NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

September 22, 2022

MATERIALS LABORATORY FACTUAL REPORT Report No. 22-071

A. ACCIDENT INFORMATION

Place	:	Kalea, Hawaii
Date	:	June 8, 2022
Vehicle	:	Bell 407 helicopter, N402SH
NTSB No.	:	ANC22FA041
Investigator	:	Aaron Sauer

B. COMPONENTS EXAMINED

Tail boom-to-aft fuselage attachment structure comprised of four aft fuselage attach fittings; four corresponding tail boom intercostals with longerons; and skin structure from a Bell 407 helicopter serial number 53118.

C. DETAILS OF THE EXAMINATION

Figures 1 and 2 show photographs of the as-received pieces and figures 3 through 5 show photographs of the parts with mating fractures positioned next to each other, as if intact, to facilitate understanding of how the pieces fit relative to each other. The tail boom separated at body station (BS) 31.92, in the area of the tail boom-to-aft fuselage joint. Approximately a 1-foot long piece of the tail boom aft of the joint was submitted for examination, along with corresponding structure forward of the joint.

The tail boom is attached to the aft fuselage structure by four bolts and corresponding nuts and washers. The threaded end of a bolt along with a corresponding nut and washers are attached to a fitting, while the head end of the bolt and corresponding washer are attached to the longeron. Examination of the tail boom revealed three of the four fuselage attachment fittings (lower left, lower right, and upper right fittings) were fractured and they remained attached to the tail boom. The fractures were located near the aft end of each fitting. The fourth fuselage attachment fitting (upper left fitting) remained attached to the longeron member on the upper fuselage structure and showed no evidence of a crack or fracture (see figures 2, 4, and 5). The attachment bolt, nut, and washers for the upper left fitting were not submitted and are presumed missing. All references to direction are made when looking forward of the helicopter, unless otherwise specified.

Fractured Lower Left Fitting

Figures 6 and 7 show photographs of the fractured lower left fitting. Bench binocular microscope examination of the lower left fitting revealed the fracture face contained evidence of crack arrest marks typical of fatigue cracking that emanated from two separate areas, arbitrarily labelled brackets “O1” and “O2” in figures 6 and 7. The fracture face was covered with debris that obscured the fine fatigue crack features. The coating on the fitting was removed with a commercial epoxy paint stripper and this process exposed the bare metal surfaces. The fracture face was cleaned by immersion in a chemical cleaning solution prescribed in American Society for Testing and Standards (ASTM) G1 for cleaning aluminum alloys. The cleaning solution contained chromic acid, phosphoric acid, and water. Scanning electron microscope (SEM) examination of fracture face revealed the ASTM chromic acid-containing cleaning solution exposed the fine fatigue striation features and micro-void coalescence features.

SEM examination of the fracture face revealed fatigue crack “O1” emanated from multiple origins at the outer surface at an area that was located slightly forward of the inner transition radius on the diagonal wall member portion of the fitting. The fatigue origin contained no evidence of pitting corrosion. Figure 8 shows an SEM image of typical fatigue striations that were located near the origin of the fatigue crack. Fatigue propagation was down and through the wall then extended to the right of the fitting. The fatigue crack region contained alternating fatigue crack features and overstress features, see figure 9. The fatigue crack terminated in the area indicated by a solid line in figures 6 and 7. The total length of this fatigue crack measured approximately 1 inch.

Fatigue crack “O2” emanated from a corrosion pit at the outer surface in an area slightly forward of the inner transition radius near the upper right end of the fitting, see area indicated by bracket “O2” in figures 6 and 7. The length and depth of the corrosion pit measured approximately 0.07 millimeter (mm) and 0.04 mm [0.003 inch and 0.002 inch], respectively. Figure 10 shows an SEM image of the corrosion pit. The fine fatigue crack features at the origin of the fatigue crack were obliterated from relative movement between mating fractur faces. The fatigue crack propagated through the wall and then extended down where it intersected the left edge of fatigue crack “O1. The fatigue crack region contained alternating fatigue crack features and overstress features. The total length of fatigue crack “02” measured approximately 0.75 inch. The terminus of the fatigue crack “O2” partially overlapped and intersected the origin of fatigue crack “O1”, but the terminus of the two fatigue cracks were on different fracture planes. A fragment containing the terminus portion of the two fatigue cracks broke away from the fitting and was held by adhesive fibers in the area near the fitting fracture face, see figures 6 and 7. The remaining portion of the fracture face that was located outside of the fatigue zone exhibited micro-void coalescence features consistent with overstress separation.

The lower left fitting was specified as having been made from single stock material, 7050 aluminum alloy in the -T7451 condition; or 7075 aluminum alloy in the -T351 or -T3 condition. The minimum hardness was based on the material grade. The minimum hardness for the 7050 material was specified as 82 HRB minimum, whereas, for the 7075 material was specified as 79 HRB, minimum.[1] The material grade was identified with an Olympus Vanta X-ray fluorescence (XRF) portable alloy analyzer. This fitting was identified as grade 7075 aluminum alloy (see table 1). Rockwell hardness testing of this fitting produced an average hardness value that exceed the minimum specified hardness values (see table 1). Electrical conductivity of the fitting was 38.5% IACS (see table 1), which was greater than the specified minimum of 38% IACS per BPS 4453 specification.[2]

Fractured Lower Right Fitting

The fracture face of the lower right fitting exhibited a rough texture on slanted planes consistent with overstress separation, see figure 11. The fitting contained a vertical crack that extended between the bolt hole and the top of the fitting. The crack was through the wall. A vertical saw cut was made on the diametrically opposite the bolt hole and this exposed the crack. The exposed fracture face exhibited a course texture on a slant plane consistent with overstress separation.

The lower right fitting was specified as having been made single stock material, material and the hardness requirements were the same as the lower left fitting. The coating on the fitting was removed with a commercial epoxy paint stripper. The paint stripper exposed the bare metal surfaces, in preparation for hardness testing, conductivity measurements, and analysis by a portable alloy analyzer. The alloy analyzer identified this fitting as grade 7075 aluminum alloy (see table 1). Hardness testing of the fitting produced an average hardness value that exceed the minimum specified hardness values (see table 1). Electrical conductivity measurement was 40.9% IACS (see table 1), which was greater than the specified minimum of 38% IACS per BPS 4453 specification.

Fractured Upper Right Fitting

The fracture face of the upper right fitting exhibited a rough texture on slanted planes consistent with overstress separation, see figures 12. The upper right fitting (see figure 18) was specified as having been manufactured from two materials. A reinforcement plate (radius block) is bonded to the forward face of the fitting. The base material for the fitting was specified as 7075-T73 aluminum alloy and a hardness of 78 HRB, minimum. The coating was removed with a commercial epoxy paint stripper. The base material for this fitting was identified by an alloy analyzer as grade 7075 aluminum alloy (see table 1). Rockwell hardness testing of the fitting produced an average hardness value that exceed the minimum specified hardness values (see table 1). Electrical conductivity measurement was 41.1% IACS (see table 1), which was greater than the specified minimum of 38% IACS per BPS 4453 specification. The radius block was specified as having been made from grade 2024 aluminum alloy (see table 2). The alloy analyzer identified the plate as grade 2024 aluminum alloy (see table 2).

[1] Material properties specified in BPS 4453.

[2] Electrical conductivity is expressed in percent International Annealed Copper Standard (percent IACS or %IACS), at 20°C by definition, where copper = 100 %IACS.

Intact Upper Left Fitting

As indicated earlier, upper left fitting remained attached to the longeron member on the upper fuselage structure and showed no evidence of a crack or fracture, see figures 2, 4, 5, and 13. The upper left fitting (see figure 13) was manufactured with a radius block that was bonded to the forward face of the fitting. The bolt hole with a portion of the upper left fitting was saw cut and extracted from the upper skin structure (saw cuts were made along the areas indicated by dashed lines in figure 13). The base material for the fitting was specified as 17-4PH CRES and identified by an alloy analyzer as grade 17-4 PH steel. The radius block was specified as 301 CRES steel and identified by an alloy analyzer as grade 301 stainless steel.

Disassembly of the Fractured Fittings and Bolt Torque Measurements

Bell Helicopter Alert Service Bulletin (ABS) 407-10-93, dated August 30, 2019, titled "Revision A to Alert Service Bulletin 407-10-93: Tailboom Attachment Hardware, Replacement of.", indicated to select a sufficient number of washers for the opposite end of bolt to obtain a minimum of one to a maximum of three threads showing beyond the nut after proper torque is obtained.[3] Examination of all the fittings revealed between one and three threads were exposed beyond the nut as required per the ABS (see table 3); and between two and five washers were installed between the nut and fitting (see table 3). Each bolt contained one washer under the head of the bolt, as require by the ABS. The same ASB indicated that threads are not to be coated with primer or corrosion preventative compound (CPC) prior to installing the nut portions. The exposed threaded portion for each bolt that extended beyond the nut was not covered with CPC. All the fittings contained orange torque paint that extended between the nut and fitting. The fittings contained red torque paint that extended between the exposed threads and nut with the exception of the lower right fitting where a trace of red torque paint was adhering to the nut. The forward face of each fitting in the area adjacent to the washers contained a counterbore (recess), see figure 7. The diameter of the counterbore was slightly larger than the diameter of the washer.

The torque required to cause rotation when tightening a nut was measured. The torque value for each fitting was measured with a torque wrench. The specified torque is based on the size of the bolt. The specified and measured torque values are shown in table 4. The measured torque of the upper right fitting measured 672 inch-pounds (in-lbs), which was greater than the specified upper limit (580 in-lbs). The measured torque of the lower left fitting measured 384 in-lbs, which was greater than the specified upper limit (370 in-lbs). The measured torque of the lower right fitting measured 240 in-lbs, which was less than the specified lower limit (360 in-lbs).

Prior to removing the attachment bolts from their respective fittings and after removing the nut and washers, the threaded portion of each bolt was examined. The threaded portion of each bolt in the area that corresponded to the position of the installed nut was not covered with iron oxide, whereas the exposed thread portions that extended beyond the installed nut

[3] The number of permitted exposed threads is also specified in Bell "Inspection and Repair" document that pertains to the tail boom, "DMC-407-A-53-01-00-00A-280A-A, Issue 001-2020/01/06", which is the same requirement as indicated in the Bell ABS. DMC stands for Data Module Code.

position were covered with superficial iron oxide. Once the bolts were disassembled from their respective fittings, the washers, nuts, and shank portion of the bolts were inspected for evidence of corrosion preventive compound (CPC). The countersunk washer under the head portion of the bolts, shank portion of the bolts, washers adjacent to the nuts, and shank portion of each bolt were covered with CPC. As indicated earlier, the threaded portion of the bolts were not covered with CPC. Small amounts of CPC were transferred to the threads as the washers were removed from the bolts. The bolts, nuts and washers were brushed cleaned with WD-40 lubricant/cleaner followed by brush cleaning with Alconox, a commercial detergent for removing iron oxide. Bench binocular microscope examination of these items revealed they contained no evidence of a crack.

Bolt Hole in the Upper Left Fitting

The cut portion with the bolt hole (see cut lines in figure 13) was ultrasonic cleaned with acetone followed by brush cleaning with Alconox. Paint stripper was not applied to this fitting. Figure 14 show photographs of the bolt hole for the upper left fitting after cleaning. Bench binocular microscope examination of the bolt hole revealed evidence of circumferential gouge and impression marks in the area indicated by a bracket; fretting; black and brown deposits consistent with iron oxide; and corrosion pits. The circumferential gouge and impression marks were more severe on one side of the hole. The fretting and pitting corrosion was not uniform around the circumference of the hole.

The hole was cut in half to expose the two halves of the hole. EDS analysis of the hole in the areas of fretting produced a spectrum that contained elemental peaks of oxygen (O) in the form of an oxide and cadmium (Cd), among other elements, that were not present in the fitting base metal. Figure 15 shows the EDS spectrum of the base metal for the upper left fitting (red outline) and overlapping EDS spectrum for the fretting areas in the surface of the hole (solid yellow background).

Bolt Hole in the Upper Right Fitting, Lower Left and Right Fitting

Figures 16 and 17 show photographs of the lower left fitting and upper right fitting, respectively. Both holes showed evidence of severe spiral gouge marks, indicted by arrows, and fine spiral scratches. The spiral gouge marks did not extend all around the bore.

Figure 18 show photographs of the upper right fitting. The hole for this fitting showed evidence of a circumferential gouge mark; fine circumferential scratches; and an isolated area of fretting. The radius block for this fitting showed no evidence of debonding from the fitting.

