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

June 9, 2022

Computed Tomography Specialist's Factual Report

CEN22FA053

A. ACCIDENT

Location:	Perry, Oklahoma
Date:	November 28, 2021
Time:	1658 central standard time
Airplane:	Bell 206B helicopter, N59600

B. GROUP

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

C. SUMMARY

On November 28, 2021, about 1658 central standard time, a Bell 206B helicopter, N59600, was destroyed when it was involved in an accident near Perry, Oklahoma. The commercial pilot sustained fatal injuries and the student pilot sustained serious injuries. The helicopter was operated as a Title 14 *Code of Federal Regulations (CFR)* Part 91 personal flight.

The internal configurations of the left actuator, middle actuator, and right actuator from the accident helicopter were documented using radiographic images that were collected from March 14-25, 2022, in Chicago, Illinois. A total of 16,946 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, the following indications were noted:

1. There were no indications of any anomalies within the manifold components (check valves, differential relief valves, spools, sleeves, or sequence valves) for any of the three actuators.

2. There were indications of medium density material found in the piston head area and within the piston cavity of the left actuator.

3. In the left actuator, there were indications of seal distortions and seal gaps in seals 1, 2, 3, 5, and 6. Seal 4 appeared to have minimal anomalies.

4. In the middle actuator, the seals appeared to have minimal anomalies except for seal 6 which had indications of voids throughout the seal.

5. In the right actuator, there were indications of seal distortions and seal gaps in seals 1 and 2. Seals 3, 4, 5, and 6 appeared to have minimal anomalies.

D. DETAILS OF THE INVESTIGATION

1.0 General

The left actuator, middle actuator, and right actuator from the accident helicopter were subjected to x-ray radiograph and computed tomography (CT) scanning to document each component's internal condition. The scanning was conducted from March 14-25, 2022, by Varex, Inc under the direction of the NTSB using the Actis 225/500 microfocus and CST 6MV 4343 HE DRZ+ 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 16,946 slices, and the total size of the combined data sets was approximately 60.5 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	Left Actuator (microfocus)	Left Actuator (Megavolt)	Middle Actuator (microfocus)	Middle Actuator (Megavolt)	Right Actuator (microfocus)	Right Actuator (Megavolt)
Number of slices	3005	1730	3501	2267	3815	2628
Voxel[1] Size - X Direction (millimeter(mm))	0.09	0.2	0.09	0.2	0.09	0.2
Voxel Size - Y Direction (mm)	0.09	0.2	0.09	0.2	0.09	0.2
Voxel Size - Z Direction (mm)	0.13	0.2	0.13	0.2	0.13	0.2
Image Projections per Revolution	1800	1080	1800	1080	1800	1080
Exposure time (milliseconds)	285.6	NA	285.6	NA	285.6	NA
Frames to Avg (frames per projection)	2	NA	2	NA	2	NA
X-ray Source Voltage (kilovolts)	222	6000	222	6000	222	6000
X-ray Source Current (mA) (microfocus system)	0.580	NA	0.580	NA	0.580	NA
Source Filter Thickness (mm)	1	10	1	10	1	10
Source Filter Material	brass	copper	brass	copper	brass	copper
Image Matrix Size (pixels)	1536 x 1536	1100 x 1100	1536 x 1536	1100 x 1100	1536 x 1536	1100 x 1100

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 all of the images, the higher density areas were shown as brighter shades of gray and lower density areas were shown as darker shades of gray. Each 2-D quadrant within the images shows a scale at the bottom of that quadrant – note that the scales in each quadrant may be different. The pointers shown in some of

[1] A voxel is a three-dimensional picture element (pixel).

the images denote specific areas of interest within that image. The numbers associated with the pointer are the gray value at the pointer location and the three positional coordinates of the pointer.

Some of the actuator seals were examined in detail. These seals were arbitrarily numbered from 1 through 6 (see figure 1). As part of the detailed examination, these actuator seal structures were "virtually unrolled" using the CT image visualization 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 114.

Review of the images determined that, when the scans were conducted, the following indications were noted:

1. There were no indications of any anomalies within the manifold components (check valves, differential relief valves, spools, sleeves, or sequence valves) for any of the three actuators.

2. There were indications of medium density material found in the piston head area and within the piston cavity of the left actuator.

3. In the left actuator, there were indications of seal distortions and seal gaps in seals 1, 2, 3, 5, and 6. Seal 4 appeared to have minimal anomalies.

4. In the middle actuator, the seals appeared to have minimal anomalies except for seal 6 which had indications of voids throughout the seal.

5. In the right actuator, there were indications of seal distortions and seal gaps in seals 1 and 2. Seals 3, 4, 5, and 6 appeared to have minimal anomalies.

