# UNITED STATES AIR FORCE
# AIRCRAFT ACCIDENT INVESTIGATION
# BOARD REPORT

**F-16C, T/N 88-0477**

**175TH FIGHTER SQUADRON**
**114TH FIGHTER WING**
**SOUTH DAKOTA AIR NATIONAL GUARD**

**LOCATION: Near March Air Reserve Base, California**

**DATE OF ACCIDENT: 16 May 2019**

**BOARD PRESIDENT: Colonel Eric Paulson**

**Conducted in accordance with Air Force Instruction 51-307**

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

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14 APR 2020

## ACTION OF THE CONVENING AUTHORITY

**The report of the accident investigation board conducted under the provisions of Air Force Instruction 51-307, *Aerospace and Ground Accident Investigations*, that investigated the 16 May 2019 mishap involving an F-16C, T/N 88-0477, owned by the 114th Fighter Wing but operated by the 144th Fighter Wing, near March Air Reserve Base, California, complies with applicable regulatory and statutory guidance, and on that basis it is approved.**

CHRISTOPHER P. WEGGEMAN
Lieutenant General, USAF
Deputy Commander

*People First... Mission Always...*

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

**F-16C, T/N 88-0477**
**Near March Air Reserve Base, California**
**16 May 2019**

On 16 May 2019, at 1539 local time, a block 40 F-16C, tail number (T/N) 88-0477, assigned to the 114th Fighter Wing (FW), Air National Guard, Joe Foss Field, South Dakota, with duties at the 144 FW, Detachment (Det) 1, March Air Reserve Base (ARB), California, crashed on approach to March ARB. There were no fatalities, but the mishap aircraft (MA) impacted a commercial warehouse, resulting in minor injuries to warehouse employees. The mishap pilot (MP), assigned to the 144 FW, Det 1, ejected before impact and sustained minor injuries. The MA, valued at $24,991,645, was destroyed, and the environmental clean-up cost was $3,937,652.

The purpose of the mishap flight (MF) was to practice an Aerospace Control Alert scramble of two F-16 fighters and to conduct aircraft intercept training. The MF consisted of a two-aircraft formation with the training activities occurring in a Military Operating Area (MOA) approximately 120 miles east of March ARB. The MP flew the number two aircraft in the formation (the "wingman") during take-off, transition to the MOA, return to base and landing. During the approach into March ARB, the MA experienced low pressure in system A of its dual hydraulic system, followed by low pressure in system B. The loss of hydraulic pressure in both the A and B systems significantly degraded the effectiveness of the MA's hydraulically actuated fight controls. Unable to maintain control of the MA, the MP ejected near the threshold of March ARB's runway 14.

The Accident Investigation Board president found, by a preponderance of the evidence, the cause of the mishap was the improper installation of two hydraulic check valves in the right Flaperon Integrated Servo Actuator (ISA), which resulted in a loss of sufficient hydraulic pressure to control the MA. A preponderance of the evidence also indicated an inadequate ISA overhaul process that lacked an effective procedure to identify improper installation of ISA check valves was a substantially contributing factor.

# SUMMARY OF FACTS AND STATEMENT OF OPINION
# F-16C, T/N 88-0477
# 16 May 2019

## TABLE OF CONTENTS

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACA | Aerospace Control Alert |
| ACC | Air Combat Command |
| AD | Active Duty |
| AF | Air Force |
| AFB | Air Force Base |
| AFE | Aircrew Flight Equipment |
| AFI | Air Force Instruction |
| AFIP | Air Force Institute of Pathology |
| AFGM | Air Force Guidance Manual |
| AFPAM | Air Force Pamphlet |
| AFPET | Air Force Petroleum |
| AFRL | Air Force Research Laboratory |
| AFTO | Air Force Technical Order |
| AGL | Above Ground Level |
| AIB | Accident Investigation Board |
| ALT | Alert PreFlight |
| ANG | Air National Guard |
| AOA | Angle of Attack |
| ARB | Air Reserve Base |
| AS | Airlift Squadron |
| ATC | Air Traffic Control |
| ATIS | Automatic Terminal Information Service |
| BMC | Basic Mission Capable |
| BPO | Basic Post-Flight |
| CA | California |
| Col | Colonel |
| CMMXS | Commodities Maintenance Squadron |
| CSFDR | Crash Survival Flight Data Recorder |
| DE | Deleware |
| DET | Detachment |
| DFLCC | Digital Flight Control Computer |
| DFLCS | Digital Flight Control System |
| DO | Director of Operations |
| DoD | Department of Defense |
| EPU | Emergency Power Unit |
| FL | Flight Lead |
| FLCS | Flight Control System |
| FOIA | Freedom of Information Act |
| FPM | Feet Per Minute |
| FPS | Fire Protection System |
| FRC | Fault Reporting Codes |
| FS | Fighter Squadron |
| ft | Feet |
| FW | Fighter Wing |
| HG | Atomic Symbol for Mercury |
| IAW | In Accordance With |
| ICAWS | Integrated Caution, Advisory and Warning System |
| ICV | Inlet Check Valve |
| IFE | In-Flight Emergency |
| IFF | Identification, Friend or Foe |
| IMDS | Integrated Maintenance Data System |
| IP | Instructor Pilot |
| ISA | Integrated Servoactuator |
| JOAP | Joint Oil Analysis Program |
| K | Thousand |
| kts | Knots |
| L | Local Time |
| LEF | Leading Edge Flap |
| Lt Col | Lieutenant Colonel |
| MA | Mishap Aircraft |
| MARB | March Air Reserve Base |
| Maj | Major |
| MAJCOM | Major Command |
| MF | Mishap Flight |
| MFL | Mishap Flight Lead |
| mL | Milliliter |
| MLG | Main Landing Gear |
| MM | Mishap Maintainer |
| MOA | Military Operating Area |
| MP | Mishap Pilot |
| MS | Mishap Sortie |
| MSL | Mean Sea Level |
| ND | Nose Down |
| NDI | Non-Destructive Inspection |
| NLG | Nose-wheel Landing Gear |
| NM | Nautical Miles |
| NORTHCOM | Northern Command |
| NOTAMs | Notices to Airmen |
| OG | Operations Group |
| OPR | Officer Performance Report |
| Ops Tempo | Operations Tempo |
| ORM | Operational Risk Management |

| | |
|---|---|
| OSS | Operation Support Squadron |
| OWS | Operational Weather Squadron |
| PA | Public Affairs |
| PAC | Production Acceptance Certification |
| PFL | Pilot Fault List |
| PFLD | Pilot Fault Listing Display |
| PH | Phase |
| PHA | Physical Health Assessment |
| PMP | Packaged Maintenance Plan |
| PR | Pre Flight |
| PSI | Pounds Per Square Inch |
| QA | Quality Assurance |
| QC | Quality Control |
| RAP | Ready Aircrew Program |
| RAPCON | Radar Approach Control |
| RTB | Return-To-Base |
| RWD | Right Wing Down |
| RWY | Runway |
| SAR | Search and Rescue |
| SD | South Dakota |
| SEFE | Standardization Evaluation Flight Examiner |
| SF | Security Forces |
| SM | Statute Miles |
| S/N | Serial Number |
| SOF | Supervisor of Flying |
| ST | Statute Miles |
| SURF | Flight Call Sign |
| T/N | Tail Number |
| TO | Technical Order |
| USAF | United States Air Force |
| US | United States |
| UT | Utah |
| TOD | Tech Order Data |
| VVI | Vertical Velocity Indication |
| WAI | Walk-Around Inspection |
| WADS | Western Air Defense Sector |
| Z | Zulu |