Bolt Holes in the Fuselage Frame

Bench binocular microscope examination of the fuselage frame[4] revealed that the bolt holes at the forward edge contained a chamfer. The chamfer edge of each hole contained no evidence of gouging or metal deformation (see figure 19). The bolt hole that corresponded to the upper left fitting contained circumferential gouge and impression marks, see figure 20. The circumferential gouge and impression marks were more severe on one side of the hole. The remaining bolt holes in the fuselage frame showed no evidence of circumferential gouge marks or impressions (see figures 21 through 23).

Material Properties and Size of the Bolts

The attachment bolts for the fittings were specified as NAS627 bolts. This specification indicated the hardness of a bolt was to be between 39 and 43 HRC. Transverse cross sections were made through the shank portion of the bolts and encased in metallurgical mounts. Rockwell hardness testing of the shank portion of the upper right and lower left bolts produced hardness values that were within the specified range, see table 5. The hardness of the lower right fitting exceeded the upper limit by one hardness point (measured 44HRC).

According to the same NAS627 specification, the material for the attachment bolts were specified as 4140, 4340, or 8740 steel. Each bolt was analyzed with an alloy analyzer. The alloy analyzer identified the materials for the lower right and left bolts as 4340 steel, whereas the material for the upper right bolt was identified as 8740 steel (see table 6). The material grade for the bolts complied with those specified by NAS627.

Size of the Bolts and Washers

The grip length of each attachment bolt and shank diameter were measured. The specified length for all the bolts are the same but the diameter of bolts for the upper fitting are different than those of the lower fitting. The specified and measured grip length of the bolts and diameter of the shank portions are shown in table 7. The grip length and diameter of the bolts were within the specified ranges.

The diameter of the washers that were installed under the nut were measured with a caliper. The results of the measurements are shown in table 8. The size of the inner and outer diameters were within specified range.

Various Views of the Tail Boom Canted Bulkhead and Fuselage Frame

Figures 24 through 27 show various views of the fuselage frame and tail boom canted bulkhead in the various stages of disassembly.

[4] "Tail boom canted bulkhead" and "fuselage frame" terminology obtained from cross section diagram in BHT-Technical Publication, titled "Tail boom, Inspection and Repair, (DMC-407-A-53-01-00-00A-280A), Issue 001", Sheet 2 of 3.

Installation of Intercostal

Bell "Inspection and Repair" document that pertains to the tail boom, "DMC-407-A-53-01-00-00A-280A-A, Issue 001-2020/01/06", indicated that intercostals with transverse rib reinforcement were effective on serial number 53555 helicopters and subsequent. The helicopter from this accident is serial number 53118 (was to be installed with standard intercostals without the transverse rib reinforcement).[5] The tail boom on the helicopter involved in this accident contained intercostals, indicating that the tail boom was disassembled at least one time since new.

Prepared by:

Frank Zakar
Senior Metallurgist

[5] Standard intercostals design that were effective for helicopter between S/N 53000 and 53554.

Table 1.
Material Properties for the Base Portion of the Fittings

Location	Specified Material	Alloy Analyzer Results	Measured Hardness	Conductivity (% IACS)	
				Specified ****	Measured
Upper Left Fitting*	17-4 PH; 155-175 KSI T.S.	17-4 PH	35 HRC*	N/A*****	N/A*****
Upper Right Fitting**	7075-T73; 78 HRB min.	7075	84 HRB	38	41.1
Lower Right Fitting***	7050-T7451; 82 HRB min. or 7075-T351 or T3; 79 HRB min.	7075	84 HRB		40.9
Lower Left Fitting***		7075	82 HRB		38.5

Notes:
(*) The base material for the upper left fitting was specified as part number 407-030-750-103, 17-4PH CRES casting per AMS5355; initial anneal (A); final 155-175 KSI tensile strength (T.S.). Per ASTM A370, titled "Standard Test Methods and Definitions for Mechanical Testing of Steel Products", this converts to approximately between 35-38 HRC.
(**) The base material for the upper right fitting was specified as part number 206-031-329-104, 7075 Aluminum alloy forging per QQ-A-367; initial/final temper is T73.
(***) The lower right and left fittings are the same part number 206-031-327.
(****) Specified by BPS4453.
(*****) Not applicable for steel.

Table 2.
Material Properties of the Radius block for the Upper Right & Left Fittings

Location	Specified Material	Alloy Analyzer Results
Upper Left Fitting	301 CRES*	301 CRES
Upper Right Fitting	2024 AL**	2024 AL

Note:
(*) The radius block for the upper left fitting was specified as part number 407-030-700-153, 0.19 inch thick 301 CRES per AMS5901; initial anneal (A); final 75 KSI tensile strength (T.S.), minimum.
(**) The radius block for the upper right fitting was specified as part number 407-030-700-155, 0.19 inch thick 2024 Aluminum alloy per AMS-QQ-A-250/4; initial/final temper is T3.

Table 3. Number of Washers Between Nut and Fitting and Exposed Full Threads		
Location	Number of Washers	Exposed Full Threads
Upper Left Nut	Missing	Missing
Upper Right Nut	2	3
Lower Right Nut	5	1
Lower Left Nut	5	1

Table 4. Measured Torque Values (*)			
Bolt	Bolt Type	Torque (in-lbs)	
		Specified	Measured
Upper Left Fitting	NAS627-30	570-580	Missing
Upper Right Fitting			672
Lower Left Fitting	NAS626-26	360-370	384
Lower Right Fitting			240

Note: (*) Measured torque values that caused rotation of the nut when turning the nut clockwise (tightening).

Table 5. Hardness of the Attachment Bolts			
Location	Specified Tensile Strength (KSI)	Specified Hardness	Measured Average Hardness (HRC)
Upper Left Nut	180 - 200	39 - 43	Missing
Upper Right Nut			41
Lower Right Nut			44
Lower Left Nut			43

Table 6. Material Grade for Attachment Bolts		
Location	Specified Material	Alloy Analyzer Results
Upper Left Nut	4140, 4340, or 8740	Missing
Upper Right Nut		8740
Lower Right Nut		4340
Lower Left Nut		4340

Table 7. Size of Attachment Bolts					
Bolt	Bolt Type	Grip Length		Shank Diameter	
		Specified	Measured	Specified	Measured
Upper Left Fitting	NAS627-30	1.865-1.885	Missing	0.4360-0.4370	Missing
Upper Right Fitting			1.872		0.4360
Lower Left Fitting	NAS626-26	1.615-1.635	1.632	0.3735-0.3745	0.3740
Lower Right Fitting			1.620		0.3740

Table 8. Washers Adjacent to Nut					
Bolt	Washer Type	Outside Diameter		Inside Diameter	
		Specified	Measured	Specified	Measured
Upper Left Fitting	NAS1149F0732P	Missing	Missing	Missing	Missing
Upper Right Fitting		0.745-0.770	0.757	0.443-0.463	0.454
Lower Left Fitting	NAS1149G0663P	0.620-0.645	0.630	0.380-0.400	0.381
Lower Right Fitting			0.640		0.389

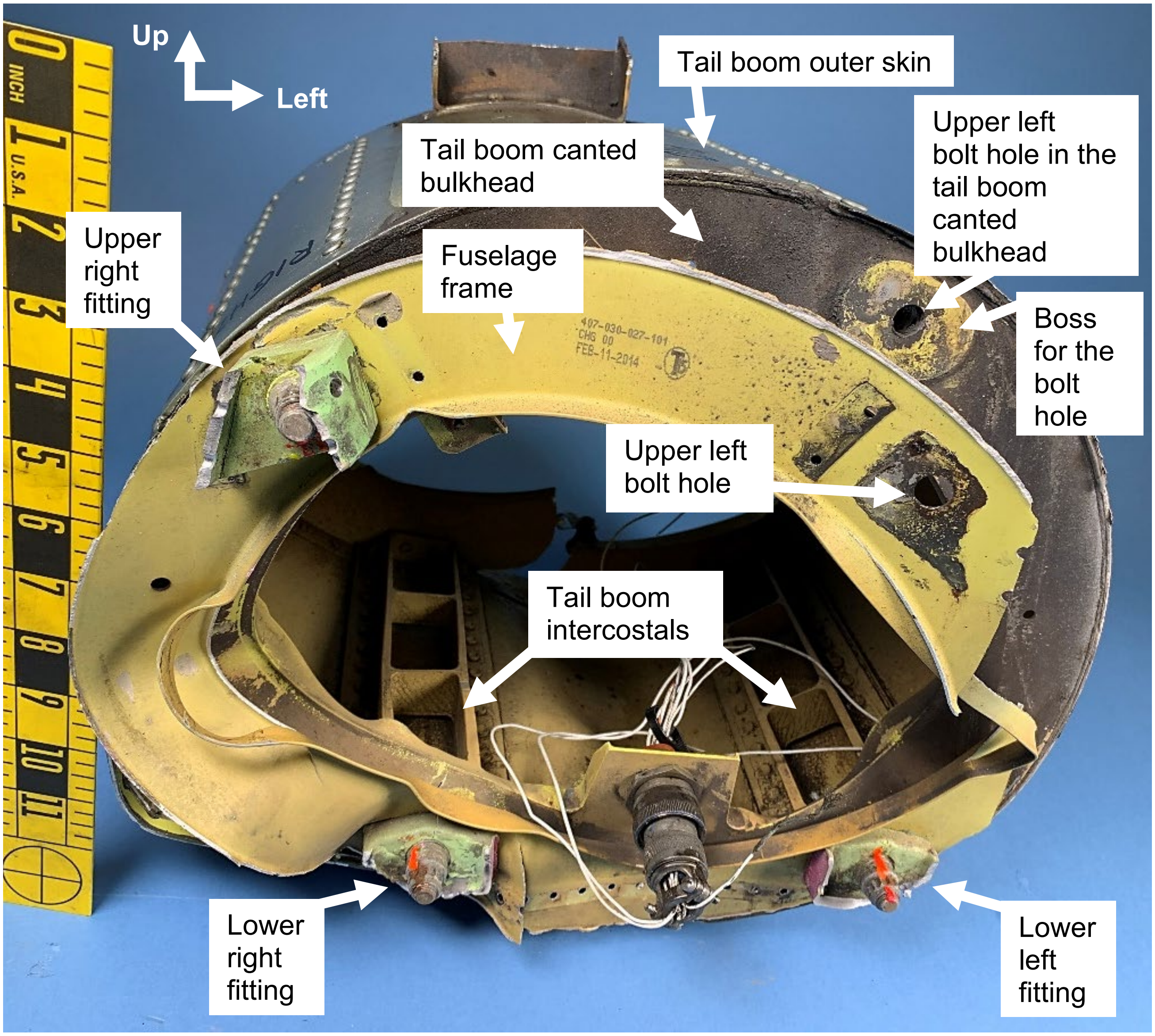


Figure 1. As-received tail boom section that separated at body station (BS) 31.92, looking aft, showing three fractured aft fuselage attachment fittings. The upper left attachment fitting and associated bolt, nut, and washers, separated from the tail boom and is presumed missing (not recovered). The hole for the upper left fitting is exposed. All references to direction are made when looking forward of the helicopter.

