NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

March 5, 2021

Computed Tomography Specialist's Factual Report

DCA20LA100

A. ACCIDENT

Location:	Camp Dwyer, Afghanistan
Date:	April 20, 2020
Time:	0800 local time
Airplane:	Sikorsky S-61N helicopter, N908CH

B. GROUP

Computed Tomography Specialist:	Scott Warren National Transportation Safety Board Washington, D.C.

C. SUMMARY

On April 20, 2020, at approximately 0800 local time, a Sikorsky S-61N, N908CH, experienced a loss of control in flight and rolled on its side during an emergency landing at Camp Dwyer, Afghanistan. The three crew members onboard were seriously injured and the helicopter sustained substantial damage. The flight was operating under the provisions of 14 CFR Part 135 as a cargo flight under contract to the Department of Defense.

In accordance with ICAO Annex 13, the NTSB accepted delegation of the investigation from the Afghanistan Civil Aviation Authority.

The internal configuration of the auxiliary servocylinder assembly, the negative force gradient (NFG) spring, and the pressure transmitter from the accident helicopter were documented using radiographic images that were collected from October 27 – November 10, 2020 in Chicago, Illinois. A total of 13,057 computed tomography (CT) slice images were examined, processed, and analyzed by the NTSB to evaluate the components.

Review of the images determined that when the scans were conducted:

1. Aux Servo:
    a. There was possible material noted within the yaw servo in the area between a set of spool lands and the sleeve. After the first scan of this area (using the 1 MV machine), other scans using a target CT technique and the microfocus machine were conducted. In those scans, the radiographic indications of the possible material were not seen in the same area as noted in the first scan (although other anomalies, in other locations, were noted). After the target CT scans, another 1 MV scan was conducted of this area using a "2x oversample" technique designed to provide increased resolution. The 2x oversample scan also showed indications of possible material in the same area as the original scan.

       Since the possible material indications appeared in the 1 MV scans, but not the target CT microfocus scans, and the two sets of 1 MV scans were done before and after the target CT scans, the most likely explanation for these possible material indications is that they are a scan artifact, and there is no actual material in this location.

    b. There were no other abnormal indications noted within the aux servo scans.

2. NFG Spring:
    a. There were indications of voids in the bolt and pin surfaces, and there was low and medium density material noted at several locations within the spring.

    b. The spring appeared to be continuous with no indications of breaks or other anomalies.

3. Pressure Transmitter:
    a. There appeared to be a gap between the end of bellows 1 and the interior plate (the bellows was not flush against the plate.

    b. There were no other abnormal indications noted within the pressure transmitter scans.

D. DETAILS OF THE INVESTIGATION

1.0 General

The auxiliary servocylinder assembly (Aux Servo), the negative force gradient (NFG) spring, and the pressure transmitter from the accident helicopter were subjected to x-ray radiograph and computed tomography (CT) scanning to document their internal conditions. The scanning was conducted from October 27 – November 10, 2020 by Varex, Inc under the direction of the NTSB using the Actis 225 and Actis 1000 1 megavolt (MV) CT systems.

For the CT scans, the components were individually loaded into the imaging unit and placed on a turntable. The components were then rotated in front of the x-ray source, and the x-rays were captured by a detector after they went through the part. The x-ray source produced a cone shaped beam of x-rays, and the portion of the part imaged was adjusted slightly after each scan was completed until the entire assembly (or region of interest of the part) was scanned. The x-ray energy levels measured by the detector were recorded at several thousand different points during each rotation, and this information was converted into slice images using reconstruction algorithms.

The components were scanned using a total of 13,057 slices, and the total size of the combined data sets was approximately 81.1 GB. The complete scan protocols are given in table 1. The digital radiograph and CT axial slice images were provided by Varex to the NTSB where they were examined, processed, and analyzed to evaluate the components.

Table 1
Scan Protocols

Component	Aux Servo 1 MV scan	Aux Servo target CT scans	Aux Servo 1 MV 2x oversample[1] scan	NFG spring	Pressure transmitter
Number of slices	1399	3431 (combined over three scans)	111	3576	4201
Voxel[2] Size - X Direction (millimeters (mm))	0.27	0.074	0.27	0.083	0.041
Voxel Size - Y Direction (mm)	0.27	0.074	0.27	0.083	0.041
Voxel Size - Z Direction (mm)	0.40	0.08	1.0	0.08	0.040
Image Projections per Revolution	1800	2160	5040	1800	1800
Exposure time (milliseconds (ms))	10	285.61	10	285.61	285.61
Frames to Avg (frames per projection)	2	2	1	2	2
X-ray Source Voltage (kilovolts)	1000	223	1000	222	222
X-ray beam flux or current (milliamps (mA))[3]	2.5 ms period, 4 pulses/view	580	2.5 ms period, 4 pulses/view	550	550
Source Filter Thickness (mm)	3.3	1	3.3	1	2
Source Filter Material	Steel	Brass	Steel	Brass	Brass
Image Matrix Size (pixels)	2048 x 2048	2048 x 2048	2048 x 2048	1024 x 1024	2048 x 2048

The data sets of slice images were examined, processed, and analyzed by the NTSB using the VGStudioMax software package to convert the axial slice data

[1] A technique known as 2-times oversampling is used to improve spatial resolution. It essentially involves acquiring one slice in a full 360-degree rotation then shifting the detector array 0.5 mm and acquiring a second slice at the same position. The two scans are algorithmically combined during reconstruction. The technique algorithmically doubles the size of the detector to oversample the data in the x, y plane.
[2] A voxel is a three-dimensional picture element (pixel).
[3] X-ray flux is shown for MV scans while current is shown for the microfocus scans. Both of these characteristics indicate the photon flux used to create the scan images.

into orthogonal slice images and a three-dimensional reconstructed image of the component. As part of the evaluation, some sections of the components were digitally removed or rendered transparent to allow closer observation of interior parts. In the images, the higher density areas were shown as brighter shades of gray and lower density areas were shown as darker shades of gray. The pointers shown in some of the images denote specific areas of interest within that image.

The images of the components were examined for any signs of missing or damaged parts, contamination, or any other anomalies. Specific results (including example images) are presented in subsequent sections of this report.

2.0 Computed Tomography Results

The computed tomography (CT) results for the components are shown in figures 1 through 52. Review of the images determined that when the scans were conducted:

1. Aux Servo:
    a. There was possible material noted within the yaw servo in the area between a set of spool lands and the sleeve. After the first scan of this area (using the 1 MV machine), other scans using a target CT technique and the microfocus machine were conducted. In those scans, the radiographic indications of the possible material were not seen in the same area as noted in the first scan (although other anomalies, in other locations, were noted). After the target CT scans, another 1 MV scan was conducted of this area using a "2x oversample" technique designed to provide increased resolution. The 2x oversample scan also showed indications of possible material in the same area as the original scan.

       Since the possible material indications appeared in the 1 MV scans, but not the target CT microfocus scans, and the two sets of 1 MV scans were done before and after the target CT scans, the most likely explanation for these possible material indications is that they are a scan artifact, and there is no actual material in this location.

    b. There were no other abnormal indications noted within the aux servo scans.

2. NFG Spring:
    a. There were indications of voids in the bolt and pin surfaces, and there was low and medium density material noted at several locations within the spring.

b. The spring appeared to be continuous with no indications of breaks or other anomalies.

3. Pressure Transmitter:
    a. There appeared to be a gap between the end of bellows 1 and the interior plate (the bellows was not flush against the plate.

    b. There were no other abnormal indications noted within the pressure transmitter scans.