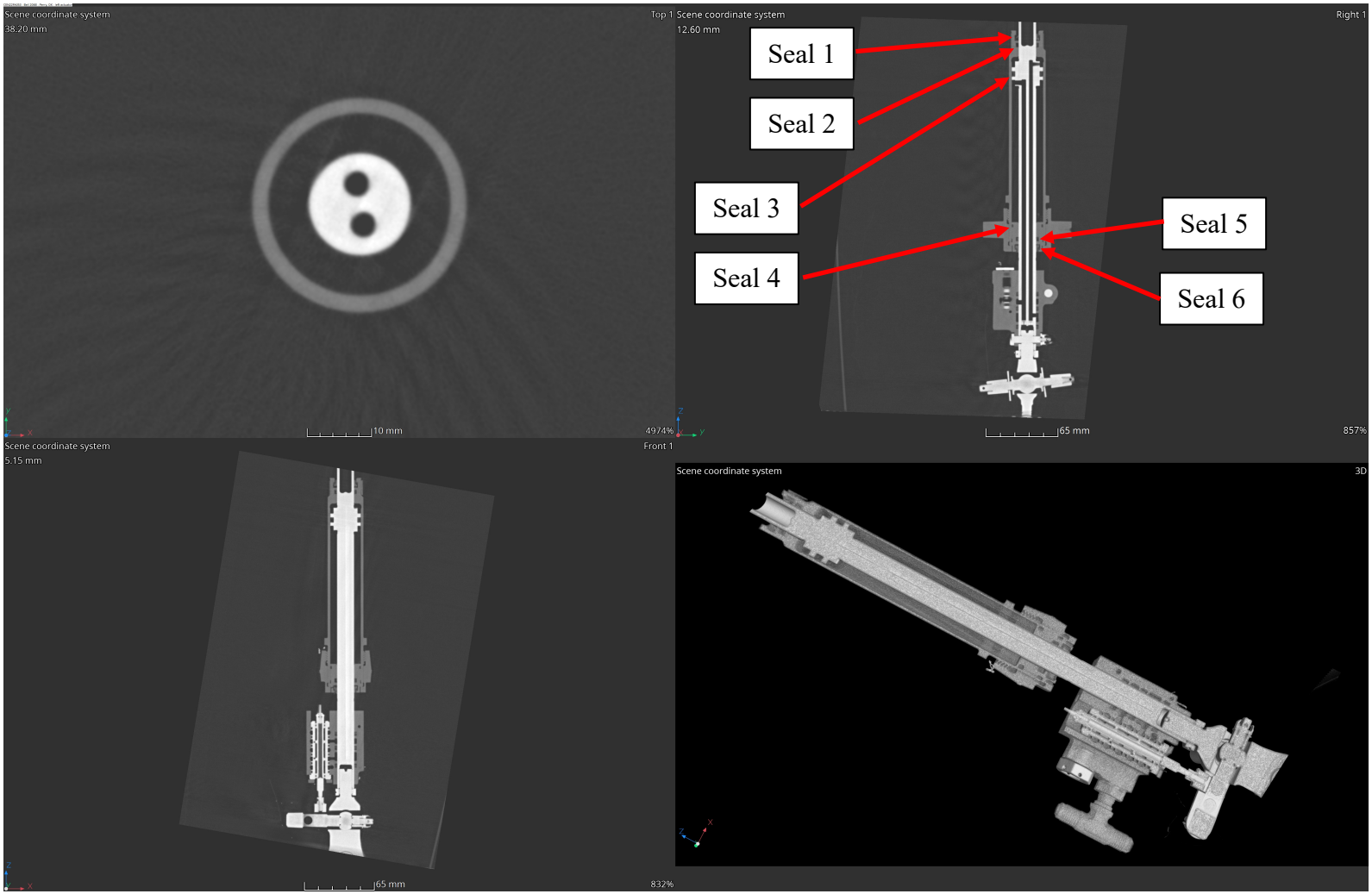


Figure 1
Left actuator – 6 MV – overview and seal locations

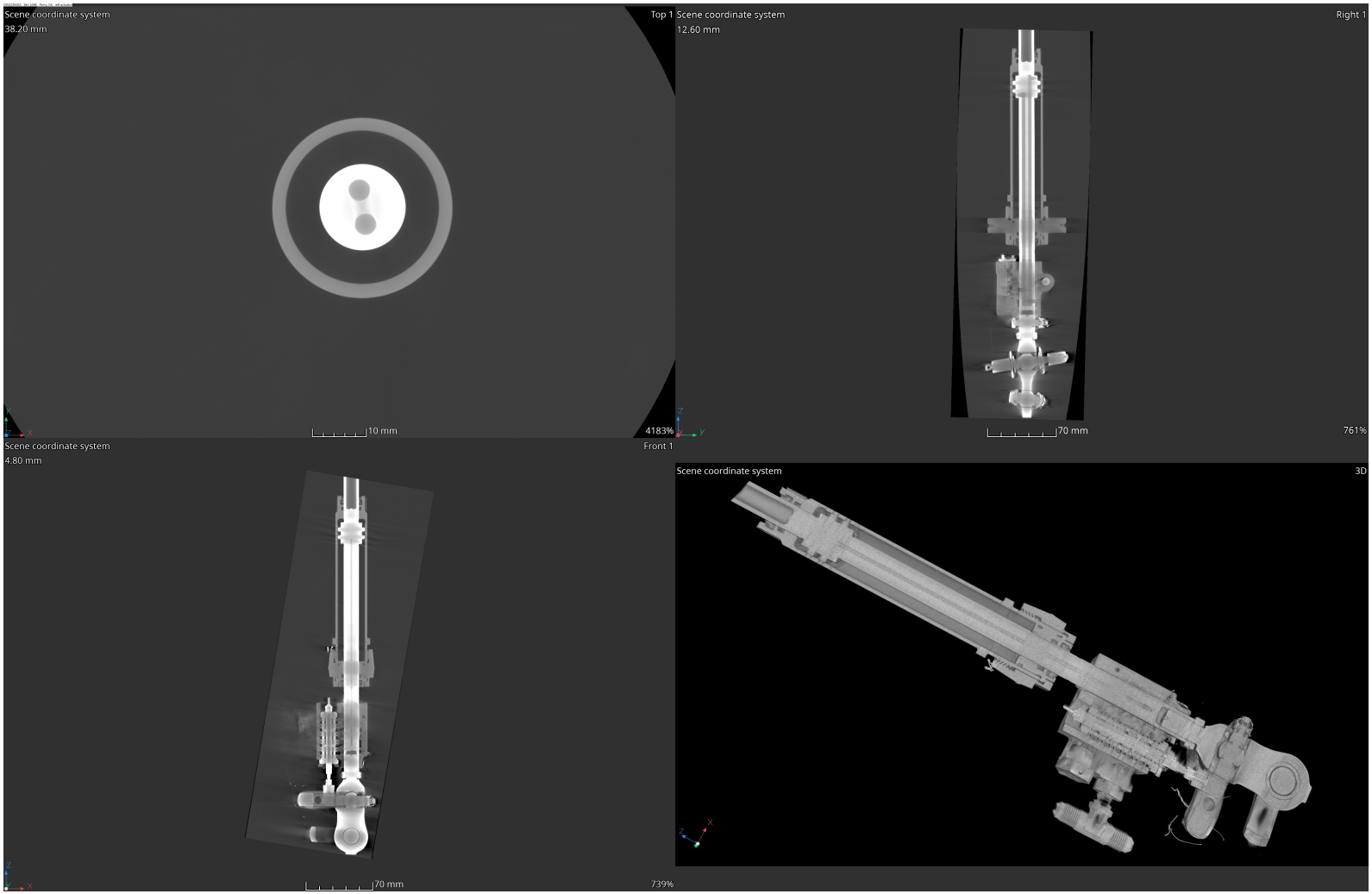


Figure 2
Left actuator – microfocus - overview

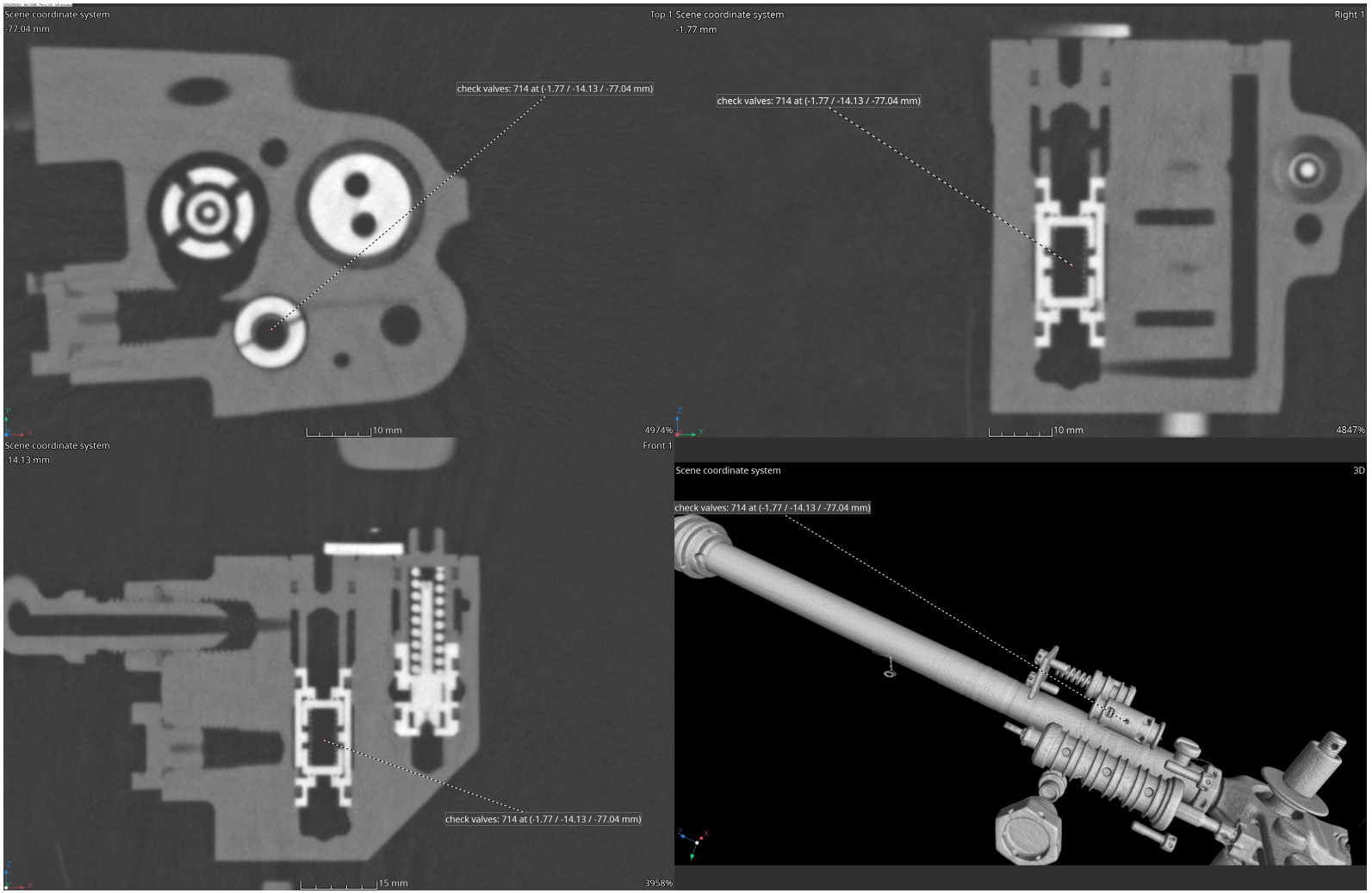


Figure 3
Left actuator – 6 MV – check valves

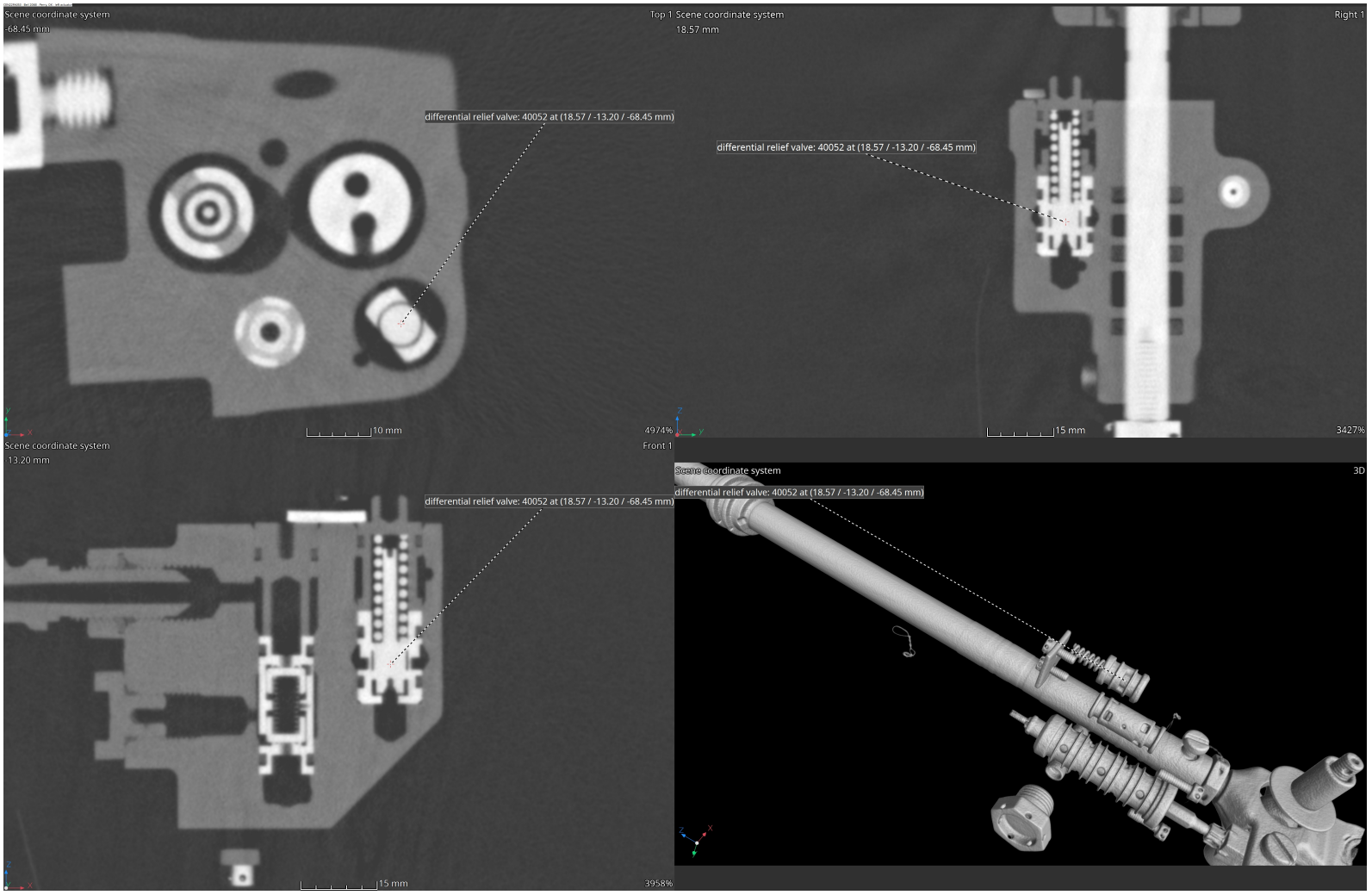


Figure 4
Left actuator – 6 MV – differential relief valve

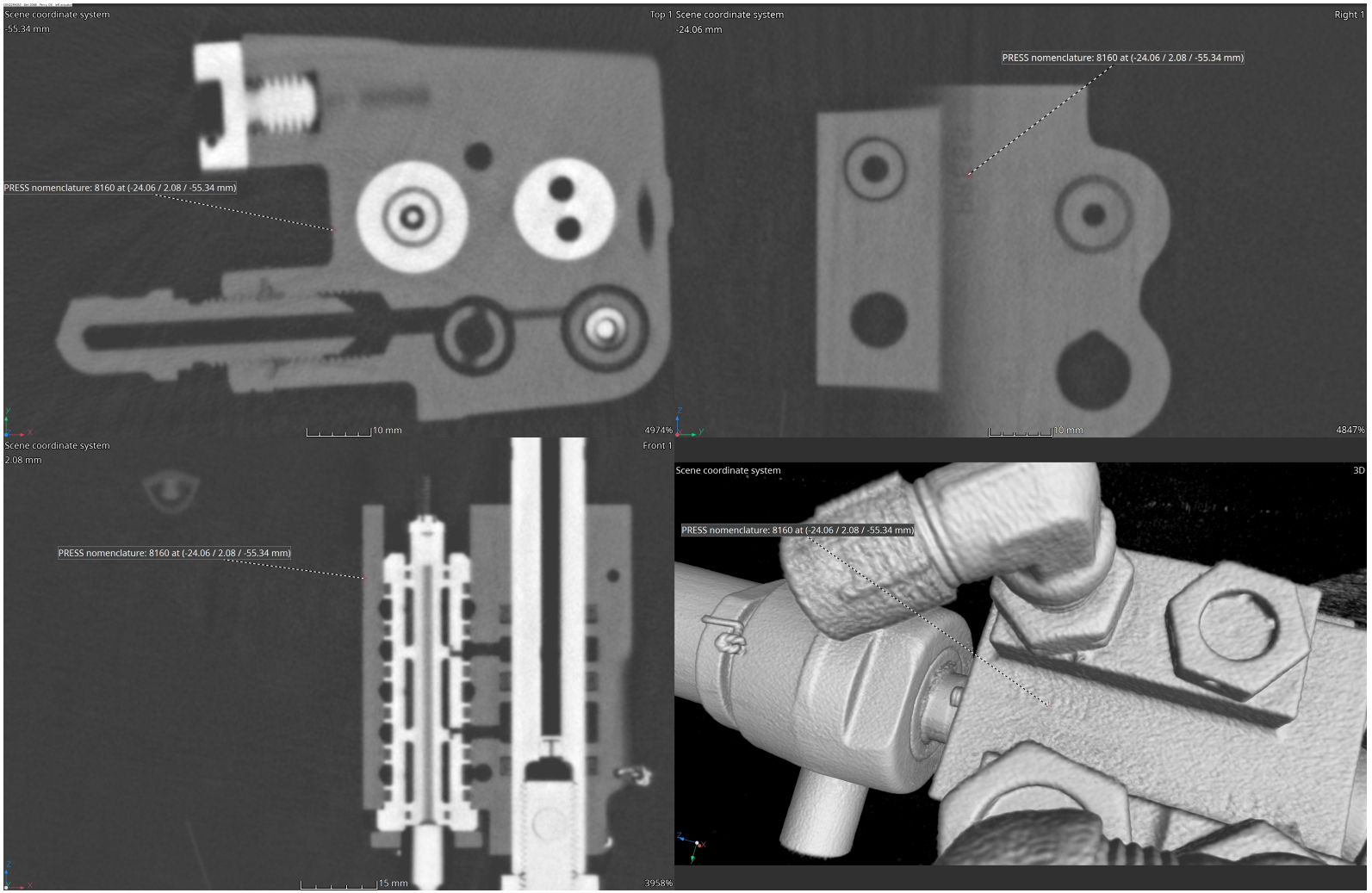


Figure 5
Left actuator – 6 MV – PRESS nomenclature

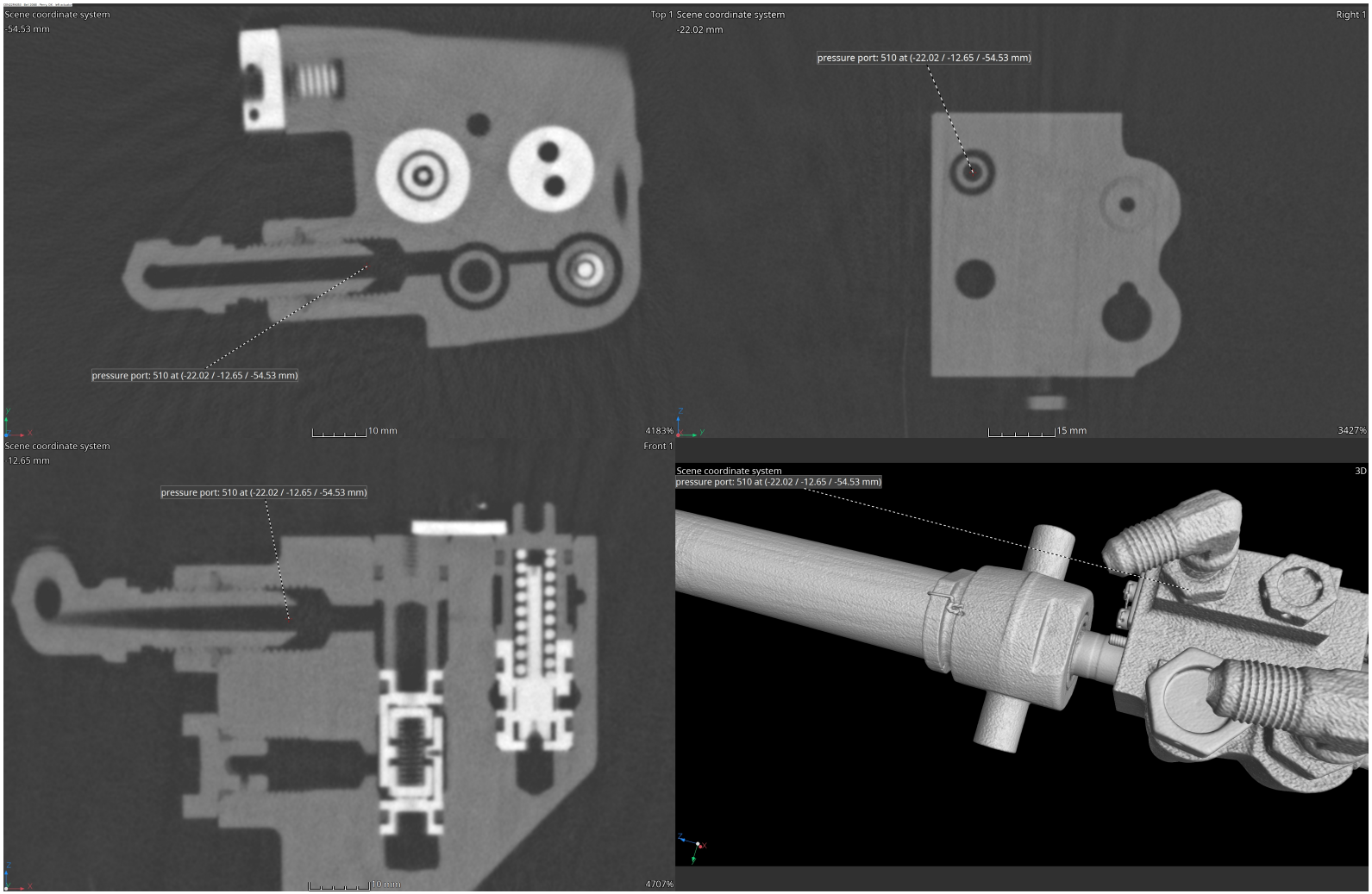


Figure 6
Left actuator – 6 MV – pressure port

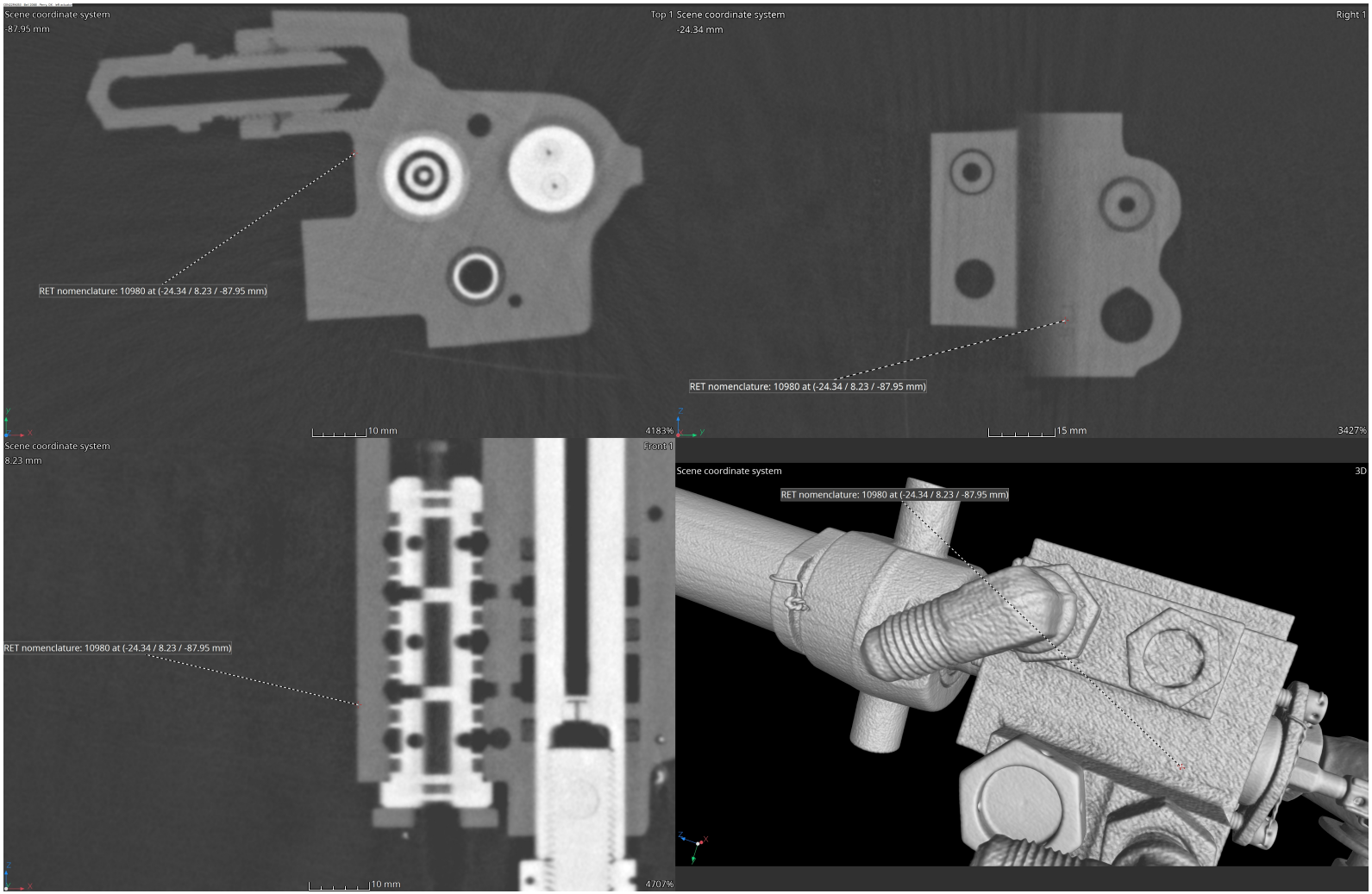


Figure 7
Left actuator – 6 MV – RET nomenclature

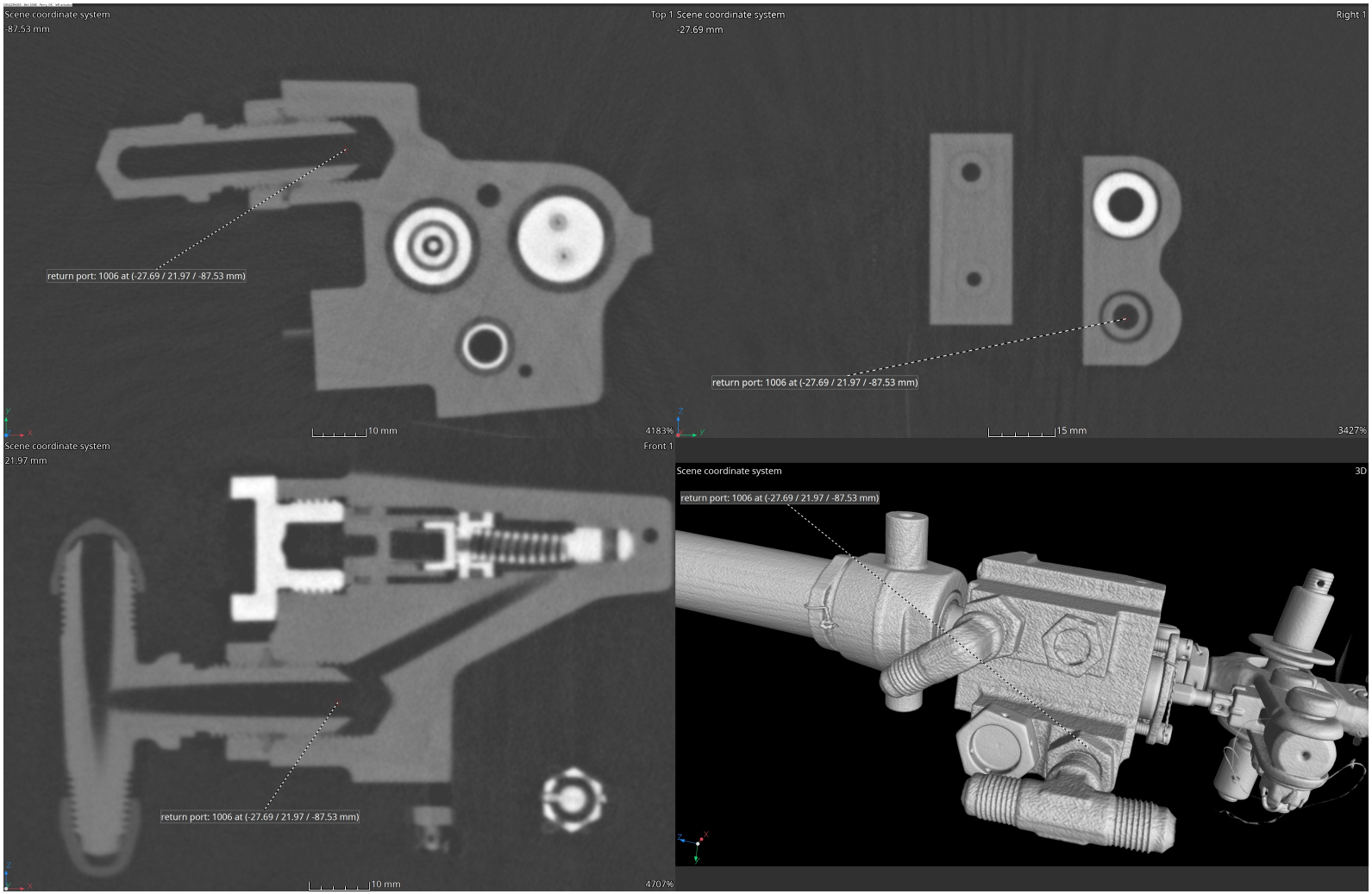


Figure 8
Left actuator – 6 MV – return port

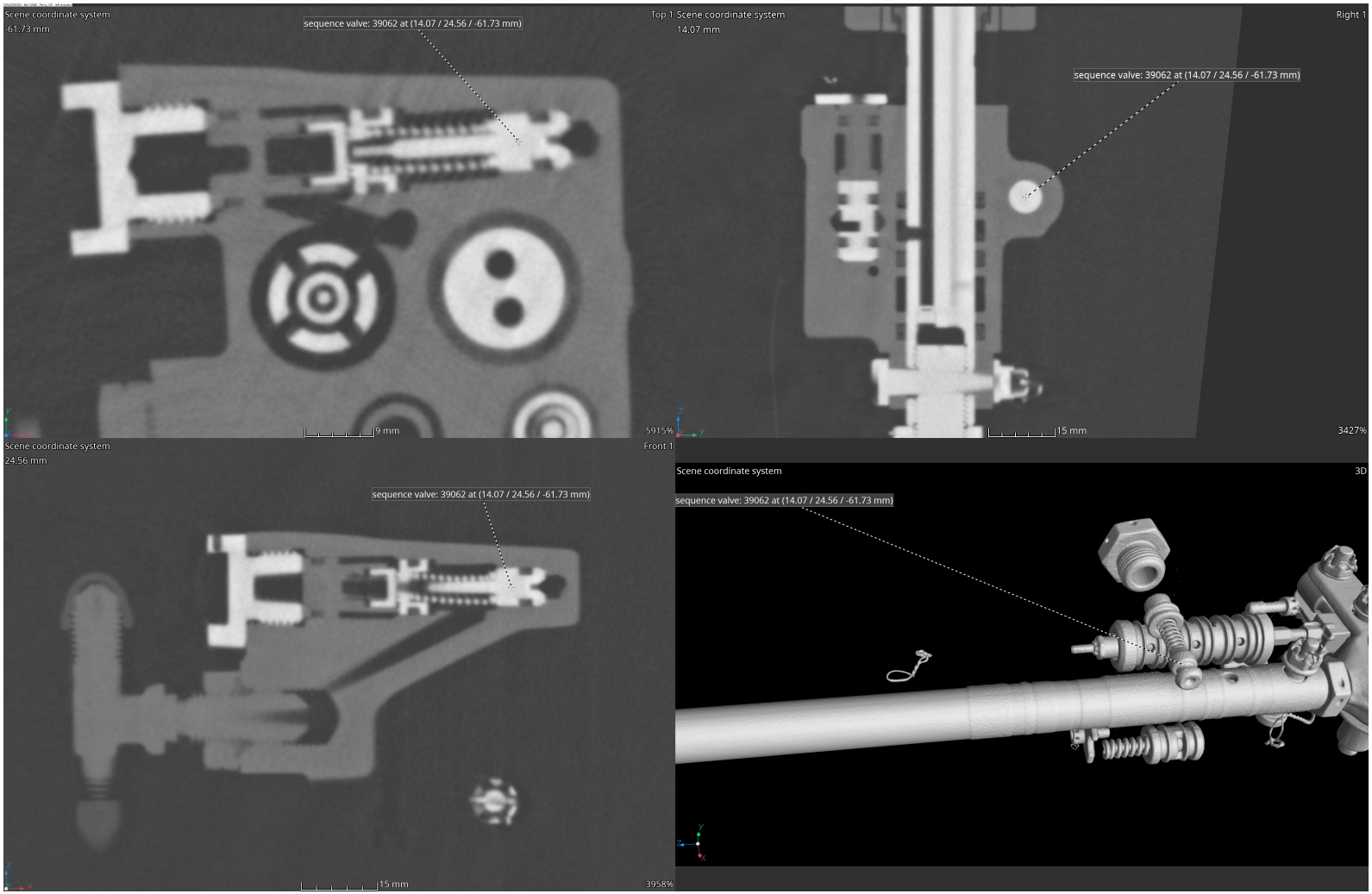


Figure 9
Left actuator – 6 MV – sequence valve

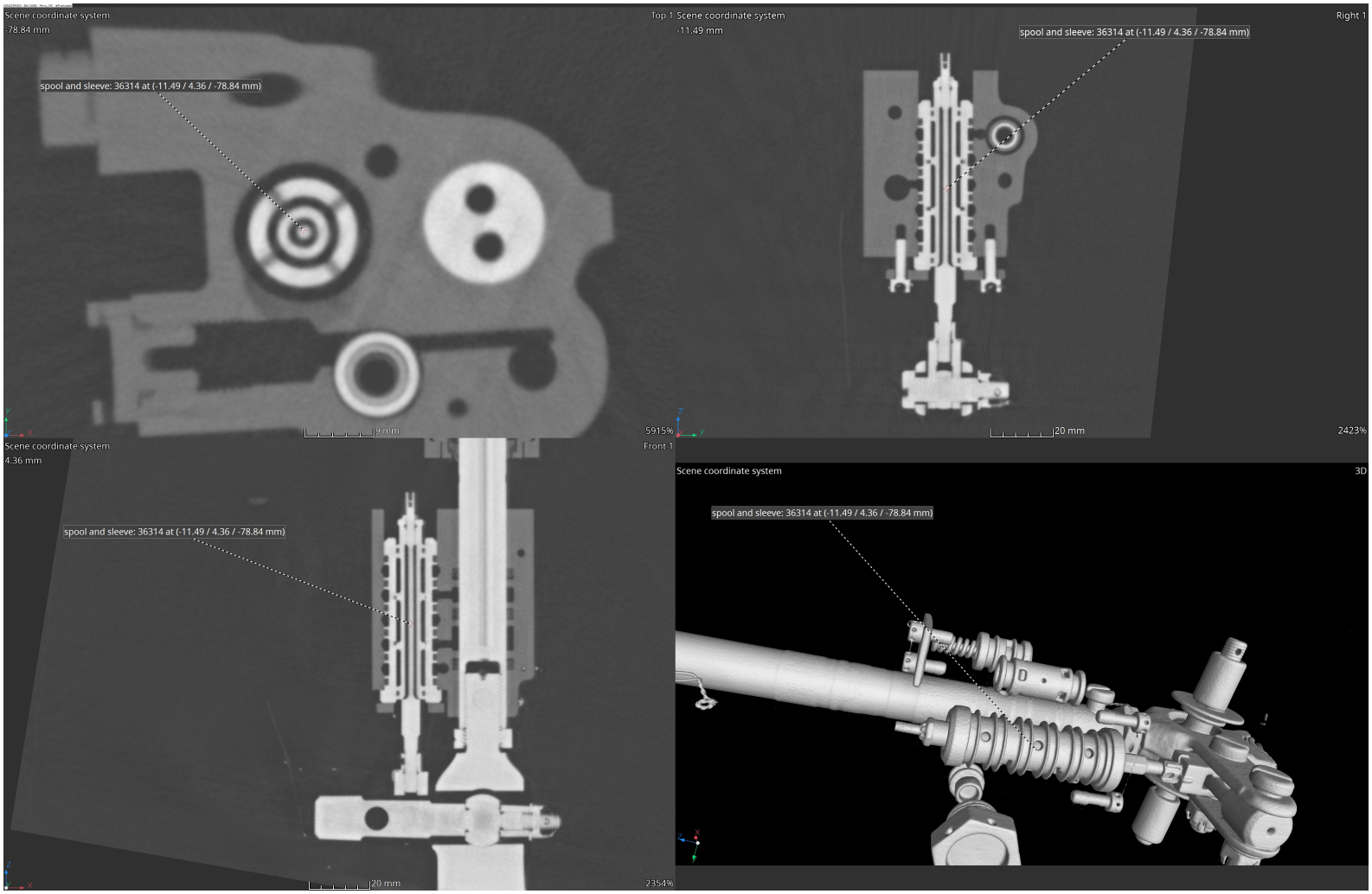


Figure 10
Left actuator – 6 MV – spool and sleeve

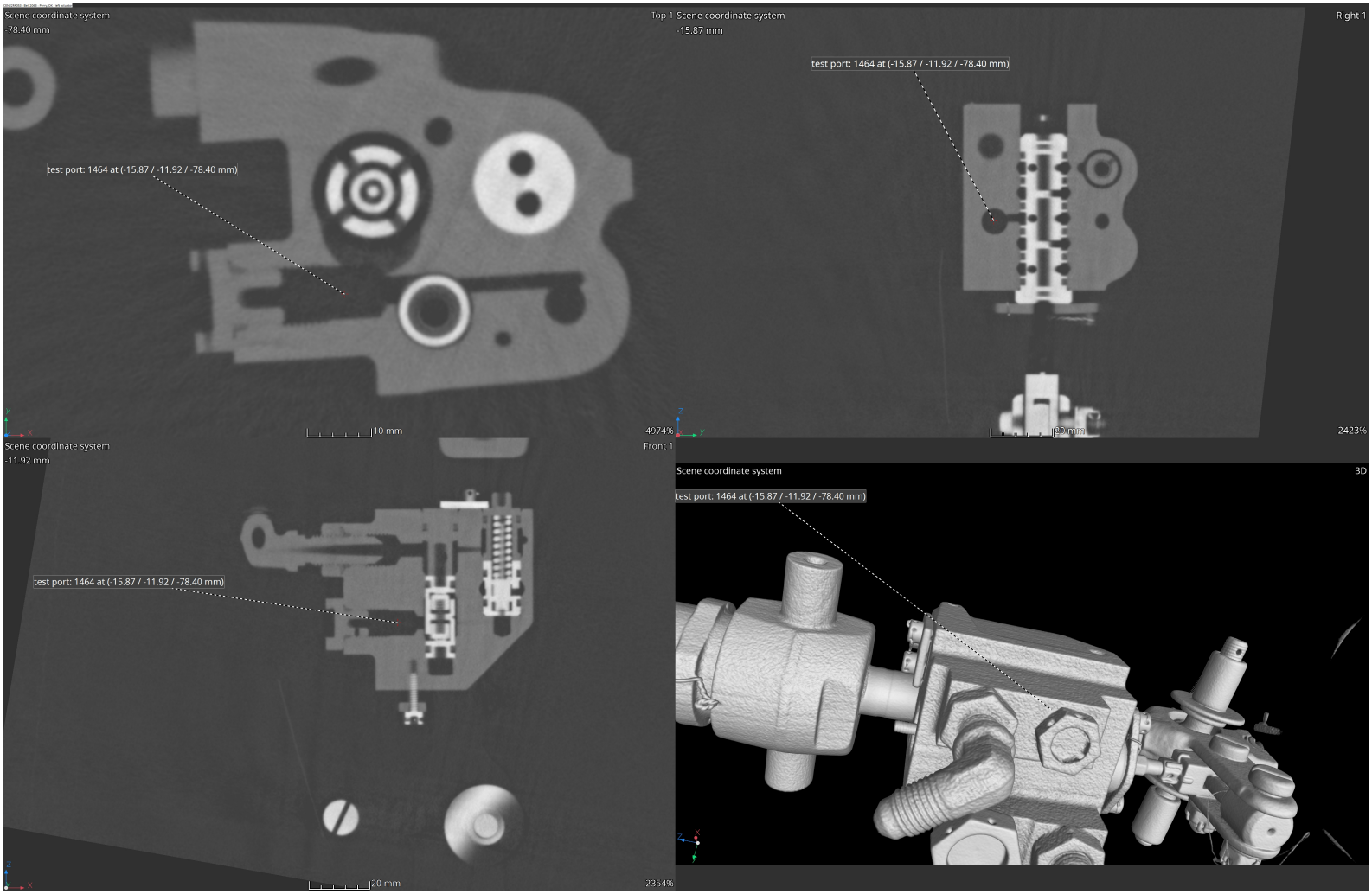


Figure 11
Left actuator – 6 MV – test port

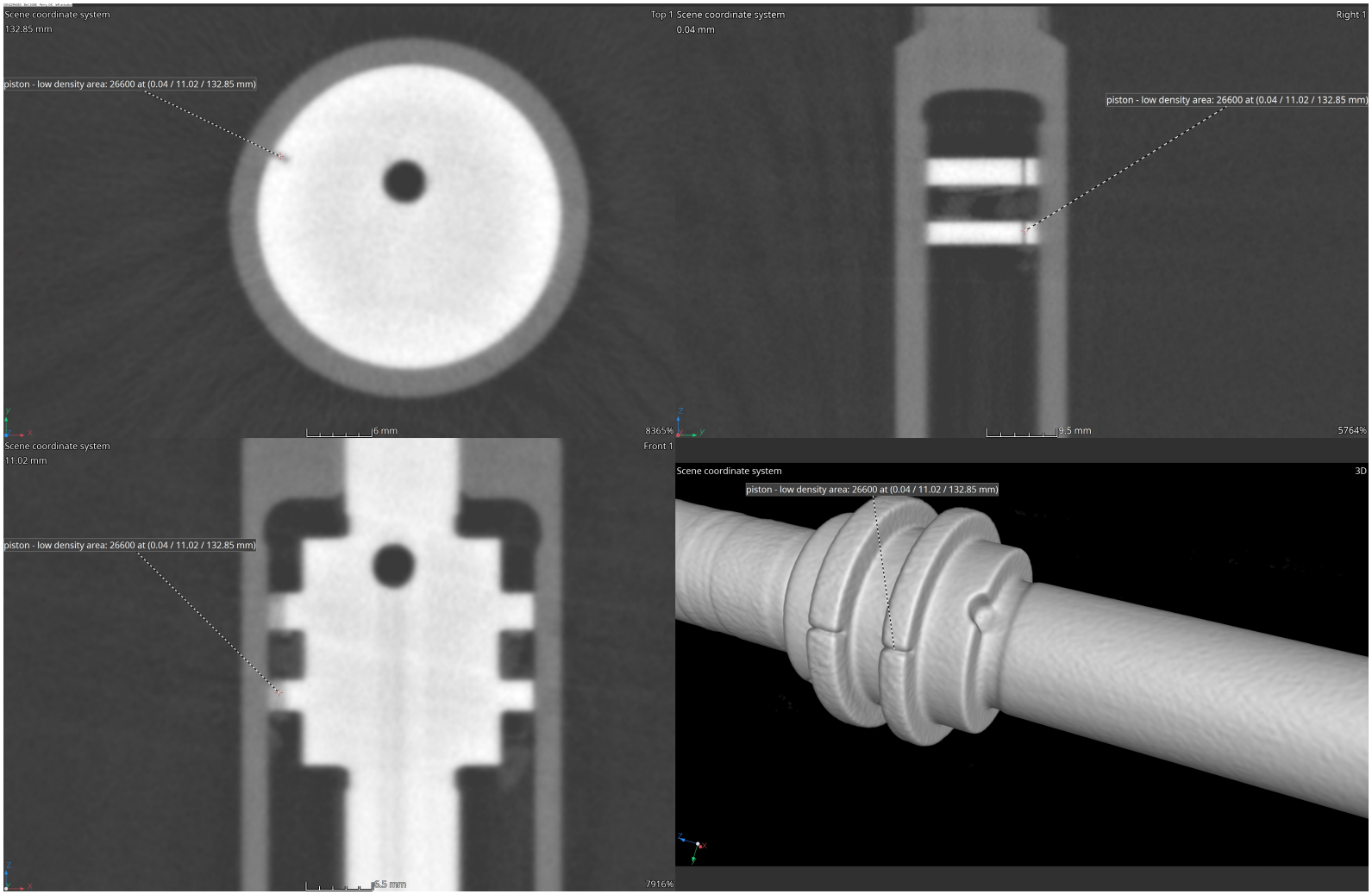


Figure 12
Left actuator – 6 MV – piston head – low density area

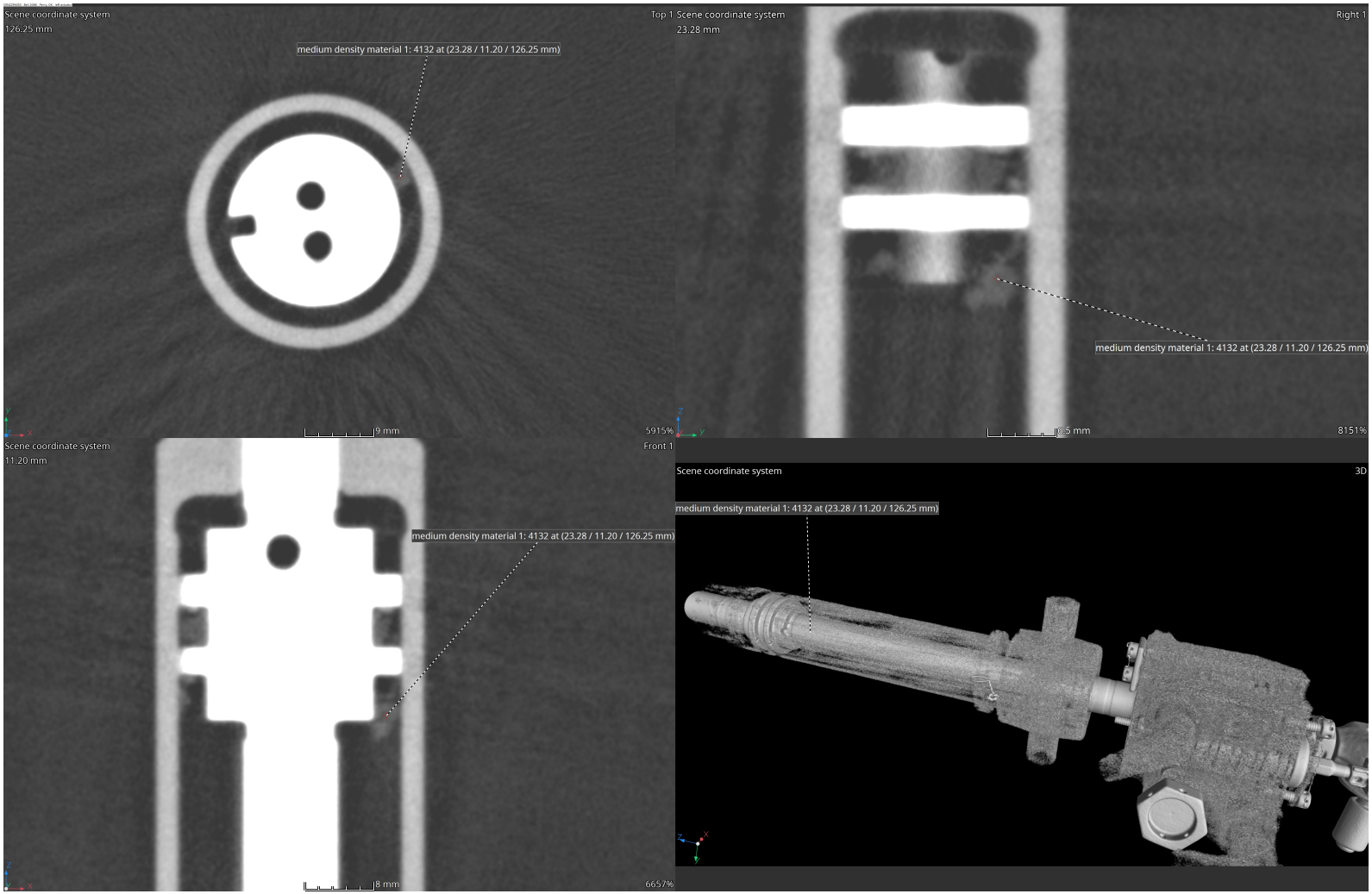


Figure 13
Left actuator – 6 MV – medium density material 1

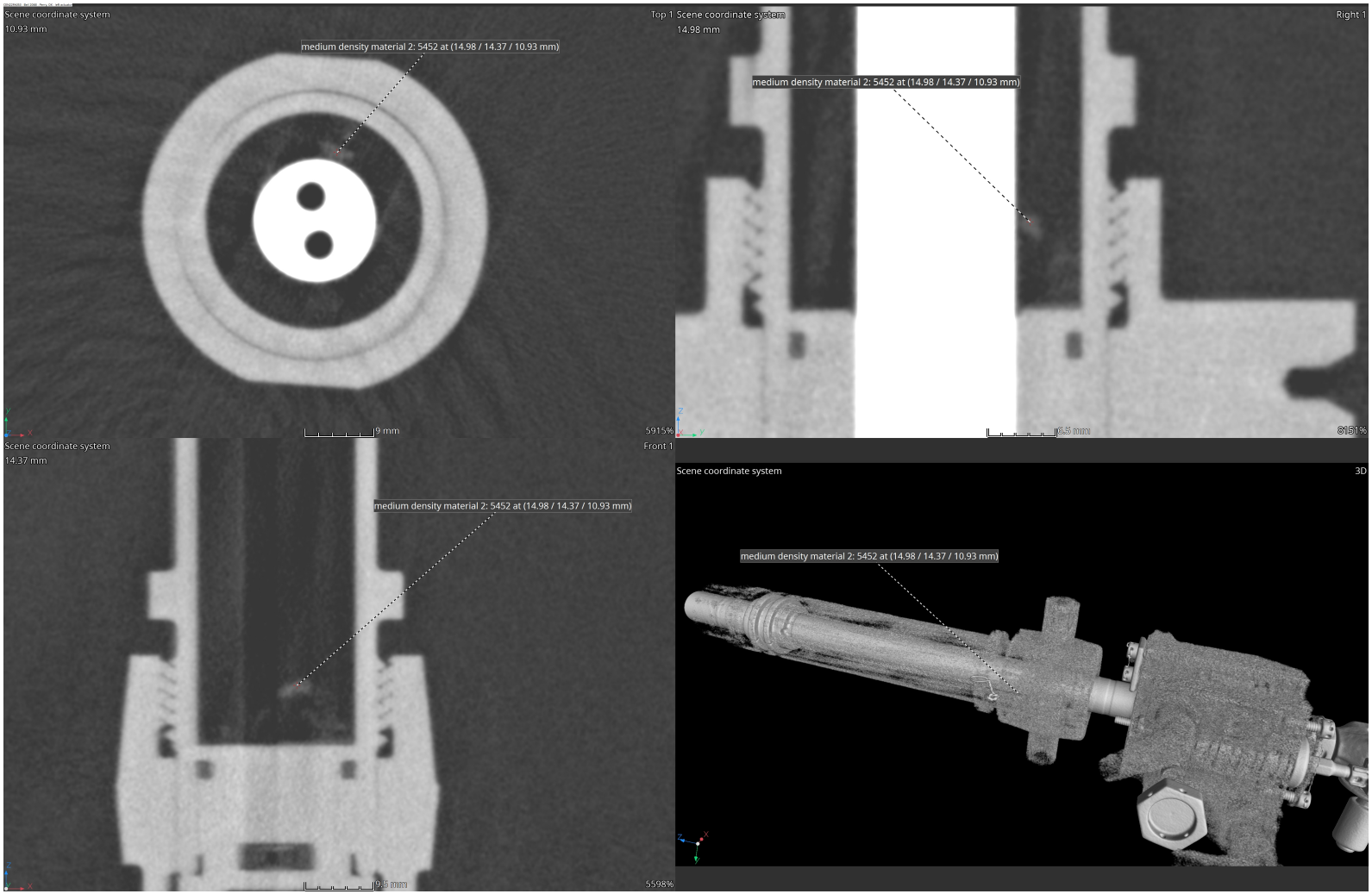


Figure 14
Left actuator – 6 MV – medium density material 2

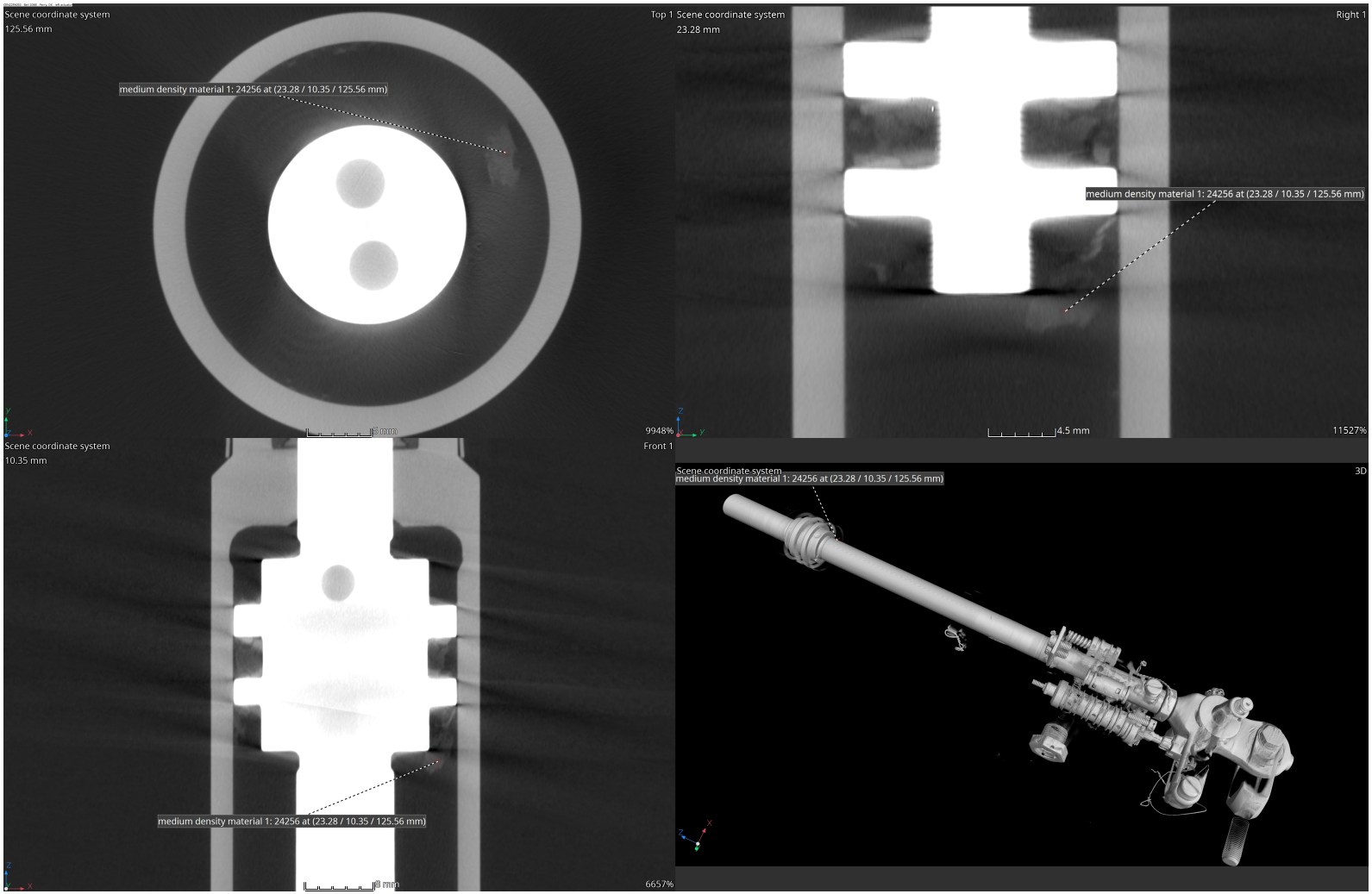


Figure 15
Left actuator – microfocus – medium density material 1

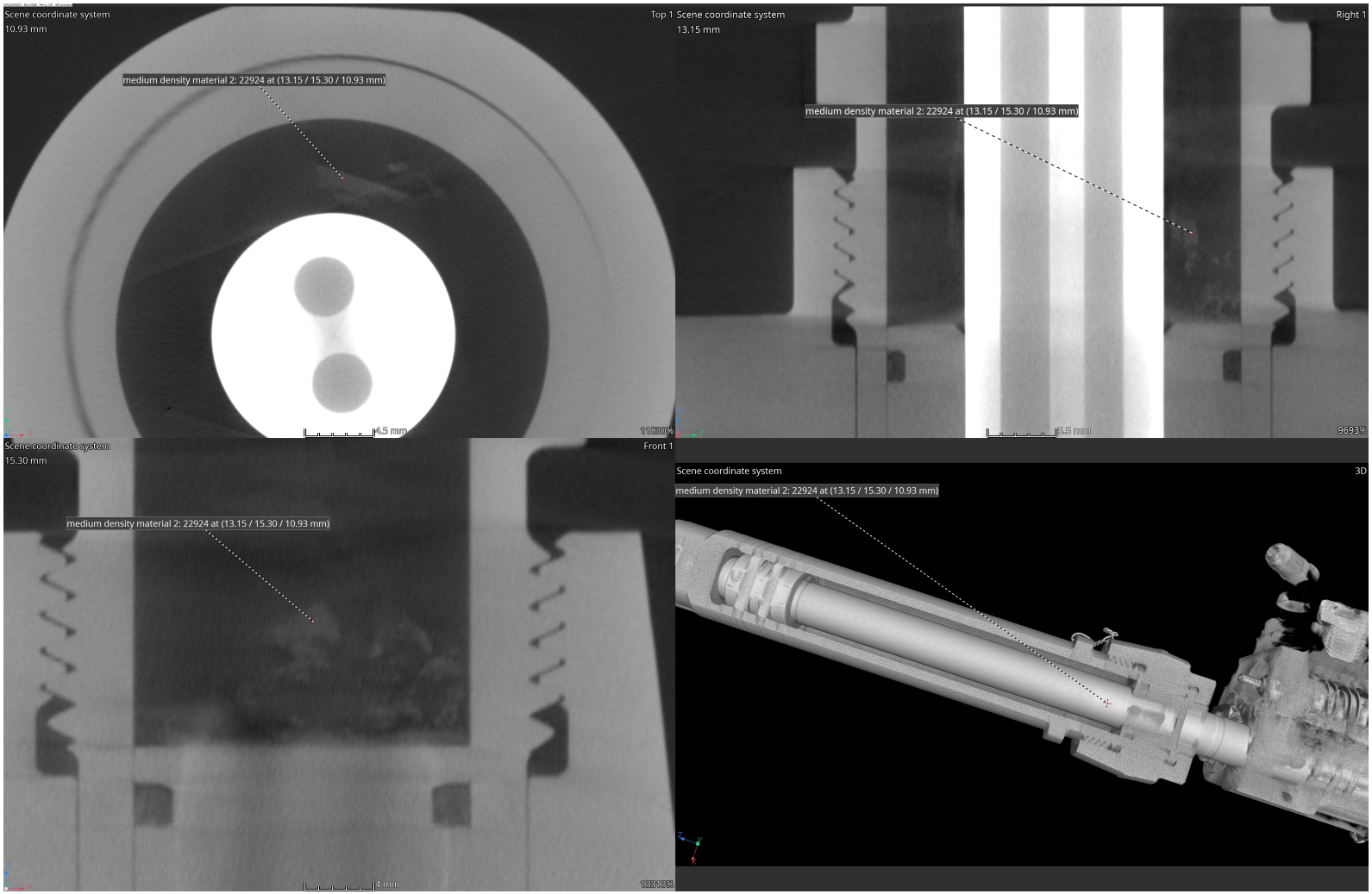


Figure 16
Left actuator – microfocus – medium density material 2

