

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



DCA21FA174

STRUCTURES

Group Chair's Factual Report

February 18, 2022

A. ACCIDENT

Location: Honolulu, HI
Date: July 2, 2021
Time: 0145 Hawaii standard time (HST)
1145 coordinated universal time (UTC)
Airplane: Boeing 737-275C, Rhoades Aviation, Inc., dba TransAir Flight 810

B. STRUCTURES GROUP

Group Chair Clinton R. Crookshanks
National Transportation Safety Board
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Los Angeles, California

Group Member John F. McLean
The Boeing Company
Seattle, Washington

Group Member Jacob Medlang
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C. DETAILS OF THE INVESTIGATION

The group met with the first responders from the US Coast Guard, examined the recovered floating debris, and performed an underwater search for the airplane wreckage July 2-11, 2021, in Honolulu, HI.

The group returned to Honolulu October 8 through November 5, 2021, to oversee and assist with the recovery of the airplane wreckage from the sea floor. Following the recovery, the wreckage was examined by the group.

The group chairman returned to Honolulu December 6-11, 2021, to retrieve the cockpit crew seats, remove the cargo from the aft fuselage, and dismantle the airplane for disposal. The airplane wreckage was released to the insurance company on December 10, 2021 with the exception of the flight recorders, the crew seats and both engines and related equipment.

D. FACTUAL INFORMATION

1.0 Airplane Overview

The Boeing 737-275C airplane is a twin-engine, narrow-body, transport category airplane (Figure 1) originally certified in 1965. The airplane is equipped with a conventional tail and retractable tricycle landing gear. The airplane is 90 feet, 7 inches long, 37 feet tall at the tail, has a fuselage diameter of 12 feet, 4 inches, has a wingspan of 93 feet, and has a horizontal stabilizer span of 36 feet. The airplane primary and secondary wing, fuselage, and tail structure is of all metal construction, primarily aluminum alloys. The accident airplane, SN 21116, was manufactured as a Convertible airplane with a large main deck cargo door in the left forward fuselage and was completed in July 1975.

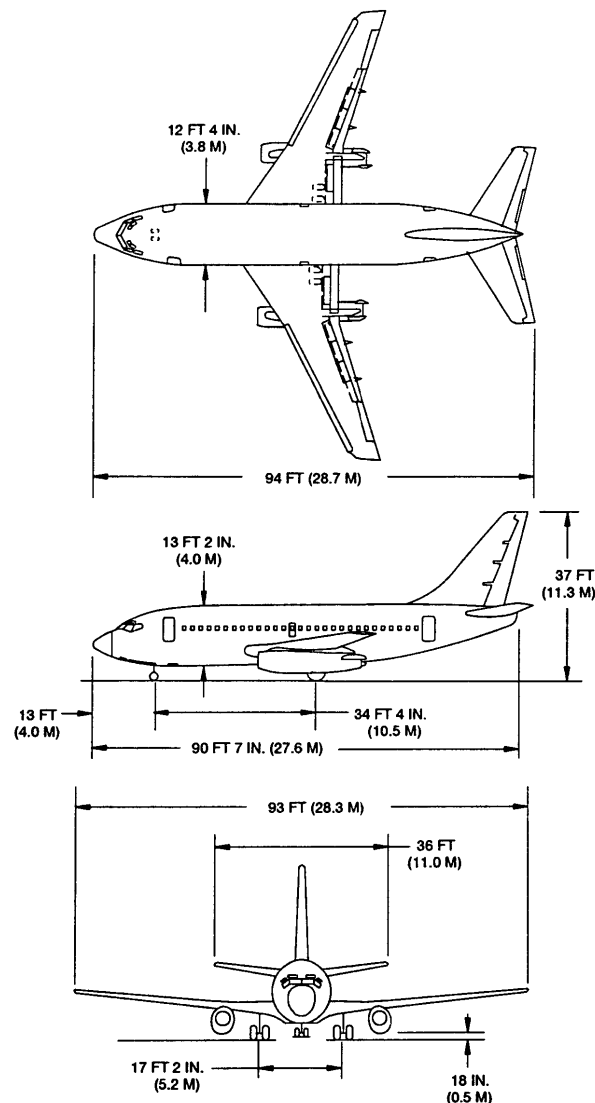


Figure 1. Boeing 737-200 3-view drawing (courtesy of Boeing)

2.0 Wreckage Search and Recovery

The details of the search and recovery are documented in the Search and Recovery Factual Report in the public docket. The search for the airplane commenced on July 3, 2021, and concluded on July 8, 2021, after a full wreckage survey was completed. The location and depth of the wreckage necessitated the use of specialized equipment under contract to the airline's insurance company, AIG Aerospace, under the direction of the NTSB. The wreckage recovery concluded on November 2, 2021, when the last of the recovered wreckage was transferred to the storage location at Kalealoa Barbers Point Harbor in Kapolei, Hawaii.

The forward fuselage section was rigged with a wire rope through the open cockpit windows and a wire rope underneath the rear of the section (Figure 2). The forward section was lifted onto the Derrick Barge (DB) Salta Verde on October 20. The enhanced ground proximity warning system (EGPWS) and all other avionics boxes in the lower fuselage were separated. The EGPWS was recovered on the seafloor October 22 and placed in distilled fresh water. The forward fuselage section was offloaded from the barge to the pier at Kalealoa Barbers Point Harbor on October 22.



Figure 2. Forward fuselage section being lifted from water (NTSB photo)

The aft fuselage section was rigged with two 12-inch-wide nylon straps at the aft end underneath the door locations and wire ropes around each wing root area (Figure 3). The aft section was recovered to the DB Salta Verde on October 30. The barge transited to Kalealoa Barbers Point Harbor and offloaded the aft section on October 31. The FDR was recovered from its rack in the aft cabin ceiling and placed in distilled fresh

water. The CVR was recovered from its rack in the lower left fuselage by cutting through the side fuselage skin and placed in distilled fresh water. The remaining recovered debris was transferred to the pier on November 2.



Figure 3. Aft fuselage section being lifted from water (NTSB photo)

3.0 Wreckage Examination

The group examined the recovered floating debris at USCG Base Honolulu on July 4, 2021. Most of the items recovered were cargo carried in the airplane to include medication and packaged fish. There were several items of airplane wreckage recovered that comprised sections of lightweight composite panels and an oxygen bottle. Sections of the nose landing gear doors and wing-to-body fairing were identified in the wreckage.

The structures group members examined the forward fuselage section October 22-26, 2021, and the aft section and other debris November 3-5, 2021.

The recovered airplane forward fuselage section from body station (STA) 178 to STA 540 separated from the remainder of the airplane. The radome was separated and not recovered. A majority of the fuselage structure below the floor at water line (WL) 208 separated from the upper fuselage along with a majority of the floor beams aft of the cockpit area near STA 277. The floor panels, seat tracks, ball-mats and cargo fittings remained with the forward fuselage near their original locations, though not intact. The nose landing gear (NLG) and wheel well separated from the airplane and were recovered. The NLG was in the retracted position on the seafloor during the initial survey. The NLG extended during recovery when it was lifted but fell back to

the retracted position after recovery. Several large, angled dents/buckles were noted in the side-skins of the forward fuselage. The left forward entry door had a large dent/buckle in the external skin with broken portions of the hinge mechanisms at both upper and lower hinges. Frame fractures below the floor line were deformed aft. Multiple skin-to-frame and skin-to-stringer locations aft of STA 400 below the floor line had pulled rivets. A single window plug was missing on the left side between frame STA 420 and STA 440. The window plug was in place prior to the recovery.

Several separated sections of lower forward fuselage structure with significant damage were recovered and identified. The lower nose compartment access door and E&E compartment access doors were recovered intact with some damage. Most of the E&E compartment access door fuselage surround structure was recovered in two pieces. One piece spanned from about STA 300 to STA 360 and stringer (S) 25R to S-28R. The second piece spanned from about STA 312 to STA 382 and S-28R to S-26L. A section of the lower left fuselage structure containing the static port was recovered with significant damage that spanned from about STA 380 to STA 525 and S-19L to S-26L. The right lower forward cargo door was recovered in three pieces, one comprised the lower half with the handle and measured about 48 inches wide by 40 inches tall, one comprised the upper aft corner and measured about 18 inches wide by 26 inches high, and one comprised the upper forward corner and measured about 26 inches wide by 27 inches high. A section of right lower fuselage structure was identified that spanned from the aft side of the cargo door at STA 490 to STA 500B and from S-17R to S-23R. A section of curled up skin with the right static port was identified than spanned from STA 390 to the forward edge of the cargo door at STA 440 and from S-22R to S-28R. A section of lower fuselage structure with the lower cargo compartment sill and mostly intact cargo floor that spanned from STA 440 to STA 540 and from S-24R to S-26L was identified. A small section of fuselage skin that spanned 3 stringers and 3 frames was buckled accordion style and not conclusively identified.

The airplane aft fuselage from STA 540 to STA 1217 separated from the forward portion of the airplane during the accident. The lower lobe of the recovered aft portion of fuselage structure was damaged and portions of belly skin were separated from the airplane. The keel beam assembly installed beneath the wing from STA 540 to STA 727 was mostly intact and separated from the airplane. A majority of the lower beam structures and AC pack components from STA 540 to STA 727 were also separated from the airplane and recovered in multiple pieces. The Wing Center Section (WCS) front spar was significantly damaged with several parts deformed into the WCS fuel tank, some pieces separated from the airplane, and a portion remained attached to the keel beam assembly. The upper and lower wing skins in the WCS were damaged aft of the STA 540 break. Much of the WCS internal structure near the front spar was significantly damaged. The panelized crown skin aft of the STA 540 break was damaged and a large chunk was peeled away but still

attached to the fuselage. The Aft Pressure Bulkhead (APB) web and pressure chord at STA 1016 were damaged along the lower half.

A section of aft lower fuselage structure was recovered and identified. The piece was partially attached to the aft fuselage during the initial survey but separated during the recovery. The piece spanned from about STA 908 to STA 996 and from S-22L to S-25R. It included a portion of the cutout for the outflow valve, a portion of the cutout for the pressure relief valve, the airstair handle recess, and the water servicing panel.

The wings remained attached to the fuselage and were mostly undamaged as observed during the initial underwater ROV survey after the accident. The inboard flaps, outboard flaps and ailerons remained attached to the trailing edges of both wings. The outboard trailing edge of the inboard flaps on both wings was at the '1' mark on the aft pylon fairings. All the spoilers remained installed on both wings. The main landing gear (MLG) were observed in the retracted position when the airplane was lifted. An examination of the MLG could not be performed.

Many of the composite panels on the wings sustained deformation of the upper skins in areas away from the edges where honeycomb was installed. The skin was pillowed downward indicating crushing of the honeycomb core. Evidence of this type of damage was noted on the left and right upper wing panels outboard of the ailerons, spoilers 1, 2, 3, 4, 5, 6, and 8, both outboard aft flaps, both inboard fore and aft flaps, and the left elevator trim tab. The ailerons suffered the most significant crushing of the honeycomb core with both the upper and lower skins pillowed inward.

Most of slat 1, all of slats 2 and 3, and leading edge flaps 1 and 2 were separated from the left wing and not recovered. About 32 inches of the outboard end of slat 1 remained attached to the left wing. The fixed leading edge structure was separated from the left wing between the root and the slat guide located about 20 feet outboard of the root. The inboard flaps sustained tearing damage from the trailing edge forward to the landing gear beam where the wing lift cable was positioned. The outboard end of the left aileron and the wing leading edge sustained tearing damage where a tag cable was positioned during recovery. The left aileron trim tab trailing edge measured about 1-1/4 inches above the left aileron trailing edge. There was some delamination of the trim tab trailing edge and the aileron had significant core crushing.

The left engine separated from the wing during the accident. The forward engine mount was separated from the wing and recovered on the seafloor. The forward inboard engine mount to wing bolt was separated and not recovered. The lug on the engine mount and the clevis on the wing fitting were intact but the outboard tang on the wing fitting clevis was deformed outboard. The forward outboard engine mount wing fitting was fractured through the three clevis lugs. The bolt remained installed in the intermediate fitting trapping the aft piece of the fractured clevis lug. The intermediate fitting remained installed on the forward engine mount. The inboard cone bolt was

separated from the forward engine mount and not recovered. The outboard cone bolt was intact and installed in the forward engine mount. A piece of the engine mount flange about 24 inches long remained attached to the outboard cone bolt with the intact engine bolt. The inboard thrust link was intact, disconnected at both ends, and embedded in the structure. One tang of the forward clevis was bent, and the nut and tail of the bolt remained installed. The other tang was intact. The aft lug was intact, and a piece of the bolt shank remained installed. The inboard thrust link wing fitting was intact and bent slightly. The outboard thrust link was intact, disconnected at both ends, and embedded in the structure. The nut and bolt tail could be seen but the rest of the forward end was hidden. The aft end of the outboard thrust link was intact with no bolt installed. The outboard thrust link wing fitting was intact. The aft engine mount remained partially attached to the wing. The outboard lug was disconnected, and the bolt was fractured in the hole. The inboard lug remained attached to the fractured bolt and the lug was bent. The engine attach bolt was separated and not recovered.

Slats 4-6 remained attached to the right wing in the extended position and were undamaged during the initial survey. Damage was sustained to slats 4-6 during recovery. Leading edge flaps 3 and 4 on the right wing were separated and not recovered. The fixed leading edge structure was separated between the root and the pylon on the right wing. Some pieces of unidentified leading edge flaps were identified in the recovered debris. The inboard flaps sustained tearing damage from the trailing edge forward to the landing gear beam where the wing lift cable was positioned. The outboard end of the right aileron and the wing leading edge sustained tearing damage where a tag cable was positioned during recovery. The right aileron trim tab trailing edge measured about 1-5/8 inches above the right aileron trailing edge. There was a fracture and deformation of the trim tab and aileron corners and the aileron had significant core crushing.

The right engine separated from the wing during the accident. The forward engine mount was intact, remained partially attached to the wing, and was rotated aft. The forward inboard engine mount to wing bolt was separated and not recovered. The engine mount was offset from the wing fitting. The clevis on the wing fitting was spread apart and the lug on the engine mount was intact. The forward outboard engine mount was intact with all bolts intact. The outboard cone bolt was separated and not recovered. The inboard cone bolt was intact and remained attached to the engine mount and to a section of engine case about 12 inches long. The inboard thrust link was intact, remained attached to the engine mount at the forward end, and was embedded in the structure. The aft lug was intact and there was a piece of the bolt shank installed. The inboard thrust link wing fitting was intact and undamaged. The outboard thrust link was intact, disconnected at both ends, and embedded in the structure. The forward and aft attach bolts were separated and not recovered. The forward and aft ends of the outboard thrust link and the wing fitting appeared undamaged. The aft engine mount was intact, rotated aft, and remained attached to the wing with the bolt. The engine attach bolt was separated and not recovered.

The empennage was mostly intact. The horizontal stabilizer, elevators, and trim tabs remained installed. The left elevator trim tab trailing edge measured ½ inch below the left elevator trailing edge. The right elevator trim tab trailing edge measured ½ inch below the right elevator trailing edge. The rudder did not have a trim tab installed. There were three distinct large impact impressions on the left stabilizer leading edge, but it and the left elevator were otherwise undamaged. There were several small impact impressions on the right stabilizer leading edge, but it and the right and elevator were otherwise undamaged. The vertical stabilizer and rudder remained installed and were mostly undamaged. There were some areas of the rudder that appeared blistered but couldn't be examined closely.

The pitch trim motor assembly was fractured from the lower gimble and included the electric actuator, the autopilot actuator, and the gearbox cable drum. The trim cable fractured ends had a splayed, broomstraw appearance consistent with tension overload. The lower gimble and gearbox remained installed on the jackscrew and the jackscrew was bent slightly. The horizontal stabilizer was free to move about the aft hinges and was observed moving stop to stop during the test lift. There was damage to the lower ends of the stabilizer cutouts on the left and right sides from overtravel leading edge down. The APU was fractured from its mounts and recovered intact in the debris field with some denting of the shroud. The APU compressor blades appeared undamaged. The APU doors were not recovered.

The thrust reverser assemblies were recovered mostly intact but damaged. The mixers were in place inside the reversers after the accident, but one mixer was removed to facilitate recovery. Most of the engine cowling was fractured and separated. The lower clam shell door on both thrust reversers was separated and recovered in the debris field.

The four cargo containers remained in the aft fuselage after the accident and were not removed during the initial examination. The forward most cargo container in the aft fuselage (position 4) was deformed upward and the front wall was partially separated. The cargo containers were removed from the aft fuselage prior to the airplane being cut up for scrap December 6-11, 2021. Each of the containers with cargo was weighed prior to being disposed and much of the cargo was waterlogged. Container SAA 4052 TXHA weighed 5260 lb and had a Tare of 478 lb. Container SAA 3026 TXHA weighed 5300 lb and had a Tare of 509 lb. Container SAA 4076 TXHA weighed 4220 lb and had a Tare of 478 lb. Container SAA 3006 TXHA weighed 5630 lb and had a Tare of 509 lb.

The following annotated photos and drawings document the observed damage to the airplane after recovery.

Figure 4 shows the left side of the recovered forward fuselage section. The section was mostly intact from STA 178 to STA 540 where it separated from the aft fuselage. Most of the structure below the floor at water line (WL) 208 was crushed, torn, and separated.



Figure 4. Left side of recovered forward fuselage section (Boeing photo)

Figure 5 shows a body station diagram of the forward portion of the airplane with the approximate boundary of the lower lobe damage on the left side indicated.

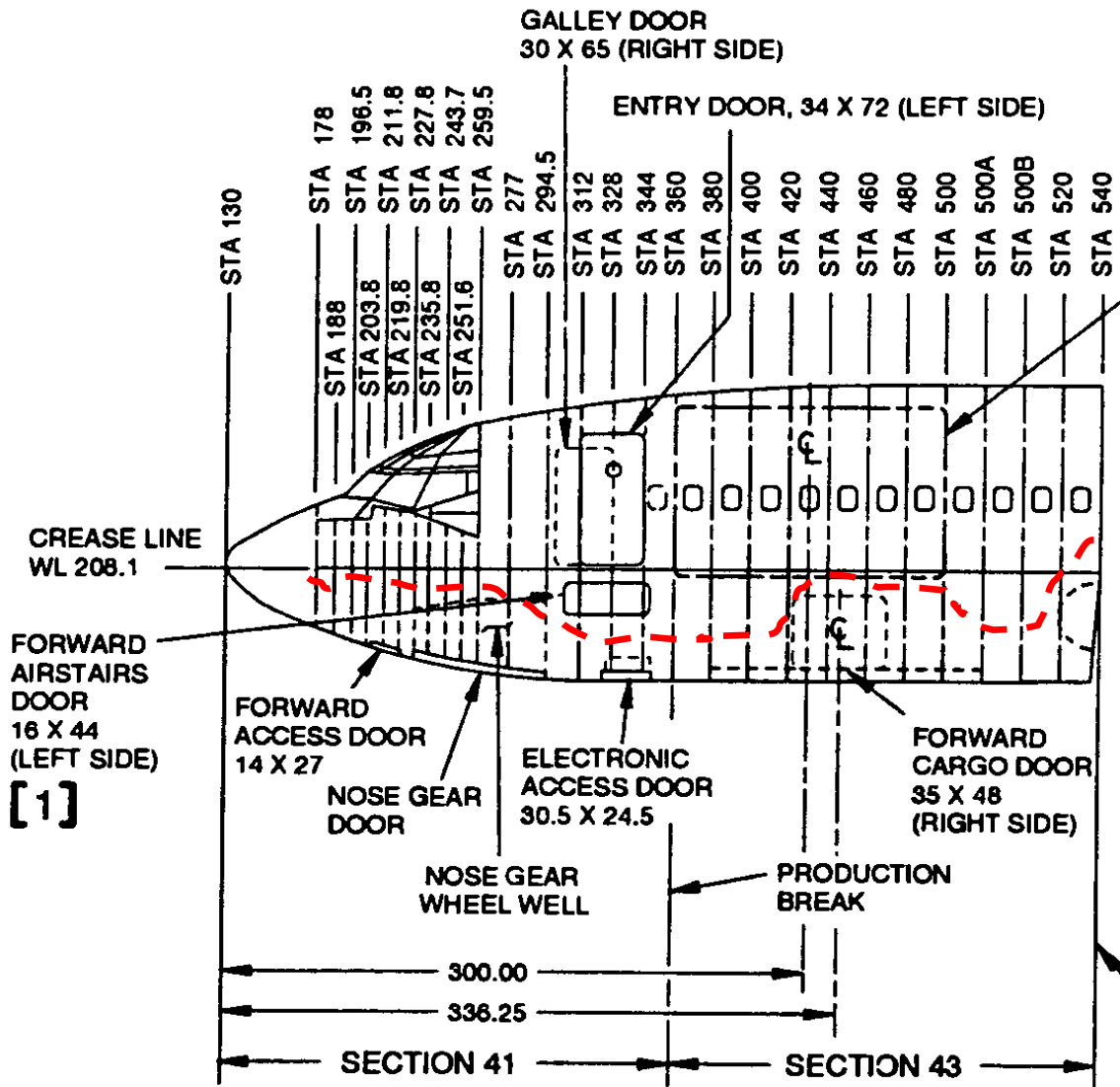


Figure 5. Left side approximate damage boundary (provided by Boeing)

Figures 6 and 7 show the right side of the recovered forward fuselage section. The section was mostly intact from STA 178 to STA 540 where it separated from the aft fuselage. Most of the structure below the floor at water line (WL) 208 was crushed, torn, and separated.

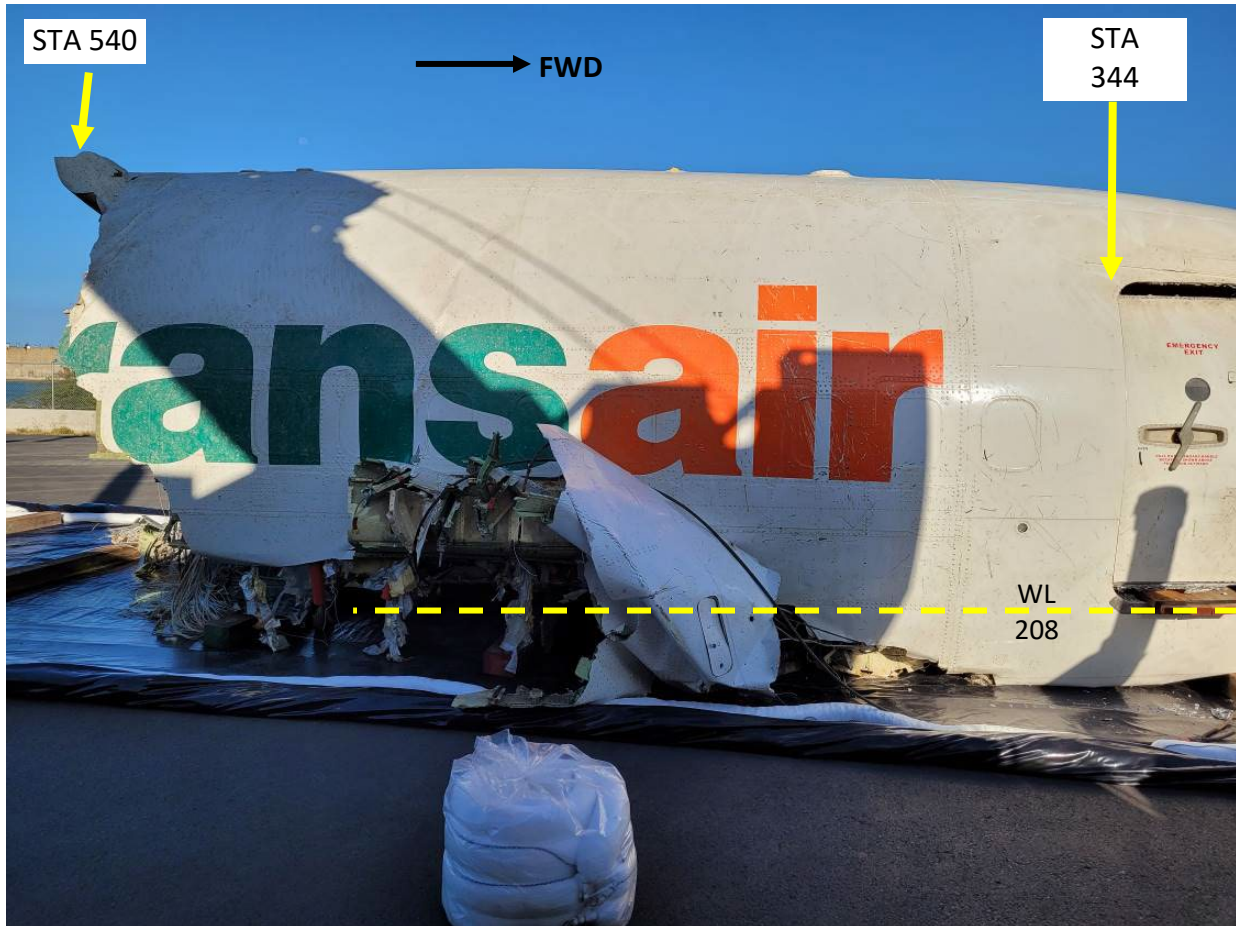


Figure 6. Right side aft view of forward fuselage section (Boeing photo)

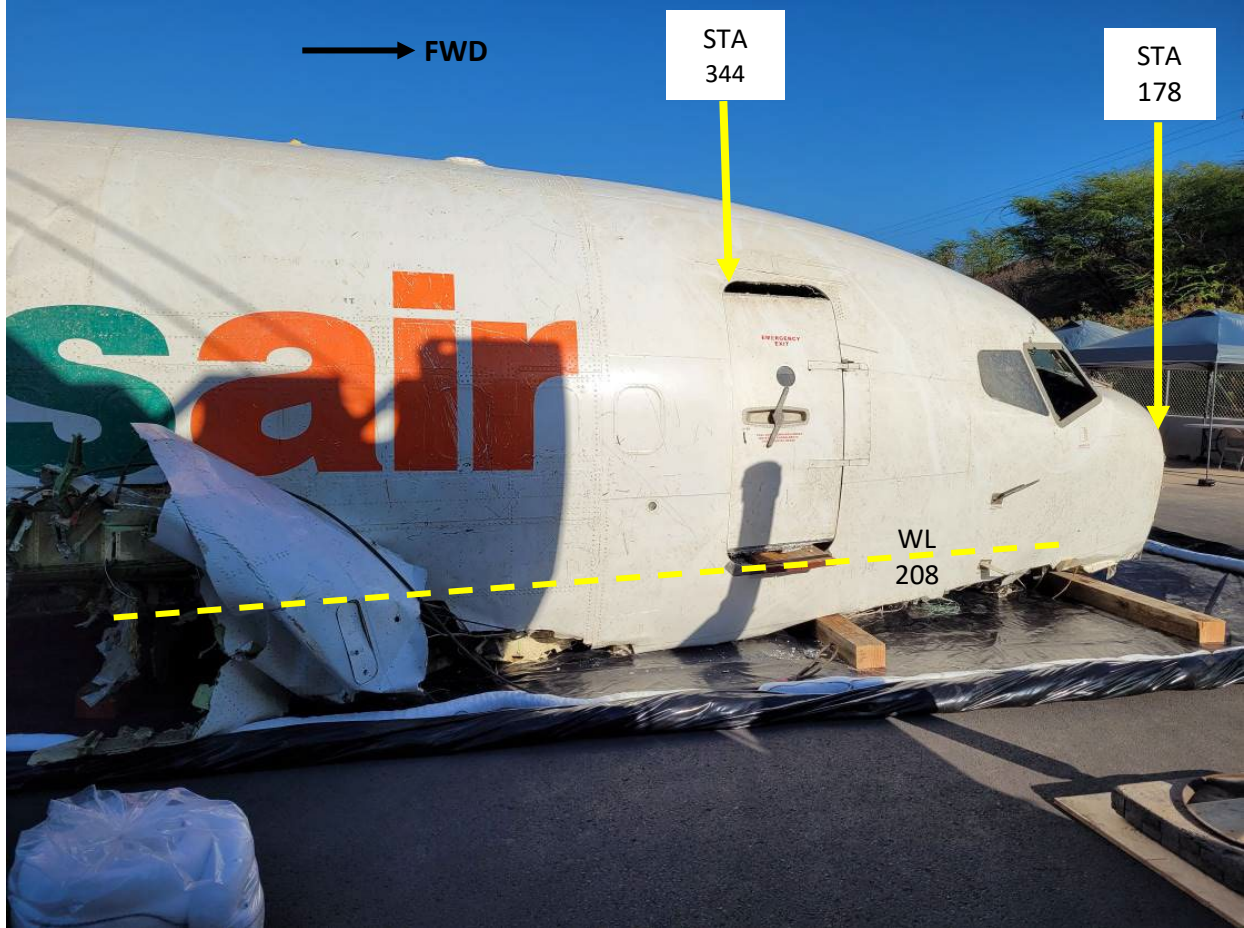


Figure 7. Right side forward view of forward fuselage section (Boeing photo)

Figure 8 shows a body station diagram of the forward portion of the airplane with the approximate boundary of lower lobe damage on the right side indicated.

