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

<u>Systems Group Chairman's Factual Report</u>

December 16, 2019

A. <u>ACCIDENT</u> DCA19MA086

Location:	Trinity Bay, Texas
Date:	February 23, 2019
Time:	1239 central standard time
Aircraft:	Atlas Air flight 3591, a Boeing 767-375BCF, registration N1217A

B. <u>GROUP</u>

<u>On-scene Investigation, February 24 – April 5, and May 7-9, 2019:</u>

Chairman:	Tom Jacky National Transportation Safety Board Washington, D.C.
Member:	Sarah Harden The Boeing Company Everett, Washington
Member:	Alex Skrabut International Brotherhood of Teamsters, APA1224 Wilmington, Ohio
Member:	John Miller Atlas Airlines Purchase, New York
Member:	Doug Tsuji Federal Aviation Administration Des Moines, Washington

<u>Elevator Power Control Assembly Examination, August 12-14, 2019:</u>

Chairman:	Tom Jacky National Transportation Safety Board Washington, D.C.
Member:	Eric East

The Boeing Company
Everett, Washington

Member: Alex Skrabut
International Brotherhood of Teamsters, APA1224
Wilmington, Ohio

Member: Kelly McGuckin
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Des Moines, Washington

Member: Jeremy Katt
Parker Aerospace
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<u>Throttle Lever Examination, August 15, 2019:</u>

Chairman: Tom Jacky
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Member: Eric East
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Member: Maureen Fallon
Federal Aviation Administration
Des Moines, Washington

Member: Chris Baker
Federal Aviation Administration
Des Moines, Washington

Member: Julio Alvarez
Federal Aviation Administration
Des Moines, Washington

<u>Center Autopilot Elevator Actuator Examination, November 18-20, 2019</u>

Chairman: Tom Jacky
National Transportation Safety Board
Washington, D.C.

Member: Jim Talay
The Boeing Company
Seal Beach, California

Member: Alex Skrabut
International Brotherhood of Teamsters Local 2750[1]
Cincinnati, Ohio

Member: Tony Venturoli
Moog, Inc.
East Aurora, New York

C. SUMMARY

On February 23, 2019, at 1239 central standard time, Atlas Air flight 3591, a Boeing 767-375BCF, N1217A, entered a rapid descent from 6,000 ft and impacted a marshy bay area about 40 miles southeast of George Bush Intercontinental Airport (KIAH), Houston, Texas. The two pilots and one nonrevenue jumpseat pilot were fatally injured. The airplane was destroyed and highly fragmented. The airplane was operated as a Title 14 Code of Federal Regulations Part 121 domestic cargo flight, which originated from Miami International Airport (KMIA), Miami, Florida, and was destined for KIAH.

The group met at the accident site from February 24, 2019 to March 3, 2019. The group assisted the recovery of the airplane and the movement of the airplane wreckage into a warehouse in Baytown, Texas. Once wreckage was moved into the warehouse, the group transitioned there and met from March 4 to April 5, 2019. The group then met at the warehouse from May 7-9, 2019 to document the pertinent airplane systems.

The following items were retained by the group for further examination (including the group's database numerical system):

1. Elevator Power Control Assemblies (all recovered units)
    - SYS205 (cylinder and manifold)
    - SYS25D (manifold) and SYS25 (cylinder)
    - SYS350 (manifold) and SYS93 (cylinder)
    - SYS351 (manifold) and SYS21 (cylinder)
2. Center Autopilot Elevator Actuator (SYS008)
3. Instrument Select Panel with two push button switches (SYS352)
4. Throttle Lever Control Stand Assembly (SYS023)
5. CVR Control Panel and Faceplate (SYS142, SYS260)
6. Mach/Airspeed Instruments, Captain and First Officer (SYS217, SYS264)
7. Seven Assorted Circuit Card Assemblies (CCAs)

[1] In October 2019, Atlas pilots left APA1224 and formed its own local chapter within IBT.

The group met at the Parker Aerospace facility in Ogden, Utah from August 12- 14, 2019 to examine the elevator power control assemblies (PCA) recovered from the accident site. The group examined the four PCA hydraulic manifolds and the five PCA cylinders recovered.

The group met at the Boeing Equipment Quality Analysis (EQA) Laboratory in Seattle, Washington, on August 15, 2019 to examine the Control Stand Thrust Lever Assembly (Boeing Part Number 253T5800-33) recovered from the accident site.

The group met at the Moog Aircraft Group facility in East Aurora, New York from November 18-20, 2019 to examine the Center Autopilot Elevator Servo (SYS008).

At the conclusion of the examinations, all pertinent documents and photographs were provided to each of the parties.

No evidence of a pre-impact system failure was noted by the group.

D. DETAILS OF INVESTIGATION

The airplane was manufactured in 1992 as a Boeing 767-375 in a passenger configuration and was converted to a freighter configuration in April 2017.

The airplane wreckage was situated in a shallow, muddy tidal bay area of an approximate depth of 1-3 feet (See Figure 1). All of the recovered wreckage was immersed in water; while some of the wreckage could be recovered by hand from the tidal bay bed, most of the wreckage was (at least) partially embedded into the tidal bay bed of mud/silt and required retrieval by hoisting the wreckage or excavating the mud. All the wreckage was fragmented by the impact of the airplane into the bay. Depending on whether it was removed by hand or by excavating from the sediment at the bottom of the bay, the wreckage was immersed in the water and mud for days or weeks[2].

Recovery was accomplished by digging/sifting the wreckage from the mud, placing the wreckage onto barges and, once moved to land, transferring the wreckage from the barges onto flatbed trailers. Smaller pieces of wreckage were placed into large volume Tyvek bags on the barges and then transferred to the flatbed trailers.

[2] Please refer to the Structures Group Factual Report for additional details regarding the recovery of the airplane.

Figure 1 - View of portion of the wreckage in Trinity Bay, prior to recovery.

The trailers of wreckage were then trucked to a warehouse in Baytown, Texas and, once inside the warehouse, the wreckage was sorted for systems components in the following manner. First, the wreckage was removed from the flatbed trailers and sorted by the Structures and Systems group members. The airplane wreckage was separated from cargo and US Mail. Once identified as airplane wreckage, the debris was either placed on the warehouse floor for further identification and/or examination or was put into storage (for components that were of no further interest). See Figure 2.

Figure 2 - Bags of wreckage in warehouse waiting to be searched.

In addition, the less dense components and cargo which floated from the impact site was recovered by authorities and taken to a local airplane hangar and later transferred to the warehouse for examination.

The systems components of further interest were identified, cataloged and entered into an electronic computer database (Excel software) with a “SYS” number identifier. Additional information (as available) from the component – part number, serial number, etc. – were also entered into the database. The SYS number identifier was then used during the group’s further documentation of the system components of interest. The System Database of cataloged components is included as Attachment 1 to this report.

As part of the recovery, an effort was made to recover and identify any of the airplane avionics’ circuit card assemblies (CCA). Most of the CCAs that were identified during the sifting of the recovered wreckage were already dry, but a few that were still wet were set aside in water for cleaning and corrosion prevention.

The CCAs were documented for any identification – assembly numbers, serial numbers, etc. (See Figures 3a and 3b). The cards were then examined for non-volatile memory components. Several CCAs were identified (see below) but the micro-chips on each of the cards were too damaged for additional examination. The following were identified:

1. Engine Full Authority Digital Engine Control (FADEC) Signal Conditioning Unit Card
2. FADEC Central Processing Unit Card
3. Flight Management Computer (FMC) A8 Card (portion of)
4. FMC A9 or A10 Cards, 3 segments from

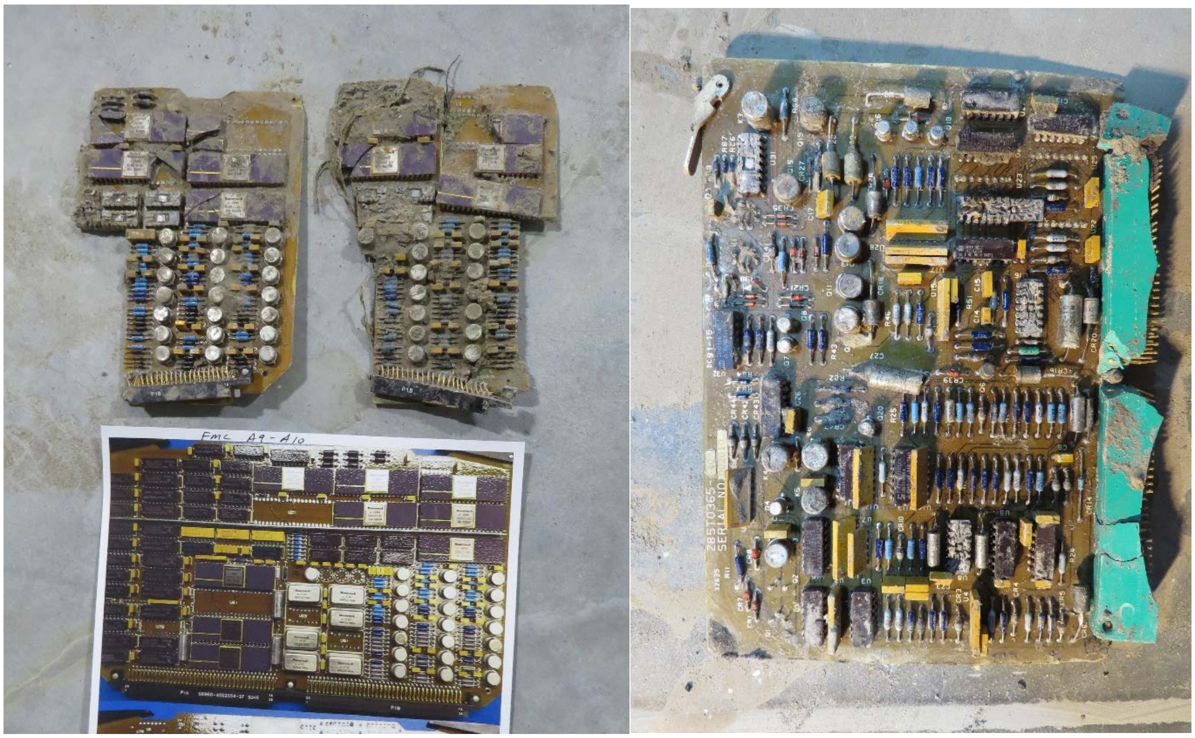

Figure 3a (left) and 3b (right) - Examples of circuit card assemblies as recovered at warehouse. Figure 3a compares the recovered segments against an intact card.

At the end of the recovery and wreckage identification process of the airplane, the group documented the pertinent aspects of the airplane systems as follows:

1.0 Flight Control Systems

1.1.0 Primary Flight Control Systems

The airplane's primary flight control systems consisted of conventional flight controls for longitudinal (pitch), lateral (roll), and directional (yaw) control.

The ailerons, elevators, and rudder flight control surfaces were powered by three hydraulic systems – Left, Right, and Center. Any one of the hydraulic systems can power all of the flight control surfaces.

The group documented each of the recovered actuators pertaining to the primary flight control systems after recovery to and identification at the warehouse.

1.1.1.0 Longitudinal (Pitch) Control System

The longitudinal flight control system consisted of two sets of linked elevator surfaces (inboard and outboard) which were attached to the rear spar of the movable horizontal stabilizer by hinges. Each outboard elevator was moved by three power control actuators (PCAs). The inboard elevator surface was linked to the outboard surface, therefore the inboard surface moved when the outboard surfaces were driven. See Figure 4.

