

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594



April 16, 2020

MATERIALS LABORATORY FACTUAL REPORT

Report No. 19-077

1. ACCIDENT INFORMATION

Place : Newport News, Virginia
Date : May 9, 2019
Vehicle : Hawker Siddeley Hunter MK58; N343AX
NTSB No. : ERA19LA169
Investigator : Eric Alleyne, AS-ERA

2. COMPONENTS EXAMINED

Main Landing Gear Upper Trunnion Strut (Right & Left)
Right Main Landing Gear Component
Part Number: 11884.S.B01
SN: 39/61/809
Tracking: 21319
Left Main Landing Gear Component
Part Number: 11884.P.B01
SN: ACC/87/59/145
Tracking: 20075

3. DETAILS OF THE EXAMINATION

On May 9, 2019, at 1015 eastern daylight time, a Hawker Siddeley Hunter MK-58 was substantially damaged during a runway excursion at Newport News-Williamsburg International (PHF), Newport News, Virginia while practicing touch-and-go landings. After the third touch-and-go landing, a hydraulic issue was observed, and the pilot decided to conduct a no-flap landing on the next approach. The airplane touched down at approximately 180 knots indicated airspeed and the right main landing gear collapsed immediately upon touch down. The airline transport pilot was not injured. The right main landing gear was removed and sent to the NTSB Materials Laboratory for examination along with the left main landing gear.

According to the service history record, the components submitted for examination were last inspected on March 27, 2018. Based on discussions about the inspection procedure with a representative from the overhaul facility, components are disassembled – including removal of pivot pins and chemically stripped of topcoat and primer prior to being inspected non-destructively. A penetrant survey method is used over all part

surfaces and supplemented with an ultrasonic inspection method over the forging seam on the outer surface which divides the main fitting in half about a plane through the strut and pivot axes. Between overhauls, an eddy-current inspection method is used every 20 landing cycles to detect flaws over the forging seam on the outer part surface. If parts meet non-destructive inspection acceptance criteria, the anodize coating is restored to blueprint requirements if removed, pivot pins are press-fit installed, other hardware installed, and primer and topcoat restored.

Figure 1 shows the main fitting of the right main landing gear upper trunnion strut, as received with some additional hardware installed including two press-fit 2.25 inch diameter steel pivot pins, one of two retaining bolts for securing the pivot pins, and two bronze flanged bushings with spacers on the pivot pins. The main fitting component, an aluminum alloy forging, fractured into two pieces through the aft pivot pin bore and strut bores. Both pivot pins were retained within the smaller fragment. The aft pivot pin within the fractured bore was dislodged approximately 0.5-0.6 inches axially aft as evidenced by axial scratches on the pin and bore surfaces, misaligned holes for the absent retaining bolt, as well as a deposit of yellow squeeze-out from a faying surface sealant applied between the main fitting bore and pivot pin which indicated the forward-most location of the edge of the pivot pin prior to being dislodged.

Figure 2 shows the similar left main landing gear, as received, with pivot pins still installed. The left main fitting fractured into two fragments through the top of the strut bore between the pivot pins, with the aft pivot pin retained in the smaller fragment and the forward pivot pin retained in the larger fragment. A small third fragment from the free surface near the strut-to-trunnion radius was also recovered that exhibited evidence of plastic deformation. A single bronze flanged bushing labeled "LH" as shown in figure 2c was submitted with the components and showed evidence of ductile fracture from a notch feature at the edge of the flange which continued into the sleeve through a hole feature and finally arrested at another elongated hole feature approximately 0.75 inches from the base of the flange.

Figure 3 shows additional hardware that was submitted and not identified to a right- or left-hand component.

There was dirt and debris on the main landing gear components and fracture surfaces that was carefully removed in the laboratory using a combination of compressed air, soft bristle brush, water, and acetone to facilitate visual examination. On the right main landing gear component, two apparent thumbnail¹ shaped crack features consistent with pre-existing progressive crack fronts were observed on the main fitting fracture surface at the base of the aft pivot pin bore. The thumbnail cracks originated near the corner radius formed at the base and sidewall of the pivot pin bore and progressed through the part towards the outer part surface and strut bore surface.

¹ Thumbnail is a term used throughout this report to describe the semi-circular or semi-elliptical shape of a pre-existing flaw in a component. It is a region of slow crack growth.

On the left main landing gear component, the fracture surface was rough and exhibited many tear ridges and shear lip features consistent with fracture due to tensile/bending overstress. Pre-existing crack features were not observed.

The remainder of this report focuses on the fractured right main fitting due to the pre-existing crack features that were observed.

X-ray Fluorescence (XRF) spectroscopy was performed on the main fitting using an Olympus Vanta-VCR hand-held alloy analyzer and results were consistent with a 7xxx series aluminum alloy containing Zinc and Magnesium as the primary alloying elements.

Local post-accident impact damage to the fracture surface of the larger main fitting fragment obscured the pre-existing crack origins so the mating smaller fragment was used for further fractographic evaluation. Figure 4 shows the fracture surface of the smaller fragment of the right main fitting and shows the pre-existing thumbnail crack features with the general direction of crack propagation. The larger of the two pre-existing thumbnail cracks was located on the bottom/inboard (extended/retracted landing gear position respectively) area of the pivot pin bore and progressed along an approximate plane formed by the strut and pivot pin axes. This feature is referred to as "pre-existing crack 1" for the remainder of this report. The smaller of the two thumbnail features was located on the outboard/bottom (extended/retracted landing gear position respectively) area of the pivot pin bore, approximately 90° around the bore in the outboard direction relative to pre-existing crack 1, and progressed approximately normal to the plane formed by the strut and pivot pin axes. This feature is referred to as "pre-existing crack 2" for the remainder of this report. From both pre-existing crack boundaries, fast fracture due to overstress continued to propagate aft along the pivot pin bore to the free edges of the part and forward around both sides of the strut bore with final separation where crack 2 met crack 1 approximately 180° around strut bore, slightly inboard/upward (extended/retracted landing gear position respectively), relative to the origins at the aft pivot pin bore. Shear lips were observed in this area on the free edges of the part. Small shear lips are present along strut outer diameter and inner diameter in the overstress region. Shear lip size increases closer to termination of the overstress region.

Figure 5 shows an annotated closer view of pre-existing crack 1 from a section excised from the smaller right main fitting fragment using wet abrasive cut-off wheel machines. The excised sample was ultrasonic cleaned using acetone. Pre-existing crack feature 1 exhibited a flat, bright sparkly gray, and somewhat granular surface appearance. Fracture ridges and radial features appeared to emanate from origins near the pivot pin bore corner radius. Pre-existing crack 1 exhibited multiple origins with at least one at the main fitting bore base and another on the sidewall, both near the shared corner radius. A feature similar to a fatigue crack ratchet mark between these origins spanned the ligament between the corner radius of the pivot pin bore and the sidewall surface of the strut bore. The pre-existing crack measured approximately 1.4 inches along the pivot pin bore sidewall, 1.0 inches maximum depth from the sidewall, 0.9 inches along the pivot pin bore base, 0.8 inches maximum depth from the base, and a maximum depth of approximately 1.1 inch from the pivot pin bore corner radius into the main fitting. A crack arrest line or

beach mark, as highlighted in figure 5, was observed from approximately 0.5 – 1.0 inch along sidewall where the crack front progressed aft along the pivot pin bore sidewall. A topographical difference was demarcated at this feature, as the thumbnail appearance is slightly darker and rougher after the beach mark as compared to the preceding crack morphology. Outside of pre-existing crack 1, the fracture surface topography was dull, rough, and exhibited chevron mark features consistent with fast fracture due to overstress.

Figure 6 shows an annotated closer view of pre-existing crack 2 from a section excised from the smaller right main fitting fragment using wet abrasive cut-off wheel machines. The excised sample was ultrasonic cleaned using acetone. Pre-existing crack feature 2 exhibited a similar flat and bright gray appearance to pre-existing feature 1 although with slightly less granular texture. Outside of this feature, topography was dull and rough, consistent with fast fracture due to overstress. Several fracture ridges and radial features emanated from what appears to be a single origin point at the corner radius of the pivot pin bore base. The bright gray pre-existing crack measured approximately 1.7 inches wide by 0.9 inches in depth relative to the origin at its largest point. The crack front progressed from the corner radius of the pivot pin bore base towards the free outer surface of the main fitting. The pre-existing crack front never reached the outer surface of the main fitting but did arrest along the surface of the interior strut bore at depths of approximately 0.9 inches and 1.4 inches from the origin. Two visible crack arrest features or beach marks demarcating a slightly darker gray topography (still noticeably brighter than subsequent fast fracture region) were observed extending the crack along the strut bore surface another 0.2 and 0.3 inches, respectively. Secondary cracks parallel to the fracture surface were observed on the adjacent pivot pin bore corner radius and top surface of the strut bore.

The fracture surfaces of the cleaned specimens were examined using a Zeiss Auriga field emission scanning electron microscope (SEM). The micrograph shown in Figure 7 was taken near an origin of pre-existing crack 1 at the pivot pin bore sidewall. Topography was relatively flat and consisted primarily of planar features. Intergranular features were observed within the pre-existing crack boundaries especially near the origins as viewed in figure 8. Outside of the pre-existing crack front, the topography was less planar and exhibited equiaxed dimple features consistent with tensile overstress. Micrographs shown in figures 9 and 10 were taken at the pre-existing crack border and show a transition from planar/intergranular fracture to a dimpled fracture consistent with tensile overstress. Although crack arrest features were visually observed within the pre-existing cracks, no evidence of fatigue striations were observed at higher magnification during SEM examination.

In conjunction with SEM examination, energy dispersive x-ray spectroscopy (EDS) was used to identify chemical constituents near the fracture origin. Major peaks of Aluminum, Zinc, Magnesium, and Oxygen were detected consistent with 7xxx series aluminum alloys and aluminum oxide corrosion product. Minor peaks of Carbon, Calcium, Silicon, and Sulfur were also detected which is consistent with some residual amount of organic matter, soil, and/or aircraft lubricants that remained on the fracture surface post cleaning. Trace Chlorine peaks were detected in local areas near fracture origins,

consistent with a corrosive media required to initiate stress corrosion cracking. The EDS spectrum that was recorded is shown in figure 11.

After sectioning the pre-existing crack areas from the right main fitting, the portion of the displaced aft pivot pin closest to the base of the pivot pin bore was back-cut and carefully removed from the main fitting fragment.

