

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



ERA25MA171

MATERIALS LABORATORY

Factual Report 25-084

February 10, 2026

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A. ACCIDENT INFORMATION

Location: Jersey City, New Jersey
Date: April 10, 2025
Vehicle: Bell 206L-4, N216MH
Investigator: Leah Read, AS-ERA

B. COMPONENTS EXAMINED

Pieces of two main rotor blades manufactured by Van Horn Aviation; P/N: 20633000-101; S/N: A303 and A304.

C. EXAMINATION PARTICIPANTS

Specialist Donald Kramer
National Transportation Safety Board
Washington, DC

D. DETAILS OF THE EXAMINATION

Two main rotor blades, manufactured by Van Horn Aviation and installed on N216MH (Bell 206L-4) were examined by the Materials Laboratory, first as part of a wreckage examination in West Springfield, Massachusetts and later at NTSB headquarters (figures 1 through 4). Each blade had been separated into an inboard and outboard piece. The pieces were originally connected by ligaments of the main laminate spars and, in the case of blade A303, the lower skin. The blades were cut during the initial on-scene phase of the investigation to separate the pieces for handling and examination. Findings from the follow-on examinations are included in this report.

1.0 Blade construction

A cross-section illustration showing the principal blade components along the main span is shown in figure 5. The blades were constructed around a foam core, an upper spar, and a lower spar. The spars were fabricated from unidirectional carbon fiber tape pre-impregnated with an epoxy resin matrix (prepreg), forming unidirectional laminate spars. The foam core filled the space between the spars and formed the afterbody of the blade. Metal nose weights were located along the leading edge, and a prepreg unidirectional laminate trailing edge strip was located along the trailing edge. The assembly was covered by plain-woven $\pm 45^\circ$ skin plies that wrapped over the leading edge; the free edges met at the trailing edge.¹ A metallic abrasion strip was bonded on top of the skin plies along the leading edge.

¹ Woven fiber fabrics (including carbon fiber) consist of two perpendicular sets of interwoven fibers

The root end of the blade was reinforced by $\pm 45^\circ$ doubler plies that were laid beneath (internal to) the upper and lower spars up to about STA 63 (figure 6a).² $0^\circ/90^\circ$ filler plies were laid over the doubler plies from the spar trailing edge back toward the blade trailing edge (figure 6a). Near the root of the blade, where the blade tapered into the grip section, the trailing face was sealed with a bonded closeout referred to as a scarf wrap.

Near the outboard end of each blade, a balance weight receptacle was located and centered at about STA 192 (the cover to the receptacle is indicated in figures 2 and 4 for blades A304 and A303, respectively). The upper and lower spars ended at about STA 202 (figure 1). The blade extended past the end of the spars about an additional 20 inches (see portion labeled 'blade tip' in figure 3) with both the leading and trailing edges tapering toward the outboard end. Near the end of the spar, the main span abrasion strip terminated (figure 1) and was lapped with and bonded to an outboard abrasion strip that extended to the outboard end. The main span trailing edge strip, about 1 inch across chordwise, also ended at about STA 202. A narrower trailing edge strip, about 9/16 inch across chordwise, was butted against the main span strip and continued along the blade tip trailing edge toward the outboard end.

2.0 Examination of blade S/N A304

Images of the blade A304 root section and upper skin are shown in figures 6a - f. The main blade spars had been cut inboard of STA 67, separating the root section from the main blade span. The skin was missing on the root section starting at about STA 36. The blade trailing edge was open, the trailing edge strip had separated and was missing, and much of the foam core had separated and was missing (almost the entirety of the afterbody and much of the core between the laminate spars). Multiple cracks and contact marks were observed along the span, some of which are described in more detail below. The blade tip was missing starting at the end of the spar, a span of about 20 inches.

After non-destructive examination, but discussed here for convenience, the upper skin covering the afterbody was cut from the blade starting at about STA 137.5 and continuing to the outboard fractured end. The skin piece was flipped over and laid on top of the upper spar (figure 7). Starting near the outboard end, similar curved crack front marks and radiating crack growth features were observed on each skin-to-core fracture surface as indicated on the respective skin-sides of each fracture (figure 7). For both the upper and lower skins, the orientation of the features was consistent with skin-to-core separation starting near the outboard end of the blade

called warp and weft. $0^\circ/90^\circ$ and $\pm 45^\circ$ designations indicate the angular orientation of these sets of fibers to the principal load carrying-direction(s) of the structure, in this case the spanwise direction of the blade.

² STA 63 (and similar usage) is a blade position designation that indicates the distance, in inches, of the location from the center of rotation of the rotor system.

and progressing inboard up to about STA 170 and from the trailing edge progressing across the afterbody toward the leading edge. Inboard of STA 170 the orientation of skin-to-core tear features became somewhat random, with some areas showing inboard progression and some areas showing outboard progression. Similarly, some regions showed progression from the trailing edge toward the leading edge and some regions showed the opposite.

Near the end of the spars, the skin plies had separated from the spars along their respective spar trailing edges. The lower skin showed more spanwise separation than the upper skin (figure 8a). The skin-to-core and skin-to-spar fracture features appeared to originate from the missing blade tip and as such, a more exact origin for the skin separations could not be conclusively determined.

The end of the blade exhibited features consistent with the blade tip separating from the end of the spar in downward bending. The end of the upper spar was deformed downward (figure 8b). The lower spar was not deformed, but foam core material had folded over the end of the lower spar near the leading edge. The main span and blade tip abrasion strips had separated at the adhesively bonded lap joint (figure 9a). The inboard portion of the adhesive was smooth and the outline of the adhesive film scrim cloth was visible, consistent with an adhesive fracture.³ The outboard portion exhibited a comparatively coarse appearance, consistent with a transition to cohesive fracture. There were no indications of preexisting delamination (such as adhesive wear debris or environmental debris). The lower side of the abrasion strip exhibited a downward bend (figure 9b). Finally, the lower skin was torn starting near the inboard end of the abrasion strip lap joint. The tear progressed inboard and toward the trailing edge from the edge of the strip, delaminating the skin from the spar (figure 10a and 10b). A yellow arrow in figures 10a and b indicates the direction of the tear.

The lower skin tear extended into the blade afterbody (figure 11). Examination of the skin to core separation in this region revealed at least one curved crack growth feature that continued across the tear, indicated by the three white arrows in figure 11. Radiating foam tear ridges in this region were oriented toward the leading edge and slightly inboard, indicated by the direction of the white arrows.⁴ The features were consistent with the skin to foam core separation occurring before the lower skin tear.

There was damage consistent with a blunt impact on the leading edge of the blade at about STA 171 with damage to the leading edge extending an additional 6 inches in the spanwise outboard direction (figures 12 and 13). The leading edge of the abrasion strip was blunted, the trailing edge of the strip was bulged and buckled,

³ Scrim cloth is a loosely woven mesh-like fabric used to carry adhesive as a thin film. The thickness of the scrim sets the thickness of the adhesive joint.

⁴ The tear ridges are linear features that are aligned in the direction of the skin to foam separation.

and the blade was bent. Scrape marks were observed in the paint on the upper blade surface, both on the bulged leading-edge strip and continuing across the blade skin immediately trailing behind the strip (figure 13).

The scrape marks continued back to a circular fracture region in the upper skin at about STA 176 (see figure 6f and 14a). Examination of the inner surface of the skin (originally bonded to the core) revealed skin tears and cracks at the location of the damage (figure 14b). Fracture features from the skin to core separation, curved crack features and radiating foam tear ridges, were observed that were continuous across the tears and cracks (figure 14b), consistent with the skin to foam separation occurring prior to the tears and cracks at this location.

There was a wedge-shaped fracture in the upper skin at the trailing edge between STA 182 and STA187.5, with additional damage and undercutting of the outer skin ply outboard of the fracture (figure 15a). There was a corresponding trapezoidal-shaped section of the lower skin that tore at two locations starting at the trailing edge and extending toward the leading edge from STA 182 and STA188.75 (figure 15b). Examination of the inner surface of the upper skin (originally bonded to the core) revealed cracks and tears in the skin. As for the previously discussed skin damage, fracture features from the skin to core separation were observed that were continuous across the tears and cracks (figure 16a). Similar conditions existed for the lower skin tear starting at STA 188.75 (figure 16b) but were inconclusive and could not be interpreted for the tear starting at STA 182 (figure 16c). Taken as a whole, the features were consistent with an impact to the top side of the blade near the trailing edge with the skin to foam separation occurring prior to the damage at this location.

Near the inboard end of the blade, the upper and lower spars exhibited damage consistent with a counterclockwise (viewed looking outboard) torsion fracture. The spars were splintered about 10 inches inboard and 26 inches outboard of the end of the doubler stack located at about STA 63 (figures 17 – 19). The upper spar had peeled from the doubler along its trailing edge (figure 17a) but had not peeled from the doubler along its leading edge (figure 17b). The opposite condition was observed for the lower spar. The lower spar's leading edge had peeled from the doubler (figure 18a) whereas its trailing edge had not (figure 18b).

Tinting and rubbing features were observed at several locations on the blade skin, scarf wrap, and blade root. At the outboard end of the blade, the lower skin piece, shown previously in figure 10b, exhibited a tinted appearance where it had previously been bonded to the spar. When examined with a digital optical microscope, the surface exhibited a flat, tinted appearance with loose carbon fibers, consistent with rubbing (figure 20). A similarly tinted appearance was noted for a piece of upper skin trailing edge still attached at the root end of the blade (figure 21a) and where the scarf wrap had disbonded from the upper surface of the blade (figure 21b).

Rubbing features were also observed on the bottom side of the blade root where the skin had separated from the doubler/laminate spar/filler ply construct. On much of the root section where the skin had separated, the surface exhibited a $\pm 45^\circ$ plain weave pattern. This pattern was an imprint of the $\pm 45^\circ$ plain weave pattern of the skin plies left in a thin layer of interply resin (figure 22a). In some areas, the resin had been rubbed away revealing the $0^\circ/90^\circ$ weave pattern of the filler plies (figure 22a) or causing fraying/rubbing of the unidirectional laminate spar (figure 22b). Blue/orange tinting was also observed in some rubbed areas (figure 22a).

3.0 Examination of blade S/N A303

The blade trailing edge had opened up between STA 36 and STA 178 (figure 23a - b). The trailing edge was intact between STA 178 and about STA 188 and was open from about STA 188 out to the tip end of the blade (figure 23c). Core material had cracked and was missing from the blade interior between about STA 72 and STA 139. The trailing edge strip was still present.

The upper and lower spars exhibited splintering around STA 76, where the blade had been cut in two, but to a lesser extent than seen on blade A304. The splintering extended about 6 inches outboard and 14 inches inboard from the cut, respectively (figure 24a and b).

The blade tip was present and exhibited torsion and bending damage. The trailing edge had opened and the tip trailing edge strip was displaced flapwise down relative to the main span trailing edge strip where they butted against one another (figure 25a). The tip leading edge abrasion strip was displaced flapwise up relative to the main span abrasion strip, tearing at the edge of the spar and near the lap joint between the two strips. The outboard end of the tip was bent flapwise up (figure 25b).

The majority of the blade tip foam core was present and had disbonded from portions of the blade skin. The upper skin exhibited an elongated separation, nominally in line with the end of the main spar, close to the leading edge, and extending toward the trailing edge (indicated by the yellow dashed region in figure 25c). Crack progression features and tear ridges radiated away from the region, consistent with skin-to-core separation extending back to the trailing edge and spanwise inboard and outboard from the main span-to-tip transition region (indicated by yellow arrows in figure 25c). The lower skin exhibited tear ridges that radiated away from the main span-to-tip trailing edge transition. The tear ridges pointed toward the leading edge and outboard (indicated by yellow arrows in figure 25d). Inboard of the trailing edge transition, the foam core fractured in the through-thickness direction and the lower skin remained bonded to the core inboard of the tip section (figures 25 a and d). At the outboard end of the blade, the upper

skin disbonded from the blade tip closeout while the lower skin remained bonded to the closeout.

Blade A303 sustained impact damage near the grip plate at the root end of the blade which caused a flap of skin to separate from the rest of the blade (figure 26a). The skin flap was rinsed with water to remove caked mud and the flap exhibited slight tinting features similar to those documented on blade A304 above (figure 26b).

4.0 Matching of ejected foam core pieces

Eleven pieces of foam core were found on top of a building adjacent to the Hoboken / NJ Transit Terminal along with one piece of aluminum aircraft structure. Seven of the pieces were matched to locations on blade A304 using the size, shape and tear patterns on the pieces. The other four could not be matched to a location on either blade. The matched pieces were located at about STA 178 (figure 27a), STA 188 (figure 27b), STA 86 (two-piece assembly shown in figure 27c), STA 68 (figure 27d), STA 106 (figure 27e), and STA 117 (figure 27f).

Submitted by:

Donald Kramer, Ph.D.
Supervisory Materials Engineer



Figure 1. Overview of S/N A304 blade pieces, upper side. The blade was fractured near the end of the spar. The blade tip (about 20 inches long) was missing.