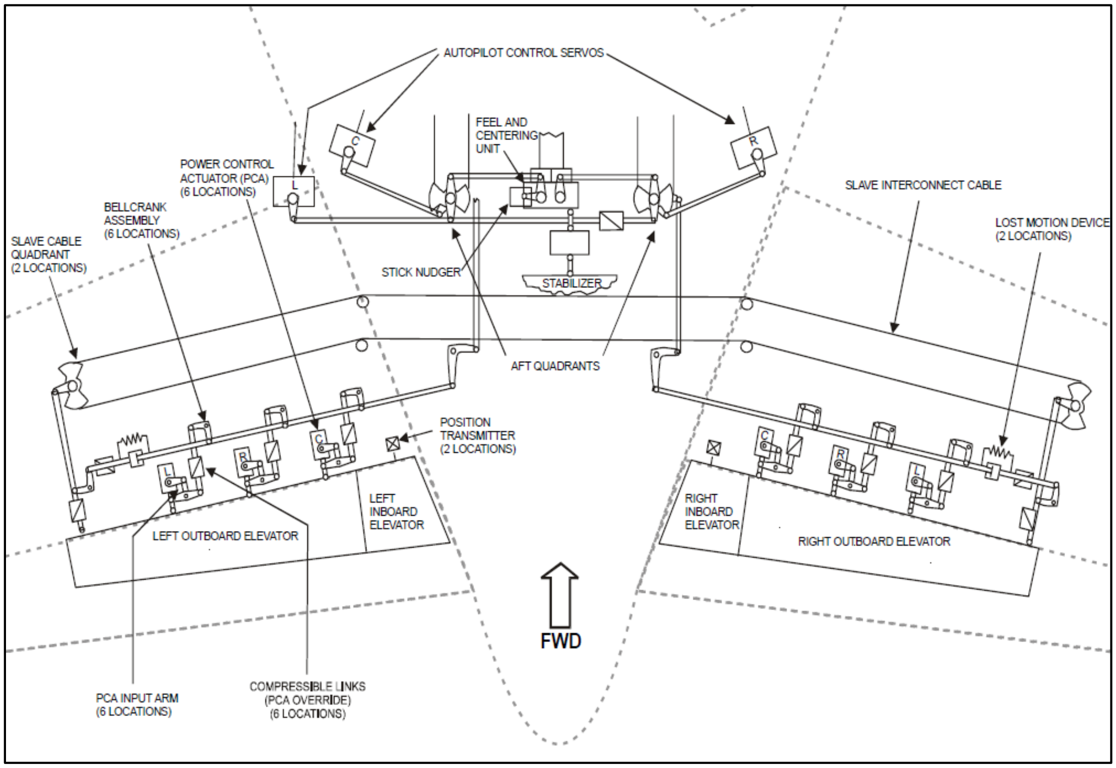

Figure 4 - Diagram of the aft 767 elevator control system components.

Each hydraulic system powered one of each of the outboard elevator surface's PCAs for redundancy within the elevator control system.

Two parallel sets – one from the captain's side and one from the first officer's side – of flight control components moved the elevator surfaces. Control column movements on the first officer's position were linked directly to the actuators for the right elevator surfaces; movement of the captain's control column resulted in movement of the left elevator surfaces. The two parallel sets of flight control components were linked together at the forward and aft override mechanisms/linkages and slave cable interconnects. Flight control commands from the captain's and first officer's control columns were transmitted through linkages and cables from the front of the airplane to the left and right aft quadrant assemblies, respectively. The aft quadrant assemblies then translate the inputs to the respective bellcrank assemblies and to input control rods for each of the three elevator PCAs for each outboard elevator surface (for a total of six elevator PCAs per airplane). See Figure 5.

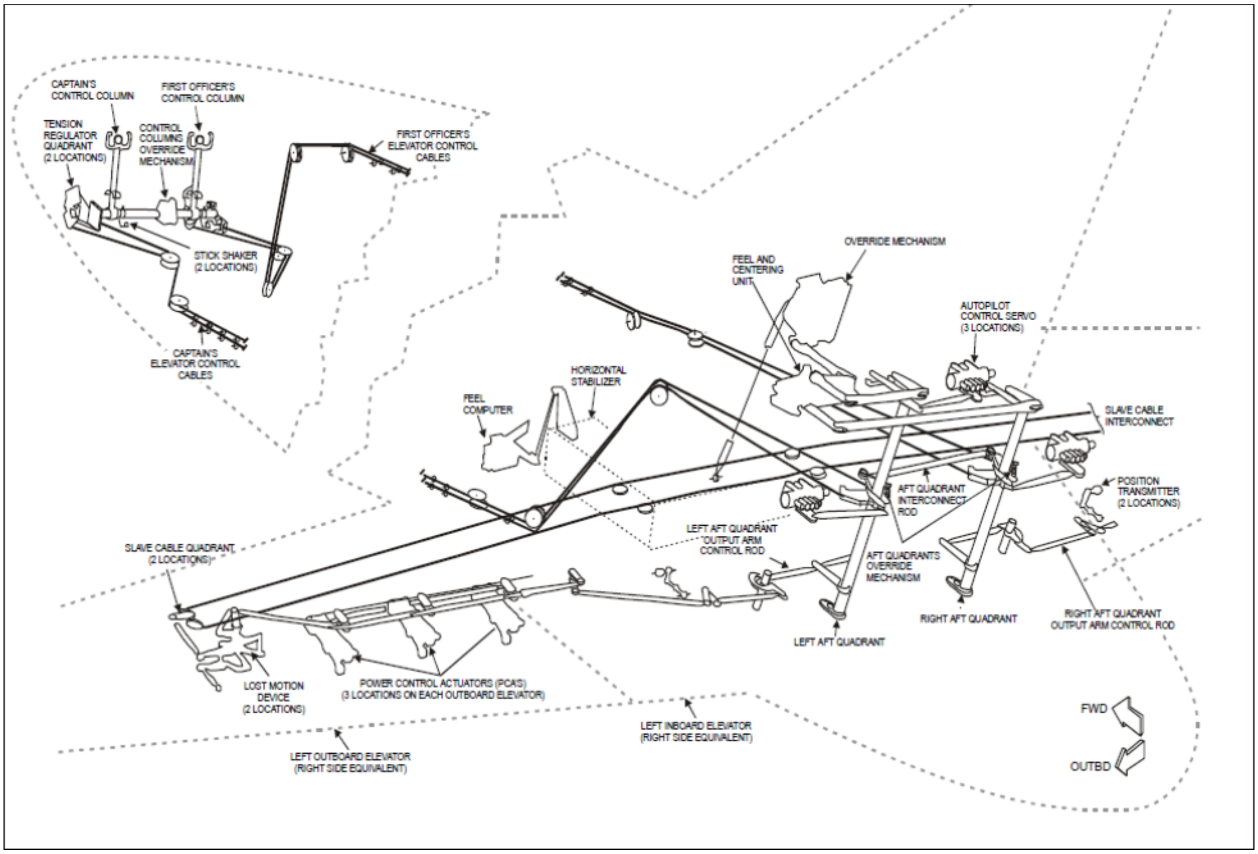

Figure 5 - Diagram of the 767 Elevator Control System

<u>Breakout between the left and right-side columns</u>

The captain's and first officer's control columns can be commanded independently because of override mechanisms at the control columns and aft quadrant. If one side of the system becomes immobilized, control column inputs on the operational side can cause full travel of the nonfailed elevator. In addition, control column inputs on the operational side can also result in nearly full travel of the elevator on the failed side through the override mechanisms. The elevator PCA's are installed with compressible links located between each bellcrank assembly and PCA input control rod to provide a means of isolating a jammed PCA, thus allowing the pilots to retain control of that elevator surface through its two remaining PCAs.

A column override force of approximately 70 pounds is required by either the pilot or copilot to separate the elevators.

1.1.1.1 Elevator PCAs: On-scene Examinations and Disassembly for Further Examination

A total of five elevator PCAs were recovered but only four PCA hydraulic manifolds. Based on a visual examination, the following components, listed by database numbers, were compared and considered to be a matched set of a hydraulic manifold and cylinder:

- SYS205 (Serial Number 2759) – cylinder and manifold
- SYS 25D (manifold) and SYS 25 (cylinder) (S/N 1547)
- SYS350 (manifold) and SYS93 (cylinder)
- SYS351 (manifold) and SYS21 (cylinder)

The component SYS07(A) was a cylinder with no manifold match.

In preparation for shipment to the manufacturer, the PCAs were disassembled to remove unnecessary attached structure and attachment hardware. In addition, the SYS350 and SYS351 manifold assemblies were detached as found and shipped. All removed elevator hinges and associated hardware items were labelled and placed at the warehouse location.

The documentation of the PCAs included the following:

A. Elevator PCA, Serial Number 2759

- Database item SYS205
- The cylinder and manifold were still connected as a PCA.
- The PCA was still attached to elevator structure component hinge.
- Parker part number: 282700-1009, Boeing specification number: S252T801-4
- Manufacturing Date: 4Q91
- 4.125" actuator extension from housing base (observable chrome extension)
- All hydraulic connections severed.
- The interconnect linkage is missing.
- Data tag is lock wired to the hydraulic manifold and not the actuator.
- Removed the lock wire at stabilizer hinge trunnion cap.
- Removed both ¾" diameter bolts from the elevator hinge.
- Removed -4 bolt @ stab side attach fitting on reaction arm due to broken bracket
- The hydraulic manifold assembly was left attached to unit as there was only one bolt missing (item 370 of CMM) and was securely attached.
- Input arm assembly was missing.

B. Elevator PCA, Serial Number 1547

- These were database items SYS25 and SYS25D. See Figure 6.
- According to Atlas records, this elevator PCA was installed as the center PCA on the left outboard elevator.
- Parker part number: 282700-1009, Boeing Specification Number: S525T801-4.
- Manufacturing Date: 2Q88
- The elevator hinge bracket and connecting hardware were still attached.
- A measured 0.750" chrome extension on actuator side, from housing base.
- Hydraulic manifold separated from the actuator attach mounting, held on by interconnect linkage.

- The change notice tag and data plate for the modifications and service bulletin data is still attached.
- The interconnect linkage still has green linkage attached.
- Removed both ¾” diameter bolts from the elevator hinge.
- Due to a broken bracket, the -4 bolt at the stabilizer side attach fitting on reaction arm was removed.
- Removed the broken interconnect rod from the hydraulic manifold input arm
- Removed the manifold assembly from the input arm, as the manifold was completely detached from PCA and only attached to overall unit by input arm.

Figure 6 - Elevator PCA Serial Number 1547, as recovered in warehouse.

C. Elevator PCA, Serial Number Unknown

- These were database items SYS350 and SYS93.
- No data plate was noted.
- The interconnect linkage was still attached to the actuator arm.
- Actuator arm was bent and measured 2.5” chrome exposed with the arm bent approximately 15 degrees in its longitudinal axis.
- The elevator hinge bracket still attached as well as attachment hardware.
- Removed the lock wire at the stabilizer hinge trunnion cap.
- Removed both ¾” diameter bolts from elevator hinge.

- Removed the -4 bolt at the stab side attach fitting on reaction arm, since the bracket was broken.
- Removed the broken interconnect rod from the hydraulic manifold input arm.

D. Elevator PCA, Serial Number Unknown

- These were database items SYS351 and SYS21.
- No data tag on actuator noted.
- Hydraulic connections were severed.
- The measured chrome actuation was 7/8" (observable chrome extension)
- The actuator was connected to elevator hinge bracket, both connections attached.
- Interconnect linkage still attached to actuator body.
- Removed lock wire at the stabilizer hinge trunnion cap.
- Removed both ¾" diameter bolts from the elevator hinge
- The rod end bearing caps failed on the actuator piston during disassembly from elevator hinge; corrosion was noted in the bearing.
- Removed -4 bolt at the stabilizer side attach fitting on reaction arm, since bracket was broken.
- Removed the broken interconnect rod from the hydraulic manifold input arm.

E. Elevator PCA Cylinder, no Manifold

- This was database item SYS07.
- In addition to the hydraulic manifold, the interconnect linkage was missing.
- No data plate was noted. However, the modification status tag (Service Bulletin, Airworthiness Directive) was still attached. No items were noted on the tag.
- The tag indicated the Part Number as 282700-1011, but no serial number noted.
- The elevator hinge bracket and connecting hardware were still attached.
- Exposed chrome was measured as 3.5".
- All the remaining connections appeared without visible damage.
- Removed the lock wire at the stabilizer hinge trunnion cap.
- Removed both ¾" diameter bolts from the elevator hinge.
- The rod end bearing caps failed on the actuator piston during disassembly from elevator hinge; corrosion was noted in the bearing.
- Removed the -4 bolt at the stabilizer side attach fitting on reaction arm due to broken bracket.

The elevator feel actuator (database SYS301), part number 65-44503-10, serial number SHL-261, was recovered and identified at the warehouse. Upon examination, two of the four hydraulic lines were sheared off, and the -3 and -4 hydraulic lines still attached and connected to a piece of structure with its fittings. Another hydraulic line was attached to the structure but disconnected from feel actuator. The fittings on either end of the actuator were separated. The actuator arm on the data plate side of actuator could be rotated and extended. The arm could be extended to 1 and 5/8" and retracted.

1.1.1.2.0 Further Examination of Elevator PCAs at Parker Aerospace

The elevator PCAs were shipped from the Baytown, Texas warehouse to the Parker Ogden, Utah facility and placed into secure storage. When the group arrived, the components were removed from storage, the shipping boxes opened, the components laid out, cataloged and then entered into the Parker incoming database.