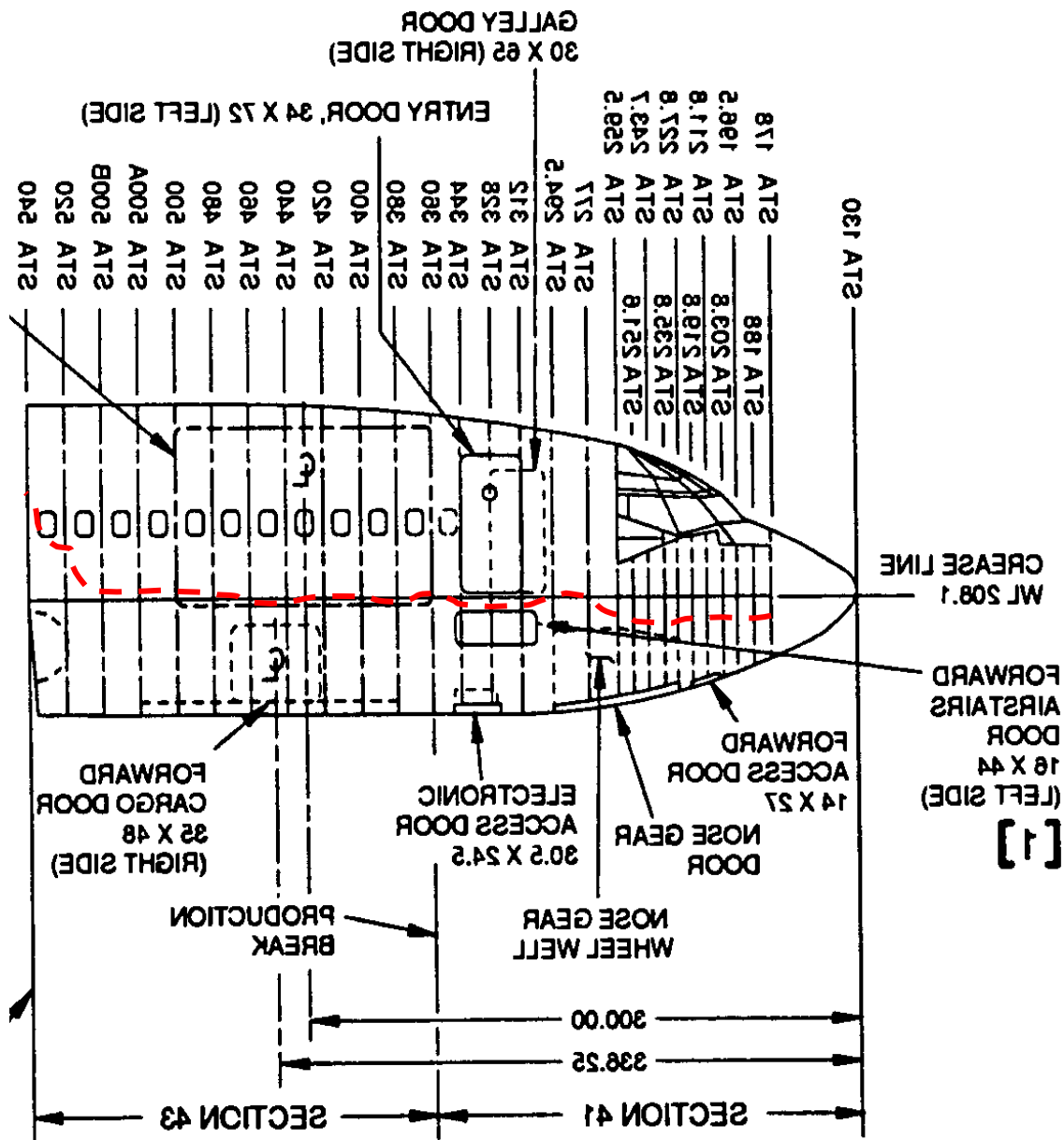


Figure 8. Right side approximate damage boundary (provided by Boeing)

Figure 9 shows the STA 178 Forward Pressure Bulkhead (FPB) with the upper portion mostly intact and the lower portion below WL 208 damaged.

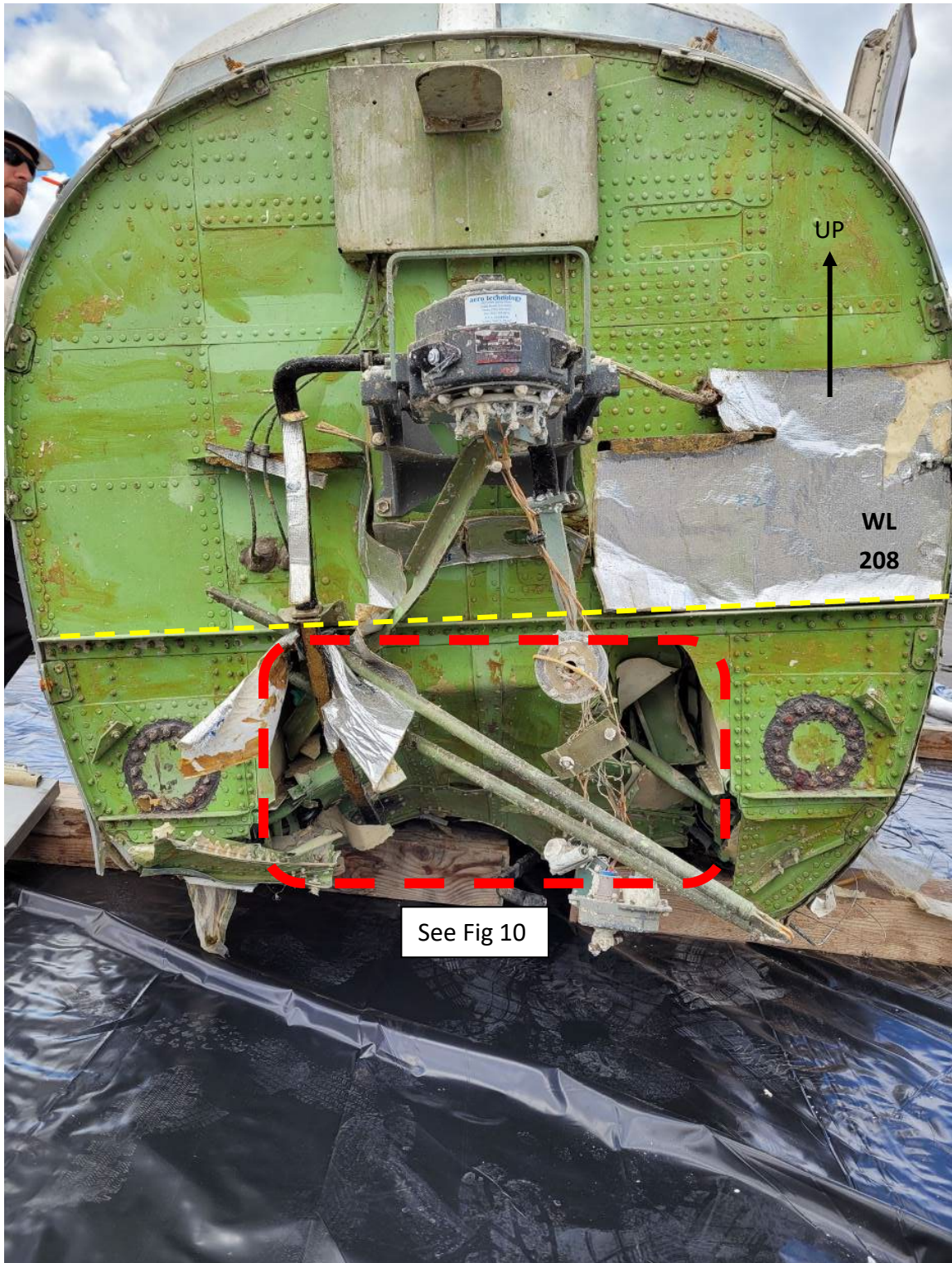


Figure 9. STA 178 FPB with lower region damaged, looking aft (Boeing photo)

Figure 10 shows a close-up of the lower damaged region of the FPB with fractures and aftward deformation.

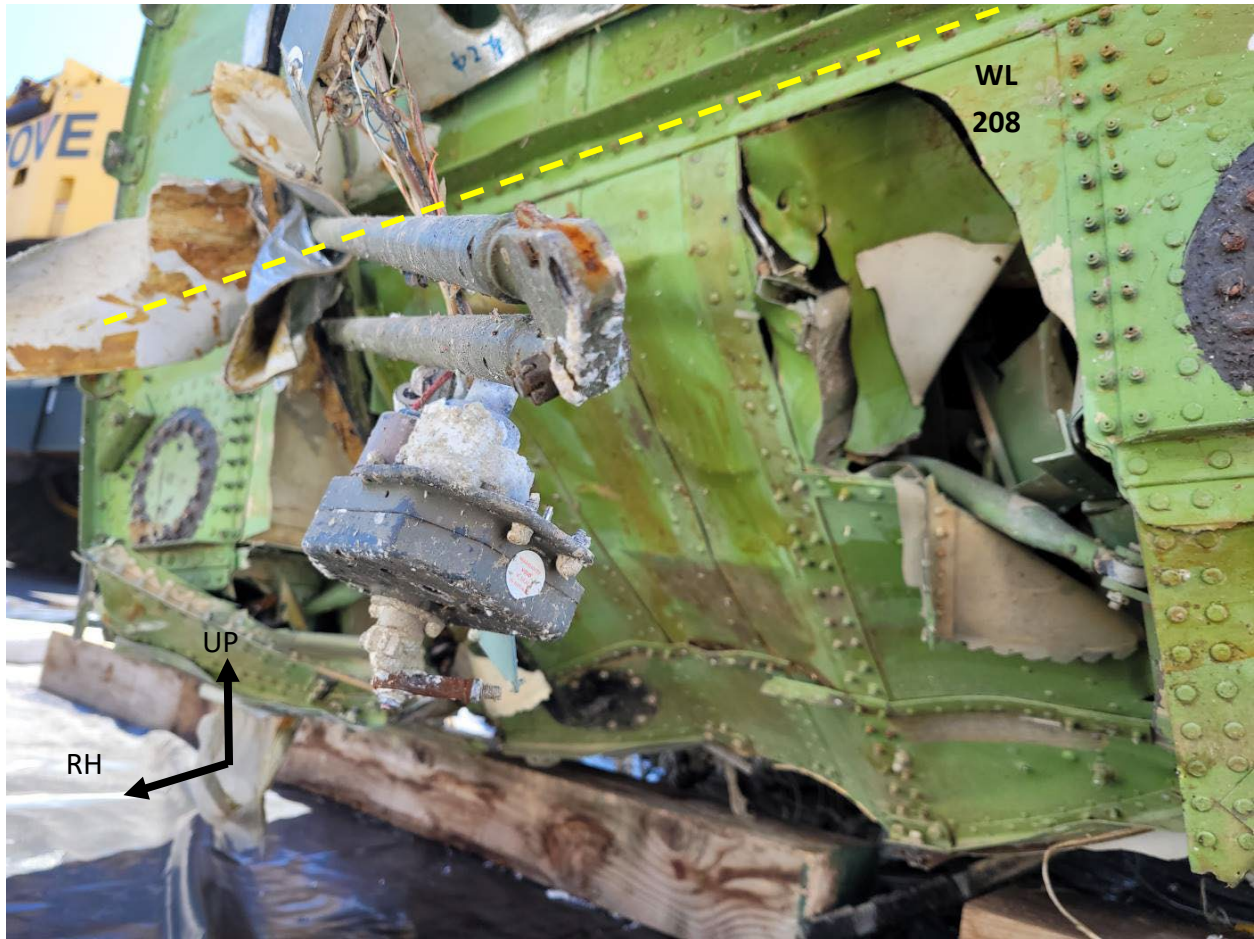


Figure 10. STA 178 FPB lower region damage close-up, looking aft/right (Boeing photo)

Figure 11 shows the STA 178 FPB drawing with the left (blue) and right (red) fractures indicated.

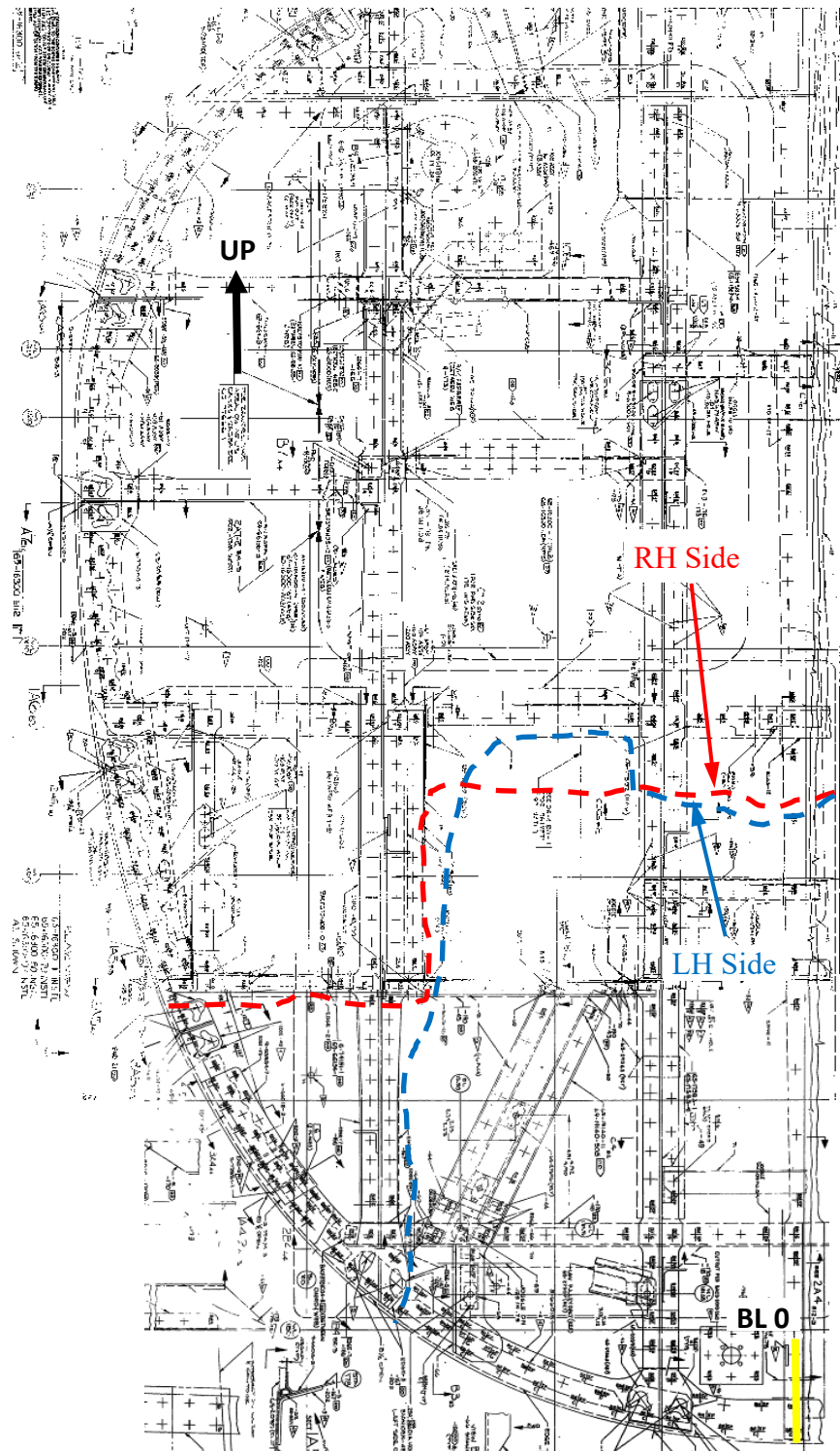


Figure 11. FPB left and right fractures (provided by Boeing)

Figure 12 shows a vertical crack about 8.5 inches long in the left fuselage skin at the STA 196.5 frame common to a dent. There were multiple dents in the left fuselage skin between the STA 178 FPB and STA 211 frame.

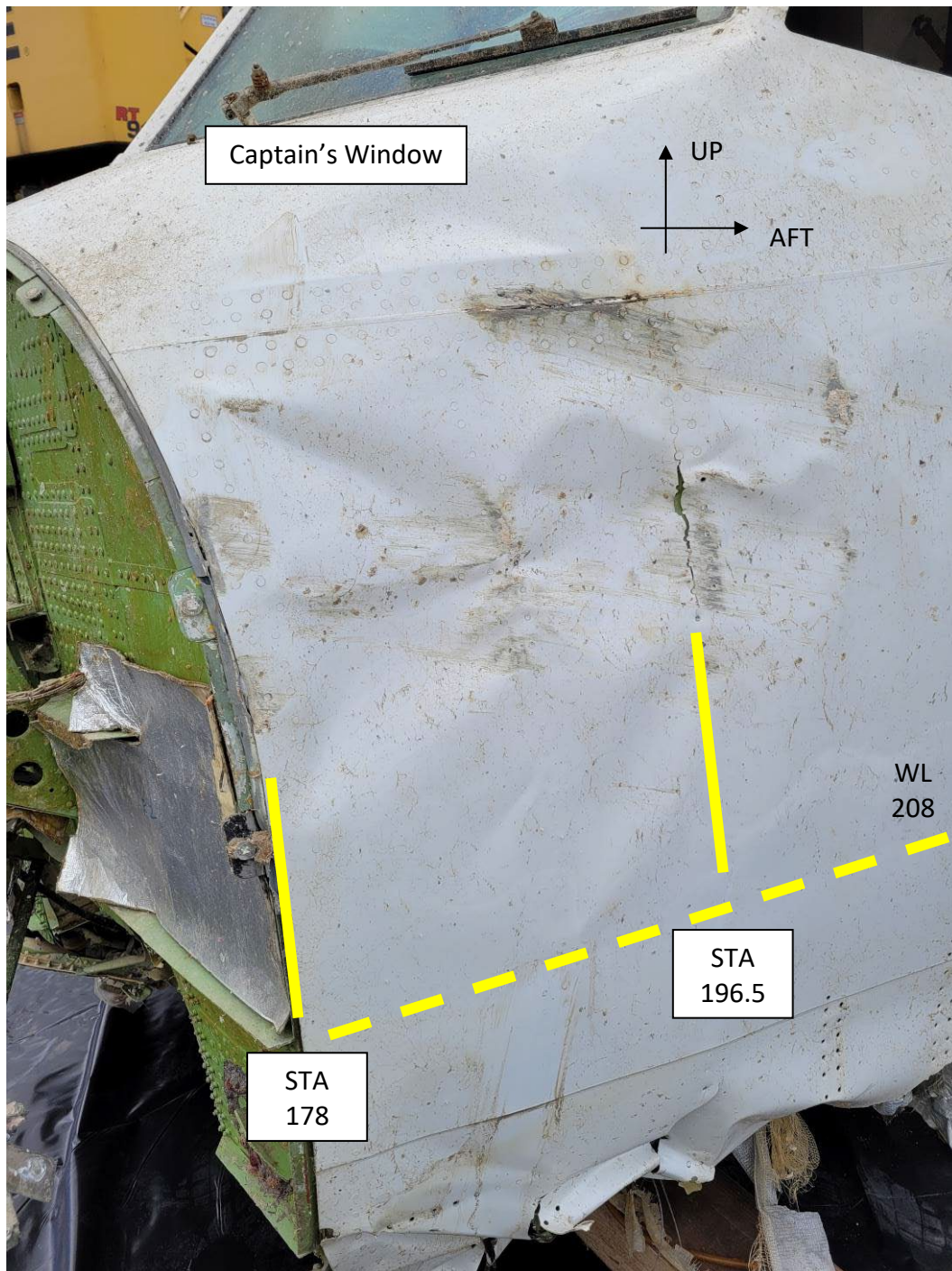


Figure 12. Left forward fuselage damage (Boeing photo)

Figure 13 shows a STA 380-420 external skin dent/buckle in the Main Deck Side Cargo Door (MDSCD) above the window belt. The missing window plug aft of STA 420 frame is also shown.

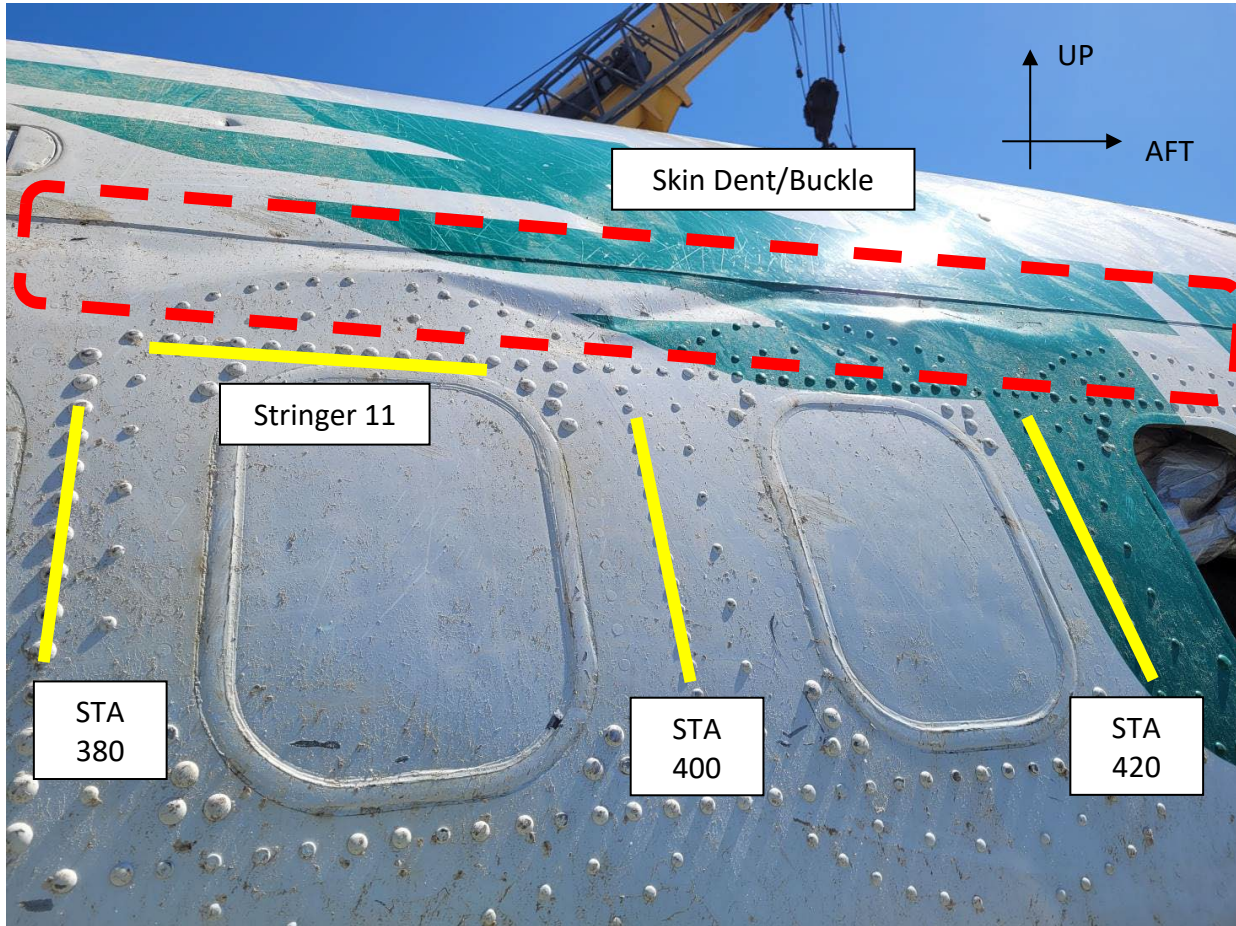


Figure 13. Main Deck Side Cargo Door external skin (Boeing photo)

Figure 14 shows the missing window plug in the left forward fuselage between STA 420 and STA 440 frames.

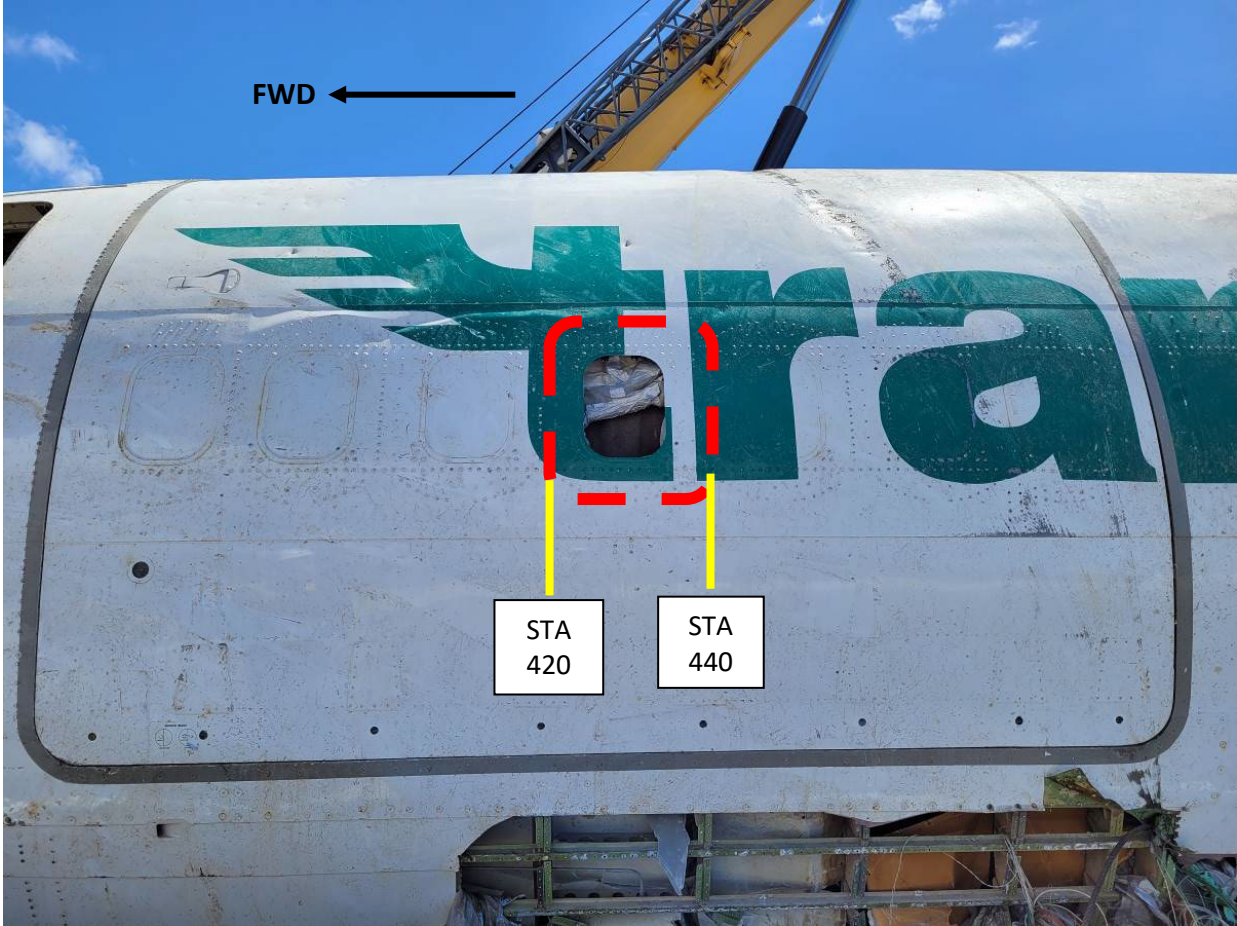


Figure 14. Missing window plug on left fuselage between STA 420 and STA 440 frames (Boeing photo)

Figure 15 shows diagonal skin wrinkles/buckles in the right forward fuselage skin near STA 435.

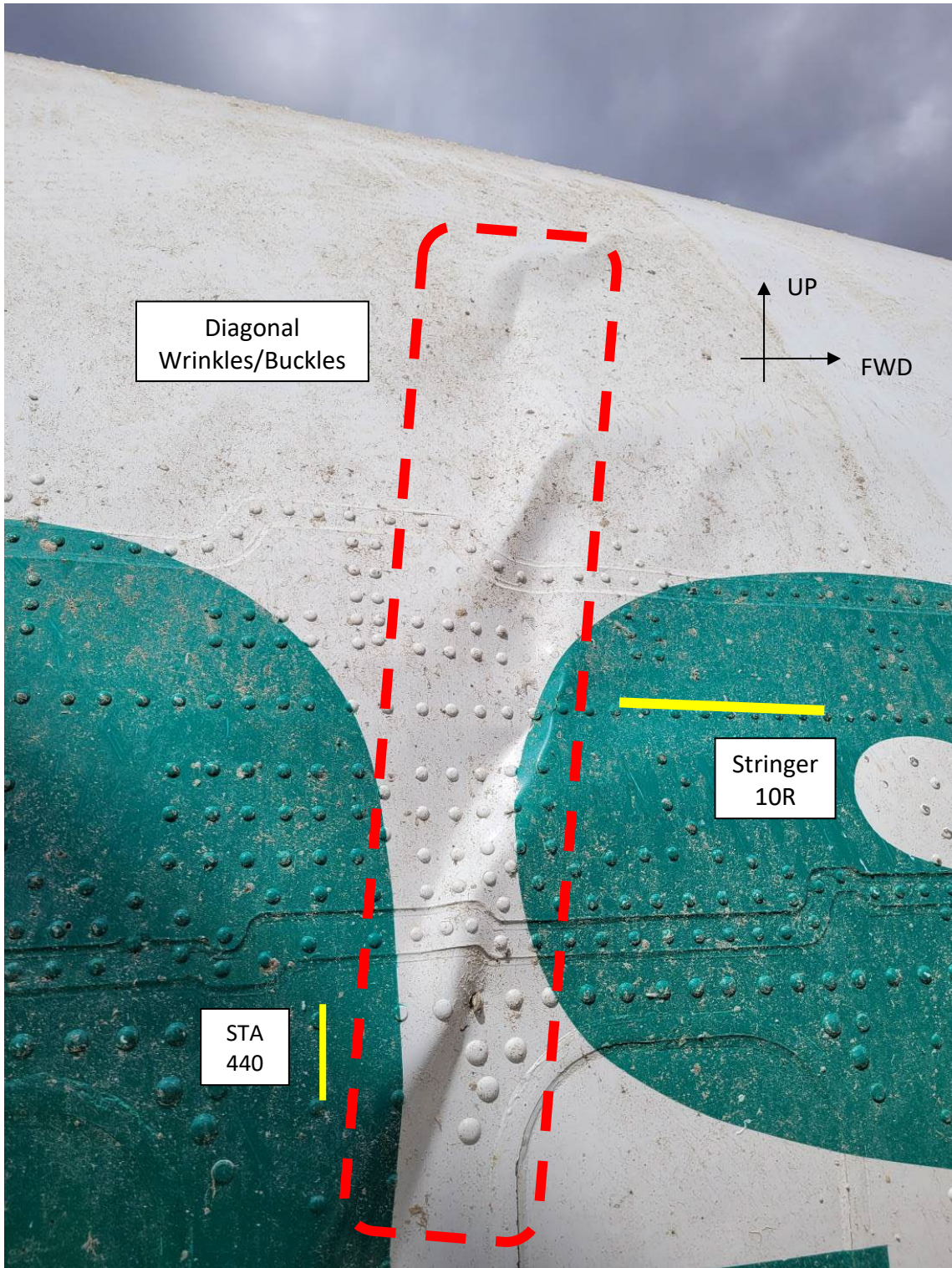


Figure 15. Right forward fuselage skin diagonal wrinkles near STA 435 (Boeing photo)

Figure 16 shows diagonal skin wrinkles in the right fuselage forward of the STA 540 separation location.

