NATIONAL TRANSPORTATION SAFETY BOARD

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

May 10, 2013.

MATERIALS LABORATORY FACTUAL REPORT Report No. 12-128

A. ACCIDENT INFORMATION

Place	:	Pukoo, Hawaii.
Date	:	November 10, 2011.
Vehicle	:	Eurocopter EC-130B4, N11QV.
NTSB No.	:	WPR12MA034.
Investigator	:	Dennis Hogenson.

B. COMPONENTS EXAMINED

1. Junction frame recovered
2. Fenestron[1] pieces recovered.
3. Tail guard, mounting plate and tail skid pieces recovered.
4. Stator, tail gearbox and hub assembly recovered.
5. Tail boom pieces recovered.
6. Tail rotor drive shaft pieces recovered.
7. Main rotor blade pieces recovered.

C. DOCUMENTS REVIEWED

1. Eurocopter Alert Service Bulletin 53A019. Check of the tail boom/fenestron junction frame.
2. Eurocopter drawing 350A234007. Junction frame.
3. Eurocopter drawing 350A230407. Tail skid.
4. Eurocopter drawing 350A234044. Quille assemblee (Keel assembly).

D. DETAILS OF THE EXAMINATION

On November 10, 2011, about 1214 Hawaiian standard time, a Eurocopter EC130 B4, N11QV, collided with mountainous terrain near Pukoo (Island of Molokai) Hawaii. The commercial pilot and four passengers were fatally injured. The helicopter was registered to Nevada Helicopters Leasing, Henderson, Nevada, and operated by Helicopter Consultants of Maui, Inc., dba Blue Hawaiian Helicopters, Maui, Hawaii. The flight was operated as a visual flight rules (VFR) sightseeing flight under the provisions of 14 Code of Federal Regulations Part 135. Visual meteorological conditions prevailed at the time of departure, and company flight-following procedures were in effect. The flight originated from the Kahului Airport, Kahului, Hawaii, about 1144.

[1] A fenestron is a multi-bladed tail rotor shrouded by a duct in a vertical stabilizer.

Pieces of the helicopter were located in a wreckage path oriented approximately west northwest of the main wreckage and the tail gearbox was located almost due north of the main wreckage. The main wreckage is illustrated in Figure 1, looking approximately southwest, with the landing gear, the tail boom and a main rotor blade identified. Wreckage was located below the landing gear, the underside of the tail boom was uppermost and wreckage was located above the main rotor blade, identified as blade “C” as in Figure 2, consistent with an inverted impact. A majority of the wreckage displayed post-impact fire and impact damage and the remainder displayed impact damage.

Although not to scale, the relative locations of significant pieces of wreckage are illustrated in the sketch in Figure 2 and the pieces identified with the report figure in which they are illustrated. As illustrated in Figure 2, the wreckage was generally oriented in a southeasterly direction terminating at the main wreckage. The first significant piece was a portion of a main rotor blade trim tab, located approximately 1,330 feet from the main wreckage, followed by the tail skid mounting plate, the tail skid, a portion of the junction frame and three pieces of the fenestron. The sketch also illustrates ground strikes, prior to the main wreckage, which were made by the main rotor blades and are identified as strikes 1, 2 and 3. At the inner end of strike 3 there was a ground impact mark containing an outer portion of one of the main rotor hub starflex[2] arms and at the outer end of strike 3 a damaged rock was located. The tail gearbox and a stator were located outside of the wreckage path, approximately due north of the main wreckage. The three main rotor blades extended outside of the main wreckage and are identified as blade “A”, “B”, and “C”. Reportedly, a valley to the west of the wreckage contained miscellaneous light weight pieces of composite material, transparencies and interior baggage items.

An investigative group was formed to examine the recovered fenestron pieces illustrated in Figures 3, 9, 42, 57 and 68 at the NTSB facility in Ashburn, Virginia and at NTSB headquarters in Washington, DC. At the NTSB facility the group also examined the recovered tail rotor drive shaft pieces illustrated later in Figure 59 and the main rotor blades illustrated later in Figure 70. The investigative group consisted of representatives from the NTSB, FAA, BEA[3], American Eurocopter, Eurocopter (France), Turbomeca and the operator.

Junction frame examination.

A major portion of the junction frame was located in the wreckage path, as indicated in Figure 2. The frame portion consisted of the inner ring, most of the rear flange and a portion of the fenestron skin. The outer edge of the forward face of the inner ring displayed a fracture face where the forward flange was originally located. At the accident site, the junction frame piece was positioned adjacent to the rear end of the fire damaged tail boom to illustrate its relative cleanliness when compared to the fire blackened tail boom and is illustrated in Figure 3 (the tail boom was rotated

[2] The basic component of the STARFLEX main rotor hub is shaped like a three pointed star and is flexible in the flapping direction due to its fiberglass construction.
[3] Bureau d’Enquetes et d’Analyses. The French accident investigation bureau.

from its original inverted impact position for the image). The red arrows indicate the fracture face on the junction frame and brown arrows indicate the mating fracture on the forward flange still in the tail boom. The rear portion of the tail boom containing the forward flange was removed by sawing along the red dashed line and is illustrated later in Figure 55. The blue arrow indicates a rectangular area of exposed rivets and the white arrow indicates a clean portion of the inner ring, both consistent with satisfaction of Alert Service Bulletin 53A019 (document 1 in section C). The green arrows in Figure 3 indicate attachments for the fairing between the tail rotor drive shaft cover and the fenestron.

A view of the junction frame piece, looking aft, is illustrated in Figure 4 with red arrows indicating the fracture face. The yellow arrow indicates a fracture at the uppermost hole and the blue arrow indicates the attached skin. The white arrow indicates an area on the inner ring, similarly indicated in Figure 3, where the surface deposit had been removed. A view of the junction frame piece, looking forward, is illustrated in Figure 5 with a yellow arrow indicating the fracture at the upper hole. The blue arrow indicates the fenestron skin and the red arrow indicates the honeycomb core. The orange arrows indicate rivets attaching the skin to the rear flange. The inner ring contains four holes and for descriptive purposes looking forward, the upper hole is designated as the 12 o’ clock position, the lower hole is designated the 6 o’ clock position, the left hole is designated the 9 o’ clock position and the right hole is designated the 3 o’ clock position. The position of the holes is also illustrated in drawing 350A234007 (document 2 in section C).The purple arrow indicates a fractured portion of the rear flange where the fracture extended from the 7 o’ clock position to the 12 o’ clock position, following the rivet line from the 9 o’ clock position to the 12 o’ clock position. The white arrow indicates a portion of a manufactured circle that originally encircled the tail rotor drive shaft and the green circle indicates a portion of a manufactured circle that originally encircled the tail rotor pitch change rod.

The forward face of the junction frame was detergent cleaned to reveal a surface similar to the area indicated by the white arrow in Figure 4. The forward face is illustrated in Figure 6 with red arrows indicating the fracture face and a yellow arrow indicating the fracture at the hole at the 12 0’ clock position. The white arrow indicates the location of the cleaned area similarly indicated in Figure 4. Examination of the forward face revealed indications of a peened identification at the approximately 5 o’ clock location indicated by the purple arrow. As illustrated in Figure 7, paint and primer were removed with a fine abrasive paper to reveal the identifications “350 A23400 720 3” (the part number confirmed by drawing 350A234007, document 2 in section C), “Lot FAB 0055 FR 0630” and Lot HP 5l 143101”. The red arrows, as in Figure 6, indicate the fracture face.

The fenestron structure piece indicated by the yellow arrow in Figure 9 was found to mate with the left side of junction frame piece and is illustrated in that position in Figure 8. The red arrows indicate a fracture face that had been separated from the junction frame fracture face indicated by the purple arrow (and by the purple arrow in Figure 5). Examination of the fracture faces revealed a grainy surface consistent with an overload event. The black arrows indicate where the skin had been deflected inwards, along a straight line, removing paint and inducing cracks in that surface. The green arrow indicates the manufactured hole for the pitch change rod similarly indicated in Figure 5.

Low magnification examination of the fracture face revealed a grainy surface with no obvious indications of any pre-existing cracks, consistent with an overload event. A more detailed examination of the fracture face was performed and the results are recorded in Materials Laboratory report 12-089.

Fenestron structure examination.

The fenestron structure recovered consisted of the upper fenestron piece, the lower fenestron piece and the tail guard piece identified in Figure 9 and located in Figure 2. The tail gearbox illustrated later in Figure 15 and located in Figure 2 is positioned inside the fenestron duct. The yellow arrow indicates the junction frame piece illustrated earlier in Figure 8. The red arrows in the duct indicate the original locations for some of the stators which support the stator ring. The stator ring contains the tail gearbox which drives the tail rotor blades within the duct. The blue and purple arrows indicate fractures oriented diagonally across the duct which are similarly indicated later in Figure 14. The brown arrow indicates a manufactured hole for the tail rotor drive shaft and the green arrow indicates a rectangular hole for the pitch change rod.

For comparison with the recovered pieces in Figure 9, the fenestron on N11QK, a sister ship to the accident helicopter N11QV, is illustrated in Figure 10 with the tail rotor blades identified. The stators are attached to the fenestron duct and are identified and numbered for reference in this report. The tail guard identified in Figure 9 and the tail skid, both illustrated later in Figure 21 are also identified. The purple arrow indicates the tail rotor drive shaft and the green arrow indicates the pitch change rod.

In order to examine the fenestron duct, the stator attachment locations were numbered 1 through 10 using the stator numbers illustrated in Figure 10. Stator locations 1 and 2 are illustrated and identified in Figure 11 with the two portions of stator 1 identified. The blue arrow indicates deformation to the left edge of stator 1, also illustrated later in Figure 16, and the brown arrow indicates the hole for the tail rotor drive shaft which appeared undamaged. The green arrow indicates the rectangular hole for the pitch change rod and the pale green arrow indicates a tear in the right skin that originated in the hole for the pitch change rod. The purple arrow indicates duct skin adjacent to the stator 1 attachment that had been torn from left to right to reveal the honeycomb indicated by the orange arrow. Stator attachment 2 displayed a fracture with no indications of contact from the stator on the duct surface.

Stator locations 3, 4, 5, 6 and 7 are illustrated and identified in Figure 12 with the tail gearbox, the stator ring, stators 5 and 6 and three tail rotor blades indicated.

Stator locations 3, 4, 5 and 7 displayed fractures with no indications of contact from the stator on the duct surface. Stator location 6 was intersected by the diagonal fracture indicated by the blue arrow in Figure 12 and in Figure 9 and the duct fitting had been extracted.

Stator locations 8, 9 and 10 are illustrated in Figure13 with the tail gearbox, the stator ring and the two portions of stator 1 identified. Stator 8 attachment had been extracted leaving the hole indicated by the orange arrow. There were no indications of contact from stator 8 on the duct surface adjacent to its attachment hole. Stator location 9 was intersected by the diagonal fracture indicated by the purple arrow in Figure 13 and Figure 9 and a portion of the hole is indicated by the blue arrow. The portion of duct between stator locations 9 and 10 was missing and a portion of the hole is indicated by the yellow arrow. As in Figure 11, the brown arrow indicates the hole for the tail rotor drive shaft and the green arrow indicates the hole for the pitch change rod with the pale green arrow indicating the tear in the skin emanating from the pitch change rod hole.

The investigative group met at the American Eurocopter facility in Grand Prairie, Texas to locate the fractures noted during the previous examination of the fenestron on a training EC-130B4 in order to contribute to an understanding of the accident sequence. The right side of the fenestron on the training helicopter is illustrated in the left image in Figure 14 for comparison with Figure 9 with the recovered pieces identified in Figure 9 identified and blue tape indicating missing structure. The left side of the training helicopter is illustrated in the right image in Figure 14 for comparison with the left image. The red and white tape indicated by the black, blue and purple arrows represents the fractures indicated by the black arrows in Figure 8 and by the blue and purple arrows in Figure 9. The black and yellow tape represents fractures that did not penetrate through the fenestron duct. The brown line represents the portion of the rear tail rotor drive shaft that was missing as illustrated later in Figure 58 and the yellow dashed line indicates the location of the junction frame. The red arrow indicates the tail rotor drive shaft #1 bearing illustrated later in Figure 64 and the white arrow indicates the leading edge of the main rotor blade, confirming that the main rotor head rotates clockwise viewed from above.

Stator assembly examination.

The tail rotor gearbox and stator assembly, and a stator ring, were found outside of the wreckage path, approximately 81 feet north of the main wreckage as illustrated in Figure 2. As designed, the tail rotor gearbox is bolted to the stator ring, the stator ring is supported in the fenestron duct by ten stators and the tail rotor gearbox drives the tail rotor hub which has ten unevenly-spaced tail rotor blades[4] as illustrated in Figure 10. Pieces of the tail rotor gearbox assembly and stator ring recovered are illustrated in Figure 15 with the gearbox, the stator ring, the remaining stators or their original location and the remaining blades identified. The folded

[4] The uneven spacing is designed to provide a lower noise level.

stator illustrated in Figure 15 and identified as stator 9 was found approximately 95 feet north of the main wreckage as illustrated in Figure 2. Fractures at what was the inner end of the stator were found to match fractures on the stator ring at the stator 9 location identified in Figure 15. The blue arrow indicates the outer portion of stator 1, similarly indicated in Figure 11, which, with the fitting indicated by the white arrow in Figure 11, was removed from the fenestron duct for examination of the stator. The yellow arrow indicates the tail rotor drive shaft input into the tail rotor gearbox illustrated later in Figure 17.

Initial examination of the recovered tail gearbox and stator assembly pieces revealed mechanical damage to the stator ring, missing and damaged stators, missing and damaged tail rotor blades, a fractured pitch control lever, the fairing and the chip detector was missing (the chip detector was found in the debris path). The stator ring and stators were removed from the tail gearbox and hub assembly for examination. Examination of the stator ring revealed a circumferential fracture, indicated by the blue arrow in Figure 15, adjacent to the right flange and extended from stator 6 counter clockwise to stator 1. The identification plate displayed the assembly number “350A23040501”, the serial number “352” and the manufacture date “09/09”. The right flange between stator 6 and 1 was missing. An almost completely circumferential fracture, indicated by the white arrows in Figure 15, was located adjacent to the left flange and extended clockwise from stator 1 to the access hole for the tail rotor drive shaft. A transverse fracture, indicated by the green arrow in Figure 15, extended between the circumferential fractures at stator 10 and the portion of stator ring below stator 10, indicated by the brown arrow in Figure 15, had been bent inwards. Examination of the fracture faces on the stator ring revealed grainy surfaces consistent with an overload event.

The two pieces of the fractured stator 1 identified in Figure 15 are illustrated in Figure 16 with a blue arrow indicating bending of the fractured end of the larger piece similarly indicated in Figure 11. The stator ring is identified and a yellow arrow indicates the tail rotor drive shaft input to the tail gearbox as in Figure 15. Measurements, allowing for the bending, revealed that the stator was complete. Examination of the fracture faces revealed slant fracture faces with grainy surfaces, consistent with an overload event, with several edges displaying a sawtooth pattern, consistent with a high speed separation. The red arrow indicates one of the sawtooth edges. The purple arrows indicate the direction of the bending on both pieces of the stator and the green arrow indicates the bending direction of the adjacent portion of the inner piece. The white arrow indicates the outer end fitting indicated by the white arrow in Figure 11.

Stator 2 was mostly missing with two fractured portions of the inner attachment bracket still riveted to the stator ring. Stator 3 was intact, straight and still attached to the stator ring. One side of the inner attachment bracket was fractured and the outer attachment was intact and still bolted to a portion of the fenestron duct. Stator 4 was mostly missing with only one fractured portion of the inner attachment bracket riveted to the stator ring. Stator 5 was mostly intact, bent, slightly twisted and displayed a fracture at its outer end. An outer portion of the stator containing the outer attachment was missing. The inner attachment bracket was intact but the lower right corner and adjacent right flange of the stator ring displayed impact damage. Stator 6 was mostly intact, relatively straight, bent at the inner attachment and displayed a fracture at its outer end. An outer portion of the stator containing the outer attachment was missing. Examination of the fracture faces on the stators revealed grainy surfaces consistent with an overload event.

Stator 7 was mostly missing with one fractured portion of the inner attachment bracket still riveted to the stator ring. Stator 8 was mostly missing with one fractured portion of the inner attachment bracket still riveted to the stator ring. Stator 9 was the stator recovered and is illustrated and identified in Figure 15. The stator was intact but folded at approximately mid-span. The inner end contained a fractured central portion of the attachment bracket and two fractured portions of the inner attachment bracket were still riveted to the stator ring. The outer attachment was intact, bent and still bolted to a portion of the fenestron duct. Stator 10 was mostly missing with an inner portion still riveted to a fractured portion of the attachment bracket which was attached to the stator ring by one rivet. Examination of the fracture faces on the stator ring revealed grainy surfaces consistent with an overload event.

Tail gearbox examination.

Examination of the rear portion of the rear tail rotor drive to the tail gearbox indicated by the yellow arrow in Figure 15 revealed a portion of the rear shaft still riveted to the rear flange. The rear flange was bolted at three equally spaced locations to a laminated flexible coupling which was bolted at three equally spaced locations to the splined end fitting. The splined end fitting drives the tail gearbox input pinion which drives the output pinion connected to the tail rotor hub. The rear portion of the rear tail rotor drive shaft is illustrated in the left image in Figure 17 with the portion of the rear shaft and its flange, the flexible coupling and the splined end fitting identified. The blue arrow indicates a portion of the flange that had been bent aft and the white arrow indicates mechanical damage to the outer edge of the coupling at its bolted attachment to the splined end fitting. The drive shaft was found to rotate smoothly clockwise looking aft, and is illustrated in the right image in Figure 17 positioned approximately 90-degrees clockwise from the left image. As in the left image, the blue arrow indicates the aft deformation of the flange and the white arrow indicates the mechanical damage to the coupling which also displayed a rearward deformation. The green arrow indicates a coupling laminate that had fractured and been displaced aft.

The drive shaft was smoothly rotated 180-degrees looking aft and is illustrated in the left image in Figure 18 with a yellow arrow indicating the coupling and a white arrow indicating mechanical damage at its bolted connection to the splined end fitting. The green arrow indicates a portion of the rear shaft that had been deformed forward by the deformation of the shaft indicated by the white arrow in the right image. In the right image in Figure 18 the blue arrow indicates the bent portion of the flange similarly indicated in the left image in Figure 17, the brown arrow indicates the inwardly deformed portion of the shaft similarly indicated in the right image in Figure 17 and the purple arrow indicates the outward and rearward curl of shaft material similarly indicated in the left image.

The tail rotor hub was removed from the tail gearbox and the tail gearbox was partially disassembled. The major pieces are illustrated in Figure 19 and identified as the splined end fitting, with the rear portion of the rear drive shaft illustrated in Figure 17 still attached, the housing, the input pinion, the output pinion and the output cover. The splined end of the splined end fitting indicated by the green arrow is normally installed in the housing at the location indicated by the yellow arrow and engages in a mating spline in the input pinion. Examination of the splines, after solvent cleaning, revealed a normal contact pattern with no damage to suggest a sudden stoppage. The input pinion drives the output pinion and an examination of the gear teeth, after solvent cleaning, also revealed a normal contact pattern with no damage to suggest a sudden stoppage.

Tail rotor hub assembly examination.

The tail rotor hub assembly removed from the tail gearbox was missing the fairing, the outer ring was distorted and fractured, blades were fractured and bent, inner and outer root bearings were missing and arms on the blade roots were bent and fractured. Removal of the center flange revealed that all the torsion/tension bars displayed compression buckling. The tail rotor hub components are illustrated in Figure 20 with the blades arbitrarily numbered 1 through 10 and their component parts identified on blade 1. The inner ring of the hub is identified and a yellow arrow indicates the location for the root inner bearing. The outer ring of the hub is identified and a brown arrow indicates the location for the root outer bearing. The splined flange is identified and provides the inner attachment for the torsion/tension bars and is normally driven by the gearbox. The hub rotates clockwise when viewed from the right. The center flange is normally connected to each of the arms on the blade roots and in operation it changes the blade pitch equally. Examination of the center flange revealed that four of its ten arms had fractured and the tips were missing. The fracture faces displayed rough grainy surfaces consistent with an overload event.

Blade 1 was bent to the left side of the hub. It was mostly intact but missing a small portion of the leading edge and displayed an indentation on the trailing edge, both within 2-inches of the tip. Approximately 50% of the outer bearing remained and approximately 90% of the inner bearing remained. The tension/torsion bar was buckled and the root arm was fractured across the attachment hole for the center flange. Blade 2 was intact but slightly twisted with curved deformations along the trailing edge. The outer bearing was missing and the tension/torsion bar was buckled. Blade 3 was bent to the left side, fractured and missing approximately 6 inches. The outer bearing was missing and approximately 80% of the inner bearing remained. The outer ring was fractured between the blade 3 bearing location and the blade 4 bearing location. The tension/torsion bar was buckled.

Blade 4 was fractured and missing approximately 9 inches. The inner and outer bearings were missing. The outer ring was fractured between the blade 4 bearing location and the blade 3 bearing location as previously noted, from the blade 4 bearing location to the left edge of the outer ring and from the blade 4 bearing location to the blade 5 bearing location. The root arm was bent and almost fractured completely across the attachment hole for the center flange which was deformed. The tension/torsion bar was buckled. Blade 5 was fractured, missing approximately 5 inches, and the tip was bent. The outer bearing was missing and approximately 75% of the inner bearing remained. The root arm was bent and almost fractured completely across the attachment hole for the center flange which was deformed. The tension/torsion bar was buckled. Blade 6 was mostly intact with a slight bend to the right. Approximately ¼-inch of the inner edge of the trailing edge was fractured and deformed outboard. The outer bearing was missing and approximately 70% of the inner bearing remained. The root arm was bent and fractured completely across the attachment hole for the center flange. The tension/torsion bar was buckled.

Blade 7 was mostly intact and bent to the right. A notch, approximately 1/8-inch wide and 1/4-inch deep was located on the trailing edge, approximately 9 3/4-inches from the root. Approximately 4 inches from the root, a 1/8-inch wide band of trailing edge was fractured and displaced outward and forward. Indentations and gouges were observed on the outer 4 inches of the leading edge. The outer bearing was missing and approximately 80% of the inner bearing remained. The root arm was bent and fractured across one side of the attachment hole which was deformed. The tension/torsion bar was buckled. Blade 8 was mostly intact and bent to the right. Indentations and gouges were observed on the outer 3 inches of the leading edge and the rear outer tip of the trailing edge was bent to the right. Approximately 30% of the outer bearing remained and the inner bearing was in place but fractured. The attachment hole in the root arm was deformed and the tension/torsion bar was buckled. Blade 9 was bent to the right, fractured and missing approximately 3 1/2 inches. The outer bearing was missing and approximately 85% of the inner bearing remained. The root arm was bent and the hole deformed. The torsion/tension bar was buckled.

Blade 10 was fractured and bent over the right side of the hub. Measurement revealed that approximately 4 1/2-inches of the blade was missing. The blade and its root had been displaced inwards severely buckling the tension/torsion bar as indicated by the brown arrow in Figure 20. The outer ring of the hub was firmly entrapped in the inner trailing edge of the blade and indicated by the white arrow in Figure 20. The root arm was bent and fractured across the center flange attachment hole. The inner and outer root bearings were missing.

Tail guard, mounting plates and skid examination.

Pieces of the tail guard, the tail skid and the mounting plate assembly were found in the wreckage path and are located in Figure 2. The tail guard piece, also identified in Figure 9, mounting plate assembly and the tail skid are illustrated and identified in Figure 21 in their approximate installed orientation and viewed from the right. The orientation was determined from the training EC-130B4, drawing 350A230407 (document 3 in section C) and drawing 350A234044 (document 4 in section). The mounting plate assembly consisted of the right and left mounting plates with a portion of the tail guard sandwiched between them and portions of the two tail skid brackets still bolted to the plates. The blue arrow indicates the right lug of the front tail skid bracket still bolted to the mounting plate assembly and the yellow arrow indicates the portion of the bracket still bolted to the tail skid. In Figure 21 the brown arrow indicates the left lug of the rear tail skid bracket, which was recovered and the white arrow indicates a portion of the left tail skid bracket still bolted to the tail skid. The orange arrow indicates the underside of the rear bracket that was exposed when the bracket was deformed to the left, fracturing the four attaching rivets.

The items in Figure 21 are also illustrated in Figure 22 in a similar orientation but viewed from the left side. The green arrow indicates the left lug of the front tail skid bracket still bolted to the mounting plate assembly. The brown arrow indicates the original location of the rear tail skid bracket lug on the left mounting plate and the white arrow indicates the right lug still bolted to the tail skid with a fracture across the bolt hole. The yellow arrow indicates vegetation trapped between the tail guard piece and the portion of the fenestron it is attached to. Details of the vegetation can be found in the Structures Factual Report.

The front bracket is bolted to the skid by two bolts along its center line and displayed two fracture faces, one for each lug. Examination of the fracture surfaces on the bracket revealed a course grainy surface consistent with an overload event. The rear bracket is bolted to the skid by two bolts along its center line and by four rivets on each side, outside of the lugs. Examination of the left fracture surface on the rear bracket revealed a coarse grainy surface consistent with an overload event. Most of the rear right lug was still present and had been displaced to the left. The lug displayed a fracture across the hole normally occupied by the bolt attaching it to the mounting plate and an examination revealed a coarse grainy surface consistent with an overload event.

The left mounting plate is illustrated in Figure 23 with a green arrow, as in Figure 22, indicating the lug of the front tail skid bracket and a brown arrow indicating one of the rivets that fasten the plate to the skin of the tail guard. The yellow arrow indicates a distinct deformation of the plate at its forward end which reduced as distance from the edge increased. A top view of the mounting late assembly is illustrated in Figure 24 with the right and left plate identified. The skin of the tail guard is identified and brown arrows indicate some of the rivets that fastened the mounting plate to it. The white arrows indicate the thickness of the honeycomb at that location and the green arrows indicate the reduced thickness at the forward end of the mounting plate assembly where the left plate is deformed. The honeycomb between the two layers of skin is identified. The front end of the mounting plate assembly is illustrated in Figure 25 with the reduced thickness of the honeycomb indicated by the green arrows as in Figure 24. The yellow arrow indicates the distinct deformation similarly indicated in Figure 23 and illustrates its smoothly curved profile at the front edge.

Examination of the tail skid revealed that the skid was bent, mechanically damaged and only portions of the front and rear brackets were still attached. The upper surface of the tail skid bracket is illustrated in Figure 26 with the remnants of the front and rear brackets identified and the forward, left and right directions indicated. The amount of bending is illustrated by the red dashed line which is a continuation of the right side of the skid adjacent to the rear bracket. The lower surface of the skid is illustrated in Figure 27 with the forward, left and right directions indicated. Mechanical damage was observed at the right rear tip of the skid located in the white box in Figure 27 and on the left edge and lower surface of the skid within the yellow box in Figure 27. Paint was missing around the front left rivet of the rear bracket within the green box in Figure 27 and lines on the surface appeared to emanate from the rivet.

The mechanical damage within the white box in Figure 27 is illustrated in Figure 28 with a relatively small area of exposed metal, indicated by the red arrow, displaying longitudinally oriented scratches on its forward and rear edges, consistent with a light scraping action.