1.1.1.2.1 Disassembly According to Component Maintenance Manual

Each manifold and cylinder were examined and disassembled according to the Parker Elevator PCA Part Number 282700 CMM task 27-30-07-99C-855-A01 disassembly procedures.

The components were disassembled and examined in the following order:

A. Elevator PCA Serial Number 2759 (SYS205)

The unit was missing the input linkage and the reaction link was still attached to the PCA. The reaction link was removed. Mud was found in the reaction link attach area of the PCA. The piston end cap was missing. The input link housing bolts were loosened, and fluid started to leak out. A relief valve was removed to relieve pressure. The input crank housing and input crank were removed. The linkage bearings turned normally. Fluid from the manifold was collected by pouring the fluid into a plastic beaker. The fluid was a green-brown color.

The crank pin and overtravel crank were removed. The overtravel crank ball was in good condition with light wear marks on the ball. The primary slide moved freely and fell under its own weight when raised in a vertical position. The control valve was serial number 2750. No chips or damaged metering edges were evident on the slide.

After the group observed disassembly of mostly intact/corrosion free SYS 205 manifold and cylinder assembly, the control valve was separated for testing.

Light washing of control valve assembly was performed to remove oil before insertion into test block. Operator calibrated test unit as shown on graph paper before performing tests as per "Test 7 - 103 Only Figure 3 & 4 Flow Gain" acceptance test data sheets (2 sheets total). Control valve successfully passed all tests.

For the cylinder, the piston rod end was removed by hand. The manifold was removed from the cylinder. The pressure fitting line had fractured and there was dirt in the pressure inlet fitting and filter. The return hydraulic tube is also fractured. Dirt was found in the compensator. The anti-cavitation and input valves were free to move normally against the spring force by hand with a plastic stick.

Both end glands and piston were removed from the cylinder. Normal wear observed on piston rod and inside cylinder with no anomalies observed.

The following serial numbers were noted for the PCA components: the piston serial number 2637 and the manifold serial number 5262.

B. Elevator PCA Serial Number 1547 (SYS25 and SYS25D)

The input crank did not turn by hand. The input crank housing and input crank were removed. The overtravel pin was removed and corrosion was observed on the exterior nut. The overtravel crank ball had normal wear and contact marks. The slide was stuck in the sleeve and had to be pulled out with a high manual force by pulling on it with safety cable. Once the slide was out far enough from the sleeve, the spring guide was removed to allow the control valve tool to clamp onto the sleeve. The sleeve was removed, and corrosion and mud were observed on the control valve sleeve in the pressure and cylinder retract and extend areas of the control valve. The control valve sleeve was serial number 5968. No chips or damaged metering edges were evident on the slide. The anti-cavitation and inlet check valves were removed and had mud on them but moved freely by manually pressing the poppet with a plastic stick against the spring force.

The piston rod end was removed by hand. The cylinder was disassembled by removing both glands and removing the piston. The piston was bent, and the piston head had left two distinct marks 1.7" from the retract end of the cylinder chamfer.

Serial numbers: Piston serial number – unknown/not legible, the manifold was serial number 1859.

C. Elevator PCA Serial Number Unknown (SYS350 and SYS93)

The components were matched together based on the fracture of the input arm (attached to the cylinder) from the input crank on the manifold.

The input link had high friction and slide did not move. Unit had silver seals labeled with a pressed "B" and "C". The rod end was loosened by hand as no torque was on the rod end. The input crank housing and input crank were removed. The linkage bearings were free to move and were not binding. Fluid was collected by pouring into a plastic container. The control valve sleeve (serial number 2915) was removed and the slide was sticking in the sleeve. The control valve was removed and had mud and corrosion on the pressure and cylinder retract and extend areas. The anti-cavitation and inlet check valves had mud on them but moved freely by pressing manually with a plastic stick against the spring force. The compensator was removed and had mud inside. The cylinder was disassembled, and the piston was approximately 1" from full extend where the piston had bent around the gland. The cylinder marks were 2.5" from the end of the rod end side of the cylinder. The bent piston lines up with the gland and cylinder ID marks.

Serial numbers: the piston was serial number 6308, and the manifold was serial number 5123.

D. Elevator PCA Serial Number Unknown (SYS351 and SYS21)

The components were matched together based on the fracture of the input arm (attached to the cylinder) from the input crank on the manifold.

The input crank housing and input crank were removed and had normal wear marks on the ball. The overtravel pin and crank were removed and had normal wear on the overcrank ball. The slide was moving but had some friction. The control valve was removed, and corrosion was in the pressure and cylinder retract and extend areas. The control valve sleeve serial number was 2929. No chips or damaged metering edges were evident on the slide. The anti-cavitation valves were removed and had mud on them but moved freely by pressing manually with a plastic stick against the spring force. The inlet check valve was not able to be removed but the poppet was able to be pressed manually as the manifold had broken away next to the inlet check valve.

Serial numbers: Piston serial number – Unknown/not legible, the manifold serial number 5186.

E. Elevator PCA Cylinder Assembly (SYS07)

The component was an elevator PCA cylinder assembly without a matching manifold. The reaction link was still attached, so it was removed.

The cylinder assembly was placed onto test fixture to allow un-torqueing and removal of the rod end. The rod end was painted green and the cylinder cad plating was in relatively good condition. The piston and glands were removed, and the piston was not bent. Normal wear was noted on the piston rod and cylinder ID in the neutral position was observed consistent with normal in-service wear. No other anomalies were noted.

Serial Numbers: the piston serial number was 3995.

1.1.1.2.2 Borescope of the Control Valves

A Parker borescope procedure was performed on the corroded control valve sleeves removed during the disassembly.

The control valve sleeve (serial number 2750) from PCA serial number 2759 (SYS 205) was observed first as a ‘clean and tested unit’ for comparison purposes; there was evidence of use, but no abnormal wear noted.

The three other control valve sleeve sets (serial numbers 5968, 2915 and 2929) contained heavy corrosion and mud that was cleaned by hand before the borescope observation. For each of the sets, the following was noted:

- The slide metering edges were intact with no chipping observed.

- The sleeve flow slots were rectangular in shape with no damage or chip sheer observed. Heavy corrosion and pitting throughout ID of sleeve.
- The pertinent sleeve flow slots were photographed and shared with the group.

At the end of the examinations, the components were placed back into secured storage.

At the conclusion of all of the examinations of the elevator PCAs and related components, the group did not identify any evidence of an elevator PCA failure.

1.1.2.0 Lateral (Roll) Control System

Lateral, or roll, movement of the airplane was controlled by two ailerons and six spoilers on each wing. The airplane has two ailerons per wing – inboard and outboard. Each aileron has two power control actuators (PCAs), for a total of eight PCAs.

The six spoilers on each wing operated in conjunction with the ailerons. Four of the outboard spoilers were flight spoilers, and the two inboard spoilers were ground spoilers.

1.1.2.1 On Scene Examination of Aileron Actuators

Seven of the eight aileron PCAs were recovered to the warehouse and identified. The PCAs were documented as follows:

1. Aileron PCA SYS071

- The PCA was still attached to aileron structure.
- The PCA was located at right hand (RH) wing station 480, the right inboard aileron.
- The data tag was missing.
- The extension of the actuator measured as 2 3/8” chrome exposure.
- The hydraulic manifold was missing and the actuator rod end (wing side) was detached from the green reaction linkage. Both the actuator rod and reaction link were attached to aileron structure; the connection hardware was noted.

2. Aileron PCA SYS236

- The PCA was located at right wing station 496.
- PCA hydraulic manifold was missing.
- A chrome extension measurement was not available since the actuator housing failed and separated from the base and reaction link connections.
- The seals were different between SYS071 (white) and SYS236 (green).

3. Inboard Aileron PCAs SYS006 and SYS013

- Both components were left (wing) inboard aileron PCAs but their position could not be determined since the data tags from both actuators were missing.
- Both were attached to a portion of the aileron structure and attachment bracket.

- The SYS006 hydraulic manifold was still attached. Both rod and linkage attachments were failed on the aileron side. The PCA was detached from the wing side at the actuator fitting. The linkage from the actuator rod was still attached but disconnected at the hydraulic housing. The chrome extension was measured as 2”.
- The SYS013 reaction linkage was disconnected from the actuator housing. The chrome extension was 2.25” as measured.
- For SYS013, the hydraulic manifold was missing.
- The SYS013 actuator manifold was separated from the reaction linkage, exposing the end of the rod.

4. Aileron PCA SYS184

- The data tag was missing but the unit was visually identified as a left-wing outboard aileron PCA.
- The rod end bearings failed in a lateral direction.
- The chrome exposure was 1 5/8” as measured.
- The PCA appeared “pulled out” of the wing structure attachment. The PCA was still attached to the aileron attachment bracket and the attachment hardware was present.
- The rod end housing seal was failed.
- The attachment bracket and reaction linkage were attached to the aileron surface.
- The hydraulic connections were severed.

5. Aileron PCA SYS178

- Component was identified as a LH outboard aileron but no data tags.
- Chrome extension measured as 1 7/16”.
- The reaction link, hydraulic housing, and connection linkage were attached.
- The PCA fitting to wing side was pulled out.
- The reaction link was attached at both ends.

6. Aileron PCA SYS014

- Was identified as a right-hand outboard aileron PCA but no data tag noted.
- Chrome extension was measured as 1 3/8”.
- The reaction link was attached on the aileron side and the hardware noted but disconnected on the aileron side. The actuator rod was attached to the aileron structure bracket, with hardware noted.
- The control linkage was attached by only one of the four attachment bolts.
- The hydraulic manifold was attached.

No evidence of a lateral control failure was noted.

1.1.3.0 Yaw Control System, On Scene Examination

A. Lower Rudder PCA (SYS 100)

- Was separated from rudder structure, but still connected to the hinge bracket and fitting.
- Serial number tag was separated during group documentation and secured to PCA.
- Part number 282900-1015, serial 2695. Modification tag indicates -1013.
- Assembly date noted as 2Q01
- The -6 (return) and -4 input and output hydraulic lines were removed for examination.
- The exposed chrome was measured as 4 15/16" actuation.
- The rod end was bent at the end of the chrome.
- The reaction link was noted as attached. The triangular fitting to the vertical stabilizer side of the link was connected could be rotated.
- The hydraulic manifold was still attached.
- Linkage and spring mechanism on the PCA were attached to the hydraulic manifold and yaw damper summing lever assembly.
- The "pogo" was noted that incorporated a secondary control path override.
- The component appeared to attach to the structure in the vicinity of V025 (vertical stabilizer database number).

B. Mid Rudder PCA (SYS053)

- Data tag indications: part number 282900-1013, Boeing S252T701-6, serial number 162, Assembly date of 3Q82.
- The modification tag had no part number but indicated service bulletins 27-120 and 27-125, both dated June 6, 1989.
- The actuator rod was bent at the connection to the rod end at approximately 20 degrees.
- The attachment hardware was present on the actuator side. The actuator attach bracket was attached but detached from the vertical stabilizer. V015 was the segment of the rudder surface still attached.
- The secondary override pogoes were still attached.
- The exposed actuator chrome was measured at 2 5/8". The triangular fitting was still attached.
- The hydraulic input and return lines were attached to the actuator and to component V008.

C. Upper rudder PCA (SYS054)

- Data tag, 282900-1013, Boeing specification S252T701-6, serial number 2216, Assembly date of 4Q97.
- No modification tag was noted.
- The PCA was detached from rudder structure V014.
- The exposed chrome was measured at 3 15/16" and the rod was bent.
- The hydraulic lines were still attached to the housing and back into V007.

1.2.0 Secondary Flight Control Systems

The airplane had the following secondary flight control systems: a yaw damper for directional control, speedbrakes for flight and ground aerodynamic braking, and leading edge and trailing edges flaps for takeoff and landing. The following were identified and examined at the warehouse:

1.2.1.0 Spoiler Actuators

The airplane had 12 spoilers – six on each wing. For each wing there were two inboard spoilers and four outboard spoilers. See Figure 7.

