



Aviation Investigation Final Report

Location:	Santa Ana, California	Accident Number:	DCA23FA417
Date & Time:	August 20, 2023, 23:15 Local	Registration:	N516AS
Aircraft:	Boeing 737-890	Aircraft Damage:	Substantial
Defining Event:	Sys/Comp malf/fail (non-power)	Injuries:	112 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

This accident occurred when the left main landing gear (MLG) of an Alaska Airlines Boeing 737-800 collapsed during landing. Postaccident examination revealed that the aft trunnion pin in the left MLG failed during landing due to a fatigue fracture. The fracture initiated from a small intergranular region below the external chromium electroplated layer. The fatigue crack, which had propagated to a depth of 0.144 inches, was large enough to cause the remaining material to fracture in tensile or upward-bending overstress during landing, resulting in the collapse of the left MLG.

Further examination of the aft trunnion pin revealed that the intergranular region where the fatigue crack initiated was located along an area with a darker visual contrast following temper etch and metallographic inspections. This region also showed an elevated reading from a Barkhausen noise inspection. The elevated readings and area of visual contrast were consistent with the area being exposed to higher temperatures becoming softer than the surrounding material. The heat exposure most likely occurred as part of the excessive grinding of the surface, performed during the maintenance overhaul of the pin that occurred on July 5, 2018, as part of the overhaul of the left MLG assembly. This area was subject to grinding to first remove the original chromium layer, and then a second grinding after the new chromium layer was applied to bring the trunnion pin into specified dimensions.

The over-tempered region and the surrounding material created an area of intergranular fracture within the material in the area where grinding had occurred. The investigation considered whether the formation of this area could have occurred during the baking and stress relief processes following aggressive grinding during the chromium removal step of the overhaul. However, after removing the chromium electroplating layer, the temper etch inspections did not detect any grinding burns. Because a temper etch inspection cannot be used after the chromium

electroplating layer was reapplied, the grinding burn likely occurred during machining after the new chromium layer electroplating process.

At the time of the left MLG assembly overhaul, the landing gear assembly had accumulated 11,116 landing cycles. The overhauled left MLG assembly was installed on the accident airplane on July 17, 2018. Afterward, the left MLG, including the trunnion pin, accumulated an additional 4,710 landing cycles.

A fatigue crack analysis performed on the aft trunnion pin fracture surface showed that the fatigue crack had been present for at least 797 landing cycles. Therefore, the crack was not present when the pin was overhauled in July 2018 but had likely developed later as a result of the grinding performed during the overhaul. Because most of the nondestructive inspection techniques used to detect damage to plated trunnion pins typically rely on identifying cracks, techniques such as magnetic particle inspection and fluorescent penetrant inspection would have been ineffective before crack initiation. However, results of this examination and previous NTSB investigations demonstrate that even relatively mild heat exposure from grinding and/or machining during overhaul can lead to cracking, which can lead to fatigue crack growth and failed landing gear components, as occurred in this accident.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

Maintenance personnel's excessive grinding of the left main landing gear's aft trunnion pin during machining, which imparted heat damage to the base metal and led to the fatigue cracking that caused the pin to fracture during landing.

Findings

Aircraft	Main landing gear attach sec - Incorrect service/maintenance
Aircraft	Main landing gear attach sec - Fatigue/wear/corrosion

Factual Information

History of Flight

Landing	Sys/Comp malf/fail (non-power) (Defining event)
Landing	Landing gear collapse

On August 20, 2023, about 2315 Pacific daylight time (PDT), Alaska Airlines flight 1288, a Boeing 737-800, N516AS, sustained substantial damage when the left MLG collapsed after landing on runway 20R at John Wayne-Orange County Airport (SNA), Santa Ana, California. The 112 passengers and crewmembers evacuated the airplane via stairs onto a taxiway with no injuries reported. The flight was operating under the provisions of Title 14 *Code of Federal Regulations* Part 121 as a scheduled domestic passenger flight from Seattle, Washington, to SNA.

