

NATIONAL TRANSPORTATION SAFETY BOARD

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



August 31, 2020

MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-045

A. ACCIDENT INFORMATION

Place : Glendale, Arizona
Date : June 2, 2020
Vehicle : OMF Aircraft OMF-100-160, N225CK
NTSB No. : WPR20LA165
Investigator : Stephen Stein, AS-WPR

B. COMPONENTS EXAMINED

Right main landing gear attachment hardware, clamp, block, and frame pieces.

C. DETAILS OF THE EXAMINATION

A photograph of the submitted right main landing gear (RMLG) attachment hardware, clamp, block, and frame pieces is shown in figure 1. The submitted components included the inboard attachment block with a fractured attachment bolt with nut attached to the lower bolt piece and the outboard attachment clamp and hardware with associated tube structure pieces that had been cut from the remainder of the fuselage frame. The longitudinal frame tube was fractured both forward and aft of the forward attachment bolt, and the aft attachment bolt was bent aft.

An overall view of the submitted RMLG inboard attachment components is shown in figure 2. The bolt was fractured in the grip near the lower side of the attachment block, and a view of the fracture surface on the upper piece is shown in figure 3. Portions of the fracture were in a plane perpendicular to the longitudinal axis and had curving crack arrest lines, features consistent with fatigue. Two fatigue regions were observed, and dashed lines in figure 3 indicate fatigue boundaries. The fatigue regions had relatively broad origin areas at locations indicated with unlabeled brackets in figure 3. The smaller fatigue region had an undulating boundary shape consistent with multiple fatigue origins, and ratchet marks were observed in the origin area associated with the larger fatigue region, also consistent with multiple fatigue origins. Relatively rough fatigue features were observed across most of the fatigue regions, and the fatigue regions extended across less than a quarter of the cross-sectional area, features consistent with fatigue with relatively high peak stresses.

The RMLG inboard attachment bolt grip was rubbed and showed circumferential contact marks as indicated in figures 4 and 5. Fatigue origins for both regions corresponded to the lower circumferential contact mark on the grip.

The fracture face on the lower piece of the RMLG inboard attachment bolt was examined using a scanning electron microscope (SEM). An SEM image of the origin area is shown in figure 6 showing relatively smooth fatigue features within approximately 150 micrometers of the surface that transition to rougher features further from the surface. An SEM image of fatigue features near the fatigue boundary is shown in figure 7 showing relatively rough fatigue features and secondary cracks consistent with high peak stresses. Figure 8 shows dimple features consistent with ductile overstress fracture at the center of the bolt.

The nut on the lower end of the RMLG attachment bolt did not move when attempted to rotate by hand. The grip of the lower piece was placed in a vice with a rubber-coated clamping surface, and torque was applied in the clockwise (tightening) direction. The peak breaking force was 4.3 pound feet. Continuing with the test, the nut was rotated approximately 60 degrees clockwise. The tare torque value was not recorded, but was lower than the peak breaking force. The nut still did not rotate by hand after the torque test was completed.

The head of the RMLG inboard attachment bolt had a concave center and had markings "NAS 6608-36 CS", consistent with a bolt manufactured in accordance with *National Aerospace Standard NAS6603 thru 6620*.¹ According to *National Aerospace Standard NAS6603 thru 6620*, the bolt material should be heat treated to obtain a tensile strength of 160,000 pounds per square inch to 180,000 pounds per square inch. In order to determine the hardness of the fractured bolt for an approximate comparison to the standard, an abrasive wet saw was used to make two parallel transverse cuts through the bolt grip, and the test surface was rough polished to a 600-grit finish. The average value of 5 hardness measurements on the grip cross-section was 38.9 HRC. According to *ASTM Standard A370-12a*,² the measured hardness corresponds to a tensile strength of approximately 177,000 pounds per square inch, which is within the tensile strength range specified for a NAS 6608-36 bolt.

An overall view submitted components from the RMLG outboard attachment area is shown in figure 9. As assembled on the airplane, the landing gear is sandwiched between a trapezoid-shaped upper clamp and a flat-plate lower clamp at the outboard attachment. The lower clamp is attached with bolts extending through vertical frame tubes forward and aft of the landing gear strut. The upper clamp has a groove on the upper face where it contacts the longitudinal frame tube when the landing gear is clamped in place by the two outboard attachment bolts.

The longitudinal frame tube was fractured in several locations, and mating fracture faces associated with the longitudinal tube are indicated in figure 9. The aft attachment bolt was bent aft, and the attached fuselage frame pieces were rotated upward and aft.

¹ *National Aerospace Standard NAS6603 thru 6620*, Aerospace Industries Association of America, Washington, D. C. (1996).

² *ASTM Standard A370-12a, Standard Test Methods and Definitions for Mechanical Testing of Steel Products*, ASTM International, West Conshohocken, Pennsylvania (2014).

At the forward attachment bolt tube, the longitudinal frame piece was fractured on both sides of the forward attachment bolt, and a piece of the longitudinal tube on the aft side of the forward attachment bolt tube was bent up and forward.

