NATIONAL TRANSPORTATION SAFETY BOARD

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

October 21, 2011.

MATERIALS LABORATORY FACTUAL REPORT Report No. 11-098

A. ACCIDENT INFORMATION

Place	:	Point Mugu, California.
Date	:	May 18, 2011.
Vehicle	:	Boeing 707-321B, N707AR.
NTSB No.	:	DCA11MA075.
Investigator	:	Bill English, AS-10.

B. COMPONENTS EXAMINED

1. #2 engine pylon to wing fittings.
2. #1 engine pylon to wing fittings.

C. DOCUMENTS REVIEWED

1. Boeing drawing 65-2536. Fitting assembly-mid spar, inboard nacelle.
2. FAA AD 93-11-02. Effective July 6, 1993.

D. DETAILS OF THE EXAMINATION

#2 engine pylon to wing fittings

On-scene, the #2 engine was located on the edge of the runway with a majority of its pylon still attached. An examination of the pylon at the point of separation revealed distinctly flat fracture faces on the remaining portions of the inboard midspar fitting. The #2 engine was recovered to a hanger for easier examination. The rear end of the pylon, at the point of separation, is illustrated in Figure 1 with the image rotated to reflect the up (UP), outboard (OUTBD) and inboard (INBD) directions as indicated. The pylon is normally attached to the wing at the overwing support contained within the red box, the midspar fittings contained within the yellow boxes and the lower spar fitting contained within the blue box.

Examination of the overwing support fitting revealed that it was approximately 35 inches long with a majority of its fairing still attached and was still connected to the front spar fitting. The forward end of the inboard overwing support fitting has two lugs which engage with the single lug on the front spar fitting. A side view of the support is illustrated in Figure 2 with the forward direction indicated. The rear end of the remaining fitting indicated by the red arrow displayed a v-shaped fracture pointing to the rear. The remaining fairing was removed to reveal that the forward end of the overwing support fitting and the front spar fitting were intact but lateral manipulation of the support fitting revealed a degree of looseness. The fitting was sawn at the red dashed line and the rear portion, illustrated later in Figure 8, was retained for a more detailed laboratory examination.

During the survey of the debris trail the second piece of the aircraft found on the runway was a sliver of material that was matched to the fracture on the overwing support fitting. The sliver was retained for laboratory examination and is illustrated and identified later in Figure 8.

The remaining portions of the outboard midspar fitting contained within the yellow box in Figure 1 are illustrated in Figure 3. The remains consisted of forward portions of the fitting's upper and lower tangs, as identified, with fracture faces located between the radii indicated by the blue arrows. The upper and lower tangs are identified on the midspar fitting illustrated in Figure 5. The fracture faces displayed rough grainy surfaces, as indicated by the purple arrows, and shear lips, as indicated by the red arrows, consistent with an overload event. The purple arrows in Figure 5 are parallel to surface lines on the overload fracture face which are referred to as chevrons[1] which point to the fracture origin, at the edge indicated by the yellow arrows. The location of the fractures on the upper and lower tangs is indicated by the red and green lines on the midspar fitting illustrated in Figure 5. In addition, the location of the outboard midspar fitting is illustrated later in Figure 7.

The remaining portions of the inboard midspar fitting contained within the yellow box in Figure 1 are illustrated in Figure 4. The remains consisted of forward portions of the fitting's upper and lower tangs, as identified, with fracture faces located between the radii indicated by the blue arrows. The fracture face on the upper tang displayed the smooth region indicated by the red arrow. The smooth region displayed an arced terminus which appeared to emanate from the upper inboard corner of the tang. The remainder of the fracture face displayed the surface lines indicated by the purple arrows which appeared to radiate from the upper inboard corner of the tang, features consistent with fatigue. The location of the fracture on the upper tang is indicated by the red line on the midspar fitting illustrated in Figure 5.

The fracture face on the lower tang displayed the smaller smooth region indicated by the green arrow in Figure 4. The smooth region displayed an arced terminus which appeared to emanate from the upper inboard corner of the tang. The remainder of the fracture face displayed the surface lines indicated by the purple arrows which appeared to radiate from the upper inboard corner of the tang, features consistent with fatigue. The location of the fracture on the lower tang is indicated by the green line on the midspar fitting illustrated in Figure 5.

[1] Marks arising from small changes in the plane of the fracture in the overstress region that always point to the fracture origin.

A portion of the #2 pylon containing the inboard and outboard midspar fittings, approximately 13 inches forward and 6 inches deep when viewed from the side, was removed for a more detailed laboratory examination and is illustrated later in Figure 8. The indications of fatigue on the inboard midspar fitting prompted a search of the accident scene for the mating fracture. The search produced what appeared to be the rear portion of the midspar fitting illustrated in Figure 5 (the lug aft of the red and green lines) protruding from what appeared to be a lump of resolidified aluminum. The fracture faces on the protruding portion of the midspar fitting displayed features similar to those illustrated in Figure 4. The resolidified aluminum lump, with the protruding midspar fitting, was retained for a more detailed laboratory examination and is illustrated later in Figure 8.

During the survey of the debris trail the first piece of the aircraft found on the runway was a piece of sheet metal that was matched to what remained of the torque bulkhead at the location indicated by the yellow arrow in Figure 1. The bulkhead piece was retained for laboratory examination and is illustrated and identified later in Figure 8.

The location of the overwing support illustrated in Figure 2, and the front spar fitting to which it is attached, is illustrated in Figure 5. The location of the midspar fittings illustrated in Figures 3 and 4, and the drag support fitting to which they are attached, are also illustrated in Figure 5. The drag support fitting is also identified later in Figure 7. An intact midspar fitting is also illustrated in Figure 5 with its upper tang, lower tang and vertical tang identified.

Examination of the lower spar fitting contained within the blue box in Figure 1 revealed the three intact lugs and one fractured lug illustrated and identified in Figure 6. Portions of the diagonal brace forward clevis, indicated by the blue arrows were retained by the pin. Fracture faces on the lug and the clevis portions displayed a uniformly rough and grainy surface consistent with an overload event.

The accident aircraft had a sister ship which was also based at Point Mugu. The sister ship was made available by the operator and had several panels removed from the #2 pylon to enable comparison with the recovered #2 pylon from N707AR. The rear of the #2 pylon on the sister ship is illustrated in Figure 7 with exposed fittings identified. The lower spar fitting is identified with the diagonal brace attached to it, and to the aft drag support fitting. The outboard midspar fitting and the drag support fitting identified in Figure 5 are also identified. The figure also illustrates the limited access to the midspar fittings.

Laboratory examination

The pieces removed from the accident scene and the #2 pylon are illustrated and identified in Figure 8. The pieces consisted of, from left to right, the resolidified aluminum lump, the pylon portion containing the midspar fittings, the bulkhead piece found on the runway, the overwing fitting and the sliver found on the runway.

Examination of the bulkhead piece identified in Figure 8 revealed a uniformly grainy fracture face inclined on a slant plane and features that mated with the pylon portion, just inboard of the outboard midspar fitting. The bulkhead piece is illustrated in Figure 9, and positioned adjacent to the mating fracture on the pylon piece, with distinct features on both pieces indicated by the blue dashed lines. The white arrow indicates the cut-out, adjacent to the outboard midspar fitting, which is similar to the cut-out indicated by the white arrow in Figure 8 and adjacent to the inboard midspar fitting.

Examination of the sliver identified in Figure 8 revealed a uniformly grainy fracture surface on a slant plane and features that mated with the inboard side of the fractured rear end of the overwing fitting. The sliver is illustrated in Figure 10 and positioned adjacent to the mating fracture on the overwing support fitting with distinct mating features indicated by the white and yellow arrows. The red arrow indicates a distinct bend at the inboard lower edge of the sliver. The fracture faces indicated by the blue arrows in Figure 10 displayed mechanical damage that had obliterated most of the fracture features but the fracture face on the outboard side, indicated by the blue arrow in Figure 8, displayed a uniformly grainy that was slightly cupped and displayed chevrons pointing to the rearmost edge of the fracture, consistent with an overload event.

The midspar fittings identified in Figure 8 were separated from the pylon piece as illustrated in Figure 11. Saw cuts were made at the white arrow, the green arrows and finally at the yellow arrows. The removed inboard and outboard midspar fittings identified in Figure 11 were then ultrasonically cleaned in a detergent solution.

The inboard midspar fitting is illustrated in Figure 12 with the upper and lower tangs identified as in Figure 4. On the upper tang, the smooth fatigue region is indicated by the red arrow, the radial lines are indicated by the blue arrows and the orange arrows indicate shear lips on the upper and inboard edges. The purple arrows indicate the radii located forward of the fracture face and indicated by the red arrow in Figure 5. The radii displayed a uniformly light grey surface not evident on the other surface of the tang. On the lower tang, the smooth fatigue region is indicated by the green arrow, the radial lines are indicated by the blue arrows and the orange arrows indicate shear lips on the upper and lower edges. The purple arrows indicate the radii located forward of the fracture face which displayed a uniformly light grey surface not evident on any other surface of the tang, consistent with only the radii being plated. A review of drawing 65-2536 revealed that on midspar fittings part number 65-2536-7 and -8, the radii, and the sides of the adjacent lug, are electroplated with chromium in accordance with Boeing specification F-1.846.

Examination of the inboard midspar fitting radii revealed that the uniformly light grey electroplated surface displayed textural differences. A view of the outboard radii is illustrated in Figure 13 with the tangs identified and the fatigue regions indicated by the red and green arrows as in Figure 12. The purple arrows indicate areas displaying a uniformly dimpled surface, the yellow arrows indicate areas displaying vertically oriented, slightly arced, parallel lines below the dimpled surface and consistent with them being machining marks below the electrodeposit and the black arrow indicates vertically oriented and slightly arced machining marks on the electroplated surface. The blue arrow on the upper tang indicates a portion of the radius normally joining the upper tang to the lower tang. A view of the inboard radii is illustrated in Figure 14 with the tangs identified and the fatigue regions indicated by the red and green arrows as in Figure 12. The purple arrows indicate areas displaying a uniformly dimpled surface and the yellow arrow indicates areas displaying vertically oriented machining marks below the dimpled surface. The black arrow indicates vertically oriented machining marks on the surface of the electroplated surface, adjacent to the fracture face. The white arrows indicate areas where the electrodeposit had been applied outside of the radii edges. The blue arrows on the upper and lower tangs indicate portions of the radius normally joining them, as indicated by the blue dashed line.

The inboard and outboard midspar fittings identified in Figure 11 were disassembled and detergent cleaned. XRF[2] analysis was performed on the inboard and outboard upper tangs which identified the material as alloy steel 4330, satisfying the material requirement in Boeing drawing 65-2536. The disassembled inboard fitting is illustrated in Figure 15 with the upper and lower tangs identified and the fatigue regions indicated by the red and green arrows as in Figure 12. An examination of the upper and lower tangs revealed no part numbers and an XRF analysis of the electrodeposit in the radii revealed that it consisted mostly of chromium, satisfying that requirement in Boeing drawing 65-2536 for the -7 and -8 part numbers. Measurement of the radii revealed an uneven curvature with a nominal radius of approximately 0.38-inch. AD 93-11-02 (document 2 in section C), effective July 6, 1993, referred to Boeing Service Bulletin 3183, dated January 28, 1988, which required that the -7 and -8 midspar fittings, with an electroplated 0.38-inch radius, were to be replaced by -23 and -24 fittings with an non-plated 1-inch radius. The AD required replacement prior to the accumulation of 12,000 flight hours or within 4 years or 4,800 flight cycles of the effective date of the AD, whichever occurred first.