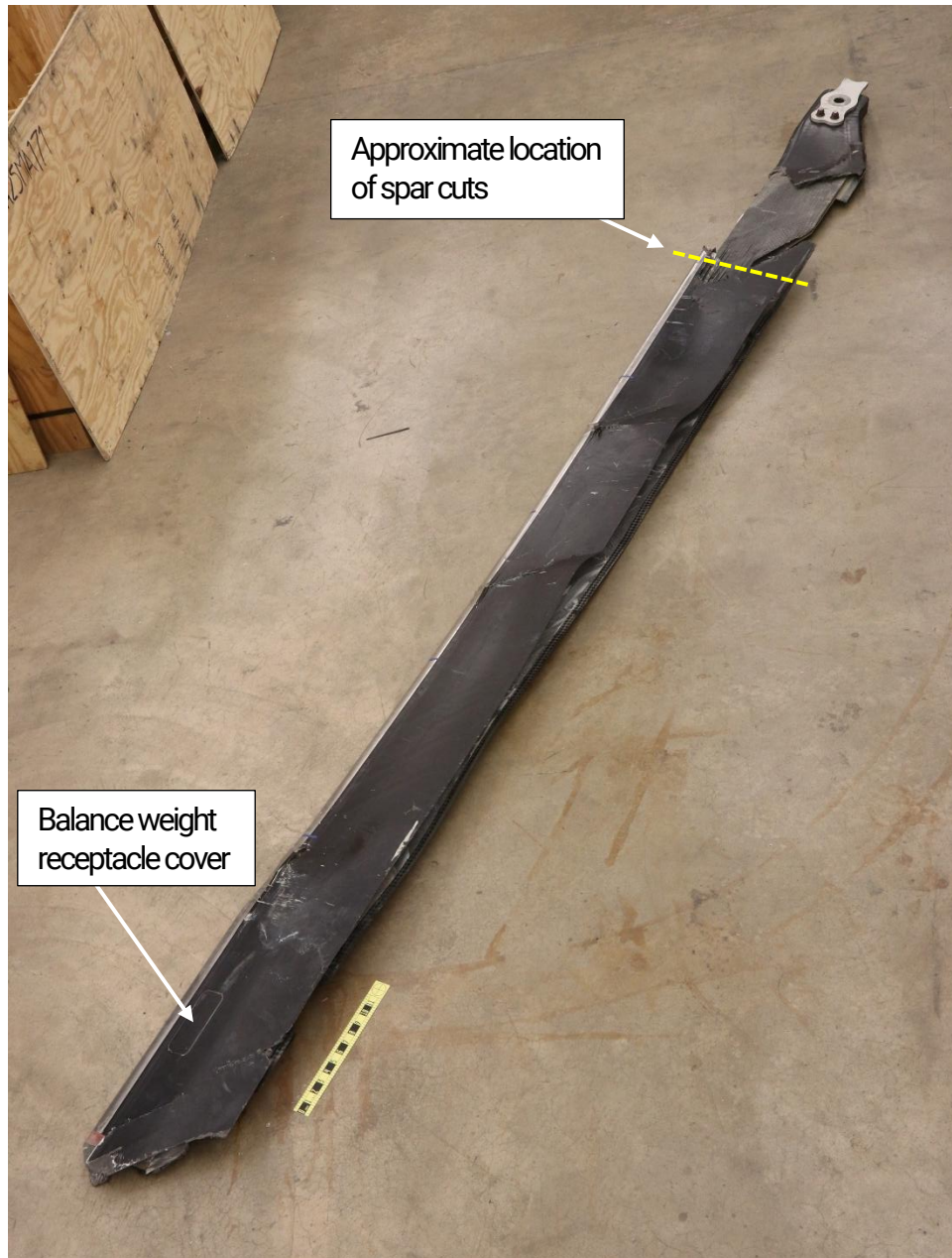


Figure 2. Overview of S/N A304 blade pieces, lower side.

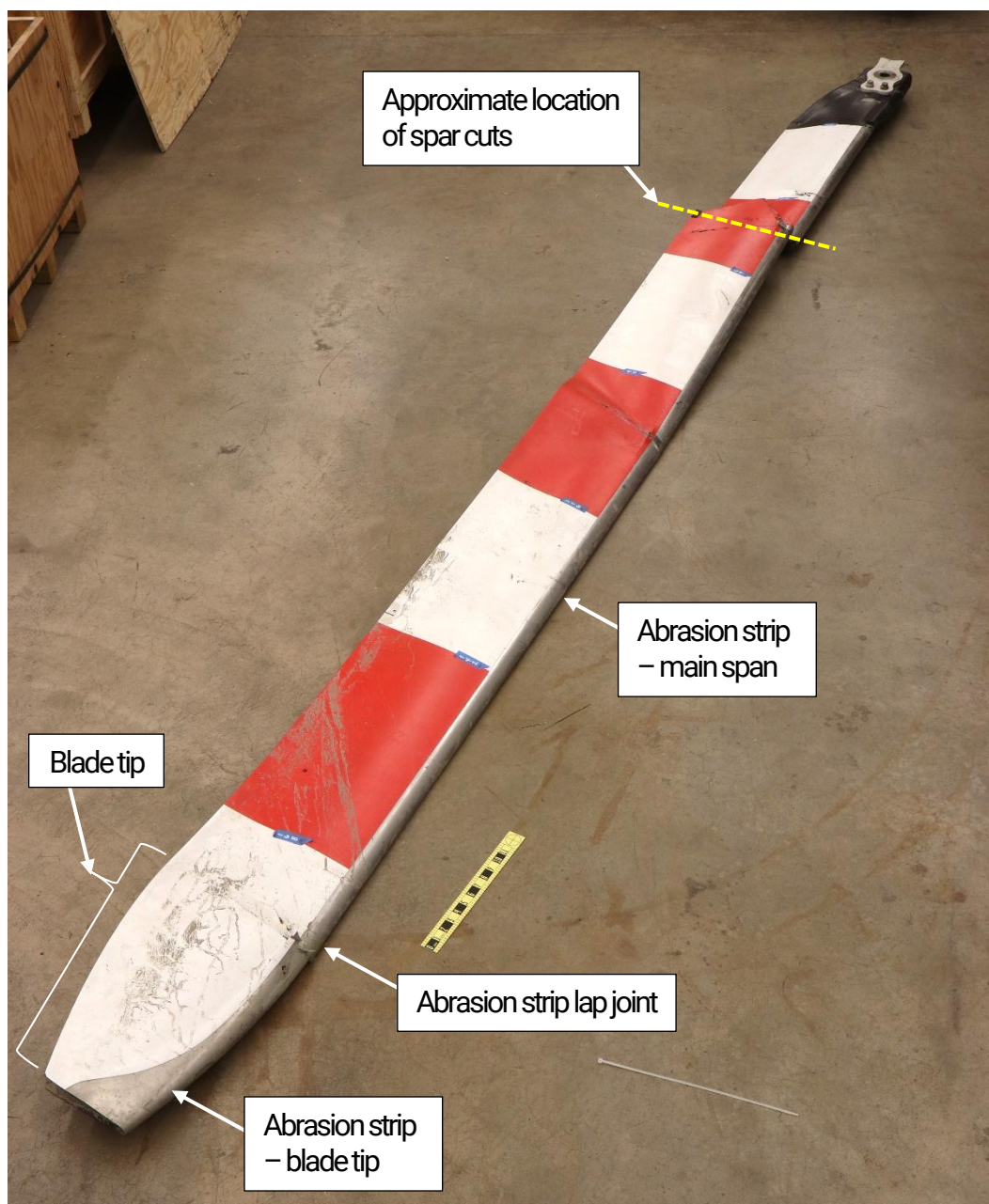


Figure 3. Overview of S/N A303 blade pieces, upper side.

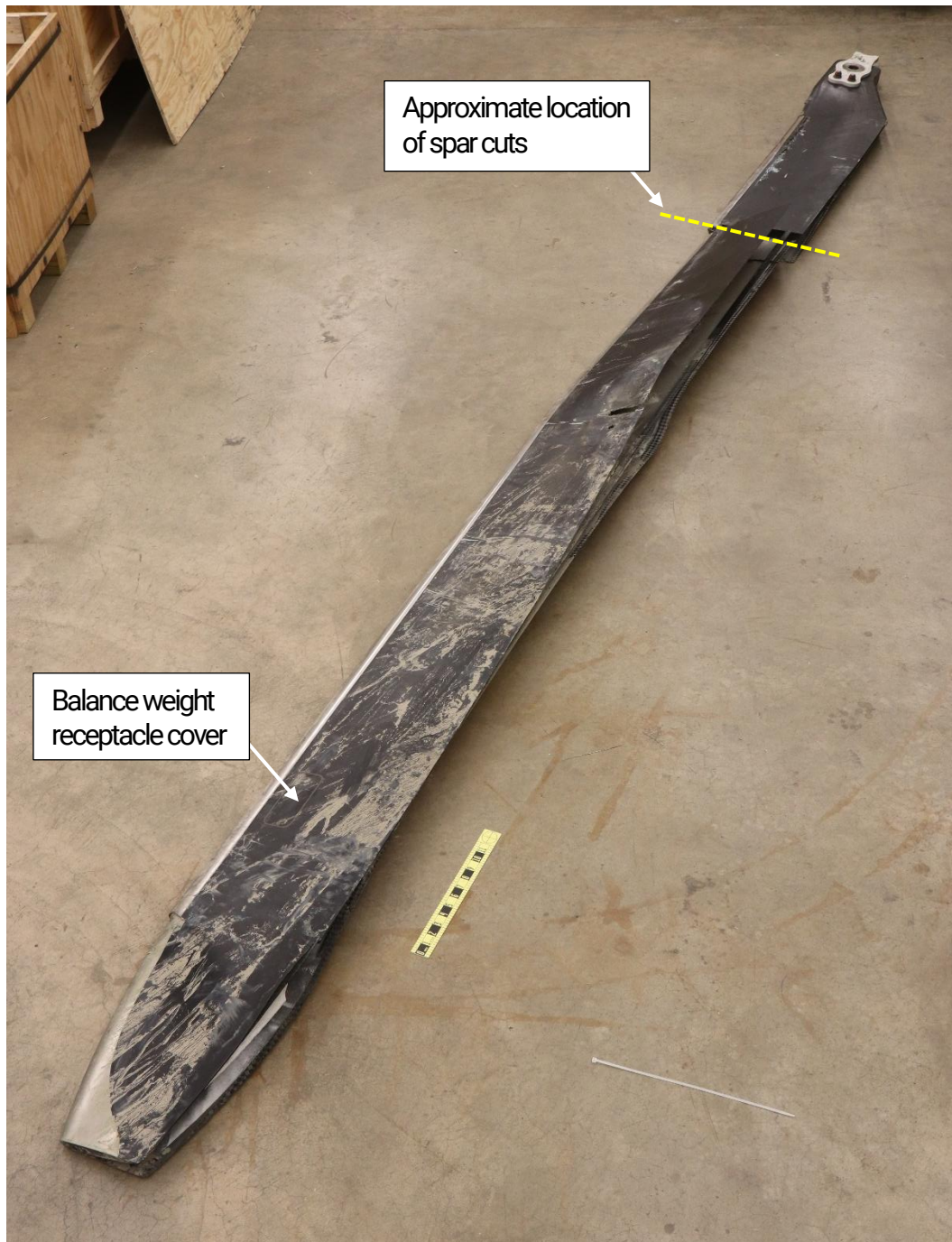


Figure 4. Overview of S/N A303 blade pieces, lower side.

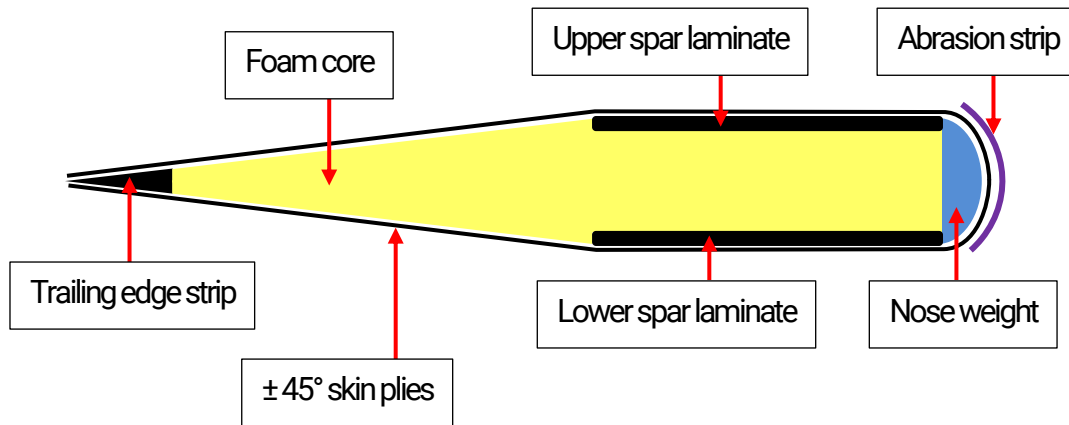


Figure 5. Cross-section illustration (not to scale) of the rotor blade construction along the main span.