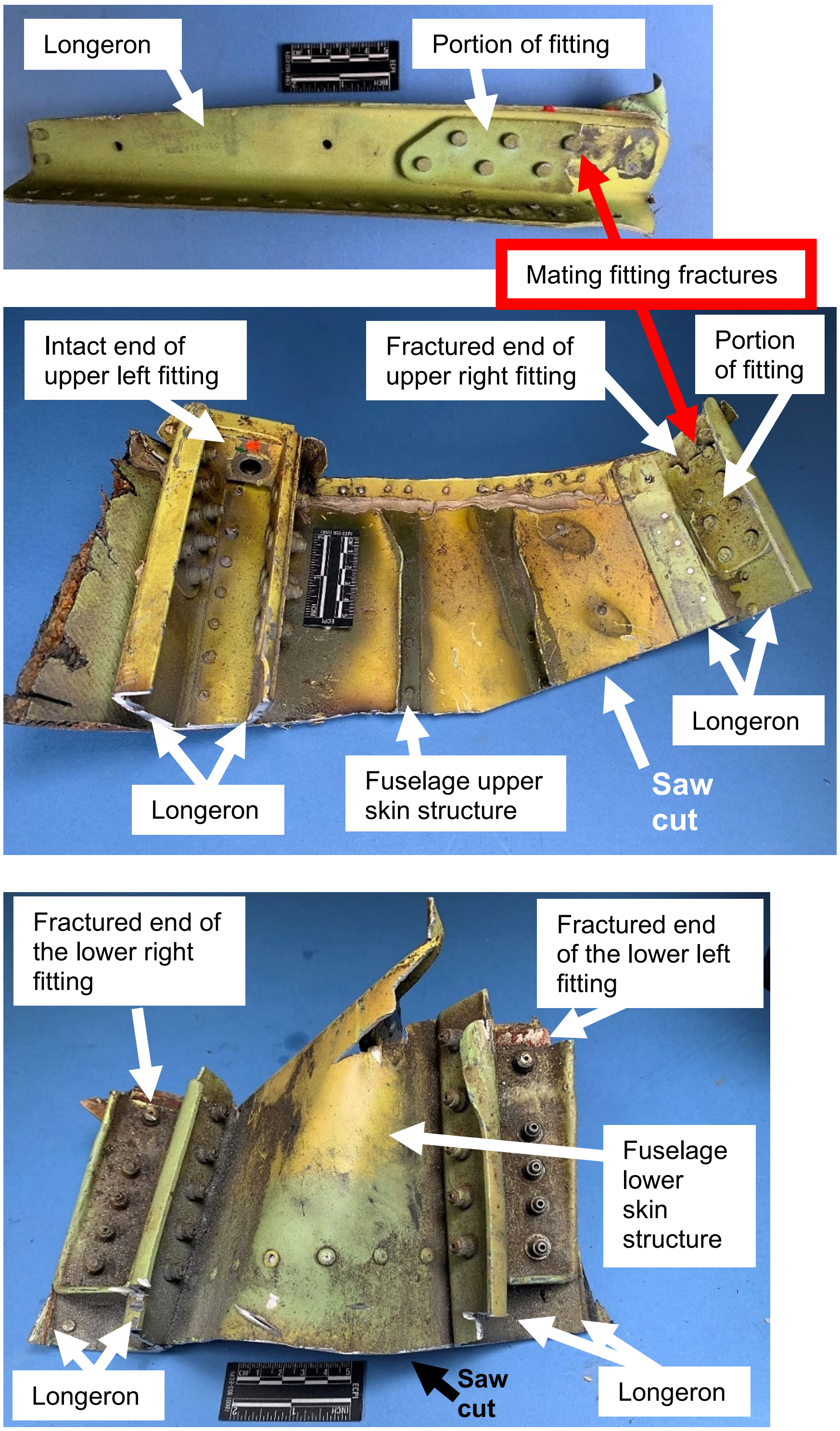


Figure 2. As-received longeron (top of page); fuselage upper skin structure, looking aft at the inner face (middle of page); fuselage lower skin structure showing the inner face (bottom of page). The mating fractures are indicated by a red arrow.

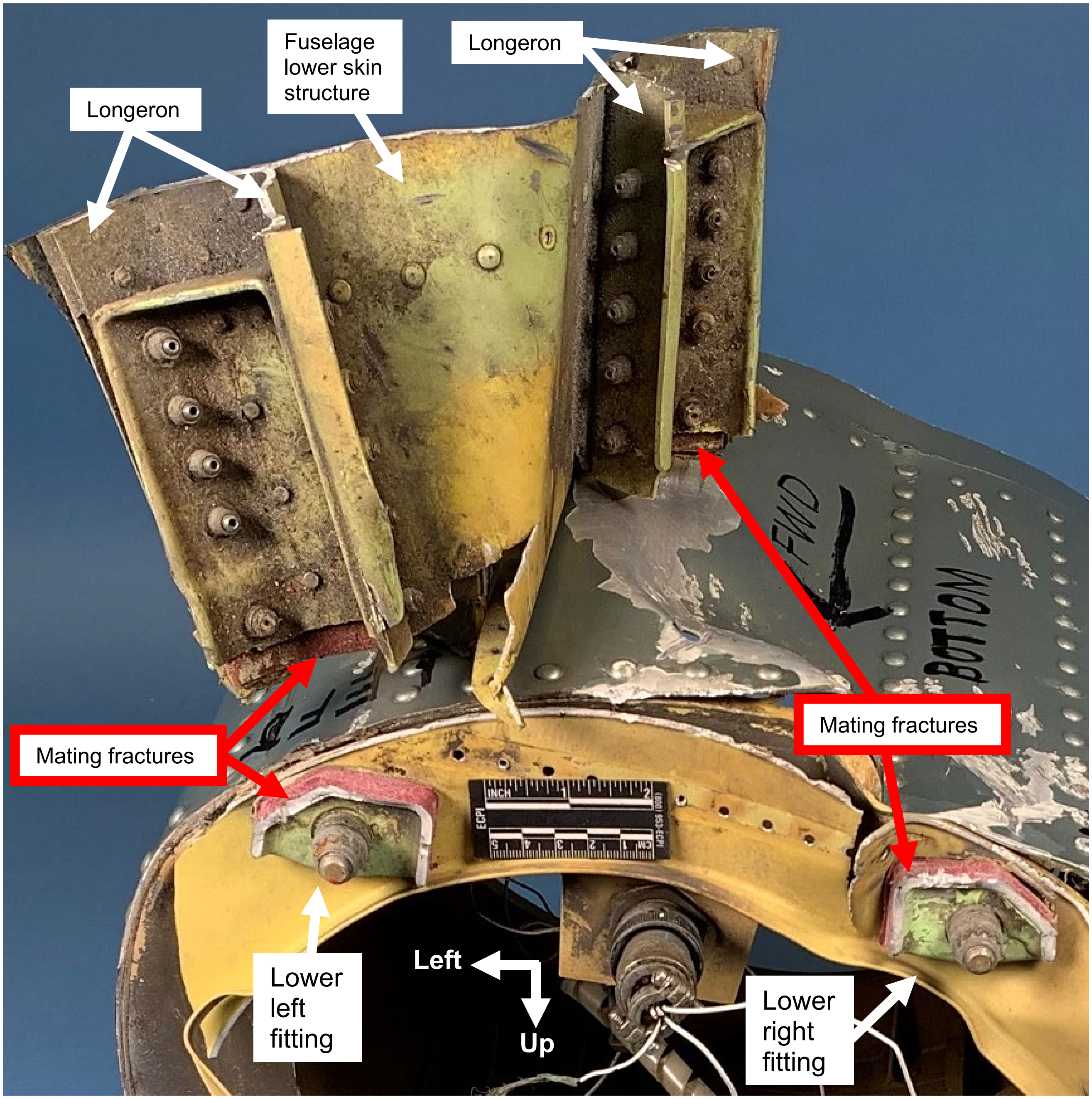


Figure 3. Tail boom looking aft and the lower skin structure showing mating fracture faces for the lower right and left fittings.

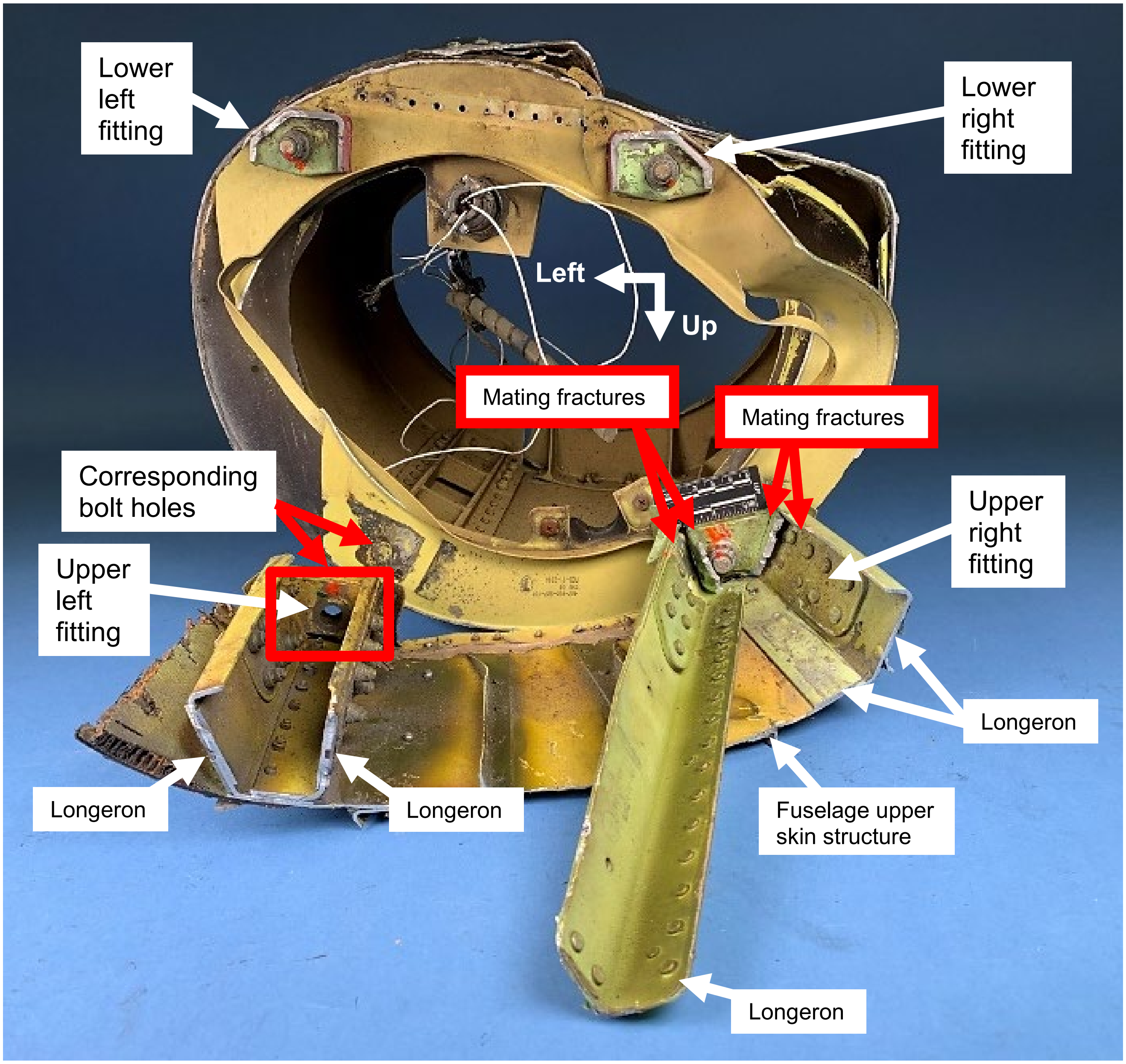


Figure 4. View of the tail boom looking aft (top of page); mating fuselage upper skin structure (center of page); and longeron (bottom of page).

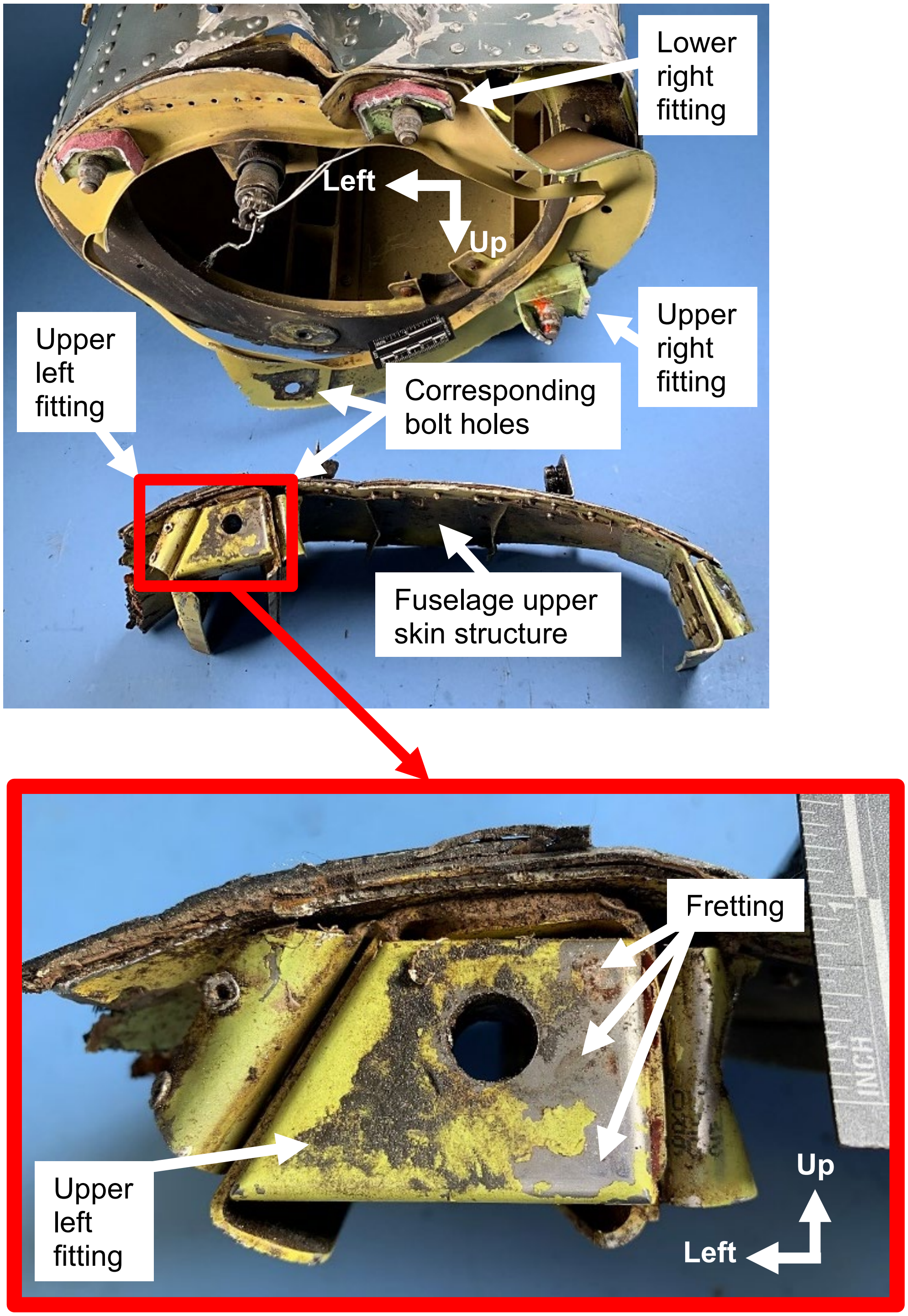


Figure 5. View of the intact upper left fitting showing the aft face (top of page) and close-up photograph of the fretting damage on the aft face of the fitting (bottom of page). Bare metal is exposed in fretting damaged area.

