

NATIONAL TRANSPORTATION SAFETY BOARD

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



April 20, 2021

MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-012

A. ACCIDENT INFORMATION

Place : Titusville, Florida
Date : 07/03/2020
Vehicle : Piper PA-46-600TP (N89MA)
NTSB No. : ERA20LA237
Investigator : Lynn Spencer

B. COMPONENTS EXAMINED

1. Portions of M600 nose gear steering horn assembly
2. Left main landing gear lower torque arm
3. Left main landing gear upper torque arm, bolt, cotter pin
4. Nose landing gear assembly
5. Steering bungee
6. Steering arm

C. DETAILS OF THE EXAMINATION

Portions of the as-received nose landing gear assembly are shown in Figure 1. Close views of the right and left turn stops for the as-received nose landing gear assembly are shown in Figure 2. In Figure 3, the right and left turn stops have been cleaned with isopropyl alcohol. As revealed in the figure, the paint is not present on the right-turn trunnion stop and strut stop and the surface texture on the trunnion stop is embossed on the surface of the strut stop. The figure also reveals partial paint loss on the left-turn strut stop.

The upper surface of the nose landing gear assembly strut is shown in Figure 4. Fractured remnants of the three bolts used to secure the steering horn assembly to the top of the strut are present as indicated in the figure. The bolt positions have been numbered for documentation purposes. Closer images of the fractured bolt remnants are superposed in Figure 4. Based on fractographic evaluation, the white arrows indicate the direction of shear loading required to fracture the bolts. Fractography indicated that Bolt 2 fractured predominately in tension with minor shear loading. Based on deformation signatures on the bolt remnants and on damage to the top of the strut housing, Bolts 3 and 1 experienced progressively greater levels of shear/bending loading, respectively.

The steering arm and bungee subassembly is shown in Figure 5. The aft or backside of the left steering arm contact pad exhibited a witness or contact mark as indicated in the figure. Closer views of the contact mark on the backside of left pad are shown in Figure 6. According to the IIC, examination of the accident airplane revealed that this contact mark is consistent with contact with the engine mount plate.

Figures 7 through 15 document the steering horn subassembly. Figures 7, 8, and 9 document the general appearance of the steering horn. In the figures, the mounting bolt holes are numbered consistent with the numbering scheme on the strut top in Figure 4. In bolt position 1, a fractured portion of the bolt consisting of the head and grip are safety-wired to the steering horn. This bolt remnant and its fracture surface is documented in Figures 16 through 20. Profile views of the steering horn in Figures 10 and 11 reveal that the bolt/axle for the left roller is bent about 7° forward and that the mounting plate has out-of-plane deformation. Such mechanical deformation resulted in strain and cracks in the paint film over the weld deposits adjacent to bolt holes 2 and 3 as documented in Figures 12 through 14. Lastly, Figure 15 documents the manufacturer's markings on the steering horn.

The fractured bolt piece from the Bolt 1 position of the steering horn is documented in Figures 16 through 20. The bolt piece fractured at the first thread adjacent to the grip as revealed in Figure 16. A metallurgical cross section prepared through the head of Bolt 1 revealed a microstructure of tempered martensite (see Figure 18). Microhardness measurements made at the core of the head cross section yielded a hardness of 319 HV500 to 328 HV500 (about 32 HRC to 33 HRC as converted via ASTM E140).

A close view of the as-received Bolt 1 fracture surface is shown in Figure 19. After cleaning in Evaporust, the fracture surface of Bolt 1 was examined using a scanning electron microscope (SEM) and the surface coating on the bolt shank was determined using standardless semiquantitative energy dispersive spectroscopy (EDS) as cadmium. The bolt in the Bolt 1 is specified to be AN4H-5A. Table 1 compares the specification requirements of the bolt with the characteristics measured on the Bolt 1 remnant.

Table 1—Nose Gear Steering Horn Mounting Bolt Measurements

AN4H-5A code	Requirements	Accident Bolt
AN4	¼-28UNF-3A	Not determined
H-5A	Cross drilled head	Yes
5	Grip length: 3/16 +/- 1/64 inch	0.227 inch
Length	21/32 +1/32 -1/64 inch	Not determined
X head marking	Non-corrosion resistant steel	Cadmium coated
Thread profile	MIL-S-7742	Not determined
Grip diameter	0.249-0.246 inch	0.247 - 0.246 inch
Rated strength	Tensile load at root diameter: 4080 lbf, minimum	For information
Hardness	Not indicated	32-33 HRC
Microstructure	Not indicated	Tempered martensite

The Bolt 1 fracture surface exhibited macroscope and microscopic features consistent with ductile overstress fracture by microvoid coalescence (see Figure 20) due to in-plane shear and bending (e.g., Mode I and Mode II loading). By matching fracture features on the bolt head remnant and the Bolt 1 remnant in the strut, the approximate position of the bolt was determined as documented in Figures 21 through 23.

The as-received left main landing gear upper and lower torque arm pieces along with a cotter pin and a bolt are shown in Figure 24. The submitted bolt was the pivot between the upper and lower torque arms. It was found at the accident site with the nut and cotter pin missing. The pivot bolt is documented further in Figure 25, with six positions shown associated with the hexagonal flats of the head. The views are numbered 1 through 6 for identification purposes. Close views of the threads are shown in Figure 26, with the same clock positions as indicated in Figure 25. Thread deformation between the cotter pin hole and the tip of the bolt is documented in Figure 27. A remnant of a stripped nut thread was observed with the bolt thread immediately adjacent to the grip. An image of the top of the bolt head in the as-received condition is shown in Figure 29. For evidence preservation purposes, the paint coating was not removed.

Michael Budinski
Chief, Materials Laboratory Division

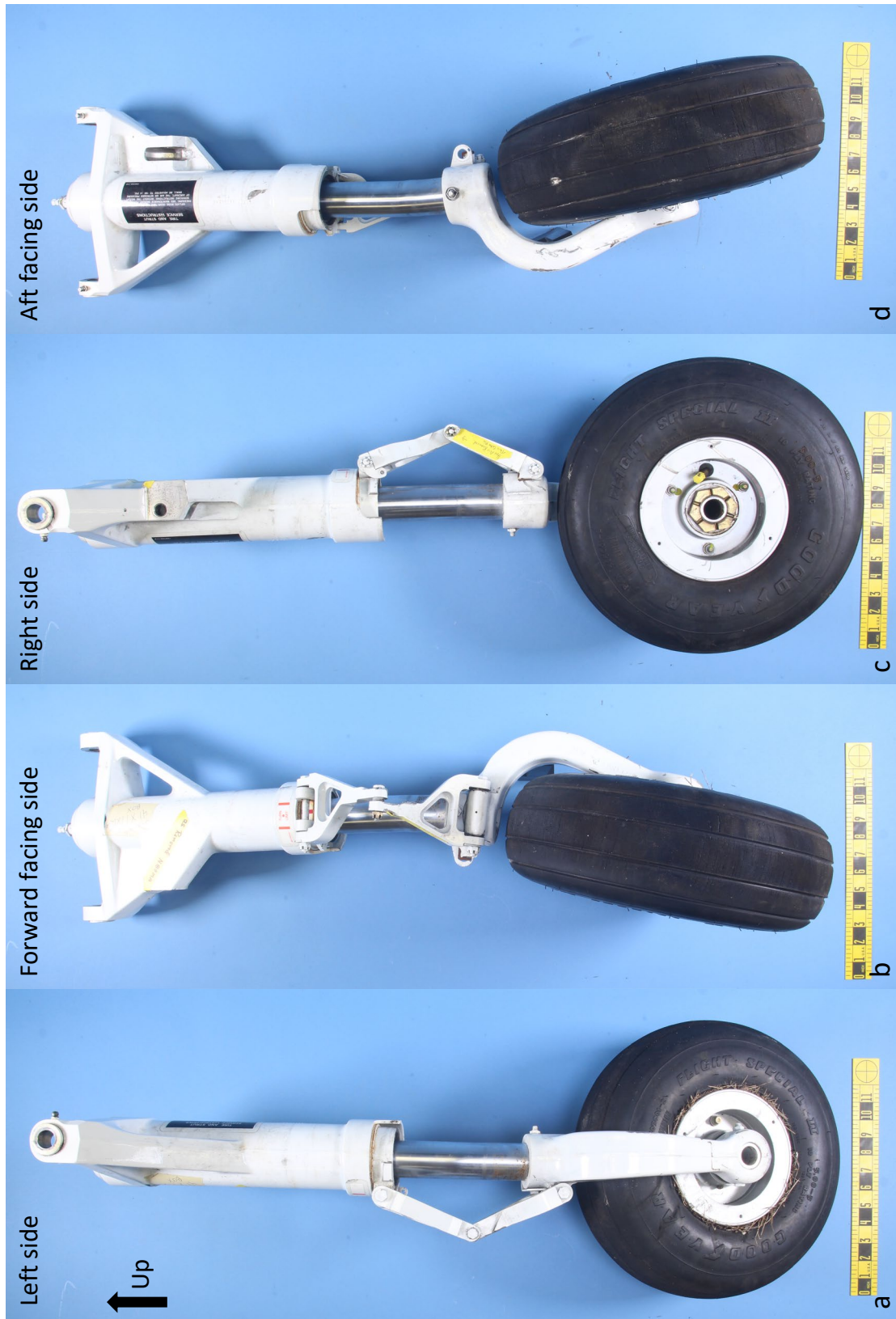


Figure 1 Forward, aft, and side views of a portion of the as-received nose gear assembly.

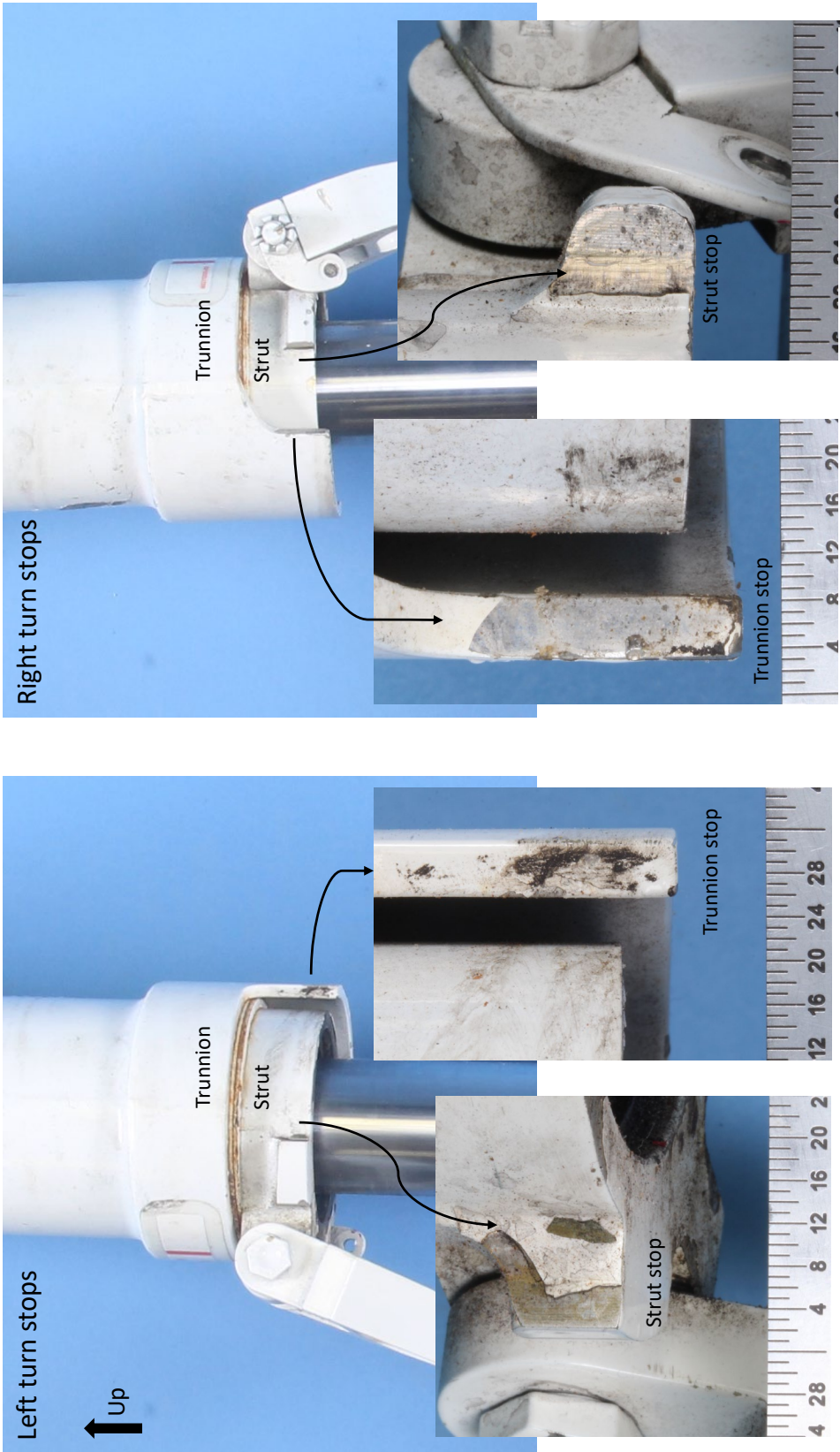


Figure 2 Views of the left and right turn stops on the trunnion and strut. As-received, before cleaning.