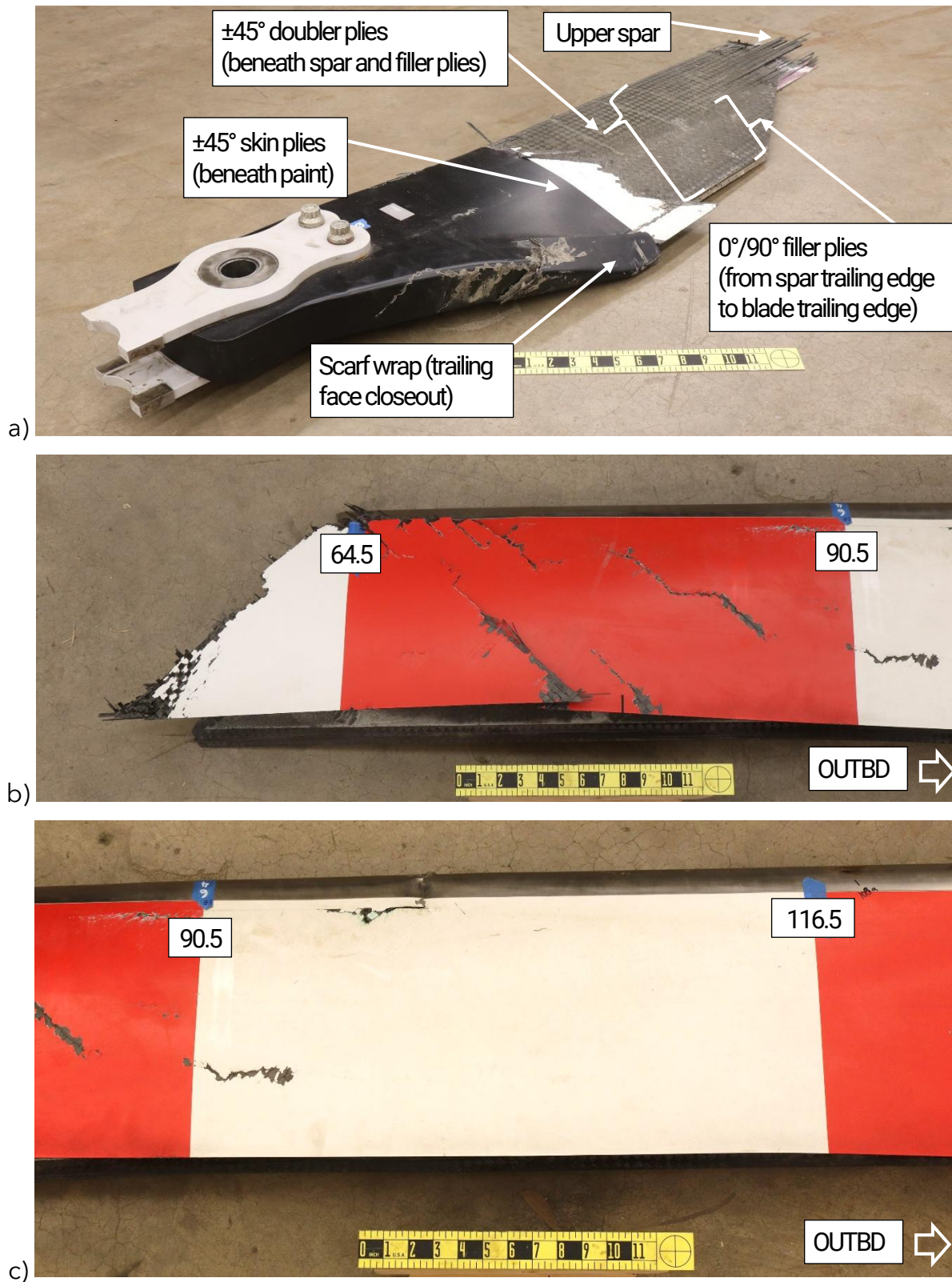


Figure 6. Images of blade A304 upper surface. Blade stations at paint stripe edges reported by station number based on the end of the spars at STA 202: a) root piece; b) STA 64.5 to 90.5; c) STA 90.5 to 116.5;

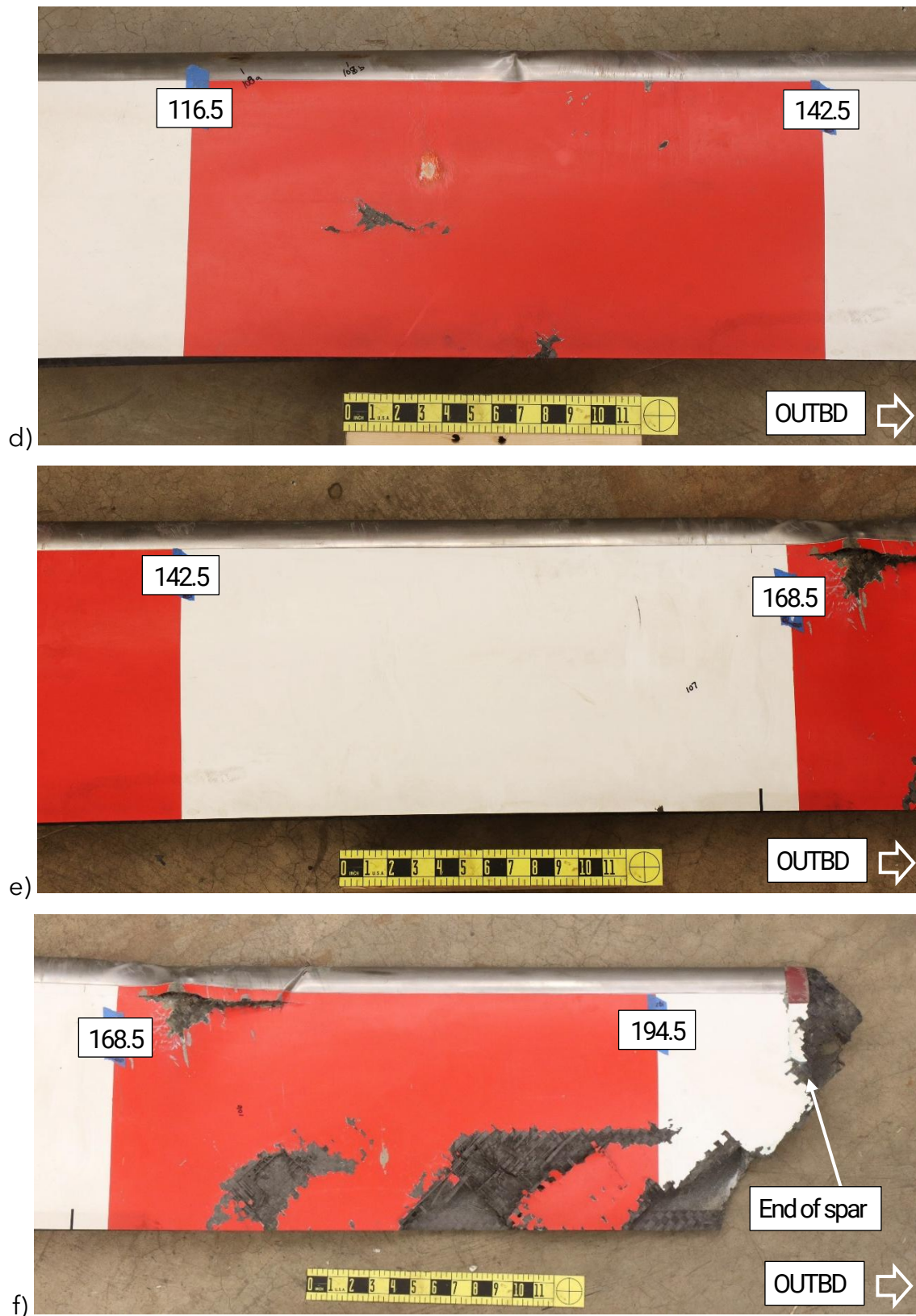


Figure 6 (cont.). d) STA 116.5 to 142.5; e) STA 142.5 to 168.5; and f) STA 168.5 to fracture at the end of the blade spar near STA 202.

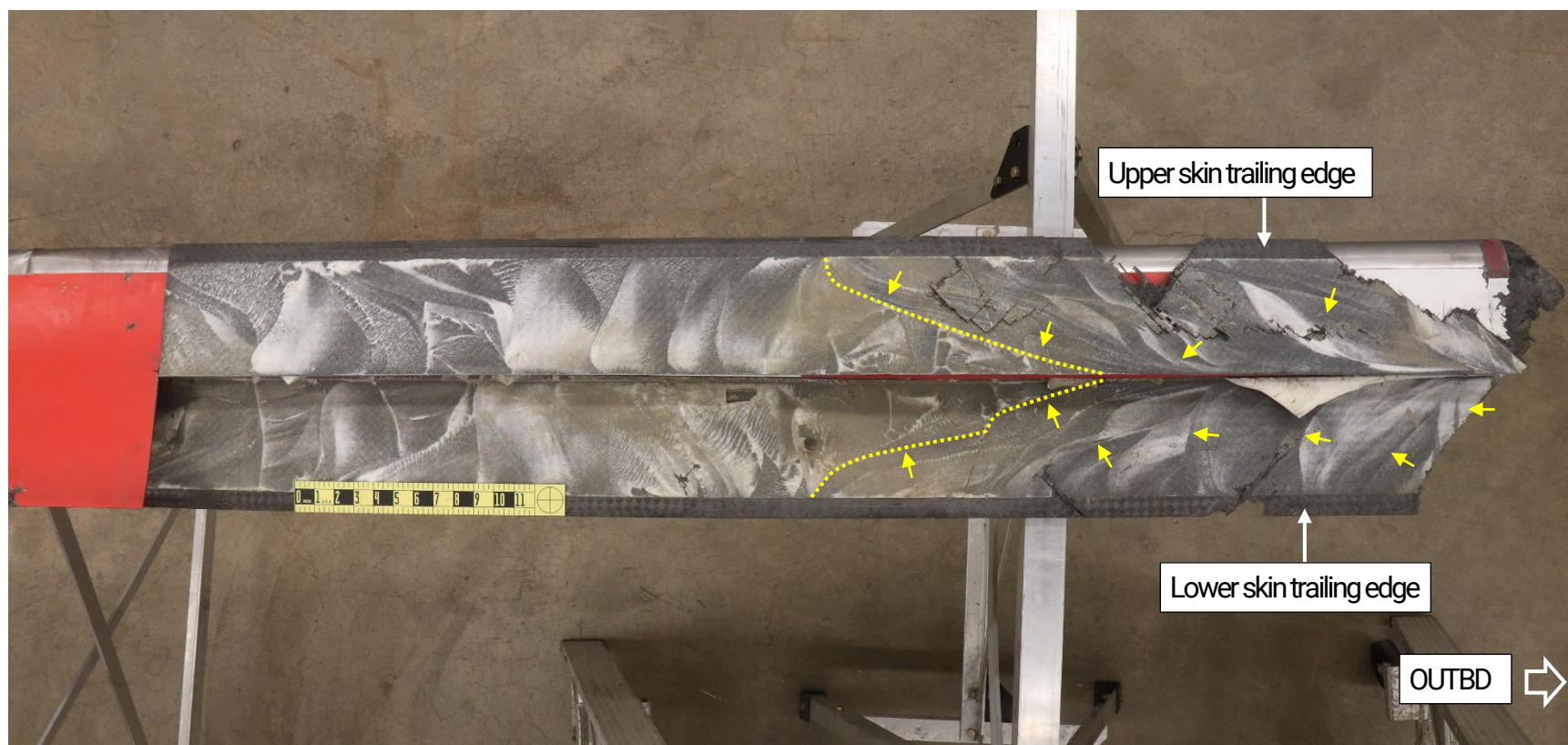


Figure 7. Blade A304 with upper skin in the afterbody section of the blade cut, flipped over, and laid on top of the spar, from about STA 137.5 to the outboard fractured end.

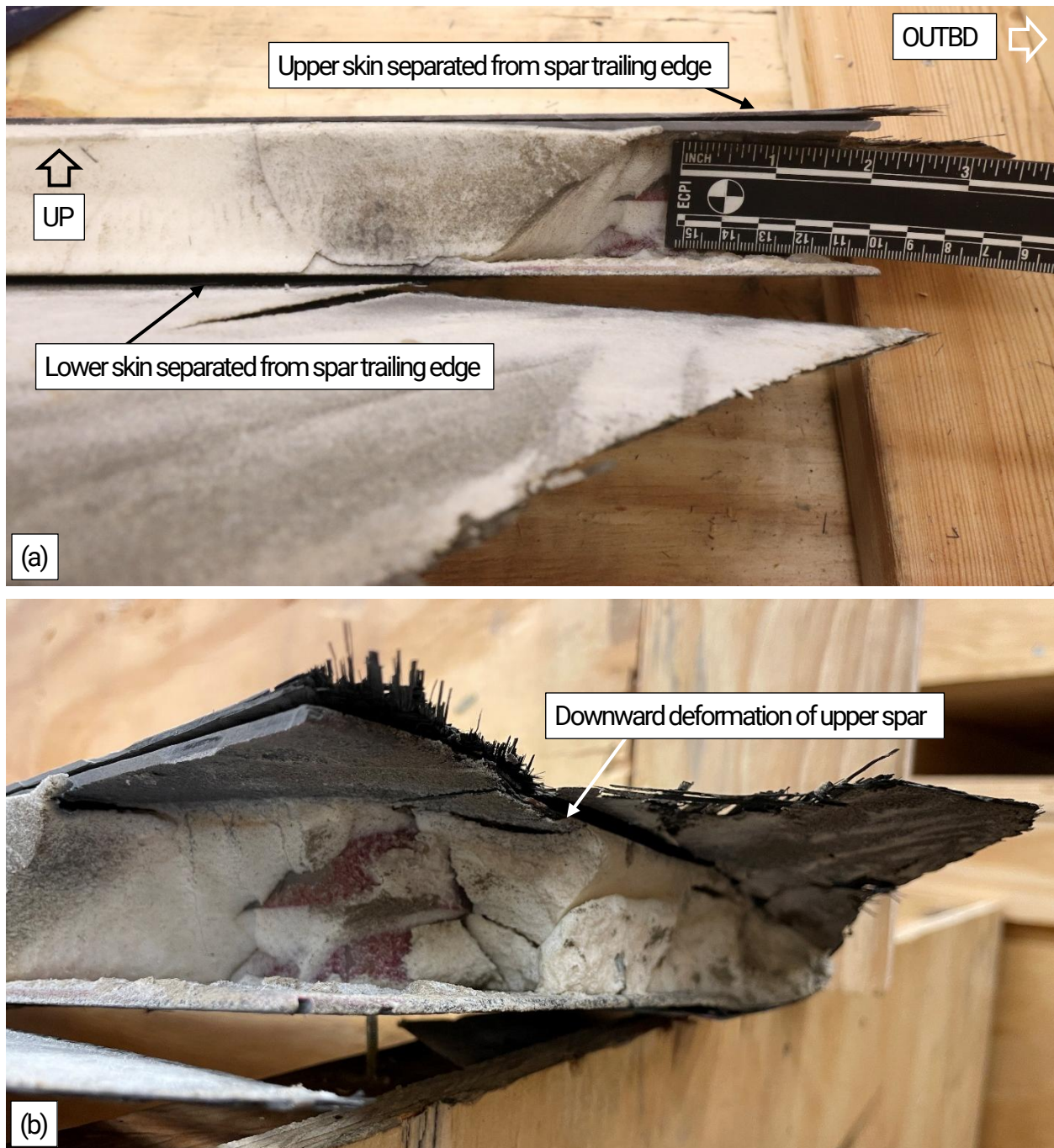


Figure 8. Fractured outboard end of main rotor blade A304: a) viewed from the trailing edge looking toward the leading edge showing skin separations from upper and lower spars and b) viewed looking inboard and toward the leading edge showing downward deformation to the end of the upper spar.

