

NATIONAL TRANSPORTATION SAFETY BOARD

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



October 23, 2019

MATERIALS LABORATORY FACTUAL REPORT

Report No. 19-057

A. ACCIDENT INFORMATION

Place : Talking Rock, Georgia
Date : March 5, 2019
Vehicle : Hughes 369D, N89ZC
NTSB No. : ERA19FA118
Investigator : Chihoon Shin, AS-40

B. COMPONENTS EXAMINED

Upper left engine mount, upper right engine mount, and lower (center) engine mount.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted engine mounts is shown in figure 1. The lower arm of the left upper engine mount was fractured, and the upper arm of the right upper engine mount was bent and cracked. Cracks were also observed in the lower engine mount. In the accident, the helicopter reportedly came to rest on its right side. The helicopter had also struck a power transmission line on August 22, 2018.¹ The helicopter reportedly developed a large vibration in the rotor system after the power line strike, and the pilot reported searching for and finding a suitable landing site. The helicopter had 328 hours time in service since the power line strike with no mention of a hard landing after the power line strike or in other records reviewed by investigators.

A close view of the fracture in the lower arm of the left upper engine mount is shown in figure 2. Fracture surfaces were on slant angles and had a matte gray appearance consistent with ductile overstress fracture. The overall fracture pattern was consistent with fracture under tensile load. Portions of the fracture surface on the outboard side of the fracture were splayed outward, and adjacent areas of the fracture were shiny and smooth as well as areas on the mating inboard side of the fracture, features consistent with post-fracture recontact between the mating sides of the fracture.

The attachment bolts at the outboard attachment locations on the left upper engine mount were removed, and a view of the outboard attachment fittings after the bolts were removed is shown in figure 3. The attachment holes on both the upper and lower arms were deformed with an elongated axis parallel to the longitudinal axis of each arm as

¹ NTSB investigation GAA18CA506.

indicated in figure 3. The hole deformation was on the outboard side of each attachment hole, consistent with a tensile overload on each arm. The faying surface on the lower arm was deformed with a convex shape, also consistent with a tensile overload on the lower arm. Corresponding shear deformation to the shanks of the attachment bolts were also observed as shown in figure 4.

As indicated in figure 1, the upper arm of the right upper engine mount was bent near the outboard end of the arm and was cracked near the inboard end. The adjustment bolt for attaching and positioning the outboard fitting on the upper arm was bent, and the outboard end was bent in the forward direction. At the inboard end of the upper arm, the crack was located in the fitting on the forward side of the arm. Parallel tension cracks were present in the paint adjacent to the crack on the forward side of the arm, consistent with bending deformation in the aft direction. The overall damage pattern of the upper arm with forward bending at the outboard end and aft bending at the inboard end was consistent with compression overload failure.

A view of the lower attach fitting at the outboard end of the right upper engine mount is shown in figure 5. The attachment hole was deformed with elongation toward the outboard edge of the fitting, consistent with tension overload. The faying face of the fitting was deformed to a convex shape, also consistent with tension overload along the arm axis.

An overall view of the lower engine mount photographed looking upward and aft is shown in figure 6. Bulkhead attachment locations at the upper forward ends of the mount are indicated. The engine attachment location is located at the intersection of the left and right arms at the lower aft end of the mount. Bolts were removed from the bulkhead attachment fittings, and no evidence of hole elongation was noted in either bulkhead attachment hole or the engine attachment hole.

Cracks were observed on the lower forward side of the left and right arms of the lower engine mount near the engine attachment location in areas outlined with rectangles in figure 6. Closer views of the cracks are shown in figure 7. Inward deformation was observed on the upper aft sides of the attachment arms approximately opposite from the crack surface. The inward deformation on the right arm is shown in figure 8. The inward deformation on the left arm was similar but less pronounced.

Before additional work examining the cracks in the lower engine mount was completed, a three-dimensional (3D) representation of the part was obtained using a Faro EDGE FaroArm coordinate measurement device fitted with a Faro Laser Line Probe HD.² An overhead image of the 3D scan is shown in figure 9. For reference, the transverse plane representing the bulkhead attachments was defined by collecting points associated with the bulkhead faying surfaces on the right and left bulkhead attachment fittings and creating a plane with a best fit to the faying surfaces. The X axis was set aligned parallel to the transverse line defined by endpoints at the bulkhead attachment hole centers, and the Y axis was set perpendicular to the transverse plane representing the bulkhead (the

² FARO Technologies, Inc., Lake Mary, Florida.

forward direction). The resulting Z axis represents the up direction. The origin was set at the midpoint between the bulkhead attachment holes at the bulkhead side of the fitting. The data from the scan was saved as an Adobe 3D PDF file, and the interactive rendering of the scan data is included in Appendix A.

A closer view of the bulkhead attachment locations as viewed from above is shown in figure 10. The transverse plane representing a best fit to the faying surfaces for the left and right bulkhead attachments is indicated by a green line in each image in figure 10. As indicated in figure 10, a gap was present between the transverse plane and the faying surface on the outboard portion of each attachment. At the inboard portion of the faying surfaces, interference contact was apparent. The transition between interference contact and a gap occurred near the middle of the attachment hole on each side as shown in an aft-facing view of the scan presented in figure 11.

