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MATERIALS LABORATORY

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A. ACCIDENT INFORMATION

Location: North Plains, Oregon
Date: July 5, 2023
Vehicle: AviaStroitel AC-5M, N40233
Investigator: Michael Hicks, AS-WPR

B. COMPONENTS EXAMINED

Inboard ends of left and right wings and carrythrough beams.

C. EXAMINATION PARTICIPANTS

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Washington, DC

D. DETAILS OF THE EXAMINATION

Overall views of the submitted wing and carrythrough beam pieces are shown as received in figure 1. Both wing pieces had chordwise cuts at the outboard ends to facilitate shipment to the NTSB Materials Laboratory. The right wing spar was fractured at the inboard end where it transitioned to the carrythrough beam, and the left wing piece was intact at the wing spar to carrythrough transition.

As installed on the glider, the tip end of the carrythrough beam extending from each wing is inserted into a reinforced slot in the closeout rib at the inboard end of the opposite wing. The wings are then secured in place with a pin that is inserted through holes in the middle of the carrythrough beams. As recovered, both wings were reportedly found 150 feet to 200 feet away from the fuselage. Recovery photographs showed the carrythrough beam from the right wing was found attached to the left wing with the pin engaged.

Views of the right wing upper and lower skins are shown in figures 2 and 3. The skins were mostly separated from each other at the leading edge but remained attached to the spar near mid chord and to each other along the trailing edge. Cracks and wrinkles were observed on the upper skin as indicated with unlabeled arrows in figure 2. The upper skin cracks and wrinkles were mostly located between the leading edge and the spar. A portion of the upper skin was missing at the inboard end of the leading edge. The upper skin at the edge of the missing portion

had a rubbed appearance, and surrounding areas on both the upper and lower skin had brown deposits that appeared to be consistent with soil.

A hole was observed on the lower surface of the wing just forward of the spar approximately 2.5 inches outboard of the inboard edge as shown in figure 4. Cracks in the paint were observed emanating from the hole to the aft and both inboard and outboard of the hole. Sliding contact marks oriented in the spanwise direction were observed around the hole, and dark colored deposits were observed adjacent to the hole and on the adjacent fracture surface.

Impact damage was observed on the lower skin at two locations on the leading edge as indicated in figure 3. A closer view of the larger area of damage is shown in figure 5. Paint at the impact sites was fractured and missing, and paint cracks radiated from the impact location. The impact damage was isolated to the lower skin and was not observed on the mating upper skin across the leading edge separation. Longitudinally-oriented black deposits and sliding contact marks were observed on the upper and lower sides of the leading edge, and some of these marks and deposits can be seen intersecting the impact area shown in figure 5.

Photographs of the glider wing as it was found in a field were reviewed. The black deposits and longitudinal scratches observed on the submitted pieces were not observed in the reviewed photographs of the right wing. Additional images of the parts in a storage container after the accident showed the right wing stored with the leading edge facing down, and the floor of the storage container appeared to consist of dark-colored wood planks.

Reddish brown deposits were observed aft of the impact area shown in figure 5. Some of the deposits fluoresced when imaged using ultraviolet (UV) lighting. A view of the lower skin as photographed using a UV light is shown in figure 6. Trails of fluorescent material were observed extending between the hole near the spar and the two impact sites with a branching trail to the reddish brown deposit aft of the inboard impact site. Upon close inspection, the trails were associated with faint cracks in the paint.

Representatives from the Smithsonian Feather Identification Lab examined 9 samples collected from the right wing piece on May 21, 2024, for evidence of feathers or deoxyribonucleic acid (DNA), including fiber-like features from the leading edge impact areas and the hole and swab samples of the surfaces that fluoresced under UV light. None of the swab samples contained viable DNA, and microscopic examination of other samples resulted in findings of plant and insect matter. No evidence of bird impact was observed.

A view of the inboard end of the right wing with the mating side of the carrythrough beam is shown in figure 7. The close-out rib forward of the spar was fractured and missing. The inboard edge of the upper skin was bent upward

between the spar and the leading edge as indicated in figure 7. The upper skin was fractured and bent downward adjacent to the vertical flange for attaching the closeout rib. In contrast, the lower skin was not bent along the inboard edge where it had fractured from the close-out rib. The portion of the close-out rib aft of the spar remained attached to the wing. Adjacent to the aft side of the carrythrough beam, the lower flange of the close-out rib was fractured from the lower skin, and the upper flange was cracked. The closeout rib damage aft of the closeout beam was associated with inboard displacement of the lower end of the rib relative to the upper end as indicated in figure 7.

Views of the right wing spar fracture are shown in figures 8 and 9. The fracture occurred in the spar at the outboard side of the reinforced area of the closeout rib. The spar caps were constructed of a fiber-reinforced composite material separated by a web constructed of wood laminate.

Next, the aileron control rod and bellcrank assemblies were disassembled from the closeout ribs. Then, a transverse cut was made through the left carrythrough beam, and chordwise and spanwise cuts were made through the left and right wing pieces as shown in figure 10. On the right wing, the upper and lower skins were already completely separated from each other inboard of the chordwise lab cut, but the upper and lower skin pieces remained partly attached at the spar. The upper skin was nearly separated from the spar, so the skin was pulled by hand to produce a lab fracture of the remaining portion.

With the upper skin separated from the lower skin and spar, the fracture surfaces at the leading edge were exposed for examination as shown in figure 11. A cream-colored filler was observed between the skin layers, and the fracture path varied between interfaces at either side of the filler. No evidence of preexisting or progressive fracture such as arrest lines or rubbing damage from mating surfaces was observed.

Next, the inboard end of the right wing spar web was cut spanwise in the horizontal plane to separate the upper cap from the rest of the spar. The lower cap remained mostly attached to the lower skin, so a transverse cut was made through the lower cap to separate the inboard two inches of the lower cap, including the fractured end, from the lower skin.

After the lower cap was cut, the surface on the outboard side of the cut was polished with abrasive paper up to 600 grit and was wiped with a damp paper towel to reveal the reinforcement layers. The resulting transverse cross-section through the right wing spar lower cap is shown in figure 12. The spar cap reinforcement appeared to consist of folded layers of glass-fiber fabric that were laid into a form in the shape of the spar cap and were likely assembled with other spar and carrythrough components, filled with resin, and cured. The fabric had been

sequentially folded along the forward and aft sides of the spar to place the reinforcement layers.