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

# SUMMARY OF FACTS

## 1. AUTHORITY AND PURPOSE

### a. Authority

On 11 July 2019, the Deputy Commander, Air Combat Command (ACC), appointed Colonel Eric C. Paulson to conduct an aircraft investigation of the 16 May 2019 crash of an F-16C, tail number (T/N) 88-0477, near March Air Reserve Base (ARB), California (CA) (Tab Y-3). On 16 July 2019, the Accident Investigation Board (AIB) convened at March ARB, CA (Tab Y-3). To aid in the investigation, the deputy commander also appointed members from the United States Air Force's (USAF) Regular and Guard components (Tab Y-3). The members appointed were an Air National Guard (ANG) Lieutenant Colonel Medical Member, an ANG Major Legal Advisor, an Active Duty (AD) Captain Pilot Member, an ANG Senior Master Sergeant Maintenance Member, and an AD Master Sergeant Recorder (Tab Y-3).

### b. Purpose

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

## 2. ACCIDENT SUMMARY

On 16 May 2019, at 1539 hours local time (L), the mishap aircraft (MA), a block 40 F-16C, T/N 88-0477, assigned to the 114th Fighter Wing (FW), Joe Foss Field, Sioux Falls, South Dakota (SD), and operated by a pilot from the 144 FW, Detachment (Det) 1, located at March ARB, CA, crashed into a commercial warehouse near March ARB while attempting to land (Tabs K-5, N-2, N-9, T-2 and V-1.14, and FF-2 to FF-3). The MF was returning from a local training mission as a two aircraft formation (Tab V-1.5 and V-1.14). Only the mishap pilot (MP) was onboard the MA at the time of the incident (Tab T-2). The MP successfully ejected from the MA prior to the crash. There were no military or civilian fatalities resulting from this accident (Tab X-4). The MA, valued at $24,991,645, was destroyed, and the environmental clean-up cost was $3,937,652 (Tab Q-12).

## 3. BACKGROUND

The following provides information regarding the various commands and units relevant to the MA, MP and the mishap flight:

**a. Air Combat Command (ACC)**

ACC is one of ten major commands (MAJCOMs) of the USAF (Tab CC-2). It is the primary force provider of combat airpower to America's warfighting commands (Tab CC-2). To support 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's mission is to support global implementation of national security strategy (Tab CC-2). ACC operates over 1,300 aircraft across 34 wings and 19 bases, comprising over 94,000 active duty and civilian personnel (Tab CC-2).

**b. Air National Guard (ANG)**

The ANG is administered by the National Guard Bureau, a joint bureau of the departments of the Army and Air Force, located in the Pentagon, Washington, District of Columbia (Tab CC-19). It is one of the seven Reserve components of the United States armed forces that augment the active components in the performance of their missions (Tab CC-19).

The ANG's federal mission is to maintain well-trained, well-equipped units available for prompt mobilization during war and provide assistance during national emergencies, such as natural disasters or civil disturbances (Tab CC-19). During peacetime, the combat-ready units and support units are assigned to most USAF MAJCOMs to carry out missions compatible with training mobilization readiness, humanitarian and contingency operations (Tab CC-19).

**c. 114th Fighter Wing (114 FW)**

The 114 FW is part of the SD ANG (Tab CC-7). The mission of the 114 FW is to deploy worldwide and execute directed tactical fighter sorties to destroy enemy forces, supplies, equipment, communications systems and installations with conventional weapons, or when directed by the Governor to protect life and property, preserve peace, order and public safety (Tab CC-5).

**d. 144th Fighter Wing (144 FW)**

The 144 FW is part of the CA ANG (Tab CC-10) The Federal Mission of the 144 FWis to provide Air Superiority in support of worldwide joint operations as well as Air Defense of the United States. Additionally, the wing provides agile combat support, and intelligence, surveillance and reconnaissance to combatant commanders around the globe (Tab CC-10). The Wing also provides a variety of homeland defense capabilities to the United States Northern Command (Tab CC-10).

**e. 175th Fighter Squadron (175 FS)**

The 175 FS is attached to the 114 FW of the SD ANG (Tab CC-7). The mission of the 175 FS is (1) to establish a training program to enable worldwide deployment and (2) to be prepared, upon implementation, to deploy, destroy enemy forces and facilities through the delivery of all types of tactical weapons compatible with the weapon system possessed in support of the roles of counter air, interdiction, and close air support (Tab CC-7).

**f. F-16C Fighting Falcon**

The F-16 Fighting Falcon is a compact multi-role fighter aircraft (Tab CC-15). It is highly maneuverable and has proven itself in air-to-air combat and air-to-surface attack (Tab CC-15). It provides a relatively low-cost, high performance weapon system and air demonstration capabilities for the United States and allied nations (Tab CC-15).

## 4. SEQUENCE OF EVENTS

**a. Mission**

On 16 May 2019, the MP departed March ARB as part of a two aircraft (2-ship) formation of F-16Cs on a practice Aerospace Combat Alert (ACA) launch and aircraft intercept training mission (Tabs T-2 and V-1.14). The MP flew as the wingman, or number two, in the formation (Tabs T-2, V-1.3 and V-2.4). The mishap flight lead (MFL) was the 144 FW Det Commander (Tab V-1.3). The MP has a total of 2,475.1 flight hours (Tab G-8). Both the MP and the MFL had significant experience piloting the F-16 aircraft (Tab T-11). The mishap flight (MF) flew to a Military Operating Area (MOA) and executed tactical intercepts, both medium and low altitude, and local area familiarization before returning to March ARB (Tab V-1.14 and V-2.5 to V-2.7). The Det Commander authorized the training mission and it was scheduled IAW the Ready Aircrew Program (RAP) tasking memo (Tabs K-2 and AA-5 to AA-6).

**b. Planning**

The MP and MFL completed their mission preparation on 16 May 2019 and began their flight brief at 1000L, IAW 144 FW General Briefing Guide and AFI 11-2F16-V3, *F-16 Operations Procedures*, dated 13 July 2016 (Tabs V-1.3, V-1.14, V-2.4, AA-25 to AA-27, and BB-6 to BB-9). The preparation included reviewing the profile for the day's flight, filling out an Operational Risk Management (ORM) sheet and ensuring all the required Go/No-Gos were complete (Tabs T-2 to T-8 and AA-27). The MF was a low risk category mission requiring no additional approval (Tab T-7). The MP and MFL also checked the current and forecasted weather for their fly window and, after reviewing the forecasted weather, the MF takeoff time was shifted by two hours due to inclement weather in the airspace (Tab V-1.14). Review of Notices to Airmen (NOTAMS) was accomplished for March ARB and potential divert airfields (Tab T-9 to T-11).

