National Transportation Safety Board
Office of Aviation Safety
Washington, DC 20594

DCA20LA138

SYSTEMS

Group Chair's Factual Report

April 5, 2023

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A. ACCIDENT

Location:	Los Angeles, CA
Date:	August 19, 2020
Time:	04:47 PDT
	11:47 UTC
Airplane:	Boeing 767-300F, N146FE

B. SYSTEMS GROUP

Group Chair	Adam Huray National Transportation Safety Board Washington, DC
Group Member	Dave Keenan Federal Aviation Administration Washington, DC
Group Member	Scott Reeves FedEx Memphis, TN
Group Member	John Miller Boeing Everett, WA
Group Member	Ian Carrero Air Line Pilots Association, International Memphis, TN

C. SUMMARY

On August 19, 2020, about 4:47 AM Pacific daylight time, FedEx flight 1026, a Boeing 767-300F, N146FE, landed after the left main landing gear failed to extend at Los Angeles International Airport (KLAX), Los Angeles, California. The airplane received substantial damage. The first officer received a serious injury while exiting the airplane using the cockpit emergency escape rope. The flight was operating under Title 14 CFR Part 121 as a domestic cargo flight from Newark International Airport (KEWR), Newark, New Jersey, to KLAX.

D. DETAILS OF THE INVESTIGATION

D.1 System Description

The aircraft is equipped with a left and right main landing gear assembly and a nose landing gear assembly. Each main landing gear assembly consists of four wheels, with each wheel having an independent brake (see Figure 1). The main gear extension and retraction system includes door-operated and gear-operated sequence valves, door and latch actuators, transfer cylinders, truck positioners, and drag and side brace lock actuators. Moving the landing gear control lever in the cockpit to the DN or UP position provides center hydraulic system pressure to extend and retract the gear.

An alternate extension system is available to unlock the landing gear and doors when the normal extension system does not. By design, the main landing gear rests on the closed main landing gear doors when the gear is up. The alternate extend system simultaneously releases the left and right main gear doors and the nose gear, allowing all three gears to free fall to the down-and-locked position. If any gear is jammed in the retracted position, the other gears can still be extended.

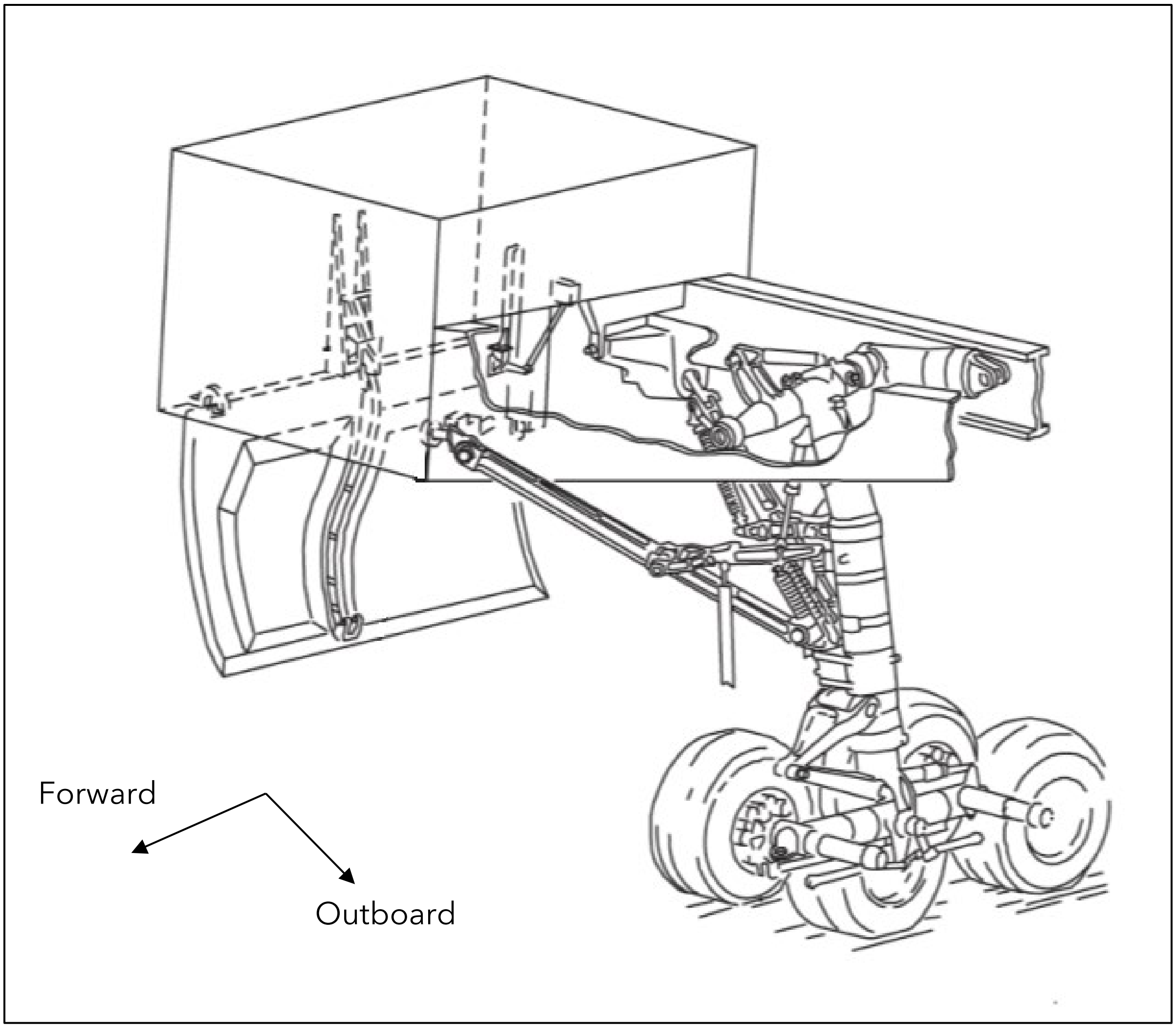

Figure 1. Aircraft Maintenance Manual schematic showing the left main landing gear. Copyright © Boeing. Reproduced with permission. Note: schematic has been altered for clarity from original source.