Mating sides of the fracture through the right wing spar upper cap are shown in figures 13 and 14. Fiber reinforcement layers were visible at the forward side of the upper spar cap, and the longitudinal reinforcement layers appeared to deviate from the spanwise direction outboard of the fracture surface. Dashed lines in figure 13 trace several of the reinforcement layers visible on the forward face of the upper cap showing observed variations in fiber alignment.

As shown in figure 14, fracture surface on the inboard side of the upper cap fracture appeared to have sustained post-fracture damage, but the surface on the outboard side appeared to be intact and mostly free of damage. As viewed on the outboard side, the fracture surface mostly had a rough fibrous appearance consistent with tensile overstress fracture. A small portion of the surface at the upper side of the fracture had a whiter flattened appearance consistent with compression failure. At the lower quarter of the fracture, the exposed longitudinal fibers were angled downward relative to the spanwise direction.

Mating sides of the right wing spar fracture through the lower cap are shown in figure 15. The fracture surfaces had a rough fibrous appearance consistent with tensile overstress fracture. A relatively large pocket of fractured resin was observed at the lower aft side of the fracture, and that portion of the fracture was the furthest outboard. A wrinkle was observed in the fibers at the lower surface forward of the resin pocket as indicated in figure 15. Additionally, brackets in figure 15 indicate fibers in the upper half of the fracture that were angled significantly downward relative to the spanwise direction.

The spar web piece attached to the lower cap piece shown in figure 15 was mostly separated from the cap but remained attached with fabric layers on the upper and forward sides. The fabric layers were cut where the web intersected the cap to separate the web from the lower cap. Then the fracture surface on the outboard side of the lower cap fracture was examined using a scanning electron microscope (SEM). The fracture surface was initially examined in the uncoated condition. However, to minimize charging effects, the surfaces were coated with a thin layer of a gold palladium alloy to reduce charge accumulation.¹

An SEM image of fracture features within the relatively large resin pocket is shown in figure 16. Smooth fracture features with Wallner lines and river patterns were observed consistent with overstress fracture.

¹ Charging is the accumulation of negative charge on the surface that develops during electron imaging of nonconductive samples in a SEM under high vacuum and can result in distorted and overexposed images.

SEM images of fiber fractures in areas above the relatively large resin pocket are shown in figures 17 and 18. Fibers were fractured in variable locations and had rough features consistent with tensile overstress fracture. No evidence of progressive fracture was observed in resin features between fibers or in fiber-resin interfaces.

Figure 19 shows fracture features through a resin-rich area forward of the relatively large resin pocket. Smooth features with Wallner lines and river patterns were observed consistent with overstress fracture.

Fracture features at the lower surface of the lower cap are shown in figures 20 and 21. Reinforcement layers at the lower surface were wrinkled in an area forward of the relatively large resin pocket as indicated in figure 20. A closer view of the lower surface outboard of the indicated resin pocket is shown in figure 21. No evidence of preexisting or progressive separation, including features such as extensive rubbed surfaces or rolled matrix material, was observed on the lower surfaces.

After the fractographic examination was complete, a vertical spanwise cut was made through the lower cap piece with the outboard fracture surface. The aft side of the longitudinal section through the lower cap was polished and wetted similar to the previously described transverse section to reveal the reinforcement layers, and views of the sectioned and polished piece are shown in figure 22. The fracture intersected wrinkles in the reinforcement layers at the upper and lower sides of the lower cap. On the upper half of the lower cap, the longitudinal fibers in the fabric were bent nearly 90 degrees relative to the spanwise direction. The bend had intact resin and showed no evidence of kinked fibers from compressive buckling, features consistent with an as-fabricated wrinkle.

A vertical spanwise cut was made through the middle of the spar and carrythrough beam on the left wing piece shown in figure 10. The forward side of the cut was then polished and prepared similar to the previous sections to reveal the reinforcement layers in the upper and lower cap. An overall view of the section through the left wing spar caps, reinforced rib segment, and carrythrough beam is shown in figure 23 with closer views of the spar caps where they intersected the reinforced rib area. The reinforcement layers were continuous from the spar caps, through the reinforced rib area, and into the carrythrough beam. In the reinforced rib area, the caps were separated by two laminated wood panels, and in the carrythrough beam section, the caps were separated by a stiff foam core.

The fabric reinforcement layers in both the upper and lower caps for the left wing spar had wrinkles at the inboard end of the spar adjacent to the reinforced rib as indicated in figure 23. The inboard wrinkle in each cap was associated with rolled fabric at the interior corner between the spar cap and the vertical face of the reinforced rib, which locally interrupted the spanwise orientation of the fibers at that location. Further outboard, the outside layers deviated inward at another wrinkle, leaving a resin-rich area at the outside surface of each cap. In the region between the

wrinkles, the spanwise fibers in the fabric deviated substantially from the longitudinal direction. On the upper cap, longitudinal fibers angled between 16 and 28 degrees from the longitudinal direction in the area between the wrinkle peaks. On the lower cap, longitudinal fibers angled between 22 and 30 degrees from the longitudinal direction in the area between the wrinkle peaks.

Submitted by:

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



Figure 1. Overall views of the submitted wing and carrythrough beam pieces.



Figure 2. Upper surface of the right wing piece.

