

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

April 13, 2022

Computed Tomography Specialist's Factual Report

WPR20LA280

A. ACCIDENT

Location: Coalinga, CA
Date: August 19, 2020
Time: 0945 pacific daylight time
Airplane: UH-1H, N711GH

B. GROUP

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

C. SUMMARY

On August 19, 2020 about 0945 Pacific daylight time, an Arrow-Falcon Exporters, Inc. UH-1H, N711GH, was destroyed when it was involved in an accident near Coalinga, California. The pilot, the sole occupant was fatally injured. The helicopter was operated as a public use firefighting flight.

The internal configurations of the collective actuator, left lateral actuator, right lateral actuator, and an irreversible valve assembly from the accident helicopter were documented using radiographic images that were collected from July 21 to July 28, 2021, in Chicago, Illinois. A total of 20,142 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. Indications of medium density particles and/or material were noted in several locations within the collective actuator, the left lateral actuator, right lateral actuator, and the irreversible valve assembly.
2. Indications of high density objects and/or particles were noted in the left lateral actuator, right lateral actuator, and the irreversible valve assembly.
3. There were indications of a bulging cap for the sequence valve of the irreversible valve assembly.

D. DETAILS OF THE INVESTIGATION

1.0 General

The collective actuator, left lateral actuator, right lateral actuator, and an irreversible valve assembly 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 July 21 to July 28, 2021, by Varex, Inc under the direction of the NTSB using the Actis 225/500 microfocus CT system.

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 20,142 slices, and the total size of the combined data sets was approximately 88.8 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	Collective Actuator	Left Lateral Actuator	Right Lateral Actuator	Irreversible Valve Assembly
Number of slices	5626	6589	6314	1613
Voxel ¹ Size - X Direction (millimeter(mm))	0.082	0.082	0.082	0.098
Voxel Size - Y Direction (mm)	0.082	0.082	0.082	0.098
Voxel Size - Z Direction (mm)	0.08	0.08	0.08	0.09
Image Projections per Revolution	1800	1800	1800	1800
Exposure time (milliseconds)	285.6	285.6	285.6	285.6
Frames to Avg (frames per projection)	2	2	2	2
X-ray Source Voltage (kilovolts)	223	223	223	220
X-ray Source Current (mA)	0.580	0.580	0.580	0.550
Source Filter Thickness (mm)	1	1	1	1
Source Filter Material	brass	brass	brass	brass
Image Matrix Size (pixels)	1536 x 1536	1536 x 1536	1536 x 1536	1536 x 1536

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 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.

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

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

1. Indications of medium density particles and/or material were noted in several locations within the collective actuator, the left lateral actuator, right lateral actuator, and the irreversible valve assembly.
2. Indications of high density objects and/or particles were noted in the left lateral actuator, right lateral actuator, and the irreversible valve assembly (see table 2).
3. There were indications of a bulging cap for the sequence valve of the irreversible valve assembly.

Table 2
High Density Object/Particle Locations

Component	High Density Object/Particle Number	Subcomponent	Location
Left lateral actuator	1	NA	Between piston wall and mounting structure
Left lateral actuator	2	NA	Between piston wall and mounting structure
Left lateral actuator	3	NA	Between piston wall and mounting structure
Left lateral actuator	4	NA	Between piston wall and mounting structure
Left lateral actuator	5	NA	Between piston wall and mounting structure
Left lateral actuator	6	NA	Top of ball joint surround structure
Left lateral actuator	7	NA	Top of ball joint
Left lateral actuator	8	NA	Top of ball joint
Left lateral actuator	9	Sleeve and spool	Between sleeve and cavity wall

Left lateral actuator	multiple	NA	Top of ball joint surround structure
Right lateral actuator	1	NA	Top of washer below ball joint
Right lateral actuator	2	NA	Top of washer below ball joint
Right lateral actuator	3	NA	Top of washer below ball joint
Right lateral actuator	4	NA	Underside of washer below ball joint
Right lateral actuator	5	NA	Underside of washer below ball joint
Right lateral actuator	6	NA	Underside of washer below ball joint
Right lateral actuator	layer 1	NA	Top of washer below ball joint
Right lateral actuator	layer 2	NA	Top of washer below lower spring seal
Right lateral actuator	layer 3	NA	Bottom of washer below lower spring seal
Irreversible valve assembly	1	NA	Hydraulic passage leading to accumulator
Irreversible valve assembly	2	Check valve A	Between check valve exterior wall and cavity wall
Irreversible valve assembly	3	Check valve A	On check valve lower flange between check valve exterior wall and cavity wall
Irreversible valve assembly	4	Check valve A	On check valve lower flange between check valve exterior wall and cavity wall
Irreversible valve assembly	5	Cylinder pressure port	Between exterior port wall and cavity wall
Irreversible valve assembly	6	Cylinder pressure port	Between exterior port wall and cavity wall
Irreversible valve assembly	7	Cylinder pressure port	Between exterior port wall and cavity wall
Irreversible valve assembly	8	Differential relief valve	Between exterior wall of moving piece and interior wall of stationary piece
Irreversible valve assembly	9	Check valve B	Between exterior wall of moving piece and interior wall of stationary piece

Irreversible valve assembly	10	Check valve B	On check valve cavity wall
Irreversible valve assembly	11	Check valve B	On interior wall of moving piece
Irreversible valve assembly	12	Check valve B	On interior wall of moving piece
Irreversible valve assembly	13	Check valve B	On flange of cavity cap structure
Irreversible valve assembly	14	Differential relief valve	On flange of cavity cap structure
Irreversible valve assembly	15	Check valve B	On flange of cavity cap structure
Irreversible valve assembly	16	Check valve B	On flange of cavity cap structure
Irreversible valve assembly	17	Check valve B	On flange of cavity cap structure
Irreversible valve assembly	18	Cylinder return port	Between exterior port wall and cavity wall
Irreversible valve assembly	19	Cylinder return port	Between exterior port wall and cavity wall
Irreversible valve assembly	20	Cylinder return port	Between exterior port wall and cavity wall