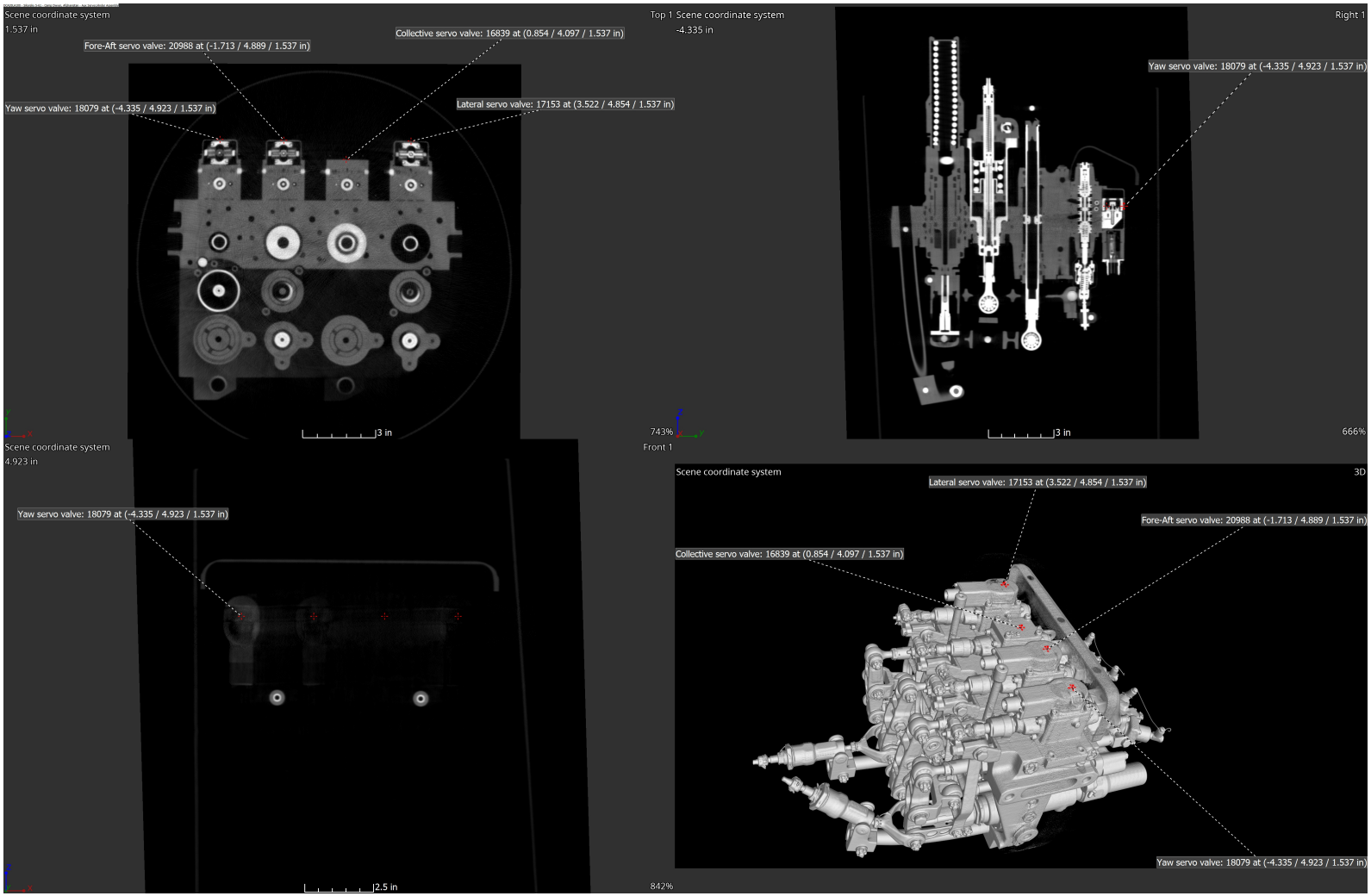


Figure 1
Aux Servo - overview

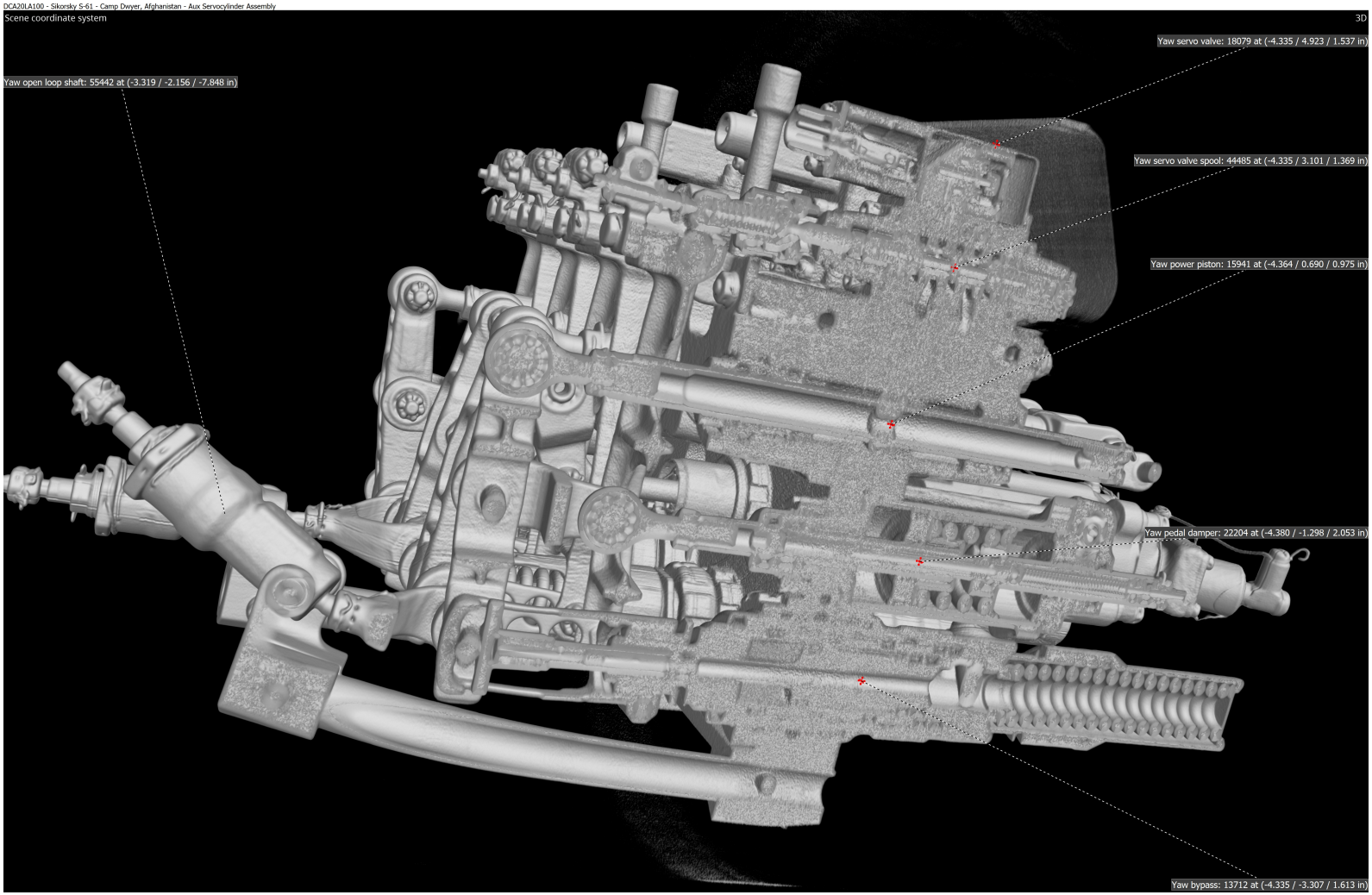


Figure 2
Aux Servo – yaw components overview

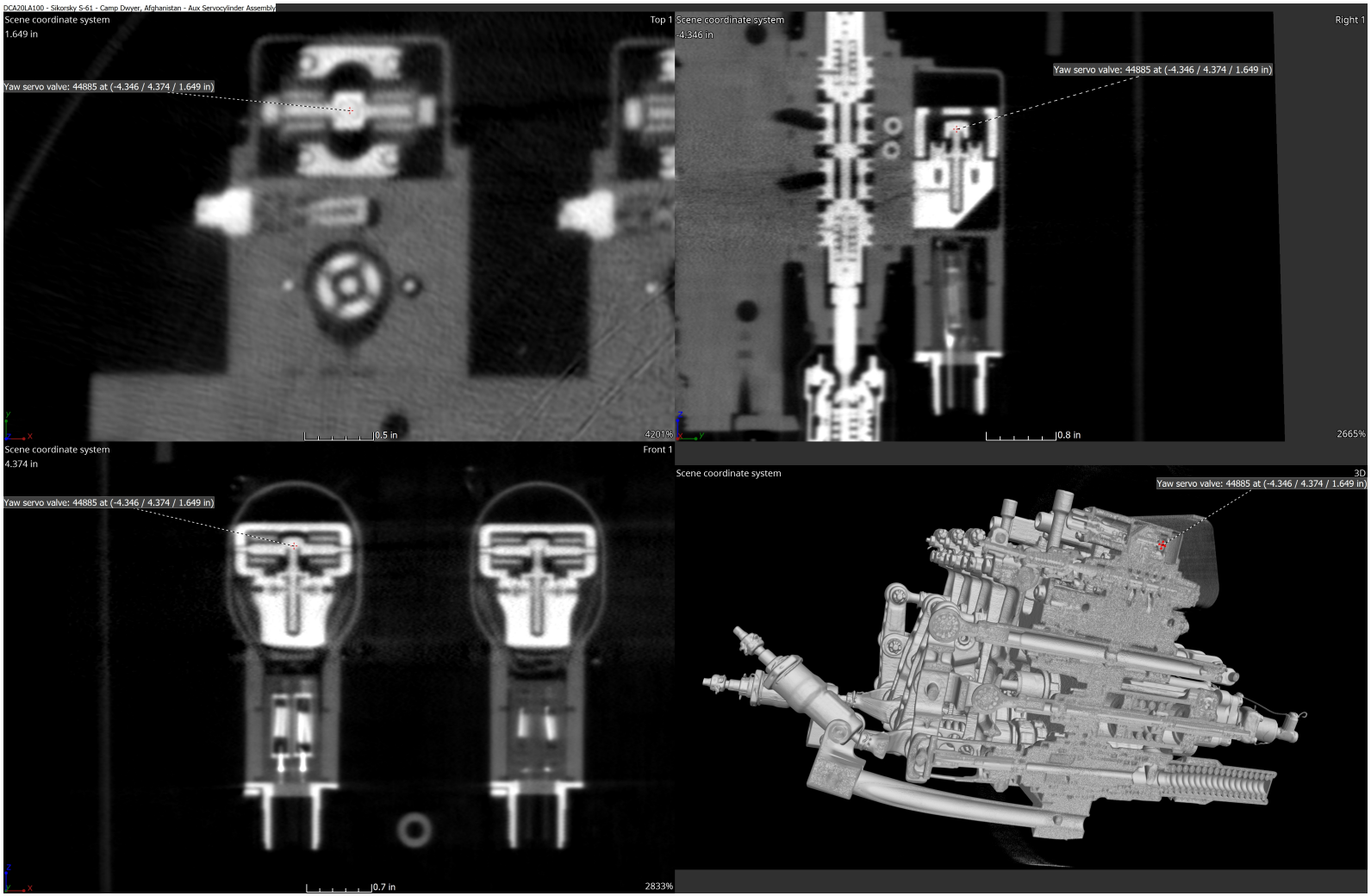


Figure 3
Aux Servo – yaw servo valve

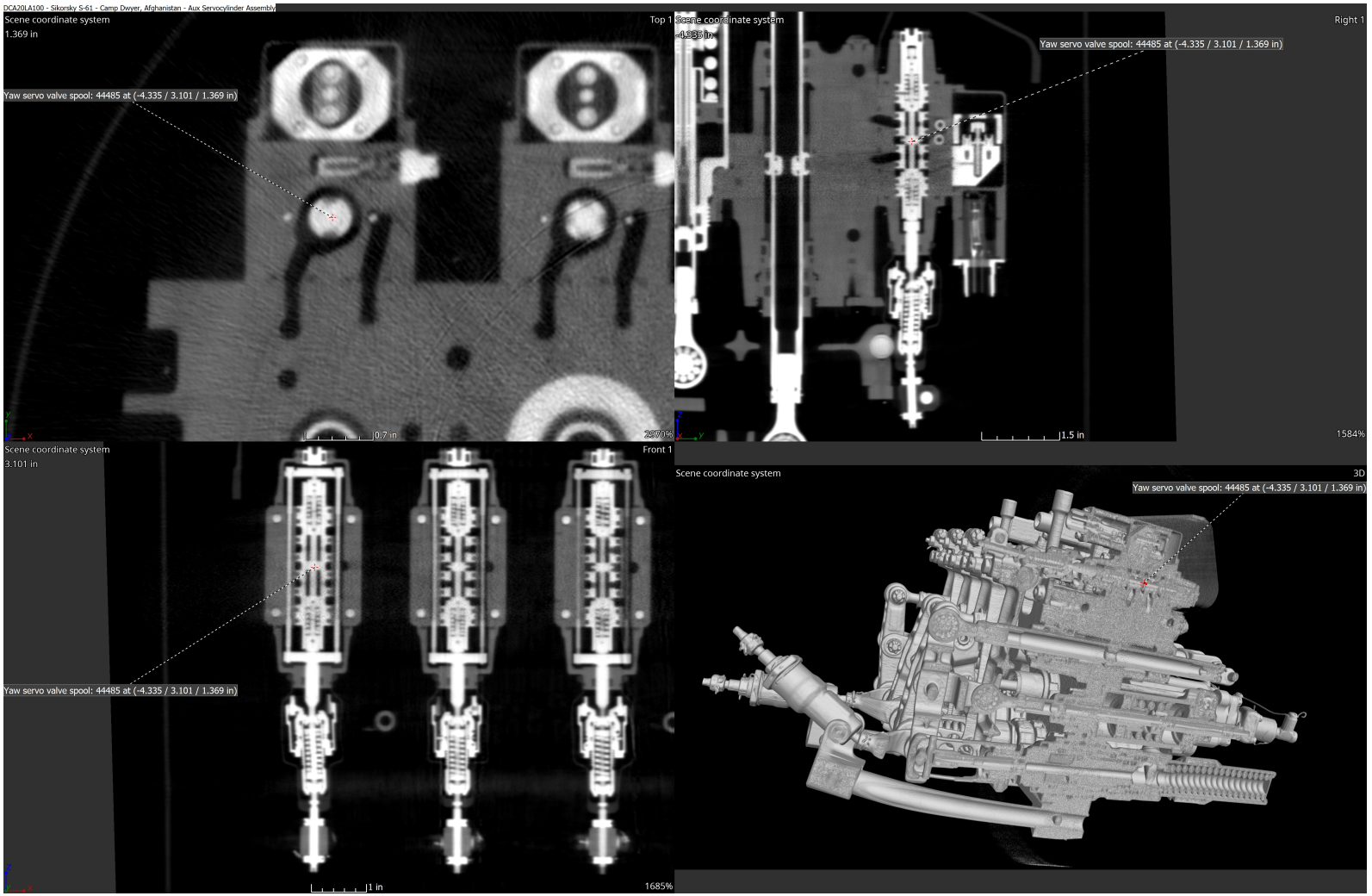


Figure 4
Aux Servo – yaw servo valve spool

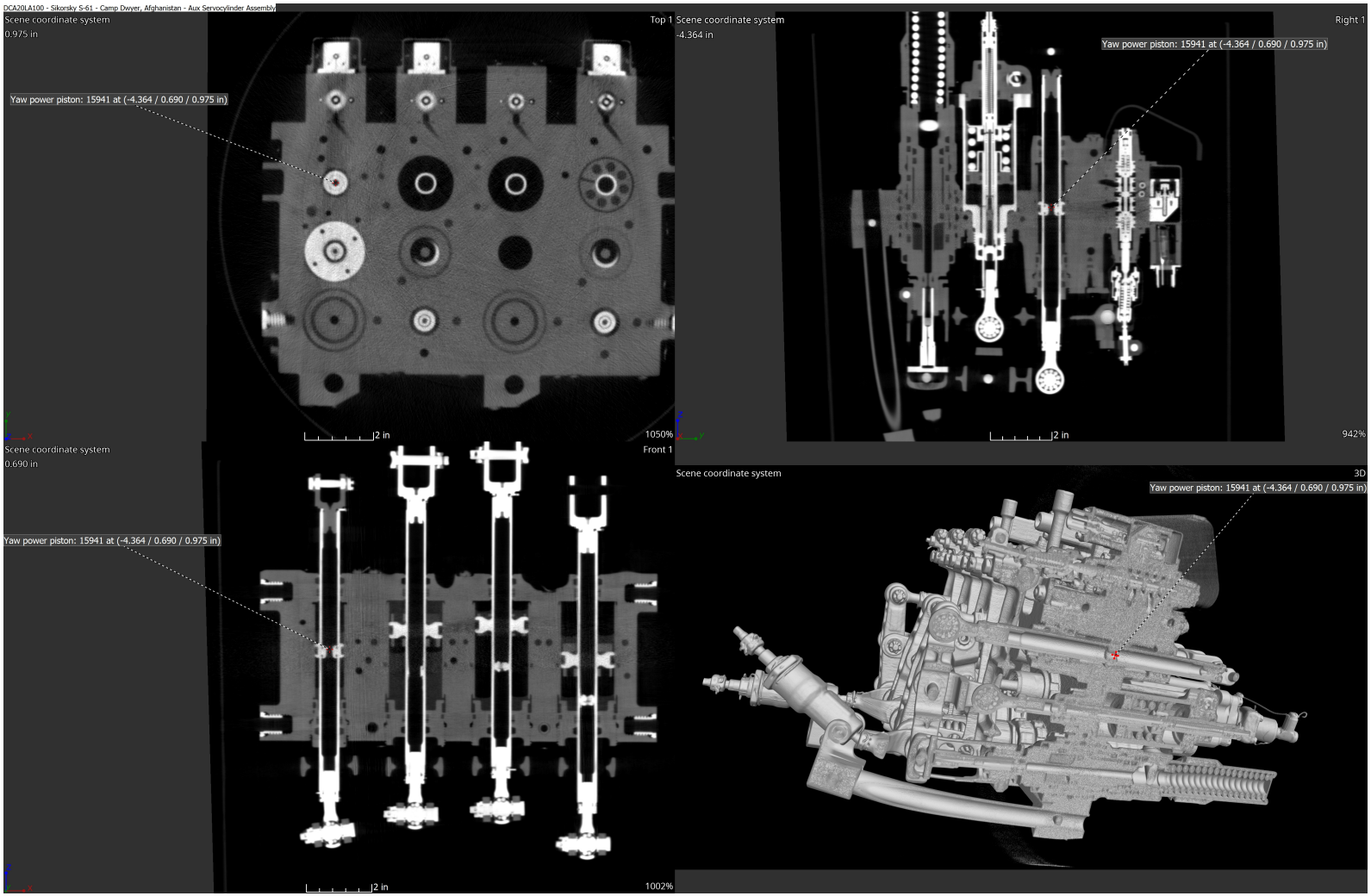


Figure 5
Aux Servo – yaw power piston

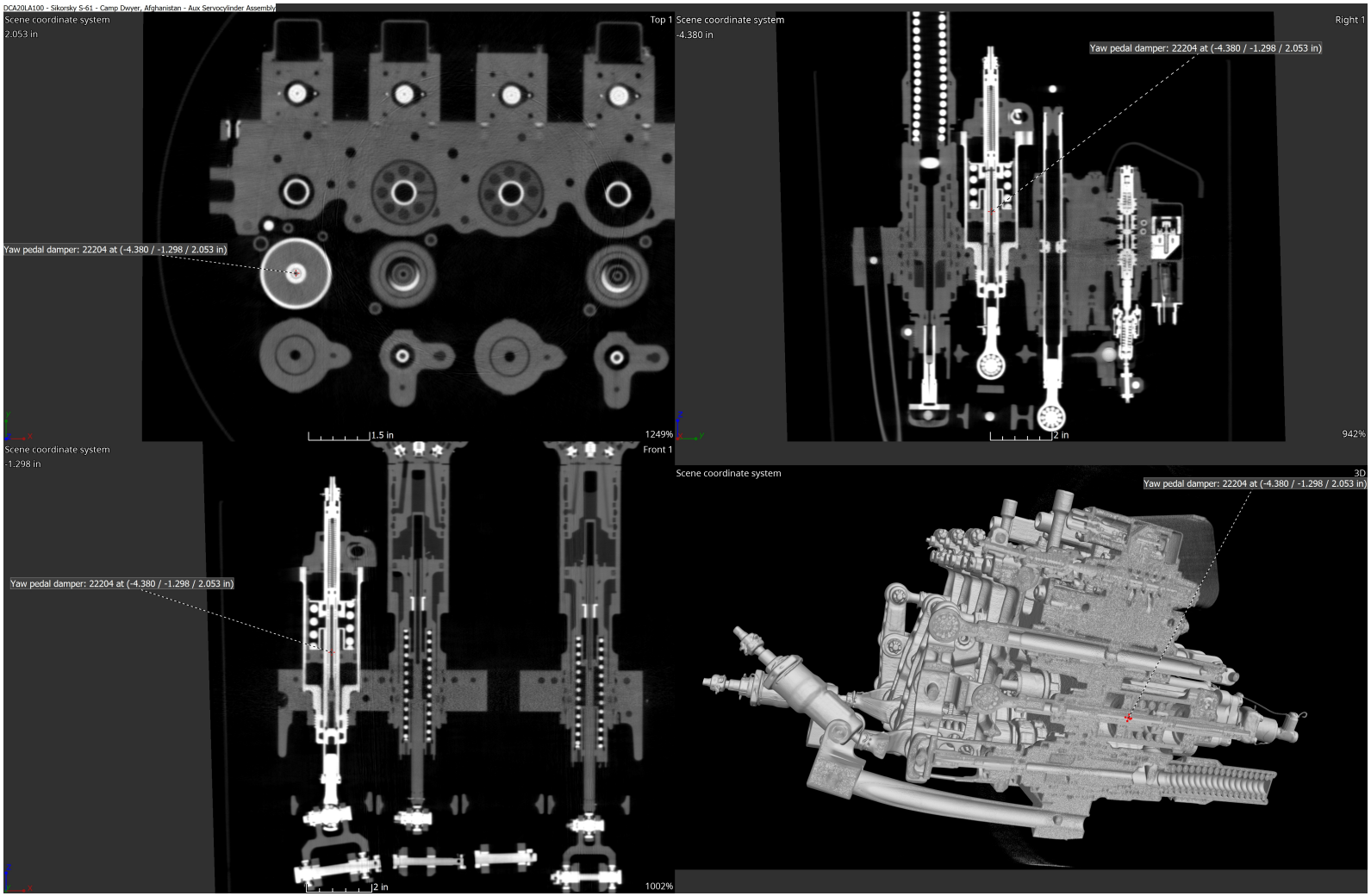


Figure 6
Aux Servo – yaw pedal damper

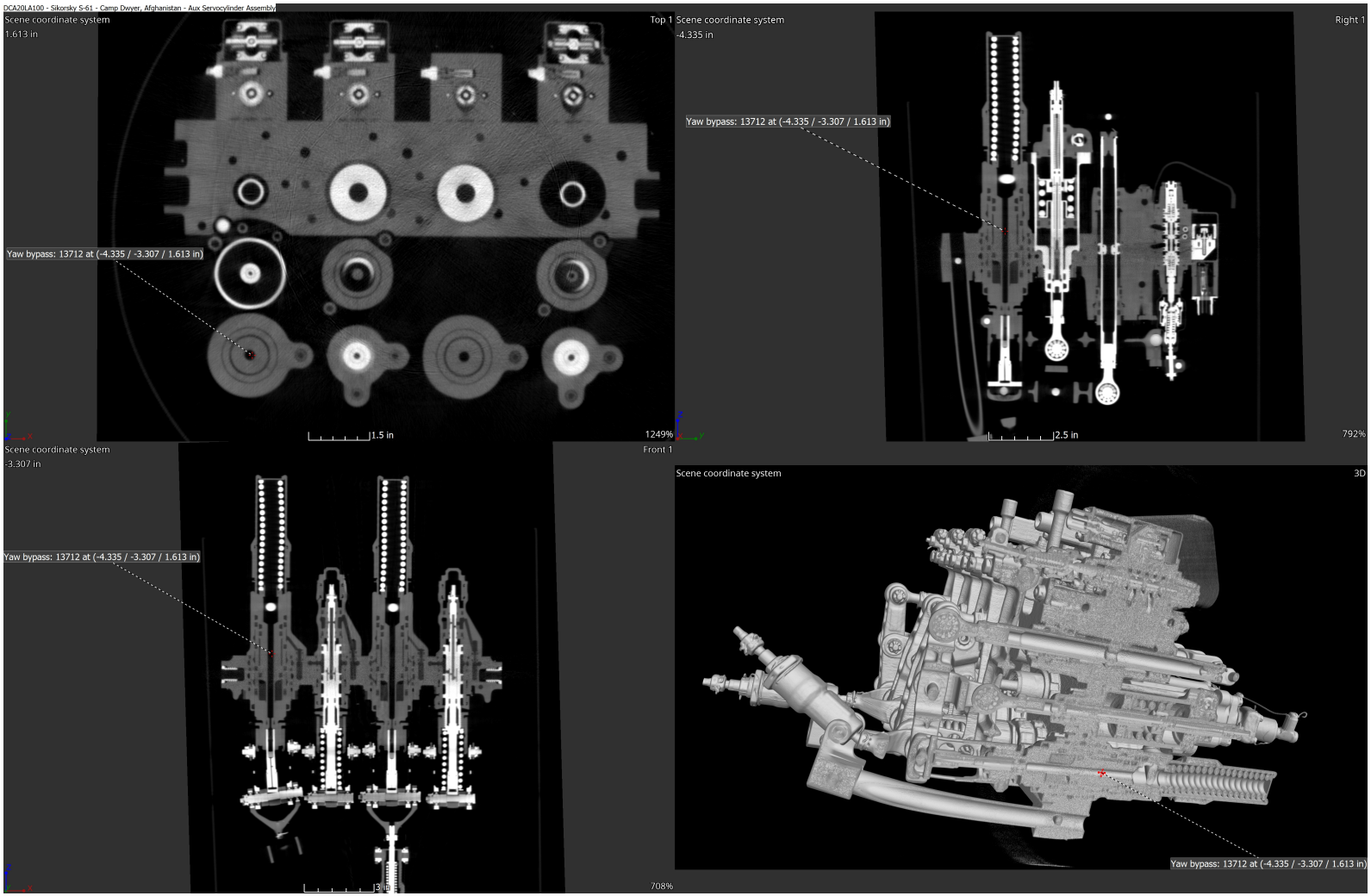


Figure 7
Aux Servo – yaw bypass

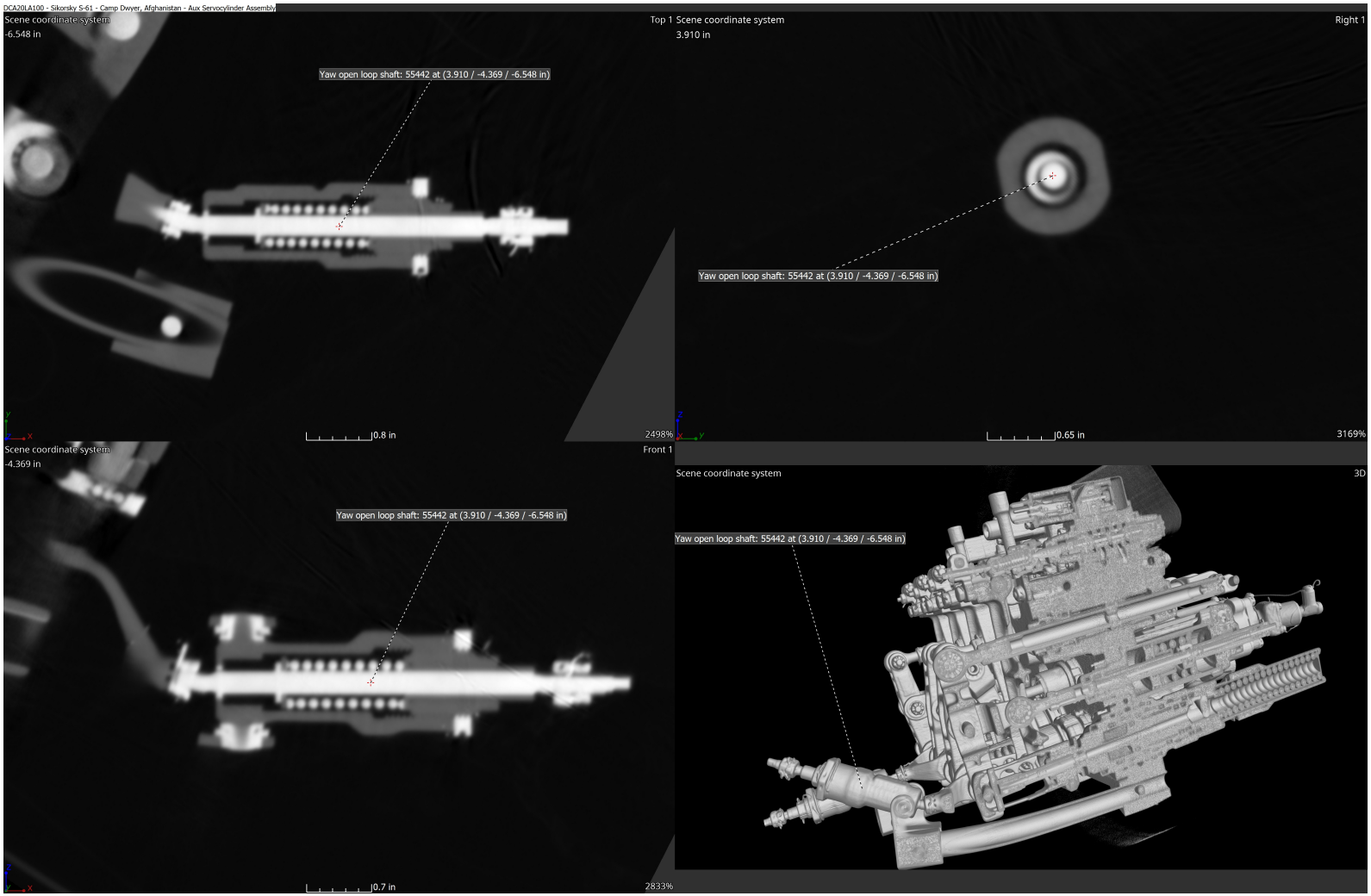


Figure 8
Aux Servo – yaw open loop shaft

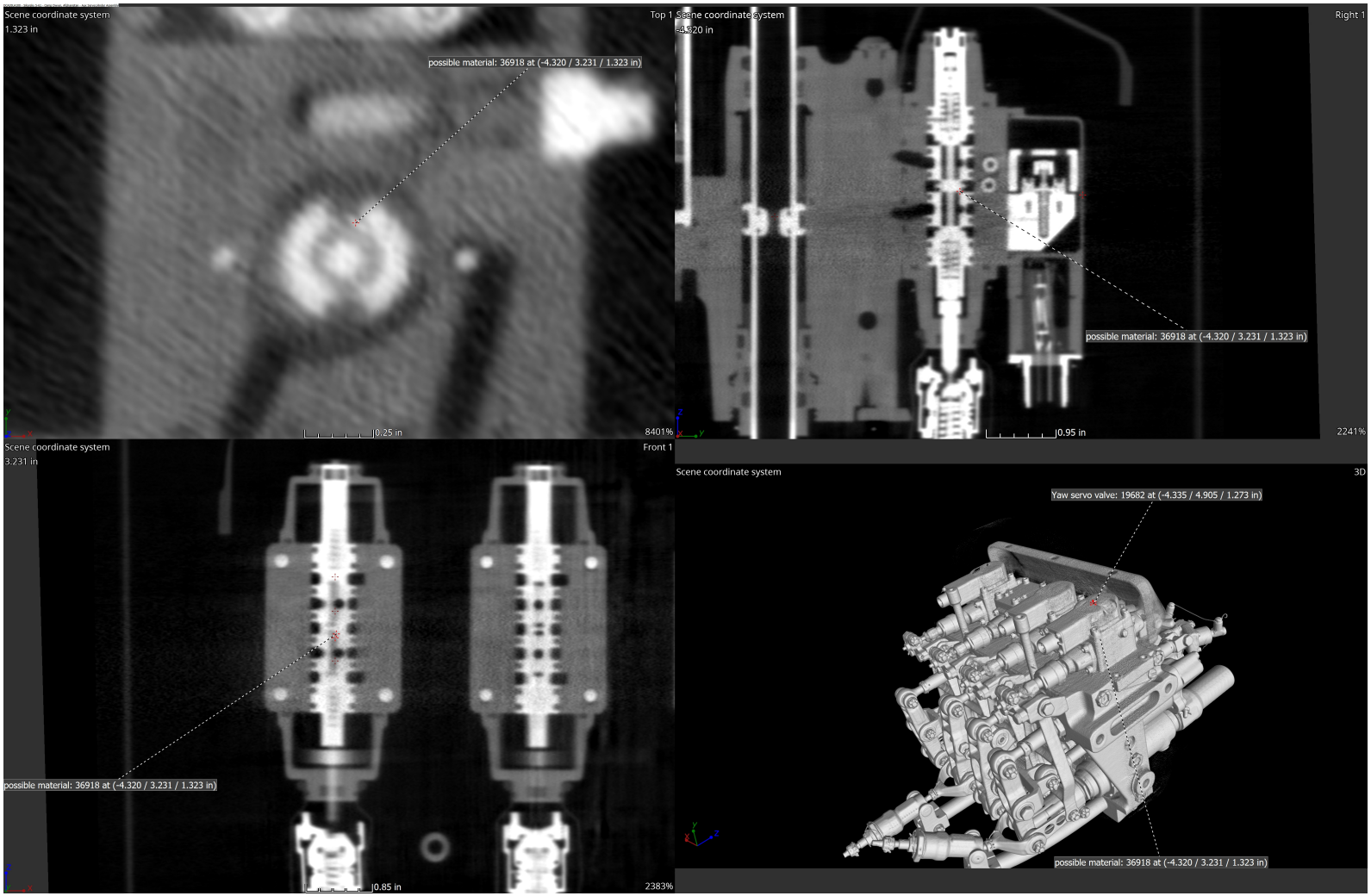


Figure 9
Aux Servo – yaw servo spool - possible material

