NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

July 17, 2013

MATERIALS LABORATORY FACTUAL REPORT Report No. 13-031

1. ACCIDENT INFORMATION

Place	:	Camp Bastion, Afghanistan
Date	:	January 16, 2012
Vehicle	:	Bell 214ST, N5748M
NTSB No.	:	DCA12FA024
Investigator	:	Dan Bowers

2. COMPONENTS EXAMINED

- Collective lever arm assembly and actuator piston
- Fuselage and stop arm near horizontal stabilizer
- Upper transmission mount bolts
- Idler link assembly
- Collective sleeve bearing retainers
- Torque shaft and support bracket

3. DETAILS OF THE EXAMINATION

3.1. Background and Ashburn Group Examination

On January 16, 2012, a Bell 214ST helicopter operated by AAR Airlift Corporation crashed approximately 7 miles south of Camp Bastion, Helmund Province, Afghanistan. All three crewmembers were fatally injured, and the helicopter was destroyed by impact forces and subsequent fire. The investigation was fully delegated to the National Transportation Safety Board (NTSB) by the Afghanistan government. All parts at the crash site were removed, crated, and shipped to the United States for group examination.

The initial examination and uncrating of the wreckage occurred at the Ashburn NTSB Training Center. Representatives from the following parties present at the initial investigation were:

- NTSB
- FAA
- Bell Helicopter
- AAR Airlift
- General Electric Engines
- Department of Defense Transportation Command

All of the wreckage delivered was carefully examined during the investigation. The wreckage was shipped in two standard shipping containers, with parts varying in size and shape from large sections of fuselage and rotor blades to small parts in large boxes mixed with dirt and gravel. Based on the description of the accident reports to date, the parties involved focused on inspection of the tail section of the helicopter and the main transmission and rotor system, displayed in Figure 1. Much of the collective housing and support components in this assembly were fractured in a manner consistent with overstress conditions. Multiple overstress fractures are typically of forces experienced during ground impact. Figure 2 shows the helicopter left side of collective, where the missing collective lever arm was located. The collective lever arm on the right side was detached from the bearing retainer, but was found in the wreckage. The collective hydraulic actuator upper rod end remained connected to the collective lever arm assembly, but it had fractured at the upper rod end's threaded connection to the actuator piston (see Figure 3). In addition, the bolt connecting the collective hydraulic actuator upper rod end to the collective lever had fractured, although the components were still attached.

The collective arm assembly, idler link assembly, several bolts, and collective bearing retainers were disconnected for later inspection. A portion of the tail fuselage was also sectioned for further analysis.

3.2. Materials Laboratory Investigation

The components described above that were removed and/or disassembled were transported to the Materials Laboratory at NTSB headquarters in Washington, DC. The information on these parts is detailed in the following sections.

3.2.1. <u>Fuselage Near Horizontal Stabilizer</u>

A section of the right side fuselage adjacent and surrounding the horizontal stabilizer arm assembly was cut and examined. Figure 4 shows the fuselage section around the horizontal stabilizer position from the outside looking inward. The fuselage had buckled and torn in multiple places, consistent with damage sustained on thin alloy sheet during impact. In most locations, the blue paint had darkened, charred and flaked off, consistent with exposure to the post-impact fire. All of the components from this area were covered in combustion products.

One of the hex bolts, located on the upper of the horizontal stabilizer ring, was missing (see Figure 5). As seen in Figure 6, the absence of the bolt allows the stabilizer clamp ring to pivot outward. Nominally, this hex bolt is affixed by a nut on the opposite side, two thin washers on either side of the bolt, and a spacer between the wing flanges. The bolt holes at the location of the missing hex bolt had not been elongated, but did exhibit some material removal at the corners parallel to the fuselage direction. This missing hex nut was not identified in the recovered wreckage. In addition, the clamp ring bolt hole on the lower aft side had been deformed and torn inward (this hex nut was still installed).

In addition to the missing hex nut on the clamp rings, there was a missing bolt where the stop arm affixes to the fuselage thru one half of a clamp ring on the upper aft side. This missing bolt allowed the stop arm to be moved. A witness mark where the stop arm had rubbed against the fuselage can be observed in Figure 5 and Figure 6. The stop arm appeared to exhibit some deformation on the lower outboard corner, but overall still held paint and primer on the potential contact surfaces with horizontal stabilizer bar. Some circumferential wear marks were identified where the washer contacts the stop arm, but no bolt hole deformation was observed.

Figure 7 shows the right side fuselage from inside looking outward (opposite of Figure 4 through Figure 6). Of note in this area, was the downward deformation of the fuselage guide flange. The flange was bent downward and torn axially and circumferentially. This damage corresponds with damage and deformation of the stop arm and missing bolts, consistent with the horizontal stabilizer moving upward on the helicopter right side and downward on the right side.

3.2.2. Bolts on the Upper Transmission Mount

Figure 8 shows one of the hex bolts removed from the transmission upper mount. The bolt head exhibited several small holes for inserting safety wire that was still present and affixed to the adjacent circular cap. The cap exhibited two concentric wear scars: the inner one corresponds to similar concentric wear marks on the underside of the bolt head. Some material loss was observed on the underside flanges of the cap (see Figure 9).

Figure 10 shows the threads of the upper mount bolt, as received. The five threads closest to the hex nut head were intact and contained debris and dirt in the root valleys. The six other threads had been sheared off. Figure 11 shows a closer view of the sheared threads, showing smear marks and material deformation away from the bolt head. This damage is consistent with the bolt being pulled outward while the threads that were sheared were still engaged.

3.2.3. Collective Lever Arm and Surrounding Components

The right collective lever arm assembly (P/N 214-010-492-105) is shown after cleaning in Figure 12. The two bolts that connect this collective lever arm to the left collective lever arm were not affixed to the part. The large bolt is P/N MS21250-10014, and the smaller bolt is P/N MS21250-04038. A fractured segment of a bolt consistent with dimensions of the large bolt was examined and is detailed in Section 3.2.6. The collective actuator output piston upper rod end was still attached to the lever by a fractured bolt (P/N 50-047-8-38/-40) with a nut and washers affixed by a cotter pin through a rod end bearing. The head of this bolt was fractured and not recovered. The upper rod end exhibited a fracture at lower surface of the nut that secures the upper rod end to the collective actuator output piston.

Select dimensional features on the collective lever arm assembly, illustrated in Figure 13 and Figure 14, were measured and are listed in Table 1. Several of the measured dimensions were outside the ranges prescribed by the manufacturer.

However, it should be noted that many of these areas have bushings, designed to help create better fits during assembly. Furthermore, these components had sustained high loads from the crash event.

As illustrated in Figure 12 through Figure 14, the collective lever arm exhibited a variety of witness marks consistent with impact with adjacent metallic components. The lower side of the arm exhibited a variety of chipped paint marks and semicircular gouges and scars (Figure 15). The nature of these witness marks is consistent with damage sustained from a single event rather than repeated contact from rubbing or fretting. The upper side of the arm exhibited less damage than the lower side. However, there was an approximately 0.5 inch depression/gouge in a fillet corner (see Figure 16). The gouge on the recovered collective lever arm matches to the gouge observed on the right side of the idler link (see Section 3.2.4).

The bolt holes for the two missing bolts exhibited indications of circumferential wear consistent with some rubbing by the adjacent washer when affixed (see Figure 17). However, there were no indications of hole enlargement or longitudinal wear marks on the inside bores. The recessed area outside of the large missing bolt was in relatively good condition: there were two small longitudinal paint chips, but no deep wear gouges.

Figure 18 shows the fracture surface of the threaded remnant of the collective actuator output piston upper rod end still inside the nut. The part exhibited a rough, dull luster with a tortuous surface texture. The fracture surface was slanted approximately 45° extending from the exterior thread roots outward from the nut to the inner bore of the part. The fracture pattern was mirrored on the mating fracture surface, shown in Figure 3. These fracture features are consistent with failure by overstress. The fracture surface exhibited rotational chevron and flow patterns, consistent with failure under torsional overstress. No indications of premature failure, such as preexisting cracks or corrosion, were found on this part.

The fractured rod end bearing pin is illustrated in Figure 19, as received. The rod end bearing was disassembled to study the pin fracture surface, shown in Figure 20. The fracture surface was slanted at an approximately 45° angle across the pin. The portions of the pin closest to the fracture showed indications of necking. The left side of Figure 20a shows two jogs on the left portion of the pin, where the rod end bearing edges were located. The river patterns on the fracture indicate the fracture started at the lowermost portion of the fracture in Figure 20a. Inspection of the fracture surface using a scanning electron microscope (SEM) shows dimple rupture. The features are indicative of failure by overstress in tension, where the pin was stretched and torn across from one side to the other (Figure 21). No indications of other failure modes were found.

3.2.4. Idler Link Assembly

The idler link assembly is shown in Figure 22 from the underside looking upward. Overall, the link assembly was in relatively good shape, with the most damage occurring below the bolt hole ends, where paint and primer had been scraped off. The thrust ring (larger) and bearing holes (smaller) on either side did not show any indication of elongation or gross deformation (see Figure 23 and Figure 24). Both the inner surfaces of the thrust ring bores showed rings of shallow circumferential wear marks. The left side thrust ring hole exhibited a wear spiral that wrapped approximately 45° around the inner surface towards the outer portion of the insert. A small longitudinal scar was also observed on the upper side of the left pin bore.

As shown in Figure 23 and 24, measurements were taken of the pin bore and bushing bolt hole, and listed in Table 1. The bearing hole could not be compared, since it still contained the attached bushing for the removed bolt. The thrust ring bores were slightly longer than the supplied tolerances.

Both underside edges of the link assembly exhibited impressions that mirrored the ones observed on the collective arm assembly shown in Figure 16. These depressions are consistent with the collective lever arms contacting the idler link. The left side depression on the idler link was approximately 0.25 inches long, whereas the right side depression was approximately 0.7 inches with more severe material smearing that matches that of the adjacent collective arm. As stated previously, the left collective lever arm was not recovered for examination.

3.2.5. Collective Sleeve Bearing Retainers

The collective sleeve bearing retainers from both sides of the collective were removed and cleaned, and they are displayed in Figure 25 and Figure 26. Each retainer contains a cylindrical roller bearing. The left bearing possessed all of its rollers and was able to spin freely without binding.

The right bearing retainer, showed in Figure 25, was significantly damaged. The bearing cage had been deformed and fractured. Twelve of the nineteen rollers were missing. The upper portion of the retainer housing had been deformed and smeared. These features are consistent with the adjacent collective lever arm pin pulling outward and downward.