Measurements were conducted using the 3D scan data for comparison to the engineering drawing for the lower engine mount. The lateral distance between the bulkhead attachment hole center points was 15.5 inches, which was consistent with the engineering drawing. The longitudinal and vertical distances between the bulkhead attachment hole center points and the engine attachment hole center point (at the upper side of the faying surface) were 2.64 inches and 3.82 inches, respectively. In comparison to corresponding dimensions noted on the engineering drawing, the longitudinal and vertical distances between the bulkhead attachment hole center points and the engine attachment hole center point (at the upper side of the faying surface) is specified as 3.074 inches and 3.439 inches, respectively.

The measurements taken using the 3D scan data did not account for any shifts in the shape of the lower engine mount or changes in relative positioning of the engine attach point due to the interference contact and gaps at the bulkhead attachment points when securely fastened to the mating structure. For further illustration, the left bulkhead attachment fitting was securely fastened to a flat plate, and a gap was observed between the plate and the right bulkhead attachment fitting as shown in figure 12. A similar gap opened between the left bulkhead attachment fitting and the plate when the right arm was securely fastened to the plate. Securely attaching the lower mount as received would require either applying force to close the gap or would require attachment to surfaces that were not oriented in the same plane. Applying force to close the gap would affect the position of the engine mount relative to the attachment fittings. The 3D measurements described in the previous paragraph assumed no forces were applied to the part.

Cracks on the lower forward surface of the lower engine mount (see figure 7) were partially obscured by paint. To expose the metal surface, the center portion of the lower engine mount was covered with Cee Bee paint remover for about 30 minutes to remove paint around the cracks. The cracked areas were then examined using an optical stereomicroscope, and the extent of cracking in each arm was approximately 25 percent of the circumference. Using a handheld hacksaw, the arms were cut on the side opposite from the crack, and the cut surfaces were squeezed together to open the crack. The resulting lab fractures are shown in figures 13 and 14. Views of the inboard sides of the

fracture surfaces for each arm are shown in figure 14 where the cracked portion is indicated. Orange oxidation covered much of the crack surfaces. Oxides on the outboard sides of the fracture surface were removed using acetate replica tape, and the surfaces were then further cleaned in a bath of acetone using an ultrasonic cleaner. The cleaned fracture surfaces were then examined using a scanning electron microscope. The crack surfaces showed ductile dimple features across most of the fracture surfaces with isolated areas of cleavage, features consistent with overstress fracture in steel including areas of weld heat affected zones. No evidence of progressive crack growth was observed.

As indicated in figure 1, a crack was present near the engine attachment location at the inboard end of the right upper engine mount. Using a handheld hacksaw, a transverse cut was made on the side of the fitting opposite the crack, and the crack was opened by squeezing the cut surfaces together. The resulting lab fracture is shown in figure 15. The fracture surface had a matte gray appearance consistent with ductile overstress fracture with no evidence of orange oxides on the surface.

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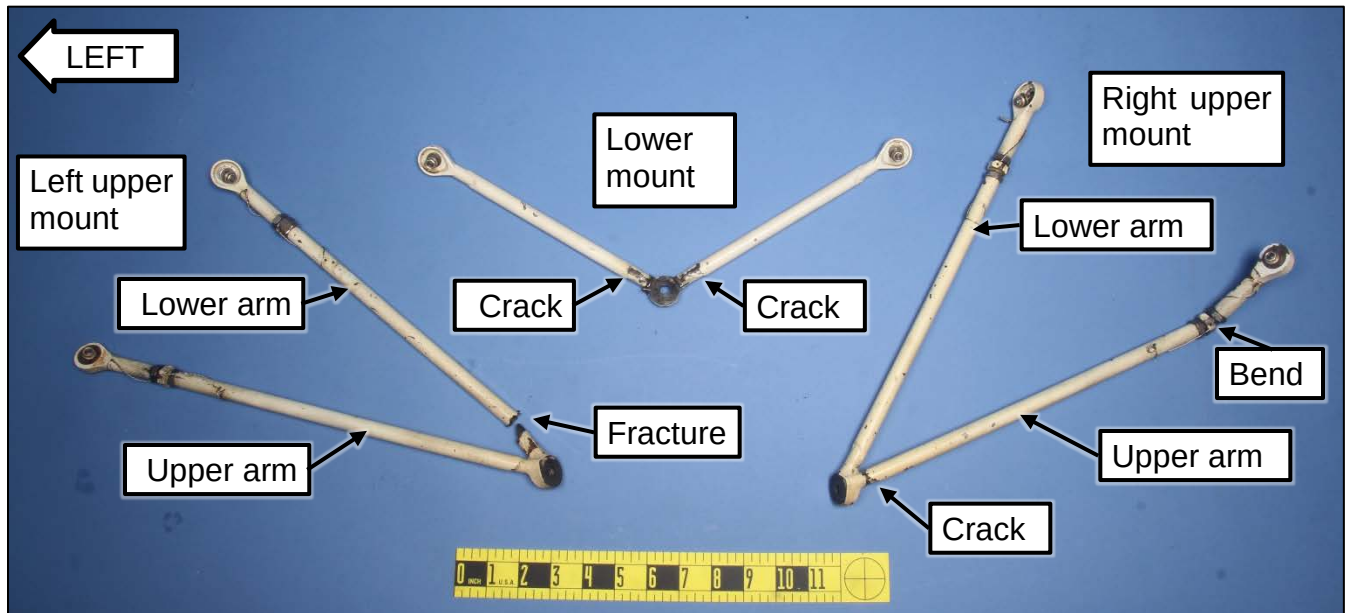


Figure 1. Overall view of the submitted engine mounts photographed as received.



