UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

F-15E STRIKE EAGLE, T/N 90-0254

391st FIGHTER SQUADRON
366th FIGHTER WING
MOUNTAIN HOME AIR FORCE BASE, IDAHO

LOCATION: SOUTHWEST ASIA

DATE OF ACCIDENT: 3 MAY 2012

BOARD PRESIDENT: COLONEL HENRY L. CYR

CONDUCTED IAW AIR FORCE INSTRUCTION 51-503

Volume One of Two

ACTION OF THE CONVENING AUTHORITY

17 SEP 2012

The Report of the Accident Investigation Board, conducted under the provisions of AFI 51-503, that investigated the 3 May 2012 mishap in Southwest Asia, involving an F-15E, T/N 90-0254, assigned to the 391st Expeditionary Fighter Squadron, complies with applicable statutory and regulatory guidance; on that basis it is approved.

WILLIAM J. REW
Lieutenant General, USAF
Vice Commander

EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION

F-15E STRIKE EAGLE, T/N 90-0254
SOUTHWEST ASIA
3 MAY 2012

On 3 May 2012 at approximately 0718Z/1118L the mishap aircraft (MA), an F-15E, tail number (T/N) 90-0254, forward deployed with the 391st Expeditionary Fighter Squadron (EFS) to the 380th Air Expeditionary Wing (AEW), Southwest Asia, impacted the ground approximately 65 nautical miles south of the host nation Air Base (AB). The mishap sortie was a training mission deployed under a Theater Support Package to the United States Central Command (CENTCOM) Area of Responsibility (AOR). The crash occurred in an unpopulated area and the mishap aircraft was destroyed with a loss valued at $45,538,495.76. The mishap crew (MC) safely ejected from the aircraft with no injuries and was quickly recovered by host nation search and rescue forces. No known civilian injuries resulted from the mishap, and only minimal damage to a few irrigation lines occurred. There was little media interest following the initial reports of the mishap.

On 3 May 2012 at 0629Z/1029L, the MA took off from the host nation AB, for a routine training sortie simulating enemy fighter tactics (Red Air) against friendly forces (Blue Air). The MC was flying as a wingman in a package of six F-15Es acting as Red Air. The MC's objective was employment of notional ordnance on a point defended by Blue Air. At 1050L the training profile began. At 1116L the mishap pilot (MP) initiated a climb from 2400 feet (ft.) to 10,000 ft. to meet airspace requirements and advanced the throttle to the maximum afterburner setting. Soon after, the MC heard a loud bang and received indications of an overheat condition in the right engine and shut it down. Near simultaneously, the MC began to experience significant uncommanded right roll and yaw of the aircraft. At 1117L, the MP jettisoned all external aircraft stores in an attempt to improve aircraft controllability; this had no apparent effect and the MP continued to struggle with the aircraft. Quickly following, the MC received indications of a fire in the right engine and Aircraft Mounted Accessory Drive. The MP employed the fire extinguisher system into the right engine. The MA then experienced complete electrical system and communications failure. With the aircraft at the prescribed uncontrolled bailout altitude and fire continuing to burn in the right engine compartment the MP used hand signals to command bailout. The MC safely ejected from the MA. The MA crashed 10-20 seconds later.

The Accident Board President found by clear and convincing evidence the cause of the mishap was catastrophic failure of the right engine. The cause of the engine failure, by clear and convincing evidence, was a rare ignition of the titanium components within the engine resulting in an extremely destructive fire. This fire led to associated failure of critical hydraulic systems, which by a preponderance of the evidence, was a substantially contributing factor to the mishap. The loss of the right engine and critical hydraulic systems made the aircraft uncontrollable and resulted in the eventual crash.

Under 10 U.S.C. 2254(d), any opinion of the accident investigators 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.

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COMMONLY USED ACRONYMS AND ABBREVIATIONS

366 FW	366 Fighter Wing
AB	Air Base
ACC	Air Combat Command
ACES	Advanced Concept Ejection Seat
ACT	Air Combat Tactics
AEF	Air Expeditionary Force
AEW	Air Expeditionary Wing
AF	Air Force
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFPD	Air Force Policy Directive
AFRL	Air Force Research Laboratory
AFSC	Air Force Specialty Code
AFTO	Air Force Technical Order
AFI	Air Force Instruction
AGL	Above Ground Level
AIB	Accident Investigation Board
AIM	Air Intercept Missile
AIS	Airborne Instrumentation System
AMAD	Airframe Mounted Accessory Drive
AOR	Area of Responsibility
ATC	Air Traffic Control
C	Celsius
CAS	Control Augmentation System
CENTCOM	United States Central Command
CFT	Conformal Fuel Tank
DDF	Deployed Debrief Facility
DEEC	Digital Electronic Engine Control
DNIF	Duties Not Involving Flying
DoD-HFACS	Department of Defense Human Factors Analysis and Classification System
DOD	Domestic Object Damage
DVRS	Digital Video Recording System
ECS	Environmental Control System
EDU	Engine Diagnostic Unit
EAMXS	Expeditionary Aircraft Maintenance Squadron
EFS	Expeditionary Fighter Squadron
EMD	Engine Monitor Display
EOT	Engine Operating Time
EP	Emergency Procedure
ES	Environmental Sensors
ft.	Feet
FDL	Fighter Data Link
FDP	Flight Duty Period
FDT	Fan Drive Turbine
FL	Flight Lead
FOD	Foreign Object Damage
FPI	Fluorescent Penetrant Inspected
FS	Fighter Squadron
FTIT	Fan Turbine Inlet Temperature
g	Gravitational Force
GCS	Ground Control Surveillance
HUD	Head Up Display
HPC	High Pressure Compressor
HPT	High Pressure Turbine
IAW	In Accordance With
ID	Idaho
IDG	Integrated Drive Generator
IFM	Inlet Fan Module
IFT	In flight time
IMDS	Integrated Maintenance Data System
ICS	Intercommunication System
L	Local
LANTIRN	Low Altitude Night Targeting and Infrared Navigation
LAO	Local Area Orientation
LRU	Line Replaceable Unit
M	Mach
MA	Mishap Aircraft
MAJCOM	Major Command
MAN	manual
MC	Mishap Crew
MFL	Mishap Flight Lead
MO	Missouri
MP	Mishap Pilot
MPCD	Multi-Purpose Color Display
MPD	Multi-purpose Display
MSL	Mean Sea Level
MTC	Mission Training Center
MW	Mishap WSO
nm	Nautical Mile
Non RLS	Non Reservoir Sensing
NOTAMS	Notices to Airmen
OCA	Offensive Counter-Air
OH	Ohio
ORM	Operational Risk Management
PC	Power Control
PIO	Pilot Induced Oscillation
PLB	Personal Locator Beacon
PRC	Portable Radio Communicator
PTO	Power Take Off
PHA	Preventive Health Assessment
RMM	Removable Memory Module

RPM	Revolutions per Minute	TOLD	Takeoff and Landing Data
RTB	Return-To-Base	UHF	Ultra High Frequency
SAR	Search and Rescue	US	United States
SPINS	Special Instructions	VHF	Very High Frequency
SRU	Shop Replaceable Units	VTRS	Video Tape Recording System
TBA	Training Business Area	VUL	Vulnerability Window
TCTO	Time Compliance Technical Order	WPAFB	Wright Patterson Air Force Base
TO	Technical Order	WSO	Weapons System Officer
TDY	Temporary Duty	Z	Zulu time
T/N	Tail Number		

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 15 Jun 2012 Lieutenant General William J. Rew, Vice Commander, Air Combat Command (ACC), appointed Colonel Henry L. Cyr as the President of the Accident Investigation Board (AIB) convened to investigate the Class A aircraft mishap involving an F-15E Strike Eagle, tail number (T/N) 90-0254, which occurred on 3 May 2012 in Southwest Asia. (Tab Y-2) Additional members appointed to the AIB were a Legal Advisor, Medical Member, Pilot Member, Maintenance Member and Recorder. (Tab Y-2) The investigation was conducted at Mountain Home AFB, ID, from 20 Jun 2012 through 17 Jul 2012 in accordance with Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*, dated 26 May 2010.

b. Purpose

This is a legal investigation convened to inquire into the facts surrounding the aircraft accident, to prepare a publicly-releasable report, and to gather and preserve all available evidence for use in litigation, claims, disciplinary actions, administrative proceedings, and for other purposes.

2. ACCIDENT SUMMARY

On 3 May 2012 at approximately 0718Z/1118L the mishap aircraft (MA), an F-15E, tail number (T/N) 90-0254, forward deployed with the 391st Expeditionary Fighter Squadron (EFS) to the 380th Air Expeditionary Wing (AEW), Southwest Asia, impacted the ground approximately 65 nautical miles south of the host nation AB. (Tab CC-2, EE-7-8) The mishap sortie was a training mission deployed under a Theater Support Package to the United States Central Command (CENTCOM) Area of Responsibility (AOR). (GG-2) The crash occurred in an unpopulated area and the mishap aircraft was destroyed with a loss valued at $45,538,495.76. (Tab L-1, P-2, CC-2-3) The mishap crew (MC) safely ejected from the aircraft with no injuries and was quickly recovered by host nation search and rescue forces. (Tab R1-2, V-1.11, V-2.6) No known civilian injuries or damage resulted from the mishap, and only minimal damage to a few irrigation lines occurred. (Tab H-2, P-2) There was little media interest following the initial reports of the mishap.

3. BACKGROUND

The MA, an ACC asset under the command of 12th Air Force, was assigned to the 391st Fighter Squadron (391st FS) of 366th Fighter Wing (366th FW) located at Mountain Home AFB, ID. At the time of the mishap, the MA was operated by the 391st Expeditionary Fighter Squadron (EFS), which was deployed in support of a Theater Support Package to the CENTCOM AOR. Maintenance on the aircraft was performed by personnel assigned to various units of the 366th FW, deployed to the 380th EAMXS, Southwest Asia. (Tab V-2.2, V-3.1, V-4.1, GG-2)

a. Air Force Command Structure and Organizational Responsibilities

(1) MAJCOM - Air Combat Command (Joint Base Langley-Eustis, Virginia)

Air Combat Command is the primary force provider of combat airpower to America's warfighting commands. To support global implementation of national security strategy, ACC operates fighter, bomber, intelligence surveillance reconnaissance, battle-management, and electronic-combat aircraft. It also provides command, control, communications and intelligence systems, and conducts global information operations. As a force provider, ACC organizes, trains, equips and maintains combat-ready forces for rapid deployment and employment while ensuring strategic air defense forces are ready to meet the challenges of peacetime air sovereignty and wartime air defense. ACC numbered air forces provide the air component to U.S. Central, Southern and Northern Commands, with Headquarters ACC serving as the air component to Joint Forces Commands. ACC also augments forces to U.S. European, Pacific and Strategic Command. (Tab EE-2)

(2) NAF – Twelfth Air Force (Davis-Monthan Air Force Base, Arizona)

Twelfth Air Force is one of four numbered air forces assigned to Air Combat Command. The Twelfth Air Force (Air Forces Southern) mission is to provide combat ready forces to Air Combat Command, train and equip 10 active duty wings and 1 direct reporting unit, oversee 18 gained Air Reserve Component units, and employ 22 airframes totaling more than 731 combat aircraft with more than 66,400 Airmen. (Tab EE-5)

(3) Wing – 366th Fighter Wing (Mountain Home Air Force Base, Idaho)

Mountain Home Air Force Base, Idaho, is the home of the 366th Fighter Wing, which reports to Air Combat Command. The mission of the 366th FW is to develop and deploy combat ready Airmen. Mountain Home AFB and the 366th Wing have a rich history that stretches back more than 50 years to the United States' entry into World War II. Although the wing itself was not activated until after World War II, it shares the World War II heritage of the 366th Operations Group, whose precursor organization, the 366th Fighter Group, stood up about the same time the base was being built. (Tab EE-7)

(4) Squadron – 391st Fighter Squadron (Mountain Home Air Force Base, Idaho)

The 391st FS "Bold Tigers" plan and conduct F-15E operations and contingency plans. The squadron maintains combat readiness of 85 personnel and 24 F -15E aircraft for short-notice, worldwide Air Expeditionary Force (AEF) operations. The squadron is mission ready to perform close air support, interdiction, strategic attack, suppression of enemy air defense and defensive counterair missions, employing the full array of U.S. Air Force capabilities including precision-guided munitions, inertially-aided munitions, night vision goggles, fighter data link and Low Altitude Navigation and Targeting Infrared for Night (LANTIRN). (Tab EE-8)

b. Aircraft

The F-15E Strike Eagle is a dual-role fighter with the capability to perform both air-to-air and air-to-ground missions. The F-15E's sophisticated avionics and electronics systems provide all-weather, day or night air superiority, air-to-ground precision combat capability, and multi-staged improvement program avionics.