3.2.6. Extra Bolt Head

Upon subsequent inspections of the debris, a fractured bolt head was found. This bolt was fractured in a 45° angle approximately 0.5 inches below the platform (see Figure 27). Two major bands of circumferential wear marks were observed, one located under the bolt head and the other at the location of a jog in the shaft. This jog coincided with the fracture initiation point on the opposite side along the witness mark, where the river patterns on the fracture surface emanate. The portions of the bolt closest to the fracture showed indications of necking and bending towards the long tip of the fracture surface.

The fracture surface, depicted in Figure 28, exhibited a dull luster and rough surface morphology. Inspection of the fracture surface using a SEM showed dimple rupture, indicative of overstress (Figure 29). These features are consistent with failure in shearing tension. No indications of other failure modes were found.

Several significant dimensions of the bolt were measured and are presented in Table 2. These data are compared with the drawing requirements for the required large bolt in the collective lever arm, P/N MS21250-10014. For the majority of the dimensions measured, the dimensions of the recovered fractured bolt are consistent with the dimensions of the specification, MS21250-10.

3.2.7. Torque Shaft and Support Bracket

A torque shaft and support bracket was recovered from the wreckage and is illustrated in Figure 30. Cracks were observed emanating from both of the bracket bolt holes. One of the bolt holes, though, had completely fractured allowing the torque shaft to move about the remaining affixed bolt. Both bolts of the torque shaft were intact with the nuts, bushings, washers, and cotter pins still in position.

The support bracket fracture surface had been partially obliterated by smearing. However, the portions of the fracture surface that had not been damaged exhibited a dull luster and tortuous surface profile. The areas near the fracture surfaces exhibited necking and the cracks exhibited rough branching. These features are indicative of overstress. No indications of preexisting flaws or material defects were observed on the support bracket.

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Materials Research Engineer

Table 1 – Comparison of specified and measured values of various dimensions on the collective lever arm, actuator piston, and idler link assembly (see Figure 13, Figure 14, Figure 19, Figure 23, and Figure 24). The values in red were outside the specified tolerances.

Dimension Number	Name	Specification Value (in)	Measured Value (in)	Comments
1	Lever pin diameter	1.1250-1.1260	1.1260	
2	Lever pin diameter (idler)	1.3150-1.3156	1.125	
3	Height between lever surfaces (high)	0.555-0.695	0.583	
4	Height between lever surfaces (minor)	0.555-0.695	0.603	
5	Height between lever surfaces (end)	0.705-0.715	0.704	
6	Large bolt hole diameter	0.630-0.635	0.628	
7	Small bolt hole diameter	0.260-0.270	0.265	
8	End bolt hole diameter	0.6250-0.6255	0.626	With bushing, 0.497 in. Specified range 0.46-0.48 in
9	Distance between small and large hole	4.297-4.327	4.297	
10	Distance between small and end hole	2.177-2.199	2.191	
11	Actuator piston hole diameter	0.4995-0.5000	0.500	
12	Bearing hole diameter	1.4995-1.5000	0.625 R 0.625 L	Measured with bushing and rubber jacket installed
13	Thrust ring hole diameter	1.6250-1.6260	1.627 R 1.627 L	

Table 2 – Comparison of selected measurements from the fractured bolt in Figure 27 with the MS21250-10 bolt specification requirements for those measurements. The values in red were outside the specified tolerances.

Bolt	Bolt Head Diameter, (A)	Bolt Shaft Diameter (B)	Bolt Head Length (H)	Bolt Head Inside Diameter (J)
MS21250-10 Specification	1.040 – 1.050	0.6230 – 0.6240	0.618	0.500
Fractured Bolt	1.045	0.625	0.628	0.483*

*Caked residue was present inside the bolt head recess during measurement.

Figure 1 – The main rotor control assembly as received in the NTSB Ashburn training facility.

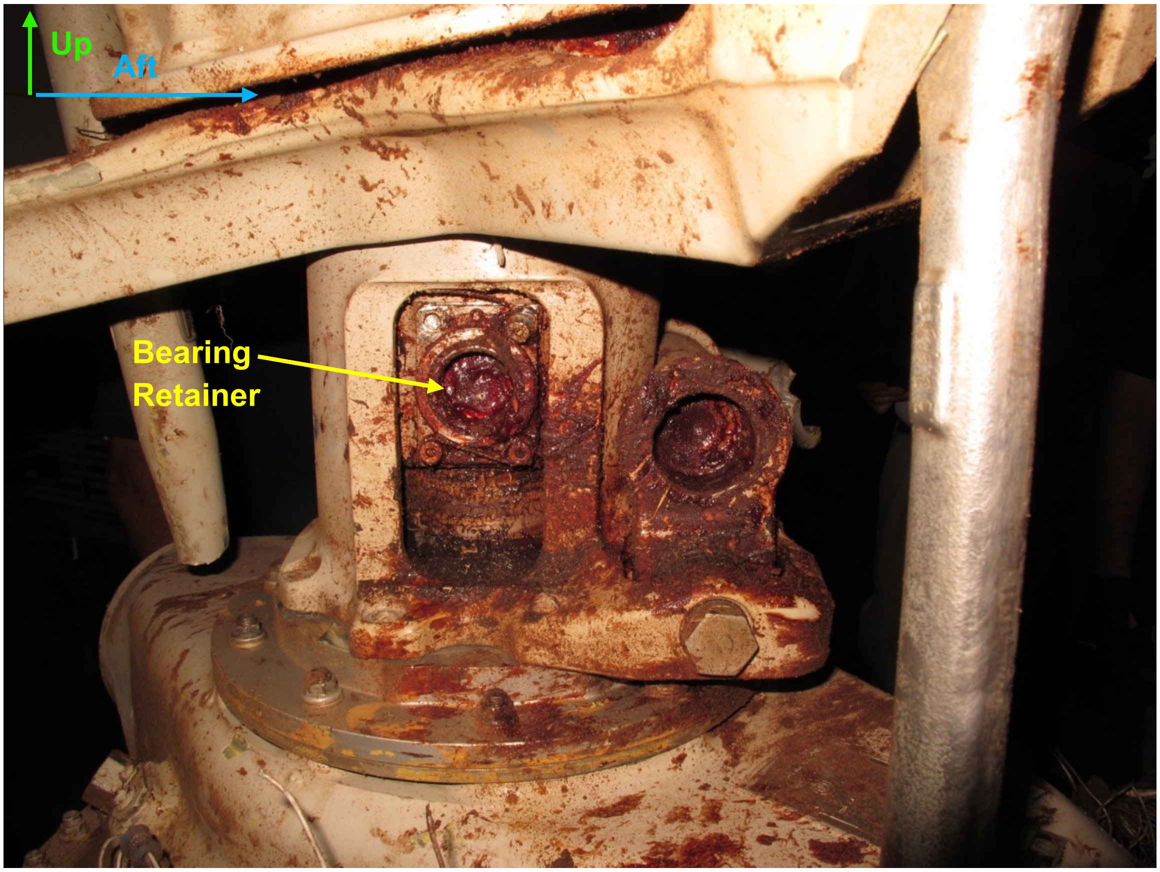

Figure 2 – Closer view of the area of interest on the swashplate assembly, showing the location of the missing collective lever assembly under the control arms from the helicopter left side.

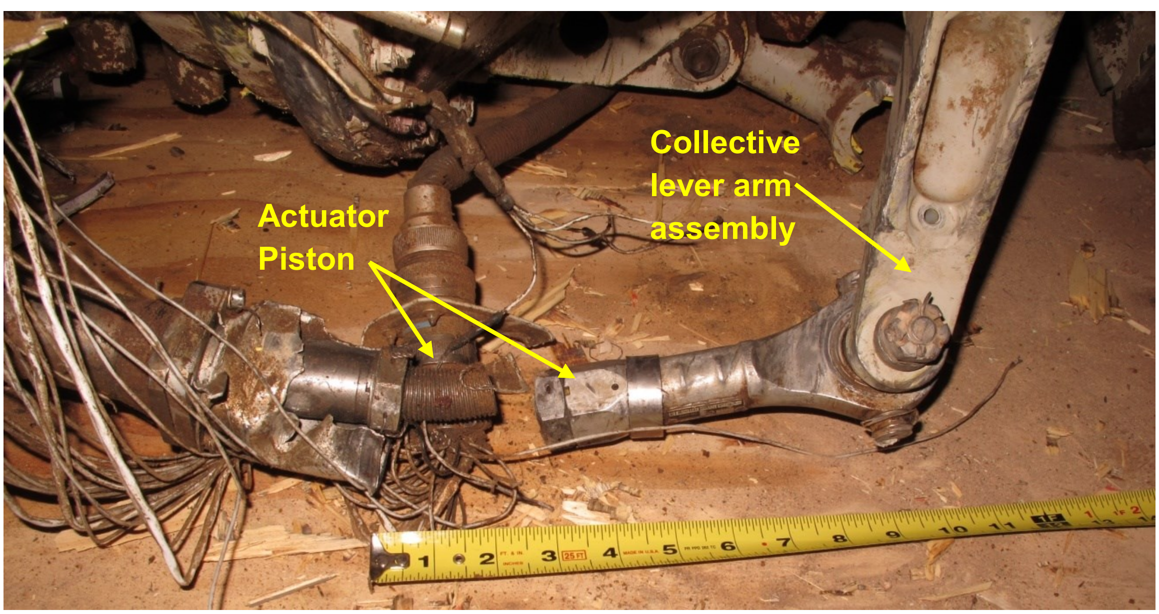

Figure 3 – The fractured actuator piston attached to the lever arm assembly.

