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

April 29, 2020

Computed Tomography Specialist's Factual Report

CEN19FA036

A. ACCIDENT

Location:	Memphis, Indiana
Date:	November 30, 2018
Time:	1028 eastern standard time
Airplane:	Cessna 525A (Citation) airplane, N525EG

B. GROUP

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

C. SUMMARY

On November 30, 2018, about 1028 eastern standard time, a Cessna 525A (Citation) airplane, N525EG, collided with trees and terrain near Memphis, Indiana. The airline transport certificated pilot and 2 passengers were fatally injured, and the airplane was destroyed. The airplane was owned and operated by EstoAir LLC under the provisions of 14 *Code of Federal Regulations* Part 91 as a business flight. Visual meteorological conditions prevailed for the flight which operated on an instrument flight rules flight plan. The cross-country flight departed Clark Regional Airport (JVY), Jeffersonville, Indiana, about 1025, with Chicago Mid-way Airport (MDW), Chicago, Illinois, as the intended destination.

The internal configuration of the left and right Tamarack Active Camber Surface (TACS) Control Units (TCU) for the Tamarack Aerospace Group[1] Active Technology Load Alleviation System (ATLAS) were documented using radiographic images that were collected from October 4-10, 2019 in Chicago, Illinois. A total of 12,278 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:

Left TACS Control Unit

1. The ballscrew extension distance was approximately 44.7 mm, and the ballscrew appeared to be near the extension limit;
2. The ground screw within the unit that had been the subject of an earlier Service Bulletin appeared to be present and secure;
3. Two screws within the unit that attached the gear train and motor compartments appeared to be broken;
4. There were two pins (that appeared to be alignment pins) within the unit that appeared to be deformed;
5. There were five screws (that appeared to be designed to hold the LVDT and motor compartment cover to structure) that were missing their screw heads. There were also five separated screw heads noted within the unit;
6. The LVDTs were noted to be at a position that appeared to be close to the maximum extension limits;
7. There were three wiring anomalies noted within the LVDT wires;
8. There were no indications of potting material around the LVDT wires at their respective exit points from either LVDT;
9. There were six bent pins noted in the 40 pin connector. One of these bent pins appeared to contact an adjacent pin assembly.

Right TACS Control Unit

1. The ballscrew extension distance was approximately 26.7 mm;

[1] Tamarack Aerospace Group (TAG) will also be referred to in the report as Tamarack or TAG

2. The ground screw within the unit that had been the subject of an earlier Service Bulletin appeared to be present and secure;
3. Several portions of the unit's gear train were displaced from their normal positions;
4. There were two screws within the unit that attached the gear train and motor compartments appeared to be broken;
5. There were two pins (that appeared to be alignment pins) within the unit that appeared to be deformed;
6. The 40 pin connector appeared to be deformed and broken in some areas. The pins within that connector appeared to be bent and out of alignment;
7. There were no indications of potting material around the LVDT wires at their respective exit points from either LVDT;
8. There was a broken wire noted in the area adjacent to the ballscrew.

D. DETAILS OF THE INVESTIGATION

1.0 General

The internal configuration of the left and right TACS control units for the Tamarack Aerospace Group Active Technology Load Alleviation System (ATLAS) were subjected to x-ray radiograph and computed tomography (CT) scanning to document their internal conditions.

The scanning was conducted from October 4-10, 2019 by Varex, Inc under the direction of the NTSB using the Actis 500/225 micro focus system.

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.

For selected areas within the components (such as the linear variable differential transformer (LVDT) and the 40 pin connector), target CT techniques were used. The target CT techniques use geometric magnification[2] to provide for enhanced resolution within a component. The field of view during these scans is reduced, but the resolution within that field of view is much better than in the overall component scans.

The components were scanned using a total of 12,278 slices, and the total size of the combined data sets was approximately 69.2 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.

[2] Geometric magnification is a scanning technique where the component is moved closer to the x-ray source. The x-ray beam passes through a smaller region within the component, and that smaller region's image information is spread across the x-ray detector. The resulting image is created at a higher resolution.

Table 1
Scan Protocols

Component	Left TACS control unit – overall scan	Right TACS control unit – overall scan	Left TACS control unit – LVDT – target CT	Right TACS control unit – LVDT – target CT	Left TACS control unit – 40 pin connector – target CT
Number of slices	1987	1701	3516	4173	901
Voxel[3] Size - X Direction (mm)	0.148	0.148	0.059	0.059	0.059
Voxel Size - Y Direction (mm)	0.148	0.148	0.059	0.059	0.059
Voxel Size - Z Direction (mm)	0.14	0.14	0.030	0.030	0.030
Image Projections per Revolution	1800	1800	2160	2160	2160
Exposure time (ms)	285.61	285.61	285.61	285.61	285.61
Frames to Avg (frames per projection)	2	2	2	2	2
X-ray Source Voltage (kV)	222	222	222	222	222
X-ray Source Current (mA)	0.575	0.575	0.5	0.5	0.5
Source Filter Thickness (mm)	1	1	1	1	1
Source Filter Material	Brass	Brass	Brass	Brass	Brass
Image Matrix Size	1024 x 1024	1024 x 1024	1024 x 1024	1024 x 1024	1024 x 1024

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.

[3] 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 94. Review of the images determined that, when the scans were conducted, the following indications were noted:

Left TACS Control Unit

1. The ballscrew extension distance was approximately 44.7 mm, and the ballscrew appeared to be near the extension limit;
2. The ground screw within the unit that had been the subject of an earlier Service Bulletin appeared to be present and secure;
3. Two screws within the unit that attached the gear train and motor compartments appeared to be broken;
4. There were two pins (that appeared to be alignment pins) within the unit that appeared to be deformed;
5. There were five screws (that appeared to be designed to hold the LVDT and motor compartment cover to structure) that were missing their screw heads. There were also five separated screw heads noted within the unit;
6. The LVDTs were noted to be at a position that appeared to be close to the maximum extension limits;
7. There were three wiring anomalies noted within the LVDT wires;
8. There were no indications of potting material around the LVDT wires at their respective exit points from either LVDT;
9. There were six bent pins noted in the 40 pin connector. One of these bent pins appeared to contact an adjacent pin assembly.

Right TACS Control Unit

1. The ballscrew extension distance was approximately 26.7 mm;
2. The ground screw within the unit that had been the subject of an earlier Service Bulletin appeared to be present and secure;
3. Several portions of the unit's gear train were displaced from their normal positions;
4. There were two screws within the unit that attached the gear train and motor compartments appeared to be broken;
5. There were two pins (that appeared to be alignment pins) within the unit that appeared to be deformed;
6. The 40 pin connector appeared to be deformed and broken in some areas. The pins within that connector appeared to be bent and out of alignment;
7. There were no indications of potting material around the LVDT wires at their respective exit points from either LVDT;
8. There was a broken wire noted in the area adjacent to the ballscrew.