The aft pivot pin bore surface of the fractured right main fitting was examined. The sidewall surface adjacent to pre-existing crack 1 had areas of corrosion pitting as shown in figure 12. Three larger circular sites approximately 0.10 to 0.15 inch diameter, two elliptical sites approximately 0.10 by 0.05 inches, and one site less than 0.05 inches in diameter occupied an area less than 0.15 inch below the fracture surface spanning from 0.12 to 0.90 inch from the corner radius of the pivot pin bore. Another grouping of similarly sized corrosion sites was observed 1.3 to 1.6 inches aft of the pivot pin bore base on the sidewall surface within 0.35 inch of the fracture surface. Comparable localized corrosion sites were observed at the mating fracture pivot pin bore sidewall, however, measurement at this area was difficult due to post fracture smearing and deformation damage to the fracture and adjacent sidewall surfaces at this location.

An anodic coating was specified for the main fitting component. There was a section of disrupted coating along the pivot pin bore sidewall, as visible in figures 12 and 13. The section of disrupted coating was observed approximately 0.12 inches from the bore base, consistent with the location of the inserted edge of the aft pivot pin prior to being dislodged, and spanned approximately 90° around the bore sidewall circumference centered about the fracture surfaces of pre-existing crack 1. The area of disrupted coating extended from this location aft approximately 2.5 inches, tapering slightly toward the bore opening. The area of disrupted anodic coating was consistent with a circumferential machining pattern on the bore sidewall surface as the coating was still intact in machine tool grooves, however the peaks were shiny and smeared to reveal exposed bare metal. The missing coating is consistent with localized relative motion and wear between the pivot pin and the main fitting bore sidewall. There was another location on the pivot pin bore base where anodic coating was missing approximately 0.2 square inches in area. This was confirmed with a contact resistance measurement using a DM-350A digital multi-meter. The area appeared visibly off-color relative to surrounding areas and registered a low electrical resistance (missing coating) where surrounding areas registered an infinite resistance (intact coating). This area did not exhibit any evidence of wear or relative motion between surfaces observed in this area.

The area contained within and adjacent to the disrupted anodic coating contained flowing stain features consistent with evidence of fluid ingress, puddling/retention, and subsequent evaporation/egression. These features were on the sidewall and base areas of the bore as shown in figures 12a and 12b. Ultrasonic cleaning using acetone did not remove these features.

An indentation on the aft pivot pin bore sidewall was observed under magnification at the location where the edge of the aft pivot pin would have been prior to

being dislodged. The indentation also aligned with the forward boundary of disrupted anodic coating near the base of the pivot pin bore and extended circumferentially a short distance away from the fracture surface. It is indeterminate whether this indentation was caused at the time of the accident or was pre-existing, such as during the pivot pin press-fit installation process or a hard landing event. The pivot pin was found retained in the trunnion portion of the fractured main fitting, however, dislodged approximately 0.5 – 0.6 inches aft. The corrosion sites on the bore sidewall between the edge of the pivot pin as-received and the location where the pivot pin was prior to being dislodged were observed under magnification and axial parallel scratches approximately 0.5 – 0.6 inches in length were observed emanating from these sites and extending aft. These scratches can be seen in figure 12 and 13. This observed condition was consistent with the corrosion sites being present prior to the pivot pin being dislodged.

Figure 13 shows a digital micrograph taken normal to the aft pivot pin bore sidewall surface adjacent to the fracture surface at pre-existing crack 1. The pivot pin bore base and corner radius is visible on the left side of the image and the fracture surface is at the top of the image. Small secondary cracks oriented parallel to the fracture surface were observed on the sidewall surface just below the fracture surface. These flaky, layered features were consistent with features typical of stress corrosion cracking.

Figure 14 shows a photograph of the forward section of the aft pivot pin that was removed from the fractured bore as the pre-existing crack features were excised. Local areas of staining which closely resembled the corrosion sites observed on the faying surface of the pivot pin bore were observed on the steel pin at the location of pre-existing crack 1. These features observed on the steel pin were not removeable with ultrasonic cleaning in acetone. The faying surface of the pin contained residual yellow sealant that was also present on the pivot pin bore sidewall surface. The fractured retaining bolt fragments submitted are also shown in this photograph. One fragment contained the hex head and a portion of the shank of length consistent with the main fitting thickness at the location of the bolt hole. The other fragment contained a portion of the shank of length consistent with the pivot pin outer diameter. The remainder of the pin containing a portion of the shank and threaded nut end was not recovered. The fragment sizes and fractures were consistent with shear fracture and indicate the bolt was present at the time the pivot pin was dislodged.

Michael Meadows
Materials Engineer

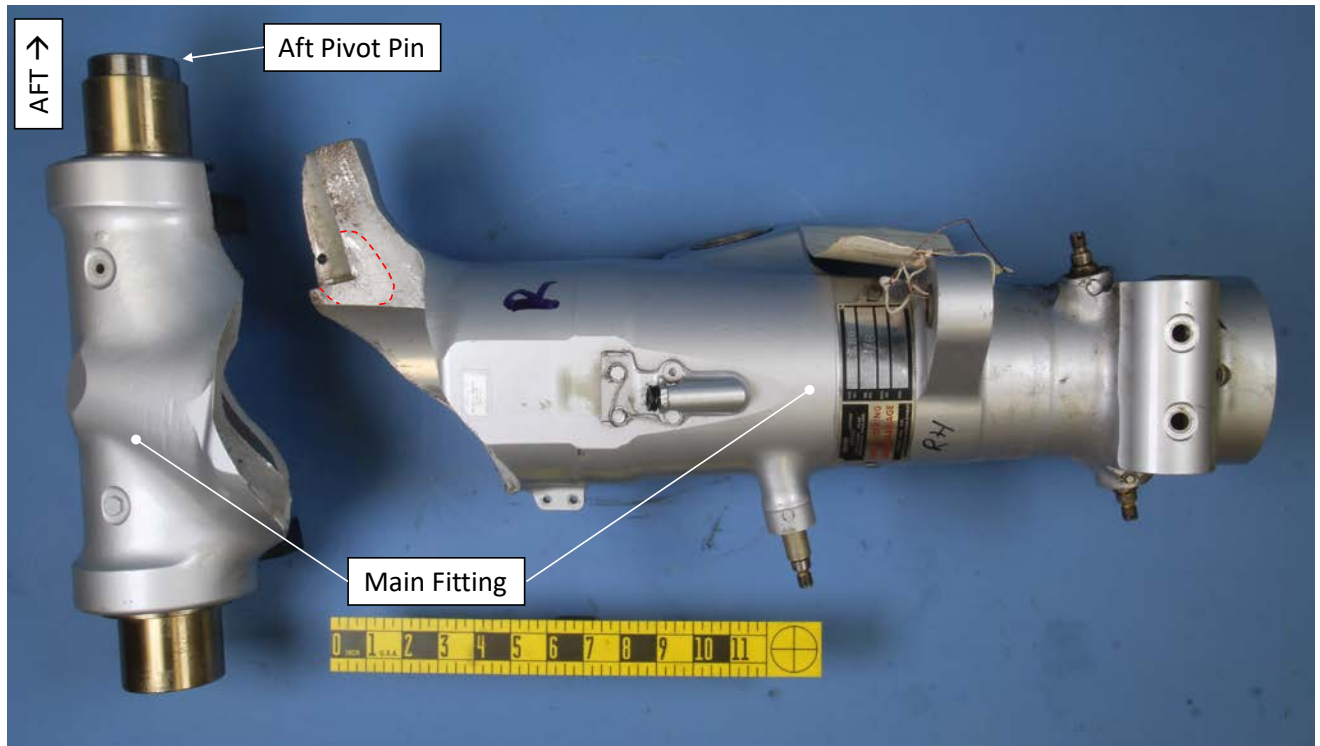


Figure 1a: Overall view of the right main landing gear as-received. The component fractured through the aft pivot pin bore of the trunnion and around the strut bore. Both pivot pins were retained in the fitting, however the aft pivot pin was dislodged approximately 0.6 inches. Bronze bushings were still installed over the pivot pins. One of the pre-existing thumbnail crack features (pre-existing crack 1) visible in this view is highlighted by the red dashed line.

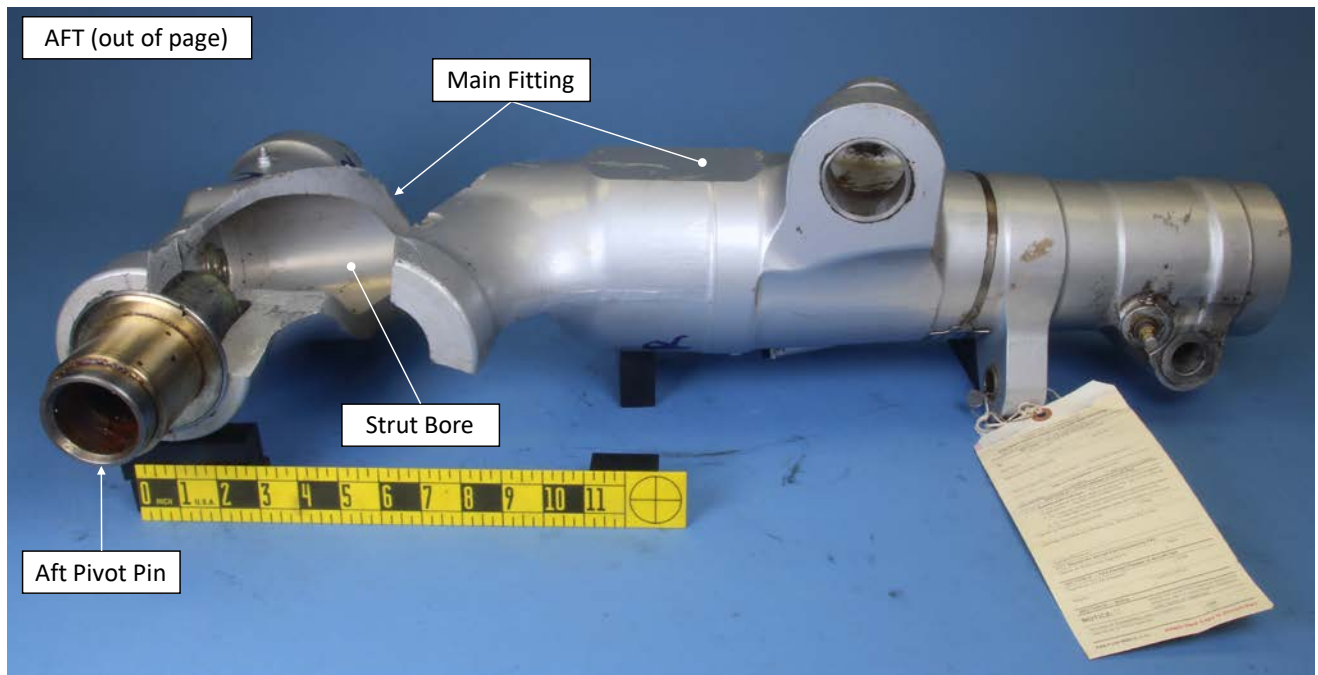


Figure 1b: Forward-Aft view of the fractured right main landing gear as-received. The component fractured through the aft pivot pin bore of the trunnion and around the strut bore. Both pivot pins were retained in the fitting, however the aft pivot pin was dislodged approximately 0.6 inches. Bronze bushings were still installed over the pivot pins. The pre-existing thumbnail crack features are not easily distinguishable from this perspective.