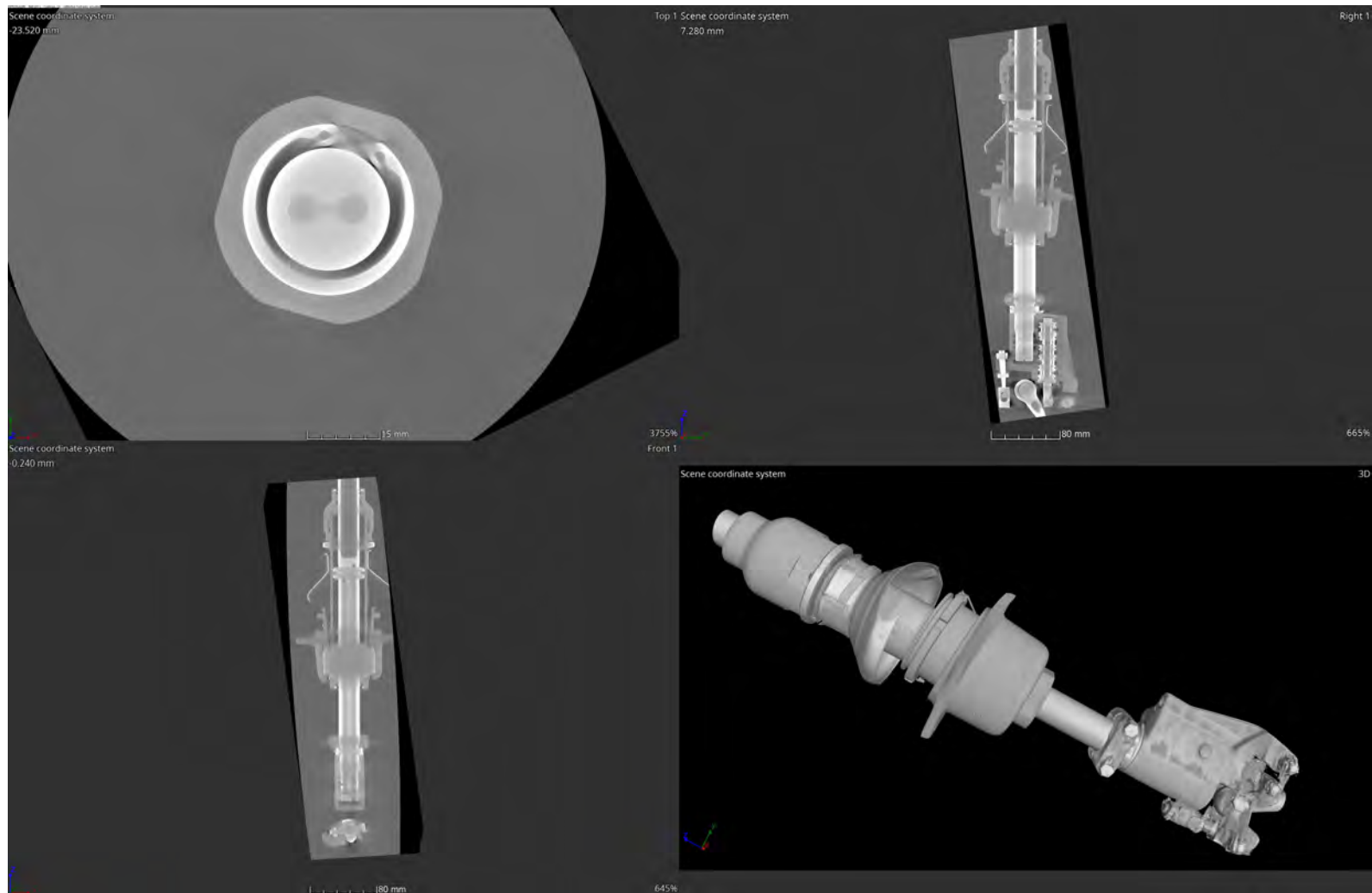


Figure 1
Collective actuator - overview

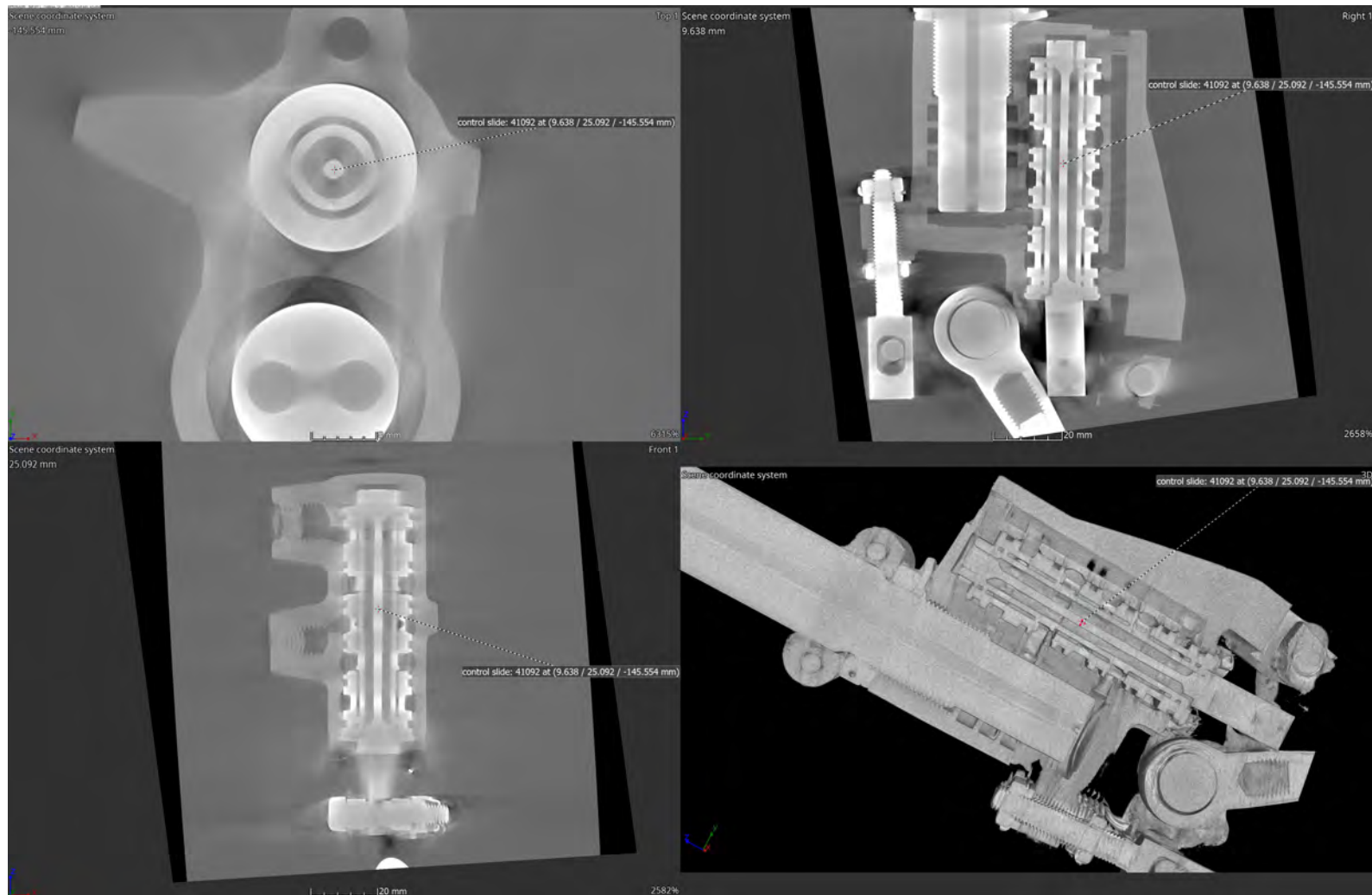


Figure 2
Collective actuator – control slide

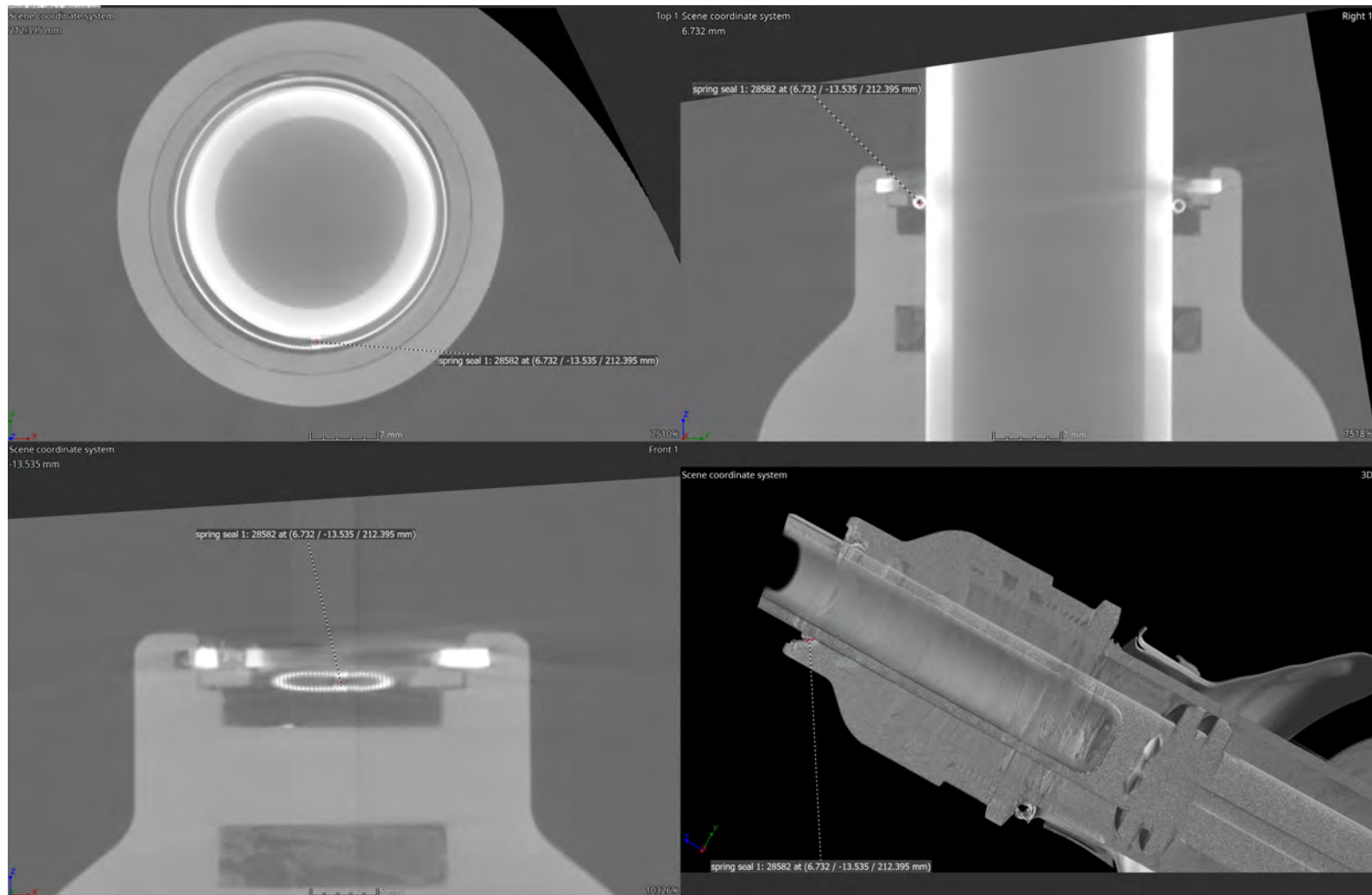


Figure 3
Collective actuator – spring seal 1

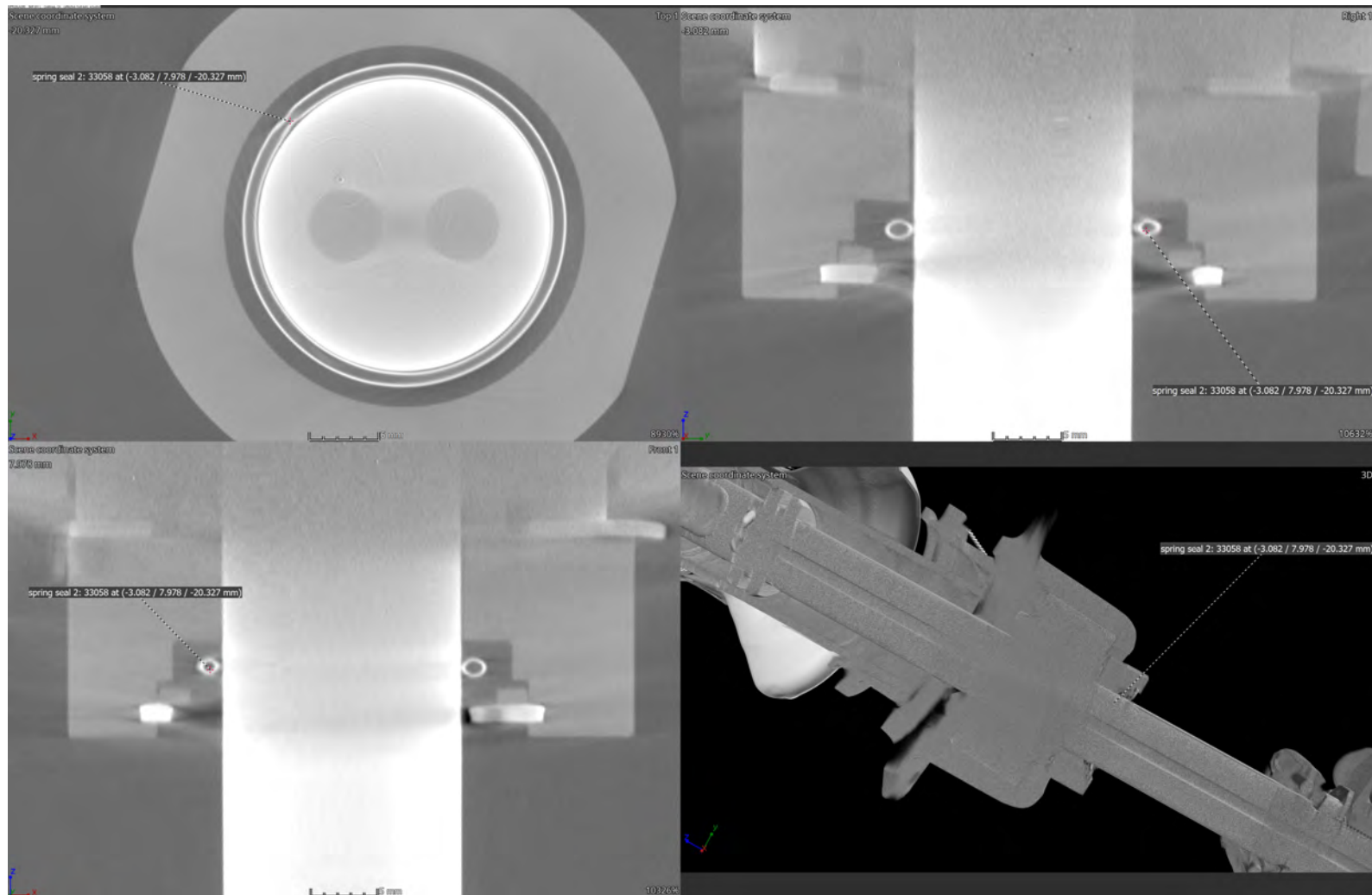


Figure 4
Collective actuator – spring seal 2

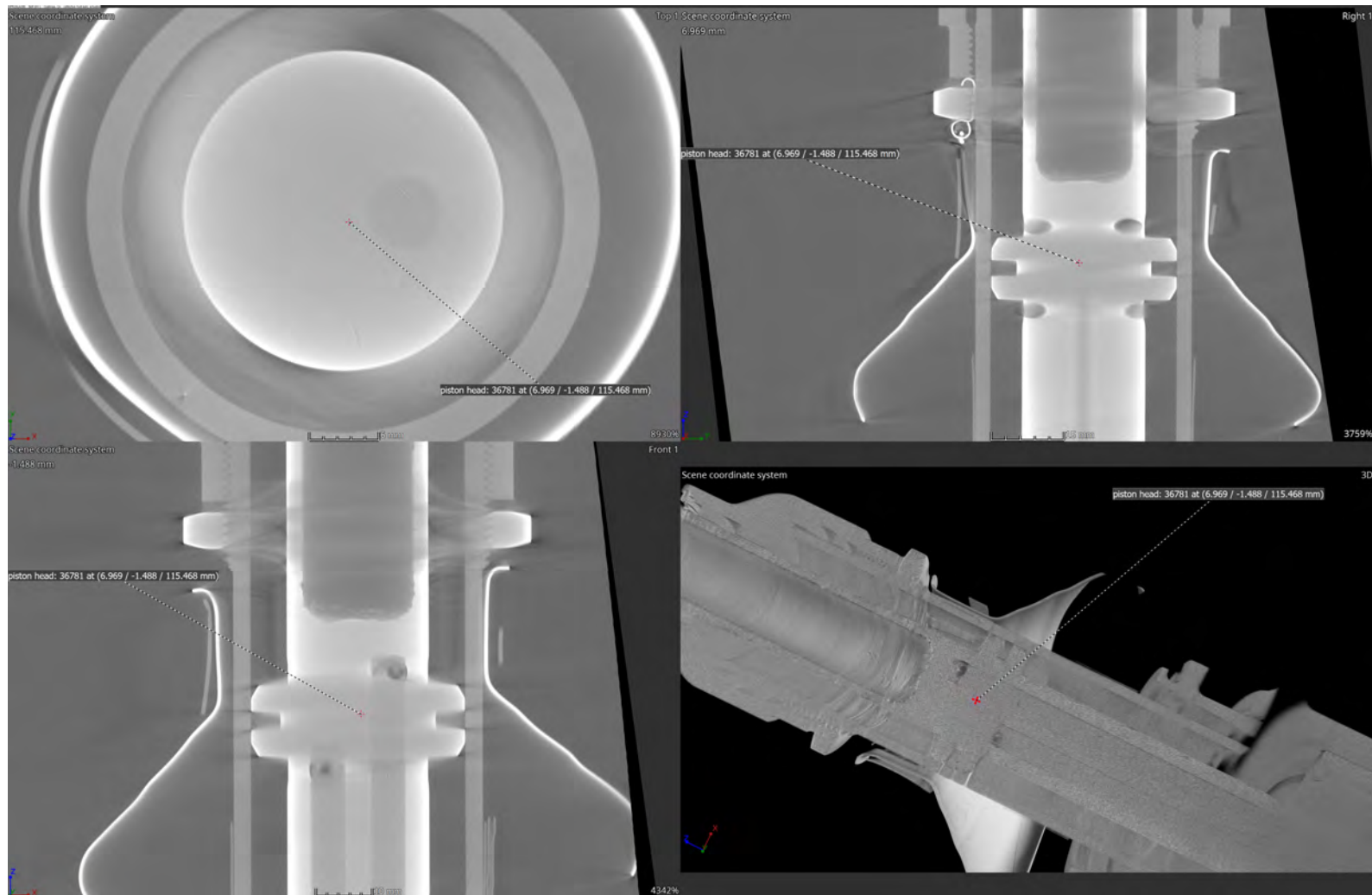


Figure 5
Collective actuator – piston head

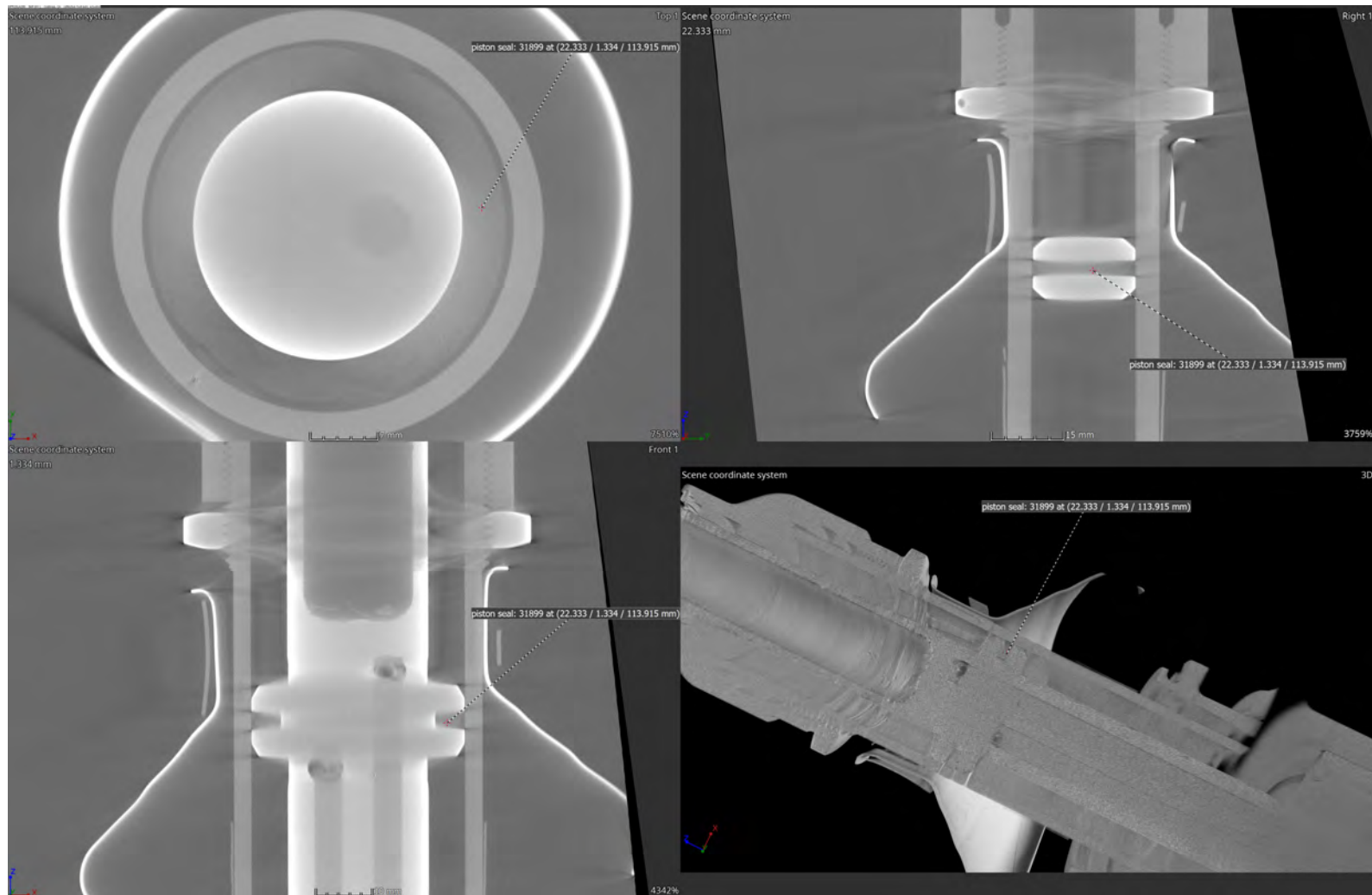


Figure 6
Collective actuator – piston seal

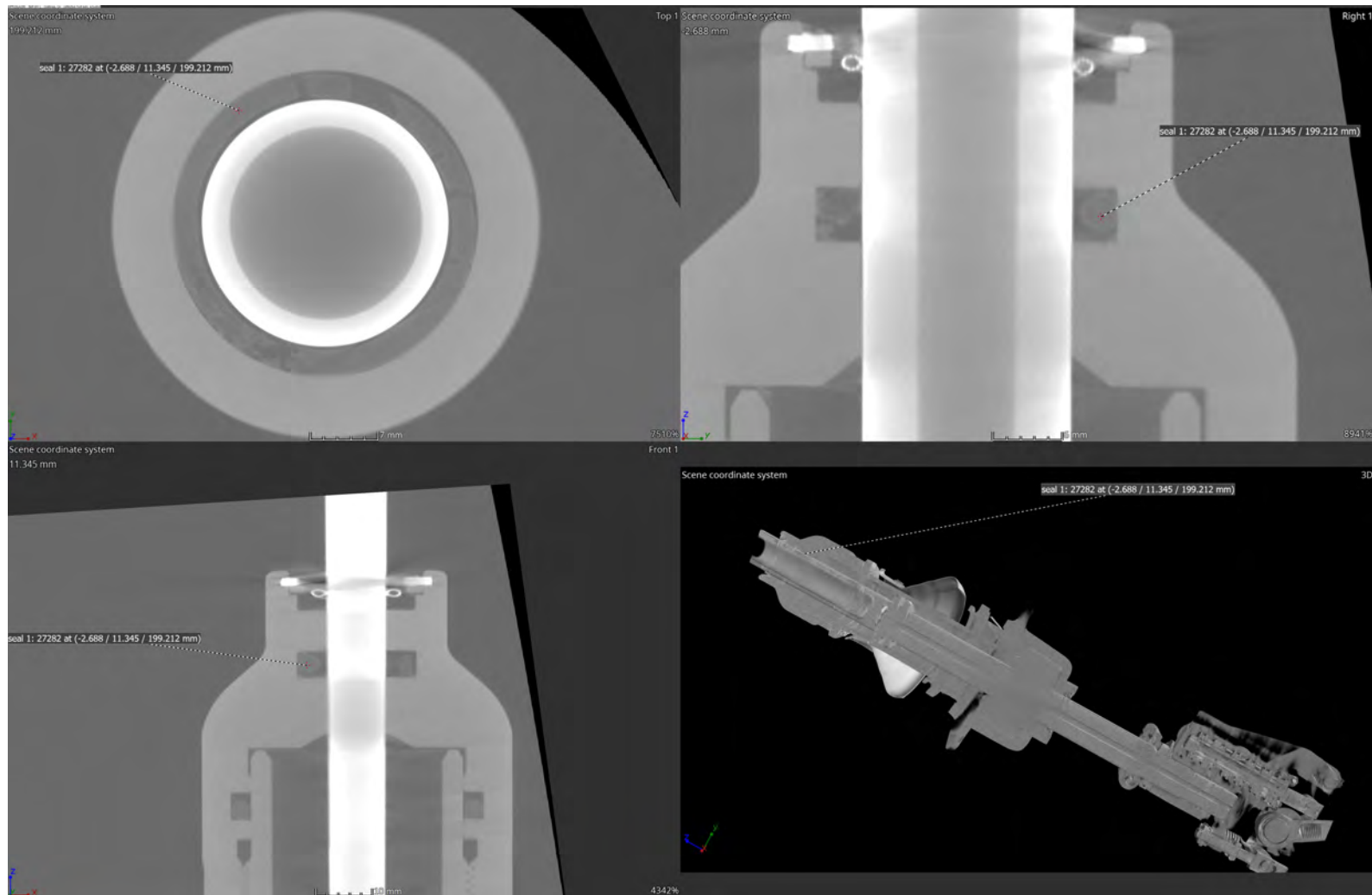


Figure 7
Collective actuator – seal 1

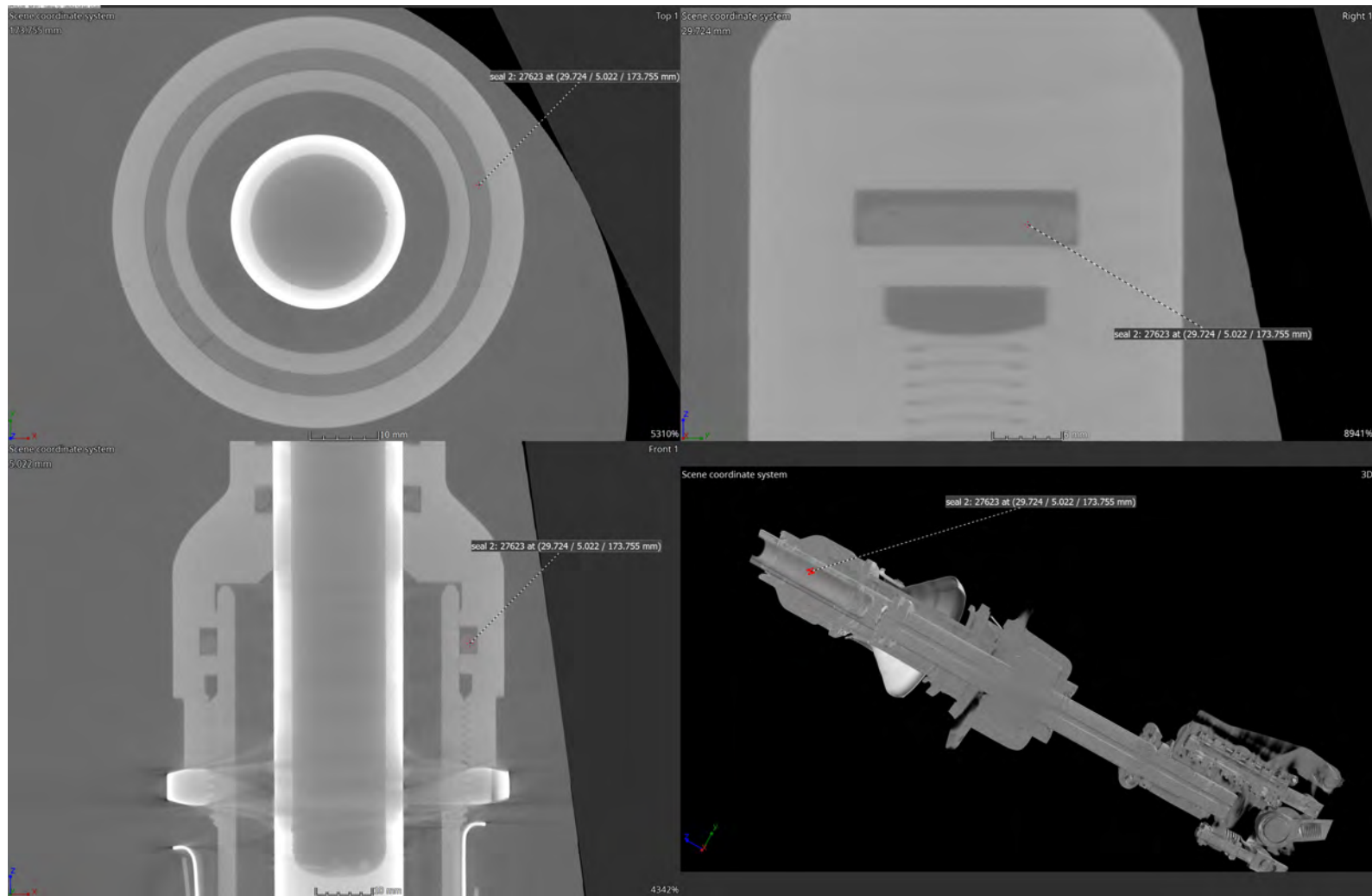


Figure 8
Collective actuator – seal 2

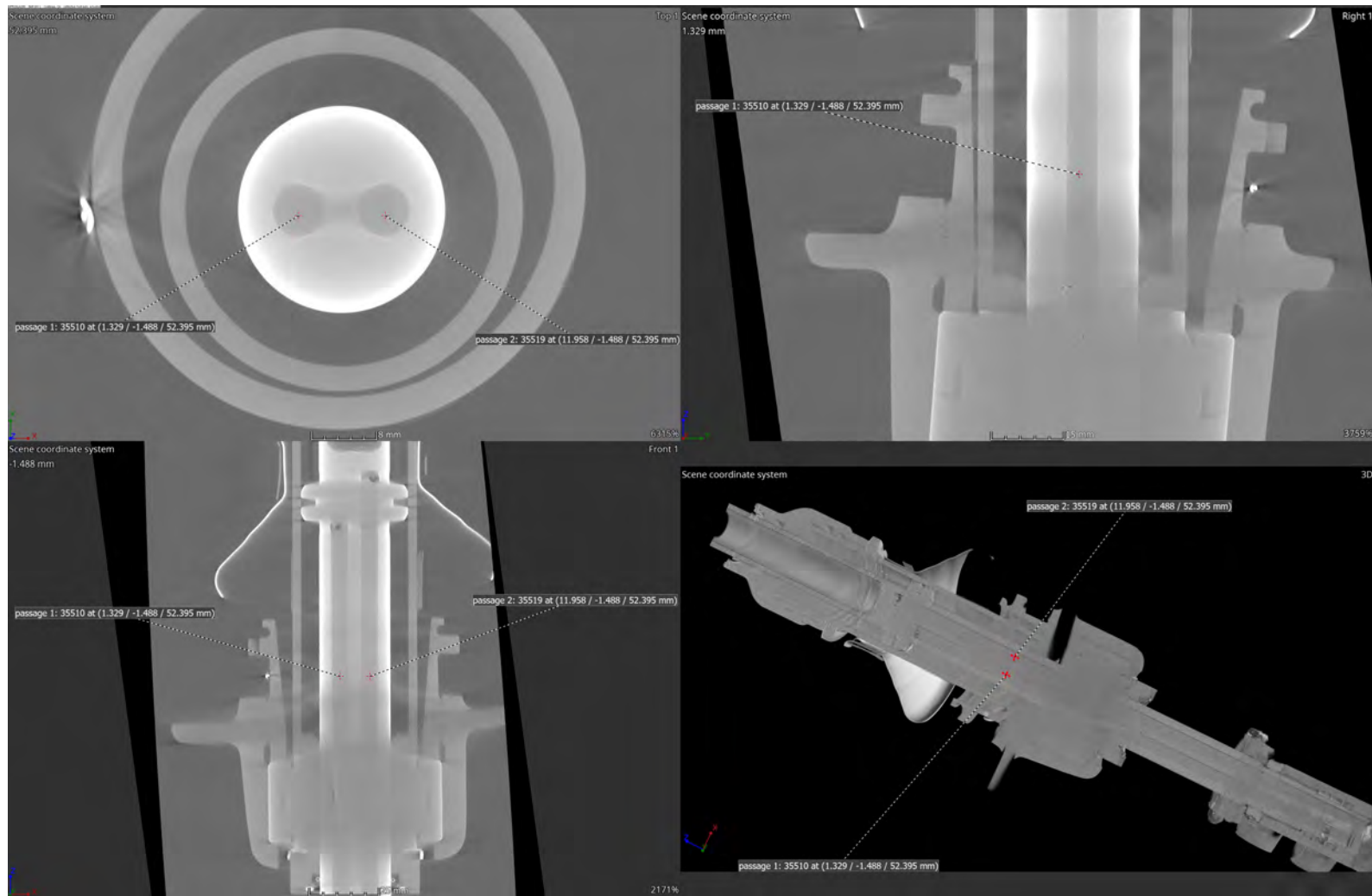


Figure 9
Collective actuator – hydraulic passages 1 and 2

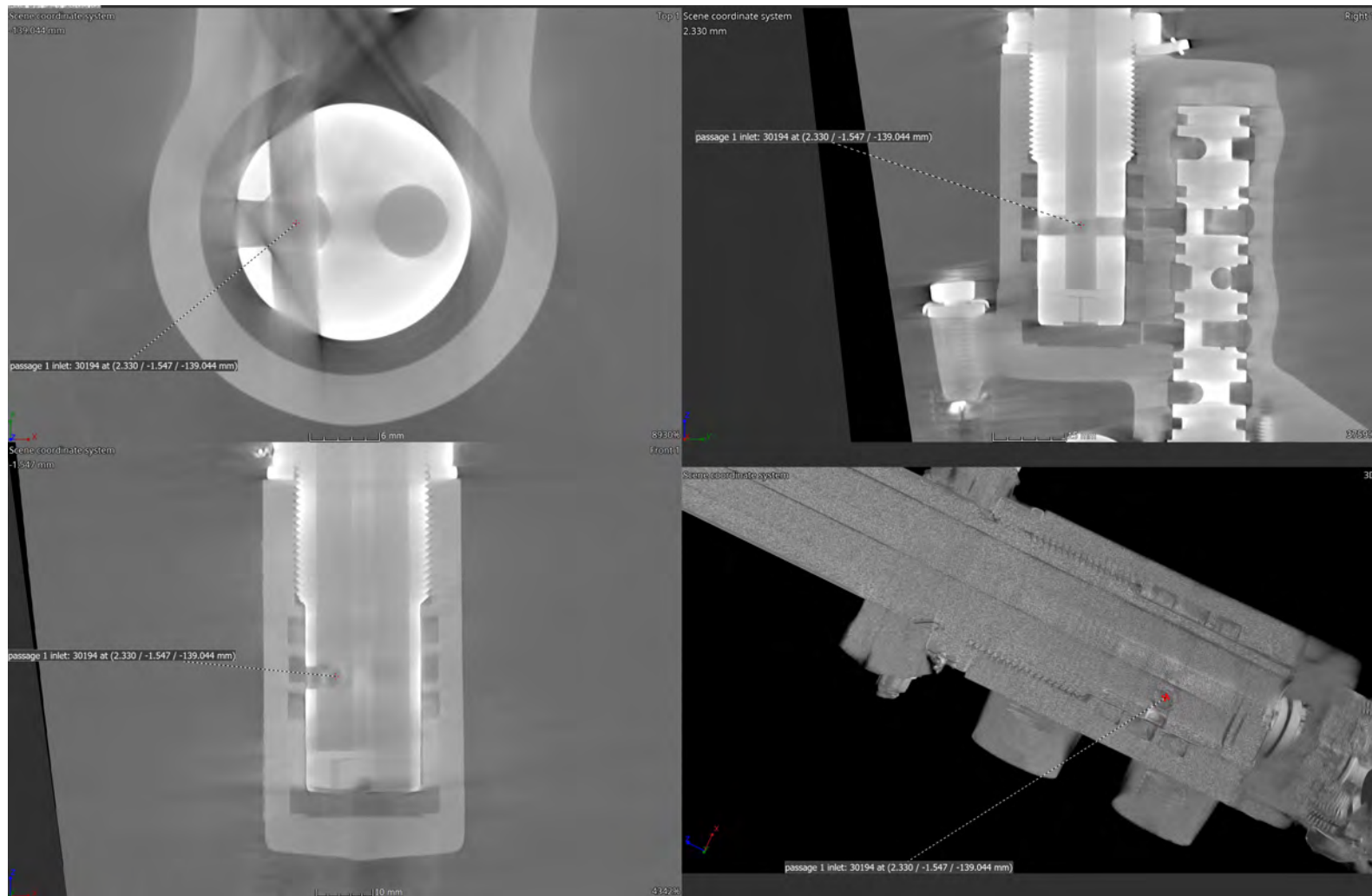


Figure 10
Collective actuator – hydraulic passage 1 inlet

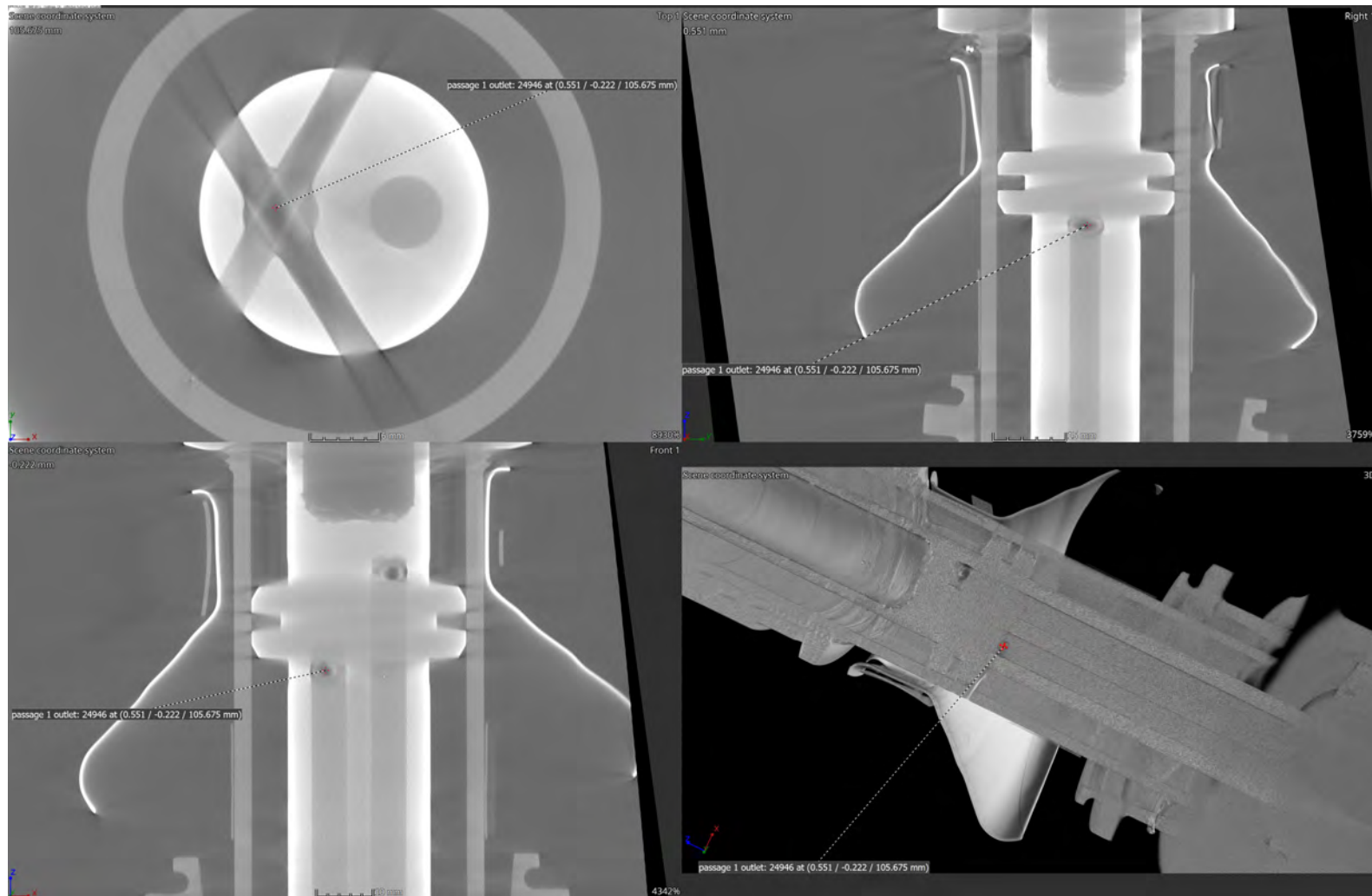


Figure 11
Collective actuator – hydraulic passage 1 outlet

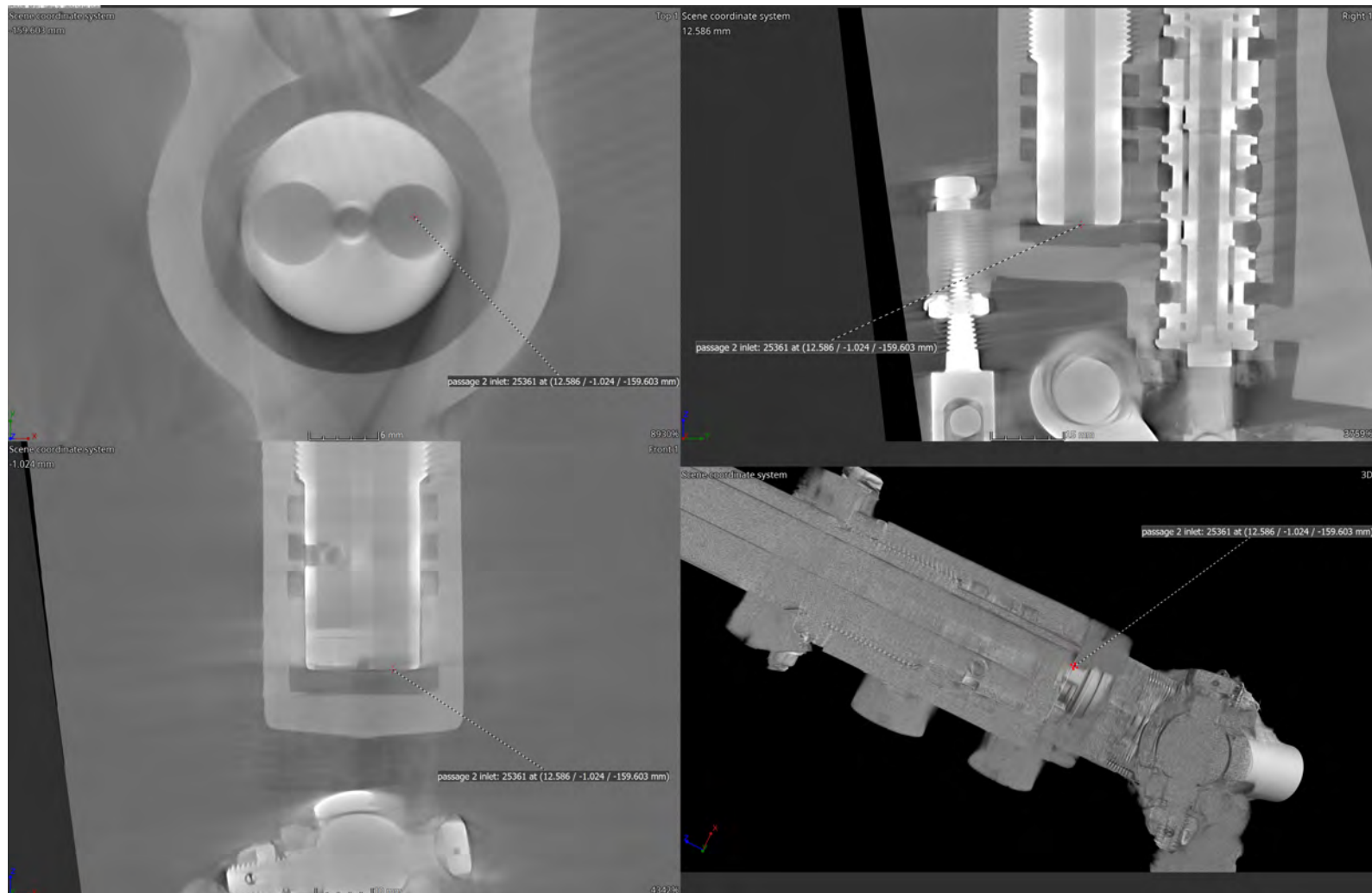


Figure 12
Collective actuator – hydraulic passage 2 inlet

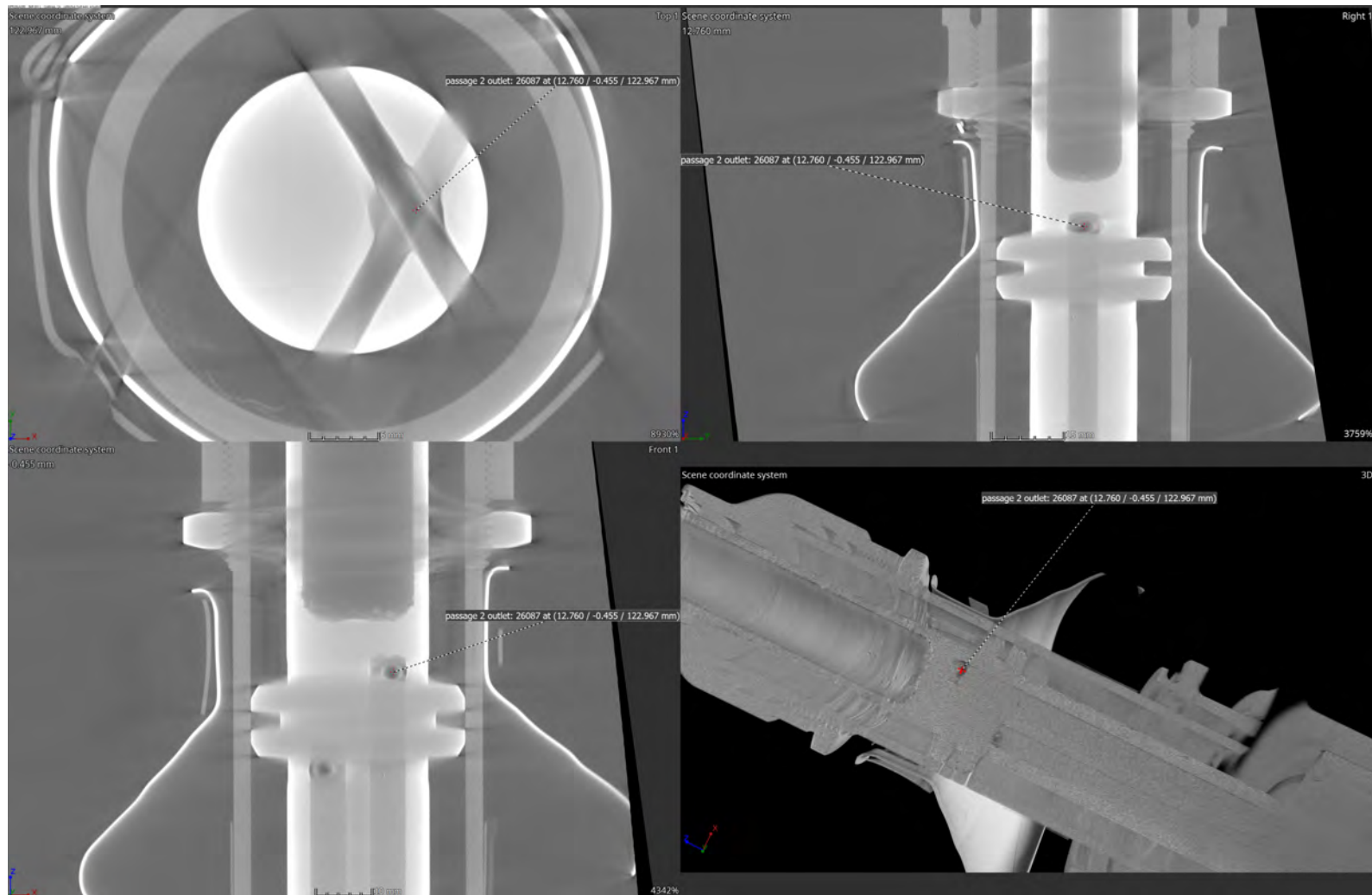


Figure 13
Collective actuator – hydraulic passage 2 outlet

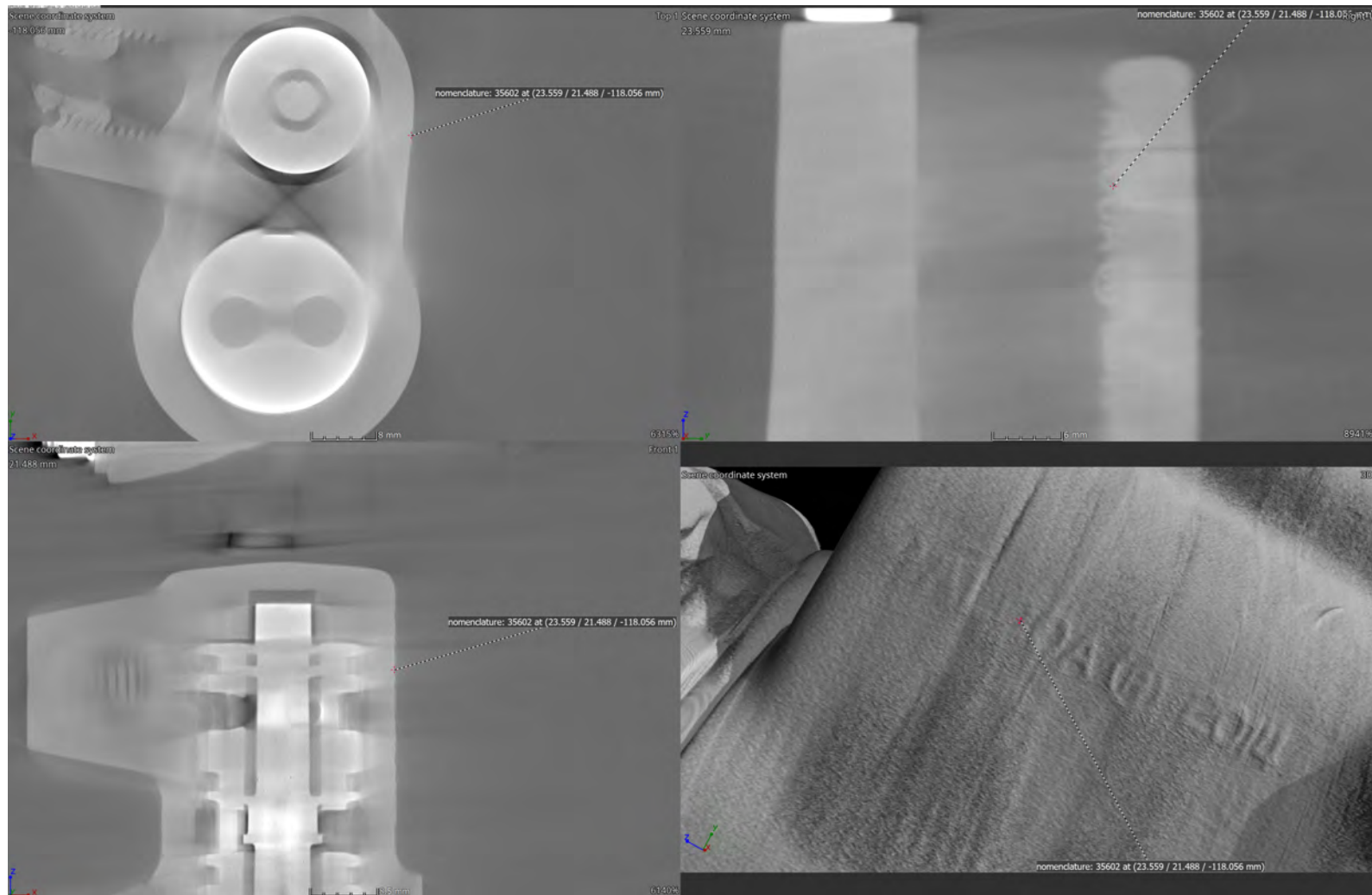


Figure 14
Collective actuator – nomenclature

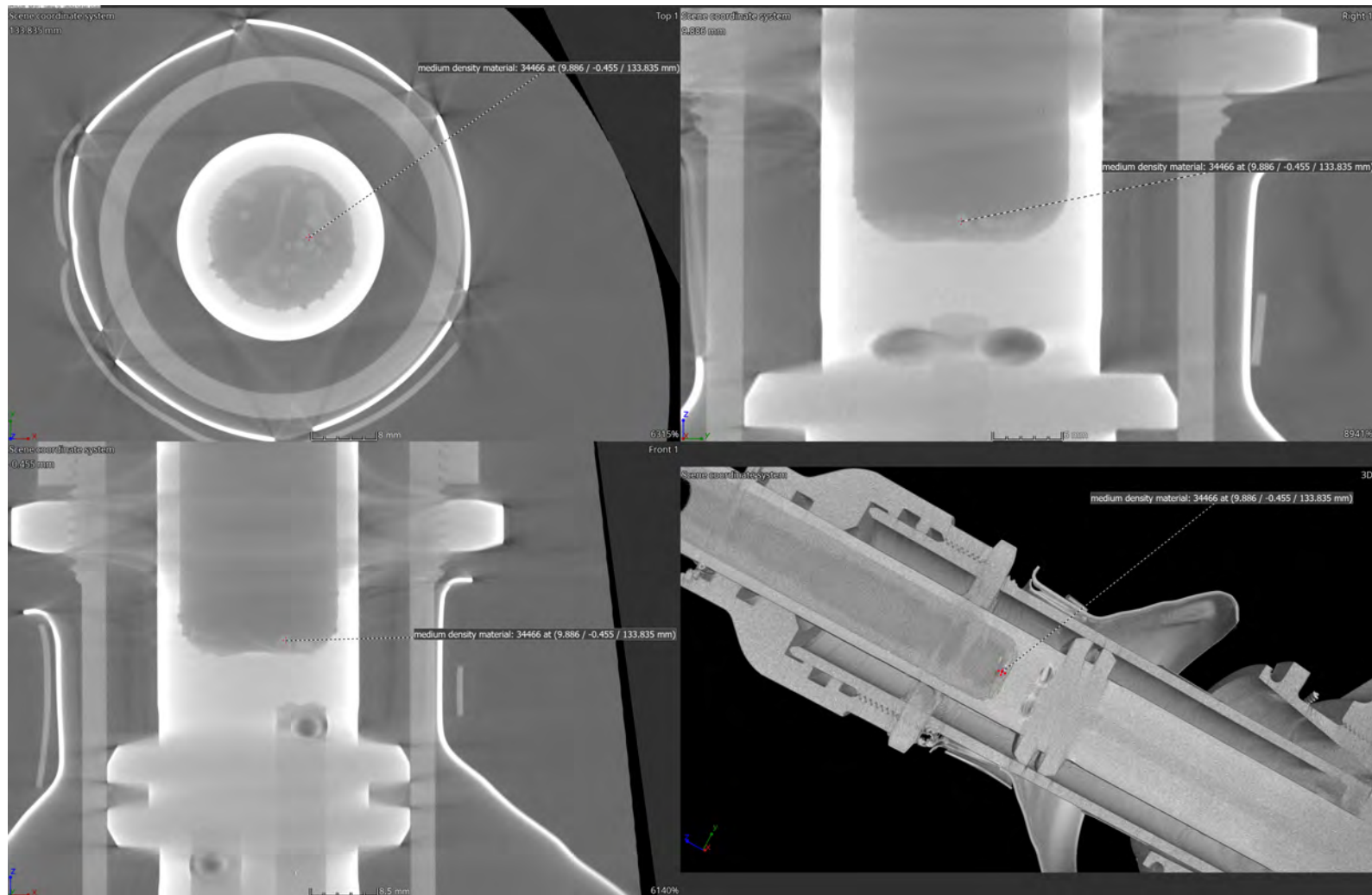


Figure 15
Collective actuator – medium density material

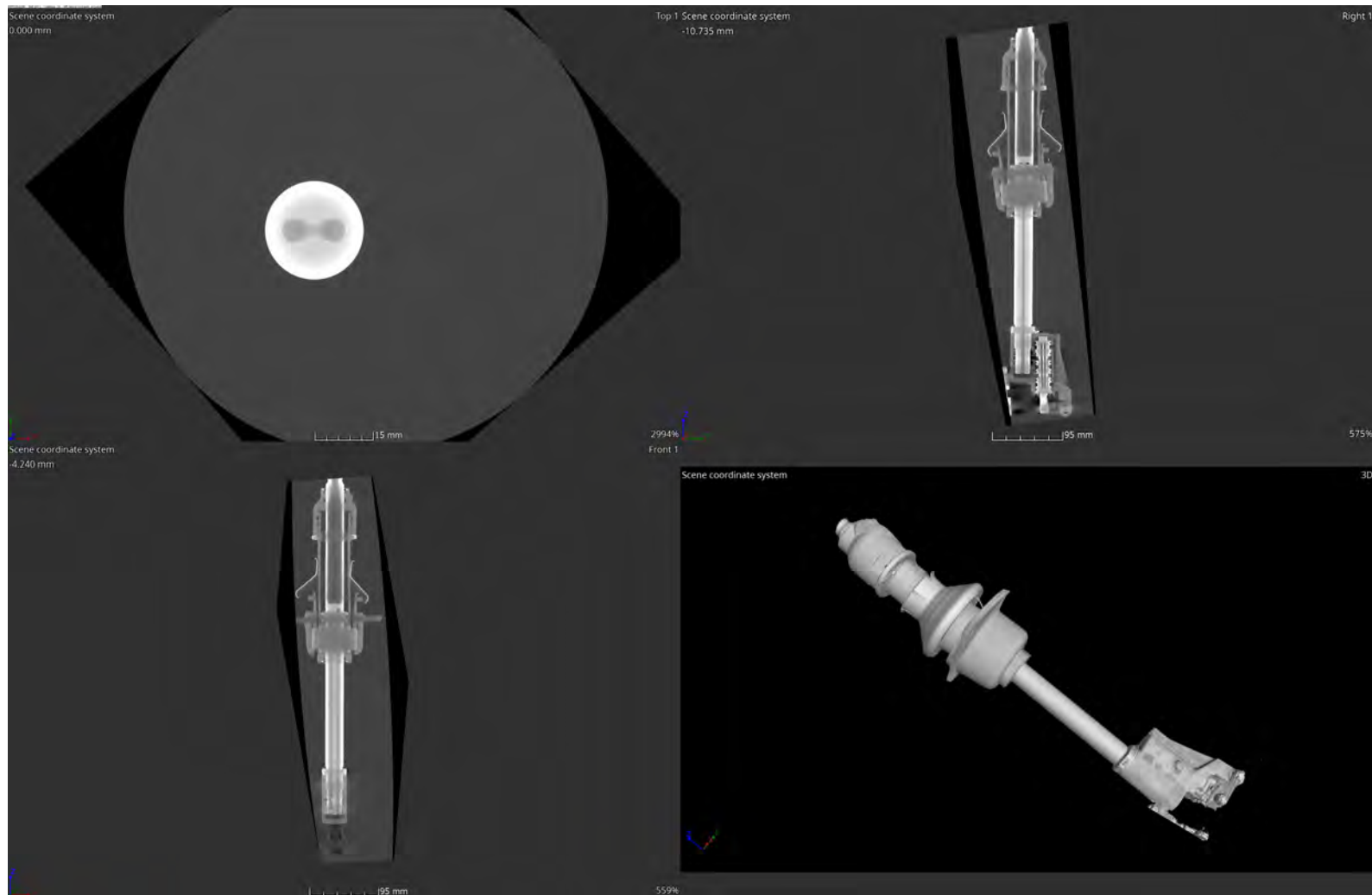


Figure 16
Left lateral actuator – overview

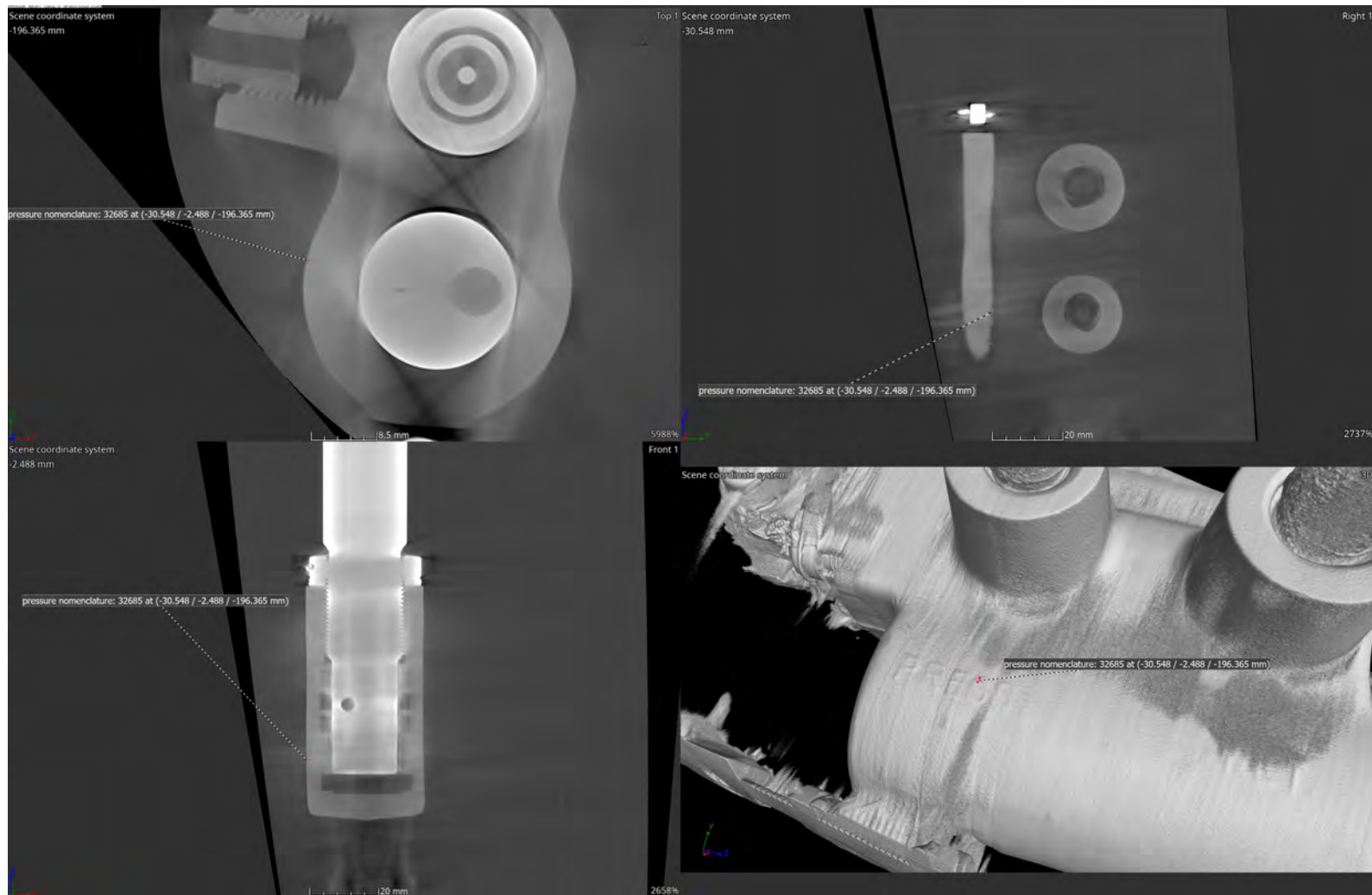


Figure 17