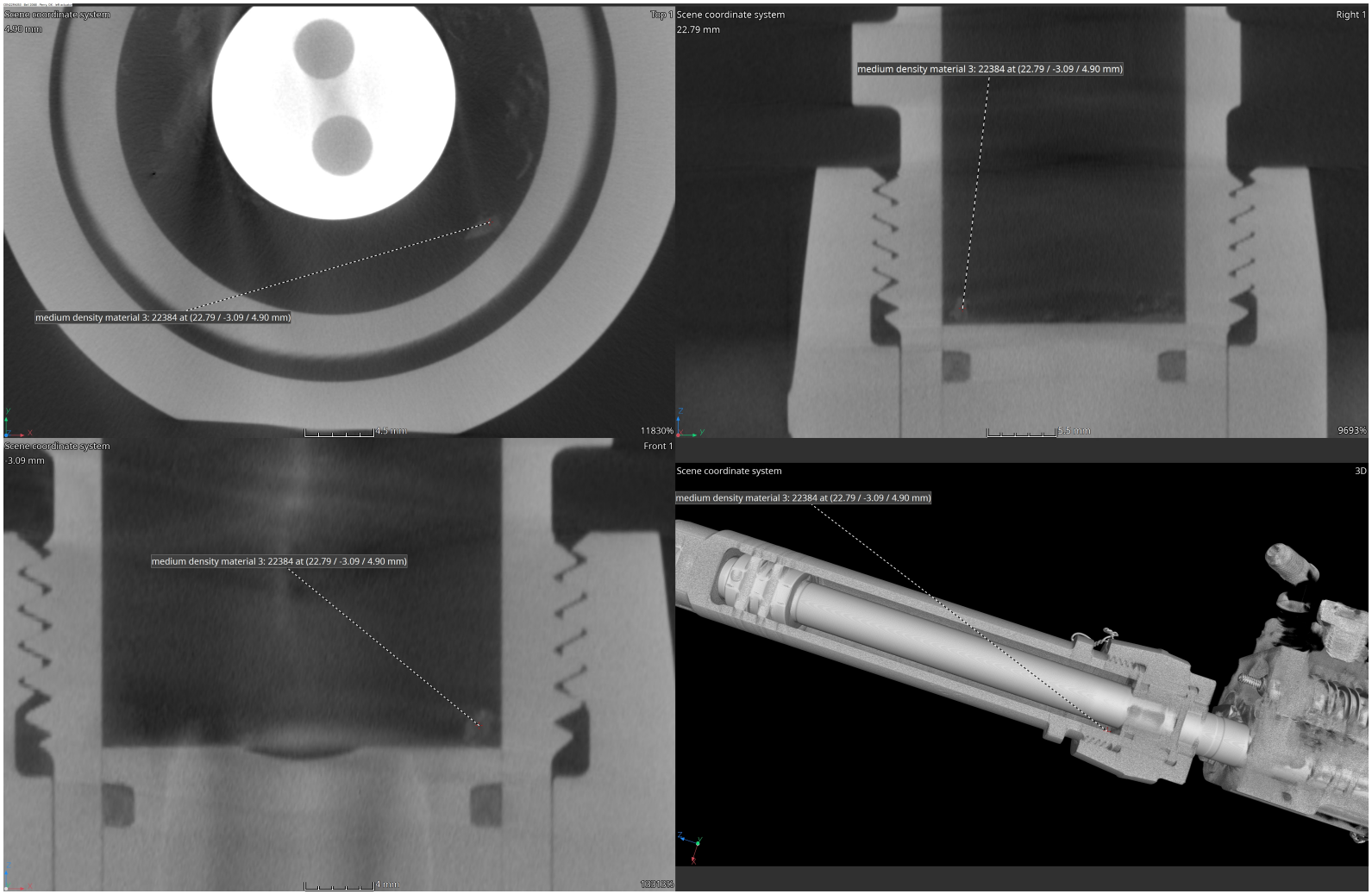


Figure 17
Left actuator – microfocus – medium density material 3

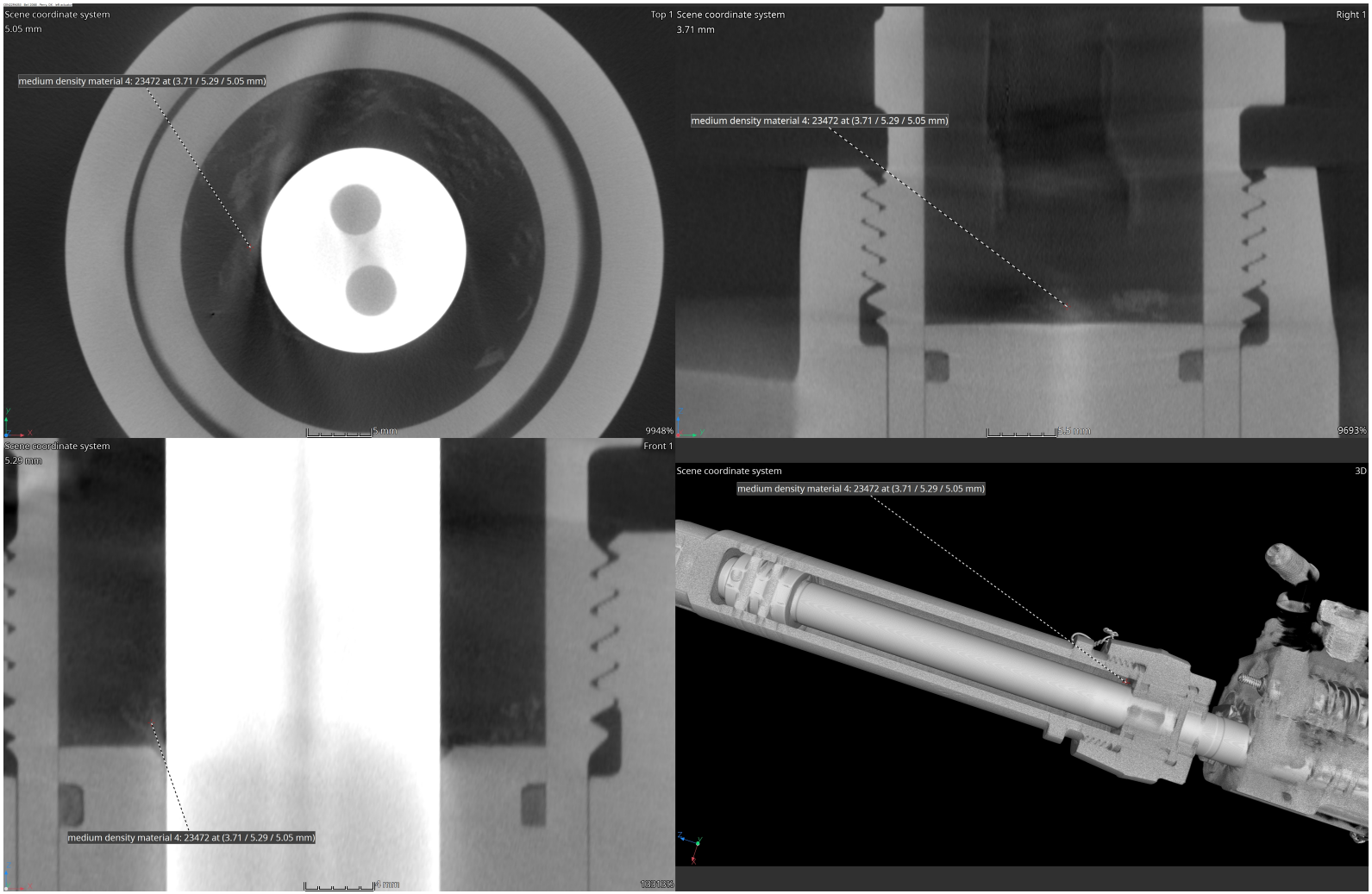


Figure 18
Left actuator – microfocus – medium density material 4

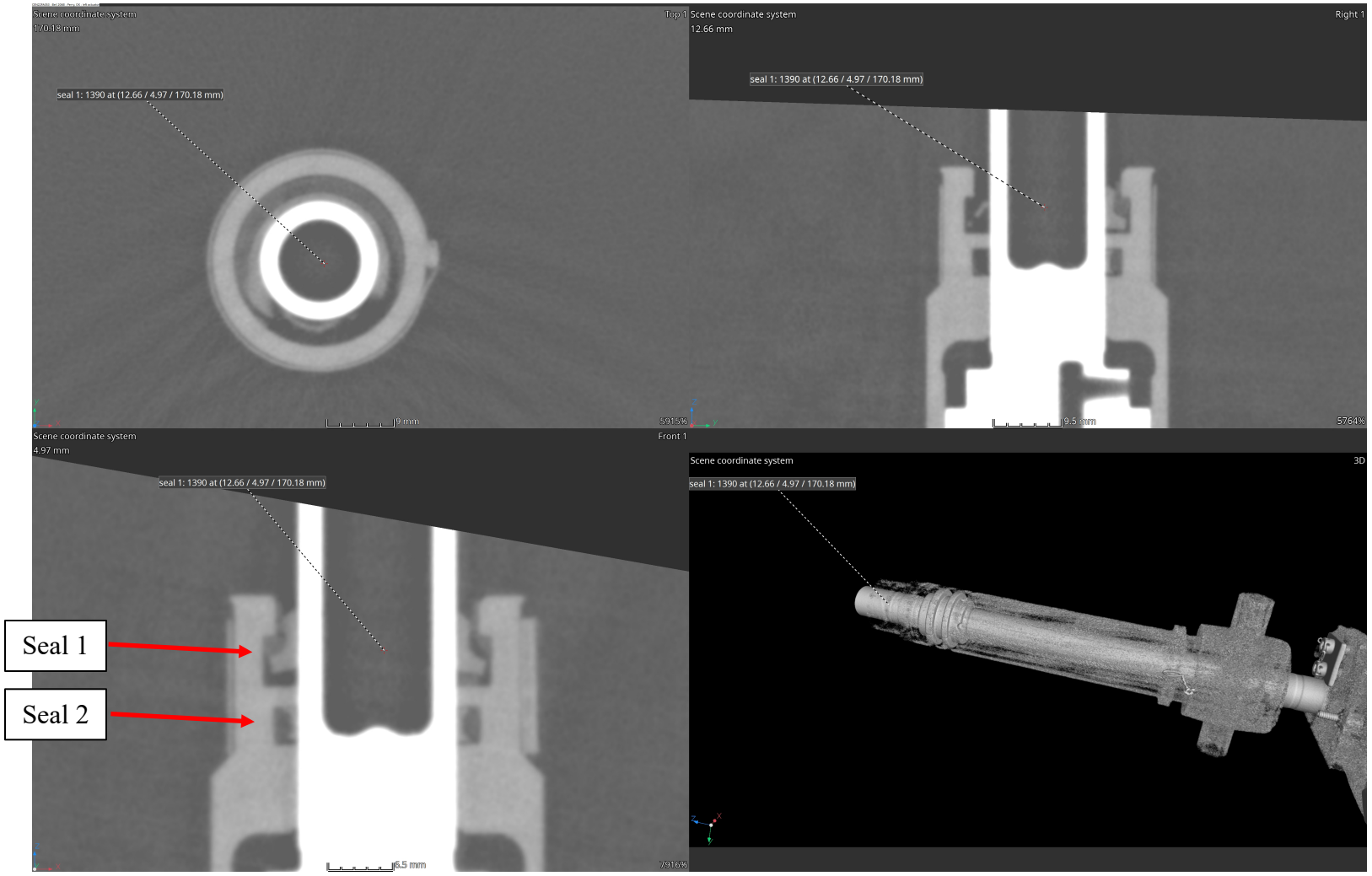


Figure 19
Left actuator – 6 MV – seal 1

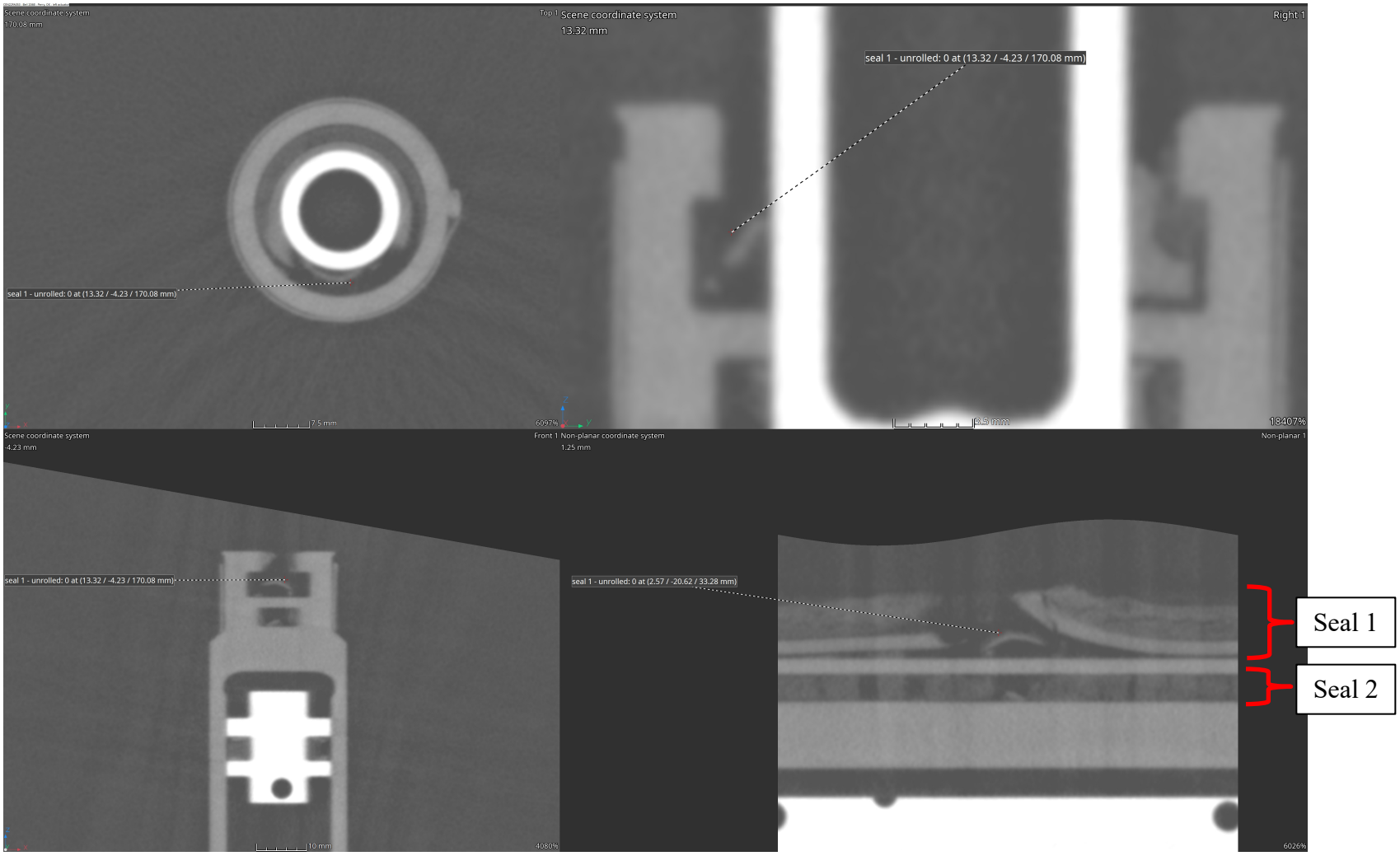


Figure 20
Left actuator – 6 MV – seal 1 unrolled

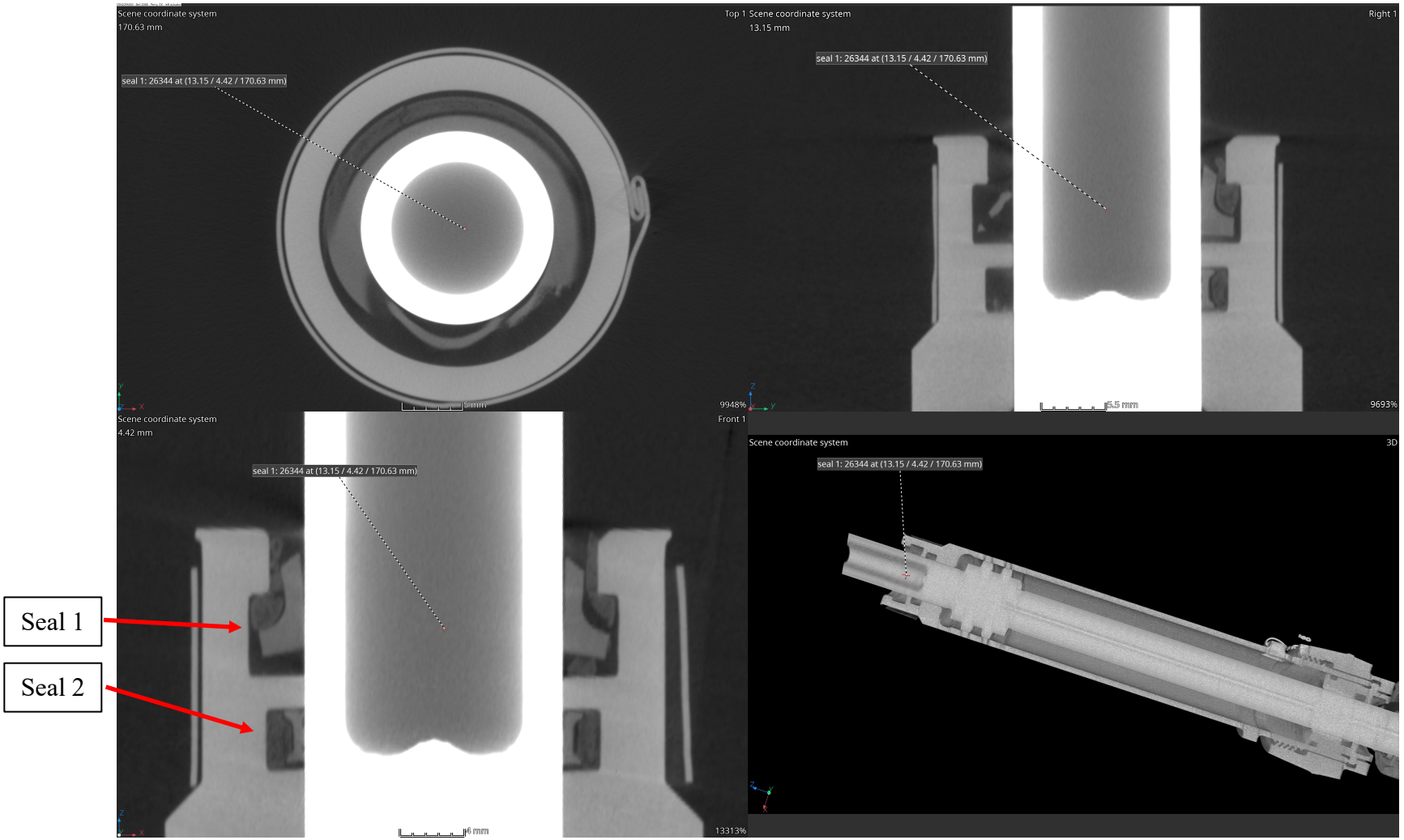


Figure 21
Left actuator – microfocus – seal 1

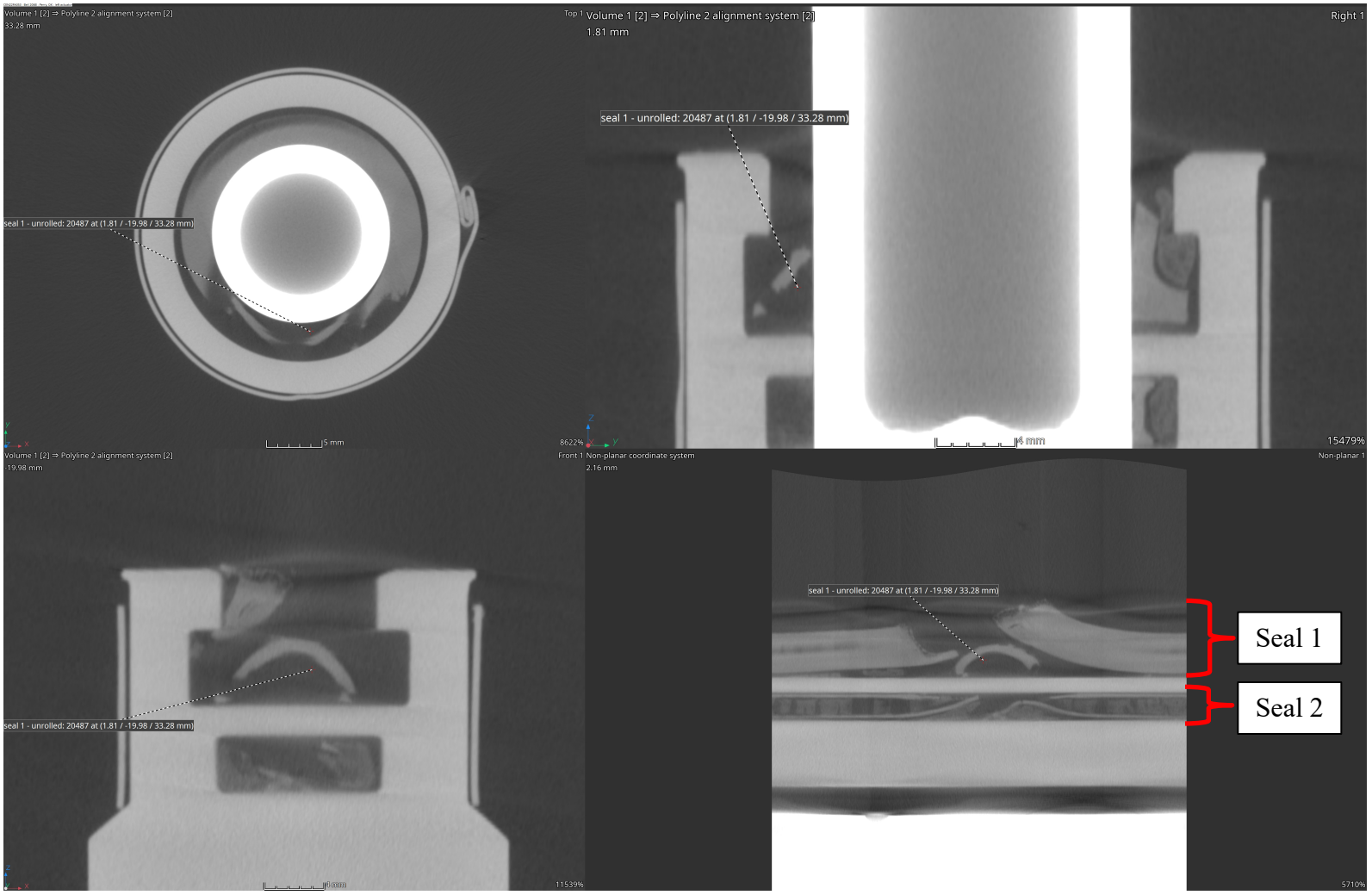


Figure 22
Left actuator – microfocus – seal 1 unrolled

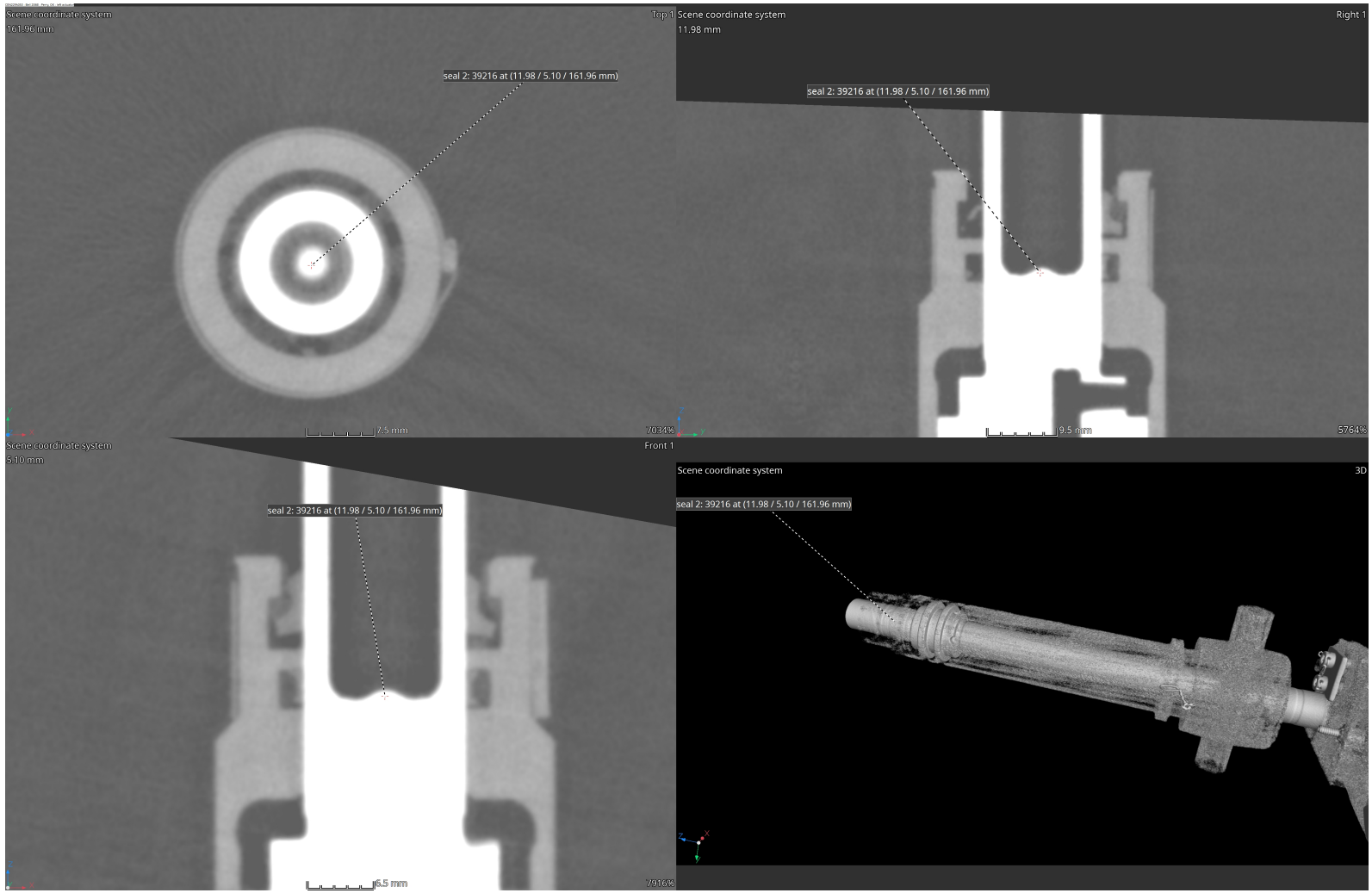


Figure 23
Left actuator – 6 MV – seal 2

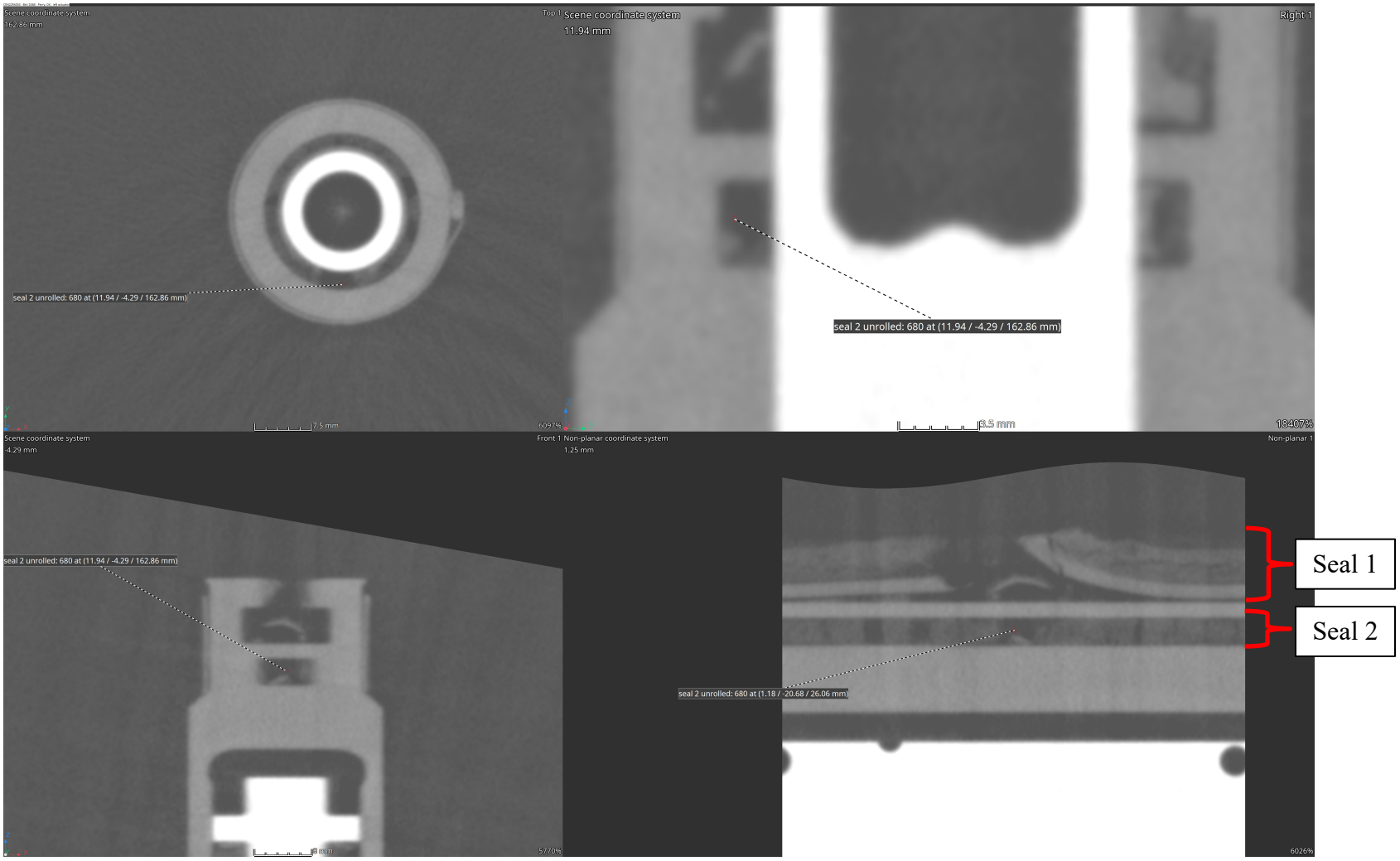


Figure 24
Left actuator – 6 MV – seal 2 unrolled

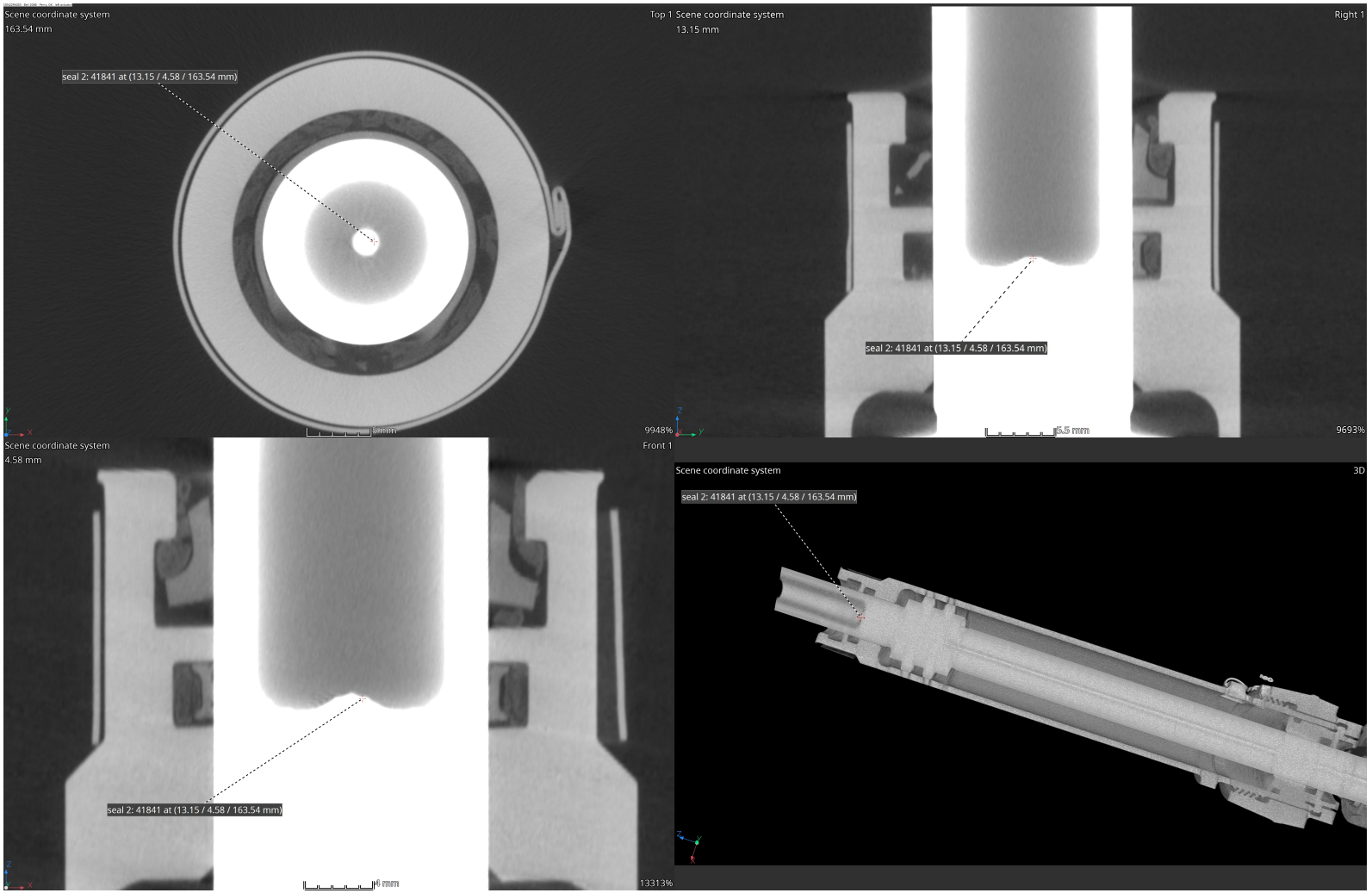


Figure 25
Left actuator – microfocus – seal 2

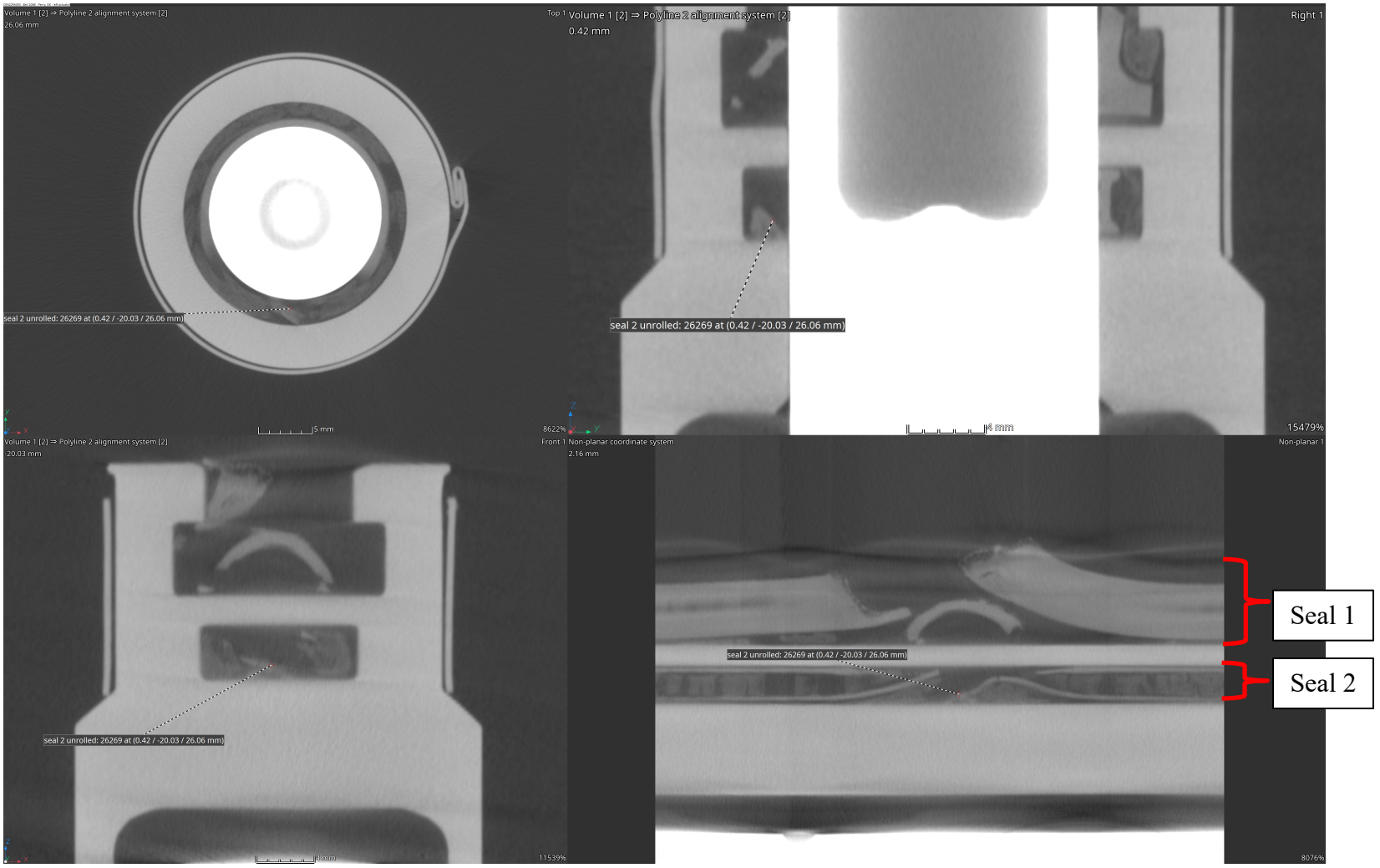


Figure 26
Left actuator – microfocus – seal 2 unrolled

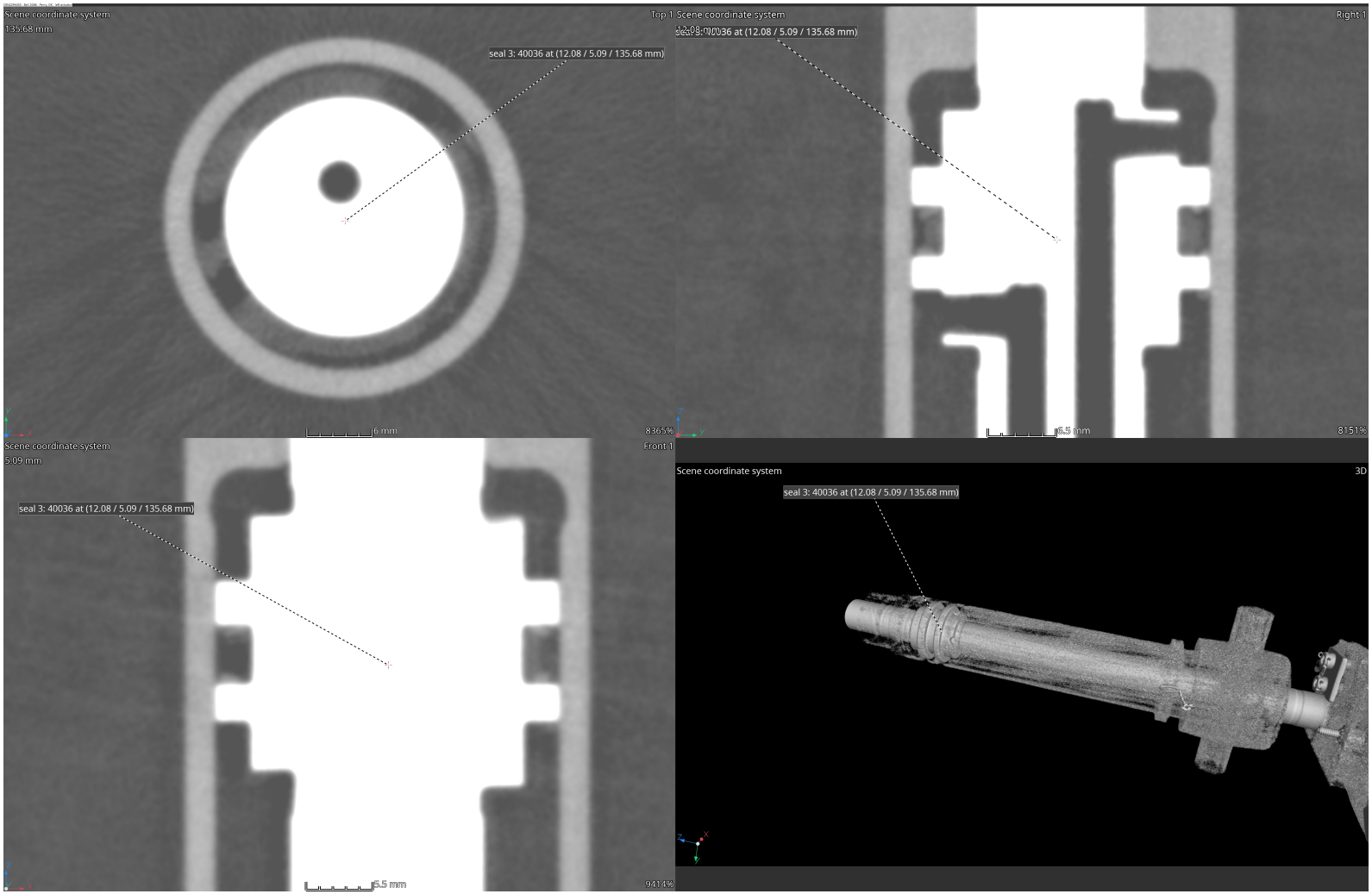


Figure 27
Left actuator – 6 MV – seal 3

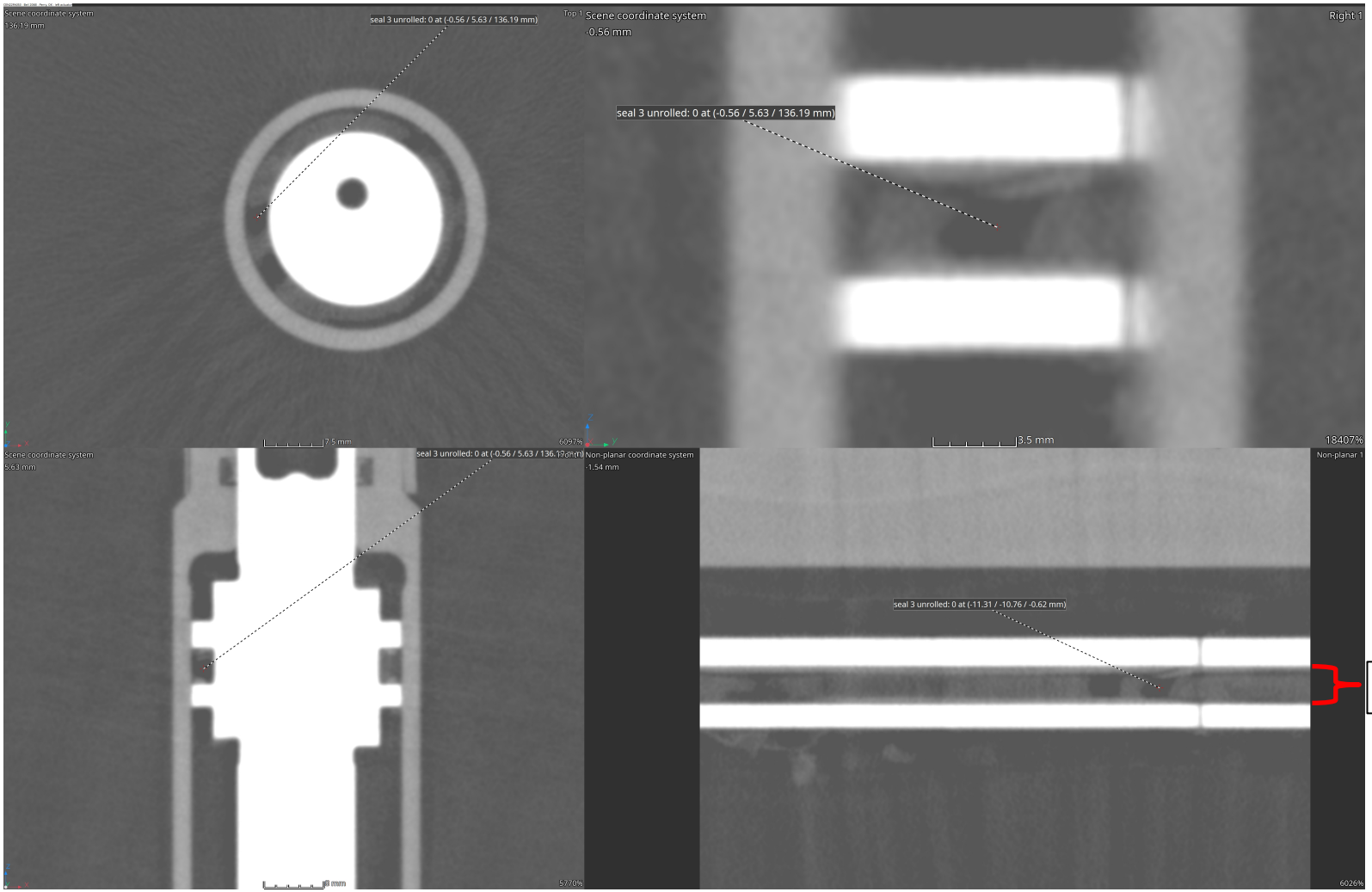


Figure 28
Left actuator – 6 MV – seal 3 unrolled

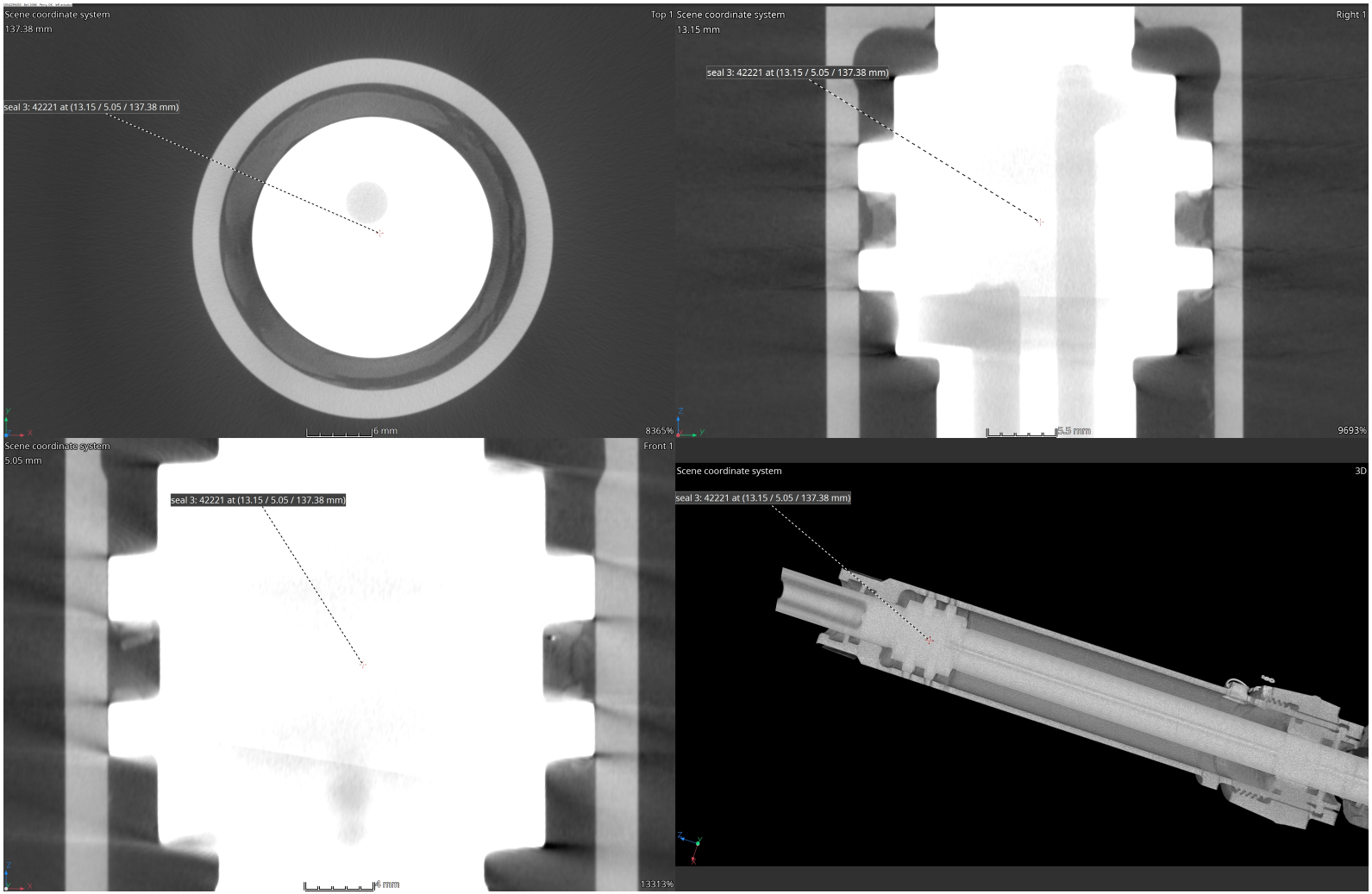


Figure 29
Left actuator – microfocus – seal 3



Figure 30
Left actuator – microfocus – seal 3 unrolled

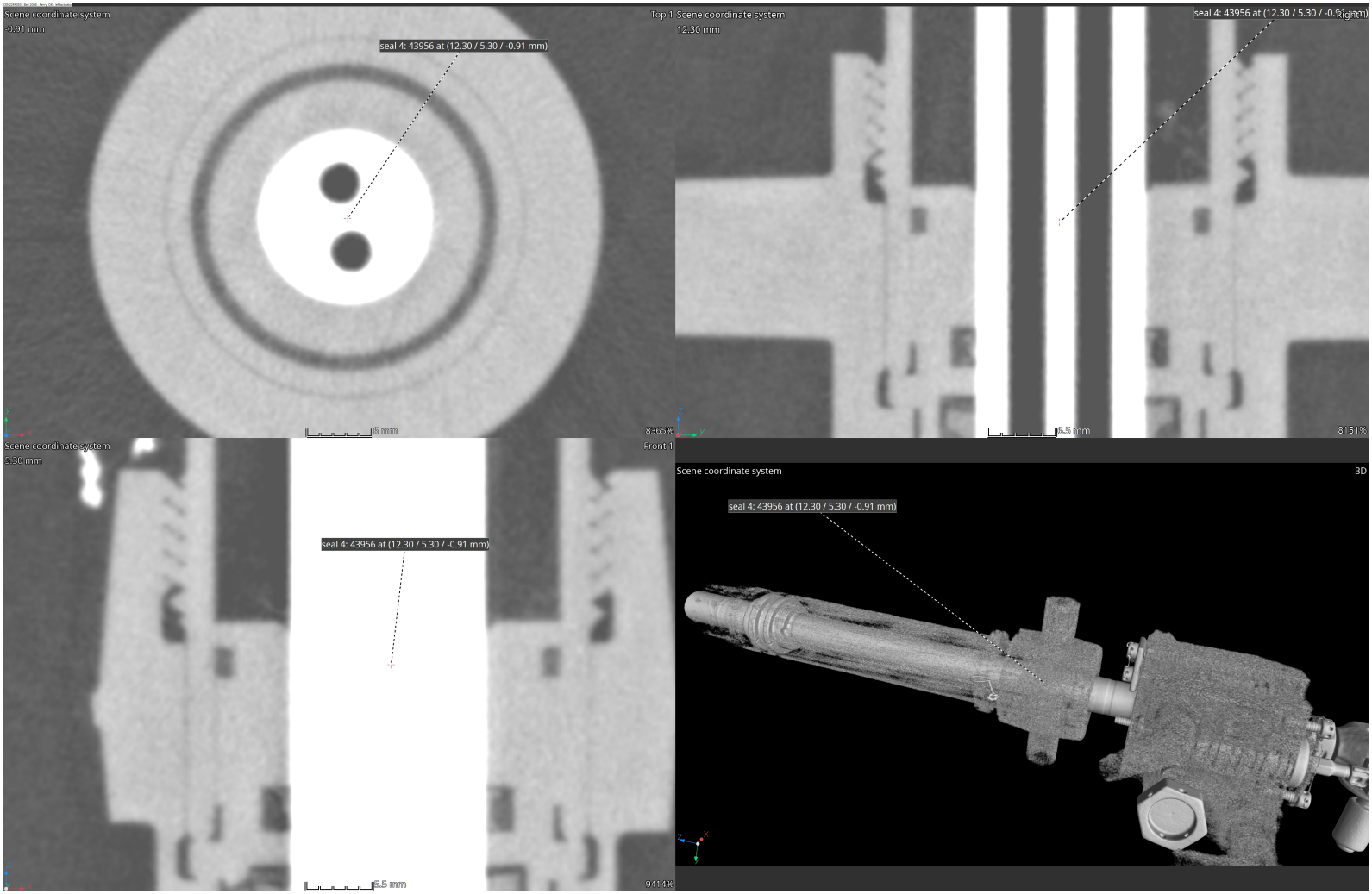


Figure 31
Left actuator – 6 MV – seal 4

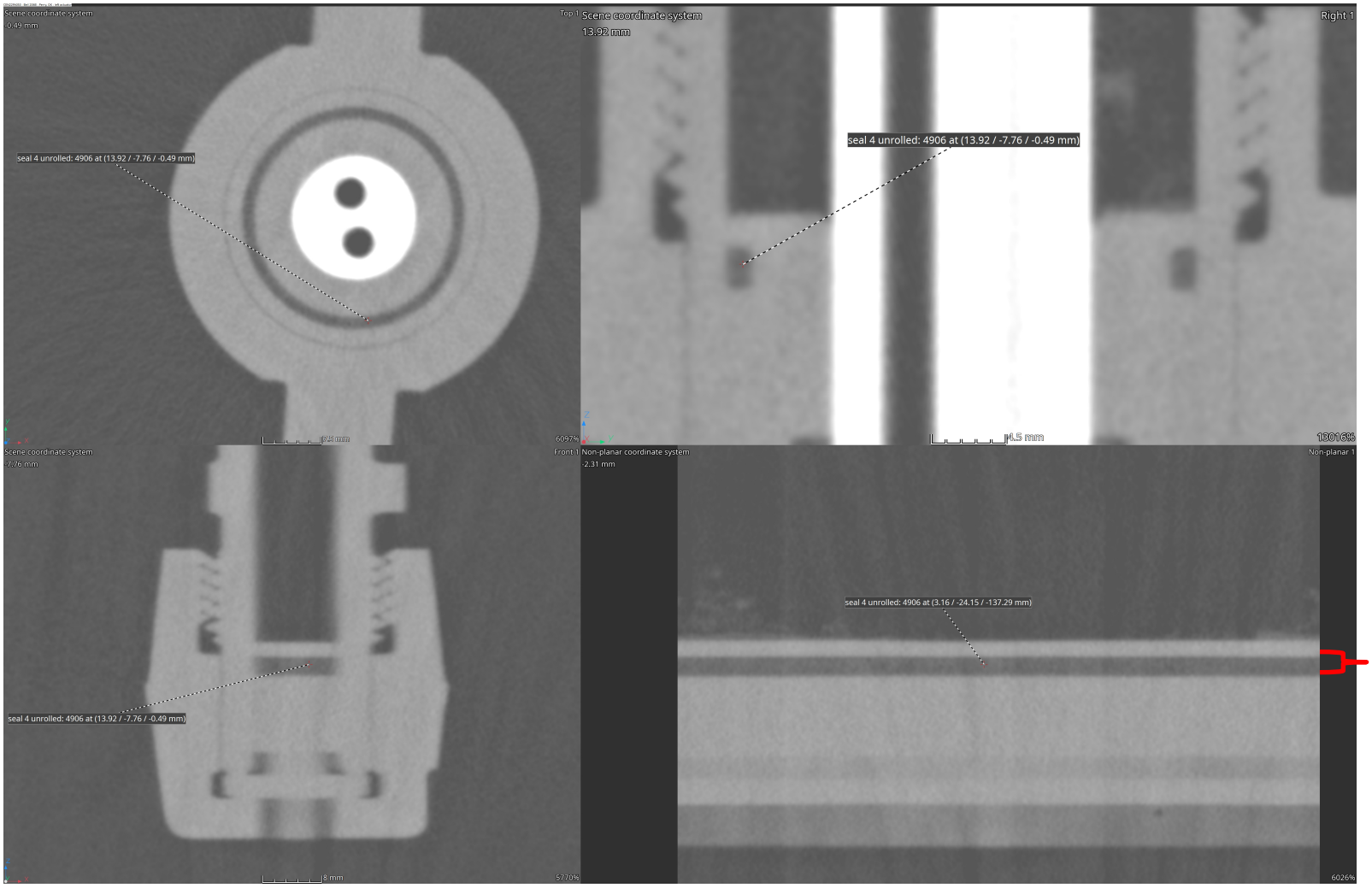


Figure 32
Left actuator – 6 MV – seal 4 unrolled

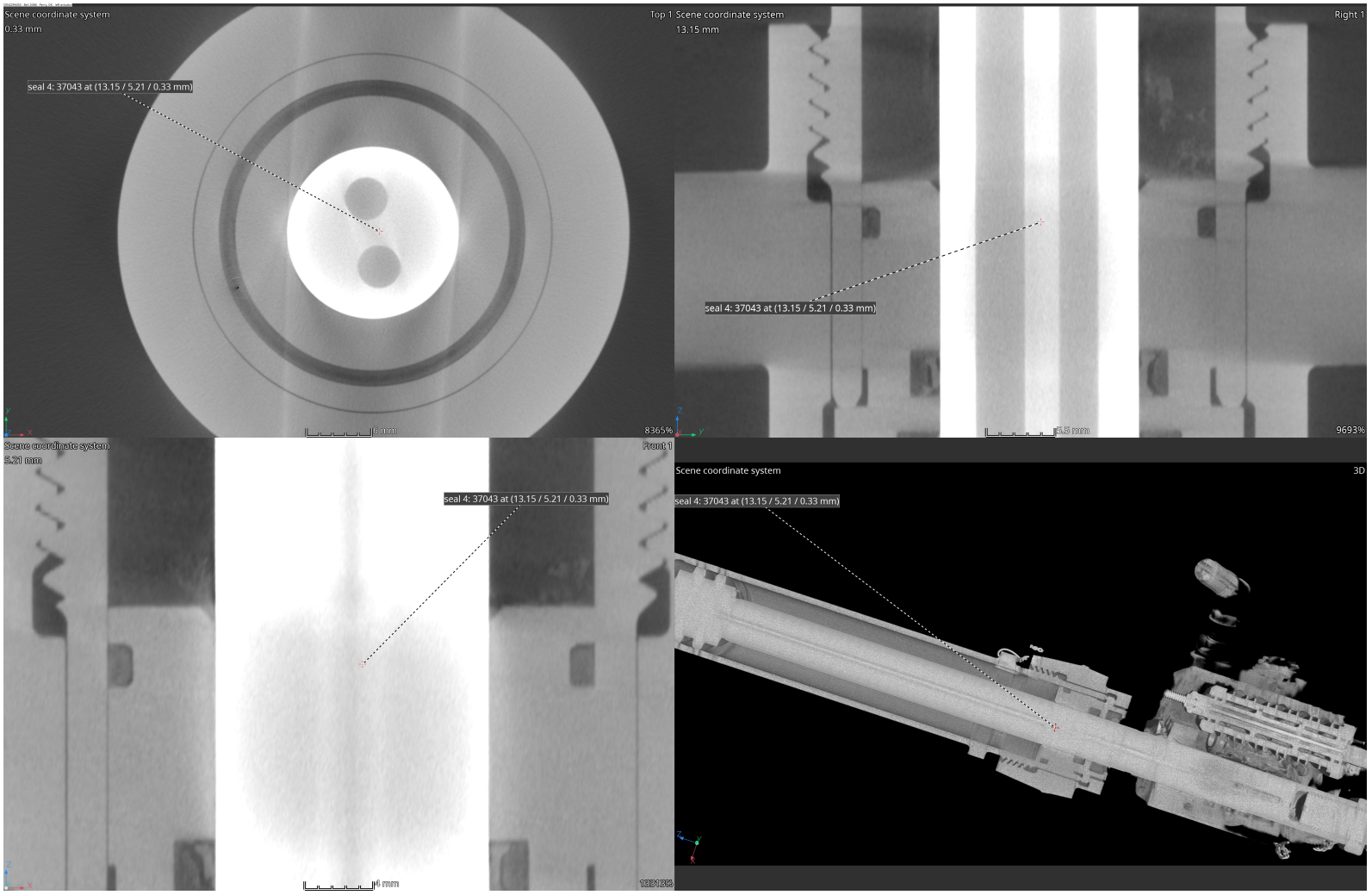


Figure 33