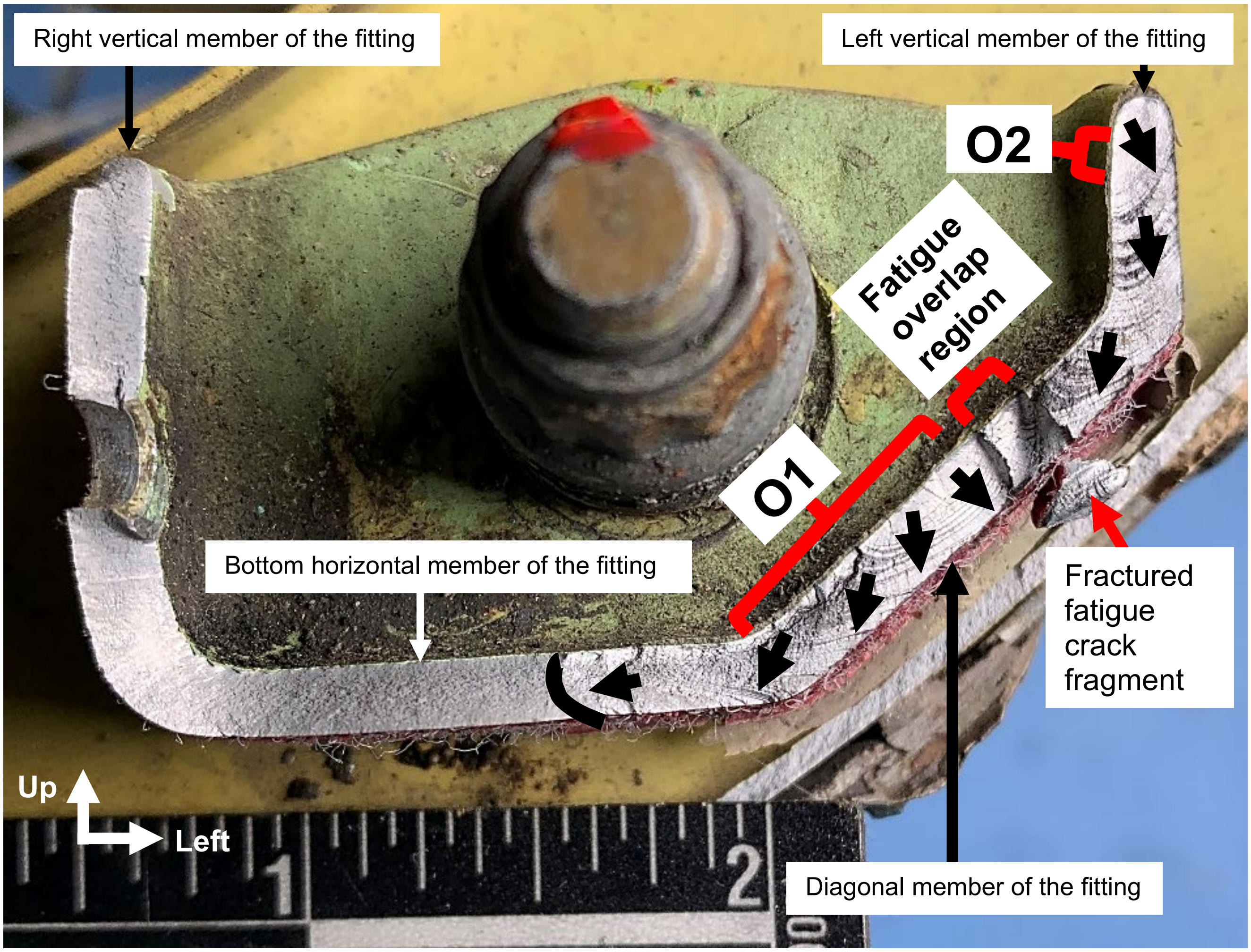


Figure 6. Close-up view of the fractured lower left fitting looking aft showing crack arrest features typical of fatigue cracking that emanated from two separate areas indicated by brackets “O1” and “O2”. The number of the fatigue origins were arbitrarily selected.

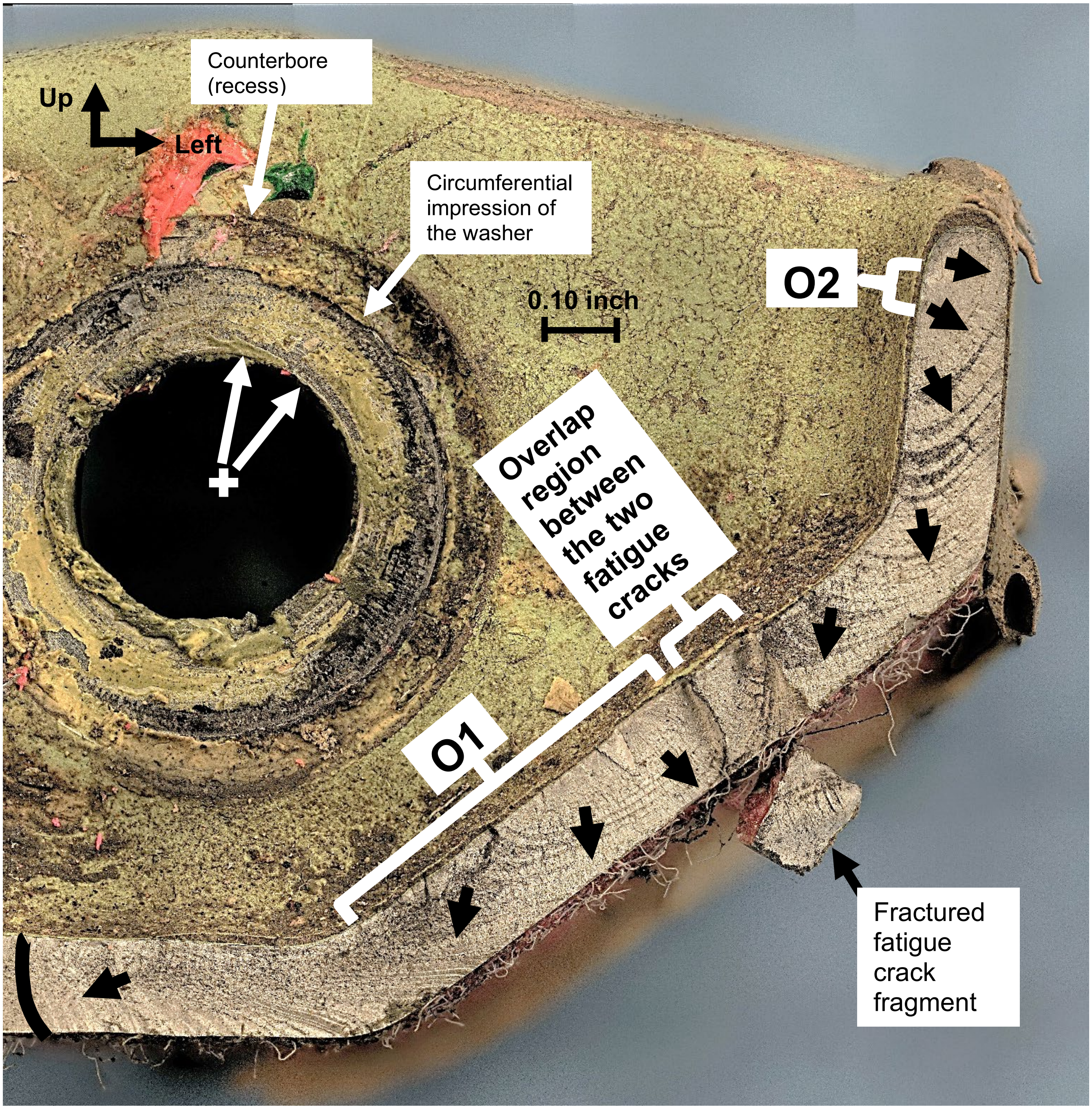


Figure 7. Close-up view of the fractured lower left fitting looking aft and at the two fatigue crack origins indicated by brackets “O1” and “O2”.

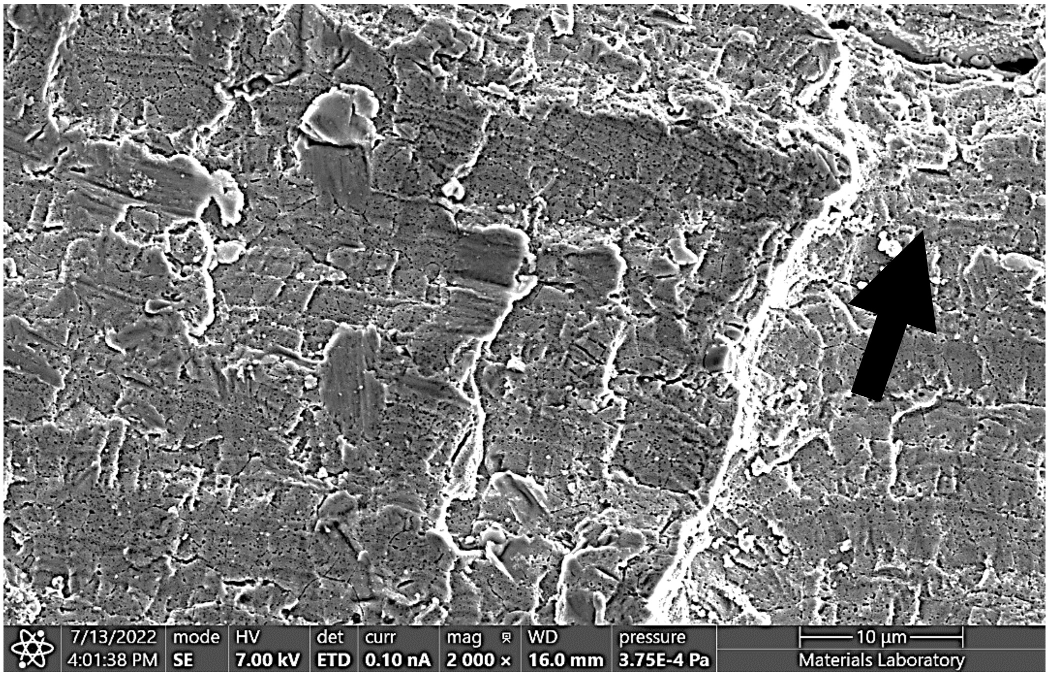


Figure 8 shows an SEM image of typical fatigue striations that were located near the origin of the fatigue crack. Fatigue crack propagation is in the general direction indicated by the arrow.

