Pilot/Controller Glossary*, 25 June 2015

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

d. Other Directives and Publications Relevant to the Mishap

(1) AFI 21-101 Shaw Air Force Base Supplement, *Aerospace Equipment Maintenance Management*, 18 April 2012
(2) AFTTP 3-3 v F-16, *Combat Aircraft Fundamentals – F-16*, 29 June 2012
(3) TO 1F-16CJ-6-11, *Scheduled Inspection and Maintenance Requirements*, 1 November 2013
(4) TO 1F-16CJ-6WC-1-11, *Combined Preflight/Postflight, End-Of-Runway, Launch and Recovery, Alert Inspections, Quick Turnaround, Basic Postflight, and Walkaround Before First Flight of Day Inspection Workcards*,1 November 2013
(5) TO 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures*, 15 June 2013
(6) TO 1F-16CJ-6WC-2, *Phased Inspection Workcards*, 1 November 2013
(7) TO 1F-16CM-1, *Flight Manual F-16C/D CCIP Aircraft*, 1 August 2012
(8) TO 1F-16CM-1-2, *Supplemental Flight Manual*, 1 May 2013
(9) TO 1F-16CM-34-1, *Avionics and Nonnuclear Weapons Delivery Flight Manual*, 1 December 2014

(10) TO 42B-1-1, *Quality Control of Fuels and Lubricants,* 1 August 2014
(11) *Shaw Pilot's Aid*, 1 October 2013
(12) *20 Operations Group Standards*, 9 June 2014

e. Known or Suspected Deviations from Directives or Publications

The Board did not find relevant known or suspected deviations from directives or publications.

13. ADDITIONAL RELEVANT AREAS

a. Governing Rules and Regulations

The FAA is the federal agency responsible for issuing flight rules governing aviators and air traffic controllers for the U.S. National Airspace System (NAS) (Tab BB-120). Title 14 of the Code of Federal Regulations (CFR) Part 91 (14 CFR Part 91) contains specific rules governing aviators and air traffic controllers (Tabs BB-162 to BB 164). The FAA issued two pertinent documents under 14 CFR Part 91, the Aeronautical Information Manual, *Official Guide to Basic Flight Information and ATC Procedures* (AIM) (Tab BB-119 to Tab BB-137), and JO 7110.65V (Tab BB-138 to Tab BB-148.

JO 7110.65V prescribes (Tab BB-139):

> … air traffic control procedures and phraseology for use by persons providing air traffic control services. Controllers are required to be familiar with the provisions of this order that pertain to their operational responsibilities and to exercise their best judgment if they encounter situations that are not covered by it.

The AIM provides (Tabs BB-120 to BB-122):

> … the aviation community with basic flight information and ATC procedures for use in the National Airspace System (NAS) of the United States. … This manual contains the fundamentals required in order to fly in the United States NAS.
>
> … This publication, while not regulatory, provides information which reflects examples of operating techniques and procedures which may be requirements in other federal publications or regulations. It is made available solely to assist pilots in executing their responsibilities required by other publications.

AFI 11-202v3 prescribes general flight rules for Air Force aviators flying Air Force aircraft; it is a common source of flight directives, including Air Force and FAA guidance (Tab BB-114).

b. Airspace Operations

The mishap occurred in Class E airspace, defined as "controlled" airspace (Tabs S-8 and BB-124). KMKS is below Class G airspace, and transitions to Class E airspace at 700' AGL (Tabs S-8, Z-11 to Z-12, and BB-125). The Class G airspace around KMKS is defined as "uncontrolled" (Tab BB-126).

MA2 was operating under VFR conditions (Tab GG-3). MA2, under VFR conditions, was not required to contact MC to operate in either the Class E airspace or the Class G airspace (Tab BB-125 to BB-126). MA2 was transmitting transponder code 1200 and Mode C in the controlled Class E airspace as required by AIM, paragraph 4-1-20 (Tabs Z-17, BB-131, and GG-3). There are no other specific pilot certifications, equipment requirements, or actions necessary for VFR operations to depart, arrive into, or fly through Class E and Class G airspace (Tab BB-125 and BB-126).

MP1 filed an IFR flight plan and received ATC clearance to operate IFR in the Class E controlled airspace as required by AIM, paragraph 3-2-1 (Tabs K-2, N-3, R-36, V-2.2, Z-17, AA-2, BB-124). MC descended MP1 to 1600' MSL, the Minimum Vectoring Altitude (MVA) (Tabs N-4, Z-17, and GG-5). The MVA is the lowest altitude to which ATC will descend IFR aircraft (Tab BB-156).

c. Air Traffic Control

The primary purpose of the ATC system is to prevent a collision between aircraft operating in the system and to provide a safe, orderly and expeditious flow of traffic (Tab BB-140). ATC's duty is to "give first priority to separating aircraft and issuing safety alerts as required" (Tab BB-140). ATC must vertically separate VFR aircraft, when receiving basic radar services (flight following), from IFR aircraft by 500' (Tab BB-144, BB-146 to BB-147). MA2 was not receiving basic service and was not in contact with MC (Tabs N-3 to N-6, Z-17, and GG-5 to GG-6). MC's duty to MA1 was to issue traffic advisories and safety alerts as applicable and IAW regulations (Tab BB-124, BB-127, and BB-140).

