



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

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Group Chairman's Factual Report

OPERATIONAL FACTORS

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Table Of Contents

A. ACCIDENT 3

B. OPERATIONAL FACTORS GROUP 3

C. SUMMARY 3

D. DETAILS OF THE INVESTIGATION 3

E. FACTUAL INFORMATION 4

 1.0 History of Flight..... 4

 2.0 Flight Crew Information 6

 2.1 The F-16 Pilot 6

 2.2 The Cessna 150M Pilot..... 7

 3.0 Medical and Pathological Information..... 8

 4.0 Aircraft Information..... 8

 5.0 Meteorological Information 9

 6.0 Aids to Navigation 9

 7.0 Communications 9

 8.0 Airport Information..... 10

 9.0 Organizational and Management Information 10

 10.0 F-16 Radar and IFF Interrogator Systems 10

 11.0 F-16 Autopilot..... 11

 12.0 Pertinent Rules and Regulations 11

 13.0 Visual Scanning Procedures (Clearing)..... 14

 14.0 55th Fighter Wing Flight Safety Program and MACA Program..... 16

F. LIST OF ATTACHMENTS 17

A. ACCIDENT

Location: Moncks Corner, SC
Date: July 7, 2015
Time: 1101 eastern daylight time (EDT)
Airplane: Lockheed Martin F-16CM, 96-0085; Cessna 150M, N3601V

B. OPERATIONAL FACTORS GROUP

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C. SUMMARY

On July 7, 2015, at 1101 eastern daylight time, a Cessna 150M, N3601V, and a Lockheed-Martin F-16CM, operated by the US Air Force (USAF), collided in midair near Moncks Corner, South Carolina. The Cessna was destroyed during the collision, and both the private pilot and passenger were fatally injured. The damaged F-16 continued to fly for an additional 3 minutes until the pilot activated the airplane's ejection system. The F-16 was destroyed following the subsequent collision with terrain and post-impact fire, while the pilot landed safely and was uninjured. Visual meteorological conditions prevailed, and no flight plan was filed for the Cessna, while the F-16 was operating on an instrument flight rules flight plan. The Cessna departed from Berkley County Airport (MKS), Moncks Corner, South Carolina, at 1057, and was destined for Grand Strand Airport (CRE), North Myrtle Beach, South Carolina; the personal flight was conducted under the provisions of Title 14 Code of Federal Regulations Part 91. The F-16 had departed from Shaw Air Force Base (SSC), Sumter, South Carolina about 1020.

D. DETAILS OF THE INVESTIGATION

The Operational Factors Group was formed on September 29, 2015 to supplement the work of the NTSB investigation team already in place. All factual information compiled by the investigation team was forwarded to the Operational Factors Group Chairman for review. The Operational Factors Group Chairman did not participate in the on-scene investigation of the accident.

On December 2, 2015, the Operational Factors Group Chairman, Human Performance Group Chairman, and NTSB Investigator-in-Charge interviewed subject matter experts from the USAF regarding F-16 procedures and Air Force safety programs. The interviews were conducted at NTSB Headquarters, Washington, DC.

On February 8, 2016, the Operational Factors Group Chairman interviewed the Cessna 150M pilot's primary flight instructor regarding the pilot's training history and flying habits. The interview was conducted by phone.

On April 13, 2016, the Operational Factors Group Chairman and the Human Performance Group Chairman traveled to Shaw AFB, SC to attend a briefing by Air Force personnel on the 20th Fighter Wing (FW) safety programs, including the Mid-Air Collision Avoidance program (MACA), and to examine an exemplar F-16 cockpit.

E. FACTUAL INFORMATION

1.0 History of Flight

The F-16 pilot was assigned to act as pilot-in-command for a single-ship operational check flight (OCF) to verify corrective maintenance on ship 96-0085. The flight was to originate at SSC and consist of practice instrument approaches at Myrtle Beach International Airport, SC (MYR) and Joint Base Charleston/International Airport, SC (CHS) before returning to SSC. The mission was authorized by the 55th Fighter Squadron (FS) Daily Operations Supervisor. Since the flight was single ship and single pilot, the pilot performed an individual flight briefing utilizing the personal briefing guide. Prior to departure, squadron personnel briefed the pilot on a range of subjects, including parking location, maintenance issues, aircraft configuration, Notices to Airmen (NOTAMs), weather, and the mission timeline. Ground operations were routine, with the exception of the aircraft's Link-16 system, which was inoperative. The Link-16 was a tactical data exchange system and not necessary for a single-ship instrument training flight.

The Cessna 150M pilot originated his flight from MKS. The airport manager at MKS reported that the pilot would typically fly to Mount Pleasant, SC for lunch, and he also enjoyed flying along the Cooper River. She recalled seeing the Cessna taxi by her office and she stated on the radio, "good morning" and "have a safe flight." She did not recall any additional communication with the pilot. Recorded security video from the airport revealed that the Cessna pilot and his passenger obtained three 5-gallon fuel containers and drove away. Sometime later, they returned and serviced the Cessna with the containers. She reviewed the airport's fueling records, which showed the pilot last purchased 7.12 gallons of 100LL fuel on June 29, 2015. She also stated that she was aware the pilot had serviced the airplane with automotive fuel in the past. The surveillance video showed that the Cessna departed from runway 23.