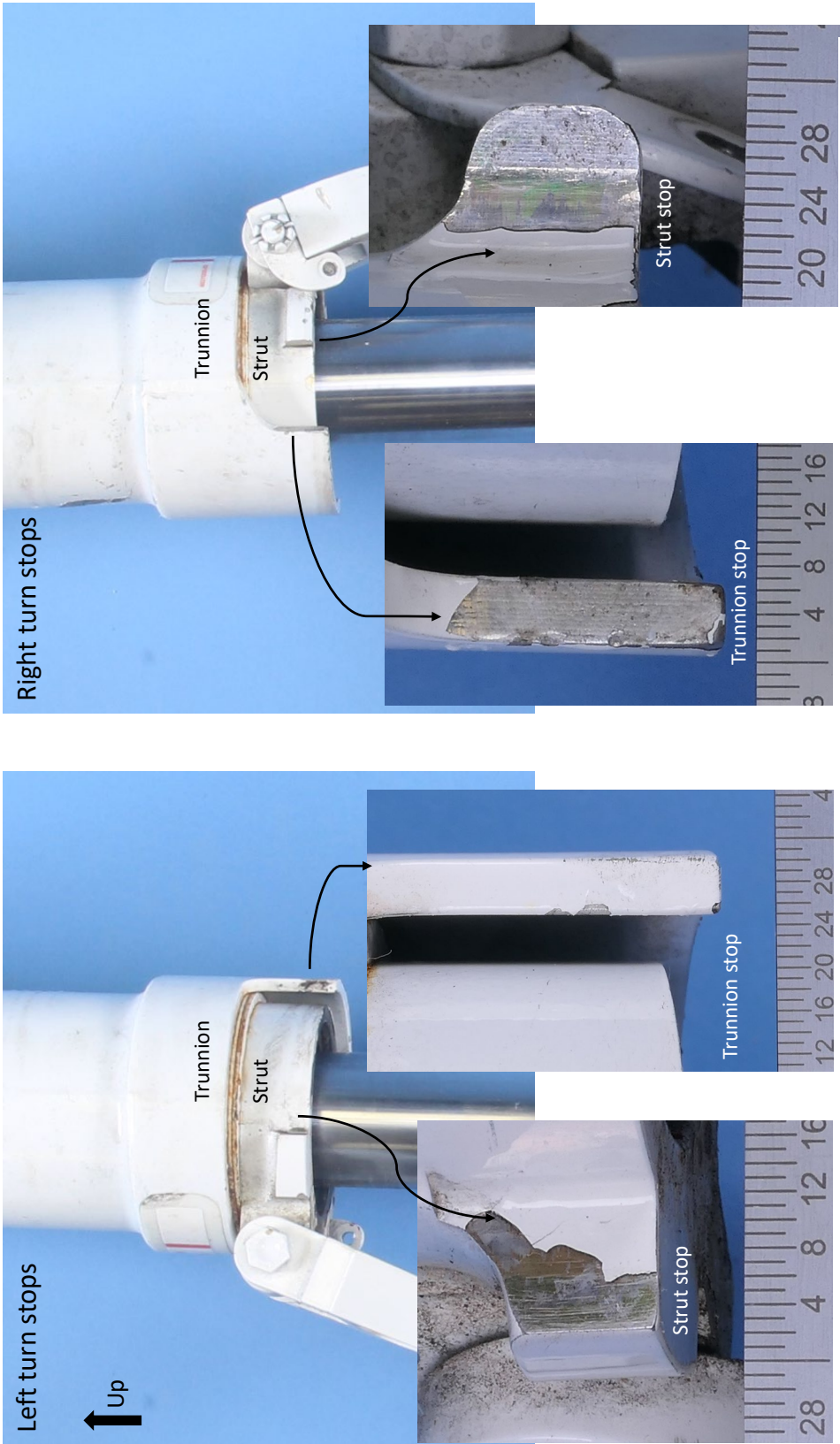


Figure 3 Views of the left and right turn stops on the trunnion and strut. The stop contact faces were cleaned with isopropyl alcohol.

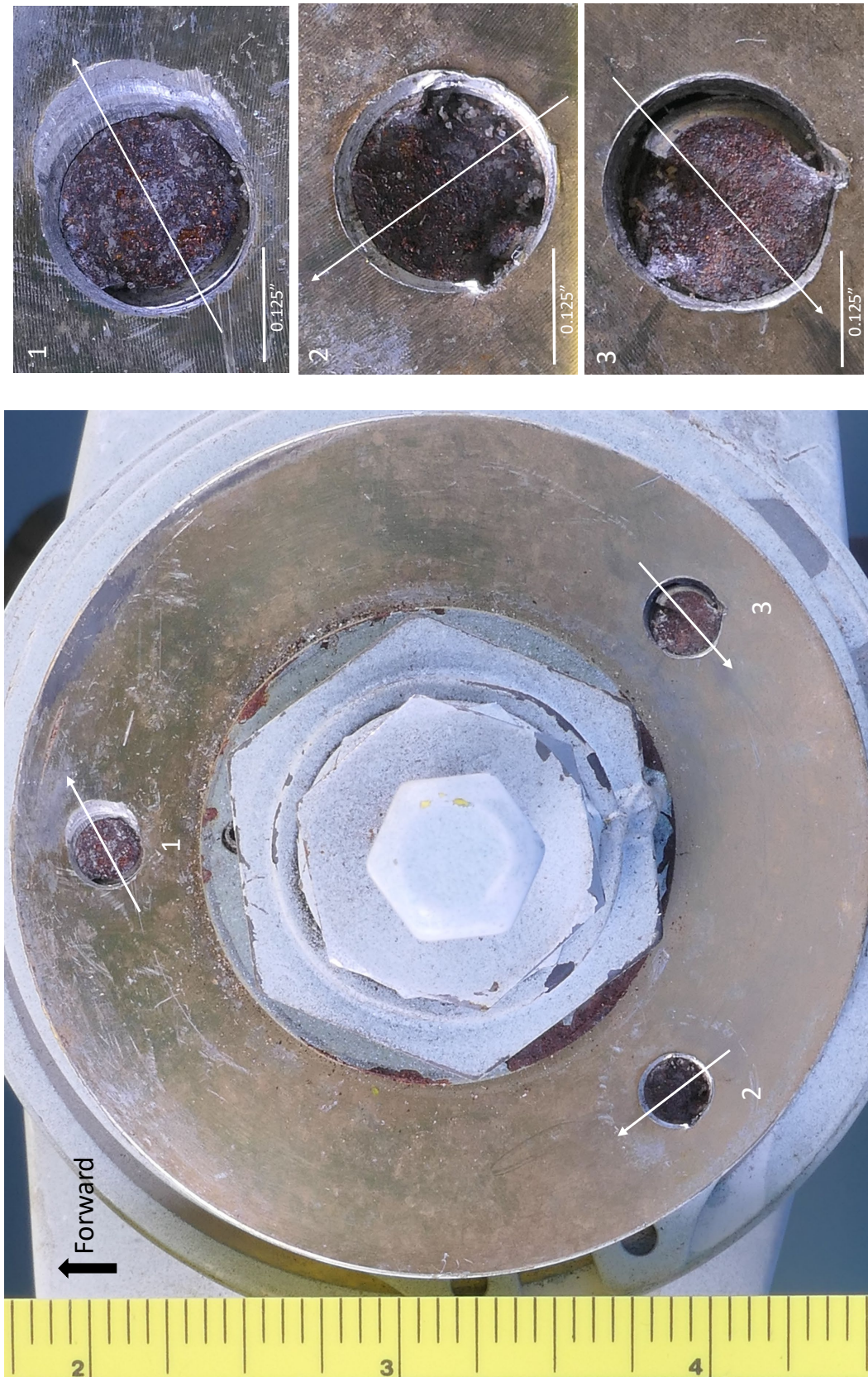


Figure 4 The top of the strut showing the remnants of three fractured steering horn mounting bolts with closer views of the fracture faces of the bolts at the right.

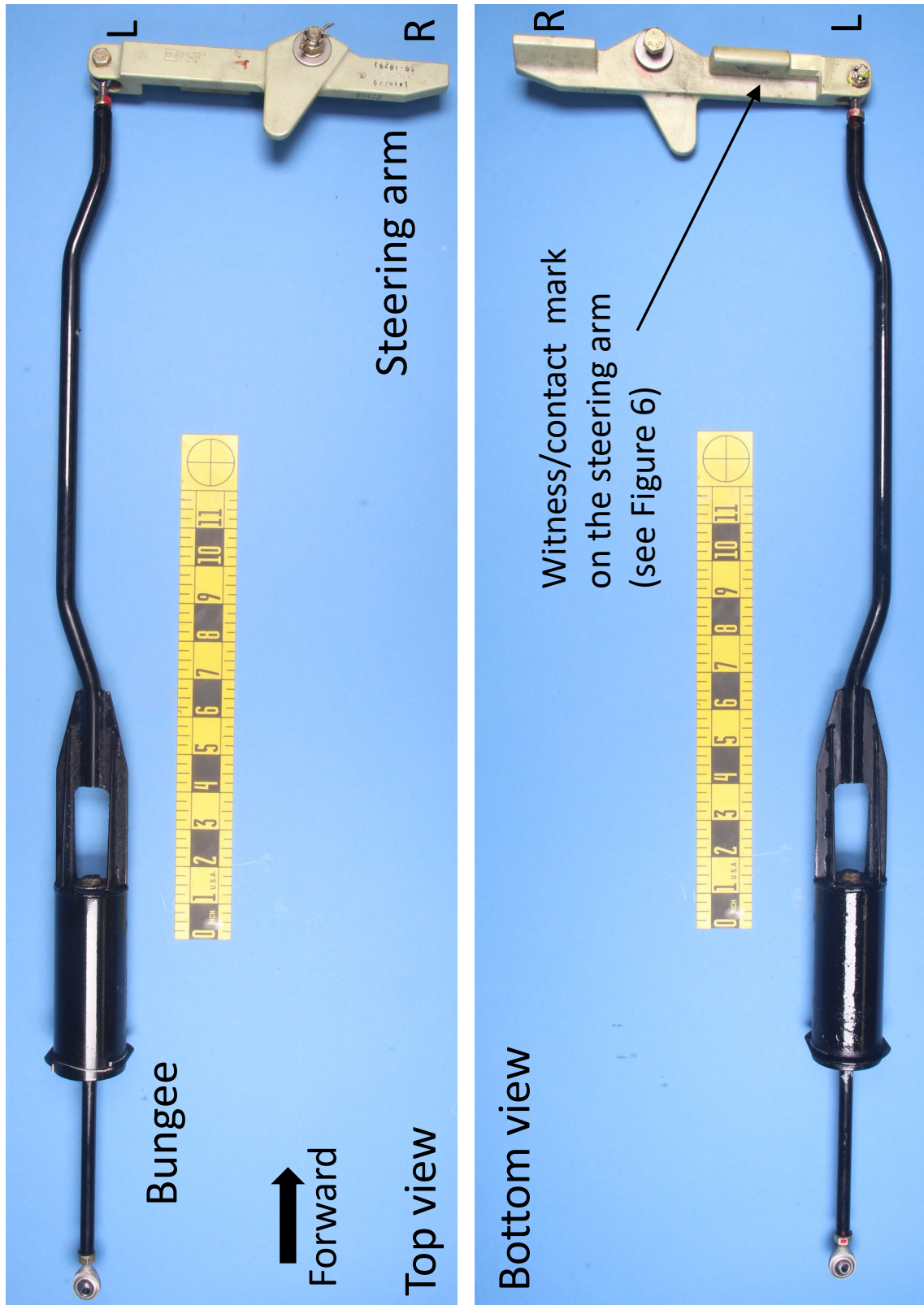


Figure 5 Views of the top and bottom of the bungee and steering arm subassembly.