**c. Preflight**

On the day of the mishap prior to the accident sortie, the MP and MFL were on alert, in crew rest and the aircraft were configured for alert (Tabs T-2 and V-1.3 to V-1.4). Preflight for alert posture on the MA was conducted the day prior by a 114 FW pilot coming off alert and another inspection of the aircraft was accomplished at 0900 the day of the mishap by 144 FW, Det 1, maintenance personnel (Tabs D-6, V-20.3, and V-20.6). At 1405L, the MF received the battle stations call and proceeded to step, preflight, and engine start for practice alert response (Tab V-1.3 and V-2.3). The MP stepped to the MA, which was configured for the Det's ACA mission (Tab D-6). During the preflight, ground operations were uneventful (Tab V-2.3).

**d. Summary of Accident**

In response to alert alarms as part of the planned practice ACA scramble, the MP and MFL proceeded to taxi to line up on runway (RWY) 14 with no abnormal aircraft indications observed by the MP or the MFL during taxi (Tab V-1.14 and V-2.5). The MFL took off at approximately 1410L and followed a standard instrument departure procedure (Tab V-1.3). The MF then proceeded to a MOA to the east for one versus one (1v1) tactical intercepts, low-level proficiency training, and local area familiarization (Tab V-1.3 and V-1.14). The training mission was uneventful (Tab V-1.5 and V-1.14).

In the vicinity of Palm Springs, CA, the MP received cockpit warnings of a possible hydraulic system issue (Tab V-2.5 to V-2.6). The MP checked the hydraulic pressure gauges and noted low pressure in hydraulic system A of the aircraft's dual hydraulic system (Tab N-2). Initially, the MP noticed fluctuation between 1500 and 2000 pounds per square inch (psi) (Tab N-4) However, as the flight progressed, the pressure fluctuated between 1000 and 2000 psi (Tab V-2.6). Normal operating pressure is 3100 psi +/- 50 (Tab DD-3). The MP referenced the aircraft checklist regarding single hydraulic failure and complied with all appropriate checklist steps (Tabs V-2.6 to V-2.9 and BB-5 to BB-6).

At approximately 17 nautical miles (NM) from March ARB, the MP configured the speed brakes and lowered the landing gear in order for the MFL to visually inspect the MA and to burn fuel more rapidly (Tab V-1.5 and V-2.6 to V-2.9). The MFL noted the speed brakes opened correctly and the landing gear was down and locked (Tab N-6). The MP did not declare an in-flight emergency (IFE), at this time, and positioned the flight for a 10 NM straight in approach to RWY 32 (Tab V-1.14, V-2.6 to V-2.9, and V-2.15 to V-2.16).

Shortly after the lowering the landing gear, the MA hydraulic pressure gauge indicated a loss of pressure from system B with pressure fluctuating around 2000 psi (Tab N-6). With the loss of hydraulic pressure in the A and B systems, the MP referred to the aircraft checklist regarding dual hydraulic failure and complied with all appropriate checklist steps (Tab V-2.6 to V-2.8).

The MP and MFL decided to have the MFL land first on RWY 32 (Tab V-1.5). The MP would then maneuver the MA to land second on RWY 14 in order to utilize the RWY 14 departure end arresting cable in the event of the failure of the MA's hydraulically actuated brakes during the landing sequence (Tabs V-2.6 to V-2.9 and BB-10). The decision for the MFL to land first was due to the potential of the MA shutting down the only active runway by utilizing the arresting cable or an inability to taxi off the runway (Tab V-2.5 to V-2.9).

The MP elected to declare an emergency because of the failing hydraulic systems (Tabs N-7, V-2.6, and V-2.15 to V-2.16). The MP, per the aircraft checklist, turned on the Emergency Power Unit (EPU) as a precaution for failure of both the hydraulic systems (Tab V-2.6 to V-2.9). After activation of the EPU, it is normal for system A hydraulic pressure to increase (Tab BB-3). The MP noted that hydraulic System A pressure appeared unaffected by the addition of the EPU (Tabs V-2.6 to V-2.9).

After the MP activated the EPU, verified the arresting cable was raised, and informed the tower the EPU had been activated, the MP aligned the MA for a straight in approach to RWY 14 (Tab V-2.16). Winds were 270 (west) at 12 knots gusting to 18 knots and no other aircraft were in the overhead pattern (Tab N-8). Roughly 1 NM short of the runway, at 300 feet above ground level (AGL) and 11 degrees angle of attack (AOA), the MA, without pilot input, began a roll to the left (Tab FF-2). The MP attempted to maintain aircraft control by selecting an appropriate power setting and countering the roll to the left with stick input (Tab FF-2). The MA responded by rolling hard to the right, inconsistent with MP stick input, to approximately 40 degrees (Tab FF-2). With the flight controls unresponsive to the MP's inputs, the MP assessed loss of aircraft control and ejected at 250 feet AGL (Tabs BB-3 and FF-2). The MA was 5 degrees nose low, in 40-degrees right hand bank and traveling at 180 knots (Tab FF-2).

**e. Impact**

The MP ejected at 1539L and, immediately thereafter, the MA impacted a commercial warehouse approximately 0.4 NM southwest of the centerline of the approach end of RWY 14, as indicated in Figure 1 (Tabs N-9, Z-2, DD-2, and FF-2). The MA impacted the warehouse at relatively shallow dive angle, with its right wing slightly low, and at a relatively slow speed (Tab FF-2). The impact parameters prevented major aircraft breakup as the aircraft went through the roof and into the building (Tab FF-2). The landing gear was down, the speed brakes were closed, and the engine was still running at the time of impact (Tab FF-2). Burnt warehouse material around the aircraft and light soot on the empennage indicate there was a small post impact fire (Tabs Z-5 and FF-2).