One of the most important characteristics of the F-15E model is the rear cockpit from where a weapons system officer (WSO) monitors aircraft and weapons status, possible threats, selects targets, and navigates the aircraft. The F-15E has two afterburning turbofan engines each capable of generating nearly 29,000 pounds of thrust and has the ability to carry up to 23,000 pounds of payload. The F-15E is also equipped with two low-drag conformal fuel tanks that can carry 1,500 gallons of fuel. Each of the tanks hold weapons on short pylons rather than conventional weapon racks, reducing drag and further extending the range of the Strike Eagle. The fighter can carry most air-to-ground weapons, including Joint Direct Attack Munitions, Laser Guided Bombs, and the Small Diameter Bomb, and it can be armed with air-to-air weapons, such as the Air Intercept Missile (AIM)-120 Advanced Medium Range Air-to-Air Missile and the AIM-9 Sidewinder. The "E" model also has an internally mounted 20-millimeter gun that can carry up to 500 rounds. For targeting, the F-15E employs the Low Altitude Night Targeting and Infrared Navigation system and Sniper Advanced Targeting Pod technology. (Tab EE-10)

4. SEQUENCE OF EVENTS

a. Mission

The mission was a routine training sortie simulating enemy fighter tactics (Red Air) against friendly forces (Blue Air). The MC's objective was employment of notional ordnance on a point defended by Blue Air. (Tab R-14-21,V-1.4, V-2.4) Higher headquarters tasked and approved the flight through normal channels and processes on 3 May 2012. (Tab K1-3, K1-4) The sortie encompassed flying to the training airspace south of the airfield, with multiple attempts to fly far enough east into friendly defended territory to achieve objectives. (Tab R-14-21, V-1.3-1.4, AA-2) The Red Air package consisted of a four-ship flight of F-15Es, callsign Dallas, of which the MC was number two (wingman), callsign Dallas 22, and an additional two-ship formation of F-15Es, callsign Dragon. A mix of two F-15Es and six F-15Cs acted as Blue Air. (Tab R-14-21)

b. Planning

The MC showed at the squadron at 0320Z/0720L. The MC attended a 0750L coordination briefing with all members of both Blue Air and Red Air. (Tab R-14-21, V-2.3) Mission planning was adequate and fully supervised by the mishap flight lead (MFL). (Tab R-14-21, V-2.4) Mission planning and briefing was accomplished in accordance with (IAW) Air Force Instructions (AFI) as well as 391st EFS directives and standards. The briefing covered all mission objectives, intelligence assessments, mission execution, emergency and recovery procedures, special interest items, flight administration, training rules, as well as weather and Notices to Airmen (NOTAMS). The MC determined minimum controlled and uncontrolled ejection altitudes to be 3,000 feet and 7,000 feet Mean Sea Level (MSL) based on terrain (2,000 feet and 6,000 feet above ground level (AGL)). (V-2.6) Additionally, the MP prepared the lineup card for all members of Red Air. The MW prepared and briefed the Red Air tactics for use against Blue Air. (Tab R-14-21, AA-2, V-2.4) The weather support squadron on location developed the squadron's weather planning strategy. The flight crews received all applicable observations and forecasts for the surrounding airfields, as well as a satellite graphic and data relating to illumination, flight level winds, and any other relevant data. The weather on the day of the mishap was clear with no precipitation. Temperatures at the time of takeoff were approximately 95 degrees Fahrenheit. (Tab F-2)

Prior to departing the squadron building for the aircraft, all aircrew received a brief from the Operations Supervisor. This brief entailed assigned aircraft with parking locations, any known maintenance issues with the respective aircraft, configurations, bird watch conditions, airfield and weather updates, as well as guidance from the squadron commander or operations officer. (Tab K13-18, K34-37, R-43-44) The Operations Supervisor was not aware of and did not brief any known maintenance issues or trend items of the MA to the MC. (Tab R-43-44)

c. Preflight

The MA was configured with the standard training ordnance loadout, one Airborne Instrumentation System (AIS) pod and external fuel tanks. (Tab D-2, S-6) The MA had a write-up for no capability to record video data via the Digital Video Recording System (DVRS) or Video Tape Recording System (VTRS). (Tab D-2) The MC performed all preflight checks IAW

appropriate technical orders. The MC did not note anything abnormal during preflight or ground operations prior to takeoff. (Tab V-1.3-1.4, V-2.3-2.4, V-2.6-2.7)

d. Summary of Accident

On 3 May 2012 at 0629Z/1029L, the MA took off from the host nation AB. The MA proceeded south to the training airspace and conducted aircraft system checks. The MC executed g-warm-up and awareness maneuvers prior to initiating their Red Air profile. The simulated air battle began promptly at 1050L. (Tab R-34) The MC executed the briefed game plan alongside the MFL until approximately 1111L when the MA continued single ship to the east after Blue Air successfully targeted the MFL and he turned westbound. (Tab V-1.4, V-2.4) The MA continued eastbound at approximately 2,400 feet AGL and accelerated to 0.91M. (Tab L-1, CC-3)

Near the eastern boarder of the training airspace, at approximately 1116:15L, the MC began a climb to 10,000 feet MSL to comply with airspace restrictions. (Tab L-1, V-1.4-1.5, V-2.4, CC-3) The MP advanced the throttles to maximum afterburner and initiated a climb to 25 degrees nose high. During the climb, the MC heard a loud bang perceived from the right engine. (Tab V-2.4) The MP decreased the aircraft pitch, allowing the aircraft nose to fall while noticing an over temperature of 1300 degrees Celsius (C) for the right engine on the Engine Monitor Display (EMD). (Tab V-1.6) The MC assessed a stall and the MP immediately brought the right throttle to Idle. The MP communicated to the MW that he was shutting down the right engine, then placed the right throttle in the off position while the MW simultaneously guarded the left throttle to prevent inadvertent shutdown. (Tab V-1.6, V-2.4) The MC felt the MA yaw and roll to the right and the MP began applying full left stick and left rudder. The MA was just a few hundred feet above the minimum uncontrolled ejection altitude of 7,000 feet MSL. (Tab L-1, CC-3) The MP communicated to the MW that he was having difficulty controlling the MA and as the MA rolled approximately 100 degrees to the right, the MP commanded "bailout, bailout, bailout." (Tab L-1, V-1.7, V-2.4, V-2.9, CC-3) While the MP was commanding the bailout to the MW, the MP assessed that the MA had stabilized and communicated to the MW, "hang on." The MP again applied full left stick and the MA sluggishly began a left roll back towards a level attitude. At approximately 1116:55L at 7,000 feet MSL and 400 knots, in an effort to increase aircraft stability and control, the MP emergency jettisoned the pylons connected to the external fuel tanks, missiles and the AIS pod. (Tab L-1, V-1.7, V-2.5, V-2.9, CC-3)

Near the same time of the emergency jettison, the MC heard "Warning, Engine Fire Right," "Warning, AB Burn Thru Right," and "Warning, AMAD (Airframe Mounted Accessory Drive) Fire" from the voice warning system. (Tab V-1.7, V-2.5) The MP noticed the corresponding lights on the Fire/Warning/Extinguish Control Panel. The MP lifted the metal guard on the Right Engine Fire Push Light, pressed the Right Engine Fire Push Light, and activated the fire extinguisher discharge switch in an upward motion. (Tab V-1.7) The MP then confirmed the throttle was in the off position. The MW communicated visual confirmation of smoke coming from the right intake and from the right bypass vent. The MP also noticed flames on the right side of the MA. (Tab V-1.8, V-2.5)

Both the MP and MW noticed each respective multi-purpose display (MPD) listed an excessive number of warnings and cautions associated with the MA. Both the MP and the

MW commented on their inability to address each individually due to the sheer number of warnings and cautions. (Tab V-1.8, V-2.5) The MP attempted to analyze the EMD confirming shutdown of the right engine, but at about that time the MA experienced complete loss of electrical power. The MP noticed the MA flight controls were still sluggish and perceived a worsening condition. The MC confirmed no screens were working in the aircraft, as well as loss of intercom, indicative of a failed emergency generator. (Tab V-1.8) The MP then looked back toward the MW, continued to see flames on the right side of the MA, and passed the MW the comm-out hand signal for ejection. The MC prepared for ejection, and the MP pulled both ejection handles, initiating the ejection sequence. (Tab V-1.8, V-2.5) The MC ejected from the MA at approximately 7,000 feet AGL and 400 knots. (Tab L-1, V-2.14, CC-3) The MC did not attempt any radio calls alerting the other airspace players of a problem prior to ejecting from the aircraft. (Tab V-1.10, V-2.13)

e. Impact

The MA impacted the ground at approximately 0718Z/1118L in an unpopulated area. (Tab CC-2) The MC landed approximately 1.2 nautical miles (nm) west-northwest, and the external fuel tanks impacted approximately 3.5 nm west-northwest of the MA impact site. (Tab H-105) Recovery crews estimate the MA impacted the ground approximately 60-80 degrees nose low inverted. There were no civilian casualties and no significant damage reported at the impact site, other than to some small trees and irrigation lines. (Tab H-105, P-4)

The approximate area encompassing the impact area was 1200 by 800 feet oriented on an approximate heading of 200 degrees. Significant damage to the MA resulted in minimal recoverable data from the crash site. (Tab H-105, J-45-53)

f. Egress and Aircrew Flight Equipment (AFE)

The MP initiated successful ejection within the performance envelope of the Advanced Concept Ejection Seat II (ACES II) ejection system. The MP experienced a Mode 2 ejection, while the MW experienced a Mode 1 ejection, despite the MA being well within the altitude and airspeed parameters for a Mode 2 ejection (see fig. 1). (Tab H-2-12)

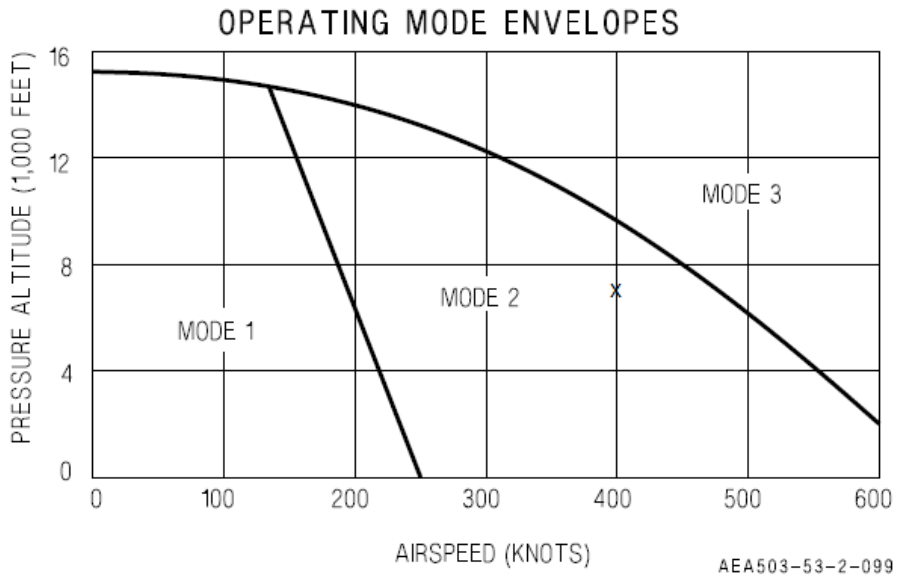

Fig. 1. Digital Recovery Sequencer Mode Selection Criteria
(MC's ejection parameters highlighted with an "X") (Tab H-2-12)

