

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN23LA208

MATERIALS LABORATORY

Factual Report 24-001

January 26, 2024

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A. ACCIDENT INFORMATION

Location: Cortez, Colorado
Date: May 18, 2023
Time: 18:00 central daylight time
23:00 coordinated universal time
Vehicle: Luscombe 8E, N2515K
Investigator: John Brannen, AS-CEN

B. COMPONENTS EXAMINED

Pieces of a main landing gear

C. EXAMINATION PARTICIPANTS

Specialist Erik Mueller, Ph.D., P.E.
Office of Research and Engineering - Materials Laboratory Division
NTSB, Washington, DC

D. DETAILS OF THE EXAMINATION

On May 18, 2023, a Luscombe 8E was substantially damaged when it was involved in an accident at the Cortez Municipal Airport in Cortez, CO. The pilot and the flight instructor were not injured. On the day of the accident, the pilots were conducting multiple landings. During the final landing, the right main landing gear collapsed. The airplane's left wing was substantially damaged during the event. Several components of the fractured landing gear were sent to the NTSB Materials Laboratory for additional examination.

Figure 1 shows the components of the right main landing gear as received. The gear assembly had fractured in three locations, labeled 1 through 3 before receipt, and will be used for reference in this report. Fracture 1 was located where the lower leg transitioned to the collar welded to the axle. Fracture 2 was located along the lower leg, approximately 3 inches from the top of the tube. Fracture 3 had occurred in the threaded fork end that affixed the strut to the lower leg. The strut also had been deformed in bending, collocated with an area of spalled white topcoat paint.

Figure 2 shows a closer view of Fracture 2 on the lower leg. This fracture exhibited mating cup and cone shapes without any out-of-plane deformation. The fractures themselves exhibited 45° slant orientations, as shown in Figure 3. The fracture surfaces were dull gray in luster, with a rough, fibrous texture. These features were consistent with subsequent overstress fracture of this part of the lower leg.

Figure 4 shows a closer view of the threaded fork end fracture at Fracture 3. The end remnant exhibited downward bending deformation next to the fracture surface, as oriented in Figure 4. Examination of the end fracture surface showed a dull gray appearance on a rough, fibrous surface texture. The general shape of the fracture surface was conical, with small 45° angled shear lips along the edges. These features were consistent with bending overstress fracture of the threaded fork end.

Figure 5 shows the mating sides of the Fracture 1 location. The mating fracture surfaces did not mirror each other in shape, with the upper fracture face on the lower leg exhibiting a flat planar shape, oriented at an angle off perpendicular to the leg direction. The mating fracture surface on the collar was jagged and partially deformed.

Figures 6 through 8 show different angles of the collar side of Fracture 1. As shown in the figures, approximately half of the fracture surface was parallel to the direction of the lower leg (shown in the upper portion in Figure 8). The other half of the fracture had been bent inward, with areas of S-shaped buckling on the edges. This bending deformation, being out-of-plane with the fracture surface, was consistent with subsequent deformation post-fracture. The fracture surface exhibited a mottled surface texture, with maroon-colored corrosion product (rust) prevalent on the surface and the interior of the leg remnant up to the collar with the axle.

Figure 9 shows the mating upper fracture surface of Fracture 1. This surface exhibited a reflective metallic color and was generally flat and planar. The surface exhibited unidirectional streaks and gouge marks. Material from the fracture exuded over the edges and flanges of the leg, but only in the one direction of the streaks (the top-facing surface edges as shown in Figure 9). These features were consistent with subsequent grinding against a planar surface of this part of the leg post-fracture.

The fracture portion of the collar was sectioned from the axle and cleaned in an ultrasonic bath of acetone to remove the paint and loose corrosion product on the part. Figure 10 shows a closer view of the fracture. The inward bent portion of the fracture surface exhibited surface streaks and grinding marks, consistent with contact from another material that deformed this wall of the fractured leg. The other half of the fracture showed two regions—one that exhibited gouging marks and localized surface damage (lower side in Figure 10) and an area absent post-fracture damage (left in Figure 10).

The undamaged region of the collar fracture surface is shown closer in Figure 11. This area exhibited localized thinning in some areas near the fracture surface. These areas were measured using digital calipers; the walls of the leg near the collar had thinned from 0.040 inches next to the axle to under 0.025 inches near the fracture. Some of the thicker areas of this part of the fracture exhibited slant fracture orientations, as illustrated in Figure 12. These areas also revealed flatter, faceted faces on the fracture

surface, though they were obscured by surface oxide thick enough to diminish underlying features visually (Figure 13). Further, the interior of the fracture exhibited layered surface oxidation and corrosion product, as illustrated in the middle and upper right in Figure 13.

The thinnest section of the fractured leg wall near the collar was sectioned and cleaned in an ultrasonic bath with water and Evapo-rust chelating agent to remove much of the surface oxide.¹ This fracture surface was examined using a field-emission scanning electron microscope (SEM). Figure 14 shows a typical area of the thicker portions of the fracture surface, exhibiting dimpled rupture consistent with overstress fracture. However, many areas of the fracture exhibited larger pock-marked features similar to dimpled rupture but were an artifact of the oxide removal cleaning process.

Figure 15 shows a closer view of the thinnest area of the fracture surface, which exhibited a general semicircle shape. Much of the surface still contained corrosion compounds, which presented as nonconductive material in the SEM. Figure 16 shows a closer portion of the edge, which, though still mainly covered in corrosion compounds, exhibited areas of exposed underlying metal from the cleaning process. The corrosion compounds still present were faceted and layered (Figure 17). The underlying metal either exhibited a flatter faceted appearance, as illustrated in the lower corner of Figure 17, or dimpled rupture, as shown in Figure 18. The dimples in Figure 18 were both equiaxed and slanted, indicative of mixed loading directions. These thinned areas exhibited fracture features consistent with overstress fracture.

The thinned area of the collar fracture was cross-sectioned for metallographic examination. Figure 19 shows one of the cut surfaces after sectioning, illustrating the thinning that occurred toward the tip of the fracture. Figure 20 shows a second cut and the degree of thinning revealed in the sections, as opposed to slanted or cup-and-cone morphologies typical of overstress fractures.

The interior of the leg near the fracture is shown in Figure 21. Besides thick corrosion product layers, the interior surface exhibited multiple pock-marked shapes consistent with corrosion pitting. One such pit near the fracture surface is highlighted in Figure 22, which is evident as connected depressions with two cracks emanating from the pit. These interior pits and cracks were common along the interior surface of the leg near the axle collar.

Figures 23 through 25 show bright-field optical micrographs of a polished cross-section through the fracture surface. The surface thinned to a small point, less than 0.01 inches in thickness, shown in Figure 25. While the exterior surface was generally smooth, the interior exhibited multiple pits, which contained corrosion products

¹ Evapo-Rust - a commercially-available chelating rust stripper currently manufactured CRC Industries, headquartered in Horsham Township, PA.

evident as light gray in the micrographs. A closer view of the largest pit in this area is shown in Figure 26. These pits were present along the interior surface and even exhibited microcracks emanating from them, as seen near the tip in Figure 25.

The polished cross-section was examined in an SEM for chemical analysis. One of the cross-sectioned pits examined is illustrated in Figure 26—this location was filled with corrosion products. The chemical composition of the sectioned leg was examined using energy dispersive x-ray spectroscopy. A typical spectrum of the polished metal is shown in Figure 28—this composition was consistent with alloy steel. The composition of the corrosion compound in the pit, demonstrated in Figure 29, was consistent with iron oxide. In addition, this oxide contained minor amounts of chlorine.

These features were consistent with general corrosion with deep pits on the interior of the lower leg at the collar joint near the axle. The corrosion progressively thinned the leg tube walls over time. The combination of missing material, pitting, and microcracks led to an overstress fracture of the leg at this location on the final landing, which led to two other subsequent overstress fractures.