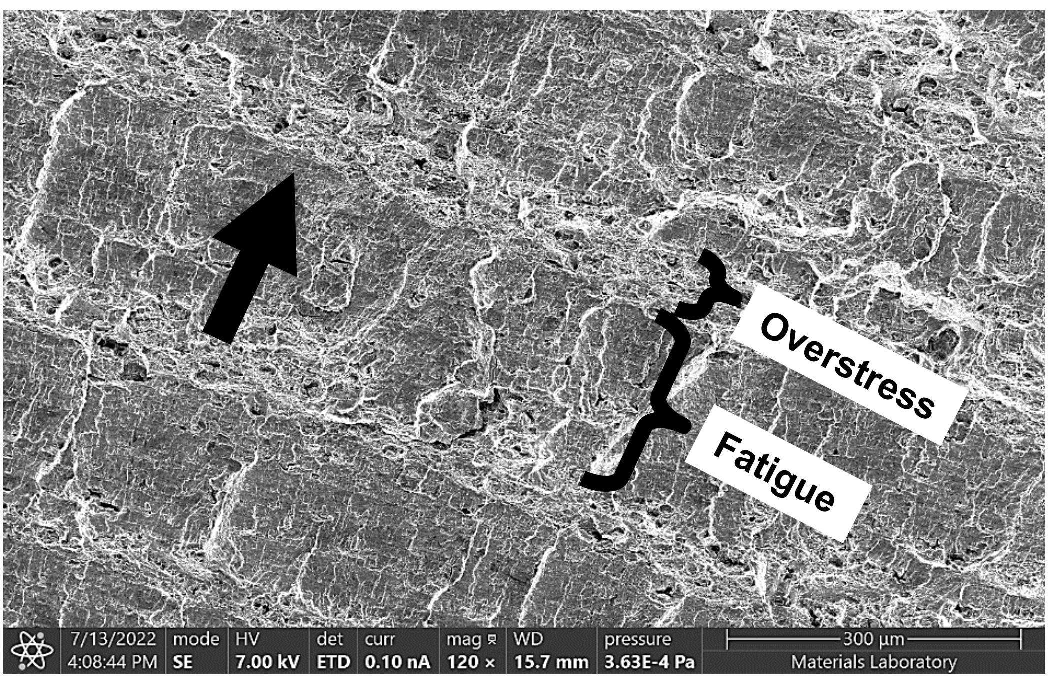


Figure 9 shows an SEM image of alternating fatigue crack features and overstress features. Fatigue crack propagation is in the general direction indicated by the arrow.

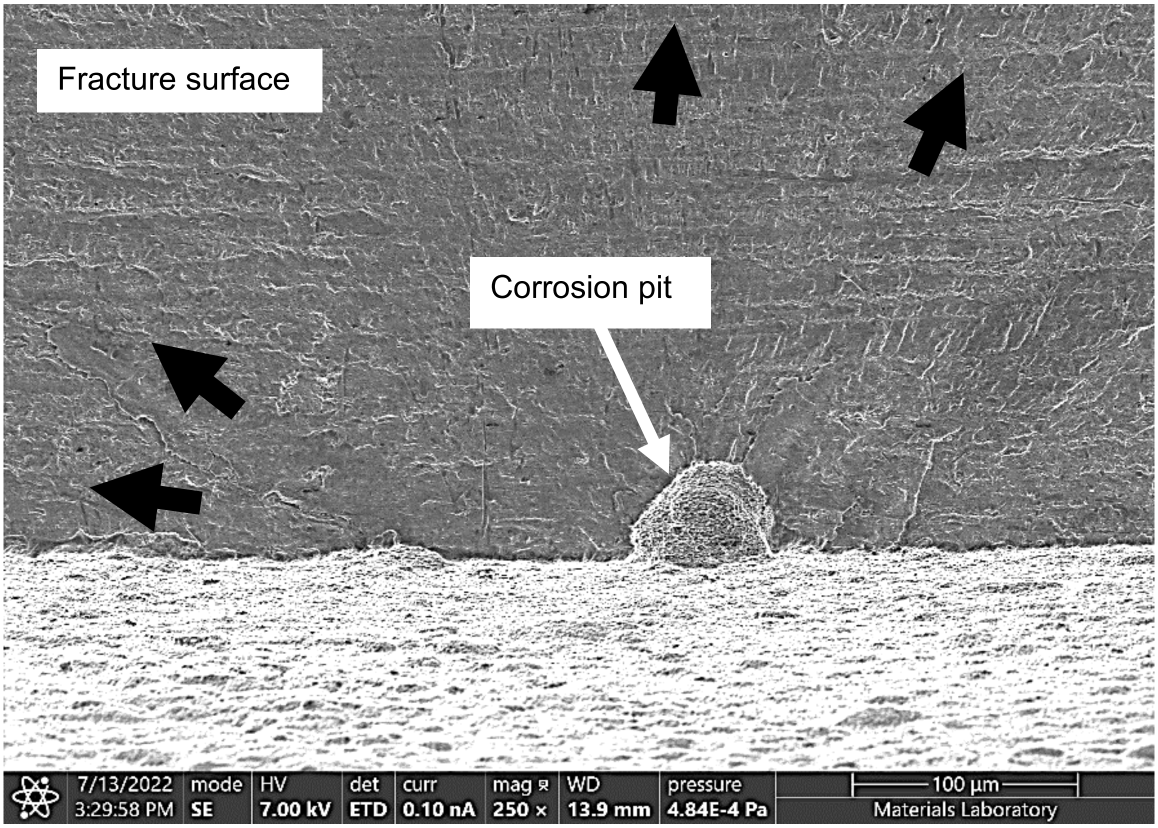


Figure 10. Scanning electron microscope image of fatigue origin “O2” that emanated from a single corrosion pit. Fatigue crack propagation is in the general direction indicated by the arrows.

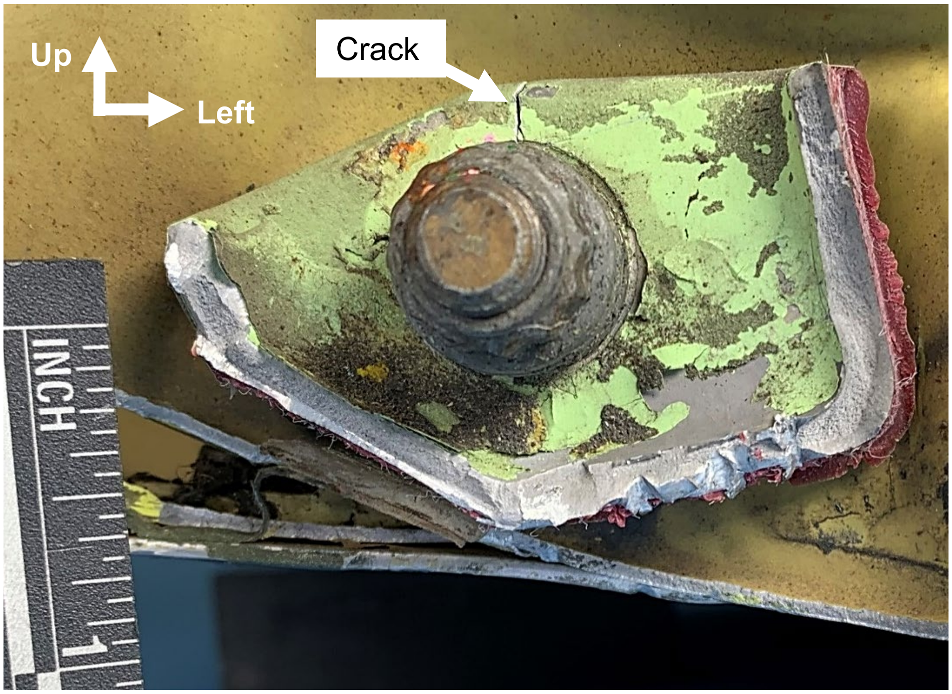


Figure 11. View of the fractured lower right fitting.

Figure 12. View of the fractured upper right fitting.

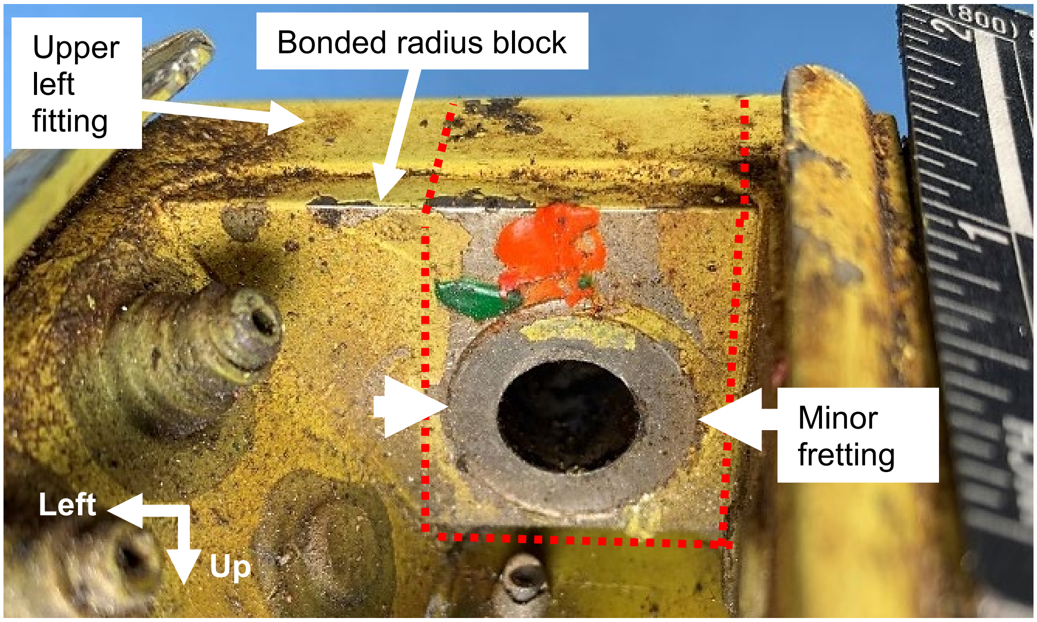
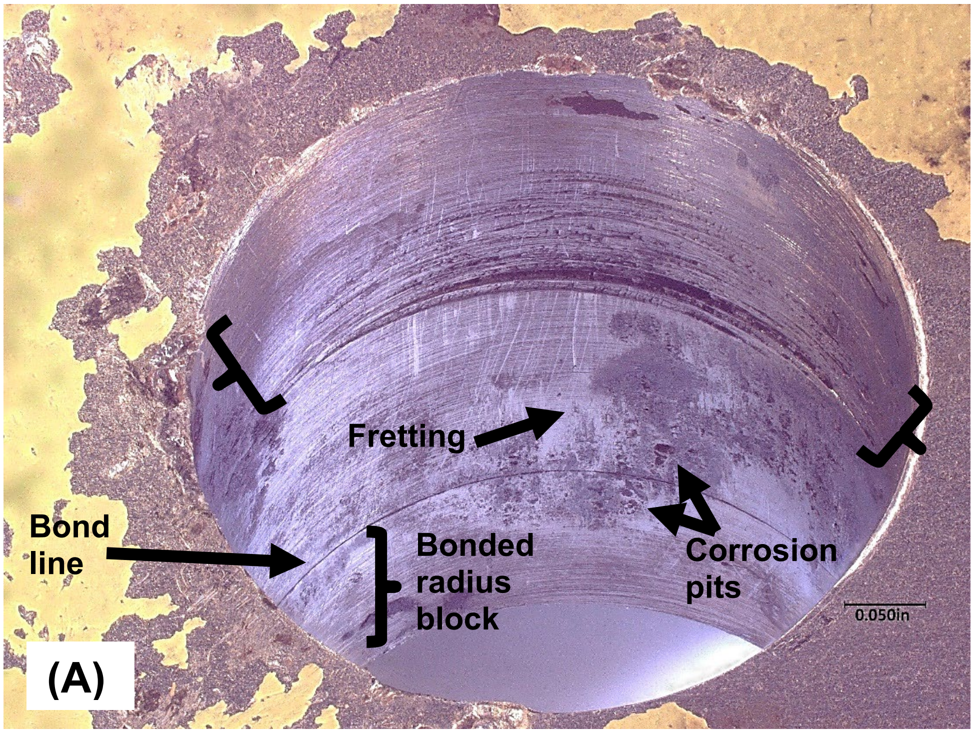


Figure 13. View looking aft at the intact upper left fitting that remained attached to the longeron. Minor fretting was noted between the arrows. Saw cuts were made along the red dashed lines to facilitate examination of the bolt hole. This is a close-up view of the hole shown in figure 4.