The flight crewmembers reported that, before the final approach fix, the airplane was fully configured for landing and on a stabilized approach and that the before landing checklist was completed. Moderate rain, shifting wind, light turbulence, and instrument meteorological conditions were encountered as the airplane descended toward the airport. About 800 ft above ground level, the flight crew visually acquired the runway, and the captain, who was the pilot flying, disengaged the autopilot and autothrottle. The airplane was aligned with the glidepath when crossing the runway threshold. The flight crew noted that all the landing gear position indicator lights were green, indicating both MLG and the nose gear were in their down and locked position.

Flight data recorder (FDR) data showed that, at 2314:57, the MLG touched down, and the nose gear touched down about 1 second later. The maximum vertical acceleration recorded at touchdown was about 1.71 G. The thrust reverser and spoiler deployment occurred normally.

According to the captain, the touchdown had a “firm jolt feeling,” and the airplane was “pulling reasonably hard” to the left. The captain overcame the left veer with rudder pedal input, and the airplane tracked the runway centerline. The captain thought that the tire on the left MLG was flat. The first officer (FO), who was the pilot monitoring, completed the after landing procedures, which included bringing the auxiliary power unit (APU) online. The captain slowed the airplane to taxi speed, and the airplane exited the runway onto a taxiway. After the airplane turned onto the taxiway, the crew noticed that the airplane was leaning to the left. FDR data indicated that the airplane came to rest at a roll attitude that was about 5° left.

The captain stopped the airplane on the taxiway, set the parking brake, and opened his cockpit window to observe the airplane. He saw that the airplane was resting on its left engine cowling (see figure 1); as a result, he immediately shut down the left engine. Inside the cockpit, the captain noted that the left MLG green position indicator light had extinguished, whereas the nose

and right MLG position indicator lights were still illuminated in green. The captain shut down the right engine after confirming the APU was running. He then made announcements to the passengers and briefed the flight attendants about the situation.



Figure 1. Collapsed left MLG and engine resting on the ground.

The FO announced, via the common traffic advisory frequency, the crew’s intention for the airplane to remain on the taxiway, and SNA airport rescue and firefighting (ARFF) responded to the scene. After ARFF personnel determined that no fuel was leaking and the flight crew confirmed that no one aboard the airplane was injured, an evacuation was performed from airstairs positioned at the left forward door.

Pilot Information

Certificate:	Airline transport	Age:	57
Airplane Rating(s):	Single-engine land; Multi-engine land	Seat Occupied:	Left
Other Aircraft Rating(s):	None	Restraint Used:	Unknown
Instrument Rating(s):	None	Second Pilot Present:	Yes
Instructor Rating(s):	None	Toxicology Performed:	
Medical Certification:	Class 1 With waivers/limitations	Last FAA Medical Exam:	April 10, 2023
Occupational Pilot:	Yes	Last Flight Review or Equivalent:	
Flight Time:	20403 hours (Total, all aircraft), 10837 hours (Total, this make and model), 10858 hours (Pilot In Command, all aircraft), 77 hours (Last 90 days, all aircraft), 47 hours (Last 30 days, all aircraft), 5 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport	Age:	52
Airplane Rating(s):	Single-engine land; Multi-engine land	Seat Occupied:	Right
Other Aircraft Rating(s):	None	Restraint Used:	Unknown
Instrument Rating(s):	None	Second Pilot Present:	Yes
Instructor Rating(s):	None	Toxicology Performed:	
Medical Certification:	Class 1 With waivers/limitations	Last FAA Medical Exam:	December 2, 2022
Occupational Pilot:	Yes	Last Flight Review or Equivalent:	
Flight Time:	10705 hours (Total, all aircraft), 483 hours (Total, this make and model), 1200 hours (Pilot In Command, all aircraft), 254 hours (Last 90 days, all aircraft), 63 hours (Last 30 days, all aircraft), 5 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Boeing	Registration:	N516AS
Model/Series:	737-890	Aircraft Category:	Airplane
Year of Manufacture:	2008	Amateur Built:	
Airworthiness Certificate:	Normal	Serial Number:	39044
Landing Gear Type:	Retractable - Tricycle	Seats:	149
Date/Type of Last Inspection:	Continuous airworthiness	Certified Max Gross Wt.:	174700 lbs
Time Since Last Inspection:		Engines:	2
Airframe Total Time:	53207.34 Hrs at time of accident	Engine Manufacturer:	
ELT:	Installed	Engine Model/Series:	
Registered Owner:	WILMINGTON TRUST CO TRUSTEE	Rated Power:	
Operator:	Alaska Airlines	Operating Certificate(s) Held:	Flag carrier (121)