Submitted by:

Erik M. Mueller
Materials Research Engineer

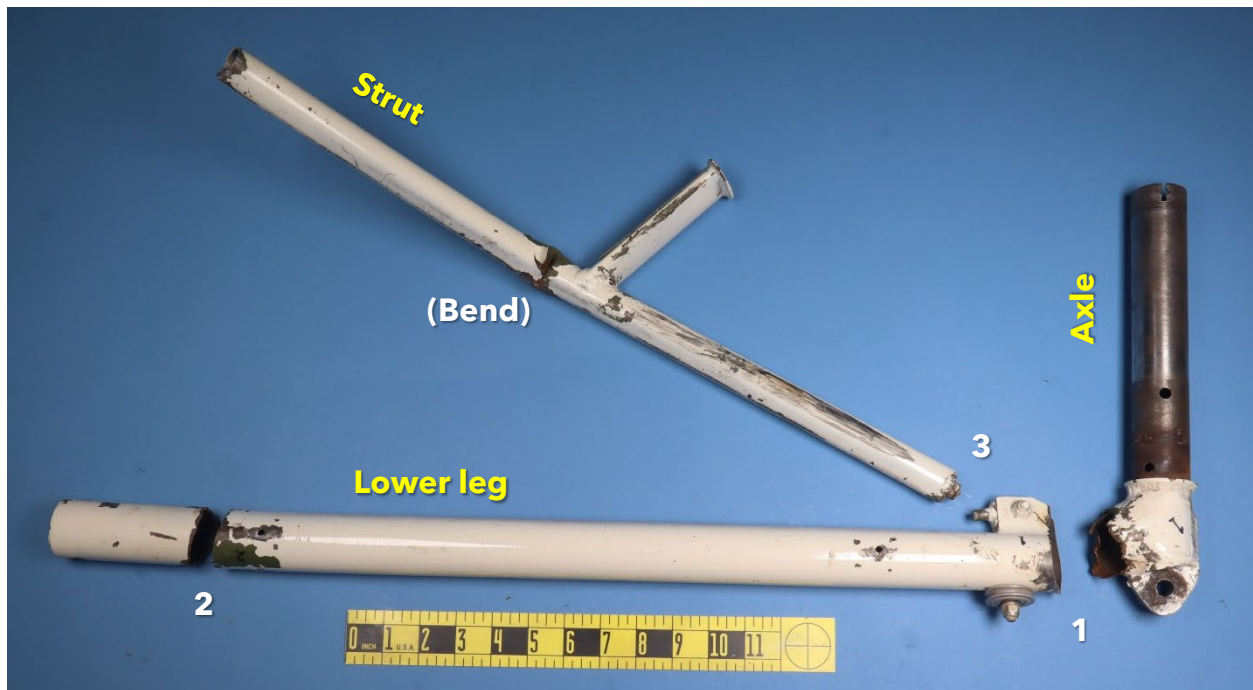


Figure 1. View of the remnants of the landing gear assembly, as received. The pre-received fracture labels are annotated on the figure in white numbers.

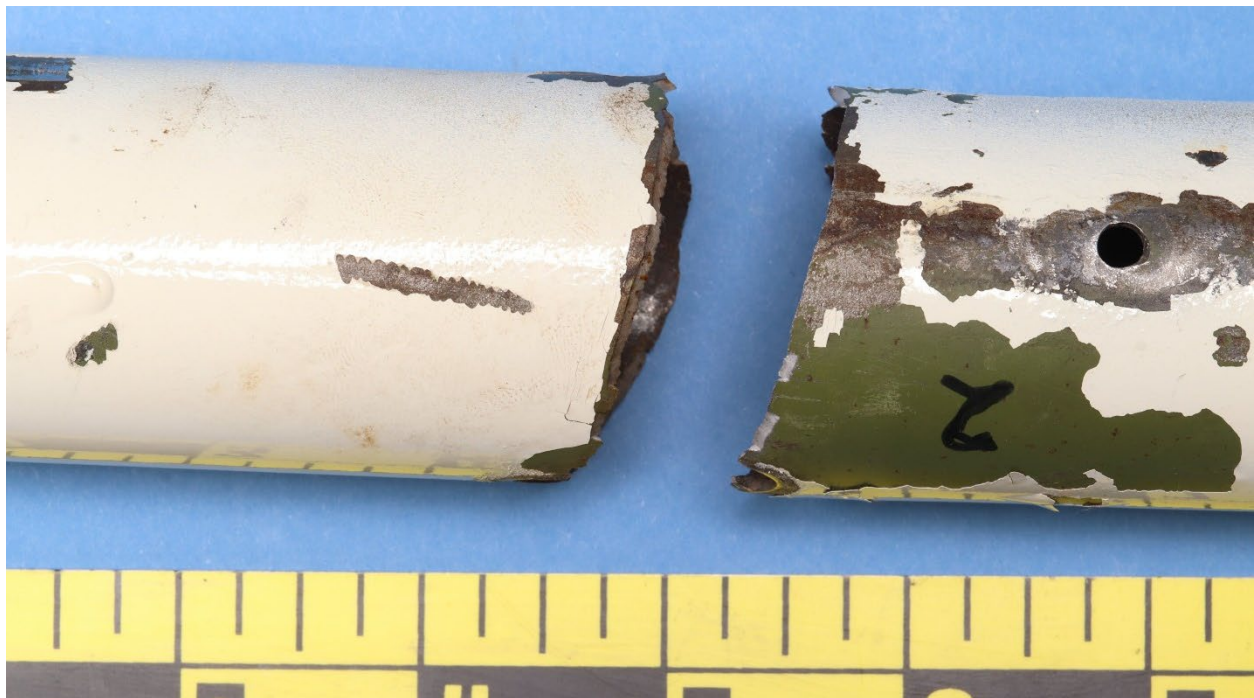


Figure 2. View of the mating sides of fracture 2, located along the lower leg.

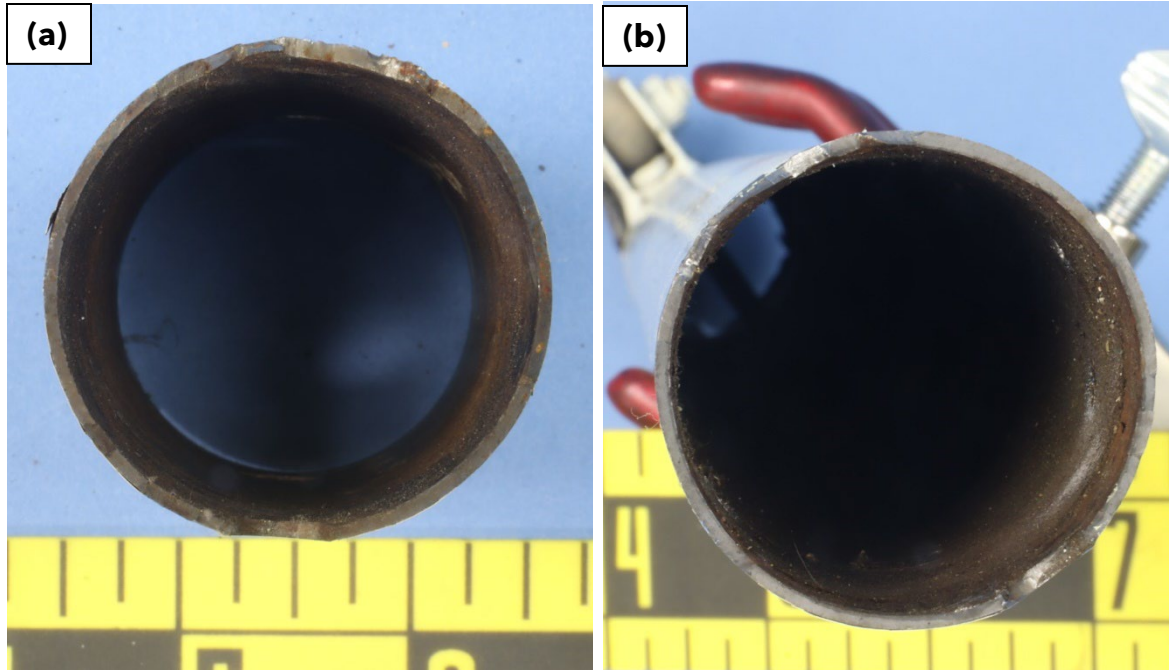


Figure 3. Mating sides of the fracture surface from (a) the upper side and (b) the lower side of the lower leg.

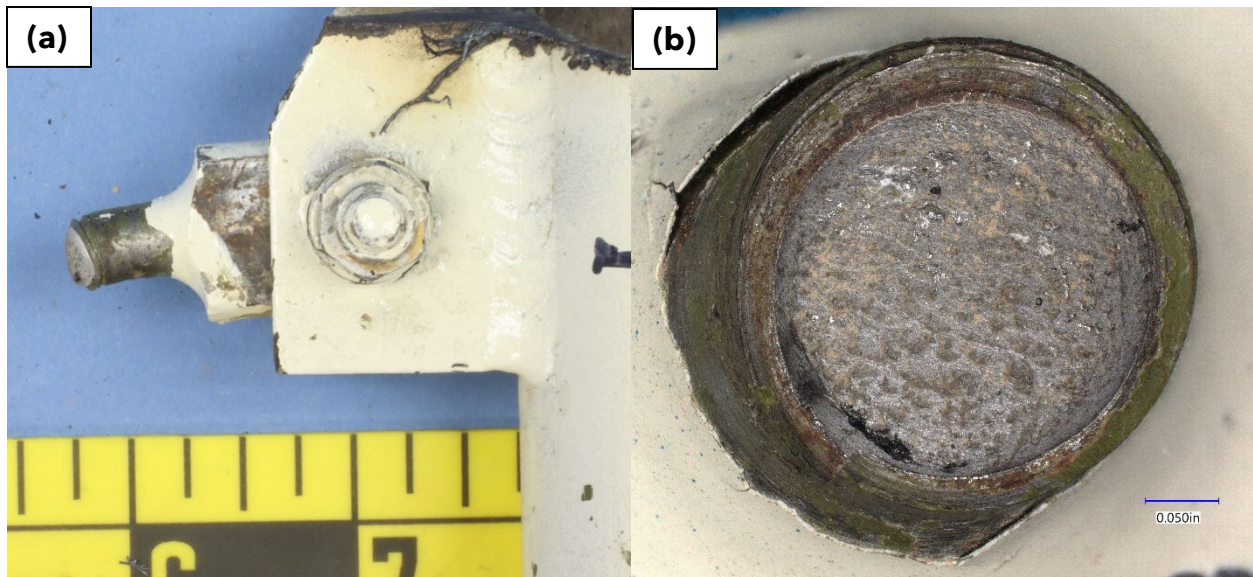


Figure 4. View of the bent and fractured threaded fork end at fracture 3 from (a) the side and (b) the fracture surface.