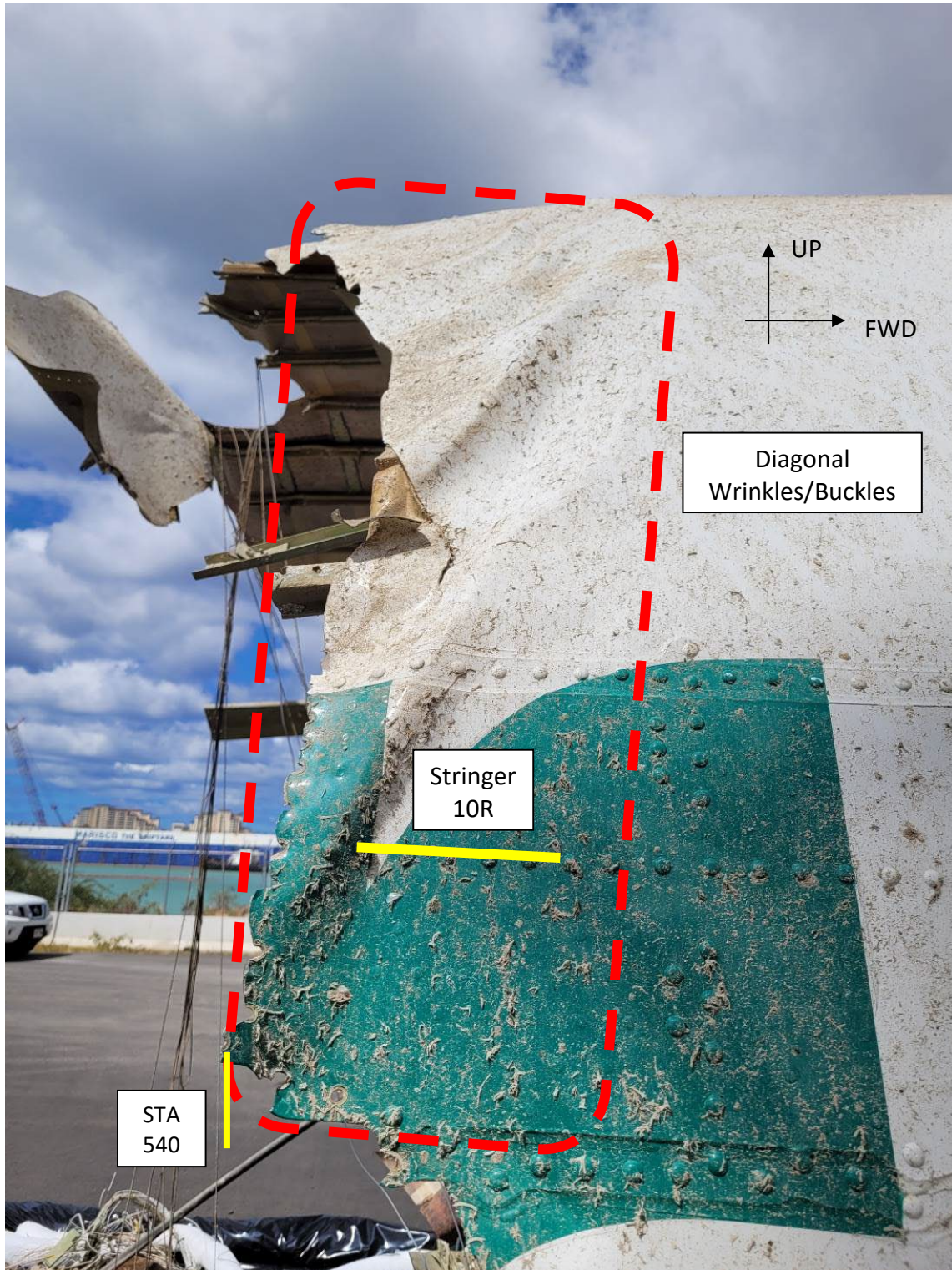


Figure 16. Right forward fuselage skin diagonal wrinkles forward of separation (Boeing photo)

Figure 17 shows the left fuselage damage between STA 400 and STA 480 below the WL 208 floor structure. Multiple rivets were pulled-through and there was aftward deformation of the STA 420, 440 and 460 frames between S-20L and S-21L, outlined in red.

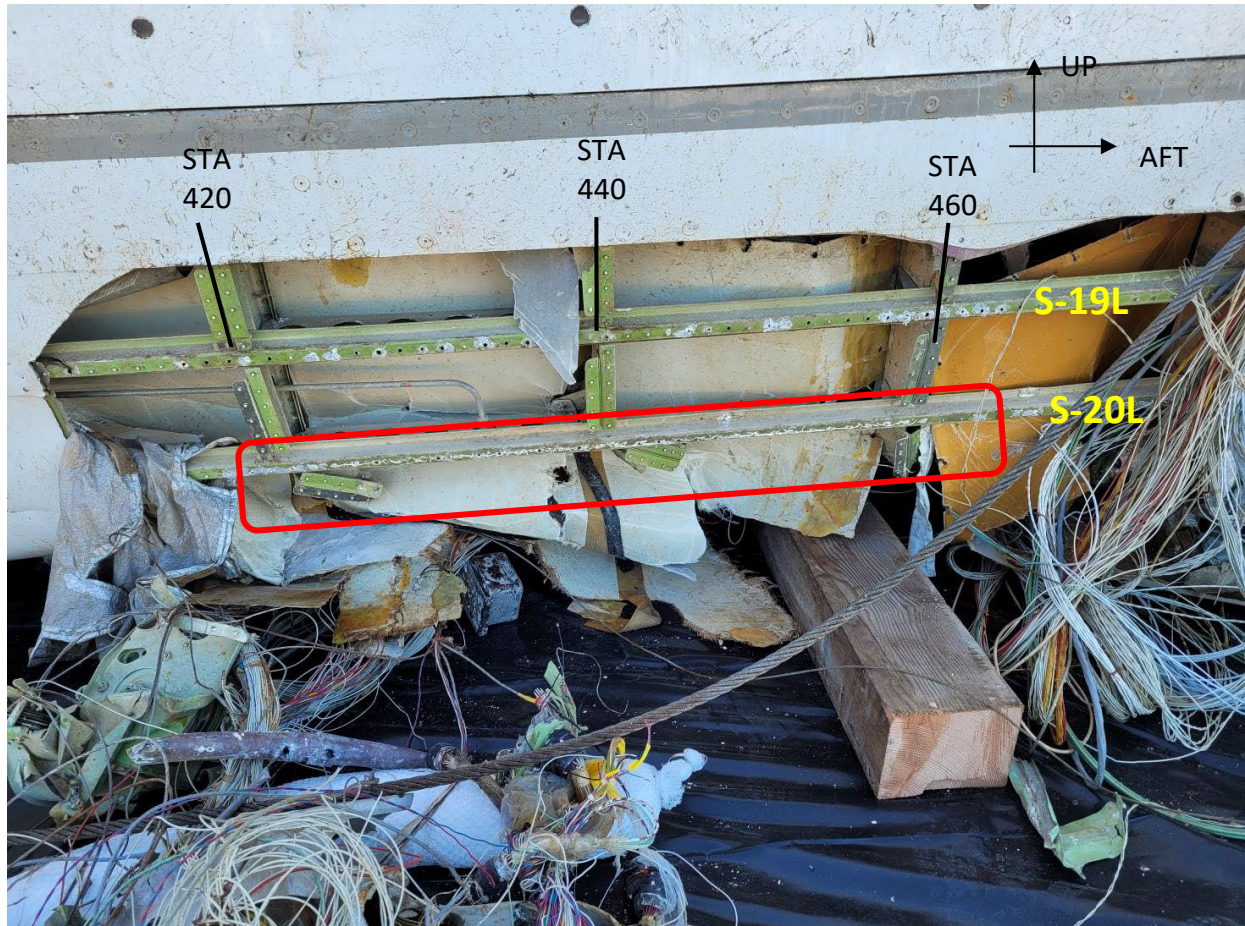


Figure 17. Left fuselage damage below floor location (Boeing photo)

Figure 18 shows a close-up of the aftward deformation of the STA 420 frame between stringer S-20L and S-21L. STA 440 and 460 frame damage between stringers S-20L and S-21L was similar.

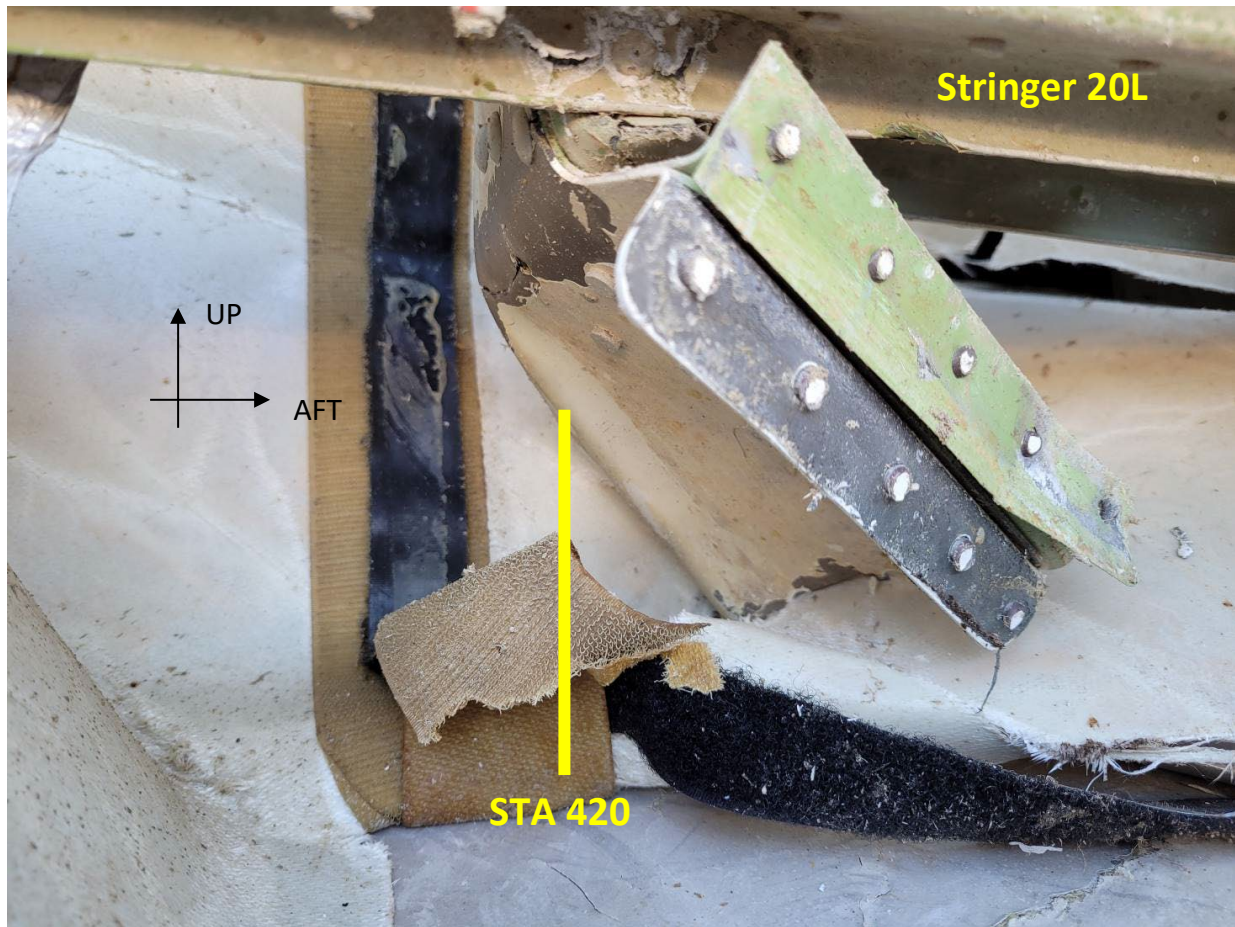


Figure 18. Left fuselage STA 420 frame damage detail (Boeing photo)

Figure 20 shows a detailed view of the forward fuselage section upper left separation region near STA 540 as outlined in red in Figure 19. The STA 540 frame is also the wing attachment location (pickle fork attachment to center section front spar).



Figure 19. Left forward fuselage (Boeing photo)

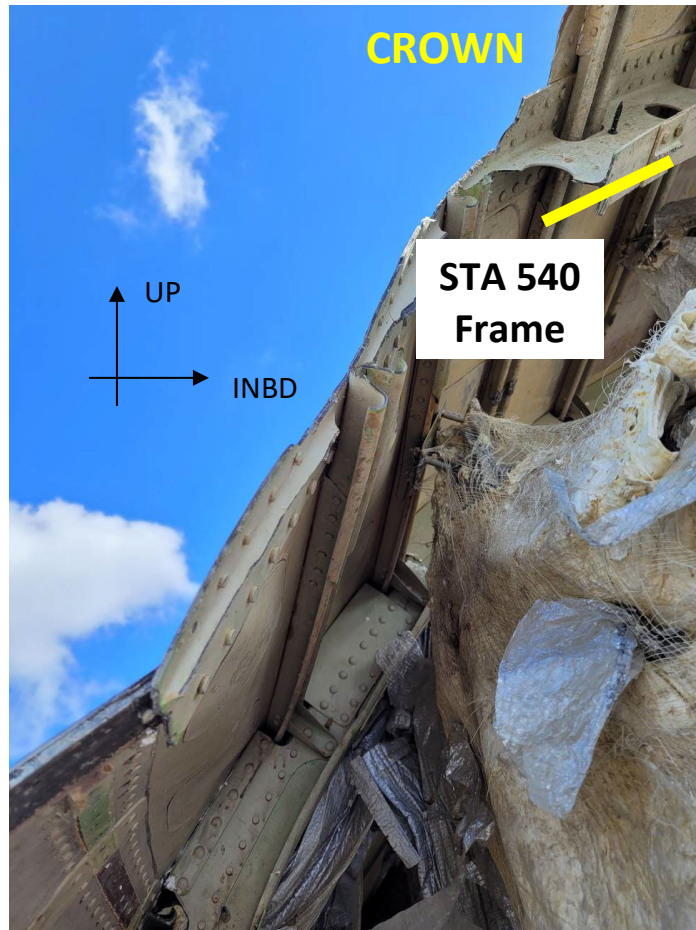


Figure 20. Left STA 540 separation location, looking up (Boeing photo)

Figure 21 shows the forward fuselage section left side separation region near STA 540. The STA 540 frame is also the wing attachment location (pickle fork attachment to center section front spar).

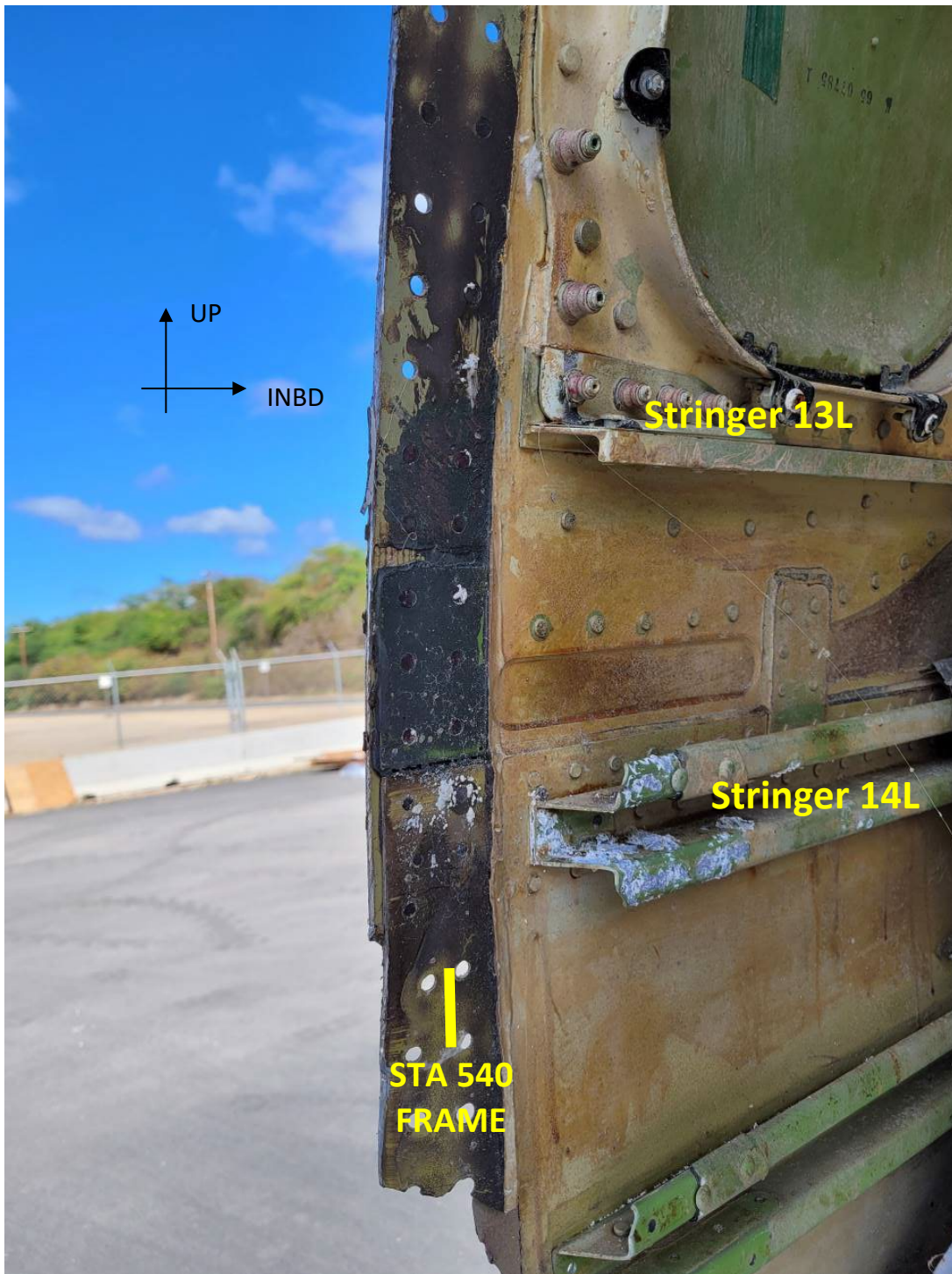


Figure 21. Left STA 540 separation location side view (Boeing photo)

Figure 22 shows the forward fuselage section Main Deck Floor structure damage. A portion of the RH floor structure was missing just right of the centerline. The ball mats remained installed along the right side of the fuselage. The LH floor substructure, although damaged, was mostly intact and in-place.



Figure 22. Main Deck Floor structure damage, looking aft (Boeing photo)

Figure 23 shows the damage to the floor structure behind the cockpit. View is looking into the cabin from the LH Forward Entry Door opening. The right floor structure was more damaged than the left.



Figure 23. Floor structure damage behind the cockpit (Boeing photo)

Figure 24 shows a right side view of the NLG and wheel well structure which separated from the forward fuselage section.

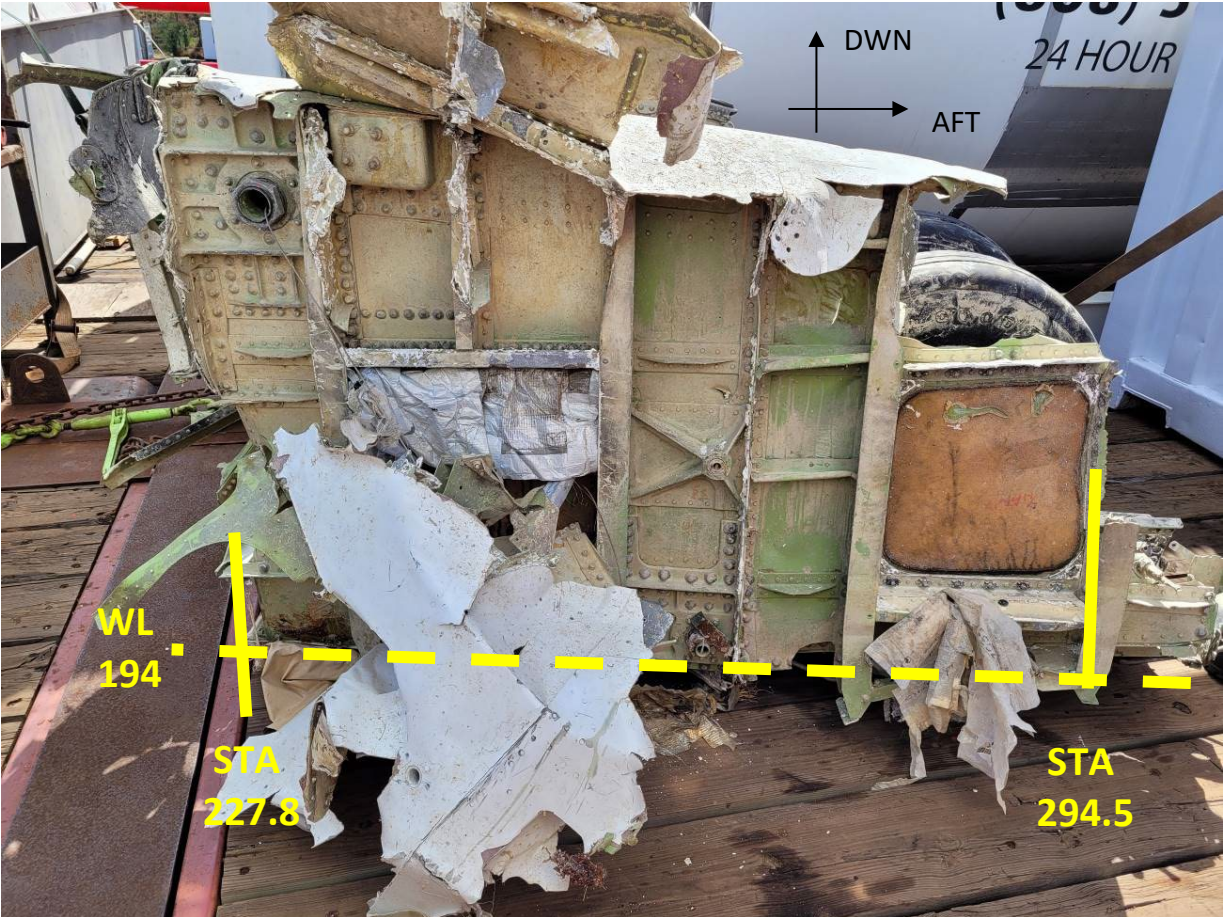


Figure 24. Right side view of NLG and wheel well structure (Boeing photo)

Figure 25 shows an aft side view (looking forward) of the NLG and wheel well structure which separated from the forward fuselage section. The aft wall of the wheel well was missing from the recovered assembly. A portion of the attaching fuselage skin panels adjacent to the wheel well were attached and flared away from the landing gear assembly as outlined in red.

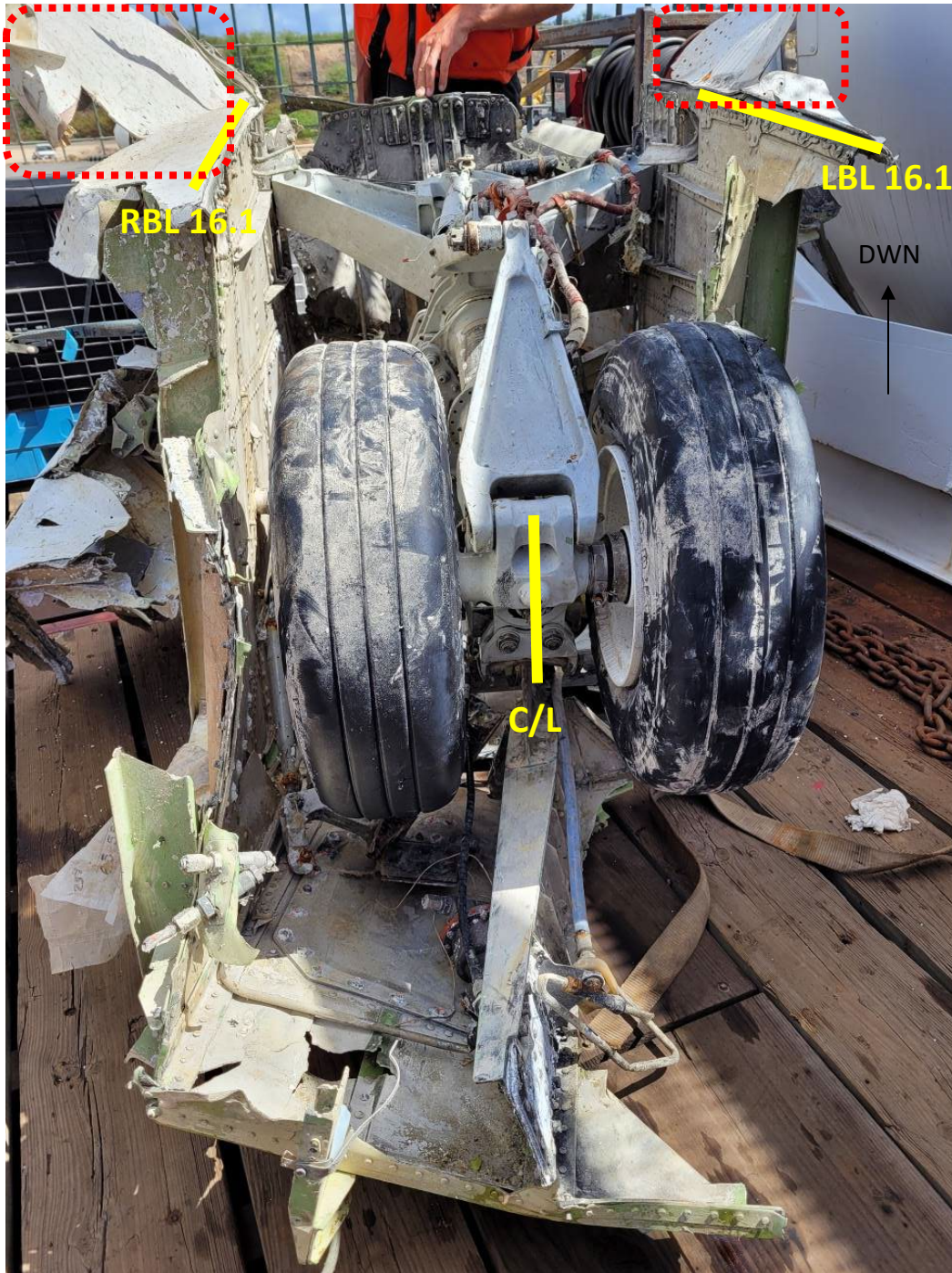


Figure 25. Aft side view of NLG and wheel well structure, looking forward (Boeing photo)

Figure 26 shows a forward side view (looking aft) of the NLG and wheel well structure which separated from the forward fuselage section. The center portion of the wheel well forward bulkhead common to the Jury Fitting was deformed aftward (i.e. into landing gear bay) as outlined in red.

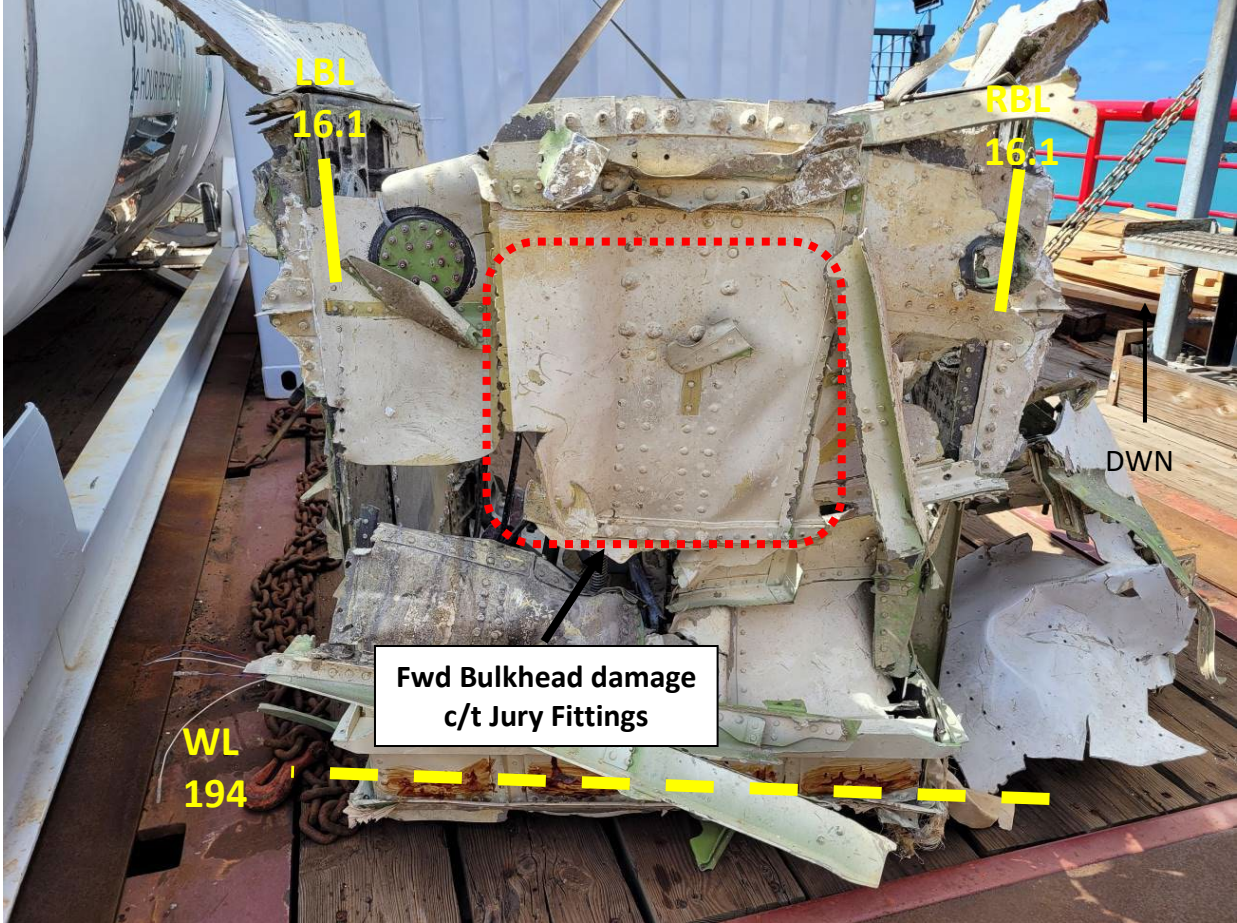


Figure 26. Forward side view of NLG and wheel well structure and forward bulkhead, looking aft (Boeing photo)

Figure 27 shows a left side view of the NLG and wheel well structure which separated from the forward fuselage section.