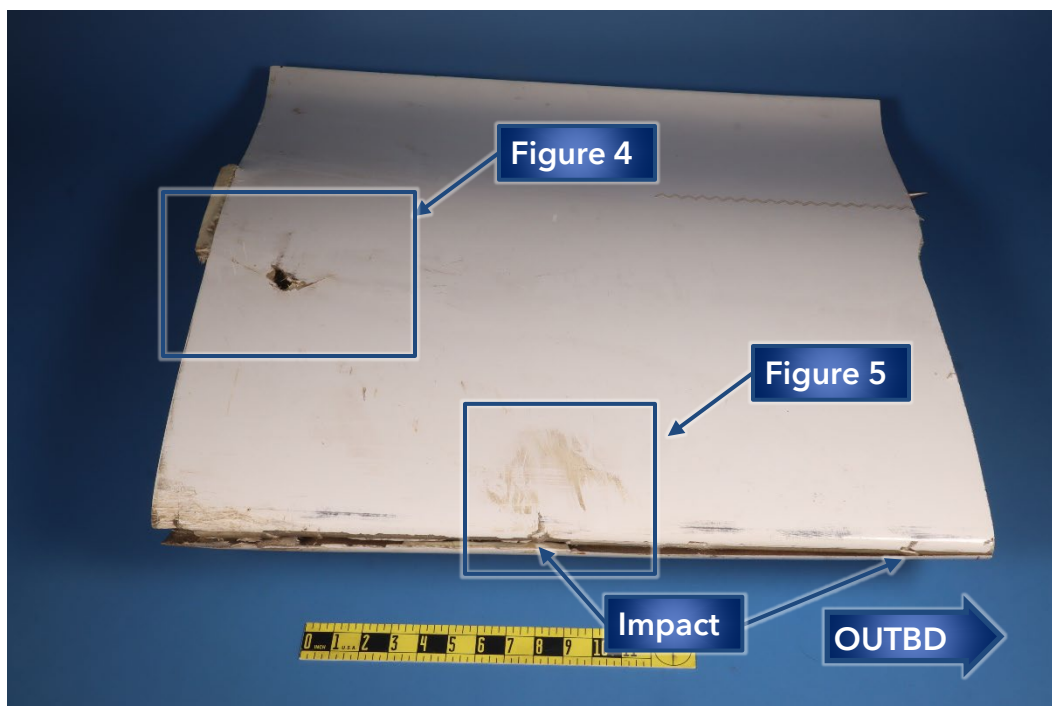


Figure 3. Lower surface of the right wing piece.

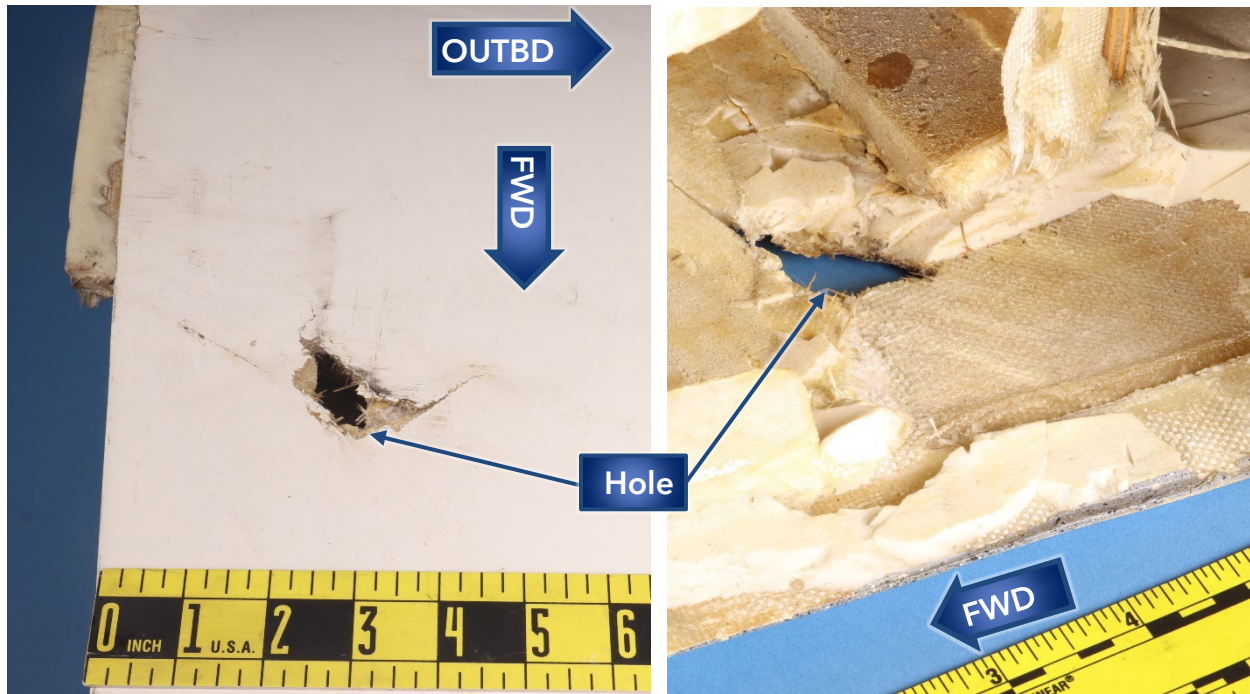


Figure 4. Inboard end of the right wing showing the hole in the lower skin forward of the spar fracture. Exterior and interior views are shown at the left and right, respectively.



Figure 5. Leading edge impact damage on the lower skin with black and brown deposits on the adjacent surfaces.

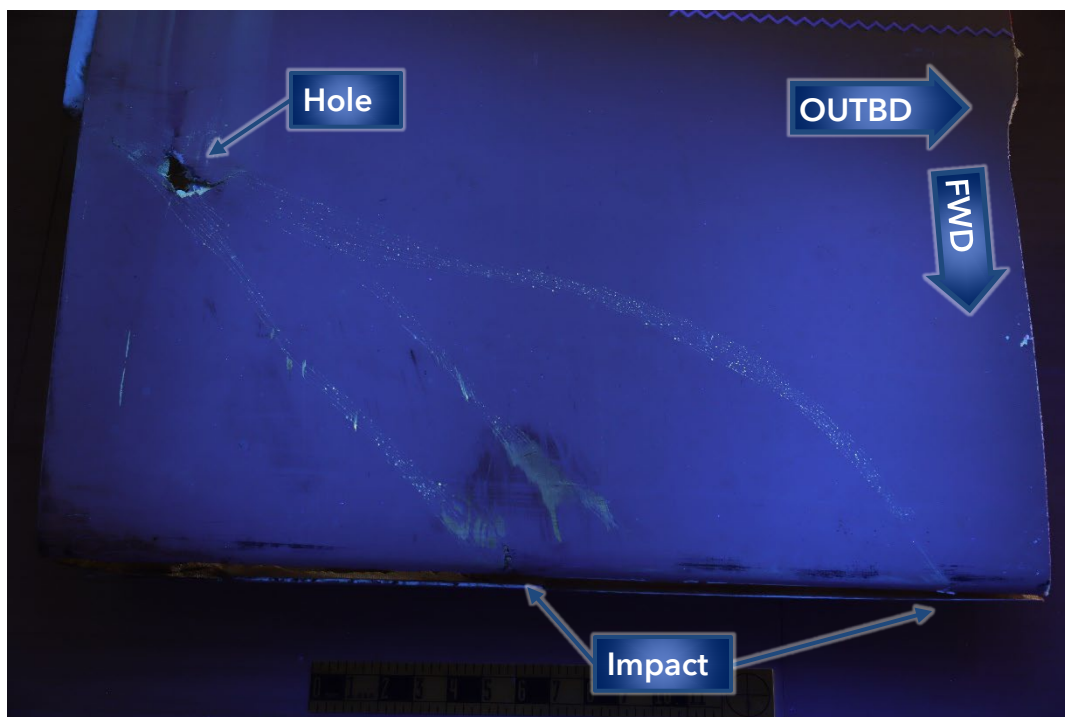


Figure 6. Lower skin under UV light showing fluorescing material between the hole and impact sites at the leading edge.

