

18 October 2024
66-ZB-H200-ASI-19375

Mr. Brice Banning
Investigator In Charge
National Transportation Safety Board
Office of Aviation Safety
Air Carrier and Space Investigations Division (AS-10)
490 L'Enfant Plaza East, SW
Washington, DC 20594-0003
Via e-mail: brice.banning@ntsb.gov

Subject: Boeing Submission for Delta Air Lines 717-200 N955AT Landing with Nose
Gear Retracted at Charlotte, NC, on June 26, 2023

Reference: E-mail, 19 September 2024, NTSB to Boeing, DCA23FA339 Technical
Review

Dear Mr. Banning,

As requested in the reference e-mail regarding the technical review, please find the attached Boeing submission on the subject accident. Per your request we are sending this electronic version to your attention for distribution within the NTSB.

We would like to thank the NTSB for giving us the opportunity to make this submission. If you have any questions, please don't hesitate to contact us.

Best regards,



Stella Weidner
Director, Product Safety

Enclosure: Boeing Submission to the NTSB for the subject accident





Submission to the
National Transportation Safety Board
for the

**Delta Air Lines 717-200 N955AT
Landing with Nose Gear Retracted
at Charlotte, NC
June 28, 2023**

**The Boeing Company
18 October 2024**



INTRODUCTION

On June 28, 2023, about 0858 eastern daylight time (EDT), Delta Air Lines flight 1092, a Boeing 717-200, sustained substantial damage when the nose landing gear did not extend before landing at Charlotte Douglass International Airport (CLT), Charlotte, North Carolina. The 104 passengers and crew evacuated with no injuries. The flight was operating as a 14 *Code of Federal Regulations* Part 121 scheduled domestic passenger flight from Atlanta, Georgia, to Charlotte, North Carolina.

Submission Abstract

- The Boeing Company, as the airplane's manufacturer, is an invited party to the investigation and provides technical and operational assistance to the National Transportation Safety Board (NTSB) in their investigation.
- The conclusions presented in this submission are based on factual information received from the NTSB, Boeing expertise, the use of analytical tools, and a methodical investigation process.
- The flight crew was unable to extend the nose landing gear prior to landing, via either the normal or alternate landing gear extension methods.
- The airplane landed with the nose landing gear partially extended.
- After the airplane stopped, the passengers and crew evacuated the airplane via the two forward doors and evacuation slides, with no injuries.
- The nose landing gear upper lock link was found completely fractured in two. This had allowed the lower lock link to swing down and contact the nose gear shock strut, which prevented the nose gear from fully extending.
- An NTSB Material Laboratory examination of the upper lock link indicated that the failure initiated at a fatigue crack that originated at a tool mark. The depth of the tool mark exceeded Boeing's acceptable surface finish requirements.
- The event upper lock link was the subject of a 2001 Boeing service bulletin, that included an inspection for tool marks and ensured a correct surface finish.
- As evidenced by the tool mark found at the failure's origin during the NTSB Material Laboratory examination, the 2001 Boeing service bulletin work instructions were not properly followed when the upper lock link was modified at a landing gear overhaul facility in 2009.
- The airplane's systems and structures otherwise performed as expected during the conditions encountered during the accident sequence.



BOEING ASSISTANCE WITH THIS INVESTIGATION

The National Transportation Safety Board (NTSB) is conducting the investigation into this Delta Air Lines 717-200 accident. Assisting the NTSB in their investigation are the Federal Aviation Administration (FAA), Delta Air Lines, Boeing, and other designated parties.

As the manufacturer of the 717-200 airplane, Boeing's specific role in this investigation has been to provide technical information regarding the airplane design, manufacture and operation to assist the NTSB.

Furthermore, the NTSB requested that all parties submit proposed findings to be drawn from the factual information established during the course of the investigation. Boeing has responded to the NTSB request with this document, which:

- Provides an assessment of the factual information and other pertinent data.
- Identifies knowledge gained from the investigation.
- Identifies conclusions and recommendations supported by the knowledge gained from the investigation.

BOEING ASSESSMENT

The Boeing assessment of the accident is based upon the facts as documented in the NTSB's factual reports. These reports are observations of the airplane and accident site, post-accident examination of airplane systems and components, airplane and component maintenance records, flight data recorder (FDR) data, and flight crew statements.



Summary of Flight Crew Statements

The flight crew reported the flight was uneventful until while on approach, at approximately 2000 feet Above Ground Level (AGL), NOSE GEAR UNSAFE was indicated after the landing gear handle was moved to Gear Down. The EFIS Configuration Page was reviewed, and the NOSE GEAR UNSAFE indication was confirmed. A go-around was then performed. Once back in level flight, the flight crew placed the landing gear handle to Gear Down and again NOSE GEAR UNSAFE was indicated. The flight crew performed the Quick Reference Handbook procedure for “Gear Unsafe”¹ and attempted an alternate gear extension without success. Another approach was initiated and after the tower informed the flight crew that the nose landing gear appeared to be retracted, a second go-around was performed at approximately 300 feet AGL. The crew subsequently attempted a second alternate gear extension, without success. The crew then decided to land with the nose gear retracted and the airplane landed on the third approach to runway 36L. The crew reported the touchdown was smooth and the nose held off until around 80kts. The nose touchdown was reported as gentle, and the airplane came to a stop with approximately 3000 feet of runway remaining.