A single brake rod is installed between each brake assembly housing and the shock strut (see Figure 2). The purpose of this brake rod is to transfer the torque generated by the brake to the main gear. The brake rod is connected to the torque arm on the brake assembly housing using a pin, tang washer, retaining bolt, and two lock screws secured by safety wire as attaching hardware (see Figure 3). For the main gear inboard brake rod pin positions, the head of the pins will be in the down direction when the gear is in the up (stowed) position, which could allow the pins to fall out if the retaining bolt and lock screws were not engaged.

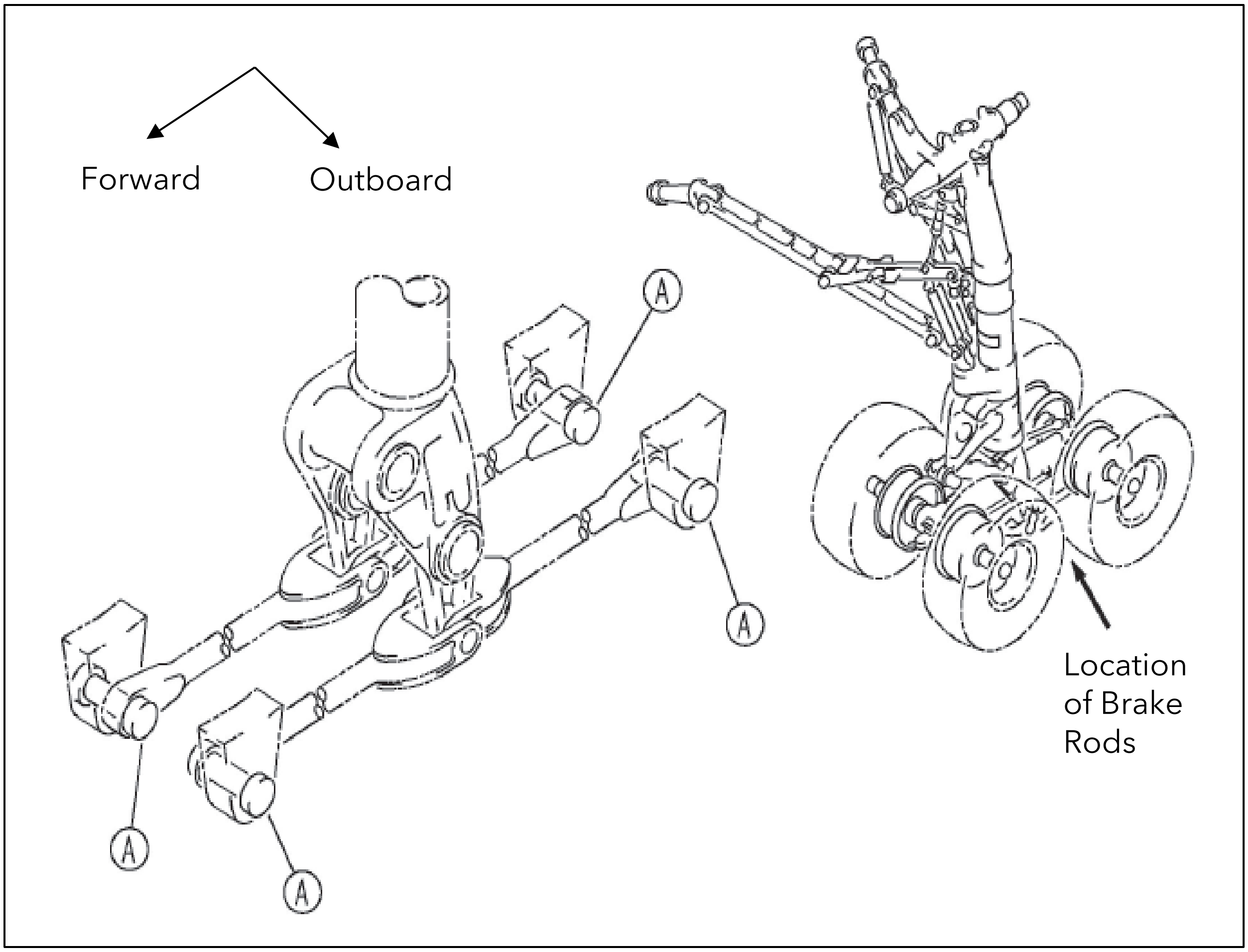

Figure 2. Aircraft Maintenance Manual schematic showing brake rods. The lines labeled "A" point to brake rod attaching hardware at the four brake assemblies on the left main landing gear assembly. Copyright © Boeing. Reproduced with permission. Note: schematic has been altered for clarity from original source.