To ease examination of the fracture faces, the fracture faces and their radii were separated from the tang by cutting along the red dashed lines in Figure 15. The paint was abrasively removed from the forward portion of the upper tang for hardness testing. Hardness testing at five (5) locations provided an average hardness of 46.4 HRC[3] satisfying the 220 – 240 ksi[4] requirement in drawing 65-2536 which converts[5] to 46-48 HRC. The fatigue region on the upper tang, indicated by the red arrow in Figures 12 and 15, is illustrated in Figure 16 with the shear lips indicated by the orange arrows in Figure 12, similarly indicated. The yellow arrow indicates the arced terminus of the fatigue region and red arrows indicate crack arrest marks within the region, features consistent with fatigue propagation. The blue arrows indicate radially oriented lines outside of the fatigue region, typical of a fast overload fracture propagating from the

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[2] Thermo Scientific Niton XL3t-980 x-ray fluorescence (XRF) alloy analyzer
[3] Hardness, Rockwell, C scale.
[4] Thousands of pounds per square inch.
[5] ASTM E-140. Standard hardness conversion tables for metals.

arced terminus. The radial lines, the arced terminus and the arc of the crack arrest marks indicate that the fatigue initiated within the red circle. The black arrow indicates the machining marks on the electrodeposit and the white arrow indicates the thickness of the electrodeposit.

The examination of the electroplated radii on both tangs of the inboard midspar fitting had revealed distinct surface features namely a uniformly electroplated surface and machining marks below the electroplated surface but slightly arced machining marks on the plated surface were observed only on the radii of the upper tang. Examination of the outboard radius on the upper tang had revealed a shear lip adjacent to the plated surface whereas the inboard radius was adjacent to the fatigue region. The inboard radius, adjacent to the fatigue region is illustrated in the left image in Figure 17 with a red arrow indicating the fatigue region, a red circle indicating the fatigue initiation zone and an orange arrow indicating a shear lip. The white arrow indicates the electroplated surface with subsurface machining marks still evident, the purple arrow indicates the electroplated surface and the black arrow indicates the machining marks similarly indicated by the black arrow in Figure 14. The yellow arrows indicate the well defined edge of the machined area and the blue arrows indicate paint remaining on the machined area.

A closer view of the area within the red box in the left image in Figure 17 is illustrated in the right image with a red arrow indicating the fatigue region. The red dashed line drawn on the edge of the chromium electroplating and the black dashed line drawn on a machining mark suggest a convergence at the black arrow, within the fatigue initiation zone. The blue arrows indicate mechanical damage on both sides of the black arrow.

The portion of the upper tang containing the fracture face was ultrasonically solvent cleaned and installed in an SEM[6] for a detailed examination. The examination revealed that the surface of the fatigue region was covered with corrosion product. A typical surface is illustrated in Figure 18 with yellow arrows indicating areas displaying surface cracking commonly described as “mud cracking”. As corrosion product can obscure, or obliterate, any fine fracture features the fracture surface was first cleaned by repeated applications of replica tape[7]. Re-examination of the fracture face in the SEM revealed that the corrosion product was still present. The corrosion product was then removed by an ASTM[8] procedure using a solution of hydrochloric acid and hexamethylene tetramine[9]. After three applications, with subsequent cleaning and examinations, the corrosion product had been removed to reveal that any finer features had been obliterated leaving only the more gross, and corroded, crack arrest marks on a corroded surface. A typical area of the cleaned surface, for comparison with Figure 18, is illustrated in Figure 19 with red arrows indicating the remains of a crack arrest mark.

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[6] Scanning electron microscope.
[7] Acetate tape and acetone used to replicate surface features and also to clean a fracture surface.
[8] American Society of Testing and Materials.
[9] ASTM G1-03 page 21, solution C.3.5.

SEM examination of the fatigue initiation site within the red box in Figure 16 revealed a corroded surface and chromium electroplating that was separating from the steel fitting. The initiation site is illustrated in Figure 20 with purple arrows indicating the chromium electroplating and red arrows indicating separations between the electrodeposit and the steel fitting. The blue arrows indicate mechanical damage on the fracture face.

The SEM survey of the fracture face also revealed fissures on the fracture face that were arced and oriented mostly parallel to the crack arrest marks. A typical area is illustrated in Fig 21 with red arrows indicating fissures and yellow arrows indicating the remains of corroded crack arrest marks.

The SEM survey of the chromium electroplating revealed internal cracks probably produced during the fracture sequence and areas containing crack arrest marks. Typical internal cracking is illustrated in the left image in Figure 22 with the red and purple arrows indicating a crack that had originated at the particle indicated by the yellow arrow. The orange arrow indicates where the crack indicated by the red arrow had penetrated to the surface indicated by the white arrow and the blue arrow indicates a secondary crack that did not penetrate to the outer surface. The black arrows indicate crack arrest marks in the areas between cracks.

The fatigue region indicated by the green arrow in Figures 12, 13 and 14 is illustrated in Figure 23 and similarly indicated. The yellow arrow indicates the arced fatigue region terminus and the orange arrows indicate the adjacent shear lips. The red arrows indicate crack arrest marks in the fatigue region and also indicate that the origin was along the edge of the radius. The blue arrows indicate ratchet marks[10] that had initiated along the edge of the radius and propagated through the electrodeposit indicated by the purple arrow. Figure 24 is a closer view of the electrodeposit edge adjacent to the fatigue region and illustrates the steps associated with the ratchet marks indicated by the blue arrows as in Figure 23. The green arrow indicates the fatigue region and the purple arrow indicates the electrodeposit surface.

The black sealant on the fitting hardware on the remaining removed portion of the pylon illustrated in Figure 11 was removed and the portion cleaned for examination. The sealant on the hardware for the inboard midspar fitting was found to lift off easily and the sealant on the hardware for the outboard midspar fitting had to be painstakingly cut off. The exposed hardware and the cleaned intervening bulkhead are illustrated in Figure 25 with the outboard and inboard midspar fittings identified. Examination of the surfaces around the hardware revealed indicators for holes but no identifications. Examination of the intervening bulkhead displayed “AS??-65-?”, “?99”, “S/O P-1956” and UNIT-001” with “T-8” partially overlaid on it and contained within the red box in Figure 25.

[10] Slight vertical steps in the fracture that link slightly offset planes of fatigue cracking at a fatigue origin area. Ratchet marks generally are aligned in the direction of cracking and taper off as distance from the origin is increased and a unified crack front is produced.

The resolidified aluminum lump identified in Figure 8 had a portion of the inboard midspar fitting protruding from its surface. The fracture face on the protruding portion of the fitting is illustrated in Figure 26 with the fatigue regions matching the fatigue regions in Figure 4 similarly indicated by the red and green arrows. The resolidified aluminum piece was x-rayed and found to contain the vertical tang still attached to the protruding lug portion of the inboard midspar fitting. The x-ray revealed the lug portion and vertical tang of the outboard midspar fitting with fracture profiles on the lug portion matching the fractures illustrated in Figure 3. Although the concentration was on the midspar fittings, the x-ray also revealed hardware sufficient to indicate that portions of the drag support fittings identified in Figure 5, were also contained.

#1 engine pylon to wing fittings.

On scene, the #1 engine pylon had separated from the engine and both were recovered to the hanger for easier examination. The #1 pylon was examined for comparison with the pylon on the #2 engine. The underside of the #1 pylon is illustrated in Figure 27 with the forward direction indicated and the forward engine mounts indicated by the green and purple arrows. The forward engine mounts are attached to the engine by “fused” bolts which are designed to break first in the event of a catastrophic failure, ensuring that the front of the engine will drop downwards. The fractured outboard mounting bolt, indicated by the green arrow in Figure 27, is illustrated in Figure 28 with the fracture faces indicated by the yellow arrows. Examination of the fracture faces revealed mechanically damaged, but rough grainy surfaces with slant “cup and cone” features consistent with an overload event. The fractured inboard mounting bolt, indicated by the purple arrow in Figure 27, is illustrated in Figure 29 with the fracture faces indicated by the yellow arrows. Examination of the fracture faces also revealed mechanically damaged, but rough grainy surfaces with slant “cup and cone” features consistent with an overload event.

The rear of the #1 pylon is illustrated in Figure 30 and oriented similar to the #2 pylon illustrated in Figure 1 with the up (UP), outboard (OUTBD) and inboard (INBD) directions indicated. The pylon is normally attached to the wing at the overwing spar fitting contained within the red box, the midspar contained within the yellow boxes and the lower spar fitting contained within the blue box.

The forward end of the outboard overwing support fitting differs from the inboard support fitting and has three lugs which engage with two lugs on the front spar fitting. The remaining overwing support on the #1 pylon consisted of the fractured front spar fitting illustrated in Figure 31 with the two fractured lugs indicated by the red arrows. Examination of the fracture faces revealed a uniformly rough grainy surface and slant planes, consistent with an overload event.

The midspar had fractured further forward than the fittings, almost directly below the front spar fitting for the overwing support. The outboard midspar area within the yellow box in Figure 30 is illustrated in Figure 32 with the midspar identified and an exposed attaching bolt indicated with a purple arrow (the remaining shank of an inboard bolt is indicated by the blue arrow). Examination of the fracture faces indicated by the red arrows revealed a uniformly grainy surface. The green arrow indicates the painted end of a midspar structural member and the yellow arrow indicates a portion of the structure that was bent inboard. The inboard midspar area within the yellow box in Figure 30 is illustrated in Figure 33 with the midspar identified and an exposed attaching bolt indicated with a purple arrow (an inboard bolt is indicated by the blue arrow). Examination of the fracture faces indicated by the red arrows revealed a uniformly grainy surface. The green arrow indicates the painted end of a midspar structural member.

The lower spar fitting on the #1 pylon is similar to the fitting on the #2 pylon illustrated in Figure 6. Three of the four lugs displayed similar fractures and the fourth lug had separated from the fitting base. The lower spar fitting is illustrated in Figure 34 after some vegetation removal and with the exposed fracture faces indicated by the yellow and purple arrows. Examination of the lug fracture faces indicated by the yellow arrows revealed uniformly grainy surfaces, slightly cupped and oriented radially to what remained of the attaching hole. Examination of the fitting fracture face indicated by the purple arrow revealed a uniformly grainy surface. The red dashed line is a continuation of the lower skin to illustrate the amount of upward deflection that had been applied to the lower spar fitting area.

A diagonal brace was recovered from the debris trail and is illustrated in Figure 35. The diagonal brace, as illustrated in Figure 7, connects the lower spar fitting to the aft drag support fitting and consists of a tube with a two lugged clevis at each end. Examination of the end of the brace identified as the forward clevis revealed that the attaching bolt was still located in the lugs and the gap between the lugs contained a lower spar fitting lug, confirming that it was the forward clevis. The forward clevis is illustrated in the left image in Figure 36 with a purple arrow indicating the fracture face on the lower spar fitting lug. The red arrows are positioned parallel to lines on the fracture surface and indicate that the fracture had initiated on the right vertical edge of the lug. The yellow arrows in the left image in Figure 36 indicate areas that did not contain a lug from the lower spar fitting but the spacing matched the lug spacing in Figure 34.