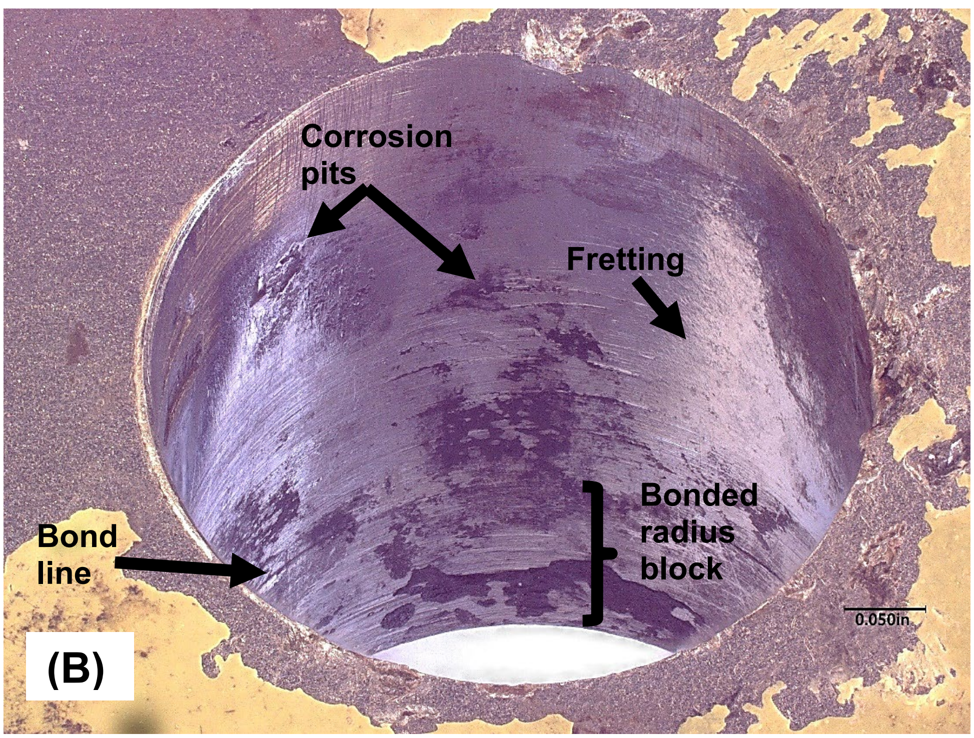


Figure 14. View "A" is looking forward into the bolt hole for the upper left fitting and view "B" is the diametrically opposite side of the same hole showing circumferential gouge and impression marks in the area between brackets, fretting (surfaces with polished appearance), corrosion deposits (back areas), and corrosion pits (photographs taken after ultrasonic cleaning with acetone followed by brush cleaning with Alconox).

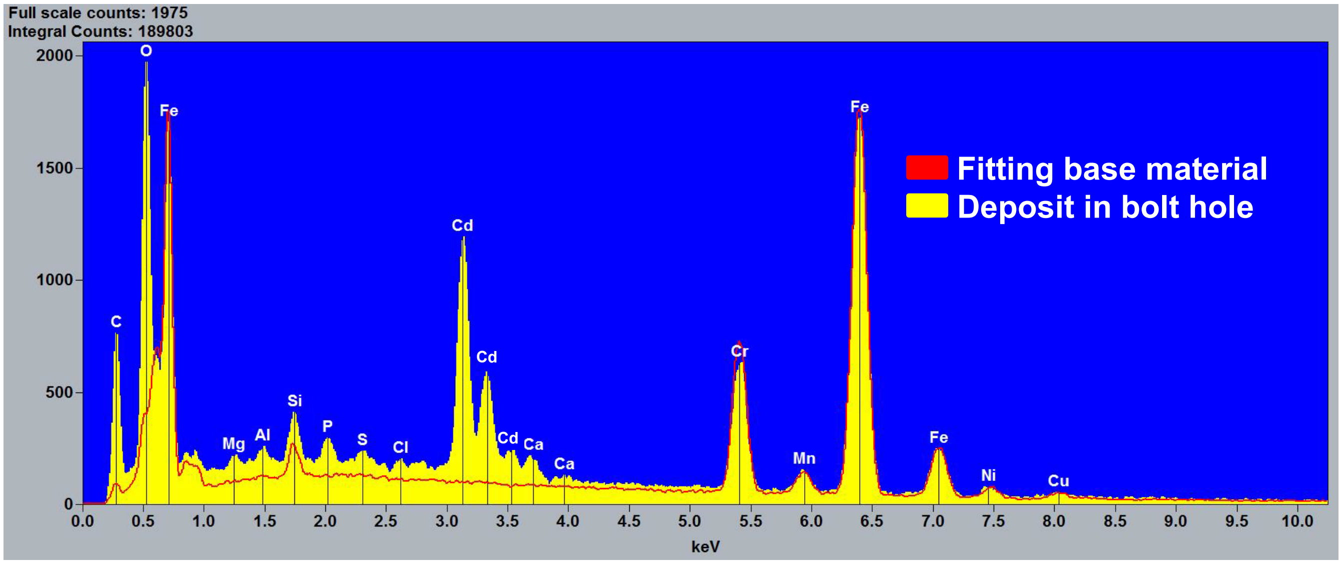


Figure 15. EDS spectrum of the base metal for the upper left fitting (red outline) and overlapping EDS spectrum for the deposits found in the surface of the hole (solid yellow background). The deposits in the bolt hole contained elemental peaks of oxygen (O) in the form of an oxide and cadmium (Cd), among other elements, that were not present in the base metal of the fitting.

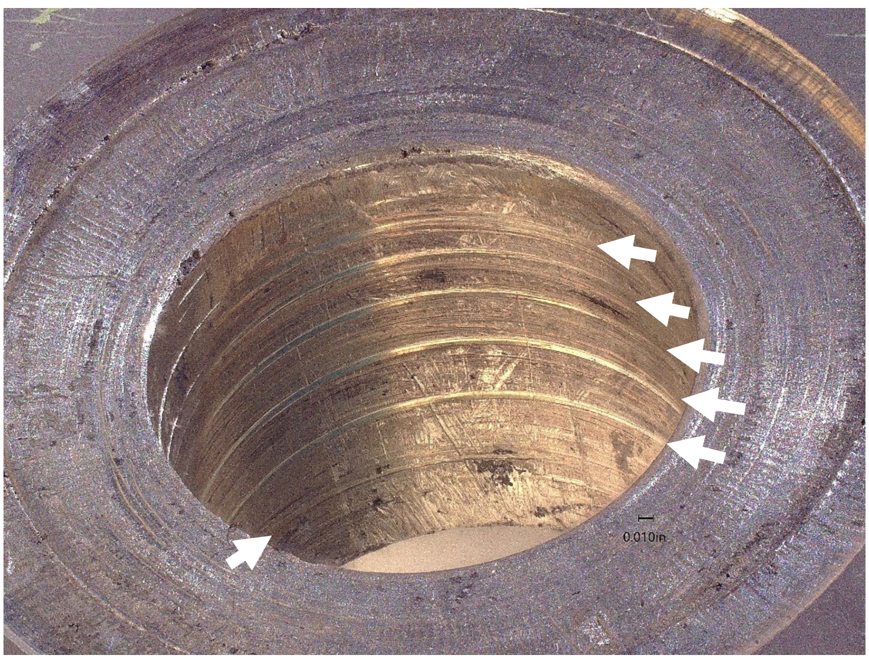


Figure 16. View looking aft into the bolt hole for the lower left fitting showing spiral gouge marks, indicted by arrows, and fine spiral scratches. Shown after removing paint from the fitting with paint stripper.

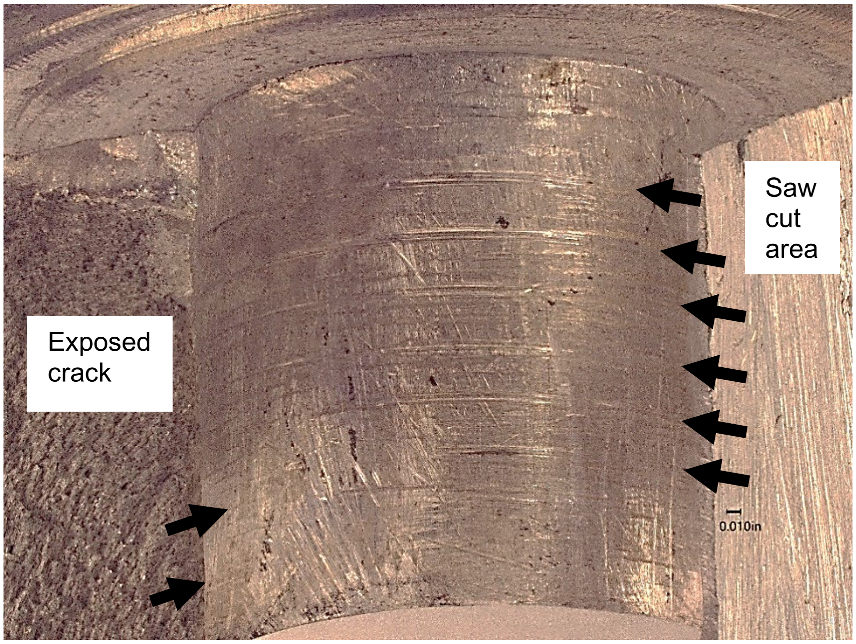


Figure 17. View looking into the bolt hole for the lower right fitting showing spiral gouge marks, indicted by arrows, and fine spiral scratches. Shown after removing paint from the fitting with paint stripper.

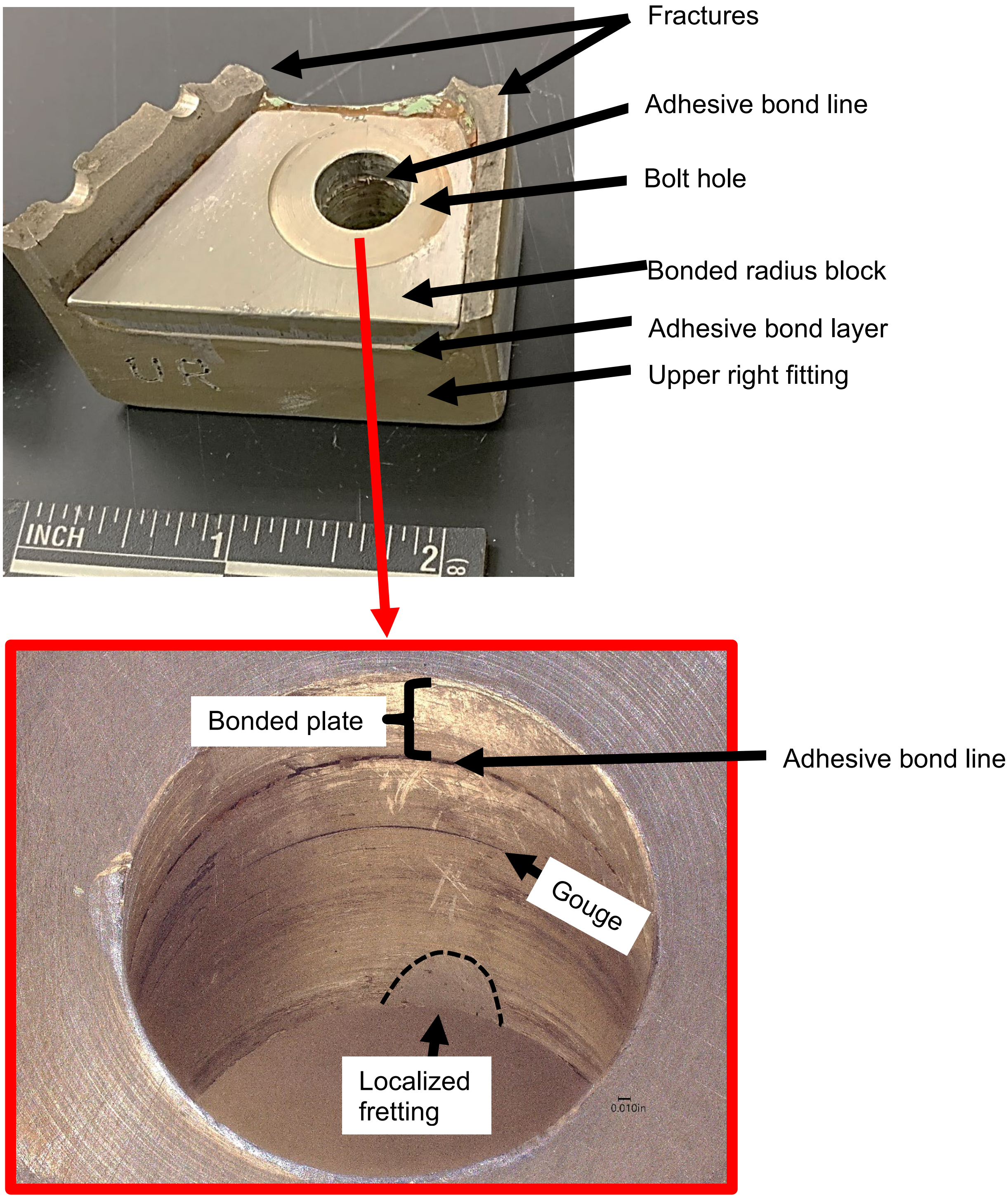


Figure 18. Overall view of the upper right fitting (top of page) and view looking aft into the bolt hole showing a circumferential gouge mark in the area indicted by an arrow; fine circumferential scratches; and an isolated area of fretting. Photographs are shown after removing paint from the fitting with paint stripper. The upper right and left fittings are manufactured with a radius block that are bonded to the forward face of the fitting. The plate showed no evidence of debonding from the fitting.