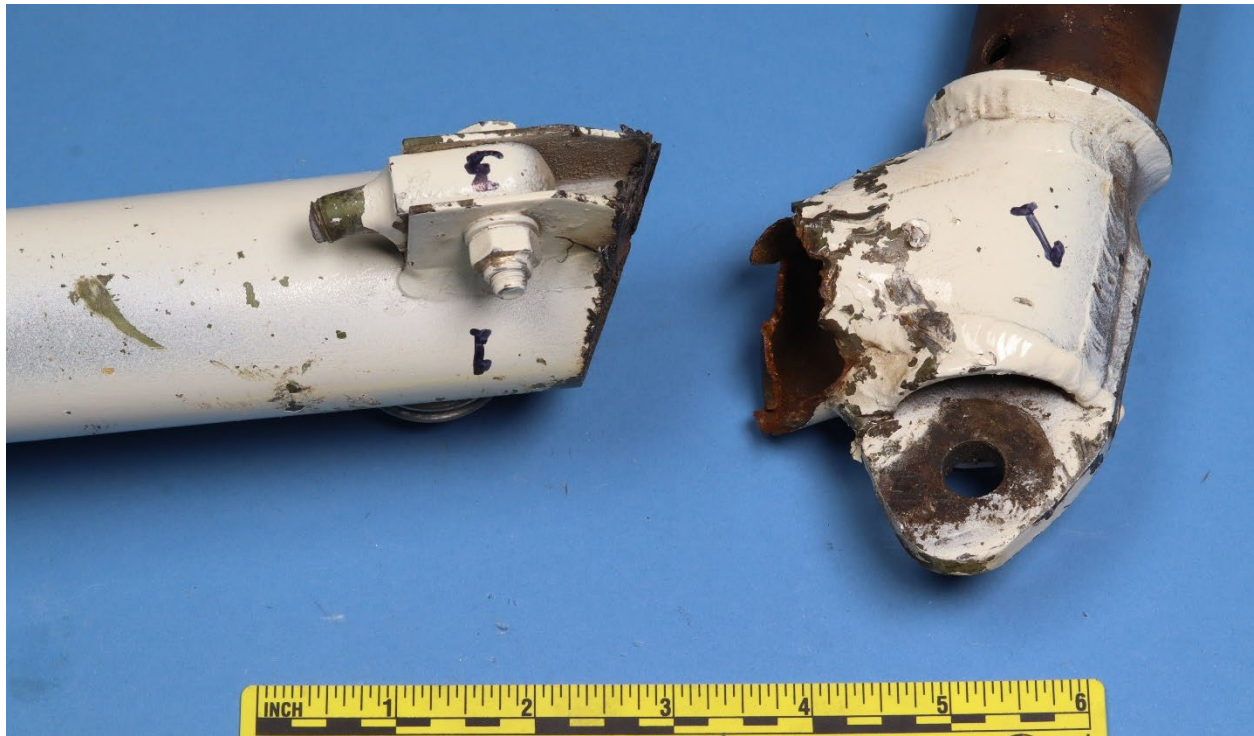


Figure 5. View of the mating sides of fracture 1 along the lower landing gear leg.



Figure 6. View of the collar side of fracture 1, showing material deformed inward on the far side, and fractures oriented in line with the leg on the near side of the figure.



Figure 7. Angled view of Figure 6, showing the deformed side of the collar, and interior corrosion products.

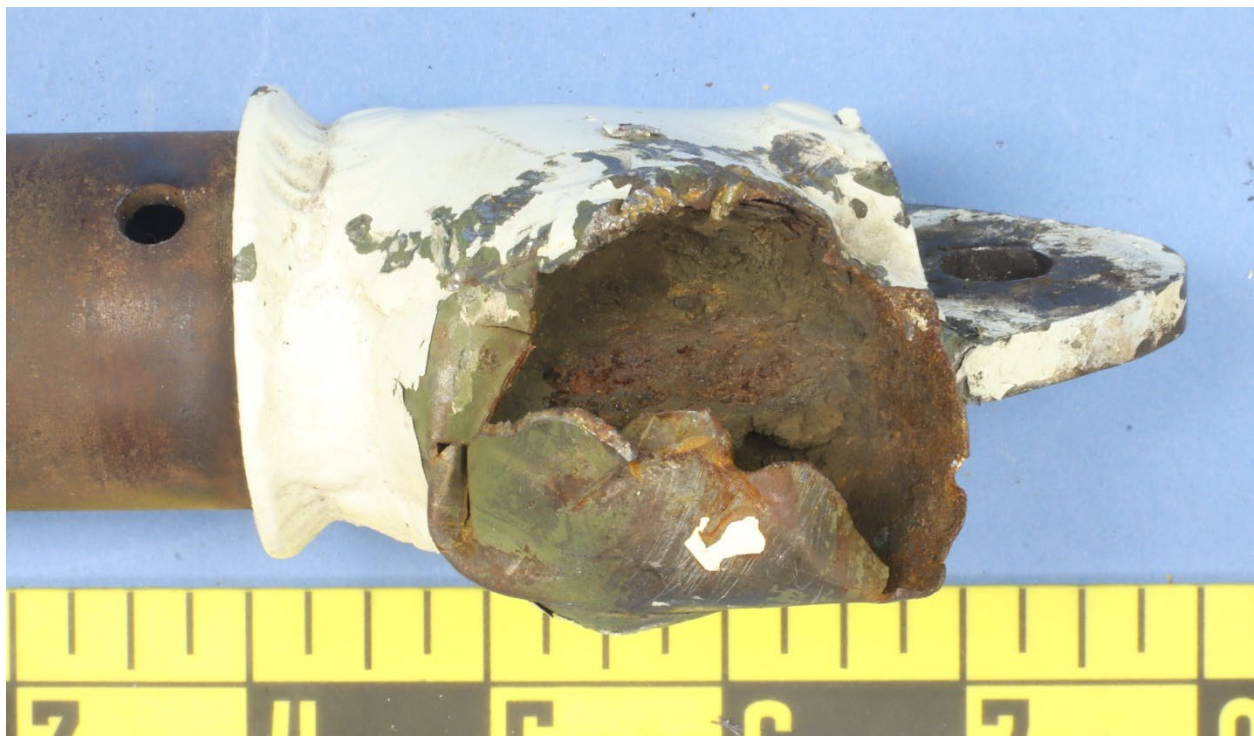


Figure 8. Inverted view of Figure 6, showing the in line half of the leg tube fracture.