After departing from SSC about 1020, the F-16 proceeded to MYR, where the pilot conducted two practice instrument approaches before continuing the flight to CHS. According to air traffic control (ATC) radar and voice communication data provided by the Federal Aviation Administration (FAA), the F-16 pilot contacted the approach controller at CHS about 1052 and requested to perform a practice tactical air navigation system (TACAN) instrument approach to runway 15. The controller subsequently instructed the F-16 pilot to fly a heading of 260 degrees to intercept the final approach course. At 1055, the controller instructed the F-16 pilot to descend from his present altitude of 6,000 feet to 1,600 feet. About that time, the F-16 was located about 34 nautical miles northeast of CHS.

At 1057:41, a radar target displaying a visual flight rules transponder code of 1200, and later correlated to be the accident Cessna, appeared in the vicinity of the departure end of runway 23 at MKS, at an indicated altitude of 200 feet. The Cessna continued its climb, and began tracking generally southeast over the next 3 minutes. For the duration of its flight, the pilot of the Cessna did not contact CHS approach control, nor was he required to do so. At 1100:18, the controller advised the pilot of the F-16, "traffic 12 o'clock, 2 miles, opposite direction, 1,200 [feet altitude] indicated, type unknown." The F-16 pilot responded and advised the controller that he was "looking" for the traffic. At 1100:26, the controller advised the F-16 pilot, "turn left heading 180 if you don't have that traffic in sight." The pilot responded by asking, "confirm 2 miles?" Eight seconds later, the controller stated, "if you don't have that traffic in sight turn left heading 180 immediately." Over the next 18 seconds, the track of the F-16 began turning southerly.

At 1100:49, the radar target of the F-16 was located 1/2 nautical mile northeast of the Cessna, at an indicated altitude of 1,500 feet, and was on an approximate track of 215 degrees. At that time, the Cessna reported an indicated altitude of 1,400 feet, and was established on an approximate track of 110 degrees. At 1100:52 the controller advised the F-16 pilot, "traffic passing below you 1,400 feet." At 1100:54, the radar-reported altitude of the F-16 remained at 1,500 feet and no valid altitude information was returned for the radar target associated with the Cessna. At that point the targets were laterally separated by about 1,000 feet. No further radar targets were received from the Cessna, and the next radar target for the F-16 was not received until 1101:13. At 1101:19, the F-16 pilot transmitted a distress call, and no subsequent transmissions were received. Air traffic control radar continued to track the F-16 as it proceeded on a roughly southerly track, and after descending to an indicated altitude of 300 feet, radar contact was lost at 1103:17 in the vicinity of the F-16 crash site. The F-16 pilot ejected from the aircraft safety and was met by first responders.

The wreckage of the Cessna was recovered in the vicinity of its last observed radar target, over the west branch of the Cooper River. The F-16 main wreckage site was located about 6 nautical miles south of the Cessna wreckage site.

The pilot was interviewed by members of the USAF Accident Investigation Board (AIB) following the accident. He reported the following. As he entered CHS-controlled airspace, the weather consisted of few to scattered clouds, with cloud bottoms about 4,000 to 5,000 feet. They were "puffy" clouds, with tops above him. There were no external or internal visual limitations that he could recall. He had the radar set up for a 20 and 40 mile range, manually alternating back and forth. He could not recall if his IFF interrogator was set up to receive mode 3 traffic. He was using a scan pattern that included looking outside, checking instruments for altitude, airspeed, and heading, and checking the radar display. While under radar vectors with CHS for the TACAN approach to CHS runway 15, he leveled the airplane at 1,600 feet msl on a heading of 260 degrees, with the autopilot engaged. He recalled the controller issuing traffic at his 12 o'clock position, two miles away, at 1,200 feet. He remarked that a two-mile call was the "...closest call I've ever received." It was "...a big alert for me." He stated that he was looking aggressively, trying to find the airplane. His primary means of looking for the traffic was visually. He then recalled a command from CHS to turn left "immediately" to a heading of 180 degrees. He used the autopilot to execute the turn so that he could continue to search outside for the traffic. The autopilot turn utilized 30 degrees of bank and standard rate (3 degrees per second

of turn). He continued to search for the traffic until he observed the Cessna directly in front of his airplane, “within 500 feet.” He applied full aft control stick inputs to avoid a collision, but it was “too late” and the collision occurred. He estimated that the time from initial sighting of the Cessna to the impact was less than one second. He attempted to maintain control of his aircraft; however, once he determined that continued flight under control was not possible, he set up for the ejection.

