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

APRIL 15, 2016

POWERPLANT GROUP CHAIRMAN'S FACTUAL REPORT

NTSB No: DCA16FA013

A. ACCIDENT

Location: Fort Lauderdale - Hollywood International Airport (FLL) - Fort Lauderdale, FL

Date: October 29, 2015

Time: 1233 eastern daylight time (EDT)

Aircraft: Boeing 767-200ER, N251MY, Dynamic International Airways

B. POWERPLANTS GROUP

Group Leader: Robert Hunsberger
National Transportation Safety Board
Washington, D.C.

Member: Wego Wang
Federal Aviation Administration
Burlington, Massachusetts

Member: Douglas Atterson
Dynamic International Airways
Greensboro, North Carolina

Member: Van Winters
The Boeing Company
Seattle, Washington

Member: Douglas Zabawa
Pratt & Whitney
East Hartford, Connecticut

C. SUMMARY

On October 29, 2015, about 1233 eastern daylight time (EDT), a Boeing 767-200ER, N251MY, operating as Dynamic International Airways flight 405, caught fire while taxiing for departure at Fort Lauderdale-Hollywood International Airport (FLL), Fort Lauderdale, Florida. One passenger received serious injuries and the remaining 89 passengers and 11 flight crewmembers received minor injuries or were not injured. The airplane sustained substantial thermal damage from the fire. Flight 405 was a scheduled charter flight en route to Caracas, Venezuela, operating under the provisions of 14 *Code of Federal Regulations* Part 121 supplemental. Visual meteorological conditions prevailed at the time of the accident.

The powerplant group comprised of members of the National Transportation Safety Board (NTSB), Federal Aviation Administration (FAA), Pratt & Whitney (P&W), Boeing, and Dynamic International Airways completed the on scene documentation of the engine and left strut from October 30-November 2, 2015. A material examination of two sections of the left engine main fuel supply line and fuel coupling assembly were completed at the Boeing Equipment Quality Analysis (EQA) laboratory from December 8-9, 2015.

During a visual examination of the left engine and strut, a fuel coupling assembly was found separated with the coupling body pushed aft on a main fuel supply line. There were indications of fuel leakage at the flange interface of the fuel supply lines where the coupling had separated including discoloration from fluid pooling in the strut compartments and streaking down the left engine cowling. There was no safety lockwire present on either the body or nut side of the fuel coupling as required in the Boeing aircraft maintenance manual (AMM), and no broken lockwire was recovered in the surrounding strut compartments. A material examination of the fuel supply lines and coupling components verified that the parts met dimensional drawing specifications and were free of defects or damage that would have affected normal operation. A simple static pressure test setup was constructed to pressurize the fuel supply lines and coupling assembly recovered from the accident airplane to better understand leak initiation under simulated operational conditions. Initial testing concluded that a fuel leak would likely not be detected until the coupling was close to separating. Boeing is developing a test plan to complete additional testing on the fuel supply line and coupling assembly to determine how vibration levels similar to those measured during flight conditions affect coupling torque in the absence of lock wire.

D. DETAILS OF THE INVESTIGATION

1.0 ENGINE INFORMATION

1.1 Engine History

According to the Dynamic International Airways records, the left engine, engine serial number (ESN) 716806 had accumulated 16,405 hours time since new (TSN), 5,229 cycles since new (CSN), 234 hours time since last inspection and 83 cycles since last inspection. Prior to the last inspection, the airplane and engines were in desert storage. The Maintenance Group Chairman's factual report provides a more thorough account of the accident airplane background and maintenance and is available in the docket.

1.2 Engine Description

The accident airplane was equipped with two Pratt & Whitney JT9D-7R4E4 engines. The JT9D-7R4E4 is a high bypass two spool turbofan engine that features a dual axial 16 stage compressor (five stage low pressure compressor, eleven stage high pressure compressor) annular combustor, and six stage turbine (two stage high pressure turbine, four stage low pressure turbine). The engine has a hydromechanical fuel control. **Figure 1**.

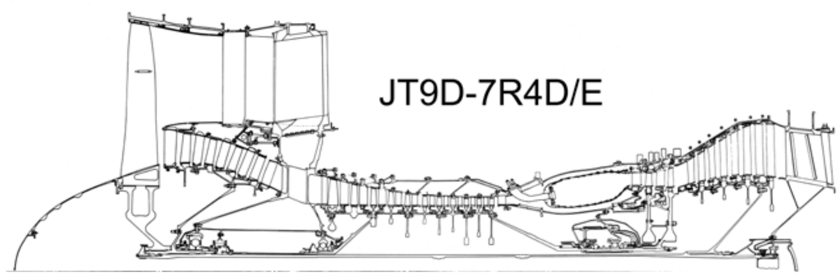

Figure 1- Pratt & Whitney JT9D-7R4 Cutaway

According to the FAA type certificate E3NE- Revision 15, the engine has a maximum continuous sea level static thrust rating of 47,500 lbs. and a takeoff sea level static thrust rating of 50,000 lbs.[1]

All directional references to front and rear, right and left, top and bottom, and clockwise, and counterclockwise are made aft looking forward (ALF). References to inboard and outboard are in relation to the fuselage.