After an initial visual examination, the piece of the longitudinal tube that had been bent up and forward was pulled back toward its original position, and the small segment of wall that kept it attached fractured to allow the piece to separate from the mating fracture. Additionally, the nut was removed from the upper end of the aft attachment bolt, and attempts were made to slide the aft frame piece off the bent aft attachment bolt. However, after unsuccessful attempts to remove the bolt with a punch and hammer, the bolt was cut at the lower end of the tube to separate the lower clamp from the aft frame piece. Figure 10 shows the pieces of the longitudinal frame tube between the attachment bolts in their approximate relative positions after the forward piece was separated from the mating fracture and with the aft attachment bolt cut.

Fracture surfaces on the longitudinal frame tube were examined closely using an optical stereomicroscope. Forward of the forward attachment, the fracture surface was deformed and substantially damaged from post-fracture recontact. Aft of the forward attachment bolt, fracture surfaces had rough fracture features on mostly slant planes consistent with ductile overstress fracture. Sliding marks were also observed on portions of the fracture surface consistent with shear fracture and post-fracture contact damage. The fracture surfaces at each fracture location on the longitudinal frame tube showed no evidence of oxidation or fracture patterns consistent with a preexisting crack.

However, evidence of deformation to the longitudinal tube associated with contact with the upper clamp before the tube fractured was observed. As noted in figure 10, the upper tube was wrinkled and creased on both sides of the aft fracture through the longitudinal tube, and the location of the wrinkles and crease corresponded to contact with the upper side of the upper clamp. At the aft attachment tube, the lower surface of the longitudinal tube was bowed upward as shown in figure 11. The lower portion of the longitudinal tube had a more reflective appearance, appearing burnished relative to the surrounding surfaces. On the aft post, two impressions of the lower aft corner of the upper clamp were observed on the inboard side of the post. One impression was surrounded by white paint consistent with the as-assembled position, and another impression was observed above the original impression consistent with the lower aft corner of the upper clamp displaced upward and rotated counterclockwise (as viewed looking outboard) relative to the as-assembled position against the aft post.

The outboard side of the aft frame piece and upper clamp are shown in figure 13. Contact marks were observed on the outboard side of the longitudinal tube corresponding to contact with the upper and aft edges of the upper clamp with the clamp displaced upward and rotated clockwise (as viewed looking inboard) relative to the as-installed position. The longitudinal tube wall was wrinkled just above the contact marks as indicated in figure 13.

An oblique view of the upper clamp is shown in figure 14. Contact marks corresponding to contact with welds between the longitudinal tube and the vertical attach bolt tubes were observed at each end of the upper side of the clamp. On the contact face with the longitudinal tube, paint was missing from the forward and aft ends, and an area at the aft end of the contact face was relatively reflective, having a burnished appearance.

The lower face of the upper clamp is shown in figure 15. Sliding contact marks corresponding to movement with the mating landing gear strut was observed near the aft outboard side as shown. The sliding contact marks were also associated with an area of dark-colored oxidation. The outboard surface adjacent to the area with sliding contact marks had a brown tint as indicated in figure 13.

The thickness of the tube wall for the longitudinal tube was measured in two locations adjacent to the fractures. The thickness at both locations measured 0.0357 inch. According to OMF Alert Service Bulletin (ASB) 1107/0002 described below, the specified wall thickness of the frame tubes is 0.058 inch.

On September 16, 2003, OMF Aircraft issued ASB 1107/0002 affecting OMF-100-160 airplanes with certain serial numbers including the accident airplane's serial number, 0013. OMF had received reports of cracks in the "outside tube of cage [fuselage frame], which supports main landing gear leg," and upon further investigation, OMF found that one manufacturer of the frames had used out-of-design dimensions for frame elements. OMF ASB 1107/0002 required that before next flight, the main landing gear leg support should be inspected in accordance with chapter 05-20-00 of the maintenance manual, and the inspection was to be repeated at 50-hour intervals. If no cracks were found, a special inspection was to be performed at the next 50-hour inspection to determine the wall thickness of the tube by measuring the wall thickness a transverse frame tube under the right-hand seat. Any cracks found were to be repaired in accordance with repair instructions provided by the manufacturer. Additionally, if a tube was found with a lower wall thickness, the tube would have to be reinforced in accordance with OMF repair instructions.

OMF Aircraft Process Specification PS-OMF 100-0006, dated October 1, 2003, provides instructions for repair of the frame tubes supporting the main landing gear leg. In the repair, the longitudinal piece above the main landing gear leg is cut from the frame as shown on an exemplar airplane in figure 15, and replacement pieces are welded into its place as shown in figure 16.