**Figure 1. Radar Approach Data (Tabs Z-2 and DD-2)**

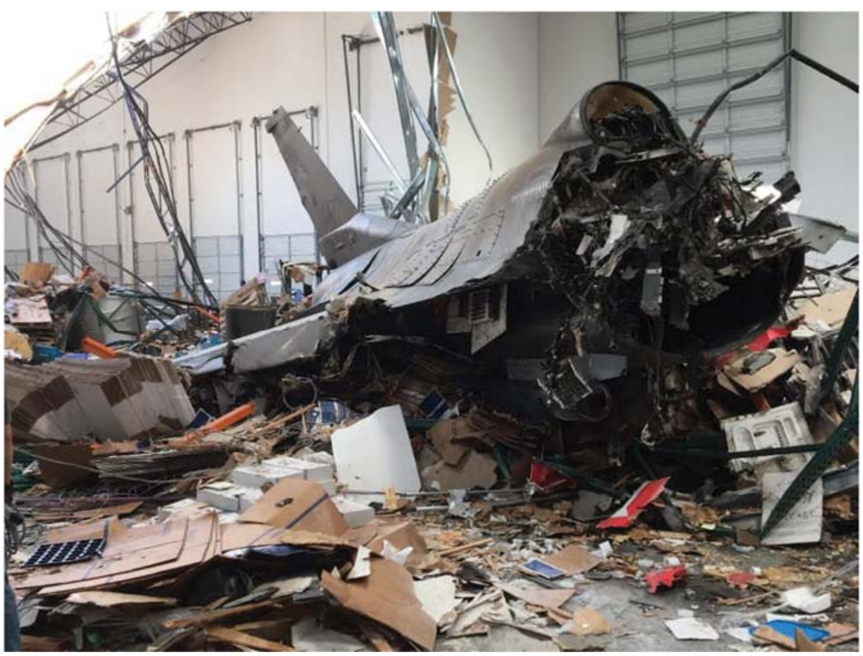

**Figure 2. MA Main Wreckage in Commercial Warehouse (Tab Z-5)**

### f. Egress and Aircrew Flight Equipment (AFE)

The MP successfully ejected within the low altitude and slow airspeed "Mode 1" envelope (Tab FF-2). The emergency escape system and related components functioned properly (Tab FF-2). The MP was current for all AFE training requirements and all flight gear inspections were current at the time of the mishap (Tab T-5). There was no notable damage to AFE from the ejection sequence (Tab FF-2). The majority of the damage came after the MP landed in the overrun of RWY 32 and was dragged on his back by the parachute (Tab FF-2). The MP was able to disconnect from his parachute relatively quickly after landing (Tab FF-3). The AFE was properly configured and maintained and functioned properly (Tab FF-3).

### g. Search and Rescue (SAR)

At 1535L, the MP notified approach control the departure end arresting cable would be required and air traffic control activated the crash protocol to prepare emergency responders for the incoming aircraft (Tabs N-7, N-8, V-38.3, and V-40.2). At 1539L, the MP ejected on short final to RWY 14 and the MP parachuted onto the runway overrun (Tabs N-9 and FF-2). The March ARB tower continued to execute the quick reference checklist in response to the mishap (Tab V-40.2 to V-40.3). Radar Approach Control (RAPCON) closed March's Class C airspace to outside aircraft and alerted local authorities (Tab V-38.3 and V-40.2). Upon seeing the MP eject, the 144 FW Det 1 maintenance team was first to respond to the MP followed shortly by postured March ARB Airfield Fire Department and Security Forces (SF) (Tab V-6.4). The first maintainer on the scene evaluated the MP's injuries and remained until medical personnel arrived (Tab V-6.4). The MP was hospitalized at Riverside University Hospital (Tab V-43.2). The MA located in a commercial warehouse 0.4 NM west of the runway as depicted in Figure 1 (Tabs V-6.3, V-15.3, V-18.3, V-40.2, Z-2, DD-2, and EE-2).

### h. Recovery of Remains

Not applicable.

## 5. MAINTENANCE

### a. Forms Documentation

The Air Force Technical Order (AFTO) 781 series of forms collectively document maintenance actions, inspections, servicing, configuration status, and flight activities (Tab EE-5). The AFTO 781 forms in conjunction with the Integrated Maintenance Data System (IMDS) provide a comprehensive database used to track and record maintenance actions and inspection histories on each individual Air Force aircraft (Tab EE-5).

IMDS and historical records for the past 30 days were reviewed and there were no recurring issues that were identified (Tab EE-5 and EE-6). Review of the AFTO 781 forms and IMDS show that maintenance documentation was accomplished in accordance with maintenance directives (Tab EE-5).

**b. Inspections**

The Pre-Flight (PR) Inspection and Basic Post-Flight (BPO) Inspection include visually examining the aerospace vehicle and operationally checking certain systems and components to ensure no serious defects or malfunctions exist (Tab EE-5 to EE-6). Phase (PH) inspections are a thorough inspection of the entire aerospace vehicle (Tab EE-6). Walk-Around Inspections (WAI) are an abbreviated PR Inspection and completed as required prior to launch IAW the applicable Technical Orders (TOs) (Tab EE-6). Alert Preflight (ALT) inspection contains minimum inspection requirements and used when placing or maintaining aircraft on alert status (Tab EE-6).

The BPO/PR inspection was complied with on 15 May 2019, at 1200L with no discrepancies noted (Tab EE-6). An ALT was accomplished on 15 May 2019, at 1400L, with no discrepancies noted (Tab EE-6). A WAI was accomplished on 16 May 2019, at 1000L, with no discrepancies noted (Tab EE-6). Total operating time of the MA was 8137.7 hours (Tab EE-6). The MA had flown 237.7 hours since the last PH inspection accomplished on 21 September 2018 (Tab EE-6). Prior to the mishap, the MA had no reported maintenance issues and all inspections were completed (Tab EE-6).

**c. Maintenance Procedures**

In January 2019, four months before the subject mishap, the 531st Commodities Maintenance Squadron (CMMXS), F-16 Flight Controls, at Hill Air Force Base (AFB), Utah (UT), overhauled the MA's right flaperon Integrated Servo Actuator (ISA) and conducted on-site operational testing prior to returning the ISA to service (Tabs U-84 and EE-6). The ISA translates electrical commands from the pilot to move flight control surfaces (Tab EE-6). Due to the significant amount of hydraulic fluid in the accident aircraft right flaperon ISA bay, the ISA was removed for further evaluation (Tabs DD-6 and EE-3).

The ISA overhaul process employed by CMMXS consisted of complete disassembly, solvent wash, and inspection of parts for serviceability (Tabs BB-36 to BB-46, and EE-6). Upon completion of inspection and appropriate parts replacement, the ISA was reassembled and sent for testing to validate operational integrity as a series of automated test are ran to ensure part reliability (Tabs U-66 to U-69, U-84, and EE-6).

**d. Maintenance Personnel and Supervision**

The 144 FW, Det 1, maintenance team performed all required inspections, documentation, and servicing for the MA prior to flight (Tab EE-5). A thorough review of maintenance activities and documentation revealed no major documentation errors (Tab EE-5). I have reviewed the training records for the maintenance members that had relevant involvement with the MA prior to the mishap on 16 May 2019 (Tab EE-6). I have concluded they were all qualified to perform their respective maintenance activities on the MA (Tab EE-6).

The 531 CMMXS completed the overhaul of the mishap ISA in January 2019 (Tabs U-84 and EE-6). Overhaul technicians receive around three months of on-the-job training and are required to assemble approximately five ISAs before certification (Tab R-280 and R-289). Once the trainer and supervisor agree the trainee can adequately complete all steps required without supervision, the trainee is certified to complete the overhaul process (Tab V-30.3). Certification training is recorded in employee Production Acceptance Certification (PAC) (Tabs T-13 to T-18 and V-36.3). All personnel in the overhaul process were trained and qualified by the current process to perform their assigned tasks (Tab T-13 to T-18).