2.0 FINDINGS

2.1 Left Engine, ESN 716806 and Cowls

A visual examination of the engine and cowls was performed beginning at the inlet. The fan blades were all intact and in good condition without indications of shingling or tip rub (**Photo 1**). All

[1]Takeoff rating of 50,000 lbs. at and below 114°F ambient temperature, sea level static.

fan blades were lightly sooted but did not exhibit thermal distress. Sections of the inlet cowl inner barrel face sheet (aluminum perforated sheet) were sagging and a piece was missing from the 10 to 12:30 positions. The face sheet was rippled and bulged from the 1 to 4 o'clock positions. The spinner was lightly sooted and the paint was bubbled on the cap. A cowl access door and a fabric strip were resting at the bottom of the engine inlet cowl. Both items were placed in the inlet after the aircraft was moved from the taxiway following the fire according to an FAA representative who was on site immediately after the event.

Photo 1- Left Engine Inlet

The inlet cowl was thermally damaged and most of the external ply on the outboard side of the engine was consumed, exposing the honeycomb. Large sections of the honeycomb were missing and the pieces that remained attached to the inlet cowl were charred and brittle from the 6 to 12 o'clock positions (**Photo 2**). A section of the outer diameter inlet cowl lip was thermally consumed from the 8 to 11 o'clock positions and the edges around the consumed area exhibited melting (**Photo 3**). On the inboard side of the engine, the inlet cowl external ply was intact but blistered and flaking. A sheet of the inlet cowl external ply was hanging from the engine at the 6 o'clock position.

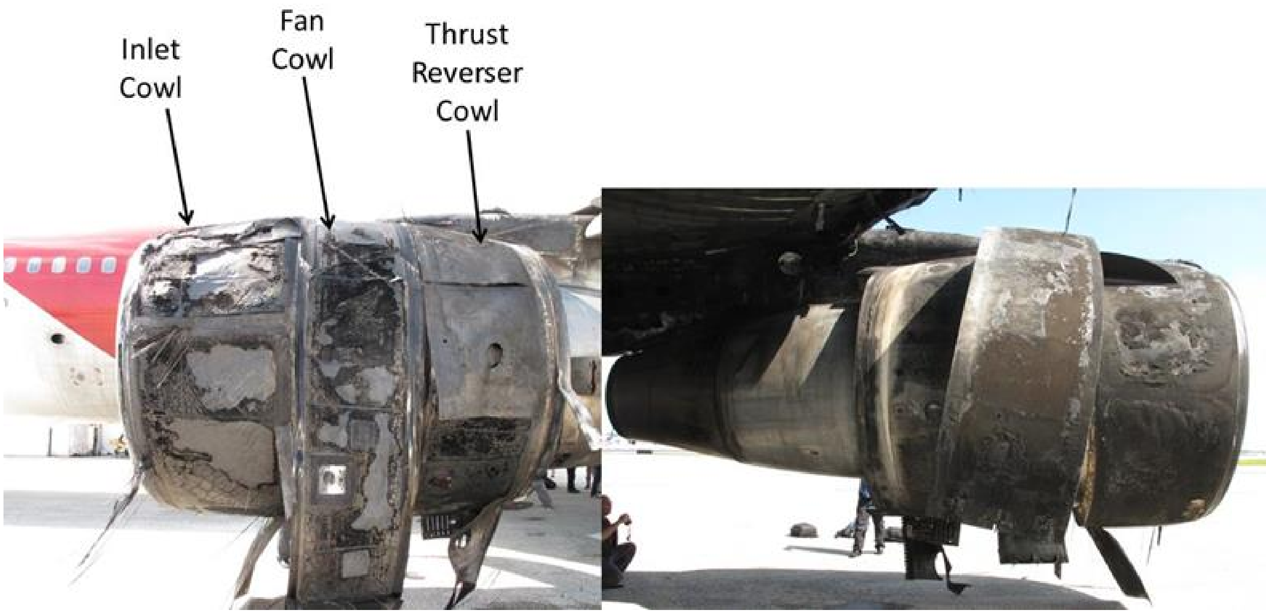

Photo 2- (L) Outboard Cowlings, (R) Inboard Cowlings

Photo 3- Inlet Cowl Forward Lip Thermal Damage

When the investigative team arrived, the inboard fan cowl was held open by the support rods and the outboard side of the fan cowl had lost rigidity from the 6 to 9 o'clock positions and was hanging freely (**Photo 2**). The fan cowl was thermally damaged and sections of the external ply on the outboard side of the engine were consumed and the exposed honeycomb was charred and brittle. The external ply on the inboard side of the engine was present but charred and flaking. The fan cowl hooks and latches were intact.

The thrust reverser cowl was thermally damaged and the external ply was peeled away from the 6 to 9 o'clock positions. The exposed honeycomb below the peeled external ply was charred and brittle but mostly intact. The external ply from the 9 to 11 o'clock positons was also separated from the honeycomb but remained resting against the case. The inboard side of the thrust reverser cowl was sooted and the external ply exhibited some flaking/charring/bubbling. Indications of fluid streaks were noted about six inches forward of the aft edge of the inboard thrust reverser cowl, originating below the forward strut fairing. The cowl surface where streaks were observed retained a majority of the white cowl paint and exhibited little thermal distress. The streak was about twelve inches wide at the gap below the strut fairing cover and tapered down to a point at the 5 o'clock position (**Photo 4**).

