UNITED STATES AIR FORCE AIRCRAFT ACCIDENT INVESTIGATION BOARD REPORT

F-35A, T/N 10-5015

58TH FIGHTER SQUADRON
33D FIGHTER WING
EGLIN AIR FORCE BASE, FLORIDA

LOCATION: EGLIN AIR FORCE BASE, FLORIDA

DATE OF ACCIDENT: 23 JUNE 2014

BOARD PRESIDENT: COLONEL GREGORY KEETON

Conducted IAW Air Force Instruction 51-503

EXECUTIVE SUMMARY
AIRCRAFT ACCIDENT INVESTIGATION

F-35A, T/N 10-5015
EGLIN AIR FORCE BASE, FLORIDA
23 JUNE 2014

On 23 June 2014, at approximately 0910 hours local time, the mishap aircraft (MA), an F-35A, tail number 10-5015, assigned to the 58th Fighter Squadron, 33d Fighter Wing, Eglin Air Force Base (AFB), experienced an engine stall and subsequent fire during takeoff roll. The Mishap Pilot (MP) aborted the takeoff, stopped on the runway and safely egressed the still burning aircraft. Emergency crews responded and extinguished the fire. There was no damage to private property and minor airfield damage. The MA engine sustained significant damage and 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 mishap aircraft have been estimated to be in excess of $50,000,000.00.

The Accident Investigation Board (AIB) president found, by clear and convincing evidence, that the cause of the mishap was a material failure of the third stage Integrally Bladed Rotor forward integral arm. Pieces of this rotor arm ejected through the upper portion of the aircraft fuselage, which severed internal fuel and hydraulic lines. The fuel and hydraulic fluid ignited and the ensuing fire encompassed the aircraft around the area where the fuselage was penetrated and aft as the MP aborted the takeoff. The MP performed an engine shut down and egressed, and the leaking fluids continued to burn on and around the aircraft. The fire was extinguished approximately seven minutes after the initial indications of a fire.

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.

SUMMARY OF FACTS AND STATEMENT OF OPINION
F-35A, T/N 10-5015
23 JUNE 2014

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

AETC	Air Education and Training Command
AF	Air Force
AFB	Air Force Base
AFE	Aircrew Flight Equipment
AFI	Air Force Instruction
AFM	Airfield Management
AFRL	Air Force Research Laboratory
AIB	Accident Investigation Board
AIB/LA	Accident Investigation Board Legal Advisor
AIB/MDM	Accident Investigation Board Medical Member
AIB/MXM	Accident Investigation Board Maintenance Member
AIB/PM	Accident Investigation Board Pilot Member
AIB/R	Accident Investigation Board Recorder
AIMWTS	Aeromedical Information Management Waiver Tracking System
ALIS	Autonomic Logistics Information System
AMU	Aircraft Maintenance Unit
ASM	Activity Security Manager
AV	Air Vehicle
BLD LEAK ENG	Bleed Leak Engine
BMC	Basic Mission Capable
BOS	Before Operations Servicing
CAPS	Critical Action Procedures
CCT	Crew Chief Trainer
CEMP	Combined Emergency Management Plan
CMMS	Computerized Maintenance Management System
CSMU	Crash Survivable Memory Unit
CTOL	Conventional Takeoff and Landing
CT	Continuation Training
DoD	Department of Defense
EFH	Engine Flight Hours
ENG STALL	Engine Stall
F/C	Fire Chief
F/L EX	Flight Line Expediter
FLT SUR	Flight Surgeon
FOD	Foreign Object Damage
FS	Fighter Squadron
FSE	Flight Safety NCO
FW	Fighter Wing
g	Gravitational Force
HCF	High Cycle Fatigue
HFACS	Human Factors Analysis and Classification System
HIT	Health Inspection Task
HYD FLUID B	Hydraulic Fluid System B
IAW	In Accordance With
IBR	Integrally Bladed Rotor
ICAWS	Integrated Caution, Advisory, and Warning System
ICC	Inverter/Converter/Controller
IP	Instructor Pilot
IPP	Integrated Power Package
JTD	Joint-Service Technical Data
L	Local Time
LM	Lockheed Martin
MA	Mishap Aircraft
ME	Mishap Engine
MFL	Mishap Flight Lead
MFO	Mission Fall Out
MMB	Mishap Mission Briefer
MOA	Military Operating Area
MP	Mishap Pilot
MS	Mishap Sortie
MX1	Crew Chief
NOTAMs	Notices to Airmen
OG	Operations Group
ORM	Operational Risk Management
P&W	Pratt and Whitney
PAIR	Production Aircraft Inspection Requirements
PHA	Periodic Health Assessment
POS	Post Operations Servicing
psi	Pounds Per Square Inch
PWL	Pratt and Whitney Legal
PWPM	Pratt and Whitney Program Manager
PWT	Pratt and Whitney Technician
QC	Quality Check
R3	Third Stage Rotor
RAP	Ready Aircrew Program
RAPCON	Radar Approach and Control
RWY	Runway
S2	Second Stage Stator
SAR	Search and Rescue
SHM	Squadron Health Management’
SII	Special Interest Item
SOF	Supervisor of Flying
TCTD	Time Compliance Technical Directives
TDY	Temporary Duty
T/N	Tail Number
T.O.	Technical Order
USAF	United States Air Force

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

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 30 July 2014, Major General Leonard A. Patrick, Vice Commander, Air Education and Training Command (AETC), appointed Colonel Gregory S. Keeton to conduct an aircraft accident investigation of a mishap that occurred on 23 June 2014 involving an F-35A aircraft, tail number (T/N) 10-5015, at Eglin Air Force Base (AFB), Florida (FL). The aircraft accident investigation was conducted by the assembled Board at Eglin AFB, FL from 13 August 2014 through 29 August 2014 in accordance with Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*. During the recessed period from 30 August 2014 through 26 February 2015, the Board recessed pending completion of the policy reviews of technical data and information collected as part of the Board's investigation for determination of compliance with the Arms Export Control Act and claimed proprietary privileges. This report only pertains to the immediate causes of the 23 June 2014 mishap and uses technical information available during the investigation by the assembled Board at Eglin AFB in August 2014 (Tabs J-2 thru J-11, J-13 thru J-89, J-90 thru J-146, J-147-J-166 and J-167). Board members included a Legal Advisor (Lieutenant Colonel), a Medical Member (Major), a Pilot Member (Captain), a Maintenance Member (Master Sergeant), and a Recorder (Technical Sergeant).

b. Purpose

This is a legal investigation convened to inquire into the facts surrounding the aircraft or aerospace accident on 23 June 2014, 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 23 June 2014, at approximately 0910 hours local time (L), the mishap aircraft (MA), an F-35A, T/N 10-5015, assigned to the 58th Fighter Squadron (FS), 33d Fighter Wing (FW), Eglin AFB, FL, experienced an engine stall and subsequent fire during takeoff roll. The Mishap Pilot (MP) aborted the takeoff, stopped on the runway and safely egressed the still burning aircraft. Emergency crews responded and extinguished the fire. (Tab V-2.5, J-4 thru J-5). There was no damage to private property and minor airfield damage. The MA engine sustained significant damage and the aft (rear) two thirds of the MA sustained significant fire damage. Total mishap damage costs were estimated to be in excess of $50,000,000.00 (Tabs P-20, P-25).

3. BACKGROUND

The MA belonged to the 58 FS, 33d Operations Group (OG), 33 FW, Air Education and Training Command, stationed at Eglin AFB, FL (Tabs CC-3 thru CC-19).