Left lateral actuator – pressure nomenclature

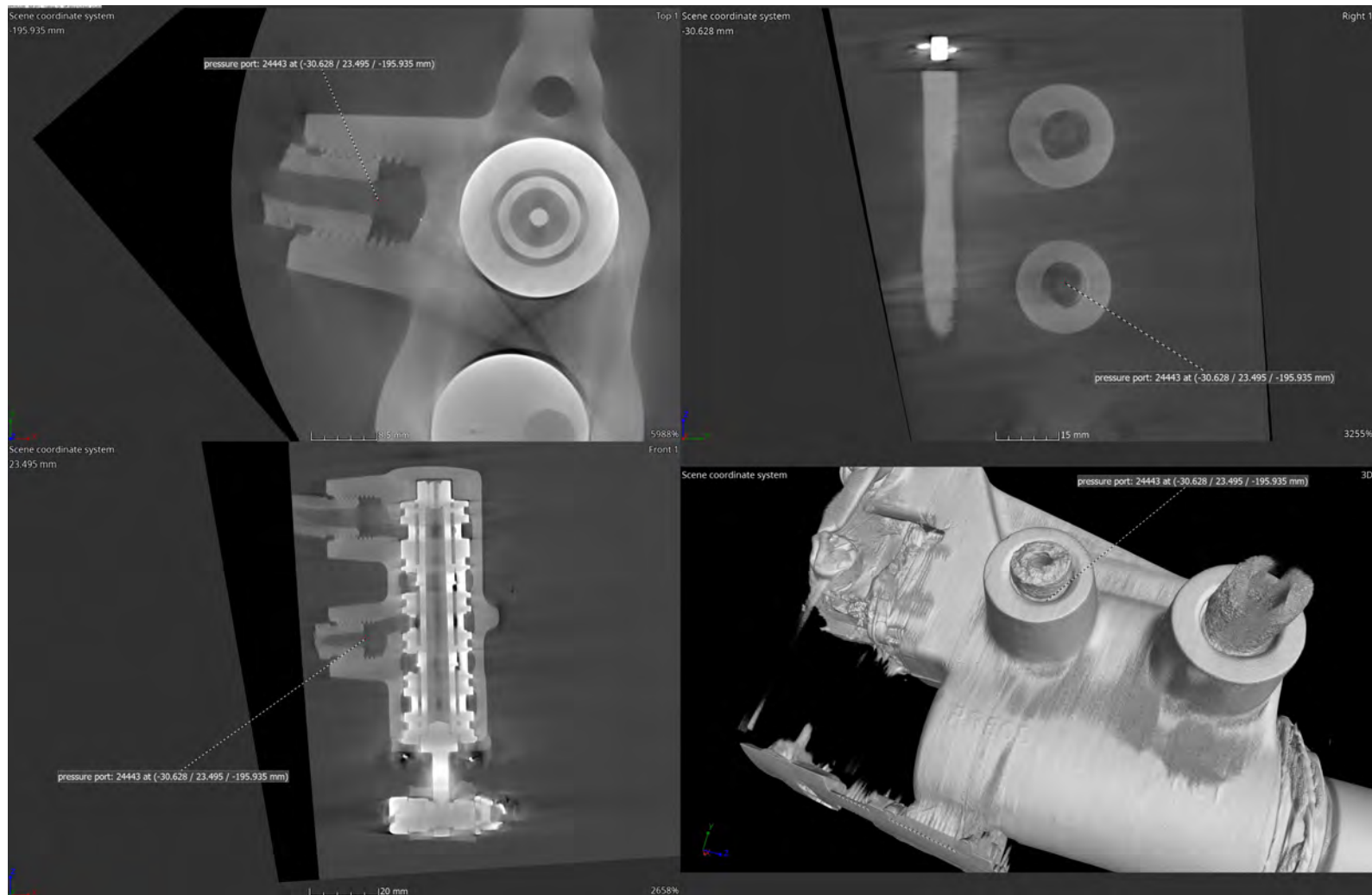


Figure 18
Left lateral actuator – pressure port

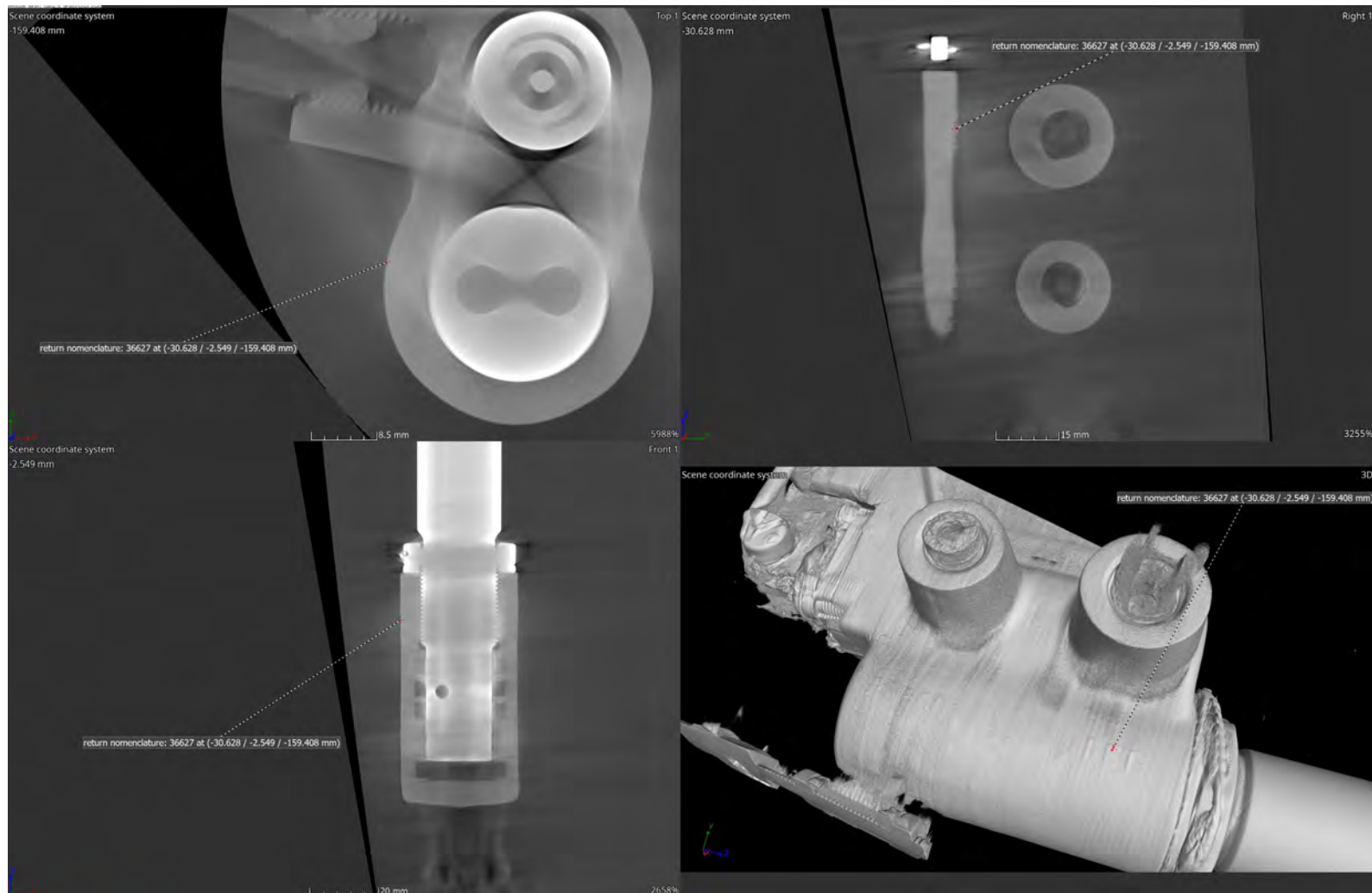


Figure 19
Left lateral actuator – return nomenclature

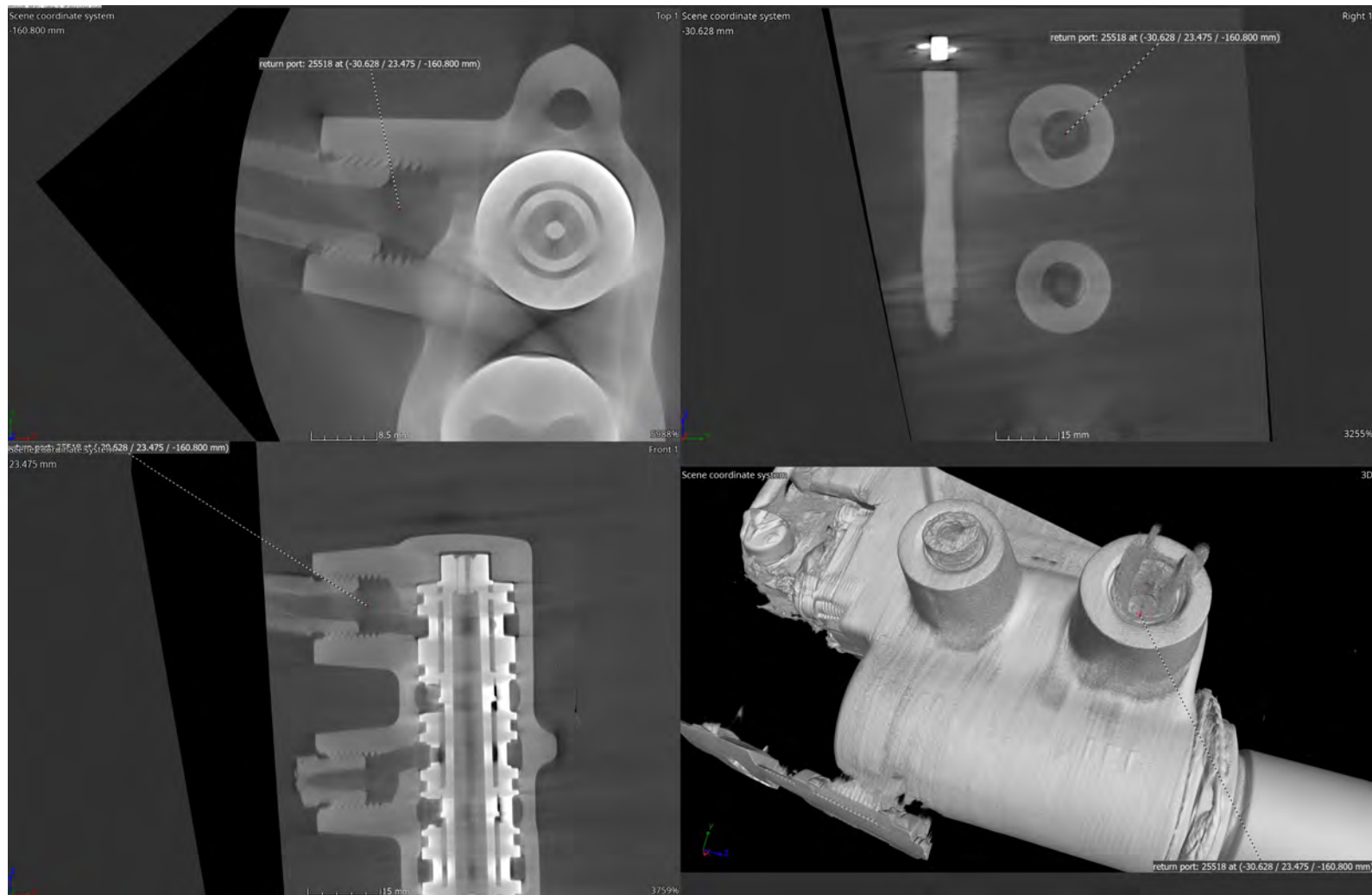


Figure 20
Left lateral actuator – return port

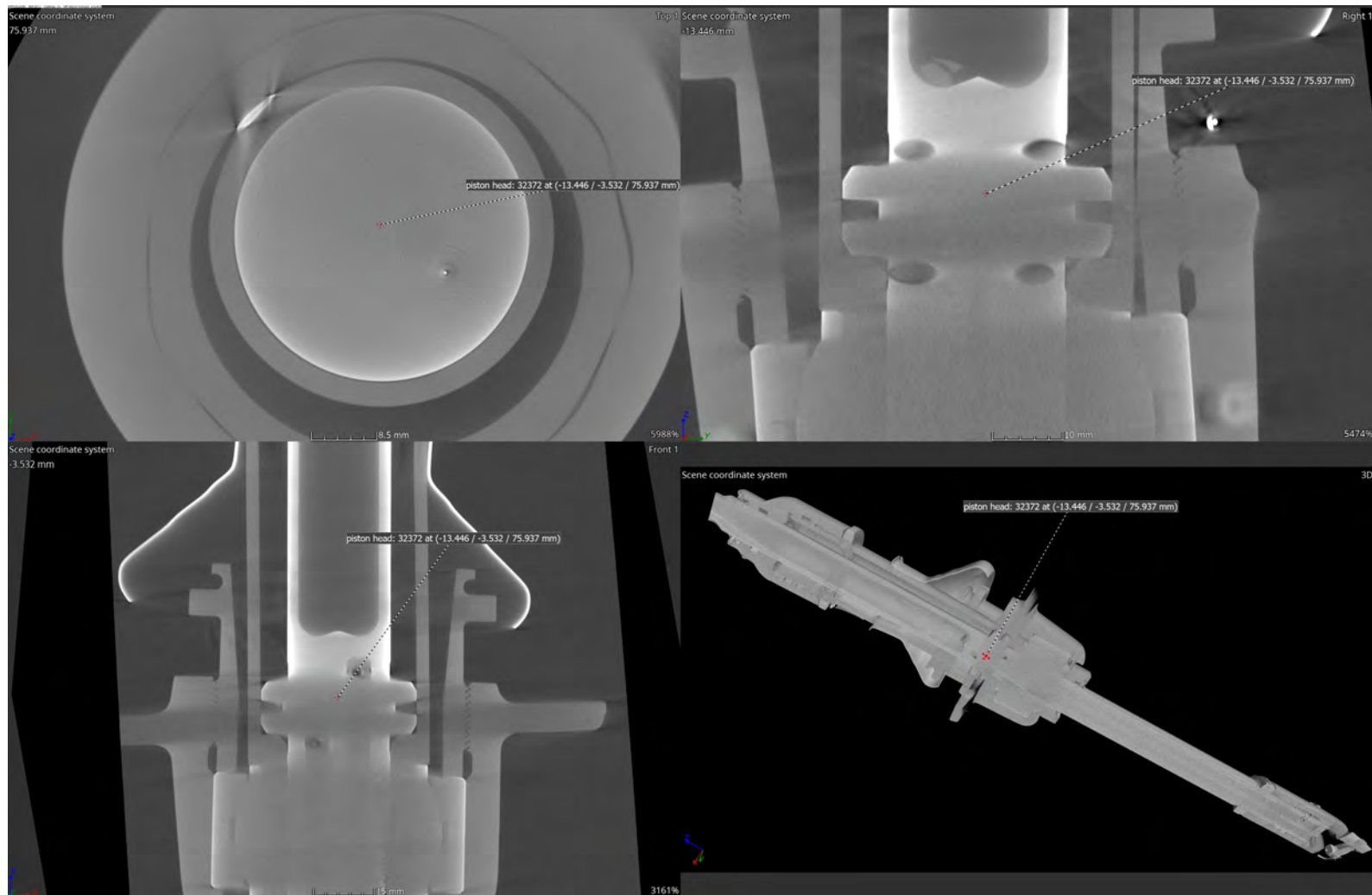


Figure 21
Left lateral actuator – piston head

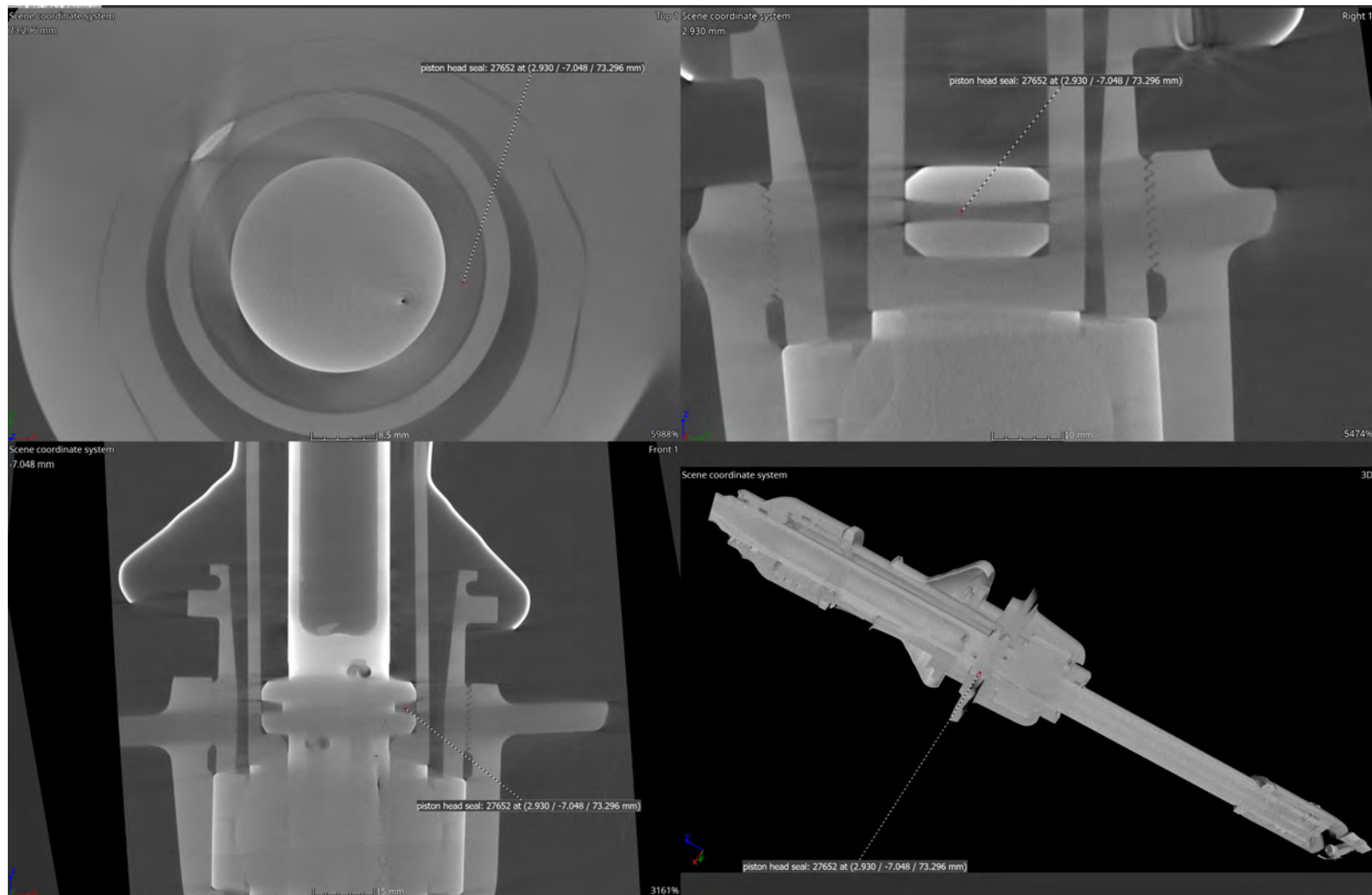


Figure 22
Left lateral actuator – piston head seal

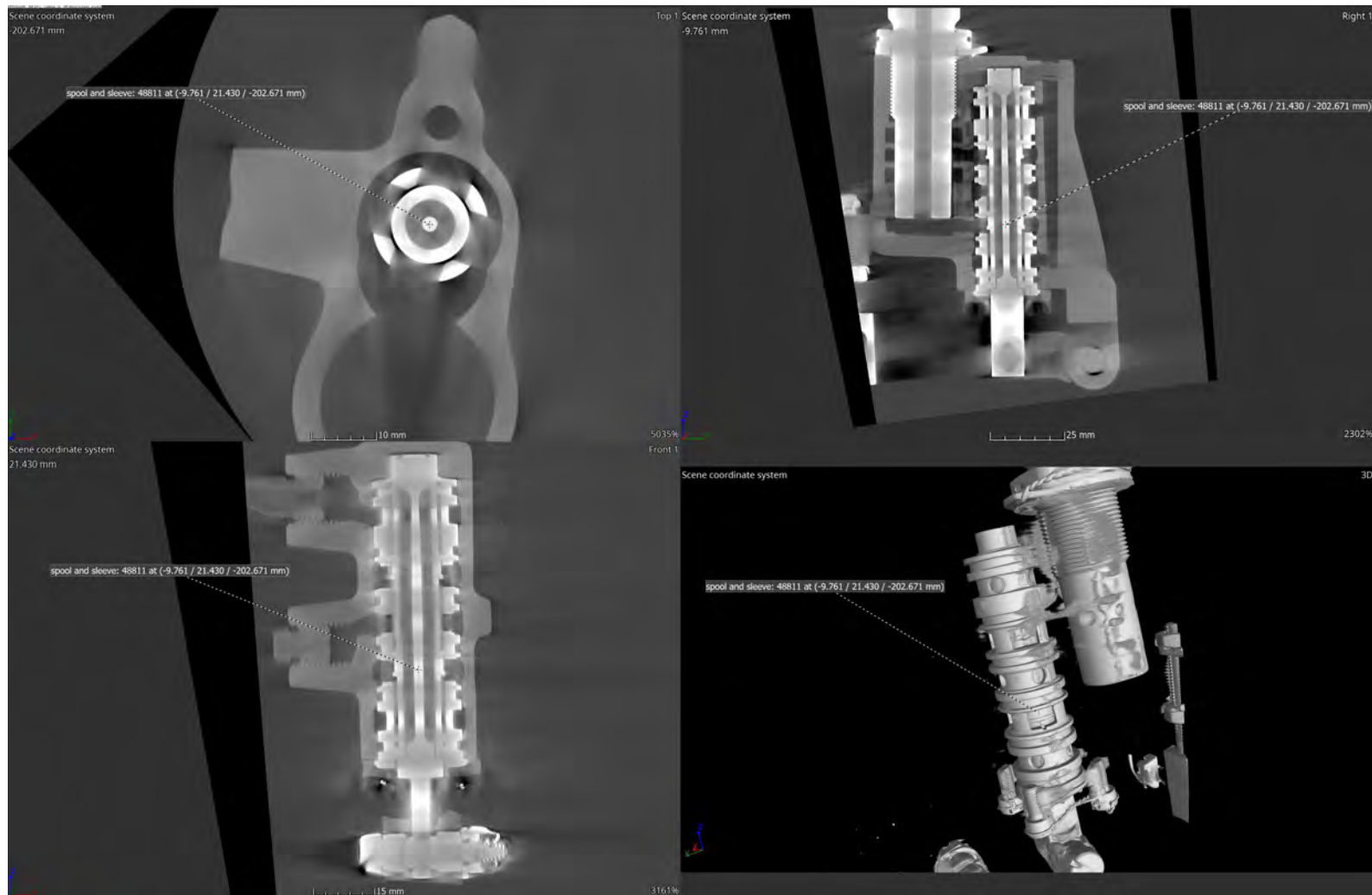


Figure 23
Left lateral actuator – spool and sleeve

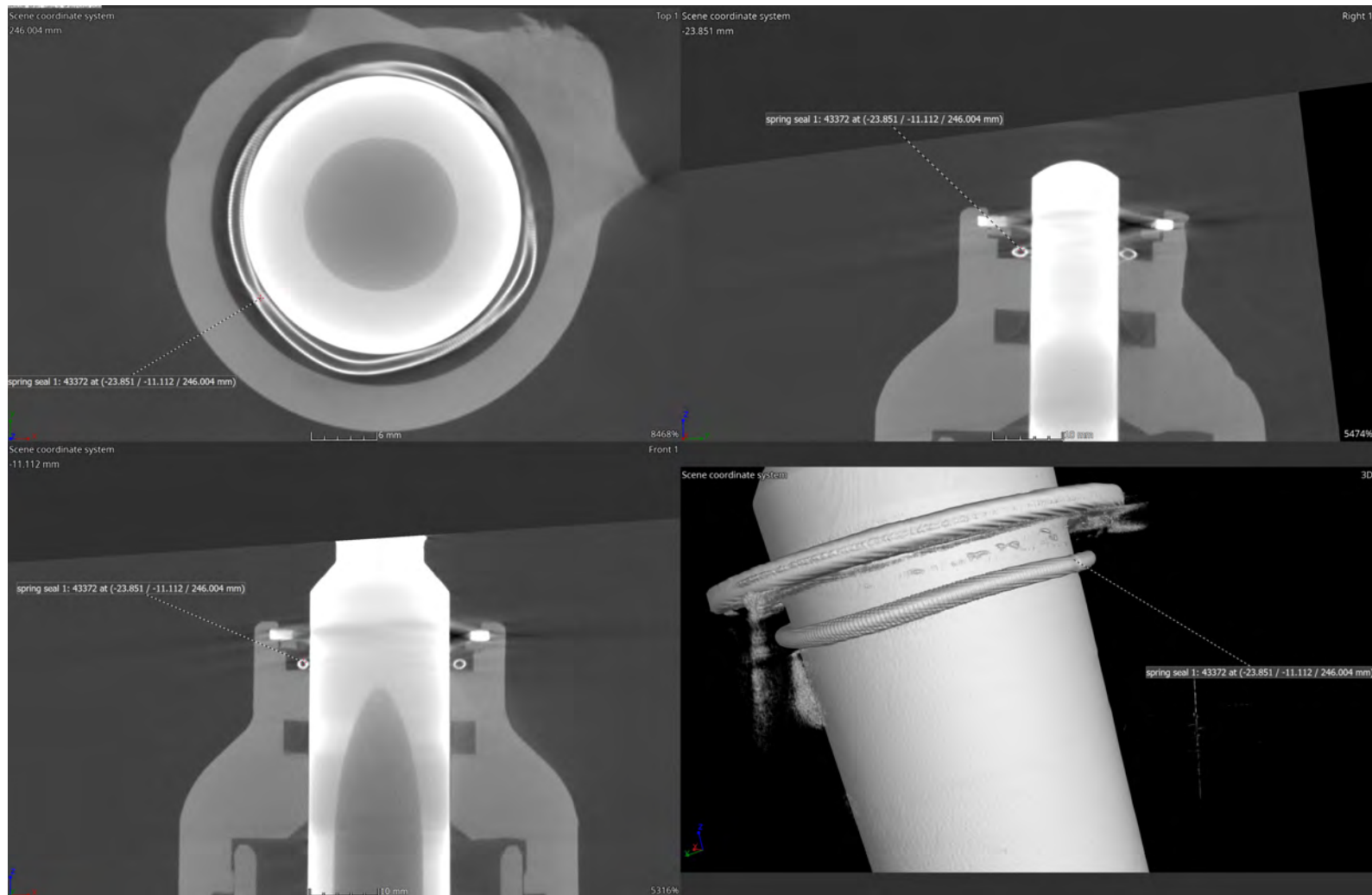


Figure 24
Left lateral actuator – spring seal 1

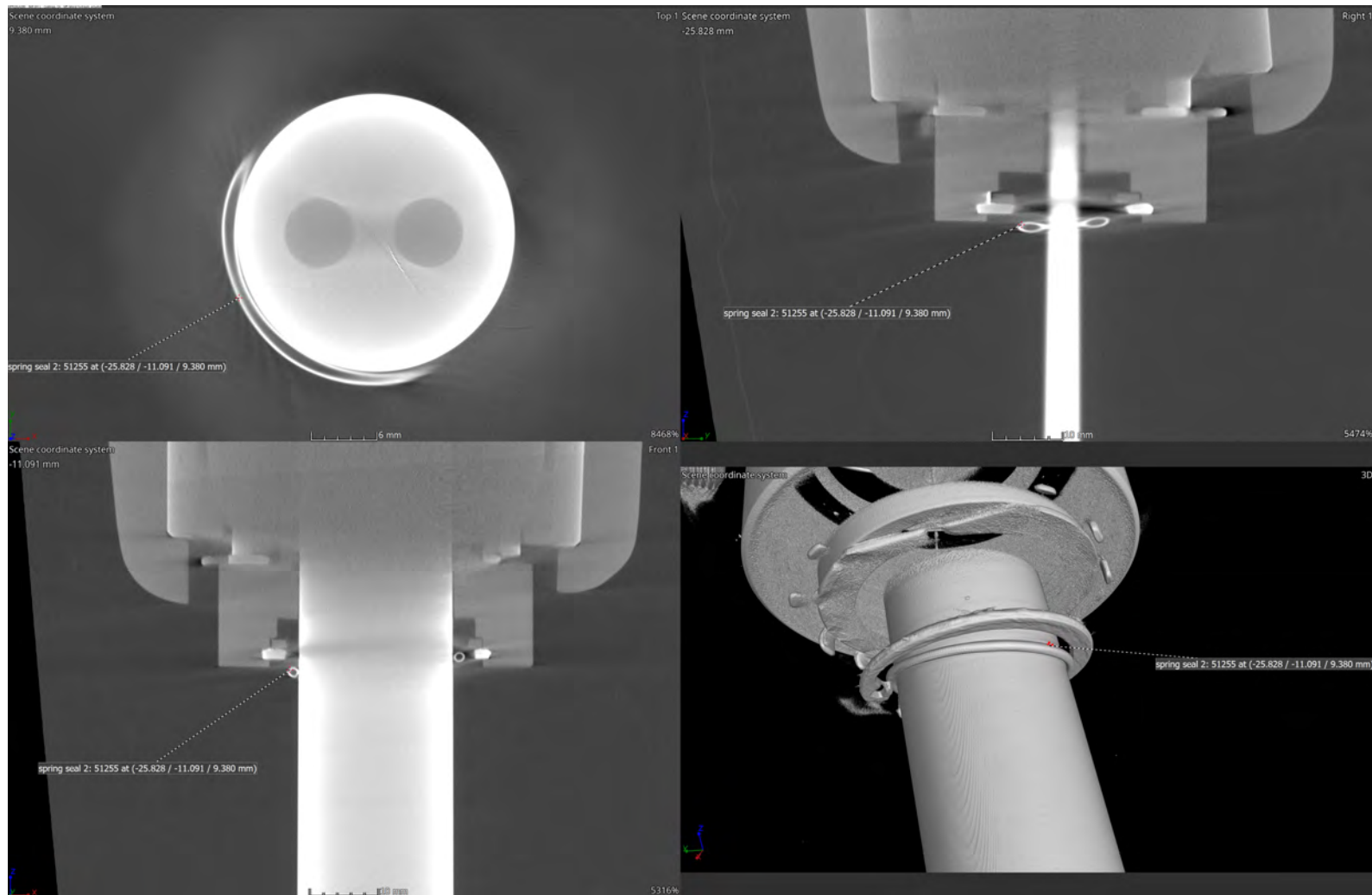


Figure 25
Left lateral actuator – spring seal 2

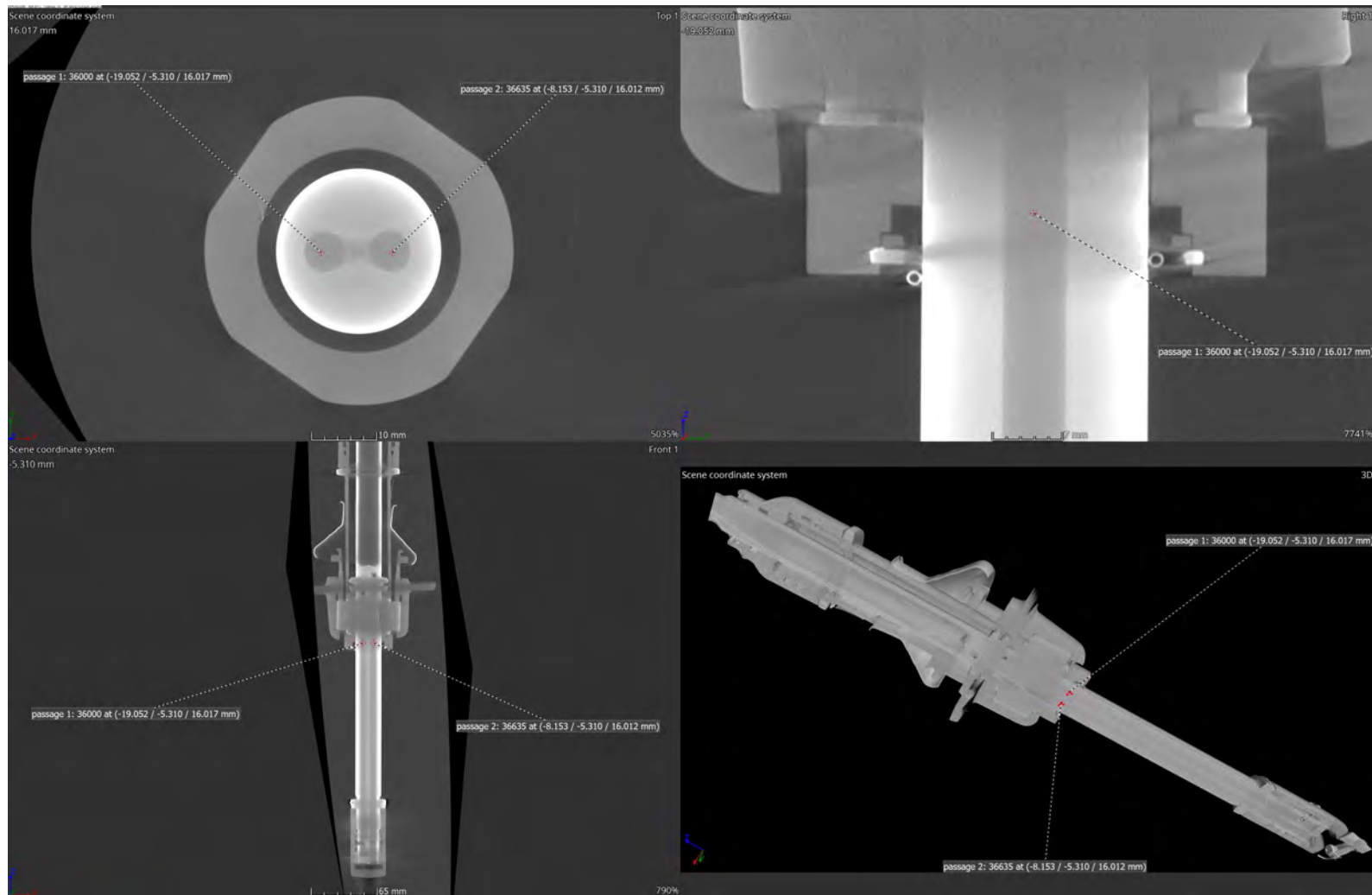


Figure 26
Left lateral actuator – hydraulic passages 1 and 2

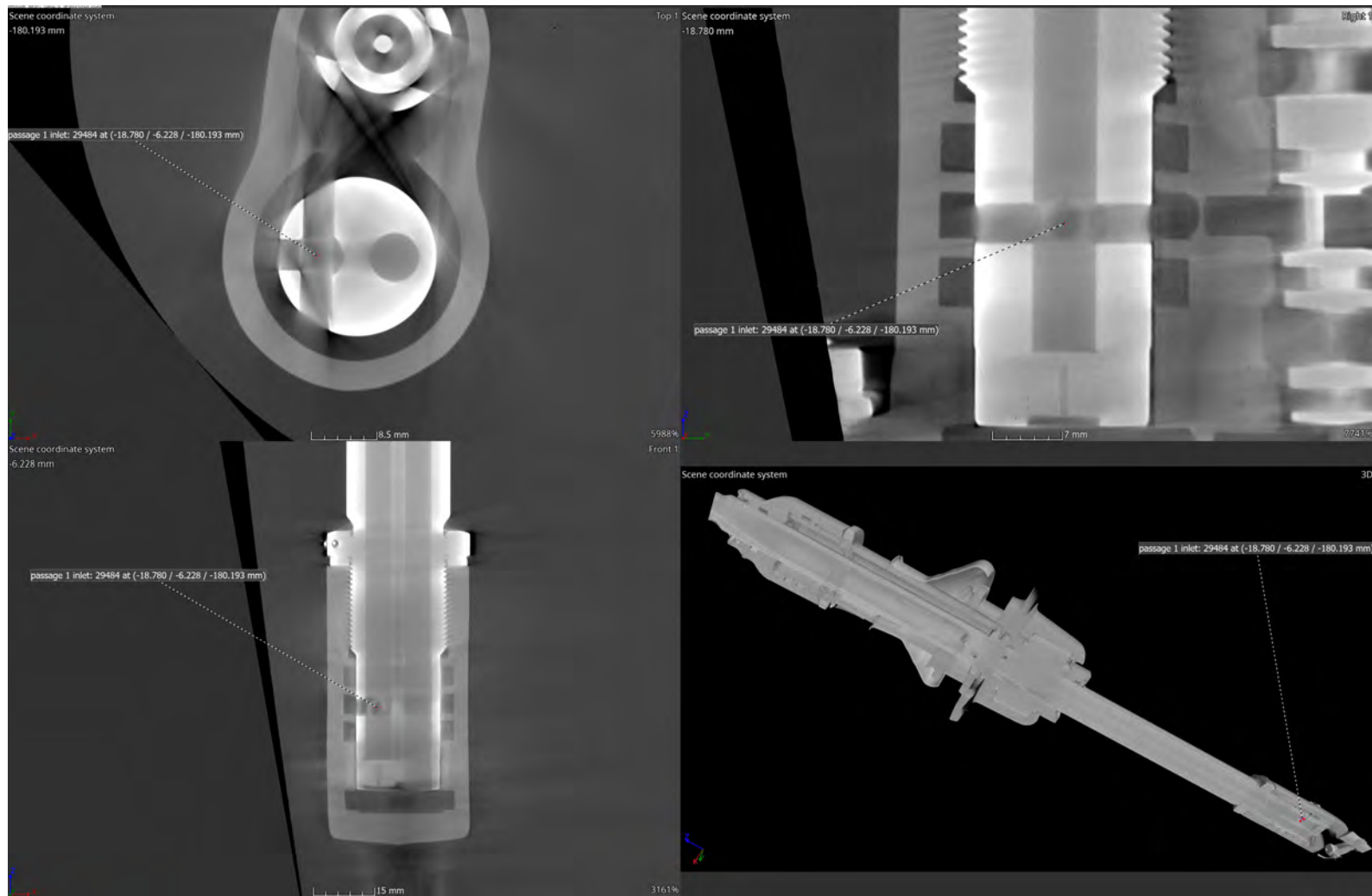


Figure 27
Left lateral actuator – hydraulic passage 1 inlet

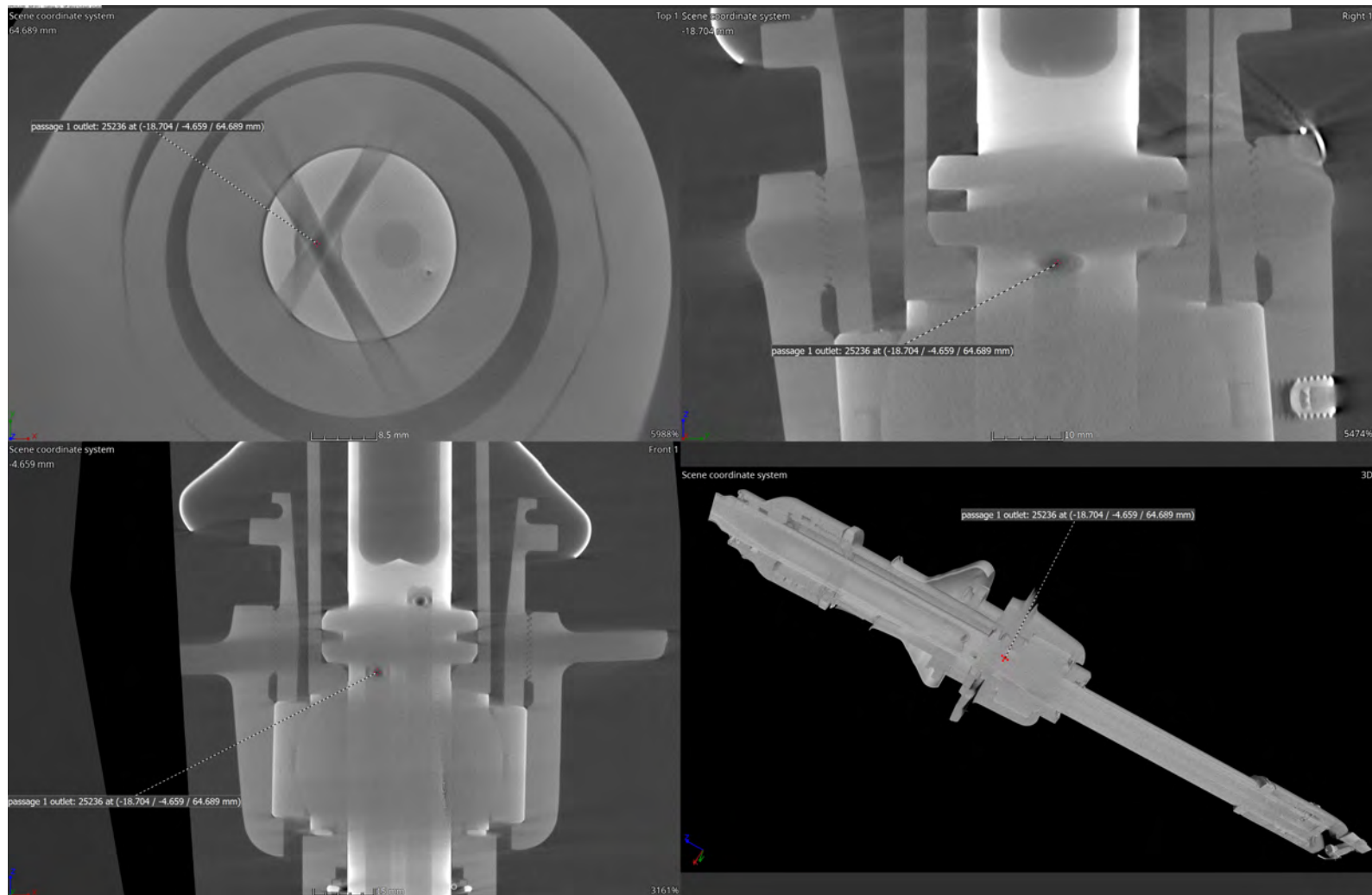


Figure 28
Left lateral actuator – hydraulic passage 1 outlet

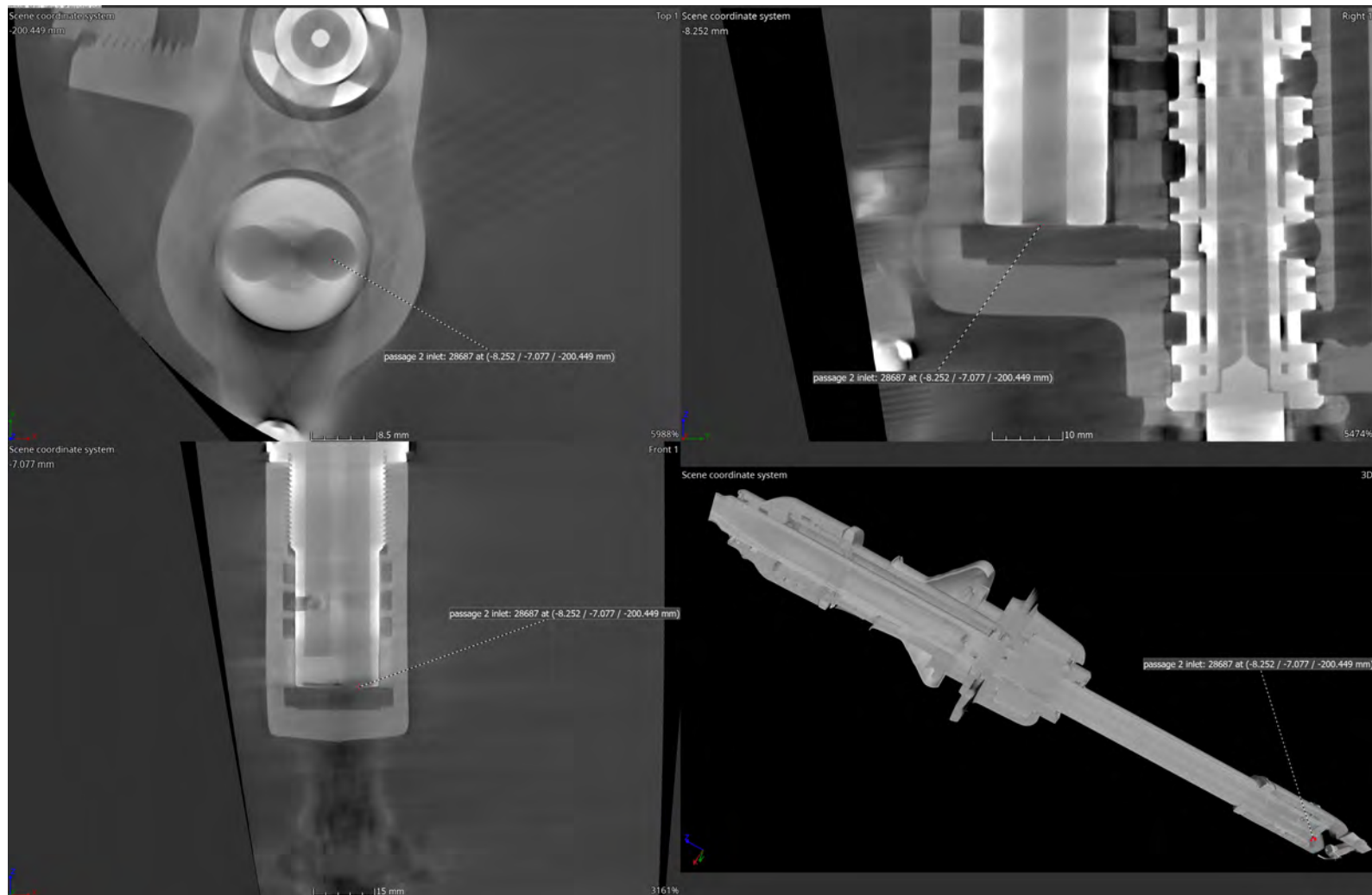


Figure 29
Left lateral actuator – hydraulic passage 2 inlet

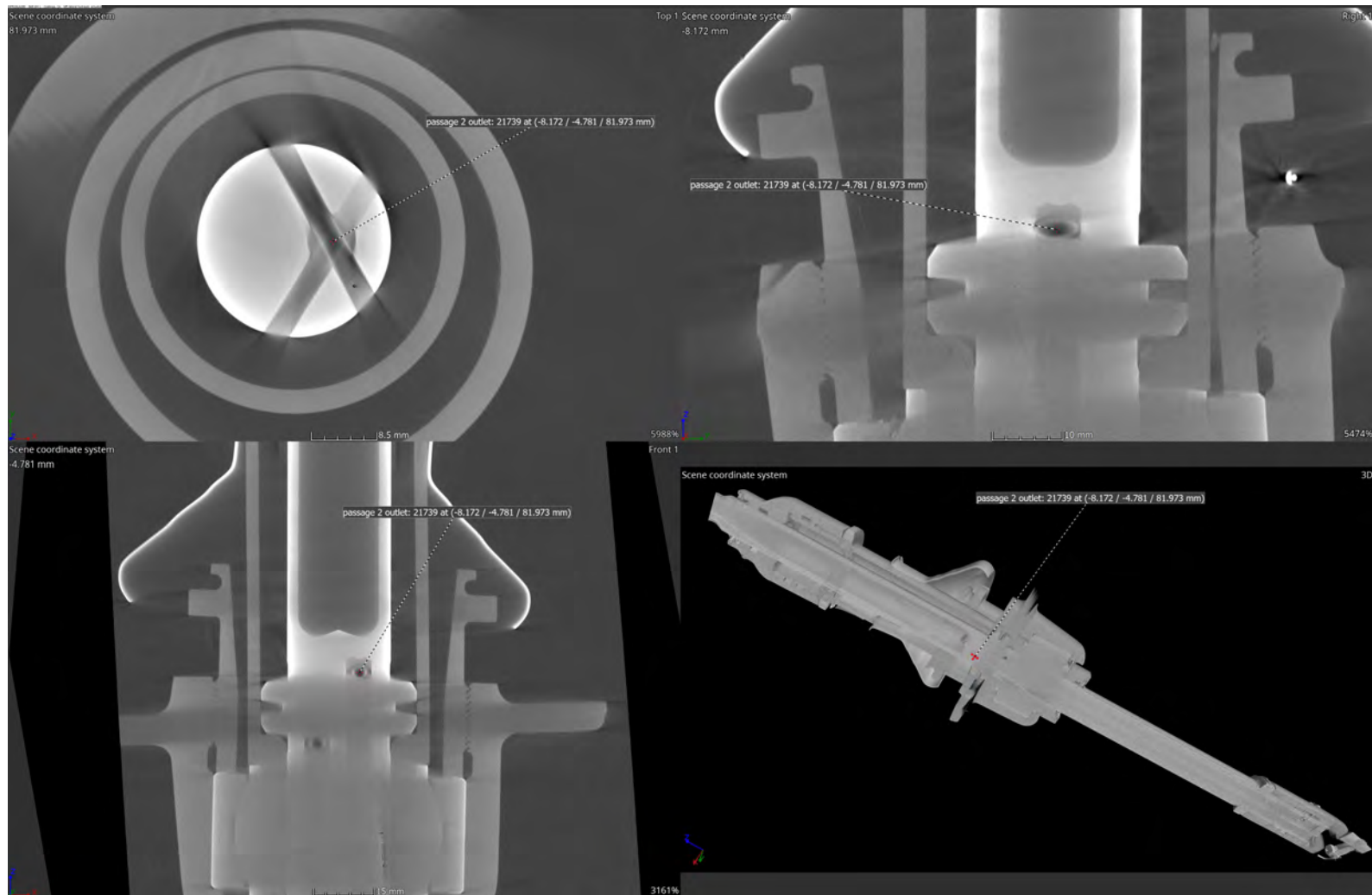


Figure 30
Left lateral actuator – hydraulic passage 2 outlet

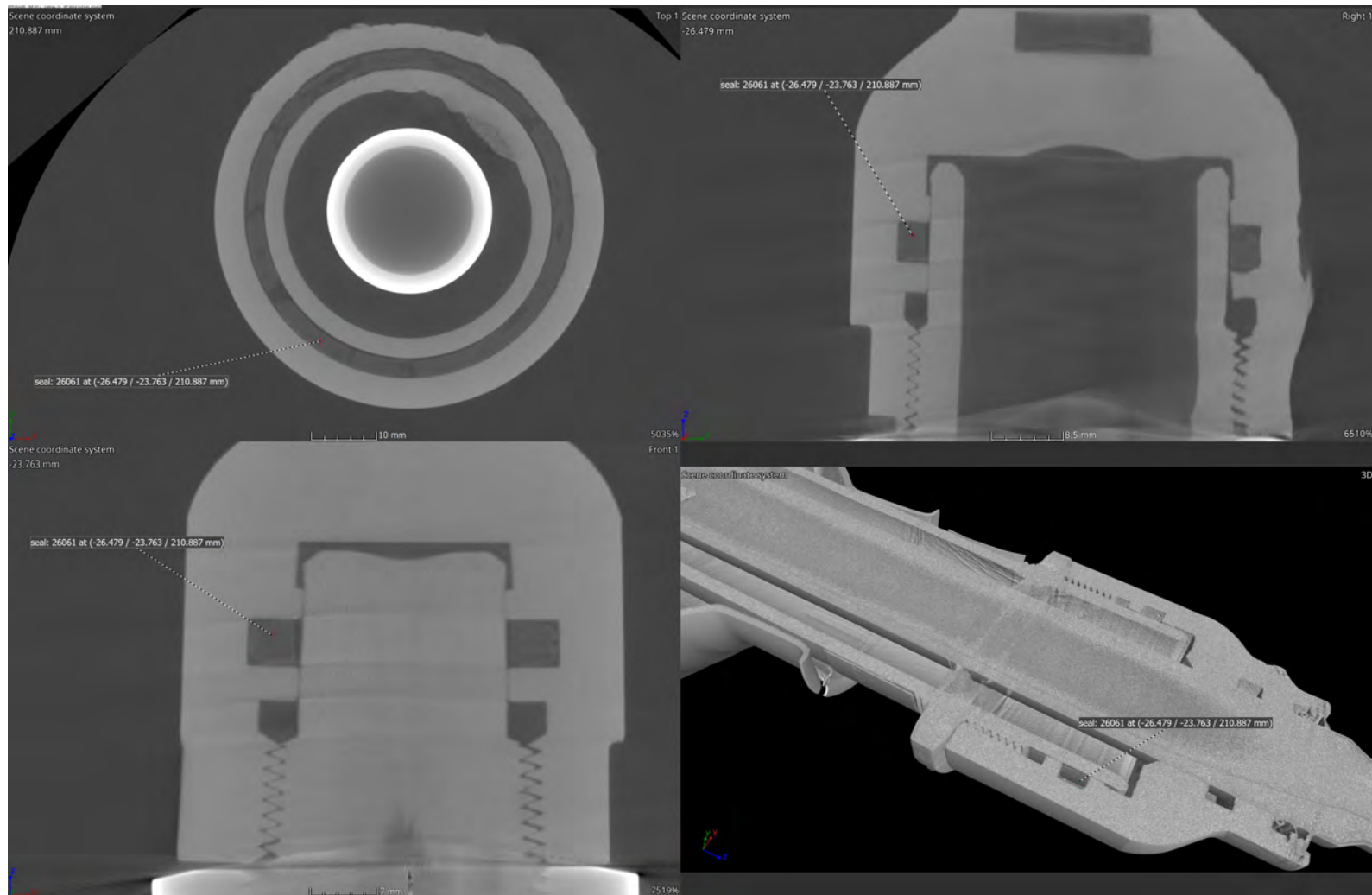


Figure 31
Left lateral actuator – seal

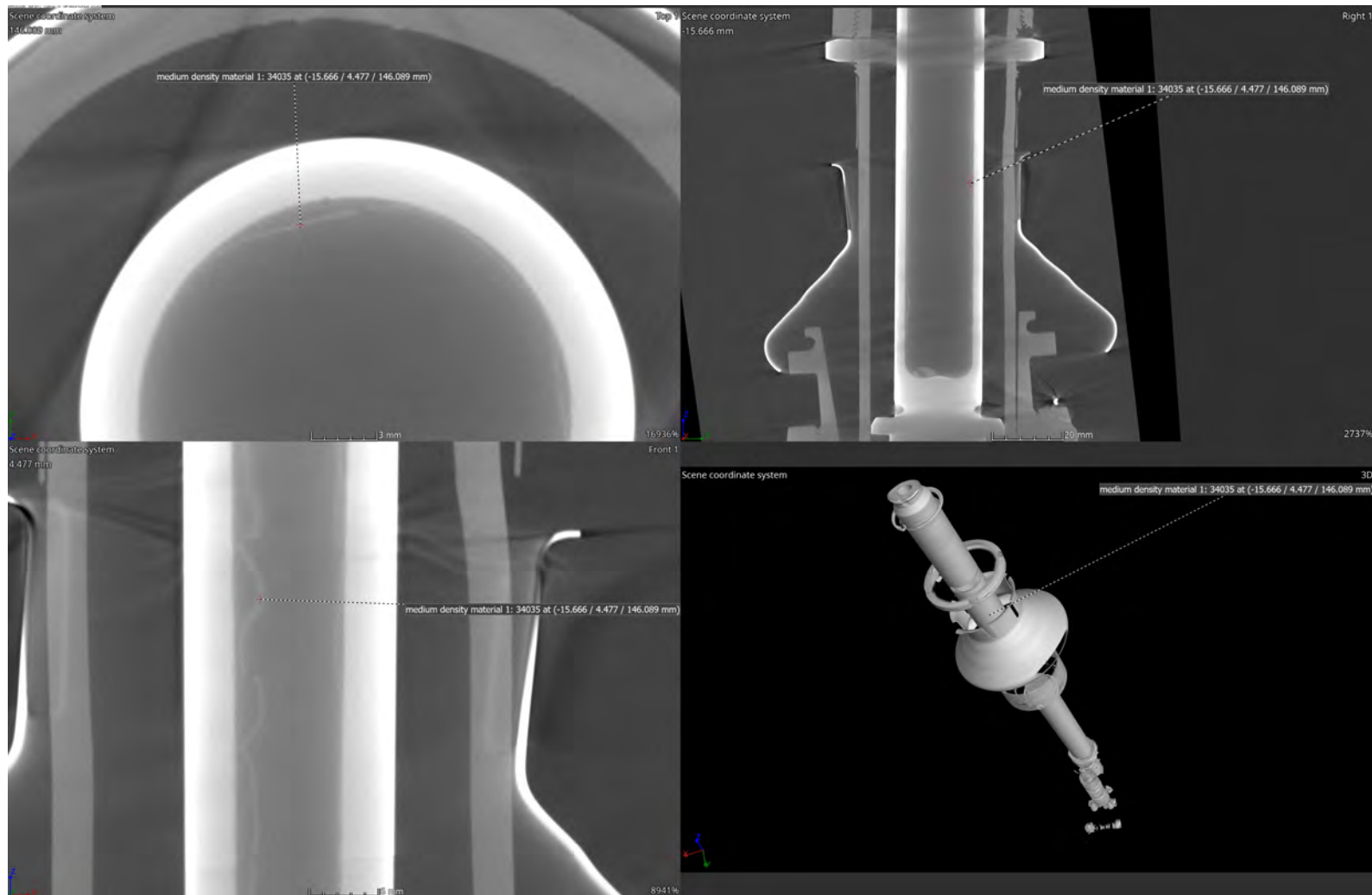


Figure 32
Left lateral actuator – medium density material 1

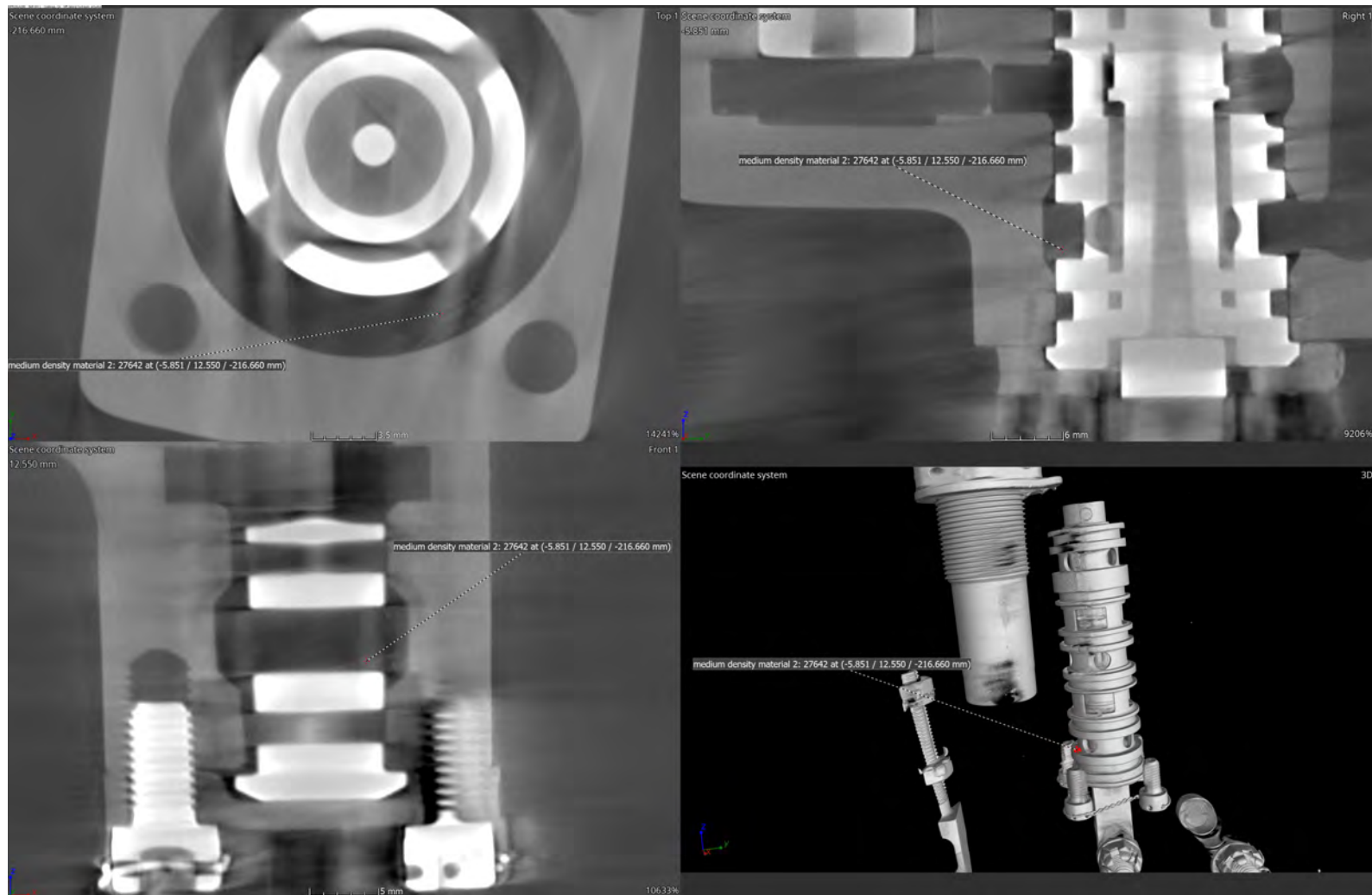


Figure 33
