UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

F-35A, T/N 12-5052

61ST FIGHTER SQUADRON
56TH FIGHTER WING
LUKE AIR FORCE BASE, ARIZONA

LOCATION: MOUNTAIN HOME AIR FORCE BASE, IDAHO

DATE OF ACCIDENT: 23 SEPTEMBER 2016

BOARD PRESIDENT: COLONEL DALE E. HETKE

Conducted IAW Air Force Instruction 51-503

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

F-35A, T/N 12-5052
MOUNTAIN HOME AIR FORCE BASE, IDAHO
23 SEPTEMBER 2016

On 23 September 2016, at approximately 0852 hours local time, the mishap aircraft (MA), an F-35A, tail number 12-5052, assigned to the 61st Fighter Squadron, 56th Fighter Wing, Luke Air Force Base (AFB), AZ, but temporarily stationed at Mountain Home AFB, ID, experienced an uncontained engine fire during engine start. The MA aborted the start and the Mishap Pilot (MP) safely egressed the still burning aircraft. Maintenance crew members responded and extinguished the fire. The aft (rear) two thirds of the MA sustained significant fire damage. While total costs as a result of this mishap have yet to be determined, damages to the MA are estimated to be in excess of $17,000,000.

The Accident Investigation Board (AIB) President found, by preponderance of the evidence, that the cause of the mishap was the tailwind present during engine start. The tailwind forced hot air into the inlet of the Integrated Power Pack, which led to a series of events resulting in insufficient torque applied to the MA engine during start, and thus the engine rotation speed slowed. At the same time, fuel continued to be supplied to the engine at an increasing rate which enabled an uncontained engine fire. The fire came out the engine exhaust and was carried along the outer surfaces of the MA by the tailwind, causing significant damage. The fire was extinguished approximately twenty seconds after the initial visual indications of a fire.

SUMMARY OF FACTS AND STATEMENT OF OPINION
F-35A, T/N 12-5052
23 SEPTEMBER 2016

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

56 FW	56th Fighter Wing
56 OG	56th Operations Group
61 FS	61st Fighter Squadron
944 FW	944th Fighter Wing
A1C	Airman First Class
ACBT	Air Combat Training
ACC	Air Combat Command
ADA	Aircraft Dispatch Actions
ADCC	Assistant Dedicated Crew Chief
ADVON	Advanced Echelon
AETC	Air Education and Training Command
AF	Air Force
AFB	Air force Base
AFE	Aircrew Flight Equipment
AFFF	Aqueous Fire Fighting Foam
AFI	Air Force Instruction
AFMAN	Air Force Manual
AFOSH	Air Force Occupational Safety and Health
AFR	Air Force Reserves
AFSAS	Air Force Safety Automated System
AFSC	Air Force Specialty Code
AFTO	Air Force Technical Order
AGL	Above Ground Level
AGSM	Anti-Gravity Straining Maneuver
AIB/JPO/SME	Accident Investigation Board Joint Program Office Subject Matter Expert
AIB/LA	Accident Investigation Board Legal Advisor
AIB/MDM	Accident Investigation Board Medical Member
AIB/MXM	Accident Investigation Board Maintenance Member
AIB/P	Accident Investigation Board President
AIB/R	Accident Investigation Board Recorder
ALIS	Autonomic Logistics Information System
AMD	Aircraft Memory Device
AME	Alternate Mission Equipment
AMU	Aircraft Maintenance Unit
AMXS	Aircraft Maintenance Squadron
Anti-K	Anti Collision
APU	Auxiliary Power Unit
AROWS-R	Air Force Reserve Order Writing System-Reserves
ASE (ACE)	Arm/Safe/Egress
ATC	Air Traffic Control
ATIS	Automated Tactical Information System
ATP	Advanced Targeting Pod
Aug	Augmenter
AWACS	Airborne Warning and Control System
BAK	Barrier Arresting Kit
BFM	Basic Fighter Maneuvers
Bio	Biohazard Flight
Blvd	Boulevard
B-man	Fire guard
BOS	Before Operations Servicing-Inspection
BOSS	Backup Oxygen Switch
C/S (CS)	Counter Strike
CAC	Common Access Card
CAM	Camera
CAMS	Core Automated Maintenance System
Capt	Captain
CAT	Category
CC	Commander
C	Celsius
CCV	Vice Commander
CD	Compact Disc
CEF	Civil Engineer Fire Department
Cert	Certification
CES	Civil Engineer Squadron
CFETP	Career Field Education and Training Plan
CG	Center of Gravity
CMBT/CMB	Combat
CMD	Command
CMD	Command
Col	Colonel
Comm's	Communications
Comm	Communication
CPT	Captain
CSMU	Crash Survival Memory Unit
CT	Continuation Training
CVN	Wing Advanced Programs Office
DAF	Department of the Air Force
DAFSC	Duty Air Force Specialty Code
Degd	Degrade
Dept	Department
DET	Detachment
DNIF	Duties Not Including Flying
DOA	Director of Operations, A Flight
Doc	Doctor
DoD	Department of Defense
DoDI	Department of Defense Instruction
DO	Director of Operations
DRU	Direct Reporting Unit
DSN	Defense Switch Network
DVD	Digital Video (Versatile) Disc
ECP	Entry Control Point
EGT	Exhaust Gas Temperature
Elev	Elevation
EMS/EM	Emergency Medical Services
EO	Executive Order
EOR	End of Runway
EOTS	Enhanced Optical Targeting System
EP	Emergency Procedure

EPS	Electrical Power System
EPU	Emergency Power Unit
ER	Exceptional Release
ES/G	Engine Start Generator
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
ETR	Engine Thrust Rating (or Requested or Required)
Eval	Evaluator
FAB	Function Access Button
FADEC	Full Authority Digital Electronic Control
FC & PS	Flight Control & Power Systems
FC	Fire Chief
FCIF	Flight Crew Information File
FCL	Flight Check List
FCLGG	Full Coverage Lower Gravity Garment
FCS	Flight Control System
F	Fahrenheit
Flt Doc	Flight Doctor
FLT	Flight
FOA	Forward Operating Area
FOD	Foreign Object Damage
FOIA	Freedom of Information Act
FOUO	For Official Use Only
FP	First Pilot
Freq	Frequency
FSD	Flight Series Data
FS	Fighter Squadron
FTRSQ	Fighter Squadron
FTRWG	Fighter Wing
FW	Fighter Wing
GD	Gear Down
Gen	Generator
GM	Guidance Memorandum
GMMP (GUMP)	Ground Maintenance Motor Pump
GPS	Global Positioning System
GS	Government Service
GU	Gear Up
HARM	Host Aviation Resource Management
HDU	Helmet Display Unit
HQ	Headquarters
HRC	Health Reporting Code
HV	Helmet Vehicle Interface
IAF	Initial Approach Fix
IAW	In Accordance With
IBR	Integral Blended Rotor
ICAWS	Integrated Caution, Advisory and Warning System
ICC	Integrated Converter Controller
ICP	Integrated Core Processor
IDLH	Immediately dangerous to life or health
IFF	Identify Friend or Foe
ILS	Instrument Landing System
IMT	Information Management Tool
INS	Instrument Navigation System
Inst/Ins	Instructor