Left actuator – microfocus – seal 4

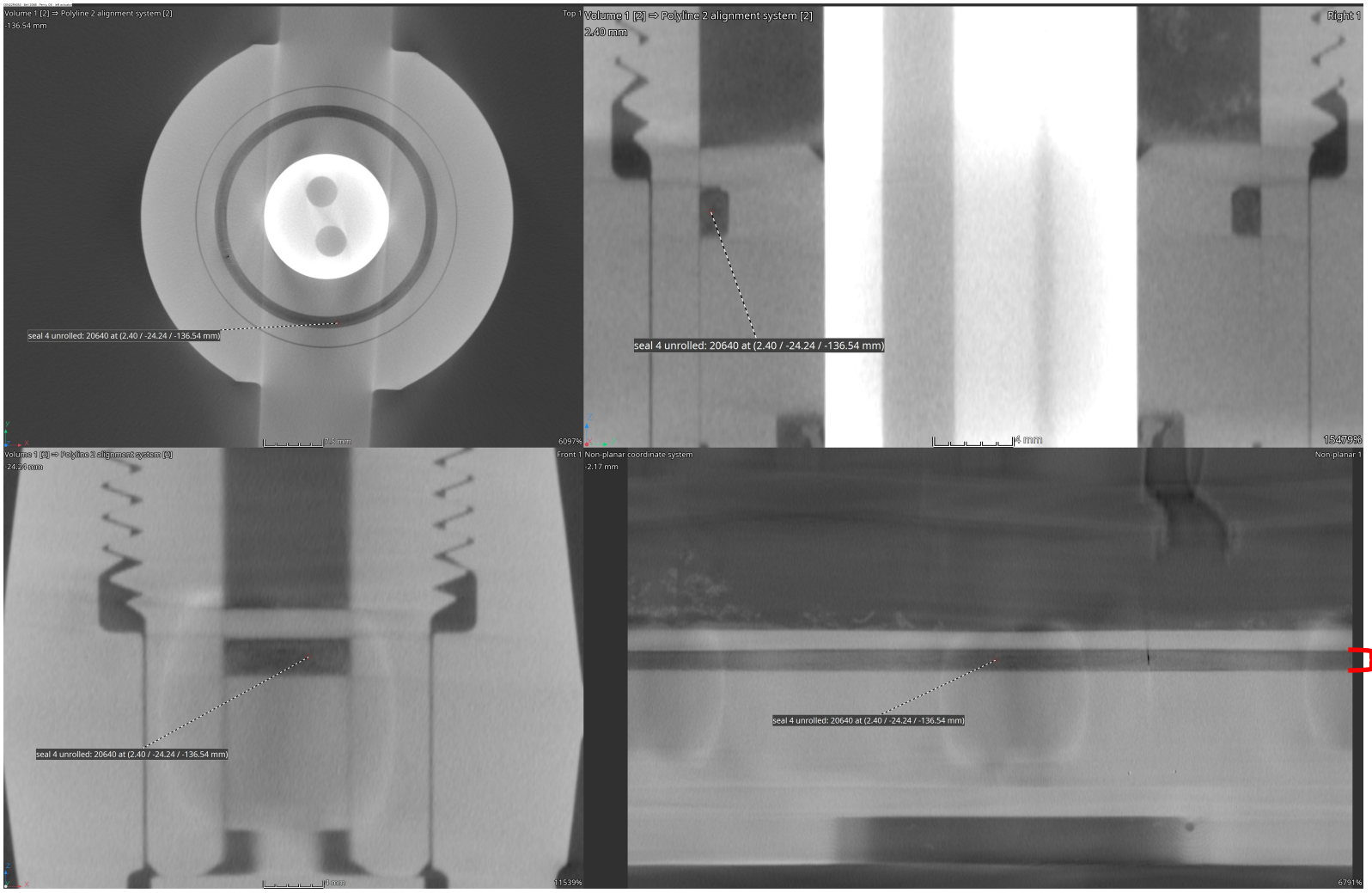


Figure 34
Left actuator – microfocus – seal 4 unrolled

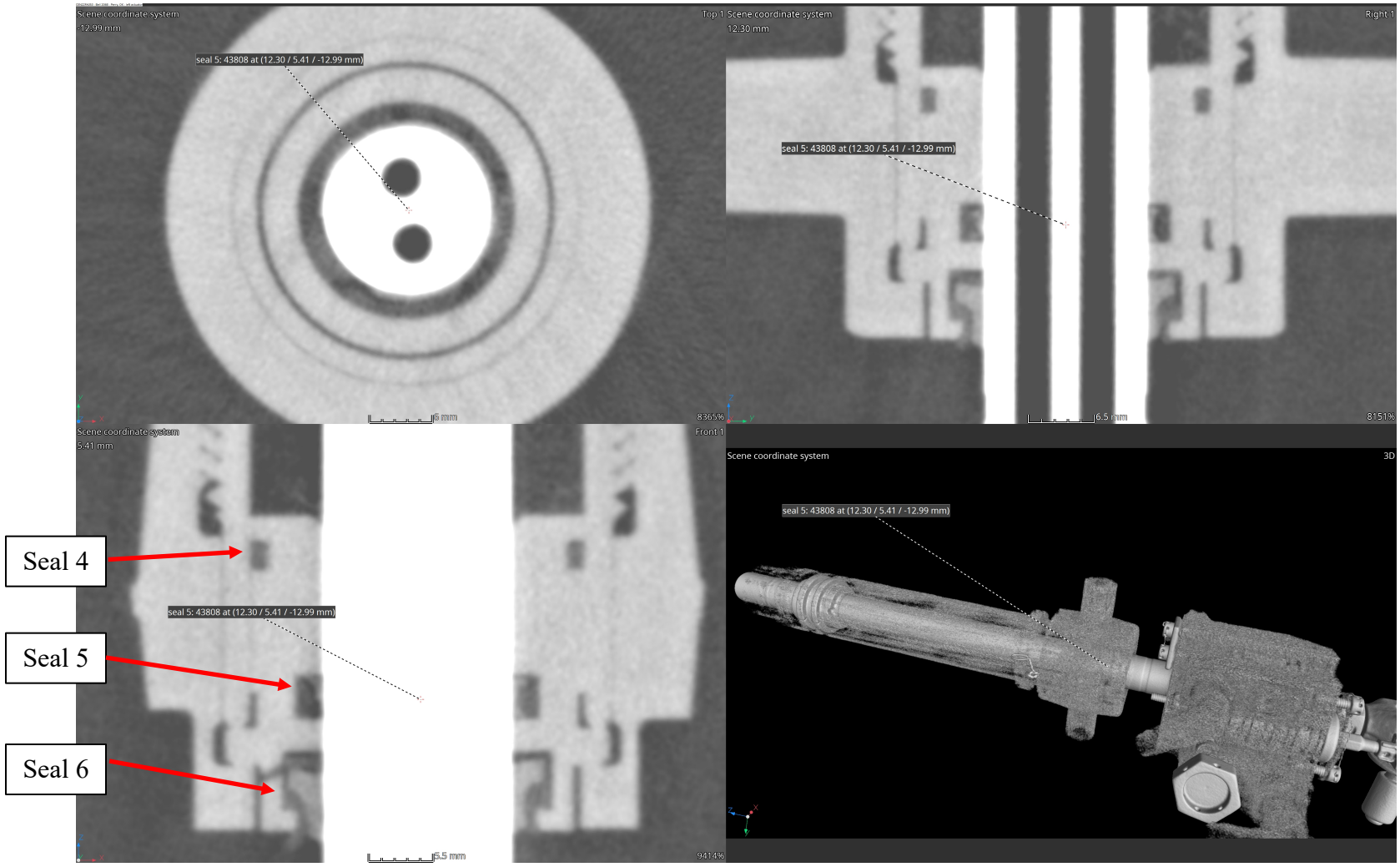


Figure 35
Left actuator – 6 MV – seal 5

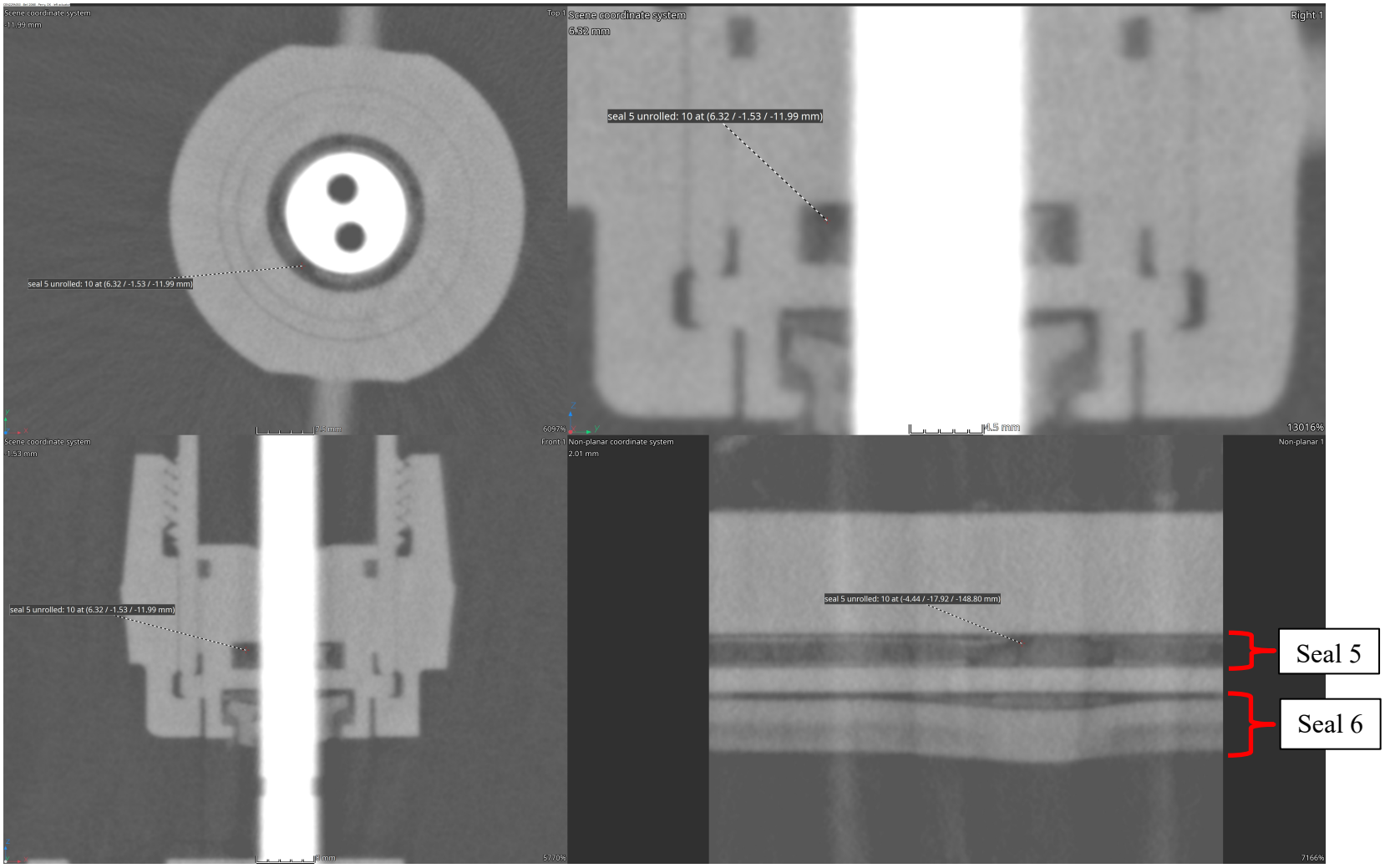


Figure 36
Left actuator – 6 MV – seal 5 unrolled

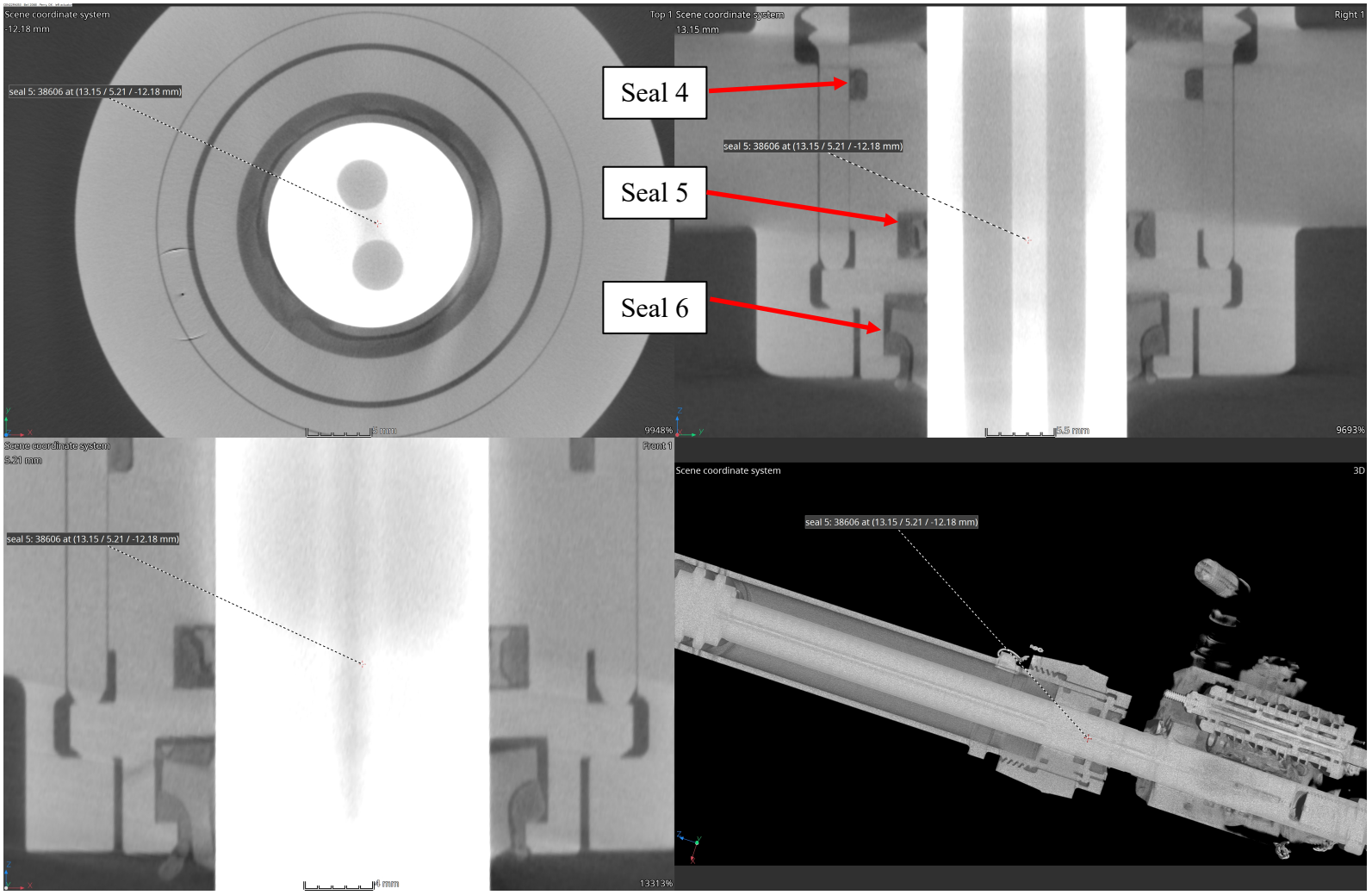


Figure 37
Left actuator – microfocus – seal 5

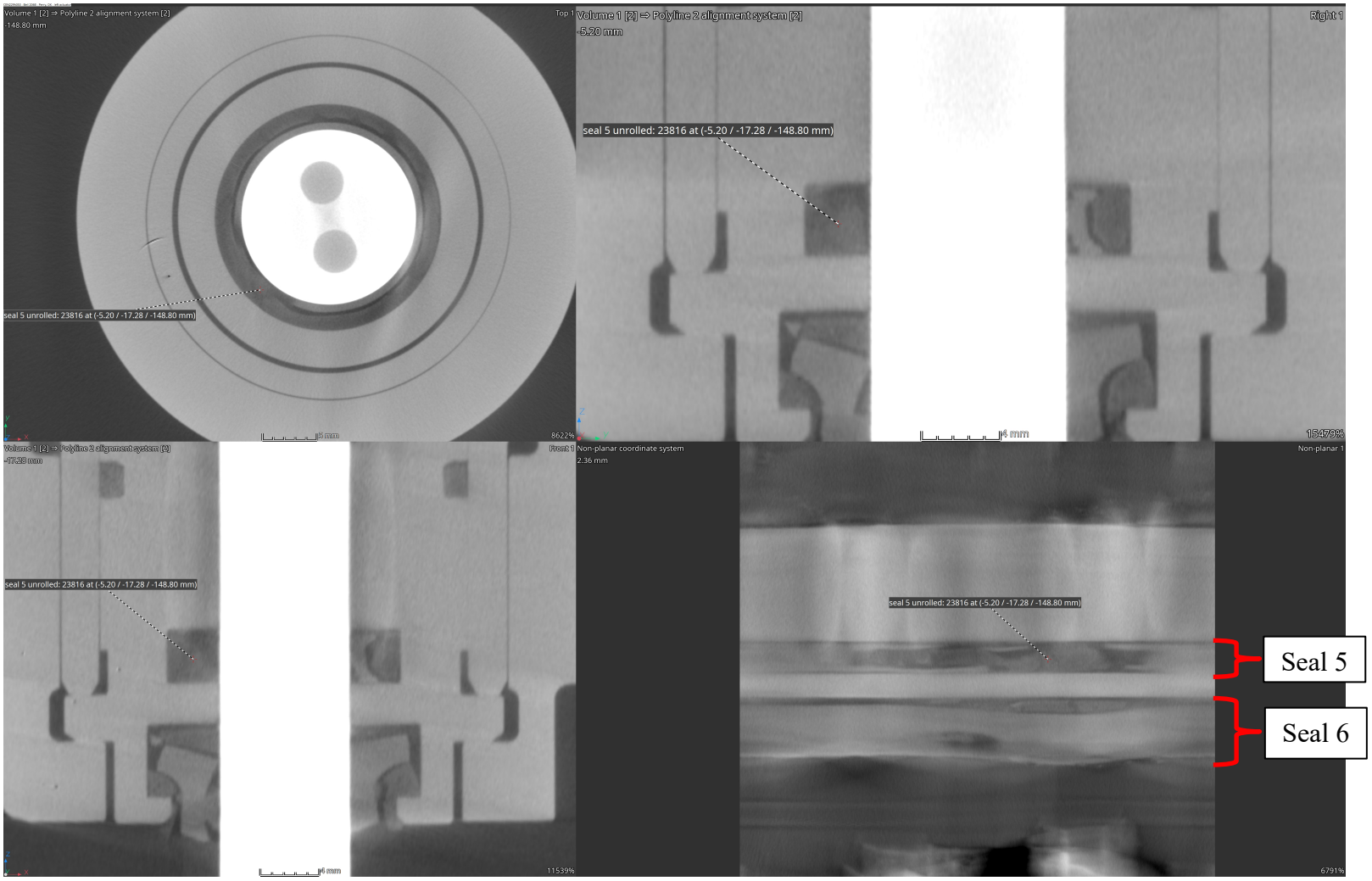


Figure 38
Left actuator – microfocus – seal 5 unrolled

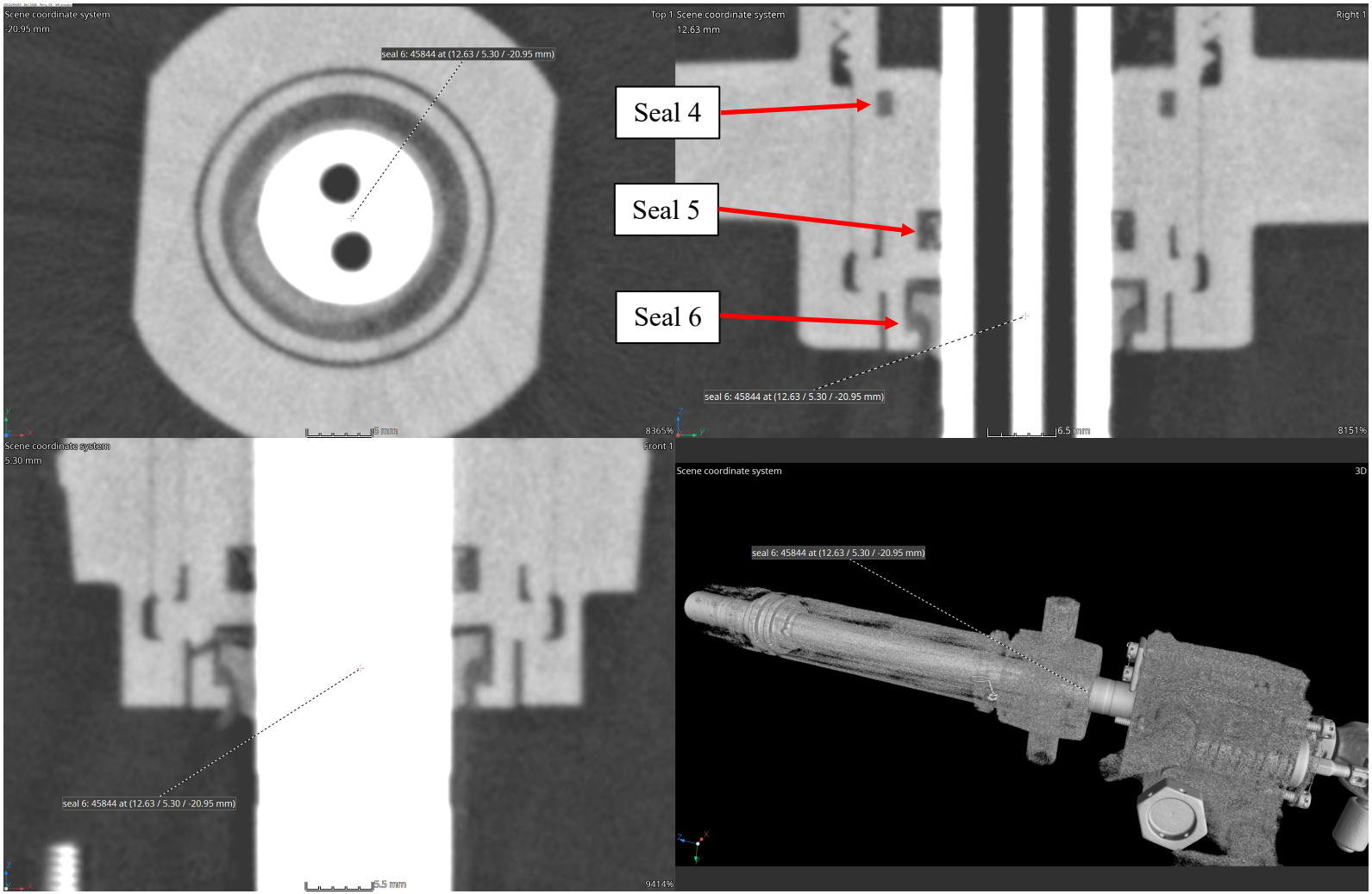


Figure 39
Left actuator – 6 MV – seal 6

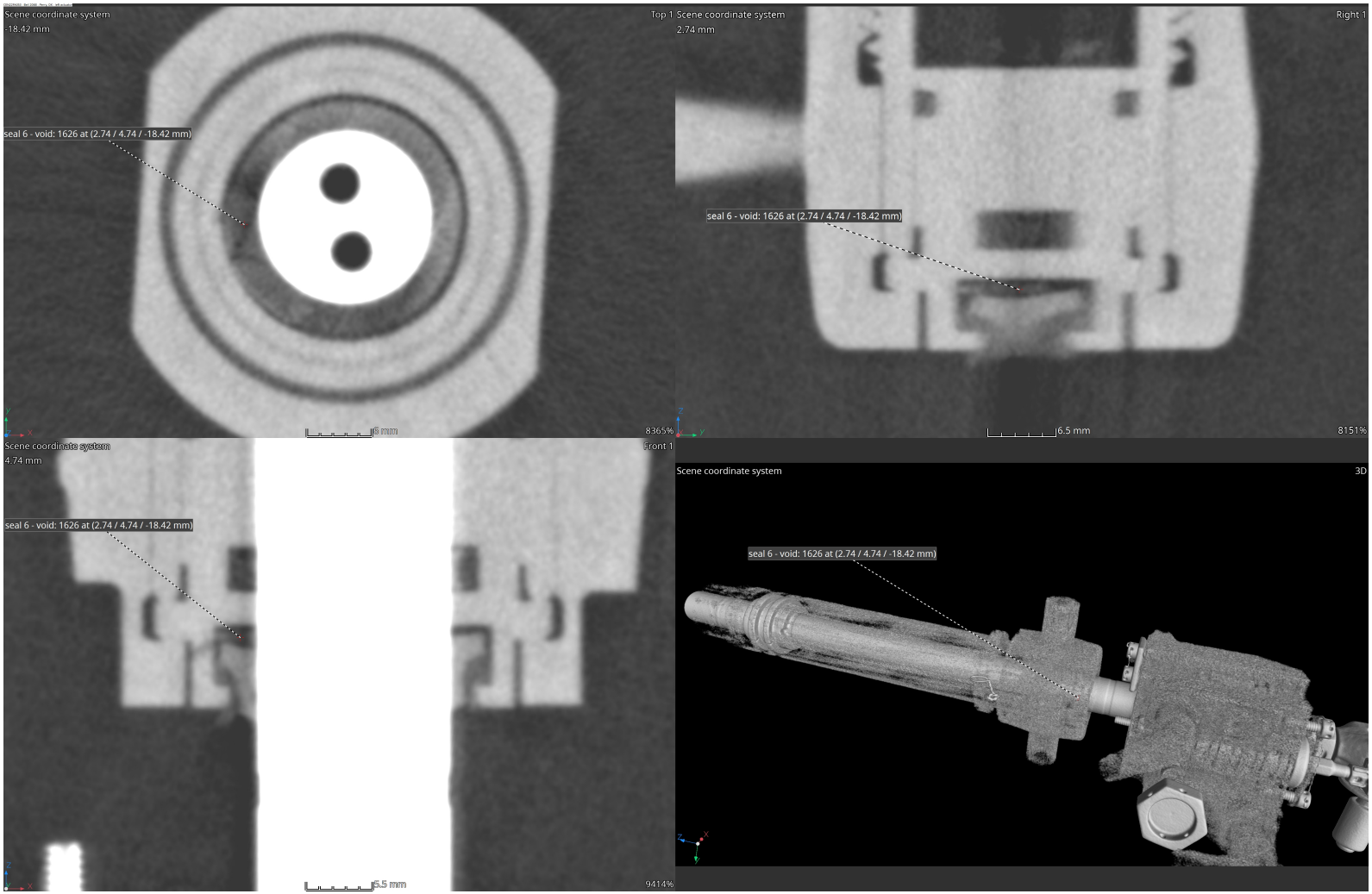


Figure 40
Left actuator – 6 MV – seal 6 void

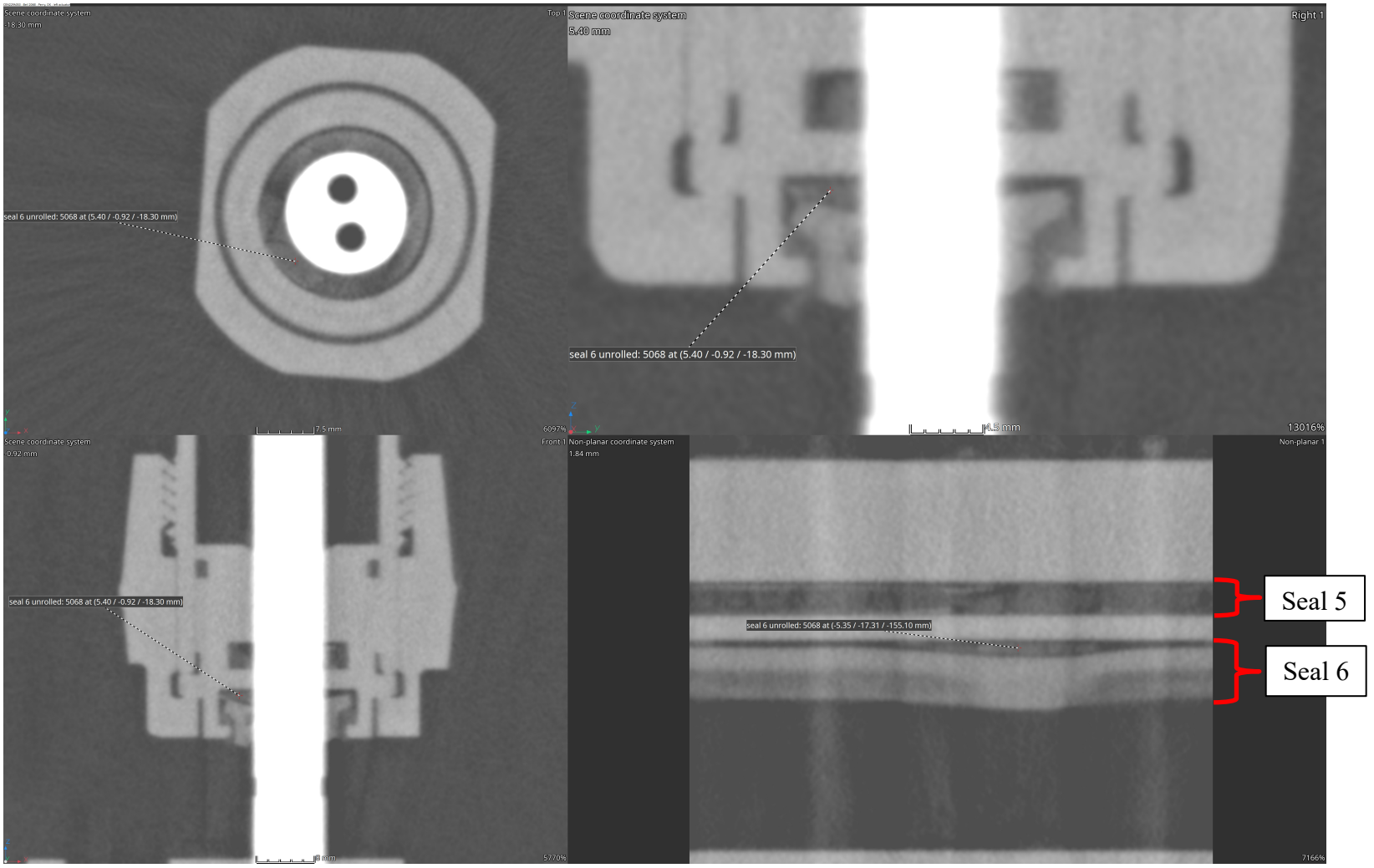


Figure 41
Left actuator – 6 MV – seal 6 unrolled

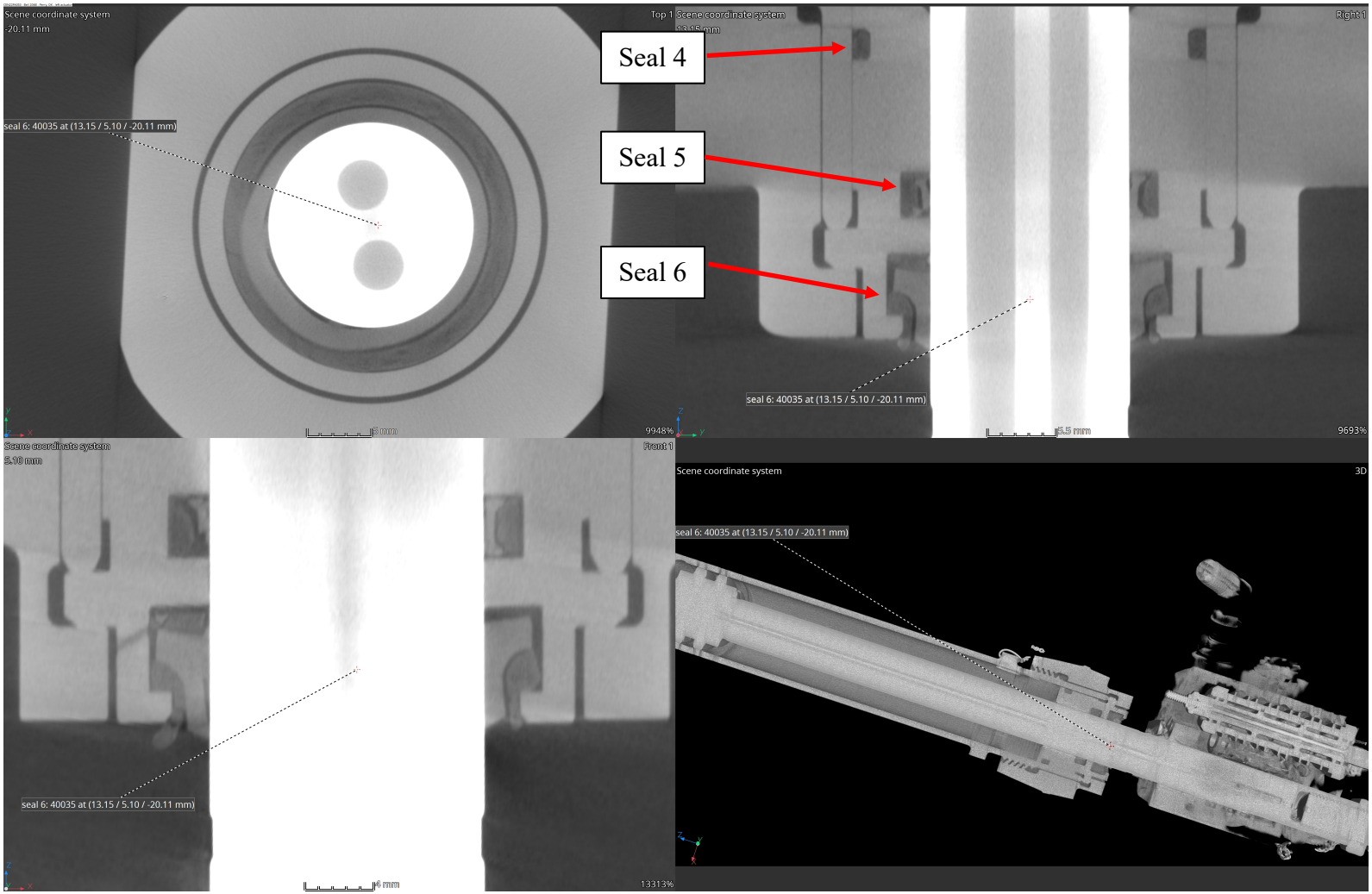


Figure 42
Left actuator – microfocus – seal 6

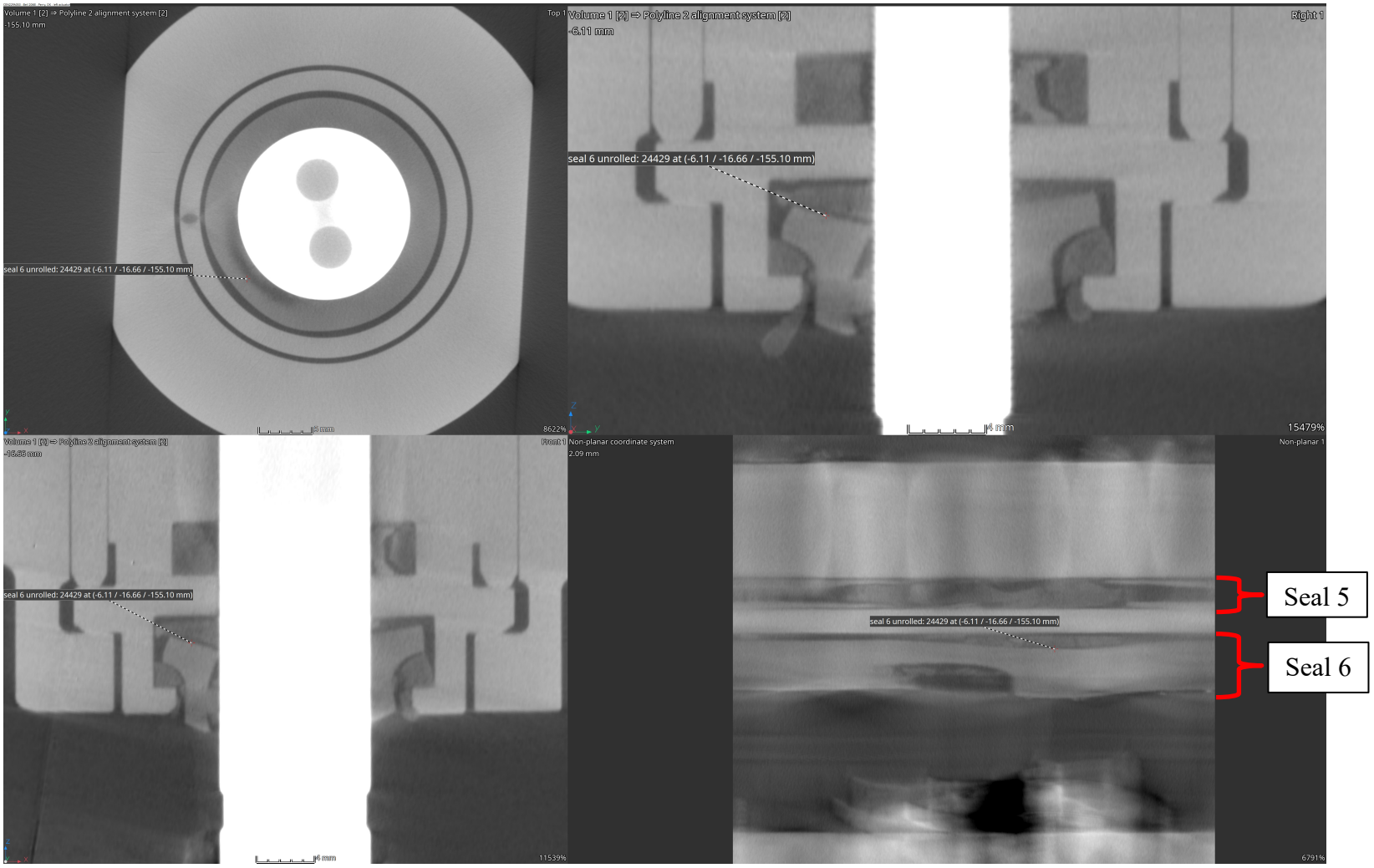


Figure 43
Left actuator – microfocus – seal 6 unrolled

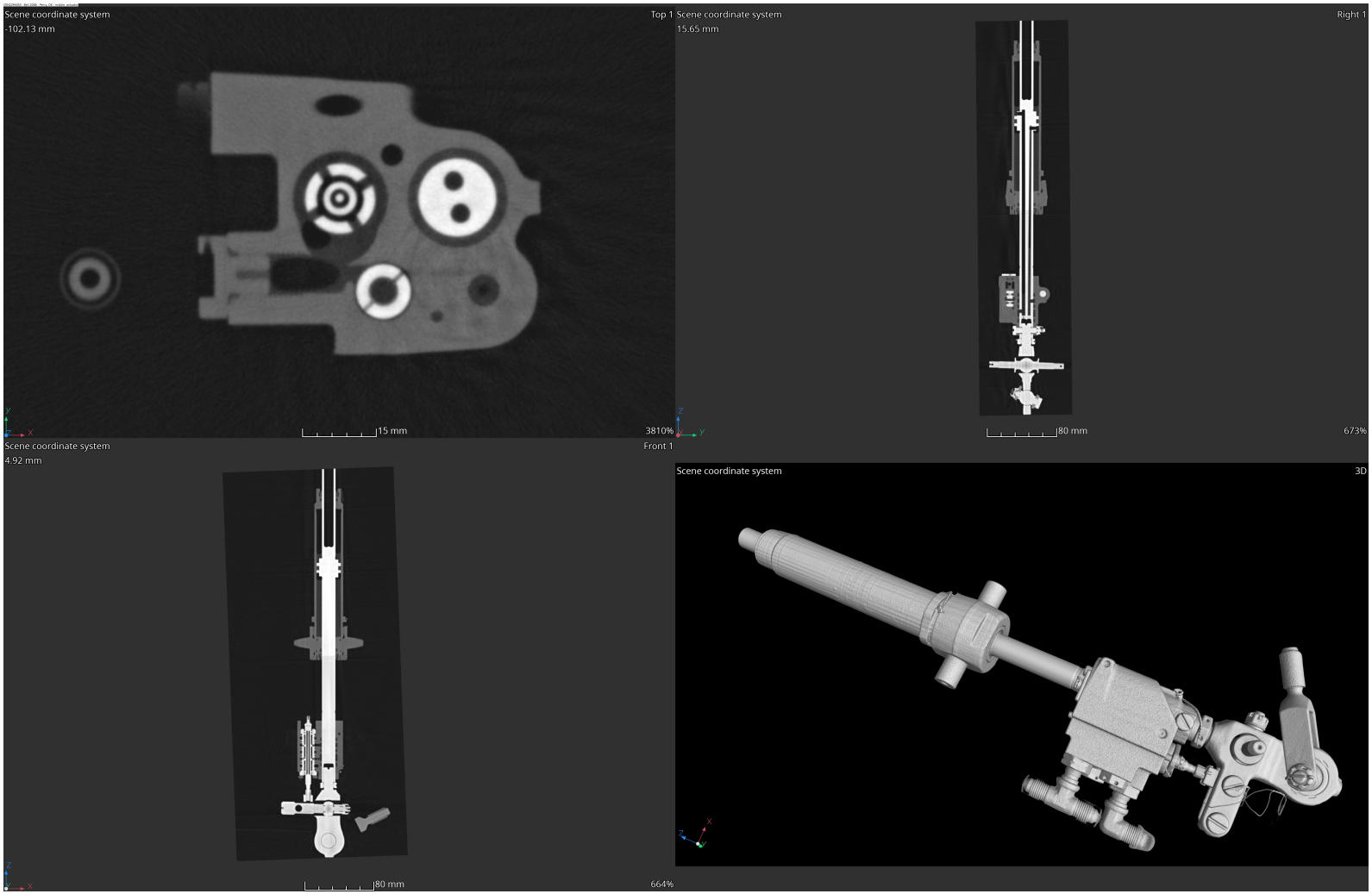


Figure 44
Middle actuator – 6 MV – overall

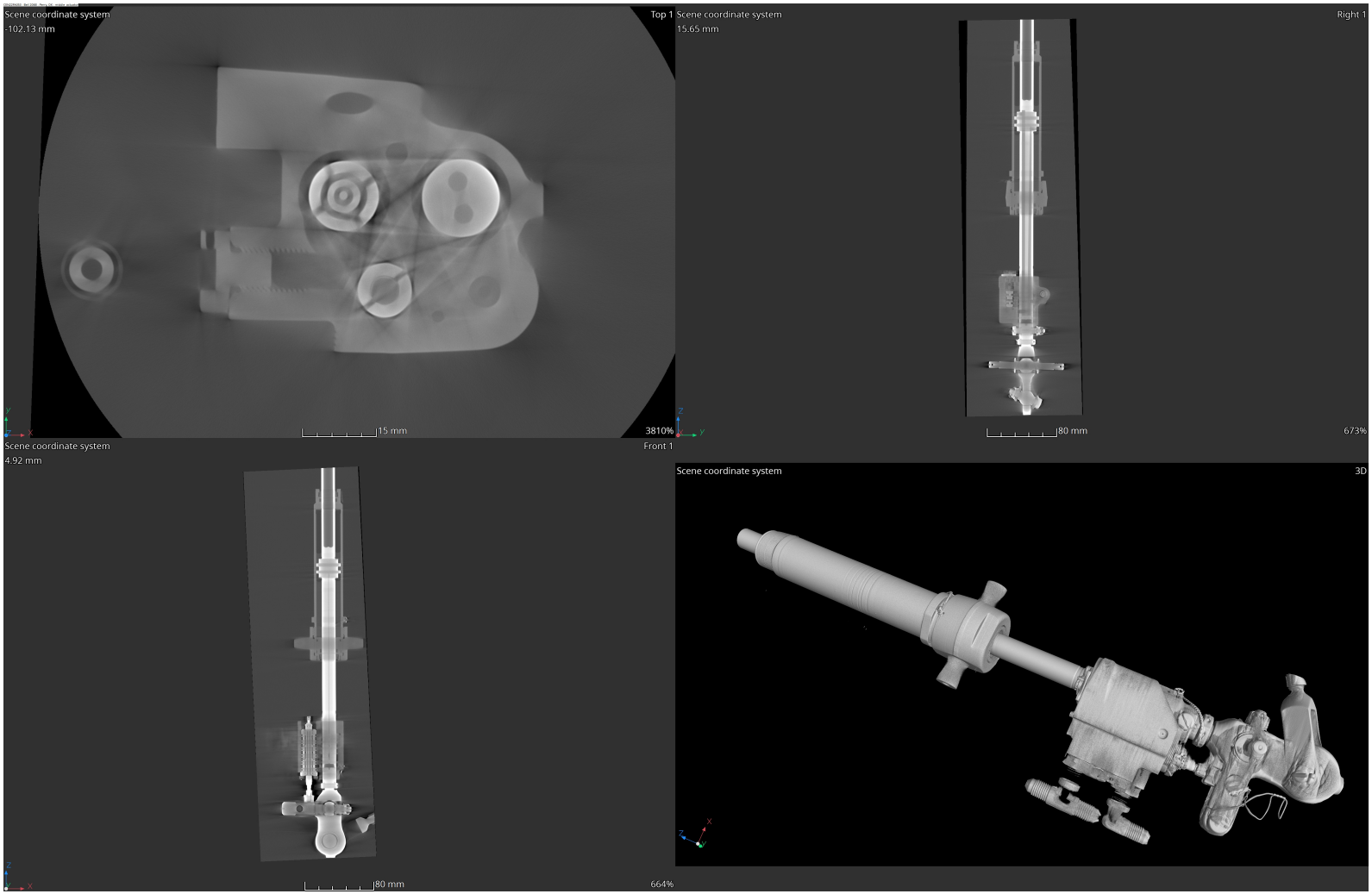


Figure 45
Middle actuator – microfocus – overall

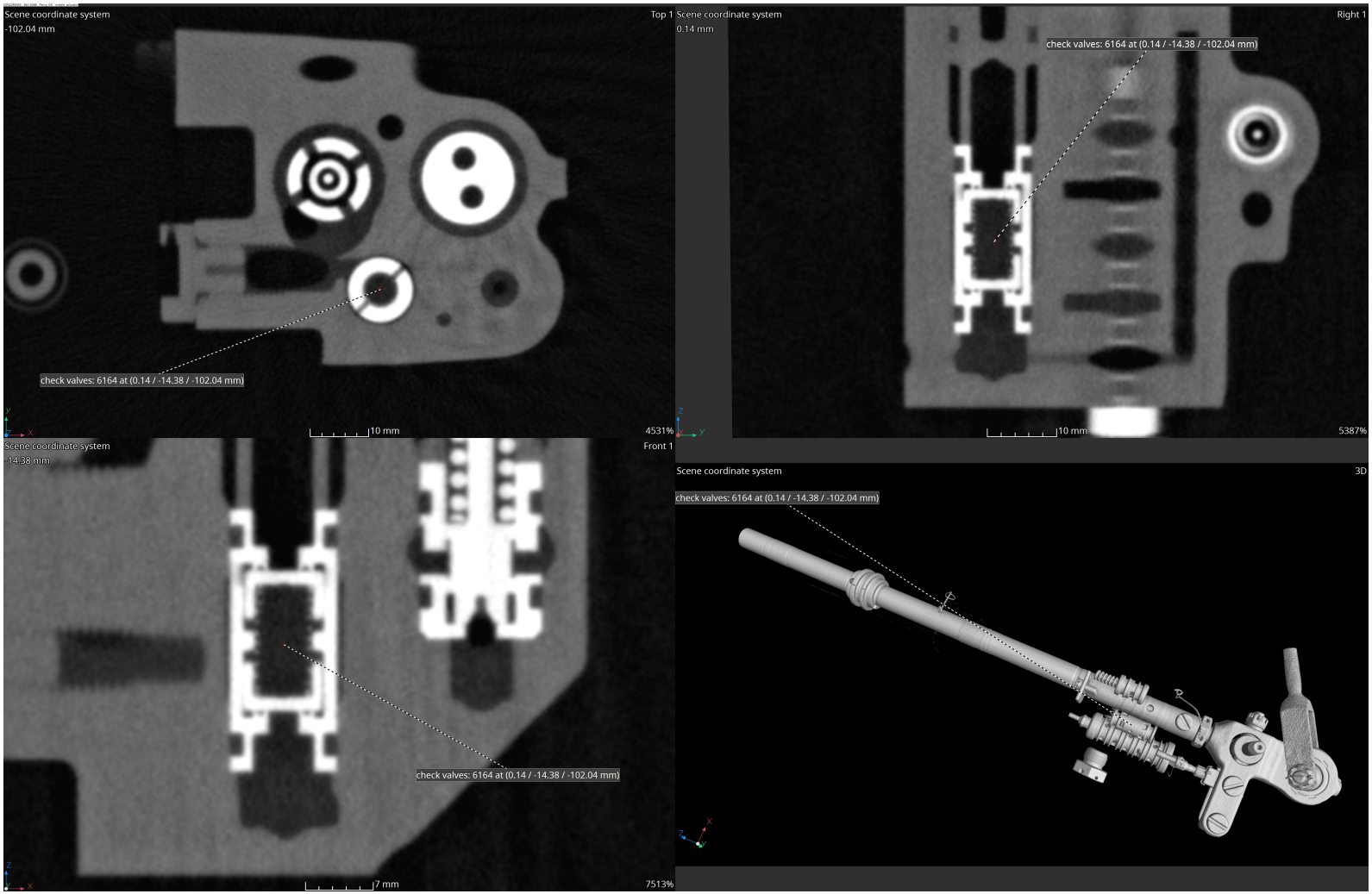


Figure 46
Middle actuator – 6 MV – check valves

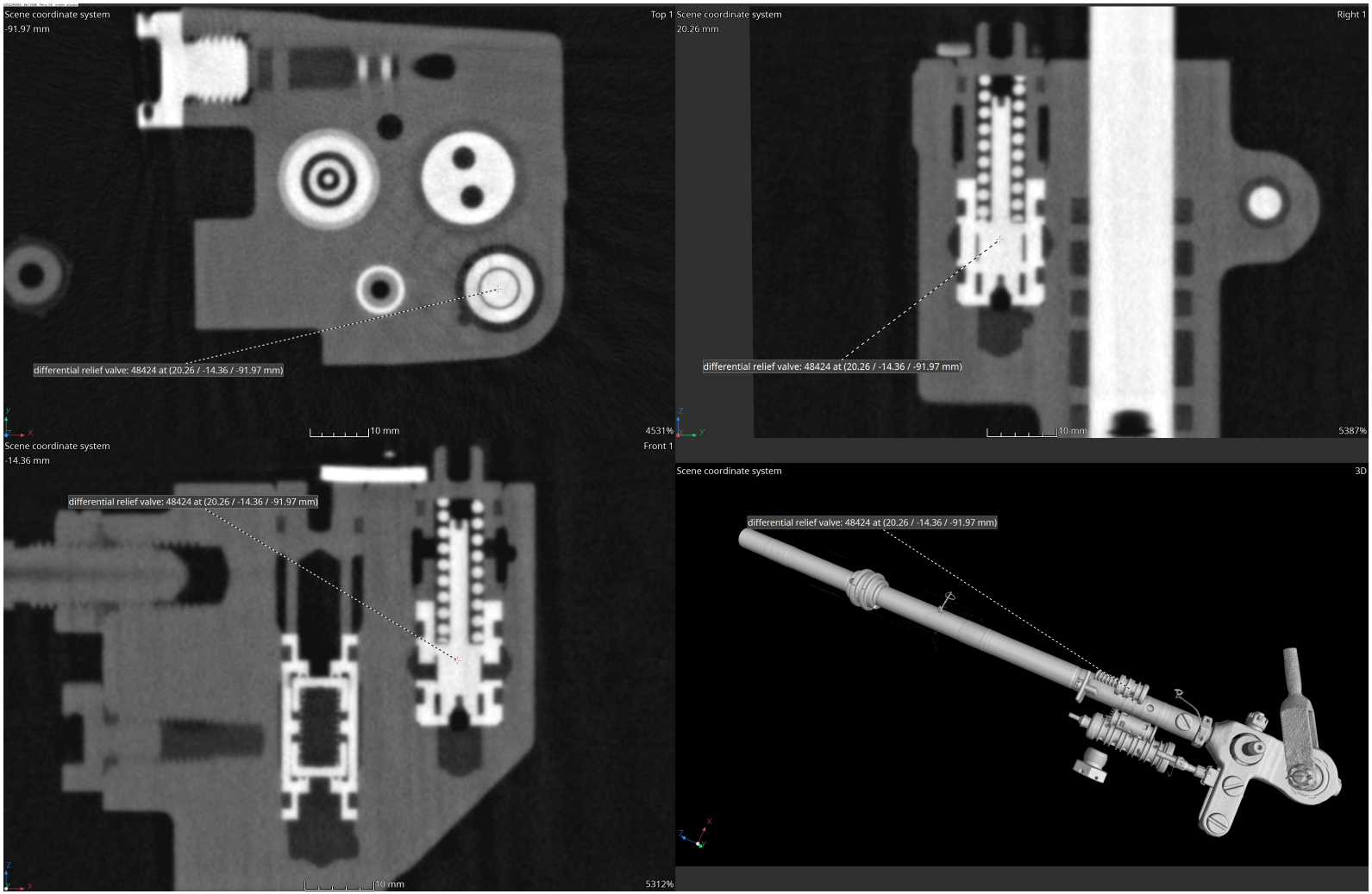


Figure 47
Middle actuator – 6 MV – differential relief valve

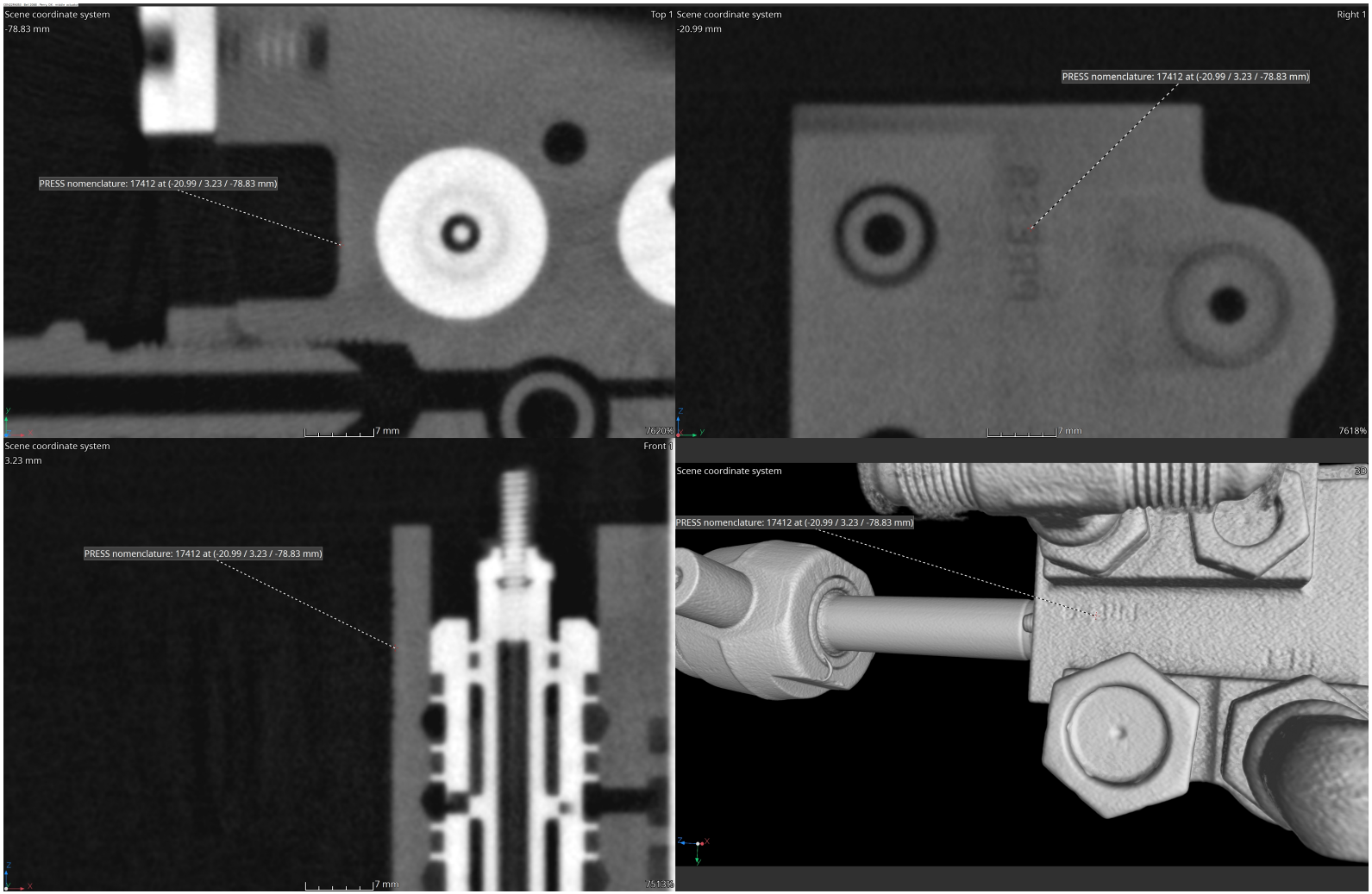


Figure 48
Middle actuator – 6 MV – PRESS nomenclature

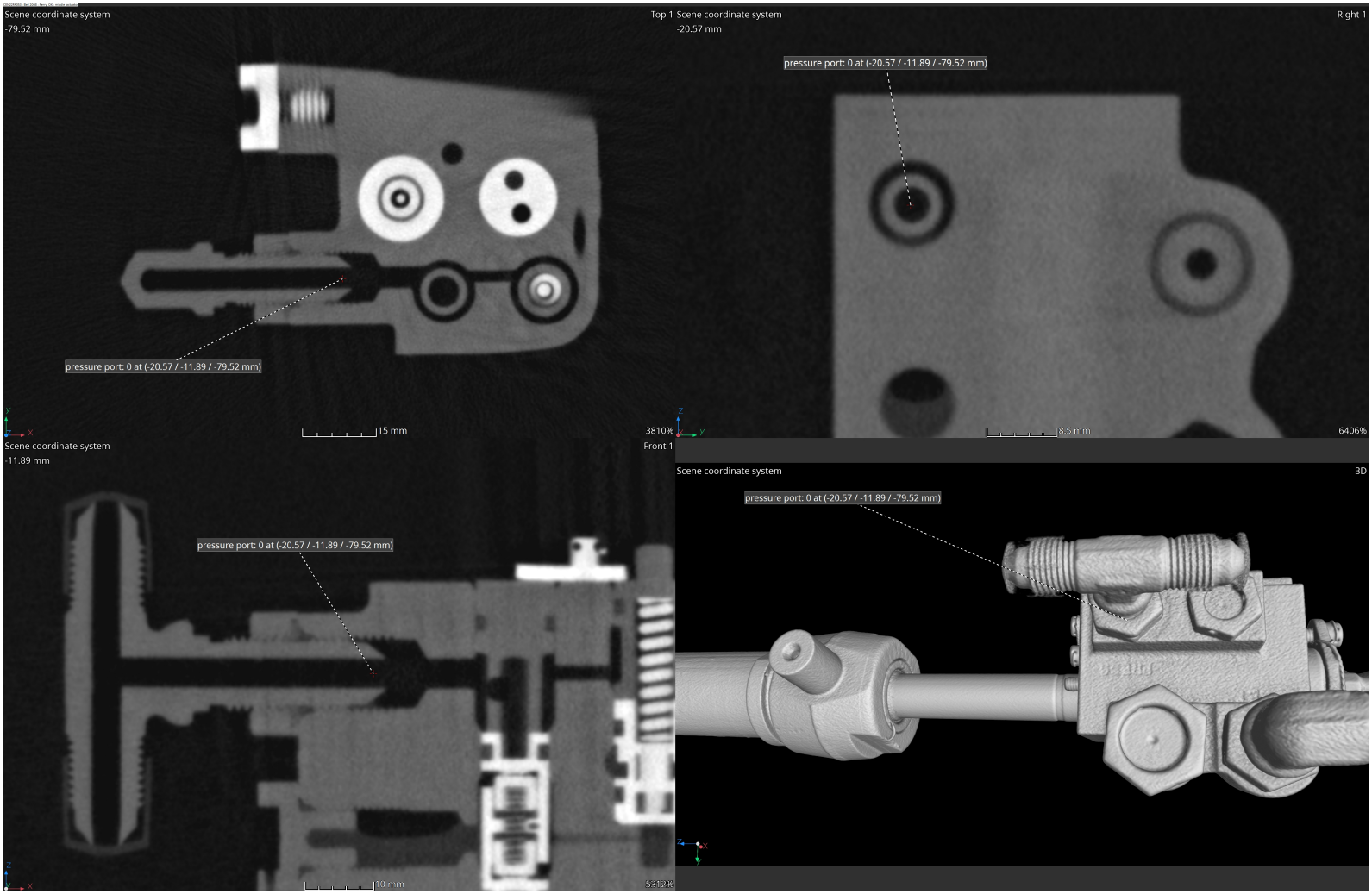


Figure 49
Middle actuator – 6 MV – pressure port