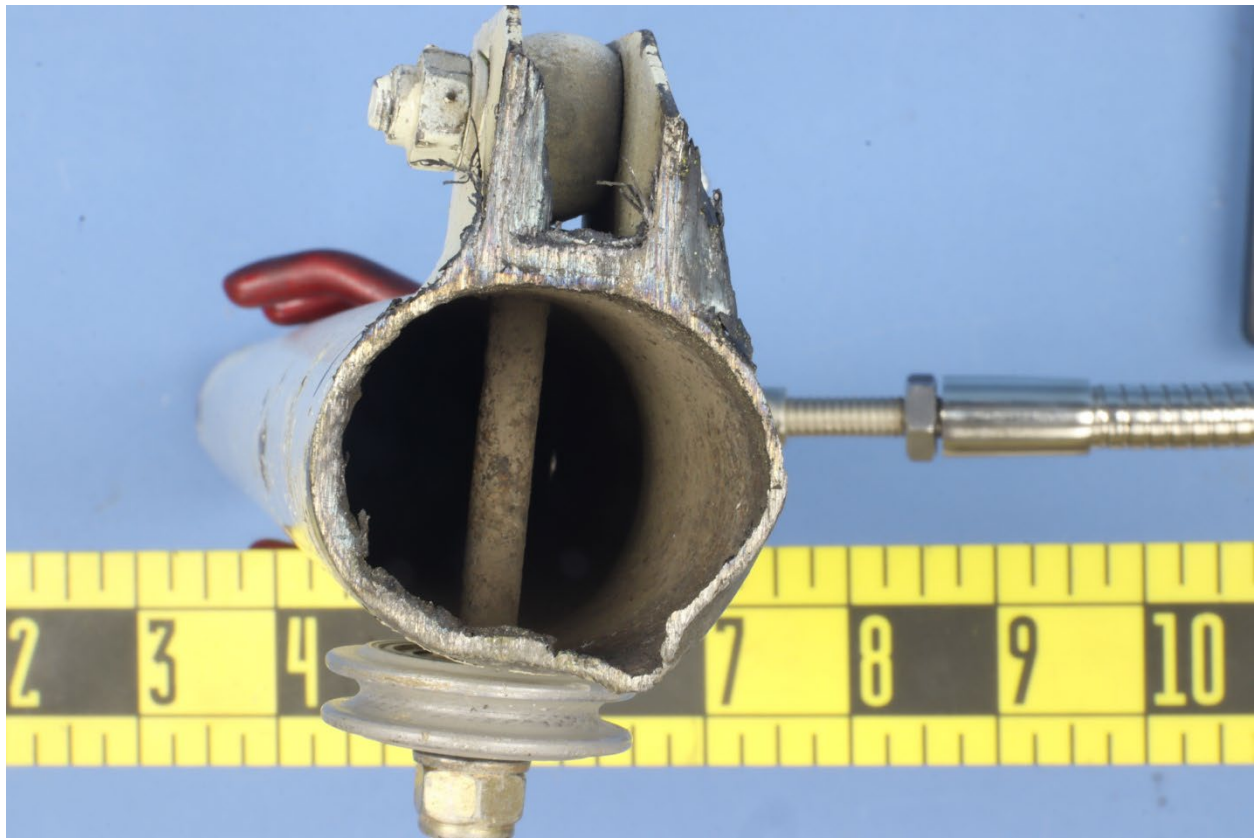


Figure 9. View of the mating side of fracture 1, showing unidirectional gouge marks.



Figure 10. Closer view of the deformed area of the tube fracture near the collar at fracture 1.



Figure 11. Closer view of the un-deformed portion of the collar fracture surface.



Figure 12. Closer view of the right side of the fracture in Figure 11, showing material thinning.



Figure 13. View of a thicker area of the fracture surface, showing layered interior compounds.

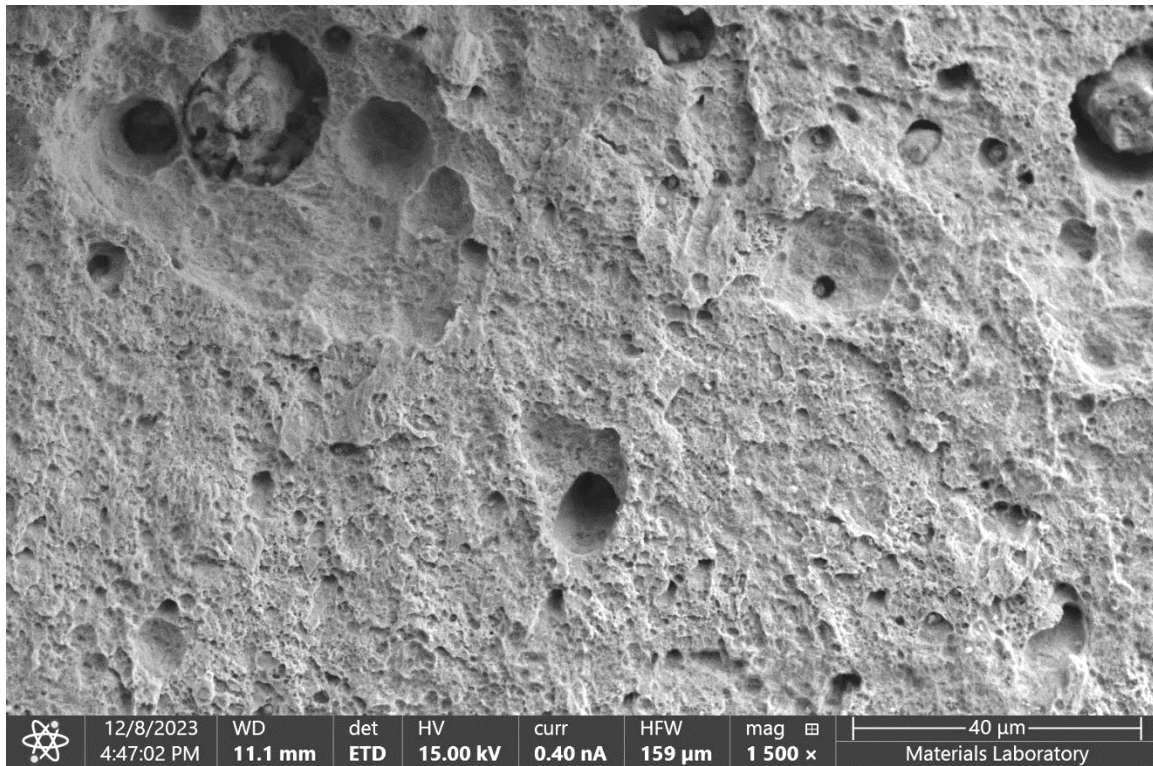


Figure 14. Secondary electron (SE) micrograph of the thicker part of the fracture surface in Figure 13, after removing the surface oxide.

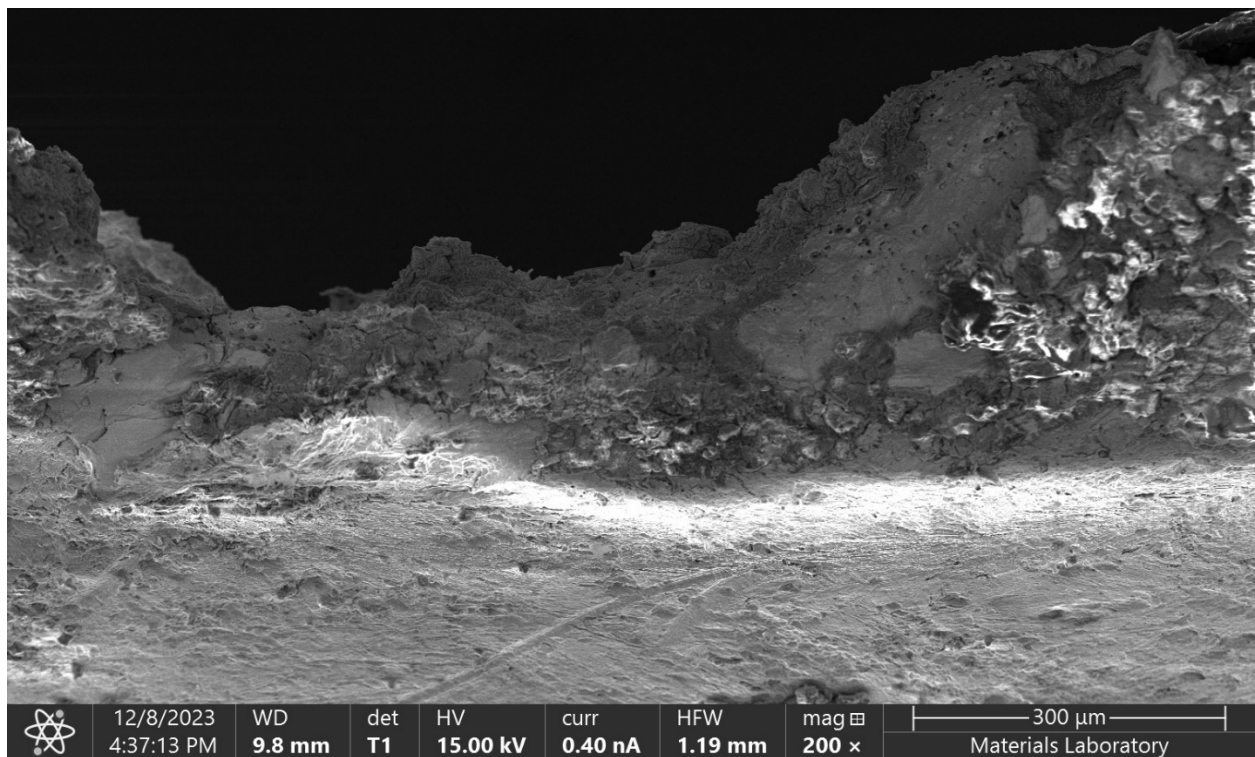


Figure 15. SE micrograph of the thinned area of the fracture surface in Figure 12.