IO	Investigating Officer
IP	Instructor Pilot
IPP	Integrated Power Pack
IPUG	Instructor Pilot Upgrade
ISB/IO	Interim Safety Board Investigating Officer
ISB/MXM	Interim Safety Board Maintenance Member
ISB/P	Interim Safety Board President
ISB/R	Interim Safety Board Recorder
ISB	Interim Safety Board
ITL	Individual Task List
JA	Judge Advocate
JFS	Jet Fuel Starter
JPO	Joint Program Office
JTD	Joint Technical Data
KMUO	Mountain Home Air Force Base Airfield Designator
Kt	Knot
kW	Kilowatt
LEP	Laser Eye Protection
LM	Lockheed Martin
LO	Low Observable
LRIP	Low Rate Initial Production
Lt Col	Lieutenant Colonel
LTC	Lieutenant Colonel
M1	Maintainer 1
M2	Maintainer 2
MA	Mishap Aircraft
MAJCOM	Major Command
Maj	Major
MBR	Member
MCC	Mishap Crew Chief
MDS	Mission Design Series
MEF	Mission Execution Forecast
MEF	Mission Execution Forecast
METAR	Routine weather report provided at fixed intervals
MFR	Memorandum for Record
MG	Maintenance Group
MIL-DTL	Military Detail
Mil	Military
MIL-STD	Military Standard
MM1	Mishap Maintainer 1
MM2	Mishap Maintainer 2
MM3	Mishap Maintainer 3
MM	Mishap Maintenance
MOC	Maintenance Operations Control
MPH	Miles Per Hour
MP	Mishap Pilot
MP	Mission Pilot
MPO	Military Personnel Office
MPS	Mishap Production Superintendent
MSgt	Master Sergeant
MT	Mountain Home
MX	Maintenance

N/A	Not Applicable
N/S	Not Specified or Non-Servicable
NATO	North Atlantic Treaty Organization
NDA	Non-Disclosure Agreement
NOTAM	Notice to Airmen
NSTR	Nothing Significant to Report
Numb	Number
NVG	Night Vision Goggles
OBOGS	On Board Oxygen Generation System
OFDA	Operational Flying Duty Accumulator
OG	Operations Group
OGV	Operations Group Evaluations
OJT	On the Job Training
OPSAT	Opposed Surface Attack Tactics
OPSEC	Operations Security
OS	Operations Supervisor
OSK	Operations Support Flight
Oth	Other
P&W	Pratt & Whitney
P/N	Part Number
P/SME	Pilot Subject Matter Expert
P1	Pilot 1
P2	Pilot 2
P3	Pilot 3
PACAF	Pacific Air Forces
PAS	Personnel Accounting Symbol
PCD	Panoramic Cockpit Display
PCL	Pilot Check List
PCN	Pavement Classification Number
PE	Pulled Engine
Perm	Permanent
PGM CD	Program Code
PHM	Prognostics Health Management
PHYS	Physical
PIC	Pilot Interface Connector
PKI	Public Key Infrastructure
PLB	Personal Locater Beacon
PLF	Parachute Landing Fall
PMA	Portable Maintenance Aid
PMD-	Portable Memory Device
Posn	Position
POS	Post Operations Servicing-Inspection
PRI ACFT	Primary Aircraft
PRI CRW POS	Primary Crew Position
Pri	Primary
Pro Supe/Pro Super	Production Superintendent
Proj	Projected
PSI	Pounds Per Square Inch
PTMS	Power and Thermal Management System
PW/FSR	Pratt & Whitney Field Service Representative
QA	Quality Assurance
QRB	Quick Release Button
Rep	Representative
Res	Resolution
RPM-	Revolutions Per Minute

S/N	Serial Number
SAT	Surface Attack Tactics
Sec Clr	Security Clearance
Sec	Secondary
SEF	Flight Safety
SEP	September
Sep	Separation
SEPT	Safety and Emergency Procedure Training
SE	Safety
SFC	Specific Fuel Consumption
SIB/AFSEC/R	Safety Investigation Board Air Force Safety Center Representative
SIB/IO	Safety Investigation Board Investigating Officer
SIB/JPOA1	Safety Investigation Board Joint Program Office Advisor 1
SIB/JPOA2	Safety Investigation Board Joint Program Office Advisor 2
SIB/LMA	Safety Investigation Board Lockheed Martin Advisor
SIB/MDM	Safety Investigation Board Medical Member
SIB/MXM	Safety Investigation Board Maintenance Member
SIB/PM	Safety Investigation Board Pilot Member
SIB/P	Safety Investigation Board President
SIB/PWA	Safety Investigation Board Pratt & Whitney Advisor
SIB	Safety Investigation Board
SII	Special Interest Item
Sim	Simulator
SIO	Simultaneous Input Output
SOAP	Spectrometric Oil Analysis Program
SOF	Supervisor of Flying
SrA	Senior Airman
SRF	Squadron Read File
SRT	Sortie
SSAN	Social Security Administration Number
SSgt	Staff Sergeant
SVC	Service
T/N	Tail Number
TACAN	Tactical Air Navigation
TAMS	Tactical Aircraft Maintenance Section
TDY	Temporary Duty
TMS	Thermal Management System
TNG	Training
TSgt	Technical Sergeant
TS	Top Secret
U.S.C.	United States Code
UAV	Unmanned Aerial Vehicle
UCMJ	Uniform Code of Military Justice
UP	Upgrade Pilot
USAF	United States Air Force
UTC	Unit Training Code
UTC	United Technologies Corporation

VFR	Visual Flight Rules	WX	Weather
Vis	Visibility	Wx	Weather
VS BIT	Vehicle Systems, Built in Test	Z	Zulu
WPAFB	Wright-Patterson Air Force Base		
WT	Wheel and Tire		

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 13 January 2017, Major General Mark Anthony Brown, Vice Commander, Air Education and Training Command (AETC), appointed Colonel Dale E. Hetke to conduct an aircraft accident investigation of a mishap that occurred on 23 September 2016, involving an F-35A aircraft, tail number (T/N) 12-5052, at Mountain Home Air Force Base (AFB), ID. The aircraft accident investigation was conducted by the assembled Accident Investigation Board (AIB) at Luke AFB, AZ, Mountain Home AFB, ID, and Joint Base San Antonio-Randolph, TX, from 17 January 2017 through 10 February 2017, in accordance with (IAW) Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*. The Board recessed from 11 February 2017 through 28 March 2017 pending policy reviews of technical data and information collected as part of the Board's investigation for compliance determination with the Arms Export Control Act and claimed proprietary privileges. This report pertains only to the immediate causes of the 23 September 2016 mishap. Board members included a Legal Advisor (Colonel), a Medical Member (Captain), a Maintenance Member (Technical Sergeant), and a Recorder (Technical Sergeant). An F-35 Joint Program Office (JPO) Engineer (NH-04) was a Subject Matter Expert (SME) for the AIB (Tab Y-5 thru Y-12).

b. Purpose

In accordance with AFI 51-503, *Aerospace and Ground Accident Investigations*, this accident investigation board conducted a legal investigation to inquire into all the facts and circumstances surrounding this Air Force aerospace accident, prepare a publicly releasable report, and obtain and preserve all available evidence for use in litigation, claims, disciplinary action, and adverse administrative action.

2. ACCIDENT SUMMARY

On 23 September 2016, at approximately 0852 hours local time (L), the mishap aircraft (MA), an F-35A, T/N 12-5052, assigned to the 61st Fighter Squadron (FS), 56th Fighter Wing (FW), Luke AFB, AZ, but temporarily stationed at Mountain Home AFB, ID, experienced an uncontained engine fire during engine start. The Mishap Pilot (MP), assigned to the 944th Operations Group at Luke AFB, AZ, safely egressed the burning aircraft (Tab V-1.6). Maintenance crews responded and extinguished the fire (Tab V-3.6, V-5.1 and V-5.2). There was no damage to private property nor to the airfield. Total mishap damage costs are estimated to be in excess of $17,000,000 (Tab P-2 thru P-5).