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).

b. 33d Fighter Wing (33 FW)

The 33 FW is a graduate flying and maintenance training wing for the F-35 Lightning II, organized under AETC. The 33 FW is an associate unit located on Eglin AFB, FL, which is an Air Force Materiel Command base. The mission of the 33 FW is to train world-class F-35 pilots and maintainers, air battle managers and intelligence personnel. The 33 FW manages the F-35 Integrated Training Center, training F-35 pilots and maintainers for the Air Force, Marine Corps, and Navy, as well as foreign nations. The wing operates five squadrons with 1,500 U.S. military, government civilian and contractor personnel assigned to the F-35 Integrated Training Center. (Tabs CC-13 thru CC-16).

c. 33d Operations Group (33 OG)

The 33 OG is comprised of the 58th Fighter Squadron, training Air Force pilots with the F-35A Conventional Takeoff and Landing (CTOL) variant; the 337th Air Control Squadron, training U.S. and allied air battle managers at Tyndall AFB; and the 33d Operations Support Squadron (Tabs CC-13 thru CC-14).

d. 58th Fighter Squadron (58 FS)

The 58 FS "Mighty Gorillas" are authorized to operate 24 assigned F-35A aircraft, planning and executing a training curriculum in support of Air Force and international partner pilot training requirements. The Gorillas also fly two Royal Netherlands Air Force F-35As (Tabs CC-13 thru CC-14).

e. F-35A – Lightning II

The Lockheed Martin F-35A Lightning II Conventional Takeoff and Landing variant is the United States Air Force's (USAF) latest 5th generation fighter. It will bring an enhanced capability to survive in the advanced threat environment in which it was designed to operate. (Tabs CC-17 thru CC-19).

The F-35A gives the USAF and allies the power to dominate the skies – anytime, anywhere. The F-35A is an agile, versatile, high-performance, 9g capable multirole fighter that combines stealth, sensor fusion, and unprecedented situational awareness (Tab CC-17).

The F-35A's Pratt & Whitney F135-PW-100 turbofan 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 (Tabs CC-18 thru CC-19).

4. SEQUENCE OF EVENTS

a. Mission

The mission was scheduled as a Continuation Training two-ship sortie (a flight of two aircraft), call sign "Thug," to Rosehill Military Operating Area (MOA), with the MP as number 02 (Tab K-4). Continuation Training sorties are typical training missions flown to keep pilots current in required maneuvers, skills and tasks. In this case, two aircraft were scheduled as a formation and the mishap pilot was in the second aircraft. Prior to the mission brief, "Thug " flight combined with "Eagle" flight, also a two-ship, to become a four-ship for simplicity in terms of departing and coming back with Air Traffic Control (Tabs K-4, V-2.3). The four-ship was renamed "Eagle" flight with the MP as number 04. Prior to takeoff, two aircraft from "Eagle" flight had slight maintenance delays, therefore the four-ship became a two-ship, with the MP as the second ship of the two-ship formation (Tab V-2.4). This sortie flew under the 58 FS allotment of flying hours for instructor pilot proficiency in accordance with the F-35 Ready Aircrew Program (RAP) Tasking Message (Tab BB-5). All USAF flying units have a yearly budget of hours for peacetime training, and the RAP tasking message delineates what missions and types of training are to occur (Tab BB-5).

b. Planning

The flight lead of the four-ship, Eagle 01, mission planned the sortie prior to the briefing (Tabs K-4, V-2.3). The briefing covered all required items in accordance with (IAW) AFI 11-2F-35v3 including Notices to Airmen (NOTAMs), Special Interest Items (SIIs), forecast weather and planned flying events (Tab V-2.3).

c. Preflight

Prior to flying, members of the four-ship "Eagle" flight accomplished all required Go/No-Go items and completed an Operational Risk Management (ORM) assessment that was approved by the Operations Supervisor (Tabs K-27, K-17). Go/No-Go items are requirements that 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 of the MA was uneventful (Tab V-2.4).

d. Summary of Accident

On Monday, 23 June 2014, at 09:09L, the MP began a takeoff on Runway (RWY) 12 at Eglin AFB (Tabs V-2.4, J-148). At the correct rotation speed, the MP began to rotate, or lift the nose wheel off the ground in anticipation of takeoff. During rotation, the MA engine stalled and displayed an ENG STALL (engine stall) Integrated Caution, Advisory, Warning (ICAW) at 09:10:06L (Tab J-82). The MP heard an audible bang and felt the aircraft decelerate about the same time the MP received the ENG STALL ICAW and the MP subsequently applied the ABORT procedure at 09:10:07L (Tabs J-83, V-2.4). The MP received other warnings and cautions including FIRE FIRE (Tab V-2.4 thru V-2.5). The ENG STALL ICAW was followed at 09:10:07L by FIRE GEAR and HYD FLUID B ICAWs (Tab J-83 thru J-84). FIRE GEAR indicated that fire detection sensors located in the wheel wells detected fire. HYD FLUID B indicated that the hydraulic fluid in system B was below minimum levels. As the aircraft slowed to a stop, numerous additional ICAWs annunciated including BLD LEAK ENG, IPP FAIL and HYD FAIL B indicating that there was hot engine exhaust detected outside of the engine and hydraulic system B no longer had any fluid (Tabs J-80 thru J-89). The MP stopped the aircraft approximately 8,000 feet down the runway following the abort procedure (Fig-12 below, Tab S-9).

The MP accomplished the EGRESS procedure at approximately 09:10:38L (Tab J-86). Two witnesses and the MP reported a visible fire and thick, black smoke around the aircraft as the MP exited the cockpit and safely evacuated the scene (Tabs R-6, R-10, V-1.4, V-2.5).

The fire continued for approximately seven minutes spreading from an initial fire on top of the aircraft to a ground fire fed by leaking fluids and a subsequent internal engine bay fire. The fire damaged the aft two thirds of the aircraft before emergency responders were able to extinguish it (Tabs J-5, J-9 thru J-10, J-80 thru J-89, S-2, S-3).

e. Impact

Not applicable.

f. Egress and Aircrew Flight Equipment (AFE)

The MP performed a ground egress of the F-35A without injury (Tabs J-4, V-2.5 thru 2.6, X-3). The MP was wearing the appropriate AFE as directed by Joint Technical Data (JTD). The MP's helmet, sleeved flight jacket and skeletal G-suit were inspected and were deemed to have no discrepancies or damage. (Tab X-7)

g. Search and Rescue (SAR)

Not applicable.

h. Recovery of Remains

Not applicable.

5. MAINTENANCE

a. Forms Documentation

The 58th Aircraft Maintenance Unit (AMU), Eglin AFB, maintained the electronic records for the MA. Tracking aircraft maintenance is accomplished via the Autonomic Logistics Information System (ALIS) while the Computerized Maintenance Management System (CMMS) application is used to document maintenance actions. Squadron Health Management (SHM) is used to track Production Aircraft Inspection Requirements (PAIR) using the Health Inspection Task (HIT) functionality, which is used to create, update, and track non-expired items and maintenance inspection requirements. Time Compliance Technical Directives (TCTD) are maintained in CMMS.

TCTD are used to process system changes, usually aircraft part upgrades, which must be accomplished within a specific time period and by a specific date. This time period is dependent upon the severity of the issue the TCTD addresses. A TCTD may also direct inspection or adjustments to equipment or parts already installed on the aircraft. Time change items are routine maintenance actions in which components are removed and replaced after a given number of flight hours or calendar days. There were no overdue TCTDs, special inspections, or time changes at the time of the mishap (Tab DD-10).

Before the first flight of the day for any aircraft, an Air Vehicle (AV) Exceptional Release (ER) must be completed. An AV ER includes a review of ALIS and its supporting applications. It serves as a certification that the authorized individual has ensured the aircraft is safe for flight. Within ALIS, the AV Release is required before Pilot Acceptance of the aircraft. The Production Superintendent completed an AV Release in ALIS prior to the mishap sortie (MS) (Tab DD-9).

All scheduled inspections were completed IAW applicable Joint-Service Technical Data (JTD) guidance with no discrepancies noted. (Tabs D-3, DD-9 thru DD-10). A detailed review of the MA's CMMS, SHM and TCTDs revealed no evidence to suggest maintenance forms documentation was a factor to the mishap (Tabs DD-9 thru DD-10).

b. Inspections

A Before Operations Servicing (BOS) Inspection is a flight preparedness inspection performed by maintenance personnel prior to flight and is valid for 24 hours once completed. BOS Inspections are performed IAW JTD module F35-AAA-A1321010000-281A-A. The purpose of the BOS Inspection is to visually inspect various areas, operationally check various systems, and check fluid levels of the aircraft in preparation for a flying period. The last BOS Inspection was completed on 23 June 2014 at 0217L with no defects noted (Tab D-3). As part of the BOS Inspection, an Engine BOS Inspection was completed on 23 June 2014 at 0111L IAW JTD module F35A-AAA-P7200010000-281B-A with no discrepancies noted (Tabs D-3, V-3.2 thru V-3.3). The Engine BOS Inspection included a Foreign Object Damage (FOD) Inlet Inspection as well as a visual inspection of the first stage components in the fan module and engine exhaust (Tab V-3.4).