The left and right MLG absorb landing forces through the tire assembly and support most of the airplane's weight when on the ground. Each MLG also transmits the wheel braking forces to the airplane structure.

A main gear shock strut provides the primary support for each MLG (see figure 2). The shock strut consists of an integral drag strut, an outer cylinder, and an inner cylinder. When the MLG extends or retracts, the shock strut rotates about two trunnion bearings and two pins (forward and aft) at the top of the outer shock strut. The forward and aft trunnion pins extend through a

trunnion bearing and support assembly in the wing and landing gear beam. Trunnion bolts keep the trunnion pins from backing out during landing gear operation.

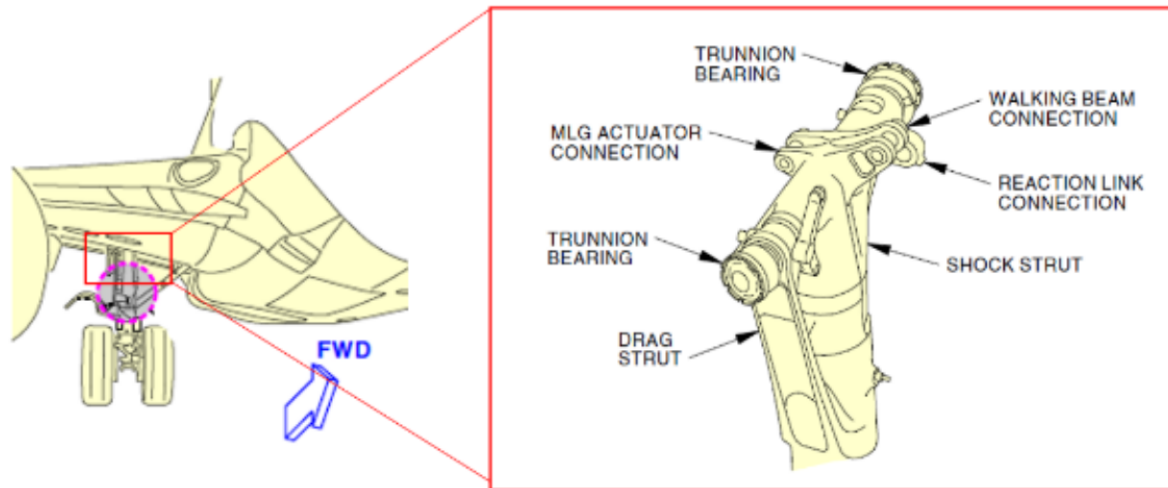


Figure 2. Illustration of the MLG components. (Source: Boeing. Image Copyright Boeing. Reproduced with permission.)

Alaska Airlines' maintenance program indicated that the left and right MLG assemblies must be overhauled every 21,000 flight cycles or 10 years. Alaska Airlines' maintenance records showed that the left MLG assembly, including the aft trunnion pin, had been overhauled by Sunvair Inc. in Valencia, California, on July 5, 2018. At that time, the landing gear assembly had accumulated 11,116 flight cycles.