The mechanical damage on the left edge of the skid, within the yellow box in Figure 27 is illustrated in Figure 29 with the installed forward direction indicated and the remnant of the front bracket lug identified. The blue, yellow and purple arrows indicate the direction of the adjacent surface scratches originating at the edge and the white arrows indicate some distinct gouges at the corner with the lower surface. The yellow ruler is used as a straight edge to indicate that a significant amount of material is missing from the lower surface of the skis adjacent to the left edge. The lower surface of the skid within the yellow box in Figure 27 is illustrated in Figure 30 with the yellow ruler again being used as a straight edge. The red arrow indicates a relatively small gap between the left edge and the ruler indicating that a small amount of material was missing. The black arrow indicates a straight gouge oriented diagonally and initiating at the left edge. The purple arrow indicates a distinct scratch oriented perpendicular to the edge and initiating at the edge. The blue arrows indicate distinctly radial scratches initiating at the edge. The white arrow indicates where paint had been removed leaving the primer and a dark deposit with a radial orientation.

The corner at the intersection of the left edge and the lower surface is illustrated in Figure 31. The red arrow indicates an undamaged corner and the black and blue arrows indicate the same corner with differing amounts of damage appearing as radii. An area at the forward end was clean, displayed a distinct pattern of scratches and is contained within the yellow box. A group of seven distinct grooves associated with some of the previously noted scratches were observed and are numbered 1 through 7. The white arrow indicates an area of paint that was removed for analysis and is illustrated later in Figure 38.

The area within the yellow box in Figure 31 is illustrated in Figure 32 with the left edge and the lower side identified. The red arrow indicated an undamaged corner and the green arrow indicates the damaged corner. The white arrow indicates where the paint sample indicated in Figure 31 was located. The yellow arrow indicates an area displaying distinct diagonally oriented scratches and the blue arrow indicates mechanical damage that had smoothed out the scratches. The green arrow indicates a v-shaped area with a distinct center line and parallel scratches on either side. The purple arrows indicate the new corner between the left edge and the lower surface which consisted of a bur where left edge material had been displaced toward the lower surface.

The remnant of the front bracket identified in Figure 26 was removed. The damaged portion of the skid illustrated in Figure 31 was removed by cutting across the skid at the red dashed line and then along the yellow dashed line in Figure 30. The seven distinct grooves identified in Figure 31 were then examined in a scanning electron microscope (SEM). An SEM micrograph of grooves 1 and 2 is illustrated in Figure 33 with the grooves identified. The blue arrows indicate material trapped in each groove and the red arrow in groove 2 indicates an entrapped particle.

The particle indicated by the red arrow in Figure 33 was analyzed by an energy dispersive spectrometer (EDS) on the SEM and elemental mapping was performed. Figure 34 illustrates the particle and the dispersion of the major elements in the particle. The upper image illustrates the particle, the middle images indicate the presence of chromium (left) and manganese (right), and the lower images indicate the presence of iron (left) and nickel (right), elements consistent with a stainless steel.

An SEM micrograph of grooves 3 and 4 is illustrated in Figure 35 with the grooves identified and blue arrows indicating entrapped material. An SEM micrograph of grooves 5 and 6 is illustrated in Figure 36 with the grooves identified and blue arrows indicating entrapped material. An SEM micrograph of groove 7 is illustrated in Figure 37 with the grooves identified and blue arrows indicating entrapped material.

The SEM examination also revealed cylindrical particles in the material trapped in the grooves. An SEM micrograph of the material trapped in groove 1 is illustrated in Figure 38 with yellow arrows indicating the particles. EDS analysis was performed on the area containing the particles and the spectra, illustrated in Figure 39, displays major peaks for carbon, oxygen, aluminum, and silicon, smaller peaks for magnesium and calcium, and traces of sodium and potassium. EDS analysis was then performed on the paint chip removed from the tail skid and indicated by the white arrow in Figure 31. The spectra displayed major peaks for carbon and oxygen, a minor peak for aluminum, and traces of silicon, magnesium and sodium. A sample of primer was removed from the tail skid and an SEM examination revealed cylindrical particles, some of which are indicated by the yellow arrows in Figure 40. EDS analysis was then performed on the primer sample and the spectra displayed major peaks for carbon, oxygen, aluminum, and silicon, smaller peaks for smaller peaks for magnesium and calcium, and traces of sodium, potassium and chlorine., similar to the EDS analysis illustrated in Figure 39.

Samples of paint and primer were removed for FTIR[5] analysis. Swabs were also taken on the painted surface and on the dark deposit in and around the gouges for FTIR analysis. The results of the analysis are presented in Materials Laboratory report 12-087.

The area within the green box in Figure 27 contained rivets with surface lines emanation from them. The area is illustrated in Figure 42 with red arrows indicating the radial lines around the forward rivet and a blue arrow indicating a radial line emanating from the adjacent rivet. The yellow arrow indicates a depression in the left edge. A dye penetrant inspection was performed on the area in Figure 42 and did not display any indications of cracks.

Tail boom examination.

A closer view of the tail boom identified in Figure 1 is illustrated in Figure 43 with the left and right portions of the horizontal stabilizer identified. The lack of longitudinal flanges for attachment of the tail rotor drive shaft cover is consistent with the tail boom being inverted. The tail boom was cut along the red dashed line and the portion indicated by the red arrow was shipped with the fenestron pieces as it contained the mating fracture to the junction frame piece as illustrated in Figure 3. A portion of the tail boom containing the tail rotor drive shaft number 1 bearing was also removed and shipped with the fenestron pieces. The tail boom was subsequently shipped to the NTSB facility in Ashburn, Virginia after being cut along the purple dashed line for shipping. In Figure 43 the rear portion of the tail boom is identified as “A” and the forward portion is identified as “B”. The investigative group was re-convened at the NTSB facility to examine the tail boom but the operator declined the invitation.

The tail boom pieces received for examination were positioned as normally installed on the helicopter and are illustrated in Figure 44 with an engine access panel that was also received. The tail boom consisted of pieces A and B, the remains of the horizontal stabilizer identified as left and right and the tip of the left horizontal stabilizer. An identification plate on the horizontal stabilizer, within the tail boom, displayed the assembly number “350A1300410101”, the serial number “TB 7356”, and the manufacture date “10/2009”. The red arrow indicates the cut indicated by the red dashed line in Figure 43 and the purple arrows indicated the cut indicated by the purple dashed line in Figure 43.

A closer view of tail boom A in Figure 44 is illustrated in Figure 45 with the right and left upper attachments for the horizontal stabilizer indicated and identified

[5] Fourier-Transform Infrared spectroscopy (FTIR) is a proven analytical technique for identifying unknown chemicals. The technique relies on the microscopic interaction of infrared light with chemical matter and produces a pattern of absorption features called a spectrum. The spectrum of each chemical is unique, and matching it with a library of spectra makes identification rapid.

and the blue arrows indicating the original location of the tail rotor drive shaft number 1 bearing illustrated later in Figure 65. Examination revealed that the right and central portions of the horizontal stabilizer had been displaced forward and the left portion had been displaced to the rear. The red arrows indicate the manufactured outer ends of the horizontal stabilizer's steel spar. A majority of the tail boom upper surface was covered in a black sooty deposit, consistent with it being adjacent to a fire. The right portion of the horizontal stabilizer displayed a sooty deposit on the paint and the remaining skin displayed fractures. The left portion of the horizontal stabilizer displayed a sooty deposit adjacent to the tail boom and outboard of the deposit the skin displayed a paintless pale yellow surface and re-solidified edges, consistent with it being in a fire. The white arrow on the right side of the tail boom indicates buckling of the skin, forward of an interior mainframe, forward of the horizontal stabilizer (the location of the mainframe is indicated by the brown arrow and the right side of the mainframe is illustrated in the right image in Figure 47). The tail boom was bent and the amount of bending is illustrated by the blue dashed line which represents the center of the tail boom forward of the mainframe and the white dashed line which represents the center of the tail boom aft of the mainframe.

The right upper attachment for the horizontal stabilizer identified in Figure 45 was found displaced forward and outboard and is illustrated in Figure 46 with the horizontal stabilizer and the tail boom identified. The red arrows indicate the fractured ends of screws in the lower plate and the blue arrows indicate the ends of the same screws in the upper plate. The yellow arrow indicated a recess in the upper plate where the main attachment bolt indicated by the purple arrow is normally located. The green arrow indicates a gap between the lower plate and the skin of the horizontal stabilizer. Examination of the horizontal stabilizer attachments can be found in the Structures Factual Report.

The forward displacement of the horizontal stabilizer on the right side of the tail boom had forced the leading edge into the adjacent mainframe. An exterior view of the leading edge is illustrated in the left image in Figure 47 with a yellow arrow indicating the deformed leading edge and a red arrow indicating forward edge of the slot for the horizontal stabilizer. The purple arrow indicates the main attachment bolt similarly indicated in Figure 46. An interior view of the leading edge is illustrated in the right image in Figure 47 with the adjacent mainframe identified. A yellow arrow indicates the leading edge and a purple arrow indicates a portion of the mainframe that had been fractured and cured forward by the leading edge. The white arrows indicate the portions of stringers that were reinforced for the horizontal stabilizer attachments.

The left upper attachment for the horizontal stabilizer identified in Figure 45 was found displaced slightly inboard and is illustrated in Figure 48 with the horizontal stabilizer and the tail boom identified. The blue arrows indicate the ends of the screws similarly identified in Figure 46. The purple arrow indicates the head of the main attachment bolt which is too close to the recess indicated by the yellow arrow to allow the installation of a socket on the head. The white arrow indicates a buckled on an adjacent doubler where the buckle is more severe at hits aft end indicated by the green arrow, consistent with the aft displacement of the horizontal stabilizer.

For comparison with the upper surface of the tail boom illustrated in Figure 45 the underside is illustrated in Figure 49 with the right and left lower attachments indicated. The blue dashed line indicates the center line of the tail boom forward of the mainframe and the white dashed line indicates the center line of the tail boom aft of the mainframe. The white arrow, as in Figure 45, indicates the buckling on the right side, forward of the mainframe and the blue arrow indicates a buckle aft of the mainframe. As in Figure 45, the yellow dashed line indicates the orientation of the horizontal stabilizer’s left spar and the black arrow indicates the fire damaged lower skin on the horizontal stabilizer. The green arrow indicates a doubler similarly indicated in Figure 45 and the purple arrow indicates a similar doubler on the right side.

Examination of the horizontal stabilizer right lower attachment revealed that the stabilizer had been displaced forward and the lower plate had rotated. The right lower attachment is illustrated in Figure 50 with the forward direction indicated. The blue arrows indicate the holes in the upper plate normally occupied by screws and nuts similarly indicated in Figures 48 and 48 and the yellow arrow indicates the recess normally occupied by the main attachment nut indicated by the purple arrow. The red arrow indicates the fractured end of a screw and the green arrow indicates the original location of the lower plate.

The left lower attachment of the horizontal stabilizer is illustrated in Figure 51 with the forward direction indicated. The blue arrows indicate the holes in the upper plate normally occupied by screws and nuts and the purple arrow indicates the main attachment nut (and cotter pin) still positioned in the recess in the upper plate. The red arrow indicates the fractured end of a screw and the green arrow indicates the original location of the lower plate.

For comparison with the left image in Figure 47, the leading edge of the horizontal stabilizer indicated by the purple arrow in Figure 45 is illustrated in Figure 52 with the forward and up directions indicated. The yellow arrow indicates the leading edge and the red arrow indicates the forward edge of the slot in the tail boom for the horizontal stabilizer. The blue arrows indicate rivets with fractured skin between them, the green arrows indicate partial rivet holes in the upper skin with fractured skin between them and the purple arrows indicate partial rivet holes in the lower skin with fractured skin between them. Examination of the fracture faces between the blue, green and purple arrows revealed a slant fracture consistent with an overload event although the features between the green and purple arrows were less defined consistent with exposure to fire.

Buckling of the upper and lower surfaces of the tail boom around the mainframe is illustrated in Figures 45 and 49. The right side of the tail boom is illustrated in Figure 53 with the forward and up directions indicated. The right and left portions of the horizontal stabilizer and the right lower attachment illustrated in

Figure 50 are identified. The location of the mainframe is indicated by the white arrow and the purple and yellow arrows indicate diagonally oriented buckling forward of the mainframe. The grey arrows indicate a buckle that is longitudinally oriented forward of the mainframe, diagonally oriented immediately forward of the mainframe, and longitudinally oriented aft of the mainframe. The blue arrow indicates buckling on the underside that is similarly indicated in Figure 49.

The left side of the tail boom is illustrated in Figure 54 with the forward and up directions indicated. The left portion of the horizontal stabilizer and the left lower attachment illustrated in Figure 51 are identified. The white arrow indicates the location of the mainframe and the blue arrows indicate the diagonally oriented buckling on the underside aft of the mainframe, similarly indicated in Figure 49. The orange arrow indicates the leading edge of the horizontal stabilizer illustrated in Figure 52 and the purple arrows indicate the fractured edge similarly indicated in Figure 52. The red arrows indicate fire damaged areas on the tail boom and the horizontal stabilizer.

The examination of the tail boom revealed fire damage to both upper and lower surfaces of the left horizontal stabilizer. The outer portion of the left horizontal stabilizer identified in Figure 44 was also fire damaged on both sides and the upper surface is illustrated in Figure 55 with the outer end of the horizontal stabilizer. The blue arrows indicate the pale yellow surface, consistent with thermal degradation of the primer, and the purple arrow indicates a grey area, with a black edge, displaying incipient melting consistent with the fire being more intense in that area. The red arrows indicate the upper and lower flanges of the horizontal stabilizer’s steel spar which was slightly twisted with corrosion on its exposed surfaces.

Examination of the fire damaged outer portion of the left horizontal stabilizer revealed mechanical damage to the leading edge and the trailing edge. A view of the outer portion, from the left, is illustrated in Figure 56 with a blue and purple arrow indicating the fire damaged areas similarly indicated in Figure 55. A red arrow indicates the relatively intact airfoil profile of the end cap and the red dashed line outlines crushing damage that had fractured the upper skin and crushed the rear end of the airfoil end cap indicated by the yellow arrow. The white arrow indicates where a portion of the leading edge between the end cap and the doubler was missing. The profile of the leading edge was intact and the skin displayed signs of incipient melting.

The front flange of the junction frame illustrated in Figure 4 remained in the rear end of the tail boom illustrated in Figure 3. The rear end of the tail boom was removed by cutting along the red dashed line in Figure 43 and shipped with the Fenestron pieces. The removed portion of the tail boom is illustrated in Figure 57, looking forward, with the right upper, right lower, left upper and left lower stringers identified. The stringers extend from the junction frame to the mainframe forward of the horizontal stabilizer and provide the upper and lower attachments for the horizontal stabilizer. The right stringers are indicated by the white arrows in the right image in Figure 47. Examination of the removed rear end of the tail boom revealed that it was no longer circular like the junction frame illustrated in Figure 4 and had been subjected to compression and lateral dislocation. To illustrate the lateral dislocation the red dashed line in Figure 57 indicates the normal 12 o' clock position and the yellow dashed line indicates the normal 6 o' clock position. The blue arrows indicate the flanges use to attach the tail rotor drive shaft cover and the green arrows, as in Figure 3, indicate the attachments for the fairing between the tail rotor drive shaft cover and the fenestron. The brown arrows indicate the fracture face and the white arrow indicates embedded soil.

The left lower stringer is illustrated and identified in Figure 58 with purple arrows indicating the manufactured rear end of the stringer. The forward flange of the junction frame is identified and the brown arrows indicate the fracture face.

Tail rotor drive shaft examination.

The tail rotor drive consists of a forward shaft, an intermediate shaft and a rear shaft that rotate clockwise when looking forward. The shafts are connected to the engine, the tail gearbox and to each other by flexible couplings similar to the one illustrated in Figure 17. The long center shaft is supported on the tail boom by four bearing assemblies mounted on elastomer bushes and one fixed self-aligning ball bearing. The intermediate shaft support bearings are numbered 1 through 5 starting at the rearmost bearing which is the fixed bearing. The recovered pieces of the tail rotor drive shaft were positioned as installed and are identified in Figure 59 with the forward direction indicated. Positioning the pieces revealed that a significant length of the intermediate shaft between bearing 2 and bearing 5 was missing and all the recovered drive shaft pieces forward of the rear drive shaft were fire damaged. The positioning also revealed that a portion of the rear drive shaft was missing.

The remaining portion of the rear drive shaft located and identified in Figure 2 is illustrated in Figure 60, positioned between the intermediate shaft and the tail gearbox. The #1 bearing is identified and the #1 bearing support on the removed portion of tail boom illustrated later in Figure 65, are identified. The red arrow indicates the rear portion of the tail boom similarly indicated in Figure 43. A white arrow indicates the rear end of the rear drive shaft illustrated in Figure 16 and the orange arrow indicates the fracture rear end of the rear drive shaft. The drive shaft between the white arrow and the orange arrow was missing and its location on the helicopter is indicated by the brown line in the two images in Figure 14. The green arrow indicates a flexible coupling at the forward end of the drive shaft which is bolted to a flange at the rear end of the intermediate drive shaft. The examination revealed that the intermediate shaft had separated from the flange at the location indicated by the black arrow, with the fracture following the circumferential line of the fasteners. The fractured rear end of the intermediate drive shaft was fire damaged and missing some material but the portion of the shaft still attached to the flange was clean

The fracture face on the intermediate drive shaft was removed for examination by sawing aft of the fasteners and forward of the #1 bearing. The fasteners, which were obscuring some of the fracture face, were removed and the disassembled piece is illustrated in Figure 61 with a red dashed line indicating the cut and the forward direction, as installed, indicated. The portion of the rear flange and the portion of the intermediate shaft are identified. A closer view of the area within the red box in Figure 61 is illustrated in Figure 62 with the rear flange and the intermediate drive shaft identified. The red arrow indicates a typical fracture face displaying a smeared surface and extending diagonally from the side of one hole to the forward end of the adjacent hole, consistent with torsional overload in a shaft rotating clockwise when looking forward. The blue arrows indicate drive shaft material, with a circumferential orientation, that had transferred to the flange during the intermediate drive shaft's rotation on the shaft portion of the flange after the fracture.

The fractured rear end of the rear drive shaft indicated by the orange arrow in Figure 60 is illustrated in Figure 63 with the fracture similarly indicated and the forward direction, as installed, indicated. Examination of the fractured end revealed fracture faces oriented on a slant plane and leaves of material, indicated by the white arrows, oriented in one direction. The red arrow and the blue arrow indicate rub marks which, indicated by the positioning, were located where the drive shaft entered the fairing between the drive shaft cover and the fenestron.

The forward end of the intermediate drive shaft contains a splined fitting that is normally inserted into a mating splined fitting at the rear end of the forward drive shaft. The fire damage on the forward end of the intermediate drive shaft and the rear end of the forward drive shaft is illustrated in Figure 64 with the shafts identified. On the intermediate shaft, the #5 bearing and the splined end of the fitting are identified. The red arrow indicates the fractured end of the intermediate shaft which had been flattened and displayed incipient melting. As previously noted and illustrated in Figure 59, most of the intermediate drive shaft between the #5 bearing and the #2 bearing was missing. The white arrows indicate remains of the forward shaft's rear fitting on the forward shaft and the intermediate shaft. The blue arrow indicates the manufactured end of the forward shaft which is manufactured from a steel alloy to resist the heat from the nearby engine exhaust.

The #1 bearing is normally installed in its flange assembly located at the rear of the tail boom. A portion of the tail boom containing the bearing flange assembly was removed from its location indicated by the blue arrows in Figure 45 and is illustrated in Figure 65 with the forward direction indicated. On the helicopter the rear flange is bolted to the front flange which is bolted to the tail boom support which is riveted to the tail boom and to the flange for the drive shaft cover. Examination revealed that the #1 bearing flange assembly had been displaced forward and to the left. The left side of the boom support had been subjected to compressive deformation but was intact. The right of the boom support was fractured and deformed. The white arrows in Figure 65 indicate mating fracture faces on the drive shaft cover's right flange. For comparison, the #1 bearing flange on the training EC-130B4 illustrated in Figure 14 is illustrated in Figure 66 with the bearing flange identified and the forward direction indicated. The rear shaft identified in Figure 60 is identified and the coupling indicated by the green arrow in Figure 60 is also identified. The pitch change rod which is normally located in the hole indicated by the green arrow in Figure 5 is identified. The green arrow indicates one of the rear fairing attachments similarly indicated in Figures 3 and 57 and the yellow arrow indicates the front fairing attachment similarly indicated in Figure 65.

Examination of the #1 bearing flanges revealed displaced material on the right side of the rear flange. For comparison, the left side of the rear flange indicated by the purple arrow in Figure 65 is illustrated in Figure 67 with the intact edge similarly indicated by the purple arrow. The displaced edge is illustrated in Figure 68 with the displaced material indicated by the blue arrow and contained between the black arrows. A side view of the right edge is illustrated in Figure 69 with the displaced material indicated by the blue arrow and contained between the black arrows.

Main rotor blades examination.

The recovered main rotor blades were found to be mechanically damaged and fire damaged. The upper surfaces of the main rotor blades are illustrated in Figure 70 with the blades identified as “A”, “B” and “C”. The red arrow indicates the fractured tip of blade “C” similarly indicated in Figure 1 and the red box contains the blade grips illustrated later in Figure 79. Briefly, the blades are constructed of a foam core with glass roving tape forming the leading edge and the trailing edge. A glass fabric skin covers the blade except for the leading edge and a polyurethane strip abutting the rear of the leading edge on the underside of the blade. The leading edge of each blade is protected from abrasion by two stainless steel cuffs, an outer cuff and an inner cuff. The yellow arrows in Figure 70 indicate the outer cuffs and the white arrows indicate the inner cuffs. The blades were examined as illustrated in Figure 70 and then inverted for examination. The examination revealed that the post impact fire had consumed the resin to expose the fibers to further fire damage which was more severe in some areas.

Blade A displayed more fire damaged area than blades B or C, with equally size portions of the outer tip not blackened by fire and with the cuff, in that portion, still attached to the leading edge. The lower surface of an outer portion of blade A is illustrated in Figure 71 to display the fire damaged fibers for comparison with the outer portion illustrated in Figure 70. The outer cuff is identified and had mostly separated from the leading edge of the blade and described a V-shape that was retained at the location on the leading edge indicated by the white arrow. The yellow arrow indicates the short portion of the outer cuff remaining at the outer end of the leading edge. The inner cuff was also mostly separated from the leading edge and retained at the location on the leading edge indicated by the blue arrow in Figure 70. An outer portion of the inner cuff displayed an increasing separation from the leading edge starting at the blue arrow. The inner portion was completely separated from the leading edge, bent to the rear almost perpendicular to the leading edge.

The outer tip of blade A indicated by the yellow arrow in Figure 71 is illustrated in Figure 72 with the outer cuff identified and a yellow arrow indicating the relatively undamaged leading edge. The blue arrow indicates fibers not fire damaged and the green arrow indicates fibers that are fire damaged. The white arrow indicates a fracture face of the cuff displaying a slant fracture consistent with an overload event.

A closer view of the v-shaped outer cuff is illustrated in Figure 73 with the retention point indicated by the white arrow as in Figure 71. The outer cuff was bent at the leading edge of the outer cuff and fractured behind the leading edge. The yellow arrow indicates a buckle at the rear edge of the outboard portion of the cuff and the blue arrows indicate buckles at the rear edge of the inboard portion of the cuff.

Blade B did not display the severity of fire damage displayed by blade A and the upper surface illustrated in Figure 70 displayed less of a blackened surface than the lower surface. The lower surface is illustrated in Figure 74 with the outer cuff identified.

The outer tip of blade B indicated by the yellow arrow in Figure 74 is illustrated in Figure 75 with yellow arrow indicating distinct indentations in the leading edge. A blue arrow indicating a penetration into the leading edge, a white arrow indicating a fracture in the lower surface of the cuff with the outer fracture face bent forward and a green arrow indicating a thin indentation in the leading edge.

Blade C displayed the least fire damage which was restricted to the inboard end as illustrated in Figure 70 and Figure 1. The outboard end had been subjected mostly to mechanical damage. An outer portion of the lower surface of blade C is illustrated in Figure 76 with the outer cuff identified. A yellow arrow indicates the damaged tip indicated by a red arrow in Figure 70 and in Figure 1 and a white arrow indicates mechanical damage to the leading edge.

A view of the damage to the tip of blade C indicated by the yellow arrow in Figure 76 is illustrated in Figure 77 looking aft with the outer cuff identified. An outer portion of the cuff was missing and the rear edge of the cuff adjacent to the fracture had been deformed outward. The fibers in the exposed blade structure and the structure behind the deformed cuff were splayed apart. The blue arrows indicate the deformed rear edges of the cuff and the black arrow indicates the splayed fibers. The red arrow indicates a scraped area on the lower surface of the cuff, a feature not observed on the opposing upper surface and a yellow arrow indicates a penetration at the leading edge of the cuff. The green arrow indicates diagonally oriented fibers previously covered by the skin indicated by the white arrow.

The mechanical damage at the location indicated by the white arrow in Figure 76 is illustrated in Figure 78 with the outer cuff identified. The white arrow indicates a distinct indentation in the leading edge and the yellow arrow indicates a portion of the cuff that had been bent at the black arrow and displaced outwards from the cuff.

The purple arrow indicates the mating fracture to the displaced portion indicate by the yellow arrow. The blue arrow indicates a second indentation in the leading edge with a brown arrow indicating buckling of the skin outboard of the fractured edge indicated by the green arrow.

The fire damaged blade grips within the red box in Figure 70 are illustrated in Figure 79 with the pins that previously attached them to the blades. The red arrow indicates the pins and the yellow arrows indicate the holes in the grips for the pins. The blue arrows indicate the remains of the fiberglass upper sleeves and the white arrow indicate the remains of the fiberglass lower sleeves.

Trim tab examination.

A main rotor blade trim tab was the first piece found in the wreckage path as indicated in Figure 2 and is illustrated in Figure 80. The trim tab was intact and was still attached to a portion of a main rotor blade trailing edge. The fire damage on the main rotor blades prevented a determination of which blade the trim tab came from.

Derek Nash
Mechanical Engineer

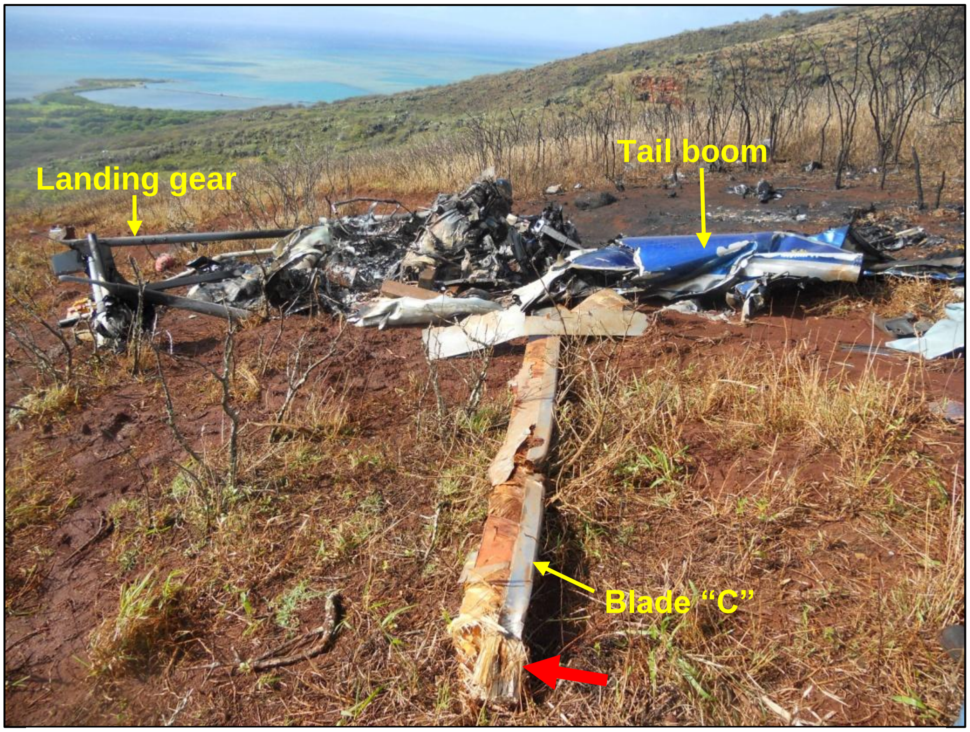

Figure 1. The main wreckage looking along the main rotor blade identified as "C" in Figure 2.