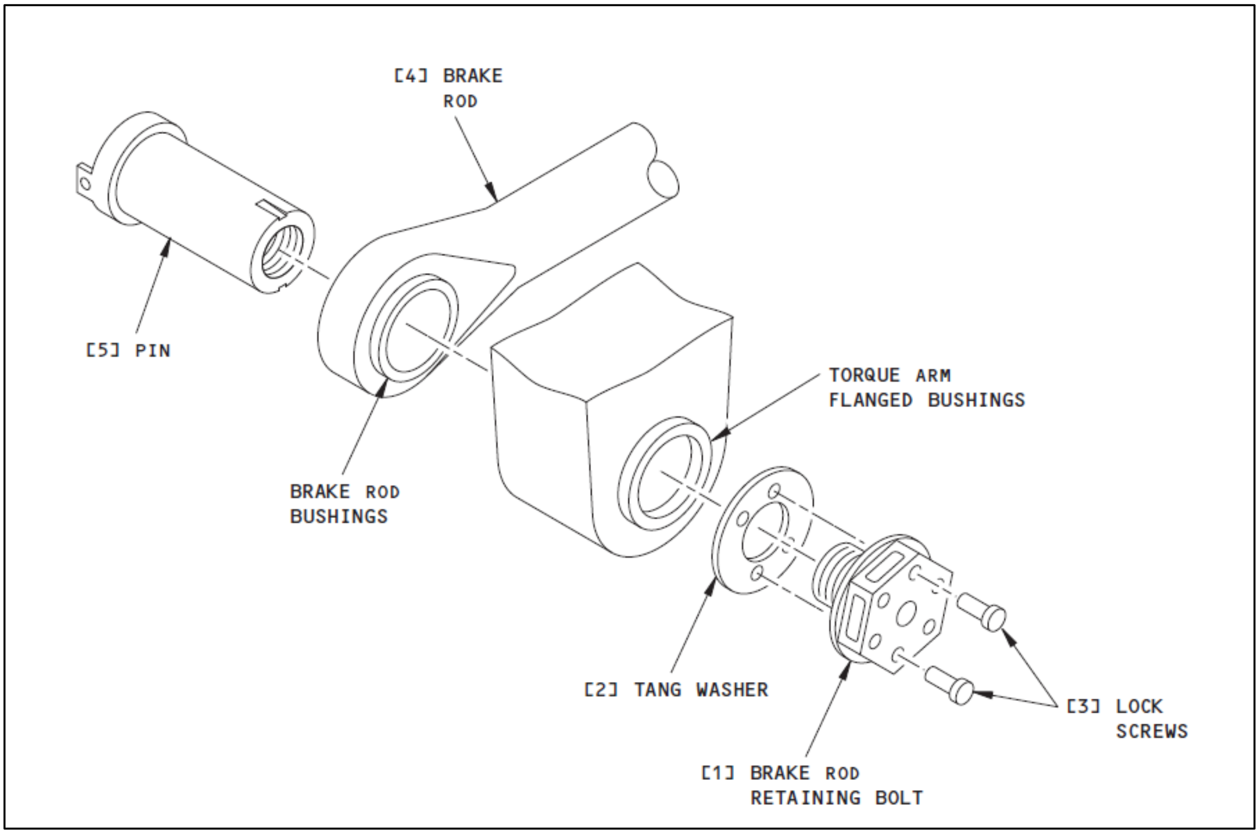

Figure 3. Aircraft Maintenance Manual schematic showing the brake rod attaching hardware at the brake assembly (see Figure 2, callout "A"). Copyright © Boeing. Reproduced with permission. Note: schematic has been altered for clarity from original source.

D.2 On-Scene Examination and Testing

The NTSB did not travel to the accident scene. The on-scene description in this section comes from FedEx, Boeing, and the FAA who were present at various stages of the aircraft recovery and testing efforts. Due to the circumstances of the accident, only the main landing gear and brake assemblies were examined by the Systems group.

Initial inspection found that the left main landing gear door was open, but the landing gear did not deploy. The aircraft was found resting on the left engine nacelle and the right main landing gear, while the nose gear and tail were suspended in the air (see Figure 4). The left engine cowling and left main landing gear door were damaged due to contact with the runway during the landing, and later aircraft examination revealed deformation of the left engine pylon structure such that several structural clearances were out of tolerance. Some cracking on the left engine pylon structure was also identified.

Figure 4. Airplane condition after accident landing. Courtesy of Boeing.

The left side of the aircraft was lifted using airbags. Inspection of the left main landing gear assembly revealed that the #6 brake rod (corresponding to the aft inboard wheel position) was not connected to the torque arm on the #6 brake assembly housing and that all attaching hardware was missing. The brake rod, which remained connected to the lugs on the shock strut, was swung out of position and hung up on the landing gear upstop (see Figure 5 and Figure 6). No damage was found to the brake assembly or associated hydraulic line.