Traffic advisories are provided to all aircraft as the controller's work situation permits (Tab BB-124). Within the NAS, ATC provides traffic advisories on VFR aircraft on a time-permitting basis (Tab BB-118). Controllers issue traffic advisories when, in the controller's judgment, aircraft proximity may diminish to less than the applicable separation minima (Tabs BB-127, BB-143 to BB-145). If a situation becomes unsafe or time critical, controllers should issue a safety alerts (Tab BB-127):

> … to pilots of aircraft being controlled by ATC if the controller is aware the aircraft is at an altitude which, in the controller's judgment, places the aircraft in unsafe proximity to terrain, obstructions or other aircraft. The provision of this service is contingent upon the capability of the controller to have an awareness of a situation involving unsafe proximity to terrain, obstructions and uncontrolled aircraft. The issuance of a safety alert cannot be mandated, but it can be expected on a reasonable, though intermittent basis. Once the alert is issued, it is solely the pilot's prerogative to determine what course of action, if any, to take. This procedure is intended for use in time critical situations where aircraft safety is in question.

Conditions, such as workload, traffic volume, the quality/limitations of the radar system, and the available lead time to react are factors in determining whether it is reasonable for the controller to observe and recognize such situations (Tab BB-141). While a controller cannot see immediately the development of every situation where a safety alert must be issued, the controller must remain vigilant for such situations and issue a safety alert when the situation is recognized (Tab BB-141 to BB-142).

IAW FAA Order JO 7110.65V, paragraph 2-1-6, the phraseology for a safety alert is (Tab BB-142):

> *TRAFFIC ALERT (call sign) (position of aircraft) ADVISE YOU TURN LEFT/RIGHT (heading), and/or CLIMB/DESCEND (specific altitude if appropriate) IMMEDIATELY.*

A controller may only use the term "immediately" "when expeditious compliance is required to avoid an imminent situation" (Tab BB-141).

When presented with the potential conflict between MA1 and MA2, MC initially issued a standard traffic advisory (Tabs N-6 and BB-143). Subsequently, MC issued a safety alert that did not include the word "advise" and did include the word "immediately" (Tabs N-6 and BB-142). MP1 considered the communication directive (Tabs N-6, V-1.15, Z-17). A pilot may only deviate from an ATC direction to protect life, for safety of flight,or when an in-flight emergency requires immediate action (Tab BB-115).

d. Deconfliction of Aircraft

A fundamental principle underlying safety in all airspace classes of the NAS is the principle of "See and Avoid" (Tabs BB-126 and BB-135). AIM section 5-5-8(a) states, "regardless of type of flight plan or whether or not under control of a radar facility, the pilot is responsible to see and avoid other traffic, terrain, or obstacles" (Tab BB-135). 14 CFR Part 91.113 spells out the rules for maintaining separation from other aircraft during VFR operations: "When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft" (Tab BB-162). AFI 11-202v3 models the AIM and CFR, but uses the term "sense and avoid" (Tab BB-118).

14 CFR Part 91 and AFI 11-202v3 provide rules to determine right of way for approaching aircraft (Tab BB-117 to BB-118 and BB-162). Specifically, when two aircraft are approaching head-on, or nearly so, each aircraft should alter course (turn) to the right (Tab BB-118 and BB-162).

(1) Human and Aircraft Reaction

"See and Avoid" is a multi-step process (Tab EE-13; Table 3). First, a pilot must see and recognize the traffic conflict and determine if it is a collision threat (Tab EE-13; Table 3). Next, a pilot must decide a course of action to avoid collision, move the aircraft controls, and then the aircraft must respond (Tabs BB-88 to BB-103 and EE-13; Table 3).

MA1 was traveling at approximately 250 knots and MA2 was travelling at approximately 69 knots (Tabs R-5, V-1.2, and Z-17). The average closure between the aircraft was approximately 300 knots (Tab Z-17). This results in distance decreasing between aircraft at a rate of one statute mile in 10.5 seconds, or 500' per second (Tab Z-17; Figure 6).