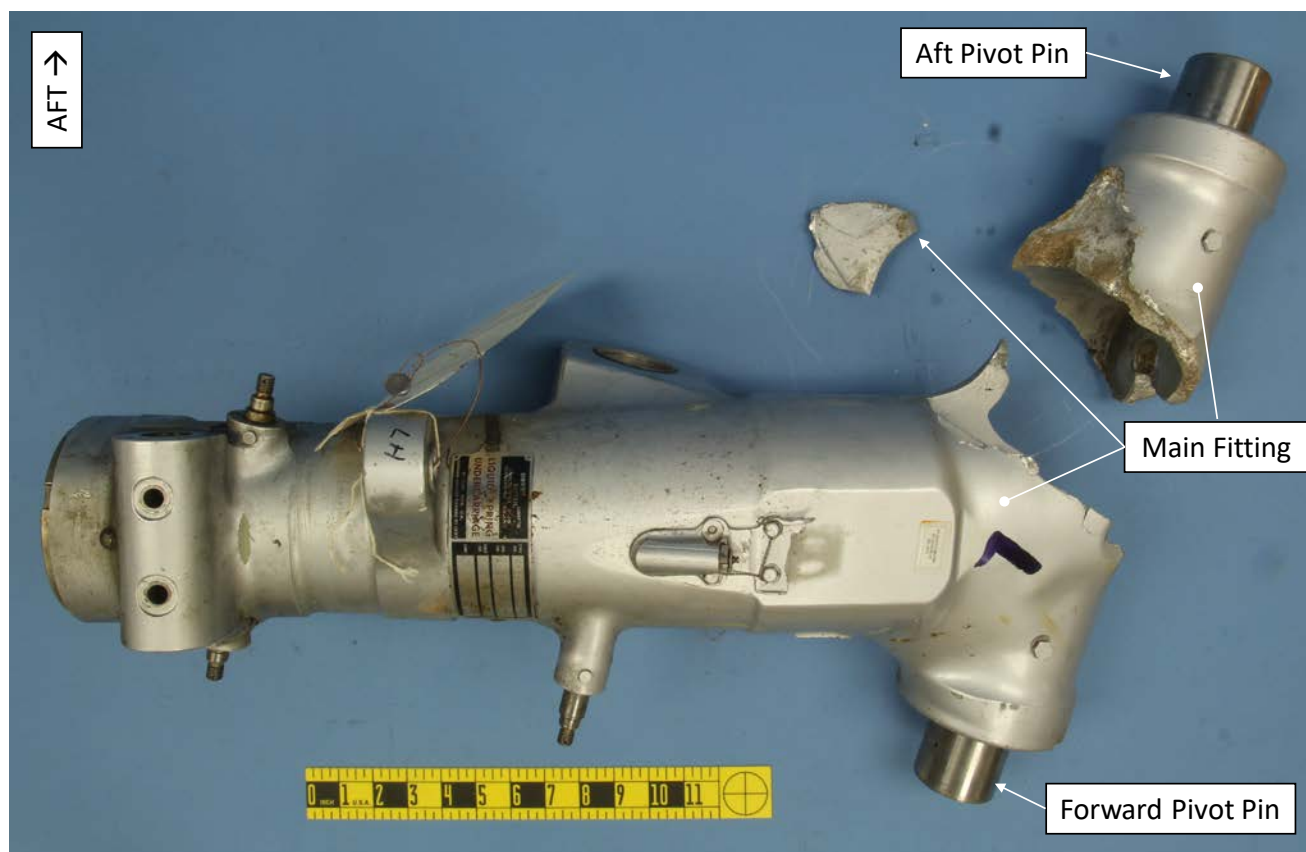


Figure 2a: Overall view of the left main landing gear as-received. The component fractured through the top of the strut bore between the pivot pins, with the aft pivot pin retained in the smaller fragment and the forward pivot pin retained in the larger fragment. Both pivot pins were retained in the fitting and neither appeared to show evidence of being dislodged. A smaller third fragment was recovered and fits the profile of the outer part surface near the strut-to-trunnion run out radius and forging seam. There were no observed pre-existing crack features observed and the fracture surface exhibited dull, rough ridge features, plastic deformation, and shear lip features over majority of the surface.

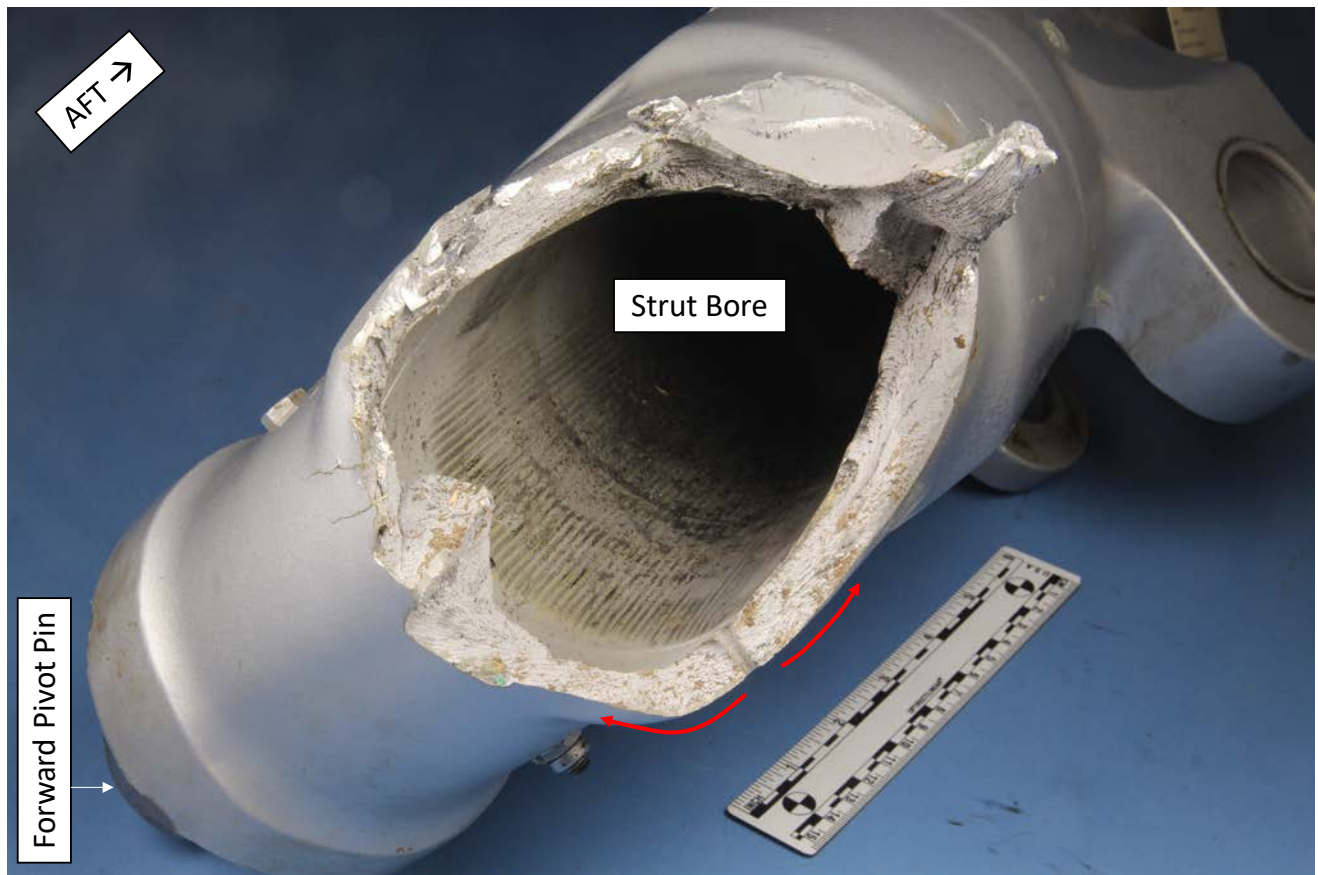


Figure 2b: View of the left main landing gear fracture surface looking down the strut bore. Dull, rough ridges, chevron marks, and shear lip features observed are consistent with tensile/bending overstress. Red arrows indicate crack propagation direction where evident.



Figure 2c: Photograph of a fractured bronze bushing received with the left main landing gear. The bushing was separate from the landing gear component as-received. The crack began at a notch feature in the flange of the bushing and arrested at an elongated hole feature in the sleeve of the bushing. Plastic deformation of the flange and sleeve is apparent.

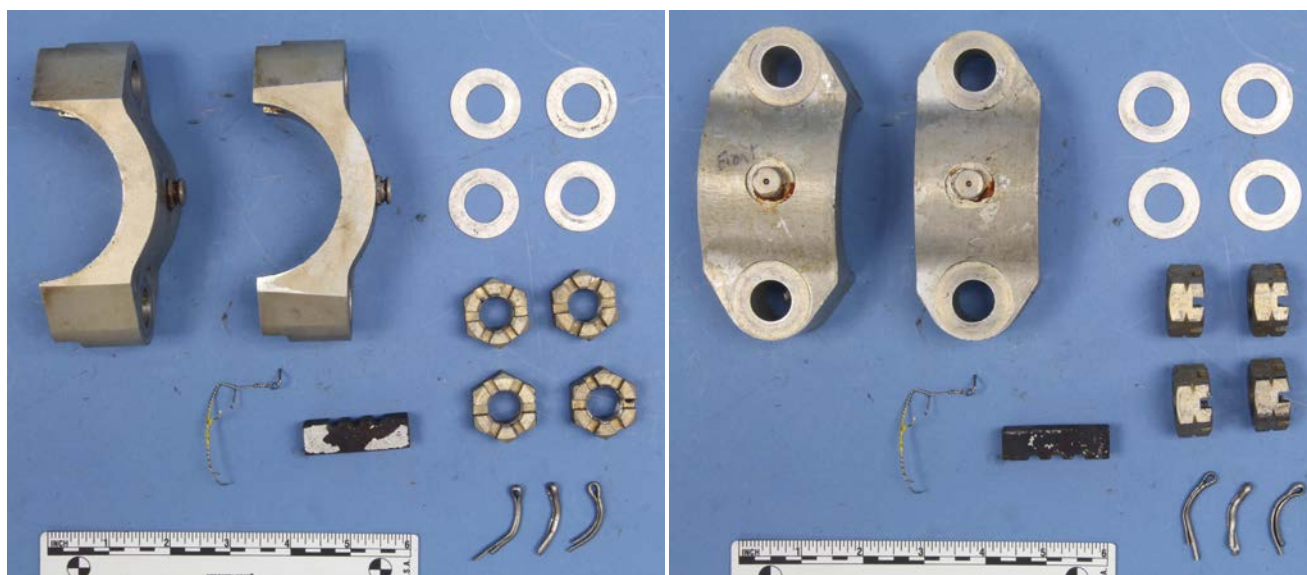


Figure 3a: Additional hardware received was not identified or clearly assignable to a particular landing gear component. The view on the right shows the same components as the view on the left with rotated or flipped orientation. These components were not documented further than this photograph.