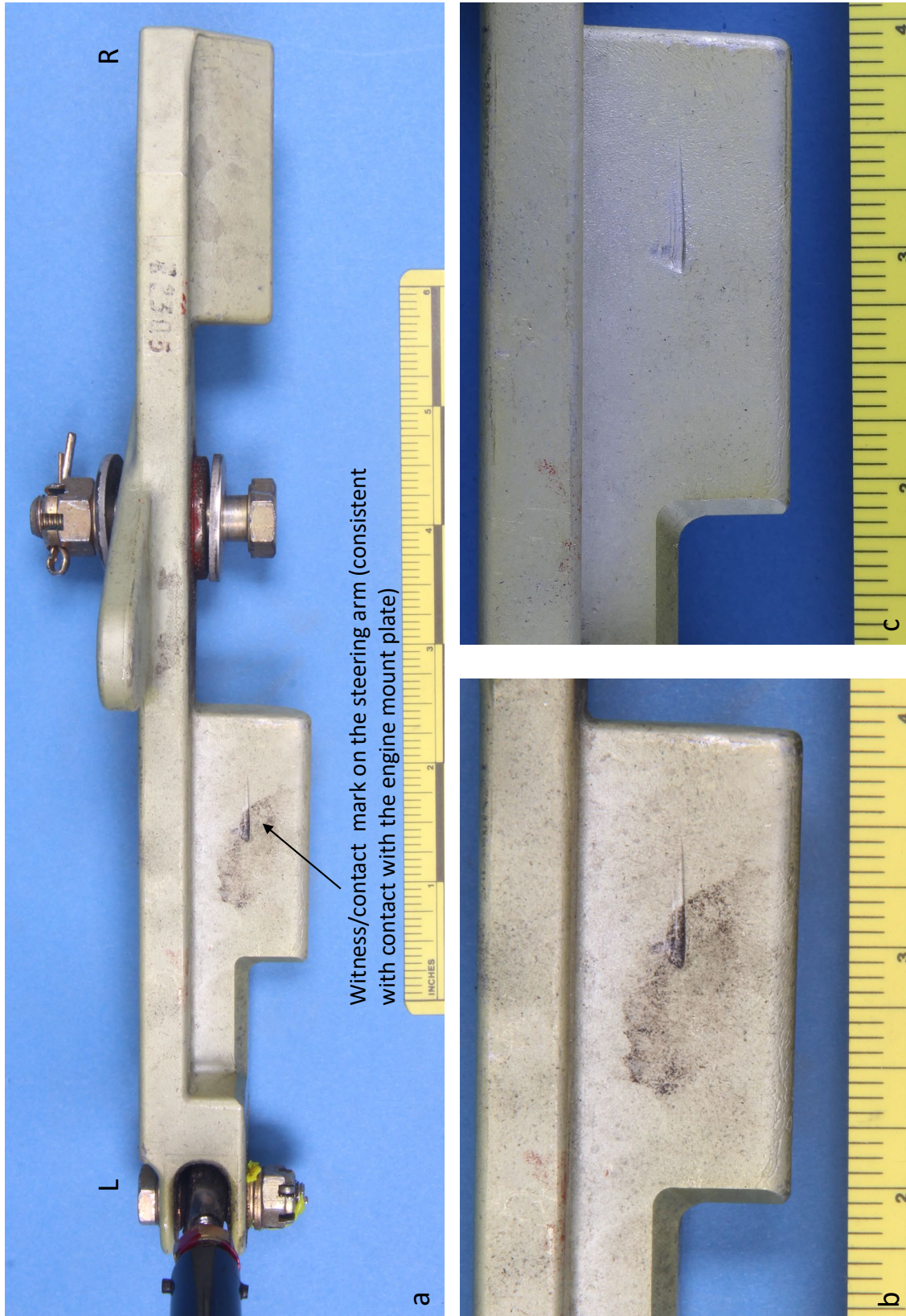


Figure 6 View of the steering arm showing a contact mark on the left side. Views b and c show closer images before and after cleaning with isopropyl alcohol.

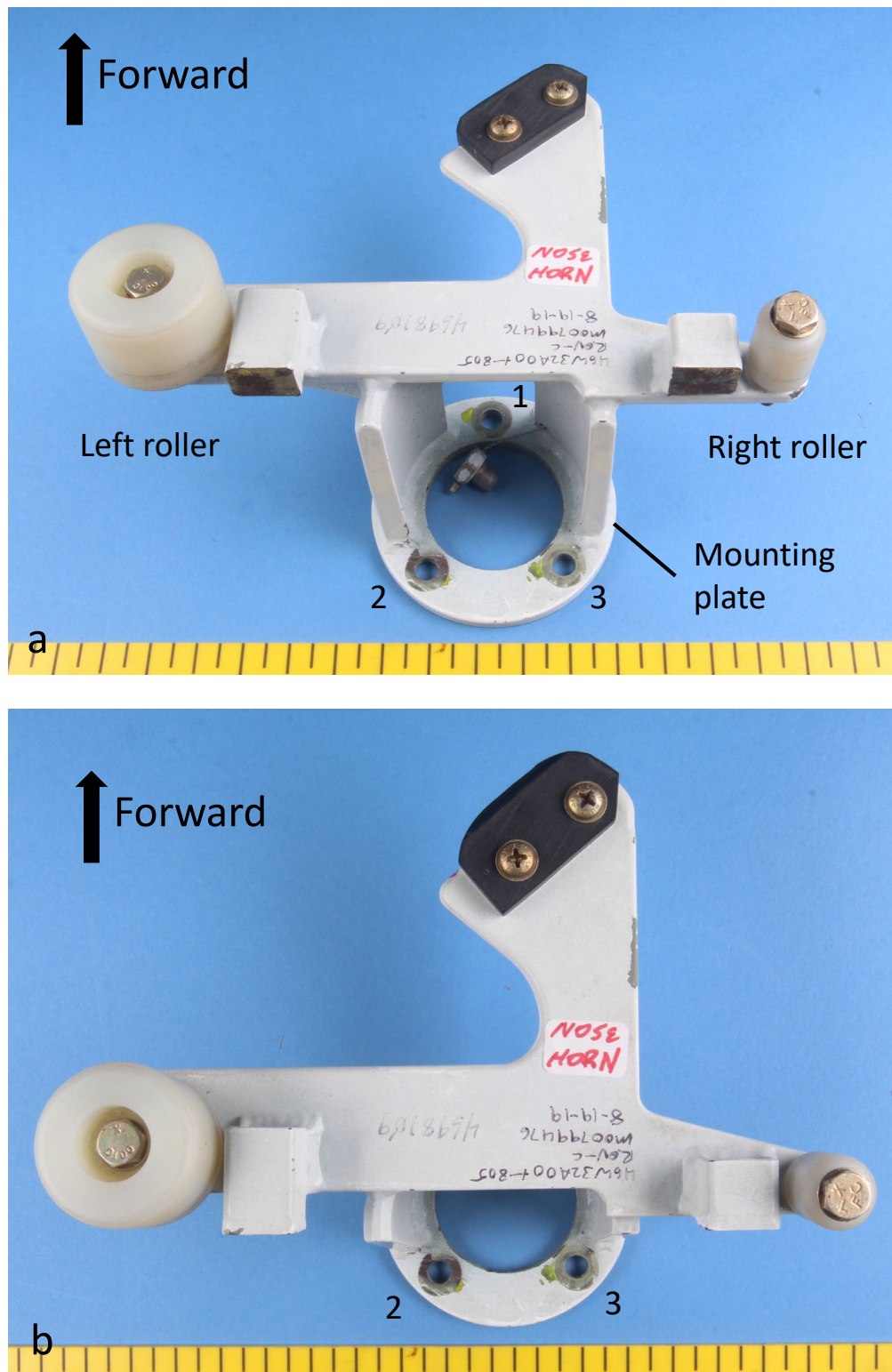


Figure 7 Images of the steering horn. View a is an oblique top view. View b is a top view.

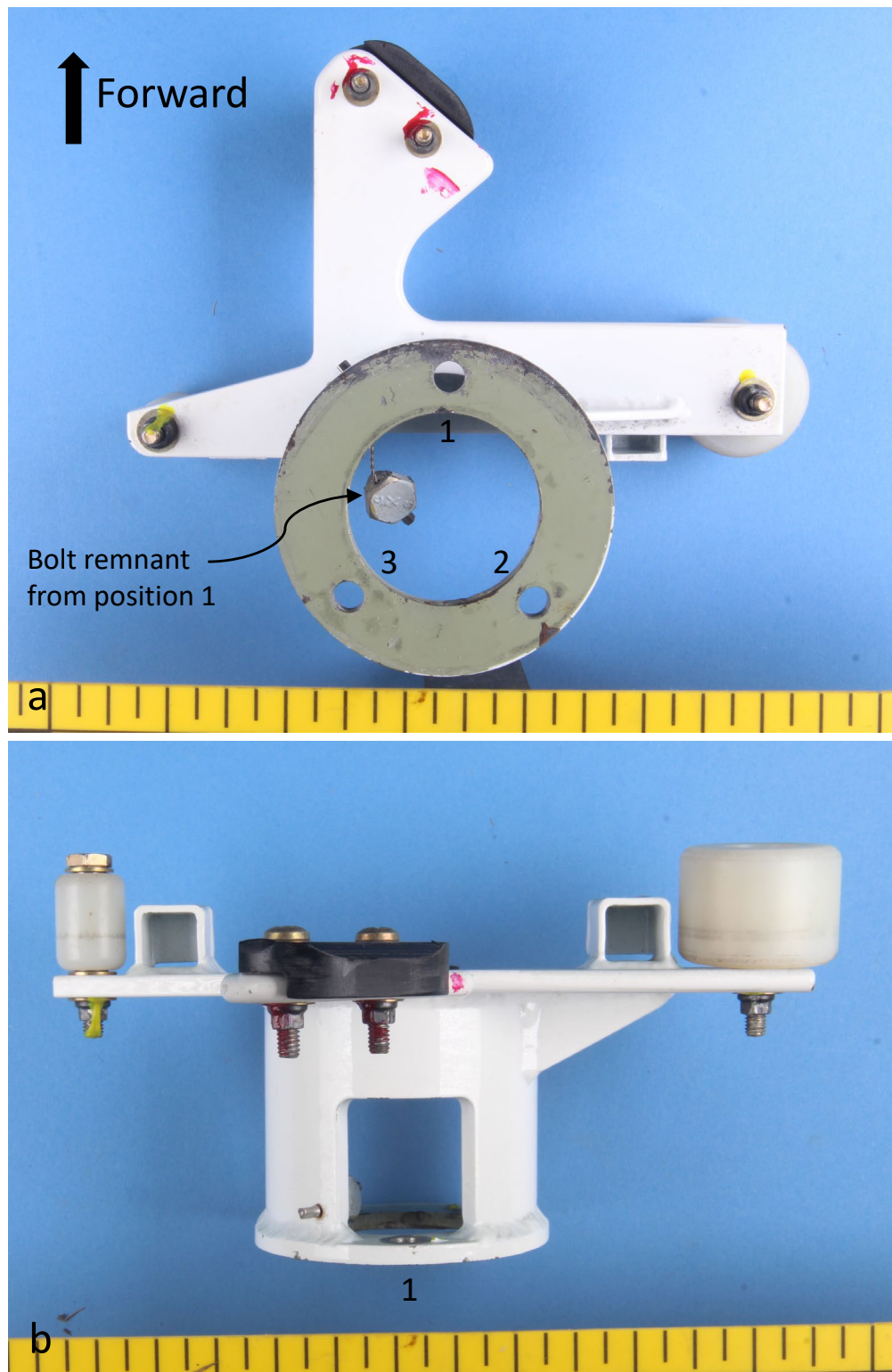


Figure 8 Images of the steering horn. View a is a bottom view. View b is looking aft.

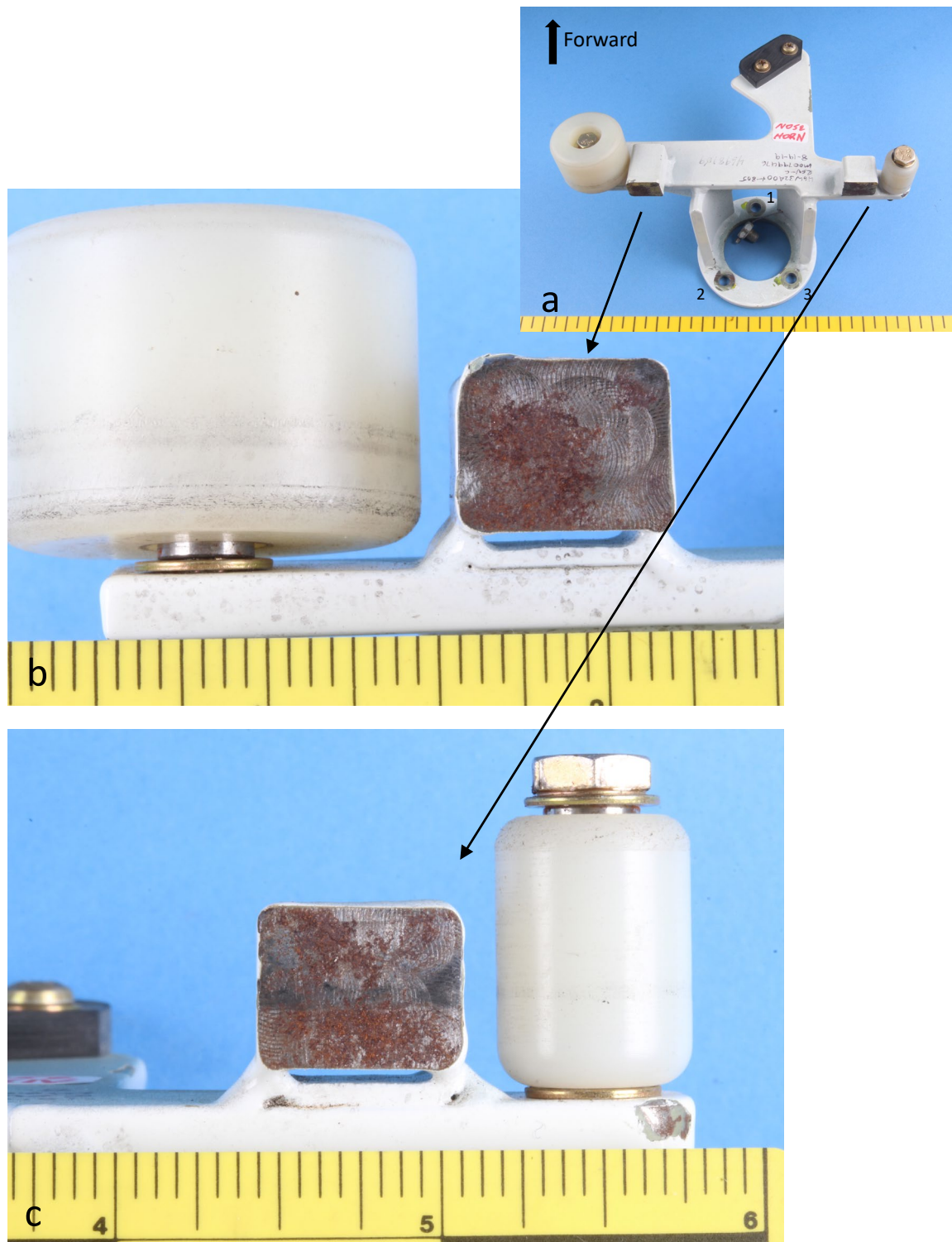


Figure 9 Images of the steering horn. Details of the rollers and pads.