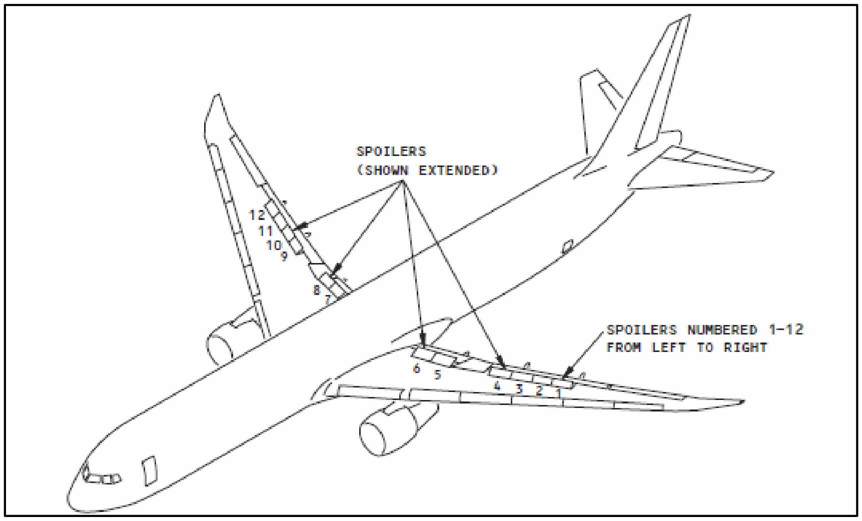

Figure 7 - Location and Numbering of Spoilers

1.2.1.1 On Scene Examination of Spoiler Actuators

Of the twelve actuators, eleven were recovered and identified at the warehouse; one outboard spoiler actuator was missing. Boeing indicated that when hydraulic pressure is removed from the spoiler actuators, the spoiler actuators will return to a retracted position.

A. Left Wing Outboard Spoiler Actuators

- Database items SYS253, SYS012, SYS212, and SYS047 were identified as outboard spoilers from the left wing.
- SYS047 was determined to be from the spoiler #1 position, based on the attached ground and control cables identification. The positions of the other actuators were undetermined.
- Each actuator was still attached to associated wing and spoiler attachment fittings and hardware.
- The data plates for SYS047 and SYS253 were not recovered.
- All four actuators were noted as at or near-fully retracted position.
- SYS 212 was noted as Boeing drawing number: 252T1401-3, serial number 3518.

- SYS012 was noted as serial number 3623
- All actuators except SYS047 had a hydraulic manifold attached.
- SYS012 and SYS212 had their electrical plug and harness still attached.
- All hydraulic lines were sheared off at the input/return plug.

B. Inboard Spoiler Actuators

- Database items SYS10 and SYS97 (left wing), and SYS96 and SYS342 (right wing) were identified as inboard spoiler actuators.
- All were separated from their respective wing structure.
- All had spoiler attachment hardware and small portions of structure attached.
- SYS010 had approximately 1" of actuator chrome extension.
- SYS010 had data plate as noted Boeing specification 252T1301-3, serial number 1662A, with hydraulic lines and electrical connection sheared off.
- SYS097 had approximately 3/4" of actuator chrome extension.
- SYS097 had hydraulic lines sheared. The electrical cannon plug was present, but the wires were pulled out.
- SYS342 was noted as Boeing specification 252T1301-3, serial number 1660A. The hydraulic lines were severed, and the cannon plug receiver noted but wires missing. Chrome extension of approximately 1".
- SYS096 was noted as Boeing specification 252T1301-3, serial number 2149A. The hydraulic line was sheared, and the cannon plug was missing. The servo valve housing was broken, and one wire pulled out. A chrome extension of approximately 1" was noted.

C. Right Wing Outboard Spoiler Actuators

- Database items SYS01, SYS63, and SYS62 were identified as right-wing outboard spoilers.
- One of the right-wing outboard spoiler actuators was not recovered.
- All the spoilers were Boeing specification 252T1401-3, with serial numbers 3634 (SYS01), 3179 (SYS062), and 313(number unreadable) (SYS063).
- SYS062 was identified as spoiler #10 and SYS63 was identified as spoiler #12. Both of these spoilers were still attached to associated wing structure.
- SYS062 was attached to RW075 (right wing structure) and SYS63 was attached to RW043. SYS001 was separated from its wing structure but had spoiler structure still attached.
- SYS062 had hydraulic and electrical lines still attached. The actuator was still attached to a segment of spoiler structure. The electrical connection appeared complete and connected; the wires ran to the wing rib number 17 area. No actuator extension noted.
- SYS063 still had an electrical connection that ran back into the wing structure to wing station 698. The hydraulic lines were severed.

- SYS001 appeared to attach into spoiler position #11. The spoiler fit the spoiler surface and the connection hardware fracture on the associated torque tube attachment. The associated wing structure was RW043. See Figure 8.
- The hydraulic connections for SYS001 were sheared and the cannon plug was still attached. The associated electrical wires, pulled from the actuator, were located within the mating wing structure.
- Based on the identified actuators, the spoiler in position #9 was the spoiler actuator not recovered.

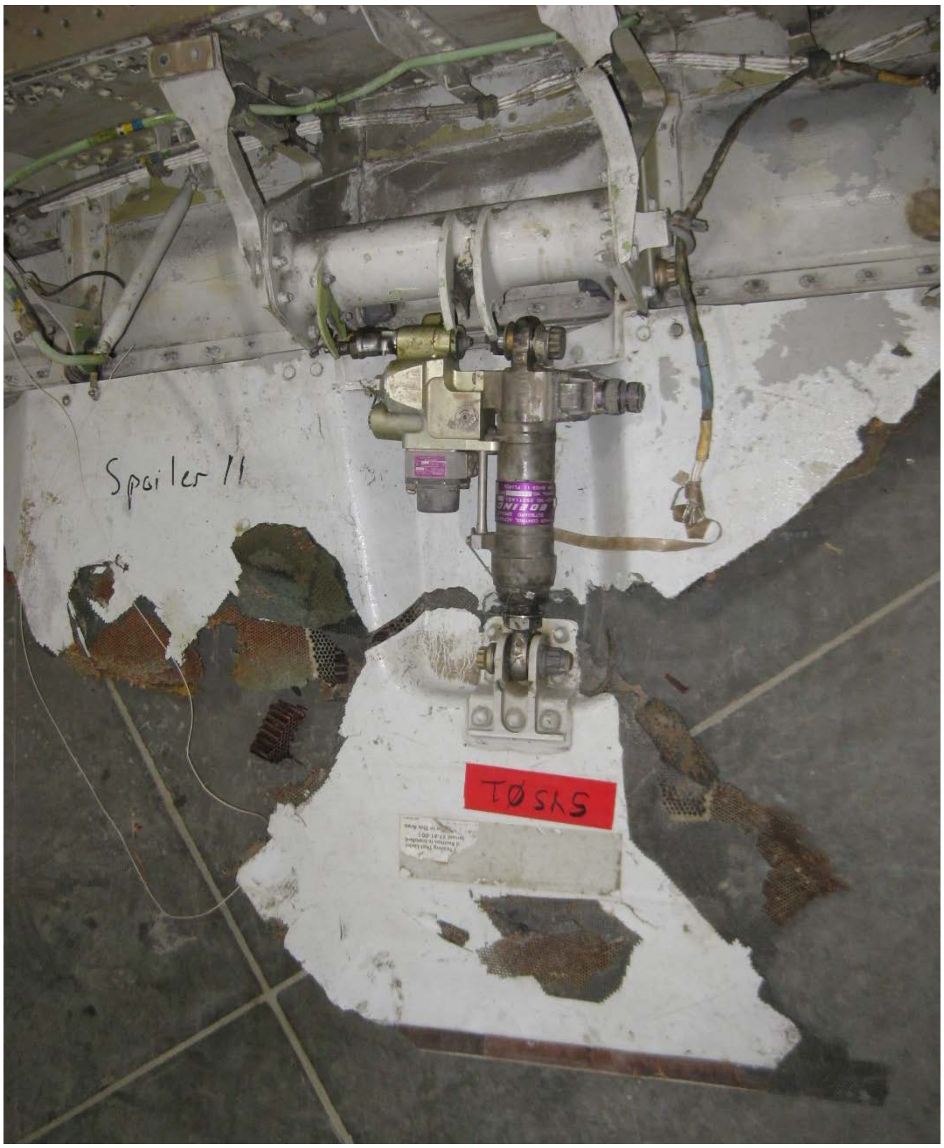

Figure 8 - Spoiler Number 11, as recovered and identified in the warehouse. Note that a portion of the spoiler flight control surface is still attached to the actuator, and the actuator is still attached to right wing structure.

1.2.2 Horizontal Stabilizer Jackscrew, On-scene Examination

- Database item SYS057 was identified as the jackscrew assembly and connected structure, while item SYS058 was identified as the differential housing assembly, part number 251T4347-1.
- The attachment structures were documented as (Horizontal Stabilizer Database) HO37, HO36, and HO38. HO36 was still connected (one piece, 2 legs) but pieces HO37 and HO38 were disconnected; they were identified as the lower connections.
- The data plate was missing.
- The jackscrew rotated freely. The threads were observed with no marks.
- The drive gear casing was fractured and there were pieces missing. The internal drive gears appeared intact.
- The blue grease seal was noted as intact.
- The measured distance from the base of the drive gear mechanism to the larger base of the screw was 11.25”. The distance from the same larger base of the screw to the end of the jackscrew was measured at 31”. However, since the jackscrew rotated freely it is possible that the measured position was different from its position at impact.

1.2.3 Wing Leading Edge Slats and Wing Trailing Edge Flaps

The leading edge (LE) slats and trailing edge (TE) flaps were extended and retracted using rotary drive actuators. Based on this construction, the configuration of the airplane’s LE slats and TE flaps, based on the recovered wreckage, was identified. Portions of the rotary drives, slat structure, and flap structure were identified but not documented.

1.2.4.0 Auto-Speedbrake (Spoiler) Control Systems

1.2.4.1 Auto-Speedbrake Retract System

The auto-speedbrake system automatically retracts the spoilers when a go around is initiated after touchdown. The system also automatically deploys the spoilers at touchdown and during a refused takeoff.

The speed brake retract switches are located under the flight deck floor. The switches are electrically connected to the speedbrake relay panel. If the switches are activated at any time when the auto-speedbrake actuator is extended, the actuator will retract and the speedbrake lever will return to the down position.

The auto-speedbrake retract logic requires the airplane air/ground sensing to be “on ground”, including left or right main landing gear tilt. Without the airplane ground sensed, the system will not retract the speedbrakes.

1.2.4.2 Load Alleviation – Auto-Speedbrake Retraction System

The airplane was modified with APB blended winglets by supplemental type certificate (STC) prior to its freighter conversion. As part of the modification, a load alleviation function was added. According to the Boeing FCOM for the Atlas-Polar 767, if the speedbrakes are deployed beyond the 50% position (as marked on the speedbrake control stand), and the load alleviation is activated, the speedbrake lever moves to the 50% position and all flight spoilers retract to one-half of their maximum position for inflight use. The function commands when both the airspeed is greater than 320 knots and the gross weight is greater than 340,000 lbs. and the flaps are retracted (up).

2.0 Auto Flight

The airplane's automatic flight control system consisted of the autopilot flight director system (AFDS) and the autothrottle system (A/T). The airplane's mode control panel (MCP) and flight management computer (FMC) controlled the AFDS and the A/T system to perform climb, cruise, descent, and approach.

2.1.0 Autopilot Description

The autopilot/flight director system (AFDS) provides automatic control of the airplane's ailerons, elevators, stabilizer, and rudder control systems for automatic flight. The system provides pitch and roll flight director commands, system warnings, and mode annunciations.

The AFDS consists of three separate autopilot systems (channels) that use a single mode control panel (in the flight deck). Each autopilot channel consists of a flight control computer (FCC) with associated servos and flight deck displays. Each FCC contains all the logic and signal handling circuitry for pitch, roll, and yaw axis control. Normal climb, cruise, descent, and approach modes are available with any channel engaged.

The FCCs provide the inputs for the AFDS operating mode displays and flight director commands on the flight mode annunciator. See Figure 9.

