NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

June 29, 2017

Airworthiness Group Chairman's Factual Report

NTSB ID No.: DCA17FA021

A. ACCIDENT:

NTSB Accident Number: DCA17FA021
Location: Chicago, Illinois
Date: October 28, 2016
Time of Accident: About 1432 Central Daylight Time
Aircraft: Boeing 767-323(ER)
Registration Number: N345AN

B. GROUP MEMBERS:

Chairman: Mike Hauf
National Transportation Safety Board
Washington, D.C.

Member: Raymond Hansen
Federal Aviation Administration
Des Plaines, IL

Member: Mike Madden
The Boeing Company
Seattle, WA

Member: Scott Causbie
The Boeing Company
Seattle, WA

Member: Diego de la Garza
American Airlines
Dallas, TX

Member: Eric Davis
American Airlines
Tulsa, OK

Member: Joshua Stanton
American Airlines
Tulsa, OK

C. SUMMARY:

C.1 Event Summary:

On October 28, 2016, at about 2:32 CDT, American Airlines flight number 383, a Boeing B767-300, N345AN, powered by two General Electric CF6-80C2B6 turbofan engines, experienced a right engine uncontained failure and subsequent fire during the takeoff ground roll on runway 28R at the Chicago O'Hare International Airport (ORD), Chicago, Illinois. The flight crew aborted the takeoff and stopped the aircraft on runway 28R and an emergency evacuation was conducted. Of the 161 passengers and 9 crew members onboard, one passenger received serious injuries during the evacuation and the airplane was substantially damaged as a result of the fire. The flight was operating under the provisions of 14 Code of Federal Regulations Part 121 as a domestic scheduled passenger flight to Miami International Airport (MIA), Miami, Florida.

C.2 Airworthiness Group Summary:

The Airworthiness Group was formed during an organizational meeting held on October 29, 2016 at the Doubletree Hotel Chicago-O'Hare Airport, Rosemont, Illinois.

On October 29, 2016, the Airworthiness Group conducted their investigation of the airplane while the aircraft remained in its final resting place on runway 28R. The investigation consisted of documenting the position of the controls within the flight deck, documenting the left and right landing gear, right wing, stabilizer and the interior of the cabin. During this phase of the investigation, the following was completed:

- Fuel from the right outboard fuel tank was manually drained.
- The outboard section of the right wing was removed from the wing.
- The No. 3, 4, 7, & 8 tire/wheel assemblies were changed.
- Cargo was removed from the forward and aft cargo compartment.
- The engine was strapped fore/aft by American Airlines for aircraft towing operations due to significant damage to the engine case in the area of the turbine failure.
- The aircraft was towed to an American Airlines Hangar for further investigation.

During the period of October 30th through November 3, 2016, the Airworthiness Group continued documenting the airplane while the aircraft remained within the American Airlines Hangar.

D. DETAILS OF THE INVESTIGATION:

D.1 Final Aircraft Position and Braking Marks on Runway 28R:

On Saturday, October 29, 2016, the Airworthiness group noted that the accident airplane was positioned approximately 9,225 feet from the threshold of 28R with approximately 3,775 feet of runway remaining. The length of runway 28R is 13,000 feet. The Airworthiness group walked runway 28R and noted that tire braking marks from the accident aircraft's left and right main landing gear tires were noticeable on the runway surface starting at approximately 6,941 feet from the threshold of 28R (or about 4,020 feet from taxiway N5[1]). The braking marks continued approximately 2,284 feet to the airplane's final position.

Figure 1 and 2 show an overhead and runway image of the Chicago O'Hare International Airport with the location where the accident aircraft began braking and its final position after stopping. Photographs of the accident airplane in its final resting position were taken by the NTSB and the Assistant Deputy Fire Commissioner of Airport Operations on Friday, October 28, 2016 and are shown in Figures 3 - 7.

Figure 1 Overhead image of the Chicago O'Hare International Airport

[1] American Airlines flight AA 383 entered runway 28R for takeoff using taxiway N5.

Figure 2 View showing the beginning of the braking marks on runway 28R

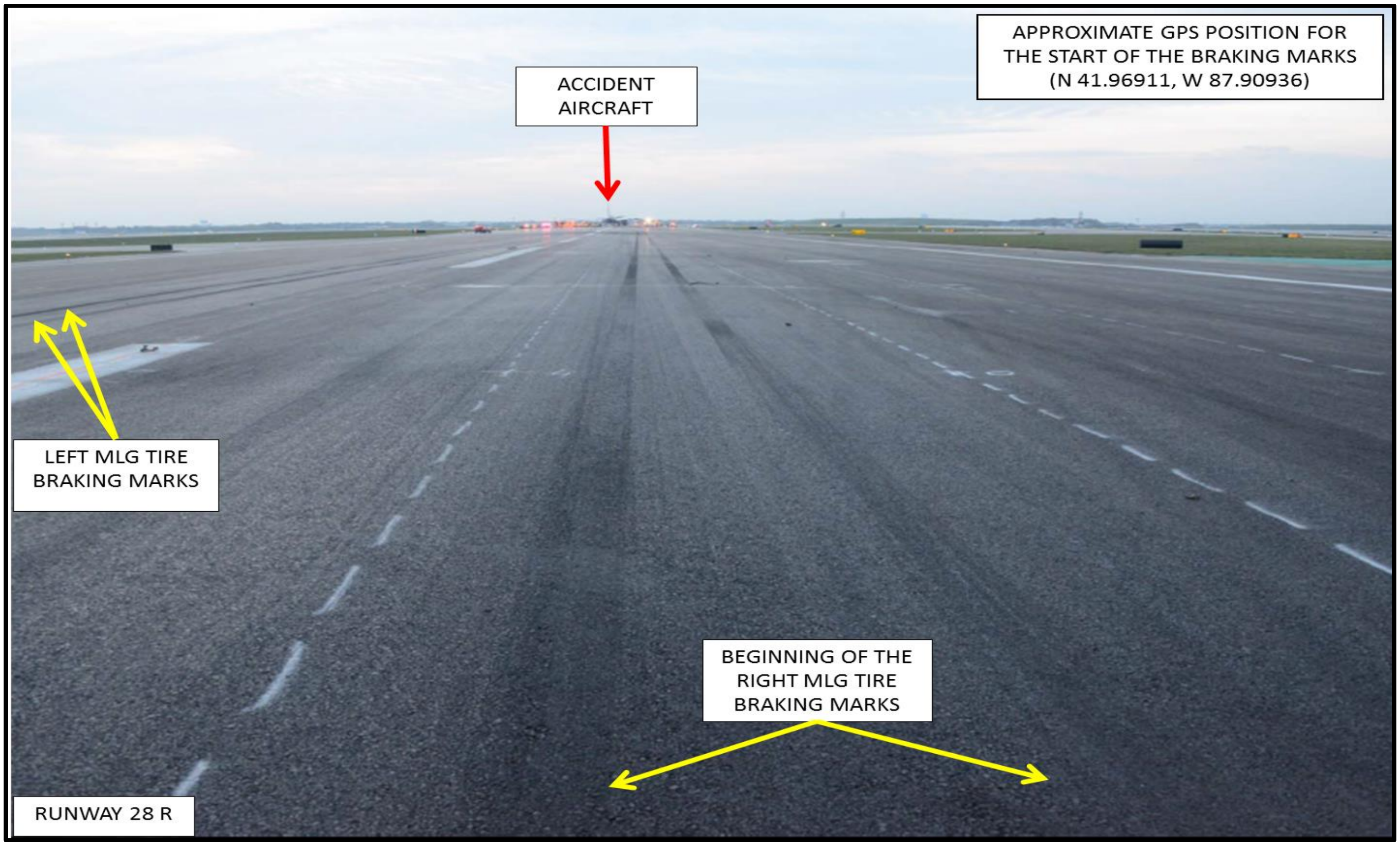

Figure 3 View showing the front of the airplane

Figure 4 View showing the forward right side of the airplane

Figure 5 view showing the right side of the airplane

Figure 6 View showing the outboard end of the right wing

Figure 7 View showing the aft portion of the left side of the airplane

D.2 Aircraft Information:

D.2.1 Hours and Cycles:

According to American Airlines Dispatch Environmental Control System (DECS), the aircraft had accumulated 50,632.3 hours and 8,120 cycles at the time of the accident.

Photographs of the airplanes registration and standard airworthiness certificate are shown in Figures 8 and 9.

Figure 8 View of the airplane registration

REGISTRATION NOT TRANSFERABLE 345

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION – FEDERAL AVIATION ADMINISTRATION
CERTIFICATE OF AIRCRAFT REGISTRATION

This certificate must be in the aircraft when operate[d]

NATIONALITY AND REGISTRATION MARKS N 345AN

AIRCRAFT SERIAL NO. 33084

MANUFACTURER AND MANUFACTURER'S DESIGNATION OF AIRCRAFT
BOEING 767-323

ICAO Aircraft Address Code: 50747756

ISSUED TO

AMERICAN AIRLINES INC
4333 AMON CARTER BLVD MD 5569
FT WORTH TX 76155

Corporation

This certificate is issued for registration purp[oses] only and is not a certificate of title. The Federal Av[iation] Administration d[oes] not determine ri[ghts] of ownership as between private persons.

It is certified that the above described aircraft has been entered on the register of the Federal Aviation Administration, United States of America, in accordance with the Convention on International Civil Aviation dated December 7, 1944, and with Title 49, United States Code, and regulations issued thereunder.

[redacted] ADMINISTRATOR

U.S. Departm[ent] of Transporta[tion] Federal Aviat[ion] Administrati[on]

DATE OF ISSUE April 30, 2003
EXPIRATION DATE January 31, 2017

Figure 9 View of the airplane standard airworthiness certificate

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION—FEDERAL AVIATION ADMINISTRATION
STANDARD AIRWORTHINESS CERTIFICATE

1 NATIONALITY AND REGISTRATION MARKS	2 MANUFACTURER AND MODEL	3 AIRCRAFT SERIAL NUMBER	4 CATEGORY
N345AN	BOEING 767-323	33084	TRANSPOR

5 AUTHORITY AND BASIS FOR ISSUANCE
This airworthiness certificate is issued pursuant to the Federal Aviation Act of 1958 and certifies that, as of the date of issuance, the aircraft to which issued has been inspected and found to conform to the type certificate therefor, to be in condition for safe operation, and has been shown to meet the requirements of the applicable comprehensive and detailed airworthiness code as provided by Annex 8 to the Convention on International Civil Aviation, except as noted herein.
Exceptions: Exemption No. 4725 from 14CFR 25.785(h)- allows one seat for a required flight attendant to be located near the overwing Type III exits.

6 TERMS AND CONDITIONS
Unless sooner surrendered, suspended, revoked, or a termination date is otherwise established by the Administrator, this airworthiness certificate is effective as long as the maintenance, preventative maintenance and alterations are perform[ed in] accordance with Parts 21, 43, and 91 of the Federal Aviation Regulations, as appropriate, and the aircraft is registered in the U[nited] States.

DATE OF ISSUANCE	FAA REPRESENTATIVE	DESIGNATION NUMBER
April 24, 2003	Paul E. Davis [redacted]	DARF750208S

Any alteration, reproduction, or misuse of this certificate may be punishable by a fine not exceeding $1,000, or imprisonment not exceed[ing] years, or both. THIS CERTIFICATE MUST BE DISPLAYED IN THE AIRCRAFT IN ACCORDANCE WITH APPLICABLE FEDE[RAL] AVIATION REGULATIONS.

FAA Form 8100-2 (8-82) U.S. GPO-2001

D.2.2 Certification & Guidance:

D.2.2.1 Certification Basis for the Boeing 767-300:

The Federal Aviation Administration (FAA) has 10 aircraft certification offices (ACO) which are responsible for approving the design certification of aircraft, aircraft engines, propellers, and replacement parts for those products. The FAA ACO in Seattle, Washington, was responsible for the certification oversight and approval for the Boeing 767-300.

On December 19, 1982, the Boeing Company applied for a transport category type certificate for the Boeing 767-300. According to Type Certificate Data Sheet[2] (TCDS) A1NM, revision 36, dated June 20, 2016, type certificate approval for the Boeing 767-300 was granted on September 22, 1986, under 14 Code of Federal Regulations (CFR[3]) Part 25 (the airworthiness standards for transport-category airplanes). The Boeing 767-300 was the second model added in a series of derivative models (or "changed aeronautical products") that were approved and added to the Boeing type certificate (TC), originally issued for the Boeing 767-200 on July 30, 1982.

The applicable certification basis for the Boeing 767-300 was the FAA's 14 CFR Part 25 Aviation Regulations as amended by Amendments 25-1 through 25-37, except where superseded by the more recent sections of the regulations as listed in the TCDS.

D.2.2.2 Turbine Engine Installation Requirements:

The certification requirements used to ensure the hazards to the airplane are minimized in the event of an engine rotor failure are contained in 14 CFR section 25.903(d). According to TCDS number A1NM, the amendment level for section 25.903 was 25-40, which became effective on May 2, 1977. Section 25.903(d) "Turbine engine installations", specifies the following:

(1) Design precautions must be taken to minimize the hazards to the airplane in the event of an engine rotor failure or of a fire originating within the engine which burns through the engine case.

(2) The powerplant systems associated with engine control devices, systems, and instrumentation, must be designed to give reasonable assurance that those engine operating limitations that adversely affect turbine rotor structural integrity will not be exceeded in service.

D.2.3 Guidance Available to Comply with 14 CFR 25.903:

D.2.3.1 FAA Order 8110.11:

FAA Order 8110.11, "Design Considerations for Minimizing Damage Caused by Uncontained Aircraft Turbine Engine Rotor Failures," published in 1975 but no longer in use, was in effect at the time of the Boeing 767 certification program[4]. The Order was distributed internally to FAA offices and to any applicant in which the Order was applicable to their design. Order 8110.11 was similar to the subsequent Advisory Circular (AC) 20-128, "Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failures," issued in 1988, and provided guidance on acceptable methods of compliance for 14 CFR §§ 25.901 and 25.903. Sections 5 and 6 of that order provide design considerations for critical systems (including fuel systems) that should be used to minimize the damage that can be caused by uncontained engine debris. Specifically, in section 6, the document describes that the flammable fluid system components, which

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[2] A Type Certificate Data Sheet (TCDS) is a formal description of the aircraft, engine or propeller. It lists limitations and information required for type certification including airspeed limits, weight limits, thrust limitations, etc.

[3] 14 Code of Federal Regulations (CFR) commonly known as Federal Aviation Regulations (FAR)

[4] Reference attachment 1.

would include main engine fuel lines, should not be installed in probable fragment impact areas if damage to any of these components will jeopardize the safety of the airplane. Section 6(a) denotes that provisions should be incorporated to assure that flammable fluids released will not impinge on ignition sources. Section 6(c) denotes that fuel tanks should not be located in impact zone areas, but when it is necessary to do so, guidance is provided to the manufacturers regarding acceptable direction of spilled fuel and appropriate testing to determine ignition potential of rotor fragments passing through or being contained within the fuel tank.

D.2.3.2 Advisory Circular (AC) 20-128:

On March 9, 1988, the FAA issued Advisory Circular (AC) 20-128 entitled "Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failures".

This AC provided for a method of compliance with 14 CFR 25.903(d) that required design precautions to be taken to minimize the hazards to an airplane in the event of an uncontained engine or auxiliary power unit (APU) failure. The AC defines dispersion angles for fragments that may be released during a fan blade or rotor failure. These angles define impact areas relative to the engine installation based on recorded observations of the results of failures both in service and in tests. The AC also provides a listing of design considerations to minimize damage to critical structural elements and systems in the airplane, and defines the fragment energy levels that can be expected from the failure of a fan blade or predicted pieces of a rotor. On March 25, 1997, this AC was cancelled and replaced by AC 20-128A[5].

Advisory Circular (AC) 20-128A included the requirements from AC 20-128 and incorporated input from an Aviation Regulation Advisory Committee, consisting of both regulatory and industry representatives, tasked by the FAA to revise guidance for demonstrating compliance to section 25.903. The AC established additional criteria to mitigate the leakage of fuel which would be susceptible to ignition. These criteria resulted in the creation of dry bay sizing criteria and minimum drip clearance distance from potential ignition sources. The AC also provides additional guidance by describing acceptable design practices that impact safe flight and landing to the crew and airplane structure and systems. The AC also introduces acceptable risk assessment methods that can be used to measure the remaining risk after prudent and practical design considerations have been taken.

D.3 Flight Deck - Documentation:

D.3.1 Information from the Assistant Deputy Fire Commissioner:

On Tuesday, November 1, 2016, the Assistant Deputy Fire Commissioner of the Chicago Fire Department, Timothy Sampey, provided the Airworthiness group with the following information:

- The engines were not running when he arrived at the aircraft.
- When he entered the flight deck, he did not touch or manipulate the left or right engine fire handles.
- At that time, Chicago Fire Department (CFD) personnel inside the aircraft utilized a Thermal Imaging Camera (TIC) to capture a heat signature from the floor area in row 34 and a Raytec camera to get an approximate temperature reading of 152 degrees Fahrenheit.
- He engaged (activated) the forward and aft cargo halon bottles. Upon activation, he heard the sound of halon being discharged.
- Approximately ten minutes after bottles were activated, the area was reassessed and the temperature had been reduced to approximately 71 degrees Fahrenheit.
- He engaged (activated) the APU fire handle.

[5] Reference attachment 2.

- Did not touch thrust levers or speedbrake lever.
- Made sure the batteries were not turned off, because he wanted to open the aft cargo door using the cargo door toggle switch.
- There was no visible smoke conditions in the cabin prior to discharging the cargo halon bottles but a small amount of residual smoke was released when sidewalls and ceiling panels were opened by CFD personnel to check for possible fire extension and smoldering.
- Aft cargo door could not be opened by toggle switch and had to be opened manually.
- Batteries were eventually switched to the off position in the event liquid extinguishing agents had to be applied to the heated area.

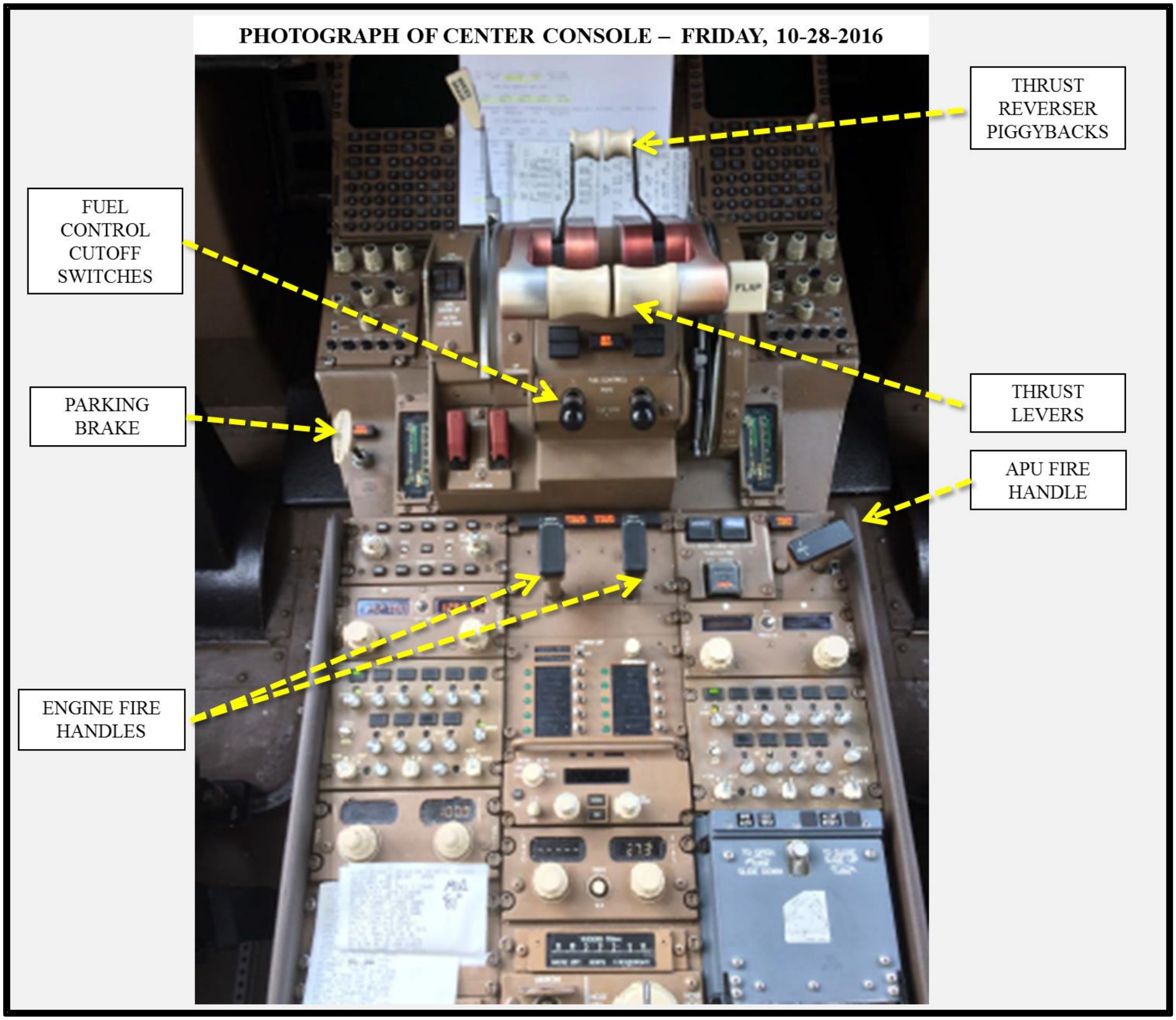
D.3.2 Controls and Indicators:

On Saturday, October 29, 2016, the Airworthiness group visually inspected and photographed the instruments, controls and displays within the flight deck while the aircraft remained in its final resting position on runway 28R (Reference Table 1 and Figure 10). At the time of the inspection, the airplane was unpowered.