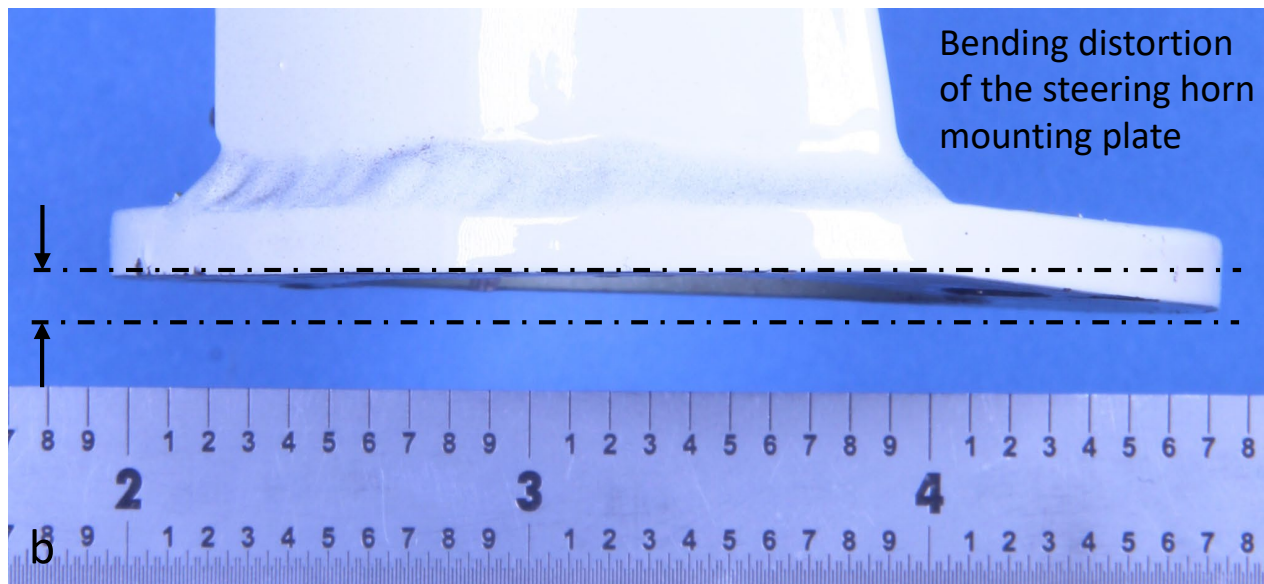
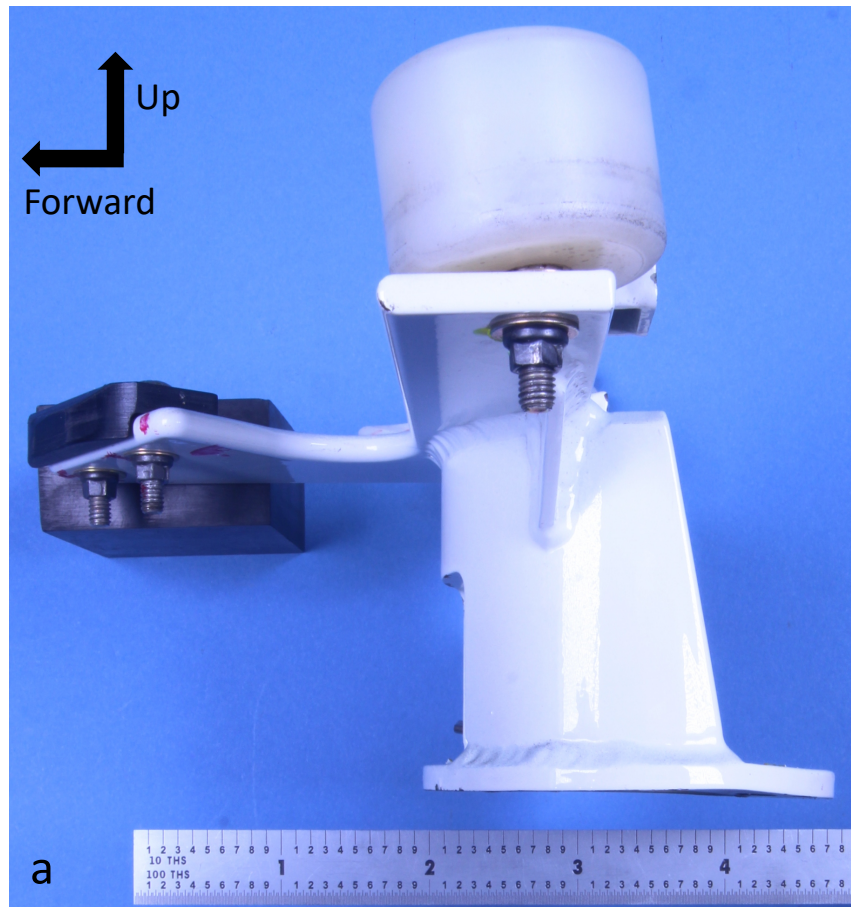


Figure 10 Profile views of the steering horn. View b shows out of plane deformation in the mounting plate.

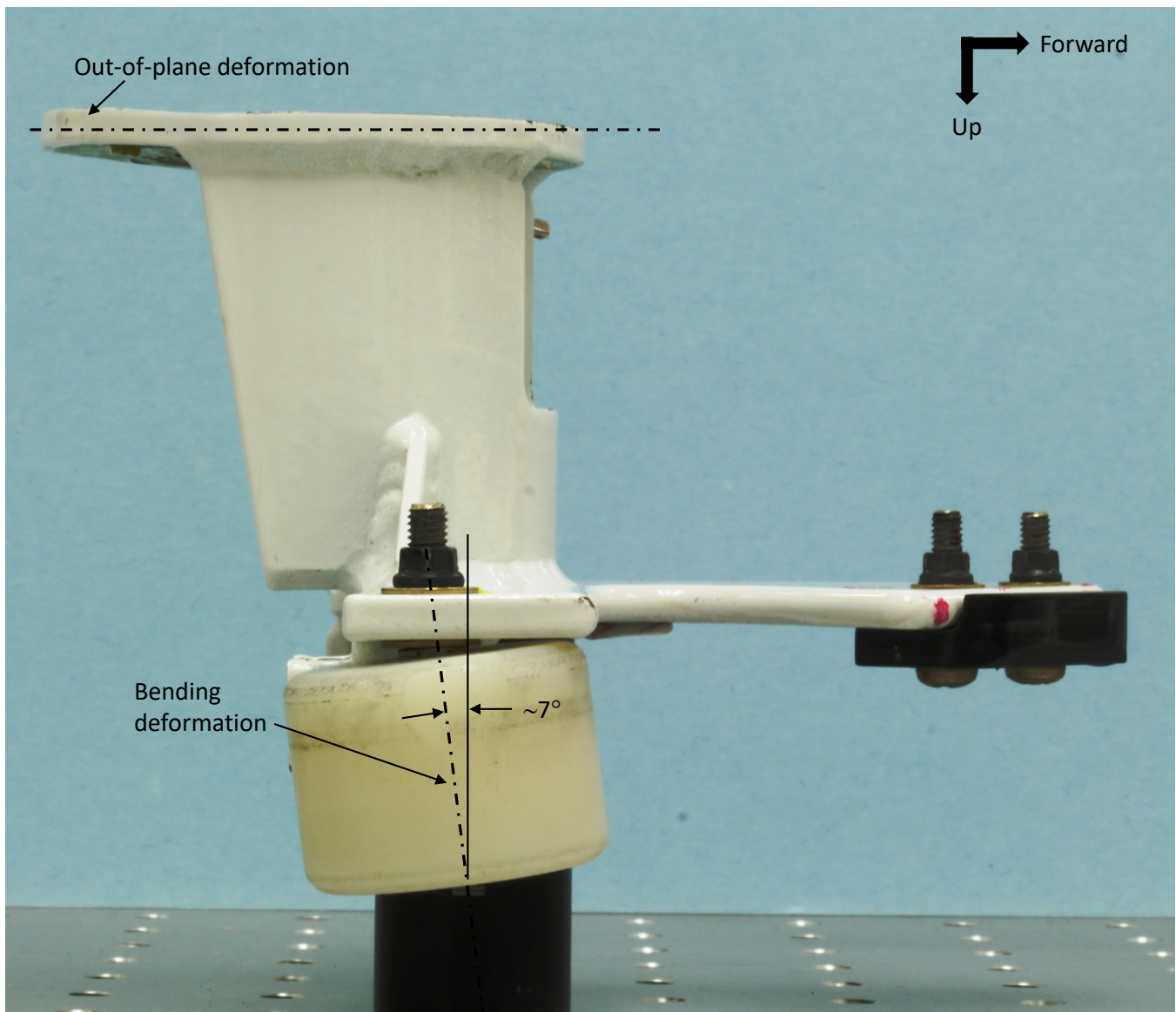


Figure 11 Profile views of the steering horn revealing out of plane deformation in the mounting plate and forward bending deformation of the left side roller axle.

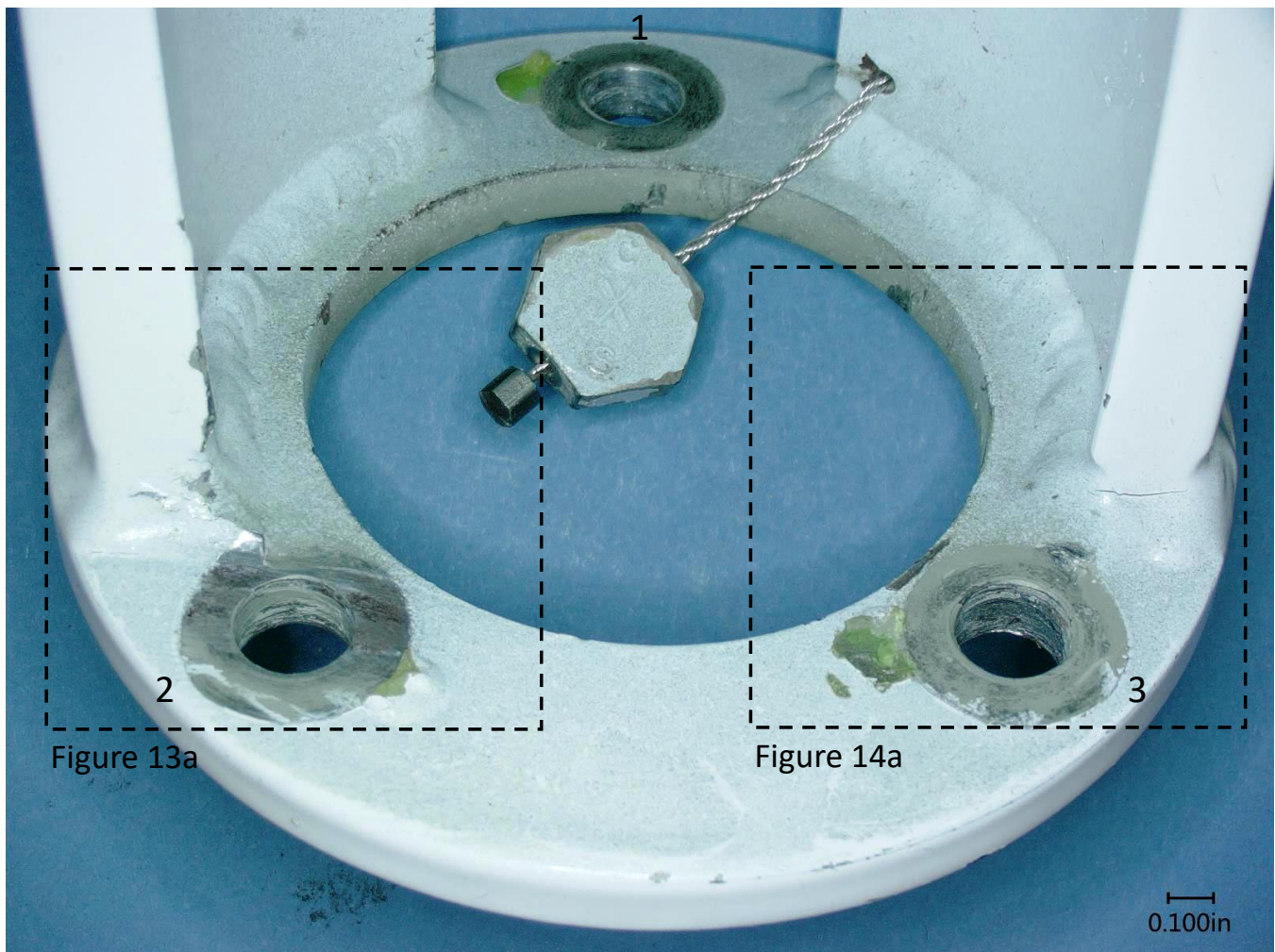


Figure 12 Views of the weld deposit between the upright and the base plate.