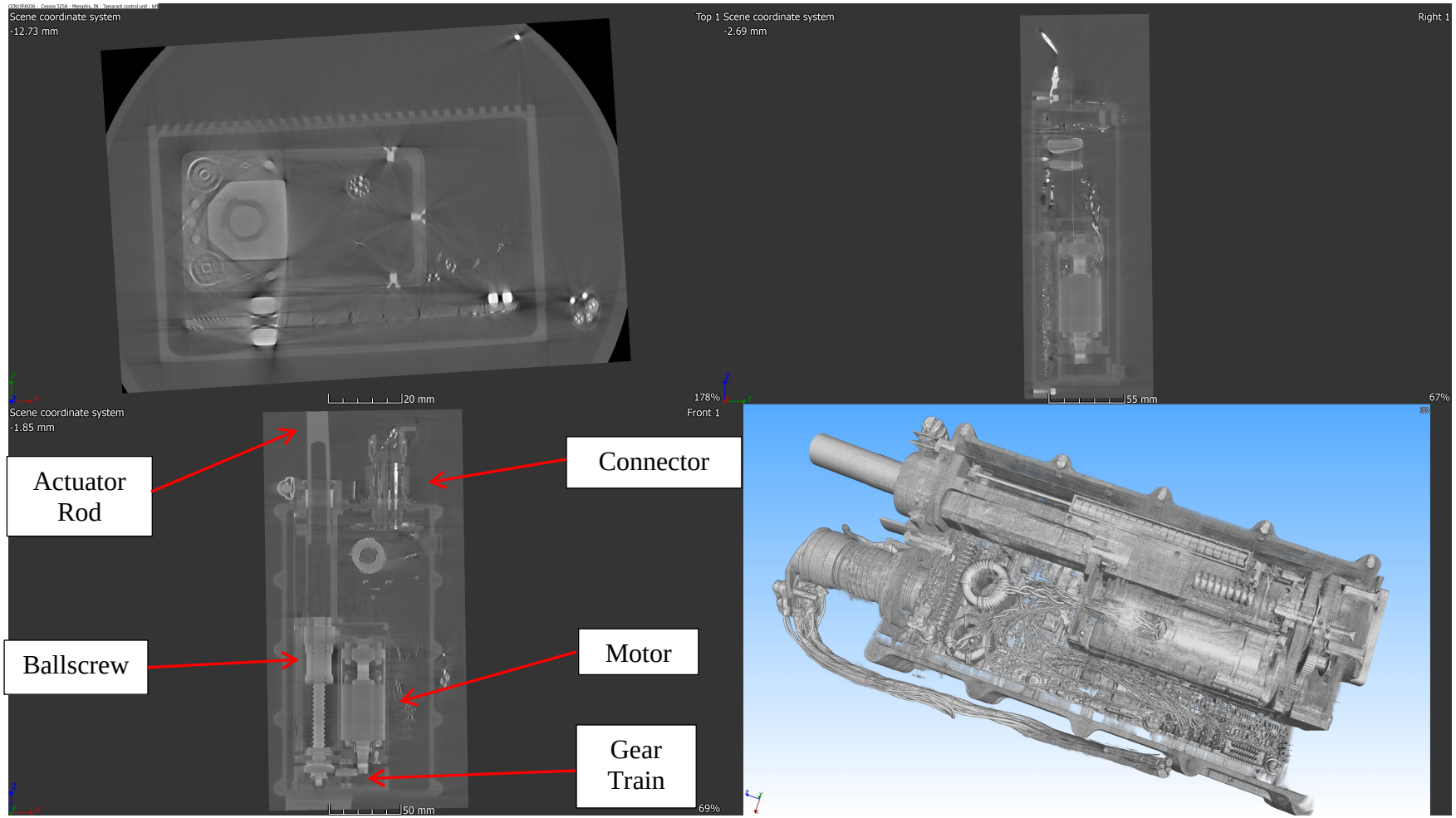


Figure 1
Left TACS control unit - overview

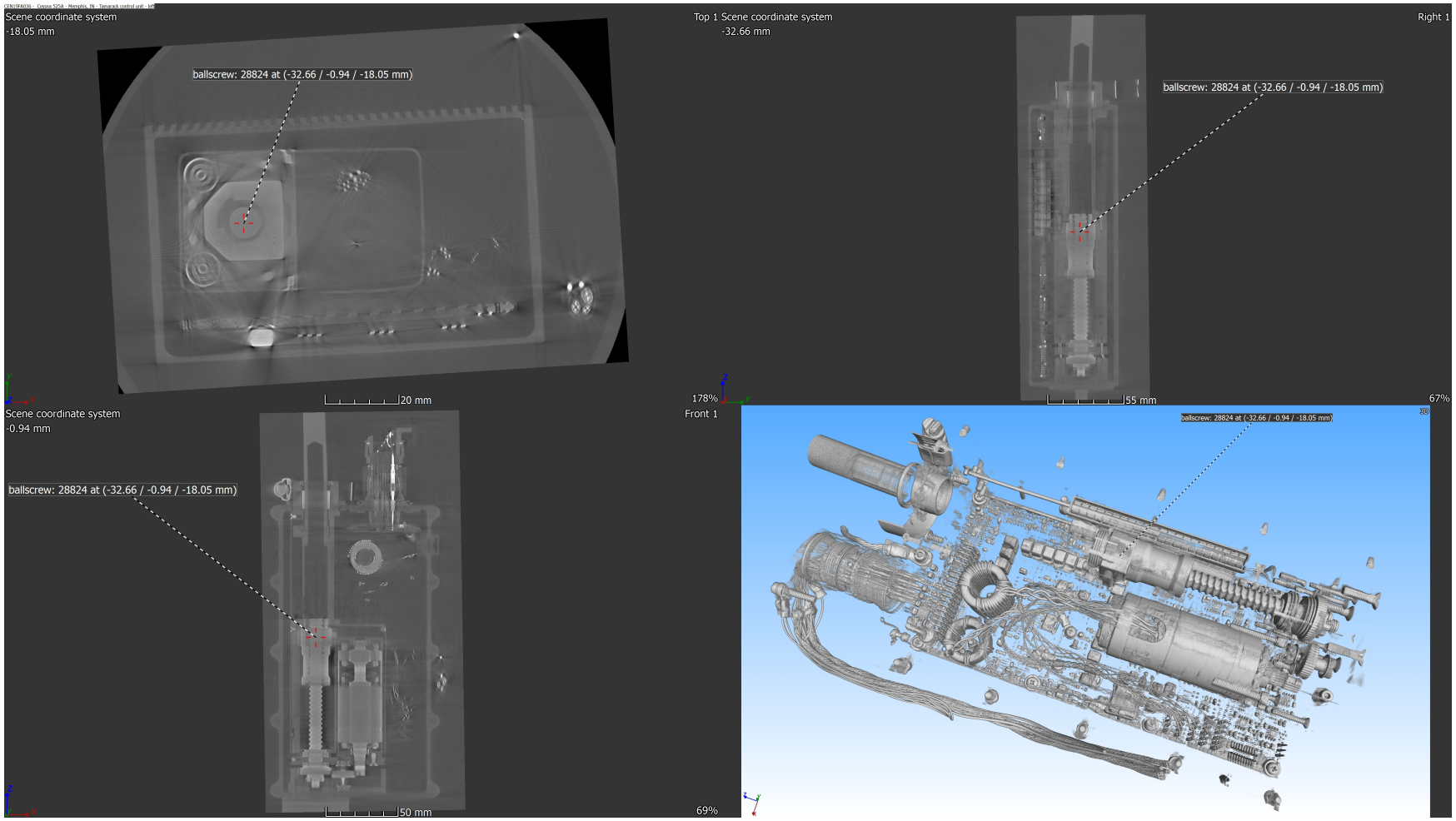


Figure 2
Left TACS control unit - ballscrew

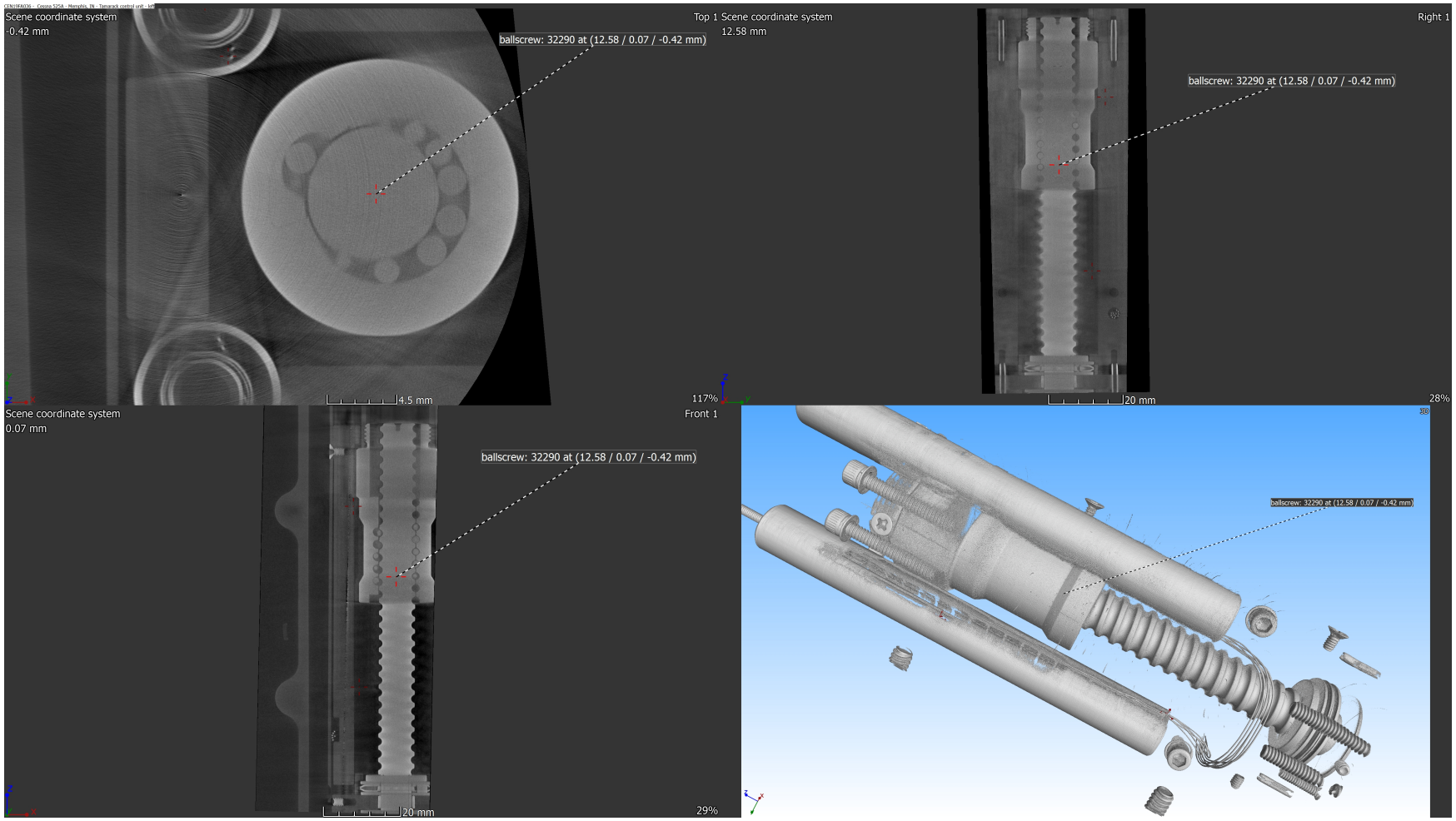


Figure 3
Left TACS control unit – target CT - ballscrew

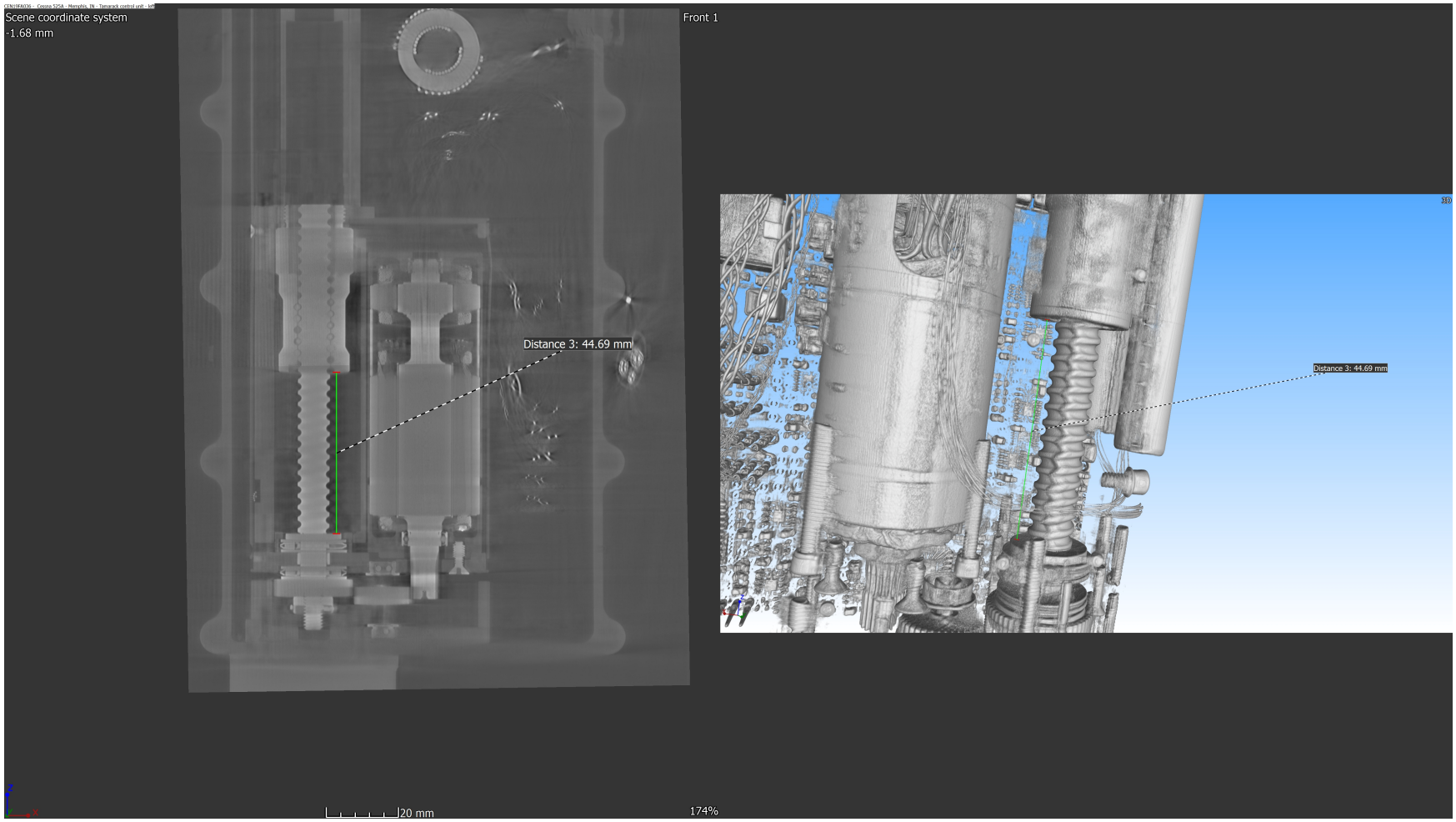


Figure 4
Left TACS control unit – ballscrew extension distance

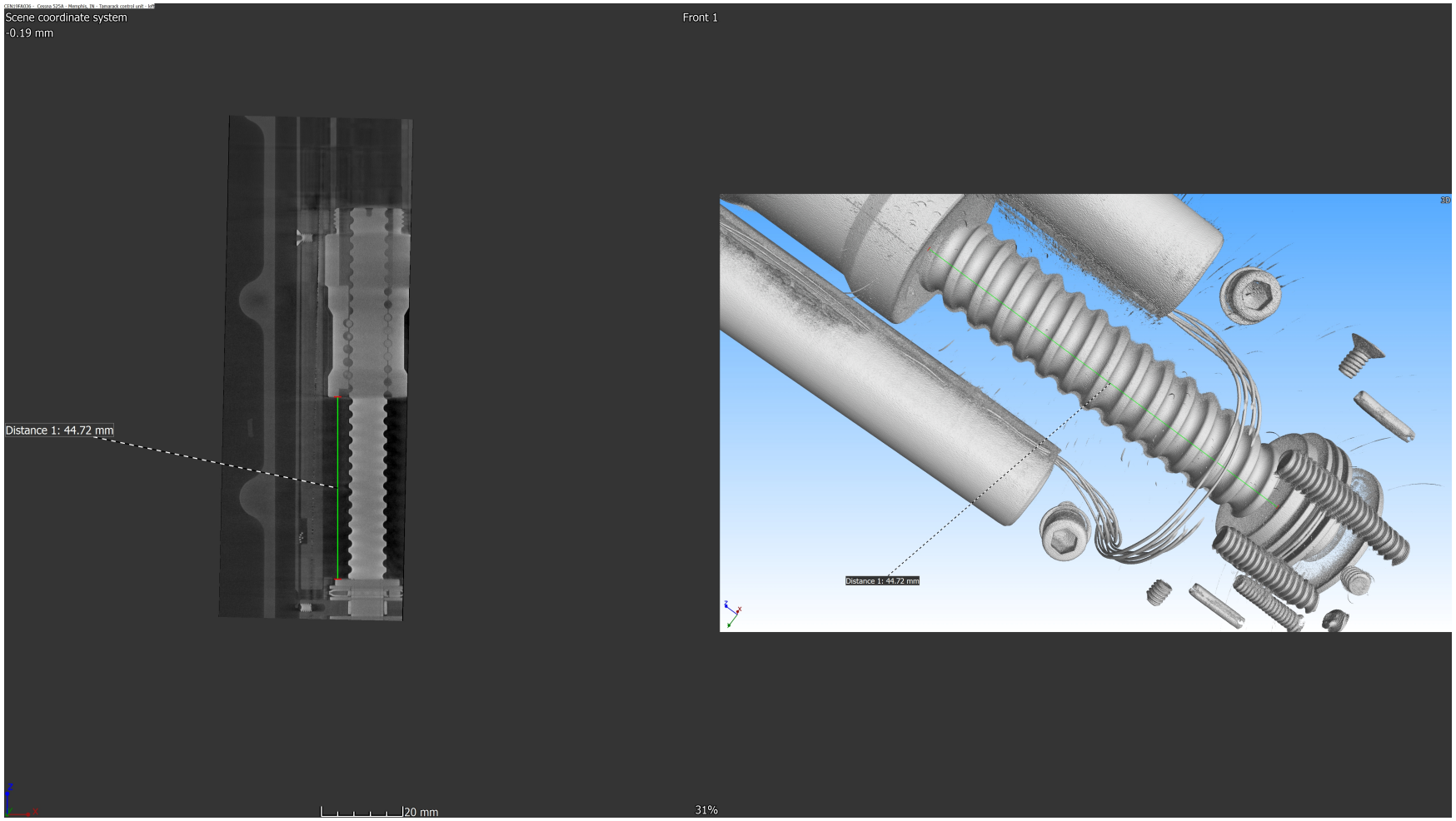


Figure 5
Left TACS control unit – target CT – ballscrew extension distance

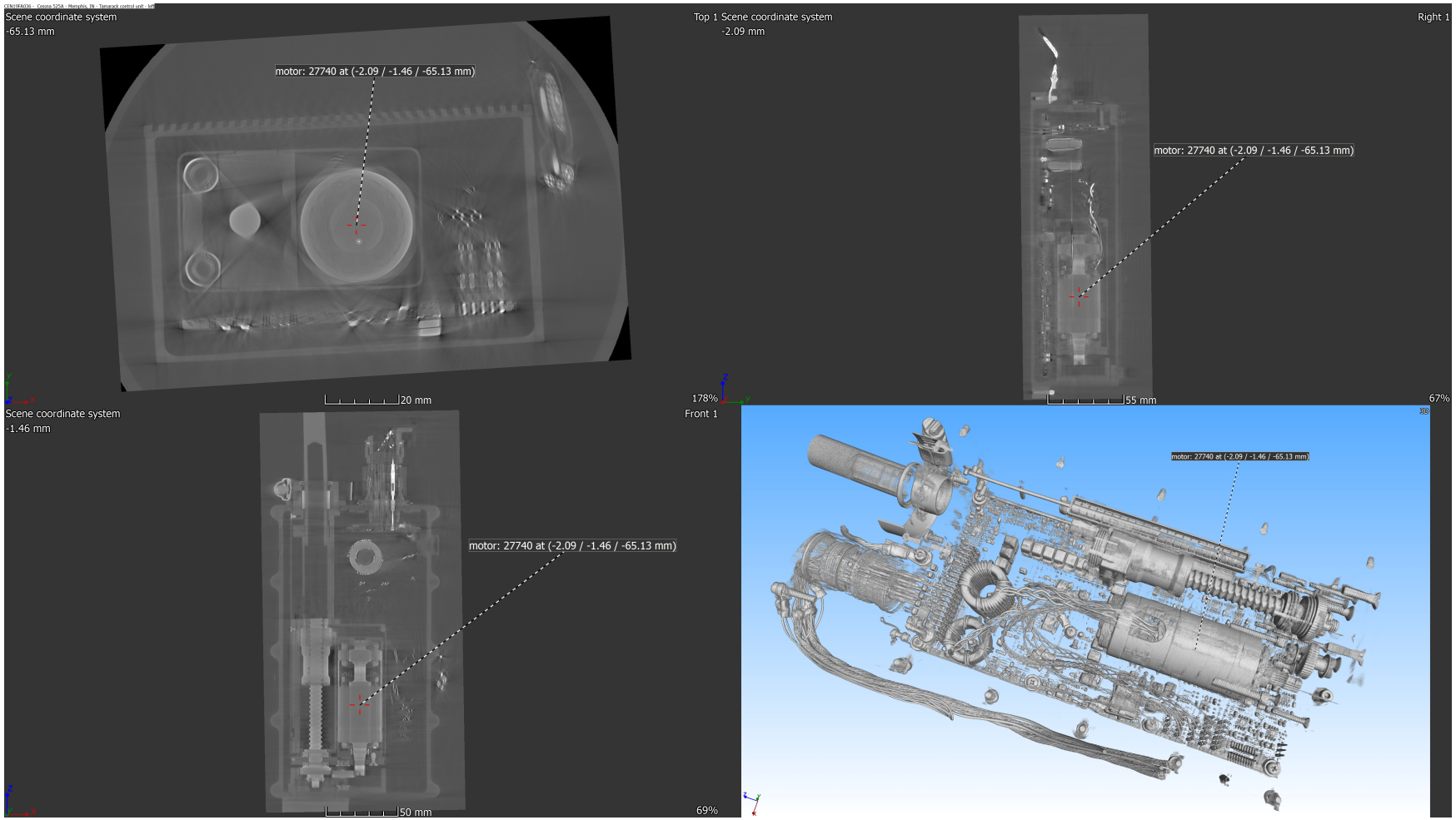


Figure 6
Left TACS control unit – motor

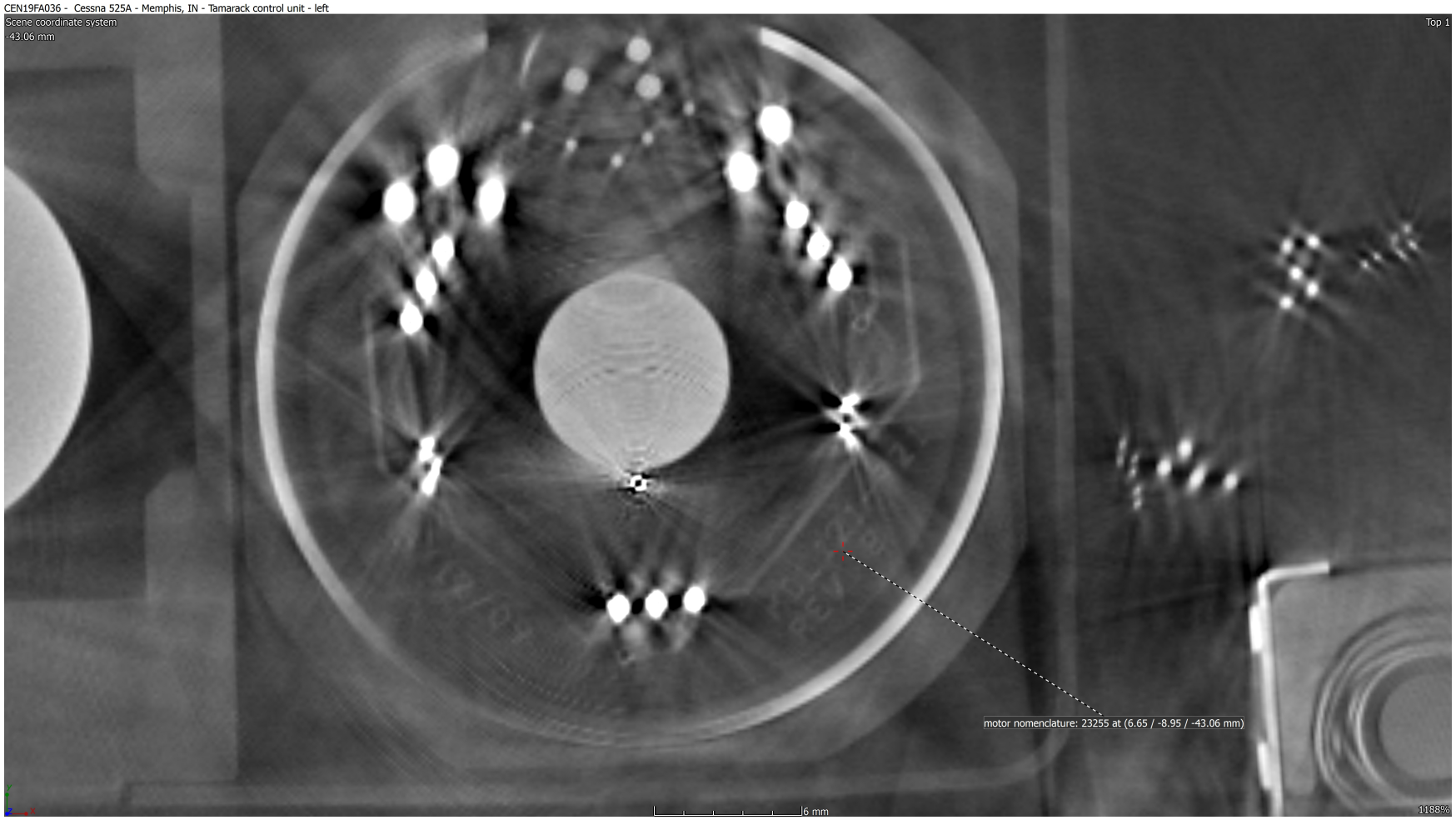


Figure 7
Left TACS control unit – motor nomenclature

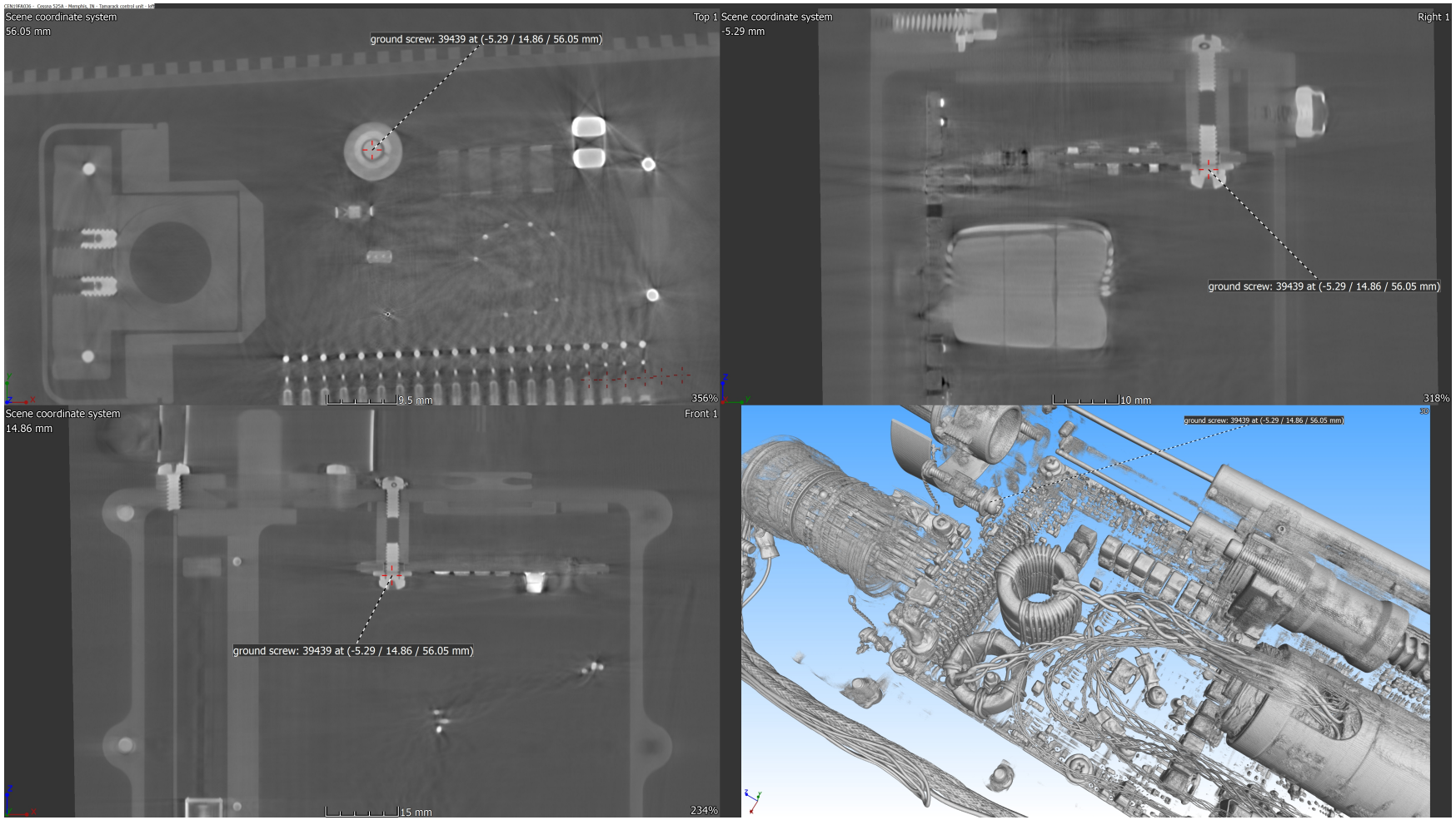


Figure 8
Left TACS control unit – ground screw

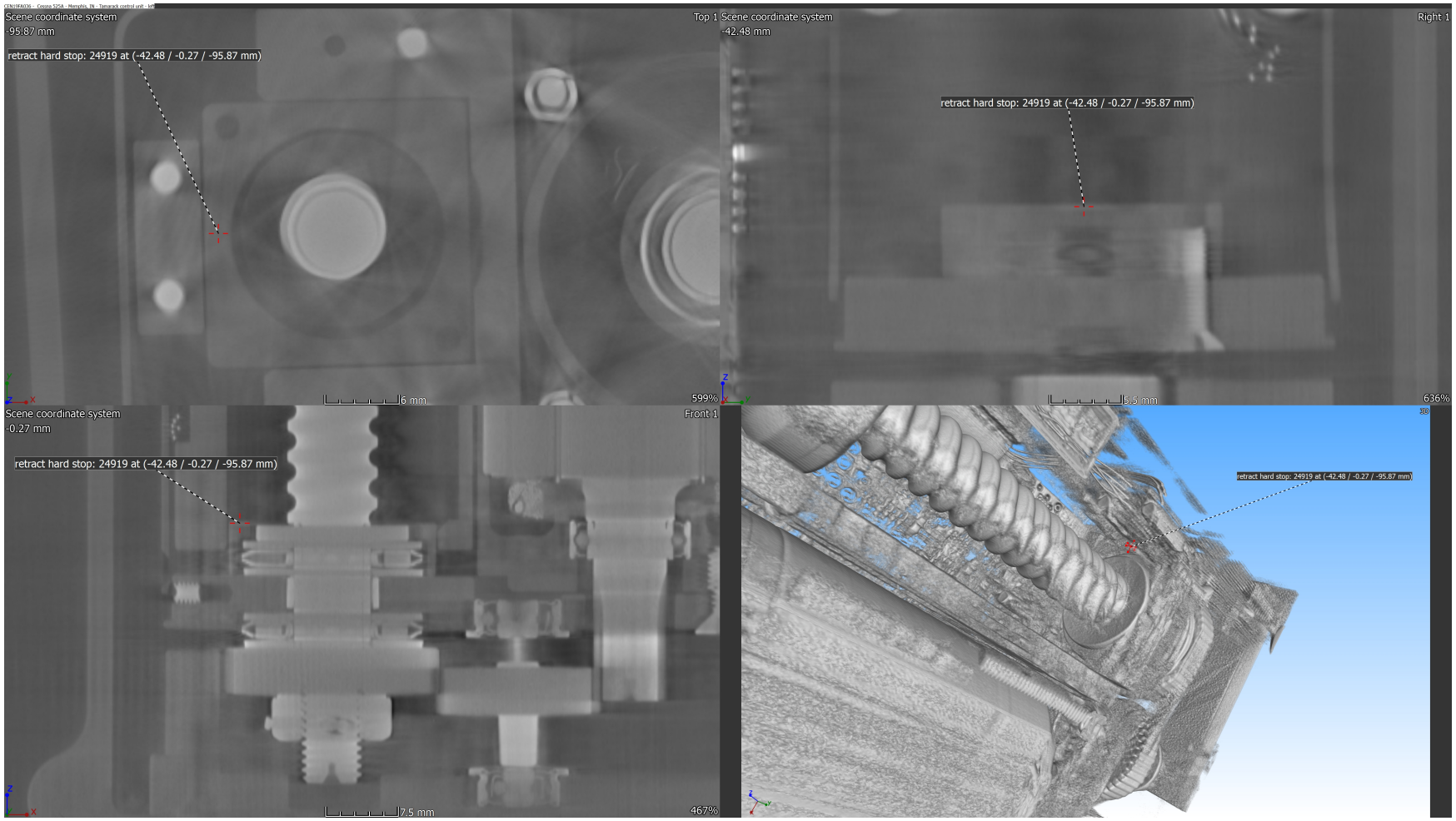


Figure 9
Left TACS control unit – retract hard stop

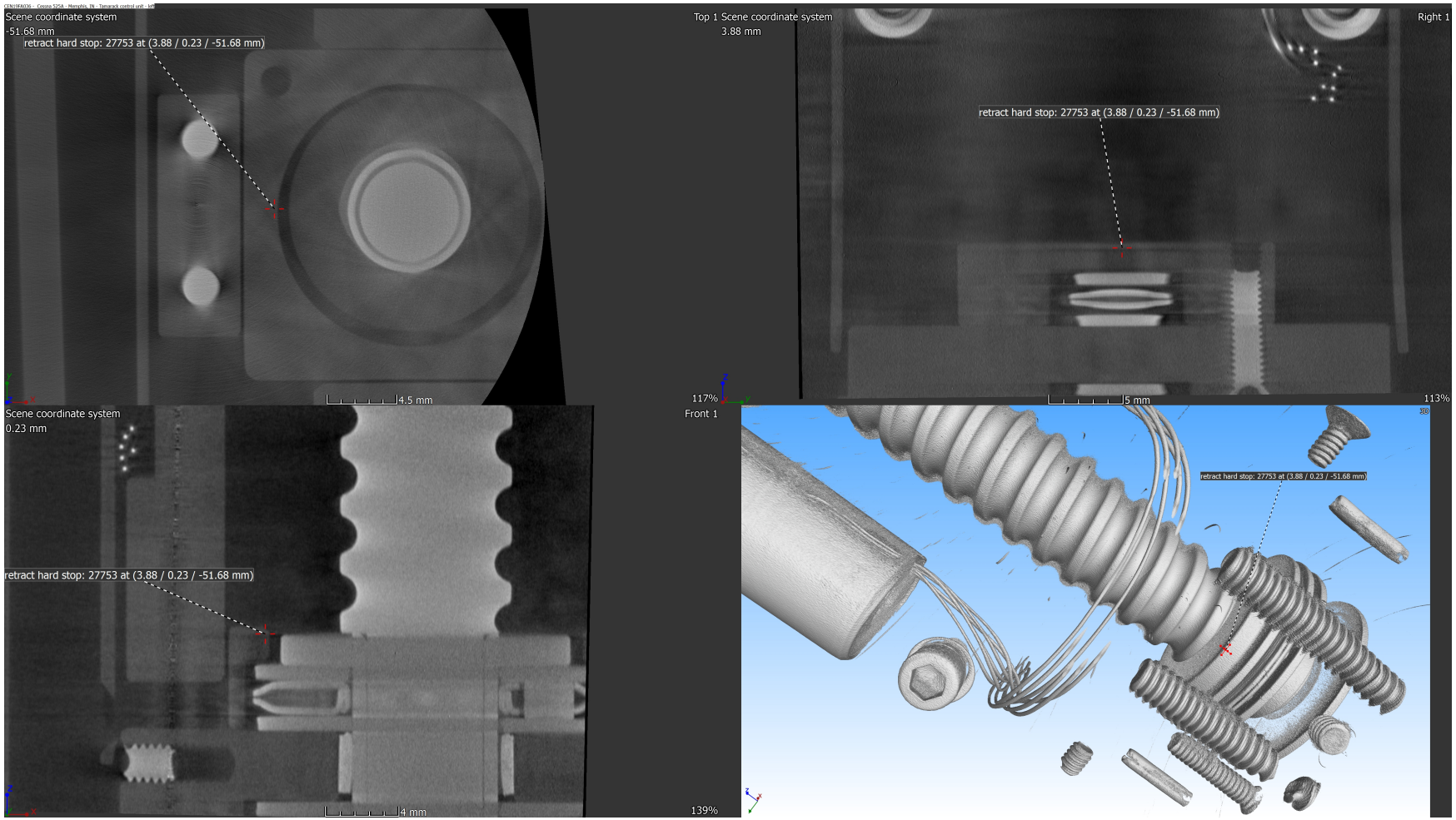


Figure 10
Left TACS control unit – target CT – retract hard stop

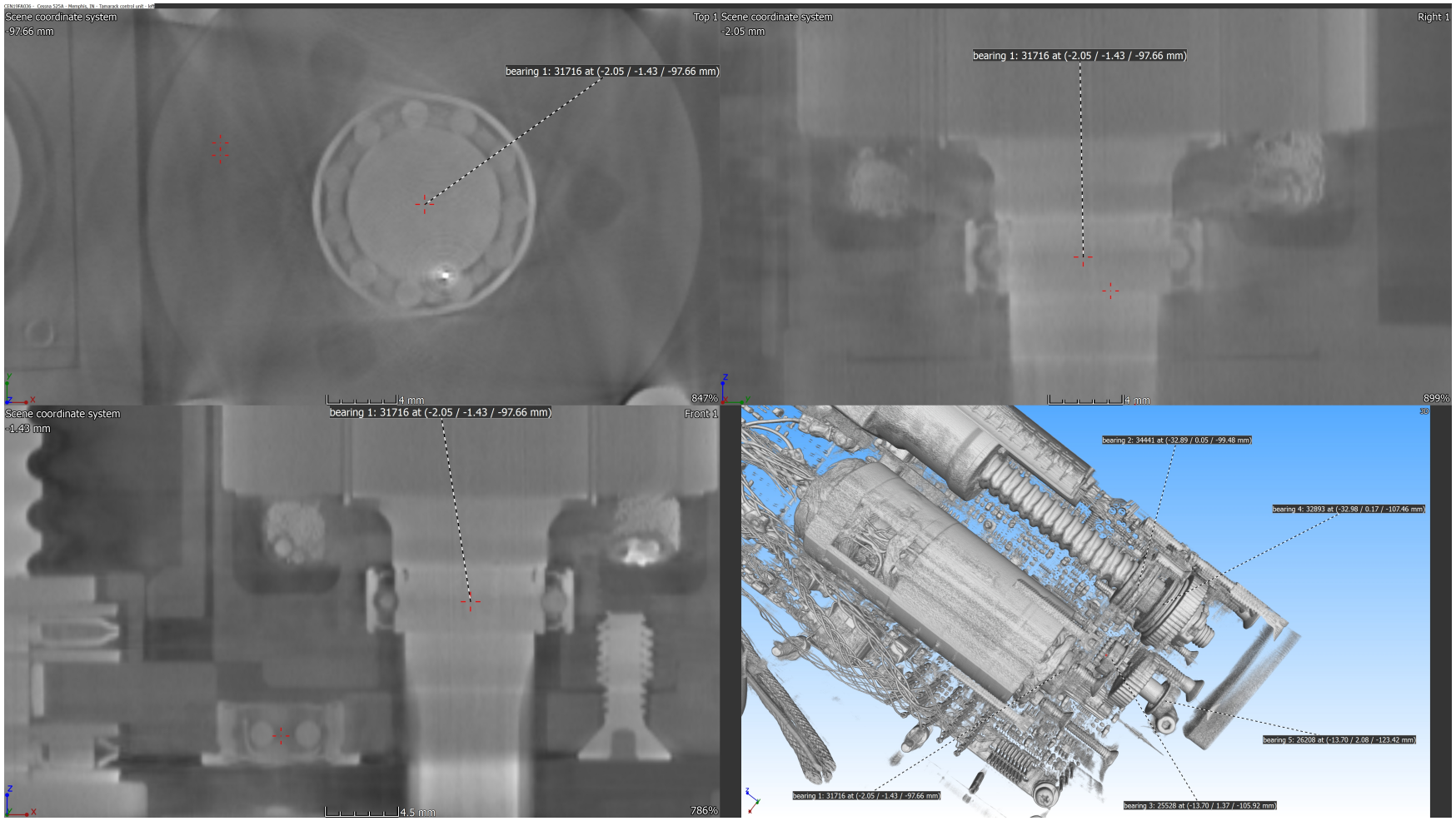


Figure 11
Left TACS control unit – bearing 1

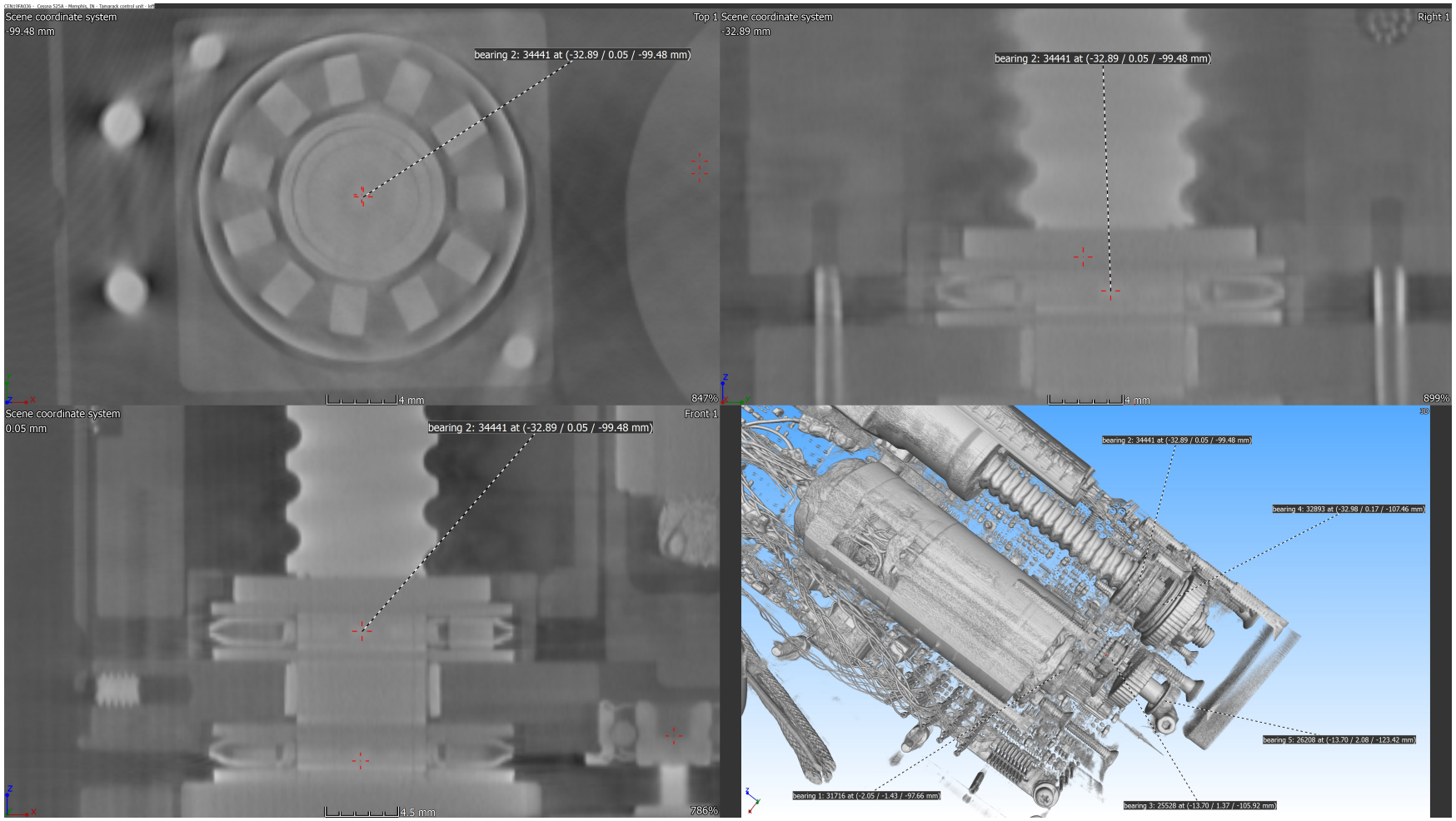