Table 1 Controls and displays within the flight deck

Control	Position
Thrust levers	Both thrust levers (throttles) were against their aft stops.
Thrust reverse levers “Piggybacks”	Stowed.
L ENG FIRE handle	Fully extended and centered.
R ENG FIRE handle	Fully extended and centered.
APU FIRE handle	Fully extended and rotated counter clockwise.
EVAC Command Switch	The guard on the evacuation command switch was found raised and the toggle switch was found in the on position.
Fuel pumps (left main and right main)	ON
Cross feed and the center pump	OFF
Cargo fire (forward and aft)	Armed
Auto Brakes	OFF
Fuel Control Cutoff Switches	Both switches were found in the down and CUTOFF position.
Flap Handle and position indicator	Positioned to 15
Parking brake	Set
Oxygen Masks	All of the oxygen masks were found stowed.
Handheld Fire Extinguisher & Protective Breathing Equipment (PBE)	Stowed

Figure 10 Center Console



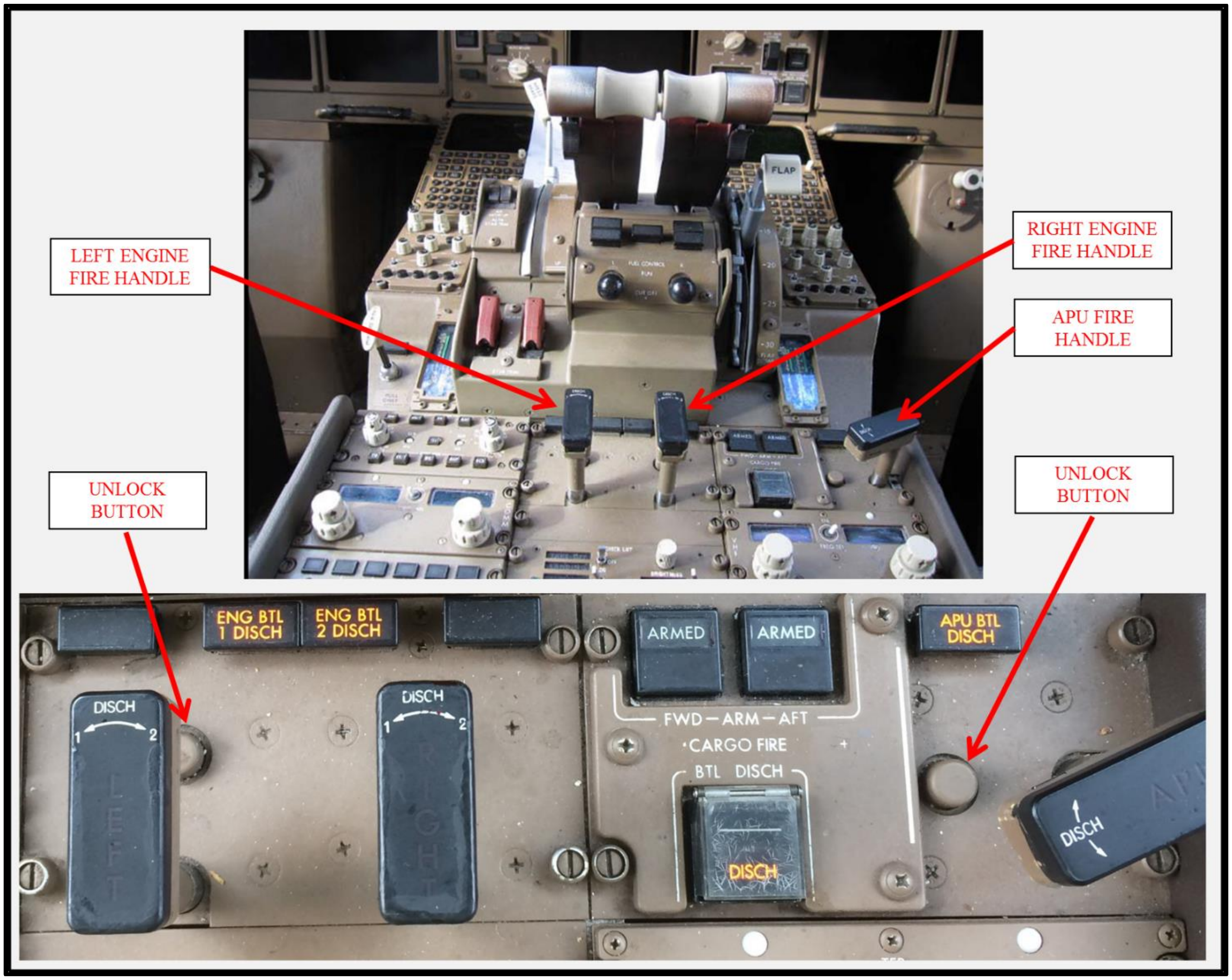
D.4 Engine Fire Extinguishing System:

D.4.1 System Description:

The airplane was equipped with an engine fire extinguishing system that can be operated by the crew to release one or two applications of extinguishing agent to a fire in either engine in the event the engine fire detection system detects a fire or an overheat condition in its respective engine.

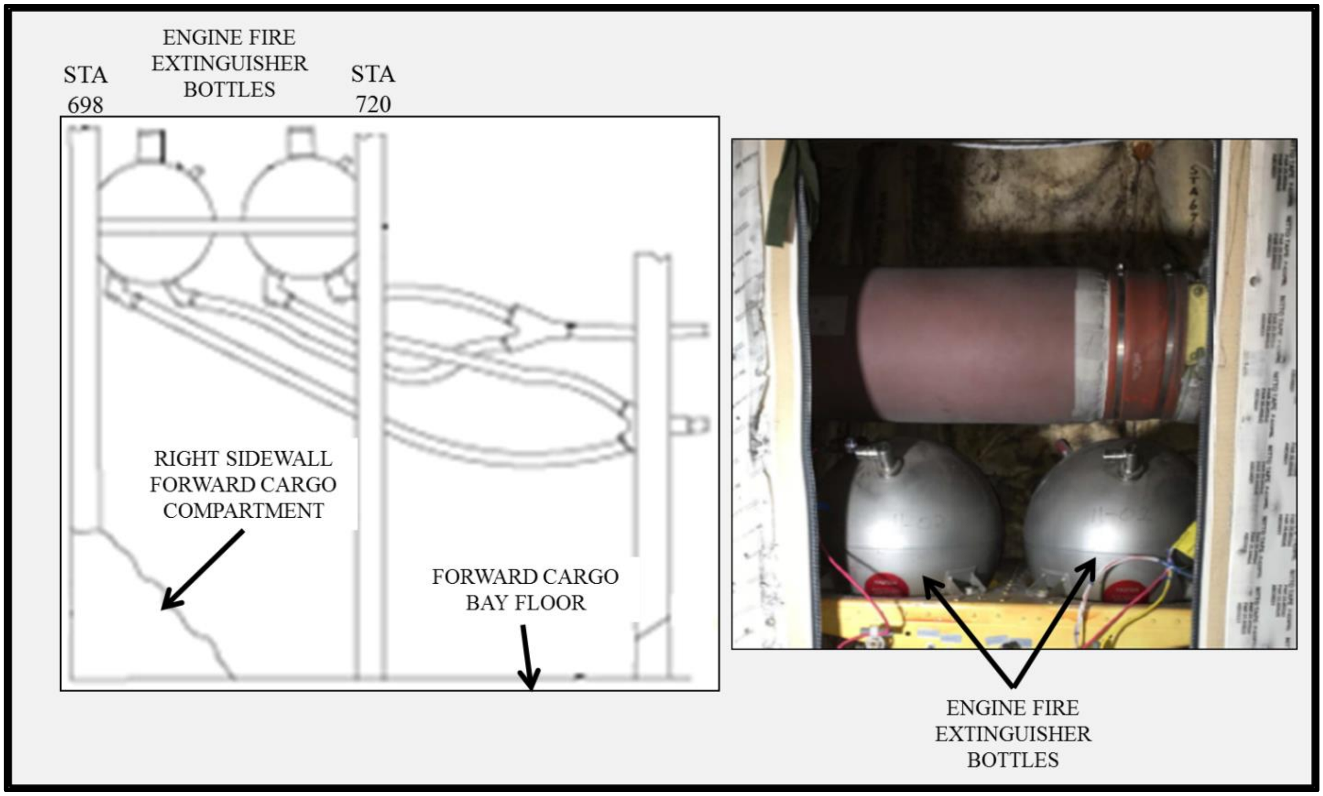
This system comprises, in part, two fire extinguisher bottles and an engine fire control panel located on the center console in the flight deck. As shown in Figure 11, there are two engine fire switch handles (one for the left engine and one for the right engine) and an APU fire switch handle located on the engine fire control panel.

Figure 11 Photograph showing the engine fire control panel.



As shown in Figure 12, the airplane was equipped with two, Pacific Scientific, engine fire extinguisher bottles located in the forward cargo compartment in the aft right cheek. Each extinguisher bottle included two squib cartridges (one per discharge port), a pressure switch, and a combined safety relief and filter port. When detonated, the squib cartridge ruptures a retaining disk in the discharge port releasing the extinguishing agent.

Figure 12 Fire extinguisher bottles



To prevent an accidental activation of the fire extinguishing system, each fire handle is locked in its down (non-activated) position by a solenoid operated mechanical interlock device connected to the fire handles shaft. The mechanical interlock can be manually unlocked by the flight crew by pressing a button located on the engine fire control panel just forward of the fire handle. It can also be unlocked automatically by the engine fire detection system when the system detects a fire or an engine overheat condition in an engine; the engine fire detection system will also illuminate a red warning light in the respective engine fire switch handle. Once the mechanical interlock is released, the fire switch handle can be operated by the flight crew by pulling the handle out and rotating it.

Pulling an engine fire switch handle to its up and fully extended position (fire switch activated) commands the following:

- Arming of the number 1 and number 2 fire extinguishing bottles.
- Closure of the fuel shut-off valve (spar valve) of the affected engine.
- Closure of the hydraulic pump supply shut-off valve of the affected engine.
- Closure of the air supply pressure regulation and shut-off valve.
- Closure of the engine high pressure fuel shut-off solenoid valve.
- Removal of power to the engine thrust reverser isolation valve.
- The affected engine’s generator field relay and generator circuit breaker are tripped.
- Fire bell is reset.

Rotation of an engine fire switch handle discharges the extinguishing agent into the appropriate engine. Rotating it fully counterclockwise discharges bottle number 1. Rotating it fully clockwise discharges bottle number 2. After rotation, the fire handle automatically returns to an off-center position.

D.4.2 On-Scene Examination:

Visual inspection showed that the left and right engine handles were found extended and centered; neither was found rotated towards their number 1 or the number 2 fire bottle position.

On Sunday, October 30, 2016, the Airworthiness group visually inspected and documented the two engine fire extinguisher bottles. Both bottles were removed from the airplane and weighed using a Chatillon hand held scale. The number 1 bottle was identified as P/N 34600012-24 and S/N 23046F1 and the number 2 bottle was identified as P/N 34600012-24 and S/N 23044F1.

As shown in Figure 13, the data label on the number 1 fire extinguisher bottle, recorded a pressure of 825 PSIG (at 70 Degrees) and a weight of 23.83 pounds. As shown in Figure 14, the data label on the number 2 bottle recorded a pressure of 825 PSIG (at 70 Degrees) and a weight of 23.92 pounds. After removal from the airplane, the weight of both bottles was measured and both were found to weigh about 10.5 pounds.

Figure 13 Number 1 fire extinguisher bottles after removal from the forward cargo compartment

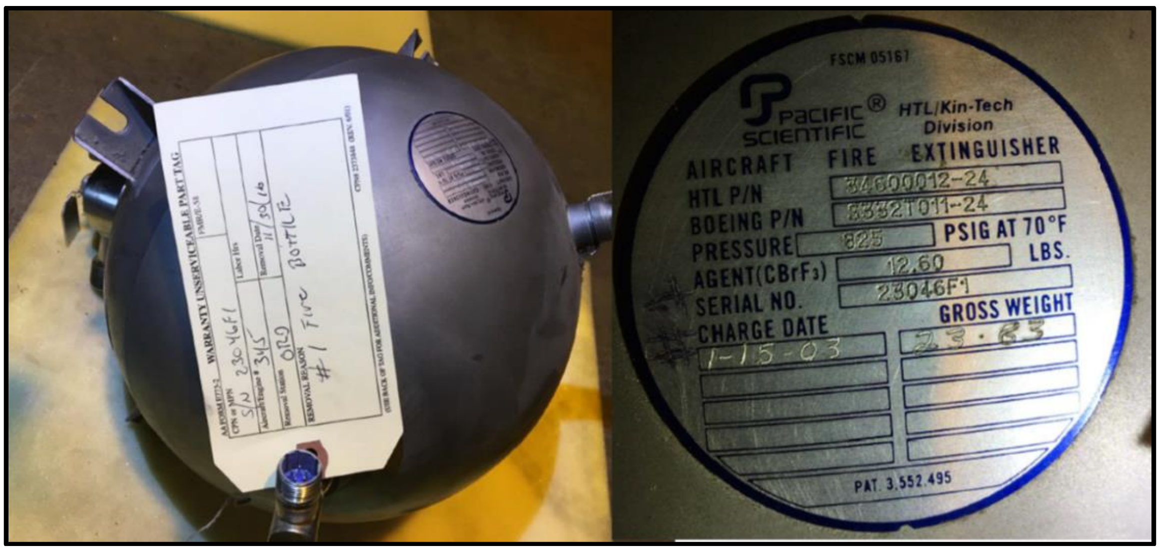
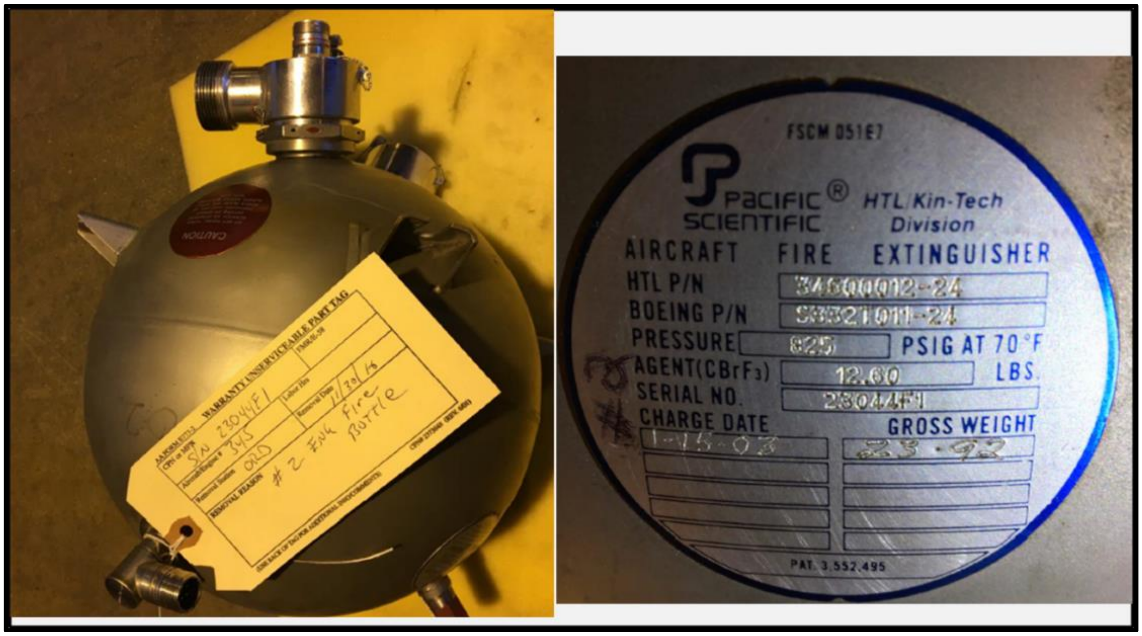


Figure 14 Number 2 fire extinguisher bottles after removal from the forward cargo compartment



D.5 Impact Damage – Right Wing, Right Main Landing Gear (MLG) Door and ECS Bay:

Examination of the right wing and the lower right side of the fuselage revealed impact damage on the upper and lower surfaces of the wing, including its leading edge, right MLG bay door, underwing wing-to-body fairing adjacent to the environmental control system (ECS) bay, and the ECS bay. Examination of the upper right side of the fuselage revealed light impact damage in several locations near the over-wing exit.

Examination of the left side of the fuselage revealed impact damage on the landing gear bay door, underwing wing-to-body fairing adjacent to ECS bay, and the ECS bay.

D.5.1 Right Wing:

Visual inspection of the accident airplane's right wing revealed that all of the impact damage to the wing was located inboard of the pylon; no impact damage was observed outboard of the right engine pylon from exiting HPT stage 2 disk or engine debris. Inspection of the upper surfaces of the right wing revealed two through-hole penetrations; one hole was located forward of the front spar in the fixed-wing leading edge panel and the other was located aft of the wing front spar between wing rib 6 and 7 in the area of the dry bay. (Reference Figure 15) Inspection of the lower surfaces of the right wing revealed one hole aft of the wing front spar between wing rib 6 and 9 in the area of the dry bay, several small holes in the dry bay access door, and a few small holes inboard of rib 6. (Reference Figure 16)

Figure 15 Damage to the right wing upper skin and leading edge

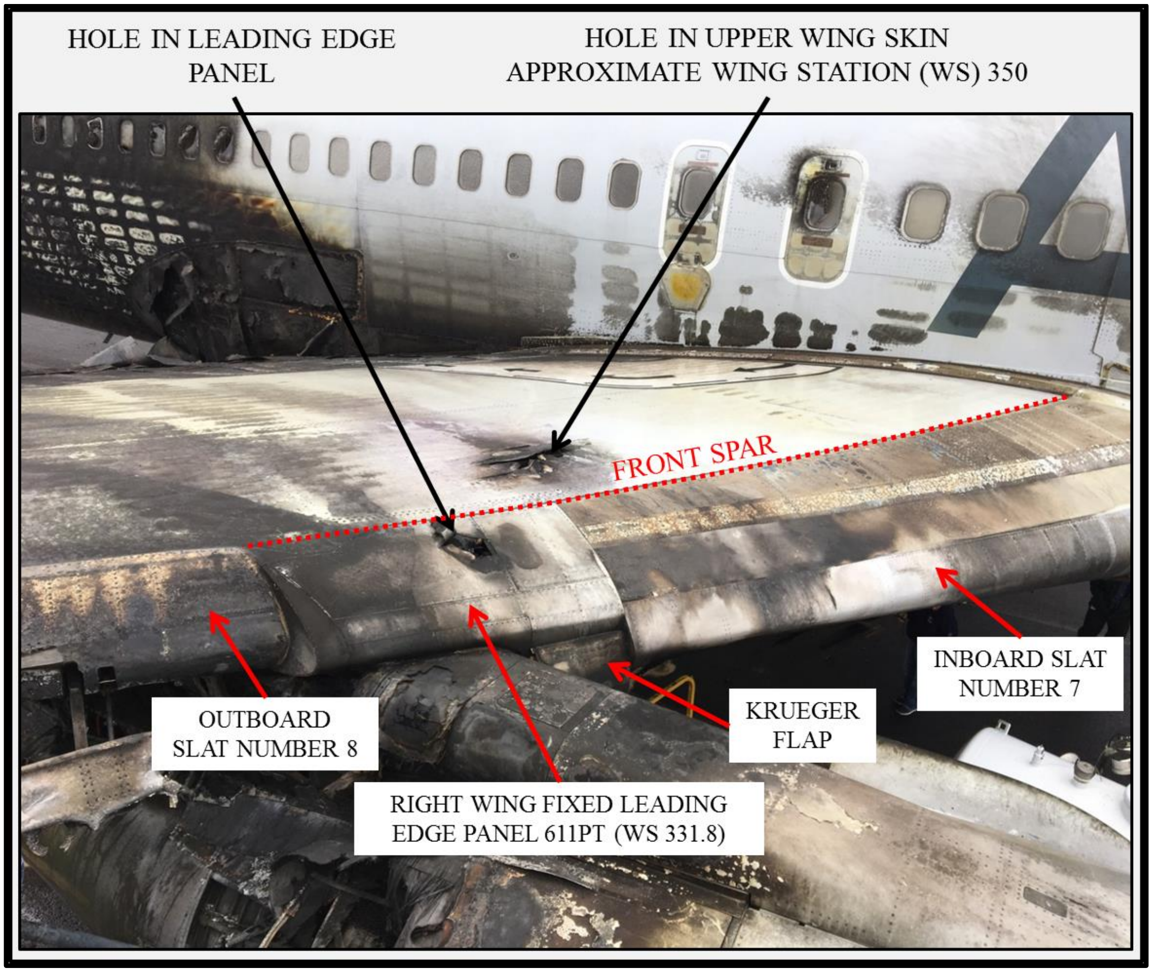
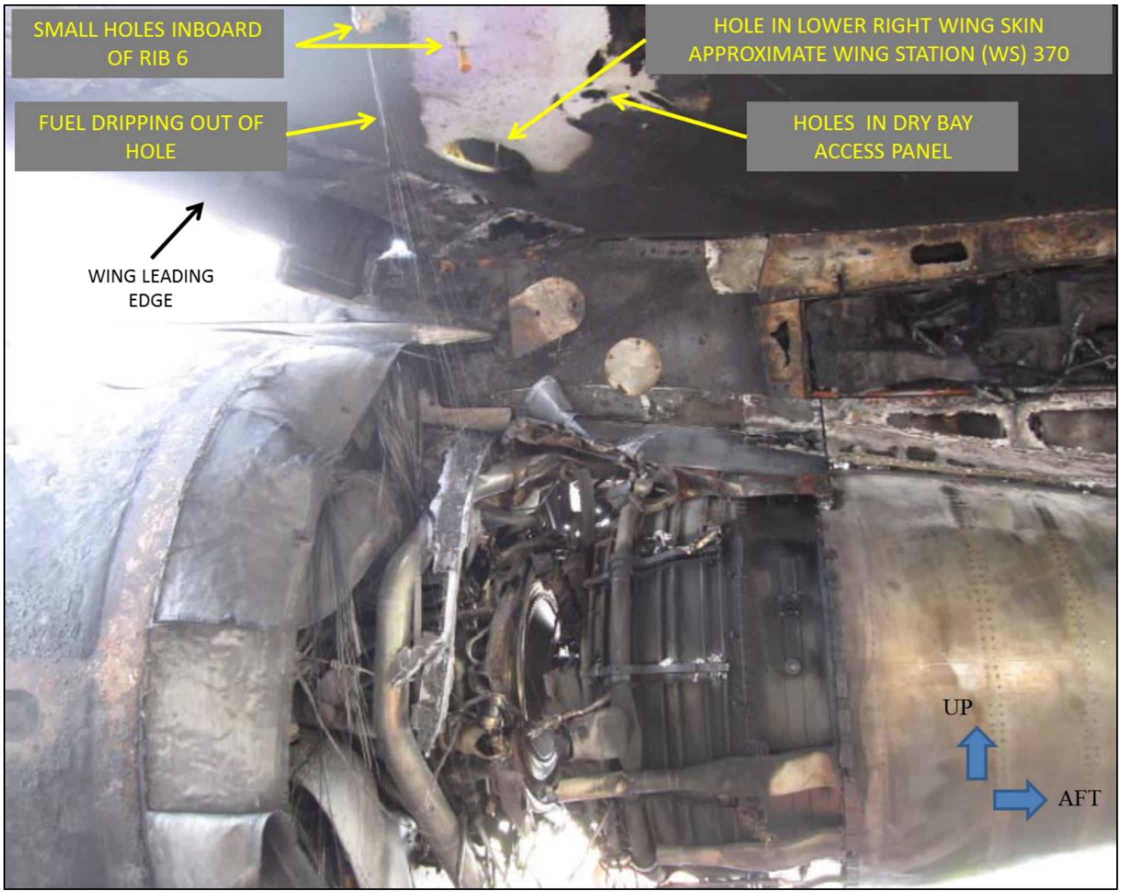