**e. Fuel, Hydraulic Fluid, and Oil Inspection Analyses**

According to the Air Force Petroleum (AFPET) office Joint Oil Analysis Program (JOAP), samples from the MA and associated servicing carts were normal and no unusual volatiles were noted (Tab D-28 to D-29). Additionally, fuel samples from the MA heat exchanger and servicing vehicle were normal and the material tested was satisfactory for use (Tab D-27, D-38, and D-40). Hydraulic fluid samples from the MA and associated servicing equipment were within normal tolerances and no volatile contamination was detected (Tab D-30 to D-37). Hydraulic system A and B samples were insufficient due to lack of quantity to complete all tests but showed no signs of volatile contamination (Tab D-36 to D-37).

**f. Unscheduled Maintenance**

On 21 March 2019, the right ISA of the MA was reported as having a possible hydraulic leak (Tabs U-5, U-6 and V-3.3). During operational checks it was determined the ISA required replacement due to flaperon movement with no side stick controller input (Tabs U-5, U-6, V-3.3 and V-3.4). On 28 March 2019, the right flaperon ISA was replaced by 144 FW, Det 1, maintainers with an overhauled ISA (Tabs U-5 to U-6, U-84, V-3.3 to V-3.4, V-6.5 to V-6.6, and EE-6). Operational checks were accomplished with no discrepancies identified (Tabs U-5, U-6, V-3.3, V-3.4, V-6.5 and V-6.6). After this ISA replacement, the MA flew 10 sorties for 16.3 hours before the incident (Tab EE-5).

The replacement ISA had been previously overhauled by the 531 CMMXS (Tabs U-84 and EE-6). The overhaul of the ISA was signed off on 28 January 2019 (Tab U-84).

## 6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

**a. Structures and Systems**

The MA impacted a commercial warehouse west of the RWY 14 centerline at March ARB and came to rest inside, as shown in Figure 2 (Tabs Z-5 and EE-2). The MA was in an upright position and relatively level, slightly nose low with an estimated 15 degrees right wing down (Tab EE-2). The crew station of the MA separated from the fuselage on impact (Tab EE-2). During the collision with the warehouse the 370-gallon fuel tanks were destroyed by the impact (Tab EE-2). The left and right wings and right horizontal tail were largely intact (Tab EE-2). There was impact damage to the leading edge flaps (LEF) and the left horizontal tail was severed (Tab EE-2). The vertical stabilizer was intact with minor damage to the top of the rudder (Tab EE-2). The MA's landing gear were extended at impact and the right main landing gear (MLG) and nose landing gear (NLG) were broken but attached (Tab EE-2). All of the MA's primary flight controls were found around the MA (Tab EE-2).

**b. Hydraulic System: Overview**

The hydraulic system is supplied by two 3000 psi hydraulic systems designated as hydraulic systems A and B (Tabs DD-3 and EE-2). Normal system pressure is 3100 +/- 50 psi (Tabs DD-3 and EE-2). Hydraulic system A contains approximately 5 gallons of fluid and hydraulic system B contains approximately 7 gallons of fluid (Tabs DD-3 and EE-2). Both systems operate simultaneously to supply hydraulic power for the primary flight controls and LEFs (Tabs DD-3 and EE-2). If one system fails, the remaining system will provide sufficient hydraulic pressure but at a reduced rate of actuation (Tabs DD-3 and EE-2). System A also supplies power to the fuel flow proportioner and the speedbrakes (Tabs DD-3 and EE-2 to EE-3). All remaining utility functions, consisting of the gun and gun purge door, air refueling system, landing gear, brakes, and nose wheel steering are supplied by system B (Tabs DD-3 and EE-3). In the event of dual hydraulic failure, the Emergency Power Unit (EPU) will activate automatically or if the pilot commands it on manually (Tabs DD-4 and EE-6). The EPU hydraulic pump then supplements pressure to Hydraulic System A, if there is hydraulic fluid remaining in the system (Tab EE-6).

The MA Flight Data Recorder (FDR) and flight computer recorded ISA fails for both A and B hydraulic systems (Tabs DD-6 and EE-3). The ISAs for the left flaperon, left and right horizontal tail, rudder, and their respective bays were inspected and found to be unremarkable (Tab EE-3). The oil cooler was also unremarkable (Tabs DD-5 and EE-3). The right flaperon ISA had no impact damage and all hydraulic lines and safety wires were intact (Tab EE-3). Hydraulic fluid had collected and remained in the bay containing the right flaperon ISA following the mishap (Tabs DD-6 and EE-3). In comparison, the left flaperon ISA was dry (Tabs DD-5 and EE-3). Due to the significant amount of hydraulic fluid in the right flaperon ISA bay, the ISA was removed and shipped for further evaluation (Tab DD-6).

**(1) Right Flaperon ISA**

The ISA translates electrical commands from pilot inputs into the flight computer which then commands movement of the flight control surfaces (Tab EE-6). There are two inlet check valves (ICV) in each ISA (one for hydraulic system A and one for hydraulic system B) (Tab EE-6). ICVs are designed to allow a controlled restricted fluid flow into the pressure inlets of the ISA to prevent backflow out of the pressure inlet ports (Tab EE-6).

The right flaperon ISA from the MA was removed and initial characterization of the part was performed by the ISA maintenance unit at 531 CMMXS (Tab DD-7). During functional testing on the test stand, hydraulic fluid immediately began leaking from both inlet check valves when pressurized to 1000 psi (Tabs DD-7 and EE-3). To get a rough estimate of the rate of fluid loss, the unit was held at 1000 psi for five minutes while leaking hydraulic fluid was collected (Tab DD-7). The collected volume measured 155 ml, not including the estimated 3 to 7 ml that was spilled or remained on the unit (Tab DD-7). This indicated a leak rate of approximately 31 ml/minute at 1000 psi, though the normal operating pressure is approximately 3000 psi (Tabs DD-7 and EE-3). The hydraulic fluid leaked from where the screw cap threads into the bodies of the inlet check valves (Tabs DD-8 and EE-3). No other leaks were found on the ISA (Tabs DD-8 and EE-3). After testing was complete, the inlet check valves were returned to the lab for further evaluation (Tab DD-8).

**(2) System A ICV**

Each ICV consists of a cap, screw threads, a retainer ring and an O-ring (Tab EE-6). These parts are collectively referred to as a "screw cap" (Tab EE-6). The screw cap screws into the ICV body (Tab DD-8). The screw cap retainer sits above the O-ring and helps to keep it in place (Tab DD-9). It is primarily the screw cap retainer and O-ring that prevent hydraulic fluid from leaking out the ICV under high pressure (Tab EE-6).