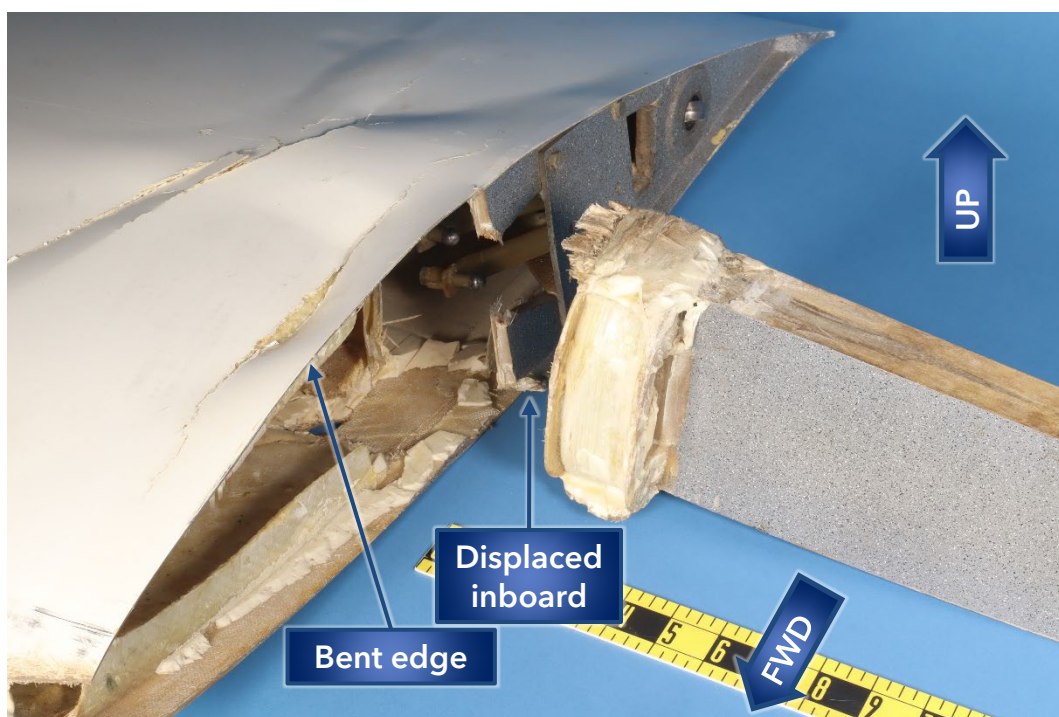


Figure 7. Inboard end of the right wing with separated carrythrough beam.



Figure 8. Inboard side of the right wing spar fracture at the outboard end of the carrythrough beam.



Figure 9. Outboard side of the right wing spar fracture at the inboard end of the wing.



Figure 10. Right and left wing pieces and carrythrough beams after sectioning.



Figure 11. Sectioned right wing lower skin (upper image) and upper skin (lower image) after the upper skin was separated from the spar and lower skin showing mating fracture surfaces at the inboard end of the leading edge bond line.

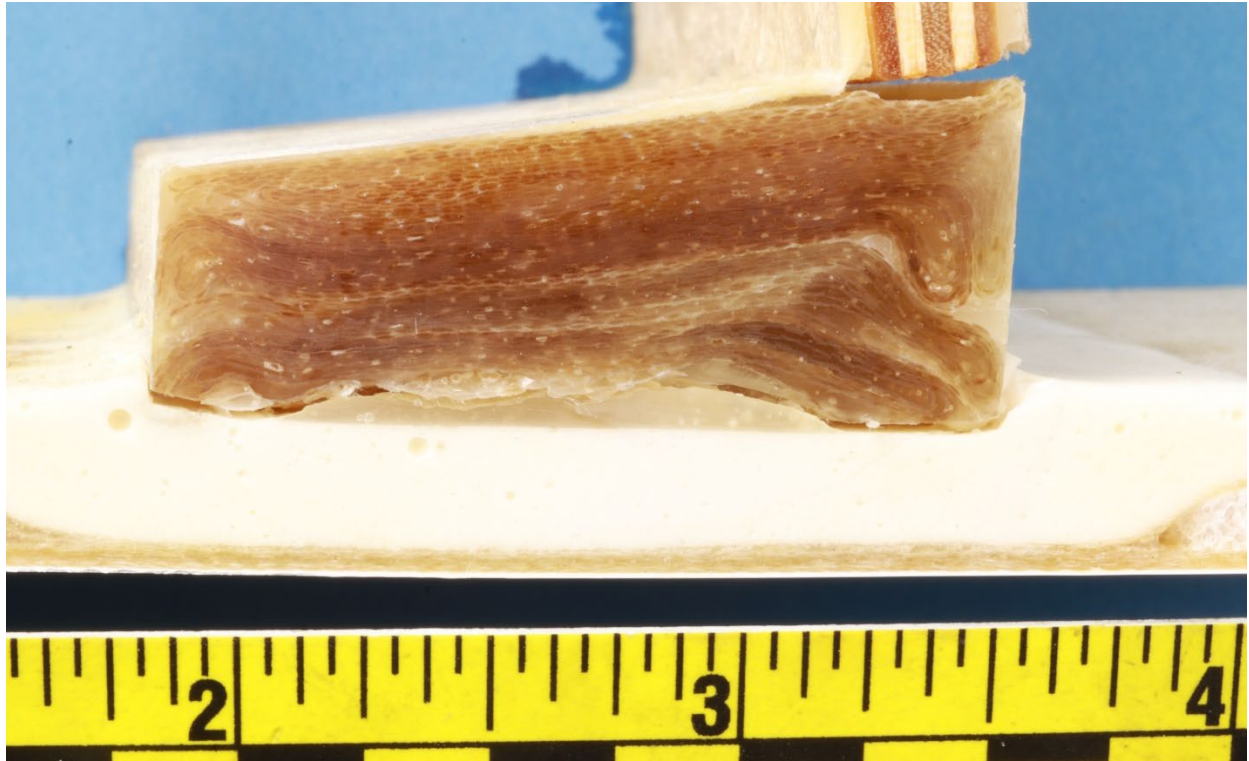


Figure 12. Transverse section through the right wing spar lower cap.