Photo 4- Thrust Reverser and Core Cowl Streaking – Inboard Side

The outboard side of the core cowl external aluminum layer exhibited thermal damage including cracking, curling, and/or materials chunking at six locations between the 7 and 9 o'clock positions (**Photo 5 and Table 1**). The inner layer of the core cowl was not breached. The remainder of the core cowl was intact and the external condition was typical of a service run engine according to Boeing and Dynamic Airways. Streaking indications in the form of darker colored residue were observed on the inboard side of the core cowl originating from the strut interface and drain holes and moving in the downward aft direction. The aft most streak indication appeared to emanate from the lower forward corner of the strut pressure relief door.

Photo 5- Core Cowl Thermal Damage, Outboard Side

Location	Dimensions (inches) Circumferential x Axial	Photo
1	10" x 2 3/4"	
2	3" x 3"	
3	6"	

4	5” x 2”	
5	4” x 4”	
6	3”	

Table 1- Core Cowl Thermal Damage- Outboard Side

The exhaust nozzle was intact and in good condition. Similar streaking indications like those noted on the inboard side of the core cowl were also observed on the forward inboard side of the exhaust nozzle originating from the strut interface and drain holes.

After opening the thrust reverser and core cowlings there was no indication of thermal distress and minor sooting was observed most concentrated near the top and aft of the core cowl.

The fan exit guide vanes and intermediate case struts were all intact. The inner face sheet aft of the reverser block doors was raised and bubbled in the 6 to 9 o’clock location. The sixth stage low pressure turbine blades were intact and in good condition. The tail cone and exhaust plug were present and undamaged. A pool of water was collected in the exhaust nozzle from the firefighting efforts (**Photo 6**).

Photo 6- Left Engine Exhaust

The cowls were raised to examine the engine. The engine cases did not exhibit any indications of uncontainment or thermal distress (**Photo 7**). There were no visual indications of fuel leakage, including areas around the main fuel supply line from the strut to the fuel pump. The engine had light sooting most concentrated at the 12 o'clock position on the aft half of the engine. There was no evidence of thermal distress on the wire insulation or clamps. The three fire loops (left upper, right upper, and lower forward) were traced around the engine and were all complete and the teflon grommets were in good condition. The oil tank was opened and the oil level was near the maximum fill line and did not have an acrid smell. The fan was rotated by hand and spun freely with concurrent rotation of the low pressure turbine blades.