Prior to landing, the crew advised the passengers that the two forward doors would likely be used for evacuation. After the airplane came to a complete stop, both doors were opened by the flight attendants, and their slides deployed. The airplane was evacuated via the two forward doors and there were no injuries.

Flight Data Recorder Information

About 3 seconds after takeoff at 7:40:33 EDT, the landing gear handle position transitioned from gear down to gear up and the nose gear down and locked parameter transitioned from true to false and remained false for the rest of the data.²

The airplane climbed to cruise altitude of about 25,000 ft pressure altitude at about 7:55:46 EDT and about 7 minutes later began its descent.³

At 8:20:13 EDT, during the first approach to Charlotte while at 2,441 ft pressure altitude, the landing gear handle position transitioned to gear down and the nose gear in transit and/or unsafe changed to true.⁴

The airplane descended to a minimum of 1,765 ft pressure altitude at 8:21:19 EDT and then subsequently climbed to about 4,000 ft pressure altitude by 8:22:51 EDT. During the climb, at 8:21:25 EDT, the landing gear handle transitioned to gear up and 4 seconds later the nose gear in transit and/or unsafe changed to false.⁵

At 8:24:05 EDT, about 1 minute after climbing and leveling off at 4,000 ft pressure altitude, the landing gear handle position transitioned back to gear down and the nose gear in transit and/or unsafe changed to true and remained true for the rest of the data.⁶

¹ Delta Air Lines Internal Memo, Delta Flight Safety-NTSB Statement Request, dated 28 June 2023, page 1

² NTSB Flight Data Recorder Specialist’s Factual Report, dated 12 April 2024, page 5

³ NTSB Flight Data Recorder Specialist’s Factual Report, dated 12 April 2024, page 5

⁴ NTSB Flight Data Recorder Specialist’s Factual Report, dated 12 April 2024, page 5

⁵ NTSB Flight Data Recorder Specialist’s Factual Report, dated 12 April 2024, page 5

⁶ NTSB Flight Data Recorder Specialist’s Factual Report, dated 12 April 2024, page 6



About 12.5 minutes later at 8:36:31 EDT, the airplane began its descent from 4,000 ft pressure altitude and at 8:40:48 EDT reached a minimum of 789 ft pressure altitude and then subsequently started to climb and at 8:41:01 EDT, the landing gear handle position transitioned to gear up.⁷

At 8:41:54 EDT, the airplane climbed and leveled to about 4,000 ft pressure altitude, about 3.7 minutes later at 8:45:35 EDT began descending, and at 8:47:09 EDT leveled off to approximately 2,500 ft pressure altitude.⁸

At 8:47:29 EDT, the landing gear handle position changed to gear down and remained gear down for the rest of the data.⁹

At 8:48:46 EDT, the airplane began its final approach and at 8:51:25 EDT, the airplane's left and right main landing gear touched down.¹⁰

At 8:51:36 EDT, the airplane's nose likely touched down, as the pitch reached -3.45 degrees, and the rate of deceleration increased.

The data ended at 8:52:03 EDT.¹¹

⁷ NTSB Flight Data Recorder Specialist's Factual Report, dated 12 April 2024, page 6

⁸ NTSB Flight Data Recorder Specialist's Factual Report, dated 12 April 2024, page 6

⁹ NTSB Flight Data Recorder Specialist's Factual Report, dated 12 April 2024, page 6

¹⁰ NTSB Flight Data Recorder Specialist's Factual Report, dated 12 April 2024, page 6

¹¹ NTSB Flight Data Recorder Specialist's Factual Report, dated 12 April 2024, page 6

Nose Landing Gear Shock Strut and Housing

The nose landing gear shock strut housing attaches to the airplane structure by the cross-arm support, as shown in Figure 1. The nose landing gear strut housing also includes side braces that take vertical and lateral loads from the nose gear. The torque links allow the piston-axle to move in and out of the shock strut cylinder while preventing the piston-axle from turning in the cylinder.¹²