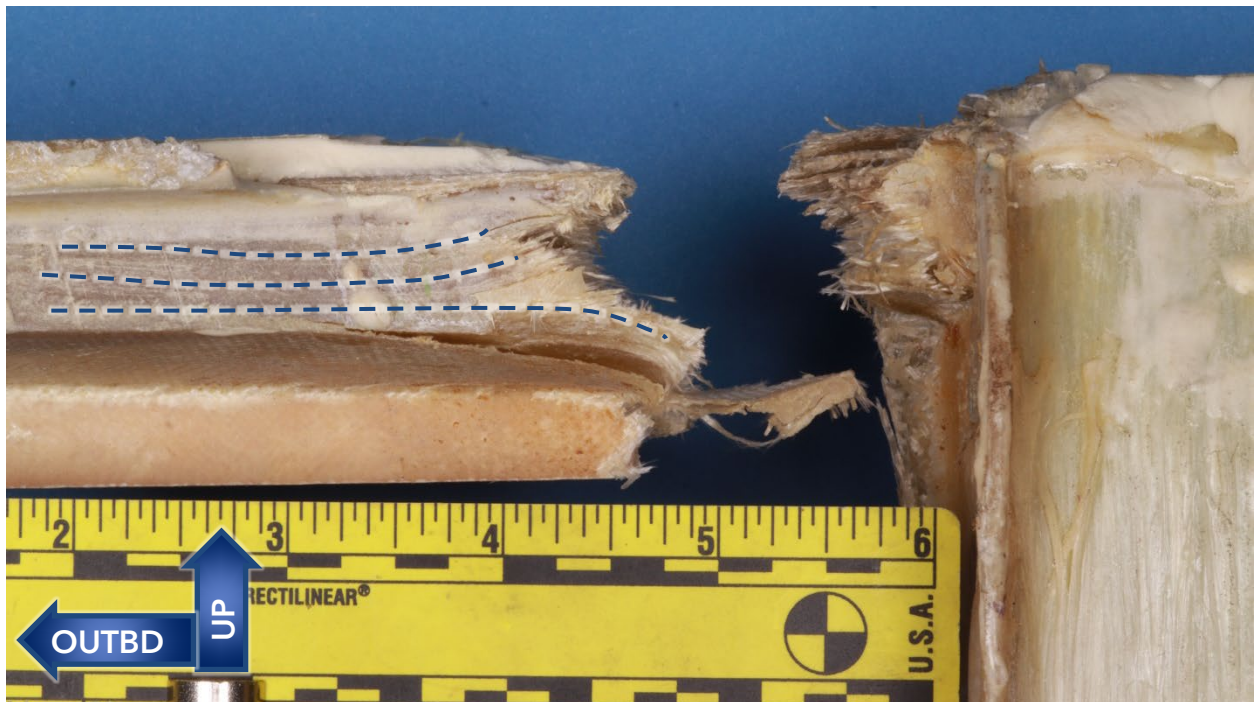


Figure 13. Mating sides of the right wing spar upper cap fracture after the outboard side was separated from the upper skin. Dashed lines indicate the orientation of reinforcement layers visible on the surface.

