

NATIONAL TRANSPORTATION SAFETY BOARD

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



May 18, 2016

MATERIALS LABORATORY FACTUAL REPORT

Report No. 16-044

A. ACCIDENT INFORMATION

Place : Ketchum, Oklahoma
Date : August 25, 2015
Vehicle : Robinson R44 II, N444KD
NTSB No. : CEN15LA379
Investigator : Jim Silliman, AS-CEN

B. COMPONENTS EXAMINED

Tail boom pieces, tail rotor drive shaft pieces, tail rotor gearbox assembly, tail rotor hub and blade pieces, tail rotor guard piece, and fuel cap.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted tail components is shown in figure 1. The tail cone was fractured around its circumference just forward of the aft bulkhead. The tail rotor drive shaft was fractured at the aft flexible coupling, and the tail rotor gearbox was fractured from the aft bulkhead. The tail rotor blades were fractured into multiple pieces, and the tip end was missing from one of the blades.

1. Tail Cone and Aft Bulkhead

A closer view of the tail cone and drive shaft fractures is shown in figure 2. The tail cone had circumferential sliding contact damage on the interior surface, and fractures were deformed outward consistent with contact with the tail rotor drive shaft flexible coupling flanges. Flanges for the tail rotor gearbox input shaft at the aft side of the flexible coupling were fractured from the shaft, and one of the flange pieces remained attached to the flexible coupling plate. At the opposite side of the coupling plate, the attachment ear of the plate was fractured and missing. All fractures for the flexible coupling were damaged by post-fracture damage, but remaining surfaces showed slant fractures consistent with overstress fracture.

The tail cone aft bulkhead as viewed from the aft looking forward is shown in figure 3. Pieces of the aft face were missing around the upper left half of the bulkhead, including the upper left threaded hole for attaching the tail rotor gearbox. A fractured flange piece from the tail rotor gearbox housing remained attached at the lower left tail rotor gearbox attachment position. The aft bulkhead was fractured through the upper right tail rotor gearbox attachment hole, and a crack intersected the lower right

attachment hole. A closer view of the crack intersecting the lower right attachment hole is shown in figure 4. The crack also intersected an area of contact damage on the upper inboard corner of the corner gusset section. The upper right tail rotor gearbox attachment hole had several sheared threads, and threads at the lower right attachment hole were mostly sheared.

Fracture features around the tail cone aft bulkhead were examined using a stereo microscope. Many areas showed post-fracture damage, but all remaining fracture features had rough matte gray features consistent with overstress fracture. Additionally, the aft bulkhead was sectioned and rivets were removed to facilitate examination of the fracture features for the crack that intersected the lower right attachment hole. After the crack was opened, the observed fracture features had a rough matte gray appearance consistent with overstress fracture. Using oblique lighting methods, the fracture features for the opened crack had a subtle radial pattern that emanated from the area of damage at the aft gusset section. No evidence of a preexisting crack was observed on any of the fractures in the tail cone aft bulkhead.

2. Tail Rotor Gearbox

The attachment locations on the tail rotor gearbox housing are shown in figures 5 and 6. As shown in figure 5, the attachment bolts remained in place within the right side of the attachment flange. Thread remnants from the aft bulkhead were trapped within the threaded shank of the lower right attachment bolt. Ears of the flanges at the right side of the gearbox housing were bent slightly aft, consistent with the left side of the gearbox housing displacing aft relative to the attached right side.

The tail rotor gearbox flange was fractured at the two attachment locations at the left side of the gearbox. Fracture features, shown in figure 6, were rough and matte gray consistent with overstress fracture. The forward edges of the inboard faces of the fractures had smeared features with a lip at the edge of the fracture consistent with sliding post-fracture contact with the mating side of the fracture as the tail rotor gearbox moved aft relative to the fractured flange pieces at the left side of the gearbox.

A view of the tail rotor gearbox positioned at the aft side of the aft bulkhead is shown in figure 7 with the left side of the gearbox displaced aft relative to the right side. In this view, the aft bulkhead had been sectioned and rivets removed to facilitate examination of the fracture features of the crack intersecting the lower right attachment hole. As shown in this view, the area of contact on the gusset section of the aft bulkhead (see figure 4) corresponded to contact with a bolt head on the displaced tail rotor gearbox.

The pitch change bellcrank remained attached to the tail rotor gearbox housing. The end fitting for the pitch change control rod was attached at the input end of the bellcrank, and the output end was attached to the pitch change control assembly. The pitch change control rod was fractured where it intersected the end fitting. Fracture features were matte gray and on a slant plane consistent with ductile overstress fracture.

3. Tail Rotor Hub

An overall view of the tail rotor hub and larger blade pieces is shown in figure 8 as viewed looking at the outboard faces. The hub was intact, but showed evidence of substantial teetering. The teeter stop shown in figure 9 had contact marks corresponding to heavy contact with the hub, and radial cracks were associated with the contact areas on diametrically opposite sides of the elastomer teeter stop. Heavy contact between the tail rotor output shaft and the hub associated with teetering was observed at the inboard side of the hub as shown in figure 10. Contact marks on the output shaft were observed on two diametrically opposite faces of the output shaft. Additionally, a contact mark was observed on the inboard face of the hub corresponding to contact with the pitch control assembly. The mark on the hub corresponding to contact with the pitch control assembly was only observed in the area shown in figure 10 and was not observed at the diametrically opposite side.

4. Tail Rotor Blades

Overall views of the tail rotor blades are shown in figures 10 and 11. For reference in this report, the tail rotor blades were arbitrarily labeled A and B as shown in figure 10. Fracture matching (see figure 12) showed two of the separate pieces recovered from a blade tip were from blade A as identified in figure 11.

The middle portion of blade B is placed adjacent to blade A in figure 11. The tips of both blades were fractured in nearly the same location with leading edge crushing and deformation toward the trailing edge. Also, the leading edge of blade A had a crack at nearly the same location as the fractured inboard end of the blade B piece shown in figure 11.