Figure 12
Left TACS control unit – bearing 2

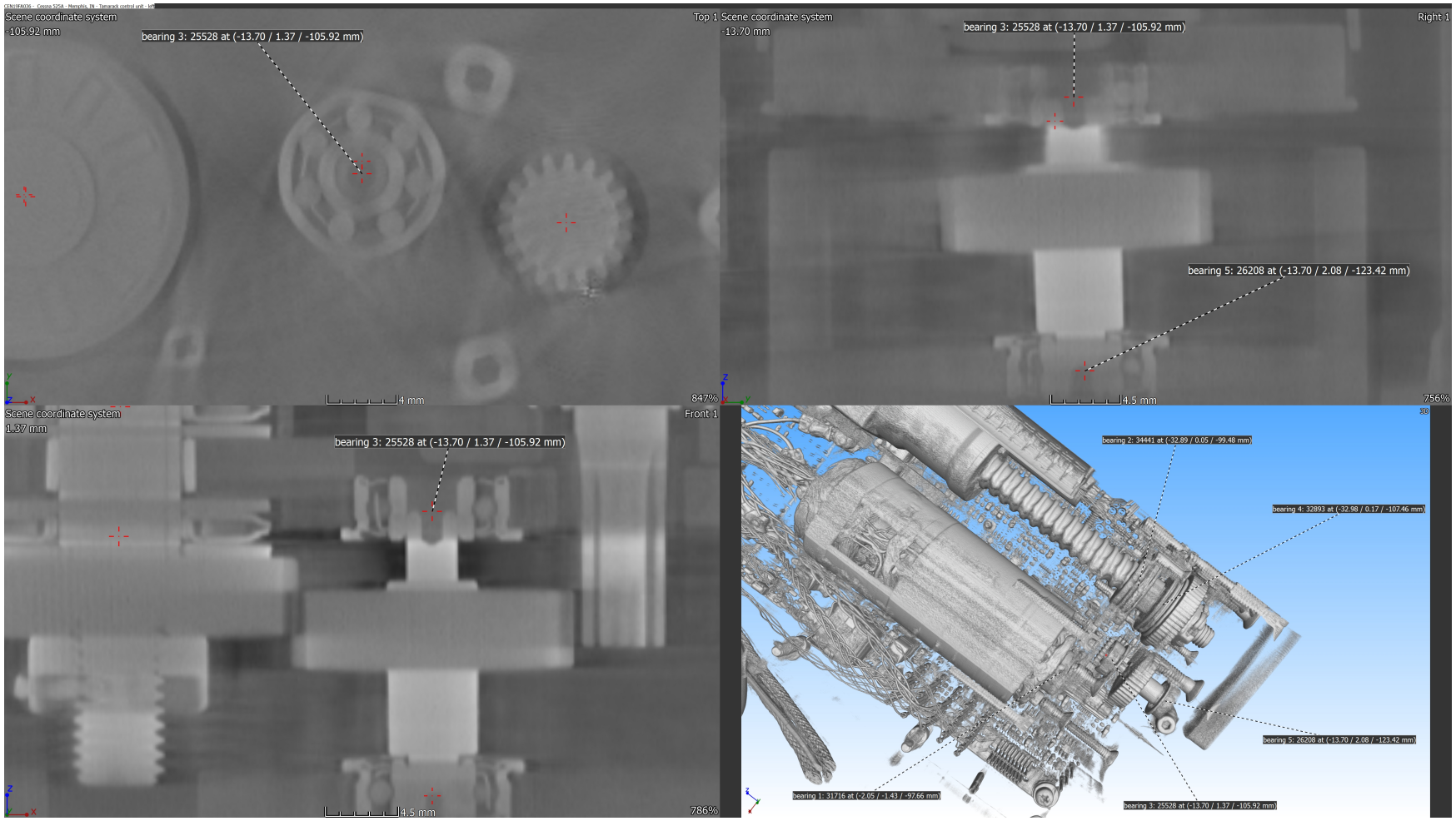


Figure 13
Left TACS control unit – bearing 3

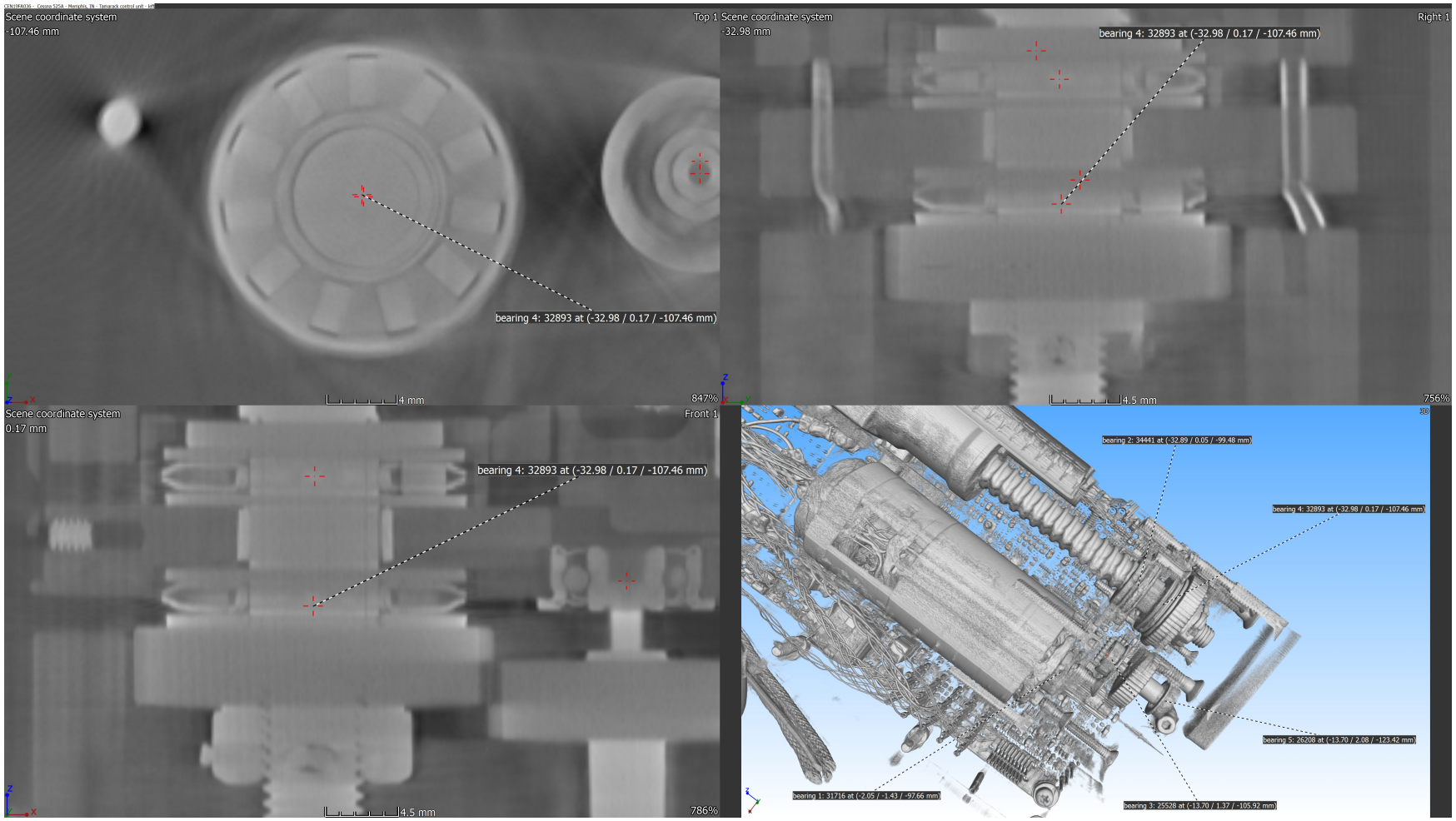


Figure 14
Left TACS control unit – bearing 4

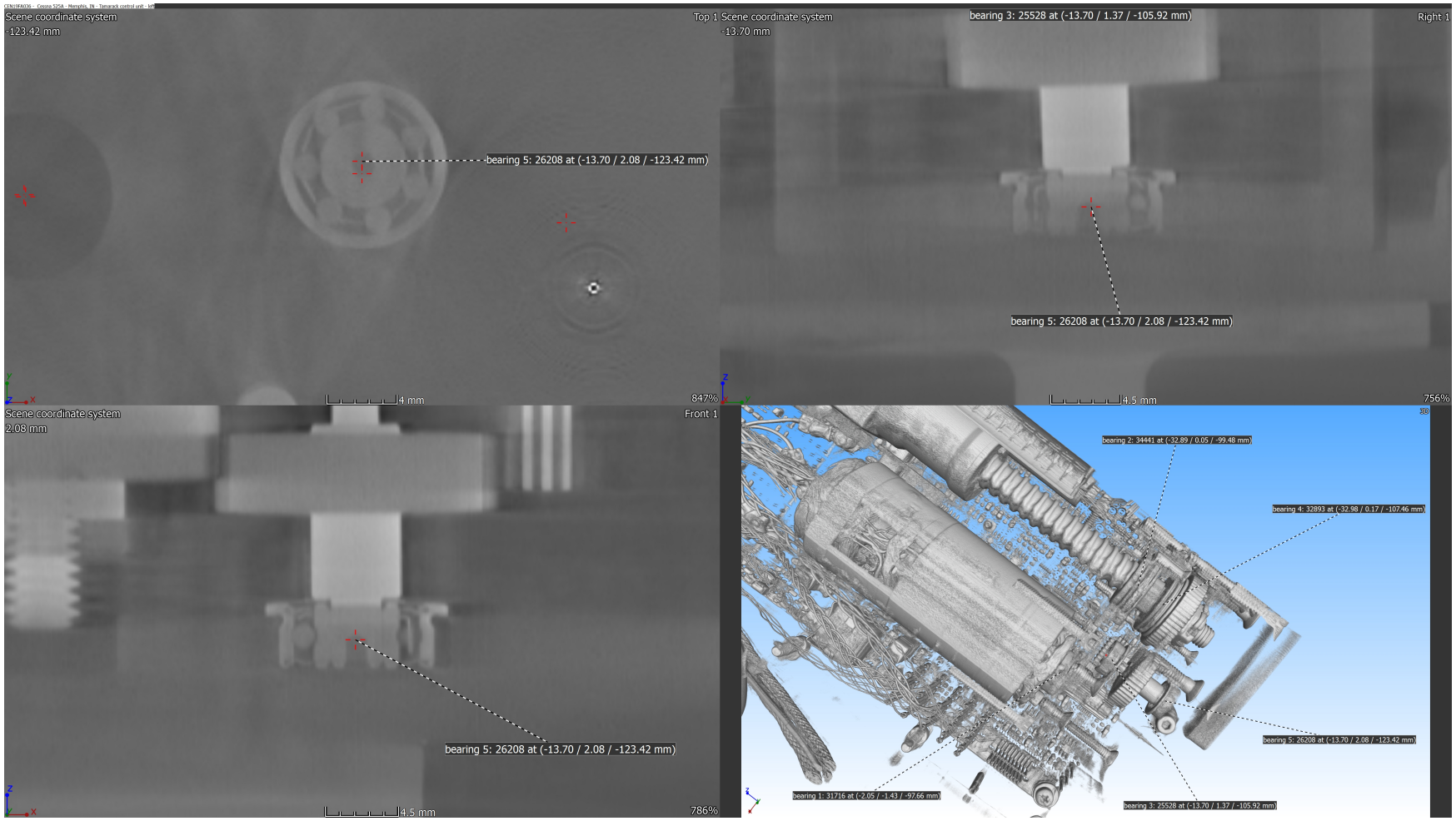


Figure 15
Left TACS control unit – bearing 5

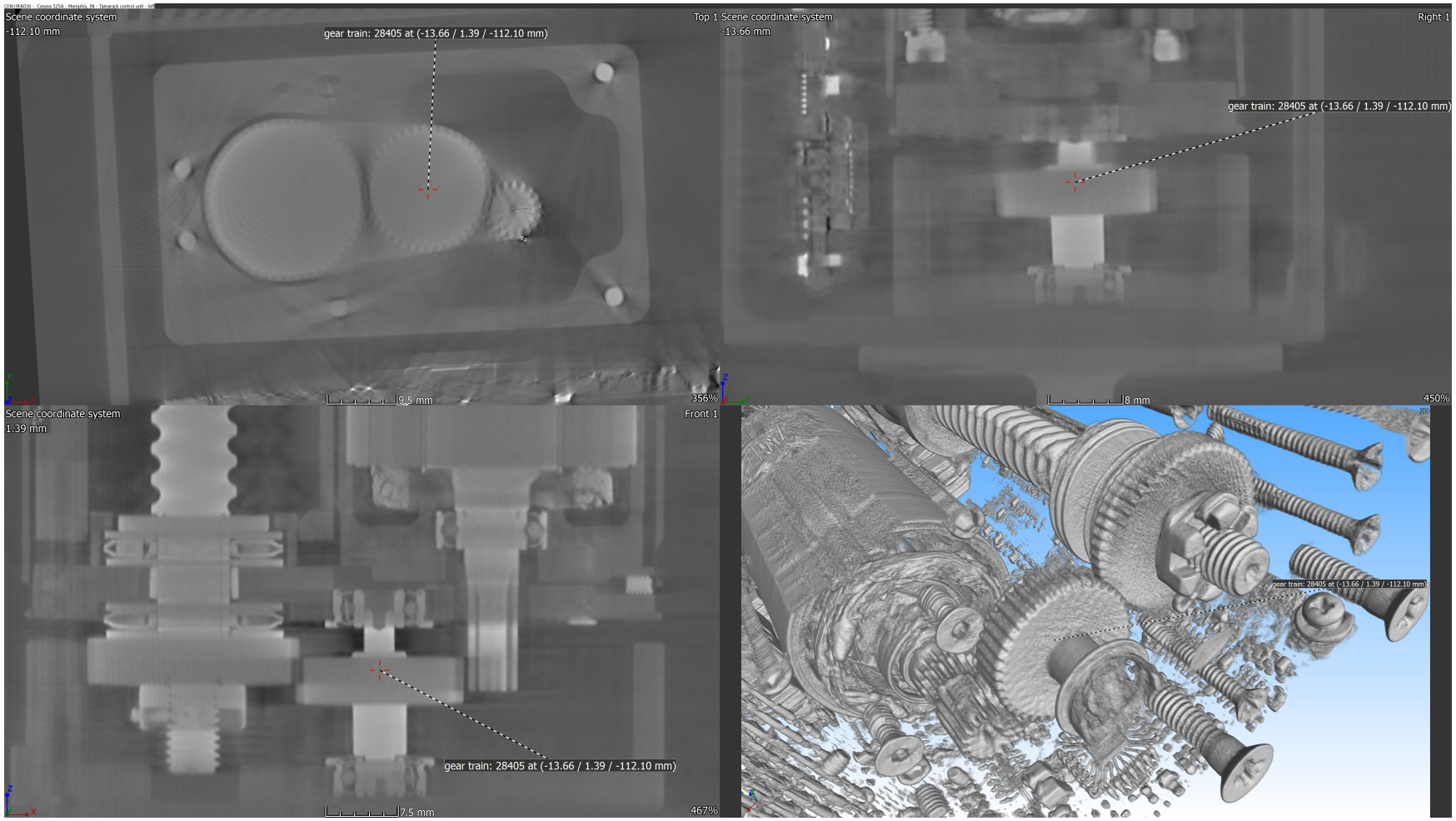


Figure 16
Left TACS control unit – gear train

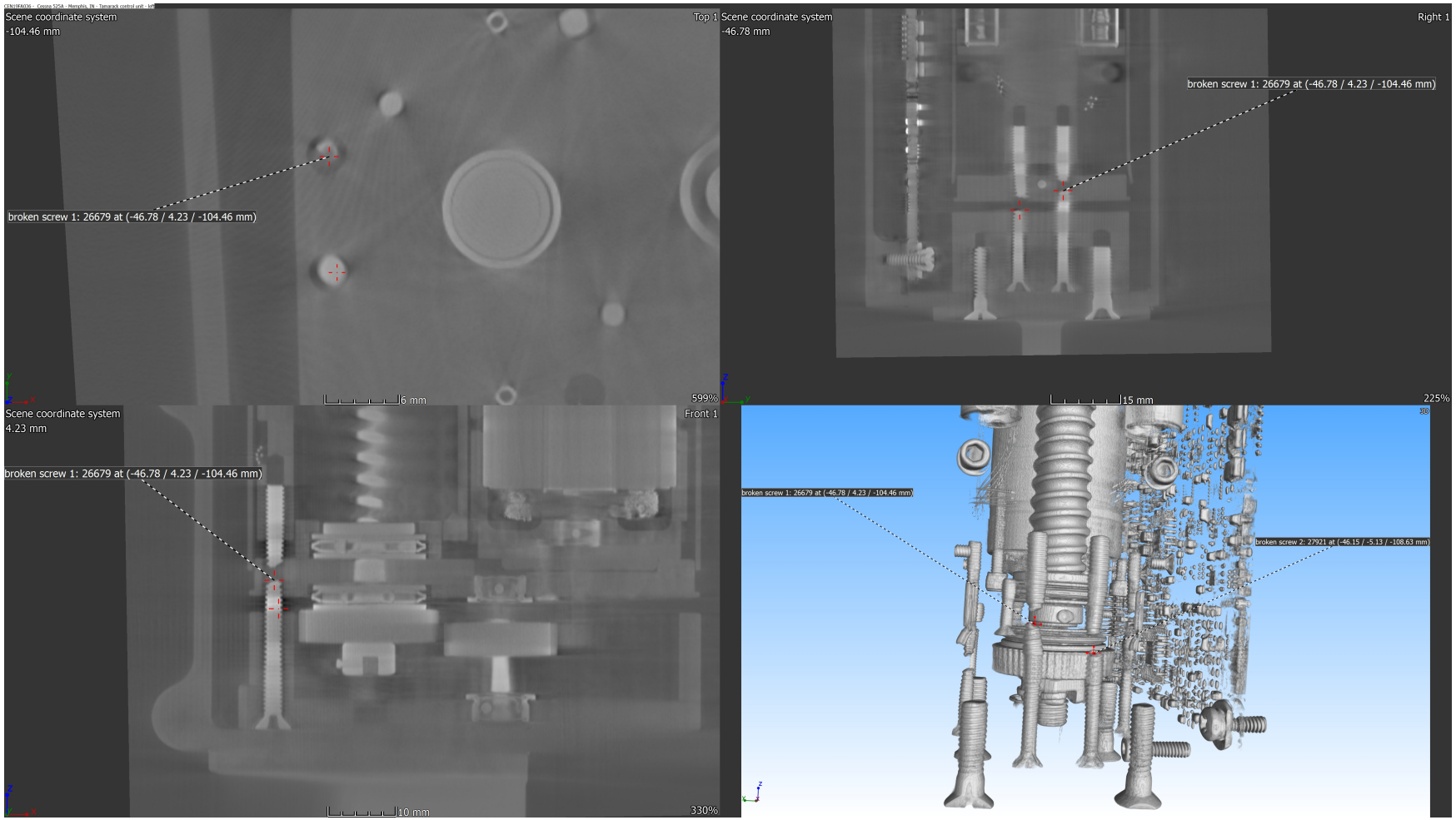


Figure 17
Left TACS control unit – broken screw 1

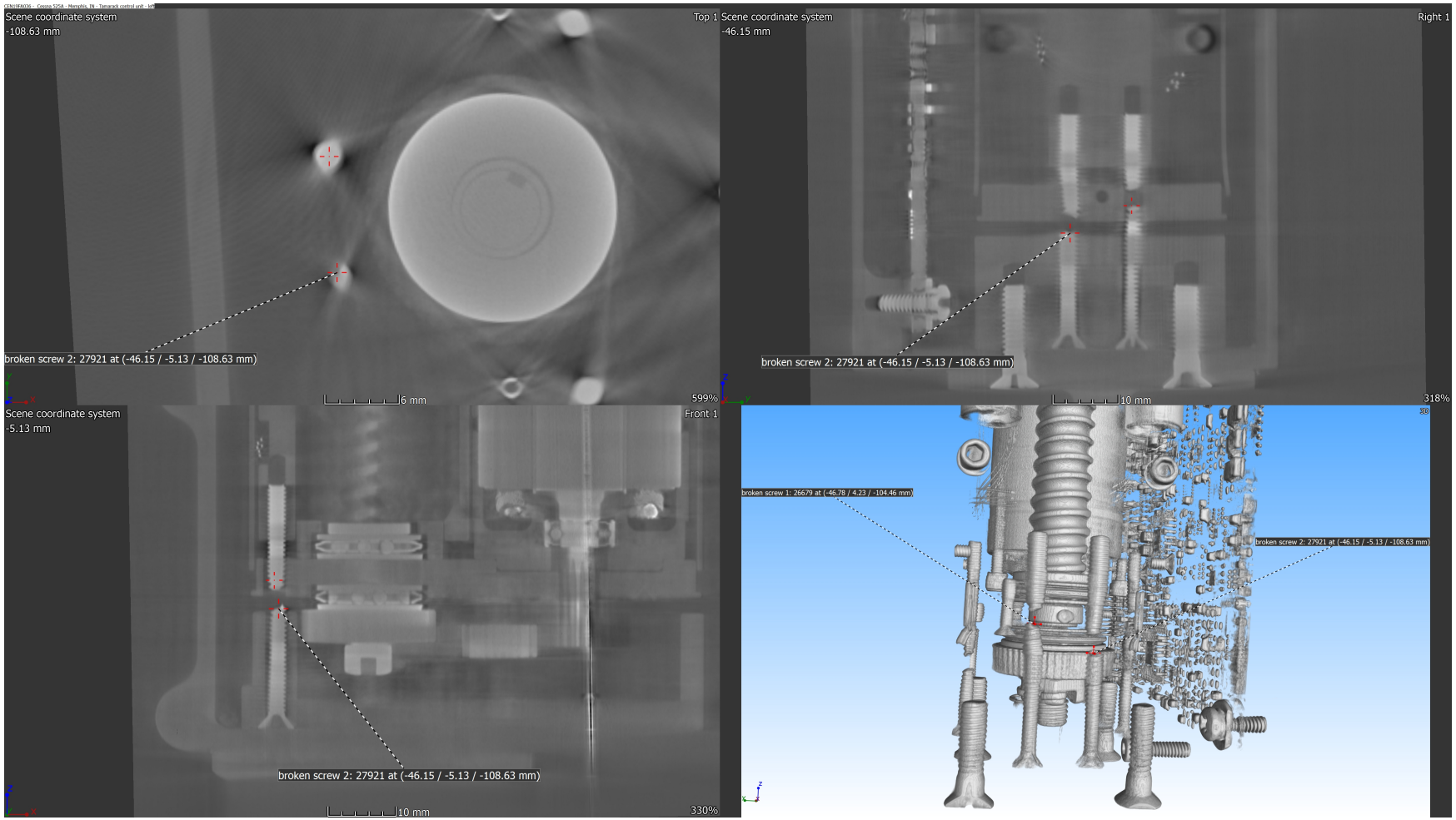


Figure 18
Left TACS control unit – broken screw 2

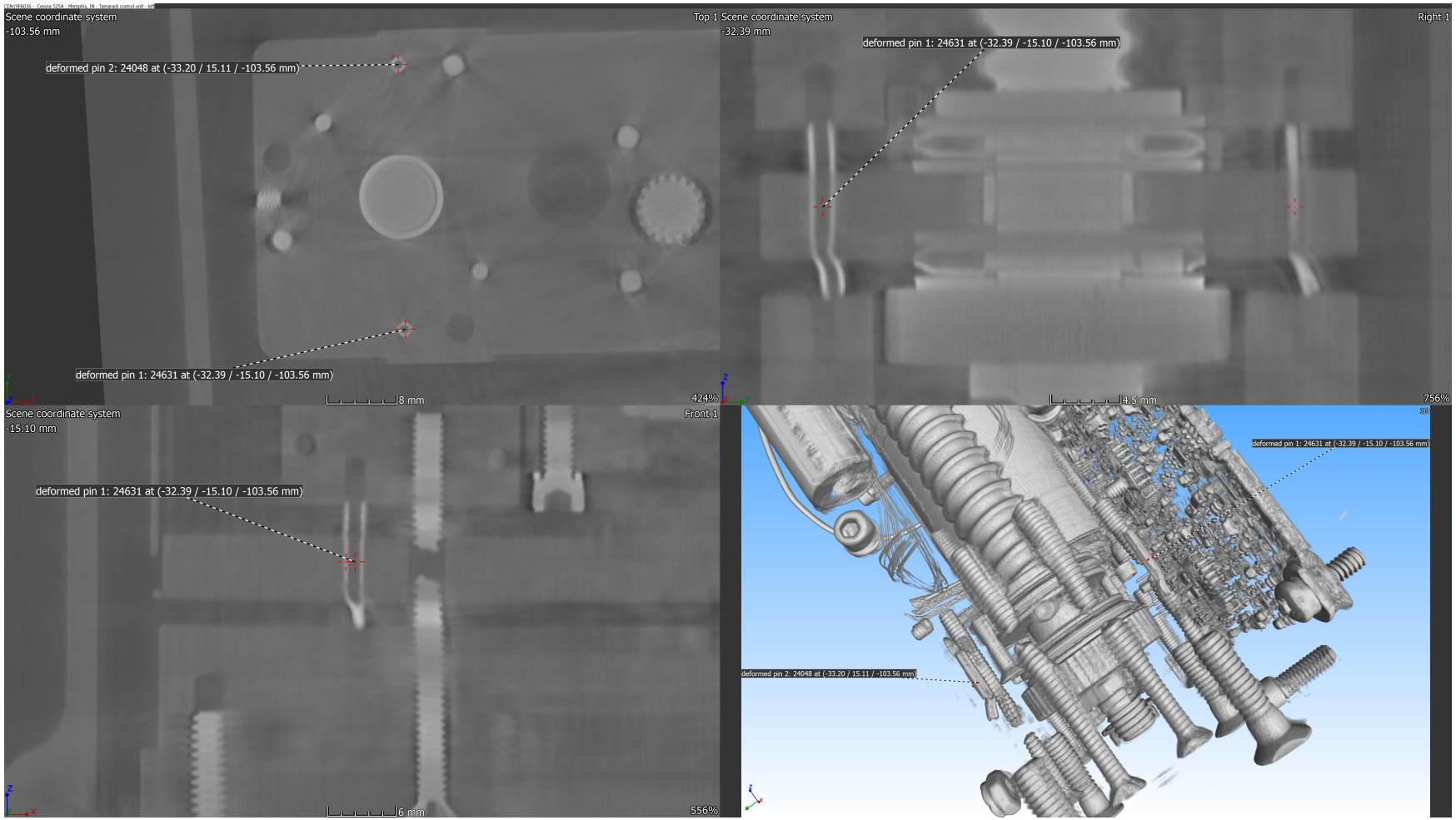


Figure 19
Left TACS control unit – deformed pin 1

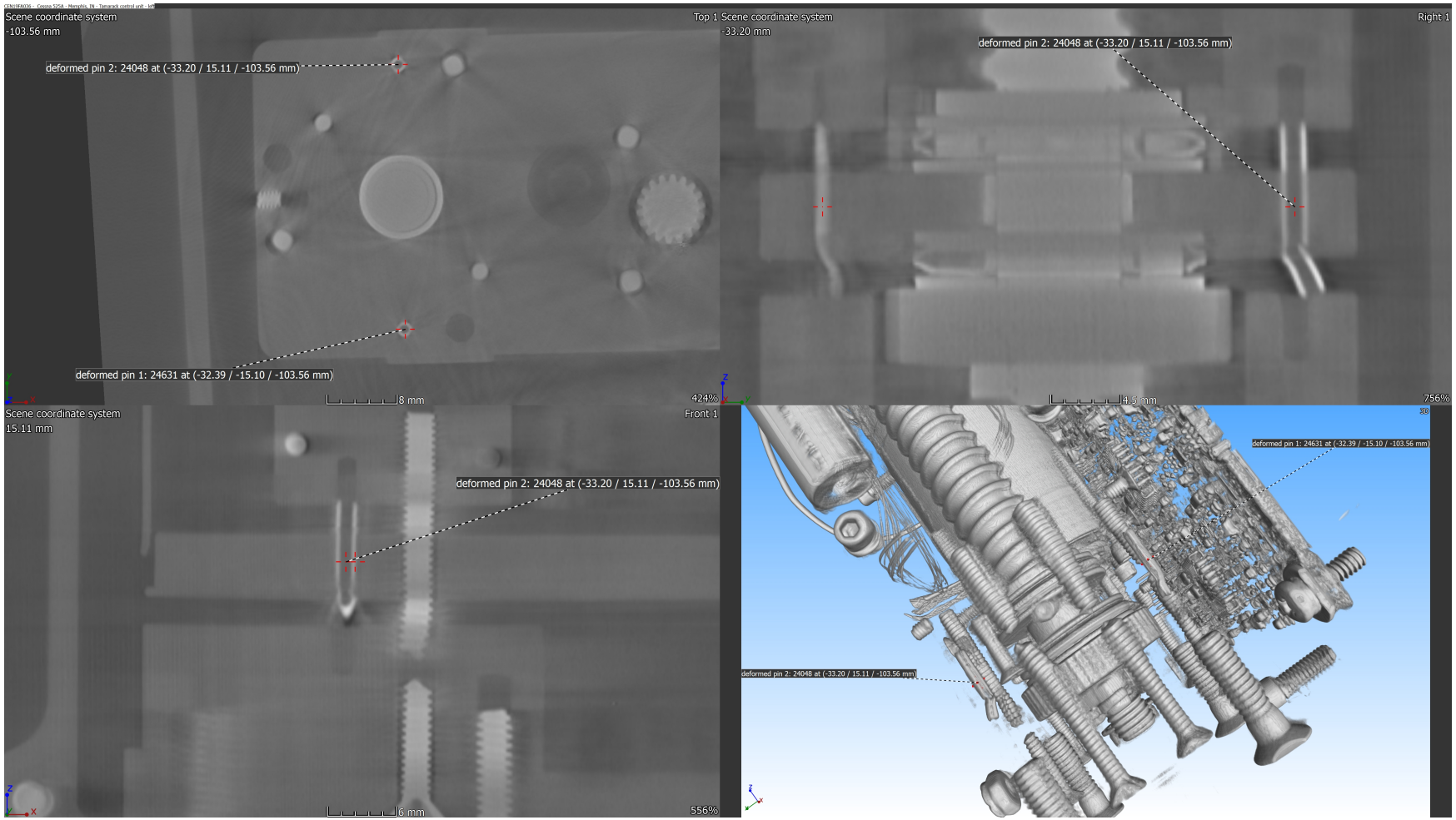


Figure 20
Left TACS control unit – deformed pin 2

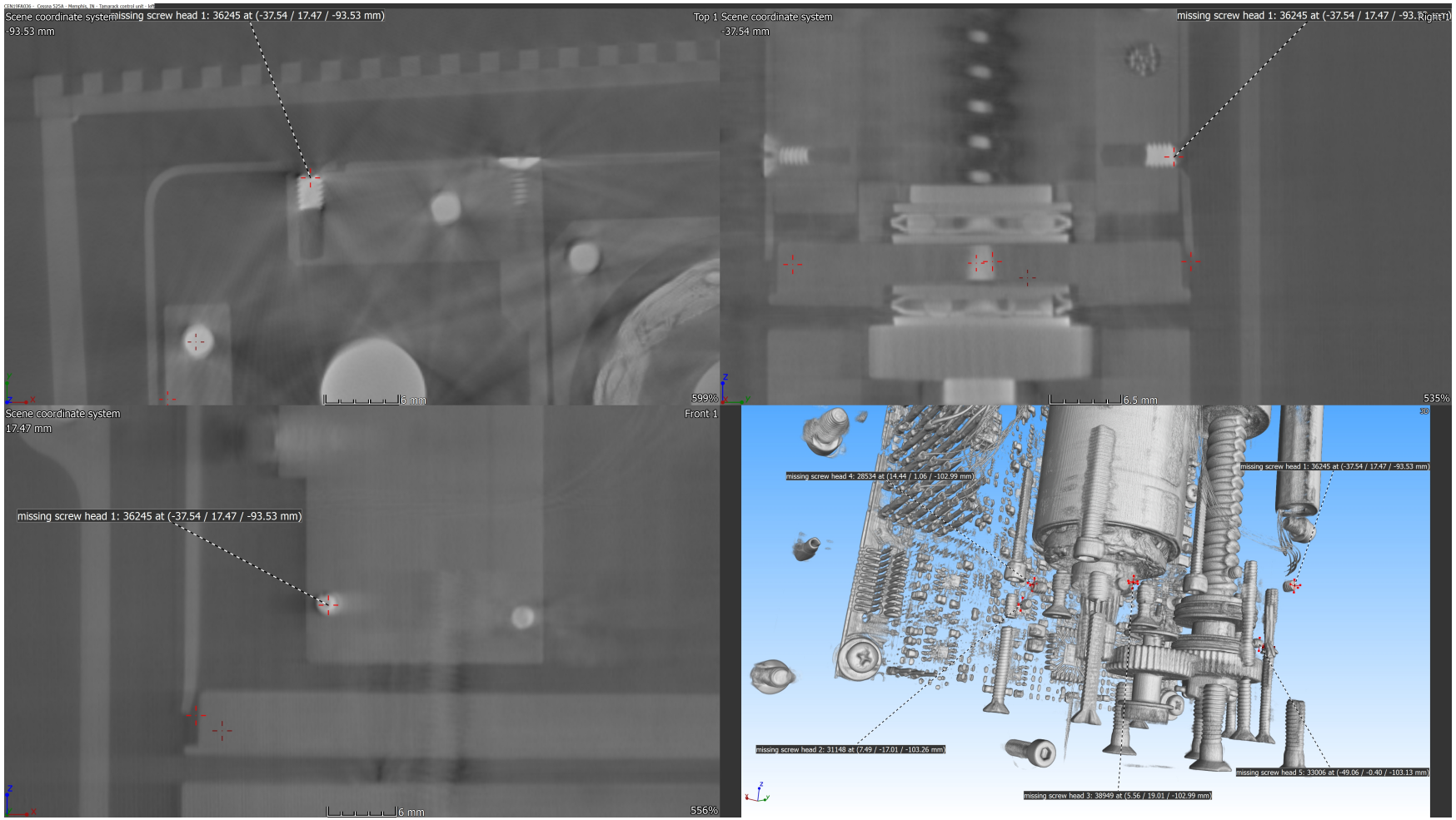


Figure 21
Left TACS control unit – missing screw head 1

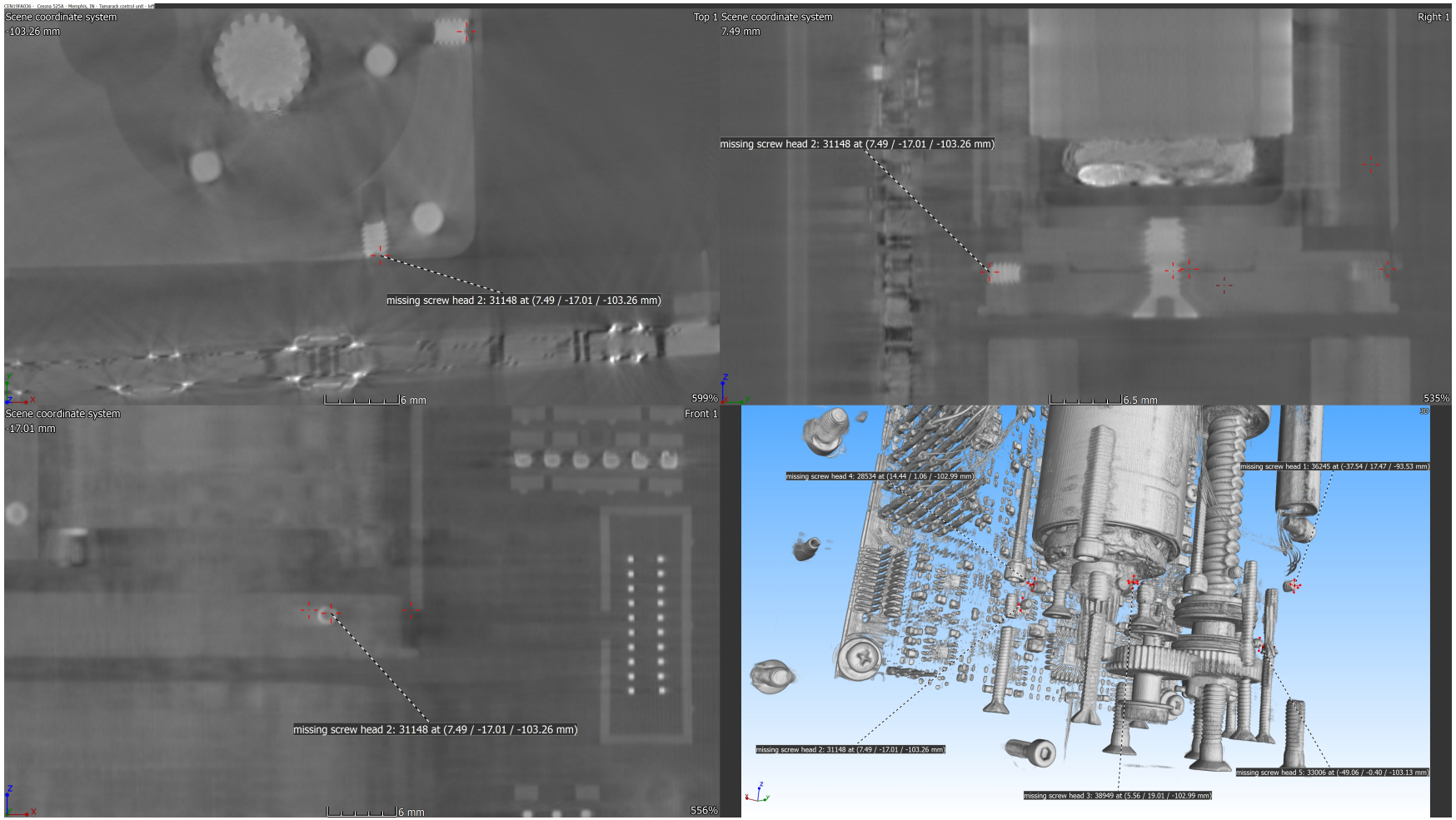


Figure 22
Left TACS control unit – missing screw head 2

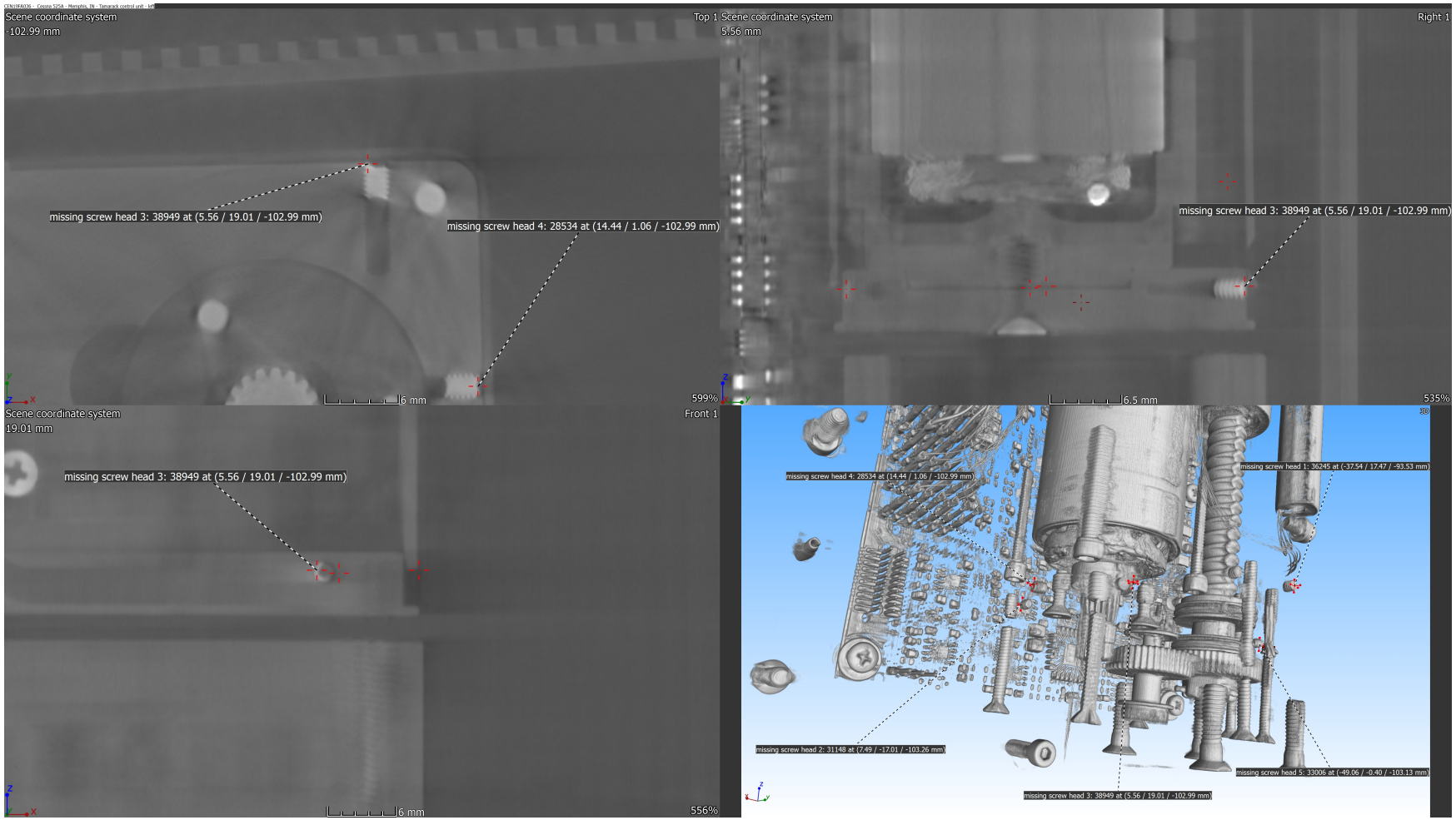


Figure 23
Left TACS control unit – missing screw head 3