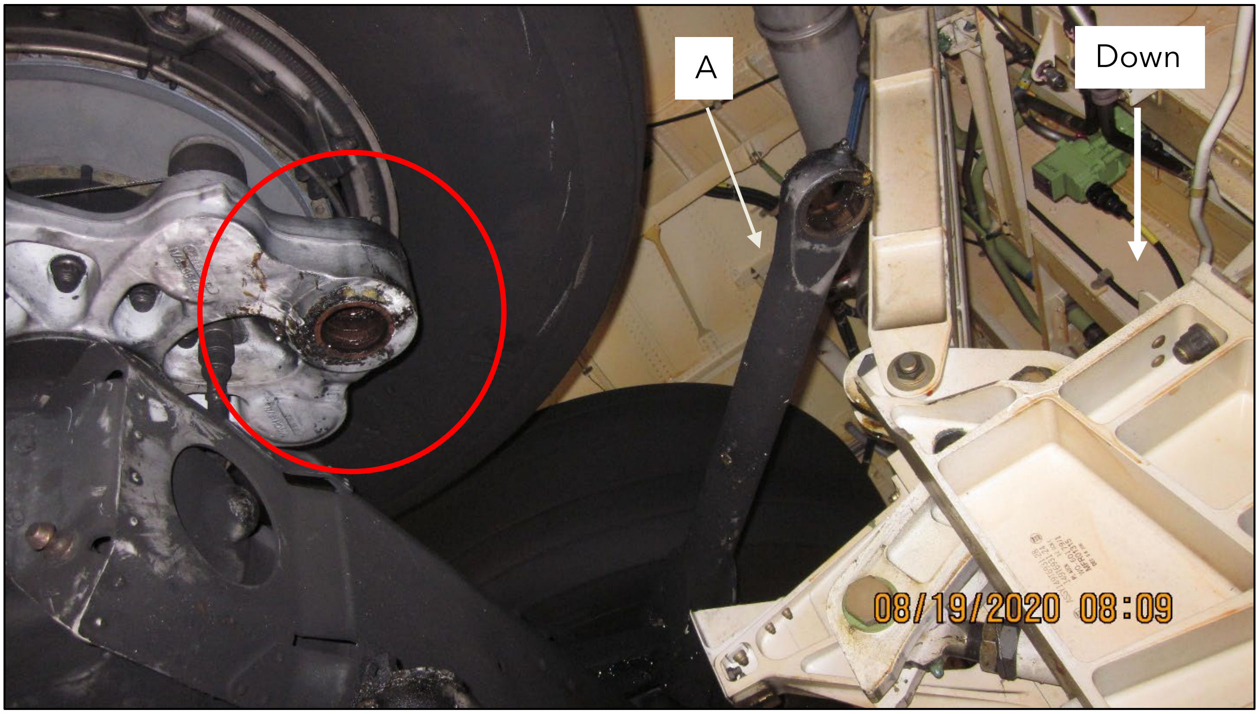

Figure 5. Photograph of the landing gear with the brake rod hung up on the landing gear upstop. Arrow "A" points to the brake rod. The red circle highlights the location where the brake rod should have been secured by the attaching hardware detailed in Figure 3. Courtesy of FedEx.

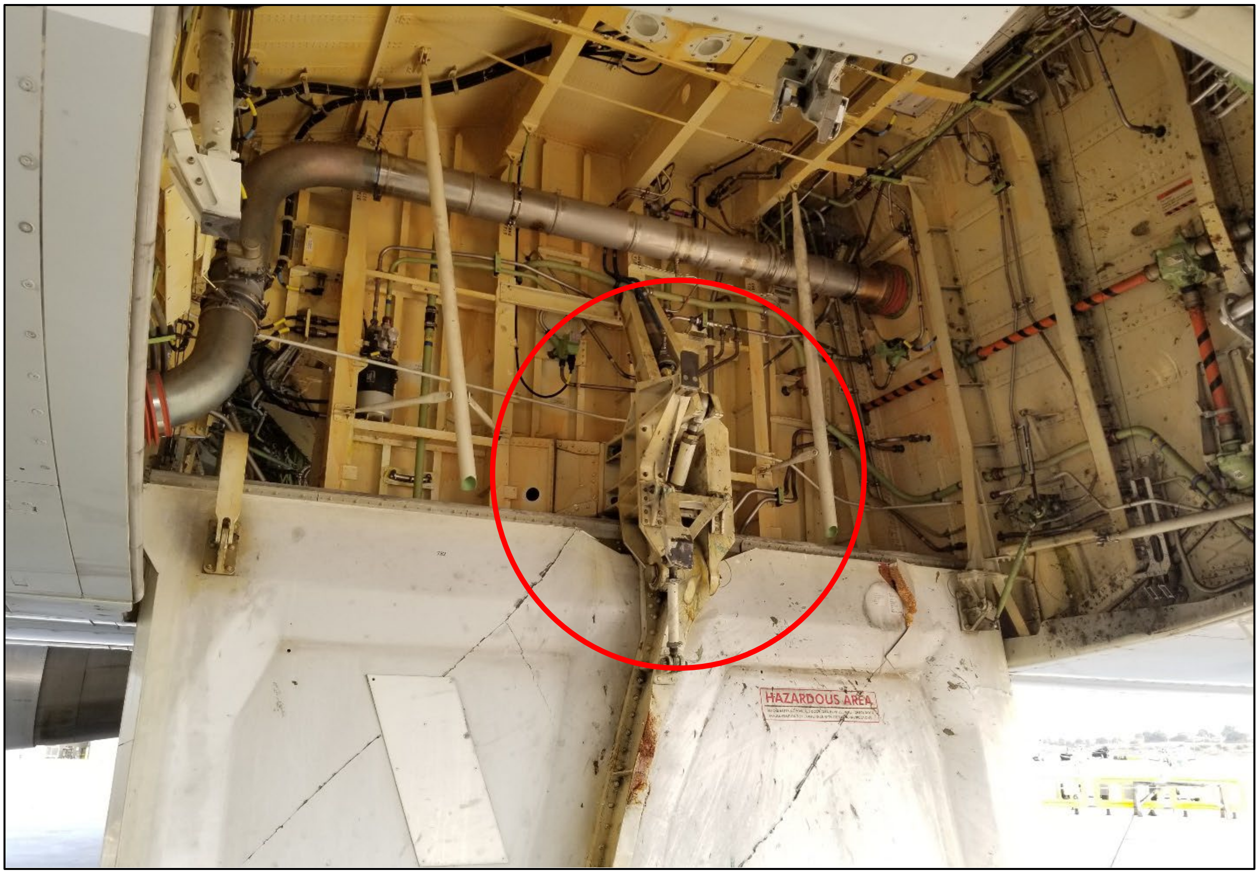

Figure 6. View of the left landing gear bay after the left main landing gear was extended. The landing gear upstop is circled in red. Courtesy of Boeing.