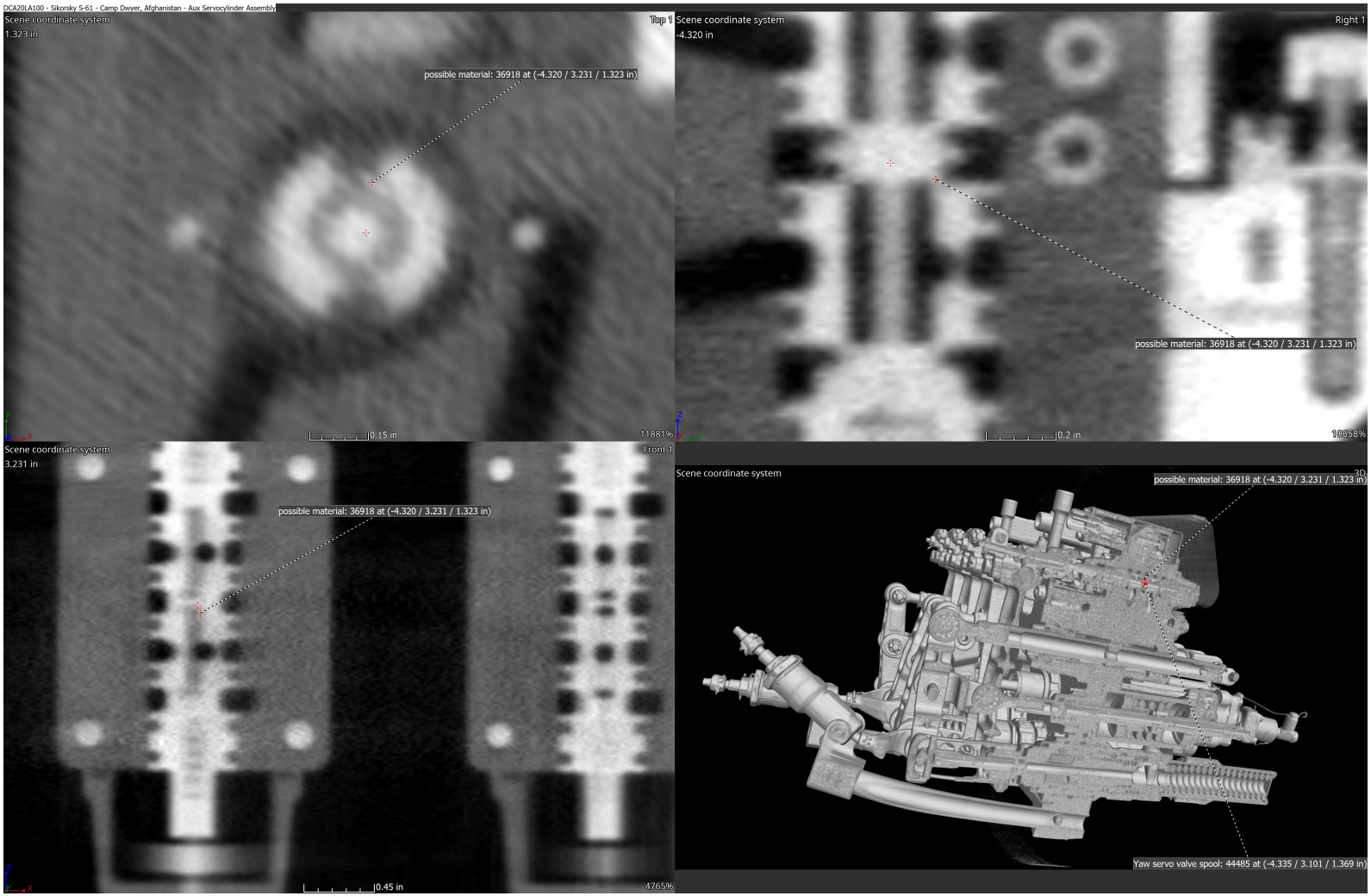


Figure 10
Aux Servo – yaw servo spool - possible material – closeup view

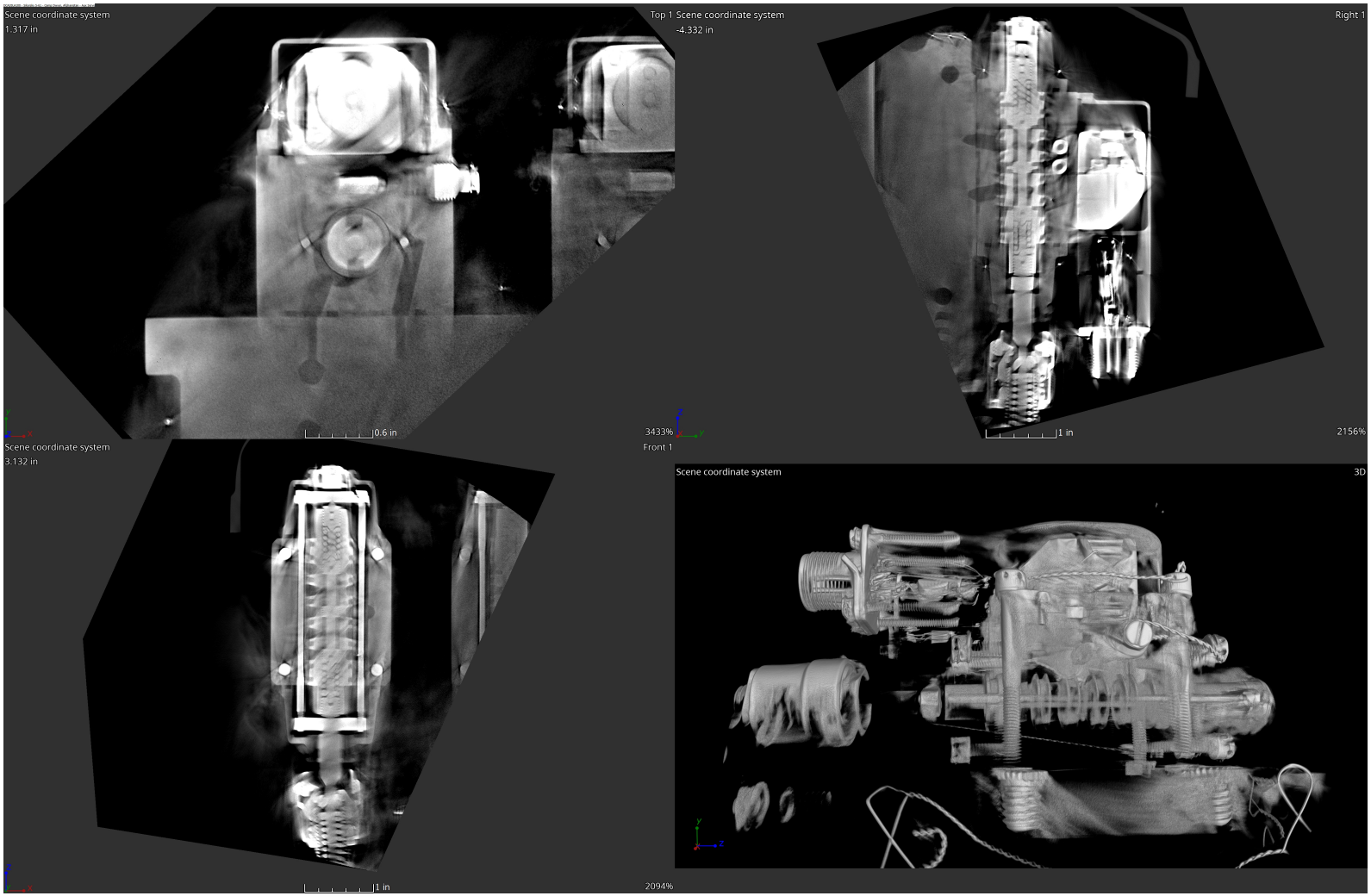


Figure 11
Aux Servo – target CT – yaw servo sleeve and spool overview

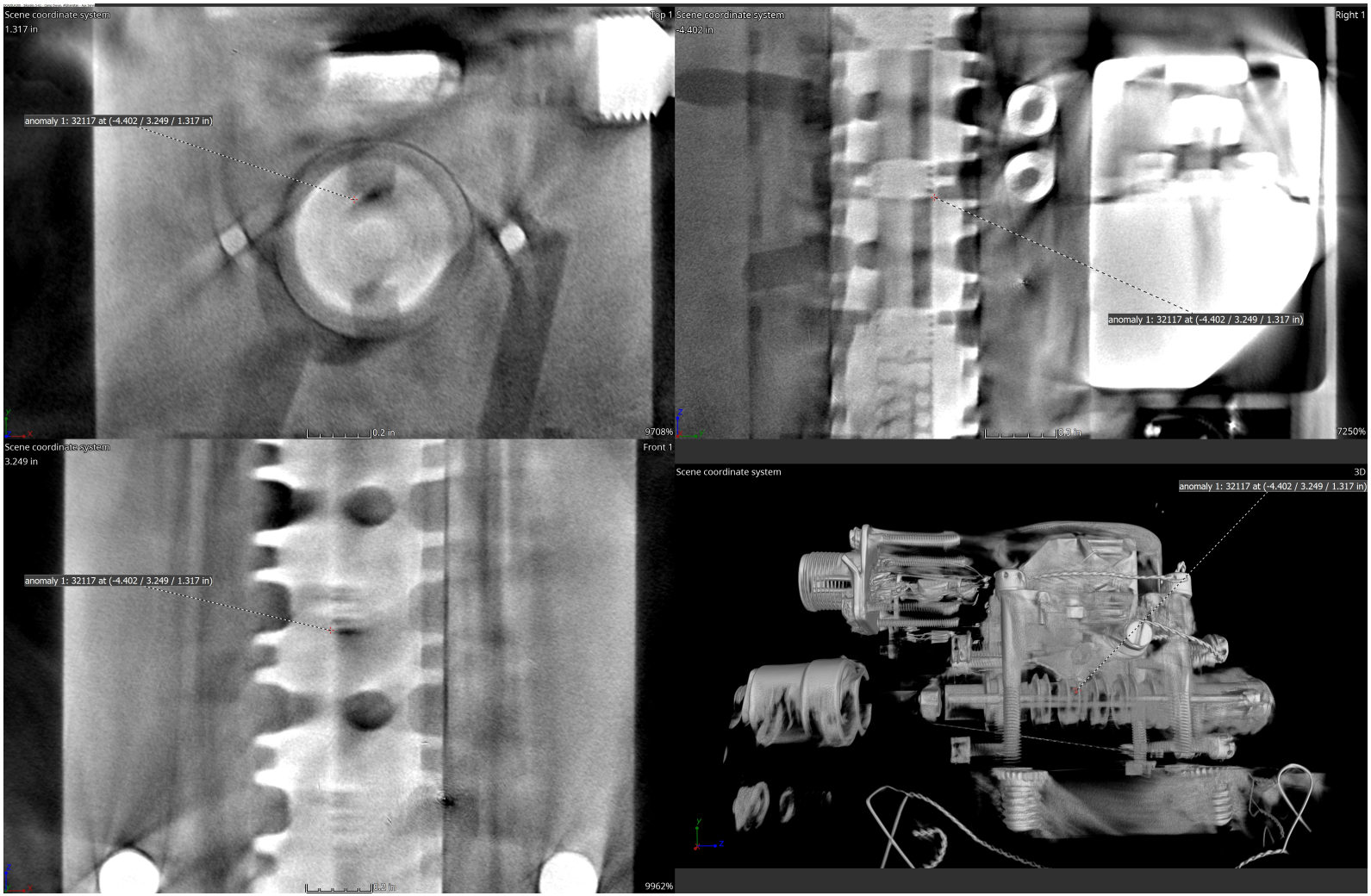


Figure 12
Aux Servo – target CT – yaw servo sleeve and spool anomaly 1

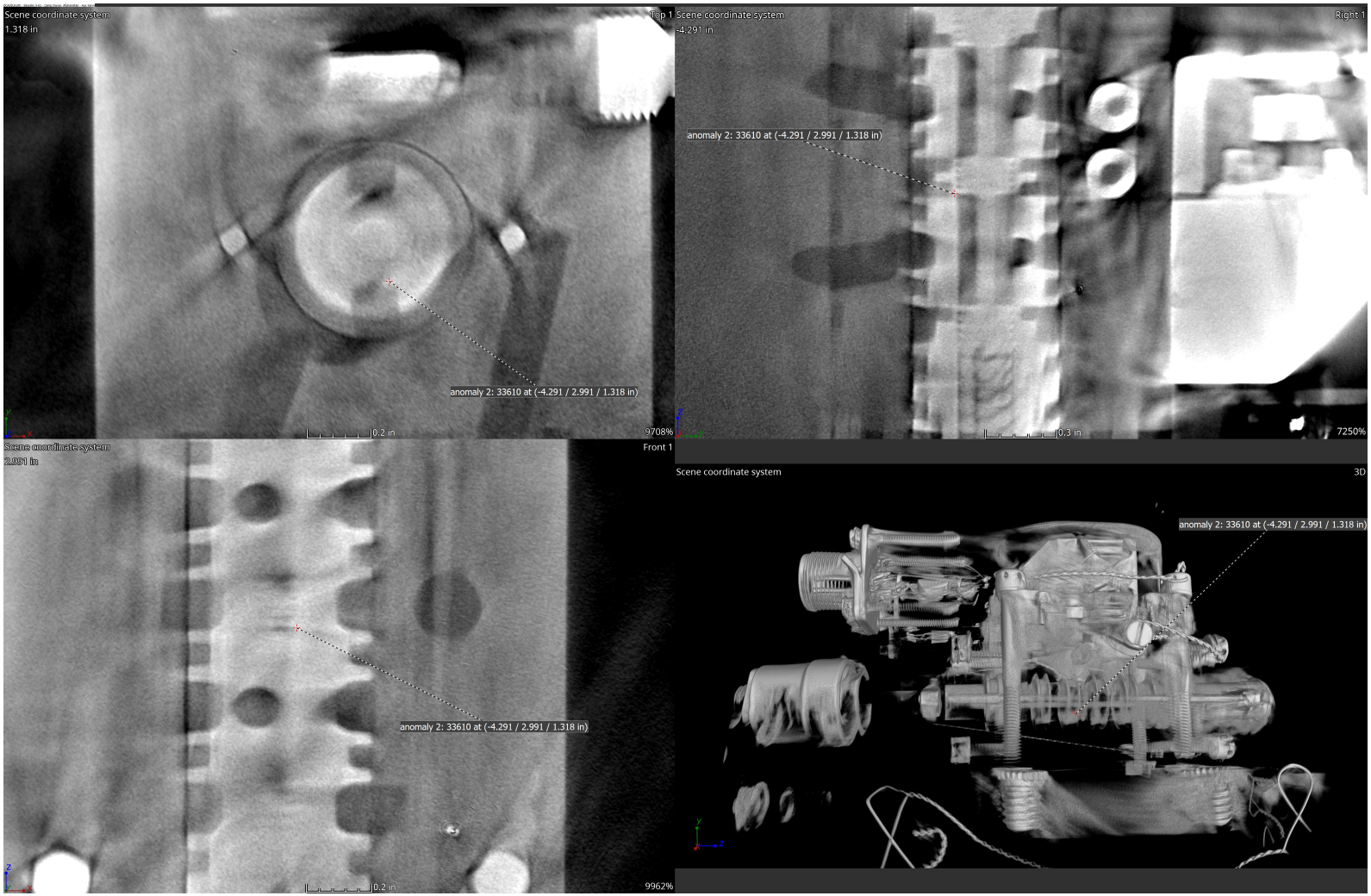


Figure 13
Aux Servo – target CT – yaw servo sleeve and spool anomaly 2

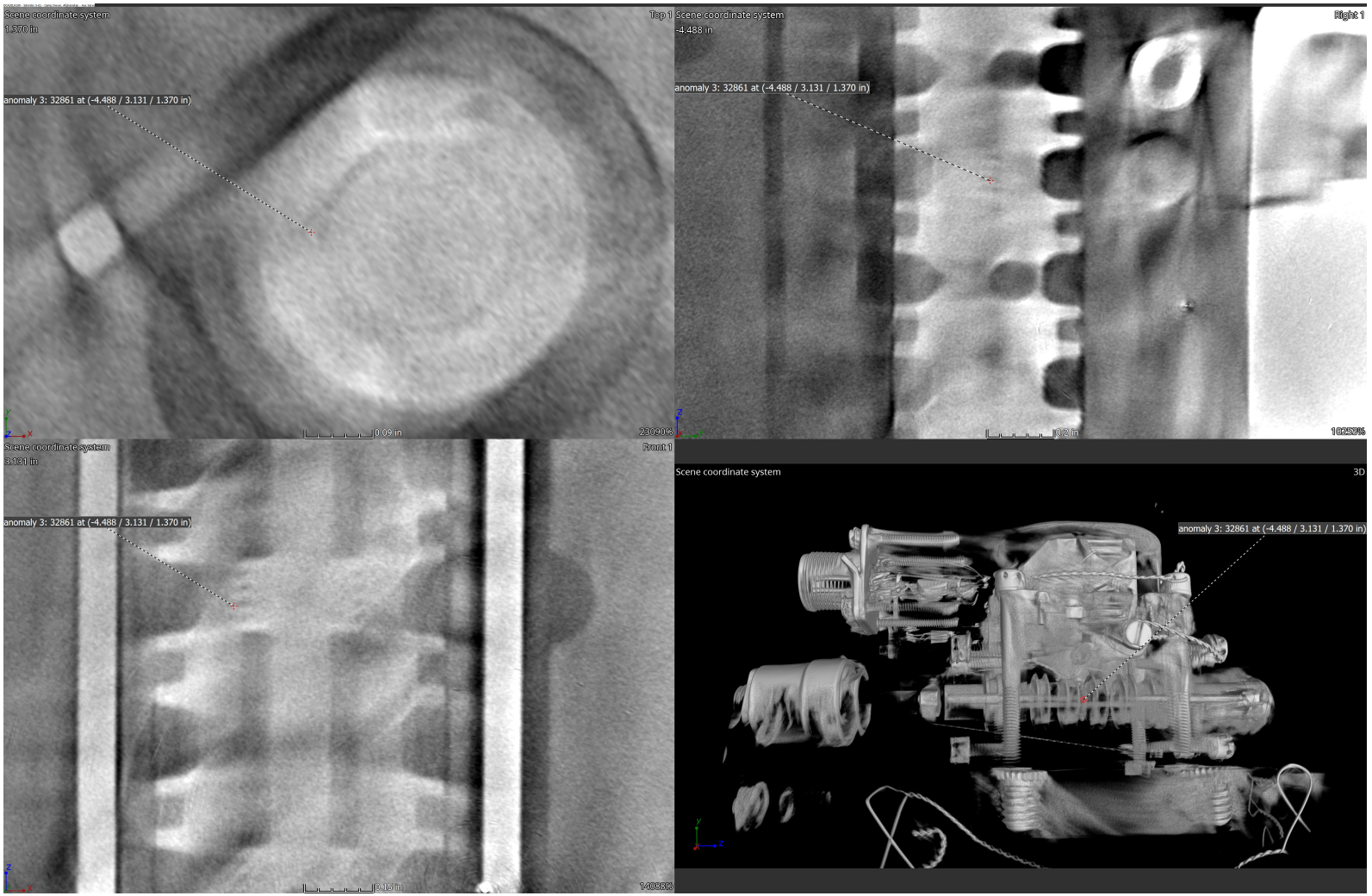


Figure 14
Aux Servo – target CT – yaw servo sleeve and spool anomaly 3

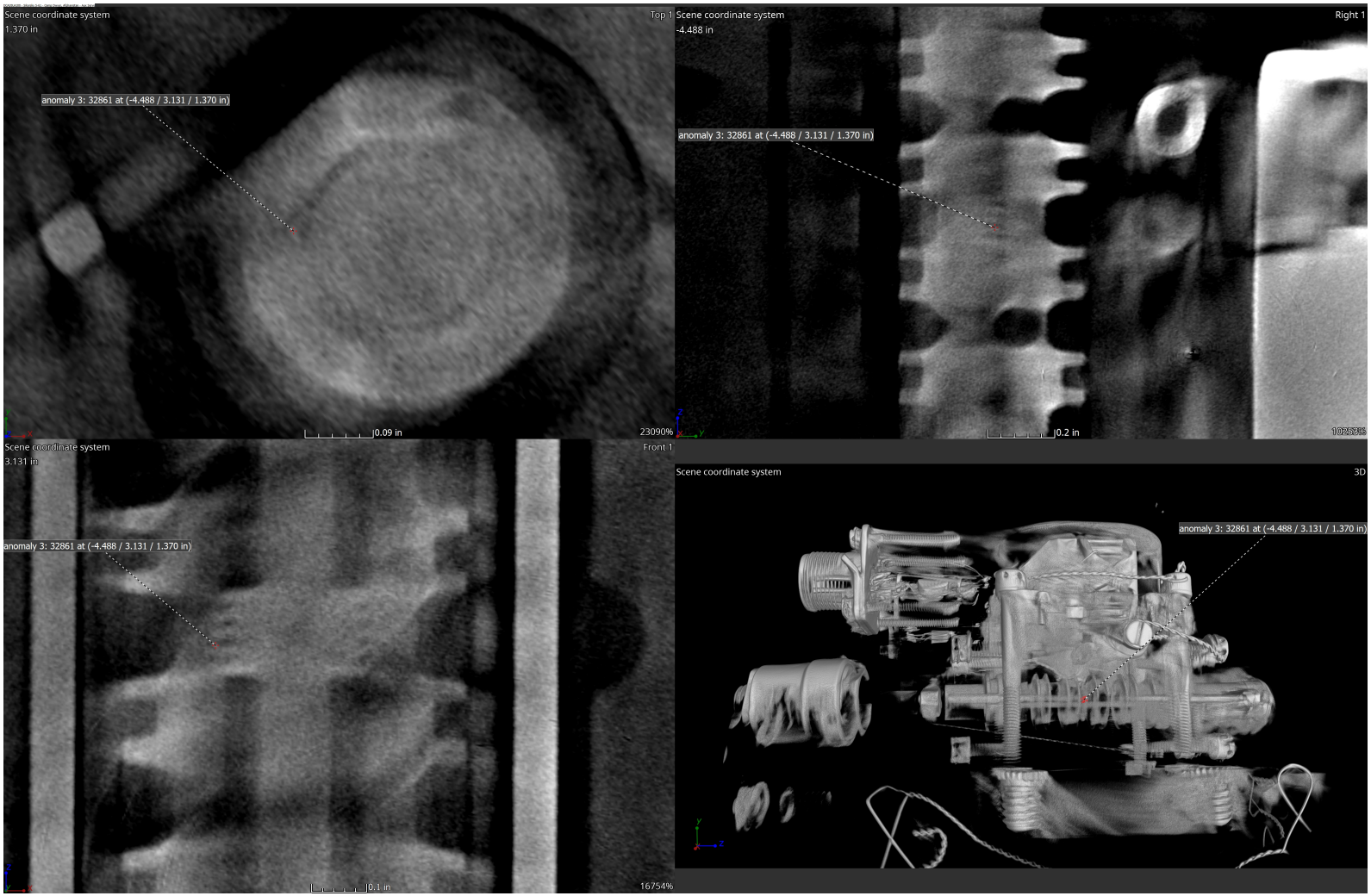


Figure 15
Aux Servo – target CT – yaw servo sleeve and spool anomaly 3 (altered contrast)