Figure 2. Closer view of the fracture in the lower arm of the left upper engine mount.

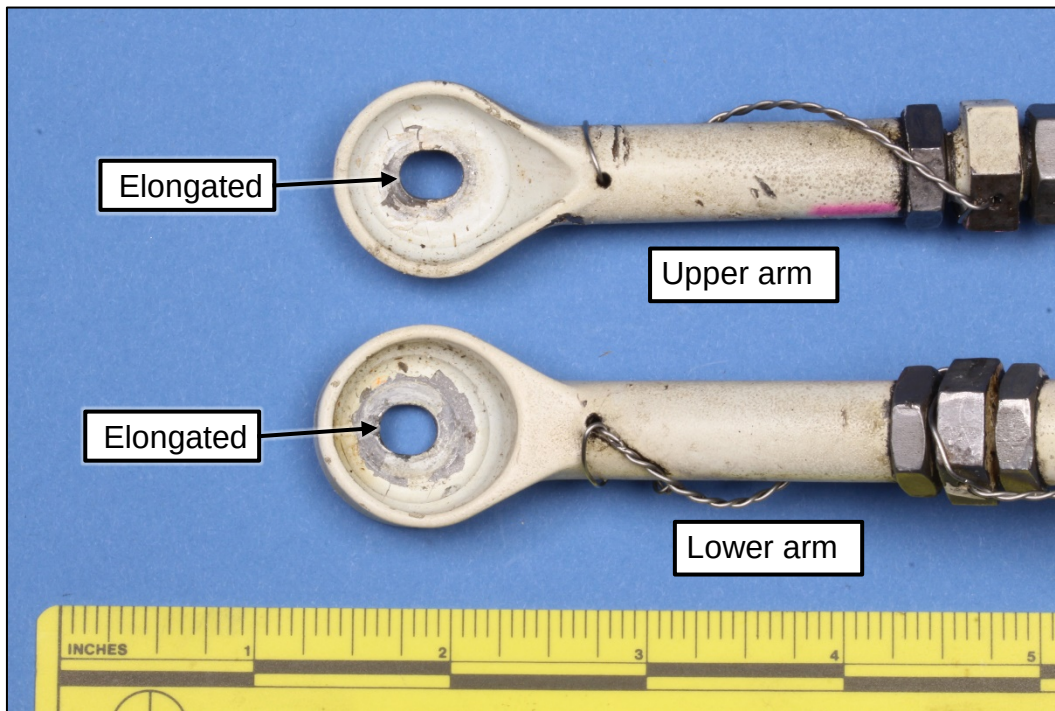


Figure 3. Attachment fittings at the left end of the left upper engine mount after the attachment bolts were removed showing elongated attachment holes.



Figure 4. Attachment bolts with deformed shanks from the left end of the left upper engine mount.