A post-accident inspection revealed that the screw cap for the system A ICV was not seated properly into the body of the valve (Tabs DD-9 to DD-14, and EE-3). Upon removal of the screw cap from the system A ICV, the retainer was found to be permanently deformed and the ends of the retainer were spread apart as depicted in Figure 3 (Tabs DD-9, EE-3, and Z-7). In addition, a portion of the O-ring was missing and the upper face of the O-ring exhibited several permanent impressions of the underside of the retainer (Tabs DD-9 and EE-3). By rotating the O-ring to line up its impressions with the underside of the retainer, the missing portion lined up with the gap between the retainer ends (Tabs DD-9 and EE-3). The retainer and O-ring were measured and compared to unused items and were determined to be correct parts (Tabs DD-14 and EE-3).

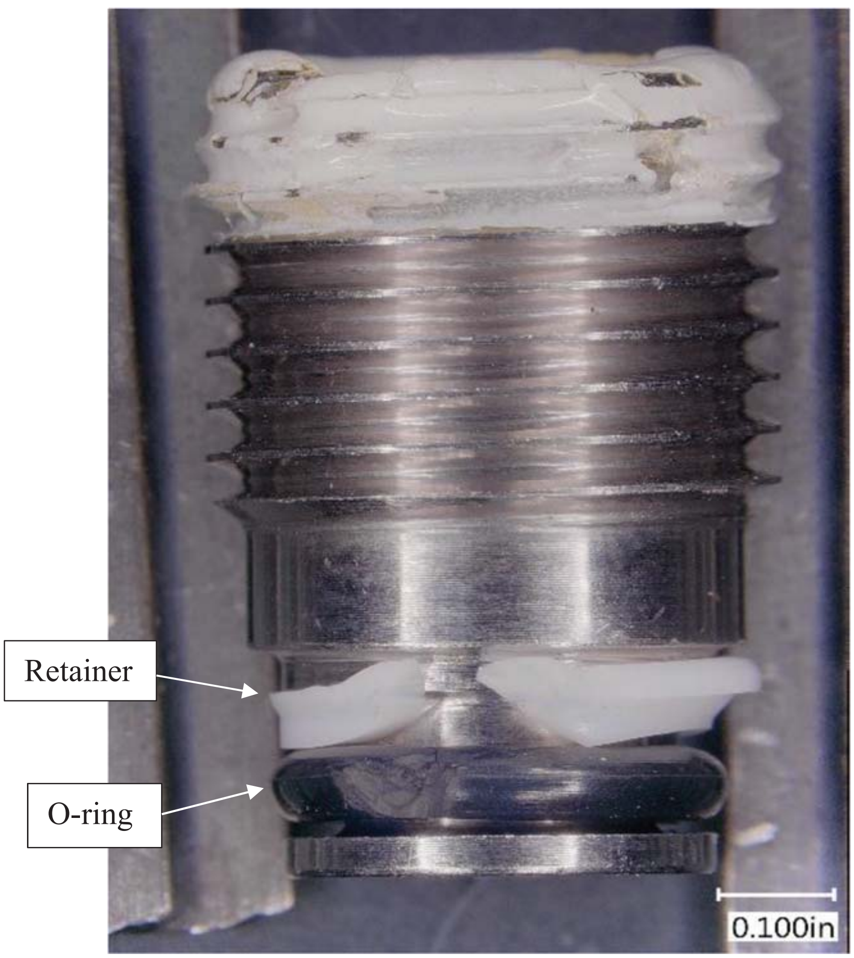


**Figure 3: System A ICV screw cap (Tab Z-7)**

### (3) System B ICV

The post-accident inspection also revealed that the screw cap for the system B ICV was not seated properly into the body of the valve (Tab EE-3). The screw cap was removed from the system B ICV and showed similar characteristics as the system A screw cap as shown in Figure 4 (Tabs Z-9, DD-12, and EE-3). The retainer was permanently deformed up over the adjacent ridge with the ends of the retainer spread apart (Tabs DD-12 and EE-3). The upper face of the O-ring exhibited several permanent impressions of the underside of the retainer (Tabs DD-12 and EE-3). A portion of the O-ring was missing (Tabs DD-12 and EE-3). Once again, by rotating the O-ring to line up with the underside of the retainer, the missing portion lined up with the gap between the retainer ends (Tabs DD-12 and EE-3).

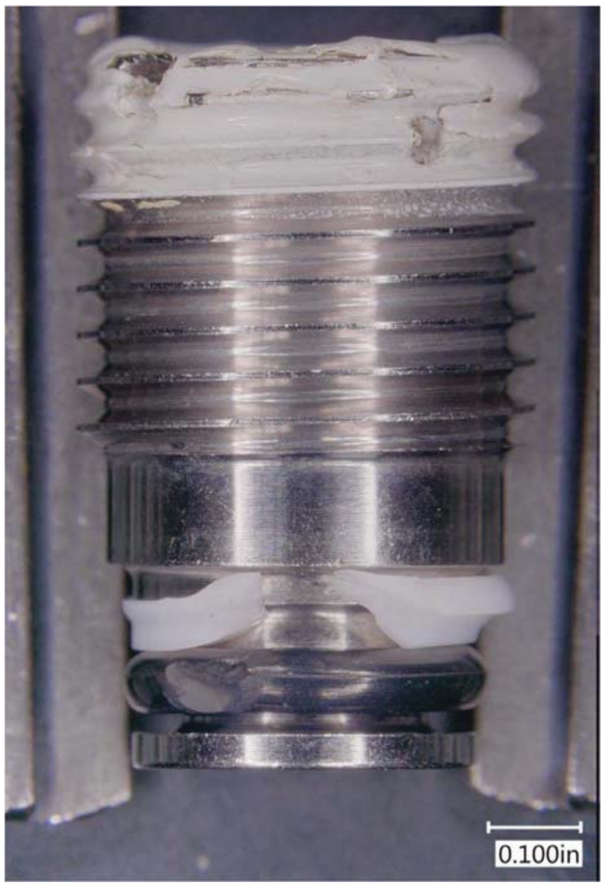


**Figure 4: System B ICV (Tab Z-9)**

### (4) Hydraulic Pressure Switch

The MA's pressure switches for hydraulic system A and B were tested and both showed improper calibration (Tabs DD-15 and EE-3). During testing the switch closed when pressure fell below 750 psi, which is lower than the specified range (1000 +/- 100 psi) (Tab DD-15). Four additional pressure switches from the supply system were submitted for testing and they all met the specification requirements with regard to the pressure at which they would illuminate the caution light inside the F-16 cockpit (Tab DD-15).

### C. Analysis

The ICVs from both systems of the ISA exhibited the same mode of failure (Tab EE-3). The retainer on the screw cap had deformed and the ends spread apart (Tab EE-3). Near the gap between retainer ends, fragments had torn away from the O-rings allowing hydraulic fluid to leak out through the threads between the screw caps and the valve bodies (Tab EE-3). The inner threads of both valve bodies exhibited anomalies (Tab EE-3).