Table 3: See and Avoid Process and Times

Action	Time (seconds)
See Object	0.1
Recognize Aircraft	1.0
Become Aware of Collision	5.0
Decision to Turn Left or Right	4.0
Muscular Reaction	0.4
Aircraft Response time	2.0
Total	12.5

Note: Table 3 assumes a pilot is already looking at the traffic conflict (Tabs BB-90 to BB-91 and EE-30)

When MP1 first acquired visual contact of MA2, MP1 estimated MA1 to within 500', and less than a second away (Tab V-1.12 to V-1.13). Although MA1 is considered a highly maneuverable aircraft at higher speeds, based on the speed and weight, when MP1 acquired visual contact of MA2 less than a second prior to impact, MP1 could not cause MA1 to move sufficiently to avoid MA2 (Tabs CC-13, V-1.13).

(2) Visual lookout

The "See and Avoid" chain requires a pilot to acquire traffic conflicts visually (Tabs BB-88 to BB-103 and EE-9 to EE-30; Table 3). However, seeing small aircraft such as MA1 and MA2 at distances sufficient to allow early avoidance is very difficult, especially at high speeds (Tabs V-1.9, V-2.3, V-3.2, V-5.1.3 to V-5.1.4, V-11.5, BB-89, BB-102, EE-9 and EE-24; Figure 6). This difficulty increases when aircraft are on a near collision course, because such a traffic conflict remains steady on the windscreen, and lacks easily detectable motion against a constant background (Tabs V-1.9, V-2.3, V-3.2, V-5.1.3 to V-5.1.4, V-11.5, BB-91, BB-102, and EE-24; Figure 6). Distractions, such as increased workload or using the radio, can also decrease the chance a pilot detecting traffic conflicts (Tab EE-23). Figure 6 depicts the relative size and difficulty of seeing aircraft such as MA1 and MA2 when pointed at each other.

DISTANCE-SPEED-TIME			
	300 KTS	**F-16CM**	**Cessna 150M**
4 MILES	**48"**		
3 MILES	**36"**		
2 MILES	**24"**		
1 MILE	**12"**		
1/2 MILE	**6"**		

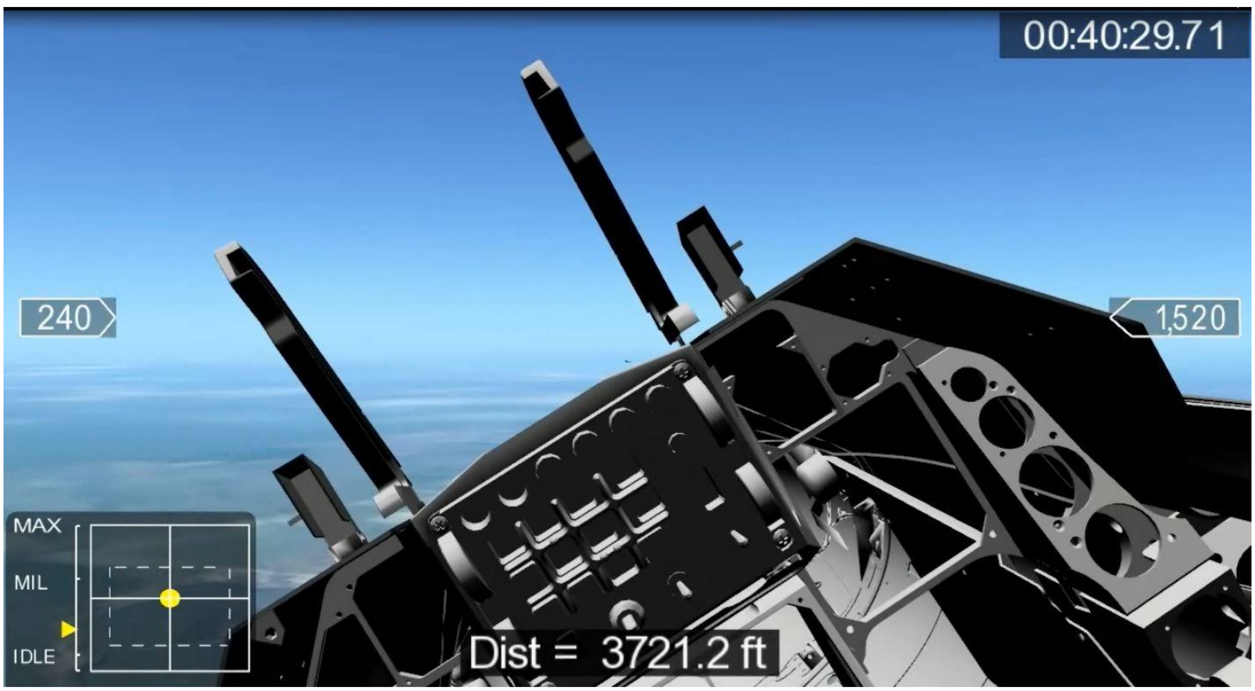
Figure 6: Distance-Speed-Time graphics of an F-16CM and Cessna 150M. Leftmost column shows distance from collision, and is shaded starting at 2.5 miles, the approximate time of the first traffic alert (Tabs N-3 and Z-17). The second column shows time until impact at a 300-knot closure, similar to that of MA1 and MA2 (Tab Z-17). The shading above 12 seconds refers to the timeline in Table 3. The graphics approximate the size the aircraft would appear at the referenced range if this graphic is viewed from 25 inches (Tab Z-18).