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. The POS Inspections are performed IAW JTD module F35-AAA-A13210300000-281A-A. The last POS Inspection was completed on 21 June 2014 at 0132L as an update to the 19 June 2014 POS Inspection, which had no defects noted (Tab D-3). As part of that POS Inspection, an Engine POS Inspection was completed on 19 June 2014 at 1542L with no defects noted (Tab D-3). Unlike POS Inspections, the subset Engine POS Inspection does not expire after 72 hours and is not required per JTD when a POS update is accomplished. There is no evidence to suggest the aircraft inspections were a factor in this mishap.

At the time of the mishap, F-35 engines also required an inspection in 25 flight-hour intervals as required by JTD F35-AAA-P7200010000-281A-B. This included a borescope of numerous parts of the engine, including the third stage rotor. However, at the time there was no requirement to inspect the plate seals of that rotor (Tabs DD-9, V-4.3). The mishap engine (ME), an F135 P&W engine, was installed in the MA at the Lockheed Martin (LM) F-35 plant in Fort Worth, Texas. The last 25 hour inspection was conducted on this engine on 17 June 2014 at 150.976 engine flight hours (EFH) with no defects noted (Tab DD-9). The inspection was completed IAW JTD module F35-AAA-P7200010000-281E-A (Tab D-3). There is no evidence to suggest the engine inspections accomplished prior to the mishap were a factor.

c. Maintenance Procedures

All maintenance records for the MA and ME were reviewed during the investigation (Tabs D-3, DD-9 thru DD-10). There is no evidence to suggest that maintenance procedures were a factor in this mishap.

d. Maintenance Personnel and Supervision

The MA was maintained by active duty military personnel from the 58 AMU as well as by contractor personnel from LM and P&W. Aircraft maintenance records and statements from maintenance personnel indicated that the BOS and dispatch inspections relating to the MS were normal and with the appropriate personnel and supervision involved. Accident Investigation Board (AIB) interviews of maintenance personnel, in conjunction with training records and special certification roster review, reflect qualified and competent maintenance personnel with appropriate supervision (Tabs DD-9 thru DD-11). There is no evidence to suggest that maintenance personnel and supervision were a factor in this mishap.

e. Fuel, Hydraulic, and Oil Inspection Analyses

Following the mishap, fluid samples from the MA and associated servicing carts were taken and tested normal with no volatile contamination noted IAW Technical Order 42B-1-1, *Quality*

Control of Fuels and Lubricants. The fluids tested were oil, fuel, hydraulic and polyalphaolefin (Tabs D-5 thru D-19). There is no evidence to suggest these fluids were a factor in this mishap.

f. Unscheduled Maintenance

Unscheduled maintenance is any maintenance action taken that is not the result of a scheduled inspection. This is normally the result of a pilot-reported discrepancy during flight operations, a condition discovered by ground personnel (such as low tire pressure or fuel or hydraulic fluid levels) or a fault indicated by the aircraft. The unscheduled maintenance performed on the MA after the last POS consisted of normal maintenance such as checking fuel and hydraulic levels and tire pressure. There is no evidence to suggest unscheduled maintenance performed on the MA was a factor in this mishap (Tabs D-2, DD-9 thru DD-10).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

(1) Engine

Tear down and analysis performed by maintenance personnel from the 33 FW and P&W indicated the initial engine malfunction occurred inside the fan module of the MA's engine, which is the forward-most section of the engine (Fig-1). The fan module consists of inlet guide vanes and three stages of fan rotors. The third stage rotor is commonly referred to as R3. A pair of plate seals encircles the forward integral arm of the third stage rotor (Fig-2). A foam strip mounted to the second stage stators aligns with the seals to improve airflow efficiency in the fan section (Fig-2). Stators are stationary pieces affixed to the outer engine casing that encircle the integral arm seals to improve airflow efficiency.

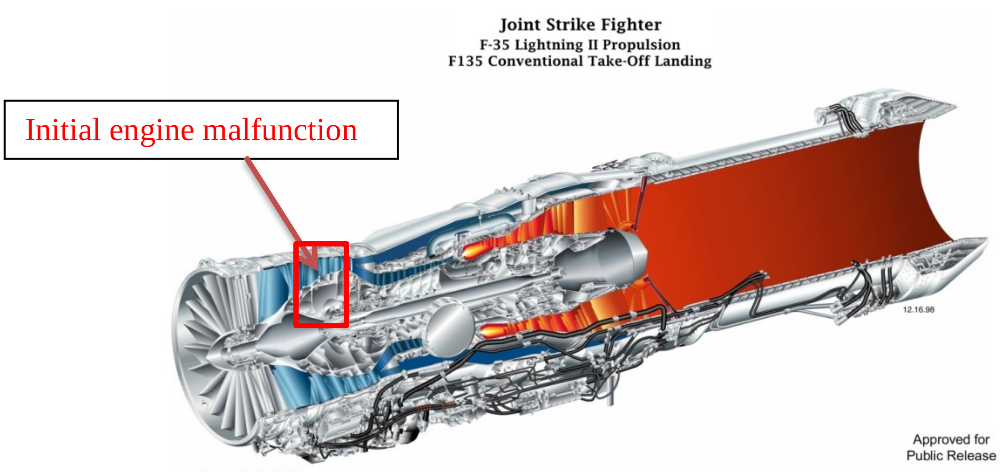


Fig-1. F135 Engine (red arrows/words added by AIB) (Tab Z-5)

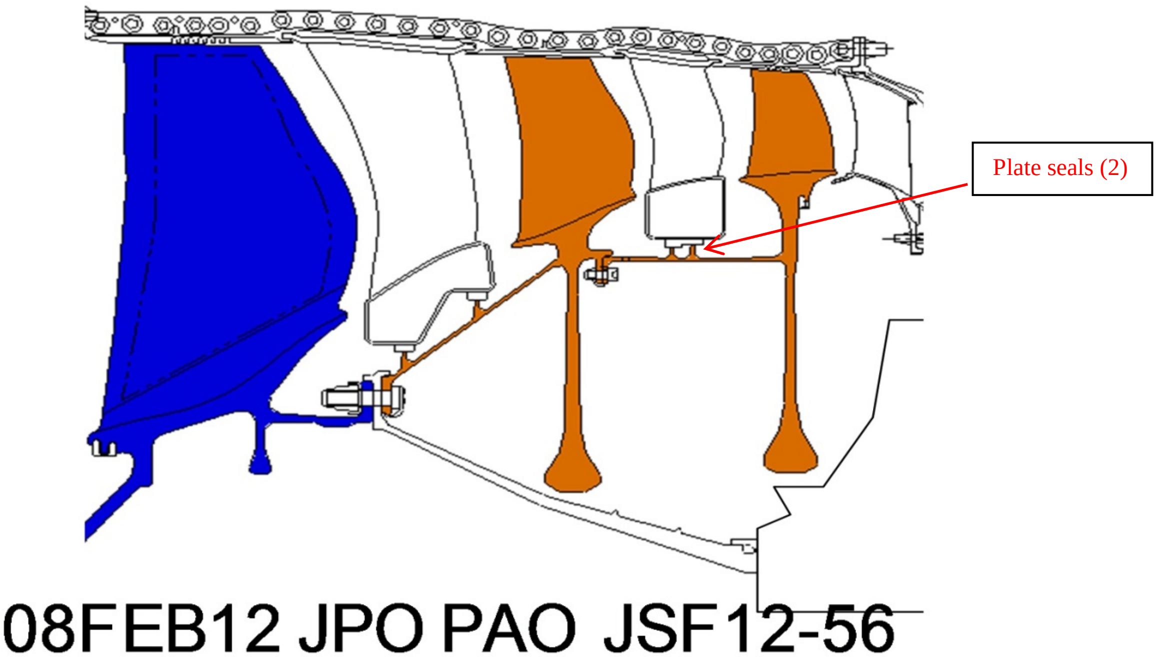


Fig-2. F135 Engine Fan Module Cross Section (arrows/words added by AIB)(Tab Z-5)

Fig-3 shows the the fracture sequence of the mishap R3 plate seal, as analyzed by P&W (Tab J-104).