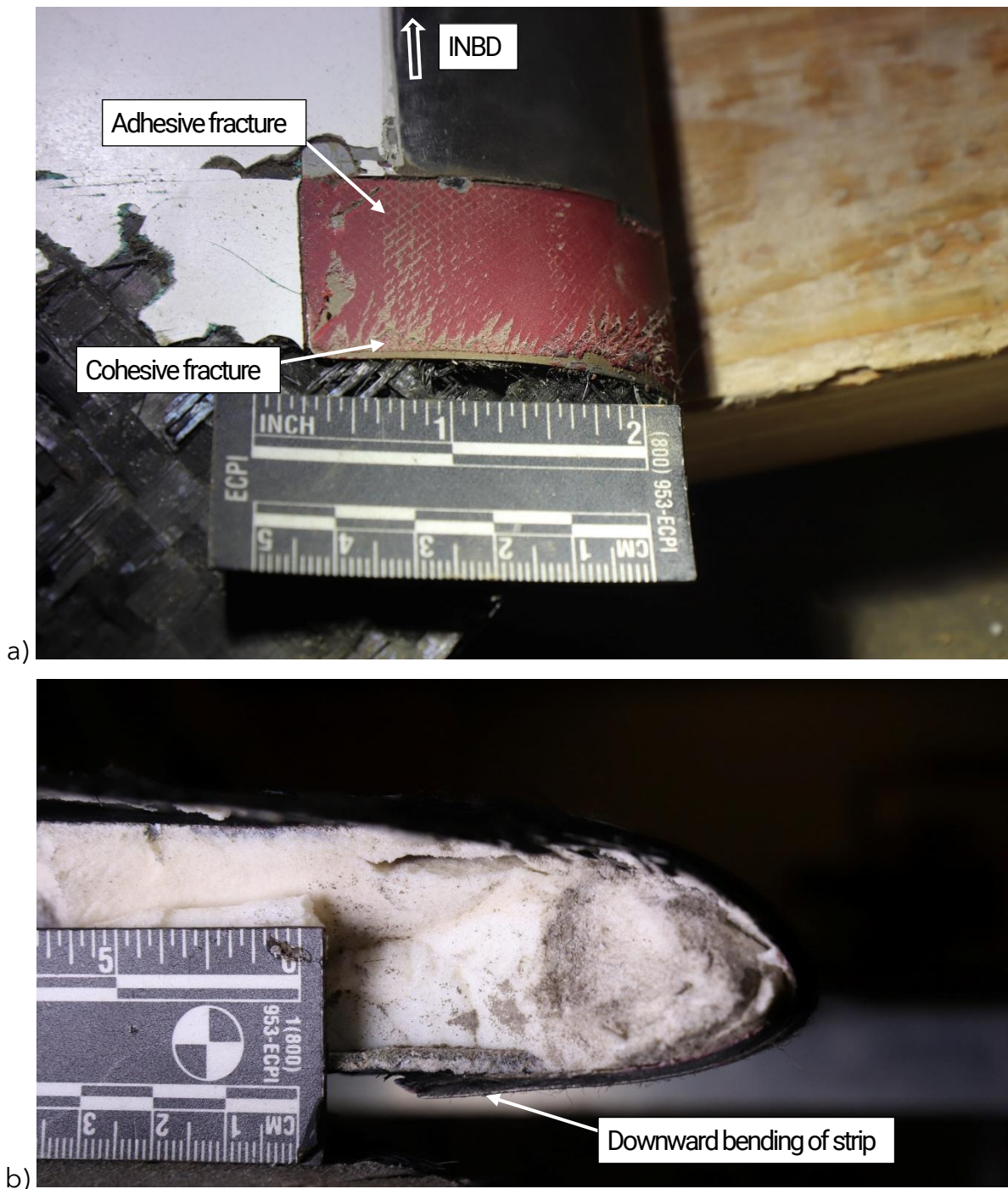


Figure 9. a) Image of the adhesive left behind on the main span abrasion strip showing adhesive and cohesive fracture and b) end view of the abrasion strip with the lower portion showing downward bending.

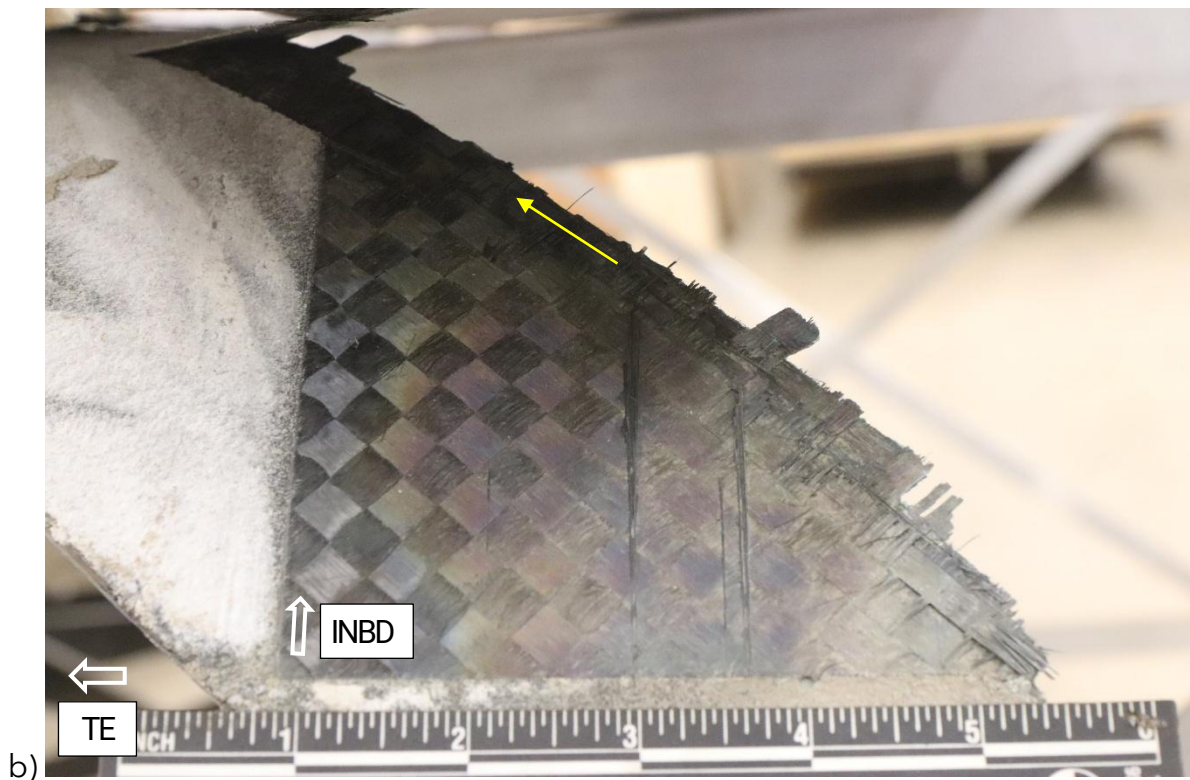
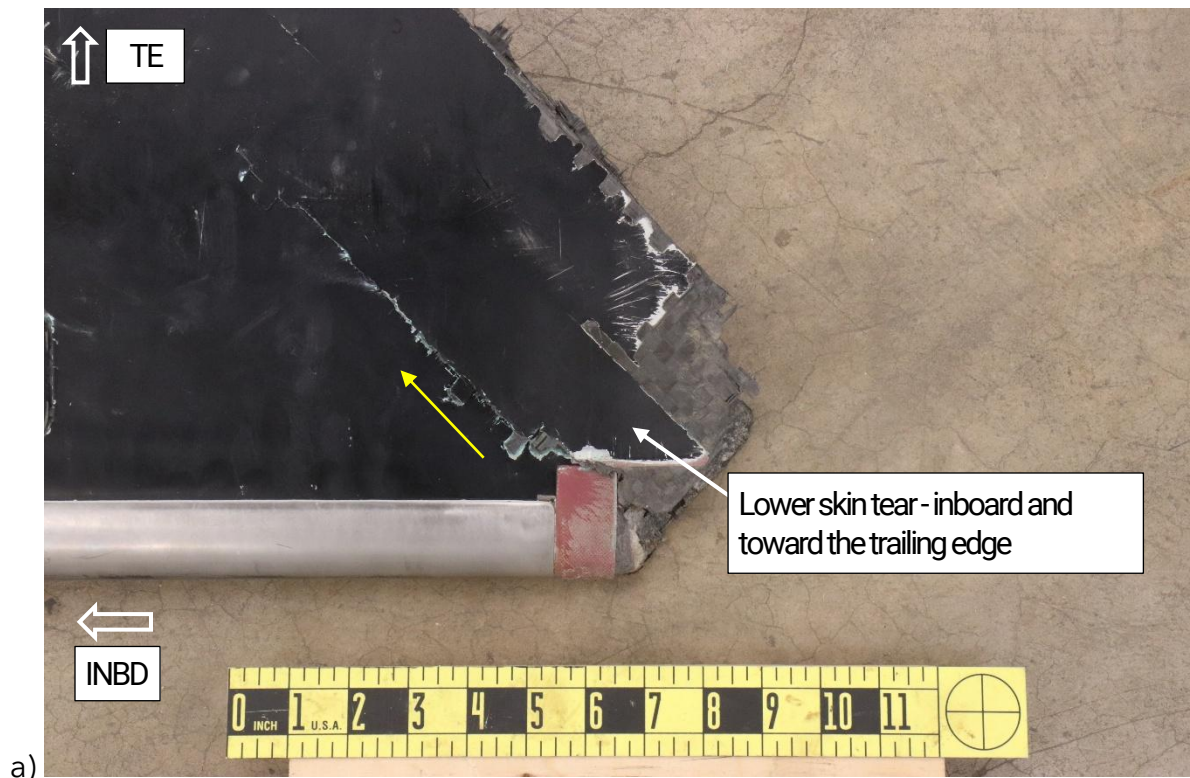


Figure 10. Lower skin tear near the end of the spar: a) lower outer surface showing tear progressing away from the edge of the abrasion strip and b) lower inner surface.

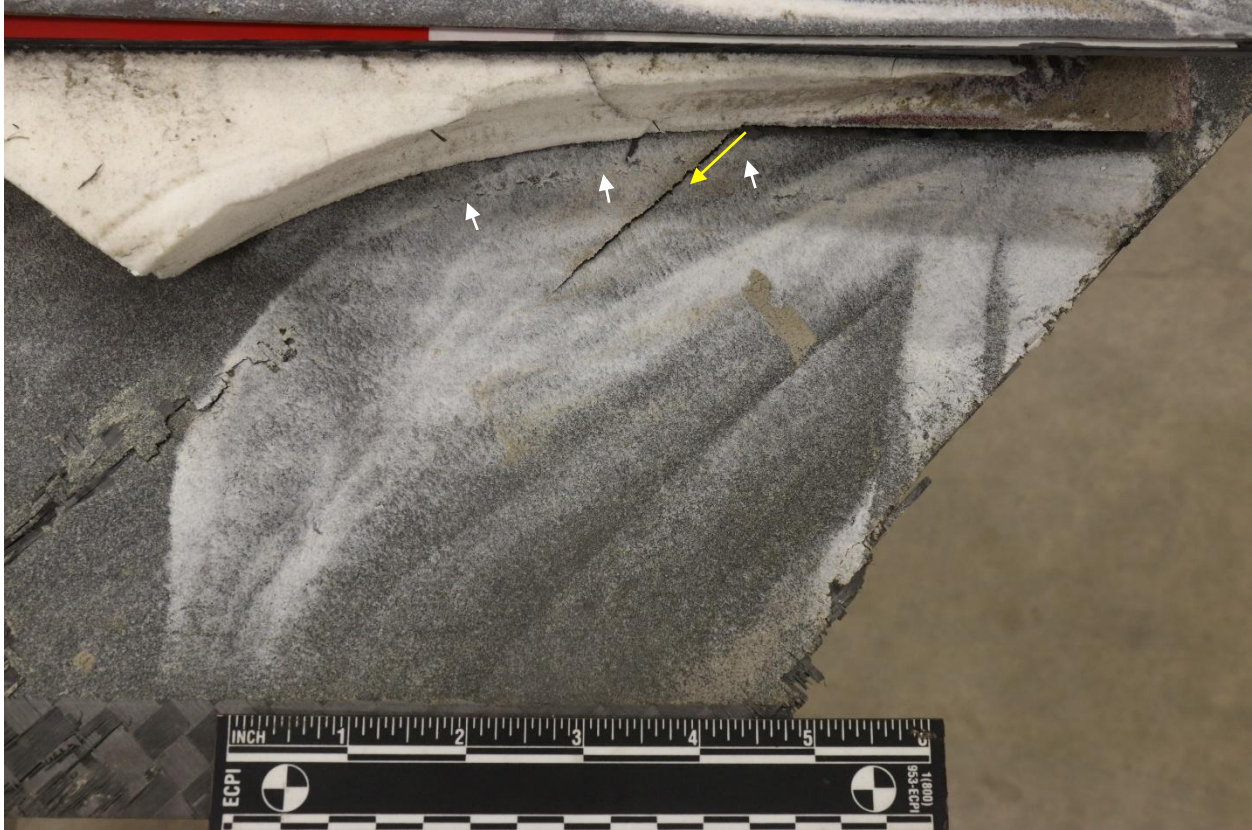


Figure 11. Image showing the tear in the lower skin progressing inboard and toward the trailing edge into the blade afterbody and across skin to foam core separation features.