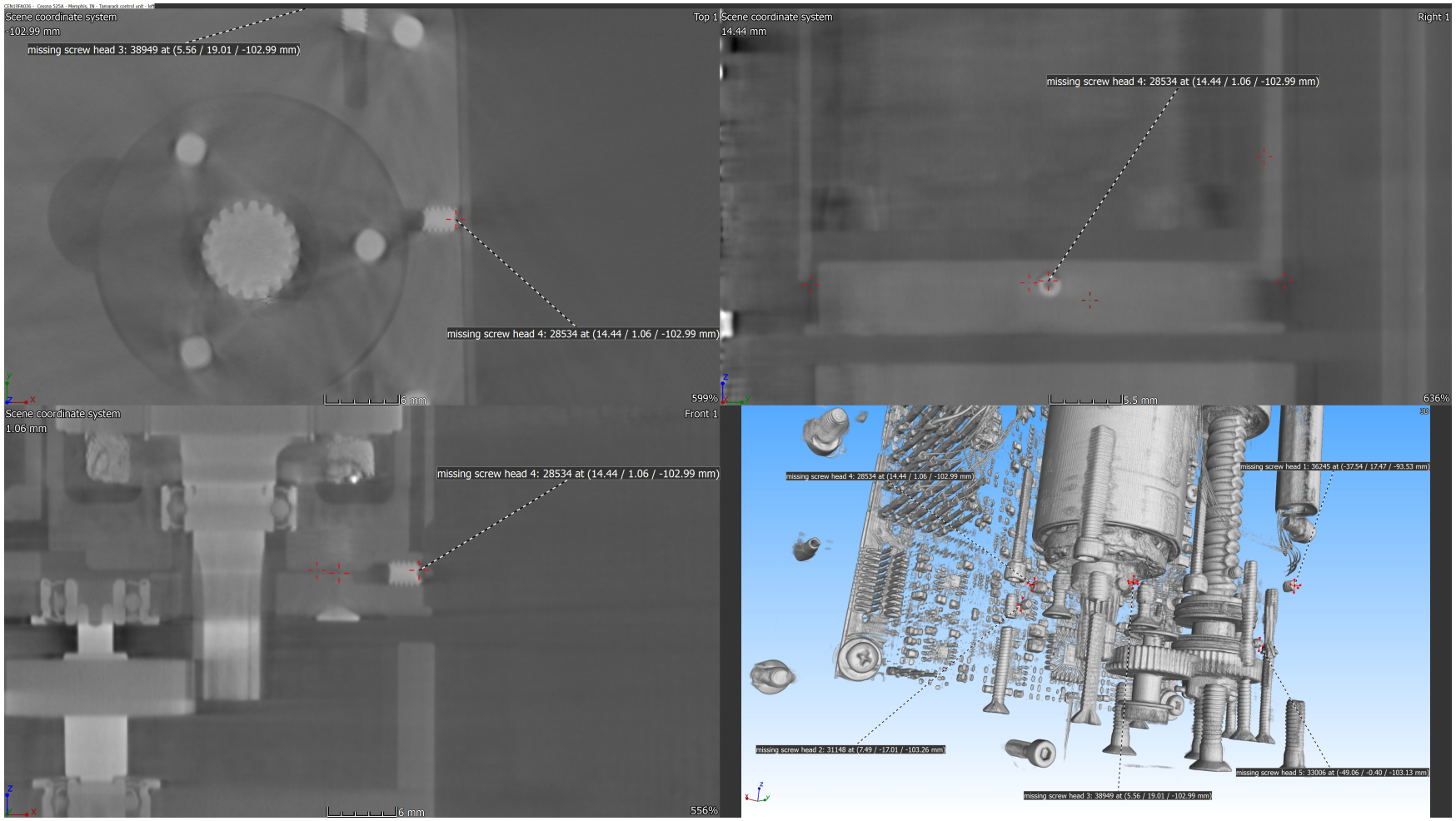


Figure 24
Left TACS control unit – missing screw head 4

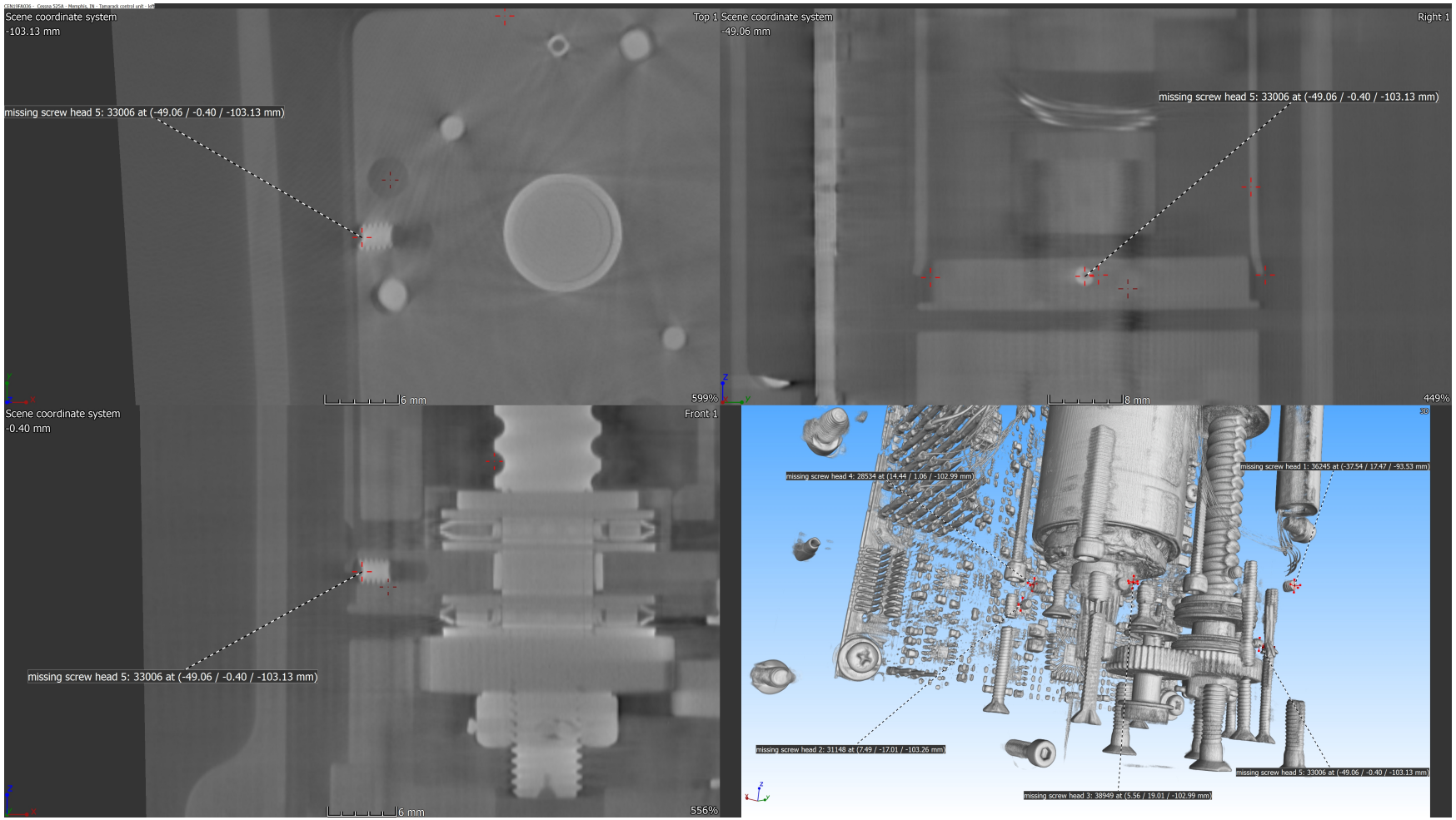


Figure 25
Left TACS control unit – missing screw head 5

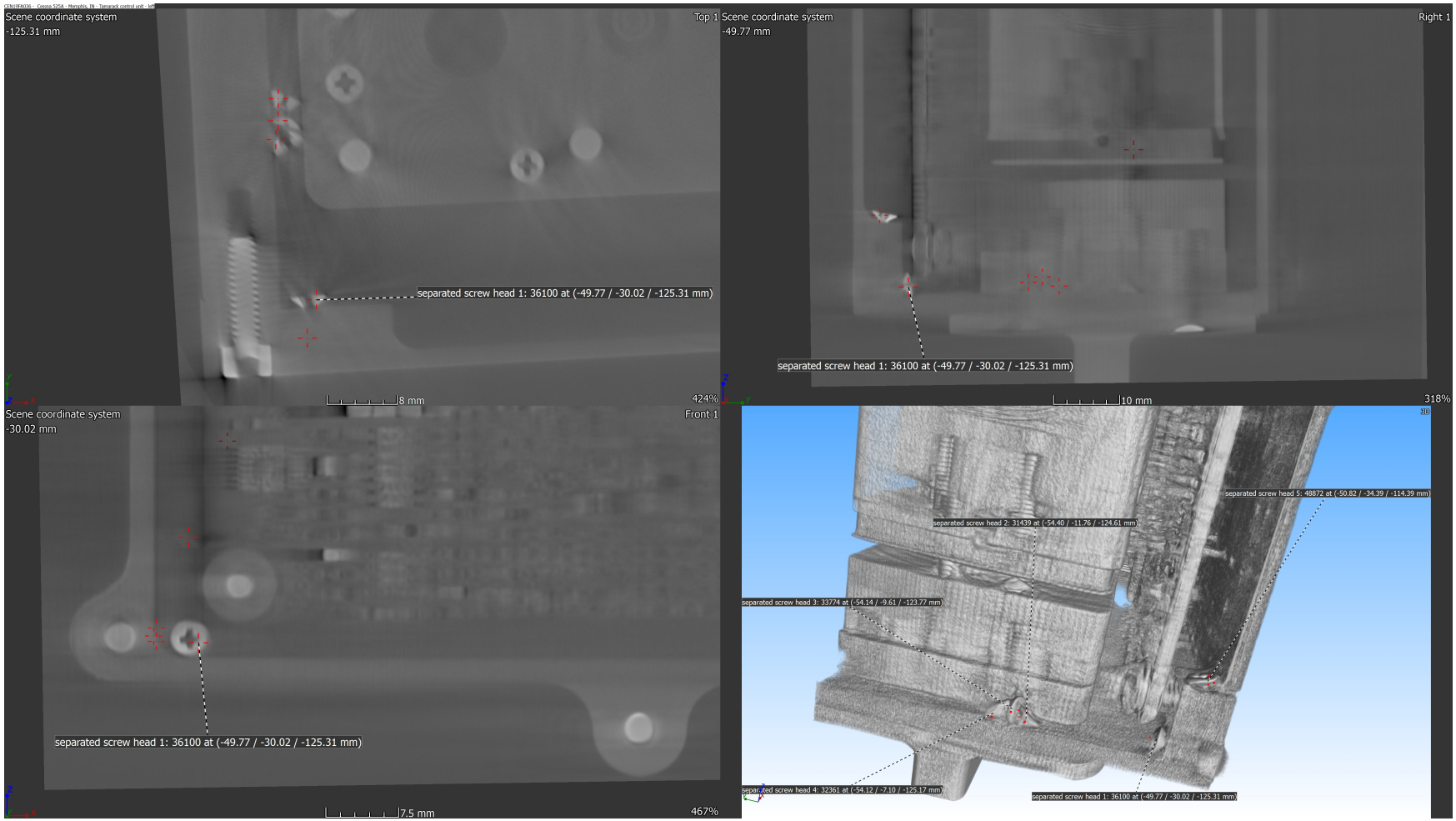


Figure 26
Left TACS control unit – separated screw head 1

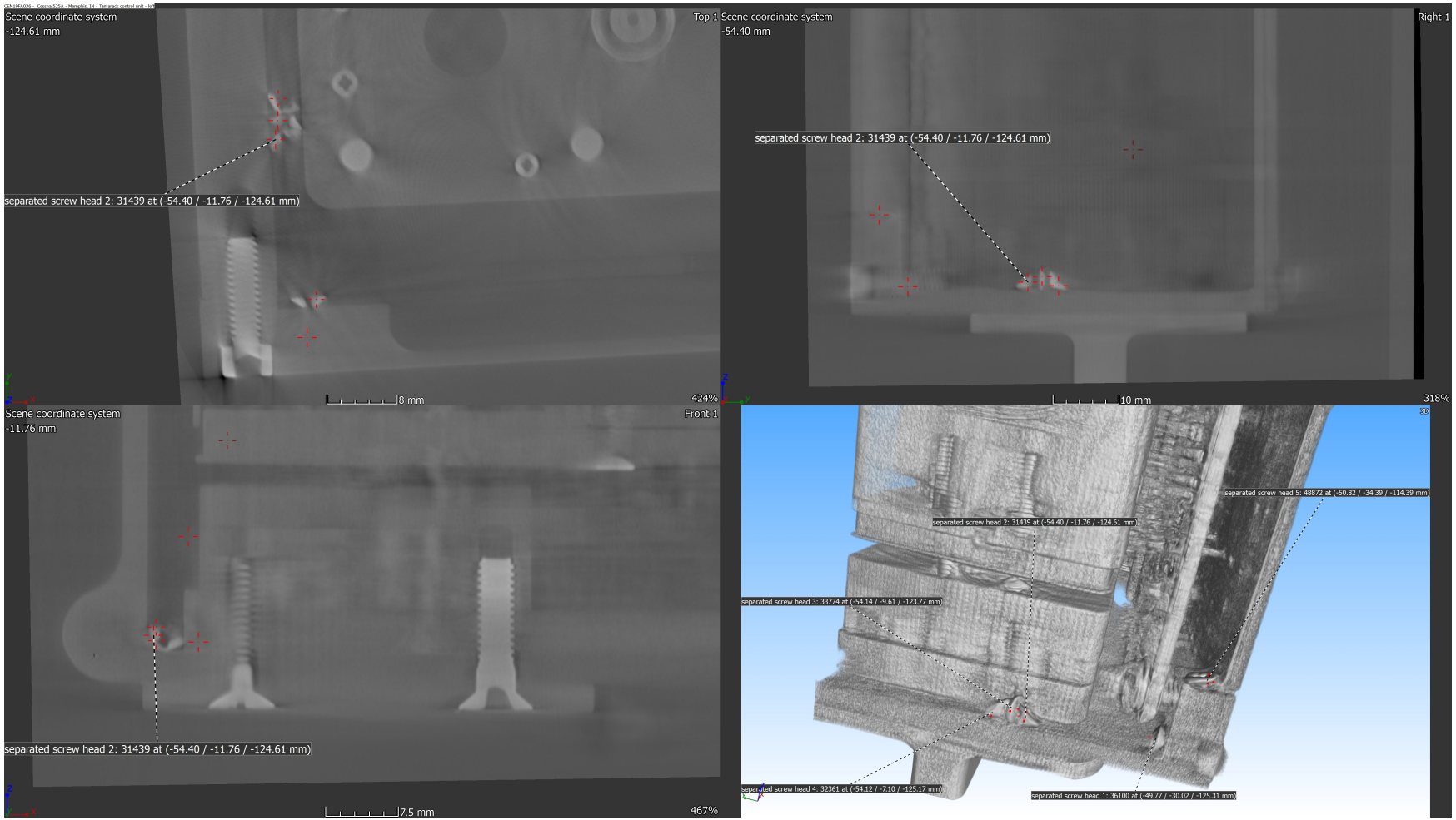


Figure 27
Left TACS control unit – separated screw head 2

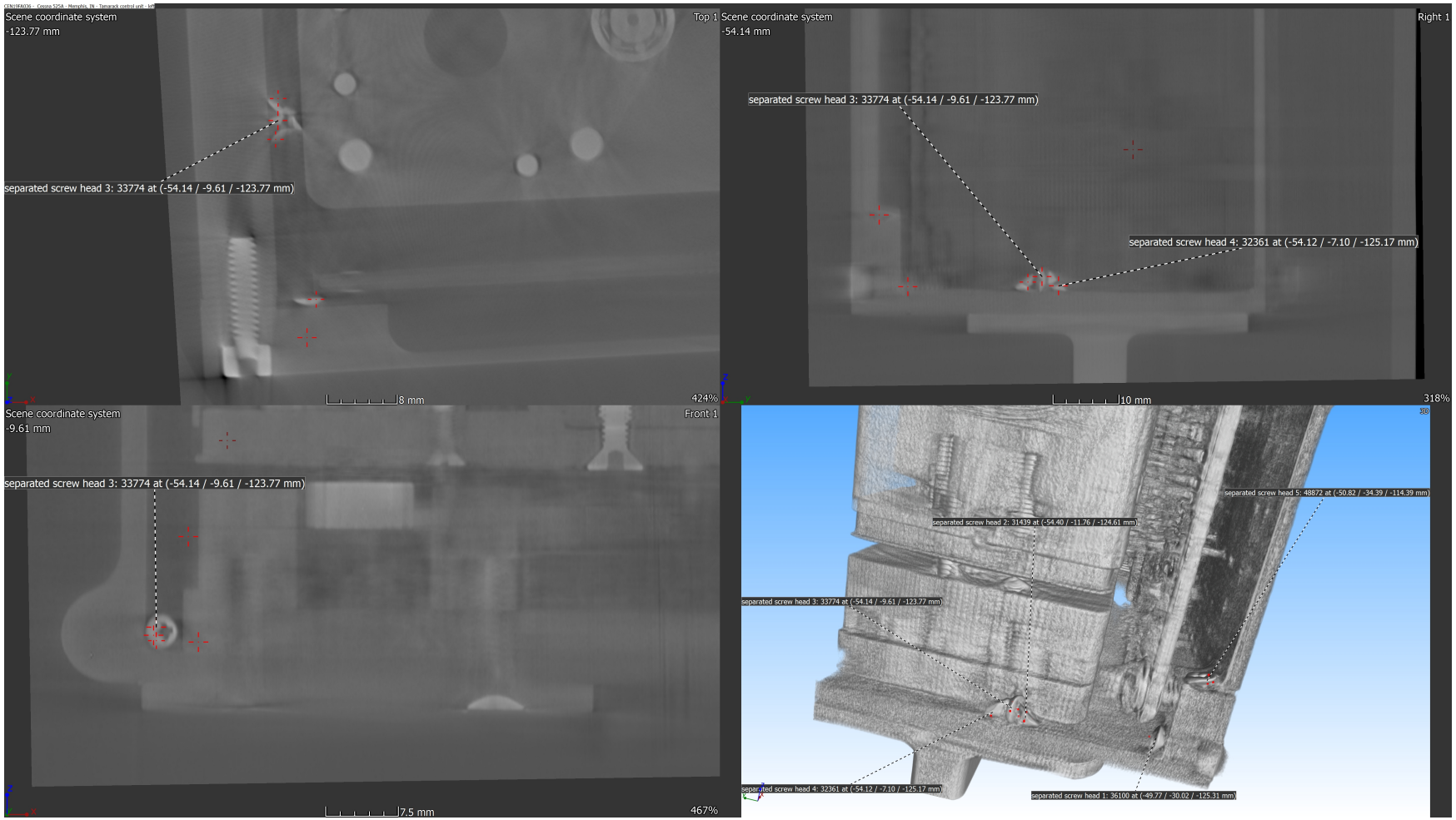


Figure 28
Left TACS control unit – separated screw head 3

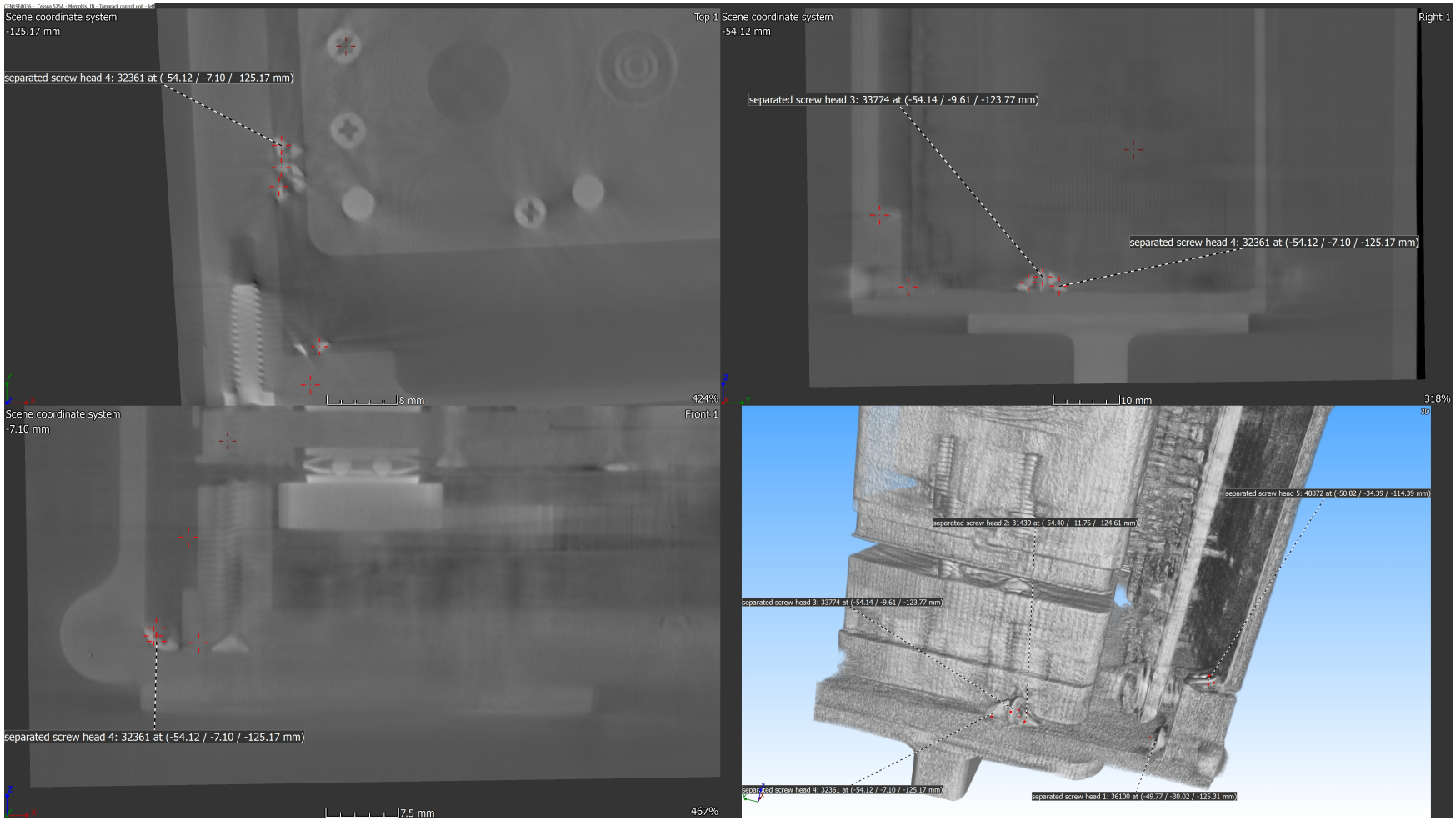


Figure 29
Left TACS control unit – separated screw head 4

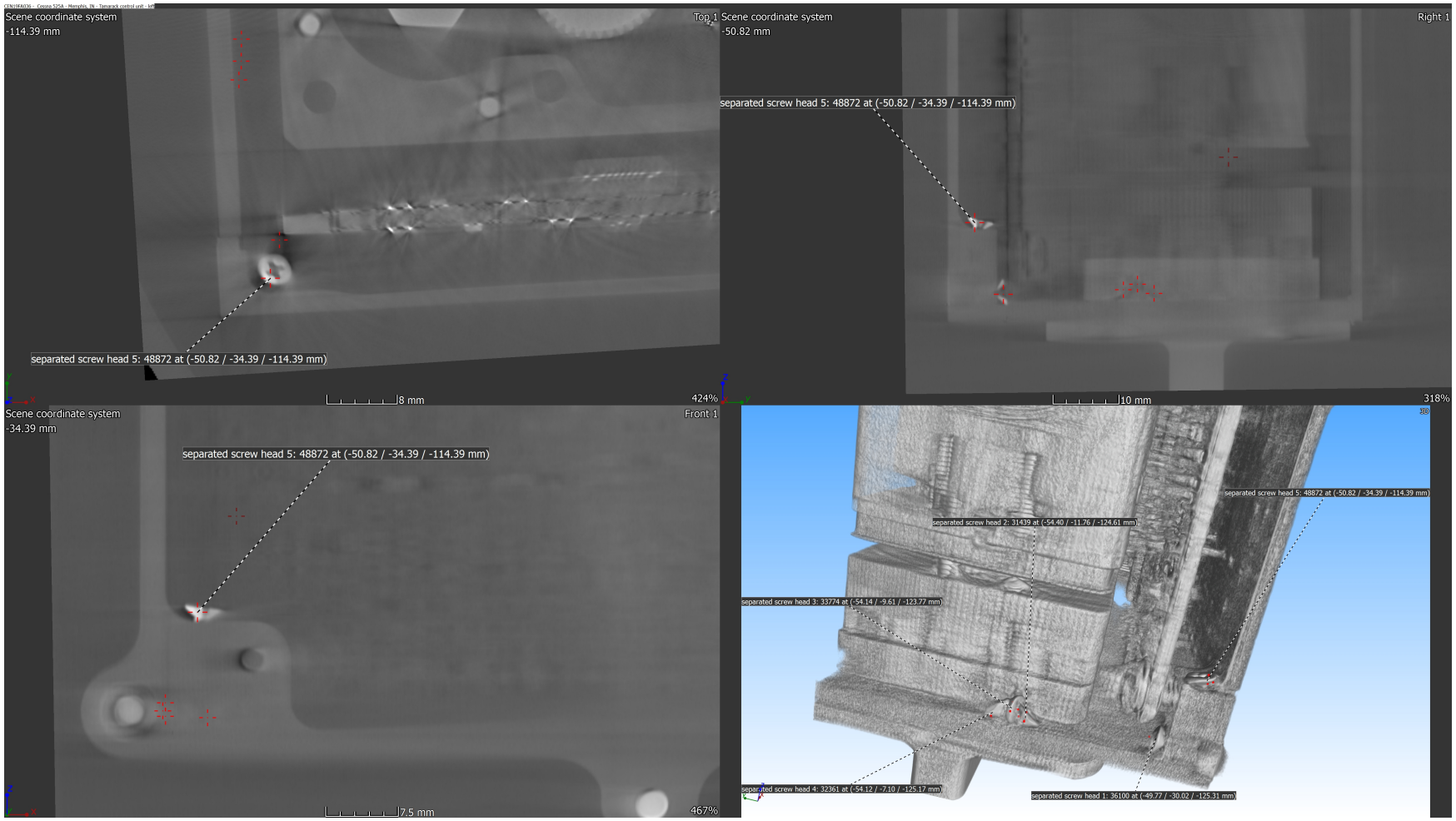


Figure 30
Left TACS control unit – separated screw head 5

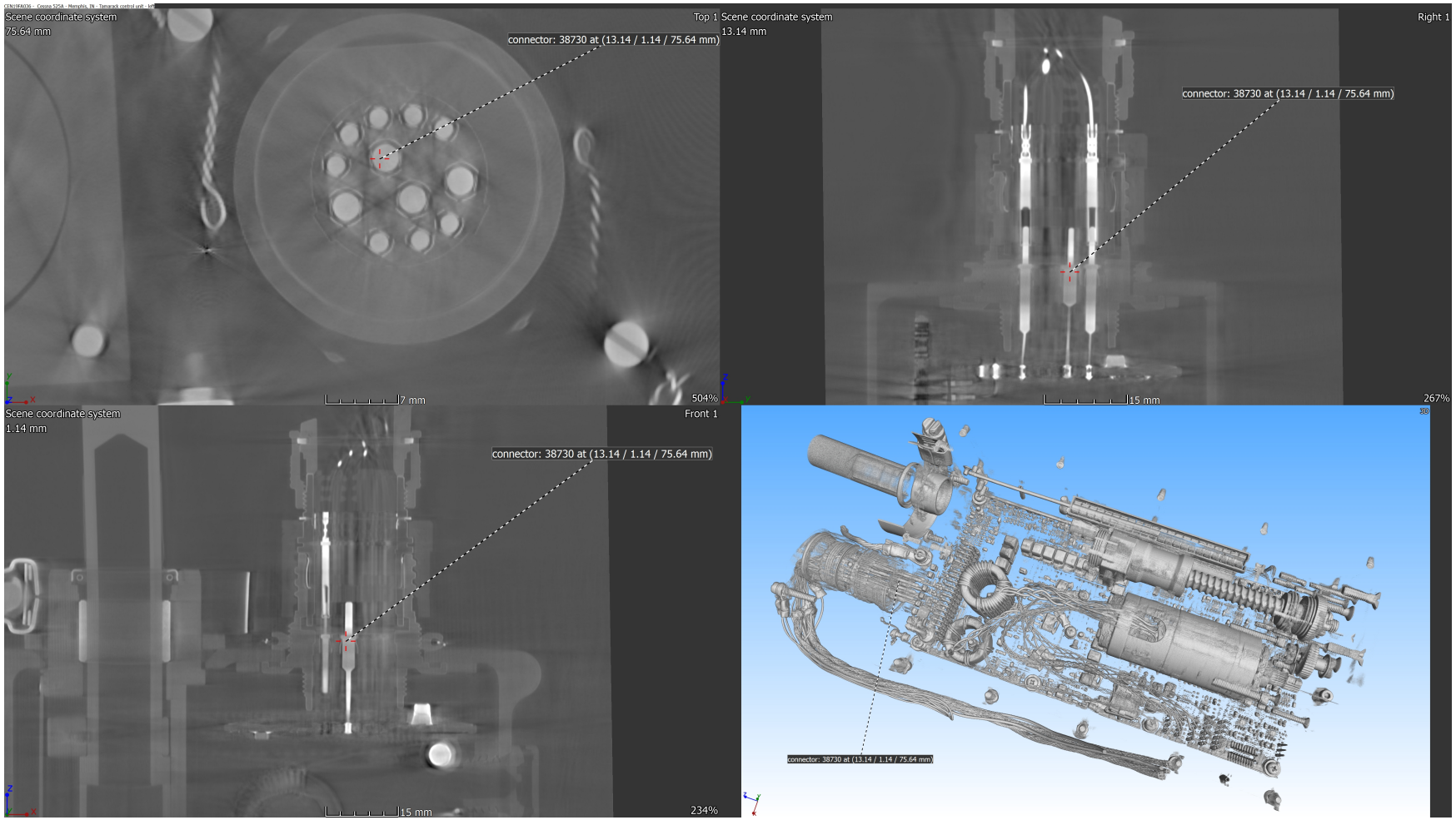


Figure 31
Left TACS control unit – connector

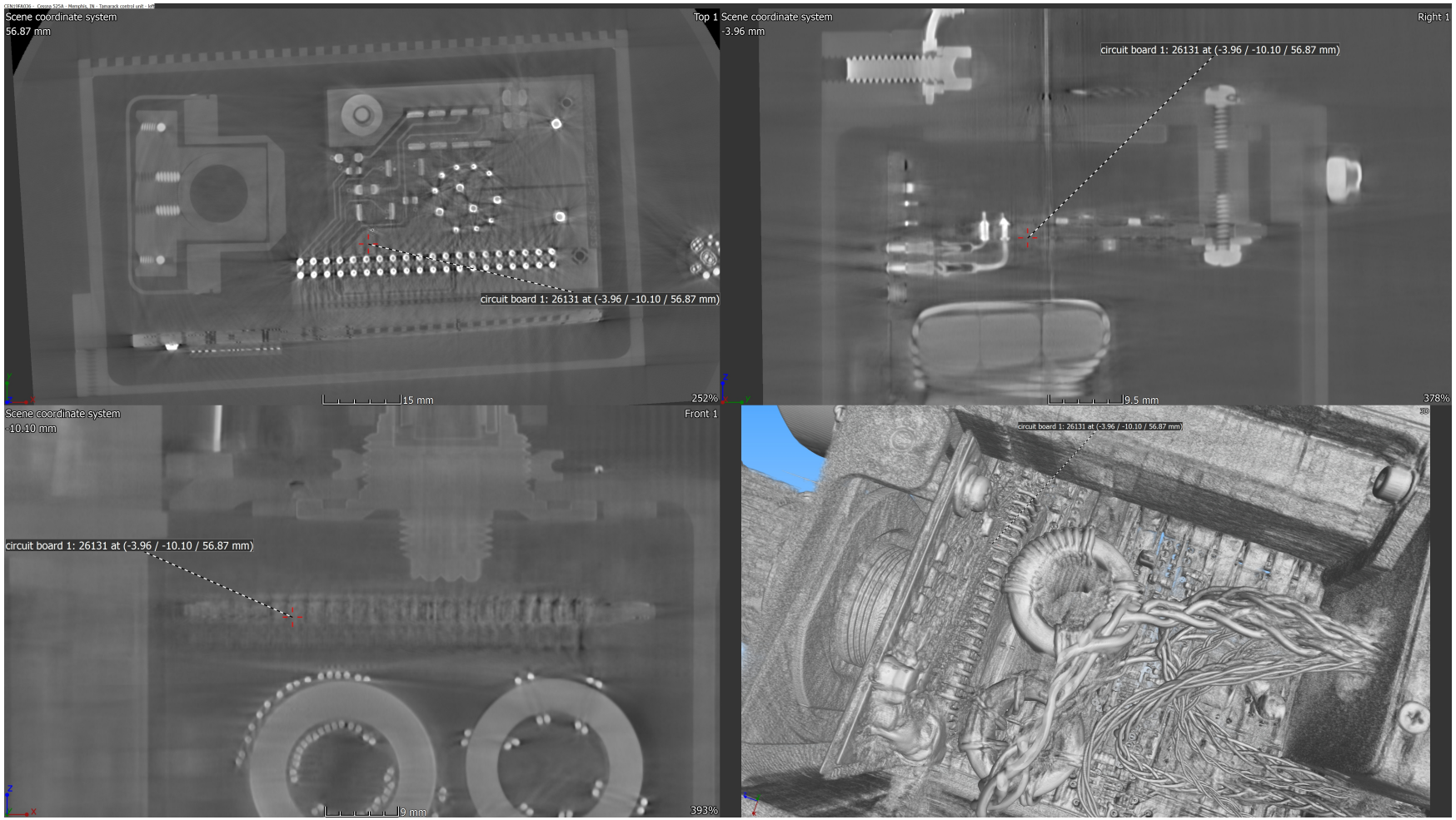


Figure 32
Left TACS control unit – circuit board 1

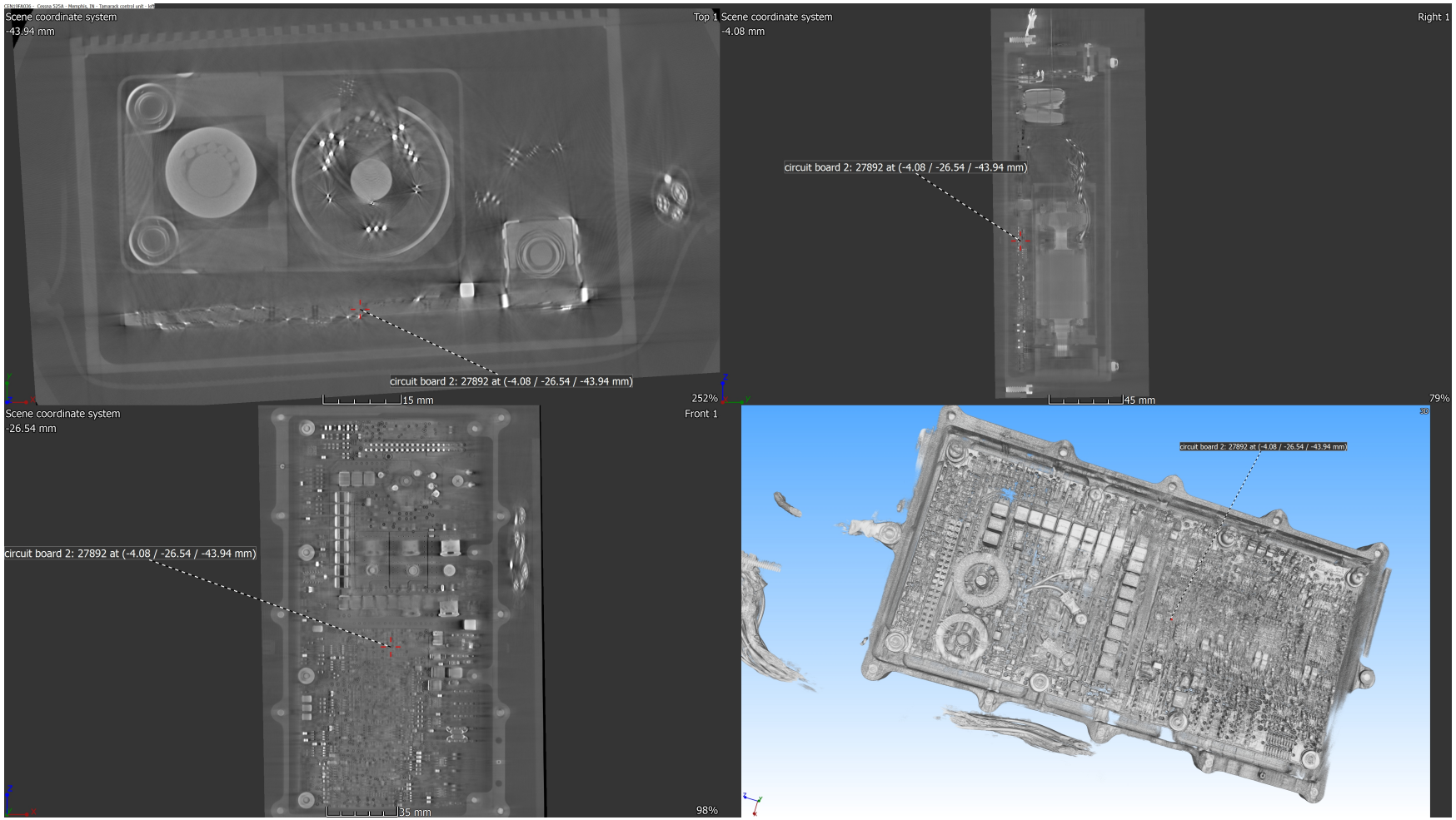


Figure 33
Left TACS control unit – circuit board 2

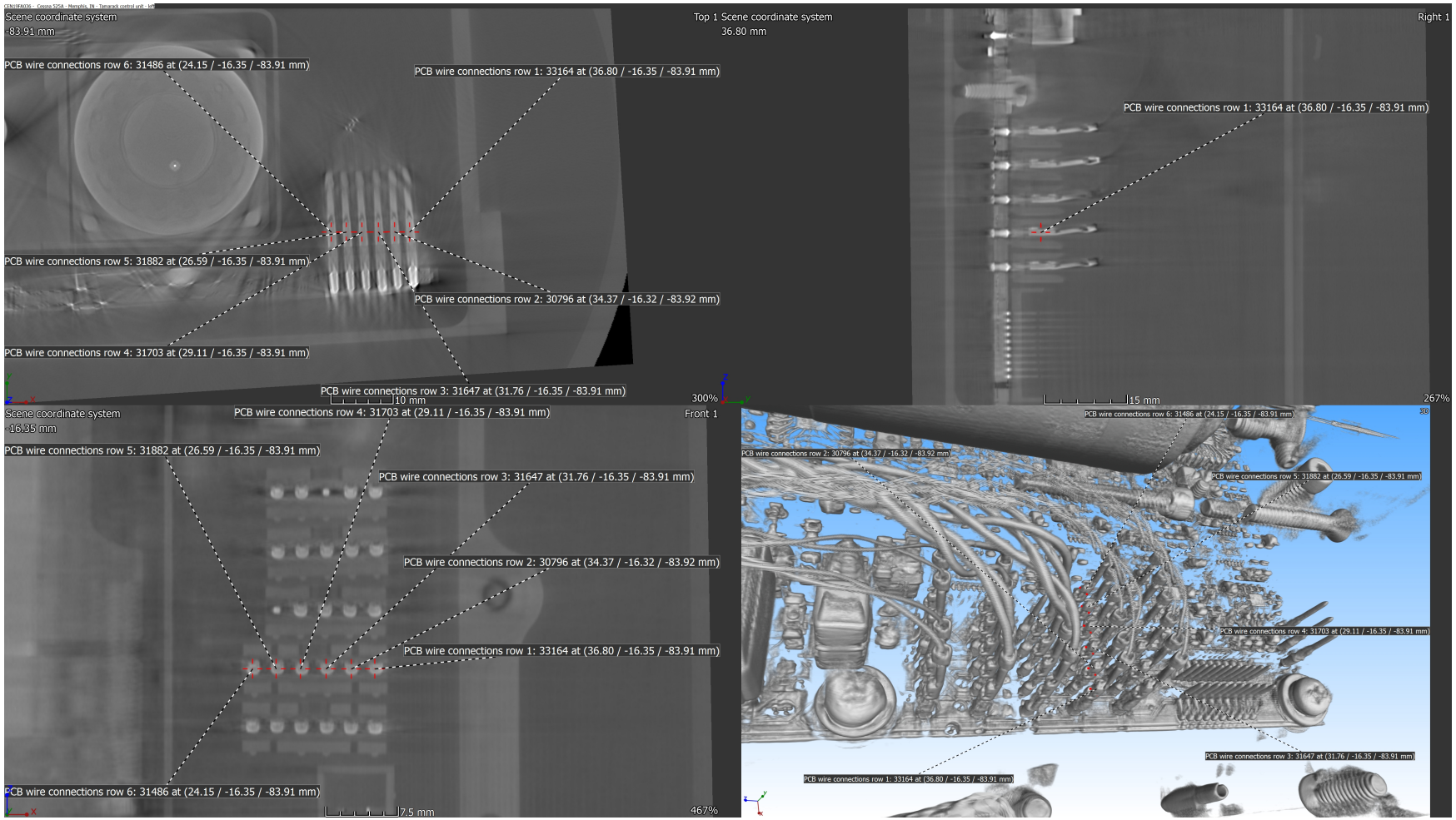


Figure 34
Left TACS control unit – printed circuit board (PCB) wire connections row 1