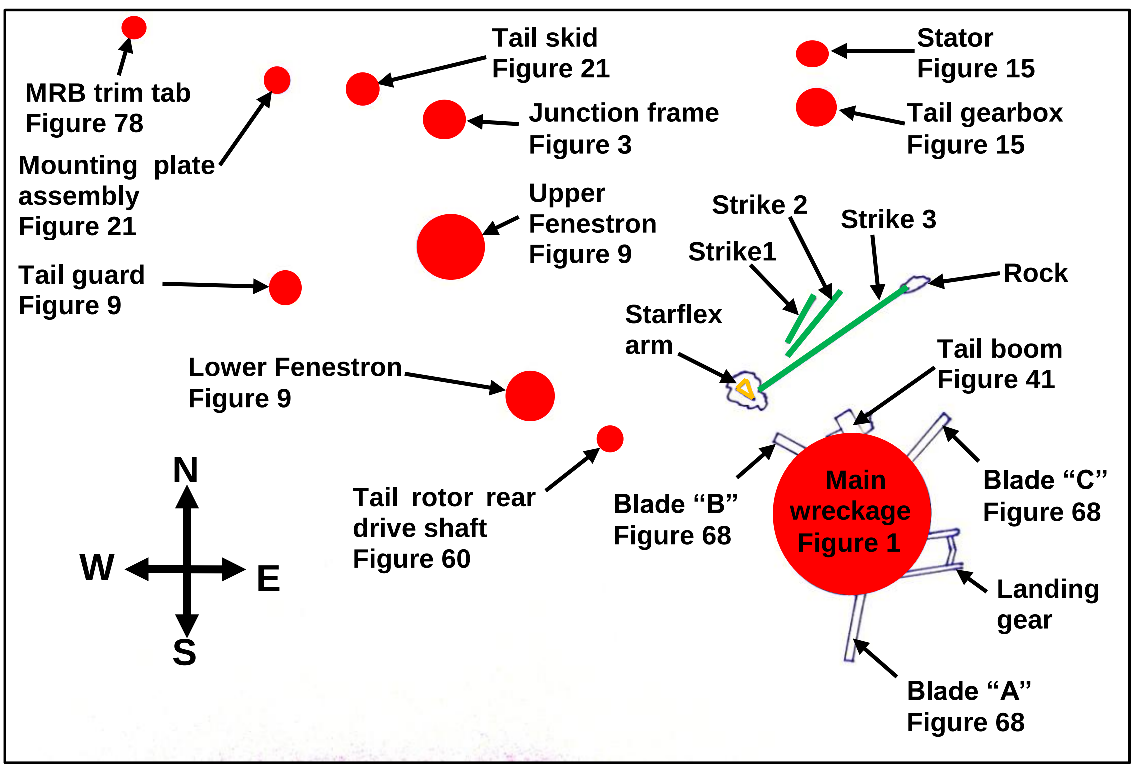

Figure 2. Schematic of wreckage trail and ground impact marks with report figure references.

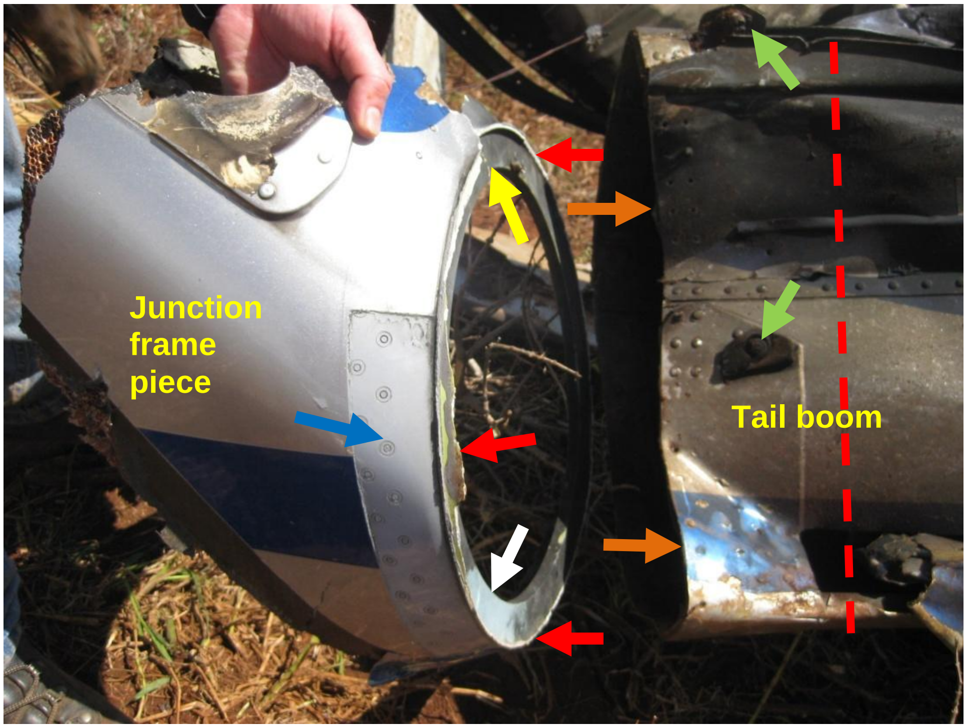

Figure 3. The junction frame piece indicated in Figure 2 positioned adjacent to its original location on the tail boom at the accident site.

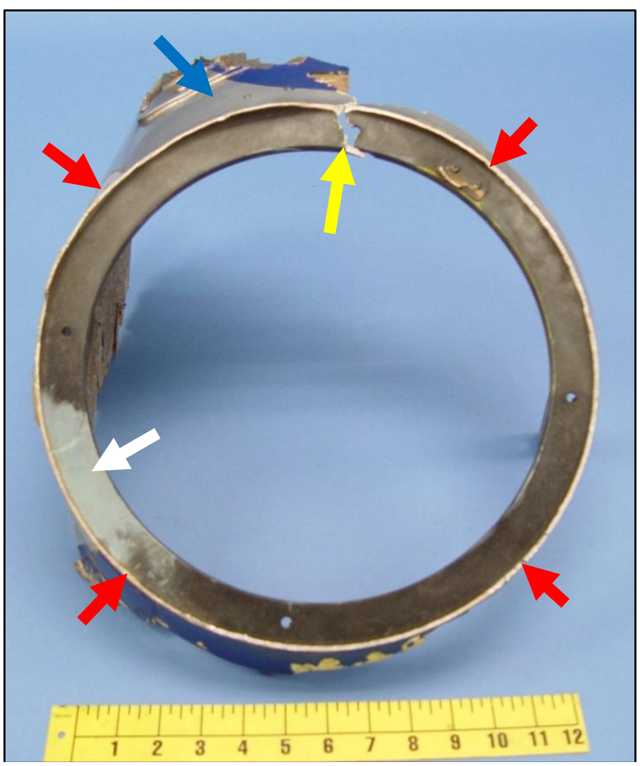

Figure 4. The junction frame piece in Figure 3 as received and looking aft.

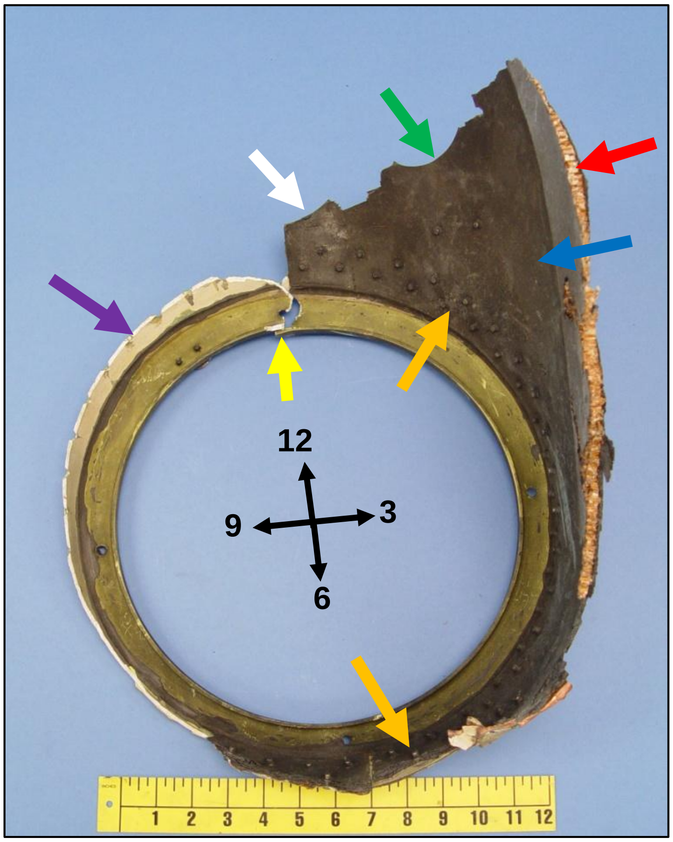

Figure 5. The junction frame in Figure 4 looking forward.

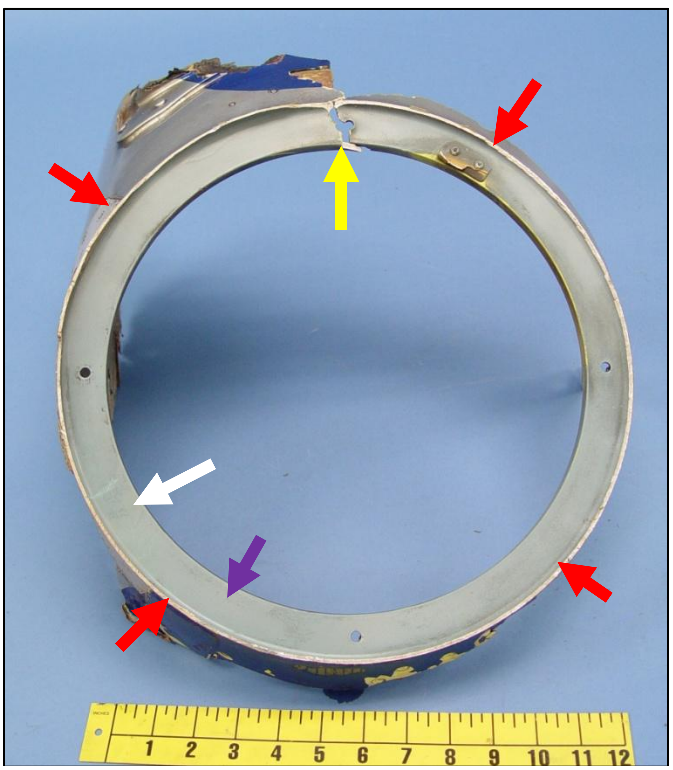

Figure 6. The junction frame in Figure 4 after cleaning.

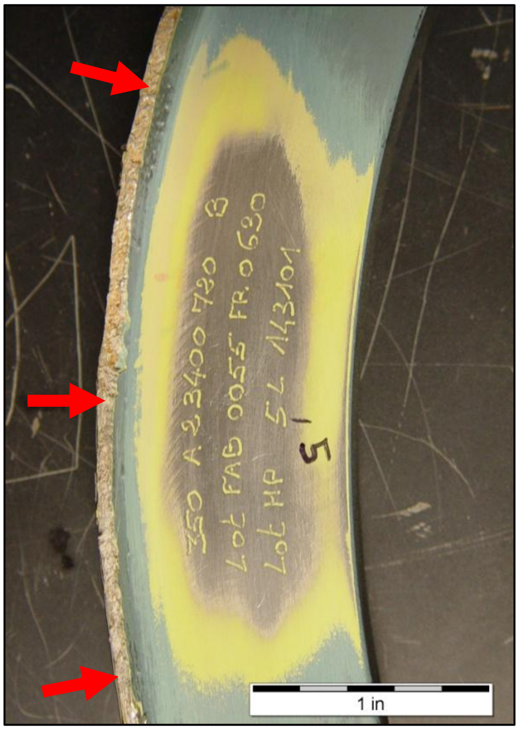

Figure 7. The junction frame identifications revealed by removal of the grey paint and the yellow primer

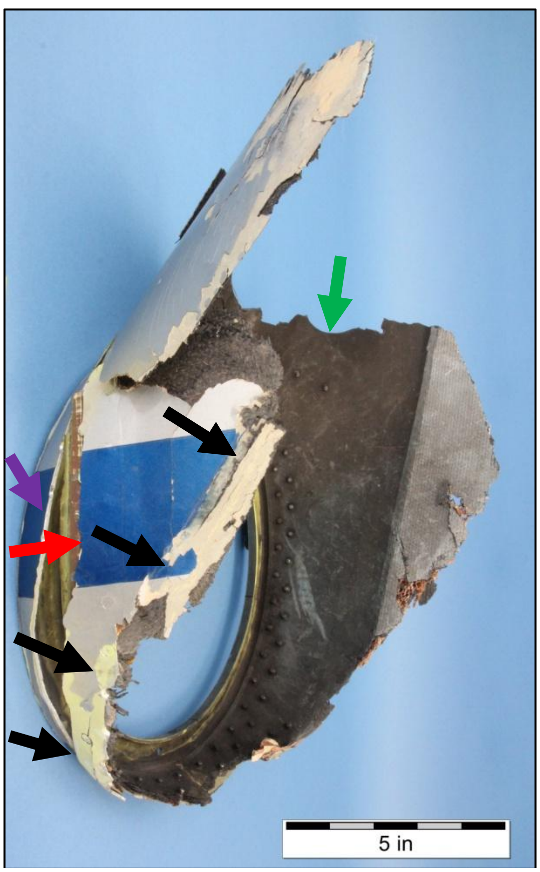

Figure 8. The junction frame in Figure 5 with the recovered mating piece indicated by the yellow arrow in Figure 9.

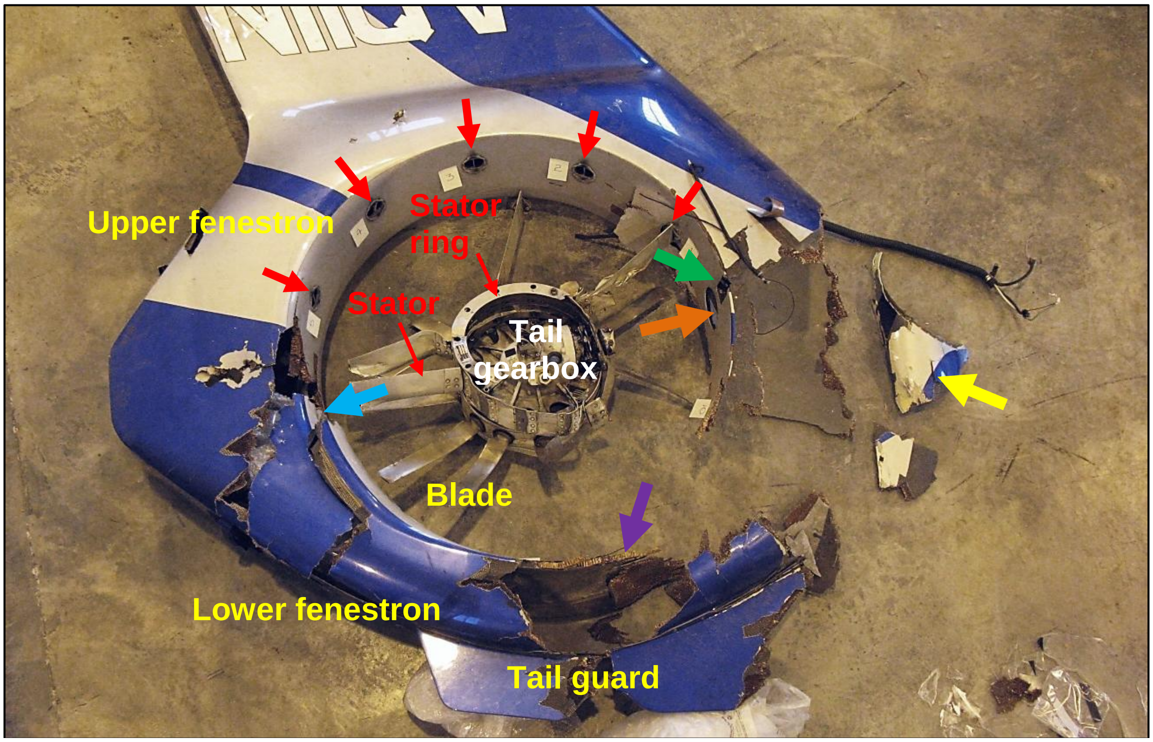

Figure 9. The recovered fenestron structure with the recovered tail gearbox positioned in the duct.

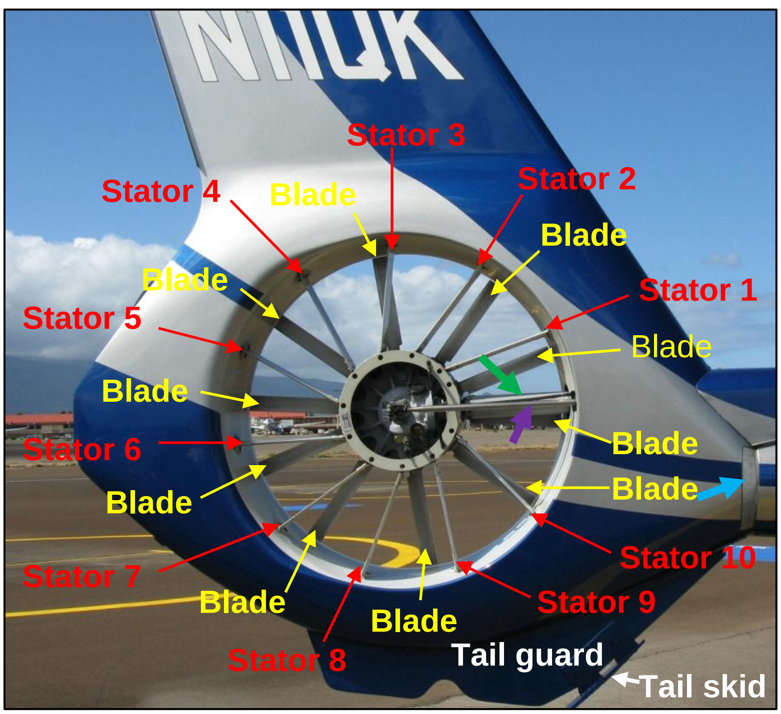

Figure 10. The fenestron assembly on N11QK.

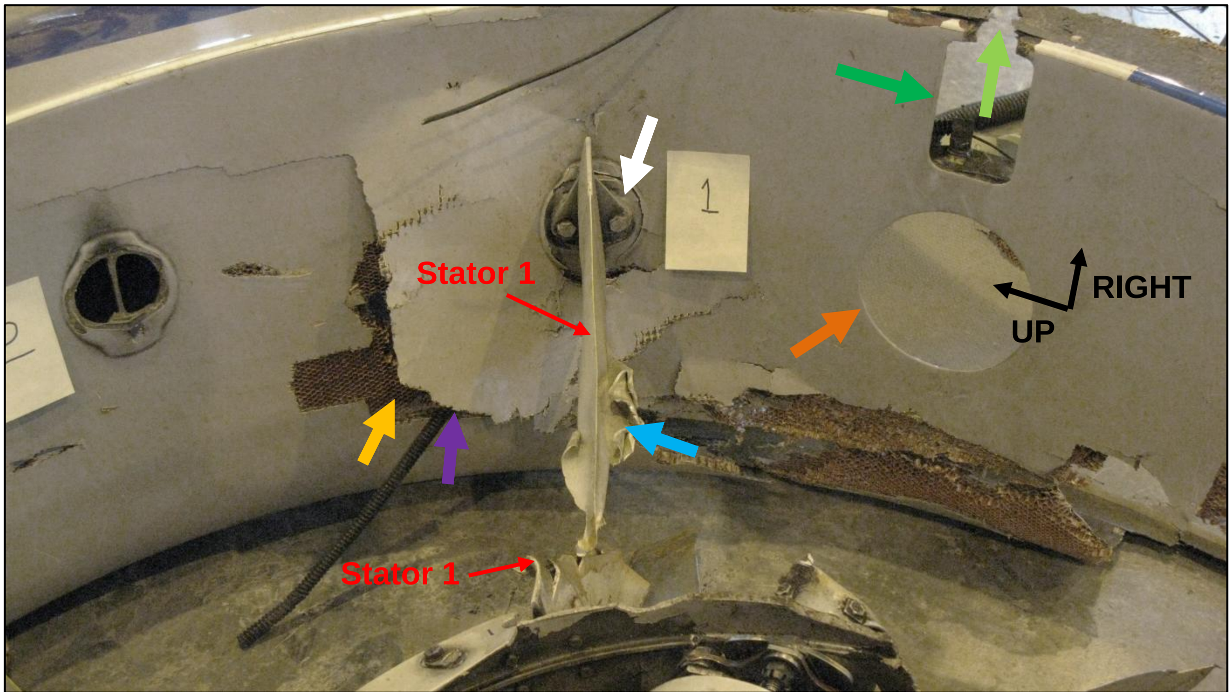

Figure 11. The upper forward portion of the duct in the recovered fenestron.

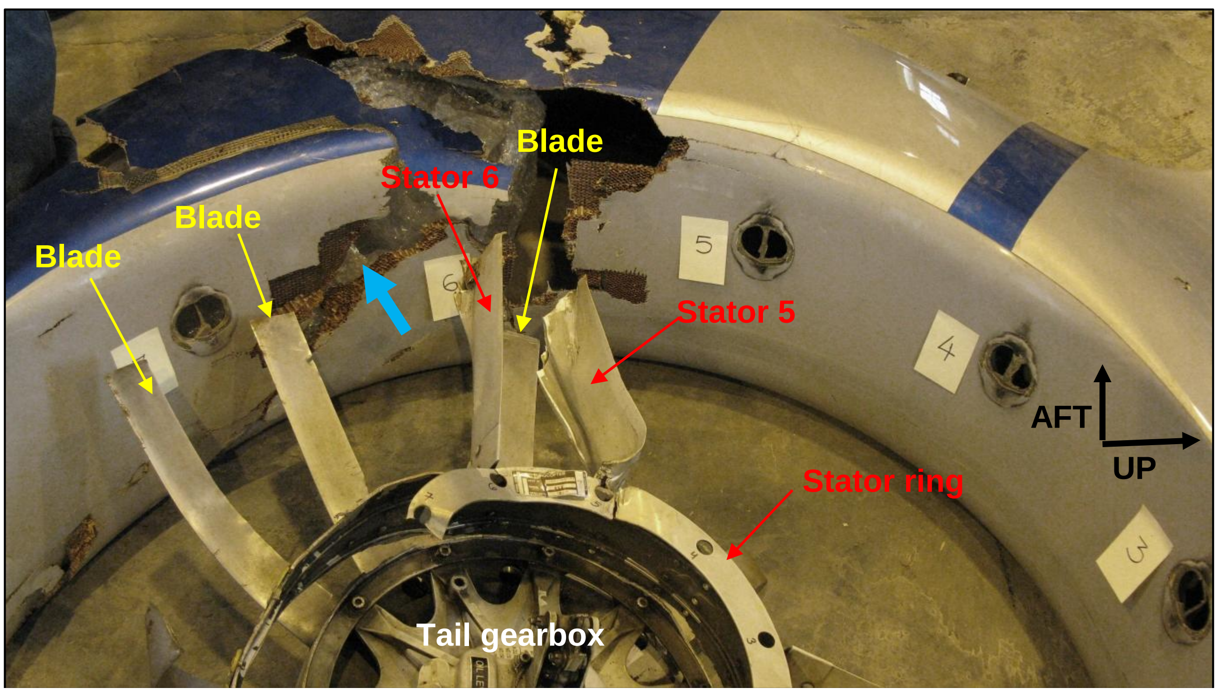

Figure 12. The rear portion of the duct in the recovered fenestron.

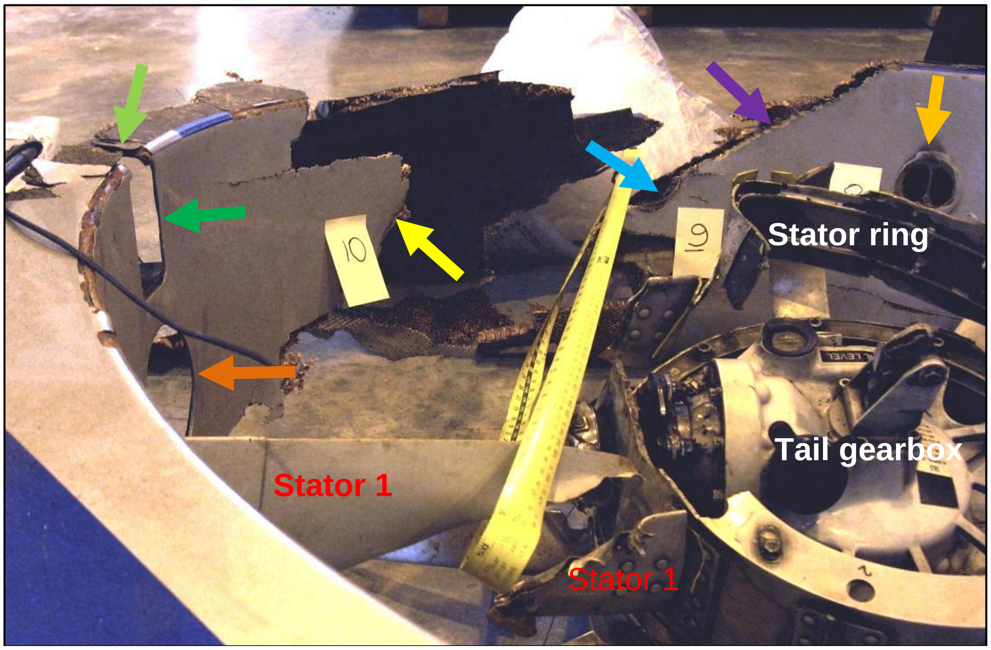

Figure 13. A lower portion of the duct in the recovered Fenestron.