Figure 16 Damage to the right wing lower skin



D.5.1.1 Dry Bay:

D.5.1.1.1 Description:

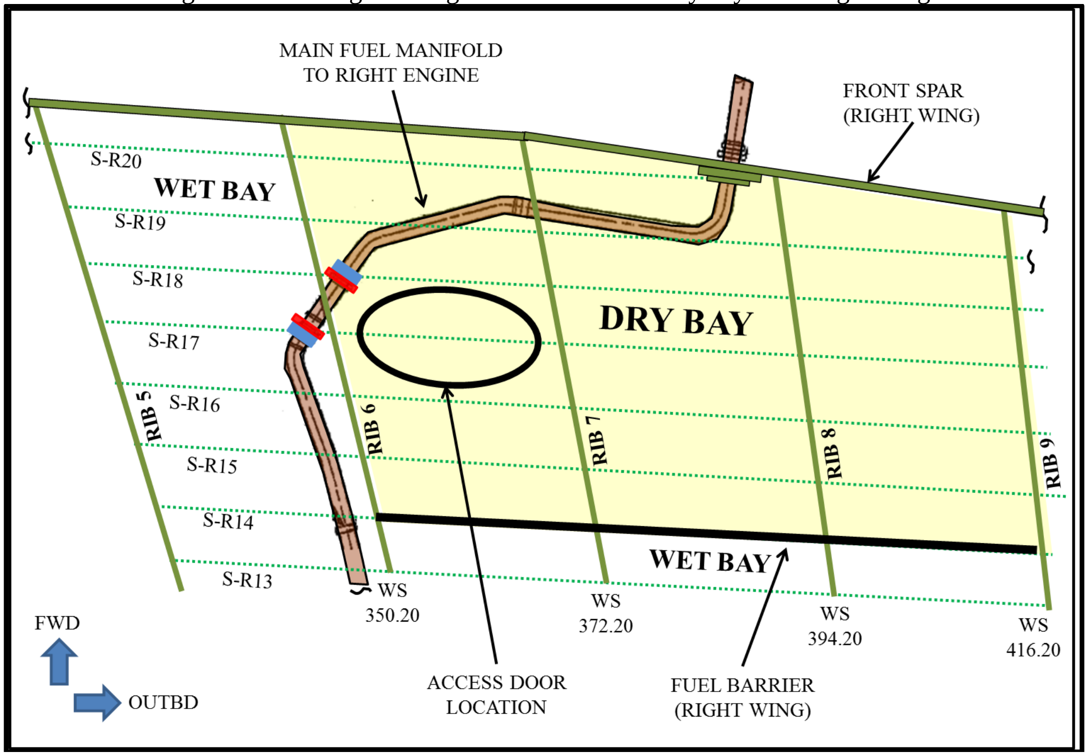
As previously stated in this report, 14 CFR 25.903(d) "Turbine engine installations" specifies (in part) that design precautions must be taken to minimize the hazards to the airplane in the event of an engine rotor failure or of a fire originating within the engine, which burns through the engine case.

Each main fuel tank contained a fuel-free compartment, identified as a "dry bay", that was located directly above the engine in the forward part of the fuel tank (Reference Figure 17). The incorporation of the dry bay was one of the major precautions taken on the fuel system to minimize the hazard to the airplane in the event of an engine non-contained failure.

In Boeing's engine burst/flammable fluid airplane safety analysis[6], Boeing indicated that the dry bay was incorporated to minimize the possibility of fuel spillage onto the engine hot section or into a fire caused by an engine burst. The dry bay was contained between ribs 6 and 9, and by the front spar and the dry bay barrier (supported by upper stringer 19 and lower stringer 14). As with the 767-200 airplane, the engine fuel feed line was routed through the dry bay with rib 6 and front spar cutouts sealed at the entry and exit. For the purpose of inspections, access into the dry bay can be gained through an elliptical access door, with maximum dimensions of 10 x 18 inches, located in the wing lower skin between ribs 6 and 7. The dry bay also contains a drain hole with a flame arrestor to permit the draining of any moisture which may accumulate within the compartment.

[6] Reference Boeing document titled, "767 airplane safety analysis, engine burst/flammable fluid leakage", dated August 1981.

Figure 17 Drawing showing the location of the dry bay in the right wing



D.5.1.1.2 Dry Bay Sizing:

An NTSB Review of FAA Order 8110.11 found that although the incorporation of a dry bay within the wing tank as a means of compliance was not included as one of the design considerations, the Order did briefly discuss punctures of the wing fuel tanks. Section 6.(c)[7] of the Order indicated that fuel tanks should not be located in the impact zone areas. If, however, it should become absolutely necessary to locate the fuel tanks in these vulnerable areas, then, fragment punctures of the fuselage fuel tanks are unacceptable if the fuel will spill into the fuselage bays, whereas punctures of the wing fuel tanks may be acceptable if the fuel spills into the airstream away from the aircraft.

According to Advisory Circular (AC) 20-128A[8], section 8, titled “Accepted Design Precautions”, if fuel tanks are located in impact areas, the following precautions should be implemented: (i) Protection from the effects of fuel leakage should be provided for any fuel tanks located above an engine or APU and within the one-third disk and intermediate fragment impact areas. Dry bays or shielding are acceptable means. The dry bay should be sized based on analysis of possible fragment trajectories through the fuel tank wall and the subsequent fuel leakage from the damaged fuel tank so that fuel will not migrate to an engine, APU or other ignition source during either in flight or ground operation. A minimum drip clearance distance of 10 inches from potential ignition sources of the engine nacelle, for static conditions, is acceptable.

According to the FAA, the specific guidance defining an acceptable minimum drip clearance distance was added to AC 20-l 28A in 1997. Following the 1989 United Airlines DC-l 0-10 accident in Sioux City and in response to the related NTSB recommendations, the FAA tasked an Aviation Rulemaking Advisory Committee (ARAC) to revise guidance for demonstrating compliance to 14 CFR 25.903. The ARAC, which included representatives from regulatory authorities and industry, established the

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7 Section 6 of the Order was titled “Location of Critical Systems and Components”

8 Reference Advisory Circular (AC) 20-128 entitled “Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure” dated 3/25/97.

dry bay sizing criteria included in the 1997 revision to AC 20-128A. The distance of 10 inches was based upon proven design practices in use at that time and balanced the need for fuel capacity in the wing fuel tanks with the regulatory requirement to minimize the hazard from uncontained engine failure.

Large transport aircraft, such as the Boeing Model 737-600/-700/-800/-900 and Airbus Model A33O, A350, and A380 series airplanes, have engines mounted in a position forward of the wing so fuel from a damaged fuel tank will not drain onto the failed engine, thus meeting the drip-clearance guidance without the need for dry bays. Based on transport aircraft service history, and without yet knowing the conclusions of investigation of the recent American Airlines 767 event, the FAA does not possess data or information that indicate the 10 inch drip clearance distance criterion is inadequate.

At the request of the NTSB, Boeing provided the reasoning, during development and certification of the 767-200 and -300, for how Boeing determined the size and location of the dry bay. According to Boeing: *"The purpose of the dry bay was to minimize the possibility of fuel spillage onto the engine hot section or into a fire caused by a turbine rotor failure. It was recognized that in order to preclude the risk of a rotor segment from penetrating into the wet bay of a wing fuel tank, the wing design would need to preclude any fuel forward of the rear most turbine stage -5 degree trajectory or move the engine forward to accomplish this. This type of design would not be accepted as being practical or an optimized design as with many other swept wing mounted engine installation due to factors like weight & balance, flutter, and additional engine burst exposure to fuselage. At the time of the 767 development program there was no industry regulations other than 25.903(d)(1) to minimize the hazard following an assumed rotor disk burst event. The dry bay design results in 10+ inches of vertical drip clearance given a rotor burst trajectory into the wet side of the dry bay*."

D.5.1.1.3 Main Fuel Feed Line Routing 767-200/300:

As previously stated, the main engine fuel feed line was routed through the dry bay. At the request of the NTSB, Boeing provided a response for why the main fuel feed line was routed through the dry bay. According to Boeing: *"In each main tank an isolated and sealed dry bay is installed over the engine turbine burst zone to minimize the possibility of fuel spillage onto the engine hot section or into a fire caused by a turbine rotor failure. The fuel line is further minimized by routing in close proximity to the engine strut structure for additional structural protection. The dry bay is a designated flammable fluid leakage zone which is vented and drained through (2) openings in the lower surface that are provided with flame arrestors. There are no ignition sources in the dry bay. The dry bay design was a feature to minimize the hazard with respect to Boeing and FAR 25.903(d)(1) requirements. Primary design considerations for minimizing fuel line length are performance of the system including suction feed capability, minimizing leakage exposure, and fire safety risks with the fuel line routed outside the wing tank in the wing leading edge.*"

D.5.1.1.4 History of Dry Bays:

At the request of the NTSB, the FAA provided the following summary on the history of dry bays:
Uncontrolled fire following an uncontained engine turbine rotor failure was identified as a potentially catastrophic failure condition when turbojet engines were introduced into commercial aviation. Uncontained engine failures typically release flammable fluids in the engine, commonly resulting in a fire. Shutting off the supply of flammable fluids to the failed engine is essential since an uncontained engine rotor failures have the potential to incapacitate some of the engine fire protection features.

For some first generation wing mounted turbojet engine installations, damage to the fuel tank could result in fuel leakage onto the engine, potentially leading to an uncontrollable fire. The design practice of providing a dry bay in areas of the fuel tanks above and adjacent to an engine was implemented to minimize the hazards of a breached fuel tank leaking on to a failed engine". The size and location of dry bays were developed to minimize the hazard of leaked fuel onto a failed engine.

Early large transport turbojet aircraft such as the Boeing Model 737-100/-200 (737 classic) and 747-100/-200 (747 classic) series airplanes developed in the 1960s, and the Model 757 and 767 series airplanes developed in the late 1970s, all included dry bays within the wing to minimize the likelihood of uncontrolled fires following an uncontained engine rotor failure. FAA Order 8110.11, published in 1975, included the following excerpt providing guidance on aircraft fuel tank design for minimizing the hazards from uncontained turbine engine failures. This guidance was part of the certification basis for the 757 and 767 aircraft and later installation of new engine models in derivatives of the 747. The order was replaced by guidance contained in AC 20-128 in 1988 which was utilized on aircraft certified during that time period such as the Airbus Model A320 series airplane. The specific guidance defining an acceptable minimum drip clearance distance was added to the AC in 1997. The need for dry bays on aircraft depends on the engine installation design configuration relative to the wing fuel tank.

From Order 8110.11, "Design Considerations for Minimizing Damage by Uncontained Aircraft Turbine Engine Rotor Failures," 11/19/1975

c. Fuel tanks should not be located in impact zone areas. If, however, should it become absolutely necessary to locate fuel tanks in these vulnerable areas, then the following observations are pertinent:

(1) Fragment punctures of fuselage fuel tanks are unacceptable if the fuel will spill into the fuselage bays, whereas punctures of the wing fuel tanks may be acceptable if the fuel spills into the airstream away from the aircraft.

(2) Appropriate testing should be accomplished to determine the ignition potential of rotor fragments passing through or being contained within the fuel tank. Reference 7 provides details of tests conducted for this purpose. These tests consisted of the firing of an IMI [Imperial Metal Industries] "HYLTTE 45" titanium projectile 8" x 2" x 5/16" (simulating a typical compressor blade), through an aluminum tank with target plates simulating the wing tanks. The projectiles were fired end-on at velocities ranging from 550 ft./sec. to 740 ft./sec. at initial temperatures ranging from 460° F. to 700 ° F.

D.5.1.1.5 On-Scene Examination:

The area of the dry bay located between ribs 6 and 7, and just aft of the front spar had penetrations through the upper and lower wing in-spar skin, a severed main fuel feed line, and holes in rib 6 (which is a barrier between the dry bay and the wet bay). Reference Figure 18

The dimensions of the hole in the lower wing in-spar skin, which is made of alloy aluminum with a thickness of approximately 0.34 inches are shown in Figure 19. The dimensions of the hole in the upper wing in-spar skin, which is made of alloy aluminum with a thickness of approximately 0.27 inches are shown in Figure 20.

As shown in Figure 21, the primary hole in rib 6 was in the upper portion of the rib just aft of the front spar. The dimensions of the hole in the rib, which is made of alloy aluminum with a thickness of approximately 0.05 inches, was approximately 10 inches by 11 inches.

The main engine fuel feed line located between ribs 6 and 7 was found completely severed and open to the dry bay. Reference Figures 22 – 23. The fuel line has an approximate diameter of two inches and is made of 0.028" wall thickness aluminum tubing.

Figure 18 Location of the holes in the upper and lower wing skin in the area of the dry bay

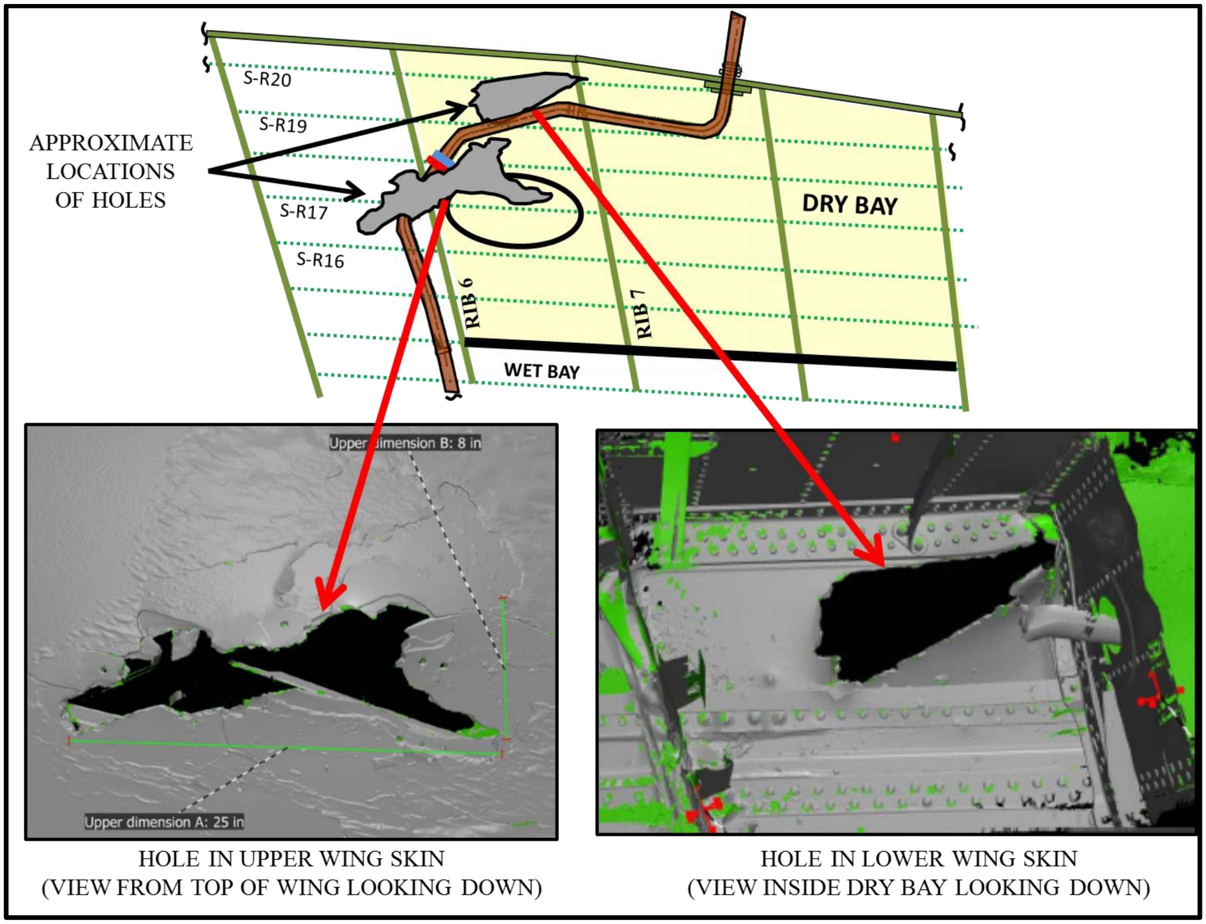


Figure 19 Close-up view of lower hole showing dimensions

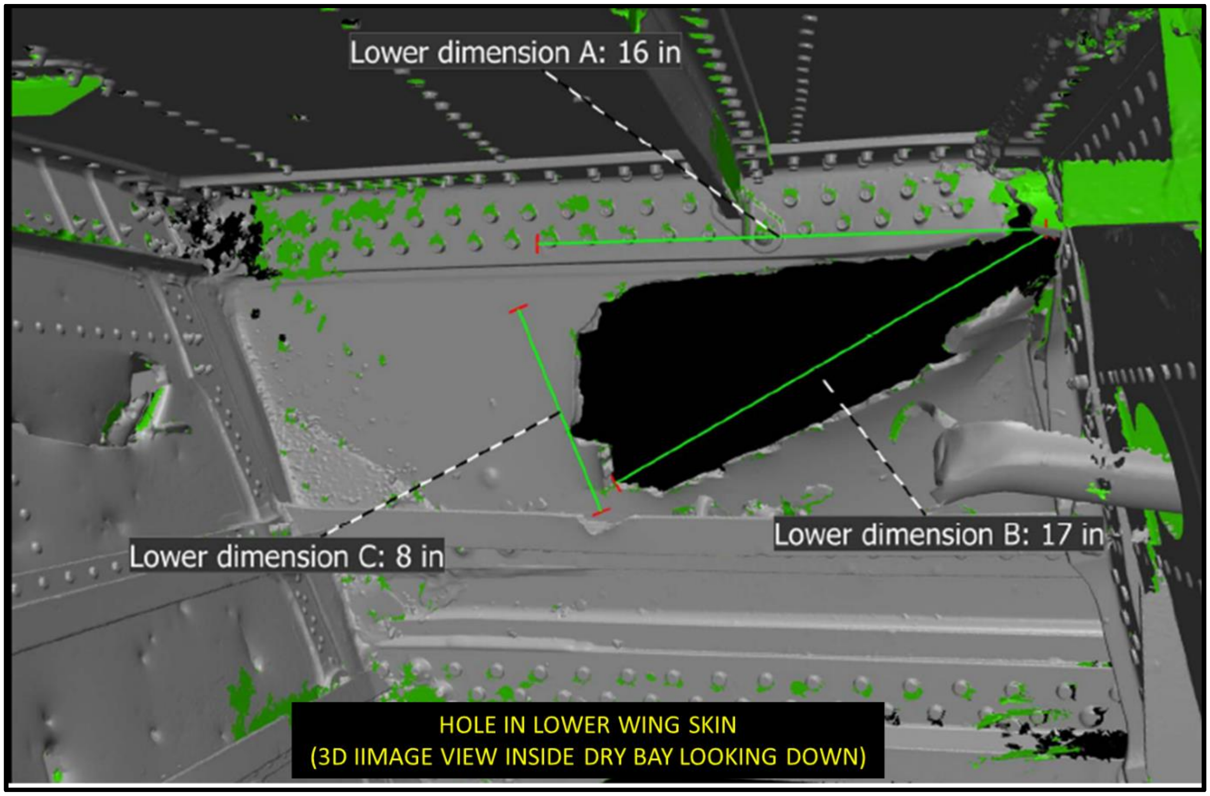


Figure 20 Close-up view of upper hole showing dimensions

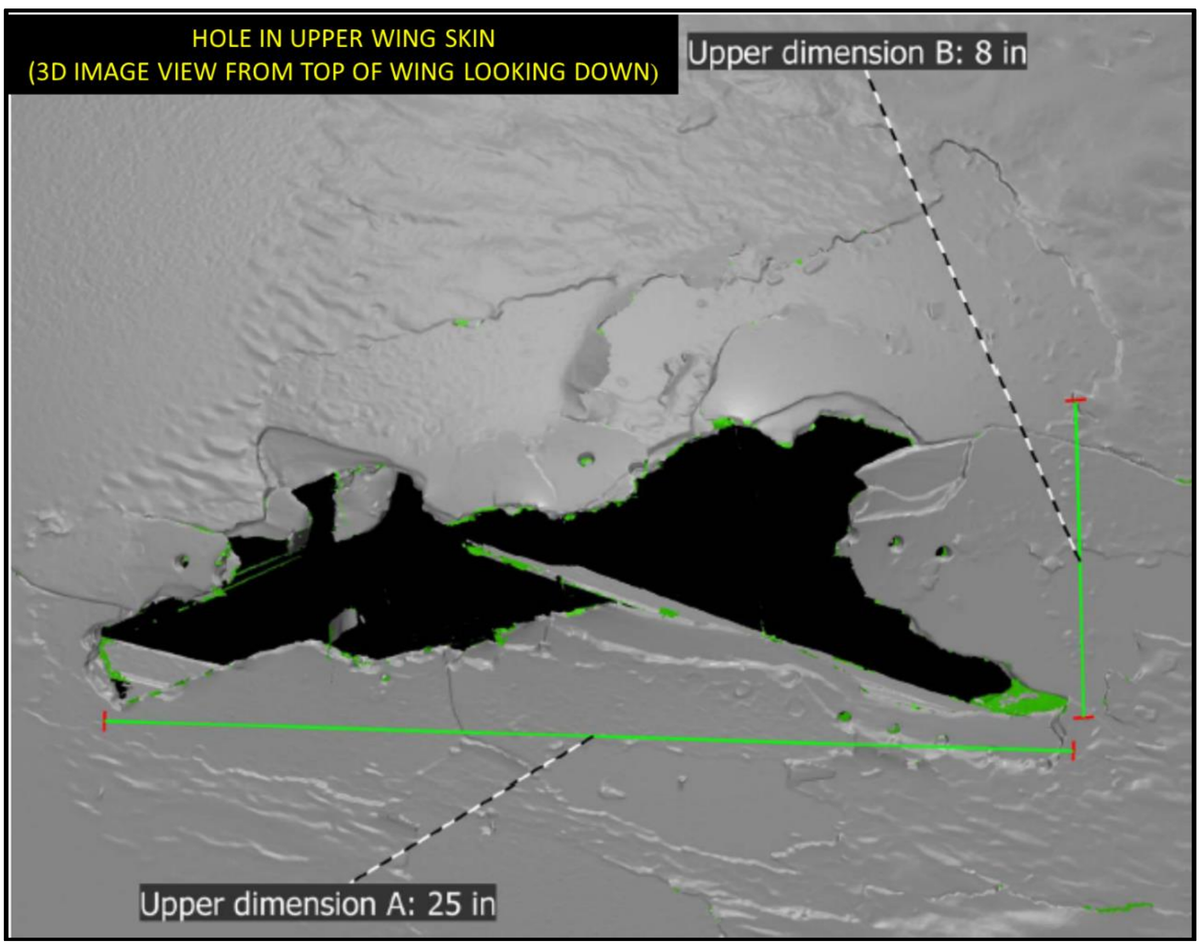


Figure 21 View showing the damage to rib number 6.