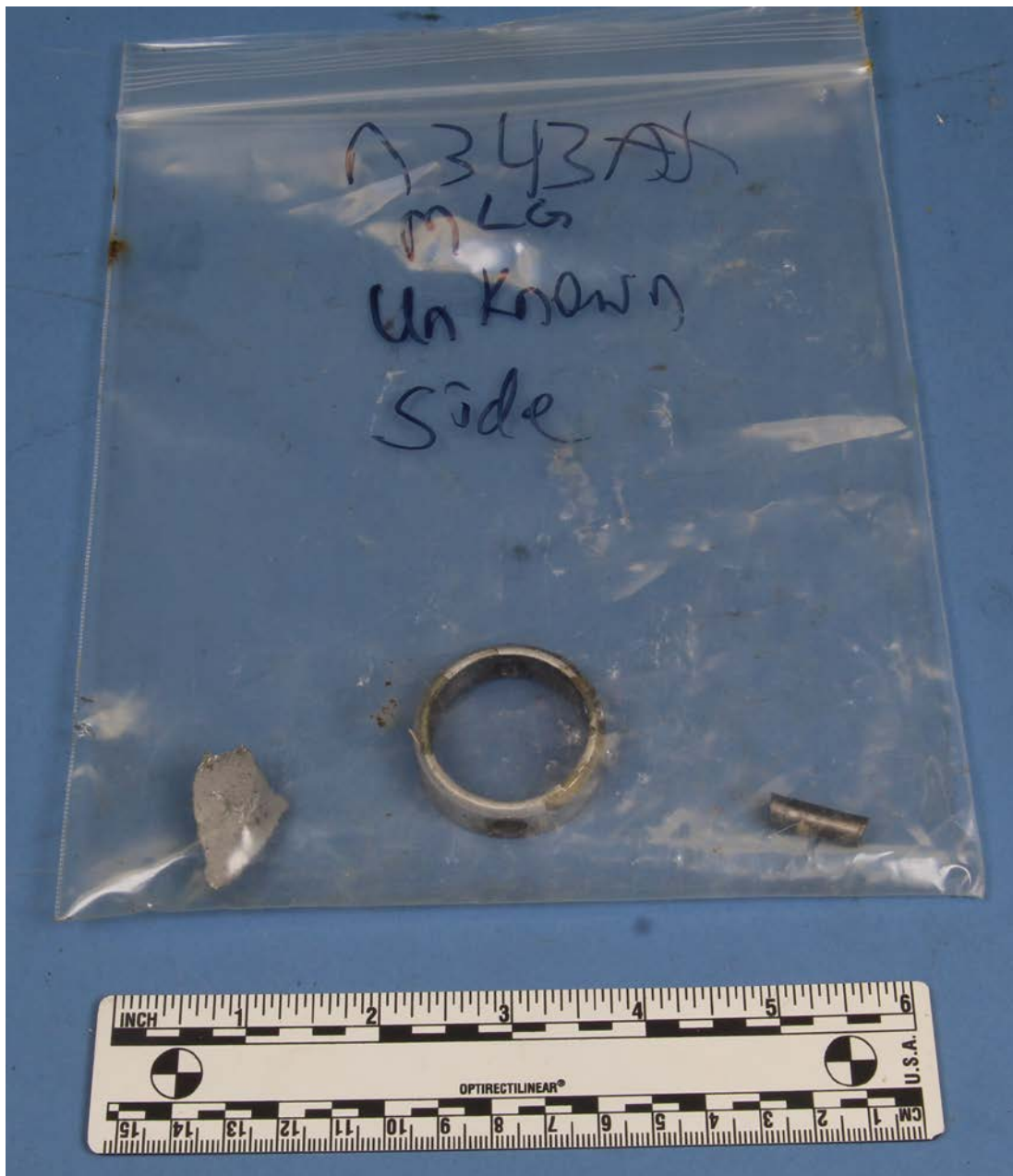


Figure 3b: Additional hardware received was not identified or clearly assignable to a particular landing gear component and was not documented any further.

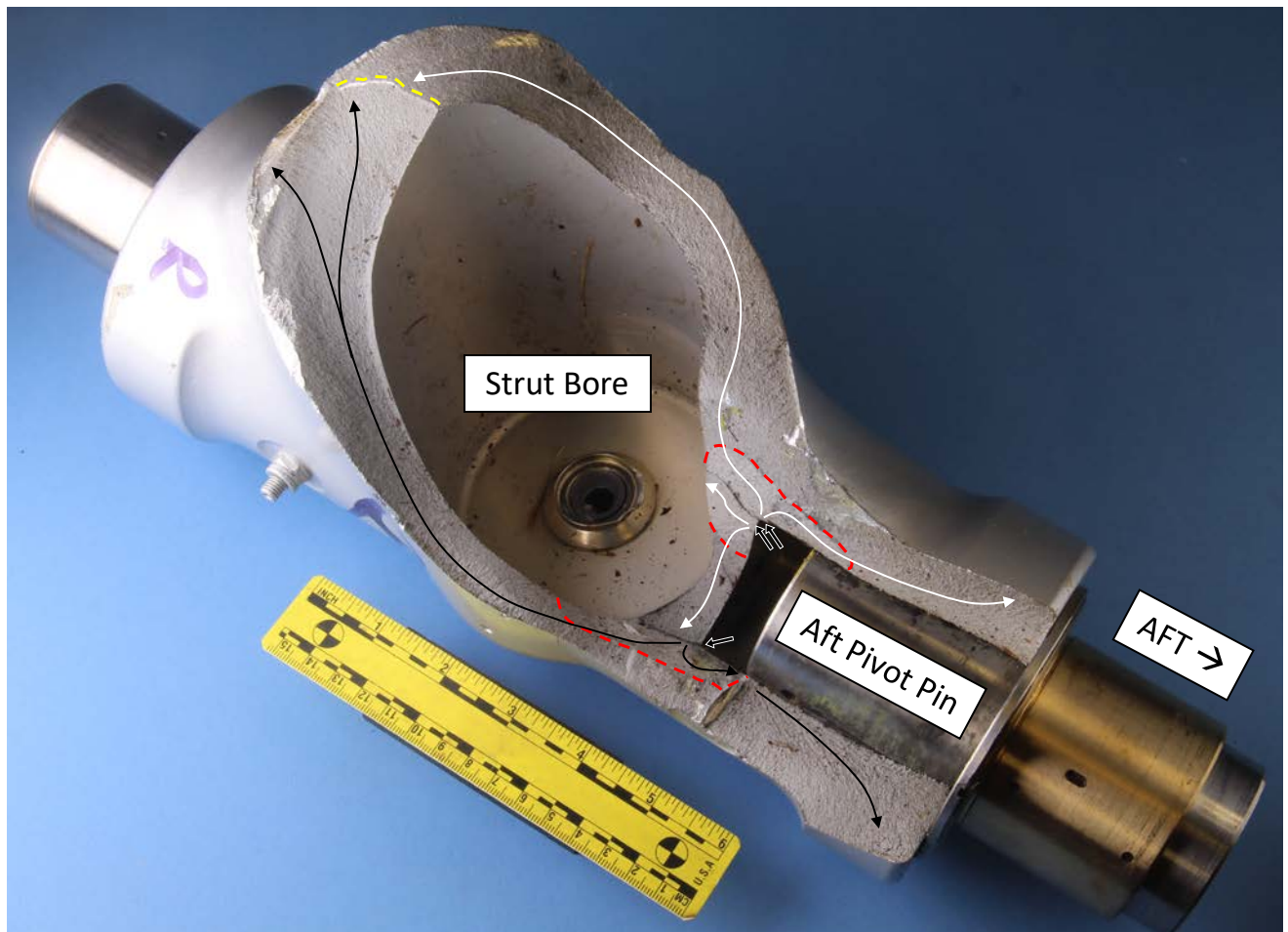


Figure 4: Fracture surface of the smaller fragment of the right main fitting containing the trunnion area. The red dashed lines show the approximate boundaries of the pre-existing cracks. Pre-existing crack 1 is oriented above the aft pivot pin in this photo and has white arrows emanating from the origin. Pre-existing crack 2 is oriented below the aft pivot pin in this photo and has black arrows emanating from the origin. These arrows show the direction of propagation. The unlabeled black arrows outlined in white indicate approximate locations of the pre-existing crack origins.