Several witnesses were located after the accident. One witness reported that he and his son were fishing from a boat in a rice field, located adjacent to the west branch of the Cooper River. While positioned near a duck blind in the middle of the rice field, he noticed the Cessna flying overhead from the direction of Old Highway 52 (roughly from west to east). He then observed a military jet flying overhead, coming from the direction of Moncks Corner (roughly from north to south). The two airplanes collided almost on top of the duck blind, at an estimated altitude of 300 yards overhead. He further described that both airplanes were “very low,” and that he had never seen airplanes flying at that low of an altitude over that specific location in the past. The military jet struck the left side of the Cessna, and debris then began falling all around them. He did not have the impression that either airplane had attempted any maneuvers immediately before the collision. A large black cloud of smoke appeared after the collision, but no fire was observed. After the collision, the military jet then “powered up,” turned right, and flew southbound, roughly along the river.

Another witness reported that he was standing in his back yard overlooking the west branch of the Cooper River with two friends. He stated that they generally liked to watch small aircraft as they flew by and would routinely wave to the pilots and observe the pilots rocking their airplane’s wings as a response. He watched and waved as a small red and white airplane (the accident Cessna) flew by from his right to left (roughly west to east). He next saw a military jet flying in the direction of the small plane, coming from his left, rear position (roughly north to south). The military jet collided with the left side of the Cessna and parts started falling down, with some landing in his yard. Other parts were falling in the river, and on the opposite shore of the river. He stated it looked as if the military jet tried to “pull up” just before impact. After the impact, the military jet turned right, and flew along the river to the south and out of sight. Once out of sight he heard several loud “bang” noises.

2.0 Flight Crew Information

2.1 The F-16 Pilot

According to USAF personnel, the pilot of the F-16, was current and qualified in the accident aircraft as a four-ship flight lead. His additional duties at the time of the accident included the position of 55th Chief of Mobility. At the time of the accident, his military flight experience was 2,383.6 hours total time, including 624.2 hours in the F-16. Included in the F-16 pilot’s total time was 1,055 hours at the controls of the MQ-1B Predator and 456.1 hours at the controls of the MQ-9 Reaper, both unmanned aerial vehicles (UAVs). His recent experience included 35.5 hours (26 flights) in the 90 days prior to the accident and 24.0 hours (17 flights) in the 30 days prior to the accident, all in the F-16. At the time of the accident, he was medically qualified for flight duty without any medical restrictions. The pilot reported that he was wearing contact lenses at the time of the accident.

The F-16 pilot's latest instrument check ride was completed on August 25, 2014, and his most recent mission (tactical) check ride was completed on March 24, 2015. According to USAF records, none of the F-16 pilot's post-pilot training check rides contained discrepancies or downgrades.

The F-16 pilot reported during a post-accident interview that he had accumulated about 50 hours of civilian flying time.. He had not flown civilian aircraft since he began initial USAF pilot training.

The F-16 pilot possessed a FAA commercial pilot certificate with airplane single engine land, instrument airplane, and airplane multi-engine land (limited to centerline thrust) ratings. The commercial certificate was obtained on May 10, 2005 through 14 CFR part 61.73 regarding special rules for military pilots. His most recent FAA medical certificate was issued on October 6, 2003. On that certificate application he reported 12 hours of civilian flying time. The medical certificate was issued with no limitations.

2.2 The Cessna 150M Pilot

The pilot of the Cessna 150M, age 30, held a private pilot certificate with a rating for airplane single engine land, which he received on December 29, 2014. His most recent, and only, FAA third-class medical certificate was issued on February 7, 2013, with no associated waivers or limitations. The pilot's personal flight logbook was recovered from the wreckage and detailed entries between May 2012 and July 5, 2015. As of the final entry in the log, the pilot had accumulated 244 total hours of flight experience, of which 239 hours were in the accident airplane make and model. He had flown about 58 hours in the 90 days preceding the accident, and about 18 hours in the 30 days preceding the accident. Review of FAA records revealed he had no history of any accidents, incidents, violations, or pending investigations.

The pilot's primary flight instructor was interviewed following the accident. He reported that the accident pilot was a "good student" and a "good pilot." Except for a few initial flights in a Piper PA-28-140, they flew and trained exclusively in the pilot's Cessna 150M. He described him as "very careful, studious, conscientious, highly motivated, and responsive." He was always prepared for his instructional flights, checking the weather, NOTAMS, and any temporary flight restrictions. He continued to fly and instruct with the pilot after he received his private pilot certificate, working with him toward his instrument training and eventually his commercial certificate.

The flight instructor also reported that the pilot displayed a strong "see and avoid" discipline. His situational awareness and his traffic acquisition skills were also very good. The pilot worked in the Charleston area and flew out of Orangeburg, SC often; they would meet there to begin their flights. The pilot was very aware of the military traffic both from SSC and from CHS and this was a routine topic of conversation on their flights. The flight instructor noted that they were usually above the Shaw F-16 traffic when they flew together. The pilot always used flight following when it was appropriate. He "enjoyed" talking to ATC and was very aware of the benefits, especially when transiting Charleston airspace when he flew his frequent flights to

Beaufort, SC. He would call Charleston ATC for weather and traffic updates. The flight instructor lent him a hand-held aviation radio during his training so that he could listen to ATC and better learn the terminology. The pilot would contact ATC for flight following without being prompted.