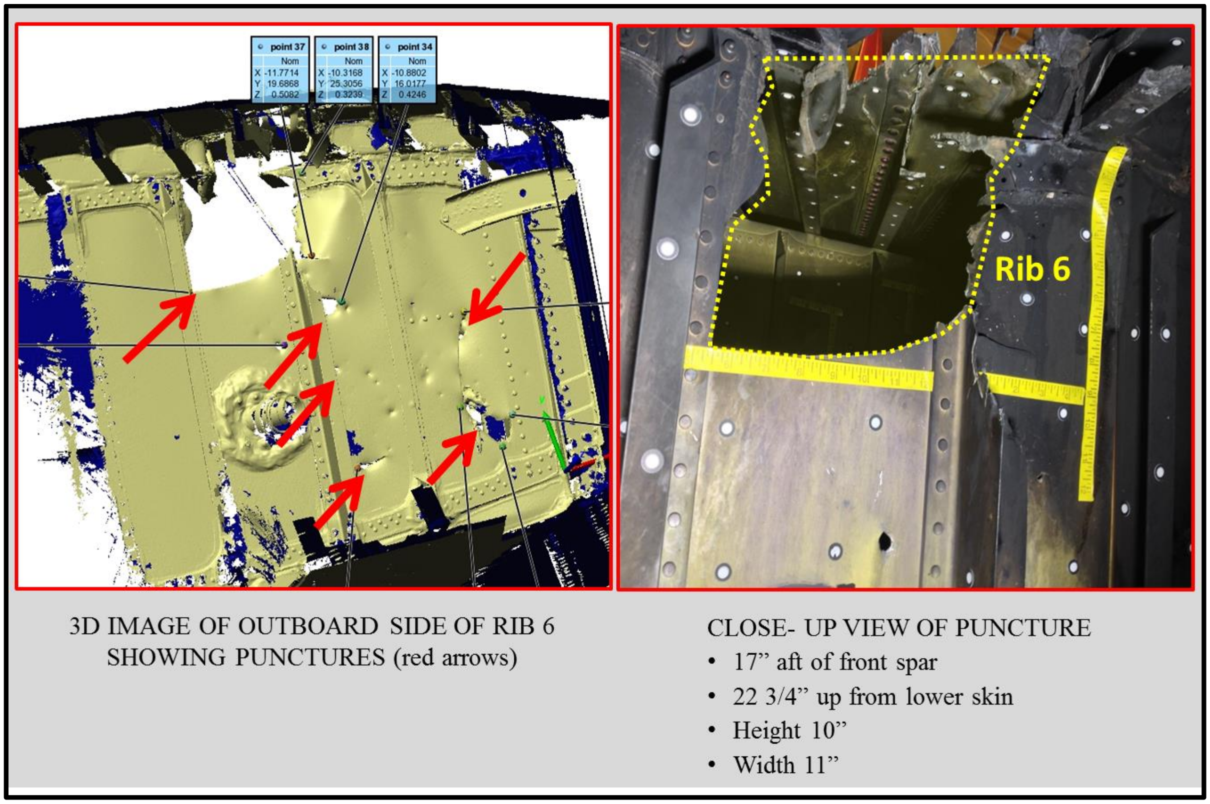


Figure 22 View of hole in lower wing skin and damaged main fuel feed line

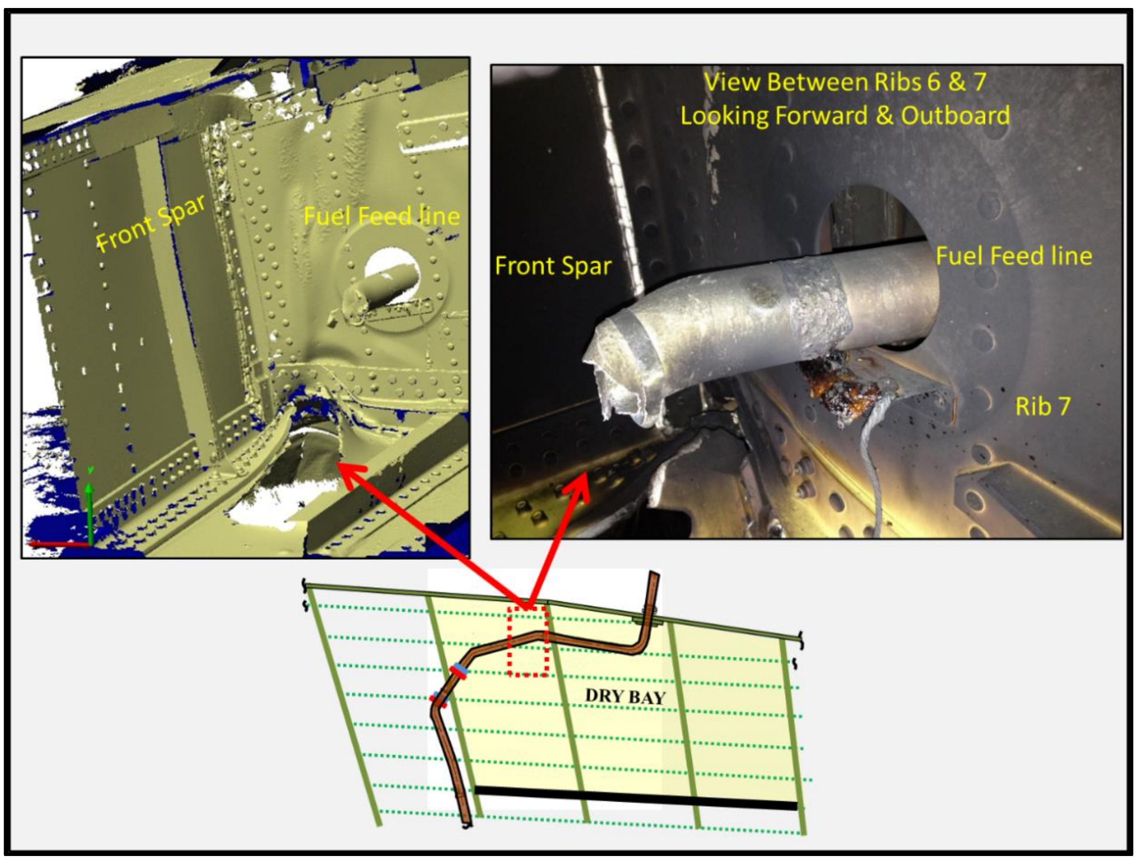
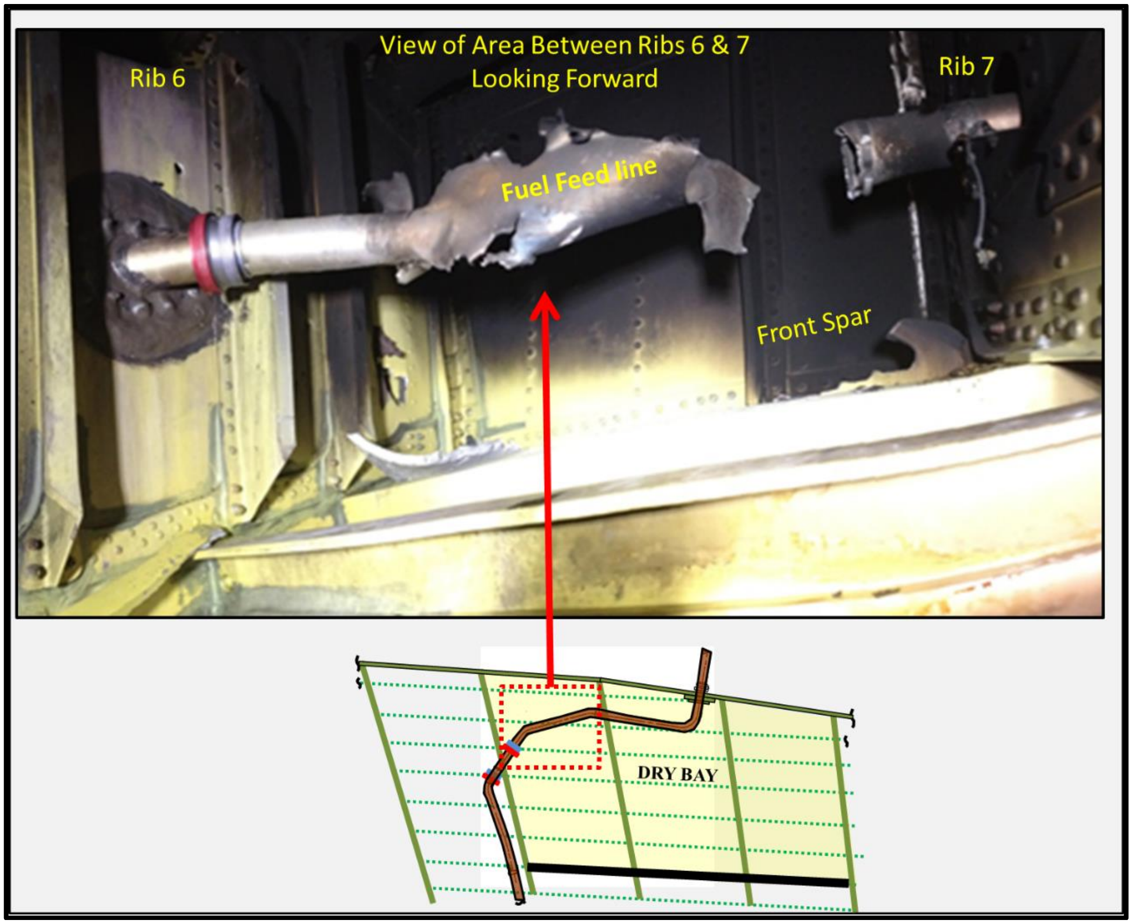


Figure 23 View of the damaged main fuel feed line



D.5.2 Right MLG Gear Bay:

Examination of the right MLG door revealed multiple areas where the door had been impacted by debris. Figure 24 provides a schematic of the landing gear door with the main impact areas highlighted by red circles and identified by letters ranging from A to J. Table 2 provides the details (location, length, width, and condition) of each of the identified impact areas. For the impact area identified as "A", the examination revealed that a fragment from the right engine (a piece of the aft flange of the HPT inner shaft) remained embedded within the top edge of the forward portion of the gear door. (Figure 25).

After the landing gear door was manually extended to its full open position, examination found a small engine fragment (approximately 1.5" by 1") resting on the inside of the door (Figure 26).

Visual inspection of the system components (flight controls, landing gear, hydraulics, etc...) contained within the MLG gear bay found no evidence of impact damage.

Table 2 Right main landing gear door impact locations

	A	B	C	D	E	F	G	H	I	J
STA	977.5	982.5	988.25	993.5	998	1007.5	1018	1023.75	1029	1052.5
RBL	93.42	84.92	92.42	65.42	71.17	67.42	59.92	66.92	72.42	69.42
Length	8.5	1	2.75	.75	.75	.75	5.5	1	2	5.5
Width	1.5	.75	.75	.25	.5	.25	1.5	.5	1.5	2
Condition	2	1	1	1	3	1	1	1	1	2

Condition 1: External skin punctured & core crushed.
Condition 2: Complete puncture.
Condition 3: External skin fiber damaged, other than heat, no core damage.

Figure 24 Drawing of right main landing gear door showing impact mark locations

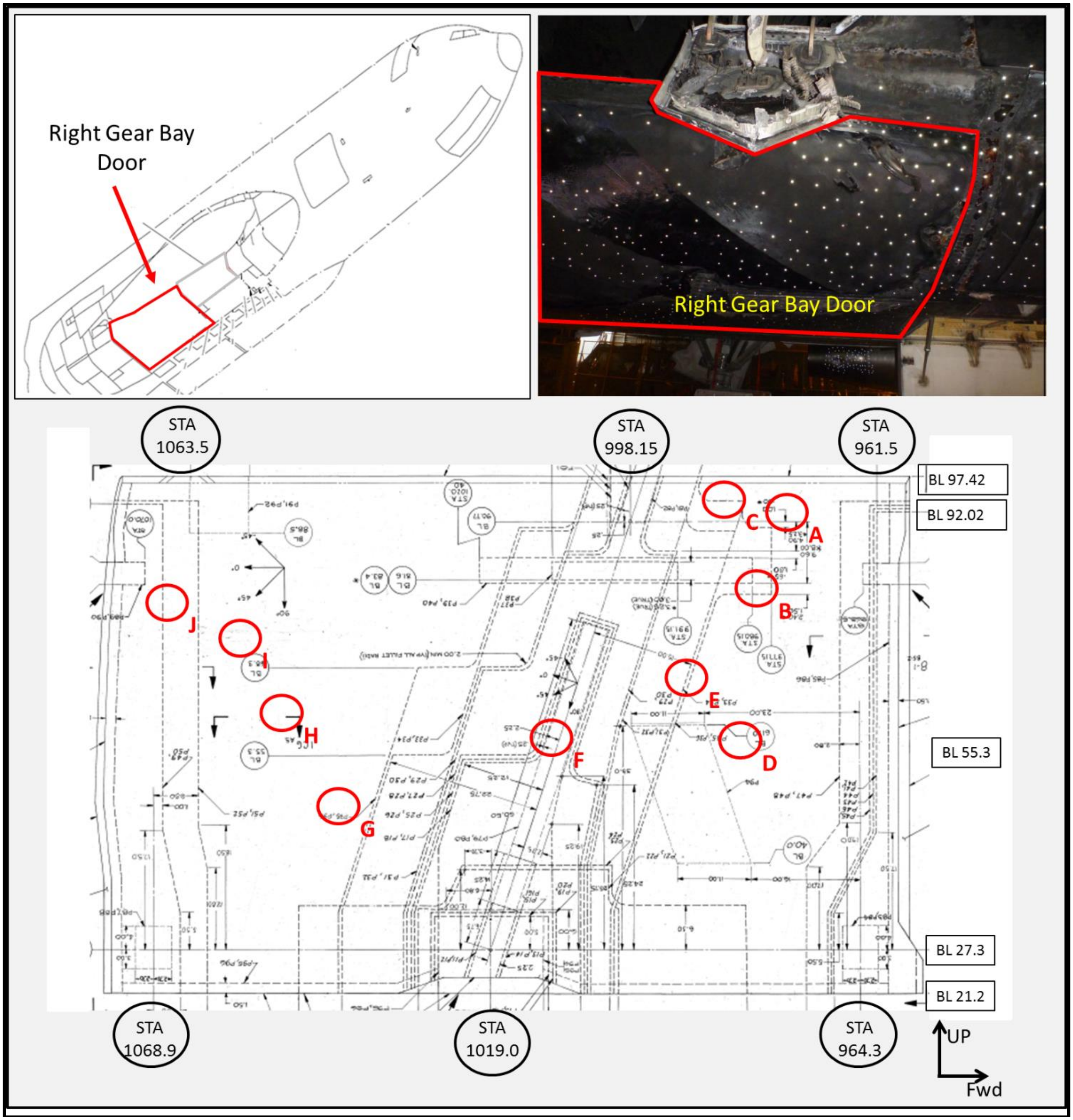


Figure 25 Photograph showing the piece of engine FOD embedded in right gear bay door

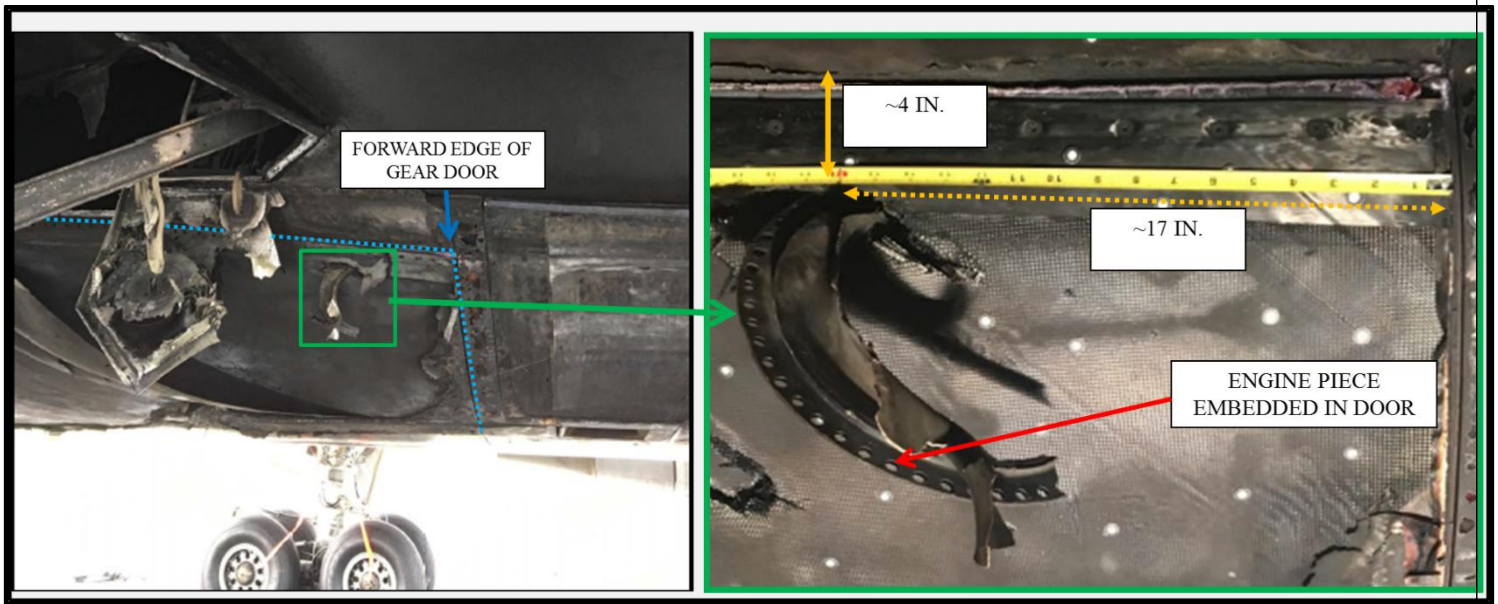
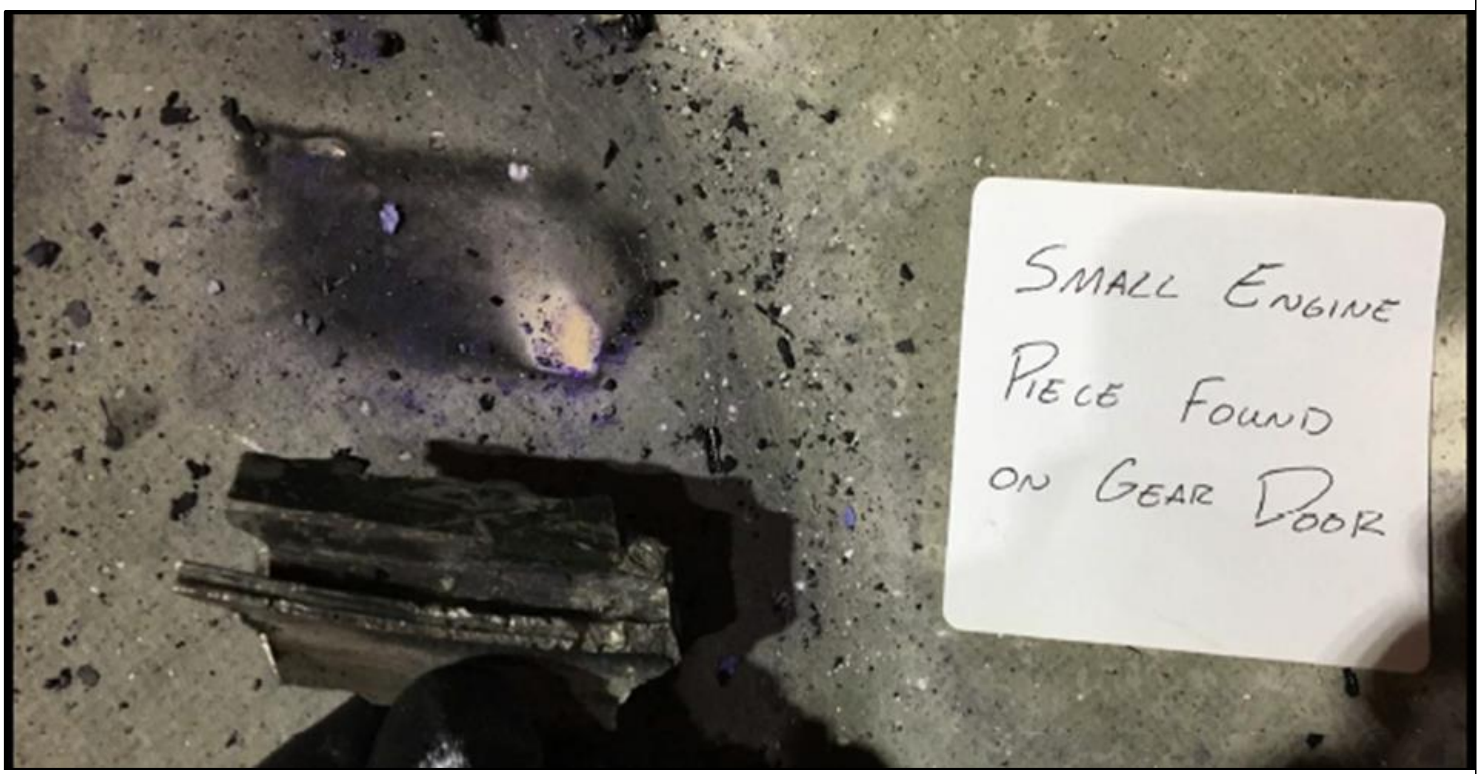


Figure 26 Small Engine piece found in right main gear bay when door opened



D.5.3 Environmental Control System (ECS) Bay - Right:

The Airworthiness Group visually inspected and documented the underwing wing-to-body fairing (adjacent to the environmental control system (ECS) bay and the ECS bay for impact damage from foreign object debris (FOD).