Fracture Sequence:

1. Fatigue progressed in the radial direction from the tip of the plate seal.
2. The crack continued in progressive tearing/overstress to the base of the plate seal and into the barrel of the integral arm.
3. The crack extended via progressive tearing in the axial direction forward and aft.
4. The final overstress fracture through the integral arm resulted in the loss of the hoop.
5. Circumferential overstress fractures occurred between the plate seals, and between the disk and forward integral arm.

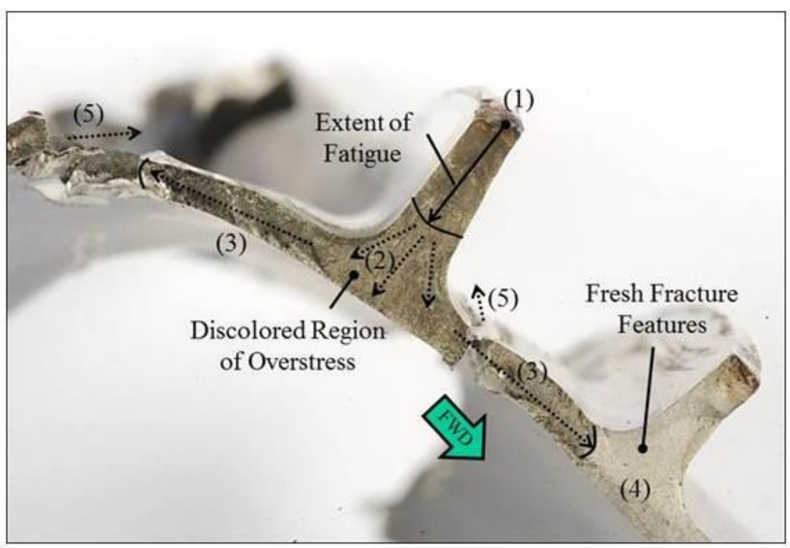


Fig-3. View of Plate Seals Showing Fracture Sequence (Tab J-104), repeated as Fig-22 and discussed in detail

The R3 Integrally Bladed Rotor (IBR) is a single piece that includes the rotor disk with blades as well as the forward integral arm. Two plate seals run concentrically around the integral arm. A series of stationary stators, commonly referred to as second stage stators (S2), are attached to the outer edge of the fan case directly in front of the R3 blades and above the R3 integral arm. A foam rub strip is adhered to the composite attachment of the stators forming a seal with the R3 integral arm plate seals to improve efficiency within the engine.

Exempt from disclosure under the Freedom of Information Act, 5 U.S.C. Section 552(b)(4) (FOIA (b)(4))

Fig-4. Intact R3 stage of fan module (Tab J-97)

Exempt from disclosure under FOIA (b)(4)

Fig-5. MA engine fan section in situ missing R3 forward integral arm (Tab J-158)

Exempt from disclosure under FOIA (b)(4)

Fig-6. ME R3 disk missing forward integral arm (Tab S-7)

Upon disassembly, the R3 was found to be missing the entire integral arm from the IBR (Tab J-157). The pieces of the R3 integral arm appeared to have punched through the top of the engine fan case (Fig-7) and fuselage at the 11 o'clock position (aft (rear) looking forward) (Tabs S-4, S-5). The fragments consisted of two large pieces measuring roughly 5-6 feet in length (Tabs J-151 thru J-152) and multiple smaller pieces (Tab J-100). (Fig-13, Fig-14)

Fig-7. Hole in top of fan case (Tab S-4)

According to analysis by P&W and the JPO, the engine damage directly related to the engine R3 integral arm liberation included the following:

- A 3" x 11" hole in the engine fan case at the 11 o'clock position (aft looking forward) vicinity between the 2d and 3d stage rotors (R2 and R3), in line with the radial plane of stator 2 (S2) (Tab J-154)

- Multiple bent and damaged fan blades (airfoils) in the 2d and 3d stage rotors (Tabs J-157 thru J-159)

- Multiple damaged stators segments in the 2d stage stator assembly between the 2d and 3d stage rotors (Tab J-158)

- Damage through the high-pressure compressor from ingested debris from the fan module (Tab J-165)

(2) Hydraulic system

The F-35A uses hydraulic power to extend and retract the landing gear, open and close various external doors, and provide braking and steering during ground operations. The system is pressurized by an engine driven pump during normal operations. Various hydraulic lines run across and along the aircraft. (Tab J-54). During the mishap, Crash Survivable Memory Unit (CSMU) (in civilian terminology, this type of device is sometimes referred to as a "black box") data indicated hydraulic system B experienced a rapid loss of fluid immediately following the engine stall (Tabs J-56, J-57). Technical experts at Lockheed Martin, P&W and the JPO believe this occurred when the R3 integral arm pieces severed three hydraulic lines (Fig-8)(Tabs J-9, J-147 thru J-148, J-152). Within 17 seconds of the lines being cut, the CSMU data showed the B system hydraulic reservoir was empty (Tabs J-56, J-57). However, hydraulic system A functioned normally to provide redundant power to the wheel brakes as the MP brought the aircraft to a stop (Tabs J-69 thru J-71, V-2.5).

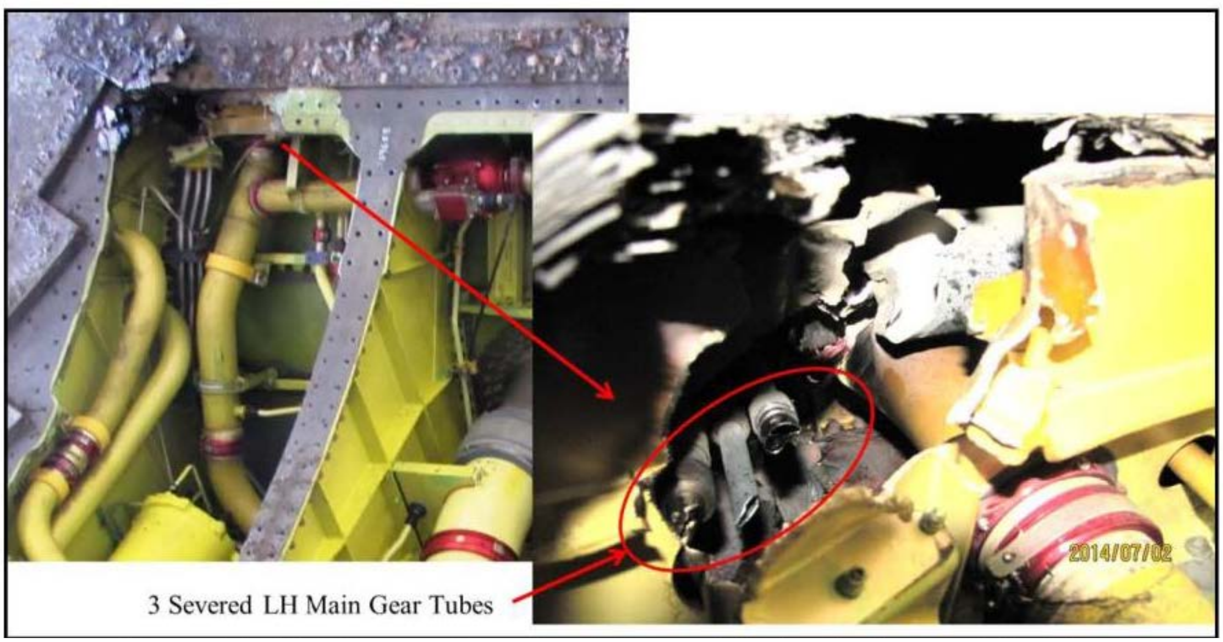


Fig-8. Hydraulic and fuel line damage at fragment exit point (pg J-61)

(3) Fuel System

The F-35A fuel system holds fuel in fuselage and wing storage tanks. It employs transfer pumps and boost pumps to manage fuel balance and provide continuous, uninterrupted fuel for engine operations (Tabs J-62, J-63).