When conducting a visual scan, or clearing, the procedure is to focus on 30 degree wide portion of the sky, focus on the ground about 4-8 miles away, then move up and scan a few inches above and below the horizon, scanning for at least 2 seconds in each sector (Tabs BB-101 to BB-103 and EE-18 to EE-19). Because of the relatively low speed traveled by aircraft such as MA2, MP2 would be required to scan a large area of the sky (approximately 180 degrees) to find potential conflicts, taking more than 15 seconds to complete a clearing scan cycle (Tabs BB-101 to BB-103, EE-19).

Anything that can interrupt direct line of sight, by such things ranging from aircraft structures to a bug splatter on a windscreen, can hamper a visual scan (Tab EE-9 and EE-14 to EE-30). At the extreme edges of influence, these can either block a pilot's vision or trap the eye, drawing a pilot's focus away from scanning (Tab EE-9 and EE-14 to EE-30; Figure 7).

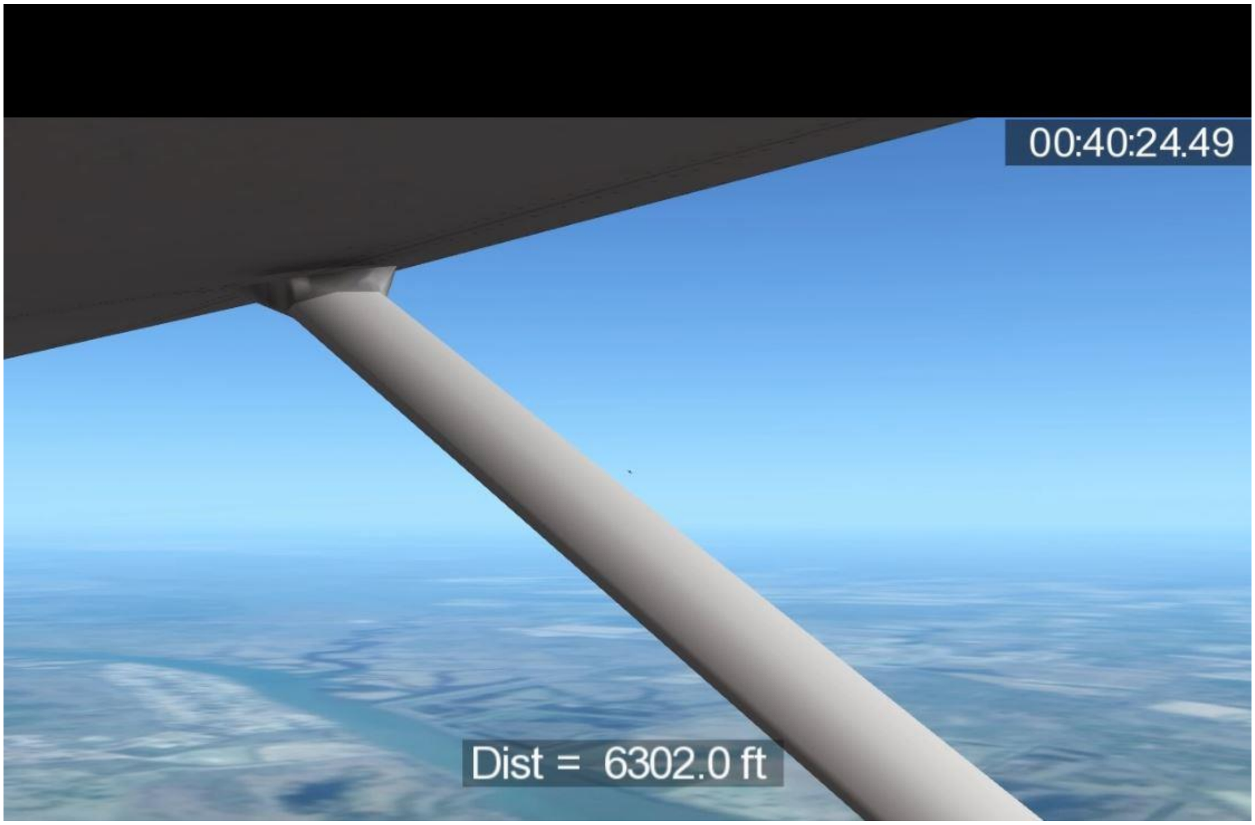
Figure 7: Example of F-16 HUD

According to modeling, prior to the turn to 180 degrees, from a range of approximately 2 miles until 3400’, MA2 was in front of MA1 and within the Head-Up Display (HUD) screen, which can display a significant amount of overlaid data (Tab Z-20; Figure 7). Inside of 3400’, the bottom of the HUD and nose of the aircraft obscured MA2 from MP1’s view (Tab Z-20; Figure 7). MP1 was looking under MA1 when MA2 came into view less than 500’ away (Tab V-1.12).



[Figure 8: Simulated view from MA1 (without HUD overlaid data): MA2 appears in center of screen before becoming obscured. (Tab Z-20)

MA2 is a high wing aircraft with a prominent wing strut (Tab Z-19). Modeling reveals MA2’s strut impeded MP2’s vision of MA1 from approximately 1 mile away until immediately before impact (Tab Z-19).



[Figure 9: Simulated view from MA2: MA1 appears in center of screen before becoming obscured by strut (Tab Z-19)]

(3) Aircraft sensors

Sensors such as radios can aid aircrew in visually acquiring traffic conflicts (Tabs BB-98 ATC Traffic Alerts provide aircrew with approximate traffic location to aid a visual scan, greatly reducing the time to acquire a traffic conflict (Tab EE-21). MP2 did not transmit on MC's frequency and was not receiving any basic radar services from MC (participating in flight following) (Tabs N-3 to N-7, BB-128 to 130, BB-152).