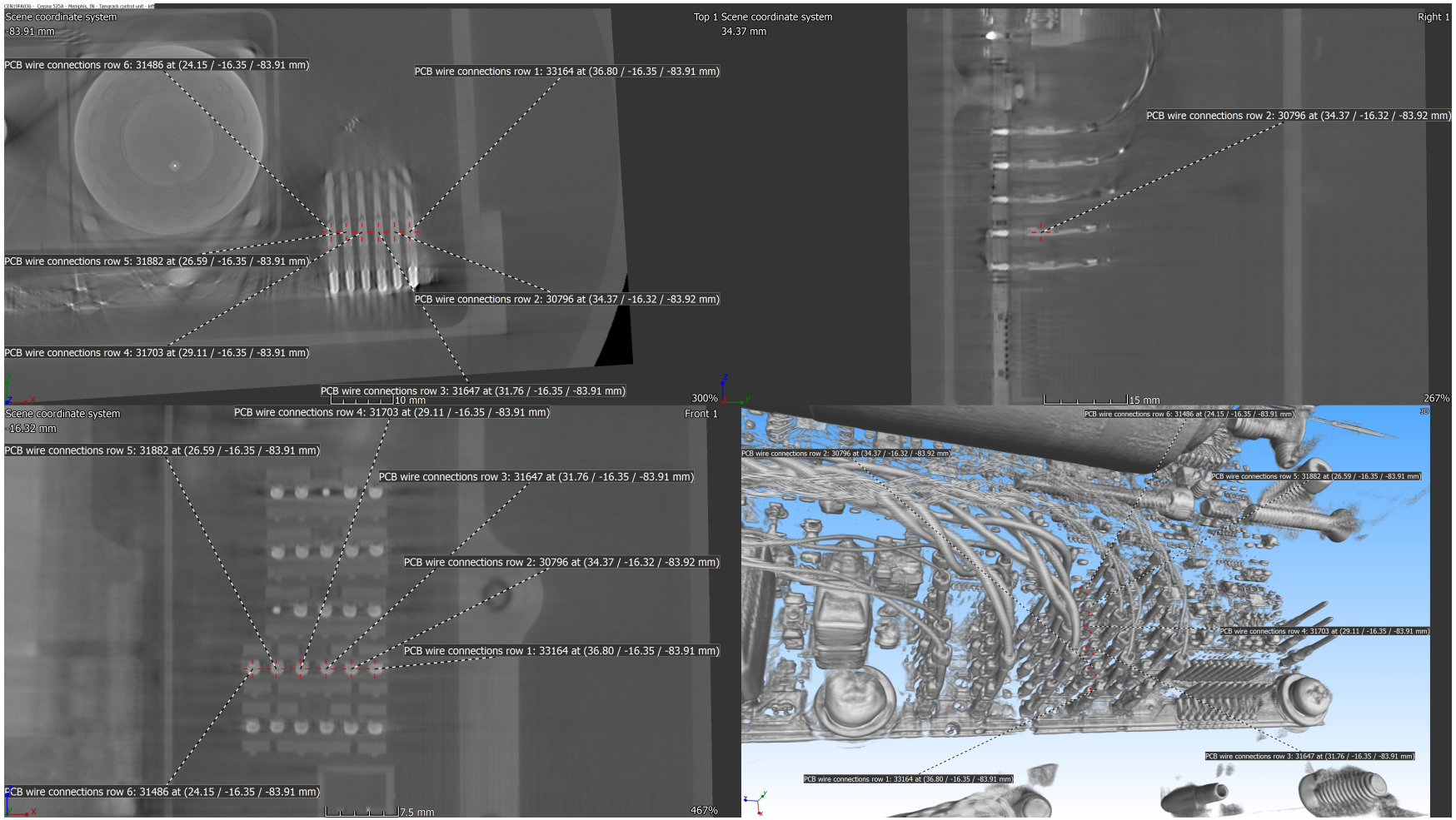


Figure 35
Left TACS control unit – PCB wire connections row 2

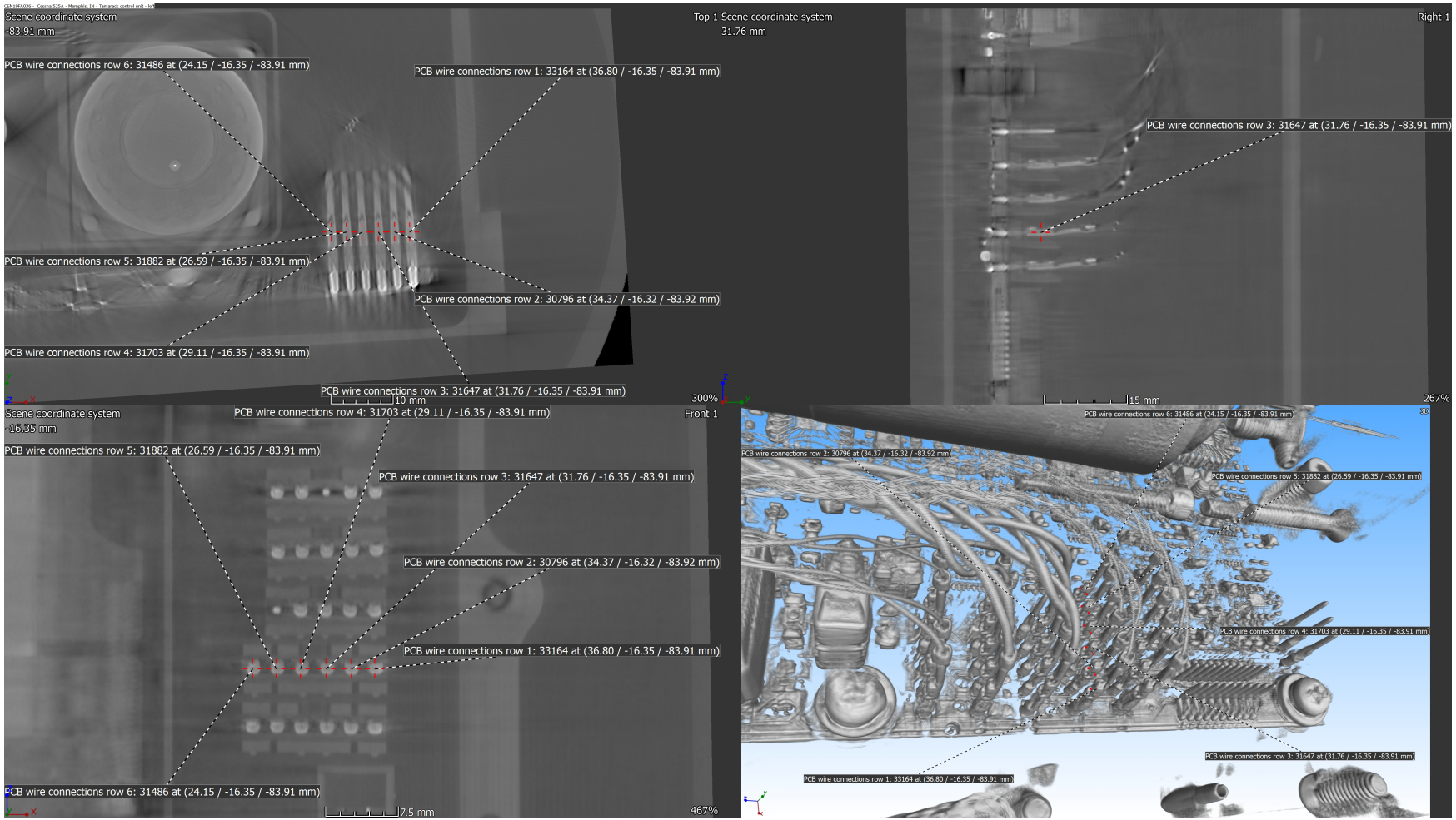


Figure 36
Left TACS control unit – PCB wire connections row 3

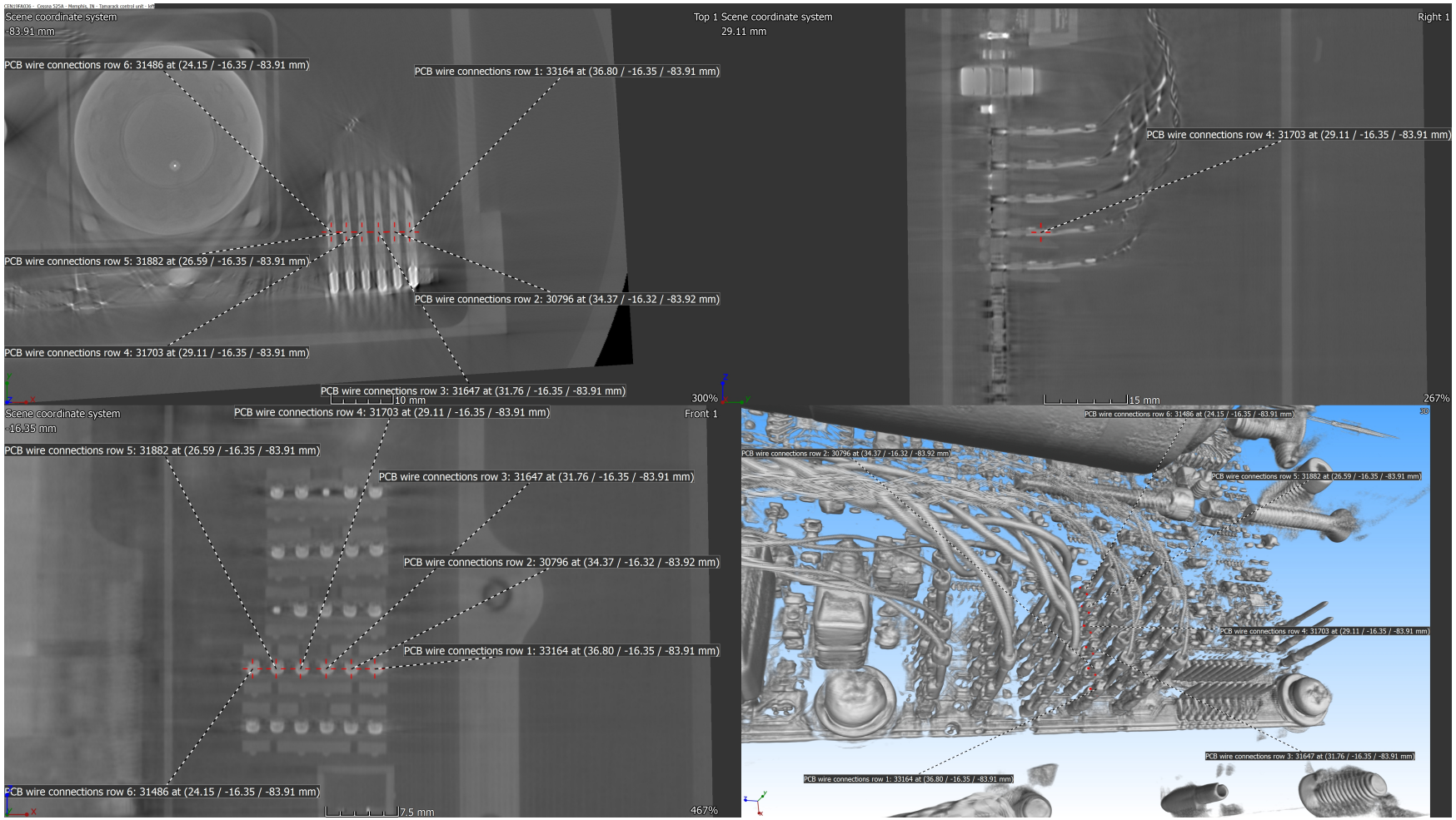


Figure 37
Left TACS control unit – PCB wire connections row 4

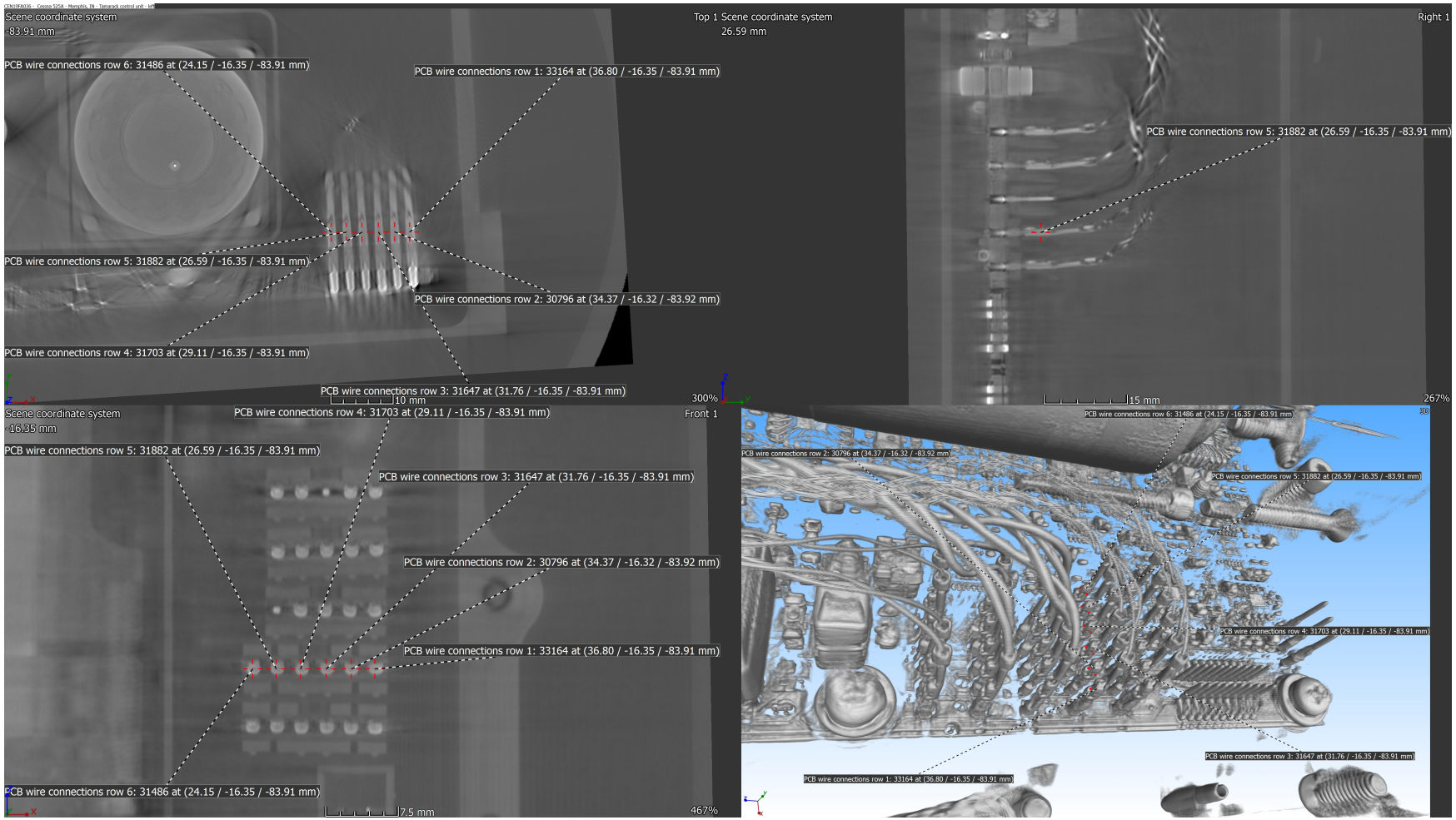


Figure 38
Left TACS control unit – PCB wire connections row 5

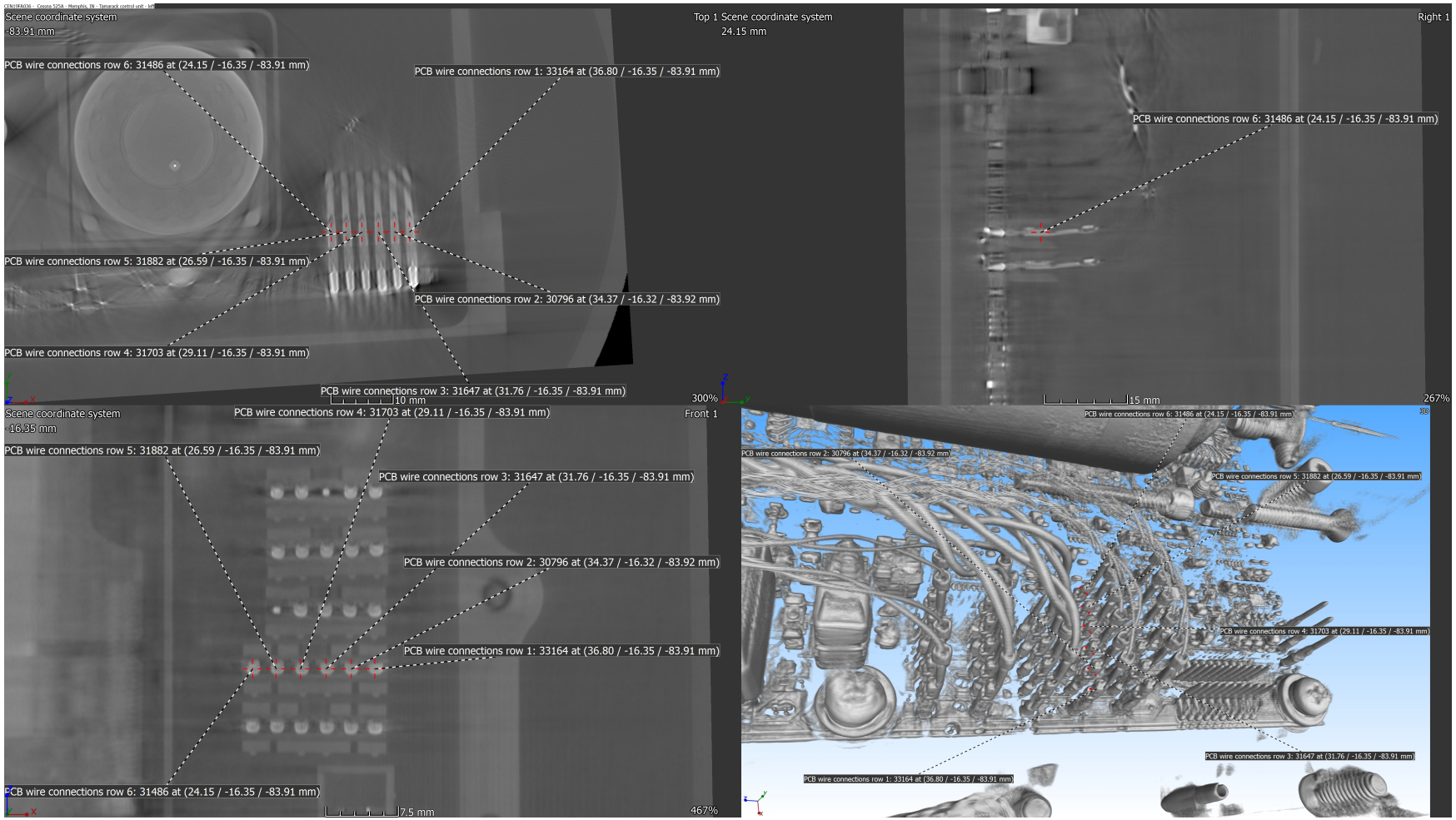


Figure 39
Left TACS control unit – PCB wire connections row 6

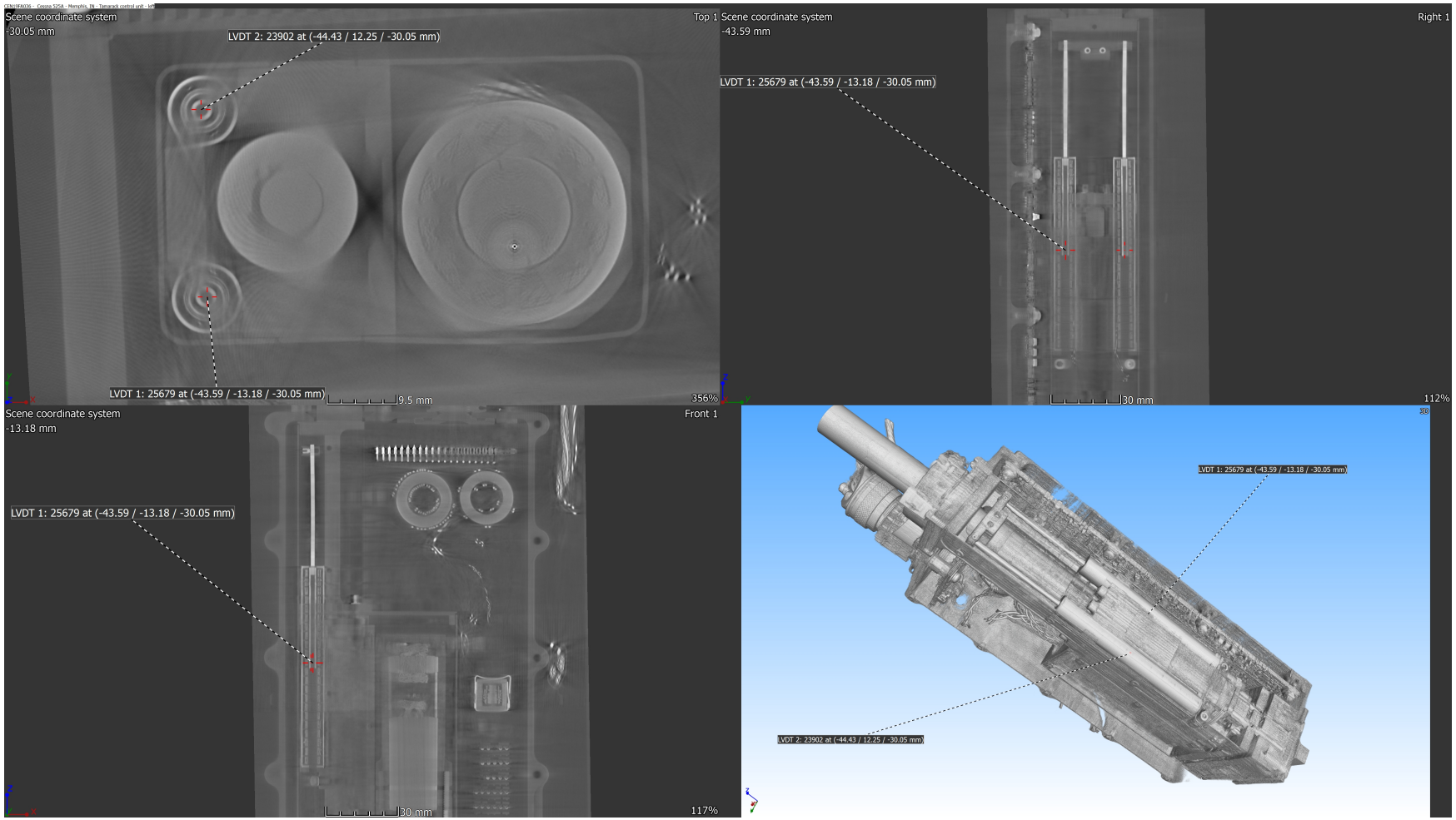


Figure 40
Left TACS control unit – LVDT 1

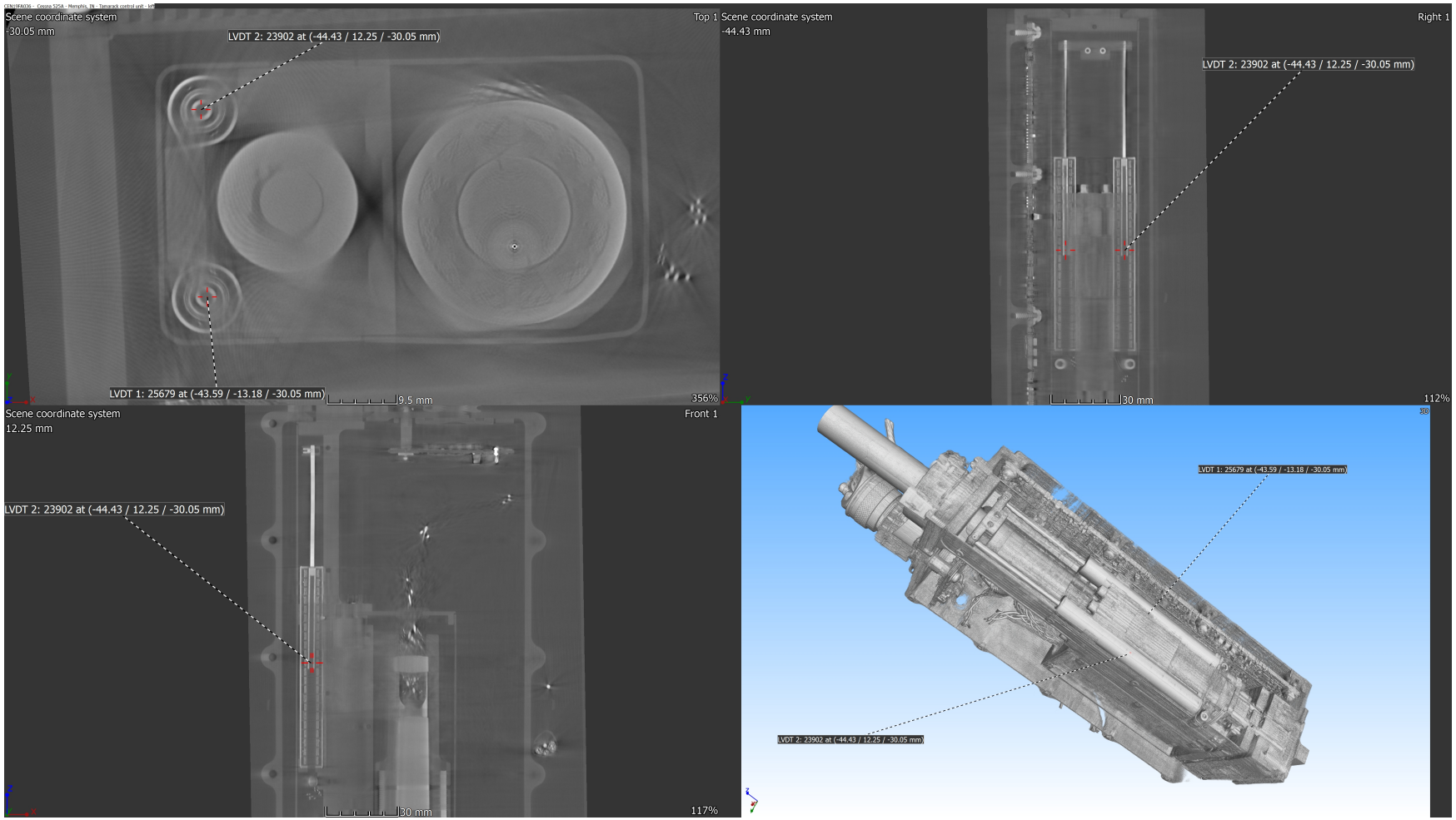


Figure 41
Left TACS control unit – LVDT 2

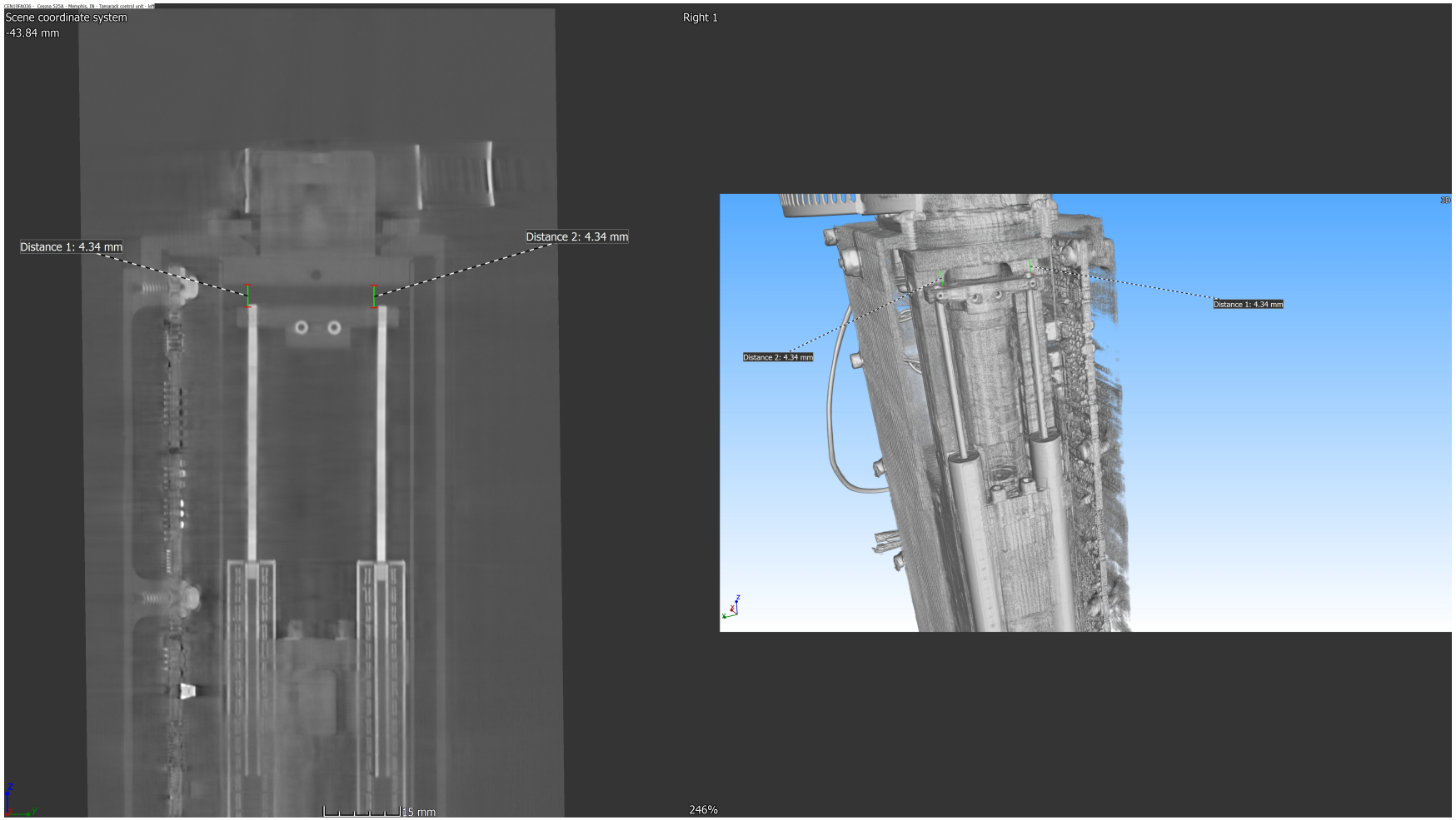


Figure 42
Left TACS control unit – LVDT to housing distance

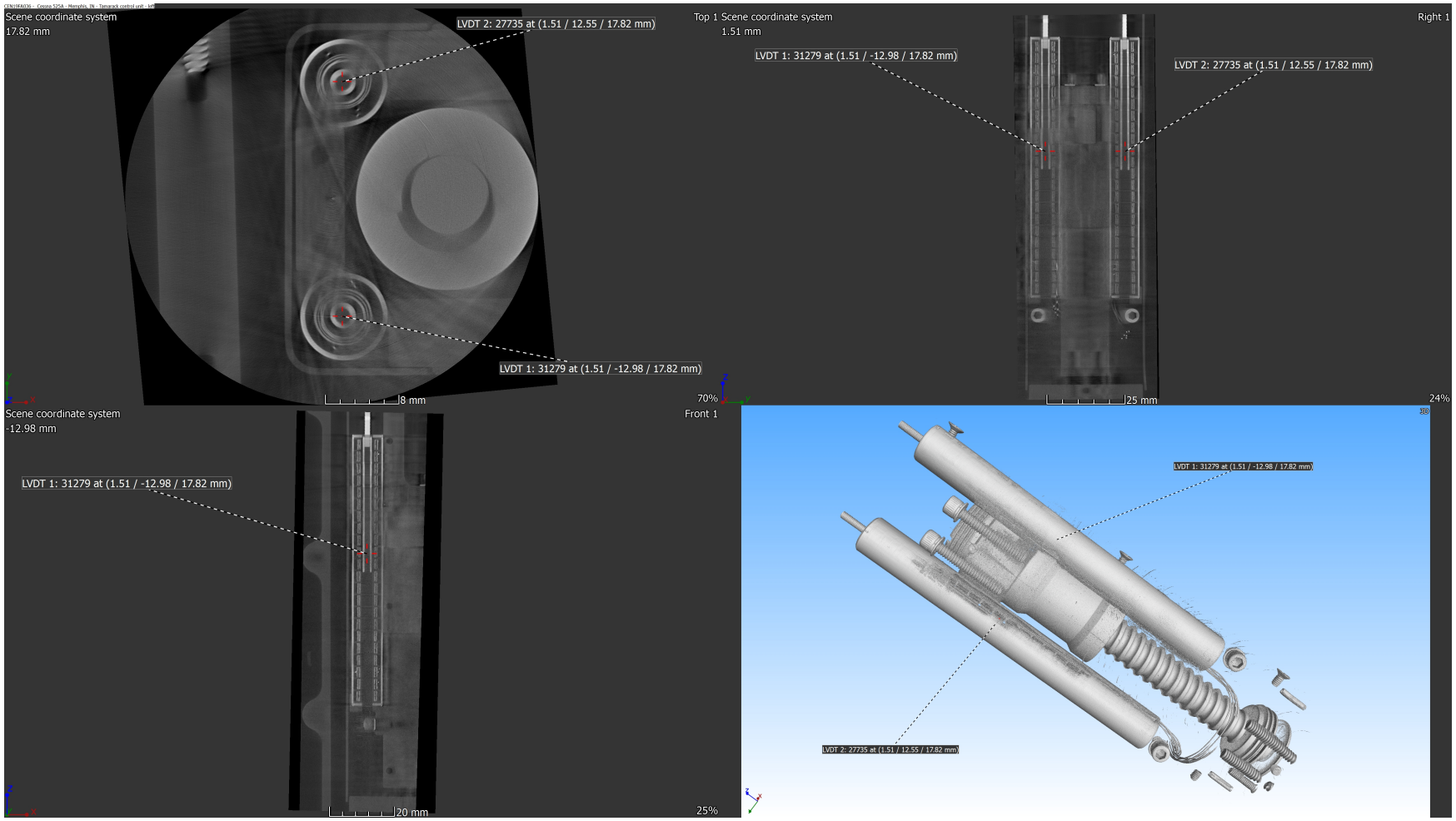


Figure 43
Left TACS control unit – target CT - LVDT 1

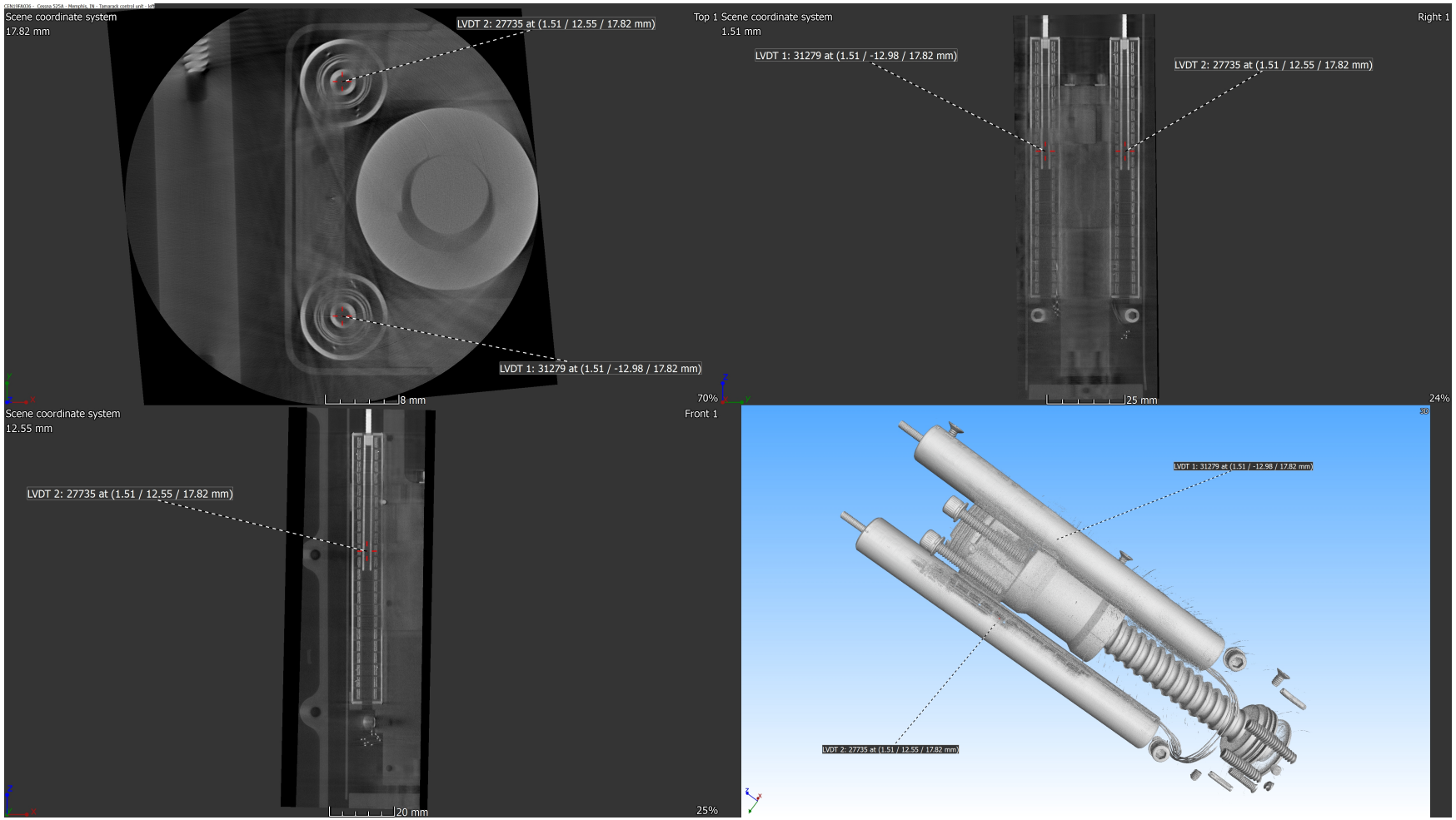


Figure 44
Left TACS control unit – target CT - LVDT 2

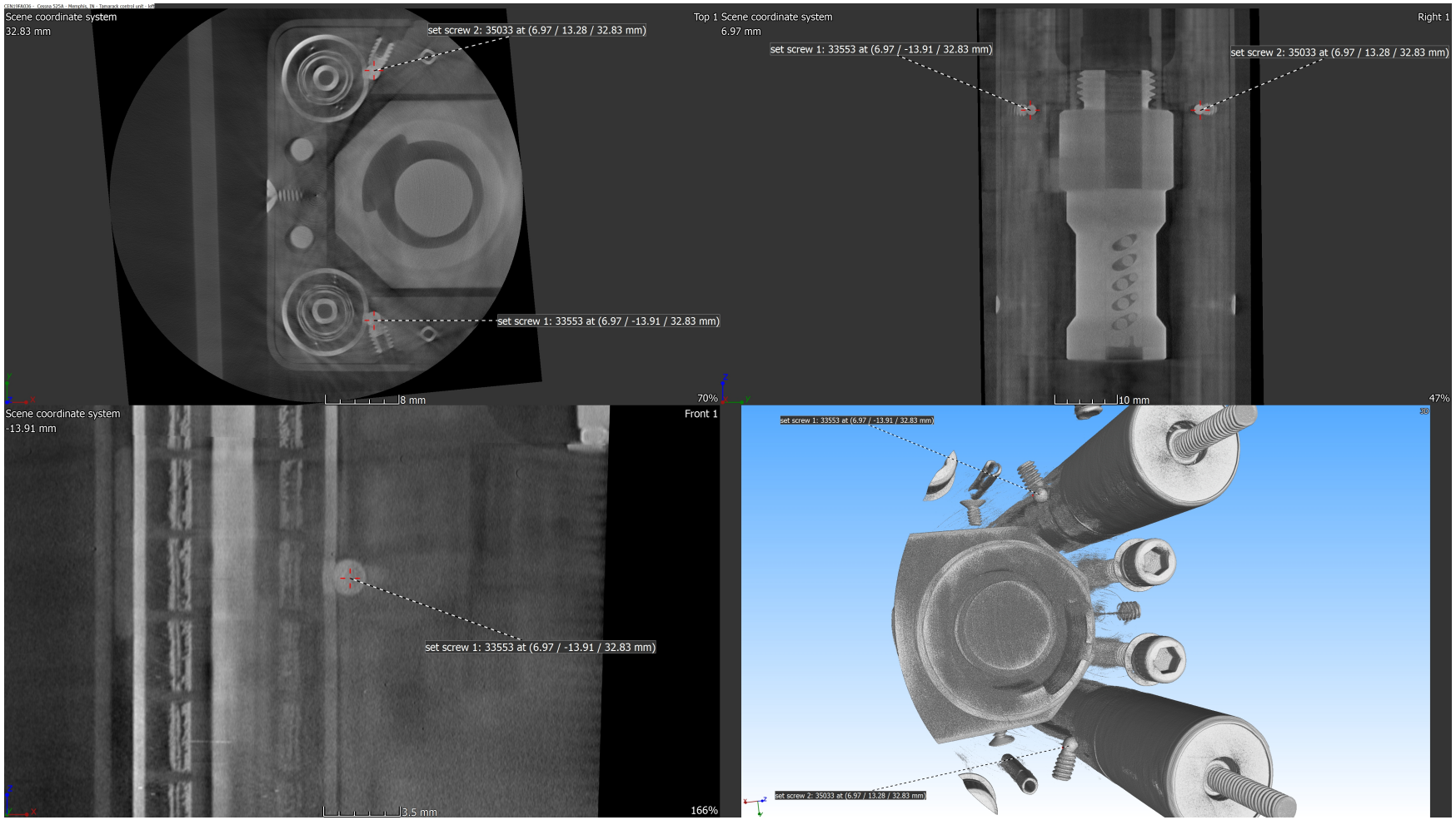


Figure 45
Left TACS control unit – target CT – set screw 1

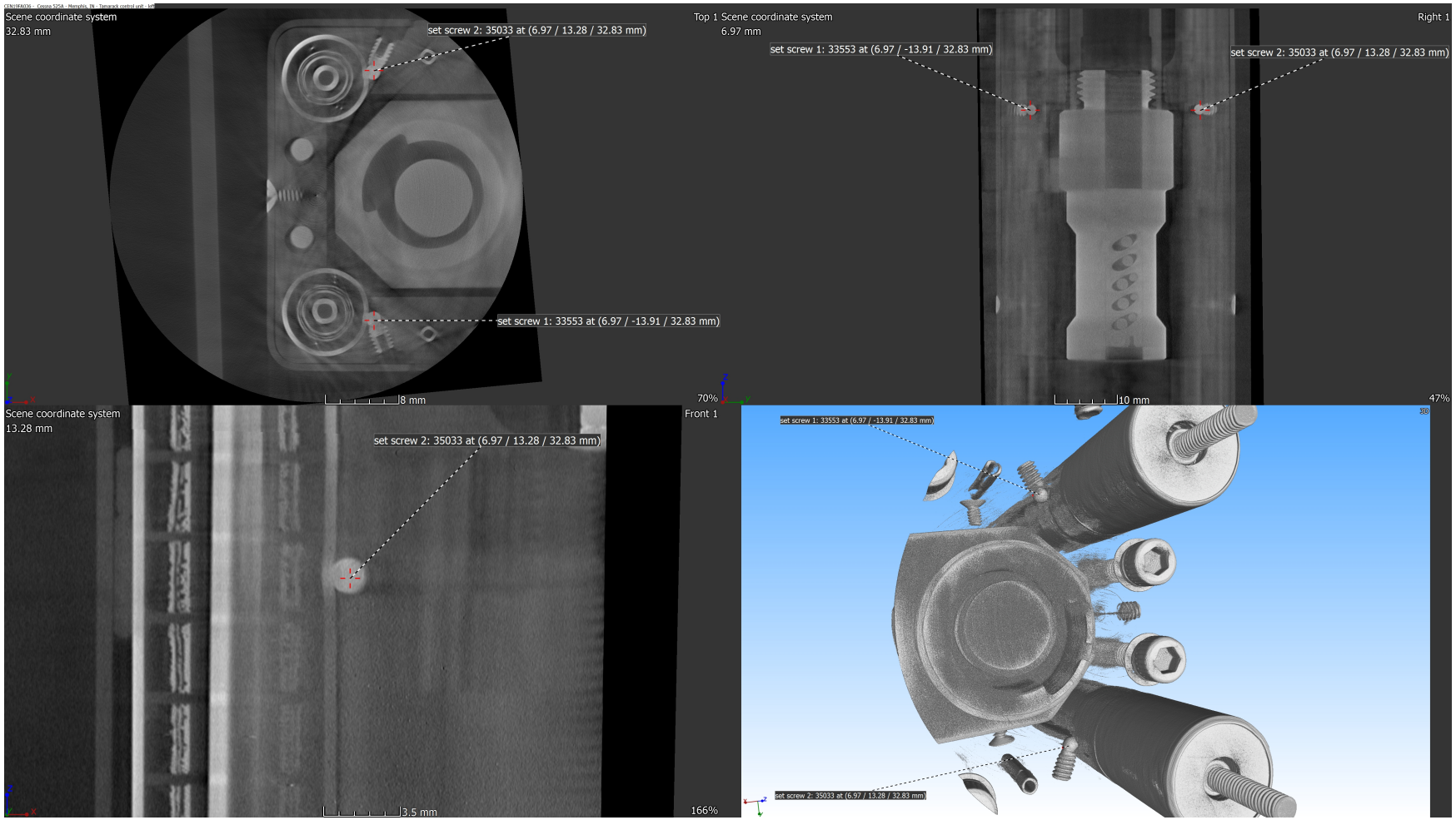


Figure 46
Left TACS control unit – target CT – set screw 2

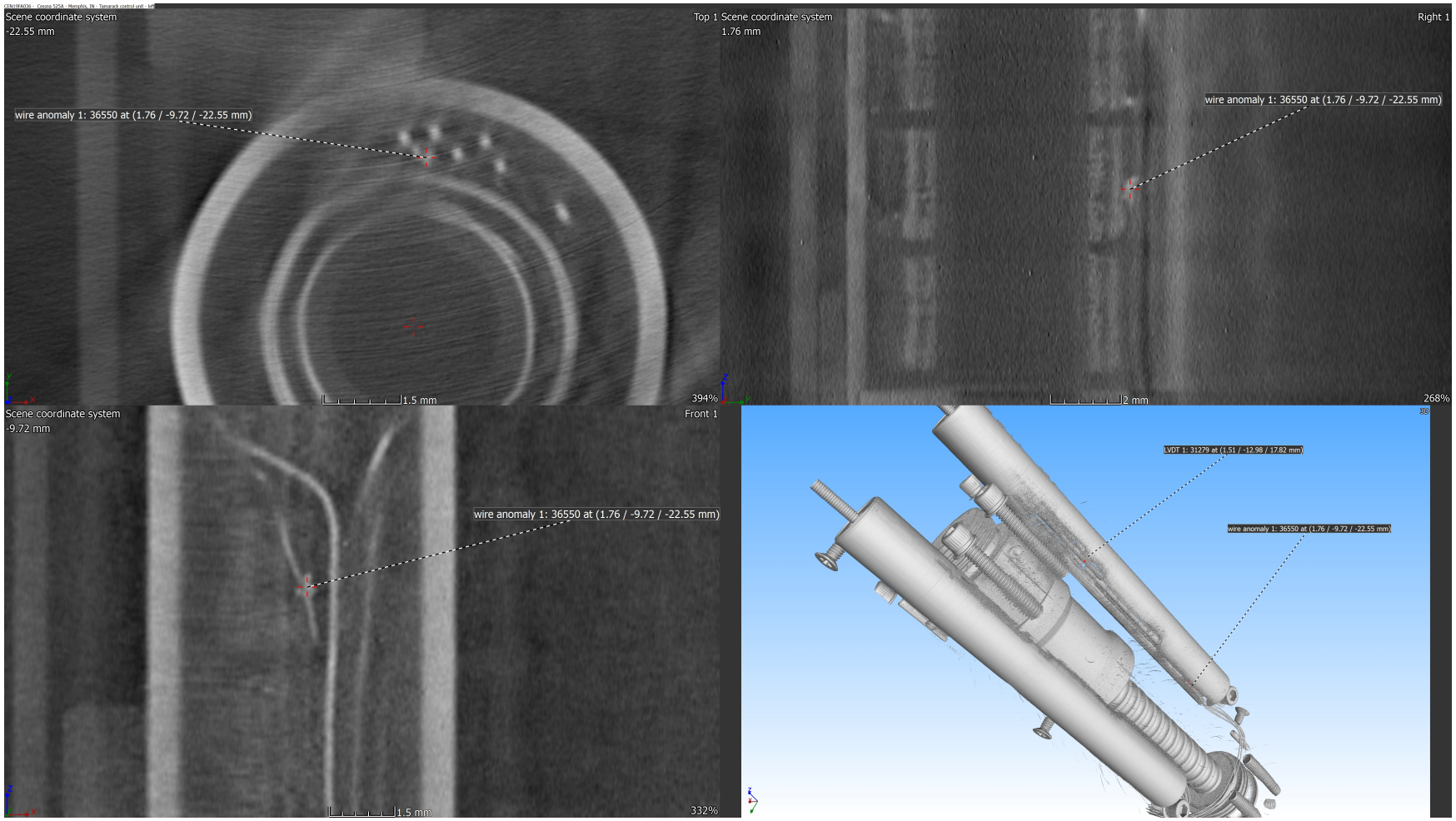


Figure 47
Left TACS control unit – target CT – wire anomaly 1

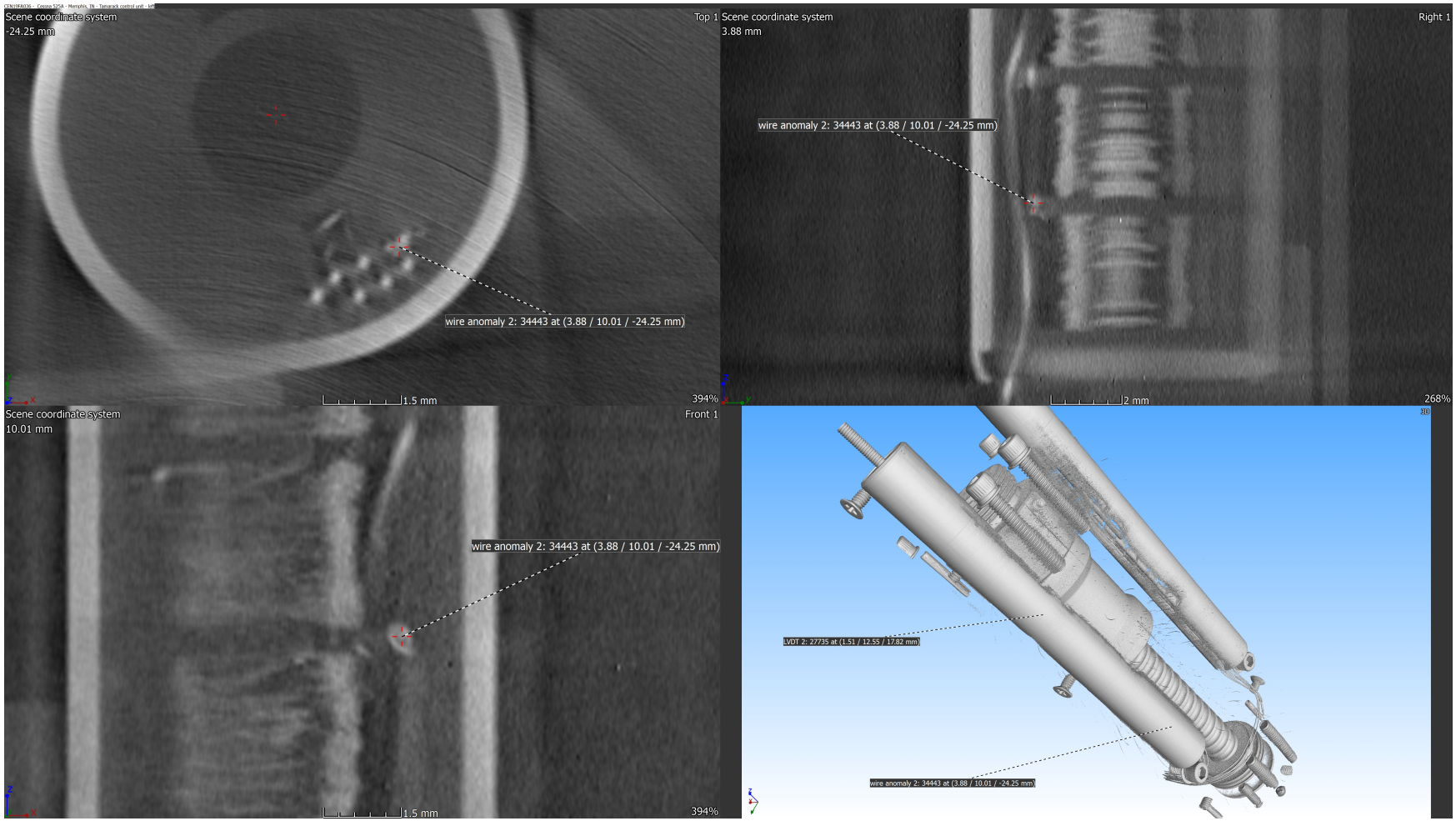


Figure 48
Left TACS control unit – target CT – wire anomaly 2