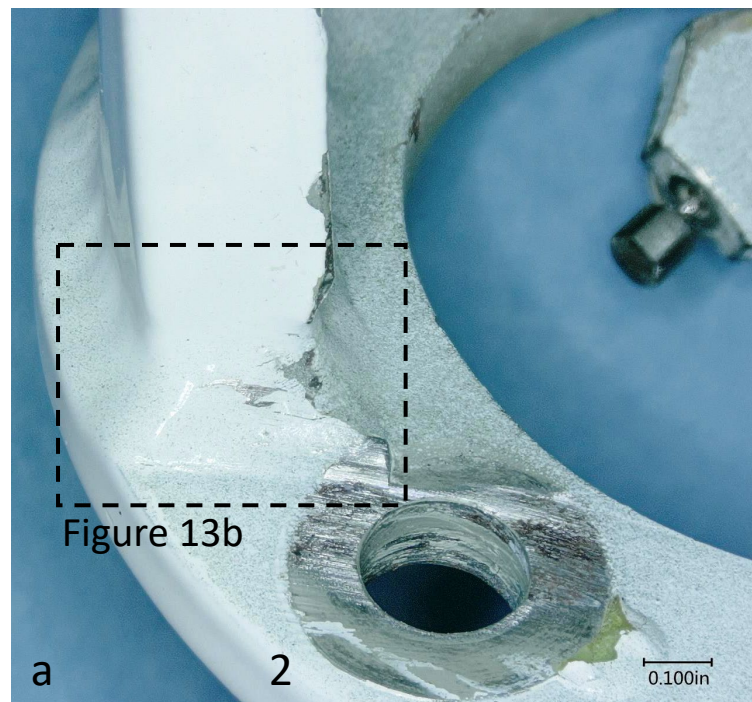


Figure 13 Views of the weld deposit between the upright and the base plate closest to bolt hole 2. Cracks in the paint film and disbonded paint are observed.

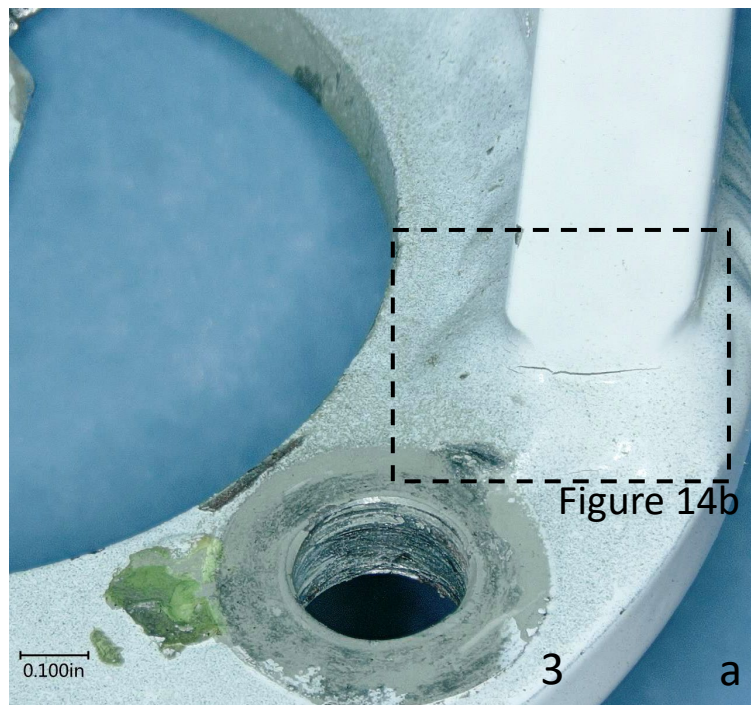


Figure 14 Views of the weld deposit between the upright and the base plate closest to bolt hole 3. Cracks in the paint film and disbonded paint are observed.

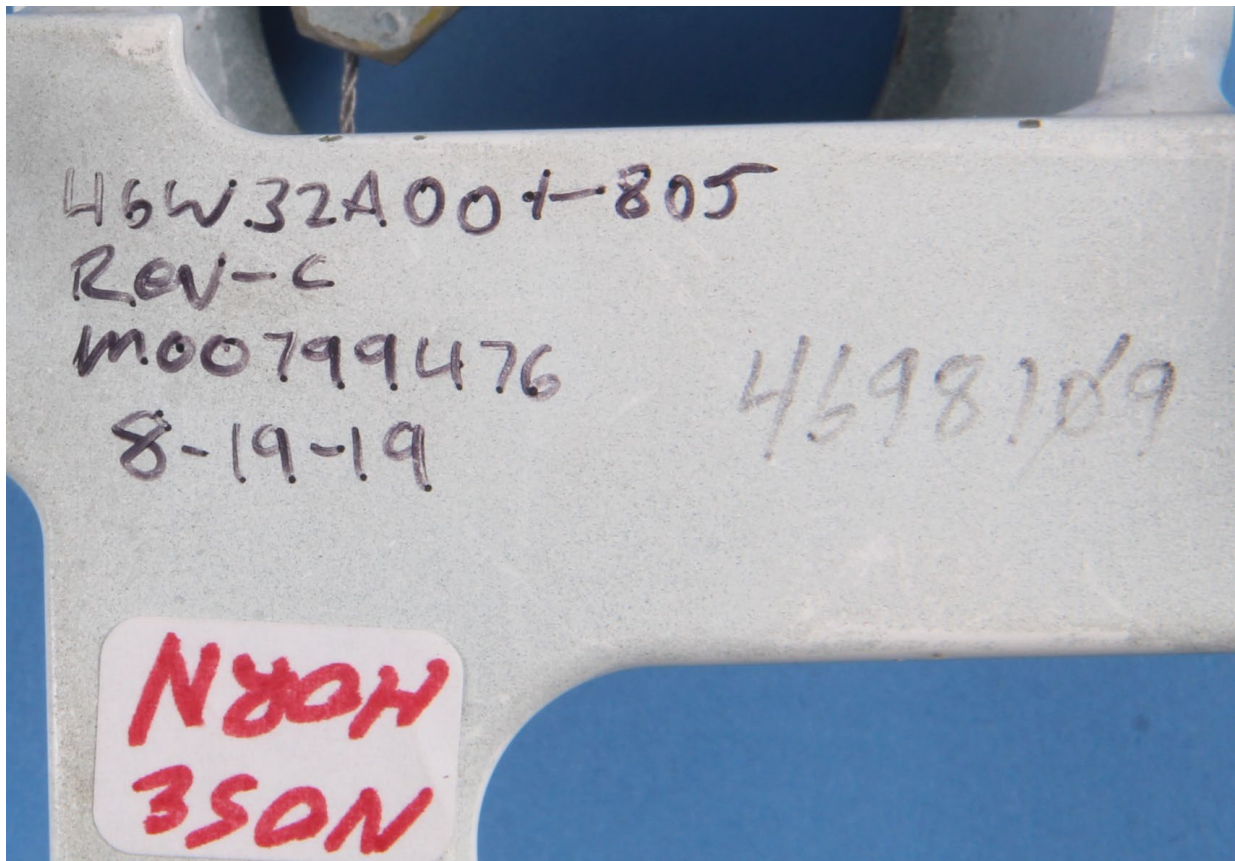


Figure 15 Image showing manufacturer identification markings.

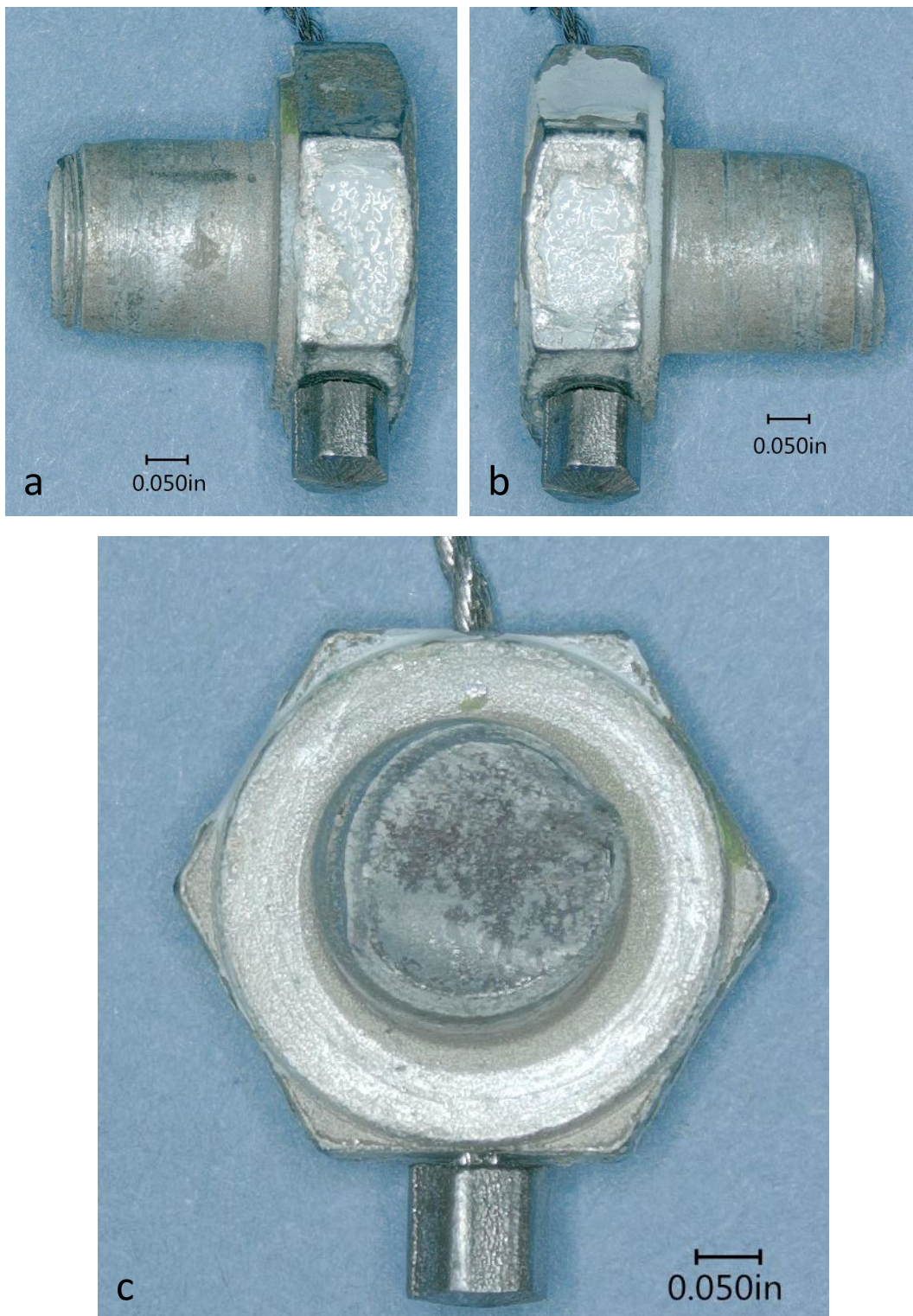


Figure 16 Digital microscope images of the Bolt 1 head and grip.



Figure 17 The top side of the Bolt 1 head revealing manufacturing markings.