Left lateral actuator – medium density material 2

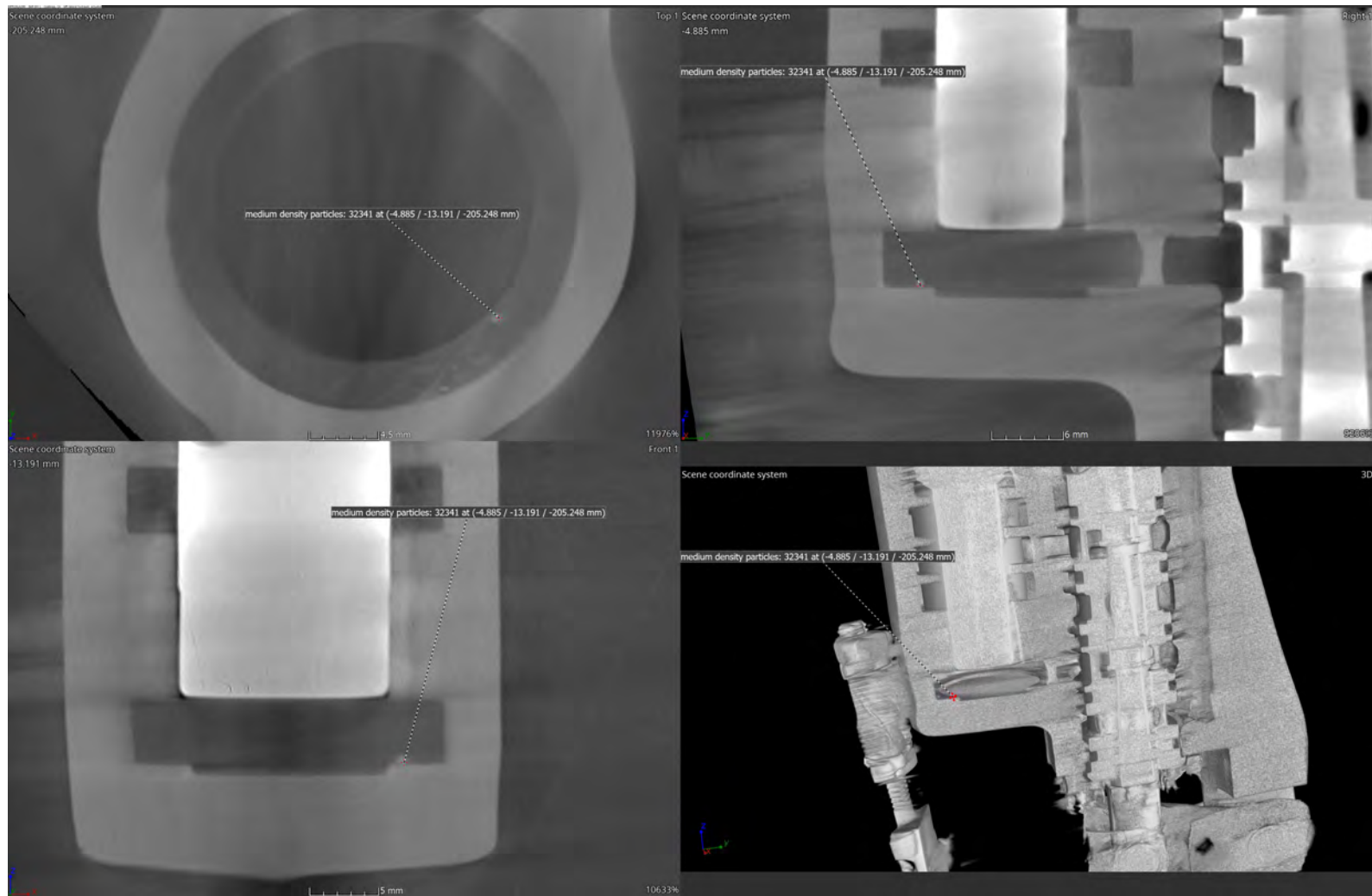


Figure 34
Left lateral actuator – medium density particles

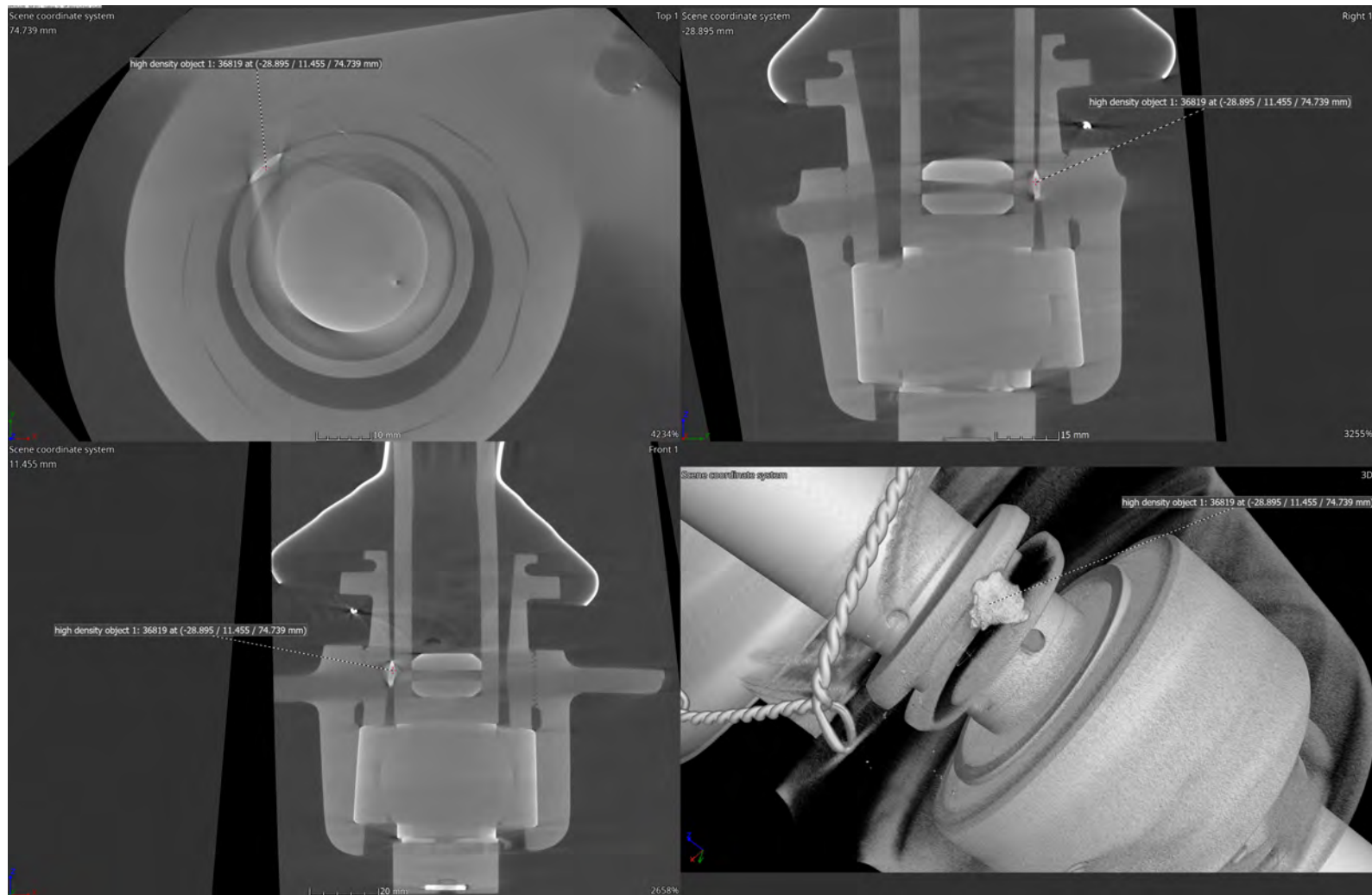


Figure 35
Left lateral actuator – high density object 1

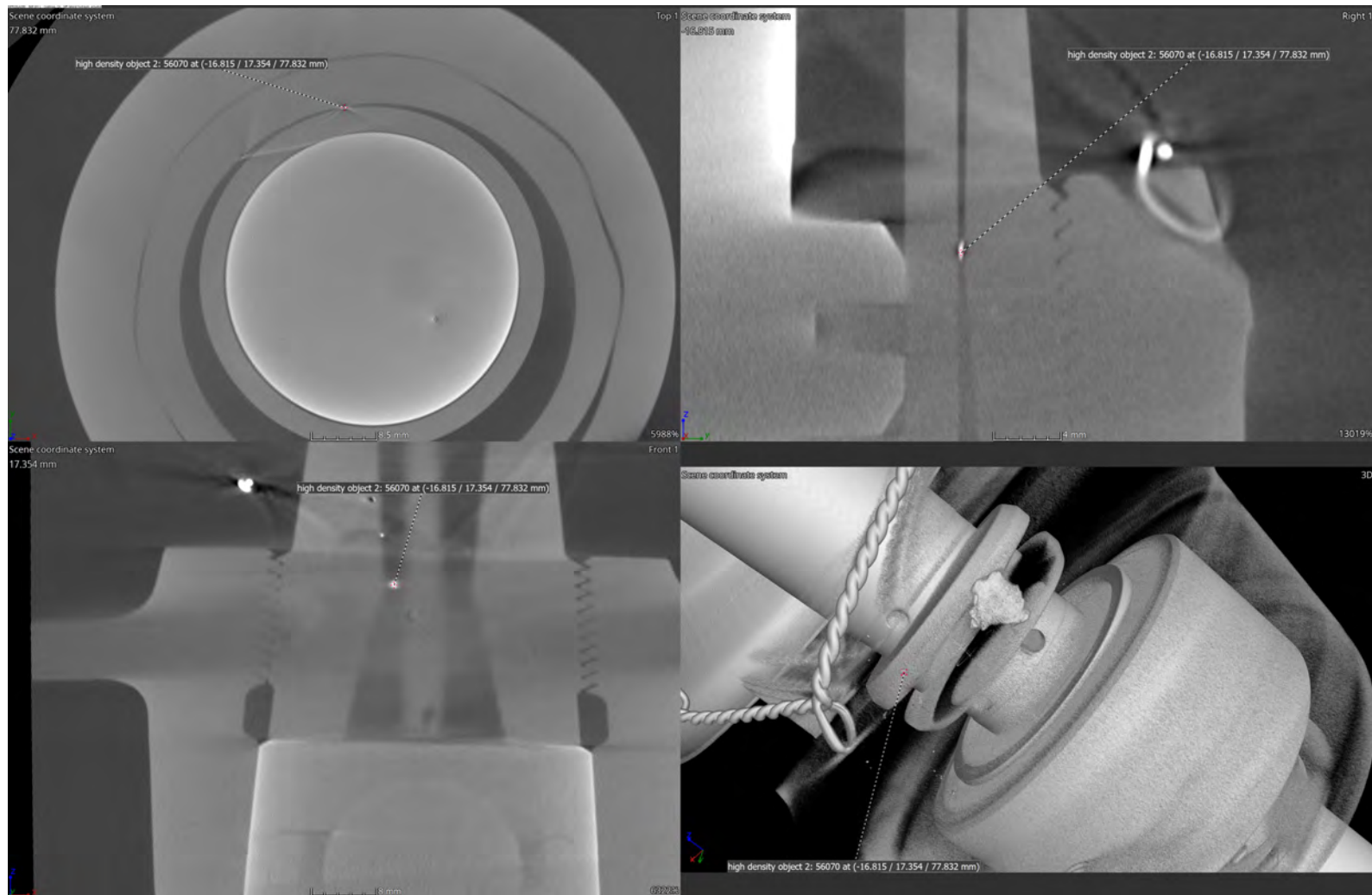


Figure 36
Left lateral actuator – high density object 2

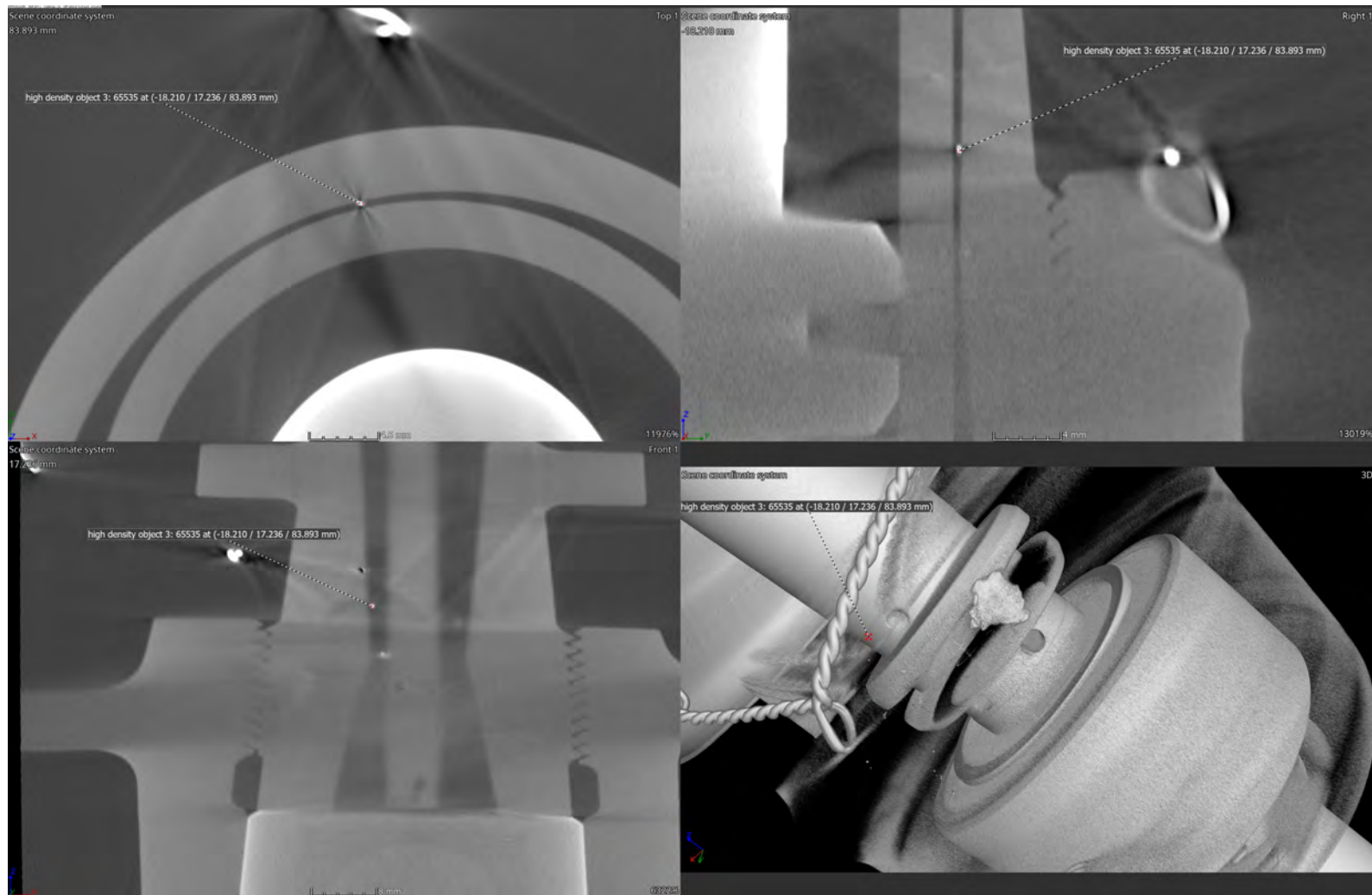


Figure 37
Left lateral actuator – high density object 3

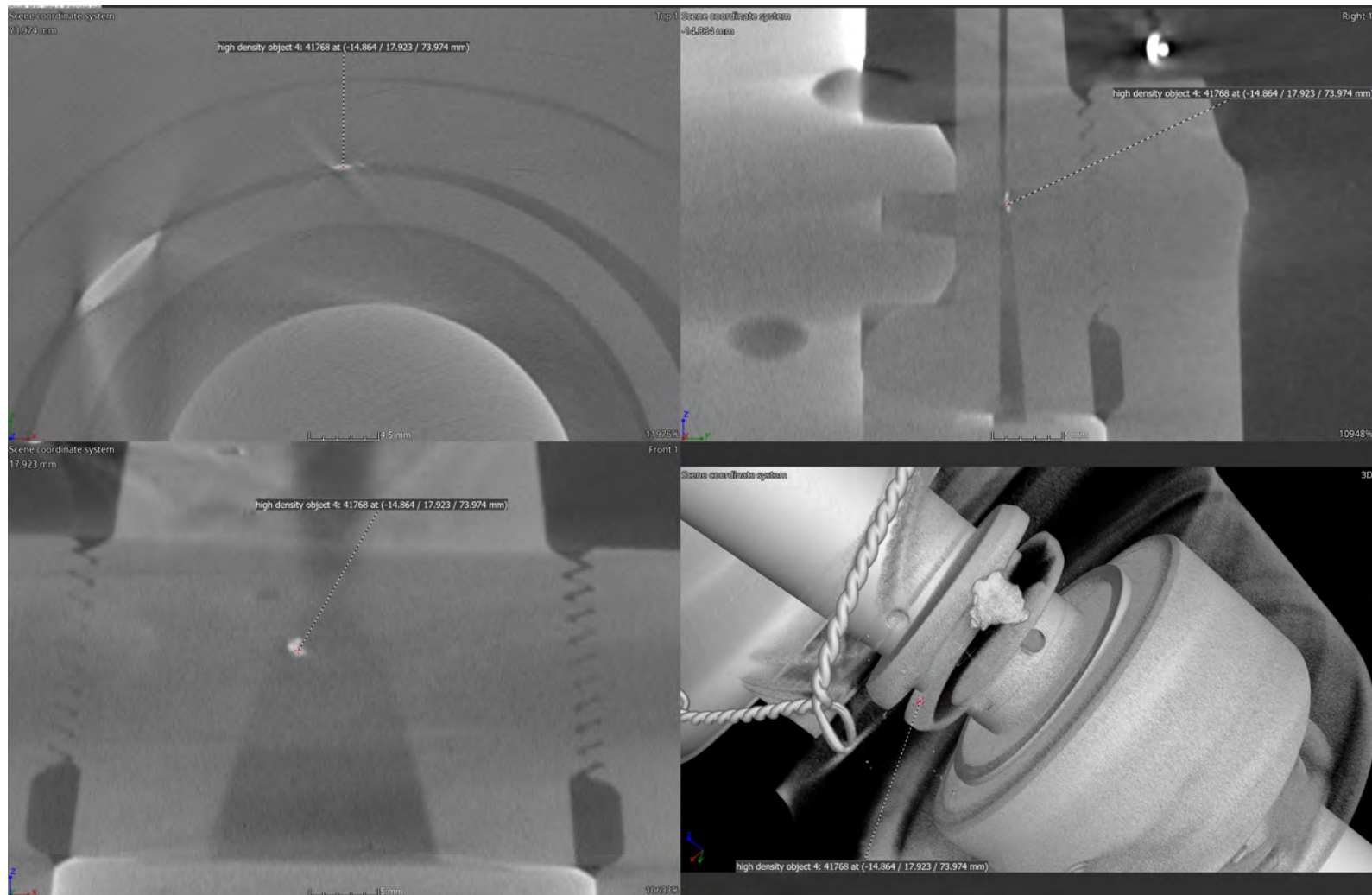


Figure 38
Left lateral actuator – high density object 4

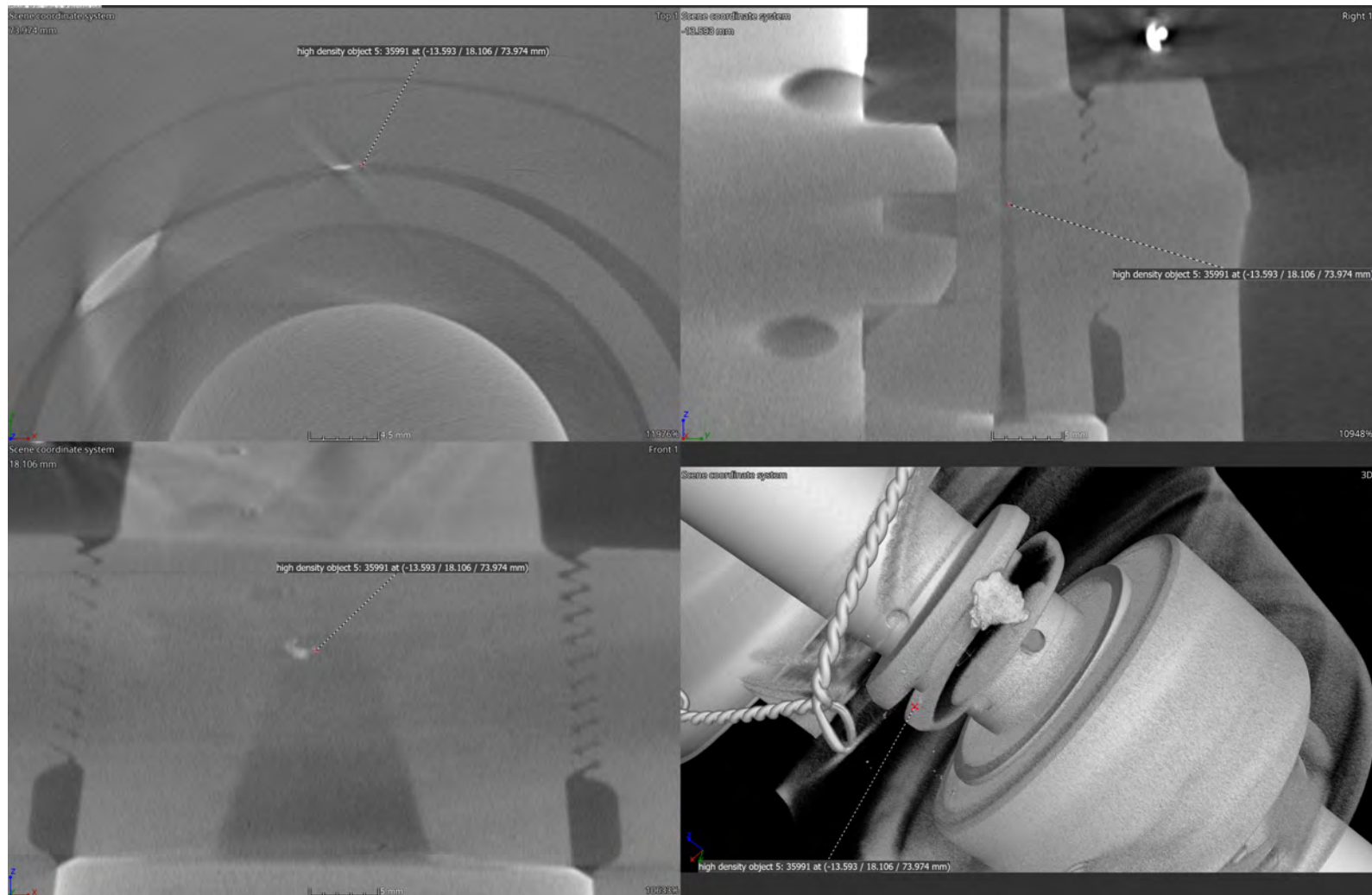


Figure 39
Left lateral actuator – high density object 5

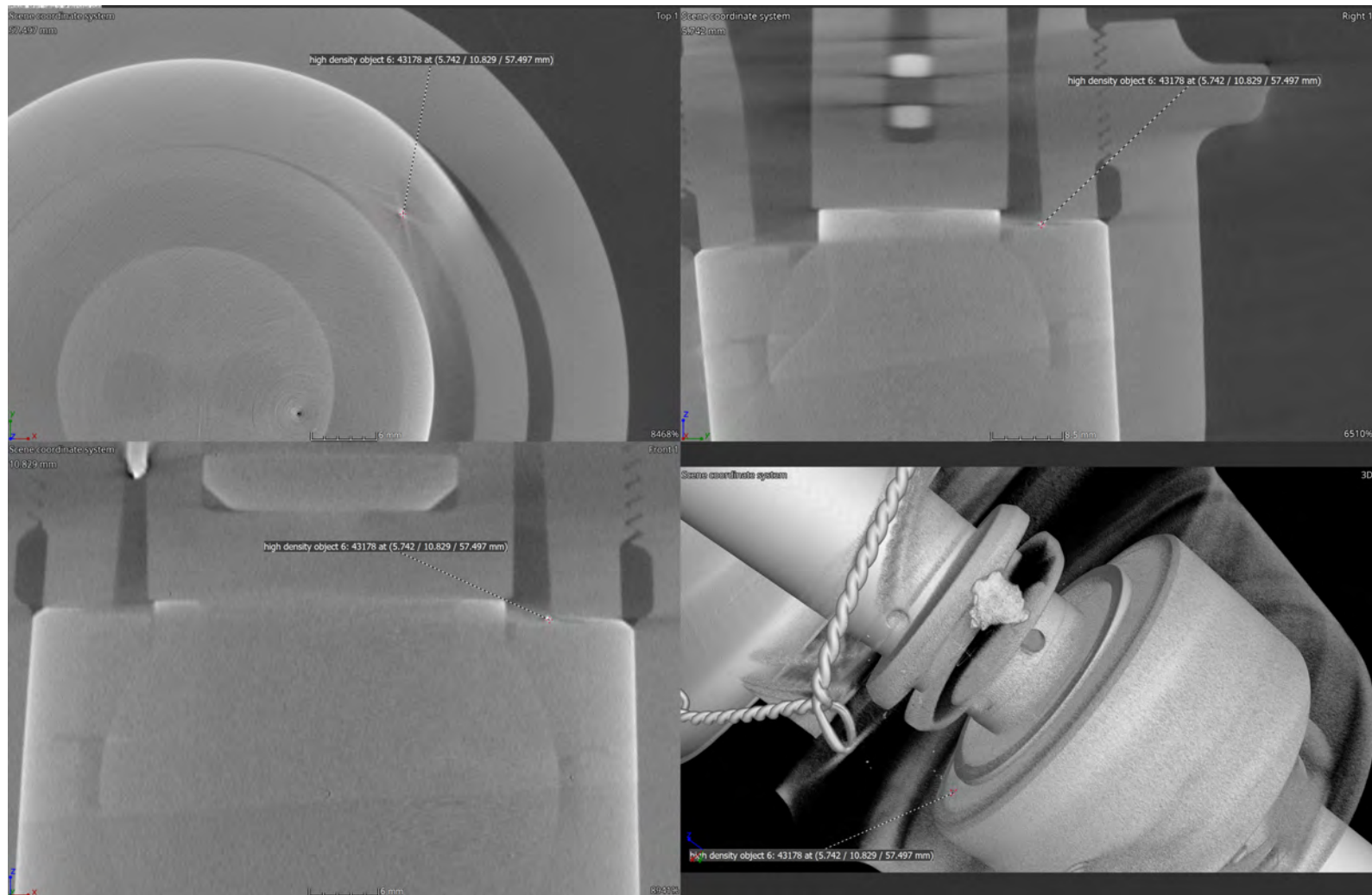


Figure 40
Left lateral actuator – high density object 6

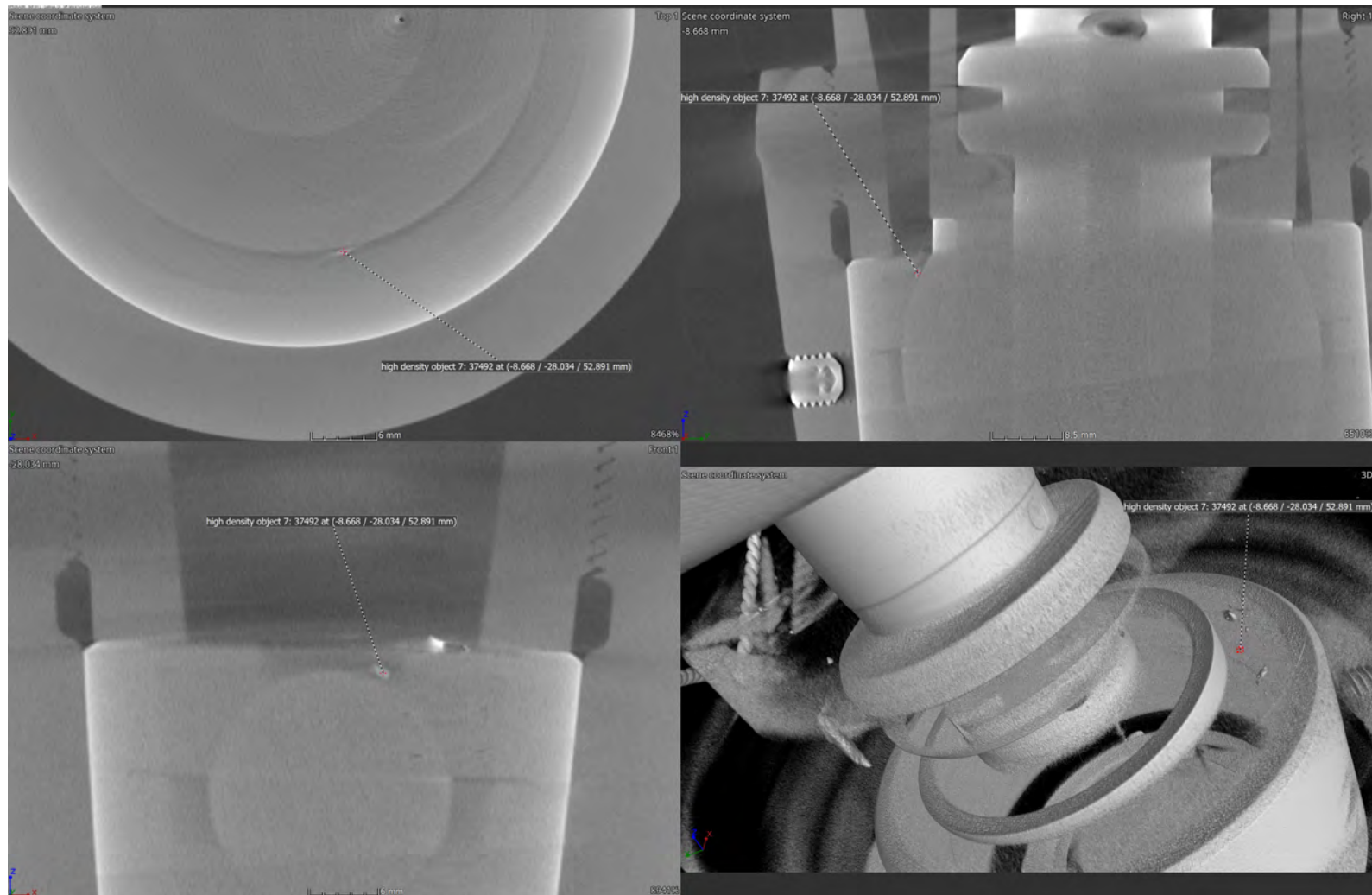


Figure 41
Left lateral actuator – high density object 7

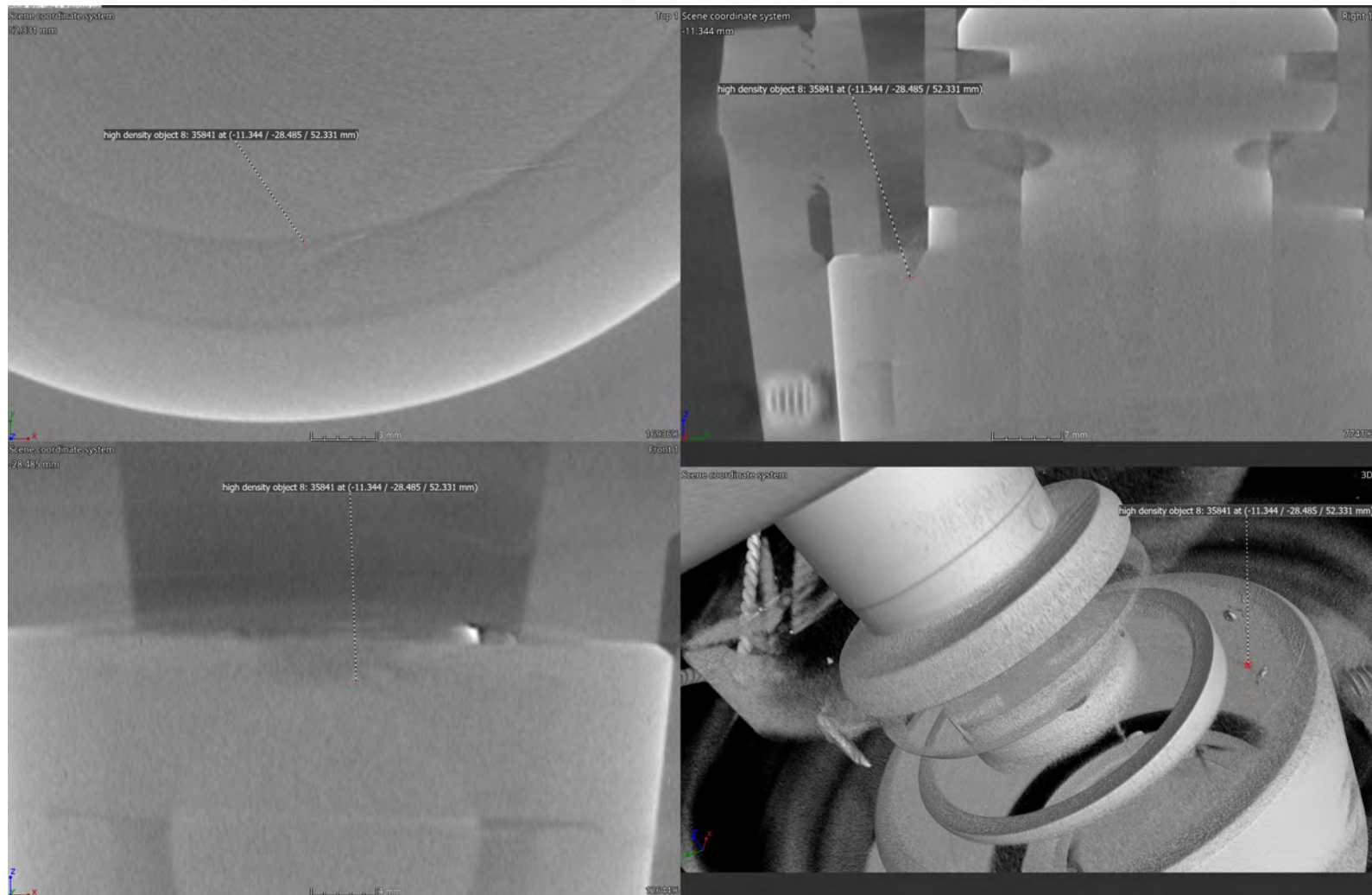


Figure 42
Left lateral actuator – high density object 8

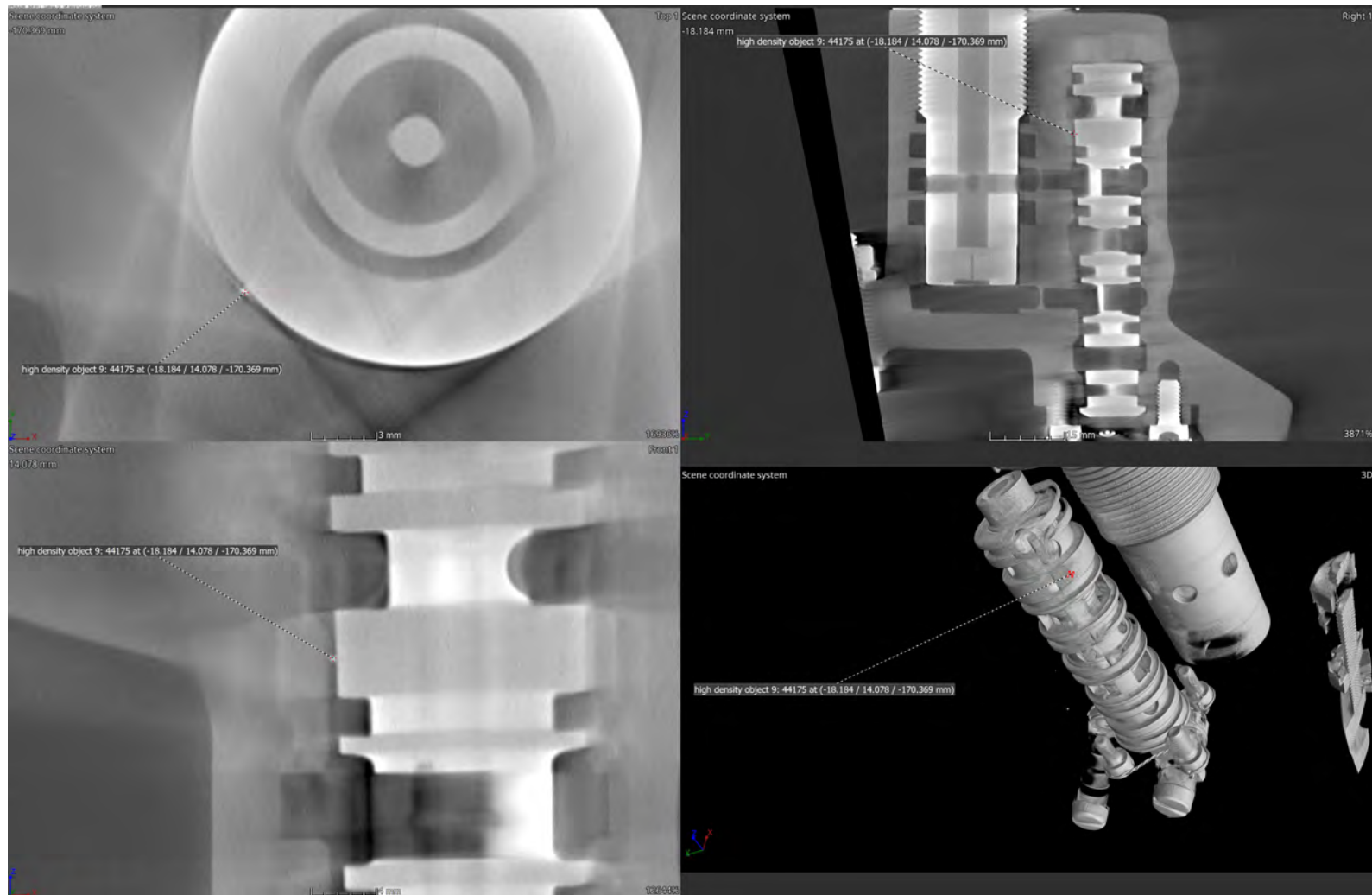


Figure 43
Left lateral actuator – high density object 9

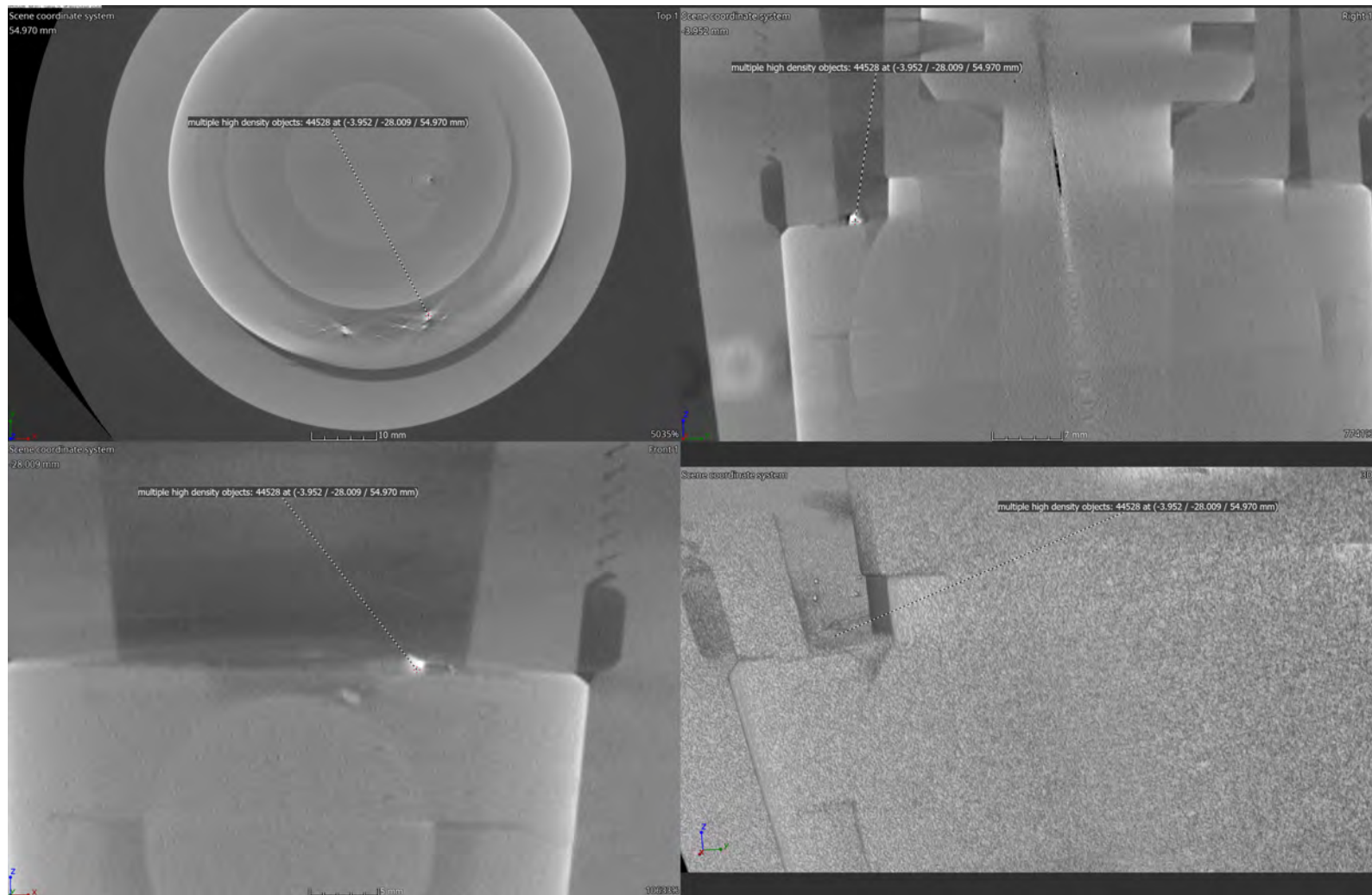


Figure 44
Left lateral actuator – multiple high density objects

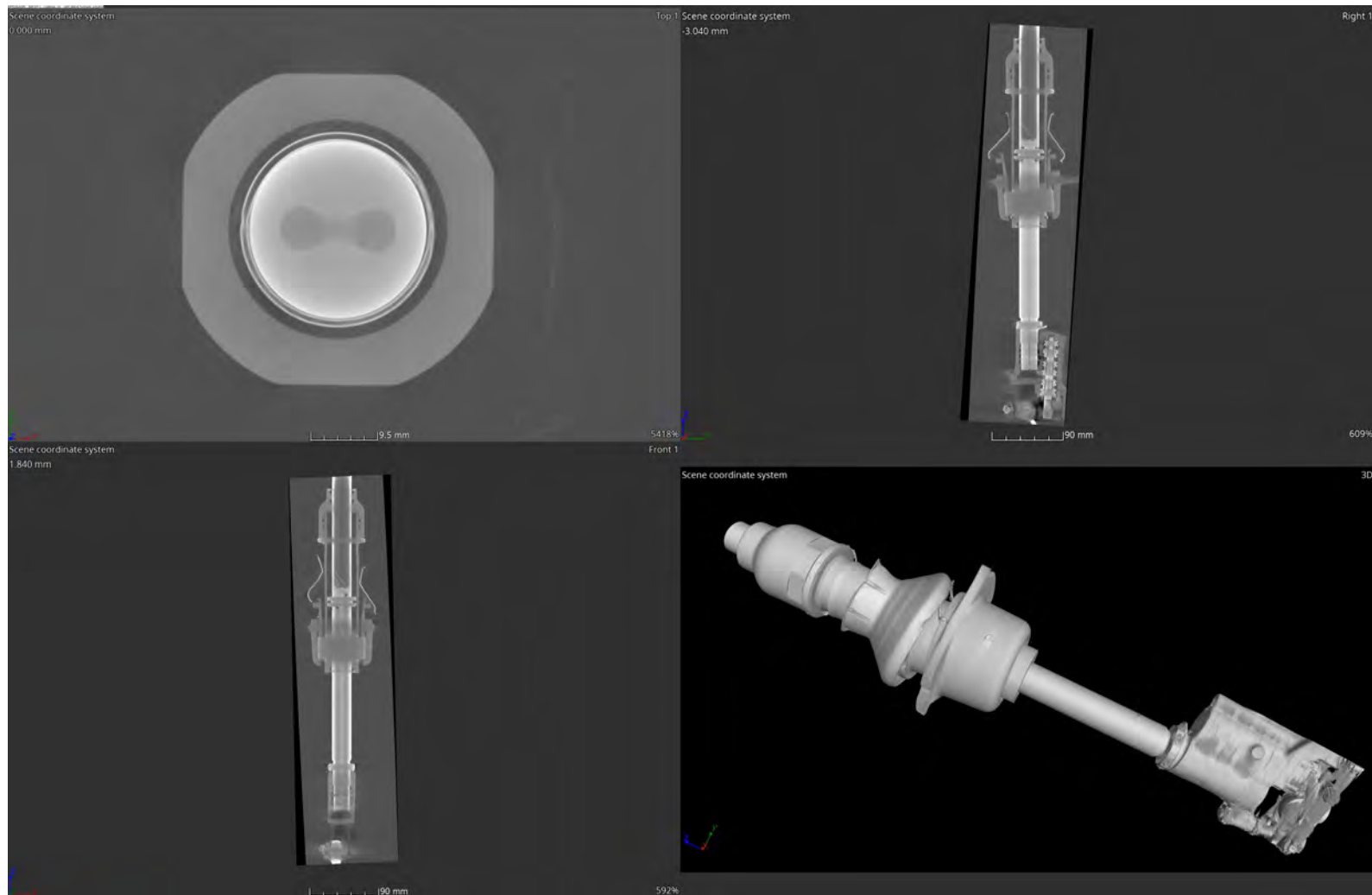


Figure 45
Right lateral actuator – overview

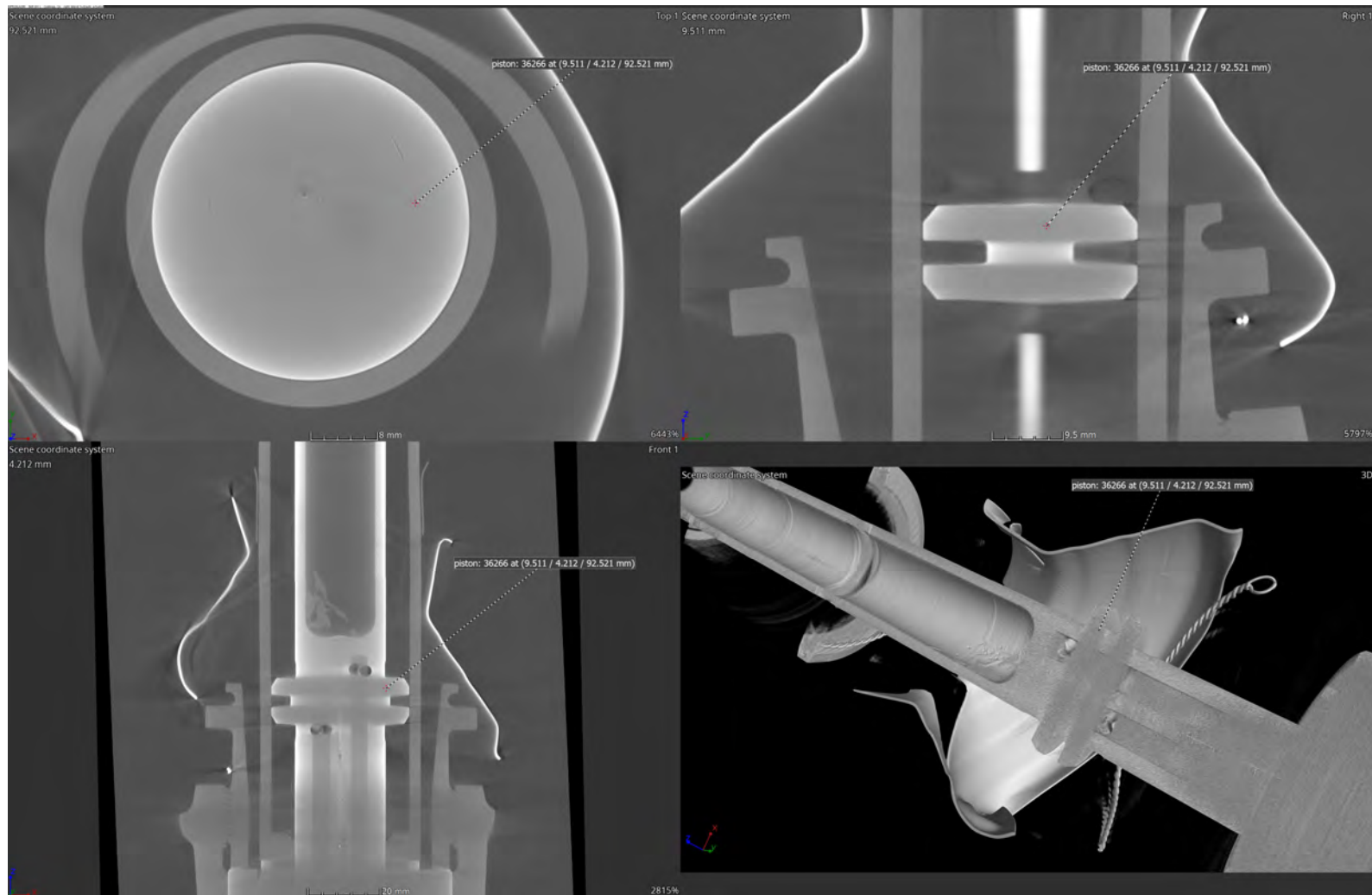


Figure 46
Right lateral actuator – piston

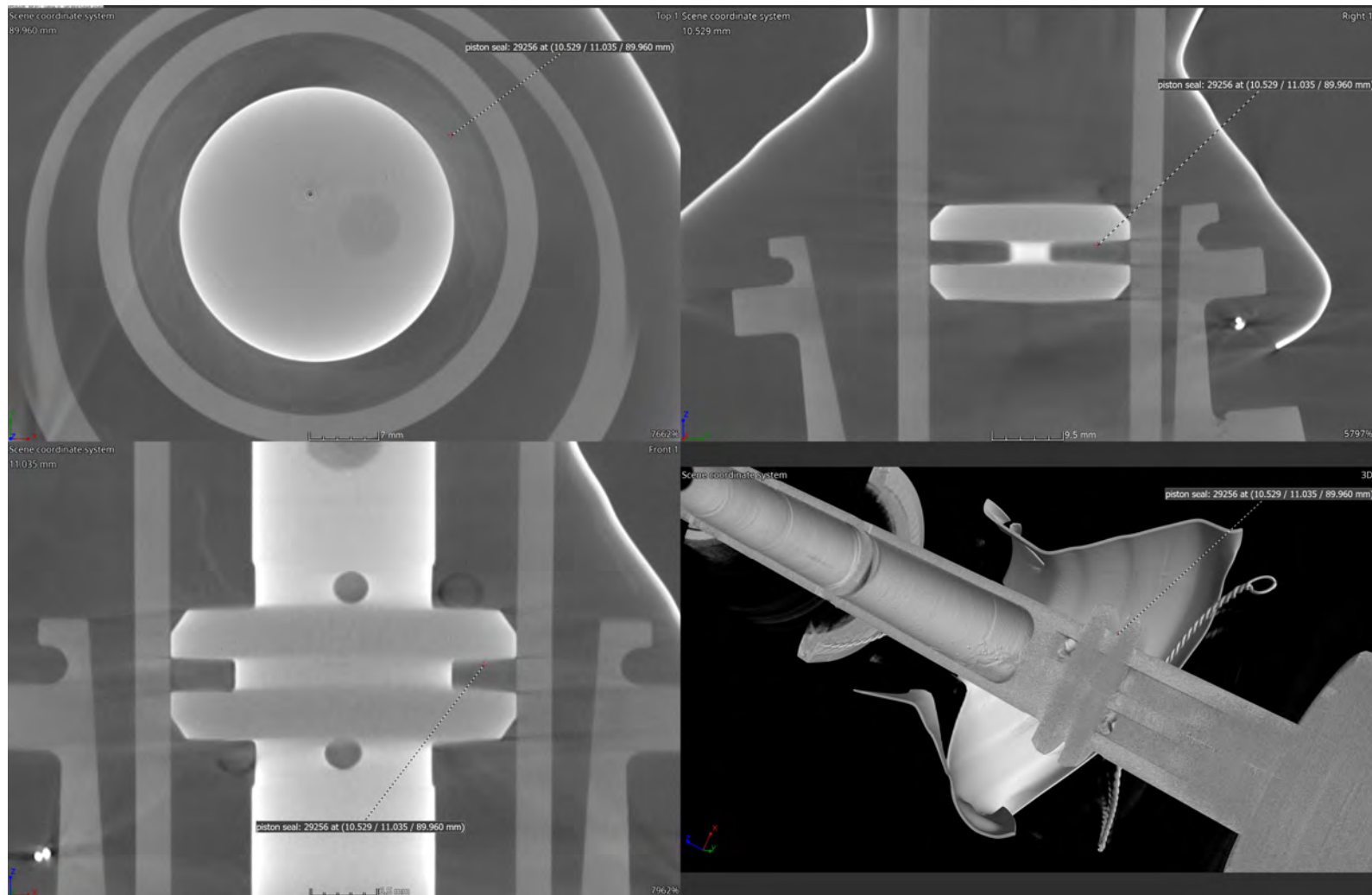


Figure 47
Right lateral actuator – piston seal

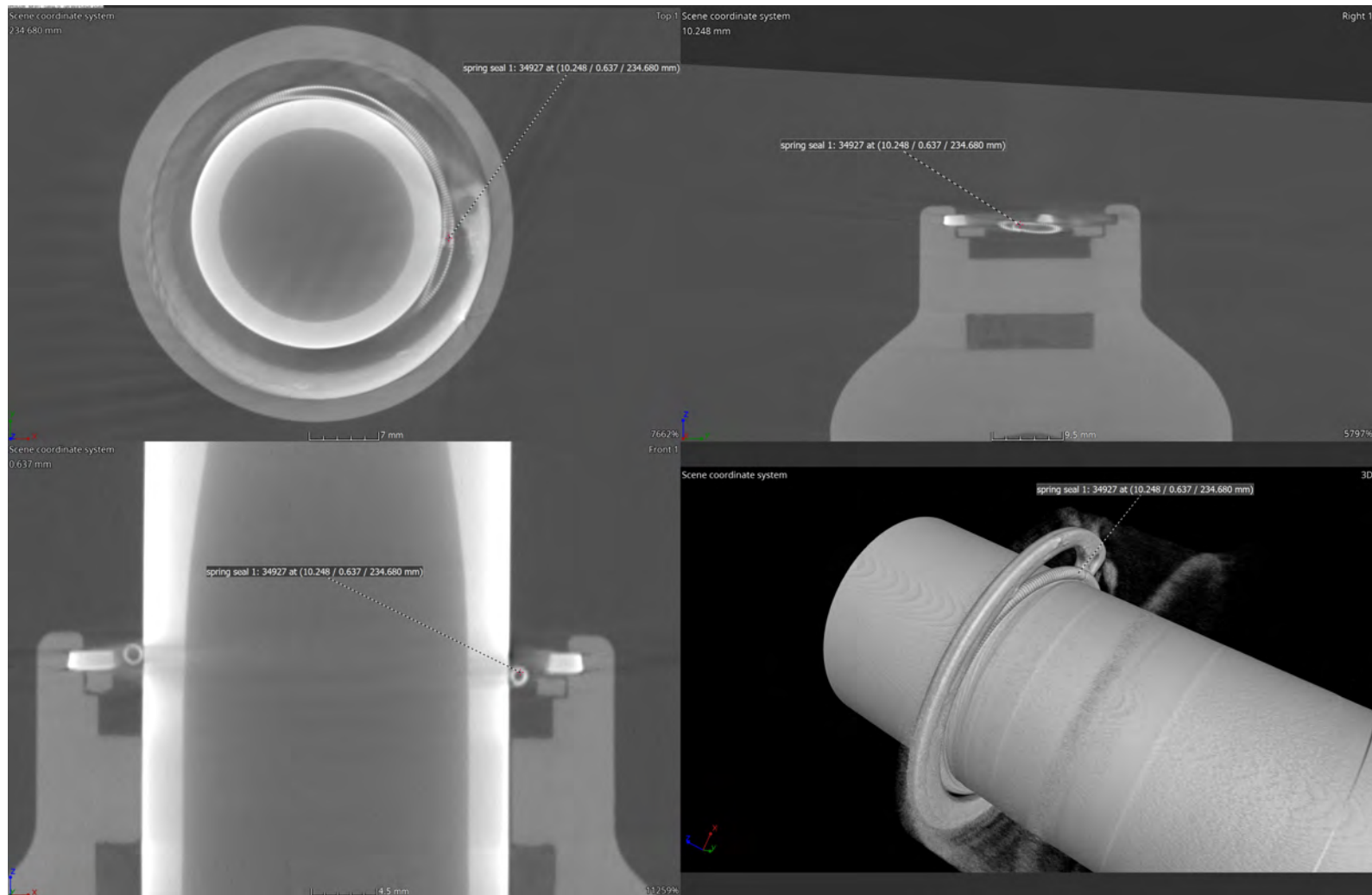


Figure 48
Right lateral actuator – spring seal 1



Figure 49
Right lateral actuator – spring seal 2