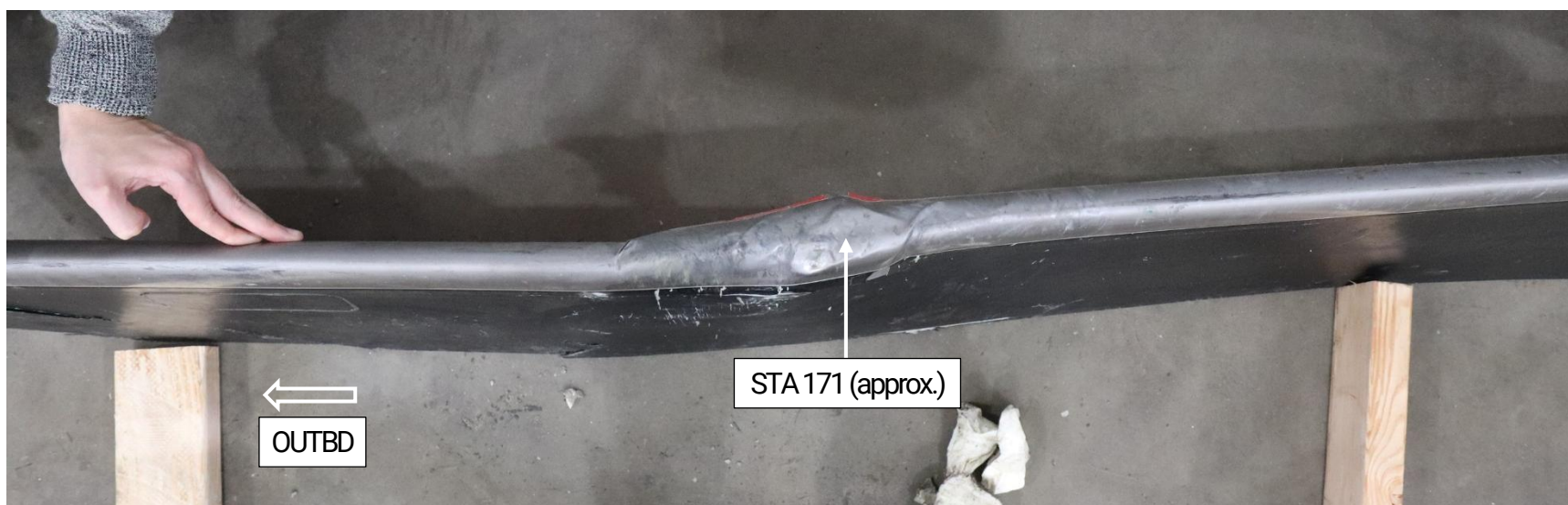


Figure 12. View of the blade leading edge indicating the location of a leading edge impact.



Figure 13. Image of the impact damage showing buckling and bulging of the abrasion strip. Multiple scrape marks in the paint are continuous across the deformed region.

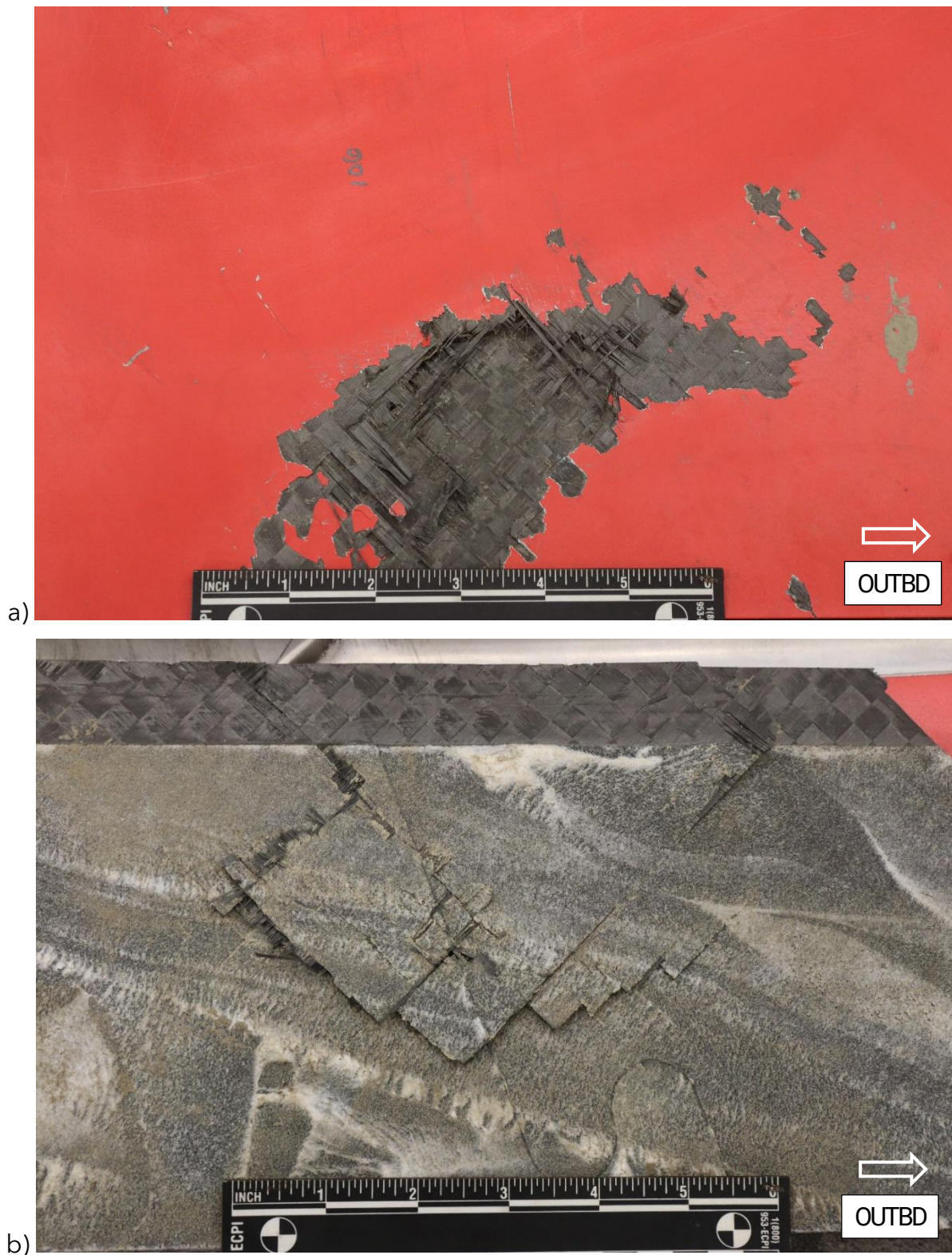


Figure 14. Circular fracture region punched into upper skin at about STA 176: a) outer surface of upper skin and b) inner surface of upper skin showing skin to foam core separation features that are continuous across cracks in the skin.

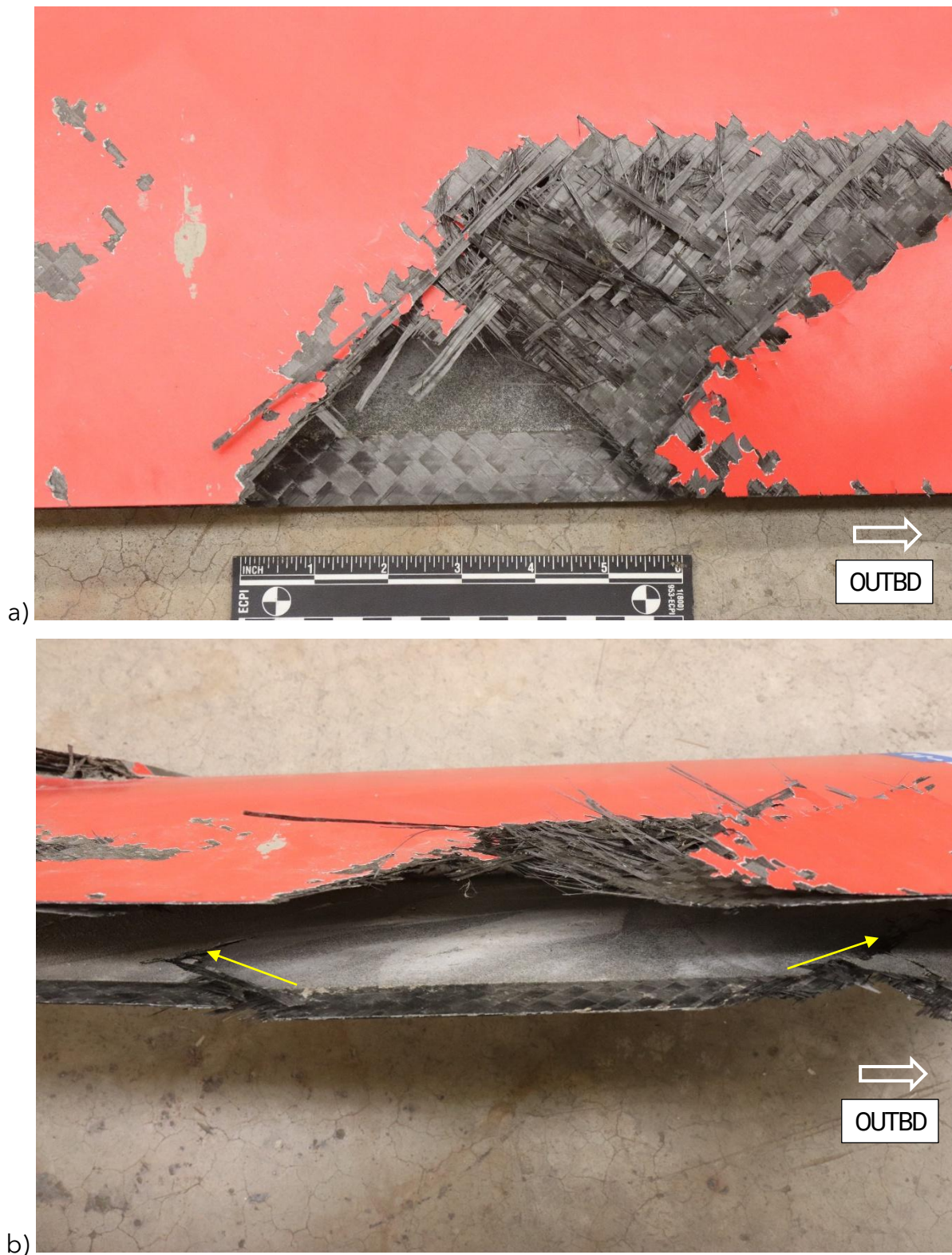


Figure 15. a) Wedge-shaped fracture in upper skin between STA 182 and STA 187.5 and b) image showing corresponding trapezoid-shaped region formed by tears in lower skin at STA 182 and STA 188.75.