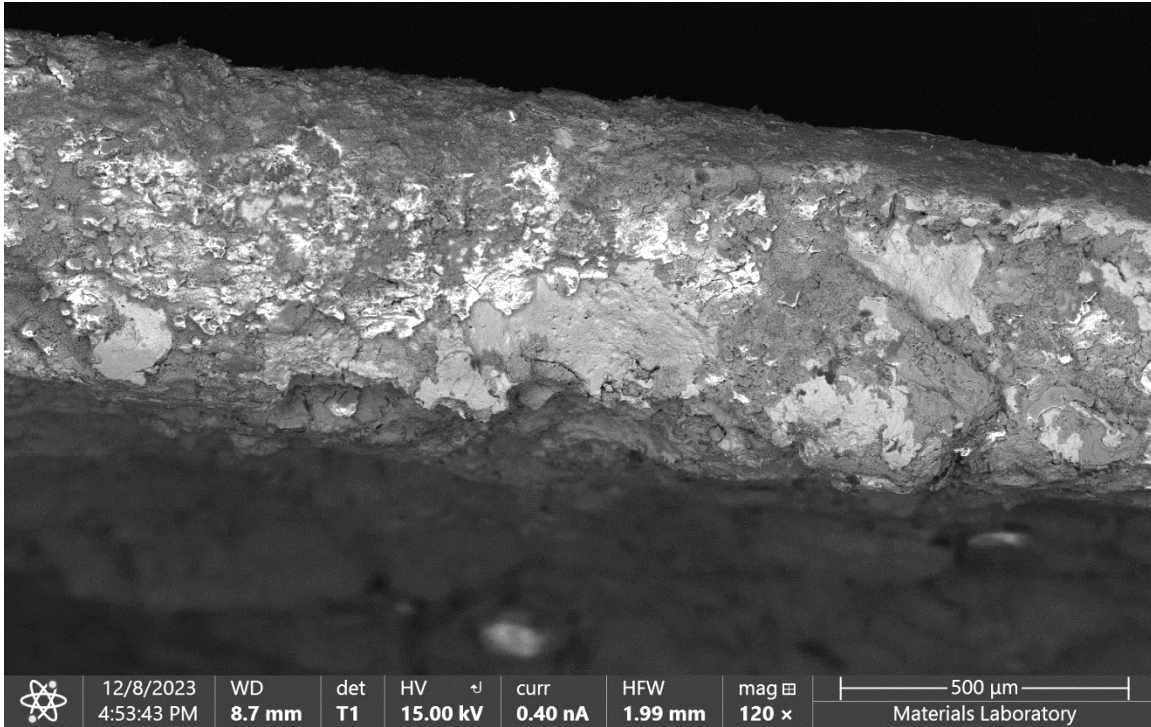


Figure 16. Backscattered electron (BE) micrograph of another portion of fracture surface that thinned to 605 μm (0.024 in).

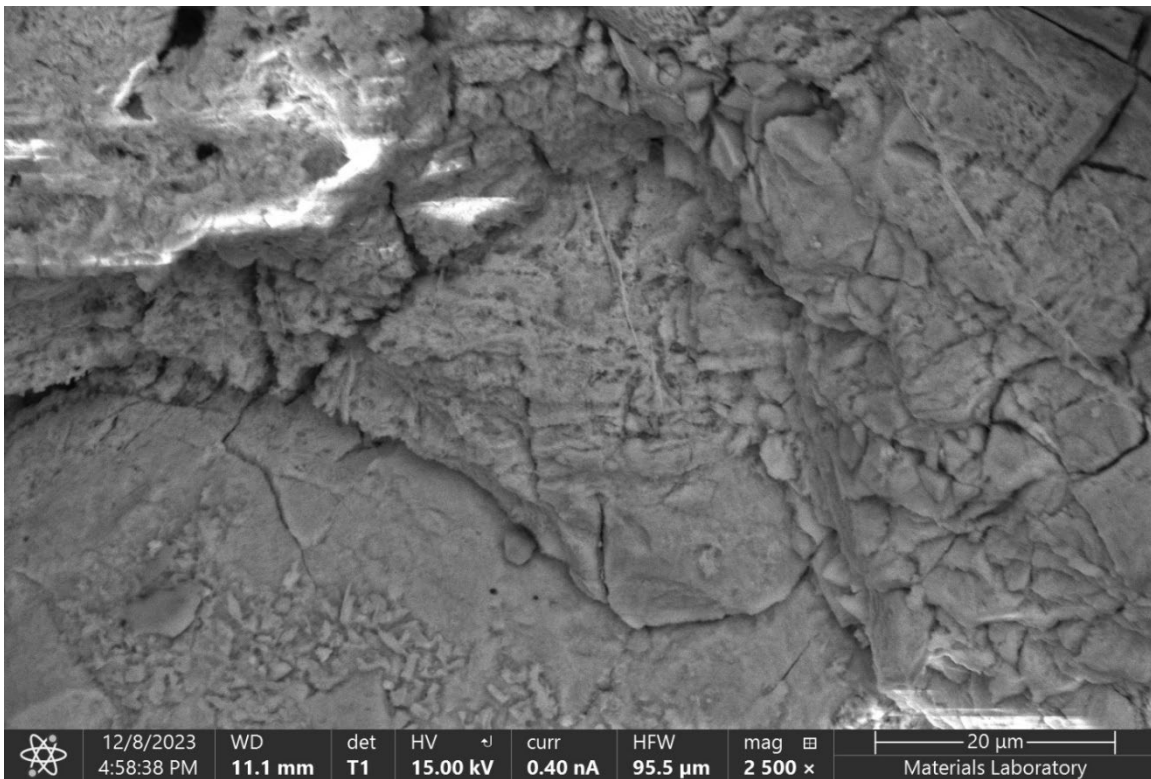


Figure 17. BE micrograph of layered surface oxide on the surface of the thin fracture surface

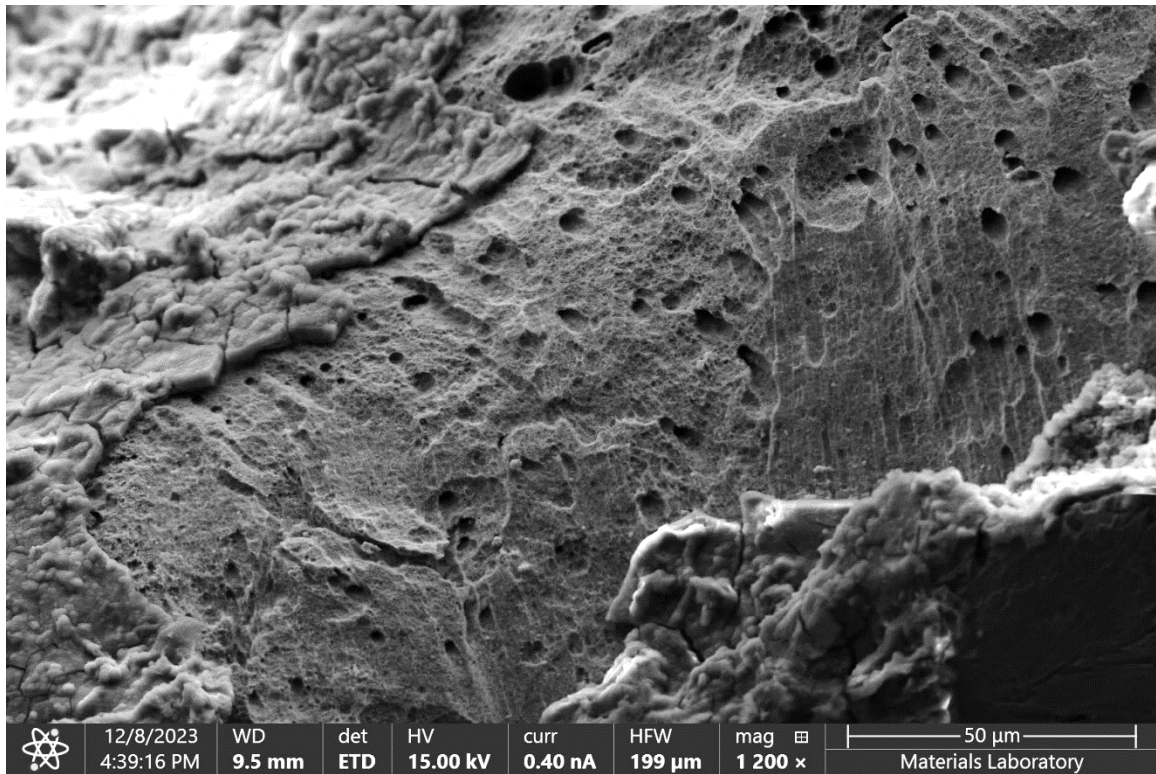


Figure 18. SE micrograph of the thinned area of the fracture where oxide had been removed.



Figure 19. Cross section through the thin fracture surface, viewed from the side.