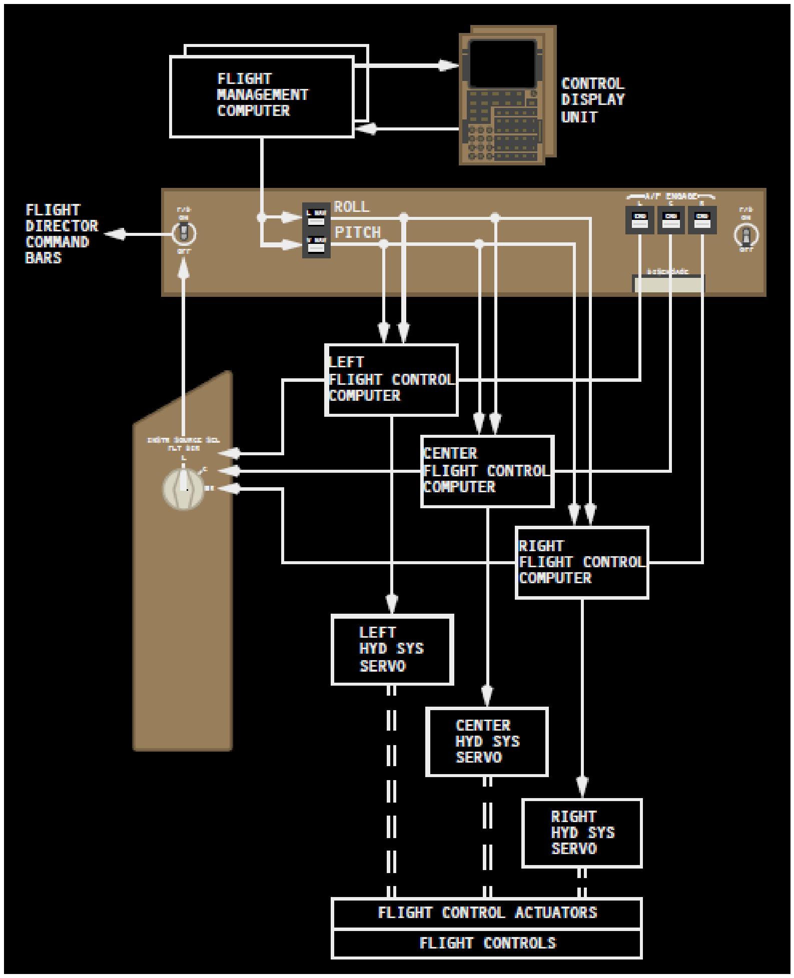

Figure 9 - Simplified schematic of autopilot/flight director system (AFDS).
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During autopilot operation, AFDS failures affecting the active mode are annunciated on the FMA. If the failure affects only the active mode, the autopilot remains engaged in an attitude stabilizing mode. A failure which affects all autopilot modes results in an autopilot disengagement accompanied by an aural warning.

The single channel autopilot output force is limited to 25 pounds at the column. An Autopilot Caution is annunciated when a single channel autopilot override occurs at the column. The design allows for the pilots to override the autopilot in normal operation and will not disconnect the autopilot.

No appreciable portions of the FCCs were identified during the recovery process.

2.1.1 On Scene Examination of Autopilot Servo Actuators

A. <u>Elevator Autopilot Servo (SYS232)</u>

- Moog Part Number: A28321-12, serial number 1420, manufacture date 1191.
- Boeing drawing S252T401-8.

- Moog model number 17-334, revision L12, which agreed with the Moog modification tag.
- The control solenoid was sheared off and the other electrical part on top was also sheared off.

B. <u>SYS 008 – Center Autopilot Elevator Servo</u>

- Identified as the Center Autopilot Elevator Servo. See Figures 10a and 10b.
- Manufacturer: Moog Aircraft Group
- Moog Part Number: A28321-12
- Serial Number: 1418
- Boeing Spec Control Drawing: S252T401-8
- Model Number: 17-334
- Revision Level: L-12
- Manufacture Date: 1191
- The identification sticker on associated structure indicated Boeing position M521, which is identified as center stab position transmission module.
- The servo was retained for further examination.

Figure 10a and 10b - The Center Autopilot Elevator Servo.

C. <u>SYS 005 – Elevator Autopilot Servo</u>

- The Moog tag was missing.
- The modification tag indicates part number A28321-10, SB 22-12

2.1.2.0 Examination of Center Elevator Autopilot Servo

Prior to the examination, the elevator auto pilot servo had been shipped from NTSB headquarters to the Moog facility and placed into secured storage.

Upon arrival of the group, the servo was removed from storage, the shipping box opened, and the servo laid out for examination.

The servo was examined using the Moog Component Maintenance Manual for Part A28321, version dated May 13/19 (rev.13), Chapter 22-10-04, Testing and Troubleshooting.

2.1.2.1 Visual Examinations

The group's examination of the servo noted the following:

- The unit was subjected to severe impact damage.
- The electrohydraulic servovalve (P/N A71882-2) cap was broken and pieces missing.
- The external arm assembly (A38321-1) was bent against the servo body and appeared to be twisted along its longitudinal axis. The attachment fitting and connection hardware were still connected to the external arm. A rod end bearing attached to the arm assembly was found attached but fractured.
- Both the pressure and return hydraulic lines were sheared off.
- The electrical connector was attached to the actuator manifold with a length of multiple wires still attached to the back of the connector. Some wires within the bundle were separated from the connector.
- The LVDTs (Linear Variable Differential Transducer) on each end of the servo actuator were bent approximately 45 degrees off center and pulled away from the manifold body. The LVDTs were attached by the internal components that spanned from the LVDT into the manifold.
- The two solenoids were stilled attached but exhibited impact damage to the housings near the top of the solenoid body. The lockwire seals were Moog seals. The potting on solenoid number two (2) was broken and internal components were visible.
- The servo's data plate was damaged and pulled away from its mounting structure but was still attached.

Based on the visual examination, the group decided that the servo was too damaged to apply hydraulic power to the unit.

The unit was then cleaned prior to further testing and examination.

2.1.2.2 CMM Testing

Of the Servo Assembly Electrical Tests, only sections 4.A, Continuity Test and 4.D, Insulation Resistance (IR) were conducted. This was due to the damaged state of the servo and that the unit had been immersed in saltwater prior to recovery and identification.

The servo failed both test chapters, based on its failure of multiple test elements of the chapters.

The portions of the CMM tests that involved the application of hydraulic pressure to the servo were not conducted. No further CMM Tests were conducted.

2.1.2.3 Disassembly of Unit

The external arm assembly was removed from the servo and compared to an exemplar arm. The external arm from the accident servo appeared bent in a direction towards the manifold and appeared to have a slight twist along its longitudinal axis.

The electrohydraulic servovalve (EHSV) was removed from the servo. The EHSV was identified as follows:

Name: Moog Electrohydraulic Servovalve

Part Number:	A71882-2
Serial Number:	39918
Manufacturer Date:	08-2000
Model:	26-284A
Stamped:	08-2011 (this was the latest overhaul date)

The data plate also indicated "For BMS 3-11 Fluids".

According to Moog records, the EHSV had also been overhauled and returned to service by Moog in September 2005.

The remainder of the broken EHSV cap was removed and the internal components cleaned of the accumulated sand and other debris. Two wires (green and yellow) running to the top of the EHSV were noted as severed but still within the unit.

The EHSV was attached to a Moog EHSV Hydraulic Test Stand for a functional test of the servo valve. Temporary wires were put in place to bridge the broken green and yellow coil wires. When electrical signal and hydraulic pressure were applied, the EHSV was noted to drive in one direction only. After additional debris was removed from the right-side top air gap, the EHSV did not respond to electrical signals, but did respond to manual movement of the armature flexure sleeve assembly (AFSA).

When the EHSV was opened, the AFSA feedback wire was noted as bent.

When the servo manifold was opened, a small amount of fluid was extracted from an internal cavity. The fluid was retained and submitted to the Moog Material and Process Engineering group for contamination testing. At the time of this report, the contamination test results for the fluid sample were not available.

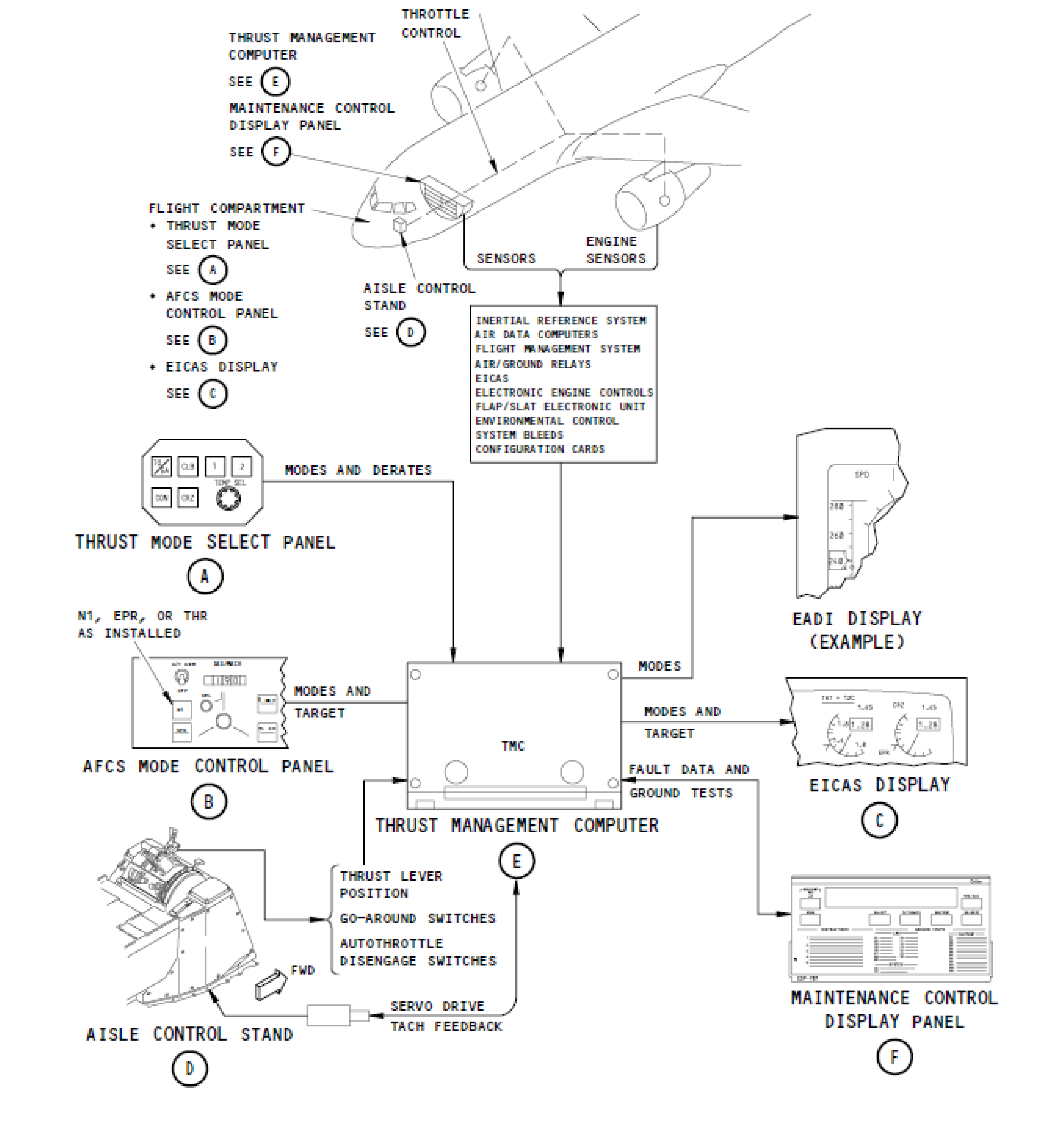
2.2.0 Autothrottle Description and Component Examination

2.2.1.0 Description

The 767 thrust management system, or autothrottle, provided thrust control based on selected modes, existing conditions, and engine limitations. The autothrottle could be operated with or without the airplane's autopilot. The flightdeck throttle levers, located on the center control aisle stand, were connected to a servomotor generator and clutch pack assembly which, when overridden by manual throttle movement (when the autothrottle is engaged) allowed manual thrust inputs. When the autothrottle was engaged it controlled the throttle lever movement. Each throttle has an autothrottle disconnect button on the outboard side of the knob. Pressing the button disconnects the autothrottle.

The Autothrottle/thrust management system is controlled by the thrust management computer (TMC). The thrust management system performs the thrust limit calculation and autothrottle functions. The commands and calculations are performed by the thrust management computer (TMC). The flightcrew selects the autothrottle modes using the autoflight control system mode control panel. The autothrottle functions depend on the mode selected and the system can control thrust, Mach, airspeed, rate of altitude change, or throttle retard rate. The auto throttle modes are displayed on the EADIs in the upper left corner of the display[3]. Thrust limit modes are displayed on the EICAS upper display units. See Figure 11 for a schematic of the Thrust Management System.

[3] The autothrottle FMA annunciations are SPD, IDLE, THR HLD, EPR, N1, FLCH, and GA (go around).