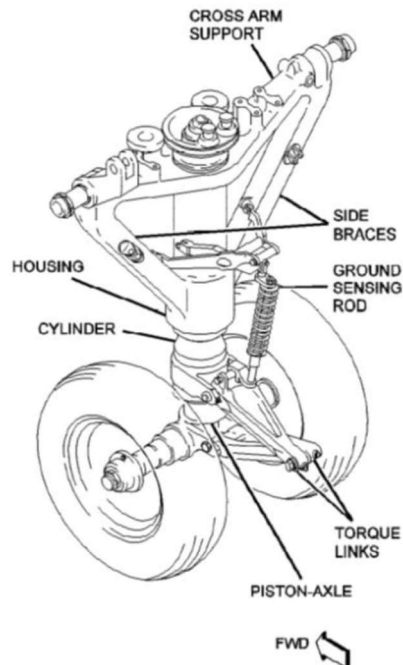


Figure 1 - Nose gear shock strut

¹² NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 4

Nose Landing Gear Braces and Actuation Components

Different braces and attachments attach the nose landing gear to the airplane and hold necessary gear positions, as shown in Figure 2. The upper and lower drag links connect together to take lateral loads from the nose gear. The lower drag link attaches to a fitting on the forward side of the strut housing. The upper drag link attaches to the torque tube. When the landing gear extends, the drag links hold the nose gear fully down and locked. When the landing gear retracts, the drag links fold up with the shock strut and hold the gear fully up and locked. Movement of the drag links turns the torque tube to open and close the forward gear doors.¹³

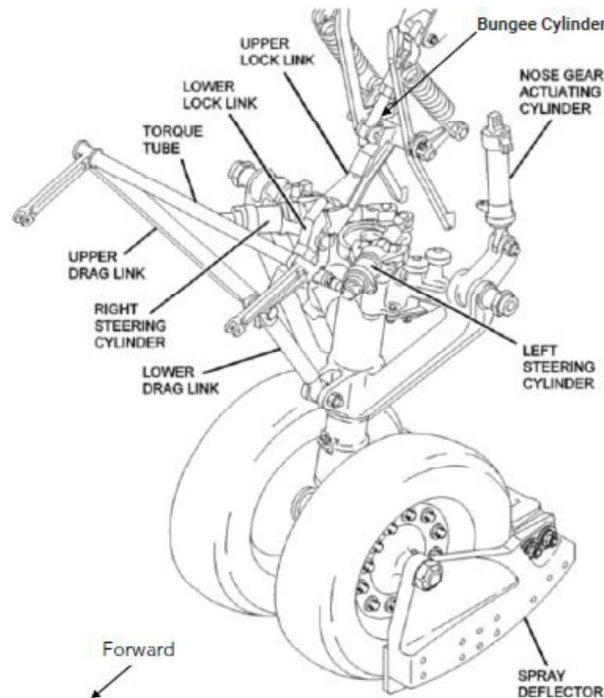


Figure 2 - Nose landing gear with braces and actuation components attached. Note only the right upper drag link is shown. The left upper drag link is identical but connects to the left side of the lower drag link and the left side of the torque tube. Also note that the spray deflector is optional on the 717 airplane.

¹³ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 5

The upper and lower lock links provide a connection between the drag links and the aft bulkhead structural member of the nosewheel well, as shown in Figure 3. The lower lock link connects to the drag links, and the upper lock link connects to the aft bulkhead in the nosewheel well. The lock links move to a mechanical over-center position with the gear fully up and fully down. This operation locks the drag links to hold the nose gear in the extended and retracted positions.¹⁴

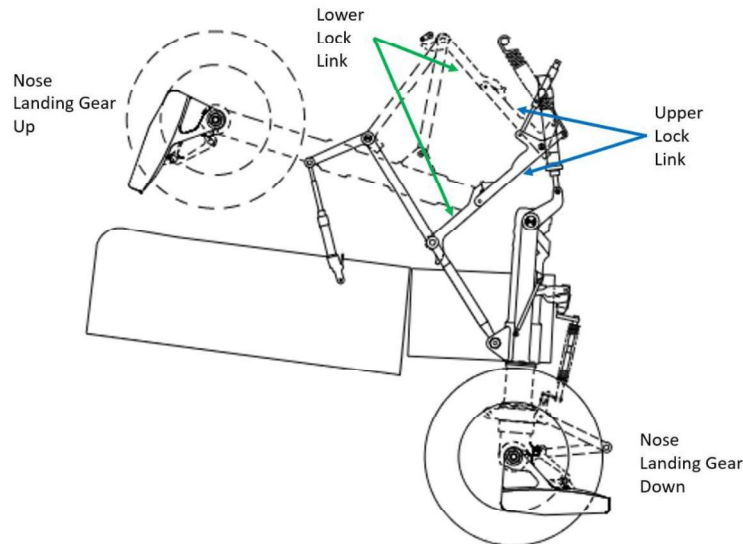


Figure 3 – Upper and Lower Lock Link Positions with Nose Landing Gear Up and Down

Normal Nose Landing Gear Actuation

The nose landing gear moves down and aft, approximately 90 degrees, for full extension. The nose landing gear actuation system uses pressure from the right hydraulic system. The landing gear control lever, located in the flight deck, positions the landing gear control valve, which supplies hydraulic pressure to extend or retract the nose gear. Hydraulic pressure also helps to hold the nose gear fully extended and retracted. Lock links also lock the nose landing gear in the fully up and fully down positions.

For nose gear extend and retract operations, hydraulic pressure goes to the nose gear bungee and retract cylinders. The nose gear bungee cylinder attaches to a fitting on the aft bulkhead in the wheel well and to the upper lock link by a lever. The bungee cylinder applies force to the upper lock link to either move and hold the lock links in a locked position, or to pull the lock links out from a locked position.