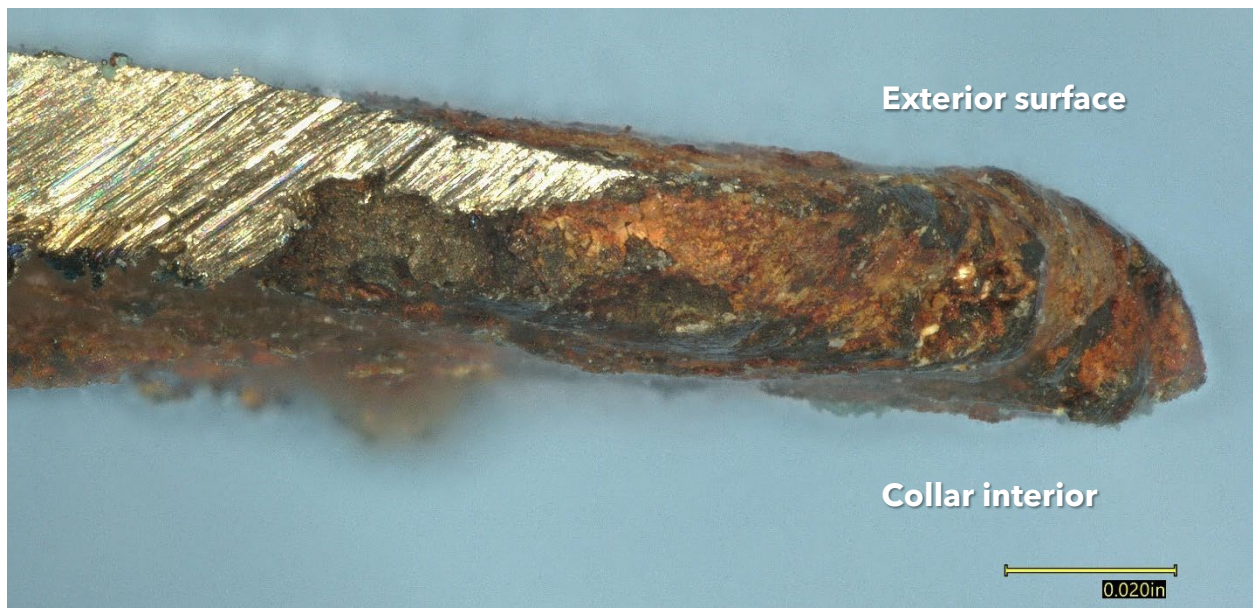


Figure 20. View of a second cross section through the thinned fracture surface.



Figure 21. View of the inside surface of the leg tube of the collar (oriented downward in Figure 20).

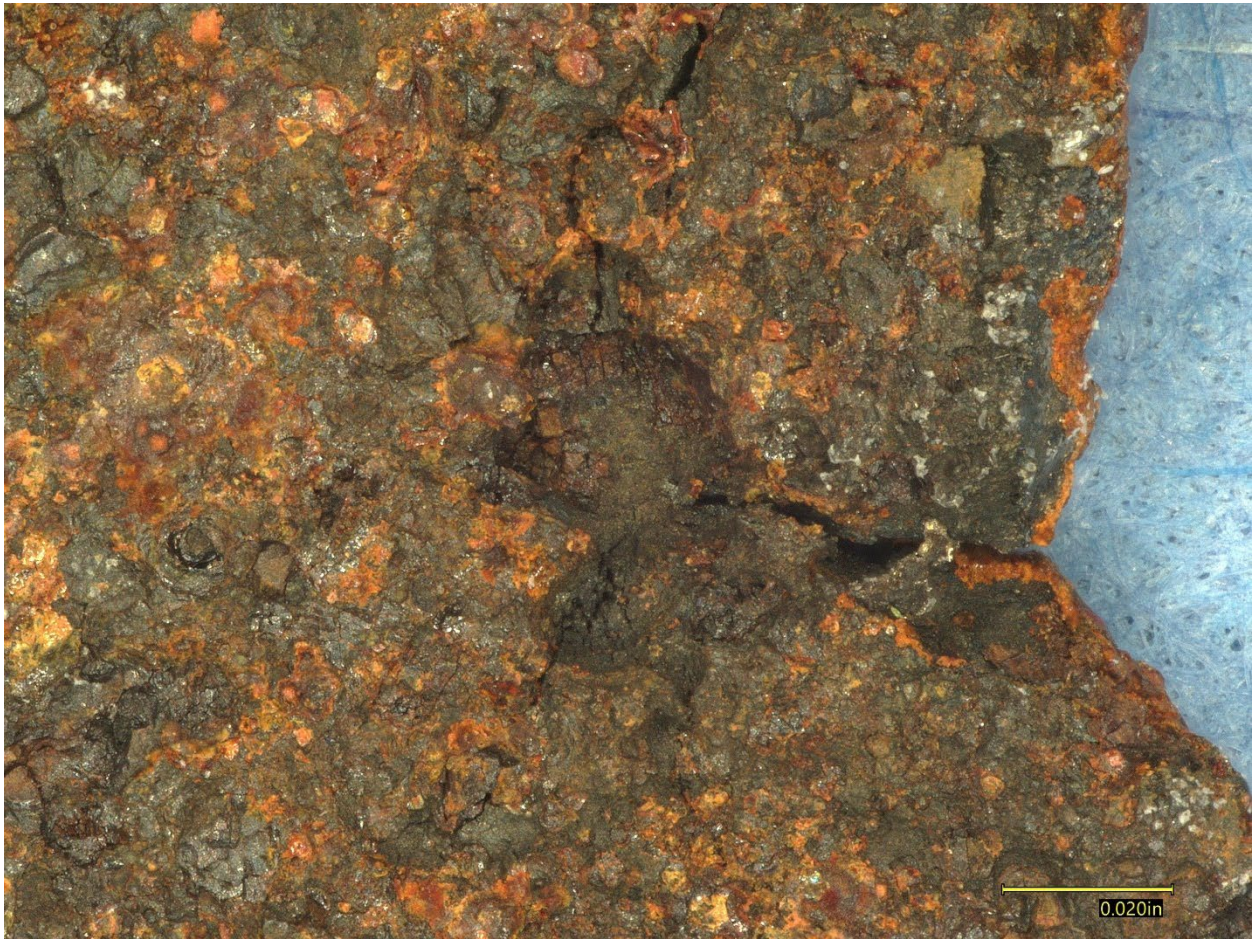


Figure 22. Closer view of a pit in Figure 23.



Figure 23. Bright field (BF) optical micrograph of a cross section through the thinnest part of the landing gear leg collar side fracture (~25X, as polished).

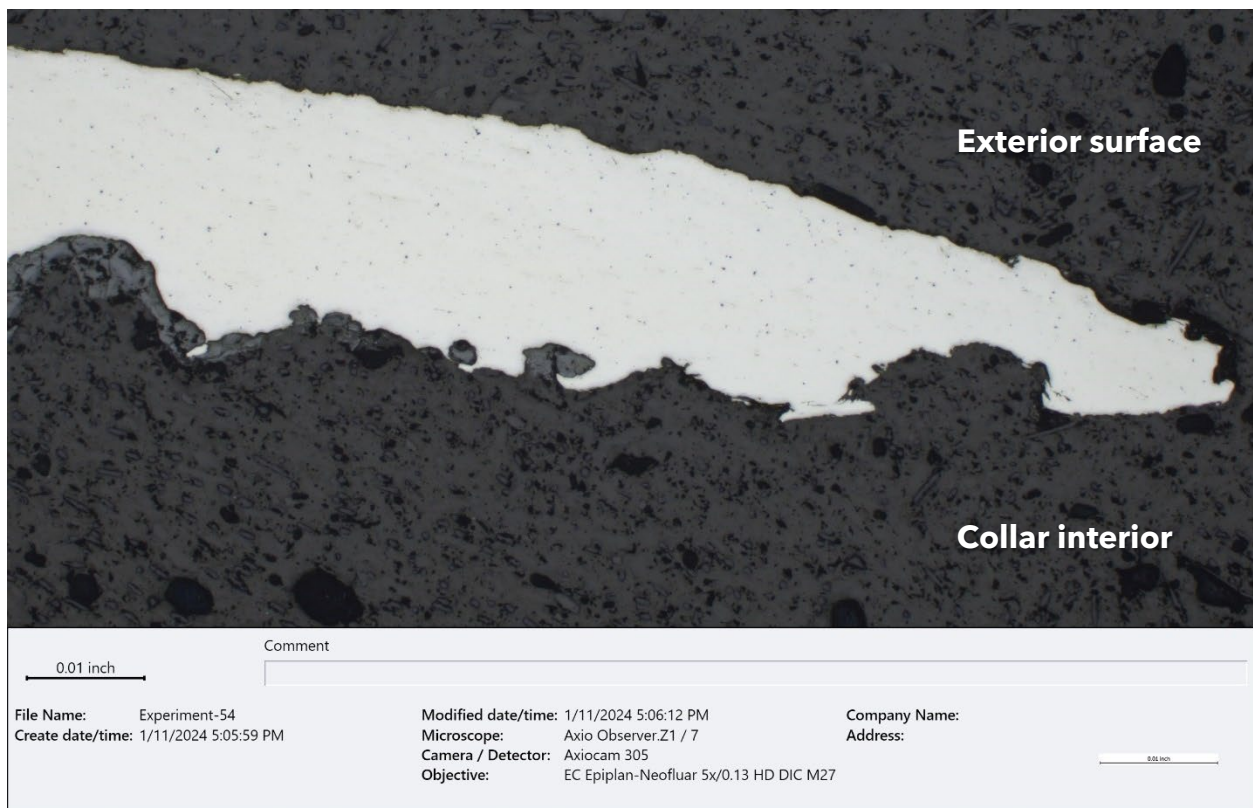


Figure 24. BF optical micrograph of the tip of the cross section in **Figure 23**, showing areas of pitting in the interior surface (~100X, as-polished).