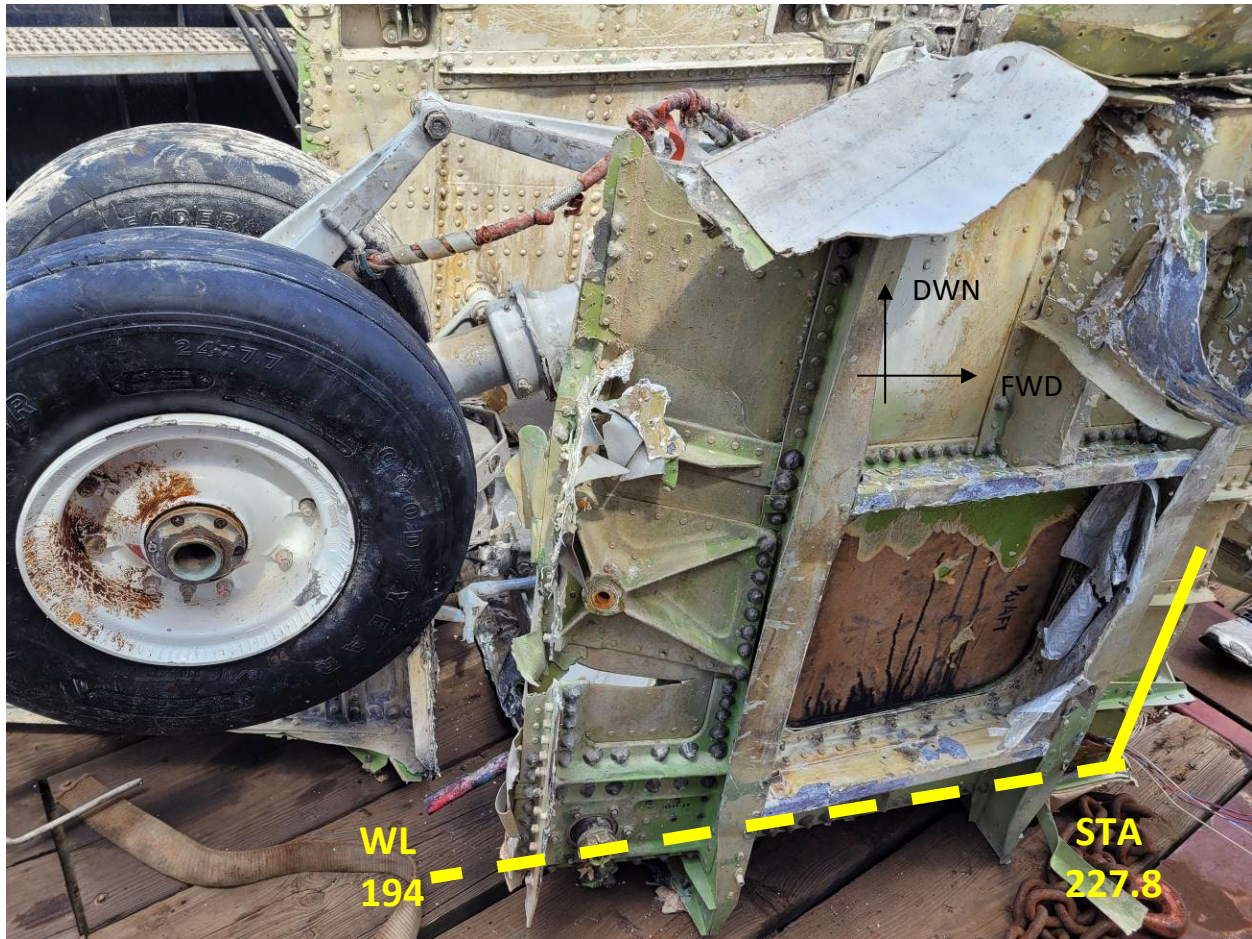


Figure 27. Left side view of NLG and wheel well structure, looking right (Boeing photo)

Figure 28 shows the inside of the lower portion of the forward wall of the wheel well structure which separated from the forward fuselage section. The lower portions of the Jury Fittings are bent aft. Damage included buckled upstanding fitting flanges on both fittings.

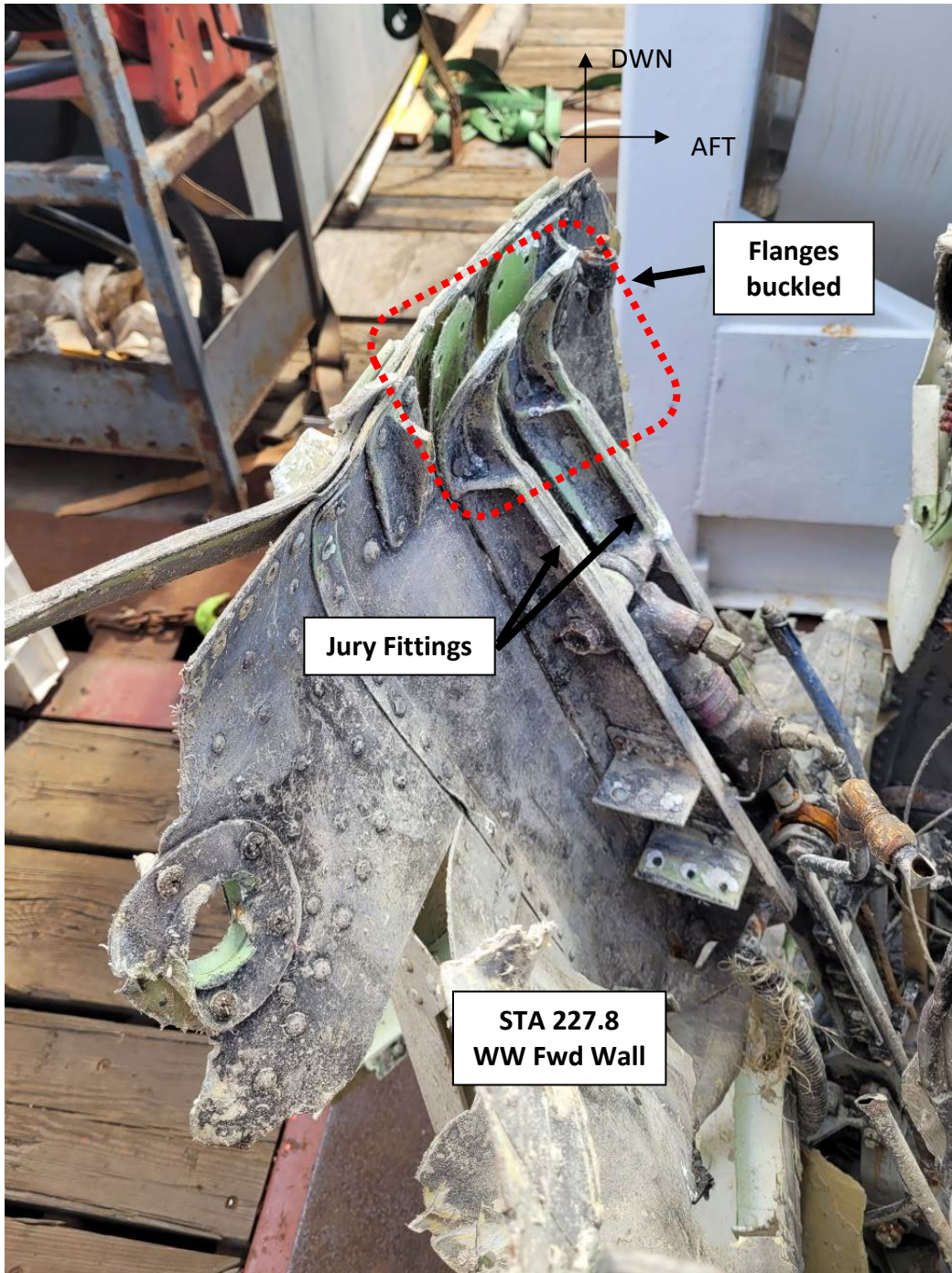


Figure 28. NLG and wheel well structure Jury Fitting damage (Boeing photo)

The LH forward entry door was ajar during the initial survey. The RH forward entry door and LH aft entry door were closed. The LH aft entry door was deactivated. The overwing exits were closed. The LH forward, RH forward, and RH aft doors were opened during the recovery and examination. Figure 29 shows the LH Forward Entry Door crease and crack damage below the lower hinge.

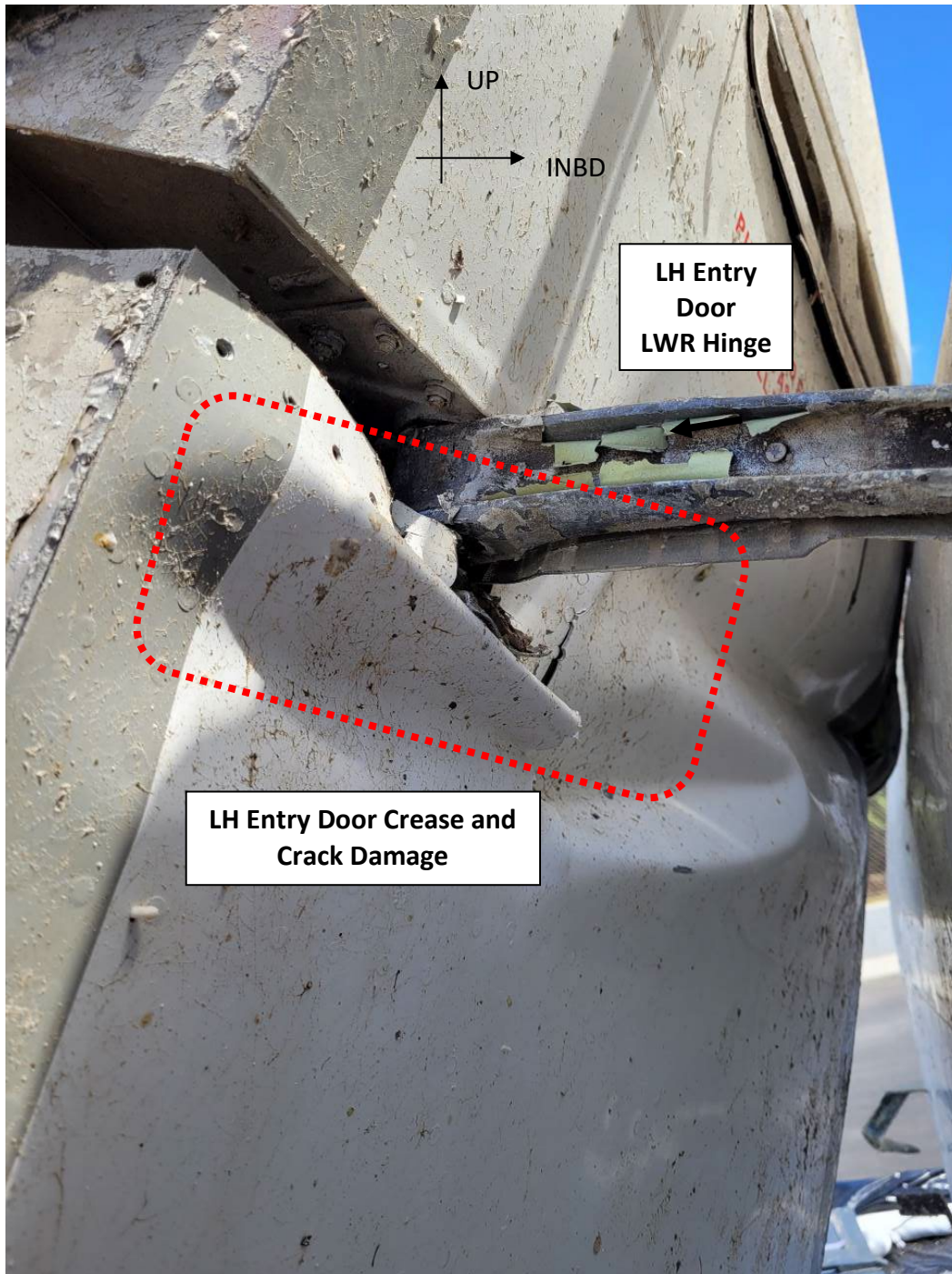


Figure 29. Left Forward Entry Door crease and crack damage (Boeing photo)

Figure 30 shows the LH Forward Entry Door exterior handle damage.

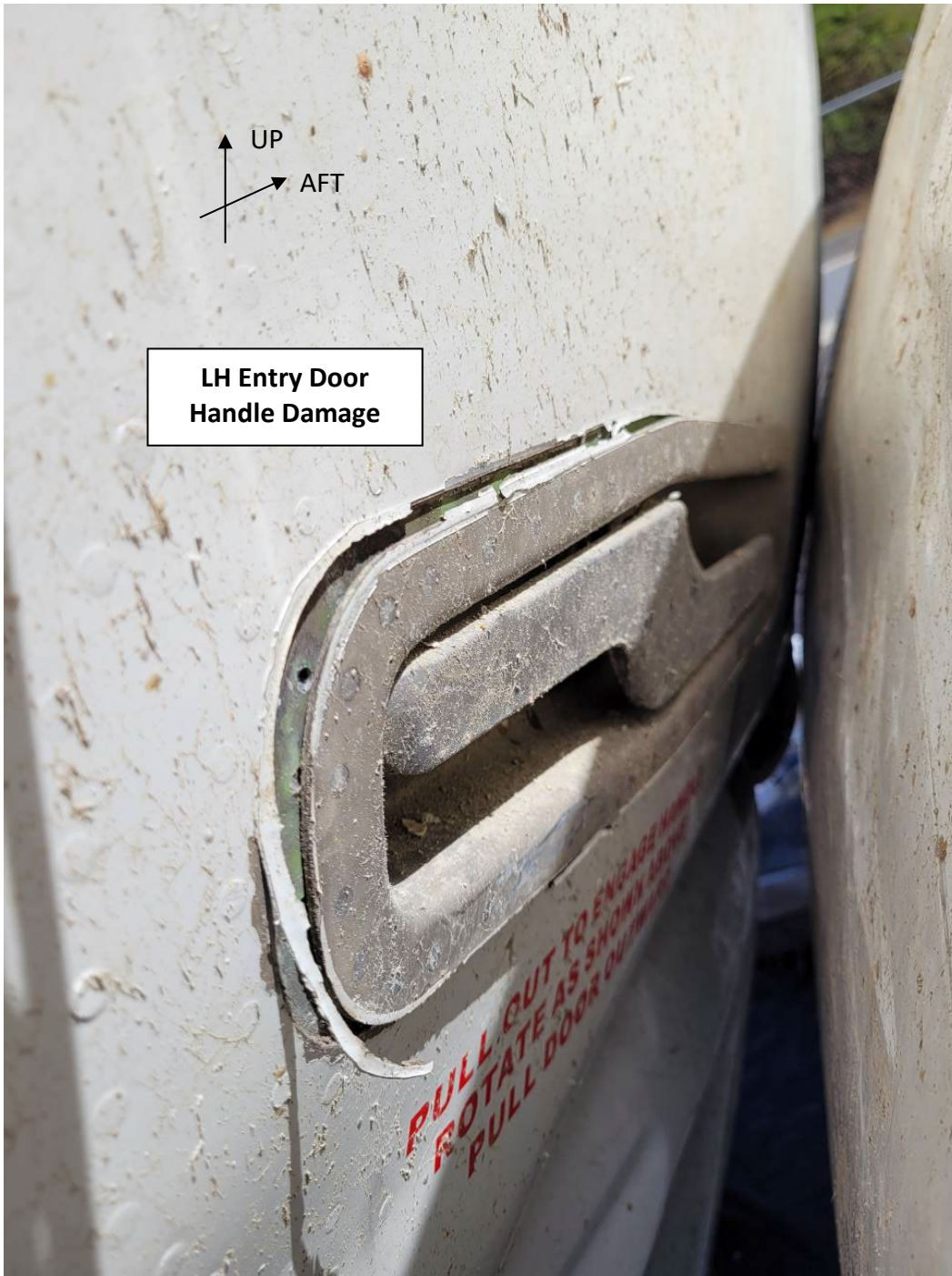


Figure 30. Left Forward Entry Door exterior handle damage (Boeing photo)

Figure 31 shows LH Forward Entry Door lower hinge mechanism rod fracture.

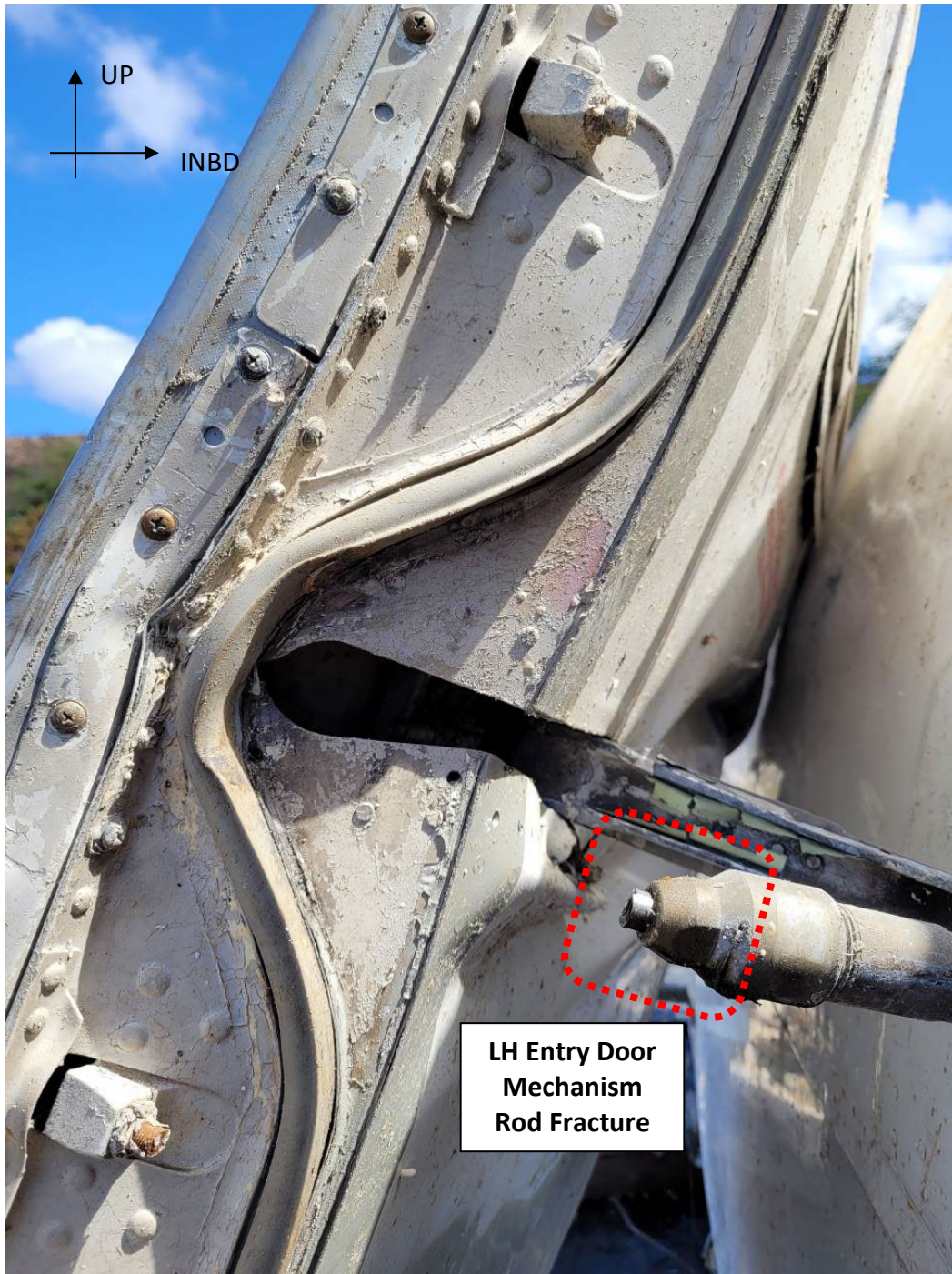


Figure 31. Left Forward Entry Door lower hinge mechanism rod damage (Boeing photo)

Figure 32 shows close-ups of the LH Forward Entry Door lower hinge mechanism rod fracture within the door and outside the door.

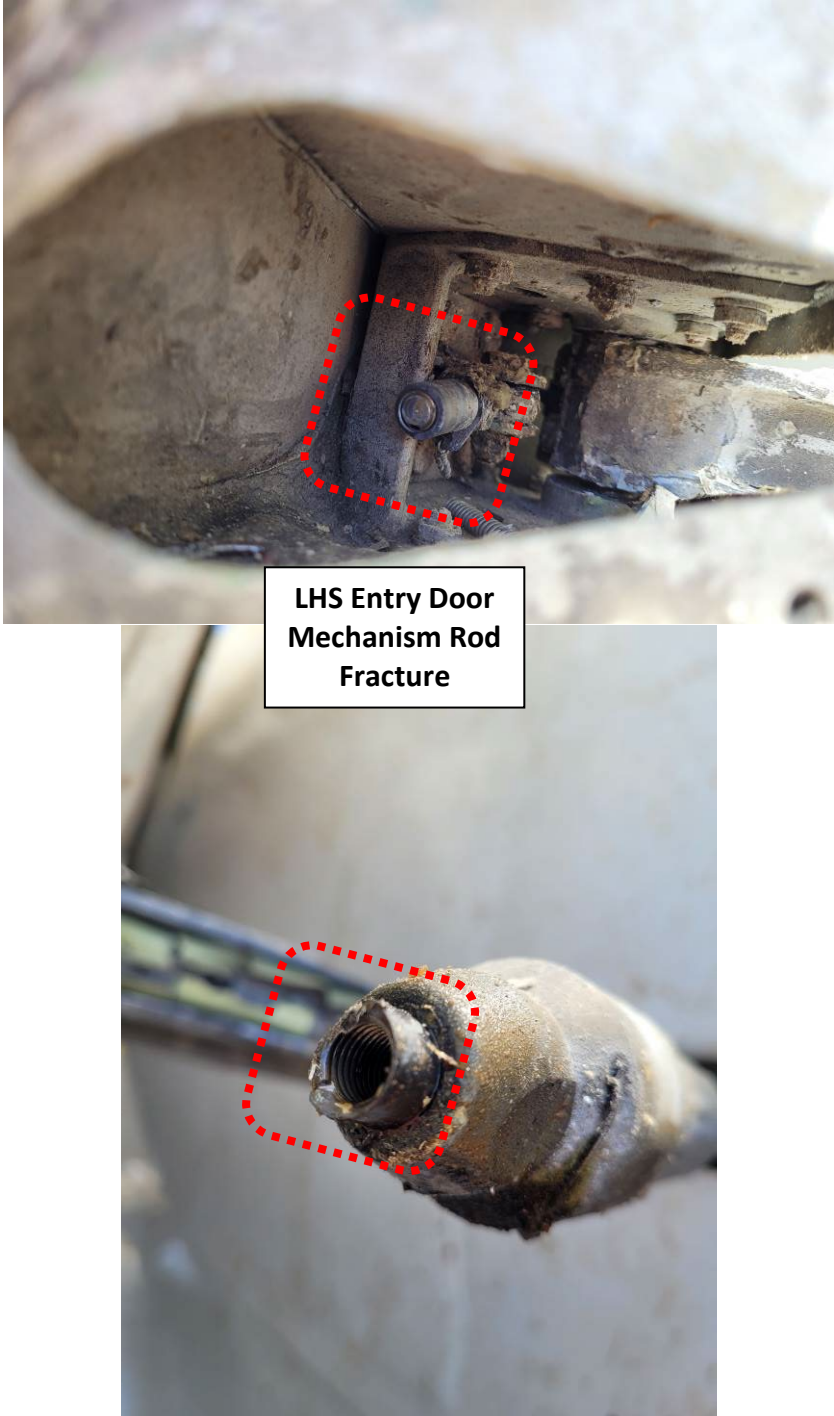


Figure 32. Left Forward Entry Door lower hinge mechanism rod fracture (Boeing photo)

Figure 33 shows close-ups of the LH Forward Entry Door upper hinge mechanism fracture at the attachment to the fuselage structure.

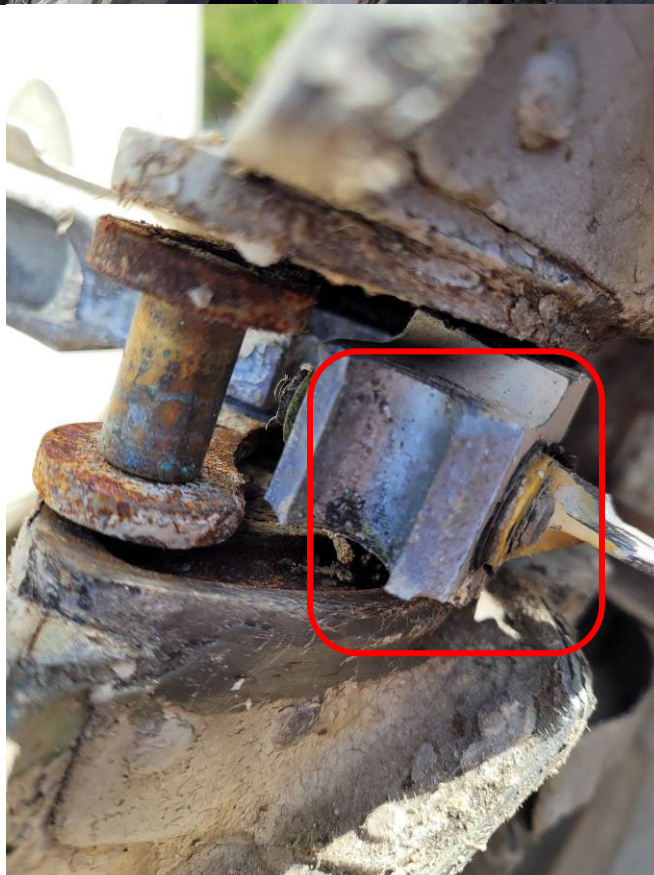


Figure 33. Left Forward Entry Door upper hinge mechanism fracture (Boeing photo)

Figure 34 shows the RH Forward Entry Door for comparison, relatively undamaged.



Figure 34. Right Forward Entry door, looking aft (Boeing photo)

Figure 35 shows the LH Entry Door lower magnesium kick pan corrosion damage. All other magnesium door parts (upper & lower, LH and RH) were similarly corroded.



Figure 35. Left Forward Entry Door lower kick pan corrosion (Boeing photo)

Figure 36 shows a view of the forward right side of the aft fuselage and right outboard wing portion of the recovered airplane. Figure 36 also shows the STA 540 separation location from the forward fuselage.



Figure 36. Right forward view of aft fuselage section (Boeing photo)

Figure 37 shows a view of the aft right side of the aft fuselage and right outboard wing portion of the recovered airplane. Figure 37 also shows the STA 540 separation location from the forward fuselage.



Figure 37. Right aft view of aft fuselage section (Boeing photo)

Figure 38 shows a view of the aft left side of the aft fuselage and left outboard wing portion of the recovered airplane. Figure 38 also shows the STA 540 separation location from the forward fuselage.



Figure 38. Left aft view of aft fuselage section (Boeing photo)

Figure 39 shows a view of the left forward side of the aft fuselage and left outboard wing portion of the recovered airplane. Figure 39 also shows the STA 540 separation location from the forward fuselage.



Figure 39. Left forward view of aft fuselage section (Boeing photo)

Figure 40 shows a view of the forward side of the recovered aft fuselage at the STA 540 separation. Figure 40 also shows the crown skin damage between the STA 540 separation and STA 639 as well as the WCS Front Spar, Spanwise Beam and upper/lower wing skin damage.

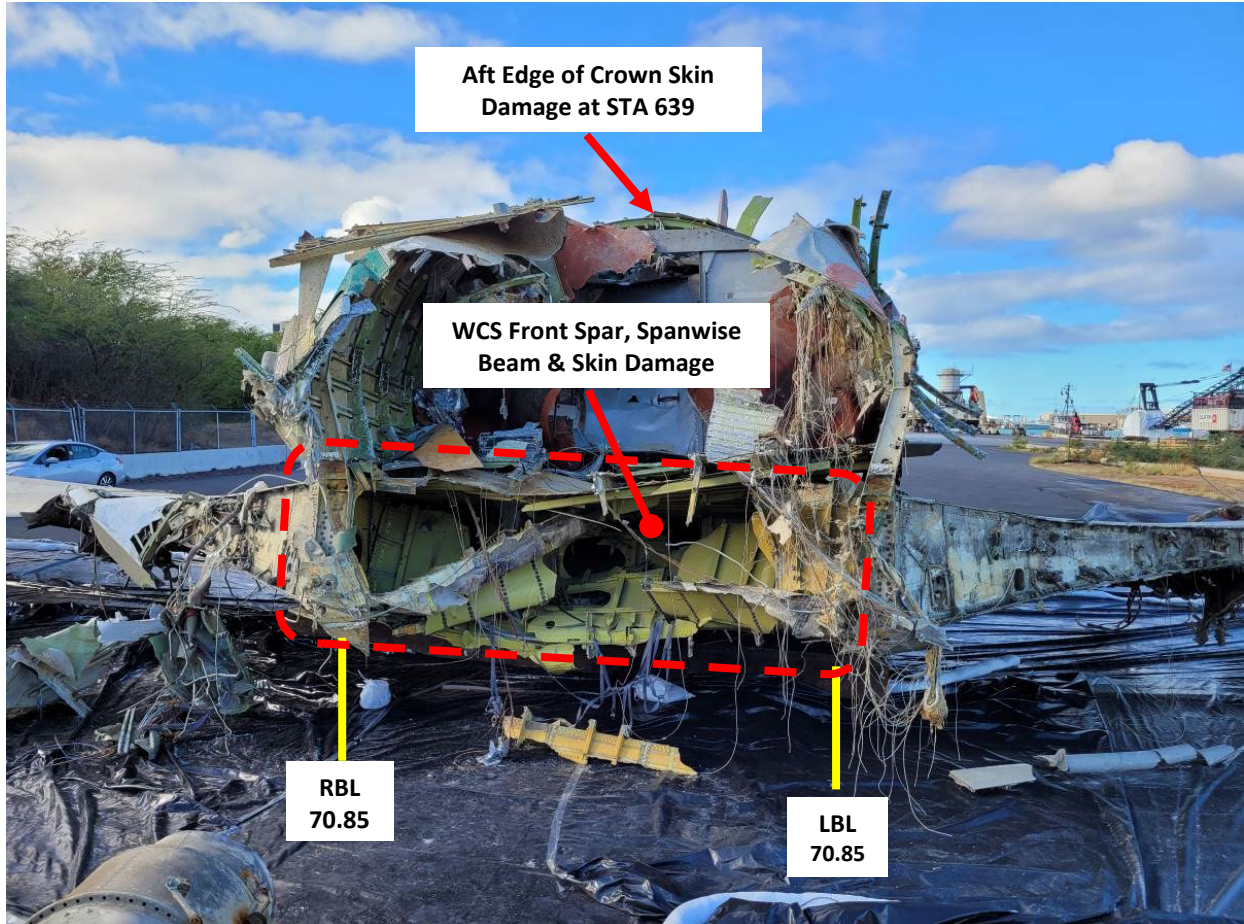


Figure 40. Forward view of aft fuselage section STA 540 separation (Boeing photo)

Figure 41 shows a forward side view looking aft of multiple recovered portions of the Keel Beam Assembly, Lower Beams & Heat Exchangers arranged as they were relationally oriented on the airplane. There was aftward deformation of the lower BL 0 portion of the Front Spar Pressure Web into the Keel Beam Assembly.