KLAX Airport Operations performed a search of the landing runway, and KEWR Airport Operations performed a search of the departure runway and adjacent areas. No components of the brake rod attaching hardware were found.

The damaged left main landing gear door was locked out and the brake rod was secured to the brake assembly housing torque lug. Normal gear extensions/retractions were performed per the 767 Aircraft Maintenance Manual (AMM) section 32-32-00 (Revision Apr 22/2020) and alternate gear extensions were performed per AMM section 32-35-00 (Revision Apr 22/2018). No anomalies were identified during these tests.

The hardware installation at the other seven brake rod attach points on the aircraft were inspected with no anomalies found. The #6 brake rod and the seven remaining brake pin assemblies were removed from the aircraft for further examination (see Section D.3 Laboratory Examinations).

FedEx stated that the only circuit breakers found open during the aircraft examination were for the Flight Data Recorder (FDR) and Cockpit Voice Recorder

(CVR). These breakers were pulled during the FDR and CVR removal following the accident.

D.3 Laboratory Examinations

The #6 brake rod and seven brake pin assemblies that were removed from the brake assembly housing torque arm ends of the other seven brake rod locations on the aircraft were submitted to the Boeing Equipment Quality Analysis Laboratory for examination. Each brake rod pin assembly consisted of a pin (P/N 161T1019-1), a tang washer (P/N 161T1021-1), a retaining bolt (P/N 161T1020-1), and two lock screws (P/N BACS12HN3U10D). The purpose for the examination of the brake rod pin assemblies was to inspect for defects that may be representative of an airplane specific problem or a hardware manufacturing lot problem.

D.3.1 #6 Brake Rod Assembly

A visual inspection of the #6 brake rod (P/N 161T1136-17, S/N RD0131) was performed. The only observed damage were shallow gouges and chipped paint on the forked end consistent with where the brake rod was contacting and hung up on the landing gear upstop during the accident sequence (see Figure 7). There were no scrape marks or gouging that indicated that the brake rod had made contact with the runway during a previous takeoff or landing. Precision measurements of the brake rod fork end bores and rod end bore were captured using a calibrated SmartScope Quest 450, with all measurements found to be within drawing limits.

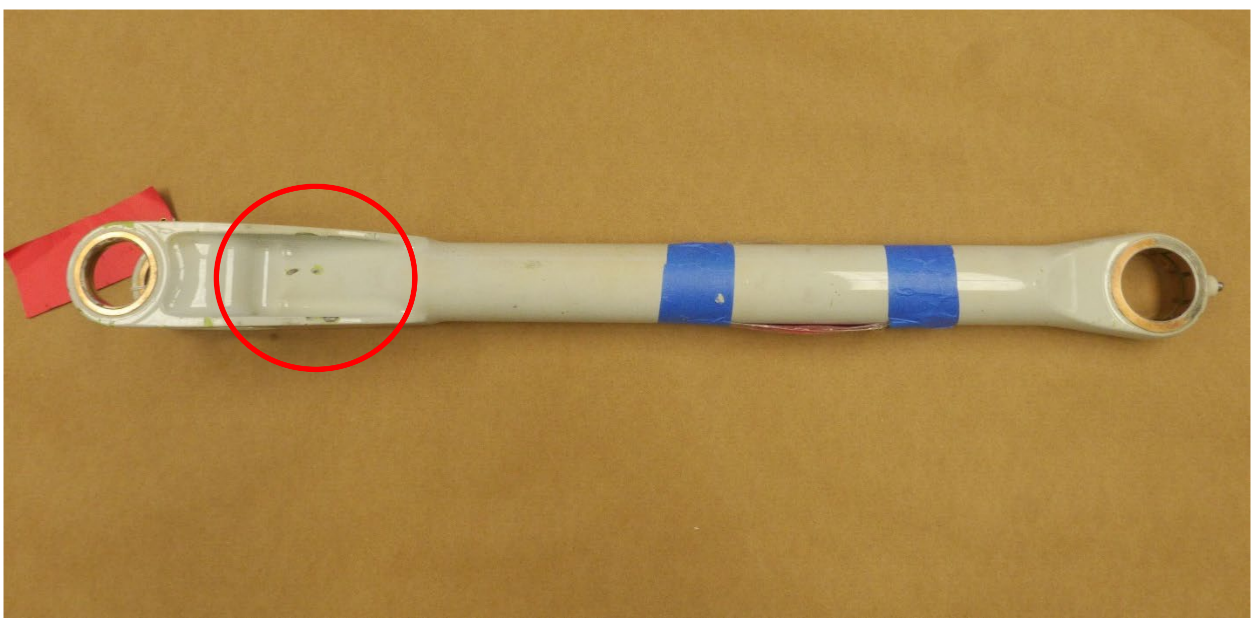

Figure 7. #6 brake rod as received at the Boeing Equipment Quality Analysis Laboratory. The red circle highlights the damage consistent with contact with the landing gear upstop. Courtesy of Boeing.

D.3.2 Brake Rod Pin Assemblies

A general visual inspection of the 7 brake rod pins and all attaching hardware (tang washer, bolt, and screws) was performed with no cracks, corrosion, or other concerning anomalies identified.