The rear end of the diagonal brace consisted of a partial clevis, consisting of one of its two lugs, and a long narrow “V” shaped fracture in the tube. The clevis is illustrated in the right image in Figure 36 with a yellow arrow indicating a fractured edge on the lug bush and a red arrow indicating mechanical damage to the adjacent lug, where the missing portion of the lug bush had originally been located. The white arrow indicates the amount of the bush that had been relocated inwards.

The “V” shaped fracture at the rear end of the diagonal brace was approximately 18.5 inches long and is illustrated in Figure 37 with the remaining rear clevis lug identified and one side of the “V” indicated by blue arrows. The yellow arrows indicate the other side of the “V” which continued past the side indicated by the blue arrows as indicated by the white arrow. Examination of the fracture faces revealed a rough grainy surface with chevrons pointing toward the rear edge of the tube. The green arrows indicate fracture faces on the portion of the clevis remaining in the tube which displayed uniformly rough grainy surfaces.

Derek Nash
Mechanical Engineer

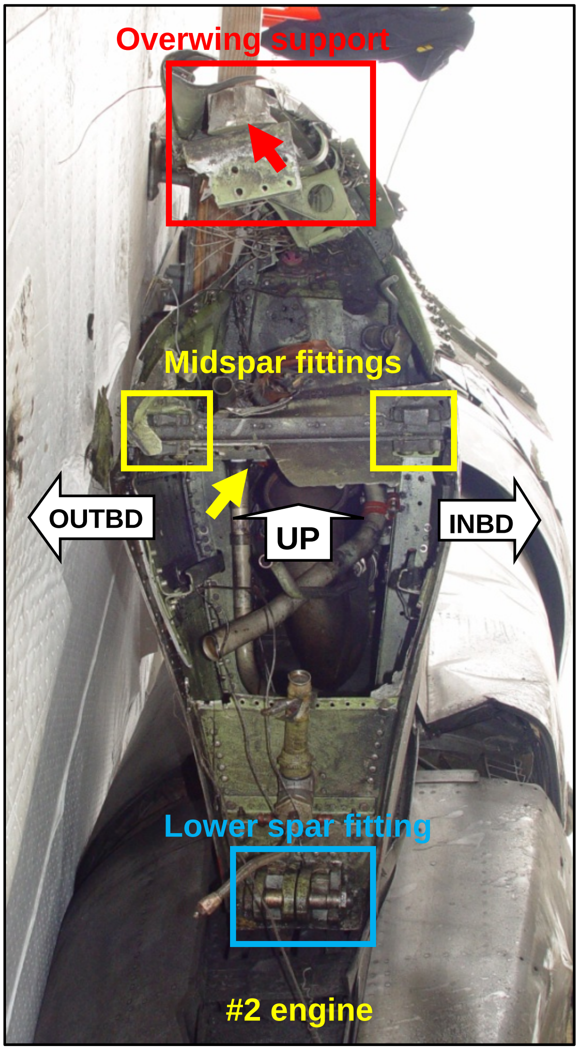


Figure 1. The rear of the #2 engine pylon as separated from the wing.

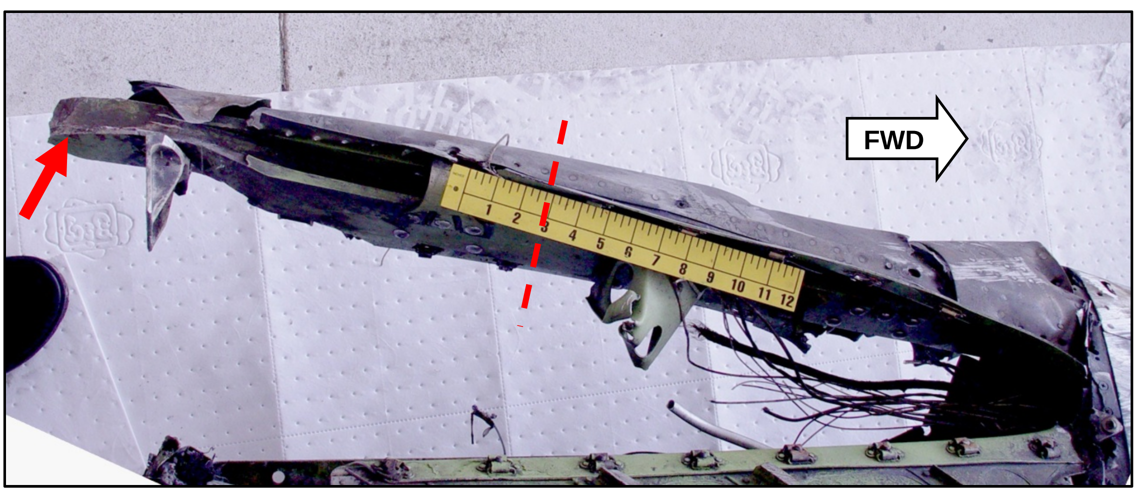


Figure 2. Side view of the overwing support contained within the red box in Figure 1.

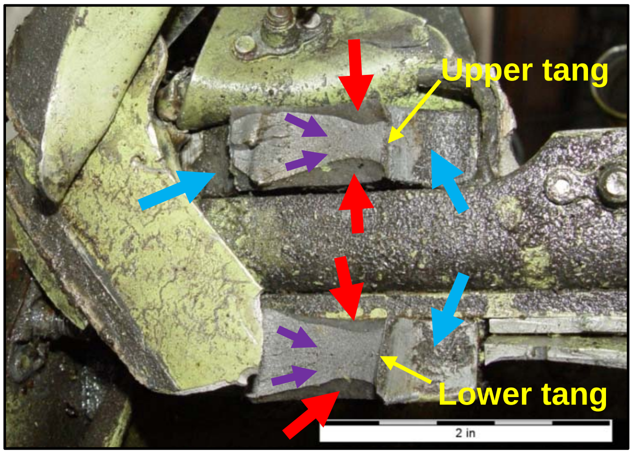


Figure 3. The remains of the outboard midspar fitting located within the yellow box in Figure 1.

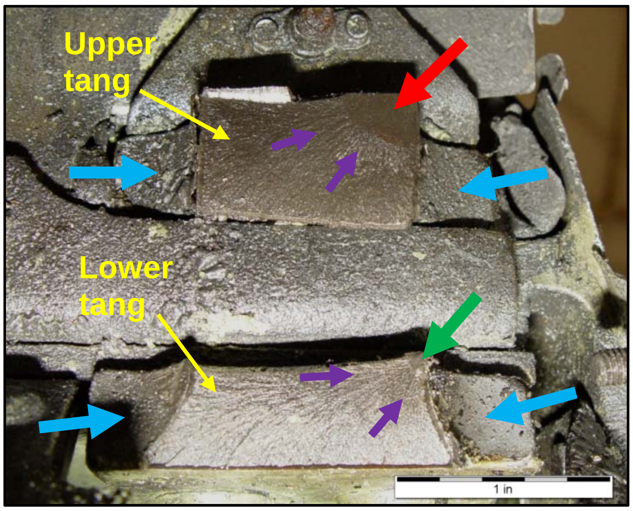


Figure 4. The remains of the inboard midspar fitting located within the yellow box in Figure 1.

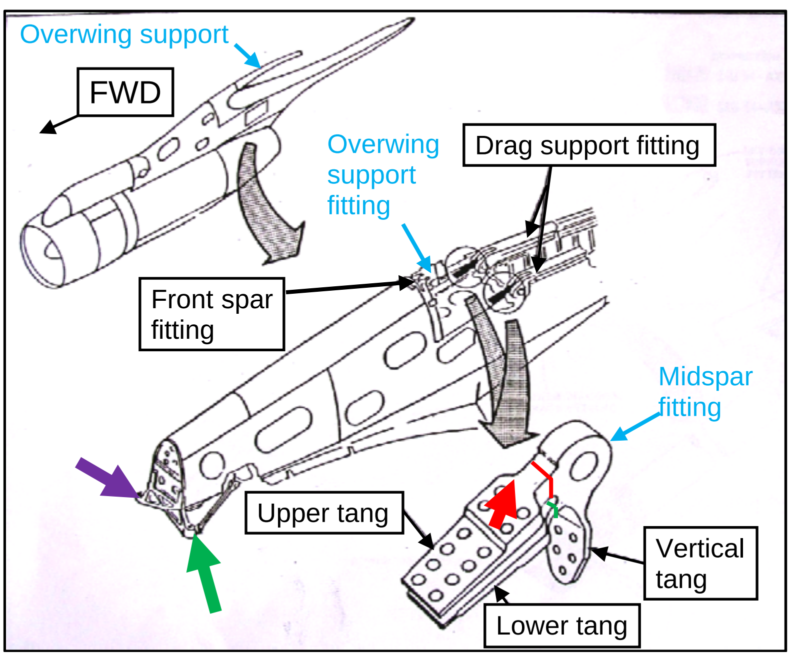


Figure 5. Drawing illustrating the location of the overwing support fitting and the midspar fittings with adjacent fittings identified.

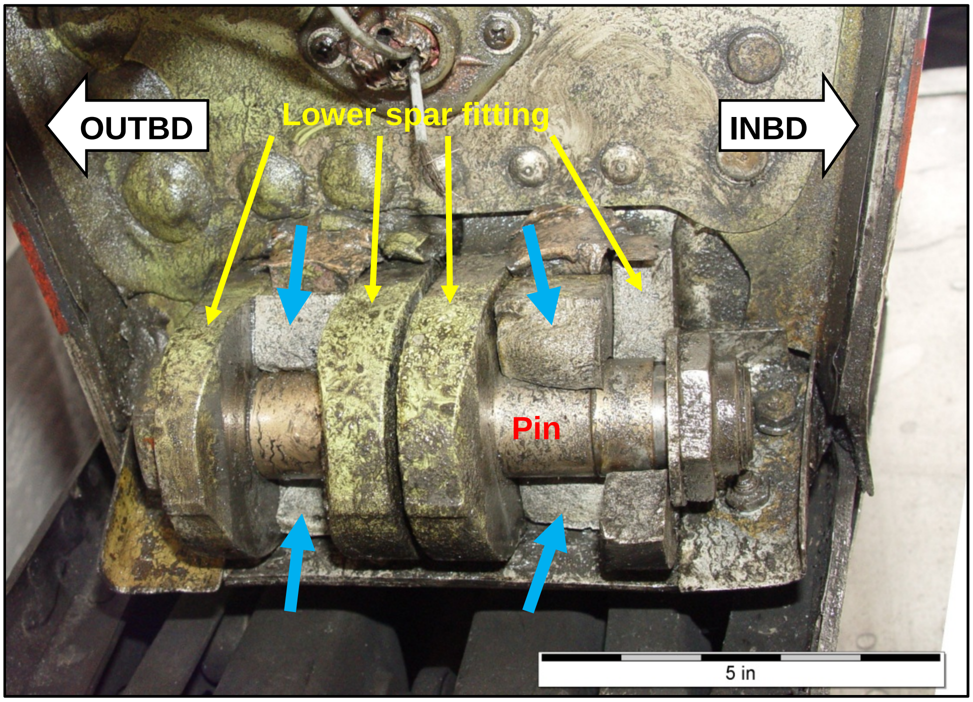


Figure 6. The lower spar fitting within the blue box in Figure 1.