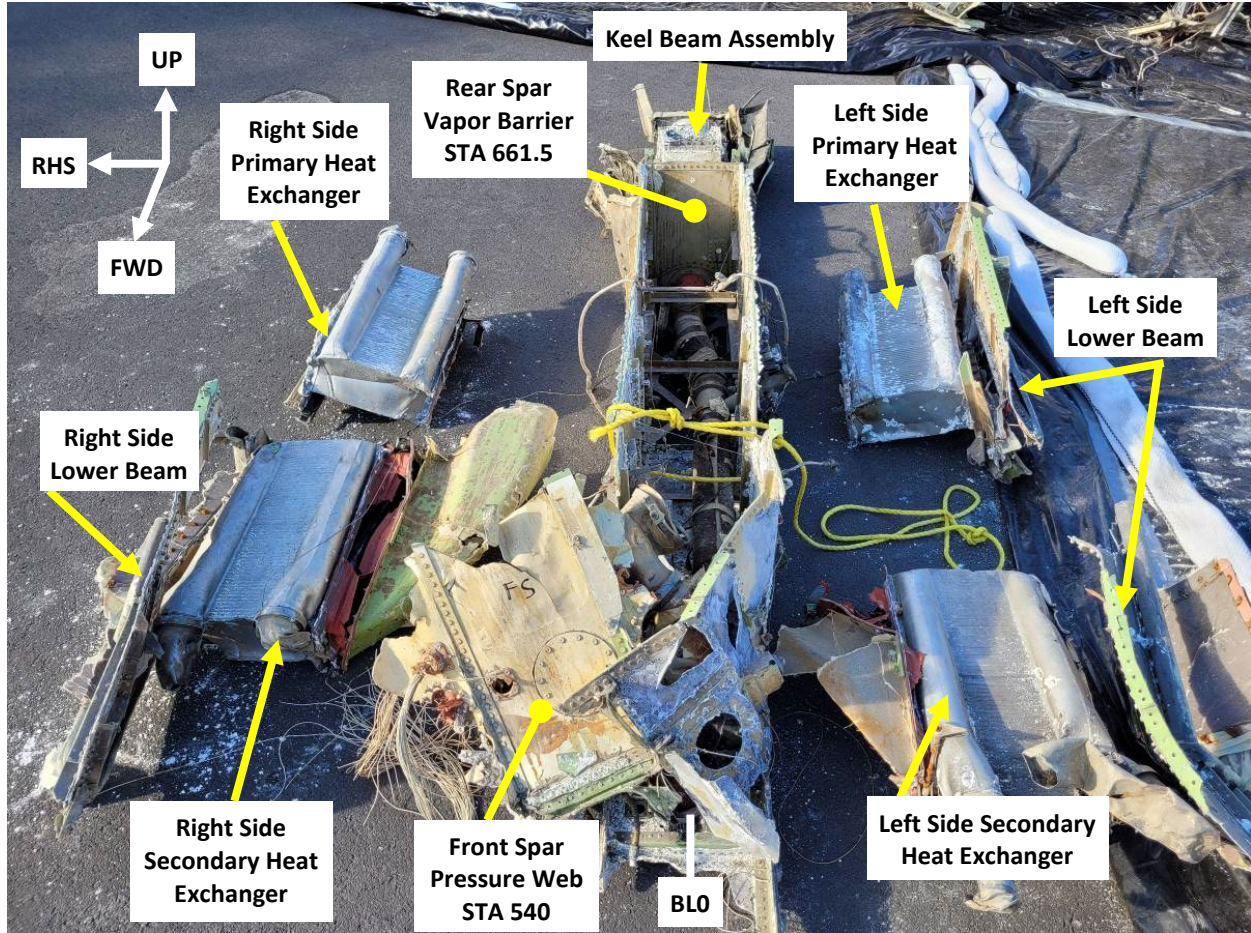


Figure 41. Forward side view of Keel Beam Assembly, looking aft (Boeing photo)

Figure 42 shows a right side view looking left of multiple recovered portions of the Keel Beam Assembly, Lower Beams & Heat Exchangers arranged as they were relationally oriented on the airplane. There was aftward deformation of the lower BL 0 portion of the Front Spar Pressure Web into the Keel Beam Assembly. The right side primary heat exchanger had a portion of the right lower beam lower chord still attached. The remaining aft portion of the lower beam remained attached in its production location on the airplane WCS.

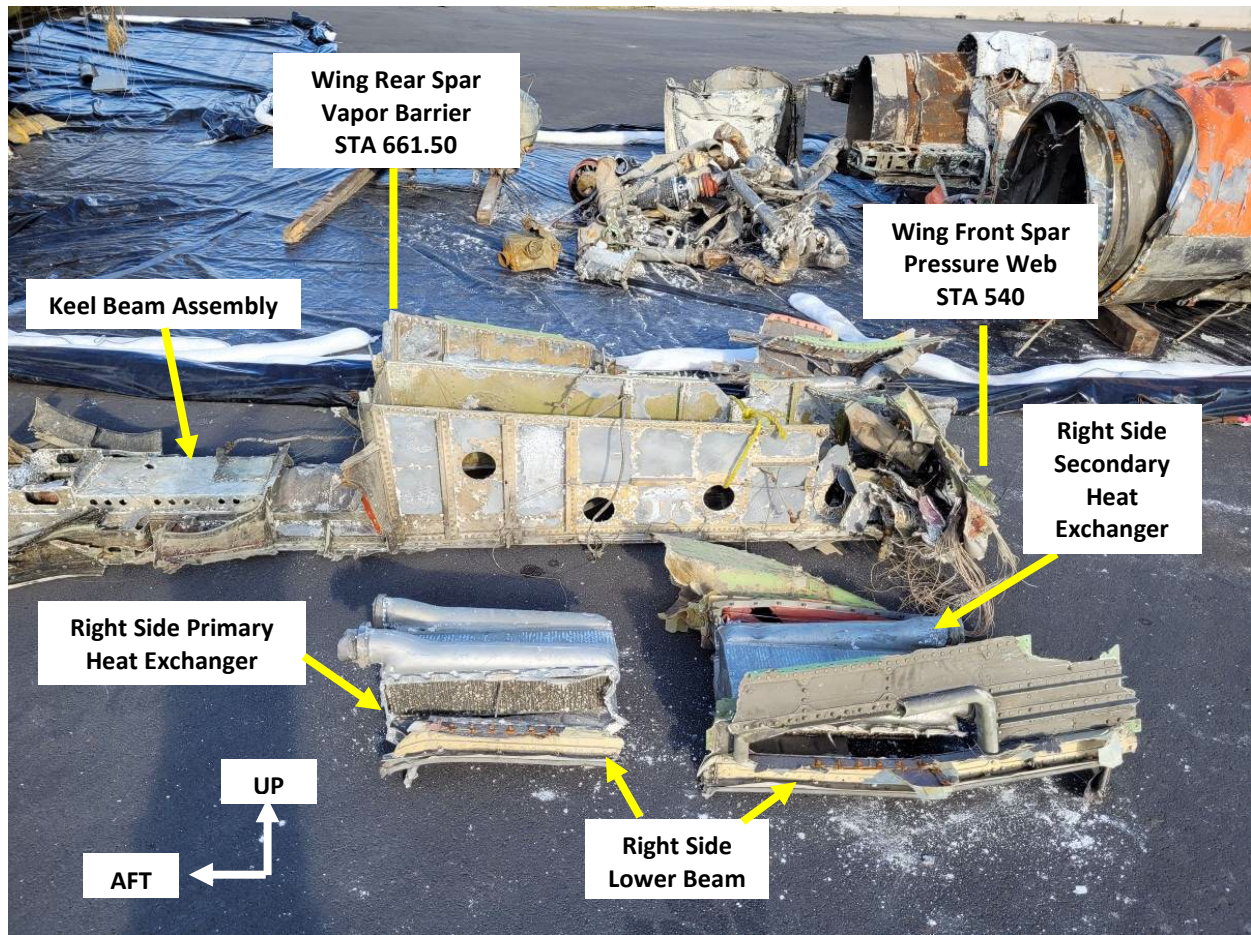


Figure 42. Right side view of Keel Beam Assembly, looking left (Boeing photo)

Figure 43 shows an aft view looking forward of multiple recovered portions of the Keel Beam Assembly, Lower Beams & Heat Exchangers arranged as they were relationally oriented on the airplane. The aft wheel well bulkhead chords were separated from the Keel Beam Assembly at STA 727.

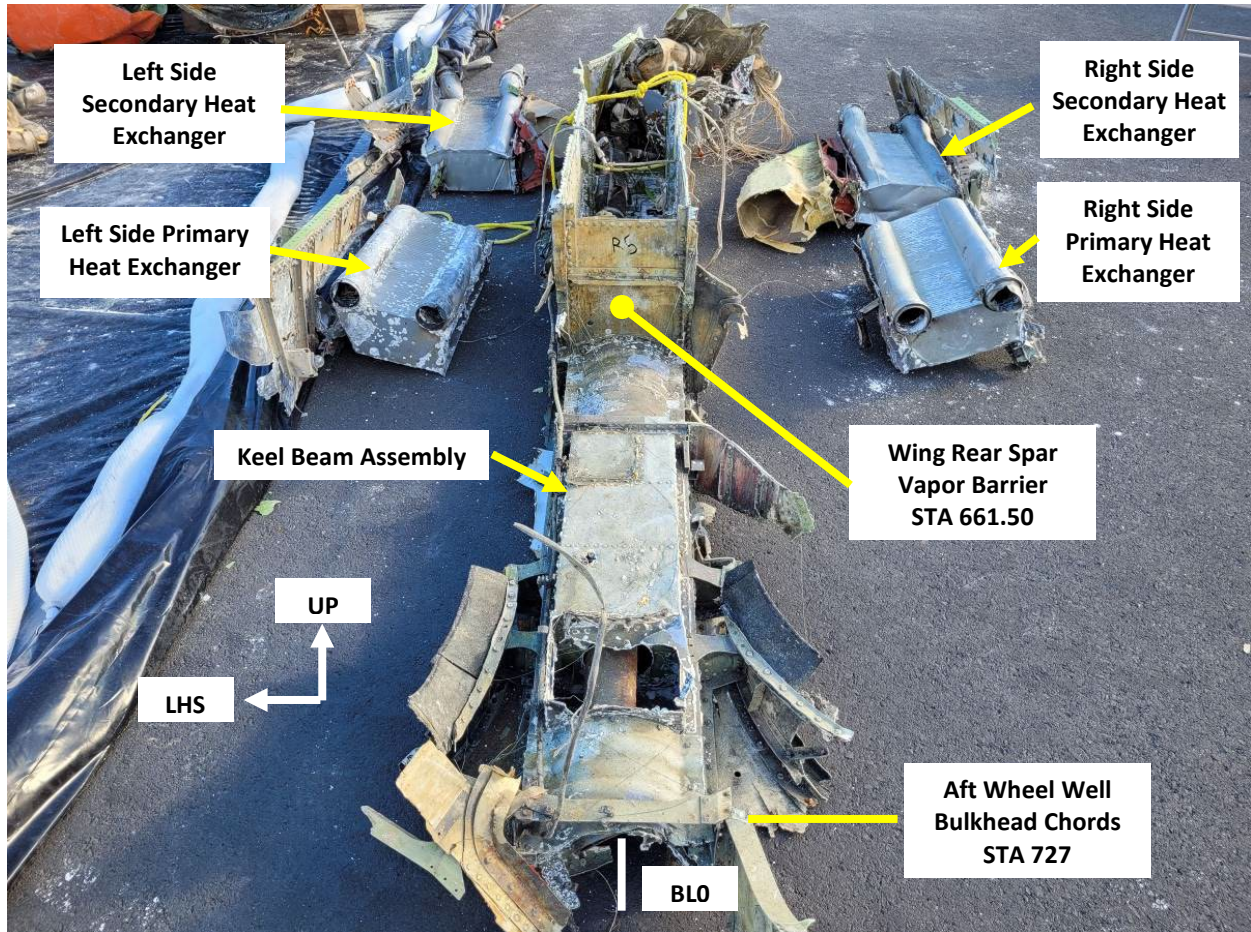


Figure 43. Aft view of Keel Beam Assembly, looking forward (Boeing photo)

Figure 44 shows a left side view looking right of multiple recovered portions of the Keel Beam Assembly, Lower Beams & Heat Exchangers arranged as they were relationally oriented on the airplane. Portions of the left side lower beams were attached to the heat exchangers. The remaining portion of the left side lower beams remained attached in their production locations on the airplane WCS.

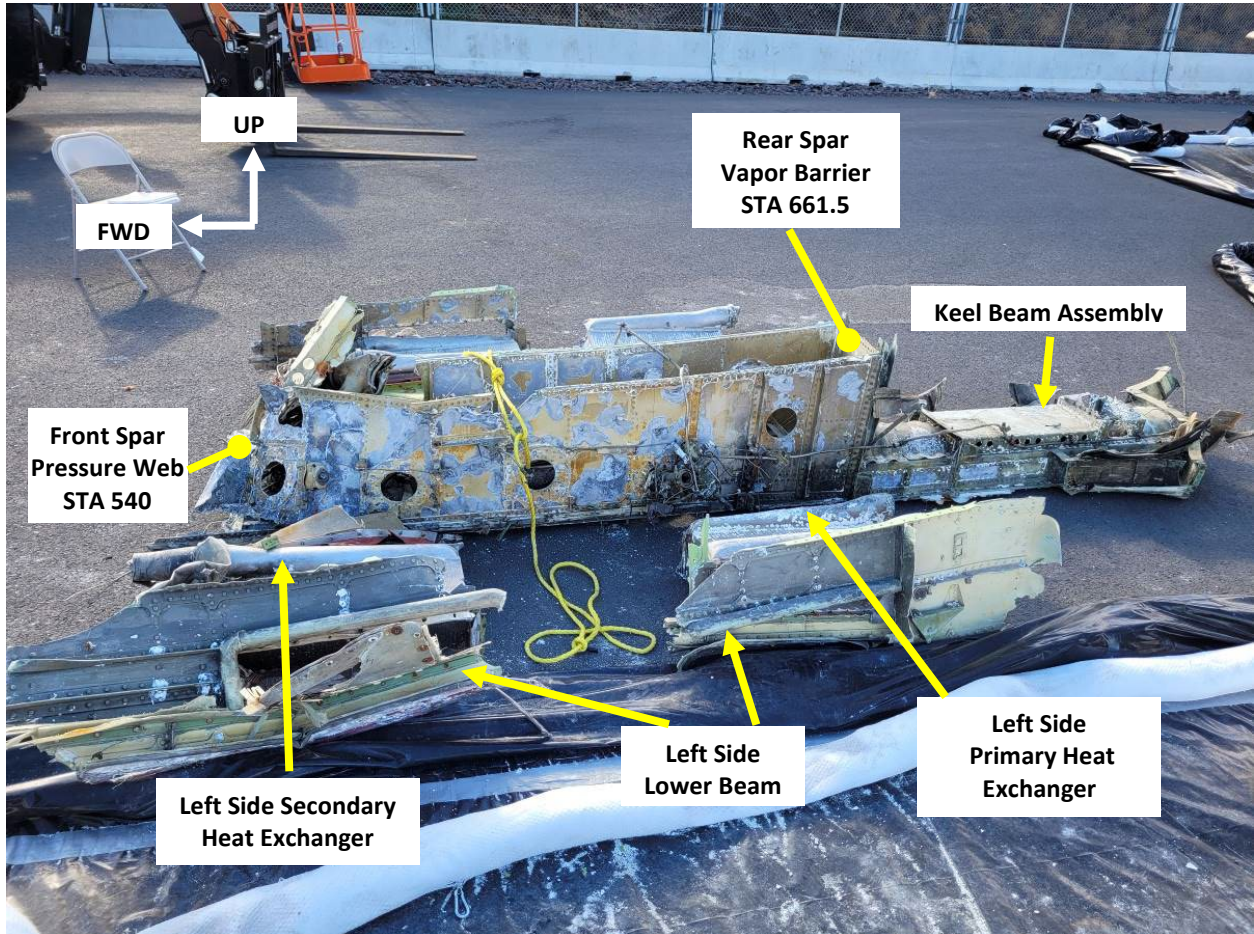


Figure 44. Left side view of Keel Beam Assembly, looking right (Boeing photo)

Figure 45 shows the WCS front spar damage at the STA 540 separation location. Portions of the Front Spar Lower Chord remained attached but were deformed up while much of the front spar web was missing or deformed aftward into the WCS fuel tank. The center portion of the Front Spar Upper Chord was found separated from the airplane and is also shown.

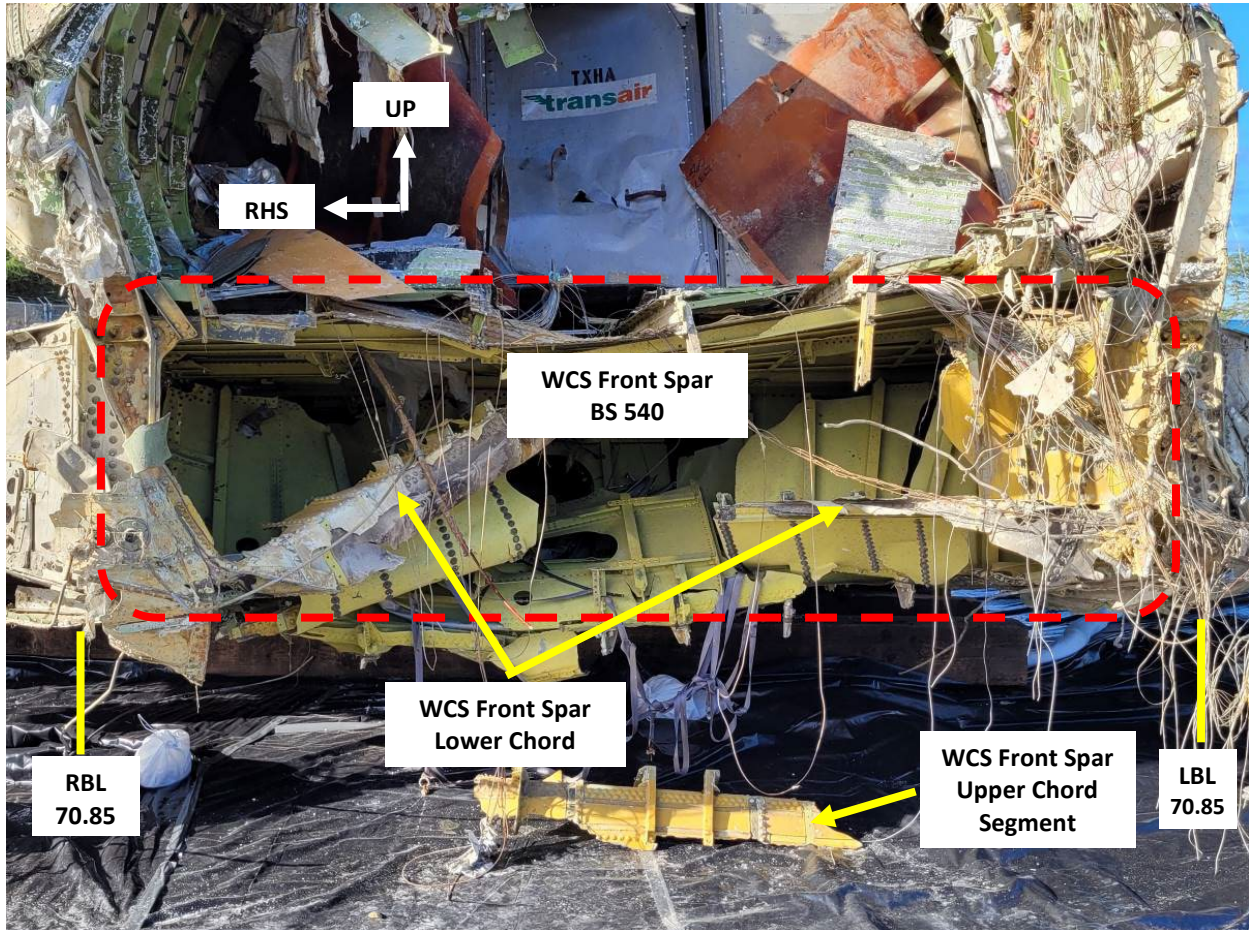


Figure 45. WCS Front Spar damage at STA 540 separation location, looking aft (Boeing photo)

Figure 46 shows the WCS Front Spar Upper Chord center portion that was found separated from the airplane held in its production location.

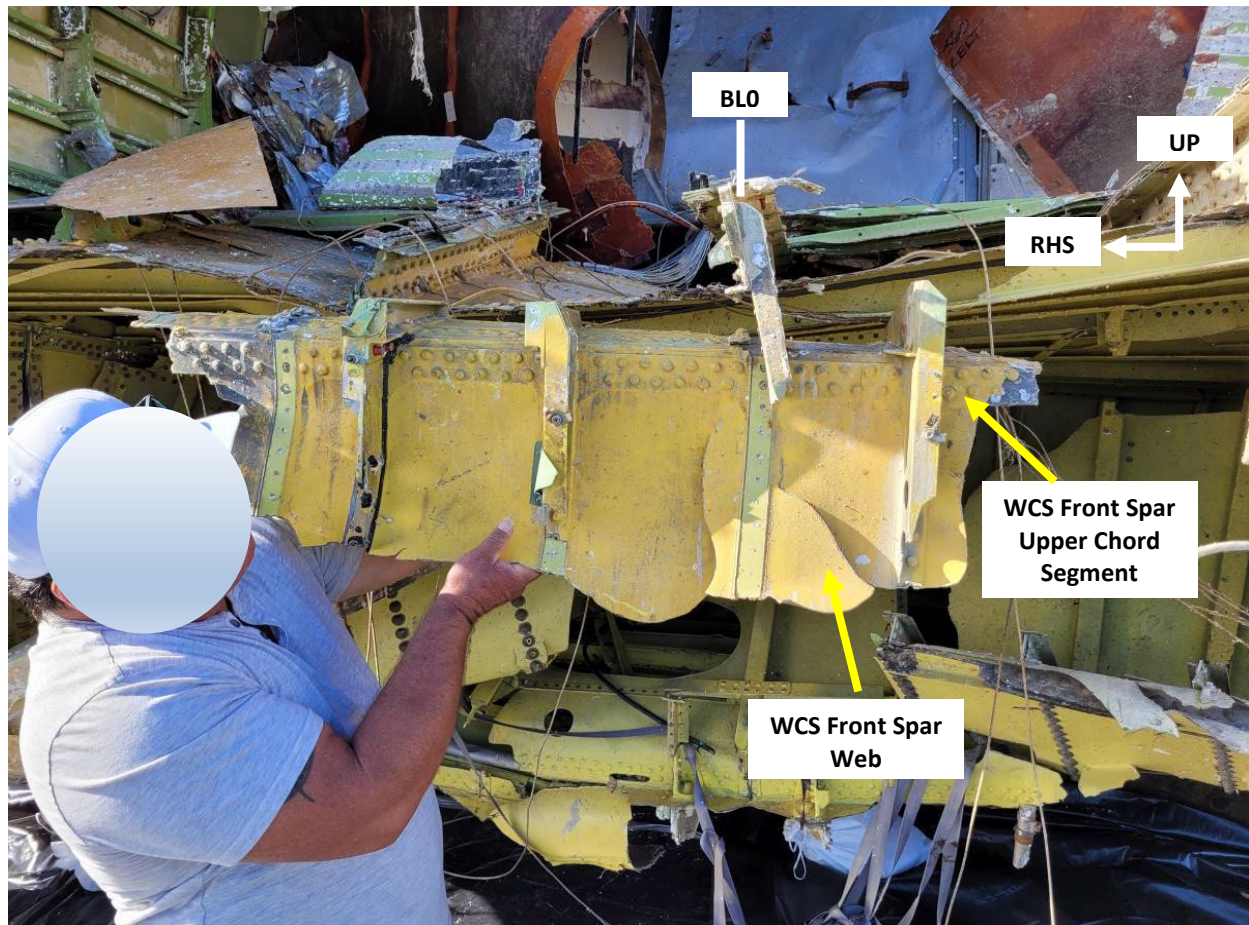


Figure 46. WCS Front Spar Upper Chord segment (Boeing photo)

Figure 47 shows the WCS Front Spar Lower Chord right side deformed upward and aft into the WCS tank.

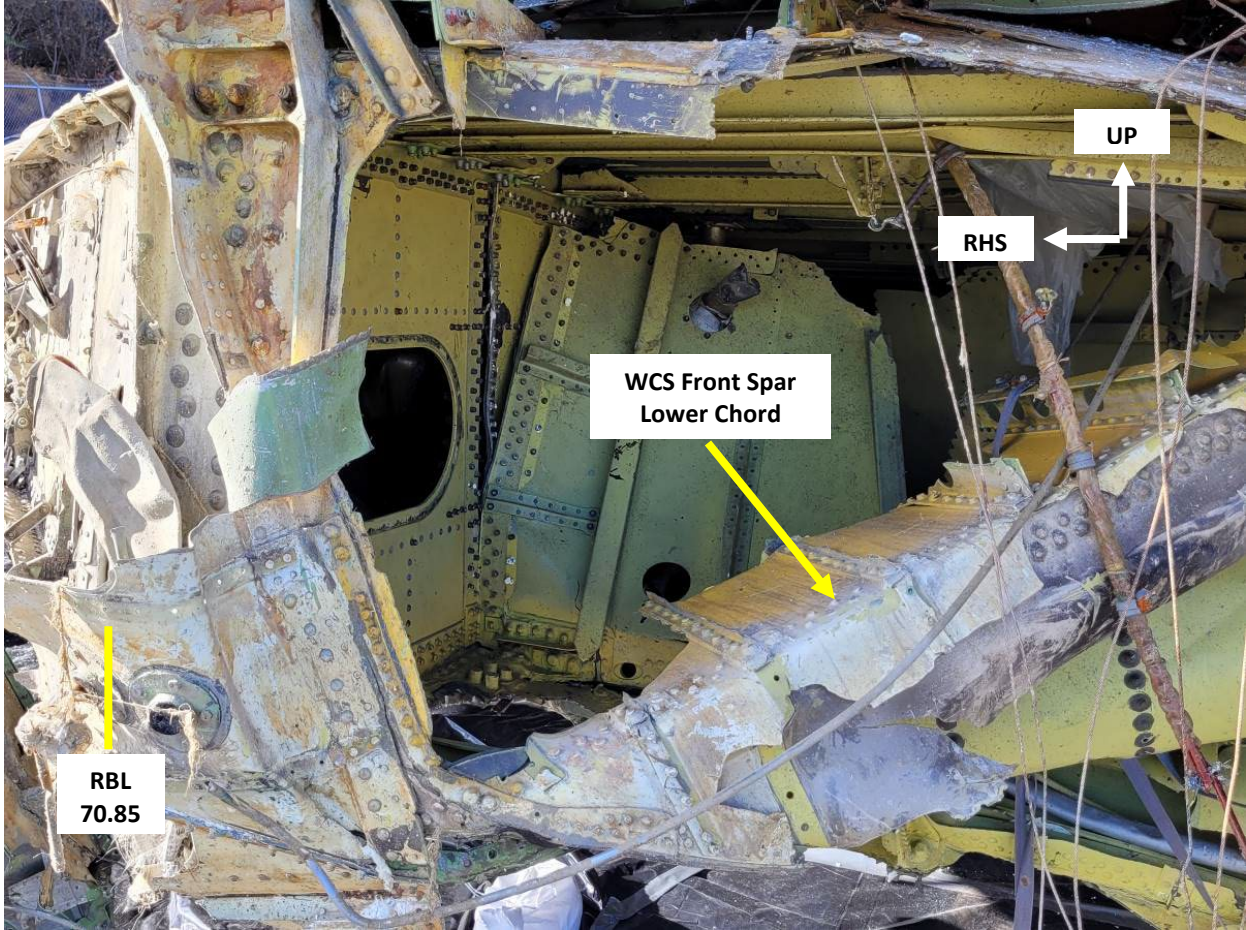


Figure 47. Right WCS Front Spar Lower Chord damage (Boeing photo)

Figure 48 shows the WCS Front Spar Lower Chord left side deformed upward and aft into the WCS fuel tank.



Figure 48. Left WCS Front Spar Lower Chord damage (Boeing photo)

Figure 49 shows the separation of the right side Spanwise Beam 2 from the Side of Body (SOB) Rib attach stiffener due to the aftward deformation of the Spanwise Beam.