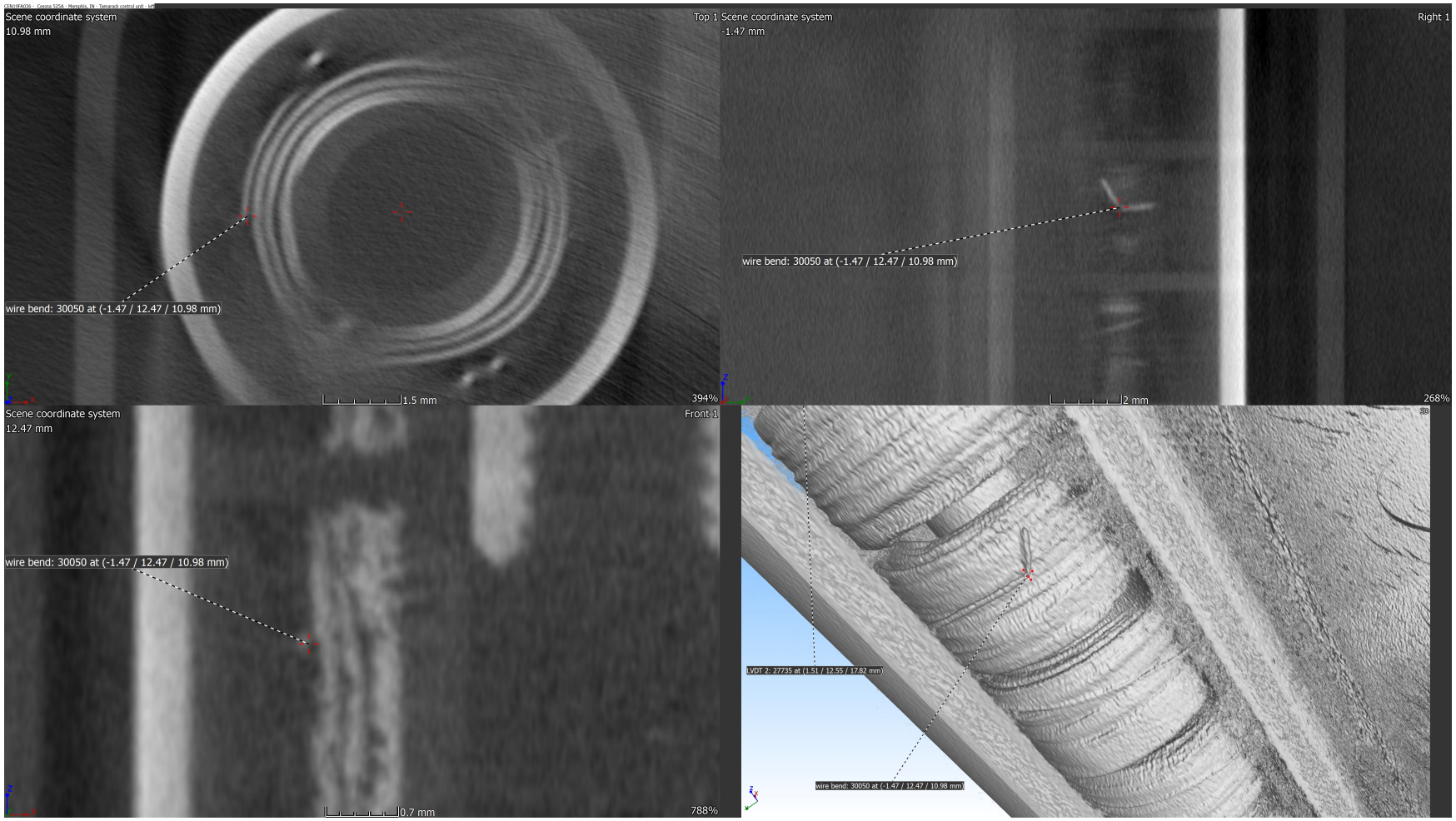


Figure 49
Left TACS control unit – target CT – LVDT 2 – wire bend

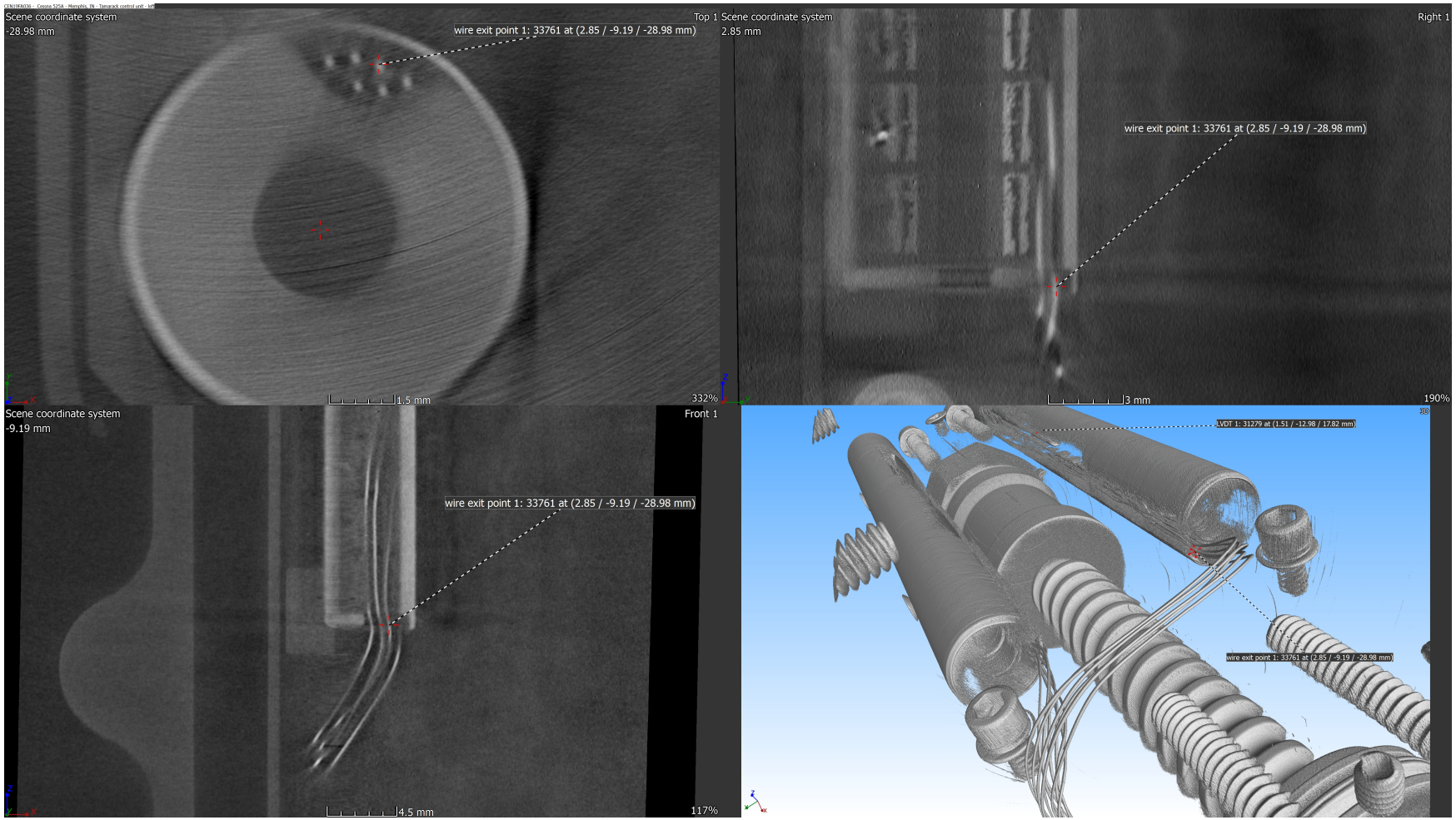


Figure 50
Left TACS control unit – target CT – wire exit point 1

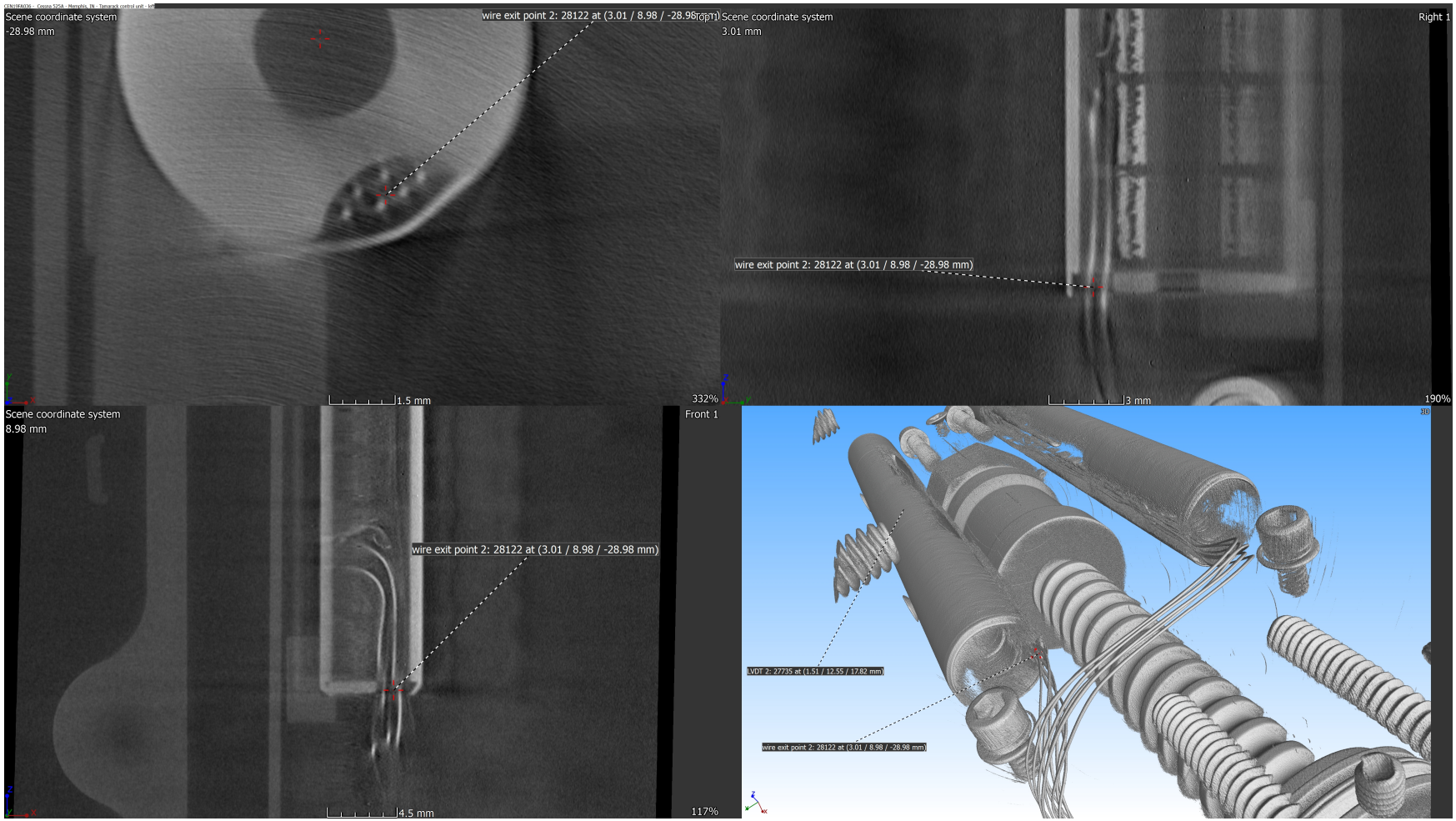


Figure 51
Left TACS control unit – target CT – wire exit point 2

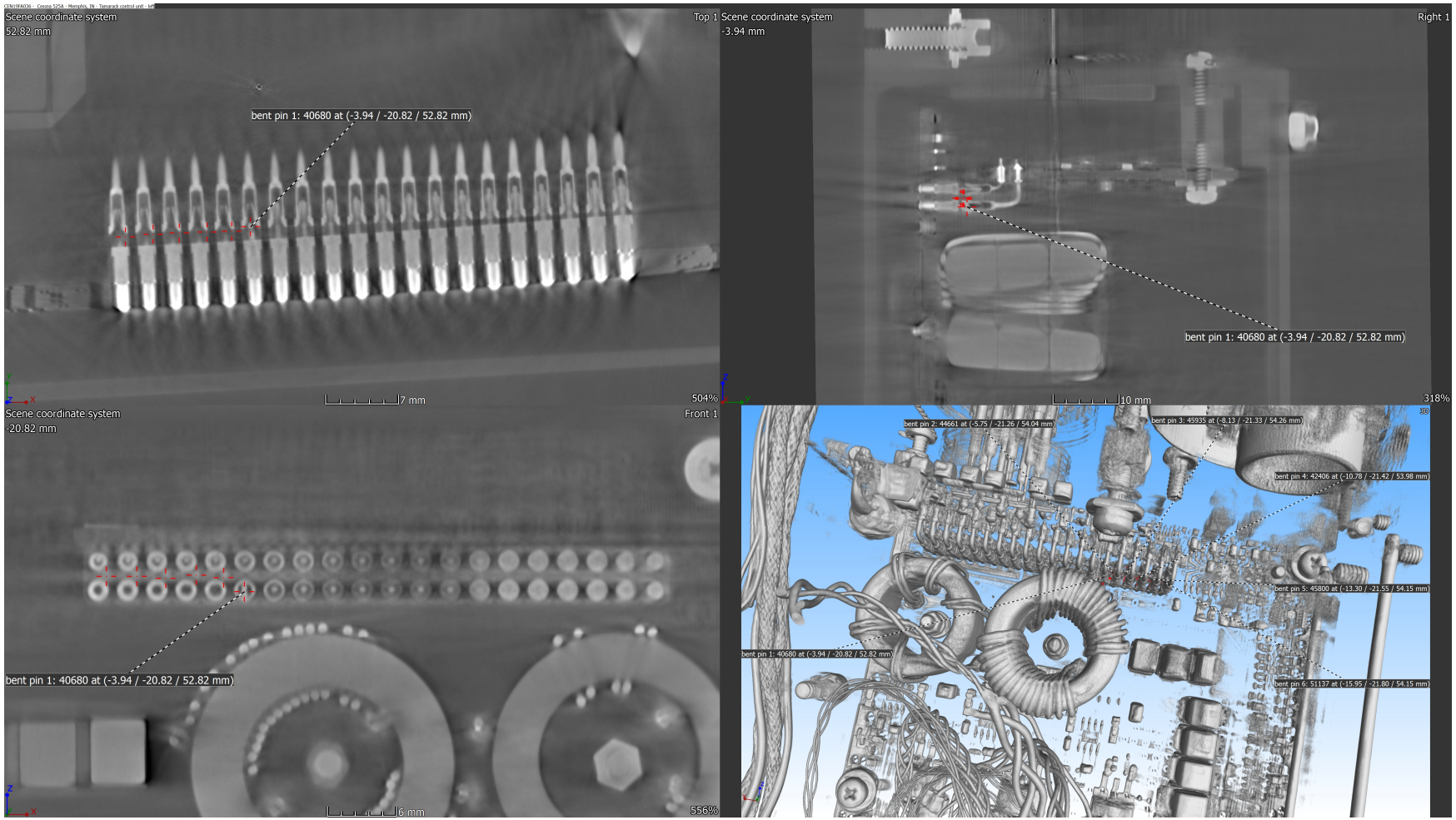


Figure 52
Left TACS control unit – 40 pin connector showing bent pins

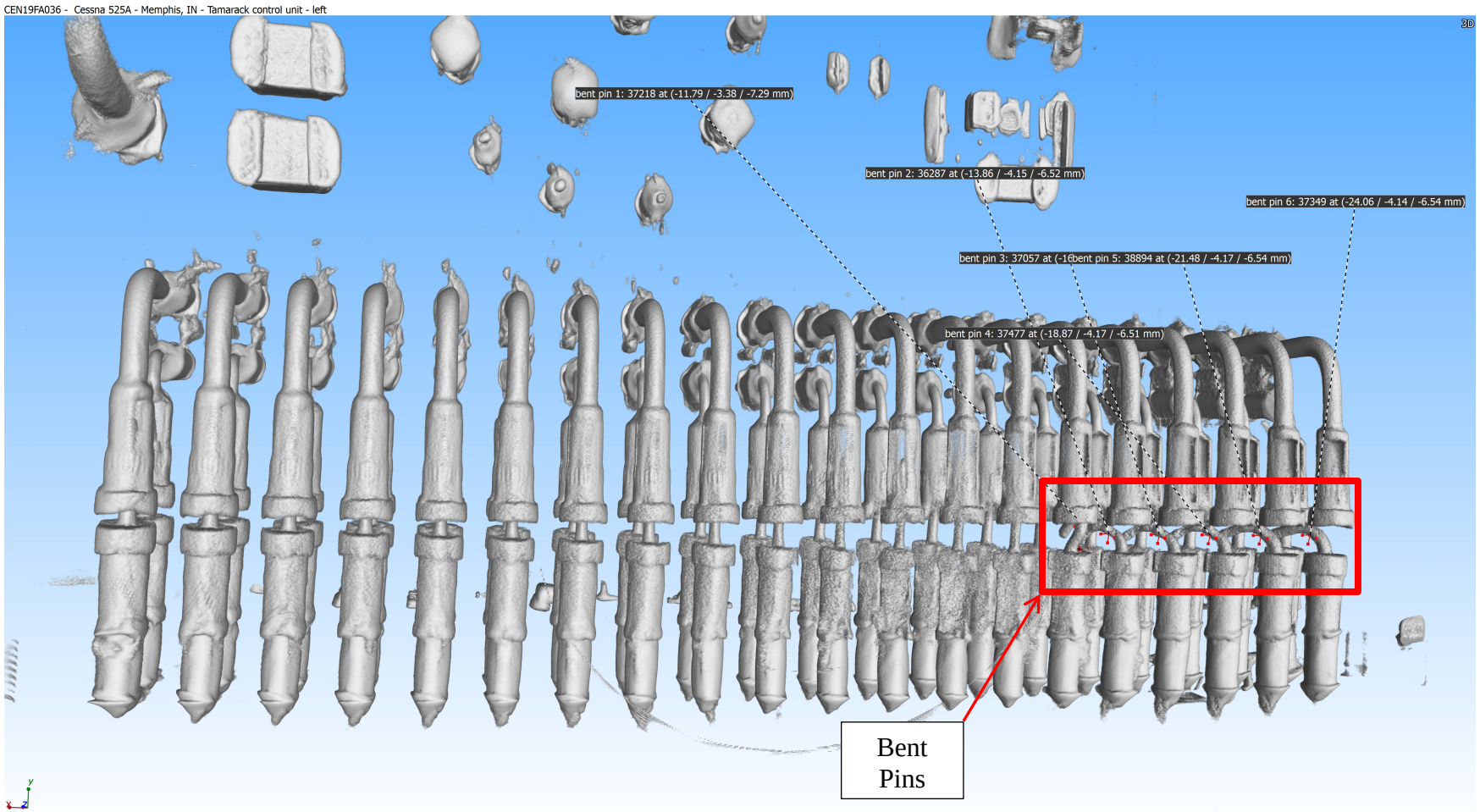


Figure 53
Left TACS control unit – target CT – bent pins overview

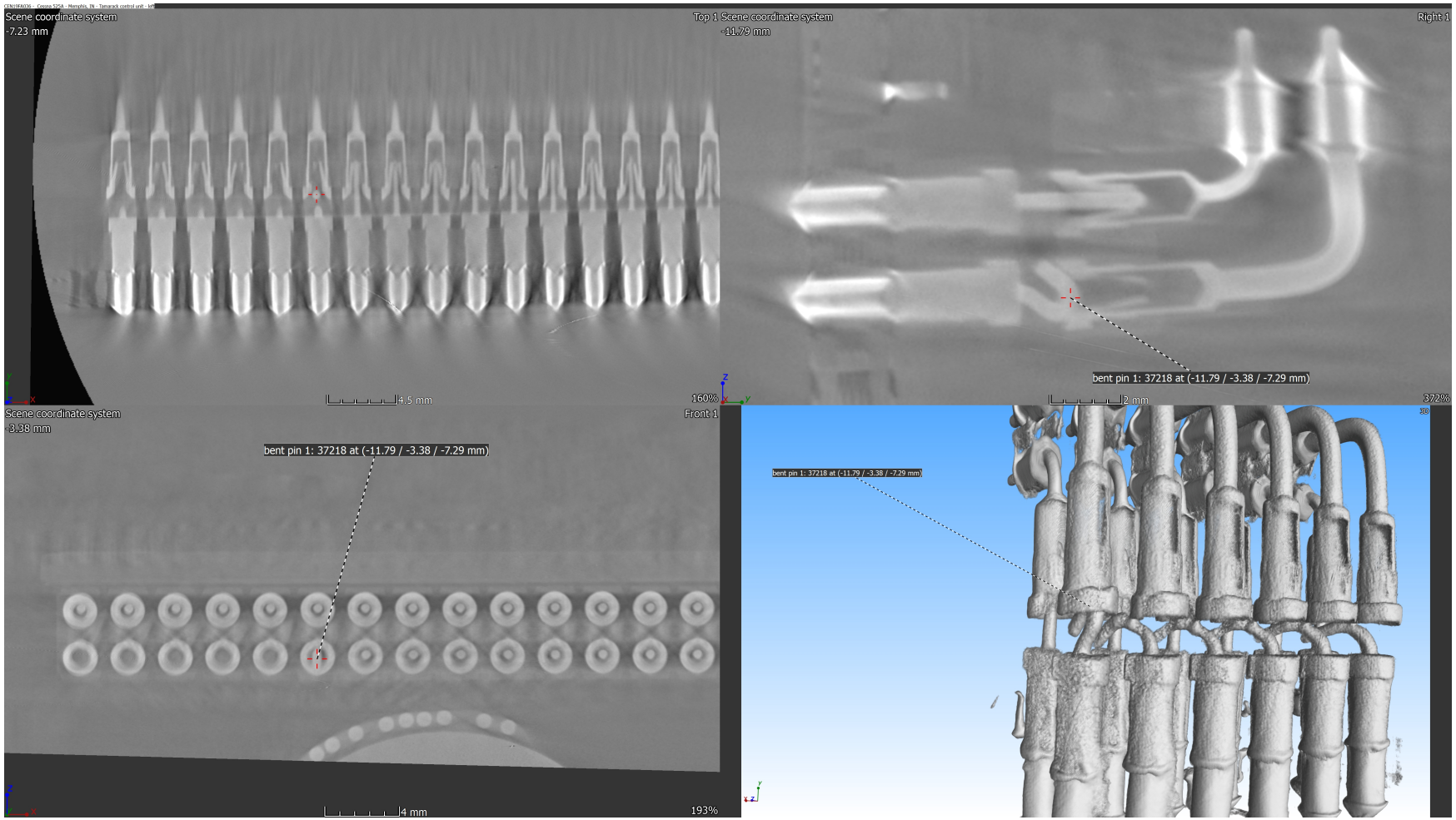


Figure 54
Left TACS control unit – target CT – bent pin 1

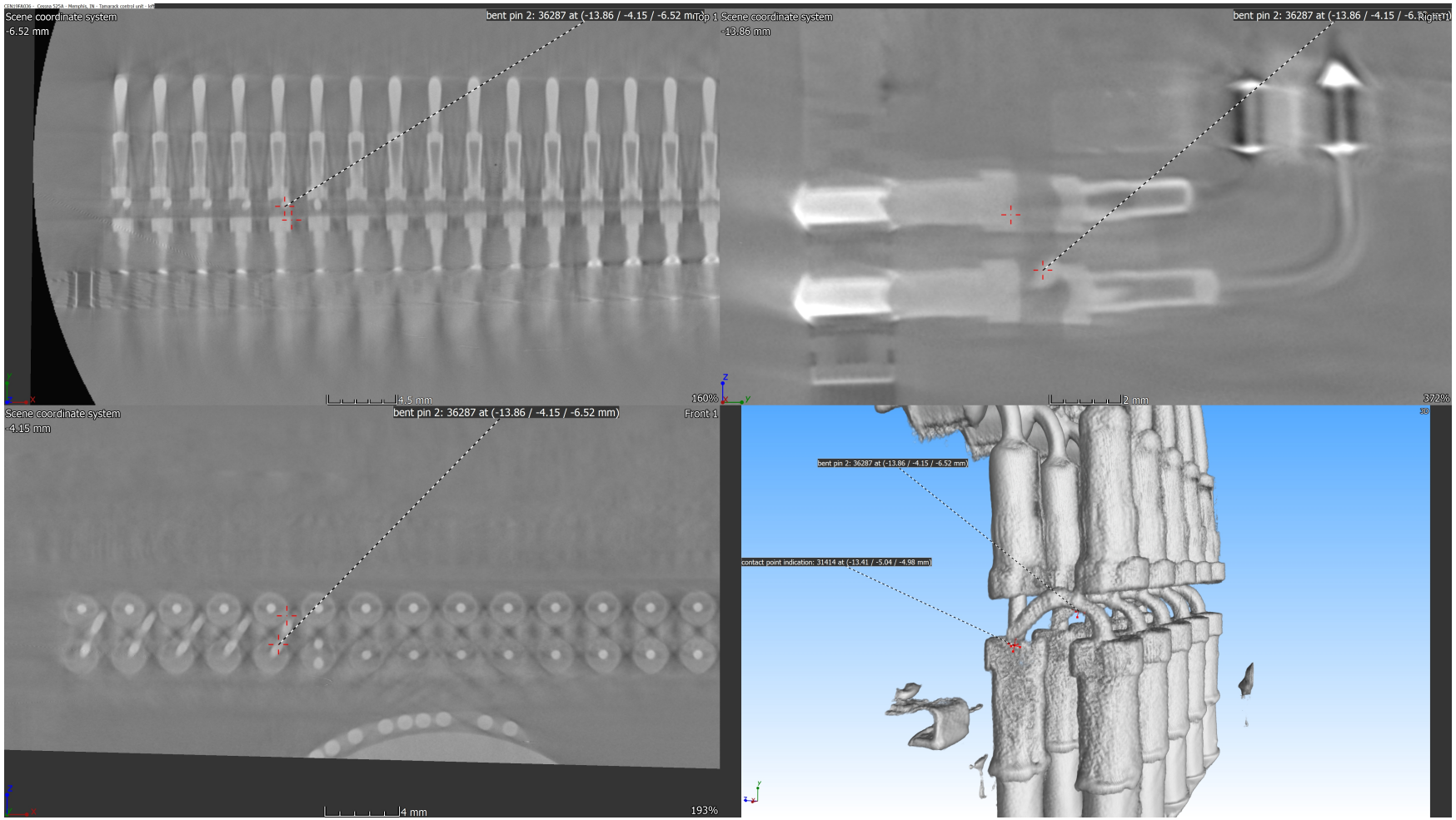


Figure 55
Left TACS control unit – target CT – bent pin 2

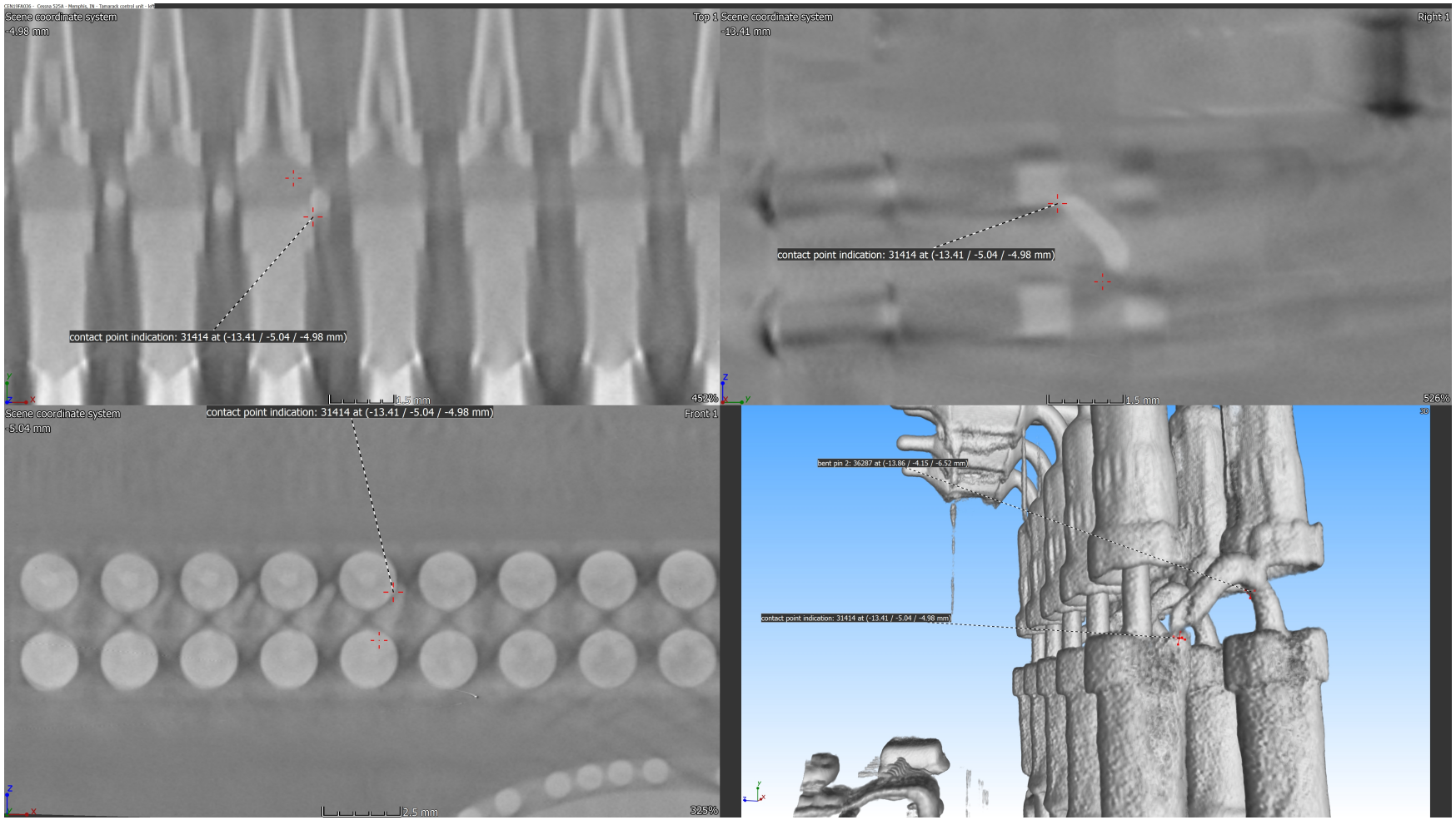


Figure 56
Left TACS control unit – target CT – contact point indication

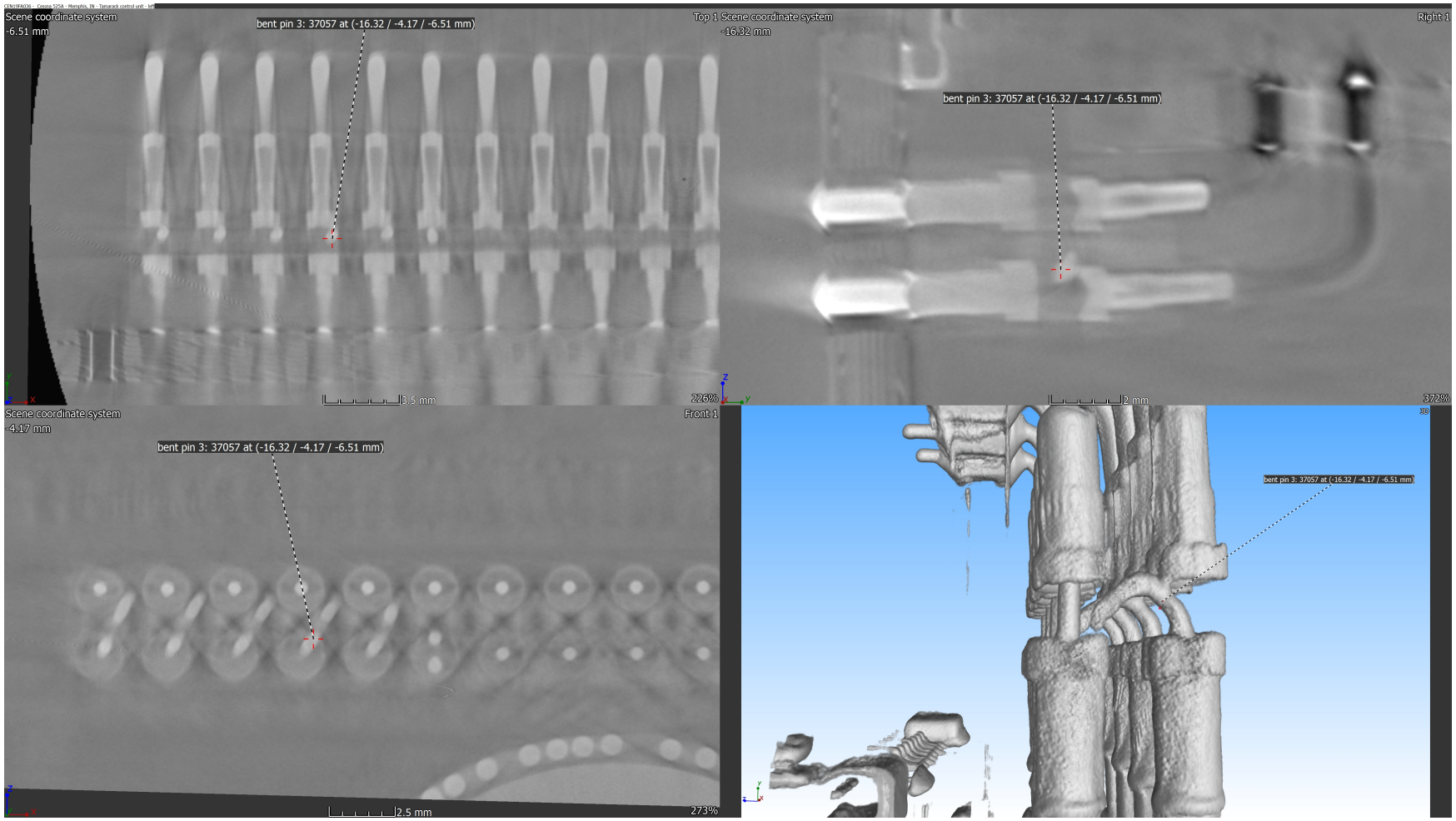


Figure 57
Left TACS control unit – target CT – bent pin 3

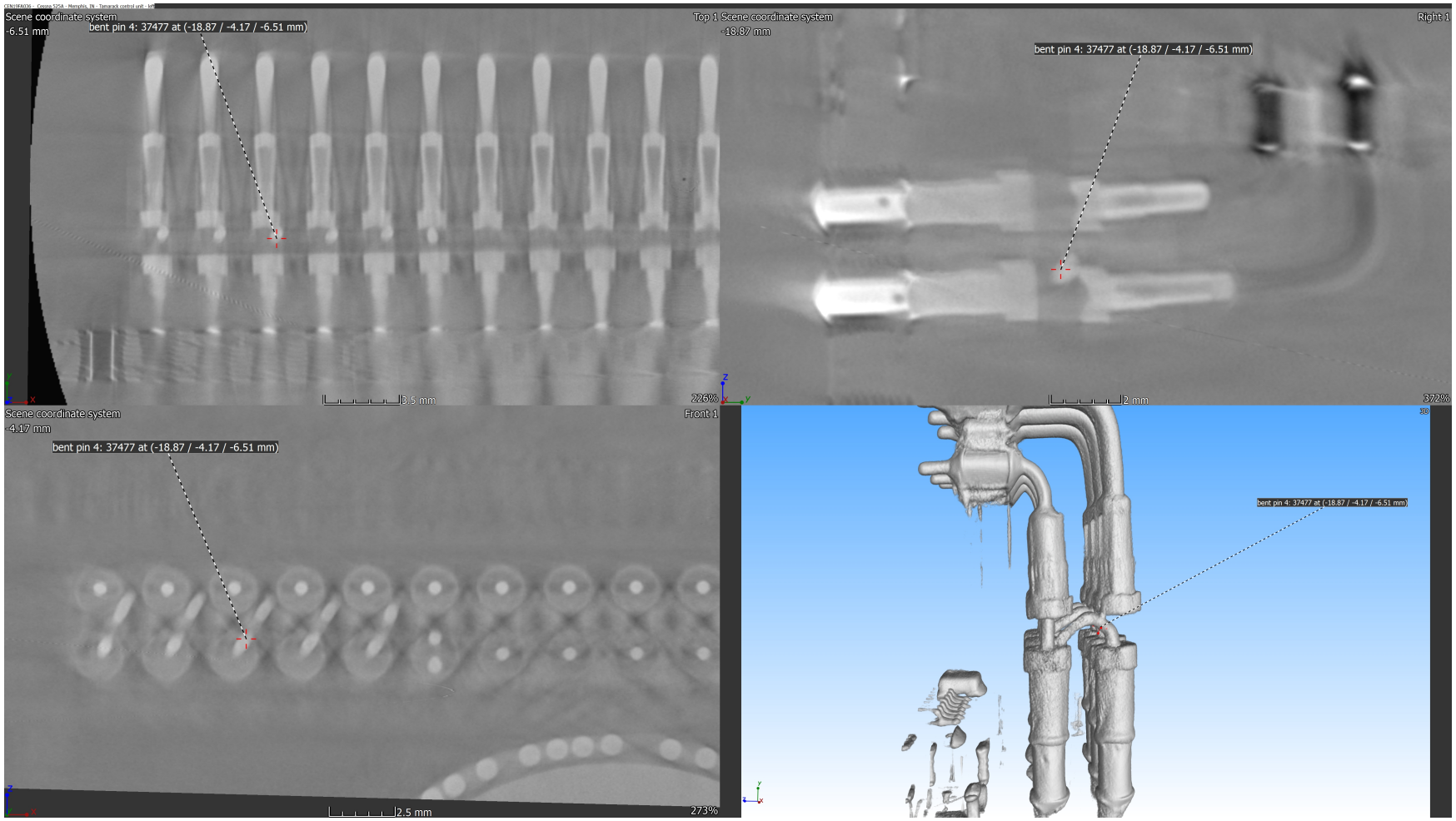


Figure 58
Left TACS control unit – target CT – bent pin 4

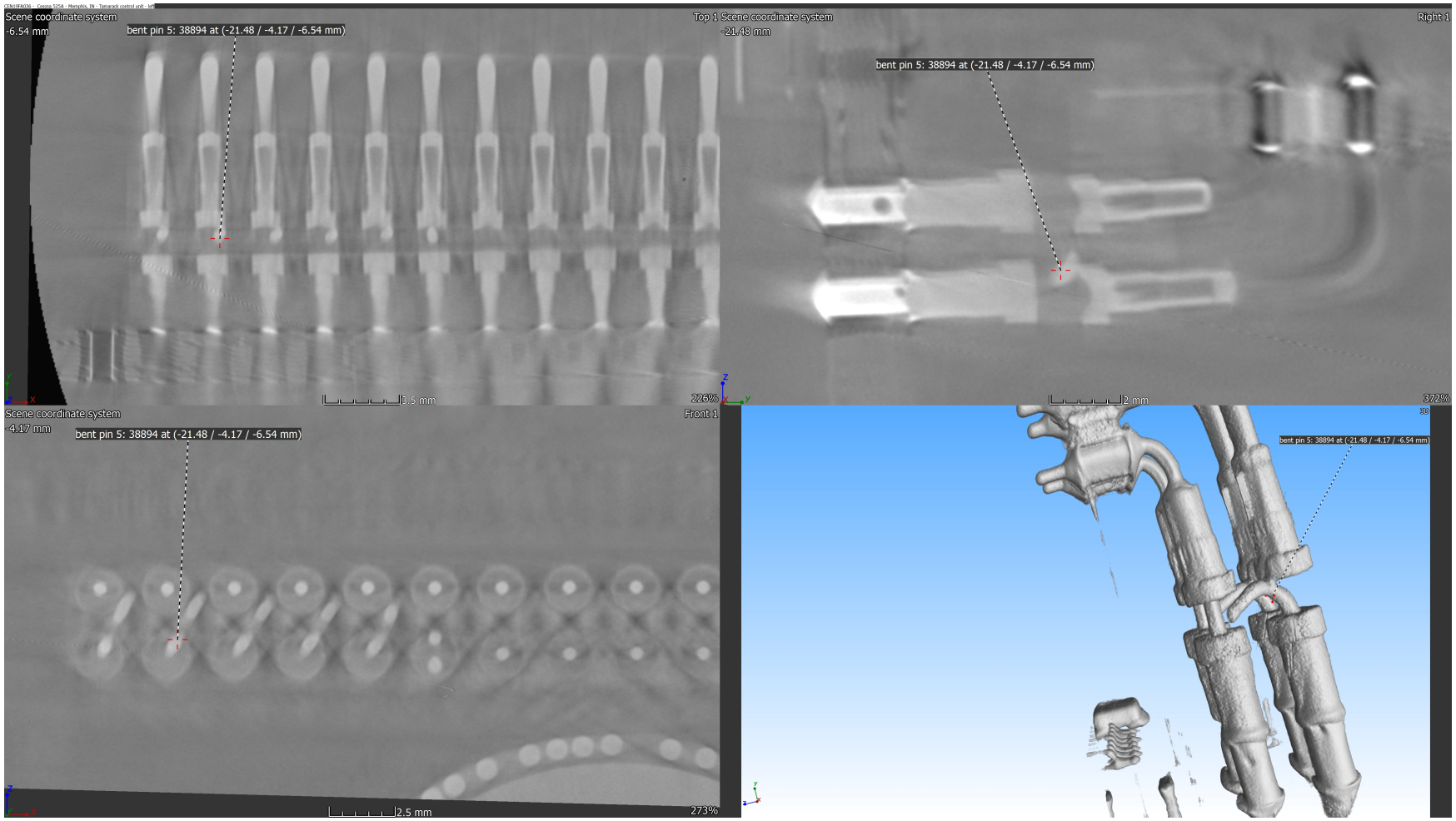


Figure 59
Left TACS control unit – target CT – bent pin 5

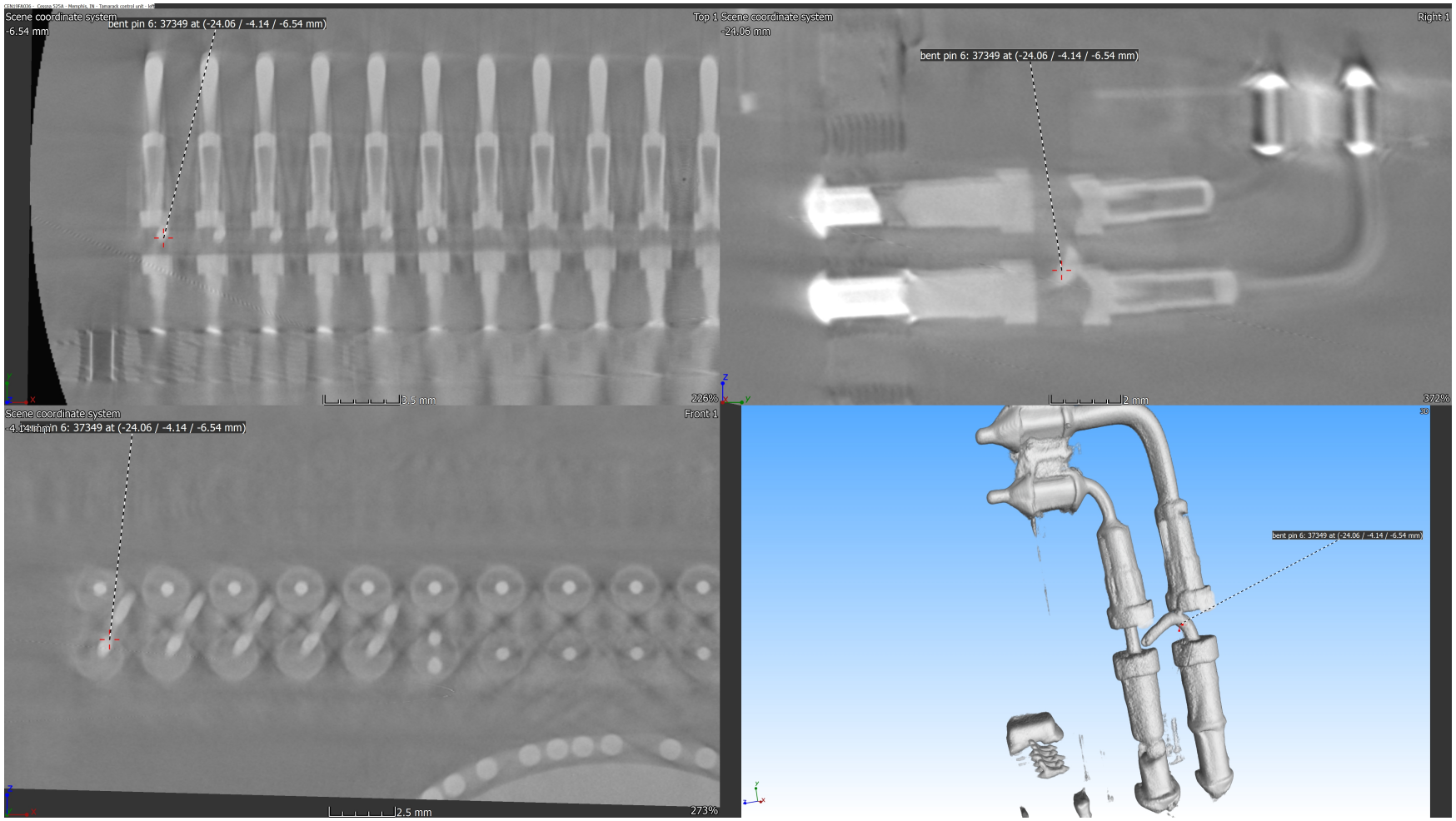


Figure 60
Left TACS control unit – target CT – bent pin 6

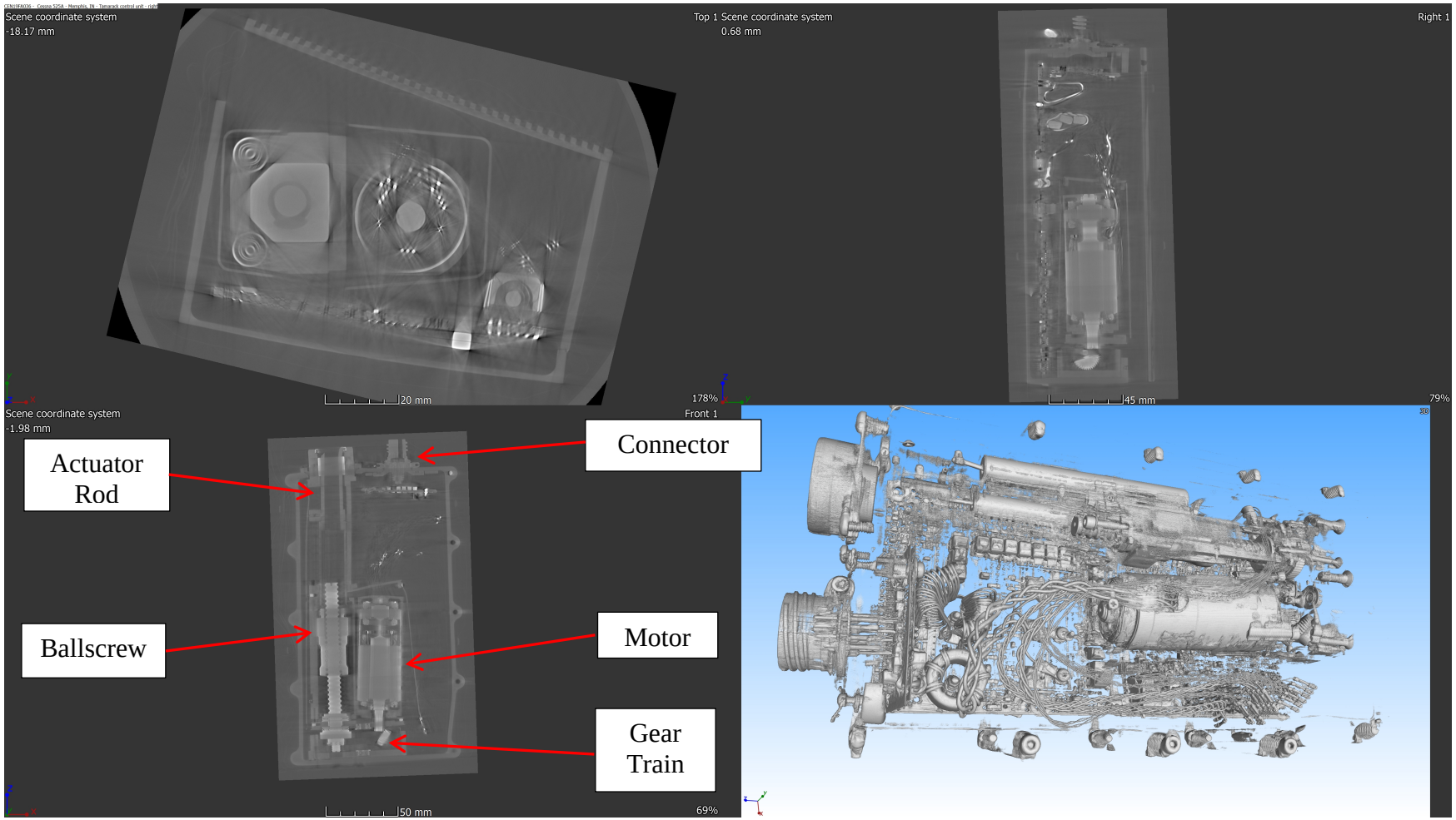


Figure 61
Right TACS control unit – overall

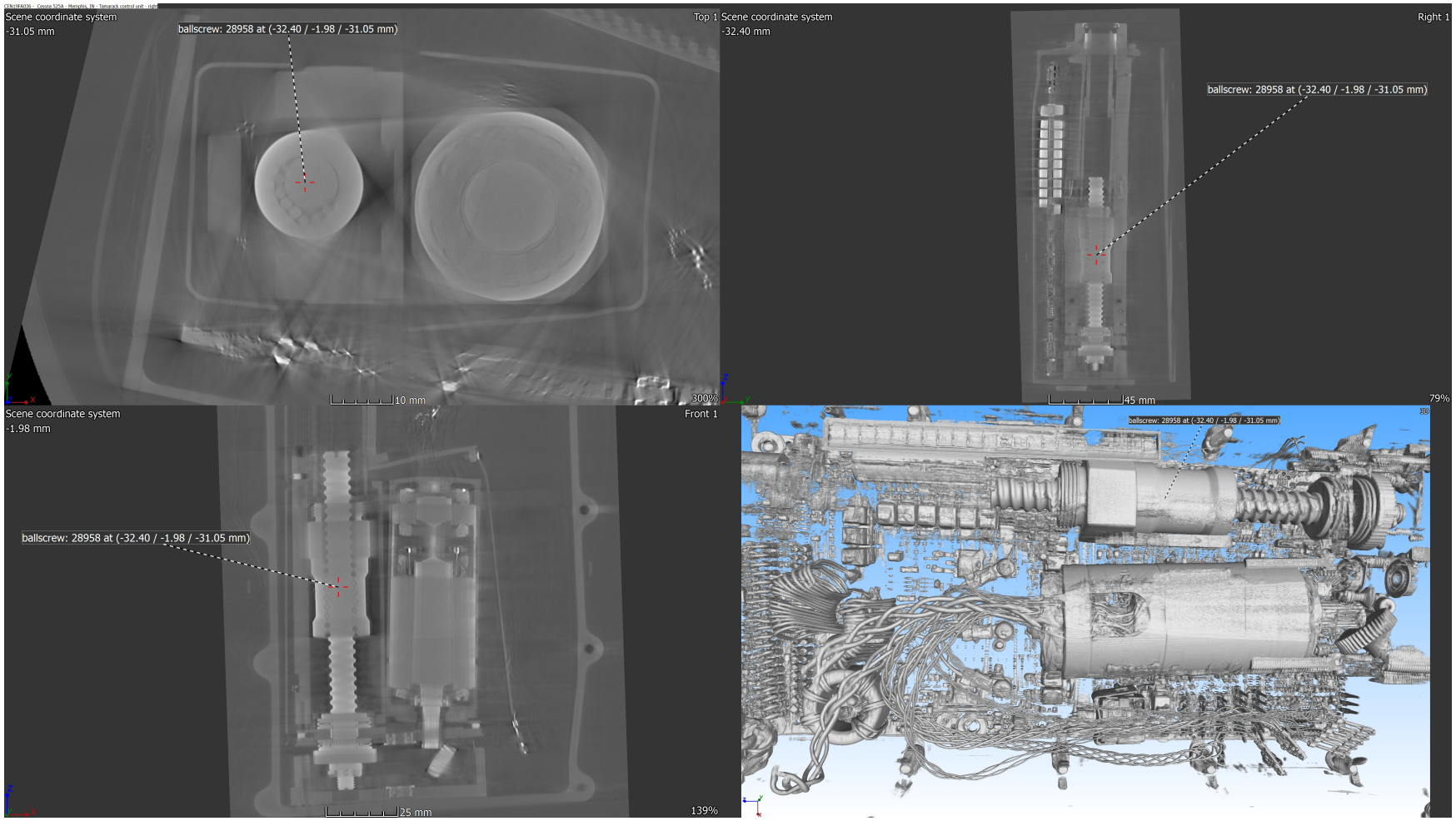


Figure 62
Right TACS control unit – ballscrew