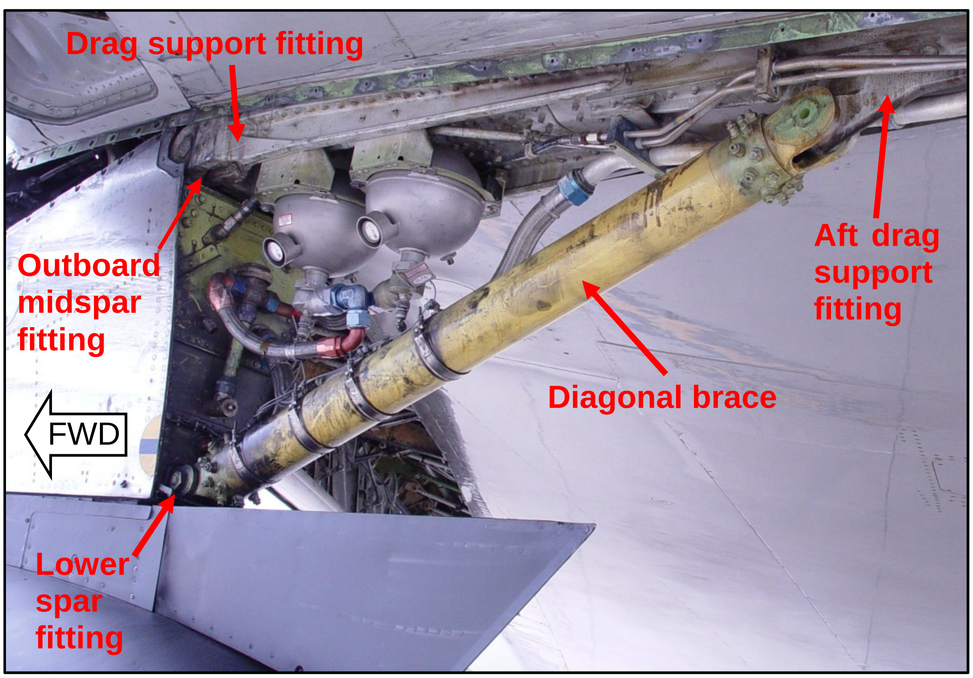


Figure 7. The location of the lower spar fitting and the outboard midspar fitting on the #2 pylon of N707AR's sister ship.

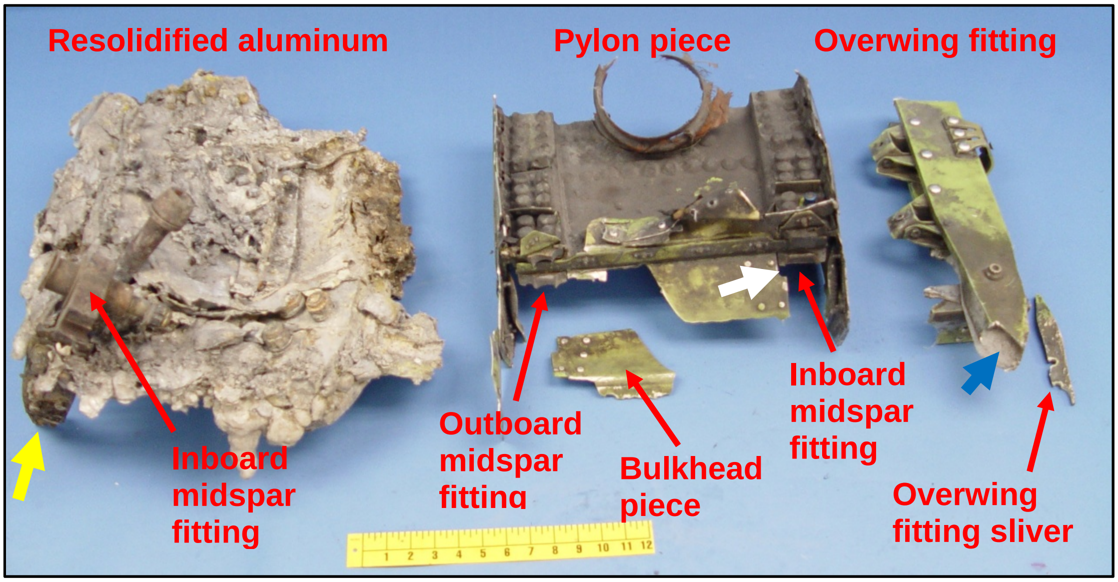


Figure 8. The pieces removed from the accident scene for further examination.

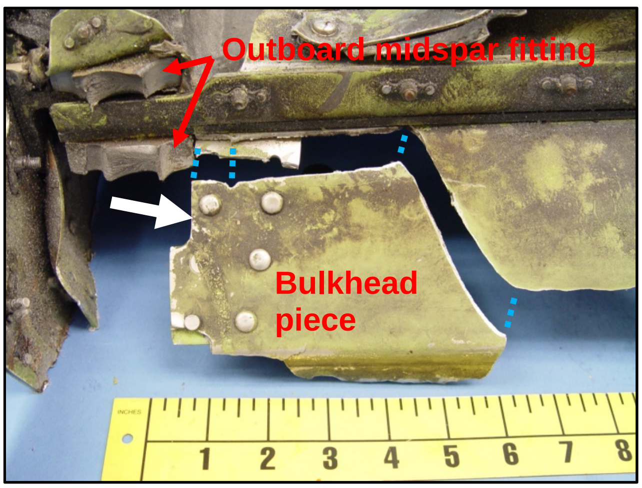


Figure 9. The bulkhead piece mated to the removed portion of the pylon.

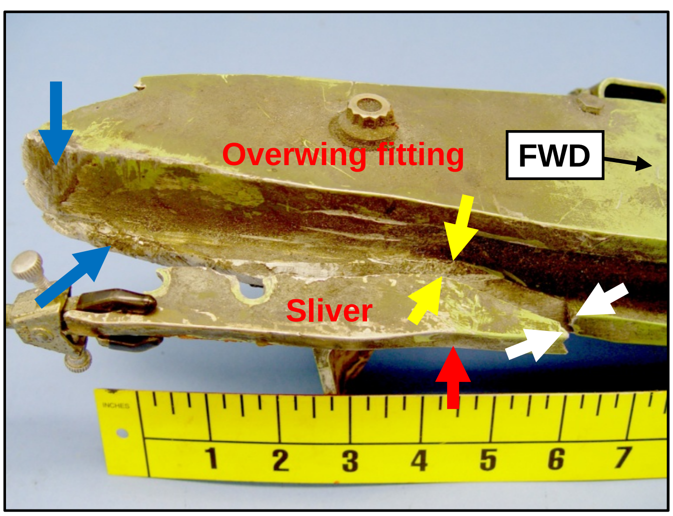


Figure 10. The overwing fitting sliver mated to the removed portion of the overwing fitting.

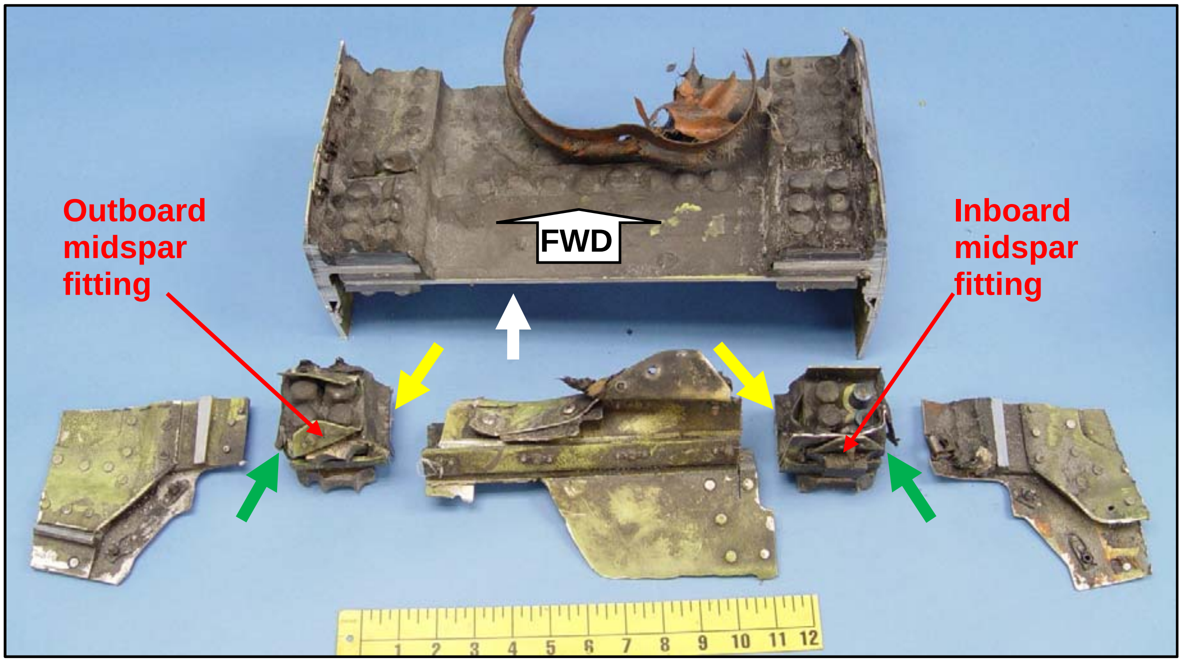


Figure 11. The inboard and outboard midspar fitting fractures removed from the removed portion of the pylon.

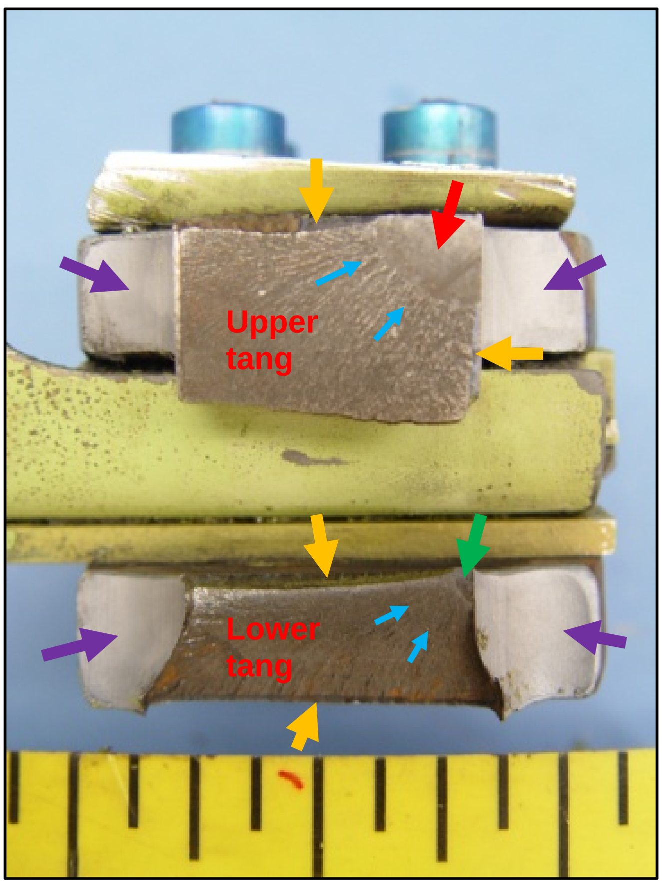


Figure 12. The fracture faces on the upper and lower tangs of the inboard midspar fitting after cleaning.