Further review of the pilot's flight activity logs revealed that he interacted with SSC AFB ATC on at least 9 occasions and he interacted with CHS ATC at least 21 times during his flight training and experience.

3.0 Medical and Pathological Information

Postaccident toxicological testing was performed on tissue specimens from the Cessna pilot by the FAA's Civil Aerospace Medical Institute. The specimens tested negative for a wide range of drugs, including major drugs of abuse. Although specimens from the airplane pilot tested positive for ethanol, the levels of ethanol were consistent with postmortem ethanol production.

Postaccident toxicological testing was performed on blood and urine specimens from the F-16 pilot by a Department of Defense Armed Forces Medical Examiner Scientist, and tested negative for carbon monoxide, ethanol, and major drugs of abuse.

4.0 Aircraft Information

4.1 Lockheed Martin F-16CM, 96-0085

The F-16 was a single-seat, turbofan-powered fighter airplane. It was not equipped with either a traffic collision avoidance system (TCAS) or automatic direct surveillance – broadcast (ADS-B) system. Its most recent 400-hour phase inspection was completed on June 4, 2014, and it had accumulated 237 flight hours since that time. Following a flight on June 11, 2015, Air Force maintenance personnel completed work on the airplane's flight control system, and subsequently cleared the airplane to return to service on July 2, 2015. The accident flight was an operated as an "operational check flight," during which the pilot was tasked with verifying the corrective maintenance performed. At the time of the accident, the airframe had accumulated 4,435 total hours of operation.

4.2 Cessna 150M, N3601V

The Cessna 150 was a single-engine, high-wing airplane with a conventional tail. It was equipped with a rotating beacon light, anti-collision strobe lights, navigation position lights, and a landing light. The operational status of each lighting system at the time of the accident could not be determined. Review of the accident Cessna's maintenance and airworthiness records revealed no evidence that any supplemental equipment had been installed to enhance the airplane's visual conspicuity. The airplane was equipped with a single VHF communication radio, and no traffic advisory system, traffic alert collision avoidance system, or automatic dependent surveillance-broadcast equipment or displays were installed.

The Cessna was also equipped with a King KT-78, mode C transponder and an Ameri-King AK-350 altitude encoder. Review of maintenance records revealed that the most recent transponder and encoder tests per the requirements 14 CFR 91.413 were completed on September 8, 2008. On July 20, 2012, and overhauled transponder and new altitude encoder of the same makes and models were installed. The units were ground tested in accordance with the procedures outlined in their respective maintenance manuals. The pitot/static system was most recently tested per the requirements of 14 CFR 91.411 on April 11, 2013. The Cessna's most recent annual inspection was completed on October 14, 2014. At the time of the inspection, the airframe had accumulated 3,651 total hours of operation.

5.0 Meteorological Information

The area forecast that included Eastern South Carolina was issued at 0445, and forecasted scattered clouds between 3,000 and 4,000 feet msl, with scattered cirrus clouds and widely scattered light rain showers and thunderstorms after 1100.

The closest facility disseminating a terminal aerodrome forecast was CHS. The last forecast published prior to the accident was issued at 0723. The forecast weather conditions beginning at 0800 and continuing through 1300 included variable winds at 4 knots, greater than 6 statute miles visibility, and few clouds at 4,000 feet above ground level (agl).

Review of weather radar imagery showed no precipitation in the vicinity of the accident site about the time of the accident.

The weather conditions reported at MKS at 1055 included calm winds, 10 statute miles visibility, scattered clouds at 2,600 feet agl, a temperature of 30 degrees C, a dew point of 22 degrees C, and an altimeter setting of 30.15 inches of mercury.

The weather conditions reported at CHS at 1055 included winds from 220 degrees true at 7 knots, 10 statute miles visibility, scattered clouds at 4,000 feet agl, a temperature of 30 degrees C, a dew point of 22 degrees C, and an altimeter setting of 30.15 inches of mercury.

At the time of the accident, the sun's angle was about 56° above the horizon at an azimuth of about 99°.

6.0 Aids to Navigation

Not applicable.

7.0 Communications

NTSB investigators interviewed the Air Combat Command (ACC) Chief of Standardization and Evaluation (STAN/EVAL), who was also qualified in the F-16, regarding the term "turn immediately" as issued by ATC and he stated that this was not standard ATC phraseology. He referred to it as "bubba comm." He indicated that, assuming there was a sense of urgency in the controller's voice and the traffic was close and not visually acquired, he would probably override

the autopilot and turn more aggressively than a 30 degree bank, standard rate turn while simultaneously increasing engine power to maximum continuous thrust to maintain the airplane's energy state and avoid bleeding off airspeed. He would use the "(1) Aviate, (2) Navigate, and (3) Communicate" system. He did not think he would use afterburner to avoid traffic if given a "turn immediately" command. He did not know what the standard terminology would be to indicate urgency. He had only heard controllers use "no delay" to initiate a climb or descent command.