The retainer deformed because the screw caps in both of the two ICVs from the ISA were not fully seated as installed within their respective valve bodies (Tab EE-3). High pressure in service caused the retainer to flow into the cavity of the low-pressure side of the seal, leaving the O-ring unevenly supported and subject to progressive degradation (Tab EE-3). Degradation to the O-rings eventually prevented them from sustaining the working fluid pressure, and hydraulic fluid leakage occurred through the gaps in the O-ring and retainer (Tab EE-3).

## 7. WEATHER

### a. Forecast Weather

The forecasted weather the day of the mishap, provided by the 25th Operational Weather Squadron, was winds from 280 west at 12 knots, unlimited visibility, scattered clouds at 2,000 feet, and broken clouds at 4,000 feet (Tab W-4).

### b. Observed Weather

On return to March ARB, the MF received March ARB Automatic Terminal Information Service (ATIS) information update DELTA, which indicated the current weather information (Tab N-4). The observed weather during the landing was winds from 270 (west) at 12 knots gusting to 18 knots, with 10 statute miles of visibility, and clouds scattered at 6000' feet (Tab W-8). The temperature was 19 degrees Celsius and the altimeter was 29.90 (Tab W-8). When the MP was on final approach, the tower updated the winds to 260 (west southwest) at 14 knots gusting to 18 knots at 1537L, and then winds at 270 (west) at 13 knots, gusting to 18 knots, at 1538L (Tab N-8).

### c. Space Environment

Not Applicable.

### d. Operations

There was no evidence located that indicated the MF was operating outside of its prescribed weather limits.

## 8. CREW QUALIFICATIONS

### a. Mishap Pilot

At the time of the mishap, the MP was current and qualified as a basic mission capable (BMC) Instructor Pilot (IP) and Standardization Evaluation Fight Examiner (SEFE), with 2,475.1 total flying hours (Tabs G-8, T-11 and BB-61). The MP's last instrument check ride and mission check ride was a combined check ride completed on 18 March 2019 (Tab T-12). The MP received no downgrades on any of his post pilot training check rides (Tab T-12).

**Table 1: MP 30-60-90 day Flying History as of the day of the mishap (Tab G-4 and G-9 to G-10)**

| MP | Hours | Sorties |
|---|---|---|
| Last 30 Days | 6.1 | 7 |
| Last 60 Days | 16.4 | 14 |
| Last 90 Days | 16.4 | 16 |

## 9. MEDICAL

### a. Qualifications

The MP was medically qualified for flying duties at the time of the mishap, with one limitation: the wearing of visual correction (Tab X-3). The MP's Aeromedical Services Information Management System was reviewed, verifying the MP held a current DD Form 2992, *Medical Recommendation for Flying or Special Operational Duty*, with no duty limiting conditions found except the pre-existing waiver for visual correction (Tab X-3). The medical review revealed no factors relevant to the mishap (Tab X-3).

### b. Health

The MP was in good health at the time of this mishap (Tab X-3). A review of the MP's medical and dental records, day of mishap, 24 hours prior, 48 hours prior, 72 hours prior, 7 days prior, 30 days prior and Aeromedical Services Information Management System report did not reveal any illnesses or duty limiting conditions, aside from the vision correction, at the time of the mishap (Tab X-3).

### c. Pathology

Toxicology samples were obtained and submitted to the Armed Forces Medical Examiner System, Dover AFB, Delaware, for analysis (Tab X-3). These tests identify carbon monoxide and ethanol levels in the blood and urine and detect traces of amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opioids, phencyclidine and sympathomimetic amines in urine (Tab X-3). The MP and all mishap aircraft maintenance crewmembers (MAMC) were tested, and all results were negative (Tab X-4).

**d. Lifestyle**

The 72 hours prior, 7 days prior histories were reviewed for MP, MFL and MAMC (Tab X-3). There was no evidence located to indicate lifestyle factors were relevant to the mishap (Tab X-3).

**e. Crew Rest and Crew Duty Time**

At the time of the mishap, the then-current version of AFI 11-202V3, General Flight Rules, dated 10 August 2016, prescribed mandatory crew rest and maximum Flight Duty Periods for all personnel who operated USAF aircraft (Tab BB-50). Crew rest for the MP complied with published guidelines (Tabs V-2.3 and X-3).

## 10. OPERATIONS AND SUPERVISION

**a. Operations**

144 FW, Detachment 1, was conducting Alert operations in support of Western Air Defense Sector (WADS) (Tabs T-2 and V-1.3). The normal operations tempo is generally four to five ACA practice scrambles a week (Tab V-1.10). The assigned pilots to the detachment fly six times a month on average, which is one additional sortie to the minimum required per the RAP tasking message (Tabs V-1.10 and AA-6).

**b. Supervision**

Supervision of the 144 FW, Det 1, operations on the day of the mishap was IAW AFI 11-418 directives (Tab BB-54 to BB-55). The MF had all required authorization, supervision, and documentation for the planned sortie (Tab T-2 to T-8 and T-11 to T-12). There was no supervisor of flying (SOF) or operations supervisor on duty, due to the limited staffing at 144 FW, Det 1 (Tab V-1.9). Per AFI 11-418, the detachment was not required to have either position filled for their alert posture (Tab BB-54 to BB-55).

## 11. HUMAN FACTORS ANALYSIS

DoD Human Factors Analysis and Classification System version 7.0, lists potential human factors that can play a role in aircraft mishaps (Tabs BB-13 to BB-35). Policy and process issues are factors of a process negatively influences performance and results in an unsafe situation (Tab BB-33).

**a. OP003 (Provided Inadequate Procedural Guidance or Publications)**

Installation guidance is a factor when written direction, checklists, graphic depictions, tables, charts or other published guidance is inadequate, misleading or inappropriate (Tabs BB-33).

The current ICV design has the potential for the retainer to catch inside the screw cap gland during installation (Tabs DD-9, DD-12, DD-16 and EE-3). If the retainer catches, it can cause the screw cap to not fully seat and leave the O-ring unsupported (Tabs DD-16 and EE-3). Over time, this can lead to failure of the O-ring and retainer, causing a leak (Tabs DD-16 and EE-3). This leak has the potential to lower pressure in the respective hydraulic systems (Tabs DD-17 and EE-3). Currently, an overhaul technician verifies the screw cap has been installed correctly by ensuring the proper torque was applied to the screw cap when it is installed (Tabs U-66 to U-69, V-27.15 and V-34.8). The amount of torque utilized is slight and therefore technicians must develop a "feel to it" (Tab V-34.8). After the ISA is reassembled during the overhaul process, it is tested to validate operational integrity which includes the performance of a leak test (Tabs EE-6 and U-68). Since the effect of an unsupported O-ring is progressive degradation, the ISA can pass the leak test during the overhaul process but still develop a leak over time (Tabs DD-16 to DD-17, EE-3, and U-68). Consequently, under current overhaul procedures, it is possible for the screw caps to be not fully seated even though the proper torque was applied and the ISA passed the post-assembly leak test (Tab EE-3 and EE-6).