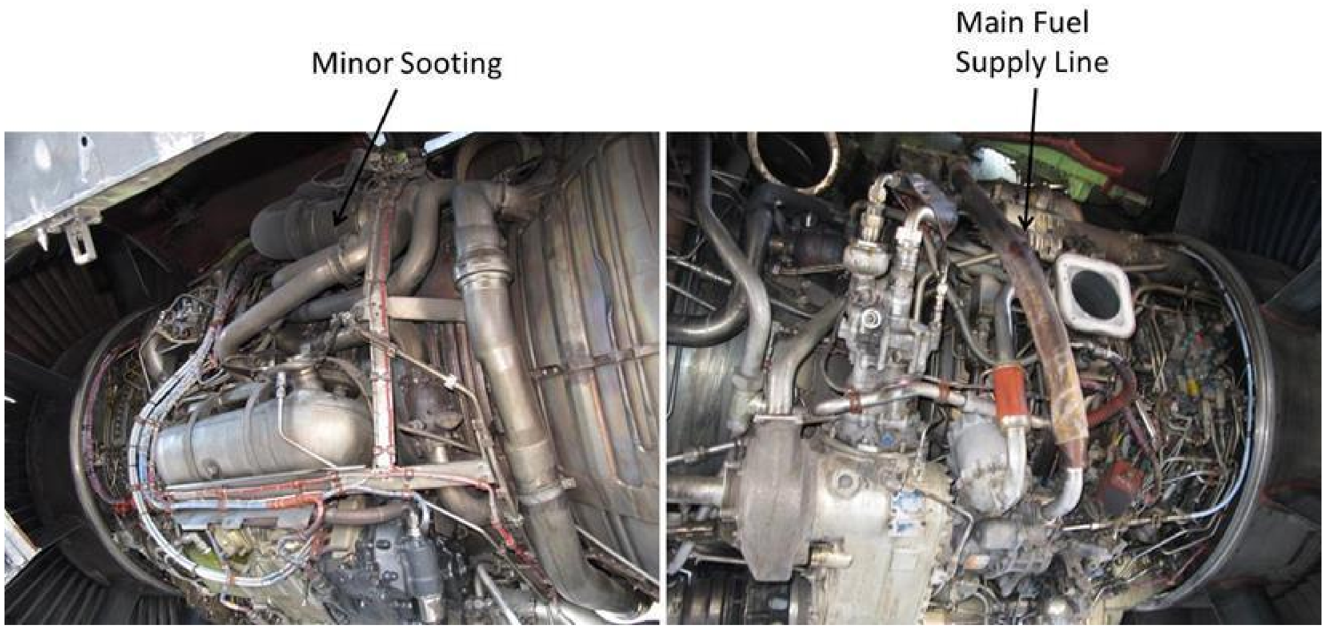

Photo 7- Left Engine (L) Left, (R) Right

2.2 Left Engine Strut

All inboard strut surfaces were blackened and sooted with the exception of a streak indication from the lower forward corner of the pressure relief door cutout. There was no burn through on any inboard strut structure surfaces. The inboard pressure relief door was open when the team arrived on scene and the inboard access panel cover was separated and not recovered. The inboard aft strut fairing access door external ply was partially consumed exposing the honeycomb at three equally spaced locations in the center of the panel (**Photo 8**). The aft most strut fairing external ply was partially consumed, exposing the honeycomb.

The outboard strut aft access panel was open when the team arrived but all visible components inside the compartment were intact and free of thermal distress with light sooting present on the aft end. The outboard strut surfaces exhibited light sooting and had no indications of thermal distress beyond paint bubbling (**Photo 9**). The strut pressure relief door was found in the closed position. The aft most section of the outboard strut fairing external ply was consumed, exposing the honeycomb.