Examination of the underwing wing-to-body fairing revealed multiple areas where the door had been impacted by FOD. Figure 27 provides a photograph and a 3D image of the fairing with the main impact areas highlighted by red circles and identified by letters ranging from A to H. Table 3 provides the details (length, width, and condition) of each of the identified impact areas. Because the impact area identified as "C", penetrated completely through the fairing, the Airworthiness Group visually inspected and documented the area within the right ECS bay compartment for FOD and impact related damage. When the ECS bay door was opened, a small section of the stage 2 (HPT blade) from the No. 2 engine was observed resting on the lower section of the door. Additionally, a small piece of the No. 2 engine's aft heat shield was found near the third (from the aft) door hinge. (Figures 28 - 29) From the ECS bay, looking outboard toward the hole in the wing-to-body fairing, a hole was observed in the body crossover air supply duct. An impact mark (no puncture) was also observed on the primary heat exchanger duct. (Figure 30 - 31).

Figure 27 Picture of damaged underwing wing to body fairing panel (looking toward airplane centerline from right side

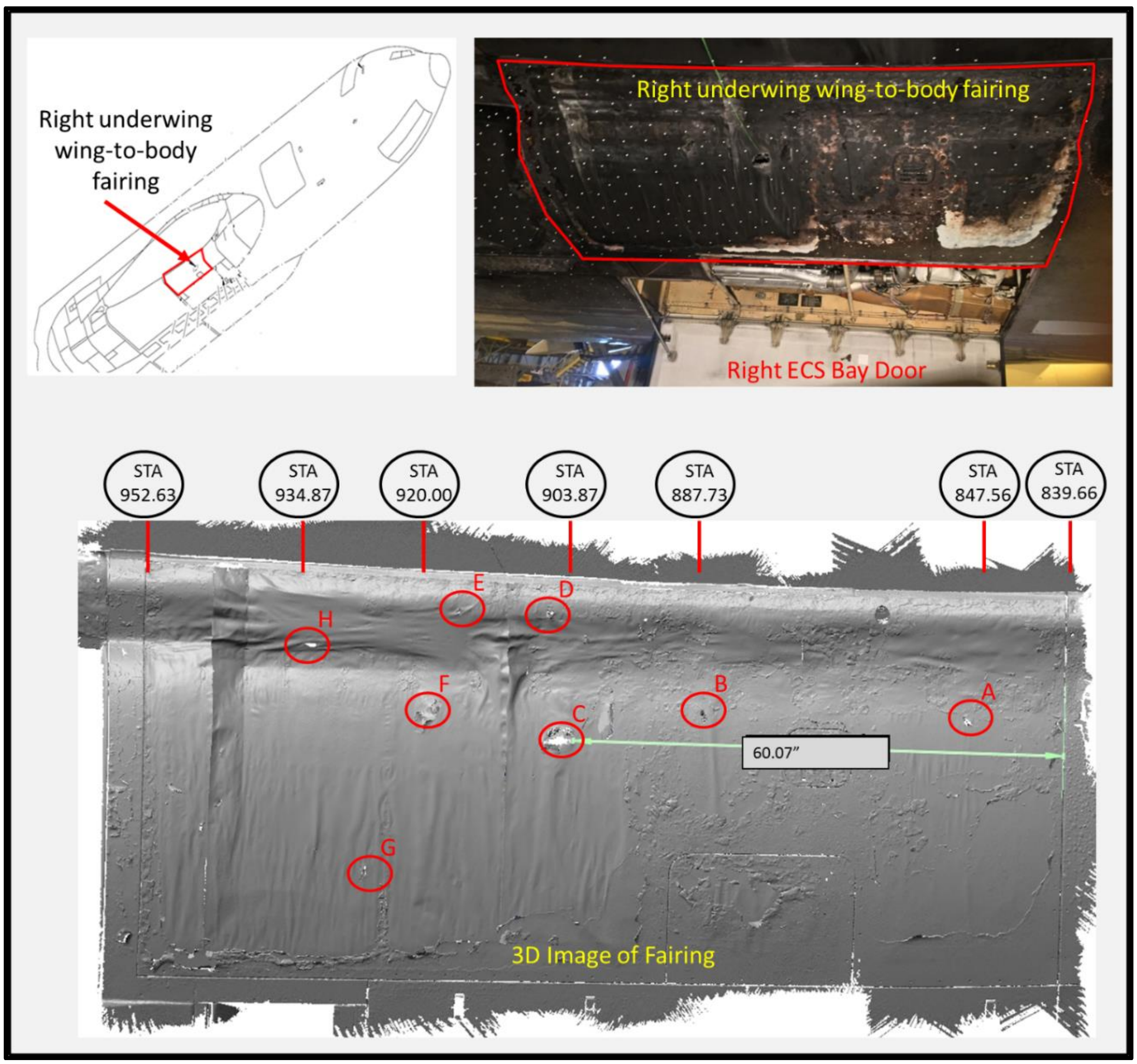


Table 3 Right main landing gear door impact locations

	A	B	C	D	E	F	G	H
Length	1.2”	1.5”	4”	0.9”	0.6”	1.2”	1.0”	0.8”
Width	0.85”	0.7”	2.2”	0.6”	0.5”	0.1”	0.25”	0.6”
Condition	Outer Skin Hole & Core Crushed	Outer Skin Hole & Core Crushed	Complete Hole	Outer Skin Hole & Core Crushed	Outer Skin Hole & Core Crushed	Outer Skin Hole & Core Crushed	Outer Skin Hole & Core Crushed	Outer Skin Hole & Core Crushed

Figure 28 View showing 2nd piece of FOD in ECS bay

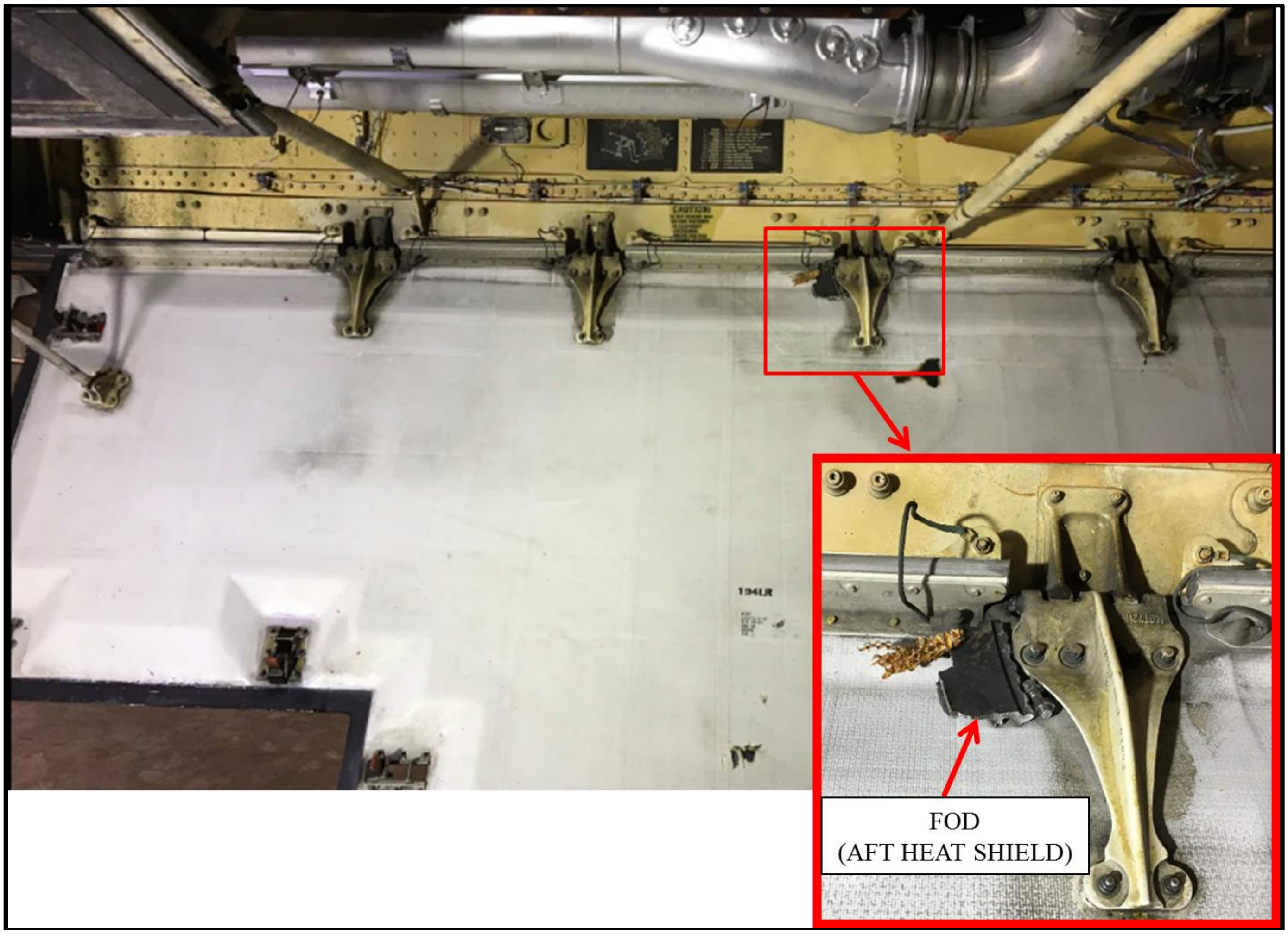


Figure 29 View of damage to right ECS bay door

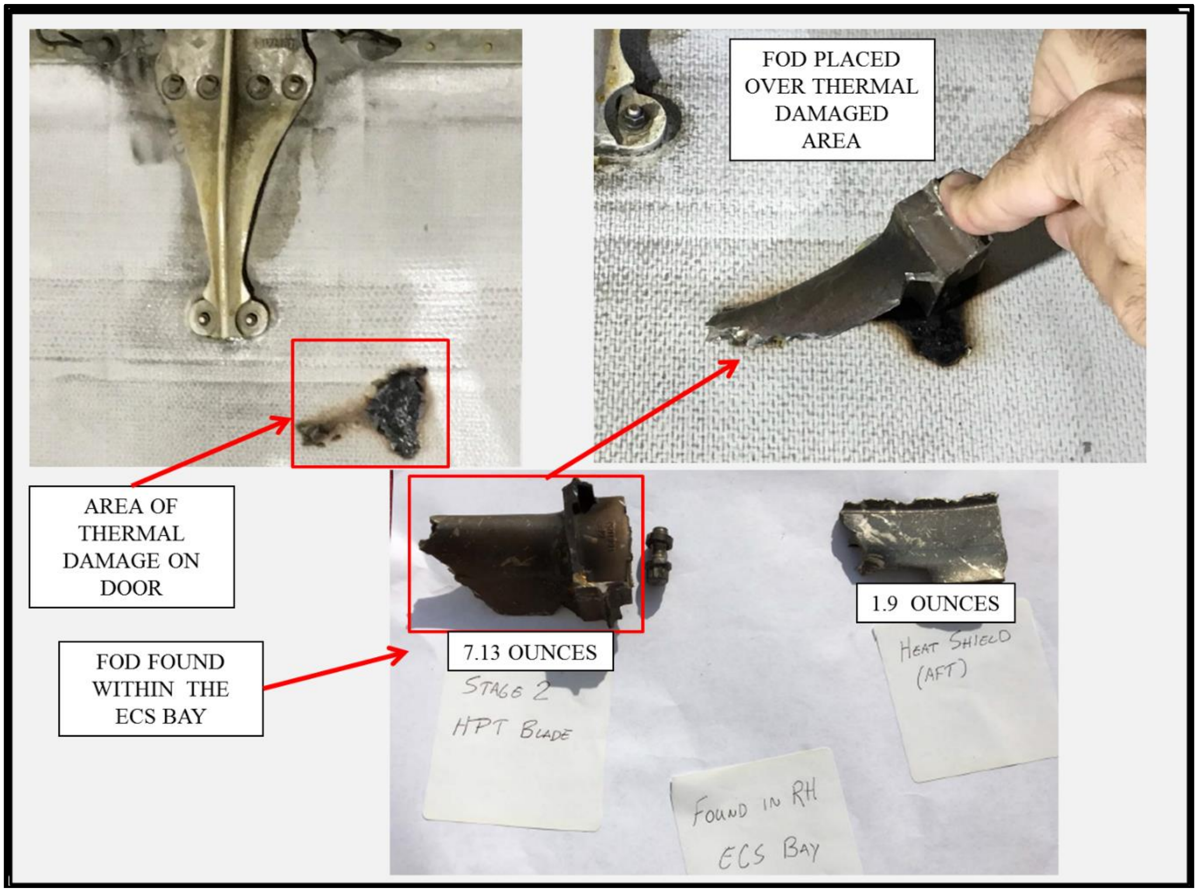


Figure 30 View of inside of ECS bay looking outboard

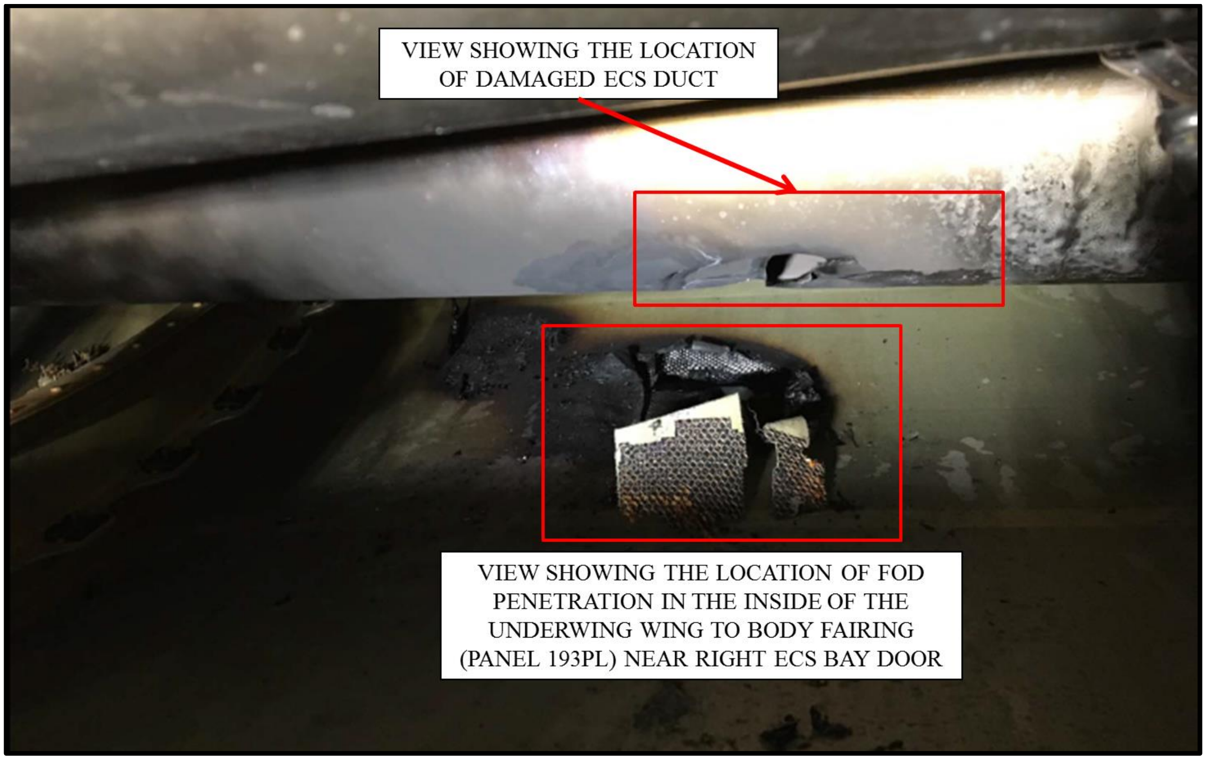
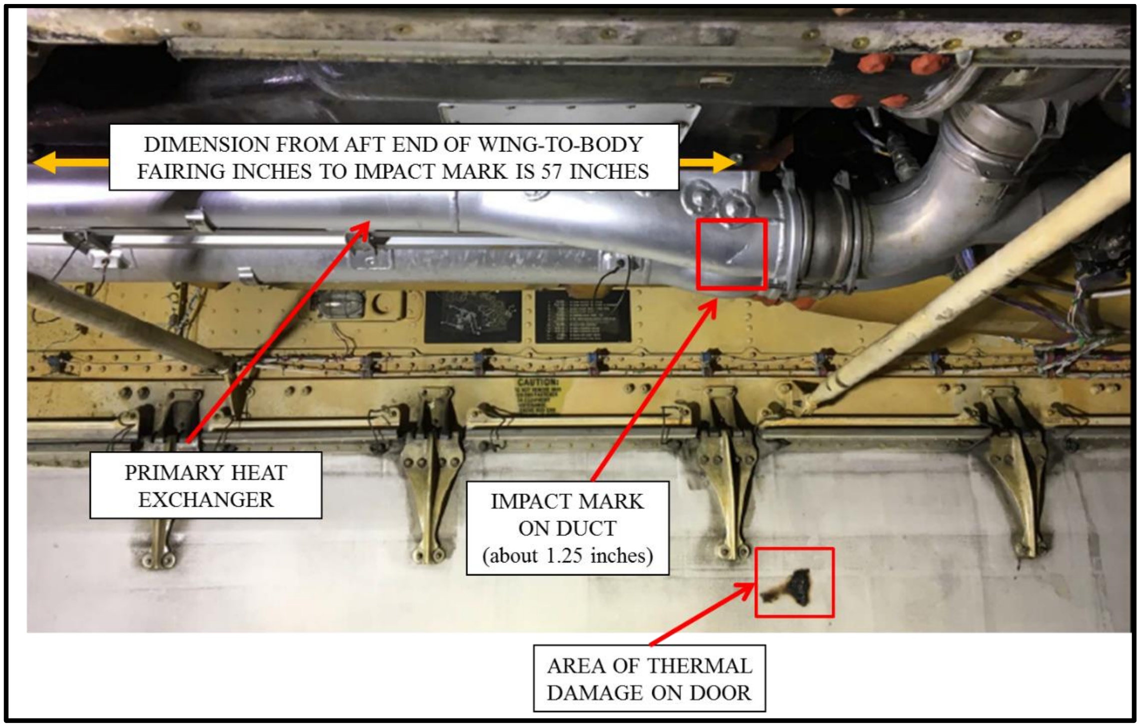


Figure 31 View of inside of right ECS bay showing impact mark on duct



D.5.4 Impact Marks Near Right Over-wing Emergency Exit:

Visual examination revealed small, non-penetrating, impact marks on the fuselage in several locations above the right wing and near the over-wing emergency exit. Reference Figure 33 and Table 4.

Figure 32 Drawing showing the location of impact marks above emergency exits

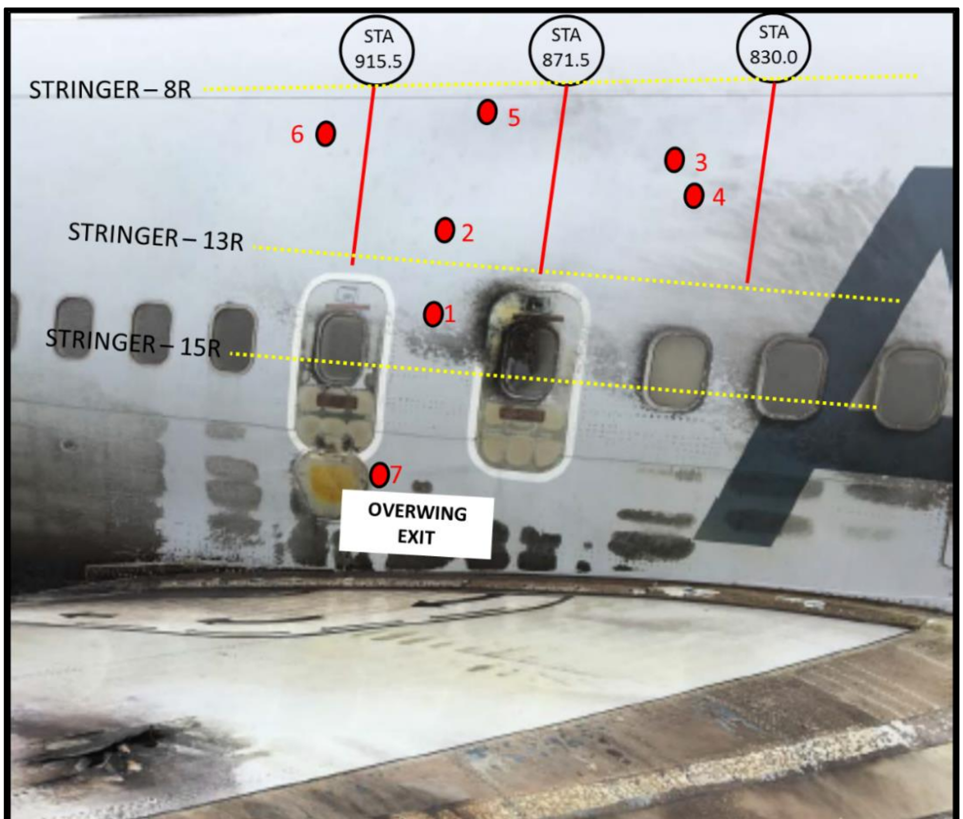


Table 4 Location of right fuselage impacts around over wing exit

Impact #	Station	Stringer	Depth (+ paint)
1	895	14.5R	.0139
2	895	12R	.0114
3	848	10R	.0119
4	842	10.5R	.0118
5	895	8.4R	.0328
6	928	9R	Only paint
7	905	21R	.05

D.5.5 Impact Marks – Left Side of Fuselage:

Visual examination revealed impact marks on the left side of the fuselage in several locations near the ECS pack bay and the landing gear. Reference Table 5 and Figures 33 through 39.

