

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

January 16, 2018

Computed Tomography Specialist's Factual Report

CEN-16-FA-372

A. ACCIDENT

Location: near Chandler Field Airport (AXN), Alexandria, Minnesota
Date: September 17, 2016
Time: 0207 central daylight time
Airplane: Agusta S.p.A A109S helicopter, N91NM

B. GROUP

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

C. SUMMARY

On September 17, 2016, at 0207 central daylight time, an Agusta S.p.A A109S helicopter, N91NM, impacted trees and terrain near Chandler Field Airport (AXN), Alexandria, Minnesota. The commercial rated pilot and two crew members sustained serious injuries and the helicopter was destroyed. The helicopter was registered to North Memorial Health Care, Brooklyn Center, Minnesota, and operated by North Memorial Medical Center under the provisions of 14 Code of Federal Regulations Part 135 as a positioning flight. Night instrument meteorological conditions prevailed at the accident site and an instrument flight rules (IFR) flight plan had been filed. The helicopter departed Brainerd Lakes Regional Airport (BRD), Brainerd, Minnesota about 0135 and was destined for the Douglas County Hospital helipad, Alexandria, Minnesota.

The internal configuration of the roll trim actuator, left roll linear actuator, right roll linear actuator, left pitch linear actuator and right pitch linear actuator were documented using radiographic images that were collected from June 1- 19, 2017 in Chicago, Illinois. A total of 21,866 computed tomography (CT) slice images were examined, processed, and analyzed by the NTSB to evaluate the components.

Review of the images indicated that, when the scans were conducted, the following items were noted:

Roll trim actuator:

- there was a crack noted in the cover;

Left roll linear actuator:

- there was an irregular material edge noted in the area of the LVDT;
- there was medium density material noted in two places within the left roll linear actuator LVDT;
- there were cracks noted in the grommet;

Right roll linear actuator:

- there were cracks noted in two locations within the grommet;
- there was a ring of material at one end of the motor cavity within the actuator;
- there was medium density material noted in the retract stop, the extend stop, the LVDT, and near the brake;

Right pitch linear actuator:

- there was a crack noted in the exterior flange of the actuator body;
- there were high density particles noted in four locations in the actuator;
- there were medium density particles noted in three locations in the actuator.

D. DETAILS OF THE INVESTIGATION

1.0 General

The roll trim actuator, left roll linear actuator, right roll linear actuator, left pitch linear actuator and right pitch linear actuator were subjected to x-ray radiograph and computed tomography (CT) scanning to document their internal conditions. The scanning was conducted from June 1-20, 2017. The scans were performed by Varex, Inc under the direction of the NTSB using the Varex Actis 1000/500 megavolt and Actis 500/225 microfocus CT systems.

For the CT scans, the components were 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 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 21,851 slices, and the total size of the combined data sets was approximately 168 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	Roll trim actuator	Roll linear actuator – left	Roll linear actuator – right	Pitch linear actuator – left	Pitch linear actuator – right
Number of slices	479	6801	6968	968	6635
Voxel Size - X Direction (mm)	0.54	0.03	0.03	0.03	0.03
Voxel Size - Y Direction (mm)	0.54	0.03	0.03	0.03	0.03
Voxel Size - Z Direction (mm)	0.40	0.03	0.03	0.03	0.03
Image Projections per Revolution	2160	2160	2160	2160	2160
Exposure time (ms)	10	285.58	285.58	285.58	285.58
Frames to Avg (frames per projection)	2	2	2	2	2
X-ray Source Voltage (kV)	1000	222	223	223	223
X-ray Source Current (mA)	NA	0.565	0.565	0.565	0.565
Source Filter Thickness (mm)	2.5	1	1	1	1
Source Filter Material	Steel	Brass	Brass	Brass	Brass
Image Matrix Size	1024 x 1024	2048 x 2048	2048 x 2048	2048 x 2048	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 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 high 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.

In some images, cylindrical structures were “virtually unrolled” using the software. This process required the identification of a path for the software to use when unrolling the data set, and it resulted in a cylindrical structure being “unrolled” to show a round surface as a flat planar 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 88. Review of the images indicated that, when the scans were conducted, the following items were noted:

Roll trim actuator:

- there was a crack noted in the cover;

Left roll linear actuator:

- there was an irregular material edge noted in the area of the LVDT;
- there was medium density material noted in two places within the left roll linear actuator LVDT;
- there were cracks noted in the grommet;

Right roll linear actuator:

- there were cracks noted in two locations within the grommet;
- there was a ring of material at one end of the motor cavity within the actuator;
- there was medium density material noted in the retract stop, the extend stop, the LVDT, and near the brake;

Right pitch linear actuator:

- there was a crack noted in the exterior flange of the actuator body;
- there were high density particles noted in four locations in the actuator;
- there were medium density particles noted in three locations in the actuator.