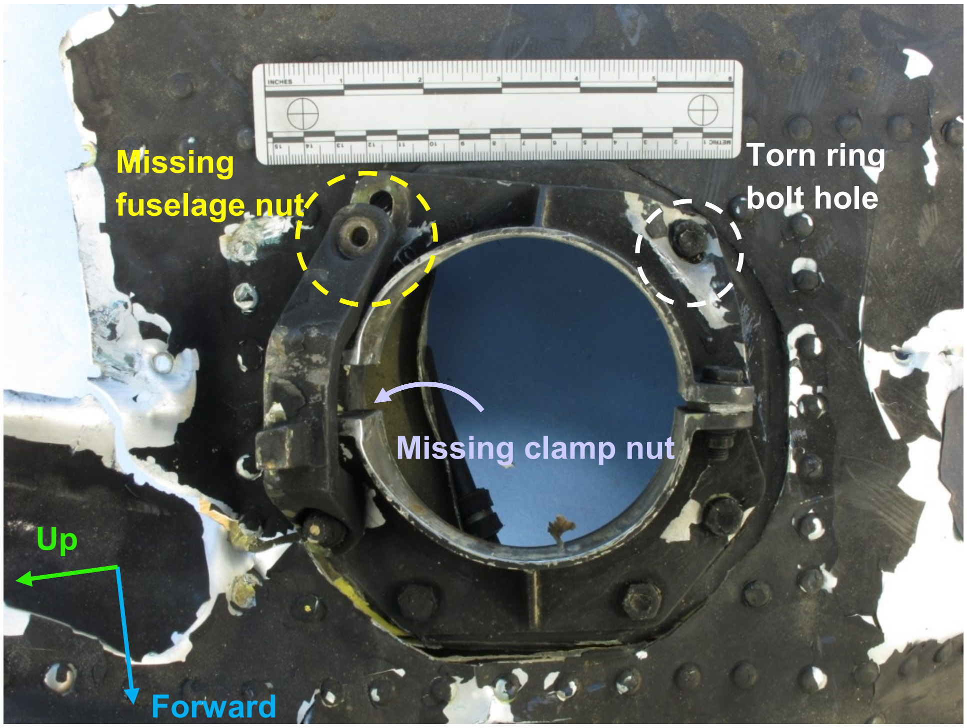

Figure 4 – The right side of the helicopter fuselage where the tail horizontal stabilizer inserts, showing the stop arm in its expected position.

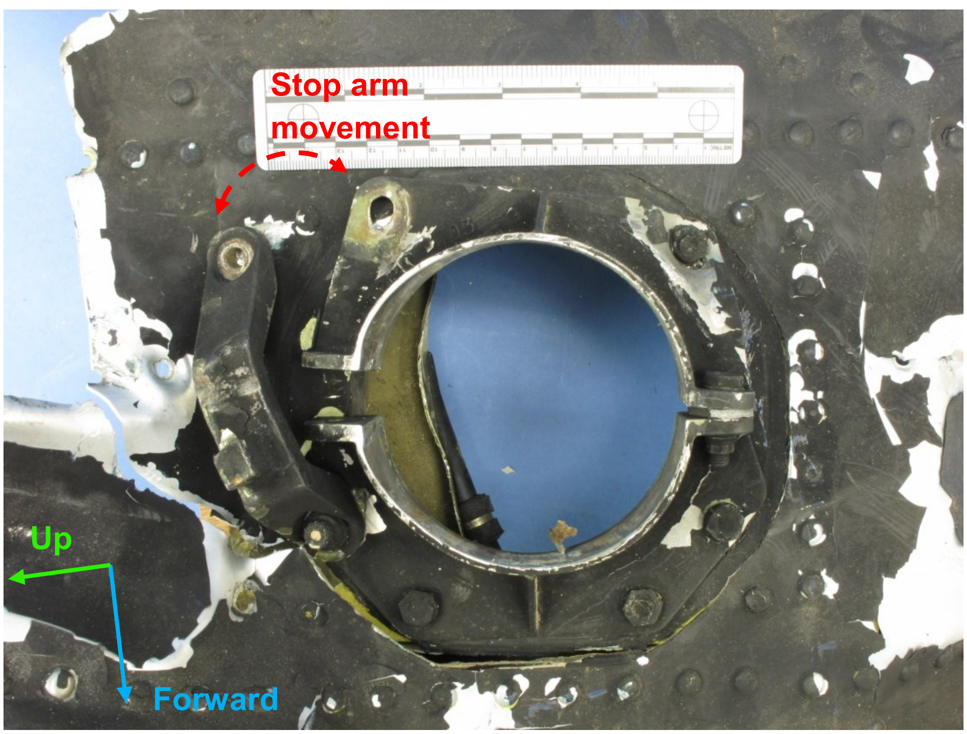

Figure 5 – Section of the fuselage where the tail horizontal stabilizer inserts, showing the stop arm in a position likely without the upper bolt. A witness mark is present where the stop arm scraped against the fuselage (see Figure 6).

Figure 6 – Position of the stop arm in relation to the fuselage witness mark. The clamping bolt on the stabilizer support cylinder was missing.

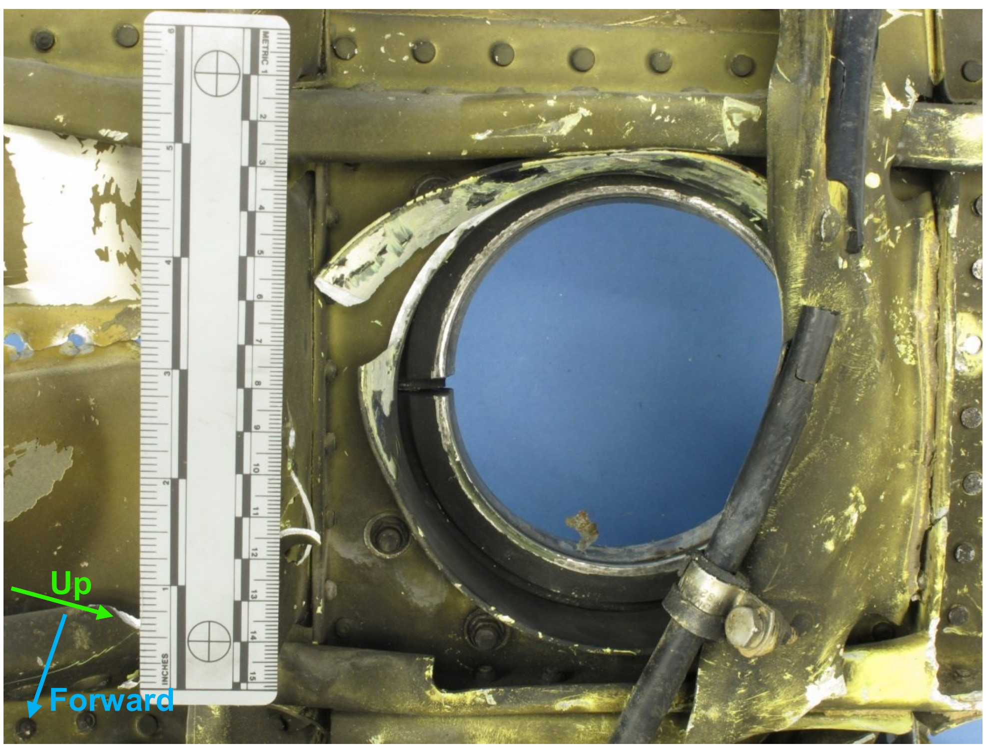

Figure 7 – Reverse side of the fuselage from Figure 4 and Figure 5 (inside), showing the deformation in the sheath indicative of a likely horizontal stabilizer position.

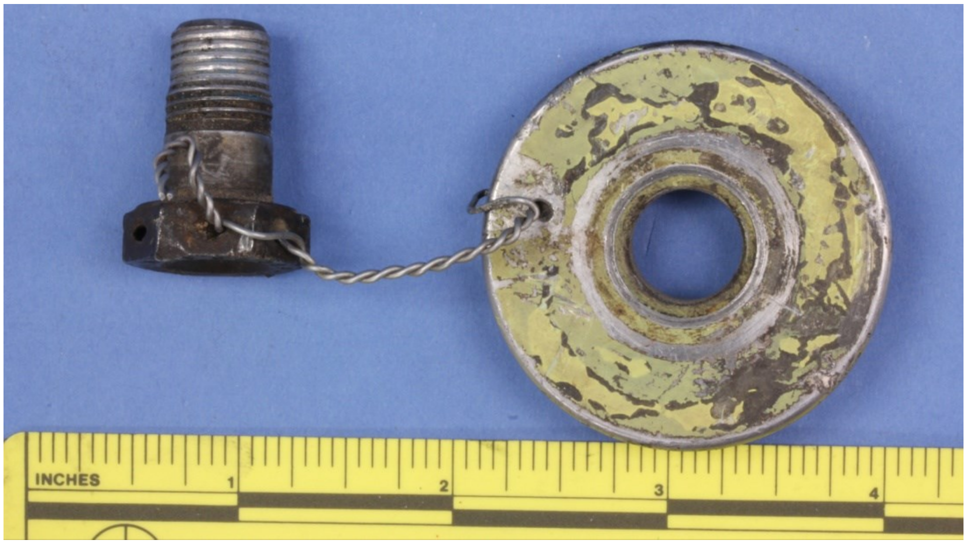

Figure 8 – The transmission upper mount bolt, as received. The washer was still affixed by safety wire.

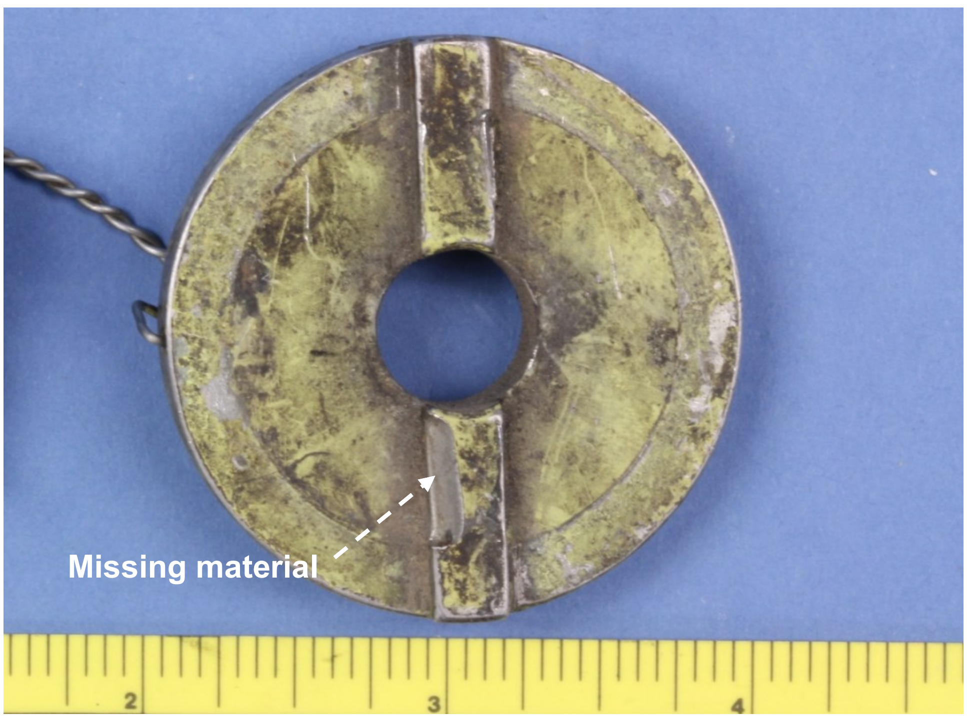

Figure 9 – Material loss on the flanges of the cap (opposite of side shown in Figure 8).