According to documentation of the overhaul procedure, during the overhaul of the aft trunnion pin the original chromium layer had been stripped from the trunnion pin by grinding its surface. After the removal of the chromium layer, a temper etch inspection and a magnetic particle inspection were completed. After these inspections and shot peening were completed, a new layer of chromium electroplating was applied to the surface of the trunnion pin. The outer diameter of the pin was then machined (by grinding) to achieve a specific diameter, and another magnetic particle inspection was completed.

The overhauled left MLG assembly was installed on the accident airplane on July 17, 2018. At that time, the airplane had accumulated 11,144 flight cycles. At the time of the accident, the airplane had accumulated 53,207 flight hours and 15,854 flight cycles. The landing gear had been installed on the airplane for 4,710 flight cycles since its installation in July 2018.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	Condition of Light:	Night
Observation Facility, Elevation:	ksna	Distance from Accident Site:	0 Nautical Miles
Observation Time:	11:05 Local	Direction from Accident Site:	0°
Lowest Cloud Condition:	Few / 1100 ft AGL	Visibility	2 miles
Lowest Ceiling:	Overcast / 1100 ft AGL	Visibility (RVR):	
Wind Speed/Gusts:	3 knots /	Turbulence Type Forecast/Actual:	Unknown / Unknown
Wind Direction:		Turbulence Severity Forecast/Actual:	Light / Light
Altimeter Setting:	29.81 inches Hg	Temperature/Dew Point:	21°C / 19°C
Precipitation and Obscuration:			
Departure Point:	Seattle, WA (SEA)	Type of Flight Plan Filed:	IFR
Destination:	Santa Ana, CA	Type of Clearance:	IFR
Departure Time:	20:36 Local	Type of Airspace:	Class C

Airport Information

Airport:	John Wayne/Orange County Airport KSNA	Runway Surface Type:	Concrete
Airport Elevation:	56 ft msl	Runway Surface Condition:	Wet
Runway Used:	20R	IFR Approach:	ILS
Runway Length/Width:	5700 ft / 150 ft	VFR Approach/Landing:	None

Wreckage and Impact Information

Crew Injuries:	6 None	Aircraft Damage:	Substantial
Passenger Injuries:	106 None	Aircraft Fire:	None
Ground Injuries:		Aircraft Explosion:	None
Total Injuries:	112 None	Latitude, Longitude:	33.675701,-117.86799

Post accident inspection found that the left MLG forward trunnion pin and its spherical bearing were in place with no visible damage to the wing spar. The inspection also found that the left MLG aft trunnion pin had fractured in half vertically across its diameter. One-half of the aft trunnion pin remained within the spherical bearing of the rear landing gear beam, and the other half remained in the outer cylinder of the MLG trunnion. The trunnion pin half that remained in

the landing gear beam spherical bearing had moved aft and was found protruding from the aft side of the bearing.

The left MLG aft trunnion pin had fractured approximately perpendicular to the length of the pin at its midspan. The trunnion pin was extracted from the airplane for further examination. The aft section of the pin was between 4.5 and 5.0 inches long, and the forward section of pin was between 5.25 and 6.0 inches long. The aft section of the trunnion pin was examined at Boeing's Equipment Quality Analysis (EQA) laboratory in Seattle, Washington with NTSB personnel present. The forward section of the trunnion pin was removed from the aircraft over a month later, and was sent to the NTSB Material Laboratory, where it was examined before bringing it to the Boeing EQA lab for additional Barkhausen and temper etch inspections. The results of the examinations at the NTSB Materials Lab and Boeing EQA lab are discussed below.

Trunnion Pin – Aft Section

When examined, the aft section of the trunnion pin was placed in approximately the same orientation as it would be installed on the airplane. Visual examination showed that most of the fracture surface was rough with a dull gray luster, and many of its edges had small shear lips. The fracture surface exhibited river patterns and chevron marks consistent with a fracture progressing from a small thumbnail crack. The damage was located at approximately the 12:00 position when looking at the fracture surface.