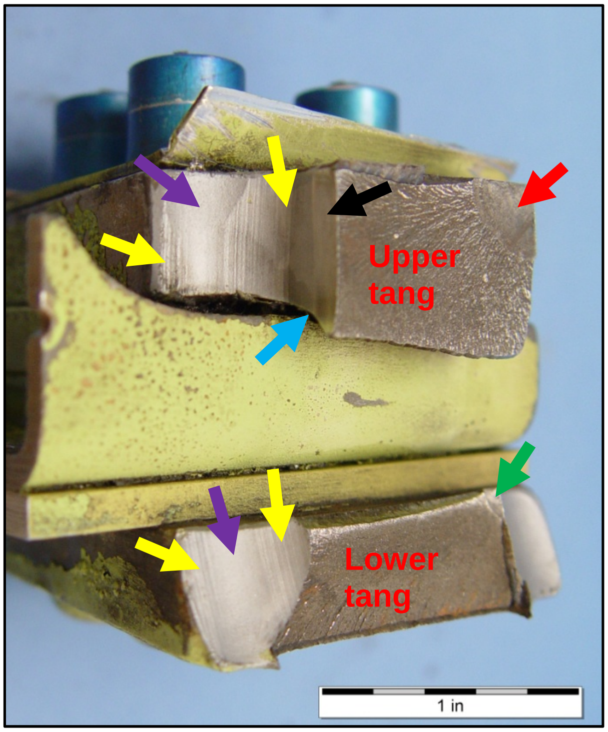


Figure 13. The outboard radii of the inboard midspar fitting's upper and lower tangs.

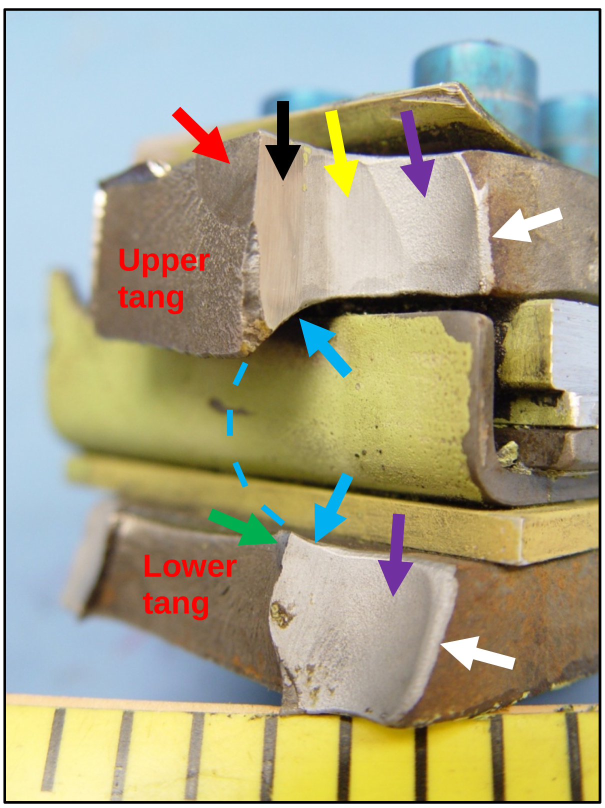


Figure 14. The inboard radii of the inboard midspar fitting's upper and lower tangs.

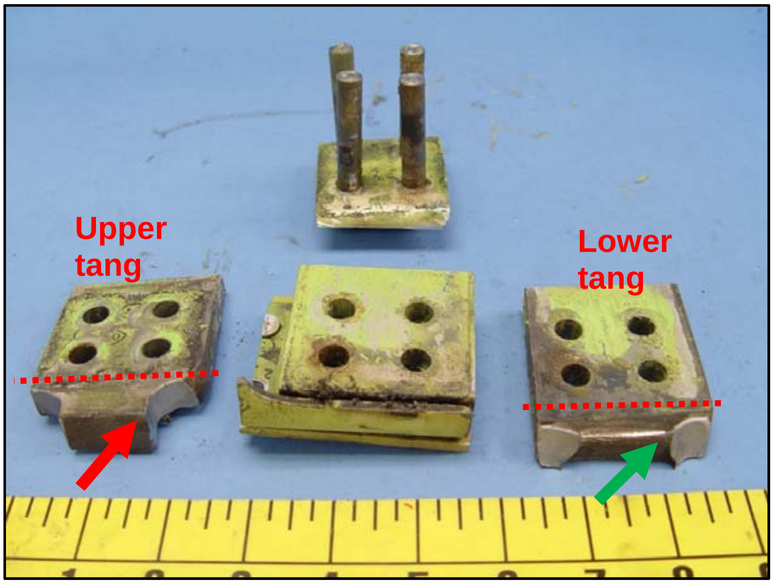


Figure 15. The disassembled inboard midspar fitting illustrated in Figures 11, 12, 13 and 14.

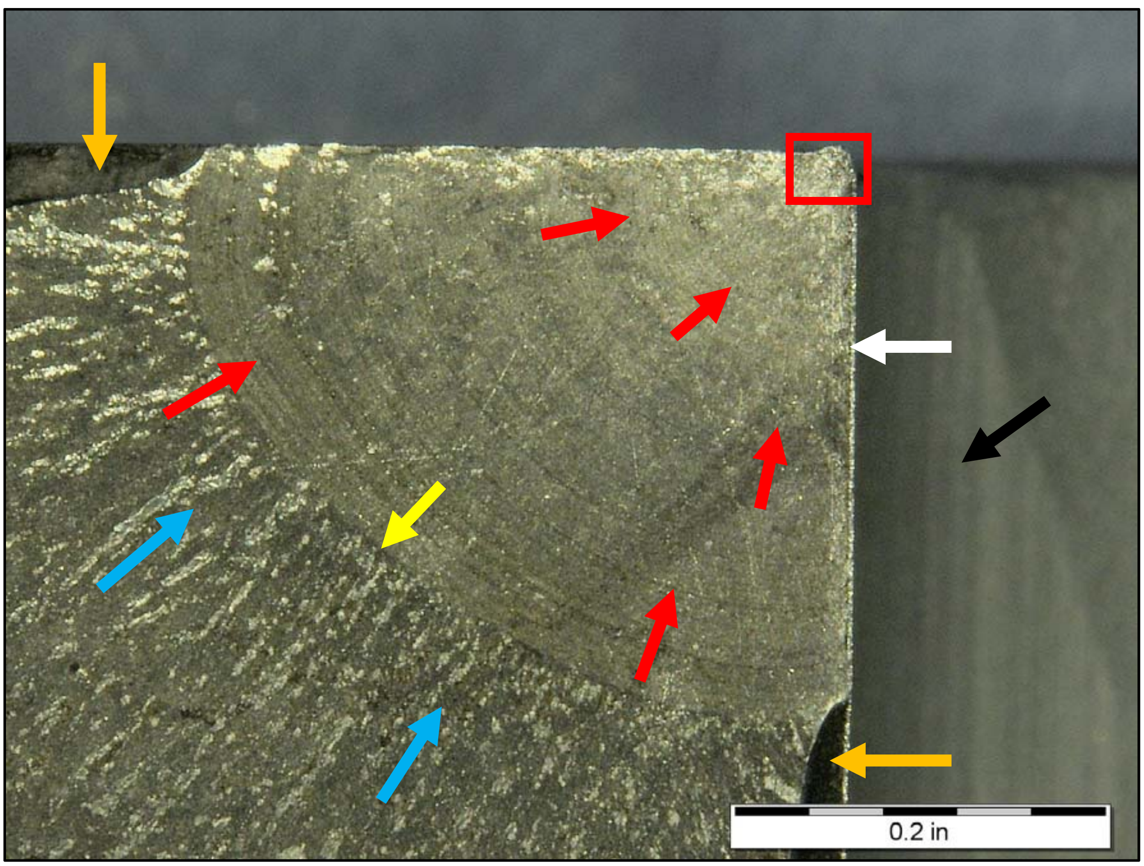


Figure 16. The fatigue region indicated by the red arrow in Figures 4 and 12.

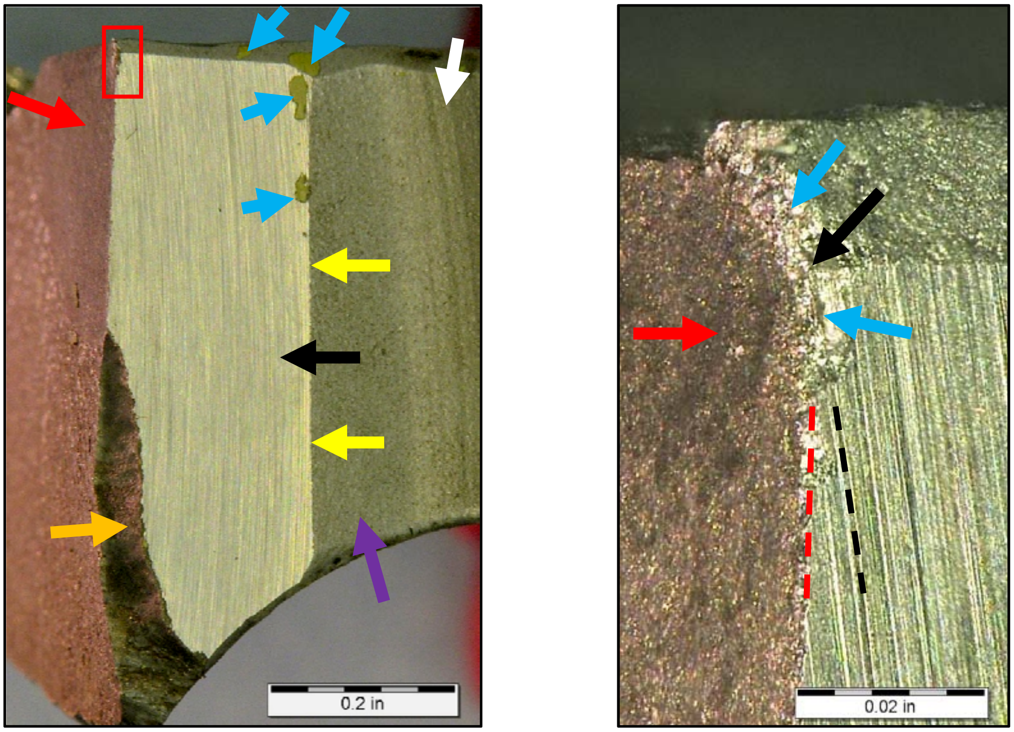


Figure 17. The inner radius of the inboard midspar fitting upper tang at the fracture face (left) and a closer view inside the red rectangle (right).