Fluorescent penetrant inspection was performed on all 7 brake rod pins, with the #4 brake rod pin showing a small, rounded surface indication and the #5 brake rod pin showing a small scoring indication. Magnetic particle inspection was performed on all 7 brake rod pins, with only the #4 brake rod pin showing an anomaly. This anomaly was the same small, rounded surface indication discovered during the fluorescent penetrant inspection. Wide field photography was used to further look at the indications identified on the #4 and #5 brake rod pins (see Figures 8 and 9, respectively). The damage on the #4 brake rod pin was consistent with mechanical damage. The damage on the #5 brake rod pin appeared as localized minor surface roughness with some small scratches in the surface plating. In both cases, the indications did not cause significant distress in the chrome plating and were consistent with minor handling damage. Precision measurements of brake rod pin #4 and brake rod pin #5 were captured using a calibrated SmartScope Quest 450 with all measurements found to be within drawing limits.

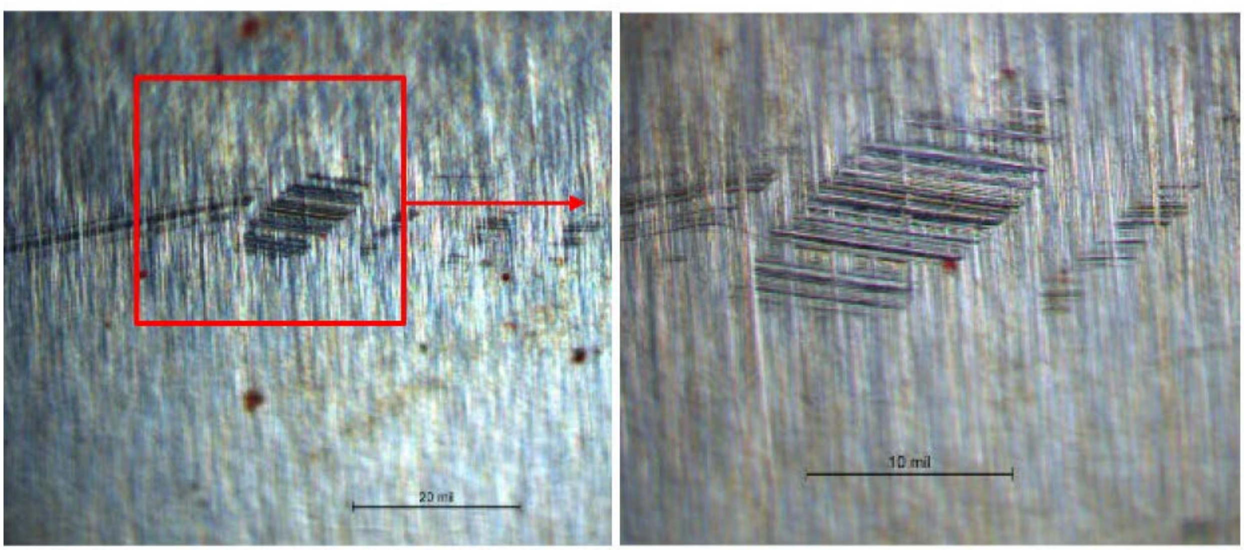

Figure 8. Wide field image showing the indications from brake rod pin #4. The indication is within the red box in the left picture and is shown at greater magnification in the right picture. Courtesy of Boeing.

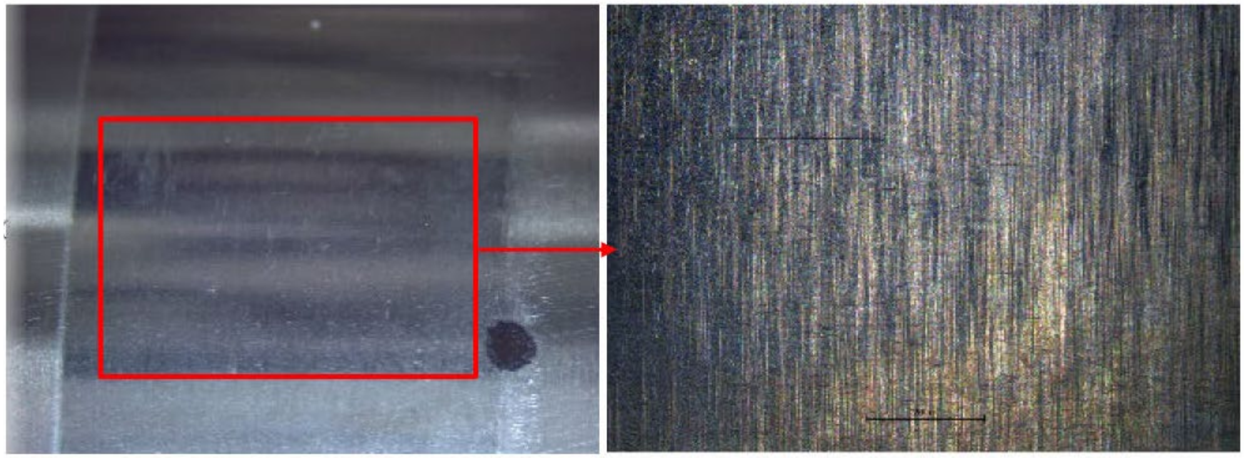

Figure 9. Wide field image showing the indications from brake rod pin #5. The indication is within the red box in the left picture and is shown at greater magnification in the right picture. Courtesy of Boeing.