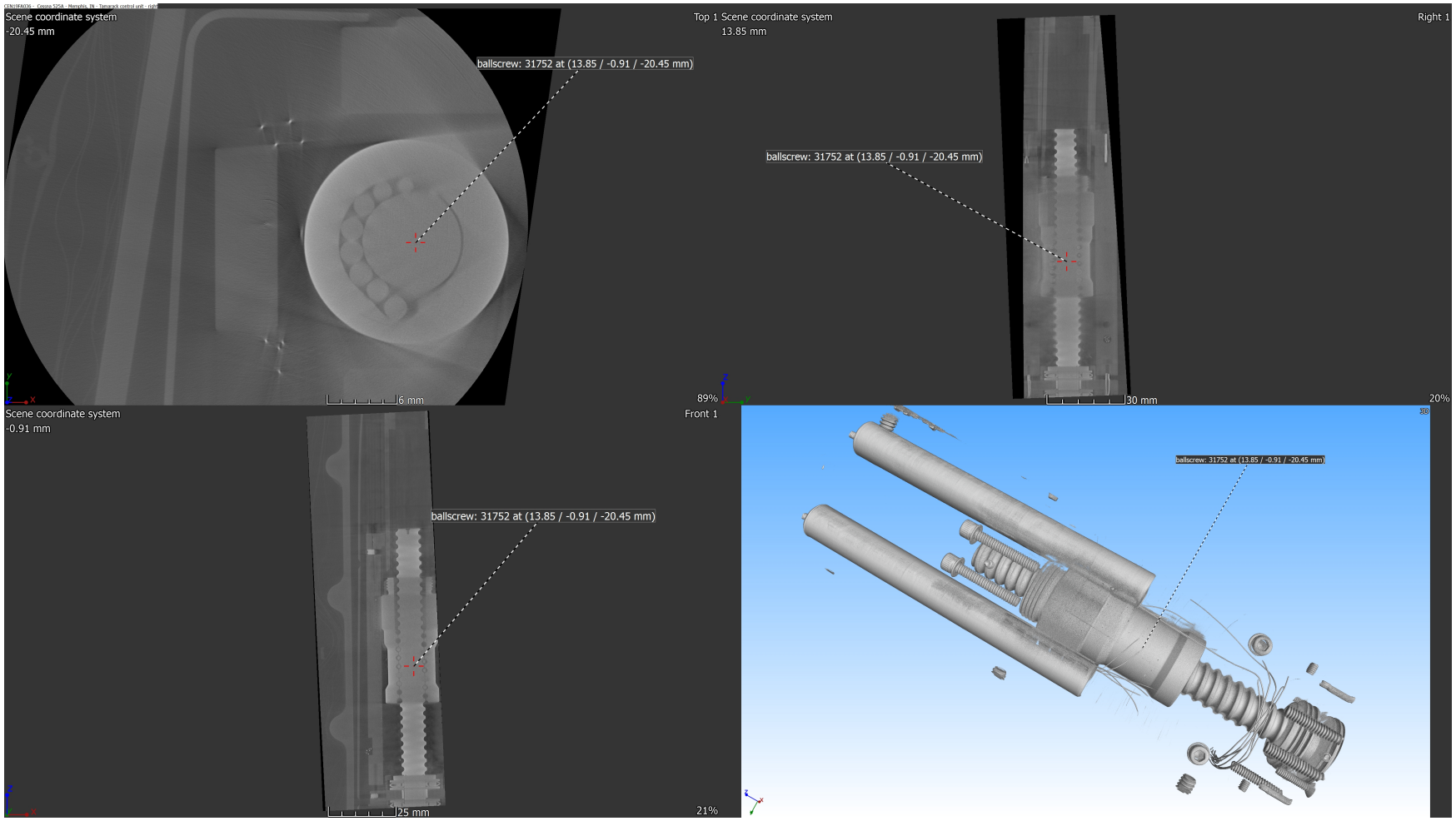


Figure 63
Right TACS control unit – target CT - ballscrew

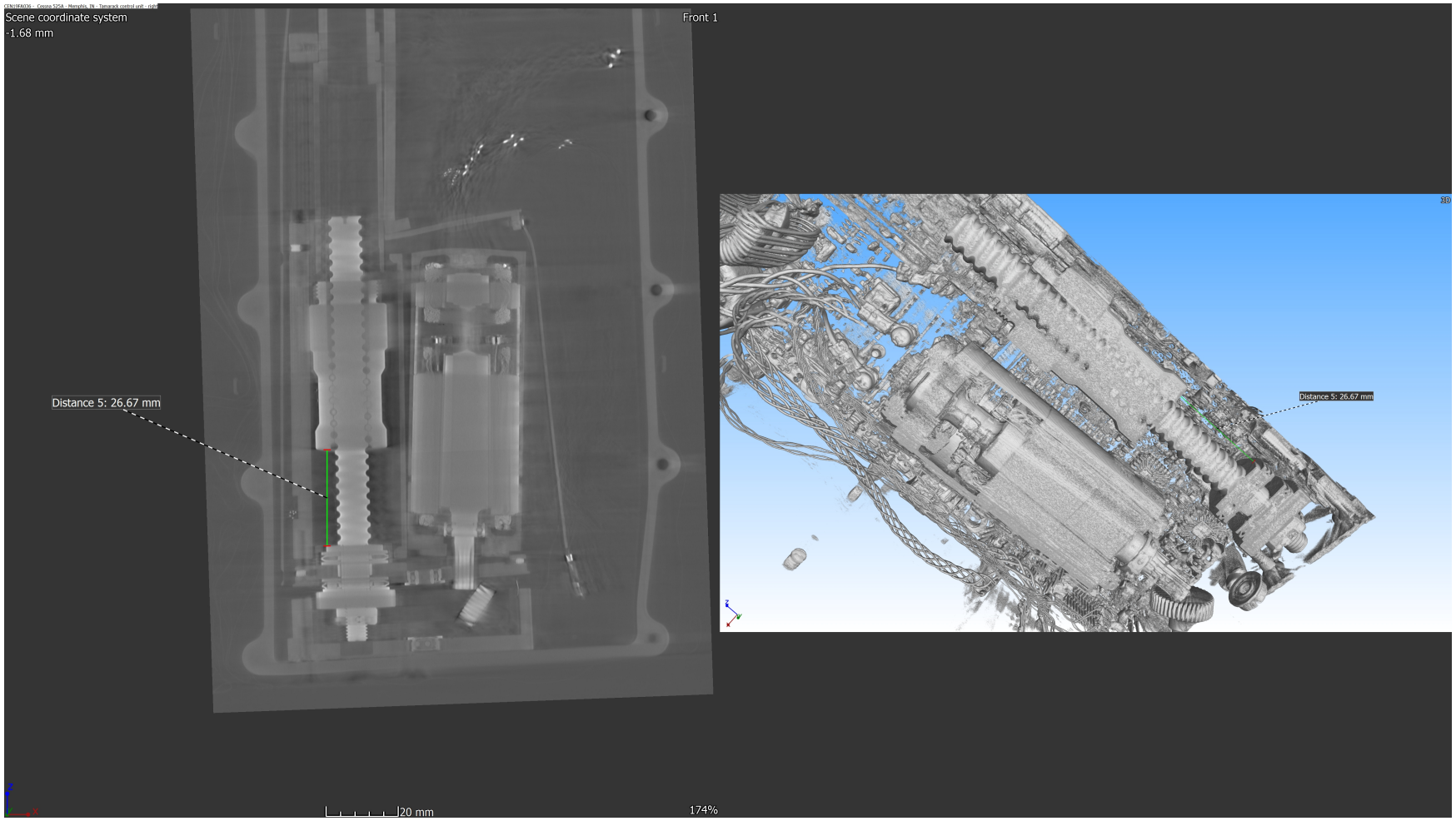


Figure 64
Right TACS control unit – ballscrew extension distance

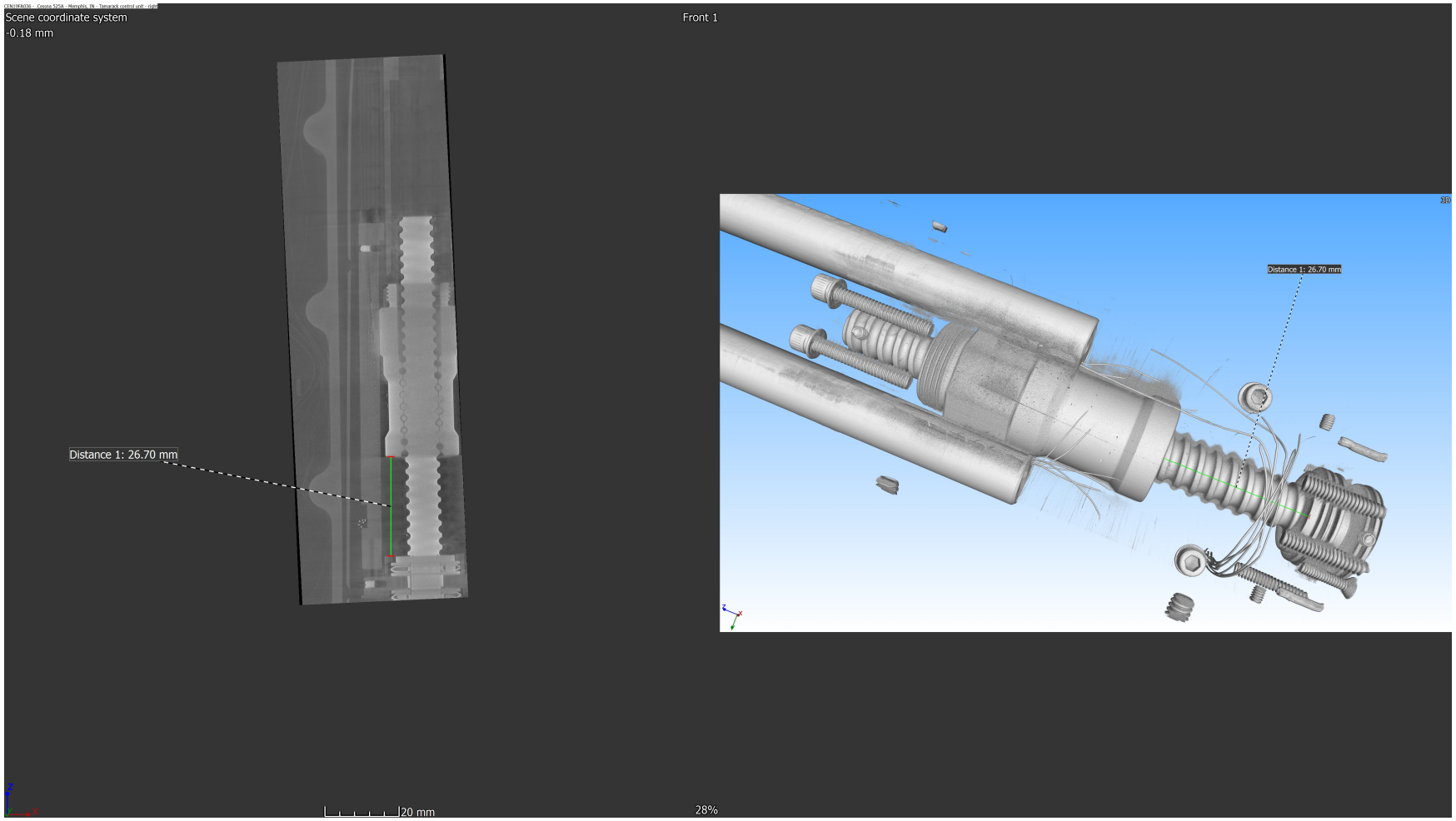


Figure 65
Right TACS control unit – target CT – ballscrew extension distance

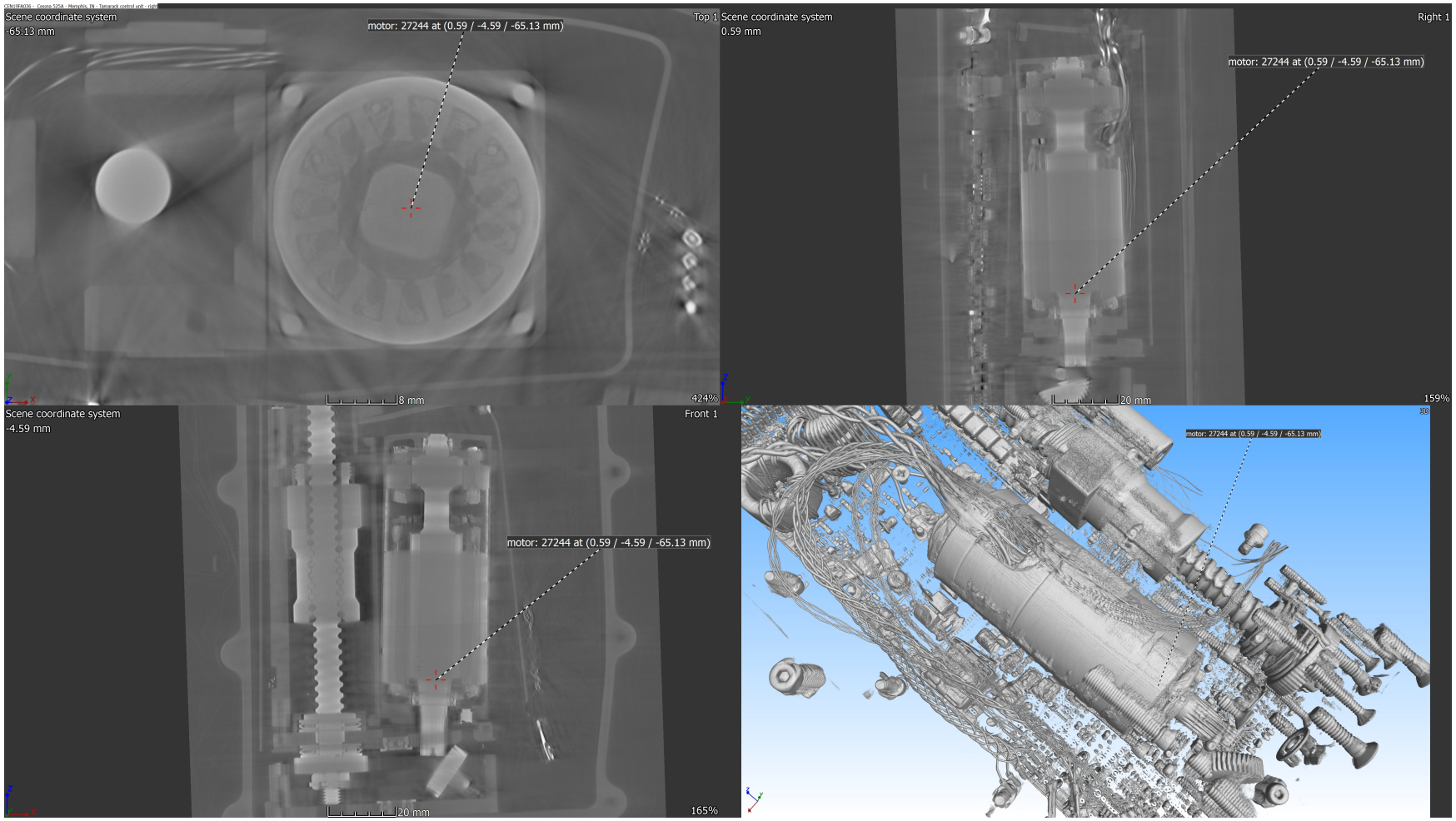


Figure 66
Right TACS control unit – motor

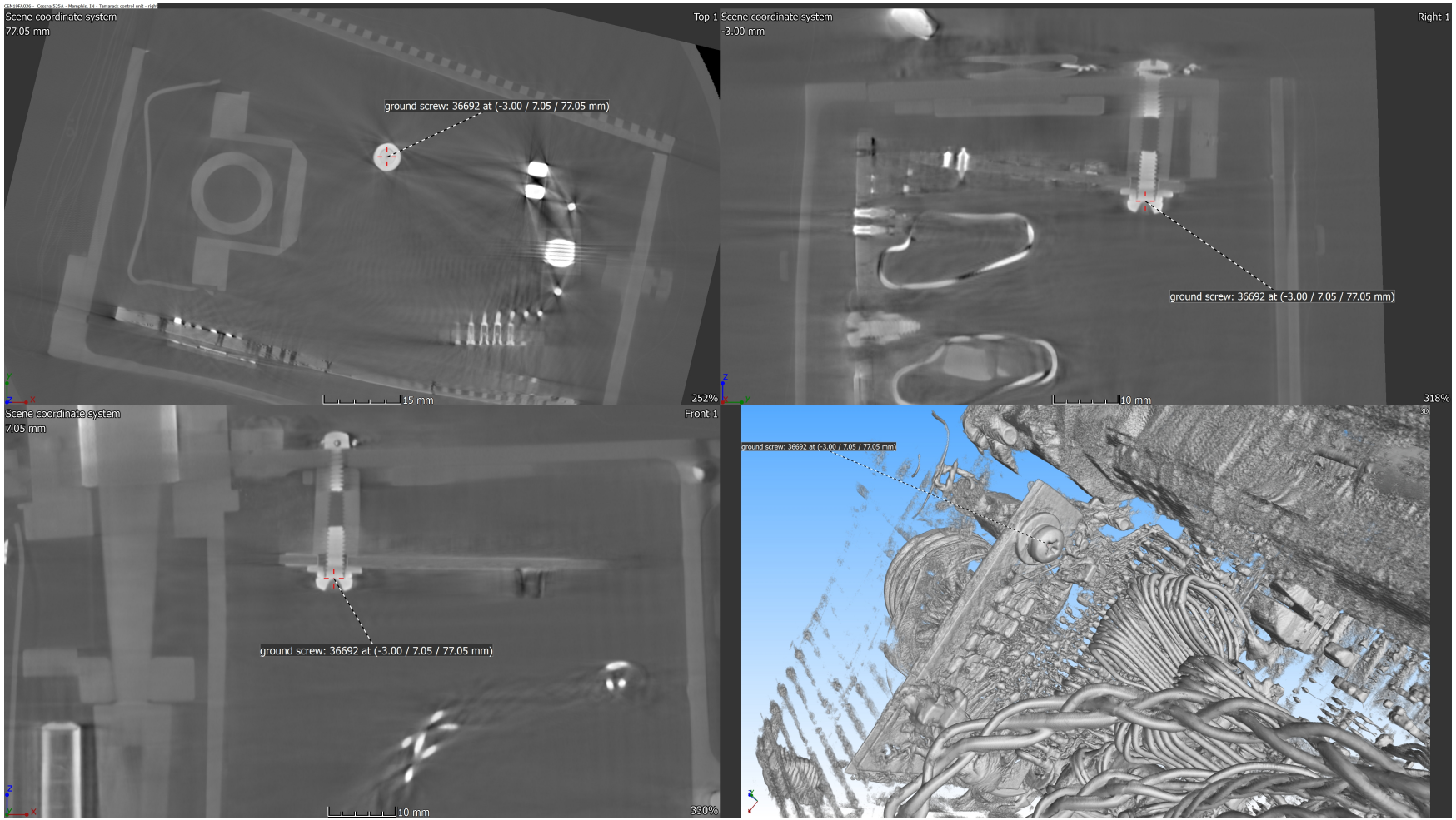


Figure 67
Right TACS control unit – ground screw

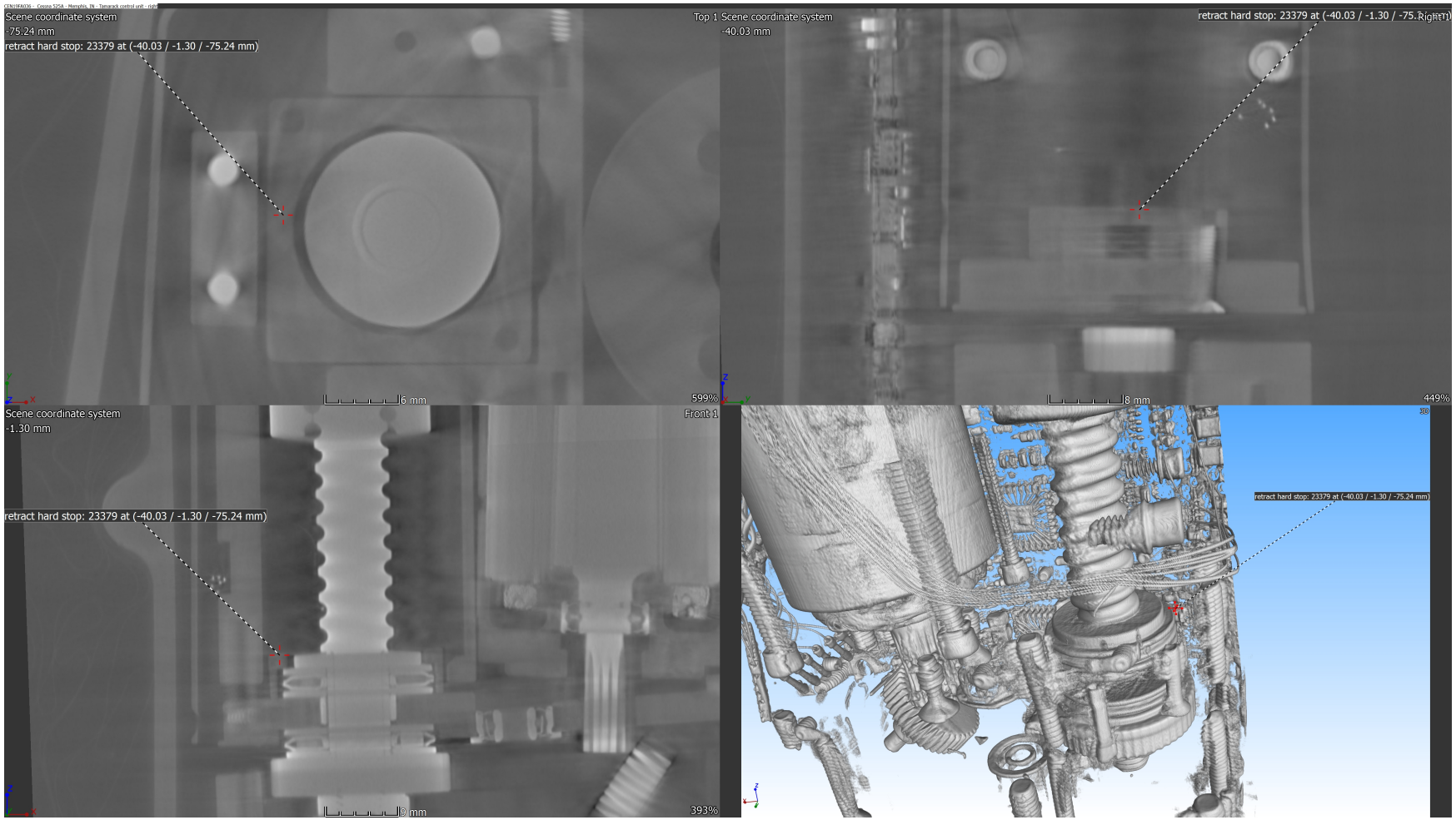


Figure 68
Right TACS control unit – retract hard stop

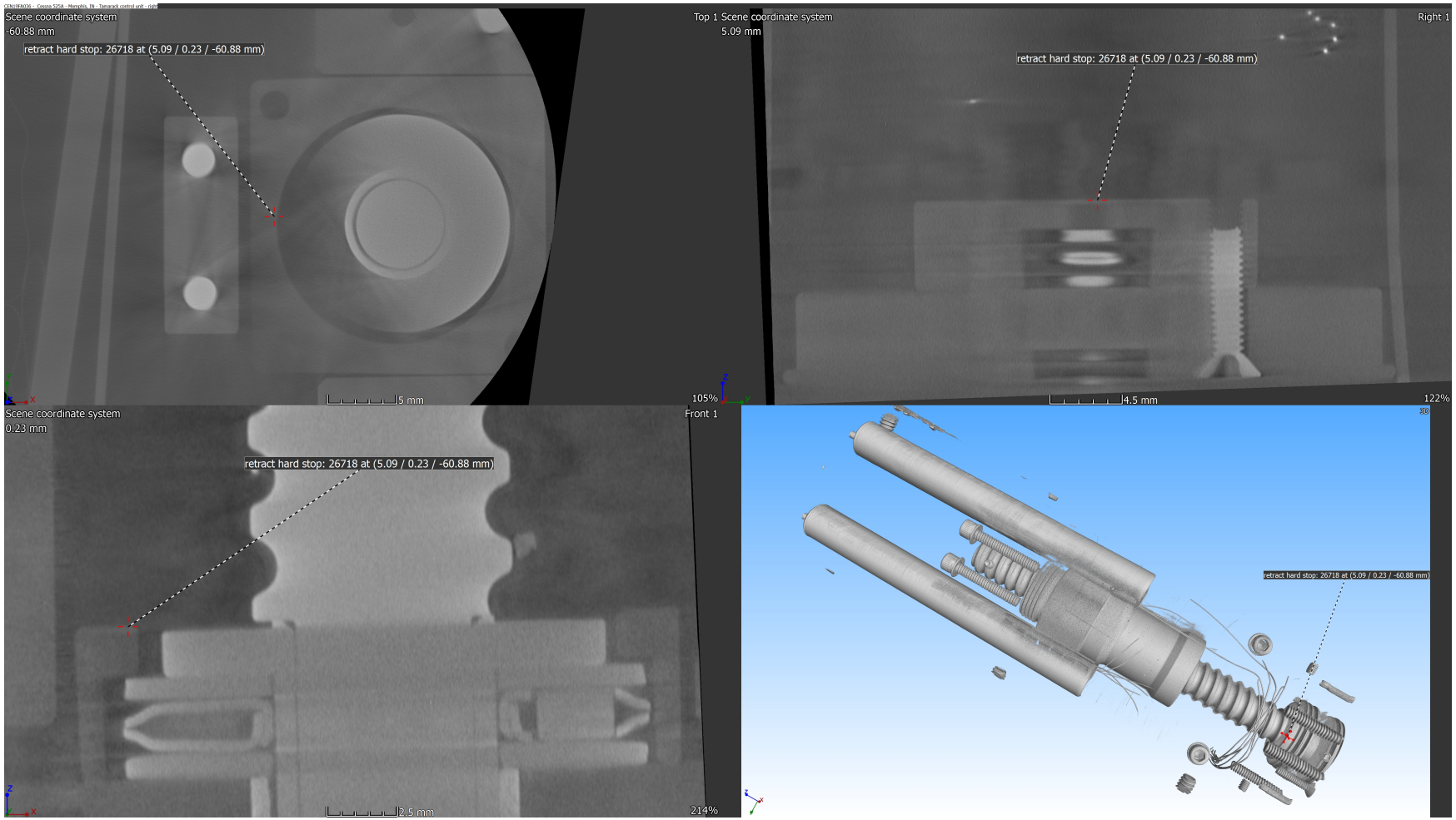


Figure 69
Right TACS control unit – target CT – retract hard stop

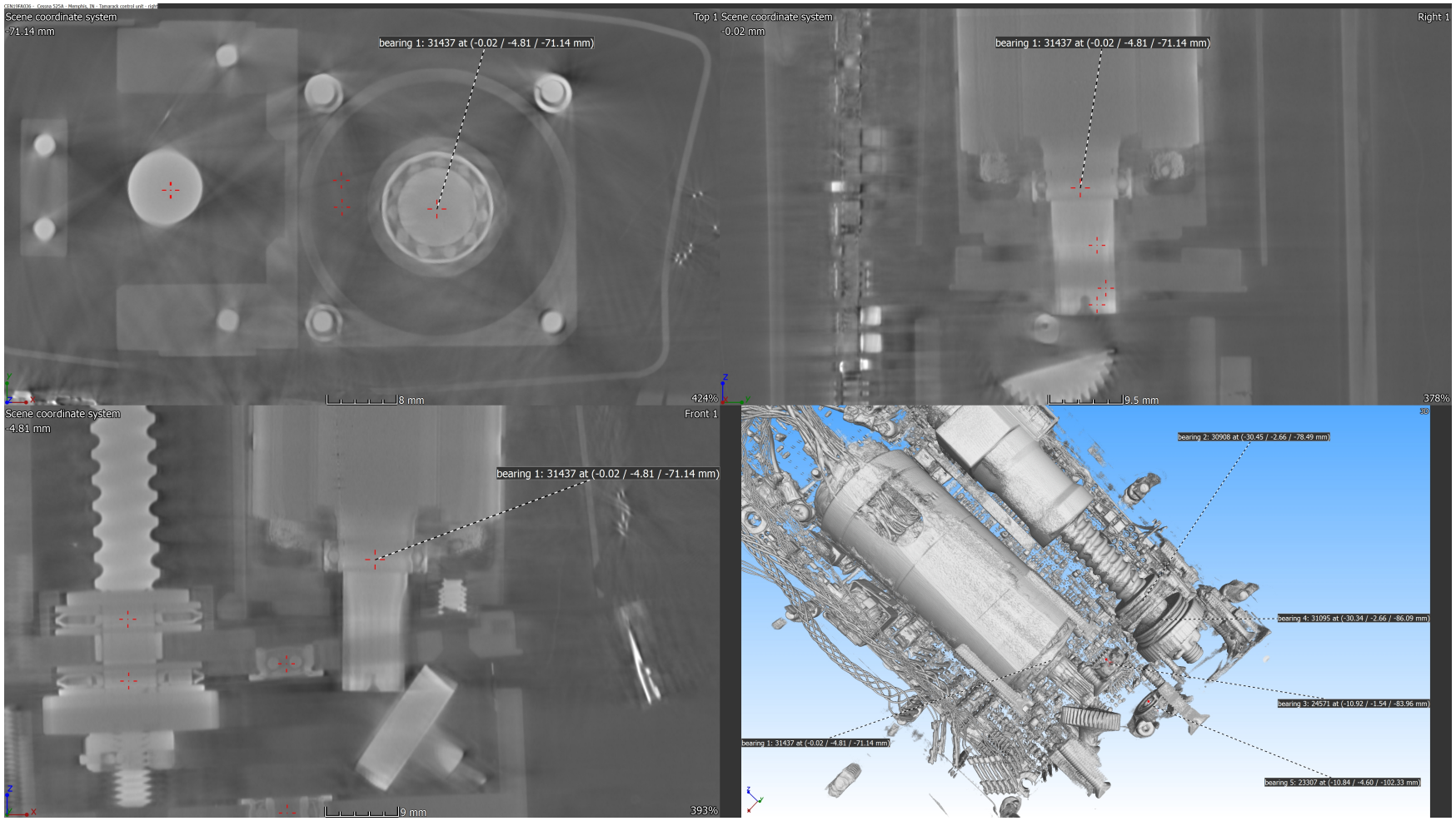


Figure 70
Right TACS control unit – bearing 1

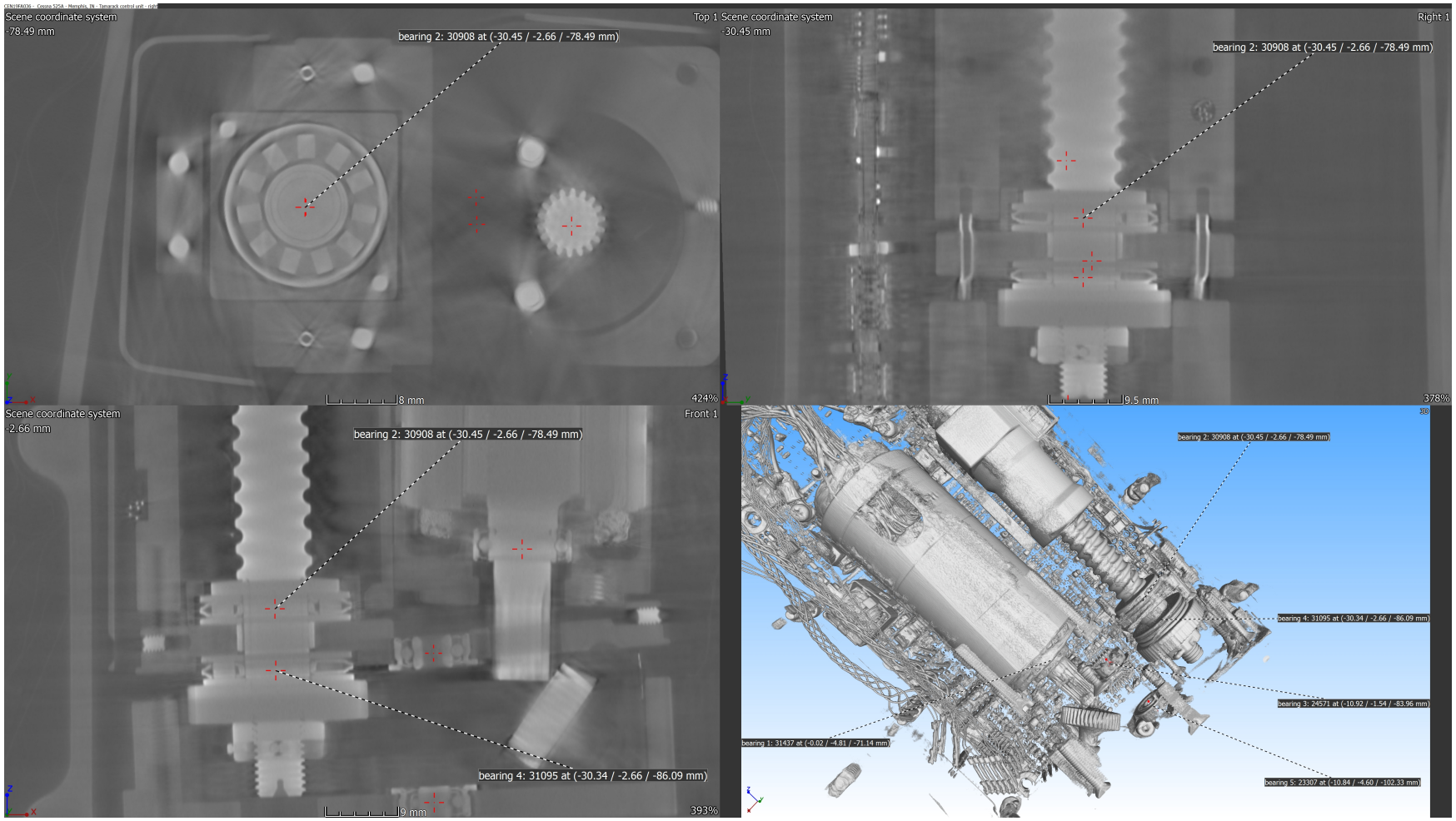


Figure 71
Right TACS control unit – bearing 2

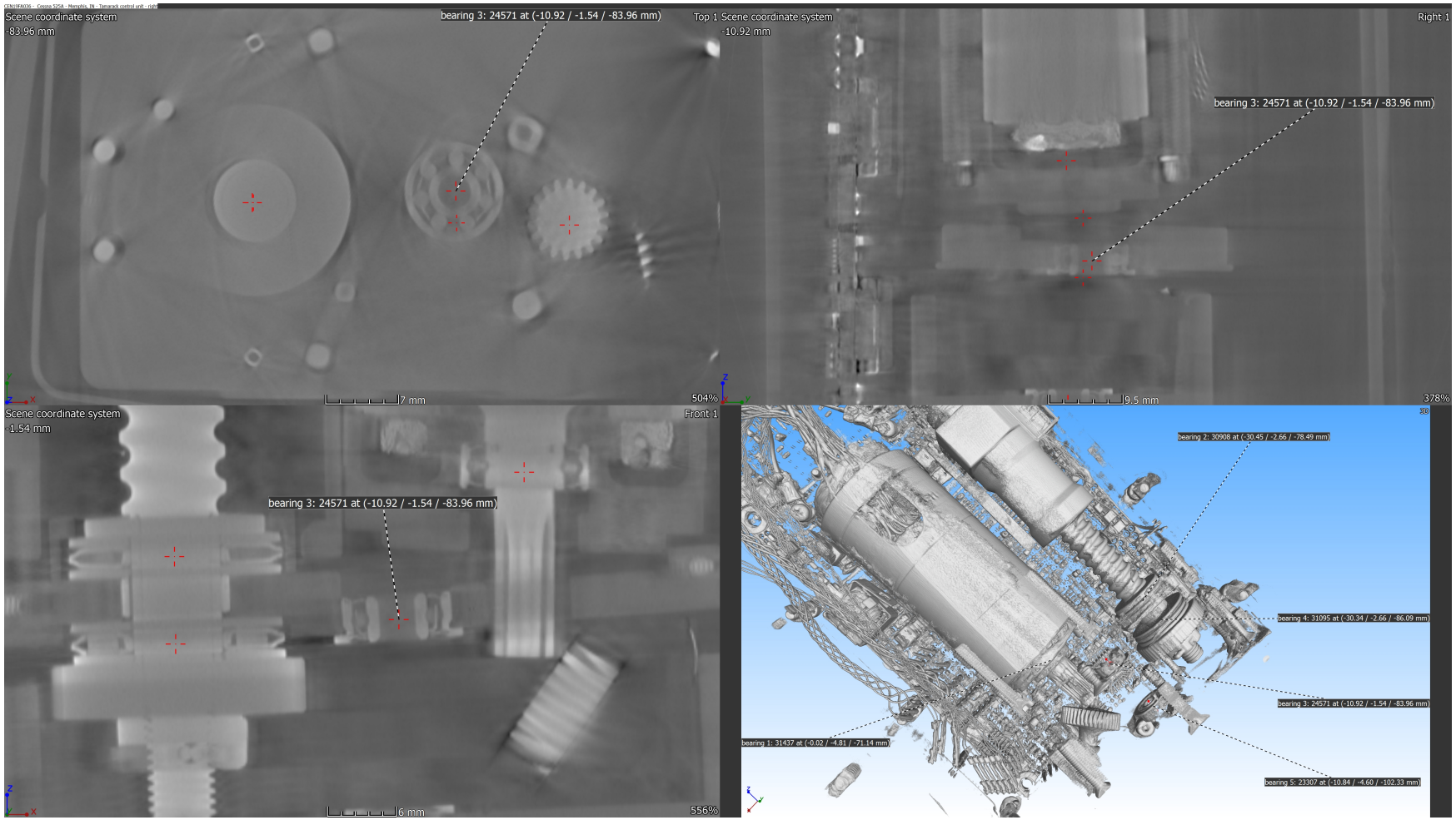


Figure 72
Right TACS control unit – bearing 3

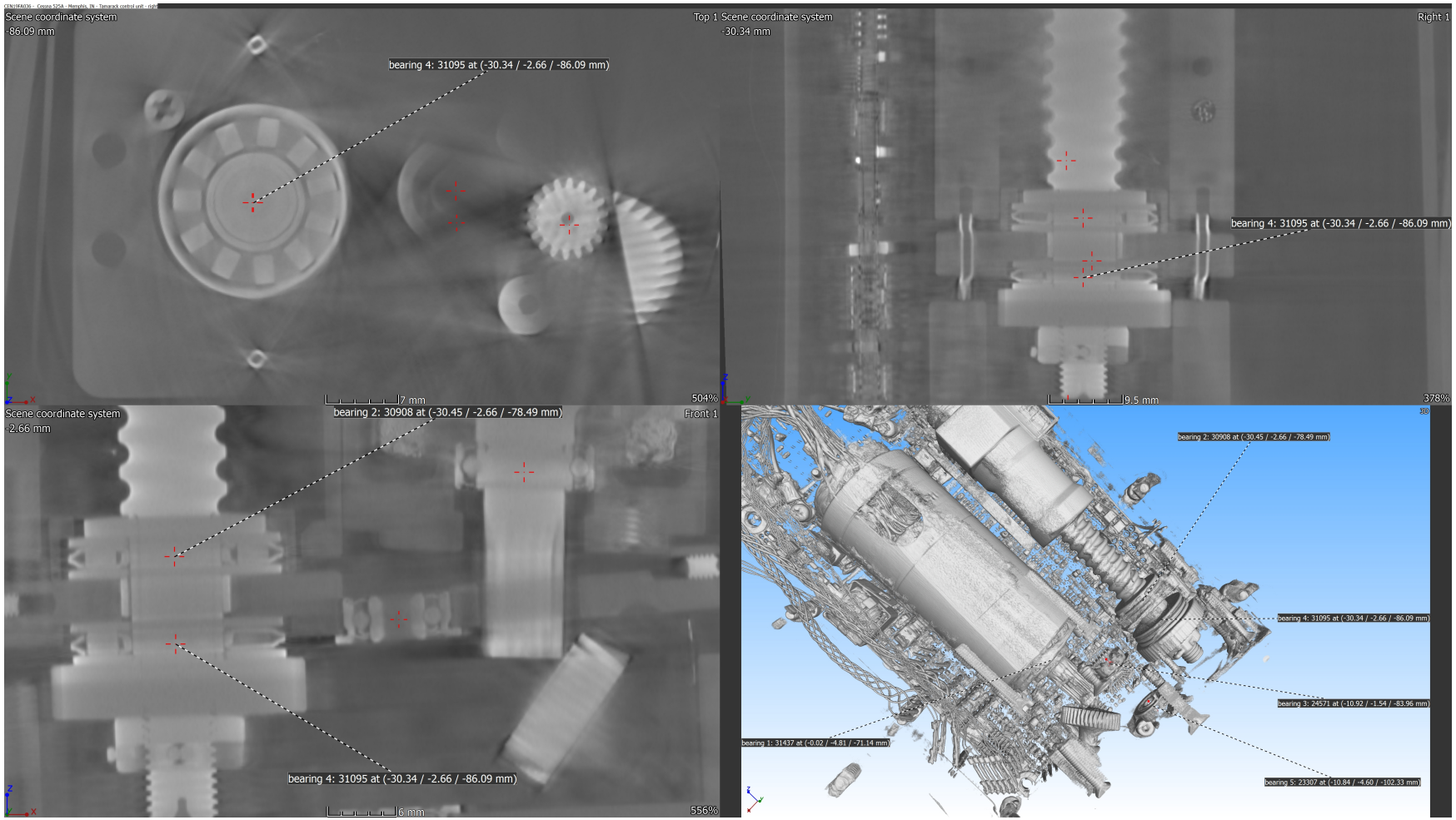


Figure 73
Right TACS control unit – bearing 4

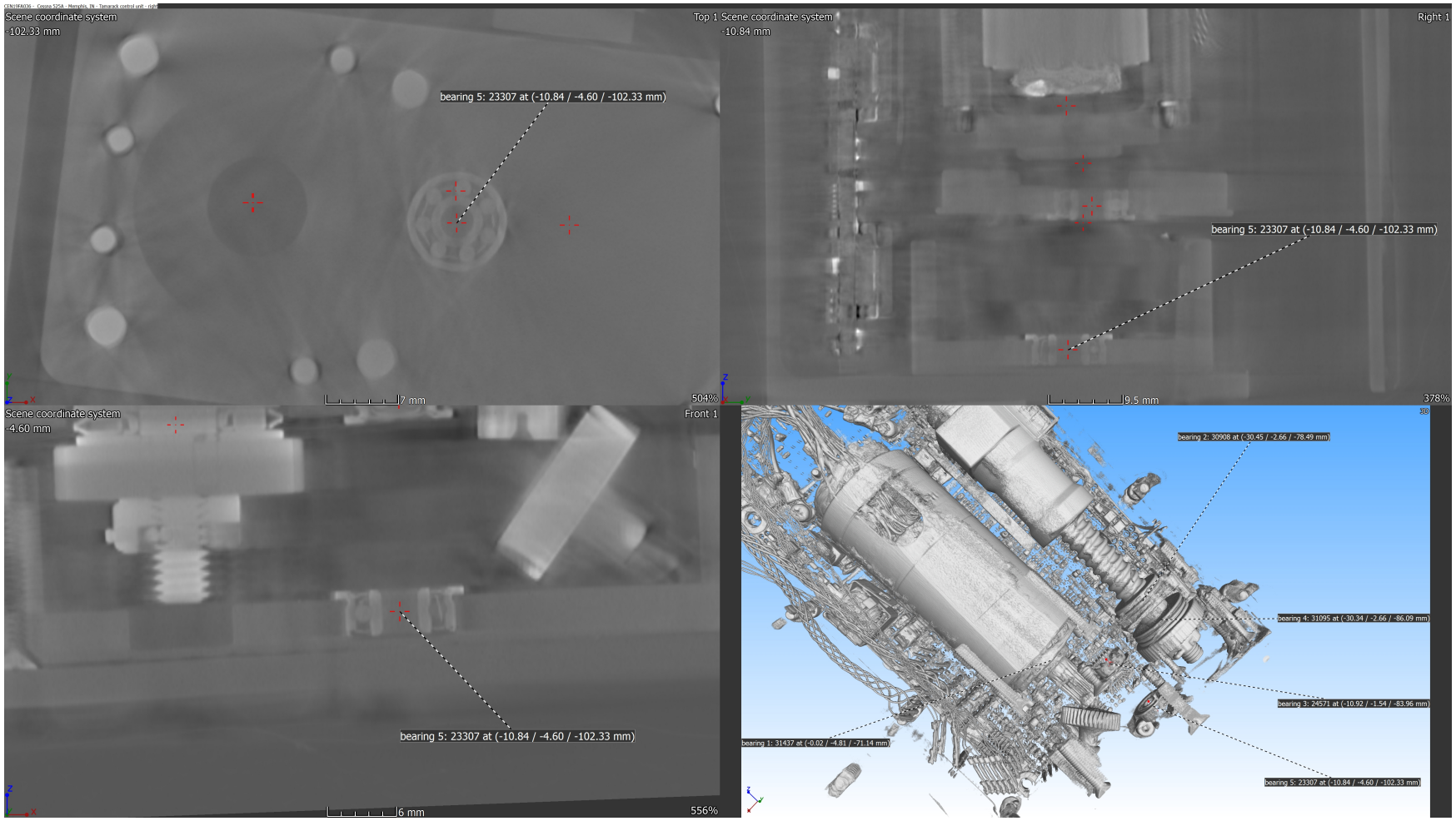


Figure 74
Right TACS control unit – bearing 5

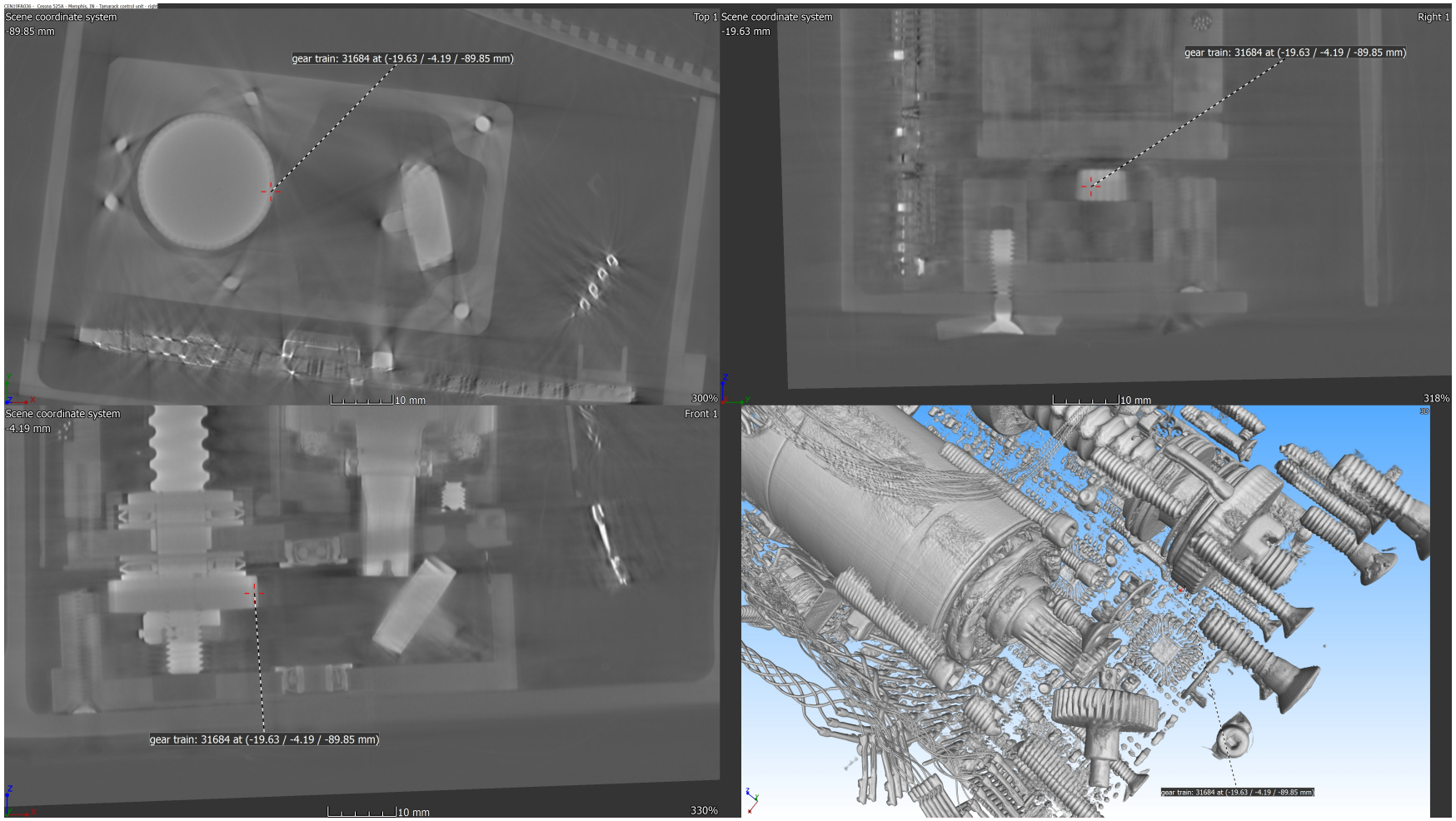


Figure 75
Right TACS control unit – gear train

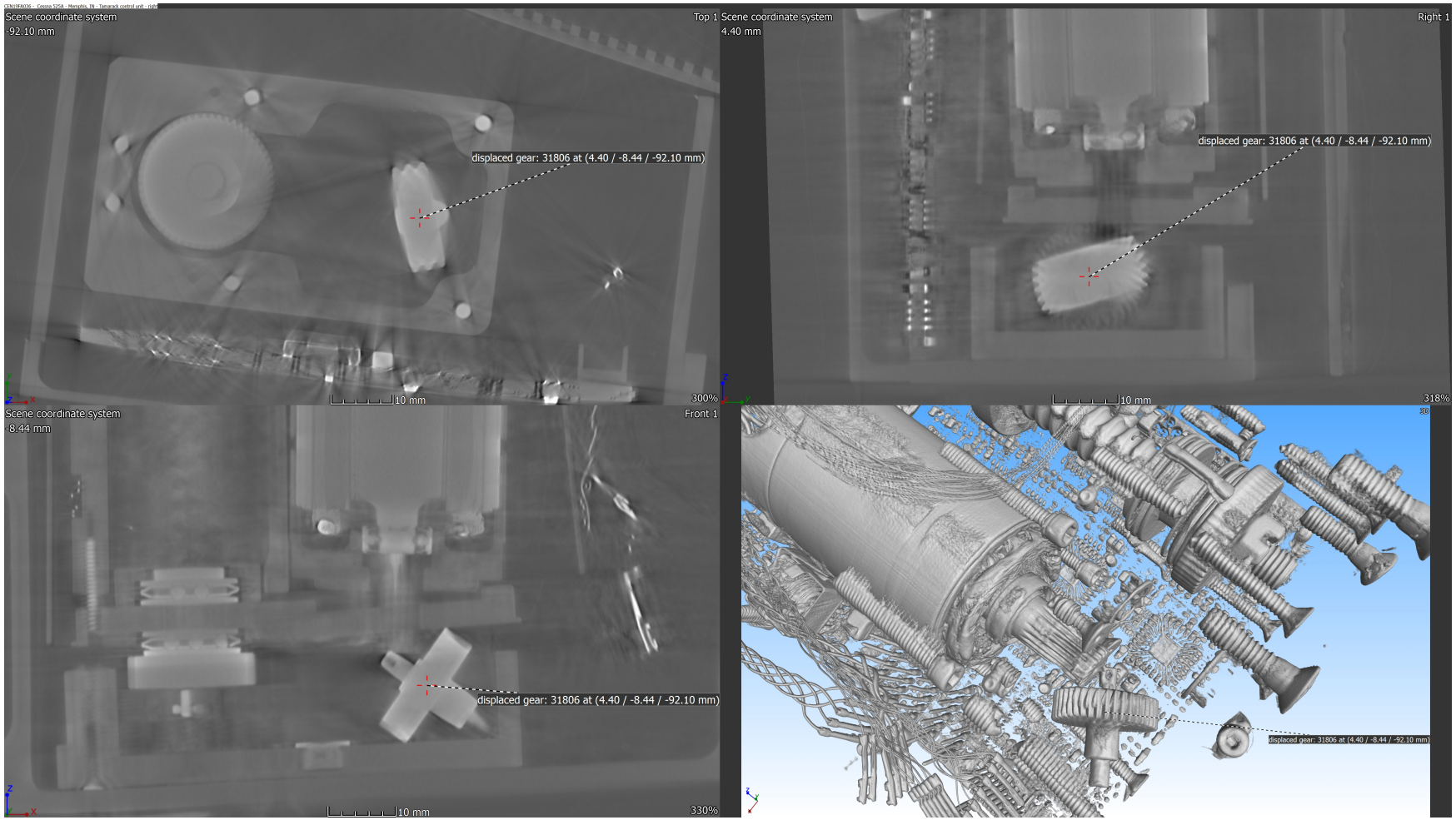


Figure 76
Right TACS control unit – displaced gear

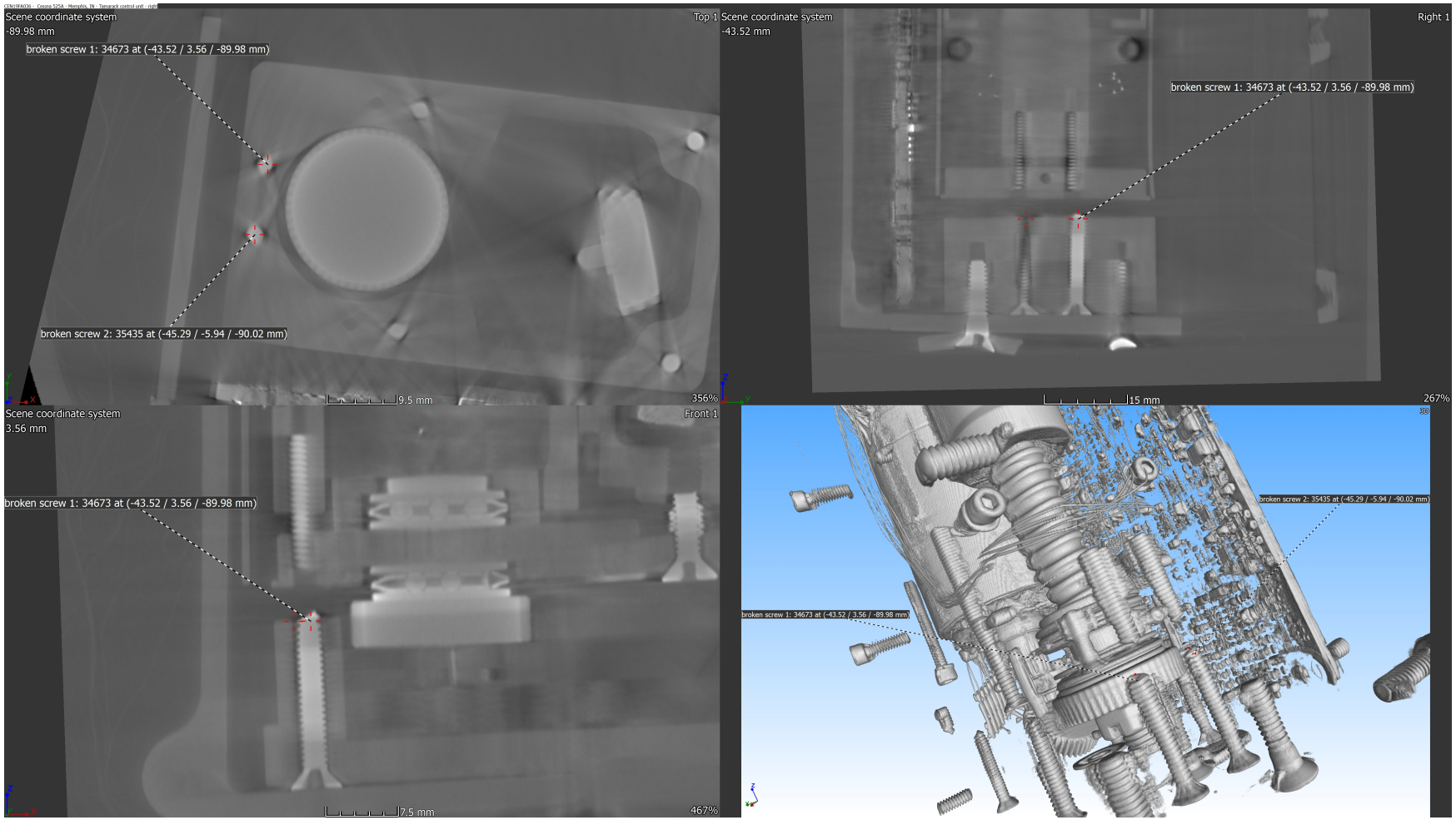


Figure 77