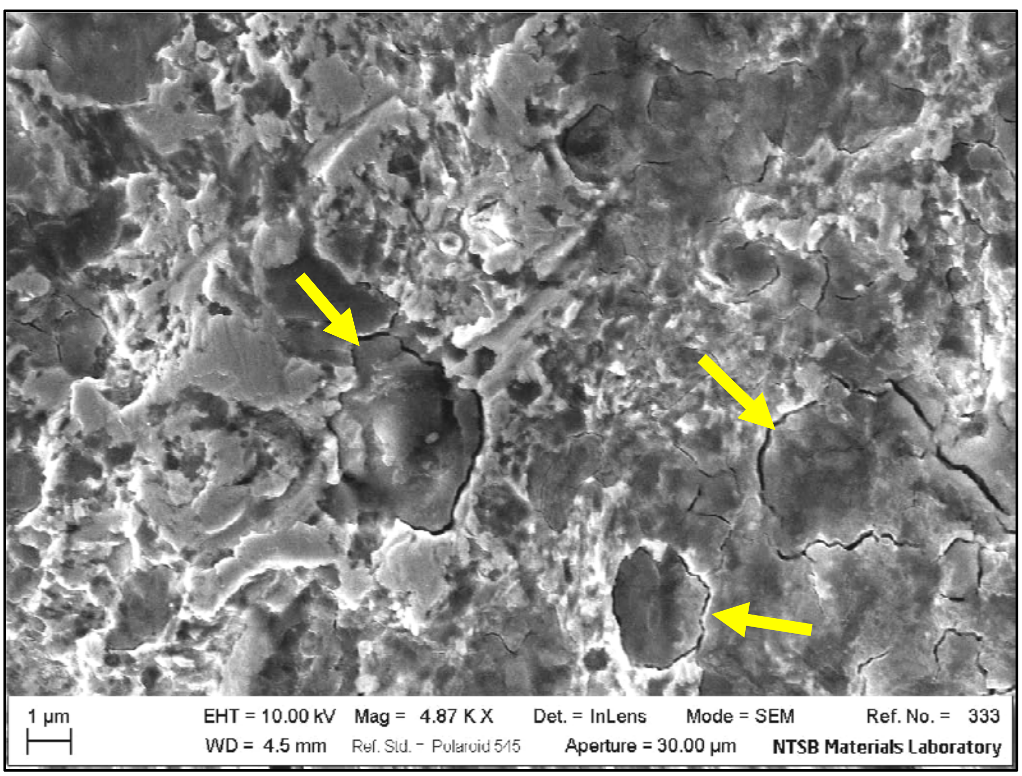


Figure 18. SEM micrograph of the typical surface in the fatigue zone before cleaning.

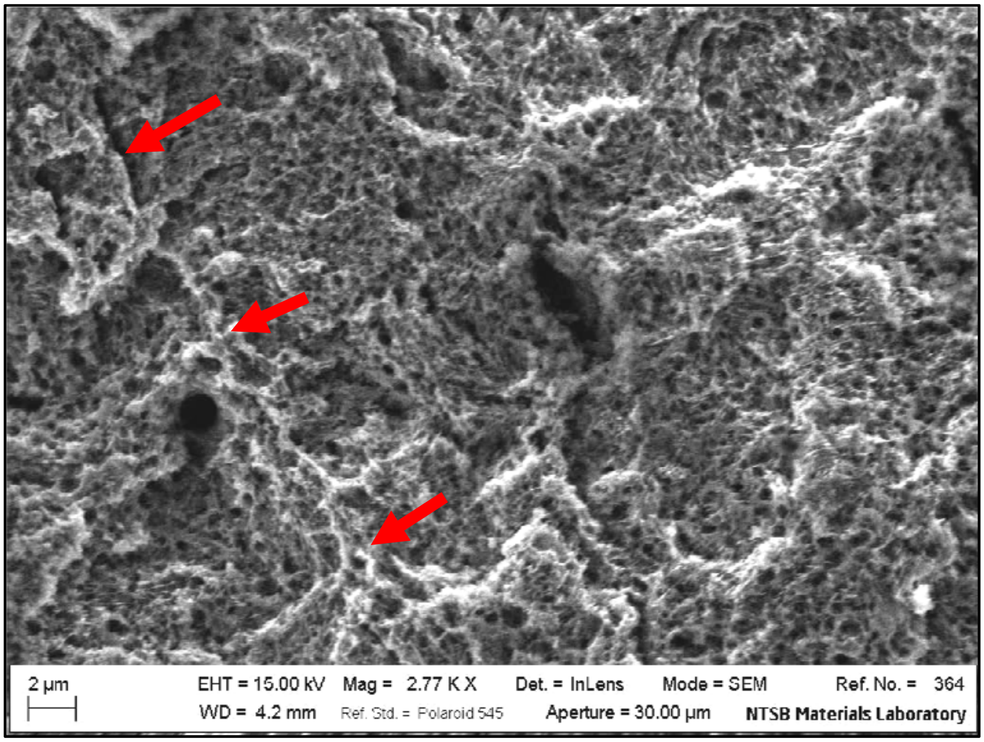


Figure 19. SEM micrograph of the typical surface in the fatigue zone after cleaning.

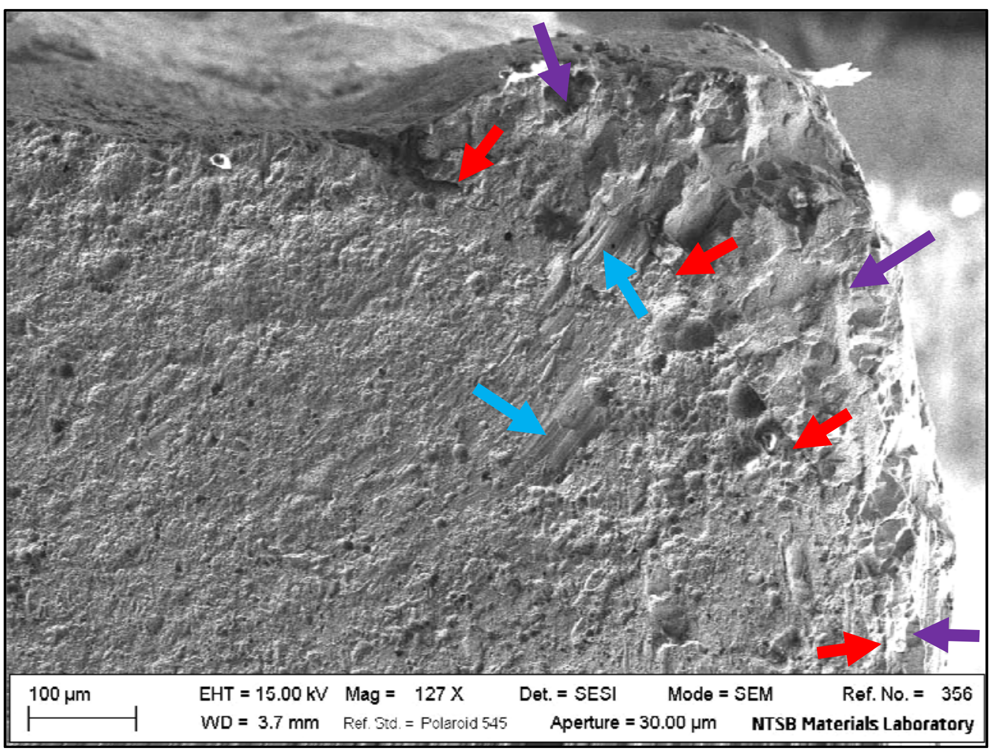


Figure 20. SEM micrograph of the initiation site within the red box in Figure 16.

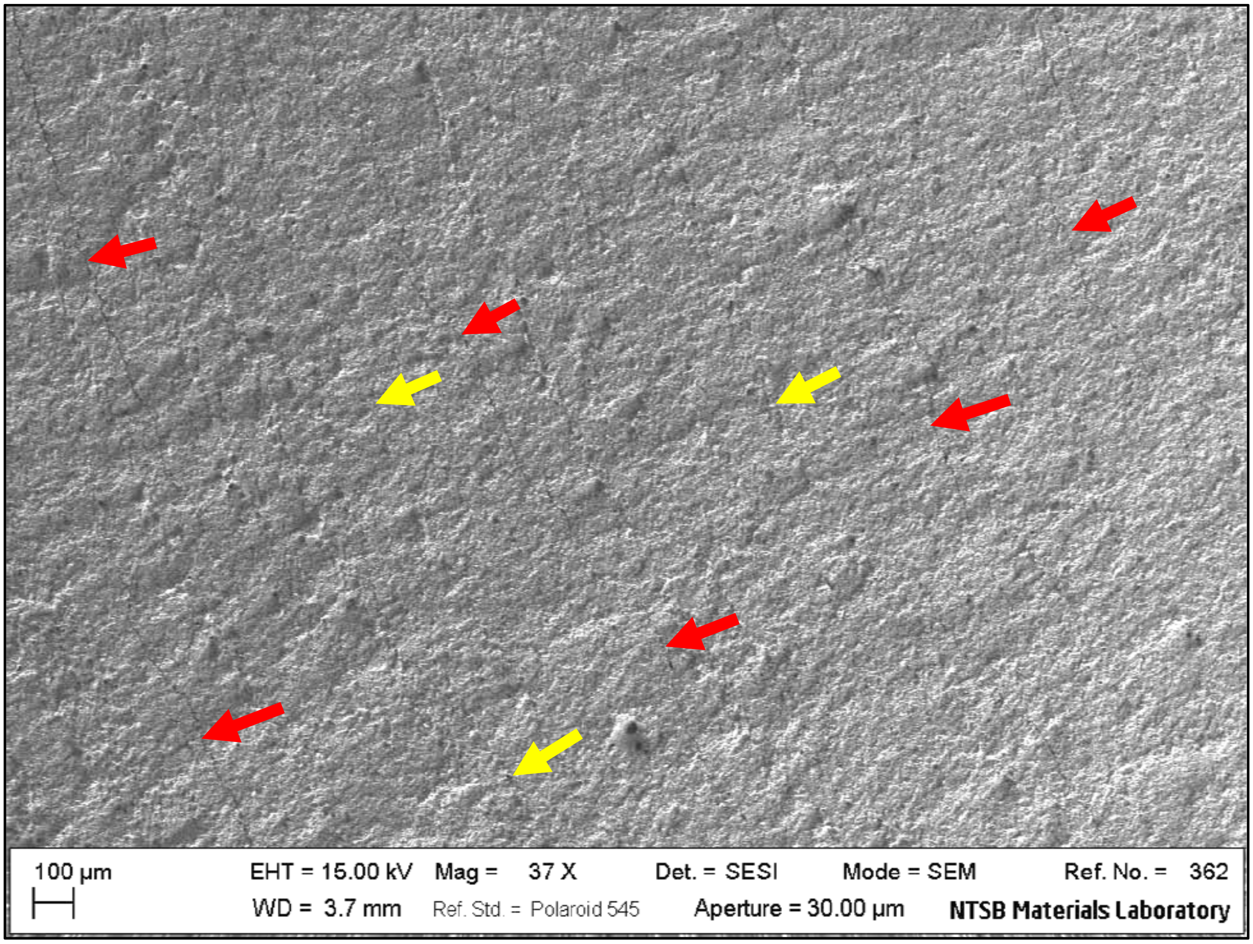


Figure 21. SEM micrograph of fissures in the fatigue zone that were revealed by the cleaning process.