The term "immediately" is defined in the FAA Pilot/Controller Glossary, which stated, "Used by ATC or pilots when such action is required to avoid an imminent situation." Additional information regarding this term is located in the Air Traffic Control Group Chairman's Factual Report, located in the public docket for this investigation.

8.0 Airport Information

MKS was the closest airport to the accident site and the departure airport for N3601V. MKS was a non-towered airport at coordinates N33:11.15, W80:02.18. The airport elevation was 73 feet above mean sea level. MKS was equipped with a single runway, designated 5/23. The UNICON/CTAF frequency was 123.05. The airport was attended daily from 0900 to 1900 local.

9.0 Organizational and Management Information

The F-16 belonged to the 55th FS, one of three fighter squadrons at Shaw AFB. The F-16 pilot was assigned to the 55th FS. The 55th FS was under the 20th Fighter Wing (FW), headquartered at Shaw, which was under the Ninth Air Force, also headquartered at Shaw, which was under Air Combat Command, headquartered at Langley, VA (a major command).

10.0 F-16 Radar and IFF Interrogator Systems

The F-16 had a radar unit installed in the nose of the aircraft. This radar was used by the pilot to locate and "lock on" to other aircraft. According to USAF personnel, it was designed to acquire fast-moving enemy aircraft, not slow-moving small, civilian aircraft. USAF personnel interviewed did not believe the radar would locate a small Cessna aircraft at takeoff or climb speed.

The radar acquired targets by direct return off the target aircraft's surface (skin paint) and not by a transponder code. It utilized aircraft closure rate rather than the airspeed of the other aircraft. The radar was limited to forward looking and could only search 120 degrees directly in front of the aircraft (60 degrees either side of center). The F-16 radar was also limited by the size of target. It was normally used up to a 40-mile range, but other settings were available.

When operating in the typical range while in search target acquisition mode, aircraft would appear on the radar display (a 5x5 inch multi-function display, or MFD) as a small, white square target. The MFDs on the F-16 were located near the pilot's knees in the cockpit. If a good target existed, a subsequent sweep of the radar would reveal a new target and the previous image would be lighter in intensity. There were no audio alerts if a new target appeared. A cursor could be

placed over the target and the target could be “locked” on the radar. After lock on, the pilot could obtain the msl altitude of the target.

There was an “identification, friend or foe (IFF)” interrogator installed on the Shaw F-16s. The target would be displayed on the radar display but it was not an integral part of the radar. The IFF interrogator could be programmed to request specific types of responses (1 to 4), with type 3 responses being the type that would be provided by most civilian aircraft with an operating ATC transponder. The interrogation process had to be initiated by the F-16 pilot. It took about 8-10 seconds to sweep and display all 4 modes, each being displayed for about 2 seconds each.

11.0 F-16 Autopilot

The F-16 had a basic autopilot, utilizing attitude hold, heading select, and steering select in the roll axis and attitude hold and altitude hold in the pitch axis. There was no capability for coupled approaches. There were three bank settings: go to heading, selected steer point and hold bank angle. While autopilot was engaged, and a new heading was selected, the airplane would turn at bank angle not to exceed 30 degrees.

Manual inputs through the control stick would override autopilot functions. If specific limits were exceeded during manual override, the autopilot would disconnect. The airplane would also likely climb or descend in the turn because it would no longer be in altitude hold.

12.0 Pertinent Rules and Regulations

12.1 Military Rules and Regulations

Air Force Instruction (AFI) 11-202, Volume 3 (General Flight Rules) dated November 7, 2014 provided pilots with “right of way” rules regarding airborne traffic conflicts:

3.17. Right-of-Way. Each pilot must take whatever action is necessary to avoid collision, regardless of who has the right-of-way. The yielding aircraft must not pass over, under, abeam, or ahead of the other aircraft until well clear.

3.17.2. Converging. When converging at approximately the same altitude (except head-on or approximately so), the aircraft to the other's right has the right-of-way. Aircraft of different categories have the right-of-way in the following order of priority: balloons, gliders, aircraft towing or refueling other aircraft, airships, rotary- or fixed-wing aircraft.

3.17.3. Approaching Head-On. If aircraft are approaching each other head-on or approximately so, each shall alter course to the right.

3.17.4. Overtaking Aircraft. An overtaken aircraft has the right-of-way. The overtaking aircraft must alter course to the right.

AFI11-202, Volume 3 (General Flight Rules) dated November 7, 2014 provided pilots with “sense and avoid” (also known as “see and avoid”) rules regarding airborne traffic conflicts:

3.18. Sense and Avoid. Pilots under instrument flight rules (IFR) or visual flight rules (VFR), whether or not under radar control, are responsible for avoiding traffic, terrain/obstacles, and environmental hazards.