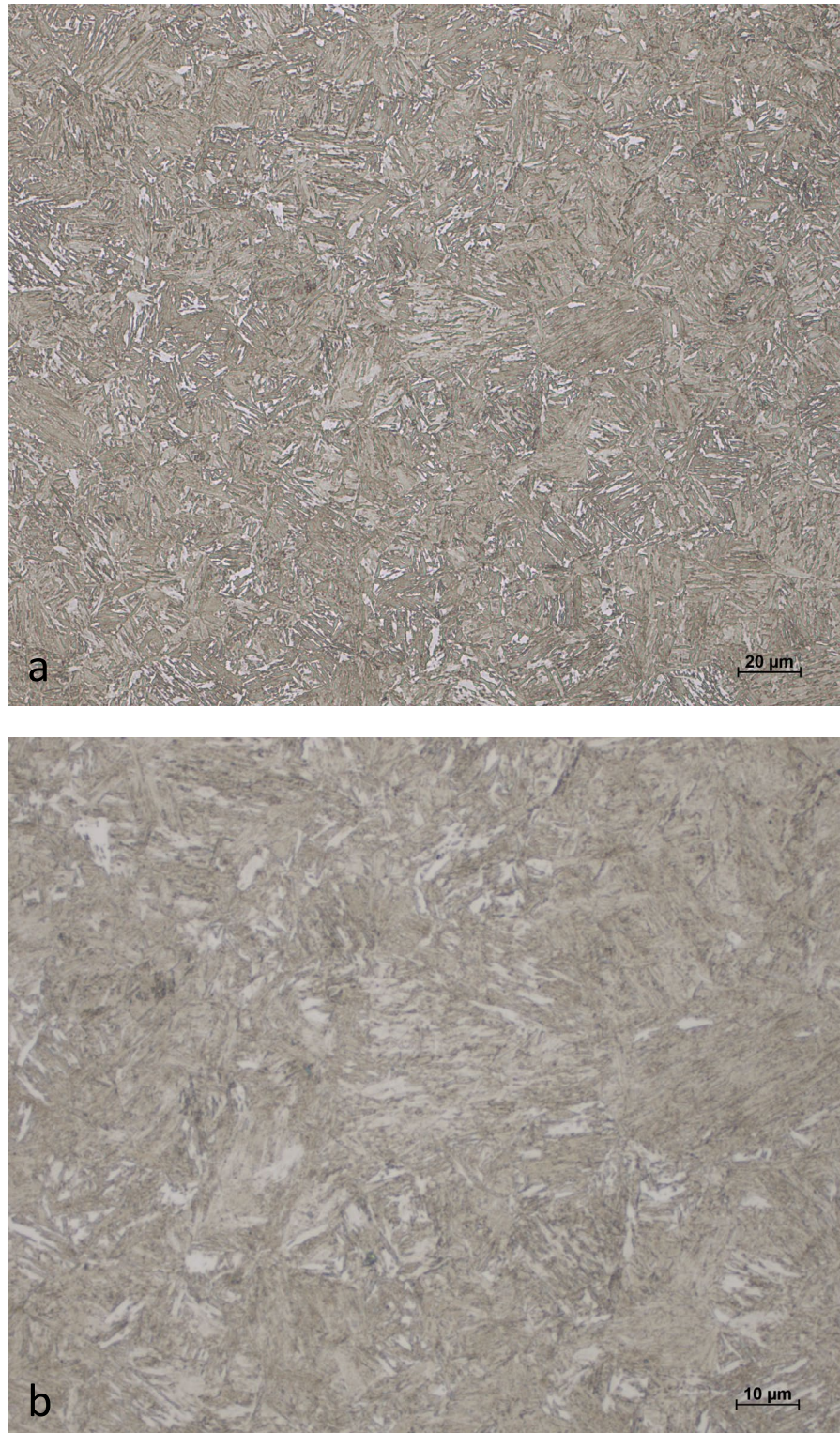


Figure 18 Brightfield optical photomicrographs of the microstructure from a cross section of the Bolt 1 head revealing tempered martensite. View a is at 500X and view b is at 1000X (original magnification). (2% nital etch)

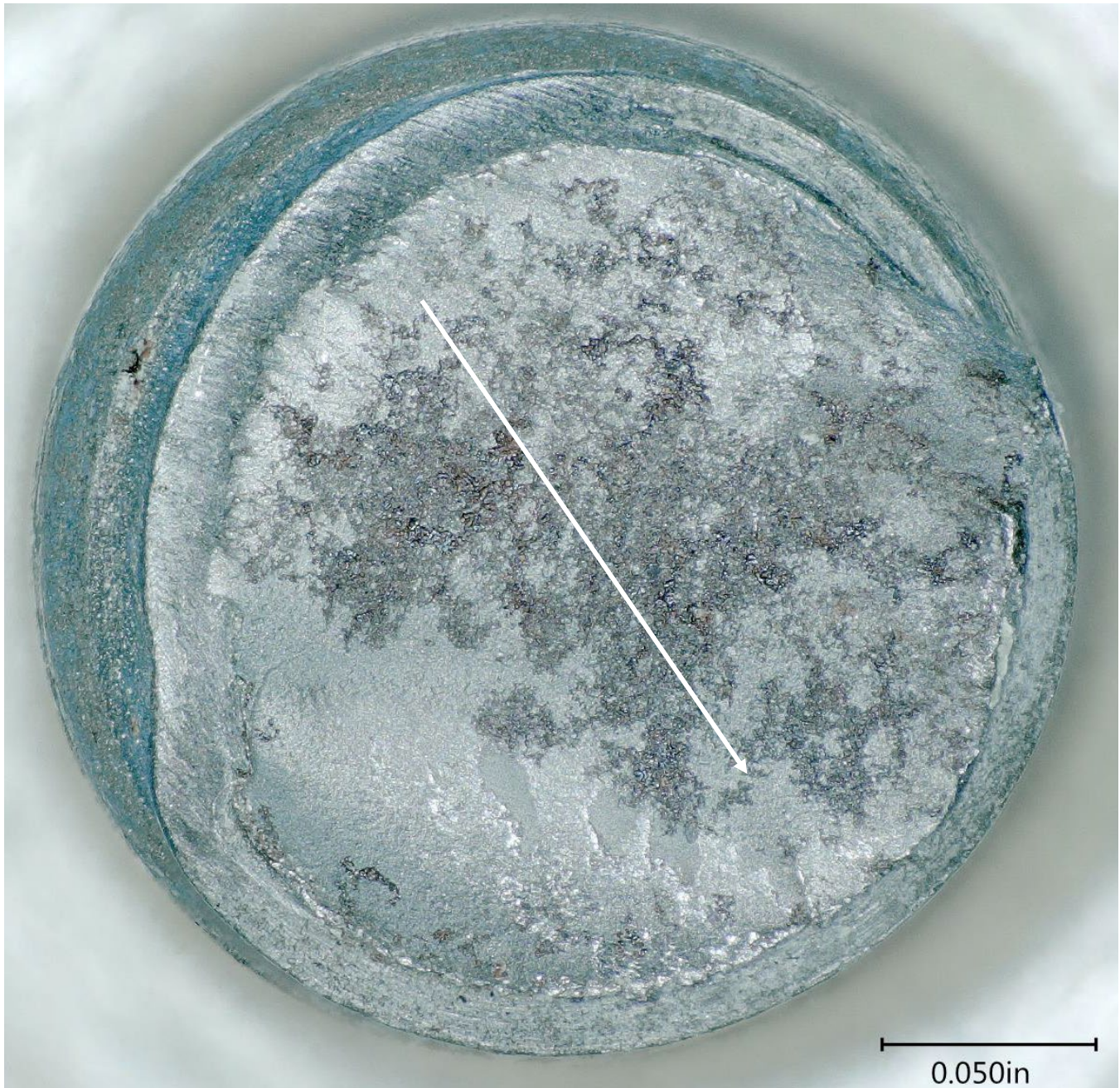


Figure 19 Digital microscope images of the Bolt 1 fracture surface. A white arrow depicts the approximate direction of fracture.

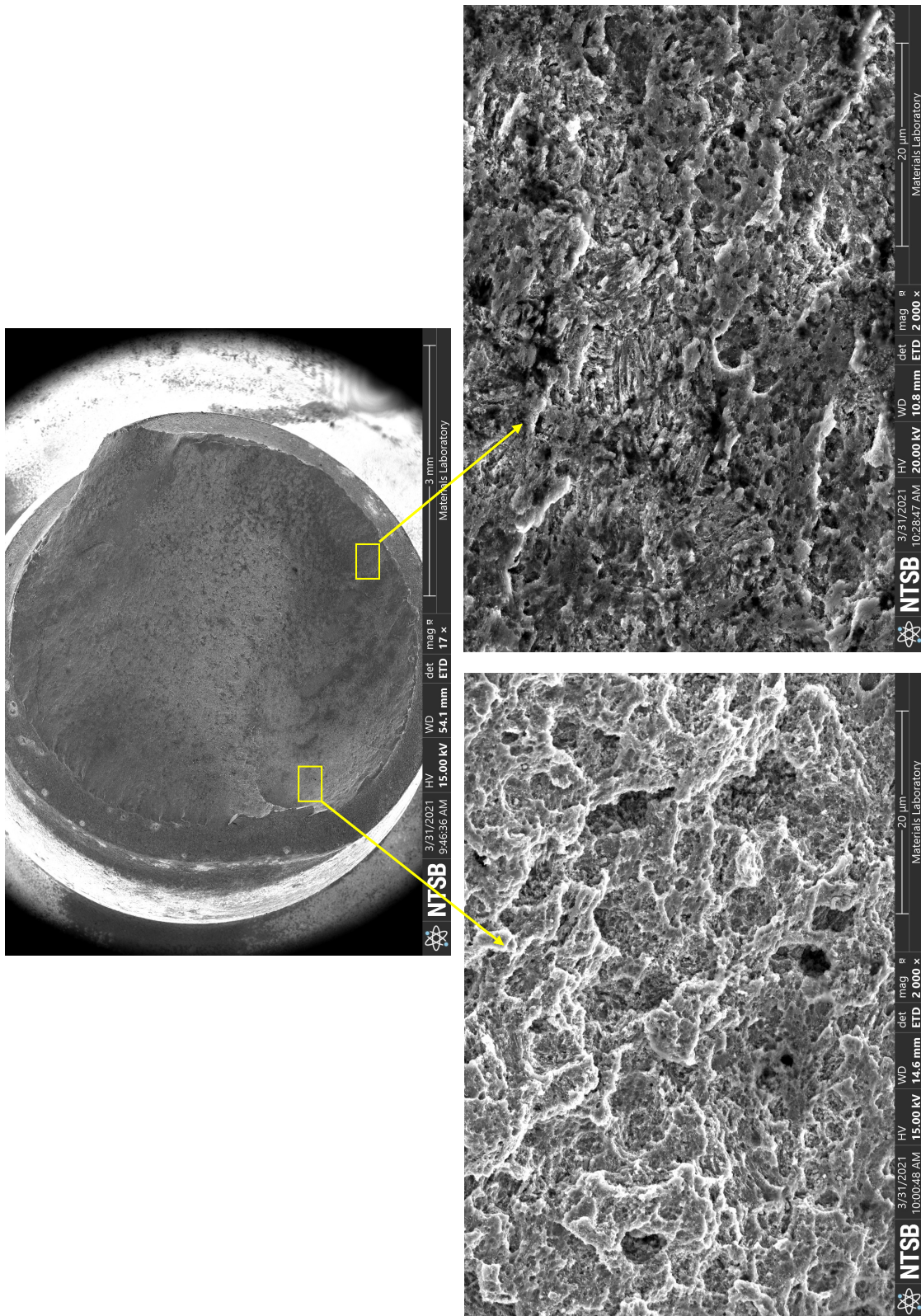


Figure 20 Secondary electron SEM images of the Bolt 1 fracture surface, showing microvoid coalescence fracture features.