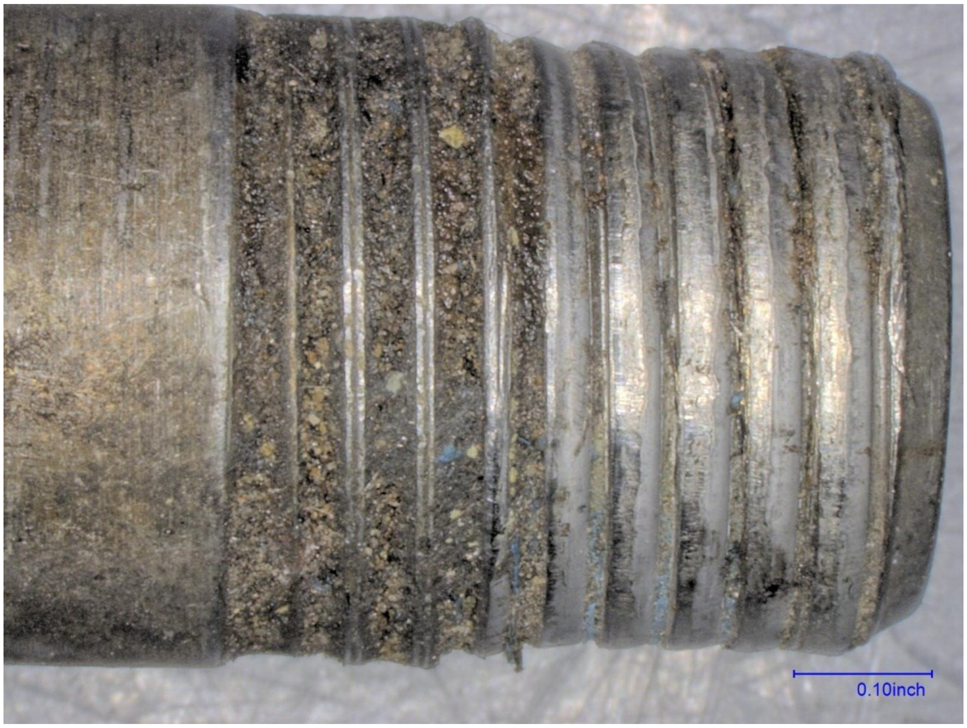

Figure 10 – Close-up of the bolt in Figure 8, showing shearing of the bolt threads (pictured on right side).

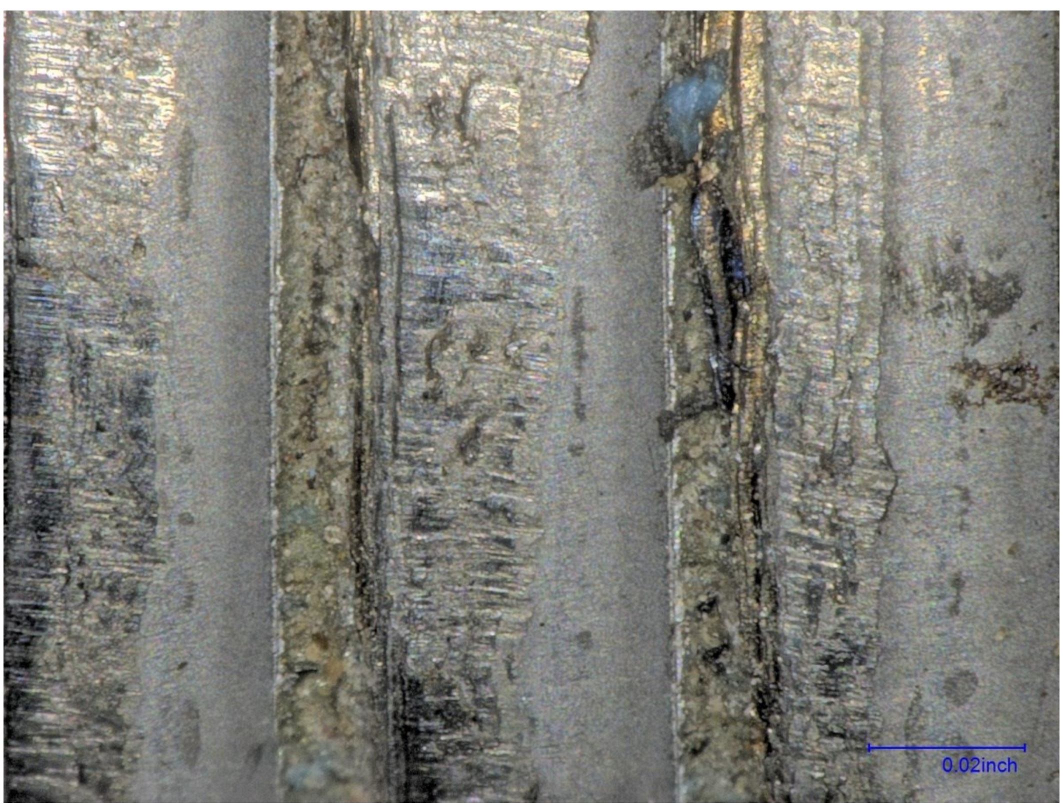

Figure 11 – Sheared threads on the bolt displayed in Figure 10.

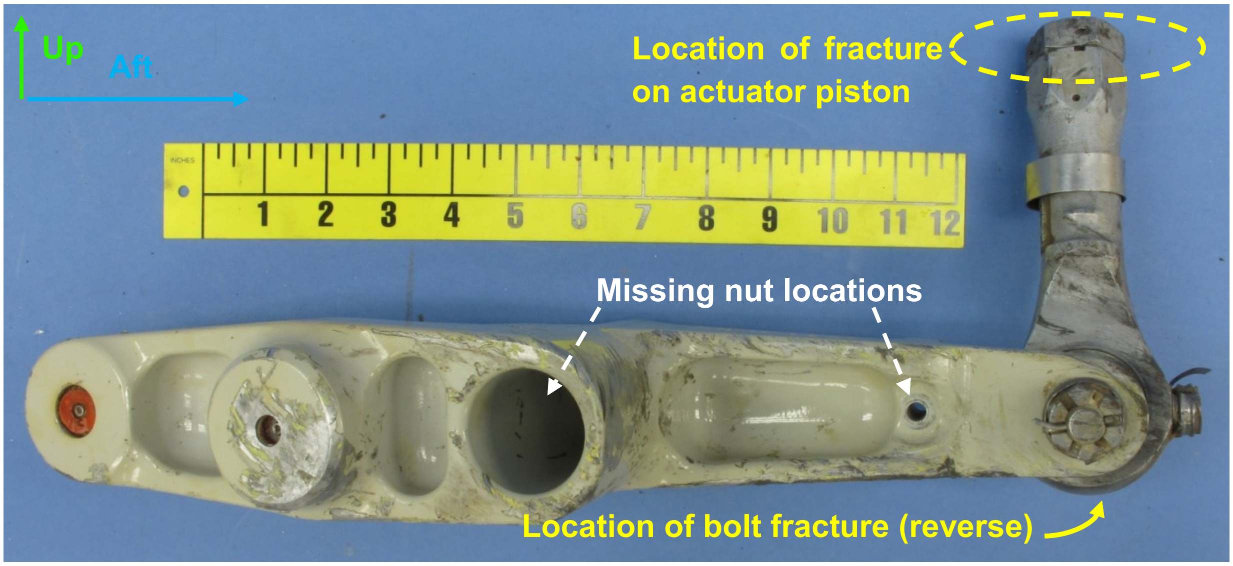

Figure 12 – The collective lever arm assembly, after removal from the collective swashplate assembly and cleaning.

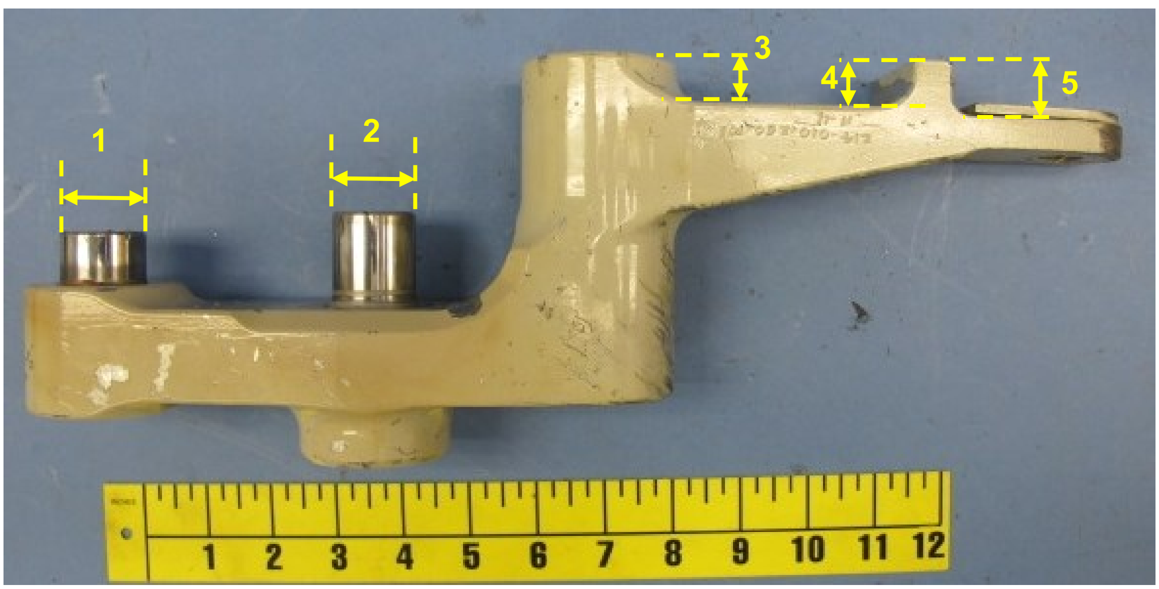

Figure 13 – The collective lever arm, from the side. The dimensions marked were measured and tabulated in Table 1.