The primary difference in a Mode 2 ejection from a Mode 1 ejection is seat drogue parachute deployment, slowing the seat prior to man-seat separation, delaying deployment of the aircrew parachute (see fig. 2). If a Mode 1 sequence is initiated in the Mode 2 regime (as in the case of the MW), there is an increased risk of injury resulting from the parachute opening at higher than desired speeds. In this mishap, however, the MW's aircrew parachute deployed fully and the MW sustained no serious injuries. (Tab H-2-12, V-2.6, V-2.15) Further investigation showed the environmental sensor that determines the Mode type of ejection from the MA's aft seat did not meet specifications during an inspection on 20 Jan 2011. (Tab H-76-77, R-53) The environmental sensor should have been condemned and replaced. Analysis of the environmental sensor was unable to determine the reason of the failure to provide a Mode 2 signal to the digital recovery sequencer in the aft seat. (Tab H-2-12, H-13-37)

Typical Event	Mode I	Mode II
Rocket catapult fires	0.00	0.00
Drogue deploys	NA	0.17
STAPAC ignites	0.18	0.18
Parachute deploys	0.20	1.17
Drogue releases from seat	NA	1.32
Seat releases from pilot	0.45	1.42
Parachute inflates	1.80	2.80
Survival equipment deploys	5.50	6.30

Fig. 2. Ejection Sequence Timeline (Tab H-2-12)

The ACES II ejection seat contains a personal locator beacon (PLB) intended to transmit emergency notification and location information via line-of-sight Ultra High Frequency (UHF), Very High Frequency (VHF), and beyond-line-of-sight satellite frequencies. The PLB has automatic and manual modes. Selection of the PLB modes is controlled via a Radio Beacon Selector switch, which is located through a cutout in the front of the seatpan. The switch is a rocker switch with two settings, MAN and AUTO. With MAN selected, the radio beacon will not activate at man-seat separation. With AUTO selected, the radio beacon activates at man-seat separation. The PLB from the MA forward and aft seats did not function as designed. The MW's PLB was completely non-functional. The MP's PLB sent a signal only to the Cospas-Sarsat satellite system, starting approximately one hour after the MA impact and continuing until recovery personnel terminated the signal at the site 24 hours after impact. (Tab J-129-164) The MP's PLB did not alert any local aircraft or radar stations via the emergency guard frequencies of 243.0 and 121.5. (Tab J-129-164, R-5-9, R-14-21) Both recovered MA ejection seats showed the selector switches were correctly set. (Tab J-129-164). Once on the ground, the MP used the survival radio to contact the MFL and to coordinate with Search and Rescue personnel. (Tab R-5-11, R-14-24, R-27-28, R-50, V-1.11)

All required aircrew flight equipment inspections were current and the MP and MW were wearing the appropriate life support equipment for a daytime training mission. While neither egress nor aircrew flight equipment were causal or contributing factors in this mishap, the inoperative MC PLBs delayed indication of the crash, with MFL and search and rescue forces reliant solely upon MP survival radio communications for awareness of the mishap.

g. Search and Rescue

After the termination of the training scenario at 0720Z/1120L, the MFL began rejoining the formation for return to base. (Tab R-14-21) The MC did not respond to any radio calls and their track had disappeared from the Fighter Data Link (FDL). At 1125:26L, while the MFL was flying the last known ground track of the MA, the MP transmitted over guard, "Any aircraft, any aircraft on guard." The MFL then recognized the severity of the situation and began acting as the initial On Scene Commander. (Tab R-14-21, CC-2) The MP placed another call on guard, "Guard, this is [MP], <unreadable>, I am in contact with the other individual." The impact site was approximately 65nm on a 170 bearing from the host nation AB. (Tab L-1, CC-2-3) The

MFL coordinated with air traffic control (ATC) for airspace deconfliction and began distributing duties to other formation members. Dallas 23 continued coordination with ATC while Dragon 31 (391st Squadron Commander as the pilot) worked to get sensors on the MC, as well as coordinate with the 391st on-duty Operations Supervisor, requesting the tasking of a refueling tanker to their location in support of the rescue. (Tab R-27-28, R-43-44) The Operations Supervisor passed that it would take approximately two hours for a refueling aircraft to reach their position. The approximate holding time of the remaining F-15Es in the airspace was 45 minutes. (Tab R-5-9, R-43-44)

Following the successful ejection, the MC started walking to a nearby structure to seek shelter. The vacant building was approximately 0.5 nm to the South. (Tab R-5-9, R-43-44) Once ensuring the building was vacant, the MC rested in the shade while awaiting rescue. (Tab R-5-9, R-14-21)

At approximately 1145L, a host nation rescue helicopter with the callsign SAR 04 took off, made initial contact with ATC at 1150L, and proceeded to the MA impact site. (Tab W-2) Upon reaching the impact site, the MFL directed the rescue helicopter to the building where the MC was waiting. The helicopter landed at approximately 1220L and picked up the MC. The helicopter then proceeded to a host nation hospital, landing at approximately 1255L. (Tab R-5-9, R-14-21, R-37, R-43-44, R-50, W-2)

5. MAINTENANCE

a. Forms Documentation

(1) General Definitions (T.O. 00-20-1)

Air Force Technical Order (AFTO) 781 series forms and a computer database known as Integrated Maintenance Data System (IMDS) document Air Force maintenance and inspection histories. In addition to scheduling and documenting routine maintenance actions, these tools allow aircrew to report discrepancies and maintenance personnel to document actions taken to resolve a reported discrepancy.

Active forms consist of the AFTO 781 series forms currently in use by maintenance personnel to record aircraft inspection, conditions and repair actions.

Inactive forms contain historical AFTO 781 series forms where all un-cleared discrepancies are carried-forward to the active forms.

Time Compliance Technical Orders (TCTOs) are used to process system changes. TCTOs are usually aircraft parts upgrades, which must be accomplished within a specified time period and by a specific date, depending on the severity of the issue indicated by the TCTO. A TCTO may also direct inspections or adjustments to parts or equipment already installed on the aircraft. Time change items are routine maintenance actions involving the removal and replacement of

components at a given interval, tracked by flight hours, engine operating hours, engine cycles or calendar days.

AFTO 781 series forms establish the use of red symbols, which indicate the level of maintenance required for each annotation. They indicate the condition, airworthiness, inspection status, servicing and the maintenance status of the particular aerospace vehicle.

- A Red X reflects that an aircraft is considered unsafe for flight or in an unserviceable condition. The unsatisfactory condition must be correct and the symbol cleared before the aircraft is considered safe for flight.

- A Red – indicates an unknown condition or inspection due on the aircraft that when accomplished could reveal a more serious condition. The aircraft is considered safe for flight with an open red dash.

- A Red / indicates a discrepancy exists on the aircraft but is not dangerous or urgent to warrant grounding of the aircraft or discontinued use.

A repeat discrepancy occurs when the same malfunction of a system/subsystem appears on the next flight or flight attempt after maintenance personnel have cleared the original discrepancy.

A recurring discrepancy occurs when the same malfunction of a system/subsystem appears on the 2nd through 4th flight or flight attempt after maintenance personnel have cleared the original discrepancy. (T.O 00-20-1)

(2) Documentation Reviewed

The investigation conducted a comprehensive review of the available maintenance documentation for the MA. This review covered IMDS data that reflected maintenance actions completed prior to the mishap, as well as the maintenance log books from the deployed location and both active and historical AFTO 781 series forms. Active AFTO 781 forms documented maintenance conducted the day prior to and the day of the mishap. These forms reflected a signed exceptional release indicating the aircraft was airworthy and had been released by maintenance to operations for flight. The review did not reveal any causal or contributory factors to the mishap. (Tab D-3-28)

(a) Active Forms

The investigation inspected all existing active aircraft AFTO 781 series forms for completeness and accuracy. There were a few documentation errors, but these did not pose a safety of flight issue and were not causal to the mishap. (Tab D-3-28)

On the day of the mishap there were 12 open discrepancies in the active AFTO 781 series forms consisting of 3 open Red dashes and 9 open Red diagonals. (Tab D-3-28) There were no overdue inspections, time changes or TCTOs at the time of the mishap. The basic post-flight/pre-flight combined inspections were annotated on the 781 H as completed on 2 May 2012

at 1330, which are valid for a 72-hour period. The inspection and exceptional release for the aircraft were properly documented, indicating the MA had a valid pre-flight prior to the mishap sortie. (Tab D-3-28)

(b) Inactive Forms

A review of the inactive forms for completeness, accuracy and maintenance actions for the MA revealed several documentation errors. However, none of the errors posed a flight safety issue and they were not causal or contributory to the mishap.

(c) Documentation Specific to Aircraft Engines

A review of aircraft and engine historical data for completeness, accuracy and maintenance actions pertaining to the engines revealed that no maintenance actions were causal or contributory to the mishap. The number 1 engine (PW0E720403) was installed into the MA on 3 Mar 2011 after major maintenance at the engine back shop and accrued 345.9 hours. Since installation, the engine has had minor maintenance accomplished, including a Digital Electronic Engine Control (DEEC) change on 15 Aug 2011. In addition, all required borescope inspections were completed on time. (Tab D-2, U-134-135)

The number 2 engine (PW0E720172) was a serviceable spare that had time change replacements for the Fan Module, Augmentor Fuel Pump and one Rear Compressor Variable Vane during the last uninstalled maintenance at the engine back shop. In addition, all borescope inspections were completed, and the engine was returned to serviceable status on 31 Jan 2012. (Tab D-30-139, D-140-306) On 11 Apr 2012, the engine was installed into the number 1 position of A91-0319. On 14 Apr 2012, it had a DEEC change for multiple fault codes and an Engine Diagnostic Unit (EDU) change on 17 Apr 2012 for an unreadable Fan Turbine Inlet Temperature (FTIT) on the EMD. (Tab U-61, U-115-117)

The engine was then removed on 20 Apr 2012 for a FTIT harness replacement. (Tab U-96, U-114) Maintenance personnel replaced the FTIT harness due to the failed flight for no reading on the EMD. (Tab U-47) The engine accrued 7.1 hours Engine Operating Time (EOT) while installed in A91-0319. On 22-23 Apr 2012, the engine was installed into the number 2 position of the MA and accrued 16.3 hours EOT prior to the mishap date. (Tab D-2, U-28, U-114)

b. Inspections

Maintenance personnel conducted scheduled inspections on the MA, appropriately documented in accordance with applicable Technical Orders (TOs). All inspections were current and none were overdue at the time of the mishap.

(1) Aircraft inspections

The inspection process of the F-15E is a phased inspection conducted on a 1200-hour cycle, broken down into three 400-hour phases. An hourly post-flight inspection is conducted at 400 hours (Phase 1), which is then repeated again at 800 hours (Phase 2), followed by a more comprehensive inspection at 1200 hours. Phase inspection teams comprised of Crew Chiefs, Avionics, Electro Environmental, Flight Control and Engine Specialists complete the inspections. The phases consist of removing aircraft panels and inspecting systems and subsystems for proper operation. In addition, the inspections check all movable surfaces to include canopy, engine inlet ramps and flight controls for proper rigging and possible damage. The last phase inspection completed on the MA was the 1200-hour inspection, accomplished at 6597.4 flight hours on 12 Sep 2011. At the time of the mishap, the MA had 6718.6 flight hours and the next phase inspection was due at 6997.4 flight hours. (Tab D-2, D-3-28, U-2)

Although all inspections were current, the aft ejection seat did not deploy as designed. The aft seat incorrectly deployed in Mode 1, whereas the front ejection seat correctly deployed in Mode 2. The last inspection on the aft ejection seat was accomplished on 20 Jan 2011. This was a 36 month inspection during which, the Environmental Sensors (ES) are tested by egress personnel for serviceability in accordance applicable TOs. The test results indicated that the aft ejection seat failed step 23 and the ES should have been removed and replaced (condemned) and not installed on the ejection seat. (Tab H-2-12, H-76-77) The ES was sent to Wright Patterson AFB, OH for tear down analysis. The tests and analysis of the ES did not identify why the aft seat selected Mode 1 under Mode 2 conditions. (Tab H-13-37) The aft ejection seat malfunction was not causal or contributory to the mishap.