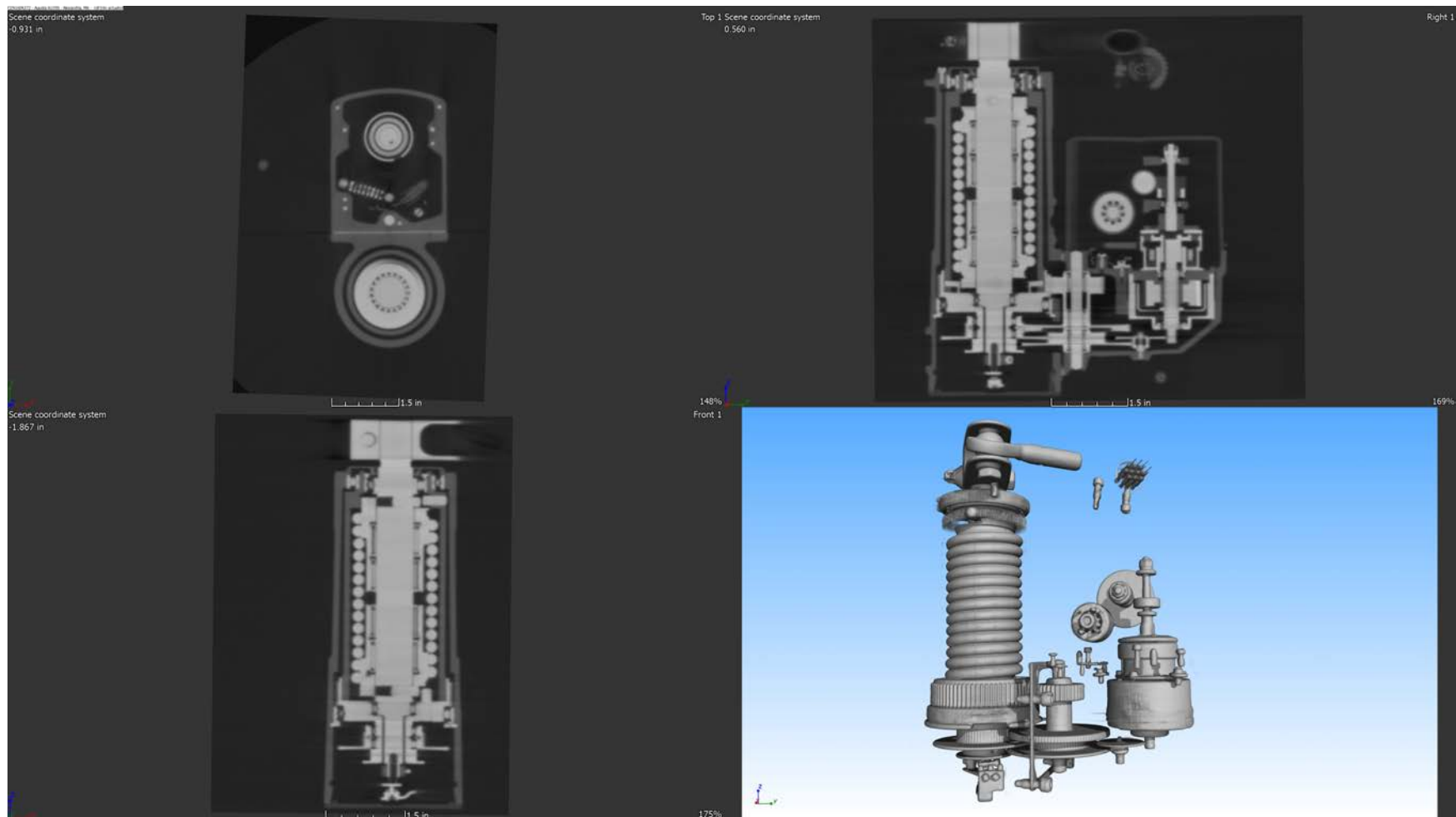


Figure 1
Roll trim actuator – overview

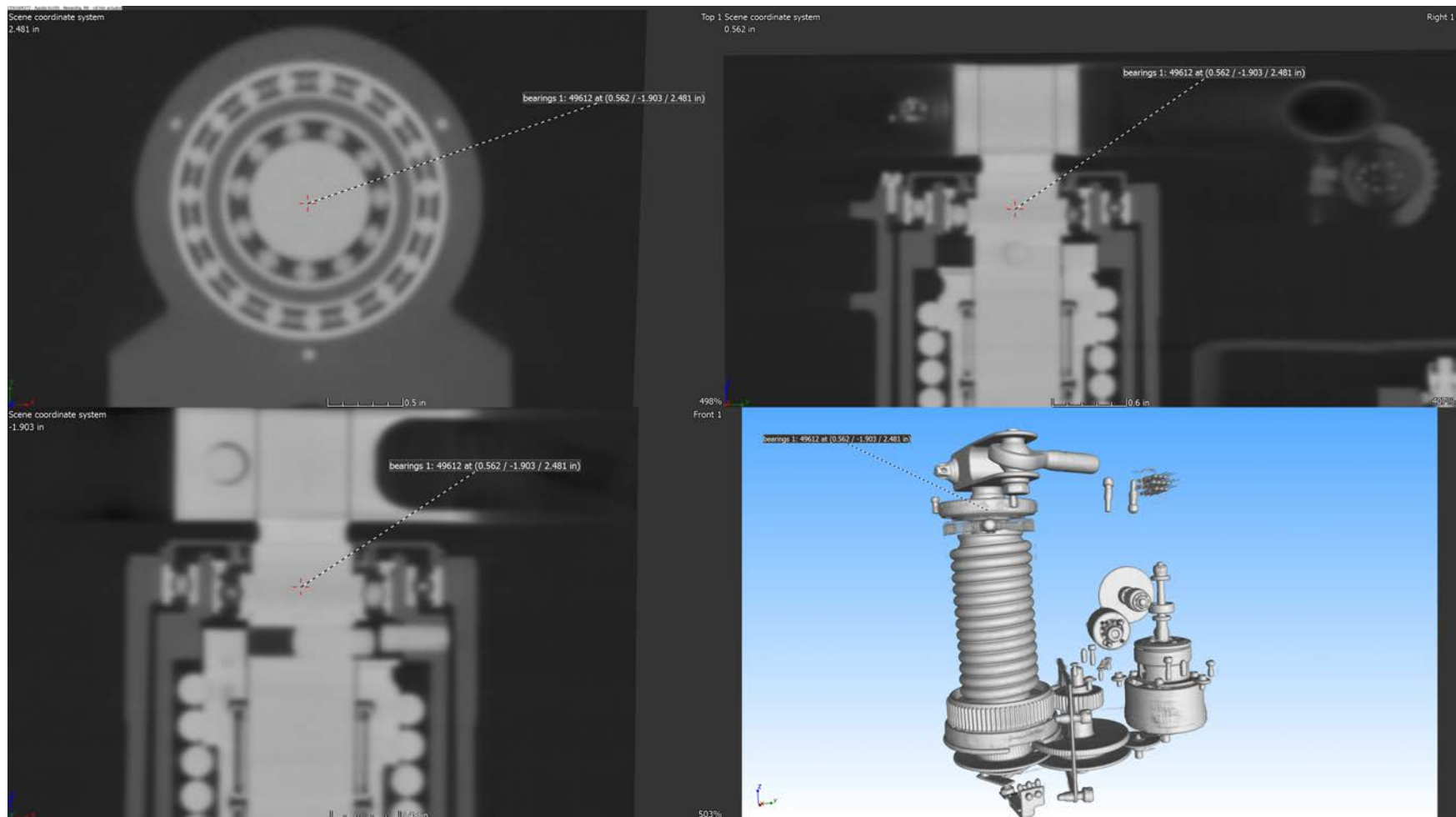


Figure 2
Roll trim actuator – bearing 1

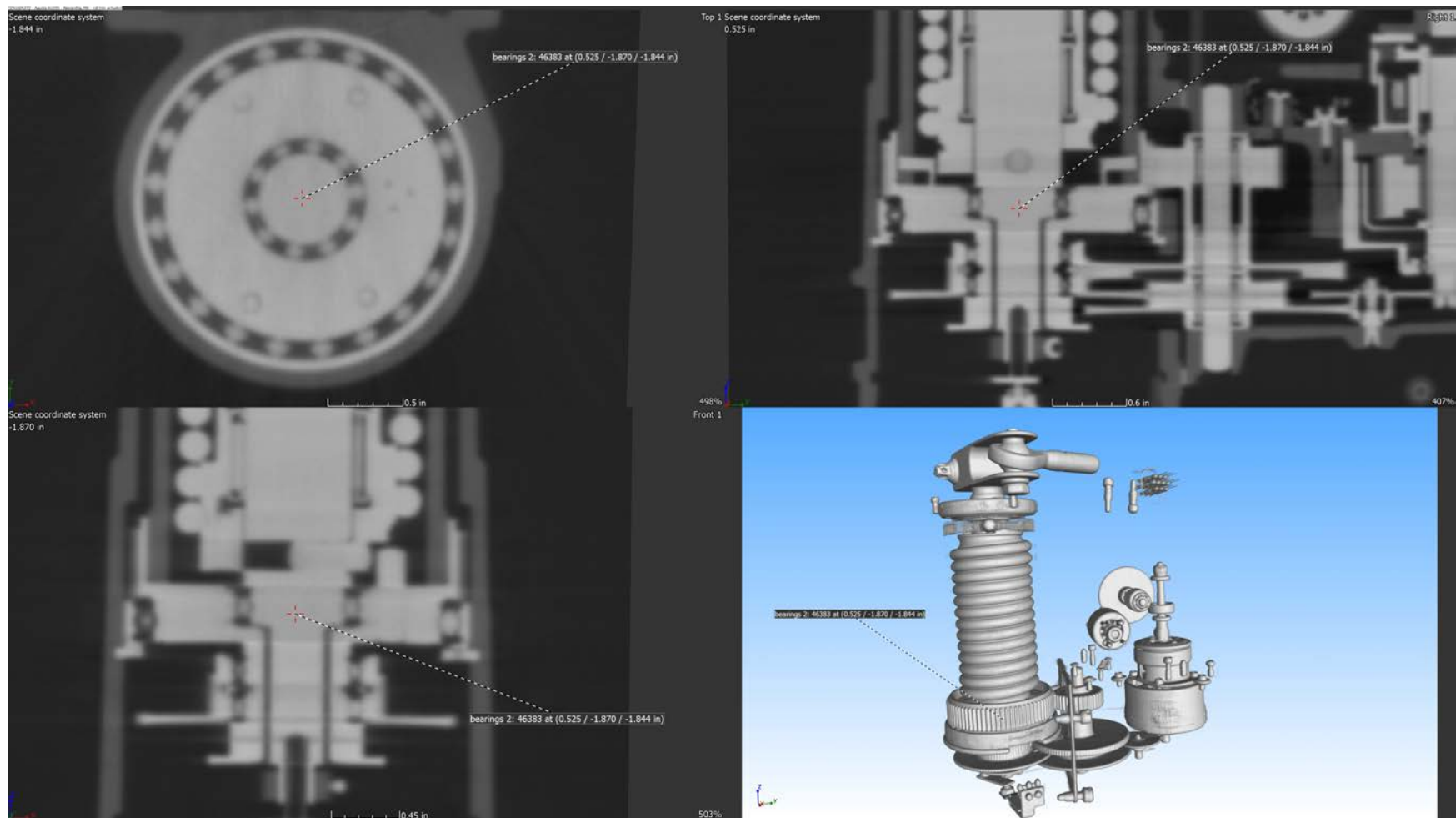


Figure 3
Roll trim actuator – bearing 2

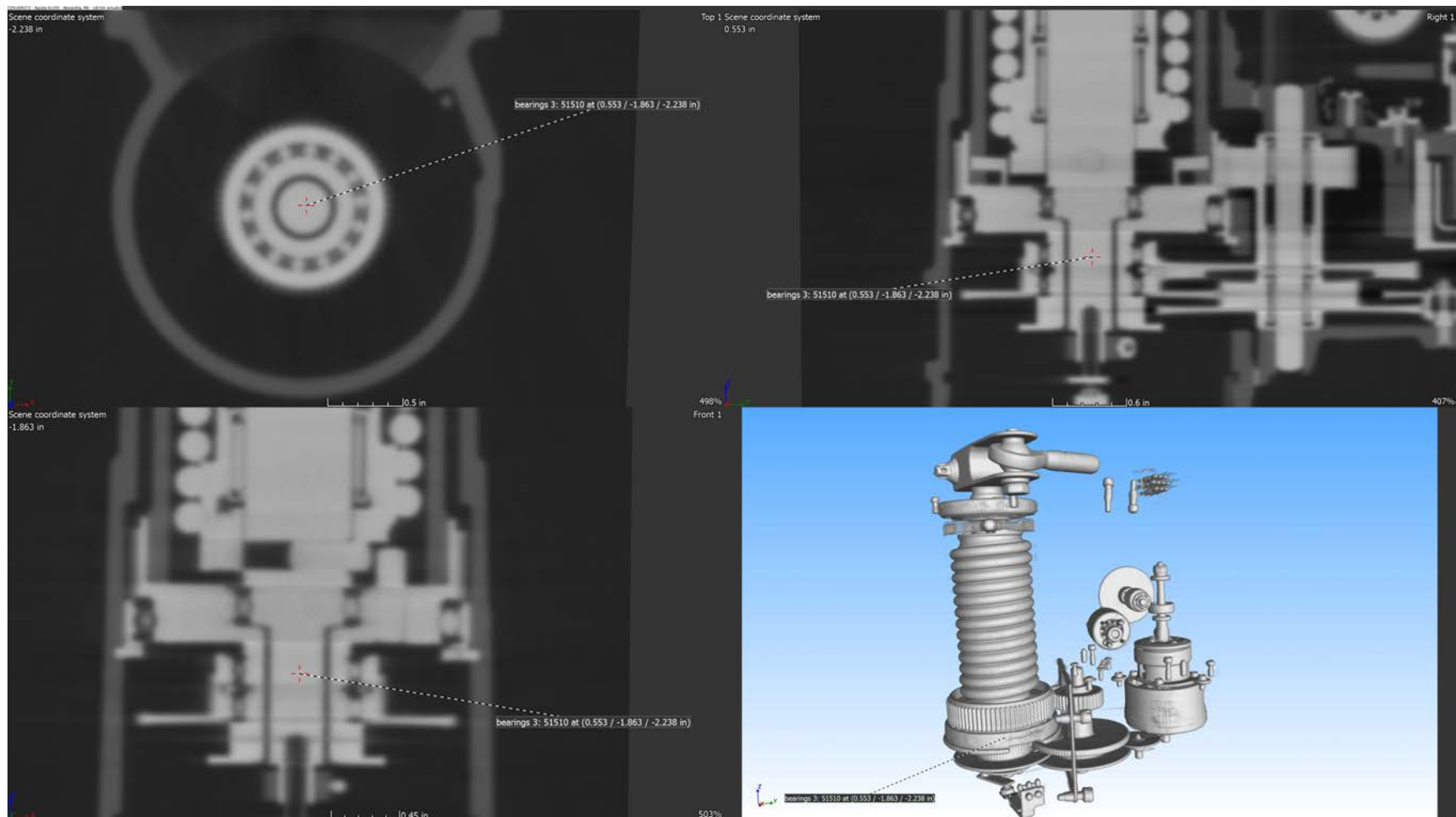


Figure 4
Roll trim actuator – bearing 3

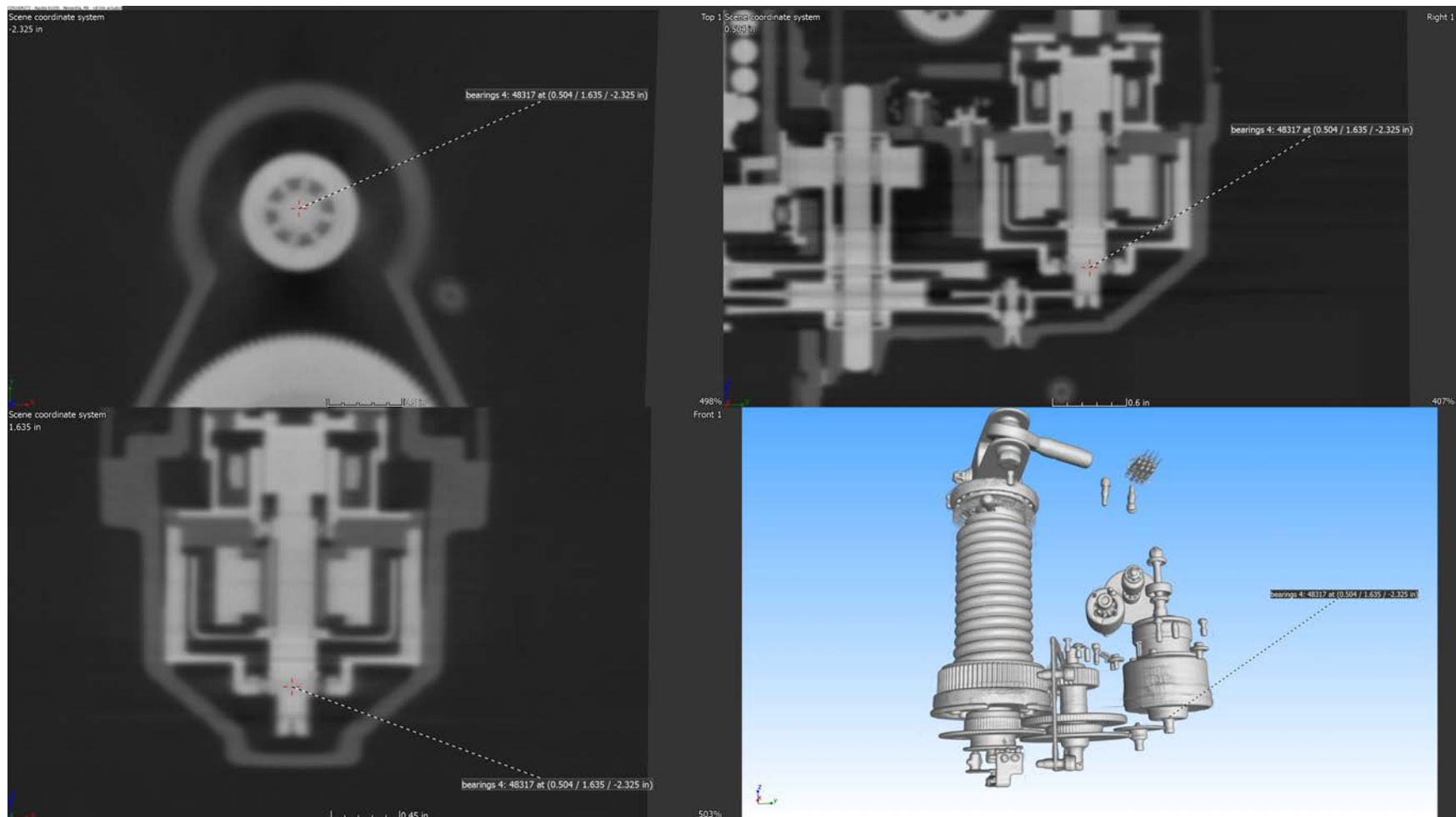


Figure 5
Roll trim actuator – bearing 4

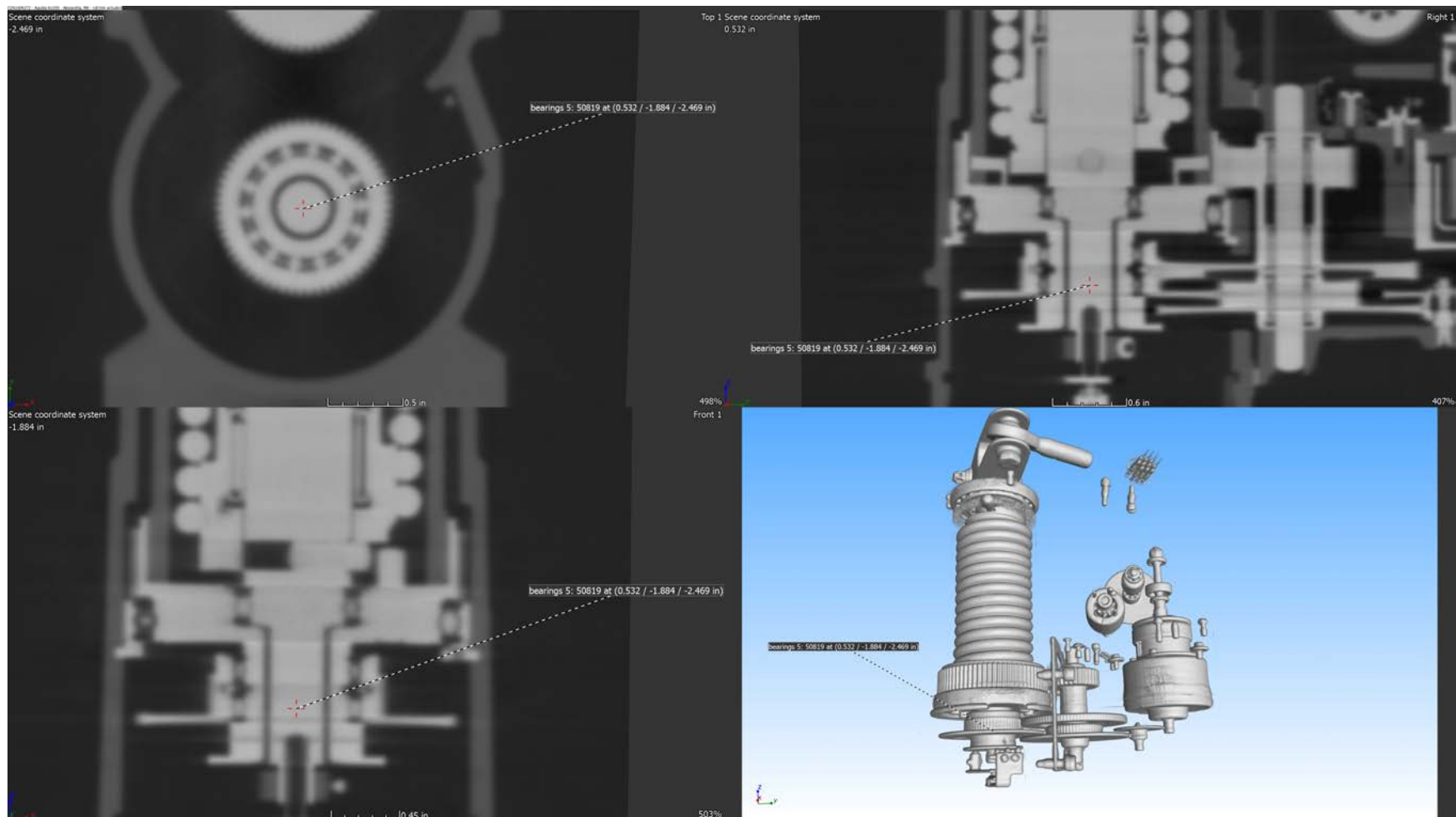


Figure 6
Roll trim actuator – bearing 5

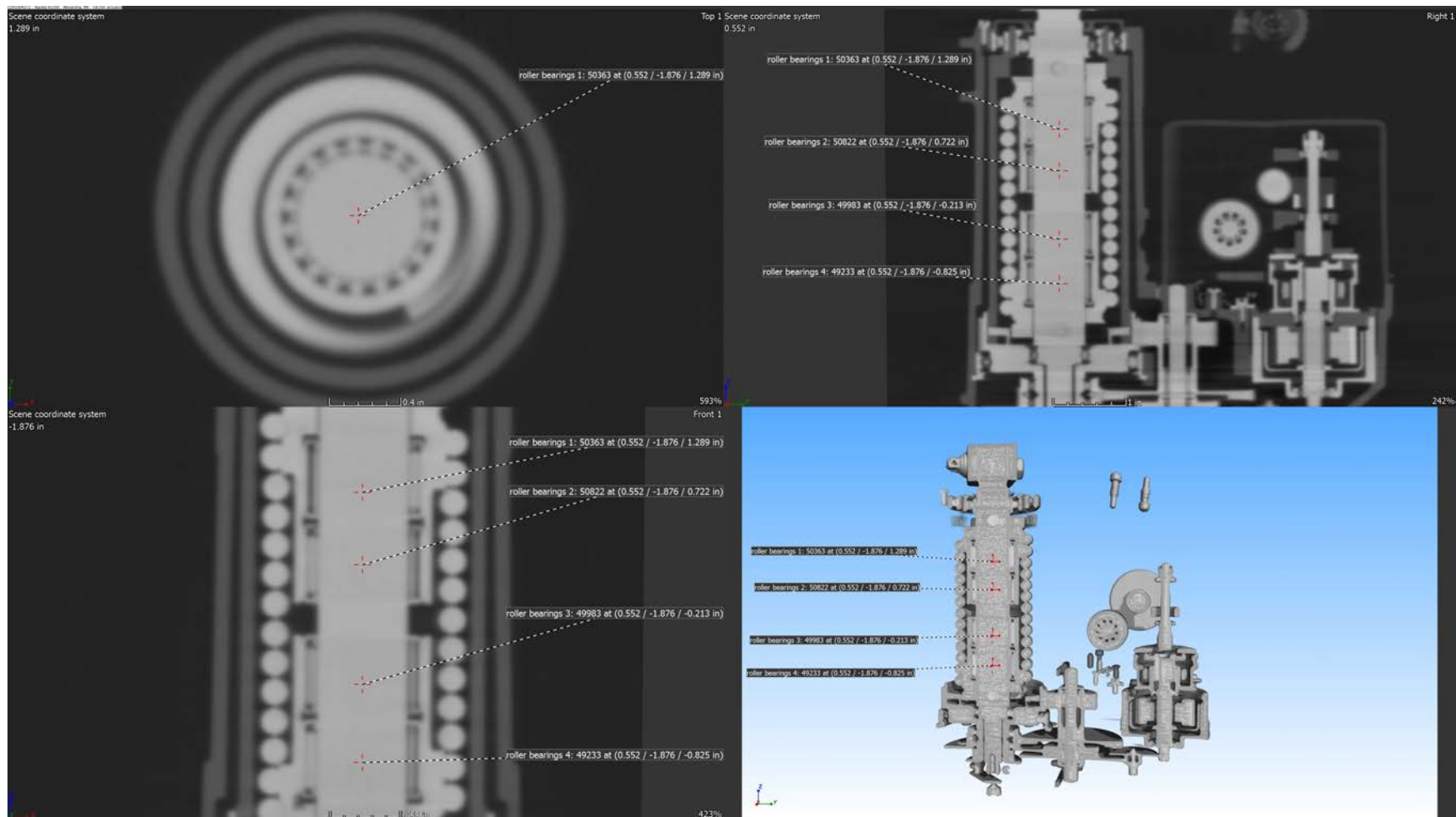


Figure 7
Roll trim actuator – roller bearings 1-4

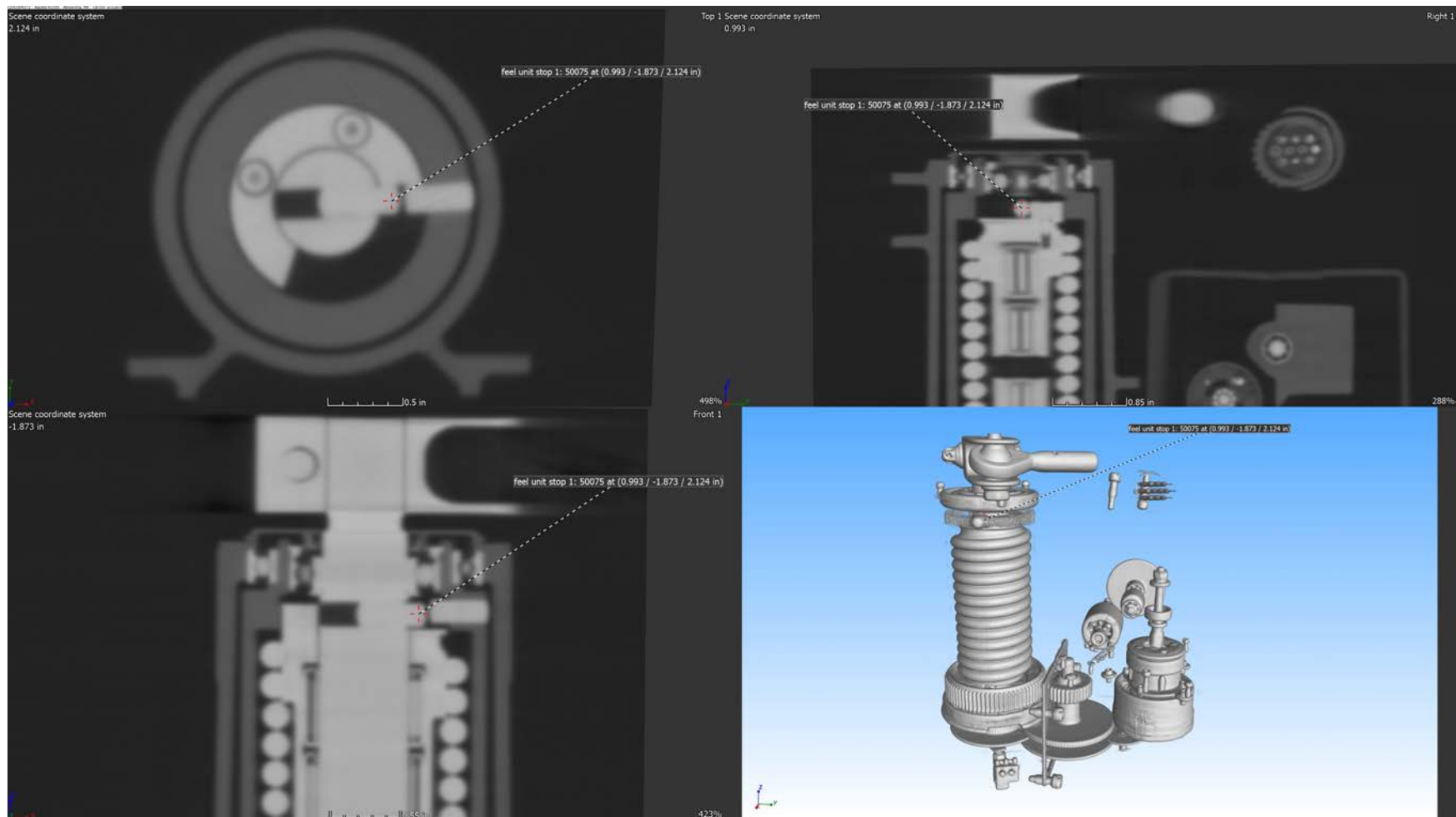


Figure 8
Roll trim actuator – feel unit stop 1

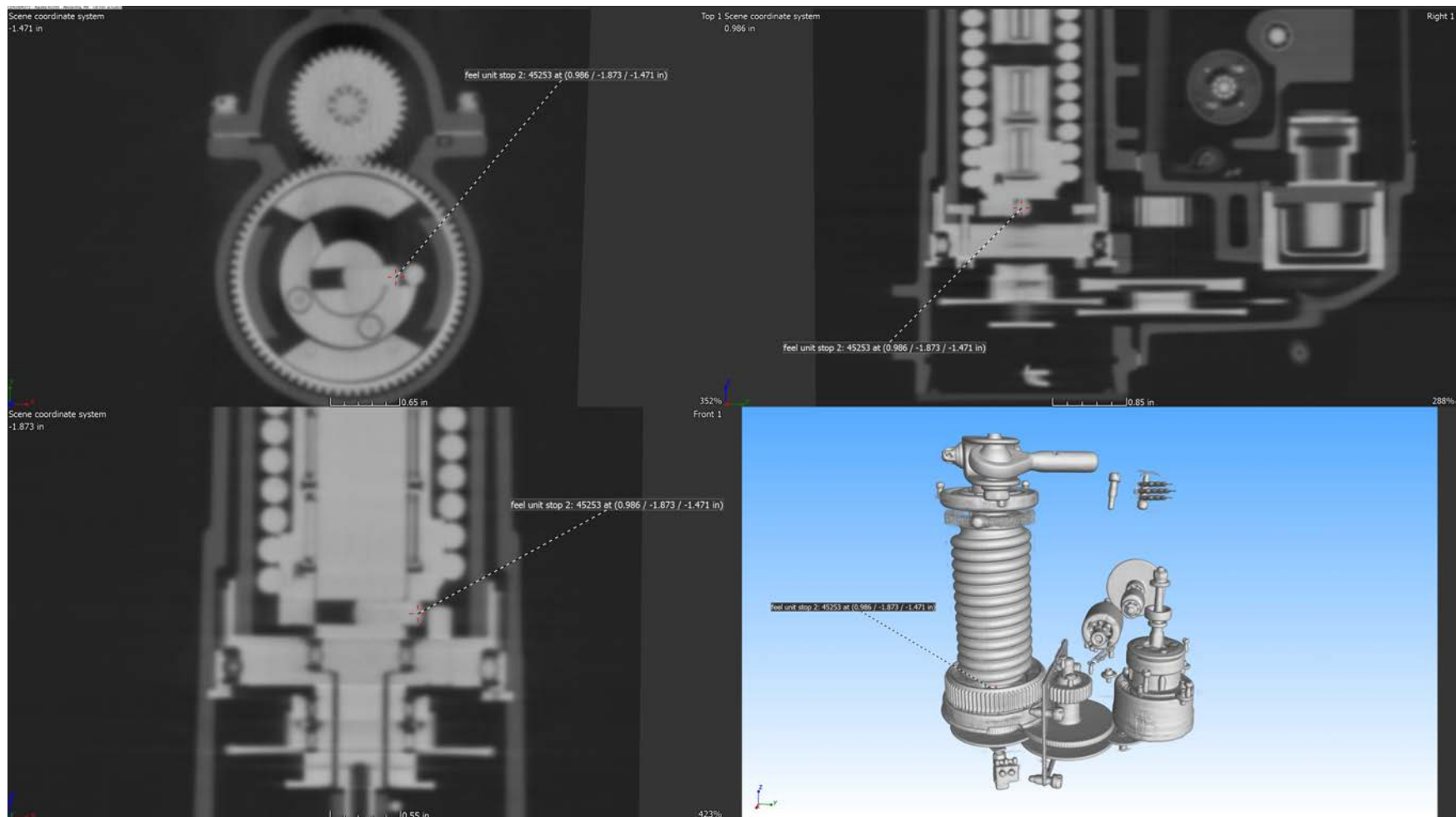


Figure 9
Roll trim actuator – feel unit stop 2

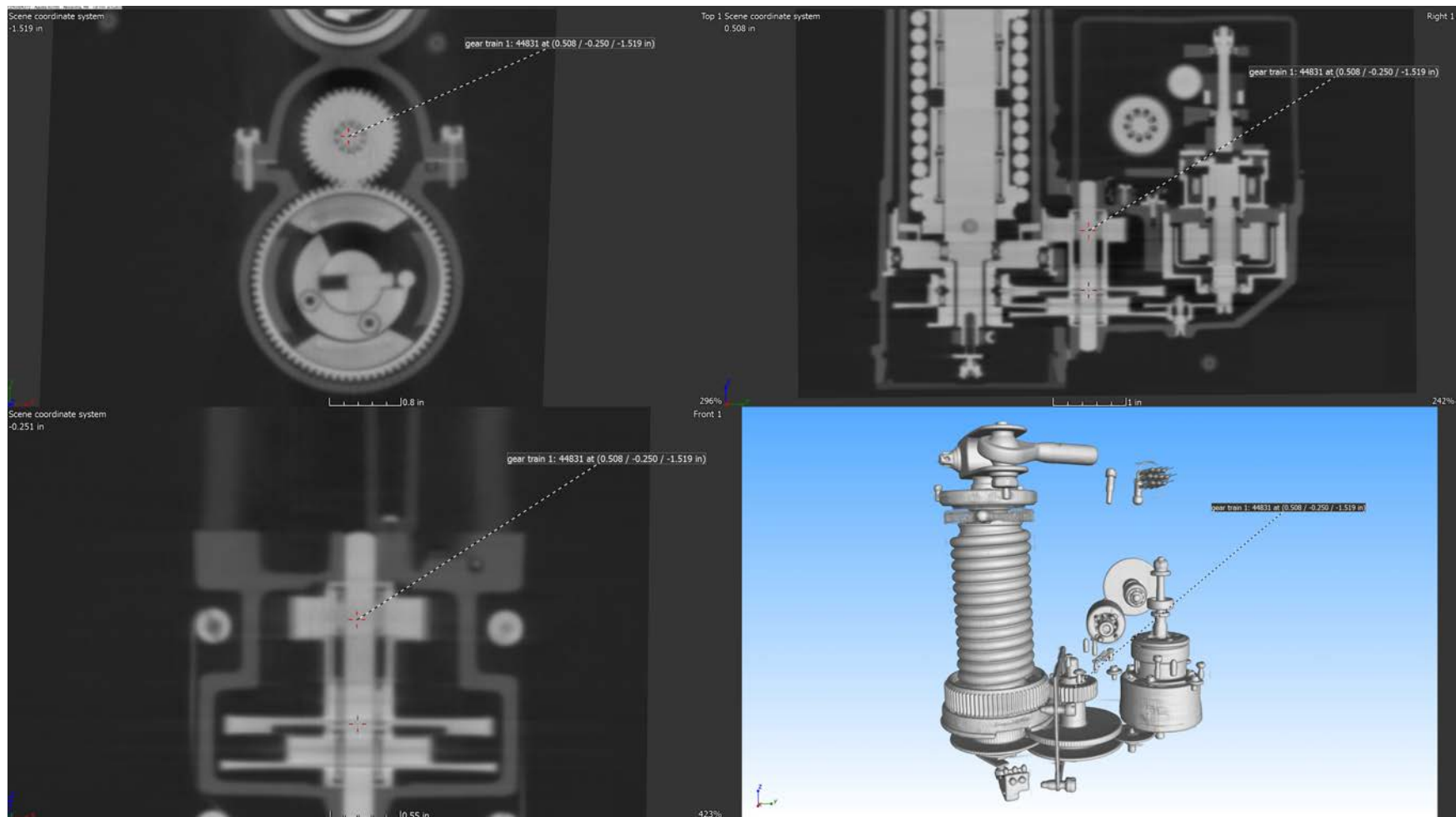


Figure 10
Roll trim actuator – gear train 1

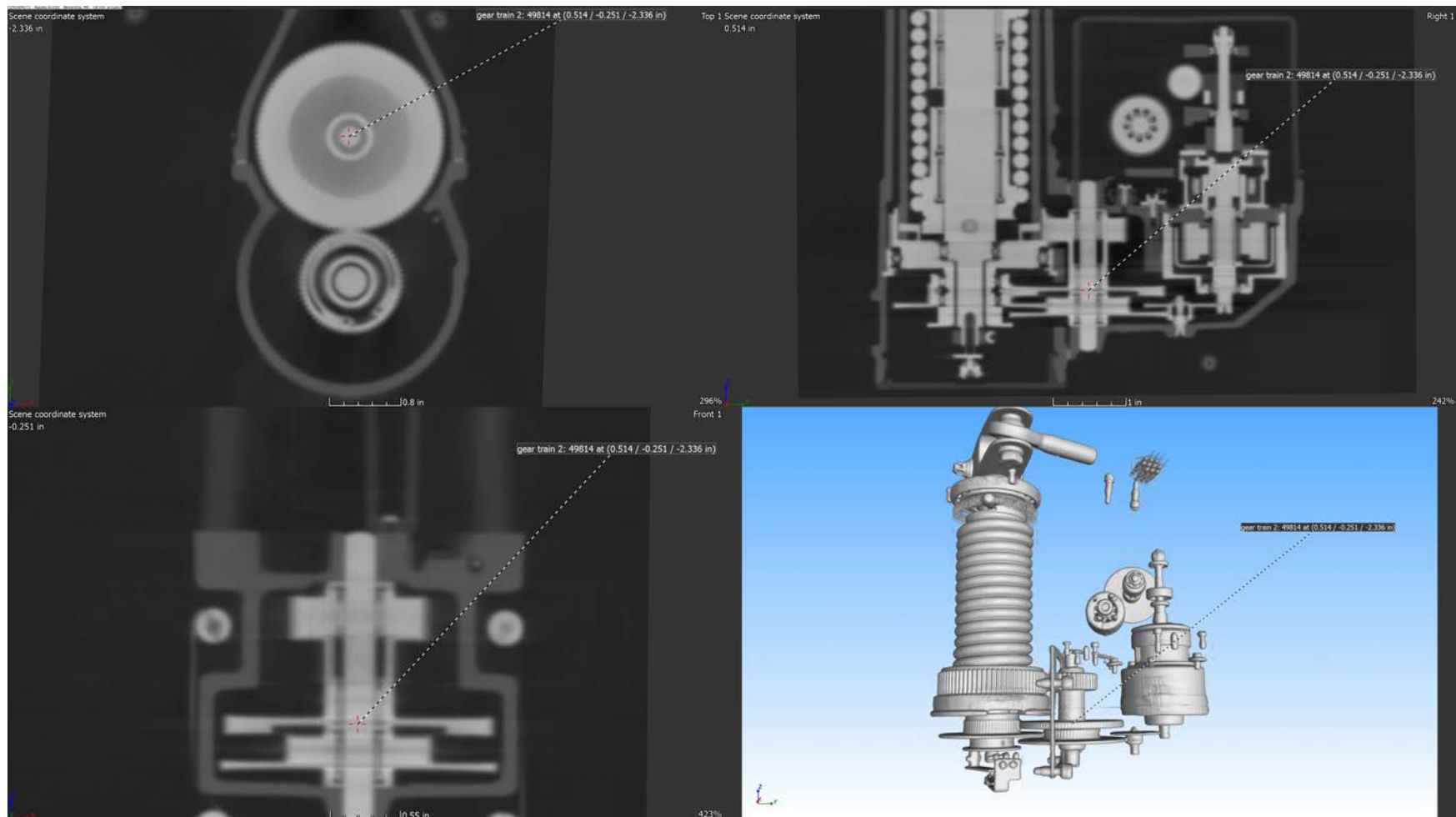


Figure 11
Roll trim actuator – gear train 2

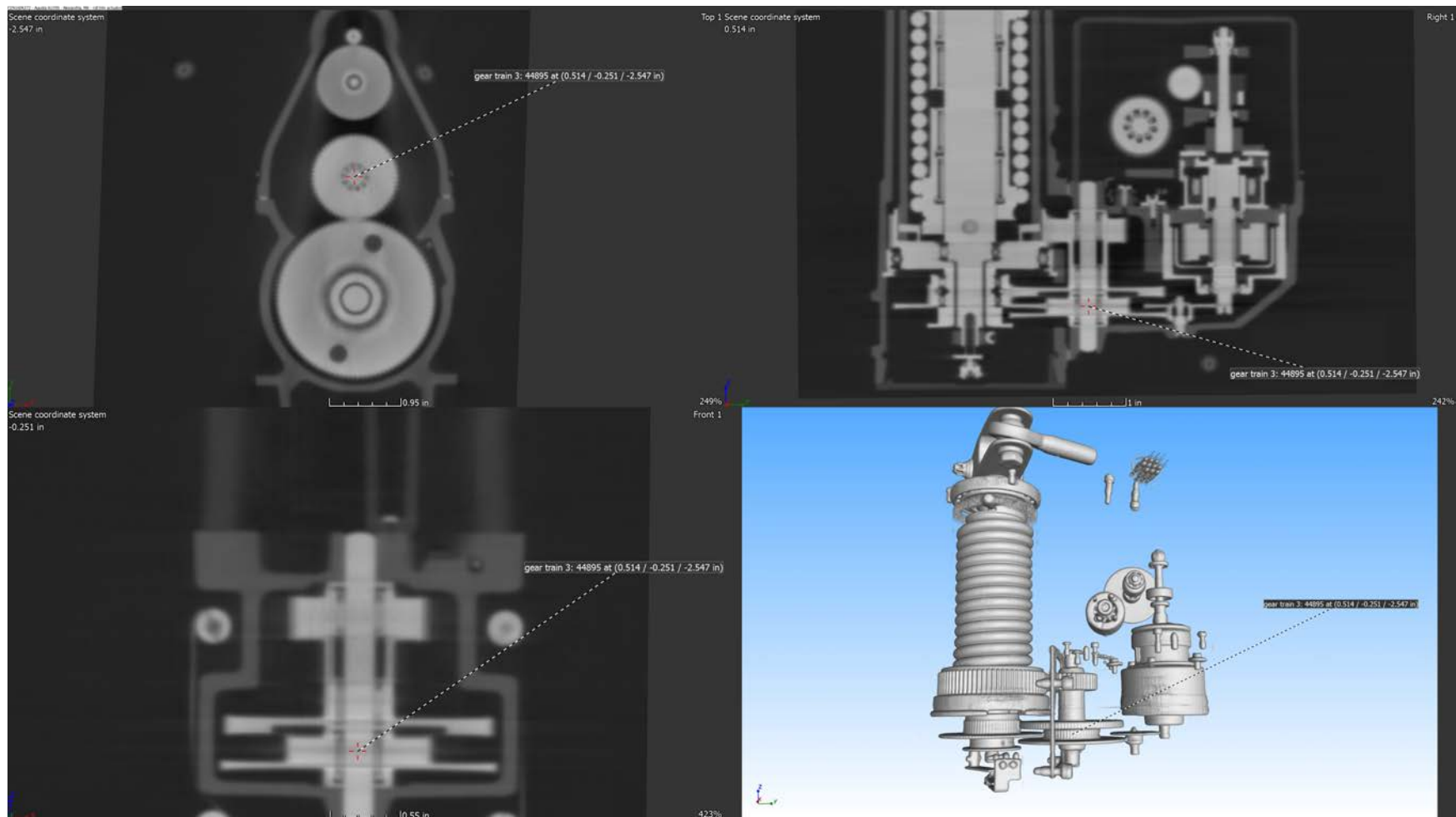


Figure 12
Roll trim actuator – gear train 3

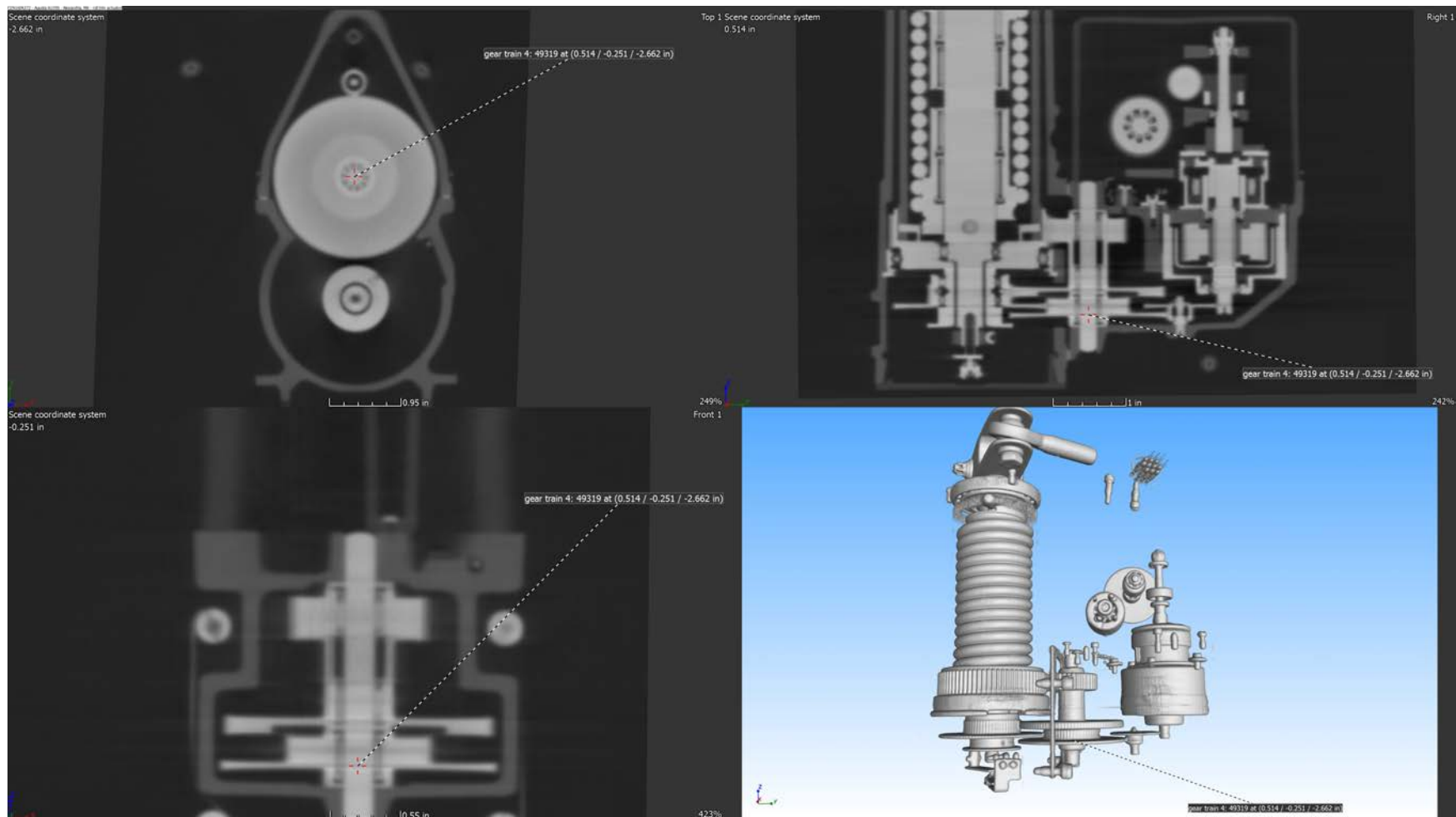


Figure 13
Roll trim actuator – gear train 4

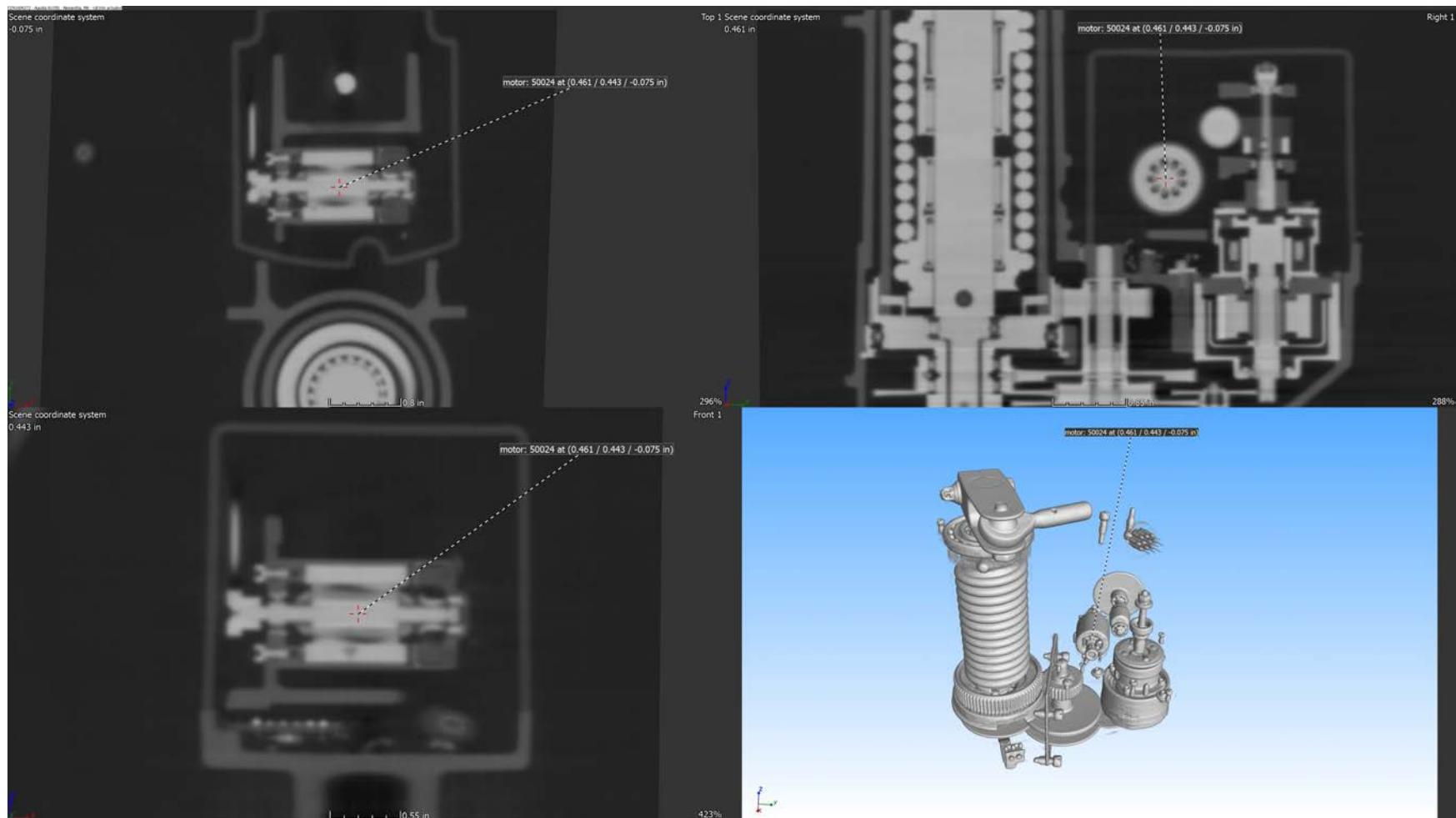


Figure 14
Roll trim actuator – motor

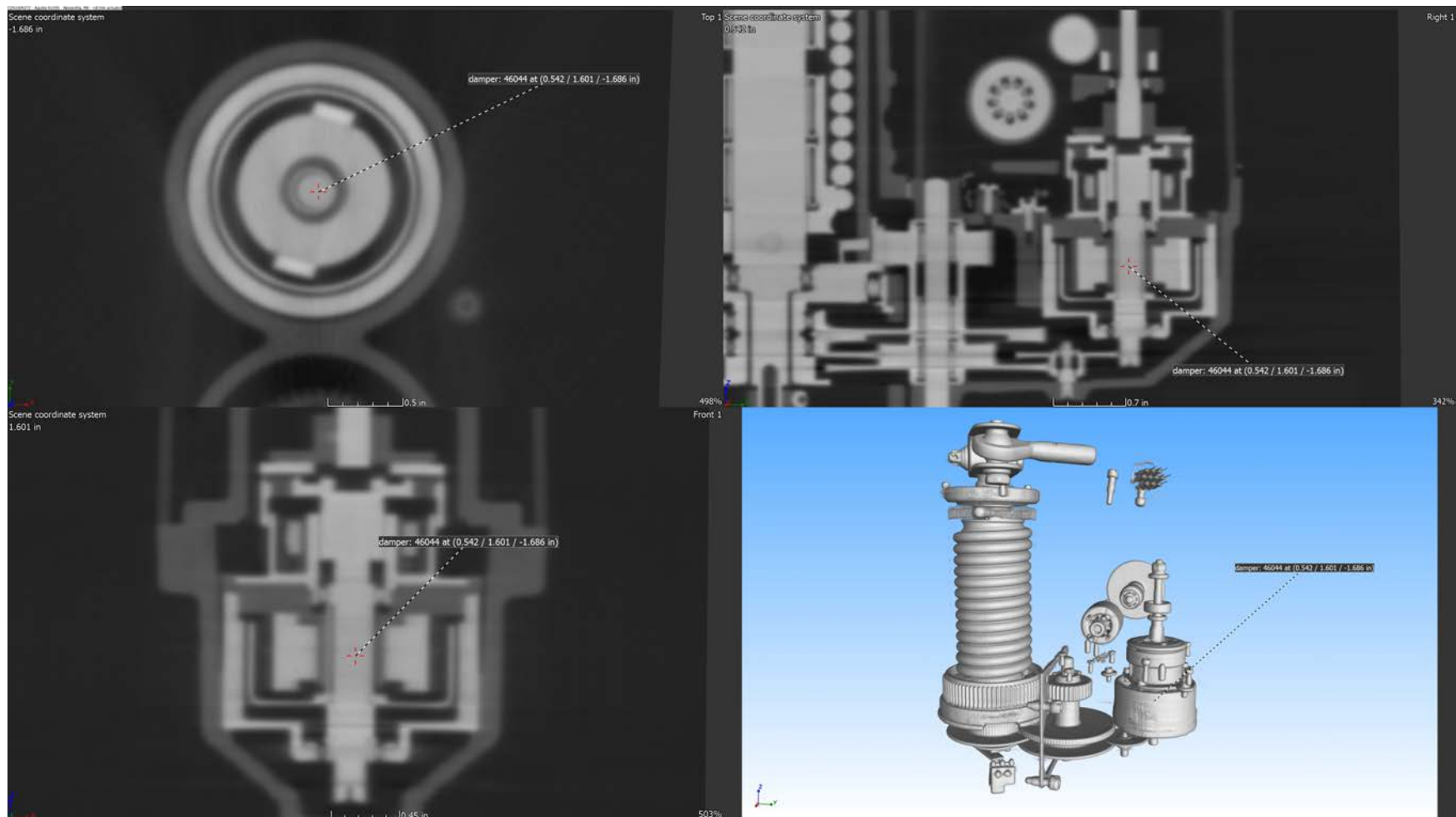


Figure 15
Roll trim actuator – damper

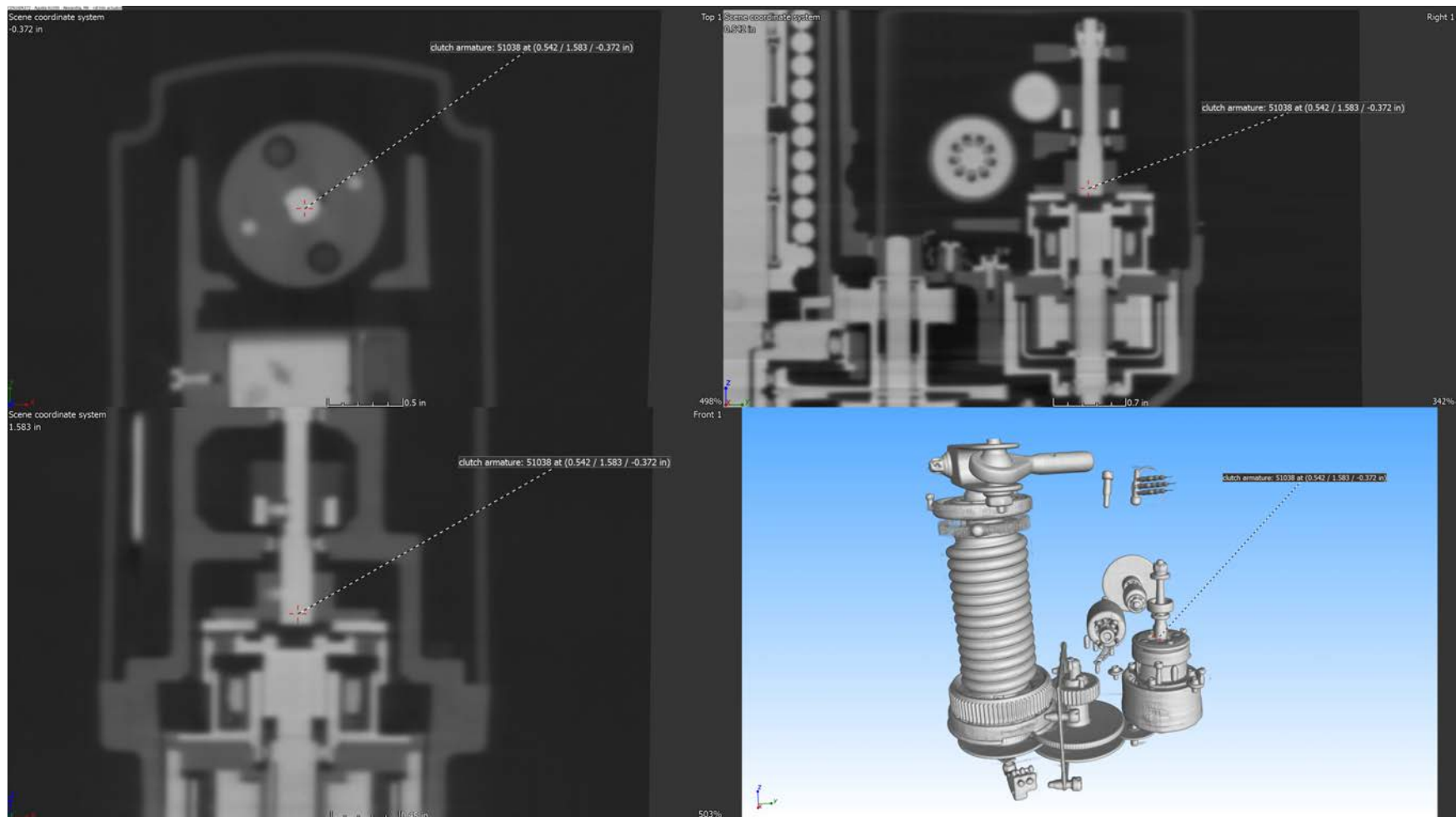


Figure 16
Roll trim actuator – clutch armature

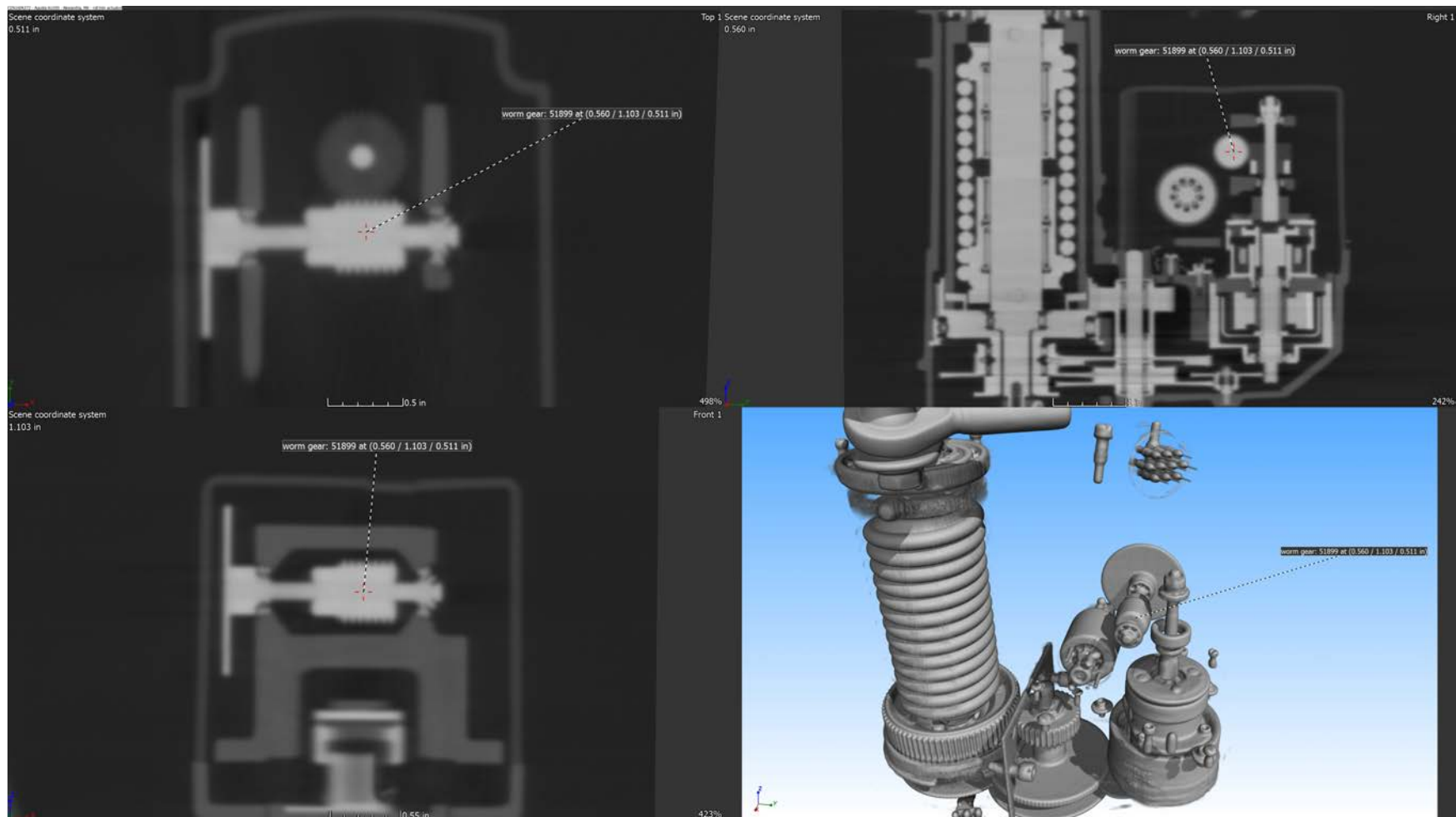


Figure 17
Roll trim actuator – worm gear

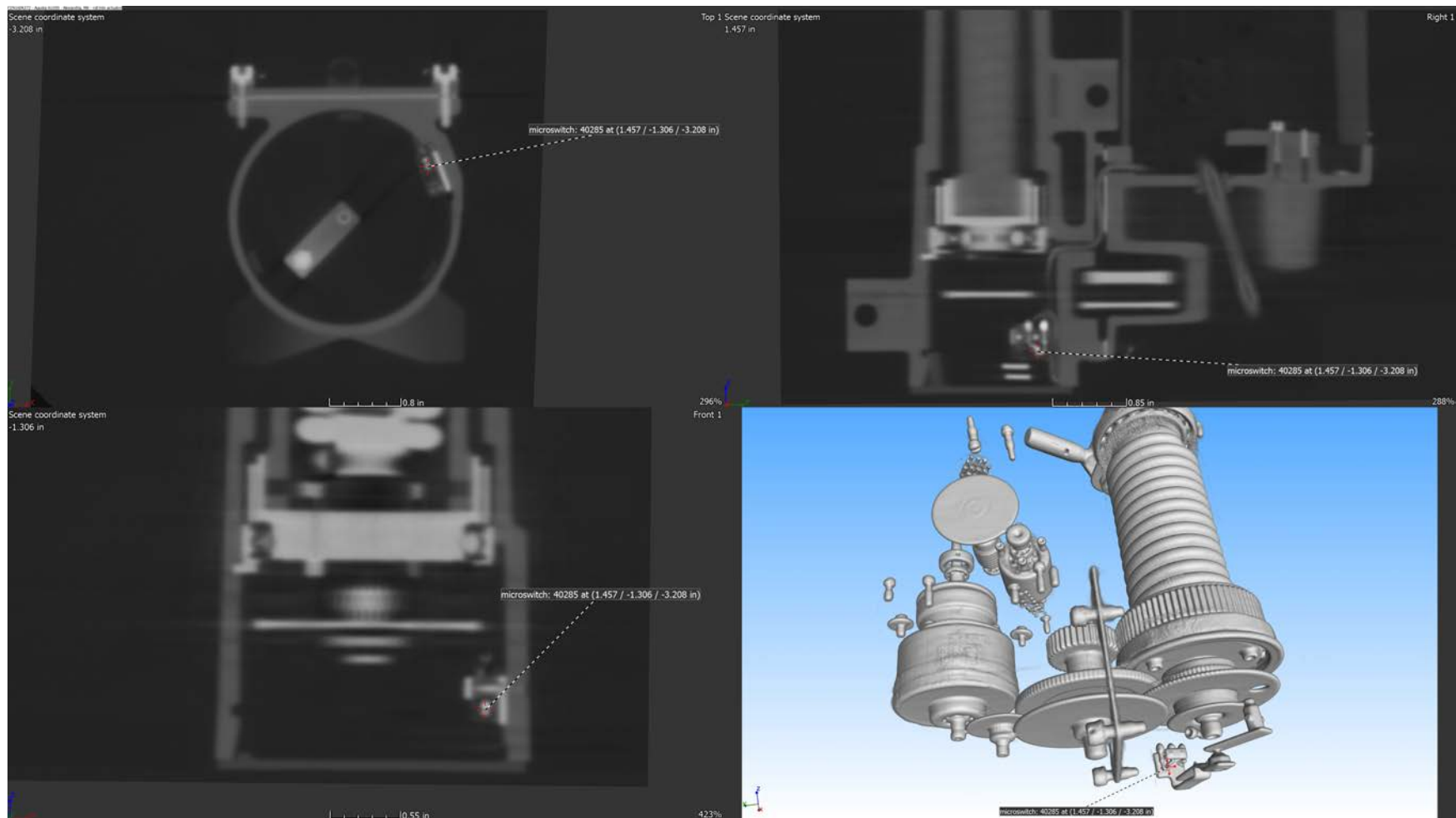