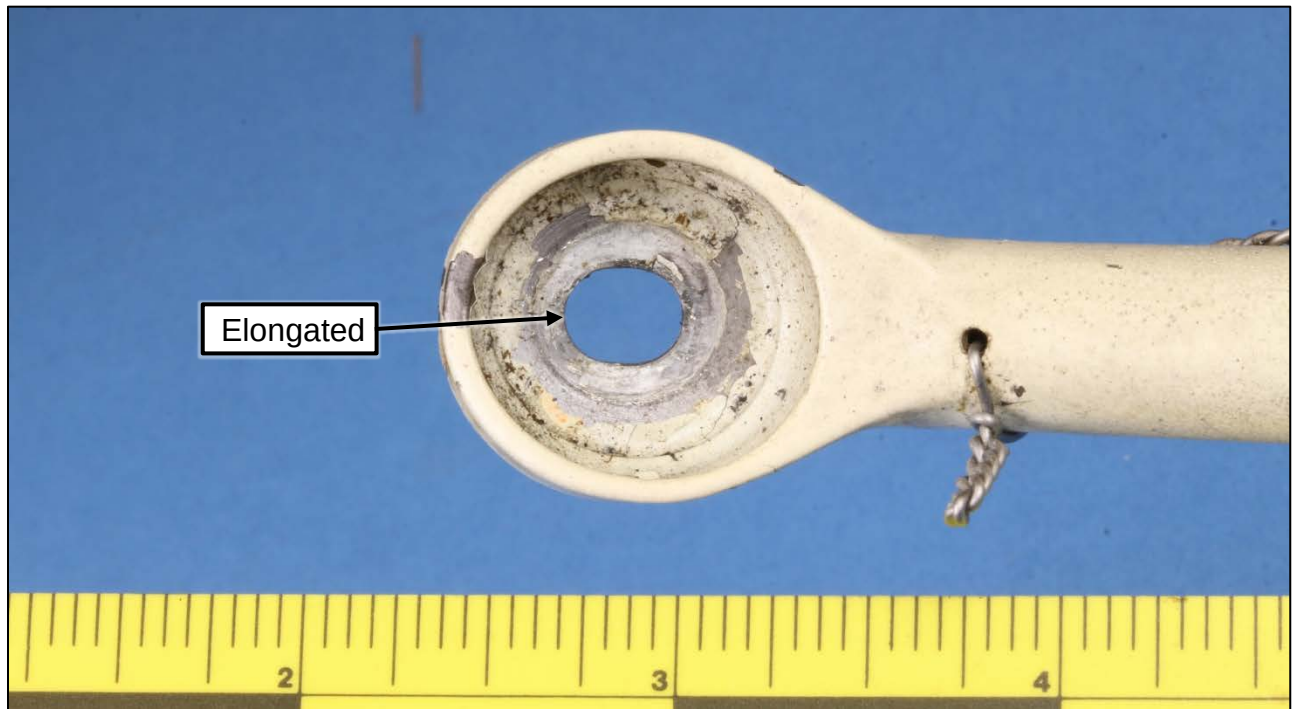


Figure 5. Attachment fitting at the right end of the lower arm from the right upper engine mount after the attachment bolts were removed showing an elongated attachment hole.

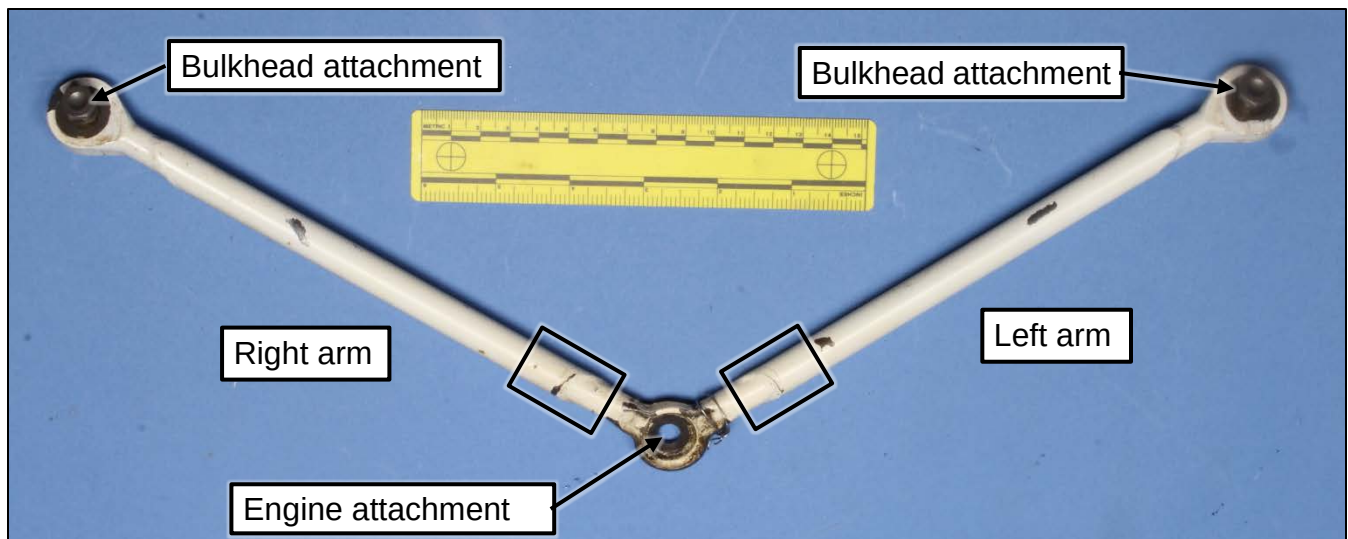


Figure 6. Photograph of the lower engine mount looking up and aft. Cracks in the lower surface of the arms near the lower engine attachment fitting are highlighted with rectangles and are shown at higher magnification in the next figure.