The nose landing gear hydraulic retract cylinder (referred to as the nose gear actuating cylinder in Figure 2) connects between the gear strut housing and the wheel well structure. During gear extension, the retract cylinder will retract to move the gear to the down position and will remain pressurized to hold the gear in the down position. If hydraulics are turned off, the actuator may slowly bleed pressure, but the actuator will repressurize when hydraulics are turned back on. During gear retraction, the retract actuator will extend to lift the gear, and will remain pressurized to hold the gear in the up position.

¹⁴ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 6

The nose landing gear forward doors operate mechanically by a linkage that connects to door drive cranks on the upper drag link. The first movement of the nose gear during retract or extend opens the forward gear doors by these mechanical linkages. The same linkages close the forward gear doors as the gear goes fully up or down. The aft doors connect directly to the gear strut by drive rods and are also driven by gear movement.¹⁵

Alternate Nose Landing Gear Extension

The alternate landing gear extension control lever is on the flight deck floor, adjacent to the right side of the control pedestal. The normal position of the lever is down. When the lever is pulled up, a cable system sets the landing gear control valve to bypass hydraulic pressure and moves the nose landing gear alternate uplock release mechanism. The release mechanism cam moves the nose landing gear lower lock link out of its over-center (locked) position and releases the nose gear. The nose landing gear can then extend by free-fall. The nose landing gear doors open and close with the gear movement in the same manner as when the gear is extended normally. After extension, the nose gear mechanically locks in the down position, as the lock links go over-center.

A mechanical latch mechanism holds the alternate landing gear extension control lever up after operation. The bypass position of the landing gear control valve prevents subsequent gear operation by hydraulic pressure. The mechanical latch can be released allowing the lever to be pushed back down.¹⁶

Airplane Recovery

The airplane came to rest on the runway centerline. On June 28, 2023, Delta Air Lines, in coordination with the NTSB via phone and the FAA Charlotte Flight Standards District Office on-scene, recovered the aircraft from the runway to a maintenance ramp.



Figure 4 - Aircraft on runway following the accident landing.¹⁷

¹⁵ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 7

¹⁶ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 7

¹⁷ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 9

On-Airplane Nose Landing Gear Examination

During the effort to recover the airplane from the runway, the nose landing gear upper lock link was found to be fractured in half. The lower half of the fractured lock link was removed, and the airplane was moved off the runway. Subsequently, the main landing gear was locked out with gear pins and the nose of the airplane was placed on a jack. The gear handle was moved to the down position, but the gear only came down slightly (axles approximately in line with the bottom of the fuselage). It was observed that because the upper lock link was fractured, the lower lock link was free to swing down to a vertical position and was contacting the top of the landing gear assembly, preventing the gear from extending.¹⁸