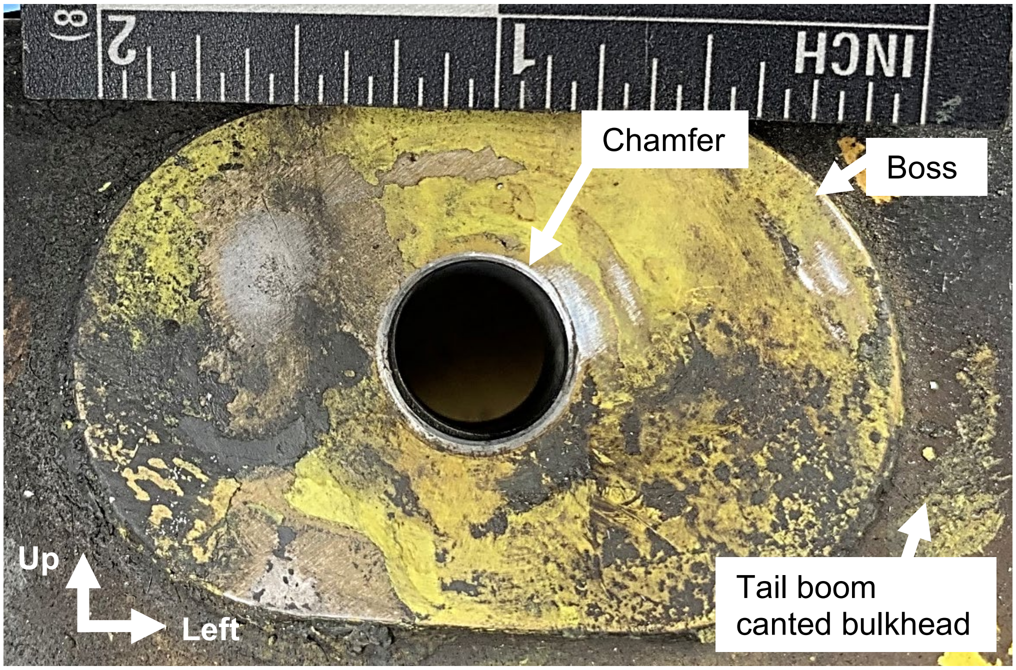


Figure 19. View looking aft into the bolt hole for the upper left fitting, after cleaning the rim portion with a cloth rag. The rim portion of the hole contained a chamfer. The chamfer portion showed no evidence of gouging or metal deformation.

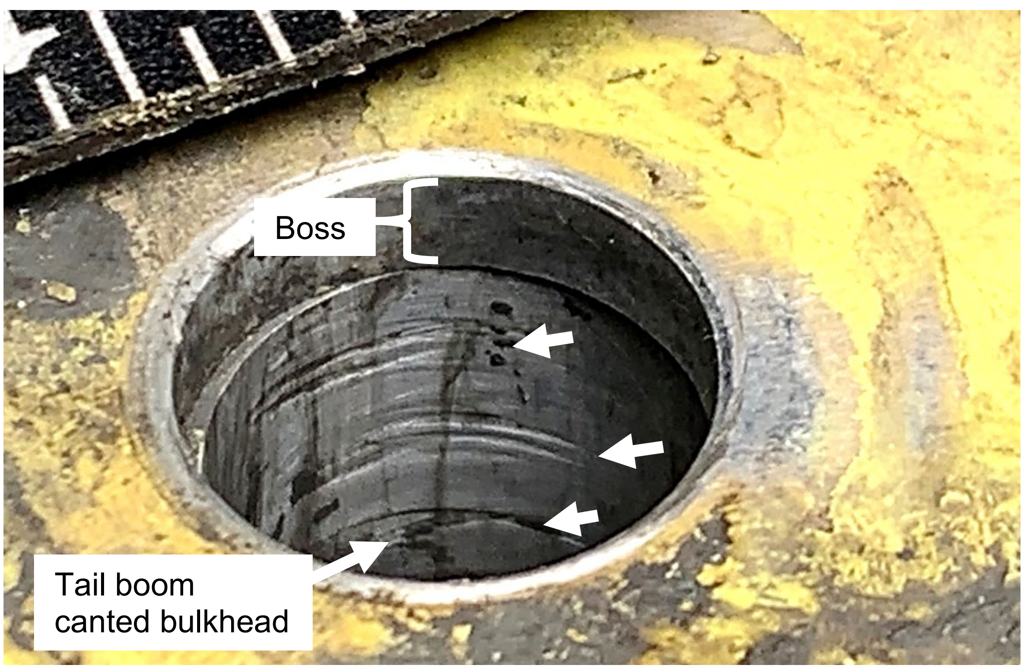


Figure 20. View looking aft into the bolt hole for the upper left fitting showing circumferential gouges, indicated by arrows.

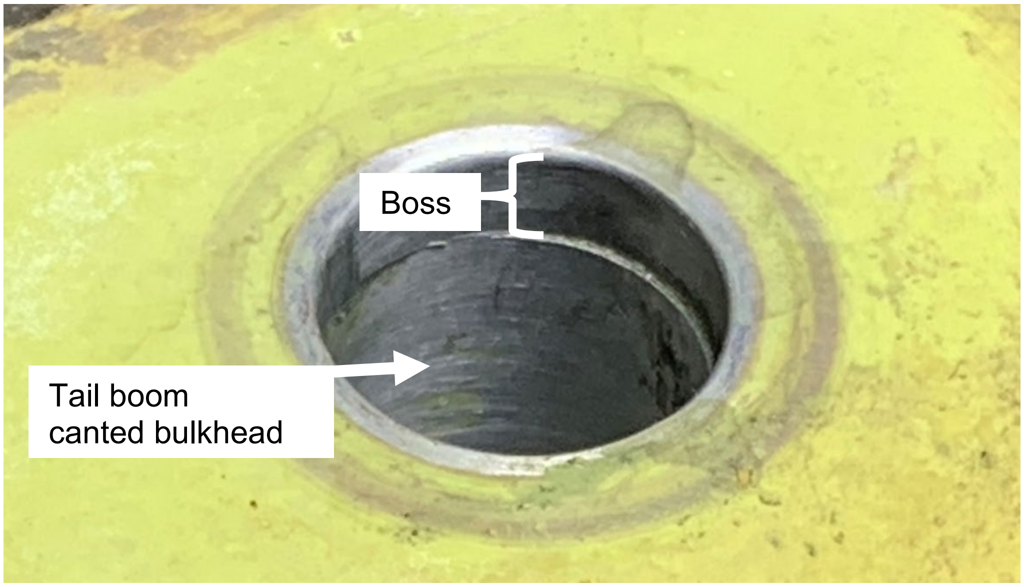


Figure 21. View looking aft into the bolt hole for the upper right fitting showing a smooth finish surface.

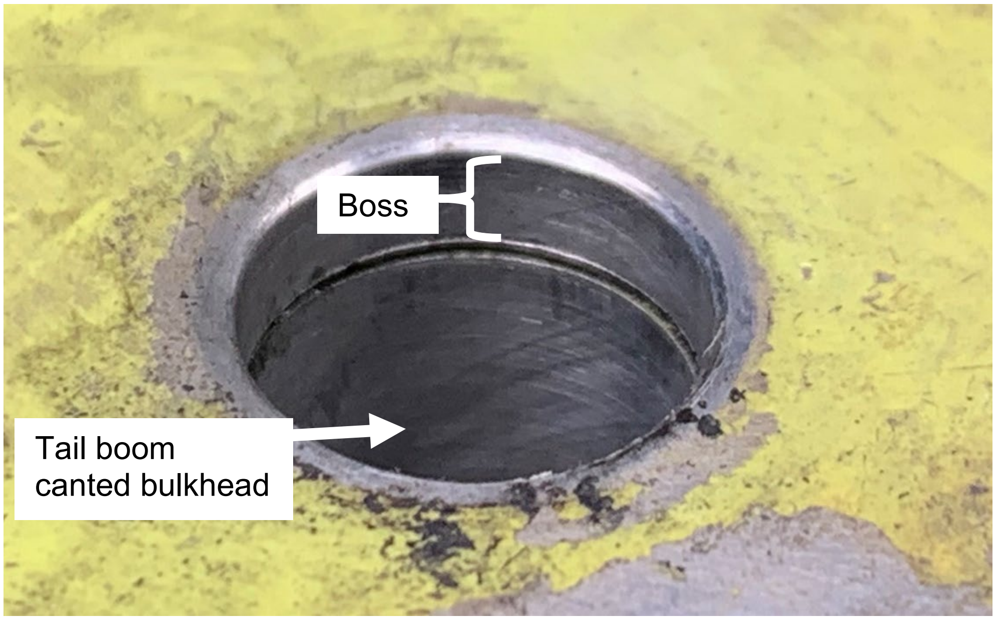


Figure 22. View looking aft into the bolt hole for the lower left fitting showing a smooth finish surface.

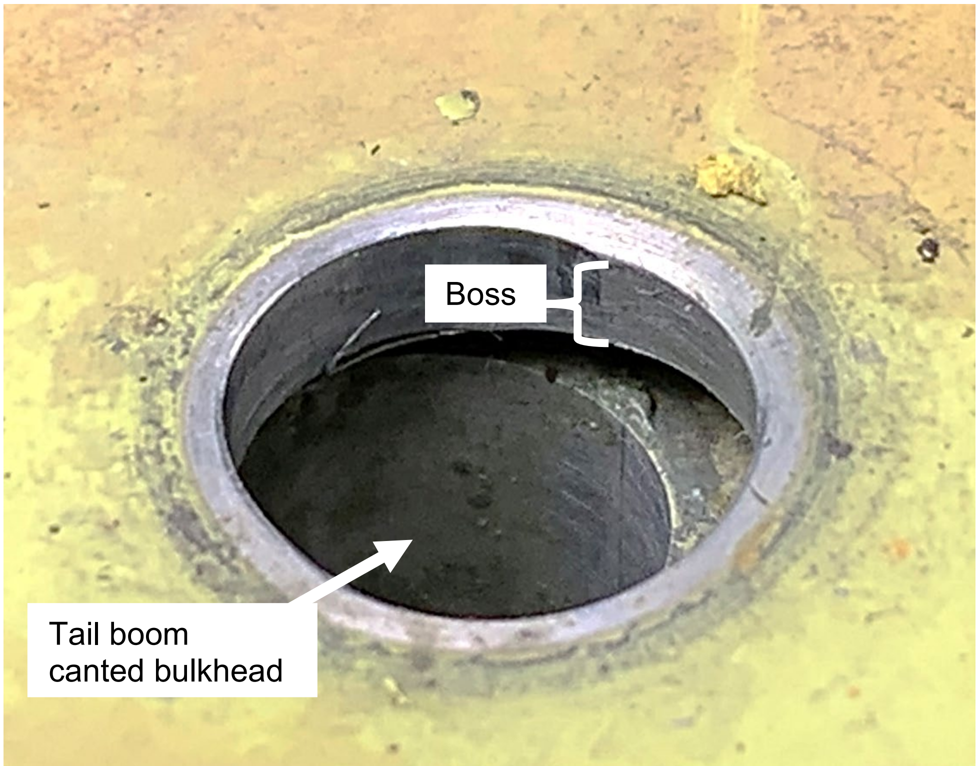


Figure 23. View looking aft into the bolt hole for the lower right fitting showing a smooth finish surface.

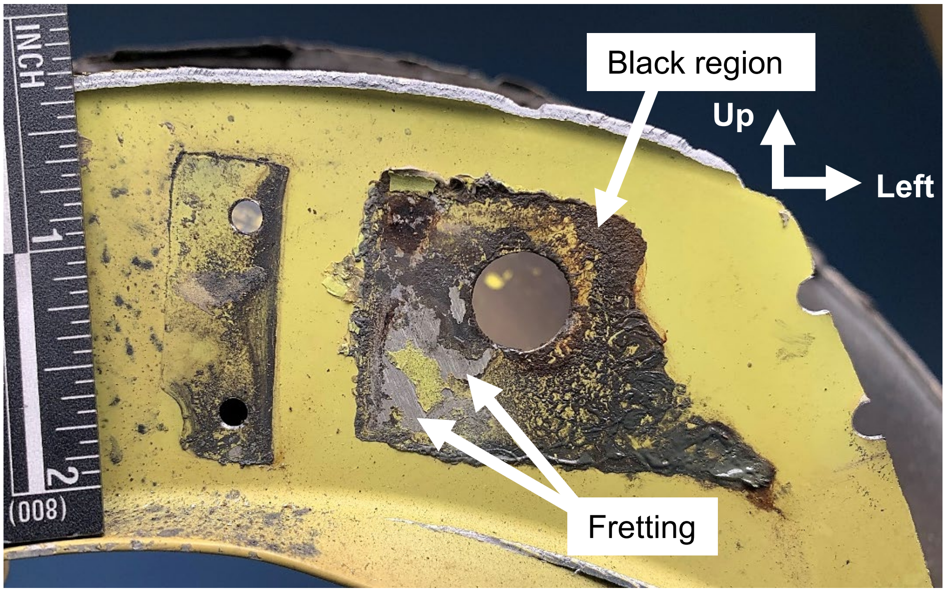


Figure 24. Forward face of the fuselage frame in the area of the bolt hole for the upper left fitting. The forward face in the area that corresponded to the location of the fitting contained a black paste-like deposit, consistent with CPC that was exposed to the environment and exhaust from the engine.