MA1 has sensors designed to allow pilots to detect and target aircraft Beyond Visual Range (Tabs T-8, BB-104). These sensors are optimized to detect fast moving combat aircraft, not slow moving general aviation (Tabs T-8, BB-104). Various Fire Controller Radar (FCR) modes filter out slow moving targets to reduce clutter and prevent non-combat related information overload (Tabs T-8, BB-104). MP1 was using MA1's radar to scan for traffic conflicts out to 40 miles (Tab V-1.9).

MA1 was also equipped with an Identification Friend or Foe (IFF) interrogator capable of querying aircraft transponders (Tabs T-8, BB-104). The IFF indicates whether a FCR contact is a friend or foe, but does not provide high-fidelity location information (Tabs T-8, BB-104). In order to interrogate a transponder code transmission such as sent by MA2, the IFF requires a pilot to request each search manually (Tabs T-8, BB-104). Evidence does not indicate whether MA1's interrogator was set to search for civilian transponder codes (Tab V-1.8).

(4) Near Mid Air Collision

A Near Mid Air Collision (NMAC) is an incident associated with the operation of an aircraft in which the possibility of collision occurs as a result of proximity of less than 500 feet to another aircraft, or a report is received from a pilot or flight crew member stating that a collision hazard existed between two or more aircraft (Tab BB-136).

To assist VFR aircraft with collision avoidance and possibly help mitigate NMAC potential, ATC can provide basic radar services (flight following) when requested by the pilot (Tabs BB-128 to 130, BB-136, BB-140, BB-146, and BB-152). Basic radar services for VFR aircraft include safety alerts, traffic advisories and limited radar vectoring when requested by the pilot (Tab BB-146). Like IFR aircraft, while receiving flight following, the VFR pilot retains the responsibility to "See and Avoid" (Tabs BB-135 and BB-162).

Figure 10 below contains an approximate overlay of a standard left-hand pattern for KMKS Runway 23 as described in AIM paragraph 4-3-3, including likely and recommended departures (Tabs V-11.2 to V-11.4, BB-119, and BB-165).