Effective December 28, 2004, Airworthiness Directive (AD) 2004-24-02 was published with the intent to detect, correct, and prevent future cracks in the tubing for the main landing gear leg, which could result in failure of the fuselage tubing assembly and potential loss of control of the airplane. Affecting the same airplanes listed in OMF ASB 1107/0002, AD 2004-24-02 requires inspections in accordance with OMF ASB 1107/0002 within 50 hours time-in-service (TIS) of the AD effective date and at 50-hour TIS intervals thereafter. If cracks are found, repairs are to be completed in accordance with manufacturer instructions before further flight. If no cracks are found, the tubing thickness

inspection is to be conducted in accordance with OMF ASB 1107/0002 within 50 hours TIS after the initial inspection for cracks, and any appropriate reinforcements are to be made as instructed by the manufacturer. No evidence of any reinforcement was found on the submitted accident airplane frame pieces.

Matthew R. Fox, Ph.D.
Senior Materials Engineer



Figure 1. Overall view of the submitted RMLG attachment hardware, clamp, block, and fuselage frame pieces.

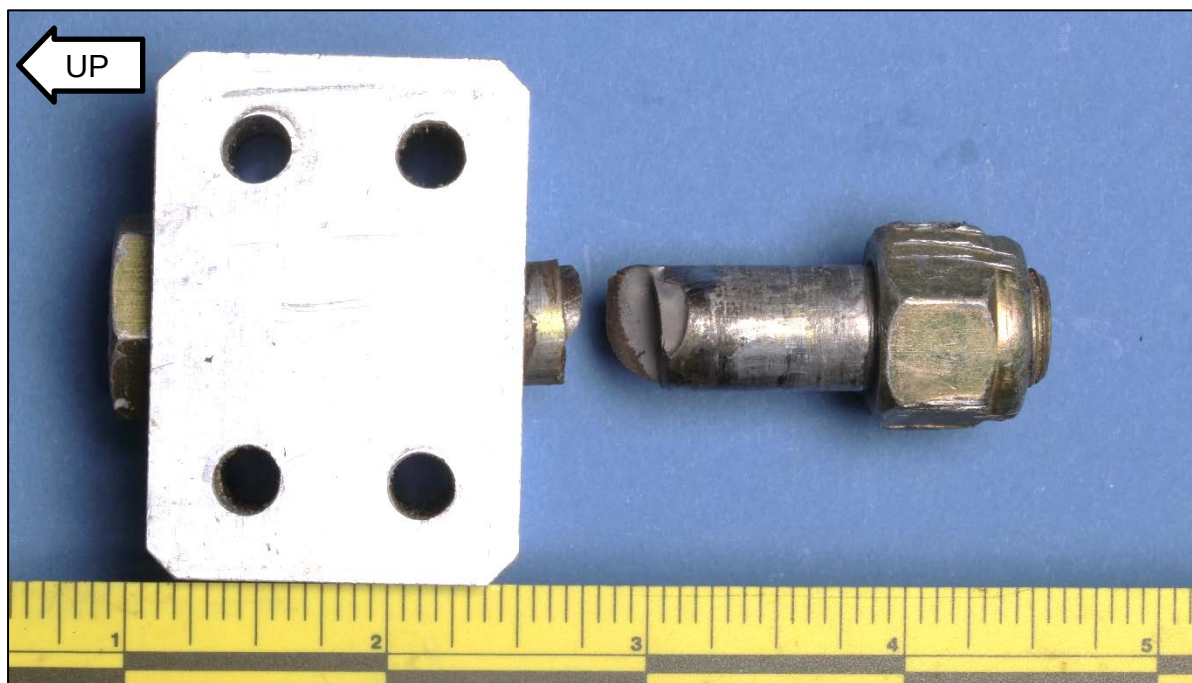


Figure 2. RMLG inboard attachment bolt, nut, and block.



Figure 3. Upper fracture face on the RMLG inboard attachment bolt. Dashed lines indicate fatigue boundaries, and unlabeled brackets indicate fatigue origin areas.