Views of the inboard face of blade A at the tip end with mating fractures placed adjacent to each other are shown in figure 12. Red paint transfer was observed on the inboard side of the fracture near the trailing edge, but the paint transfer did not continue across the fracture to the adjacent fractured skin piece. The inboard skin of the blade was crushed from the leading edge and displaced inboard. On the tip piece, the outboard skin was folded over the inboard face as indicated in the upper image in figure 12. Two sets of overlapping sliding contact marks were observed on face of the folded piece of outboard skin. The underlying sliding contact marks were oriented in the chordwise direction corresponding to the original position of the outboard skin. Overlapping sliding contact marks were angled relative to the underlying marks and were oriented in the chordwise direction corresponding to the folded position shown in figure 12.

The leading edges and fractures from blades A and B were examined closely for evidence of contact with a foreign object. The leading edges were examined under a black light. Small areas consistent with insects fluoresced under the light, but no larger areas of fluorescing material were observed. No evidence of feathers or vegetation were found. Paint transfer observed on the blade surfaces was either red or white,

consistent with contact with the blade guard or the empennage structure (the helicopter was painted white).

Close views of the crushed leading edge of the blade A tip area are shown in figure 13. Heavy impact consistent with contact with a metallic object was observed at the blade tip leading edge as indicated in figure 13. Adjacent to the heavy contact area, the leading edge was crushed, and gray material consistent with primer was observed on the leading edge surface, also indicated in figure 13. The primer material was analyzed using energy dispersive x-ray spectroscopy (EDS). Additionally, a sample of paint and primer was sampled from the tail cone and also analyzed using EDS. The EDS spectrum of the transferred primer on the blade A leading edge was comparable to the primer sampled from the tail cone.

Impact marks and paint transfer at the leading edge of blade B are shown in figure 14. The leading edge was deformed, and sliding contact marks and paint transfer were present on the inboard face as shown in the lower image in figure 14. Unlabeled arrows in figure 14 indicate sliding contact marks associated with white paint transfer. The contact marks curved from the leading edge toward a spanwise orientation toward the tip, crossing over the area of red paint transfer.

Fractures of the skin on both blades were examined visually. The fractures were formed on slant angles consistent with ductile overstress fracture.

5. Fuel Cap

The fuel cap was recovered near the start of the debris trail from the accident helicopter. Close views of the fuel cap are shown in figure 15. No evidence of heavy impact marks or paint transfer from the tail rotor blades were observed on the fuel cap.

Matthew R. Fox
Senior Materials Engineer

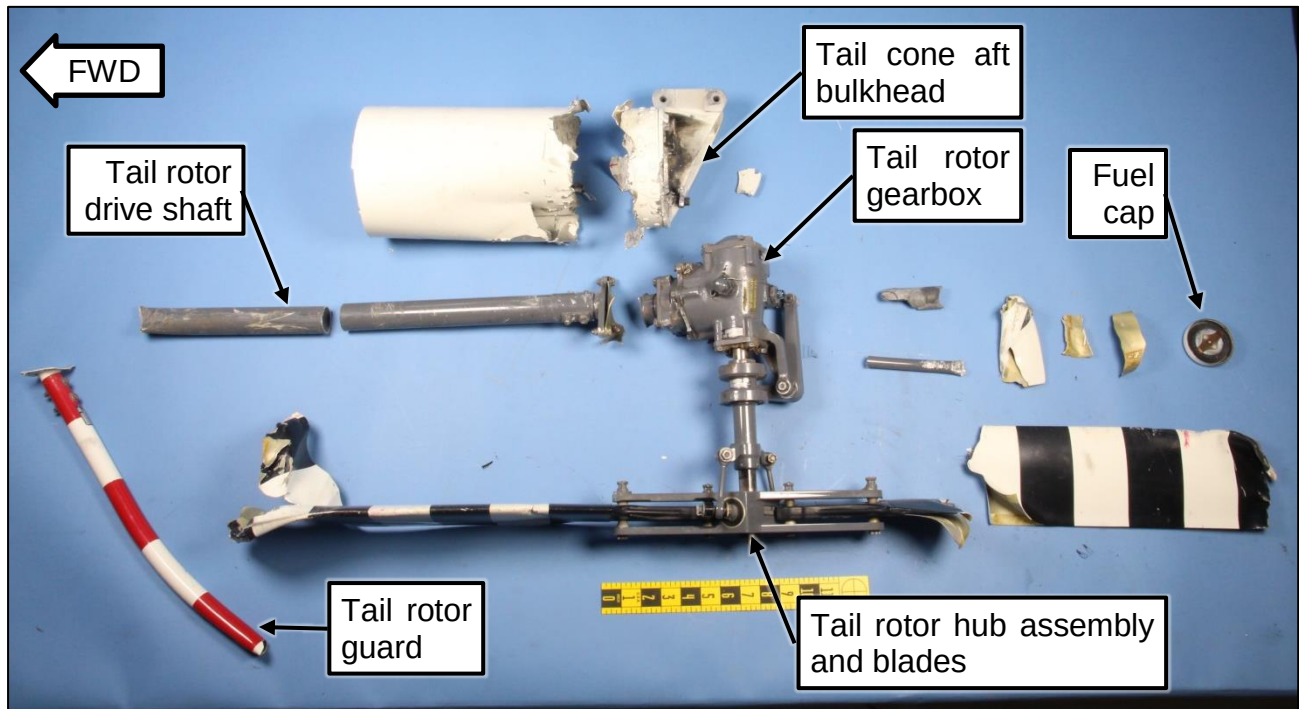


Figure 1. Overall view of the submitted components.