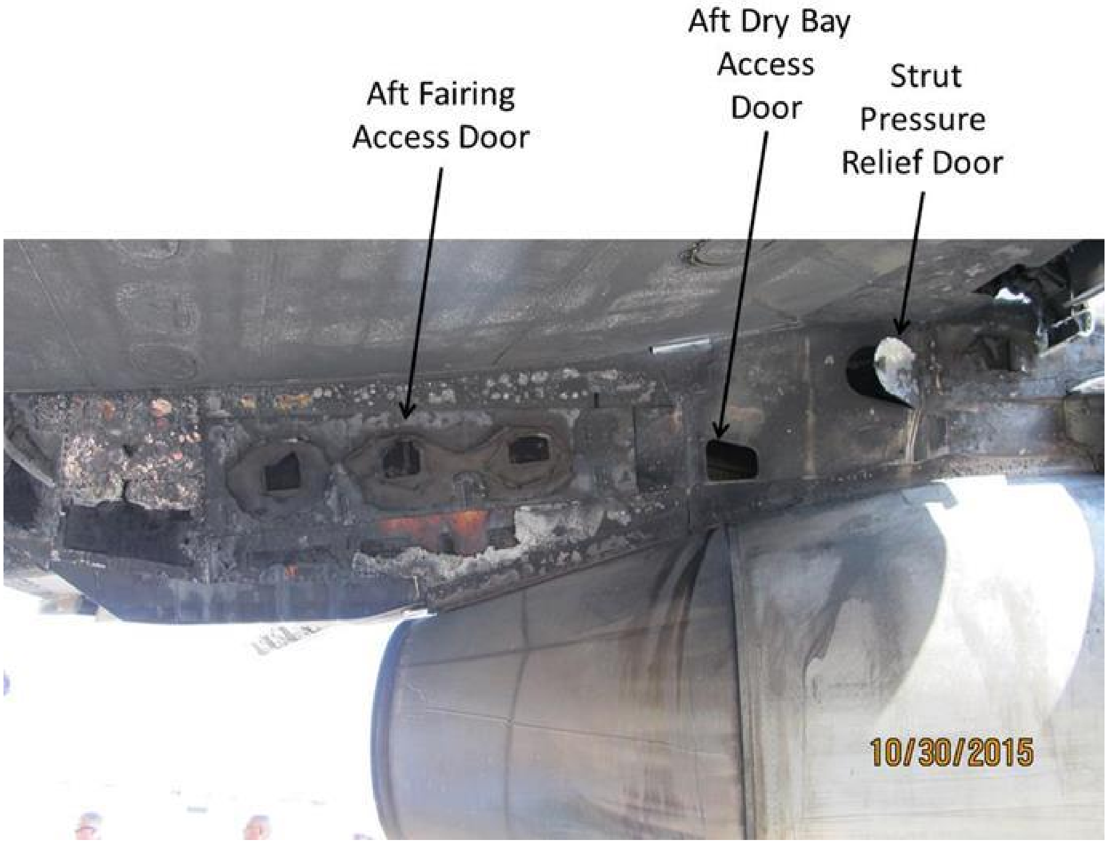

Photo 8- Engine Strut - Inboard Side

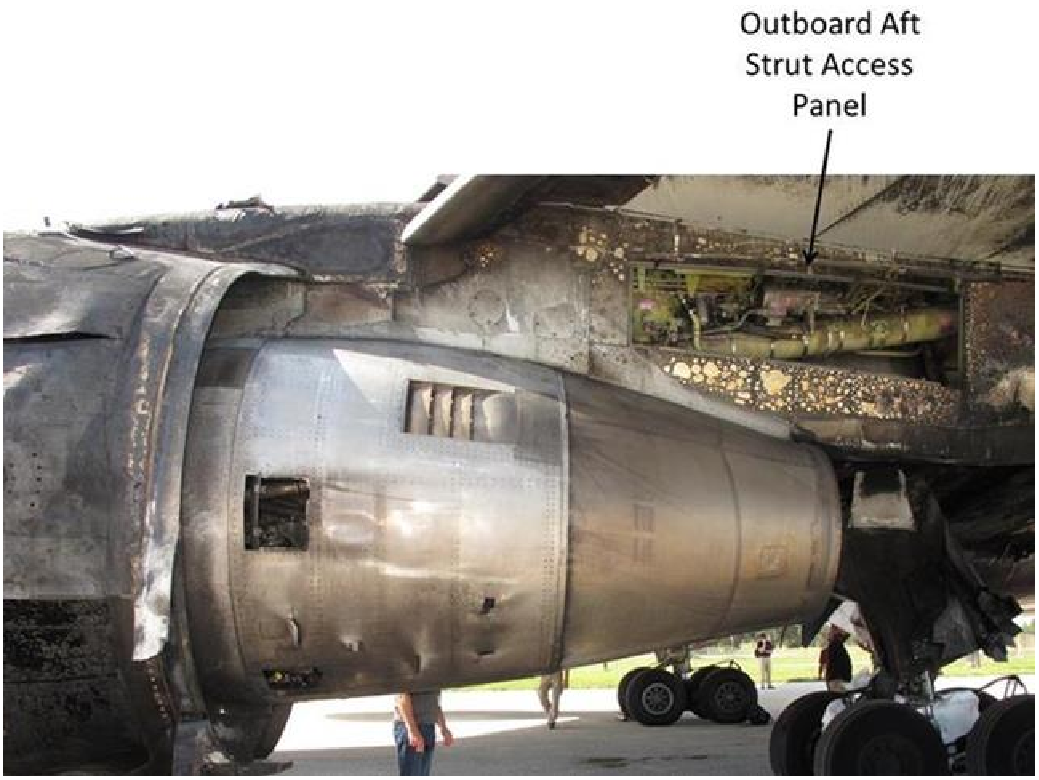

Photo 9- Engine Strut – Outboard Side

The upper strut fairings were charred but remained intact. The pressure relief door on the forward strut faring (thumbnail fairing) was found open.

2.2.1 Strut Upper Spar Structure

The left wing leading edge access panel above the left engine was removed to document the aft strut compartment and main fuel supply line (**Photo 10**). The compartment smelled strongly of fuel and light sooting was observed. Between nacelle stations 192 and 234, the fuel supply line features a full flex coupling assembly (**Figure 2**). The coupling body was found disconnected and resting loosely near the wing spar fuel coupling (**Photo 10**). The remaining components of the fuel coupling were located adjacent to the fuel supply tube mating flanges. The aft retaining ring and o-ring were displaced in the aft direction and the nut, forward o-ring and retaining ring were displaced in the forward direction. The retainer halves remained clamped around the mating tube flanges and were free to rotate (**Photo 11**). Lockwire was not present in either the coupling body or nut assembly lockwire holes and the team was unable to locate the lockwire in the surrounding compartments. All lockwire holes in both the coupling body and nut were observed to be intact with no break-through. The forward bonding clamp was present but loose on the fuel supply line. No aft bonding clamp or bonding jumper was present or recovered. An exemplar photo of the fuel coupling in the correct installation configuration from the right engine is shown in (**Photo 12**).