3.18.1. Standard IFR separation is provided between aircraft operating under IFR in controlled airspace. Within the National Airspace System (NAS), ATC provides traffic advisories on VFR aircraft on a time-permitting basis. Outside the NAS, consult ICAO and country-specific guidance outlined in the FCG and FLIP.

AFI11-202, Volume 3 (General Flight Rules), ACC Supplement I, dated November 28, 2012, included pilot preflight briefing procedures regarding mid-air collision avoidance:

2.7.3.1. In order to increase awareness on potential conflicts with other aircraft, aircrews will brief the following special subject on every sortie: Radar/visual search responsibilities for departure, en route, recovery and high density traffic areas; and mid-air collision avoidance (from other military aircraft and/or civilian aircraft).

AFI11-202, Volume 3 (General Flight Rules), ACC Supplement I, dated November 28, 2012, included pilot procedures during practice instrument approaches in VMC:

5.16.2. Practice Instrument Approaches. Approaches conducted in other than actual IMC. The pilot must still be able to see the ground, surrounding terrain, and when established on the final segment of the approach, the airport environment. Practice instrument approaches, including approaches flown under VFR will be conducted IAW Chapter 8 of this instruction. Practice approaches may be conducted without a safety observer (as defined in paragraph 5.16.1.2) if the pilot is instrument qualified and current in the type of approach flown. When flying a practice approach without a safety observer, the pilot must maintain a composite crosscheck that maintains situational awareness with terrain and other traffic. The pilot is not relieved of the responsibility to see and avoid other traffic, terrain and obstacles.

AFI11-202, Volume 3 (General Flight Rules), ACC Supplement I, dated November 28, 2012, included pilot procedures for “see and avoid” while operating in VMC:

5.4. See and Avoid. Pilots operating in VMC, under IFR or VFR, whether or not under radar control, are always responsible to see and avoid other traffic, terrain, and obstacles.

AFI11-202, Volume 3 (General Flight Rules), ACC Supplement I, dated November 28, 2012, included information on ATC separation procedures between military pilots operating under IFR and VFR aircraft:

5.4.1. Standard IFR separation is provided between aircraft operating under IFR in controlled airspace. Within the NAS, ATC provides traffic advisories on VFR aircraft on a time-permitting basis. Outside the NAS, the crew should consult ICAO and country specific guidance outlined in the FCG and FLIP.

AF111-2F-16, Volume 3 (F-16 -- Operations Procedures), dated December 18, 2013, addressed F-16 procedures for simulated instrument flight:

4.1.3. Simulated Instrument Flight. Simulated instrument flight requires a qualified safety observer in the aircraft or in a chase aircraft. The observer may occupy either seat of the F-16B/D provided the intercom is operable. Use the radar to aid in clearing the area. Pilots in F-16A/C aircraft may not log simulated instrument flight without a chase. They may fly multiple approaches in VMC without a chase, but will place their primary emphasis on seeing and avoiding other aircraft. Chase aircraft may move into close formation on final for a formation landing provided simulated instrument flight is terminated.

Table A.3.1, under the same regulation, provided collision avoidance information in the General Briefing Guide. The regulation required pilots to brief, prior to every flight, the following emphasis items:

Collision Avoidance

Radar/Visual Search Responsibilities

Departure/Enroute/Recovery High Density Traffic Areas

Mid-Air Collision Avoidance

From Other Military Aircraft

From Civilian Aircraft

12.2 Civilian Rules and Regulations

The FAA Aeronautical Information Manual (AIM) – Official Guide to Basic Flight Information and ATC Procedures, dated April 3, 2014, included pilot procedures for see and avoid:

5–5–8. See and Avoid

a. Pilot. When meteorological conditions permit, 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.

The AIM also described operations to/from airports without an operating control tower and the use of a Common Traffic Advisory Frequency (CTAF):

4–1–9. Traffic Advisory Practices at Airports Without Operating Control Towers

a. Airport Operations Without Operating Control Tower

1. There is no substitute for alertness while in the vicinity of an airport. It is essential that pilots be alert and look for other traffic and exchange traffic information when approaching or departing an airport without an operating control tower. This is of particular importance since other aircraft may not have communication capability or, in some cases, pilots may not communicate their presence or intentions when operating into or out of such airports. To

achieve the greatest degree of safety, it is essential that all radio-equipped aircraft transmit/receive on a common frequency identified for the purpose of airport advisories.

b. Communicating on a Common Frequency

The key to communicating at an airport without an operating control tower is selection of the correct common frequency. The acronym CTAF which stands for Common Traffic Advisory Frequency, is synonymous with this program. A CTAF is a frequency designated for the purpose of carrying out airport advisory practices while operating to or from an airport without an operating control tower. The CTAF may be a UNICOM, MULTICOM, FSS, or tower frequency and is identified in appropriate aeronautical publications.