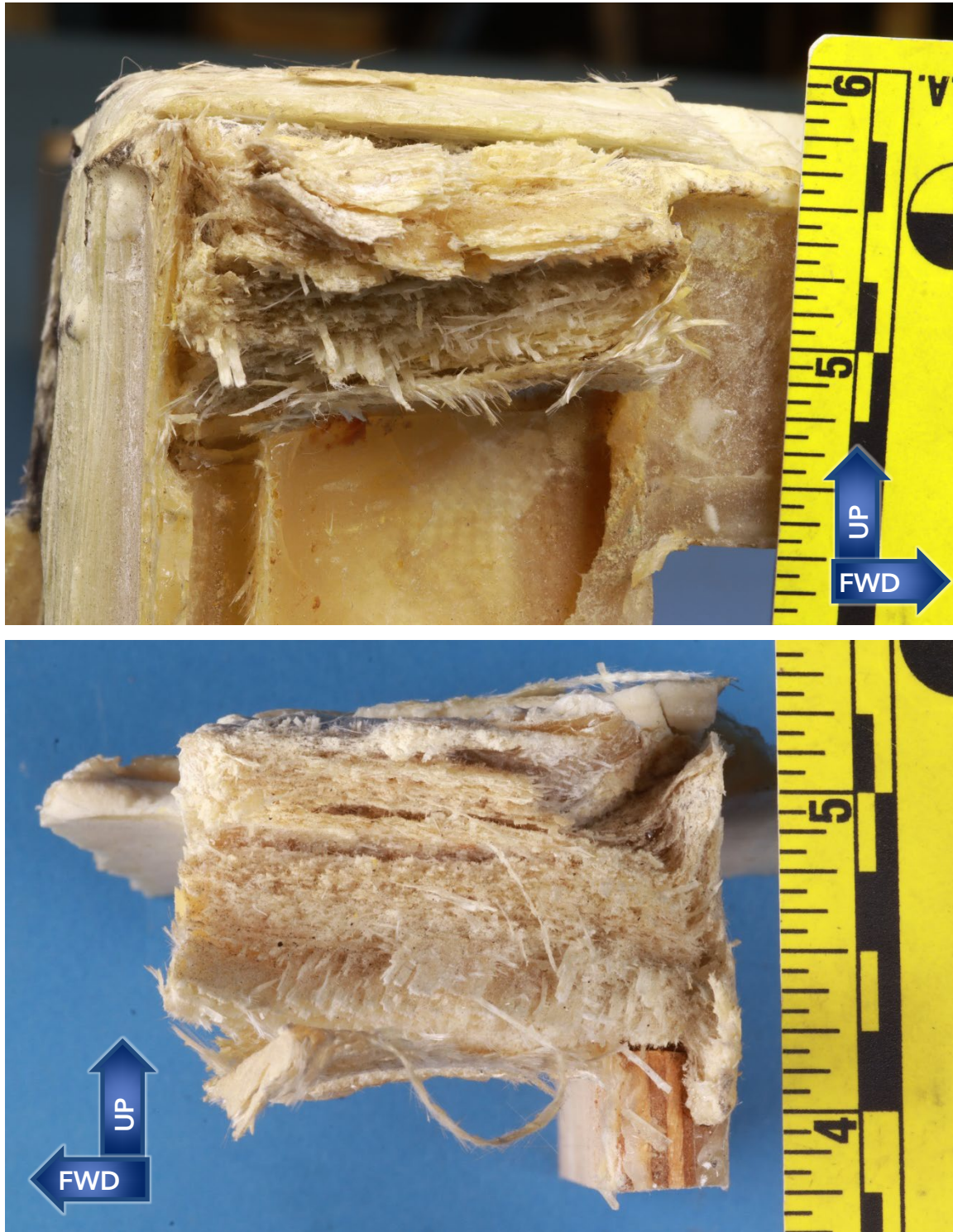


Figure 14. Inboard side (upper image) and outboard side (lower image) of the right wing spar upper cap fracture.

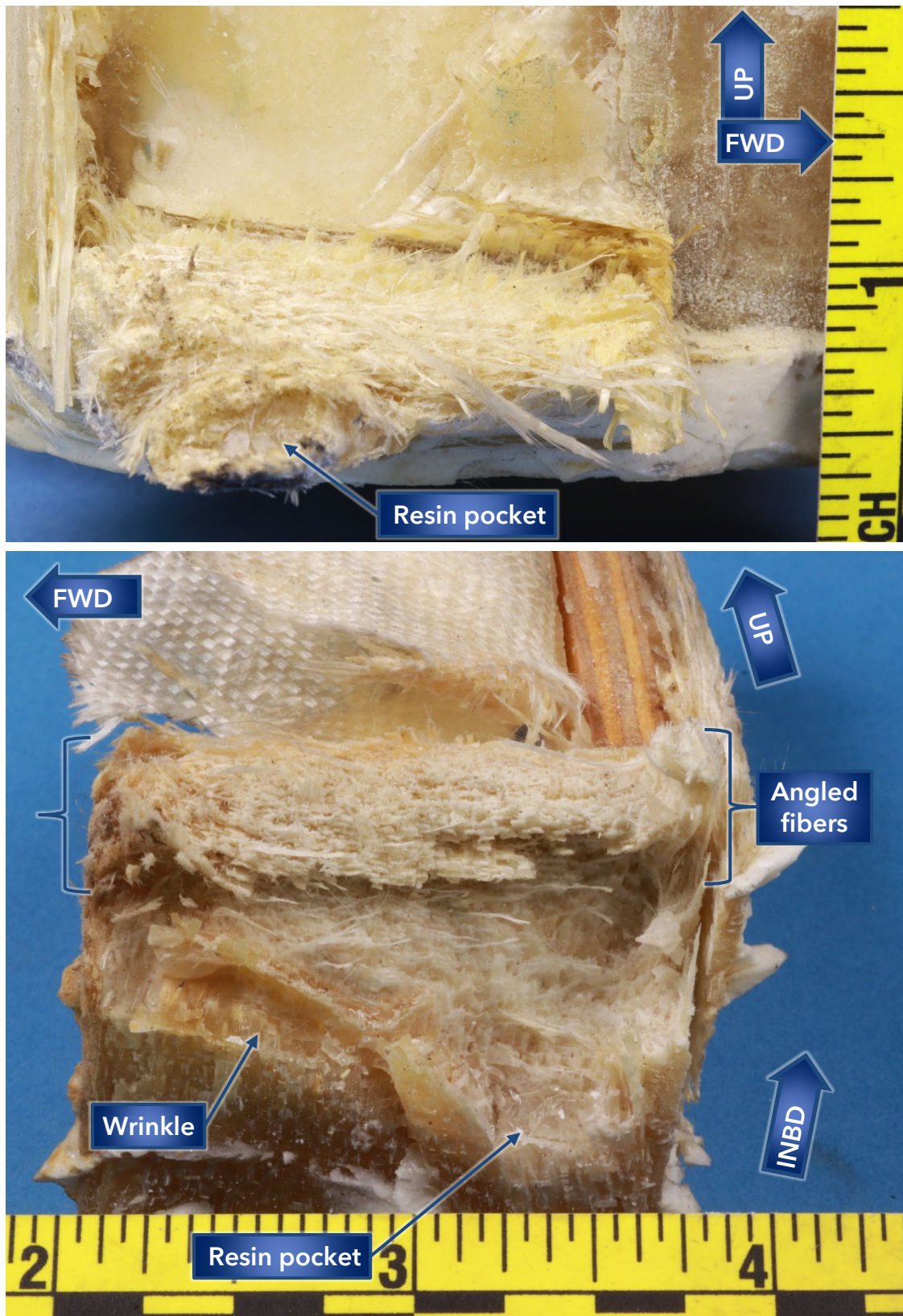


Figure 15. Inboard side (upper image) and oblique view of the outboard side (lower image) of the right wing main spar lower cap fracture.