The #4 and #5 brake rod pins and their attaching hardware (tang washer, bolt, and screws) were sectioned and mounted for further evaluation. All sectioned parts demonstrated microstructures consistent with heat treating as called out in the respective drawings. Micro-hardness testing on all sectioned parts revealed that they were within their respective drawing hardness limits except for brake pin #5 which had an average Rockwell C (RC) hardness reading of 55.6 after 10 readings were taken (drawing requirement is 52-55 RC). There were no anomalies identified with the pin to suggest that the material properties associated with the slightly elevated hardness reading had any negative effect on the pin in this application.

Primer and topcoat samples were taken from various components to verify that the appropriate materials were used. The primer and topcoat for components in this assembly are Boeing Material Specification (BMS) 10-11 primer and BMS 10-60 topcoat. Fourier transform infrared (FTIR) spectroscopy was performed to identify the chemical bonding of the coating. Energy dispersive X-ray spectroscopy (EDS) was used to identify the chemical compositions of the coatings. FTIR and EDS indicated that the coatings were consistent with BMS 10-11 primer and BMS 10-60 topcoat.

The grease and corrosion inhibiting compounds were also evaluated. The requirements on the engineering drawing were for the grease to be Royco 11-MS and the corrosion inhibiting compound to be MIL-C-11796 Class 1. The testing found the grease to be consistent with BMS 3-33 and the corrosion inhibiting compound to be consistent with BMS 3-38. AMM 32-11-20 does allow for the use of BMS 3-38. BMS 3-33 is used frequently in that area but is not used for that specific location. While BMS 3-33 was not the specified grease, there was no significant damage identified to the chrome plate on the pins.

The #4 and #5 pins, #4 and #5 retaining bolts, and #4 and #5 washers were sent out for optical emissions spectroscopy for chemical analysis. The pins met the drawing requirements of Aermet 100 (Aerospace Material Specification (AMS) 6532), the retaining bolts met the drawing requirements of 4330M (BMS 7-122), and the tang washer material met the drawing requirements of 15-5 (BMS 7-240). The remnant pieces of the retaining screws did not allow for enough material for optical emission spectroscopy. Chemical analysis was performed by EDS. The screw material was consistent with the drawing requirements of A286 (AMS 5737).

Surfaces of the pins and retaining bolts were evaluated metallographically to ensure coatings were applied correctly. The surfaces evaluated were representative samples of the coatings on the part. The chrome plating thickness on the shaft of pins 4 and 5 met drawing requirements.

The Cadmium-Titanium plating and primer application in the key-way of pin #4 and pin #5 was evaluated. The drawing requirement was 0.0005″ to 0.0007″ of Cadmium-Titanium (Cd-Ti) plating (with a chromate treatment) and one coat of BMS10-11, Type I primer 0.0003″ to 0.0008″ thick. The key-way for pin #4 and pin #5 was sectioned to identify the coatings and measure their thicknesses. In both cases, the Cd-Ti plating and primer were present in the key-way. For pin #4 the Cd-Ti measured from 0.0005″ to 0.0008″ and the primer measured 0.0009 to 0.0010″. For pin #5 the Cd-Ti measured from 0.0005 to 0.0028″ and the primer measured from 0.0003 to 0.0019″. It should be noted that the Cd-Ti was applied per BAC 5804 which does allow for up to 0.002″ of localized plating due to high current density areas. On both pins there were some observations where in local areas the primer and Cd-Ti exceeded the maximum values. In these areas the coatings were intact and there was no observable corrosion on the parts.

The Cd-Ti plating, BMS 10-11 primer, and BMS 10-60 coating were evaluated on the top of the head of the two pins. The drawing requirement was for Cd-Ti plate (w/chromate treatment), two coats of BMS 10-11 Type I primer and BMS 10-60 Type I enamel. In this region, the thickness requirement for the Cd-Ti plating was 0.0005″ to 0.0008″, the requirement for the two coats of primer was 0.0008″ to 0.0016″, and the topcoat requirement was 0.0014″ to 0.0024″. All coatings were present on both pins in the evaluated section. The coatings on pin #4 were evaluated with the Cd-Ti thickness measured at 0.0002″ to 0.0004″, the primer measured at 0.0019″ to 0.0020″, the topcoat measured at 0.0015″ to 0.0018″. The coatings on pin #5 were evaluated with the Cd-Ti thickness measured at 0.0002″ to 0.0004″, the primer measured at 0.0019″ to 0.0020″, the topcoat measured at 0.0015″ to 0.0018″. On both pins there were some observations where in local areas the primer and Cd-Ti were not within the required values. In these areas the coatings were intact and there was no observable corrosion on the parts.

In addition to the #4 and #5 pins being evaluated for their coatings, the #4 and #5 retaining bolts were also evaluated. The threads of the retaining bolts were evaluated for Cd-Ti. The drawing requirement for Cd-Ti plating on the threads was 0.0005″ to 0.0007″ thick with chromate treatment. The following coating measurements include the Cd-Ti plating, the corrosion inhibitive compounds, and grease that were present. The coatings on the threads of the retaining bolt for the #4 assembly measured approximately 0.0004″ to 0.0008″. The coatings on threads of the retaining bolt for the #5 assembly measured approximately 0.0003″ to 0.0006″. It was also found that the Cd-Ti plating was not continuous and missing in some areas, consistent with mechanical removal due to wear and/or service. The integrity of both retaining bolt threads were intact and there was no visible corrosion.