Table 5 Location of left side of body impacts:

Impact #	Station	Buttline	Waterline	Figure #
H	895	LBL 92	122	33
I	999	LBL 83	117	34
J	1022	LBL 98	110	35
K	1099	LBL 87	120	36
L	990	LBL 127	117	37-38
M	1000	LBL 143	127	39

Figure 33 Impact H, ECS pack bay left side

Figure 34 Impact I, Main gear door left side

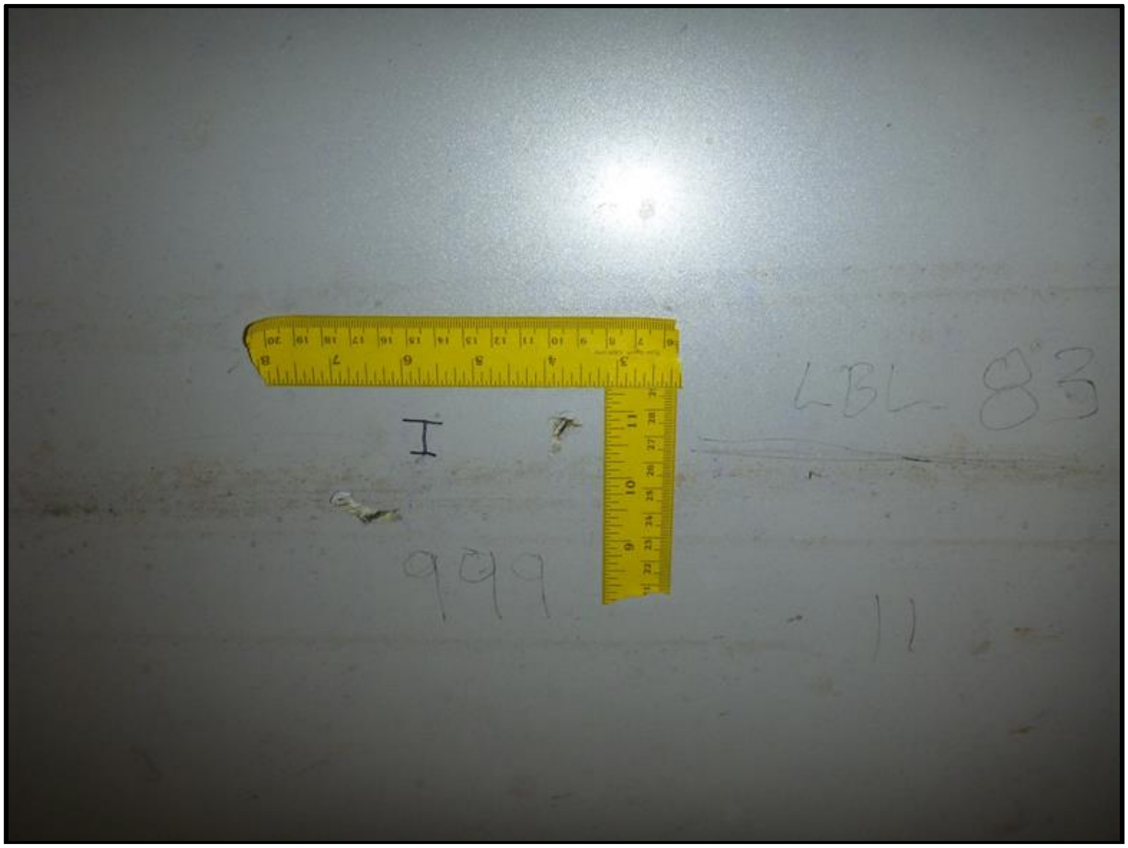


Figure 35 Impact J, Main gear door left side

Figure 36 Impact K, Left side of body door

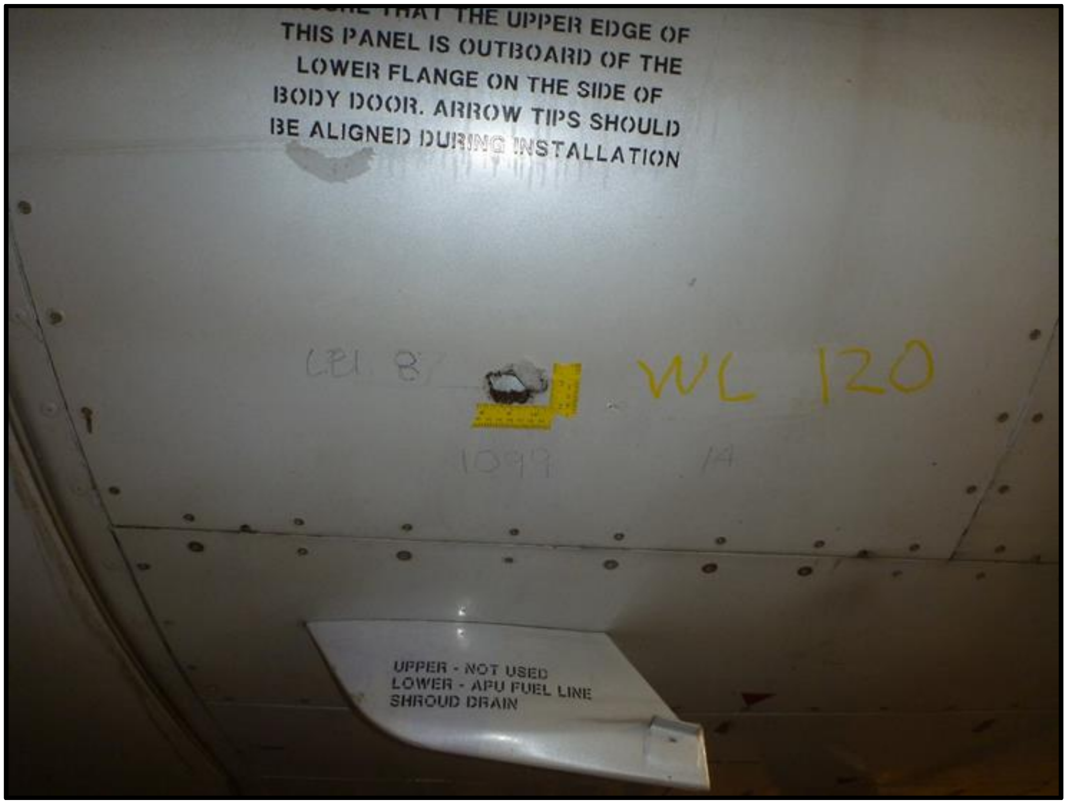


Figure 37 Impact L, Left main gear drag strut door

Figure 38 Impact L, left main gear drag strut door

Figure 39 Impact M, left main gear drag strut link

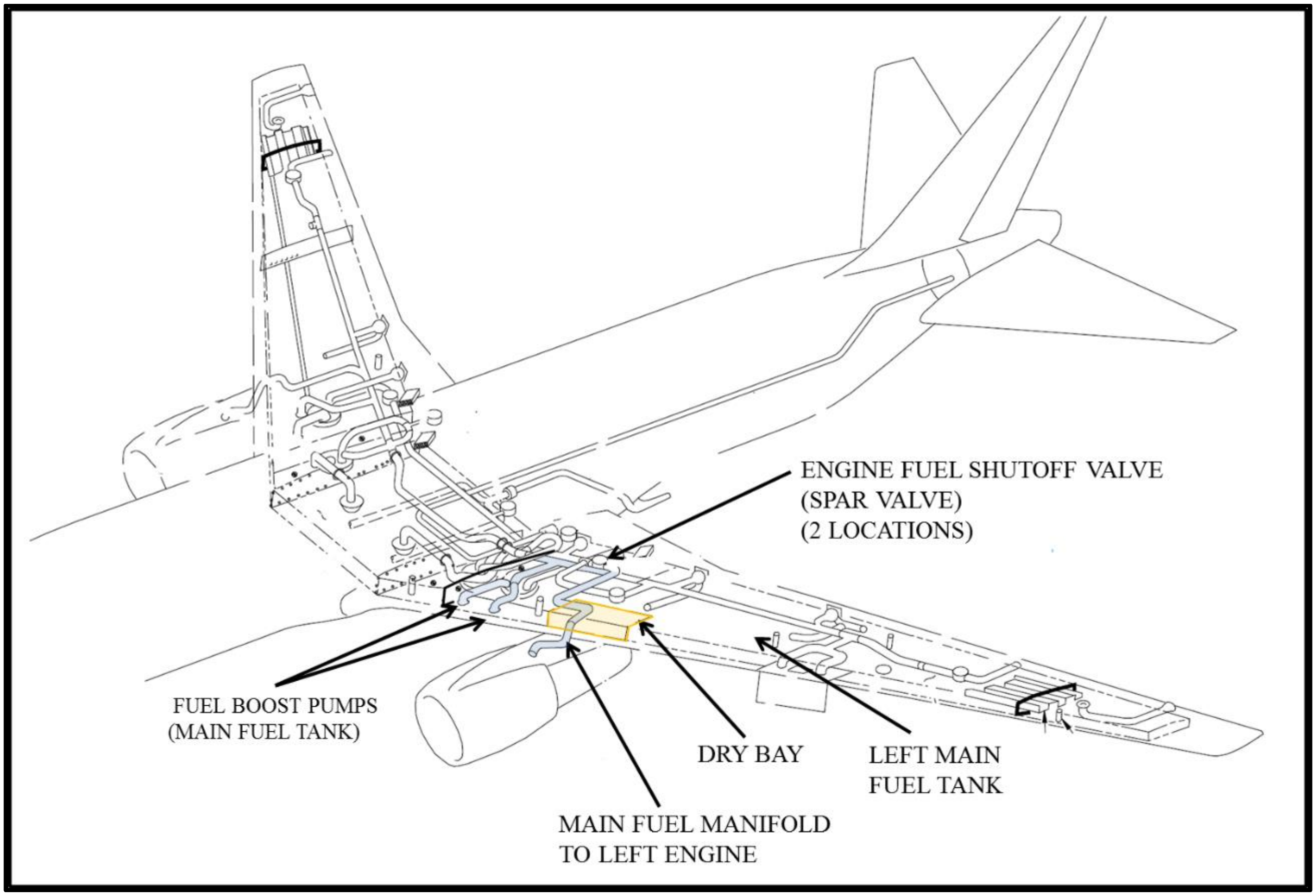
D.5.6 Airframe Fuel Storage and Engine Fuel Supply:

The Boeing 767-300 airframe fuel supply system stores and independently delivers fuel to the No. 1 (left) and the No. 2 (right) engine (Reference Figure 40). Fuel for the engines is stored in three fuel tanks: a left main wing tank, a right main wing tank, and a center wing tank. Each main fuel tank, which extends from wing rib number 3 to rib 31, contains a fuel-free compartment "dry bay" located directly above the engine between ribs 6 and 9 in the forward part of the fuel tank. Reference section D.5.1.1 of this report for information regarding the dry bay.

Each main fuel tank also contains two electrically driven fuel boost pumps, identified as forward pump and aft pump, for providing the motive flow of fuel to the engines. The outlet port of each fuel boost pump is connected to the fuel feed manifold, which is routed through the fuel tank to the engine fuel shutoff valve (spar valve) and then forward and outboard, through the dry bay, to each engine.

According to Boeing, with both boost pumps operating, the flow rate and pressure of the fuel within the main engine fuel line during takeoff is approximately 42 gallons per minute (GPM) for an engine burn rate of about 17,000 pounds/hour. Boeing also indicated that the flow rate and pressure of the fuel within the main engine fuel line would be approximately 107 GPM with no restrictions within the two-inch diameter main engine fuel line with both boost pumps operating.

Figure 40 – Engine fuel supply system



D.5.6.1 Fuel Information:

During the on-scene activities, American Airlines provided the investigation team with the fuel upload and off-load information as shown in tables 4 and 5[9]. Using a fueling truck, ASIG, removed 2,917 gallons of fuel from the left main fuel tank (Reference attachment 3).

While the airplane remained in its final resting place on runway 28R, fuel from the right outboard fuel tank was manually drained, siphoned, from the tank into containers. American Airlines provided the investigation team with an estimate of the gallons recovered from the airplane based on the number/quantity of containers that were filled reference table 5.

Table 4 Fuel upload information:

	Left Wing Tank (Tank 1) (Lbs./Gallons[10])	Center Tank (Tank 2) (Lbs./Gallons)	Right Wing Tank (Tank 3) (Lbs./Gallons)	Total Fuel (Lbs./Gallons)
Quantity required at gate release	21,003 / (3,093)	0	21,003 / (3,093)	
Gauge reading after refueling[11]	21,200 / (3,122)	0	21,300 / (3,137)	
Total fuel at gate release				42,500 / (6,259)

Table 5 Fuel off-load information:

	Left Wing Tank (Tank 1) (Lbs./Gallons)	Center Tank (Tank 2) (Lbs./Gallons)	Right Wing Tank (Tank 3) (Lbs./Gallons)	Total Fuel (Lbs./Gallons)
Fuel quantity removed from the fuel tanks after event.	19,806 / (2,917[12])	0	6,450 / (950)	
Calculated quantity of fuel burned during the taxi & takeoff roll.	1,394 / (205)	0	1,000[13] / (147)	
Total quantity of fuel accounted for	21,200 / (3,122)	0	7,450/ (1,097)	28,650/ (4,219)

Table 6 Estimated fuel loss

	Left Wing Tank (Tank 1) (Lbs./Gallons)	Center Tank (Tank 2) (Lbs./Gallons)	Right Wing Tank (Tank 3) (Lbs./Gallons)
Gauge reading after refueling	21,200 / (3,122)	0	21,300 / (3,137)
Total quantity of fuel accounted for	21,200 / (3,122)	0	7,450/ (1,097)
Estimated fuel loss	0	0	13,850/ (2,040)

9 Source data: ASIG upload information & AAL dispatch records. ASIG off load fuel records for LH tank.
10 Total gallons after dividing by actual density (6.79 lb./gal).
11 The total fuel added at refueling was 24,100 lbs.
12 Reference attachment 3
13 Approximate value because the engine failed during takeoff.

D.5.7 Engine Fuel Shutoff:

D.5.7.1 Description:

Each engine installation was equipped with an engine fuel-shutoff-valve (spar valve) to provide a means of shutting off the fuel flow to each engine's nacelle as required by the requirements of 14 CFR 25.1189[14]. The spar valve was located in each engines fuel feed line between the fuel boost pumps and the engine on the wing rear spar between ribs number 4 and 5.

Operation of the spar valve (fully open or fully closed) is controlled by the position of its respective engine fire handle switch and its engine fuel control switch. The valves position is indicated to the flight crew by the SPAR VALVE light, which is located on the P10 quadrant stand.

Opening of the valve is accomplished by switching the engine fuel control switch (engine start lever) to the RUN position.

Closing of the valve can be accomplished by either switching the engine fuel control switch to the CUTOFF position or by pulling the engine fire handle up. Both of these actions will also close the high pressure shutoff valve (HPSOV) located in the main engine control (MEC). The engine shutoff procedure for Engine Fire, Severe Engine Damage, described in the emergency procedures of the 767-300ER Flight Manual require that the engine start lever be switched to CUTOFF and the fire handle pulled in this sequence. This procedure ensures that two independent closure signals are sent to the spar valve.

D.5.7.2 Flight Data Recorder Data and On-Scene Examination:

The position (open or closed) of each engines spar valve during and after the uncontained engine failure was determined by reviewing flight data recorder (FDR) data and by visually examining the position of each valve's indicator on the airplane.

For the right engine, FDR data revealed that its engine fuel cutoff discrete transitioned from zero (ON) to 1 (OFF) approximately 25 seconds after the engine experienced an uncontained failure. Shortly thereafter, the data revealed that the engine's fire handle discrete transitioned from zero (non-activated) to 1 (activated or "pulled"). Figure 41 provides a graph showing these transitions.

For the left engine, FDR data revealed that its engine fuel cutoff discrete and its fire handle discrete remained at zero through the end of the data.

While the airplane was in the American Airlines hangar, each spar valve was visually confirmed to be in its CLOSED position (reference Figure 42).

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14 Requirement 14 CFR 25.1189, "Shutoff means" states: Each engine installation and each fire zone specified in §25.1181(a)(4) and (5) must have a means to shut off or otherwise prevent hazardous quantities of fuel, oil, deicer, and other flammable fluids, from flowing into, within, or through any designated fire zone.

Figure 41 FDR data showing engine fuel-cutoff information

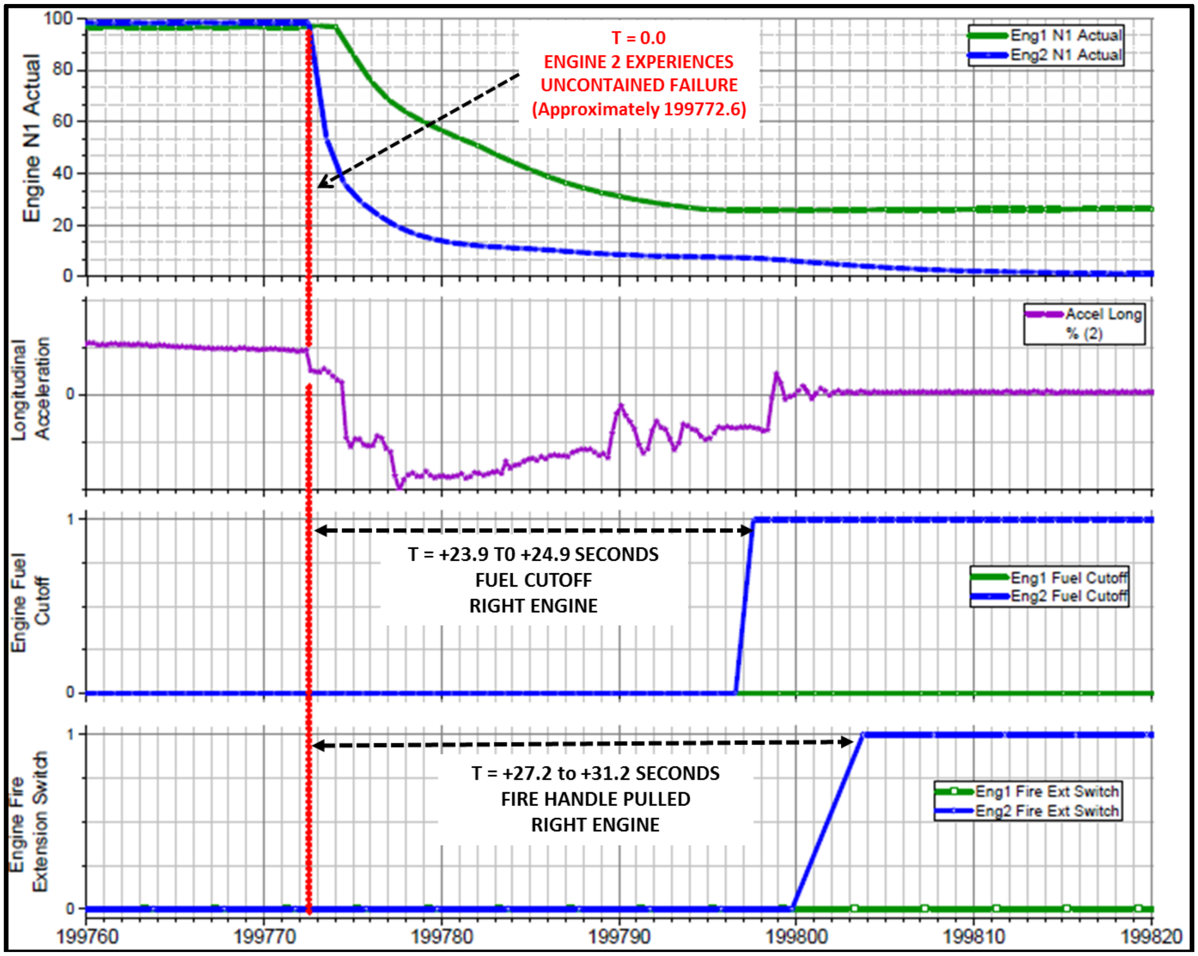
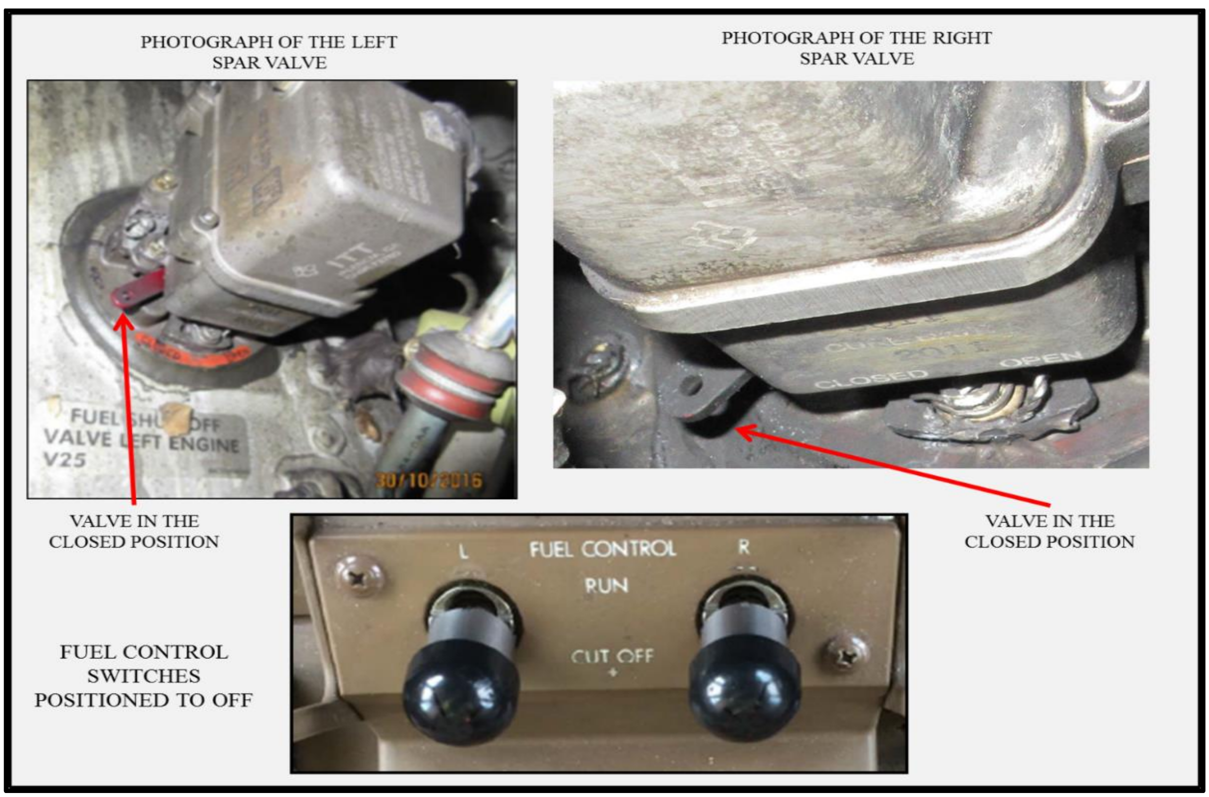


Figure 42 Spar valve positions



D.6 Thermal Damage to the Airplane:

D.6.1 Fuselage Thermal Damage:

The right side fuselage skin exhibited thermal damage in the form of missing and charred paint, skin buckling, and thermal skin cracks from frame station 764 to the horizontal stabilizer. The aft wing-to-body fairing had severe damage consisting of delamination, burned resin and burned/missing face sheets. There were 35 thermally crazed windows on the fuselage extending from station (STA) 796 back to and including the viewport on door 4R at frame station 1510. Both panes of the window at seat 30 were melted leaving a small opening at the bottom of the window. Reference Figure 43 - 45.