This thumbnail crack exhibited diverse colors with crack arrest marks. These features were consistent with pre-existing fatigue cracking in this pin section. The thumbnail crack dimensions, which were measured with a digital optical microscope, were 0.144 inches deep and 0.391 inches long (the linear length on the outer diameter). This subsurface intergranular region measured 0.016 inches deep by 0.290 inches long inside the thumbnail crack.

A Barkhausen noise inspection analysis detected elevated readings near the fracture surface. The highest readings were in areas with visible physical damage to the pin surface and near the thumbnail crack. Boeing indicated that these readings appeared to indicate residual stress in the base metal.

A fluorescent penetrant inspection and a magnetic particle inspection showed no indications of an abnormal network of cracks were observed on the surfaces of the part. Small cracks parallel and adjacent to the fracture surface were found in the chromium electroplated layer. These cracks were observed near the fracture origins. Additional indications were observed on the surface in areas that exhibited impact damage.

Trunnion Pin – Forward Section

The forward section of the aft trunnion pin had features on its fracture surface that mirrored those on the aft section of the aft trunnion pin, including a thumbnail crack along the edge.

A closer examination of the initiation region of the thumbnail crack, including the chromium electroplating surface layer and the darker subsurface intergranular layer, was conducted. The examination showed that small ratchet marks were present on the thumbnail crack adjacent to the intergranular area and below an area of the fractured external chromium electroplating layer. The plating layer exhibited layered fan-shaped characteristics with radiating features. The faceted morphology of the area was consistent with fracture between grain boundaries. Much of the intergranular surfaces exhibited ridged or smooth surface features with clear triple points and some secondary cracking.

Beyond the intergranular region, the thumbnail crack exhibited fatigue striations consistent with fatigue crack propagation. These striations originated along the edge of the intergranular region of the fracture surface. The ratchet marks, which were consistent with multiple initiation sites, indicated that the fatigue crack started along stress concentrations created by the morphology of the initial intergranular zone. An abrupt change in fracture features was observed at the end of the fatigue thumbnail crack. Outside the striations comprising the fatigue, the fracture surface exhibited dimpled rupture, which was consistent with subsequent overstress fracture of the pin during the accident landing.

Overall, the fracture features of the thumbnail crack were consistent with multiple crack initiation sites along the facets of the intergranular region. These smaller cracks had coalesced during early crack propagation, as evidenced by the ratchet marks in that portion of the fatigue crack.

Flight recorders

The event airplane was manufactured in 2008 and was operating such that it was required to be equipped with a flight data recorder (FDR) that recorded, at a minimum, 91 parameters, as cited in 14 *CFR* Part 121.344(f). The parameters evaluated for the purpose of this investigation appeared to be in accordance with federal FDR carriage requirements, except left brake pressure (Brake Press-LT) and right brake pressure (Brake Press-RT). For more detailed information, see the Flight Data Recorder - Specialist's Factual Report located in the docket.

The aircraft began its descent about 2245. During final approach, the airplane encountered a 60-degree crosswind with a recorded windspeed reaching 43 knots before decreasing closer to touchdown. At 2314:57, the MLG touched down, and the nose gear touched down 1 second later. The maximum vertical acceleration recorded at touchdown was about 1.71 g. The thrust reverser and spoiler deployment occurred normally, and the airplane came to rest with its left wing rolled about 5 degrees to the left.

The aircraft was required to be equipped with a cockpit voice recorder (CVR) that recorded at a minimum the last 2 hours of aircraft operation. The L-3/Fairchild FA2100 model CVR records a minimum of 120 minutes of digital audio stored on solid state memory modules. Four channels are recorded: one channel for each flight crew member, one channel for a cockpit observer, and one channel for the cockpit area microphone. All used channels had good to excellent quality audio and a summary was created of the audio associated with the descent, approach, and landing, up to the time the aircraft exited the runway for taxiway echo.

