

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN23LA405

MATERIALS LABORATORY

Factual Report 24-050

August 26, 2024

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A. ACCIDENT INFORMATION

Location: Giddings, Texas
Date: August 7, 2023
Vehicle: Alisport SRL Silent 2 Electro, N321AD
Investigator: Mitch Gallo, AS-CEN

B. COMPONENTS EXAMINED

Aft fuselage section forward of empennage

C. EXAMINATION PARTICIPANTS

Specialist Matthew R. Fox, Ph.D.
NTSB
Washington, DC

D. DETAILS OF THE EXAMINATION

Overall views of the submitted fuselage piece are shown in figures 1 and 2. The 33.5-inch long piece was from the aft end of the fuselage forward of the empennage. The damaged area of the fuselage is shown in figure 3 before it was sectioned from the aircraft. As shown in the image, cracks on the upper side of the fuselage were located up to approximately 30 inches forward of the vertical stabilizer.

Skin cracks observed on the sectioned piece are shown circled in figures 1 and 2. As shown in the side views in figure 1, the skin cracks were oriented approximately 45° relative to the transverse plane on both the left and right side. Additionally, longitudinal cracks were observed on the upper and lower sides of the fuselage. The 45° cracks intersected the longitudinal crack at the lower side of the skin as indicated by the continuous boundary around the cracked areas. On the upper side of the fuselage, the cracks oriented at 45° were separate from the longitudinal crack as indicated with separate circled areas shown in figure 2. The longitudinal crack on the upper side of the fuselage was located between 7 and 11 inches away from the cut end and was difficult to see visually. To aid in detection and photography, a fine black powder was rubbed over the surface to help reveal the cracks in the white paint for the photograph shown in the lower image in figure 2.

The fuselage skin was made from fiber reinforced polymer composite materials with both glass fiber and carbon fiber fabric reinforcement. The fuselage skin was constructed of two halves (left half and right half) that were spliced together at the upper and lower sides as indicated in figure 4. At each splice location, the skin layers butted together, and strips of glass-fiber reinforced fabric were bonded to the interior surfaces to form single strap butt joints.

A portion of the upper skin containing the longitudinal crack and a section of the upper splice was cut from the remainder of the fuselage skin using a hand-held cutting tool with an oscillating diamond-coated blade. Views of the exterior and interior surfaces of the sectioned piece are shown in figure 5. On the interior side, a portion of the strap had a lighter appearance within the region shown bounded by dashed lines in the lower image in figure 5. The change in color was consistent with a disbond between the strap and the skin.

The aft end of the piece shown in figure 5 was sectioned approximately $\frac{3}{4}$ inch away from the end using a water-cooled abrasive saw. The aft face of the sectioned piece was then rough polished by hand using silicon-carbide paper at successively finer grit size up to 1200 grit to prepare the surface for materialographic examination. Images of the prepared cross-section as viewed using optical microscopy are shown in figures 6 and 7, and images using a scanning electron microscope (SEM) are shown in figure 8.

The middle of the splice between the left and right skin halves is shown in figure 6. Resin filled the gap between the butt ends of the left and right skin layers and the area between the strap and the skins. The resin layer was approximately 0.10 inch thick on the right side of the splice and became thinner toward the left side as shown in figure 7. The skin and strap layers were closely bonded to each other at the left side of the splice. A vertical crack was observed at the butt joint as indicated with an unlabeled bracket in figure 6. The upper end of the vertical crack intersected a smaller transverse crack at the lower side of the strap.

The SEM images of the cross-section shown in figure 8 were obtained using a backscatter detector in composition mode.¹ The displayed images are collections of individual SEM images that were stitched together to show overall views of the layup in the single strap splice to the left and right of the butt joint. Glass fibers appear lighter gray relative to the carbon fibers and resin, and voids appear relatively dark. Fiber orientations were determined by relative elongation of fibers ends where they intersected the transverse plane with little or no elongation to 0-degree fibers, intermediate elongation to ± 45 -degree fibers, and relatively high elongation associated with 90-degree fibers. All fibers were observed in bundles consistent with fabric construction. No evidence of glass fiber roving was observed, including in the resin pocket between the strap and the skin.