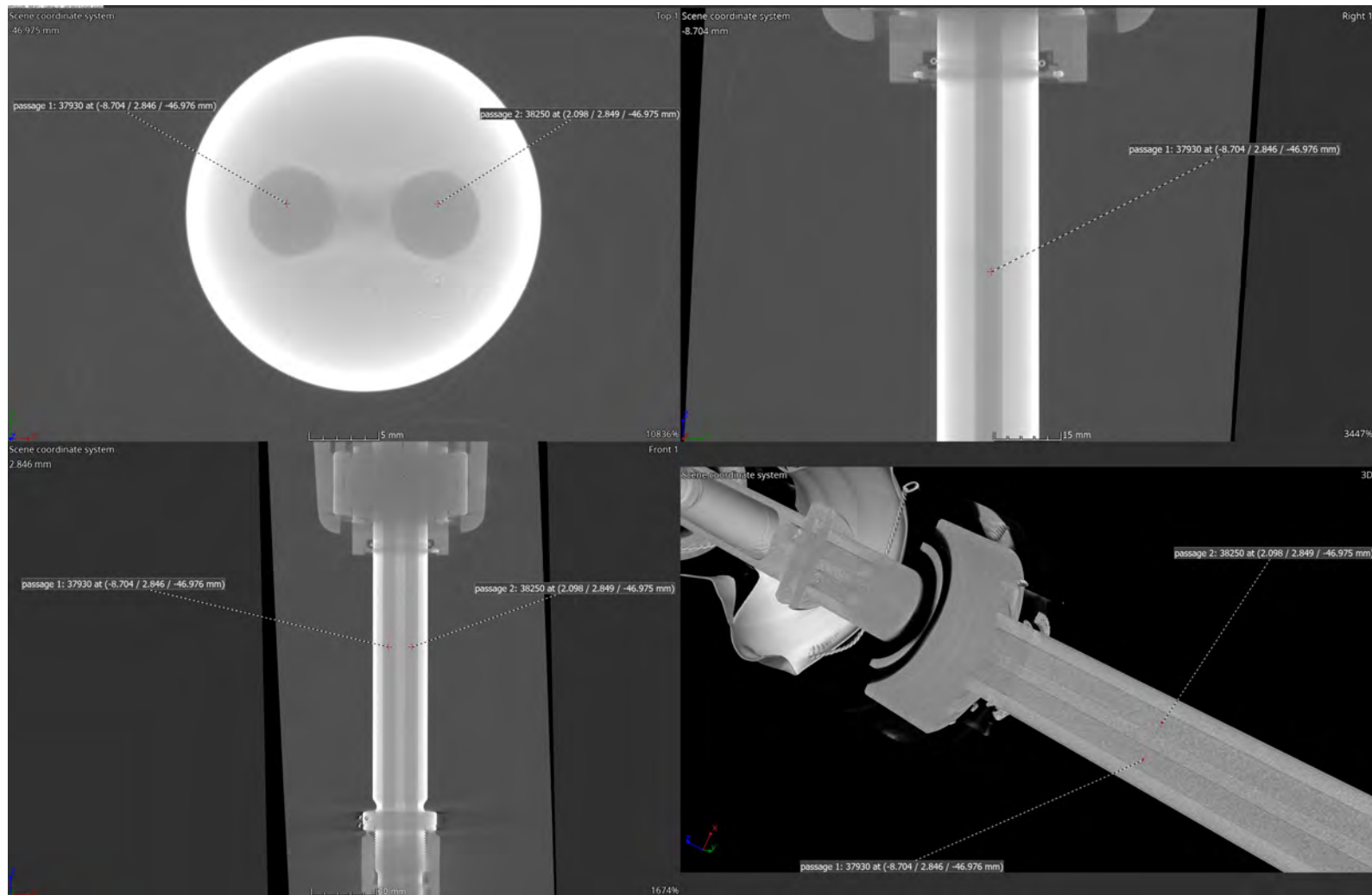


Figure 50
Right lateral actuator – hydraulic passages 1 and 2

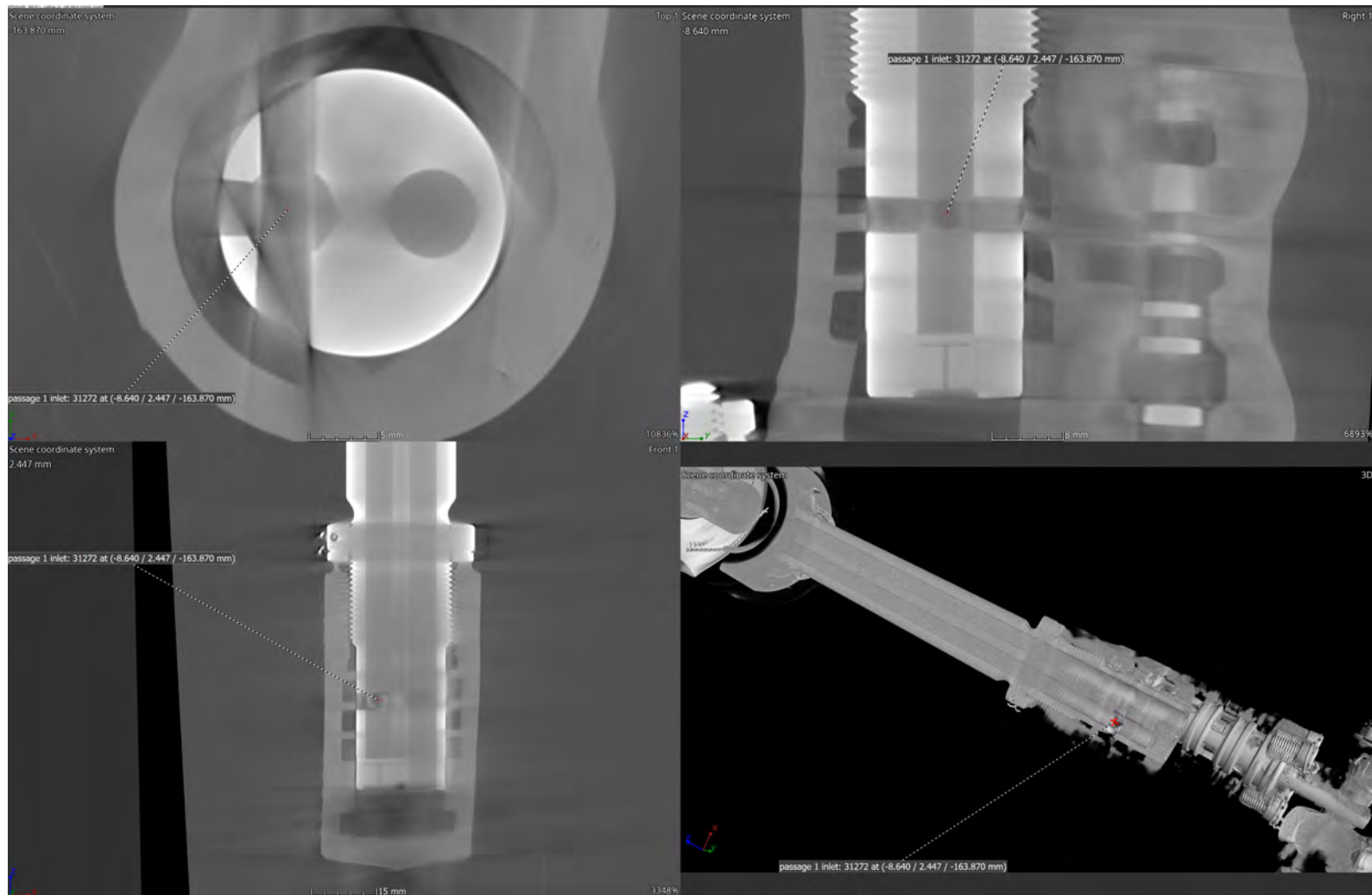


Figure 51
Right lateral actuator – hydraulic passage 1 inlet

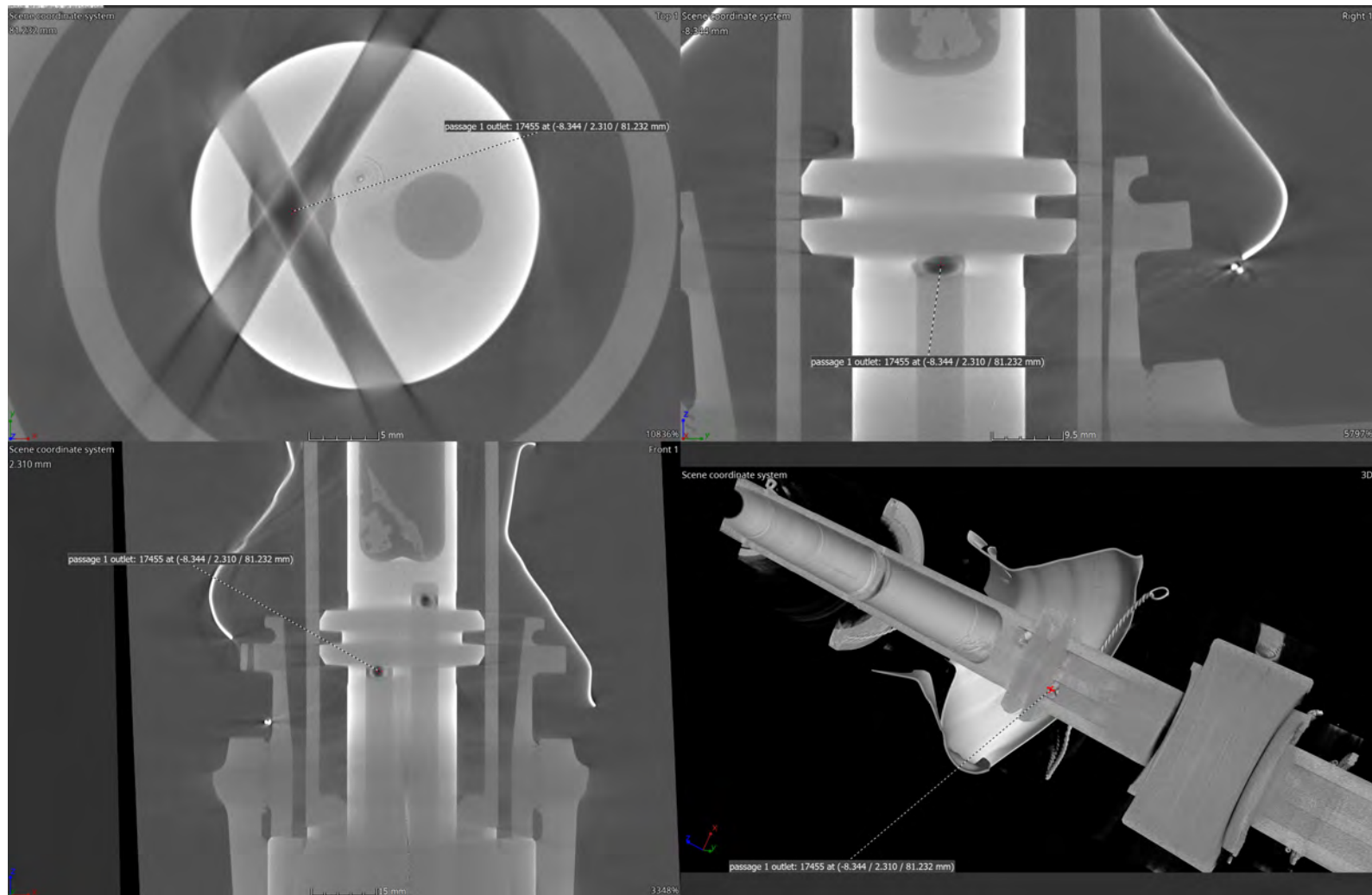


Figure 52
Right lateral actuator – hydraulic passage 1 outlet

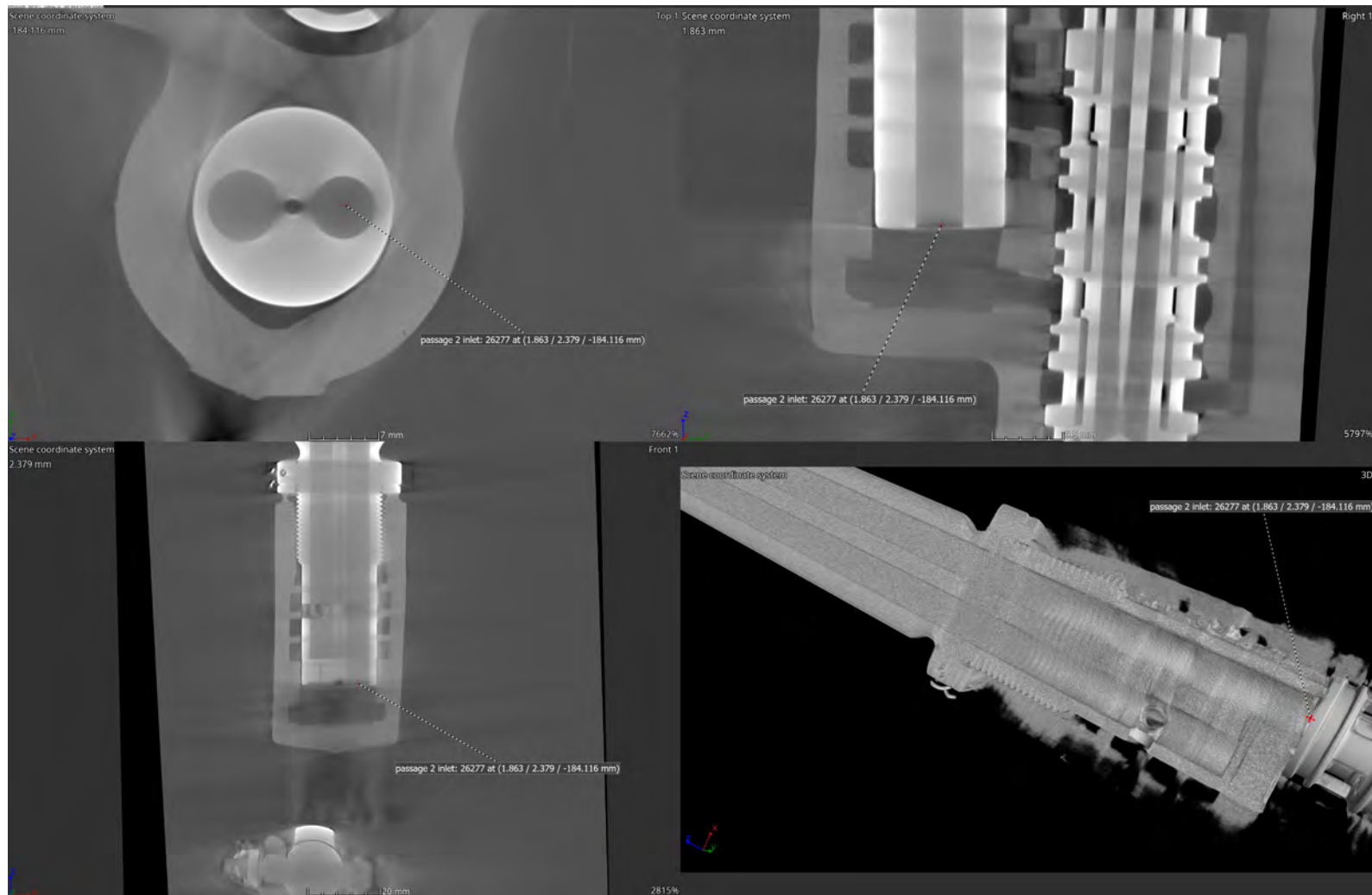


Figure 53
Right lateral actuator – hydraulic passage 2 inlet

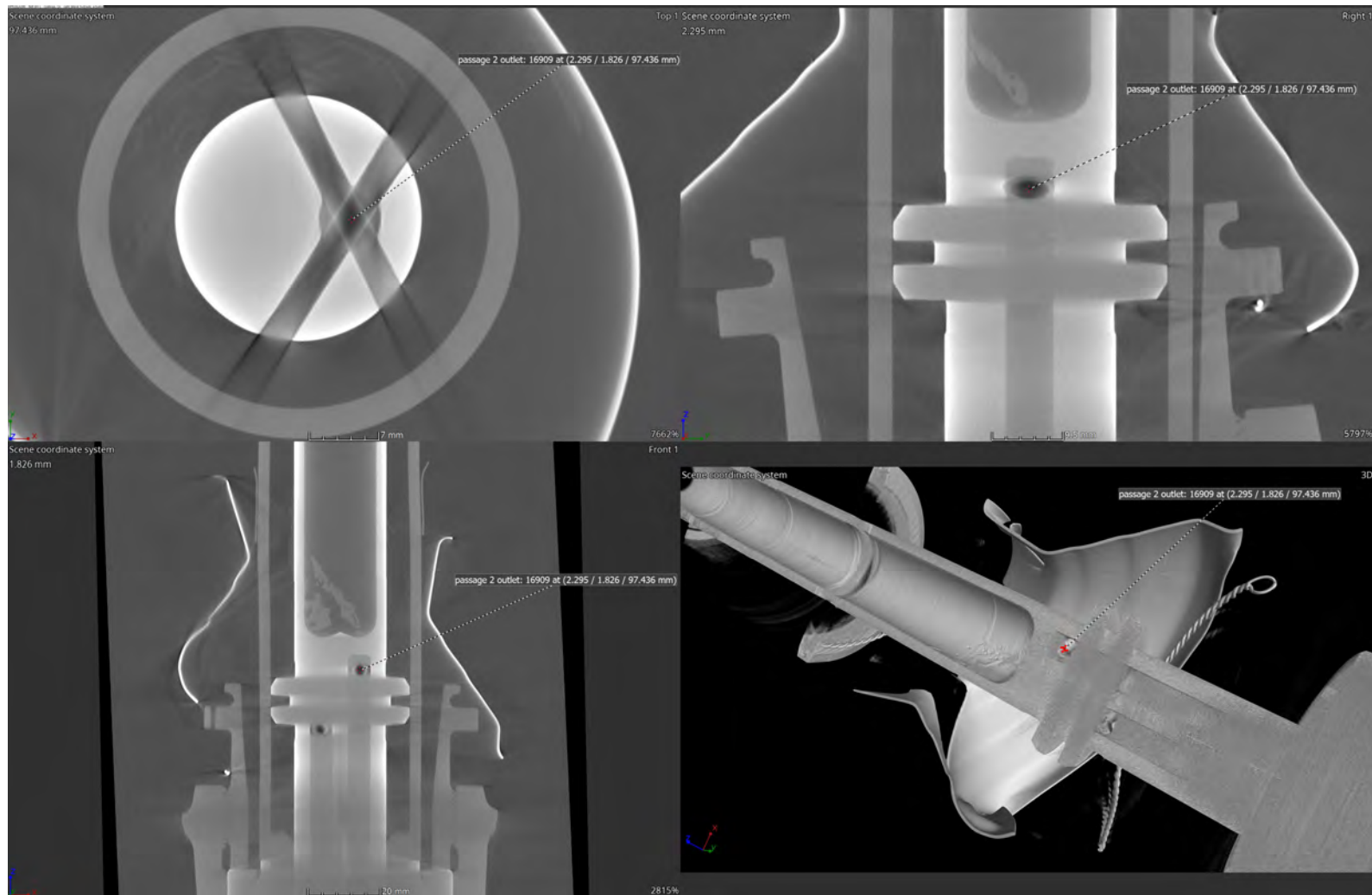


Figure 54
Right lateral actuator – hydraulic passage 2 outlet

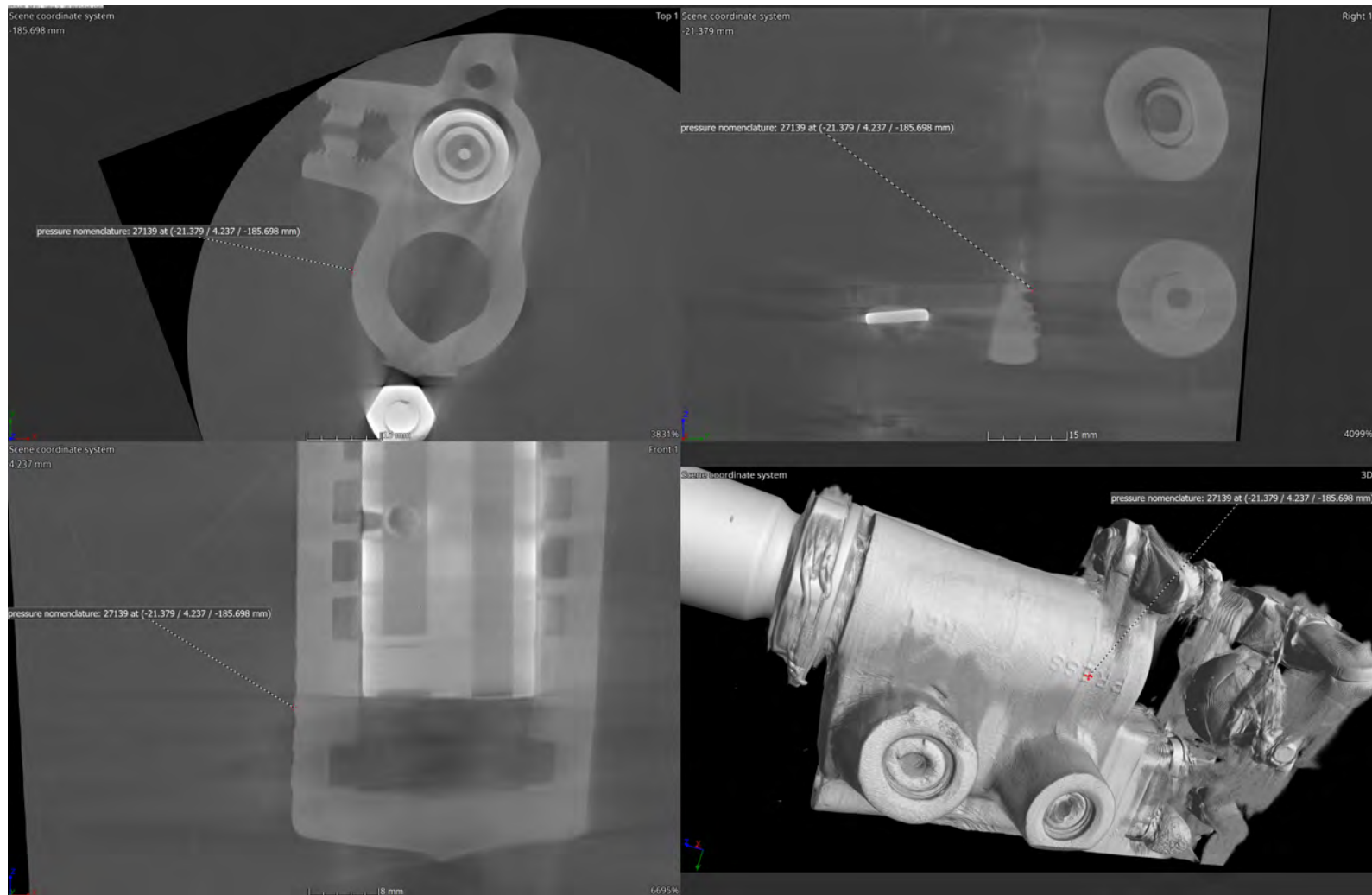


Figure 55
Right lateral actuator – pressure nomenclature

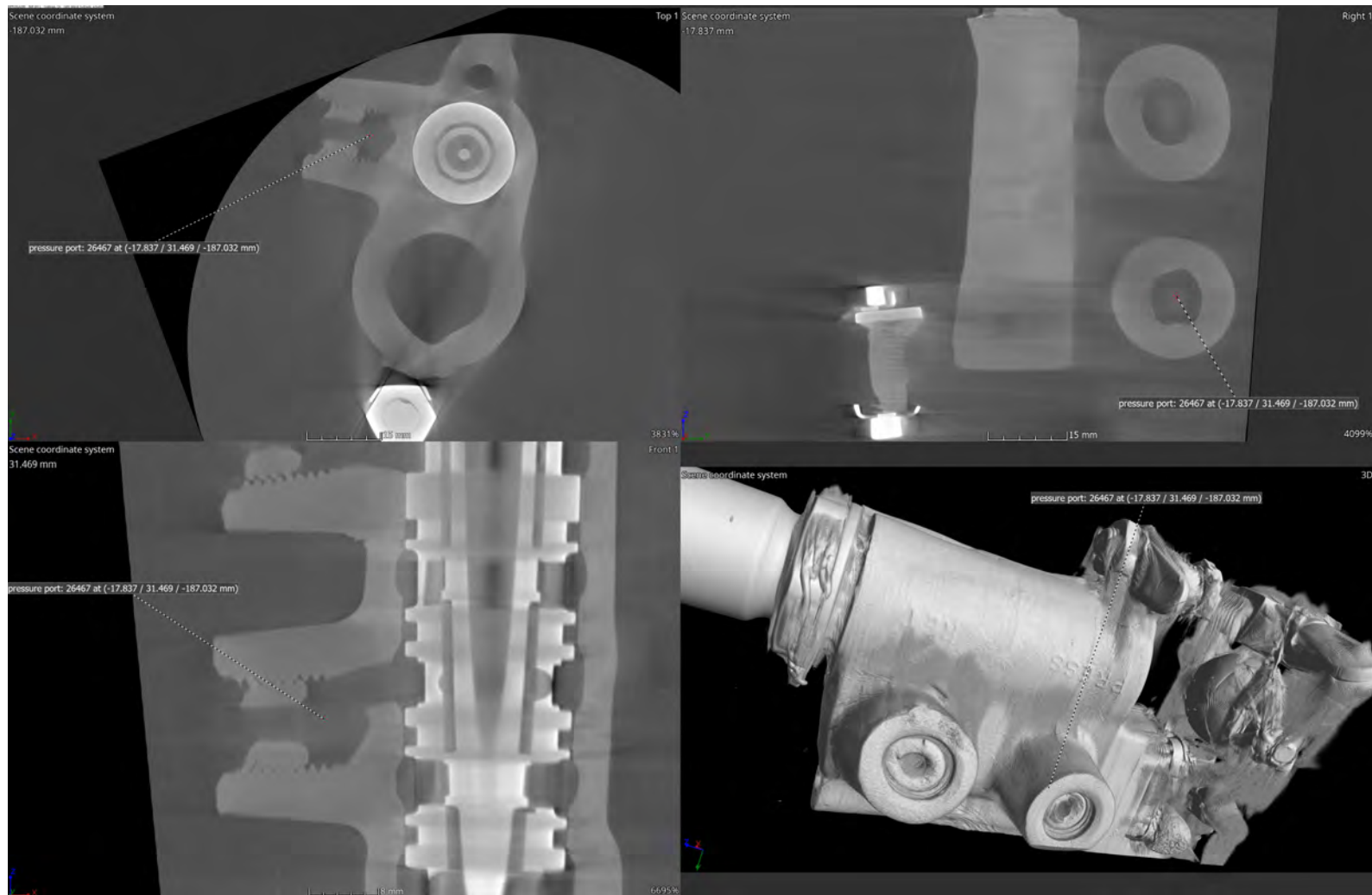


Figure 56
Right lateral actuator – pressure port

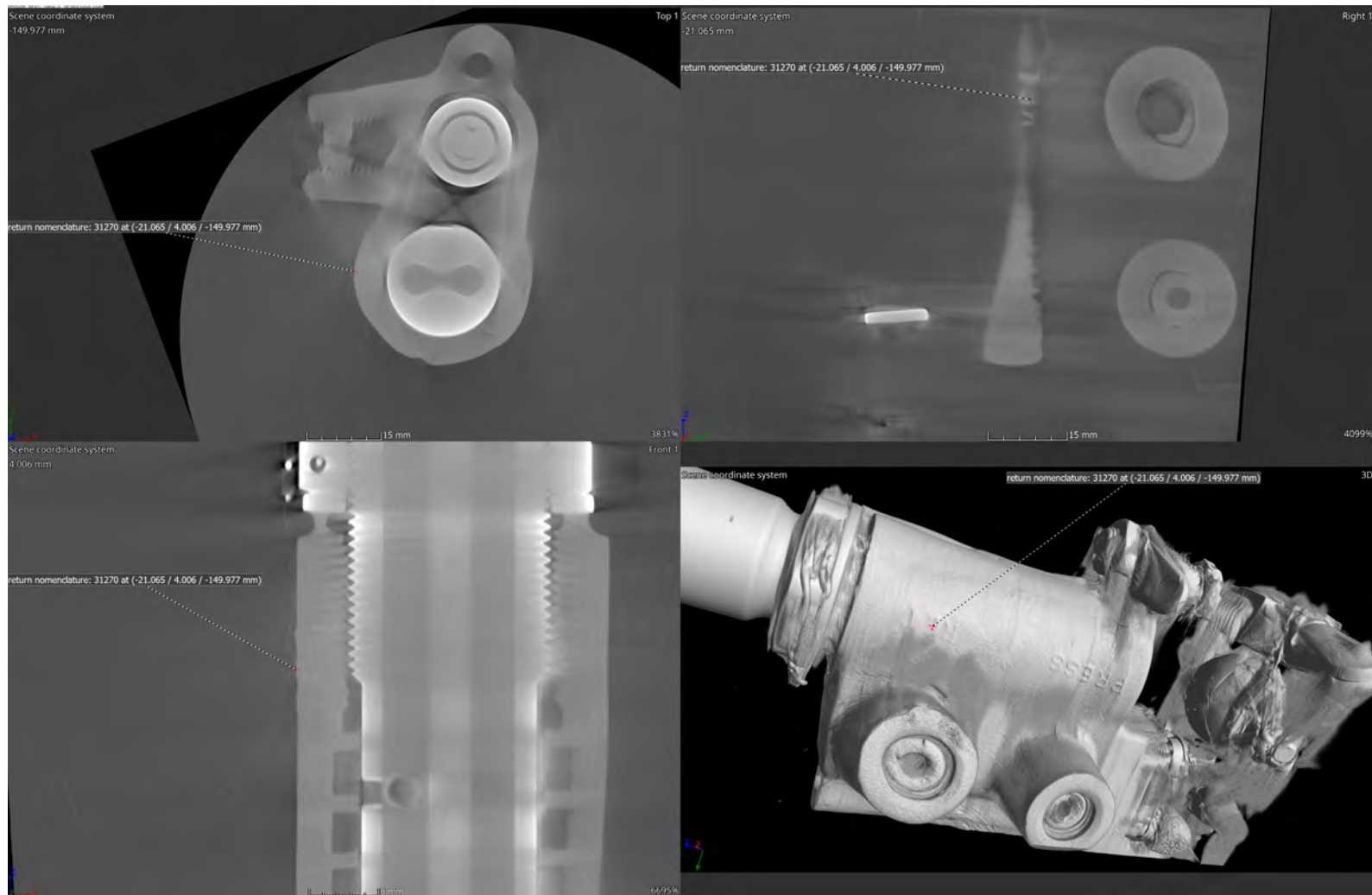


Figure 57
Right lateral actuator – return nomenclature

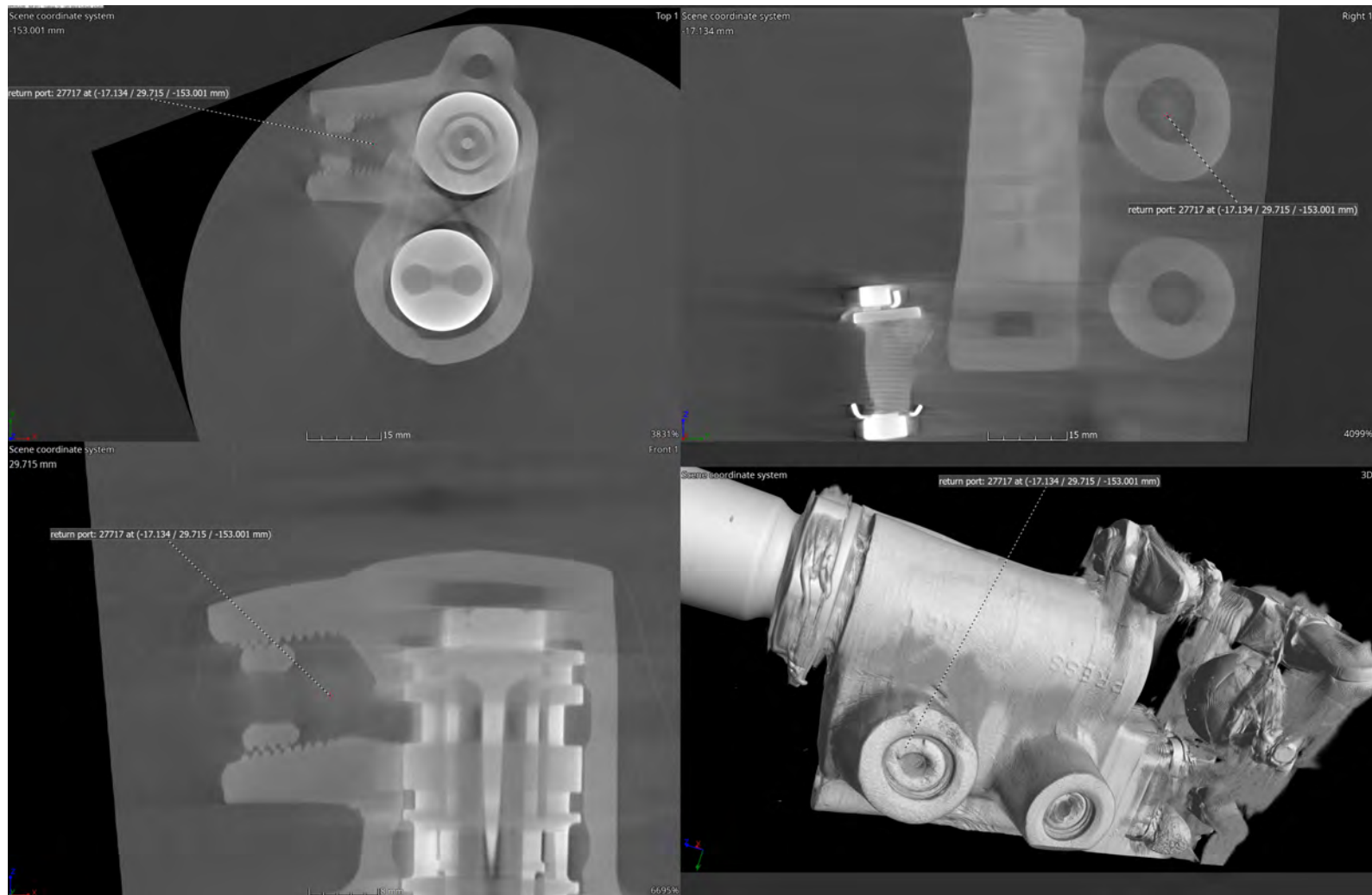


Figure 58
Right lateral actuator – return port

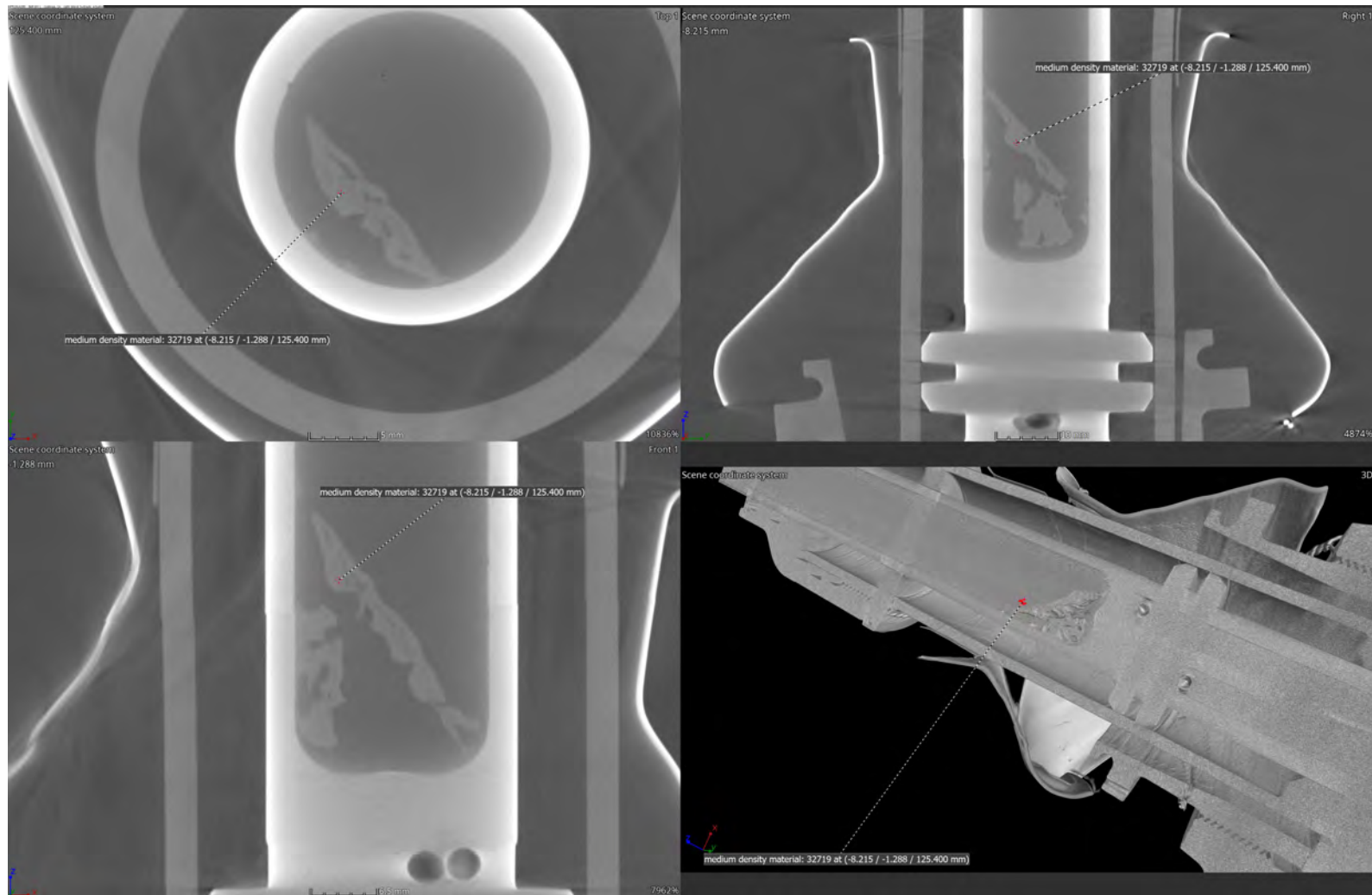


Figure 59
Right lateral actuator – medium density material

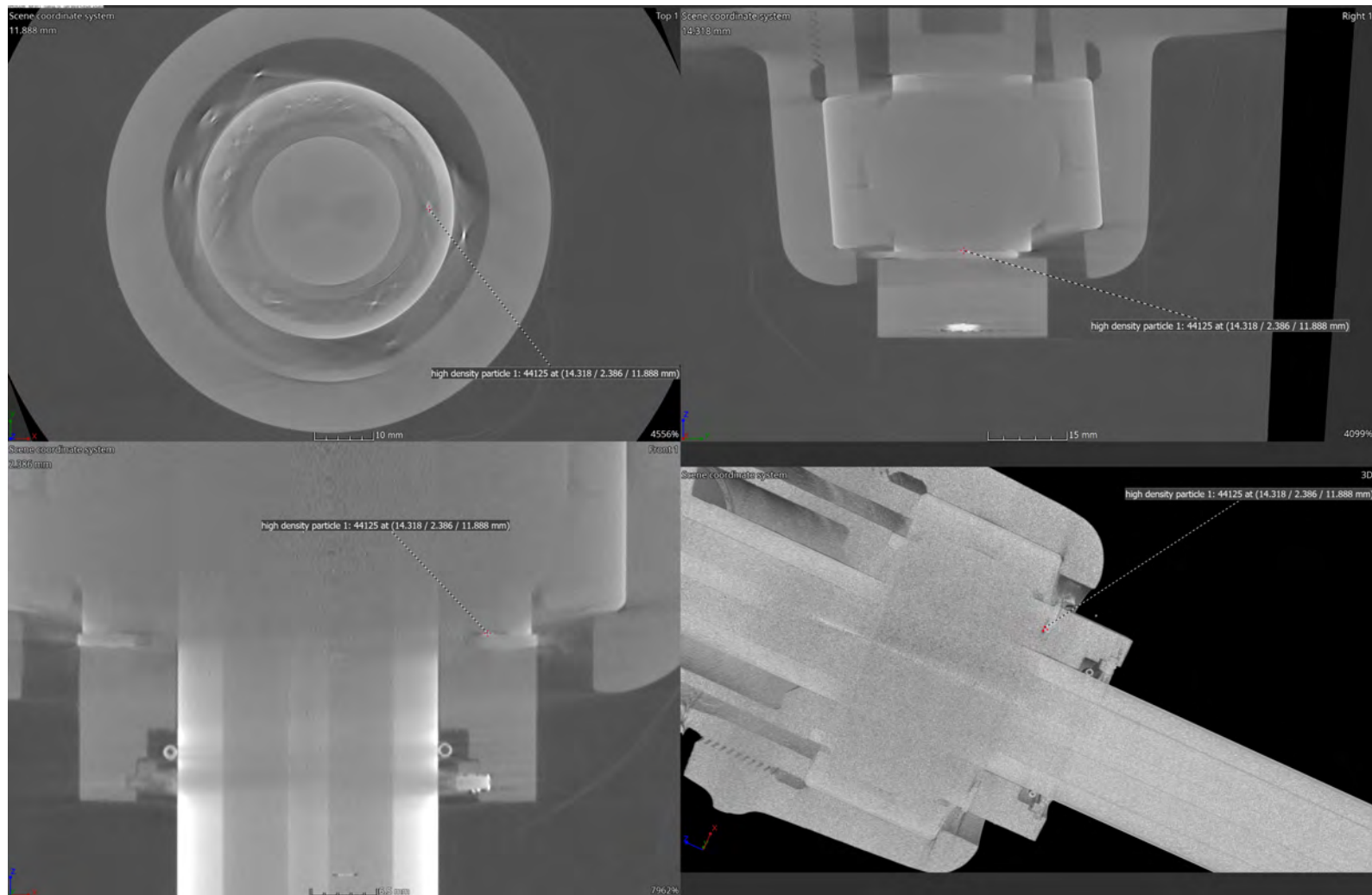


Figure 60
Right lateral actuator – high density particle 1

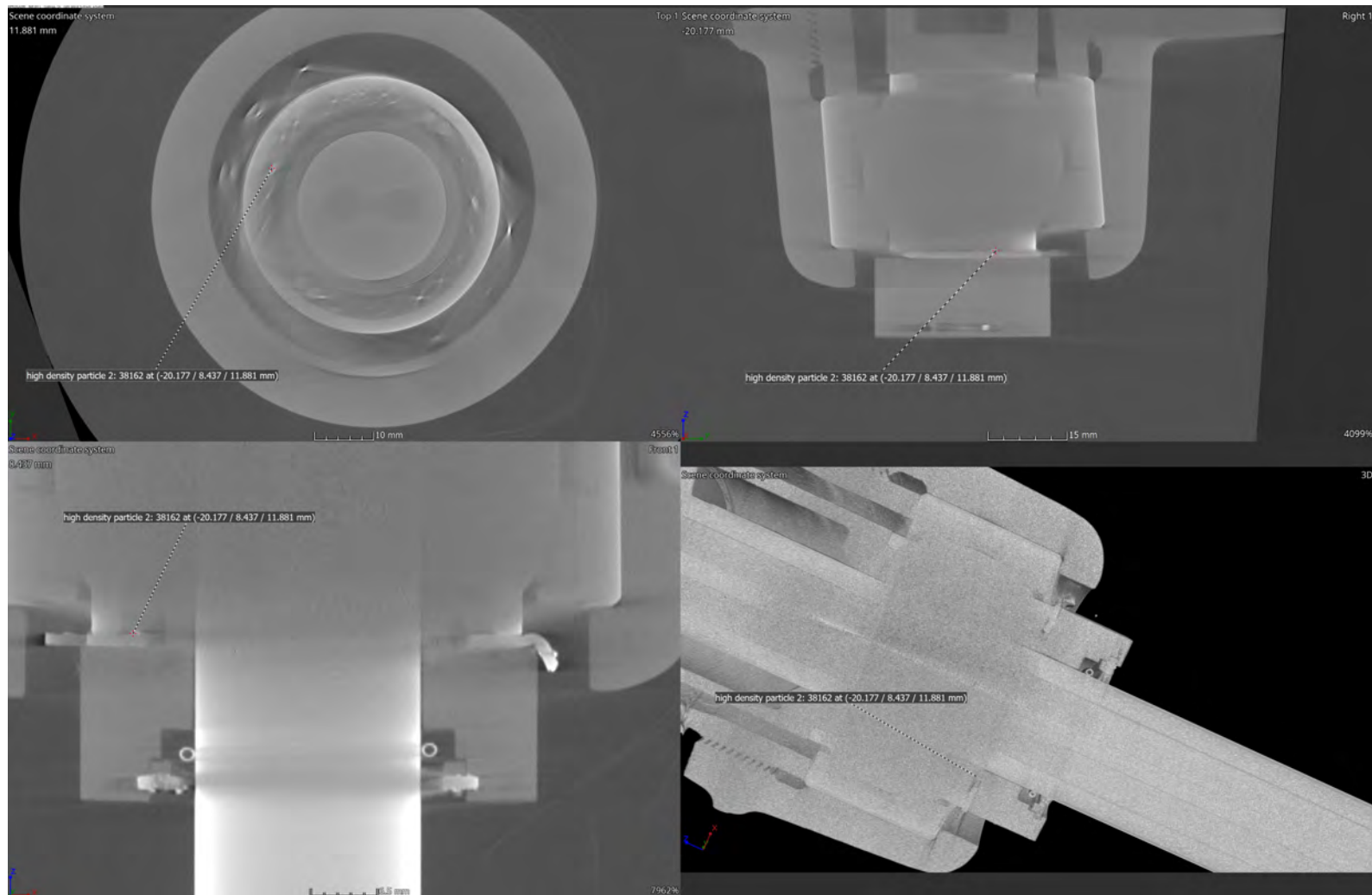


Figure 61
Right lateral actuator – high density particle 2

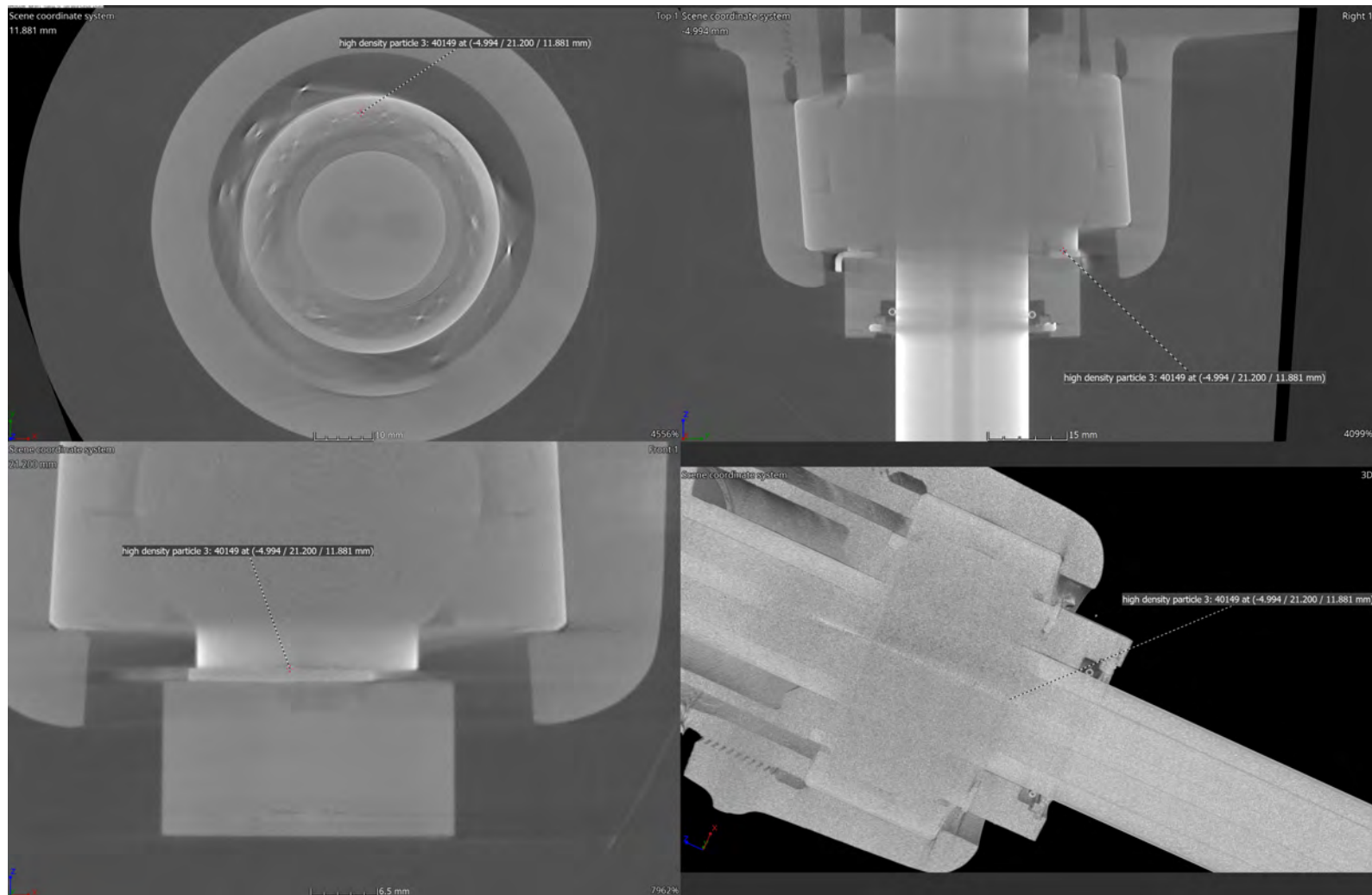


Figure 62
Right lateral actuator – high density particle 3

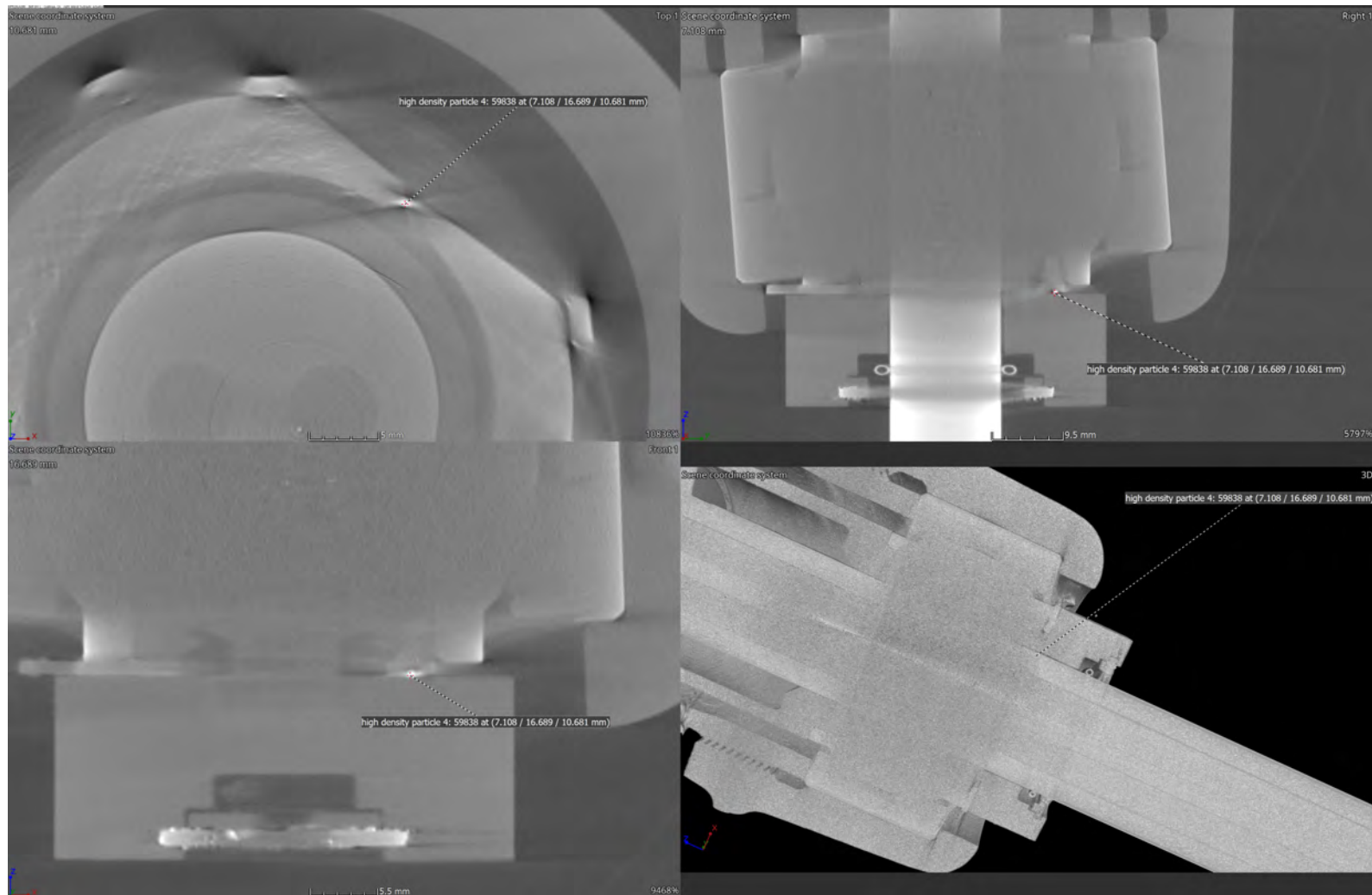


Figure 63
Right lateral actuator – high density particle 4

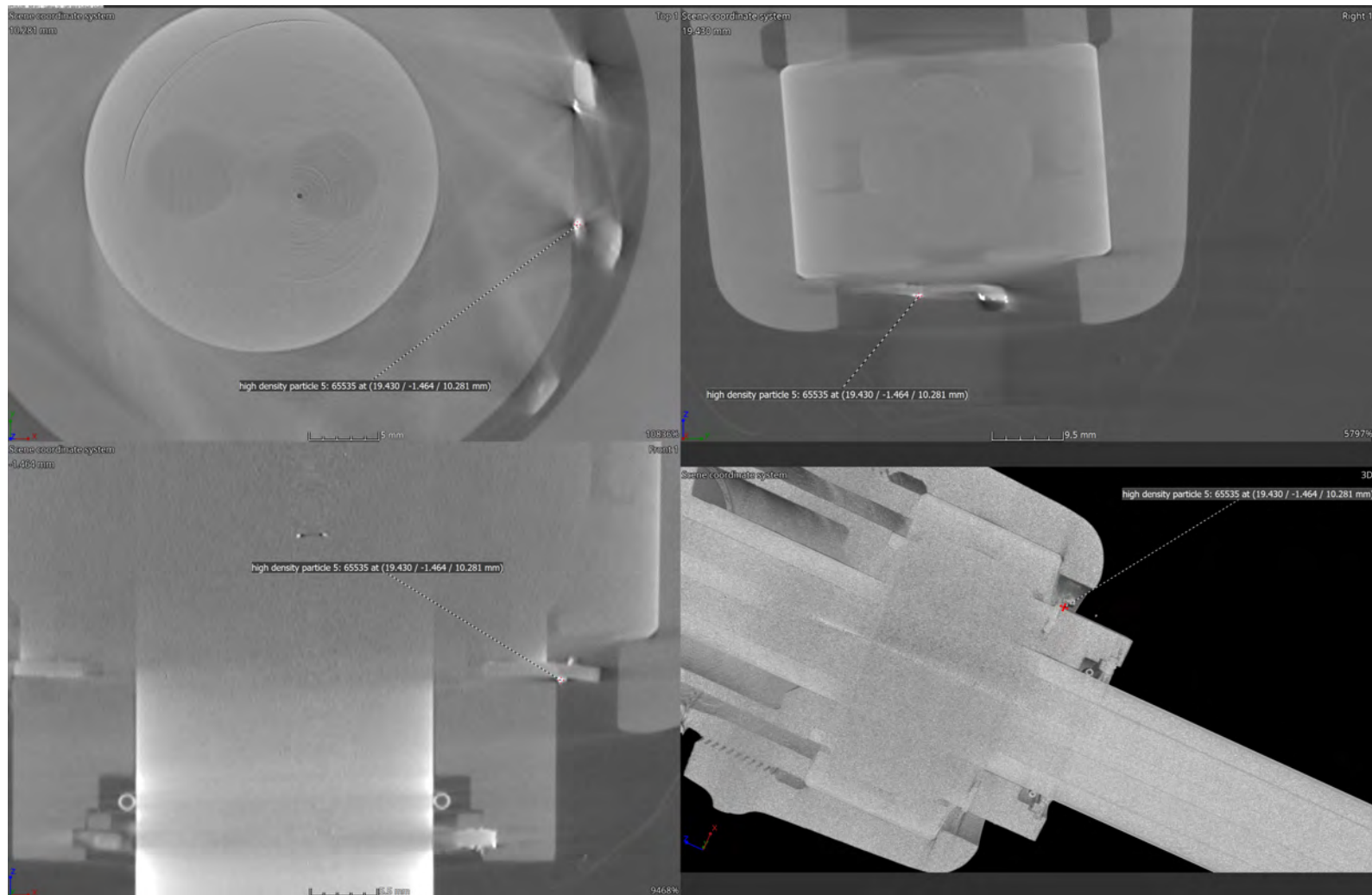


Figure 64
Right lateral actuator – high density particle 5