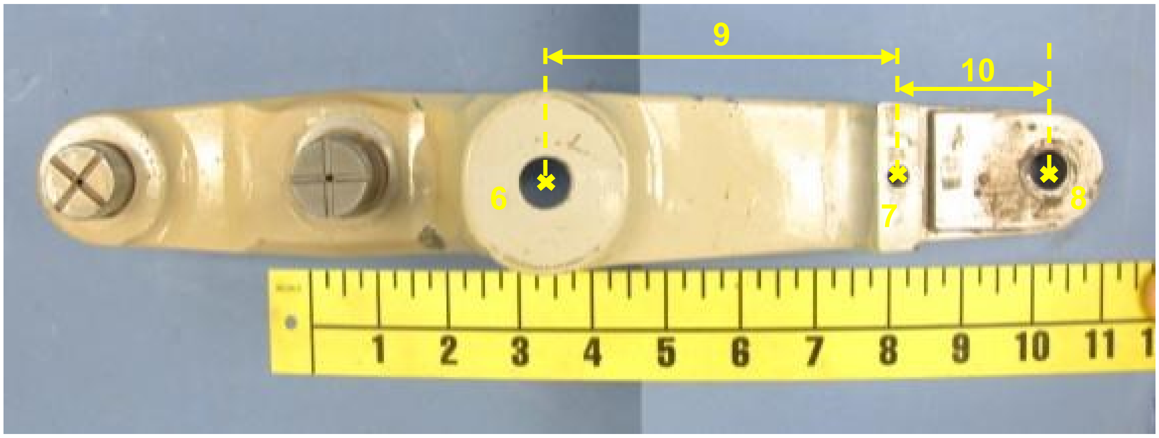

Figure 14 – The collective lever arm, from the inside. The dimensions marked were measured and tabulated in Table 1.

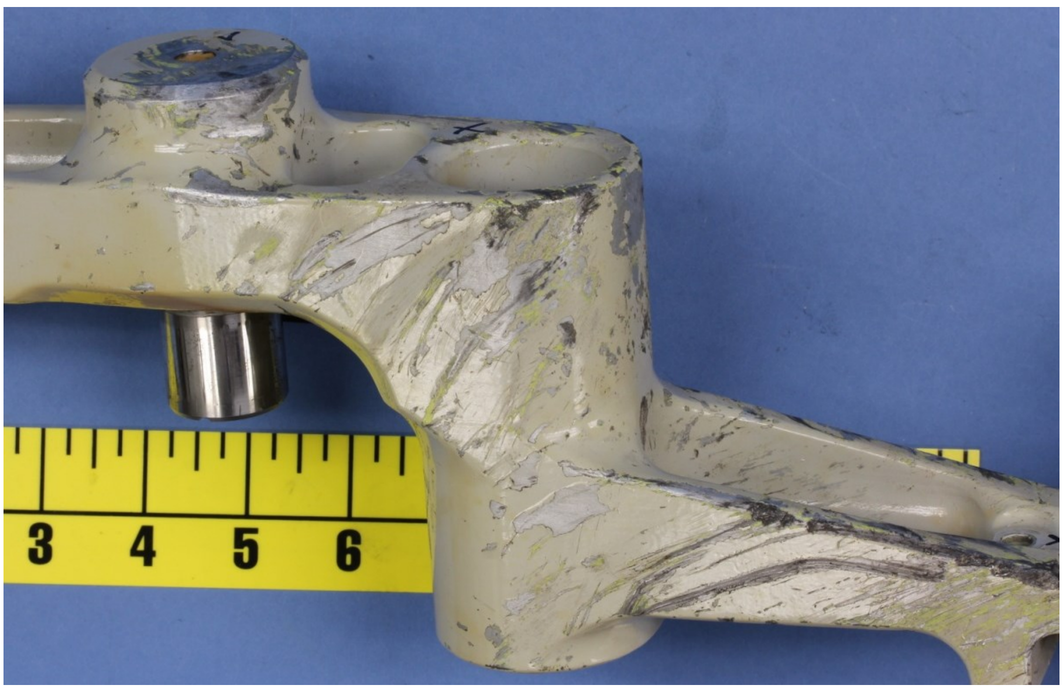

Figure 15 – Damage to the lower side of the lever arm.

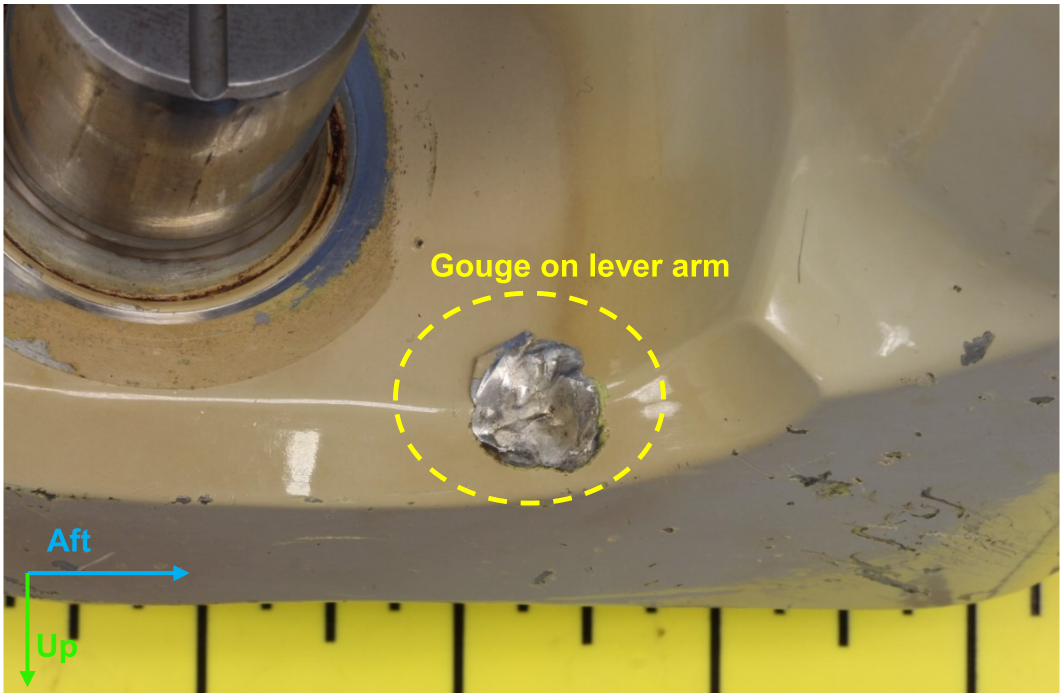

Figure 16 - Large depression on the upper side of the lever arm.

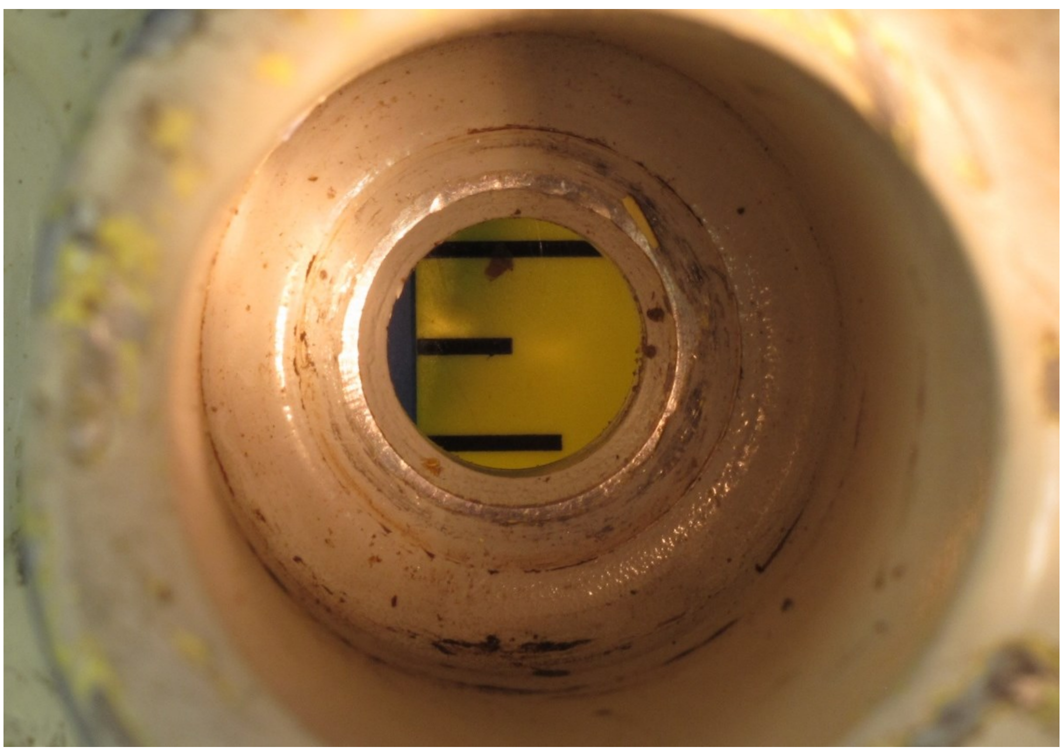

Figure 17 – The recessed bolt hole for bolt P/N MS2150-10014 (missing), showing circumferential wear on the outboard side.

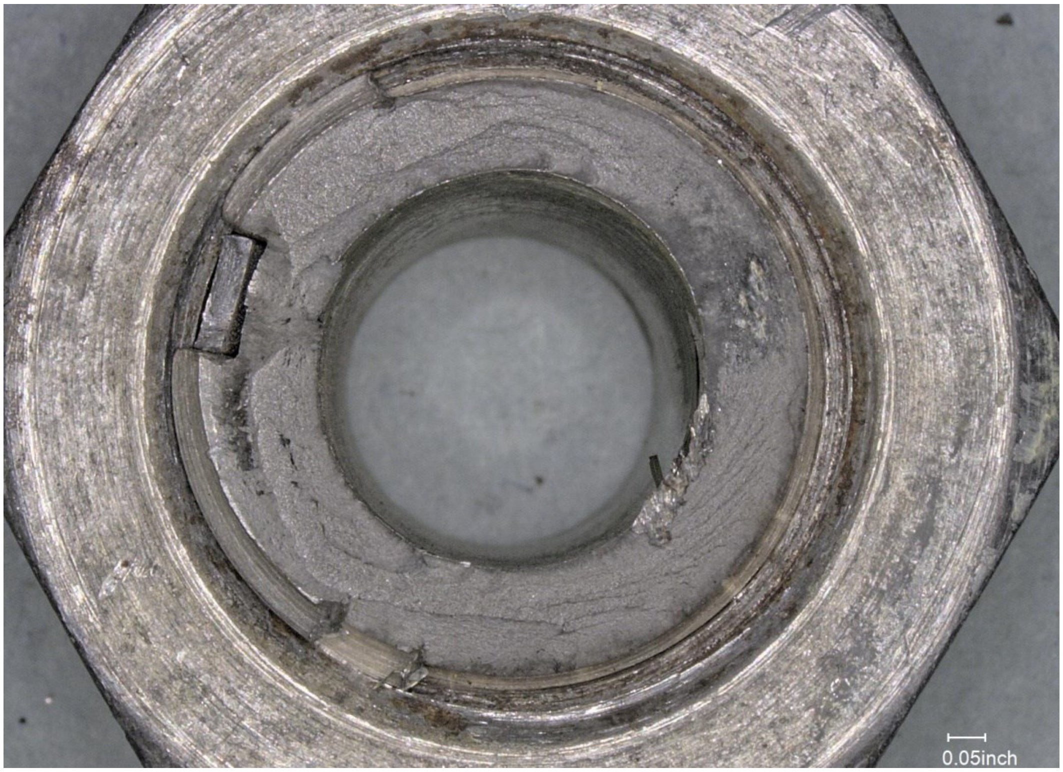

Figure 18 – Fracture surface of the upper rod end that attaches to the collective actuator output piston at the nut, showing indications of overstress.