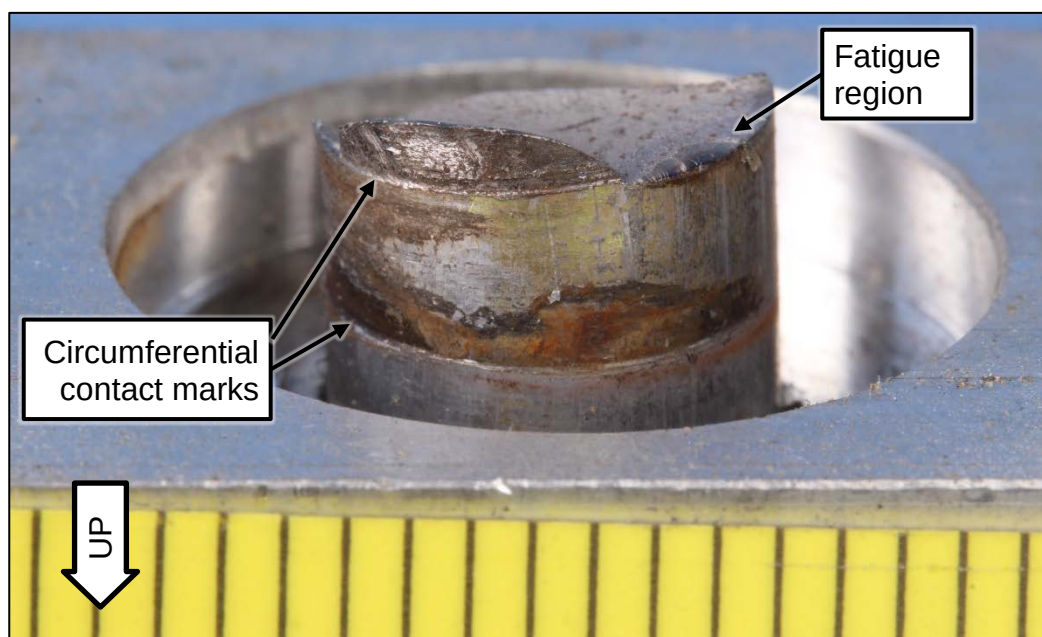


Figure 4. Close view of the grip adjacent to the upper fracture face on the RMLG inboard attachment bolt upper piece.

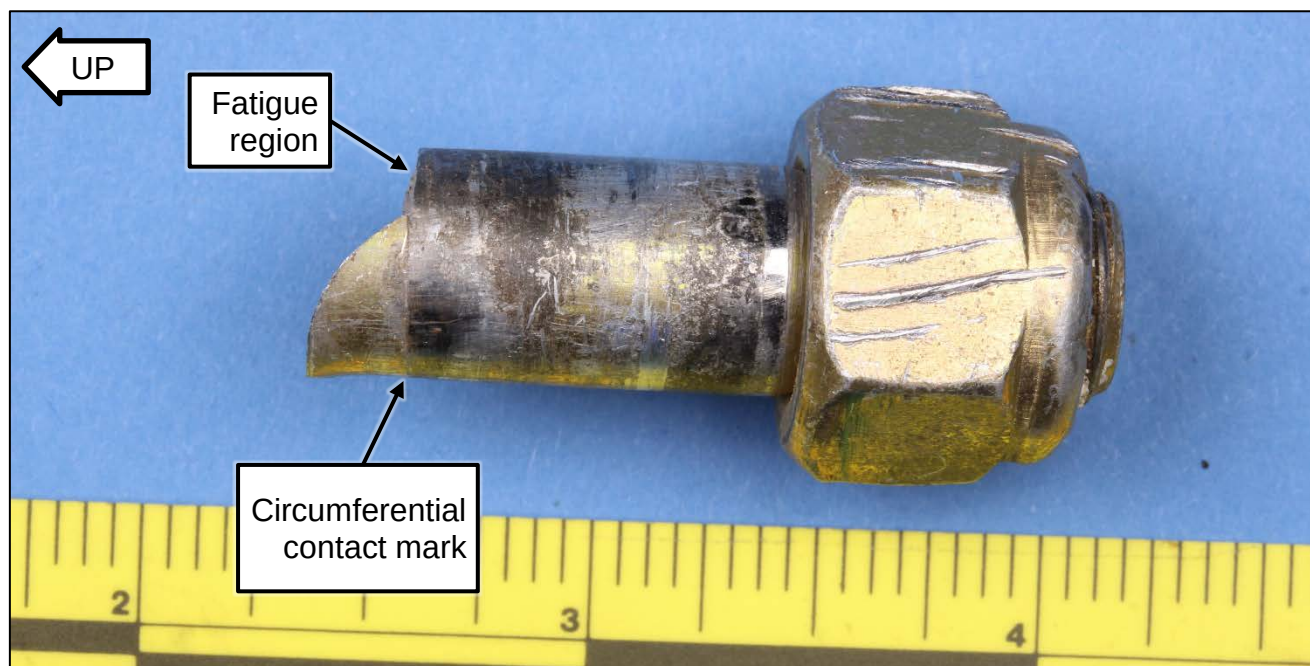


Figure 5. Side view of the lower piece of the RMLG inboard attachment bolt with attached nut.