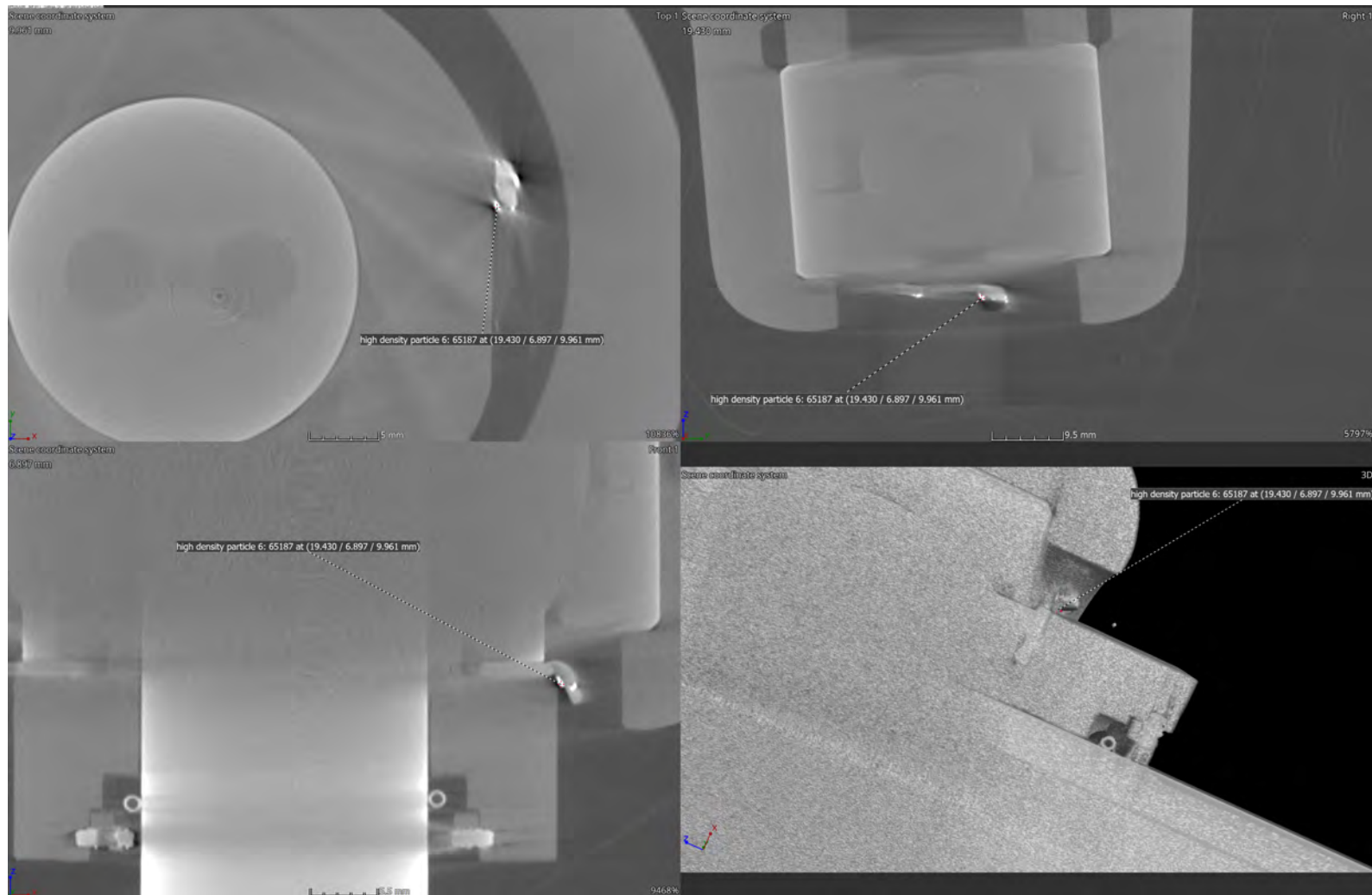


Figure 65
Right lateral actuator – high density particle 6

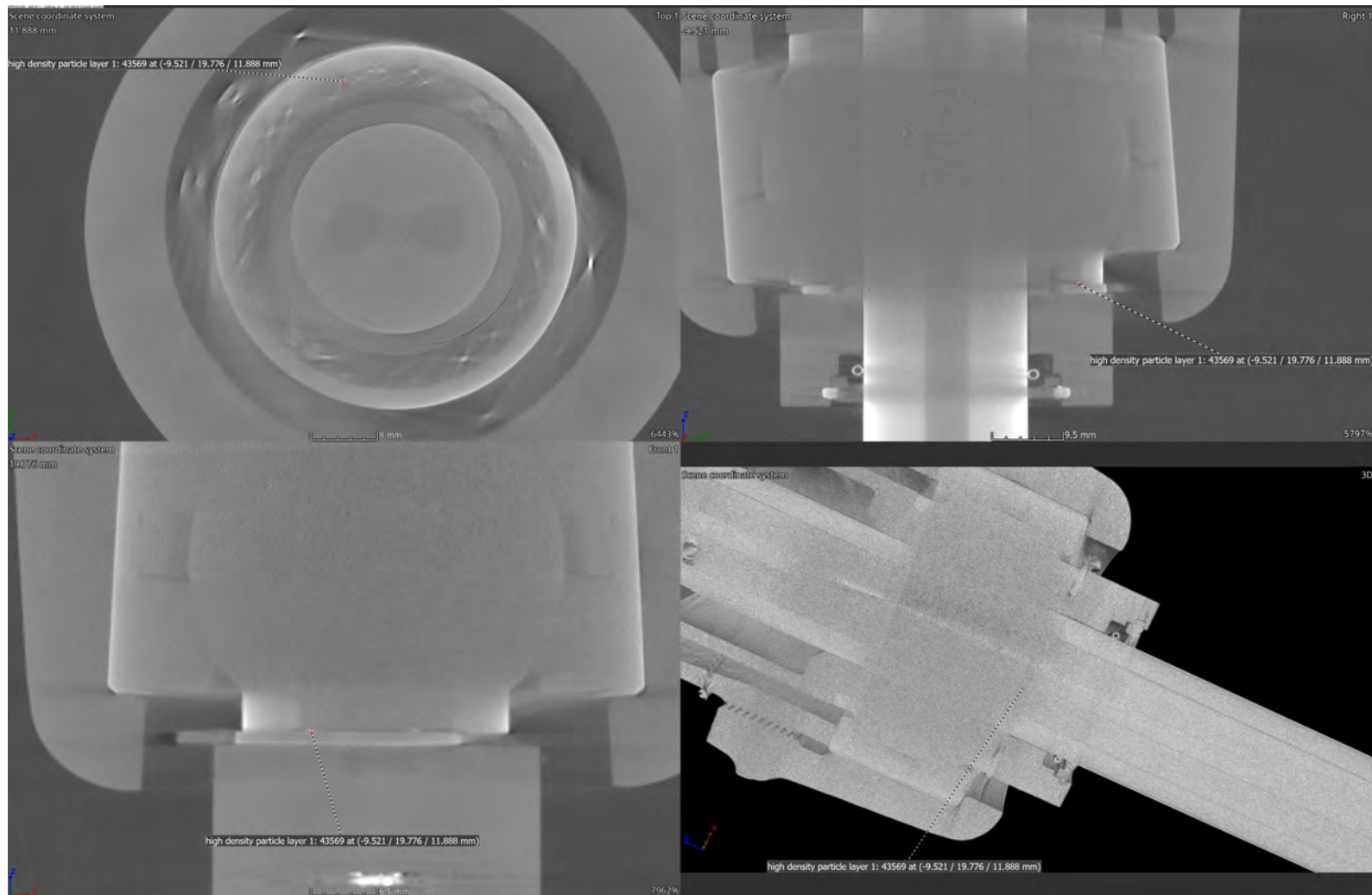


Figure 66
Right lateral actuator – high density particle layer 1

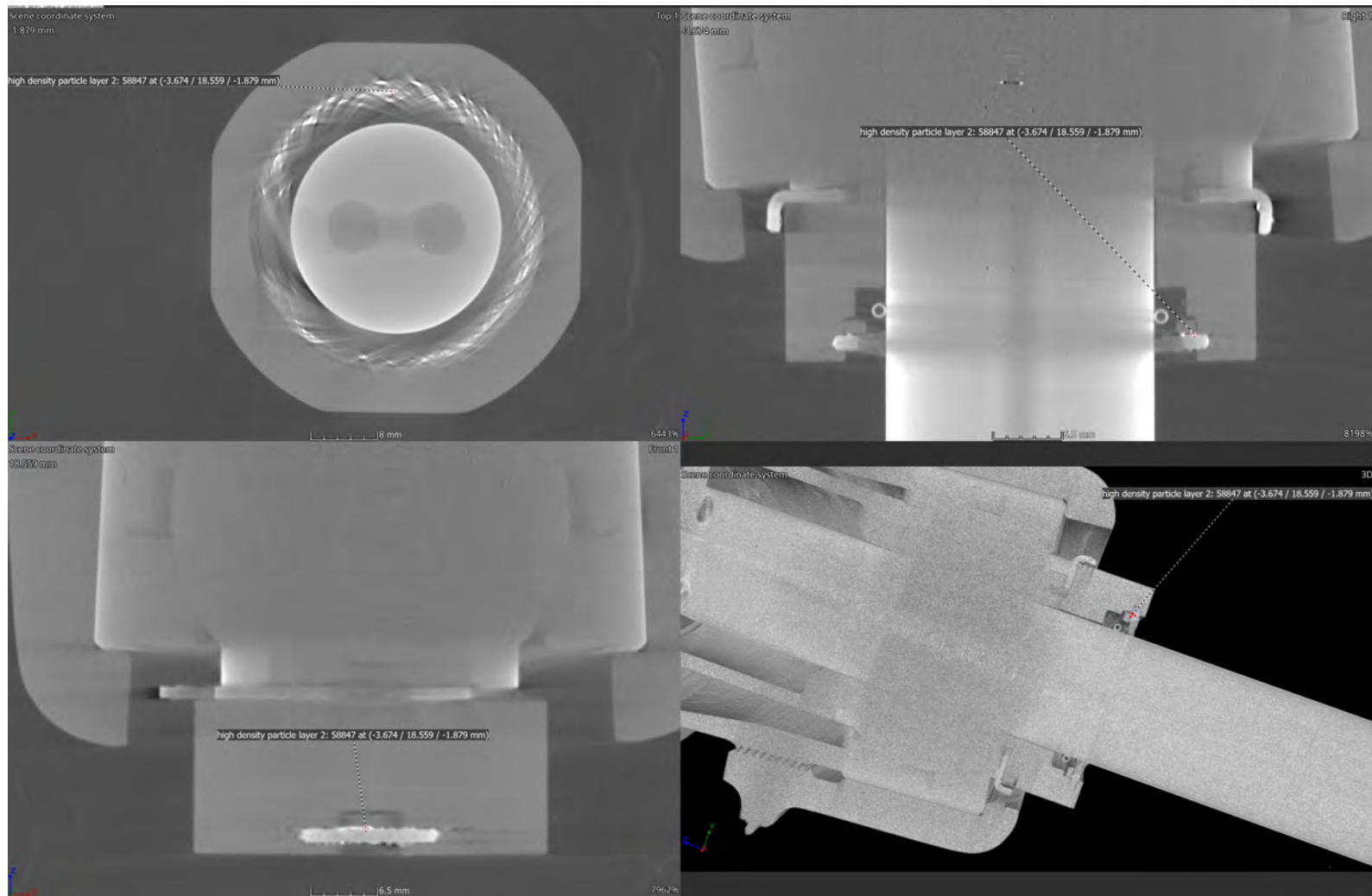


Figure 67
Right lateral actuator – high density particle layer 2

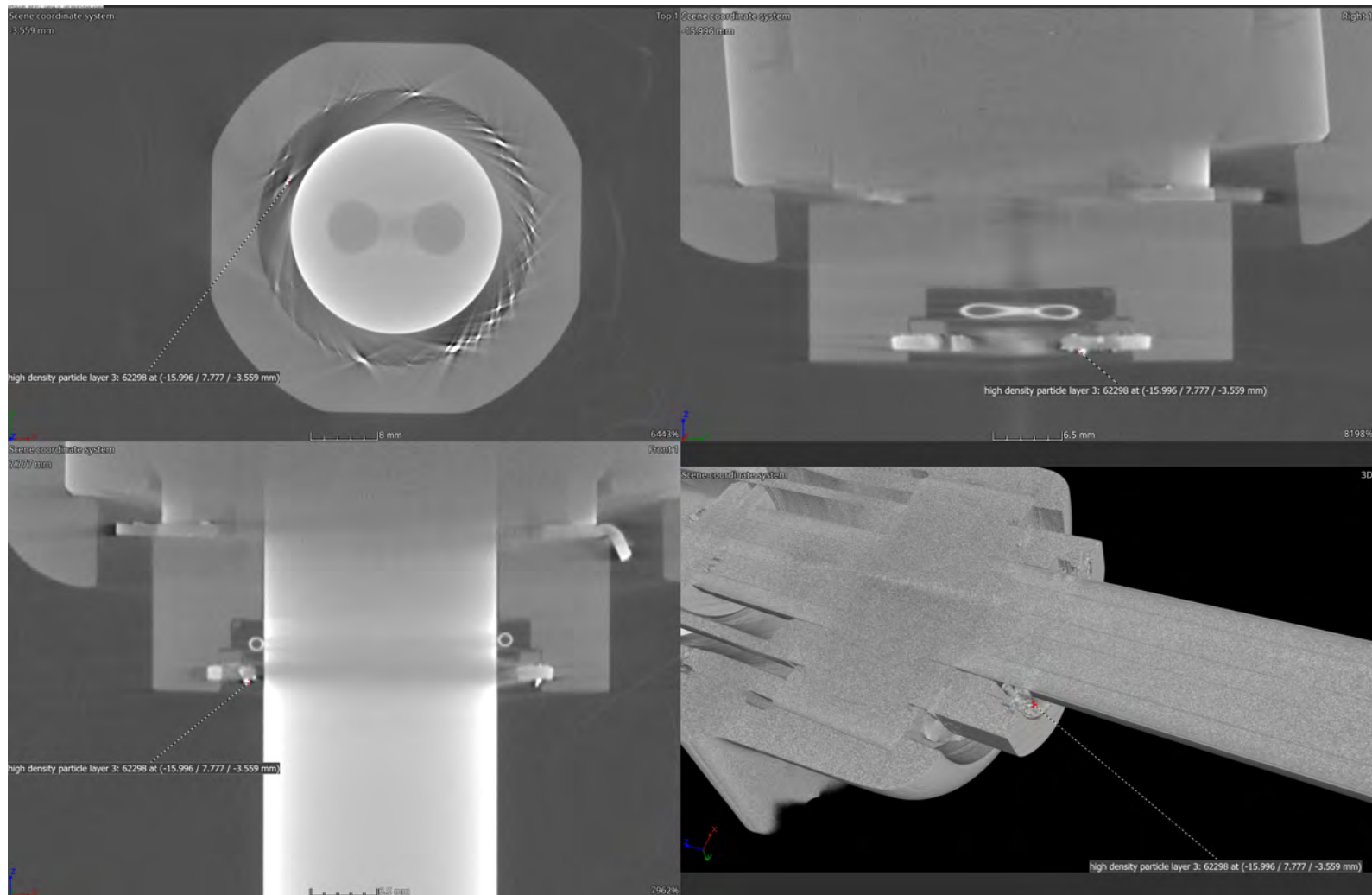


Figure 68
Right lateral actuator – high density particle layer 3

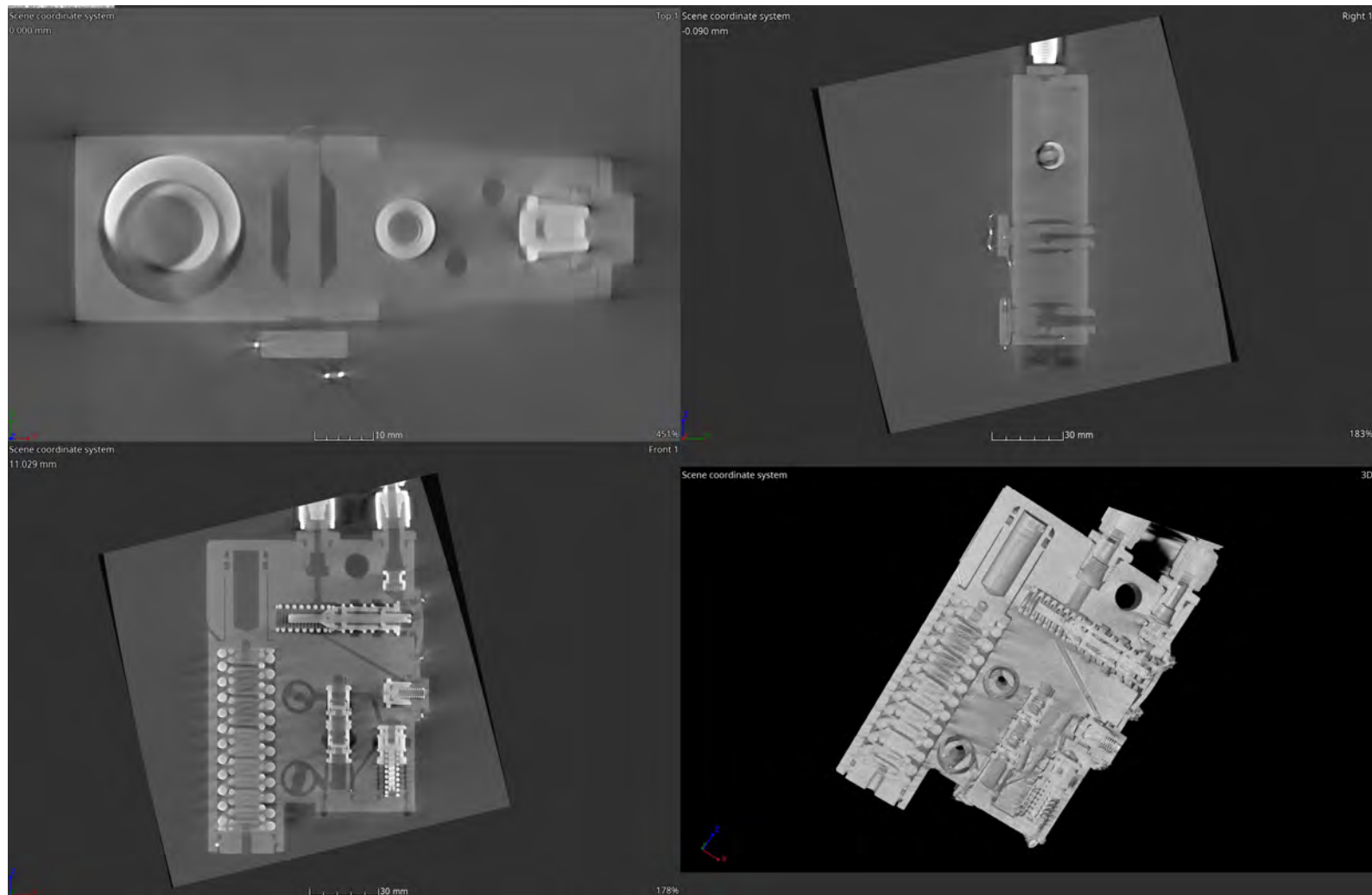


Figure 69
Irreversible valve assembly – overview

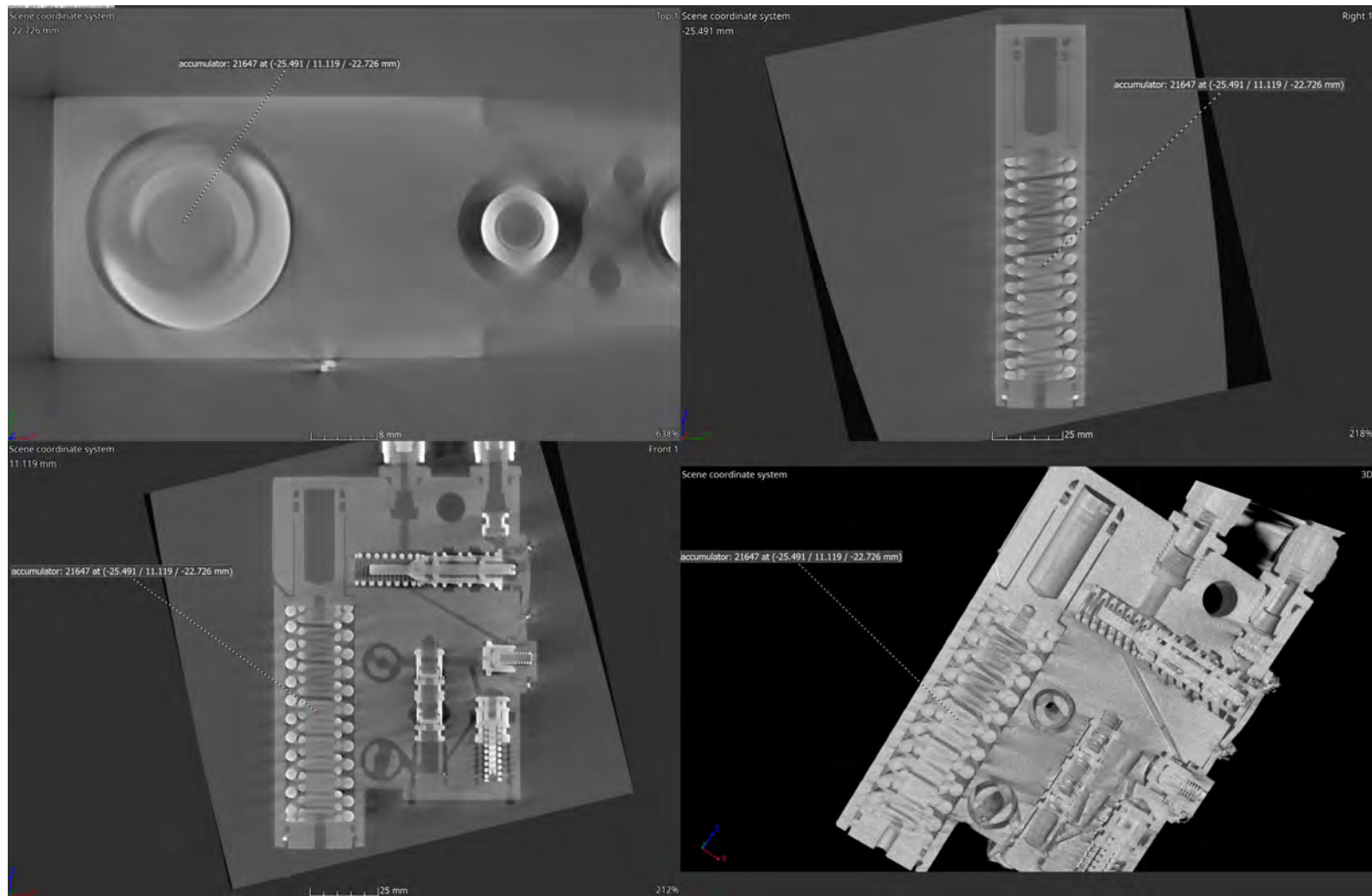


Figure 70
Irreversible valve assembly – accumulator

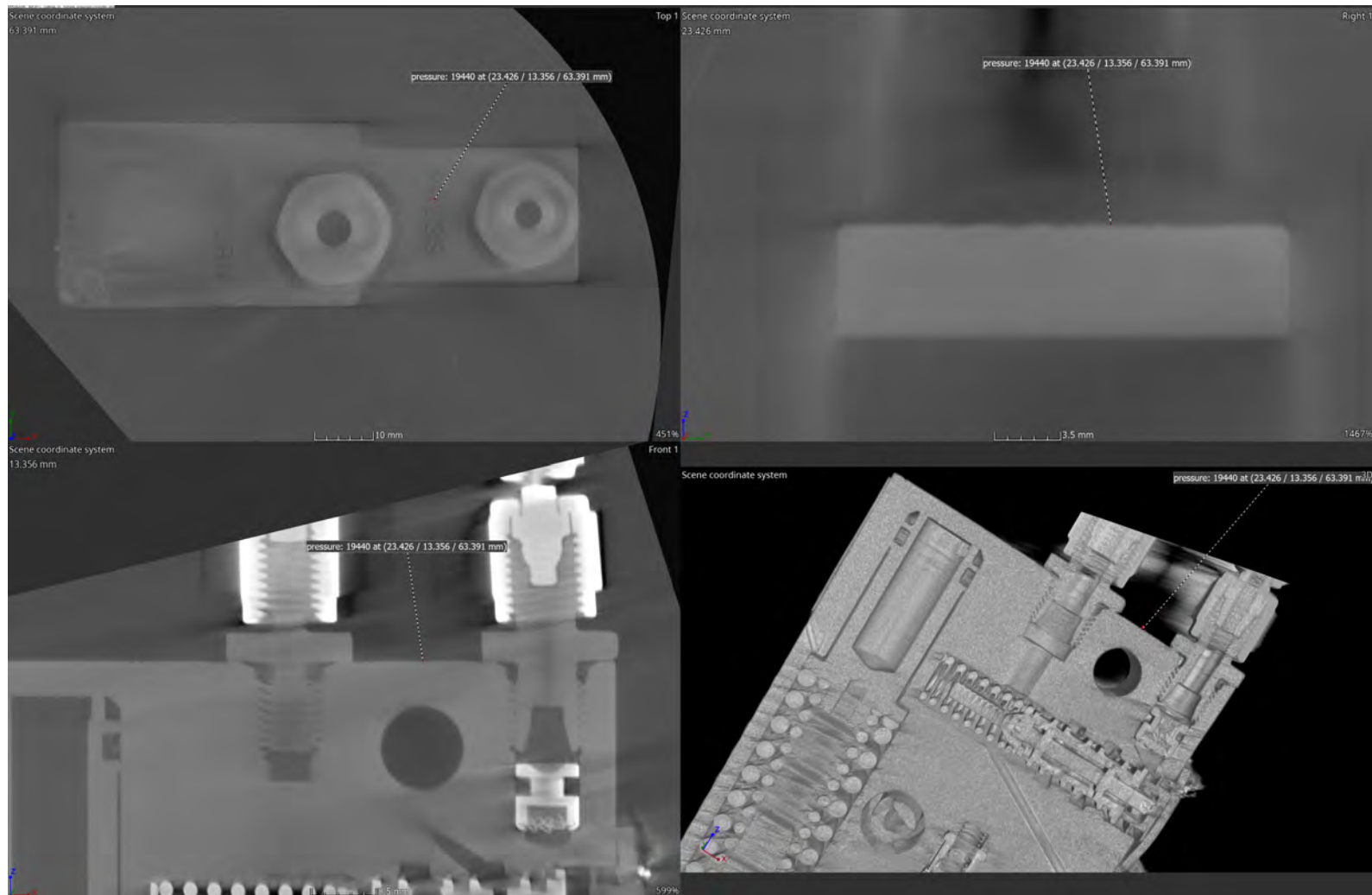


Figure 71
Irreversible valve assembly – pressure nomenclature

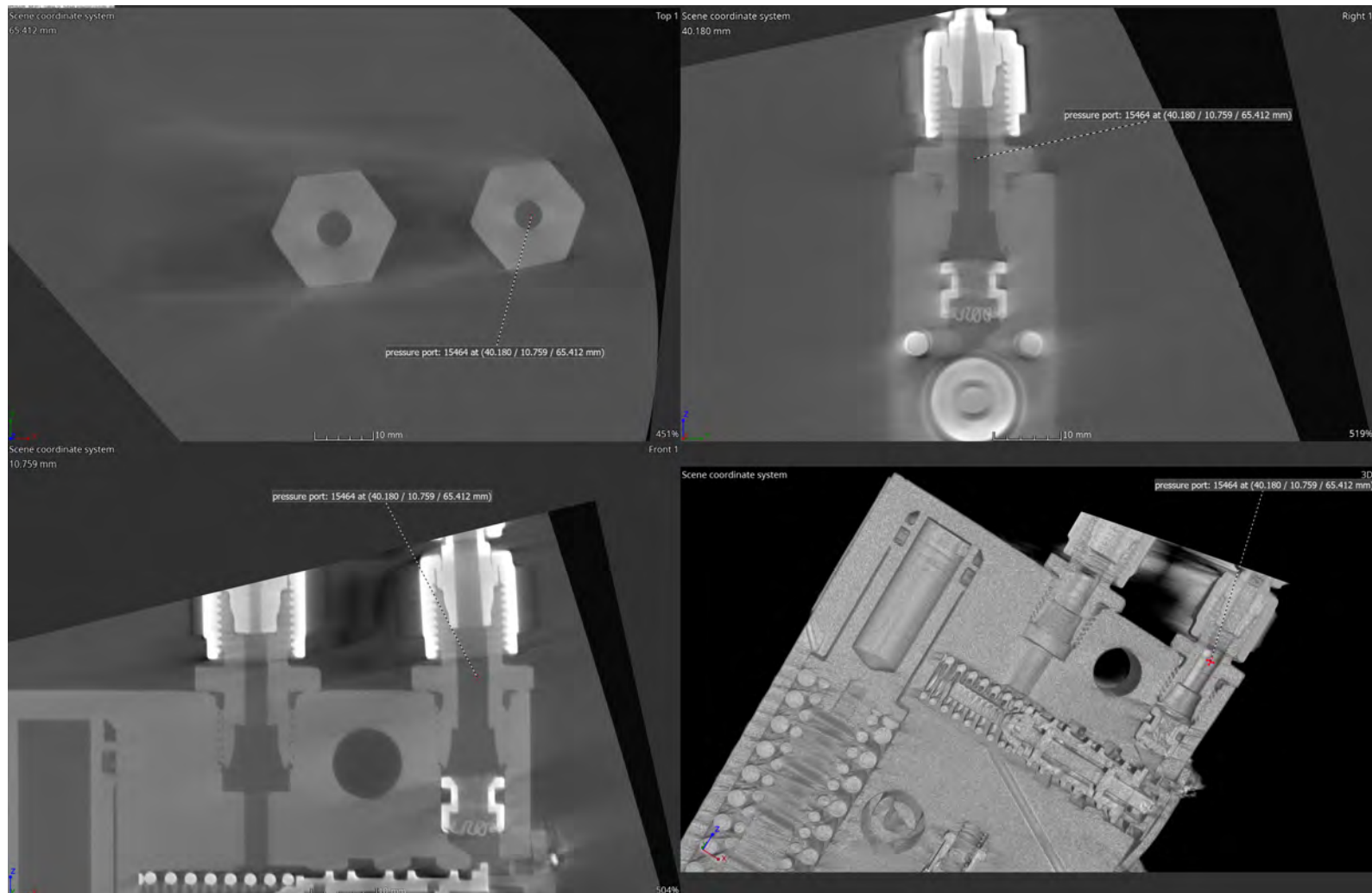


Figure 72
Irreversible valve assembly – pressure port

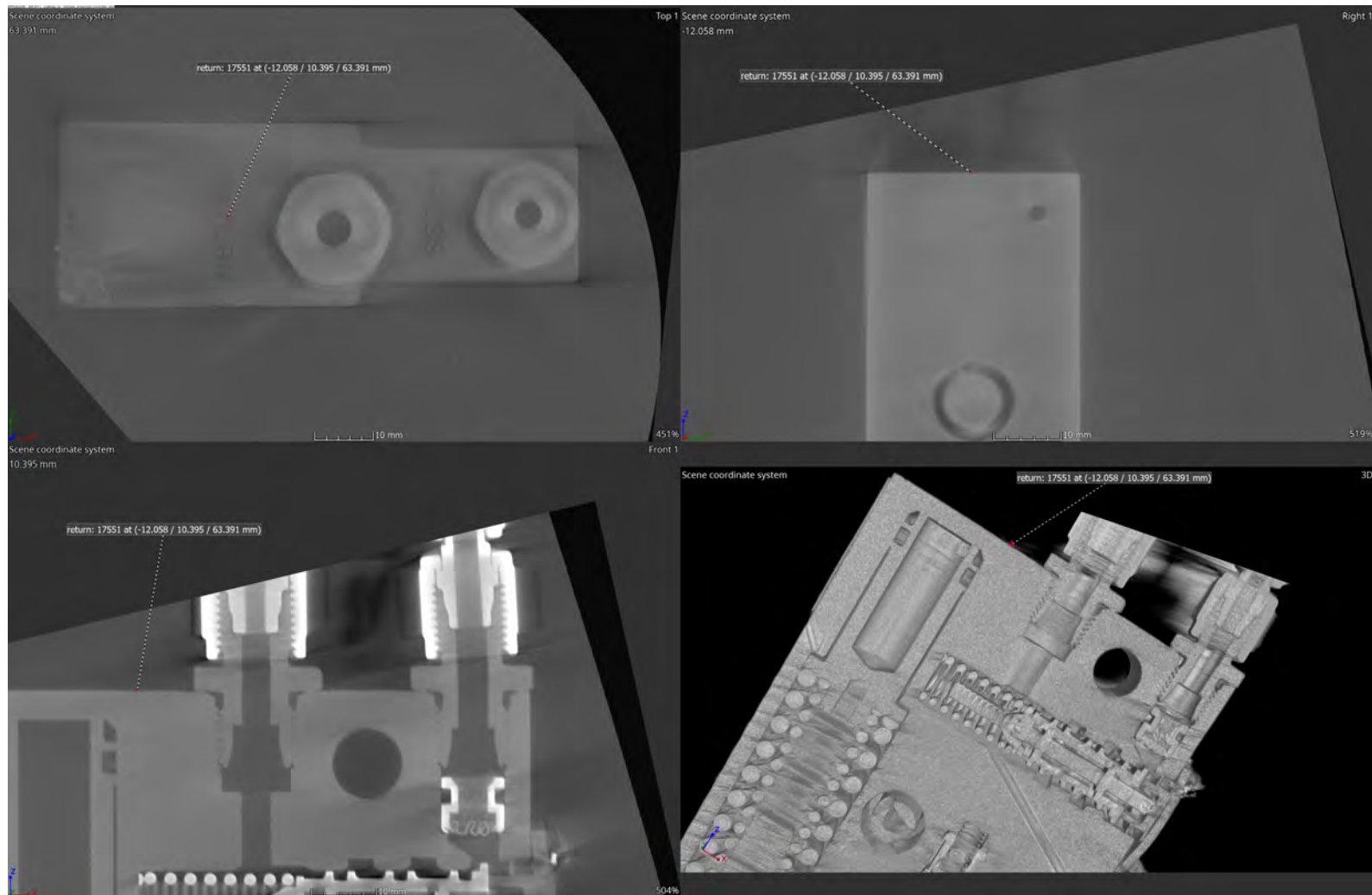


Figure 73
Irreversible valve assembly – return nomenclature

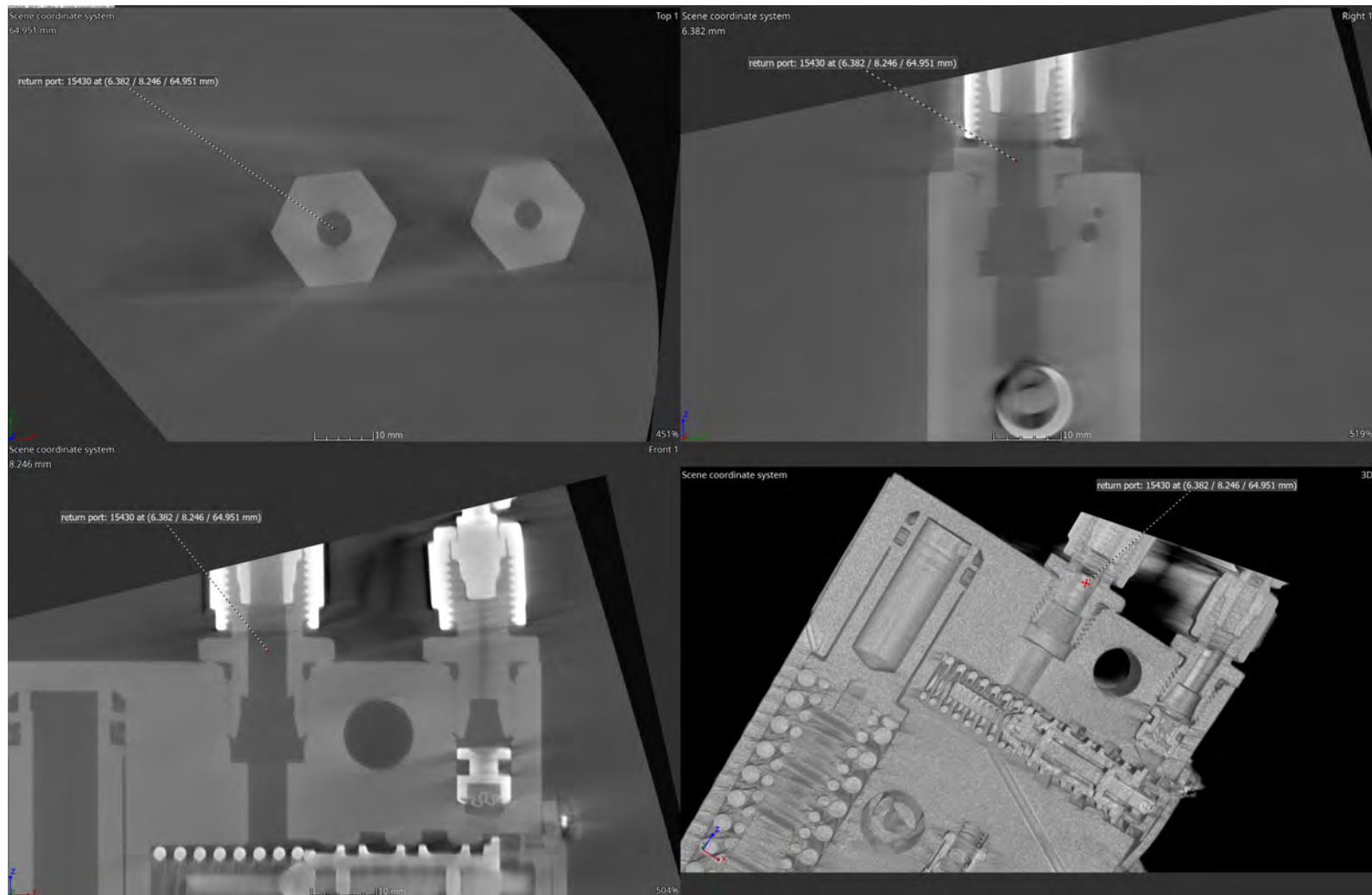


Figure 74
Irreversible valve assembly – return port

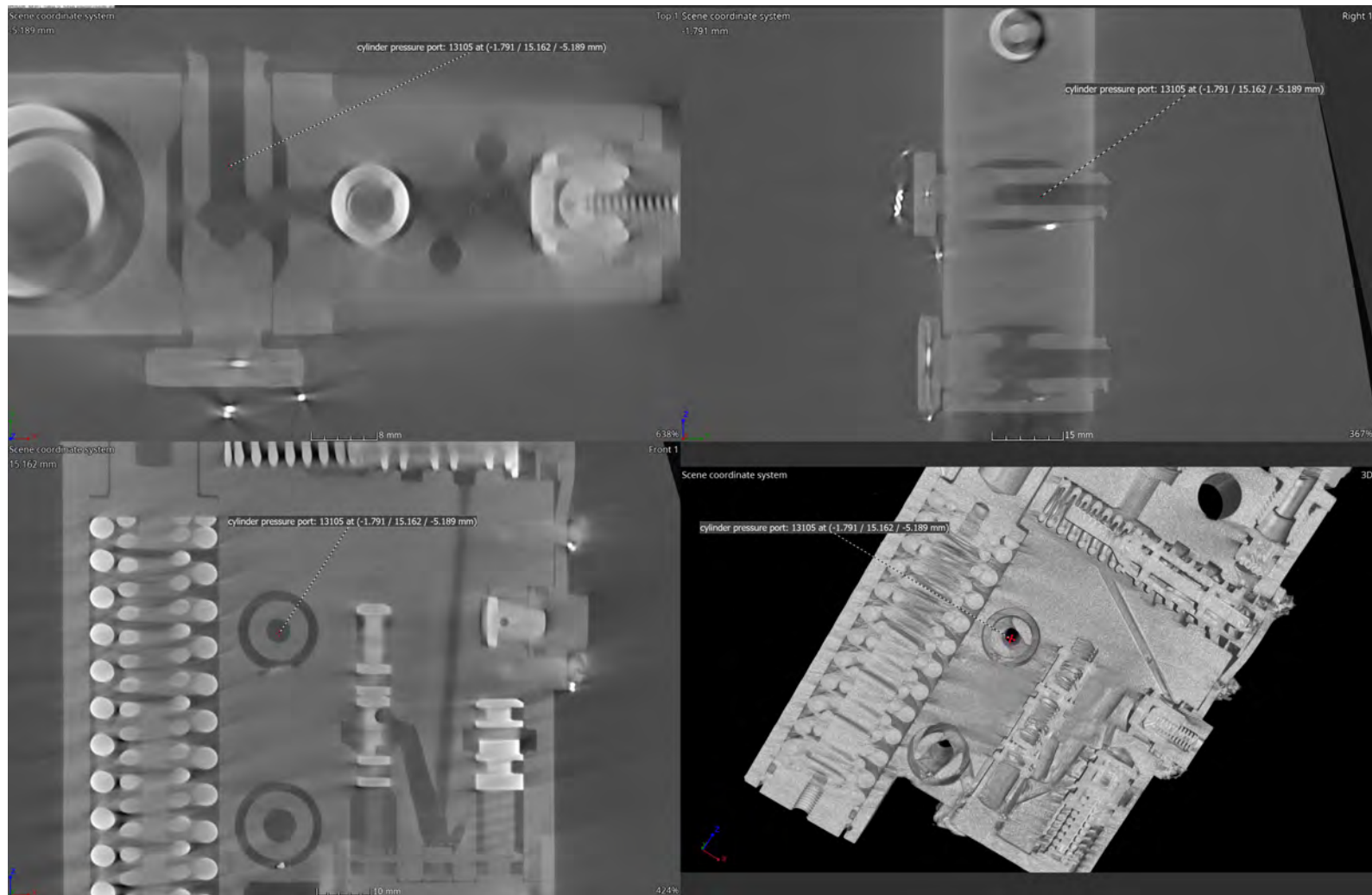


Figure 75
Irreversible valve assembly – cylinder pressure port

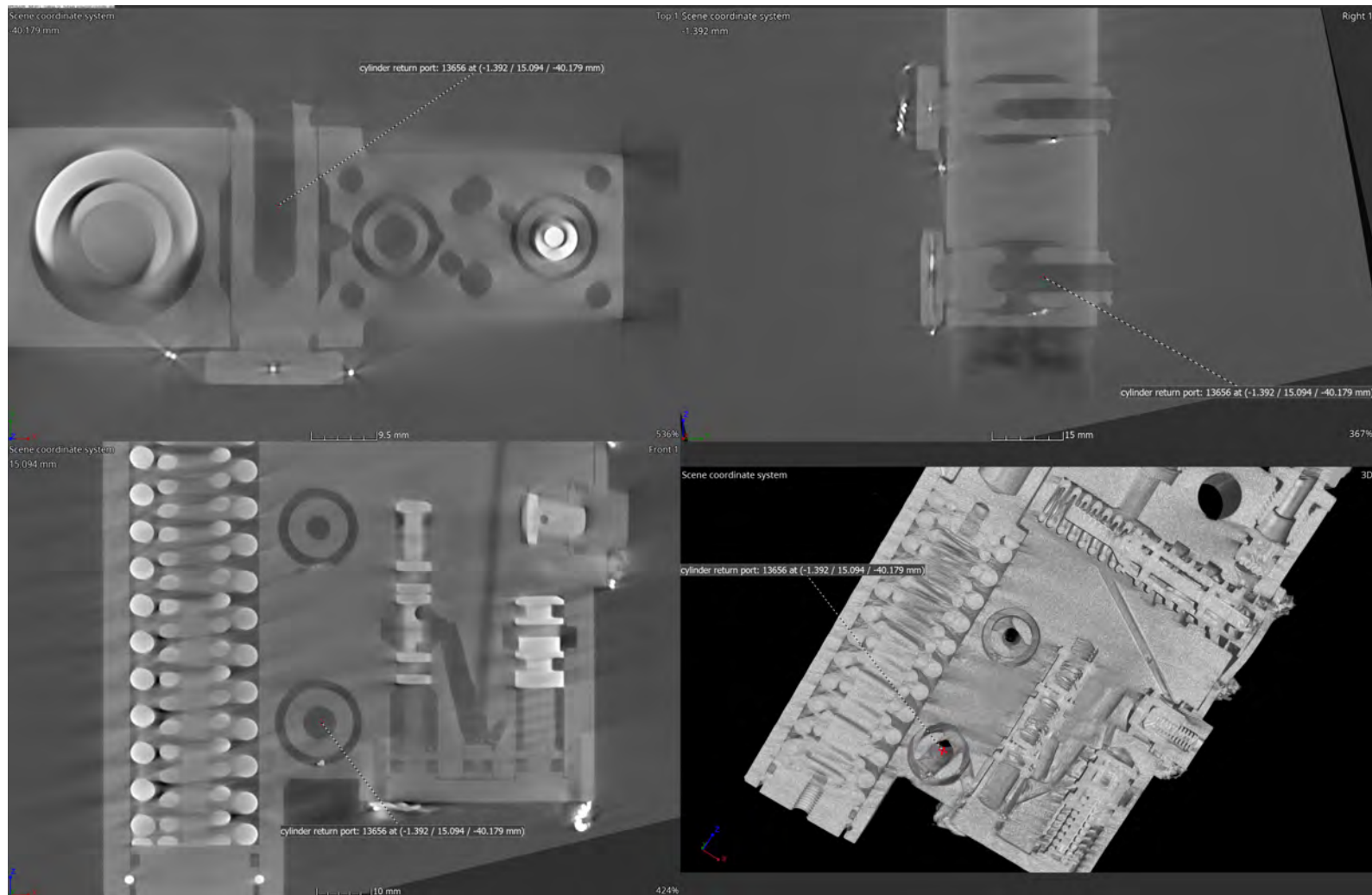


Figure 76
Irreversible valve assembly – cylinder return port

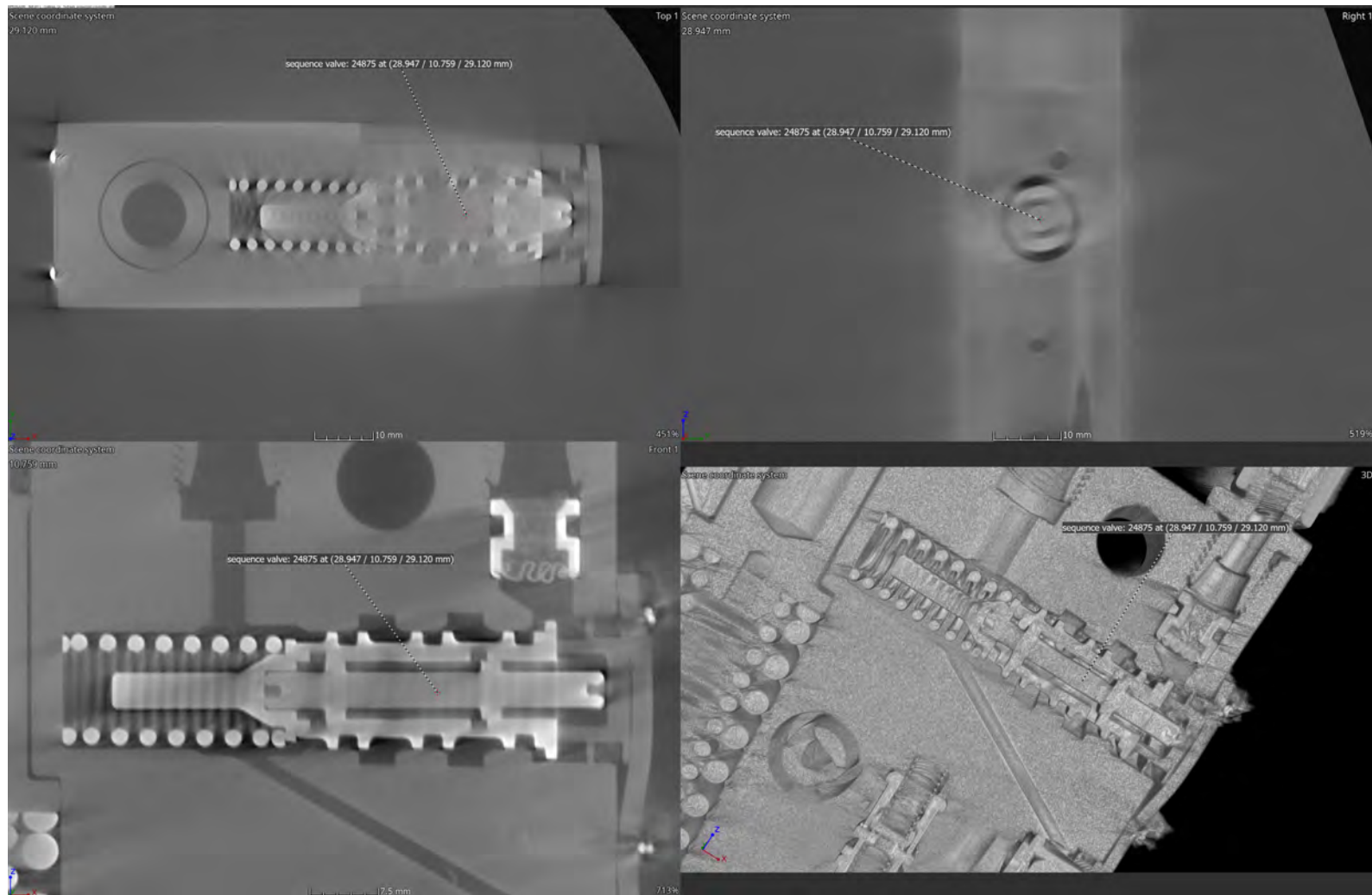


Figure 77
Irreversible valve assembly – sequence valve

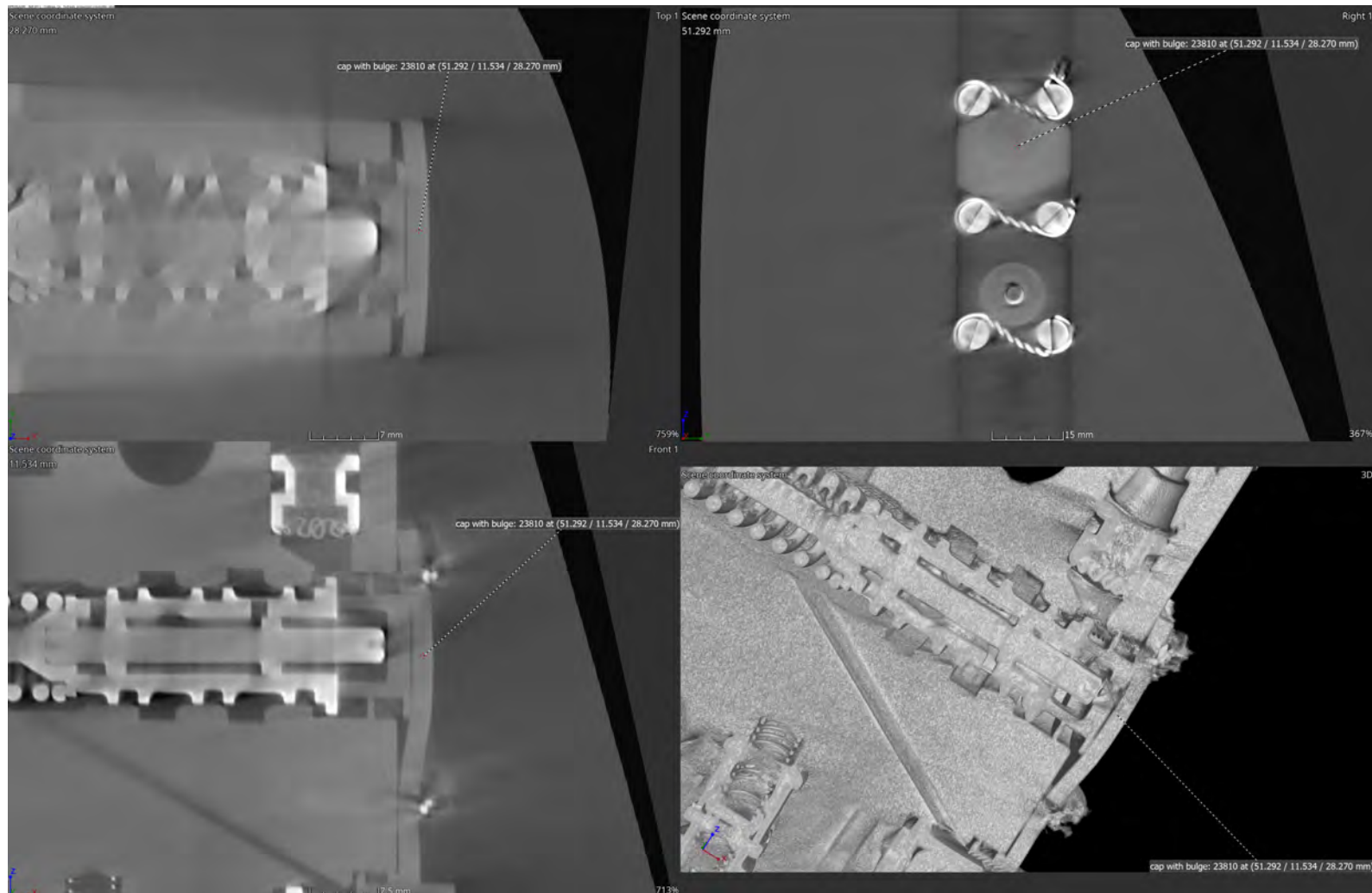


Figure 78
Irreversible valve assembly – cap with bulge

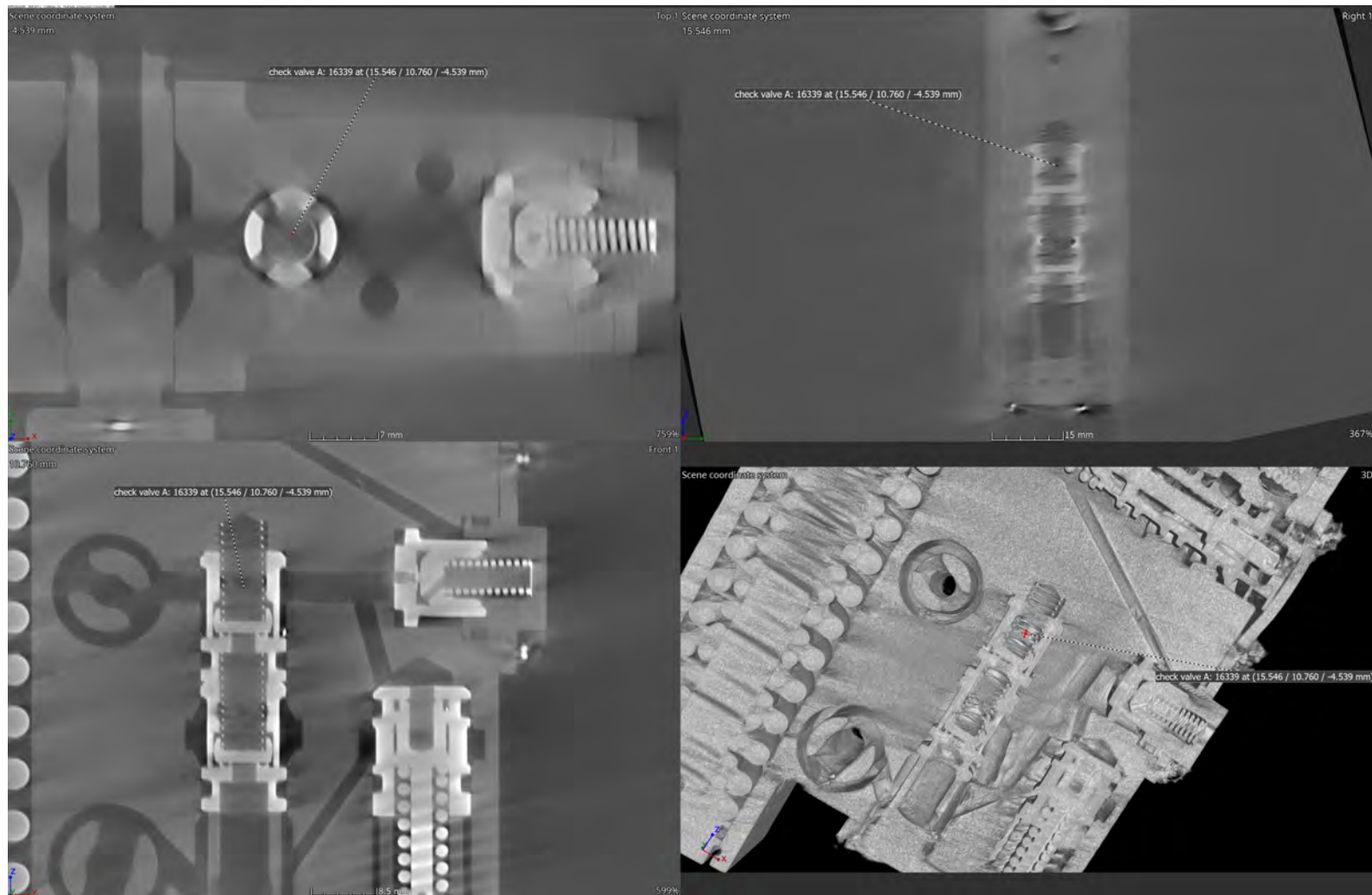


Figure 79
Irreversible valve assembly – check valve A