Information about the construction of the fuselage for the accident aircraft was limited. Alisport engineering drawing T-SE-X37017, revision 4, dated August 6, 2004, titled Silent Ellisse (Silent 2) fuselage lamination scheme was obtained and

¹ SEM images produced using a backscattered electron detector in composition mode have contrast that is associated with atomic number of the elements in the image. Areas with elements having higher atomic numbers appear as a relatively lighter shade of gray compared to areas having elements with lower atomic numbers.

reviewed. The drawing indicated each half of the fuselage skin at the damaged location forward of the empennage would consist of 1 layer $\pm 45^\circ$ glass fiber, 1 layer $0/90^\circ$ glass fabric, 1 layer $\pm 45^\circ$ carbon fiber, and 1 layer $0/90^\circ$ glass fiber starting from the outside surface as shown in the upper image in figure 9. The longitudinal joint between the halves was shown as an overlap joint with 6 threads of glass roving (represented by a blue dashed line in figure 9) in the dished portion of the joint. Details of how the fuselage halves were to be bonded together were not included in the available information.

The accident aircraft was serial number 2077 manufactured in 2016. The as-built construction at the location of the materialographic section as illustrated in the lower image in figure 9 showed skins with one additional $\pm 45^\circ$ glass fabric layer on the exterior, one additional $\pm 45^\circ$ carbon fabric layer in the middle, and one additional $0/90^\circ$ layer on the inner surface of the skin on the right side only, relative to the reference build drawing. Additionally, the joint between the two halves was a single strap butt joint instead of the overlap splice shown in the reference drawing. The strap consisted of four layers at the centerline and to the right of the butt joint. To the left of the joint, the layers of the strap tapered to one layer ending approximately 4 inches from the butt splice. No evidence of 0° glass roving was observed in the as-built splice. Although the skin layers had a mix of fabric orientations with some layers in the $0/90^\circ$ orientation and others in the $\pm 45^\circ$ orientation, all four layers of the strap were oriented in the $0/90^\circ$ orientation. A red dashed line in the lower image in figure 9 illustrates the approximate crack locations in the splice as observed in the cross-section shown in figure 6.

The interior surface of the fuselage near the forward cut end is shown in figure 10, where two areas of the upper splice area are shown circled. These areas had a distinctly lighter appearance relative to the surrounding areas, consistent with areas of voids or disbonds. The longitudinal crack on the upper side of the fuselage (see figure 2) was located in this area of the fuselage at a location corresponding to the 0 to 4-inch marks on the ruler shown in figure 10.

Submitted by:

Matthew R. Fox, Ph.D.
Chief Technical Advisor - Materials

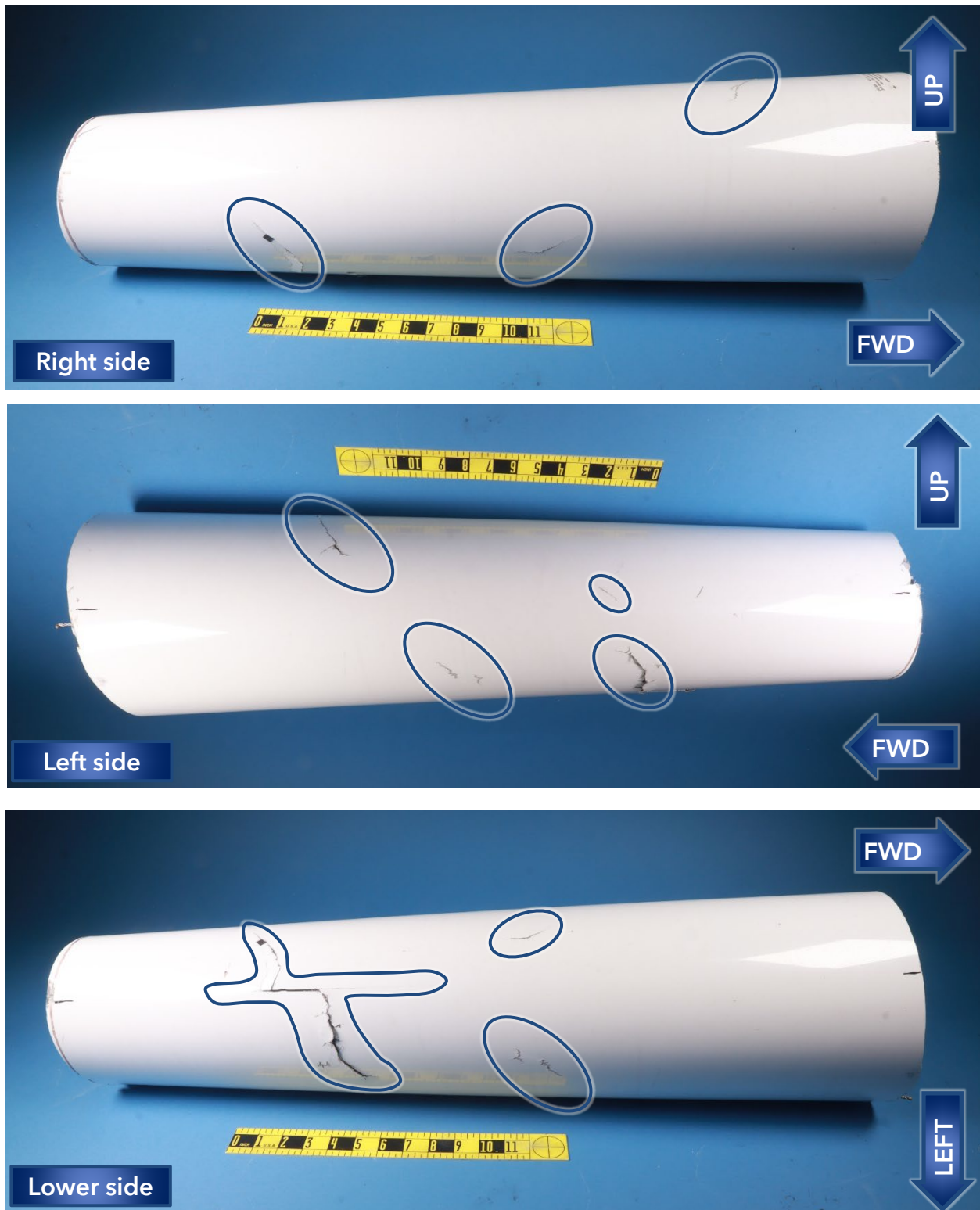


Figure 1. Overall views of the submitted fuselage section showing the right side (upper image), left side (middle image), and lower side (lower image). Locations of cracks are outlined.

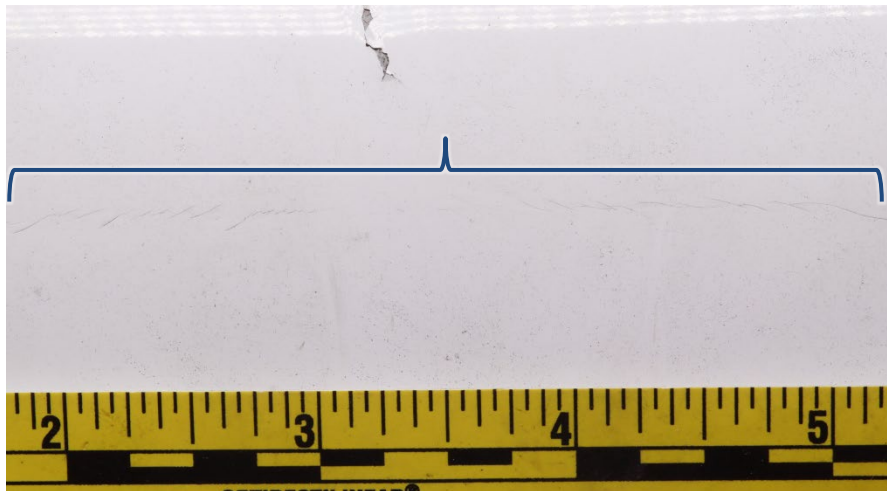
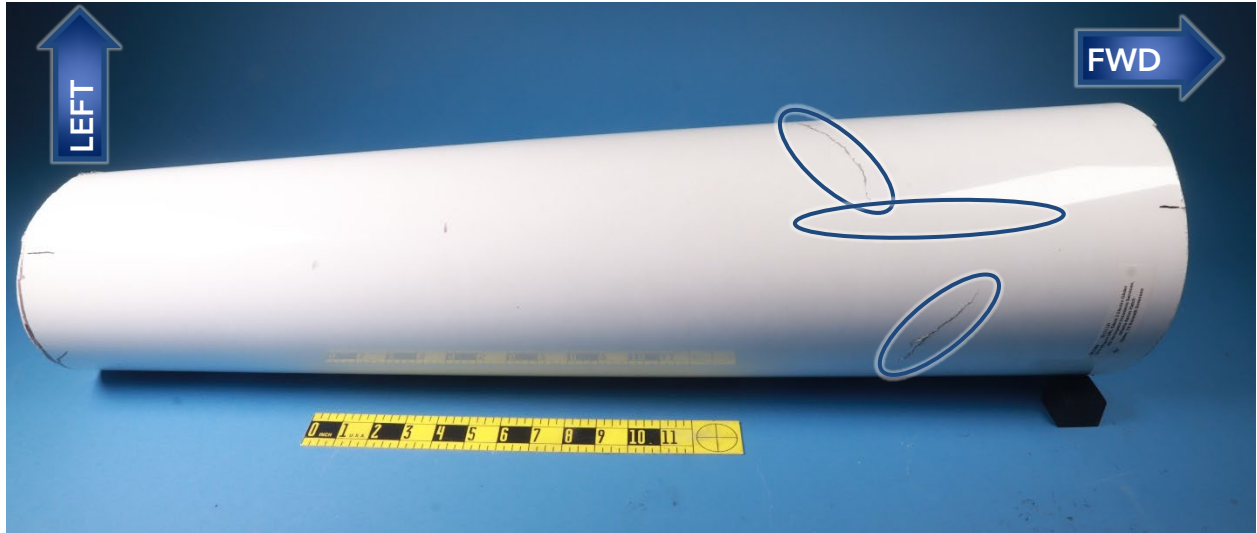