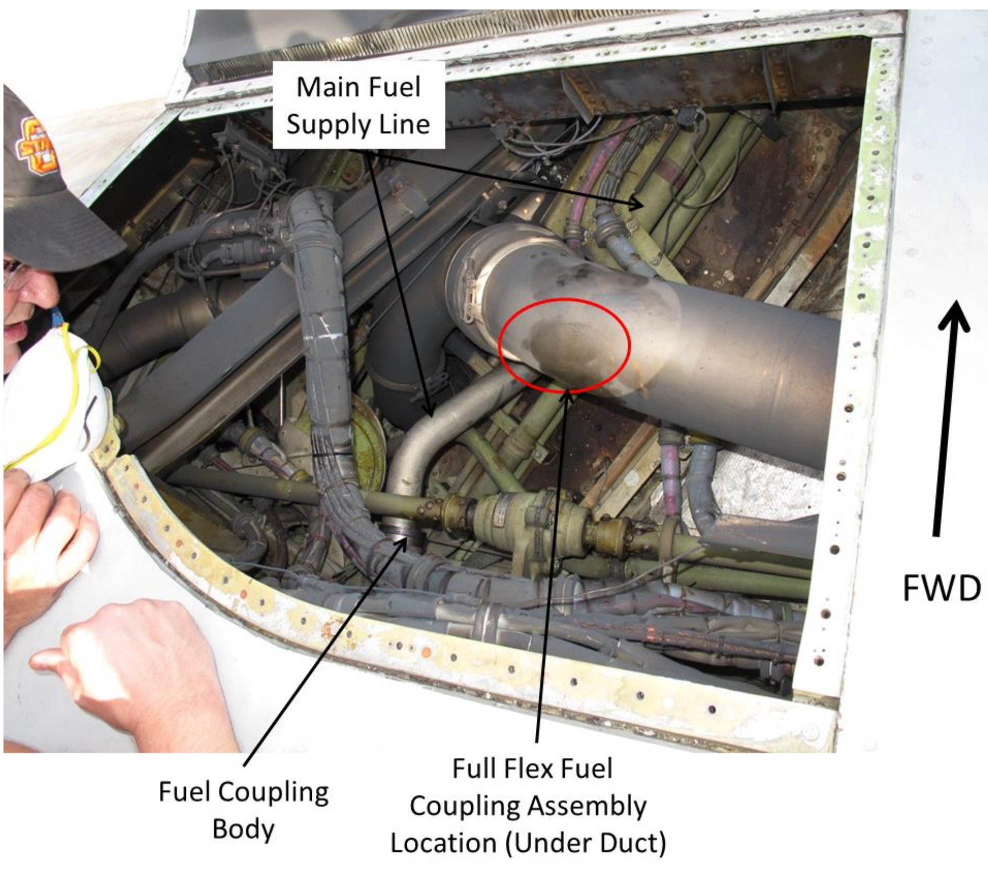

Photo 10- Leading Edge Access Panel Compartment

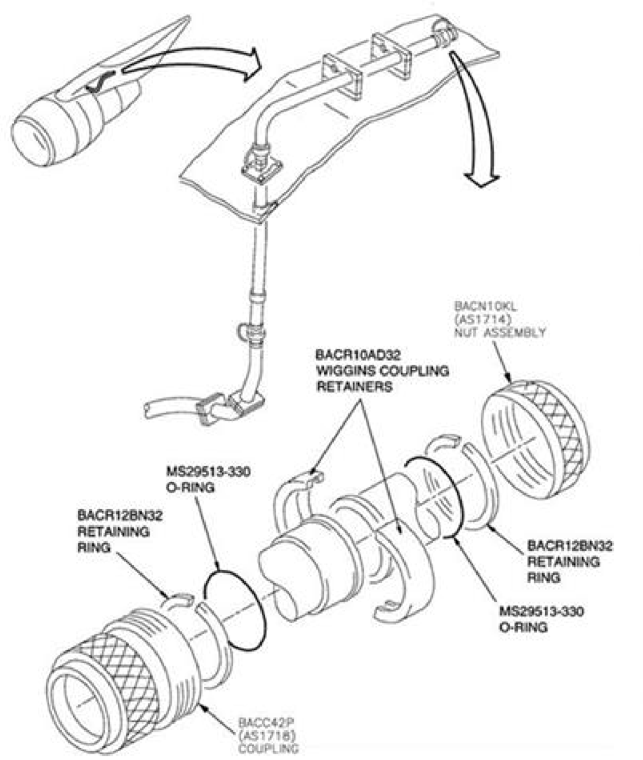

Figure 2- Full Flex Fuel Coupling Assembly Parts Breakdown

Photo 11- Fuel Coupling Assembly, As Found In-situ

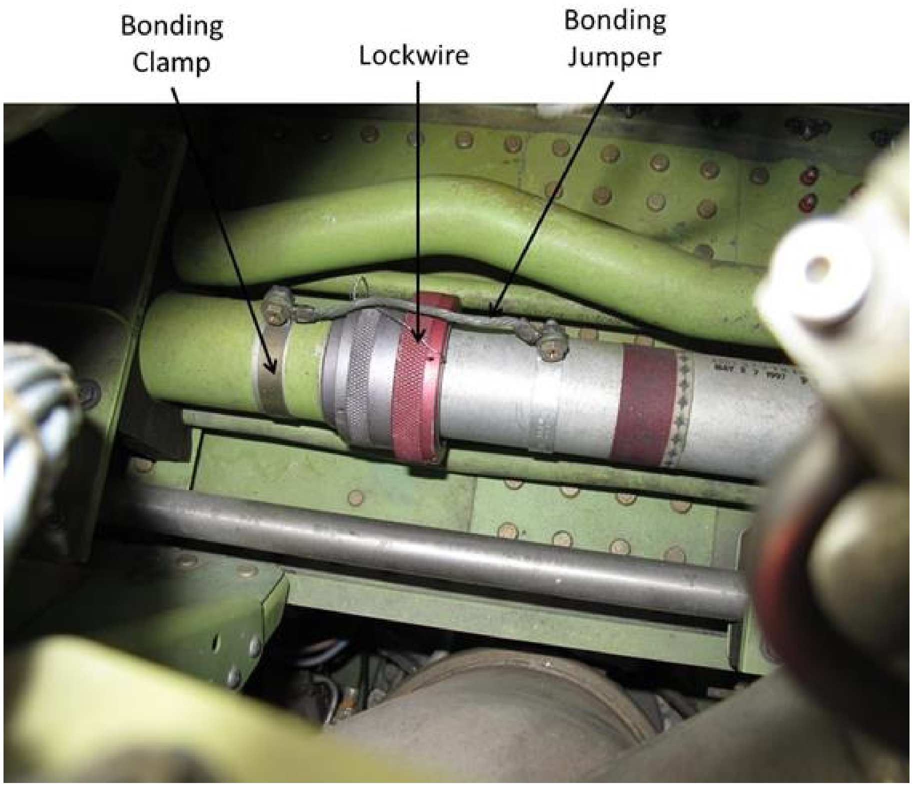

Photo 12- Exemplar Fuel Coupling and Bonding Jumper (Right Engine)