3. BACKGROUND

The MA belonged to the 61 FS, 56th Operations Group (OG), 56 FW, AETC, stationed at Luke AFB, AZ. (Tabs CC-3 thru CC-36).

a. Air Education and Training Command (AETC)

AETC's primary mission is to recruit, train and educate Airmen to deliver airpower for America. It was established and activated in January 1942, making it the second oldest major command in the Air Force (AF) and its training mission makes it the first command to touch the lives of nearly every AF member. The command's vision is to forge innovative Airmen to power the world's greatest AF. The command's organization includes the AF Recruiting Service, two numbered air forces, and the Air University. AETC has more than 29,000 active duty members, 6,000 Air National Guard and AF Reserve personnel, and 15,000 civilian personnel. The command also has more than 11,000 contractors assigned. AETC flies approximately 1,300 aircraft. (Tab CC-3 thru CC-12).

b. 56th Fighter Wing (56 FW)

The 56 FW is the largest Fighter Wing in the world as part of Air Education and Training Command, and home to 23 squadrons with both F-35A Lightning II aircraft and F-16s. On 21 May 2015, the 56 FW conducted a change of mission ceremony including the F-35 Lightning II as part of the wing's new mission statement. The wing is also responsible for three additional squadrons under the 54th Fighter Group located at Holloman Air Force Base, New Mexico. (Tabs CC-13 thru CC-15).

c. 56th Operations Group (56 OG)

The 56 OG has operational control and responsibility for the entire fighter-training mission at Luke. The group is composed of an operations support squadron, a training squadron, eight fighter squadrons and two detachments. The unit supports the wing's mission to train the best F-16 Fighting Falcons and F-35A Lightning II pilots in the world.
(Tabs CC-22).

d. 61 Fighter Squadron (61 FS)

The 61 FS is Luke Air Force Base's first squadron to fly the Lockheed F-35A Lightning II, the Air Force's newest fighter. The 61 FS, known as the "Top Dogs", train instructor pilots and initial qualification pilots for Air Combat Command assignments. (Tab CC-23 thru CC-28).

e. F-35A – Lightning II

The Lockheed Martin F-35A Lightning II Coventional Takeoff and Landing variant is the United States Air Force's (USAF) latest 5th generation fighter. The F-35A is an agile, versatile, high-performance, 9g capable multirole fighter that combines stealth, sensor fusion, and unprecedented situational awareness. (Tab CC-29). It will bring an enhanced capability to survive in the advanced threat environment in which it was designed to operate. (Tab CC-29).

The F-35A's engine produces 43,000 pounds of thrust and consists of a 3-stage fan, a 6-stage compressor, an annular combustor, a single-stage high-pressure turbine, and a 2-stage low-pressure turbine. (Tab CC-30).

f. 944 Fighter Wing (944 FW)

The 944 FW is the Reserve associate unit to Luke AFB's 56 FW. They provide instructor pilots to train Active-Duty student pilots for their multi-role mission. The instructor pilots are in the 69th Fighter Squadron within the 944th Operations Group and 944 FW. (Tab CC-33 thru CC-36).

4. SEQUENCE OF EVENTS

a. Mission

The mission was scheduled as a Continuation Training four-ship sortie (a flight of four aircraft), call sign "Topdog", to the Mountain Home Range Complex consisting of the Paradise, Owyhee, and Jarbridge Military Operating Areas (MOA) (Tabs GG-3 and V-1.2). Continuation Training sorties are typical training missions flown to keep pilots current in required maneuvers, skills and tasks. In this case, four aircraft were scheduled as a formation and the MP was in the third aircraft. This sortie was scheduled to fly under the 61 FS allotment of flying hours for instructor pilot proficiency IAW the F-35 Ready Aircrew Program (RAP) Tasking Memo (Tab BB-25 thru BB-29). All USAF flying units have a yearly budget of hours for peacetime training, and the RAP Tasking Memo delineates what missions and types of training are to occur (Tab BB-25 thru BB-29).

b. Planning

The flight lead of the four-ship, Topdog 01, mission planned the sortie prior to the briefing and then briefed the other flight members (Tabs V-1.2 and GG-3). The briefing covered all required items IAW AFI 11-2F-35v3, including Notices to Airmen (NOTAMs), Special Interest Items (SIIs), forecast weather and planned flying events (Tabs R-104 thru R-106, V-1.2 to V-1.3 and BB-4 to BB-5).

c. Preflight

Prior to arriving at the aircraft, members of "Topdog" flight accomplished all required Go/No-Go items and completed an Operational Risk Management (ORM) assessment which was approved by the Operations Supervisor (Tabs K-2, T-7 thru T-16 and HH-3). Go/No-Go items are requirements which must be accomplished prior to flight, such as reading safety notices or accomplishing required training events. ORM assessments are made prior to every flight and take into account relevant factors that could affect the safety of the flight to include weather, aircrew fatigue levels and complexity of the mission. Preflight inspection of aircrew flight equipment (AFE) and the MA was accomplished uneventfully (Tabs V-1.3, HH-3 and HH-8). The MA had an electrical issue during the initial steps of the start procedure, but the MP successfully cleared the issue IAW the pilot checklist before initiating engine start (Tab V-1.4 and V-2.5). The electrical issue had no impact on the mishap.

d. Summary of Accident

On Friday, 23 September 2016, at approximately 0852L, the MP initiated an aircraft engine start on the parking ramp at Mountain Home AFB, ID, by placing the engine switch on the MA to RUN. Twenty four seconds later, hot gas was ingested into the Integrated Power Pack (IPP) inlet causing a corresponding increase in the IPP Exhaust Gas Temperature (EGT) (Tab DD-20). An IPP FAIL Integrated Caution, Advisory, Warning (ICAW) occurred 19 seconds later as the IPP performed an auto shutdown due to an EGT over-temp (Tab DD-20). The IPP FAIL ICAW was followed four seconds later by a FIRE GEAR ICAW, which indicated fire detection sensors located in the main landing gear wheel wells detected fire (Tab DD-9). During these events, several aircraft maintenance members witnessed flames come out of the engine exhaust, and then surround the aircraft moving toward the front of the MA (Tab V-2.5, V-3.3, V-4.5 and V-5.1). The Mishap Crew Chief informed the MP of the fire (Tab V-2.5). The MP accomplished most of the EGRESS procedures and safely evacuated the scene while maintenance crew members used a fire bottle (large fire extinguisher) to extinguish the fire (Tabs V-3.5, V-5.1 and BB-23). The fire burned for approximately 20 seconds (Tab DD-9 and DD-10). The fire damaged the aft two thirds of the MA's middle fuselage area before it was extinguished (Tabs P-3 thru P-5, Z-11, Z-13, Z-15 and Z-17).

e. Impact

Not applicable.

f. Egress and Aircrew Flight Equipment (AFE)

The MP performed a ground egress of the MA and sustained minor injuries as a result of the fire, to include burns on his head, neck, face, and ears (Tabs V-1.5 thru V-1.7, X-3, Z-3 and Z-5). The MP was wearing the appropriate AFE as directed by Joint Technical Data (JTD) and all AFE items were in serviceable condition with current inspections (Tab HH-8). The MP's helmet, sleeved flight jacket and skeletal G-suit were inspected post-mishap and damage was found mainly on the helmet (Tab FF-3). However, all items worn by the MP during the incident will be replaced due to the possibility of fuel coming in contact with the equipment (Tabs P-2 and FF-3).

g. Search and Rescue (SAR)

Not applicable.

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

The 61st Aircraft Maintenance Unit (AMU), Luke AFB, AZ, maintained the electronic records for the MA. Aircraft maintenance records are compiled in the Autonomic Logistics Information System (ALIS) which is used to create, update, and track non-expired items and maintenance inspection requirements. A detailed review of ALIS revealed maintenance forms documentation was consistent with applicable standards and no discrepancies were observed (Tab HH-8).

b. Inspections

Before the first flight of the day for any aircraft, an Air Vehicle (AV) Exceptional Release (ER) must be completed. The Production Superintendent completed an AV ER and documented it in ALIS prior to the mishap event IAW applicable AFI 21-101 (Tabs V-4.3 to V-4.4 and BB-32).

A Before Operations Servicing (BOS) inspection is a flight preparedness inspection performed by maintenance personnel and must be completed prior to aircraft flight. A Foreign Object Damage (FOD) Inlet inspection as well as a visual inspection of the engine's first stage components in the fan module and engine exhaust are incorporated into the BOS inspection. The last BOS inspection was completed on 22 September 2016 at 1920L with no defects noted (Tabs V-8.1 to V-8.2, V-10.1 and HH-8). The inspection was valid for 24 hours, which included the time of the mishap.