Figure 2. Overall view of the upper side of the submitted fuselage section (upper image), where locations of cracks are outlined. The lower image shows a closer view of the longitudinal crack as indicated with an unlabeled bracket after the surface was rubbed with a fine black powder to help reveal the crack in the white paint.



Figure 3. View of the damaged fuselage before it was sectioned from the aircraft. (Image provided by the aircraft owner)

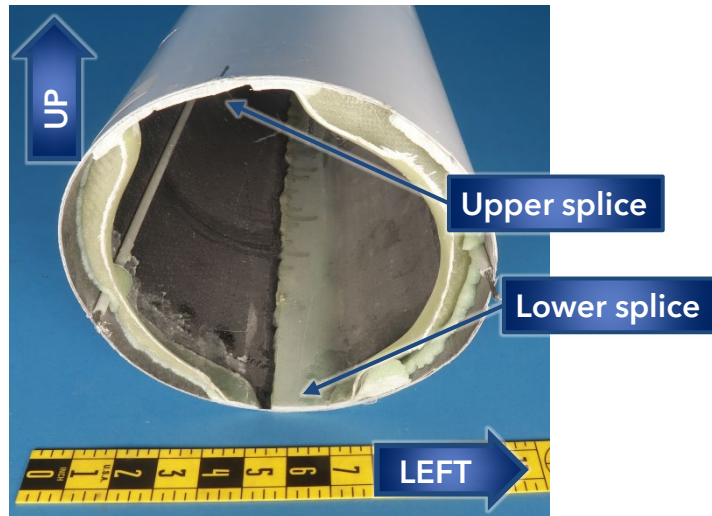


Figure 4. End view of the fuselage section showing longitudinal splice locations for the fuselage skin halves.