Exempt from disclosure under FOIA (b)(4)

Fig-9. F-35A Fuel system diagram (Tab J-62)

During the mishap, a fuel transfer tube, refuel tube and fuel siphon tube located over the engine in a fuel tank (Fig-9) were all partially or completely severed by the R3 integral arm ejection (Fig-10) (Tab J-152). During engine operation, the fuel transfer tube is pressurized. After being partially severed, this tube leaked a significant amount of pressurized fuel feeding the subsequent external and internal fires (Tabs J-7, J-8, J-62 thru 68).

Part numbers are exempt from disclosure under FOIA (b)(4)

Fig-10. Fuel system damage (Tab J-68)

(4) Electrical System

Ten seconds after the initial engine stall, the Inverter/Converter/Controller (ICC) number 2 failed due to a system ground fault indication caused by damage from the R3 integral arm ejection (Tab

J-72). The loss of ICC 2 resulted in less than normal electrical power to the aircraft and a loss of some non-critical functions.

(5) Airframe Structure and Skin

Fig-11. Hole in top of aircraft (Tab S-5)

A hole (10 x 7 inches) in Panel 3331 (top of fuselage) directly above and corresponding to the hole in the engine fan case was discovered post mishap with the composite plies/fibers splayed outward (Fig-11) (Tabs J-7 thru J-8). This panel covers parts of the fuel tank that was damaged and another fuel tank (Tab J-7). Three hydraulic lines and four fuel tubes (discussed in paragraph 6.a.(3) above) were damaged or severed at this location (Tabs J-61, J-68).

In summary, most outer surfaces of the aircraft skin and panels aft of the air refueling door were damaged by the fire while the interior bays covered by these panels exhibited a layer of soot with minimal or no damage (Tabs J-5 thru J-9, S-2). The interior of the engine bay also exhibited scorching and some metal deformation due to intense heat (Tabs J-14, J-15).

b. Evaluation and Analysis

Initial borescopic examination and limited disassembly of the ME for visual inspection of the fan was conducted at P&W's Eglin AFB facility in FL. Subsequent full teardown and analysis of the ME was conducted at P&W's West Palm Beach, FL facility, with additional materials laboratory and analytical support provided by personnel at P&W's East Hartford, CT facility and the Air Force Research Laboratory (AFRL) facility at Wright-Patterson AFB, OH (Tab J-147).

(1) Analysis 1 – Engine R3 Failure

Engineering analysis by P&W and the JPO indicates that during the MA's takeoff roll at 0910L, the R3 forward integral arm catastrophically failed and liberated from the engine (Tab J-147). This failure immediately caused an engine stall as the MP began to rotate for takeoff (Tab J-148). The liberated pieces of the R3 forward integral arm subsequently punctured the engine fan case and ejected out of the top of the aircraft falling just north of the runway while the aircraft continued to roll down the runway and eventually stopped (Fig-12, Fig-13). Following the aircraft mishap, a sweep of the airfield located several pieces of this debris (Tabs R-2, R-4). Simulation by the AIB in an F-35 simulator and review of the CSMU data timeline show the location of the recovered debris coincident with the time of R3 failure (Tabs S-4.1, DD-3, J-81). The debris found post-mishap was identified as portions of the R3 IBR forward integral arm and composite debris (Tab J-151).

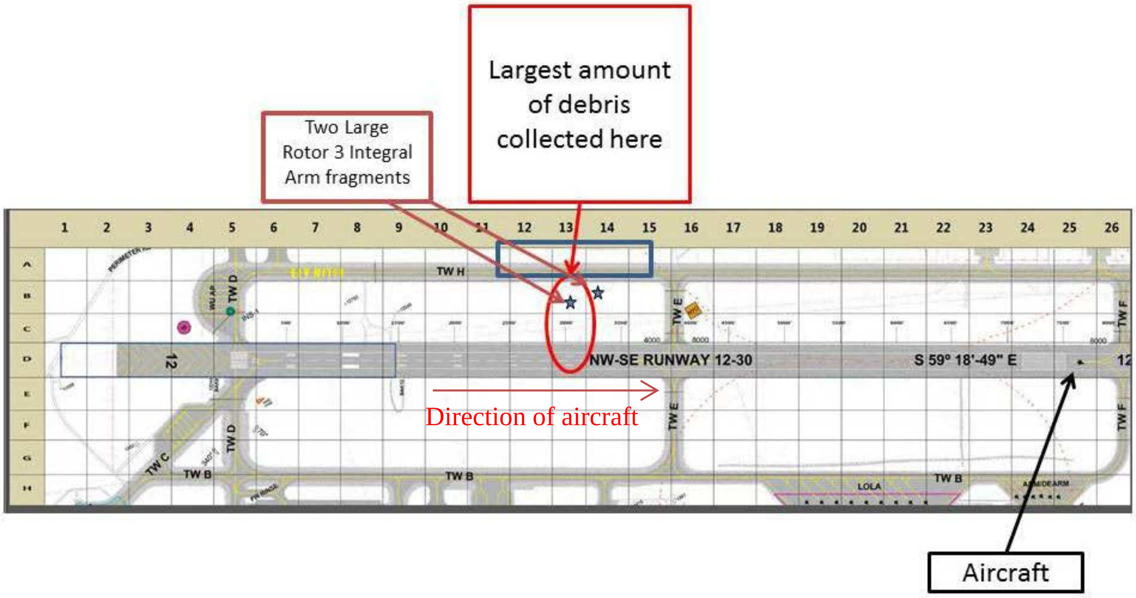
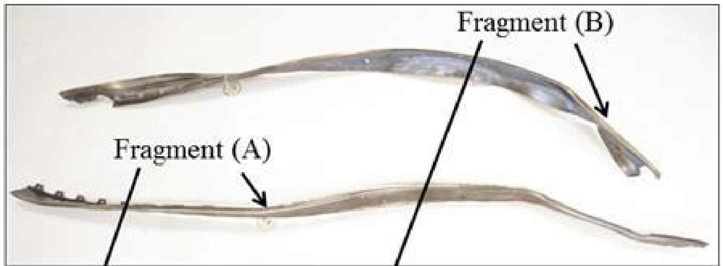


Fig-12. Location of debris along runway (Tab S-9)

Fig-13. Fragment of R3 forward integral arm (Tab S-3)

Engineering analysis by P&W demonstrated that the R3 forward integral arm fractured initially in an axial direction between the second and third stage rotors (forward-aft direction). The forward integral arm also fractured circumferentially between the forward and aft plate seals and between the aft plate seal and the R3 disk. These fractures produced two elongated fragments measuring roughly 5-6 feet in length and numerous smaller fragments (Tab J-98, J-100, J-151 thru J-152).



Exempt from disclosure under FOIA (b) (4)

Fig-14. Two main pieces of R3 forward integral arm found along runway (Tab J-98 and J-152)

Exempt from disclosure under FOIA (b) (4)

Fig-15. Undamaged example of R3 Forward Integral Arm (Tab J-97)

Based on the P&W engineering analysis, the cause of the fracture in the R3 forward integral arm was determined to be due to High Cycle Fatigue (HCF) progression following a hard tip rub event (Tab J-92). HCF progression describes the weakening of the R3 forward integral arm after repeated loads were imparted during continued engine operations after the initial hard rub event. The hard tip rub event occurred where the R3 plate seals contacted the foam rub strips along S2 (Fig-16) (Tab J-93).

Exempt from disclosure under FOIA (b)(4)

Fig-16. Plate seal and rub strip diagram (Tab J-96)

Analysis of the ejected forward integral arm fragments demonstrated evidence of a hard tip rub, which resulted in a brief occurrence of extremely high temperatures (Tab J-122). This event occurred at an undetermined time prior to the mishap; however, no evidence indicates that the engine or aircraft had been operated outside of the designed flight envelope (the operating parameters and capabilities of the aircraft) (Tab DD-7).

Evidence of the hard tip rub and subsequent extreme temperature included heat tinting, metal smearing and heat check cracking adjacent to the primary axial fracture location on the R3 aft (rear) plate seal (Tabs J-92 and J-166).