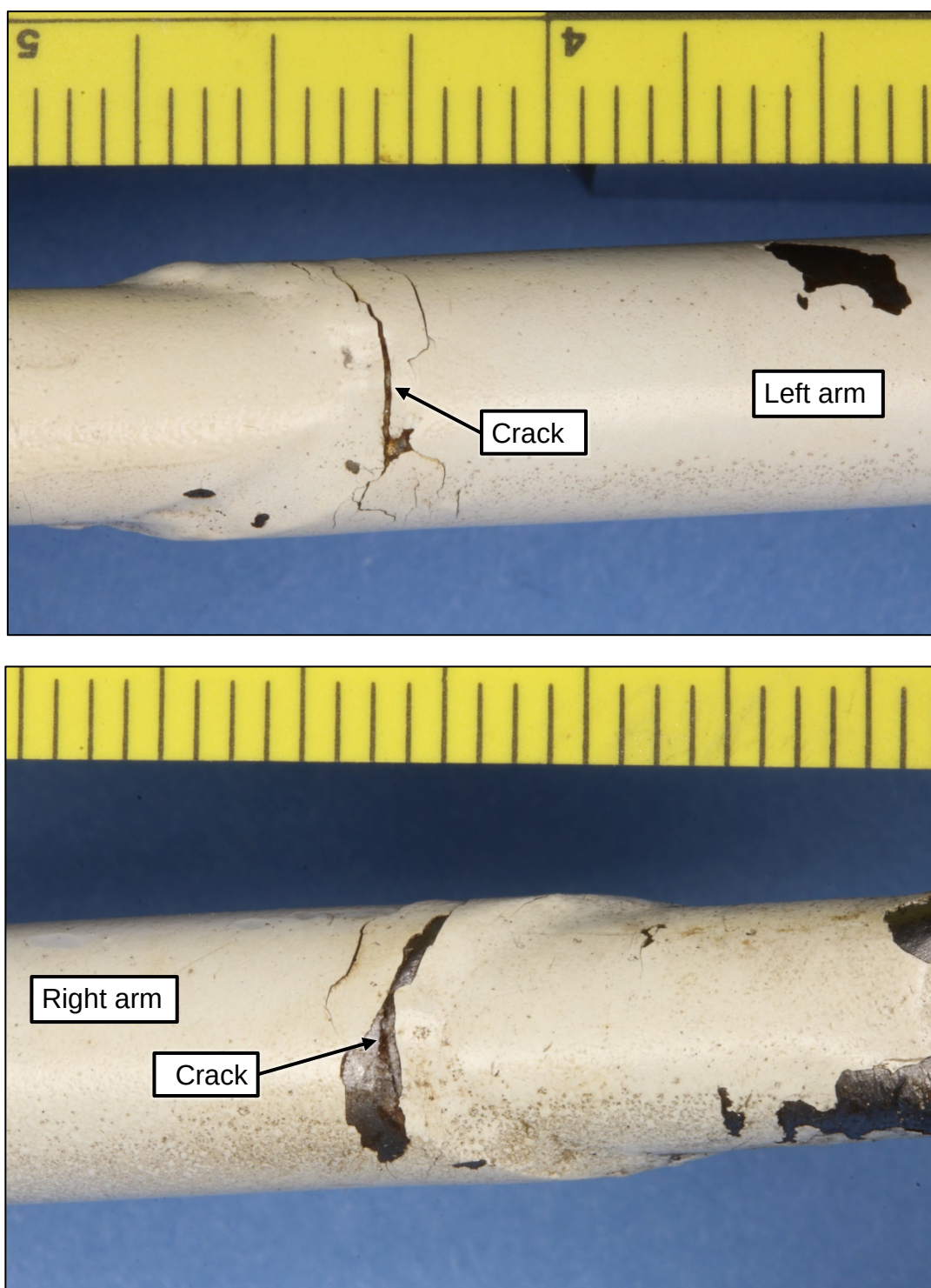


Figure 7. Closer views of cracks on the lower surface of the lower engine mount near the engine attachment fitting in areas indicated with rectangles in the previous figure.

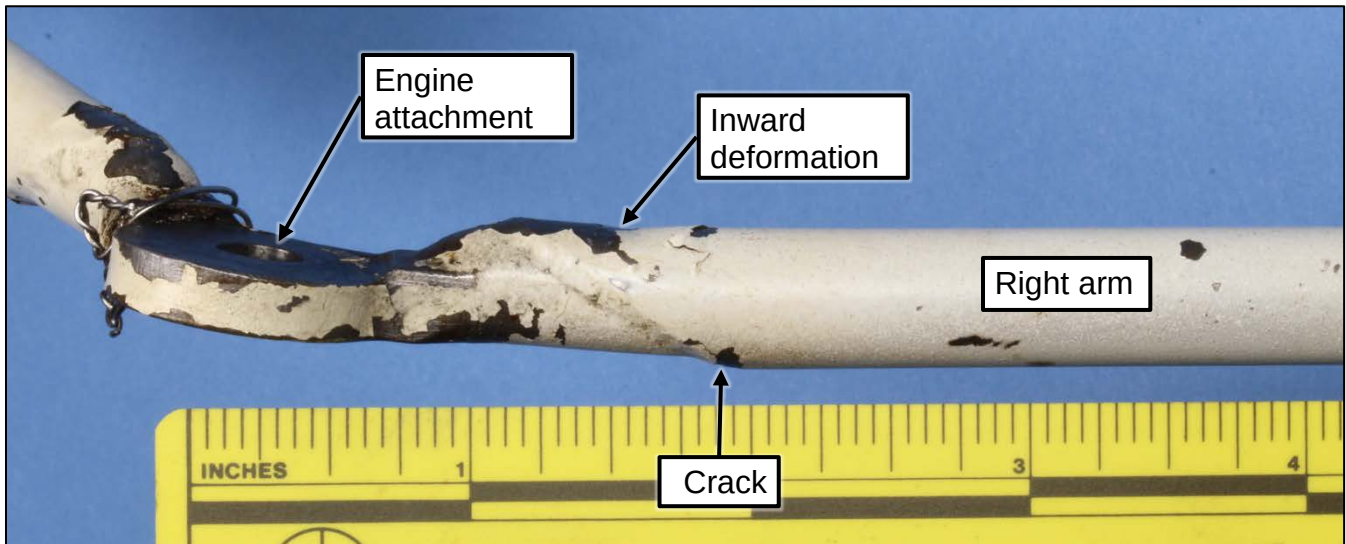


Figure 8. Side view of the lower engine mount showing inward deformation on the upper aft side of the right arm near the engine attachment fitting.