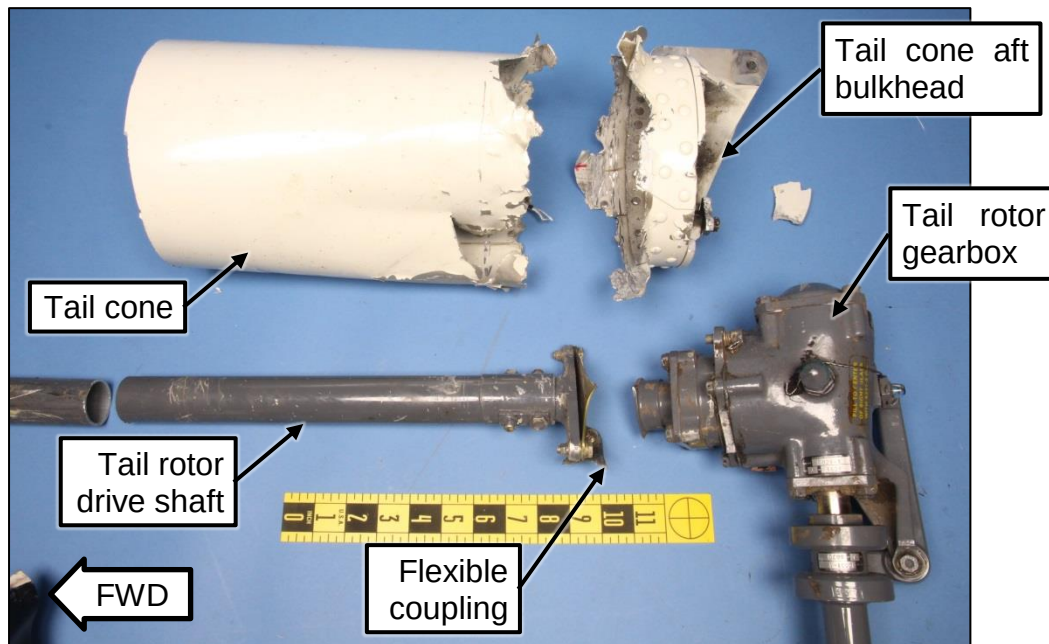


Figure 2. Closer view of the fractured tail boom and tail rotor drive shaft.

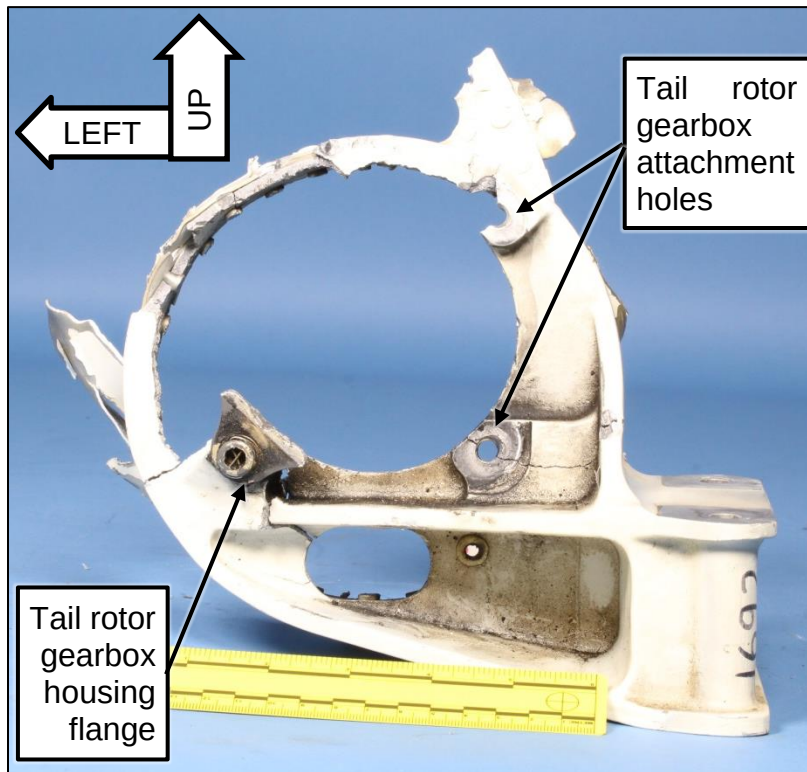


Figure 3. Tail cone aft bulkhead as viewed looking forward.

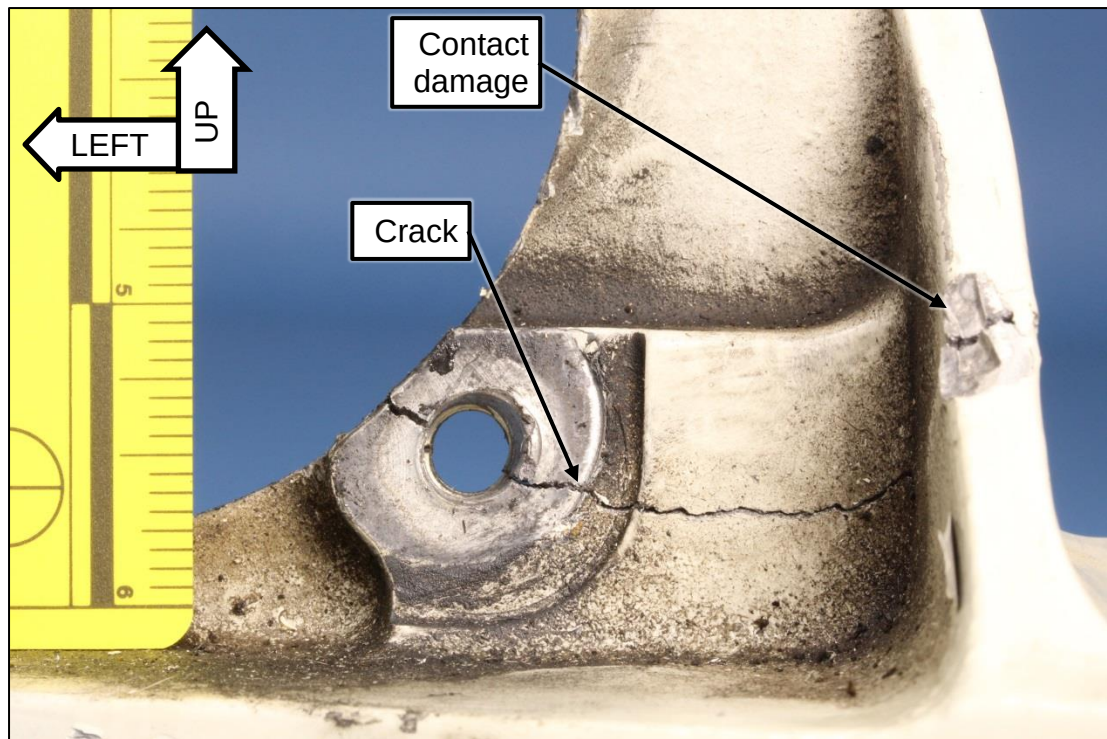


Figure 4. Close view of a crack intersecting both the lower right tail rotor housing attachment hole and the indicated area of contact damage on the aft flange.