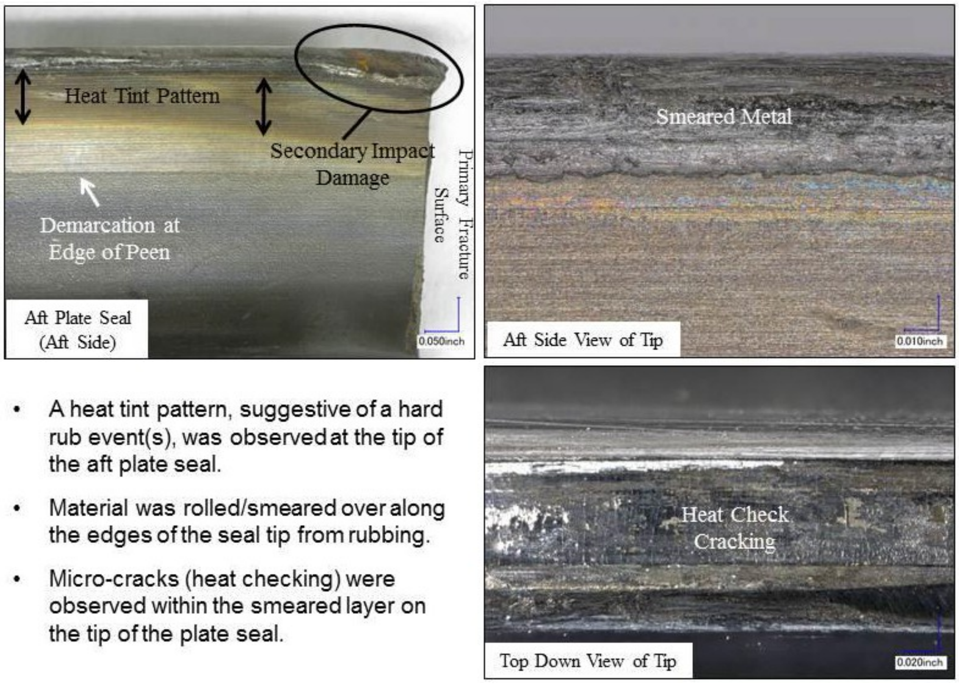


Fig-17. Heat Tinting, Metal Smearing, Micro-Cracks in Aft Plate Seal (Tab J-106)

This heat damage from the hard tip rub induced a structural change in the composition of the microstructure and caused cracks to form in the R3 plate seal (Fig-17 thru Fig-20) (Tabs J-106, J-123). This heat damage can be seen in Fig-18 by the difference in color and texture.

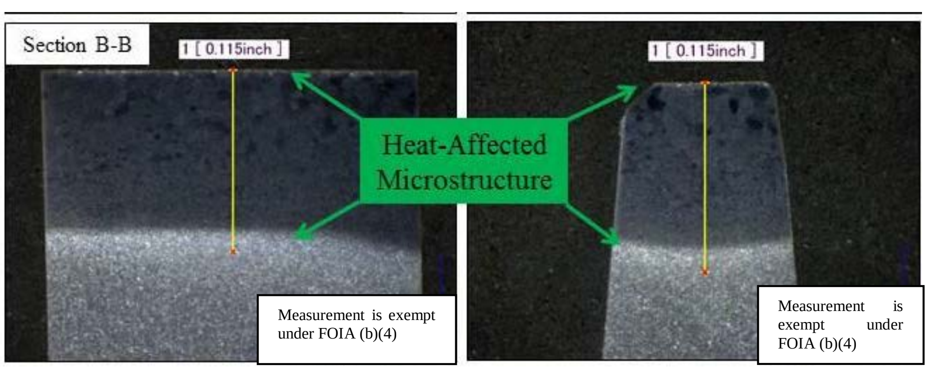


Fig-18. Aft plate seal adjacent to fracture showing heat damage (Tab J-119)

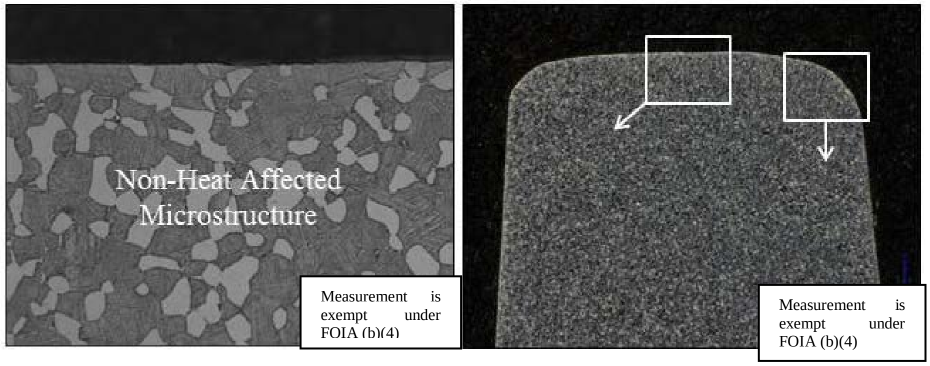


Fig-19. Aft Plate Seal 180 degrees from fracture location (Tab J-131)

Micro-cracks formed on the aft plate seal of the R3 and extended radially further into the seal. These micro-cracks along the R3 plate seal eventually weakened the metal enough to allow a large axial fracture to develop, which became structurally unstable and led to the catastrophic material failure (Fig-20) (Tab J-93).

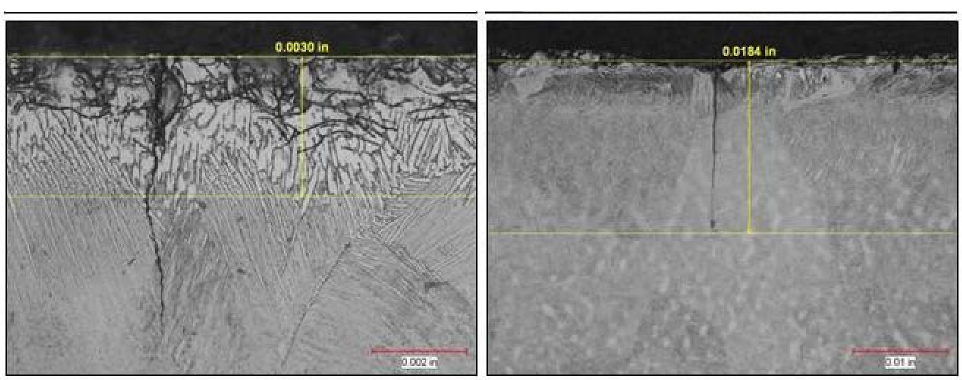


Fig-20. Radial cracks in heat affected microstructure extending .018 inch radially (Tab J-123)

The extent of the heat tint pattern on both the forward and aft plate seals is depicted in Fig-21. The location of the eventual catastrophic fracture is depicted as the red line on top of the blue shaded heat tint area.

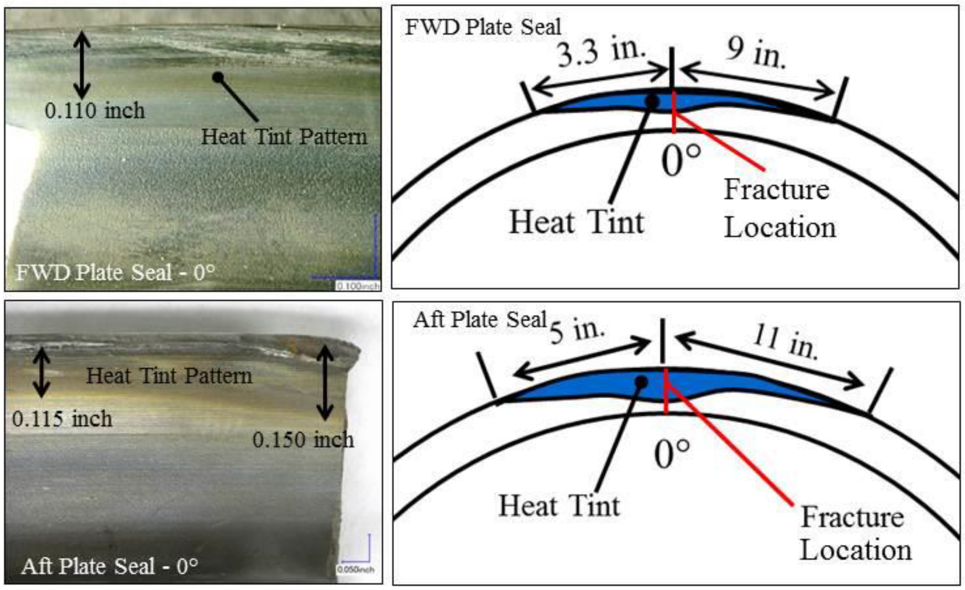


Fig-21. Total extent of heat tint damage (Tab J-139)

Once the plate seals of the R3 were damaged by the hard tip rub event and subsequent heating, the micro-cracks began to expand into a larger fracture eventually leading to the ejection of the entire forward integral arm out of the aircraft (Fig-22) (Tabs J-92 thru J-93).