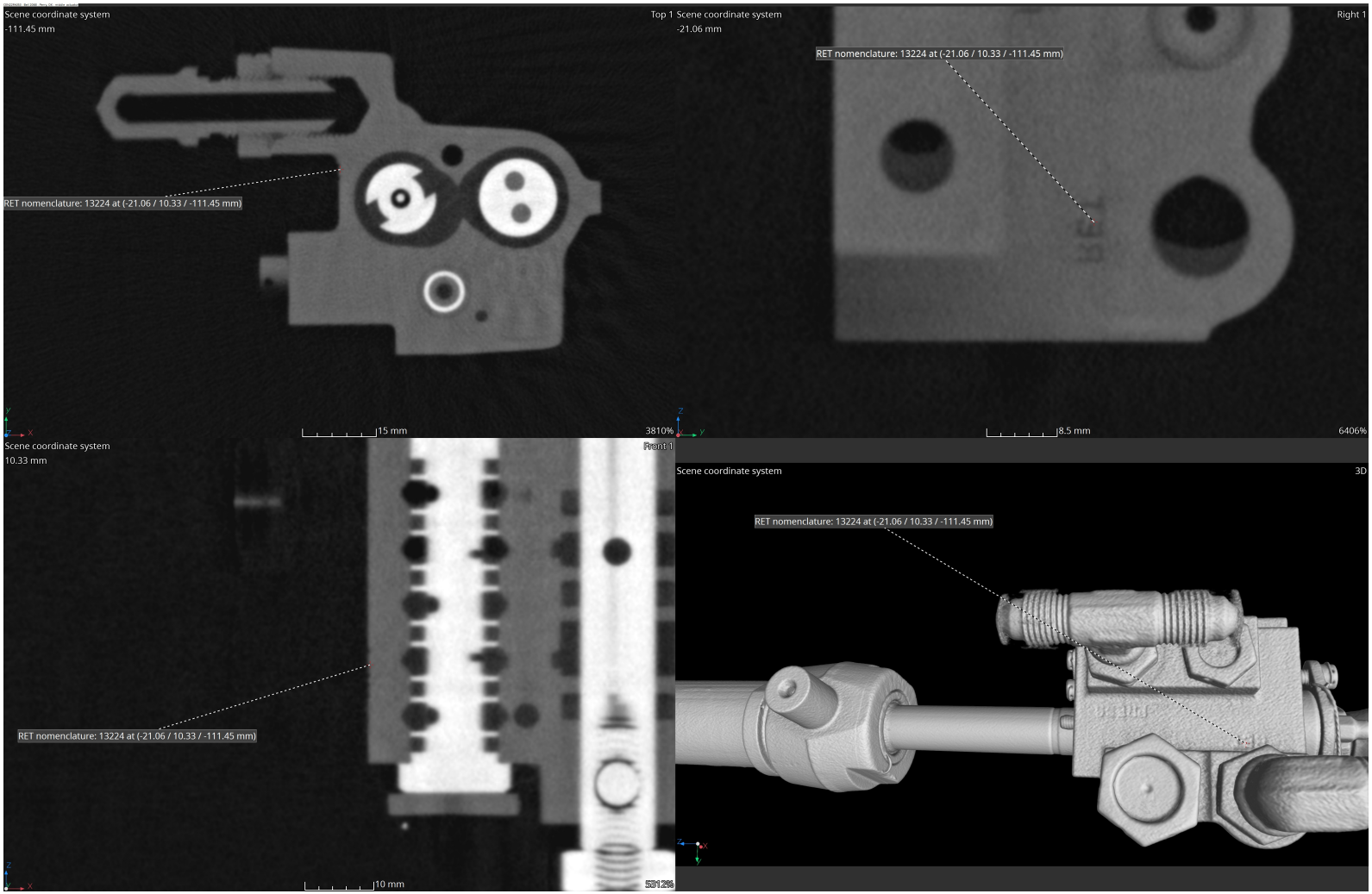


Figure 50
Middle actuator – 6 MV – RET nomenclature

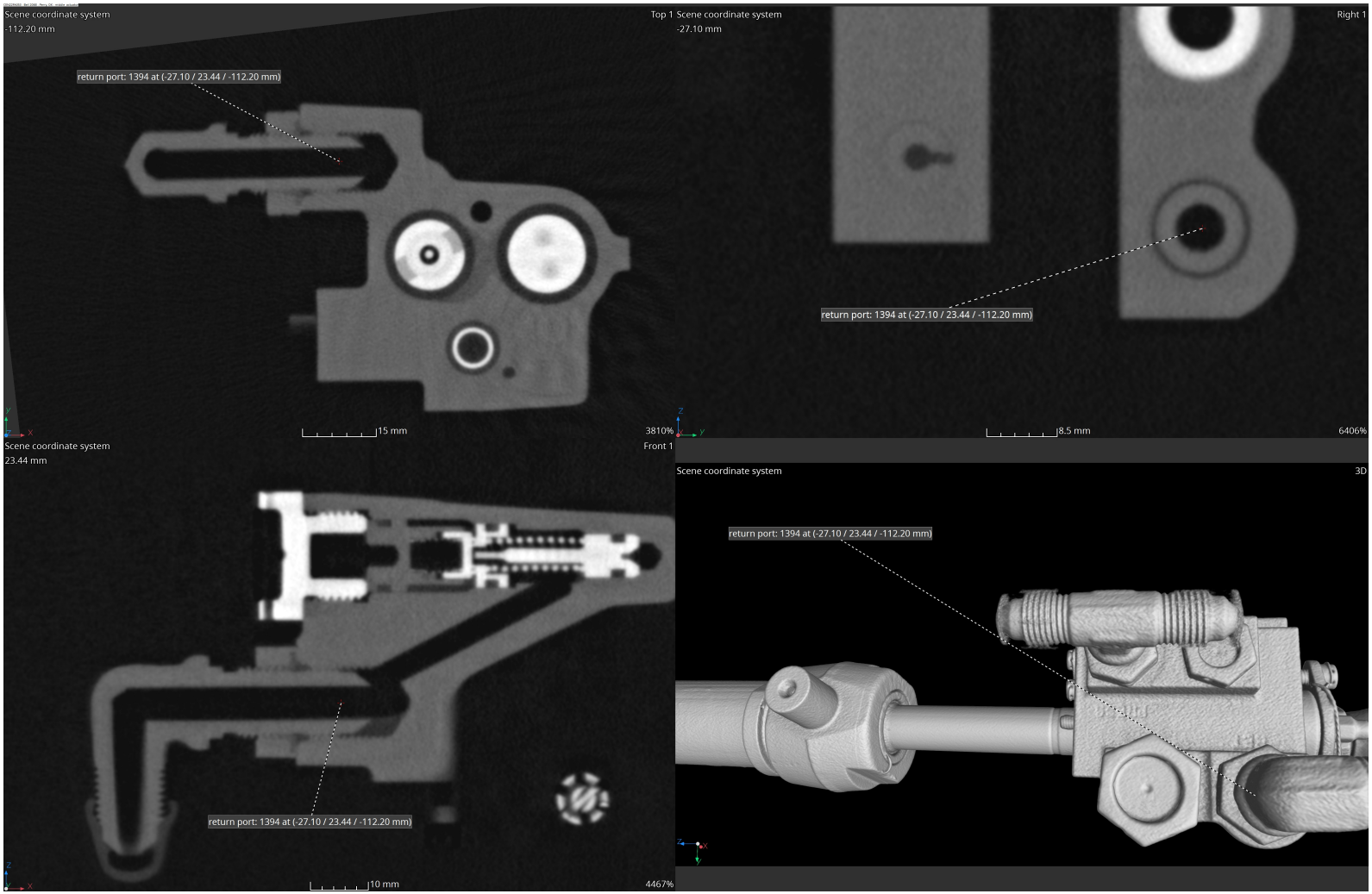


Figure 51
Middle actuator – 6 MV – return port

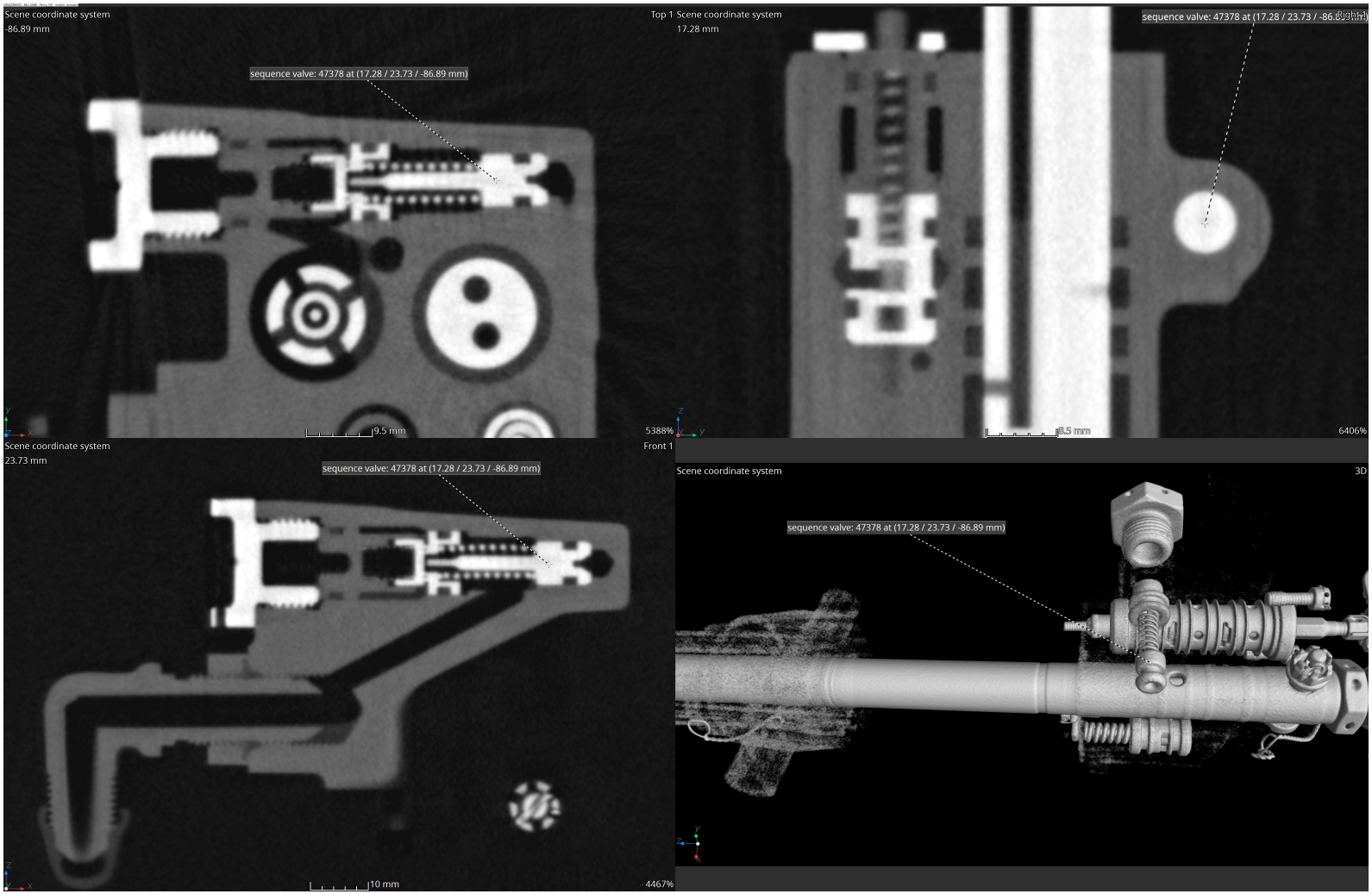


Figure 52
Middle actuator – 6 MV – sequence valve

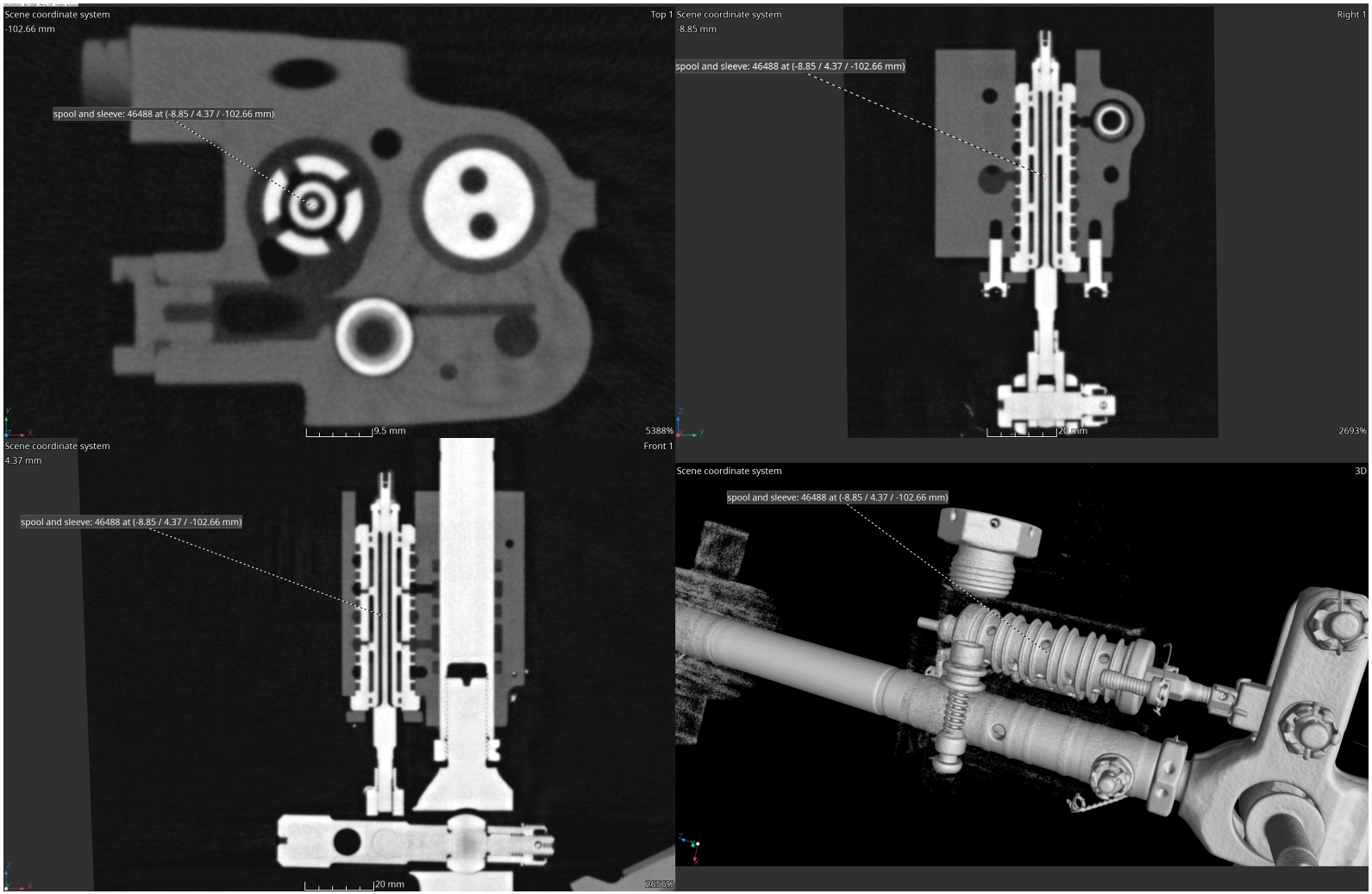


Figure 53
Middle actuator – 6 MV – spool and sleeve

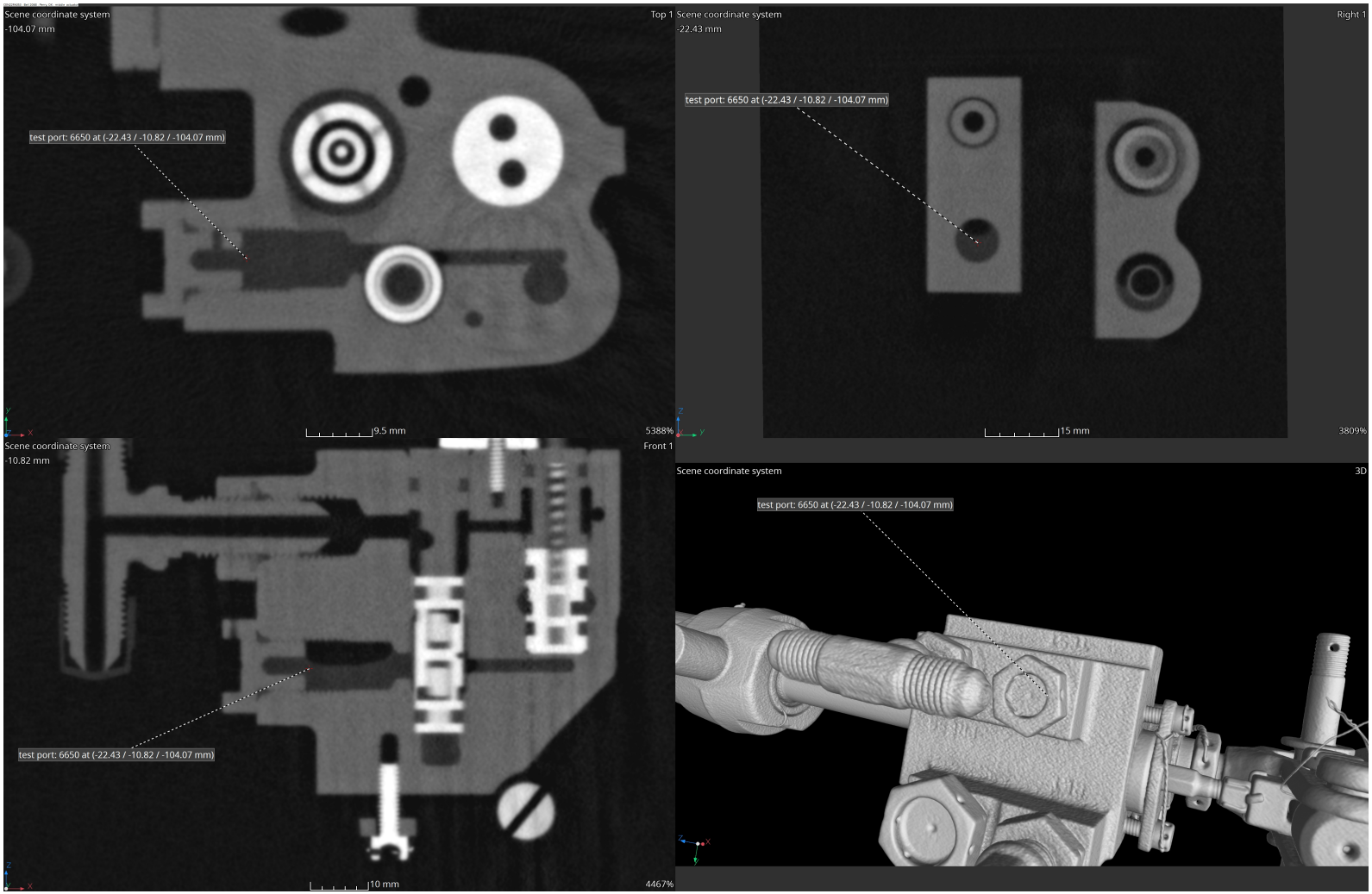


Figure 54
Middle actuator – 6 MV – test port

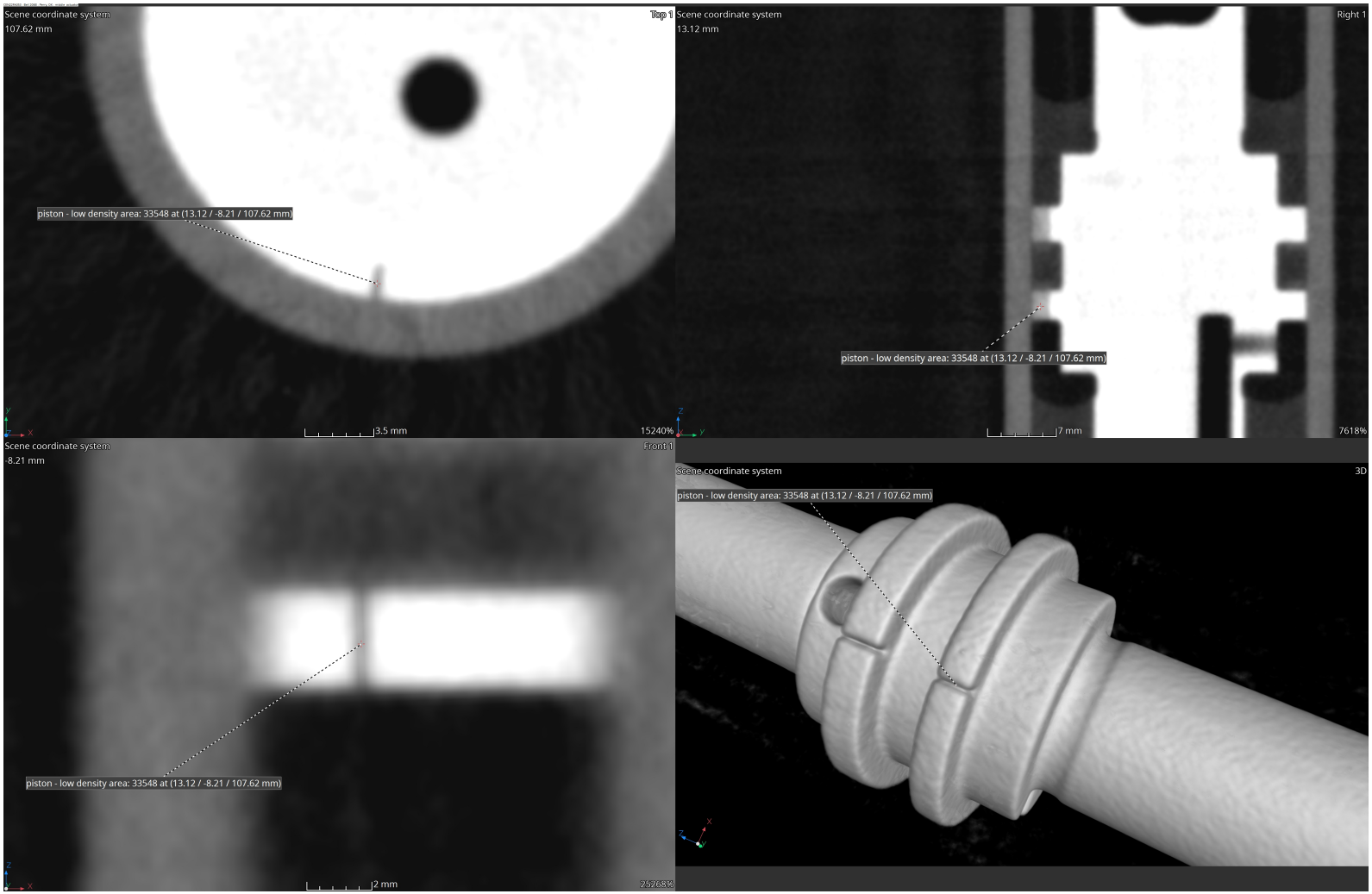


Figure 55
Middle actuator – 6 MV – piston head – low density area

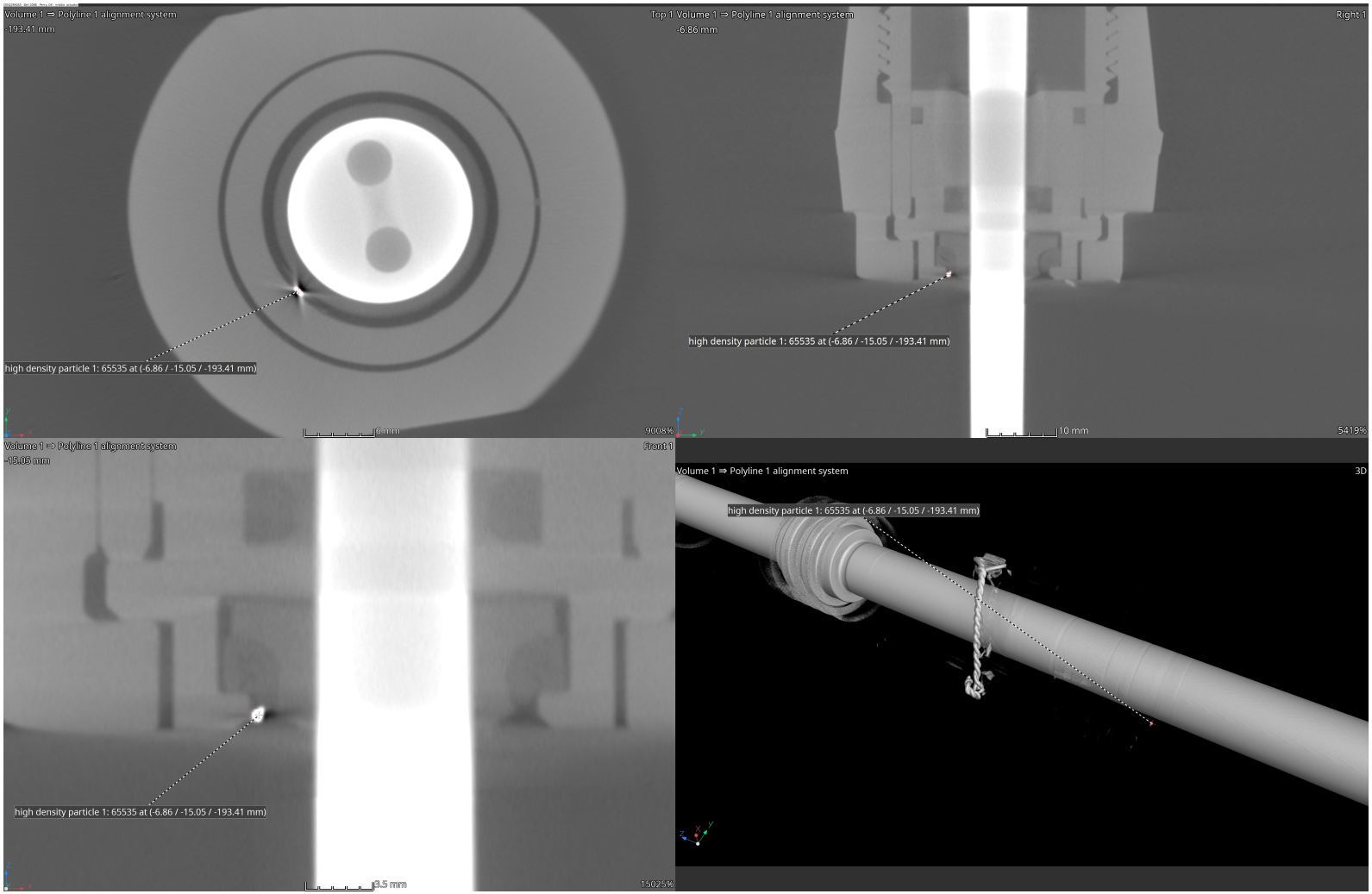


Figure 56
Middle actuator – microfocus – high density particle 1

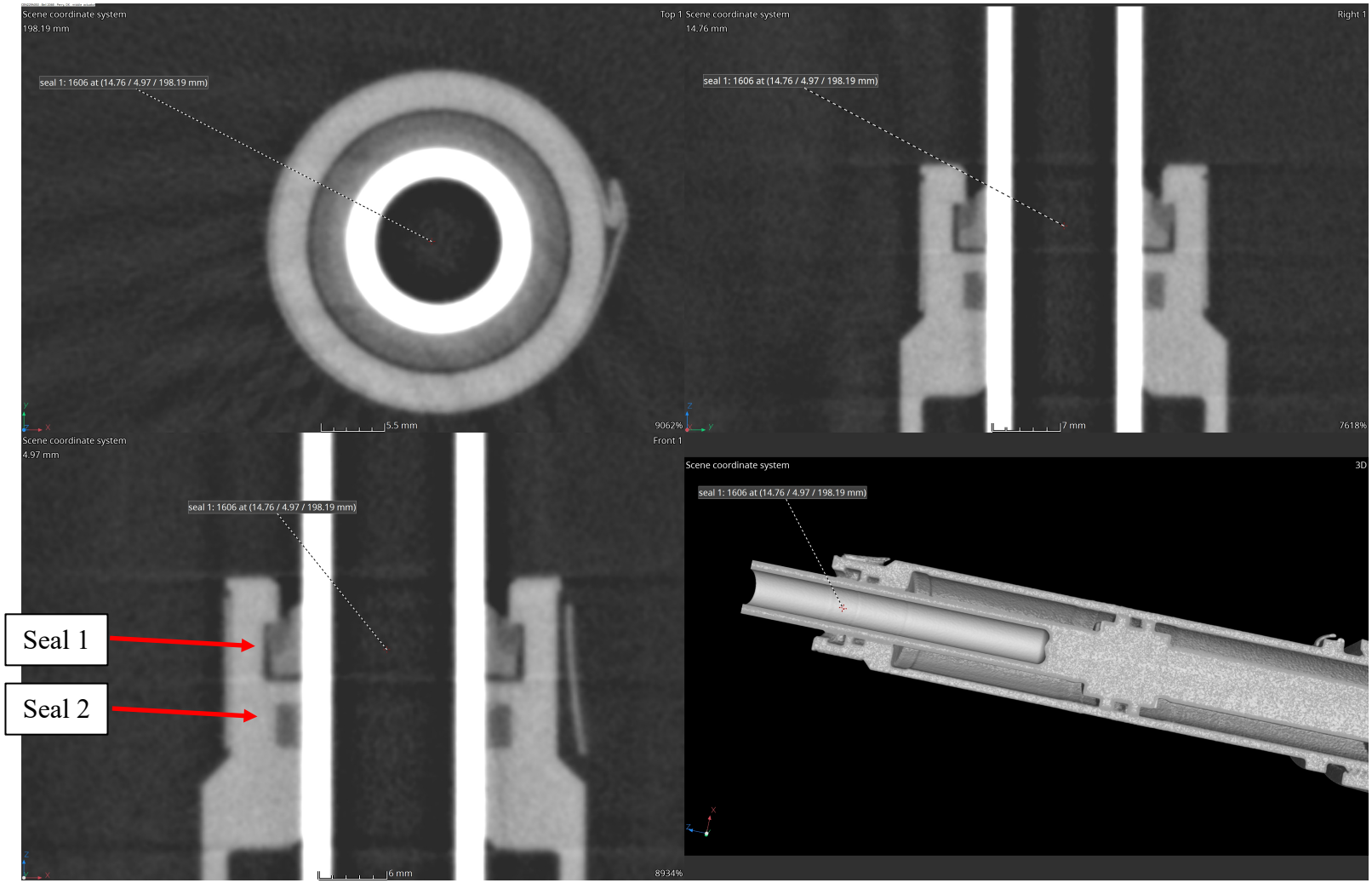


Figure 57
Middle actuator – 6 MV – seal 1

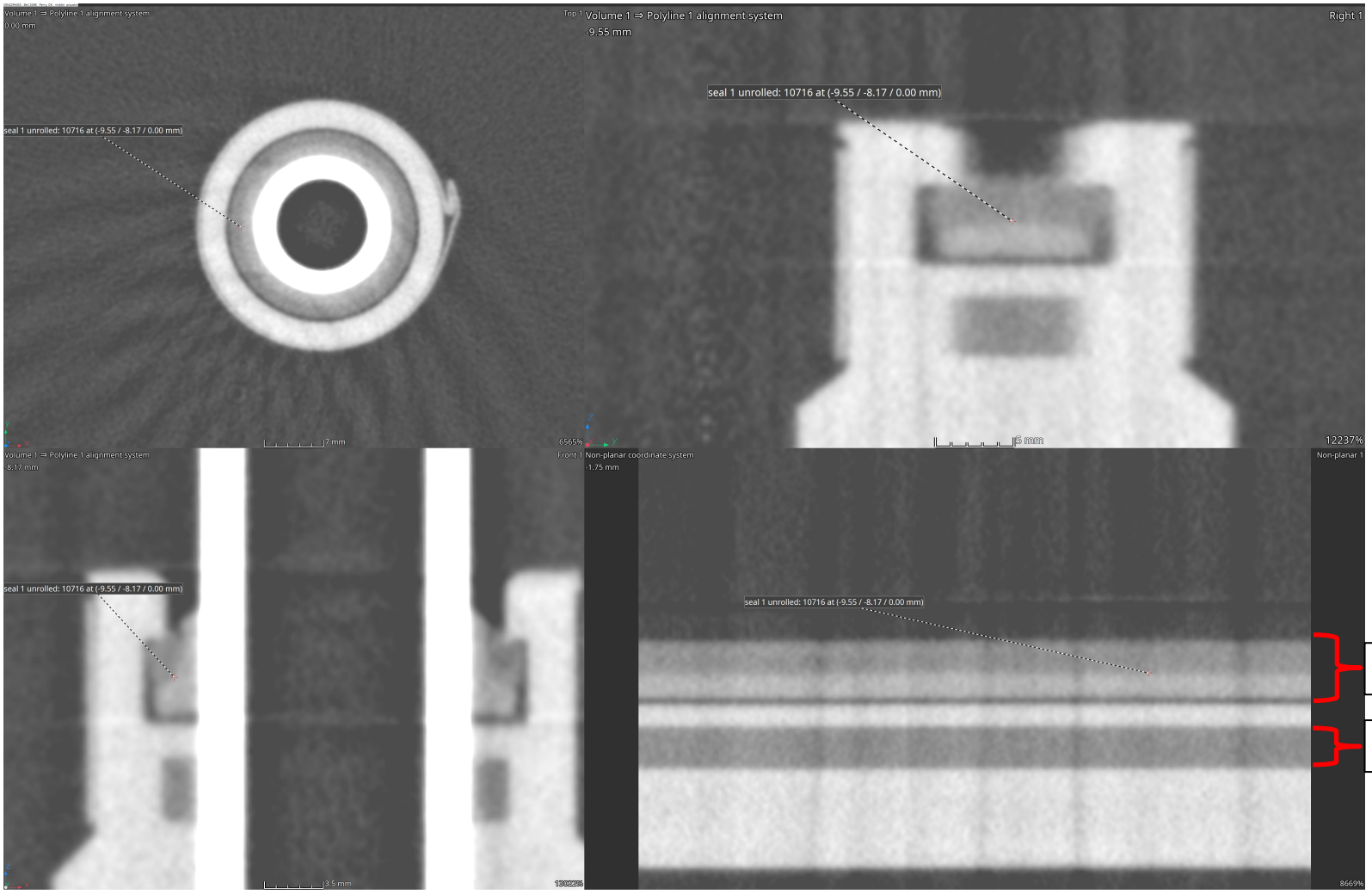


Figure 58
Middle actuator – 6 MV – seal 1 unrolled

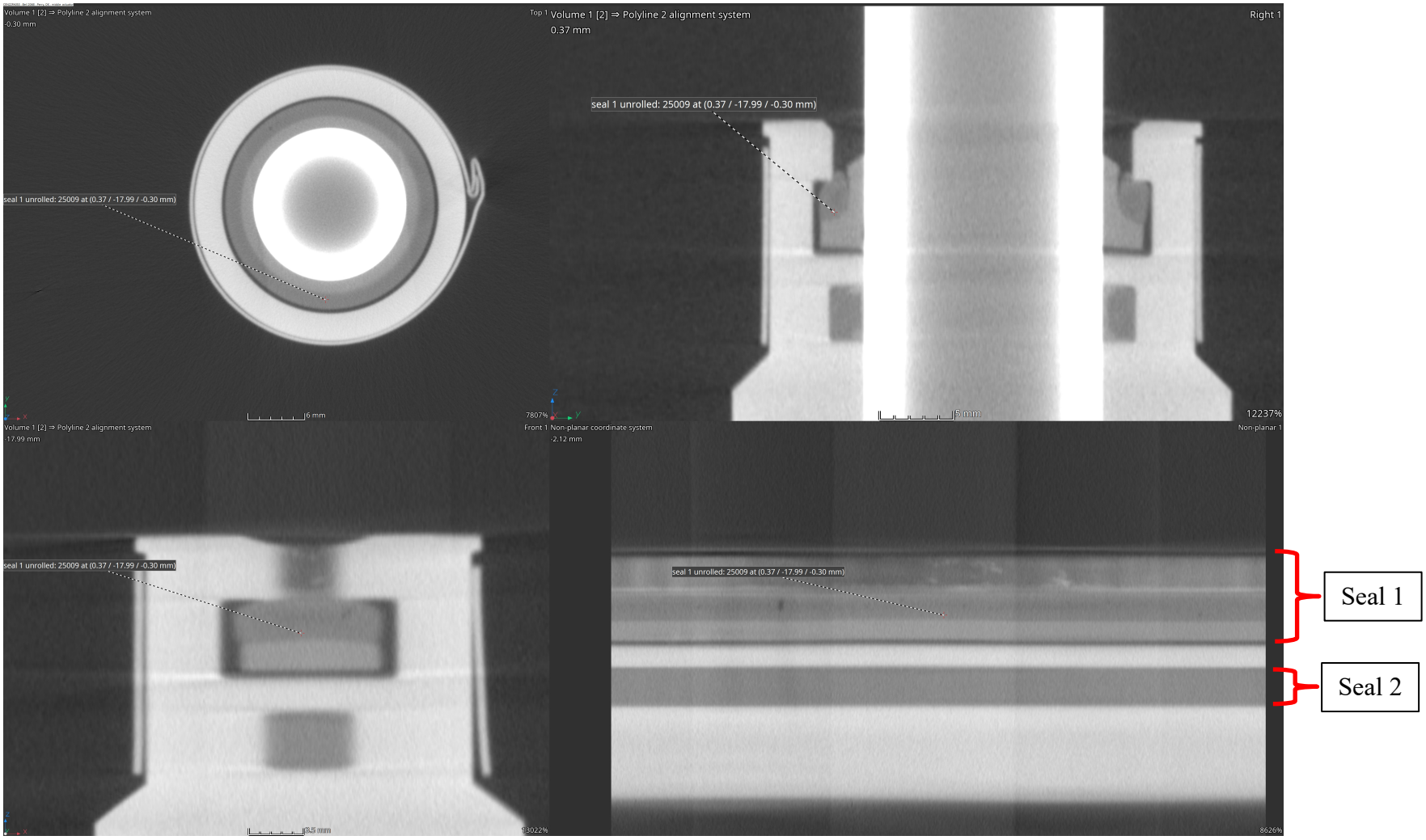


Figure 59
Middle actuator – microfocus – seal 1 unrolled

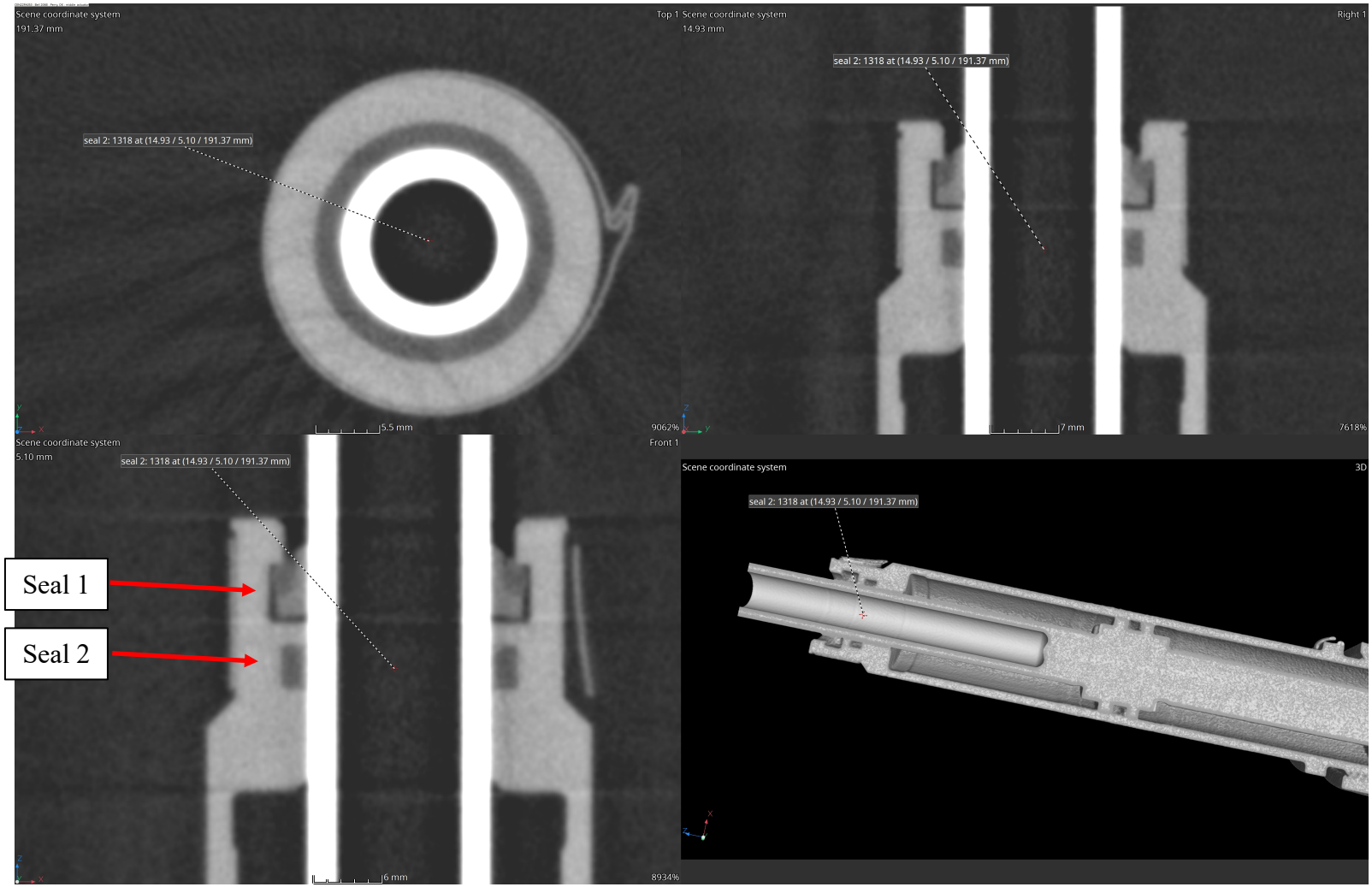


Figure 60
Middle actuator – 6 MV – seal 2

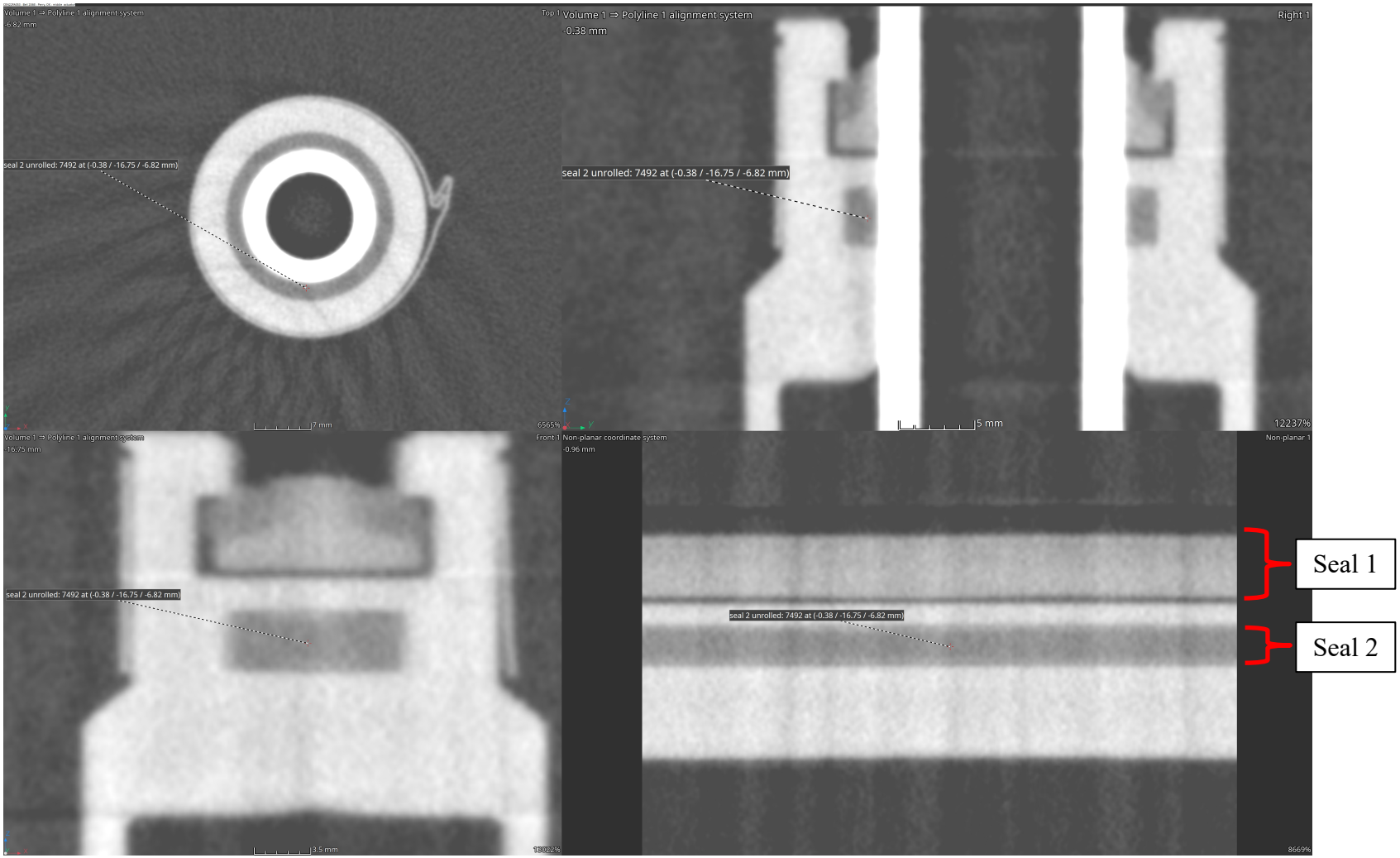


Figure 61
Middle actuator – 6 MV – seal 2 unrolled

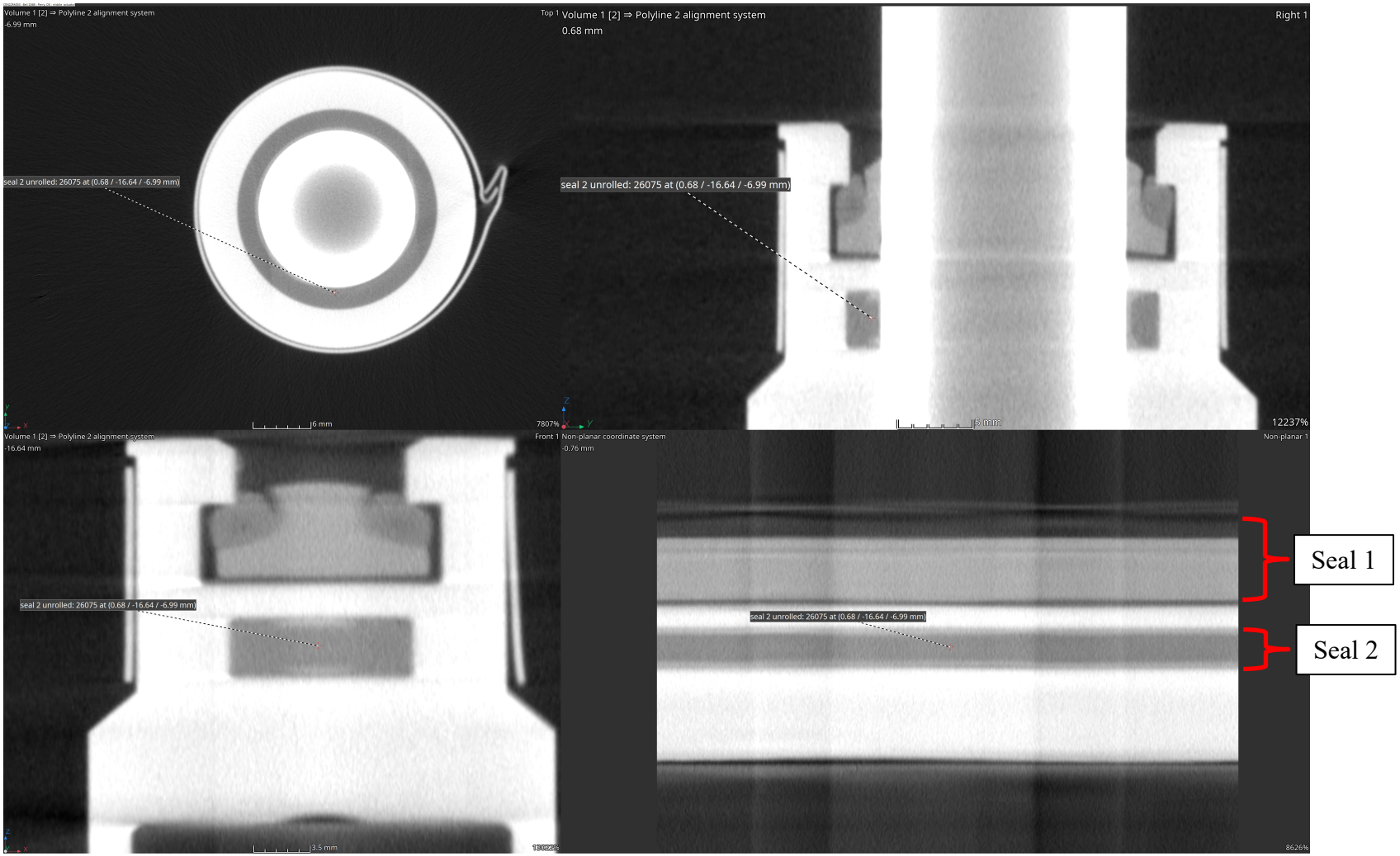


Figure 62
Middle actuator – microfocus – seal 2 unrolled

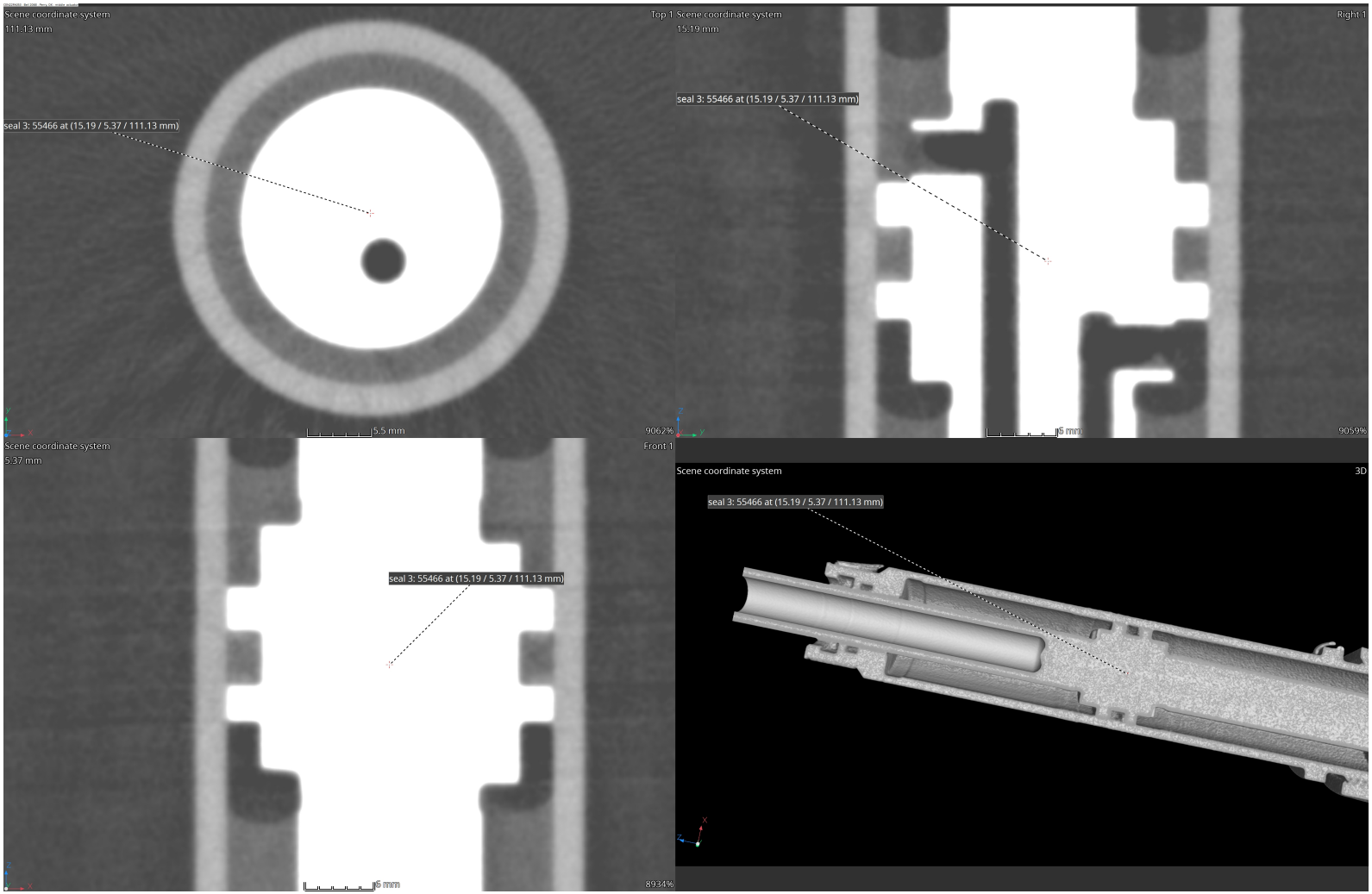


Figure 63
Middle actuator – 6 MV – seal 3

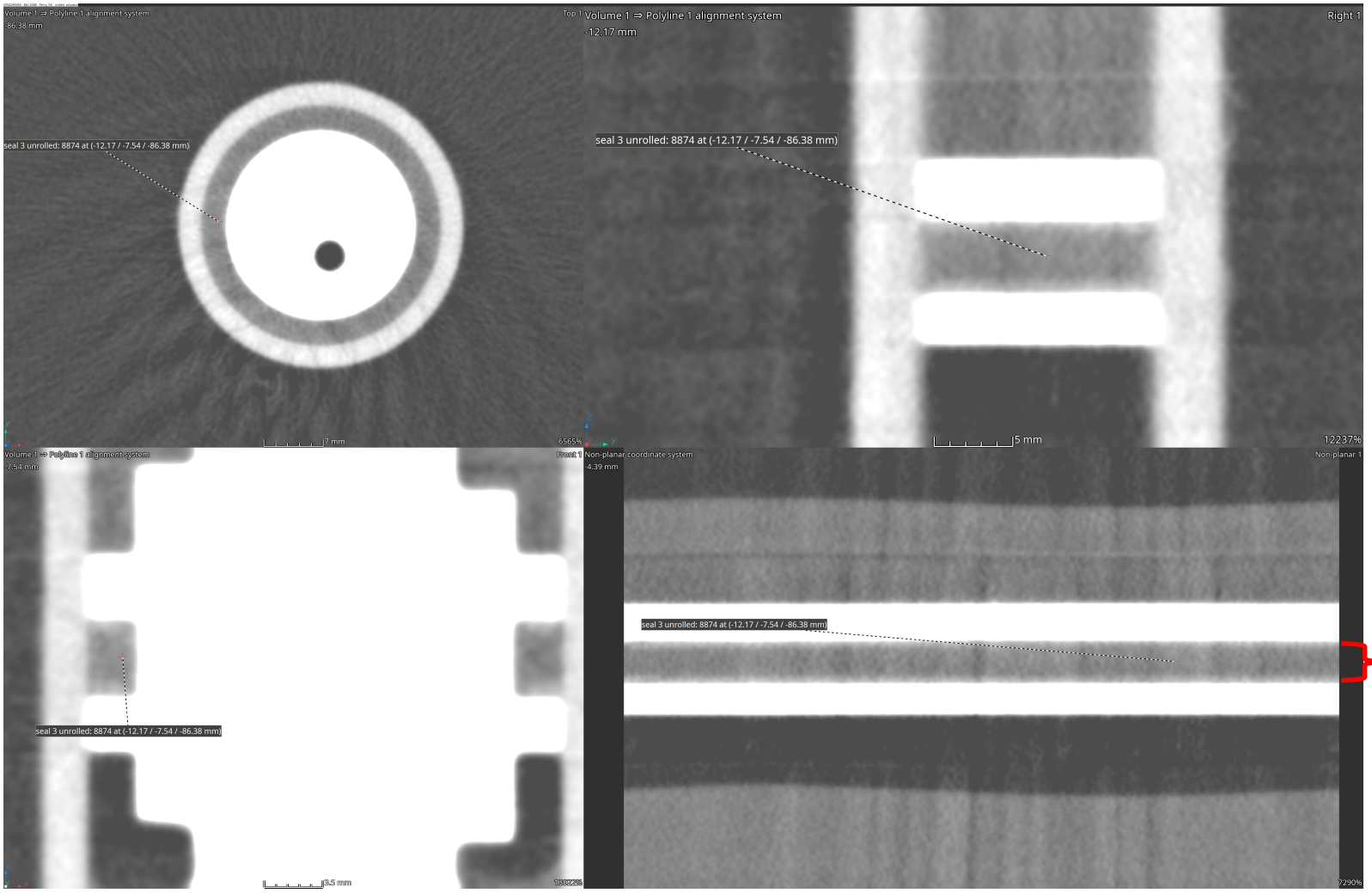


Figure 64
Middle actuator – 6 MV – seal 3 unrolled



Figure 65
Middle actuator – microfocus – seal 3 unrolled

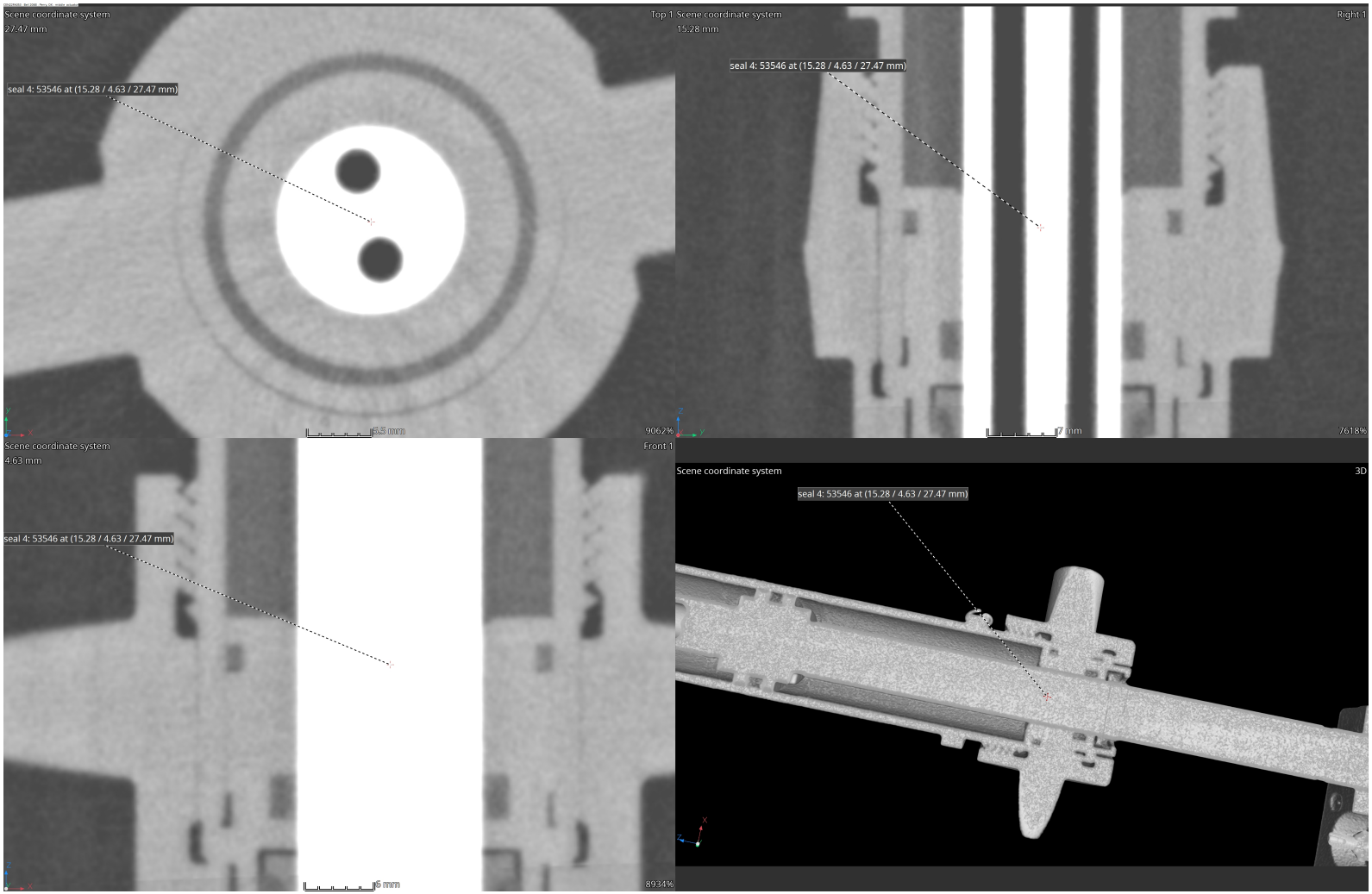