Tests and Research

A fatigue crack growth rate analysis was performed by counting striations at intervals along the crack depth to better understand how long the fatigue crack had been present. The fatigue striation counts were taken at 32 random and unique places on the fracture surface, with the distances from the initiation site recorded.

The fatigue crack growth rate analysis found that a total of 797 flight cycles had occurred from the intergranular initiation site used as the origin to the end of the crack. The crack depth steadily increased over time, corresponding with an expected increase in crack growth rate. The number of landings since the aft trunnion pin's last overhaul was 4,710 flight cycles. These data indicate that the fatigue crack had not been present at, or before, the part overhaul.

Additional Information

In a review of National Transportation Safety Board investigations and assisted international investigations, there were four similar main landing gear trunnion pin failure accidents involving Boeing 737 aircraft. Those investigations were:

April 13, 2015 - Jet Airways Boeing 737-800, VT-JGA:

Jet Airways flight 9W-2423 (Delhi -Varanasi-Khajuraho–Delhi) was involved in an accident at Khajuraho Airport at 0751 UTC. During landing Roll, 15 seconds after touchdown, at

speed 36 knots, left main landing gear aft trunnion pin broke and aircraft started deviating to the left of center line. The aircraft came to stop on runway with damage to the LH landing gear and resting on LH engine.

March 3, 2016 - Jet Airways Boeing 737-900, VT-JGD:

While operating scheduled domestic passenger flight 9W-354 from Delhi to Mumbai with 120 passengers and 8 crew on 03-03-2016 was involved in an accident at Chhatrapati Shivaji International (CSI) Airport, Mumbai. The aircraft had safely landed on runway 27 at 16:22 UTC and was about to vacate the runway via taxiway N9 when the right main landing gear collapsed.

July 16, 2018 - Gol Airlines Boeing 737-800, PR-GGD:

During landing, at the moment of touch, a loud noise was heard by the cabin crew. The aircraft taxied by its own means to the apron, where passengers disembarked normally. When conducting the post-flight inspection, the maintenance team identified a leakage of hydraulic fluid and the breakdown of a component of the right main landing gear.

December 22, 2019 - United Airlines Boeing 737-800, N87513

This accident occurred when the left main landing gear of a United Airlines Boeing 737-800 collapsed during the landing roll. Both flight crewmembers reported that the airplane had touched down smoothly on the runway centerline, but the first officer reported that he then felt the airplane "shudder" and tilt left wing down. Postaccident examination found that the aft trunnion pin in the left main landing gear failed during the landing due to a fatigue crack.

Administrative Information

Investigator In Charge (IIC):	Hauf, Michael
Additional Participating Persons:	Rick Domingo; Alaska Airlines; Seattle, WA Nathan Williams; Boeing Commercial Airplanes Mitch Mitchell; FAA; DC Fred Baisch; AMFA Marc Henegar; ALPA
Original Publish Date:	May 22, 2025
Last Revision Date:	
Investigation Class:	Class 2
Note:	
Investigation Docket:	https://data.nts.gov/Docket?ProjectID=192903

The National Transportation Safety Board (NTSB) is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant events in other modes of transportation—railroad, transit, highway, marine, pipeline, and commercial space. We determine the probable causes of the accidents and events we investigate, and issue safety recommendations aimed at preventing future occurrences. In addition, we conduct transportation safety research studies and offer information and other assistance to family members and survivors for each accident or event we investigate. We also serve as the appellate authority for enforcement actions involving aviation and mariner certificates issued by the Federal Aviation Administration (FAA) and US Coast Guard, and we adjudicate appeals of civil penalty actions taken by the FAA.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, “accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties ... and are not conducted for the purpose of determining the rights or liabilities of any person” (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB’s statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)). A factual report that may be admissible under 49 *United States Code* section 1154(b) is available [here](#).