Figure 18
Roll trim actuator – microswitch

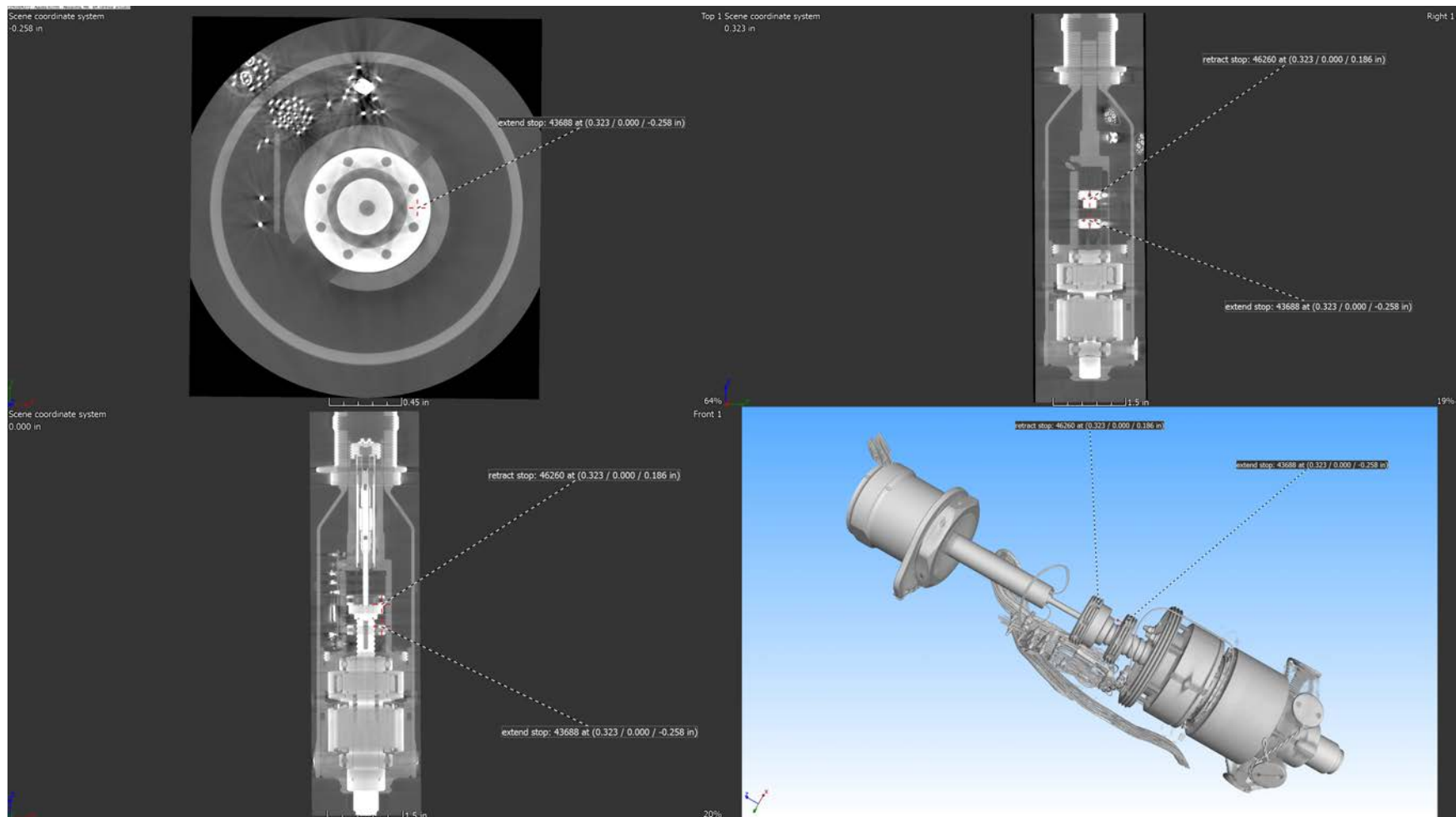


Figure 20
Left roll linear actuator – overview

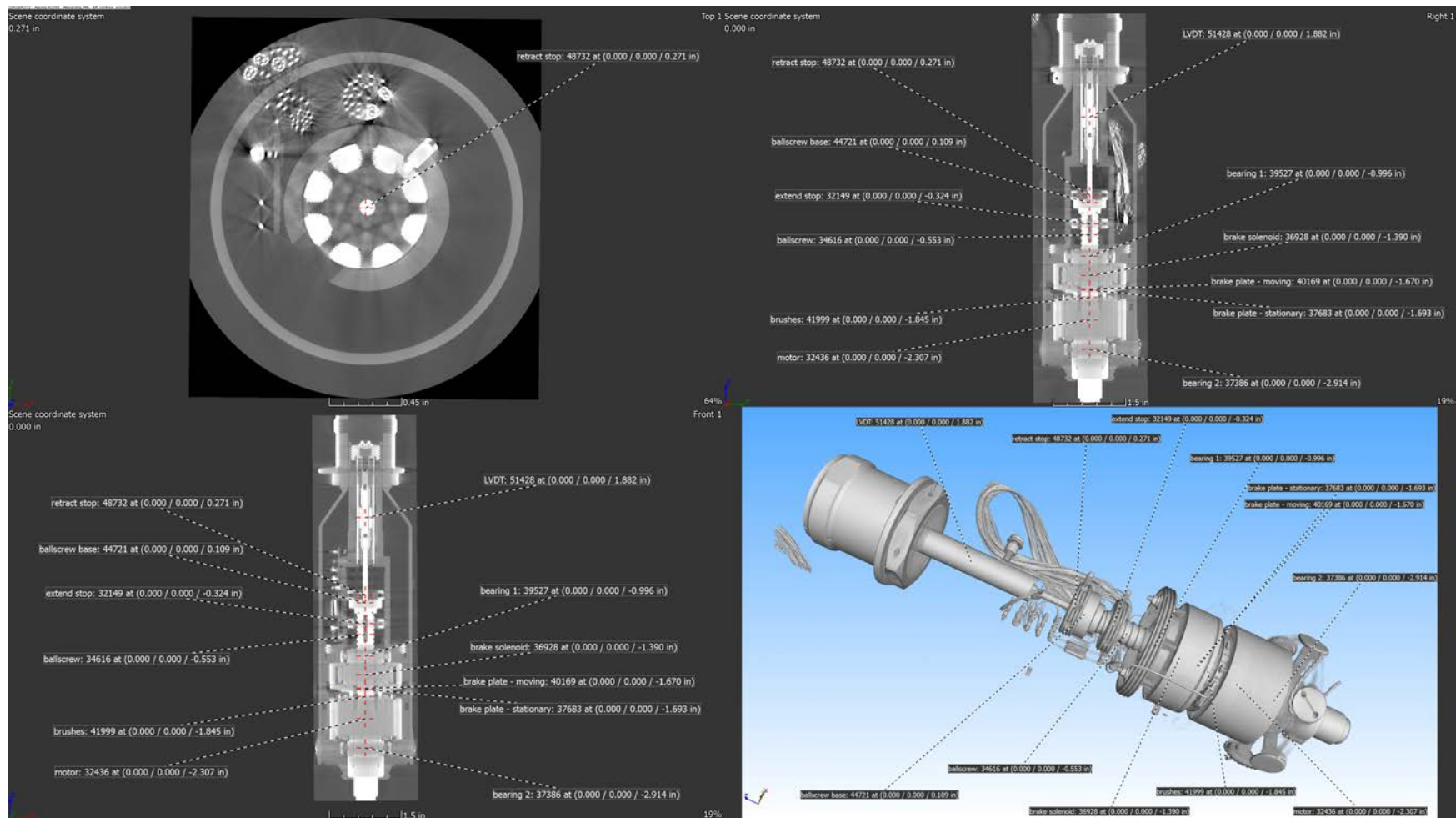


Figure 21
Left roll linear actuator – overview 2

CEN16FA372 - Agusta A109S - Alexandria, MN - left roll linear actuator

Scene coordinate system

0.000 in

Front 1

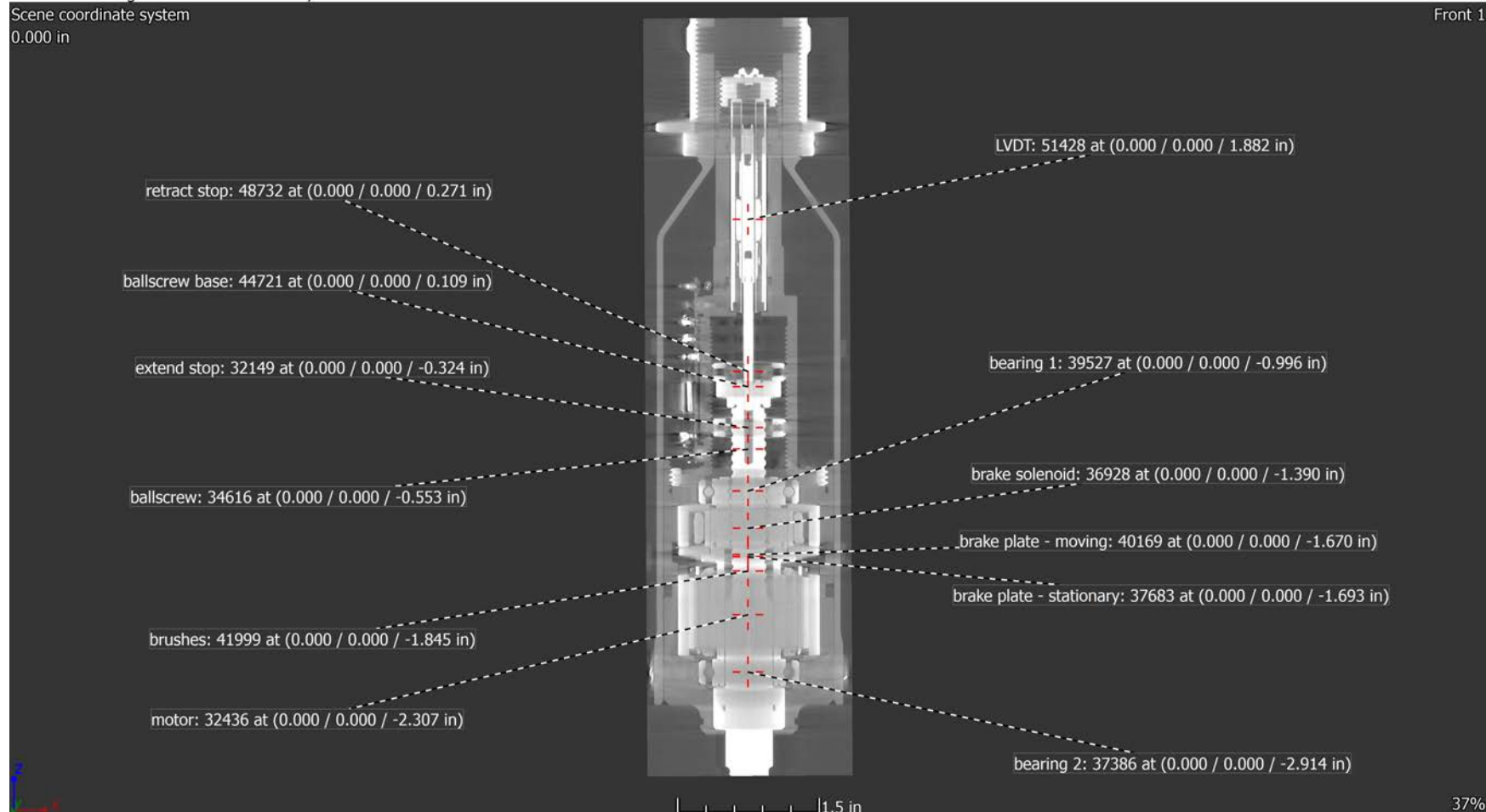


Figure 22
Left roll linear actuator – overview – front view only

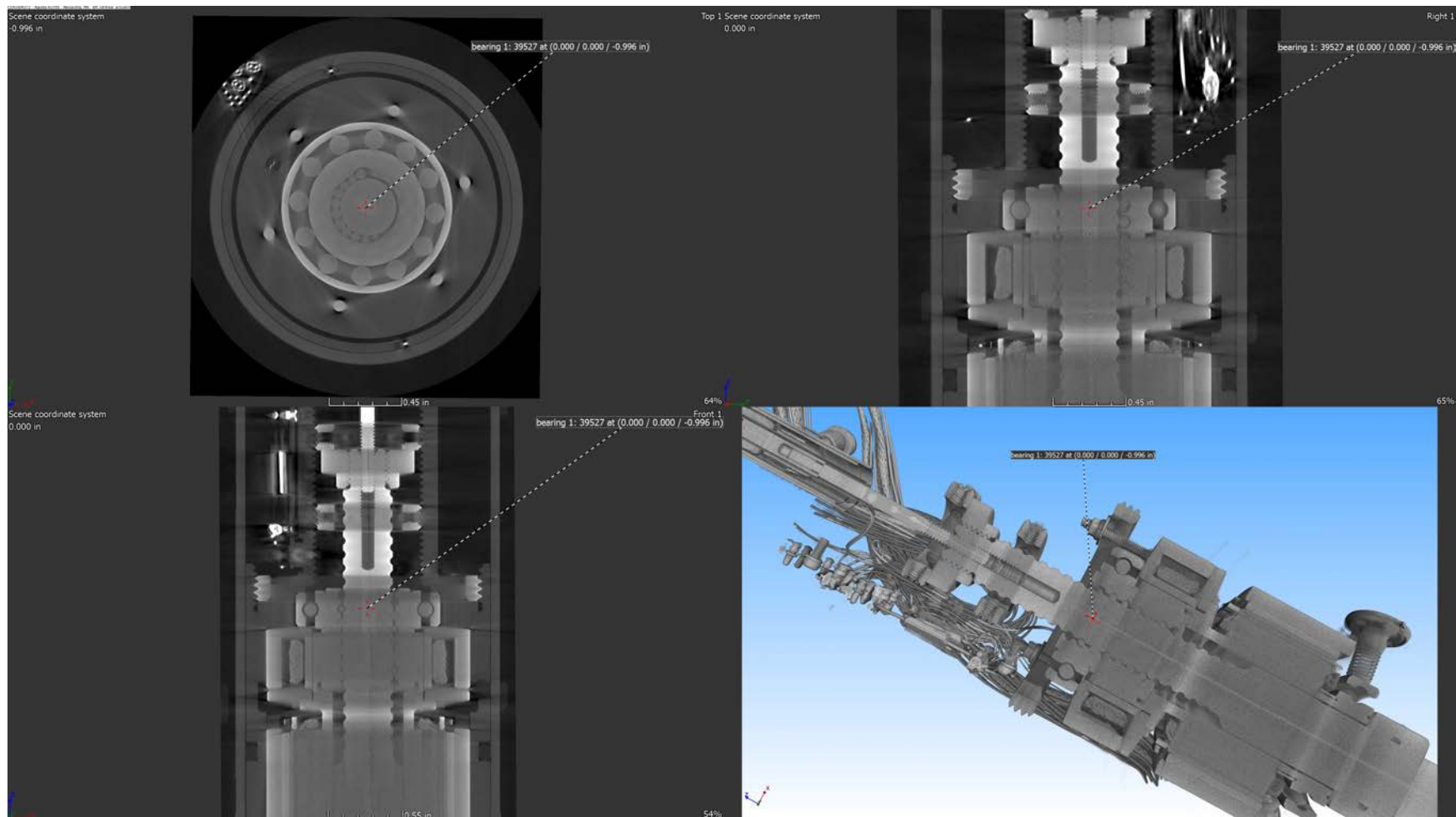


Figure 23
Left roll linear actuator – bearing 1

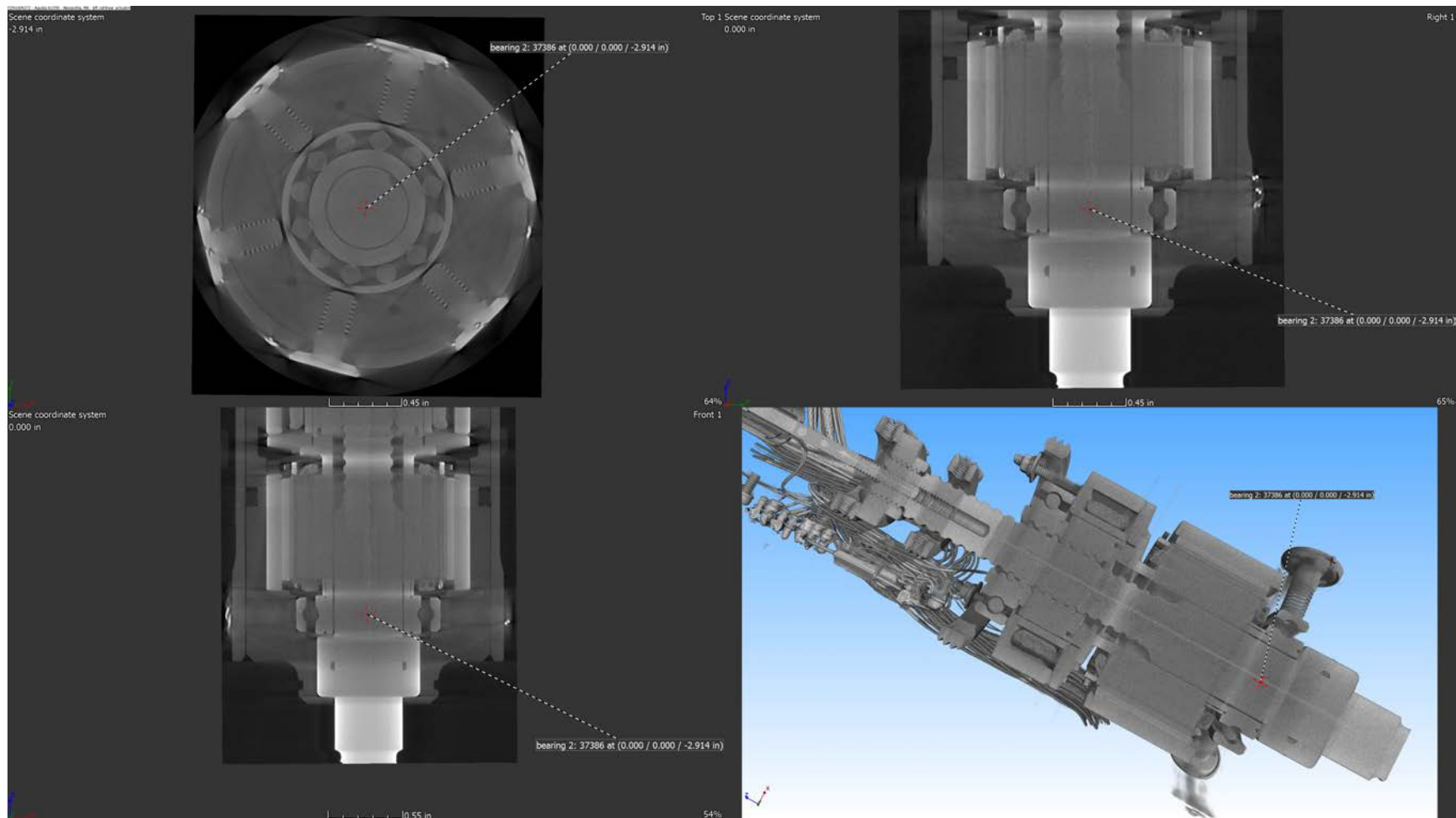


Figure 24
Left roll linear actuator – bearing 2

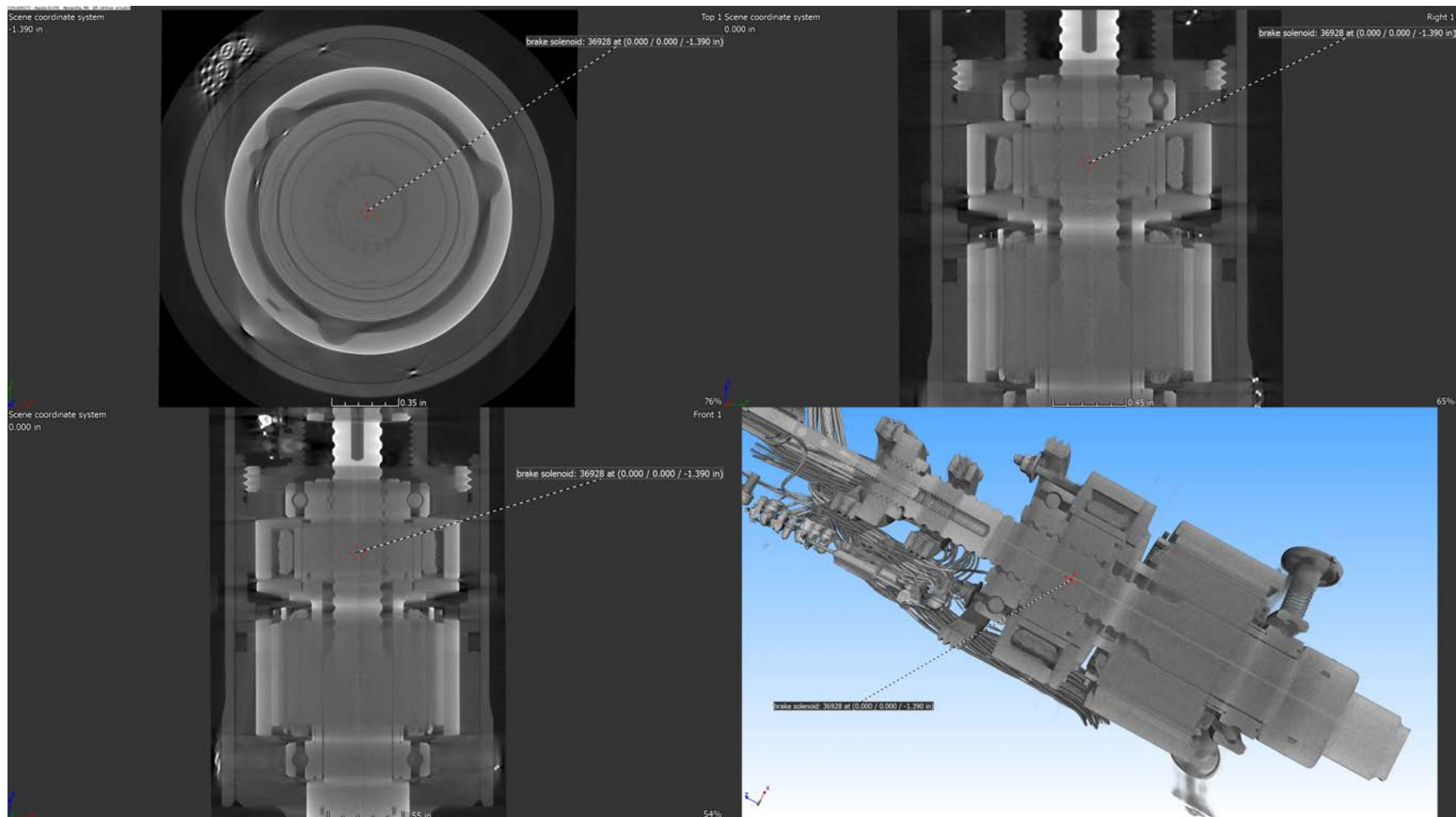


Figure 25
Left roll linear actuator – brake solenoid

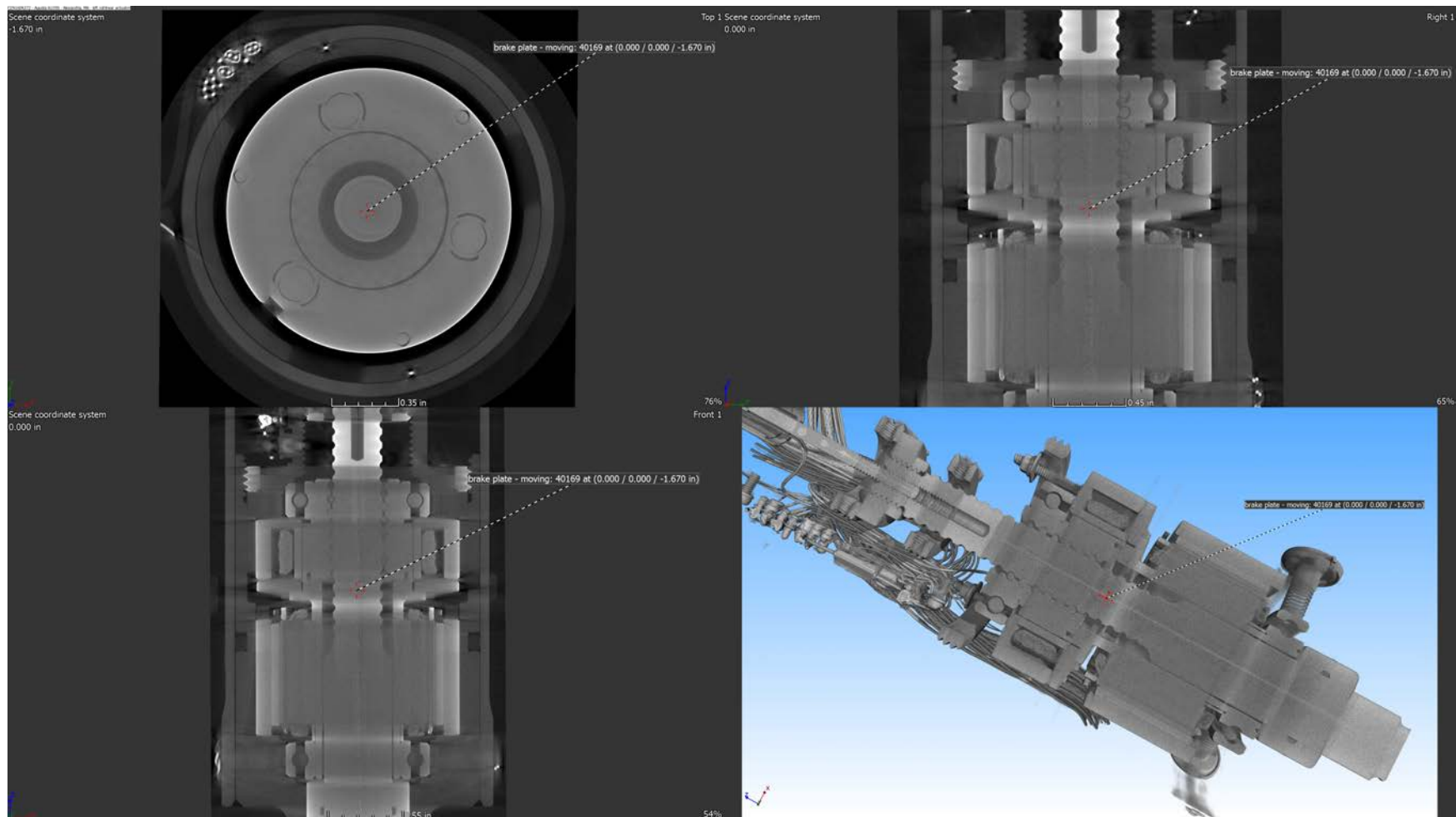


Figure 26
Left roll linear actuator – brake plate - moving

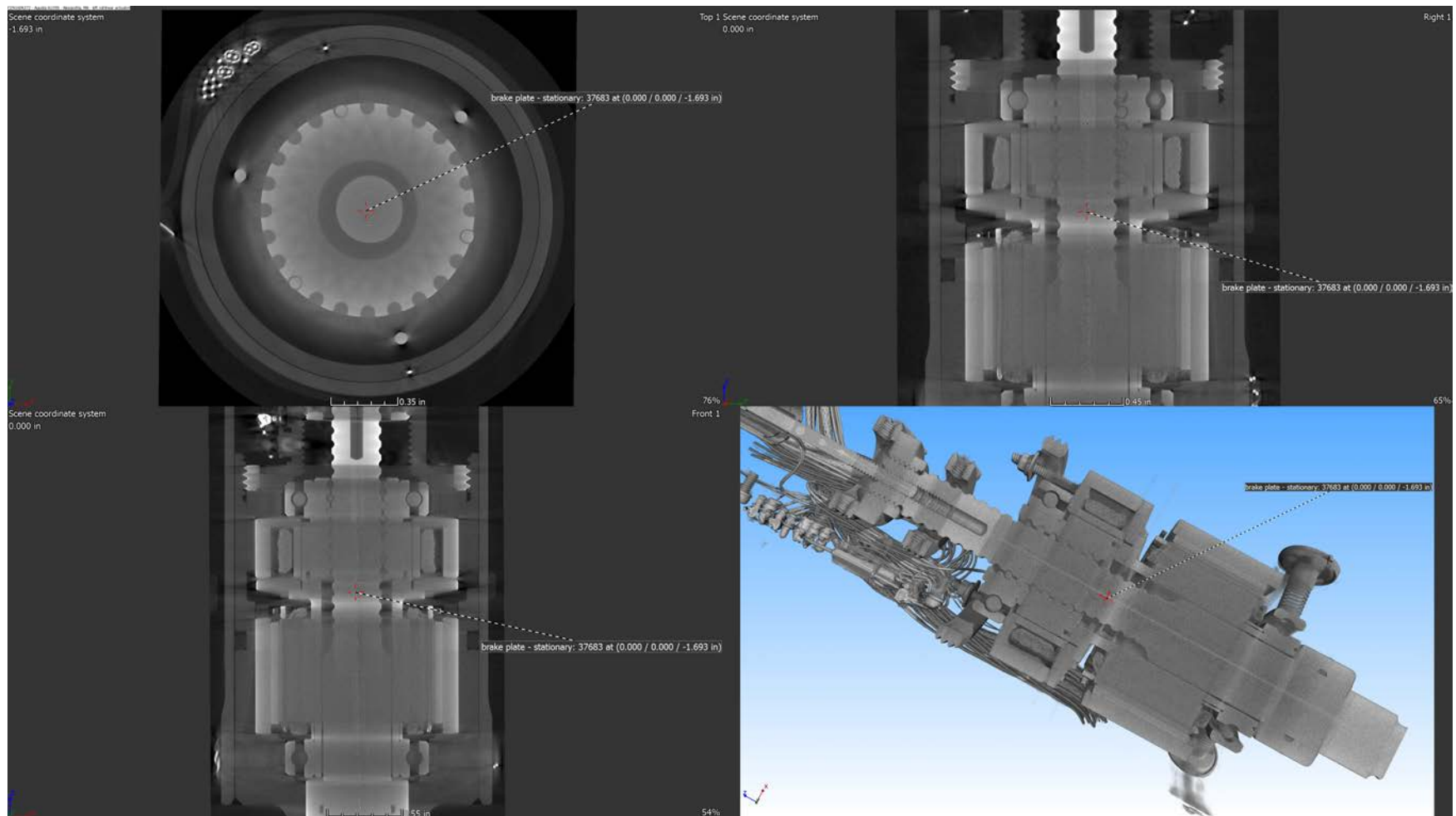


Figure 27
Left roll linear actuator – brake plate - stationary

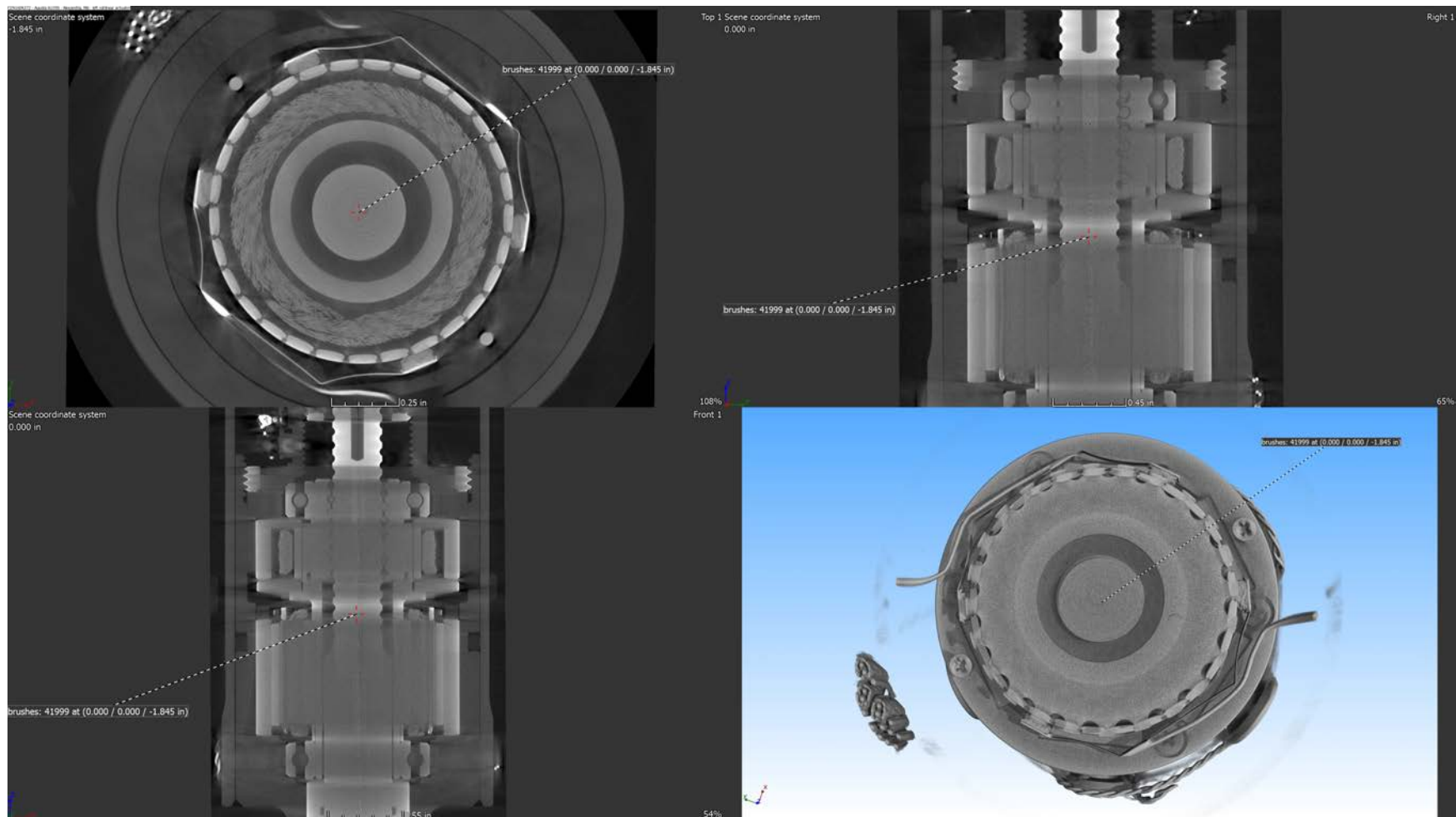


Figure 28
Left roll linear actuator – brushes

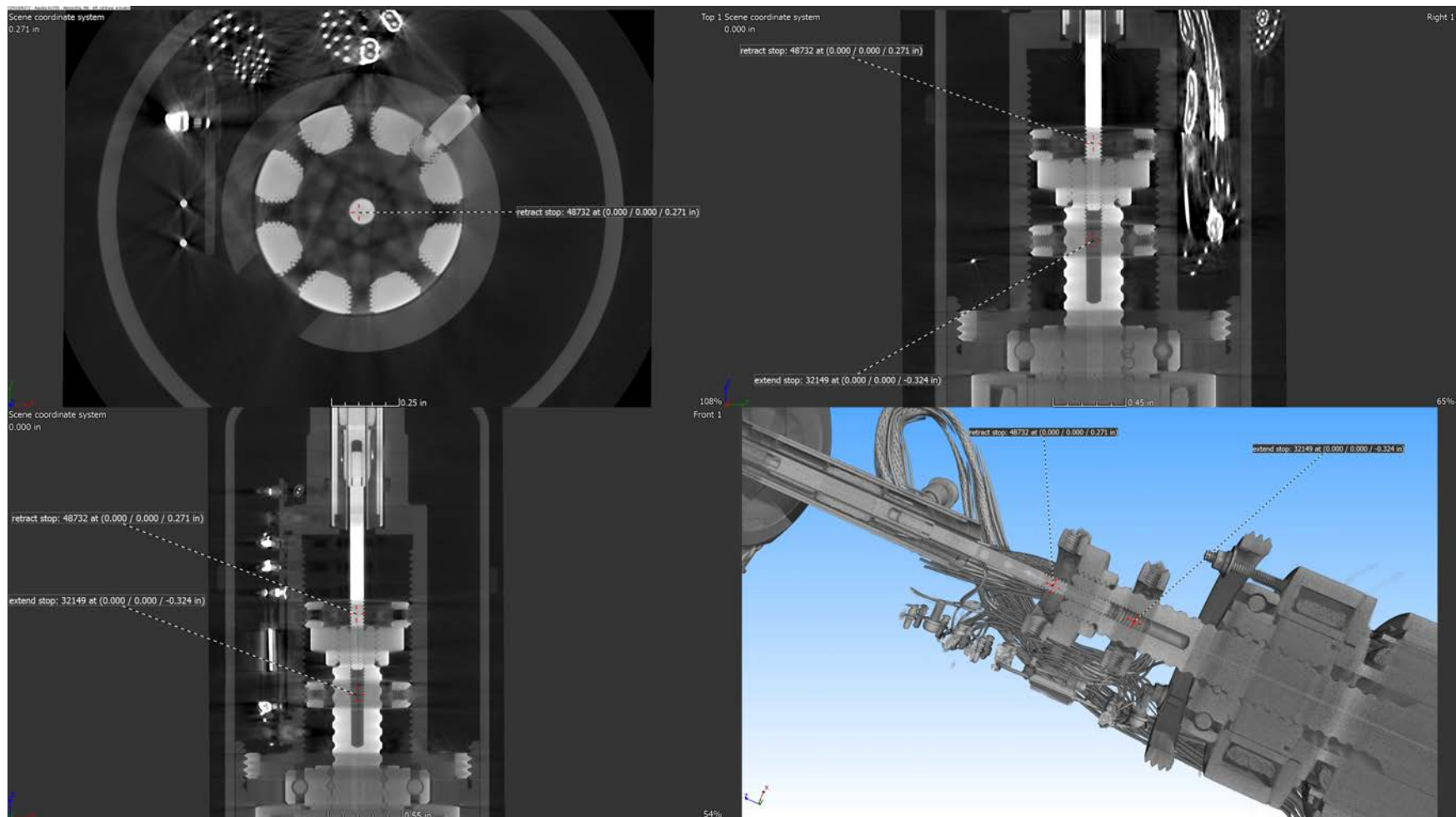


Figure 29
Left roll linear actuator – extend and retract stops

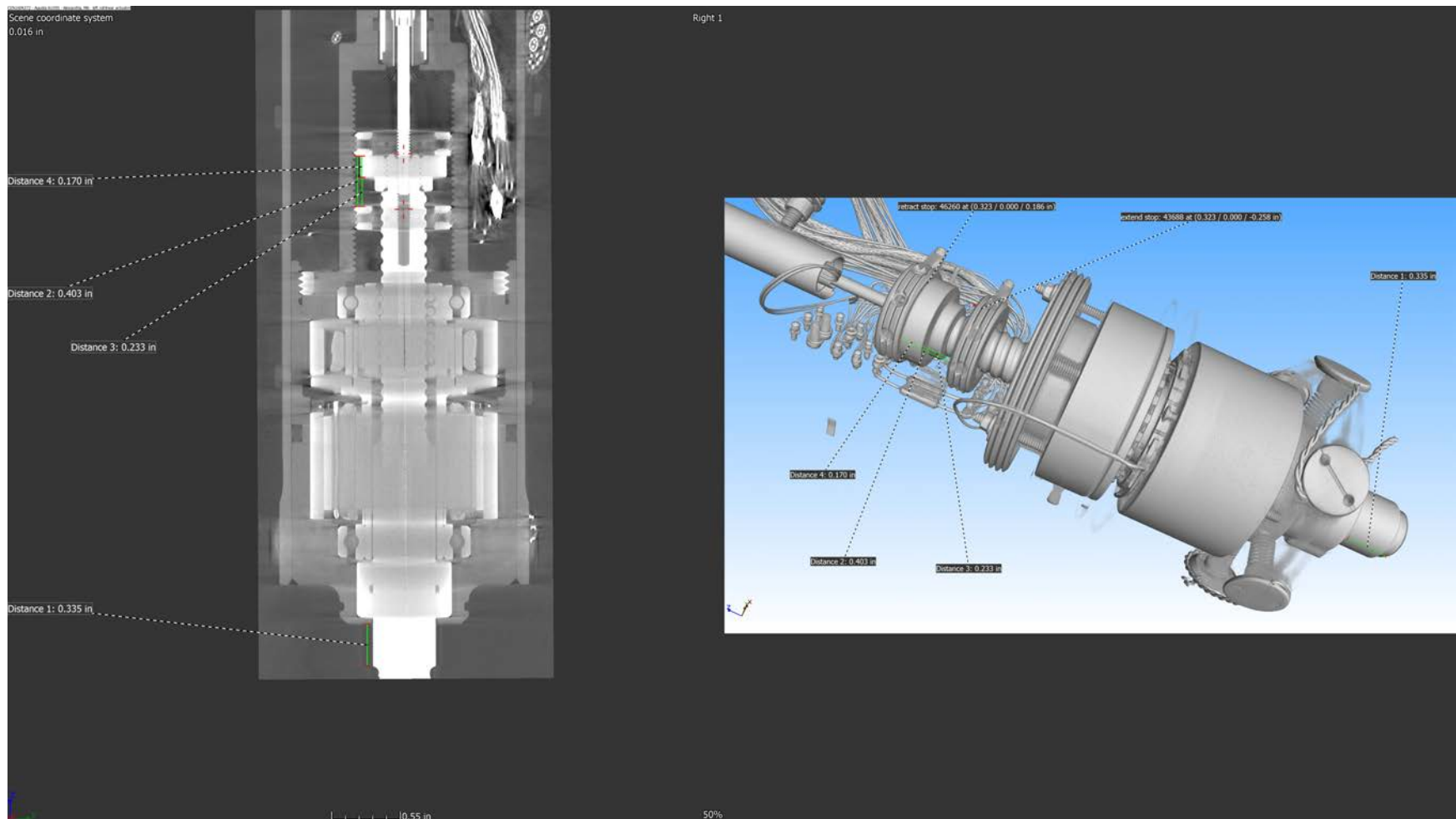


Figure 30
Left roll linear actuator – position measurements

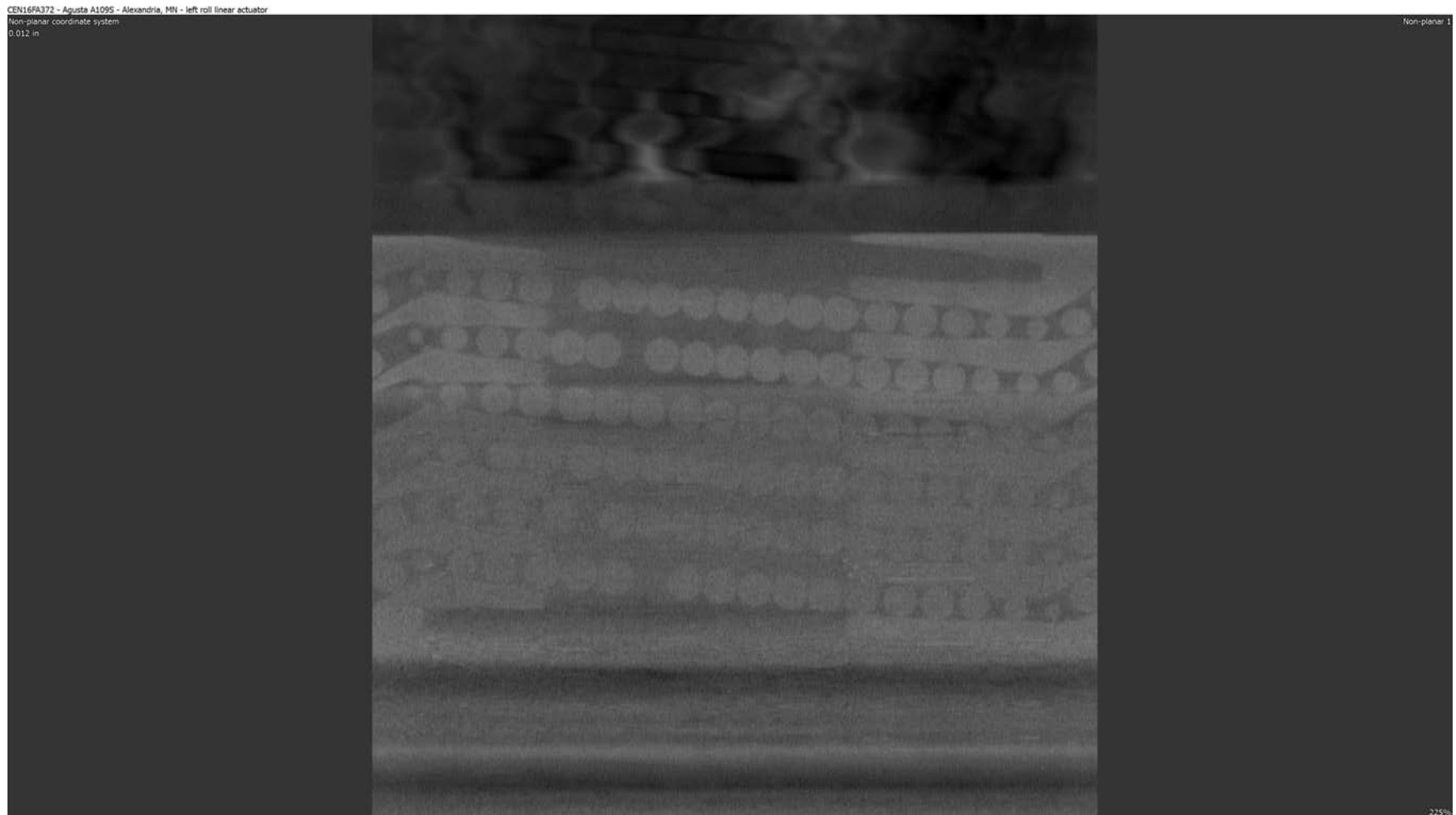


Figure 31
Left roll linear actuator – ballscrew tracks – virtually unrolled

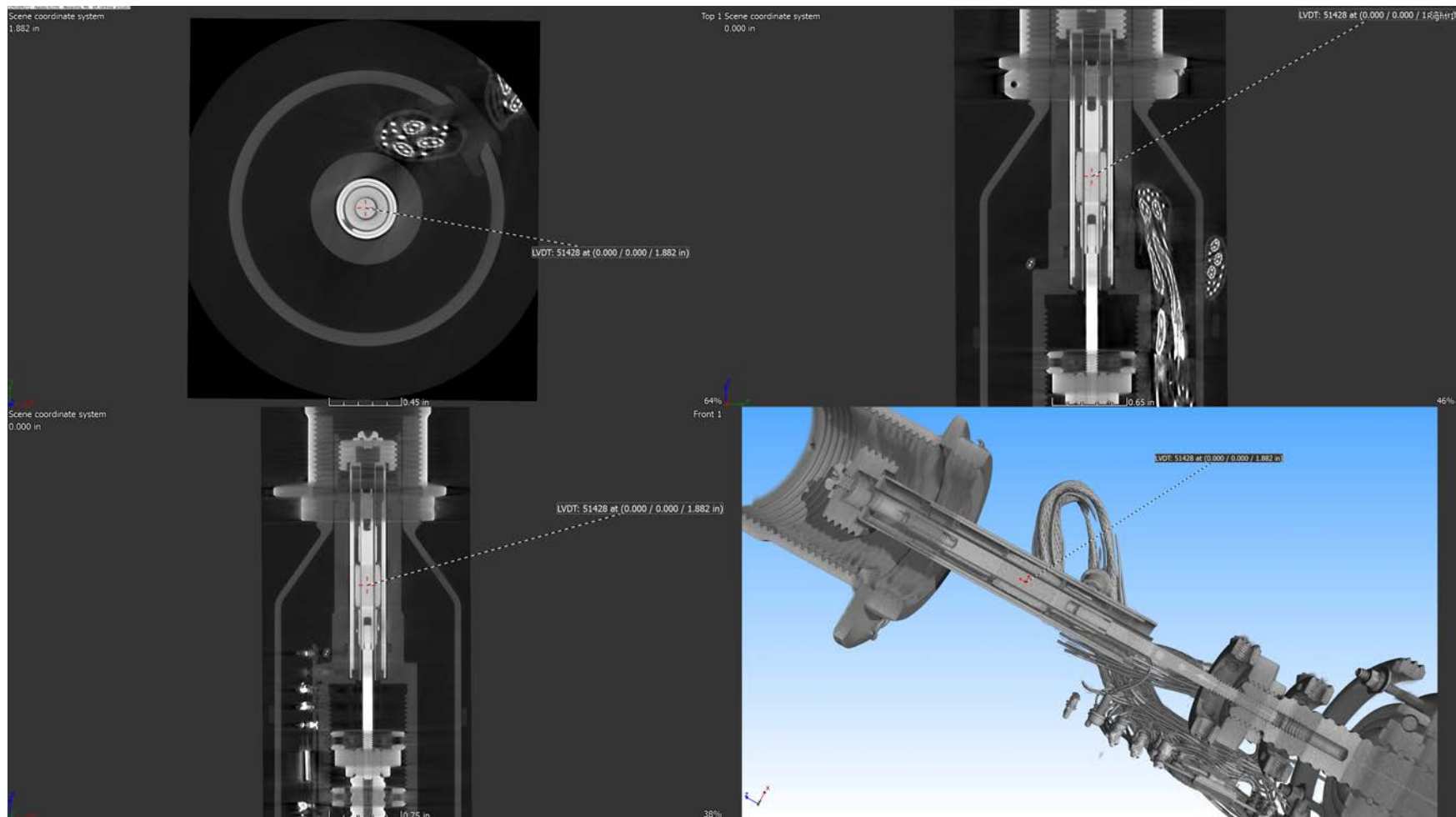


Figure 32
Left roll linear actuator – linear variable differential transformer (LVDT)