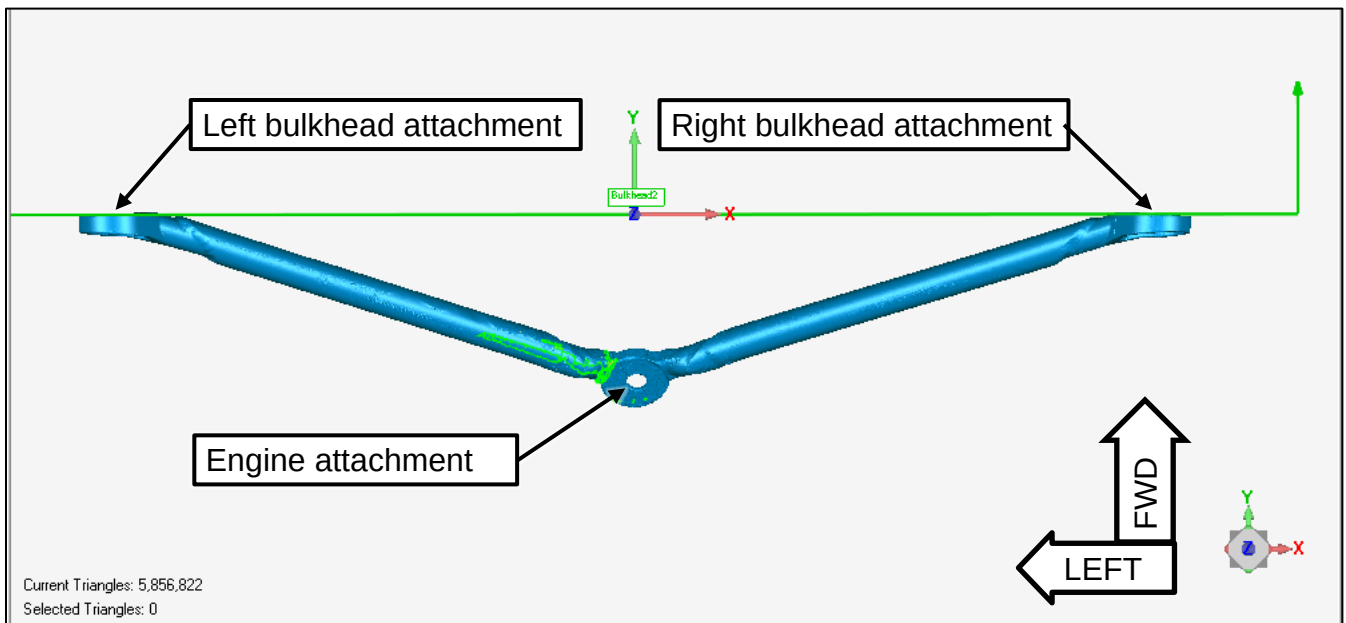


Figure 9. Image of 3D scan data of the lower engine mount as viewed from above. Closer views of the bulkhead attachments are shown in the next figure.