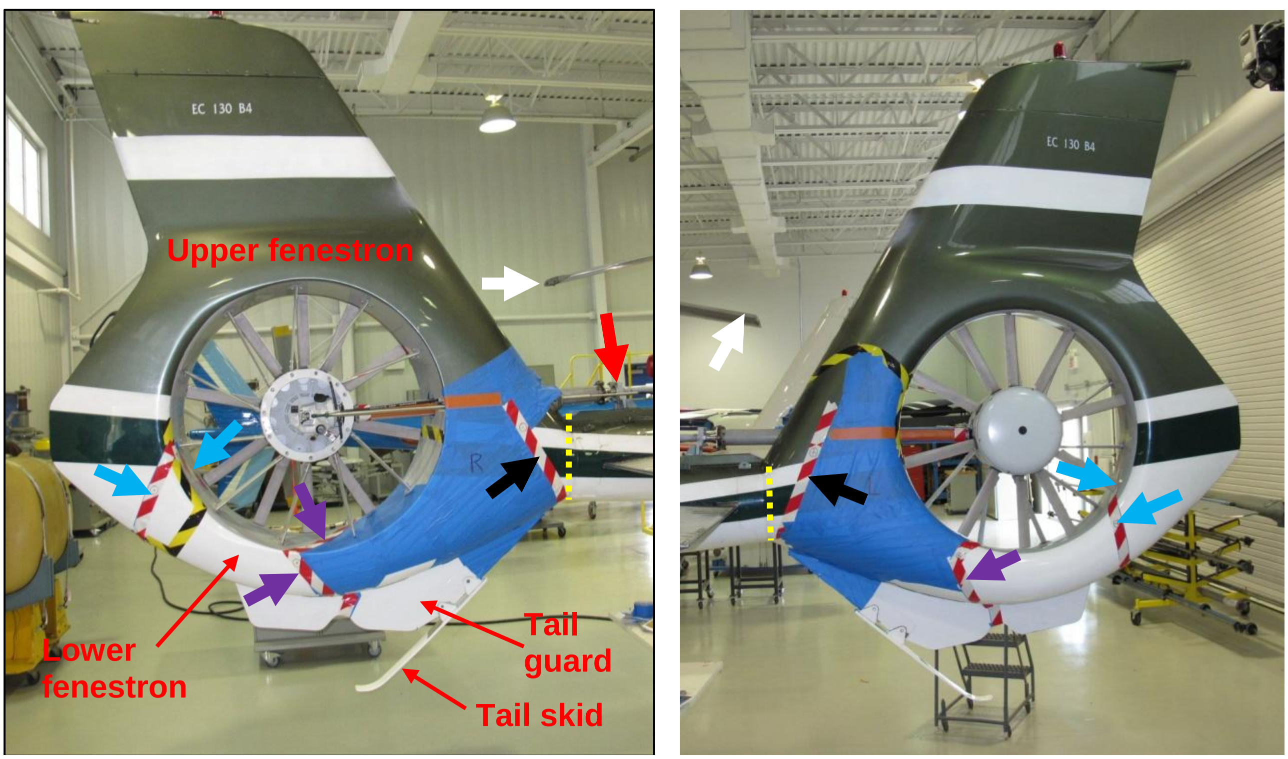

Figure 14. Right and left sides of the Fenestron on a training EC-130B4 that was used to locate the fractures observed on the accident Fenestron illustrated in Figure 9.

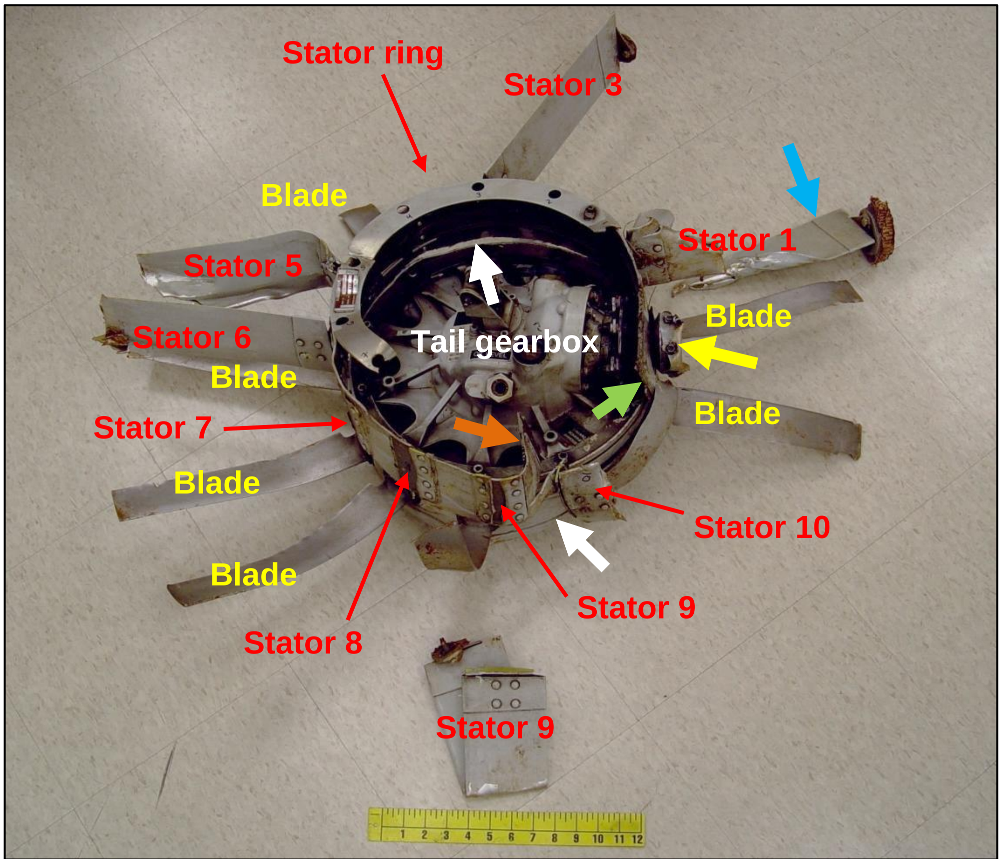

Figure 15. The right side of the tail gearbox and stator ring assembly recovered.

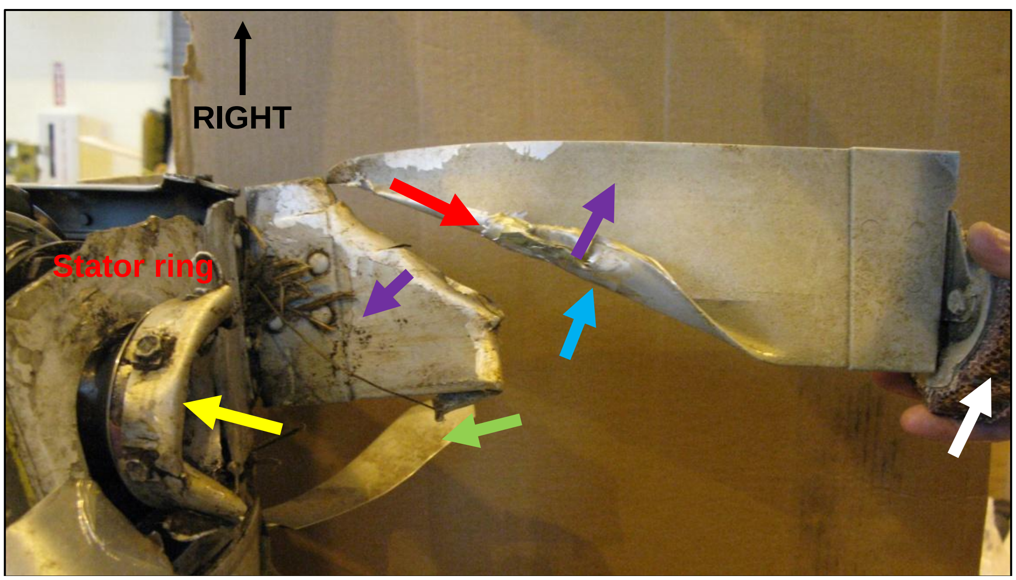

Figure 16. The fractured stator 1 identified in Figures 11 and 15.

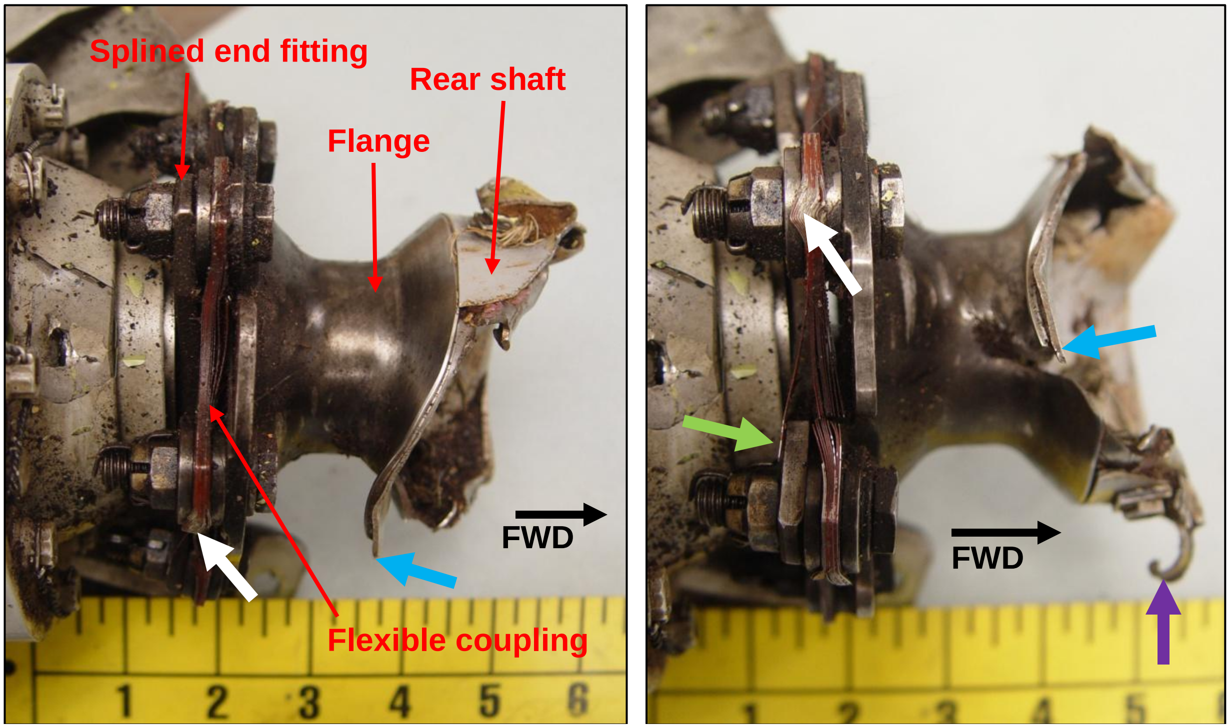

Figure 17. The rear drive shaft connection to the tail gearbox (left) and with the shaft rotated 90-degrees clockwise (right).

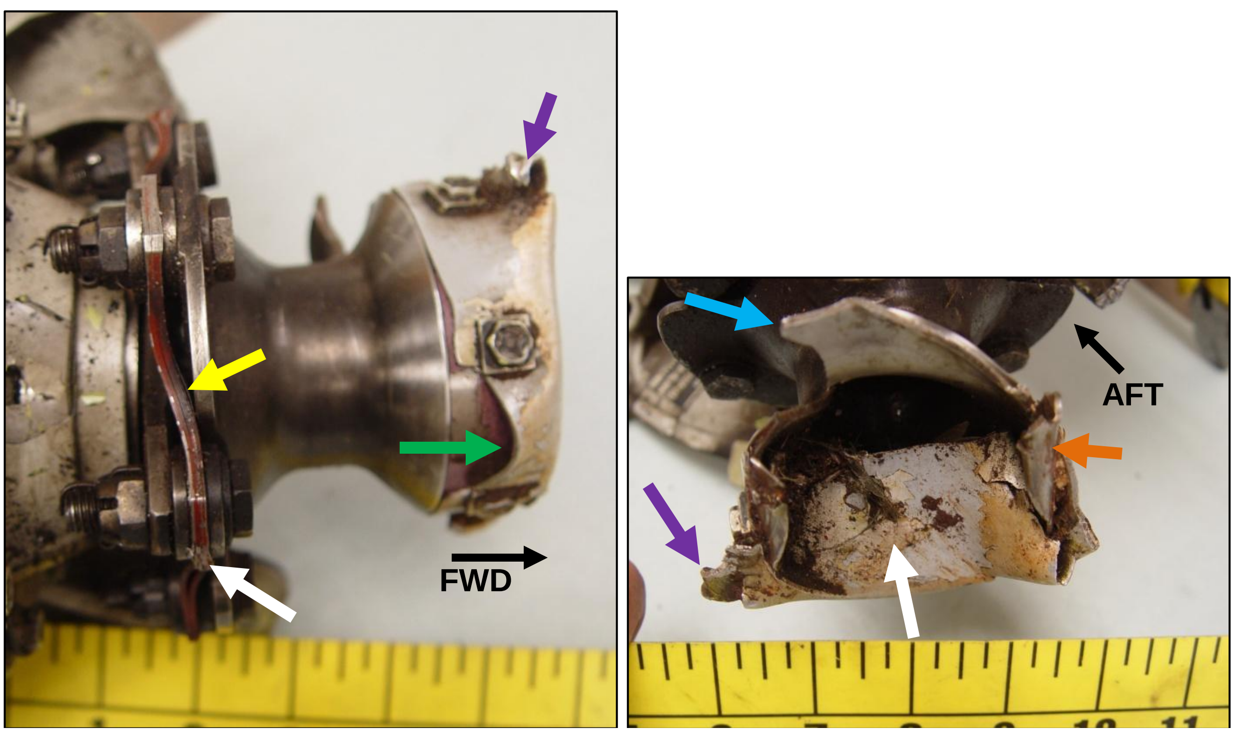

Figure 18. The rear drive shaft connection to the tail gearbox with the shaft rotated 180-degrees (left) and a view of the forward end of the drive shaft (right).

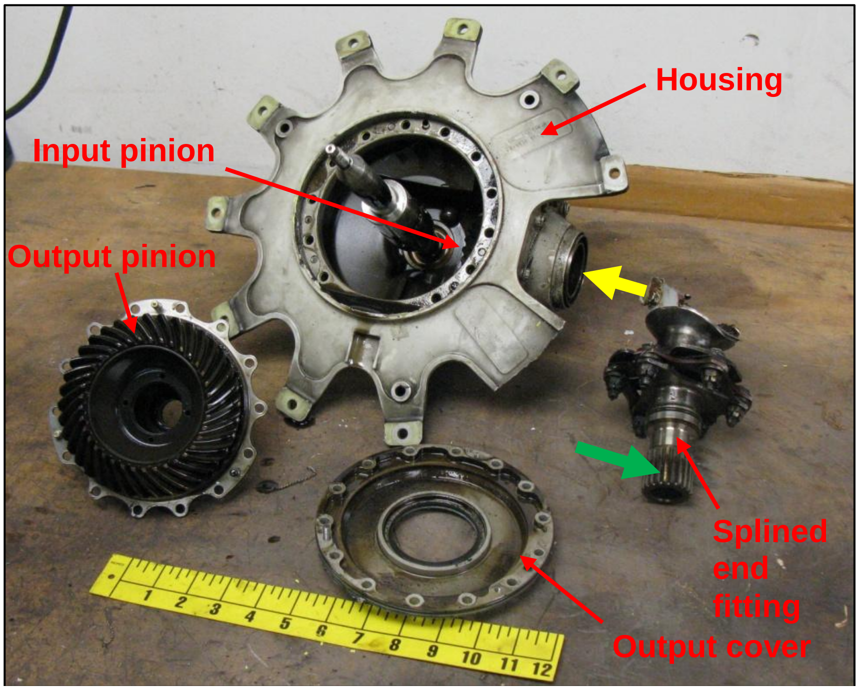

Figure 19. The tail gearbox removed from the stator ring and partially disassembled.

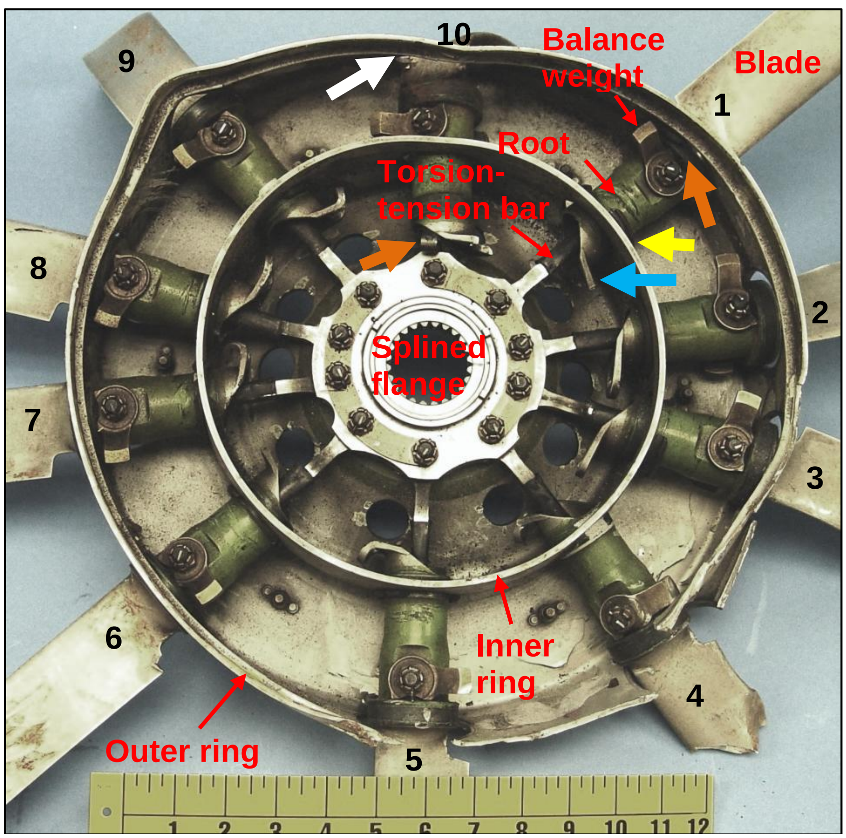

Figure 20. The tail rotor hub removed from the tail gearbox.

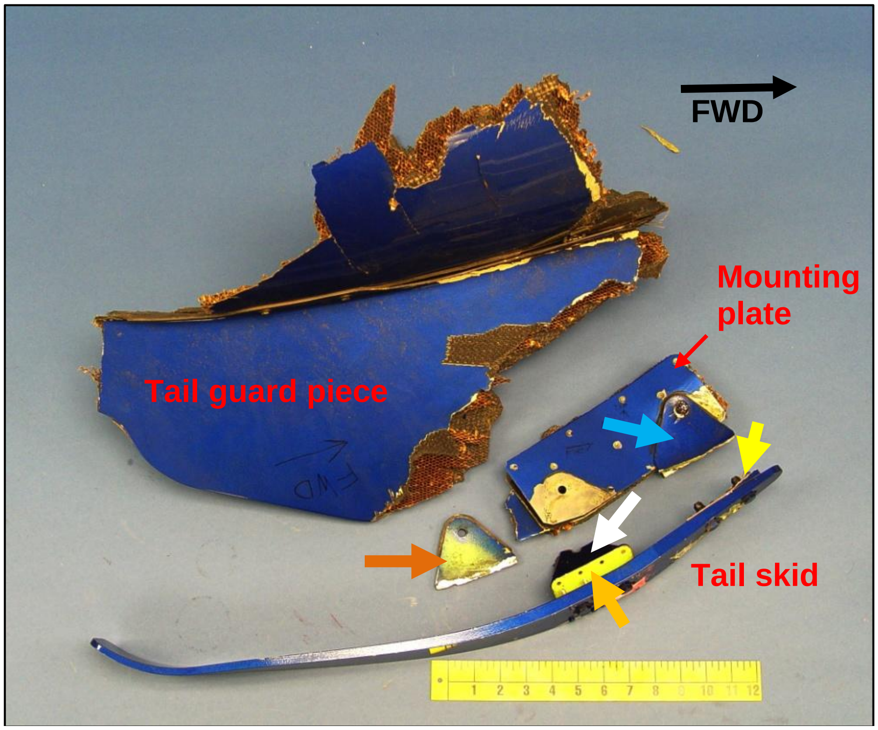

Figure 21. The recovered portion of the tail guard, the mounting plate assembly and the tail skid, right side.

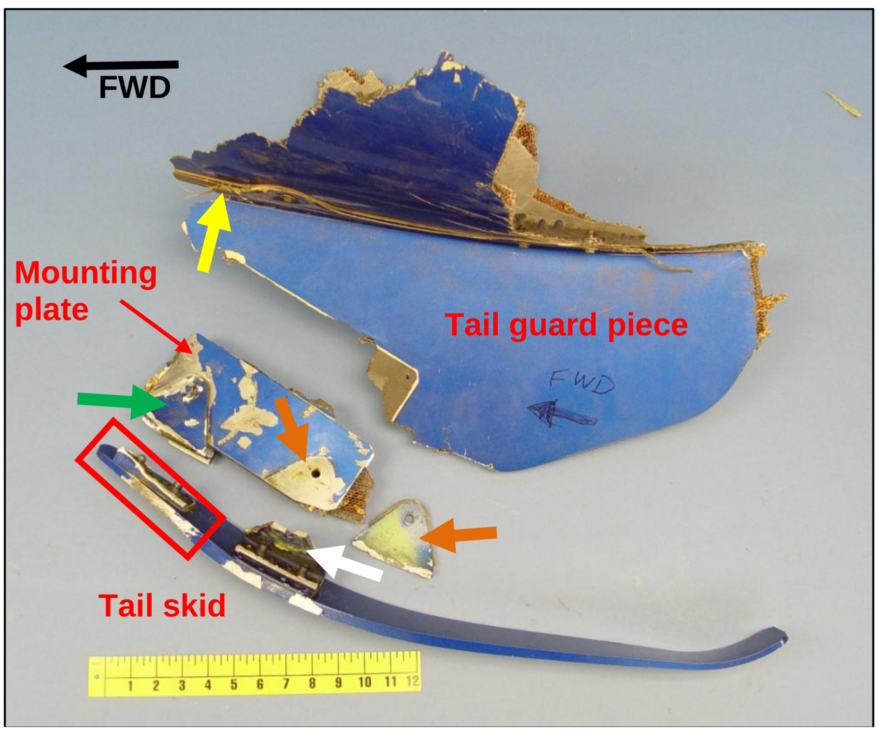

Figure 22. The recovered portion of the tail guard, the mounting plate assembly and the tail skid, left side.

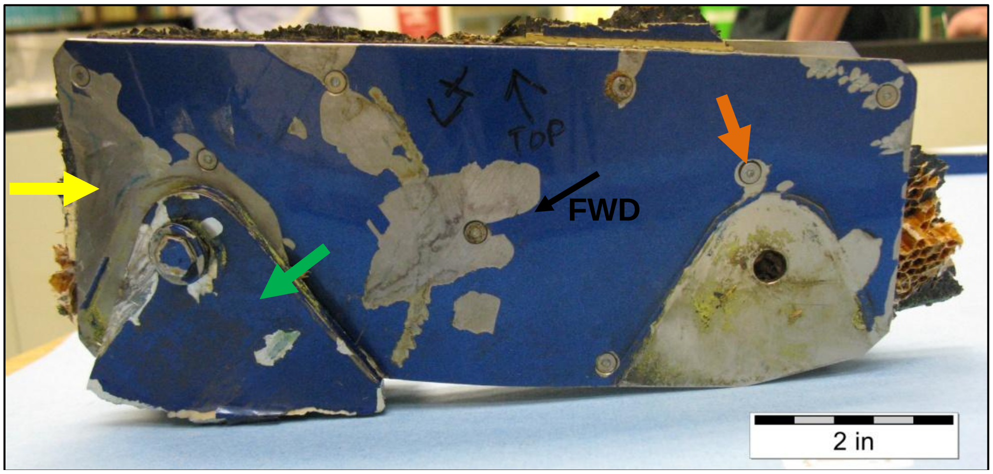

Figure 23. The left mounting plate.

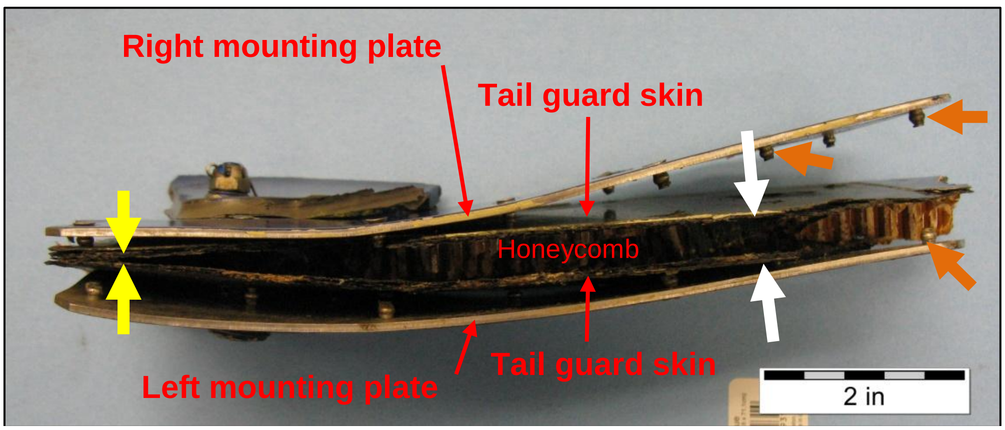

Figure 24. The mounting plate assembly viewed from above.

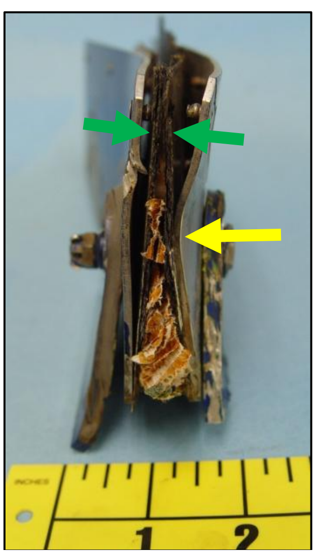

Figure 25. The forward end of the mounting plate assembly.

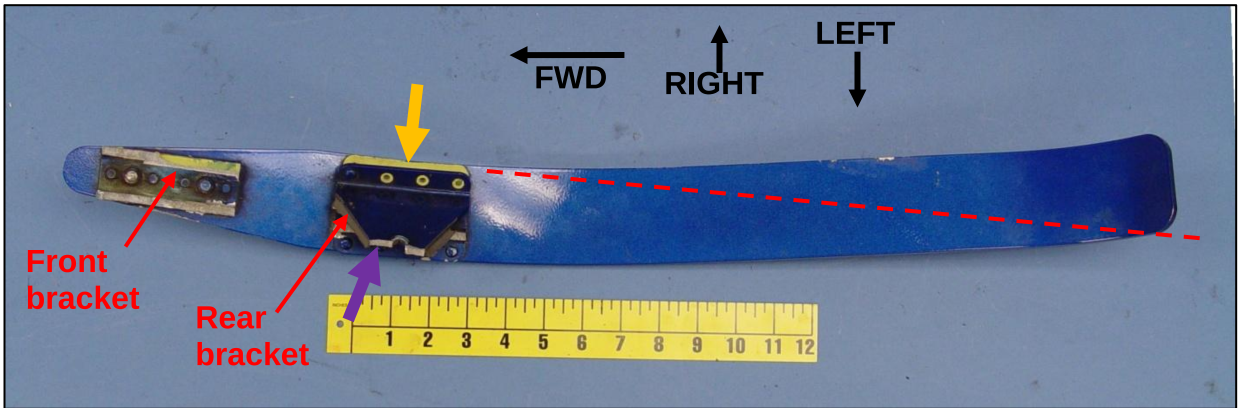

Figure 26. The upper side of the tail skid.