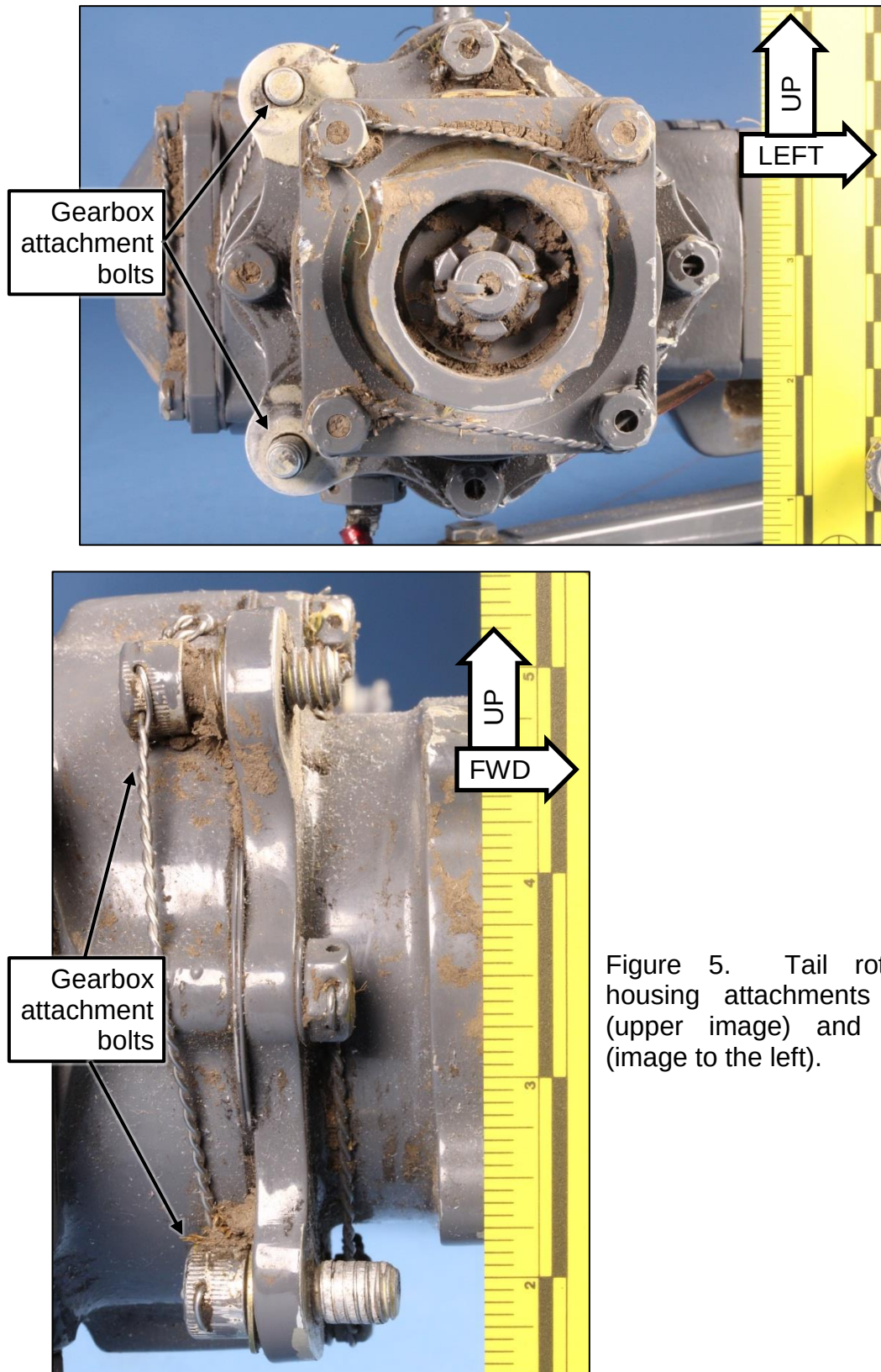


Figure 5. Tail rotor gearbox housing attachments looking aft (upper image) and looking left (image to the left).