The center of this thermally damaged region exhibited skin buckling and multiple cracks in the skin between frames 1197 and 1197+110, and from stringer 17R and 29R. There was approximately a 3” x 1-1/2” hole between frames at 1197+22 and 1197+44, and stringers 23R and 24R. Reference Figures 46, 47, & 48. The interior insulation blanket was charred at this hole, but no worse than the others in the heat affected zone (see aft cargo notes for additional information).

Figure 43 Thermal damage to the right side of the fuselage

Figure 44 Thermal damage on the right side fuselage skin

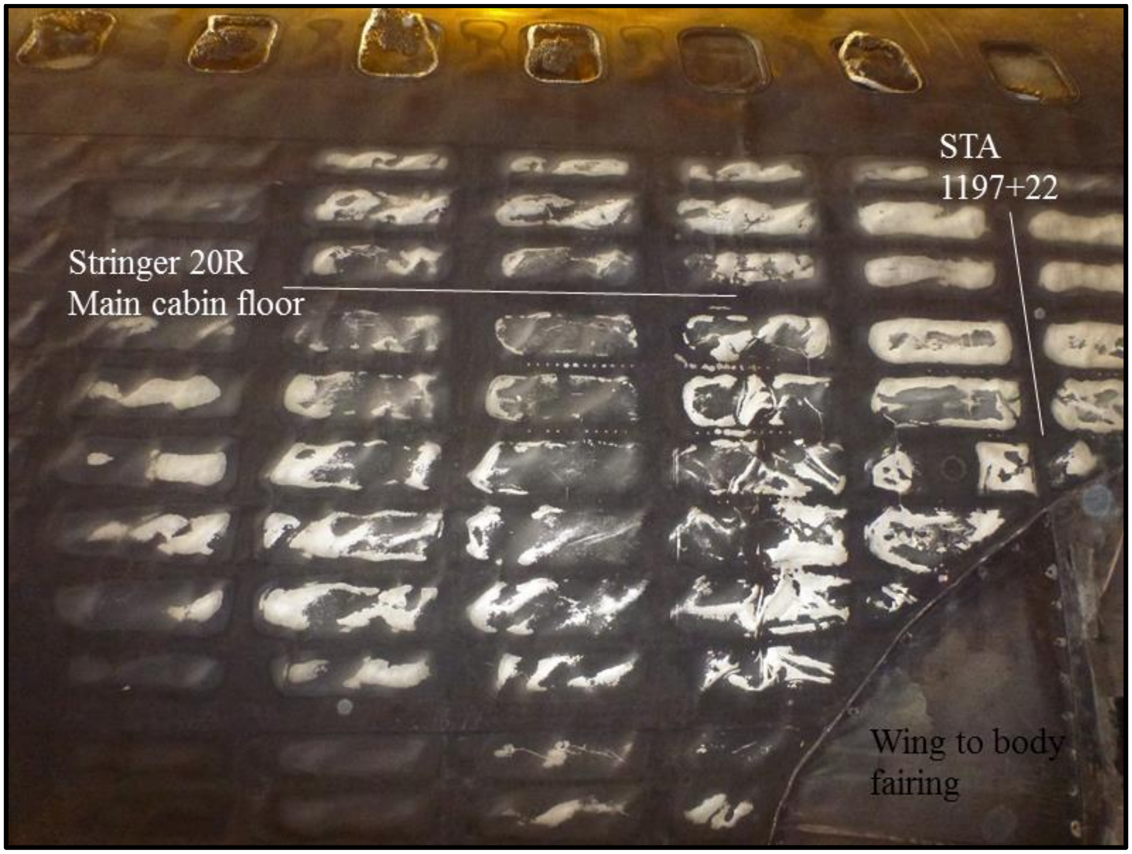
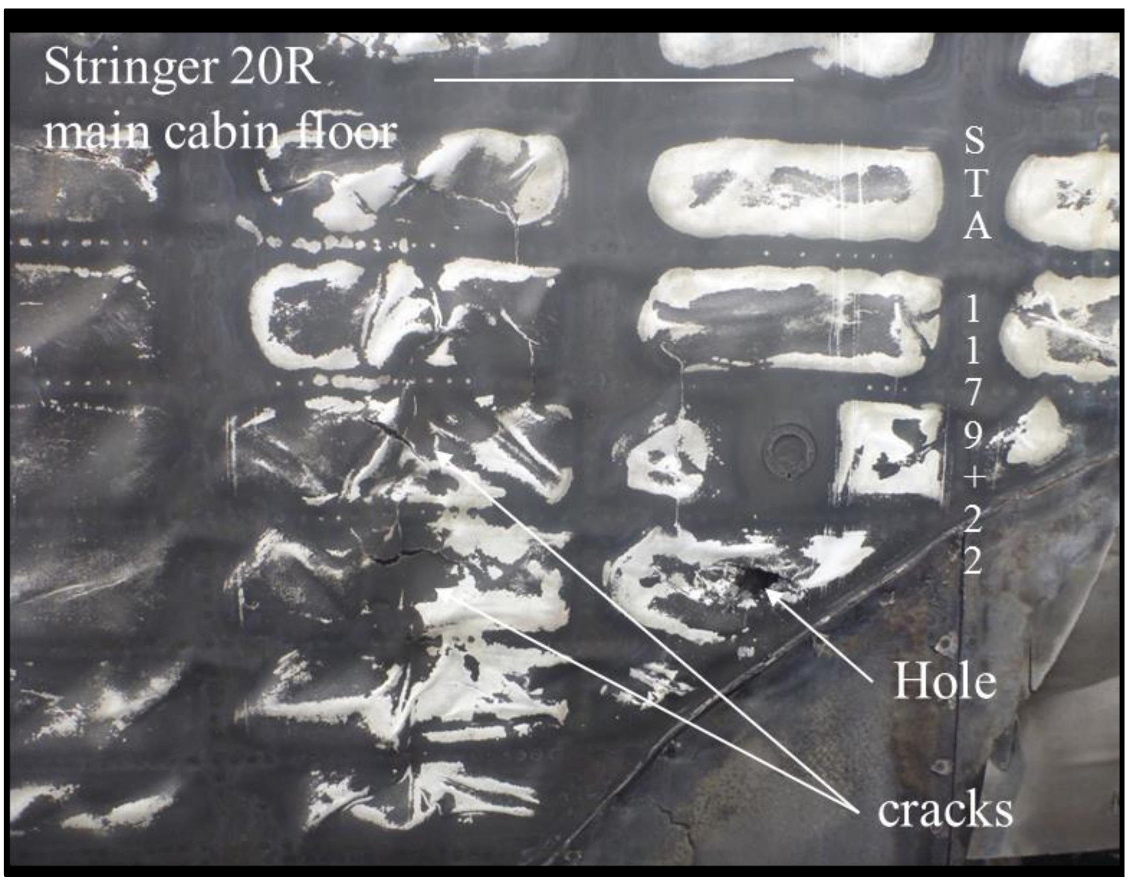


Figure 45 Multiple thermal cracks and hole in fuselage skin



D.6.2 Right Wing Thermal Damage:

The majority of the lower wing in-spar skin and ribs outboard of wing station 800 were found consumed. The outboard end of the right wing was found sagging and touching the ground at the wing to winglet interface. Reference Figure 46 – 50.

The right wing was equipped with six aluminum leading edges slats numbered from 7 to 12 with number 7 being located the closest to the fuselage. Visual examination of the leading edge slats revealed that leading edge slat number 7 was in its extended position and was found mostly intact with some warping of the upper trailing edge wedge visible on its outboard end. Leading edge slats (8-12) were also found extended and mostly consumed with only remnants attached to the main track ends. Multiple titanium leading edge anti-ice tubes, which were installed inside the leading edge slats, were found on the tarmac under the aircraft. The wing anti-ice supply tube, which was installed in slat #8 was found hanging down from wing, held on by the supply branch.

The right wing was equipped with inboard and outboard trailing edge flaps comprised of aluminum, aluminum honeycomb, and fiberglass composite.

Visual examination of the trailing edge flaps revealed that the inboard main flap and the inboard aft flap were badly damaged with only partial substructure remaining. The outboard flap was mostly consumed with only small portions of the flap remaining attached to the aft end of the flap tracks.

The wing's fixed upper and lower leading edge panels, fixed leading edge bullnose, spoilers, landing gear doors and ailerons were fabricated of resin impregnated fiberglass, aramid, and/or graphite face sheet sandwich construction with non-metallic or aluminum honeycomb core. Visual examination found that these devices had varying degrees of the following conditions: delamination; resin absent with only fibers remaining; mostly or fully consumed.

Figure 46 View looking inboard at right wing bent down and contacting the tarmac

Figure 47 View looking up and inboard at right wing underside in area of bend in wing.

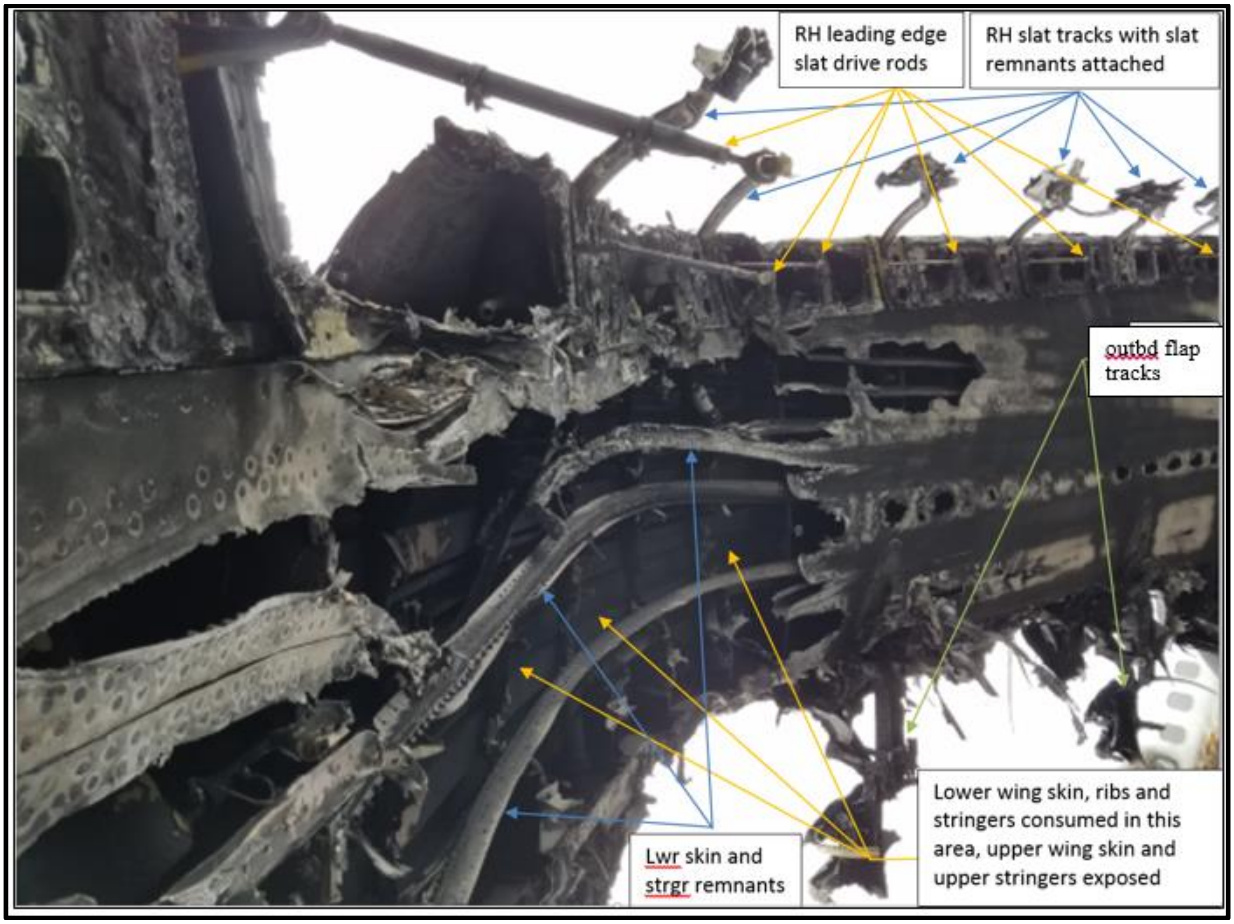


Figure 48 View looking aft and up at wing from WSTA 825-960 showing front spar buckles

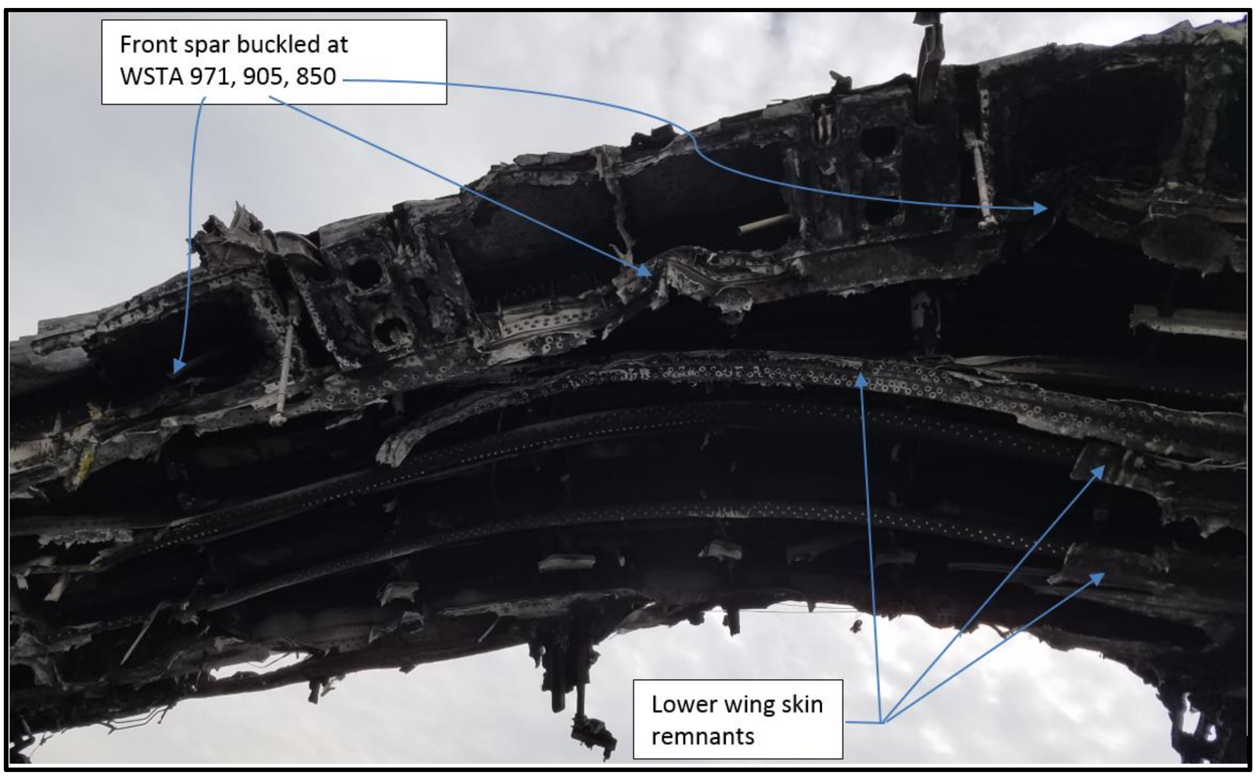
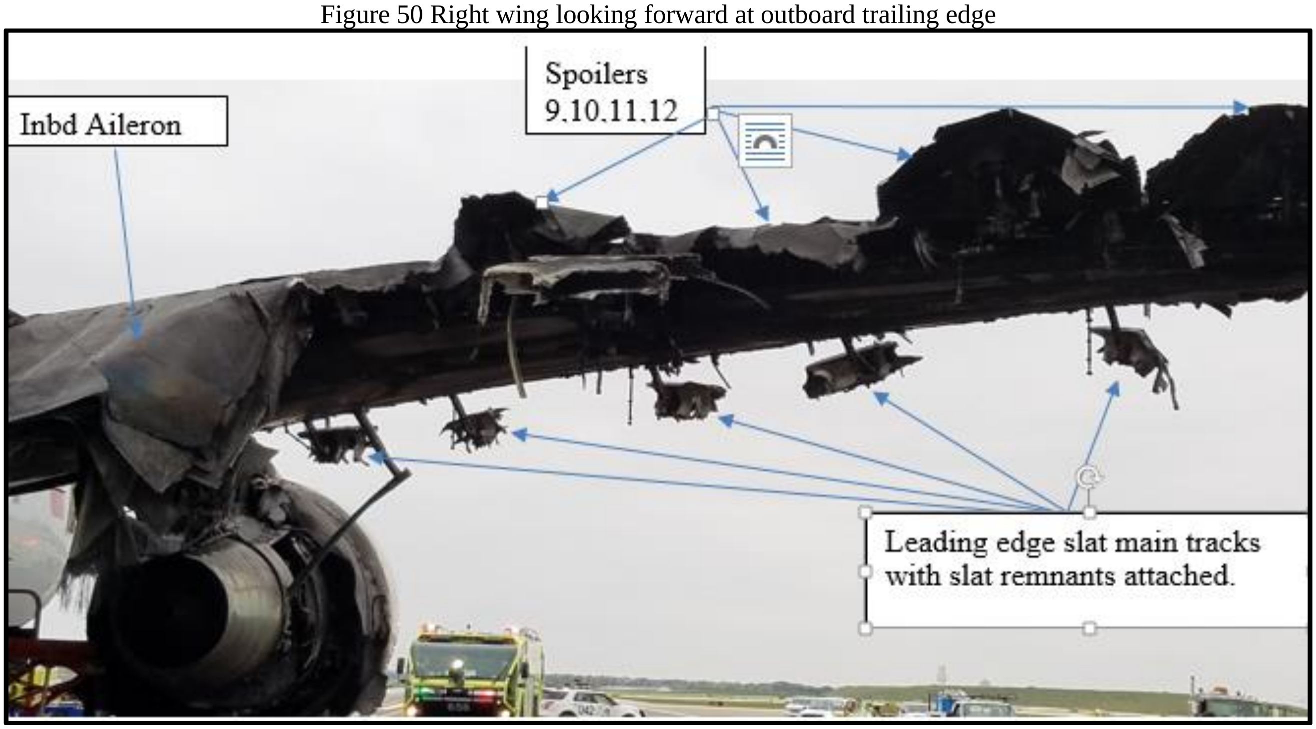


Figure 49 View of right wing looking forward and inboard at outboard bend section

Figure 50 Right wing looking forward at outboard trailing edge



D.6.3 Horizontal Stabilizer (Right) and Vertical Stabilizer Damage:

Visual examination revealed that the right horizontal stabilizer had impact damage on its leading edge surface; the stabilizer also appeared to be slightly sagging. Reference Figure 51. The stabilizer lower in-spar skin had been consumed outboard of stabilizer auxiliary spar station number 290 and the upper in-spar skin was found warped and upper stringers were found cracked and split in some areas, the ribs were found intact.

Visual examination revealed that the stabilizer leading edge panels (aluminum honeycomb) and the trailing edge and elevator (fabricated from resin impregnated fiberglass, and/or graphite sandwich construction with non-metallic or aluminum core) had varying degrees of the following conditions:

delamination; resin matrix absent with only fibers remaining; mostly or fully consumed. The severity of thermal damage increased from the stabilizer's inboard position to outboard. Reference Figure 52 – 53.

Visual examination revealed that the vertical stabilizer had evidence of delamination on its right side skin panel between the auxiliary spar and the front spar. Reference Figure 54.