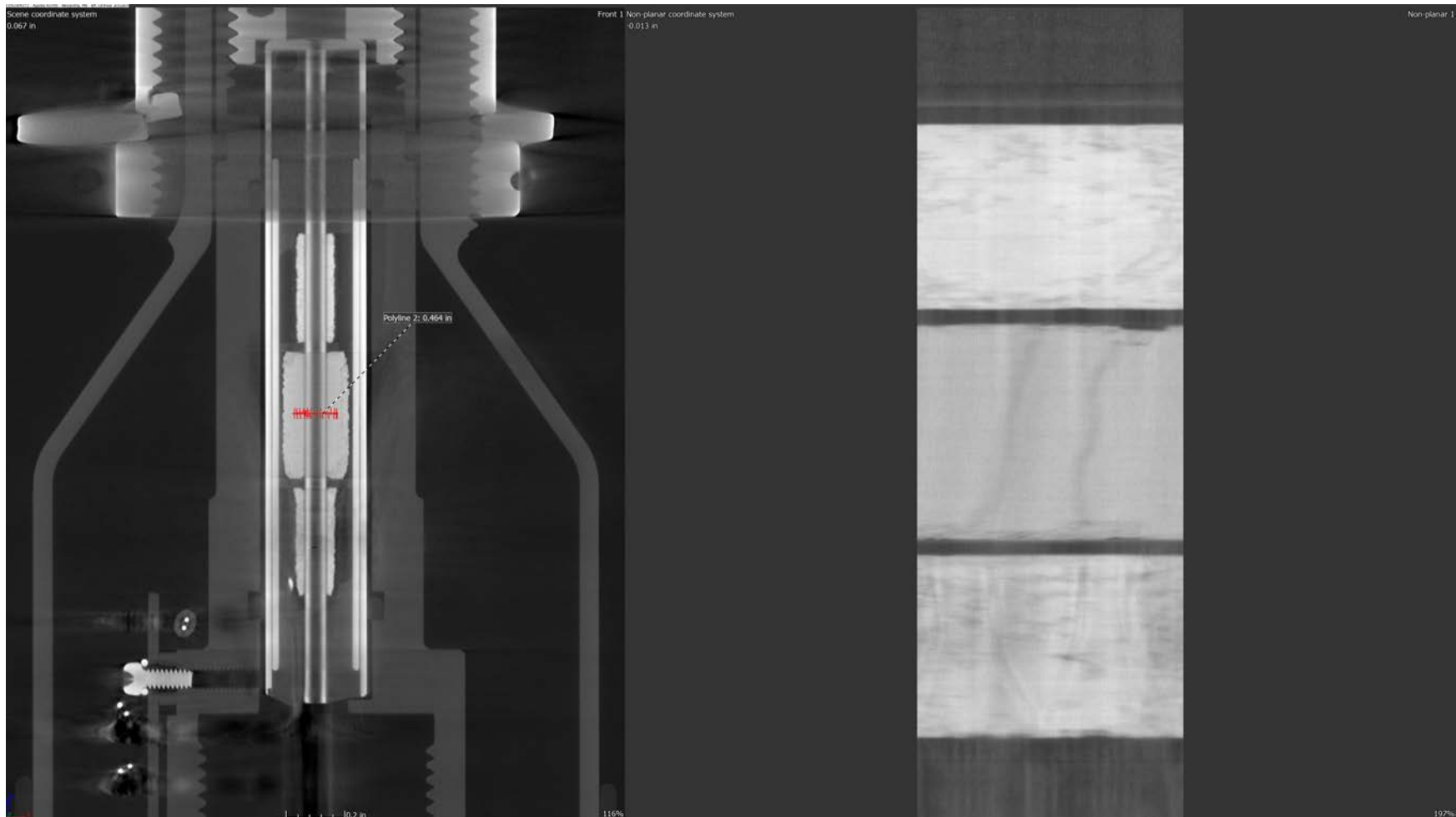


Figure 33
Left roll linear actuator – LVDT coils – virtually unrolled



Figure 34
Left roll linear actuator – LVDT connections – virtually unrolled

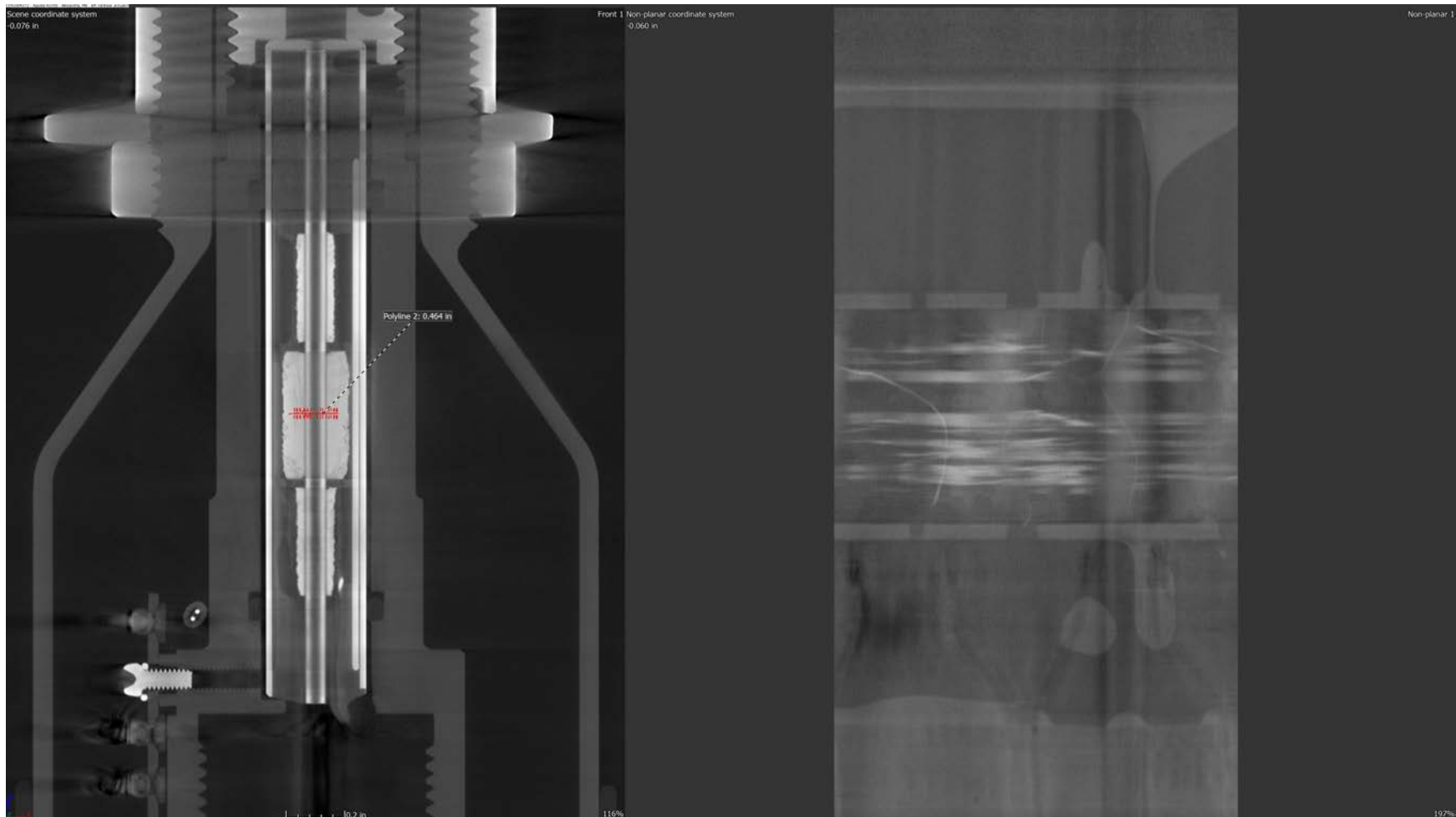


Figure 35
Left roll linear actuator – primary coil – upper surface – virtually unrolled

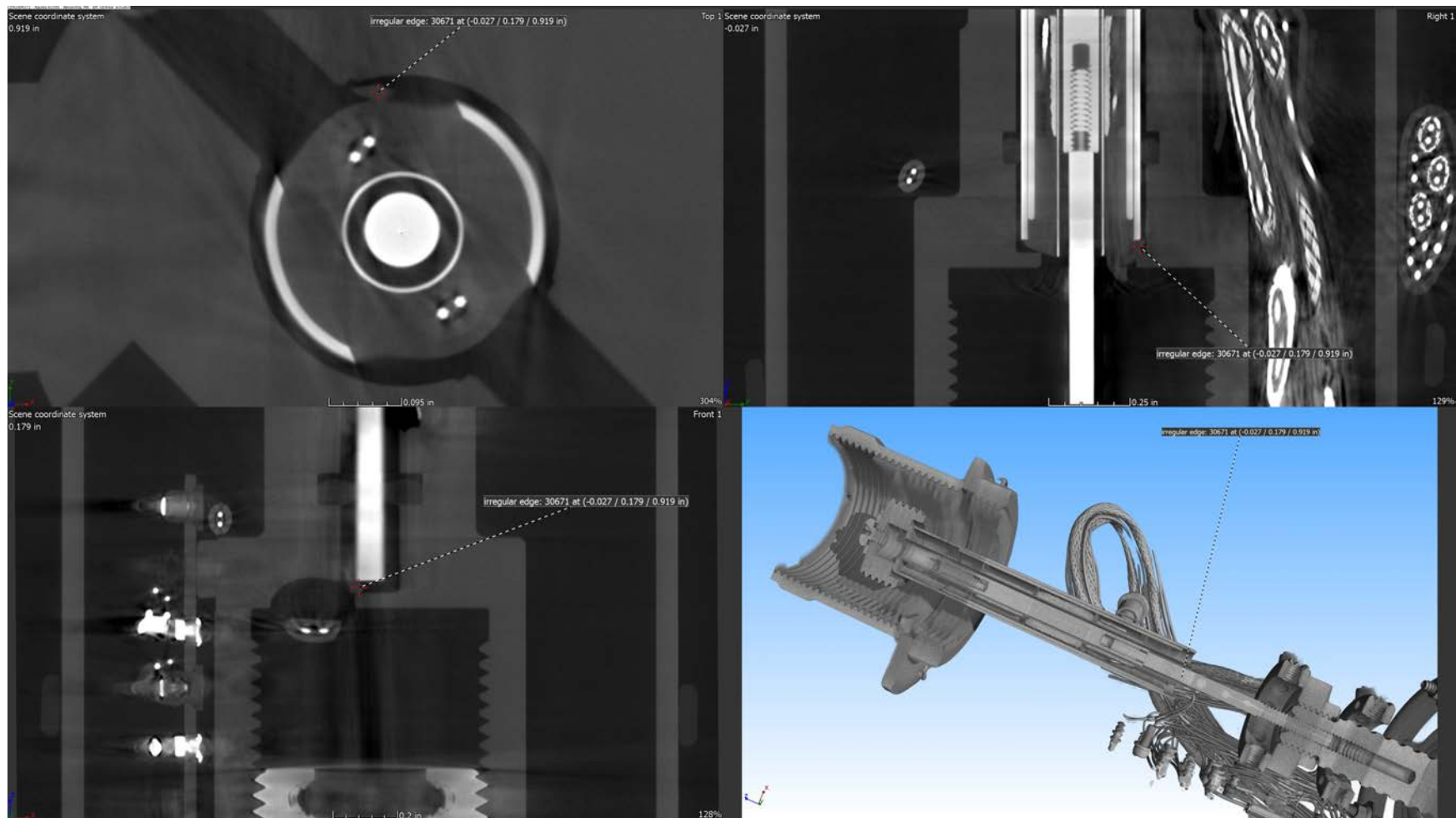


Figure 36
Left roll linear actuator – LVDT – irregular edge

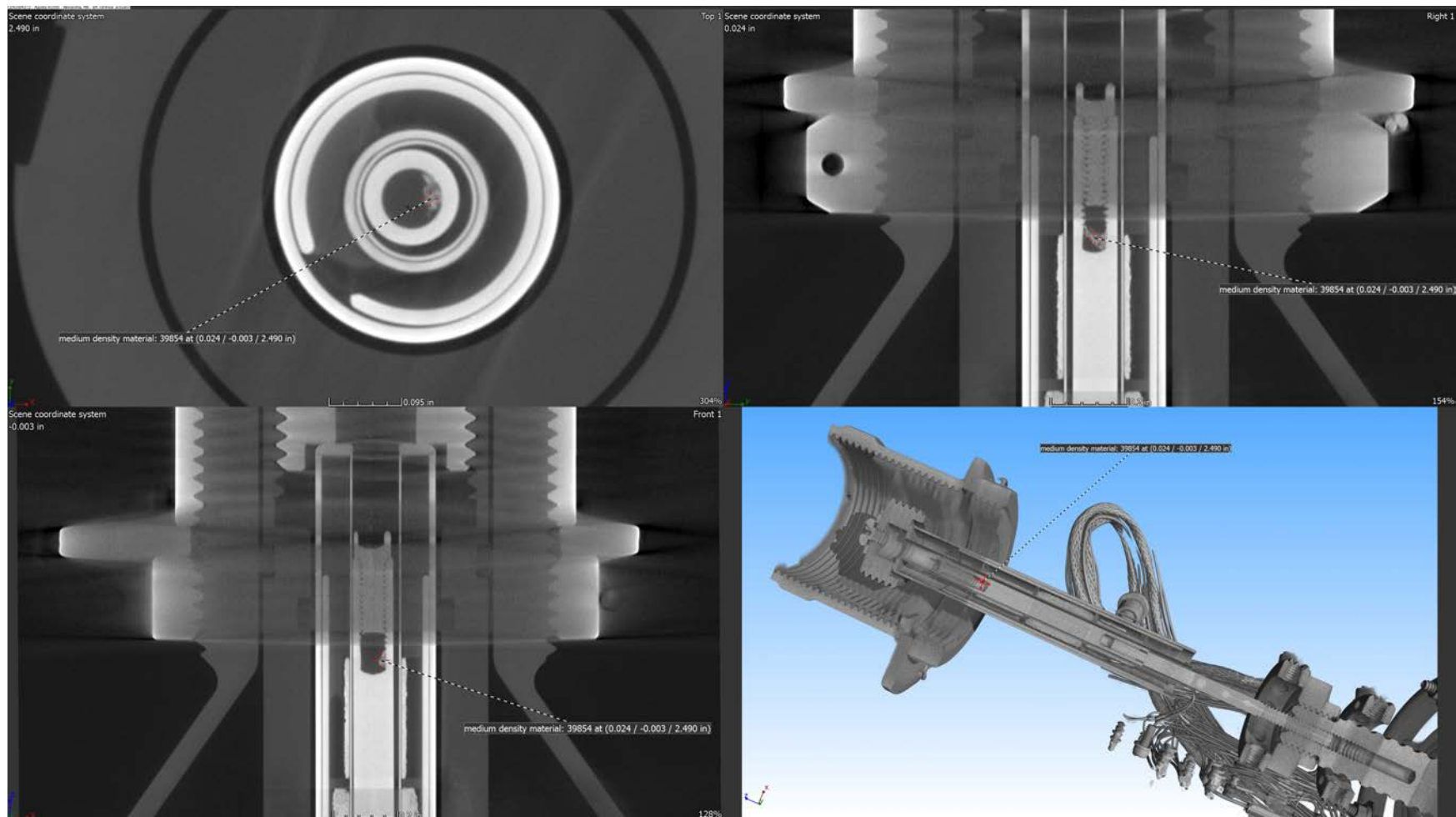


Figure 37
Left roll linear actuator – medium density material in LVDT

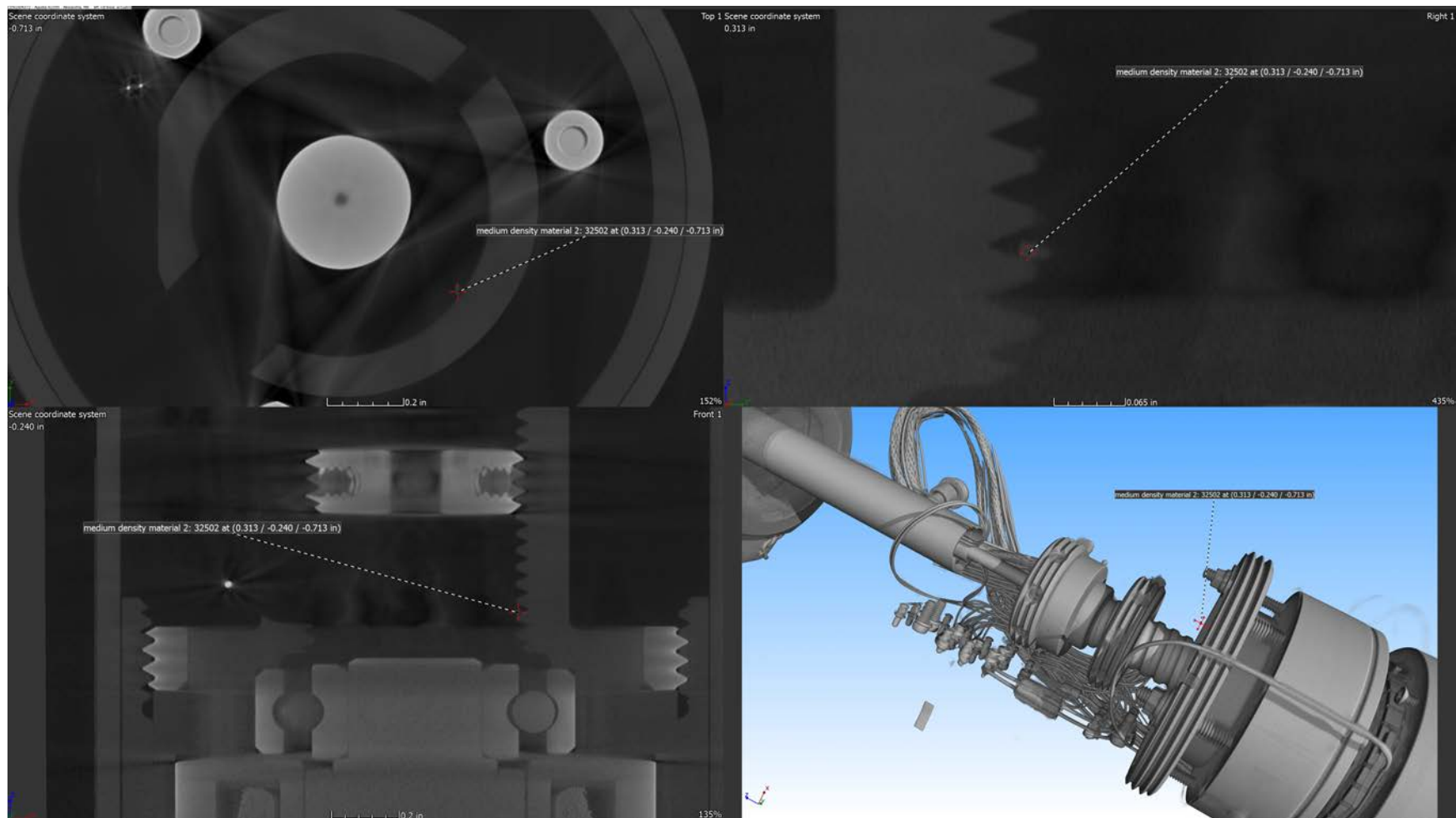


Figure 38
Left roll linear actuator – medium density material in LVDT – second location