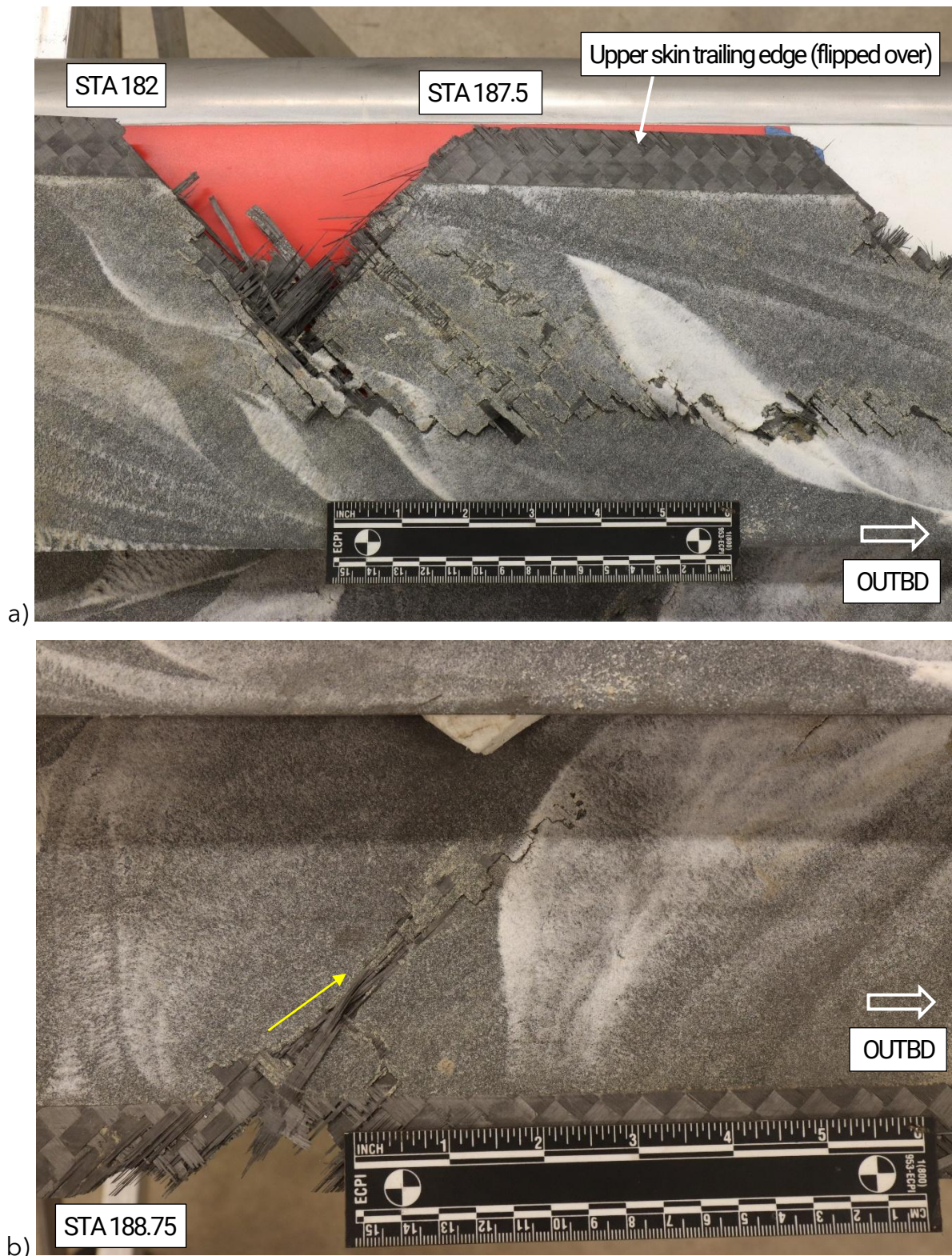
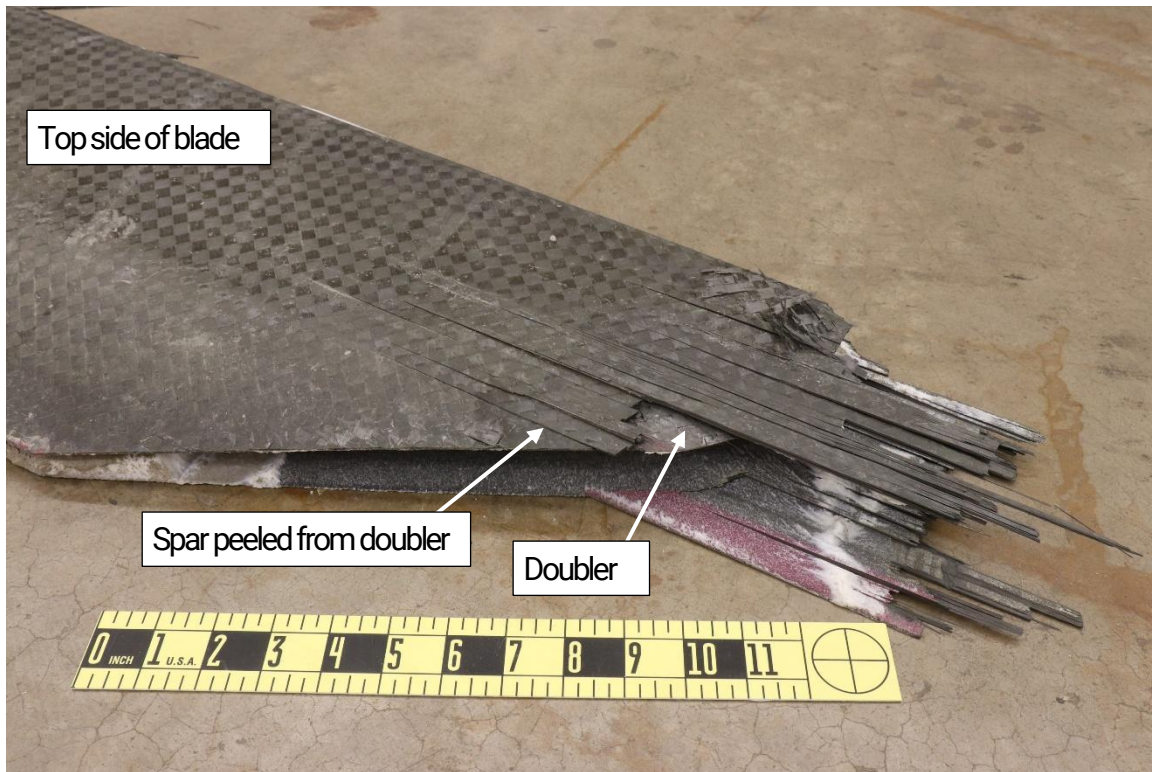


Figure 16. Inner surface of upper skin at wedge-shaped fracture showing skin to core separation features that are continuous across cracks in the skin; b) inner surface of the lower skin showing the outboard tear extending into a continuous skin to core separation feature; and



Figure 16 (cont.). c) inner surface of the lower skin showing the inboard tear with an inconclusive determination of continuity of the skin to core separation features.



a)



b)

Figure 17. Blade A304 root section upper surface: a) trailing side view showing the upper spar's trailing edge peeled from the doubler and b) leading edge view showing the upper spar's leading edge attached to the doubler.

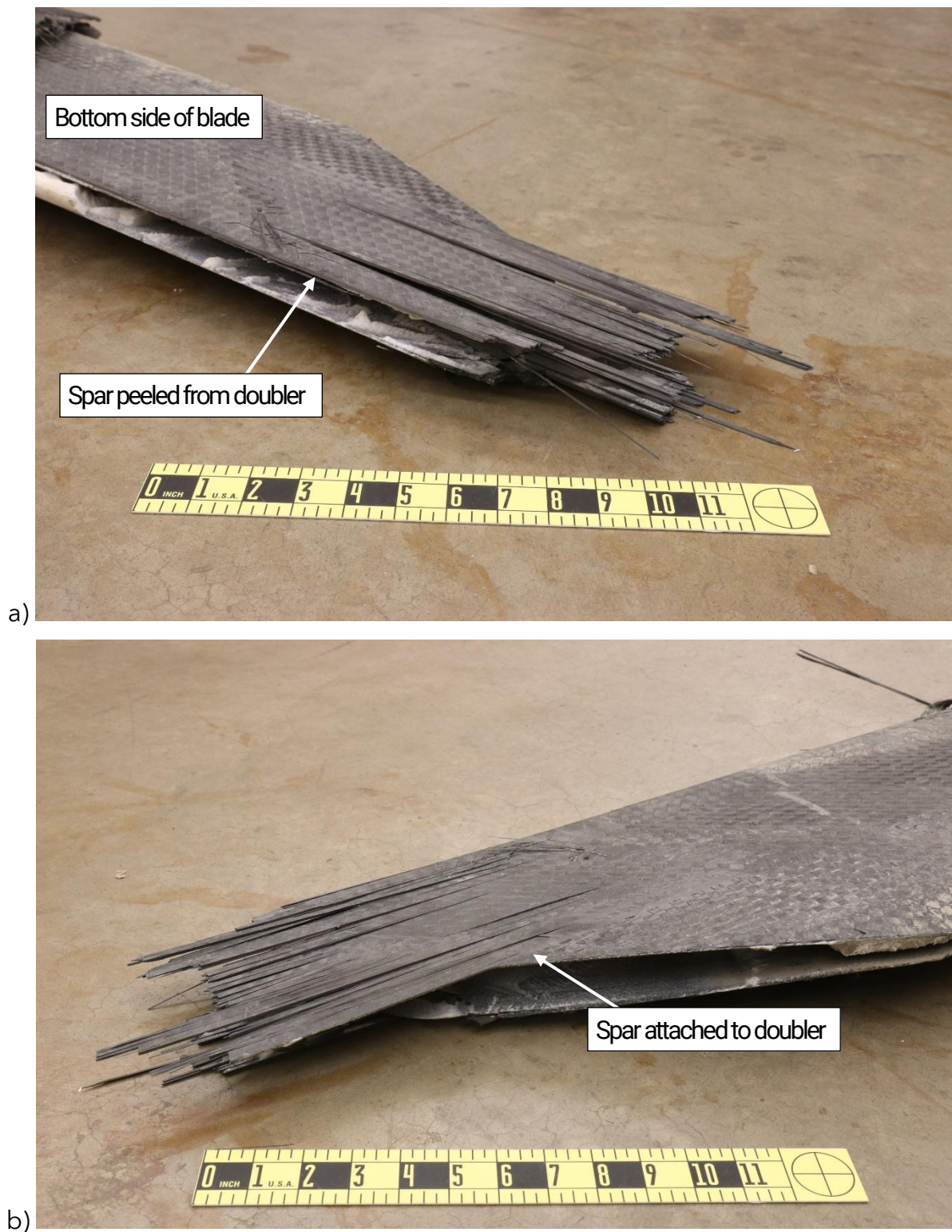


Figure 18. Blade A304 root section lower surface: a) leading edge view showing the leading edge of the lower spar peeled from doubler and b) trailing edge view showing the lower spar's trailing edge attached to the doubler.



Figure 19. Images of upper and lower spars splintering about 26 inches outboard of the doublers.

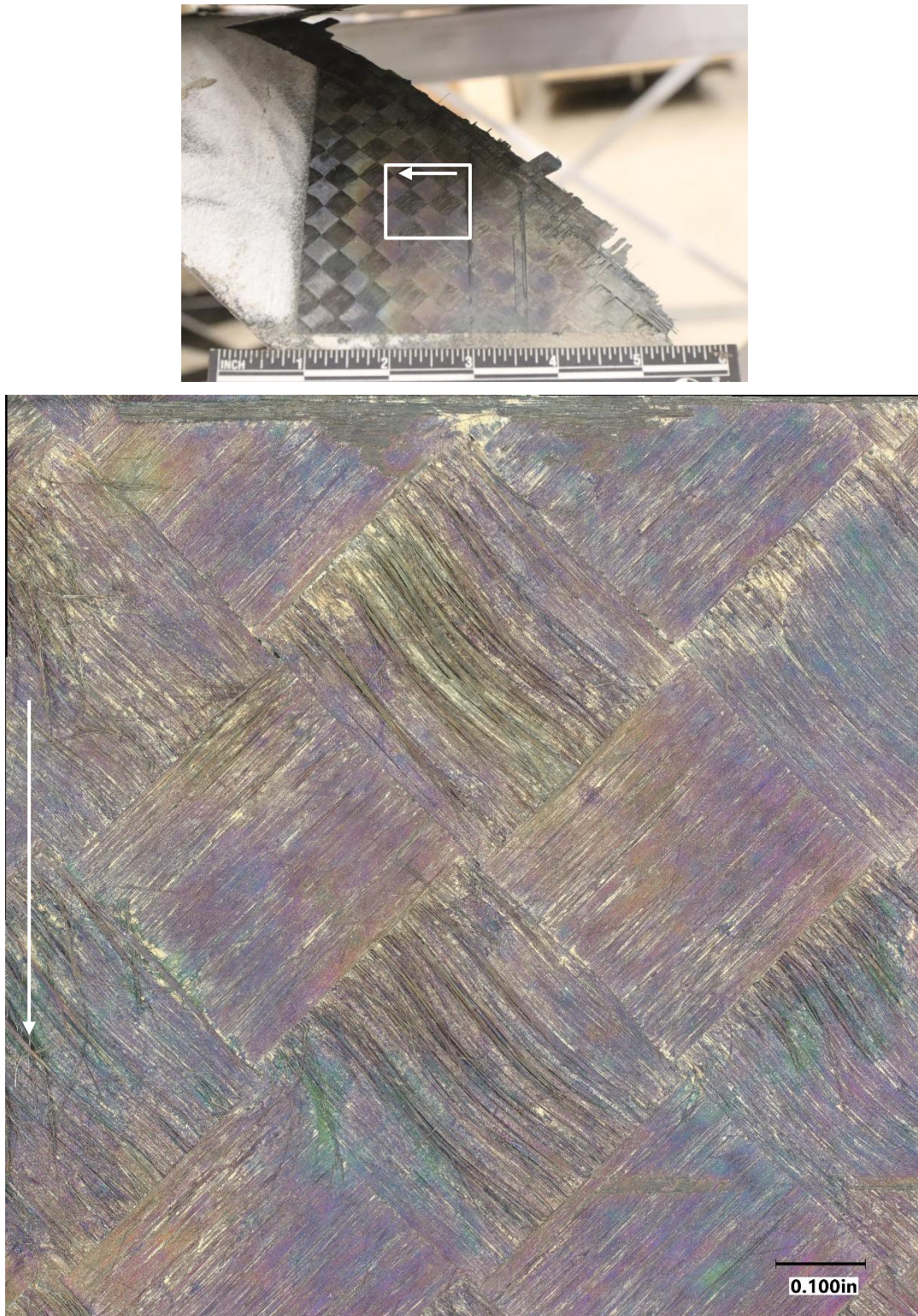
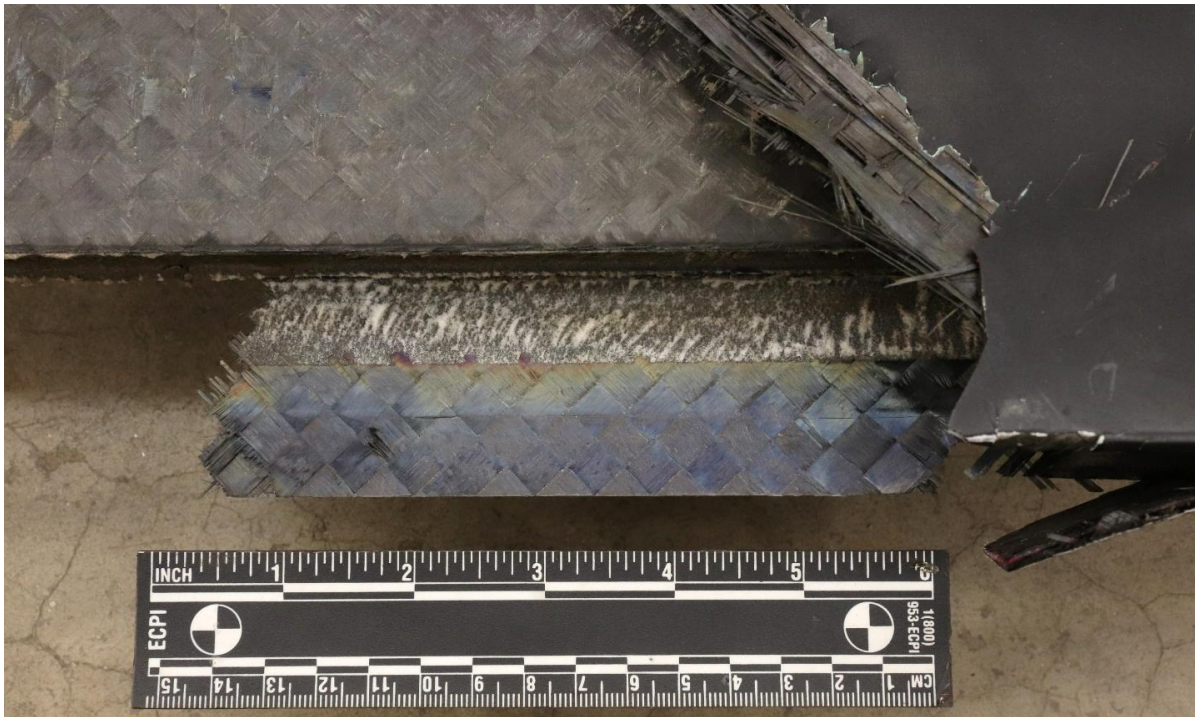
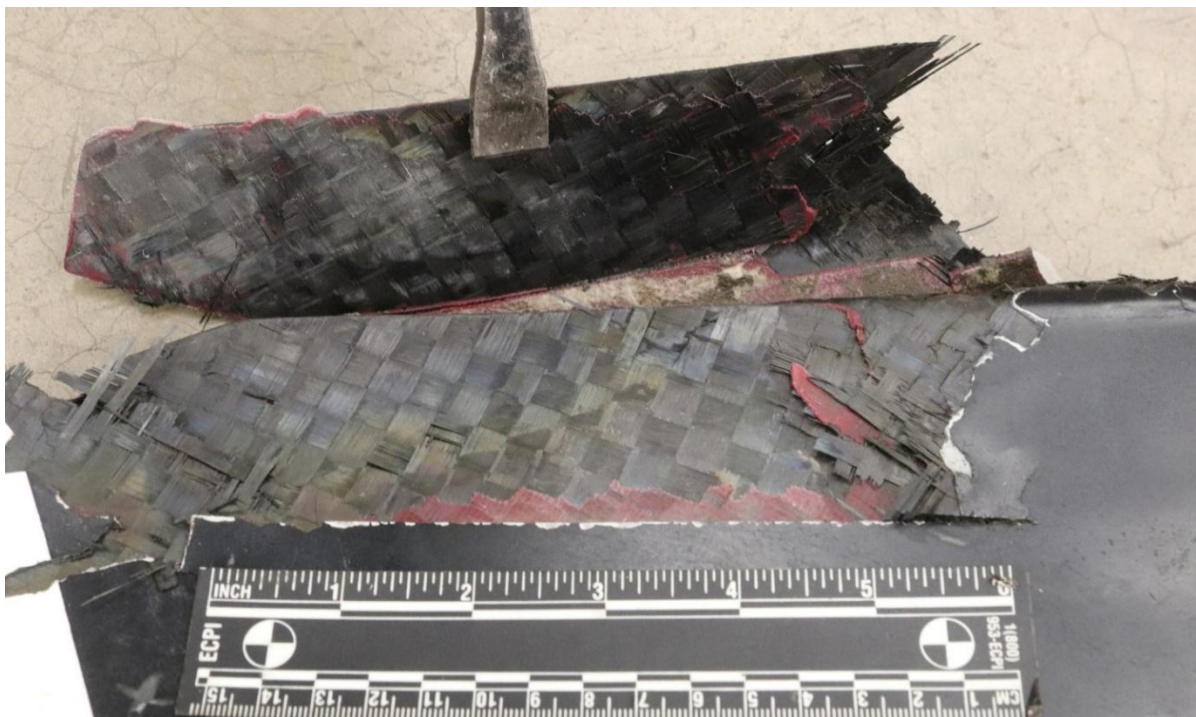