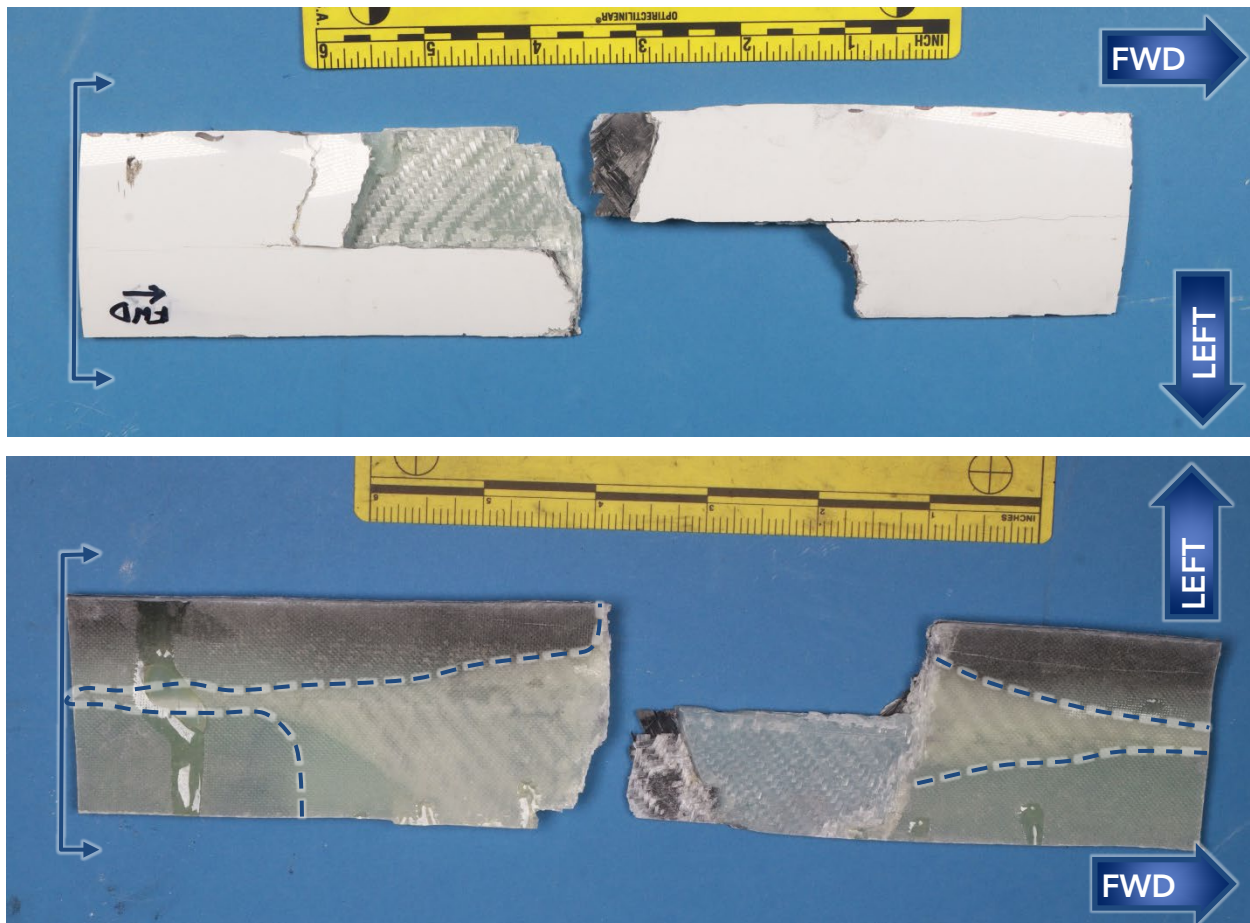


Figure 5. Piece of fuselage skin removed from the cracked lower splice. Arrowed lines indicate the location of a transverse materialographic section at the aft end of the aft piece. Dashed lines in the lower image indicate a lighter region likely associated with strap disbonding.