The AIM describes the following recommended communication procedures regarding departure aircraft on the CTAF:

c. Recommended Traffic Advisory Practices

1. Pilots of inbound traffic should monitor and communicate as appropriate on the designated CTAF from 10 miles to landing. Pilots of departing aircraft should monitor/communicate on the appropriate frequency from start-up, during taxi, and until 10 miles from the airport unless the CFRs or local procedures require otherwise.

Title 14, CFR Part 91.113, General Operating and Flight Rules, addressed aircraft right-of-way rules. The following are excerpts from the 91.113:

Except water operations.

(b) General. 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. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

(d) Converging. When aircraft of the same category are converging at approximately the same altitude (except head-on, or nearly so), the aircraft to the other's right has the right-of-way.

(e) Approaching head-on. When aircraft are approaching each other head-on, or nearly so, each pilot of each aircraft shall alter course to the right.

13.0 Visual Scanning Procedures (Clearing)

Air Force pilots were taught scanning for traffic techniques during initial pilot training in the Beechcraft T-6 Texan II. The accident F-16 pilot also began his military flight training in the T-6. Air Force Manual (AFMAN) 11-248, dated January 19, 2011, T-6 Primary Flying, addressed clearing procedures in section 1.16:

1.16. Clearing. Each crewmember is responsible for collision avoidance - regardless of rank, experience, or cockpit position - whether instrument flight rules (IFR) or VFR. The three primary tools for clearing in the T-6 are eyes, radios, and the Naval Aircraft Collision Warning System (NACWS) or Traffic Advisory System (TAS). In addition, air traffic control (ATC) shares aircraft separation responsibility with the pilot and provides separation between IFR and participating VFR aircraft operating in controlled airspace. Pilots have the responsibility to clear the aircraft in all directions, and although the use of radar monitoring, assigned areas, or ATC separation can assist in ensuring clearance, it does not relieve pilots of the responsibility. The following principles apply to clearing regardless of flight conditions:

1.16.1. Visual detection is the most important factor in clearing for other aircraft. The following methods can help the pilot see other aircraft:

1.16.1.1. Visual Scanning. Search an area with an arc of approximately 20 to 30 degrees at a time and focus on a distant point (cloud, ground reference, etc.) within the arc for 3 to 5 seconds. After cross-checking instruments in the cockpit, it is necessary to refocus on a distant point because the eye will naturally focus at a distance of about 18 inches.

1.16.1.2. Heading Changes. When on a collision course, another aircraft appears stationary in the canopy and is difficult to see. The eye most readily detects line of sight (LOS) motion. Slight heading changes can create the relative movement required for detection of the other aircraft. This method is most effective when ATC or NACWS provides traffic alerts for aircraft that are not acquired visually.

1.16.1.3. Wing Flashes. When an aircraft is known to be close but not visually acquired, a wing flash or rock can create the necessary movement for detection.

An Air Force STAN/EVAL pilot was interviewed by NTSB investigators after the accident and he reported the following regarding clearing procedures. Scanning procedures and techniques were extensively covered in T-38 and F-16 flight training programs. He stressed the “first look, then turn” philosophy, meaning that a turn should not be initiated without first clearing in that direction. Scanning was taught as a tactic, and could be employed in formation or single ship. Wingmen provided support by clearing for traffic.

He described the overall tactical scan pattern for aircraft operating in formation, and the specific pattern that was taught to F-16 pilots. This pattern included looking for hazards in front of the airplane that were near and far, checking the area around their wingman, checking aft of their aircraft, and checking the radar display inside the cockpit; radar was the last to be checked. He added that it was typical to scan the sky in sections, 10 degrees at a time. It helped to focus on a specific point of the ground, or a cloud in the sky, to calibrate the eyes. There was essentially no difference in scanning procedures between VFR and IFR rules, assuming VMC in both cases. Wingmen were admonished if the flight lead saw traffic before the wingman saw it. He was less comfortable when flying single ship and would have a heightened awareness of traffic.

He estimated that, if conducted properly, scanning should consist of looking outside 75% of the time and looking at radar 25% of the time. He reiterated that concern for traffic is higher while flying single ship. He also stated that the head-up display (HUD) did not obstruct his view when scanning for traffic at the 12 o'clock position.

Scanning procedures for civilian pilots was addressed in the Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-24A). The following excerpts were contained under section 13, Airport Operations, Collision Avoidance:

14 CFR part 91 has established right-of-way rules, minimum safe altitudes, and VFR cruising altitudes to enhance flight safety. The pilot can contribute to collision avoidance by being alert and scanning for other aircraft. This is particularly important in the vicinity of an airport.

Effective scanning is accomplished with a series of short, regularly spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10°, and each should be observed for at least 1 second to enable detection. Although back and forth eye movements seem preferred by most pilots, each pilot should develop a scanning pattern that is most comfortable and then adhere to it to assure optimum scanning. Even if entitled to the right-of-way, a pilot should yield if another aircraft seems too close.