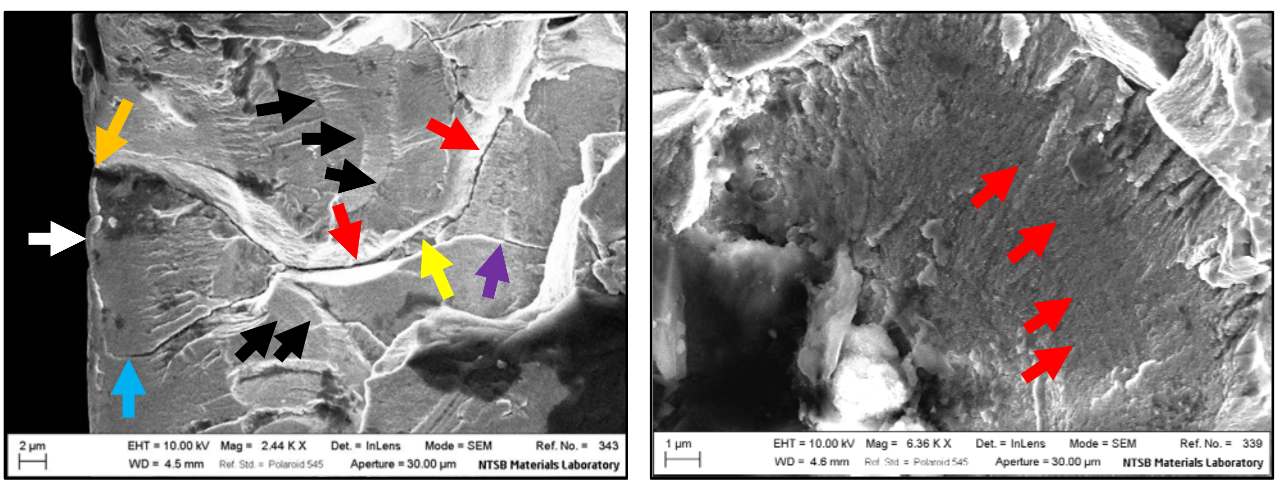


Figure 22. SEM micrographs of cracking (left) and fatigue (right) in the chromium plating.

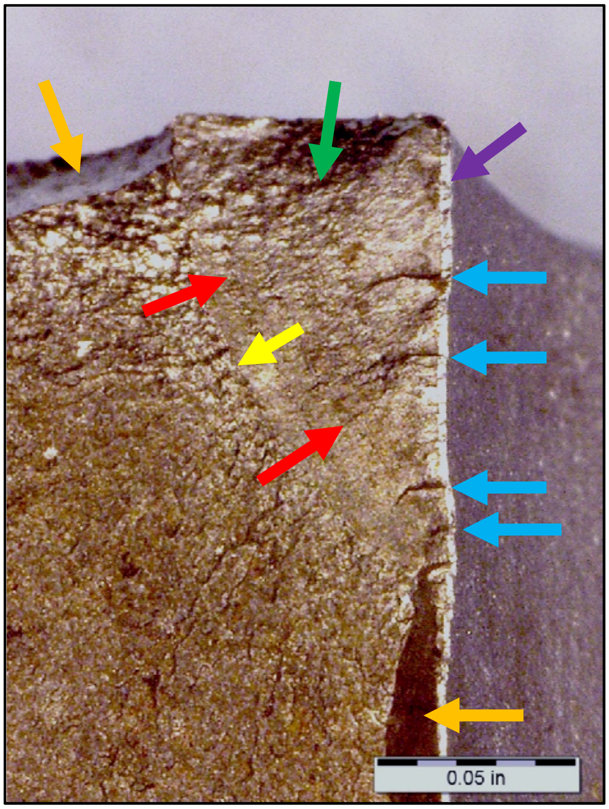


Figure 23**.** . The fatigue zone indicated by the green arrows in Figure 4 and 12.

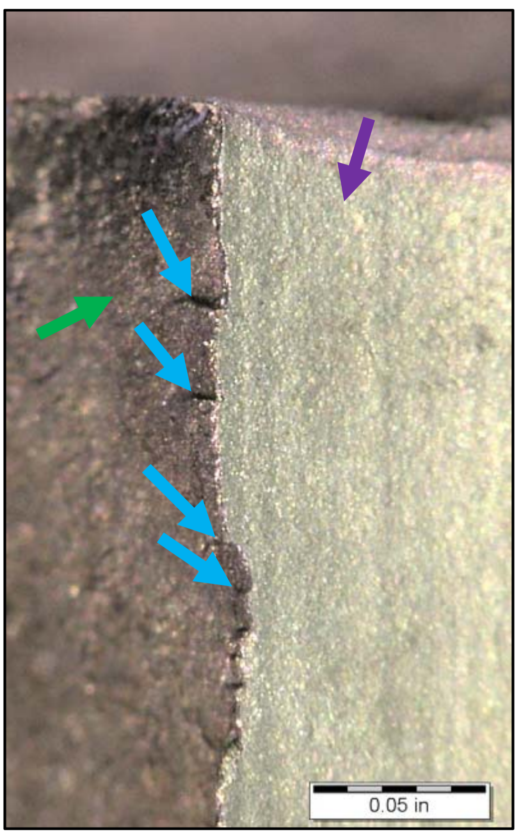


Figure 24. The inner radius of the inboard midspar fitting lower tang adjacent to the fatigue zone.

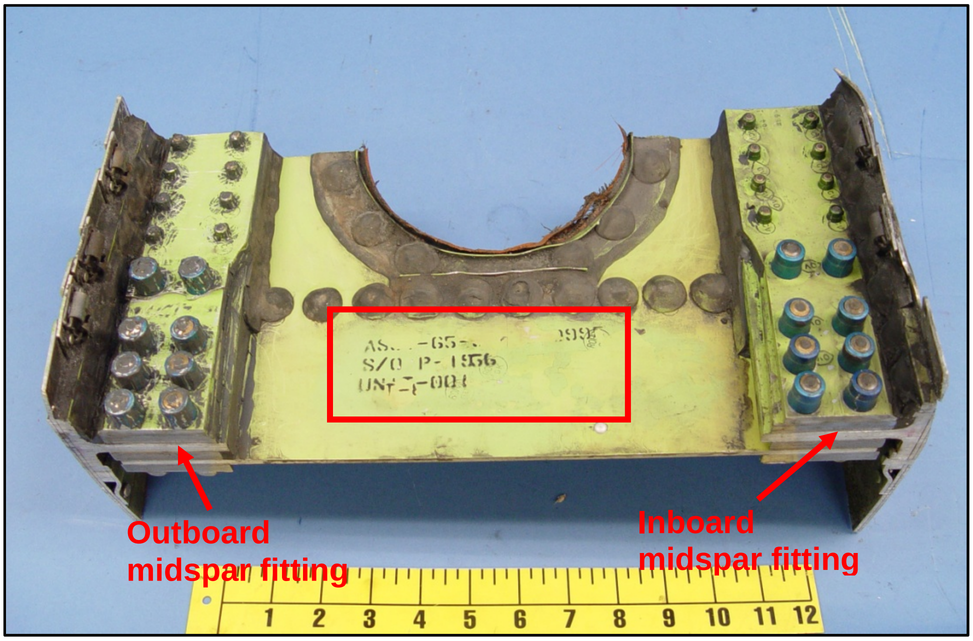


Figure 25. The upper surface of the removed portion of the pylon after removal of the sealant and cleaning.

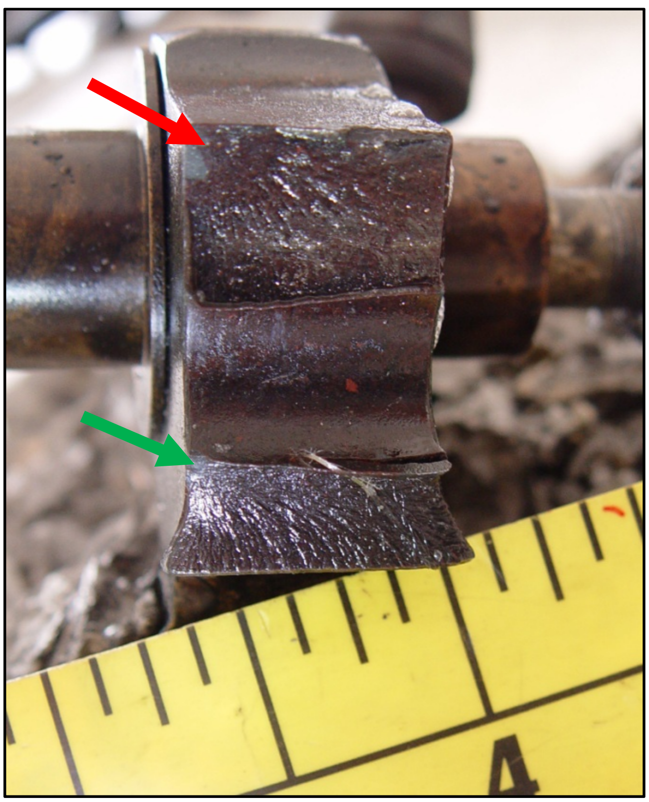


Figure 26. The fracture face on the portion of the inboard midspar fitting found mostly encased in the resolidified aluminum.

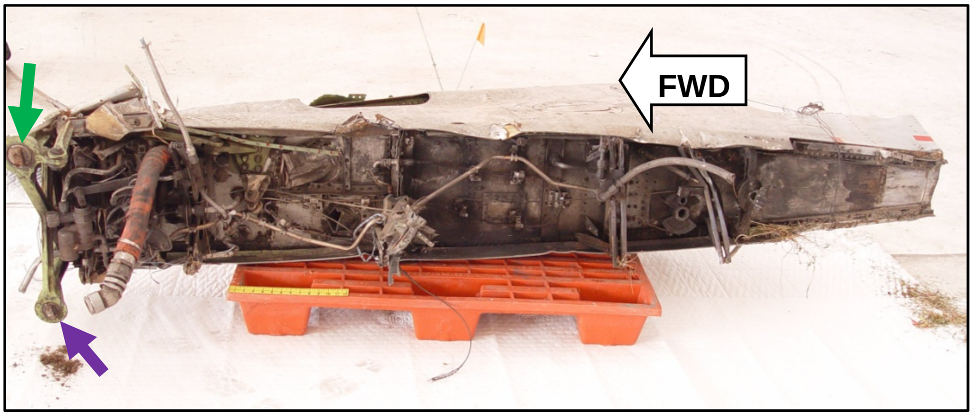


Figure 27. The underside of the recovered #1 engine pylon.

Figure 28. The outboard forward engine attachment indicated by the green arrow in Figure 27 and in Figure 5.

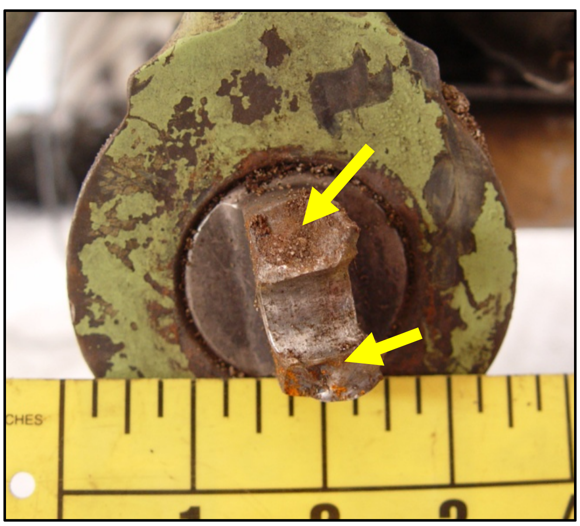


Figure 29. The inboard forward engine attachment indicated by the purple arrow in Figure 27 and in Figure 5.