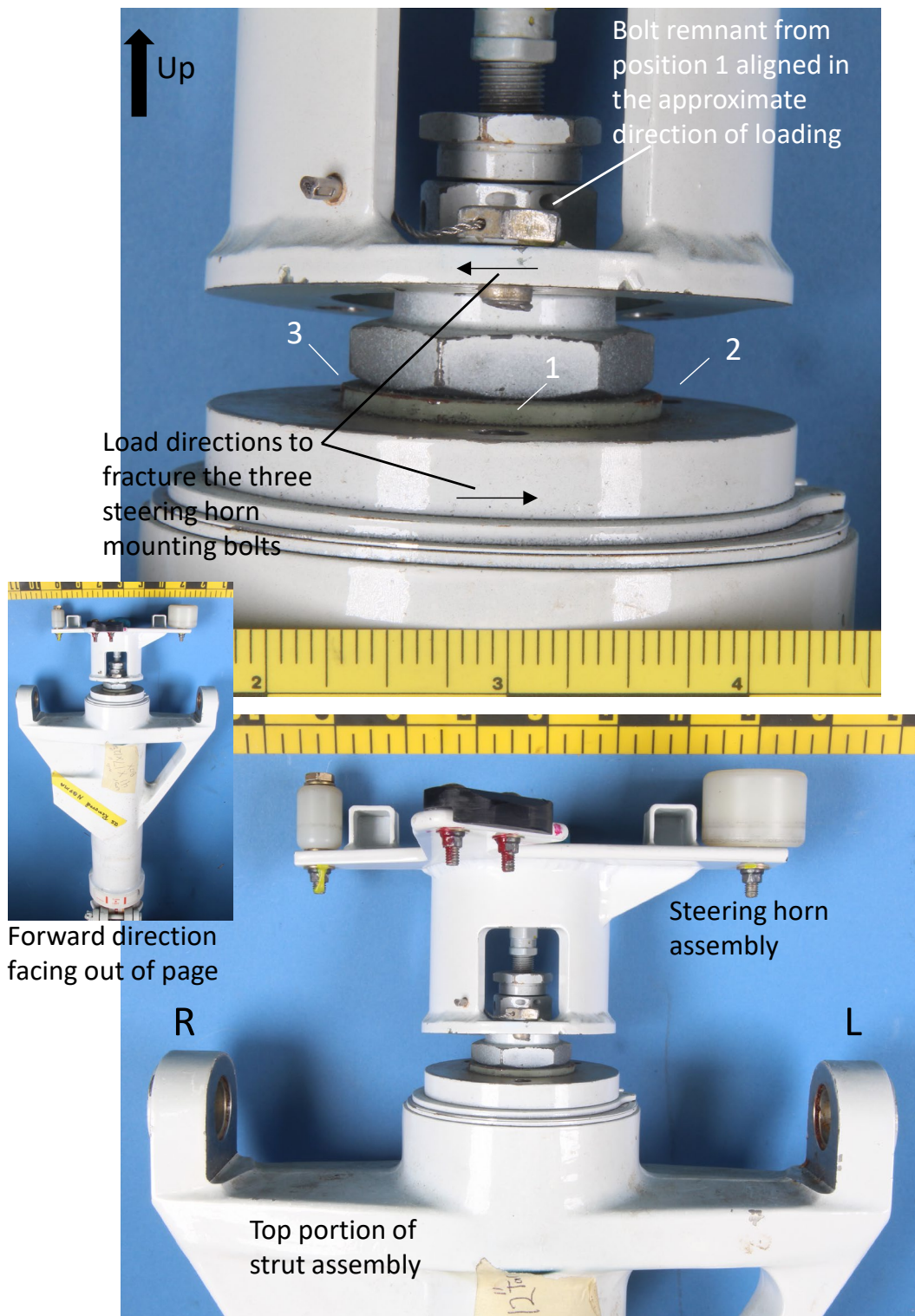


Figure 21 Views of the steering horn placed in close proximity to the top of the strut on the nose gear assembly.

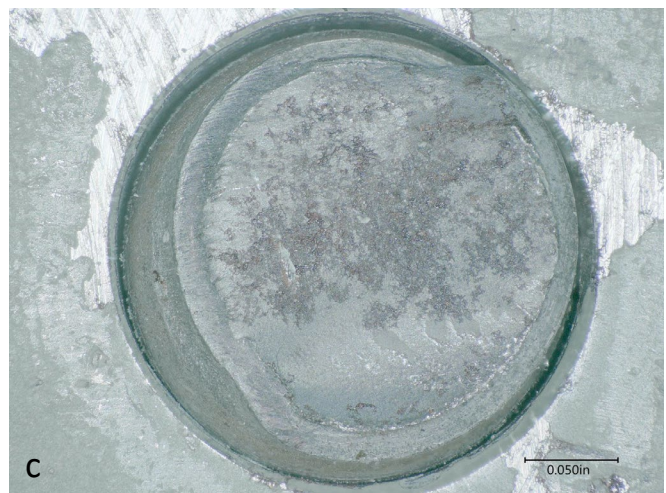
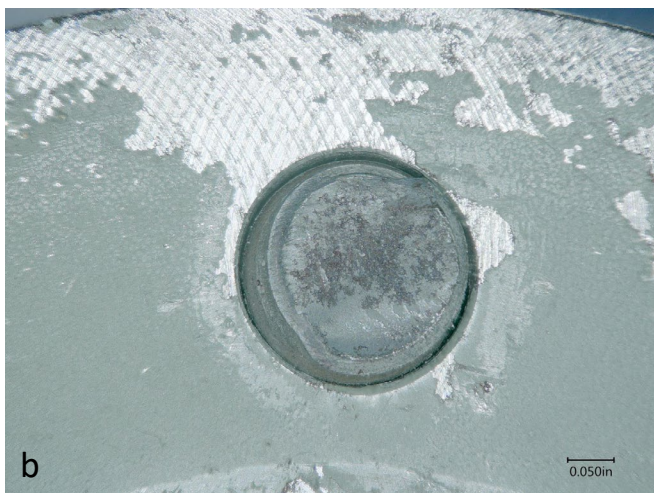
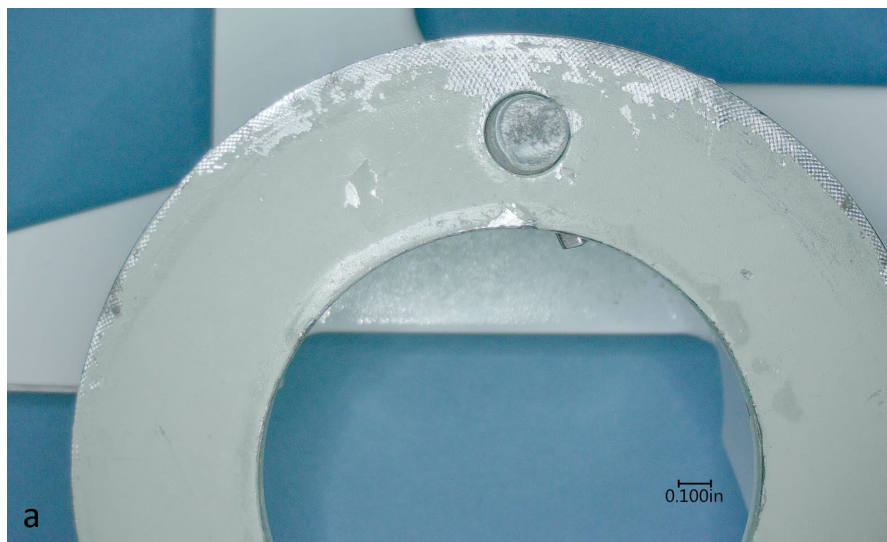


Figure 22 Bottom view of the steering horn with the Bolt 1 remnant in place, oriented in its approximate position at the time of fracture.

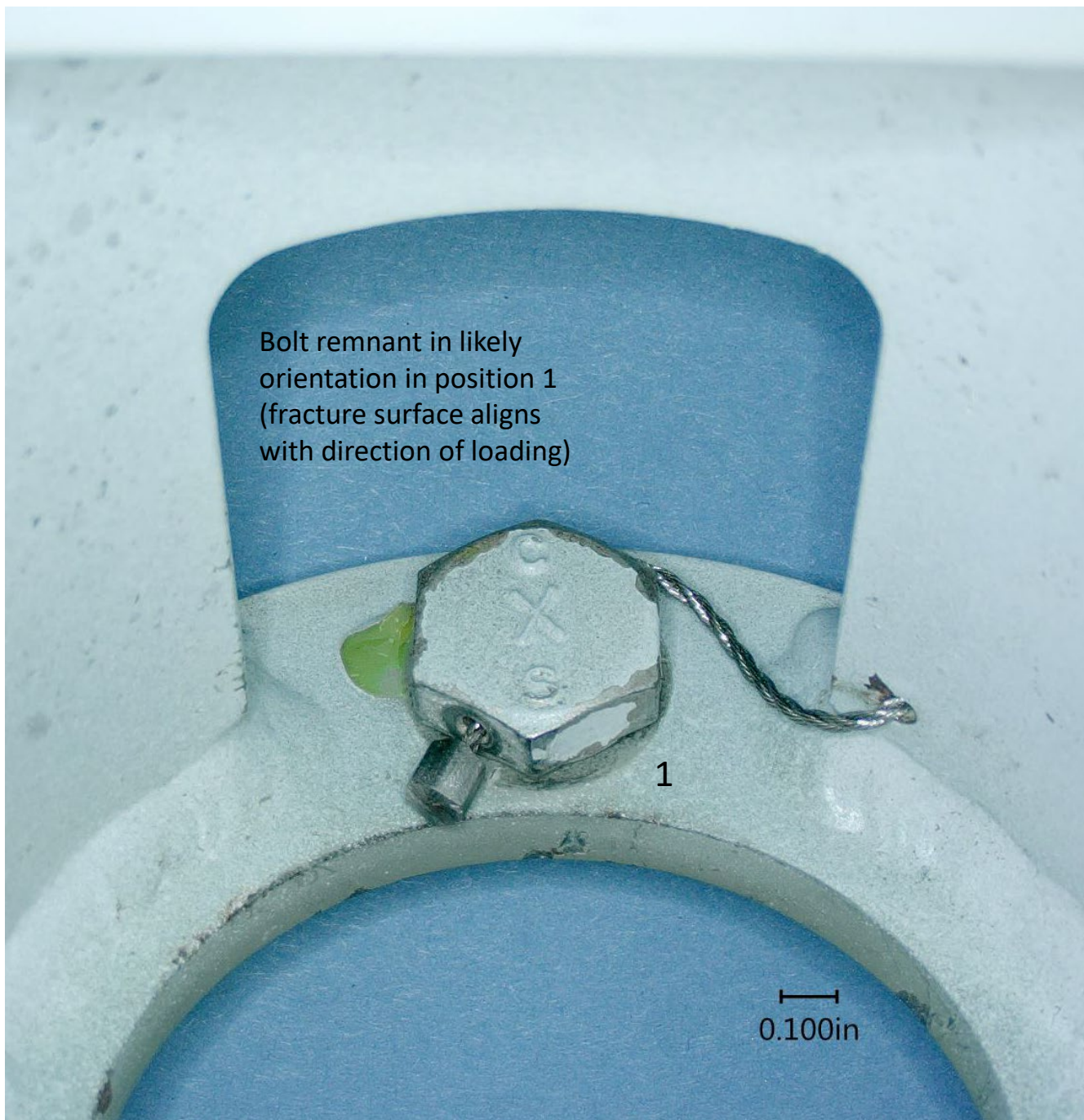


Figure 23 Oblique top view of the steering horn with the Bolt 1 remnant in place, oriented in its approximate position at the time of fracture.

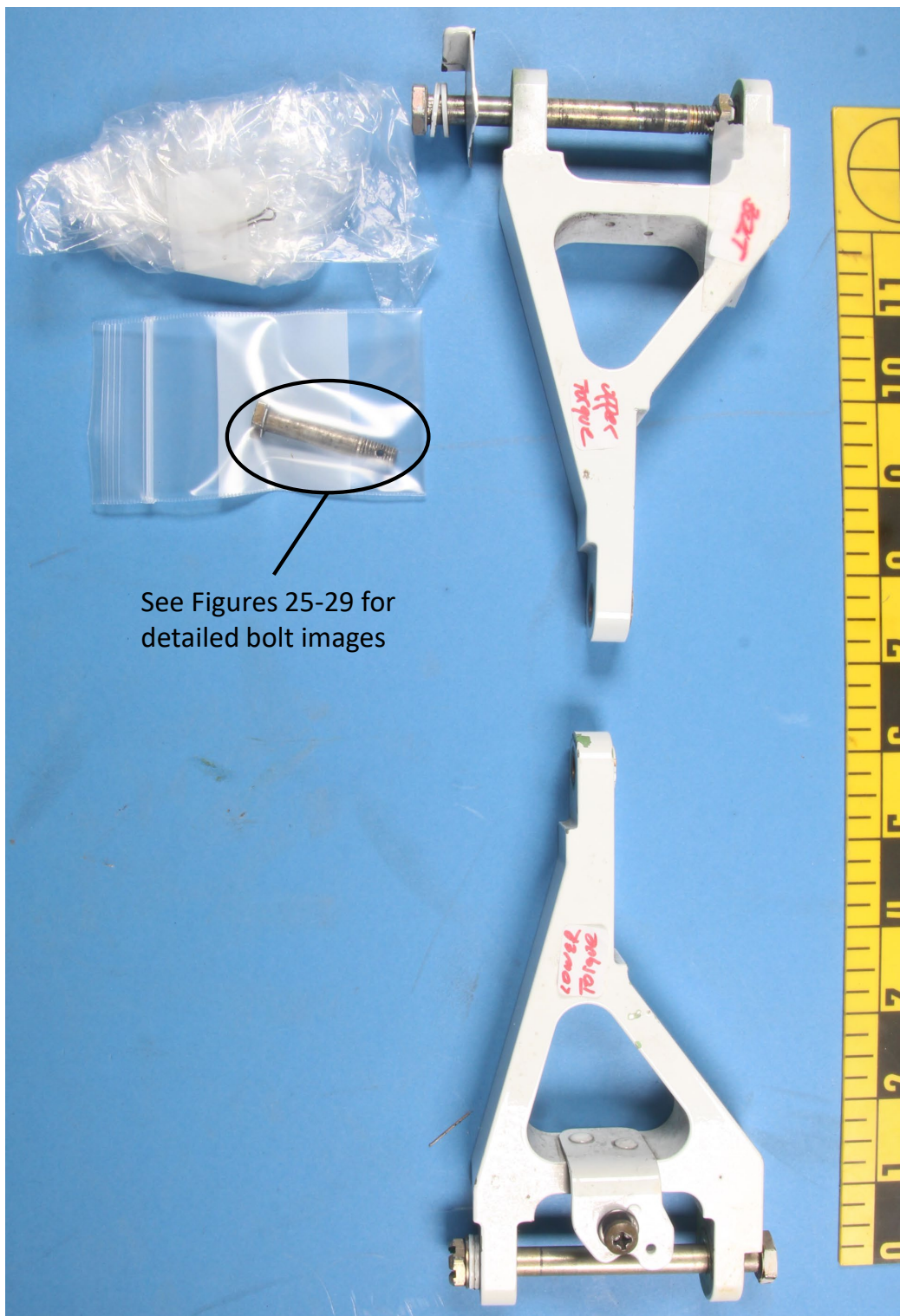


Figure 24 The as-received left main landing gear upper and lower torque arm pieces along with a cotter pin and a bolt.