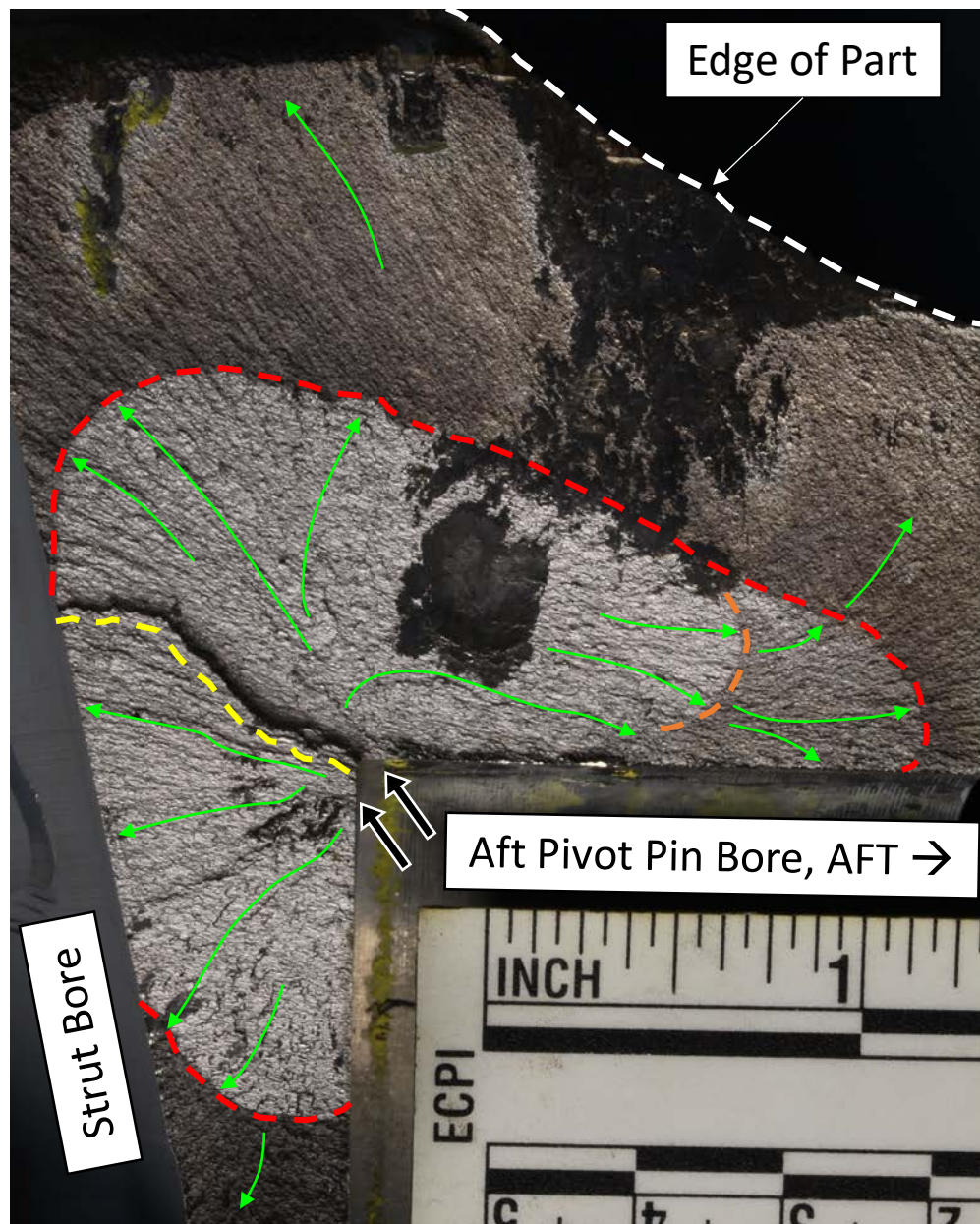


Figure 5: A closer photograph of pre-existing crack location 1 using oblique lighting to highlight fracture features. The red dotted line indicates the visible boundary of the pre-existing progressive crack feature. The bold black arrows outlined in white indicate the approximate location of the crack origins. The green arrows highlight the approximate direction of crack propagation. The yellow dotted line highlights a ratchet mark feature. The orange dotted line indicates a beach mark feature and a topographical demarcation in the pre-existing crack front.

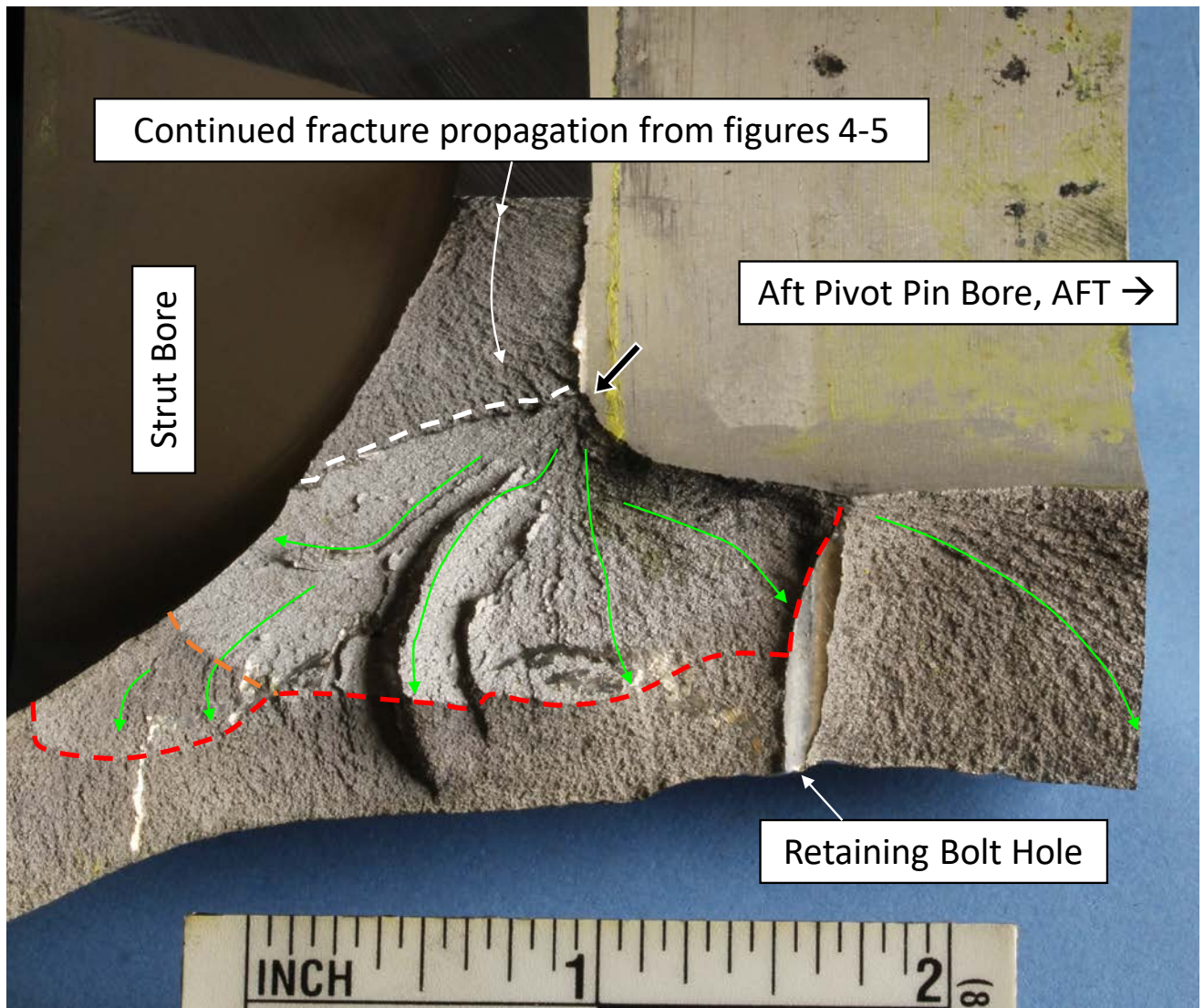


Figure 6: A closer photograph of pre-existing crack location 2 using oblique lighting to highlight fracture features. The red dotted line indicates the visible boundary of the pre-existing progressive crack feature. The bold black arrows outlined in white indicate the approximate location of the crack origins. The green arrows highlight the approximate direction of crack propagation. The orange dotted line indicates a beach mark feature and a topographical demarcation in the pre-existing crack front. The white arrow and dotted line highlight the direction and termination of the fracture originating from pre-existing crack 1.

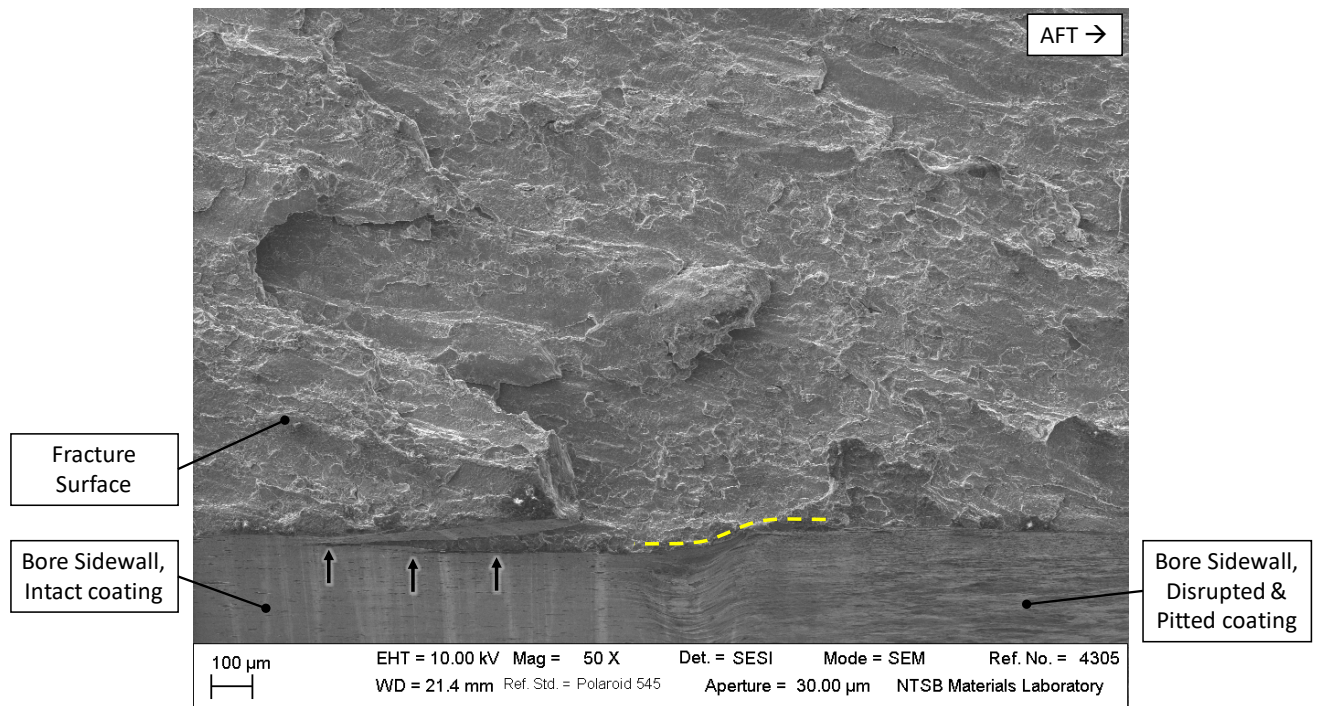


Figure 7: A scanning electron micrograph of the pre-existing crack 1 fracture surface at the pivot pin bore sidewall. Fracture topography was relatively flat and consisted primarily of planar features. The jog of locally deformed pivot pin bore sidewall surface highlighted with the yellow dashed line corresponded with the location of the inserted edge of the pivot pin prior to being dislodged. To the right of the jog was disrupted anodic coating and local pitting corrosion of the sidewall. To the left of the jog were secondary cracks in the sidewall oriented parallel to the fracture surface as indicated by the unlabeled arrows.