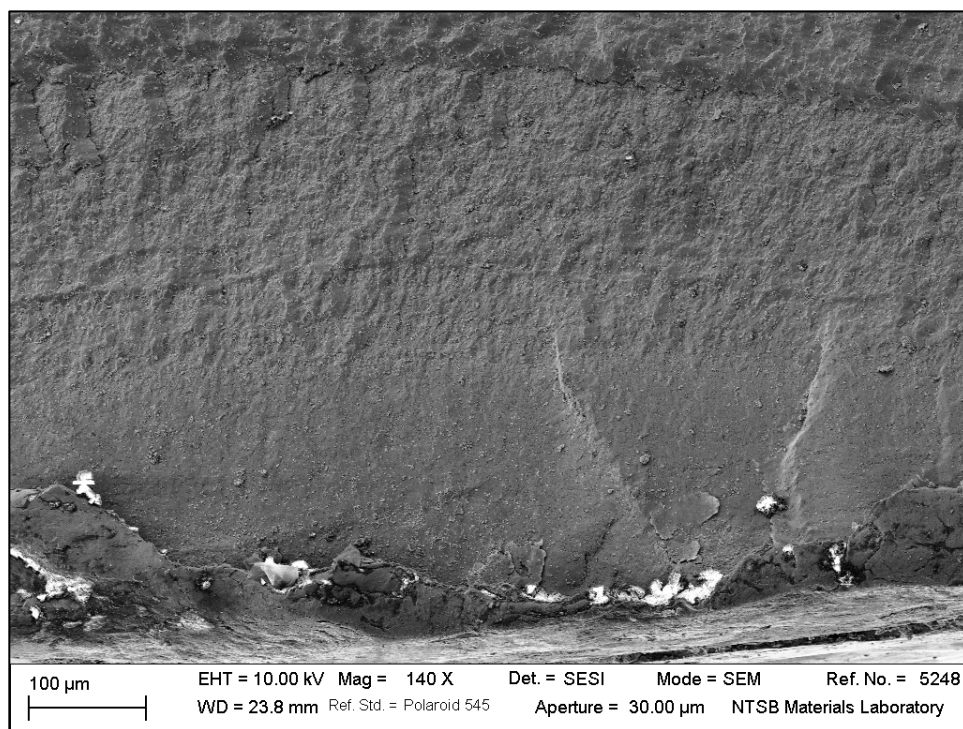


Figure 6. SEM image of the lower face of the inboard attachment bolt fracture showing the fatigue origin area of the larger fatigue region.

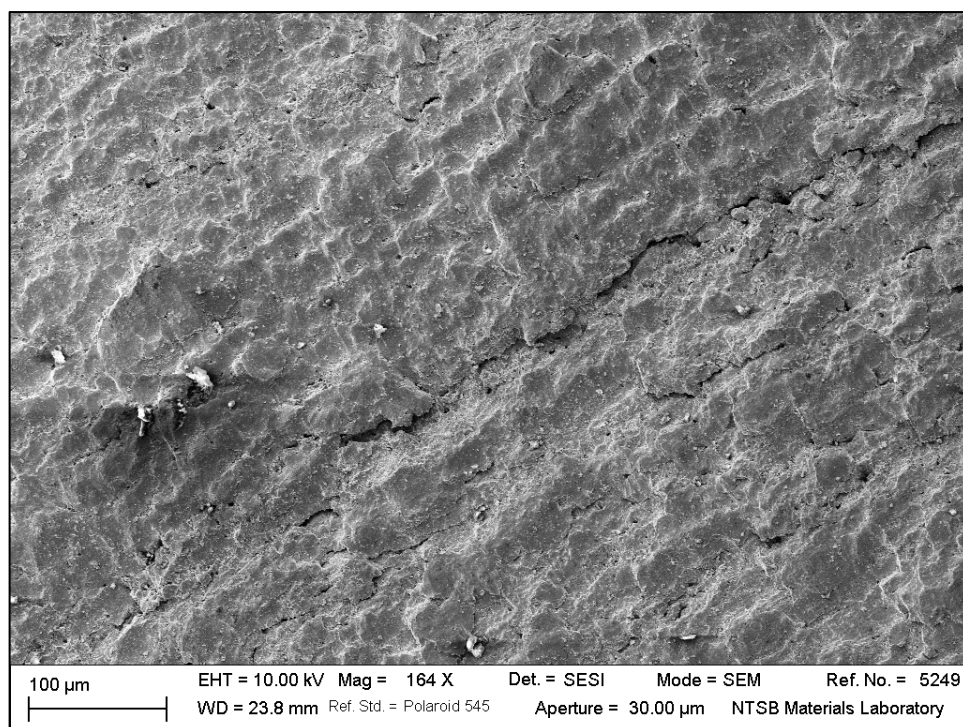


Figure 7. SEM image of the lower face of the inboard attachment bolt fracture showing fatigue fracture features near the boundary of the larger fatigue region.