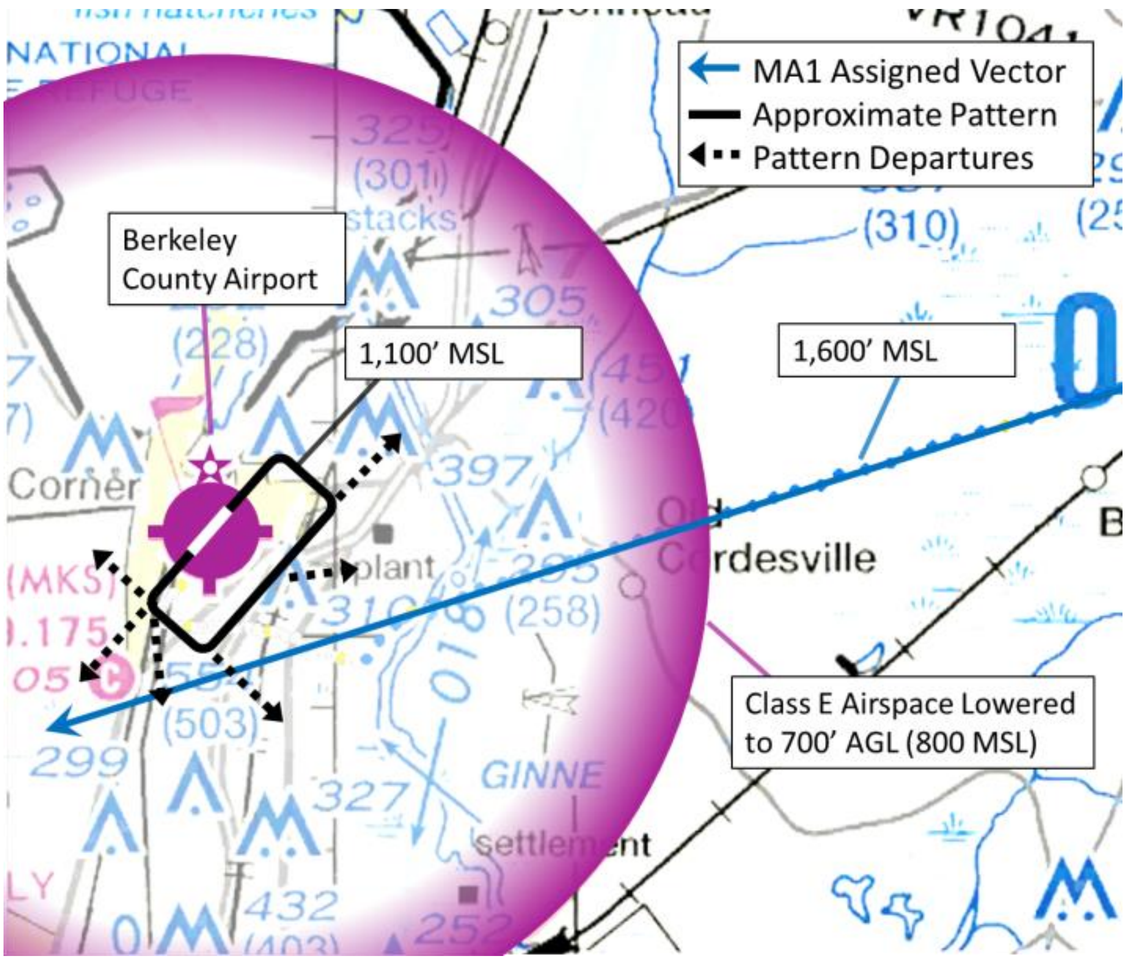


Figure 10: Overlay of KMKS Pattern and MA1 Vector on Sectional Chart (Tabs M-2, S-8, V-11.1, and Z-17). MA1 Assigned Vector (extended flight path) is from Figure 2. Class E Airspace lowers from 1200' to 700' AGL to transition instrument approaches into uncontrolled airfields without towers, such as KMKS (Tabs Z-11 to Z-12 and BB-125).

MC assigned MA1 a heading and altitude at the MVA of 1600' MSL (Tab GG-3). Without contact with MA2, MC could not validate MA2's altitude or verify MP2's intended flight path (Tabs N-3 to N-6, Z-17, and GG-3 to GG-5). Instructing MA1 to fly on a heading of 260 (southwest) placed MA1 on a course to cross roughly two miles south of the departure end of KMKS Runway 23 (Figure 10; Tabs Z-9, Z-17, GG-3 to GG-5). MC's heading and altitude placed MA1 within proximity of aircraft departure routes at KMKS (Figure 10).

//Signed//

24 October 2016

SCOTT A. KINDSVATER
Major General, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

F-16, T/N 96-0085
Moncks Corner, South Carolina
7 July 2015

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

I find, by a preponderance of the evidence, that there are two causes of this mishap: (1) the Mishap Air Traffic Controller (MC) issued a radar vector directing the F-16 Mishap Pilot (MP1) to immediately turn left to 180 degrees (south) placing the F-16 (MA1) and Cessna 150M (MA2) on a collision course; and (2) MP1 and the pilot of MA2 (MP2) were not able to see and avoid each other in time to prevent collision.

I find, by a preponderance of the evidence, that each of the following factors substantially contributed to the mishap: (1) MC directed MA1 to fly on a course and at an altitude that would increase potential for conflicts by passing in close proximity to the departure routes of an uncontrolled airfield; (2) MP1 and MP2 did not use available systems which may have increased situational awareness; and (3) MC did not provide MP1 with traffic information in time for MP1 to identify the conflict before MC issued the immediate left turn instruction.