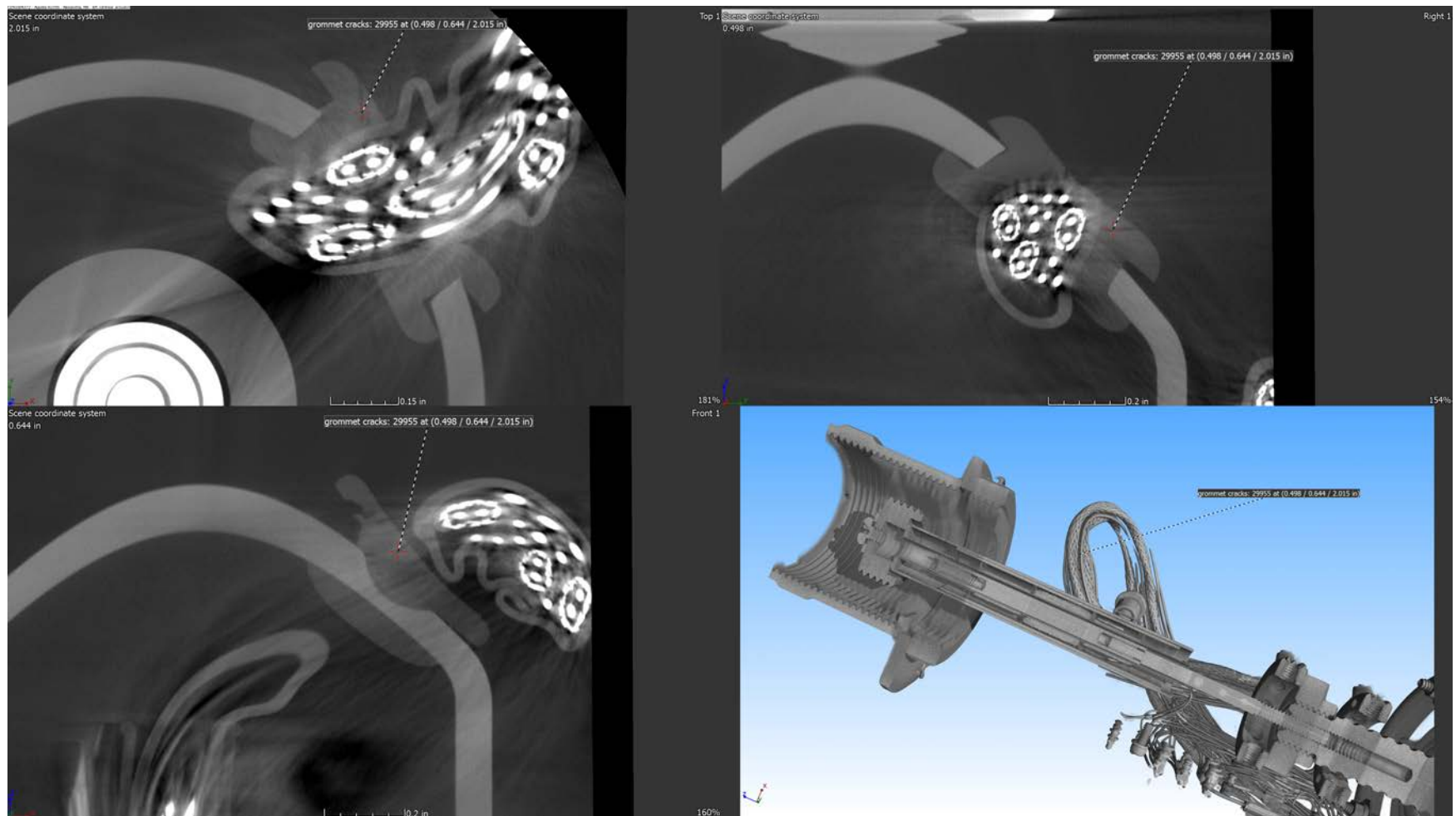


Figure 39
Left roll linear actuator – grommet cracks

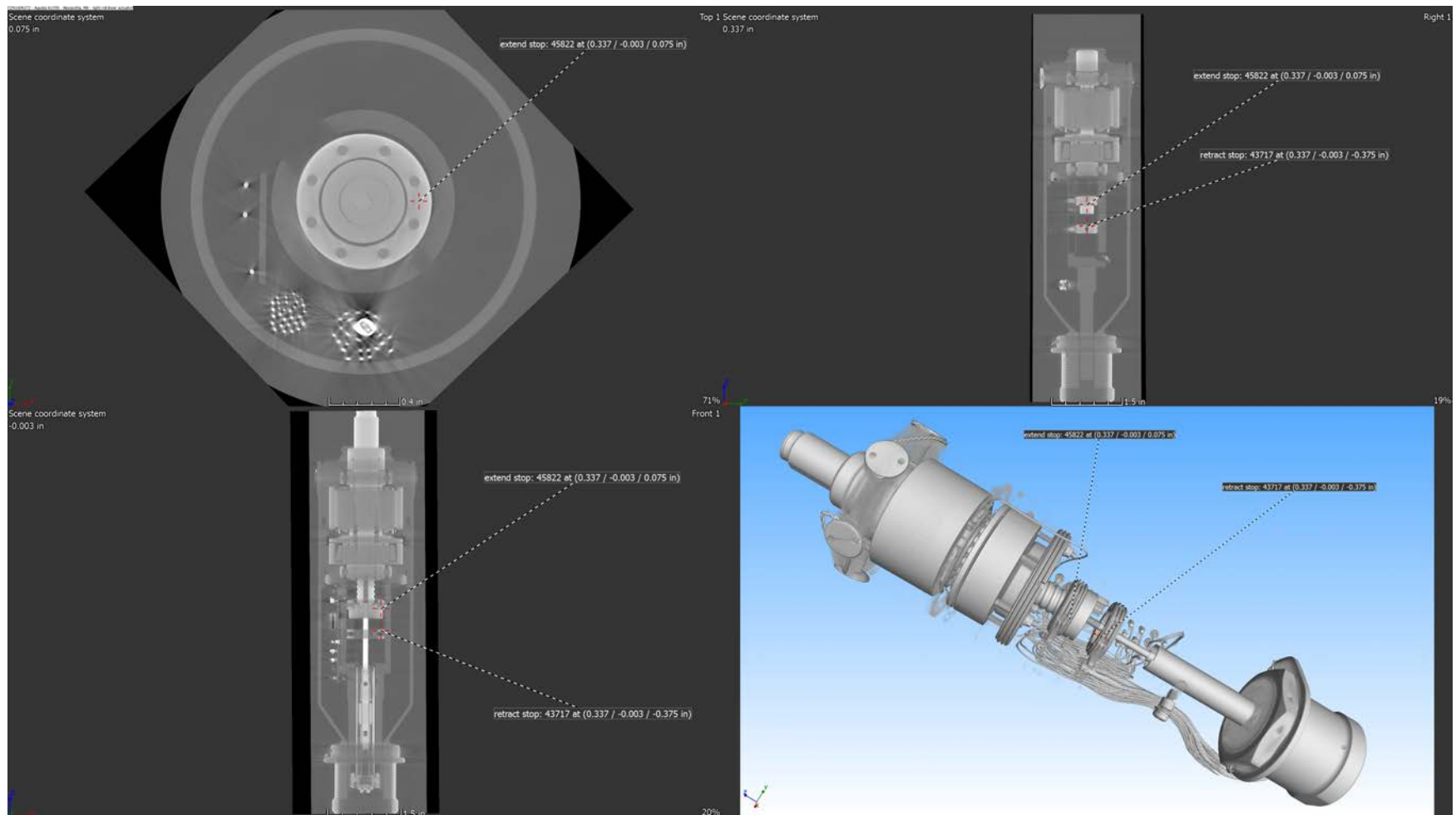


Figure 40
Right roll linear actuator – overview

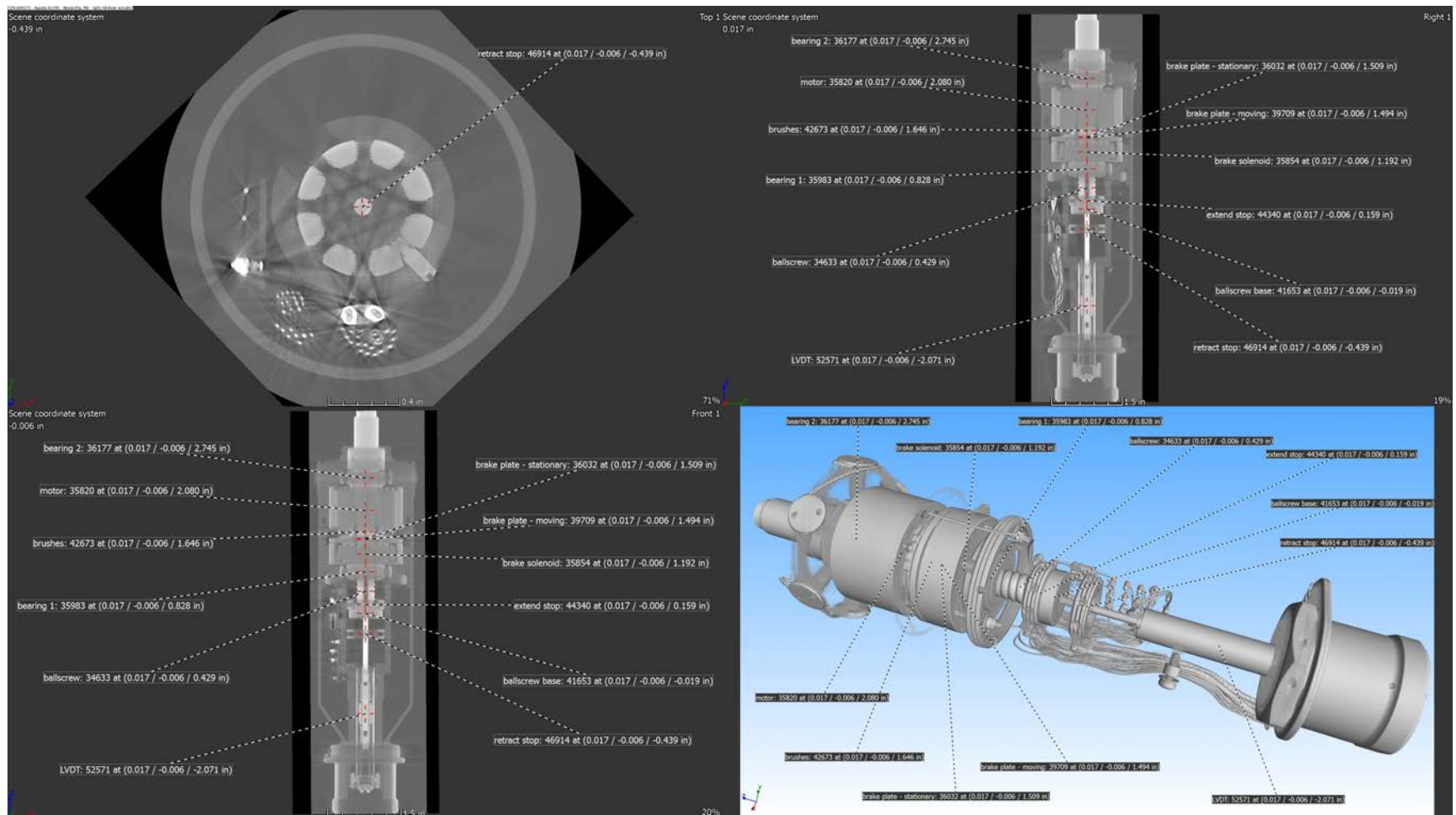


Figure 41
Right roll linear actuator – overview 2

CEN16FA372 - Agusta A109S - Alexandria, MN - right roll linear actuator

Scene coordinate system

-0.006 in

Front 1

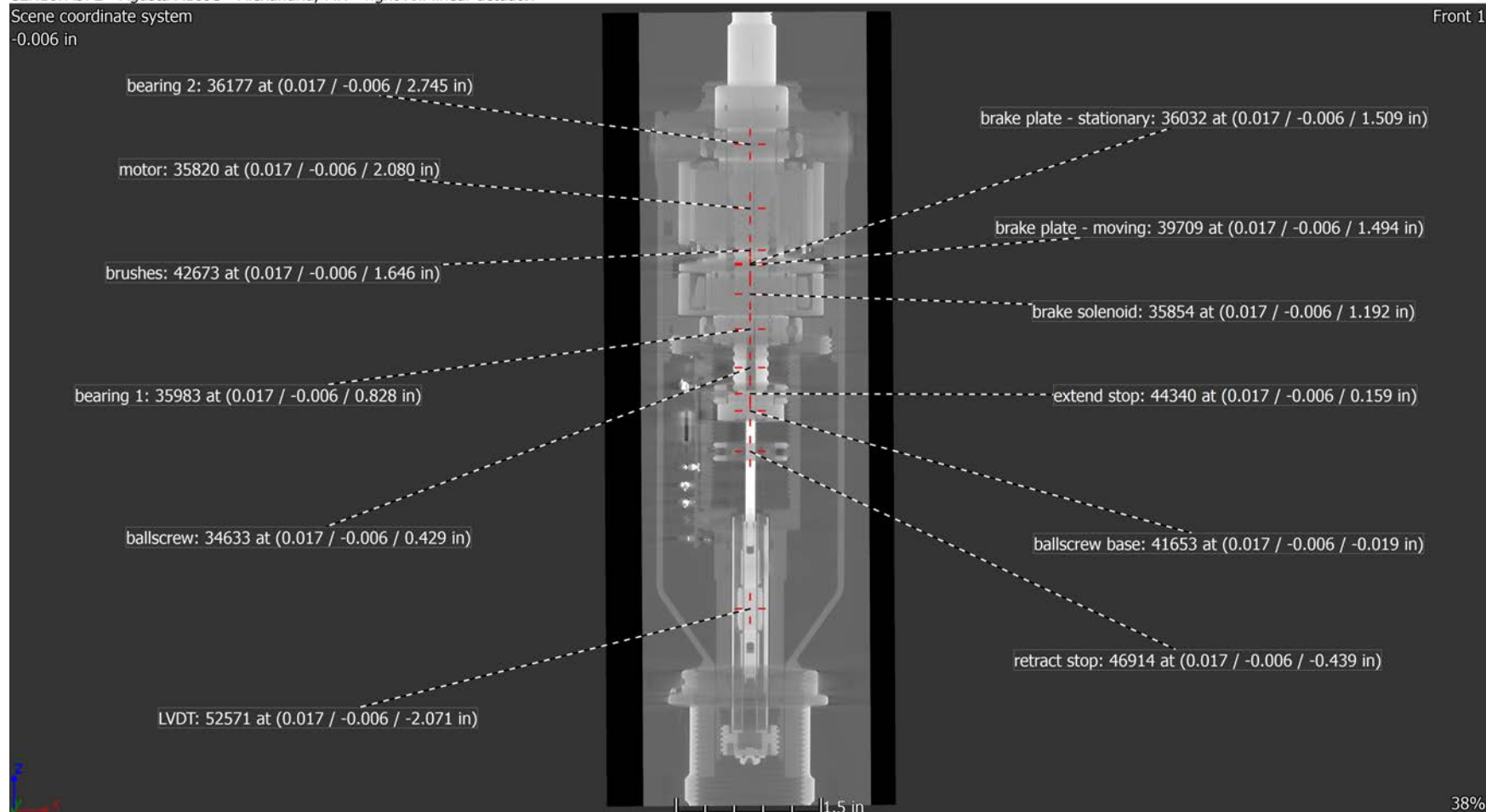


Figure 42
Right roll linear actuator – overview – front view only

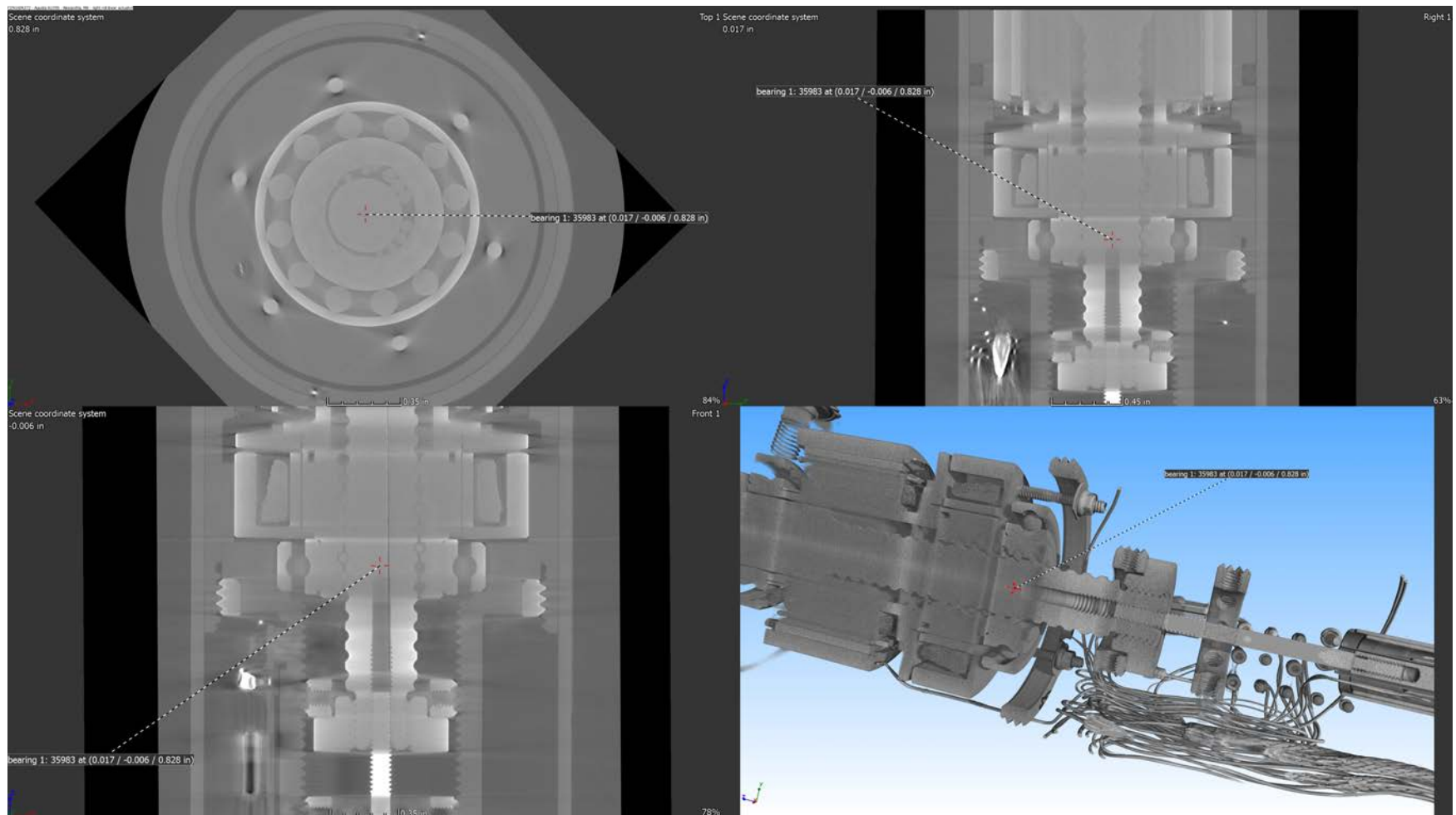


Figure 43
Right roll linear actuator – bearing 1

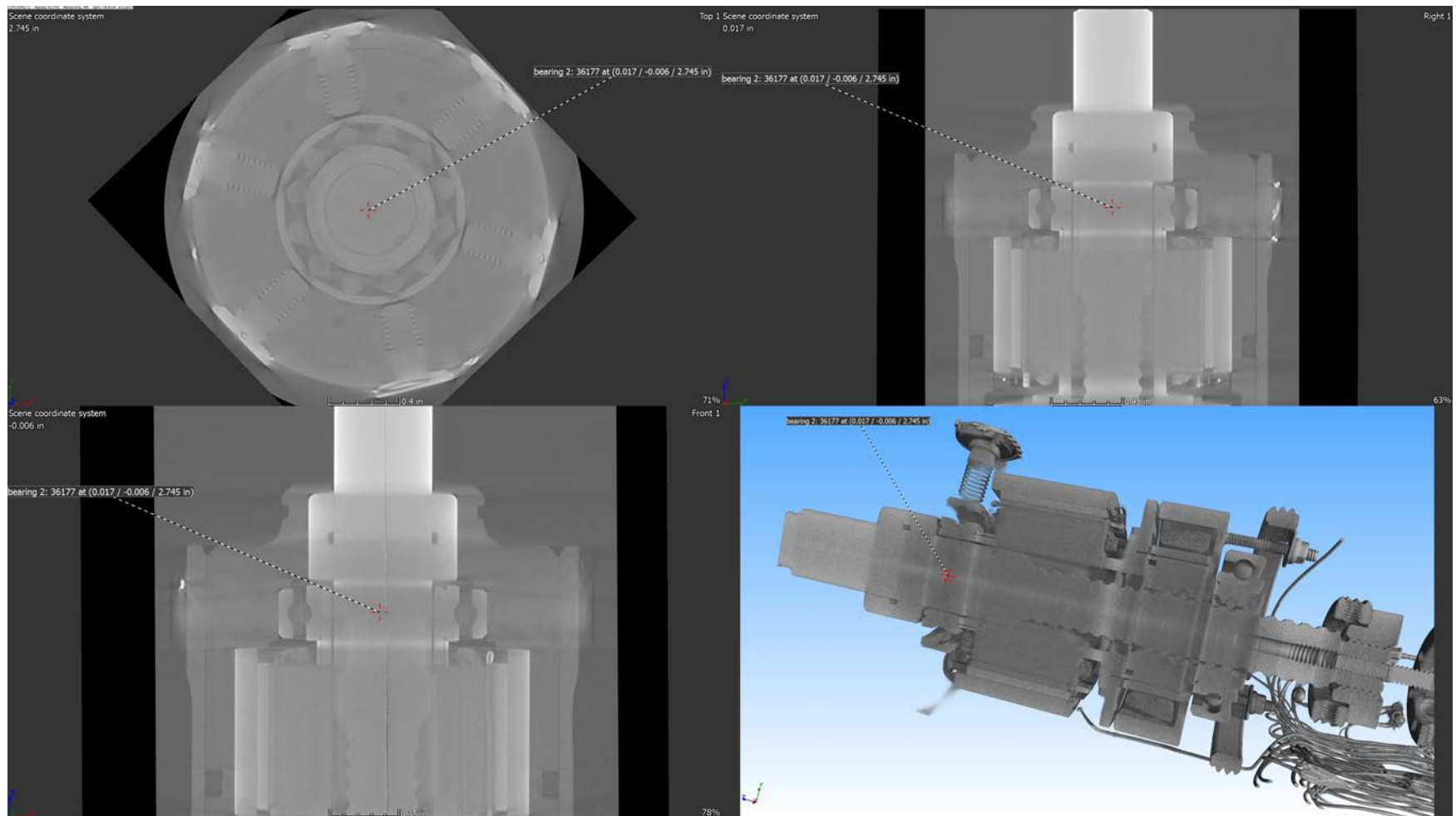


Figure 44
Right roll linear actuator – bearing 2

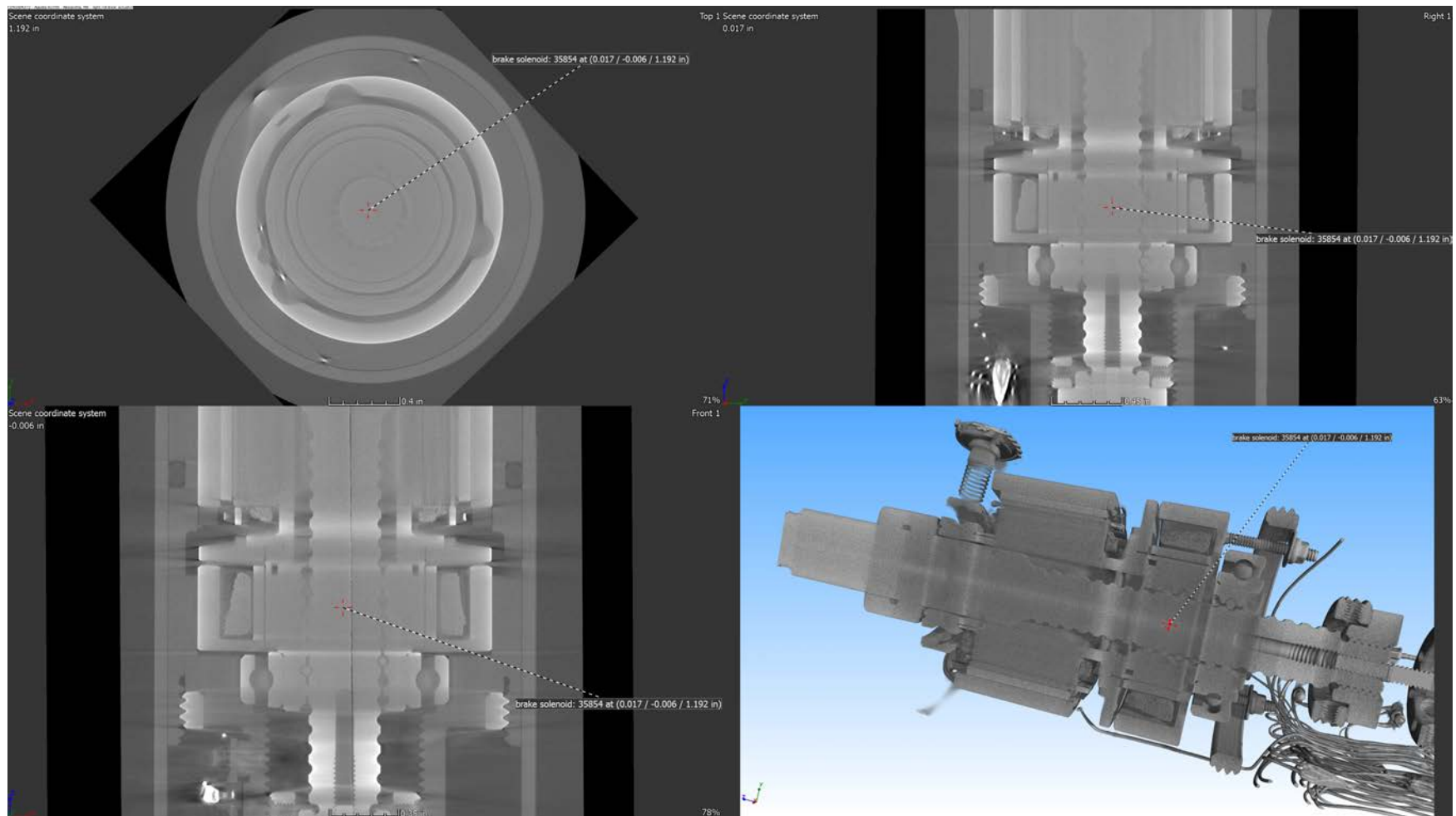


Figure 45
Right roll linear actuator – brake solenoid

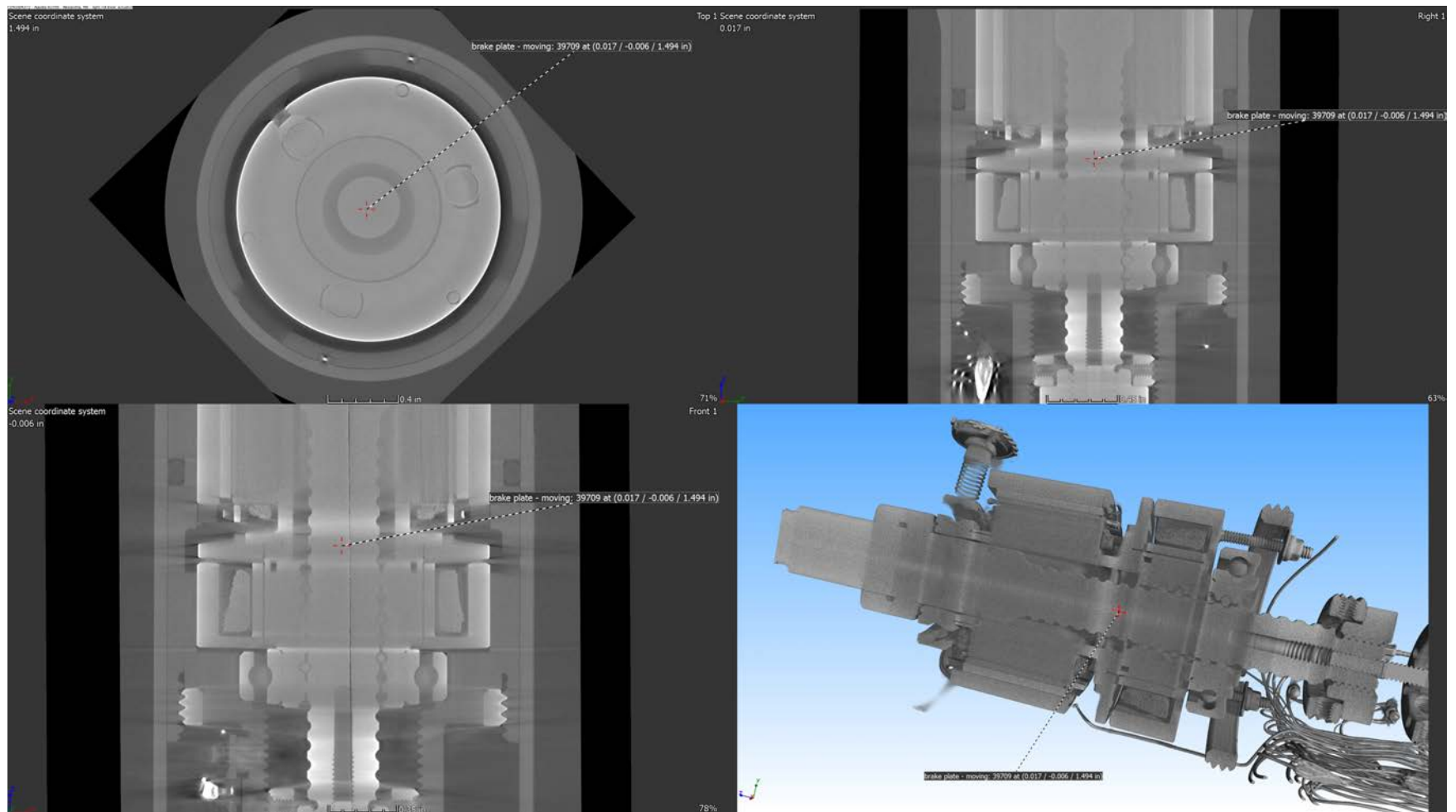


Figure 46
Right roll linear actuator – brake plate - moving

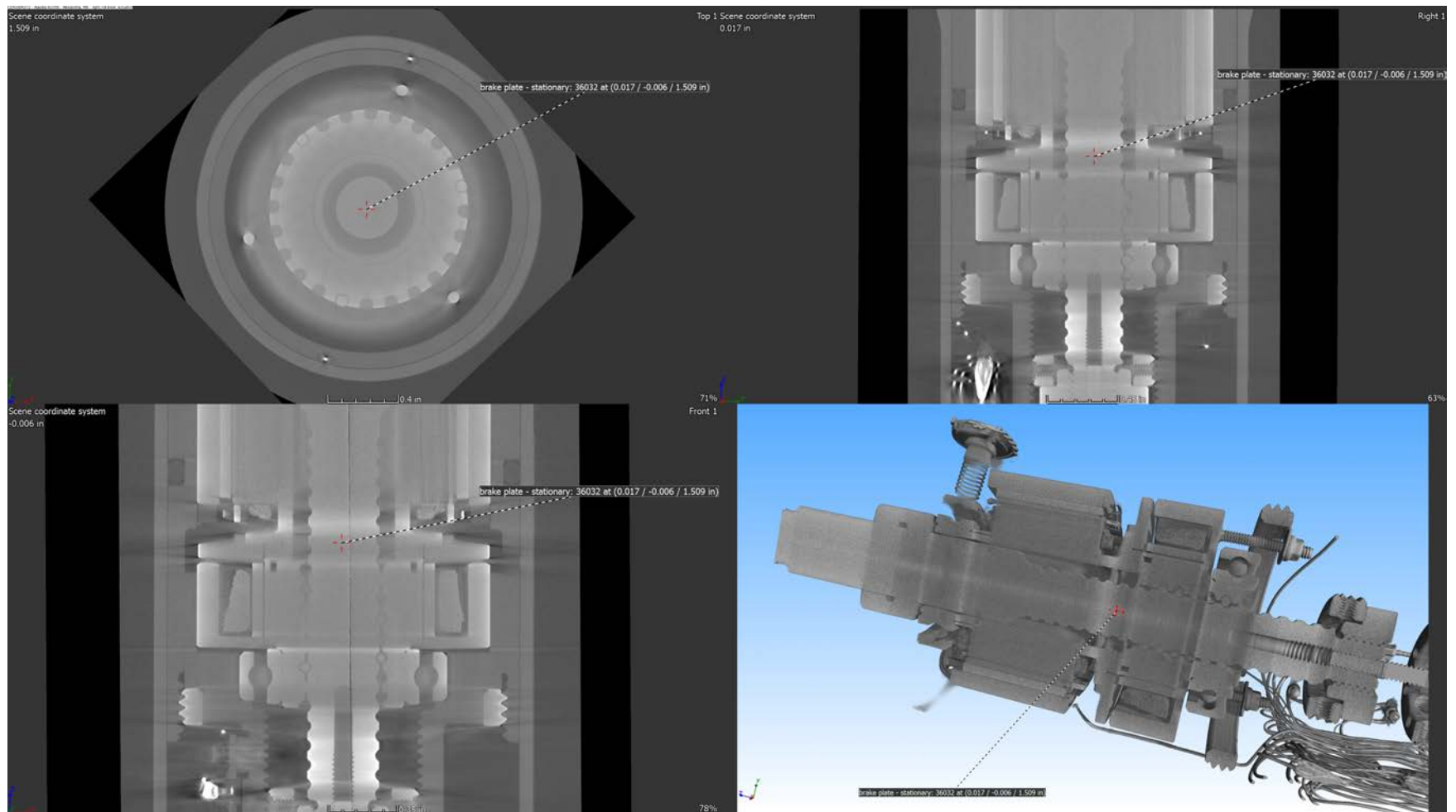


Figure 47
Right roll linear actuator – brake plate - stationary

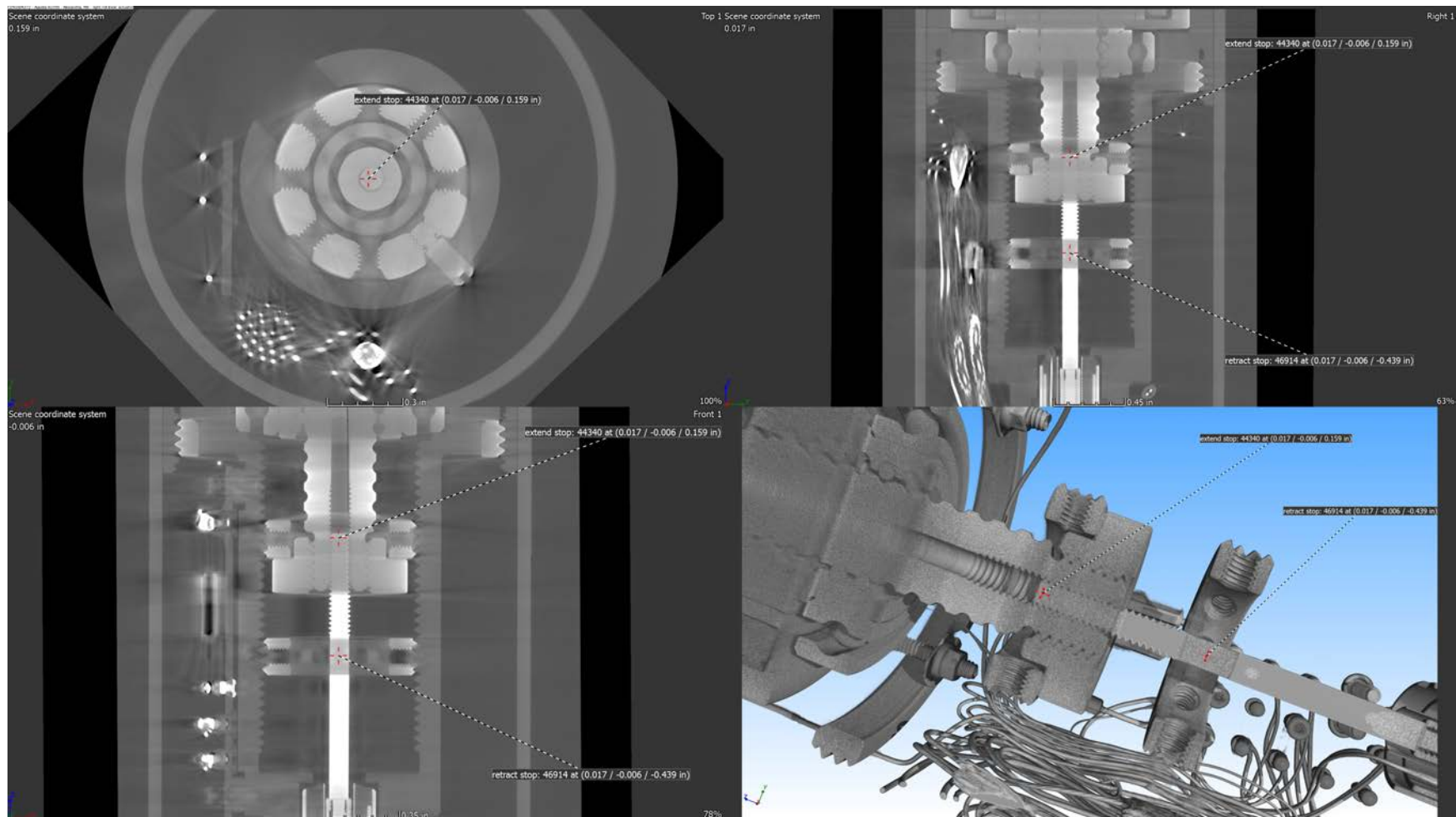


Figure 48
Right roll linear actuator – extend and retract stops

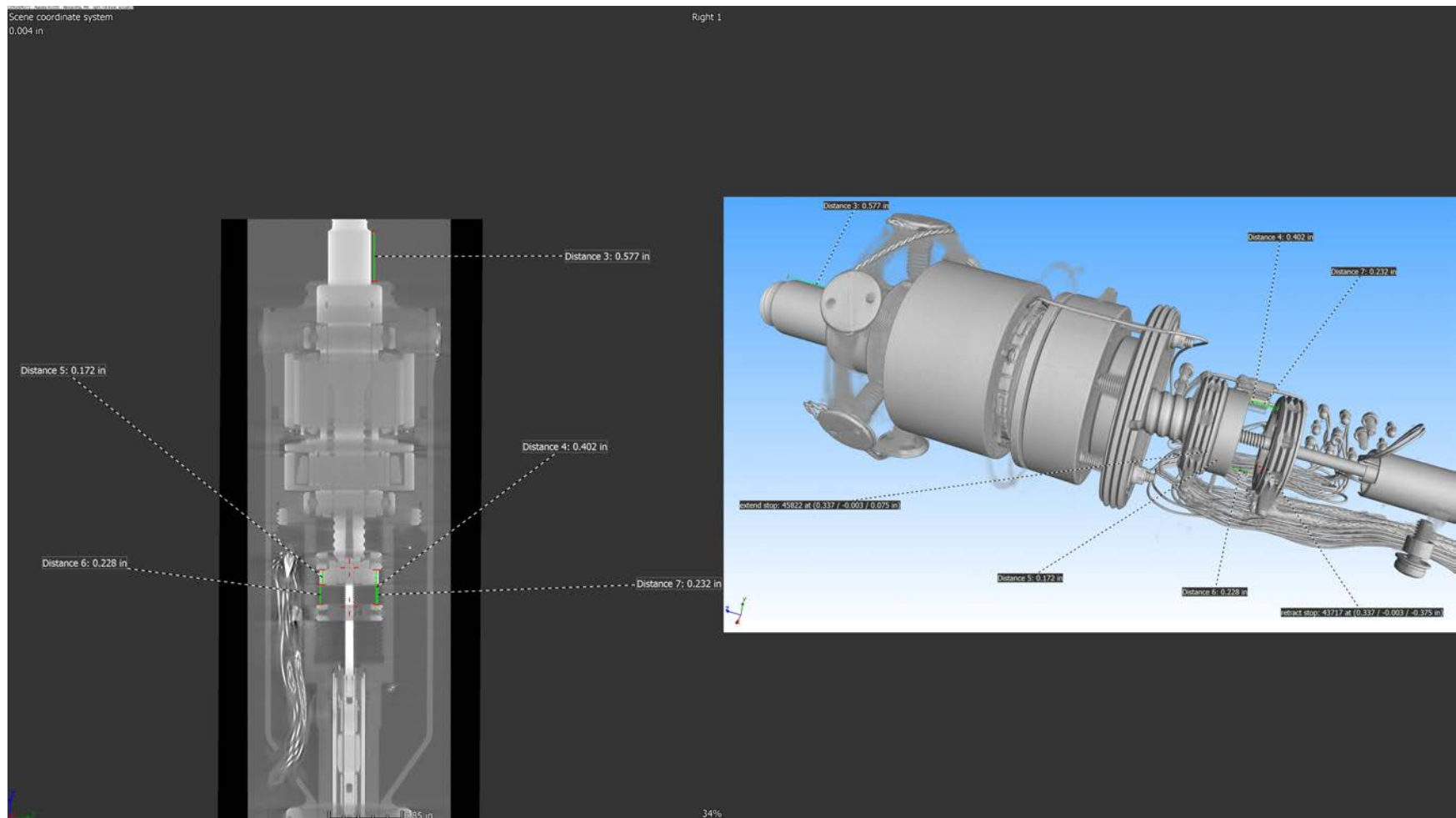


Figure 49
Right roll linear actuator – position measurements

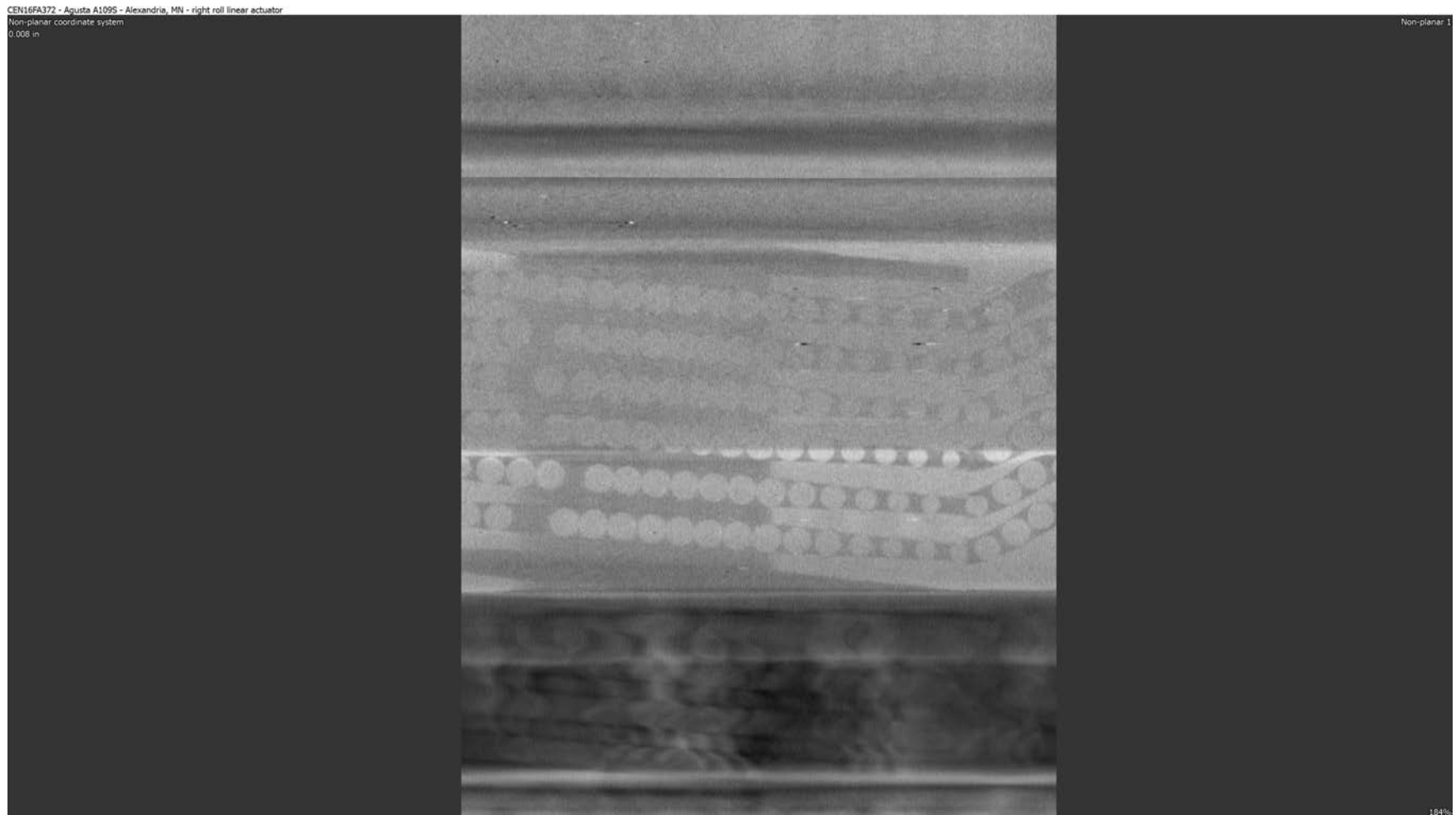


Figure 50
Right roll linear actuator – ballscrew tracks – virtually unrolled

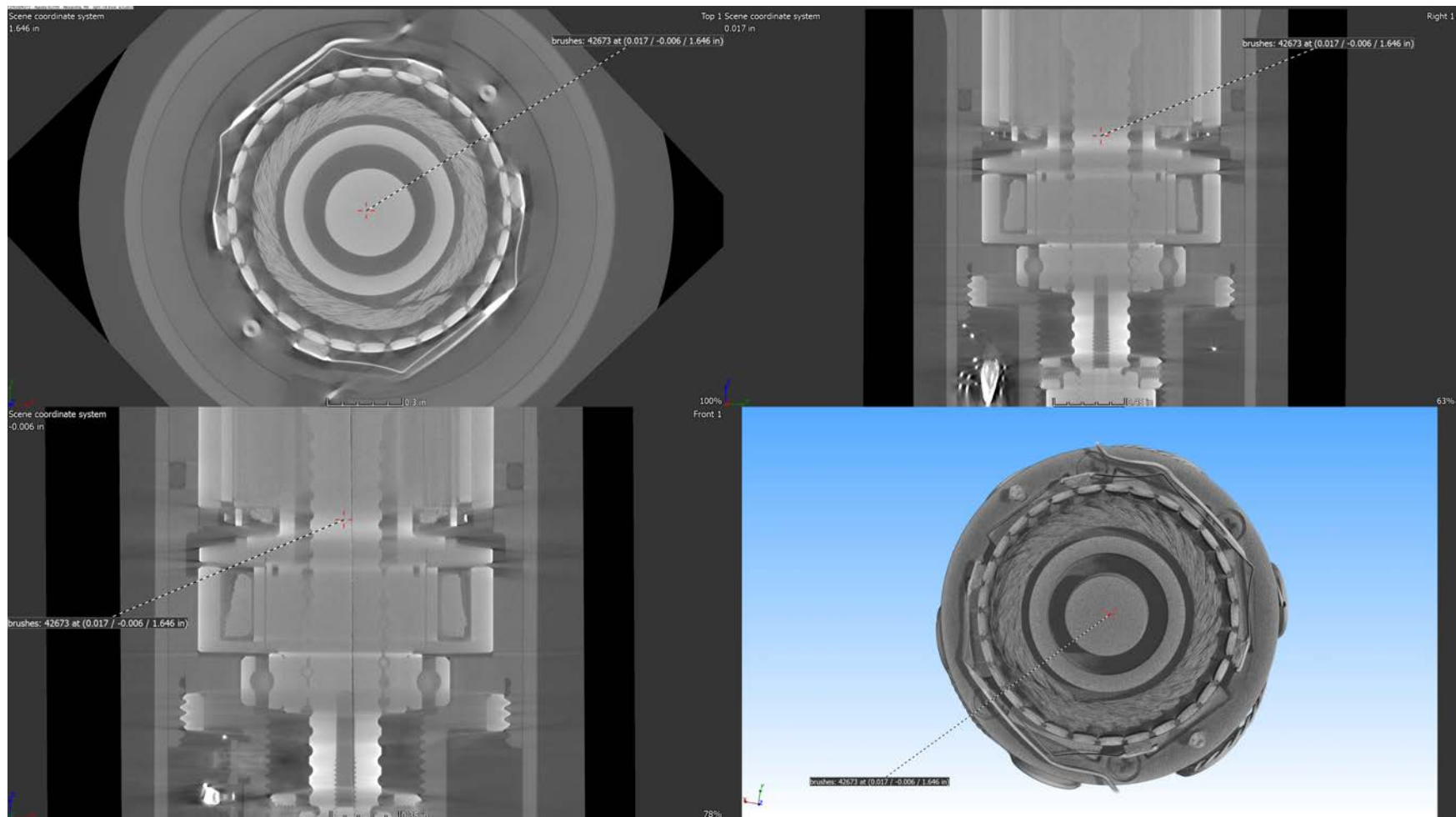


Figure 51
Right roll linear actuator – brushes

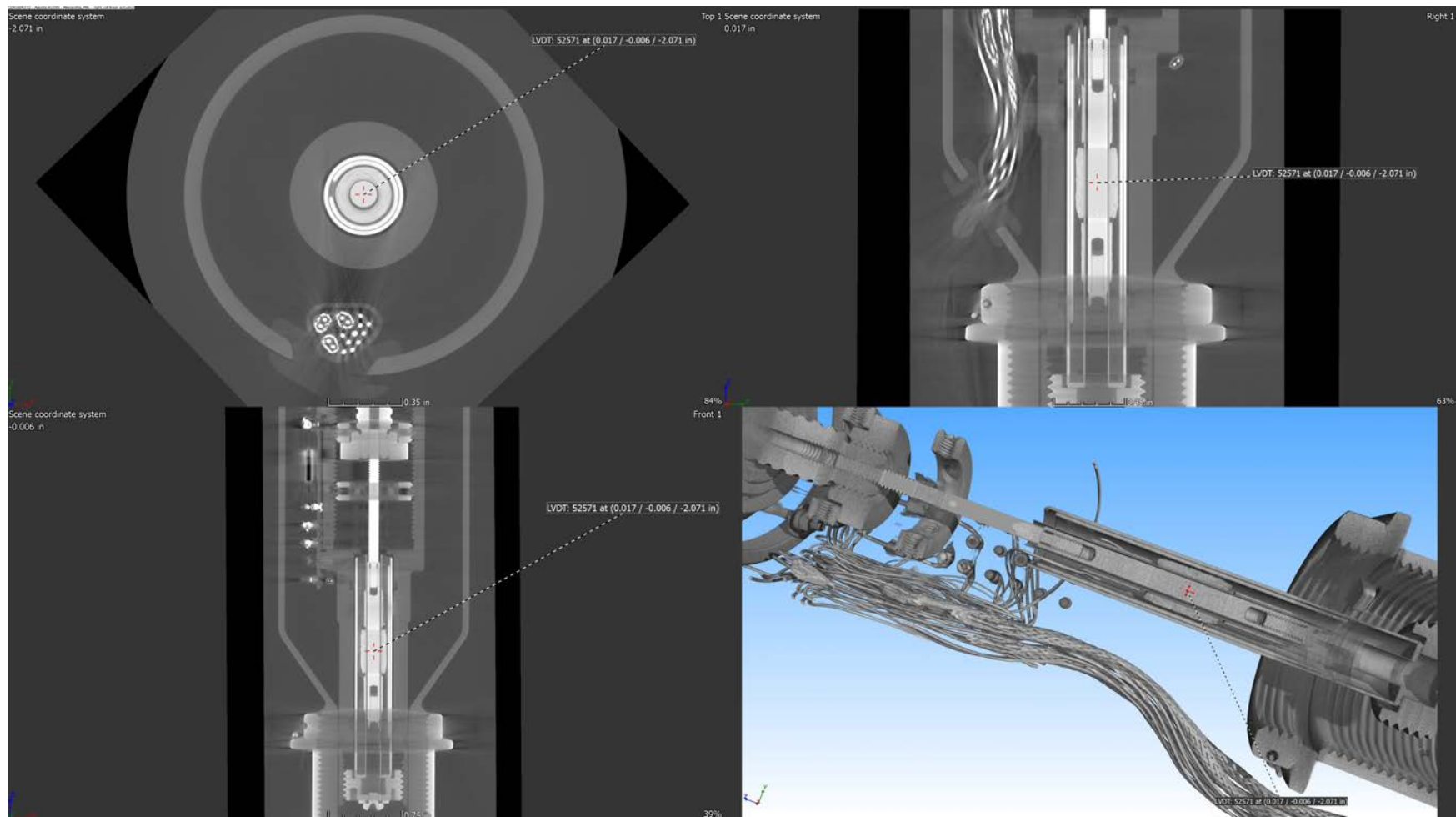


Figure 52
Right roll linear actuator – LVDT

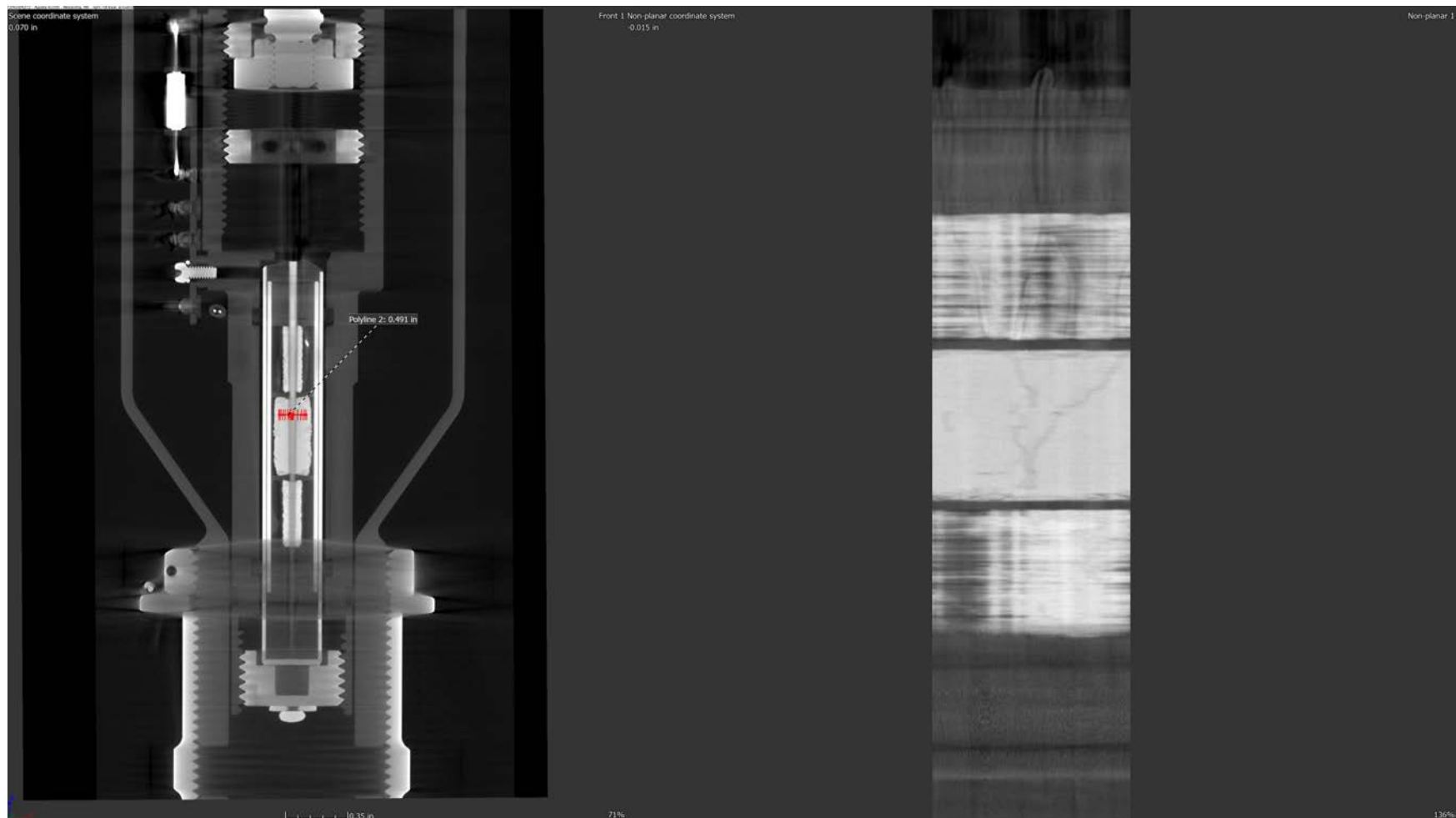


Figure 53
Right roll linear actuator – LVDT coils – virtually unrolled

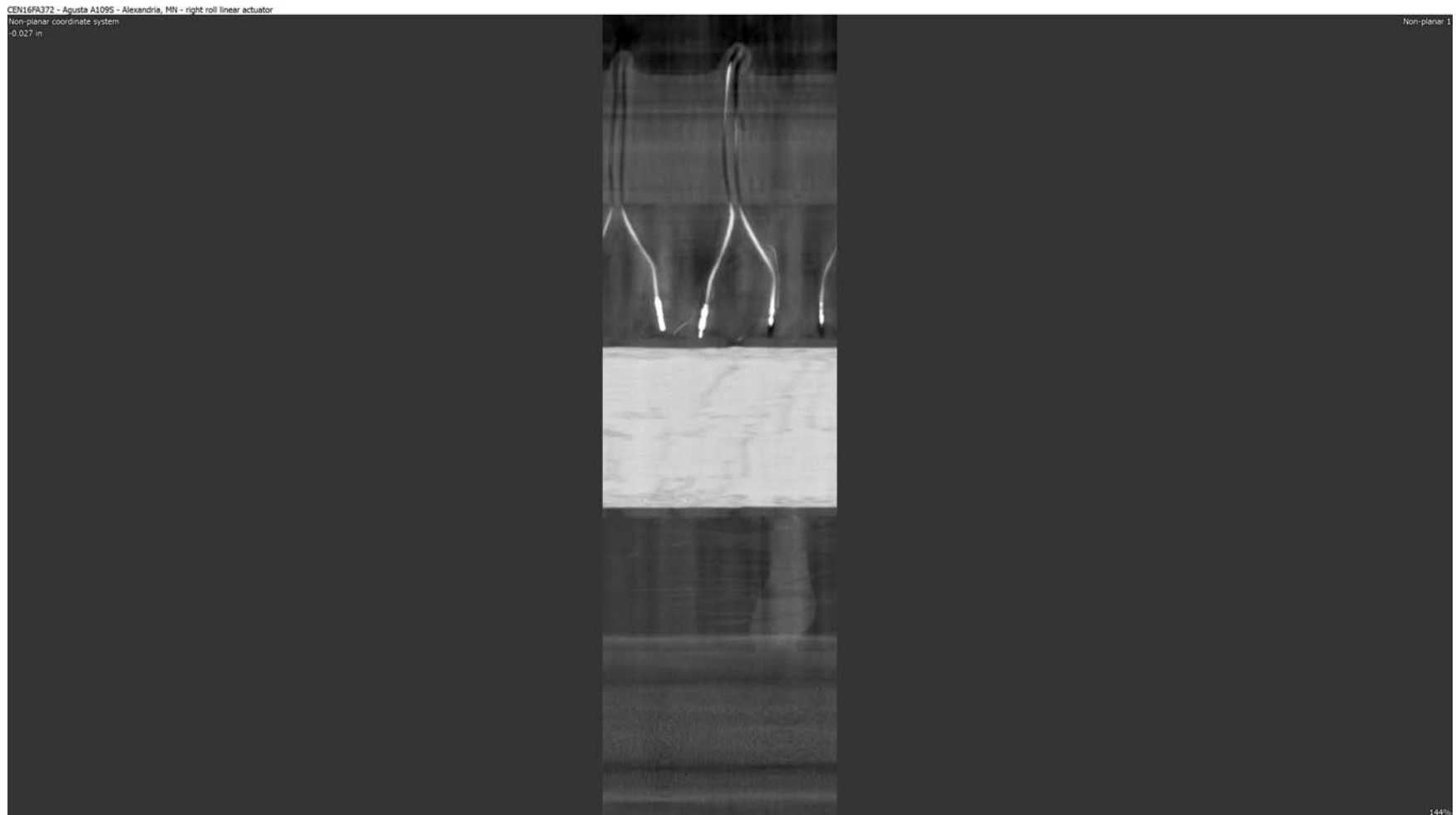


Figure 54
Right roll linear actuator – LVDT connections – virtually unrolled

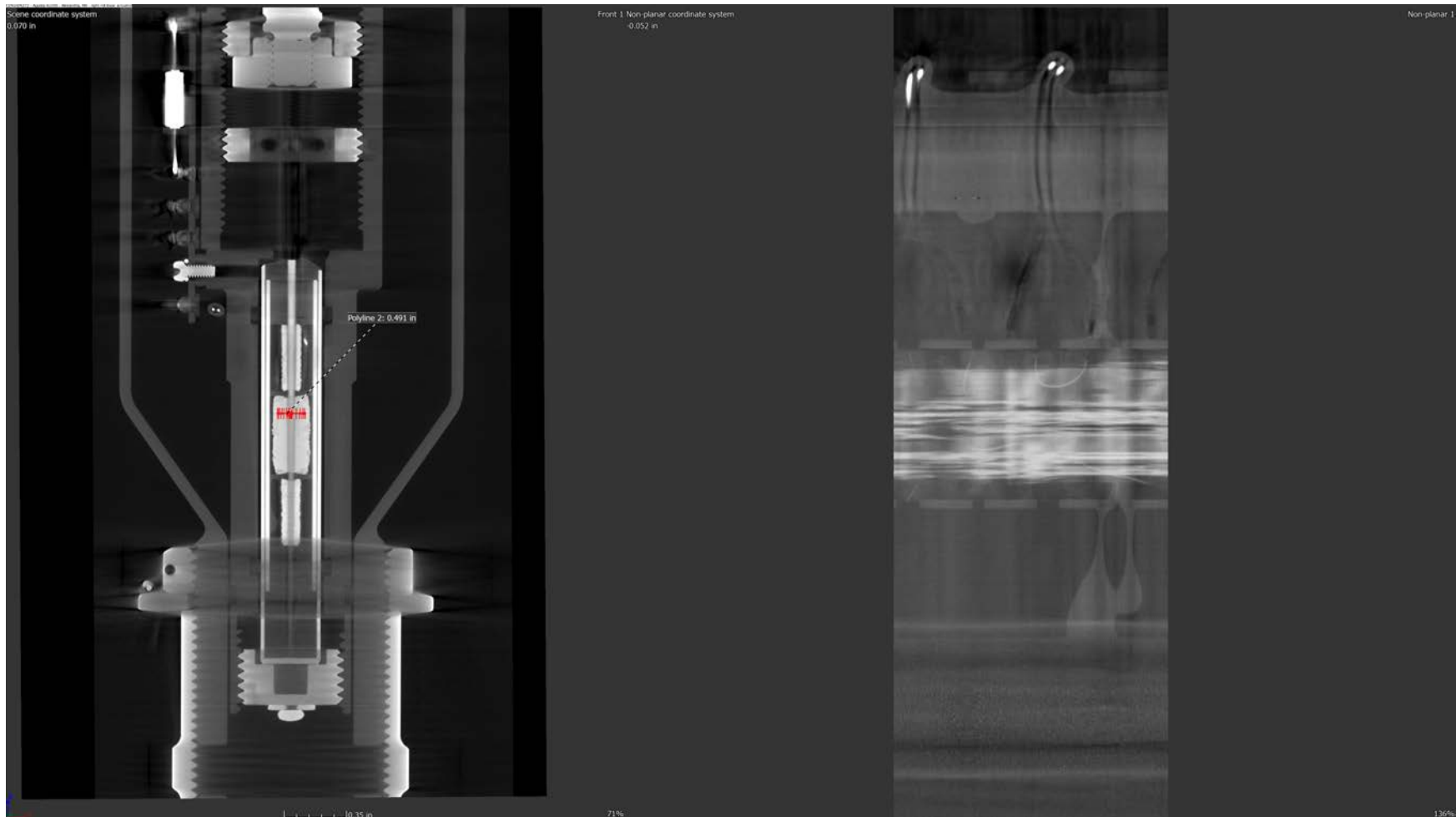


Figure 55
Right roll linear actuator – primary coil – upper surface – virtually unrolled