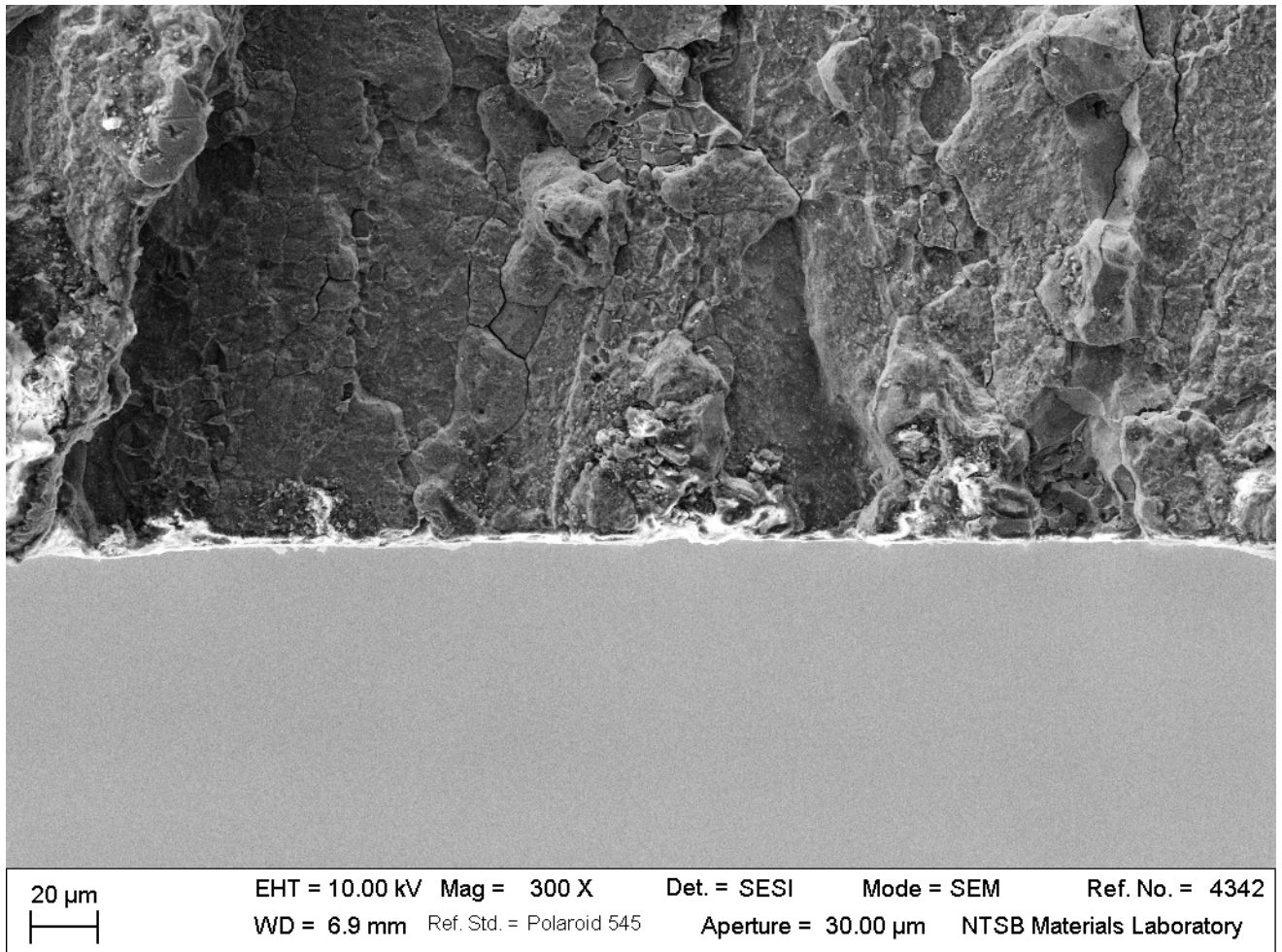


Figure 8: A higher magnification scanning electron micrograph of pre-existing crack 1 fracture surface near origin showed intergranular fracture features.

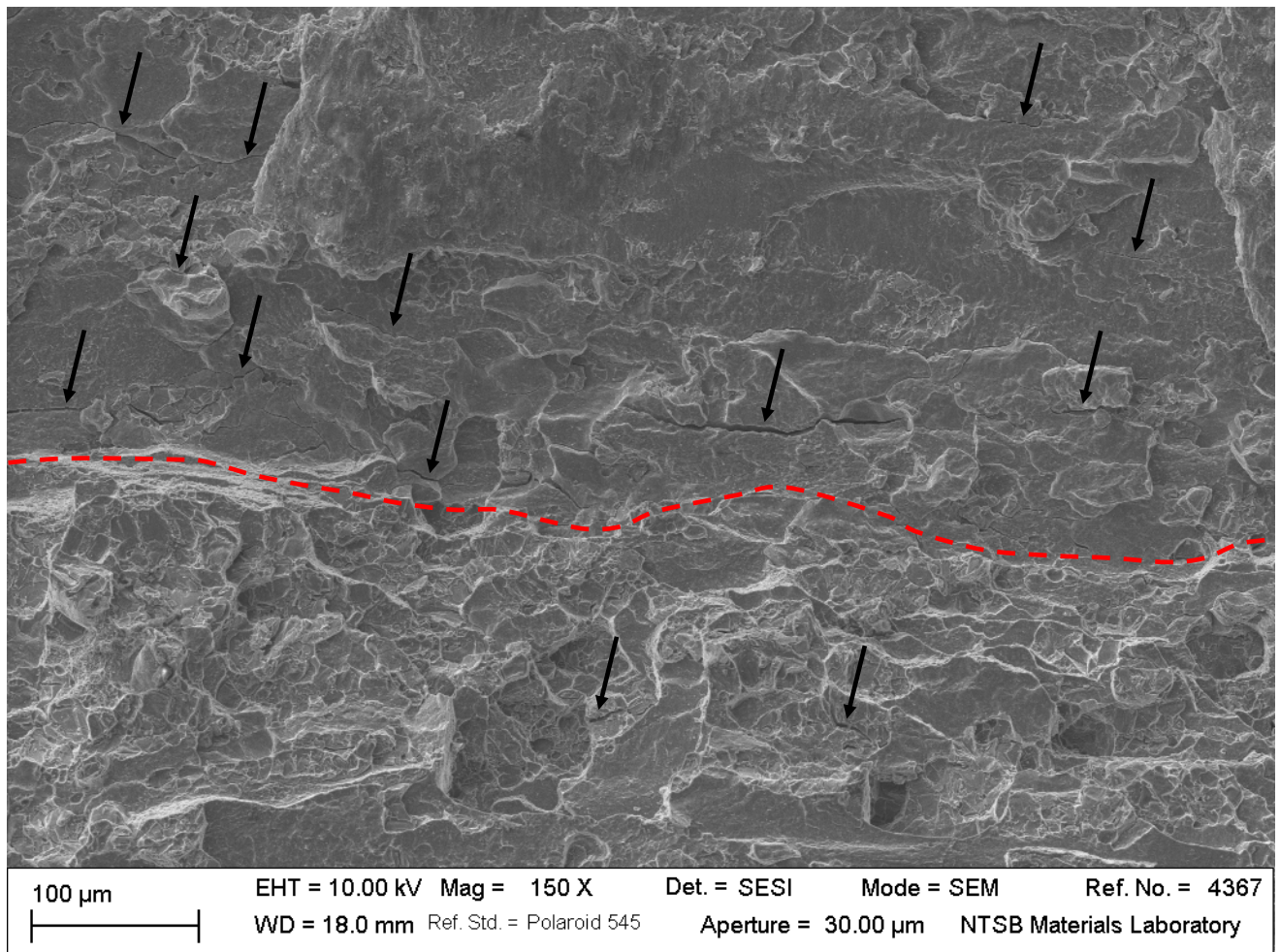


Figure 9: Scanning electron micrograph of the pre-existing crack boundary demarcated by a red dashed line. Above this line was inside of the crack front and below this line was outside of the crack front. Secondary cracks consistent with intergranular branched cracking were observed as identified by unlabeled arrows. Immediately outside of the crack front showed significantly less secondary cracking and more evidence of ductile dimples consistent with tensile overstress.