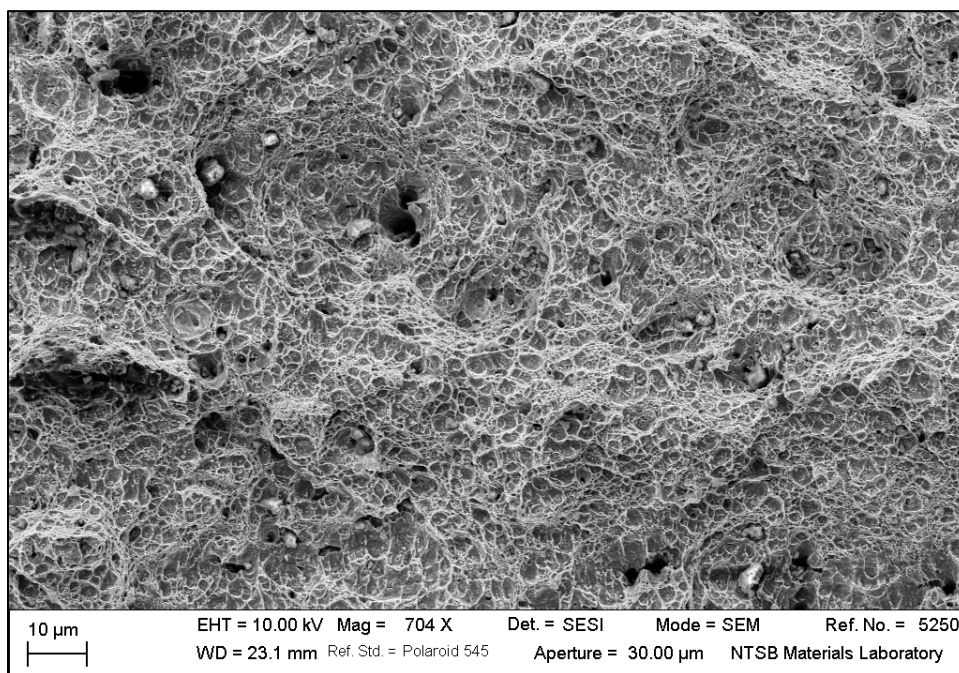


Figure 8. SEM image of the lower face of the inboard attachment bolt fracture showing dimple features near the center of the bolt.

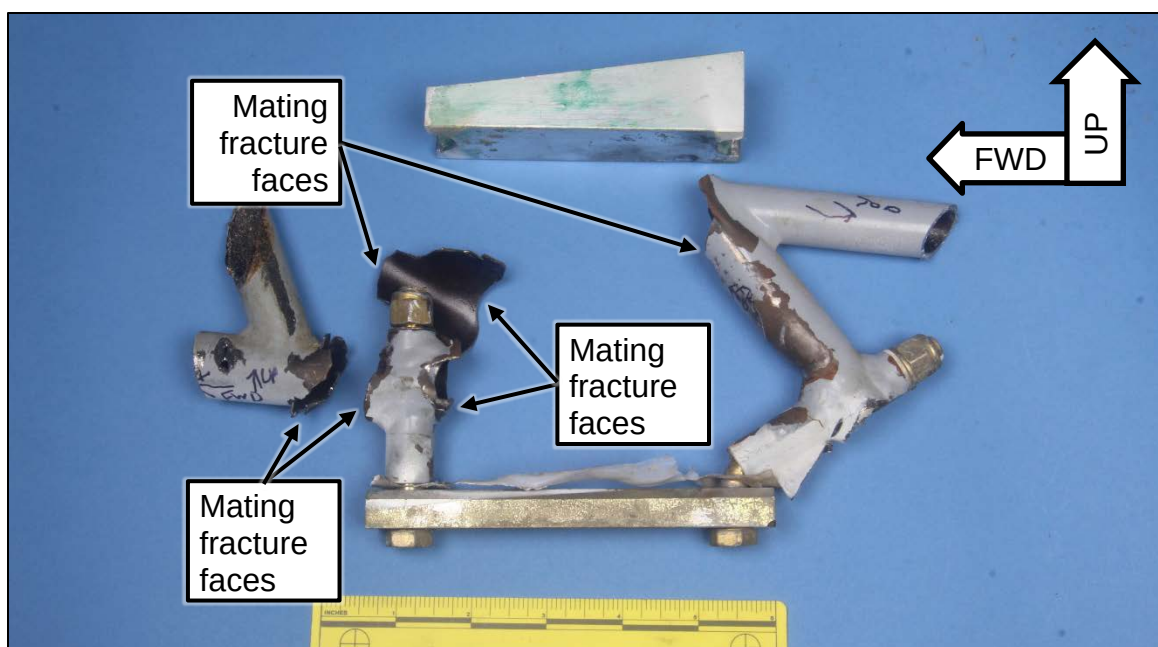


Figure 9. Overall view of the RMLG outboard attachment area. Mating fracture surfaces in the longitudinal frame tube are identified.