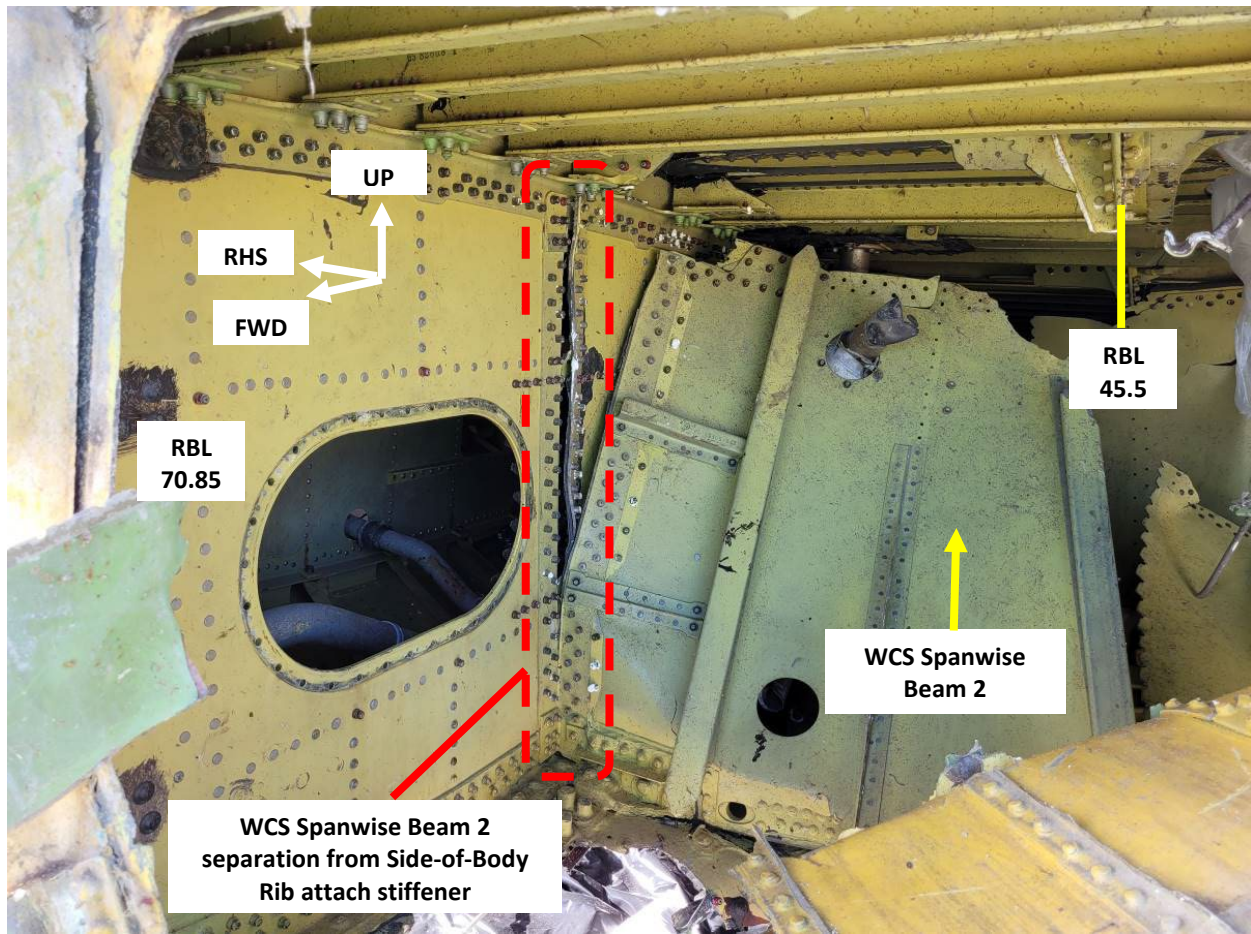


Figure 49. Damage to the right side WCS Spanwise Beam 2-to-SOB Rib attach stiffener (Boeing photo)

Figure 50 shows the right side of the Spanwise Beam 2 Upper Chord and Web fracture due to the aftward deformation of the spanwise beam web. The left side of the Spanwise Beam 2 Upper Chord was found to be fractured similarly.

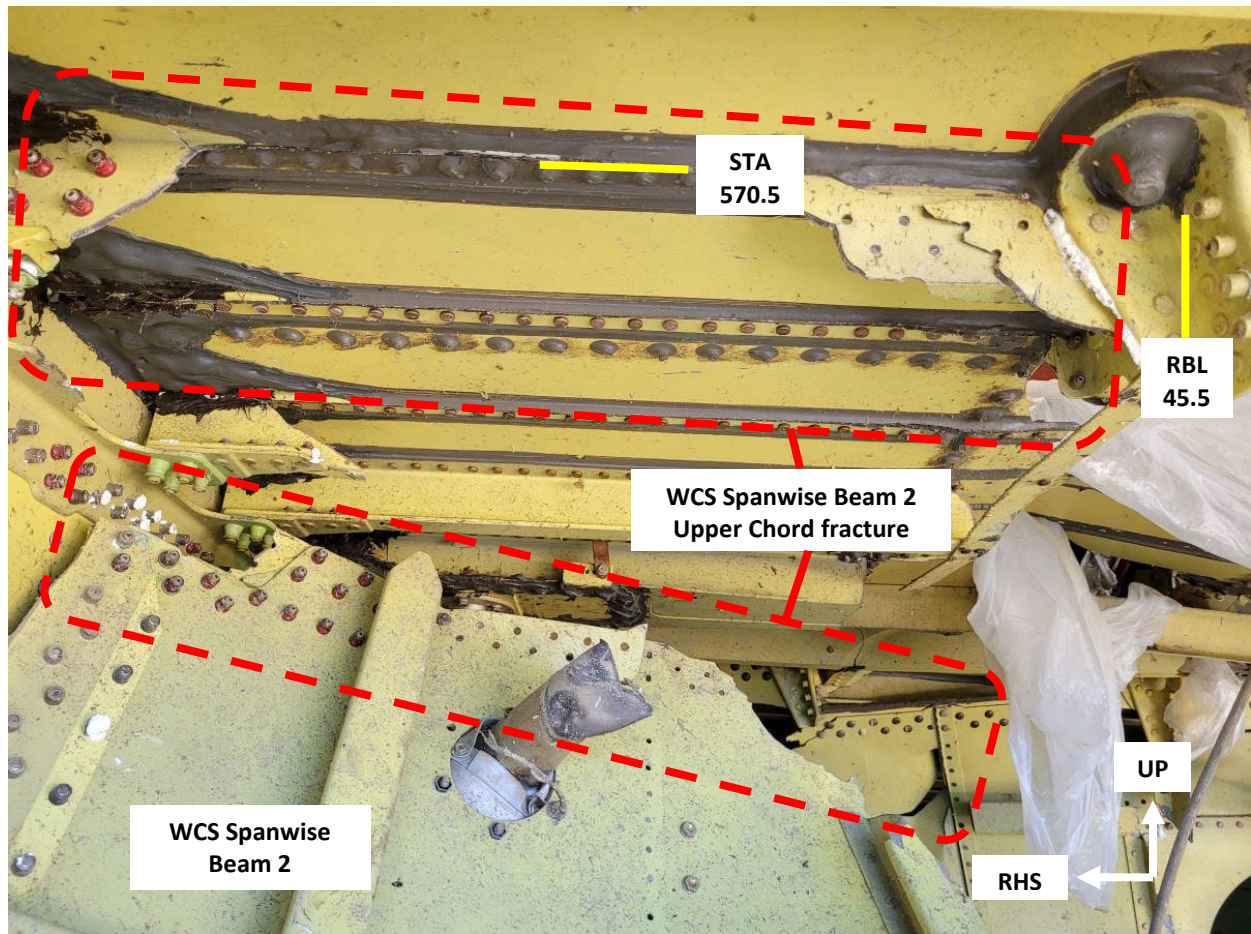


Figure 50. Damage to right WCS Spanwise Beam 2 Upper Chord (Boeing photo)

Figure 51 shows both WCS spanwise beams rotated and deformed aftward. There was less damage to the further aft Spanwise Beam 1 relative to the more forward Spanwise Beam 2.

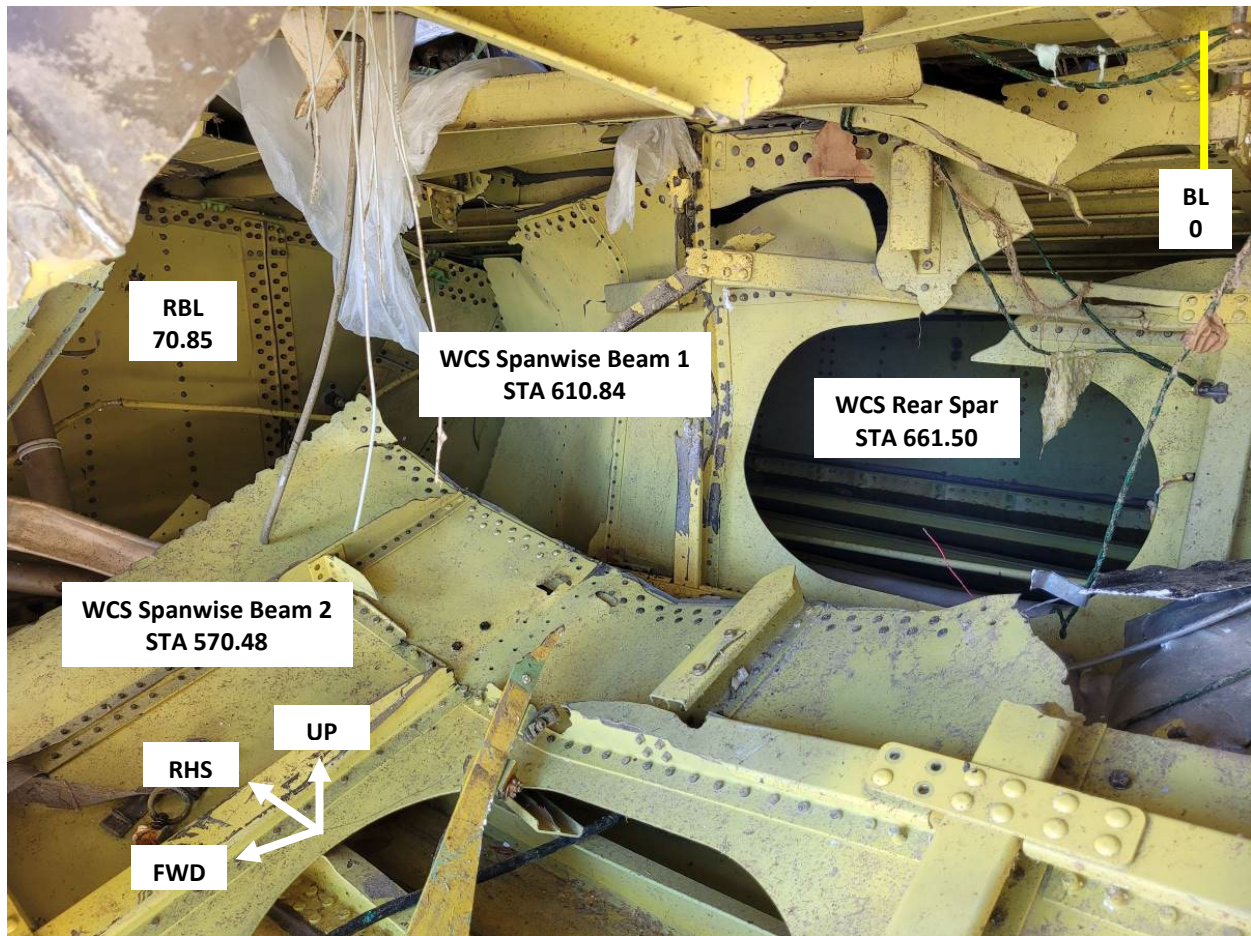


Figure 51. Damage to WCS Spanwise Beams 1 & 2 (Boeing photo)

Figure 52 shows a view of the WCS rear spar looking through the damaged Spanwise Beam 1 pass-through. The rear spar was the only undamaged spanwise shear structure in the Wing Center Section.

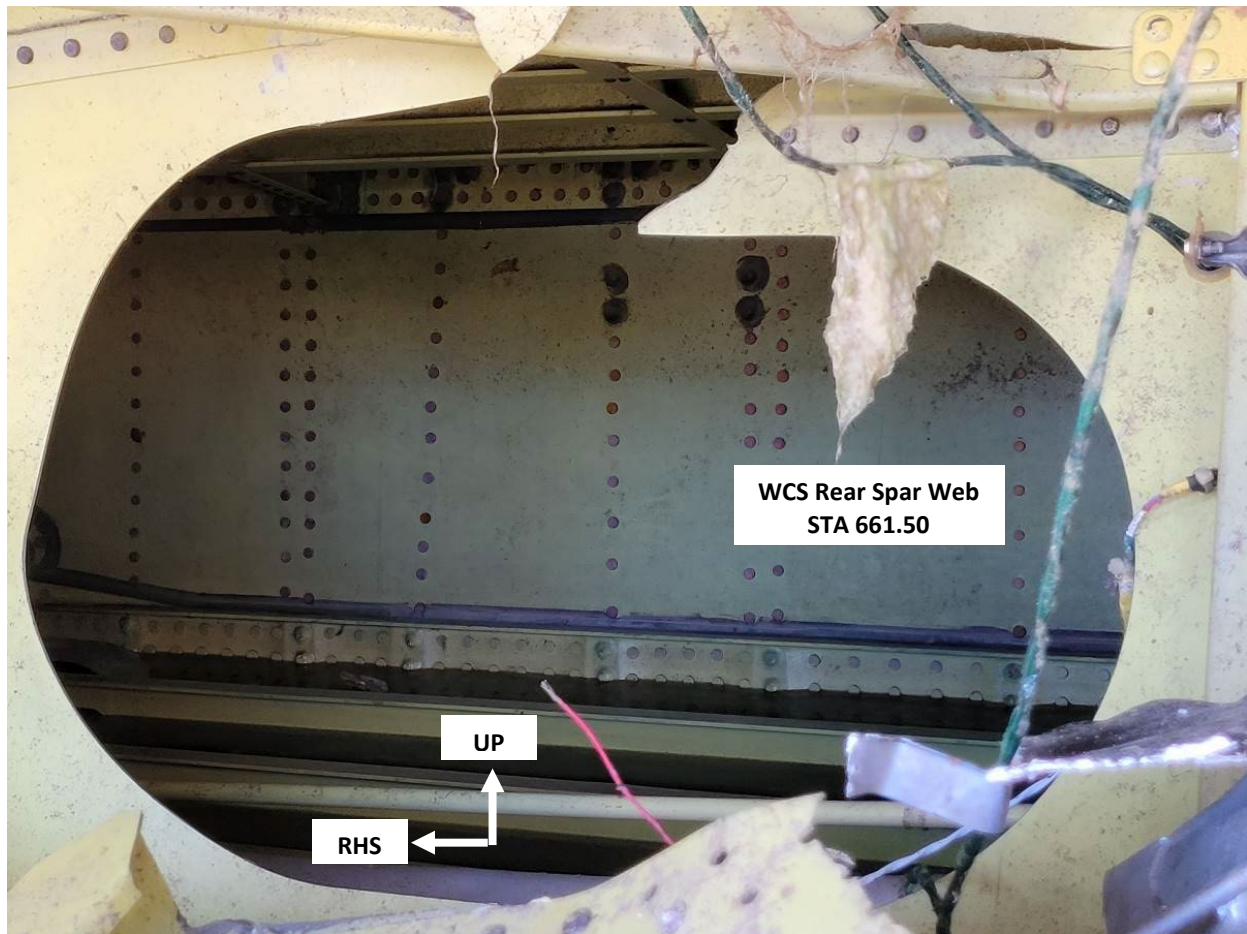


Figure 52. Rear Spar web and chords viewed through Spanwise Beam 1 pass-through (Boeing photo)

Figure 53 shows multiple WCS upper skin panel stringers fractured near the BL 0 floor beam attachment. Some of the stringers were separated at the fasteners attaching to the upper skin while others were failed through the base flange of the stringer.

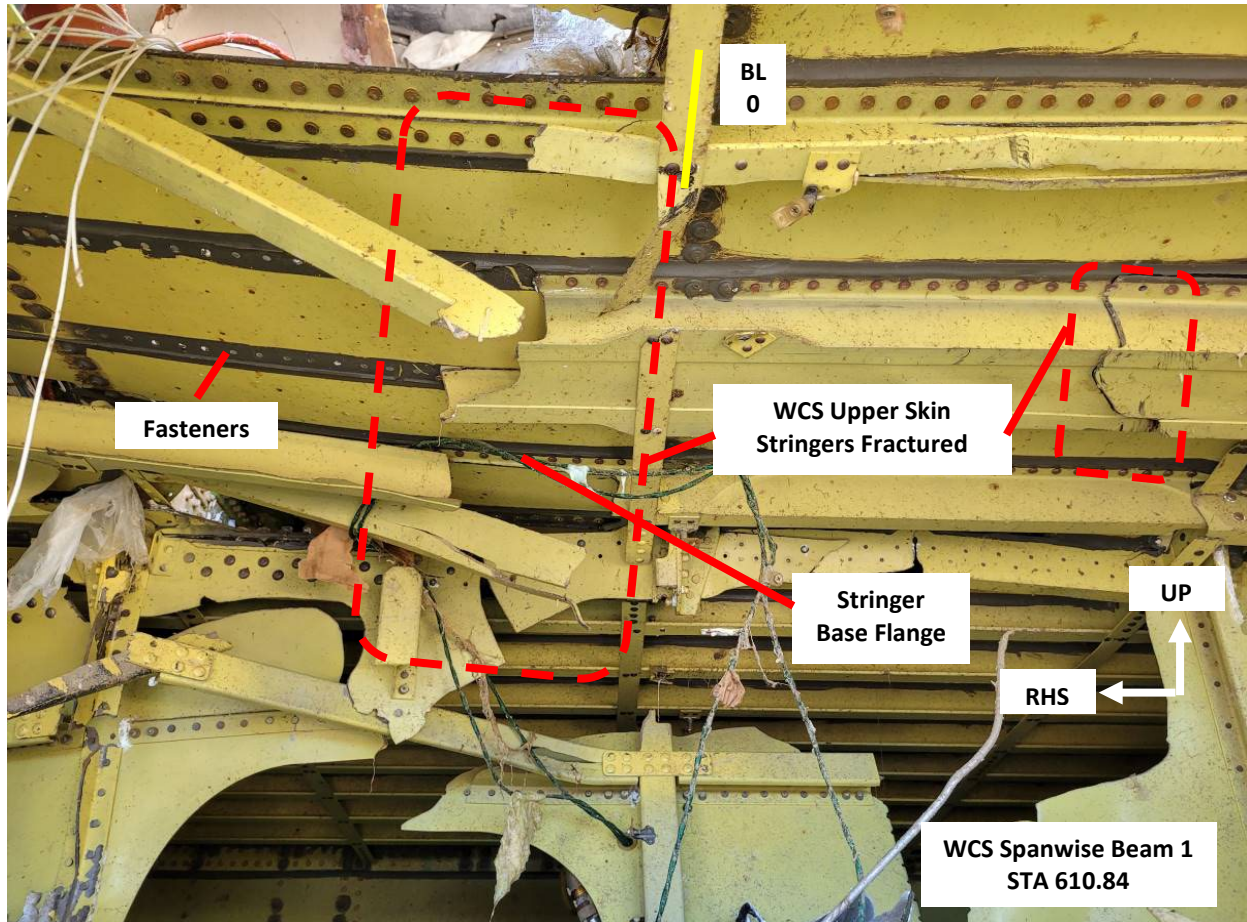


Figure 53. Upward aft view of WCS Upper Skin Panel and fractured stringers (Boeing photo)

Figure 54 shows the left side WCS upper forward skin panel separation at the SOB attachment.

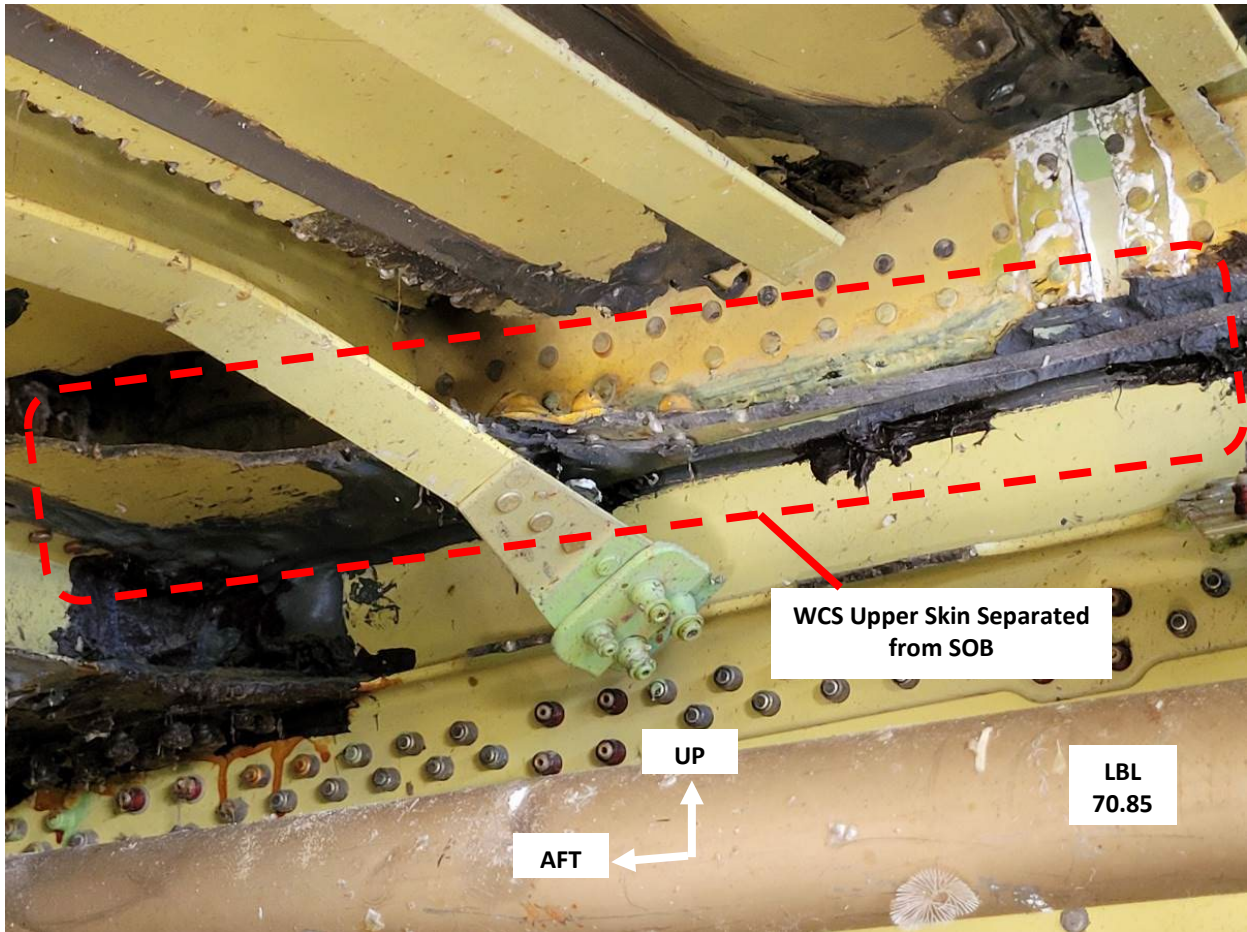


Figure 54. Upward close-up view of left side WCS Upper Skin separation at Side-of-Body (Boeing photo)

Figure 55 shows the left side view of the WCS lower skin panel fracture between Spanwise Beams 1 and 2.

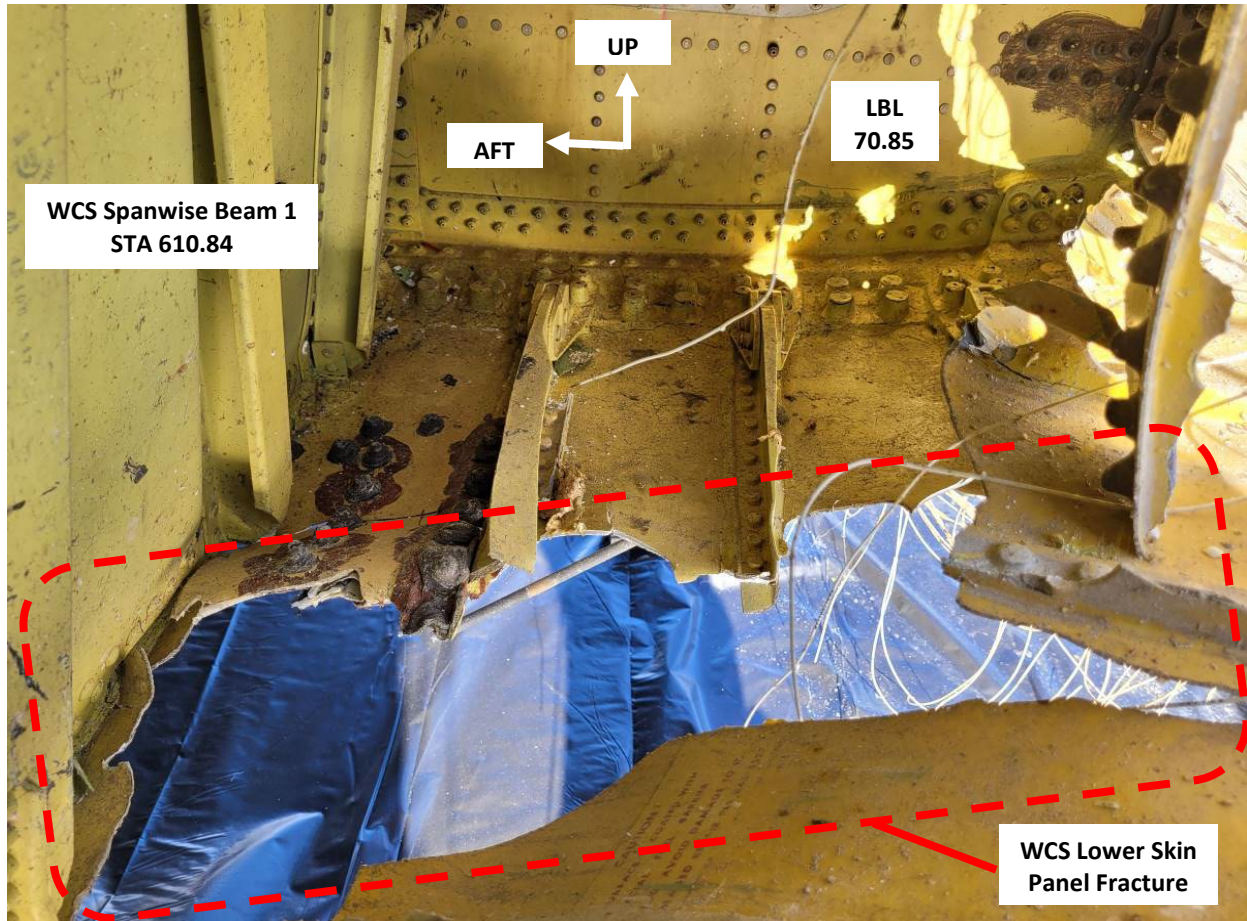


Figure 55. Left side WCS Lower Skin fracture between Spanwise Beam 1 and 2 (Boeing photo)

Figure 56 shows the underside of the WCS where the left lower external beam was attached to the WCS lower skin panel. The lower beam upper chord flange was still attached to the skin panel.

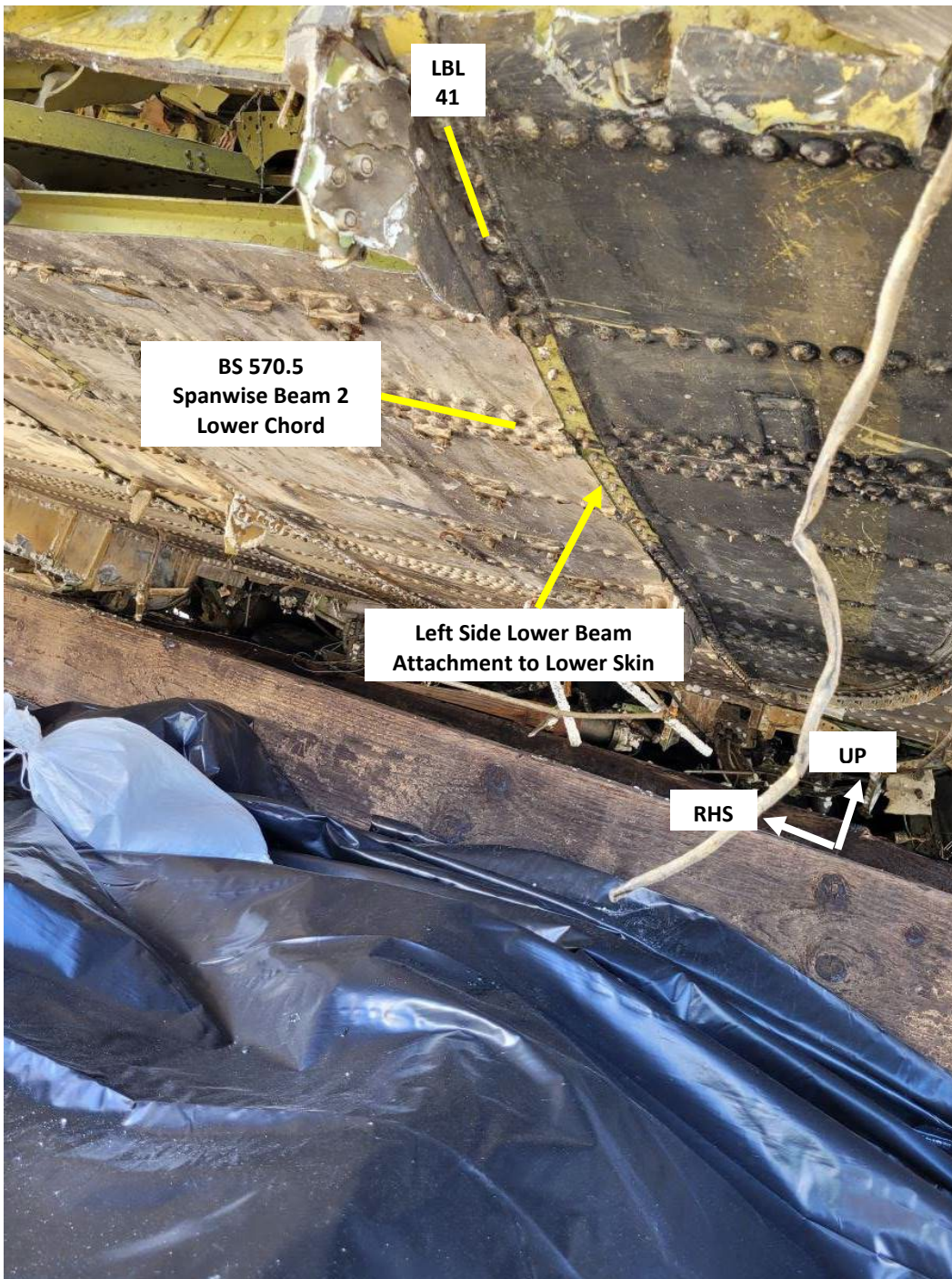


Figure 56. WCS Lower Skin left Lower External Beam attach point damage (Boeing photo)

Figure 57 shows the underside of the right lower external beam with a large portion still attached to the WCS lower skin panel.