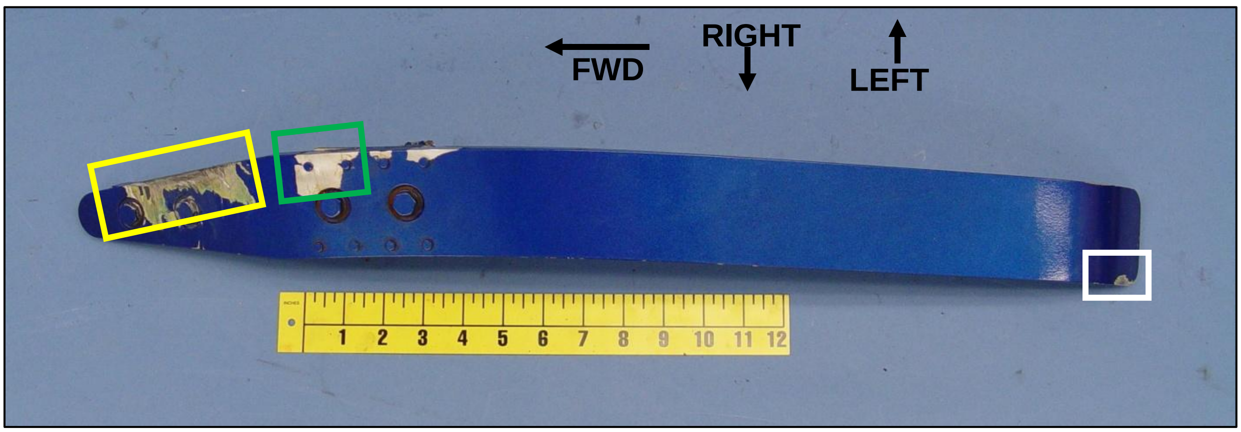

Figure 27. The lower side of the tail skid.

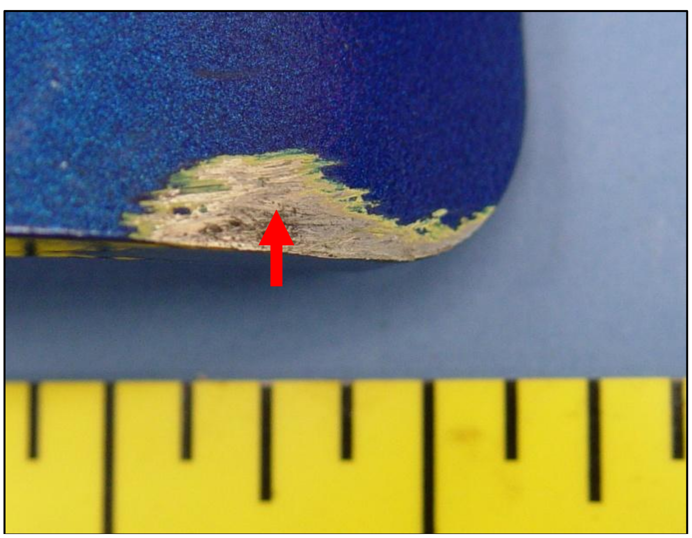

Figure 28. The right rear tip of the tail skid within the white box in Figure 27.

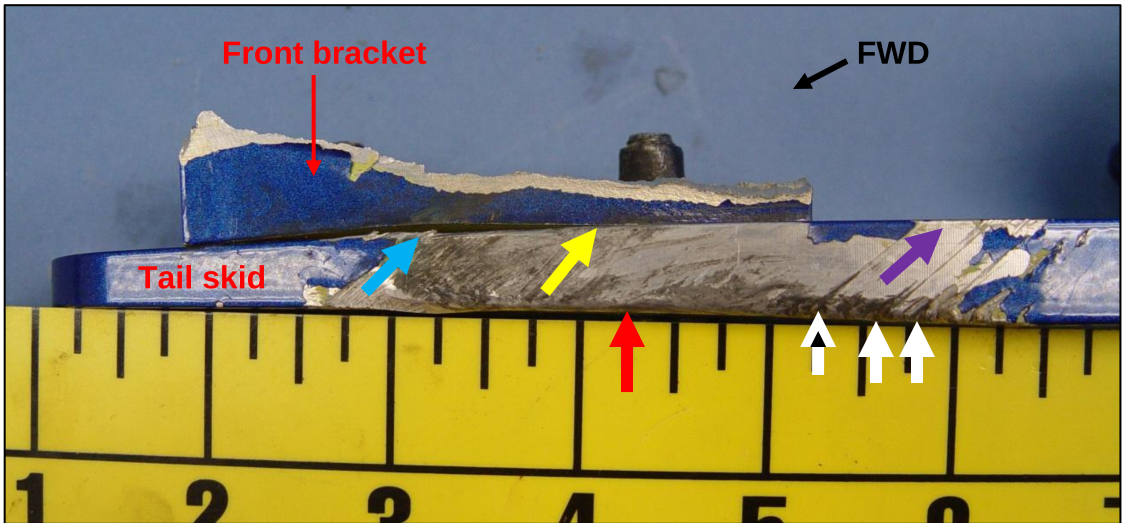

Figure 29. The left forward end of the tail skid within the red box in Figure 22.

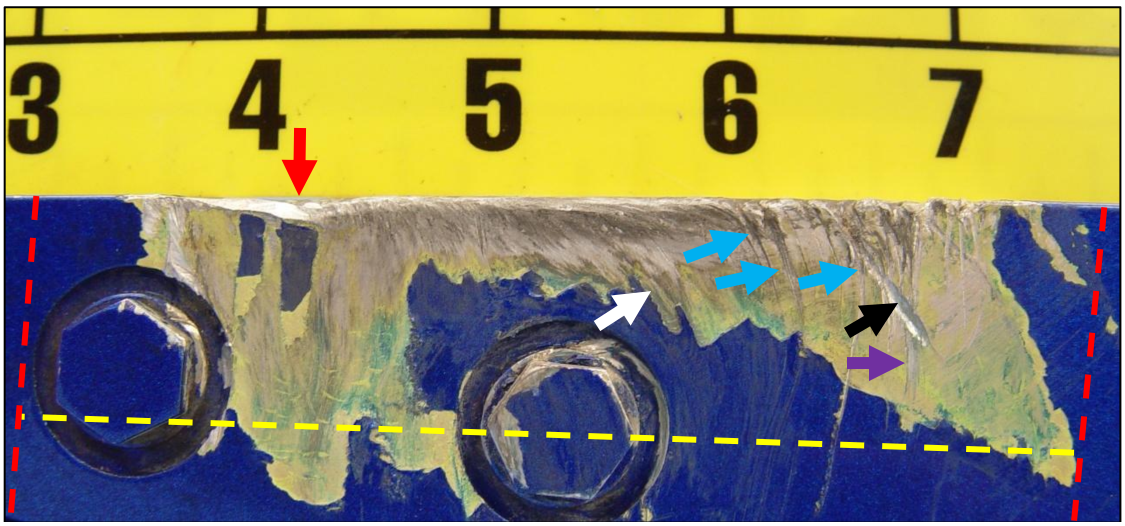

Figure 30. The lower side of the left forward end of the tail skid illustrated in Figure 29 and contained within the yellow box in Figure 27.

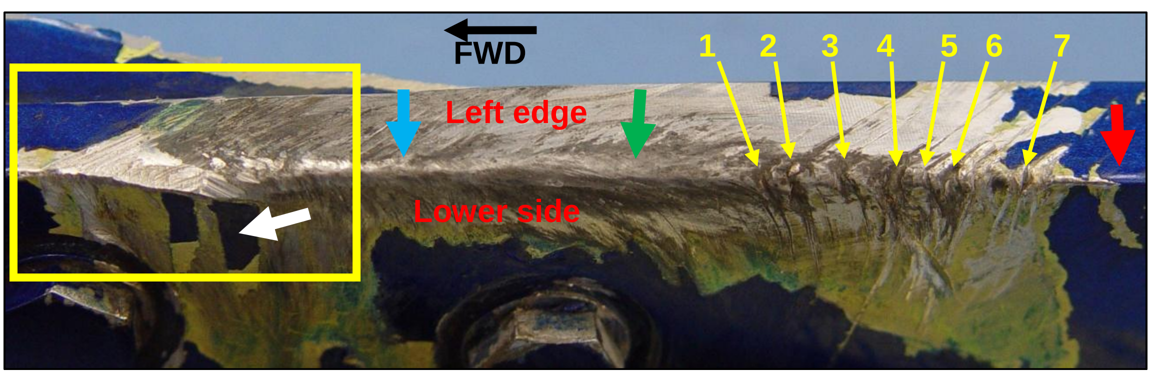

Figure 31. The left forward edge and underside of the tail skid illustrated in Figures 29 and 30.

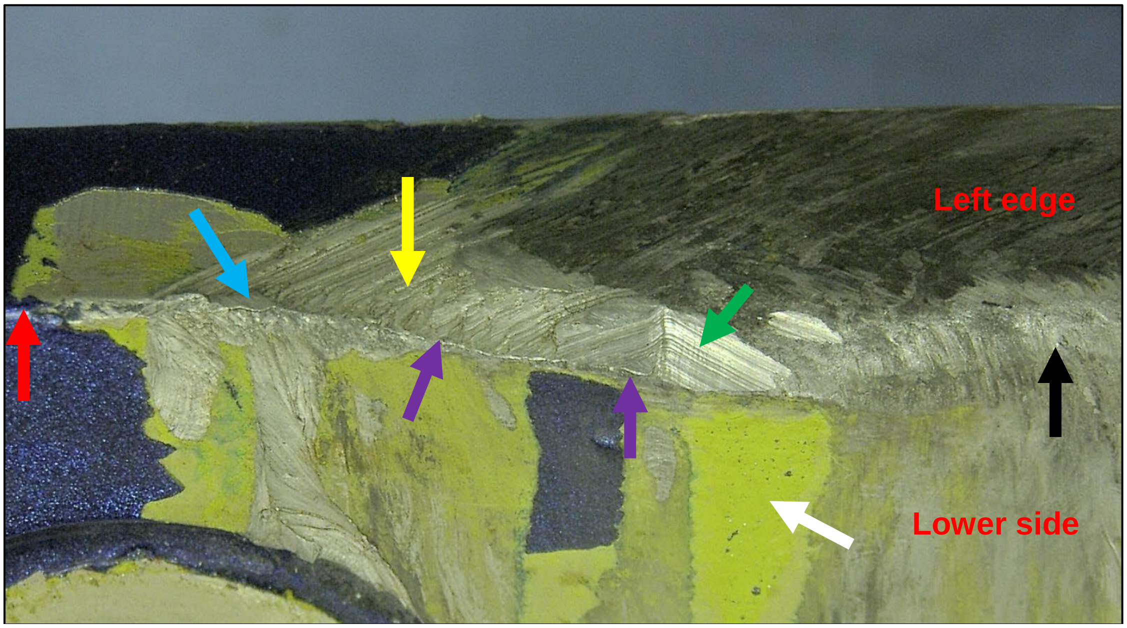

Figure 32. The left forward edge and underside of the tail skid within the yellow box in Figure 31.

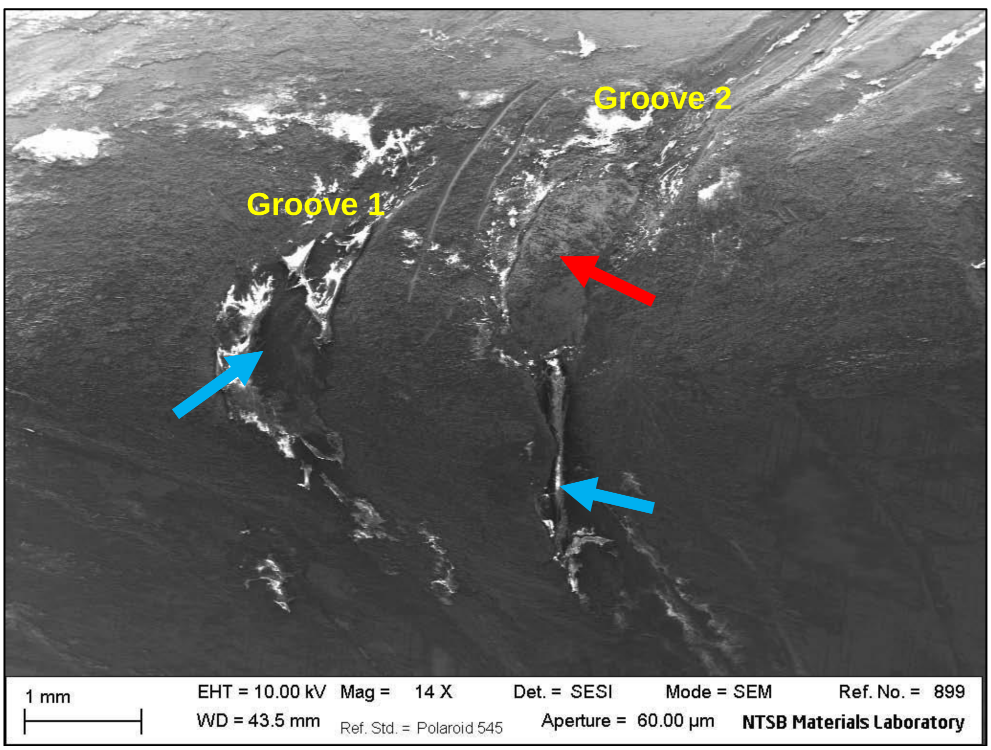

Figure 33. SEM image of the grooves identified as “1” (left) and “2” (right) in Figure 31.

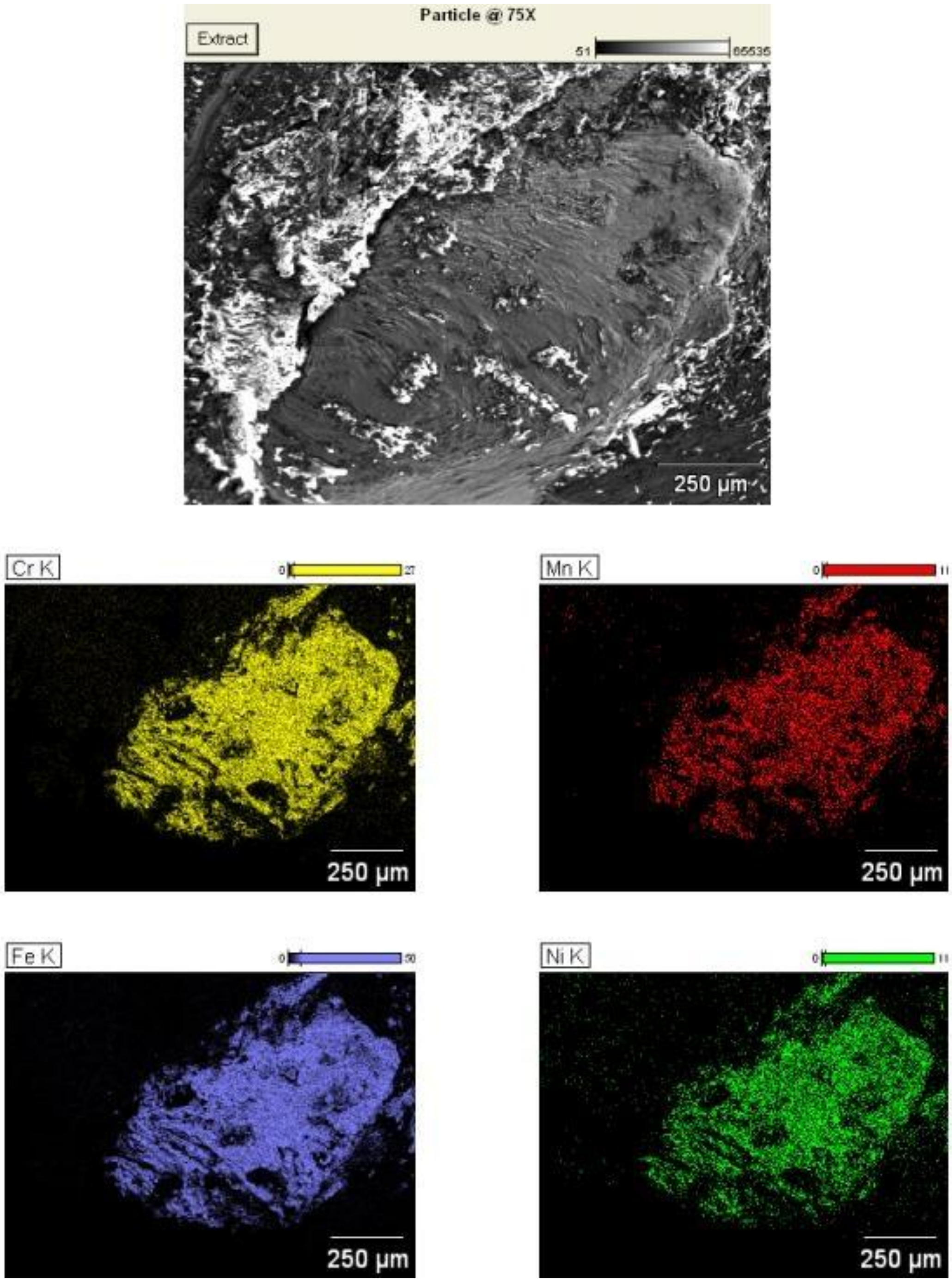

Figure 34. EDS map of major elements in the particle in groove 2 and indicated by the red arrow in Figure 33.

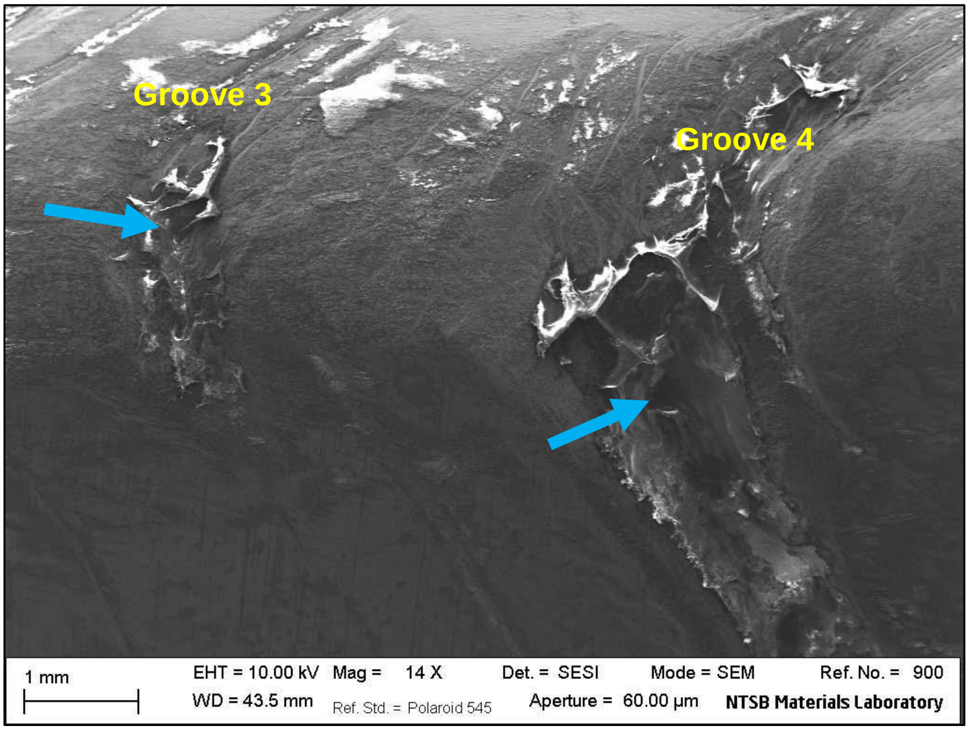

Figure 35. SEM image of the grooves identified as “3” (left) and “4” (right) in Figure 31.

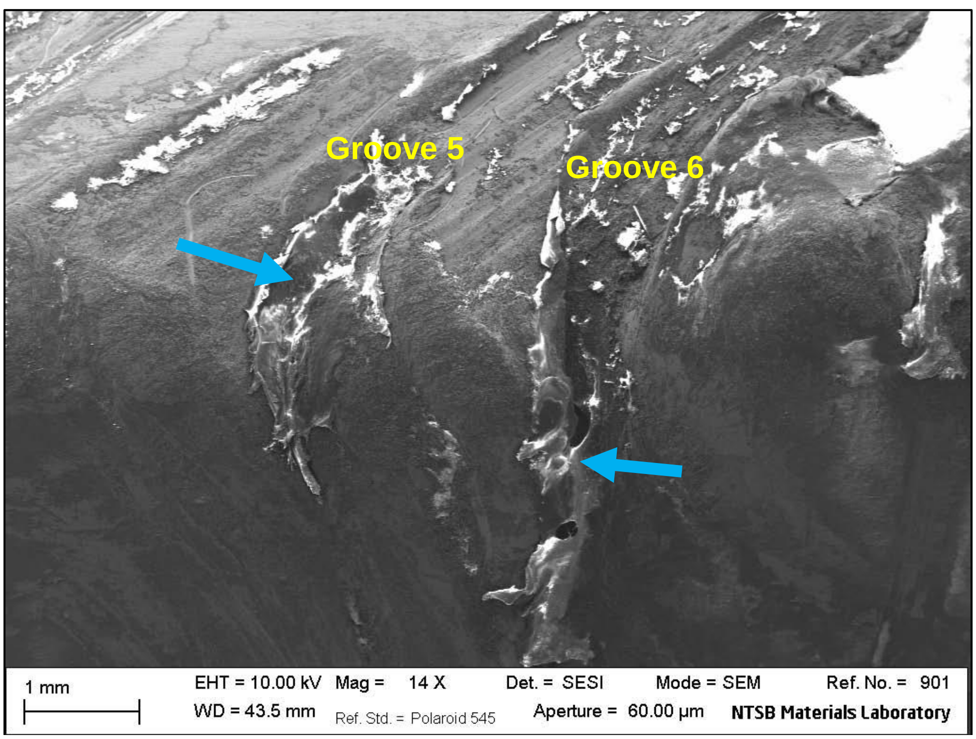

Figure 36. SEM image of the grooves identified as “5” (left) and “6” (right) in Figure 31.

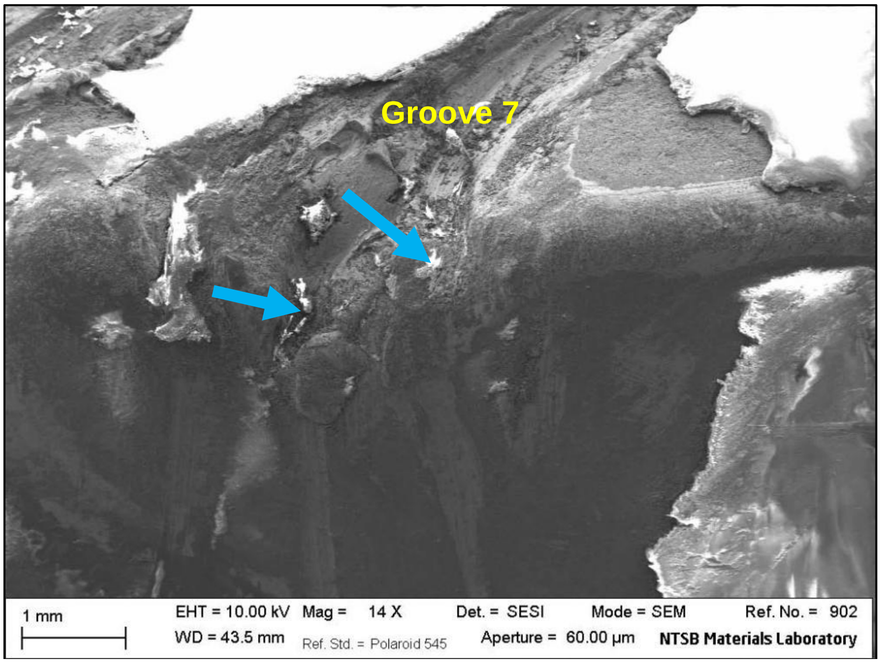

Figure 37. SEM image of the groove identified as “7” in Figure 31.

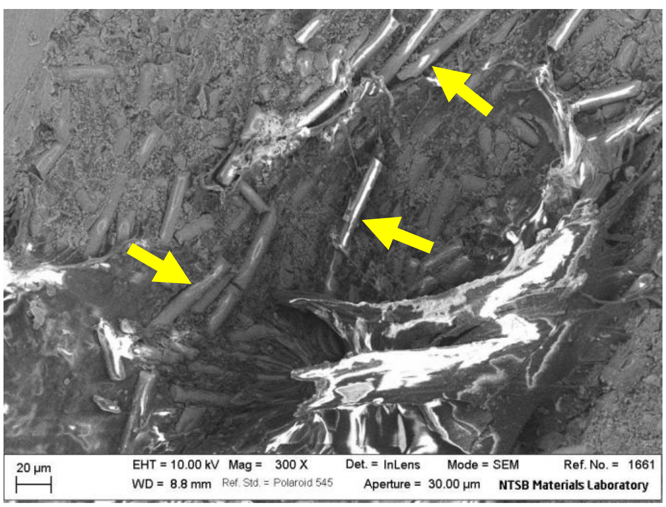

Figure 38. SEM micrograph of the material in groove 1.

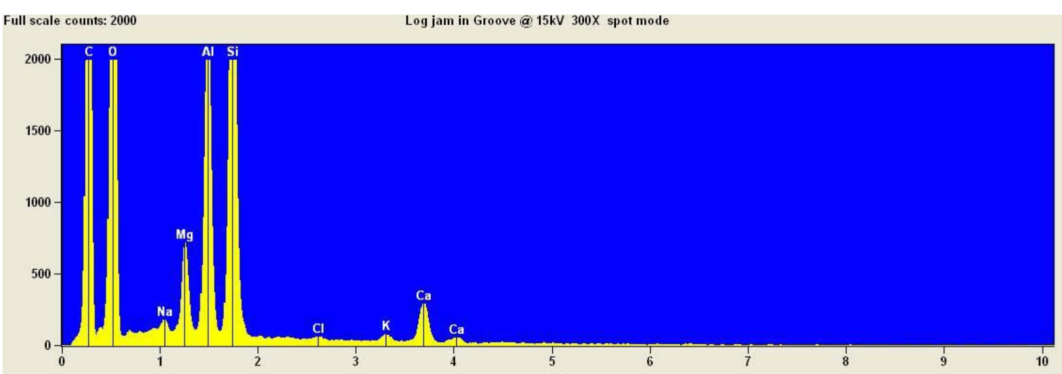

Figure 39. EDS spectra of the area in Figure 38 containing the cylindrical features.