(2) Engine inspections

The F-15E engine inlets and exhausts are visually inspected prior to and after every flight and before and after every engine maintenance run. Each engine requires 100 hour, 200 hour and 400 hour inspections, tracked by in flight time (IFT). All engine inspections were current and none were overdue at the time of the mishap. Engine components and modules have limited lifetimes in accordance with applicable TOs that are tracked by EOT and cycles which are grouped into two categories: Line Replaceable Units (LRUs) and Shop Replaceable Units (SRUs). IMDS did not show any modules or components due for time change at the time of the mishap.

c. Maintenance Procedures

Maintenance procedures on the MA were performed in accordance with applicable TOs and AFIs at the time of the mishap, except for minor maintenance documentation discrepancies not causal to the mishap.

(1) AFSC Maintenance Procedures

Maintenance procedures are specific to an Air Force Specialty Code (AFSC) and require personnel to be trained and qualified on theory of operation, system schematics, isolating malfunctions, performing operational checks and LRU removal and installation. Training and qualifications for maintenance personnel are tracked and monitored electronically in the Training Business Area (TBA) system. In addition, AFTO 781 series forms and IMDS must reflect all maintenance actions conducted on an aircraft's systems and subsystems.

d. Maintenance Personnel and Supervision

Maintenance personnel assigned to the 380th EAMXS maintained the MA. Maintenance personnel statements indicate all preflight activities relating to the mishap sortie were normal and all personnel involved in the prefight and launch were qualified. The individual training records and the special certification roster for all personnel performing maintenance on the MA reflected proper training and full qualifications on all tasks accomplished. The organizational structure at the deployed location mirrors home station operations. Operations supervision indicated they have a great working relationship with maintenance. The operations supervision engaged with maintenance on a daily basis and saw no issues with maintenance practices and procedures. (Tab V-3.1)

e. Fuel, Hydraulic, and Oil Inspection Analysis

Following the mishap, fuel samples were taken from the fuel truck that refueled the MA on 2 May 2012 and tested at Wright Patterson AFB, OH. The fuel analysis recorded passing results for all fluids. (Tab D-307)

Hydraulic fluid samples taken post-mishap from the hydraulic mule that serviced the MA on 30 Apr 2012 were also sent to Wright Patterson AFB, OH, for testing. The hydraulic fluid analysis recorded failed results for water, but was within the acceptable operating standards for the aircraft. (Tab D-307)

Following the mishap, oil samples were taken from the oil-servicing cart used to service the MA prior to the flight. These samples were also sent to Wright Patterson AFB, OH for analysis. The oil analysis recorded passing results for all fluids. (Tab D-307)

No fluid samples were obtained post-accident from the MA. No evidence was found to indicate that servicing equipment, fuel, hydraulic fluid, oil or tools contributed to the mishap in any way. (Tab D-307)

f. Unscheduled Maintenance

Review of the 90-day history in IMDS and the historical AFTO 781 series forms reflected numerous unscheduled maintenance actions relating to radar malfunctions, 031 hydraulic leak, video tape recording system, right main landing gear hydraulic line, exterior lighting, right hydraulic system leaks on multiple occasions, number two engine change for augmentor repair and other discrepancies for the MA. (Tab U-4, U-6)

Maintenance completed all corrective actions for unscheduled maintenance in accordance with applicable TOs and AFIs. There is no indication of unscheduled maintenance being a factor in the mishap.

6. AIRCRAFT AND AIRFRAME

a. Affected Aircraft and Airframe Systems

Upon impact, the aircraft created a scatter field measuring approximately 800 ft. by 1200 ft. (see fig. 3). The main wreckage consisted of a large crater with both engines still attached to the aircraft structure forward of the crater with both wings and left and right empennage sections nearby (see fig. 4). The forward and center fuselage sections were not identifiable at the wreckage site. The majority of the debris field was forward of the crater with small pieces of the wreckage surrounding the area in a radial pattern. Evidence of all flight control surfaces remained either installed or nearby to their respective airframe locations. (Tab J-45-53, H-105, J-88-110, J-225-276)

Fig. 3. Overview of Mishap Site (Tab S-4)

Fig. 4. Mishap Site Crater (Tab Z-2)

b. Condition of Systems

(1) Structural and Flight Control System

On site crash investigation focused on the recovery of the primary left and right flight control actuators to include the horizontal stabilator actuators, aileron actuators and rudder actuators, cables for the horizontal stabilizers and ailerons, and main hydraulic system components. (Tab J-45-53, J-225-276)

(a) Flight Control Components

The F-15E hydro-mechanical flight control system consists of bellcranks, cables, and control rods connecting the control stick and rudder pedals in the cockpit to the hydraulic actuators that move the control surfaces. The Control Augmentation System (CAS) enhances and backs up the mechanical system. (Tab J-45-53)

Mishap site investigation revealed that all six flight control actuators were located in their respective sections, and the linkage and hardware were properly installed at all locations. There is no evidence to indicate the actuators were causal to the mishap. (Tab J-45-53)

The horizontal stabilator cables connect the bellcranks from the front of the wing root to the aft of the wing root, translating movement of the control stick to the input arm of the stabilator actuators. Each side of the aircraft has two cables, an upper and lower, that consists of two halves connected by a turnbuckle. (Tab J-45-53) Only two sections of left and right cables were

recovered from the site, both were sent to the Air Force Research Laboratory Failure Analysis Lab (AFRL/RXSA) at Wright Patterson AFB, OH. The lab determined the cables broke from overload at the time of impact. (Tab J-2-240) The additional left and right system cables were not recovered, and therefore, could not be analyzed. (Tab J-45-53)

The aileron cables that connect the front and aft bellcranks of the lateral system have a significantly lower failure rate than the longitudinal system since they do not contact a pulley assembly that drives excessive wear of the cable. No lateral cables could be located at the mishap site. Both wing root sections remaining at the site had suffered major damage and no cables were recovered from the impact crater. (Tab J-45-53)

(b) Hydraulic System

Three separate systems provide hydraulic power for the aircraft: two power control systems, (PC 1 and PC 2), and the utility system. PC 1 (left) and PC 2 (right) provide hydraulic power to their respective flight controls (flap, aileron, rudder, stabilator). The utility system provides hydraulic power for aircraft subsystems such as landing gear, brakes, and inlets. It also serves as a backup for flight controls in the event of a PC failure as well as providing hydraulics to the emergency generator in the event of a left or right generator failure. (Tab J-45-53, DD-4-5)

The PC1 hydraulic pump, left utility pump and left Integrated Drive Generator (IDG) are installed on the left Airframe Mounted Accessory Drive (AMAD) with the PC2 hydraulic pump, right utility pump and right IDG installed on the right AMAD. When the left or right engine reaches idle or above, the engine drives the AMAD via the Power Take Off (PTO) shaft, operating each respective system. Each of the separate hydraulic systems, PC1, PC2, and the utility system, contains two circuits, circuit A and circuit B. The two circuits in each system exist to provide redundancy throughout the aircraft, designed to back-up the flight controls if one of the separate systems fails. If a leak occurs in any circuit, the reservoir level of that system (PC1, PC2 or utility) drops and circuit A is shut off. If the leak is in circuit B, the reservoir level continues to drop causing circuit A to be restored and circuit B is shut off. If the leak occurs within a utility non-reservoir level sensing (non-RLS) circuit, circuit A is shut off then restored as circuit B is shutoff. Under this circumstance, a complete utility failure eventually occurs and system pressure goes to zero.

Investigators at the mishap site recovered the forward section of the utility reservoir. They discovered the inner piston intact and sent the entire assembly to The Boeing Company in St. Louis, MO, for tear down analysis in an attempt to determine the approximate utility hydraulic level remaining in the reservoir at the time of impact. (Tab J-45-53) This analysis determined the utility hydraulic reservoir was empty prior to impact. The circuit A piston was in the "on" position and the circuit B piston was in the "off" position. (Tab J-225-276) This is indicative of an inflight compromise of a non-RLS line. With the reservoir empty of fluid, the Utility hydraulic system would not be functional, making the Emergency Generator inoperative and removing the primary back-up to the aircraft's right and left hydraulic systems. With the right hydraulic system already inoperative due to the shut-down of the right engine, this would make the right rudder and aileron unresponsive to MP inputs; operation of the right stabilator would be degraded.

(2) Aircraft Components and Systems of Interest

Initial mishap site investigation revealed that both engines were still attached to the aircraft structure after ground impact. Both engines experienced significant compressive forces during ground impact and were compressed to approximately one third of their normal lengths. The Inlet Fan Module (IFM) 1st stage disks had separated from both engines at impact and were located at the mishap site. (Tab J-88-110) All 1st stage fan blades had separated from the disk and were scattered around the mishap site. None of the recovered 1st stage blades had damage that could clearly be identified as Foreign Object Damage (FOD) or Domestic Object Damage (DOD) that was present prior to the mishap flight. Foreign Objects are objects from an external source originating outside of the engine. Domestic objects are objects that originate from within the engine due to failure of an engine part. No FOD or DOD could be clearly identified on the 2nd or 3rd stage fan blades. Post mishap analysis revealed that both engines were wind milling at the time of impact. (Tab J-88-110)

(a) Engine Electronic System Components

Mishap investigators conducted a search of the mishap site for engine components with electronic data recording capability. Site investigation did not locate either engine EDU, and only one DEEC was located. (Tab J-88-110) The recovered DEEC was shipped to the manufacturer for evaluation of the condition of memory chips to determine if any pertinent engine data could be recovered. Visual inspection determined that the DEEC was too badly damaged/burned to positively identify the serial number. Thus, analysis could not positively determine which engine the DEEC was installed on prior to the mishap. (Tab J-83-87, J-88-110) Post-recovery analysis showed that DEEC U307 Non-Volatile Memory Chip had no internal issues and its data was downloaded and recovered. The recovered data was determined to be valid, as the DEEC internal memory usage locations contained expected and appropriate data. There were no DEEC-detected faults present in U307. (Tab J-83-87, J-88-110)

The engine control system consists of an onboard engine digital control that tracks engine and airframe data, known as a DEEC, with a mechanical backup system. The engine mounted stator generator provides power for the DEEC. The DEEC controls engine operation from idle to maximum afterburner (primary mode). The mechanical control system only allows for non-afterburner engine operation (secondary mode). When the DEEC detects an abnormal engine anomaly that prohibits primary mode operation, the engine will automatically transfer to secondary mode. Without an operable DEEC, the engine will not operate in an afterburning setting. (Tab DD-20)

The MC reported that the number 2 engine anomaly (PW0E720172) occurred at maximum afterburner, which indicates the DEEC was operational at the time the anomaly occurred and should have recorded fault codes consistent with the occurrence. (Tab DD-2, DD-20, V-1.5, V-2.4) If the recovered DEEC was installed on the right engine it would have recorded fault codes that occurred during the engine anomaly, such as the FTIT overtemp, stall, stagnation or an engine die-out if N2 RPM dropped below 55% with the throttle at or above idle. The DEEC did not contain any of these faults. (Tab DD-4, DD-20, J-83-87)

If the DEEC was installed on the number 1 engine (PW0E720403) and the engine were to flame out from loss of fuel, the DEEC should have recorded a 1030 die-out fault. The DEEC would not record an engine die-out fault if the throttle was below idle, placed in cutoff, and N2 RPM dropped below 55 %. (Tab DD-4, DD-20) In addition, as soon as total electrical failure occurred, the DEEC should have recorded a Mach number fail due to loss of Mach number control input from the aircraft. While it is possible that the left engine stator generator failed and prevented the DEEC from recording a fault, it is unlikely that both a stator generator failure and fuel starvation occurred simultaneously. (Tab DD-2, J-83-87) Based upon post-mishap technical analysis and discussions with system experts, the AIB assesses the DEEC found at the mishap site came from the left engine and recorded appropriate data until impact.

(b) Number 1 (Left) Engine

The number 1 engine (PW0E720403) remained structurally intact and evidence supports the engine was wind milling at impact and not operating at normal speeds. The IFM received the initial impact damage and the rest of the engine compressed on top of the IFM. Evidence that supports wind milling of the engine includes: (Tab J-88-110)

- Fractured 4th stage High Pressure Compressor (HPC) blades that "stacked up" where they were fractured off and remained in that location.
- Damaged 13th stage HPC blades, which bent in direction of rotation due to contact with the exit, guide vanes. Bending in the direction of rotation is consistent with low rotational speed at impact.
- Bending of the trailing edge tip of the 2nd stage High Pressure Turbine (HPT) blades.
- 4th stage Fan Drive Turbine (FDT) blade tips were slightly bent and had evidence of wind milling rotation damage to the honeycomb airseals located radially outboard of the blade tips.