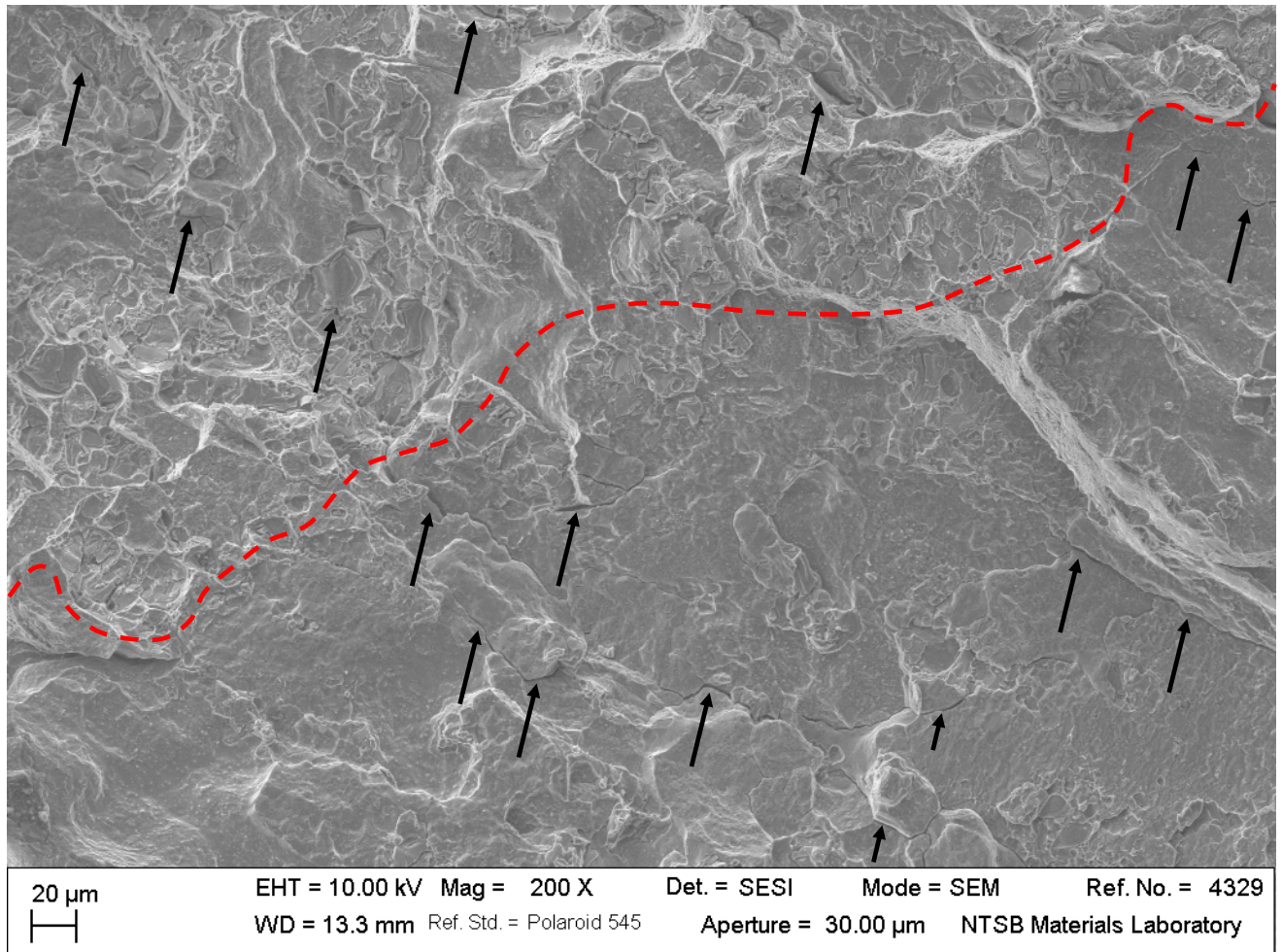


Figure 10: Another scanning electron micrograph of the pre-existing crack boundary at a different location relative to figure 9 demarcated by a red dashed line. below this line was inside of the crack front and above this line was outside of the crack front. Secondary cracks consistent with intergranular branched cracking were observed as identified by unlabeled arrows. Immediately outside of the crack front showed significantly less secondary cracking and more evidence of ductile dimples consistent with tensile overstress.

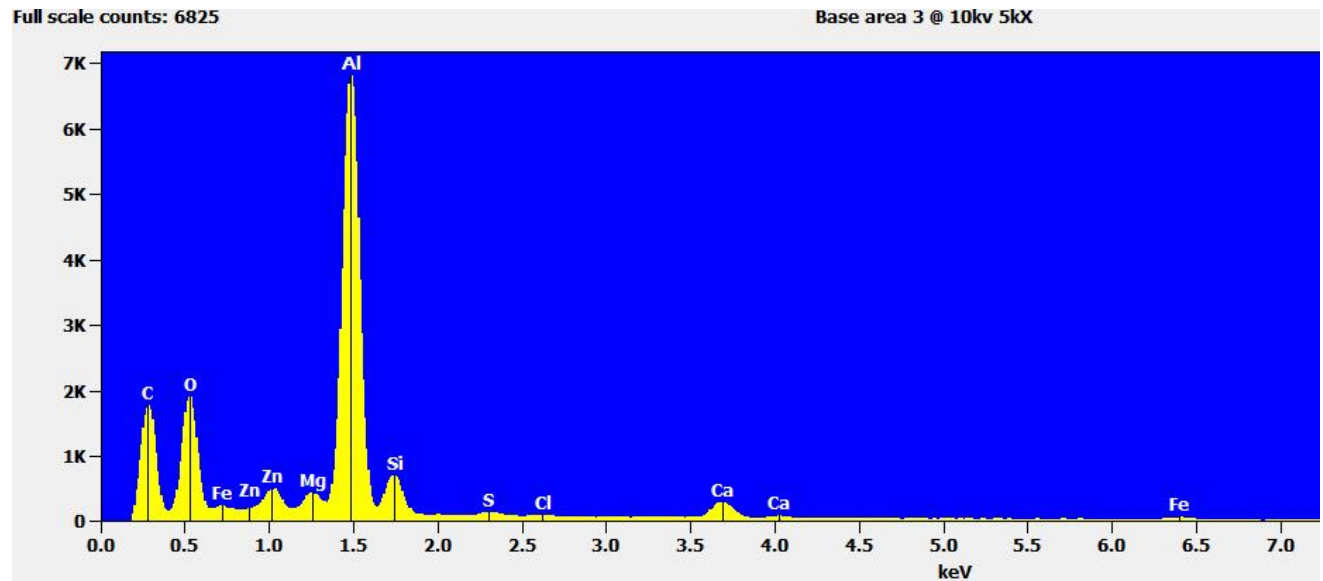


Figure 11: EDS spectrum acquired near pre-existing crack origins showed the presence of trace amounts of chlorine.

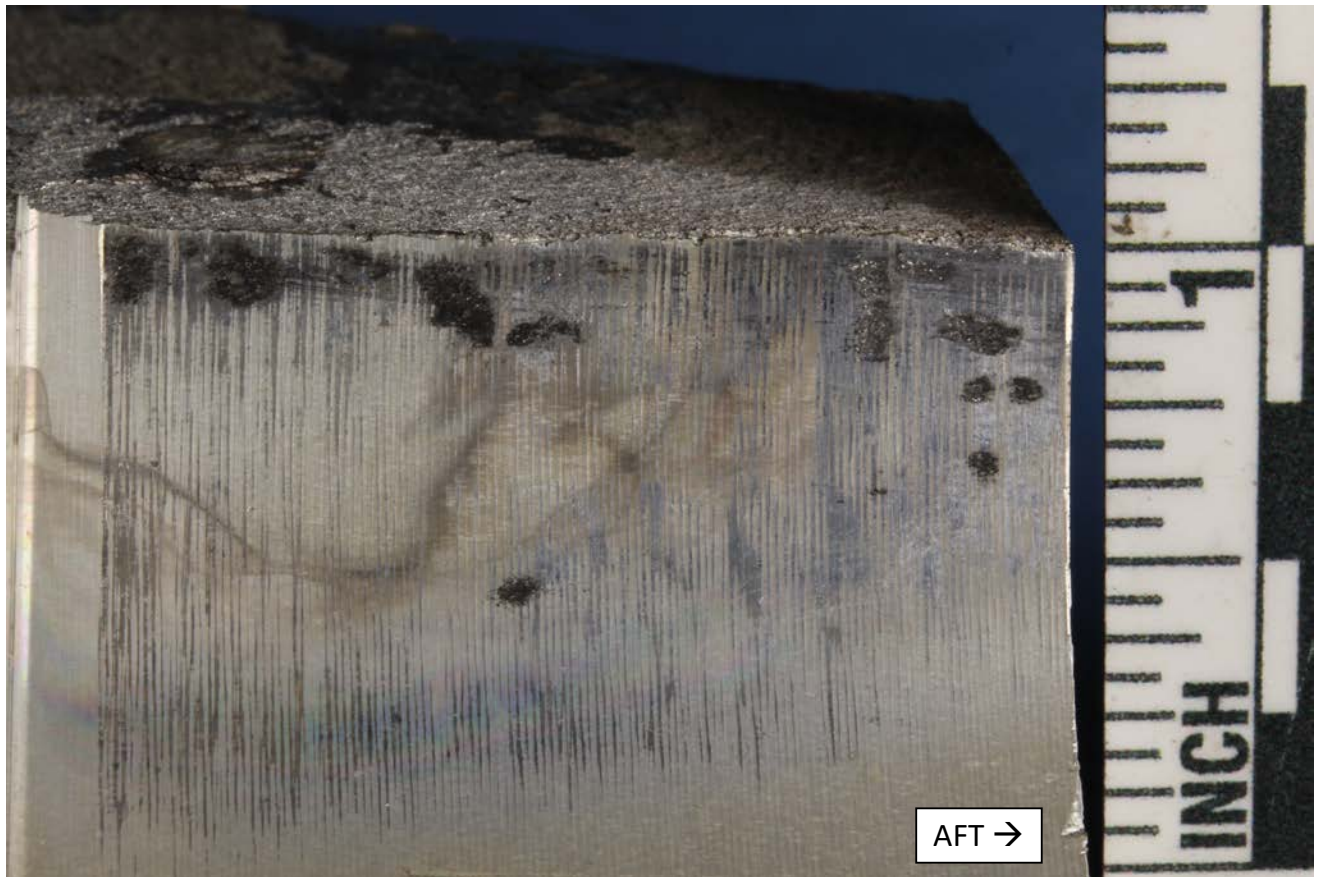


Figure 12a: A photograph of the pivot pin bore sidewall at pre-existing crack 1. On the sidewall surface near the fracture surface at the top of the image there were local corrosion sites visible as dark, round, rough features. A local area of disrupted anodic coating resembled the circumferential machining pattern of the bore surface where relative motion between the pivot pin and bore faying surfaces removed portions of the coating. Flowing stained lines were observed which were consistent with evidence of fluid ingress, puddling, and egression. Scratches approximately 0.5 – 0.6 inches long as measured forward to aft were observed beginning at corrosion sites which indicated corrosion sites were present at the time the pivot pin was dislodged.