Figure 57. WCS Lower Skin right Lower External Beam attach point damage (Boeing photo)

Figures 58 and 59 show the aft fuselage upper skin deformation and wrinkling between STA 807 and STA 908 and S-4 and S-10 on the left and right sides, respectively. The aft lift straps were placed in this area during the recovery of the aft fuselage. There was also buckling of the skins and stringers noted between frames 727A and 727B that spanned from S-11R to S-1.

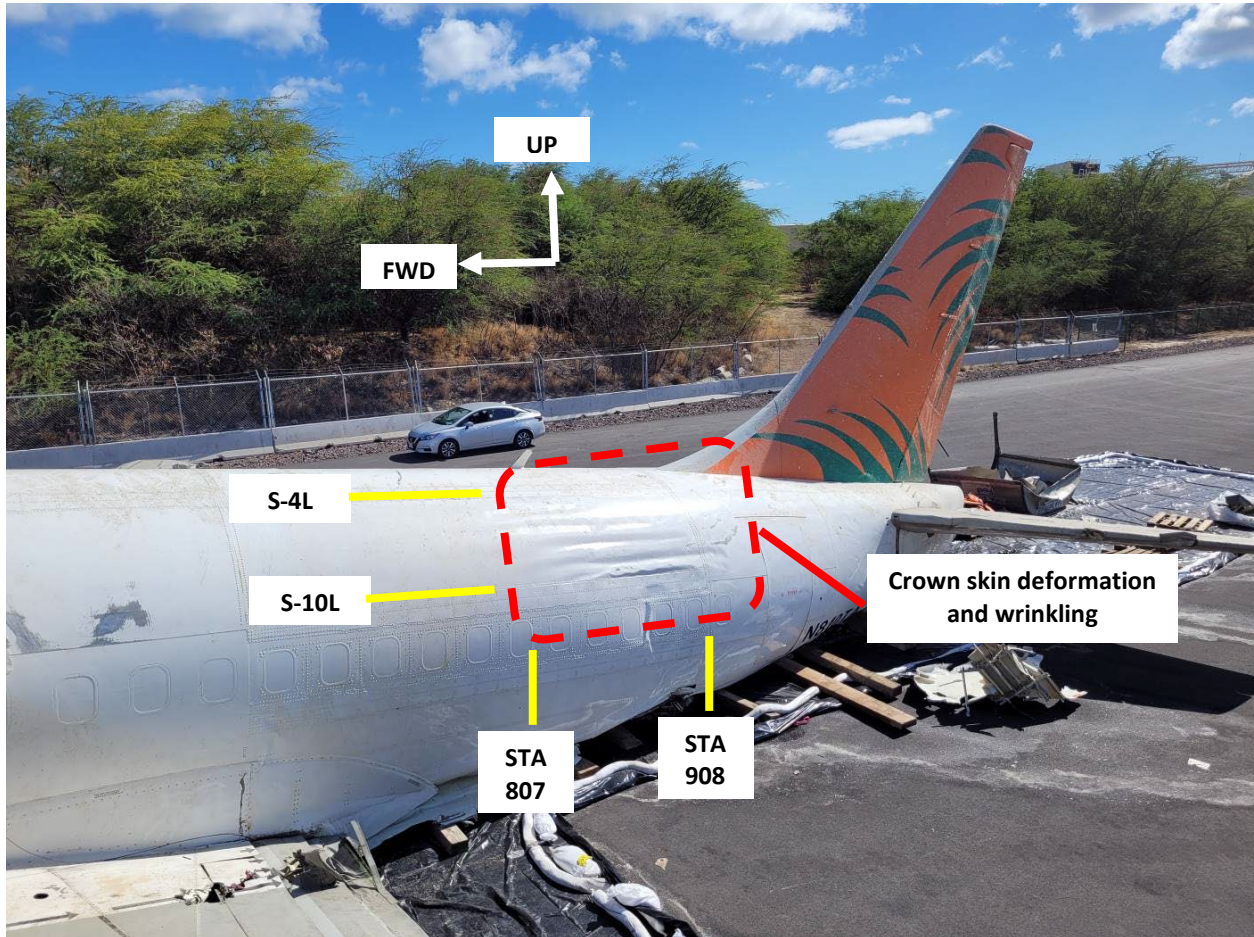


Figure 58. Left aft fuselage upper skin deformation and wrinkling (Boeing photo)

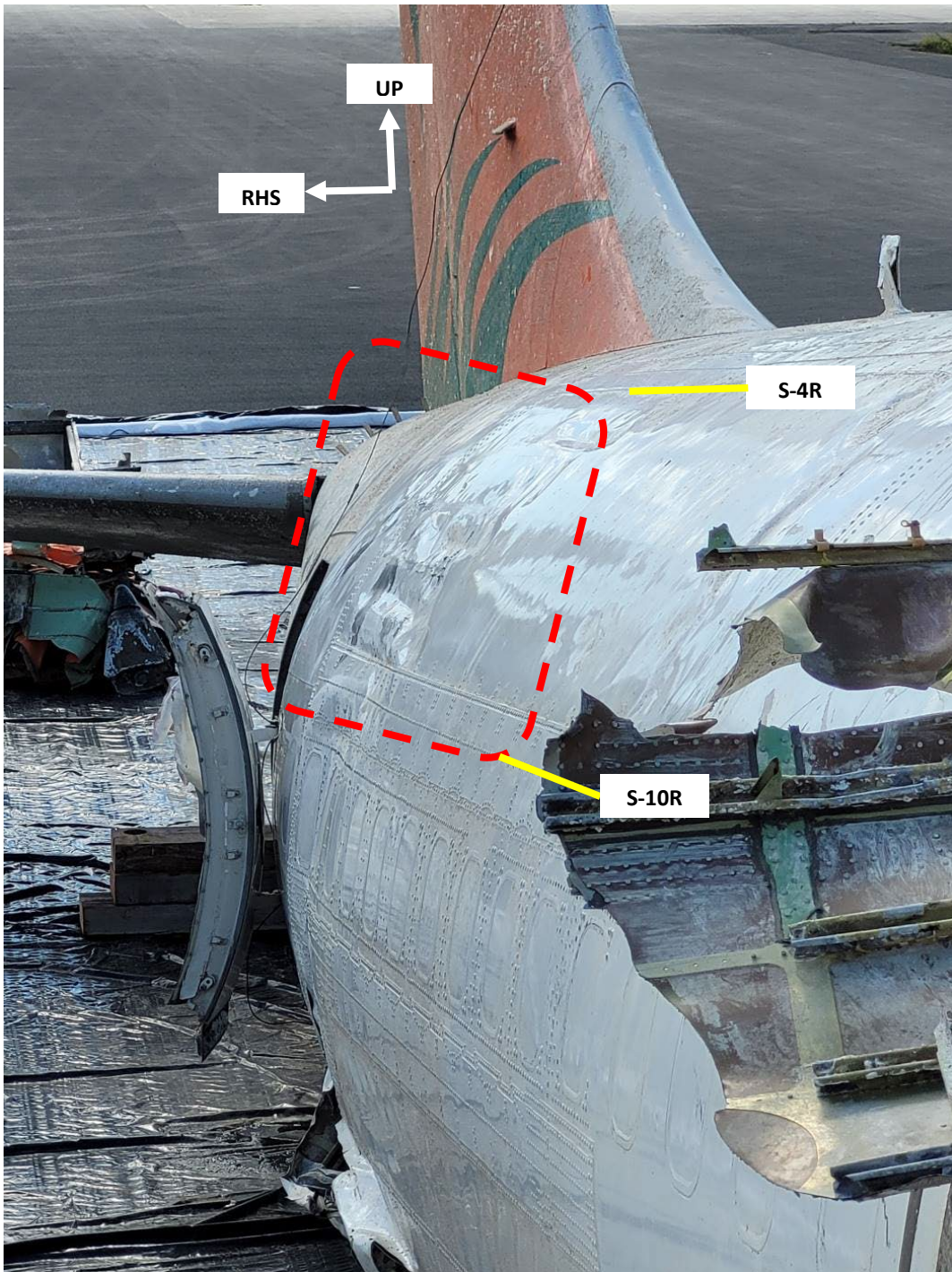


Figure 59. Right aft fuselage upper skin deformation and wrinkling (Boeing photo)

Figure 60 shows the damage to the upper crown skins aft of the fuselage separation near STA 540.

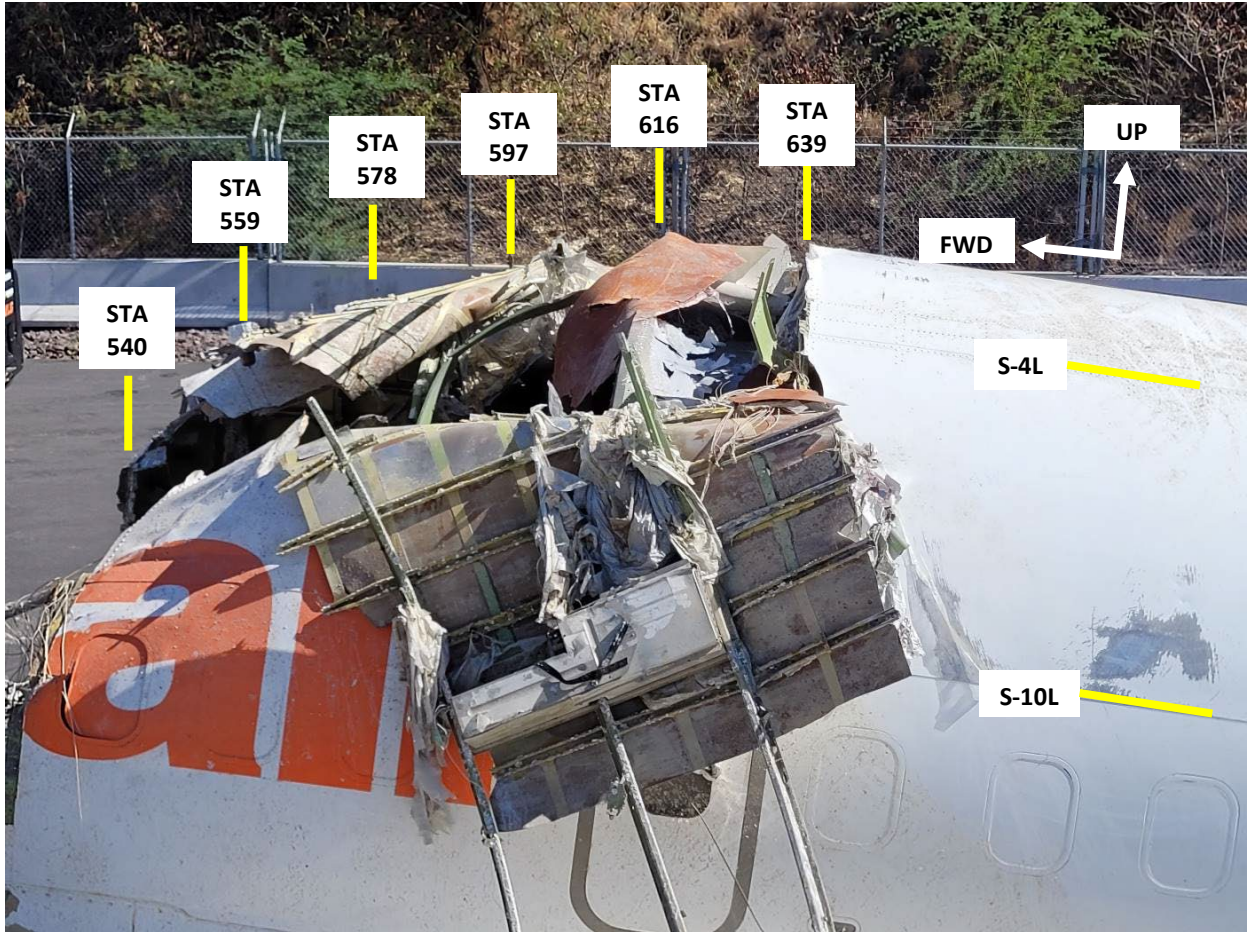


Figure 60. Fuselage crown skin damage aft of STA 540 separation (Boeing photo)

Figure 61 shows the Aft Pressure Bulkhead (APB) Pressure Web and Pressure Chord damage along the lower lobe of the fuselage. The pressure chord was deformed aftward along the BL 0 belly skin and the pressure web was fractured aftward with the chord. A portion of the pressure web and chord was missing.

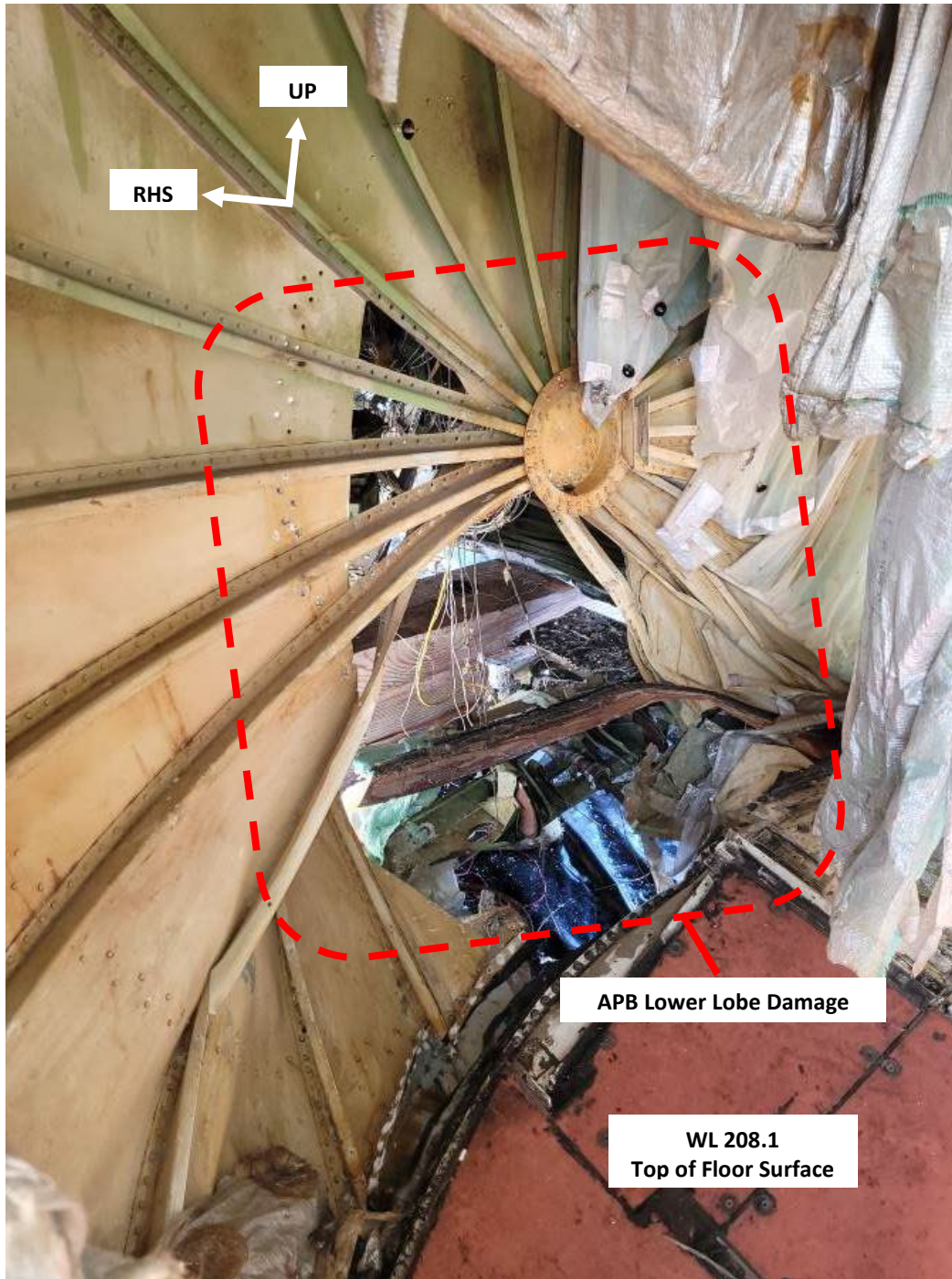


Figure 61. Aft Pressure Bulkhead damage, looking aft/down (Boeing photo)

Figure 62 shows the Horizontal Stabilizer Trim Jackscrew still attached to the Texas Star at the upper ballnut. There was a slight bend in the jackscrew. The lower end of the jackscrew mechanism was fractured from the bulkhead.

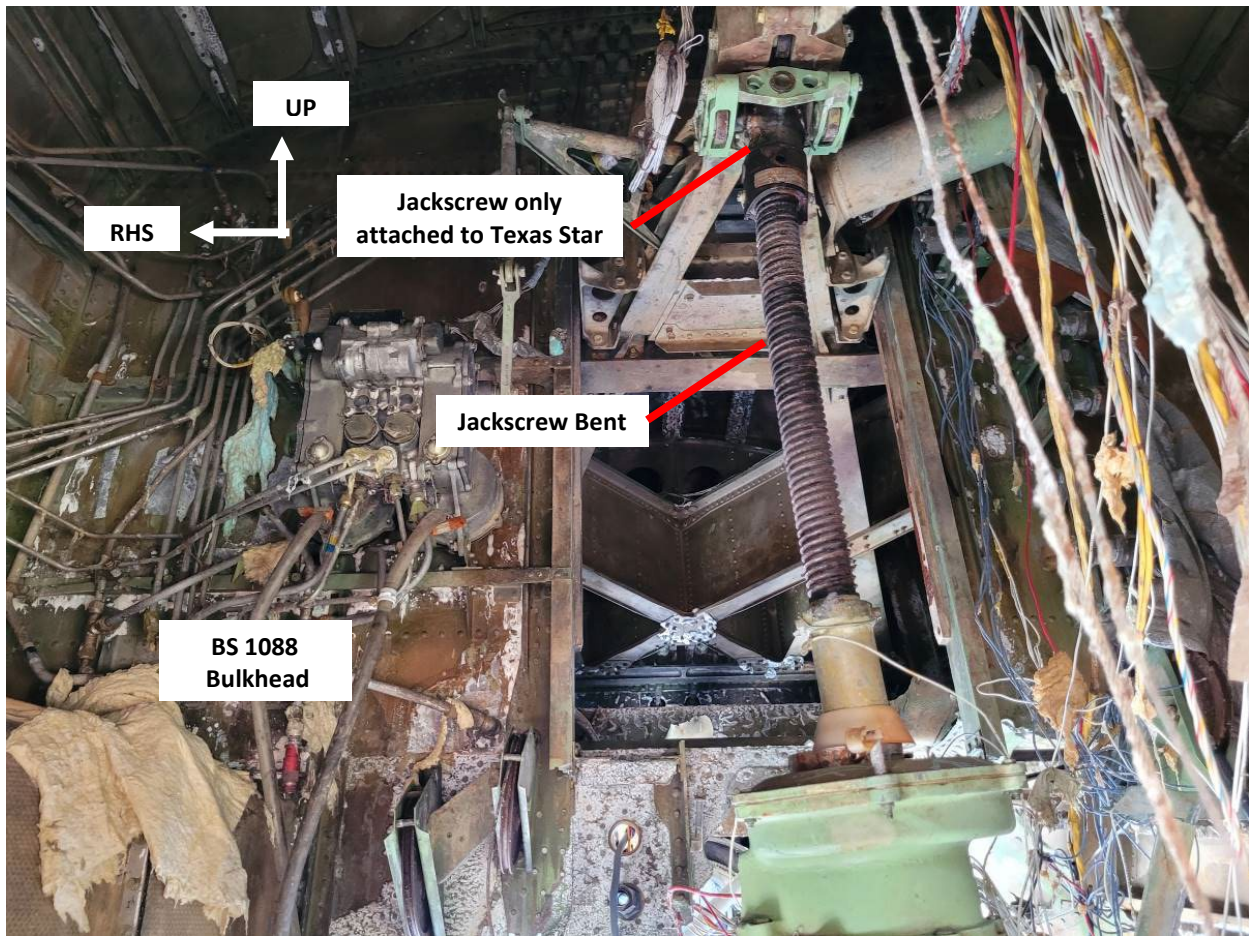


Figure 62. Horizontal Stabilizer Trim Jackscrew damage (Boeing photo)

Figure 63 shows the Horizontal Stabilizer Trim Jackscrew lower mechanism. A portion of the mechanism was fractured away and a portion of the BS 1088 bulkhead was still attached to the jackscrew mechanism assembly.

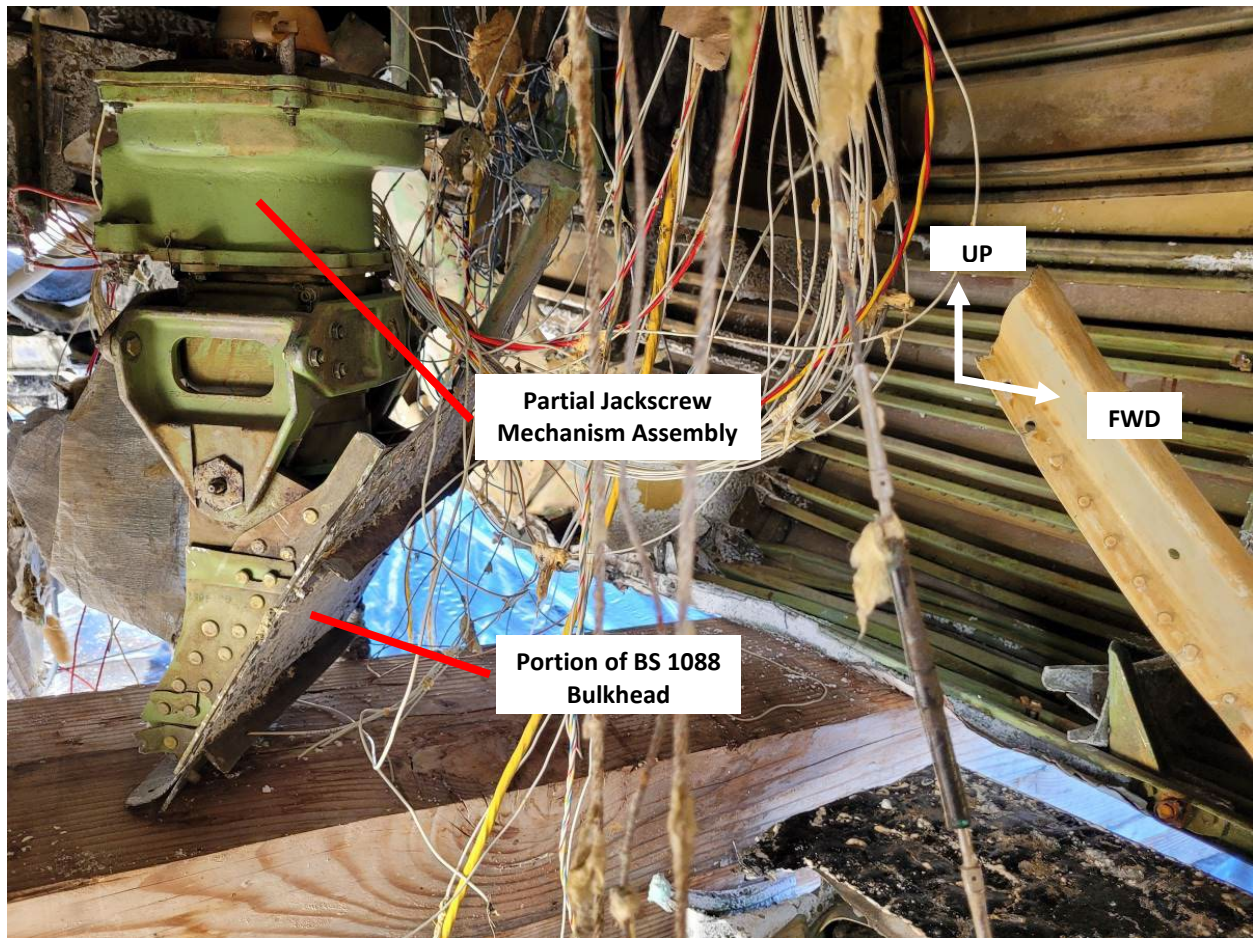


Figure 63. Horizontal Stabilizer Trim Jackscrew lower mechanism (Boeing photo)

Figures 64, 65 and 66 show the Horizontal Stabilizer Trim Jackscrew gearbox, cable drum and actuators that were separated from the aircraft and recovered in the debris field.

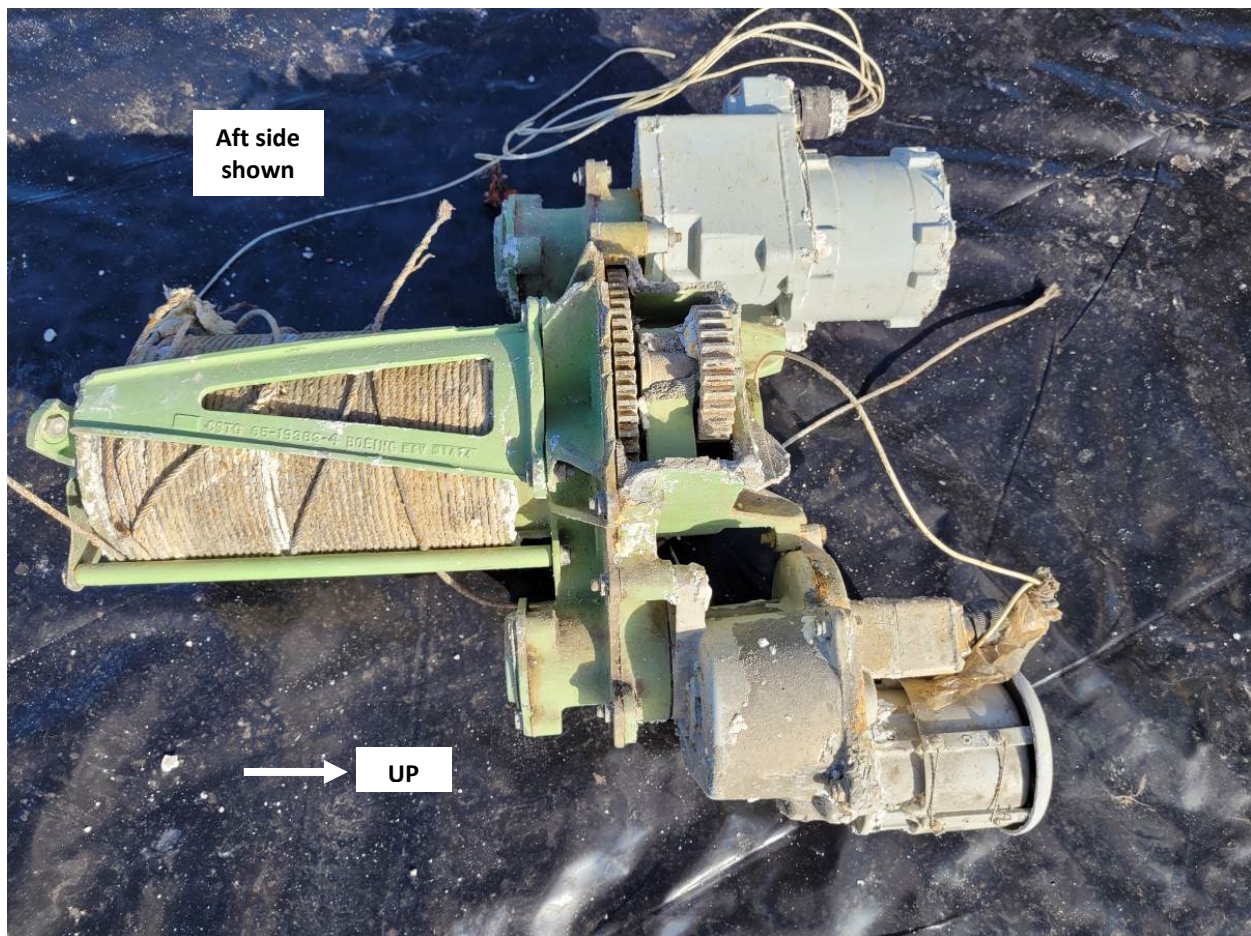


Figure 64. Separated Horizontal Stabilizer Trim Jackscrew gearbox, cable drum, and actuators (Boeing photo)

Figure 65 shows a close-up of the fracture at the lower end of the cable drum.