Thrust Management System

Figure 11 - Schematic of the Thrust Management System.

The basic TMC functions were:

- Calculate thrust limits and settings or follow FMC thrust settings
- Detect and transmit autothrottle failures
- Actuate the thrust levers

According to Boeing, the maximum-commanded autothrottle thrust lever movement rate for a normally functioning system is 10.5° per second; manual throttle lever movement can exceed this rate.

2.2.2 Go Around Mode and Switches

One of the thrust management system modes is the Go Around (GA) mode. GA mode is selected by pressing one of the two go-around switches ("paddles") below each of the throttle lever knobs (See Figure 12). The GA Mode is armed when the flaps are selected (out of the retracted position) and typically selected when an airplane is on approach to landing and the flight crew chooses to abort the approach and "go around" for another attempt at landing. In general, for the 767 thrust management system, activation of the go around mode causes the throttles to advance (add power) and the airplane's autoflight system to pitch the airplane's nose up in anticipation of arresting the airplane's descent and, in most cases, preparation for a lateral deviation away from the airport.

Figure 12 - 767 throttle stand, throttle levers, and Go Around switches (circled in red). Photograph is not of the accident airplane.

According to Boeing, pushing either GA switch activates a go around using multiple autopilots, a single autopilot, or flight director only. When the flight director (F/D) switches are not on, pushing either GA switch displays the flight director bars on the electronic attitude display instrument (EADI). The reference thrust limit changes to the GA value when GA mode arms (or glideslope is captured). The arming is not annunciated. The GA mode remains armed until two seconds after the airplane reaches five feet radio altitude.

Pushing either GA switch during this period of the approach engages the GA mode. The mode remains active even if the airplane touches down while executing the go–around. The GA switches are interlocked with the thrust reversers to prevent GA mode engagement during reverse thrust operation.

More specifically, when pushing either GA switch:

• Roll and pitch activate in GA on the flight mode annunciator (FMA).
• Autothrottle increases thrust to maintain a climb rate of at least 2,000 fpm.
• Roll commands bank to maintain ground track.
• AFDS increases pitch to hold existing speed or the selected MCP speed, whichever is higher, as thrust increases.
• If the flap setting is 20 or less, a thrust mode other than go–around can be selected.
• The flight director provides windshear guidance during GA if windshear detected

The thrust levers are automatically advanced for a positive rate-of-climb when a go-around switch is pressed.

Each GA switch contains a set of micro-switch contacts that provide discrete inputs to the Left, Right, and Center Flight Control Computers (FCC) as well as the Thrust Management Computer (TMC). See Figure 13.

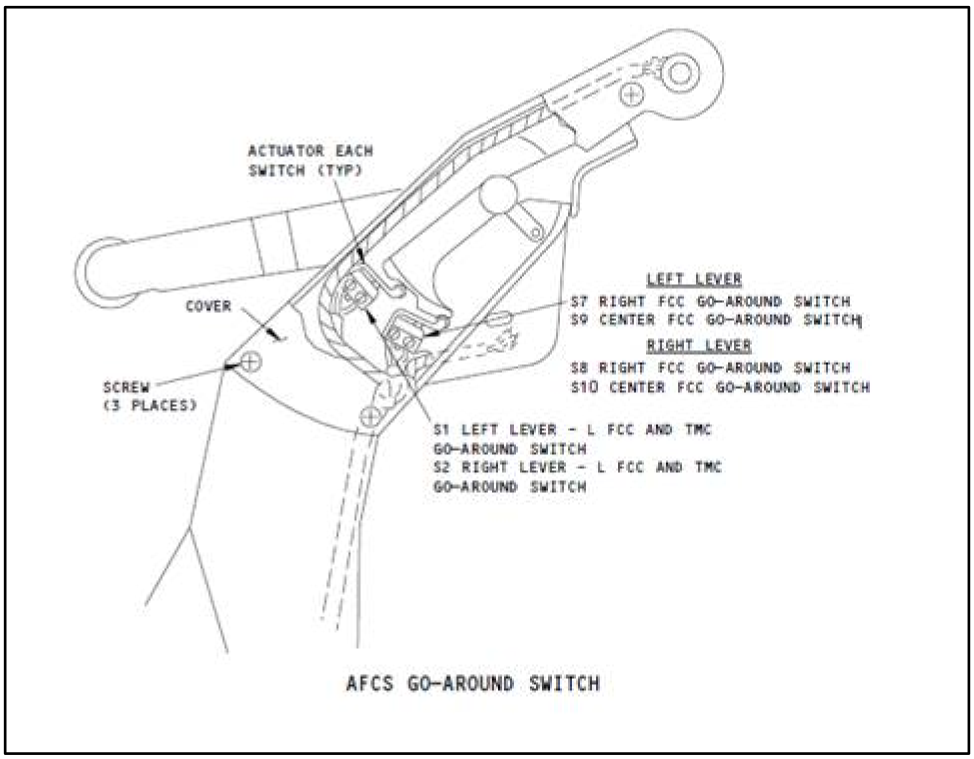


Figure 13 - Schematic of Go Around Switches and Connected Wiring.

2.2.3.0 Control Stand Thrust Lever Assembly Examination at Boeing Equipment Quality Analysis Laboratory

The control stand thrust lever assembly was shipped from the Baytown warehouse to the NTSB's regional office in Federal Way, Washington. An NTSB investigator hand-carried the shipping box to and witnessed storage in the Boeing Equipment Quality Analysis (EQA) Laboratory secured storage. See Figure 14.

Figure 14 - Control Stand Thrust Lever Assembly and associated structure, as received at the Boeing EQA Laboratory.

2.2.3.1 Radiographic Imaging and Visual Examinations

Prior to the group's arrival, the NTSB investigator from the Federal Way regional office witnessed the digital radiography (DR) and computed tomography (CT) imaging of the component. The component was then replaced into secured storage until the group's arrival.

Upon arrival, the group reviewed the DR of the entire assembly and CT scans of the area of the go-around switches and associated wiring.

The throttle levers were removed from secure storage, the shipping box opened, and the components laid out.

2.2.3.2 Examination of Go-Around Switches

The group examined the go-around switches on the throttle levers. The plate covering the three go-around micro-switches on both throttles were missing. On the left throttle lever, the go around trigger was missing except for a portion above the pivot point. The actuator arm on the S1 switch was misaligned outboard and the S7 actuator arm was bent outboard and contacted the S9 actuator arm. The S9 actuator arm did not appear misaligned.

On the right throttle, a portion of the cam end of the go-around trigger was noted rotated “aft” and wedged against the back wall of the lever; the portion of the trigger also jammed/depressed the S2 switch actuator arm. The cam end portion of the go-around trigger was removed and the S2 switch actuator arm was released. Once released, the S2 actuator arm could be actuated by hand.

Aside from the noted observations, no other visible evidence of damage to any of the six switches was noted.

A continuity check of the six switches was accomplished. Using a digital multimeter, the continuity of each switch was checked at the base of the switch and at the end of the switch’s wires at the end of their respective runs at the base of the throttle levers where the wires were severed. For each check the switch was actuated by pressing the actuator arm onto the switch plunger.

The results were as noted in the following tables:

Right Throttle Lever

Switch #	Where measured	Resistance	Actuates?
S10	At Switch	0.06 Ohms	Yes
S10	At End of Wires	0.24 Ohms	Yes
S8	At Switch	0.09 Ohms	Yes
S8	At End of Wires	0.24 Ohms	Yes
S2	At Switch	0.08 Ohms	Yes
S2	At End of Wires	0.24 Ohms	Yes

Left Throttle Lever

Switch #	Where measured	Resistance	Actuates?
S1	At Switch	0.05 Ohms	Yes
S1	At End of Wires	0.23 Ohms	Yes
S7	At Switch	0.04 Ohms	Yes
S7	At End of Wires	0.21 Ohms	Yes
S9	At Switch	0.04 Ohms	Yes
S9	At End of Wires	0.23 Ohms	Yes

No evidence of any pre-impact failure or damage was noted for either of the two go-around switches.

2.2.3.3 Examination of Autothrottle Disconnect Switches

The left (S3) and right (S4) autothrottle disconnect switches were examined. The left autothrottle disconnect switch was noted as separated from the throttle knob but still connected by the wires, while the right autothrottle disconnect switch was found intact in the throttle knob.

A continuity check of the left and right autothrottle disconnect switch wires was accomplished. The continuity of the wires was checked from the switch ring terminal to each switch's wires at the end of their respective runs at the base of the throttle levers where the wires were severed. The resultant values were as follows:

Left Disconnect Switch Wire Number and Measured Resistance

Wire 13:	0.15 Ohms
Wire 14:	0.20 Ohms
Wire 15:	0.12 Ohms
Wire 16:	0.16 Ohms

Right Disconnect Switch – Wire Number and Measured Resistance

Wire 17:	0.15 Ohms
Wire 18:	0.16 Ohms
Wire 19:	0.15 Ohms
Wire 20:	0.15 Ohms

Due to the damaged condition of the left autothrottle disconnect switch, continuity checks of the switch ring terminals could not be performed. The left switch wires were cut to allow examination of the switch under a digital microscope. A small amount of corrosion and particulates were observed. No further examination of the switch was accomplished.

The knob was removed from the right throttle lever. Continuity checks of the switch ring terminals of the right autothrottle disconnect switch were performed but no continuity in either switch position (normal or actuated) was noted. The switch was examined under a digital microscope; further examination of the right autothrottle disconnect switch using DR indicated the normally closed contacts indicated possible misalignment or area of low density between contacts. Then an attempt was made to remove the switch from the throttle lever arm, including cutting the four switch wires. However, looseness in the ring terminal was noted around wires 17 and 18; intermittent continuity could be observed by manipulating the terminals by hand. Based on the unsuccessful attempts to remove the switch and the intermittent continuity, the group decided no further examination was necessary.

On December 6, 2019, Boeing provided a report of the EQA activities titled Examination of Control Stand Thrust Lever Assembly. The report is included in Attachment 2.

3.0 Flight Instruments and Control Panels

The group sorted through the recovered and cataloged parts to identify and group the components from the forward instrument panels, aisle stand, overhead panels, etc.

3.1 Components Identified from the Forward Instrument Panels

A. First Officer's Mach/Airspeed Indicator (SYS 217)

- This was a round analog flight instrument
- Manufacturer's serial number: 98113956
- Mod Status: A-F marked
- Model: SI-800
- Boeing part number: S231T100-4
- Honeywell part number: 4039891-906
- MFR: 58960, DMF: 11638
- The instrument's front face and forward internal components were missing. The dust cover was split open in the forward area. The rear and connector plugs were also missing.

B. Integrated Standby Flight Display (ISFD) (SYS078)

- Thales Serial Number: C16221021305
- Thales part number: C16221LA03
- Boeing part number: S231A120-6

The following cataloged items in the database were determined to be from the front instrument panels: SYS78, SYS95, SYS123, SYS152, SYS177, SYS199, SYS206, SYS207, SYS217, SYS244, SYS264, SYS286, SYS297, SYS303, SYS316, SYS321, SYS323, SYS331, SYS352, and SYS363.

3.2 Components Identified from the Center Aisle Stand and Control Yokes - Examination at Warehouse

The auto pilot disconnect buttons were noted on both control yokes.

A. Throttle Levers (SYS023)

- The component consisted of the levers and associated hardware and linkages
- Connected at center axle, left and right linked together.
- The left throttle auto-throttle disconnect switch was pulled out of knob (missing) and lever.
- The left go-around microswitches were present but the activating arm was missing. The microswitches appeared to work.
- The actual go-around switches on both throttles were missing. Internal microswitches were present. All of the micro switches on the RH side appeared

to actuate. Switches are labelled S10, S8 and S2 (RH), and LH switches are labelled S1, S7 and S9.

- The LH thrust reverser lever was broken and knob missing. The knob did not appear to be connected to anything internally.
- The RH auto-throttle disconnect switch appeared to function normally.
- For more information, please refer to Section 2.2.3, Control Stand Thrust Lever Assembly Examination at Boeing Equipment Quality Analysis Laboratory of this report.

B. Speed Brake Lever and Aisle Stand Frame (SYS349)

- The circumference of the lever speed brake rail was 7". There was a bent, compressed area of the outer frame just above the speed brake rail that corresponded to approximately 1.5" aft of the forward/stowed detent – 1.5" is the most aft portion of the bent outer frame. The center of the compressed frame was ~3/4" aft of the forward/stowed detent. See Figure 15.