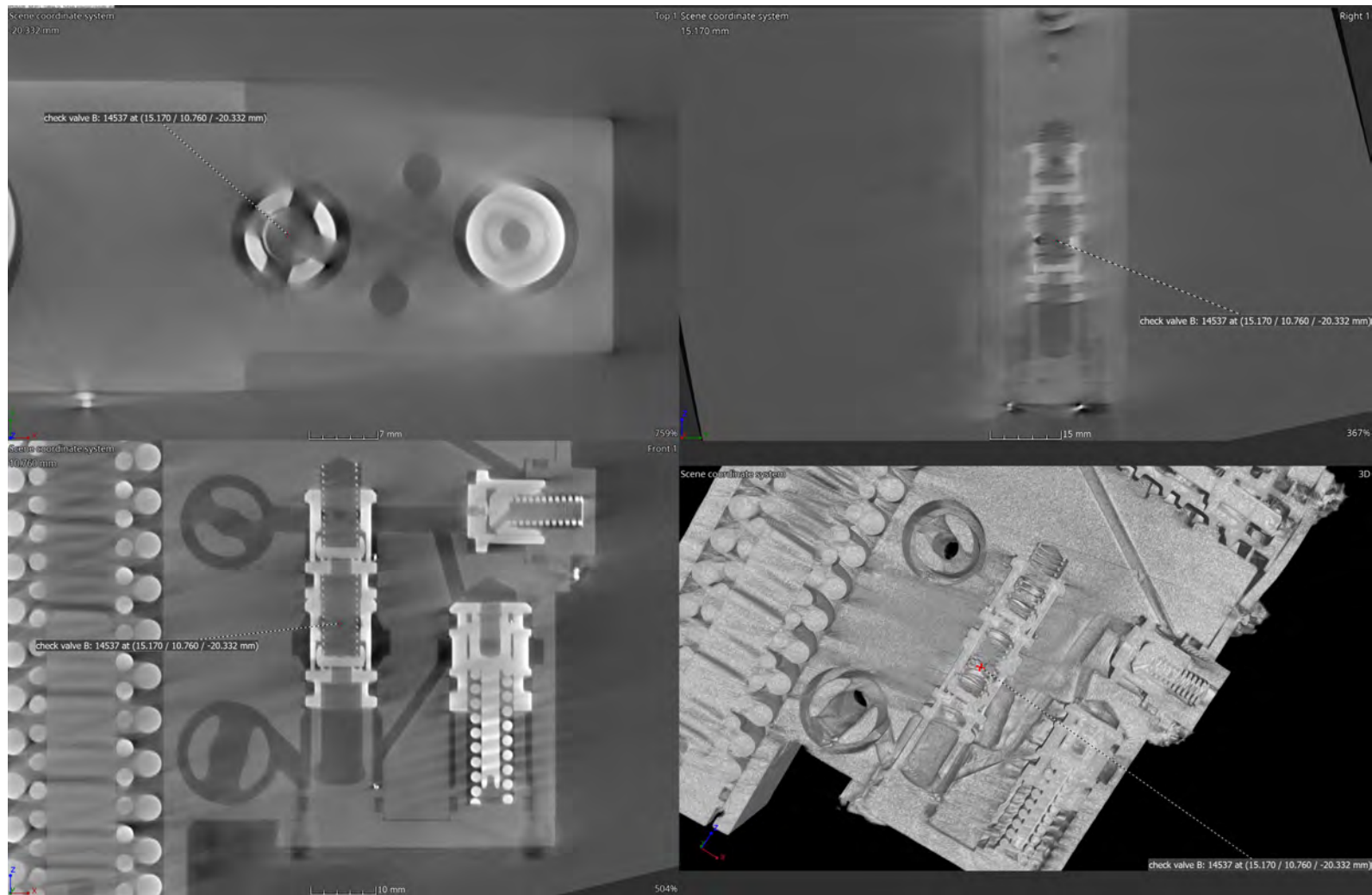


Figure 80
Irreversible valve assembly – check valve B



Figure 81
Irreversible valve assembly – thermal relief valve

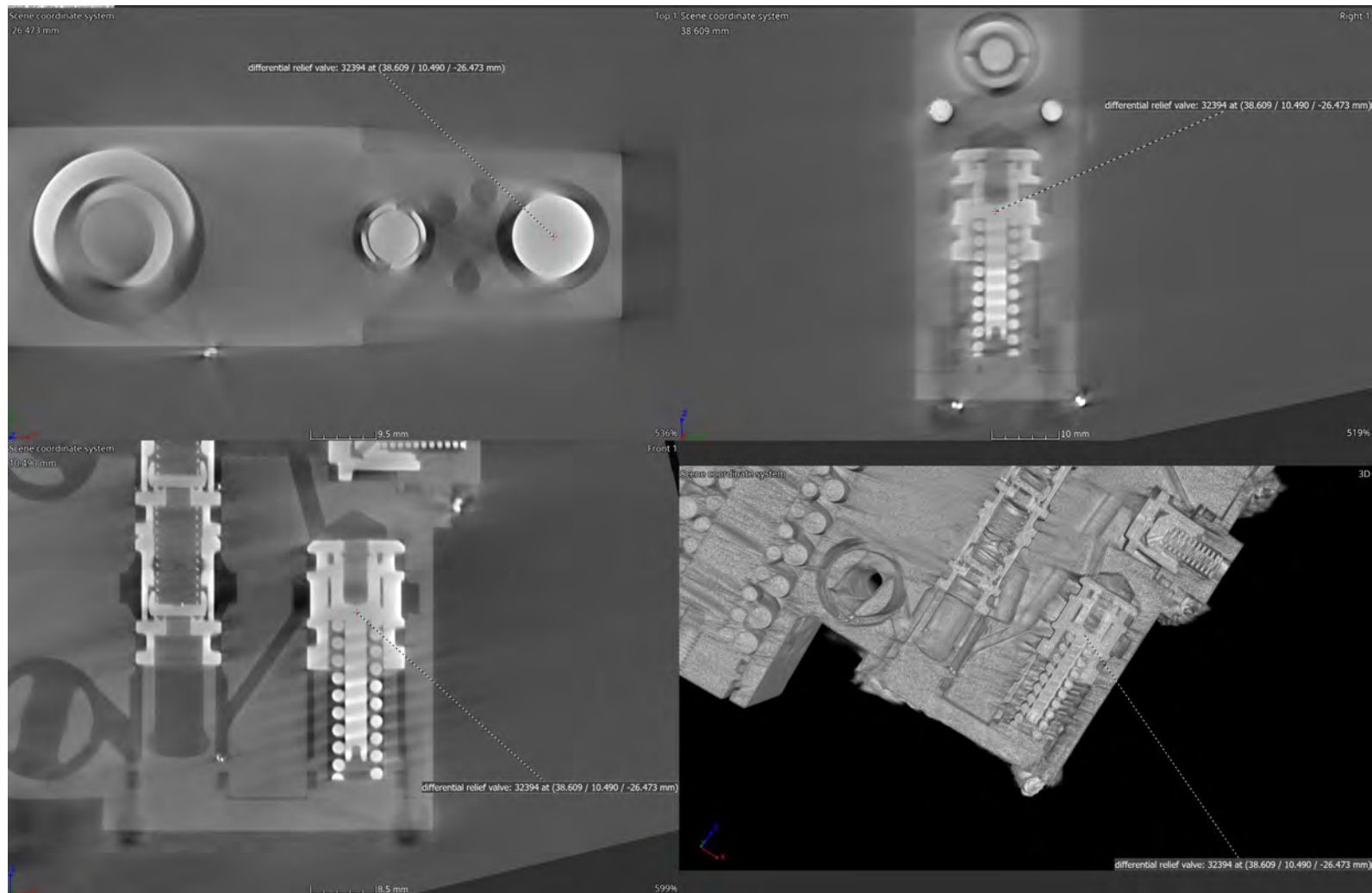


Figure 82
Irreversible valve assembly – differential relief valve

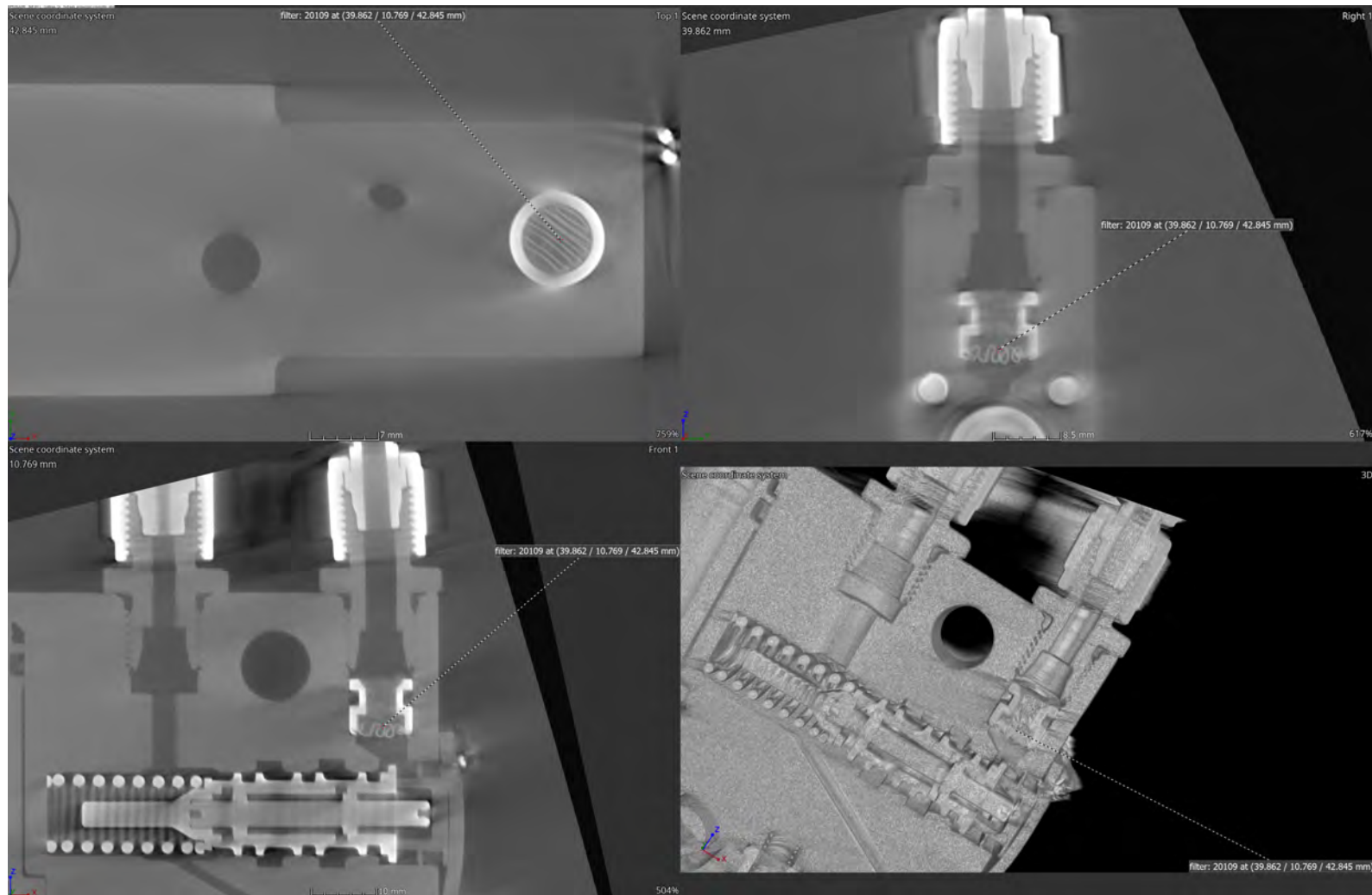


Figure 83
Irreversible valve assembly – filter

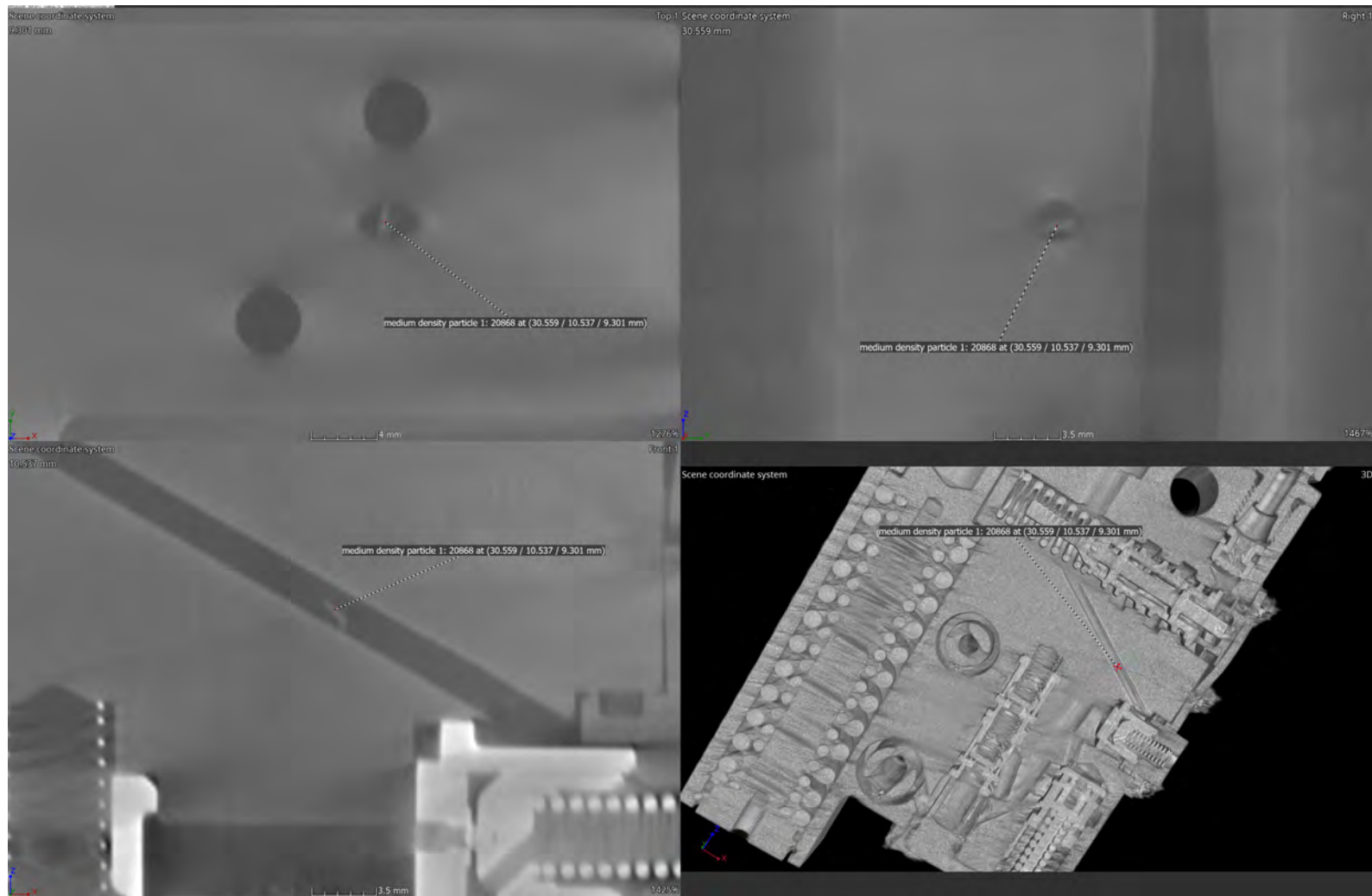


Figure 84
Irreversible valve assembly – medium density particle 1

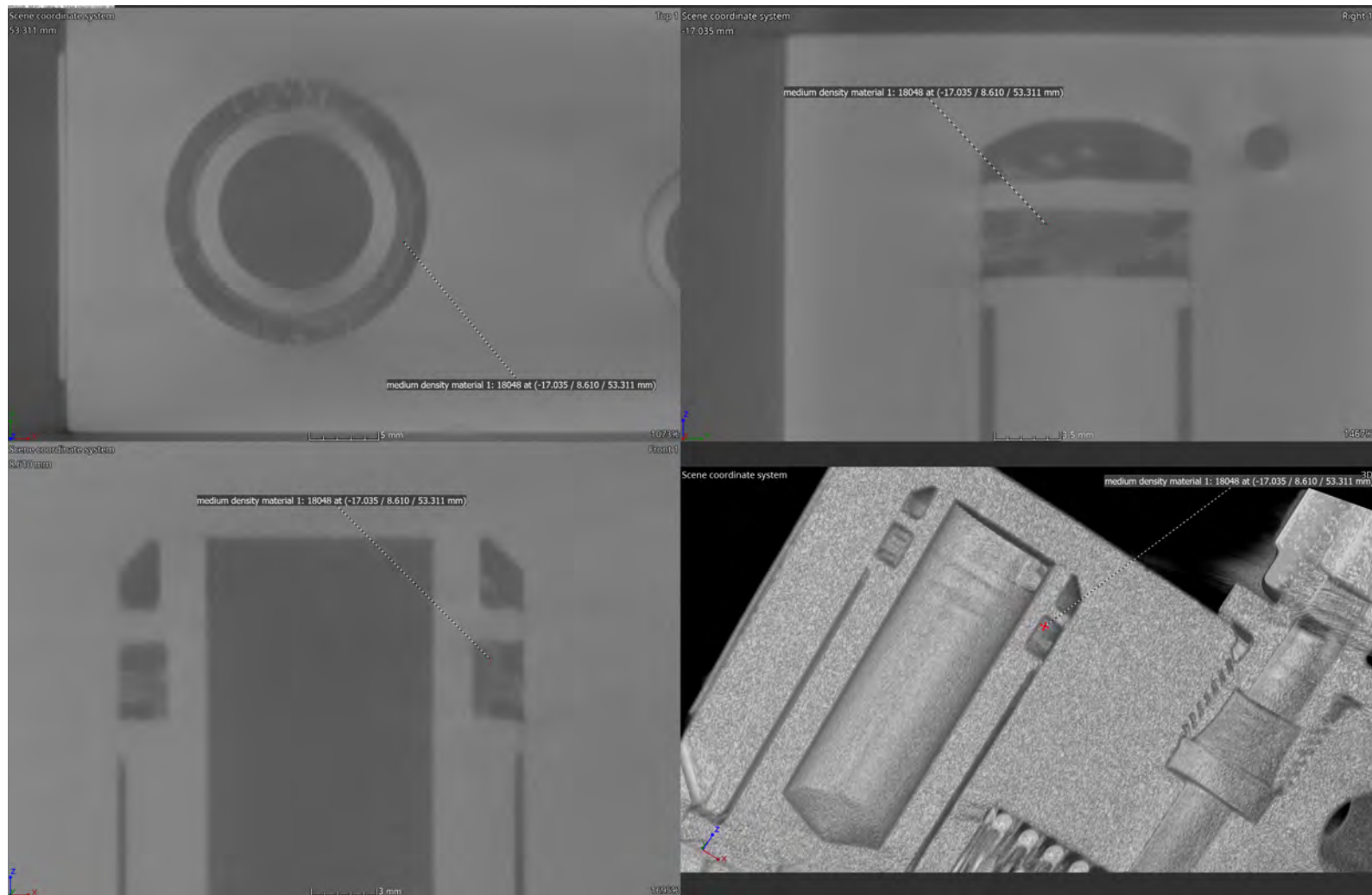


Figure 85
Irreversible valve assembly – medium density material 1

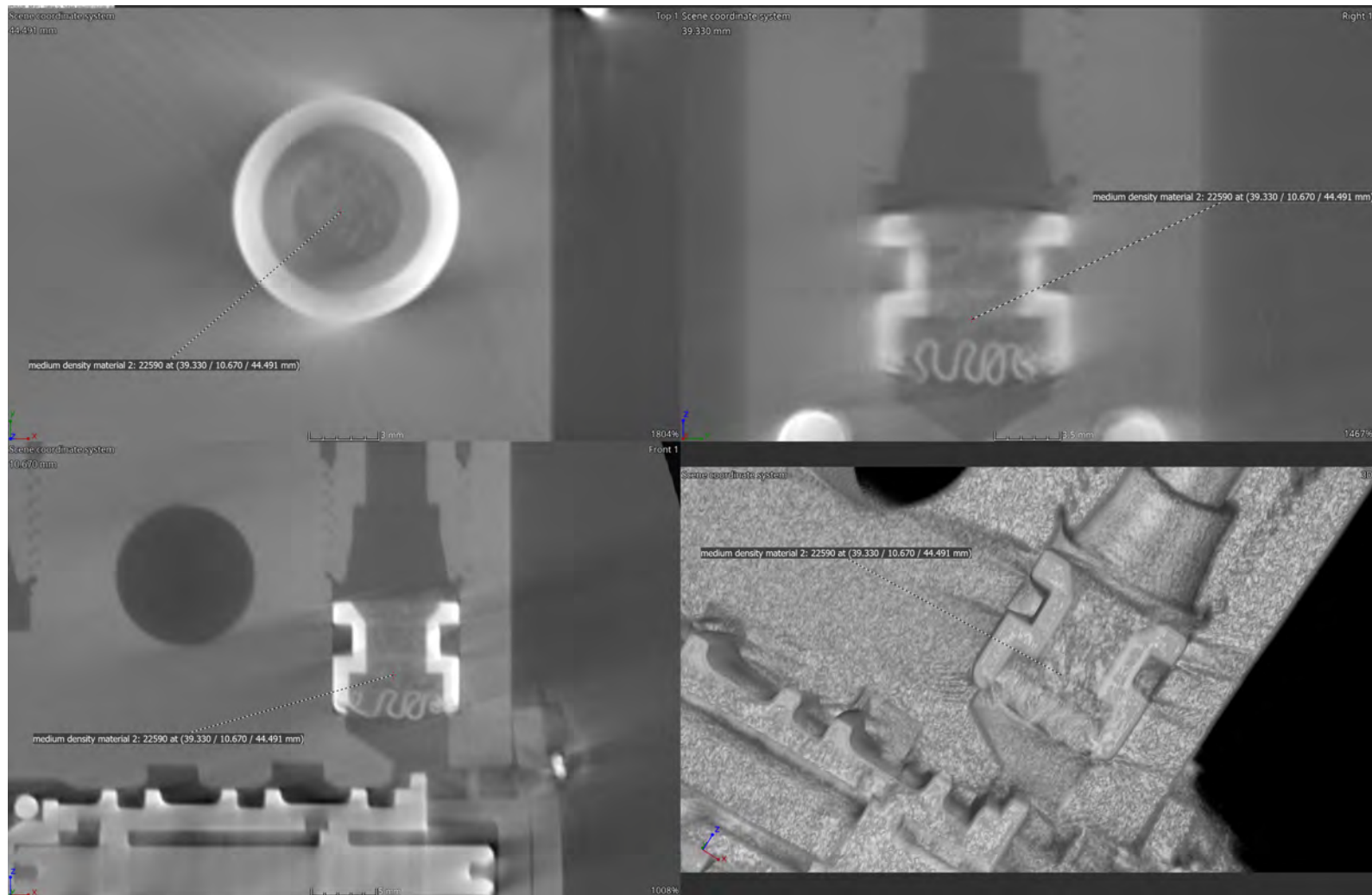


Figure 86
Irreversible valve assembly – medium density material 2

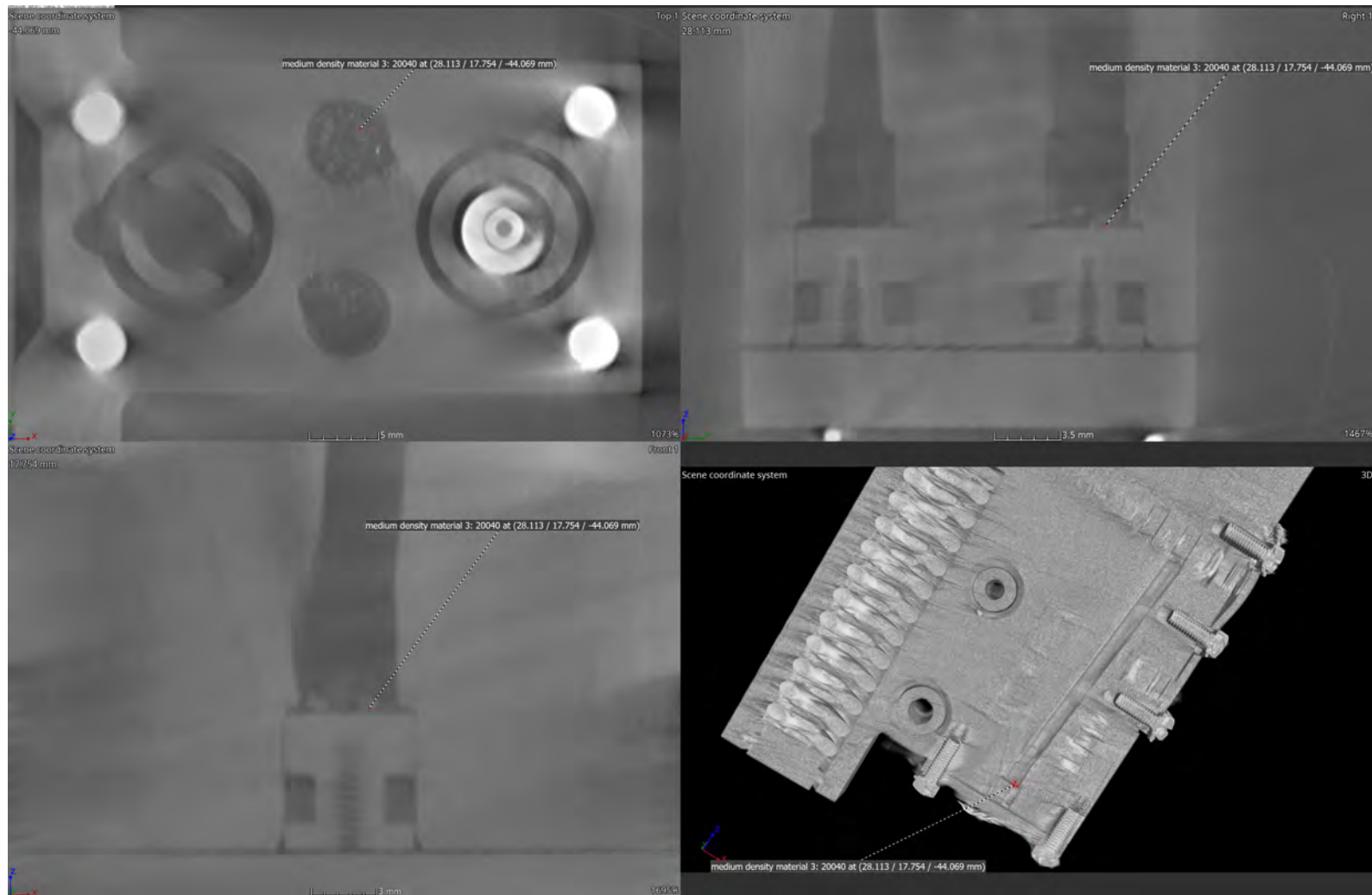


Figure 87
Irreversible valve assembly – medium density material 3

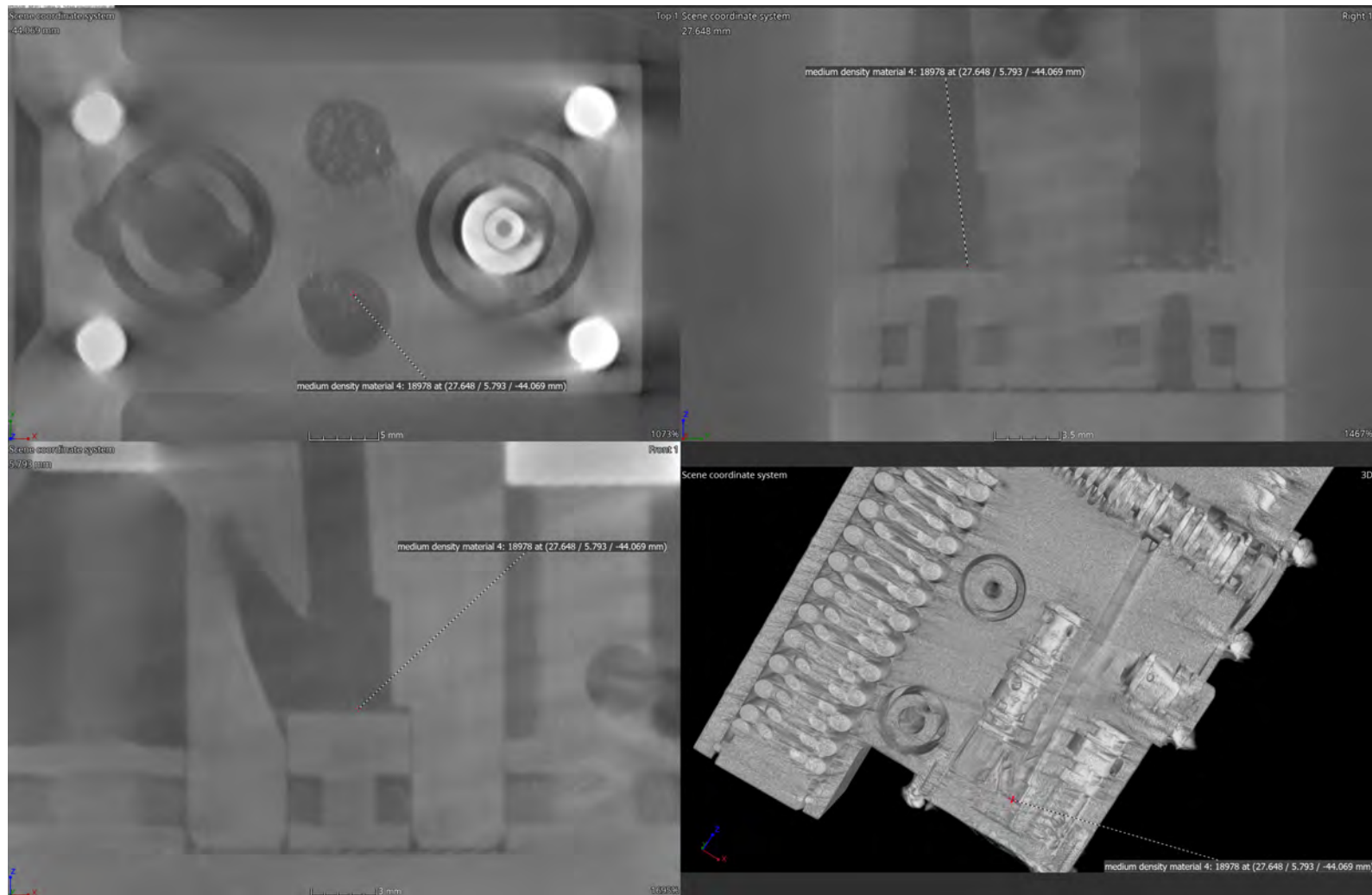


Figure 88
Irreversible valve assembly – medium density material 4

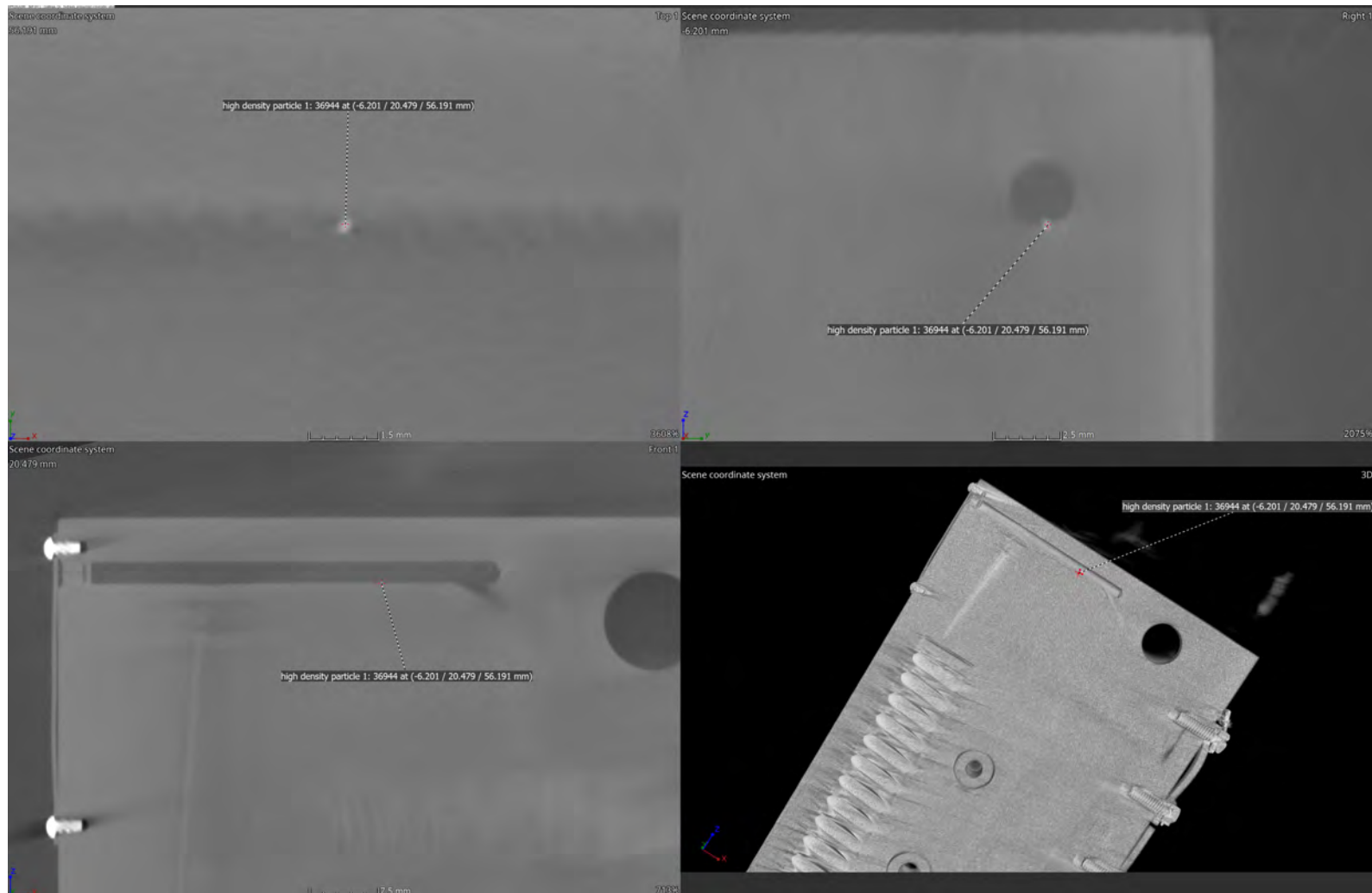


Figure 89
Irreversible valve assembly – high density particle 1

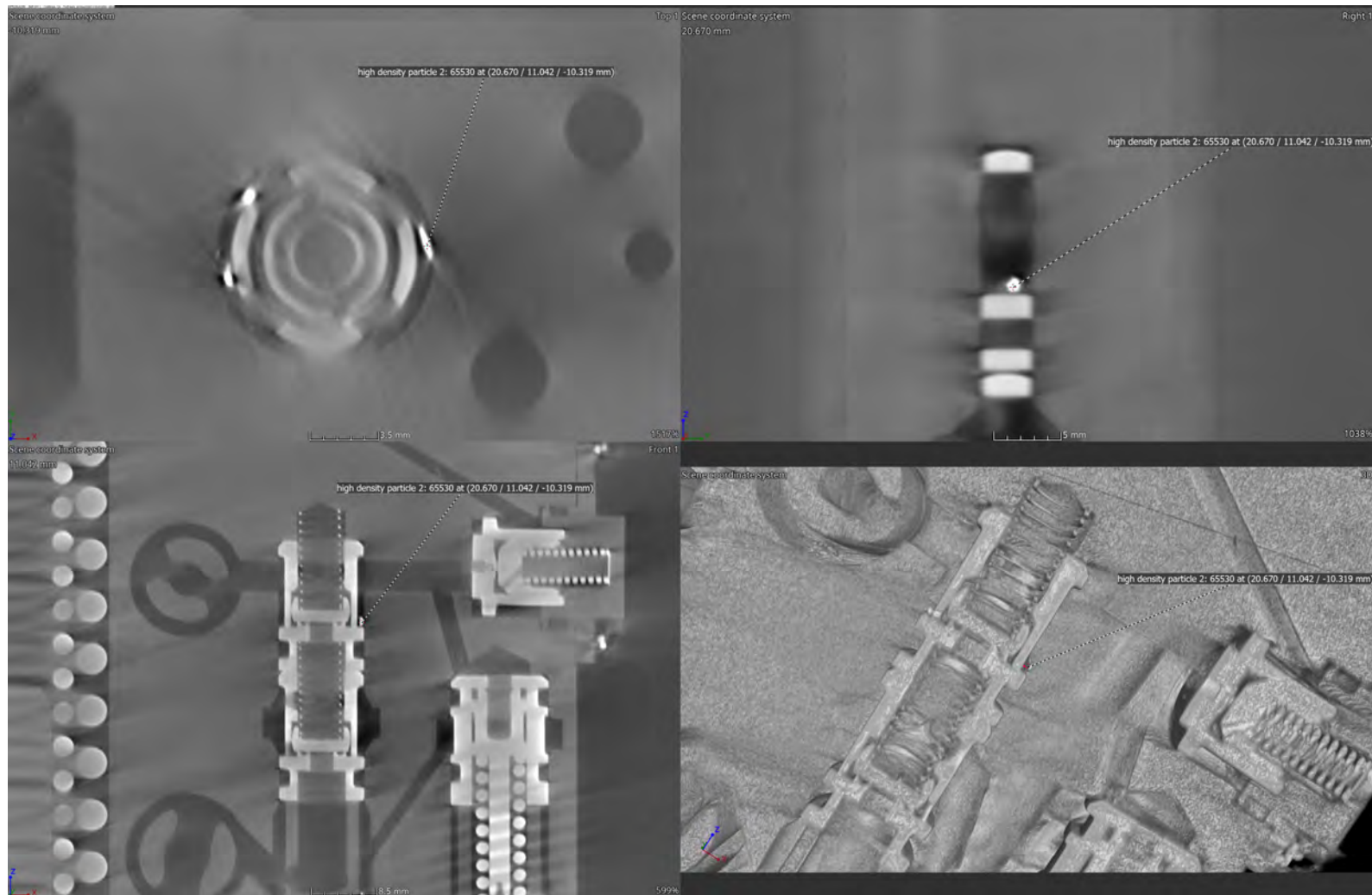


Figure 90
Irreversible valve assembly – high density particle 2

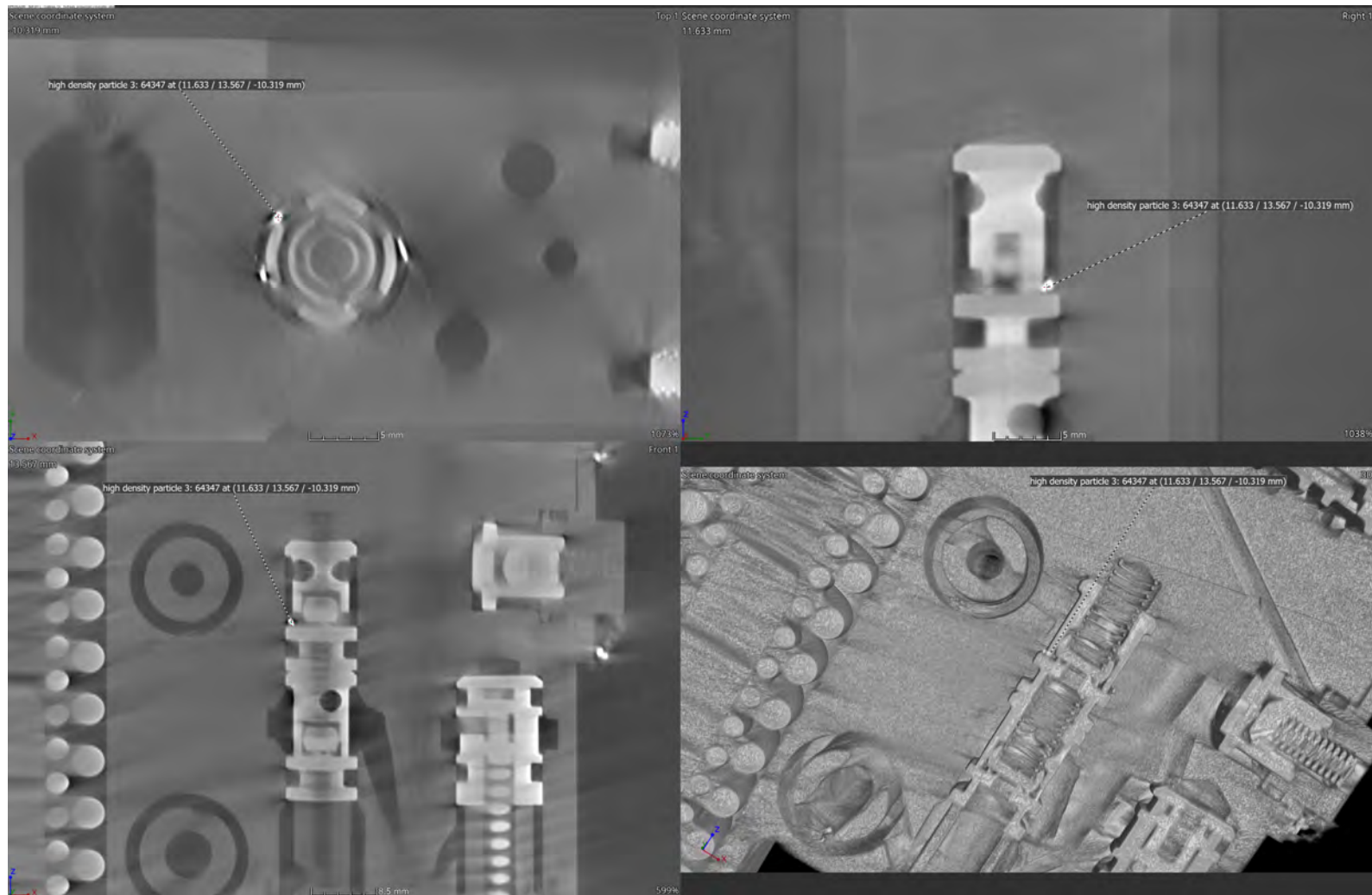


Figure 91
Irreversible valve assembly – high density particle 3

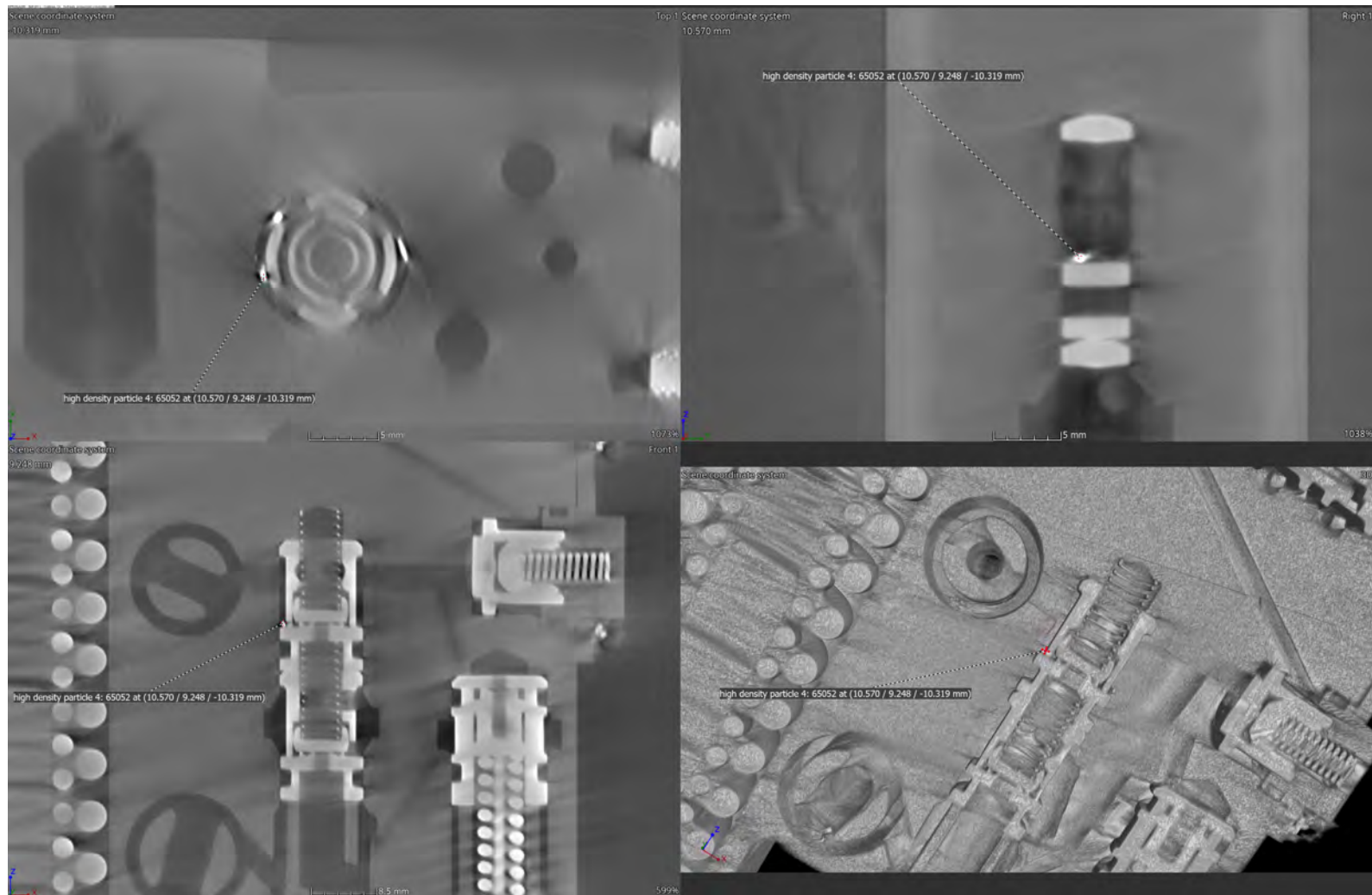


Figure 92
Irreversible valve assembly – high density particle 4

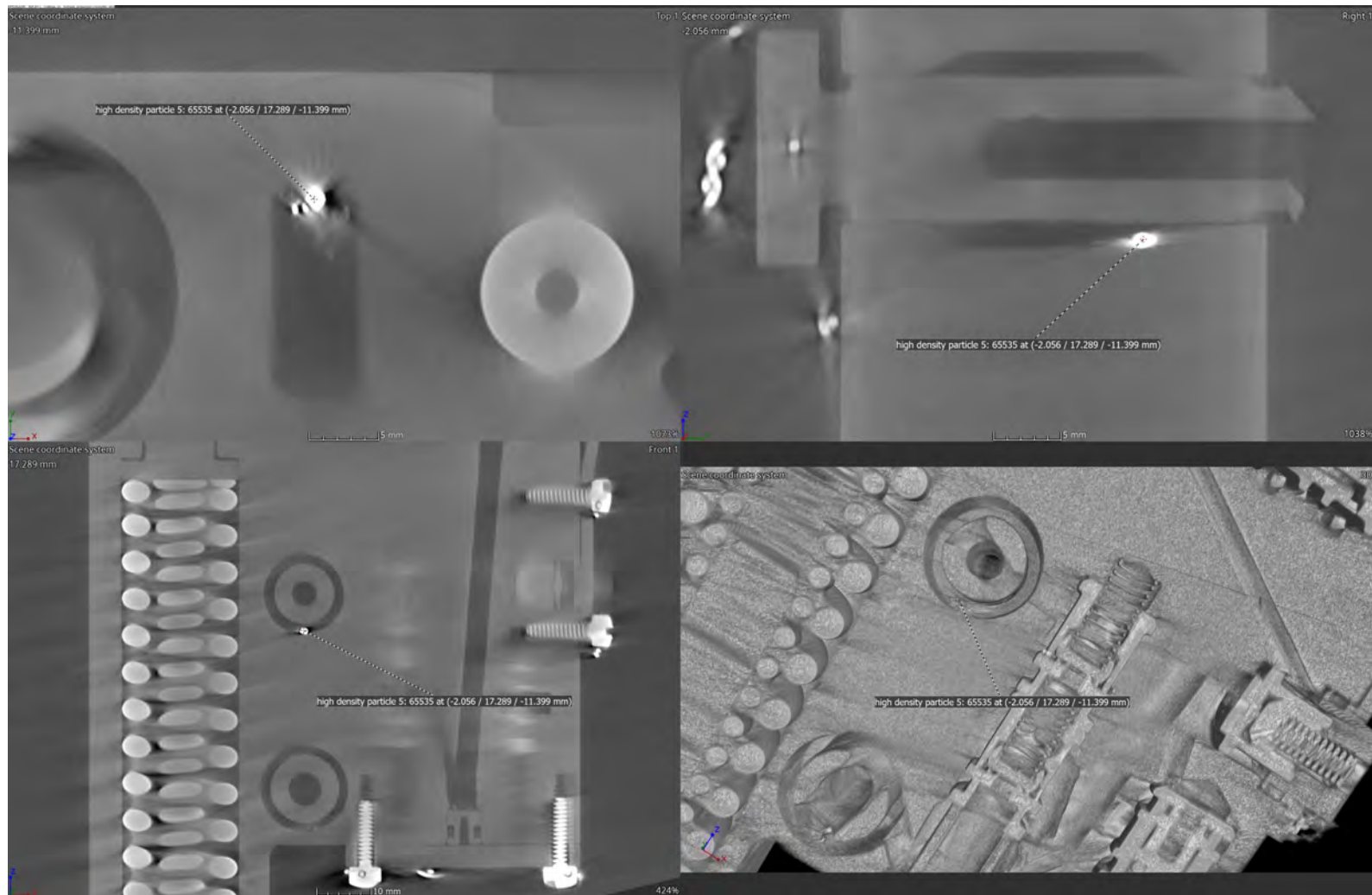


Figure 93
Irreversible valve assembly – high density particle 5

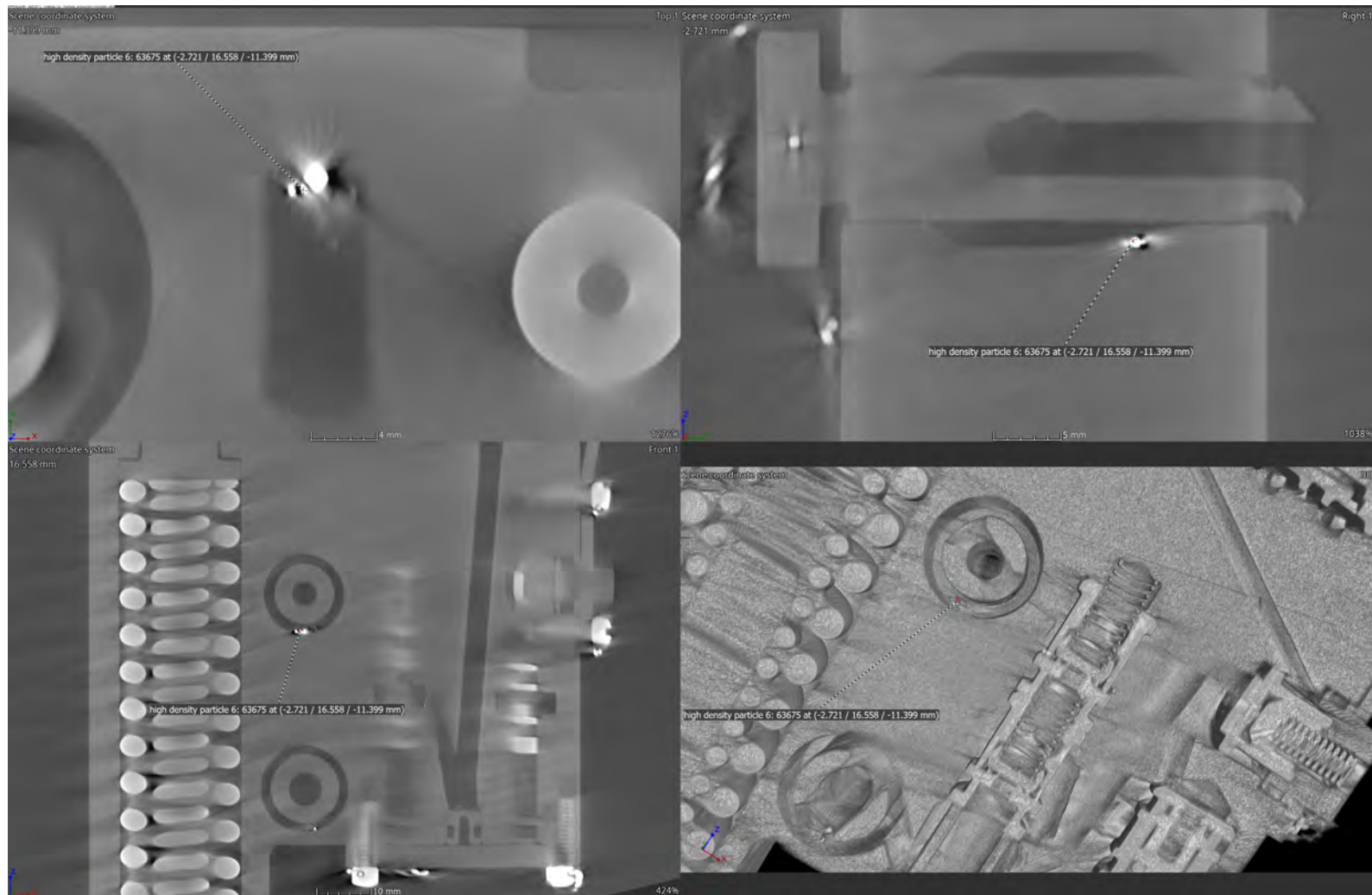


Figure 94
Irreversible valve assembly – high density particle 6