There is no evidence to indicate the number 1 engine was casual or contributory to the mishap. (Tab J-88-110)

(c) Number 2 (Right) Engine

The number 2 engine (PW0E720172) showed evidence of a titanium fire in the compressor section. The engine was severed aft of the compressor split case, and evidence of the titanium fire was visible in the rear compressor section when reviewed at the mishap site. The engine was recovered and investigation focused on the Core Module and compressor section, and the hardware condition upstream of the compressor. (Tab J-88-110) The HPT and FDT were inspected internally using an Olympus iPlex borescope to establish the condition of these components. The IFM 2nd and 3rd stage blade disks remained with the rest of the engine (see fig. 5). There were numerous fan blades remaining in their respective positions in the 2nd and 3rd stage blade disks. (Tab J-88-110) Evidence from the IFM, HPT and FDT was used to determine the engine was wind milling at the time of impact. (Tab J-88-110)

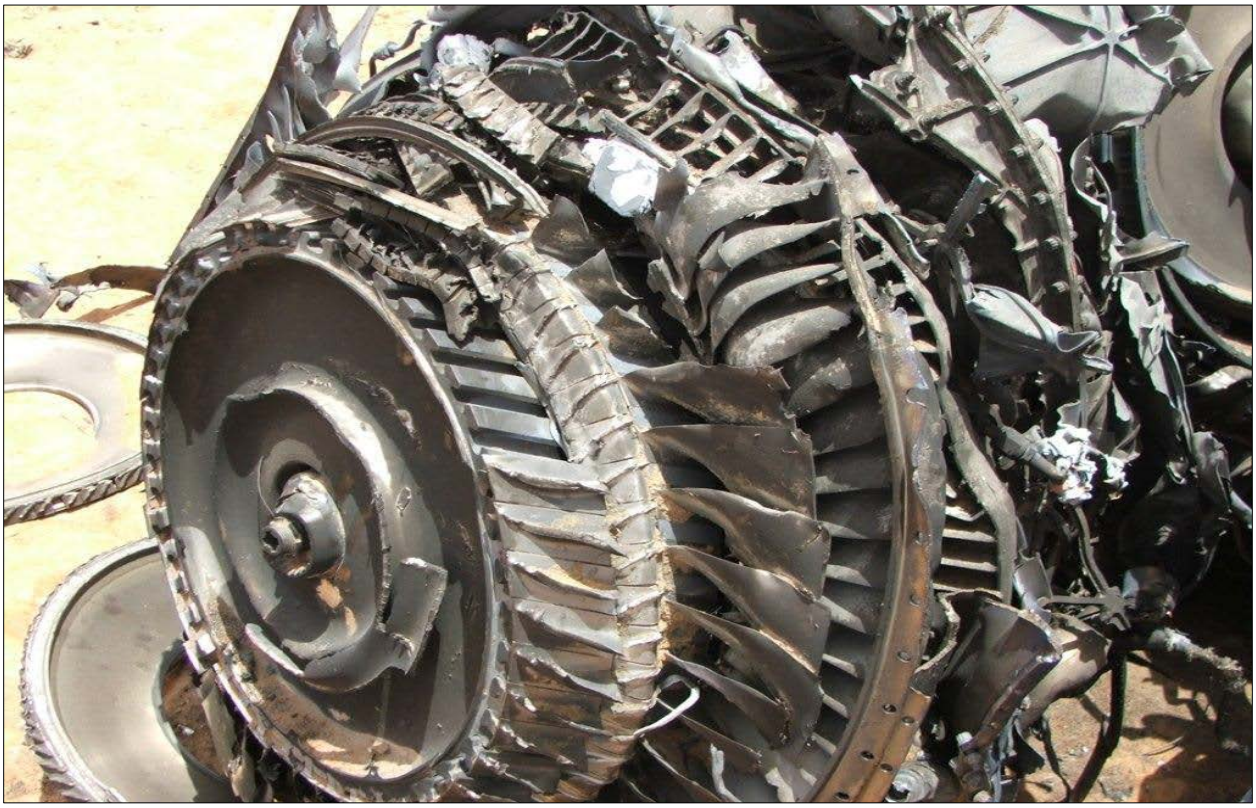

Fig. 5. PW0E720172 Inlet Fan Module (Tab J-98)

The compressor was the primary focus of the investigation due to the evidence of a titanium fire at the 5th, 6th and 7th stages of the compressor. A review of historical data on aircraft turbine engine titanium fires indicated that the primary causes of titanium fires include mechanical friction from foreign or domestic objects trapped between the case and blades, rotor imbalance or shift, case displacement, blade shift due to stall or aerodynamic heating due to stall. (Tab J-88-110, DD-10) The investigation focused on these potential causes and was able to rule out all but Domestic Object Damage as the cause of the titanium component fire. (Tab J-88-110)

The 4th stage compressor blades were eroded and had high temperature discoloration on the trailing edges. All blade roots were accounted for and the blade lockring used to secure the blades into the disk was intact. (Tab J-88-110) There were four blades with possible evidence of FOD or DOD on the leading edges of the blades. This damage was confirmed to be ground impact damage by the Pratt & Whitney Metallurgical Lab. (Tab J-25-35, J-54-82, J-88-110)

Although post-mishap analysis was able to localize that the titanium component fire began in the 5th stage of the engine, it was unable to determine the cause. All 5th stage blade roots were accounted for except for one blade root. None of the recovered blades were fractured below the blade platform. The recovered 5th stage blade surfaces were damaged both mechanically and by the titanium fire. The Metallurgical Labs at both Tinker AFB, OK, and Pratt & Whitney conducted a lab analysis of the engine blades. (Tab J-2-24, J-36-44, J-54-82) The blade roots were inspected to determine if fatigue cracks existed in the blade root area. The inspection of the

5th stage blades did not find any cracks present. (Tab J-2-24, J-88-110) Lack of fatigue cracks indicates no structural pre-existing condition at the root of the engine blade prior to the mishap.

The 6th through 13th stage blades were all damaged and had evidence of consistent mechanical damage due to liberated material from upstream in the compressor and fire damage subsequent to the mechanical damage. (Tab J-88-110) The blades were circumferentially scored and reduced to the same relative heights on each stage. Circumferential scoring occurs when a stage of blades rotating at the normal operating speed encounter material that is travelling rearward through the compressor. The damage to the 6th through 13th stage blades occurred during the inflight event and was not ground impact damage. (Tab J-88-110)

Post-mishap analysis localized the start of the titanium component fire to the 5th and 6th stages of the engine. Analysis was also able to determine the core of the mishap engine did not shift forward or rearward, eliminating one potential cause of the fire. The compressor case was removed for investigation. The 4th through 9th case was damaged by fire and impact. The case was severed by a titanium fire at both the 5th and 6th stage area, creating three separate pieces of the case. The 5th and 6th stage blade area was completely burned through for the entire circumference of the case, with the greatest damage at the 4 to 5 o'clock position, viewed aft looking forward. (Tab J-88-110) The 7th stage area was burned, but not through the case. The 8th through 13th stage area was not burned through, but had melted material covering the blade air seal abradable material. The abradable material in those locations did not display any blade tip rubbing other than what is normally seen in the compressor. When the radial location of the compressor is not maintained correctly during engine operation, (rotor/blade shift/imbalance or case displacement) the blades will contact the abradable material and create deep rubs; this was not evident in the mishap engine. (Tab J-88-110)

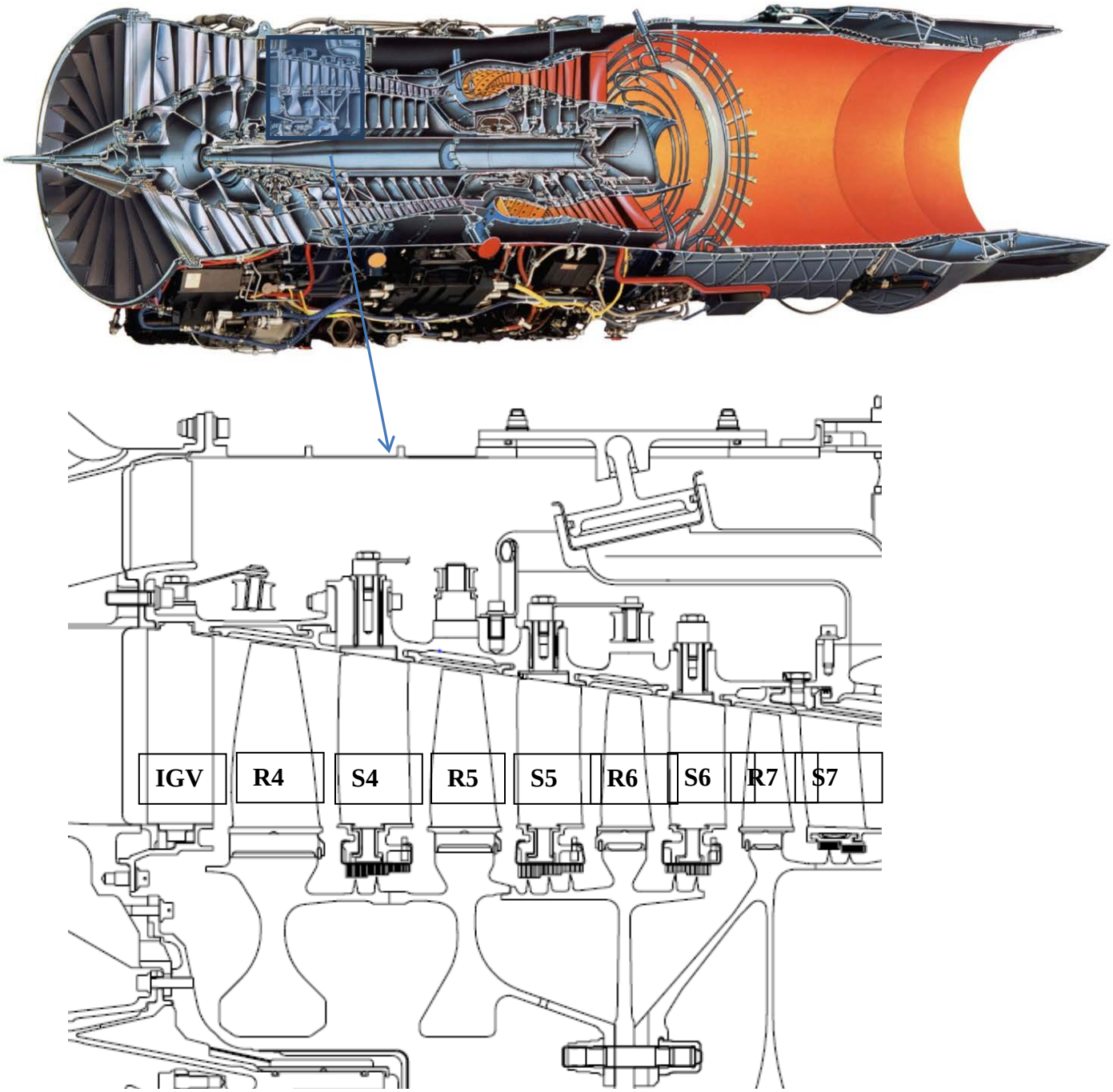

Fig. 6. Cross Section of the forward Portion of the High Pressure Compressor

c. Testing and Analysis

Parts of the MA were identified for shipping and analysis. This included flight control cables and actuators sent to Wright Patterson AFB, OH (WPAFB) (Tab J-45-53, J-2-240, J-225-276), ejection seat ES sent to WPAFB (Tab H-13-75) and Personnel Locator Beacons sent to WPAFB. (Tab J-129-164) An engine DEEC was sent to Pratt & Whitney in East Hartford Connecticut (Tab J-83-87), right engine (PW0E720172) 4th stage HPC blades and vanes were sent to Tinker AFB Metallurgical Analysis, OK, and Pratt & Whitney (Tab J-25-35, J-54-82) and right engine 5th Stage blades were sent to Tinker AFB, OK Metallurgical Analysis and Pratt & Whitney. (Tab J-2-24, J-36-44, J-54-82)