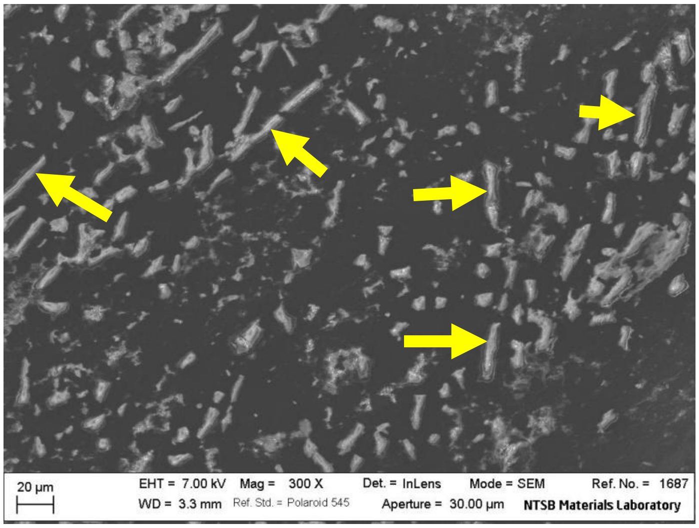

Figure 40. SEM micrograph of primer sample removed from the tail skid.

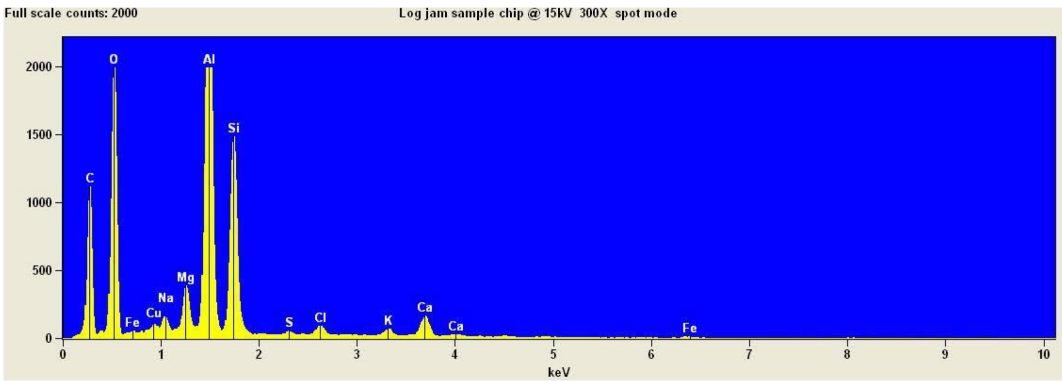

Figure 41. EDS spectra of primer sample in Figure 40.

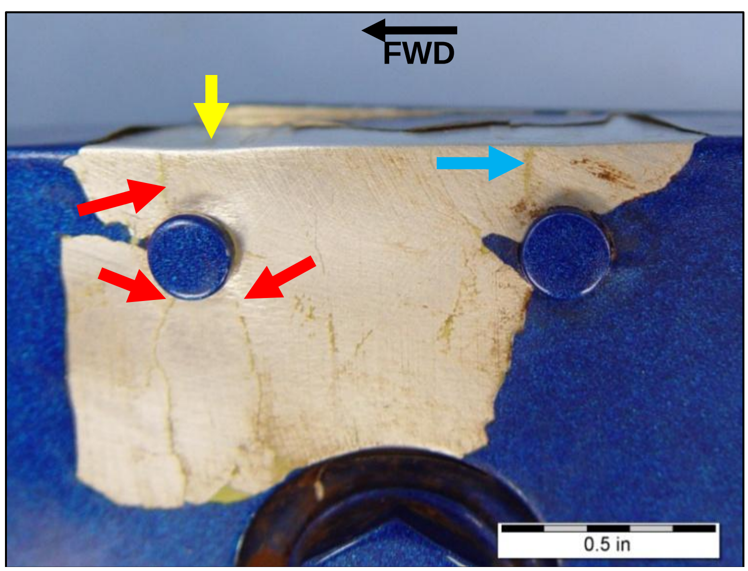

Figure 42. The underside of the tail skid contained in the green box in Figure 27.

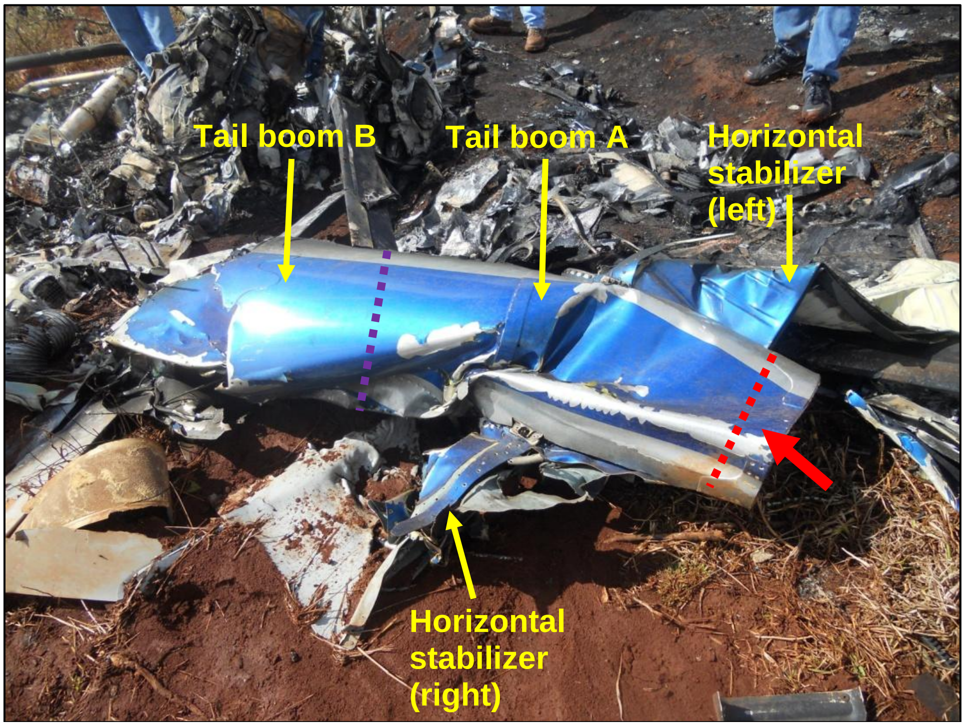

Figure 43. The tail boom and attached horizontal stabilizer at the accident site and identified in Figure 1.

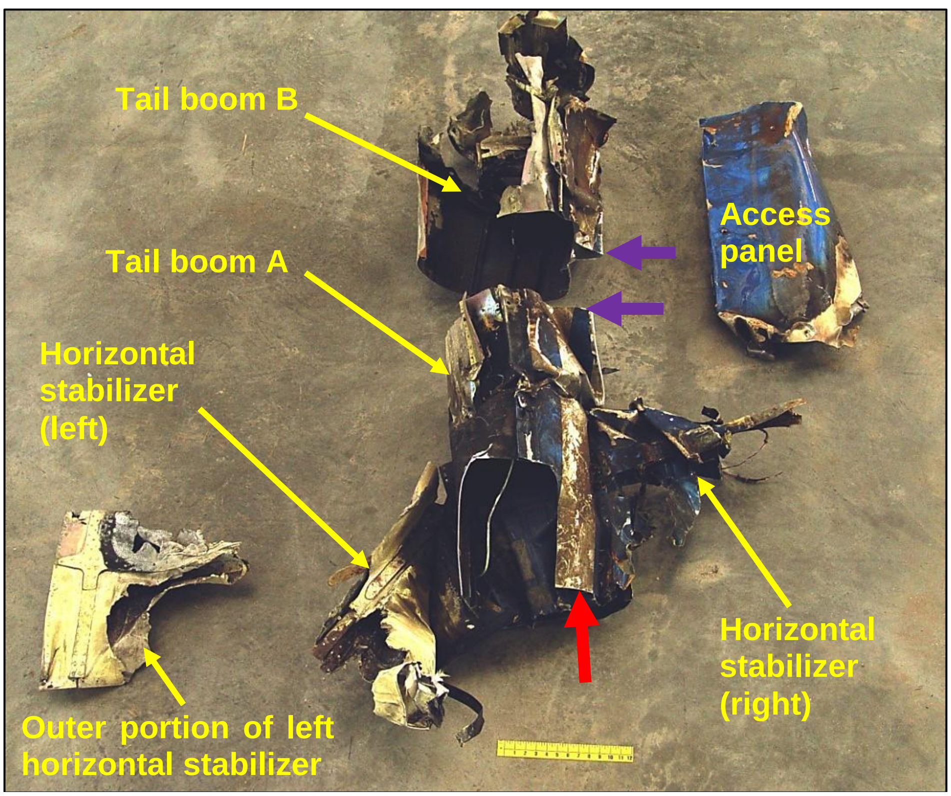

Figure 44. The tail boom pieces received for examination.

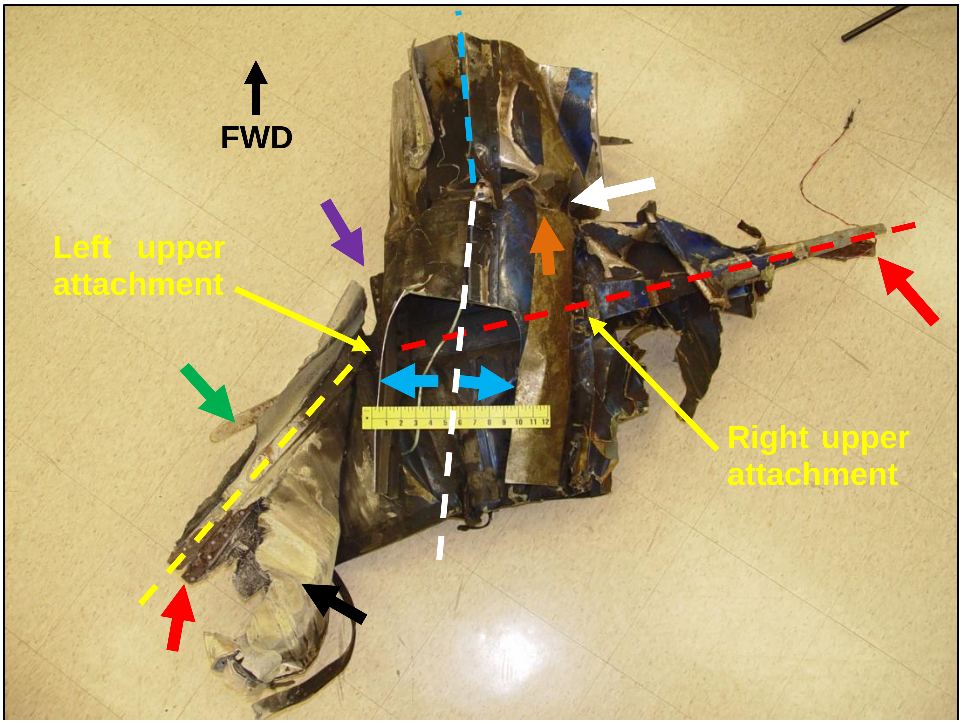

Figure 45. The upper side of tail boom piece A and the horizontal stabilizer.

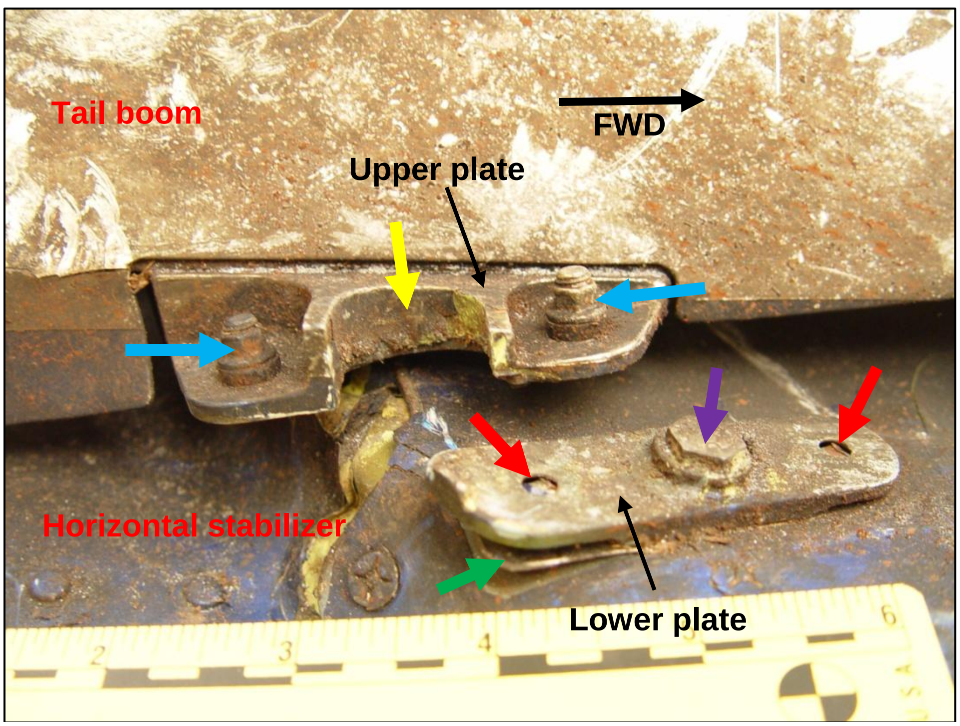

Figure 46. The right upper horizontal stabilizer attachment.

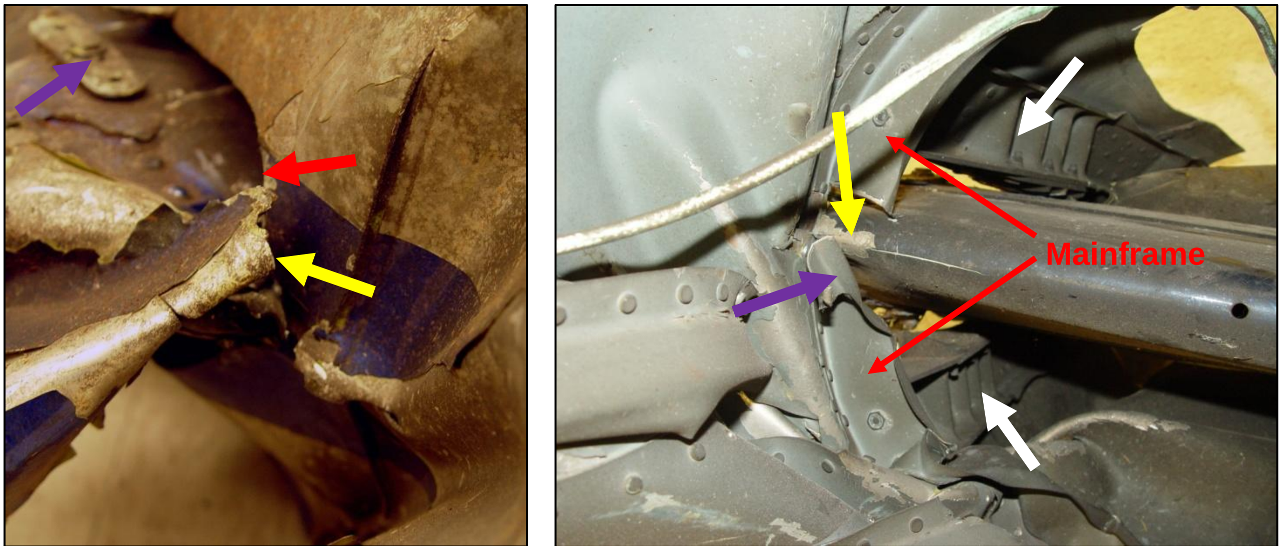

Figure 47. An exterior view (left) and an interior view (right) of the horizontal stabilizer leading edge, right side.

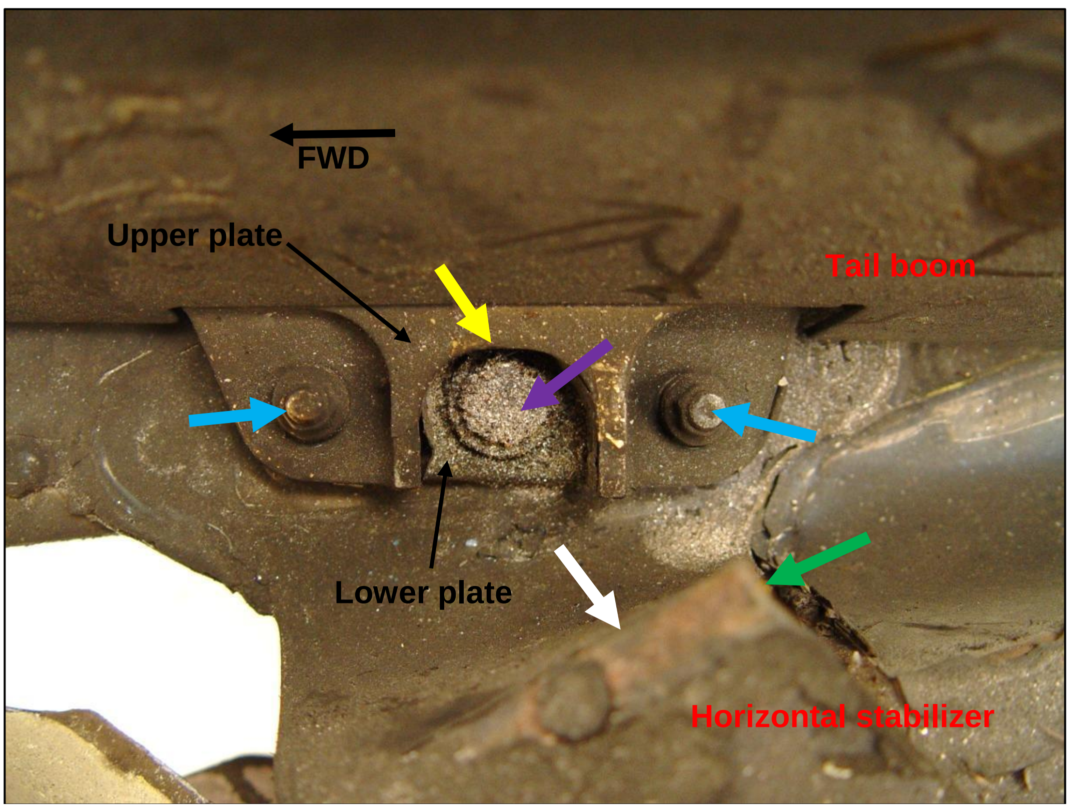

Figure 48. The left upper horizontal stabilizer attachment.

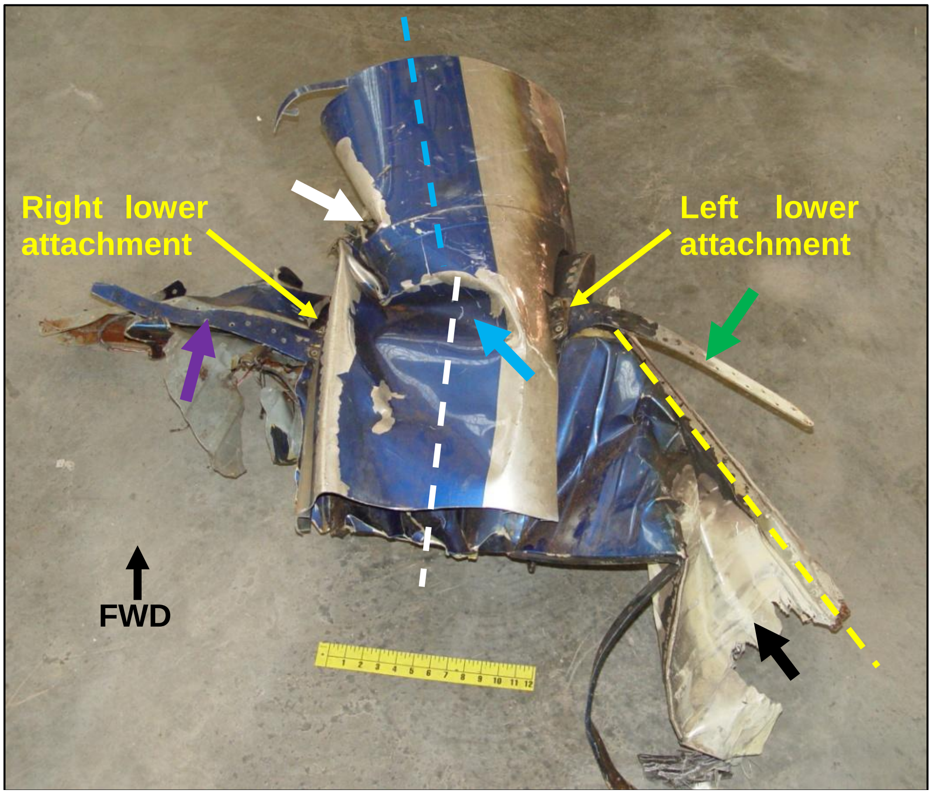

Figure 49. The underside of tail boom piece A with the remaining horizontal stabilizer.

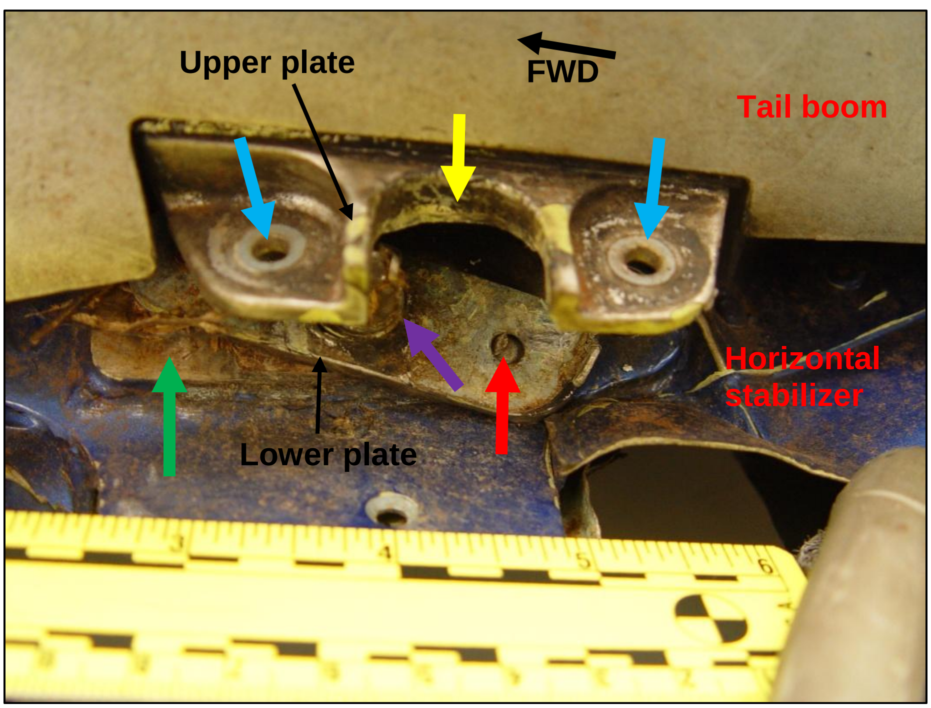

Figure 50. The right lower horizontal stabilizer attachment.

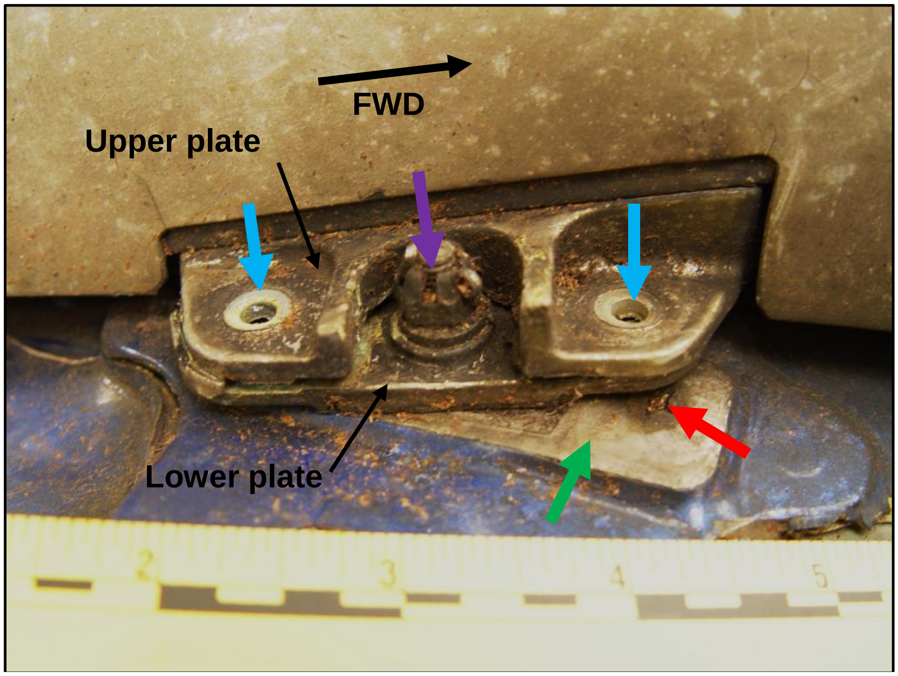

Figure 51. The left lower horizontal stabilizer attachment.

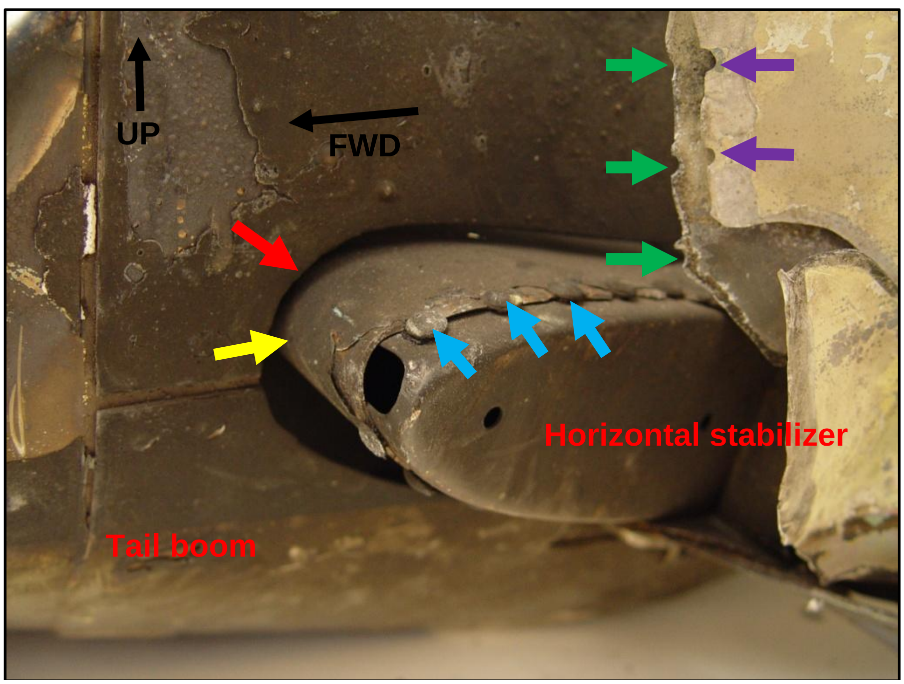

Figure 52. The left leading edge of the horizontal stabilizer.