Figure 25 Digital microscope images of the pivot bolt between the left main landing gear upper and lower torque arm pieces.

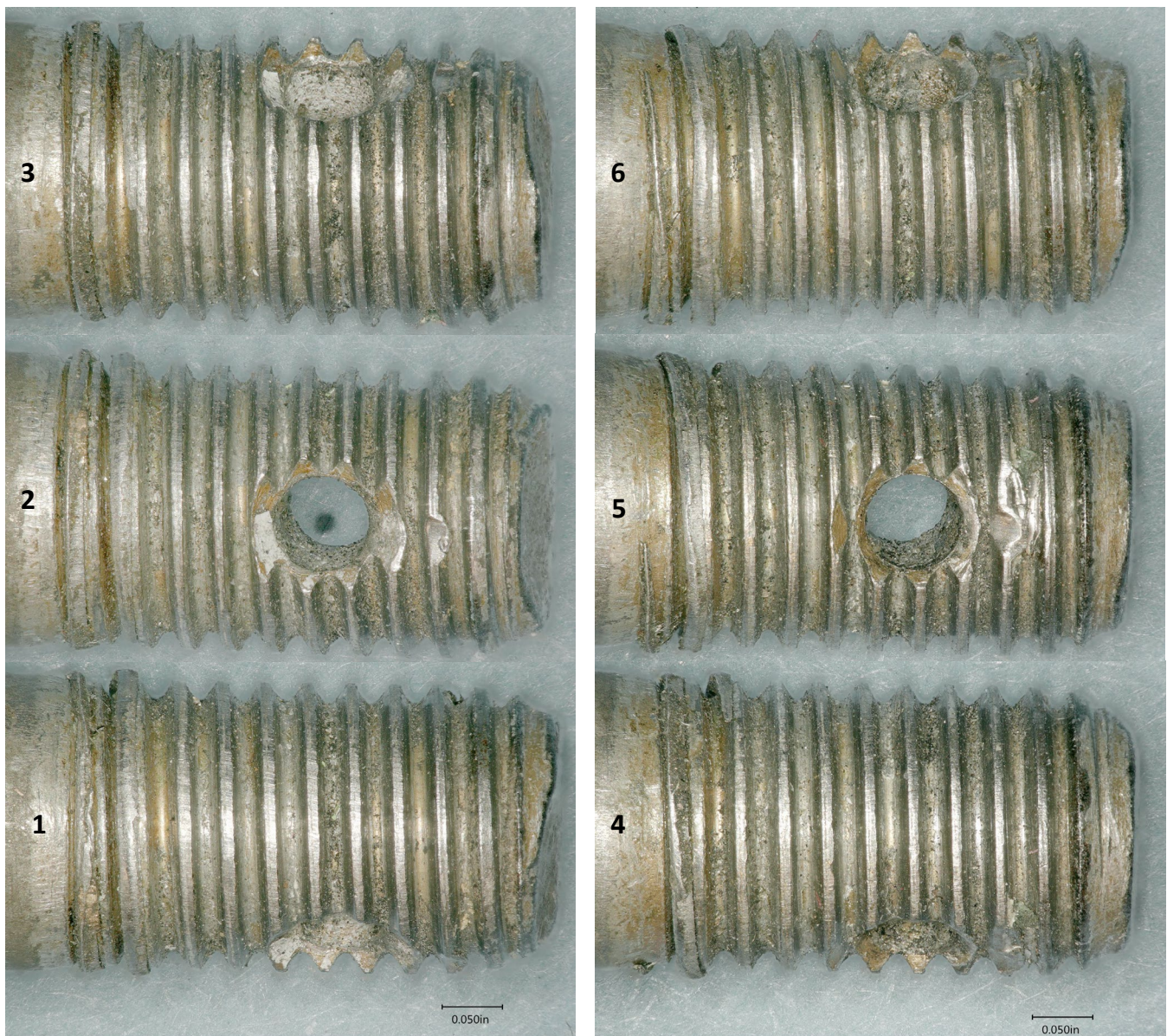


Figure 26 Digital microscope images of the threads in Figure 24.

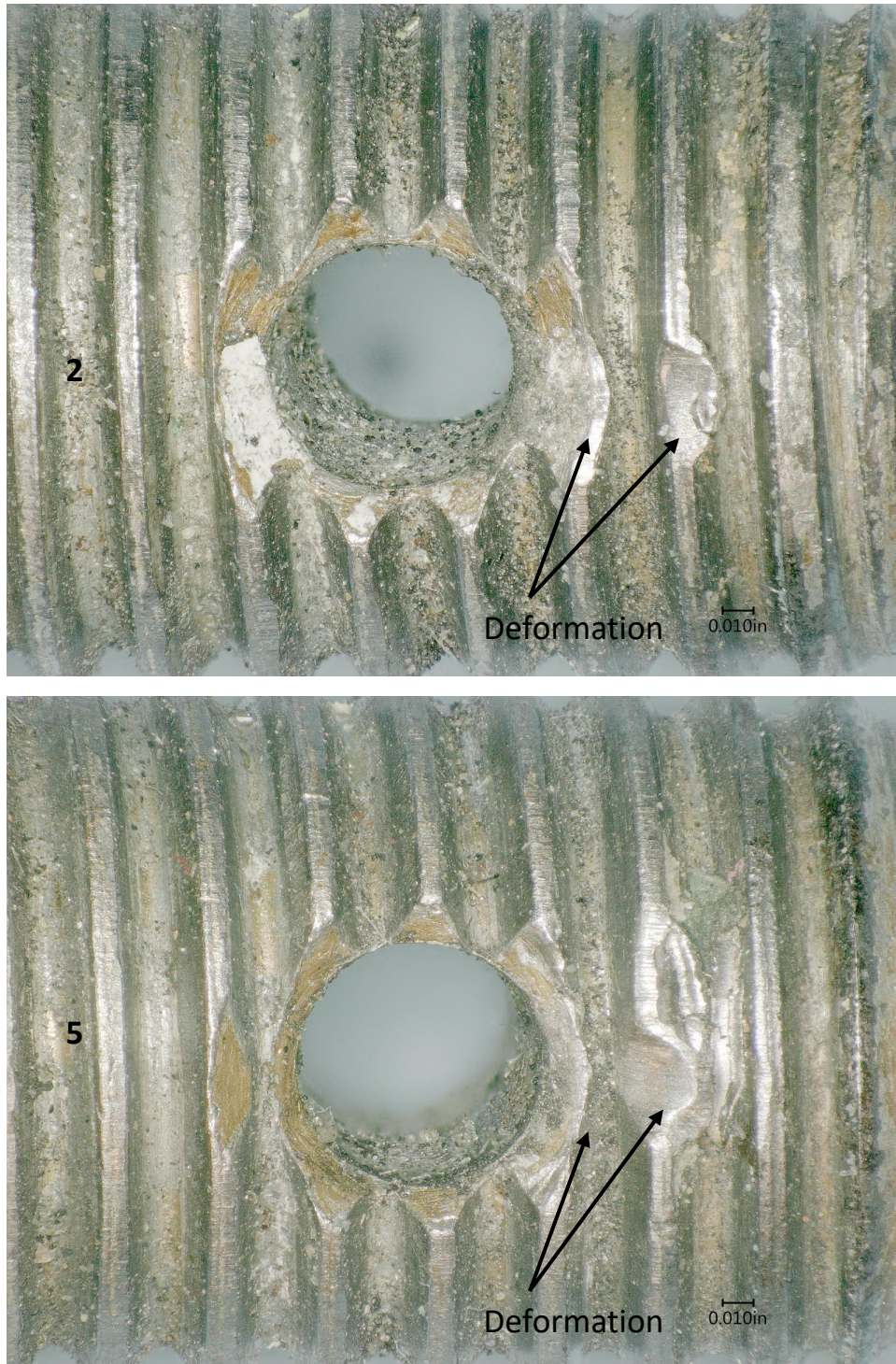


Figure 27 Digital microscope images showing close views of deformation to the threads (see Figures 25 and 26 for orientation).

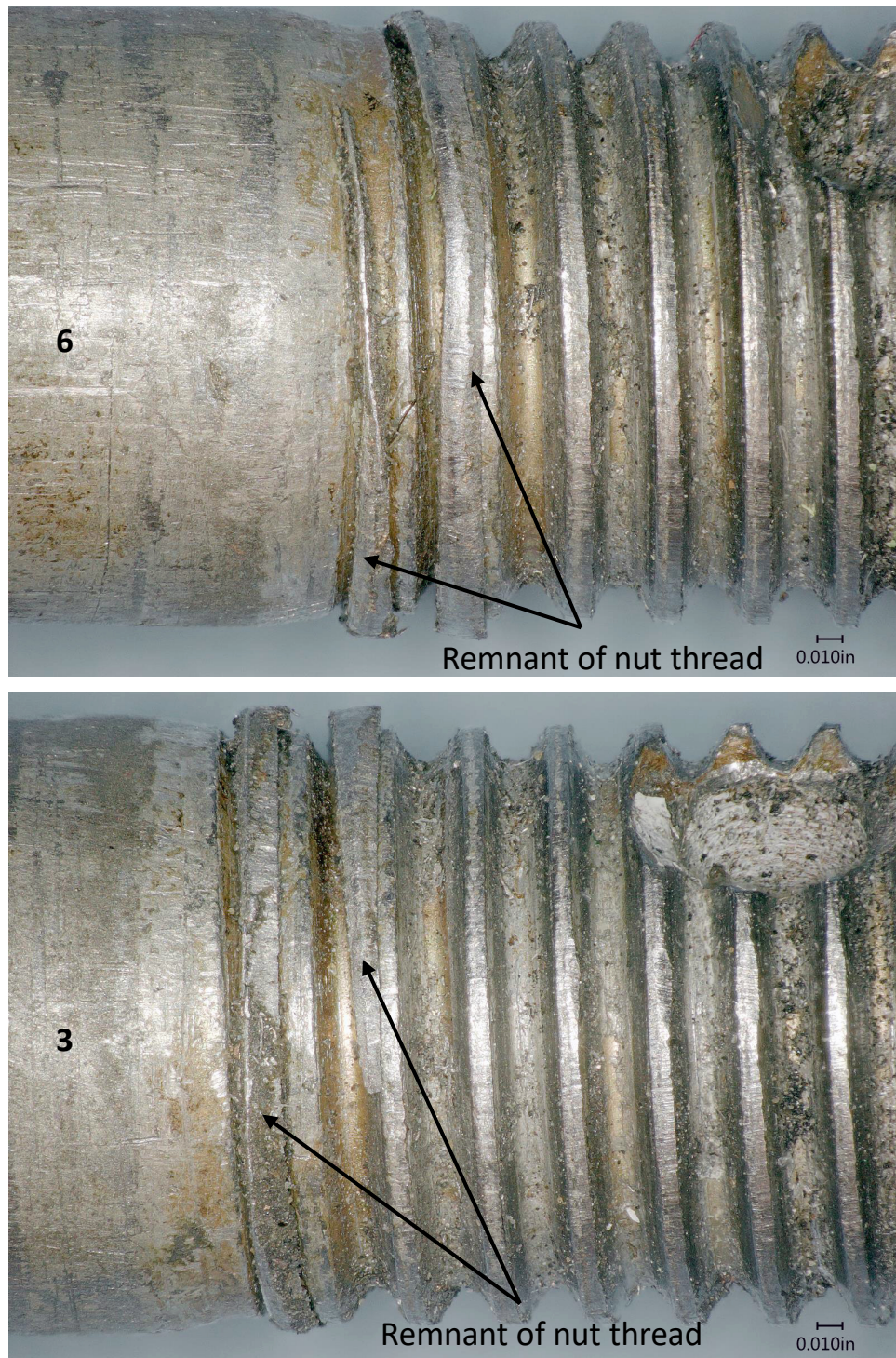


Figure 28 Digital microscope images showing remnants of nut threads within the bolt threads. See Figures 24 and 25 for orientation.



Figure 29 Top view of the pivot bolt in Figure 24.