Figure 66
Middle actuator – 6 MV – seal 4

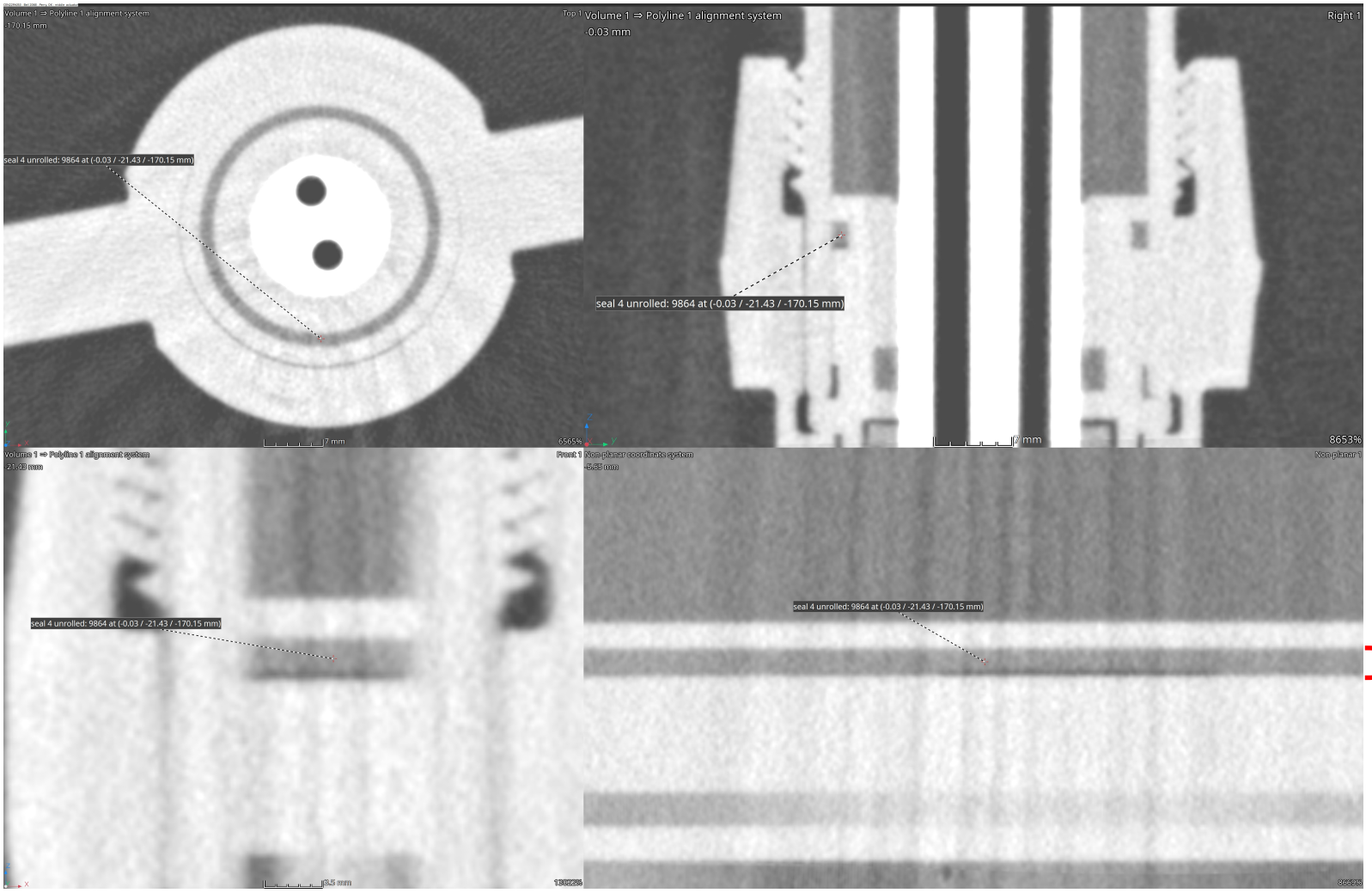


Figure 67
Middle actuator – 6 MV – seal 4 unrolled

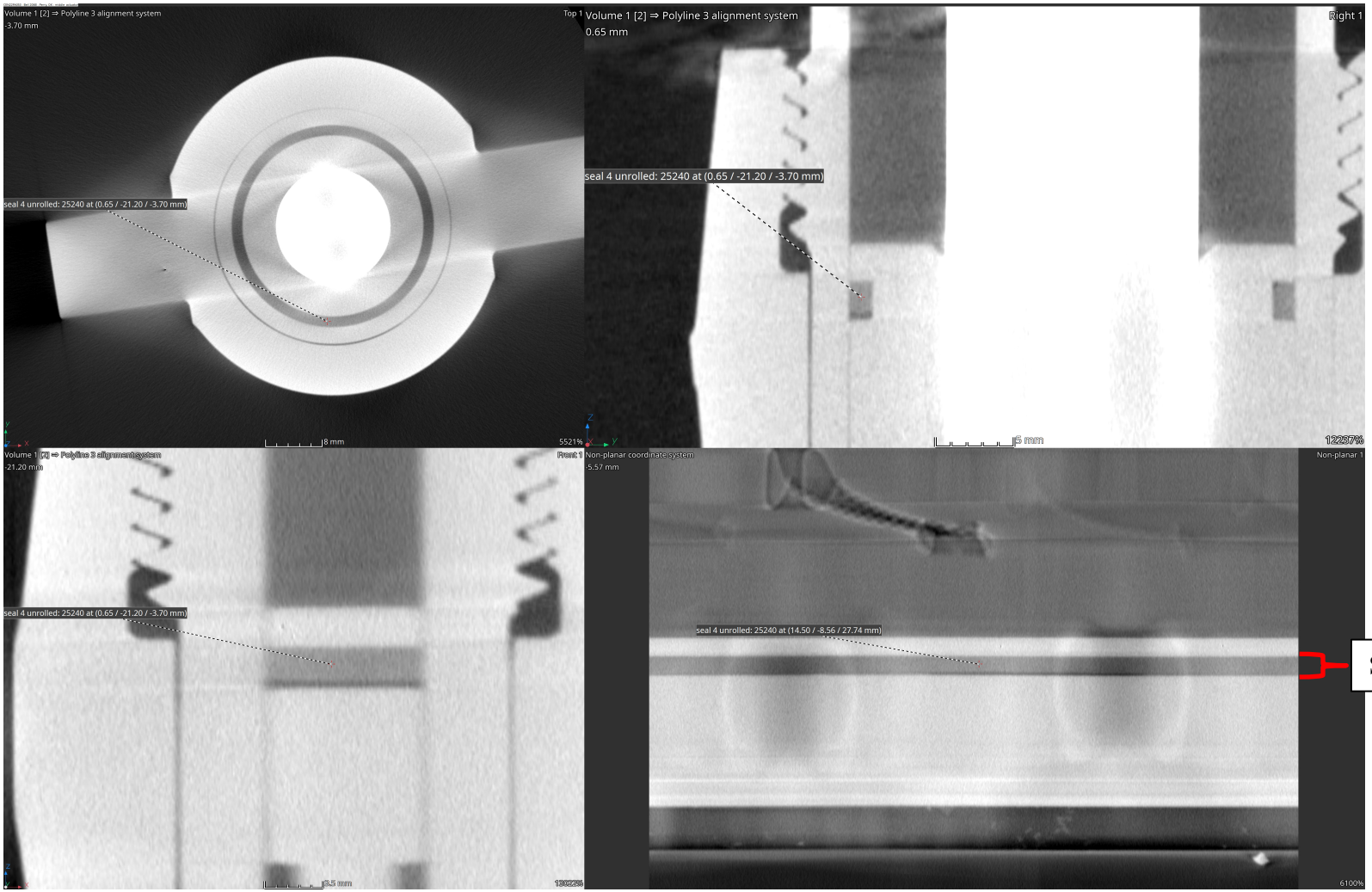


Figure 68
Middle actuator – microfocus – seal 4 unrolled

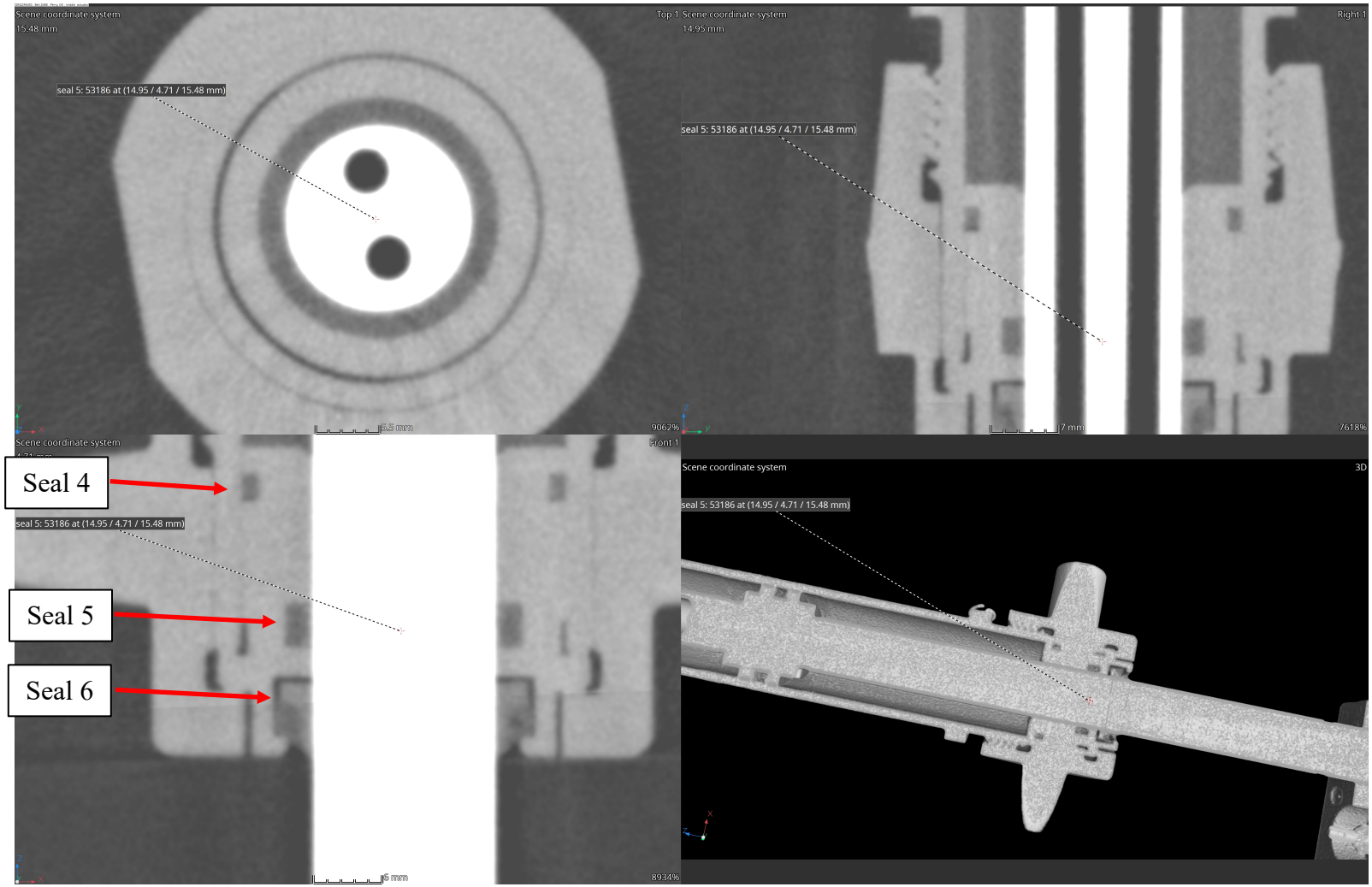


Figure 69
Middle actuator – 6 MV – seal 5

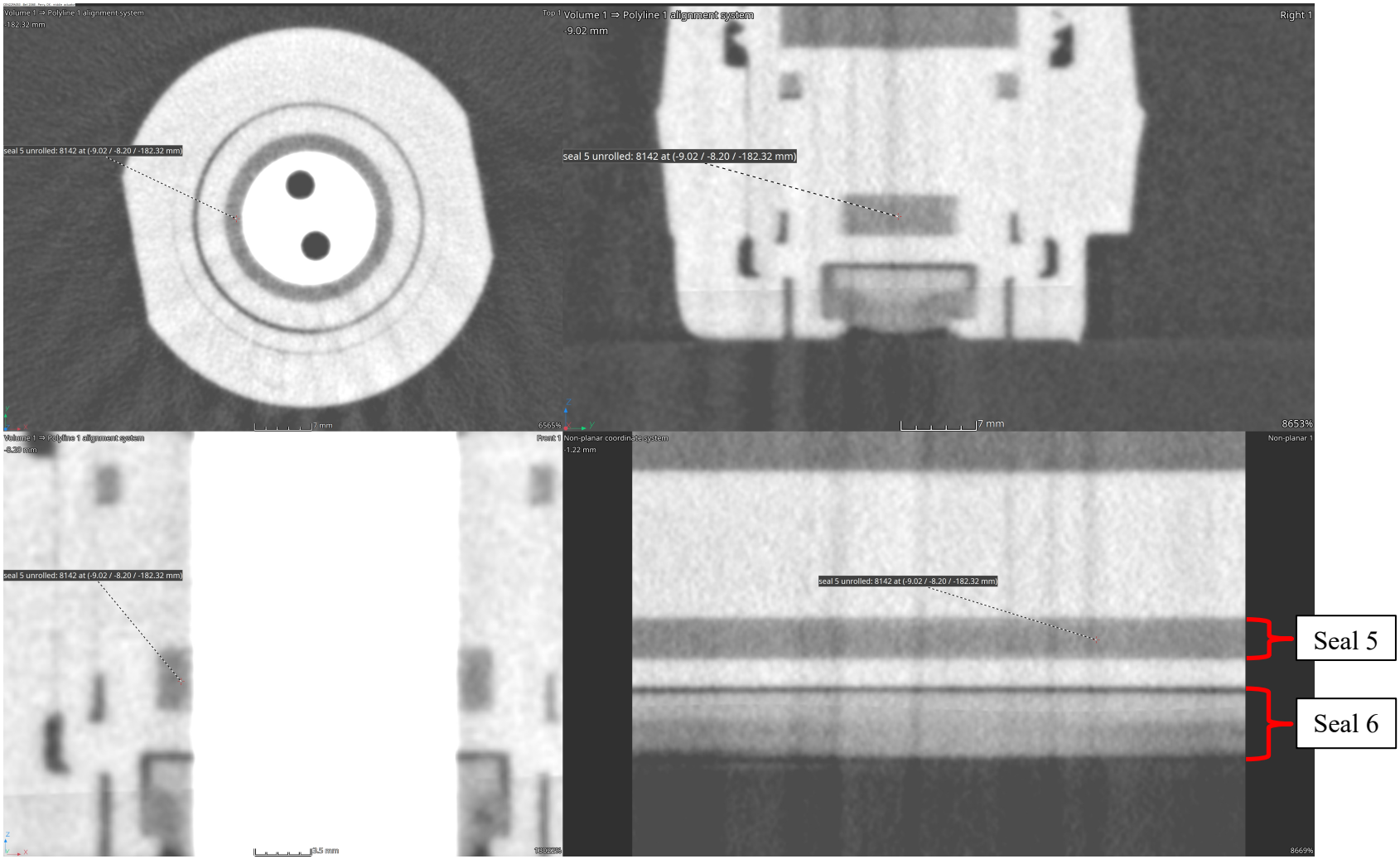


Figure 70
Middle actuator – 6 MV – seal 5 unrolled

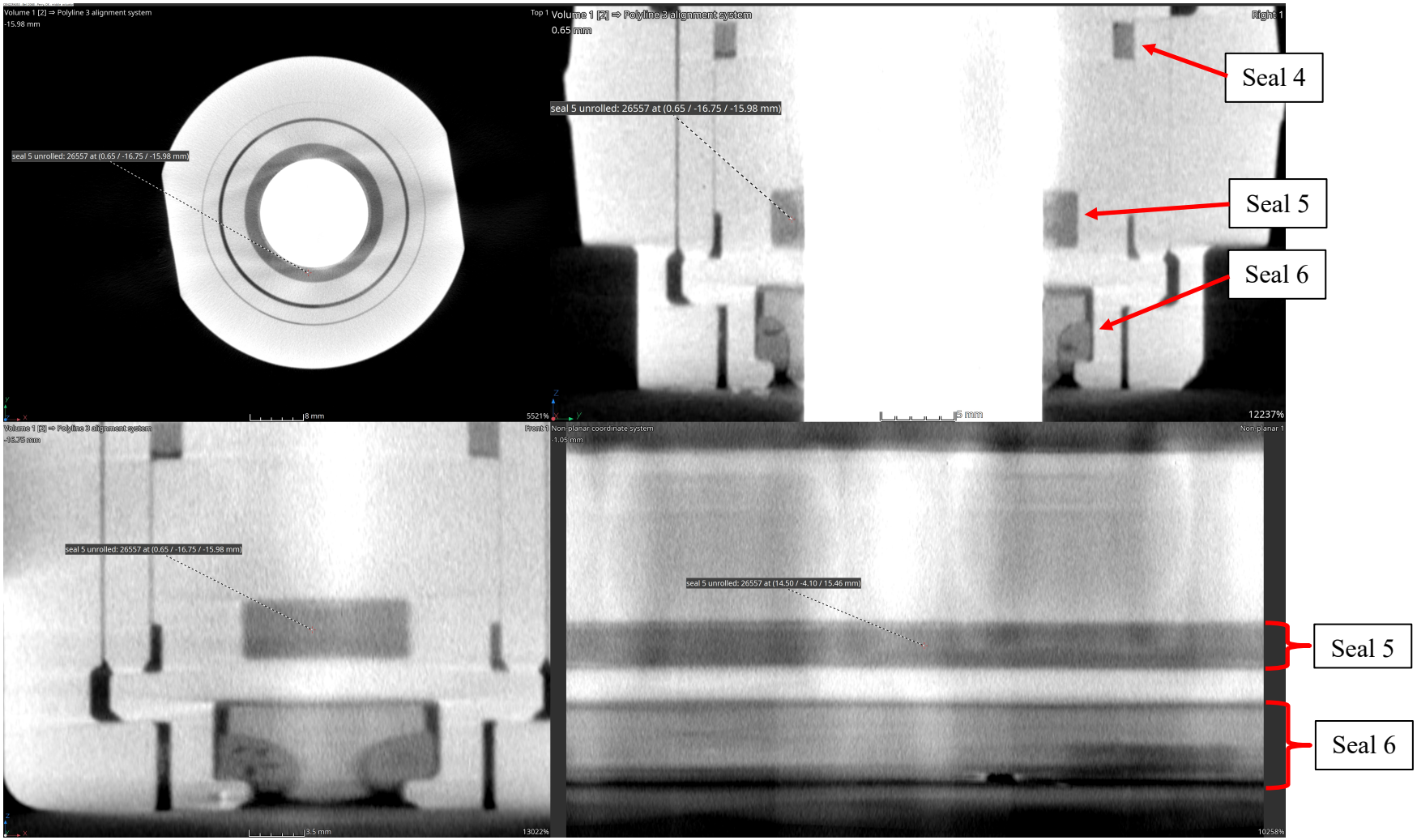


Figure 71
Middle actuator – microfocus – seal 5 unrolled

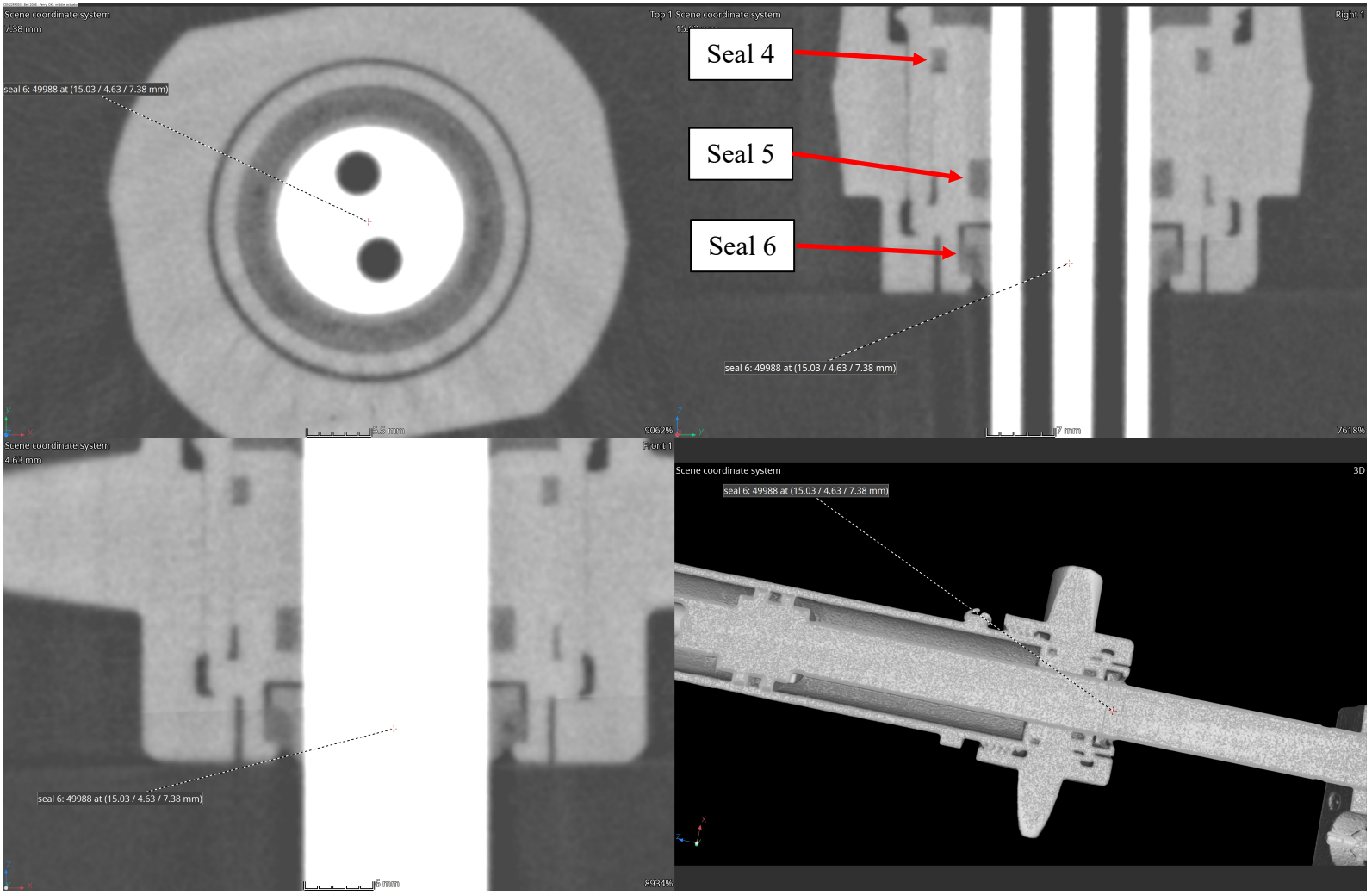


Figure 72
Middle actuator – 6 MV – seal 6

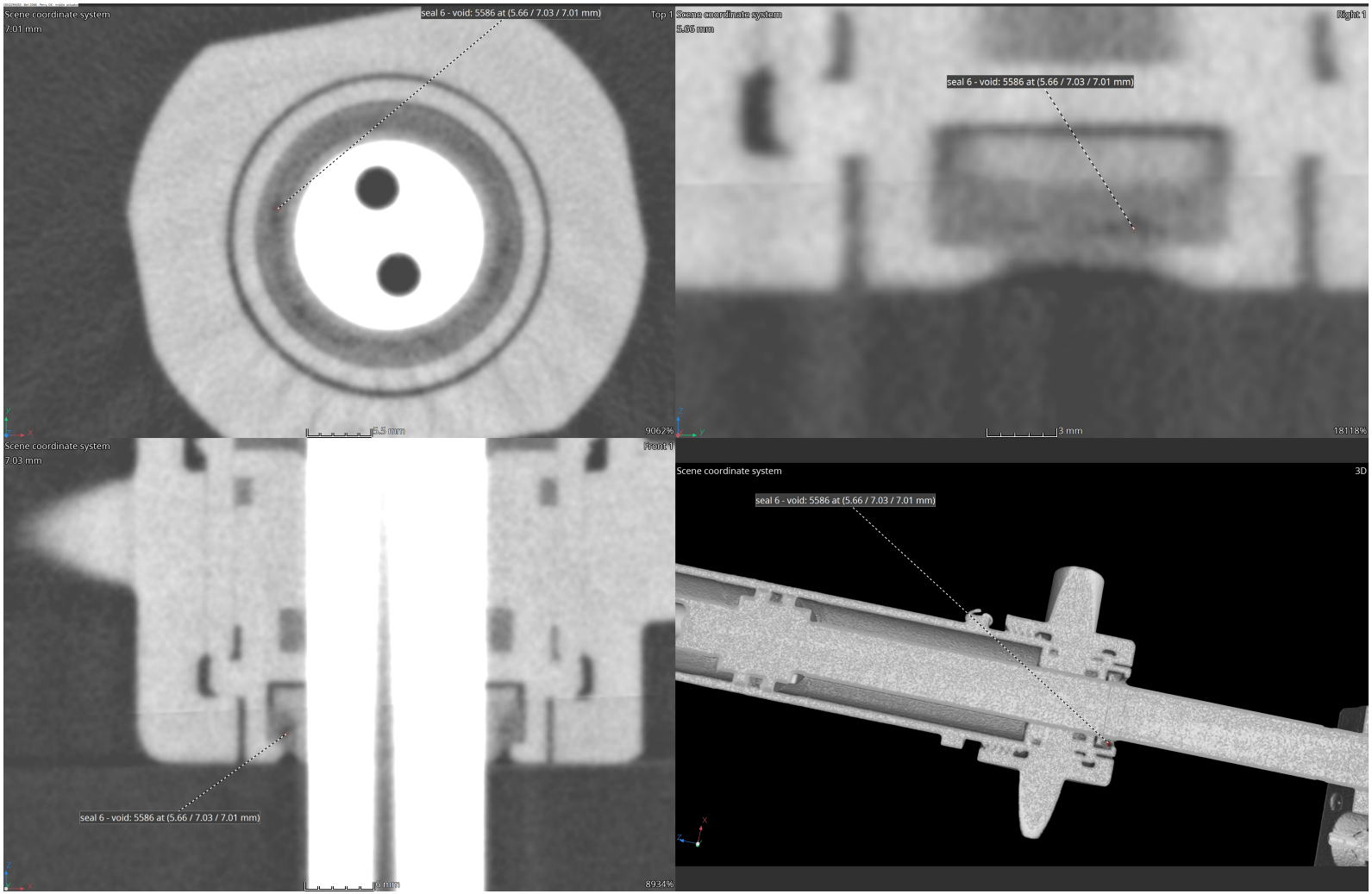


Figure 73
Middle actuator – 6 MV – seal 6 void



Figure 74
Middle actuator – 6 MV – seal 6 unrolled

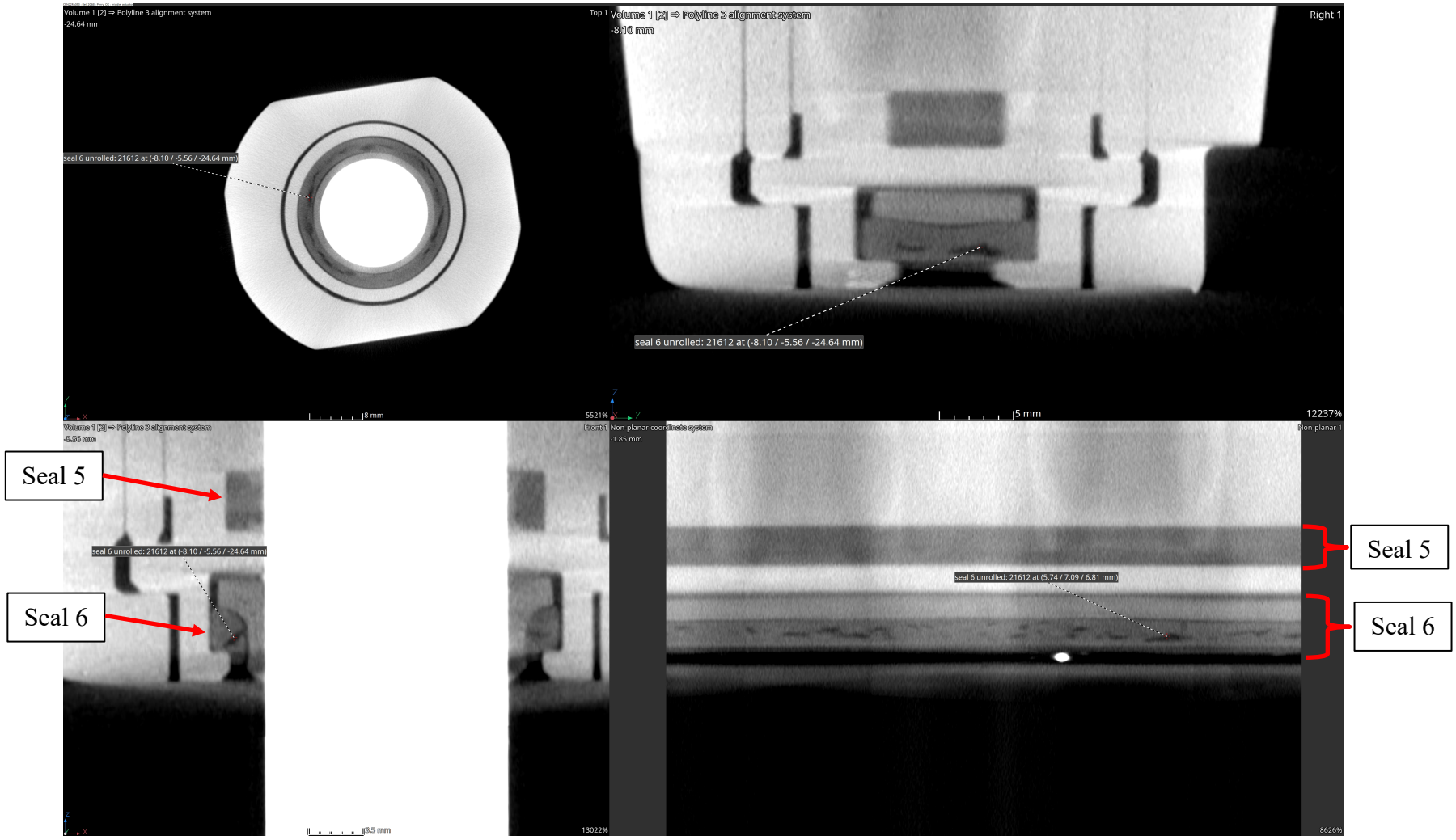


Figure 75
Middle actuator – microfocus – seal 6 unrolled

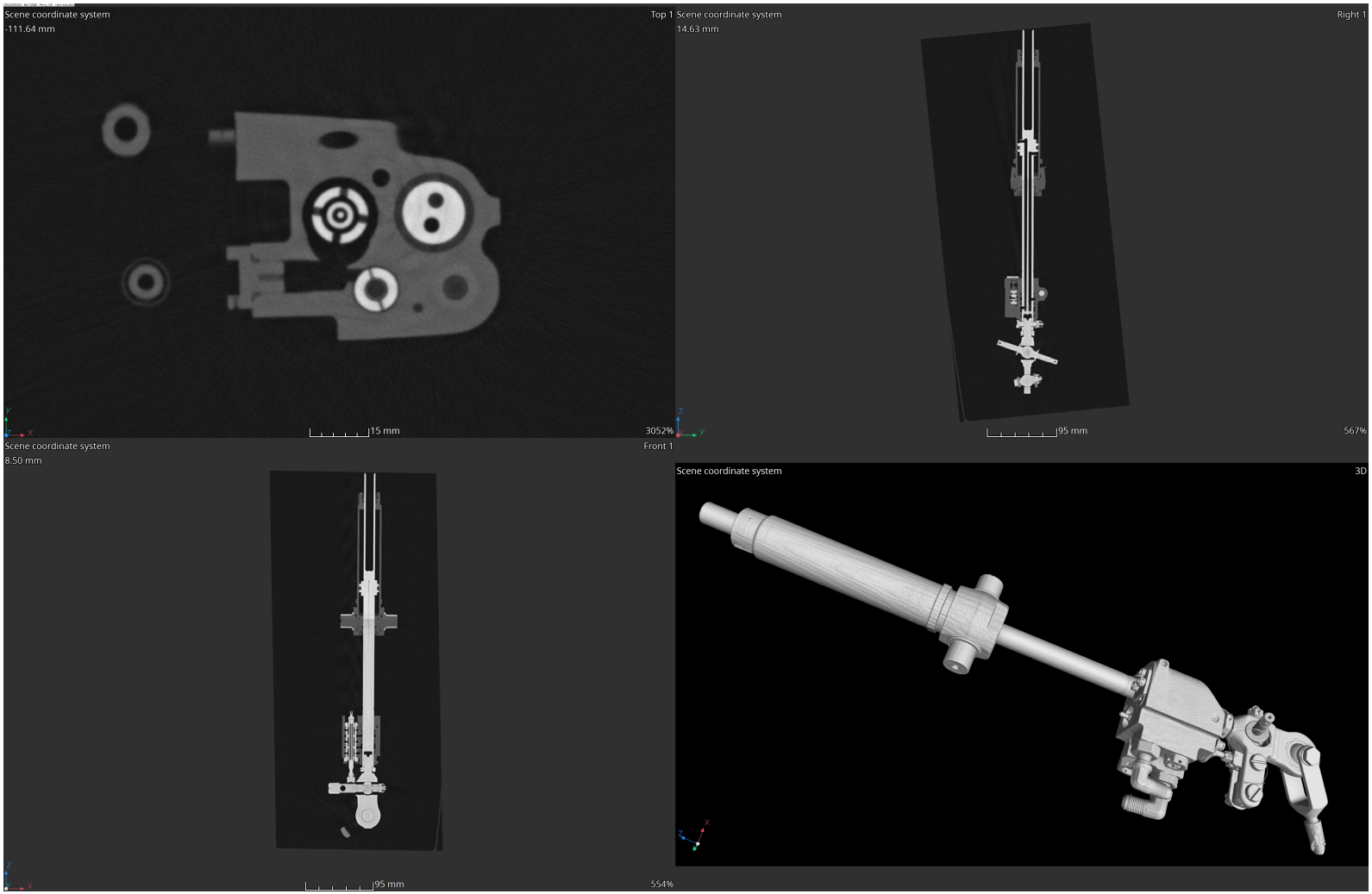


Figure 76
Right actuator – 6 MV – overview

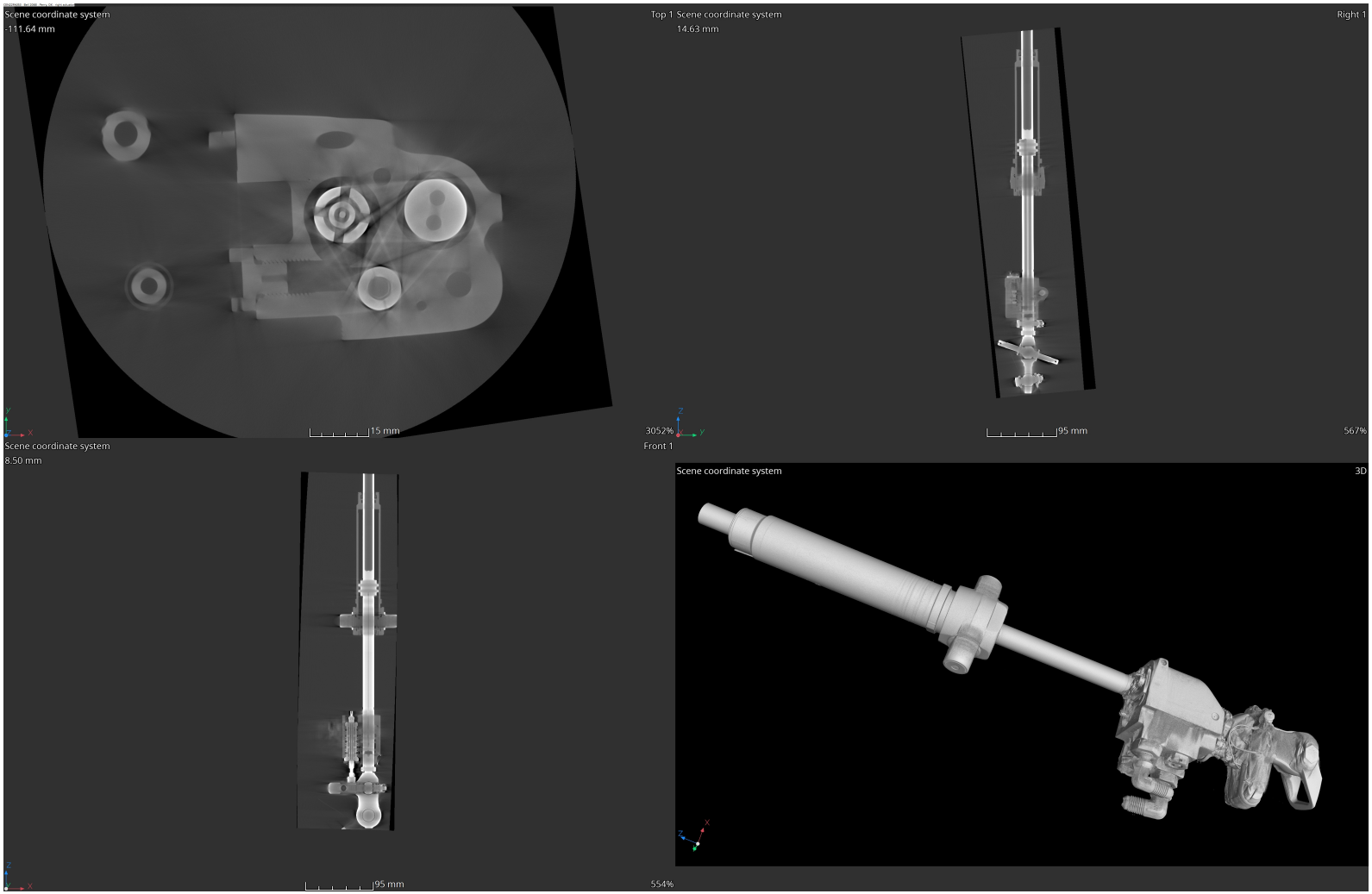


Figure 77
Right actuator – microfocus – overview

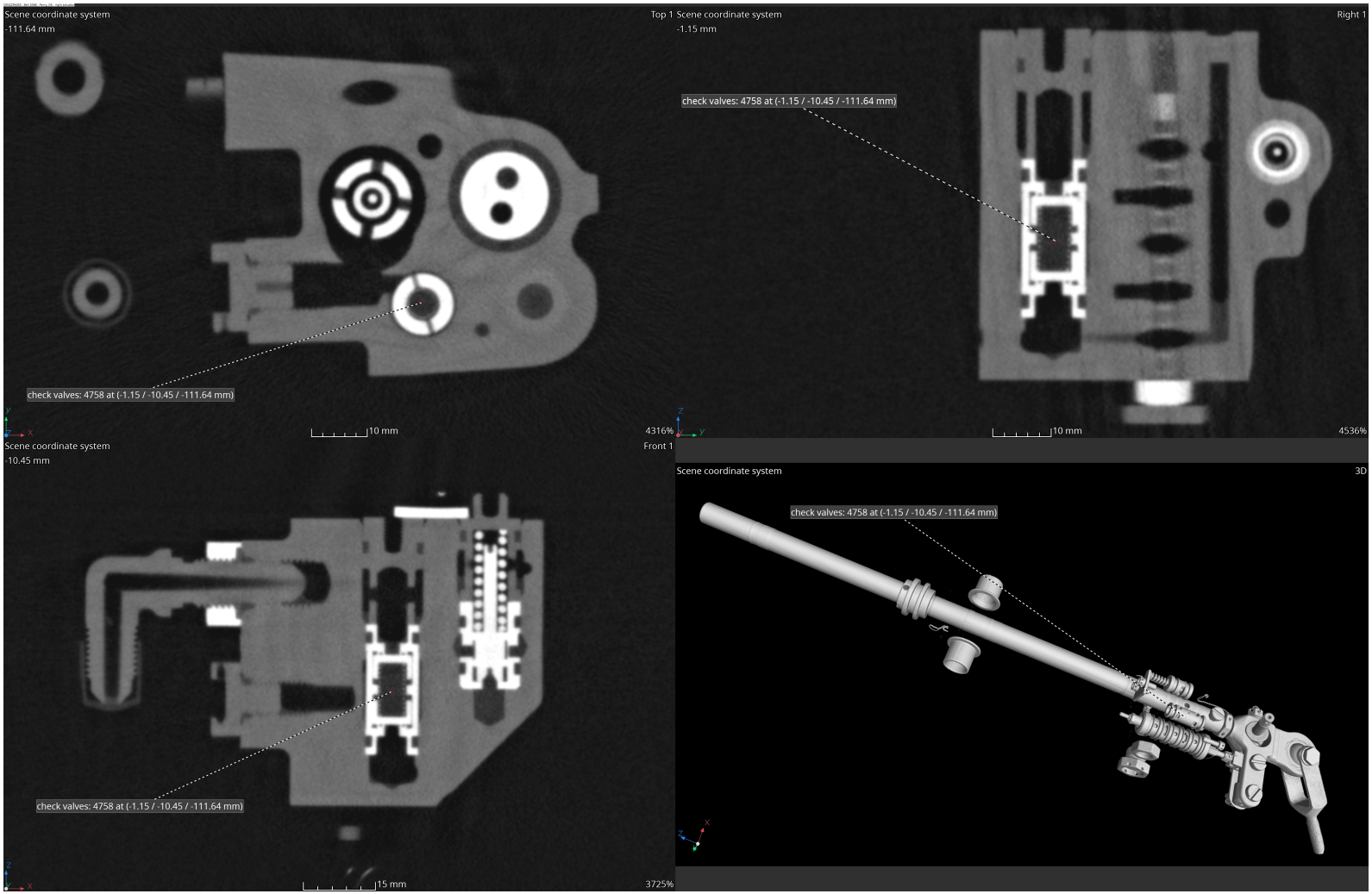


Figure 78
Right actuator – 6 MV – check valves

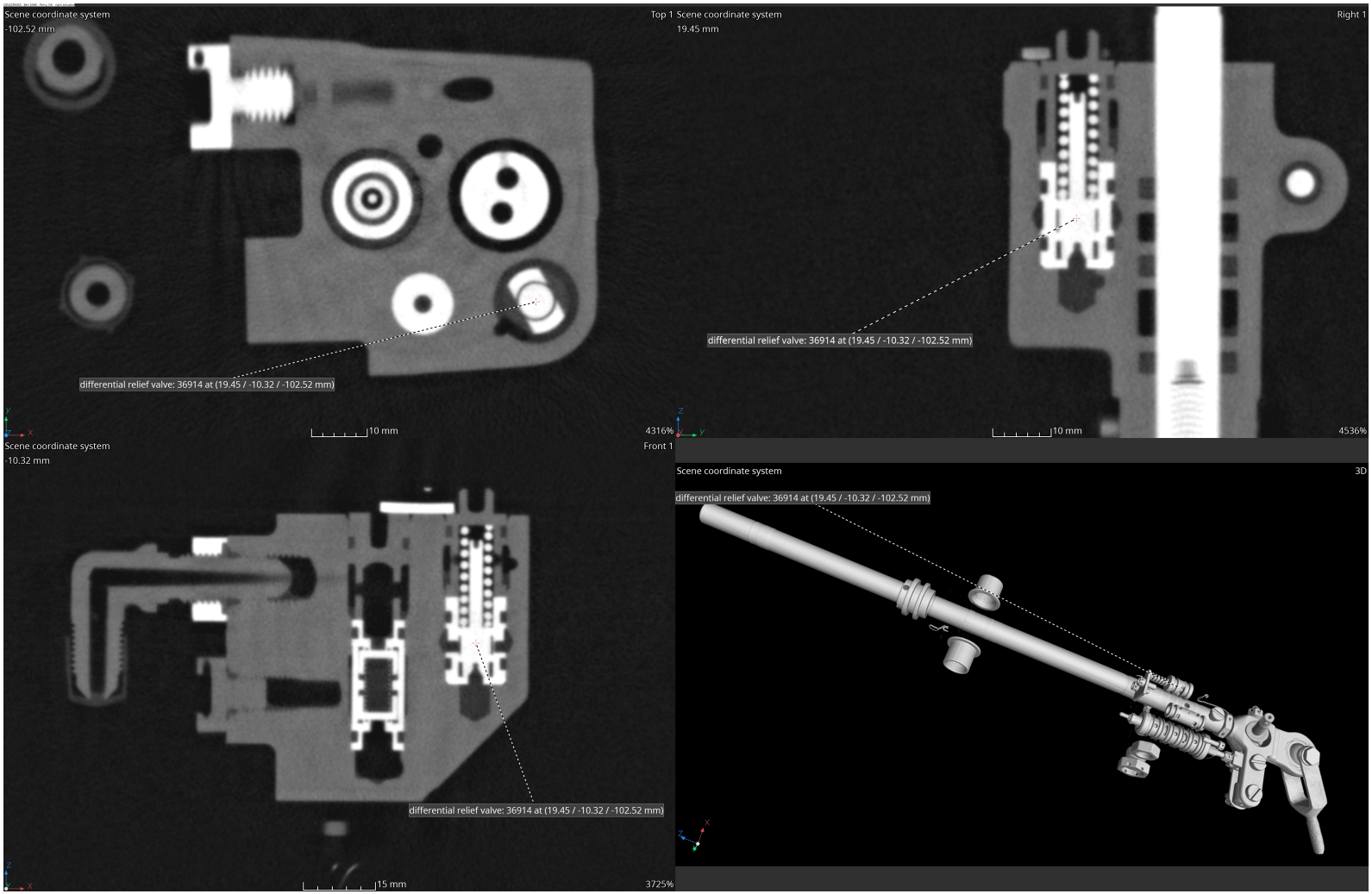


Figure 79
Right actuator – 6 MV – differential relief valve

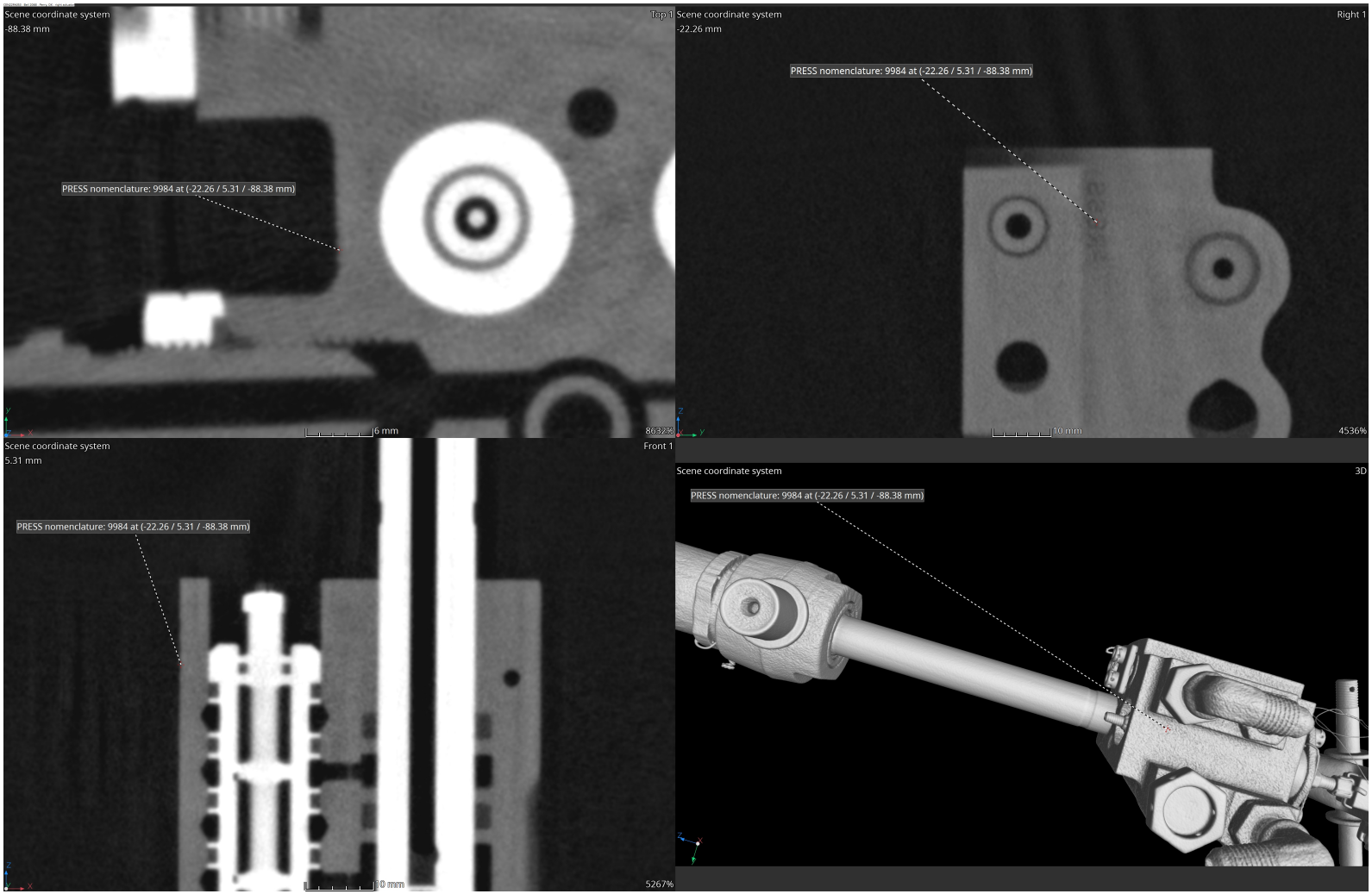


Figure 80
Right actuator – 6 MV – PRESS nomenclature

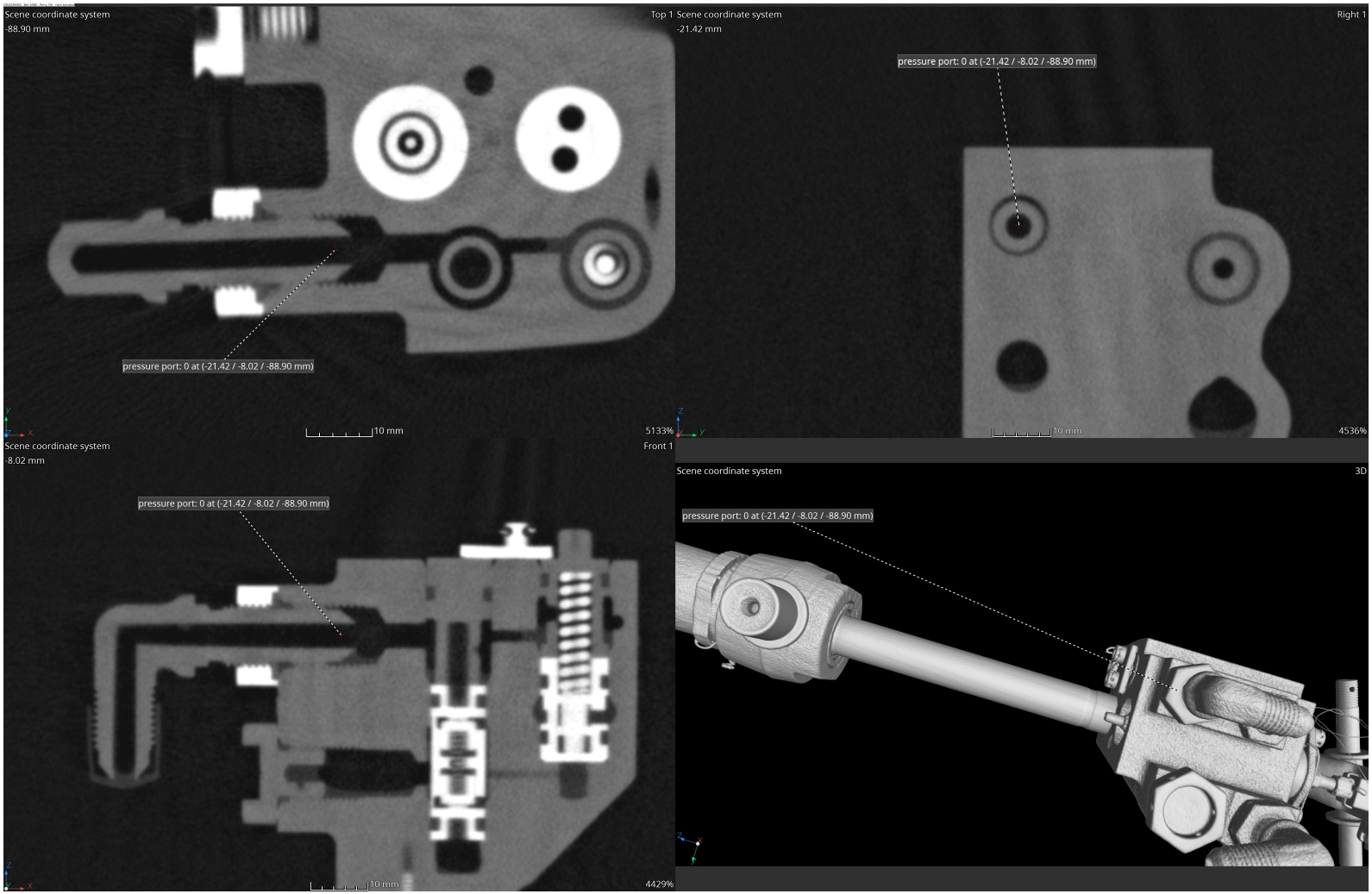


Figure 81
Right actuator – 6 MV – pressure port

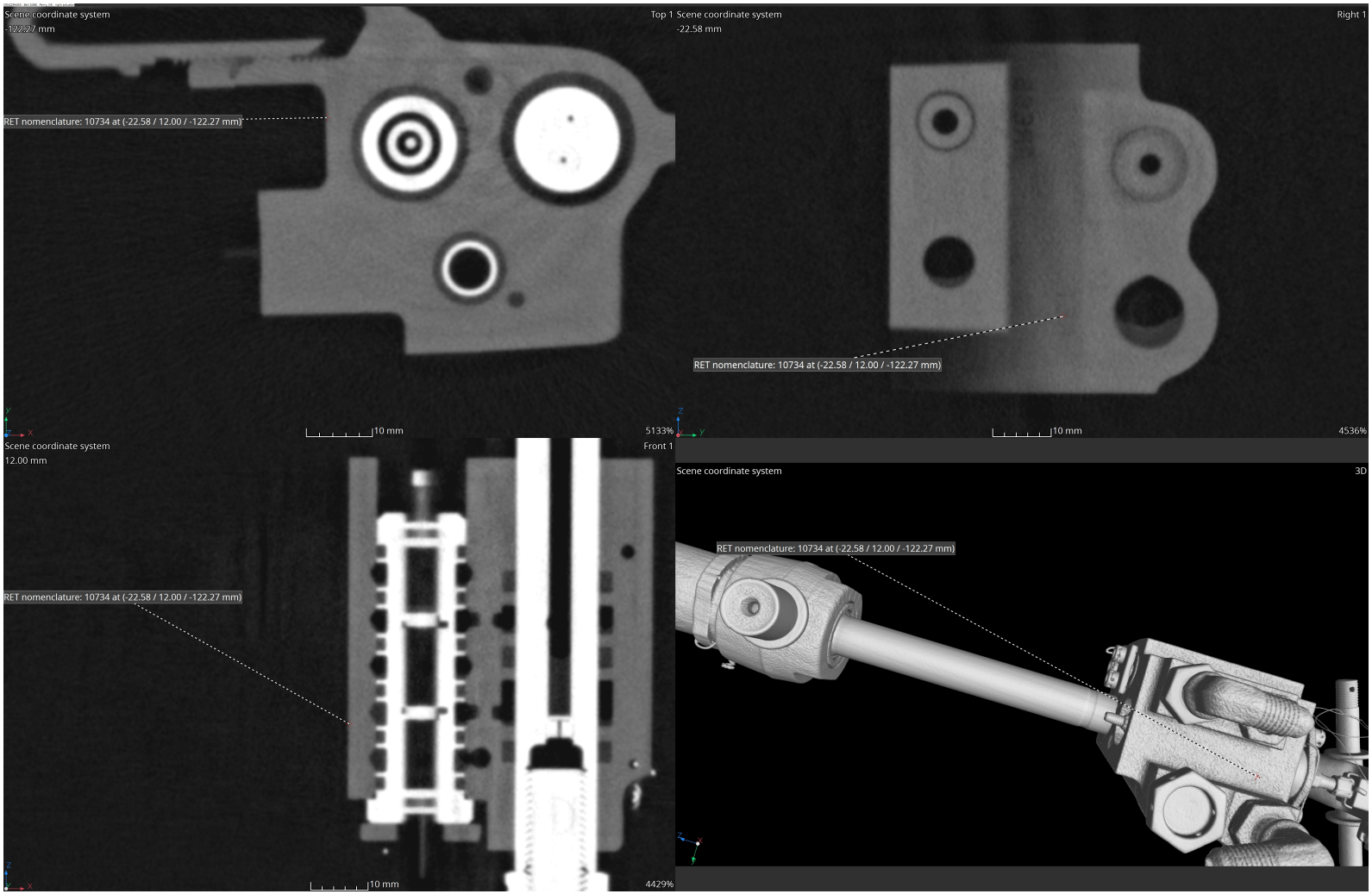


Figure 82
Right actuator – 6 MV – RET nomenclature