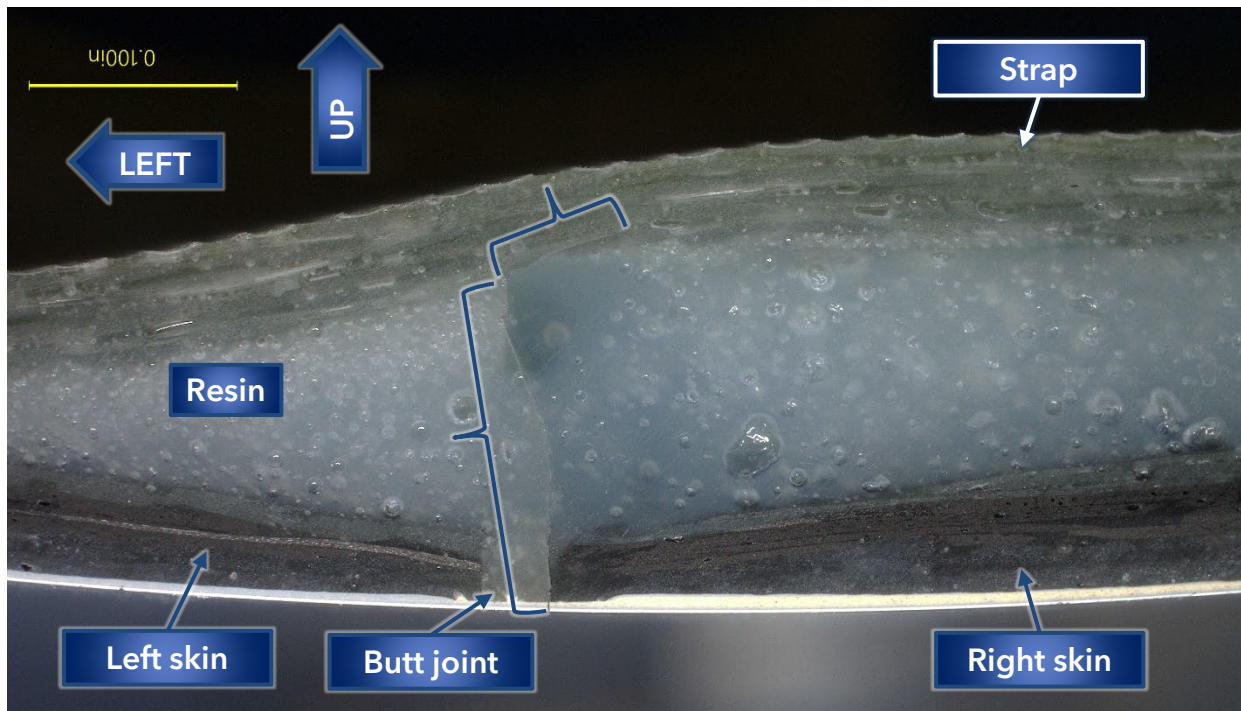


Figure 6. Materiallographic section showing the middle of the single strap splice where the butt ends of the fuselage skin halves were joined. Unlabeled brackets indicate the location of a vertical crack through the butt joint intersecting a smaller transverse crack at the lower side of the strap.

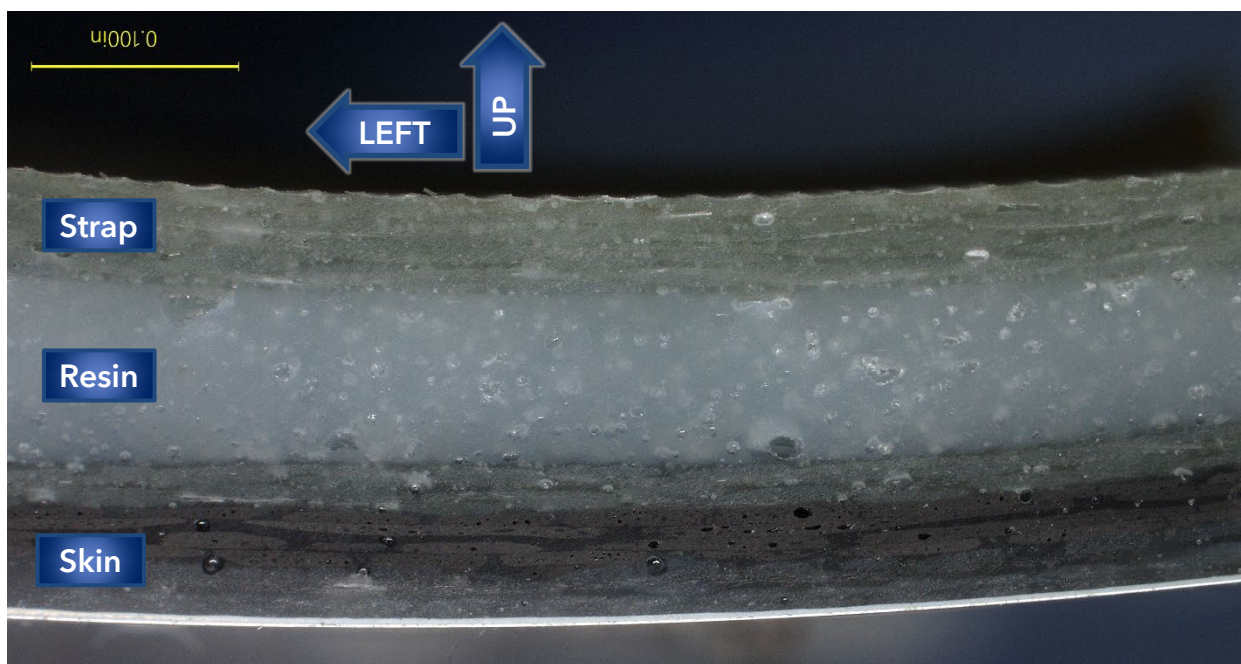


Figure 7. Materiallographic section of the splice to the right of the butt joint showing the 0.1-inch thick resin layer between the strap and the skin.