The evaluation of the right engine (PW0E710172) indicated an unidentified component failed for an unknown reason during normal engine operation. A titanium fire was initiated in the inner diameter of the compressor case in the 5th, 6th and 7th areas. Compressor material liberated and mechanically damaged all of the compressor blades aft of the 5th stage. The titanium fire at the 5th and 6th stage area in the split case burned through the compressor case for nearly the entire 360 degree circumference of the case. The titanium fire subsequently burned through the Front Fan Duct in numerous areas and into the aircraft engine bay. (Tab J-88-110)

Titanium fire duration of burn is dependent on operating conditions and is accompanied by temperatures as high as 6000 degrees Fahrenheit/3315 degrees Celsius. (Tab DD-8) The energy created by the fire destroys surrounding material, including steel and nickel alloys, by burning and melting. An "uncontained titanium fire" occurs when the fire burns through the engine casings and into the engine bay. (Tab DD-8-9) This can severely damage airframe structures and components resulting in degraded or complete loss of aircraft systems (see fig. 7). At high rotational speeds, an uncontained fire can burn through the engine case in a mere 10-15 seconds, depending on the casing material and thickness. (Tab DD-12)

The onboard fire extinguishing system uses Halon 1211 as the aircraft's fire extinguishing agent. The F-15 fire extinguisher was designed to extinguish a typical fire associated with the ignition of combustibles such as fuel and oils, not a fire with the intensity of a titanium fire. (Tab DD-6) The fire containment system and firewalls are designed to withstand a 2000 degree Fahrenheit fire for 10 minutes, well below the 6000 degrees Fahrenheit experienced during a titanium fire. The system is for one time use and is not assessed to be an effective extinguishing agent for titanium fires. (Tab DD-6-12)

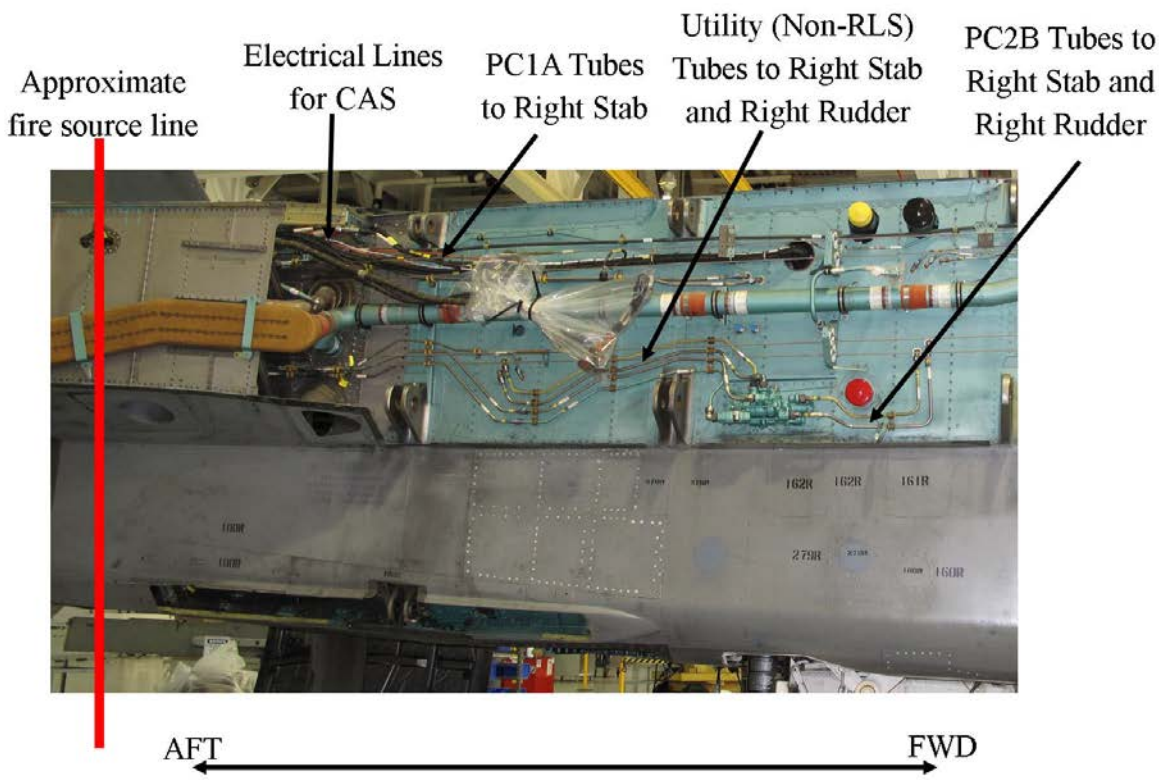

Fig. 7. Red line depicts likely burn-through location of titanium fire from engine bay in close proximity to PC1, PC2, and Utility hydraulic lines.

d. Simulator Evaluation

The AIB conducted simulator evaluations in the F-15E Mission Training Center (MTC) between 22-29 Jun 2012 at Mountain Home AFB, ID, and in the F-15E advanced cockpit simulator at The Boeing Company, St. Louis, MO, on 6 Jul 2012. The simulator is capable of presenting a variety of emergency, normal flying and combat operational simulations. Additionally, the F-15E advanced cockpit simulator at The Boeing Company is able to replicate specific aircraft malfunctions in a more localized fashion compared to the MTCs utilized by operational F-15E squadrons at their respective locations. The AIB conducted approximately 10 trials in the MTC at Mountain Home AFB, ID, to obtain general knowledge of aircraft responsiveness to multiple system failures such as hydraulics, electrics, fuels, and engines. The AIB performed 34 trials while at The Boeing Company. These trials focused on specific aircraft flight control failures relating to the parent systems previously mentioned. The AIB used information collected from MC interviews, data recovered from the AIS pod and expert opinions/analysis to make some assumptions about failed aircraft systems/components in the mishap sequence (see table 1). (Tab DD-2, DD-4-5)

Table 1 Simulation Trials conducted at The Boeing Company simulator

Trial #	Control Surface Variable	Outcome
1-10 (Failed CAS, PC1A , PC2, R Stabilator and R Rudder)	R Rudder 15 degrees right	Full left stick and rudder required for controlled flight
11-22 (Repeated using Trial 1-10 Parameters)	R Rudder 30 degrees right	Full left stick and rudder maintained 20 degrees of right bank
23-28 (Failed CAS, PC1A, PC2, Utility Hydraulics, R Stabilator and R Rudder)	No surface deflections	Full left stick and rudder in addition to aft stick required to command left roll with left stabilator.
29 (Repeated using Trial 23-28 Parameters)	R Stabilator 15 degrees down	Immediate loss of aircraft control
30 (Repeated using Trial 23-28 Parameters)	R Stabilator 5 degrees down	Immediate loss of aircraft control
31-33 (Repeated using Trial 23-28 Parameters)	No surface deflections, commanded left throttle off	Complete electrical failure after 5 seconds
34	No surface deflections	Recreation of flight profile leading to impact

The MA was equipped with an AIS pod that recorded basic aircraft parameters (including airspeed, altitude, attitude, and g's). Thus, only limited data was recovered for analysis prior to the AIS pod jettison. All other parameters for simulator evaluation were derived from witness statements and aircraft recovery analysis. Available evidence indicated the MA was at approximately 2,400 ft. AGL and 0.91M when the MP initiated a maximum AB, 4-g wings level climb to 25 degrees nose high. (Tab L-1, CC-3) Evidence supports that an anomaly associated with a compressor stall in the right engine caused a titanium fire. (Tab J-88-110) The MP reported shutting down the right engine after witnessing an overtemp associated with the stall/stagnation. (Tab V-1.6) Within a few seconds of the anomaly, the aircraft rapidly rolls/yaws approximately 100 degrees to the right and the heading changed 60 degrees to the right. (Tab L-1, CC-3) AIB members replicated this abrupt maneuver by failing the hydraulic lines and electric lines to the right side flight controls of the aircraft. (Tab DD-4, J-225-276) These failures eliminated all control inputs to the right side of the aircraft. The MP recalled full left control stick and full left rudder inputs to achieve and hold approximately 10-30 degrees of right bank attitude. (Tab L-1, V-2.13, CC-3)

Several trials conducted at The Boeing Company demonstrated how possible deficiencies with the aircraft flight control surfaces could replicate the aircraft performance described above. The trials focused on single control surface failures in a defined percentage deflection, as well as a combination of control surface failures. The trials were unable to exactly replicate the degraded aircraft performance described by the MP; however, the trials indicated that with no ability to manipulate the control surfaces on the right side of the aircraft, and with only very small deflections in even one of those flight control surfaces, the aircraft was nearly uncontrollable.

Prior to jettison of the AIS pod, the last recorded data shows the MA oscillating in pitch in excess of 10 degrees up and down; the MP also recalled the nose "shaking up and down". (Tab L-1, V-1.8, CC-3) The simulator was unable to model precisely what the stabilator would do with all hydraulic and electric power removed. However, trials indicated without hydraulic control the stabilator produced a dampening effect that worked counter to the pilot's inputs. With even small deflections, testing showed a pilot induced oscillation (PIO). (Tab DD-5)

The AIB sought to explain the possible cause of complete electrical failure shortly before the MC bailed out of the aircraft. Possible causes include fuel starvation to the left engine, failure of the left generator and shutdown of the left engine. (Tab DD-2-3) Fuel starvation or left generator failure would have registered fault codes on the recovered DEEC. (Tab DD-2) As there were no fault codes on the DEEC, the AIB concluded these causes were unlikely. The AIB tested the engine shutdown option at The Boeing Company simulator by commanding the left engine off with the throttle at the conclusion of the ENGINE FIRE INFLIGHT checklist. Simulation trials showed shutting down the left engine caused total electrical failure in five seconds. This is consistent with MP accounting of the time elapsed from executing the ENGINE FIRE INFLIGHT checklist until the MA experienced complete electrical failure. (Tab V-1.8) This would also be consistent with post-mishap analysis indicating the left engine was wind milling at the time of impact. (Tab J-88-110)

It is important to note that the simulator is not an exact replication of the MA, but a simulation of a notional F-15E with a similar configuration. Simulator trials may not perfectly replicate the precise sequence of events or systems malfunctions/failures experienced by the MC, but the trials demonstrate aircraft performance under artificial system malfunctions/failures that informed the AIB regarding the MA's likely performance on 3 May 2012.

7. WEATHER

a. Forecast Weather

The forecast weather for takeoff at the host nation AB was sky clear conditions, unlimited visibility, and winds 180 degrees at nine knots. Forecast surface temperature was 97 degrees Fahrenheit with a freezing level at 15,000 ft MSL. Winds at 5,000 ft. AGL were 030 degrees at five knots. (Tab F-3)

b. Observed Weather

Observed weather at the mishap location was clear skies, unrestricted visibility but with a layer of dust and haze at lower altitudes below 2000 ft. AGL. (Tab V-2.9) The weather remained unchanged throughout the time of recovery, with an observed temperature of 109 degrees Fahrenheit at the time of recovery. (Tab W-2)

c. Space Environment

Not applicable.

d. Operations

The mission complied with weather requirements (AFI 11-202, Vol. 3, *General Flight Rules*, dated 22 Oct 2010 with ACC Supplement, dated 9 Mar 2012, and AFI 11-214, *Air Operations Rules and Procedures*, Change 2, dated 2 Jun 2009). Weather was not a factor in the conduct of the mission or the mishap.