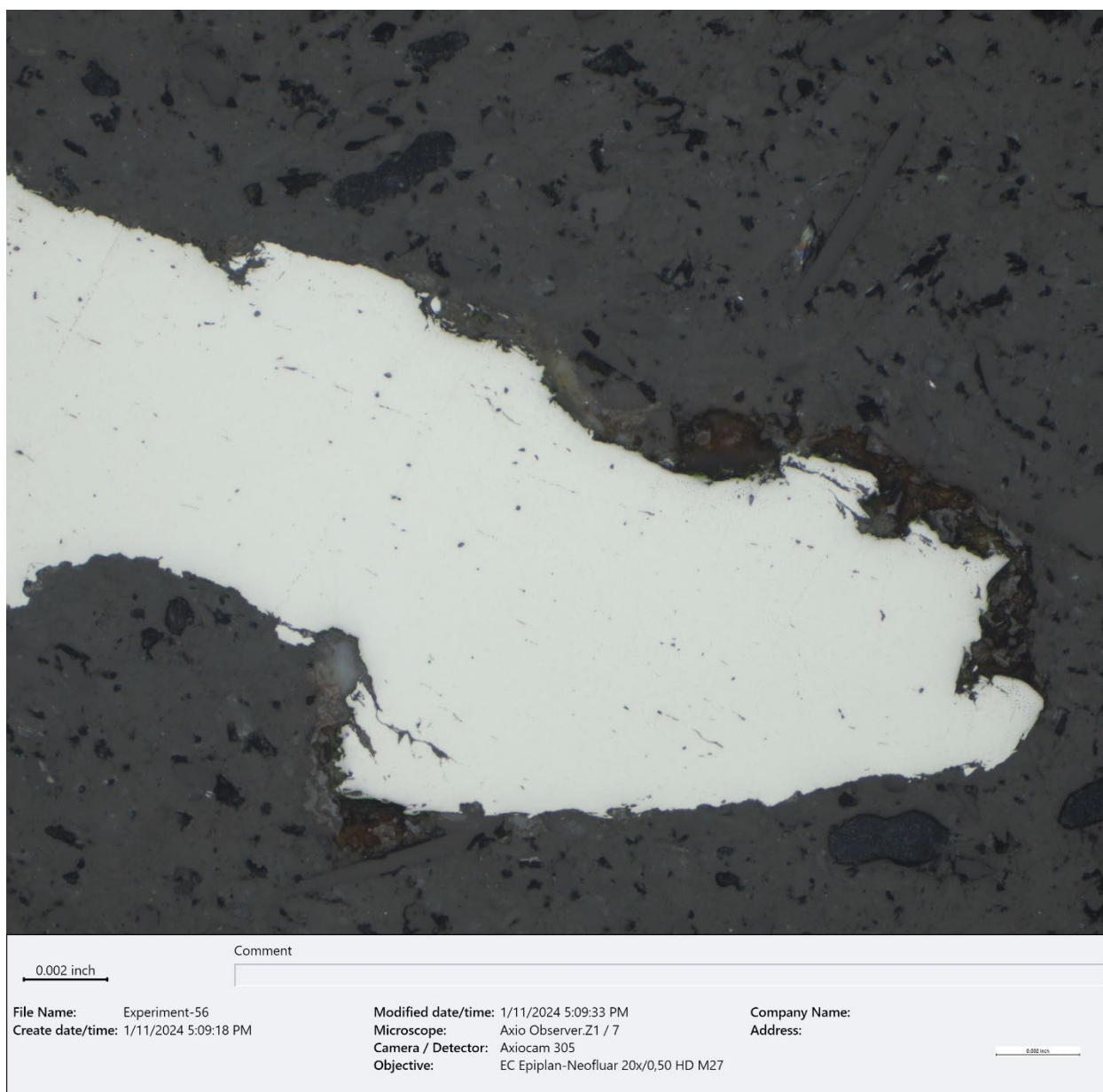


Figure 25. BF optical micrograph of the pit in **Figure 24**, showing pitting along the surfaces, with internal cracks emanating from the interior pit (~200X, as-polished).

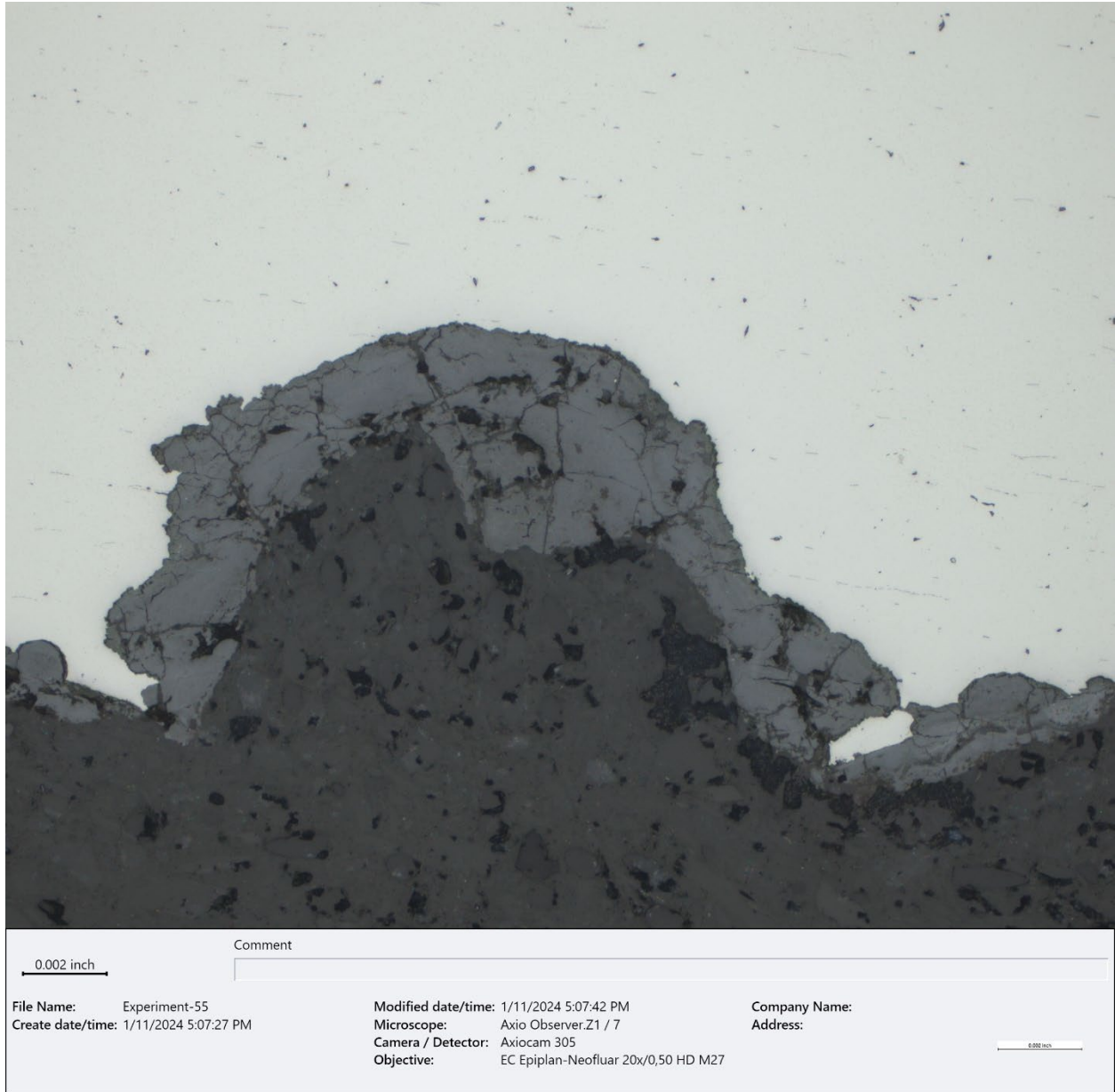


Figure 26. BF optical micrograph of a interior surface pit, showing nonmetallic compounds (light gray) inside the pit (~200X, as-polished).