Fracture Sequence:

1. Fatigue progressed in the radial direction from the tip of the plate seal.
2. The crack continued in progressive tearing/overstress to the base of the plate seal and into the barrel of the integral arm.
3. The crack extended via progressive tearing in the axial direction forward and aft.
4. The final overstress fracture through the integral arm resulted in the loss of the hoop.
5. Circumferential overstress fractures occurred between the plate seals, and between the disk and forward integral arm.

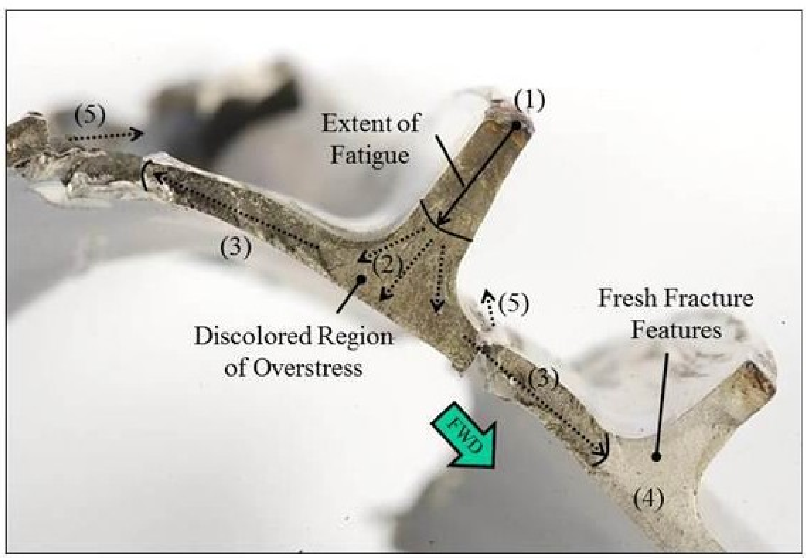


Fig-22. Fracture Sequence (Tab J-104)

In summary, P&W's analysis concluded that a hard rub interaction between the R3 plate seals and the S2 rub strips produced extreme heat that damaged the structure of the seals. This heat damage resulted in multiple micro-cracks of the aft plate seal which eventually led to a catastrophic fracture. The fracture produced two main projectiles which punctured the fan case and upper fuselage of the aircraft severing fuel and hydraulic lines. This led to the mishap aircraft's engine stall and subsequent fire. (Tabs J-92 thru 94, J-147).

(2) Analysis 2 – Fire

An exterior fire on the MA during takeoff roll was reported by multiple witnesses of the event (Tabs R-4, R-6, V-1.4). Aircraft sensors detected this fire during takeoff and was verified by extensive damage to the interior and exterior of the aircraft post-mishap (Tabs J-4 thru J-9).

Fig-23. Fire damage post mishap (Tab S-2)

Based on the evidence and their analysis, P&W and the JPO concluded that the initial fire started when the R3 forward integral arm fragments were liberated and punctured the engine fan case. These fragments traveled through a fuel tank severing multiple pressurized hydraulic lines and fuel tubes. These pressurized fluids then rapidly atomized as they exited the aircraft into the airstream. The catastrophic engine failure due to the R3 failure provided an ignition source for the fuel that was no longer contained within the fuel system. The fire, fueled by pressurized hydraulic fluid and JP-8, burned on the dorsal side of the aircraft fuselage, aft of the aerial refueling door (Tabs J-7 thru J-9).

After the MP brought the MA to a stop on the runway and shut down the engine, pressurization to the fuel and hydraulics stopped as designed per JTD (Tab O-2). Photographic evidence shows the fire continued underneath the aircraft, fed by leaking fuel (Fig-24). At 09:13:55L, aircraft fire detectors reported a fire in the engine bay, likely due to the auto-ignition of leaking fuel in the engine bay from the heat of the ground fire. The Fire Chief reported the fire under control 7 minutes and 22 seconds after the initial engine stall was recorded on the MA CSMU (Tab J-5).

Fig-24. Ground fire post aircraft shutdown (Tab S-3)

7. WEATHER

a. Forecast Weather

The weather forecast predicted scattered clouds at 4000’, broken clouds at 12000’, winds 220 degrees at 12 knots and visibility of 4 statute miles (Tab F-2).

b. Observed Weather

An observation taken at 0855L reported few clouds at 2500’, scattered clouds at 16000’ and broken clouds at 25000’. Winds were recorded at 010 degrees at 4 knots. The temperature was 27 degrees Celsius (80 degrees Fahrenheit) and the runway was dry (Tab F-6).

c. Space Environment

Not applicable.

d. Operations

There is no evidence to suggest that weather was a factor in this mishap.

8. CREW QUALIFICATIONS

a. Mishap Pilot

The MP was a current and qualified F-35A Instructor Pilot with a current Form 8 flying evaluation (certificate of aircrew qualification) dated 9 April 2014 (Tab G-18). The MP was current and qualified in all aspects of the planned mission (Tabs G-12, G16). The MP was classified as Basic Mission Capable (BMC) based on sortie look back (Tab G-21). BMC is a term used to identify the proficiency of aircrew based on the number of sorties and training they have received in a given timeframe.

The MP had a total of 984.5 flight hours at the time of the mishap, of which 33.8 hours was in the F-35A (Tab G-5). The MP had a total of 113.6 hours as an Instructor Pilot in the F-16 and 8.1 hours as an Instructor Pilot in the F-35A.

Recent flight time is as follows (Tab G-6):

	Hours	Sorties
Last 30 Days	15.1	11
Last 60 Days	19.7	14
Last 90 Days	28.6	21

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 (PHA) was performed on 12 December 2013. The MP's annual dental examination was performed on 15 November 2013. The medical records contained a current Air Force Form 1042, Medical Recommendation for Flying or Special Operational Duty, dated 12 December 2013. Review of the Aeromedical Information Management Waiver Tracking System (AIMWTS) database, a computer system for tracking aircrew medical waivers, showed the MP did not have a medical waiver at the time of the mishap (Tab X-3). There is no evidence to suggest that the MP's physical and medical qualifications were factors in this mishap.

b. Health

The AIB Medical Member reviewed the medical and dental records in addition to the 72-hour/14-day histories of the MP. 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. There were no injuries associated with this egress. (Tabs V-2.6, X-3). There is no evidence to suggest the MP's health was a factor in this mishap.

c. Toxicology

Immediately following the mishap and in accordance with safety investigation protocols, blood and urine samples were collected on the MP and relevant maintenance personnel and submitted to the Armed Forces Medical Examiner System at Dover AFB for toxicological analysis. Blood samples tested negative for ethanol and carbon monoxide levels. Urine drug screen testing was negative for amphetamine, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates, and phencyclidine by immunoassay or chromatography. (Tabs X-3 and X-5).

d. Lifestyle

MP testimony, 14-day/72-hour histories and the medical chart of the MP revealed no lifestyle factors relevant to the mishap (Tabs V-2.6 thru 2.7, X-3).

e. Crew Rest and Crew Duty Time

Air Force Instruction (AFI) 11-202, Volume 3, AETC Supplement, *General Flight Rules*, dated 20 September 2012, prescribes mandatory crew rest and maximum Flight Duty Periods for all personnel who operate USAF aircraft (Tab O-2). Based upon witness testimony and supplemental history, crew rest was in accordance with paragraph 9.8 of AFI 11-202, Volume 3 (Tabs V-2.7, X-3). There is no evidence to suggest crew rest was a factor in this mishap.