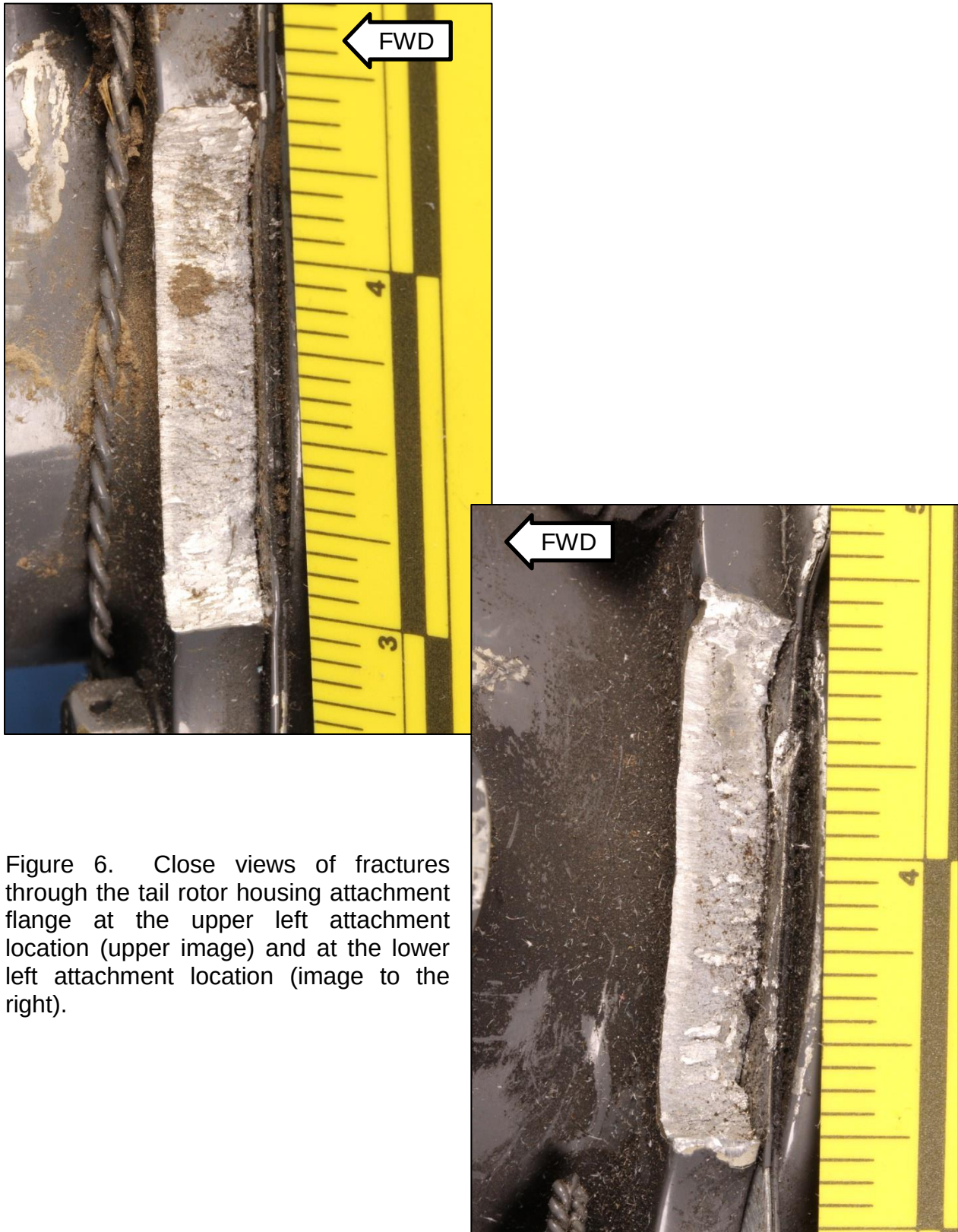


Figure 6. Close views of fractures through the tail rotor housing attachment flange at the upper left attachment location (upper image) and at the lower left attachment location (image to the right).

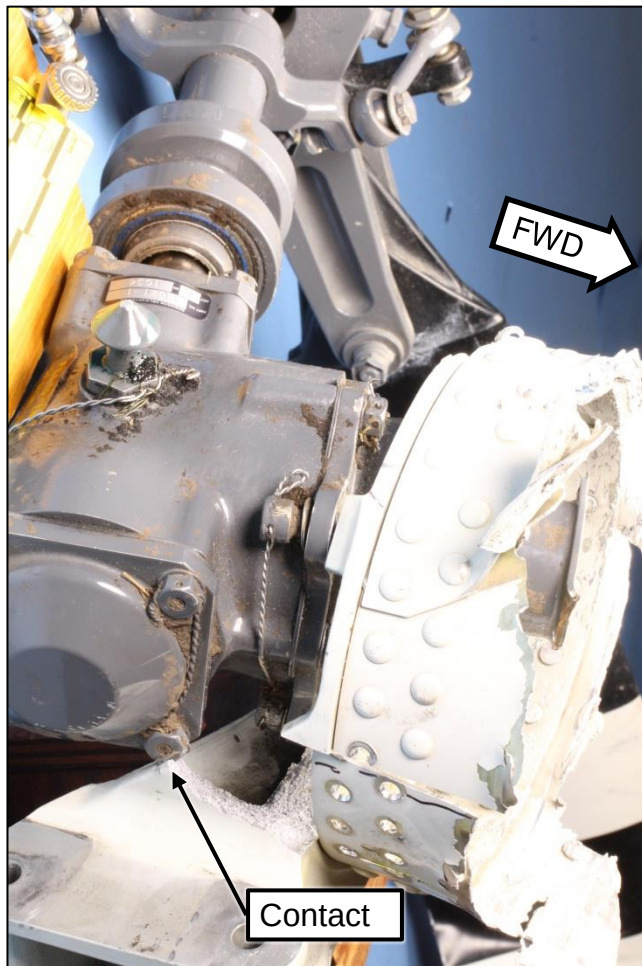


Figure 7. Tail rotor gearbox positioned at the aft side of the tail cone aft bulkhead after sectioning to open the crack through the lower right attachment hole. An area of corresponding contact between a bolt head on the lower right side of the gearbox and corresponding deformation on the aft bulkhead is indicated. (See figure 4 for a view of the crack and contact damage on the aft bulkhead).

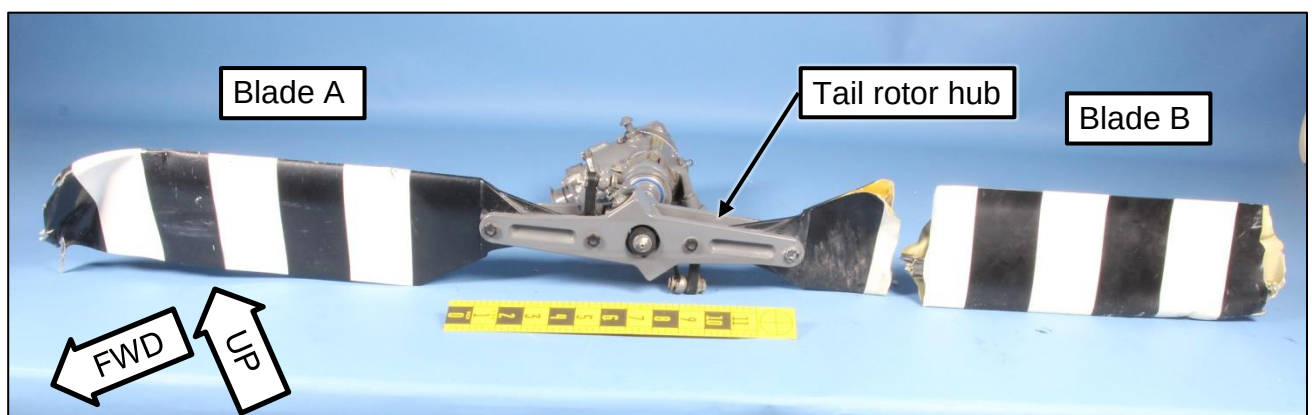


Figure 8. Overall view of the tail rotor hub and larger blade pieces.