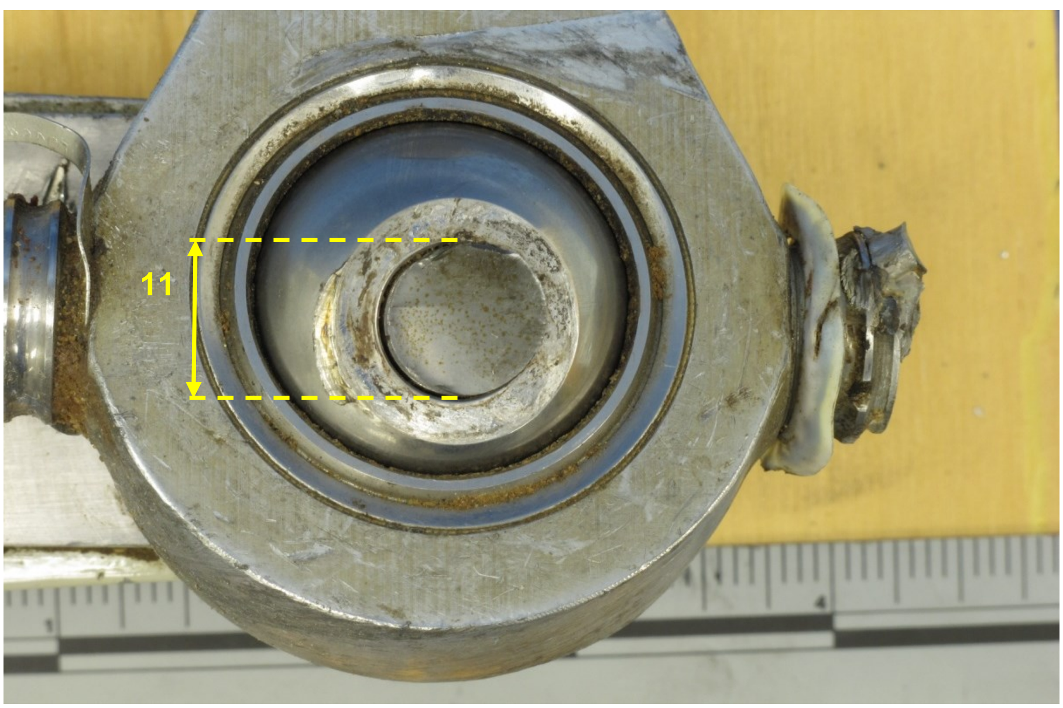

Figure 19 – The fractured bolt attaching the rod end bearing of the actuator piston to the collective lever arm assembly. The measured dimension is listed in Table 1.

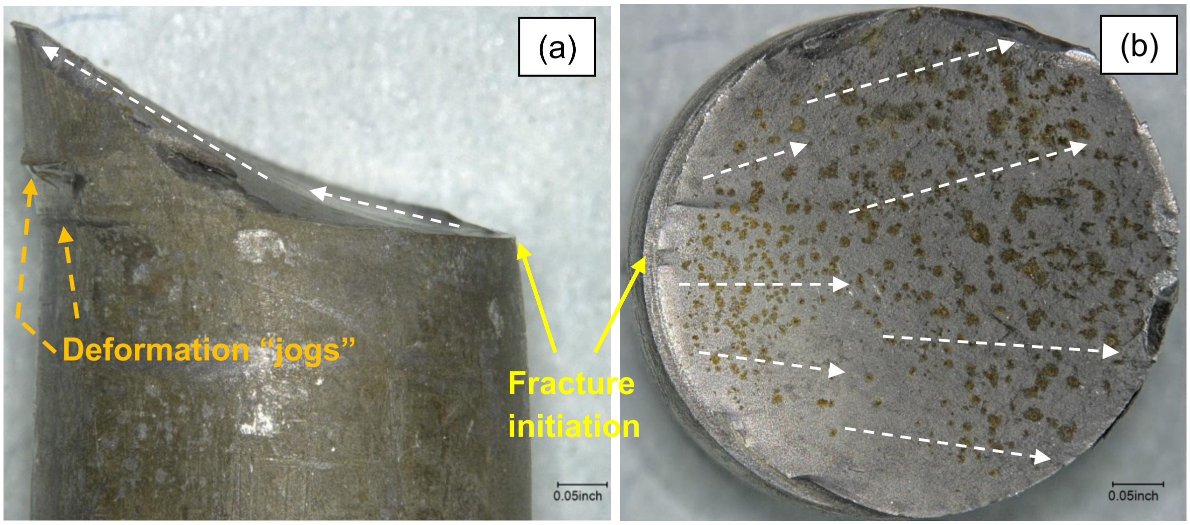

Figure 20 – The fractured bolt from Figure 14 after removal and cleaning, showing the fracture surface from (a) the side and (b) the face. The white arrows indicate the fracture direction.

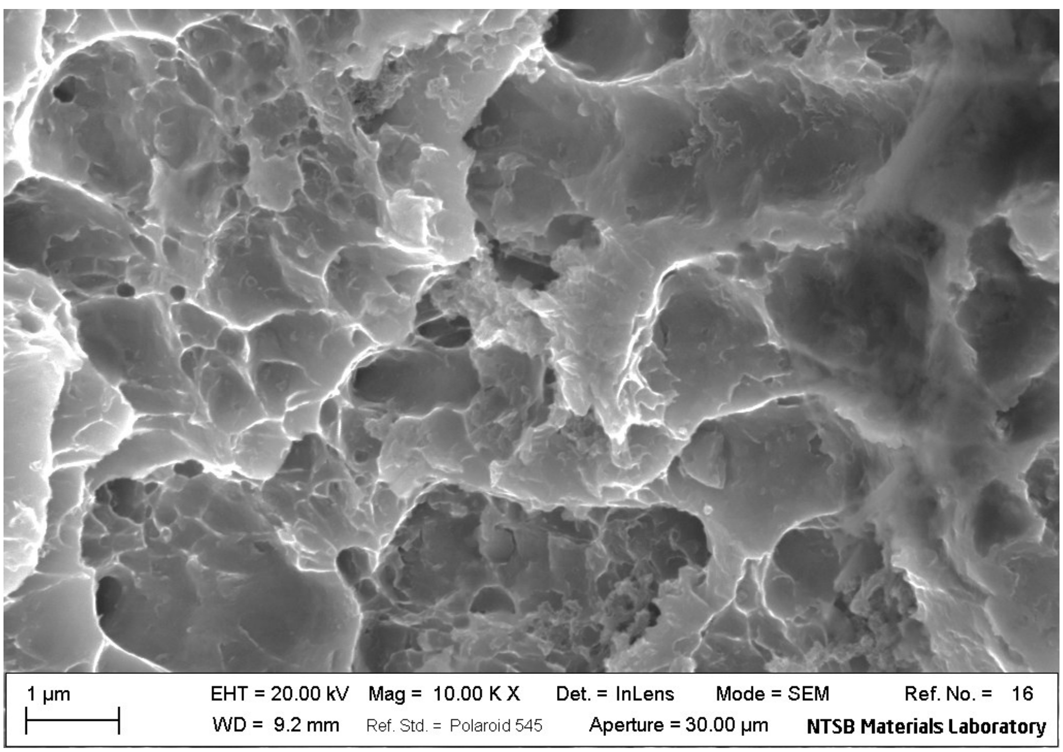

Figure 21 – Secondary electron (SE) micrograph of the fracture surface of the bolt from the actuator piston, showing dimple rupture indicative of overstress.

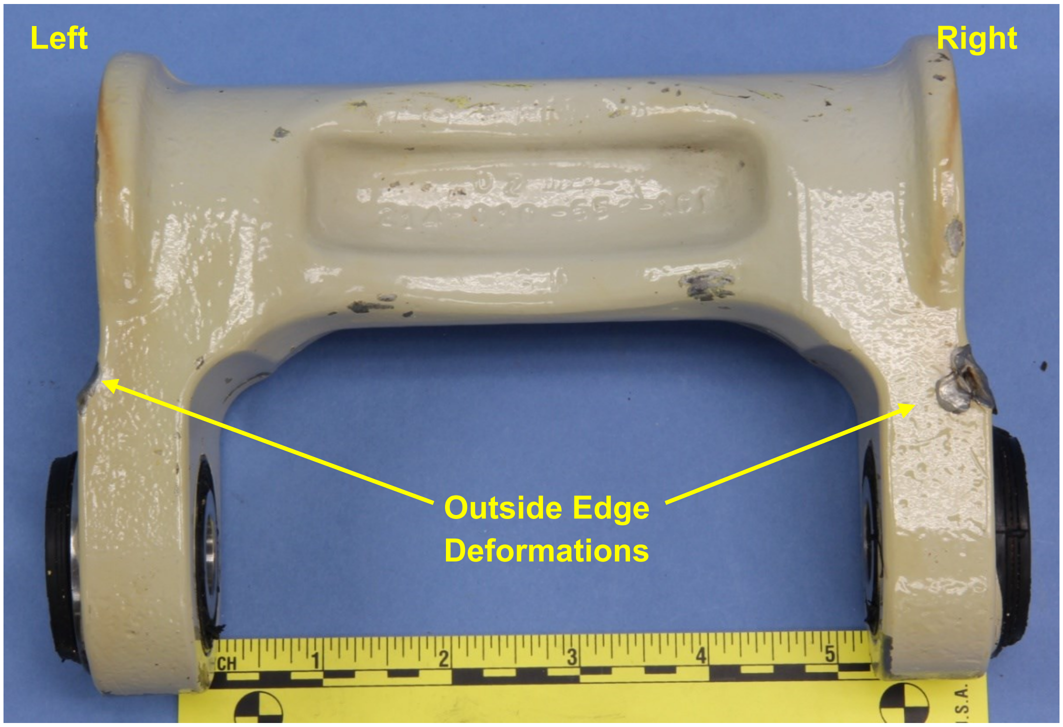

Figure 22 – The idler link assembly, after removal from the collective assembly and cleaning, aft-looking forward. Two witness marks were noted where the link can contact the collective arms.