Figure 20. Tinting and rubbing of the lower skin piece that disbonded from the spar at the outboard end of the blade. A white box in the upper image indicates the location of the lower image. The white arrow in both images is positioned at the inboard side of the image area and points toward the trailing edge.



a)



b)

Figure 21. Tinting feature on blade A304: a) remaining piece of the upper skin at the trailing edge and b) piece of the scarf wrap that disbonded from the blade root.

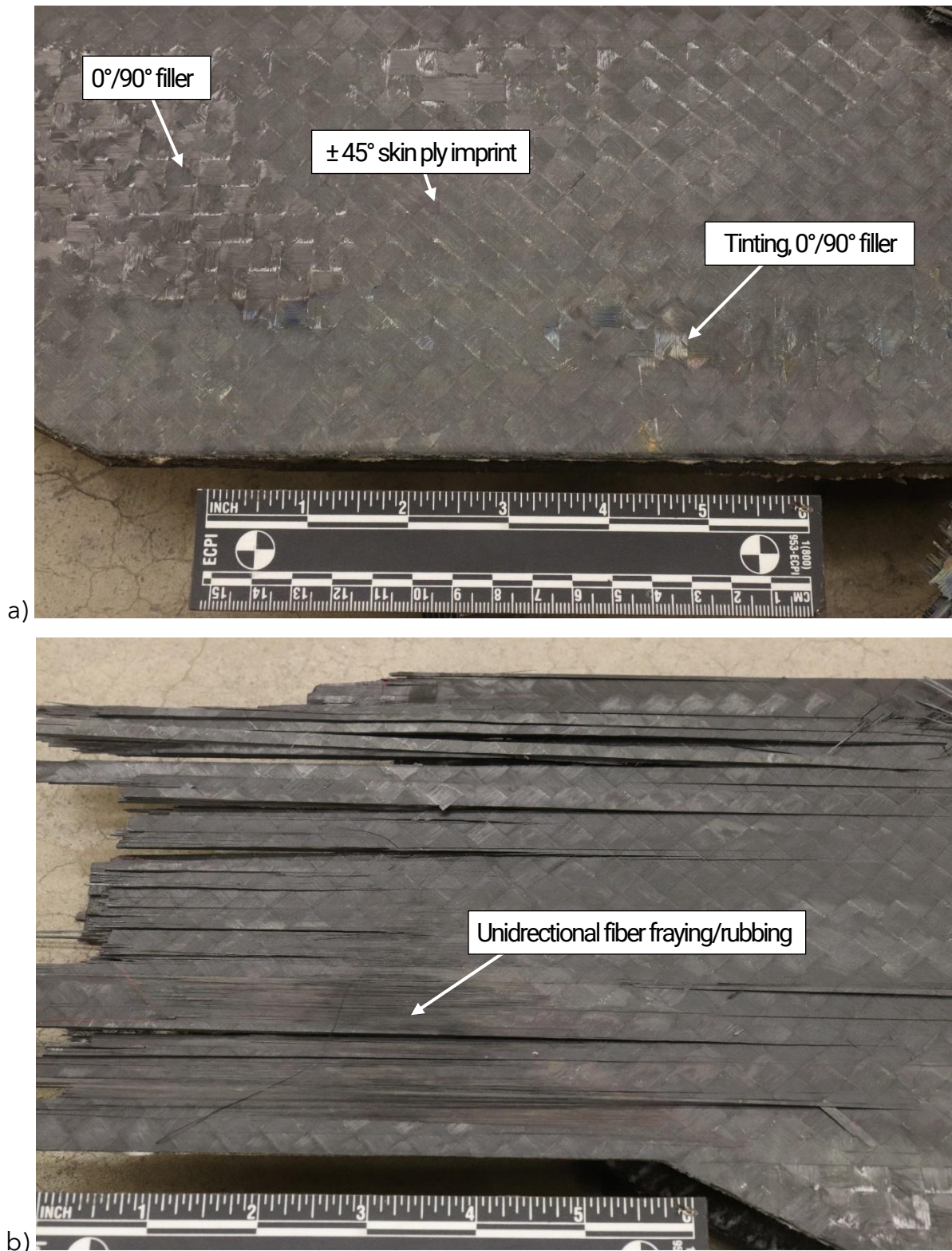


Figure 22. Images of blade A304 lower surface at the blade root: a) image showing $\pm 45^\circ$ imprint in resin from separated skin plies and $0^\circ/90^\circ$ filler plies where the resin has rubbed away and b) image showing region on unidirectional laminate spar where the $\pm 45^\circ$ imprint has also been rubbed away.

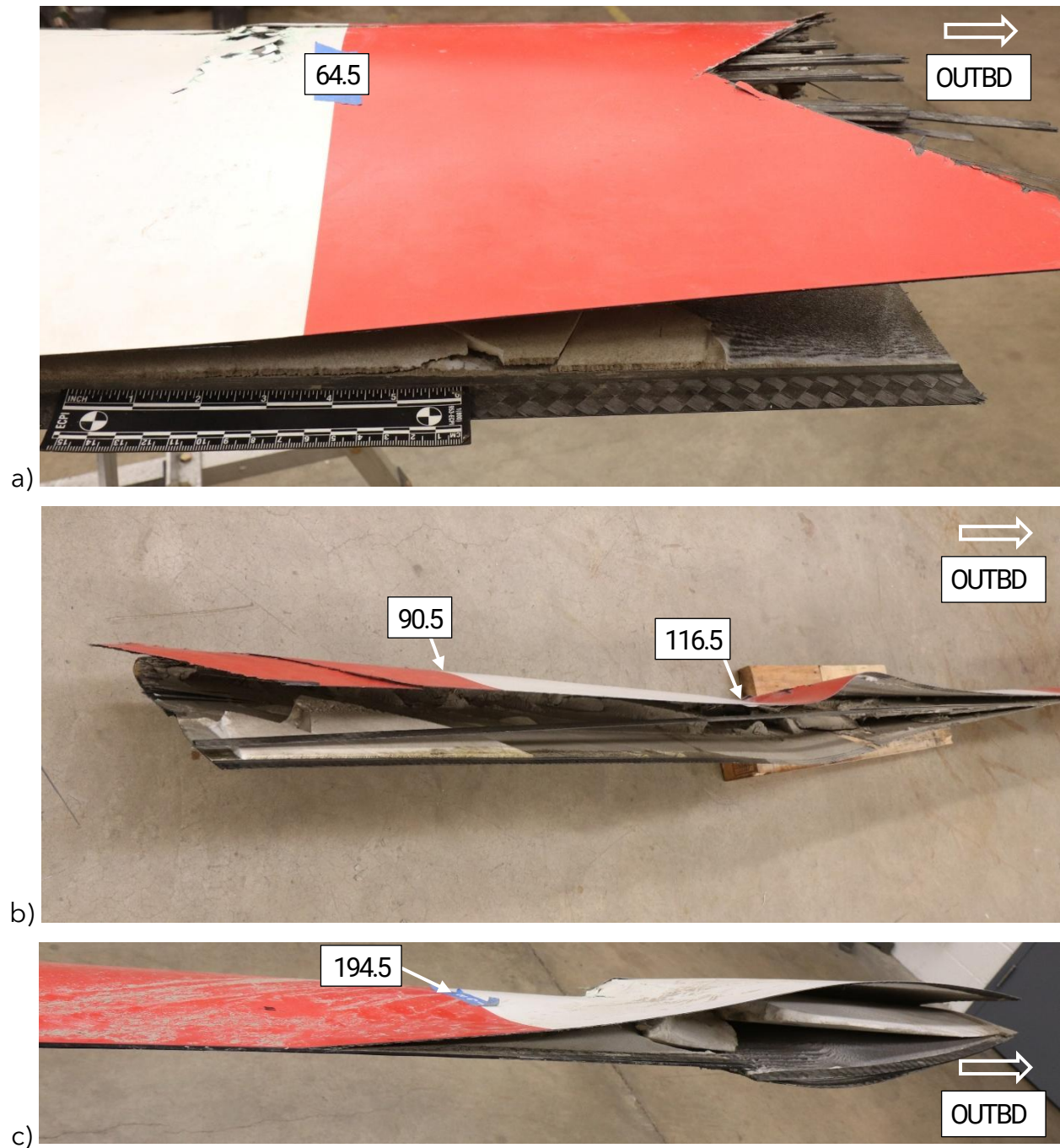


Figure 23. Images of blade A303: a) Trailing edge opening up near the root end of blade; b) trailing edge opening up toward STA 178; and c) trailing edge opening up outboard of STA 188.



a)



b)

Figure 24. Splintering of the upper and lower spars on blade A303 on either side of the cut at STA 76: a) splintering about 6 inches outboard and b) splintering about 14 inches inboard.