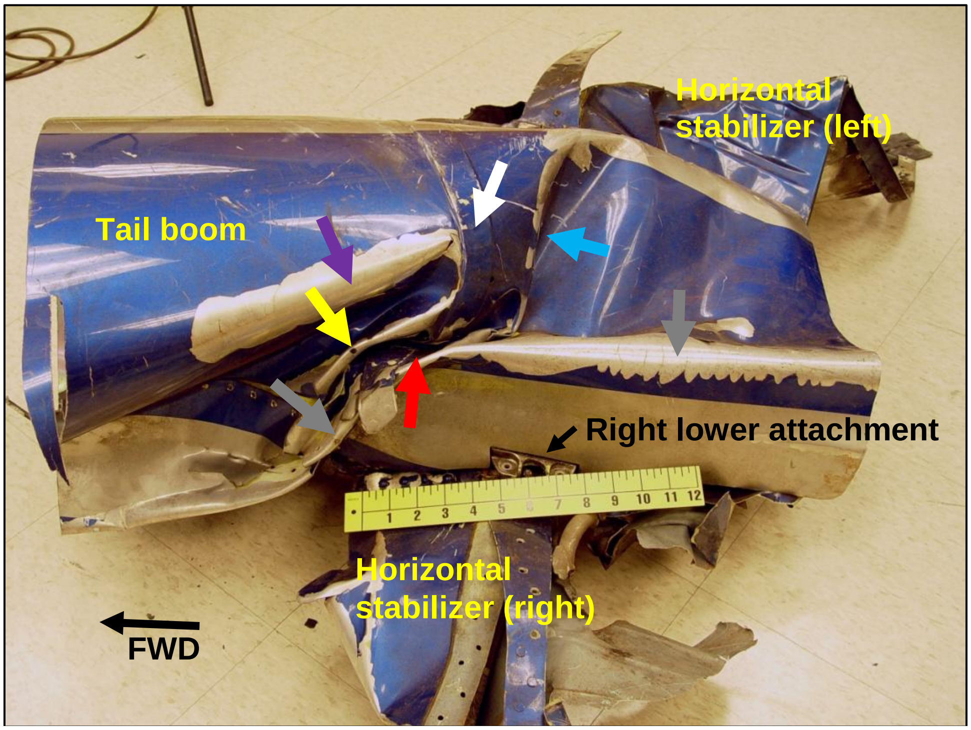

Figure 53. Buckling at the right side of the tail boom.

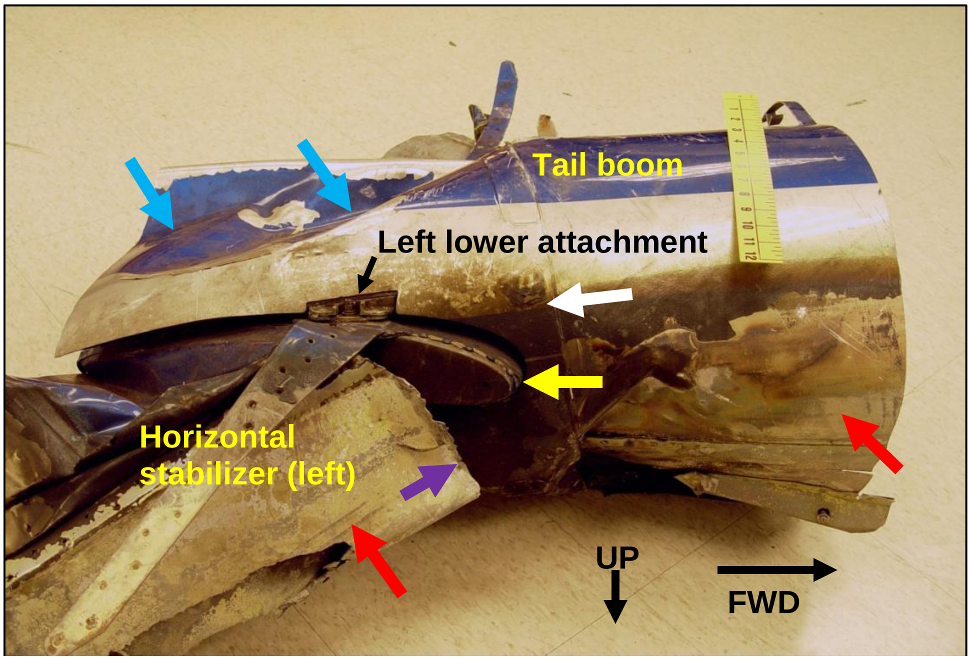

Figure 54. Buckling at the left side of the tail boom.

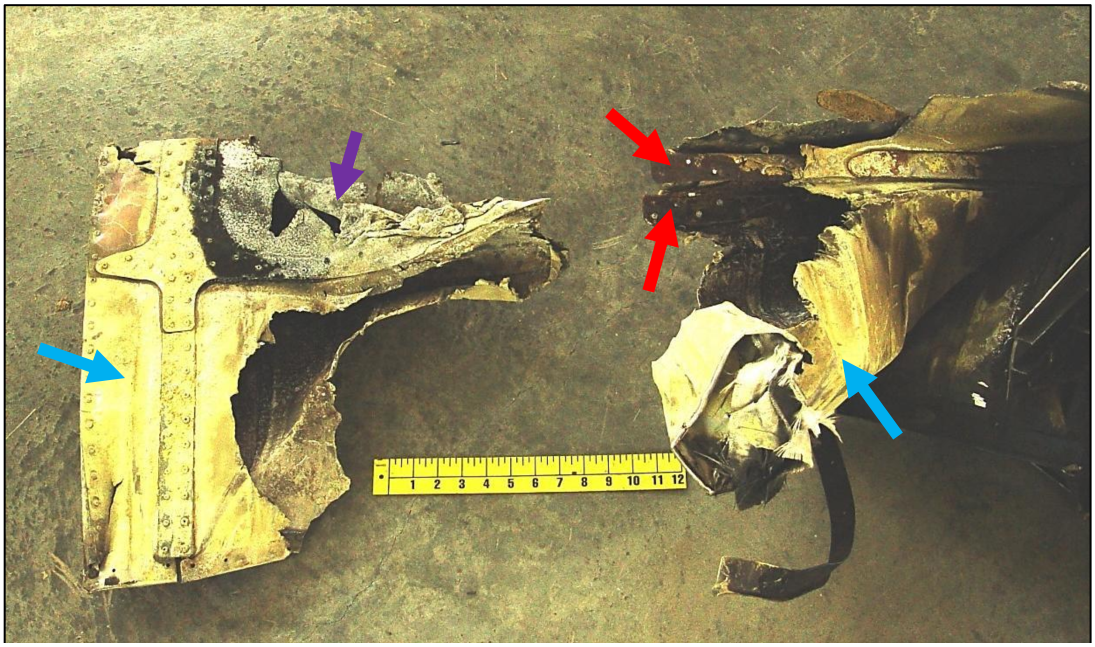

Figure 55. The tip and outboard end of the left horizontal stabilizer.

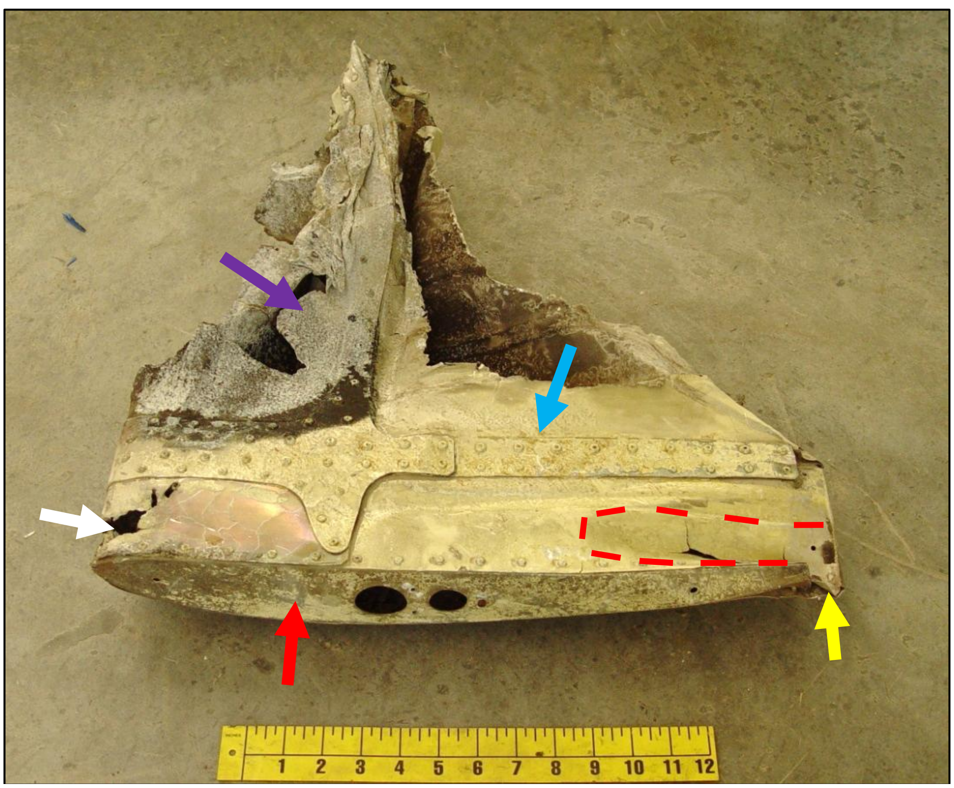

Figure 56. The tip of the left horizontal stabilizer looking inboard.

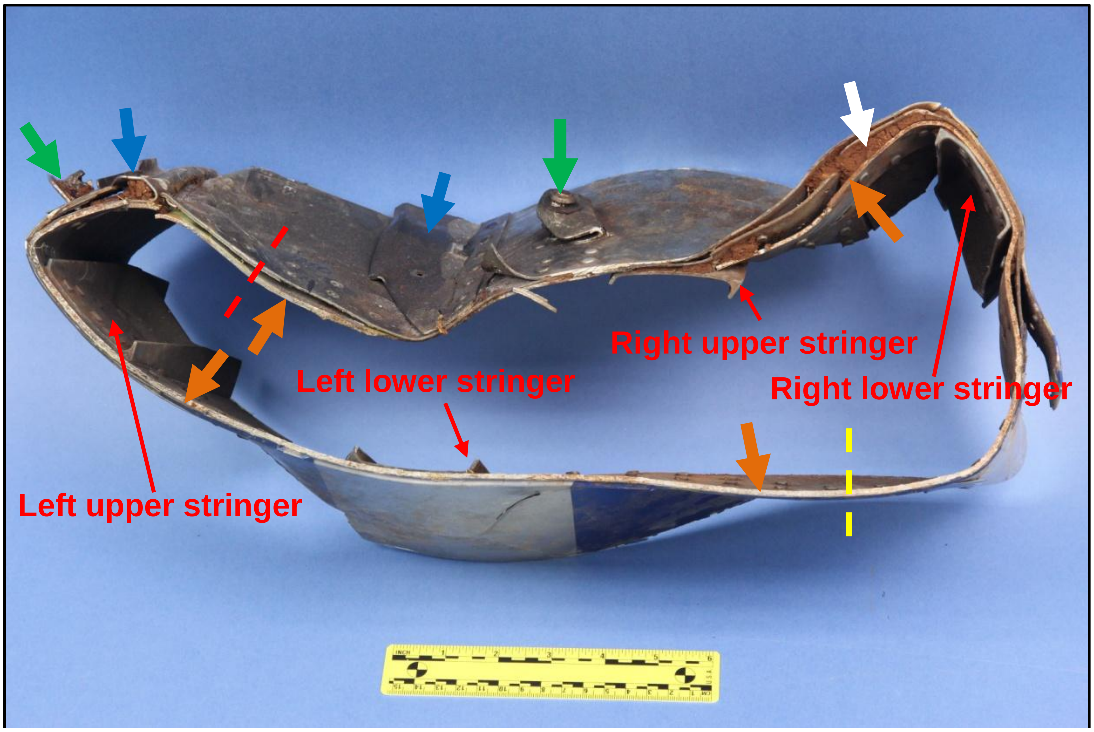

Figure 57. The rear portion of the tail boom indicated by the red arrow in Figure 43, looking forward.

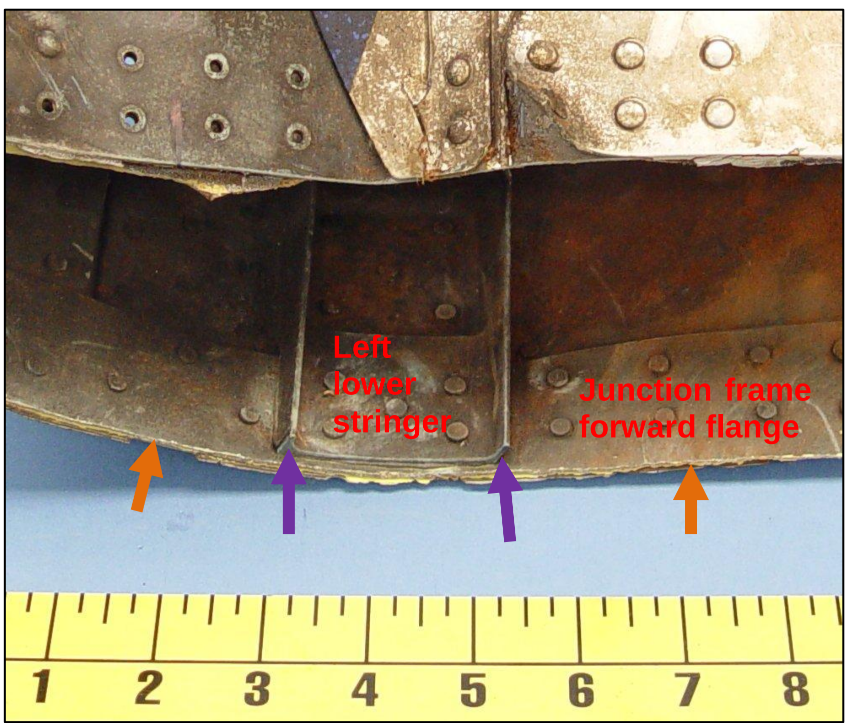

Figure 58. The left lower stringer and the fractured forward flange of the junction frame.

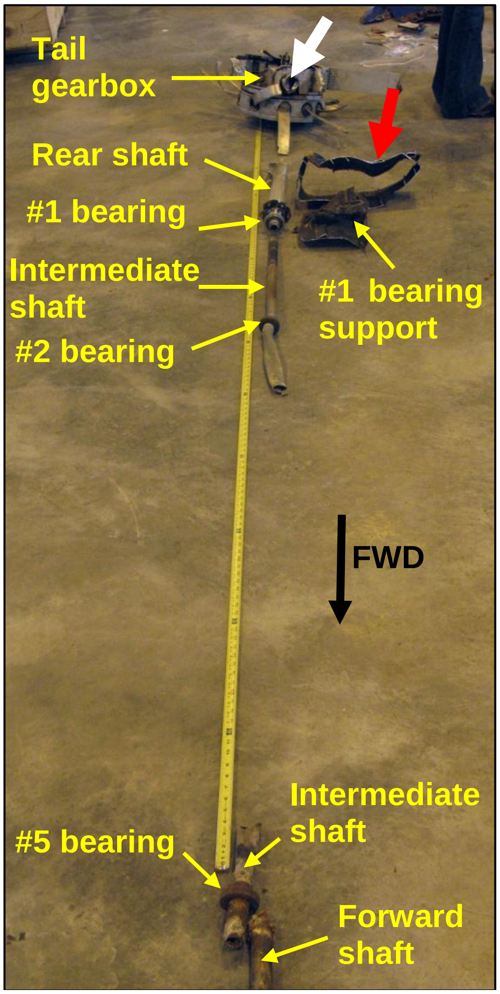

Figure 59. The tail rotor drive shaft pieces recovered.

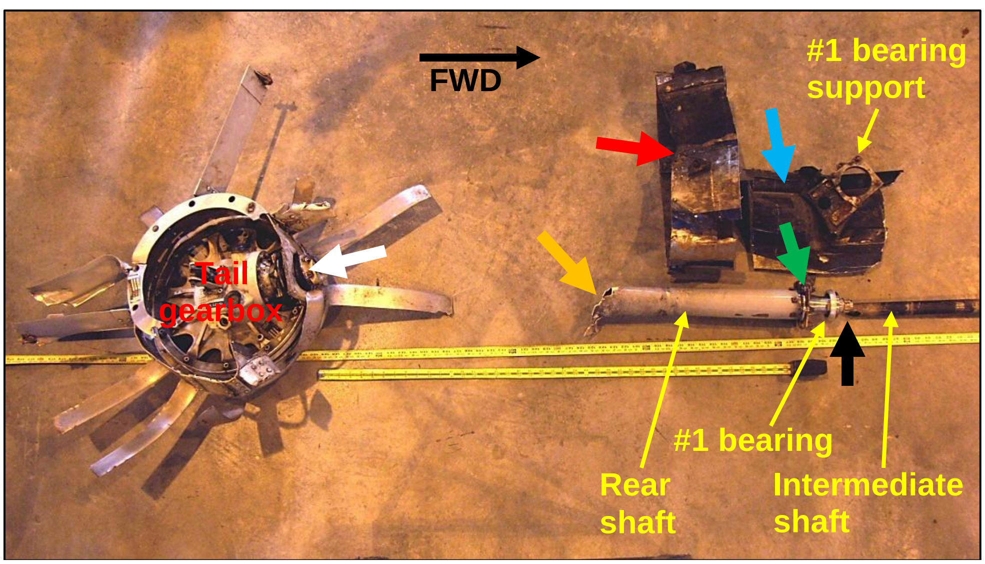

Figure 60. The rear pieces of the tail rotor drive shaft pieces recovered.

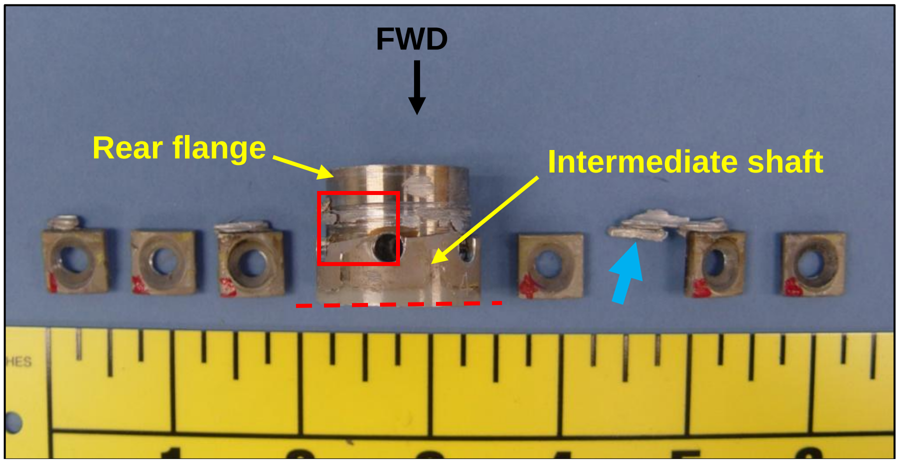

Figure 61. The disassembled portion removed from the forward end of the rear drive shaft.

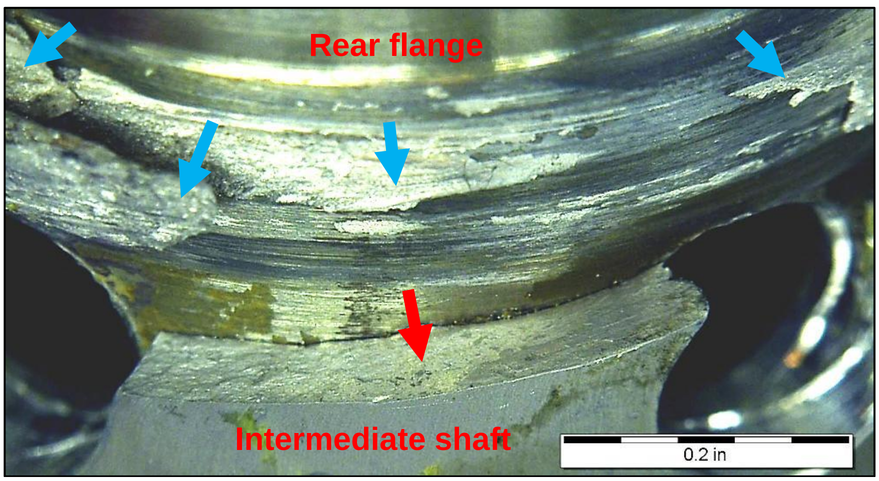

Figure 62. A typical fracture on the intermediate shaft.

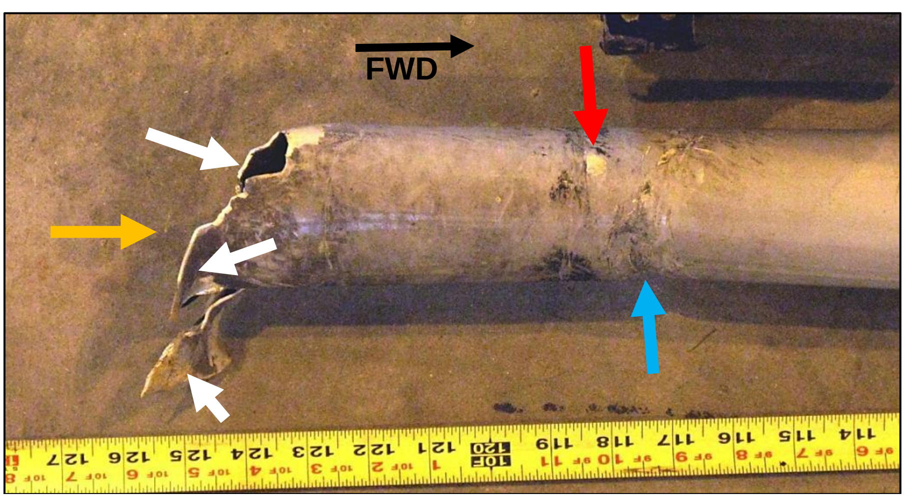

Figure 63. The fractured rear end of the tail rotor rear drive shaft.

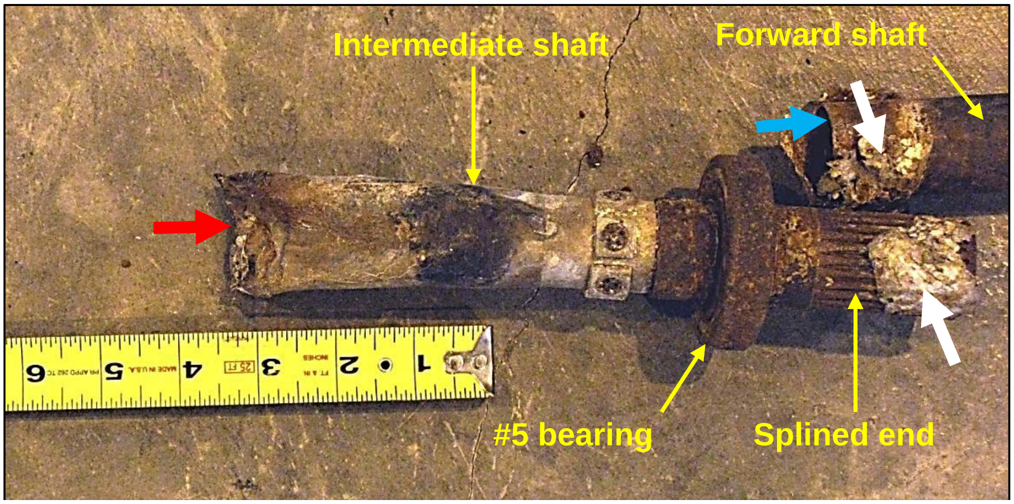

Figure 64. The forward pieces of the tail rotor drive shaft recovered.

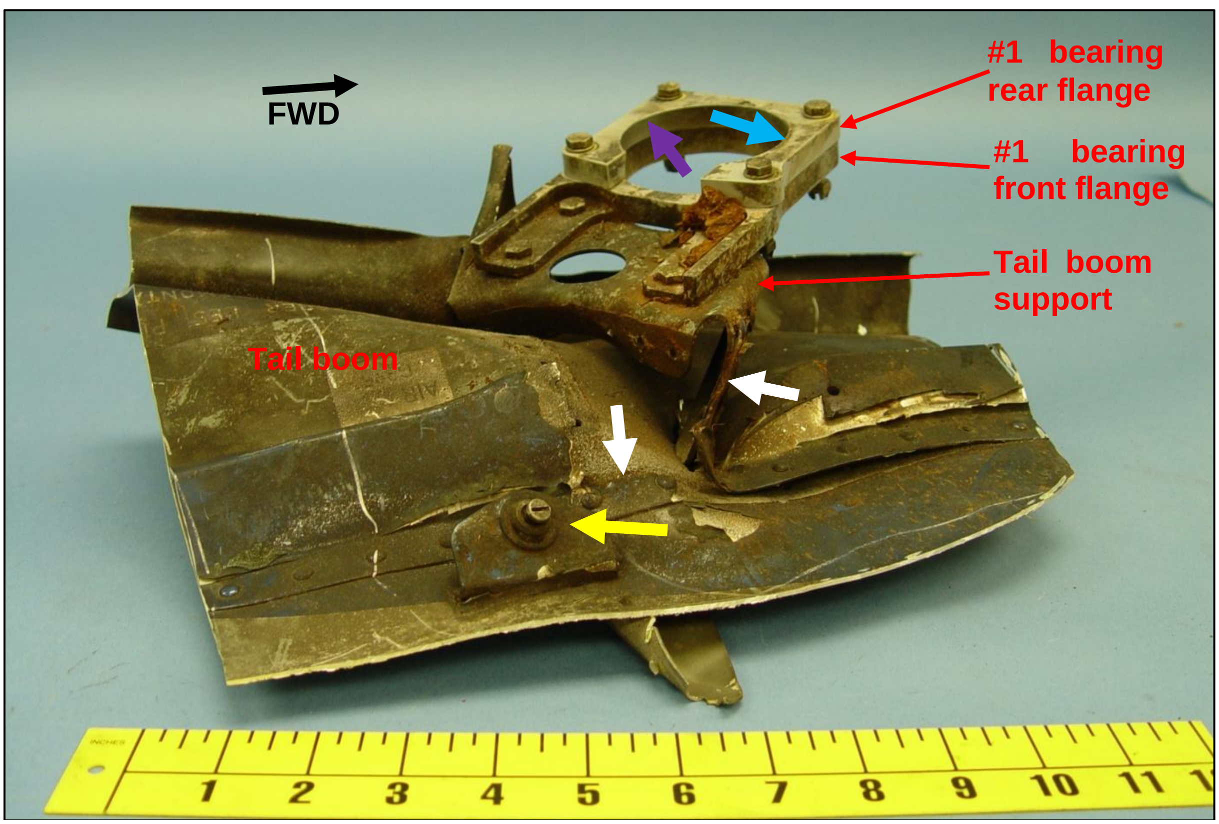

Figure 65. The #1 bearing flange assembly and tail boom piece removed from the location indicated by the blue arrows in Figure 44.

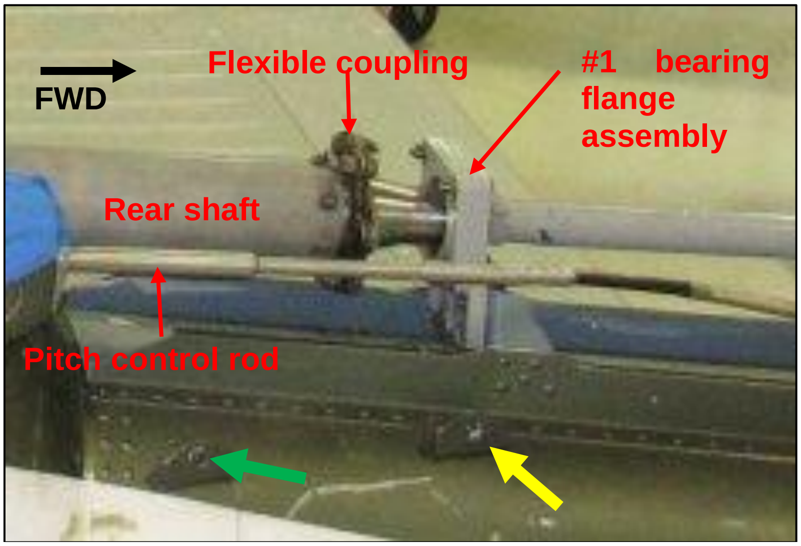

Figure 66. The #1 bearing flange assembly on the training EC-130B4 and indicated by the red arrow in Figure 14.