8. CREW QUALIFICATIONS

a. Mishap Pilot

The MP was a fully qualified, experienced four-ship flight lead in the F-15E. All necessary flight currencies were up-to-date and all required training for the planned mission was current IAW AFI 11-2F-15E, Volume 1, *Flying Operations, F-15E Aircrew Training*, dated 31 Mar 2011. The MP completed his most recent instrument qualification in the F-15E on 3 Dec 2010 and his most recent mission qualification checkride in the F-15E on 27 Jul 2011. The MP completed his four-ship flight lead upgrade with average progression and performance on 12 Dec 2011. The MP had a total of 515.8 hours of military flying time and of this total, the MP had 458.1 hours of primary F-15E time. The MP met all currency and training requirements prior to the mishap sortie, and was qualified for the mission (see table 2). (Tab G-3-93, G-190-199, K-8, K-22-30)

Table 2 MP 90 Day look-back (Tab G-3-93)

	Hours	Sorties
Last 30 Days	21.4	14
Last 60 Days	35.8	17
Last 90 Days	58.4	29

MP qualifications were not contributory to this mishap.

b. Mishap Weapons System Officer (WSO)

The MW was a fully qualified, experienced instructor WSO in the F-15E aircraft. All necessary flight currencies were up-to-date, and all required training for the planned mission was current IAW AFI 11-2F-15E, Volume 1, *Flying Operations, F-15E Aircrew Training,* dated 31 Mar 2011. The MW performed his most recent mission qualification on 20 Dec 2011 and received

his initial instructor qualification on 7 Sep 2011. The MW had a total of 603.7 hours of military flying time and of this total, the MW had 595.1 hours of primary/instructor F-15E time. The MW completed his instructor upgrade with average progression and performance on 2 Sep 2011. Of note, the MW did not accomplish any F-15E training during the months of January and February while he was on temporary duty (TDY) status at Squadron Officer School in Maxwell AFB, AL. The MW met all currency and training requirements prior to the mishap sortie, and was qualified for the mission (see table 3). (Tab G-94-188, G-203-214, G-215, K-8, K-22-30, T-2)

Table 3 MW 90 Day look-back (Tab G-94-188)

	Hours	Sorties
Last 30 Days	29.5	8
Last 60 Days	41	17
Last 90 Days	41	17

MW qualifications were not contributory to this mishap.

9. MEDICAL

a. Qualifications – Mishap Crew (MC)

The AIB medical member reviewed all available MC medical and dental records in their entirety. At the time of the mishap, both the MP and the MW were medically qualified for flight duty without restrictions. Annual flight physical examinations (Preventive Health Assessments) were current for both the MP and MW.

b. Health

Medical and dental record review indicated that the MP and MW were in good health and had no performance-limiting condition or illness prior to the mishap. There was no evidence any medical or dental condition of the MP or MW contributed to the mishap. Review of post-mishap medical records for the MP and MW revealed no significant injuries.

c. Toxicology

Toxicology samples were drawn on the day of the mishap from the MP, MW and 30 maintenance members who had recently serviced the MA. Blood and urine samples were submitted to the Armed Forces Medical Examiner System (AFMES), Dover AFB, DE, for toxicological analysis. Testing included carbon monoxide and ethanol levels in the blood and urine screening for drugs. The AIB medical member reviewed the results of the toxicology screening in their entirety. All toxicological results were normal for all individuals tested.

d. Lifestyle

Review of the 72-hour and 14 day histories of the MP, MW and pertinent maintenance crewmembers as well as interviews with the MP and MW, revealed no lifestyle factors, including

medication or supplement use, alcohol use, unusual habits, behaviors or stressors which were causal or contributory to the mishap. (Tab V-1.3, V-1.12, V-2.3, V-2.15)

e. Crew Rest and Crew Duty Time

Air Force Instructions require crewmembers to have proper crew rest, as defined in AFI 11-202, Volume 3, *General Flight Rules*, dated 22 Oct 2010, Incorporating ACC Supplement 9 Mar 2012, prior to performing in-flight duties. Crew rest is defined as a minimum 12-hour non-duty period before the designated flight duty period (FDP) begins. During this time, an aircrew member may participate in meals, transportation, or rest, as long as he or she has the opportunity for at least eight hours of uninterrupted sleep. Without a waiver, the FDP is limited to a maximum of 12 hours for a single-pilot aircraft. This period begins when an aircrew member reports for a mission, briefing, or other official duty.

A review of the duty cycles of the MP and MW leading up to the mishap indicated that both had adequate crew rest. Both the MP and MW indicated they were well rested and had no complaints. The MC did not exceed the FDP. Both the MP and MW indicated they did not suffer from undue stress, fatigue, sleep cycle disturbance, or lack of rest prior to or during the mishap sortie. Fatigue was not a causal or contributory factor in this mishap. (Tab V-1.3, V-1.12, V-2.3, V-2.15)

10. OPERATIONS AND SUPERVISION

a. Operations

The 391st EFS is a skilled combat squadron with a total of 34 assigned pilots, 62% of whom are experienced, and 26 assigned WSOs, 50% of whom are experienced. Ten of the 34 assigned pilots are qualified as instructors, while five of the 26 assigned WSOs are instructors. (Tab K-22-30). To be considered "experienced", F-15E crewmembers must meet an AFI-mandated level of 500 hours in the aircraft. At the time of the mishap, the operations tempo of the 391st EFS had recently picked up with the addition of more jets arriving from Mountain Home AFB, ID. The tempo was still considered in the realm of normal operations. (Tab V-4.1) There were no indications that 391st operations contributed to the mishap.

b. Supervision

Supervision at the squadron, group, and wing level was sufficient and appeared engaged. Additionally, the 391st EFS squadron commander was present for the brief to the MC, acting as the FL of the separate two-ship of F-15Es conducting Red Air. (Tab K-8) The squadron commander also participated in the search and rescue of the MC. (Tab R-14-21, R-27-28)

The calculated Operational Risk Management (ORM) level of the mission was GREEN. This is the lowest level of risk and places the authority to continue the mission with the aircraft commander or flight lead. Specific items considered in the ORM assessment were inexperienced aircrew in the formation, 4vX (Four versus unknown number of adversaries), Air Combat Tactics (ACT), detailed flight planning, 12-13 hours of crew rest and operations tempo. The Operations Supervisor on duty was experienced and qualified. (Tab K-20-22)

11. HUMAN FACTORS

a. Overview

The AIB considered all human factors as prescribed in the Department of Defense Human Factors Analysis and Classification System (DoD HFACS) as delineated in AFI 91-204 Attachment 5, 24 Sep 2008, to determine those that were potentially causal or contributory to the mishap. The DoD-HFACS describes four main tiers of factors that may contribute to a mishap. From most specific (applied to an individual) to most general, they are: Acts, Pre-Conditions, Supervision, and Organizational Influences. After reviewing the facts of the investigation, including witness testimony, human factors believed to be present in this mishap are enumerated below. **No human factor was causal or contributory to this mishap.**

b. Noncontributory Human Factors

(1) Acts

Acts are those factors that are most closely tied to the mishap, and can be described as active failures or actions committed by the operator that result in human error or unsafe situations. No MC Acts were causal or contributory to the mishap. Based upon the reported complete loss of power inflight and assessed wind milling of the left engine at impact, the AIB does find it likely the MP inadvertently shut down the left engine while performing the ENGINE FIRE INFLIGHT checklist. This action would have had little impact on the mishap sequence of events as both the persistent fire in the right engine and the loss of aircraft control already met bailout criteria at the time this would have occurred.

(2) Preconditions

Preconditions are factors in a mishap if active and/or latent preconditions such as conditions of the individuals, environmental or personnel factors affect practices, conditions or actions of individuals and result in human error or an unsafe situation.

(a) Environmental Factors

Environmental Factors are factors in a mishap if physical or technological factors affect practices, conditions, and actions of an individual and result in human error or an unsafe situation.

(i) Seating and Restraints

Seating and Restraints is a factor when the design of the seat or restraint system, the ejection system, seat comfort or poor impact-protection qualities of the seat create an unsafe situation. The MW seat performed a Mode 1 ejection in Mode 2 conditions, which has the potential to cause injury. (Tab H-2-12) The MW did not sustain any significant injuries. As such, the ejection seat malfunction was noncontributory to the events of this mishap.

(b) Conditions of Individuals

Conditions of Individuals are factors in a mishap if cognitive, psycho-behavioral, adverse physical state, or physical/mental limitations affect practices, conditions or actions of individuals and result in human error or an unsafe situation.

(i) Cognitive Task Oversaturation

Cognitive Task Oversaturation is a factor when the quantity of information an individual must process exceeds their cognitive or mental resources in the amount of time available to process the information. Both the MP and the MW commented on their inability to troubleshoot the large amount of warnings displayed on the MPD. (Tab V-1.8, V-2.5) Despite inability to process all the information, the mishap crew recognized the critical warning of RIGHT ENGINE FIRE and ensured completion of the corresponding ENGINE FIRE INFLIGHT checklist to include proper ejection from the aircraft. (Tab V-1.7-1.8, V-2.4-2.5) Cognitive task oversaturation was not causal or contributory to this mishap.

(ii) Channelized Attention

Channelized Attention is a factor when the individual is focusing all conscious attention on a limited number of environmental cues to the exclusion of others of a subjectively equal or higher or more immediate priority, leading to an unsafe situation. Channelized Attention may be described as a tight focus of attention that leads to the exclusion of comprehensive situational information. The mishap crew recognized the critical warning of RIGHT ENGINE FIRE and ensured completion of the corresponding ENGINE FIRE INFLIGHT checklist to include proper ejection from the aircraft. (Tab V-1.7-1.8, V-2.4-2.5) While the mishap crew was clearly channelized on resolution of this emergency procedure (no radio calls, other warnings not addressed etc.) (Tab V-1.8, V-1.10, V-2.5, V-2.14), their prioritization was appropriate considering the catastrophic events occurring with the jet. Channelized Attention was not causal or contributory to this mishap.

(c) Personnel Factors

Personnel Factors are factors in a mishap if self-imposed stressors or crew resource management affect practices, conditions or actions of individuals and result in human error or an unsafe situation.

(i) Cross-monitoring performance

Cross-monitoring performance is a factor when crew or team members failed to monitor, assist or back-up each other's actions and decisions.

(ii) Communicating Critical Information

Communicating Critical Information is a factor when known critical information was not provided to appropriate individuals in an accurate or timely manner.

(iii) Personnel Factor Analysis

The MC ran two emergency procedure checklists: SINGLE ENGINE OVERTEMP and ENGINE FIRE INFLIGHT. During SINGLE ENGINE OVERTEMP checklist, the MC describes crew coordination where the MP informed the MW of critical information (he was shutting down the right engine) and the MW responded with guarding the left throttle to cross monitor the MP's performance. (Tab V-1.6-1.7, V-2.4) During the ENGINE FIRE INFLIGHT checklist, no communication of the checklist between the crew was reported. (Tab V-1.7-1.8, V-2.4-2.5, V-2.11-2.14) The MW did not again guard the left throttle, and in his statement, the MW was unsure exactly what parts of the checklist were completed. (Tab V-2.11-2.14) While both the communication of critical information and the subsequent cross monitoring of performance were sub-optimal during the ENGINE FIRE INFLIGHT checklist, the AIB found that aircrew coordination did not change the mishap outcome or significantly change the mishap sequence of events. Personnel Factors were not causal or contributory to this mishap.

(3) Supervision

Supervision is a factor in a mishap if the methods, decisions or policies of the supervisory chain of command directly affect practices, conditions, or actions of individuals and result in human error or an unsafe situation. There is no evidence that any supervisory factors resulted in human error or the creation of an unsafe situation. Supervision was not causal or contributory to this mishap.