I developed my opinion by analyzing data from Air Traffic Control radar data replays, voice recordings, accident modeling and animations, photographs, Federal Aviation Administration and Air Force technical orders, regulations, and guidance, engineering analysis, witness testimony, available flight data, information provided by technical experts, NTSB evidence, and F-16 flight simulations.

2. BACKGROUND

Over 30 miles away from the eventual collision, MA1 entered KCHS airspace and MP1 contacted MC, as required by Instrument Flight Rules (IFR) in controlled airspace. MC placed MA1 on a flight path to pass about 2 miles south of Berkeley County Airport (KMKS) at 1600’ Mean Sea Level (MSL). 1600’ was the lowest altitude MC could have directed MA1 to fly, the Minimum Vectoring Altitude (MVA). This altitude avoided the standard pattern altitude at KMKS by 500’, but also placed MA1 on an intersect path with normal departure routes of aircraft leaving KMKS flying under Visual Flight Rules (VFR).

MA2, flying under VFR and appropriately using a radar transponder, first appeared on MC's radar departing KMKS to the southwest at 200' MSL. MP2 did not contact MC, and was not required to contact MC under FAA regulations. MC assumed MP2 intended to stay below 1000' MSL, within the KMKS traffic pattern to practice landings.

MC did not advise MP1 of MA2's presence for the next 2-3 minutes, until MA2 had already broke MC's assumption by climbing above 1000' MSL. During that time, MA1 and MA2 closed the distance between them significantly. MC did not see or hear an earlier collision alert. MC made the first traffic advisory to MP1 when MA2 was about 2 miles away, a very close distance for aircraft closing in towards each other at 300 knots. MP1 did not have any previous indication of MA2's presence. MC advised, "[MA1], traffic, twelve o'clock, two miles, opposite direction, one thousand two hundred indicated, type unknown." MA2 was still climbing at that time.

It is highly unlikely MP1 or MP2, or any pilot in a similar situation, could have seen the other aircraft prior to the traffic advisory from MC. Both pilots clearly complied with all applicable rules and regulations, and I found no evidence of any deviations of FAA regulations by either pilot.

Four seconds after the 2-mile advisory, MC told MP1 to turn left if MP1 did not see MA2. MP1 did not hear that instruction because MP1 was fixated on finding MA2, and asked MC to confirm the distance. MC responded by directing MP1 to "turn left, heading 180, immediately" if MP1 did not see MA2. MP1 still did not see MA2, which at the time was a small dot on the horizon and behind MA1's Heads-Up-Display (HUD). MP1 immediately acknowledged MC's instruction and began a standard rate turn. At this time, MA2 was southwest of MA1; the left turn placed MA1 on a collision course with MA2.

MC made a decision to turn MA1 left because MC believed it would deconflict the aircraft "quicker" and that MA1 could "turn on a dime;" both assumptions were wrong. The instruction, as given, required MP1 to expeditiously begin a standard rate turn, or a 30-degree bank.

3. CAUSE

a. Control Instructions to Turn Left to 180

MA1 and MA2 were on course to have a close pass (within a mile but outside of a few thousand feet). I was not able to view MC's radar equipment during my investigation; however, MC's radar data did not provide MC high-resolution data of MA2's flight path. At the 2-mile advisory, MA2 was in a constant climb from take-off, so after MA2 left the pattern vertically above 1000' MSL, it would be reasonable to assume MA2 was going to continue to climb. However, without verbal contact, a flight plan, or flight following for MA2, MC could not know MP2's intentions.

When MC issued the first traffic call to MA1, MA2 was already south of MA1's flight path, and continuing further southeast. Any turn of MA1 to the south would increase the likelihood of collision. Had MC issued a right turn or climb, this would have avoided the conflict. When MC phrased the safety alert to turn left with the word 'immediately,' this was an imminent situation avoidance directive that MP1 could only disregard for an emergency or to preserve safety of flight. Because MP1 did not have MA2 in sight at that time, MP1 did not have a basis to disregard that directive. But for MC's directive for MA1 to turn to a heading of 180 (south), the two aircraft would not have collided.

b. See and Avoid

Collision avoidance, both in the air and on the ground, is one of the most basic responsibilities of a pilot in visual conditions. The see and avoid principle is critical to the U.S. National Airspace System. See and avoid required MP1 and MP2 to see and recognize a traffic conflict with sufficient time to choose a course of action and maneuver to avoid a collision. Prior to MC's "turn left" directive, MA1 and MA2 were essentially beyond the reasonable capability of the pilots to see each other. It is very difficult to find small aircraft visually until very short distances, and even more difficult when the two aircraft are on a near-collision course. Once placed on a collision course without prior visual contact, neither MP1 nor MP2 saw each other in sufficient time to prevent the mishap. Additionally, various cockpit structures impeded the ability of each pilot to see each other. MP1 saw MA2 right before impact. I do not believe MP2 ever saw MA1 until right before impact because MA2 continued to climb.