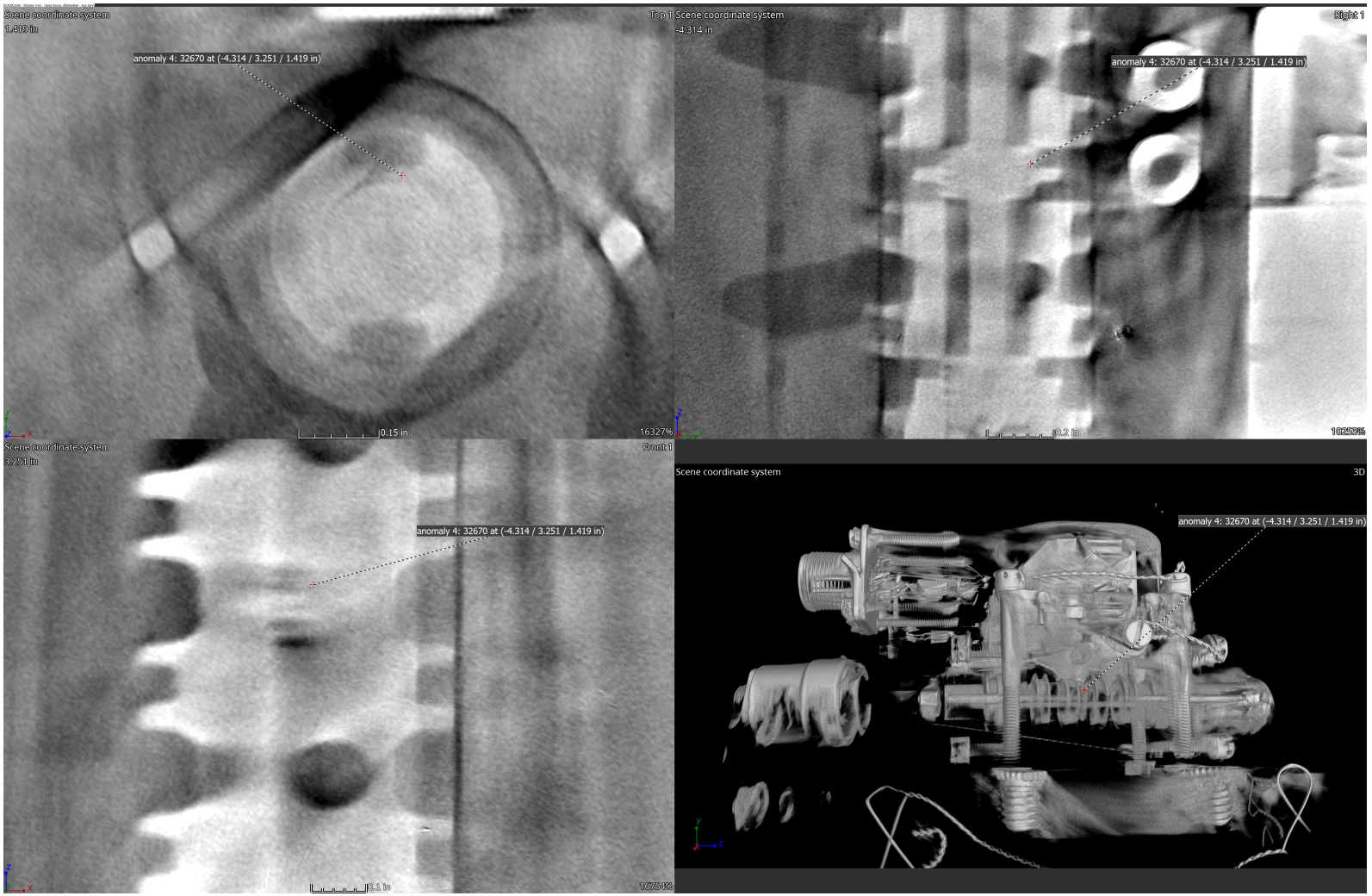


Figure 16
Aux Servo – target CT – yaw servo sleeve and spool anomaly 4

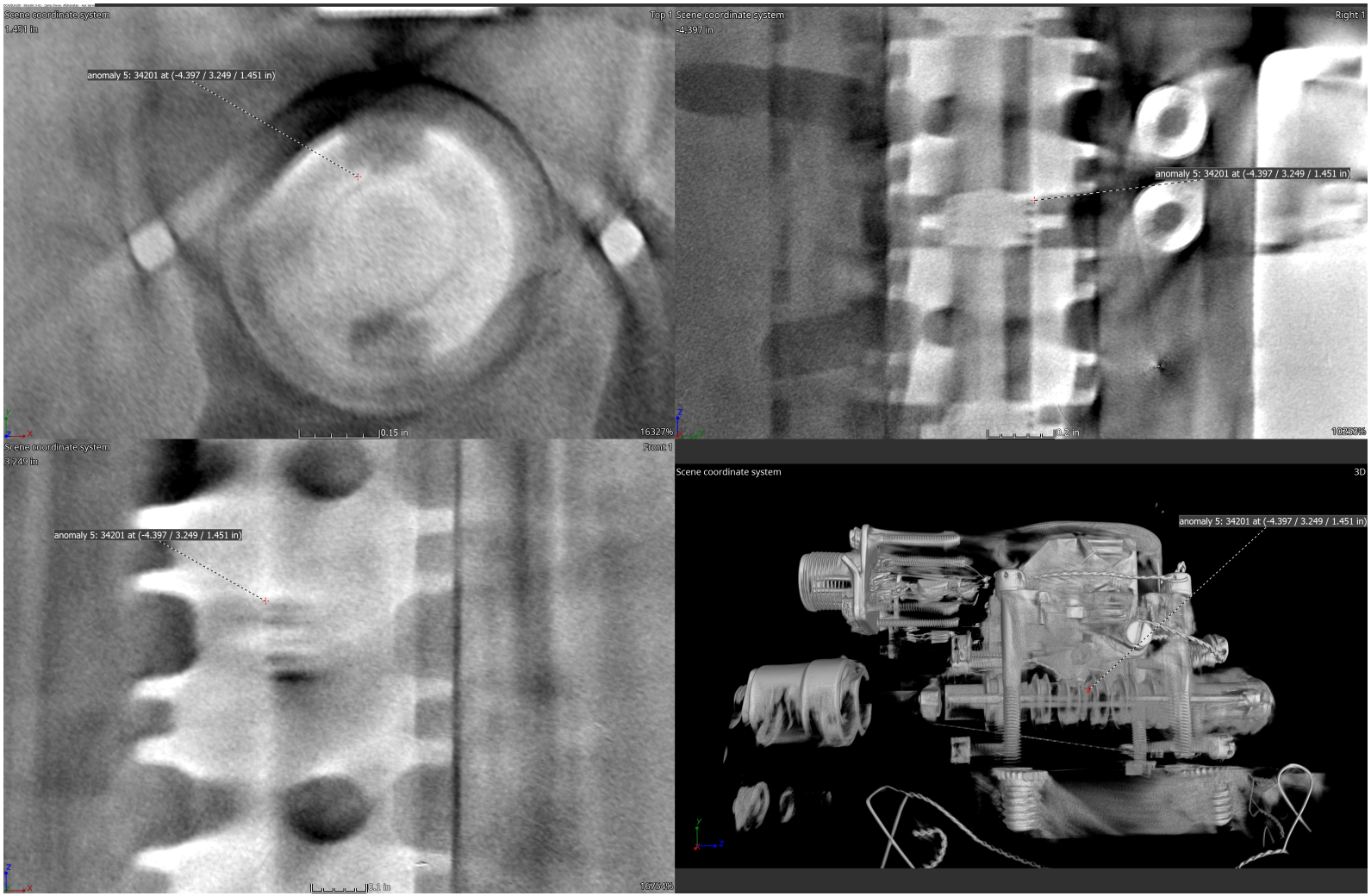


Figure 17
Aux Servo – target CT – yaw servo sleeve and spool anomaly 5

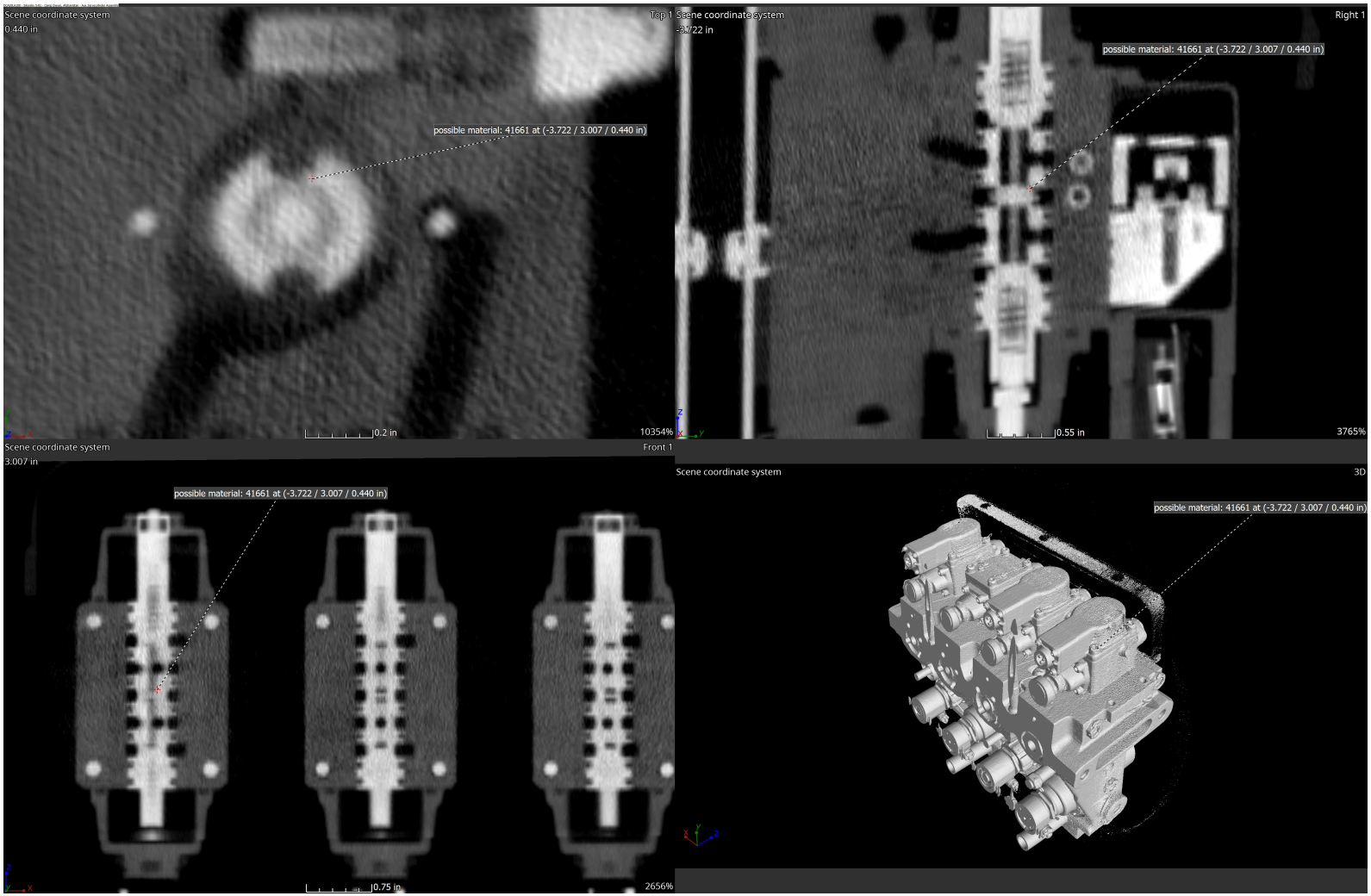


Figure 18
Aux Servo – 2x oversample – yaw servo spool - possible material

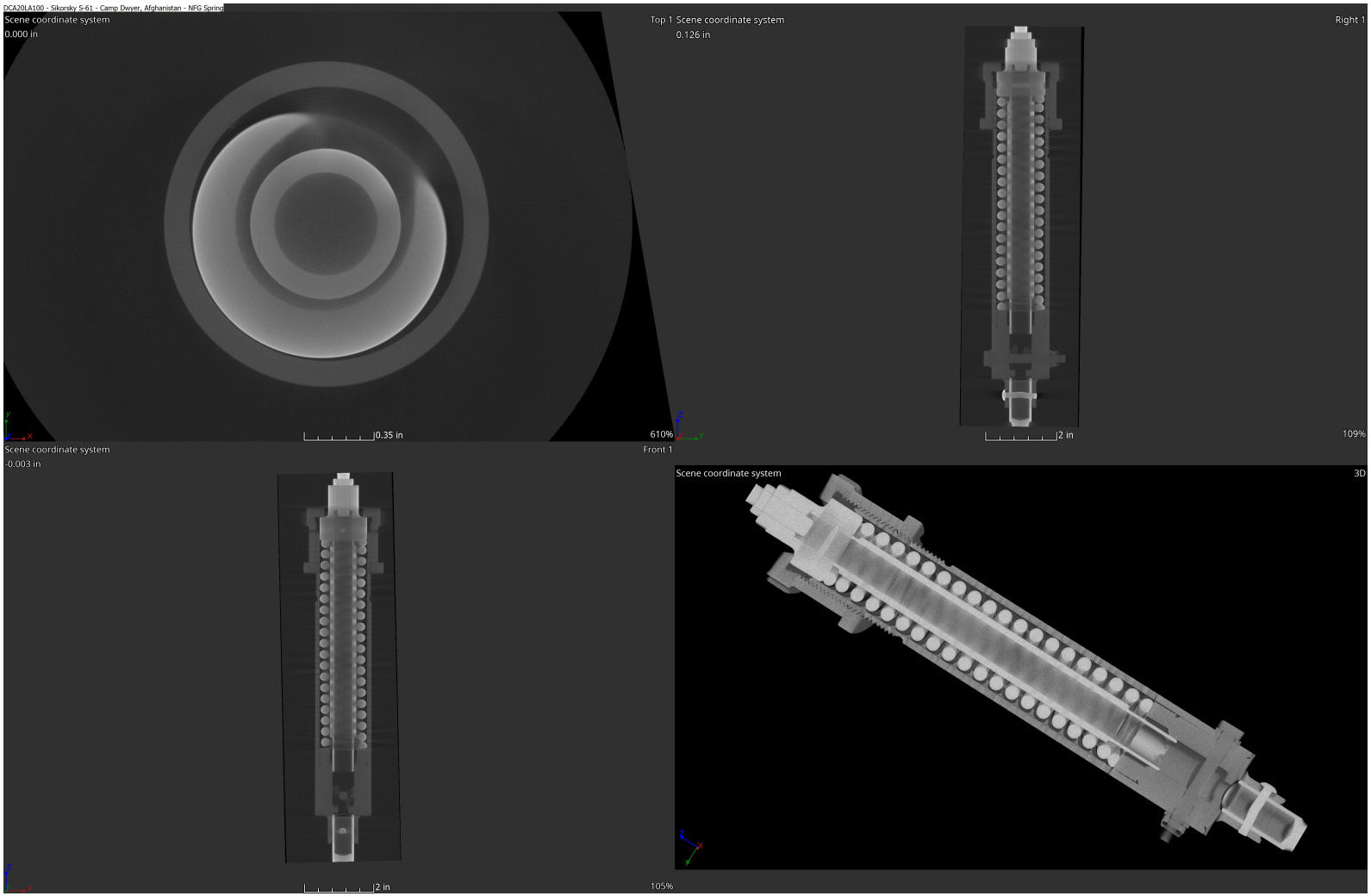


Figure 19
NFG spring - overview

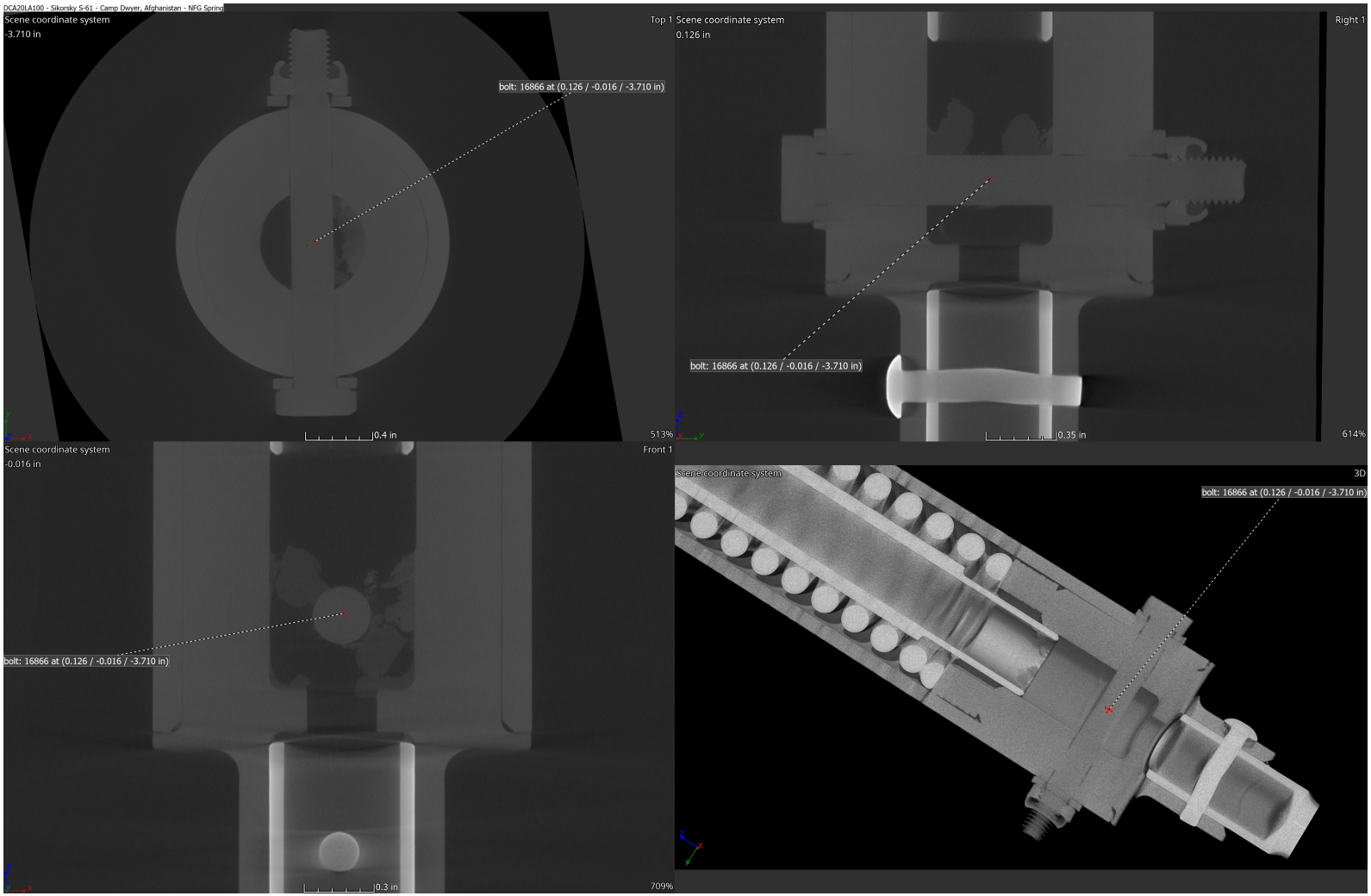


Figure 20
NFG spring - bolt

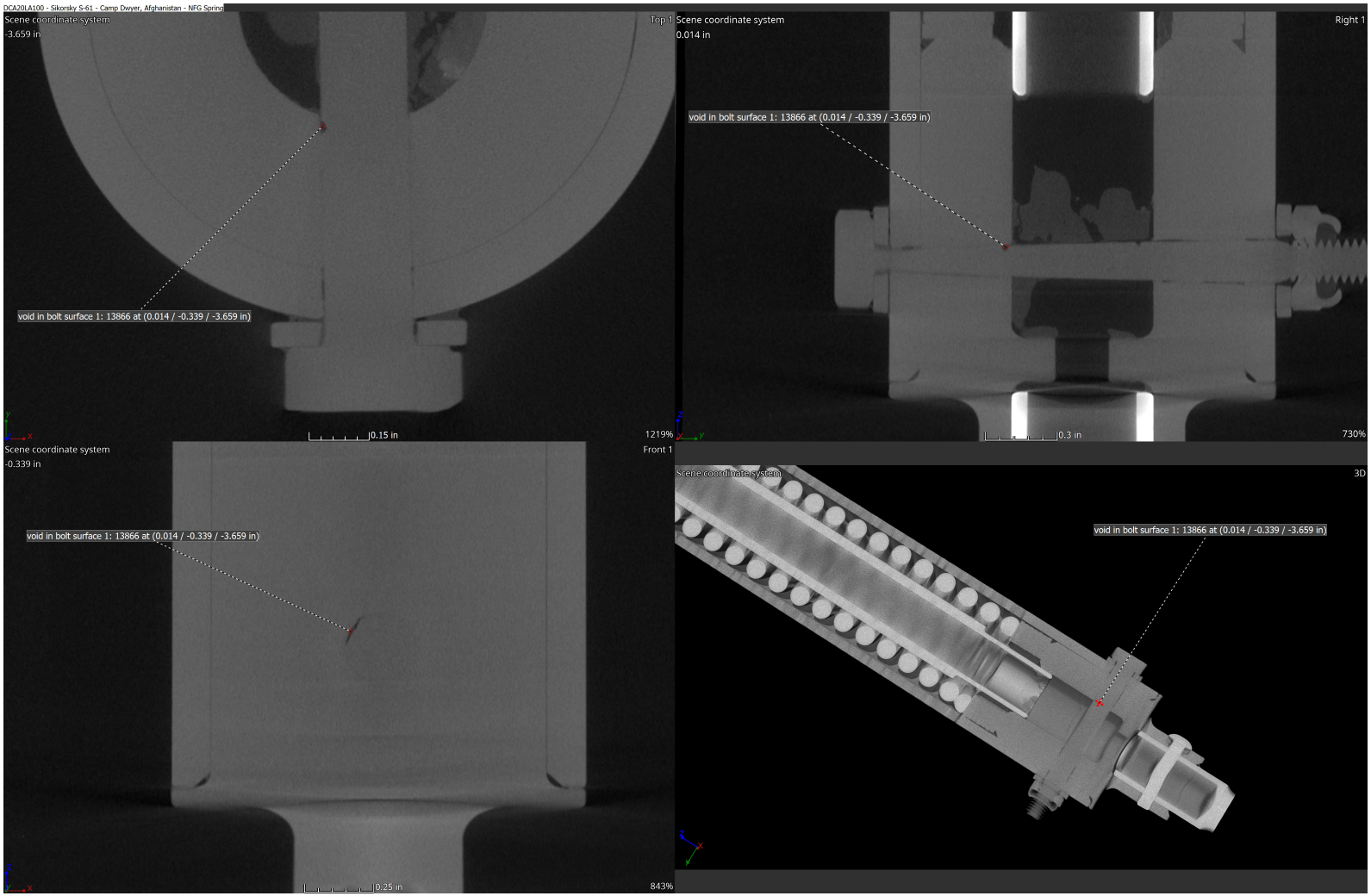


Figure 21
NFG spring – void in bolt surface 1

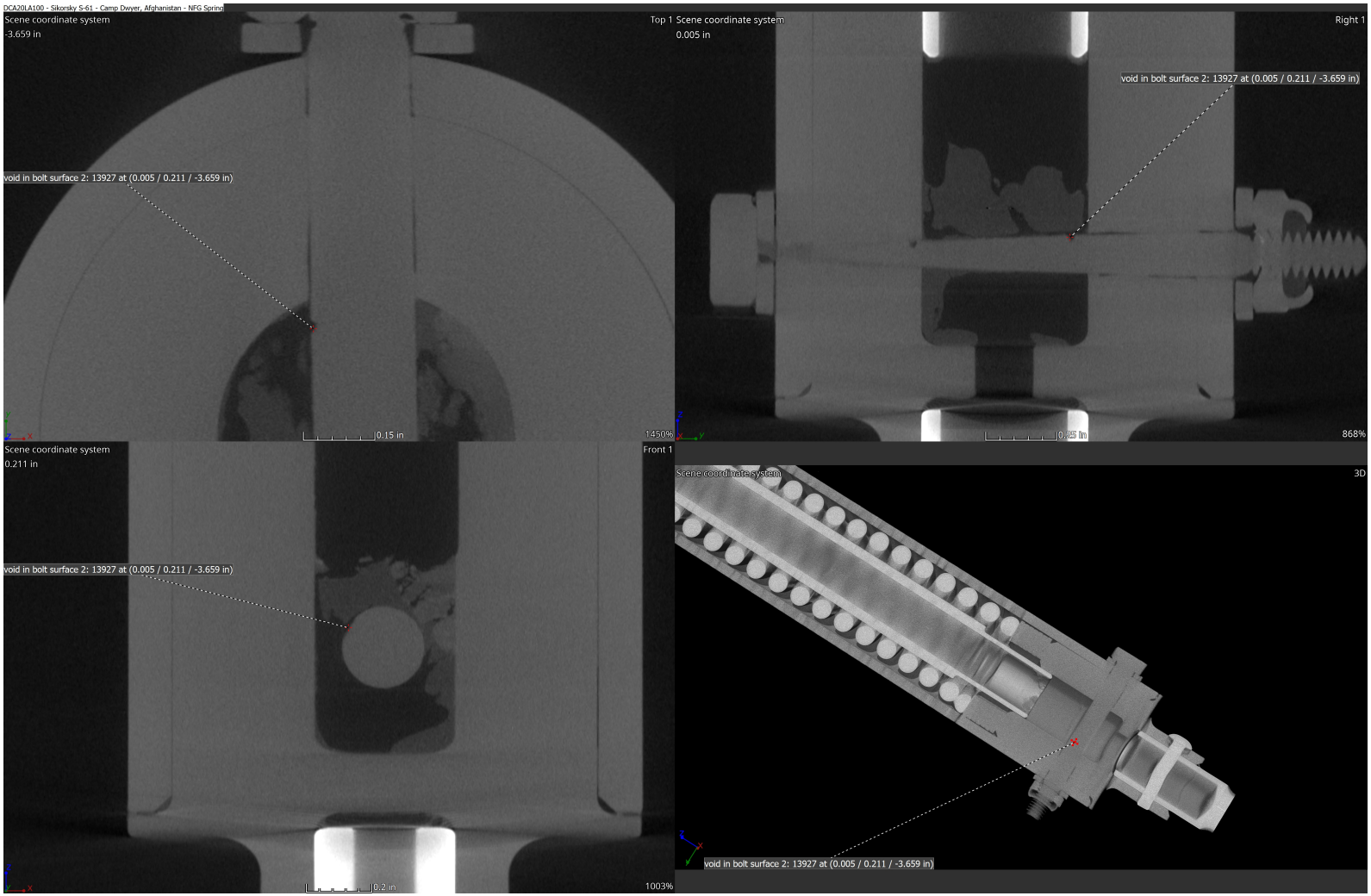


Figure 22
NFG spring – void in bolt surface 2