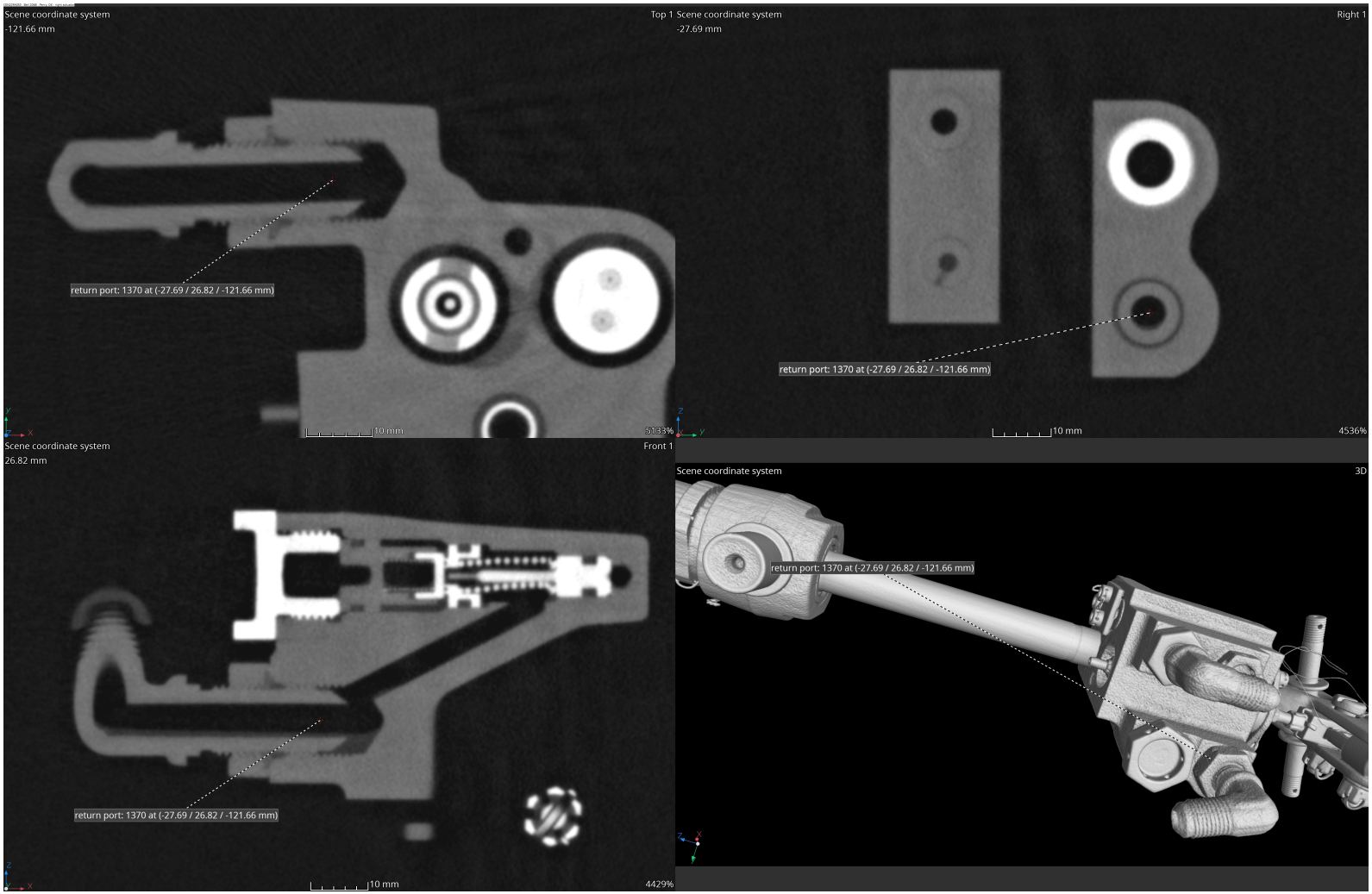


Figure 83
Right actuator – 6 MV – return port

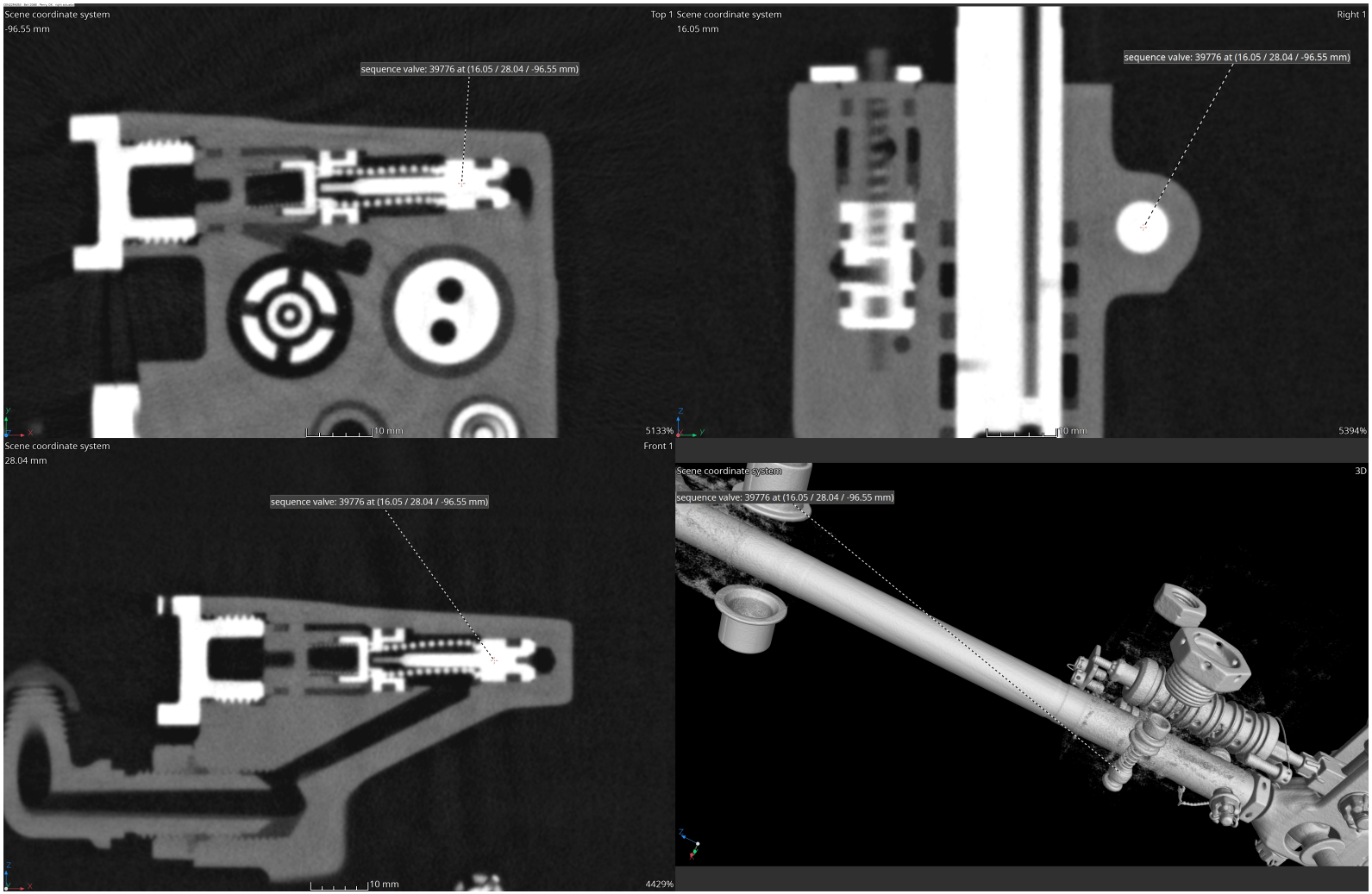


Figure 84
Right actuator – 6 MV – sequence valve

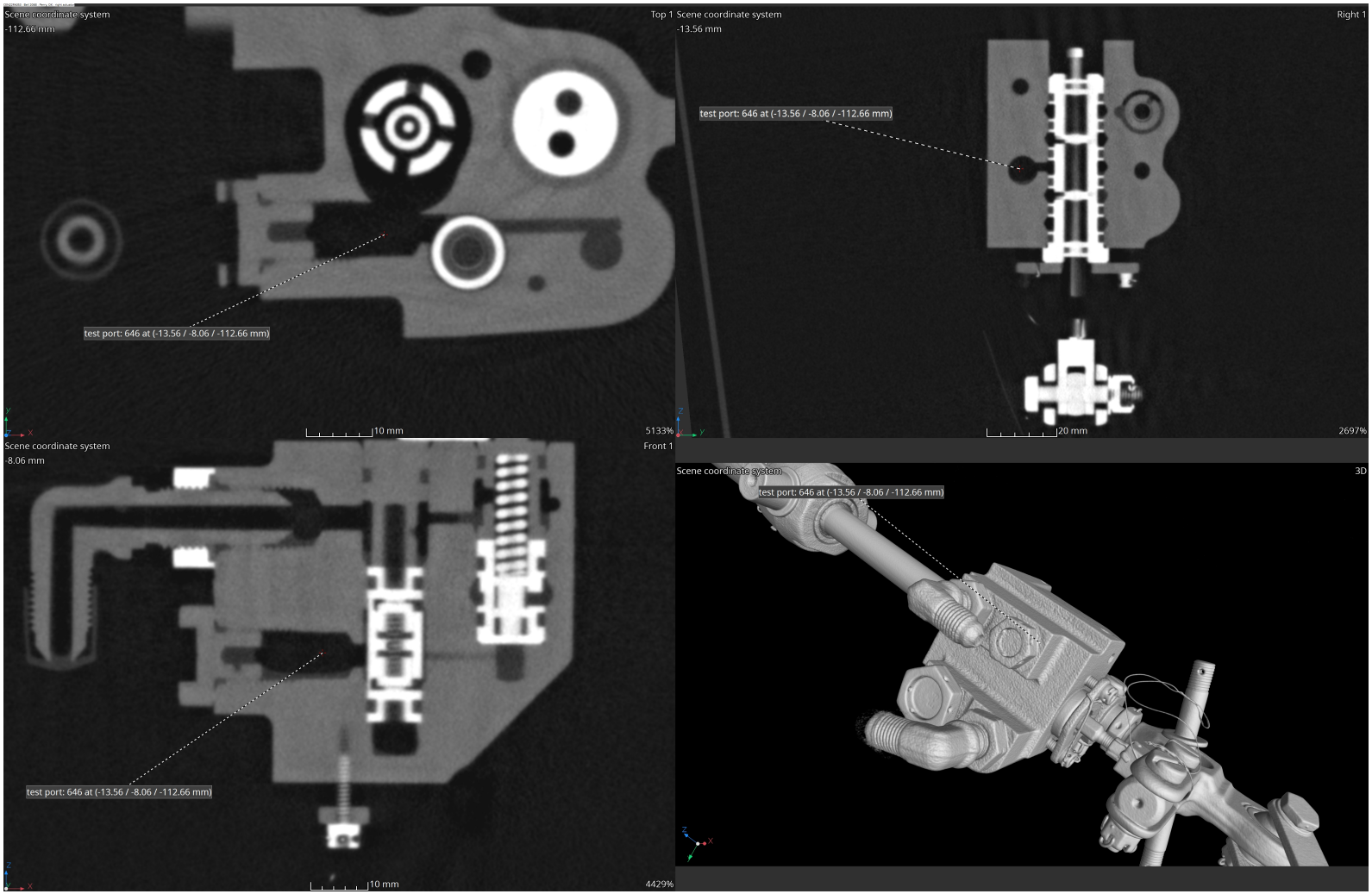


Figure 85
Right actuator – 6 MV – test port

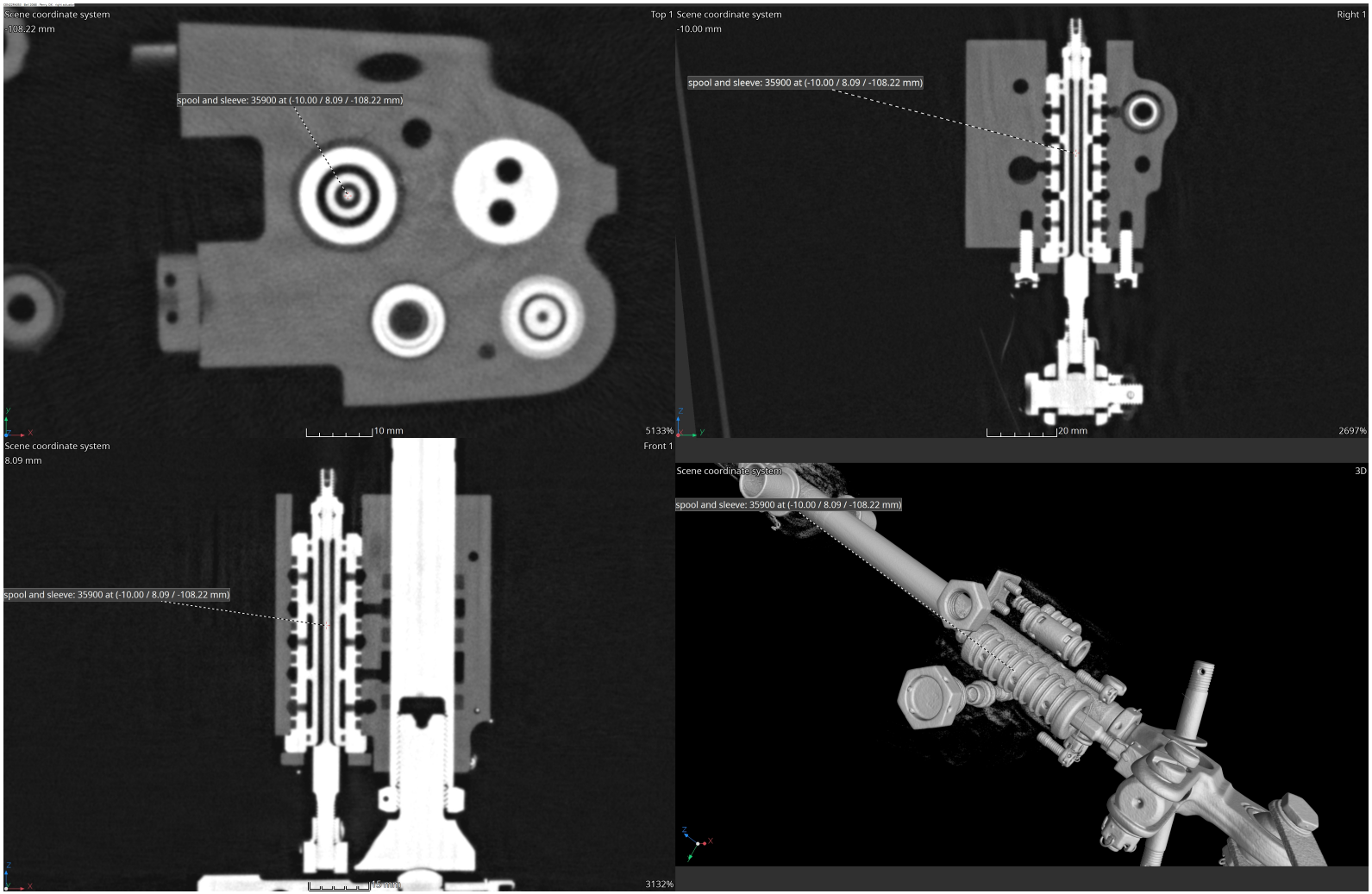


Figure 86
Right actuator – 6 MV – spool and sleeve

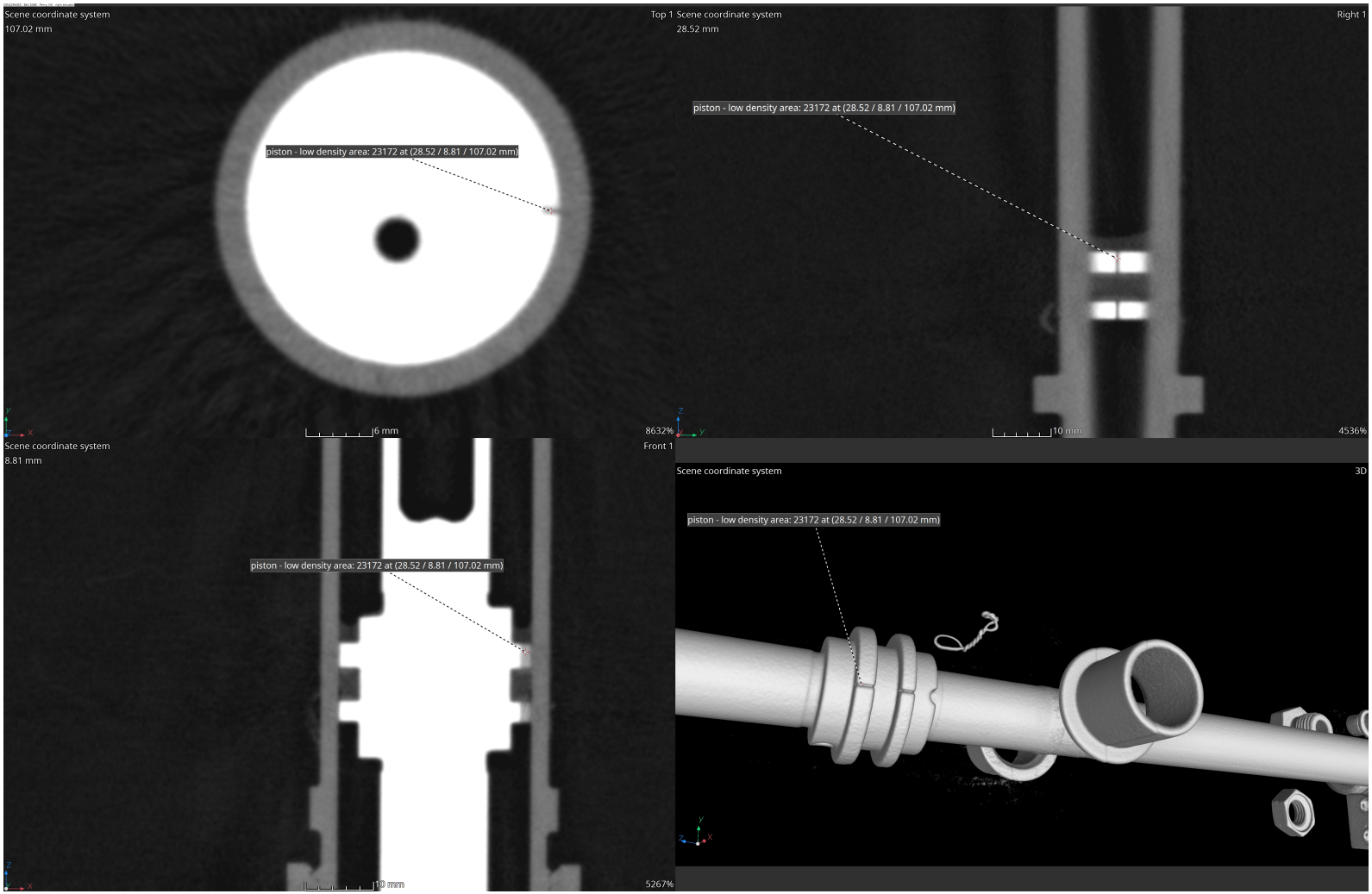


Figure 87
Right actuator – 6 MV – piston head – low density area

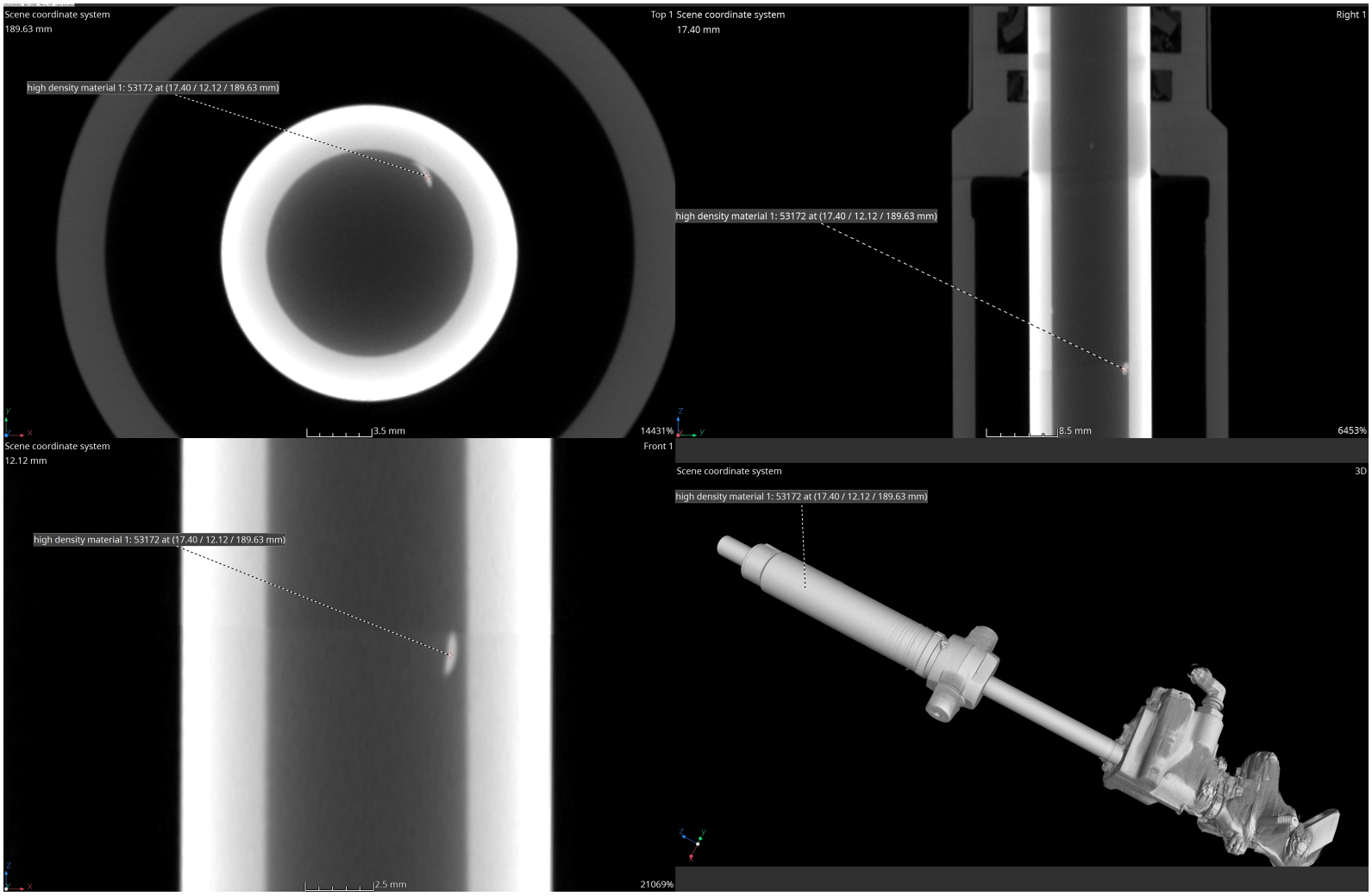


Figure 88
Right actuator – 6 MV – high density material 1

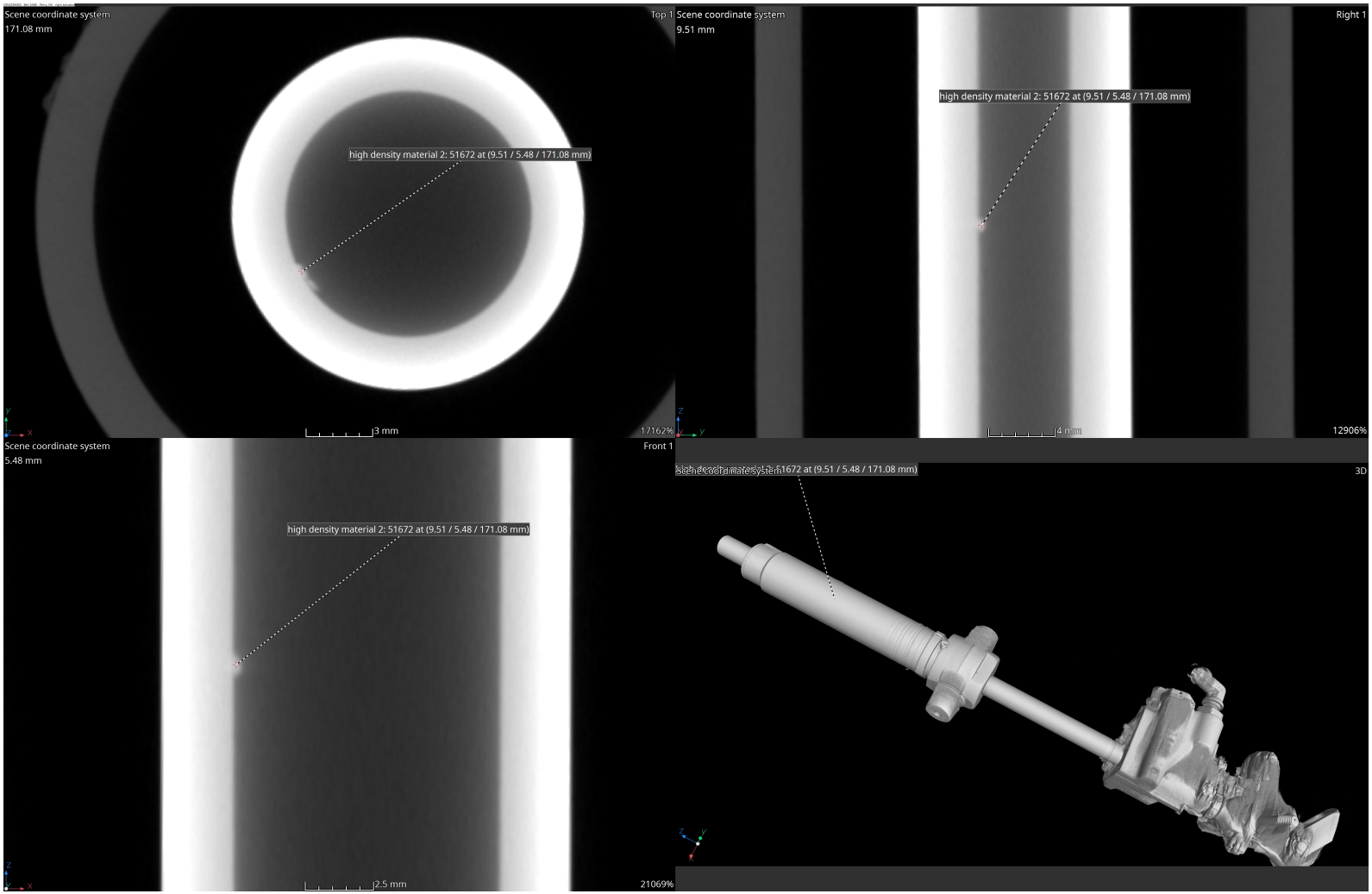


Figure 89
Right actuator – 6 MV – high density material 2

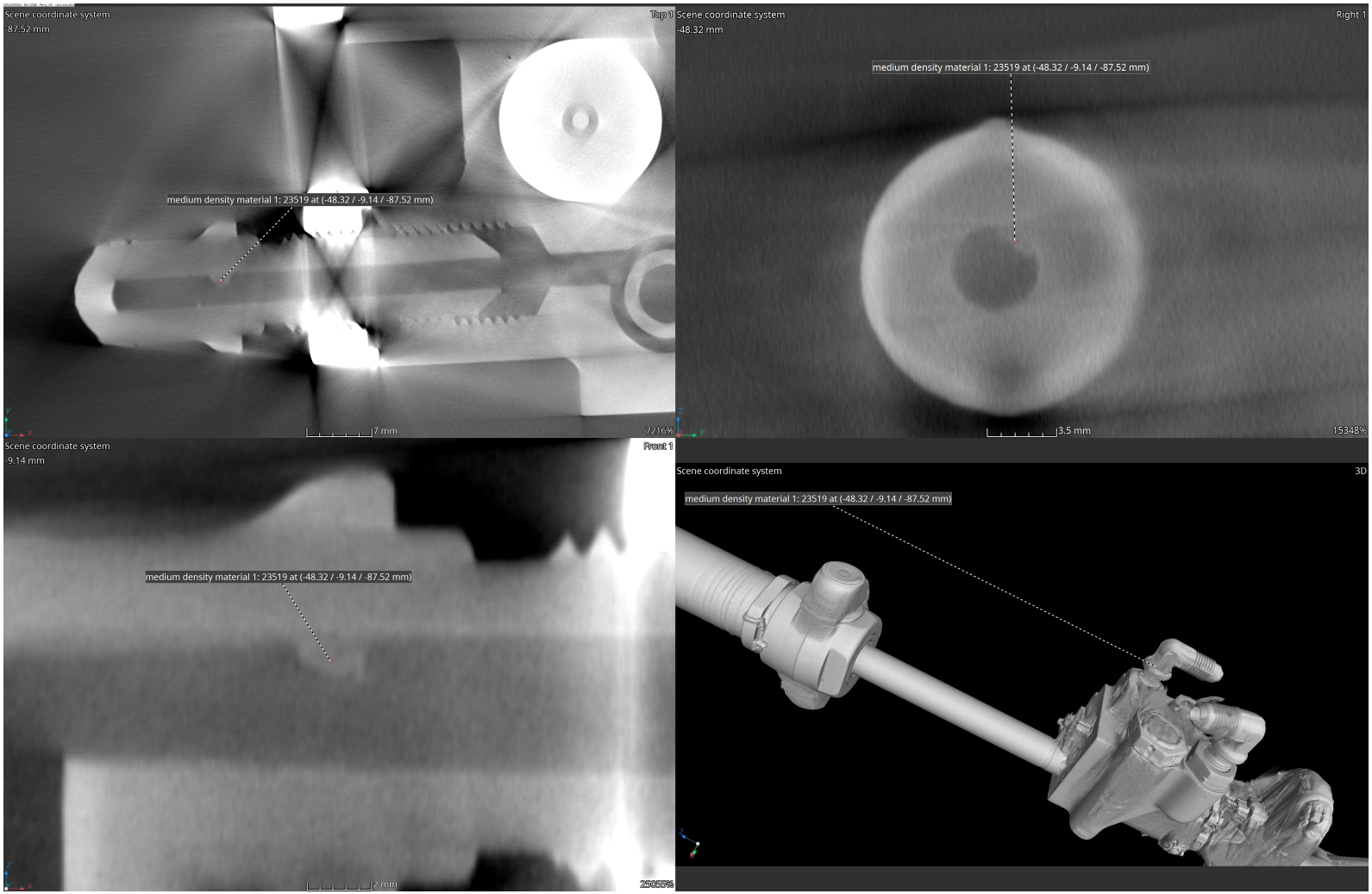


Figure 90
Right actuator – microfocus – medium density material 1

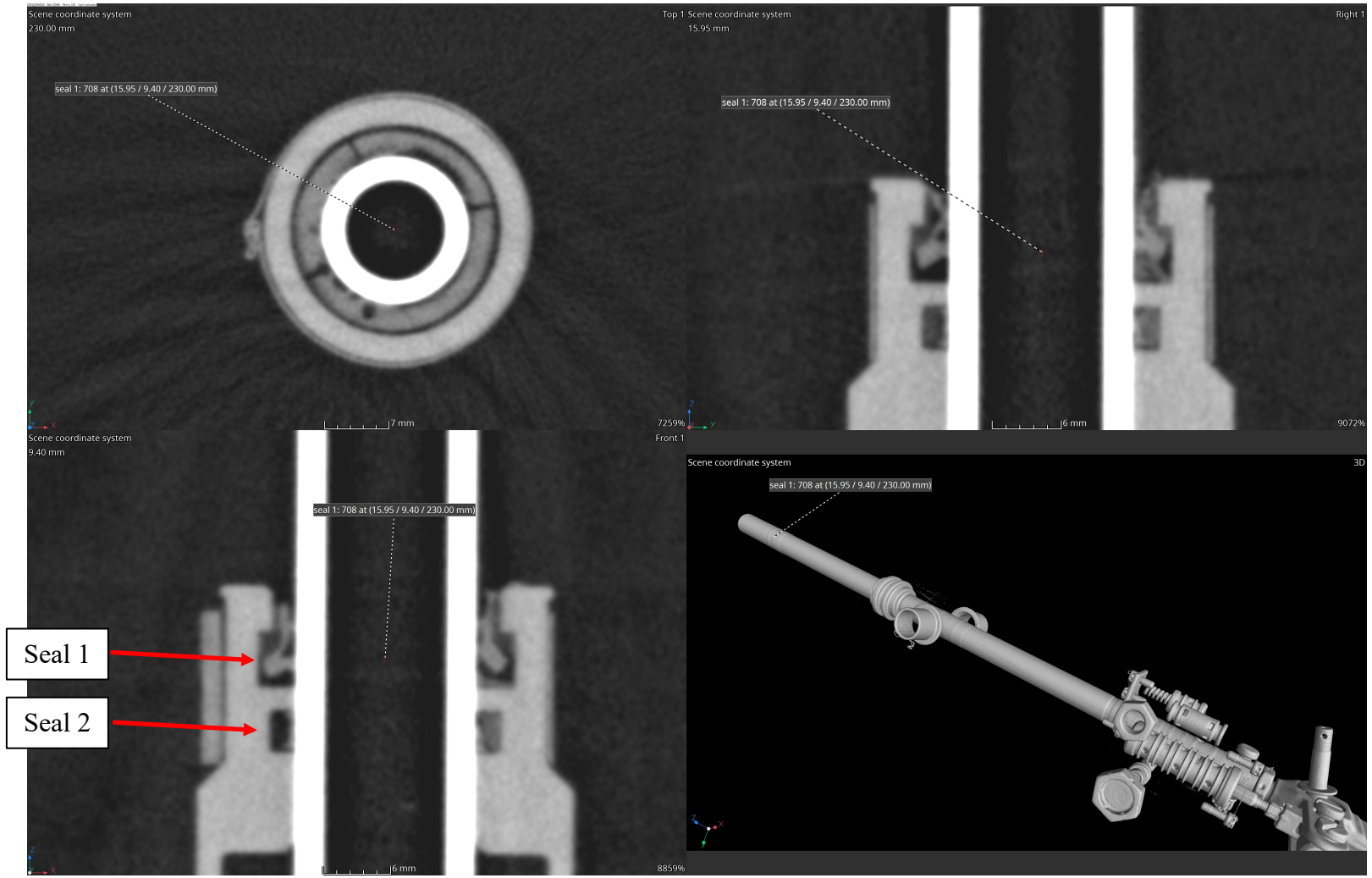


Figure 91
Right actuator – 6 MV – seal 1

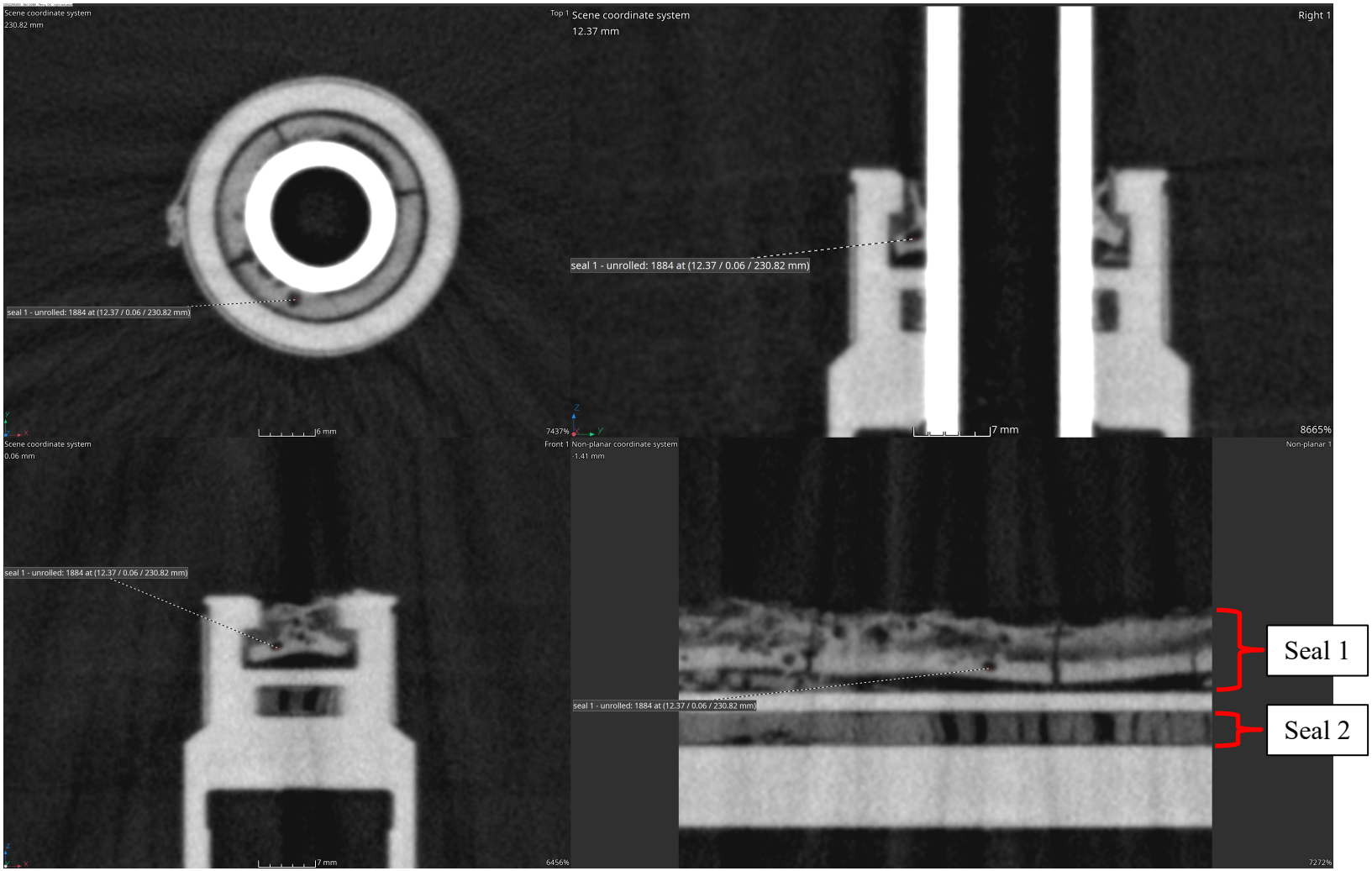


Figure 92
Right actuator – 6 MV – seal 1 unrolled

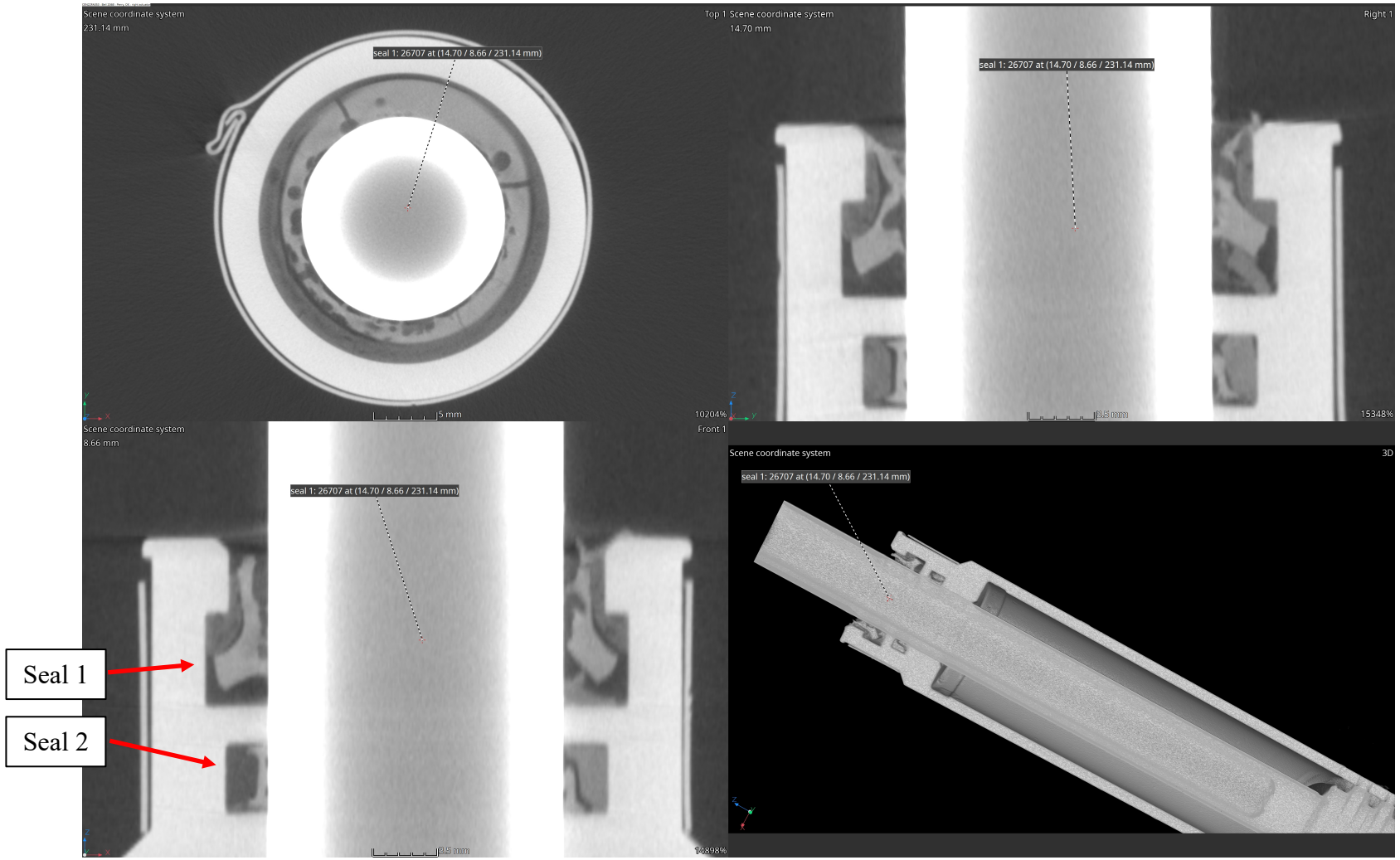


Figure 93
Right actuator – microfocus – seal 1

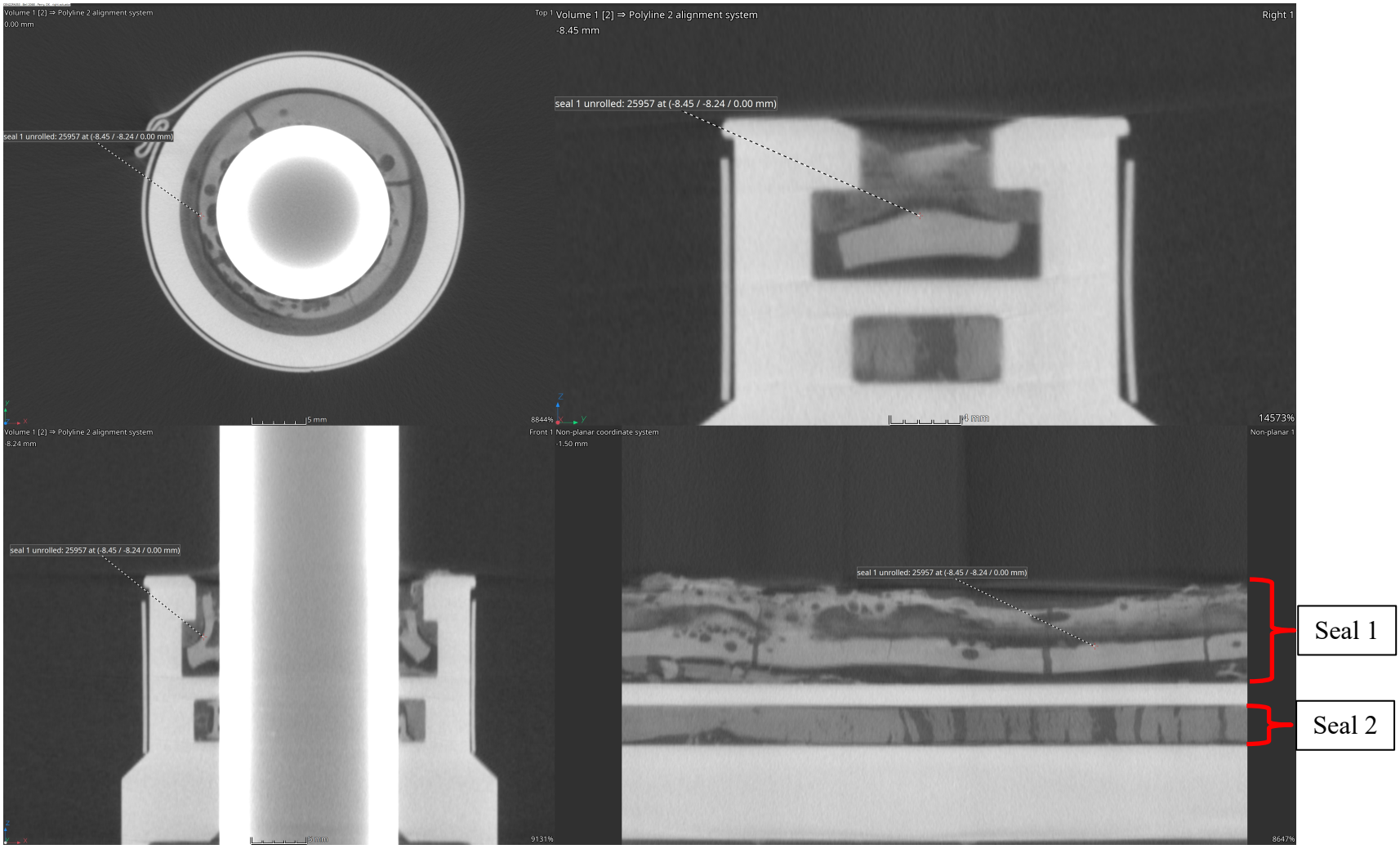


Figure 94
Right actuator – microfocus – seal 1 unrolled

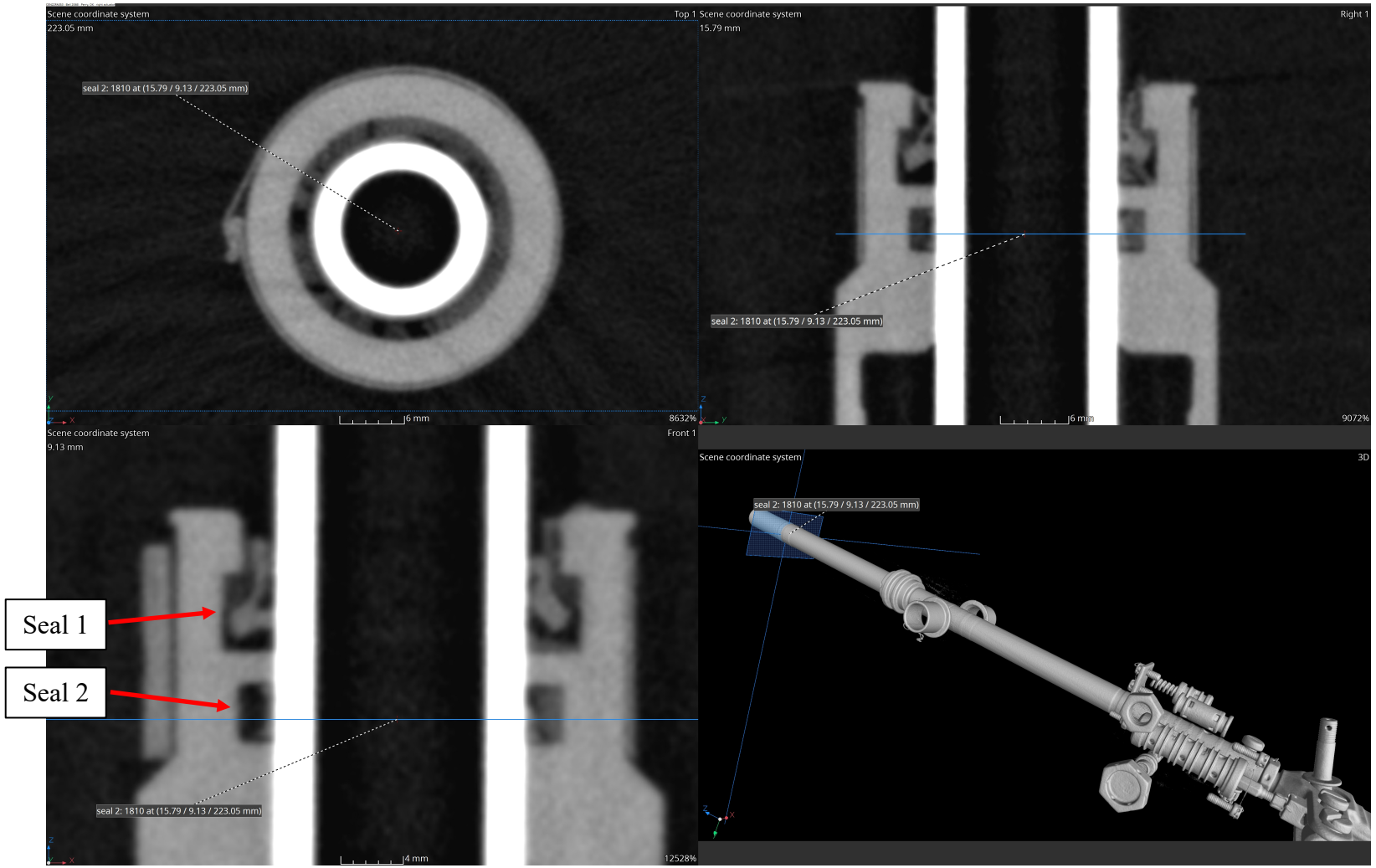


Figure 95
Right actuator – 6 MV – seal 2

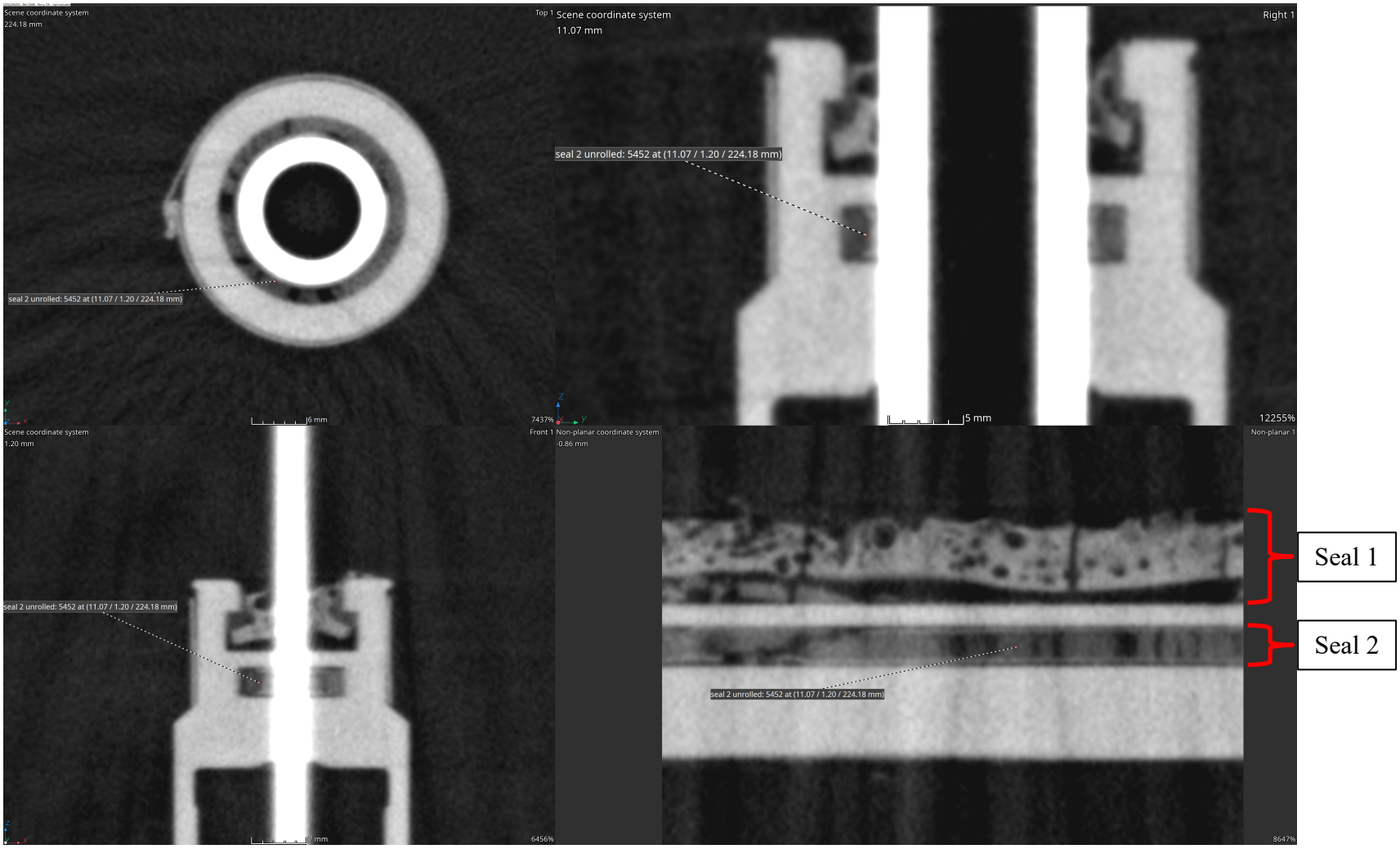


Figure 96
Right actuator – 6 MV – seal 2 unrolled

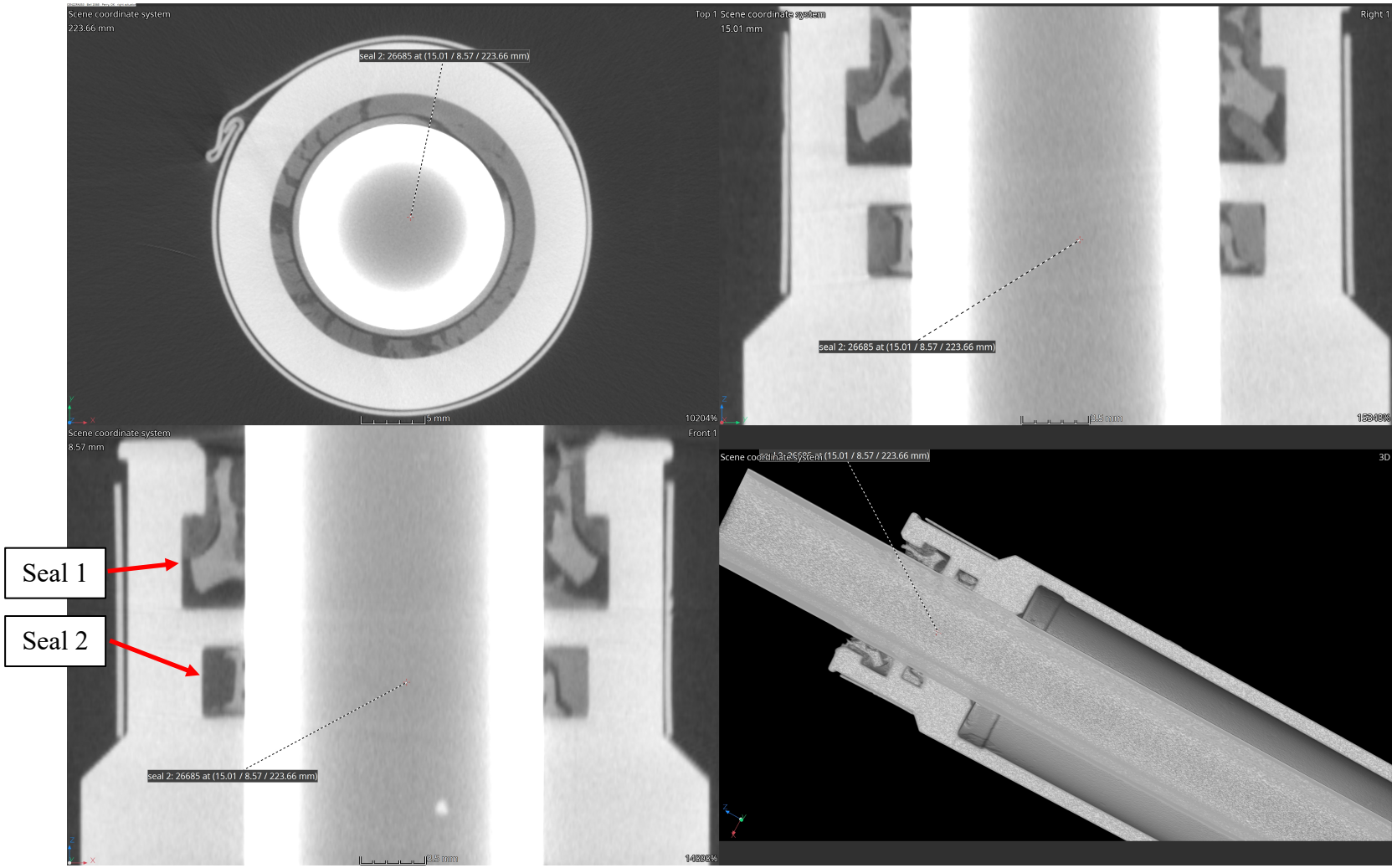


Figure 97
Right actuator – microfocus – seal 2

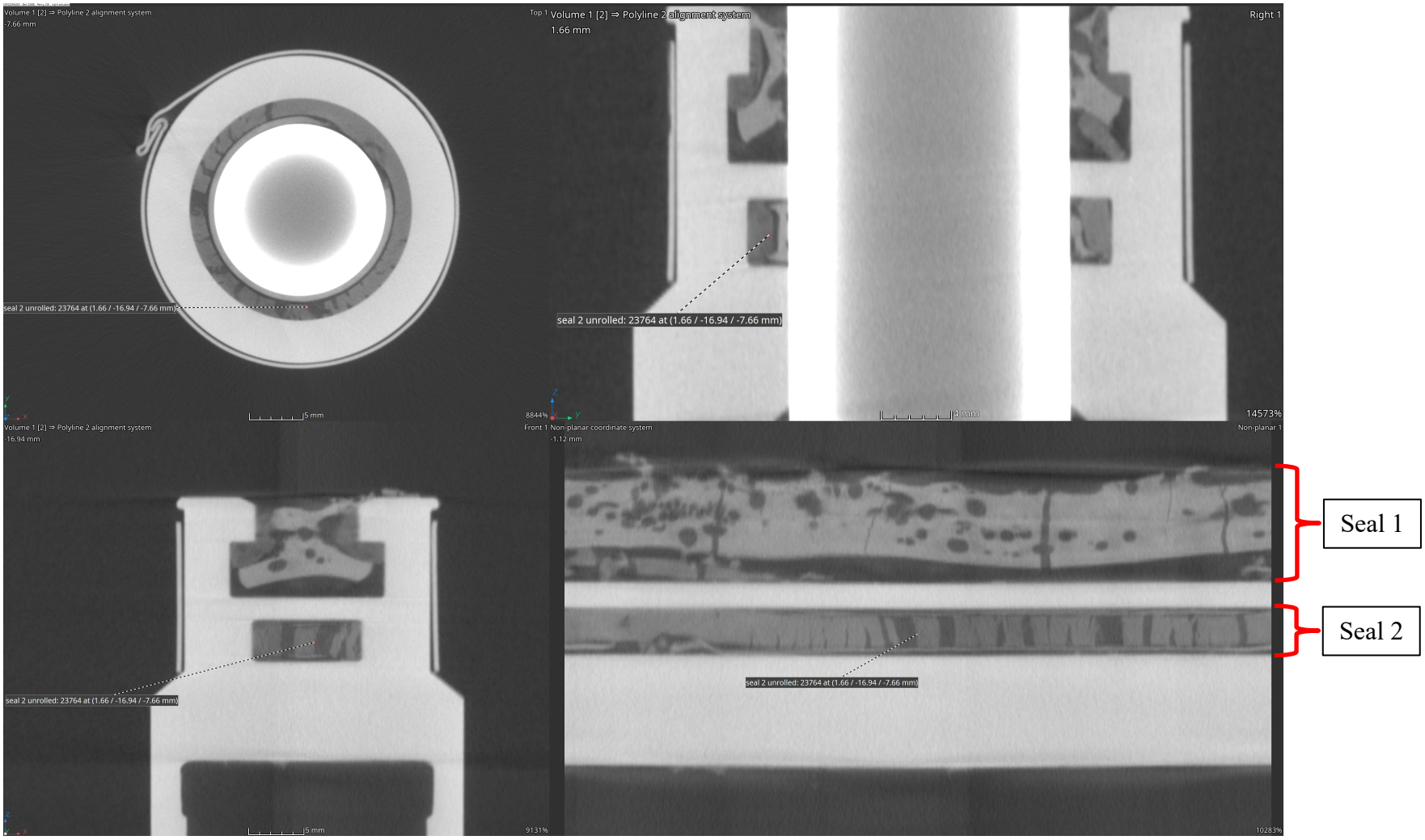


Figure 98
Right actuator – microfocus – seal 2 unrolled