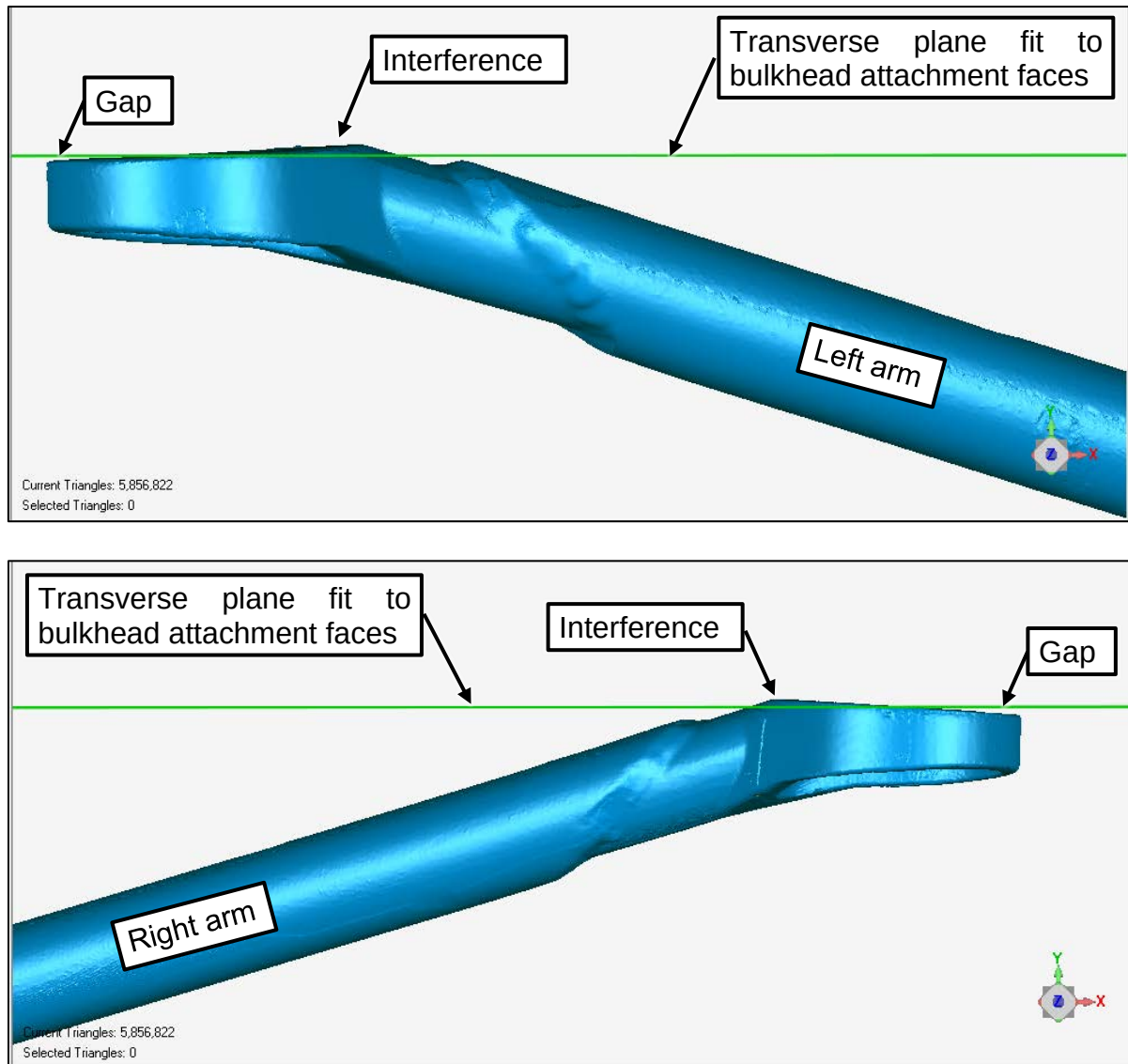


Figure 10. 3D scan images of the left (upper image) and right (lower image) bulkhead attachment locations on the lower engine mount. A green line represents the transverse plane fit to the contact faces on the left and right bulkhead attachment fittings. Interference contact areas were noted on the inboard sides of the bulkhead attachment faces, and gaps were noted at the outboard sides of the bulkhead attachment faces.

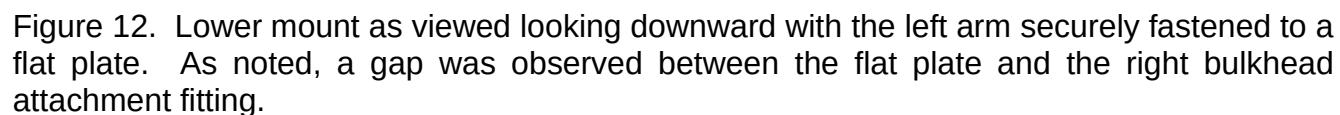
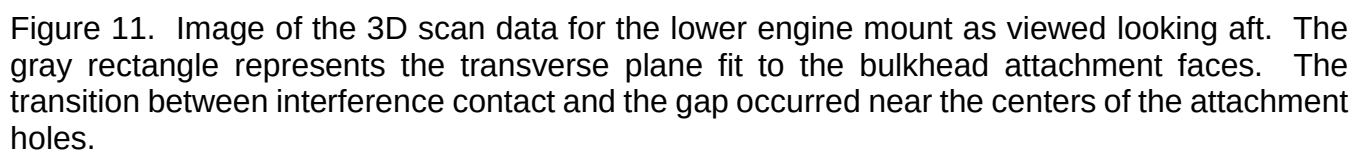




Figure 13. Lower side of the lower mount as viewed looking upward and aft photographed after cracks had been opened by lab fracture.