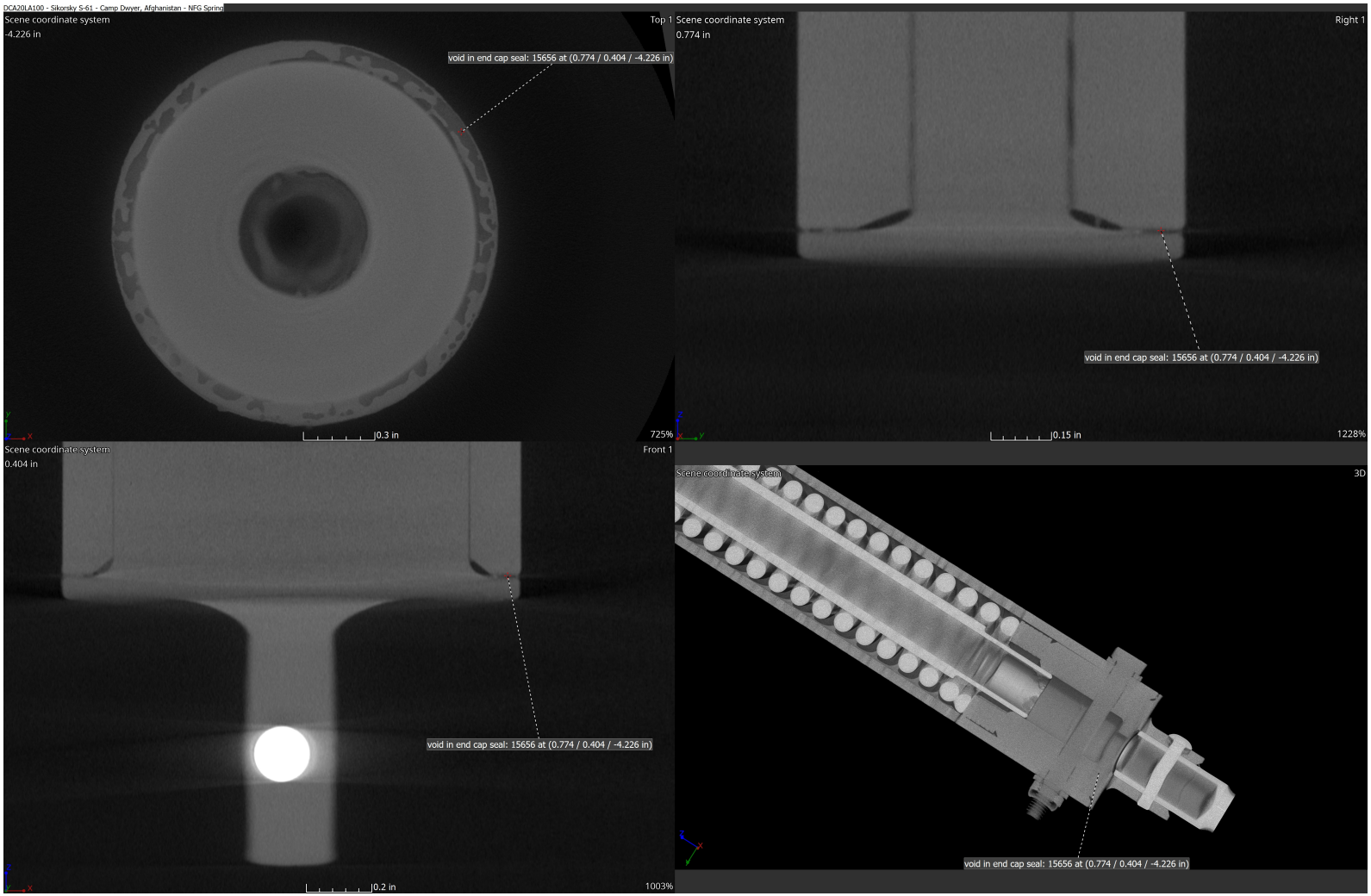


Figure 23
NFG spring – void in end cap seal

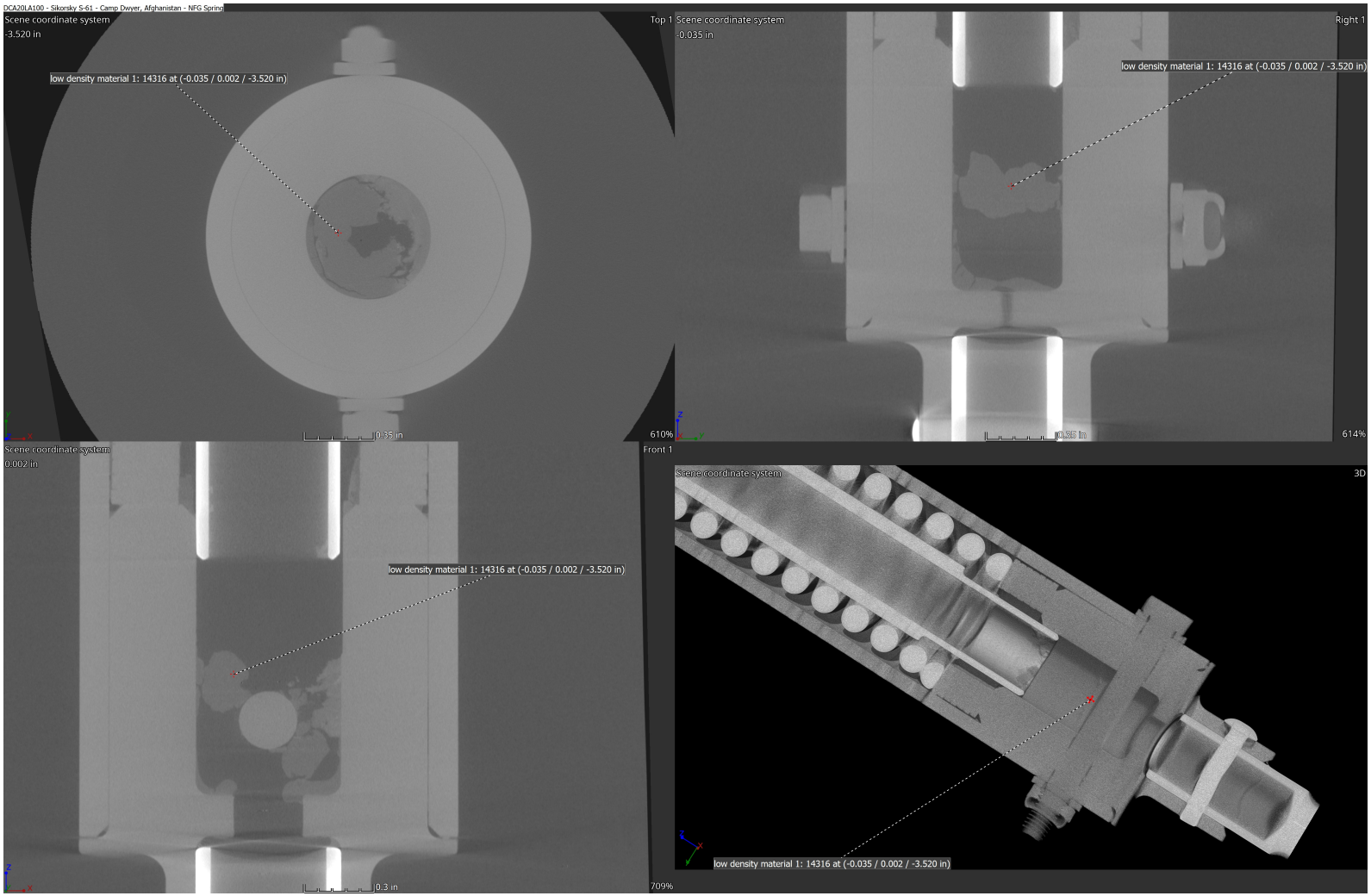


Figure 24
NFG spring – low density material 1

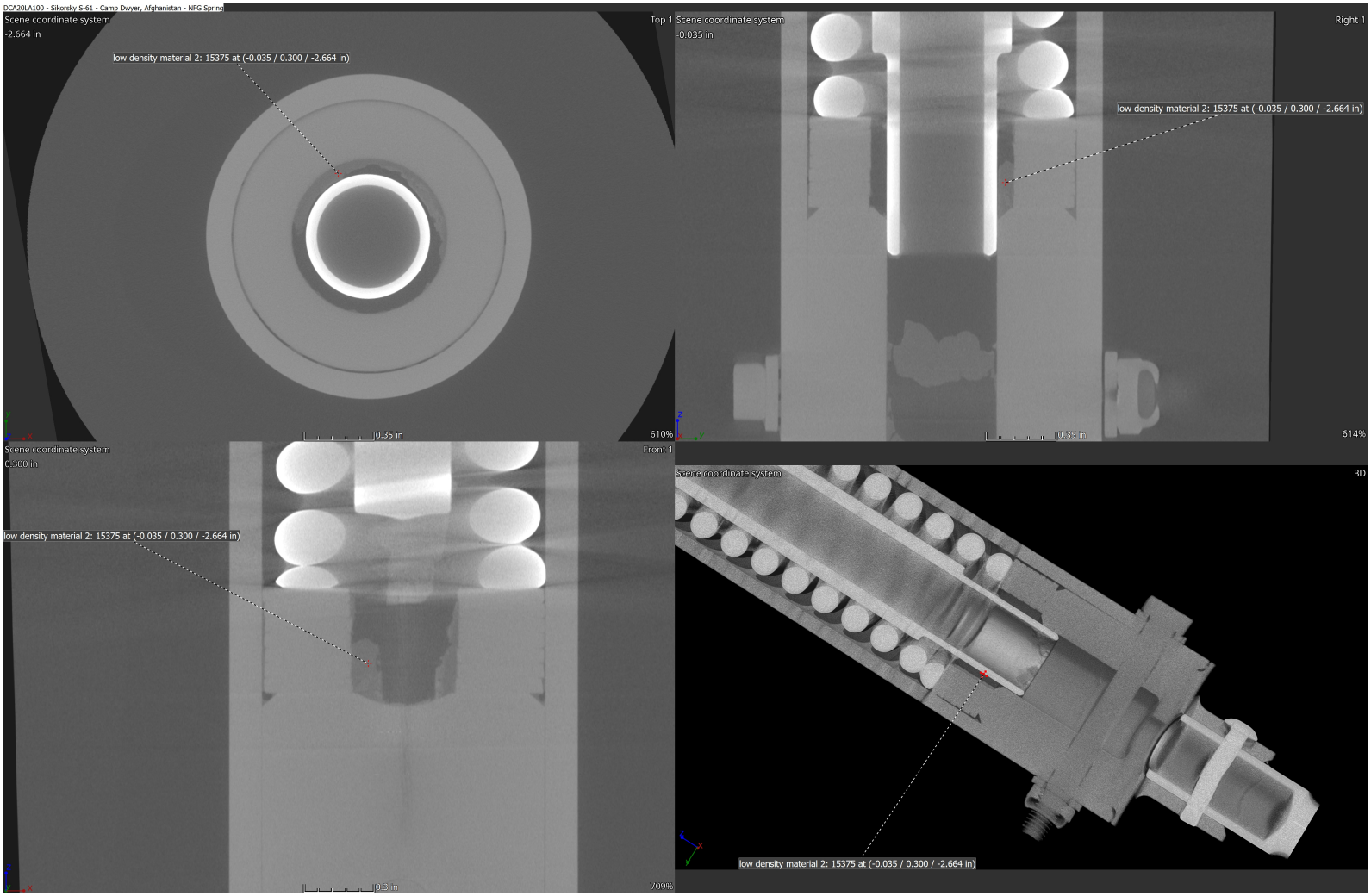


Figure 25
NFG spring – low density material 2

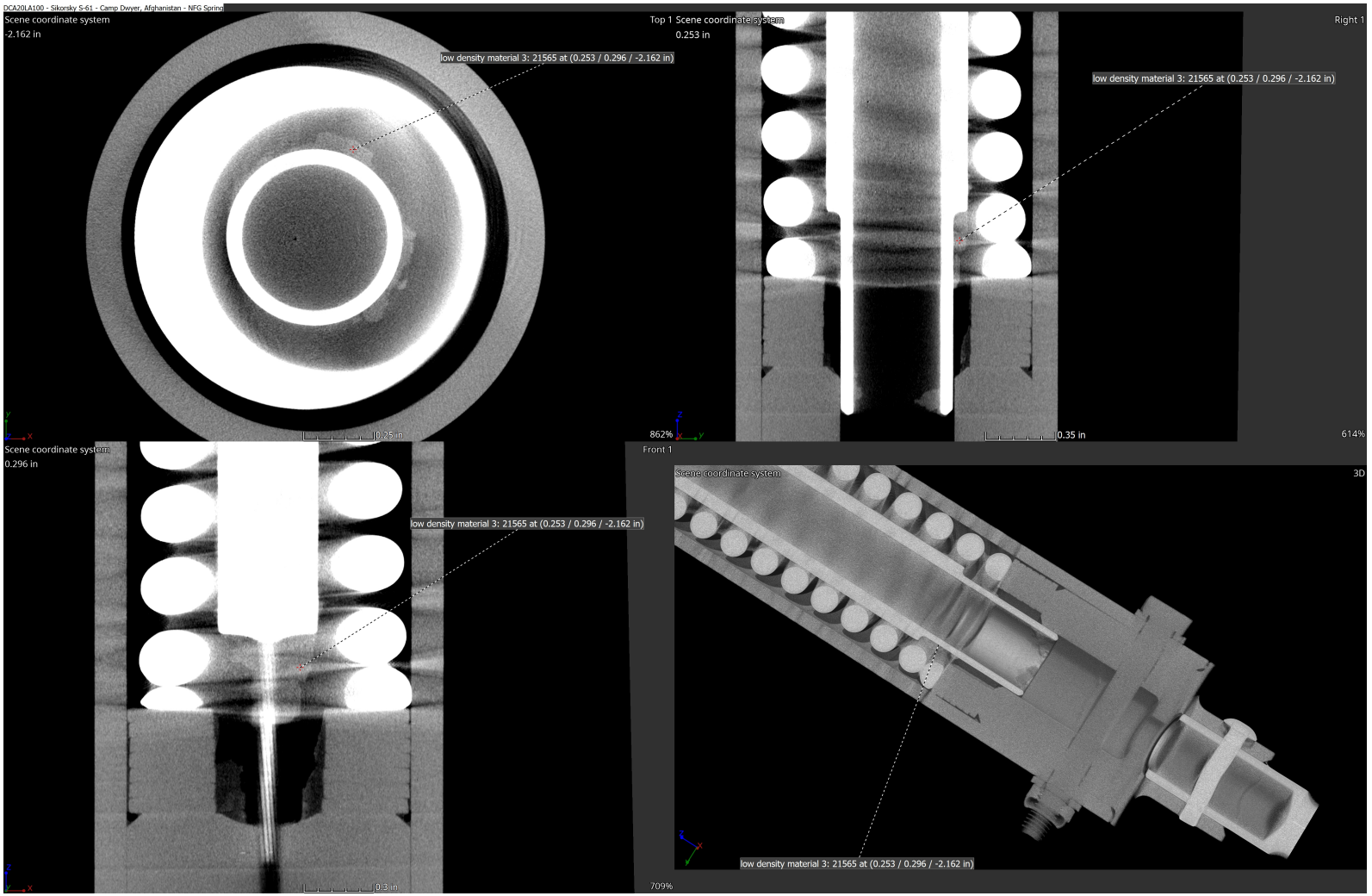


Figure 26
NFG spring – low density material 3

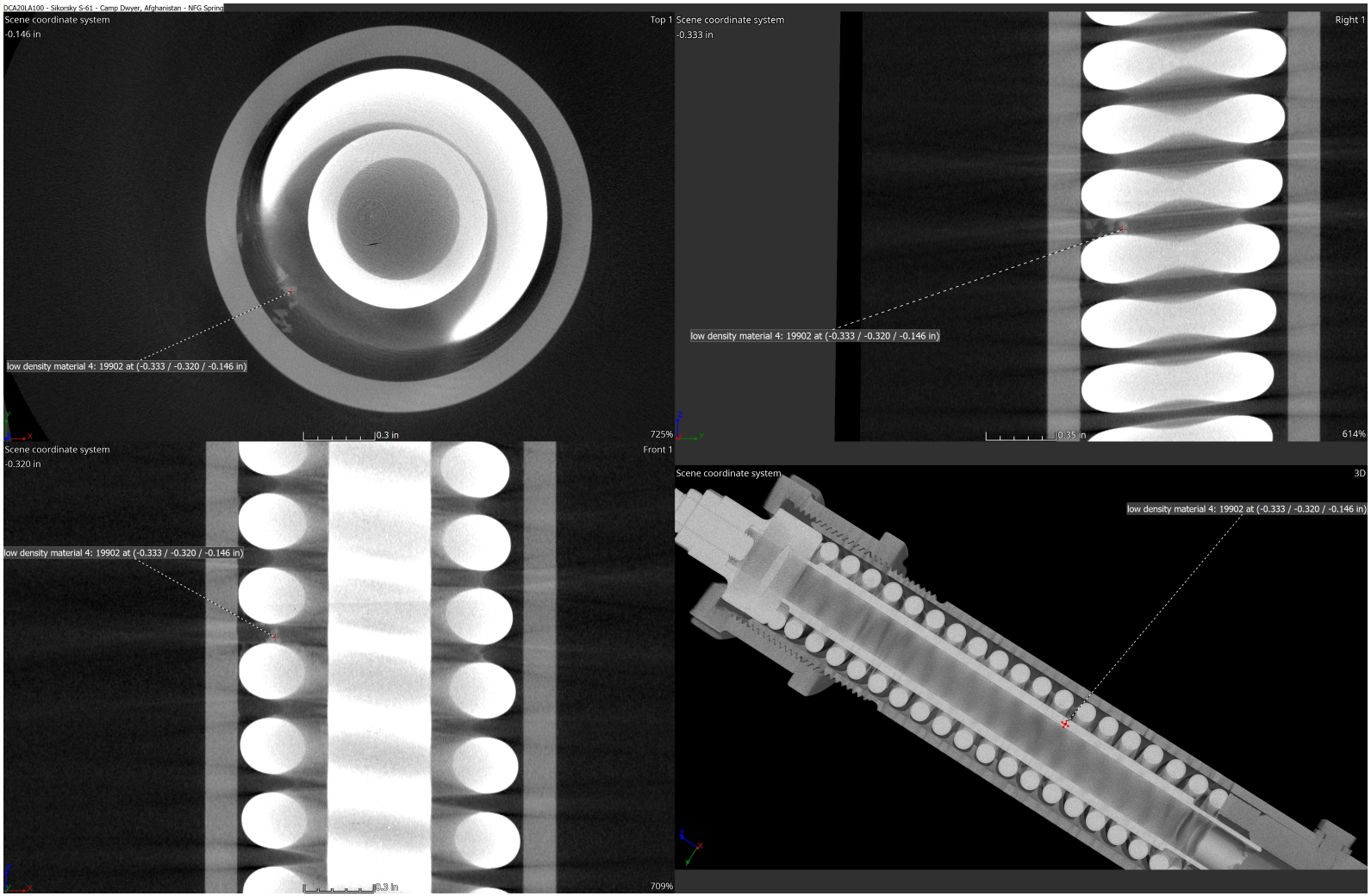


Figure 27
NFG spring – low density material 4

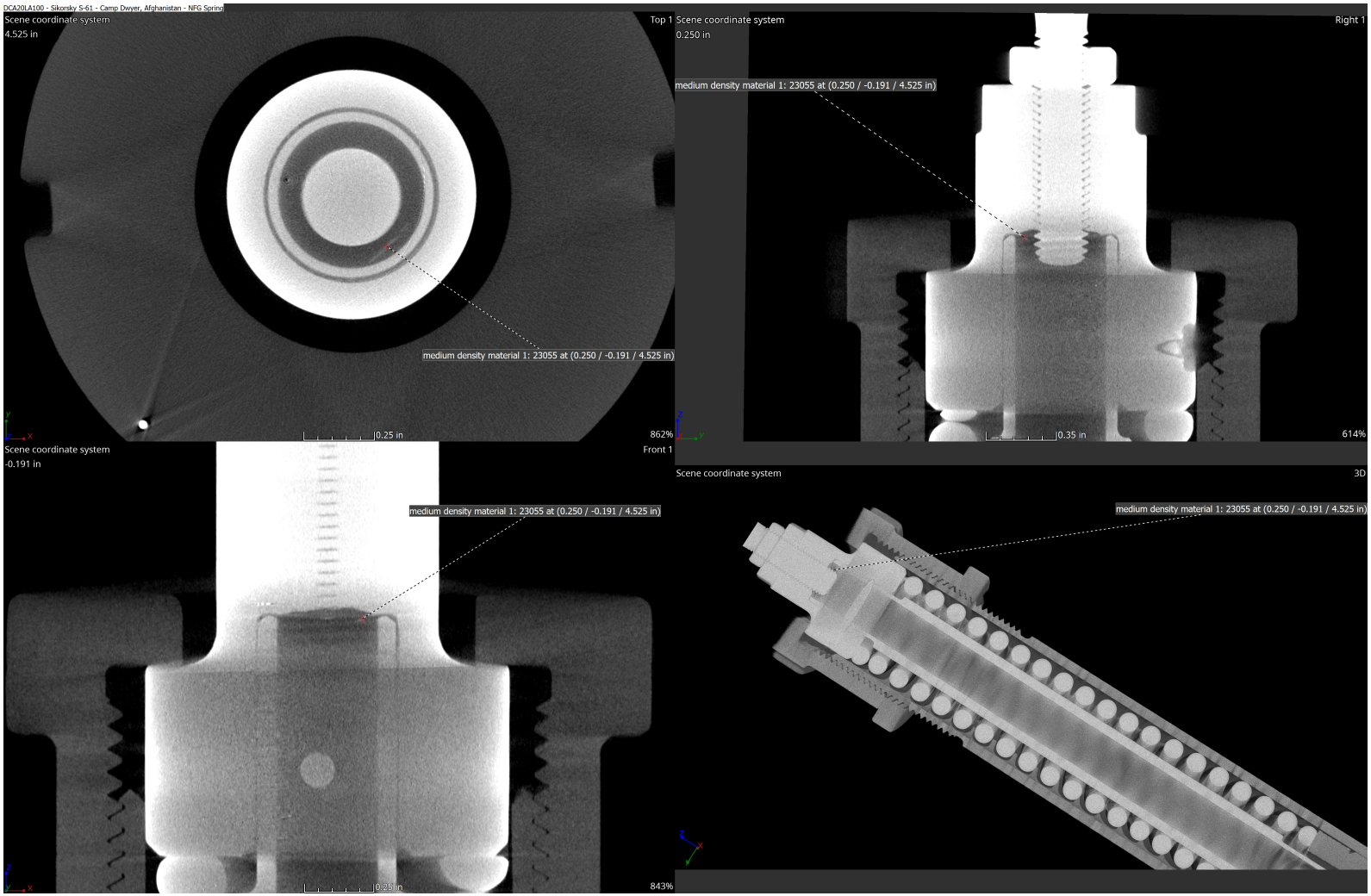


Figure 28
NFG spring – medium density material 1

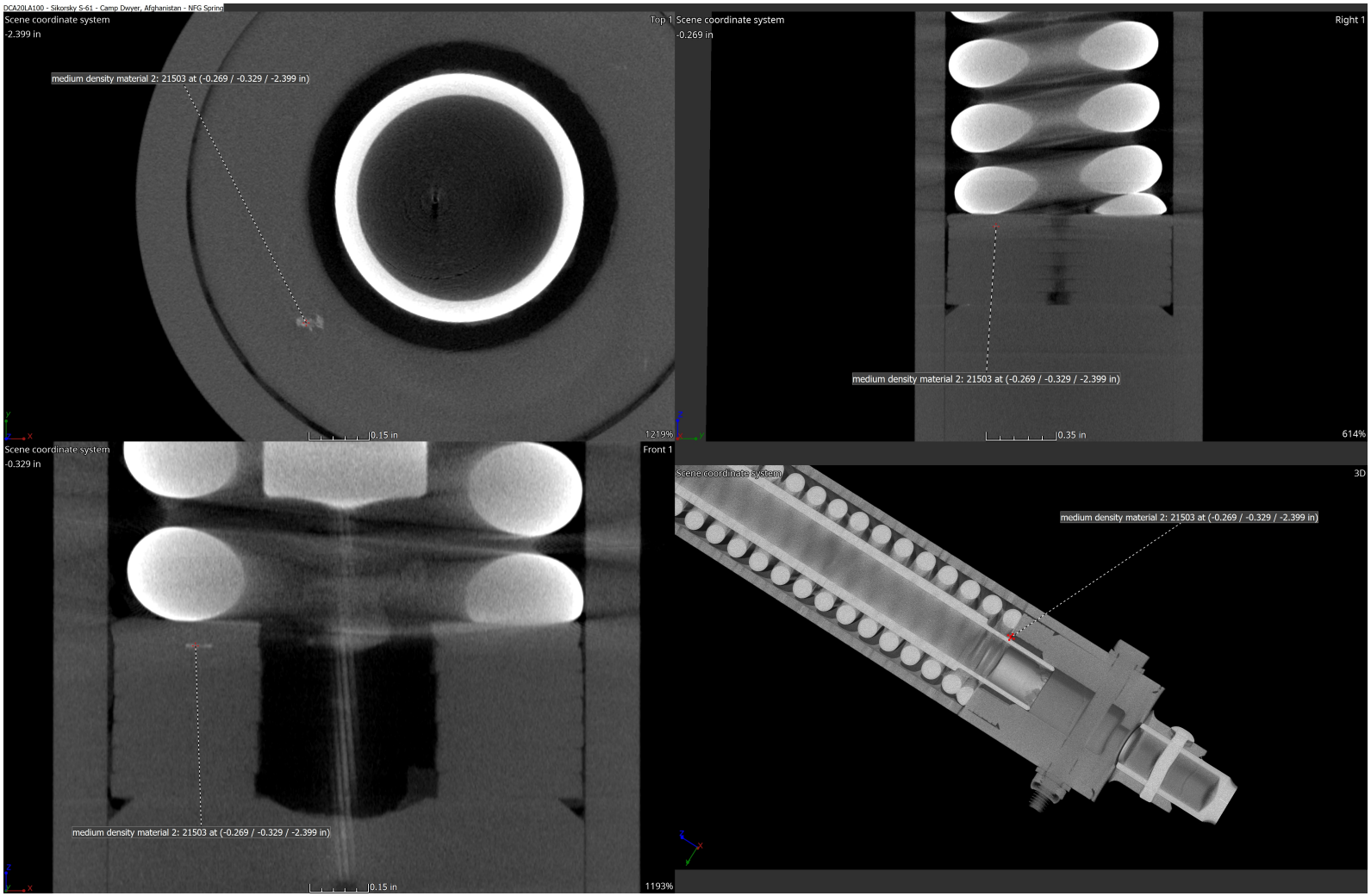


Figure 29
NFG spring – medium density material 2

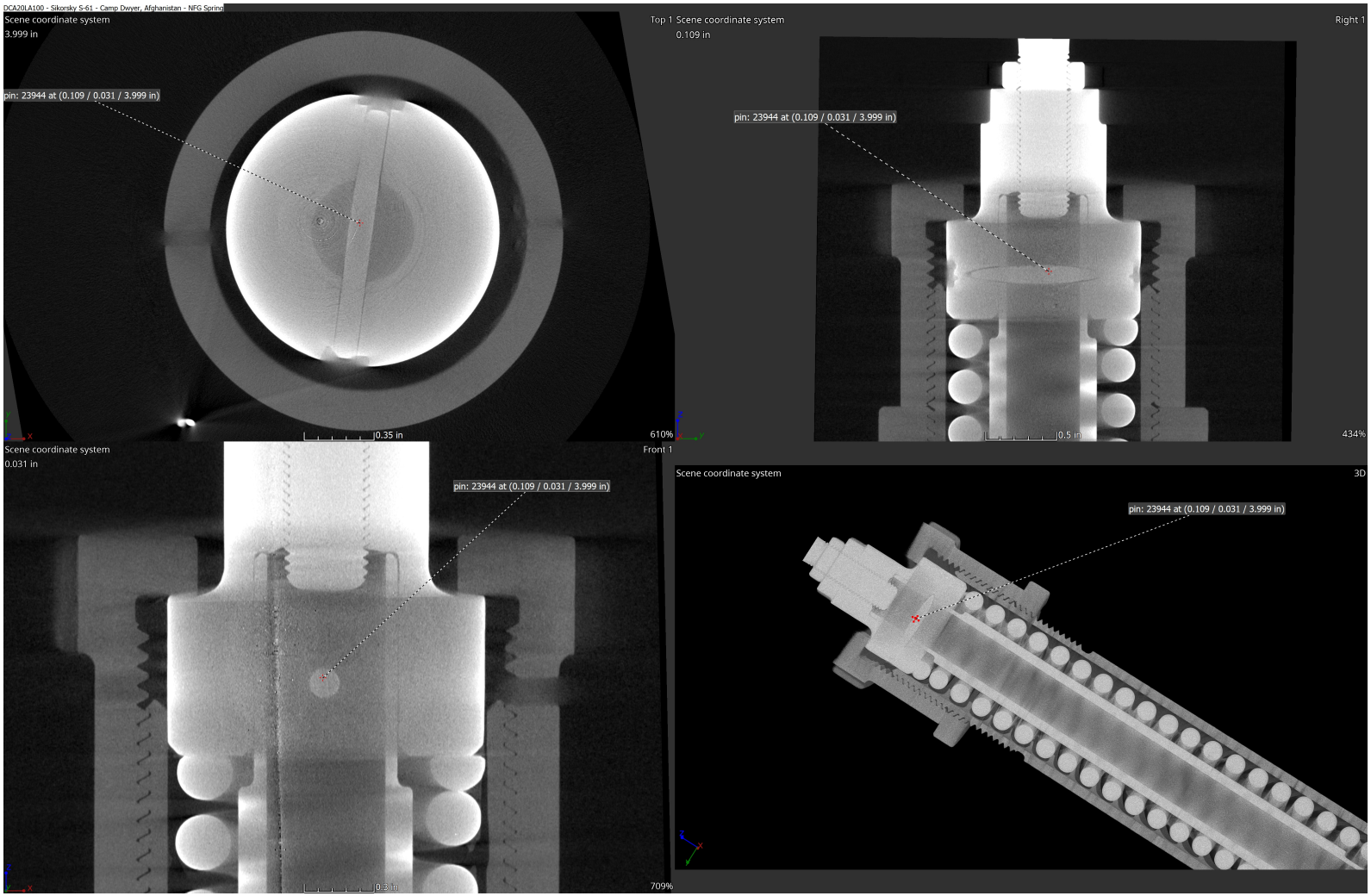


Figure 30