The mid and forward upper spar strut covers were removed to view both compartments. The upper mid strut compartment was sooted but had no signs of thermal damage (**Photo 13**). The main fuel supply line feeds through the aft fairing compartment bulkhead and then has a 90 degree elbow that leads down towards the engine main fuel pump. The full flex fuel coupling located at the elbow that passes through the spar web was intact, secured, and was verified to have the proper configuration per installation drawings (**Photo 14**). Channel locks were required to remove the fuel coupling body. The spar web between the aft and mid strut compartments is sloped downward and bounded by a bulkhead on the forward end. The streaking indications on the inboard thrust reverser cowling were adjacent to the upper mid strut compartment bulkhead. The forward upper strut compartment had very light sooting but was otherwise unremarkable (**Photo 15**).

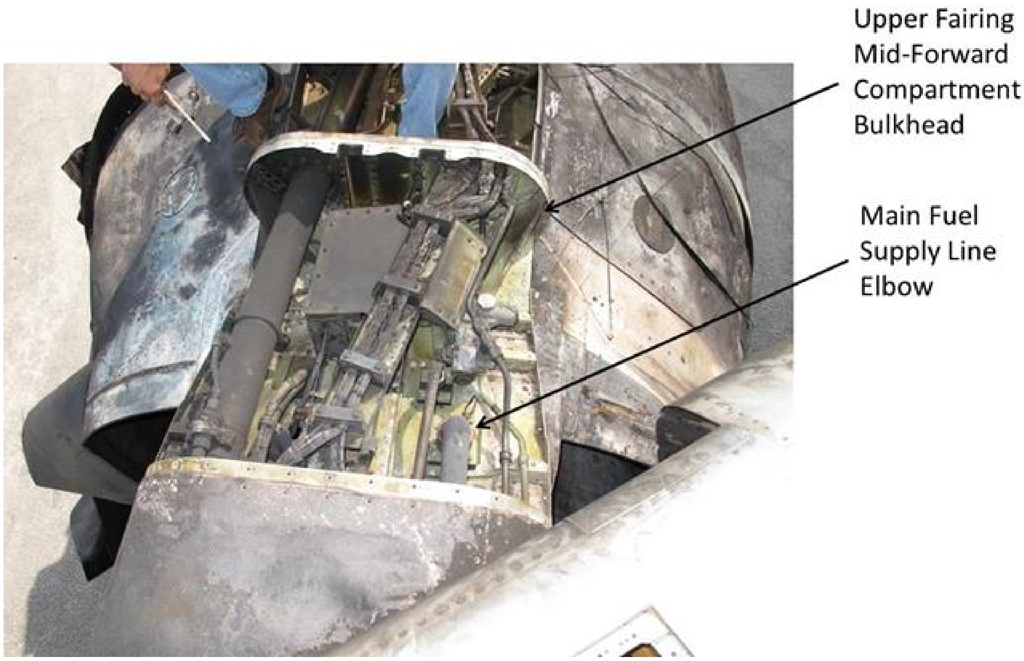

Photo 13- Upper Mid Strut Fairing Compartment

Photo 14- Upper Mid Strut Compartment Fuel Supply Line Fuel Coupling

Photo 15- Upper Forward Strut Compartment

The lower mid and aft strut compartments were viewed through the inboard forward strut access panel and pressure relief door. The mid compartment had light sooting and no indications of thermal damage. The main fuel supply line was visible and did not exhibit any thermal damage or fuel leakage. The lower aft strut compartment was viewed through the inboard pressure relief door and had heavy sooting and some indications of thermal distress on wire insulation consistent with fire. The strut dry bay compartment was viewed through the aft dry bay access door and was found unremarkable.

2.2.2 Strut Drain Test

To verify that the drains associated with the left engine aft strut compartment were not obstructed a drain leak test similar to what is called out in Boeing task card 54-002-01-01 was performed. The 767 strut system features a series of compartment pass-through drain holes that provide a way for leaked fluids to be collected and expelled through a drain manifold that is connected to the drain mast at the bottom of the engine (**Figure 3**). During the test, one gallon of water was poured into the strut compartment at the location of the disconnected main fuel supply line fuel coupling at a rate of about 60 ounces per minute. At the bottom of the engine at the drain mast manifold a bucket was placed to collect the water. The test confirmed that the drains were open and almost the entire gallon of water was recovered in about 4-5 minutes.