A Post Operations Servicing (POS) Inspection is an after flight inspection performed by maintenance personnel and is valid for 72 hours once completed. A POS is required after the last flight of the day or after a period of extensive maintenance operations and includes inspection of the engine. The last POS Inspection was completed on 22 September 2016 at 1922L in conjunction with the BOS inspection, with no defects noted (Tabs V-8.1 to V-8.2, V-10.1 and HH-8).

At the time of the mishap, F-35A engines required a data review after every flight to verify all engine parameters were met and there were no reported discrepancies requiring maintenance actions (Tab HH-7 to HH-8).

All scheduled inspections, engine data reviews and borescope inspections were completed IAW applicable JTD guidance with no discrepancies noted (Tab HH-7 to HH-8).

c. Maintenance Procedures

All maintenance procedures for the MA were reviewed during the investigation with no discrepancies observed (Tab HH-8).

d. Maintenance Personnel and Supervision

A thorough review of maintenance personnel, supervision, and training was conducted during the investigation with no discrepancies observed (Tabs G-9 thru G-41, V-4.2 to 4.3 and HH-8).

e. Fuel, Hydraulic, and Oil Inspection Analyses

No fluid samples were taken from the MA or associated servicing carts. After review of all evidence, there is no reason to believe any of the fluids were causal to the mishap.

f. Unscheduled Maintenance

A thorough review of maintenance records, including unscheduled maintenance performed on the MA, was performed during the investigation with no discrepancies noted (Tab HH-8).

6. AIRFRAME VEHICLE SYSTEMS

a. Structures and Systems

(1) Engine

The fire which surrounded the engine exhaust nozzle section led to damage of multiple external nozzle segments and multiple exhaust nozzle covers (Tab P-2).

(2) Main Landing Gear

The F-35A landing gear wheel wells are equipped with optical fire detectors. Crash Survivable Memory Unit (CSMU) (sometimes referred to as the "black box") data analysis indicated the main landing gear optical fire detectors were the first to detect a fire 47 seconds after the engine switch was set to RUN (Tab DD-8 and DD-9). The main landing gear fire detectors indicated fire was present for 20 seconds (Tab DD-9). The fire caused damage to multiple landing gear surfaces, surrounding areas and components in the left and right main landing gear wheel wells (Tab P-3 thru P-5) (See Figs-1, 2).

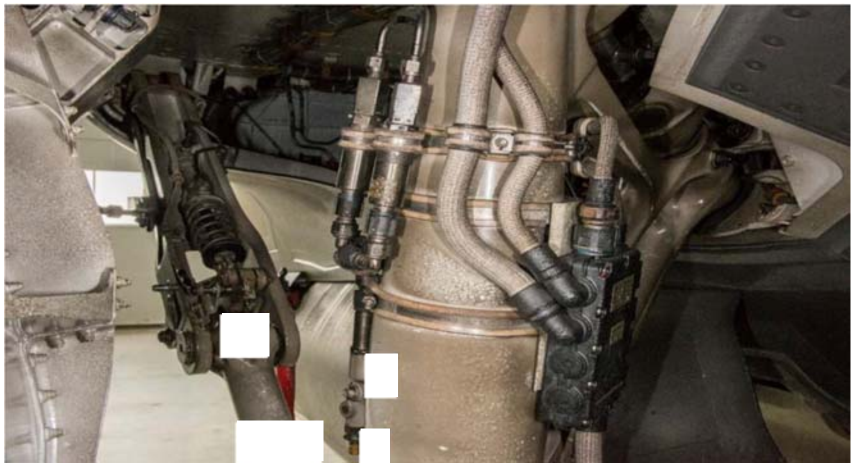

Fig 1. Left Side Landing Gear (Tab Z-11)

Fig 2. Right Side Landing Gear (Tab Z-13)

(3) Integrated Power Pack

The IPP was removed by 56 FW maintenance personnel and inspected by a Lockheed Martin IPP SME revealing the IPP requires replacement (Tab P-3).

(4) Weapon Bays

The F-35A aircraft weapon bays are located on the underneath portion of the aircraft on both the right and left side. The bays house various components and cables which allow aircraft systems to operate. The weapon bays have both inner and outer doors which close when commanded. Typically, the weapon bay doors remain open for ground procedures, to include engine start sequence, and are then closed after engine start. During the mishap, the open doors allowed the fire to enter both weapon bays causing damage to aircraft surfaces, panels, multiple system components, and multiple system wiring cables (Tab P-3 thru P-5) (See Figs-3, 4).

Fig 3. Right Side Weapon Bay (Tab S-6)

Fig 4. Left Side Weapon Bay (Tab Z-15)

(5) Airframe Structure and Skin

Many outer surfaces of the aircraft on the aft two thirds of the MA's center fuselage section exhibited varying degrees of fire damage. The majority of the damage occurred on the aircraft's aft most surfaces, mainly along the center portion of the jet, including the top, sides, and underneath portions of the aircraft. However, minor damage was noted on some surfaces even forward of the cockpit (Tab P-3 thru P-5) (See Figs-5, 6, 7).

Fig 5. Lower Left Section of Mishap Aircraft (Tab S-4)

Fig 6. Lower Right Section of Mishap Aircraft (Tab S-4)

Fig 7. Top Rear Aircraft (Tab Z-17)

b. Evaluation and Analysis

(1) Integrated Power Pack

The IPP is a mechanical system with a conventional auxiliary power unit and an emergency power unit combined. The IPP operates in two primary modes: burn mode (when the IPP is powering itself using its own combustion motor) and bleed mode (when the IPP is powered via bleed air from a running aircraft engine). During burn mode, air is drawn into the IPP motor through the IPP inlet and, after combustion, the air is pushed out through the IPP exhaust duct. (Tab DD-10).

The IPP is a major component for a normal F-35A aircraft ground engine start. The IPP is started and runs in burn mode for a few minutes before the pilot initiates aircraft engine start by moving the engine switch in the cockpit to RUN. The IPP then provides electrical power to the Integrated Converter/Controllers (ICCs), which in turn provide and regulate electrical power to the Engine Starter/Generator (ES/G). The ES/G converts the electrical power into mechanical power which is transferred to a shaft that rotates the aircraft engine during engine start. (In this respect, the ES/G performs just like a starter on a car). Once the aircraft engine reaches a self-sustaining rotation speed, the start sequence through the ES/G, ICCs, and the IPP is complete and the IPP transfers to bleed mode. (Tab DD-10 thru DD-12).

The Power and Thermal Management System (PTMS) monitors the entire start sequence. The PTMS monitors IPP inlet temperature because if the temperature rises, indicating hot-gas ingestion, the IPP motor becomes less efficient and turns at a slower speed. The PTMS recognizes this and takes action to return the IPP to full speed. The actions taken include reducing the electrical output to the ICCs (this reduces the load on the IPP) and increasing fuel flow to the IPP motor. These actions, known as hot-gas ingestion logic, continue until either the condition is cleared or an unsafe system operation is reached, which would then cause the PTMS to shut down the IPP. One indication of unsafe system operation is the IPP EGT becoming too high. (Tab DD-10 thru DD-12).

The MA IPP started and performed normally up through the beginning of aircraft engine start on the day of the incident. However, the IPP inlet temperature rose 24 seconds after the initiation of aircraft engine start (Tab DD-20) (See Fig-9). The only sources of hot gas in the vicinity were the IPP exhaust and the engine exhaust from the MA (See Fig-8).