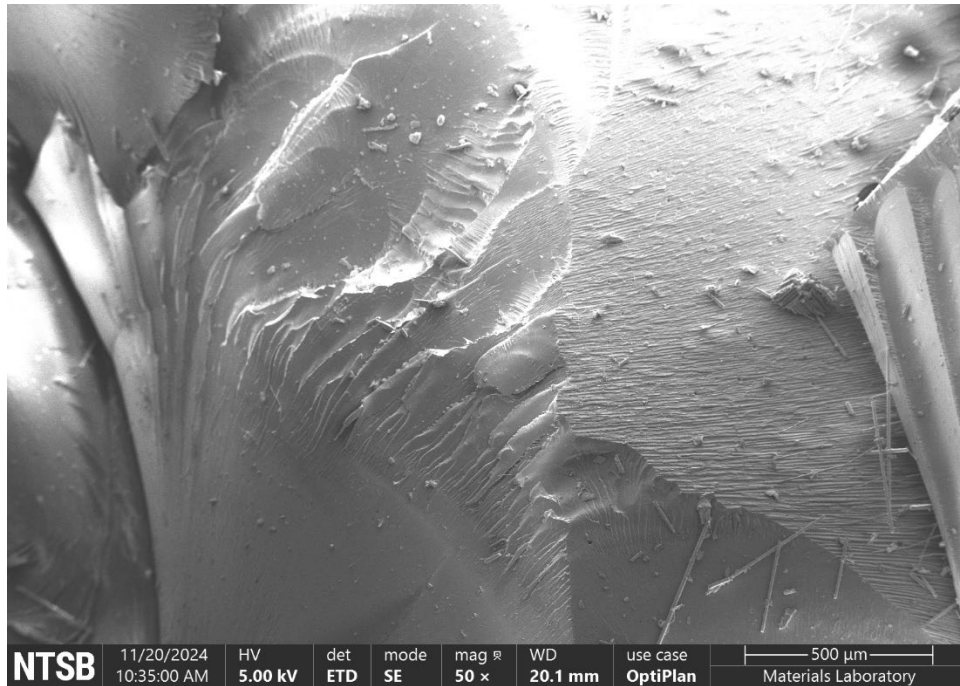


Figure 16. SEM image of fracture features in the resin pocket on the outboard side of the fracture through the right wing spar lower cap.

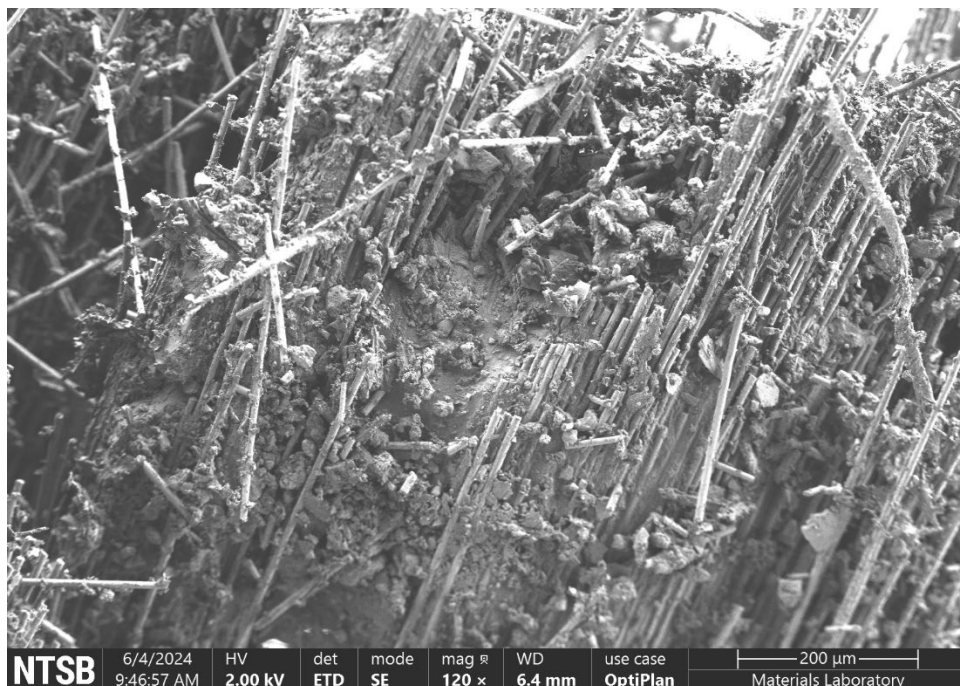


Figure 17. SEM image of fracture features above the resin pocket on the outboard side of the fracture through the right wing spar lower cap.

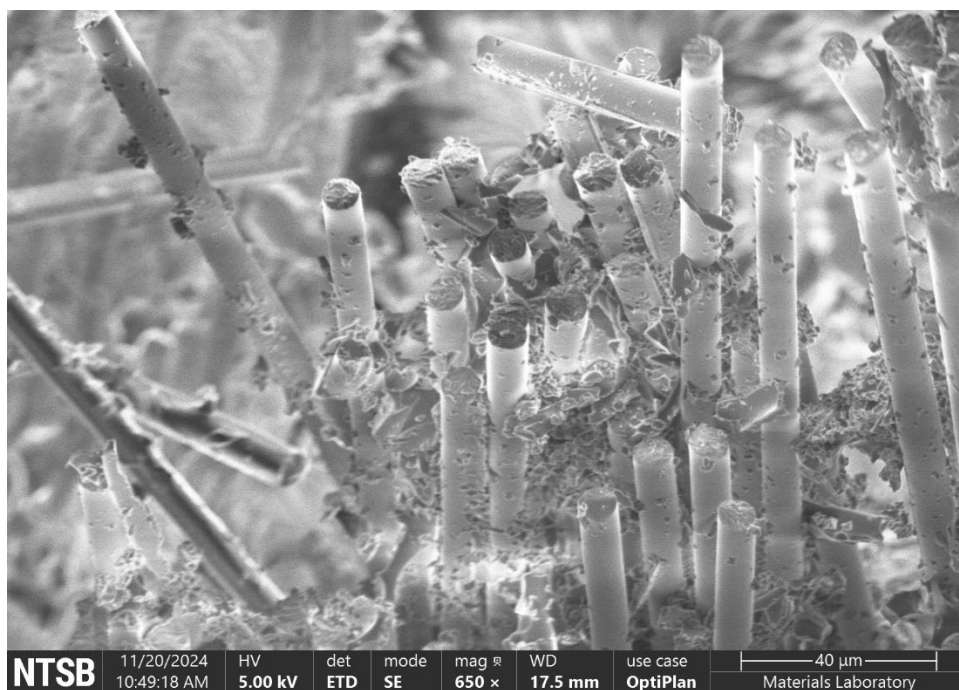


Figure 18. SEM image of fractured fibers in an area above the resin pocket on the outboard side of the fracture through the right wing spar lower cap.



Figure 19. SEM image of a resin rich area above the wrinkle forward of the resin pocket on the outboard side of the fracture through the right wing spar lower cap.



Figure 20. Montage of SEM images stitched together to show fracture features at the lower surface of the right wing spar lower cap outboard of the fracture.