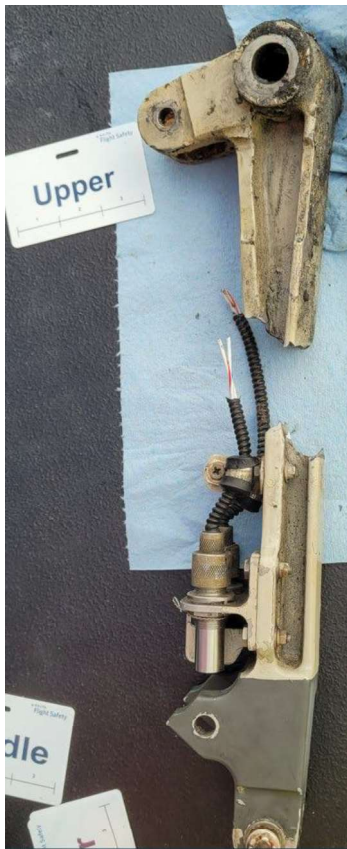


Figure 4 - Fractured upper lock link¹⁹

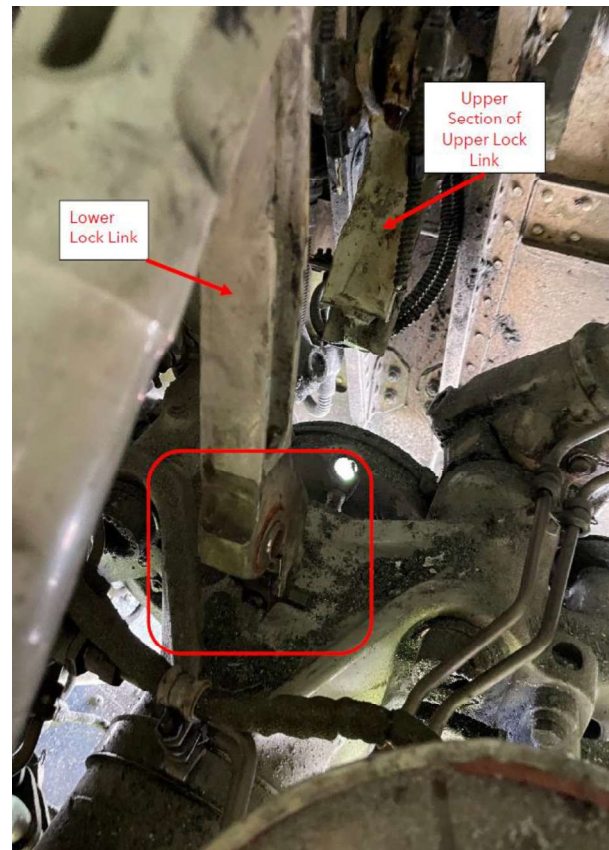


Figure 5 - Lower lock link contacting nose gear assembly in foreground. The upper section of the fully fractured upper lock link is in the background and the lower section had been removed. View looking down and aft.²⁰

Except for the fractured upper lock link, there was no significant damage observed common to the nose landing gear assembly. The bungee springs were intact and attached at both ends. The drag links were connected, and the center joint was free to pivot with hand force. The grease fitting for the right side bearing on the lower drag brace fork end was missing. The bungee cylinder and retract actuators were intact, connected, and there were no indications of

¹⁸ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 13

¹⁹ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 14

²⁰ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 15



hydraulic leaks at the connections. The alternate extension handle was pulled and the release mechanism cam in the nose wheel well was observed to rotate slightly more than 90° down. The wheel well and gear were examined for any indications of a canted nose wheel, and none were identified. This is consistent with the observations that during airplane recovery from the runway the nose gear wheels were found in a straight orientation. The landing gear control valve (located in the right main gear wheel well) was intact, connected, and there were no indications of hydraulic leaks at the connections.²¹

With the aircraft's nose still on a jack, the airplane's auxiliary hydraulic pump was activated. With the landing gear handle in the gear up position, the gear retracted to the full up position. The lower lock link was secured away from the top of the nose landing gear assembly. The landing gear handle was moved to the down position, and the nose landing gear then extended to the full down position. The upper section of the upper lock link was removed, and a new upper lock link was installed, and the original lock link's shims were used to install the new lock link. The gear was then operated up, down, up using the normal gear extension handle. The nose gear and nose gear doors operated with no anomalies observed. The alternate gear extension handle was then pulled, and the nose gear deployed with no anomalies observed. The alternate gear extension handle was stowed, and the nose gear was cycled normally.²²

Aircraft Maintenance Records

The maintenance logbook was found in the aircraft and held log pages dating back to May 28, 2023. Log page 4936513 recorded that MEL deferral 28-22-01 for the forward right boost pump was active. No other MELs/CDLs were recorded as active. A cursory review of the logbook did not identify any other anomalies suspected of contributing to the accident.²³

Safe Life Limit and Part's Record

All Safe Life Limit parts have a limited service life. These parts are serialized, and operators are expected to have a tracking system to account for the number of flight cycles accumulated on these parts.

The 717 nose landing gear upper lock link has a Safe Life Limit of 46,500 landings, which is the mandatory replacement time for this part. Once removed, the lock link is permanently removed from service, regardless of the condition of the lock link.

It is not uncommon for safe life limited landing gear components to transfer among various airplanes. These components are subject to overhaul, and it is common industry practice for an overhauled landing gear assembly or landing gear component to be installed on a different airplane than from what it was removed. The fractured upper lock link had been installed on two other airplanes prior to its installation on the accident airplane.

Delta Air Lines provided to the investigation records of the cycles accumulated on the fractured lock link since its initial delivery. This included records from a previous operator. Based on review of maintenance records, airplane delivery records, and Boeing/McDonnell Douglas Engineering Orders (E.Os) it was determined Upper Lock Link S/N 0007 had accumulated 41,257 FC prior to failure²⁴.

²¹ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 7

²² NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 17

²³ NTSB Systems Group Chair's Factual Report, dated 01 August 2024, page 18

²⁴ NTSB Materials Laboratory Factual Report, dated 21 February 2024, page 6

Upper Lock Link Failure Analysis

The fractured Upper Lock Link was sent to the NTSB Material Laboratory for examination. The following part identification information was observed stamped or vibro-etched on the web of the aft piece:

3914464-509 V
~~3914464-505~~
S/N 0007

The component was fractured at approximately mid-span, between 7.2 and 7.9 inches from the forward lug. The section height of the component was 1.122 inches as measured on the forward piece, just below the point of fracture. A relatively shiny and flat thumbnail shaped region approximately 1.07 inches wide by 0.42 inch deep was observed emanating from the lower surface with visible curved crack arrest (beach) marks, consistent with a progressive fatigue cracking mechanism. Outside of the thumbnail shaped region, the fracture surface was rougher and exhibited a generally matte appearance. Figure 6 shows a view of the lower surface of the part adjacent to the fracture origin area which exhibited evidence of horizontal and vertical scratch features near the fracture surface and under the paint layer.