Figure 9. Close view of the teeter stop. The stop was deformed corresponding to contact with the hub, and radial cracks were present adjacent to the contact area.

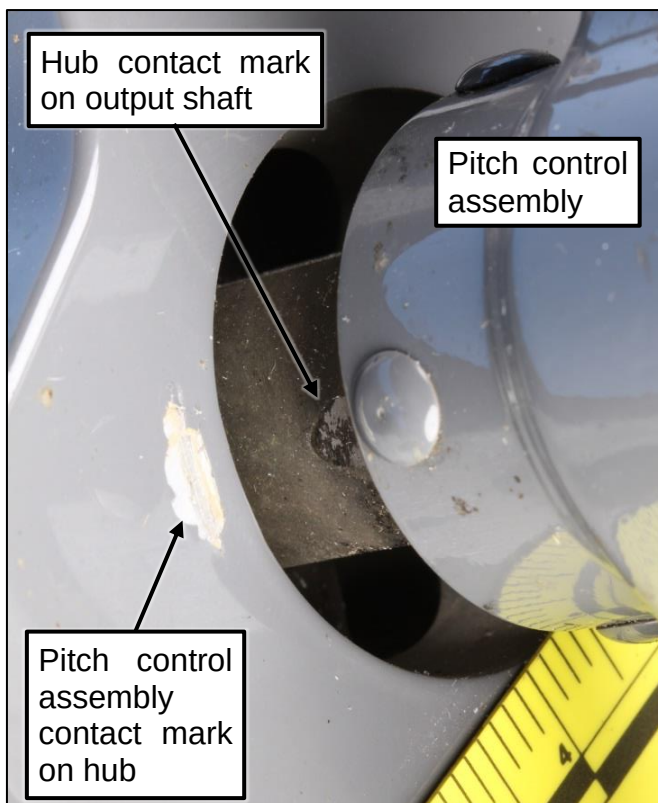


Figure 10. Inboard side of the hub showing contact areas between the hub and both the output shaft and the pitch control assembly.

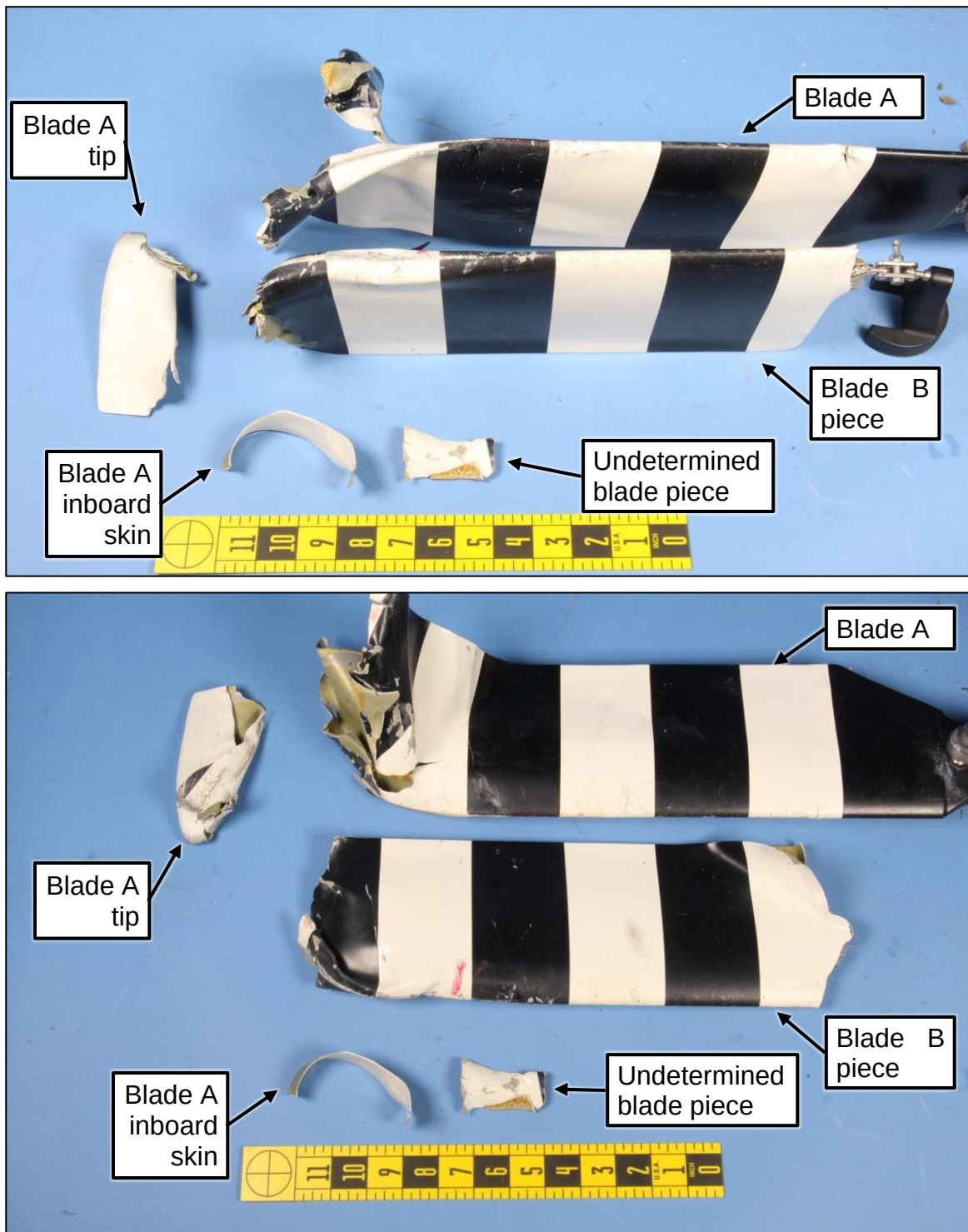


Figure 11. Blades A and B placed side by side showing symmetric damage patterns looking at both the outboard (upper image) and inboard (lower image) faces of the blades.