Figure 15 - Speed Brake Rail with finger pointing to the compressed area of the outer frame.

- The speed brake rail was still connected to the aisle frame, and the lever was attached to aisle frame via the rotary connector.
- The aft 2/3 of the speed brake frame appeared normal, as did the very front of the frame. The frame itself was bent and deformed.
- SYS359 was the other half of the frame. There was a corresponding impact mark where the speed brake lever meets on that side.

The following cataloged database items were noted from the aisle stand, control column, and rudder pedals: SYS004, SYS023, SYS028, SYS030, SYS067, SYS076, SYS104, SYS179, SYS198, SYS200, SYS215, SYS222, SYS256, SYS261, SYS266, SYS304, SYS326, SYS345, SYS349, SYS353, SYS355, SYS358, and SYS359.

3.3 P-11 Panels Identified

- SYS272 was identified as Panel P11-2
- SYS273 and SYS74 were identified as Panel P11-3 (both sub panels are considered the P11-3)
- SYS275 identified as Panel P11-4
- SYS276 – Panel P11-5
- SYS277 and SYS278 – P11-6 (both sub panels are considered to be P11-6)
- SYS279 – Panel P6-5
- Panel P11-1 was not recovered.
- Each of the P11 panels were deformed and much of the identification placards are missing. Most of the breakers were missing; of the breakers that remained, the indication of position would not be accurate; most of the associated wiring behind the panels was missing.

3.4 P-6 and P-61 Panels Identified

- P61 panel – identified as SYS320 and SYS329.
- SYS140, SYS149, SYS279, SYS280, SYS296, SYS305, and SYS330 comprised the P6 panel.
- SYS279 was the P6-5 panel. Some of the identification placards remained in place but all the circuit breakers were missing. The panel was deformed.
- SYS305 was a portion of the P6-3, Left AC Bus circuit breaker panel. The H-18 circuit breaker position on the panel was the EQUIP COOL SUPPLY FAN 1 15A breaker, but the breaker was missing.
- SYS296 was the P6-2 LEFT DC BUS Circuit breaker panel. The panel was deformed, and all the circuit breakers were missing.

3.5 P-5 Overhead Panel Identified

The following cataloged database components were identified as parts of the P5 Overhead Panel:

- SYS124 was the Caution Panel. Seventeen of the panel's 28 light assemblies remained. The panel frame was bent and compromised with many of the lights missing but was still attached to wiring. The frame stanchion was broken off. The three cannon plugs were attached.
- SYS105 was the RH HF radio panel, based on wiring harness label on the cannon plug. The center switch was in the "OFF" position. The faceplate was partially broken and separated from the chassis.
- SYS112 was the Compartment Temperature panel with indicator. The faceplate was missing, and the cannon plug attached.

- SYS113 was the copilot side (most outboard) Duct Pressure and Bleed Air System panel. All switches were missing but the duct pressure indicator was attached by its wiring. The left pressure was indicated as 37 psi and the right pressure was indicated as 25 psi. The cannon plug and harness were still attached. The faceplate was missing, and the frame was bent but intact.
- SYS116 was the Hydraulic System control panel, located on the LH side forward left (captains' side). The frame was missing, and no rotary switches were noted but the push button Korry switch was still there. Both engine driven pump switches were in the "ON" position. The faceplate was missing, but all five cannon plugs were still attached and locked.
- SYS117 was the Cockpit Lights and Logo Light control panel. Only the overhead panel rotary switch remained, and all the other switches were missing. The frame was noted but bent. The entry light switch was broken, the test switch broken, the logo light switch missing, and the indicator light switch appeared to be in the BRIGHT position. No wiring harness or cannon plug were noted.
- SYS119 was the Cabin Altitude Controller subpanel, on the right-hand side of the panel. The cabin altitude switch was noted in the Neutral position. The needle indicated (pointed) in the full closed position. The mode select switch was noted in the Auto 2 position. The landing altitude switch was missing and the auto rate knob missing. Both cannon plugs were attached. The wiring harness was cut at ~18" to facilitate examination.
- SYS121 was the Satcom and HF switching panel. The faceplate was missing but all four switches remained. The backing frame was detached but remained. No wiring harnesses were noted.
- SYS127 was the Temp Control Panel. The frame was bent/deformed but the entire frame remained. All of the knobs were missing. The cold/warm indicator in the upper left corner was noted. The pack control switches were sheared off. The wiring harness and canon plugs were noted with the harness cut at 18" to facilitate examination.
- SYS129 was the Emergency Lights, Ram Air Turbine, Engine Start, and Fuel Jettison panels. No knobs were noted but their posts remain. No faceplate was noted, and the emergency light switch remained; no other switches were noted. The cannon plugs and harnesses were noted, some panel stanchions remained but were separated.
- SYS131 was the Anti-Ice panel, Rain Repellent, and Anti-Collision Light panel. One ON switch was noted from the anti-ice panel. One light and one alternate switch was noted. The wires from the cannon plugs were cut at a length of 18". The frame was noted but the faceplate was missing. The windshield wiper panel faceplate was mostly there but the knobs were missing. The wiring harness was cut at 18" with the cannon plugs attached. For the light panel, all four switches remained as well as the three wing, landing, and nose gear light switches. The faceplate was missing but the frame was present. The two cannon plugs were noted.
- SYS135 was the Fuel Management panel in the center section of the overhead panel. The frame was missing, and one single, complete switch was still attached, noted in the ON position. All three cannon plugs were still attached

and locked, with 18” of cut wire harness attached.

- SYS136 was the ELT and IRU panel. The ELT frame and box were noted. The ELT switch was noted in the ON position and the red flap was noted up. The ON light was missing, and the test/reset button was noted. The inertial reference mode panel and box chassis were intact but only a portion of the front frame and faceplate remained. The system display knob was attached and in the Center position. The digital readout was missing, the 12-button keypad was missing, and eight of the twelve left/center/right IRU faceplates were noted. All of the twelve lights remained, although all were damaged. All three of the alignment switches were missing, but the posts/switch shafts remained; all were bent. All three cannon plugs were attached and locked. The wire harnesses were cut at 18” for the examination.
- SYS138 was the Fuel Quantity panel. The box remained but no LCD readout, no faceplate, or frame noted. Several wires were pulled from the three cannon plugs, but the plugs were still attached. Five circuit cards were noted inside the box.
- SYS142 was the CVR control panel. This component goes with SYS260, the CVR panel faceplate. The erase button was missing, and the test button remained but was inoperative. The frame and microphone were missing.
- SYS143 was the pilot’s call panel. All eleven switches were noted. The identification for the bottom row switches remained, but the identification for the top row was missing. The cannon plug was attached with 18” wire remaining.
- SYS147 was the left-hand HF panel. About half the faceplate was missing but the frame and box were mostly intact. Three of the four knobs were present, but the center switch was missing. Half of the digital readout screen was missing. The cannon plug was attached.
- SYS156 was the Yaw Damper and Anti-Skid control panel. No frame or faceplate was noted. The three push buttons remained: two buttons indicated ON, but the other button had no faceplate. The wiring harness and two cannon plugs remained but were not locked.
- SYS157 was the back portion of the Window Heat panel. Three of the four switches were present, and both cannon plugs were attached to the approximately 3’ of structure.
- SYS201 was a single rotary switch from the Equipment Cooling panel. All of the faceplate was missing, and all five lights were missing. The rotary dial appeared to be in the vertical/AUTO position.
- SYS246 was the Main Cargo Alert panel. The right-hand switch remained but the switch guard and most of the faceplate was missing. The alert switch was missing. The frame remained with two stanchions noted. The only cannon plug was attached with 18” wire connected.
- SYS344 was the Cargo Heat Control Panel. Two of the three switches remained but the FWD switch was missing. The AFT and BULK switches indicated ON. The cannon plug was noted but no wire was attached.
- SYS347 was the Fuel Control Panel. The panel matched with SYS135. The entire frame was present, but it was crushed and with no faceplate noted.

- SYS111 and SYS295 were audio speakers and SYS115 was a light.

4.0 Landing Gear

The airplane was fitted with a nose gear and two main landing gears. All three landing gears were recovered and documented as follows:

4.1 Left Main Landing Gear (SYS362)

- The entire shock strut housing was noted with only recovery equipment damage on surface.
- The upper trunnion area was intact with pivot points present (plating torn off rear pivot, which exposed the entire brass core). The small airframe side bracket was attached to this trunnion area in two places.
- The retract strut actuator rod end was attached at the upper trunnion arm.
- One upper side brace was present but fractured at the uplink connection point. The other upper side brace was missing at the strut housing. The lock actuator piston (but none of the housing) was attached to the brace.
- The entire down lock/lower drag brace was present. The upper portion of the drag brace stayed attached to the airframe wheel well structure, which was torn out above the main pivot point for the down lock brace.
- The down lock link was completely missing and none of the springs were present.
- The shock strut was at a full extended position with the oleo piston exposed.
- The torque links were complete and connected with all hardware noted.
- Two of the four wheels were present with one deflated tire attached to aft inboard wheel.
- The rear brake assemblies and axles were connected.
- The front to rear truck connection/axle was complete but with hairline fractures radiating back from the front truck position.
- Both front wheels, brake and axle assemblies were missing.
- Portions of all four brake rods were present (two complete but bent; two split forward of the connection point in a similar area). The complete rods were held in place with a bungee cord from the recovery operations.
- The truck positioner was attached at the rear truck; the housing was fractured at the oleo strut attachment; the piston was bent. One hydraulic line was attached.
- Two hydraulic lines were attached to the anti-skid unit at the rear outboard brake assembly; the anti-skid unit was detached but held near assembly with wheel brake housing material.

4.2 Right Main Landing Gear (SYS361)

- The entire shock strut housing was present. There was one large split/crack at the bottom portion.
- The upper trunnion area was intact with pivot points present.

- A small portion of the retract strut actuator piston and rod end was attached at the upper trunnion arm.
- One upper side brace was present but fractured about 8” from the uplink lock actuator. The other upper side brace was missing at the strut housing. The lock actuator piston was attached to the brace.
- The down lock/lower drag brace was noted. The upper portion of the drag brace was fractured approximately 11” down the link from the fuse pin.
- The down lock link was fractured at the mid-span position.
- Two uncoiled downlock springs were present.
- The shock strut was at a full, collapsed position with none of the piston exposed.
- The torque link was broken at the strut housing side but attached to wheel truck.
- Two of the four wheels were present. One deflated tire was attached to the aft inboard wheel.
- The rear brake assemblies and axles were connected. One hydraulic brake line was attached.
- The front to rear truck connection/axle was perpendicularly split approximately 12” aft of the front truck axle.
- Both of the front wheels, brake and axle assemblies were missing.
- Three of the four brake rods were noted, but all were damaged.
- The truck positioner was attached at the rear truck. The housing was fractured at oleo strut attachment. One hydraulic line was attached.

4.3 <u>Nose Landing Gear (SYS360)</u>

- The component consisted of the nose landing gear actuator support beam, upper drag strut, and one retract actuator.
- The upper drag strut pivot points appeared intact on both sides.
- The lower portion of the upper drag strut was broken at the pivot joint, with a portion of the lower drag still present on other side. A small portion of the damaged forward lock link was attached at this pivot point. Some cracking damage was visible in this area.
- The upper support beam was still attached at the pivot point of the upper drag strut, with the attaching hardware present.
- The upper portion of the actuator was damaged at the attachment spindle area (support beam side) but was still in its normal position, with the attachment hardware noted.
- One hydraulic line was still attached to the actuator.
- The lower rod end of the actuator at the piston end was detached, and the brass bearing was frozen approximately 180 degrees out of its normal position.

5.0 Navigation

The airplane was equipped with both analog-display and electronic flight instruments. On both the captain’s (left) and first officer’s (right) side, the primary flight instruments included both traditional, (round) dial/indicator pneumatic instruments and electronic cathode ray tube (CRT) electronic flight instruments. See Figure 16.

Figure 16 - The First Officer's Flight Instrument Panels. Note: this photograph was taken during the airplane’s freighter conversion in 2017.

The analog-display instruments included:

- Airspeed/Mach indication
- Altimeter
- Vertical speed
- Radio/Magnetic Instrument
- Clock

The electronic flight instruments included:

- Horizontal Situation Indicator;
- Attitude Director Indicator (including airspeed indication and flight mode annunciation);
- Integrated Standby Flight Display

In addition to the EFIS system instruments, the airplane’s two engine indicating and crew alerting system (EICAS) displays were located between the two flight crewmembers, arranged vertically.