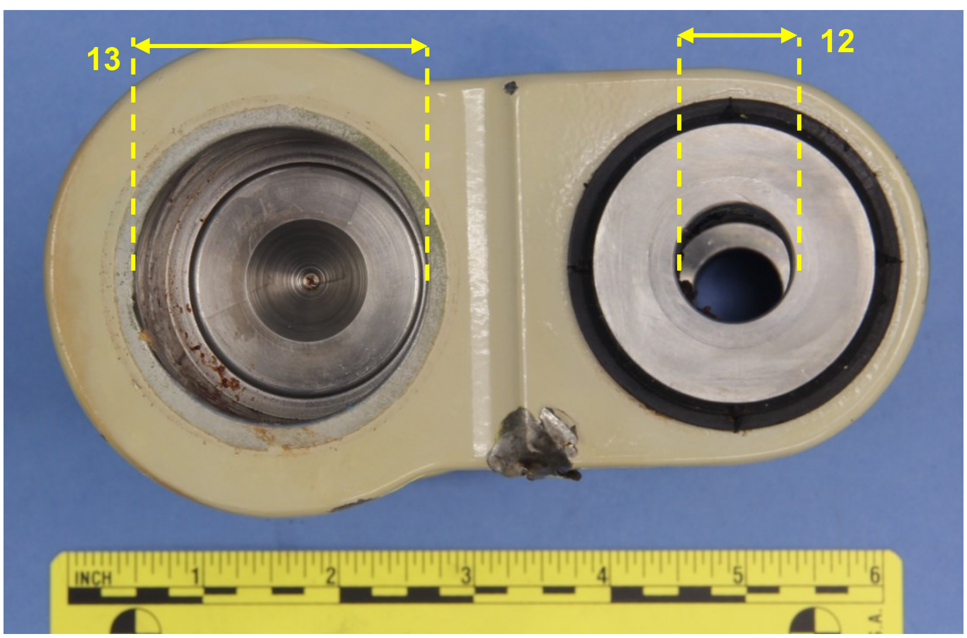

Figure 23 – The idler link assembly from the right side. The dimensions marked were measured and tabulated in Table 1.

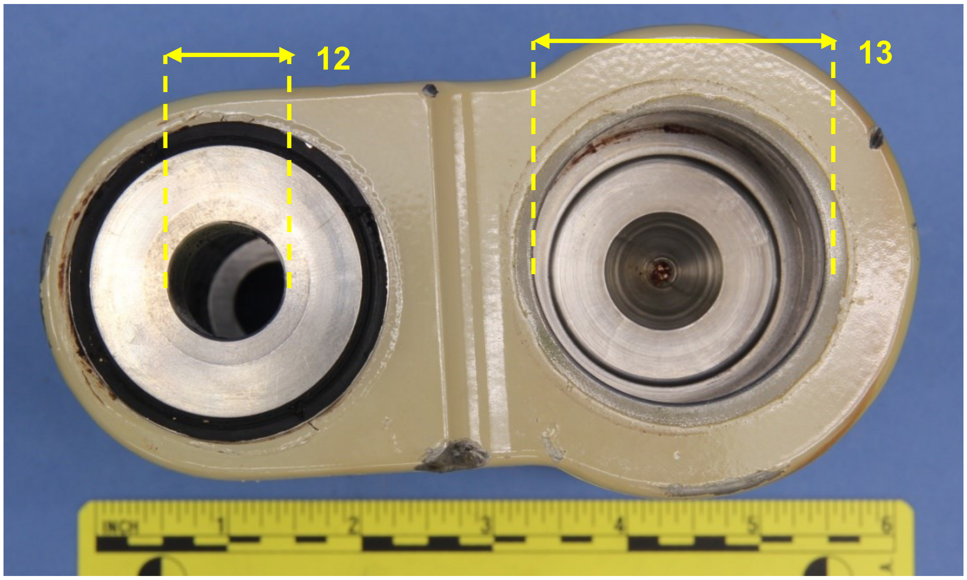

Figure 24 – The idler link assembly from the left side.

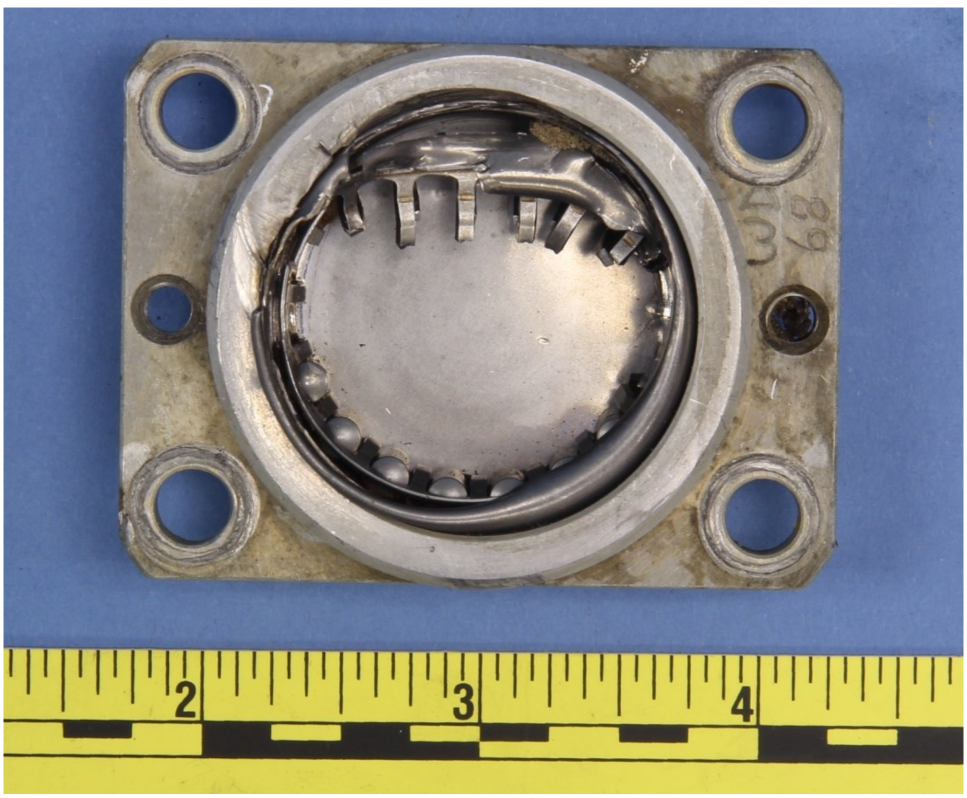
Figure 25 – Collective sleeve bearing retainer (right).

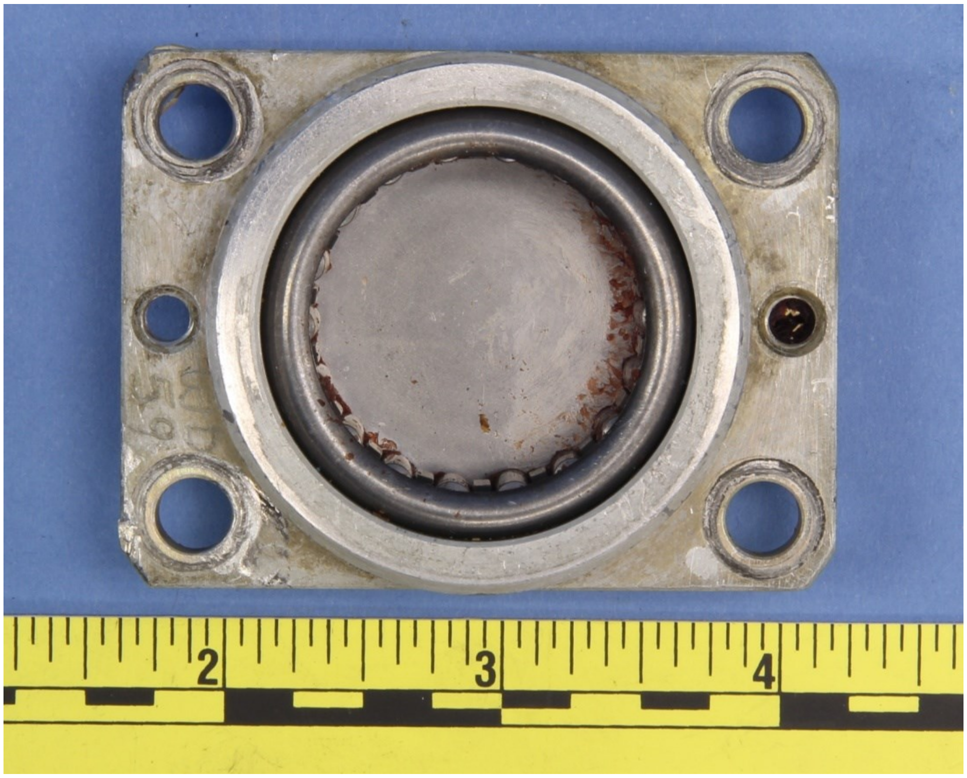

Figure 26 – Collective sleeve bearing retainer (left).

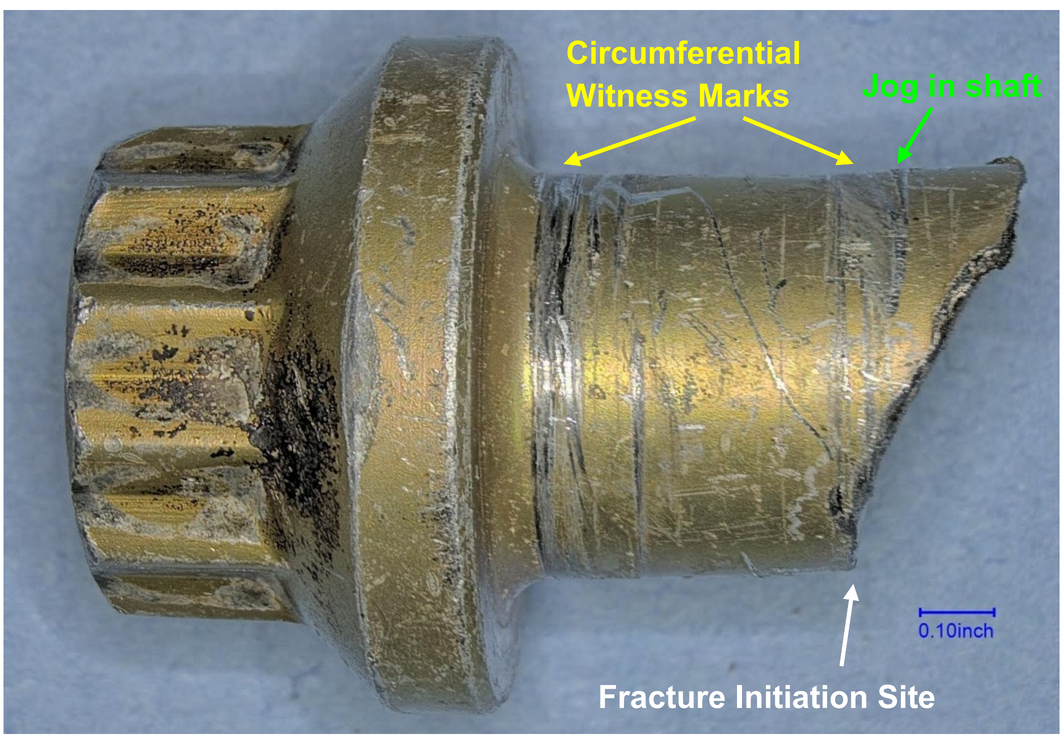

Figure 27 – The recovered external wrenching bolt from the side, showing circumferential witness marks, and a jog in the bolt shaft corresponding with the wear mark along the fracture initiation site.