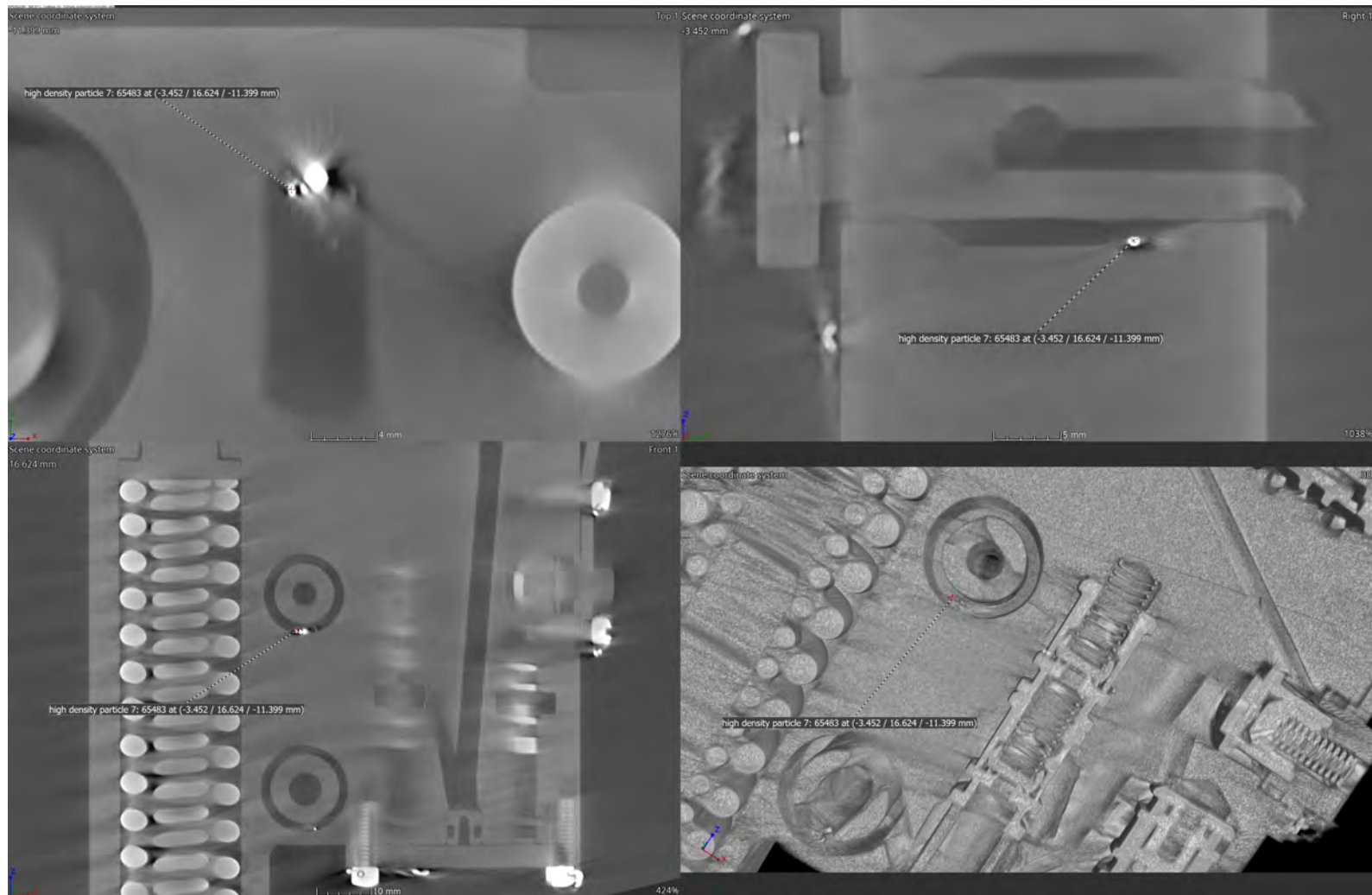


Figure 95
Irreversible valve assembly – high density particle 7

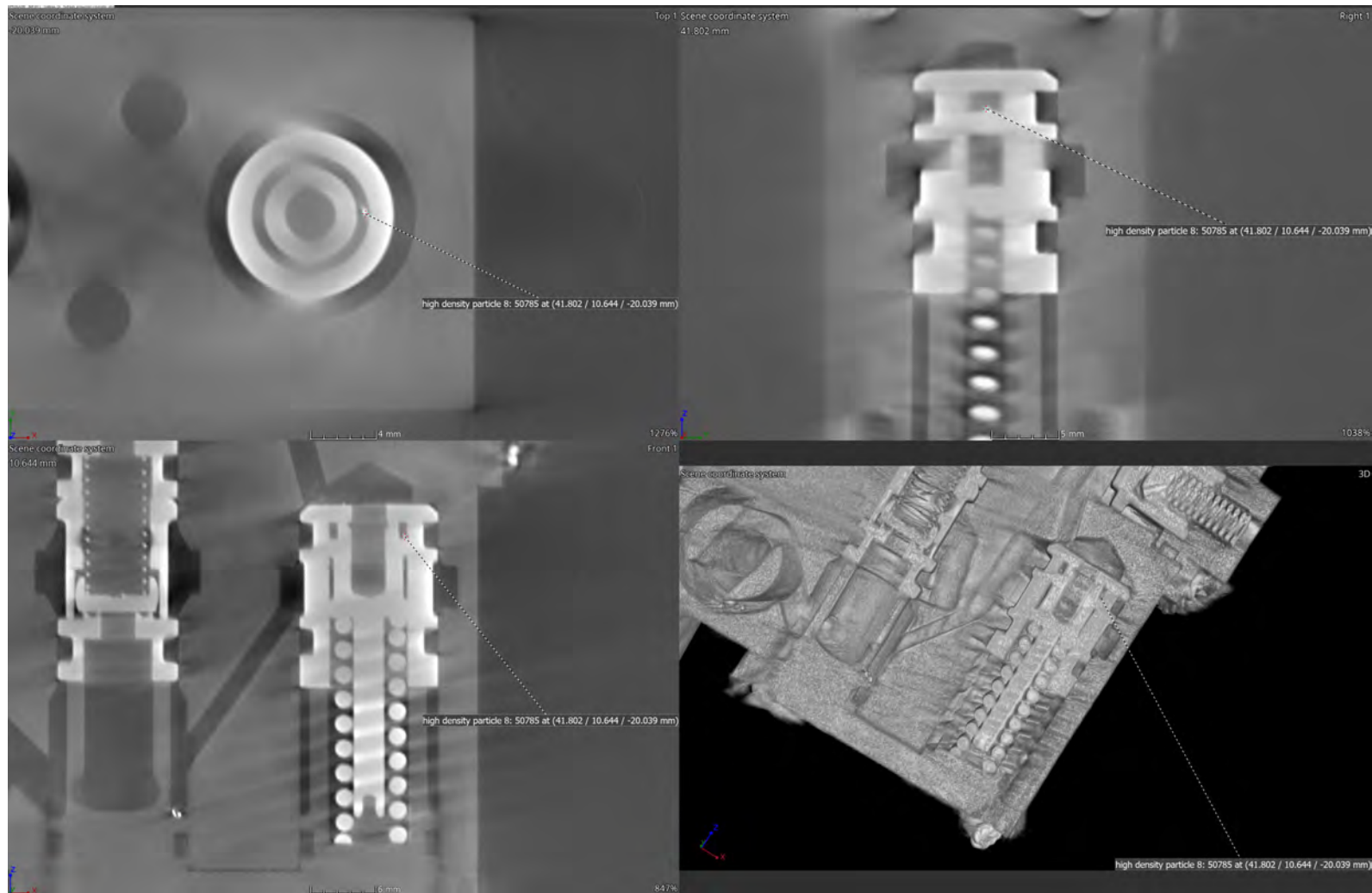


Figure 96
Irreversible valve assembly – high density particle 8

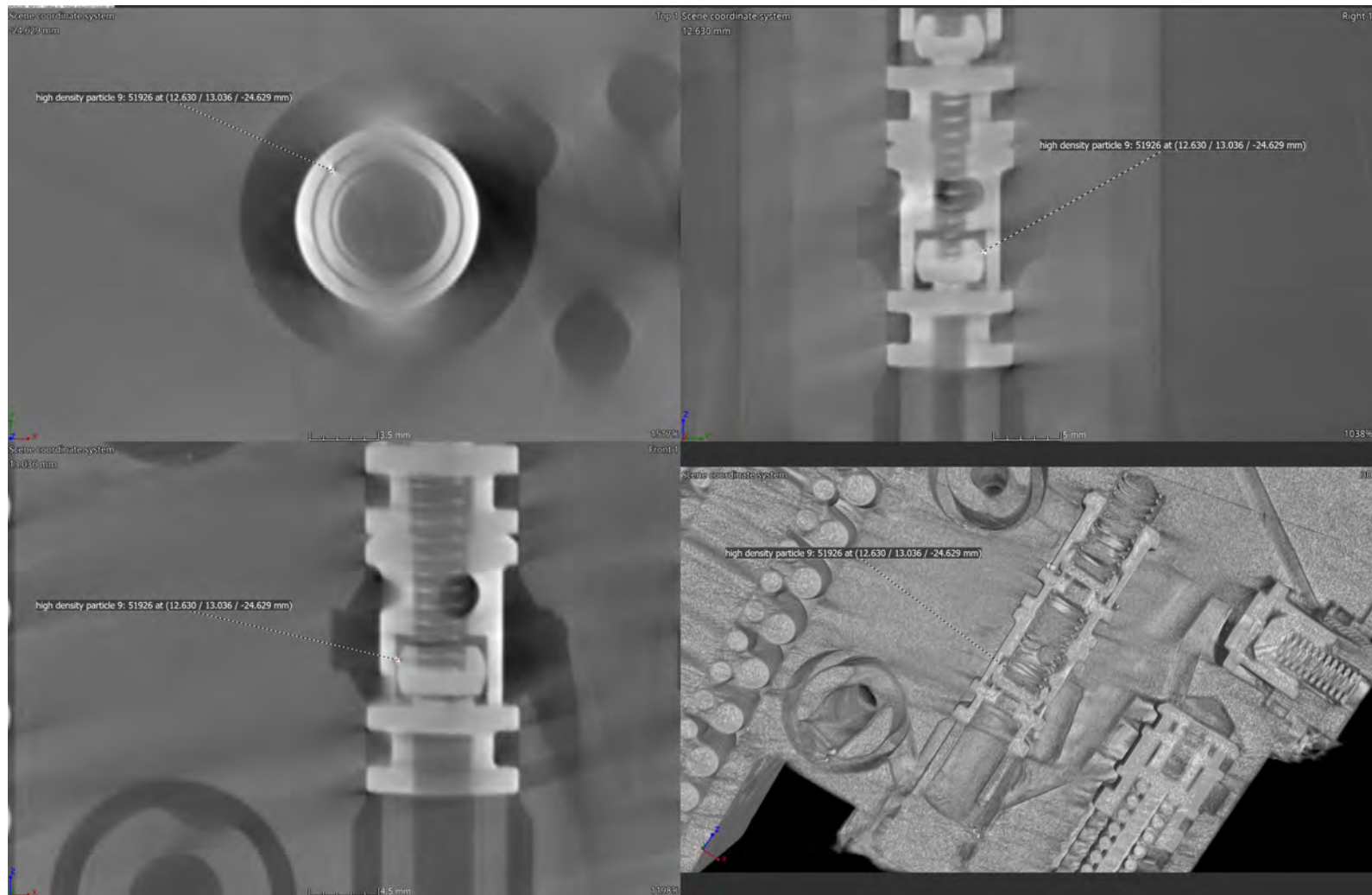


Figure 97
Irreversible valve assembly – high density particle 9

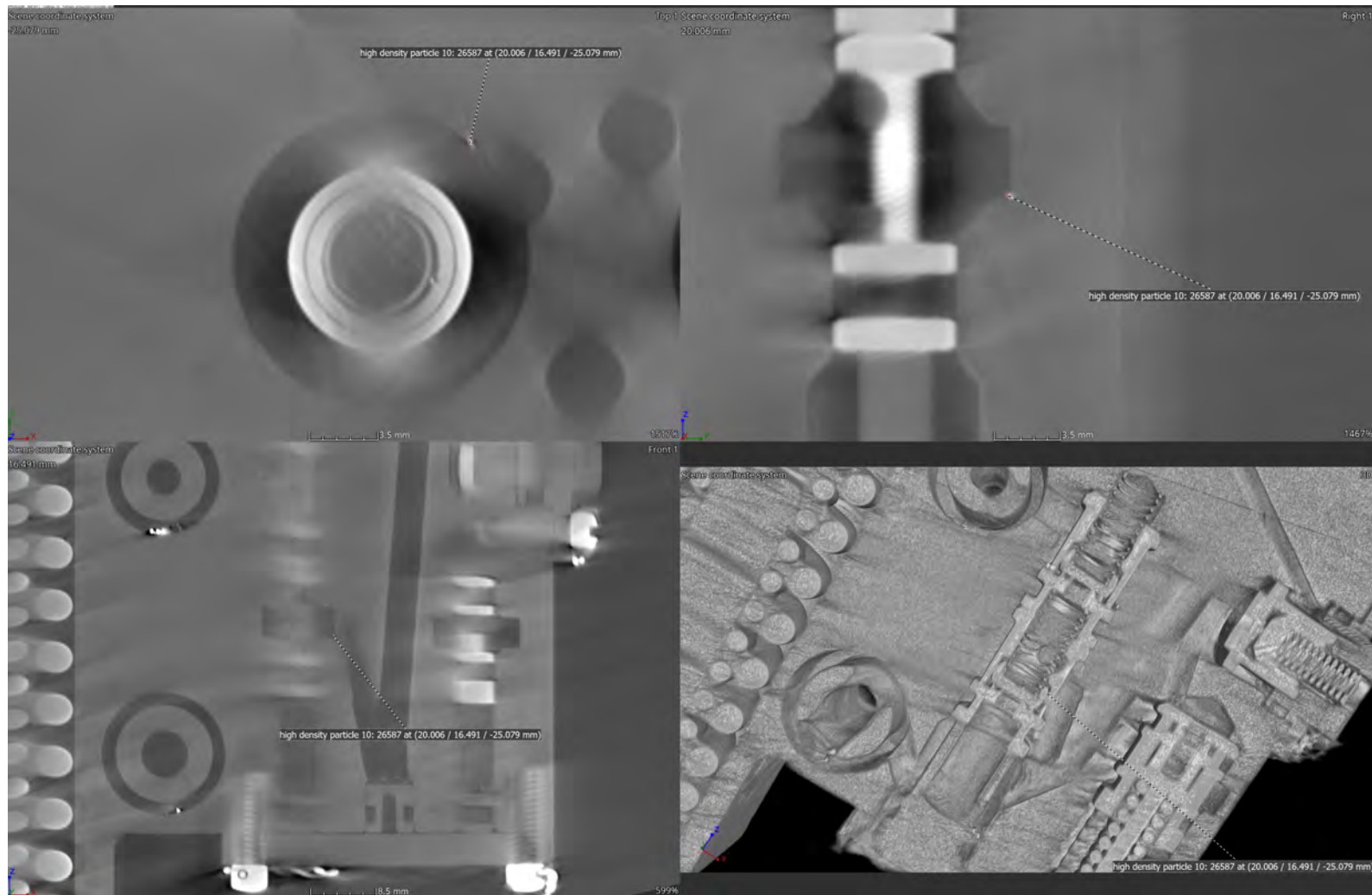


Figure 98
Irreversible valve assembly – high density particle 10

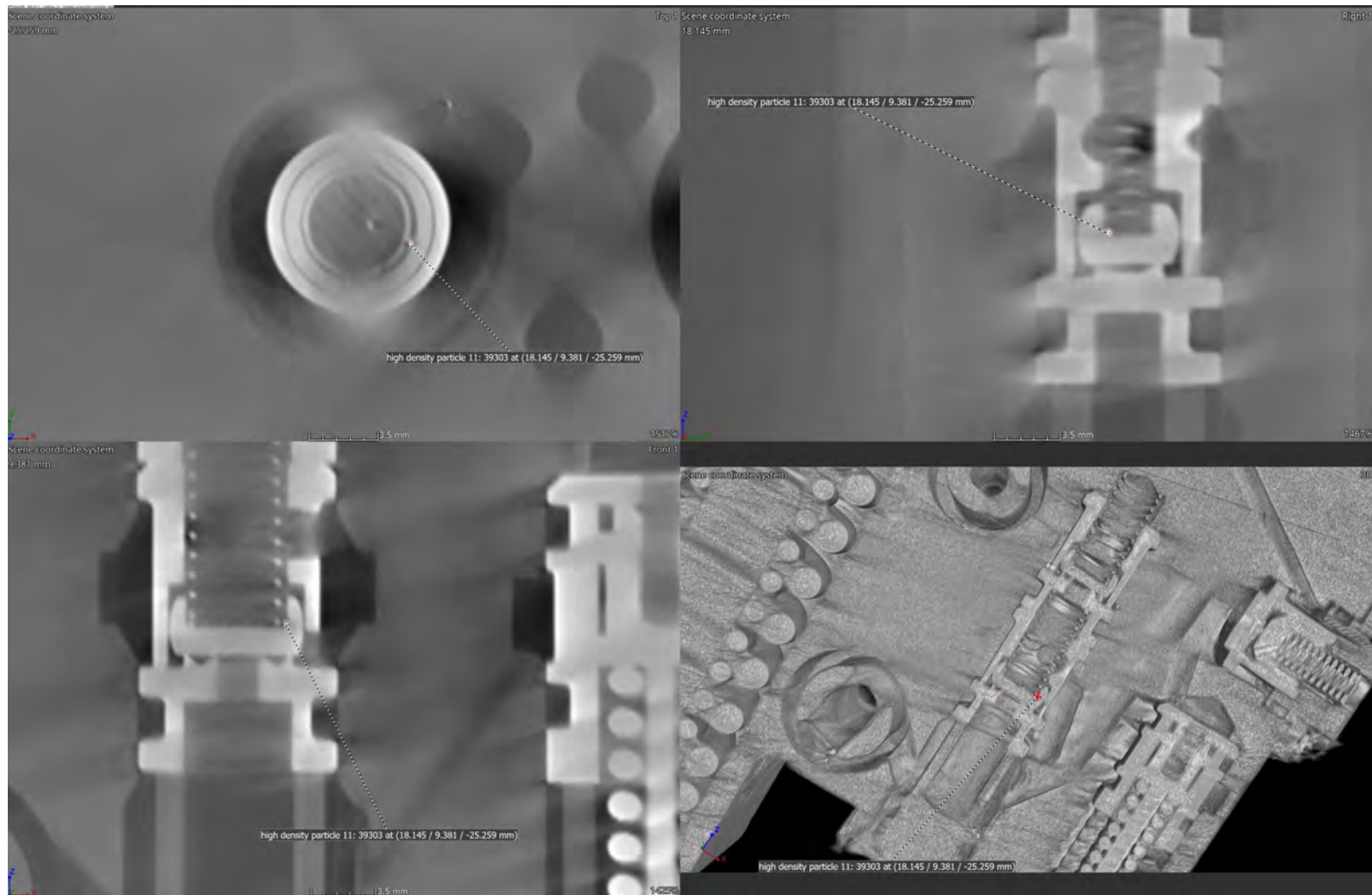


Figure 99
Irreversible valve assembly – high density particle 11

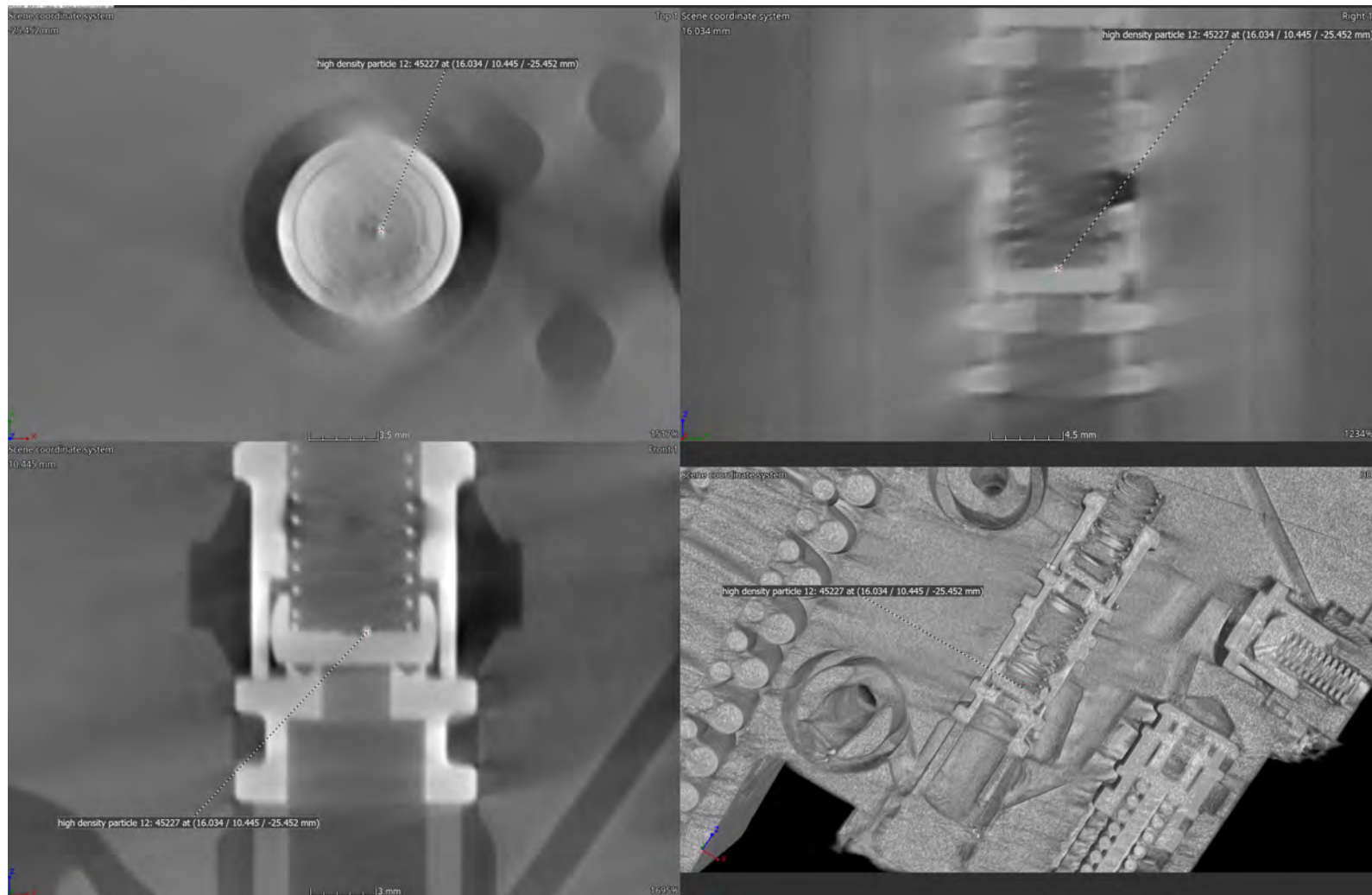


Figure 100
Irreversible valve assembly – high density particle 12

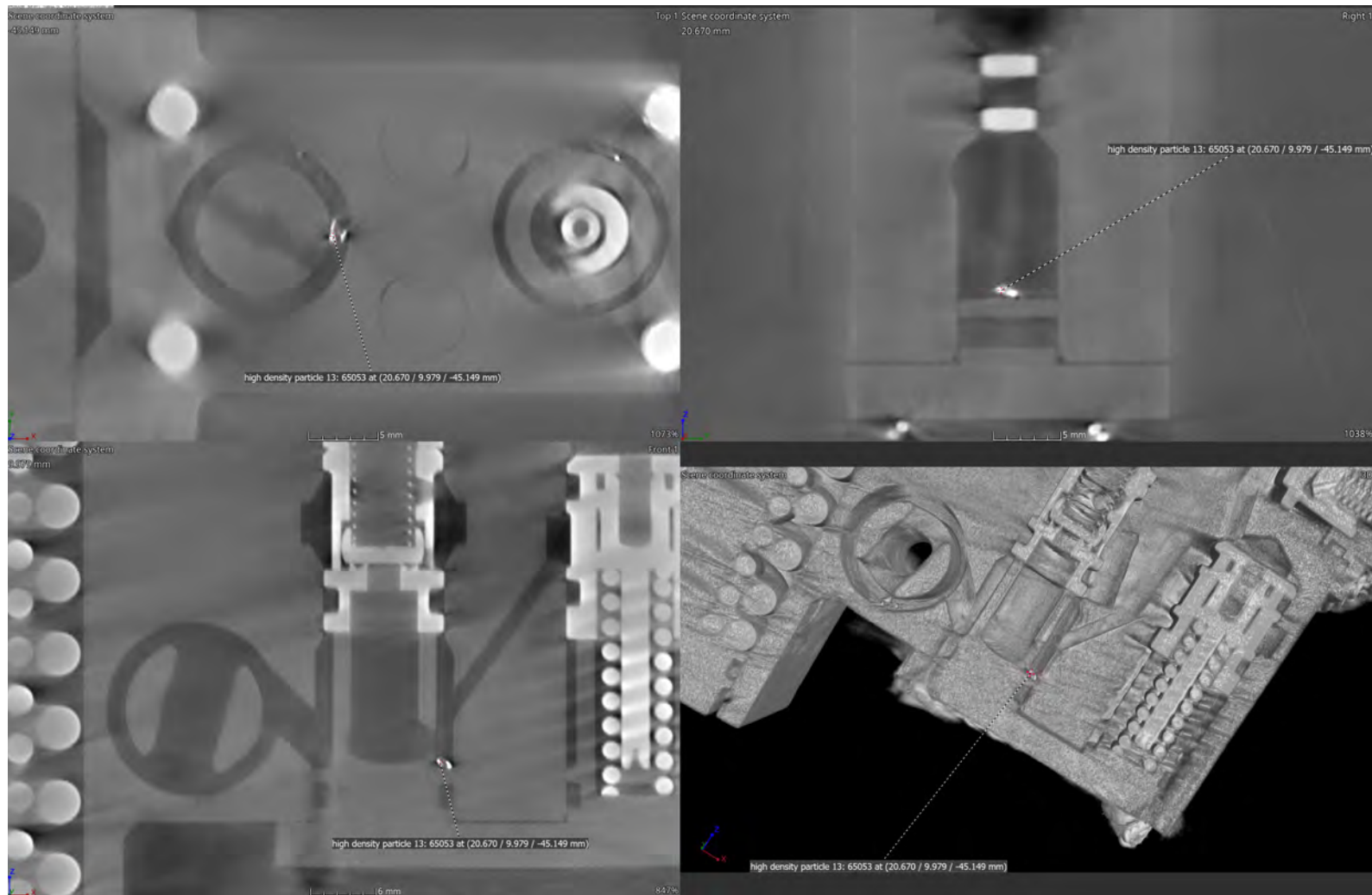


Figure 101
Irreversible valve assembly – high density particle 13

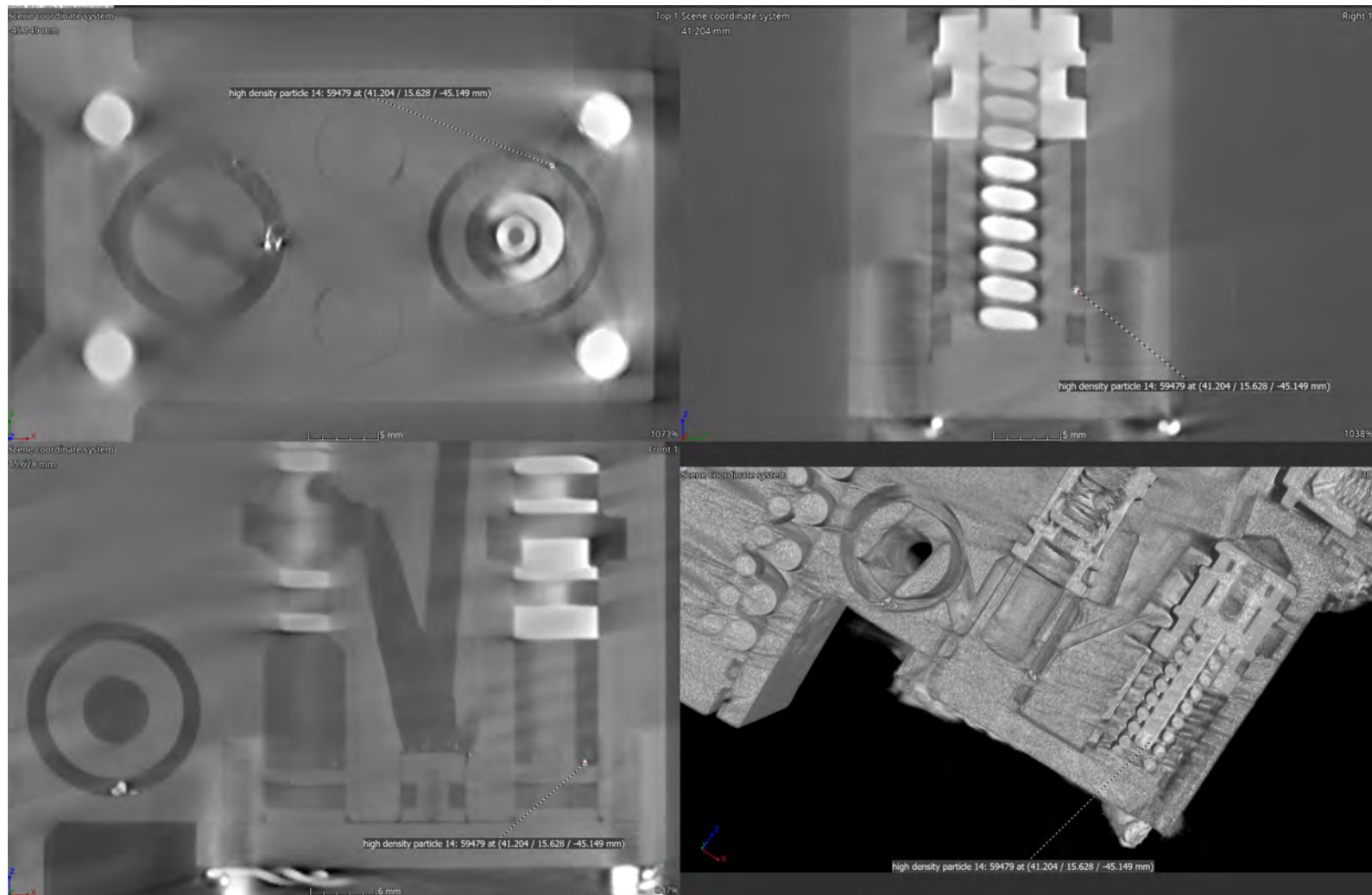


Figure 102
Irreversible valve assembly – high density particle 14

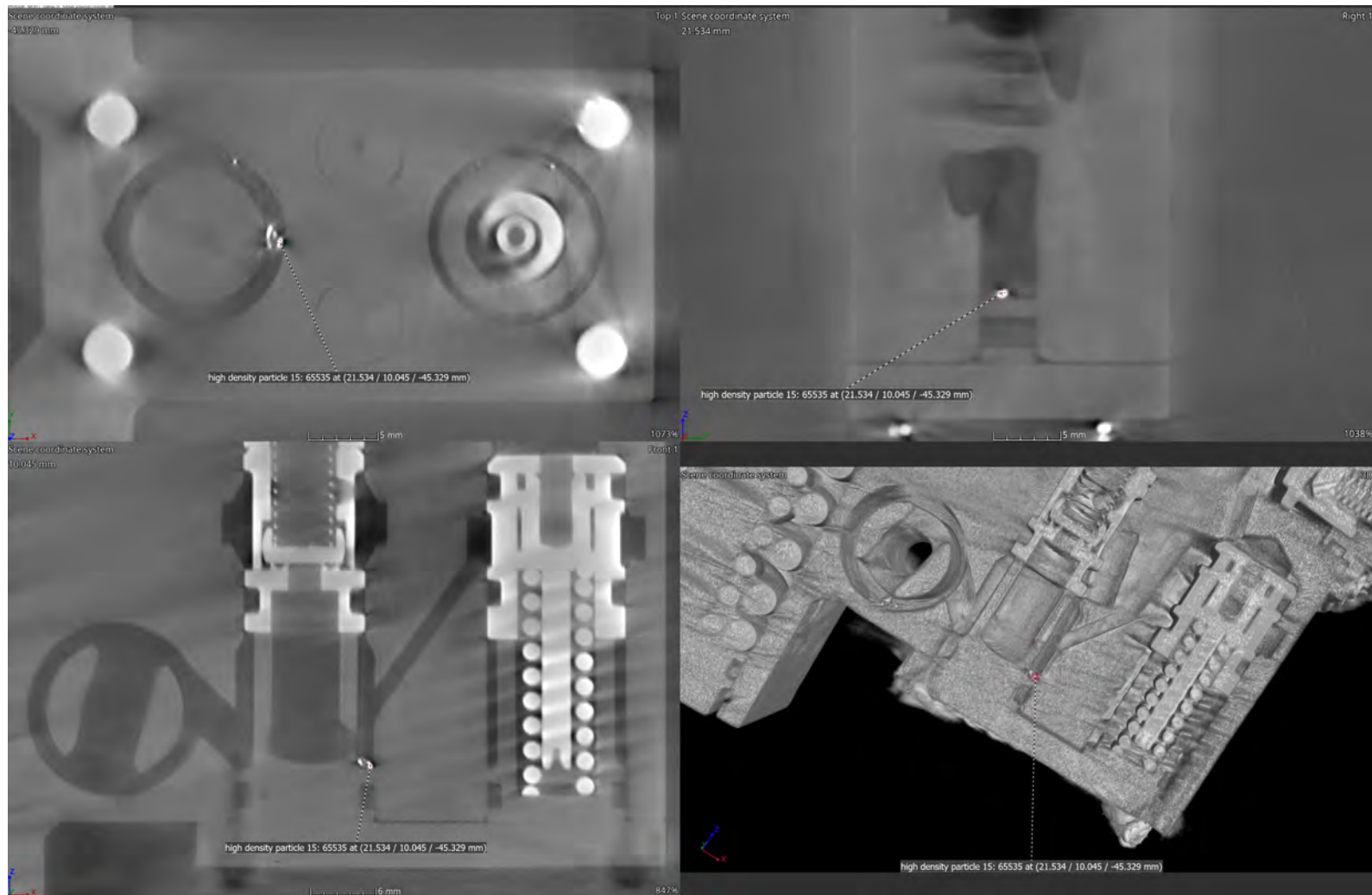


Figure 103
Irreversible valve assembly – high density particle 15

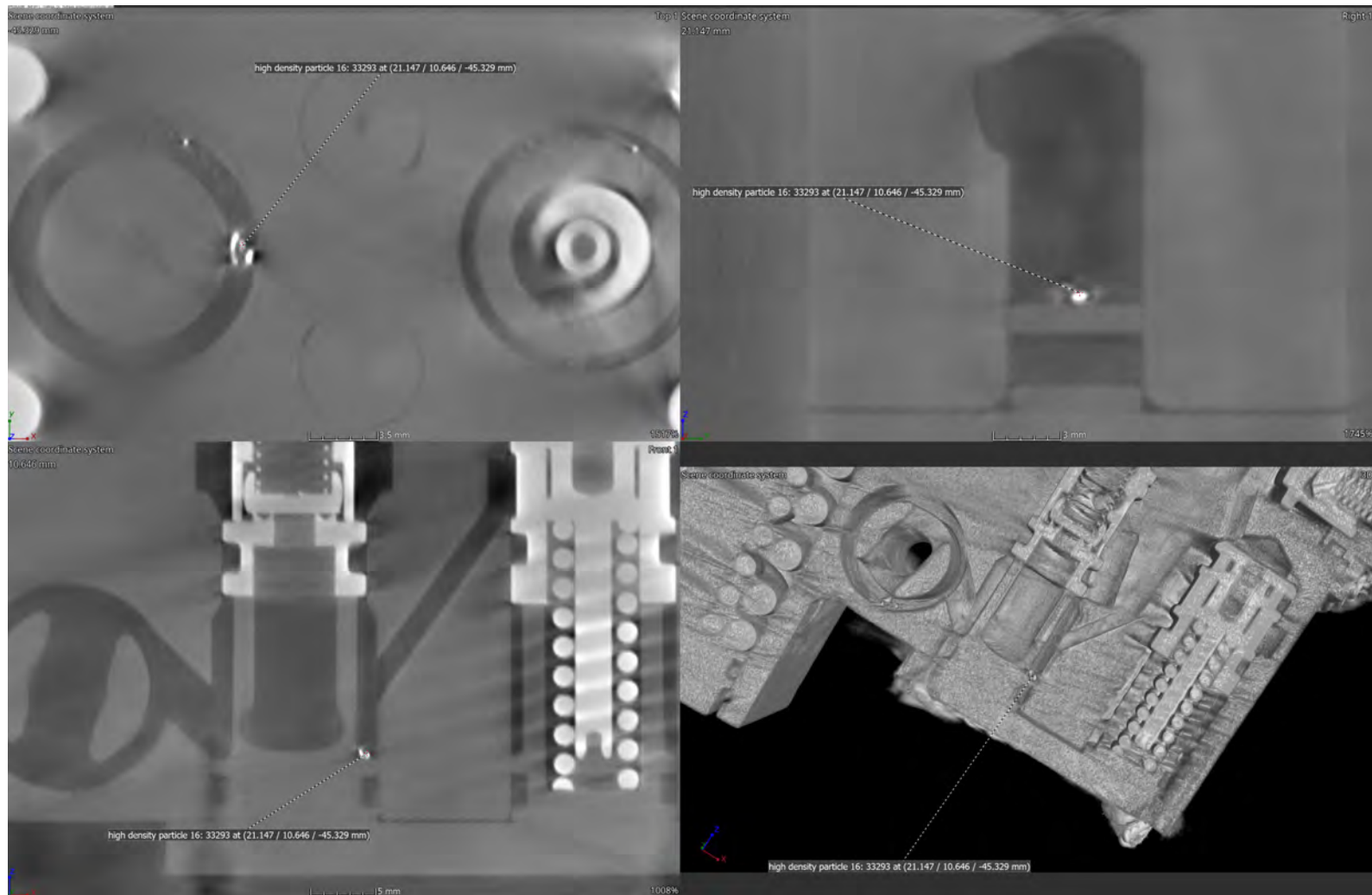


Figure 104
Irreversible valve assembly – high density particle 16



Figure 105
Irreversible valve assembly – high density particle 17

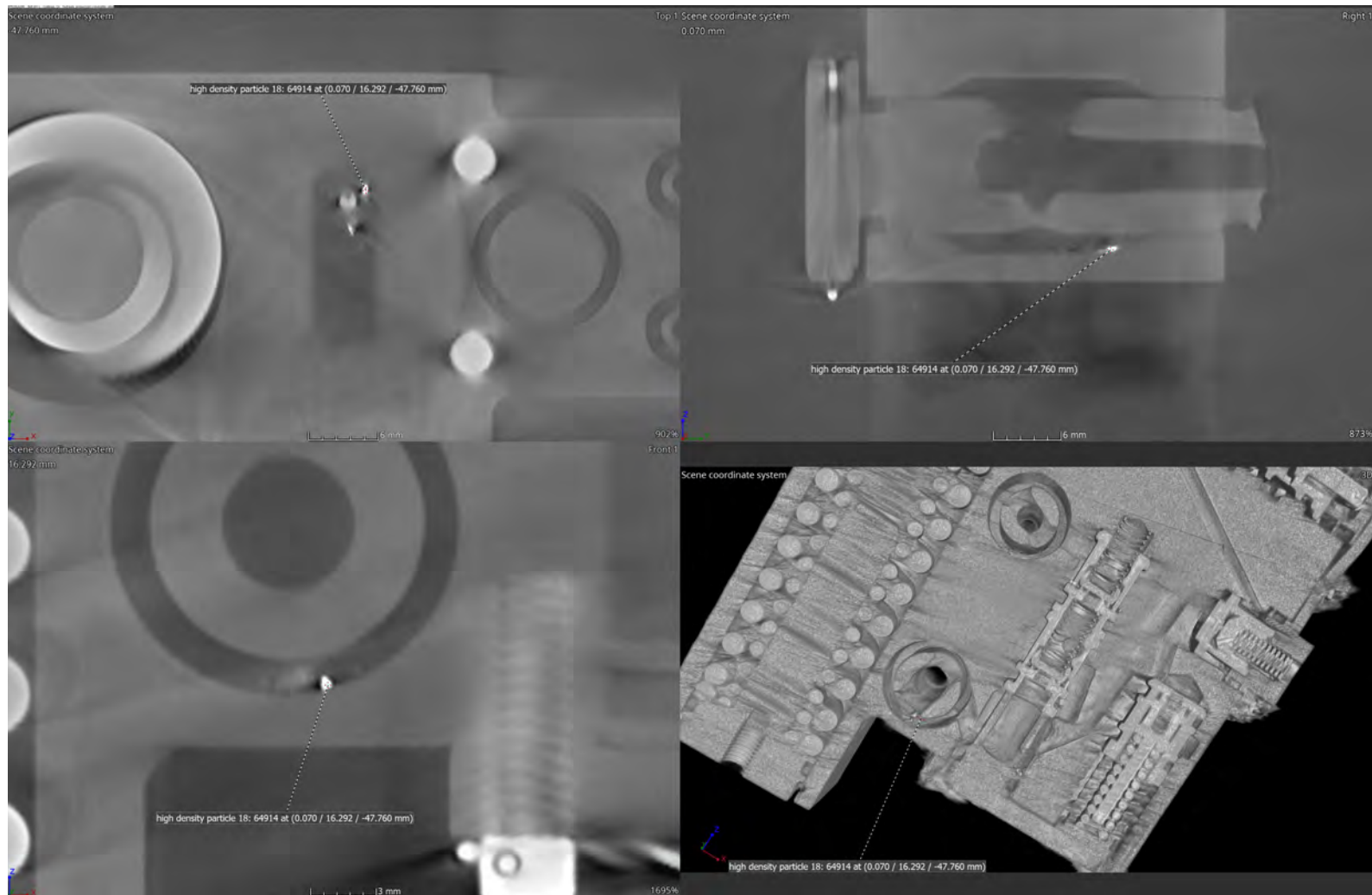


Figure 106
Irreversible valve assembly – high density particle 18

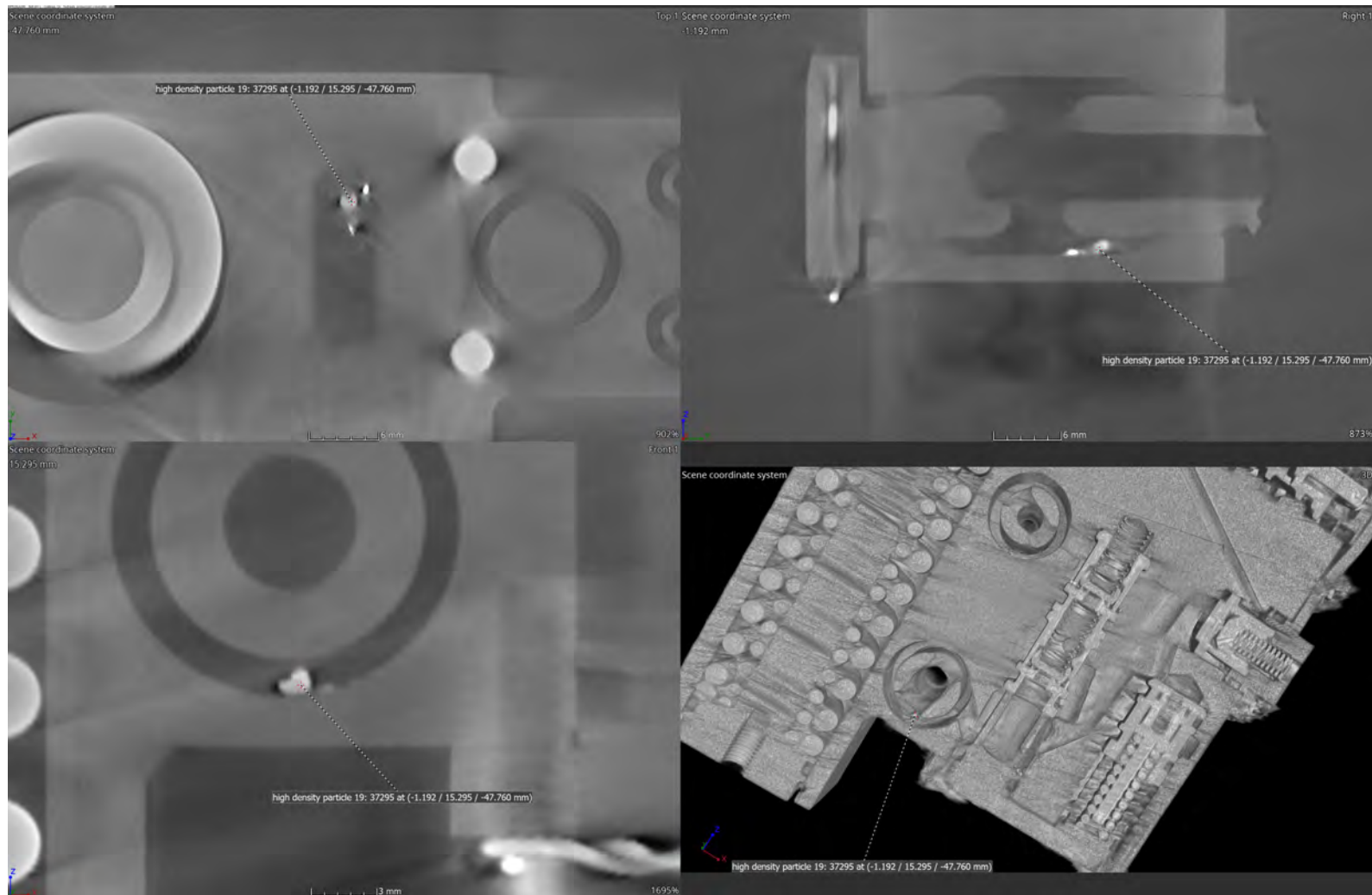


Figure 107
Irreversible valve assembly – high density particle 19

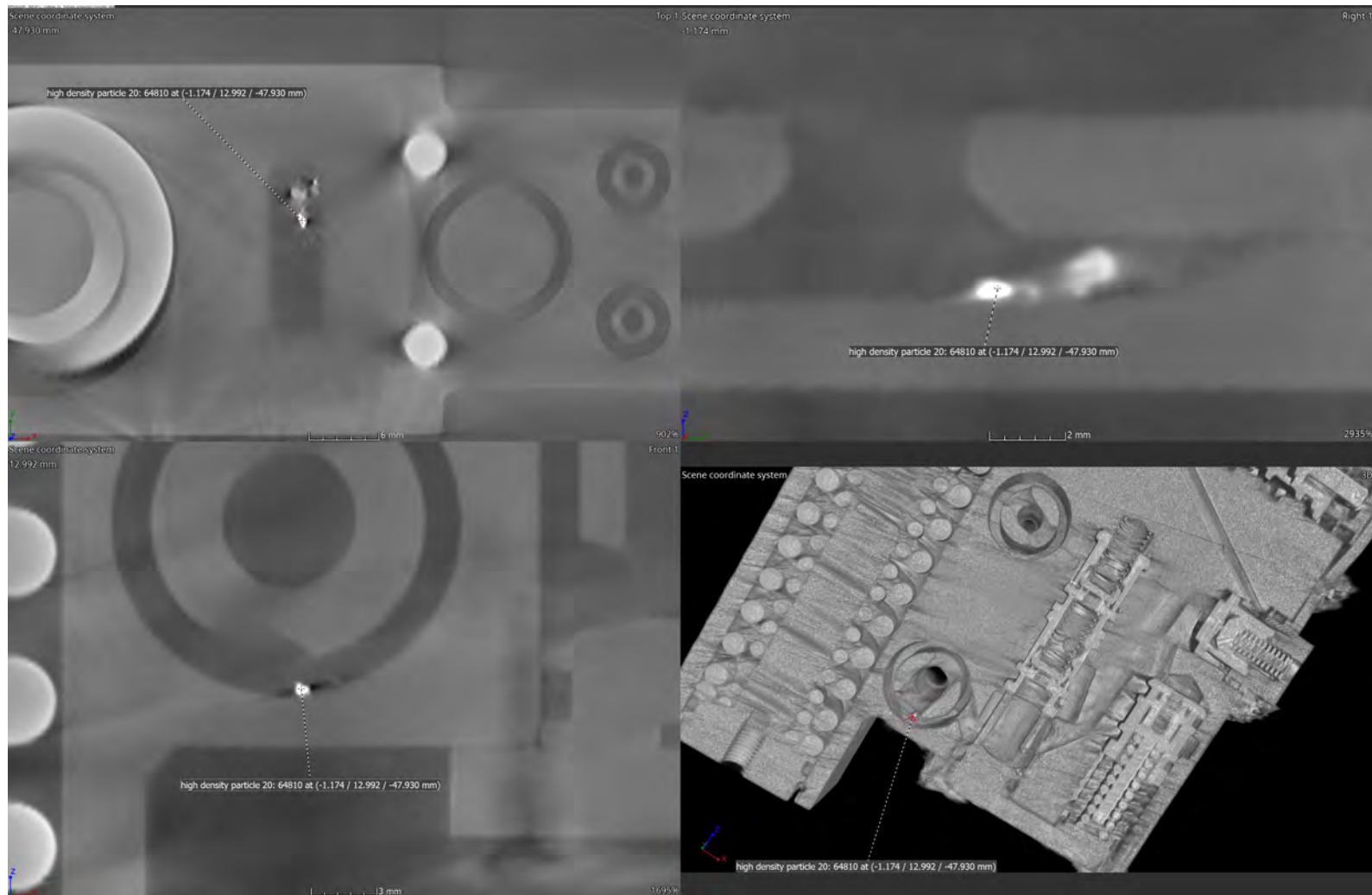


Figure 108
Irreversible valve assembly – high density particle 20

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