NFG spring – pin

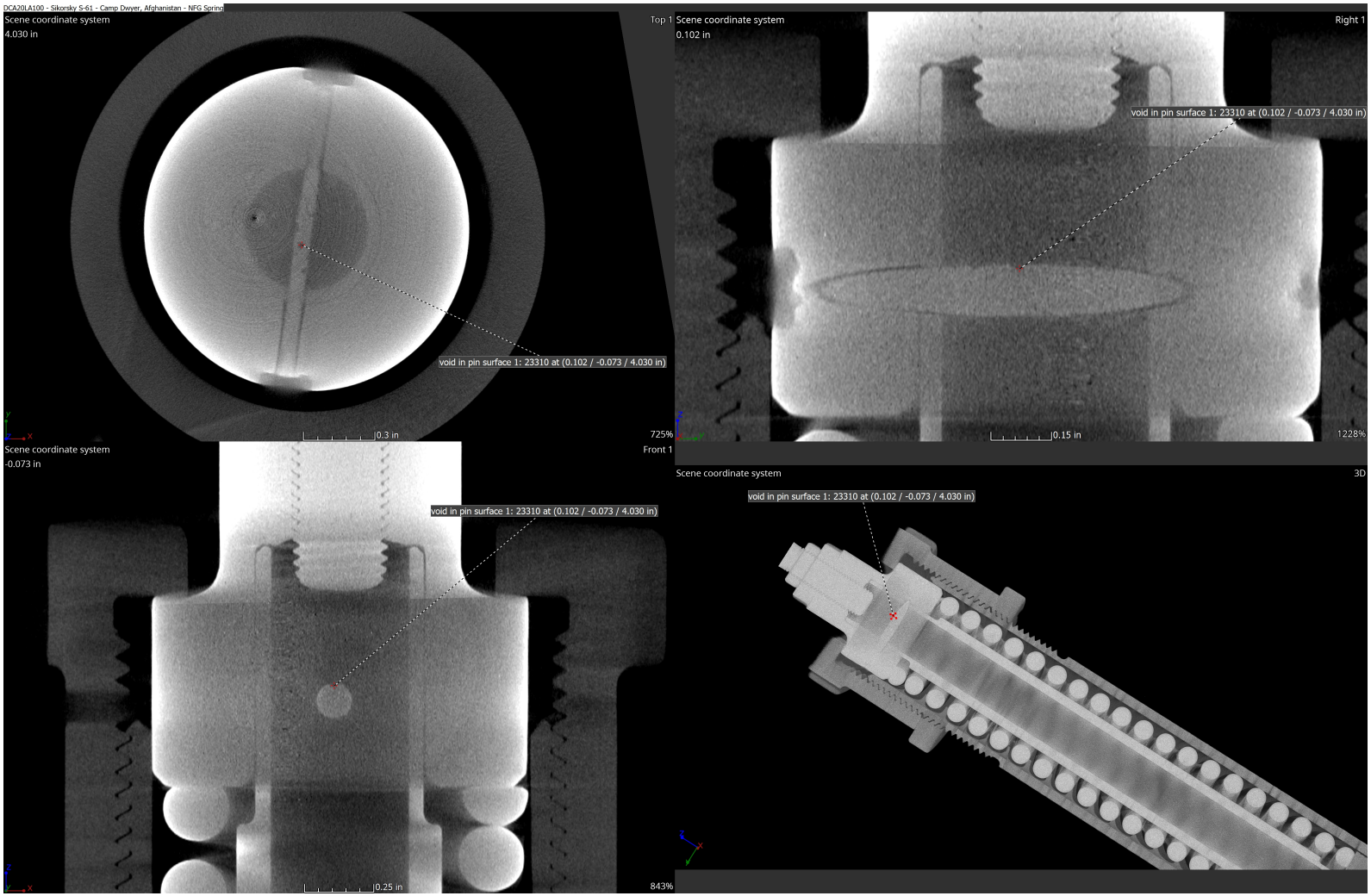


Figure 31
NFG spring – void in pin surface 1

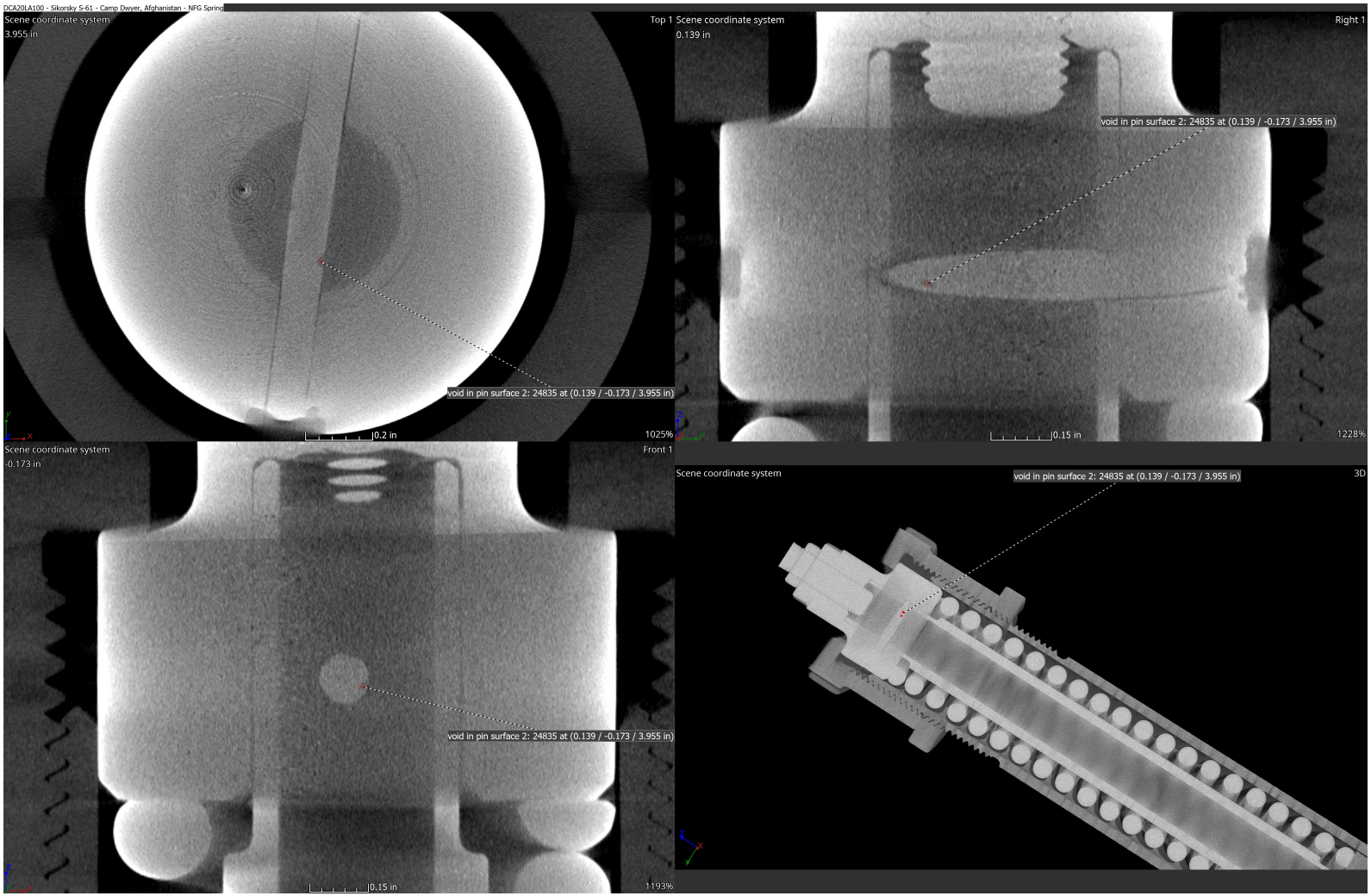


Figure 32
NFG spring – void in pin surface 2

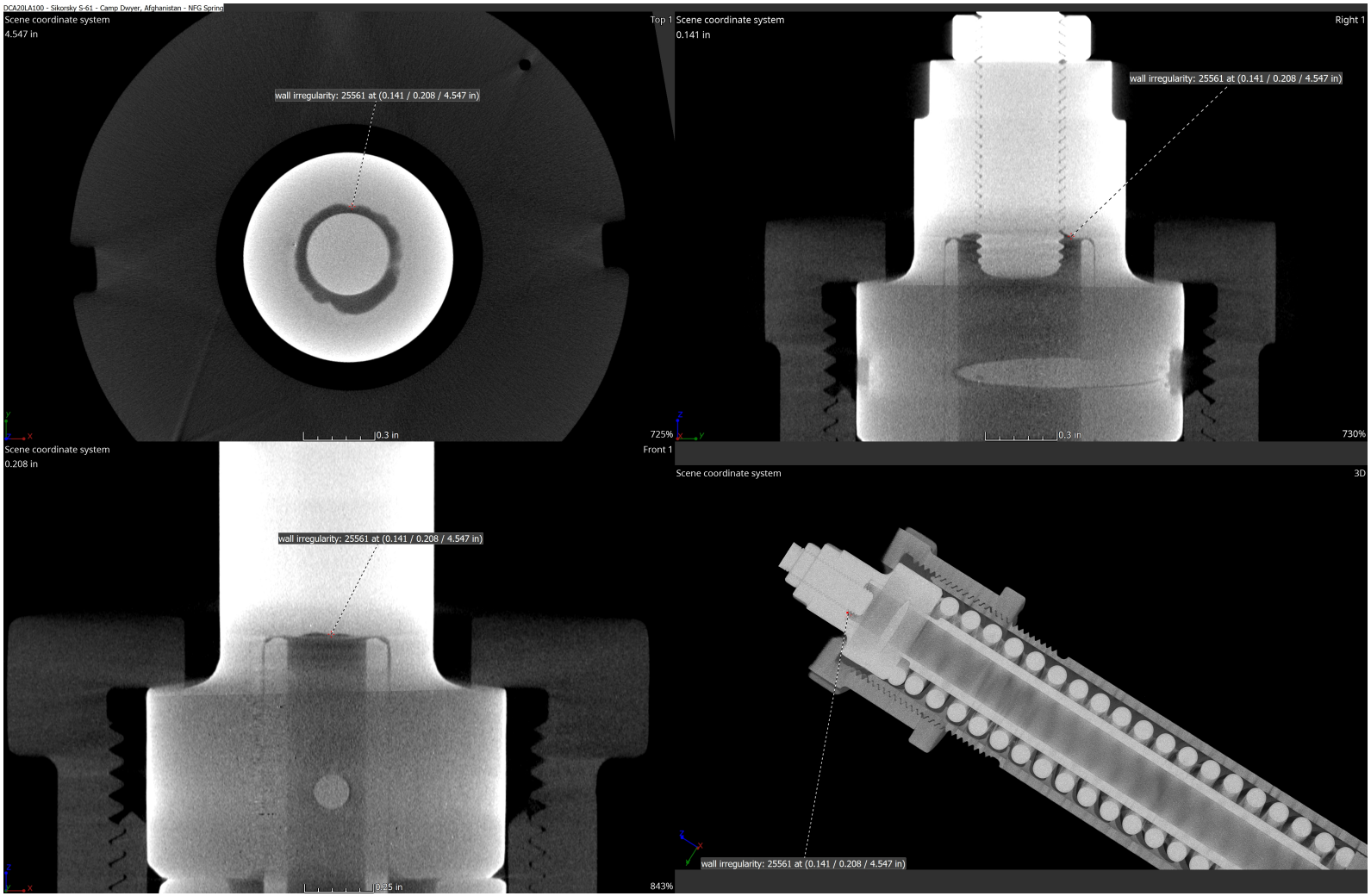


Figure 33
NFG spring – wall irregularity

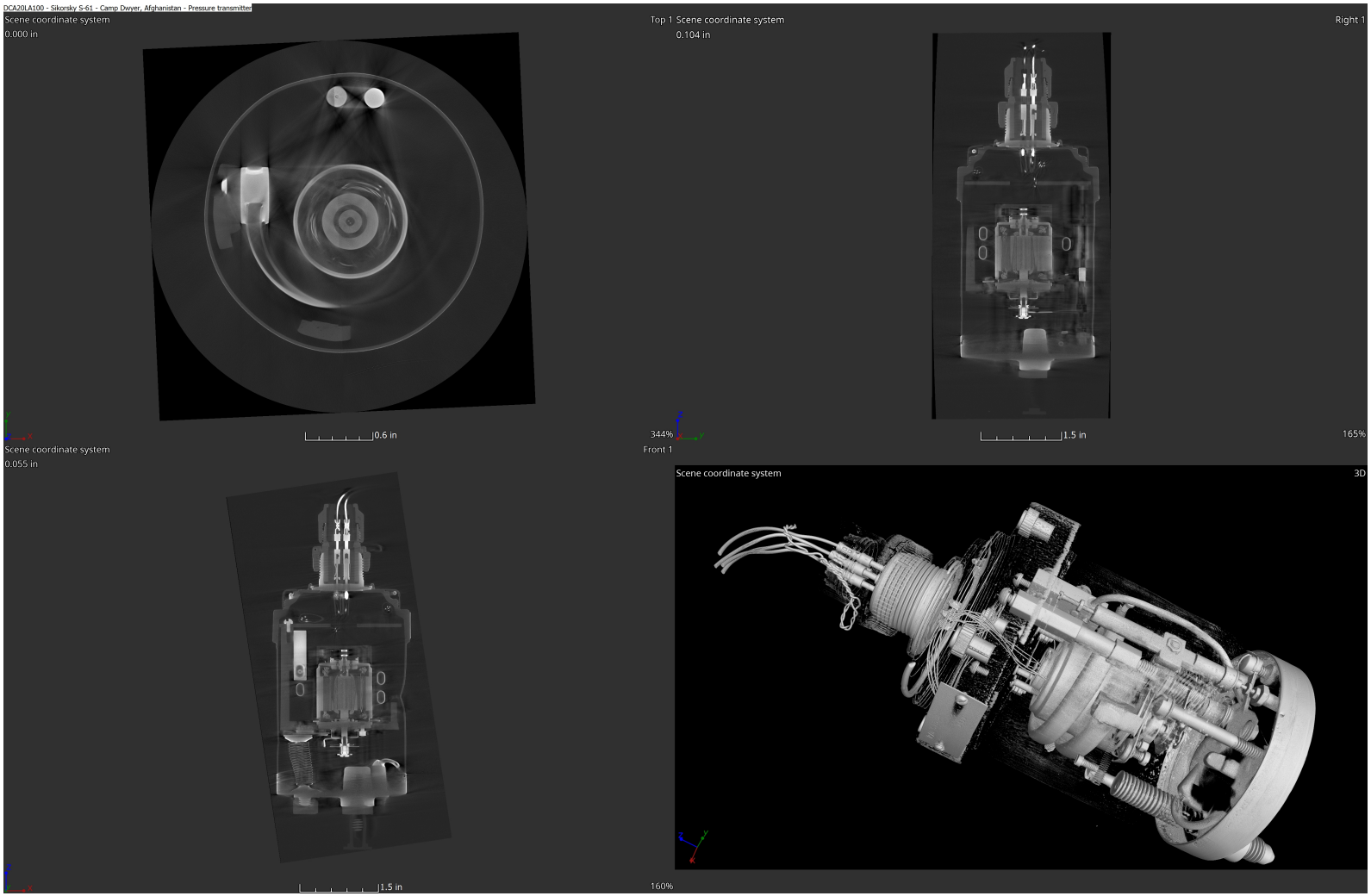


Figure 34
Pressure transmitter - overview

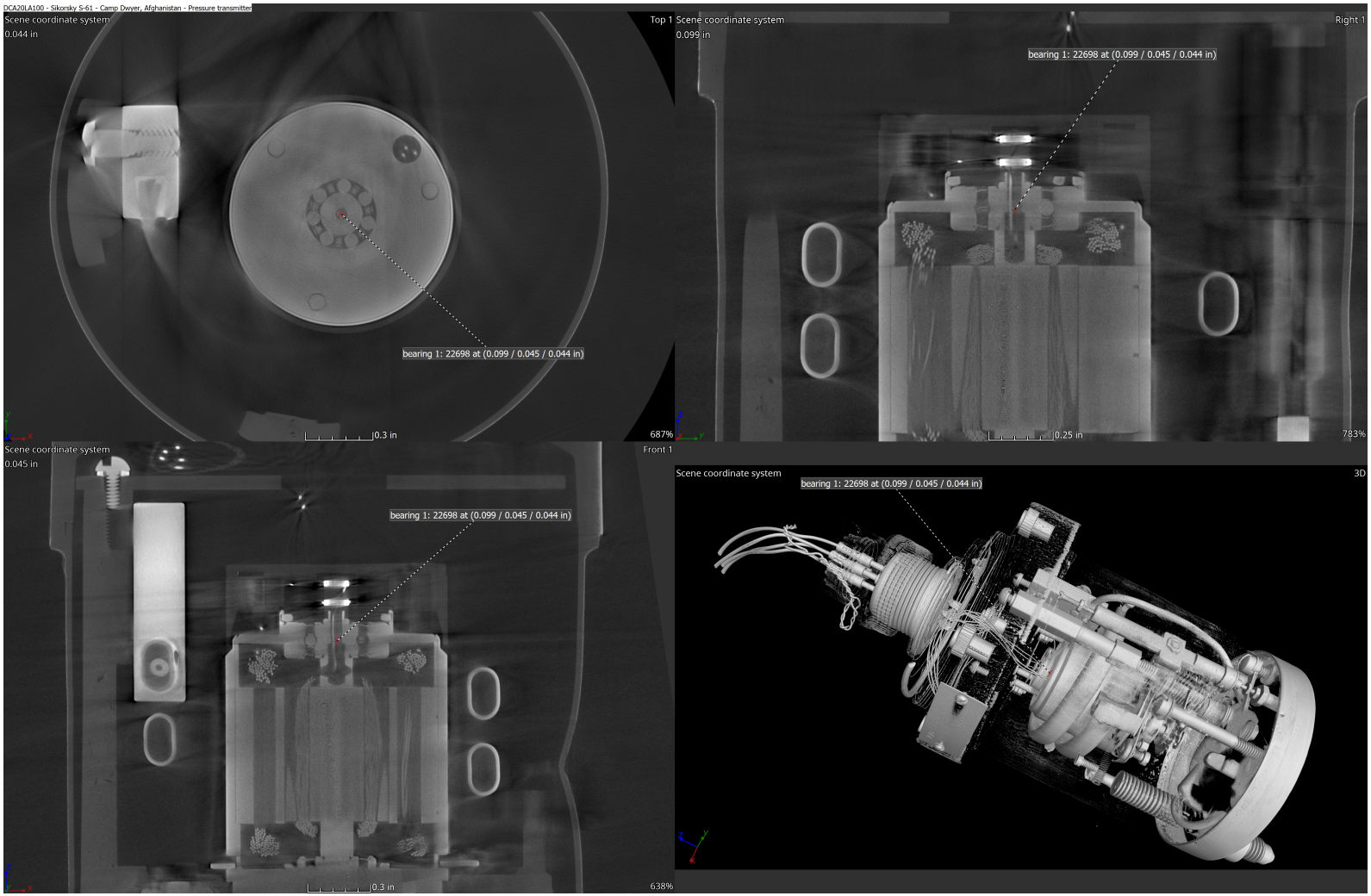


Figure 35
Pressure transmitter – bearing 1

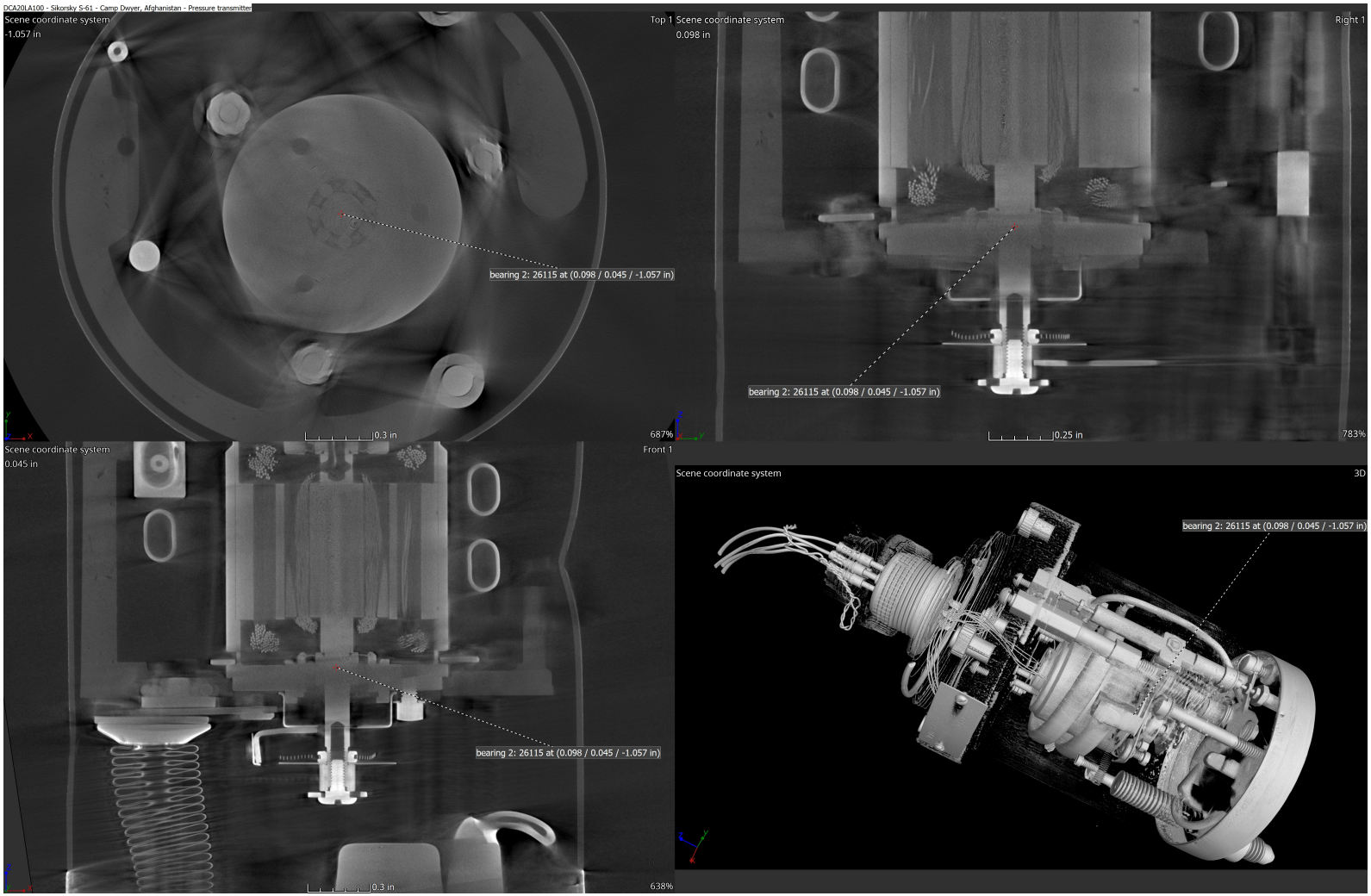


Figure 36
Pressure transmitter – bearing 2

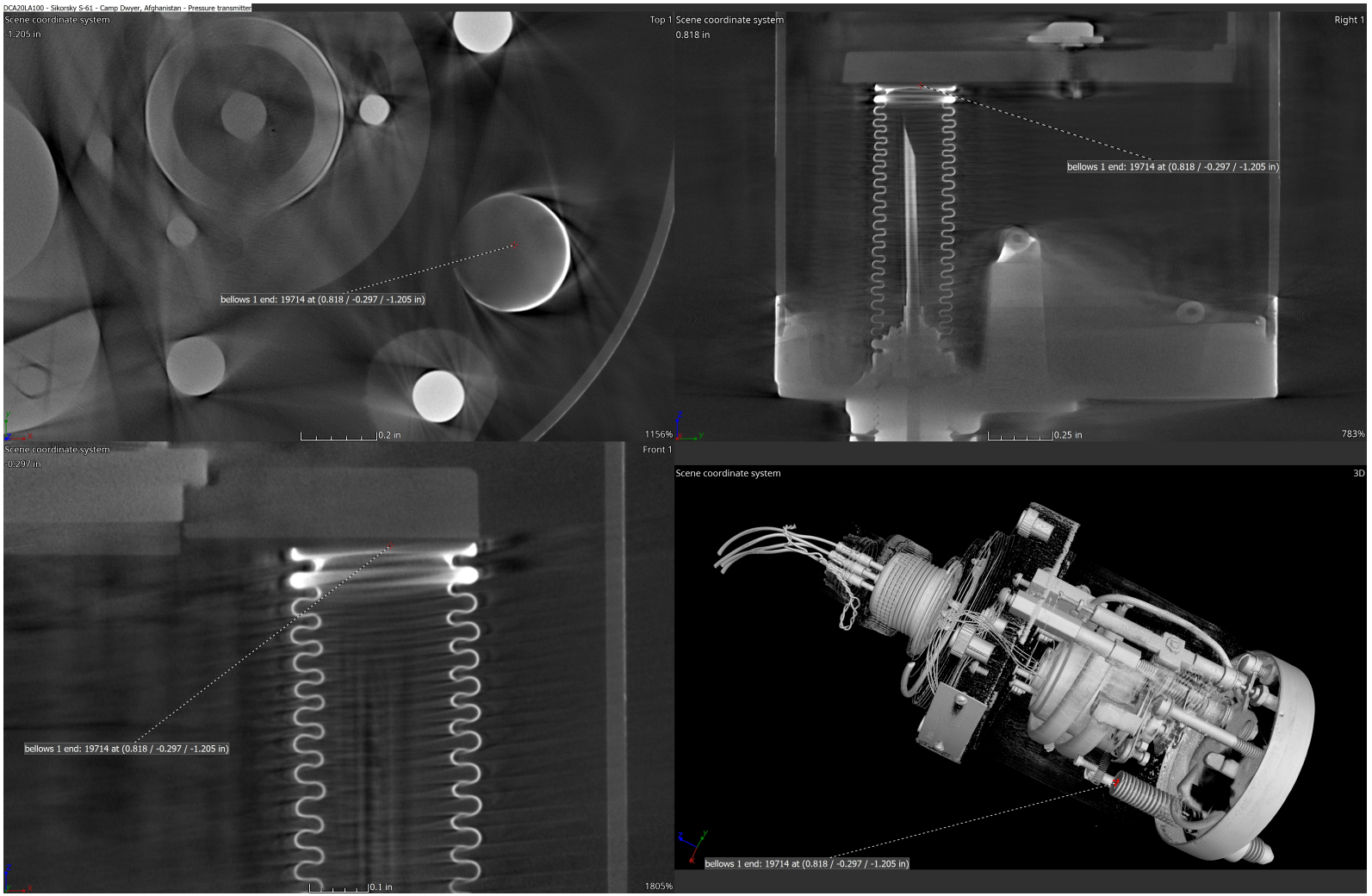


Figure 37
Pressure transmitter – bellows 1 end

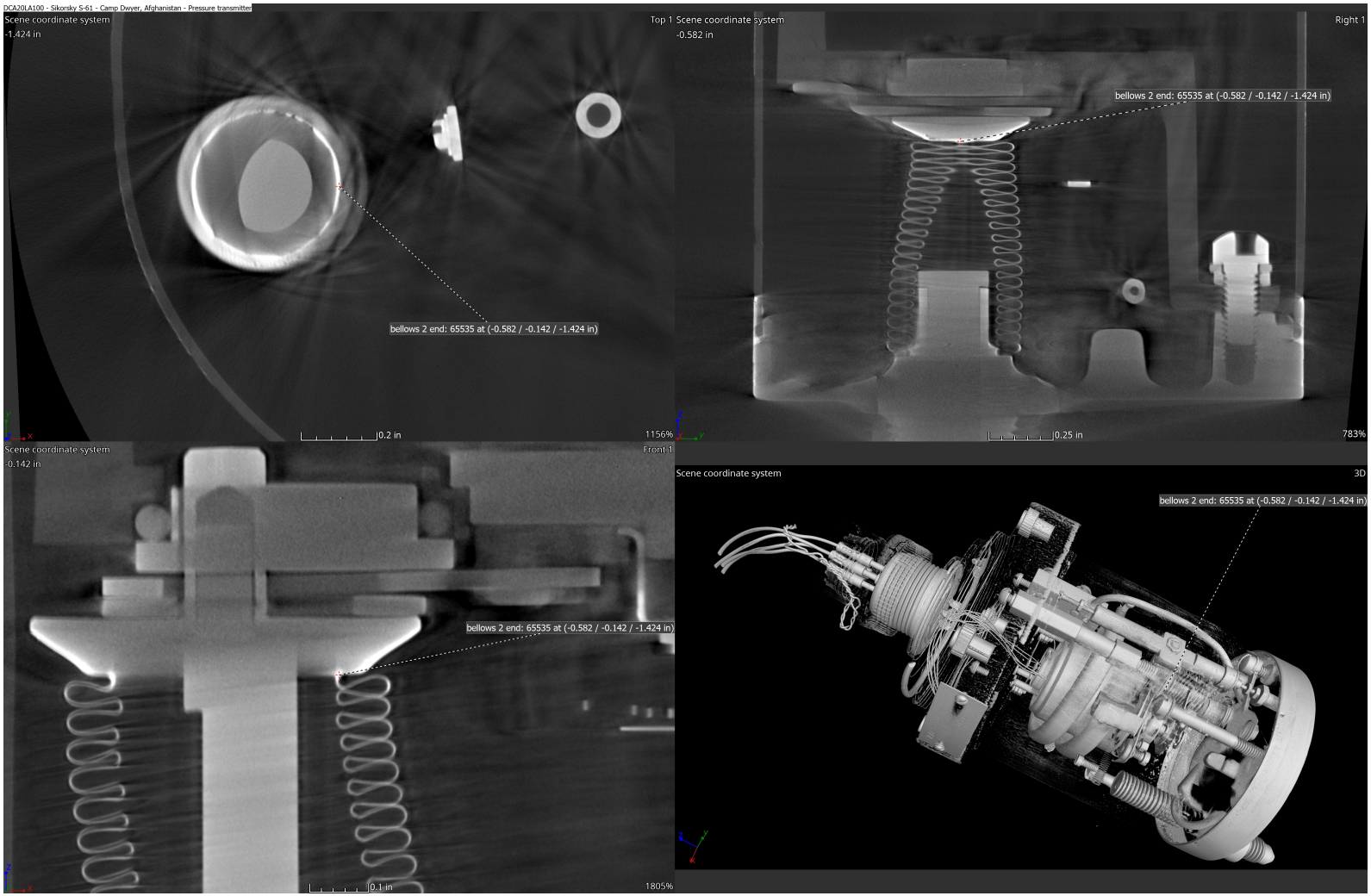


Figure 38