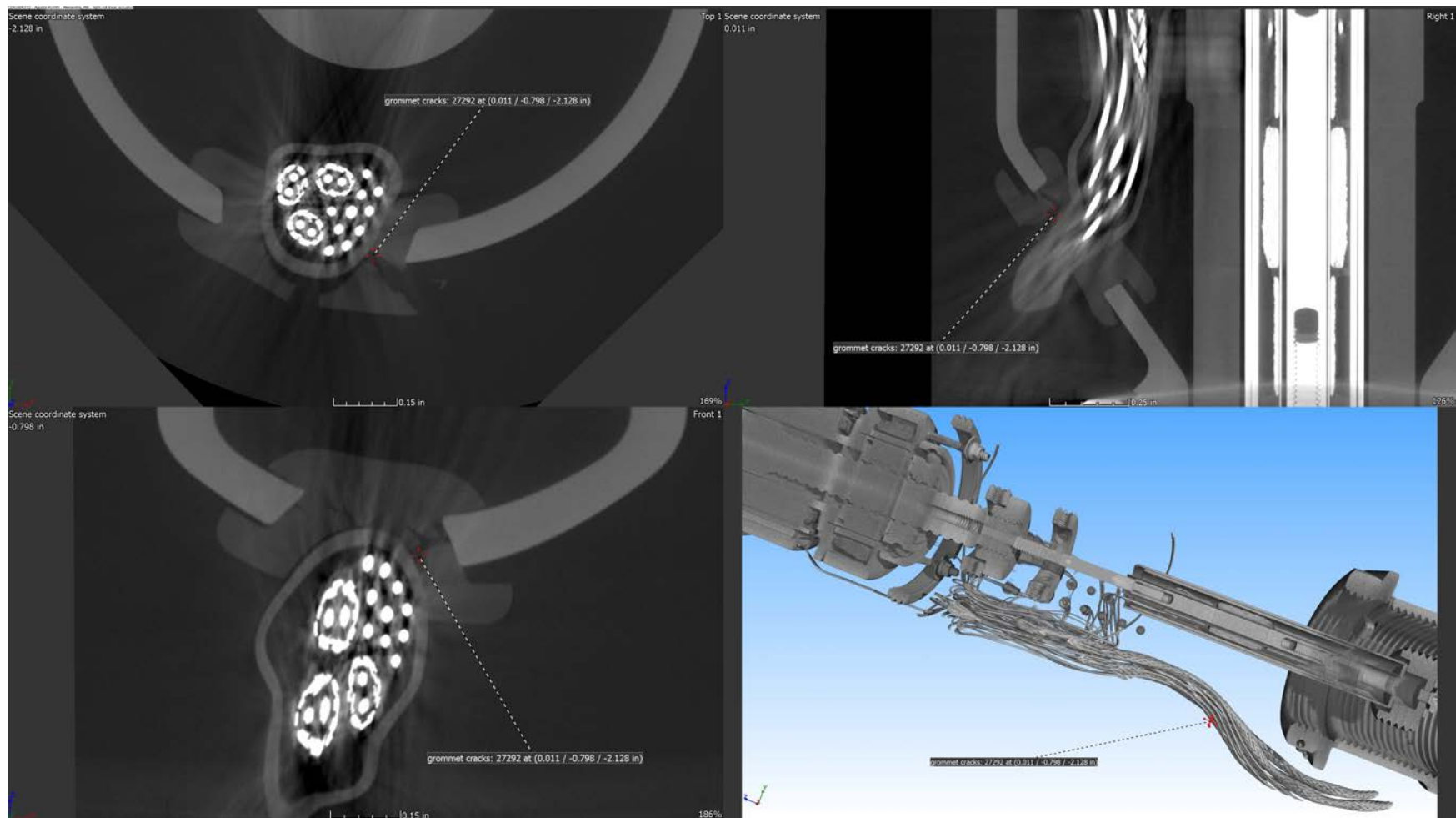


Figure 56
Right roll linear actuator – grommet cracks

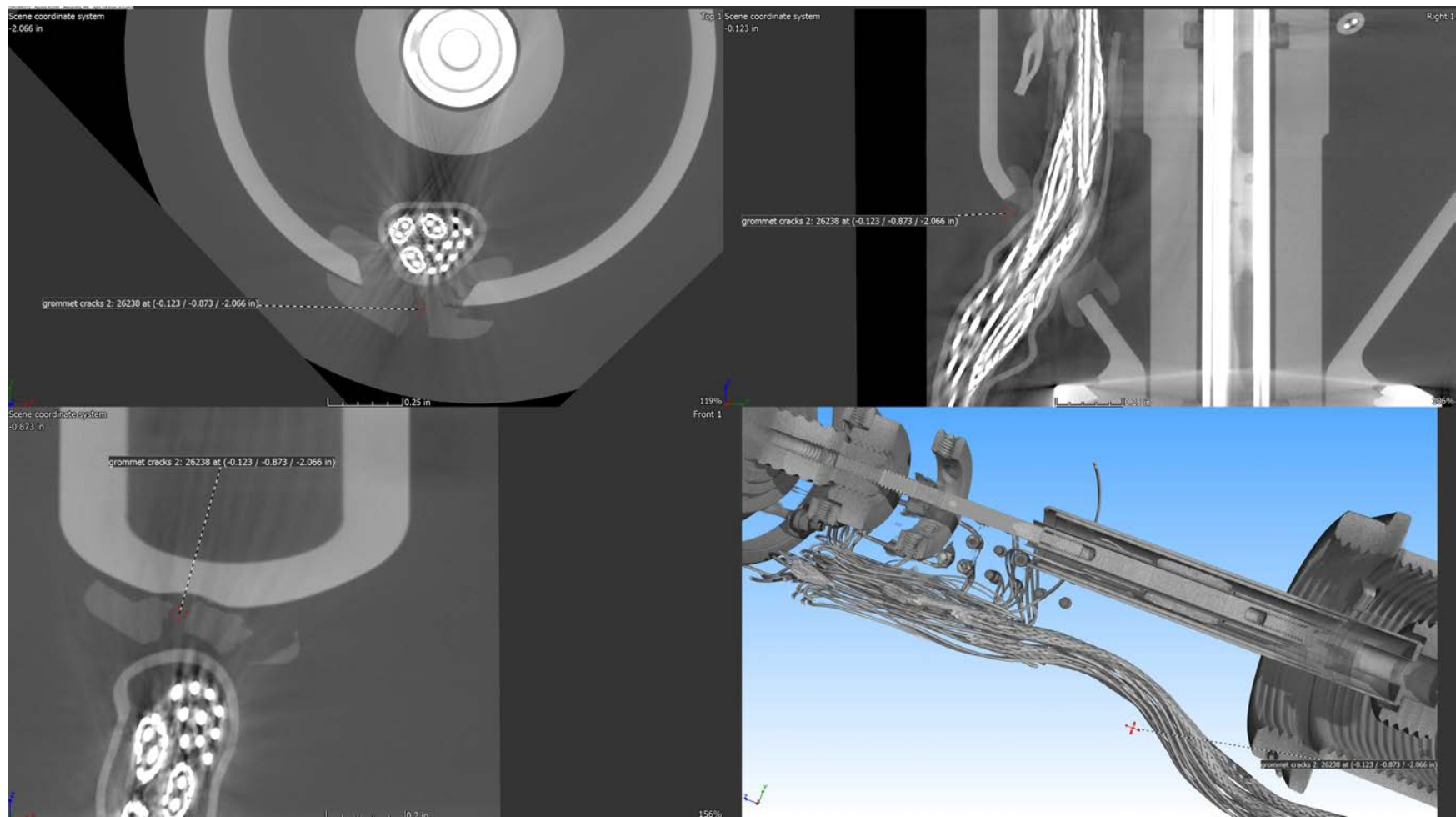


Figure 57
Right roll linear actuator – grogmet cracks – location 2

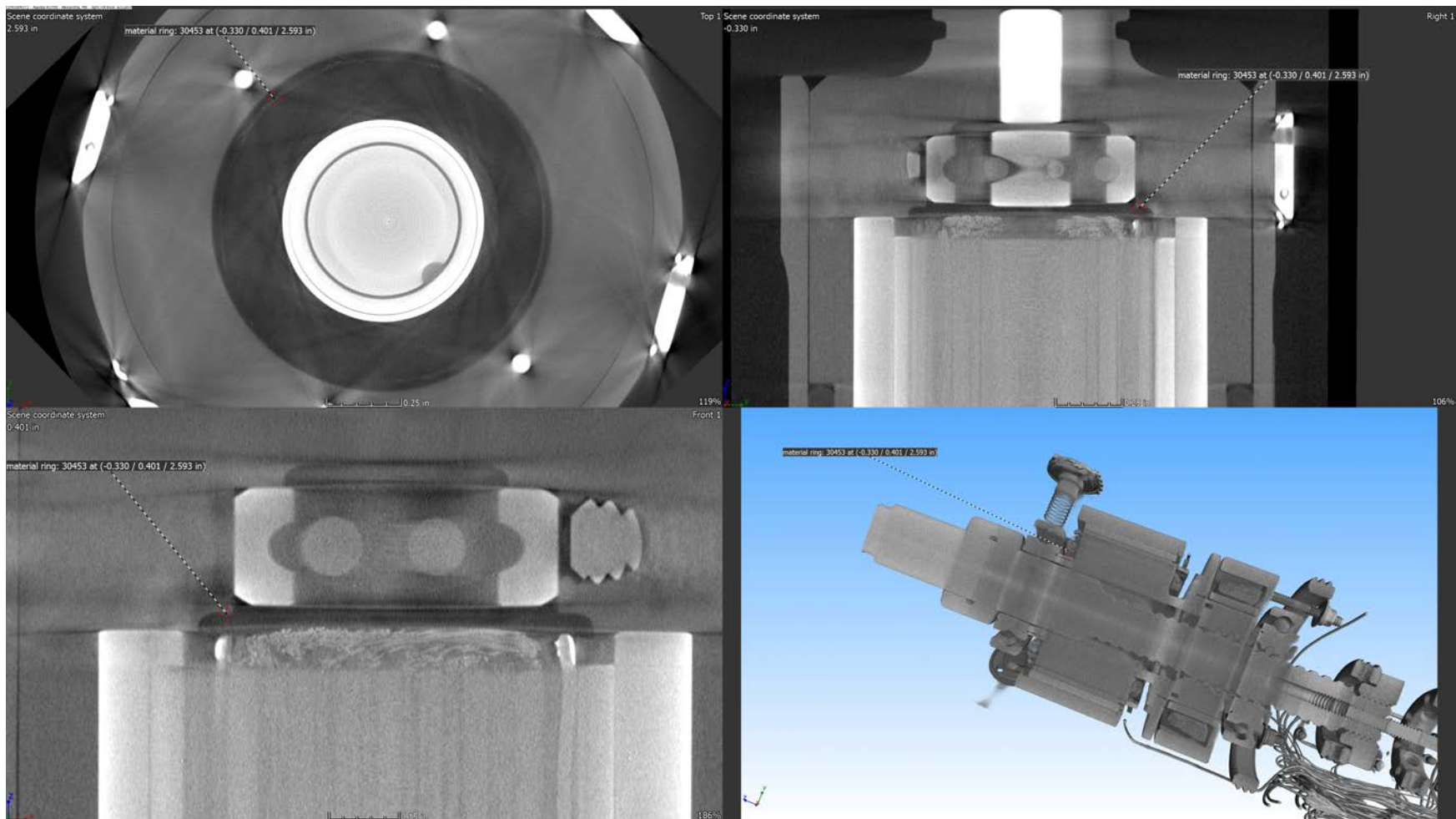


Figure 58
Right roll linear actuator – material ring near motor

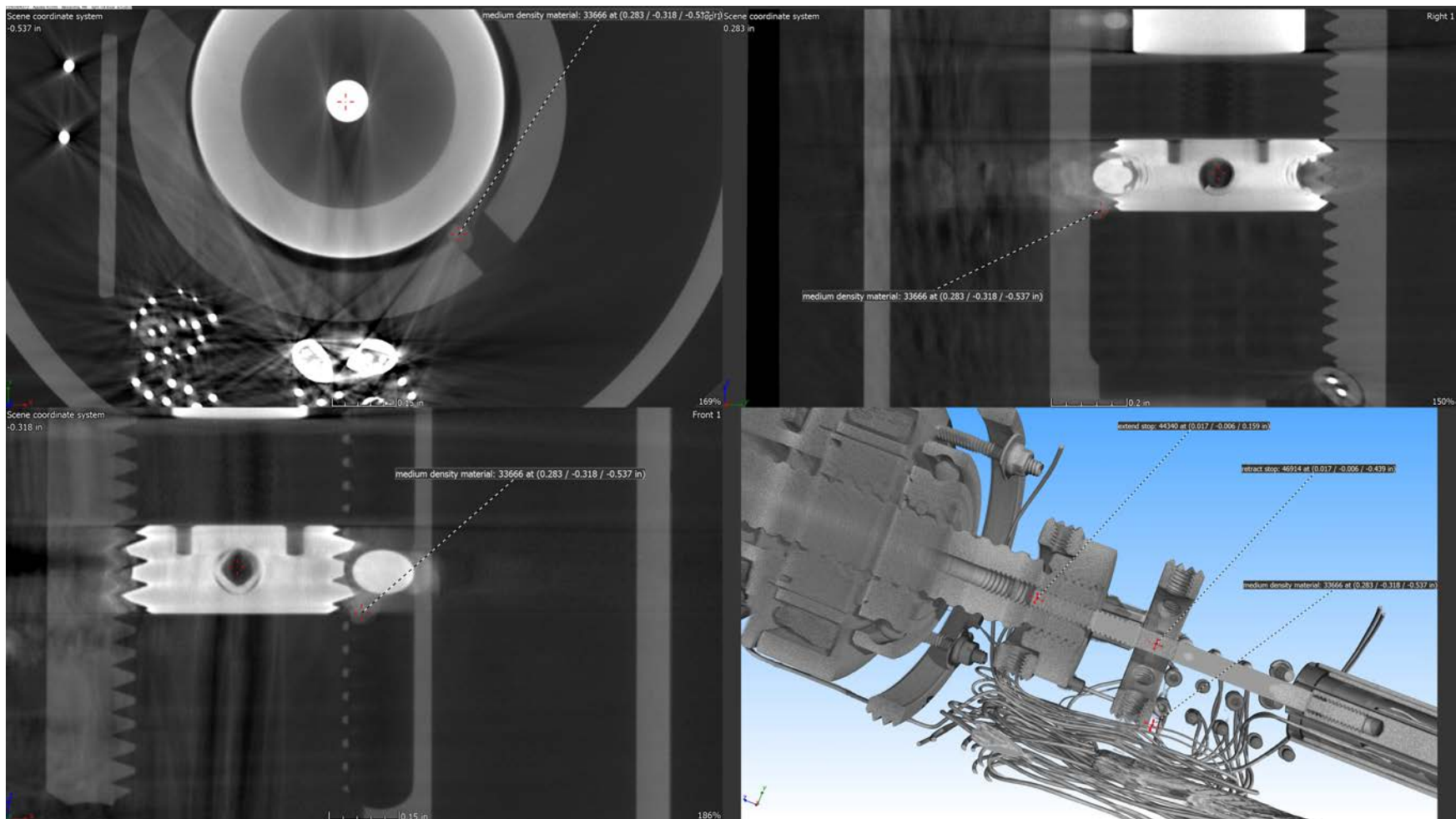


Figure 59
Right roll linear actuator – medium density material in retract stop

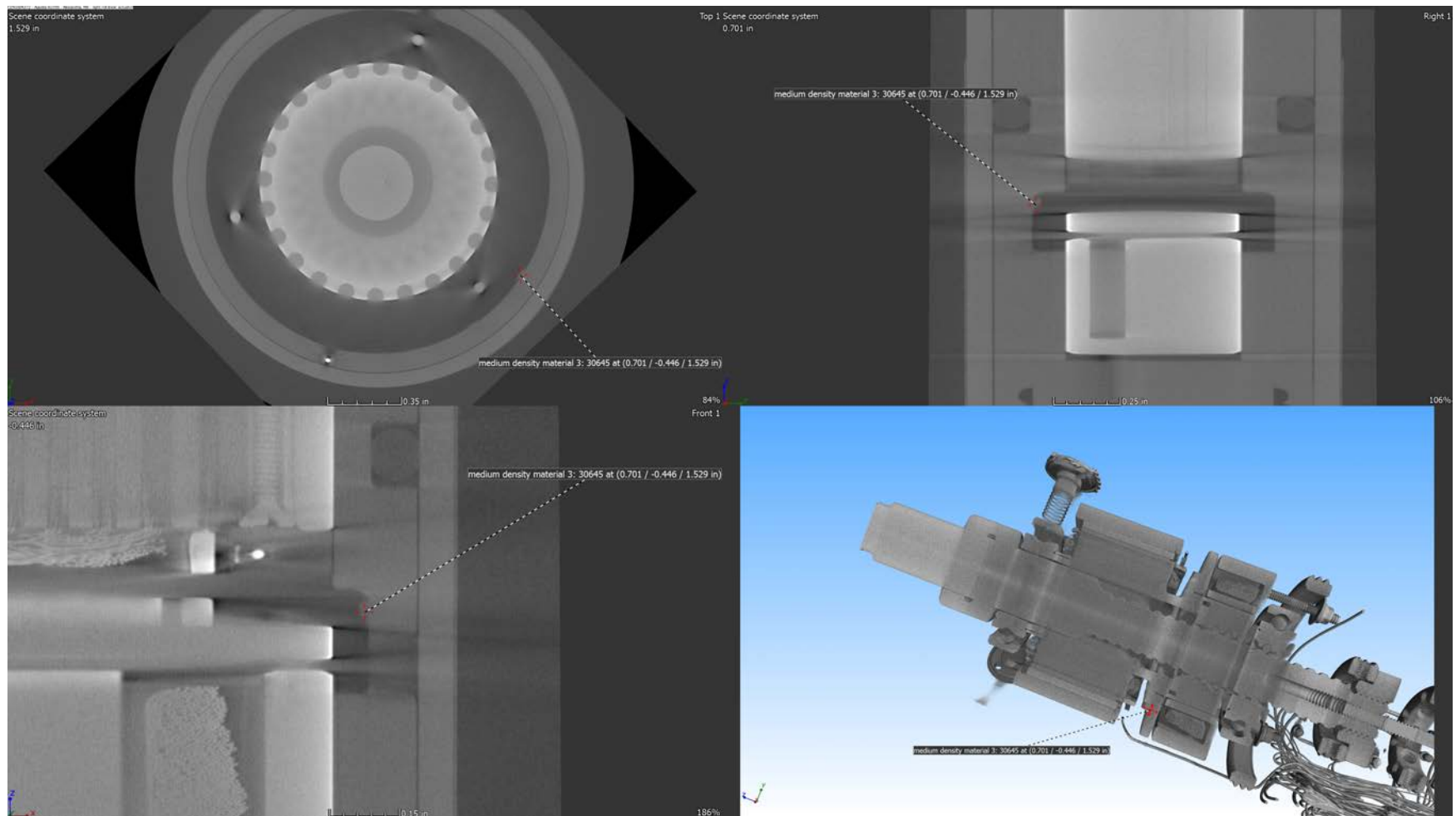


Figure 60
Right roll linear actuator – medium density material near brake

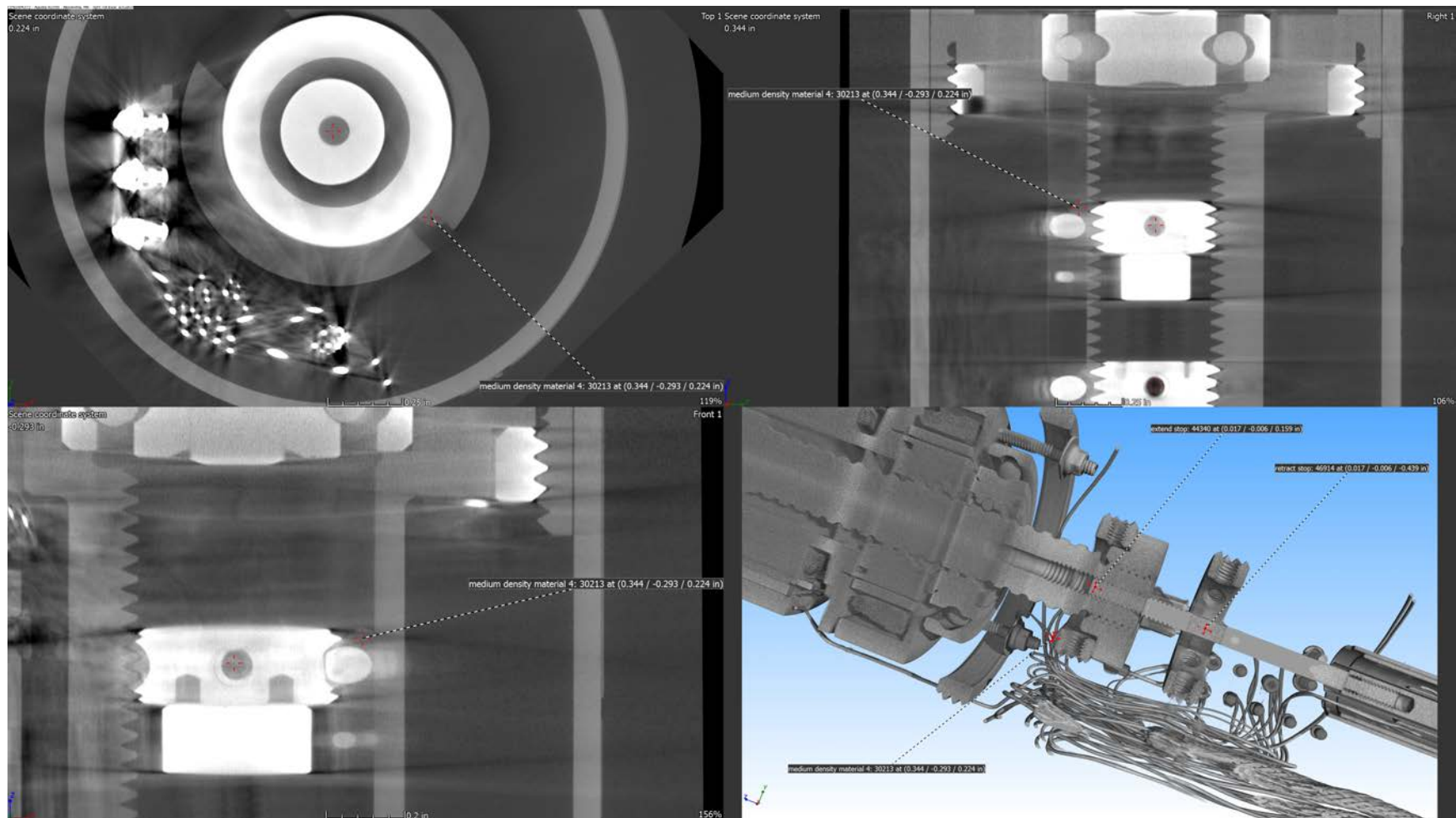


Figure 61
Right roll linear actuator – medium density material near extend stop

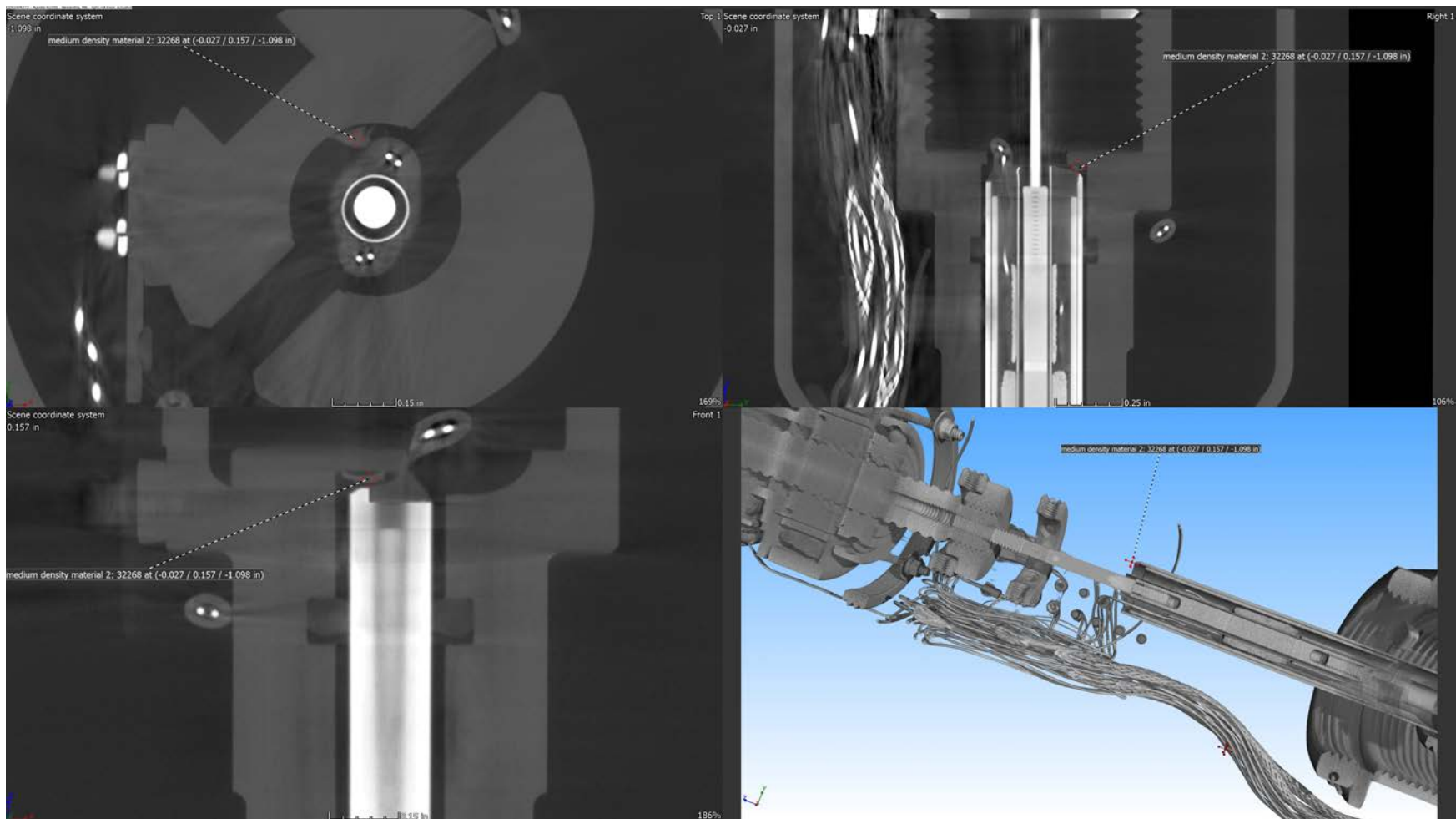


Figure 62
Right roll linear actuator – medium density material near LVDT

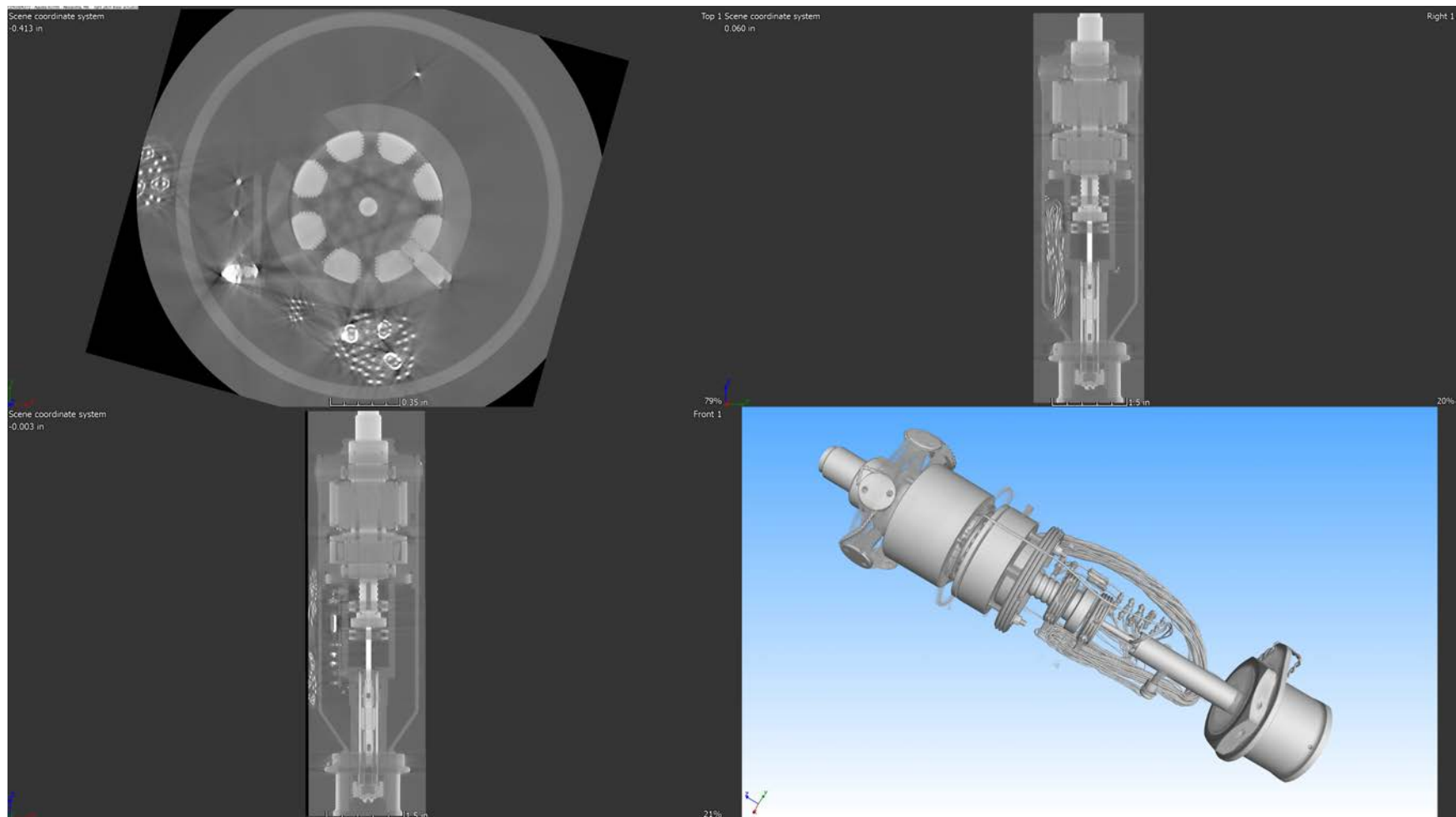


Figure 63
Right pitch linear actuator – overview

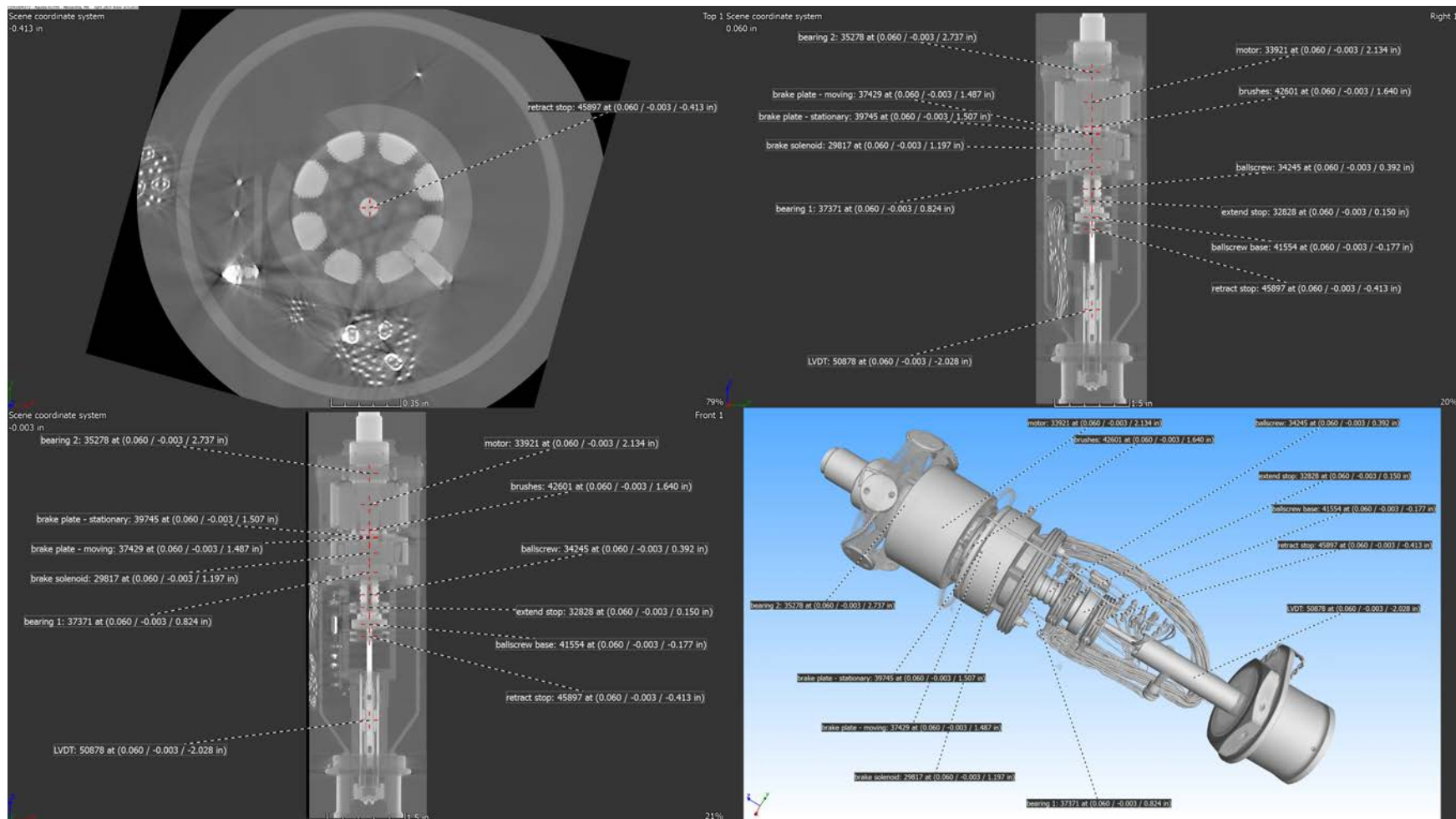


Figure 64
Right pitch linear actuator – overview 2

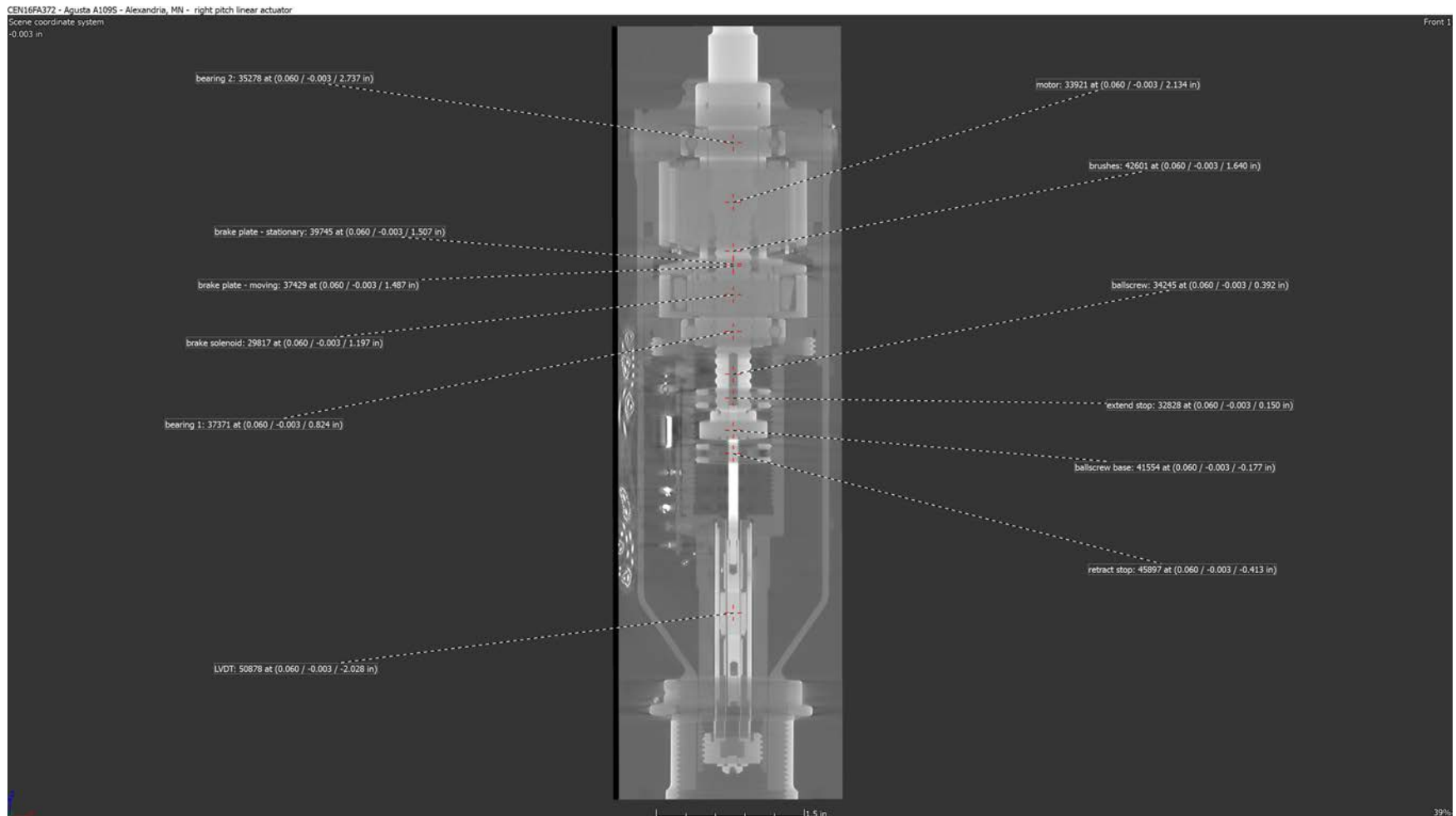


Figure 65
Right pitch linear actuator – overview – front view only

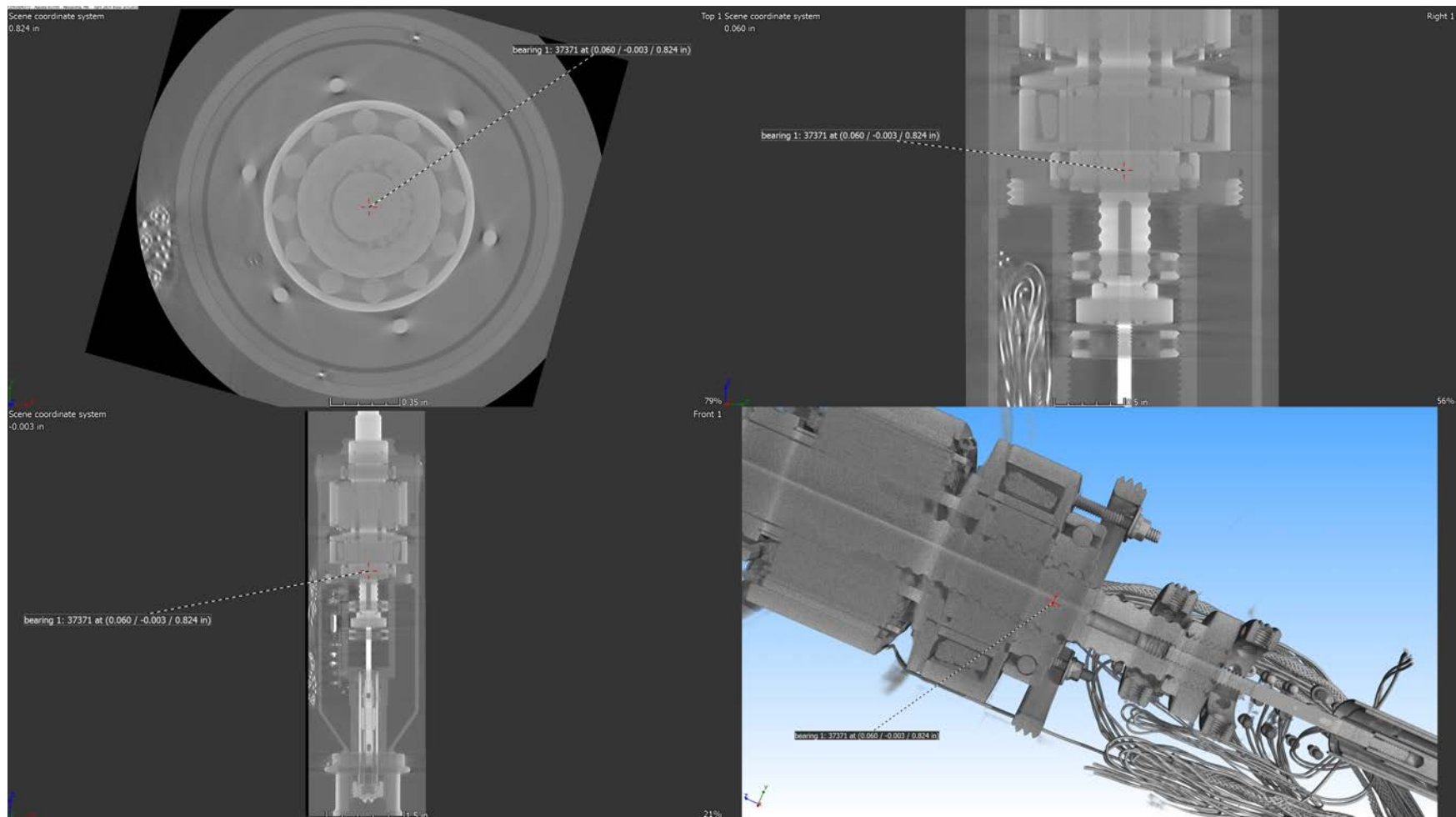


Figure 66
Right pitch linear actuator – bearing 1