Figure 6 – Digital microscope images of the fracture origin area and adjacent lower surface on the forward piece.²⁵

²⁵ NTSB Materials Laboratory Factual Report, dated 21 February 2024, page 10

A section cut was performed on the forward piece of the upper lock link approximately 0.6 inch below the fracture surface to facilitate closer examination. Figure 7 shows a digital microscope image of the cleaned fracture surface. The fracture origin area, as marked by a yellow bracket, was observed on the lower surface of the part near a parting line feature. A prominent ratchet mark (tool mark) was observed at the origin area as indicated by the blue arrow. The overall appearance of the fracture surface was consistent with cyclic tensile or bending loads and progressive fatigue fracture from the lower surface with and an overstress dominated fracture mode at final separation. The surface adjacent to the fracture surface near the origin area showed evidence of vertical and horizontal scratch features near the parting line.

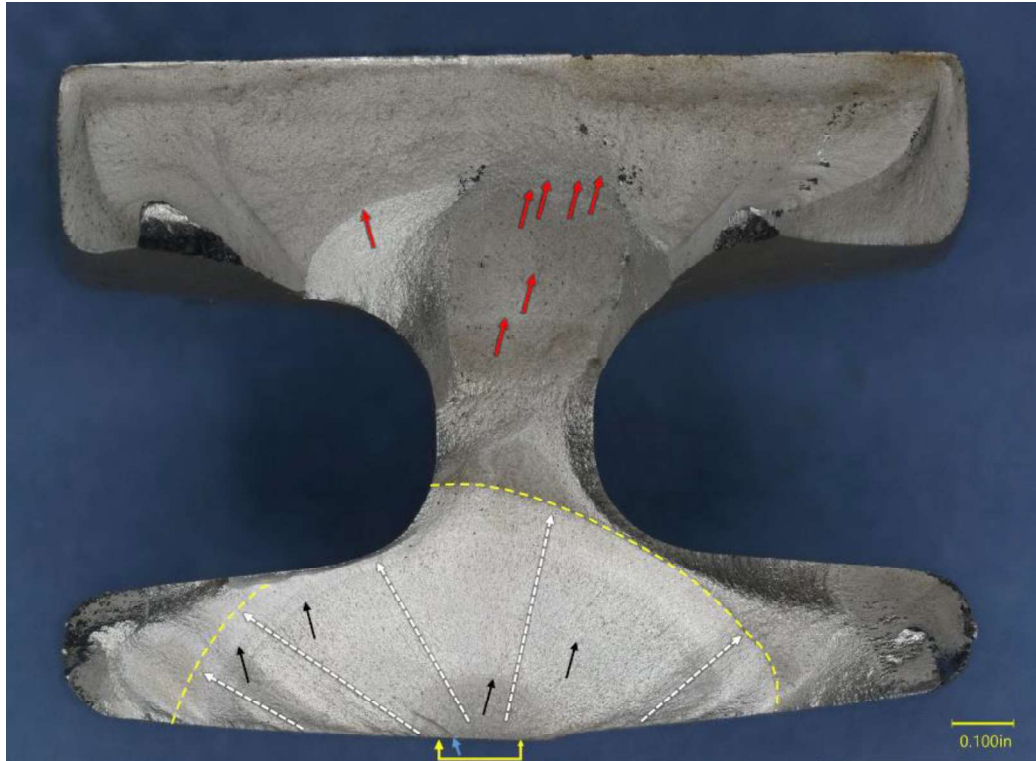


Figure 7 – A digital microscope image of the cleaned fracture surface on the forward piece of the upper lock link. The fracture origin area is indicated by a yellow bracket with progressive crack growth direction indicated by white arrows. A ratchet mark was observed as indicated by the blue arrow.²⁶

²⁶ NTSB Materials Laboratory Factual Report, dated 21 February 2024, page 11

The fracture plane at the origin was oriented parallel to a horizontal scratch feature just below the fracture surface, as indicated by a black arrow in Figure 8. Surface roughness profile measurements were performed longitudinally and transversely along the parting line and the lower surface away from the parting line. Roughness measured over a 0.03-inch sampling length on the lower surface was 59-66 micro-inches compared to 185 – 508 micro-inches on the parting line. Roughness measured over a 0.1-inch sampling length was performed in the longitudinal direction and resulted in values of 86 micro-inches and 347 micro-inches for the lower surface and parting line, respectively.²⁷



Figure 8 - A digital microscope image of the lower surface of the forward lower lock link piece adjacent to the fracture origin area. Visible horizontal and vertical scratches were observed. The fracture plane was oriented parallel to a horizontal scratch as indicated by the black arrow.²⁸

Upper Lock Link In-Service History

In 2000, an MD-80 operator reported an incident where an airplane was unable to extend the nose landing gear during landing. The airplane landed with the nose gear up, which resulted in moderate damage to the nose gear doors, avionics door, and adjacent structure. Following the event, the nose landing gear upper lock link was found completely fractured. Boeing determined that tool marks across the parting plane caused stress concentrations and cracks developed along the lock link's parting plane.