Pressure transmitter – bellows 2 end

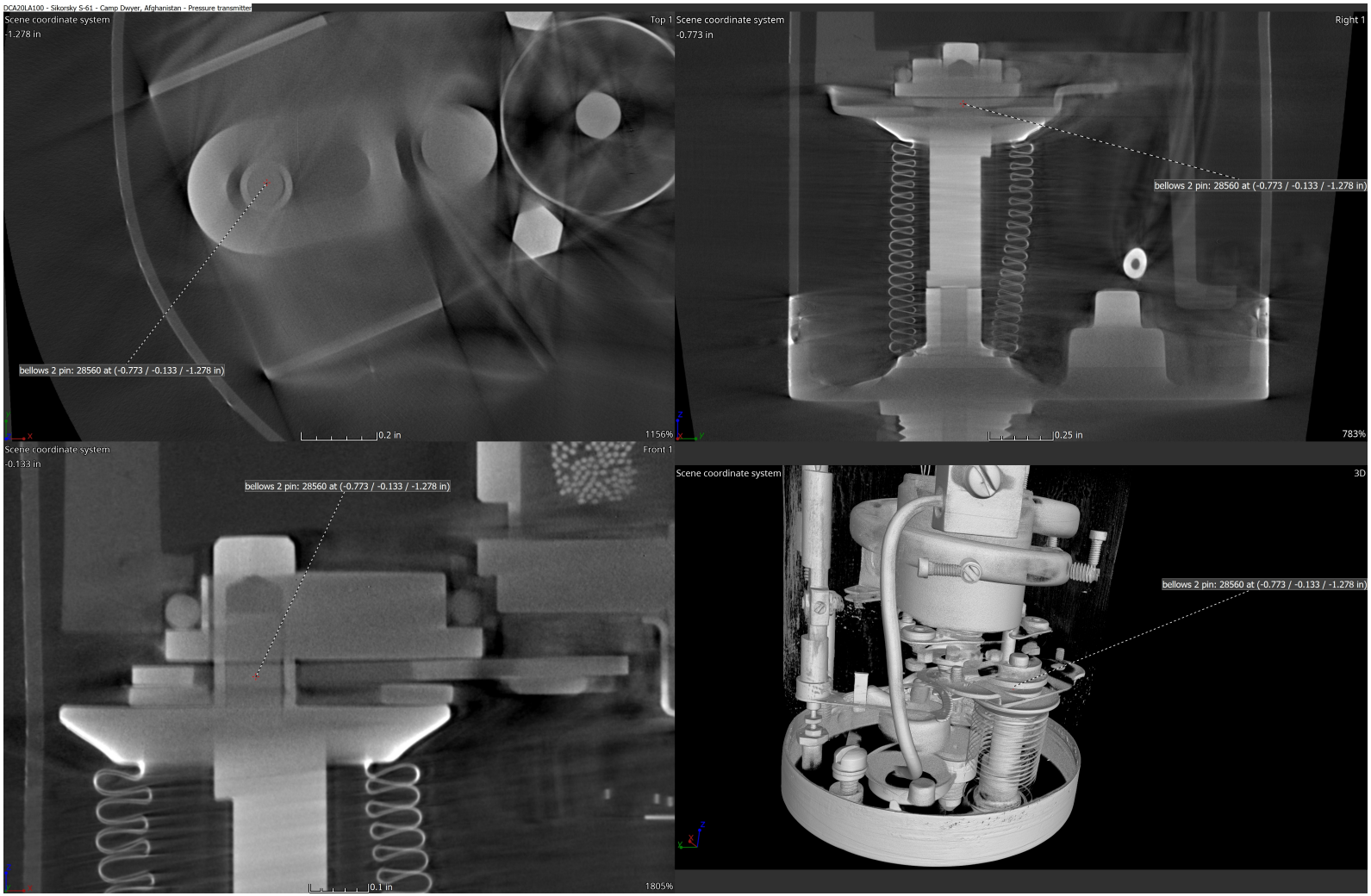


Figure 39
Pressure transmitter – bellows 2 pin

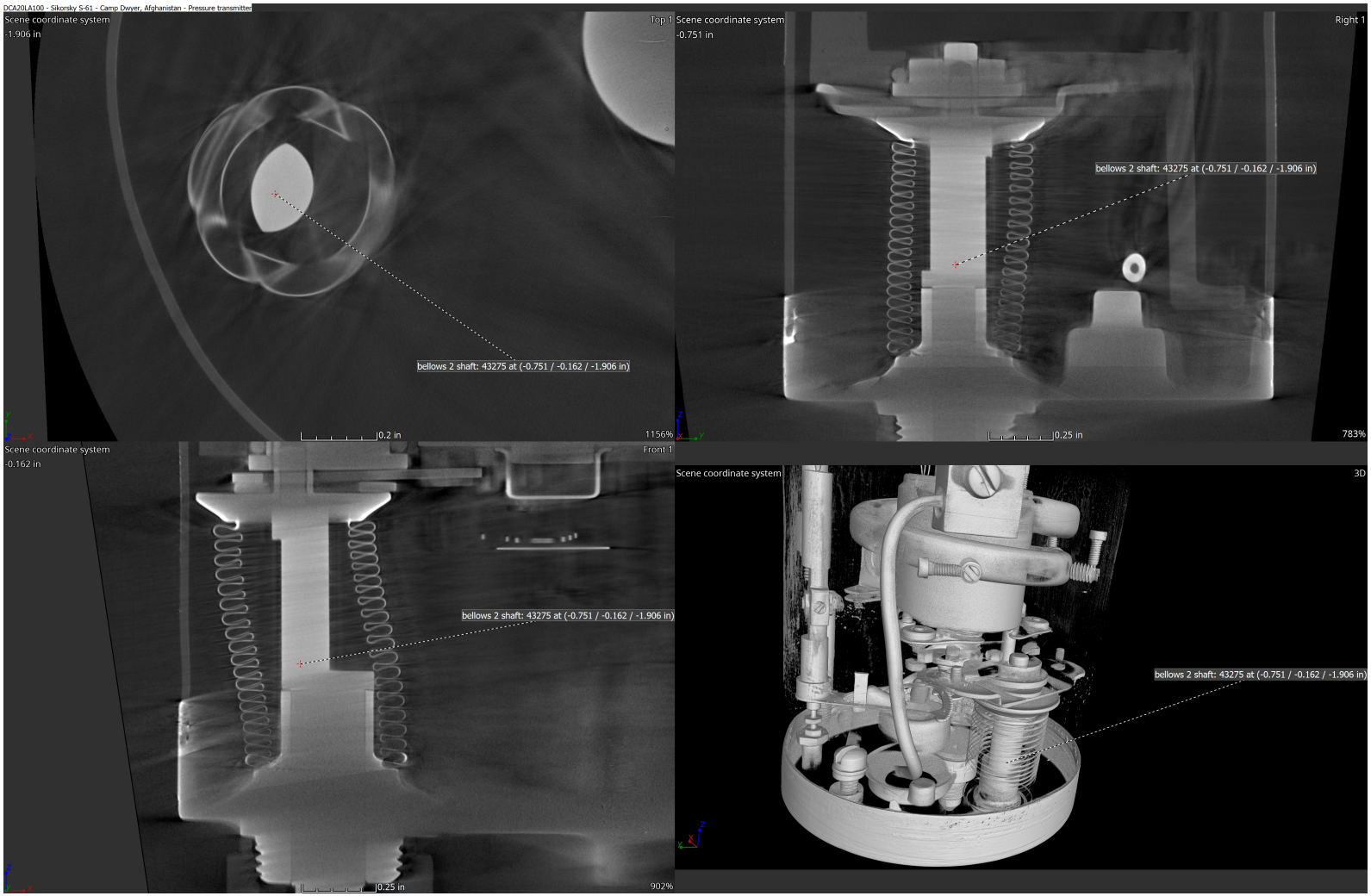


Figure 40
Pressure transmitter – bellows 2 shaft

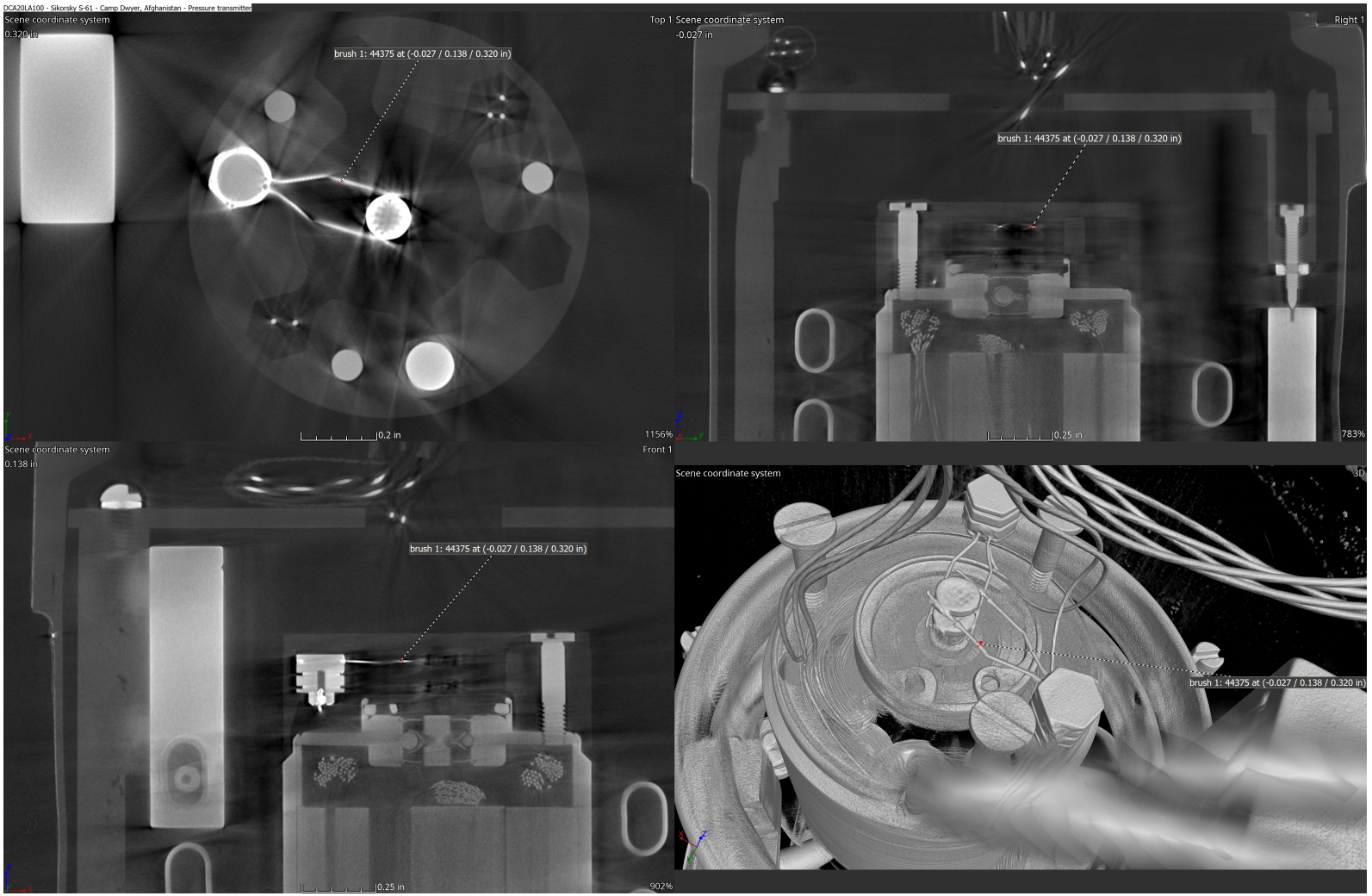


Figure 41
Pressure transmitter – brush 1

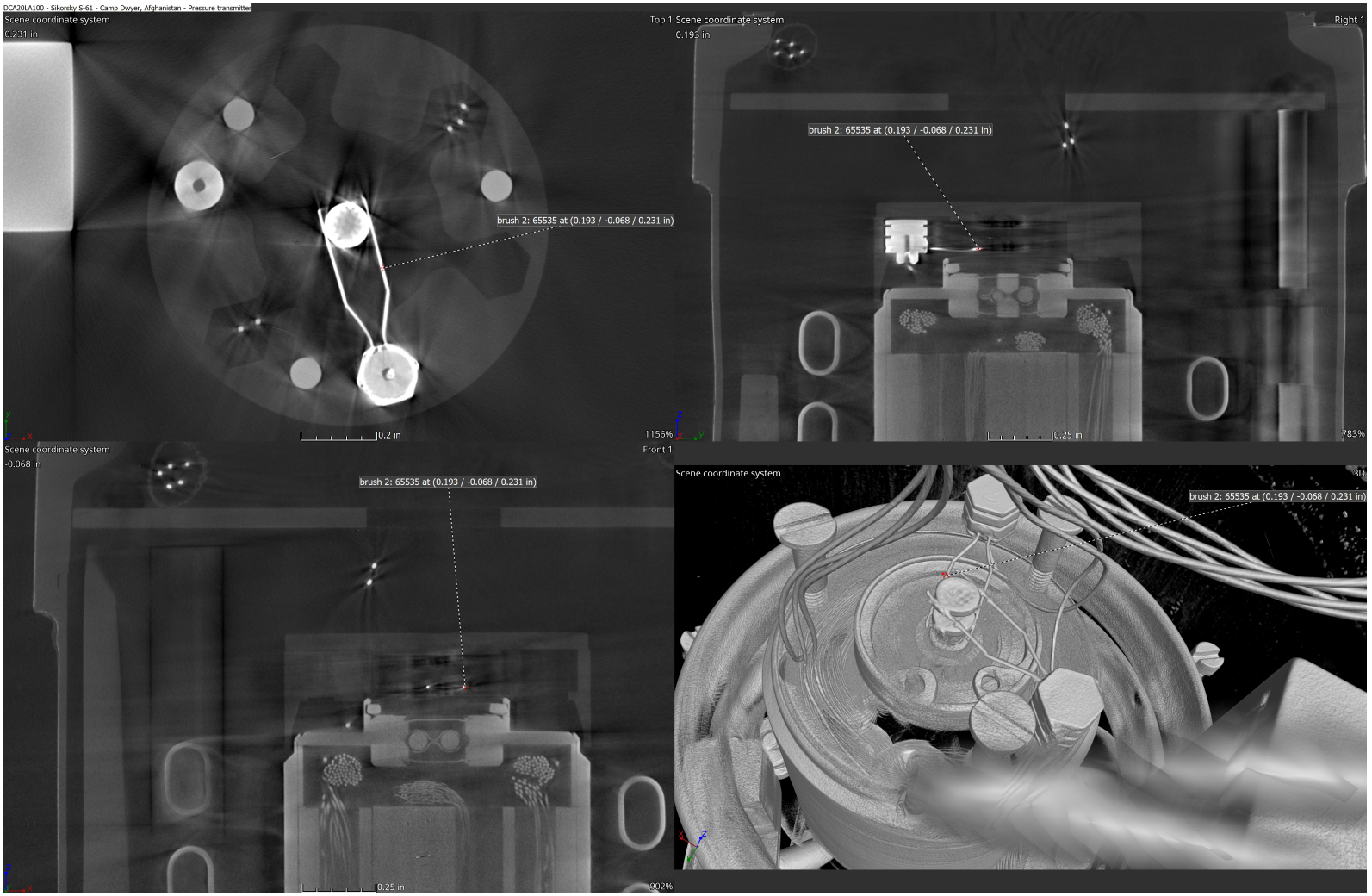


Figure 42
Pressure transmitter – brush 2

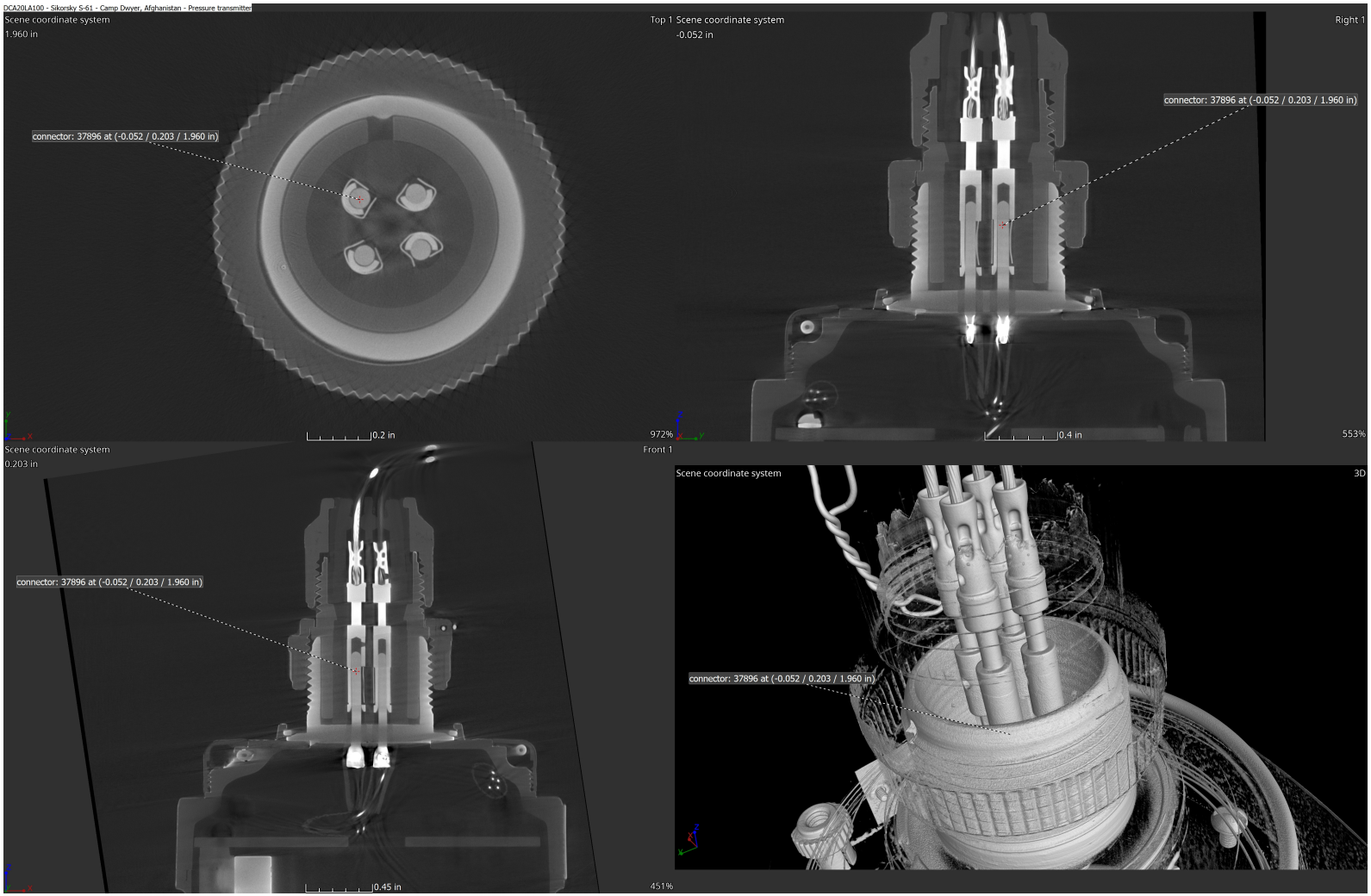


Figure 43
Pressure transmitter - connector

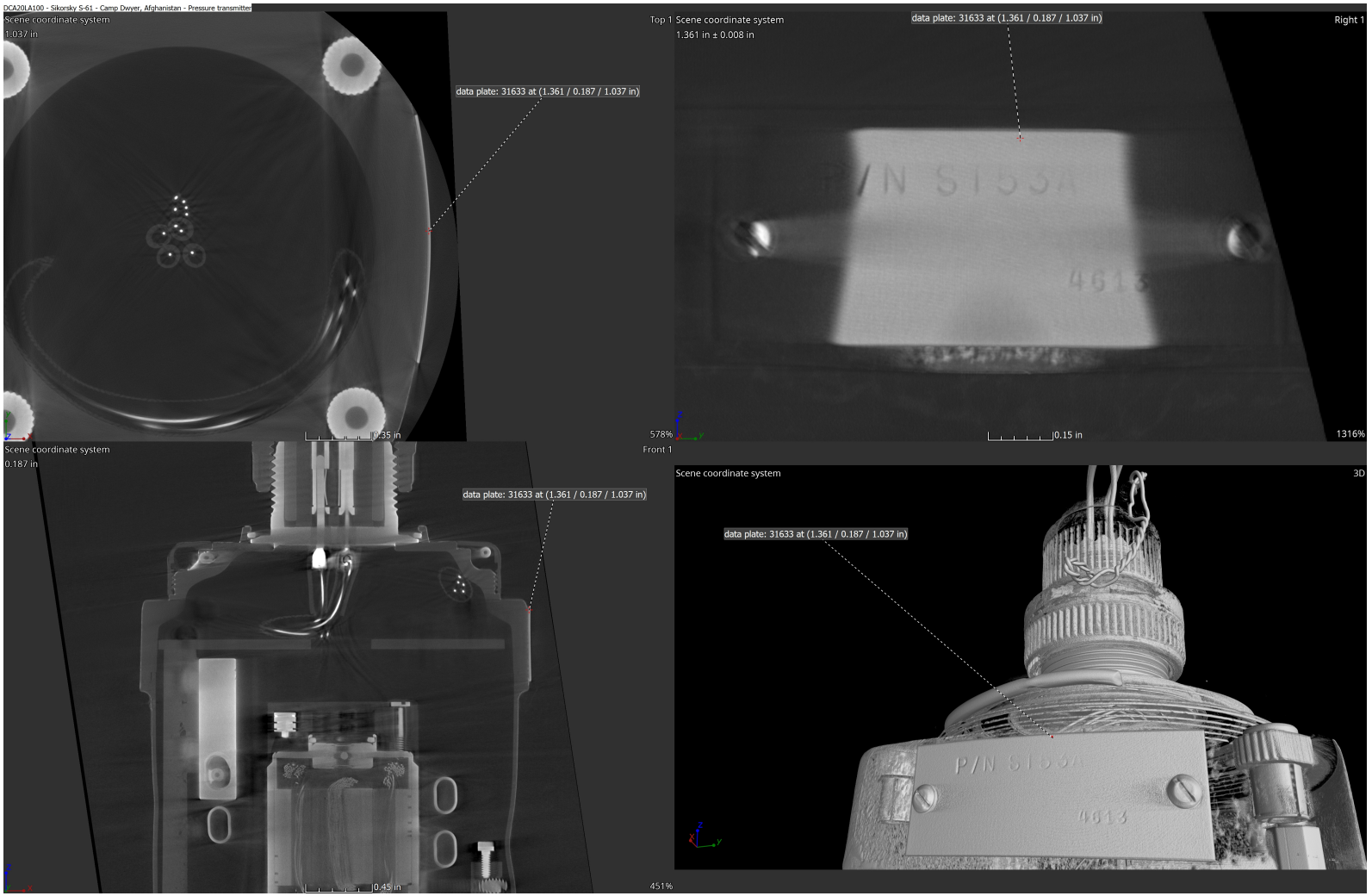


Figure 44
Pressure transmitter – data plate

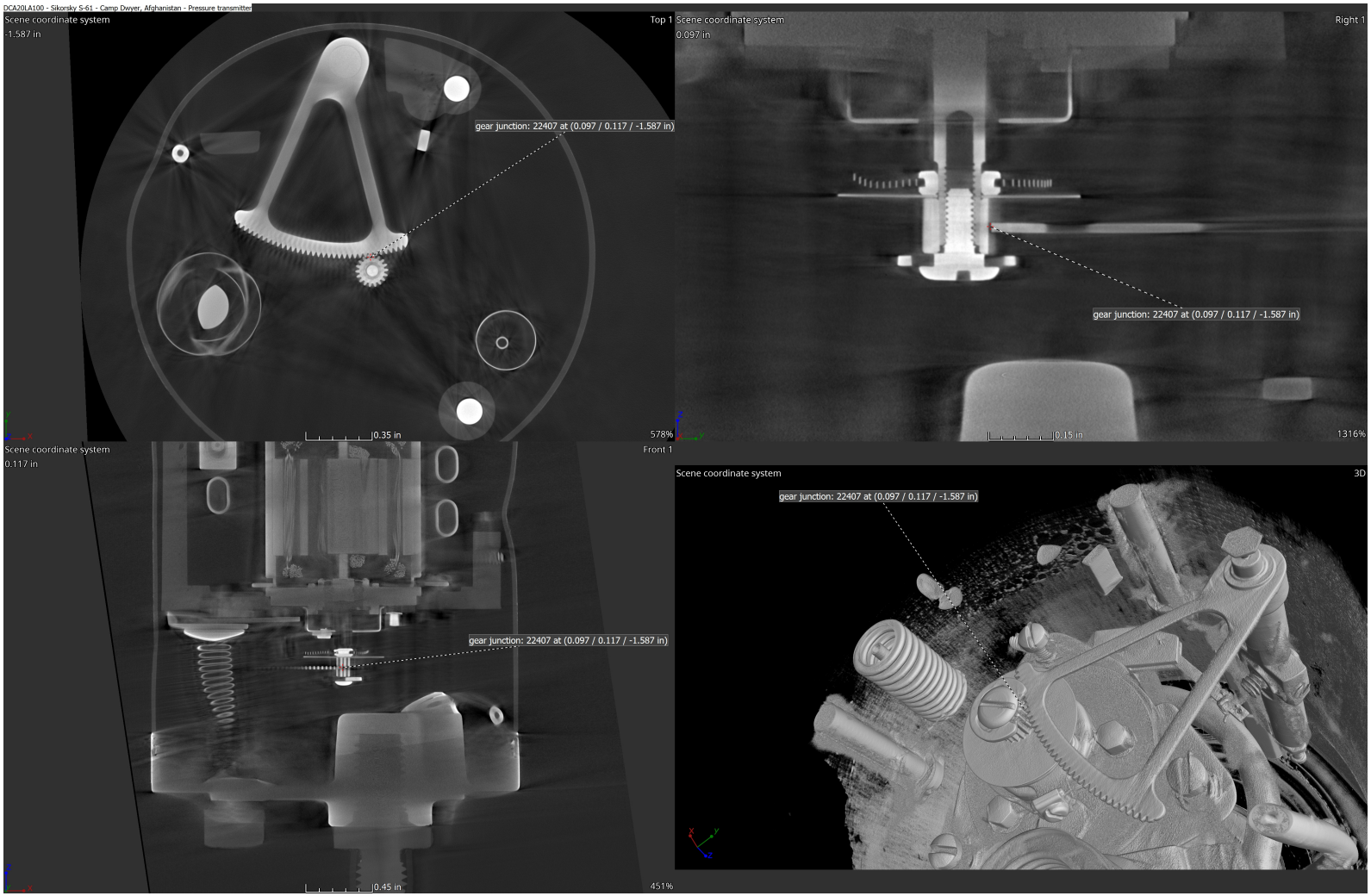


Figure 45
Pressure transmitter – gear junction