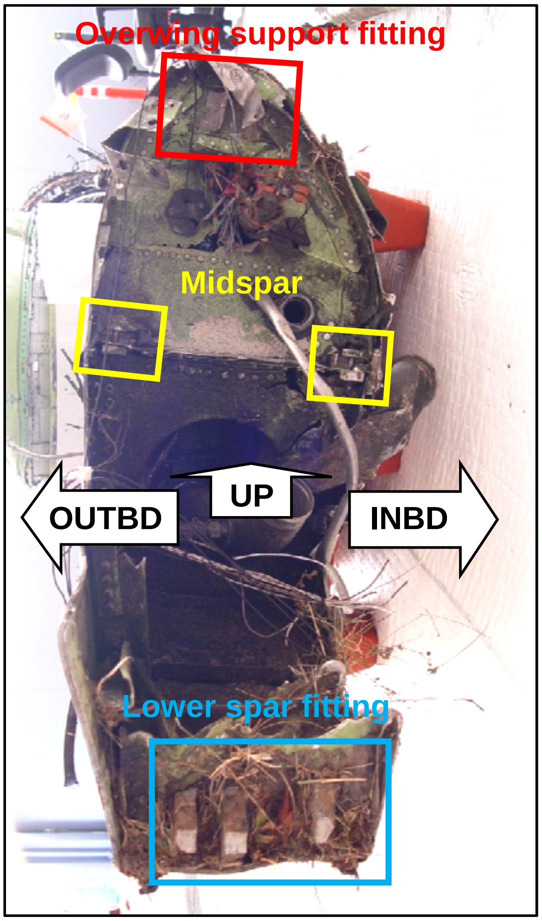


Figure 30. The rear end of the #1 pylon illustrated in Figure 27.

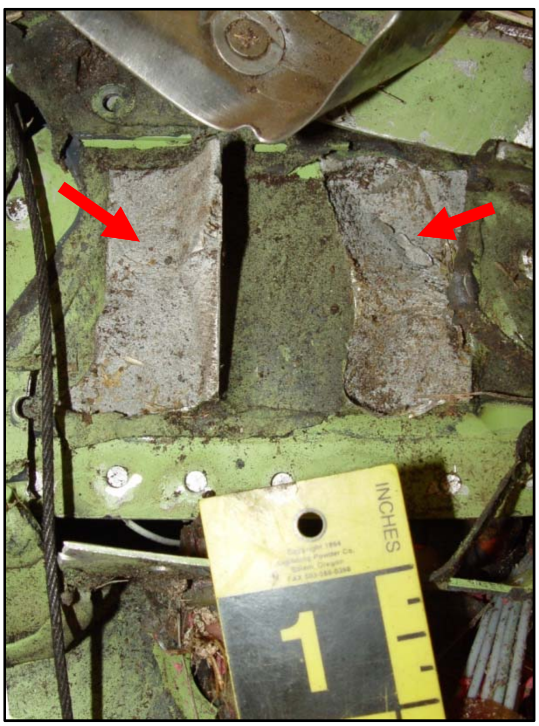


Figure 31. The overwing support fitting within the red box in Figure 30.

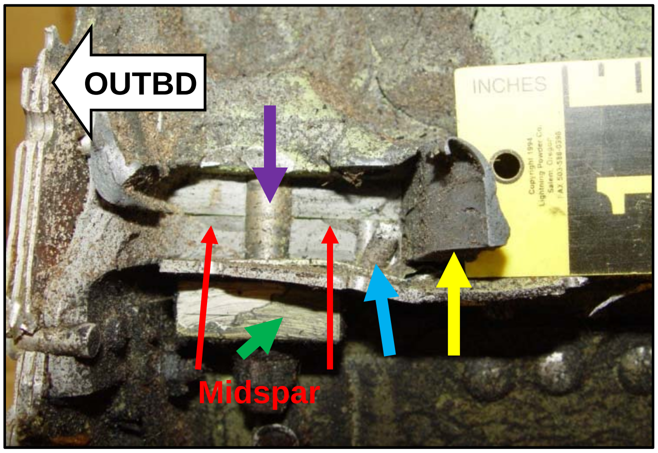


Figure 32. The outboard midspar within the yellow box in Figure 30.

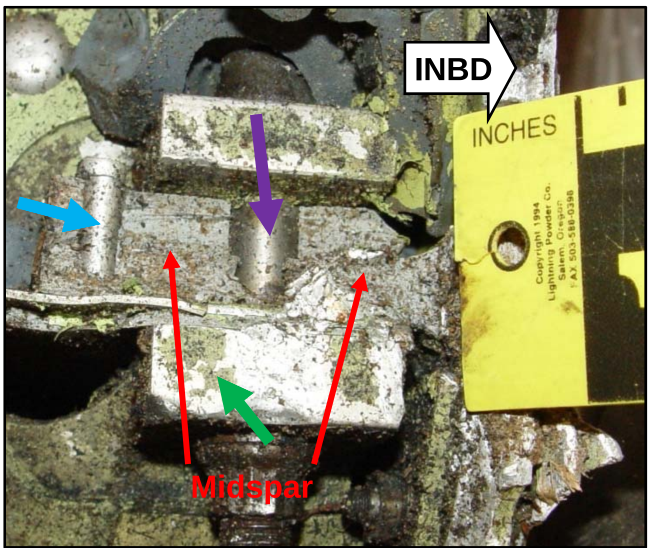


Figure 33. The inboard midspar within the yellow box in Figure 30.

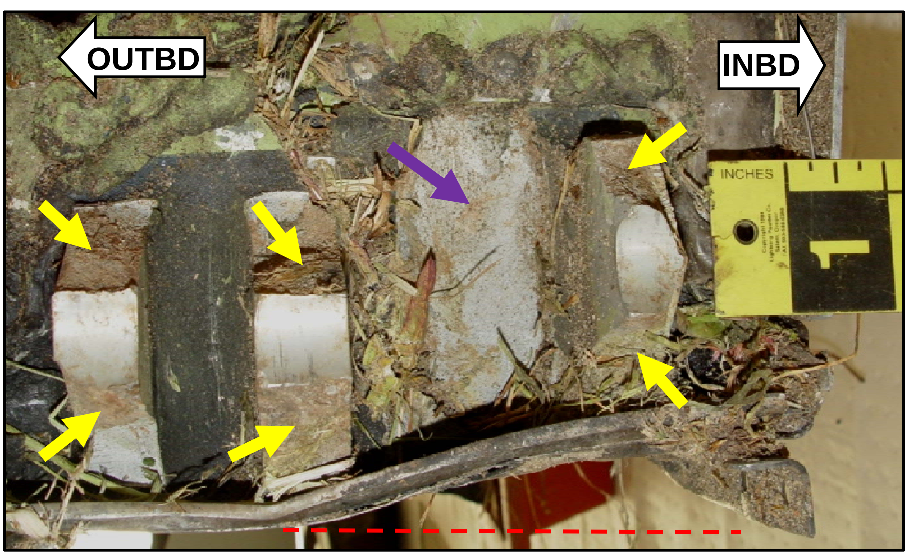
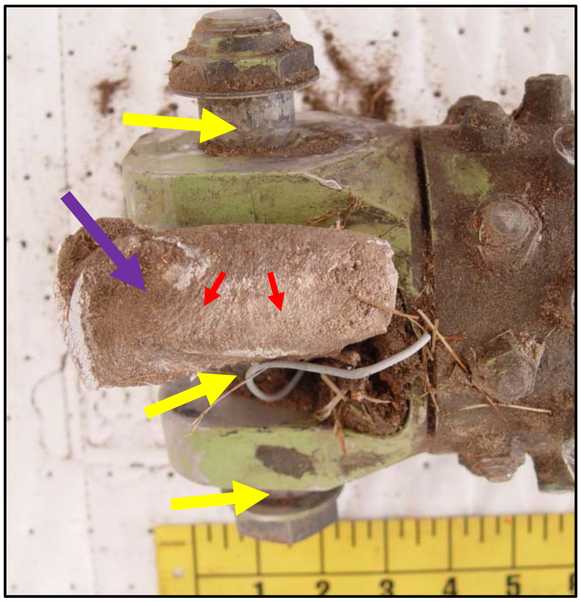


Figure 34. The lower spar fitting within the blue box in Figure 29.

Figure 35. The #1 pylon diagonal brace.



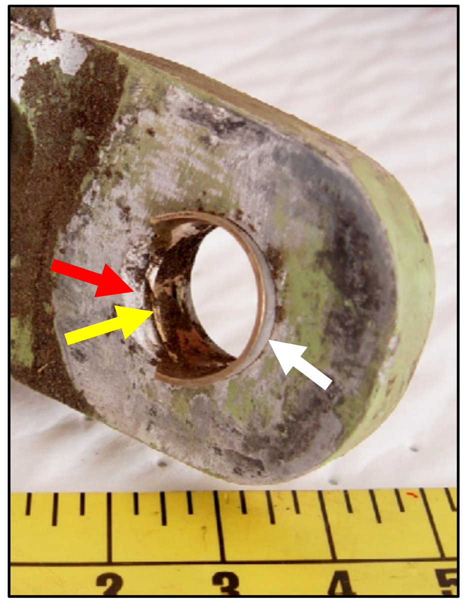


Figure 36. The forward clevis (left) and the rear clevis lug (right) identified in Figure 35.

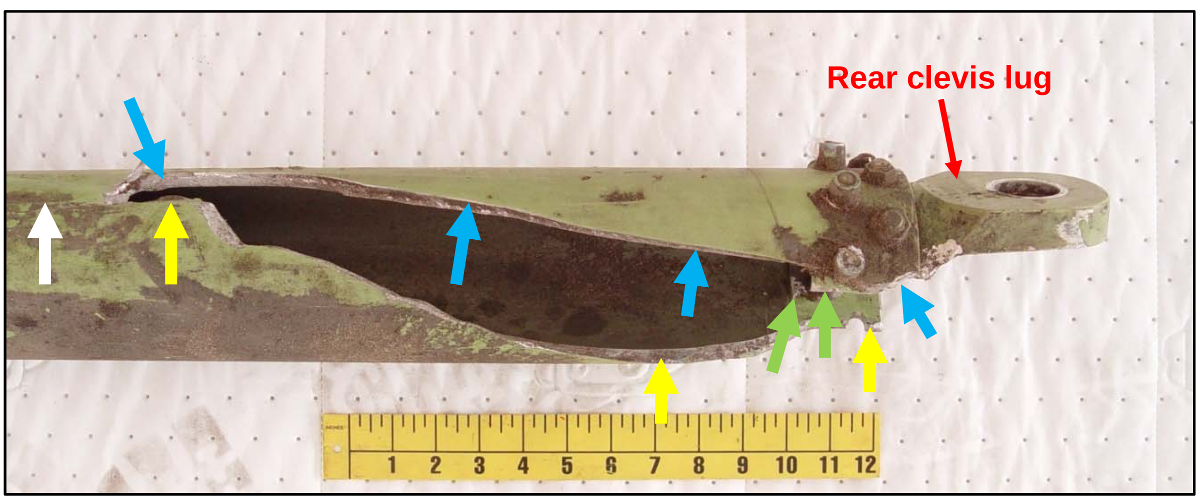


Figure 37. The fractured tube at the rear end of the diagonal brace illustrated in Figure 35.