(4) Organizational Influences

Organizational influences are factors in a mishap if the communications, actions, omissions or policies of upper-level management directly or indirectly affect supervisory practices, conditions or actions of the operator(s) and result in system failure, human error or an unsafe situation. There is no evidence that any Organizational Influences resulted in system failure, human error or an unsafe situation in this mishap. Organizational Influences were not causal or contributory in this mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Directives and Publications Relevant to the Mishap

(1) AFI 11-2F-15E, Volume 1, *F-15E—Aircrew Training*, 31 Mar 2011
(2) AFI 11-2F-15E, Volume 2, *F-15E—Aircrew Evaluation Criteria*, 7 Dec 2011
(3) AFI 11-2F-15E, Volume 3, *F-15E—Operations Procedures*, 11 Aug 2009
(4) AFI 11-202, Volume 3, *General Flight Rules*, 22 Oct 2010, Incorporating ACC Supplement 9 Mar 2012

(5) AFI 11-214, *Air Operations Rules and Procedures*, 22 Dec 2005, with Change 2 dated 2 Jun 2009
(6) AFI 11-301, Volume 1, *Aircrew Flight Equipment (AFE) Program*, 25 Feb 2009, Incorporating ACC Supplement 23 Apr 2010
(7) AFI 11-418, *Operations Supervision*, 15 Sep 2011
(8) AFI 48-123, *Medical Examinations and Standards*, 24 Sep 2009 with Change 2 dated 18 Oct 2011
(9) AFI 51-503, *Aerospace Accident Investigations*, 26 May 2010
(10) AFI 91-204, *Safety Investigations and Reports*, 24 Sep 2008
(11) *Air Force Tactics, Techniques and Procedures (AFTTP) 3-3.F-15E, Combat Aircraft Fundamentals F-15E*, 4 Nov 2011
(12) Technical Order (T.O.) 1F-15E-1-2-1, *F-15E Flight Manual*, 1 Jul 2009 with Change 3 dated 15 Jan 2012.
(13) T.O. 1F-15E-34-1-1, F-15E *Nonnuclear Weapon Delivery Manual*, 1 Jul 2009 with Change 2 dated 15 Jan 2012.

b. Maintenance Directives and Publications

(1) AFI 21-101, *Aircraft and Equipment Maintenance Management Combat Air Forces (ACC)I*, 28 Dec 2010
(2) AFI 21-124, *Oil Analysis Program*, 8 Dec 2010
(3) T.O. 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies and Procedures*, 15 Jul 2011, Incorporating ACC Supplement 28 Dec 2010.
(4) T.O. 1F-15E-2-DV-1, *Integrated Maintenance Information System*, 15 Nov 2011
(5) T.O. 1F-15E-2-00GV-1, *General Vehicle-Aircraft Design*, 15 Nov 2011
(6) T.O. 1F-15E-2-24SD-00-1, *Schematic Diagram-Electrical*, 1 Jun 2012
(7) T.O. 1F-15E-2-29GS-00-1, *General System-Hydraulic Power*, 15 Dec 2011, Change 20
(8) T.O. 1F-15E-2-71GS-02-1, *General System-Power Plant*, 15 Nov 2011
(9) T.O. 1F-15E-2-71FI-02-1, *Fault Isolation-Power Plant*, 15 Nov 2011
(10) T.O. 2J-F100-1-CD-6, *Interactive Electronic Technical Manual with Engine Automated Work Package*, 15 Jan 2012, Revision 31
(11) T.O. 2J-F100-56-5, *Intermediate Maintenance Instruction, Aircraft Engine*, 15 Sep 2006, Change 56
(12) T.O. 42B-1-1, *Quality Control of Fuels and Lubricants*, 15 Jun 2011

NOTICE: The AFIs listed above are available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**

c. Known or Suspected Deviations from Directives or Publications

The aft ACES II ejection seat was inspected on 20 Jan 2011. During this 36-month inspection, egress personnel tested the Environmental Sensors (ES) for serviceability in accordance with applicable TOs. The test results indicated that the aft ejection seat failed step 23 of the

inspection. The ES should have been removed and replaced (condemned) and not installed on the ejection seat. (Tab H-2-12, H-76-77)

13. NEWS MEDIA INVOLVEMENT

News media interest in the mishap was low. There were no known media reports or inquiries beyond 4 May 2012.

14. ADDITIONAL AREAS OF CONCERN

a. Aircrew Flight Equipment

Although not causal or contributory to the mishap, the AIB notes with concern the striking similarity between the inadequate performance of the Personal Locating Beacons and the MW's ACES II ejection seat in this mishap and similar malfunctions during the 24 Oct 2011 mishap involving an F-15C aircraft at Nellis AFB, NV. (Tab H-2-12, H-76-77, J-129-164, FF)

(1) Personal Locating Beacon

Neither of the MC's PLB performed as expected. The MW's PLB was completely inoperative and the MP's PLB sent out a delayed signal on a satellite radio frequency but not on either monitored line-of-sight emergency frequencies. (Tab J-129-164, R-5-9, R-14-21) Due to this malfunction, ATC and the MFL were unaware of the mishap until the MP was able to call manually via his survival radio after landing on the ground. (Tab R-5-11, R-14-21, R-22-24, R-27-28, V-1.11) Should the MC have been incapacitated in the ejection from the aircraft, awareness of their mishap and subsequent location would have been significantly delayed.

(2) ACES II Ejection Seat Performance

The MW's ACES II ejection seat incorrectly performed a Mode 1 ejection well into Mode 2 altitude and airspeed parameters. In a Mode 2 ejection, the ACES II seat deploys a drogue chute to slow the speed of the seat prior to deployment of the main parachute. This reduces the opening shock experienced by the crewmember, with the intent of minimizing flailing injuries. (Tab H-2-12, V-2.6, V-2.15) An environmental sensor that facilitates proper mode employment of that ACES II seat had failed a previous inspection and was not replaced. (Tab H-76-77, R-53)

24 August 2012

HENRY L. CYR, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

F-15E, T/N 90-0254
Southwest Asia
3 MAY 2012

Under 10 U.S.C. 2254(d), any opinion of the accident investigators 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.

On 3 May 2012 at approximately 0718Z/1118L the mishap aircraft (MA), forward deployed with the 391st Expeditionary Fighter Squadron to the 380th Air Expeditionary Wing, Southwest Asia, impacted the ground approximately 65 nautical miles south of the host nation Air Base. The mishap sortie was a training mission deployed under a Theater Support Package to the United States Central Command (CENTCOM) Area of Responsibility (AOR). The crash occurred in an unpopulated area and the MA was destroyed with a loss valued at $45,538,495.76. The mishap crew (MC) safely ejected from the aircraft with no injuries and was quickly recovered by host nation search and rescue forces. No known civilian injuries resulted from the mishap, and only minimal damage to a few irrigation lines occurred. There was little media interest following the initial reports of the mishap.

I find by clear and convincing evidence the cause of the mishap was catastrophic failure of the right engine. Additionally, I find by clear and convincing evidence the cause of engine failure was a rare ignition of the titanium components within the engine resulting in an extremely destructive fire. Based upon the condition of the engine after the crash it was not possible to determine the cause of the fire. However, post-flight analysis ruled out all but Domestic Object Damage as the origin of the fire. The resulting fire caused associated failure of critical hydraulic and electrical systems. The loss of the right engine and critical systems made the aircraft uncontrollable, resulting in the eventual crash.

I find by a preponderance of evidence that the loss of aircraft hydraulic systems was a substantially contributing factor to the mishap. The loss of the PC2 and utility hydraulic systems and the likely loss of the secondary PC1A system made the aircraft uncontrollable, compounding the engine fire emergency.

1. DISCUSSION OF OPINION

a. Background

The MC was comprised of an experienced 4-ship flightlead-qualified pilot and experienced instructor Weapon Systems Officer (WSO). Both crewmembers were highly regarded by their squadron leadership for their motivation and expertise. The Mishap Pilot (MP) had been deployed since mid-March 2012 and flown 14 sorties; the Mishap WSO (MW) had deployed on

15 Apr 2012 and was on his first flight in theater, a Local Area Orientation sortie. The MC was flying as a wingman in a package of six F-15Es acting as Red Air. The Red Air package was tasked to attack several ground targets which were being defending by a Blue Air package consisting of a 6-ship of F-15Cs and 2-ship of F-15Es. The unit's operational tempo was characterized as low, with the recent arrival of additional F-15Es and aircrew increasing operational tempo to moderate. The MC received proper crewrest prior to the mishap sortie. With the sortie taking place during the day and consistent with the MC's circadian rhythm, fatigue was not considered a factor.

Mission preparation, pre-flight briefings, ground operations, takeoff, climb and initial sortie training profile events were all uneventful.

After initially flying the training profile with the flightlead as a 2-ship formation, the MA separated from lead and continued to ingress towards the intended target as a single ship. At 1116:20L, the MP initiated a climb from 2400 feet to 10,000 feet to meet airspace requirements and advanced the throttle to the maximum afterburner setting. Passing through approximately 5500-6000 feet the MC heard a loud bang. The MC observed an overtemp condition on the right engine and shut it down. Near simultaneously, the MP began to experience controllability issues that caused the aircraft to roll and yaw to the right. To overcome the uncommanded roll and yaw to the right, the MP applied full left aileron and full left rudder; the aircraft responded in a sluggish manner. Upon shutting down the right engine, the MC lost use of the PC2 hydraulic system and right electrical generator. Through both post-mishap technical analysis and flight simulator evaluation, I assess the MA lost its utility hydraulic system due to the uncontained engine fire. Loss of both the PC2 and utility hydraulic systems made further operation of the right side control surfaces uncontrollable. In addition to providing primary and back-up hydraulic pressure for operation of aircraft systems, the utility hydraulic system provides the power to run the emergency generator. Loss of the utility system made the emergency generator inoperative. Loss of both the right electrical generator and emergency generator resulted in only the left electrical generator to provide aircraft power.

At 1116:35L, with the aircraft in approximately 100 degrees of right roll, the MP initially called for MC bailout. In the midst of the ejection sequence, the MP aborted the action with the intent to put the aircraft in a more level attitude. At 1116:55L, upon rolling the aircraft left, back to approximately 10 degrees right roll attitude, the MP jettisoned the external stores in an attempt to improve aircraft controllability; this had no apparent effect and the MP continued to struggle with aircraft control. Quickly following, the MC received audible and warning panel indications of a fire in the right engine and Aircraft Mounted Accessory Drive. The MP initiated the ENGINE FIRE INFLIGHT checklist and employed the fire extinguisher system in an attempt to put out the fire in the right engine compartment. At approximately 1117L, the MA experienced complete electrical failure, resulting in a loss of aircraft instrumentation and communications systems.

At this point, the MP looked to the rear of the aircraft and saw there was still fire coming from the right engine compartment. With the aircraft at the prescribed uncontrolled bailout altitude and fire continuing to burn in the right engine compartment, the MP used hand signals to communicate with the MW to initiate bailout. The MC safely ejected from the aircraft. The

aircraft crashed approximately 10-20 seconds later in a 60-80 degree nose-low and inverted attitude.

b. Cause

I have developed my opinion on the cause of this mishap and its contributing factors through a thorough consideration of flight data, witness testimony, assistance by subject matter experts, flight simulator testing, technical analysis of post-crash aircraft components, comprehensive human factors analysis and a review of supporting documentation, to include aircraft maintenance records, individual training and medical records, Air Force and contractor technical guidance and Department of Defense and Air Force instructions. Through this review, I determined that aircrew training and qualifications, weather conditions, flight and organizational supervision, operational tempo and initial sortie profile events were not causal or contributory to the mishap.

At the point in the sortie where the MP initiated a climb, applied maximum afterburner and the MC heard a loud bang, for an unknown reason, a fire of the titanium components began in the 5th stage of the right engine. The fire in the right engine reached temperatures of approximately 3315 degrees C, quickly burning through the engine casing and into the fuselage. This caused catastrophic damage to the remainder of the engine due to thermal and domestic object damage and to surrounding aircraft structure due to thermal damage, leading to associated failure of critical hydraulic and electrical systems. Post-flight analysis ruled out all but Domestic Object Damage as the origin of the fire. However, due to the post-mishap condition of the 5th stage section of the engine I was unable to determine by clear and convincing evidence the source of the DOD. The loss of the right engine and critical systems made the aircraft uncontrollable, resulting in the crash.

c. Substantially Contributing Factor

I find by a preponderance of evidence the loss of two of the aircraft's three hydraulics systems and a portion of the remaining system was a substantially contributing factor to the crash. The loss of these systems added significantly to the complexity of the situation faced by the MC. The F-15E is built with redundant hydraulic and electrical systems to minimize the likelihood a single emergency will make the aircraft unflyable. Due to the catastrophic failure of the right engine, the MC lost access to the primary hydraulic and electrical systems for that side of the aircraft. Under normal conditions, redundant left side and utility systems would have mitigated the loss of right side systems. With the subsequent loss of the utility hydraulic system, the crew lost emergency generator power and redundant control of the right side control surfaces. Although the continuing engine fire warranted bailout of the aircraft, the controllability problems induced by loss of critical hydraulic systems equally met bailout criteria.

2. CONCLUSION

I find by clear and convincing evidence the cause of the mishap was catastrophic failure of the right engine. In addition, I find by clear and convincing evidence the cause of the engine fire was a rare ignition of the titanium components within the engine resulting in an extremely destructive fire. The resulting fire caused associated failure of critical hydraulic and electrical systems. I find by a preponderance of evidence that the loss of aircraft hydraulic systems was a substantially contributing factor to the mishap as it made the aircraft uncontrollable. Both the ongoing engine fire and uncontrollability of the MA met bailout criteria. After attempting appropriate emergency procedures the MC safely ejected from the aircraft. The MA crashed soon after.

24 August 2012

HENRY L. CYR, Colonel, USAF
President, Accident Investigation Board