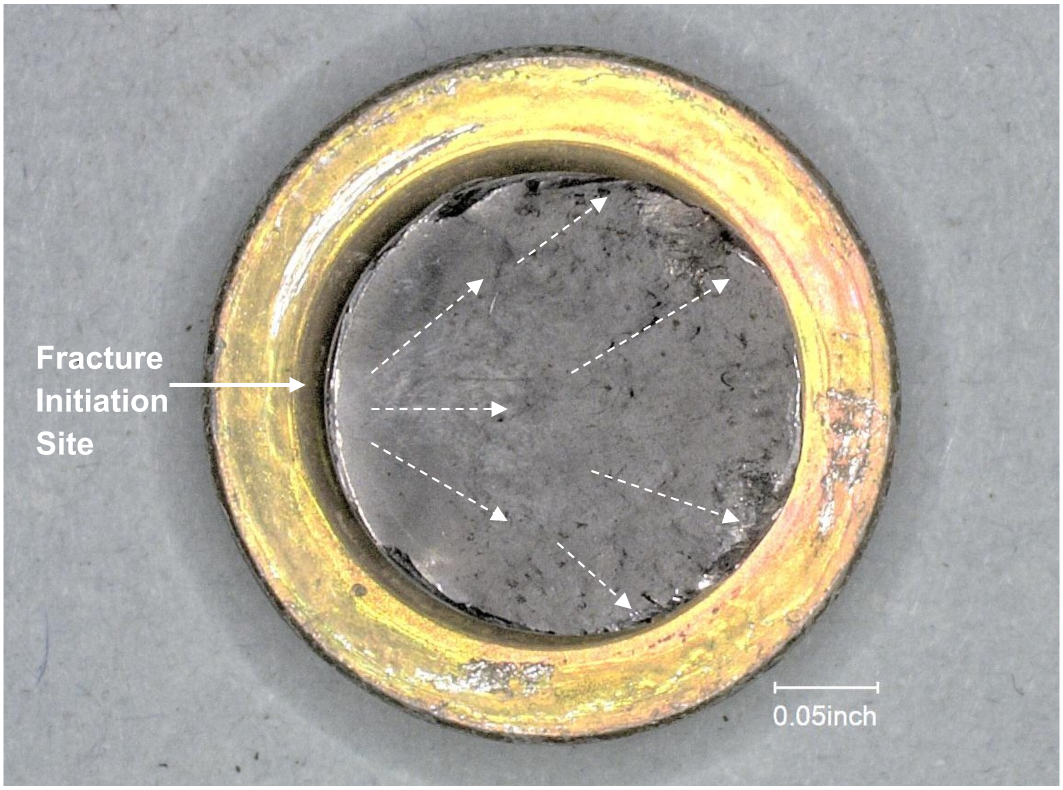

Figure 28 – Fracture surface of the recovered bolt. The fracture initiation and direction are noted (arrows).

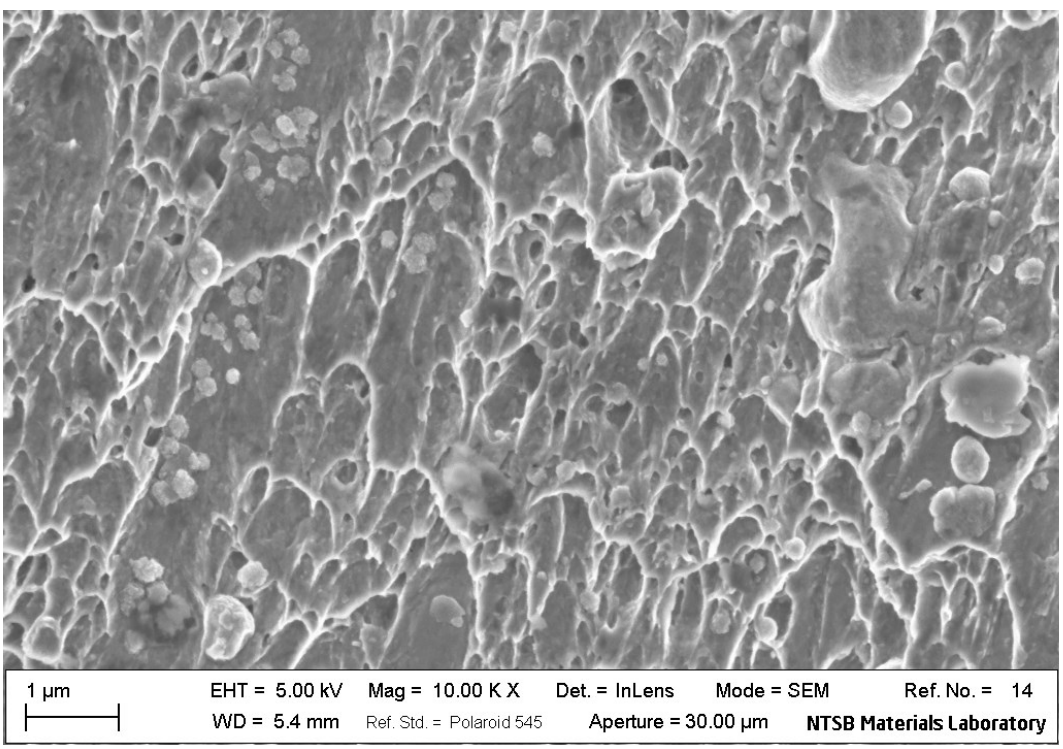

Figure 29 – SE micrograph of the fractured bolt from the actuator piston, showing dimple rupture indicative of overstress.

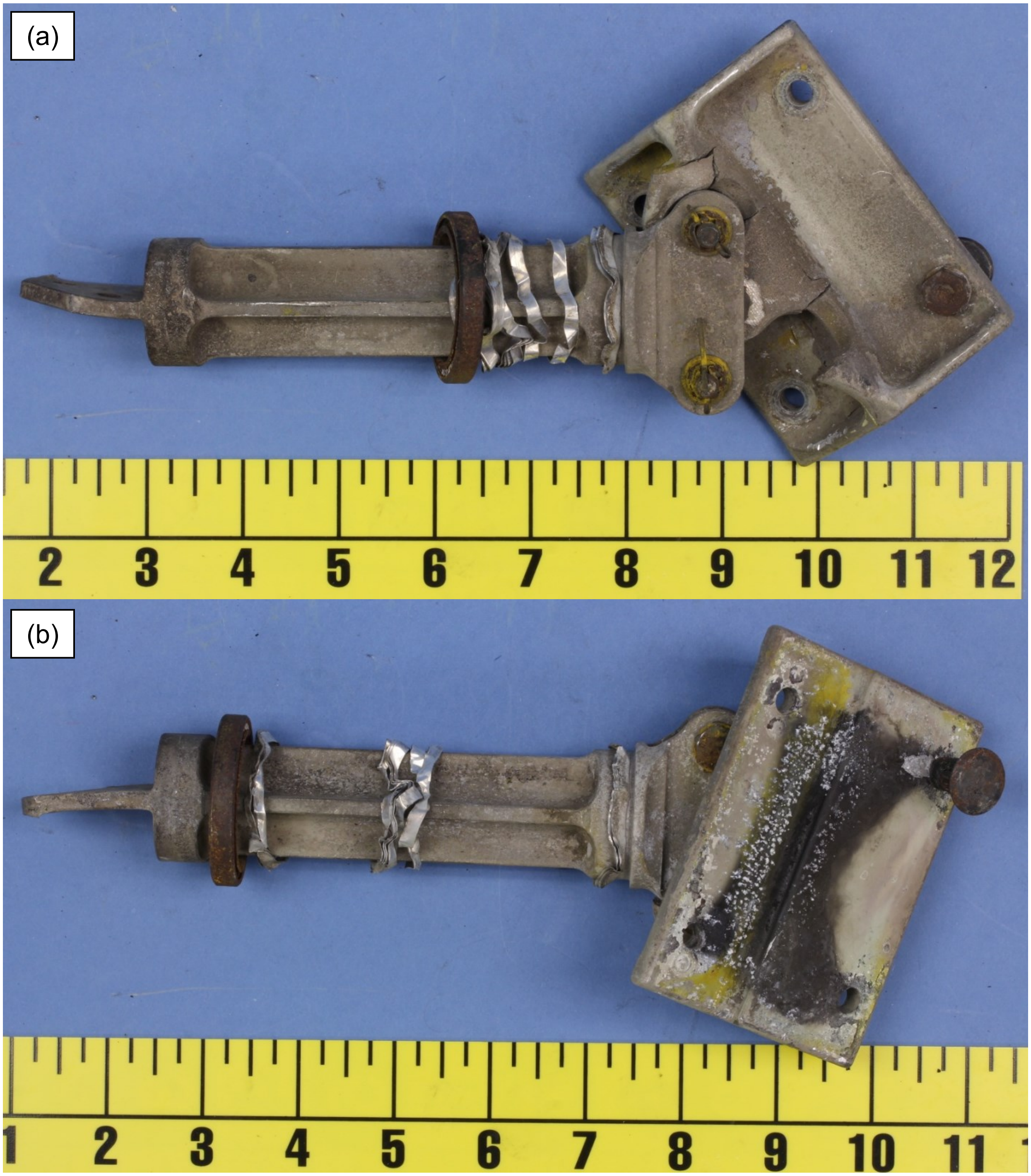

Figure 30 – Torque shaft and support bracket from opposite sides (a) and (b).