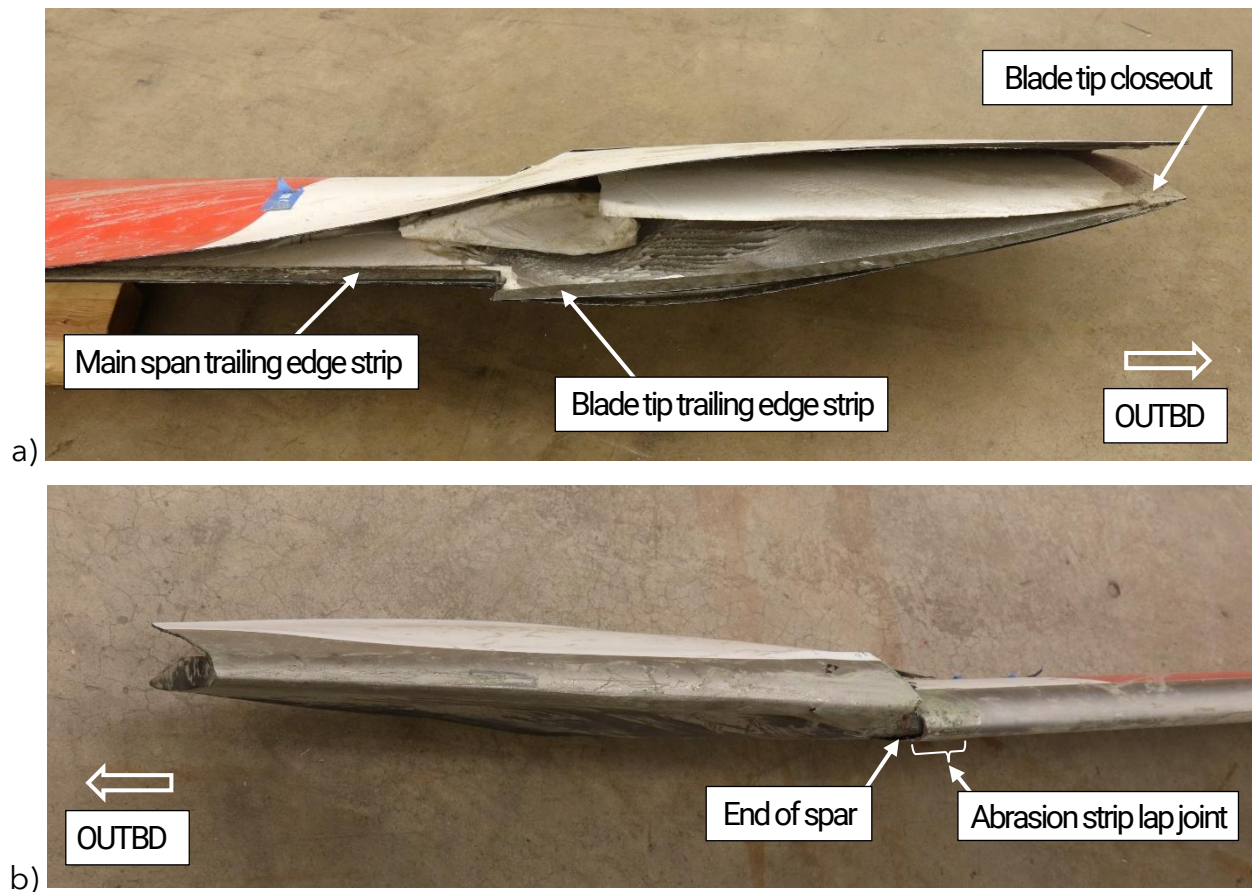


Figure 25. Images of the blade A303 blade tip: a) view of the trailing edge showing downward displacement of the blade tip trailing edge strip; b) view of the leading edge showing flapwise upward shear displacement of the abrasion strip near the end of the spar and an upward bend of the blade outboard of the spar.

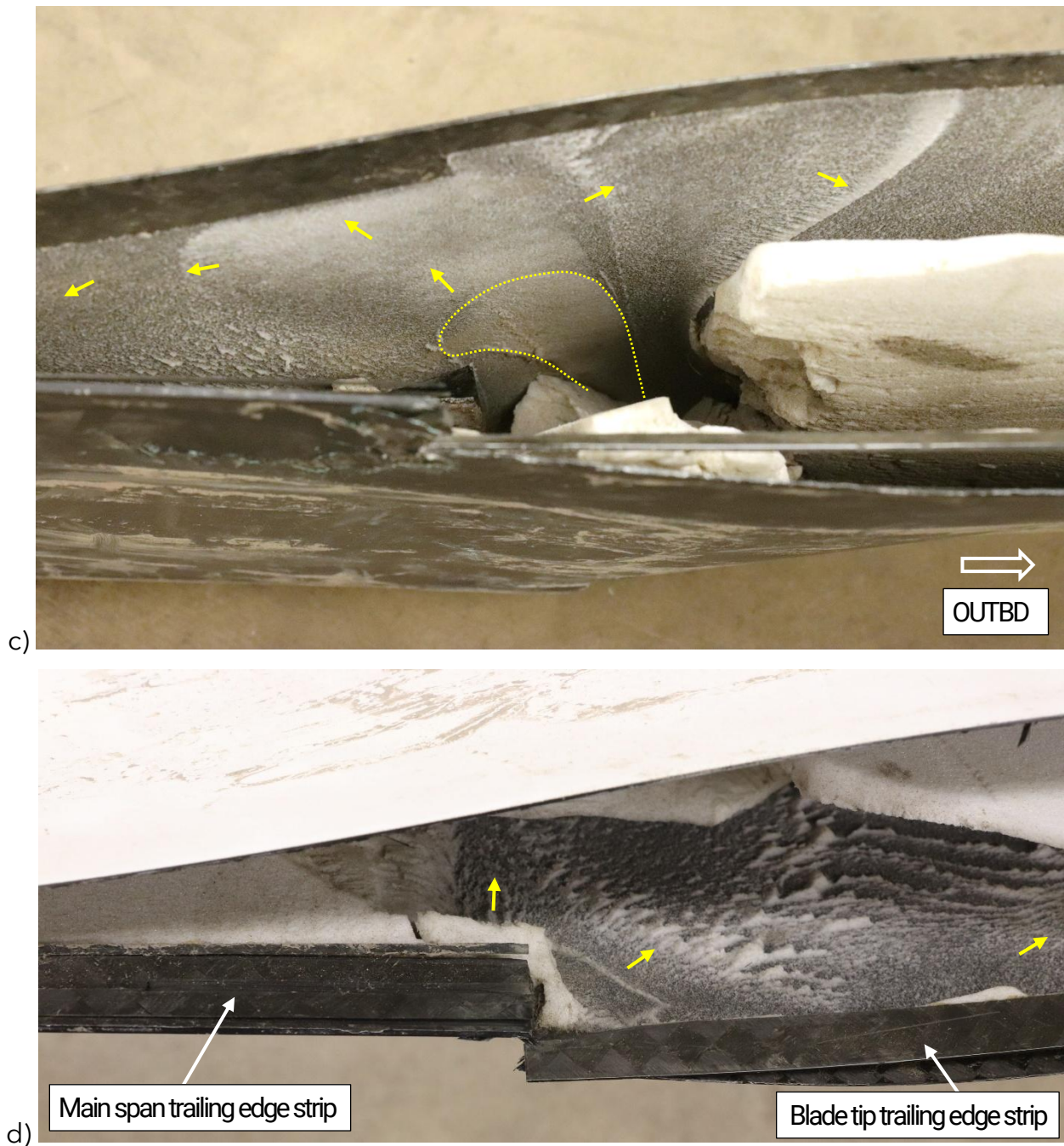


Figure 25 (cont.). c) closer view of the upper skin separation from the core. An elongated separated region was observed near the leading edge, indicated by the yellow dashed line. Yellow arrows indicate the local direction of skin separation; and d) closer view of the trailing edge strip transition showing tear ridges radiating away from the main span-to-tip trailing edge transition.

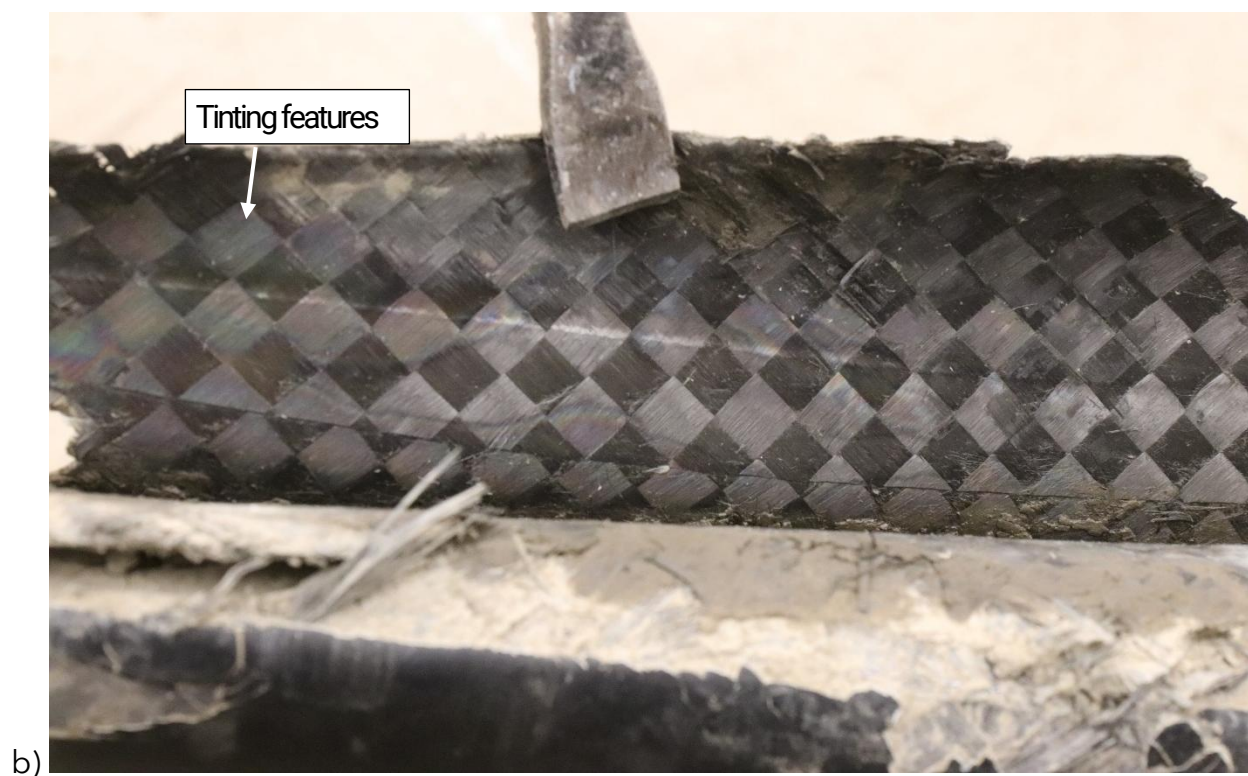
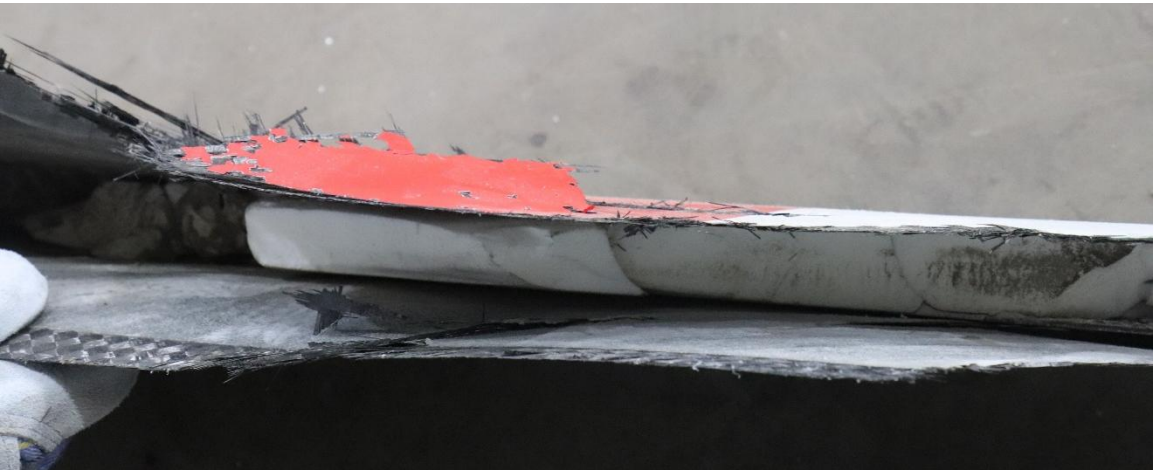


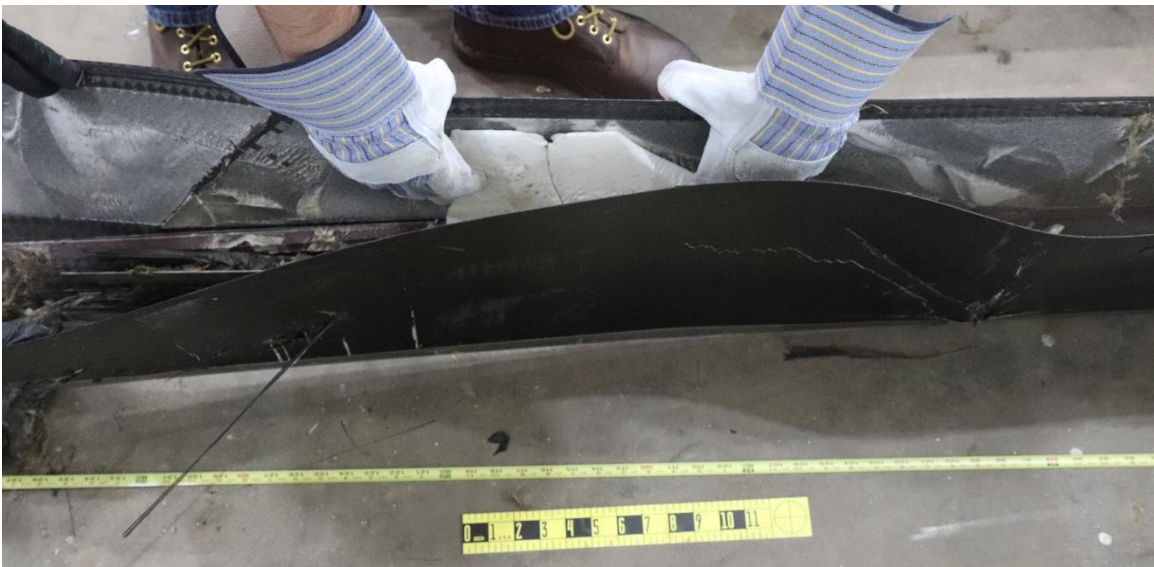
Figure 26. a) Flap of torn skin material on blade A303 along the leading edge near the blade grip and b) image showing slight tinting of the separated skin after cleaning.



a)



b)



c)

Figure 27. Locations of matched foam core pieces on blade A304: a) STA 178; b) STA 188; c) 2-piece assembly at STA 86;



d)



e)



f)

Figure 27 (cont.). d) STA 68; STA 106; and STA 117.