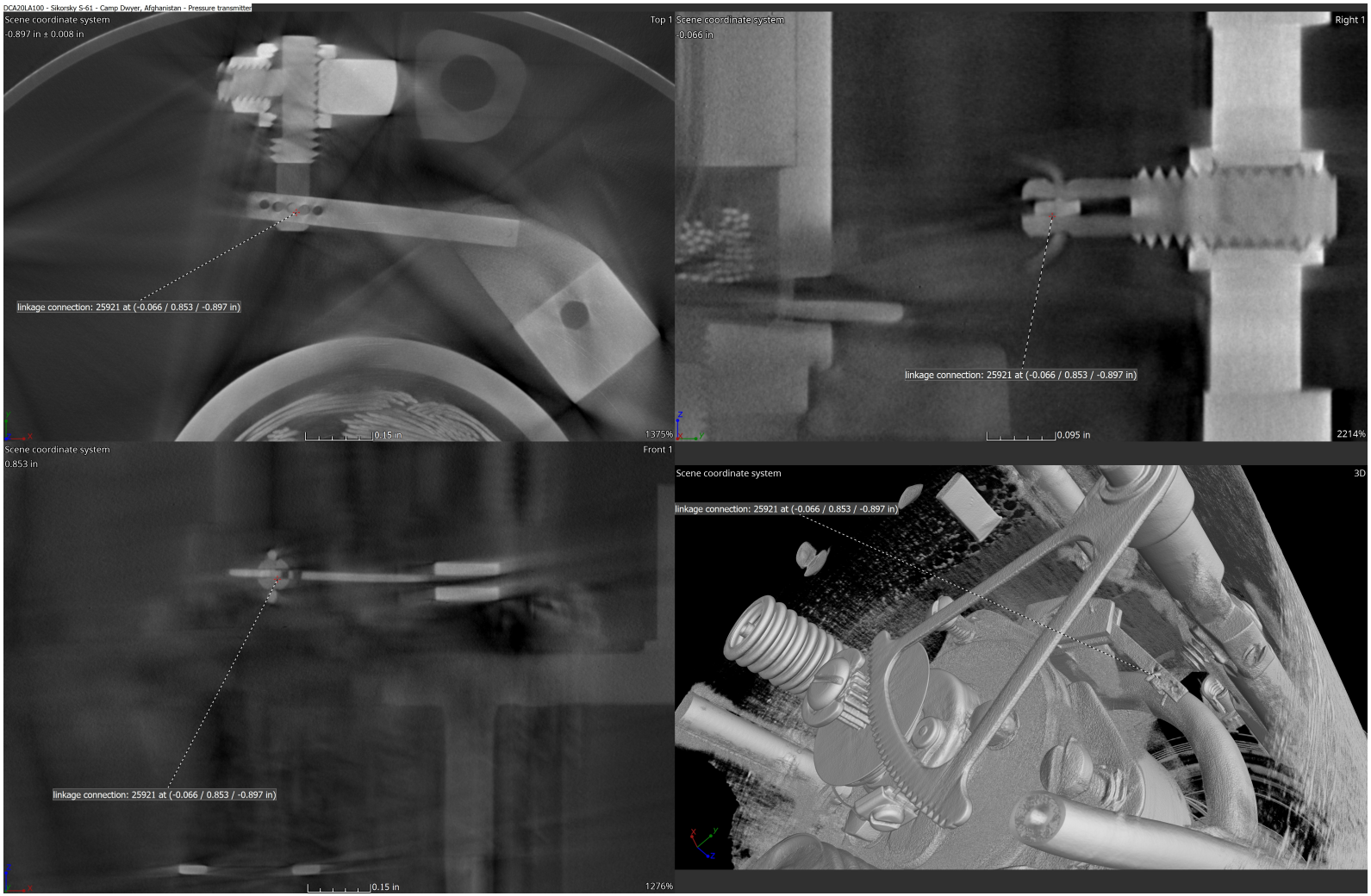


Figure 46
Pressure transmitter – linkage connection

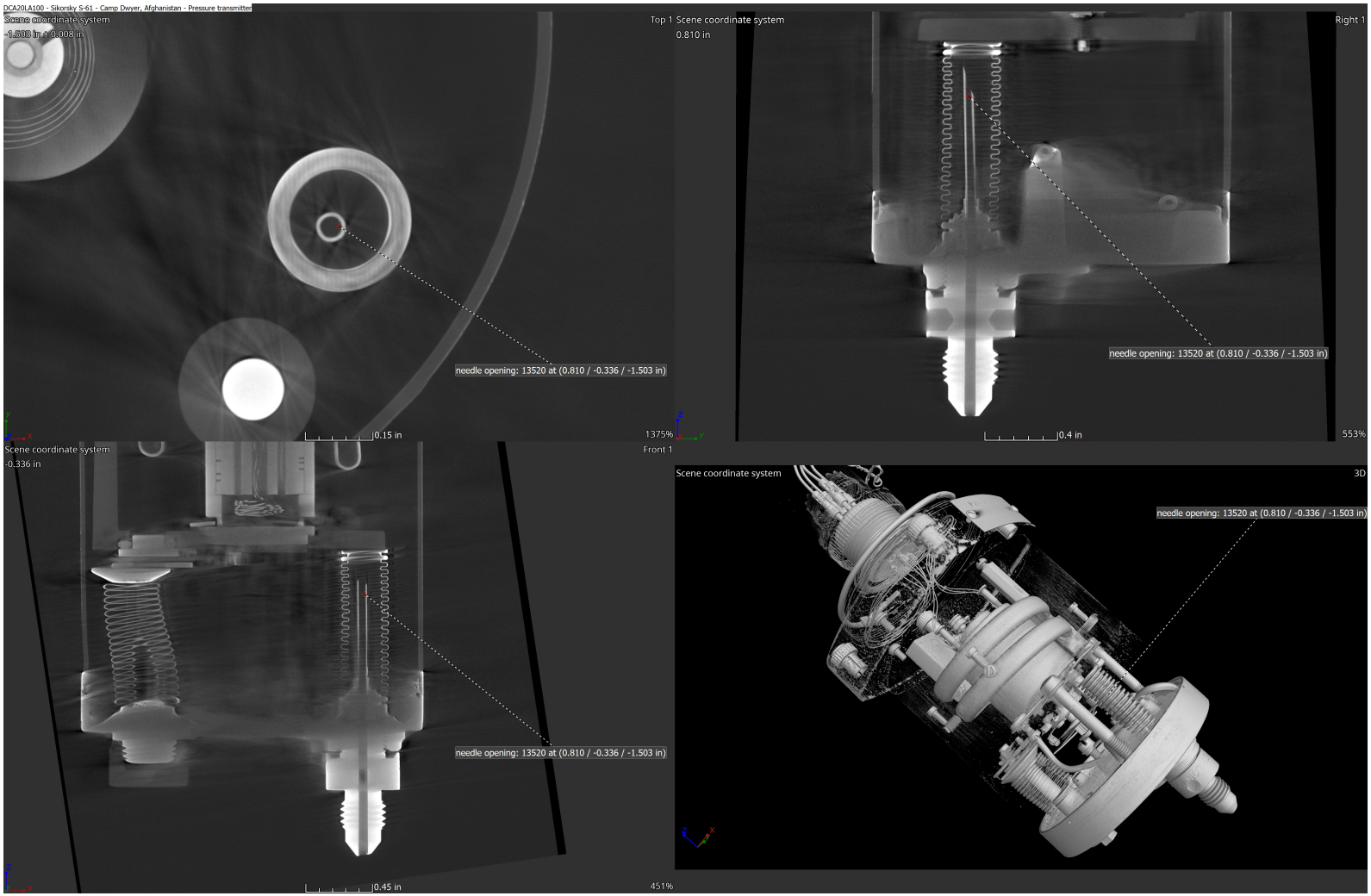


Figure 47
Pressure transmitter – needle opening

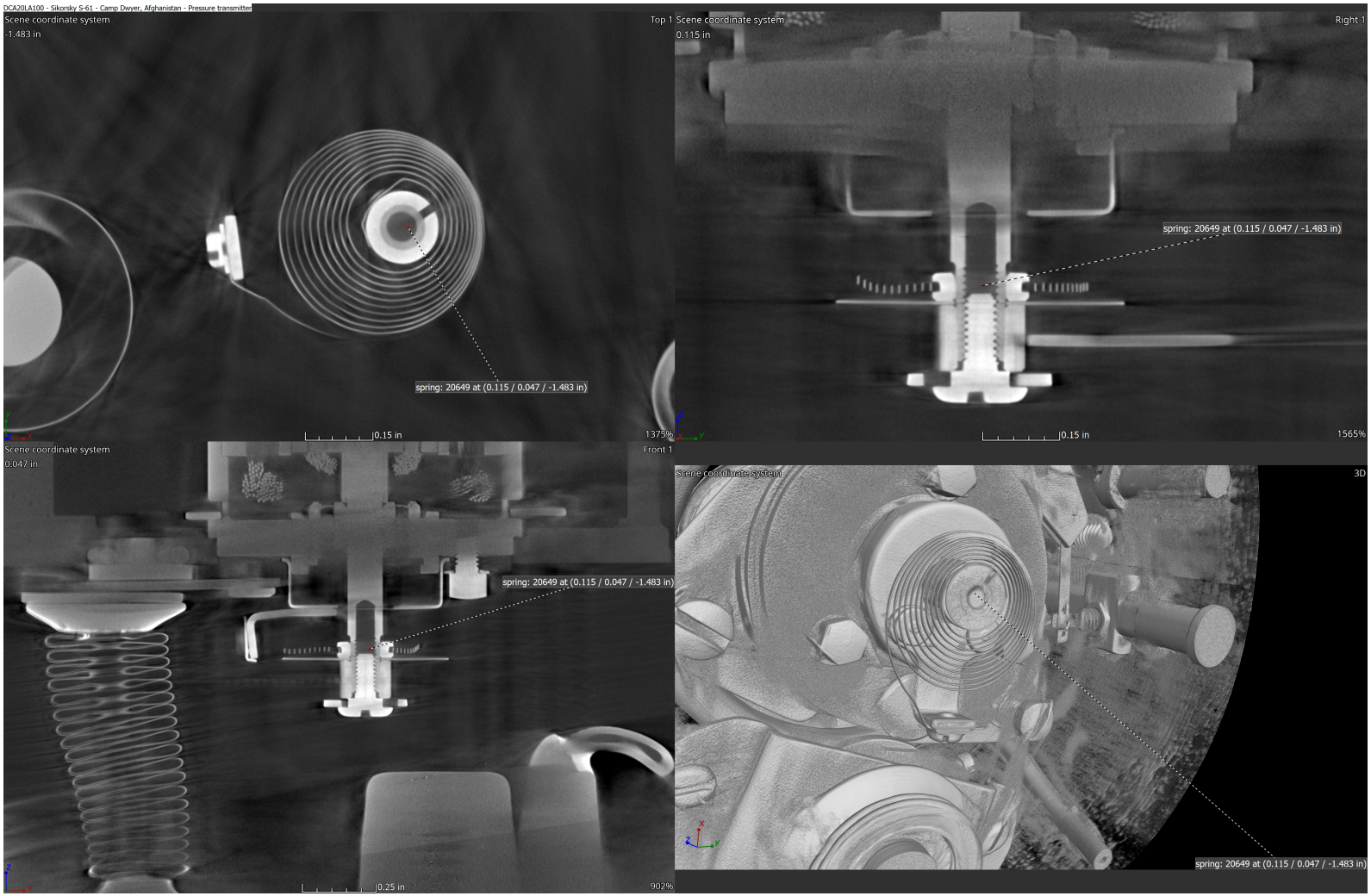


Figure 48
Pressure transmitter - spring

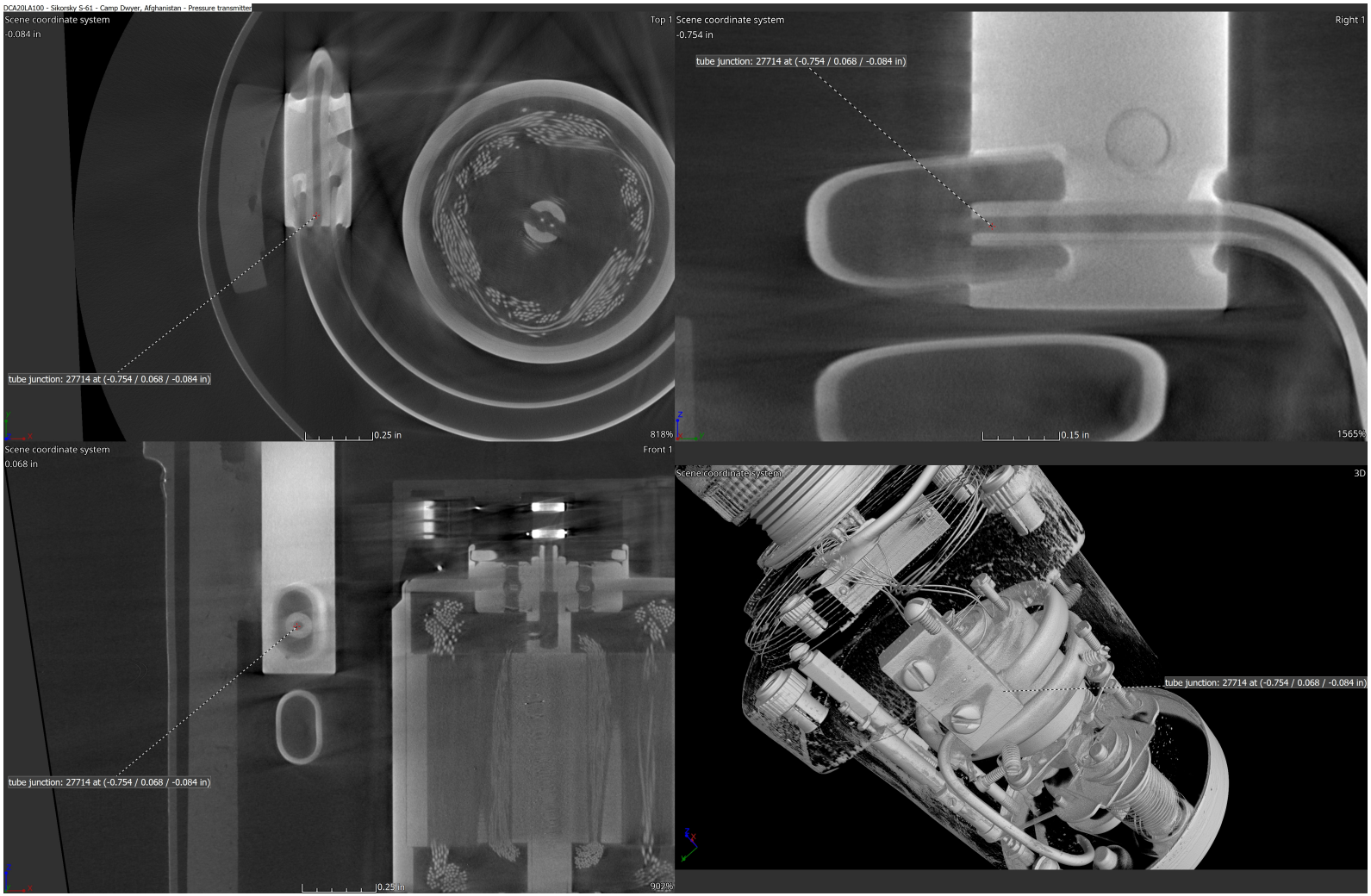


Figure 49
Pressure transmitter – tube junction

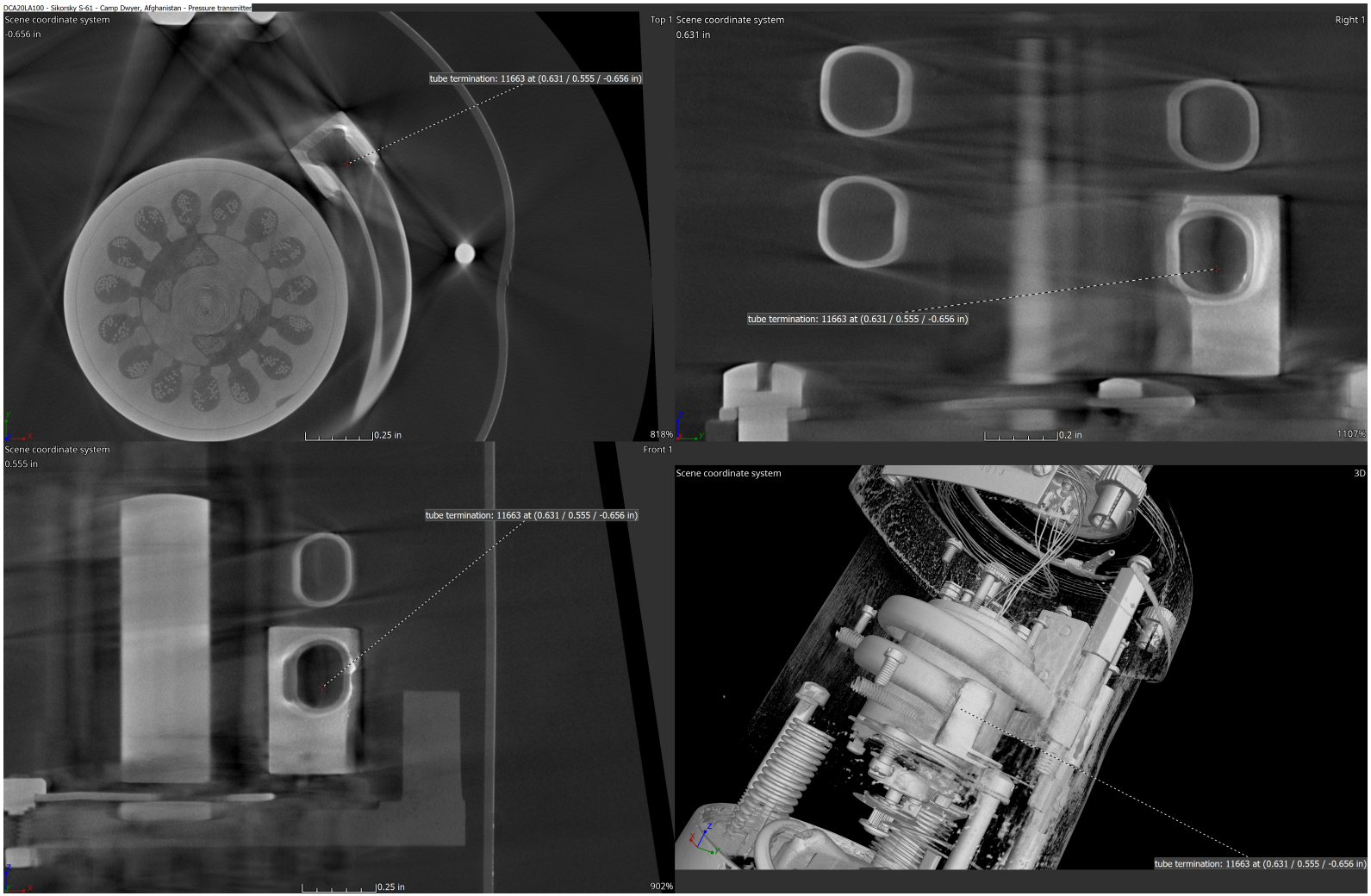


Figure 50
Pressure transmitter – tube termination

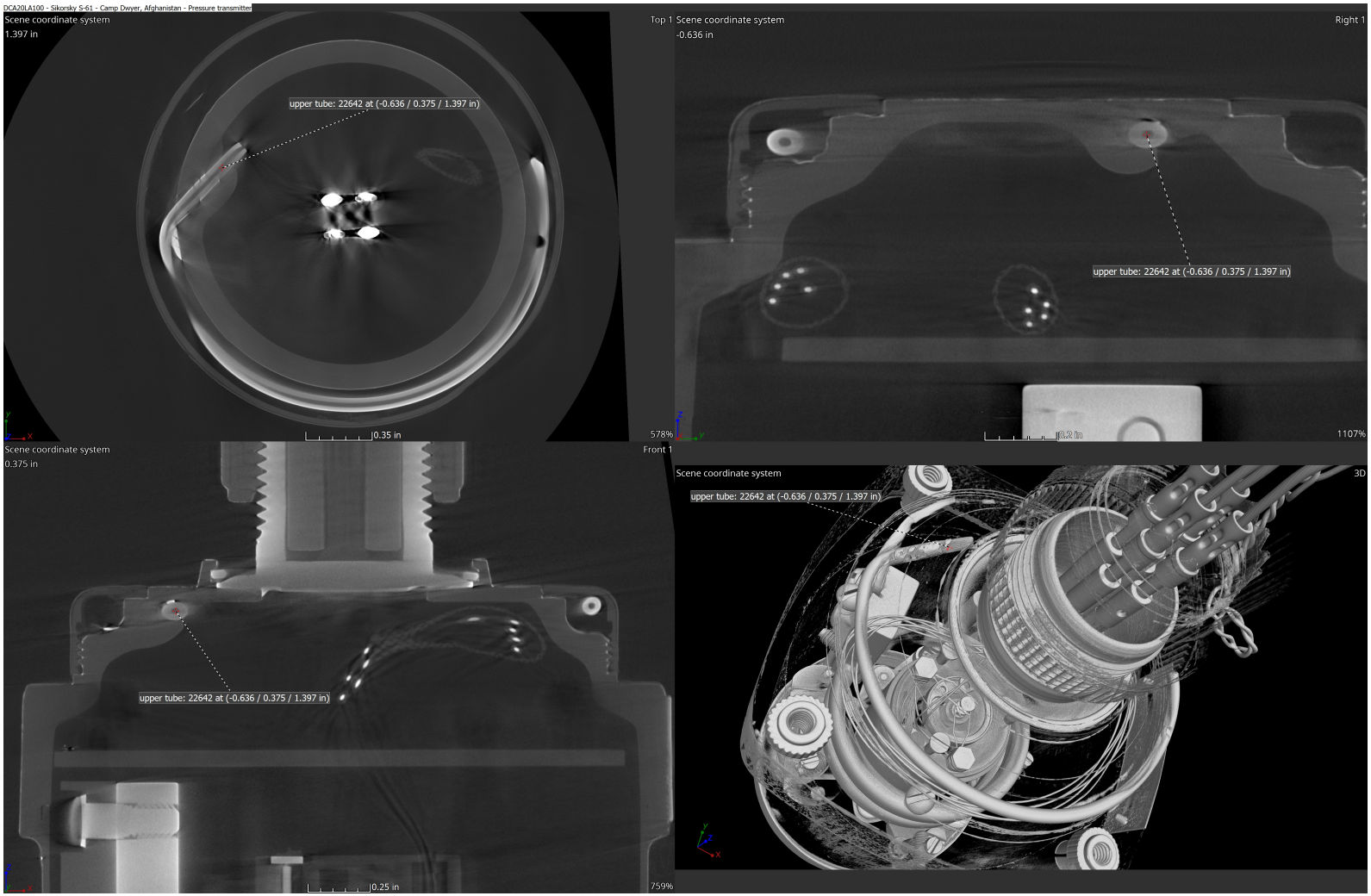


Figure 51
Pressure transmitter – upper tube

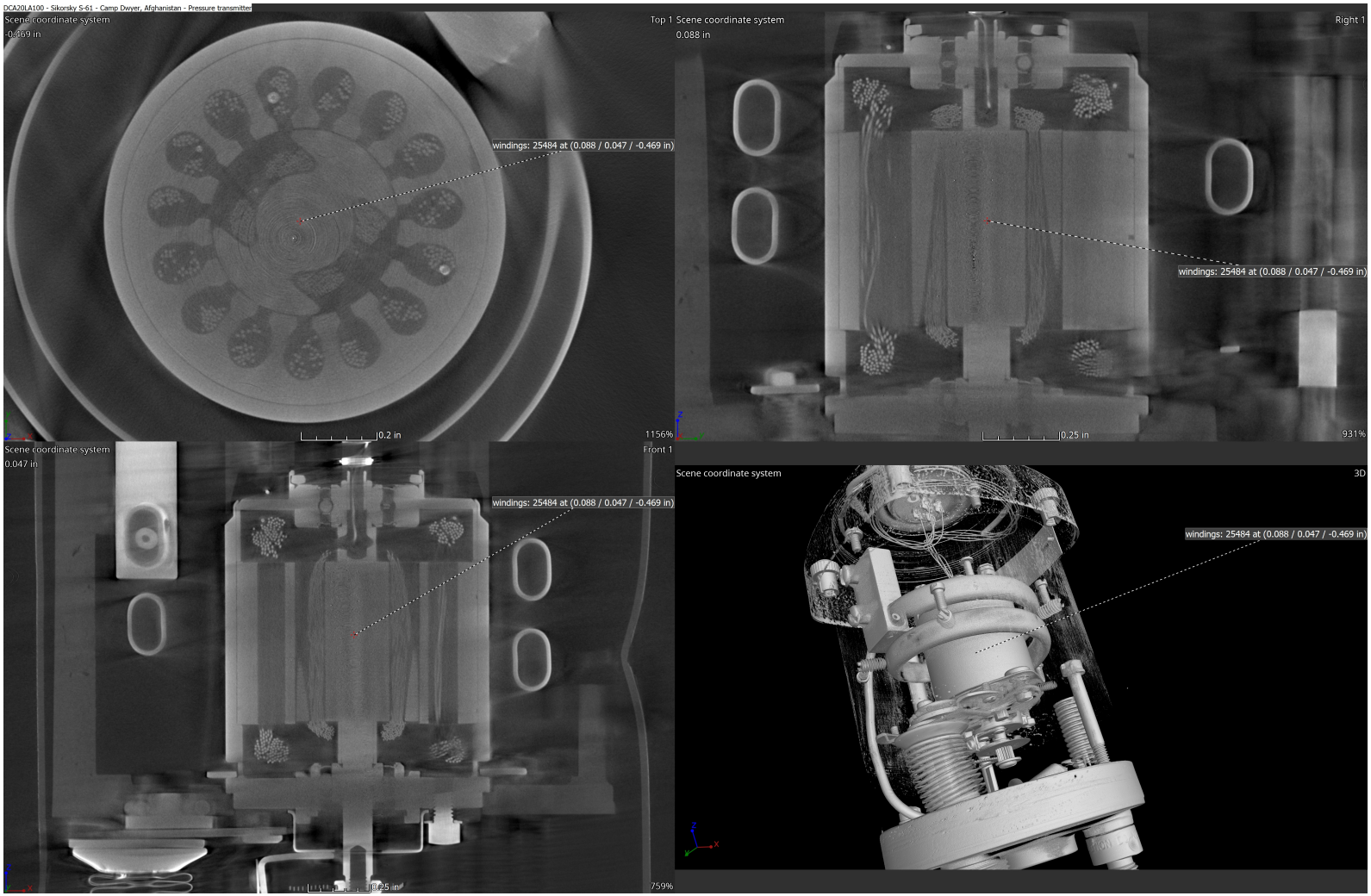


Figure 52
Pressure transmitter - windings

Scott Warren
Lead Aerospace Engineer
(Computed Tomography Specialist)