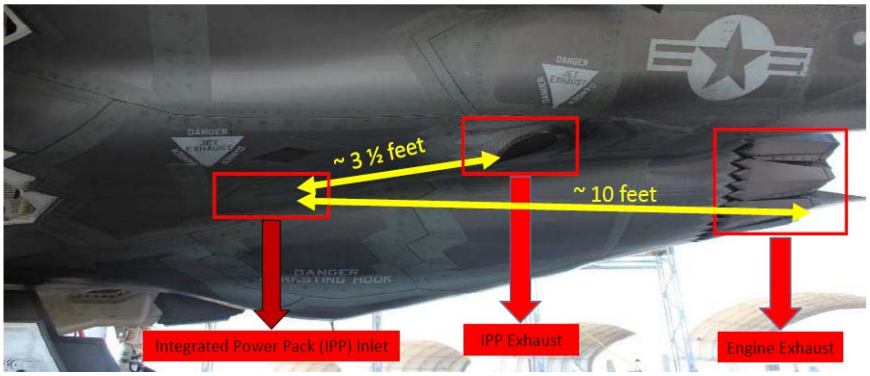

Fig 8. IPP Inlet and Exhaust Reference (Tab Z-9)

In response to the increased IPP inlet temperature, the PTMS began taking actions IAW the hot-gas ingestion logic. Power to the ICCs and ES/G was reduced (See Fig-10). Increased fuel was added to the IPP motor which contributed to increasing EGT (See Fig-11). These actions continued for 17 seconds, until the threshold for an IPP EGT over-temp was reached (Tab DD-20). The PTMS commanded the IPP to shut down two seconds later (Tab DD-20 and DD-21). The IPP and PTMS performed as designed (Tab DD-21). (See Figs-9, 10, 11).

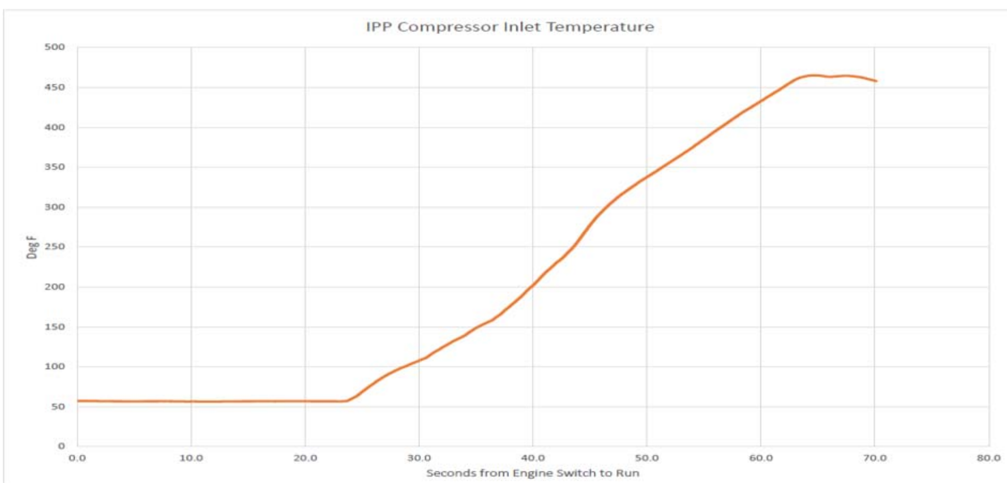

Fig 9. IPP Compressor Inlet Temperature (Tab Z-19)

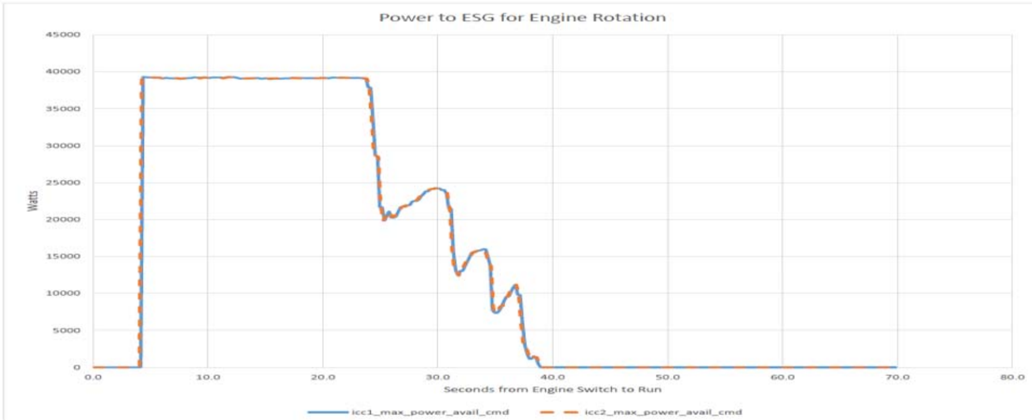

Fig 10. Power to ES/G for Engine Rotation (Tab Z-23)

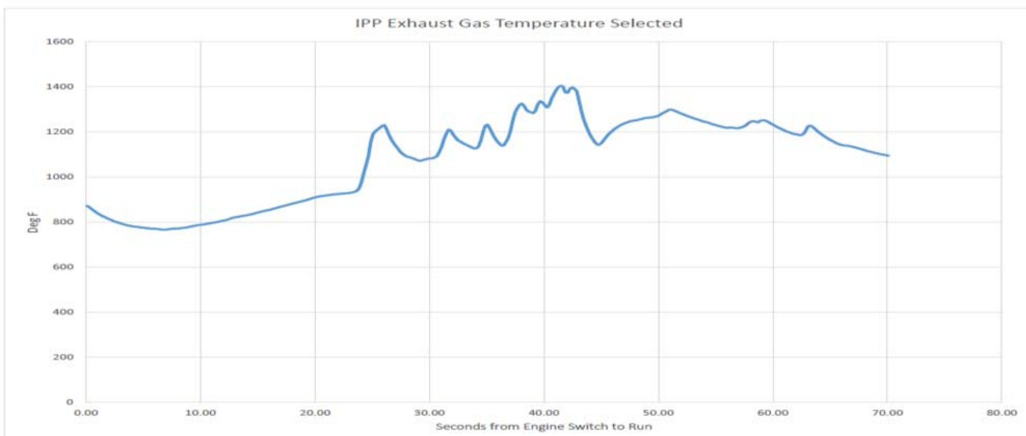

Fig 11. IPP Exhaust Gas Temperature (Tab Z-21)

(2) Engine

The F135 engine, developed by Pratt & Whitney, is a two spool, axial flow engine which provides up to 43,000 pounds of thrust. It contains compressor, combustion, turbine, and exhaust sections, similar to other jet engines (See Fig-12). The F135 engine initially is rotated by the ES/G during a normal start sequence. Once the ES/G accelerates the engine to a certain speed, fuel and ignition are provided to begin combustion. The ES/G and combustion then combine to accelerate the engine to increased speeds. When the engine reaches a speed at which it can sustain rotation by combustion alone, the ES/G stops providing rotation assistance. (Tab EE-5).

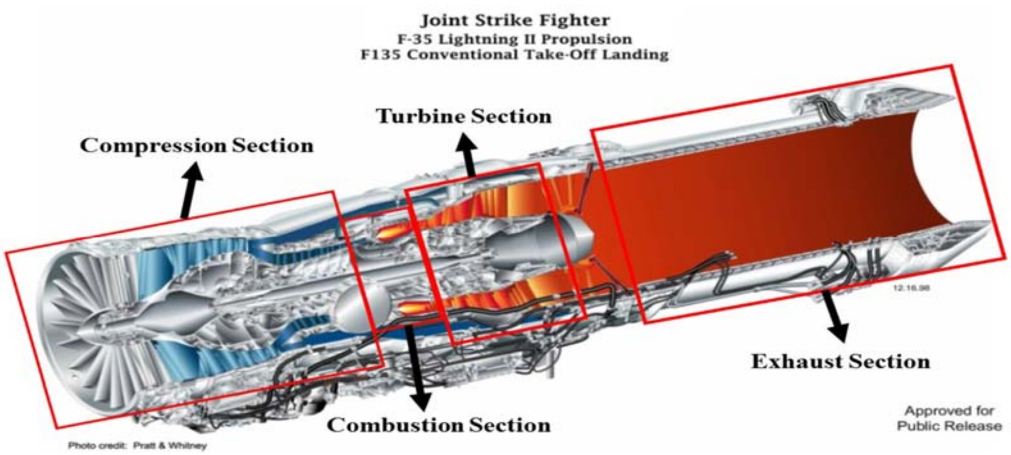

Fig 12. Engine Cutout Diagram (Tab Z-7)