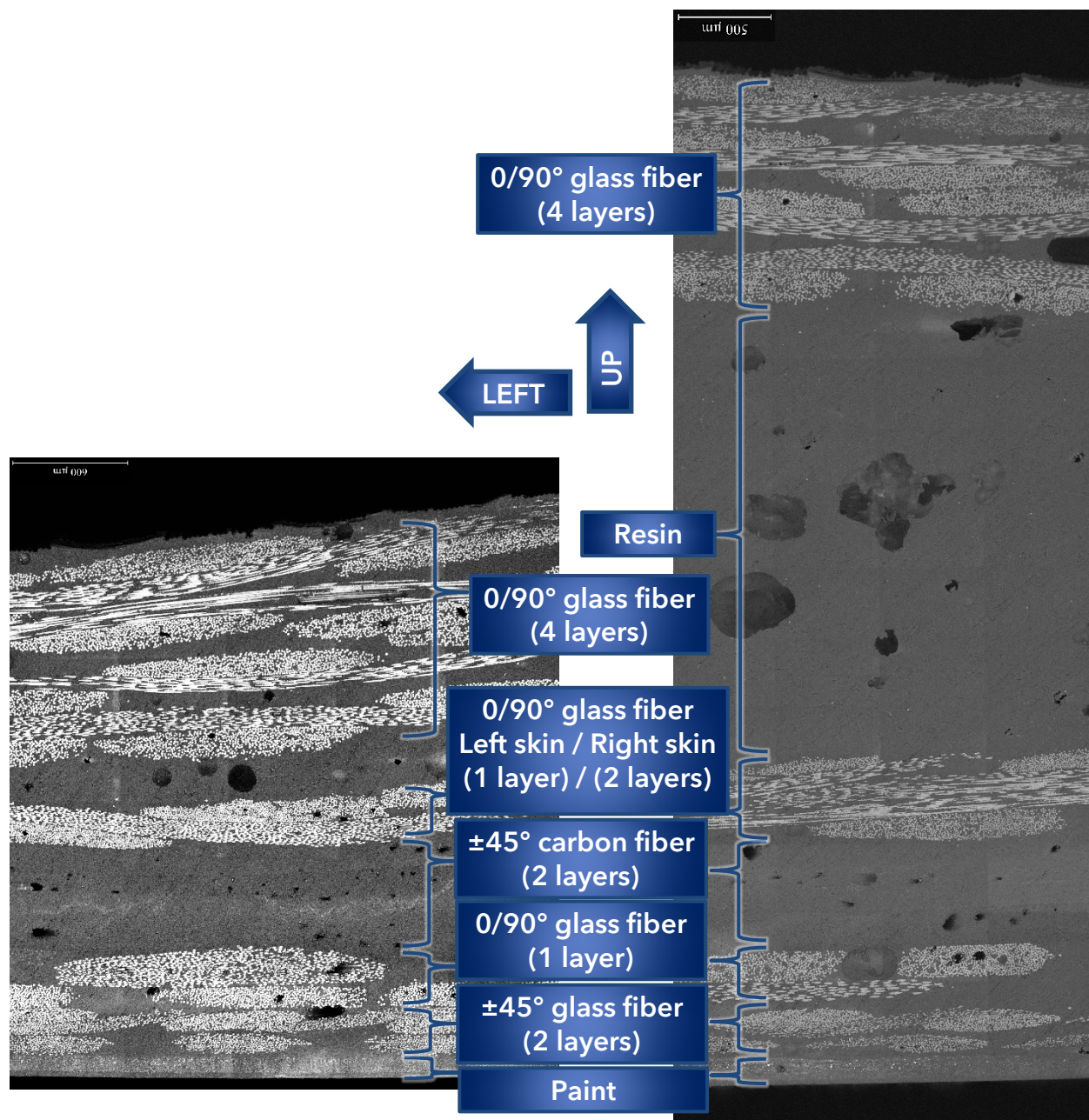


Figure 8. SEM images stitched together to show the cross-section on the left side (left image) and right side (right image) of the single strap splice.