As the 717 upper lock link is similar to the MD-80 upper lock link, Boeing issued Engineering Order (E.O.) 3914464 Rev Z, to inspect 717 upper lock links to ensure their parting planes were free of scratches, nicks, or tool marks, and to verify a 125 micro-inches surface finish. Additionally, the E.O. ensured a minimum section height of 1.045 inches. Upper lock links

²⁷ NTSB Materials Laboratory Factual Report, dated 21 February 2024, pages 3-5

²⁸ [NTSB Materials Laboratory Factual Report, dated 21 February 2024, page 12](#)

that were inspected and/or reworked per the E.O. were reidentified from P/N 3914464-505 to P/N 3914464-509. This E.O was performed on upper lock links prior to delivery.

In 2001, Boeing became aware of information which indicated that E.O. 3914464 Rev Z may have been inadequately performed on 23 upper lock links. As a result, Boeing issued Service Bulletin 717-32-0002 in December 2001, to recommend operators with the 23 suspect upper lock links perform an on-wing eddy current inspection of the nose landing gear upper lock link. If cracks were found by the eddy current inspection, the service bulletin provided two options: (1) remove, modify, re-identify, and re-install the lock link, or (2) remove and replace with a new or modified upper lock link. The service bulletin modification instructions ensured the parting planes were free of scratches, nicks, or tool marks, and verified a 125 micro-inches surface finish. The service bulletin also ensured a minimum section height of 1.045 inches. Upper lock links that were reworked per the service bulletin were marked with a "V" after the part number (i.e. 3914464-509 V).

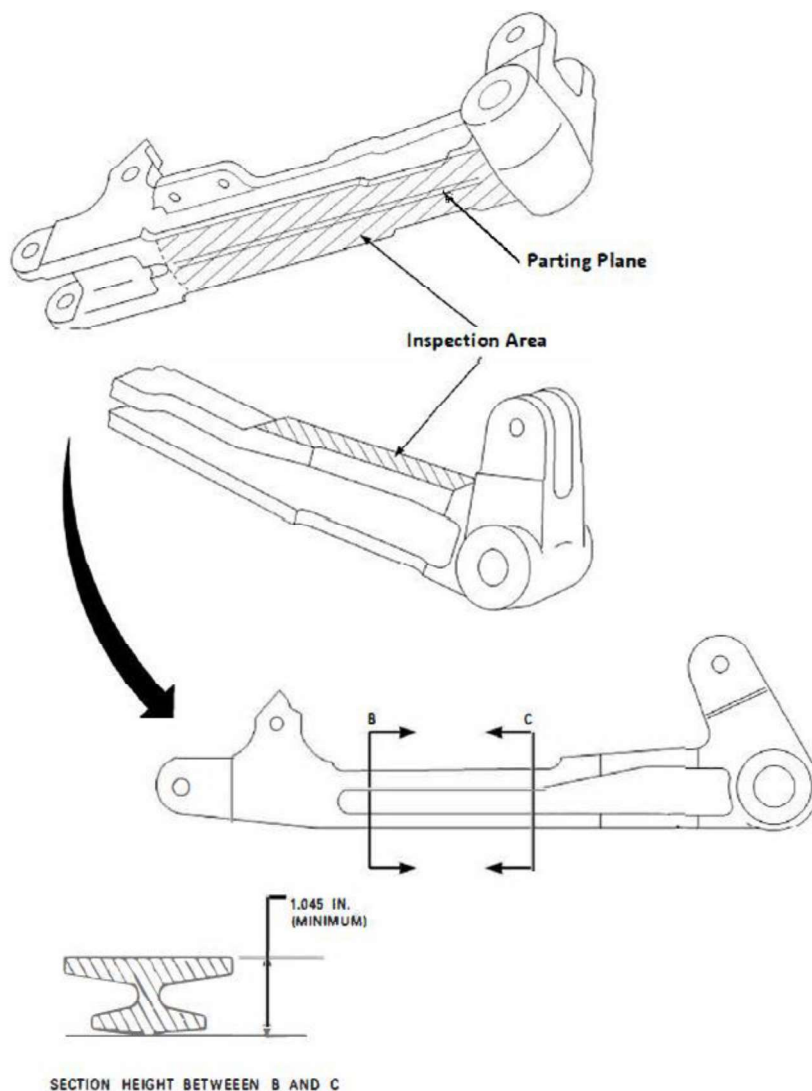


Figure 8 – Service Bulletin 717-32-0002 inspection areas



The upper lock link that was removed following the Delta Air Lines June 2023 accident, S/N 0007, is included in the effectivities of both Boeing Engineering Order 3914464 Rev Z and Boeing Service Bulletin 717-32-0002. A maintenance records review by the investigation determined that in June 2009, the link was removed from the aircraft it was delivered on and Boeing Service Bulletin 717-32-0002 was incorporated at a landing gear overhaul facility. Evidence that both the E.O. and service bulletin were performed are documented by the NTSB Material Laboratory's finding that the upper lock link was identified as:

3914464-509 V
~~3914464-505~~
S/N 0007

Boeing Service Bulletin 717-32-0002 work instructions were not properly followed on upper lock link S/N 0007, as a tool mark was found at the origin of the fracture.