The engine's rotation speed is monitored during start and if acceleration slows or stagnates after combustion has begun, the engine will try to correct the situation by adding fuel at an increasing rate. The fuel flow will continue increasing until the issue is resolved, a hardware limit is encountered or the rotation drops below a set speed. (Tab EE-10)

Analysis performed by P&W showed the MA engine's start was normal until just after combustion began (Tab EE-7) (See Fig-13). Approximately 24 seconds after start initiation, acceleration of the MA engine began to slow because power to the ES/G decreased due to increased IPP inlet temperature (See Figs-10, 13). Approximately nine seconds later (33 seconds after start initiation), increased fuel was added to the engine because of the slowed acceleration (See Fig-14). At approximately 39 seconds after start initiation, the ICCs stopped providing power to the ES/G (See Fig-10). At this time, the aircraft engine rotation was powered by combustion alone, which was insufficient to support engine acceleration, resulting in engine speed deceleration (See Fig-13). Increasing fuel flow to the aircraft engine continued until approximately 62 seconds after engine start initiation (See Fig-14). All systems operated as designed (Tab EE-12).

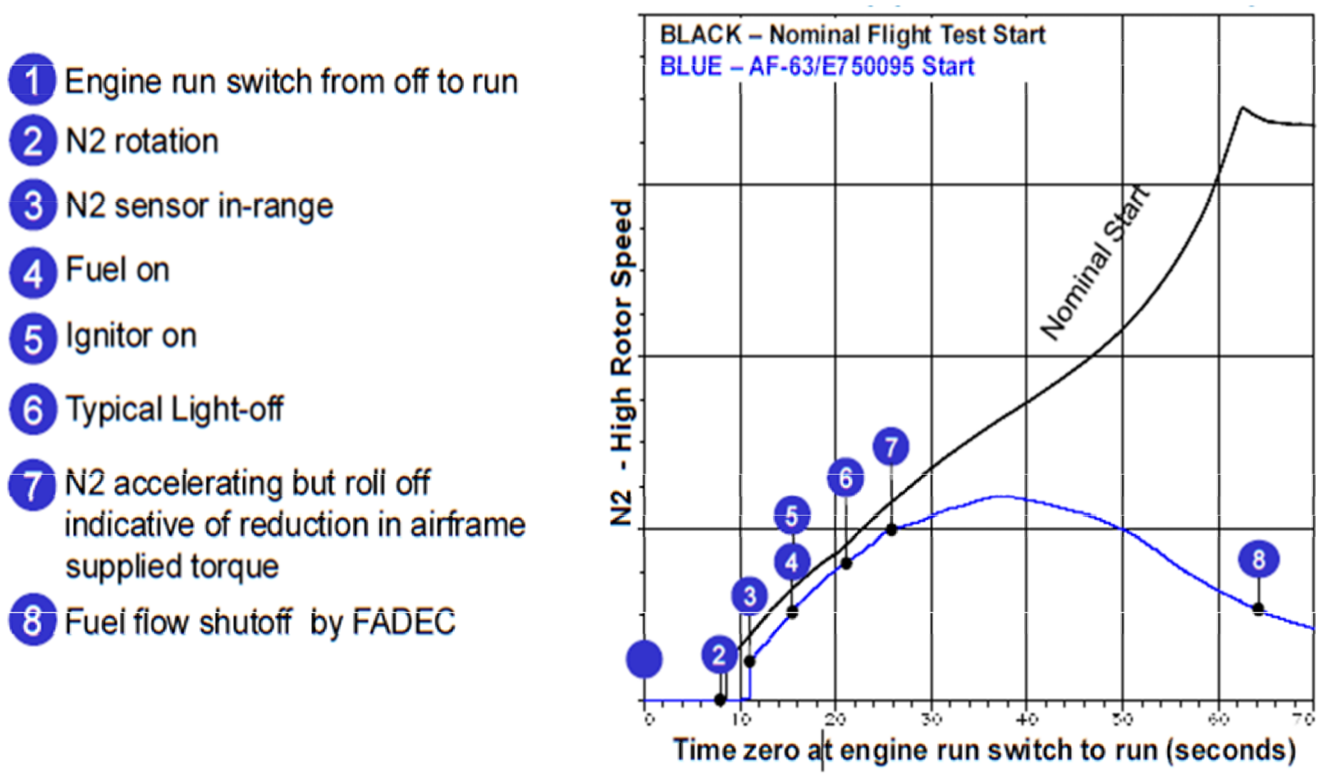

Fig 13. Significant Events During Engine Start (Tab EE-7)

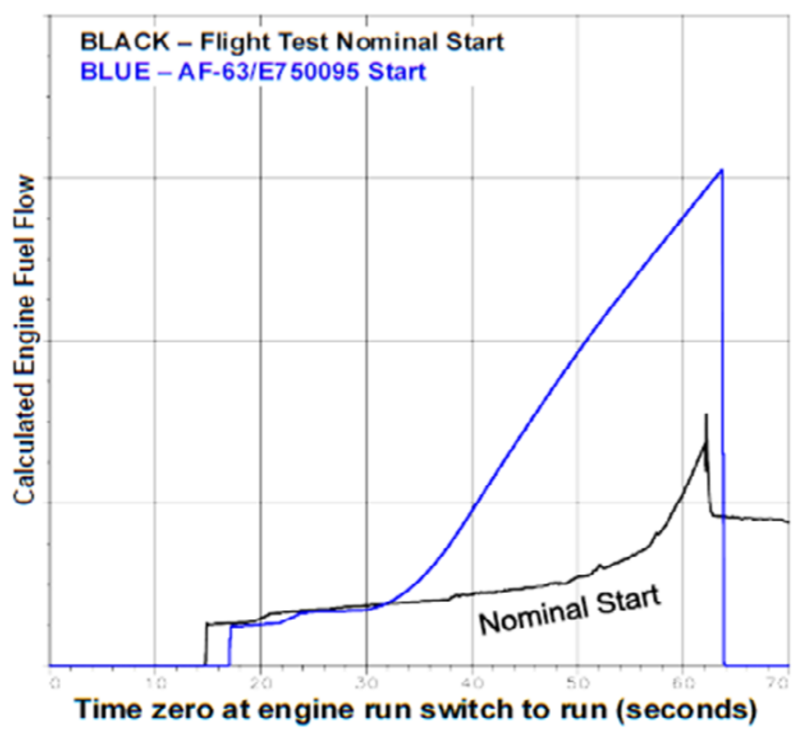

Fig 14. Fuel Flow During Engine Start (Tab EE-10)

(3) Fire

The F135 engine, like all combustion engines, has a fire in it while running. Under normal circumstances, the fire is contained in the combustion section of the engine. During this mishap, however, the fire became uncontained due to the increased amount of fuel added while the engine rotation speed was slowing. Once the uncontained fire started coming out the aircraft exhaust, the tailwind carried it rapidly along the exterior surfaces of the jet (Tab V-1.5 to V-1.6, V-2.5, V-3.4, V-4.5 and V-5.1 to 5.2).

(4) Wind

A wind sensor on the airfield recorded winds of 300 degrees at 34 knots at 0850L, and 290 degrees at 29 knots gusting to 37 knots at 0853L (Tab F-3). The MA engine start was initiated at approximately 0852L. The MA was parked facing a 120 degree heading. Therefore a direct tailwind of 30 knots or greater was present during engine start (See Fig-15).