Figure 51 View of the right horizontal stabilizer leading edge, looking aft and inboard from aux spar station 230

Figure 52 View of the right horizontal stabilizer looking inboard from the outboard end of the stabilizer

Figure 53 View of the underside of the horizontal stabilizer looking up and inboard from below its outboard tip

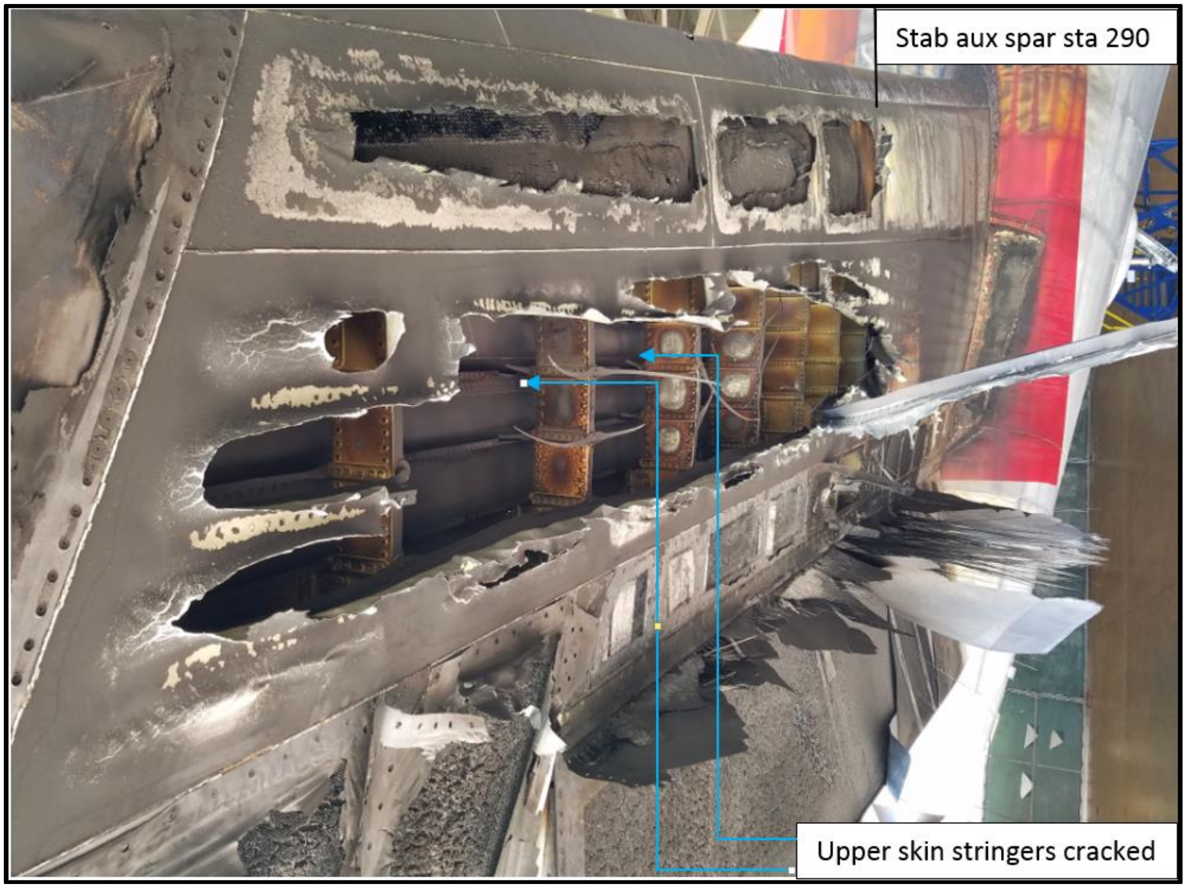
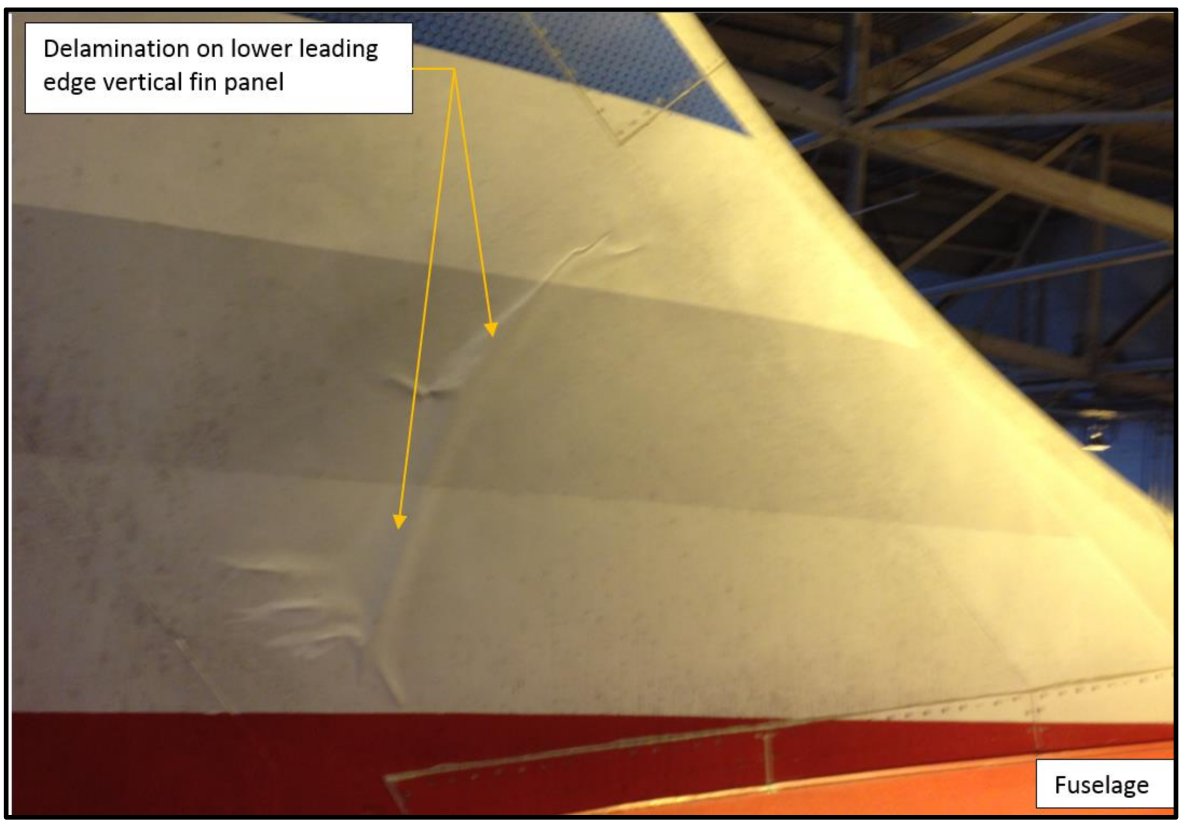


Figure 54 Vertical Stabilizer showing delamination

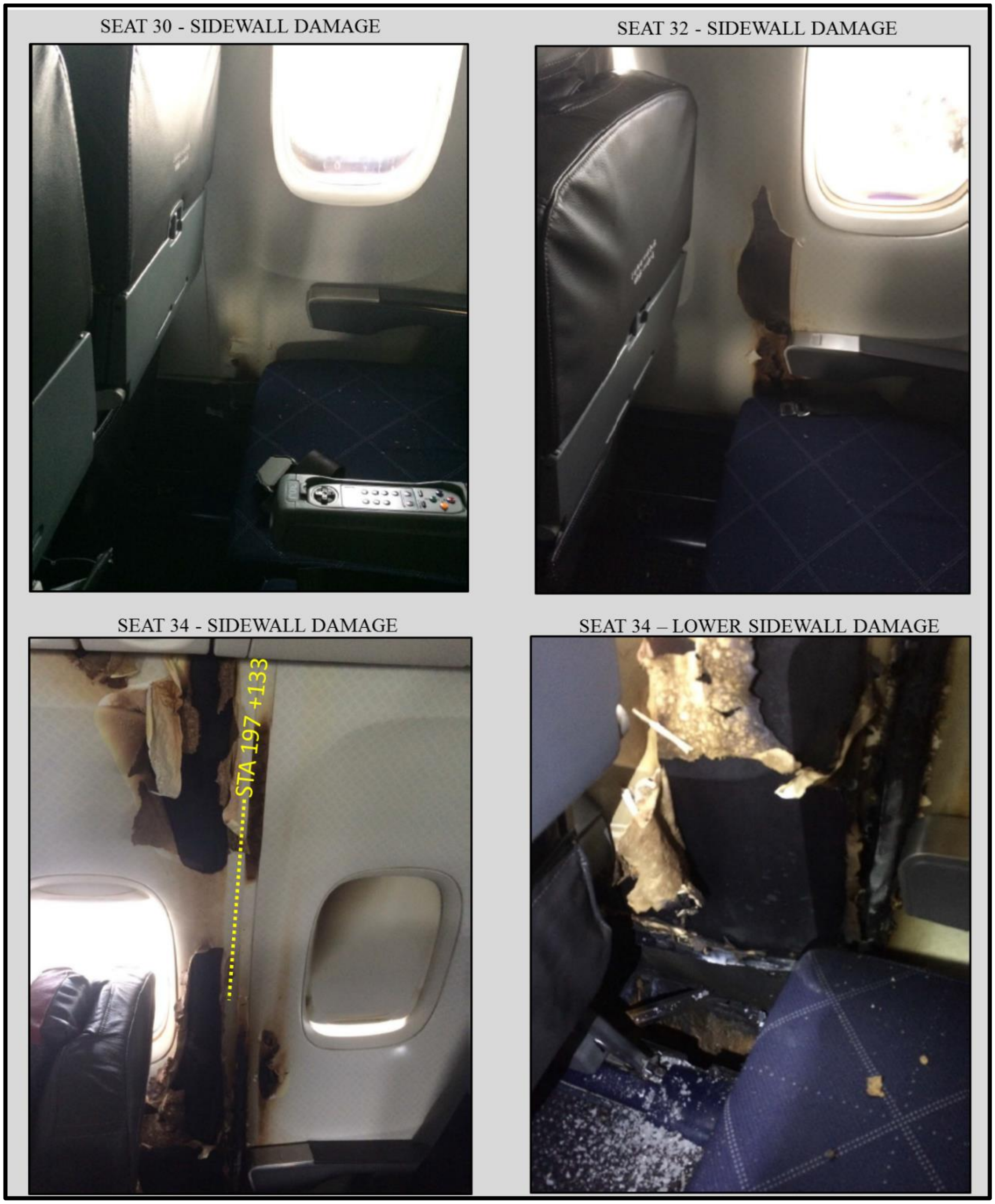


D.7 Passenger Cabin:

D.7.1 Information from the Assistant Deputy Fire Commissioner

According to the Assistant Deputy Fire Commissioner, the responding Fire Fighters removed the sidewall panels at seats 30 to 33, and partially removed the panels at seats 28 to 29 and at seat 33/34, for verifying there was no fire behind the sidewall panels. The Fire Fighters also cut and lowered the ceiling panels from seat 31 to 35 (station 1149+44 to 1241), and removed the insulation at seat 34. The Assistant Deputy Fire Commissioner confirmed there were no flames inside the airplane or behind the ceiling and sidewall panels. The Fire Department took pictures of the interior damage prior to removing the panels (Reference Figure 55).

Figure 55 Sidewall Damage at seat locations 30 to 34



D.7.2 On-Scene Examination:

The visible damage (other than crazed windows) was limited to the interior sidewall panels at seats 30, 32, 34, and 35. The damage to the panels consisted of melting and charring of the decorative laminate, and charring to their inboard and outboard sides. (Reference Figure 56).

Visual inspection revealed that the most significant damage occurred at seat 33/34 (station 1197+110 to 1197+132). There was thermal damage to the interior sidewall consisting of melting of laminate and charring of the panel (inboard and outboard sides) and consumption of the majority of the resin along the aft edge of the panel. The top row of louvers on the plastic air grill (below the bottom of the panel) was charred and melted. There was a slight amount of soot on the sidewall panel above it and on the outboard surface of the seat armrest. The outboard edge of the bottom seat cushion fabric was charred, exposing the foam fire-blocking material, reference Figure 57. The insulation blanket behind the stowage bins was charred, and the cover film was gone. The char extended up into the crown. There were some wires above the stowage bins that had their insulation burned off, indicating the cover film had burned. The cover film self-extinguished at approximately stringer 6R. Reference Figure 58.

In addition to the insulation blanket damage observed near seats 34/35, the inboard and outboard sides of the insulation blankets between seats 28 to 32 also had varying degrees of thermal damage consisting of melted cover film and charred areas. The charring extended into the crown just above the stow bins. Reference Figures 59 through 60. The corrosion inhibiting compound (CIC) on the interior skin was charred, and there were skin cracks visible just above the floor level at seats 31 and 32 (station 1197+22 to 1197+88), Reference Figures 61 through 62. There were no visible cracks at seat 34 (station 1197+110 to 1197+132).

Figure 56 Damage to sidewall panels

Figure 57 Seat 34 charred seat cushion

Figure 58 Charred insulation and wiring in crown above seat 34

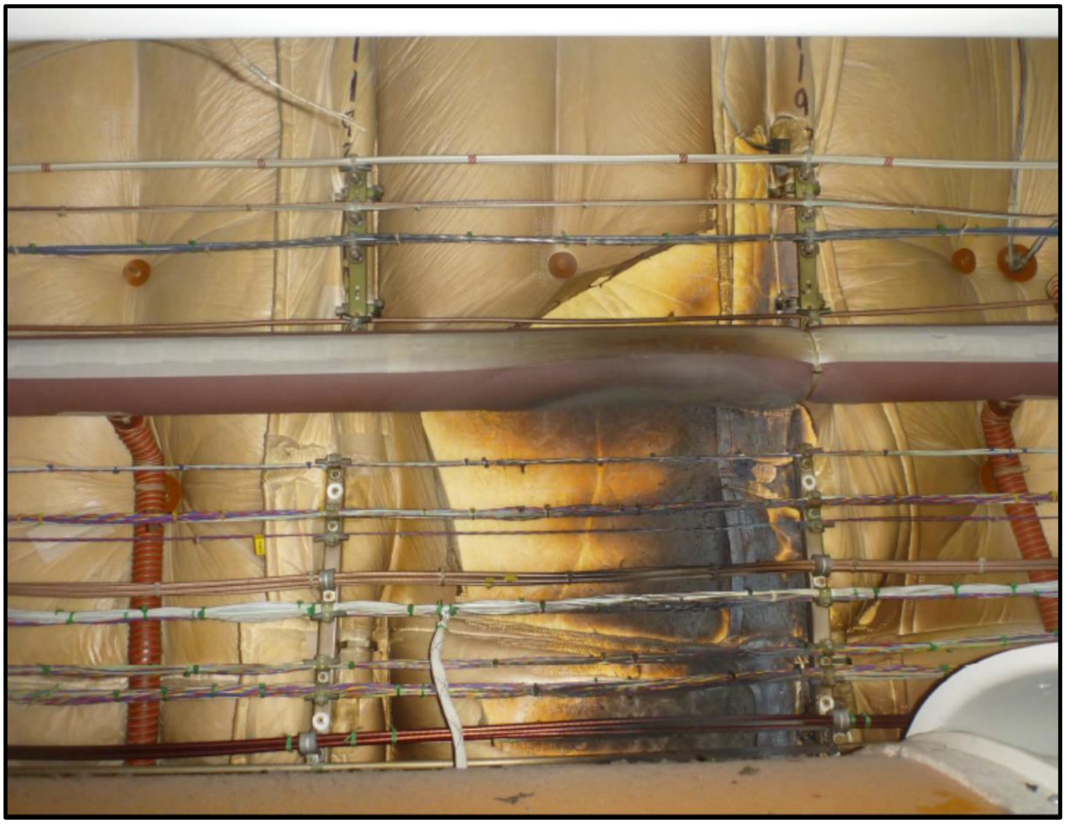


Figure 59 Charred insulation blankets and melted window at seat 30

Figure 60 Charred insulation at seats 33 through 34

Figure 61 Charred insulation and CIC on skin at seat 34

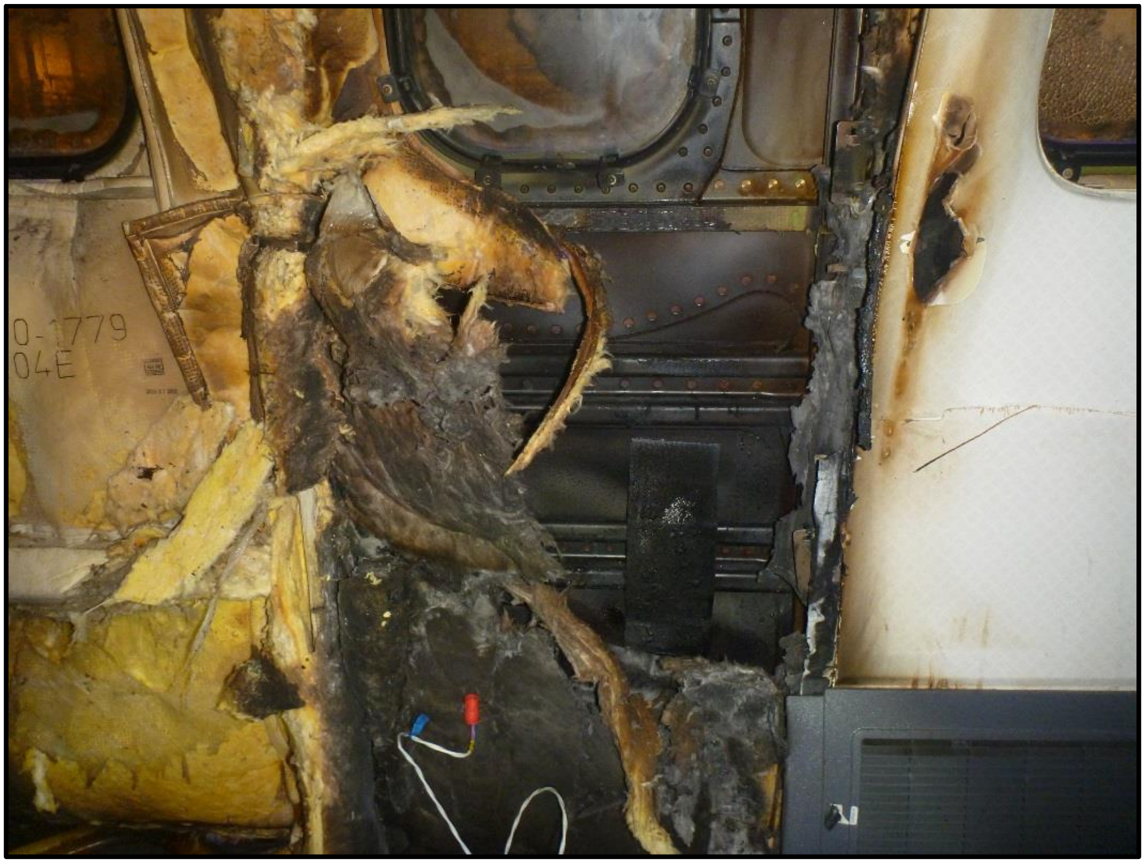


Figure 62 Charred insulation and crack in skin at seat 31

D.8 Aft Cargo Compartment:

As shown in Figure 63, the aft cargo compartment looked normal, all the liners were in good condition and the joints taped. There were no signs of any heat damage or soot.

The liners on the right side were removed so that the insulation blankets could be inspected. The insulation blankets from station 1153 to 1241 had varying degrees of thermal damage with the greatest damage between station 1197+22 and 1197+132. The damage consisted of charring of the blanket and cover film. Reference Figures 65 through 67.

The blankets were pulled back to reveal the damage on the backside and on the skin. The backside of the insulation blankets, between stations 1197 and 1197+132 were all charred to varying degrees, with the heaviest damage between stations 1197+22 and 1197+132. The skin was heavily charred, there were multiple cracks through the skin and several stringers were twisted and stringer 25R was cracked at station 1197+120. The frame at station 1197+44 was twisted over a length of five stringers. The insulation blanket between stations 1197+22 and 1197+44 (at the location of the hole in the skin) was charred around the hole, but was grey/white at the hole. Reference Figures 64 through 66.

Figure 63 Aft cargo compartment (looking forward)

Figure 64 Insulation blanket damage

Insulation STA 1197 to 1197+22

STA 1197 to 1197+22 (note the cracks)

Insulation STA 1197+22 to 1197+44

STA 1197+22 to 1197+44 (note hole/cracks)

Insulation STA 1197+44 to 1197+66

STA 1197+44 to 1197+66 (note the cracks)

Figure 65 Insulation blanket damage

Insulation STA 1197+66 to 1197+88

STA 1197+66 to 1197+88

Insulation STA 1197+88 to 1197+110

STA 1197+88 to 1197+110

STA 1197+110 to 1197+132

Cracked stringer 25R at STA 1197+120

Figure 66 Insulation blanket damage

D.9 Cabin Safety:

When the APFA/AA Cabin Safety investigator arrived on-scene, none of the slides remained attached to the aircraft; all of the slides had been removed from the aircraft due to high winds at Chicago. The APFA/AA Cabin Safety investigator confirmed with the FAA Cabin Safety Inspector, Chicago FSDO that prior to removal from the aircraft the 1R door slide had fully deployed.

On October 29, 2016, the APFA/AA Cabin Safety investigator conducted a visual investigation of the interior of the airplane while the aircraft remained in its final resting place on runway 28R. The visual inspection revealed the following:

1. Door 1L was found armed and open with its ramp stand in place. Reference Figure 67.
2. Door 1R was found open and in a disarmed position. Reference Figure 68.
3. Door 4L was found open and in an armed position. Reference Figure 69.
4. Door 4R was found closed and in an armed position. Reference Figure 70.
5. Door 2L and 3L (over wing exits) were found removed and placed on the passenger seats. Reference Figure 71
6. The manual inflation handle (at door 2L and 3L) cover remained snapped closed (indicating slides deployed automatically) Reference Figure 72.
7. Over wing exits 2R and 3R were found closed. Reference Figure 73
8. A check of emergency equipment at flight attendant (FA) jump seats showed that only FA #3 at 4R door removed flashlight prior to evacuation.
9. All other emergency equipment remained in original stowage locations including megaphones.

Figure 67 Door 1L was armed and open with ramp stand in place

Figure 68 Door 1R was found open and in a disarmed position

Figure 69 Door 4L

Figure 70 Door 4R

Figure 71 Doors 2L/3L Over Wing Exits (OWE) open

Figure 72 Manual inflation handle cover

Figure 73 Doors 2R/3R OWE closed

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