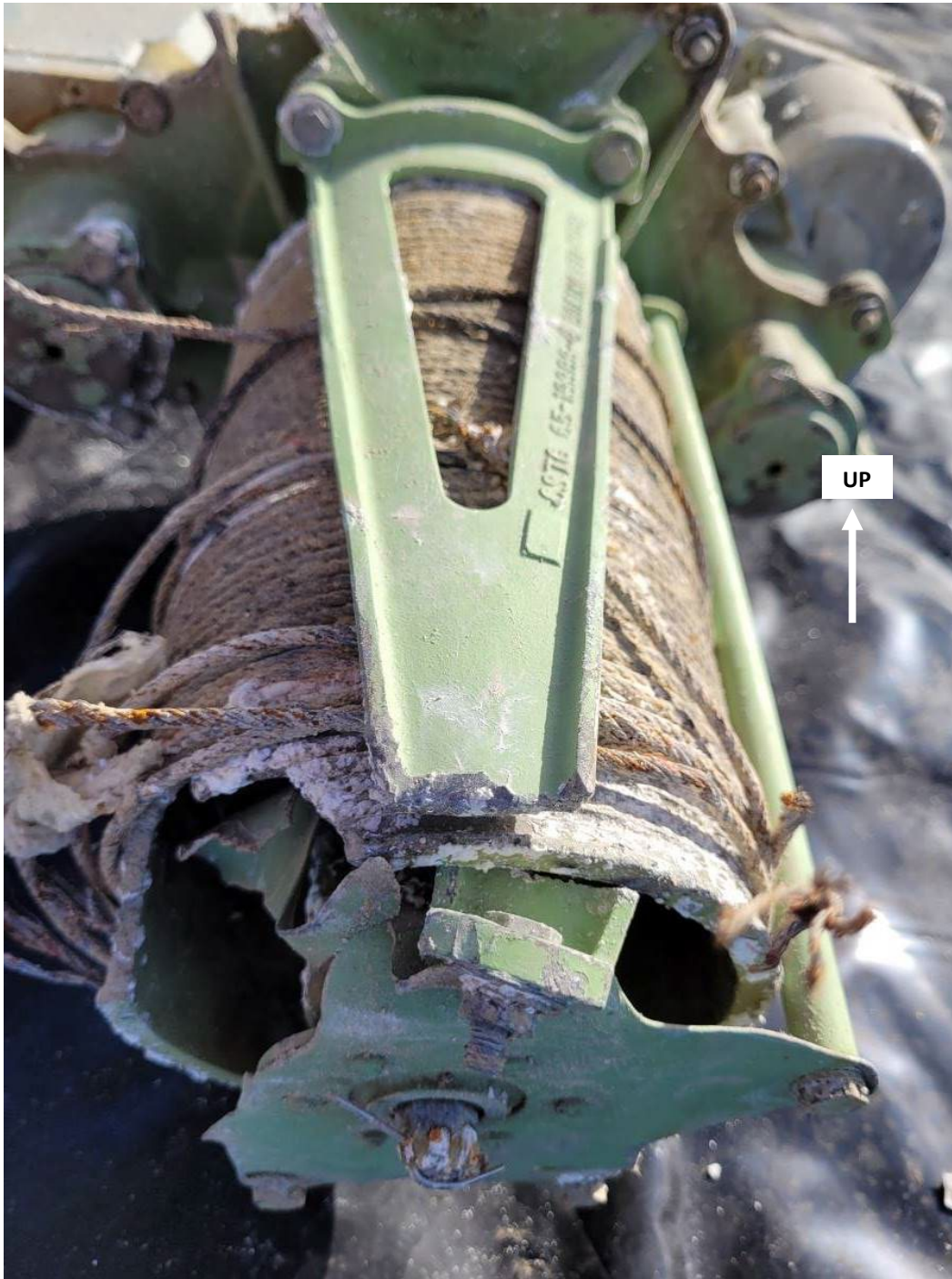


Figure 65. Close-up view of jackscrew cable drum damage (Boeing photo)

Figure 66 shows the fracture of the gearbox housing where it separated from the Jackscrew assembly.

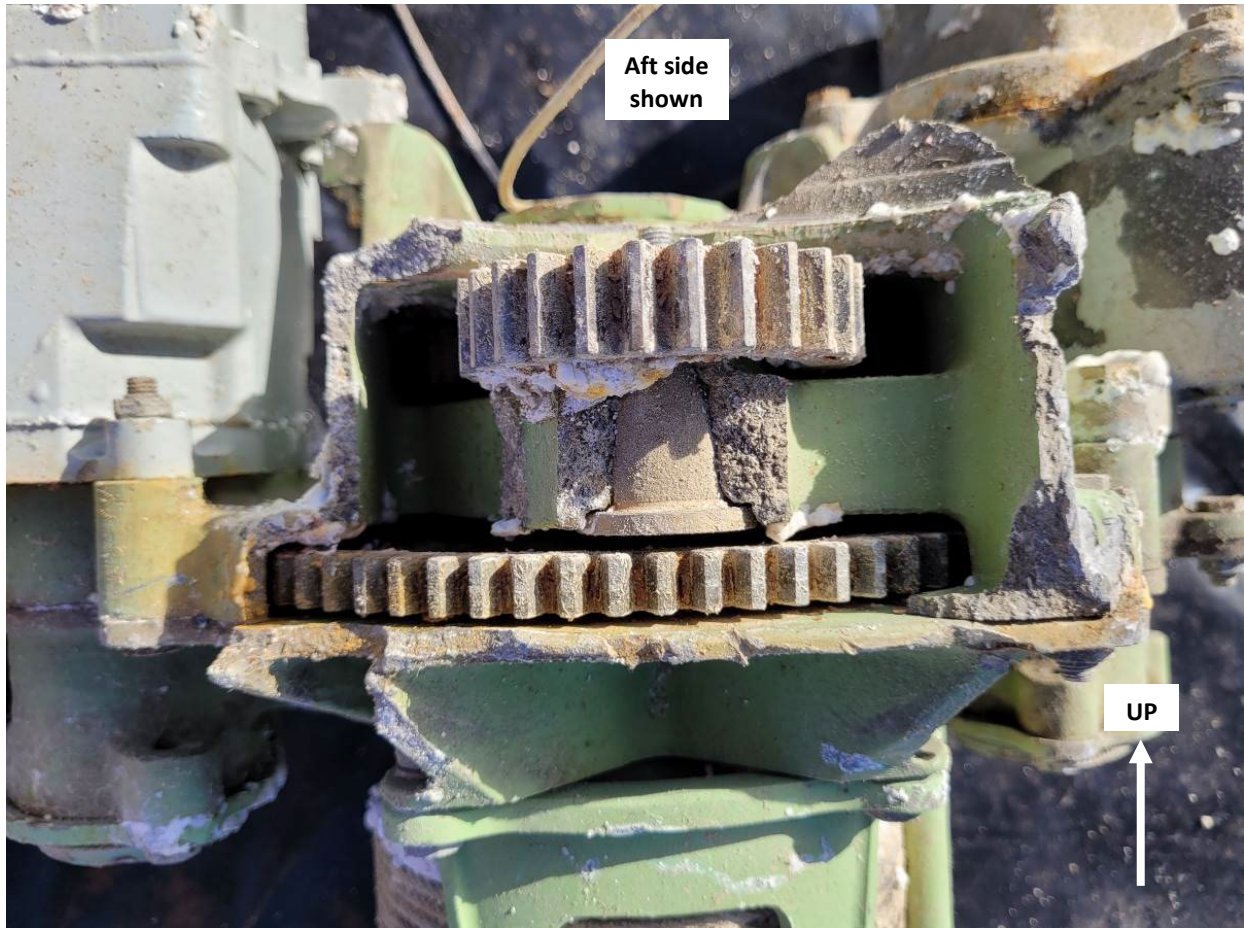


Figure 66. Close-up of jackscrew gearbox fracture (Boeing photo)

Figure 67 shows the left outboard aft flap honeycomb core crush damage. This damage was evident on a majority of honeycomb core assembly parts on the aircraft.

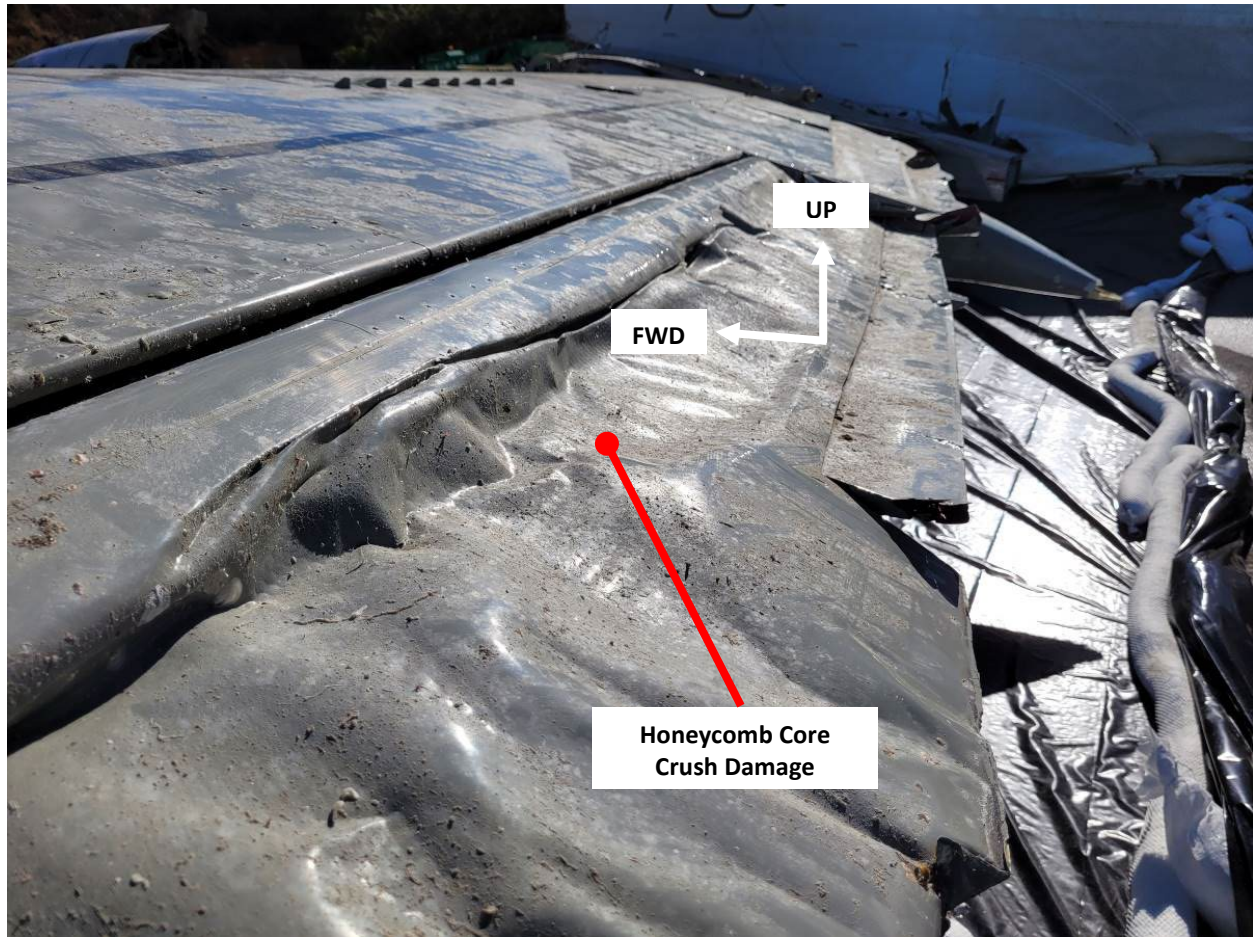


Figure 67. Left outboard aft flap honeycomb core crush damage (Boeing photo)

Figure 68 shows the left engine pylon area with the recovered forward engine mount.

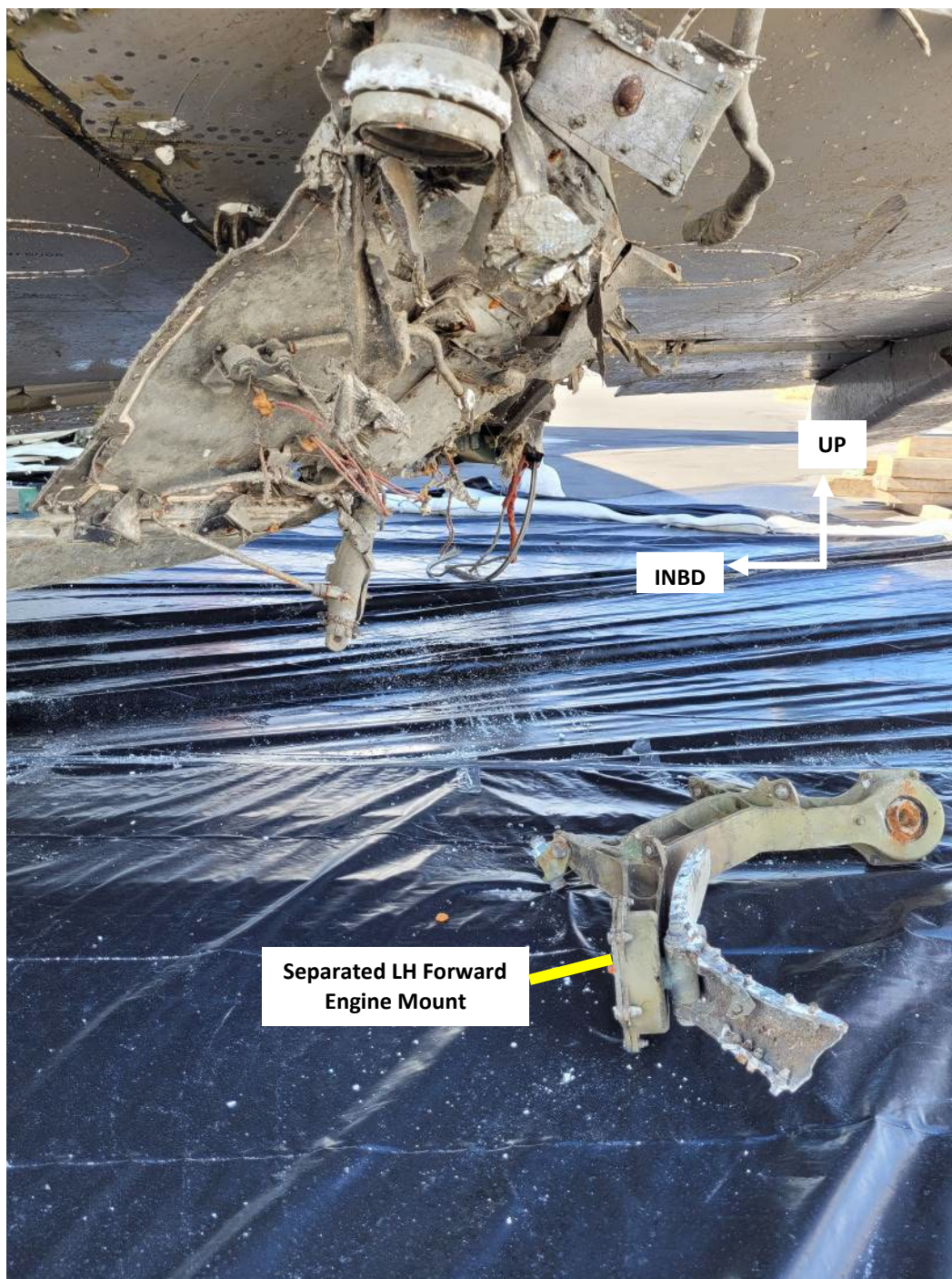


Figure 68. Left engine pylon area and separated forward engine mount (Boeing photo)

Figure 69 shows the right engine pylon area with the forward engine mount still attached.

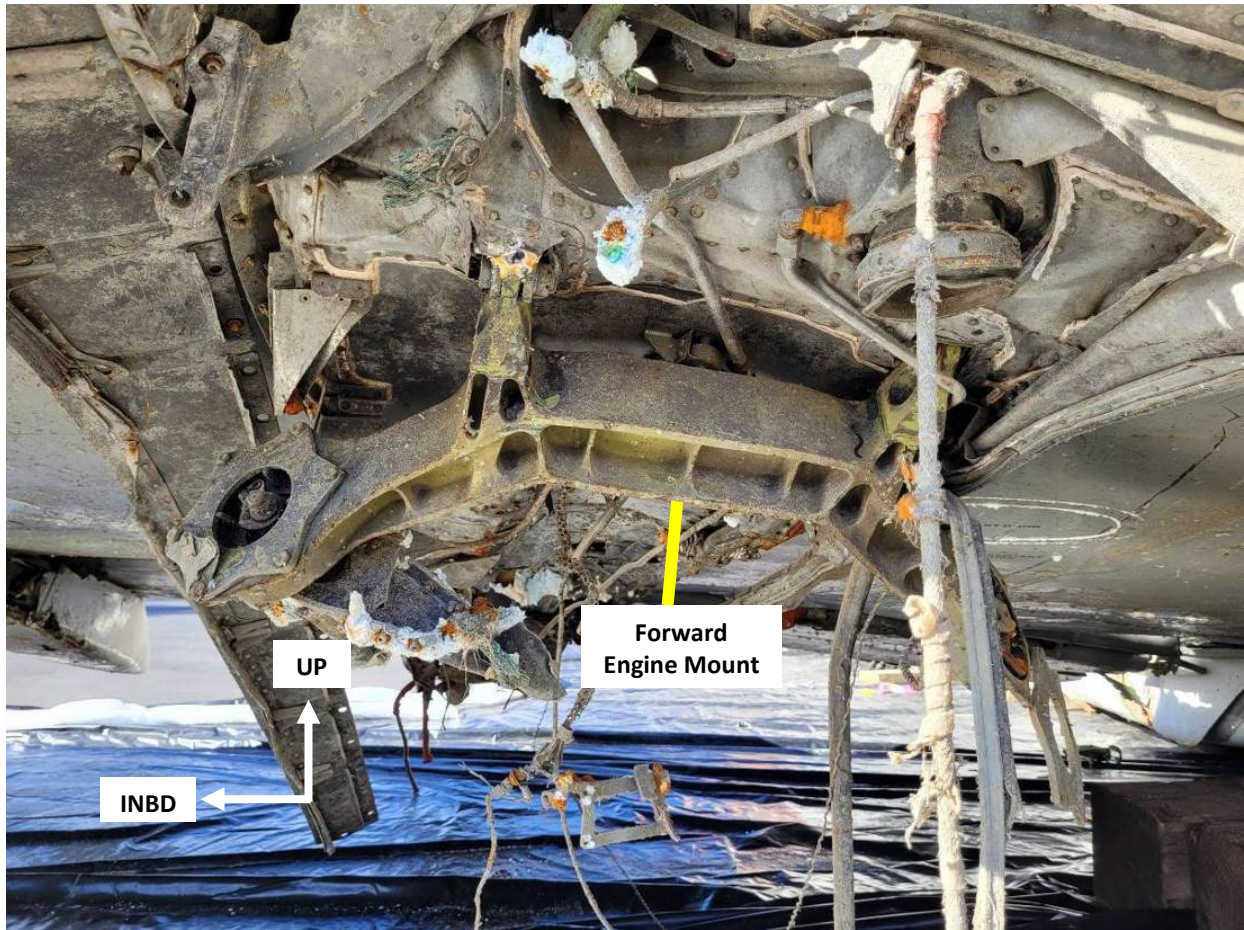


Figure 69. Right engine pylon area (Boeing photo)

Figures 70 and 71 show the tearing damage to the left inboard flap, spoiler, and trailing edge panels from the trailing edge forward to the MLG Beam where the lift cables were situated during recovery. The right wing had similar damage.

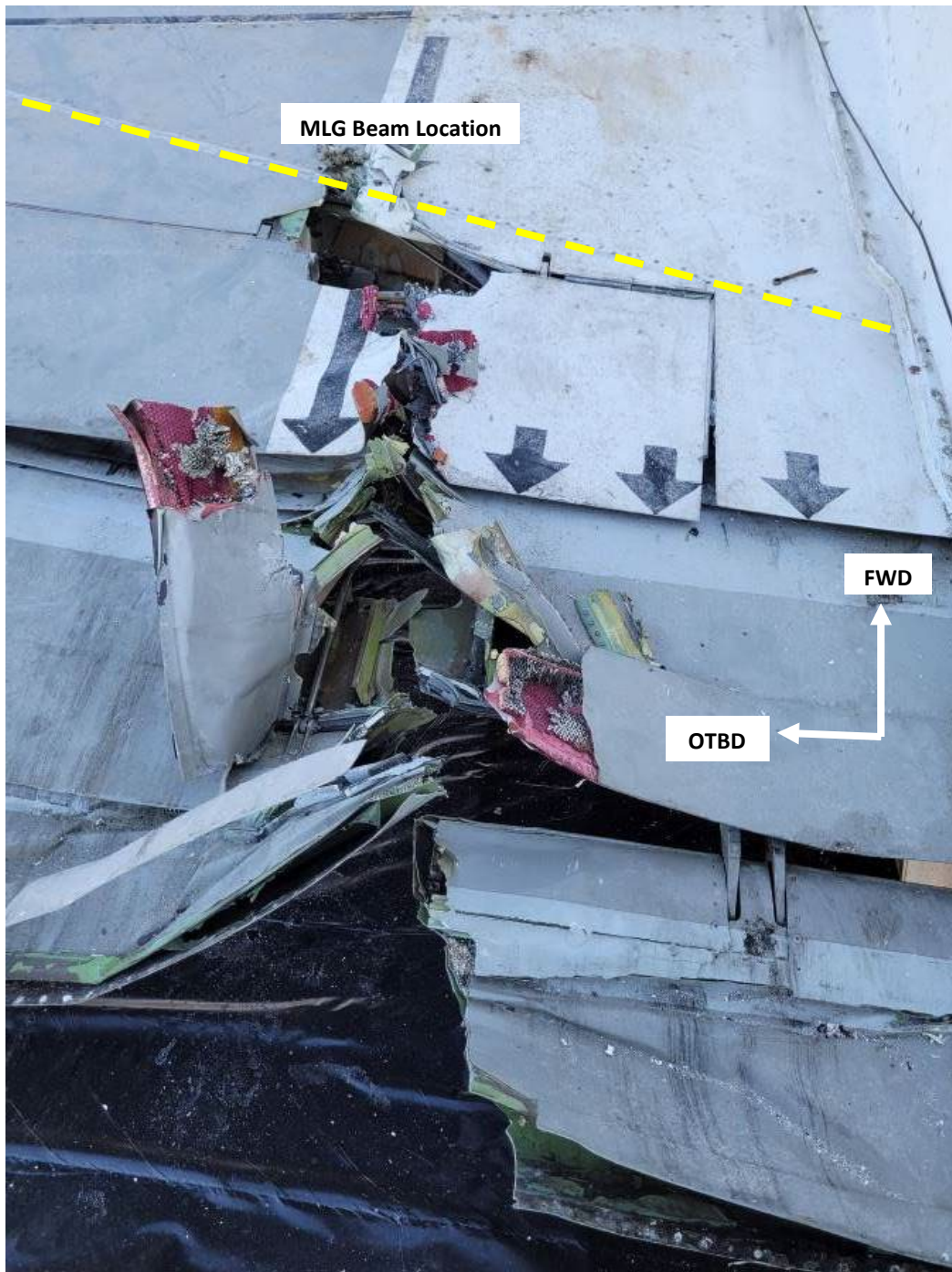


Figure 70. Left wing trailing edge damage, looking down/forward (Boeing photo)



Figure 71. Left wing trailing edge damage close-up of MLG Beam (Boeing photo)

Figure 72 shows the APU door opening in the lower aft fuselage. The APU doors were not recovered.

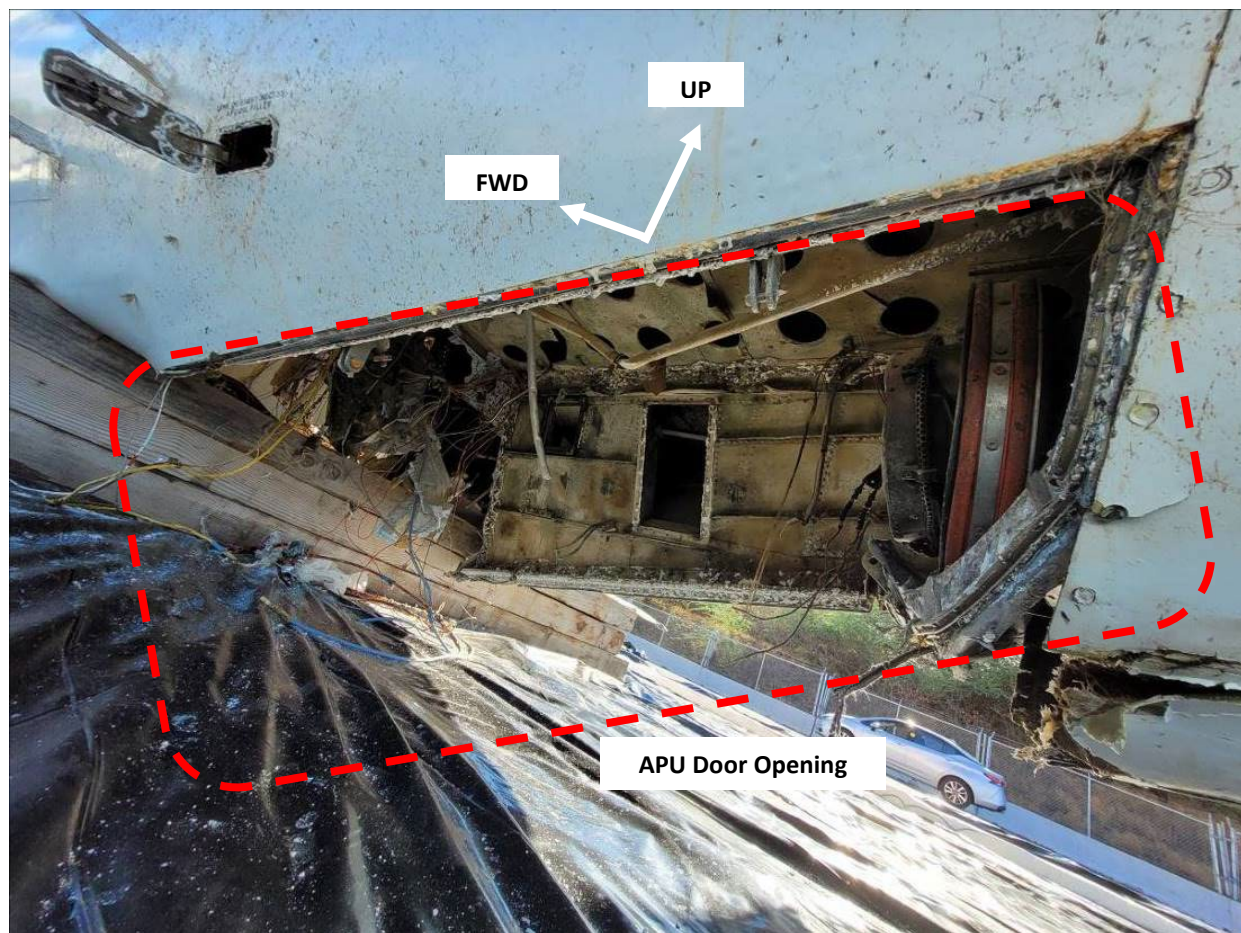


Figure 72. APU door opening (Boeing photo)

Figure 73 shows the APU that was separated from the airplane and recovered in the debris field.



Figure 73. Recovered APU (Boeing photo)

Figure 74 shows the cut area on the lower right fuselage skin required to remove the Cockpit Voice Recorder (CVR).

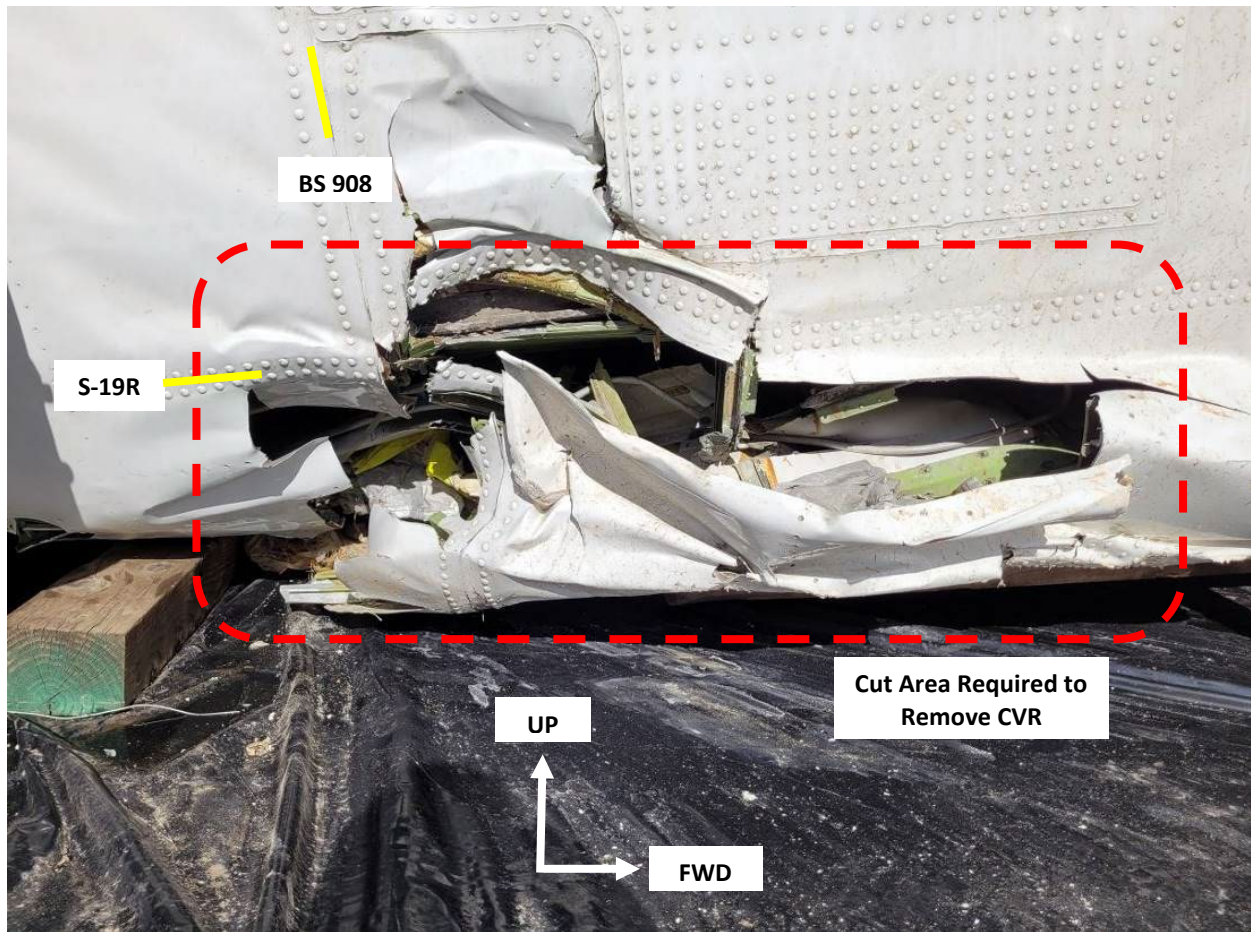


Figure 74. Right lower fuselage cut area (Boeing photo)

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