10. OPERATIONS AND SUPERVISION

a. Operations

The operations tempo of the 58 FS was average to low based on a comparison with a comparable F-16 Formal Training Unit squadron. The primary mission of the 58 FS is to train new F-35A pilots. Availability of aircraft, number of students in the pipeline, complexity of mission sets, and the frequency of Temporary Duty (TDY) and deployments all affect operations tempo (Tab DD-5).

Due to the fact that the F-35A production and developmental test phases are being conducted simultaneously, there are multiple restrictions on the F-35A flight envelope (the operating parameters and capabilities of the aircraft) that reduce the number of mission types to which the squadron trains currently. There are limited short-duration TDYs for some personnel, and no deployments for the aviators. These items all reduce complexity for the pilots and reduce operations tempo (Tab DD-5).

The squadron's instructors are all previously experienced Instructor Pilots in their previous fighter aircraft; however, the level of experience in the F-35A for most is very low due to their recent transition to the aircraft. Due to extended groundings, low aircraft utilization rates and software immaturity, the squadron has not been able to accrue significant hours or experience (Tab DD-5). However, there is no evidence to suggest operations tempo was a factor in this mishap.

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, monitoring student syllabus progression and accomplishing formal flying and simulator evaluations of the squadron instructors and students (Tab DD-5). There is no evidence to suggest the level of supervision was a factor in this mishap.

11. HUMAN FACTORS

The Board evaluated human factors relevant to the mishap using the analysis and classification system model established by the Department of Defense (DoD) Human Factors Analysis and

Classification System (HFACS) guide, implemented by AFI 91-204, *Safety Investigations Reports*, dated 12 February 2014 (corrective actions applied on 10 April 2014) (Tab BB-3). There is no evidence to suggest that human factors were an issue in this mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publically Available Directives and Publications Relevant to the Mishap

(1) AFI 11-202V3, AETC Supplement, *Flying Operations General Flight Rules*, 10 January 2012
(2) AFI 11-2F-35V3, AETC Supplement, *F-35A Operations Procedures*, 2 January 2013
(3) AFI 11-401, *Aviation Management*, 9 January 2013
(4) AFI 11-418, AETC Supplement, *Operations Supervision*, 20 May 2014
(5) AFI 13-201, *Space, Missile, Command and Control Airspace Management*, 21 August 2012
(6) AFI 13-204, *Airfield Operations Career Field Development*, 9 May 2013
(7) AFI 21-101, *Aircraft and Equipment Maintenance Management*,
(8) AFI 21-101, Eglin AFB Supplement, *Aircraft and Equipment Maintenance Management*, 20 July 2011
(9) DODI 6055.06, *Fire and Emergency Services Program*, 21 December 2006
(10) EGLINAFBI 11-201, *Air Operations*, 1 May 2013

NOTICE: All directives and publications listed above are available digitally on the Air Force Departmental Publishing Office website at: http://www.e-publishing.af.mil 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, *Aerospace Equipment Maintenance Inspection, Documentation, Policies and Procedures*
(2) T.O. 00-35D-54, *USAF Deficiency Reporting, Investigating and Resolution*
(3) T.O. 1-1-300, *Maintenance Operational Checks and Check Flights*
(4) T.O. 42B-1-1, *Technical Manual Quality Control of Fuels and Lubricants*
(5) 58 FS F-35, *Standards 58 FS Operations Standards*
(6) F-35A-FCL-001 F-35A, *Pilots Checklist* (-1CL Equivalent), Dated 21 August 2013, Change 4.1
(7) F-35A JTD, *Joint Tech Data* (Maintenance Tech Data Equivalent) Issue: 20 June 2014
(8) F-35A FSD, *Flight Series Data* (-1 Equivalent) Issue: 3 June 2014
(9) ALIS-CMMS, *Aircraft Maintenance Data*
(10) EAFB PLAN 91-204, Eglin AFB, *Mishap Response Plan*
(11) T.O. 42B-1-1, *Quality Control of Fuels and Lubricants*
(12) T.O. 42B2-1-3, *Fluids for Hydraulic Equipment*
(13) JSF AEI 2ZUA28013, Rev A, *Fuel Tank Draining*
(14) ALIS-SHM, *Aircraft Maintenance Data*

c. Known or Suspected Deviations from Directives or Publications

None.

13. ADDITIONAL AREAS OF CONCERN

Not applicable.

Exempt by FOIA (b)(6)

17 March 2015

GREGORY S. KEETON, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

F-35A, T/N 10-5015
EGLIN AIR FORCE BASE, FLORIDA
23 JUNE 2014

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 June 2014, at approximately 0910 hours local time, the mishap aircraft (MA), an F-35A, tail number 10-5015, assigned to the 58th Fighter Squadron, 33d Fighter Wing, Eglin Air Force Base (AFB), experienced an engine stall and subsequent fire during takeoff roll. The Mishap Pilot (MP) aborted the takeoff, stopped on the runway and safely egressed the still burning aircraft. Emergency crews responded and extinguished the fire. There was no damage to private property and minor airfield damage. The MA engine sustained significant damage and the aft (rear) two thirds of the MA sustained significant fire damage. Total mishap damage costs were estimated to be in excess of $50,000,000.00.

I find by clear and convincing evidence that the cause of the mishap was a material failure of the third stage Integrally Bladed Rotor forward integral arm. Pieces of this rotor arm ejected through the upper portion of the aircraft fuselage, which severed internal fuel and hydraulic lines. The fuel and hydraulic fluid ignited and the ensuing fire encompassed the aircraft around the area where the fuselage was penetrated and aft as the MP correctly aborted the takeoff. The MP performed an engine shut down and egressed while the leaking fluids continued to burn on and around the aircraft. The fire was extinguished approximately seven minutes after the initial indications of a fire.

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

2. CAUSE

The mishap was caused when the third stage rotor (R3) of the fan module fractured. This fracture occurred on the R3 forward integral arm and was caused by High Cycle Fatigue following a hard tip rub event on the aft plate seal of the integral arm. The aft plate seal experienced heat damage from a hard tip rub against a strip of foam material attached to the second stage stator. Evidence of this hard tip rub was observed on the recovered segments of the

R3 integral arm. This included thermal and physical damage consisting of temper discoloration (heat tinting), metal smearing, and heat check cracking. This heat damage eventually caused a fracture to occur axially through the forward integral arm. Subsequent fracturing occurred circumferentially between the forward and aft plate seals and between the aft plate seal and the R3 disk.

As these pieces of the R3 forward integral arm fractured and liberated from the rotor assembly, they damaged sections of the second stage stator assembly, which in turn damaged the airfoils of the second and third stage rotors and high-pressure compressor. The integral arm fragments then punched an exit hole in the fan case approximately 3 x 11 inches that was coincident with the radial plane of stator 2 (and the integral arm). As the fragments continued on their outward trajectory, they penetrated an internal fuel tank where they completely or partially severed fuel and hydraulic lines. The integral arm fragments finally exited the aircraft at the forward inboard corner of the panel directly above the fuel tank causing a hole approximately 10 x 7 inches with the composite plies/fibers splayed outward.

The subsequent fire was caused by the uncontained fuel and hydraulic fluid from the severed lines of the damaged fuel tank. Before engine shutdown occurred, several severed lines were pressurized, which caused rapidly atomized, flammable fluids to envelope the aircraft aft of integral arm fragment expulsion. The engine failure ignited this fuel and the resulting fire significantly damaged the upper and internal aircraft surfaces. As the Mishap Pilot stopped and shut down the mishap aircraft, fuel continued to leak and burn inside and underneath the aircraft, which caused additional damage until it was extinguished.

3. CONCLUSION

By clear and convincing evidence, I find the cause of the mishap was material failure of the third stage Integrally Bladed Rotor forward integral arm caused by a hard rub event that created heat damage on the aft plate seal of the integral arm. This failure in the fan module of the engine caused the subsequent aircraft fire, which resulted in damage to the aircraft and airfield in excess of an estimated $50,000,000.00.

[redacted]

17 March 2015

GREGORY S. KEETON, Colonel, USAF
President, Accident Investigation Board

INDEX OF TABS