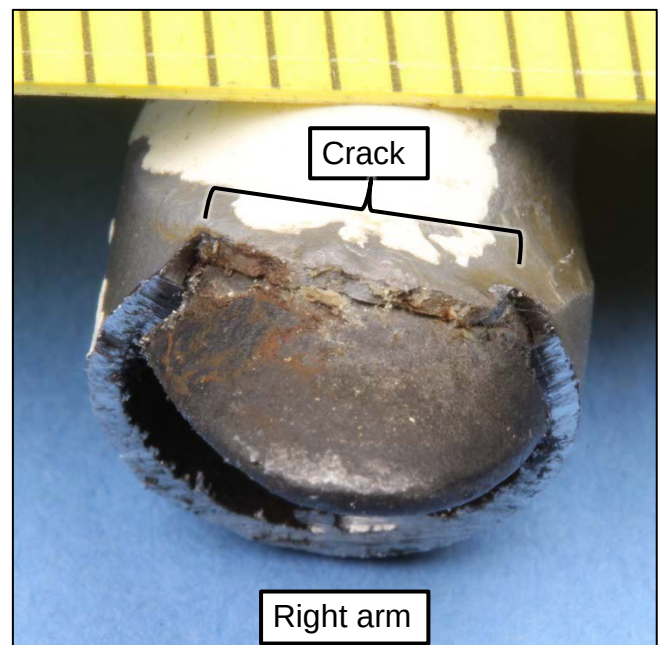
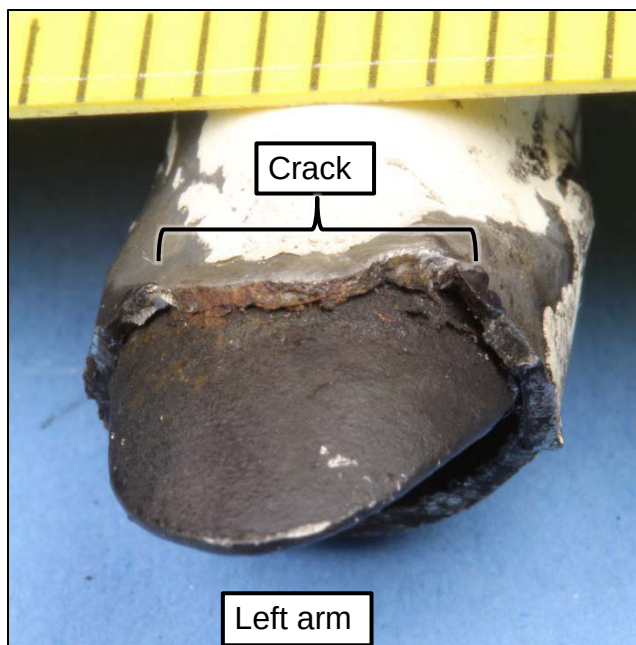
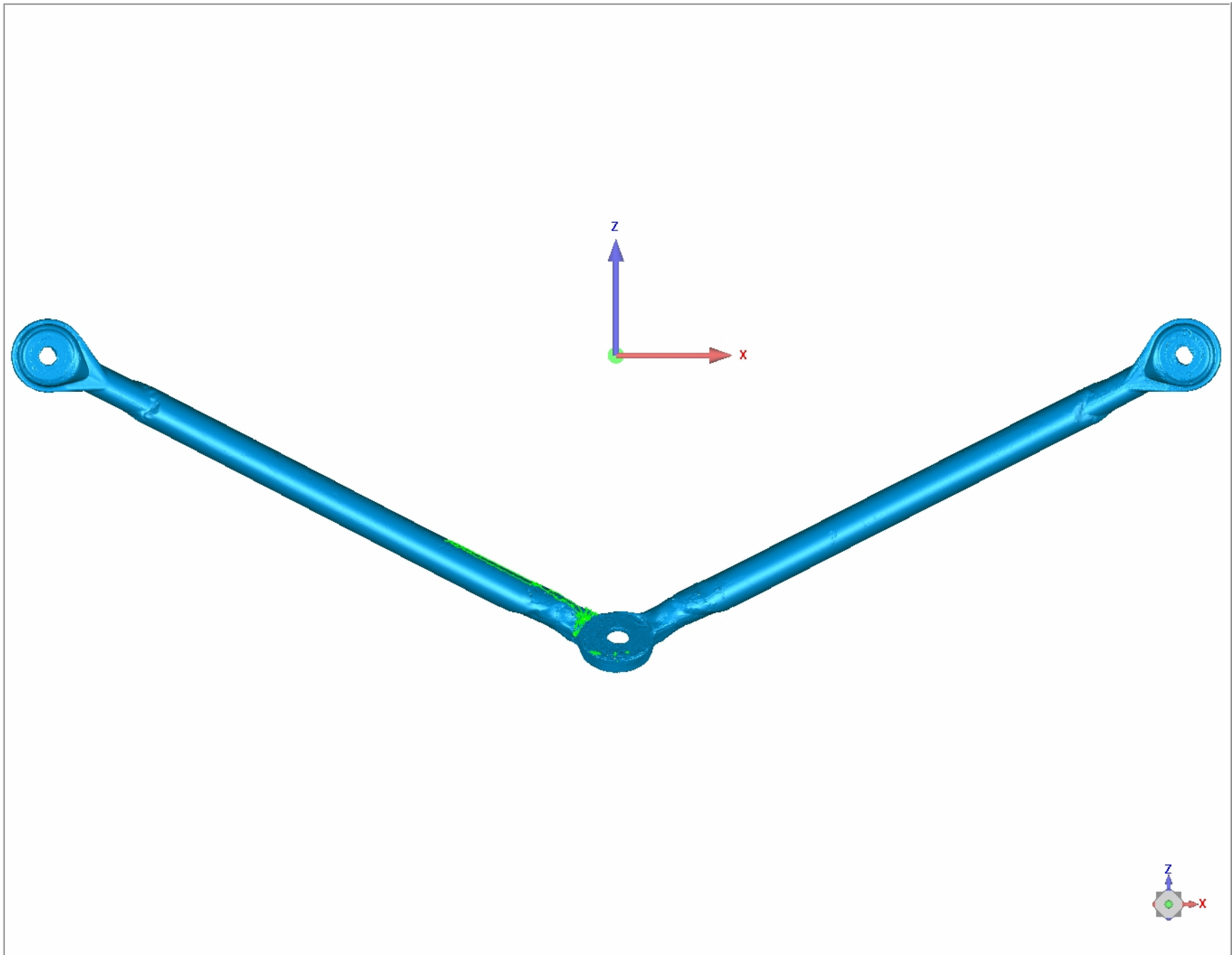


Figure 14. Fracture features of cracks in the lower engine mount photographed after the cracks were opened in the lab.



Figure 15. Fracture features of the crack in the upper arm of the right upper engine mount photographed after the crack was opened in the lab.

D. APPENDIX A: ADOBE 3D PDF RENDERING OF THE LOWER ENGINE MOUNT



Click on the image to activate the 3D Model.