The inner diameters of the #4 and #5 retaining bolts were evaluated for Cd-Ti and primer. The drawing requirement for this area was Cd-Ti 0.0005″ thick minimum, two coats of BMS 10-11 Ty I primer 0.0008″ to 0.0016″ thick, and MIL-C-11796 corrosion inhibiting compound. Retaining bolt #4 had inconsistent covering of primer, and Cd-Ti could not be visually detected in some areas. The primer thickness measured from 0.0007″ to 0.0019″ in some regions, while other regions had no primer. The Cd-Ti was not easily identifiable on the area with inconsistent primer application. Corrosion inhibiting compounds and grease were adequately applied and there was no visible surface corrosion. Retaining bolt #5 had improved primer coverage and inconsistent Cd-Ti coverage. The primer measured 0.0012″ to 0.0015″. Retaining bolt #5 had sufficient grease and corrosion inhibiting compounds and no visible corrosion was found.

The specified coatings for the top of the retaining bolts were Cd-Ti (0.0005″ thick minimum), two coats BMS 10-11 primer (0.0008″ to 0.0016″), and one coat BMS 10-60 Ty I 707 Gray (0.0014″ to 0.0024″). Retaining bolt #4 had Cd-Ti thickness of 0.0002″ to 0.0004″, in a continuous layer but under the 0.0005″ minimum requirement. The primer thickness measured was 0.0015″ to 0.0016″ and the topcoat measured 0.0014″. Both the primer and topcoat were applied in a uniform continuous manner. Retaining bolt #5 had Cd-Ti thickness of 0.0002″ to 0.0004″, in a continuous layer but under the 0.0005″ minimum requirement. The primer thickness measured was 0.0016″ to 0.0019″ and the topcoat measured 0.0008″ to 0.0012″. Both the primer and topcoat were in a continuous layer. No visible corrosion was identified on either retaining bolt.

The chrome plating on the two retaining bolts were evaluated. The drawing requirement was for 0.0015″ to 0.0020″ of chrome plating. Two areas were evaluated on each retaining bolt. The thickness on both the #4 and #5 retaining bolts measured 0.0014″ to 0.0016″. The chrome plating thickness on the retaining bolts while at certain locations was under the minimum on average met the minimum end of the plating range. No corrosion was identified on either bolt.

D.4 Maintenance History

Airplane: Boeing 767-300F
Registration: N146FE
Serial Number: 43551
Hours: 5,958
Cycles: 2,608
Manufacturing Date: 2017

FedEx reported that the last time the #6 brake rod was removed and replaced was on July 18, 2020 during a #6 brake assembly change, and that 73 cycles had occurred between this maintenance activity and the accident flight. The two maintainers who performed the #6 brake assembly change were interviewed and did not recall anything unusual or concerning about the installation of the #6 brake or #6 brake rod.

A review of the maintenance history between the #6 brake rod change and the accident time, as well as the month prior to the #6 brake rod change, revealed the following maintenance activities related to the #6 brake/brake rod:

June 30, 2020 - Brake temperature light on after landing. # 6 wheel reached a high of 6.[1] Corrective action was to perform inspection with no defects noted.

July 11, 2020 – After landing brake temperature light illuminated with left truck indicating 7 after block-in at gate. Corrective action was to perform inspection with no defects noted.[2]

July 18, 2020 – Two occurrences of #6 high brake temperature were reported. Also, the #6 brake was being monitored for wear. Corrective action was to remove and replace the #6 brake temperature sensor and the #6 main landing gear brake assembly (replacements occurred on July 18-19, 2020).

July 22, 2020 – Brake temperature light after shutdown. Brakes 1,3,4,5,6,7,8 displayed 5. Performed inspection of brakes and tires with no defects noted.

[1] A brake temperature monitoring system indicates the temperature of each main gear brake to the crew. The individual brake temperatures are displayed as values between 0 to 9, corresponding to a temperature range of 105°C to 758°C.
[2] It is unknown which specific brakes were reading high during this discrepancy report.

August 14, 2020 – Ground time succeeds cooling time. Performed brake temperature adjustment test.[3] Checked good per AMM 32-46-00-5.[4]

August 19, 2020 – The #6 main tire starting to show cord.[5] The #6 main tire was removed on August 26, 2020, during the accident investigation process.

FedEx further reported there were no items deferred per the Minimum Equipment List during the accident flight.

The Boeing 767 AMM, Revision 130, dated APR 22/2020, Section 32-11-20, contained the removal and installation procedures for the main gear brake rods used at the time of the last #6 brake rod removal. FedEx uses a customized version of this manual, with version 130.7, dated August 21, 2019, current at the time of the #6 brake rod removal. A group review of both sets of instructions did not reveal any major concerns; however, some minor areas for improvement were identified. On 22-Aug-2021, Boeing released a revision to the AMM that made the following changes:

- Figure 601/32-11-20-990-815-003, View A-A, removed a single lockwire between two screws and now shows two lockwires.
- Step 3.F.(1)(s) now points to the Figure 401 detailing the retaining bolt and the individual lockwire installation.
- Step 3.F.(1)(r) contains a note that visual measurement of the installation may not be accurate and calipers or a go/no-go gauge is recommended.[6]
- Figure 401/32-11-20-990-809-004, Sheet 3, now shows two tangs on the tang washer.
- Step 3.F.(1)(f) and associated Warning adds language to ensure the tang washer has two tangs and both are engaged.
- Step 3.F.(1)(p) now includes torque in both in-lbs and ft-lbs to prevent inadvertent stripping of the lock screws.

Submitted by:

Adam Huray
Aircraft Systems Investigator

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[3] Note this test does not call for removal of the brake rod.
[4] It is unknown which specific brakes were reading high during this discrepancy report.
[5] This writeup occurred before the flight prior to the accident flight. Repetitive tire inspections before every flight were in place and complied with on the accident flight to ensure airworthiness of tire.
[6] Following the accident, FedEx developed a go/no-go gauge to be used in this manual step.