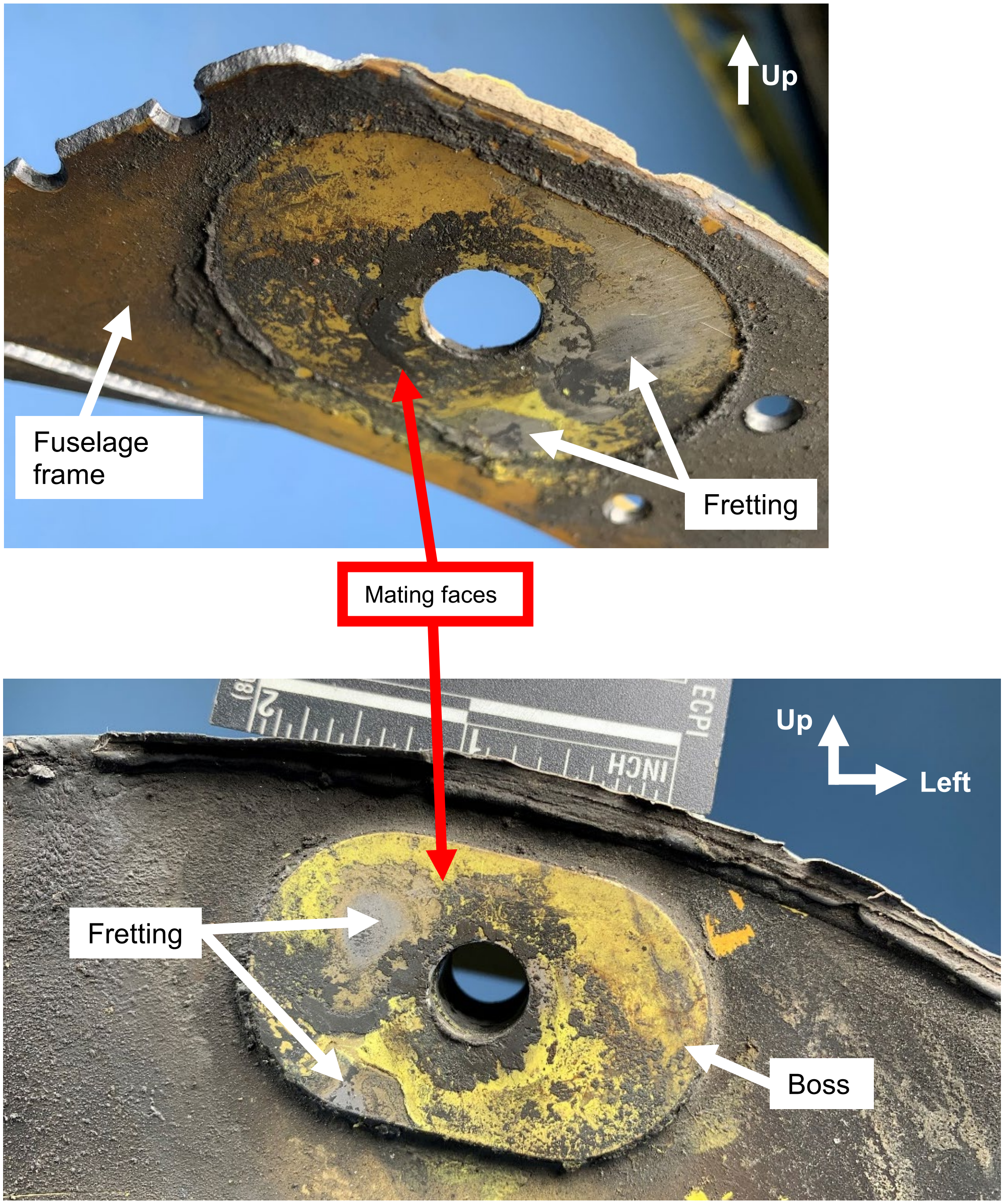


Figure 25. Aft face of the fuselage frame in the area of the bolt hole for the upper left fitting (top of page) and the mating forward face of the tail boom canted bulkhead in the area of the same bolt hole (bottom of page). The mating faces show evidence of fretting.

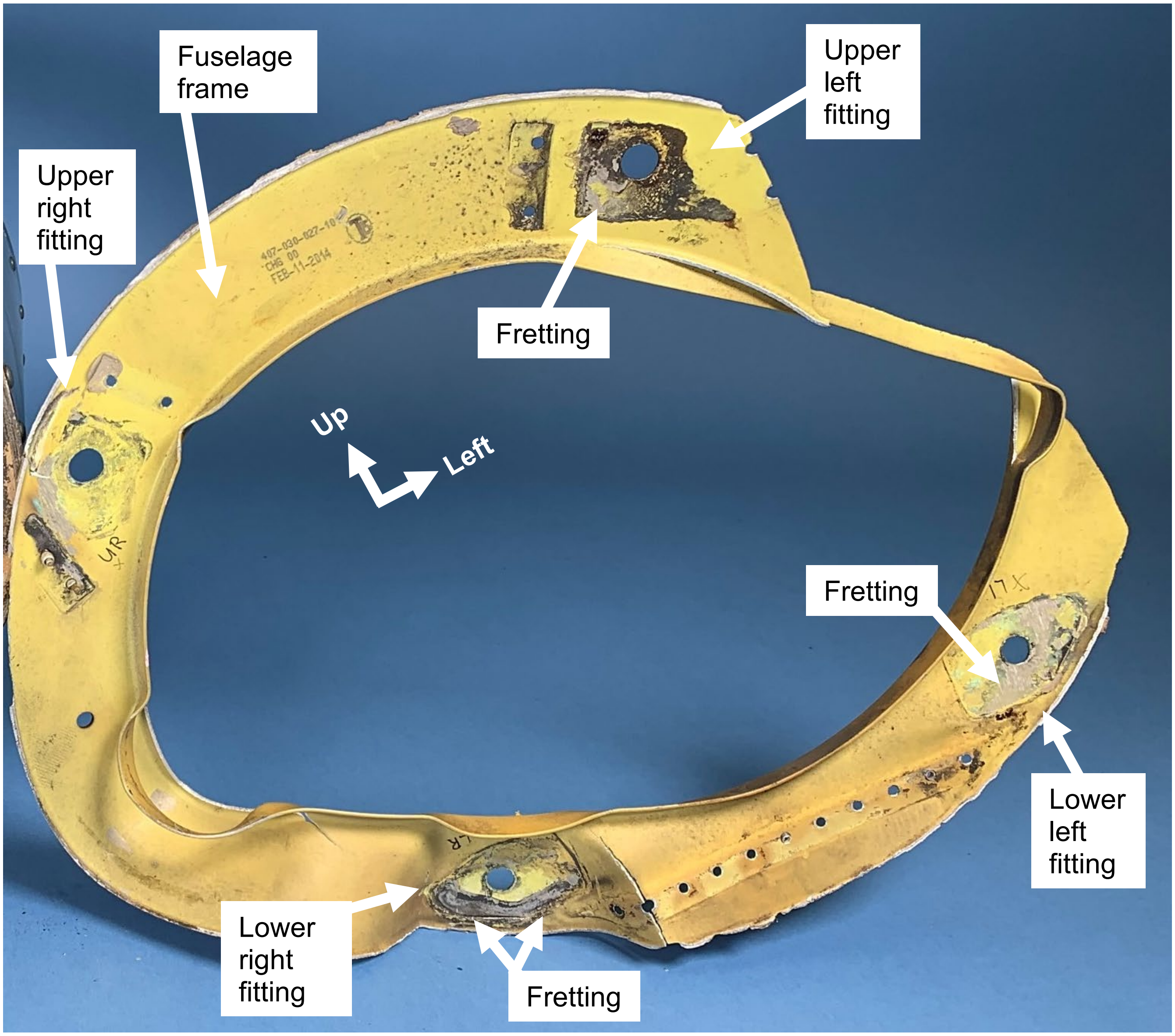


Figure 26. View looking aft at the fuselage frame after the fittings were disassembled. The forward surface of the fuselage frame in the areas that corresponded to upper left fitting exhibited a black deposit of CPC, consistent with exposure of CPC to the environment and exhaust from the engine, whereas the areas that corresponded to the remaining fittings exhibited for the most part clean CPC (yellow-green past-like texture).

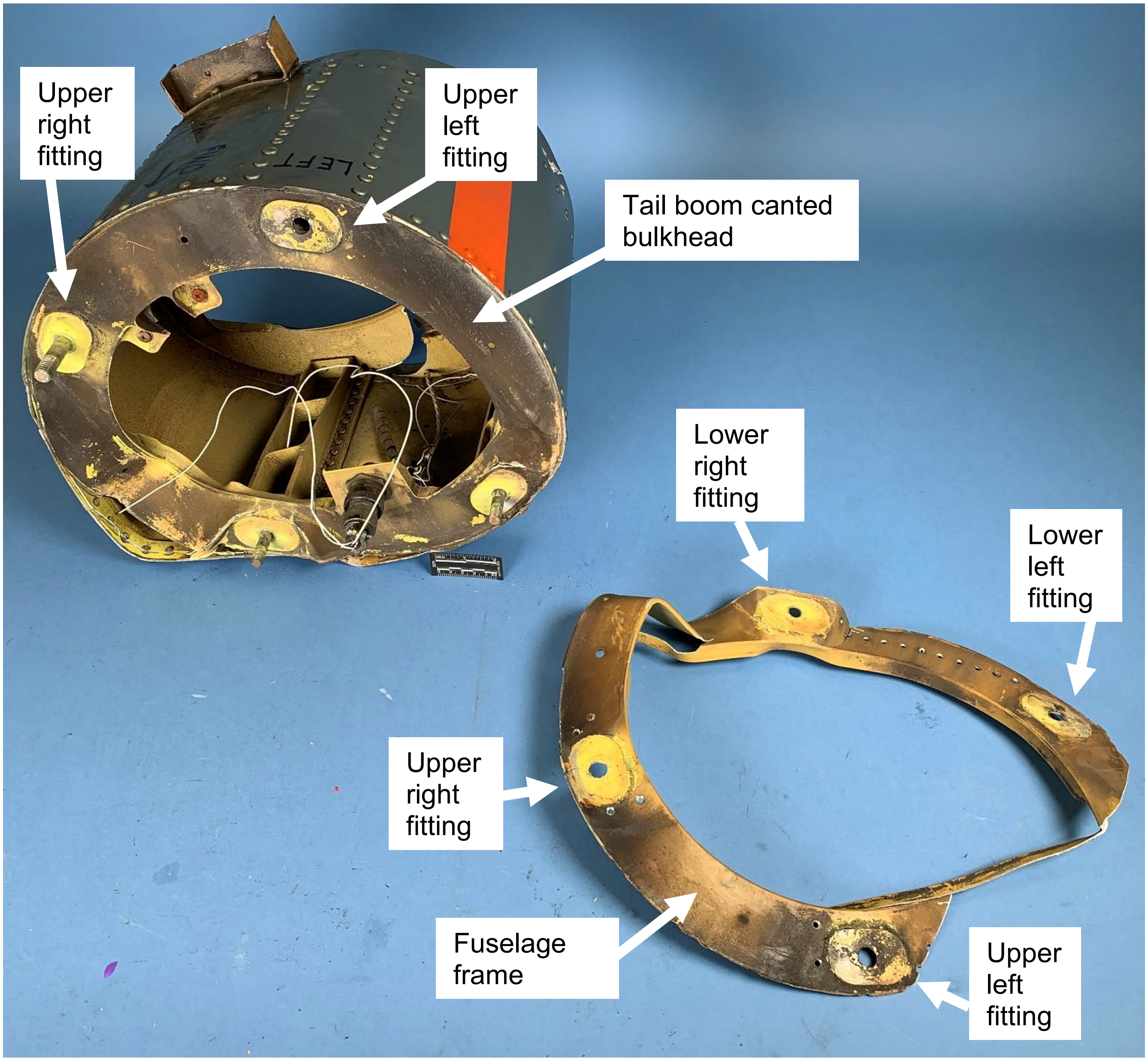


Figure 27. View of the exposed tail boom canted bulkhead after removing the fuselage frame. The forward face of the fuselage frame is shown in this photograph.