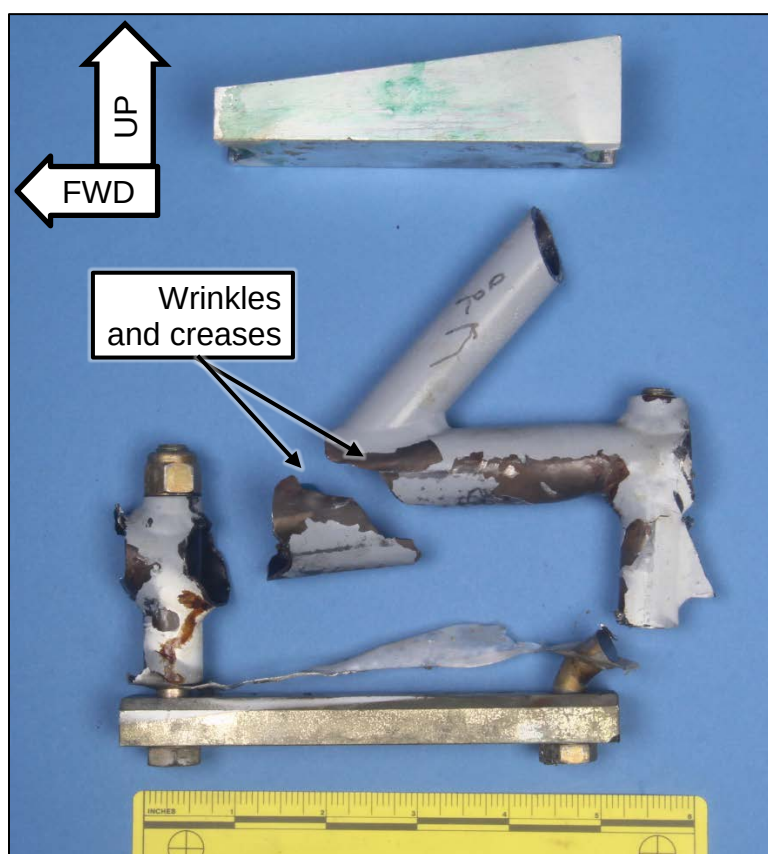


Figure 10. View of the RMLG outboard attachment area with fractures in the longitudinal frame tube placed in close proximity after cutting the aft attachment bolt.

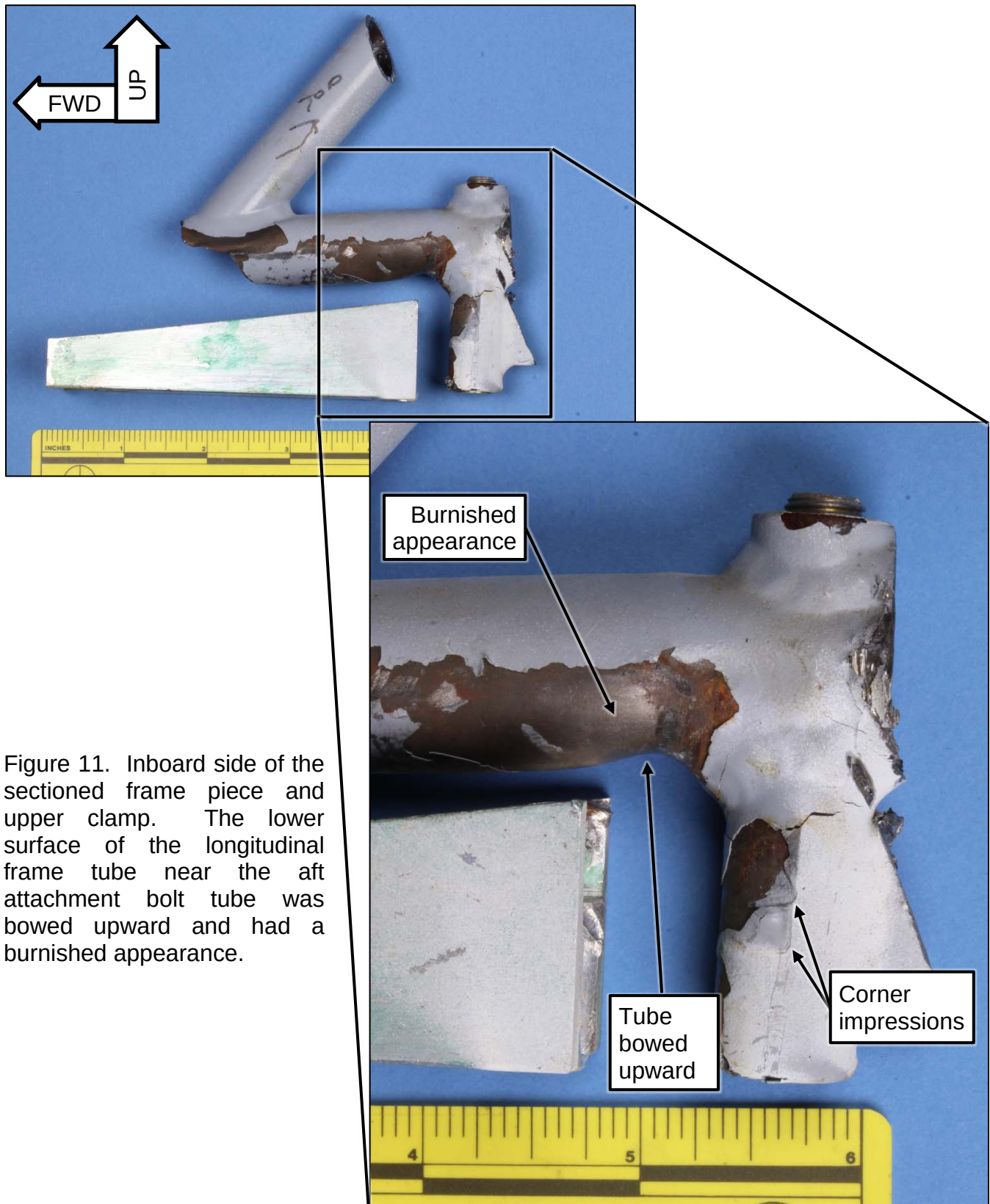




Figure 12. Outboard side of the sectioned frame piece and upper clamp. A wrinkle in the tube wall and marks consistent with contact with the upper corner of the displaced upper clamp are indicated. An area of brown tint is shown on the upper clamp.