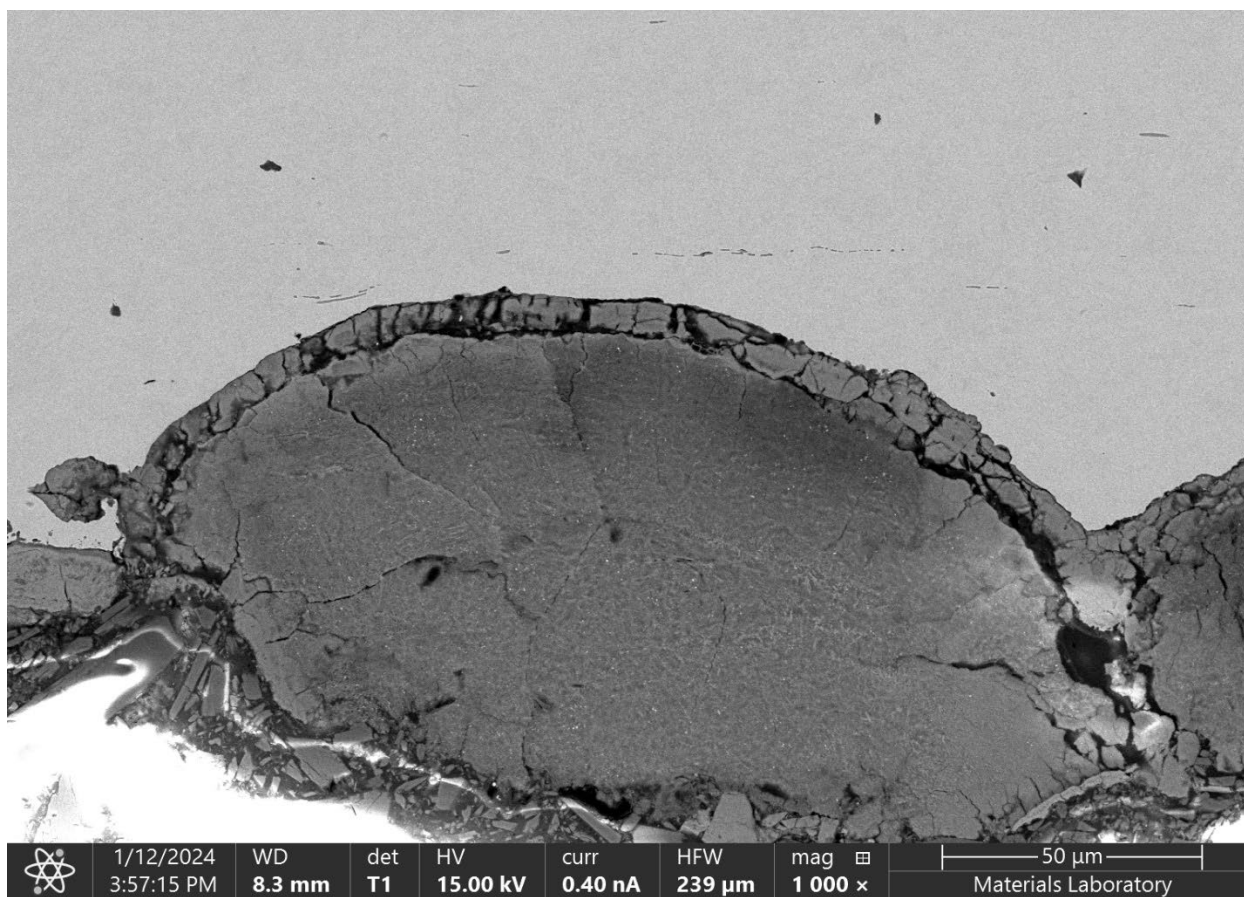


Figure 27. BE micrograph of a smaller, but intact pit, showing the non-metallic corrosion compounds in darker gray.

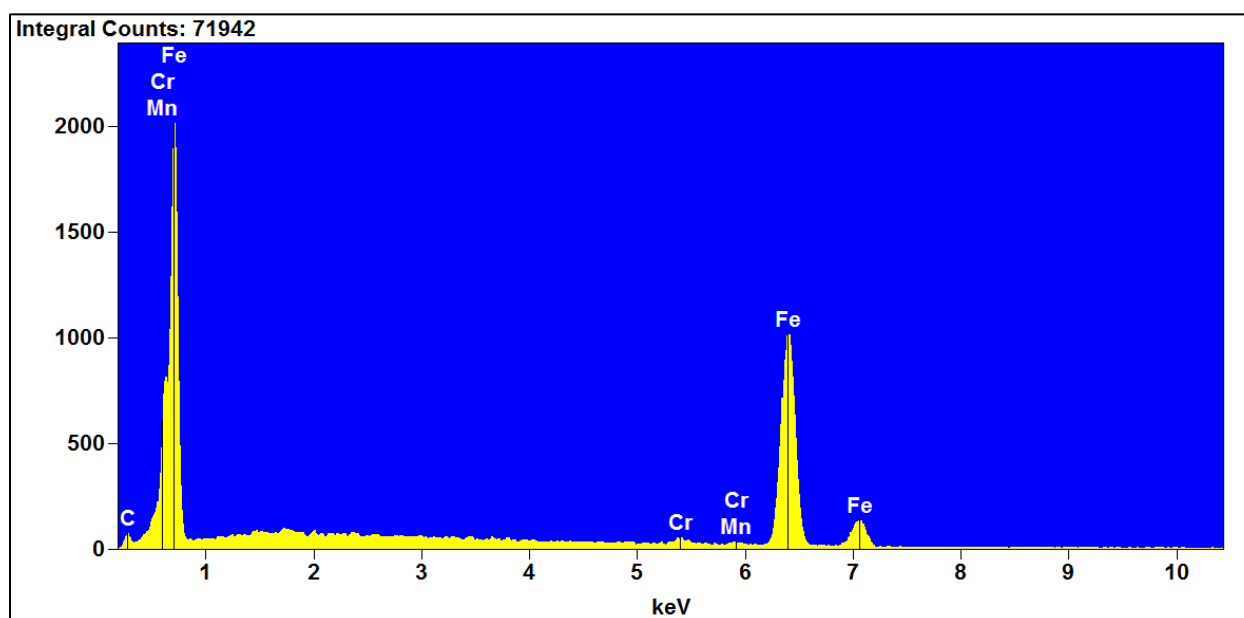


Figure 28. EDS spectrum of a typical area of the cross sectioned landing gear remnant (lighter colored) in **Figure 27**.

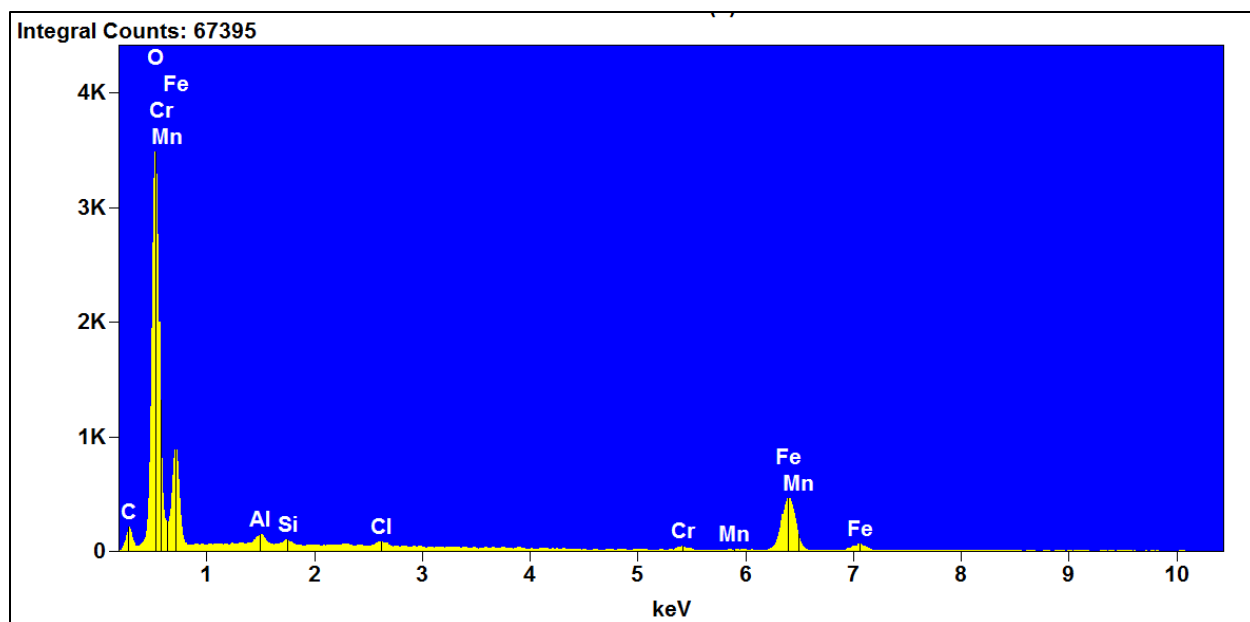


Figure 29. EDS spectrum of the nonmetallic (dark gray) material in the corrosion pit in **Figure 27**.