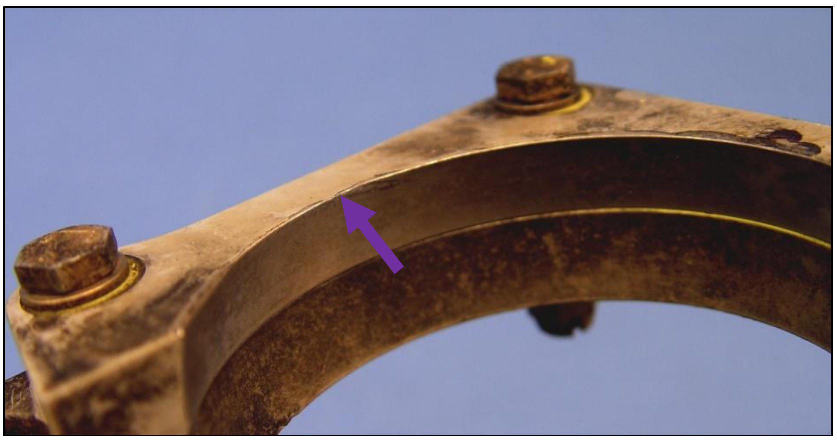

Figure 67. The left rear edge of the #1 bearing rear flange indicated by the purple arrow in Figure 63.

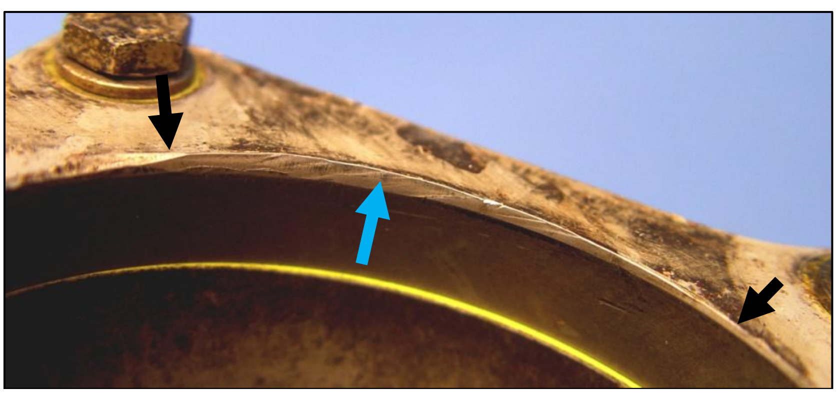

Figure 68. The right rear edge of the #1 bearing rear flange indicated by the blue arrow in Figure 63.

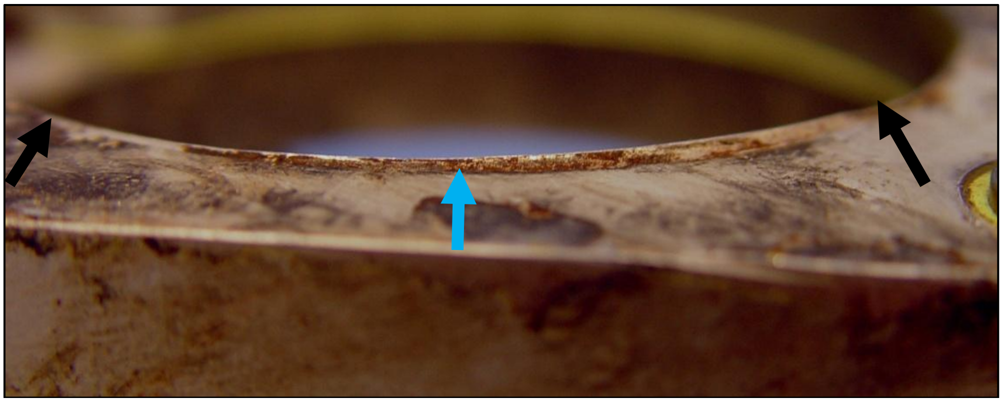

Figure 69. The right rear edge of the #1 bearing rear flange, looking inwards.

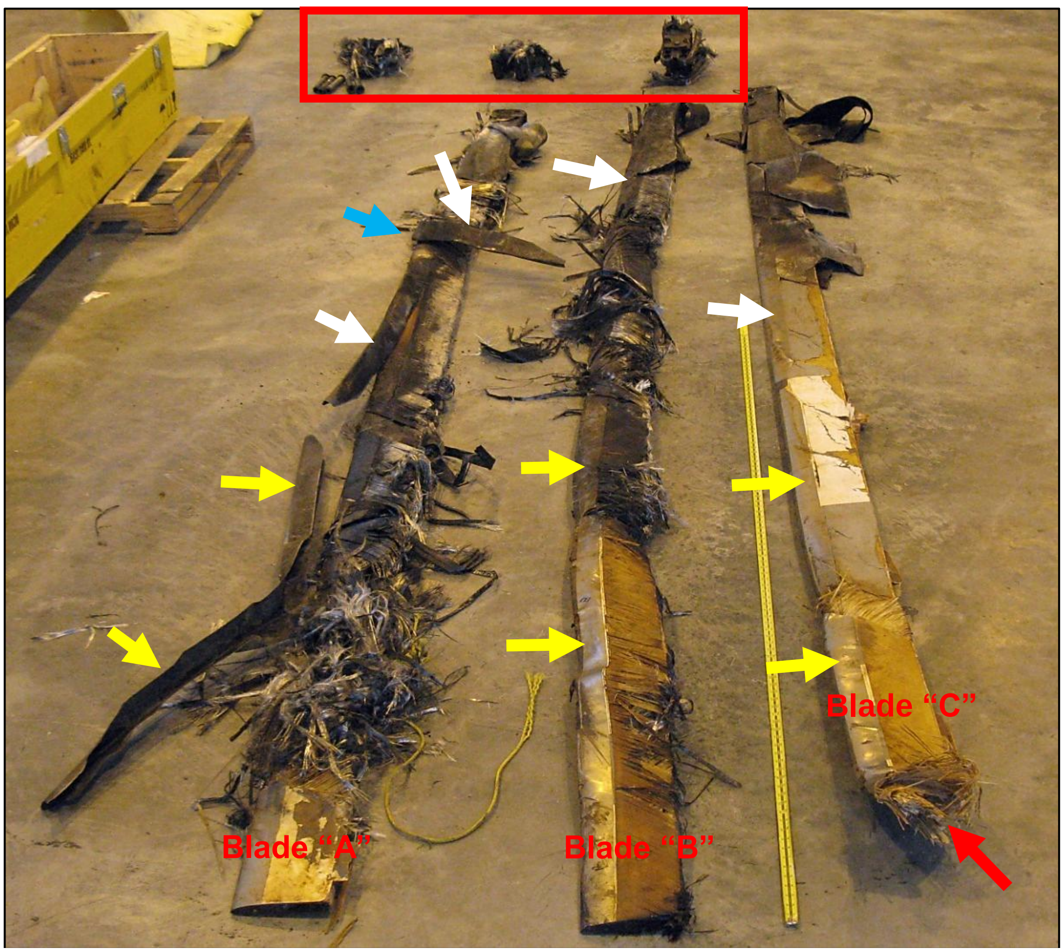

Figure 70. The upper surfaces of the recovered main rotor blades.

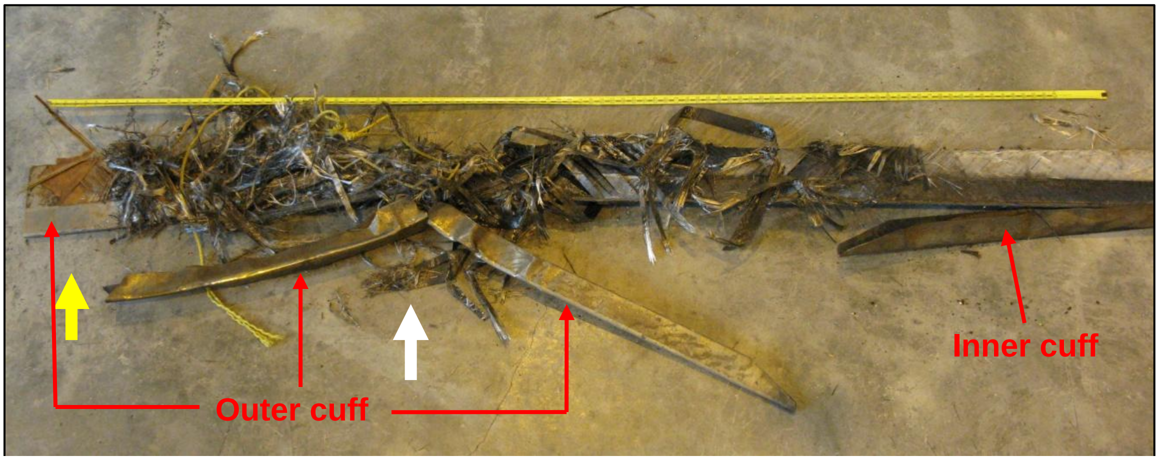

Figure 71. The lower surface of an outer portion of blade "A"

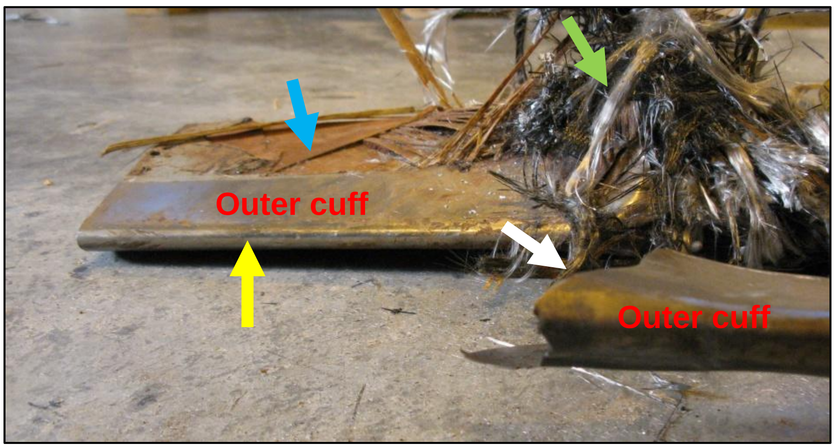

Figure 72. The leading edge of blade "A" indicated by the yellow arrow in Figure 71.

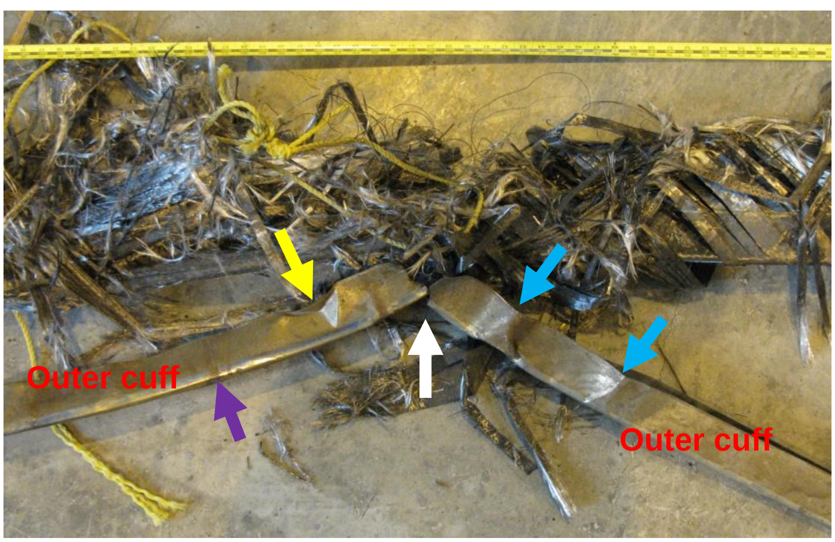

Figure 73. The leading edge of blade "A" indicated by the white arrow in Figure 71.

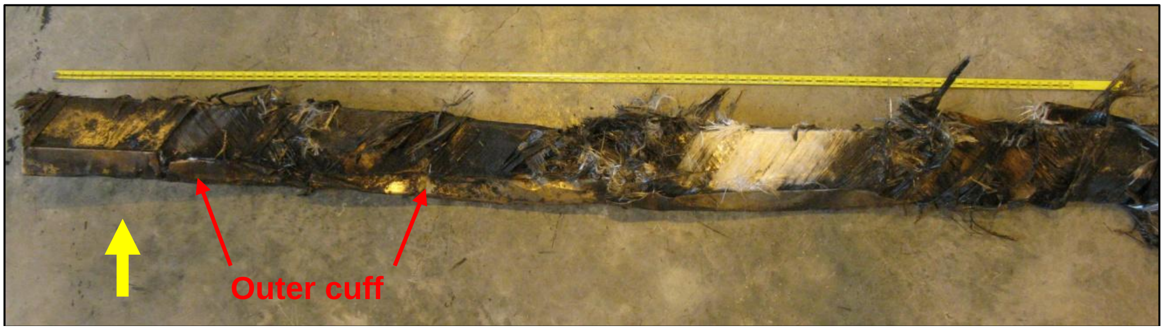

Figure 74. The lower surface of an outer portion of blade "B".

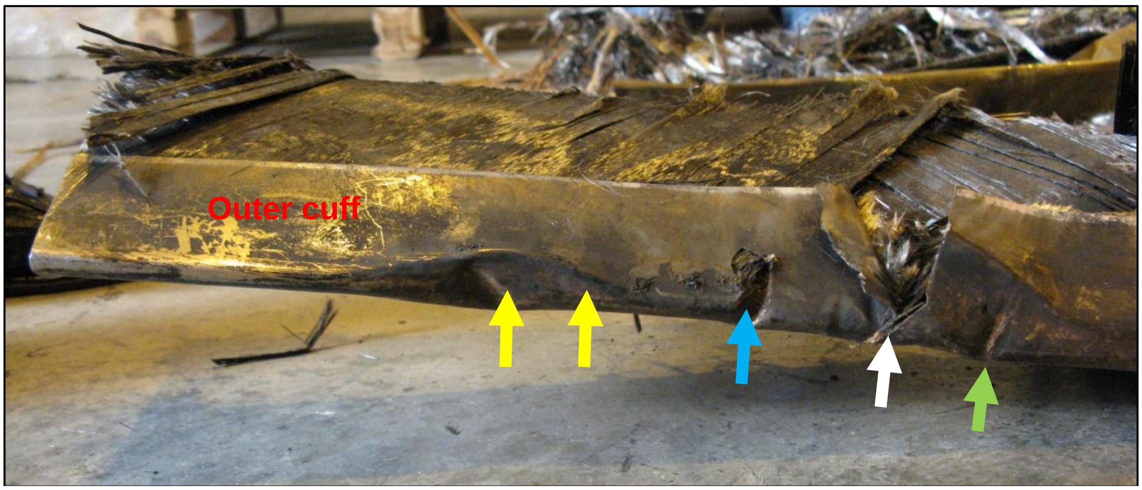

Figure 75. The leading edge of blade "B" indicated by the yellow arrow in Figure 74.

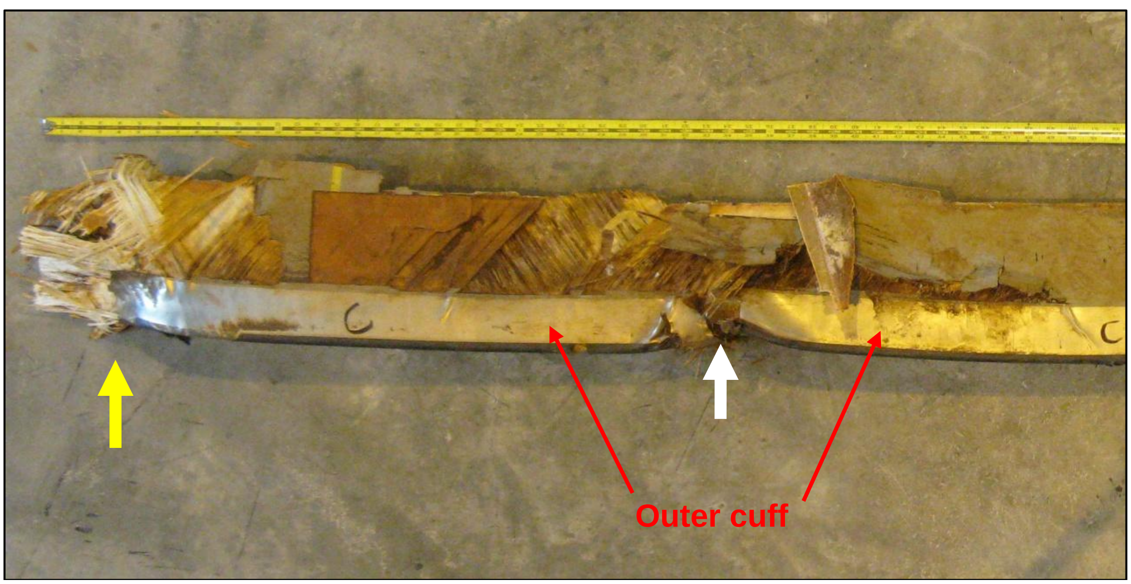

Figure 76. The lower surface of an outer portion of blade "C".

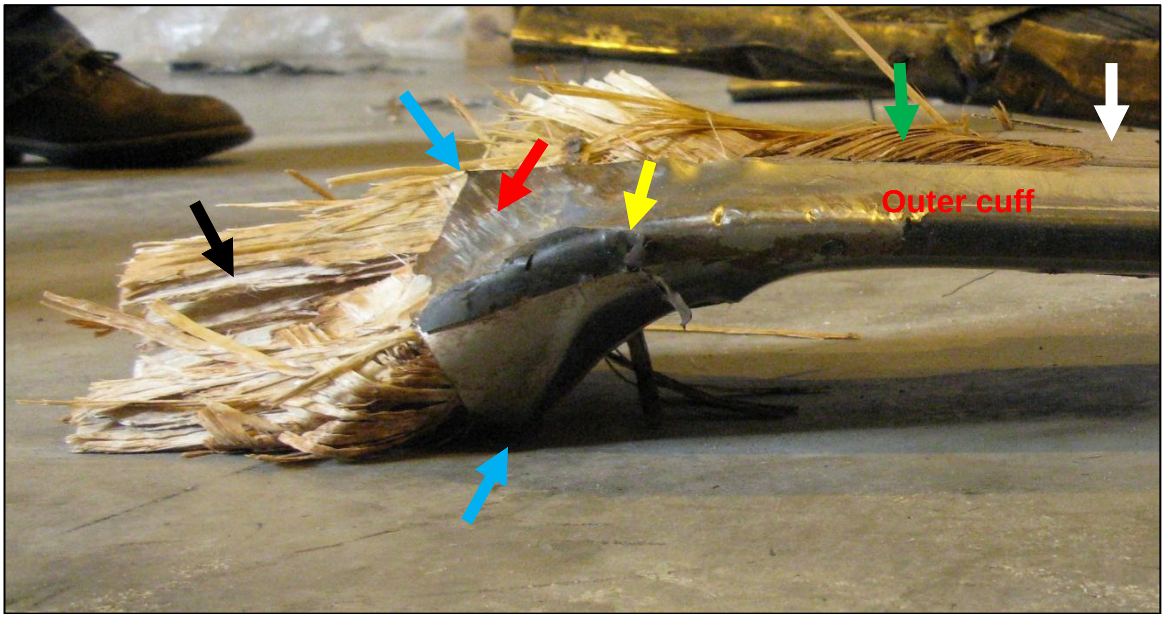

Figure 77. The leading edge at the outboard end of blade "C" indicated by the yellow arrow in Figure 74 and the red arrow in Figure 1.

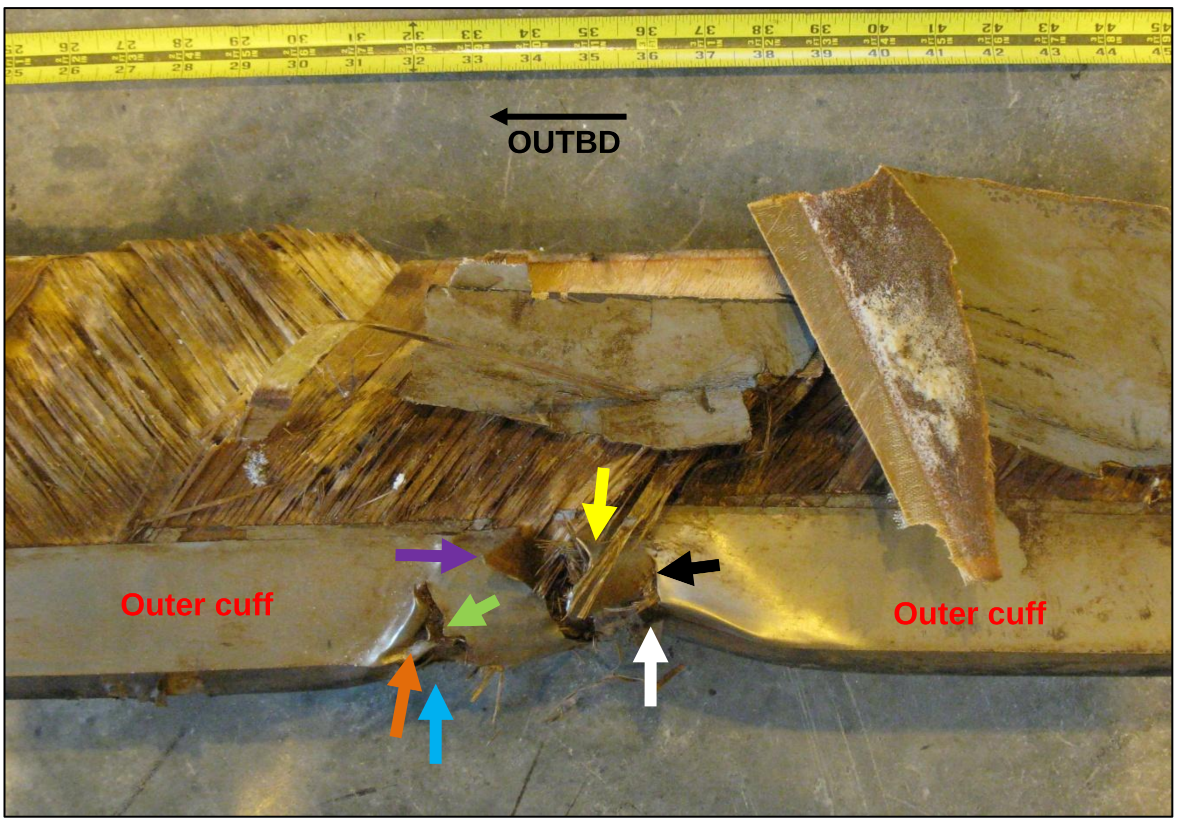

Figure 78. The leading edge of blade "C" indicated by the white arrow in Figure 76.

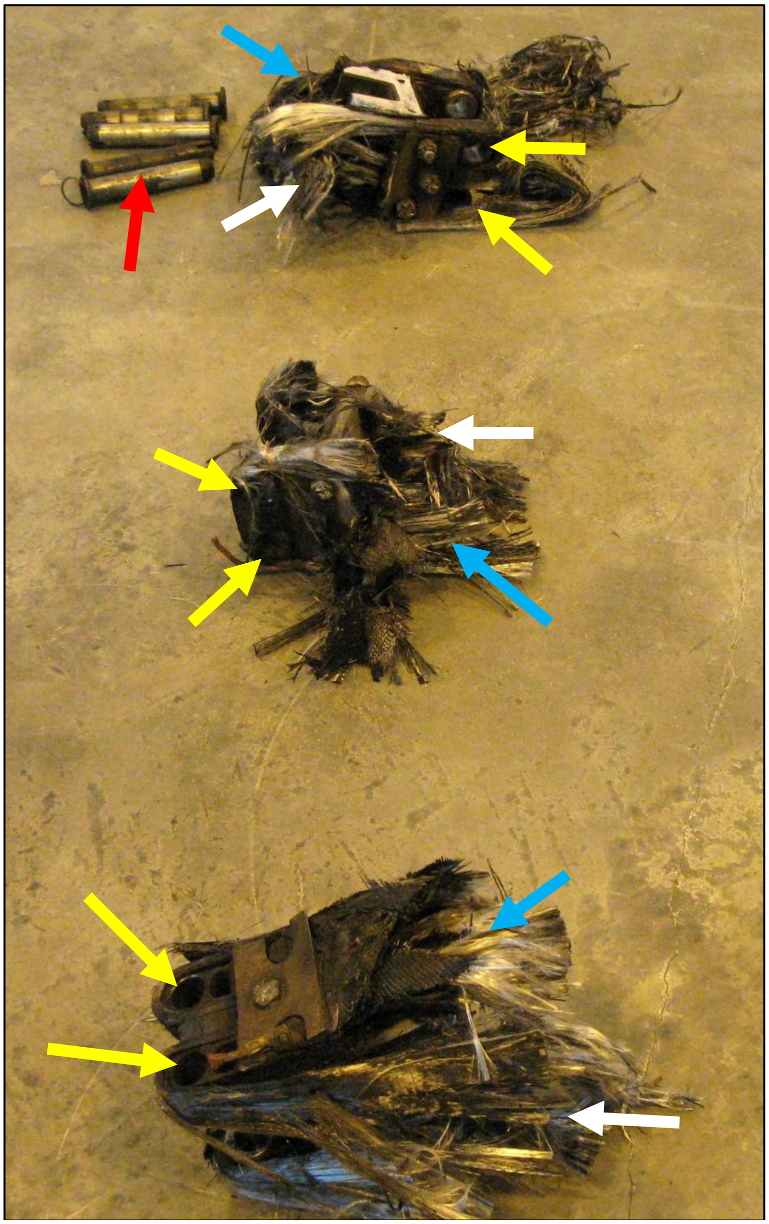

Figure 79. The outer ends of the main rotor head sleeves in the red box in Figure 69.

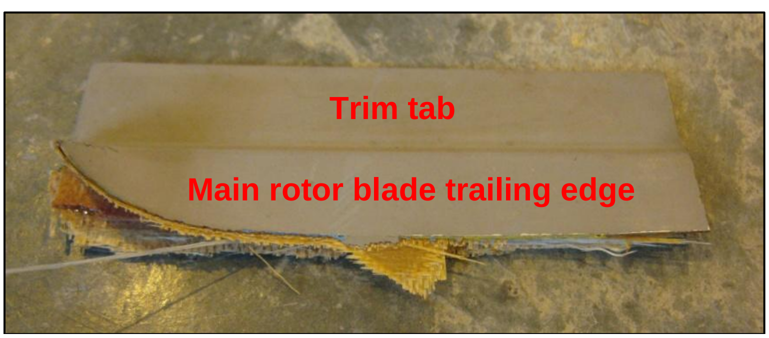

Figure 80. The main rotor blade trim tab recovered.