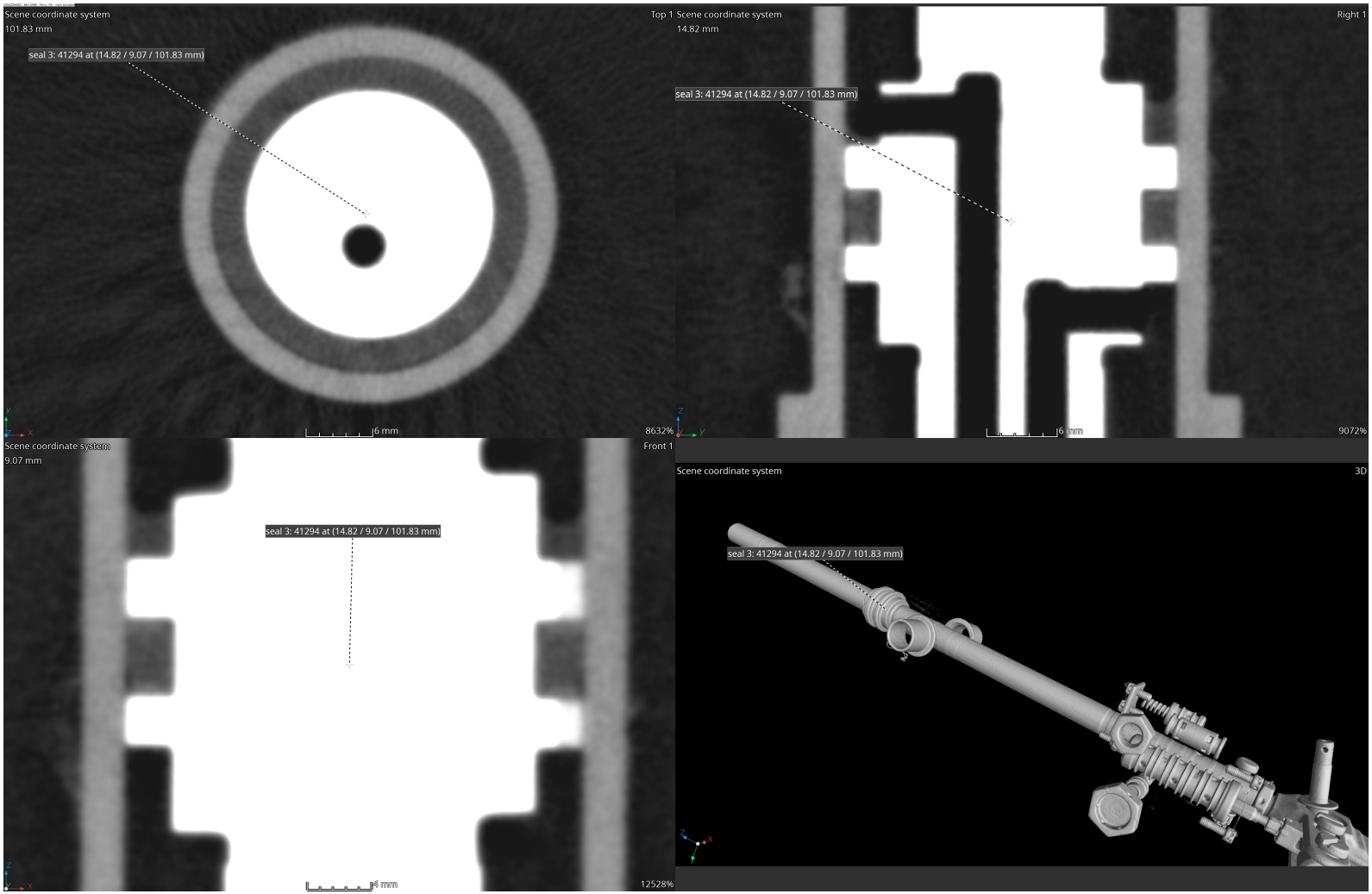


Figure 99
Right actuator – 6 MV – seal 3

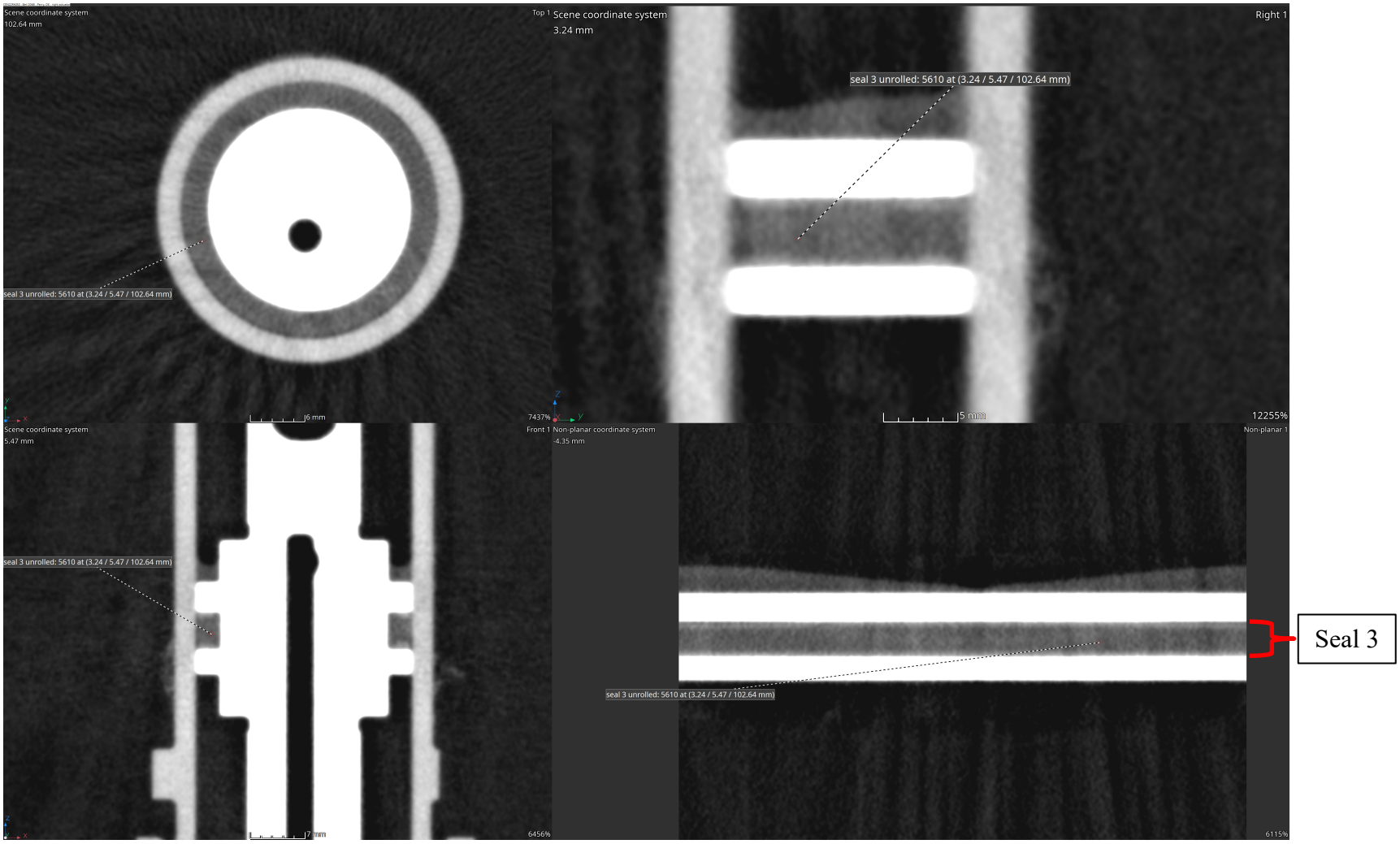


Figure 100
Right actuator – 6 MV – seal 3 unrolled

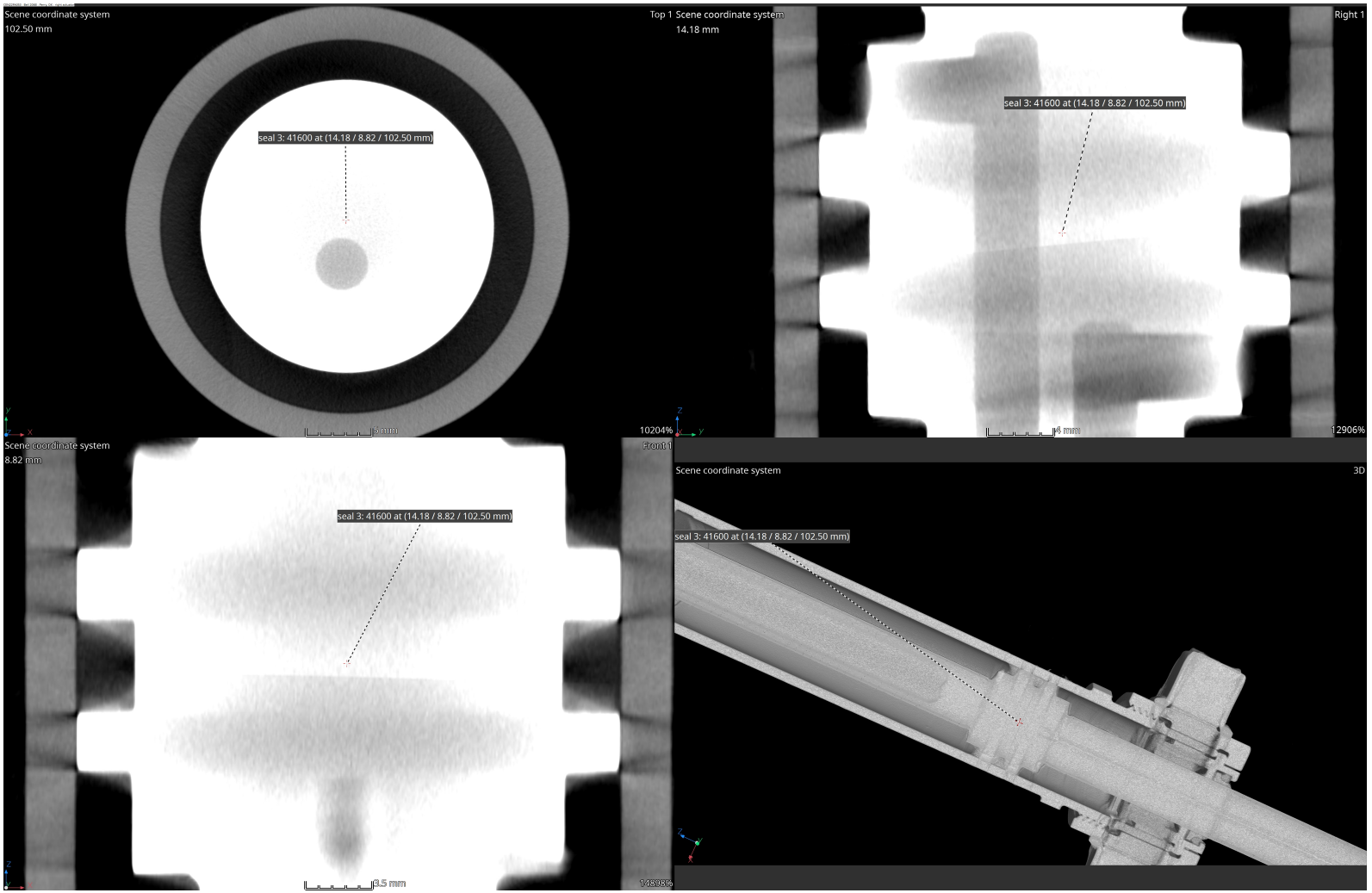


Figure 101
Right actuator – microfocus – seal 3

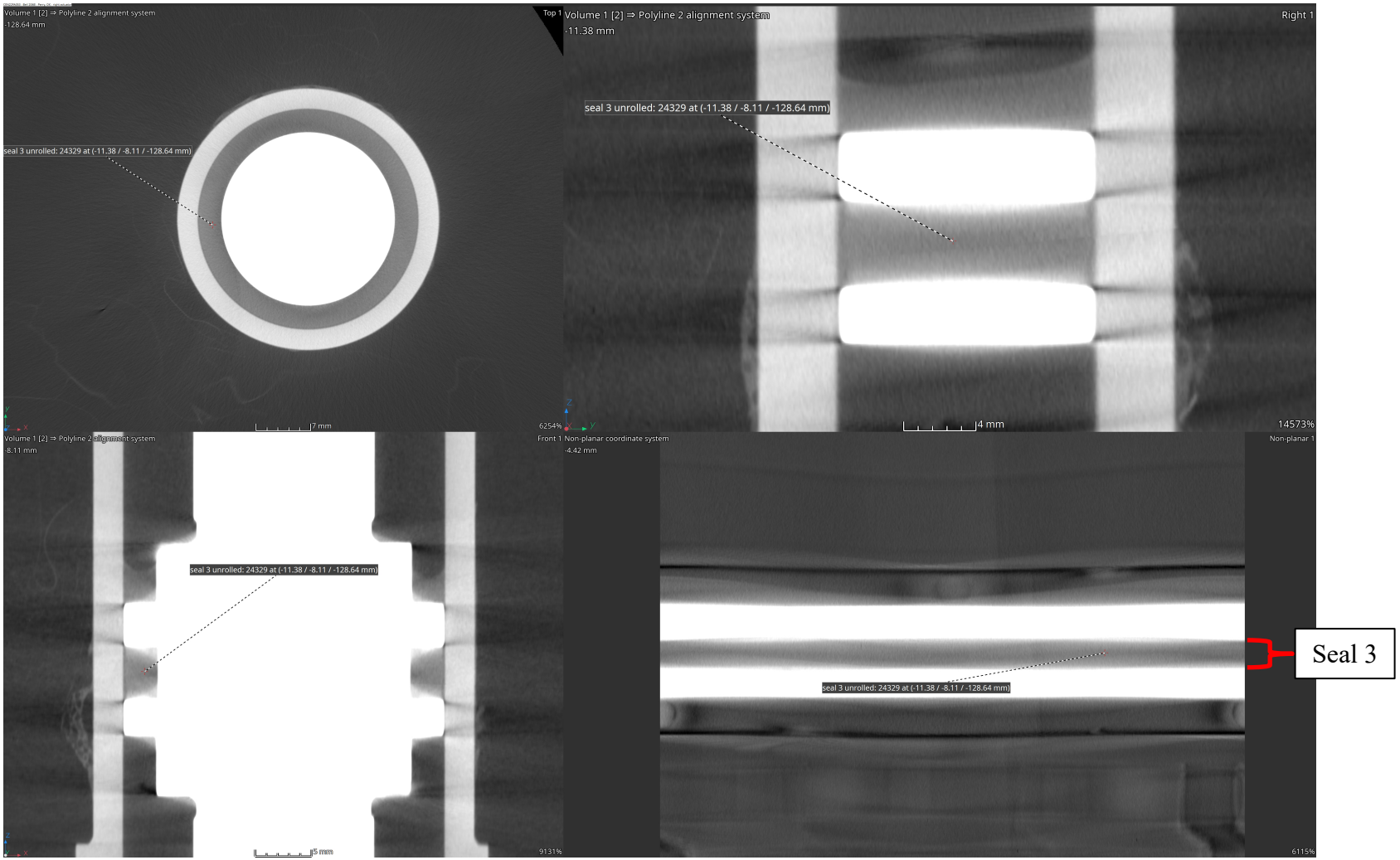


Figure 102
Right actuator – microfocus – seal 3 unrolled

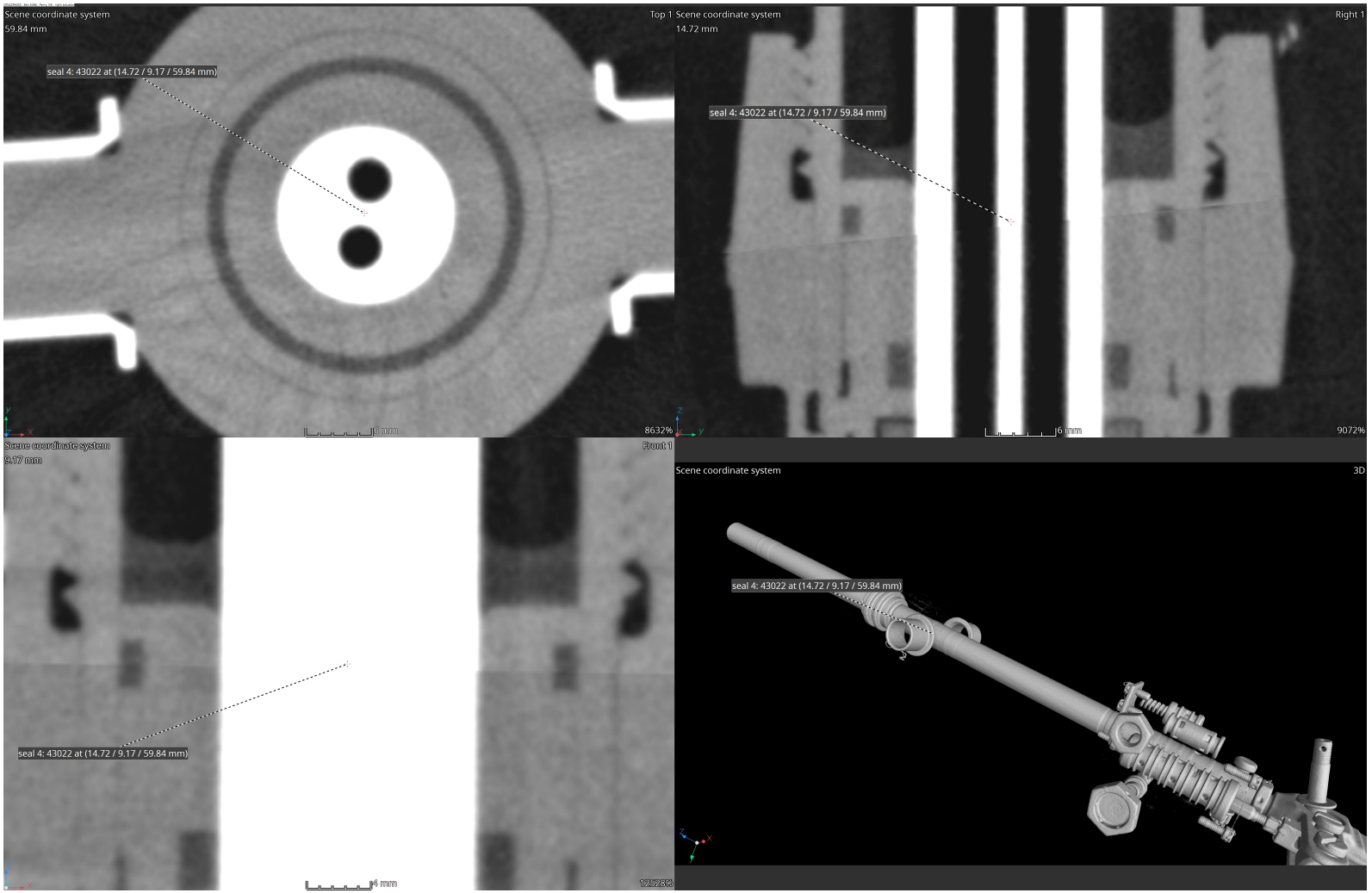


Figure 103
Right actuator – 6 MV – seal 4

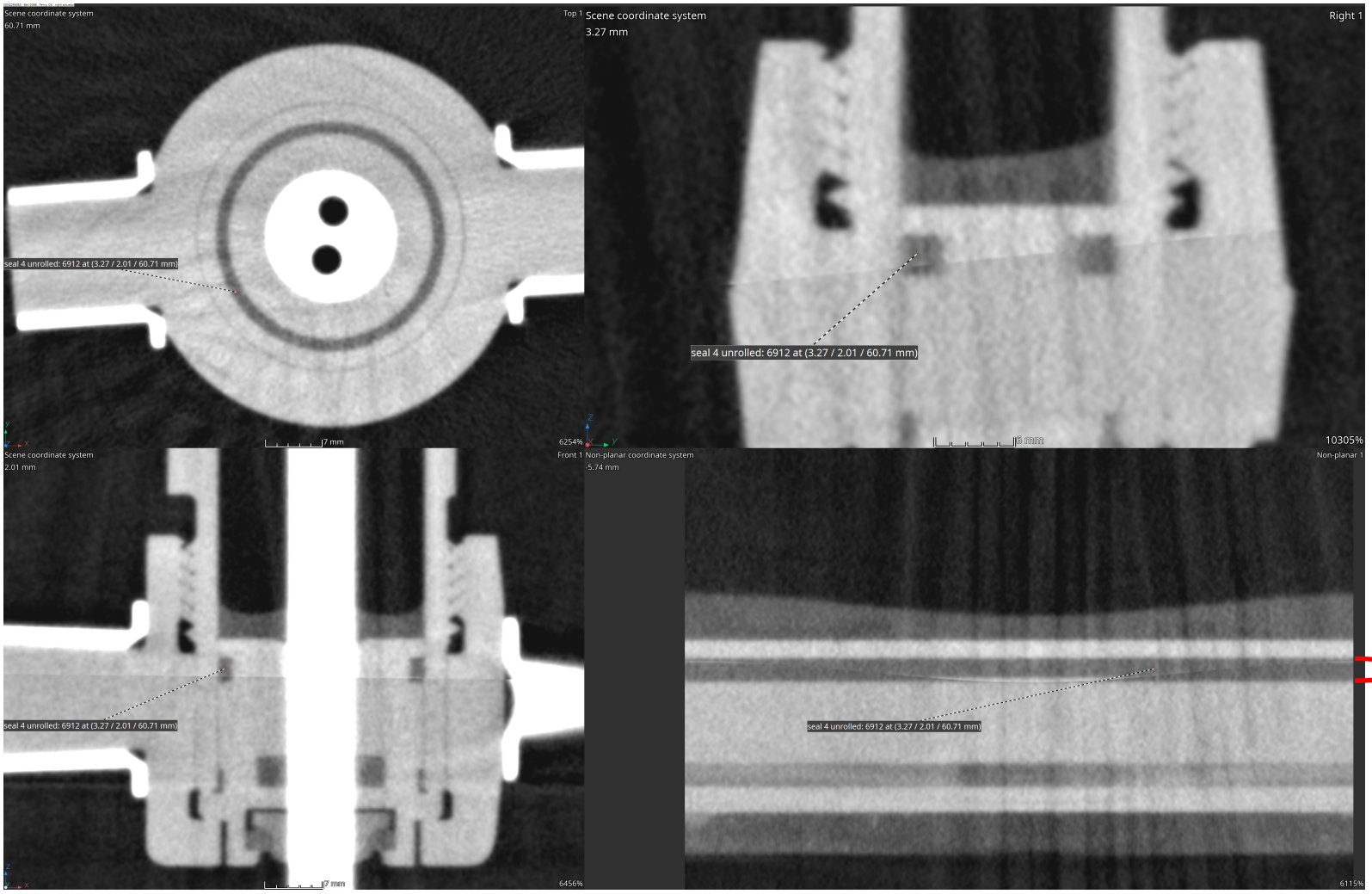


Figure 104
Right actuator – 6 MV – seal 4 unrolled

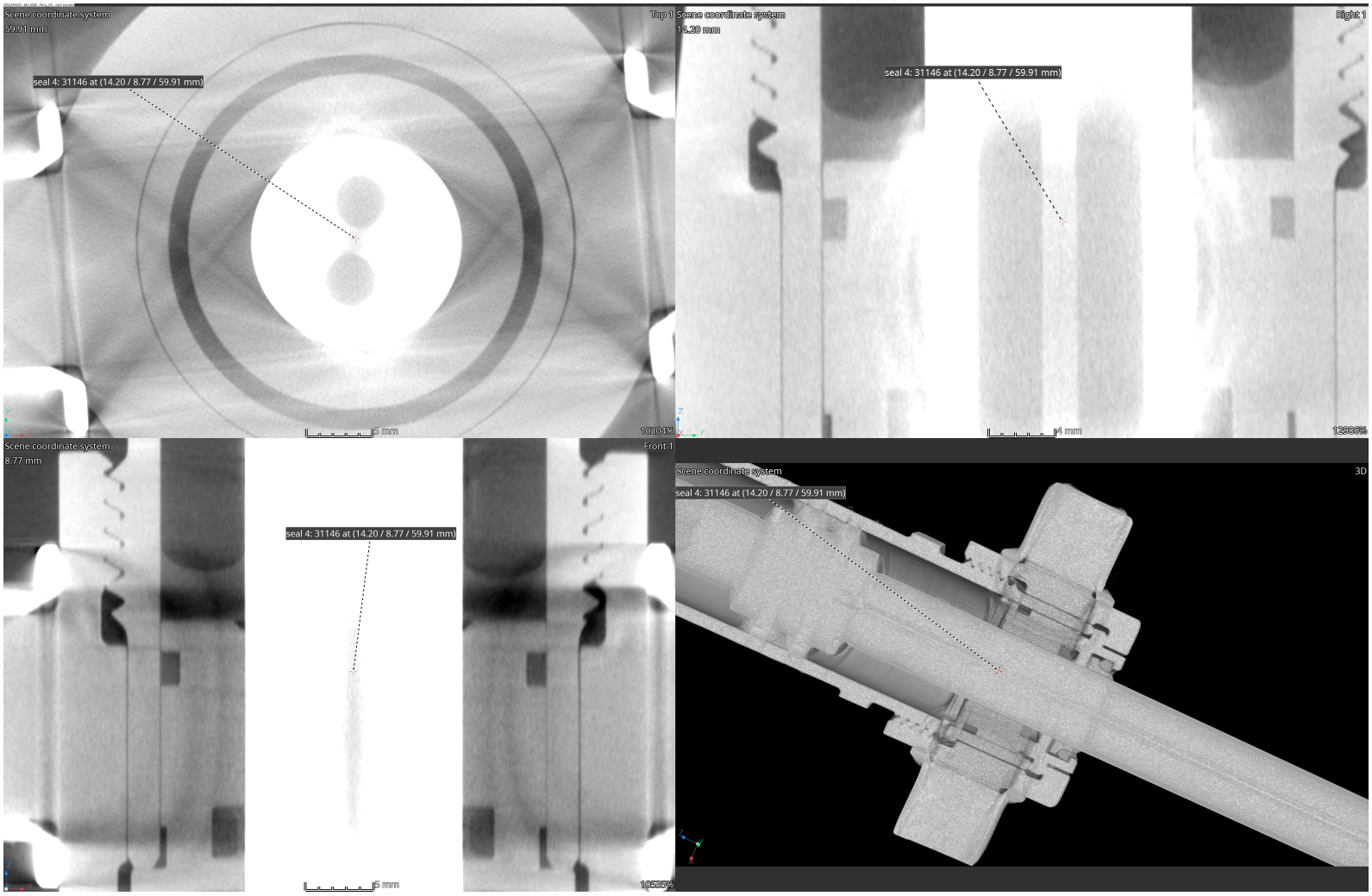


Figure 105
Right actuator – microfocus – seal 4

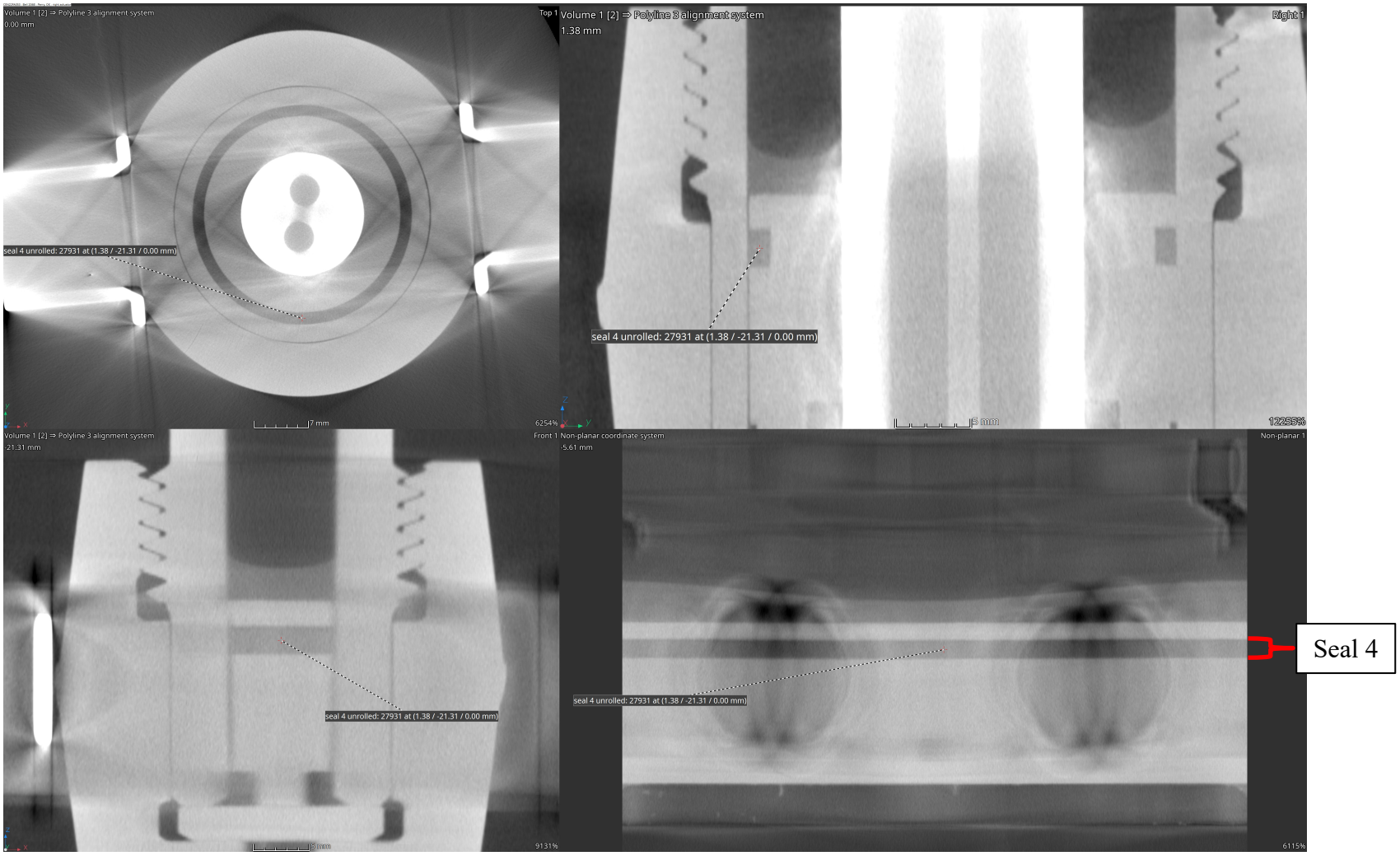


Figure 106
Right actuator – microfocus – seal 4 unrolled

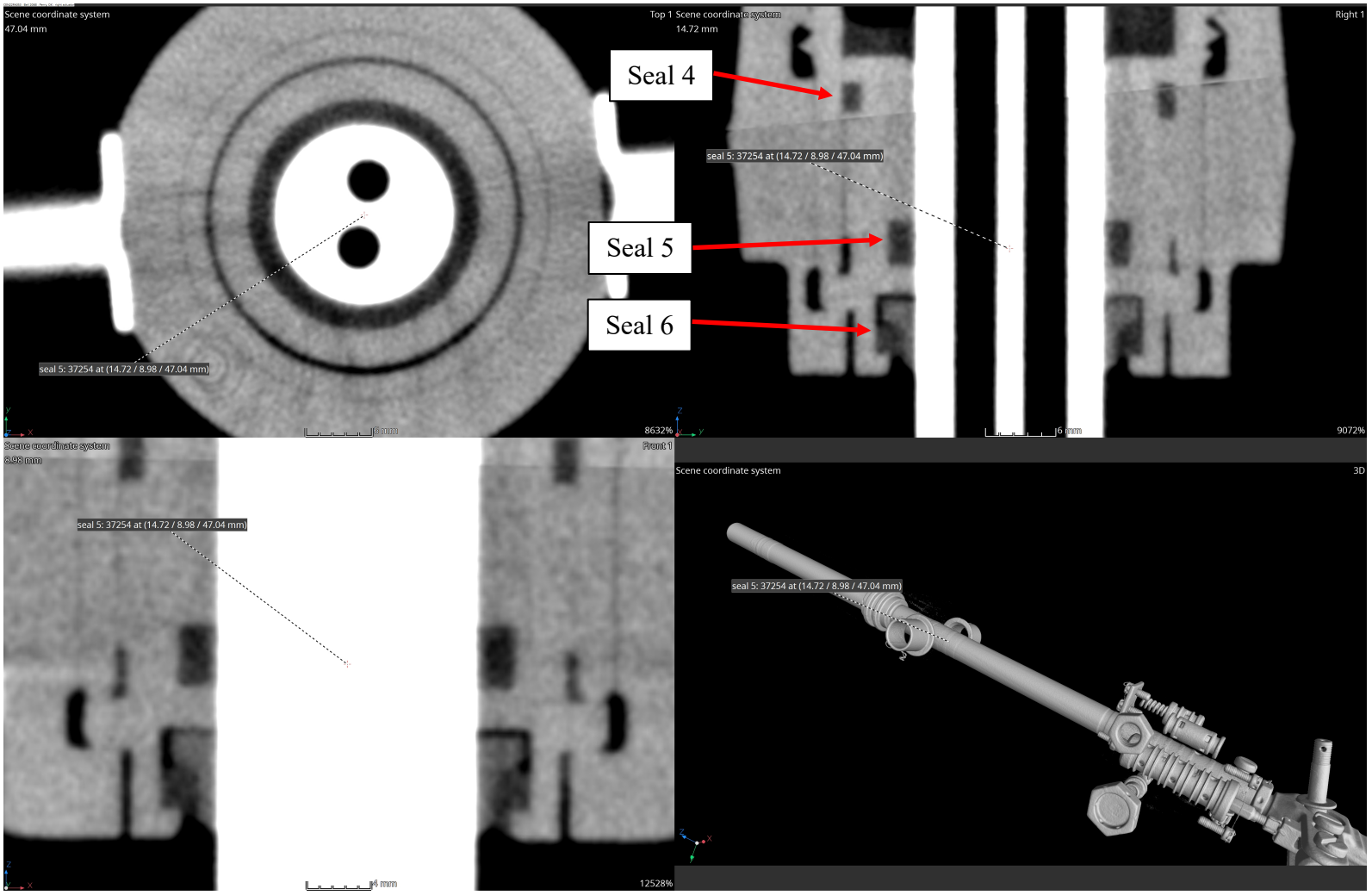


Figure 107
Right actuator – 6 MV – seal 5

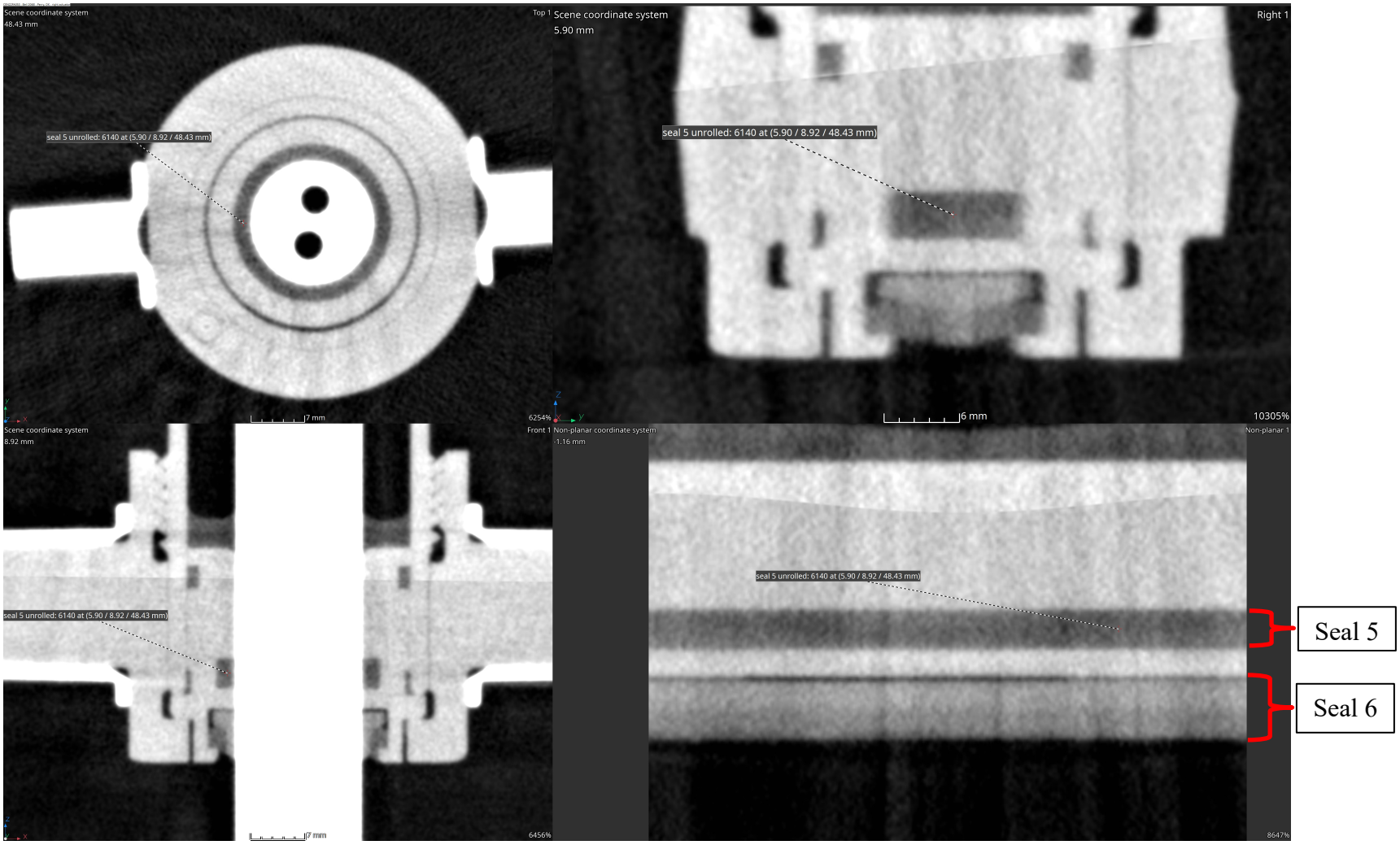


Figure 108
Right actuator – 6 MV – seal 5 unrolled

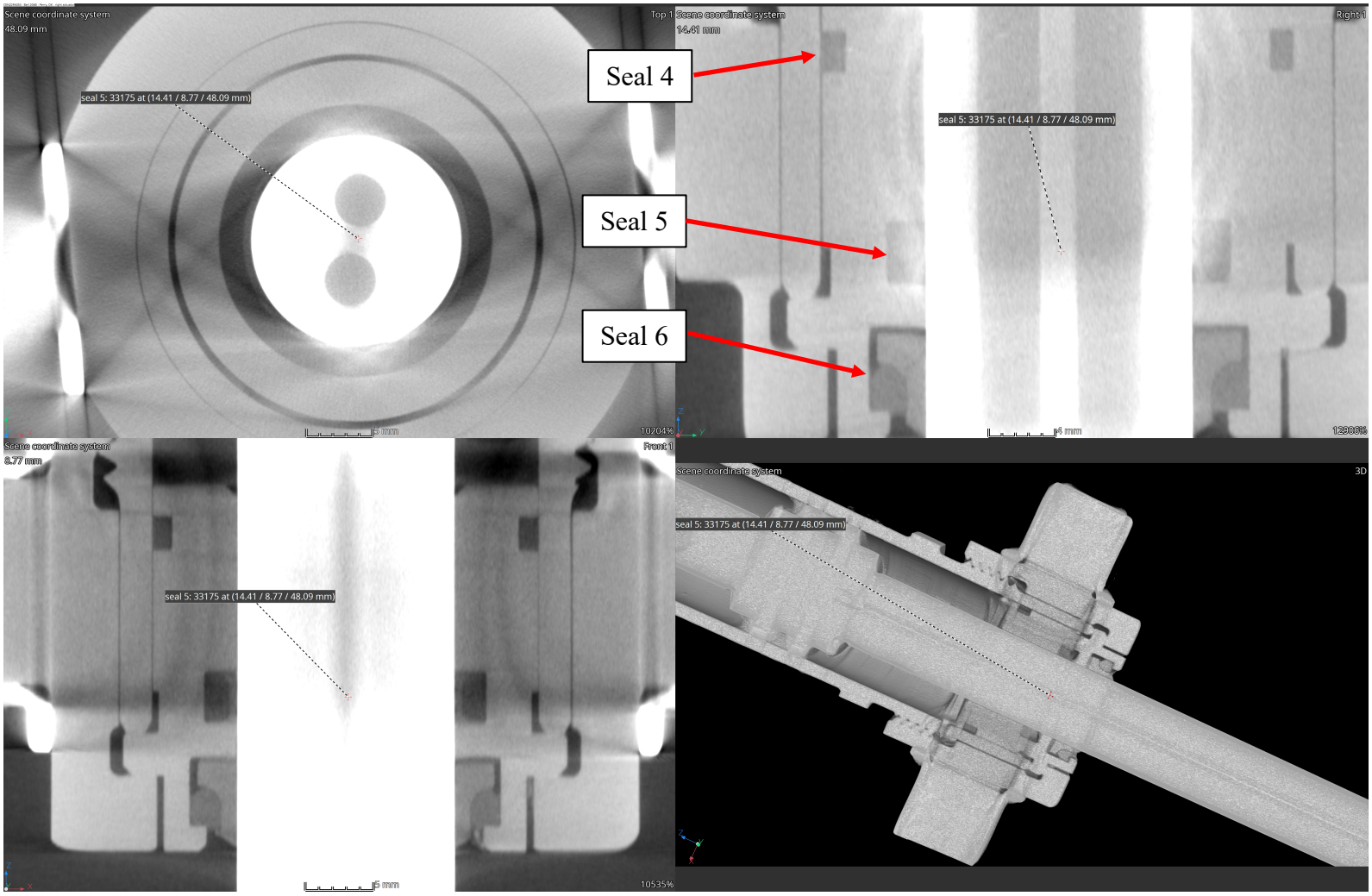


Figure 109
Right actuator – microfocus – seal 5

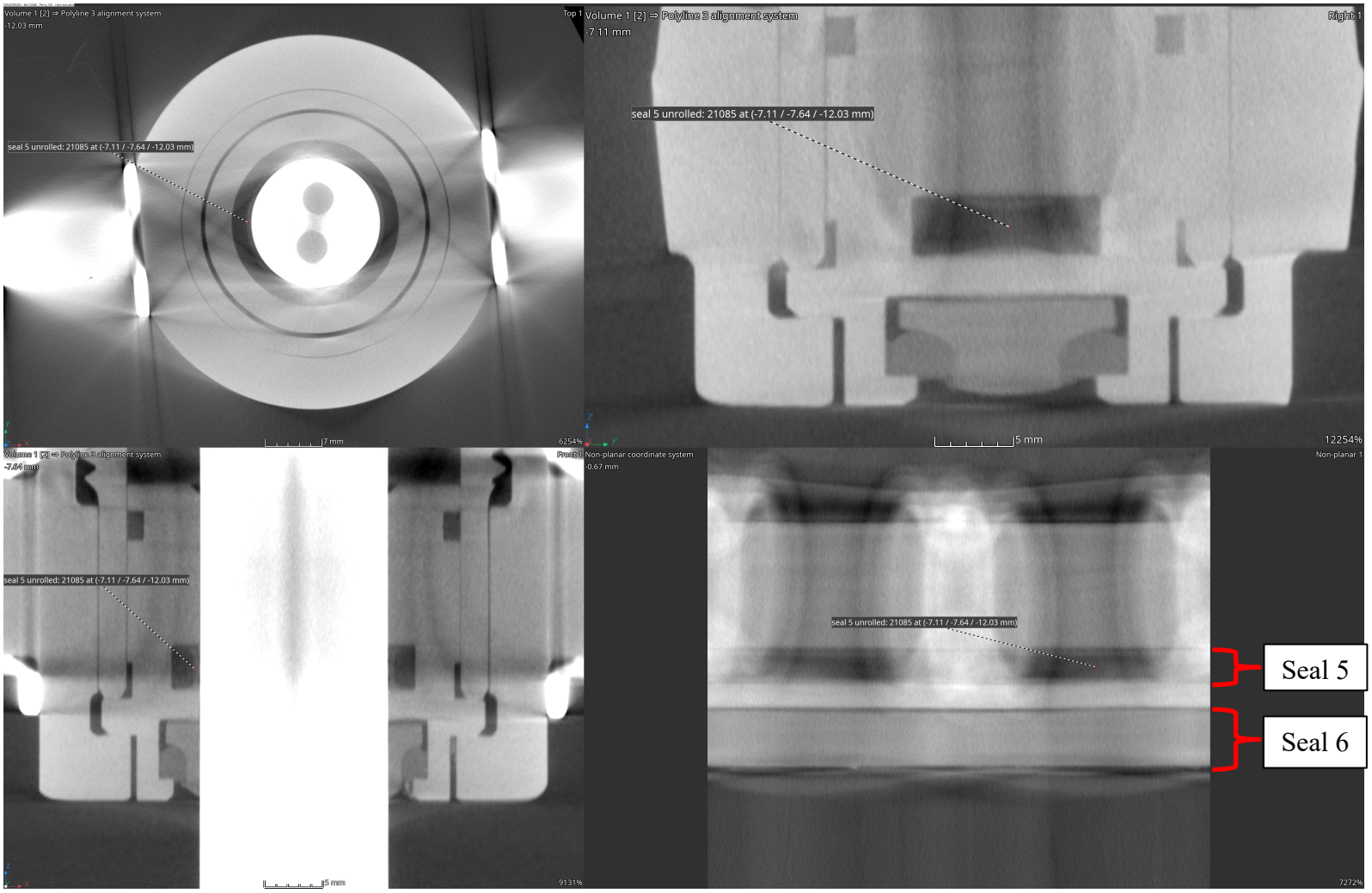


Figure 110
Right actuator – microfocus – seal 5 unrolled

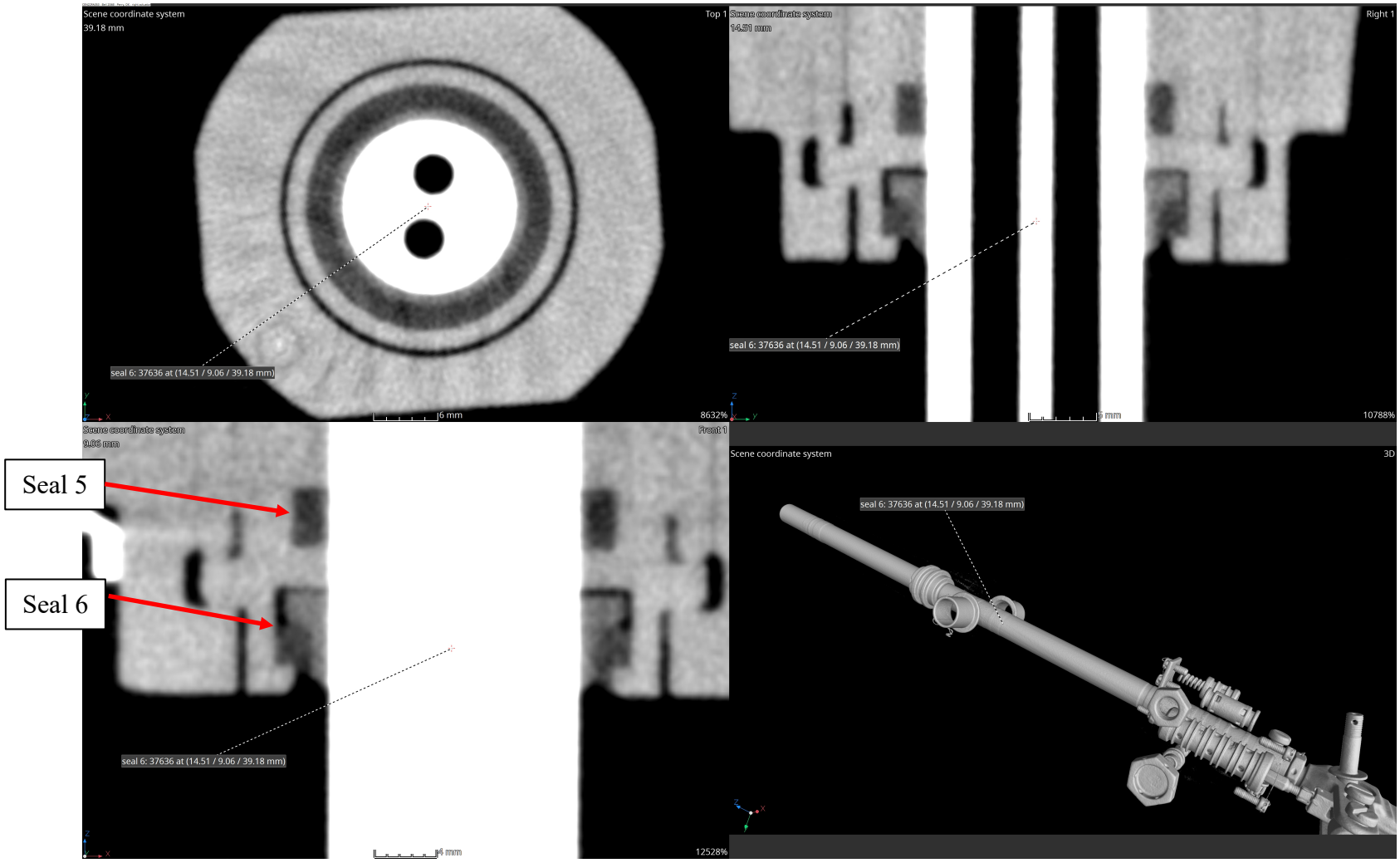


Figure 111
Right actuator – 6 MV – seal 6

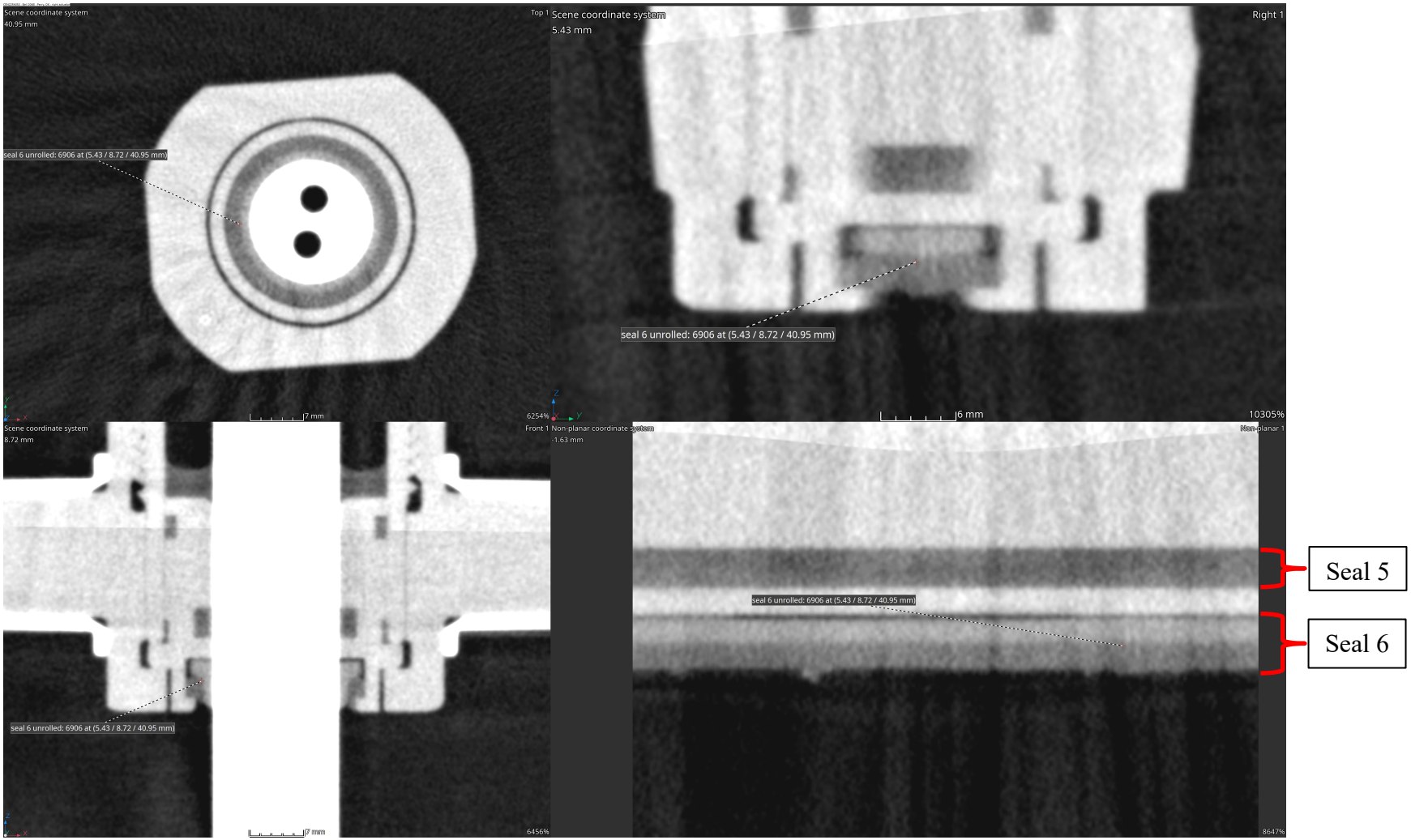


Figure 112
Right actuator – 6 MV – seal 6 unrolled

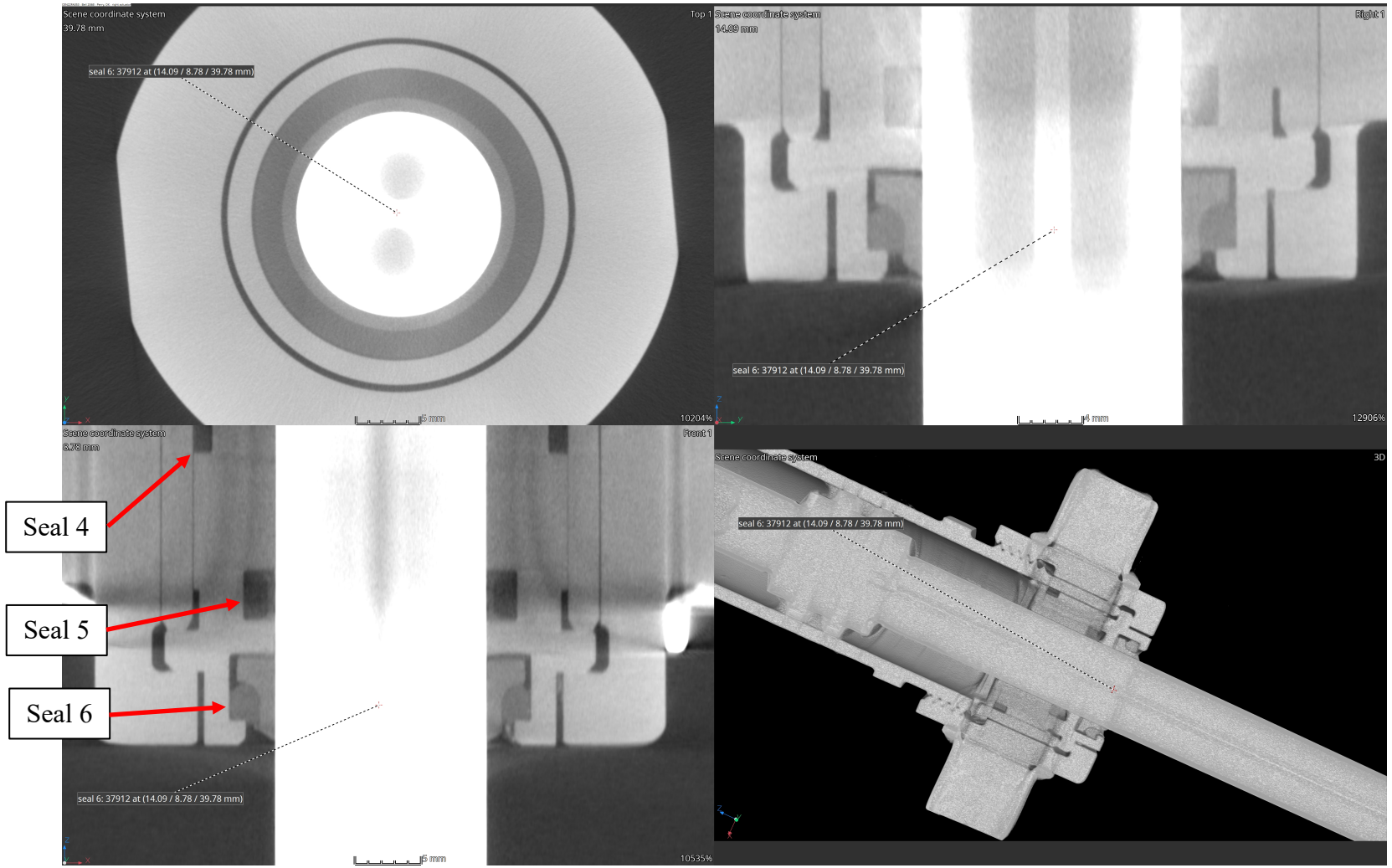


Figure 113
Right actuator – microfocus – seal 6

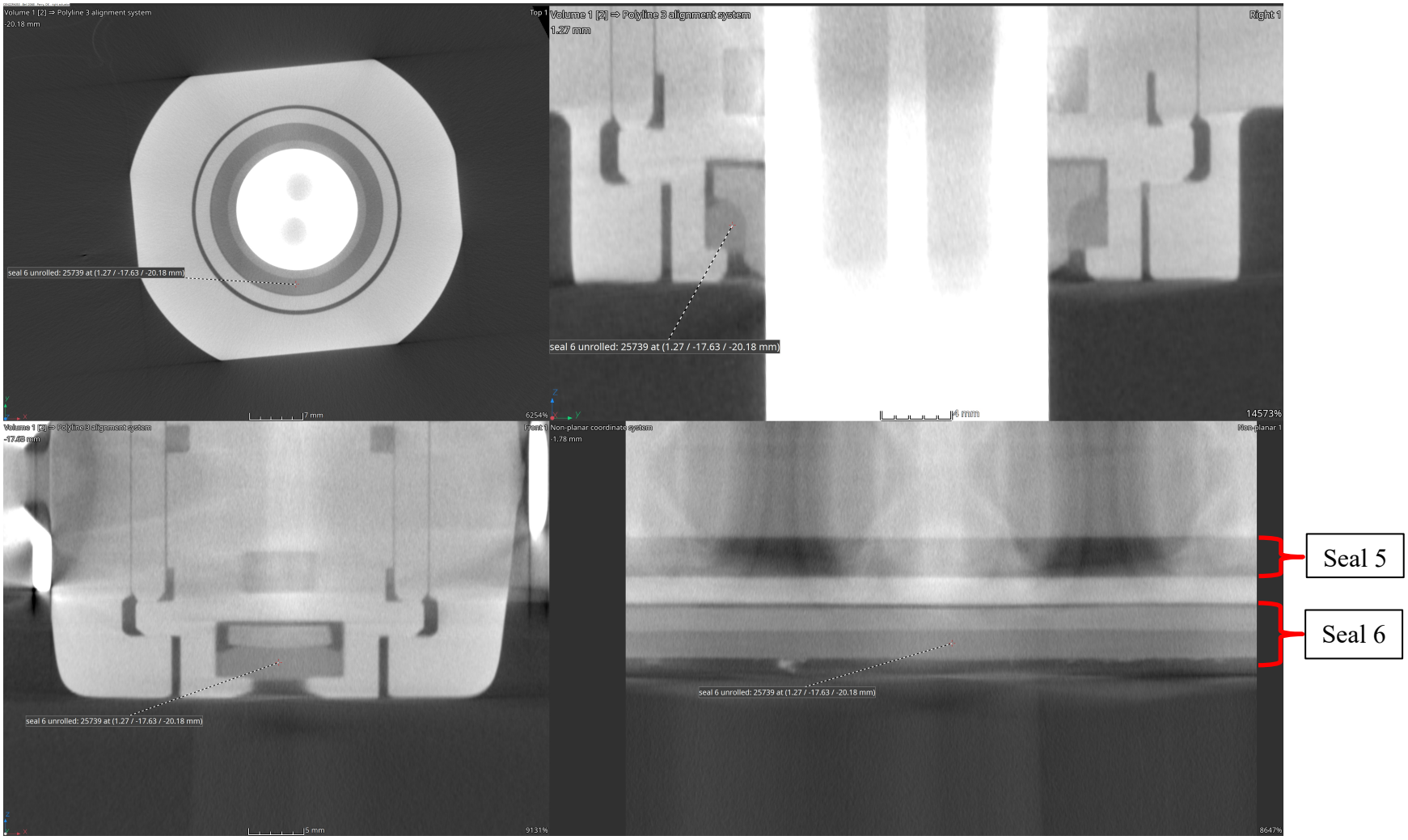


Figure 114
Right actuator – microfocus – seal 6 unrolled

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