Section 13 also provided procedures and considerations assist a pilot in collision avoidance under various situations (climbs and descents, straight and level, traffic patterns, etc.) and described the sight limitations of high and low wing aircraft.

14.0 55th Fighter Wing Flight Safety Program and MACA Program

The 20th FW Safety office was led by a Chief of Safety (a Lieutenant Colonel), supported by a Chief of Flight Safety (a Captain) and two non-commissioned officers. The Chief of Safety reported to the Wing Commander. The ACC Safety office provided oversight of the wing safety program. Each of the three fighter squadrons had an attached flight safety officer (FSO) to assist in the administration of the flight safety programs and perform liaison and investigation duties as required. All FSOs at Shaw were trained in safety program management and aircraft investigation procedures.

The USAF has developed a Mid-Air Collision Avoidance (MACA) program and its required elements were detailed in Air Force Instruction (AFI) 91-202 (June 24, 2015). According to AFI 91-202, Air Force flying units must have established a written MACA program. The unit safety office was responsible for its creation, documentation, and upkeep.

The 20th FW Safety office administered the Shaw MACA program. The required elements included a MACA pamphlet and a poster. According to the ACC Chief of Safety, the Shaw MACA program was "very robust" at the time of the accident. The MACA program was primarily designed for use in the civilian community. The program included civilian outreach and incorporated interaction with the Aircraft Owners and Pilots Association (AOPA), FAA Flight Standards District Offices (FSDOs) and local airports and fixed base operators (FBOs). ACC staff inspected wing safety office and its MACA program every two years.

According to 20th FW Safety office personnel, activities related to MACA were coordinated with two other military bases, Charleston Joint Base and McEntire Joint National Guard Base (JNGB). Safety officers combined and coordinated their efforts to reach the civilian flying community. The outreach area included all of South Carolina and some areas of Georgia and North Carolina. 20th FW Safety staff reported that safety officers from the three bases would visit local airports to discuss safety issues, drop off MACA materials, and ensure that the MACA program was receiving proper coverage. Other opportunities for community outreach and MACA program dissemination included a general aviation fly-in and a community airshow, both scheduled for 2016 at Shaw.

The Charleston Joint Base Flight Safety office held a MACA seminar at MKS in June, 2012, January, 2014, and March 2015. According to the MKS airport manager, the March, 2015 event was lightly attended. The seminar was held on a Thursday, and she tried to move it to the weekend to increase attendance. The only attendees were USAF and MKS staff; no local pilots attended.

AF Form 651, Hazardous Air Traffic Report (HATR) and AF Form 457, USAF Hazard Report, would be available and utilized. The most common tool for reporting a near midair collision for Air Force pilots was the HATR. The unit safety offices would investigate the HAPs and HATRs. Investigations and trends would be briefed at safety meetings (quarterly at Shaw).

NTSB investigators reviewed the Shaw MACA program materials provided after the accident. The written program was divided into sections, covering the following topics: Shaw AFB and McEntire JNGB local area procedures, including F-16 IFR and VFR departure and arrival procedures, military special use airspace, controlled airspace, types of military aircraft in the local area and their specific tactics and procedures, and MACA and ATC points of contact information. The 20th FW Safety office also maintained a public web site with the MACA products and other safety information for civilian pilots. Sample MACA materials are included in the public docket for this investigation.

F. LIST OF ATTACHMENTS

- Attachment 1: NTSB Memorandum for Record – USAF SME Interviews
- Attachment 2: NTSB Memorandum for Record – Cessna Flight Instructor Interview
- Attachment 3: NTSB Records of Interview (3) – Witnesses
- Attachment 4: NTSB Records of Interview – MKS Airport Manager
- Attachment 5: AIB Record of Interview with F-16 Pilot*
- Attachment 6: Information from USAF: F-16 Radar/IFF/Safety Programs
- Attachment 7: F-16 Pilot's Records
- Attachment 8: AIB Review of F-16 Pilot's Qualifications (Memo)
- Attachment 9: Cessna Pilot's Logbook Excerpts
- Attachment 10: Cessna 150M Maintenance Logbook - Excerpts
- Attachment 11: F-16 Maintenance Summary Report
- Attachment 12: NTSB Memorandum for Record – Weather Information
- Attachment 13: Excerpts – AFI 11-2F-16V3
- Attachment 14: Excerpts – AFI 11-202V3

Attachment 15: Excerpts – AFI 11-202V3 ACC Supplement
Attachment 16: Excerpts – AFMAN 11-248 T-6 General Flying
Attachment 17: Excerpts - AIM
Attachment 18: 14 CFR Part 91.113
Attachment 19: Excerpt – FAA Pilot/Controller Glossary
Attachment 20: Excerpt – Pilot’s Handbook of Aeronautical Knowledge
Attachment 21: Shaw AFB F-16 General Briefing Guide
Attachment 22: Shaw AFB MACA Products
Attachment 23: Charleston Joint Base MACA Products
Attachment 24: Toxicology Report – Cessna 150M Pilot

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