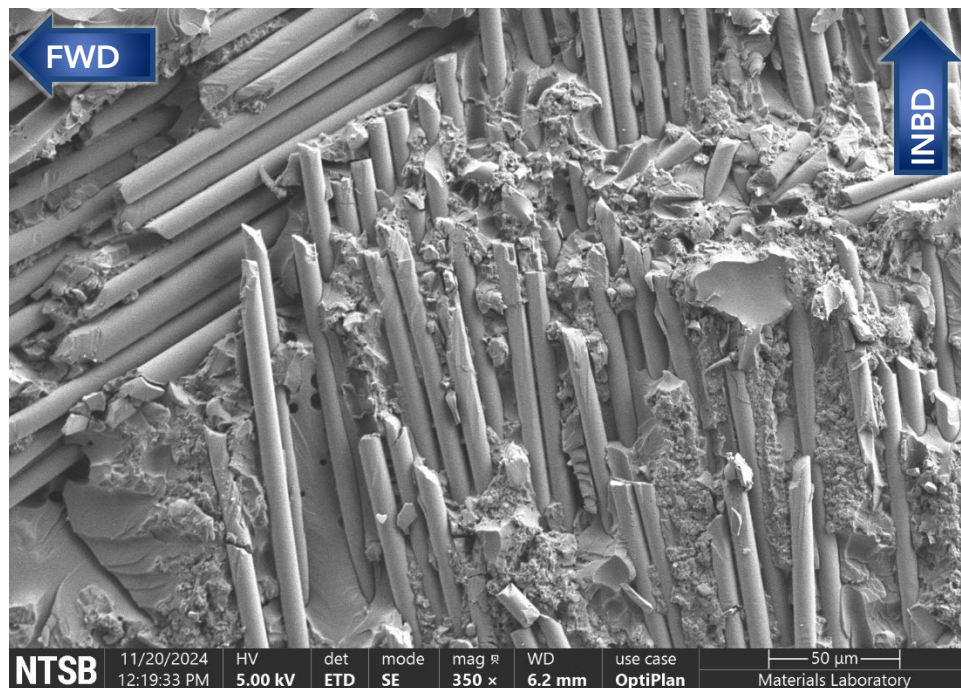


Figure 21. SEM image of the lower surface of the right wing spar lower cap showing fracture features outboard of the fracture through the resin pocket.



Figure 22. Spanwise cross-section through the right wing spar lower cap piece showing composite layers outboard of the fracture surface.

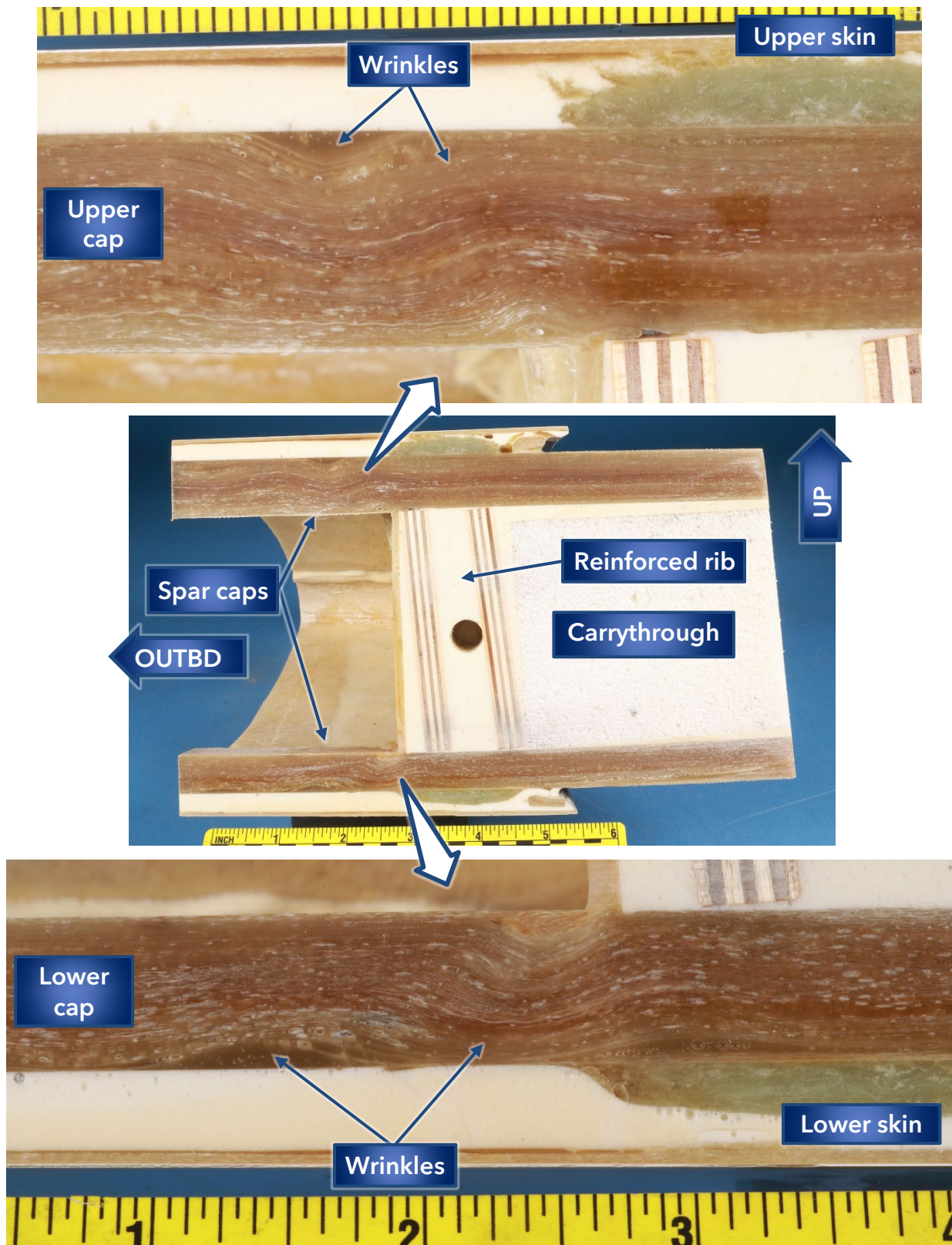


Figure 23. Views of the spanwise cut through the left wing spar and carrythrough structure at the closeout rib showing wrinkles in the fiber reinforcement layers outboard of the rib in the spar upper and lower caps.