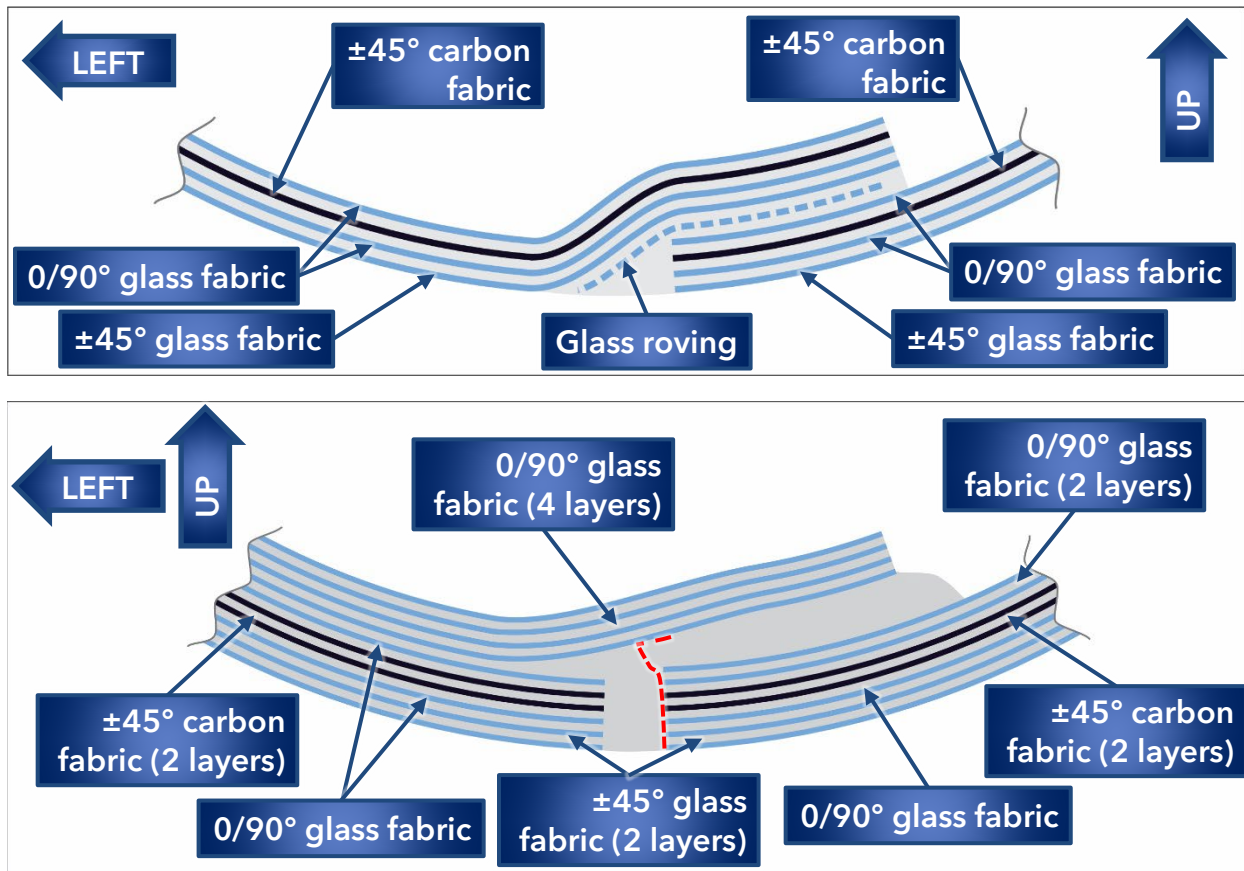


Figure 9. Diagrams of the layup for the skin at the lower splice between the two fuselage halves showing a comparison between the skin layup schedule as presented in an Alisport engineering drawing from 2004 (upper image) and the as-built structure, manufactured in 2016, observed in a cross-section of the accident aircraft fuselage (lower image). Glass fiber reinforcement layers are shown in blue, and carbon fiber reinforcement layers are shown in black. The dashed red line in the lower image indicates the approximate crack path observed in the materialographic cross-section through the single strap splice.



Figure 10. Interior surface of the fuselage at the upper splice location. Areas circled had a lighter appearance consistent with a disbond or void. The longitudinal crack shown in figure 2 was between 7 and 11 inches away from the cut end, which corresponds to the 0 to 4-inch marks on the ruler shown in this image.