## 12. GOVERNING DIRECTIVES AND PUBLICATIONS

### a. Publicly Available Directives and Publications Relevant to the Mishap

(1) AFI 51-307, *Aerospace and Ground Accident Investigations*, dated 18 March 2019
(2) AFI 51-307, ACC Supplement, *Aerospace and Ground Accident Investigations*, dated 3 December 2019
(3) AFI 11-202V3, General Flight Rules, dated 10 August 2016
(4) AFI 48-123, Medical Examinations and Standards, dated 5 November 2013

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

### b. Other Directives and Publications Relevant to the Mishap

(1) DoD Human Factors Analysis and Classification System 7.0
(2) F-16 RAP Tasking Memorandum, Aviation Schedule, dated 1 October 2018
(3) T.O. 1F-16CM-1CL-1, dated 14 December 2018
(4) AFI 11-2F-16 V1, Flying Operations, F-16 Pilot Training, dated 20 April 2015
(5) AFI 11-2F-16V3, *F-16 Operations Procedures*, dated 13 July 2016
(6) AFI 11-418 Flying Operations Supervision, dated 14 October 2015

**c. Known or Suspected Deviations from Directives or Publications:** None.

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Date: 2020.04.07

7 April 2020

ERIC C. PAULSON, Colonel, USAF
President, Accident Investigation Board

# STATEMENT OF OPINION

**F-16C, T/N 88-0477**
**Near March ARB, California**
**16 May 2019**

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

## 1. OPINION SUMMARY

On 16 May 2019, at 1539 local time (L), a block 40 F-16C, tail number (T/N) 88-0477, assigned to the 114th Fighter Wing (FW), Air National Guard, Joe Foss Field, South Dakota, with duties at the 144 FW, Detachment (Det) 1, March Air Reserve Base (ARB), California, departed controlled flight on approach to March ARB. The mishap pilot (MP), assigned to the 144 FW, Det 1, ejected and sustained minor injuries. The mishap aircraft (MA) impacted a commercial warehouse, resulting in minor injuries to warehouse employees. While there were no fatalities, the mishap aircraft (MA), valued at $24,991,645, was destroyed. The environmental clean-up cost was $3,937,652.

The mishap occurred upon return to March ARB from a training mission in a Military Operating Area (MOA). The flight was executed as a two-aircraft formation to the MOA for one versus one (1v1) aircraft intercept training, low-level local area familiarization training, and formation return to March ARB. The MA was the number two aircraft in the formation. Upon return, the MA experienced loss of hydraulic pressure followed by loss of effectiveness of flight control input by MP. The MP successfully ejected near the approach end of runway (RWY) 14 at March ARB. The MA remained airborne briefly before impacting a commercial warehouse.

Upon seeing the MP eject, 144 FW, Det 1, personnel went to aid the MP, followed shortly by March ARB first responders. The MP received initial care and was then transported by ambulance to Riverside University Hospital.

The Accident Investigation Board president found, by a preponderance of the evidence, the cause of the mishap was the improper installation of two hydraulic check valves in the right Flaperon Integrated Servo Actuator (ISA), which resulted in a loss of sufficient hydraulic pressure to control the MA. A preponderance of the evidence also indicated an inadequate ISA overhaul process that lacked an effective procedure to identify improper installation of ISA check valves was a substantially contributing factor.

I developed my opinion after interviewing witnesses, including the MP; the mishap flight lead (MFL); maintenance personnel from the 144 FW, Det 1, and the 114 FW; as well as system experts at the 309th Maintenance Group, the Ogden Air Logistics Complex at Hill Air Force Base (AFB), Utah, and the Air Force Research Laboratory at Wright-Patterson AFB, Ohio. Additionally, I reviewed applicable Air Force directives, information and reports provided by technical experts and other witness testimony. I also analyzed recorded flight data, engineering analysis and laboratory testing reports.

## 2. CAUSE

I find by a preponderance of the evidence that the cause of the mishap was the improper installation of two hydraulic check valves in the right ISA, which resulted in a loss of sufficient hydraulic pressure to control the MA.

The dual hydraulic system supplies 3100 pounds per square inch (psi) plus or minus 50 psi to operate various aircraft components, including flight controls. Hydraulic system A and B operate simultaneously to supply hydraulic power for the primary flight controls. If one system fails, the remaining system will provide enough pressure to actuate the flight controls. The ISA translates electrical commands from pilot inputs into the aircraft flight computer that then commands movement of the flight control surfaces. The two Inlet Check Valves (ICV) on each ISA (one for hydraulic system A and one for hydraulic system B) allows for controlled restricted fluid flow into the pressure inlets of the ISA to prevent backflow out of the pressure inlet ports. Each ICV on the MA contains an O-ring and retainer to prevent hydraulic fluid from leaking.

In the event of dual hydraulic failure, the Emergency Power Unit (EPU) will activate automatically or if the pilot commands it on manually. The EPU hydraulic pump then supplements pressure to Hydraulic System A, if there is hydraulic fluid remaining in the system. In this instance, deformed retainers in the ICVs in the MA's right flaperon ISA resulted in degradation over time of the ICVs' O-rings and retainers. The original retainer deformation was due to improper ICV assembly. This condition allowed hydraulic fluid to leak from both systems resulting in decreased hydraulic pressure to move flight control surfaces. The MP set up to land as soon as possible, but the system had lost enough pressure on final approach to prevent the MA from sustaining controlled flight. When the flight controls became unresponsive to the MP's inputs, the MP assessed loss of aircraft control and elected to eject at 250 feet above ground level. The MA was 5 degrees nose low, in 40-degrees right hand bank and traveling at 180 knots.

## 3. SUBSTANTIALLY CONTRIBUTING FACTORS

I find by a preponderance of the evidence one factor substantially contributed to the mishap: an inadequate ISA overhaul process that lacked an effective procedure to identify improper installation of ISA check valves..

Under the circumstances, it was possible for the ICV retainer to catch inside the ICV screw cap during installation causing the screw cap to not be fully seated. The 531 CMMXS did not have procedures to check and identify the distortion of installed retainers. It was possible for ICV screw caps to be not fully seated even though the correct torque was applied to the screw caps during installation and the ISA passed the post-assembly leak test. Over time, high pressure in service can, and in this case did, cause the retainer to flow into the cavity of the low-pressure side of the seal, leaving the O-ring unevenly supported and subject to progressive degradation. Distress over time to the O-rings allowed fragments to tear away, preventing them from sustaining the working pressure, and leakage ensued. Since both ICVs failed in the same manner, hydraulic pressure decreased from system A and B.

## 4. CONCLUSION

The Accident Investigation Board president found, by a preponderance of the evidence, the cause of the mishap was the improper installation of two hydraulic check valves in the right Flaperon Integrated Servo Actuator (ISA), which resulted in a loss of sufficient hydraulic pressure to control the MA. A preponderance of the evidence also indicated an inadequate ISA overhaul process that lacked an effective procedure to identify improper installation of ISA check valves was a substantially contributing factor.

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7 April 2020

ERIC C. PAULSON, Colonel, USAF
President, Accident Investigation Board

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