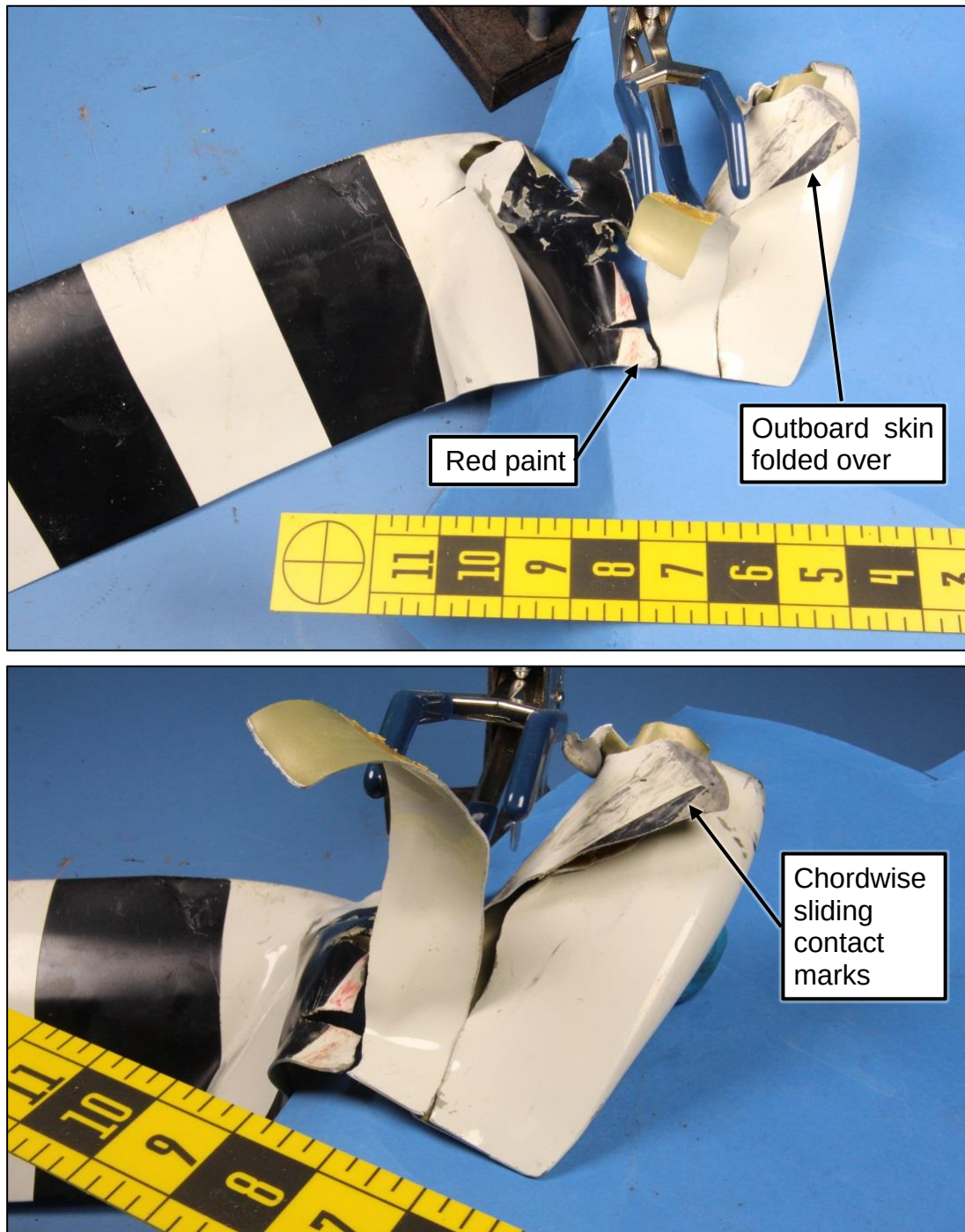


Figure 12. Two views of the tip end of blade A, inboard face, with mating fractures placed in close proximity. The outboard skin of the blade tip piece was folded over the inboard face with chordwise sliding contact marks aligned with the original orientation and overlapping sliding contact marks oriented chordwise in the folded position.