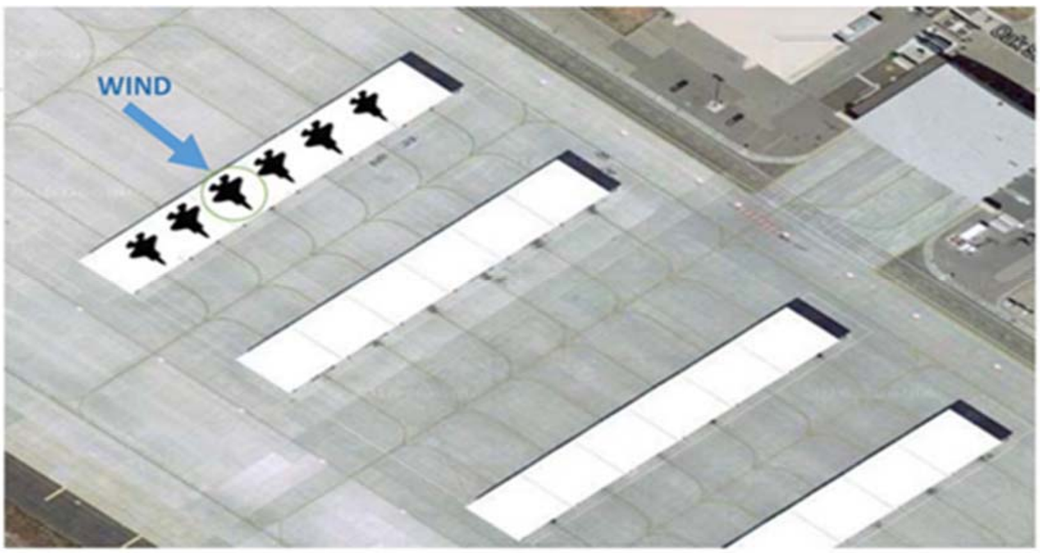

Fig 15. POSITION OF MA WITH RELATIVE WIND (Tab Z-25)

7. WEATHER

a. Forecast Weather

The weather forecast predicted clear skies, winds 320 degrees at 35 knots gusting to 45 knots and 7 statute miles of visibility (Tab F-2).

b. Observed Weather

An observation taken at 0909L reported skies clear below 12,000 feet. Winds were recorded at 300 degrees at 30 knots gusting to 36 knots. The temperature was 10 degrees Celsius (50 degrees Fahrenheit) and the runway was dry (Tab F-3).

c. Space Environment

Not applicable.

d. Operations

Operations were conducted and systems were operated within the designated limits. There was a NOTE in the pilot checklist stating issues could occur when starting the aircraft engine when a tailwind was present (Tab BB-24). However, there was no mention of a tailwind limit.

8. CREW QUALIFICATIONS

The MP was current and qualified as an F-35A Instructor Pilot (IP) with a current Form 8 flying evaluation (certificate of aircrew qualification), dated 25 March 2016 (Tab G-45). The MP was current and qualified in all aspects of the planned mission (Tab G-6 thru G-8).

The MP had a total of 2121.9 flight hours at the time of the mishap, of which 65.7 hours were in the F-35A (Tab G-3). The MP had a total of 751.9 hours as an IP in the F-16 and 20.9 hours as an IP in the F-35A (Tab G-3).

Recent flight time is as follows (Tab G-4):

	Hours	Sorties
Last 30 days	10.3	7
Last 60 days	11.8	8
Last 90 days	22.1	15

9. MEDICAL

a. Qualifications

The MP was medically qualified for flying duties at the time of the mishap. The MP's most recent annual military Periodic Health Assessment was performed on 22 December 2015 (Tab X-3). The MP's annual dental examination was performed on 7 October 2015 (Tab X-3). The medical records contained a current AF Form 2992, Medical Recommendation for Flying or Special Operational Duty, dated 17 May 2016 (Tab X-3). Review of the Aeromedical Information Management Waiver Tracking System database showed the MP had an approved waiver, dated 14 November 2002 with an indefinite expiration date (Tab X-3).

b. Health

The MP's records reflected good health and no recent performance-limiting illness prior to this mishap (Tab X-3). The MP successfully ground egressed from the MA. The injuries associated with ground egress were limited to minor burns, which completely healed (Tabs X-3, Z-3 and Z-5).

c. Pathology

Immediately following the mishap and IAW safety investigation protocols, blood and urine samples were collected from the MP and relevant maintenance personnel and submitted to the Armed Forces Medical Examiner System, Dover AFB, DE, for toxicological analysis. All blood samples tested negative for ethanol and carbon monoxide levels (Tab X-3 and X-5). All urine drug screen tests were negative (Tab X-3 and X-5).

c. Lifestyle

MP testimony, 72-hour/7-day histories and the medical chart of the MP revealed no lifestyle factors relevant to the mishap (Tabs R-8 thru R-12, R-13 to R-14, R-20 and X-3).

e. Crew Rest and Crew Duty Time

AFI 11-202, Volume 3, General Flight Rules, dated 10 Aug 2016, prescribes mandatory crew rest and maximum Flight Duty Periods for all personnel who operate USAF aircraft. Based upon witness testimony and supplemental history, crew rest was IAW AFI 11-202, Volume 3, paragraph 2.1 (Tabs R-4, R-8, R-9, X-3 and BB-8).

10. OPERATIONS AND SUPERVISION

a. Operations

A thorough review of 61 FS operations was conducted and no discrepancies or abnormalities were observed (Tab HH-5).

b. Supervision

The supervision for daily flying operations comes primarily from the Operations Supervisor, a daily duty manned by senior pilots in the squadron who brief all pilots before they fly. The Operations Supervisor is available to assist in the event of malfunctions and generally is the authority for immediate operational decisions. The Director of Operations is involved in squadron supervision by approving the daily flying schedule and accomplishing formal flying and simulator evaluations of the squadron instructors (Tabs R-95 and HH-5).

11. HUMAN FACTORS ANALYSIS

The Board evaluated human factors relevant to the mishap using the analysis and classification system model established by the Department of Defense Human Factors Analysis and Classification System guide, implemented by AFI 91-204, Safety Investigations Reports, dated 12 February 2014 (updated per MFR dated 19 January 2017) (Tab BB-14 thru BB-20).

a. Human Factor 1 OP003 (Procedural Guidance/Publications)

The pilot checklist in use at the time of the accident contained a NOTE on the ENG START ABNORM page, indicating engine start with a tailwind may cause IPP FAIL, requiring movement of the engine switch to the OFF position (Tab BB-24). This NOTE was not included as part of the ENG START checklist (Tab BB-22).

b. Human Factor 2 OP004 (Organizational Training Issues/Programs)

Pilots were not trained on tailwind engine start procedures and were not aware of any specific concerns related to tailwinds. Additionally, they did not have knowledge of specific limits or engine parameters to monitor during engine start, other than simply identifying that the aircraft displays were green/yellow/red. (Tabs V-1.3, V-1.5, V-9.2, V-9.3 and V-9.4).

c. Human Factor 3 PE205 (Automation), OC003 (Perceptions of Equipment), PC206 (Overconfidence), PC208 (Complacency), PC101 (Inattention)

The F-35A engine start process is heavily automated, which drove a perception among pilots the aircraft handled virtually all of the starting procedures and so long as the dials were "green" there were no problems (Tabs R-18, R-20, V-1.5 and V-9.7).

d. Human Factor 4 AE102 (Checklist Error), PC106 (Distraction), PE107 (Thermal Stress – Heat)

Upon recognition of the aircraft fire, MP initiated egress procedures per the F-35A pilot checklist (Tabs V-1.6 and BB-23). The MP stated he lifted the cover for the engine switch with the intent to turn it off, but could not recall whether he had actually moved the switch to the OFF position (Tab V-1.6 and V-1.7).

The aircraft memory indicated the engine switch was never moved to the OFF position (Tab DD-24). Further, examination of the switch immediately following the incident found it in the RUN position (Tabs S-6 and HH-9). Based on this objective evidence, the MP failed to move the engine switch to OFF, as directed by the checklist.