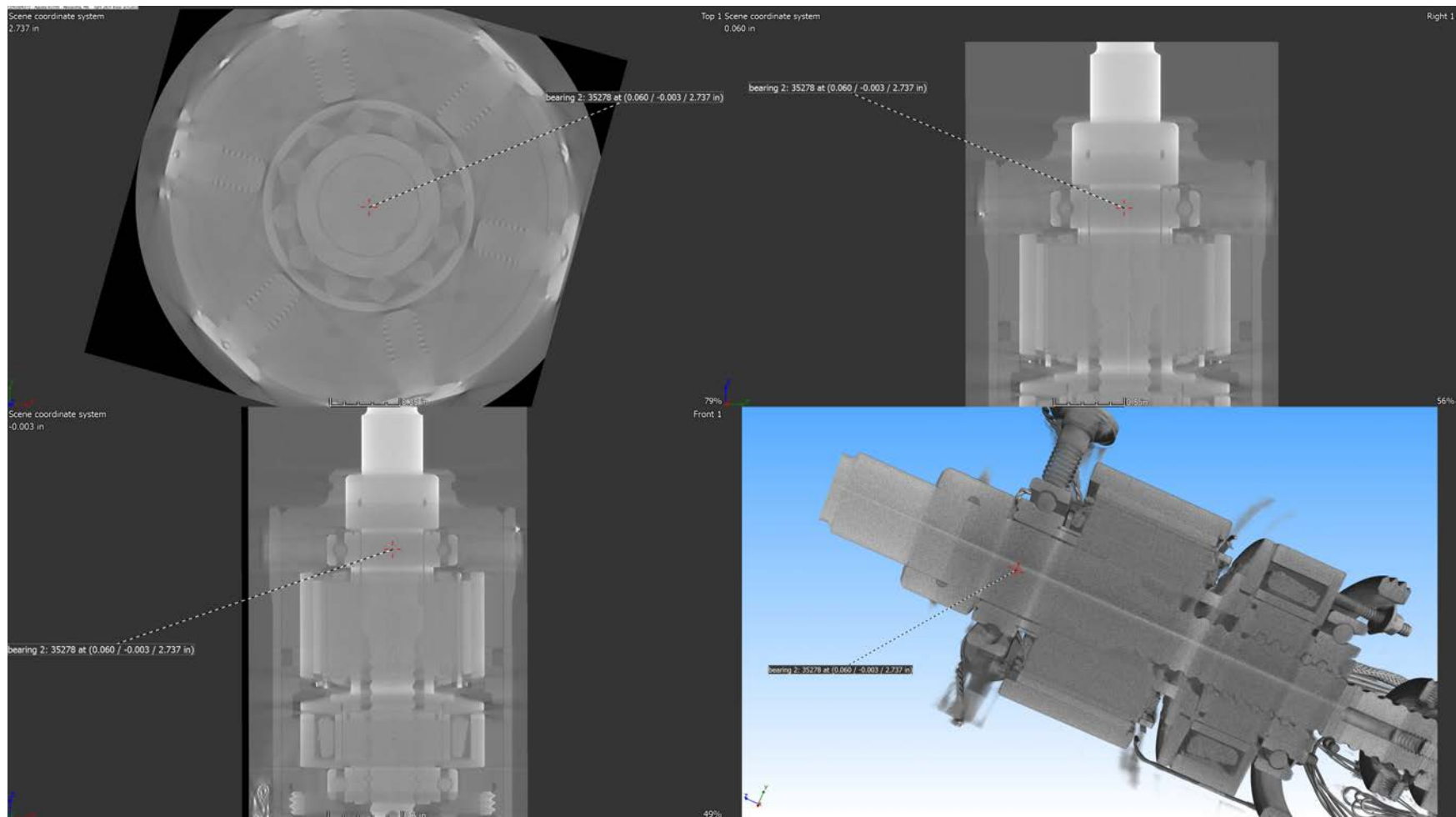


Figure 67
Right pitch linear actuator – bearing 2

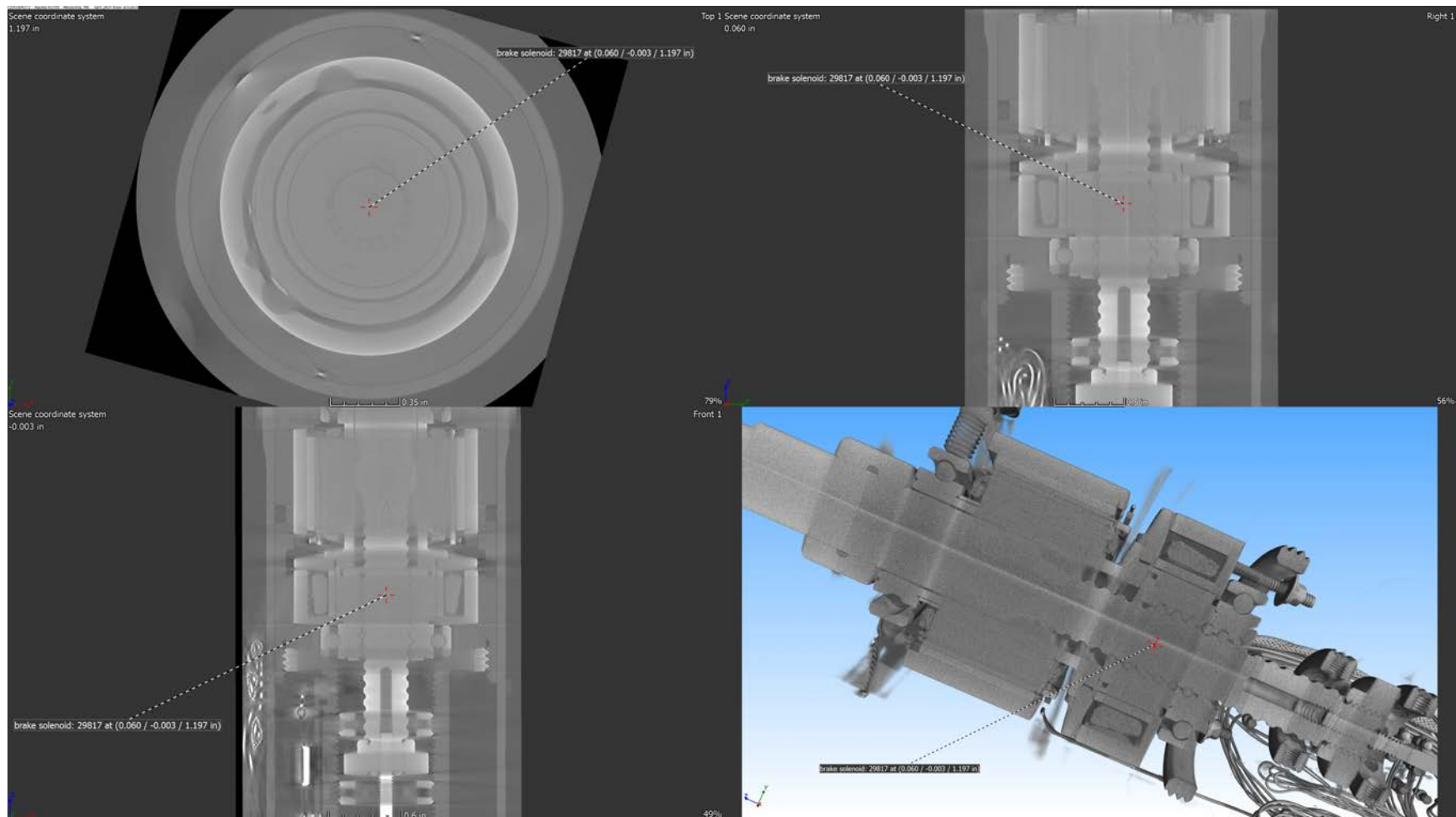


Figure 68
Right pitch linear actuator – brake solenoid

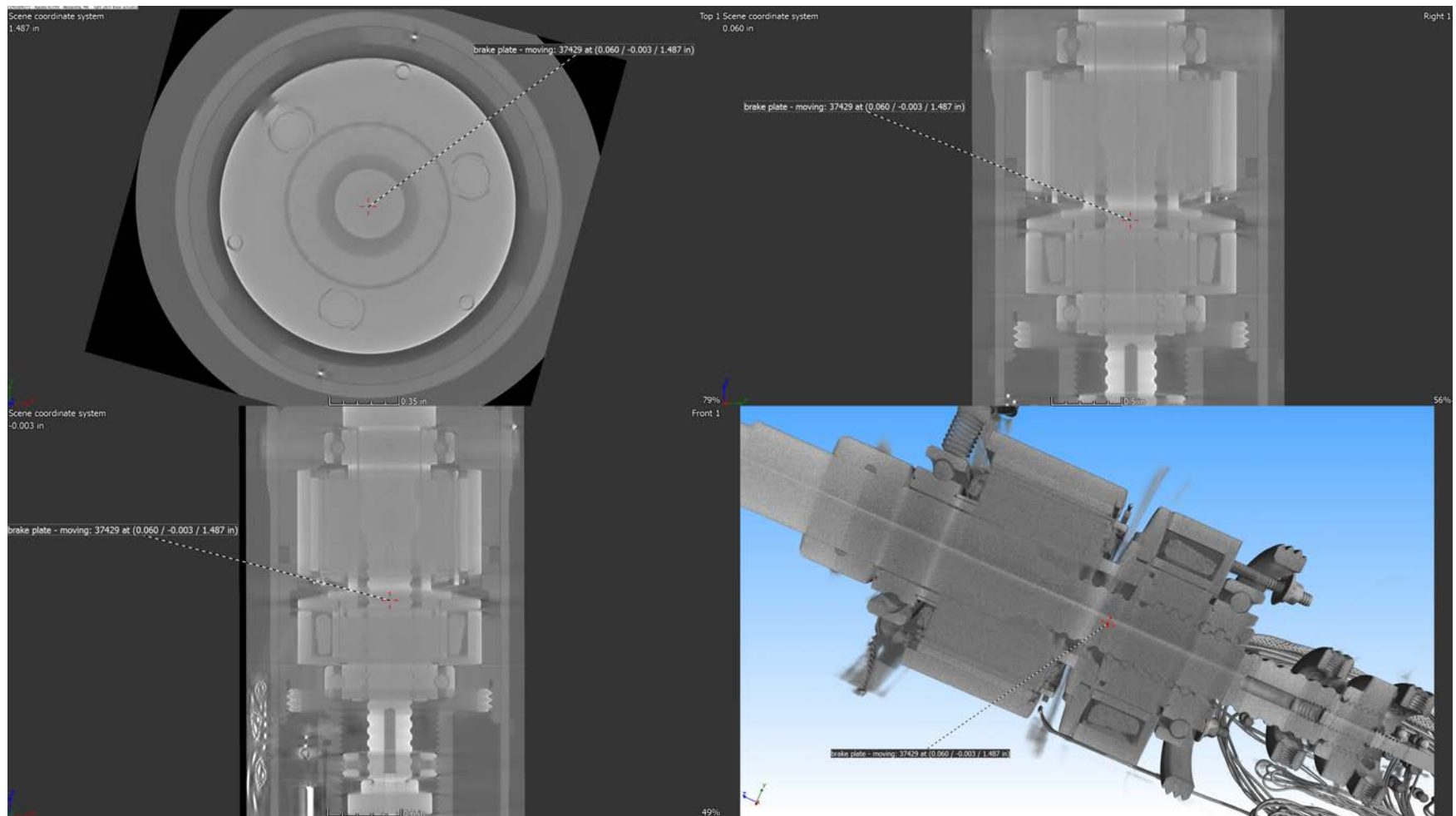


Figure 69
Right pitch linear actuator – brake plate - moving

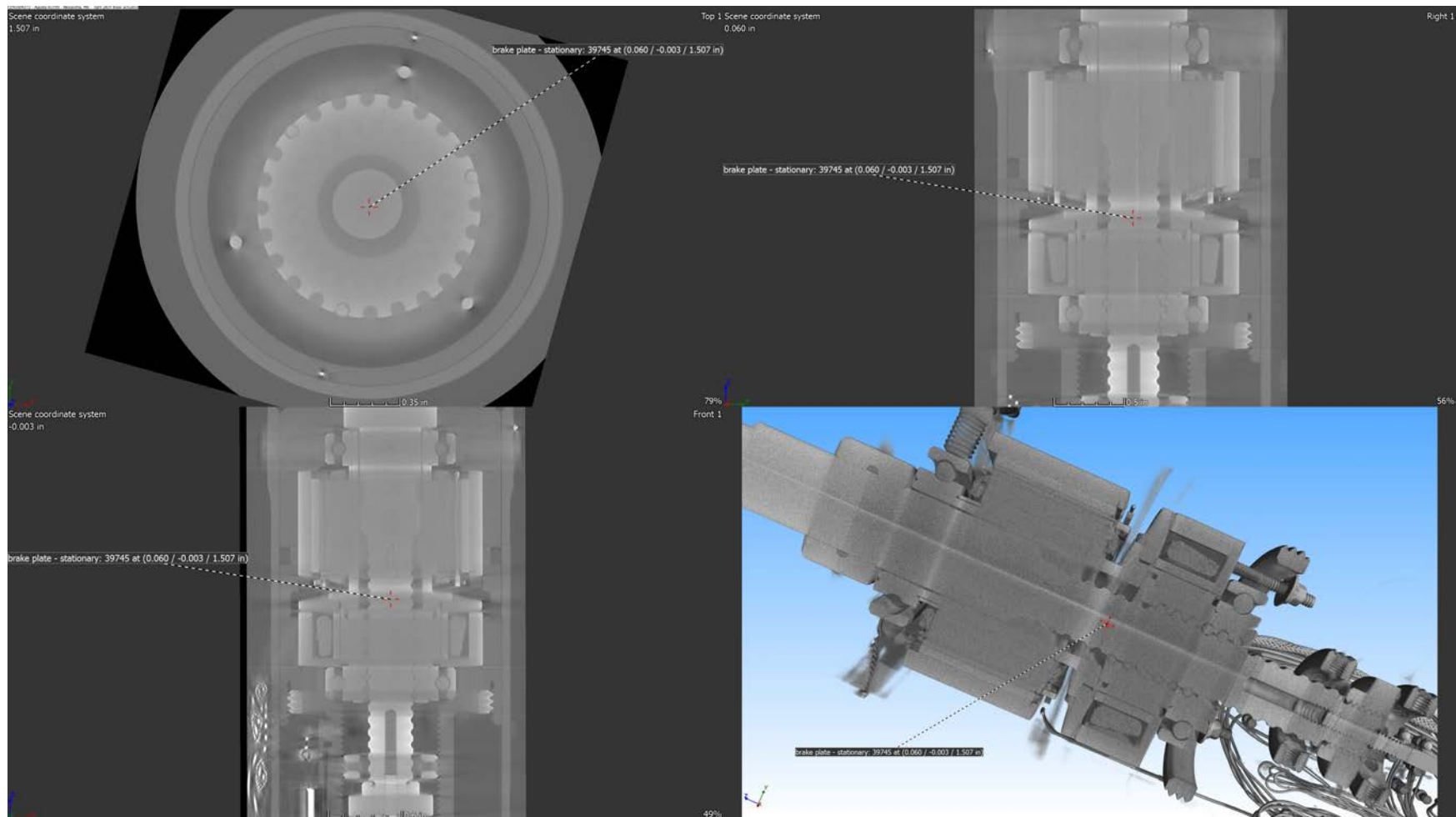


Figure 70
Right pitch linear actuator – brake plate - stationary

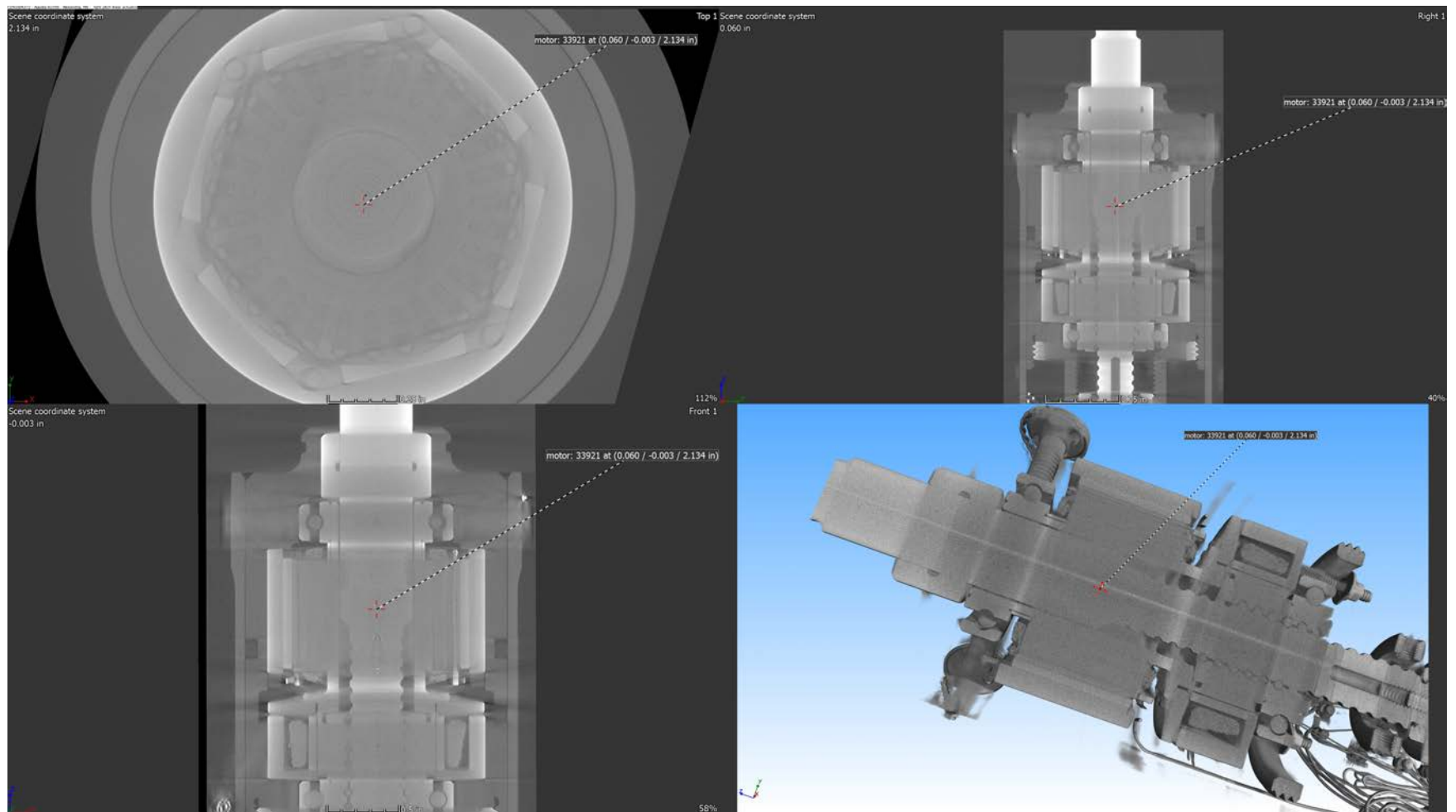


Figure 71
Right pitch linear actuator – motor

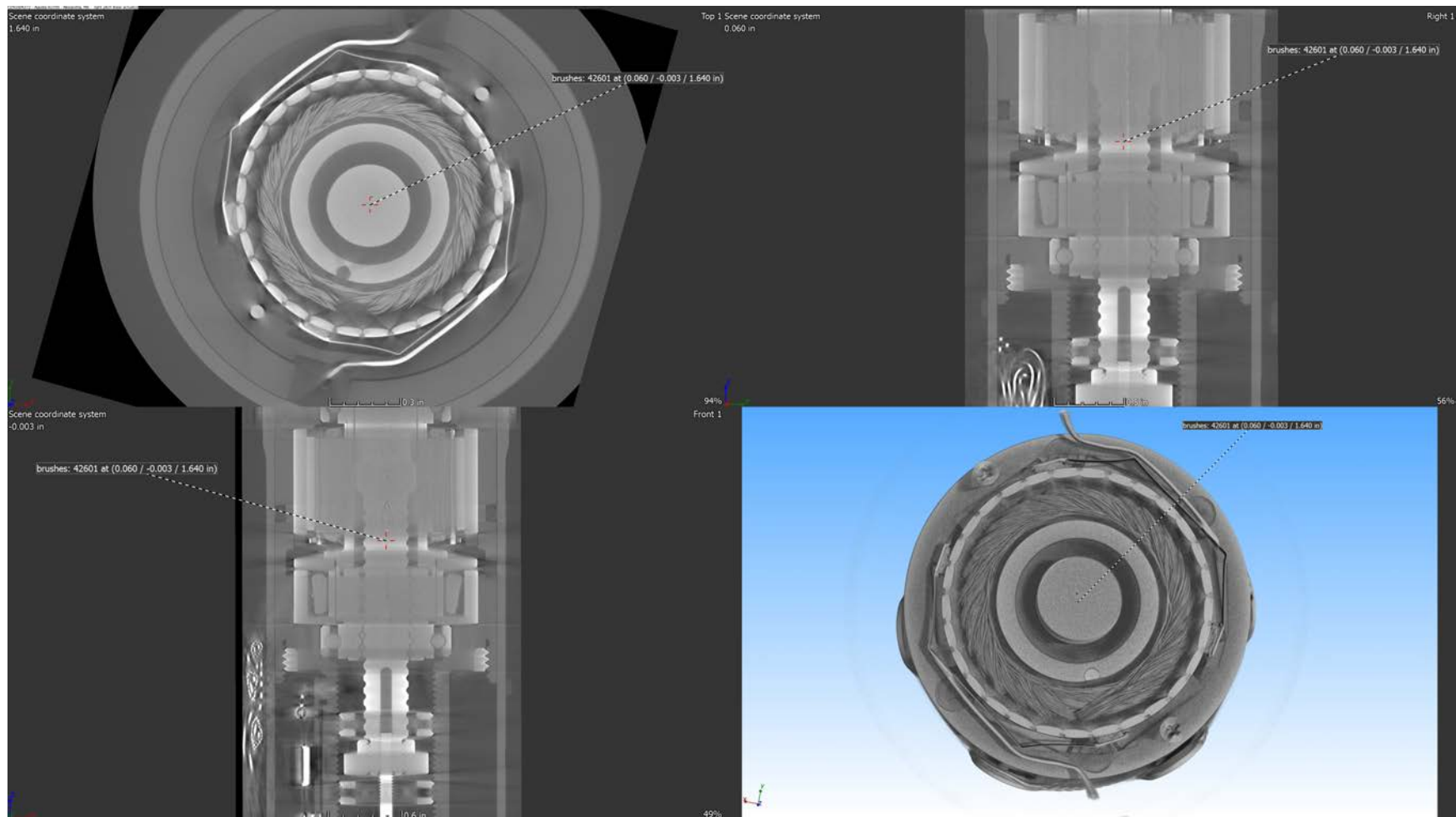


Figure 72
Right pitch linear actuator – brushes

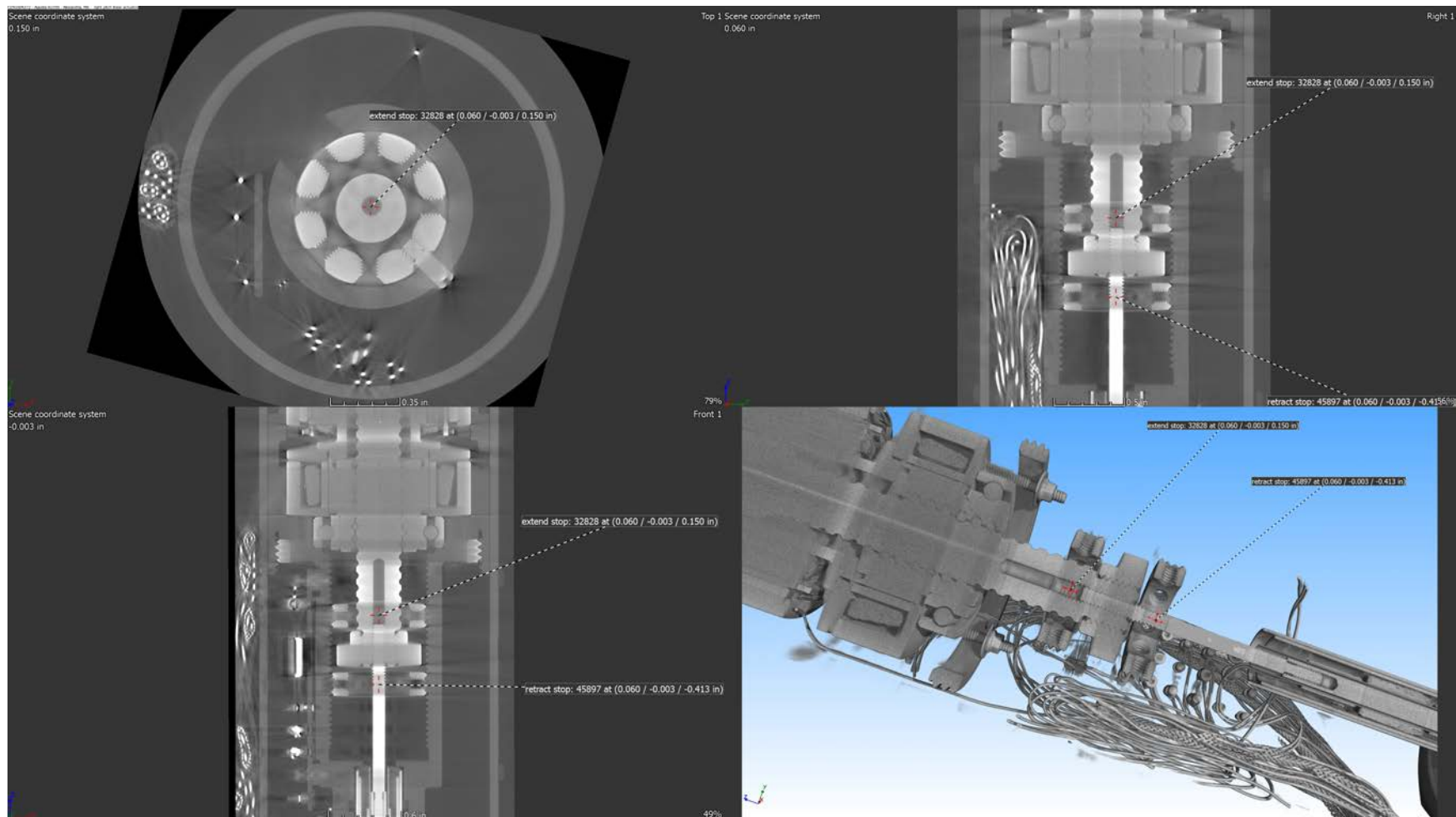


Figure 73
Right pitch linear actuator – extend and retract stops

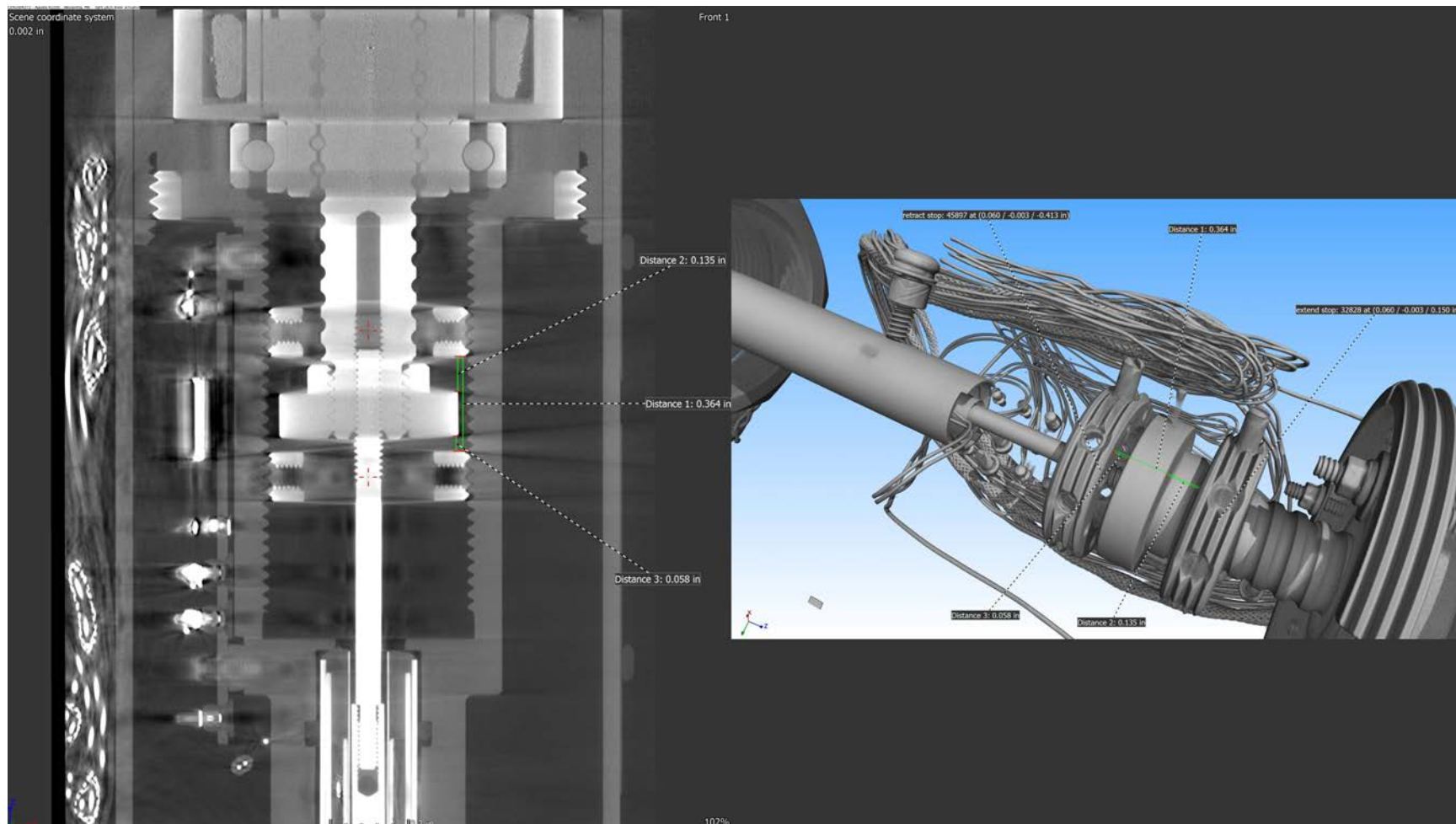


Figure 74
Right pitch linear actuator – position measurements

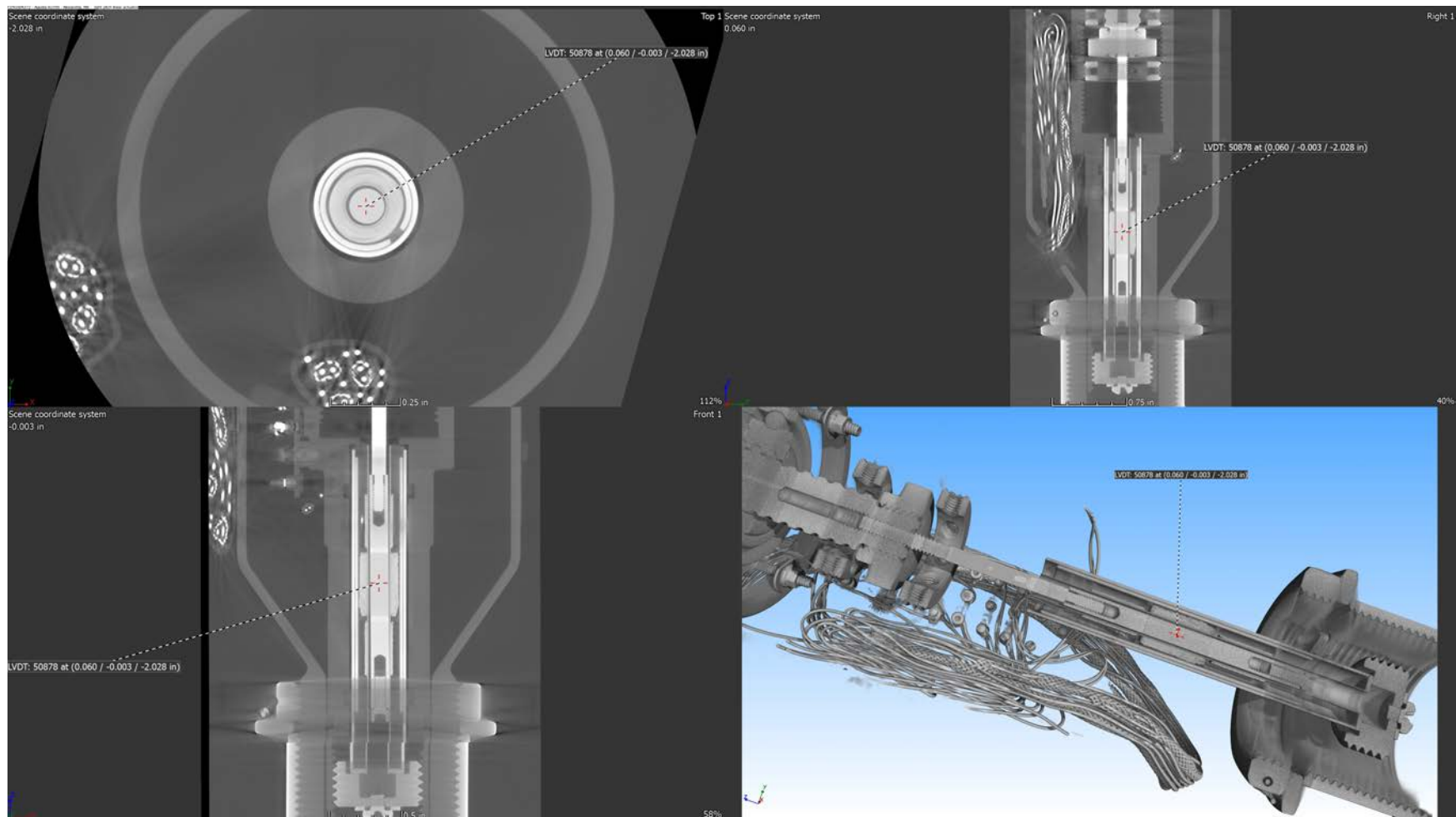


Figure 75
Right pitch linear actuator – LVDT

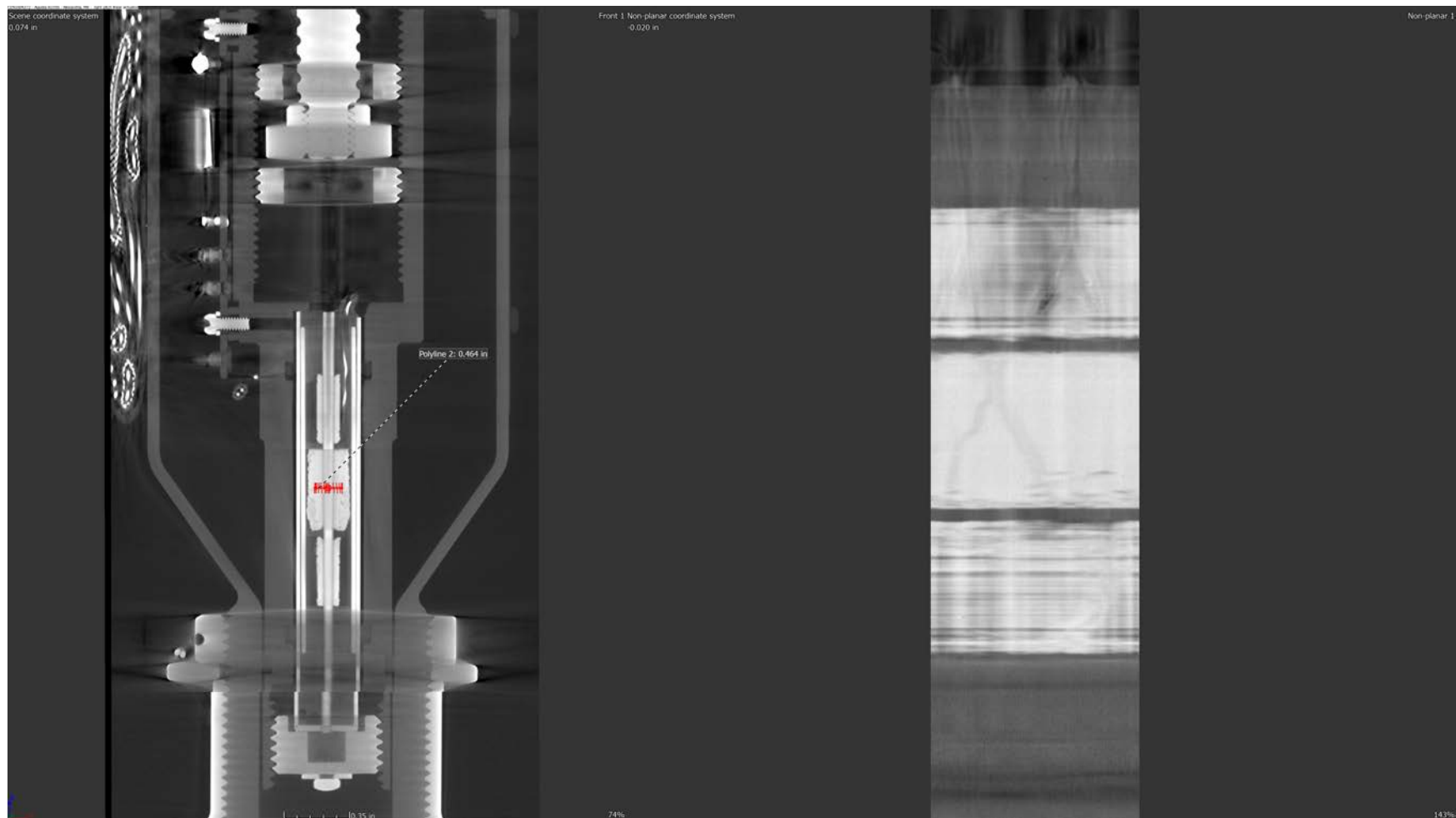


Figure 76
Right pitch linear actuator – LVDT coils – virtually unrolled



Figure 77
Right pitch linear actuator – LVDT connections – virtually unrolled

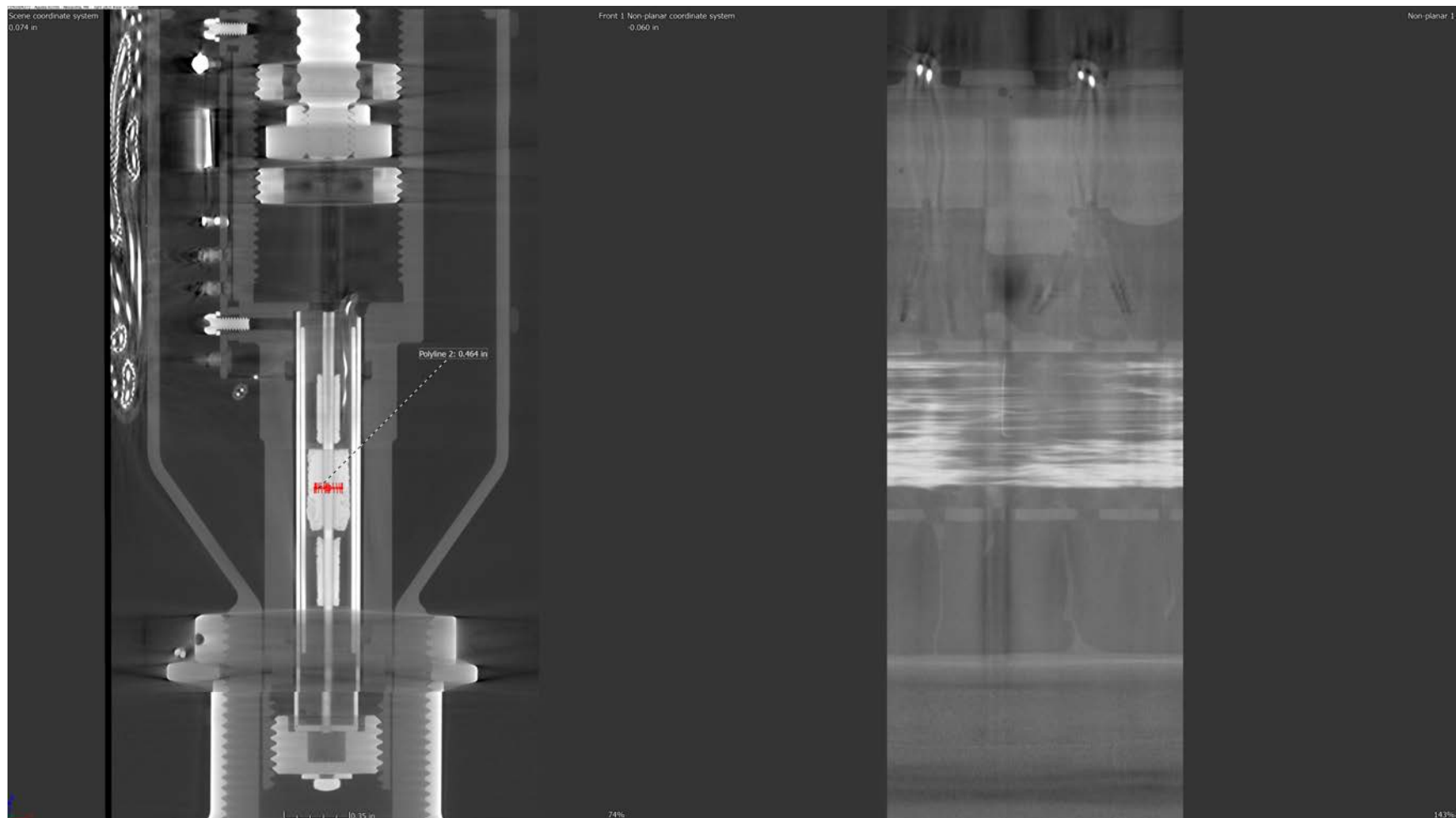


Figure 78
Right pitch linear actuator – primary coil – upper surface – virtually unrolled