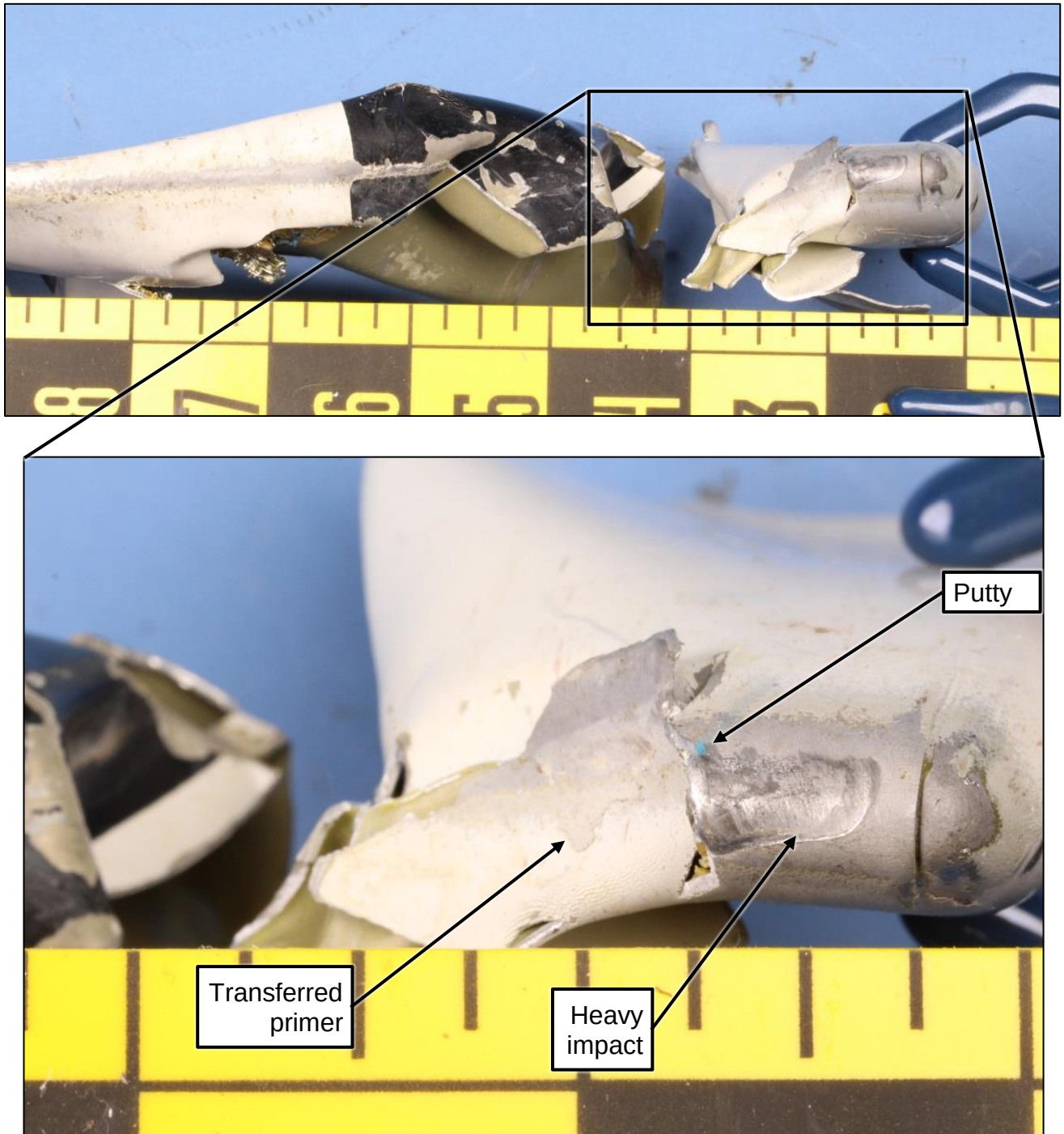


Figure 13. Blade A leading edge tip damage showing an area of heavy impact and an area of transferred material consistent with primer.

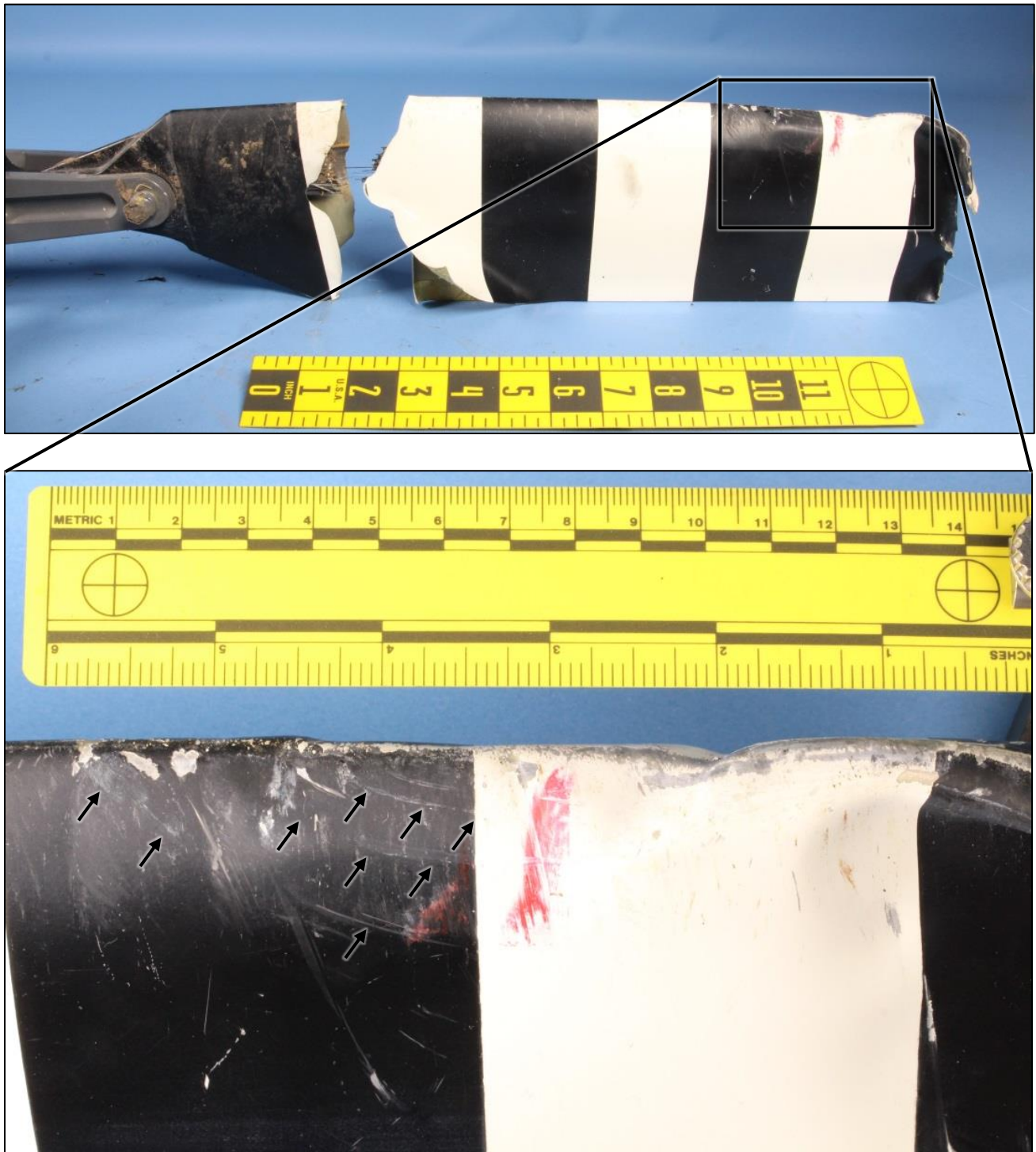


Figure 14. Inboard side of blade B leading edge showing an area of contact damage and paint transfer marks. Unlabeled arrows in the lower image indicate sliding contact marks with white paint transfer curving from the leading edge toward the spanwise direction toward the blade tip.



Figure 15. Exterior (upper image) and interior (lower image) faces of the fuel cap.