The MP was under duress and distracted immediately upon recognition of the fire (Tab V-1.6). The burn injuries sustained to his head, neck, face, and ears are further supportive of the urgency surrounding his circumstances and the necessity to prioritize egress from the aircraft above all else (Tabs R-4, R-18, R-19, R-43, R-74, R-91, V-1.5 to V-1.6, V-1.7, V-4.5 to V-4.6, V-5.1 to V-5.2, X-3, Z-3 and Z-5).

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 11-2F-35V3, AETC Supplement, *F-35A Operations Procedures,* 2 January 2013
(2) AFI 11-2F-F35AV3, *Flying Operations F-35A – Operations Procedures,* 7 June 2012
(3) AFI 11-202V3, *Flying Operations General Flight Rules,* 10 August 2016
(4) AFI 11-401, AETC Supplement, *Aviation Management,* 29 February 2016
(5) AFI 11-418, AETC Supplement, *Operations Supervision,* 20 May 2014
(6) AFI 13-201, AETC Supplement, *Space Missile, Command and Control,* 23 January 2013

(7) AFI 13-204, *Luke Airfield Operations and Base Flying Procedures,* 19 March 2015
(8) AFI 21-101, AETC Supplement, *Aircraft and Equipment Maintenance Management,* 18 November 2015
(9) AFI 21-101, Luke AFB Supplement, *Aircraft and Equipment Maintenance Management,* 7 May 2015
(9) AFI 11-201, *Flying Operations,* 31 March 2009
(10) AFI 91-204, AETC Supplement, *Safety Investigations and Reports,* 29 December 2015

NOTICE: All directives and publications listed above are available digitally on the Air Force Departmental Publishing Office website at: http://www.e-publishing.af.mil or the Official Department of Defense Website: http://www.dtic.mil/whs/directives/index.html.

b. Other Directives and Publications Relevant to the Mishap

(1) T.O. 00-20-1, AETC, *Aerospace Equipment Maintenance Inspection, Documentation, Policies and Procedures*
(2) T.O 00-35D-54, *USAF Deficiency Reporting, Investigating and resolution*
(3) LCL 366FW-10-11, 366th Maintenance Group Emergency Action Procedure for Aircraft Maintenance Squadron
(4) F-35A FSD, *Flight Series Data* (-1 Equivalent) Issue: September 20 2016
(5) F-35A JTD, Joint Technical Data (Maintenance Technical Order Equivalent) Issue: 20 September 2016
(6) ALIS-SHM, *Aircraft Maintenance Data*
(7) ALIS-CMMS, *Aircraft Maintenance Data*
(8) F35A-FCL-001 F-35A, *Pilots Checklist,* 8 June 2016

c. Known or Suspected Deviations from Directives or Publications

None.

Dale E Hetke

9 May 2017

DALE E. HETKE, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

F-35A, T/N 12-5052
MOUNTAIN HOME AFB, IDAHO
23 SEPTEMBER 2016

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

1. OPINION SUMMARY

On 23 September 2016, at approximately 0852 hours local time, the mishap aircraft (MA), an F-35A, tail number 12-5052, assigned to the 61st Fighter Squadron, 56th Fighter Wing, Luke Air Force Base (AFB), AZ, but temporarily stationed at Mountain Home AFB, ID, experienced an uncontained engine fire during engine start. The MA aborted the start and the Mishap Pilot (MP) safely egressed the still burning aircraft. Maintenance crew members responded and extinguished the fire. The aft (rear) two thirds of the MA sustained significant fire damage. While total costs as a result of this mishap have yet to be determined, damages to the MA are estimated to be in excess of $17,000,000.

I find by preponderance of the evidence, the cause of the mishap was the tailwind present during engine start. The tailwind forced hot air into the inlet of the Integrated Power Pack (IPP). The hot air ingestion resulted in a series of events leading to insufficient torque being applied to the MA engine during start; and thus the engine rotation slowed down. At the same time, fuel continued to be supplied to the engine at an increasing rate to compensate for the reduced rotation speed. The increasing fuel and slowing of the engine rotation enabled an uncontained fire. The fire came out the engine exhaust and was carried along the outer surfaces of the MA by the tailwind, causing significant damage. The fire was extinguished approximately twenty seconds after the initial visual indications of a fire.

I developed my opinion by analyzing factual data from historical records, engineering analysis, witness testimony, information provided by technical experts, Air Force directives, and Technical Orders.

2. CAUSE

The mishap was caused by a tailwind blowing hot air from either the MA IPP exhaust or MA engine exhaust into the IPP inlet. The hot air entering the IPP inlet started a sequence of events ultimately ending in an uncontained engine fire.

The F-35A Power and Thermal Management System (PTMS) monitors several systems on the aircraft including the IPP. The IPP inlet air temperature is one parameter monitored by the PTMS during aircraft engine start. When the IPP inlet air temperature increased, the IPP motor slowed down. The PTMS attempted to restore the IPP motor back to normal operating speed by reducing IPP electrical power output and increasing the amount of fuel to the IPP motor. The reduction of electrical power output meant a reduction of electrical power going to the Engine Starter/Generator (ES/G), which converts that electrical power into mechanical power used to turn the aircraft engine during engine start. Therefore, the ES/G was unable to turn the aircraft engine at speeds required for a normal start. The power to the ES/G continued decreasing until it reached zero.

However, as the ES/G began to lose power, the aircraft engine acceleration slowed prior to reaching a self-sustaining rotation speed. And, since engine combustion had already began, an increasing amount of fuel was delivered to the engine in an effort to increase combustion and overcome the slowing acceleration. The increasing amount of fuel was not able to overcome the loss of ES/G power and the engine continued to slow. The increasing fuel and slowing engine led to a fire too big to remain contained within the engine combustion section. The fire quickly grew and reached outside the engine exhaust, where it was then carried across the outer surfaces of the aircraft by the tailwind and caused significant damage.

3. SUBSTANTIALLY CONTRIBUTING FACTORS

a. Procedural Guidance/Publications

Neither publications nor guidance and training were adequate for the circumstances surrounding this incident. IPP and engine start issues with a tailwind were known prior to the incident. However, the publications were written and communicated in such a way that the F-35A pilot community had only vague awareness of the issue. This vague awareness led to inadequate training for engine starts with a tailwind. Training also resulted in complacency and an over-reliance on aircraft automation. Thus, the MP was not trained adequately and was not as ready for the abnormal engine start and resulting fire as he could have been. Preponderance of evidence shows if there had been an expectation of engine startup problems with a tailwind, the MP may have relied less on aircraft automation, and may have identified an abnormal engine start earlier.

b. Checklist Error

The fire's ferocity and close proximity impaired the MP's ability to follow the checklist. The MP did not move the engine switch to OFF in accordance with the EGRESS checklist while he was egressing the MA. Within the first few seconds of the fire, the flames had reached the main landing gear and the Crew Chief was telling the pilot there was a fire. The fire burned for at least 20 seconds around the outside of the aircraft. It stands to reason that if the engine switch had been moved to OFF at the first indication of fire, fuel would have been shut off to the engine nearly immediately and the fire would not have burned as long.

However, the MP was under duress immediately upon recognition of the fire and was in imminent danger during his egress. The burn injuries sustained to his head, neck, face, and ears are further supportive of the urgency surrounding his circumstances and the necessity to prioritize egress from the aircraft above all else.

4. CONCLUSION

By preponderance of the evidence, I find the cause of the mishap to be the tailwind present during aircraft engine start. The tailwind blew hot air into the IPP inlet, starting a sequence of events ending in an uncontained engine fire. The fire came out of the aircraft engine exhaust and was carried along the outer surfaces of the MA, resulting in estimated damage to the aircraft in excess of $17,000,000. Procedural guidance/publications and checklist error were substantially contributing factors to the overall extent of damage.

9 May 2017

DALE E. HETKE, Colonel, USAF
President, Accident Investigation Board

INDEX OF TABS