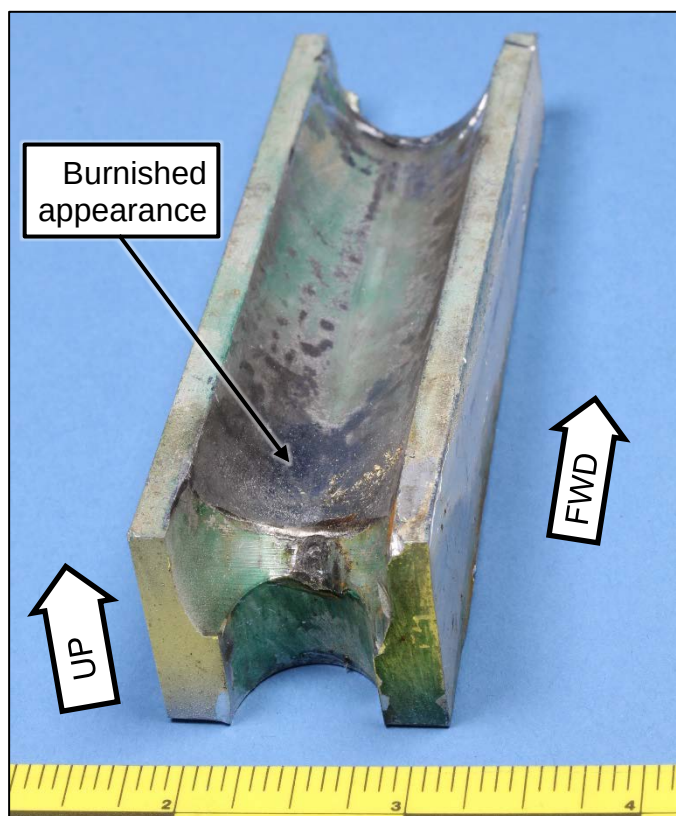


Figure 13. Oblique view of the upper aft side of the upper clamp showing an area with a burnished appearance near the aft end of the frame contact surface.

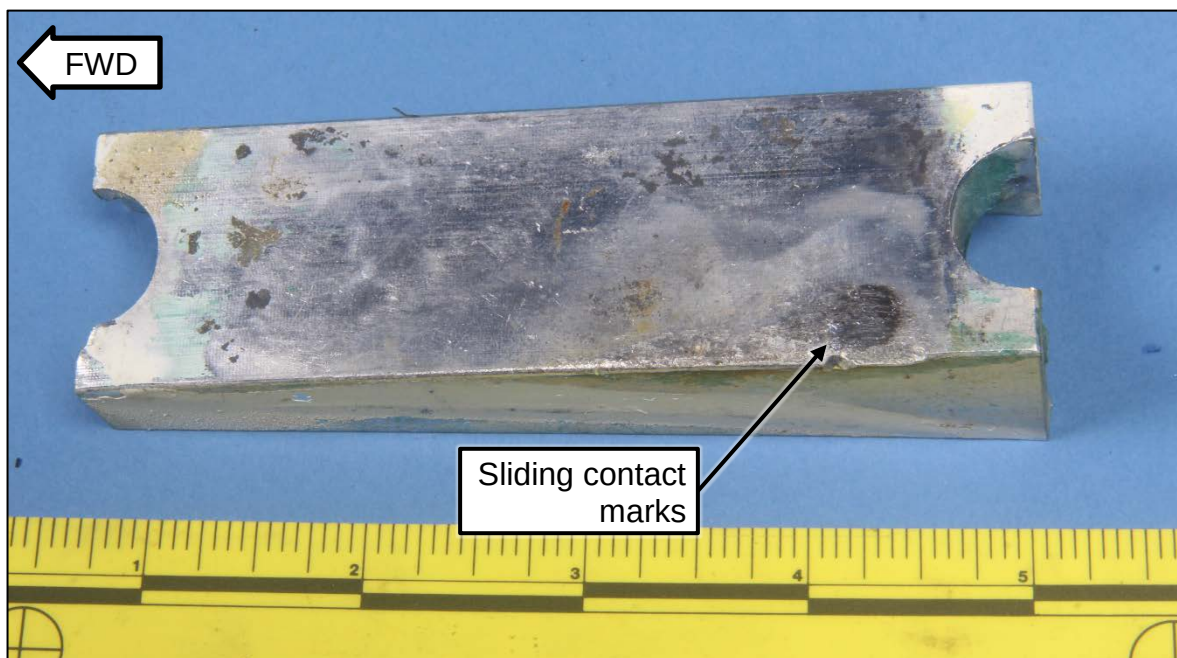


Figure 14. View of the underside of the upper clamp showing an area of sliding contact marks that was discolored dark near the outboard edge of the lower surface.



Figure 15. Image from OMF Process Specification PS-OMF 100-0006 showing the frame piece cut from the left side of the fuselage of an exemplar airplane being repaired.



Figure 16. Image from OMF Process Specification PS-OMF 100-0006 showing the frame repair on the left side of the exemplar airplane after the replacement pieces are welded into place.