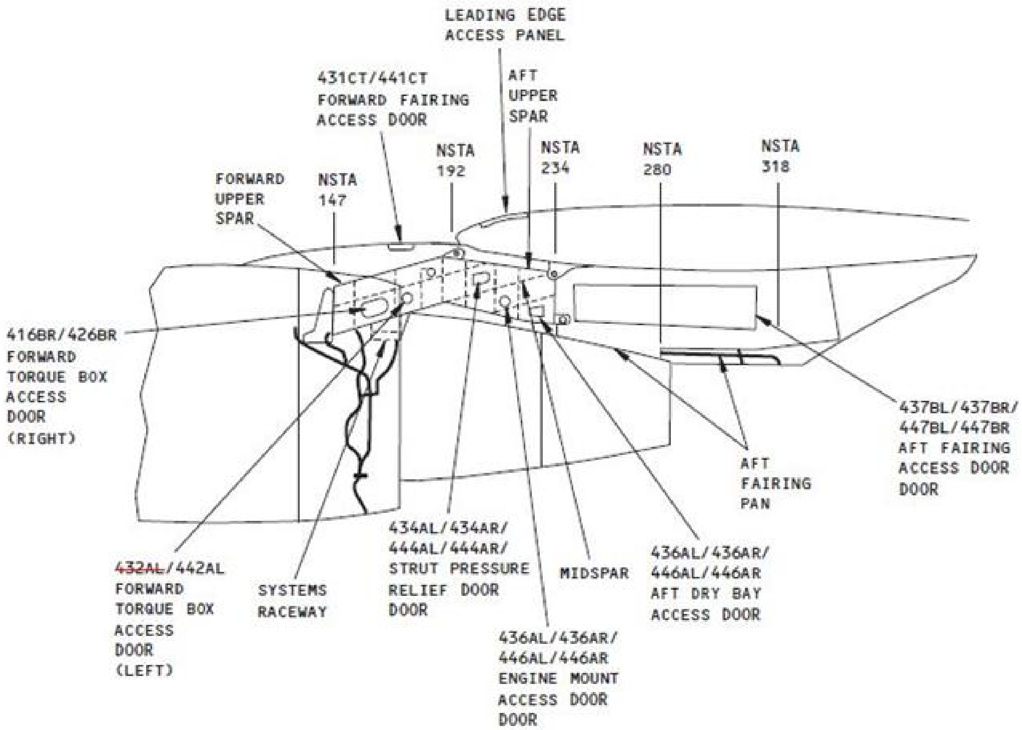

Figure 3- Boeing 767 Strut Drain System and Access Doors/Panels

2.3 Spar Valves

The left and right spar valve indicators were both in the closed position (**Photo 16**). This is consistent with the valves operating correctly following selection of the run-cutoff switch in the cockpit.

Photo 16- (L) Left Spar Valve (R) Right Spare Valve, Both Closed

2.4 Fire Bottles

The left engine No. 1 and 2 fire bottles were accessed in the cargo hold. Each fire bottle features a switch that is held open by pressure and closes when the fire bottles have been discharged. Using an ohmmeter, a pin check confirmed the circuit was closed indicating both bottles were discharged. The bottles were not removed for weight measurements because the group did not have access to anti-static caps to safeguard the squib charges.

3.0 FUEL IGNITION SOURCE

Video of the event was captured by airport surveillance cameras, but all footage was captured on the right side of the airplane rather than the left side where the fire occurred. The initial flash as the fire ignited was visible but a determination of the fire origin could not be made from video or during the onsite evaluation.

The flight data recorder (FDR) was downloaded at the NTSB Recorders Laboratory in Washington, DC and included an engine exhaust gas temperature (EGT) parameter. The highest recorded value during taxi was 452^{o}C (845.6^{o}F). The heat transfer from the exhaust gas through the exhaust nozzle exterior surface would have resulted in temperatures high enough for a hot surface ignition source to be available to ignite the fuel originating from the engine strut leak. The complete flight data recorder specialist's report is available in the docket.

4.0 FULL FLEX FUEL COUPLING ASSEMBLY EXAMINATION

Two sections of the left engine main fuel supply line and the fuel coupling assembly were shipped to the Boeing EQA lab for material inspection and testing (**Photo 17**). The material examination found that all components met dimensional specification except the o-rings which had an inner diameter and width thickness measurements below Aerospace Standard AS29513 specifications. These values are consistent with an o-ring that has taken a compression set during service use. Minor damage was also noted on the fuel supply line ferrule flange, coupling body threads and retaining halves that was considered normal wear for the age of the components according to Boeing. A binocular examination of the fuel coupling body lockwire holes identified material wear around two of the four holes.

Photo 167- Left Engine Main Fuel Supply Lines and Fuel Coupling Assembly, as received at Boeing

A test setup was constructed using the accident hardware to pressurize the fuel lines and coupling assembly in order to simulate operating conditions except vibration. Water was used as the fluid and a pressure regulator was plumbed to maintain the pressure at about 28 pounds per square inch (psi)[2]. The accident fuel lines and coupling assembly (including the recovered o-rings) were assembled in accordance with the Boeing 767 AMM. The coupling nut was backed off about ¼ turn under constant pressure and monitored for leaks. A steady leak did not occur until about $3^{3/4}$ turns, ¼ turn before the coupling separated. A full report of material analysis and test results titled "Boeing EQA Lab Report #AS12458- Fuel Leak at Flexible Coupling in Left Hand (LH) Engine Strut" is available in the docket.

Boeing plans to perform additional vibration and pressure impulse testing on the accident coupling hardware in 2016 to evaluate the effects vibration has on coupling nut torque and back off characteristics in the absence of lock wire. The vibration spectrum that will be used for testing will be based on levels measured in strut during normal engine operation.

Robert Hunsberger
Aerospace Engineer
Propulsion

[222] According to the Boeing 767 manual the fuel system pressure is 26 to 45 psi. 28psi was chosen as a nominal value for testing.