KNOWLEDGE GAINED DURING THE INVESTIGATION (Findings)

- The following knowledge gained is pertinent to drawing conclusions:
- The flight crew was unable to extend the nose landing gear prior to landing, via either the normal or alternate landing gear extension methods.
- The airplane landed with the nose landing gear partially extended.
- After the airplane stopped, the passengers and crew evacuated the airplane via the two forward doors and evacuation slides, with no injuries.
- The nose landing gear upper lock link completely fractured in two, which allowed the lower lock link to contact the nose landing gear shock strut. This prevented the nose landing gear from fully extending.
- The event upper lock link is a Safe Life Limited part and adequate records were retained throughout the part's life. The failure occurred prior to the upper lock link reaching its mandatory removal time.
- Following a 2000 MD-80 nose gear up landing, after an upper lock link failed due to tool marks, Boeing issued an E.O. to inspect 717 upper lock links for tool marks, correct surface finish, and a minimum section height. Reworked upper lock links were reidentified from P/N 3914464-505 to P/N 3914464-509. The event upper lock link was in the effectivity of the Boeing E.O.
- Boeing became aware of information that indicated that the E.O. may have been inadequately performed on 23 upper lock links. Therefore, Boeing issued Service Bulletin 717-32-0002 in 2001 to inspect for cracks in the upper lock link. If a crack was found, the part was to be inspected for tool marks and a correct surface roughness. The part was modified, if necessary and a modified part was to be marked with a "V" after its part number. The event upper lock link was in the effectivity of the Boeing Service Bulletin and a "V" was found marked after the part number on the fractured lock link, S/N 0007.
- The NTSB's Laboratory examination found that the fracture origin area had a tool mark and an unacceptable surface finish on the event fractured lock link, S/N 0007.
- As Boeing Service Bulletin 717-32-0002 had been performed on upper lock link S/N 0007 prior to its fracture, but an unacceptable surface roughness and a tool mark were found at the origin of the fracture, Boeing Service Bulletin 717-32-0002's work instructions had not been properly followed during the 2009 overhaul of this upper lock link.



CONCLUSIONS

Boeing believes that the evidence supports the following conclusions for the accident:

This nose landing gear up landing accident resulted from a failure of the landing gear's upper lock link, P/N 3914464-509V. The failure was due to a fatigue crack that originated at a tool mark, which exceeded the allowable surface roughness for the lock link. When the lock link failed, the lower lock link was free to swing down to a vertical position and contacted the top of the landing gear shock strut, which prevented the gear from extending. The upper lock link was found with a "V" marked after the lock link's part number, indicating Boeing Service Bulletin 717-32-0002 had been incorporated on the failed lock link. This service bulletin recommended inspections for tool marks and verification of correct surface roughness on twenty-three 717 upper lock links. As a tool mark that exceeded the acceptable upper lock link surface roughness was found at the fracture origin of the event lock link's failure, Boeing Service Bulletin 717-32-0002's work instructions had not been properly followed when the service bulletin was incorporated by a landing gear overhaul facility in 2009.



RECOMMENDATIONS

Boeing makes the following recommendations based on the knowledge gained:

- Operators perform the initial and repetitive on-wing inspections for cracks on all in-service 717 nose landing gear upper lock links, per the forthcoming Boeing Alert Service Bulletin 717-32A0043, until the lock links are inspected per the July 2024 revision to the Boeing 717 Overhaul Manual 32-21-2.
- Operators ensure that during overhaul of nose landing gear upper lock links, they are completely striped of paint and the parting plane area surface finish inspected, followed by an inspection for cracks, per the July 2024 revision to Boeing 717 Overhaul Manual 32-21-2.

BOEING ACTIONS

As a result of this investigation, Boeing has:

- Notified the three current operators of 717 airplanes of this accident.
- Provided a recommendation to each of the 717 operators to perform a high frequency eddy current inspection of in-service nose landing gear upper lock links, as well as those in the operator's spares inventory, to inspect for cracks.
- Requested the operators' results of the high frequency eddy current inspections. The fleet inspections were completed in January 2024, with no reported crack findings.
- Revised the Boeing 717 Overhaul Manual 32-21-2, in July 2024, to require that at the next and subsequent overhauls upper lock links be stripped of paint, the parting plane area be fluorescent-penetrant inspected for surface imperfections (scratches, nicks, and toolmarks), and high frequency eddy current inspections be performed on top and bottom sides of the link to check for existing cracks.
- Initiated a new Alert Service Bulletin 717-32A0043, effective for all 717 airplanes, to recommend an on-aircraft initial and repetitive high frequency eddy current inspections on in-service upper lock links. Closing action for Boeing Alert Service Bulletin 717-32A0043 will be the inspection and overhaul of upper lock links, per the July 2024 revision of Boeing Overhaul Manual 32-21-2.