For both pneumatic and electronic, the instrument source select switches were located on the P1 (Captain’s) and P3 (First Officer’s) panels. The panels are on the outside of the respective forward flight deck panels. The instrument source select switches provided captain/FO selection of alternate data sources in the event of failure of the main data source. See Figure 17.

Figure 17 - The First Officer's Instrument Source Select Switch Panel, inside white box. Note: this photograph was taken during the airplane’s freighter conversion in 2017.

The source select switch panels contain three push-button switches – the electronic flight instrument (EFI), Inertial Reference System (IRS), and Air Data switches – below two dial selection switches for the Flight Director and Navigation source. Each of the push-button switches were two-position (in/out) push-button switches. For each switch, the “out” position is considered the normal position, while depressing the switch places the system into the “Alternate” source selection; this action lights the “ALTN” portion of the switch.

5.1 Analog Display Instruments

5.1.1 Description of Instruments

The airplane's altitude and airspeed were displayed on air data instruments based on the atmosphere outside the airplane. The instruments were classified as either electric or pneumatic displays. The pneumatic displays receive their information from the airplane's pitot and static system via the air data computers (ADC), while the electric displays receive their information from other avionic units utilizing data buses.

5.1.2 Air Data System Instrument Source Select Switch

The air data system instrument source select switch provides the source of the displayed information for the respective position's Mach/airspeed indicator, primary altimeter, and standby airspeed indicator.

For the air data system select switch, the normal position is "blank" position. For the captain, that means air data is taken from the left air data computer (ADC), while, for the first office, the right air data computer is the normal position. The alternate (ALTN) position is the opposite – captain information from the right ADC and left ADC for the first officer.

5.1.3 Other Analog Display Instruments

The other analog instruments included the vertical speed indicator (VSI), radio/magnetic instrument (RMI) and clock. The VSI received its information from the inertial reference system (IRS) and the IRS Source Select switch could be used to select the IRS source.

5.2.0 Electronic Flight Instrument System (EFIS)

5.2.1 Description

The Electronic Flight Instrument System (EFIS) provided the main displays for most of the airplane's navigation systems. The EFIS used two cathode-ray tube (CRT) multi-color displays – the Electronic Horizontal Situation Indicator (EHSI) and the Electronic Attitude Director Indicator (EADI) – on each of the captain's and first officer's displays. The EFIS displayed the following information:

- Pitch, roll, and directional data,
- Map displays and flight path data;
- Weather radar data;
- Radio Altitude and decision height;
- Autopilot mode data;
- Airspeed vertical "tape" on left-side of EADI;
- Input system fault annunciations.

Information displayed on EFIS is produced by three independent symbol generators – Left, Center, and Right. The Left and Right Symbol Generators were dedicated to the corresponding side of the EFIS. If a fault is detected, either display set can be switched to the center symbol generator. See Figure 18 for a schematic of the EFIS.

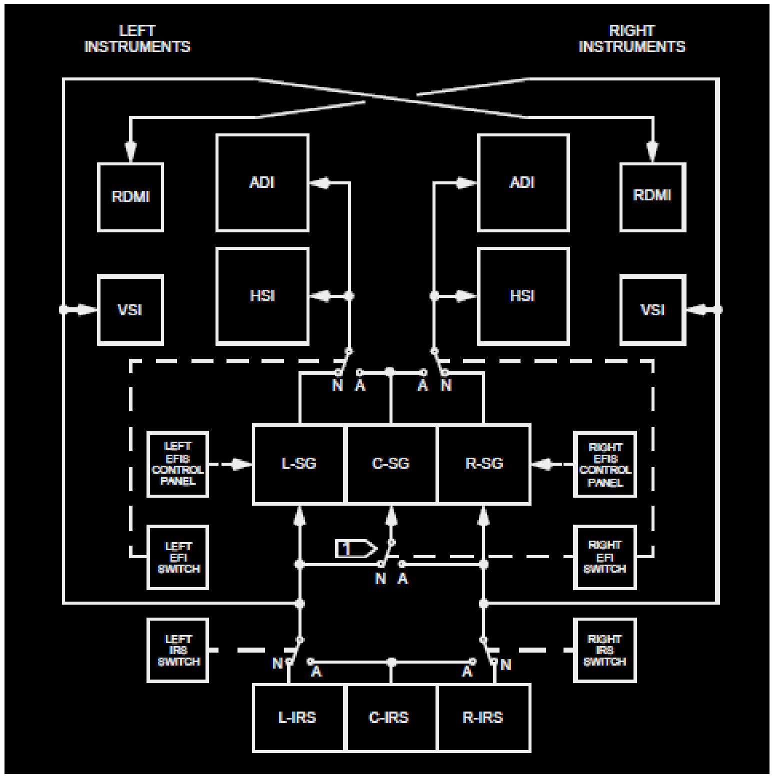


Figure 18 - Schematic of EFIS, including relationship with analog instruments.
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5.2.2 Electronic Flight Instruments (EFI) Switch

The electronic flight instruments (EFI) switch selects the EFIS symbol generator, ILS receiver, and radio altimeter used as the source of information for the respective position's electronic flight instruments - ADI and HSI.

For the normal "blank" position, the source would be that side's symbol generator, ILS receiver, and radio altimeter; for the captain, the left side, and the first officer, the right. For both sides, when the switch is selected to the alternate (ALTN) position, the source was then the center symbol generator, center ILS receiver, and center radio altimeter. If both pilots select the ALTN (center) source on their EFI switch, an EICAS message (INSTR SWITCH) is displayed.

5.2.3 Videos of Instrument Source Select Changes and Failure Indications

Several videos of instrument source select change scenarios were created by the International Brotherhood of Teamsters and the NTSB Operational Factors Group. The videos were recorded in an Atlas sister ship or in the Atlas 767 simulator cab. The videos showed the changes in the EFIS instrument when the EFI and/or IRS source selection switches were operated.

The videos were provided to the investigation team. Collins Aerospace, the manufacturer of the EFIS system, provided a letter dated June 9, 2019, titled "Atlas Air 767 Display Scenarios" and provided insight to the videos, summarized as follows:

1. Video 20190410_135931.mp4, Example of EFI Source Select Switch Use

The video was of the First Officer's EFIS displays and provided a demonstration of the F/O's EFI source select switch use, from the right SG to the center SG and back again.

According to Collins, when the EFI source was switched from Normal to Alternate, power was removed from the right SG and the center SG was powered on. It took approximately two seconds for the center SG to power up, resulting in blank displays on the F/O's EADI and EHSI. After the two seconds, the F/O's EADI and EHSI were driven by the center SG. The switch took approximately two seconds for the power to be removed from the right SG, the F/O's EADI and EHSI go blank (black), power applied to the center SG, the SG initialized, and the displays return.

Later in the video, the EFI switch was pressed again (which transitioned the source from alternate to normal), which returned the displays to the right SG. When the switch was pressed, the EADI and EHSI blanked, power to the center SG was removed, the right SG was powered and started to initialize, and the displays returned, driven by the right SG.

Collins studied the aircraft wire diagrams and determined the non-selected SG would not be powered when the EFI switch was in normal and the right SG would not be powered when the EFI switch is in ALTN. This resulted in a two-second period where the EFIS displays are blank while the selected SG initialized. Therefore, by cycling the EFI source switch and waiting for the displayed information to return, the flight crew member could "reset" the normal SG selection.

2. Video 20190410_140043.mp4, An example of switching to a Center SG that is not powered

In this video, when the EFI switch was pressed to select the alternate SG, first, both displays blanked as power was removed from the right SG. Then the center SG received power and started to initialize. When the circuit breaker to the center SG was pulled, the displays blanked. The displays remained blank until the EFI switch was returned to the normal position, the right SG received power, initialized, and the information displayed.

3. Video 20190410_141646.mp4 - Operation with the Center IRS Source Failed

The video started with an EFI button switch to the center SG and a failed center IRS. The video first showed the switch to the center SG and showed how the display behaved with a failed center IRS. Since the IRS Select Switch is in the normal position, the center SG showed the IRS data from the right IRS.

The F/O's EFI switch was then pressed again, which set EFI source state back to normal. The right SG was powered and then showed data from the right IRS. No fail flags were observed.

The IRS button was pressed to select the alternate (center) IRS as its source. Since the center IRS had its circuit breaker pulled, fail flags are shown for data that depended on the IRS. The speed tape was shown without fail flags since it is sourced from the air data system via the SG.

The F/O's vertical speed indicator (to the right of the EFIS displays) was blanked and showed a V/S fail flag.

Finally, Collins Aerospace provided a picture of an EADI in a failed condition. The failure condition depicted was a failed airspeed bus source that provided airspeed information to the selected symbol generator. If the failure were due to a failure of the air data system, then the Mach/airspeed indicator would also show a failure flag. See Figure 19.

Figure 19 - EFIS Displays with Airspeed Flagged. The Airspeed Flag is circled in red.

5.3 Terrain Avoidance and Warning System

5.3.1 System Description

The airplane was equipped with a Terrain Avoidance and Warning System (TAWS). For various flight conditions, the TAWS provided aural and visual warnings for airplane proximity to terrain.

According to Atlas, the airplane was equipped with a Honeywell Enhanced Ground Proximity System (EGPWS) unit. In addition, a discrete warning display module was installed on flight deck instrument panel P1.

5.3.2 TAWS Simulation by Honeywell

The airplane's Terrain Avoidance and Warning System (TAWS) unit was not identified during the wreckage recovery efforts.

The flight data recorder (FDR) parameters related to the TAWS did not indicate a recorded evidence of a warning; all of the pertinent EGPWS discrete parameters were in the "OFF" state for the entire accident sequence.

Honeywell was asked to simulate the operation of the EGPWS using the available recorded data – FDR, recorded radar data, and ADS-B information.

In a letter to the NTSB received on September 9, 2019, Honeywell provided the results of their simulation. The letter indicated that:

- A simulation of the airplane's accident profile was accomplished using an EGPWS 965-0976-003-236-236 MK-V in the Honeywell lab in Redmond, Washington.

- Parameters in both files were recorded at approximately 1 Hertz[4]. Data samples between the two source files (provided by NTSB) were synchronized using the time stamp. Data in between recorded frames were linearly interpolated. Data beyond the last recorded frames were linearly extrapolated until the derived radio altitude value became negative.

- Some data parameters, including True Track and Vertical Speed, were derived values provided by NTSB.

- With the limitations as described, the simulation calculated the following alert:

  - Mode 4 "Too Low Terrain" at extrapolated radio altitude = 262 ft (between 18:39:2.313 and 18:39:2.453)

- The Mode 4 alert was triggered at a time after the last recorded FDR radio altitude data point, very close to the ground impact, approximately 500 milliseconds from the last recorded frame in FDR file. Since the triggered alerts occurred after the last recorded radio altitude data, it is probable that the real radio altitude values seen by EGPWS during the accident flight differed

[4] • The EGPWS received these parameters at a higher rate on the actual aircraft installation.

from the extrapolated values and produced a different result (e.g., no alert). It is also possible that the aircraft has impacted ground prior to radio altitude becoming 0 feet.

- The EGPWS Look-Ahead function's terrain envelope was not penetrated.

- The change of radio altitude values near the end of the FDR recording was considered excessive by the EGPWS and flagged for internal reasonableness. The flag caused the EGPWS simulation to disregard the radio altitude data for three seconds. This logic flag, when combined with the EGPWS time guard prior to the first issuance of a Mode 1 (sink rate/pull up) alert envelope penetration, would have delayed the issuance of a Mode 1 alert until after the end of the FDR recording.

6.0 Cargo and Cargo Loading Systems

The cargo restraint system included all bulkheads, latches, locks, 9G nets, rails, and stops in the cargo compartment and belly of the aircraft. The B-767-300BCF main cargo deck floor contained floor lock assemblies designed to provide restraint for ULDs in certain cargo loading configurations.

During the recovery of the airplane from Trinity Bay, parts identified as components of the cargo containers, cargo loading, and securing systems were separated and examined. No evidence of any pre-impact failures was noted. See Figures 20a and 20b.

Figure 20a and b: Examples of the Cargo Loading and Securing System Components, as recovered in the Baytown warehouse.

Items that were identified as cargo (either United States mail or Amazon packages) or personal effects were separated at the warehouse and collected.

Tom Jacky
Aerospace Engineer (Systems)

Attachment 1 – Systems Database of Recovered and Identified Components
Attachment 2 – Boeing Commercial Airplanes Equipment Quality Analysis Report - Examination of Control Stand Thrust Lever Assembly