At high closure speeds such as 300 knots, the see and avoid process is difficult and requires significant time and distance. MC's unexpectedly close traffic call, immediately followed by instructions to turn, short-circuited MP1's see-and-avoid process. By the time MP1 saw MA2, or MP2 saw MA1, if ever, there was insufficient time to react and maneuver to prevent the collision. If either pilot had seen the other in time to maneuver to avoid, the two aircraft would not have collided.

4. SUBSTANTIALLY CONTRIBUTING FACTORS

I find, by a preponderance of evidence, that three separate factors involving MC, MP1, and MP2 each substantially contributed to the mishap by creating a scenario where a lack of situational awareness in a time-critical situation left little or no room for error. None of the substantially contributing factors caused the accident, and all were acts or decisions allowable under current regulations and guidance. However, the (a) the flight path given to MP1 by MC; (b) MP1 and MP2 not using available systems to increase situational awareness; and, (c) the timing of MC's traffic advisory each created an environment where any error, such as a left turn without sufficient awareness of the relative location of MA2 to MA1, could lead to collision.

a. Flight Path near an Uncontrolled Airfield

MC assigned MA1 a heading of 260 degrees and a descent to the MVA of 1600 feet. This set the conditions for conflicts with any aircraft operating out of KMKS. Although procedurally allowed, this placed MA1 on a flight path projected to pass close to the departure end of the KMKS runway, on an intersect with normal departures routes. Placing MA1 in close proximity to an uncontrolled field required significant vigilance to avoid the development of a conflict. There is insufficient evidence to conclude this, by itself, would have prevented the mishap.

b. Use of Systems

Both pilots clearly complied with all applicable rules and regulations, and I found no evidence of any deviations of FAA regulations by either pilot. However, there were systems available which may have improved or enhanced situational awareness of other aircraft and potential conflicts to MP1, MP2, and MC: MP2 did not make use of Air Traffic Control (ATC) services, and MA1's sensors, as configured, did not provide MP1 with information concerning the presence of MA2. These would have increased all mishap parties' situational awareness and aided each pilot with the difficult task to see and avoid other aircraft. There is insufficient evidence to conclude this, by itself, would have prevented the mishap.

(1) MA1 Sensor Configuration

MP1 could have used MA1's systems to scan for civilian transponders, like the one used by MA2. This may have provided a temporary snapshot of MA2's position without altitude, and increased MP1's situational awareness prior to the traffic calls from MC. Detected early enough, this may have provided MP1 knowledge of MA2's position in sufficient time to avoid a conflict for safety, despite MC's communication. While beneficial to increased situational awareness, there is insufficient evidence to conclude this, by itself, would have prevented the mishap.

(2) MP2 use of Air Traffic Control Services

Under the current National Airspace System, MP2 was not required to file a flight plan, establish two-way radio communications with MC, or request basic radar services (flight following) while operating under VFR. Had MP2 made use of these systems, MC may have known MP2's flight path intentions and could have provided basic radar services to deconflict other traffic. MP2 could have received traffic advisories and communication from MC to aid in visual search and finding other aircraft. While beneficial to increased situational awareness, there is insufficient evidence to conclude this, by itself, would have prevented the mishap.

c. Timeliness of Traffic Information from MC

MC had no communication or control of MA2 but assumed MA2 would maintain a particular route and altitude around KMKS. When MP2 climbed out of the KMKS traffic pattern, MA1 and MA2 were in a potential Near Midair Collision with minimal time to see and avoid, and then to subsequently deconflict flight paths. MC's technique of basing control instructions for a controlled aircraft on a set of assumptions regarding an uncontrolled aircraft, led to insufficient time to address the conflict once identified. Had MC notified MP1 of MA2's initial appearance on radar sooner, it would have allowed more time for MP1 to gain situational awareness, and possibly see and avoid MA2. There is insufficient evidence to conclude this, by itself, would have prevented the mishap.

5. CONCLUSION

I find, by a preponderance of the evidence, that there are two causes of this mishap: (1) MC issued a radar vector directing the F-16 Mishap Pilot (MP1) to immediately turn left to 180 degrees (south) placing the F-16 (MA1) and Cessna 150M (MA2) on a collision course; and (2) MP1 and the pilot of MA2 (MP2) were not able to see and avoid each other in time to prevent collision.

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//Signed//

24 October 2016

SCOTT A. KINDSVATER
Major General, USAF
President, Accident Investigation Board

INDEX OF TABS