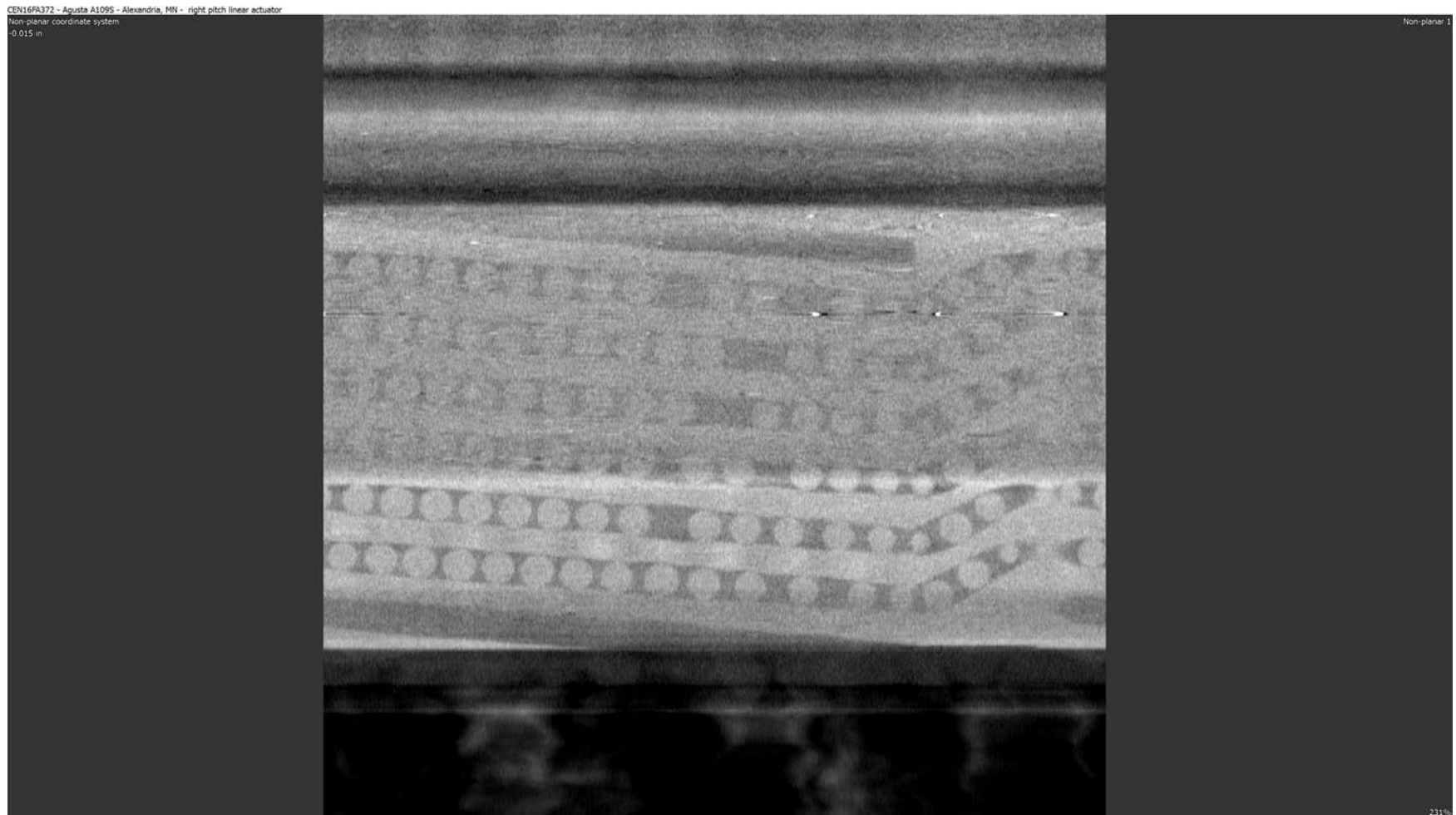


Figure 79
Right pitch linear actuator – ballscrew tracks – virtually unrolled

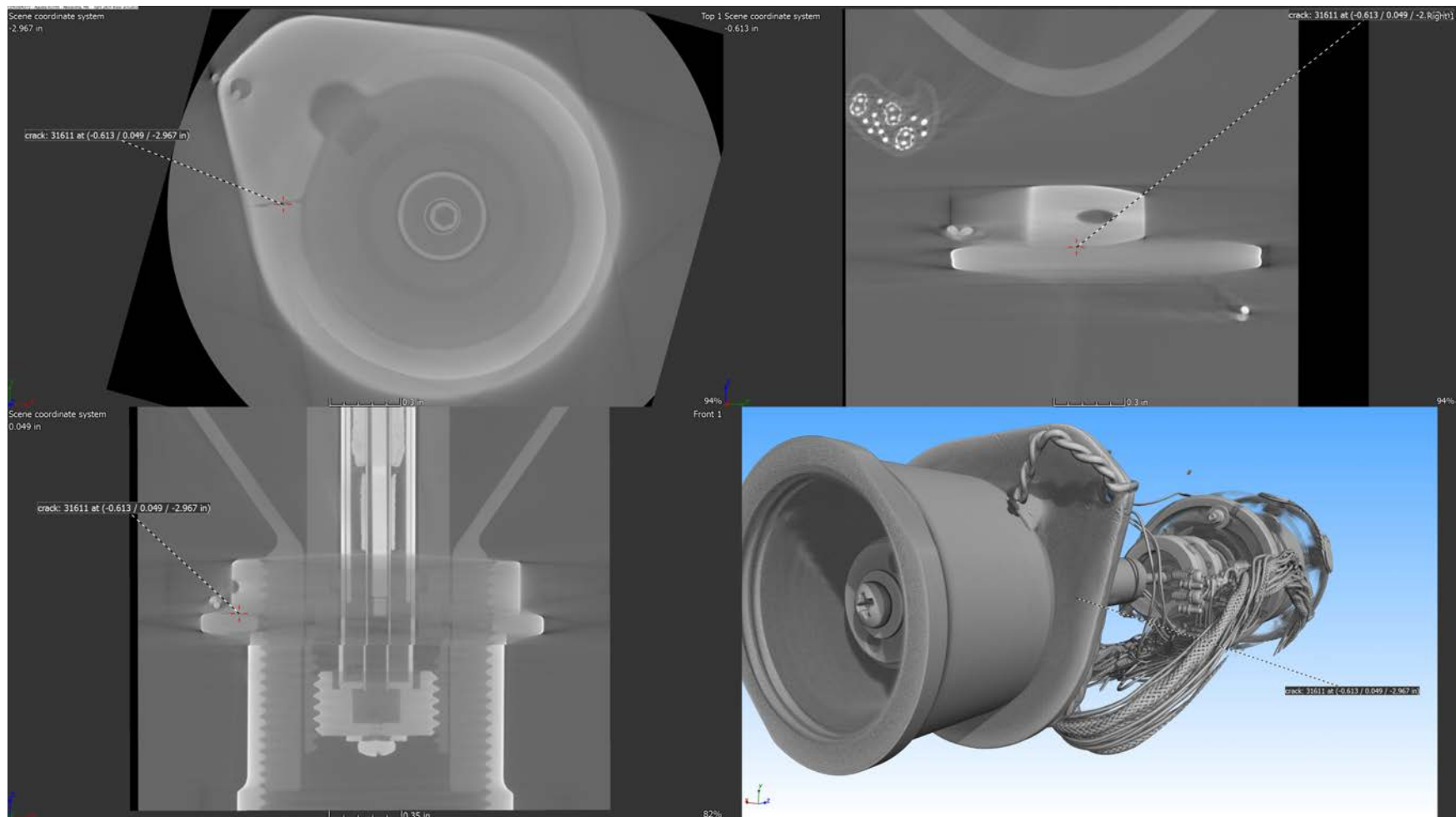


Figure 80
Right pitch linear actuator – crack in flange

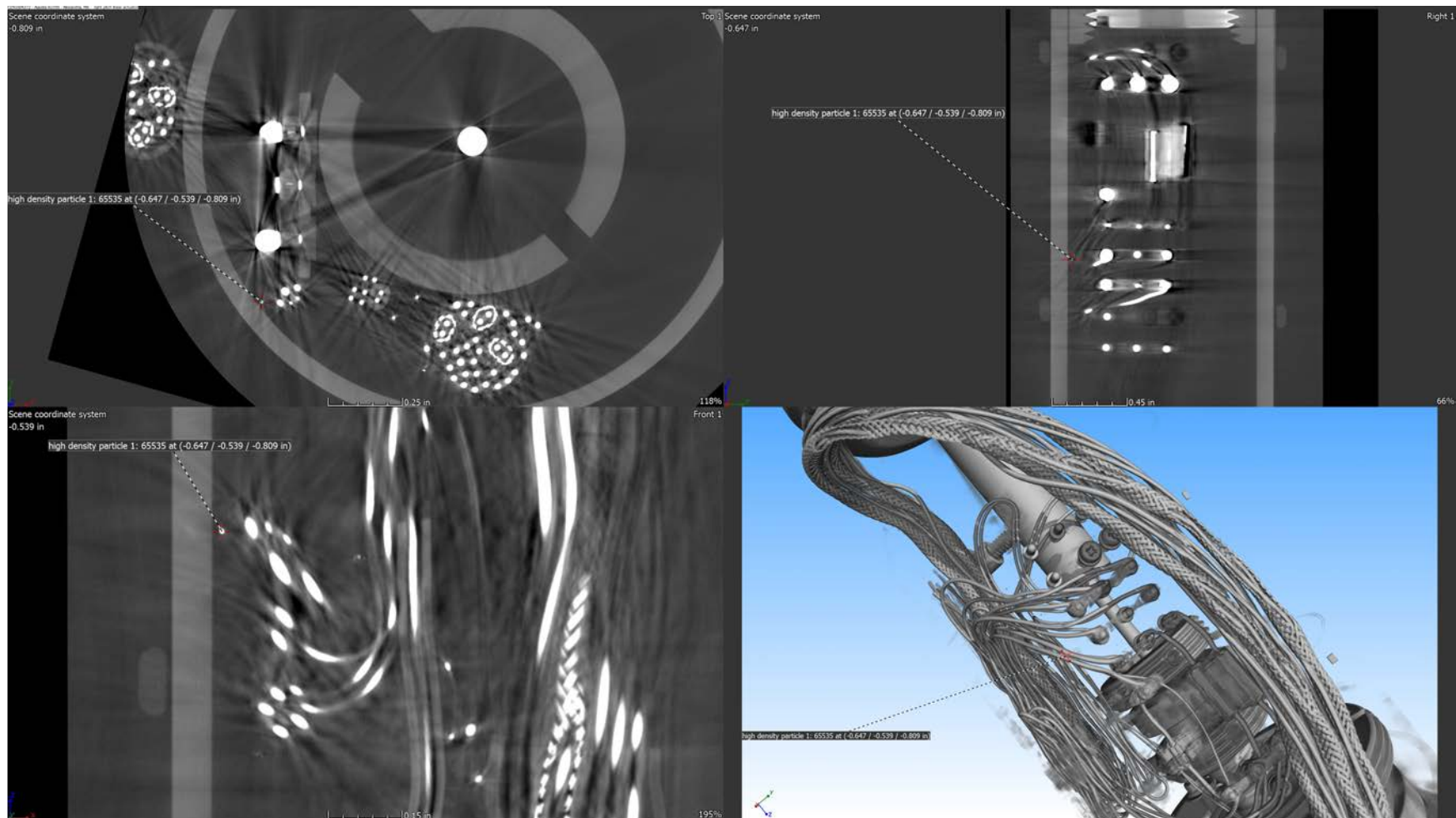


Figure 81
Right pitch linear actuator – high density particle 1

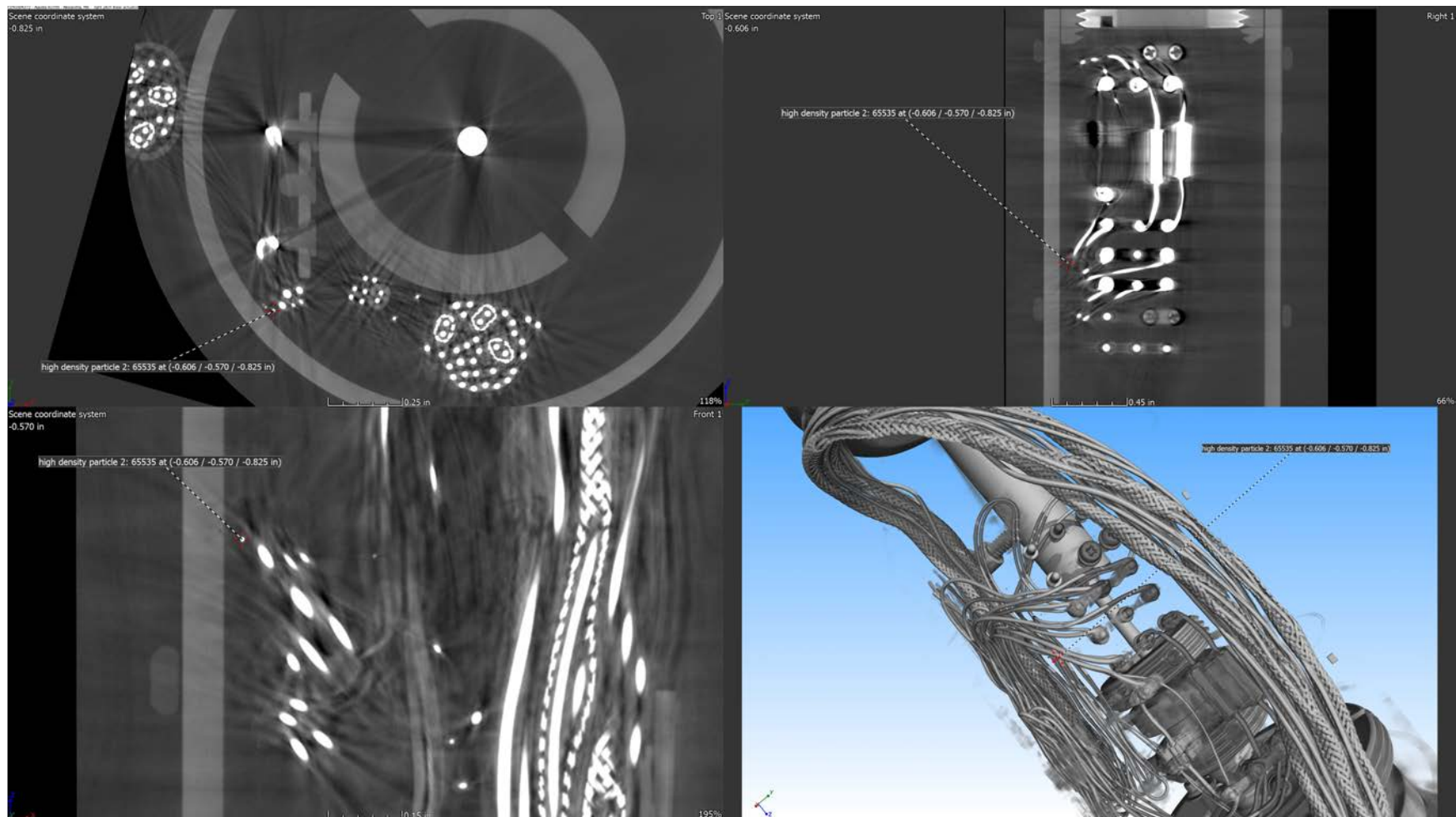


Figure 82
Right pitch linear actuator – high density particle 2

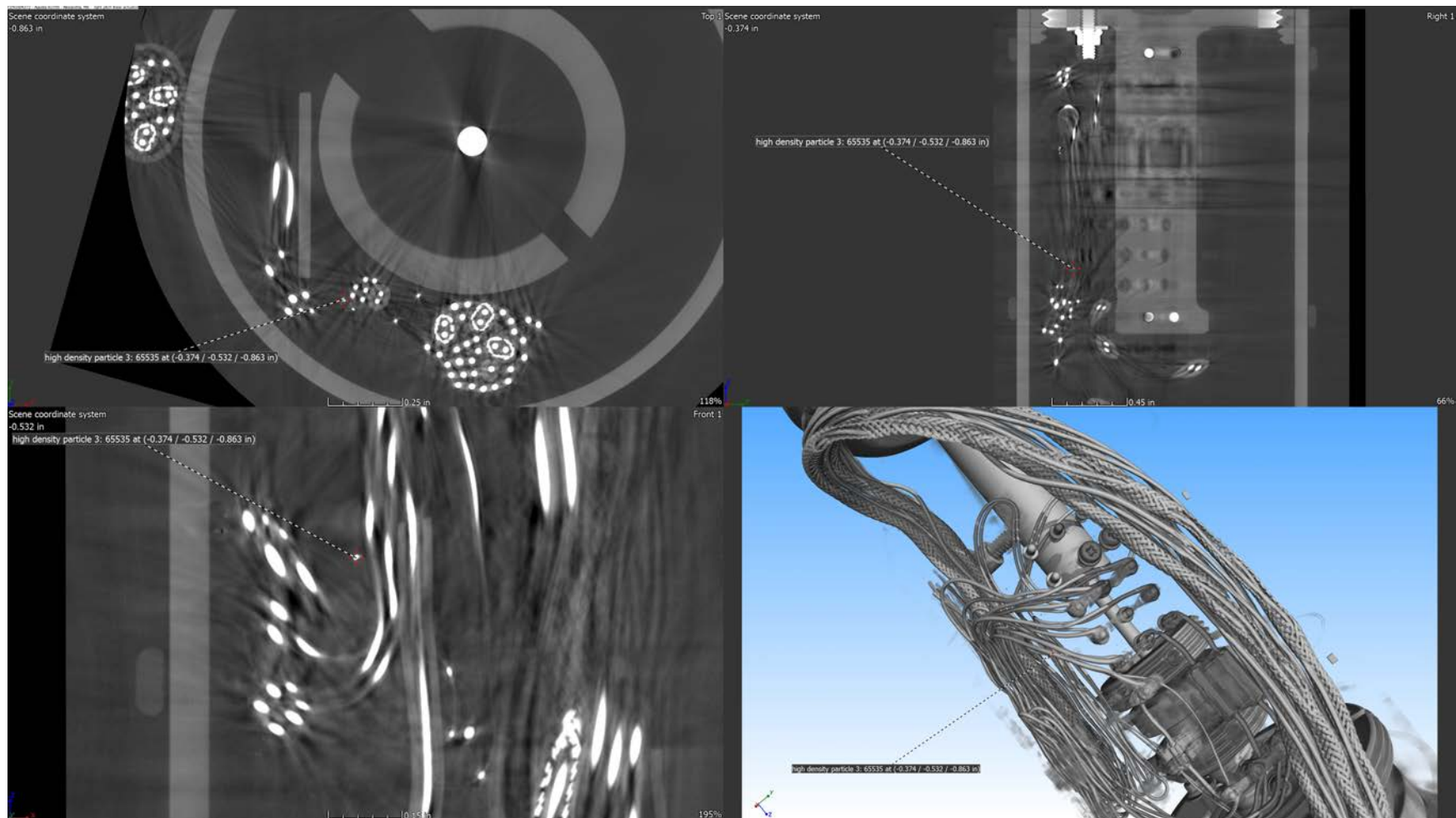


Figure 83
Right pitch linear actuator – high density particle 3

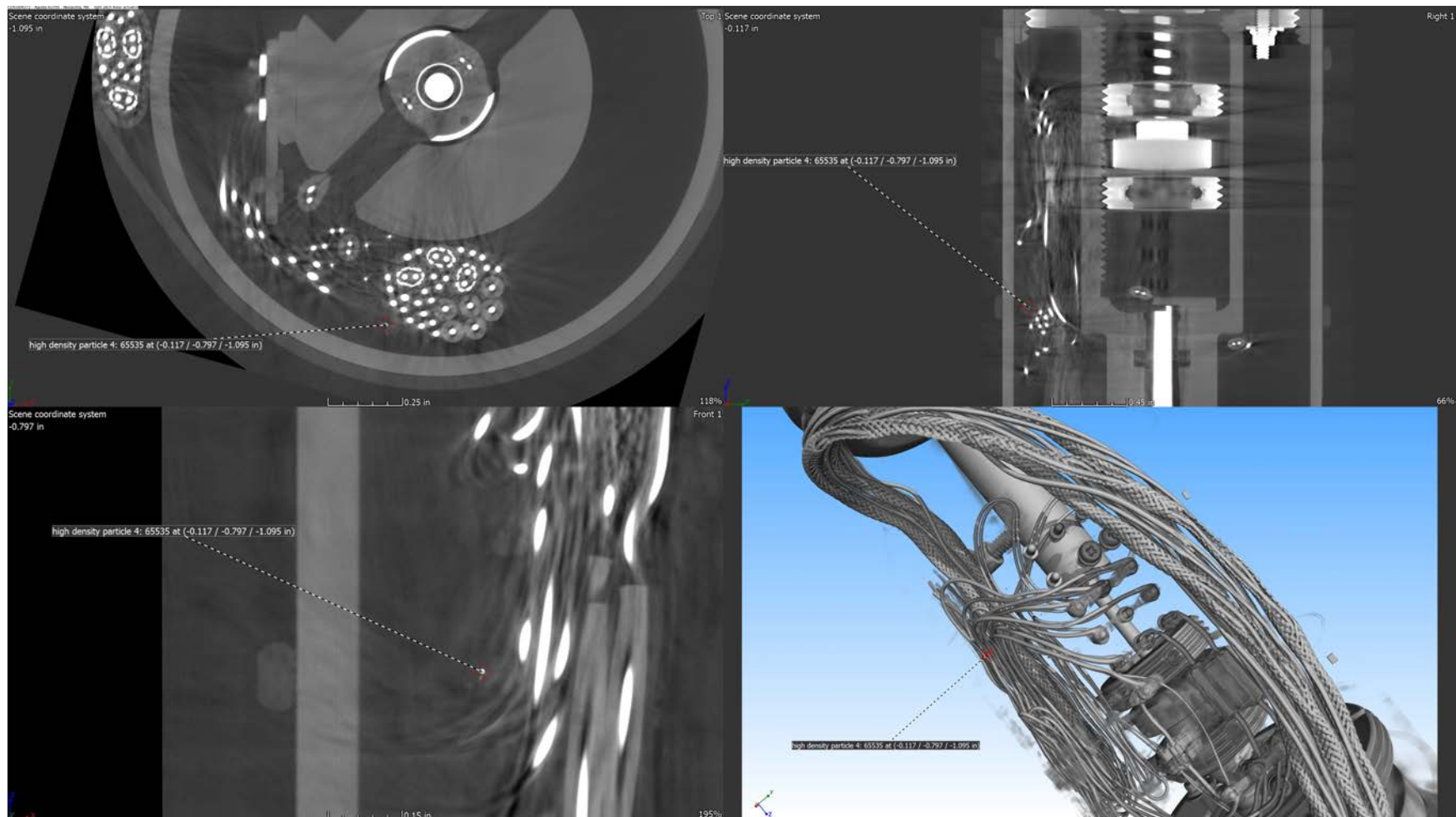


Figure 84
Right pitch linear actuator – high density particle 4

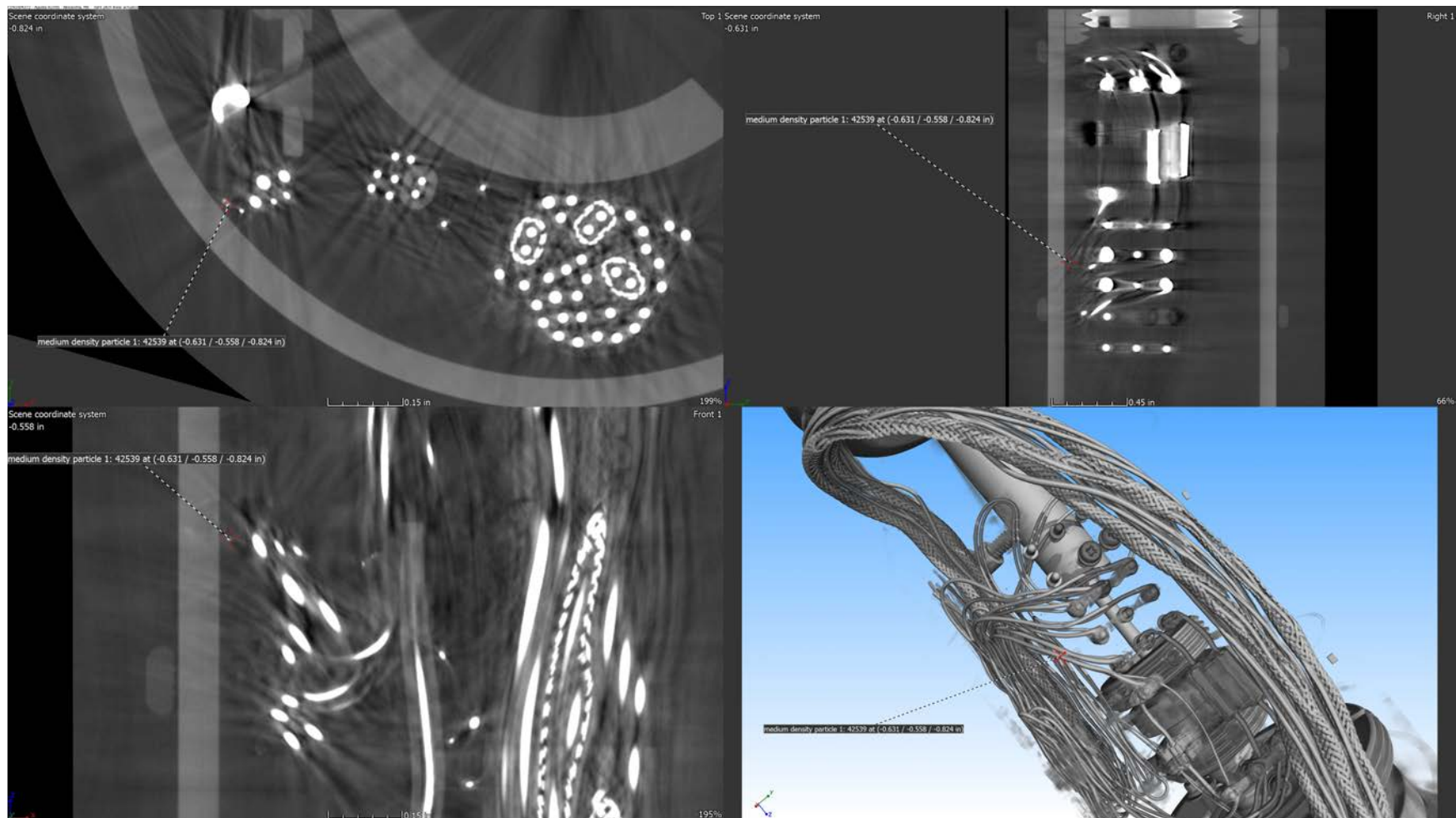


Figure 85
Right pitch linear actuator – medium density particle 1

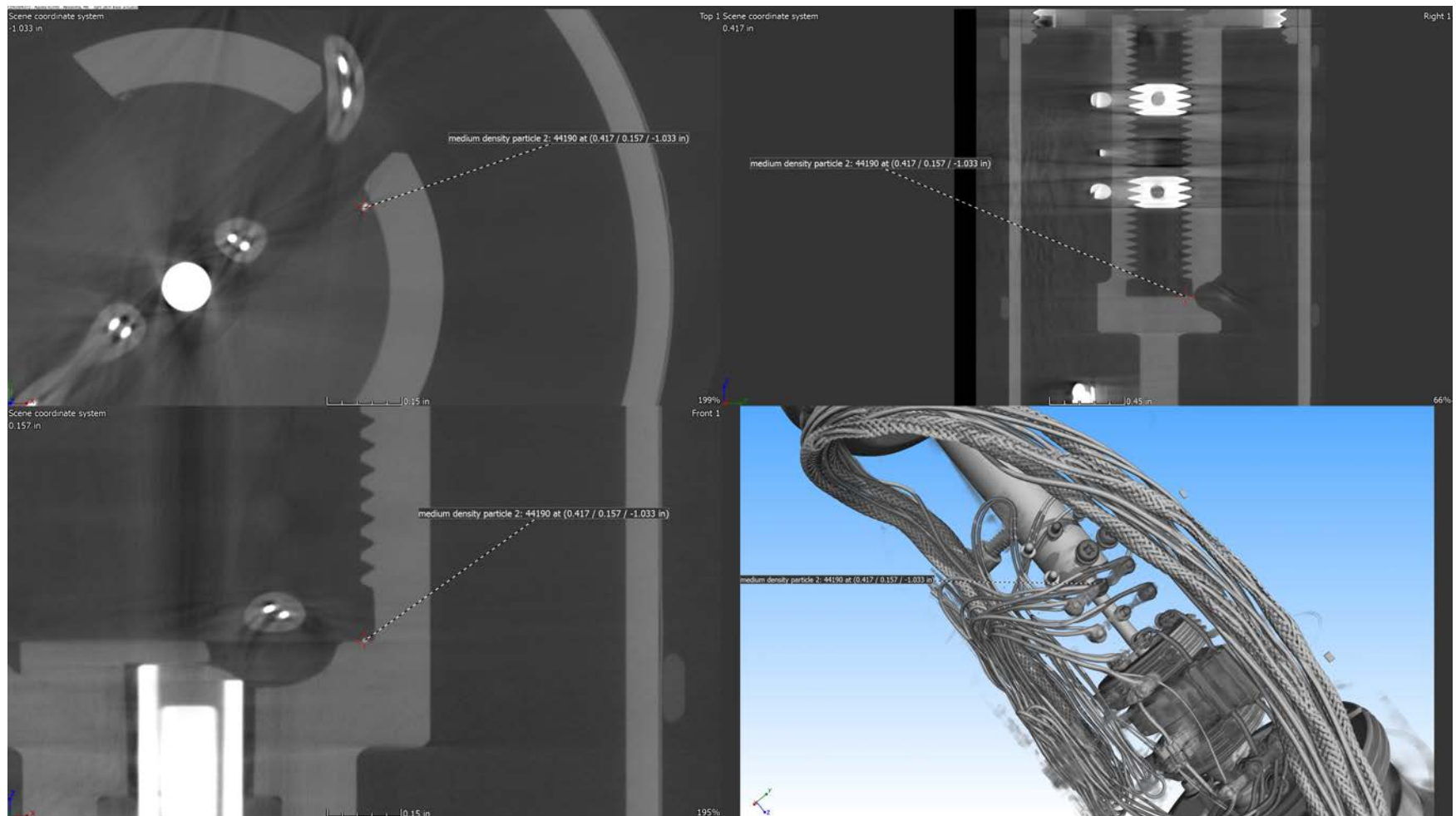


Figure 86
Right pitch linear actuator – medium density particle 2

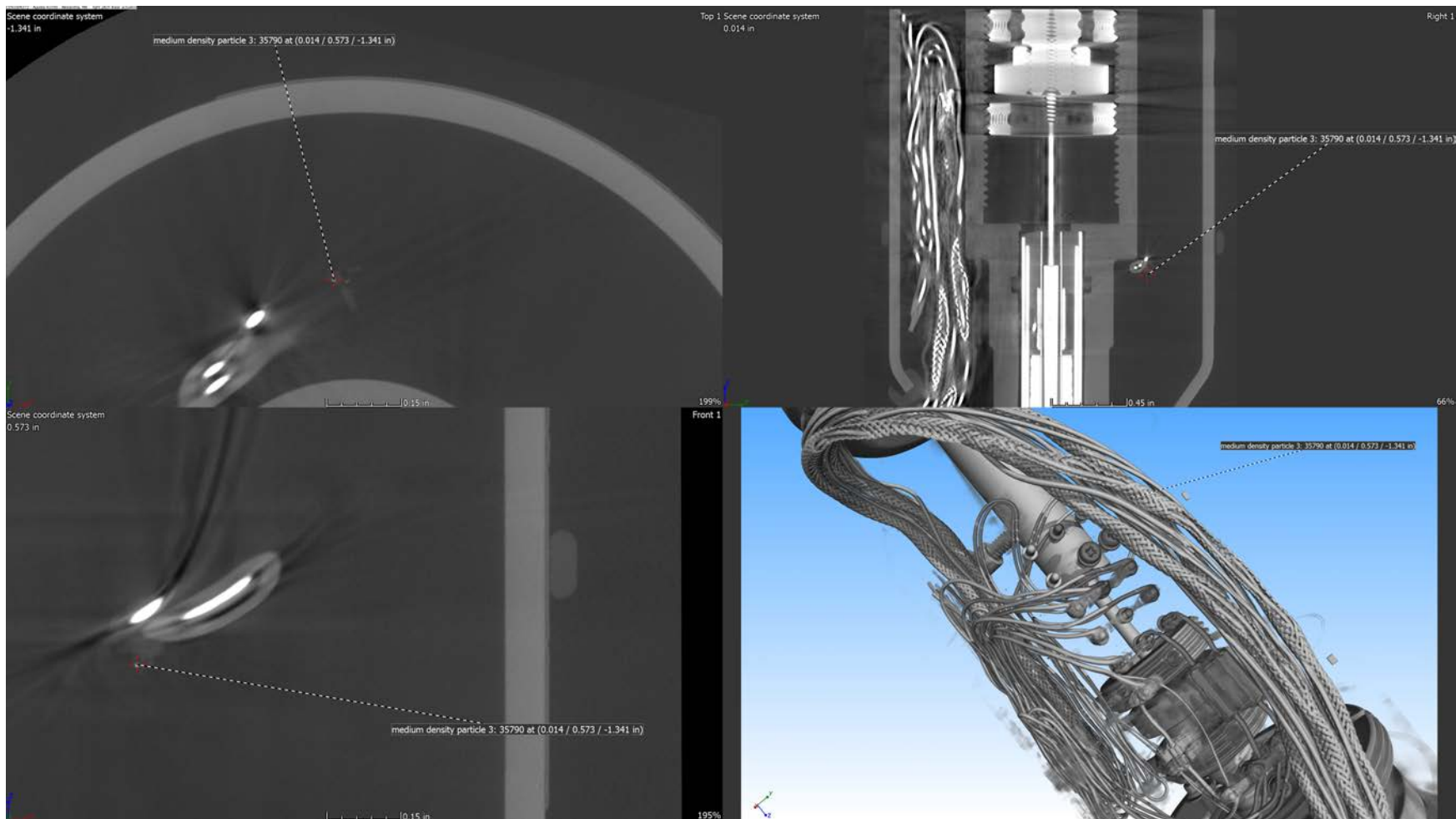


Figure 87
Right pitch linear actuator – medium density particle 3

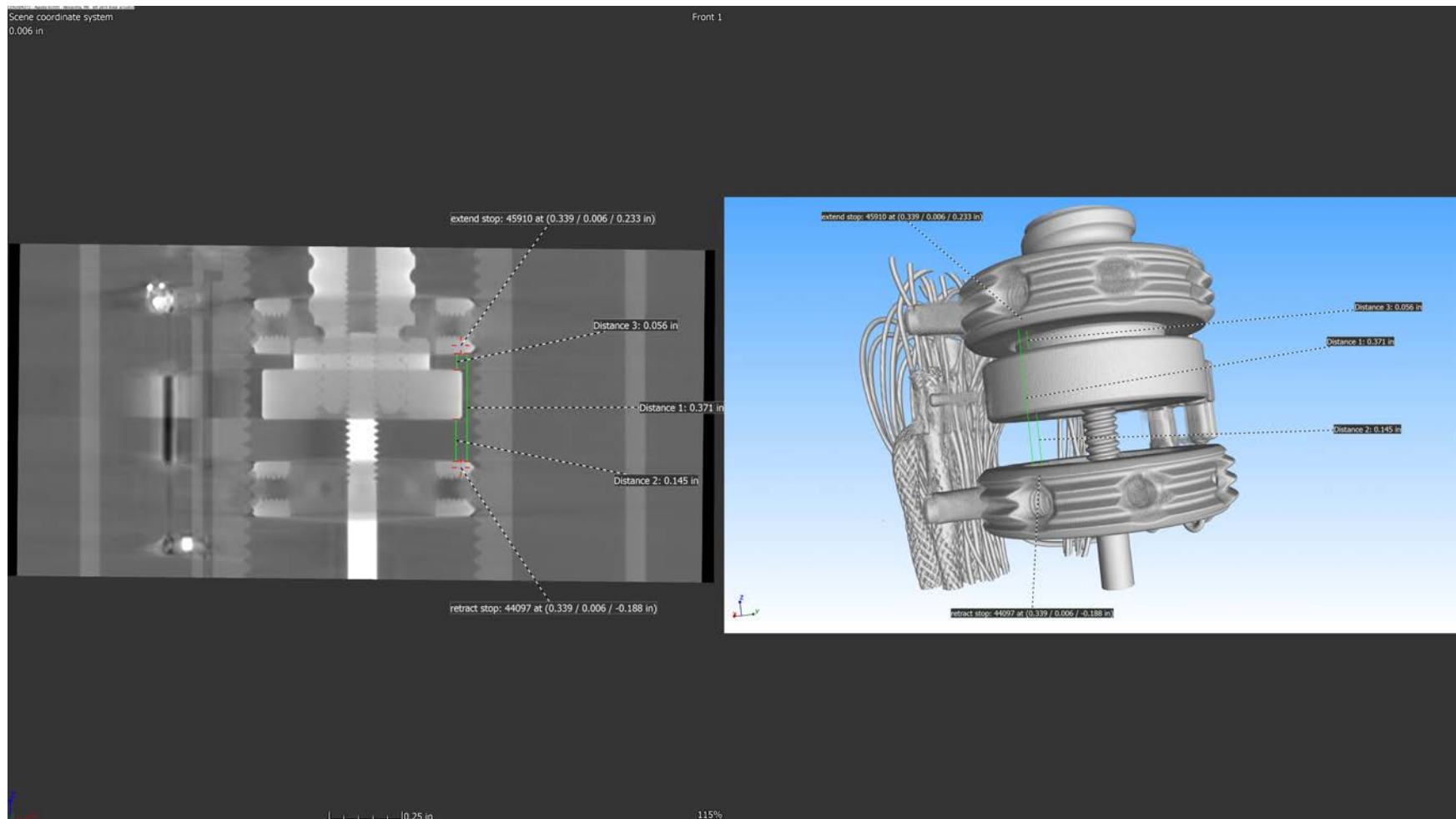


Figure 88
Left pitch linear actuator – position measurements

Scott Warren
Lead Aerospace Engineer
(Computed Tomography Specialist)