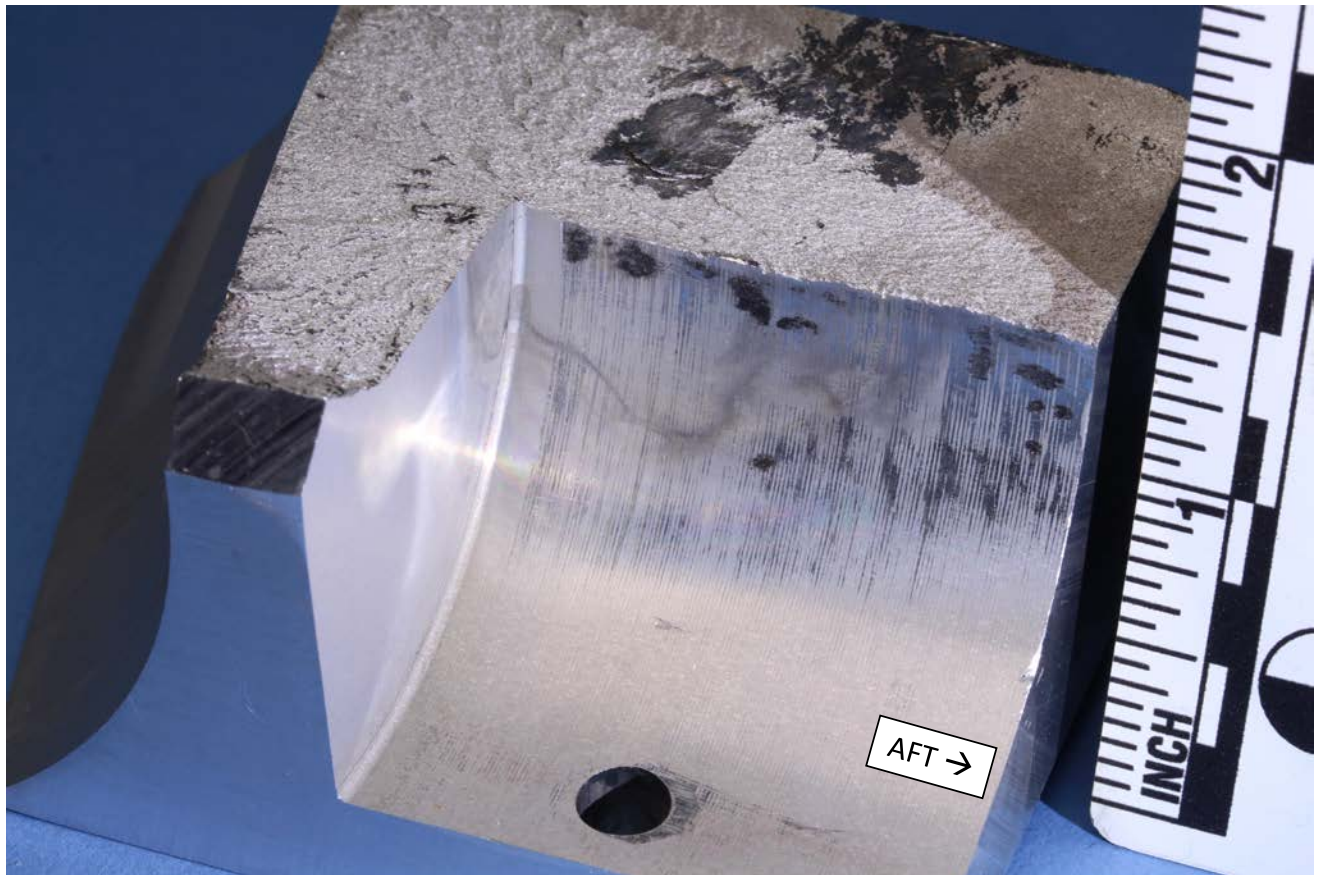


Figure 12b: A photograph similar to figure 12a but showing an isometric view of the pivot pin bore section near pre-existing crack 1.

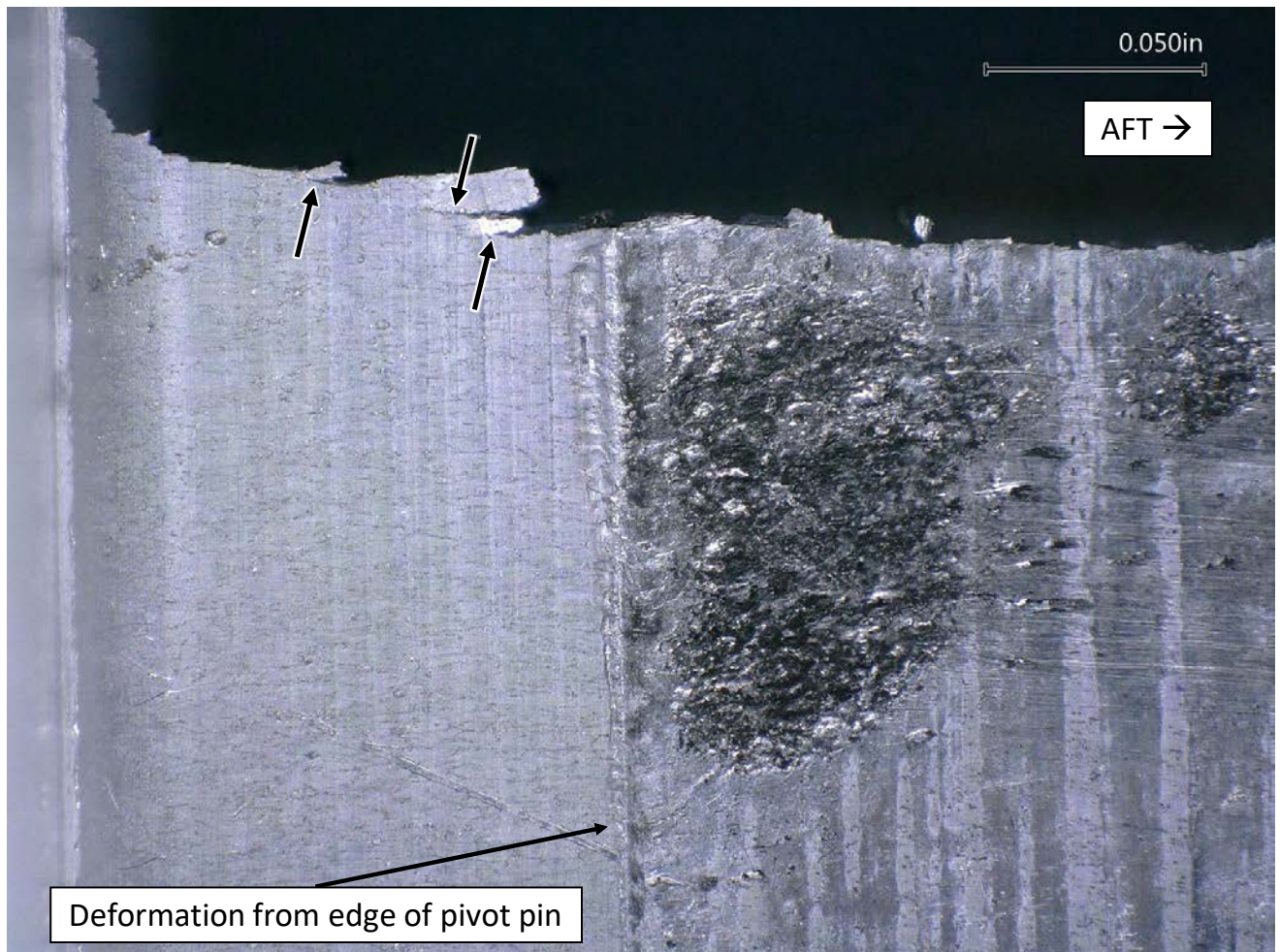


Figure 13: A digital micrograph of the aft pivot pin bore sidewall at pre-existing crack 1 near the corner radius at the base of the bore. A flaky, layered appearance of secondary cracks adjacent and parallel to the fracture surface was observed as indicated with unlabeled arrows. The local sidewall deformation from the inserted edge of the pivot pin was apparent from the fracture surface down to the location indicated. This feature also demarcated the boundary between intact (left side) and disturbed (right side) anodic coating. The dark pitted corrosion sites were also observed where the steel pivot pin contacted the bore sidewall near the fracture surface.

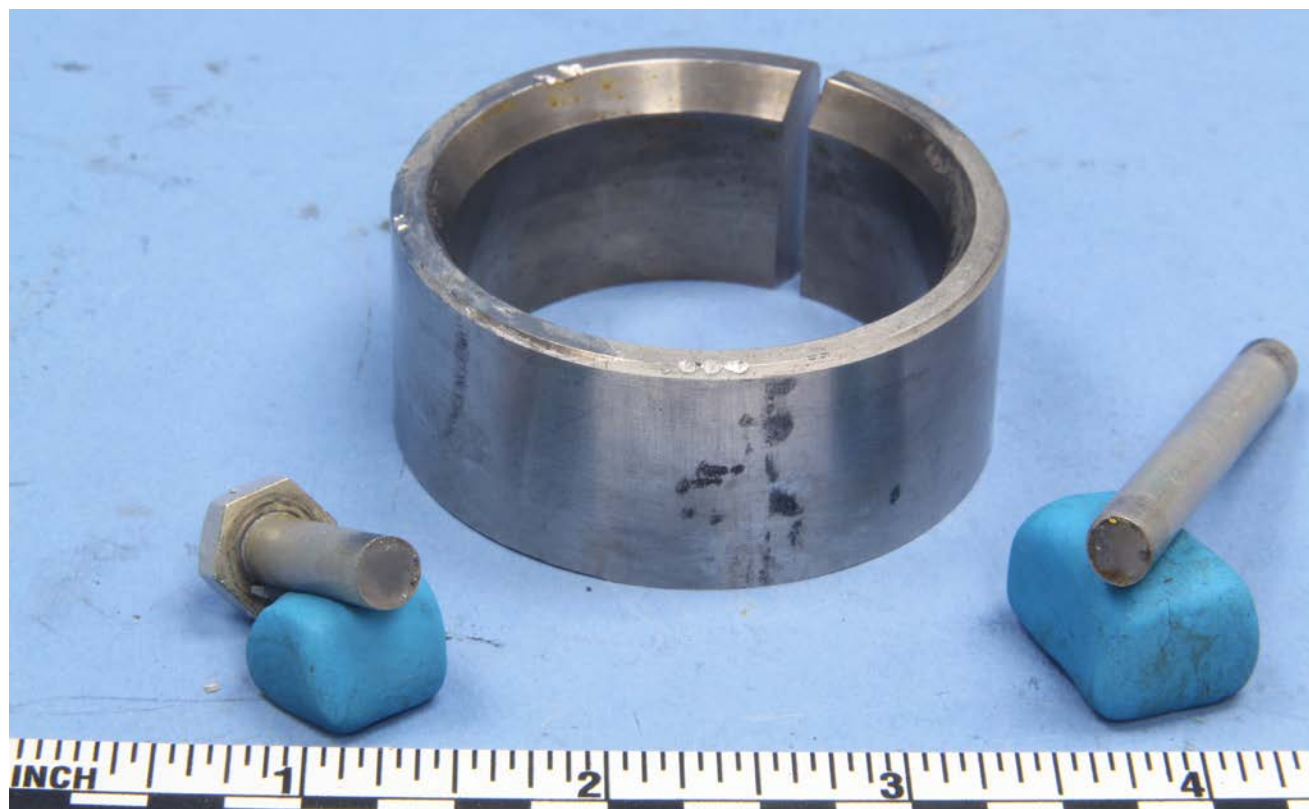


Figure 14: A photograph of the forward section of the aft pivot pin that was removed from the fractured bore. The staining observed on the outer surface of the pivot pin correlated with the corrosion sites on the bore sidewall surface near the fracture surface of pre-existing crack 1. Of the fractured retaining bolt fragments shown, the hex head portion had length consistent with the main fitting thickness at the location of the bolt hole and the shank fragment had length consistent with the pivot pin outer diameter. The fragment sizes and fractures were consistent with brittle shear fracture.