Right TACS control unit – broken screw 1

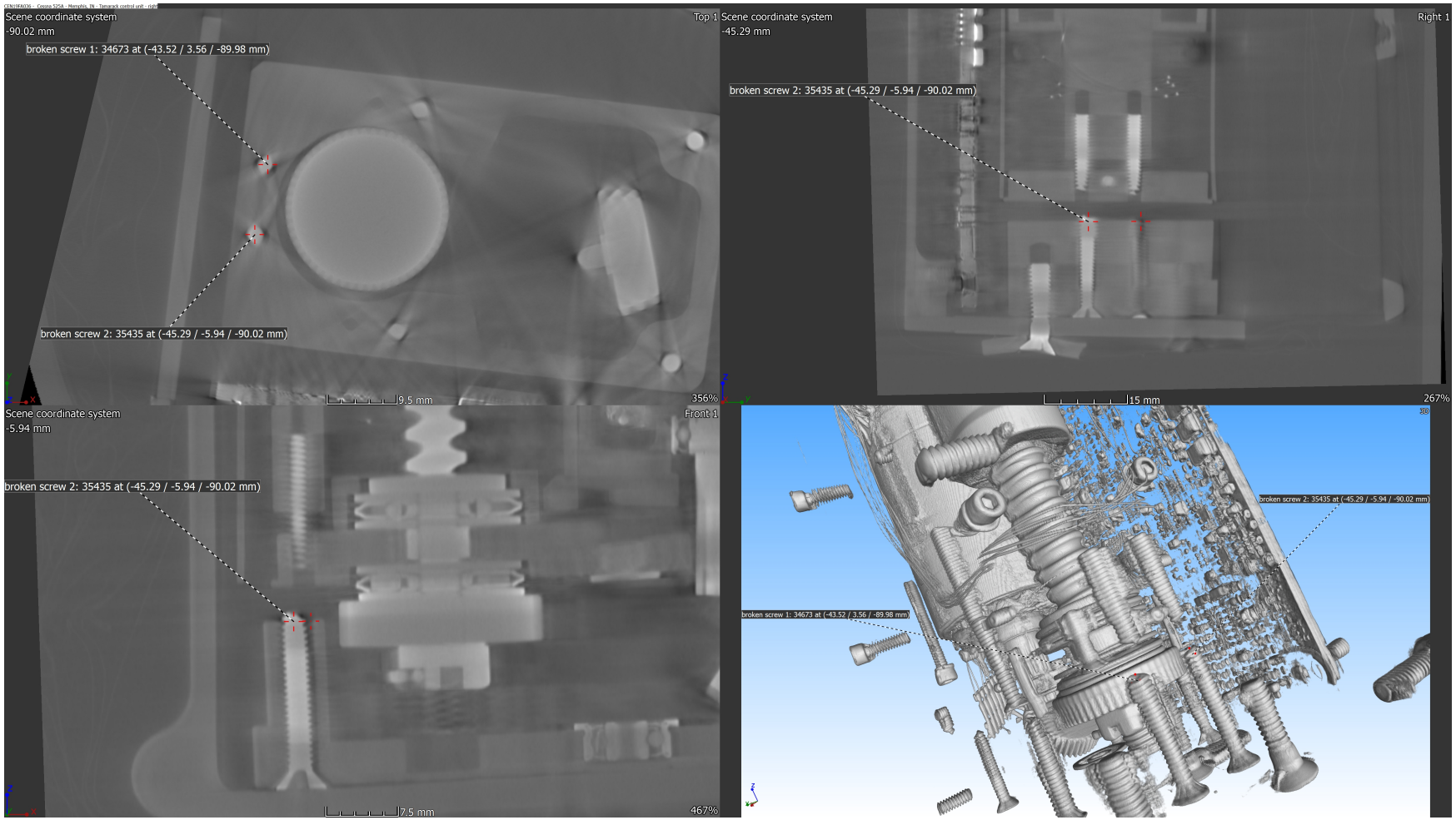


Figure 78
Right TACS control unit – broken screw 2

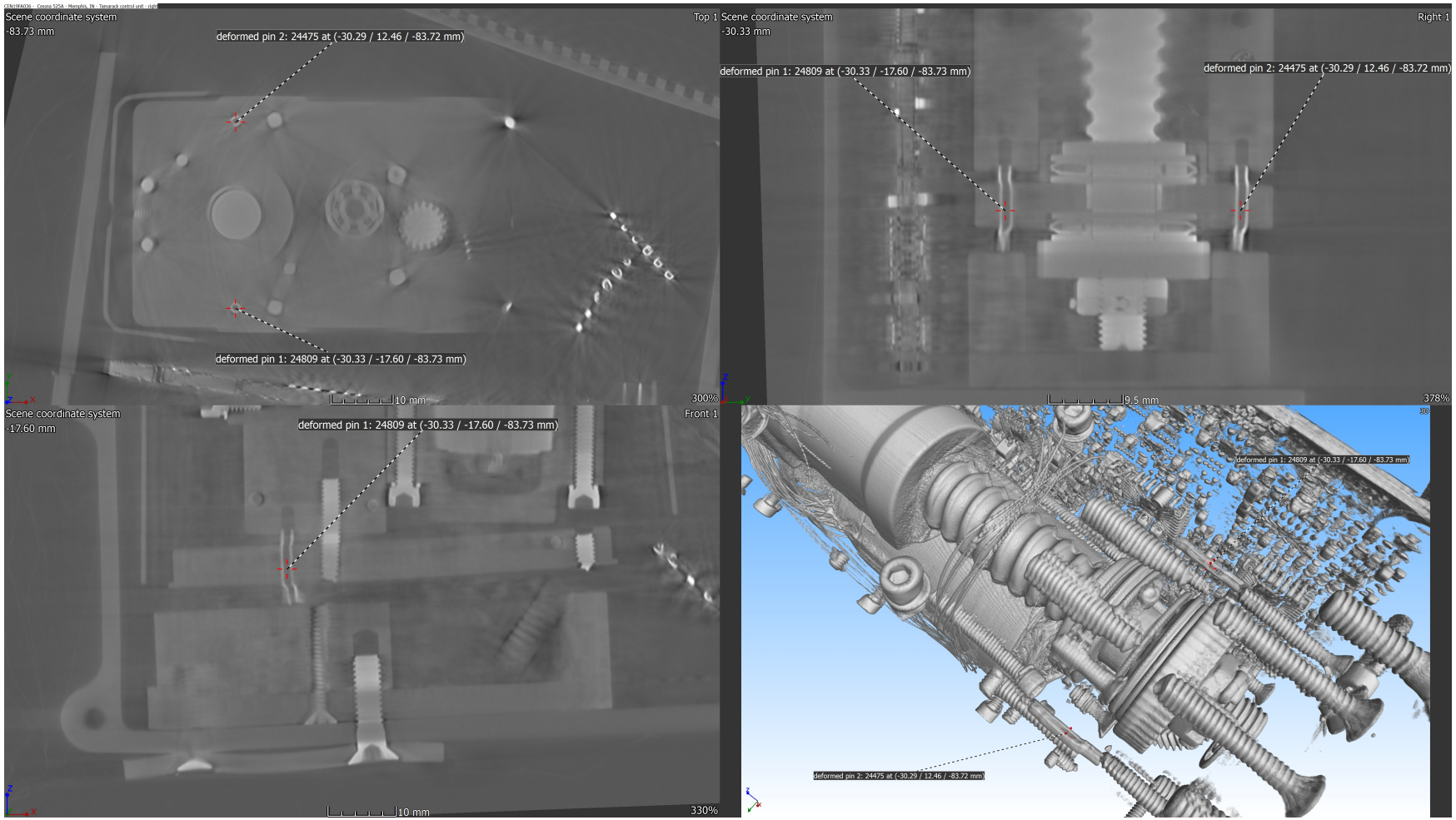


Figure 79
Right TACS control unit – deformed pins 1 and 2

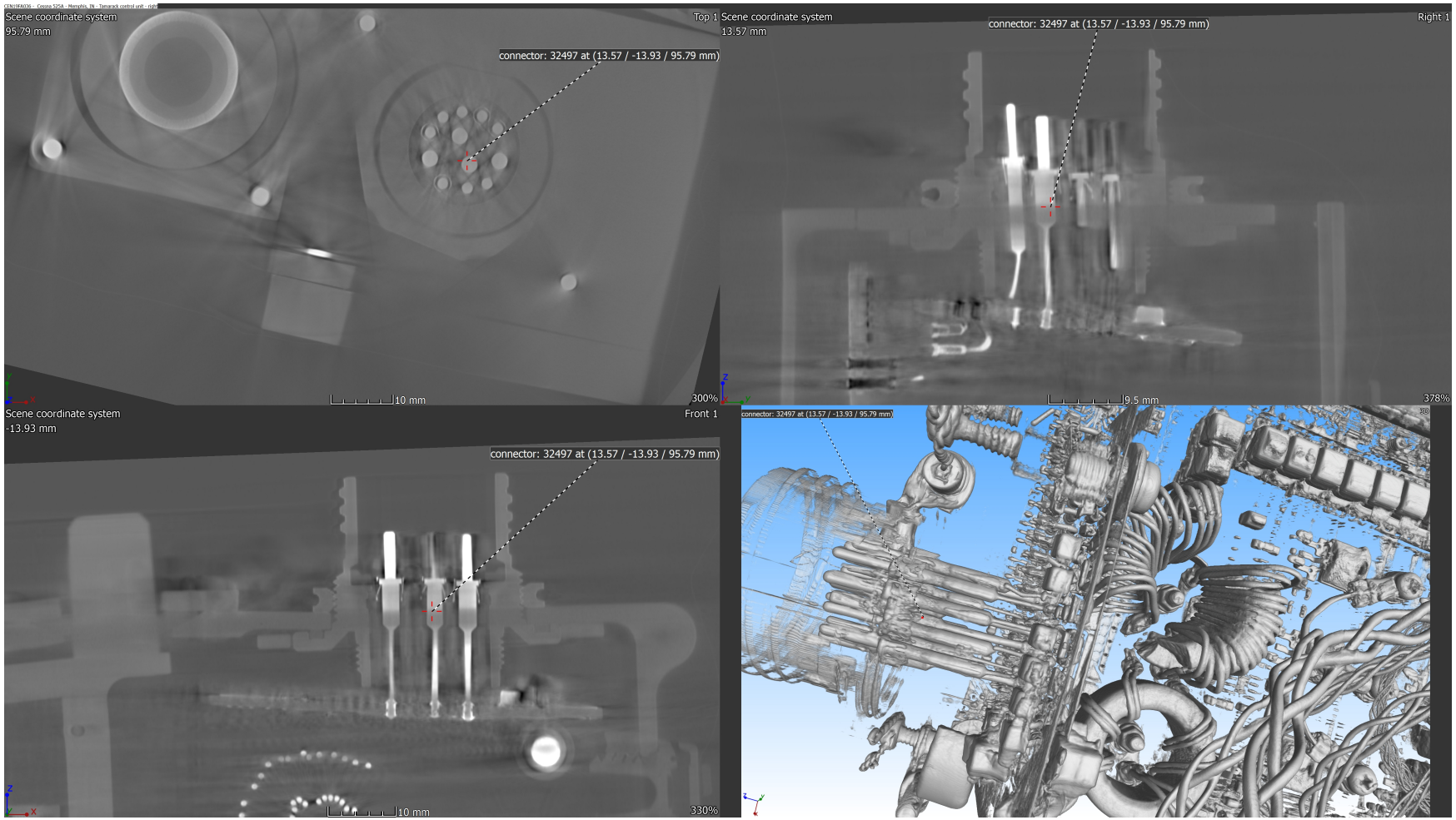


Figure 80
Right TACS control unit – connector

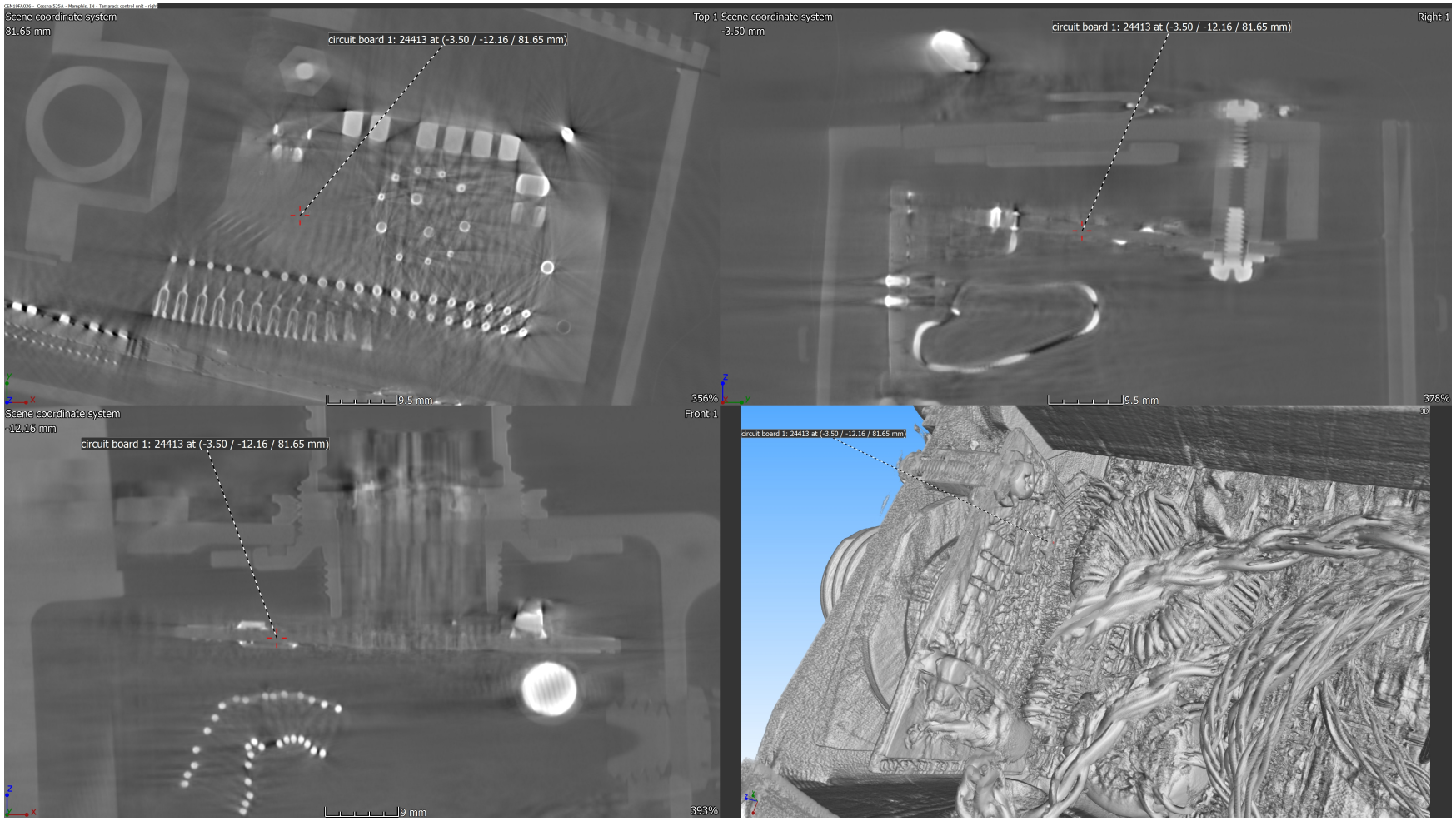


Figure 81
Right TACS control unit – circuit board 1

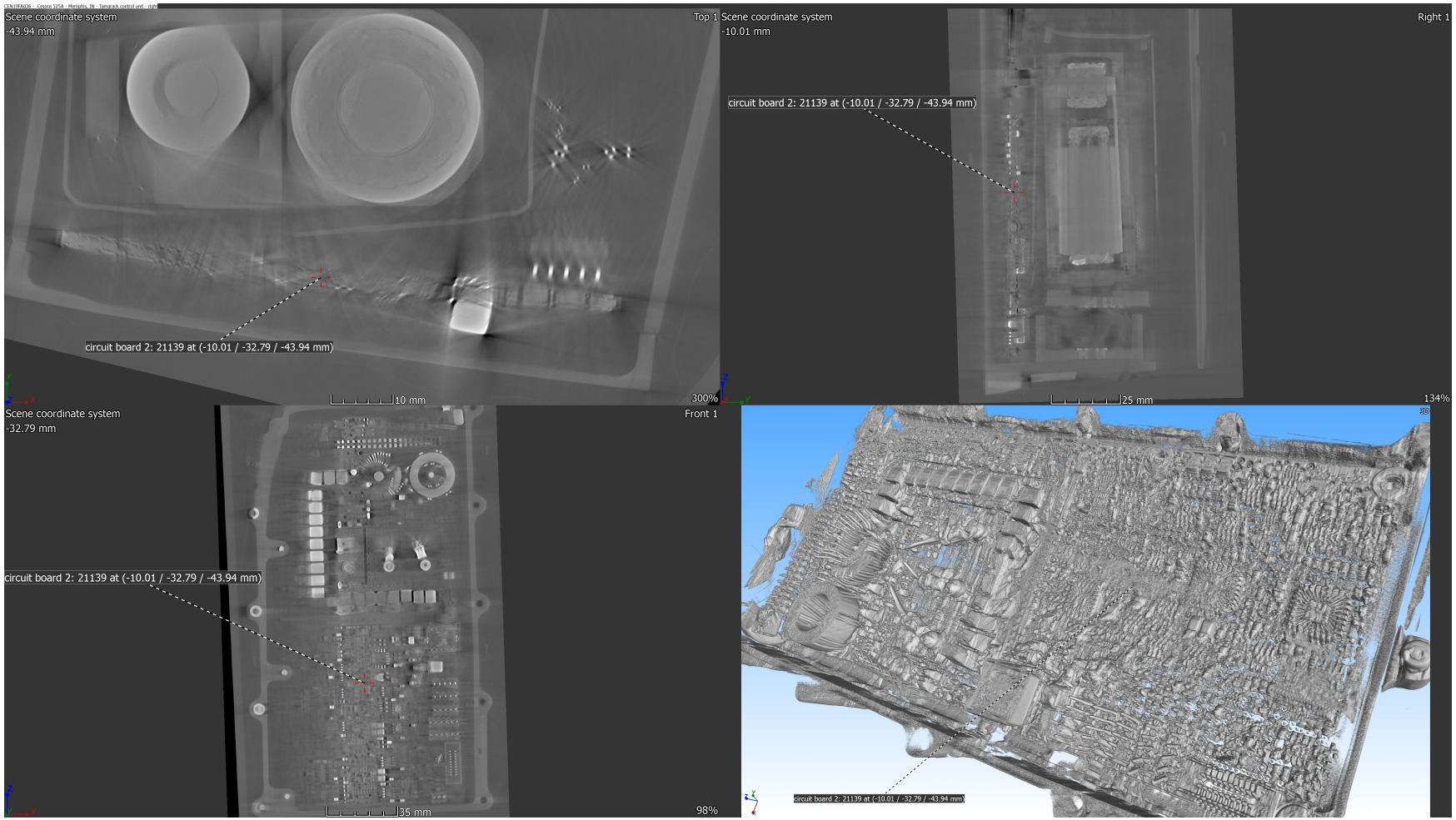


Figure 82
Right TACS control unit – circuit board 2

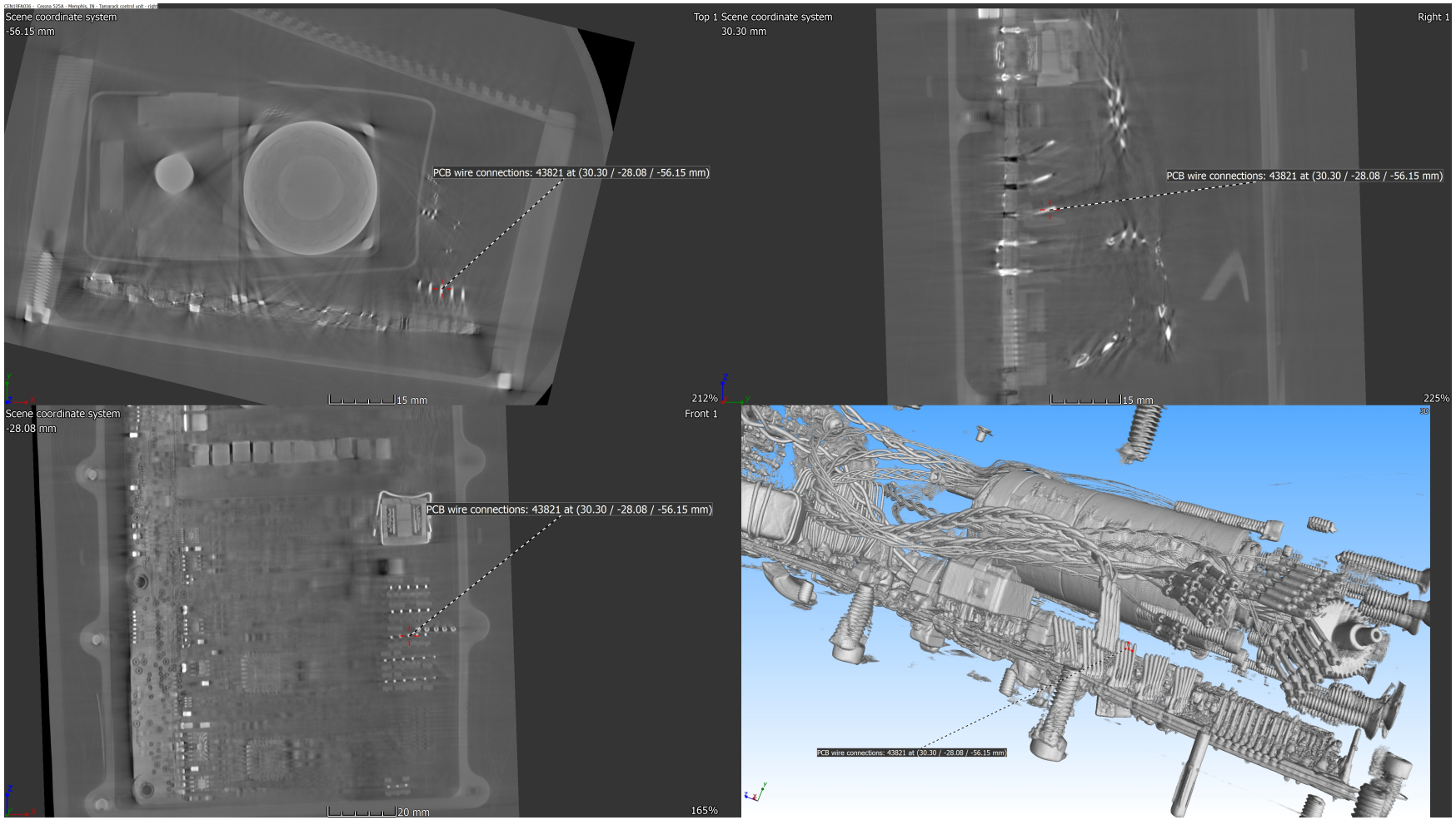


Figure 83
Right TACS control unit – PCB wire connections

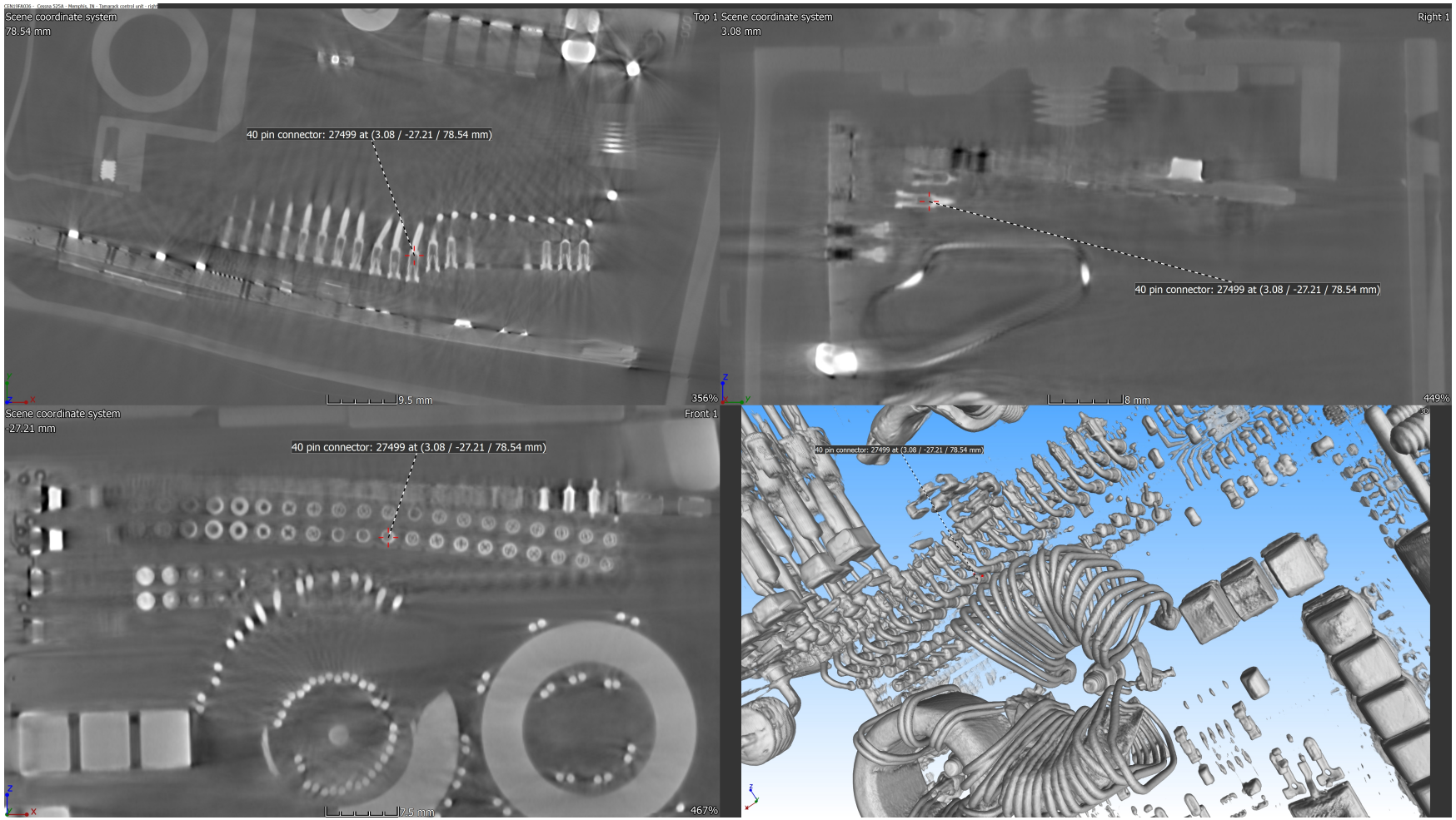


Figure 84
Right TACS control unit – 40 pin connector

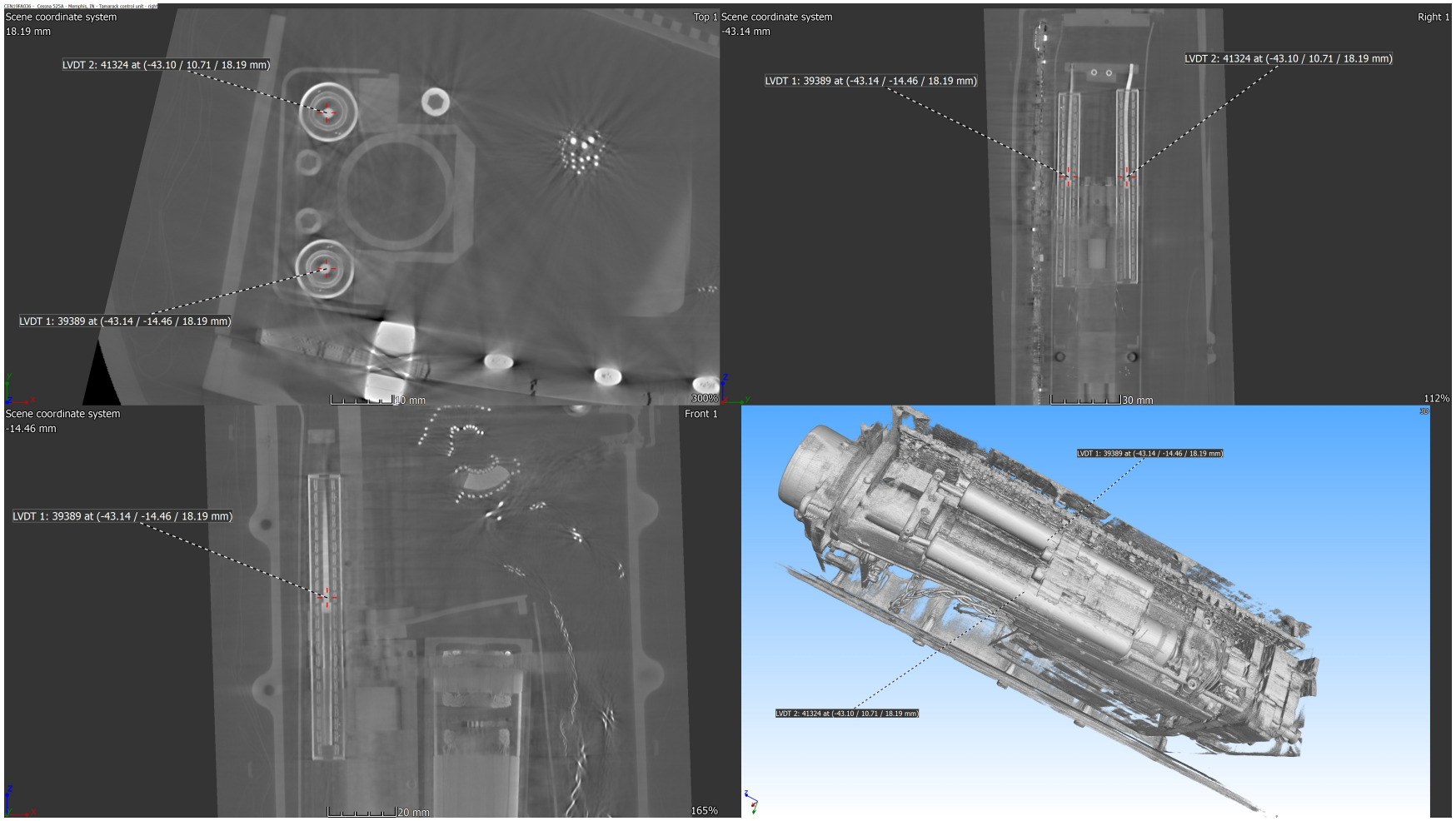


Figure 85
Right TACS control unit – LVDTs 1 and 2

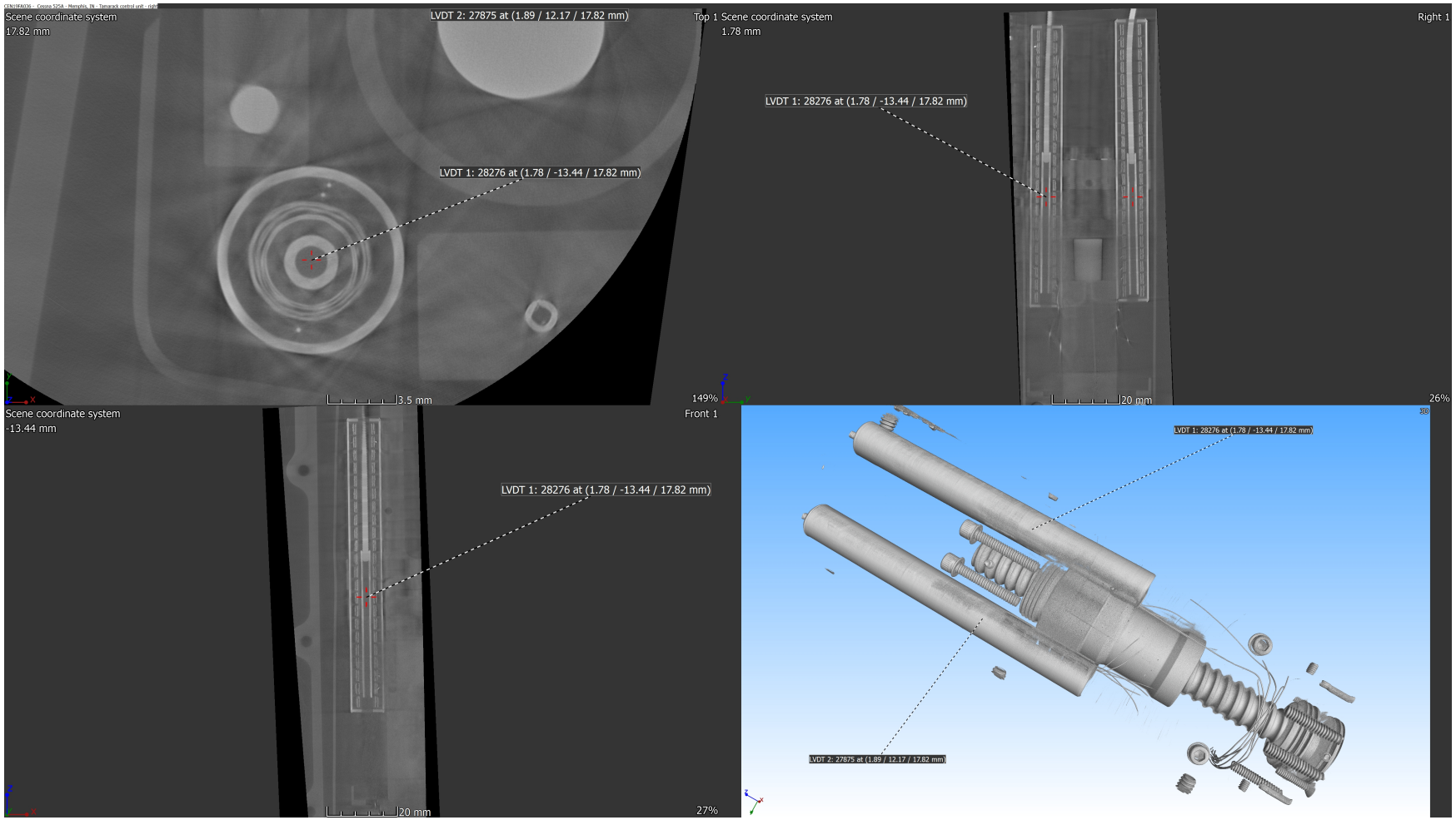


Figure 86
Right TACS control unit – target CT – LVDT 1

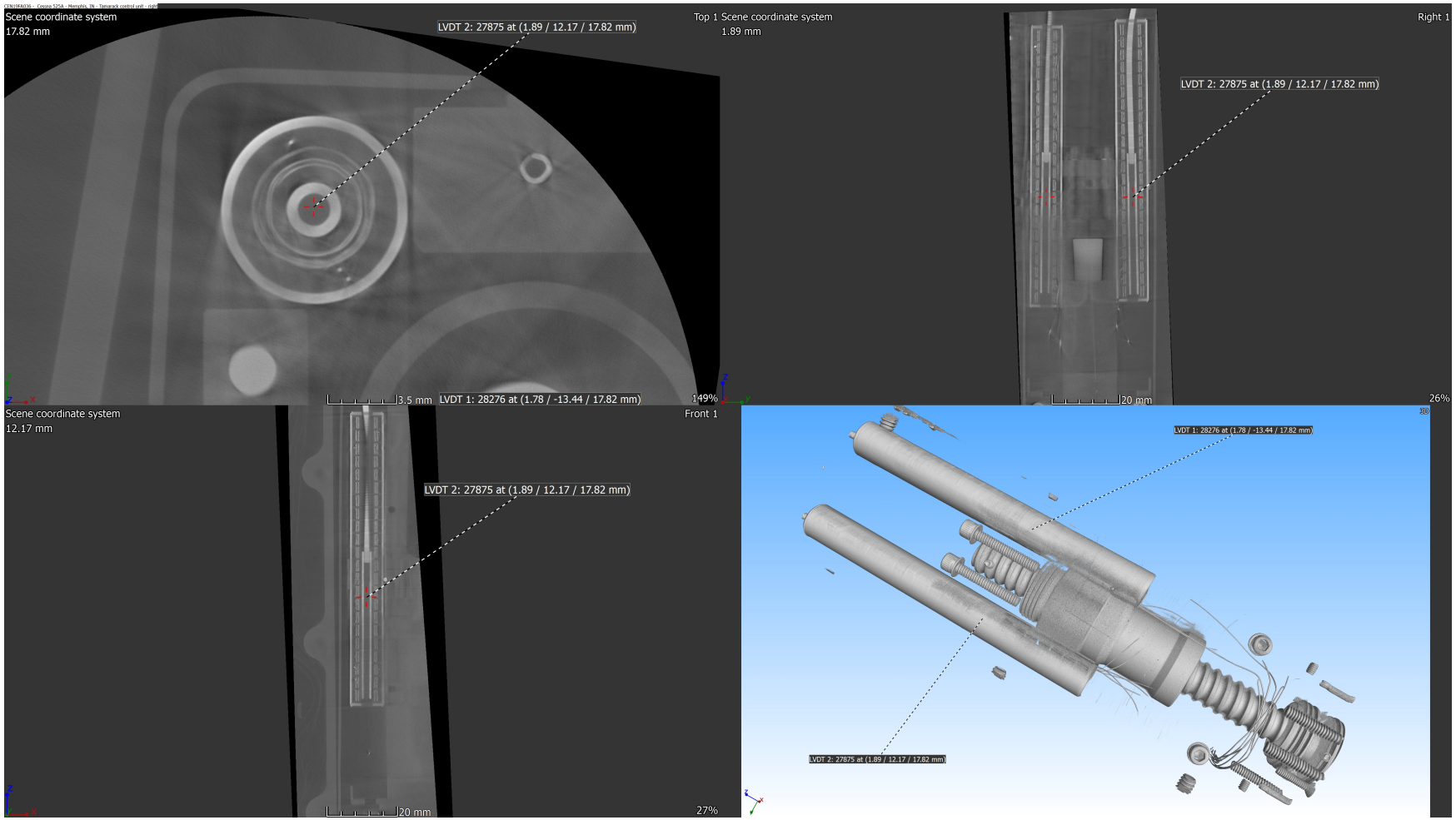


Figure 87
Right TACS control unit – target CT – LVDT 2

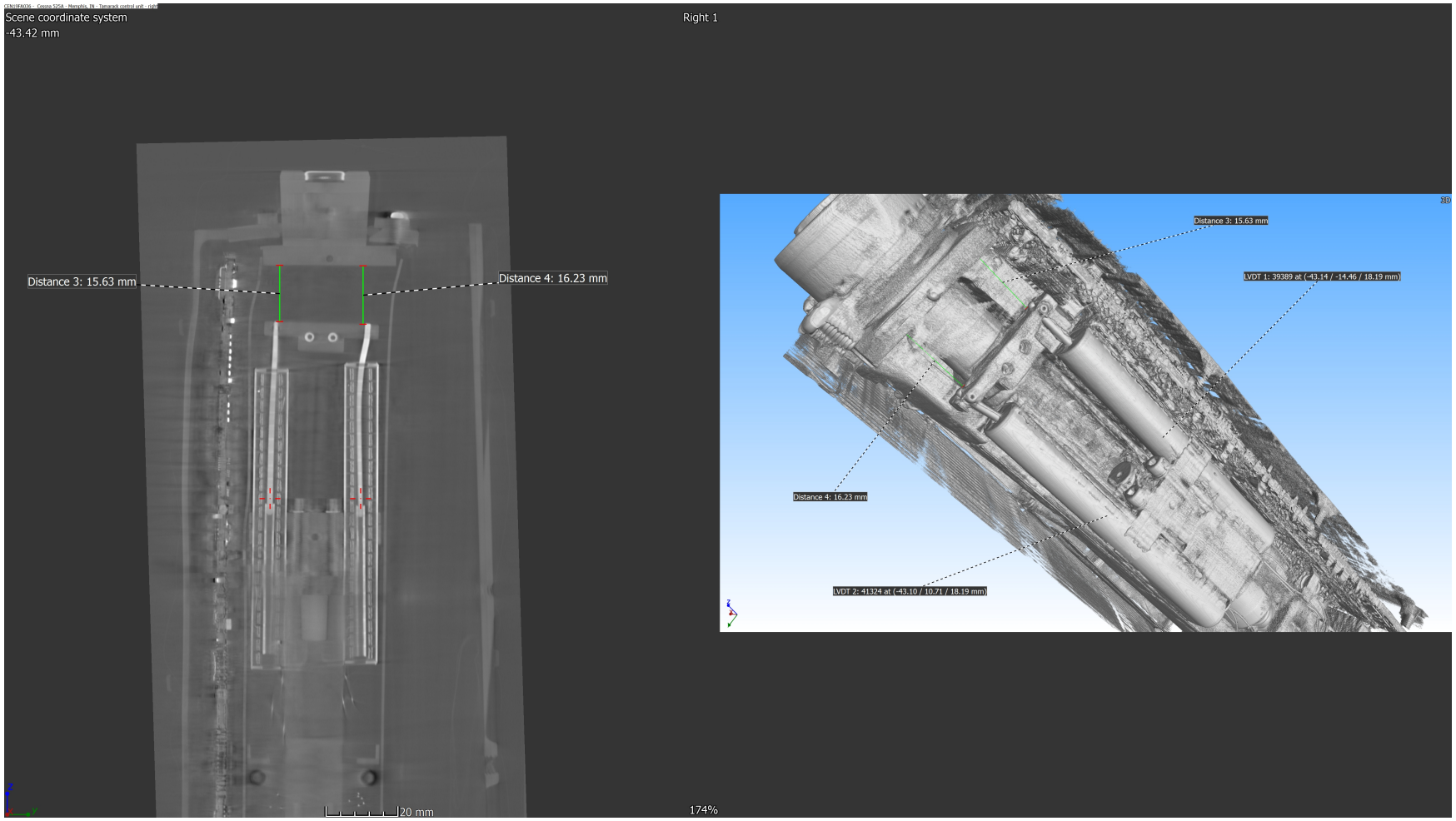


Figure 88
Right TACS control unit – LVDT bracket to housing distance

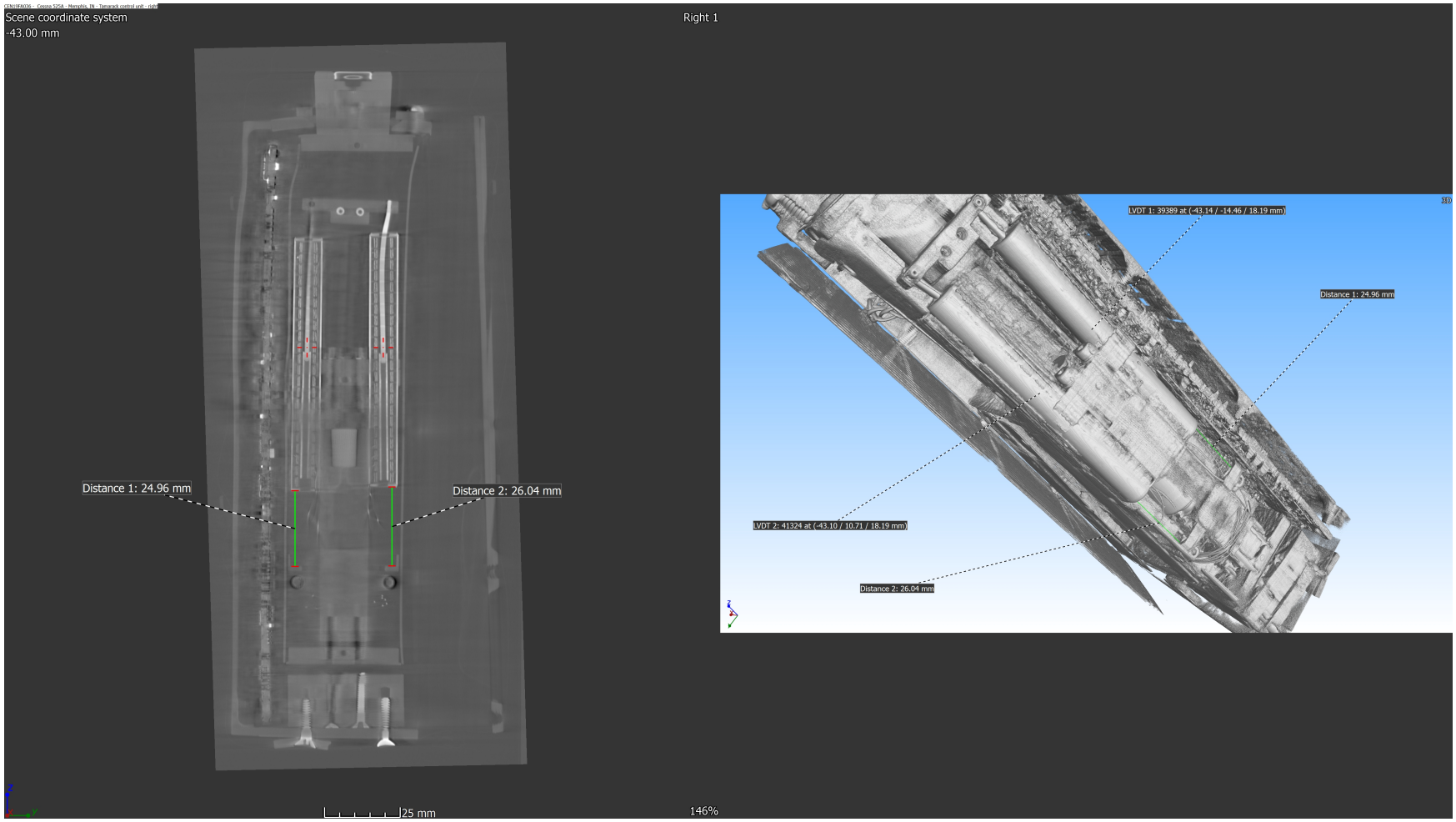


Figure 89
Right TACS control unit – LVDT displacement distances

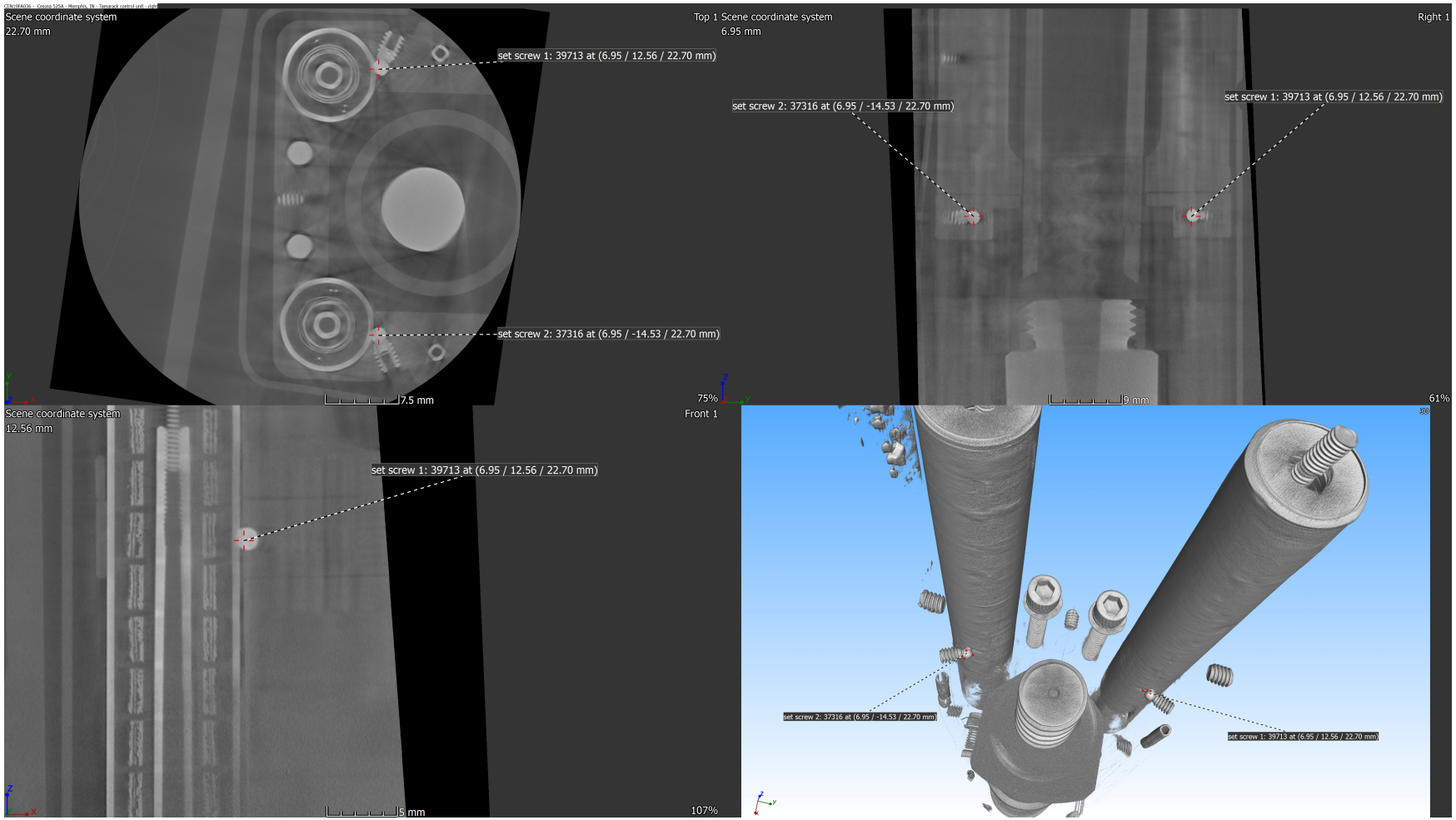


Figure 90
Right TACS control unit – target CT – set screw 1

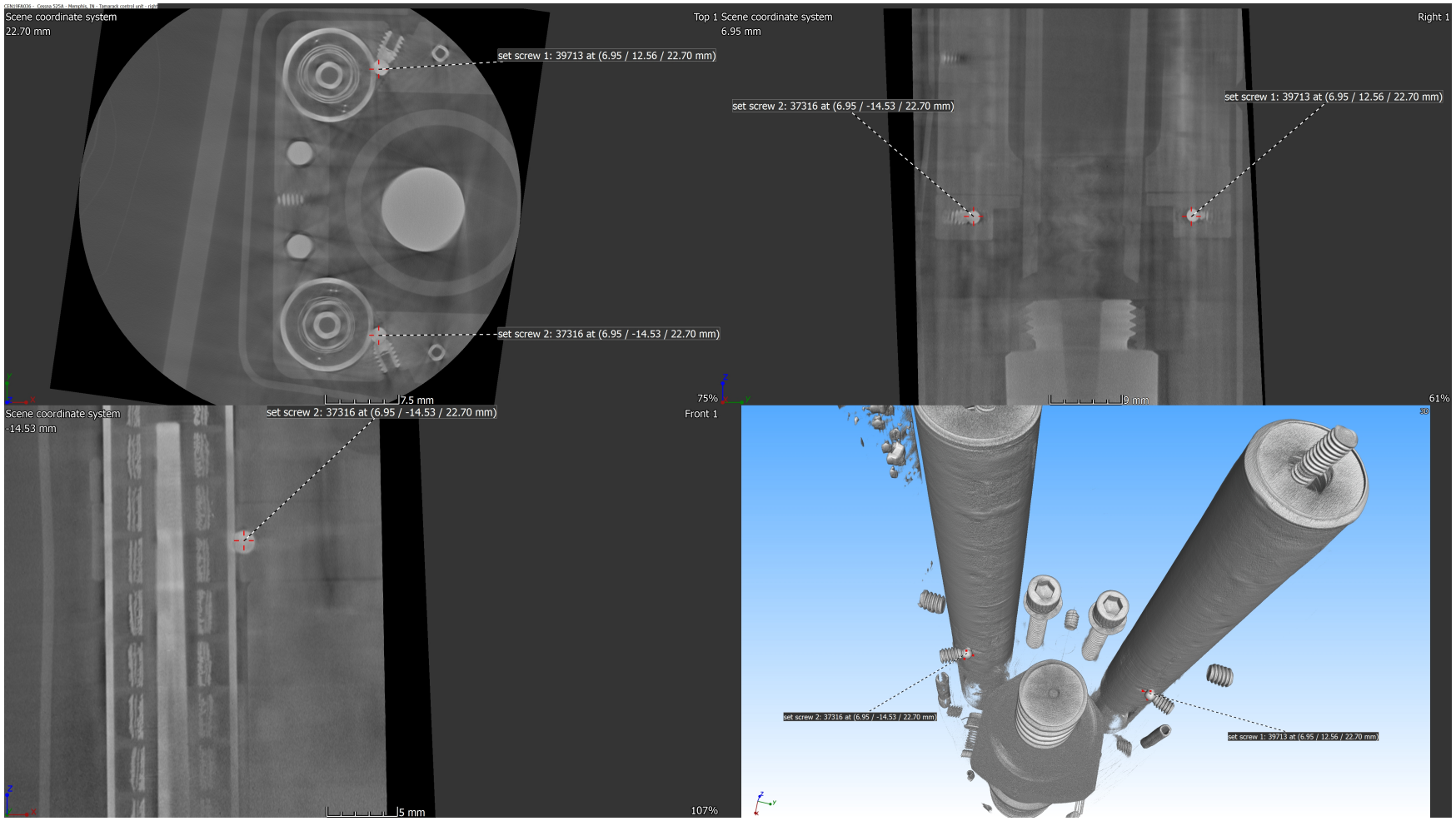


Figure 91
Right TACS control unit – target CT – set screw 2

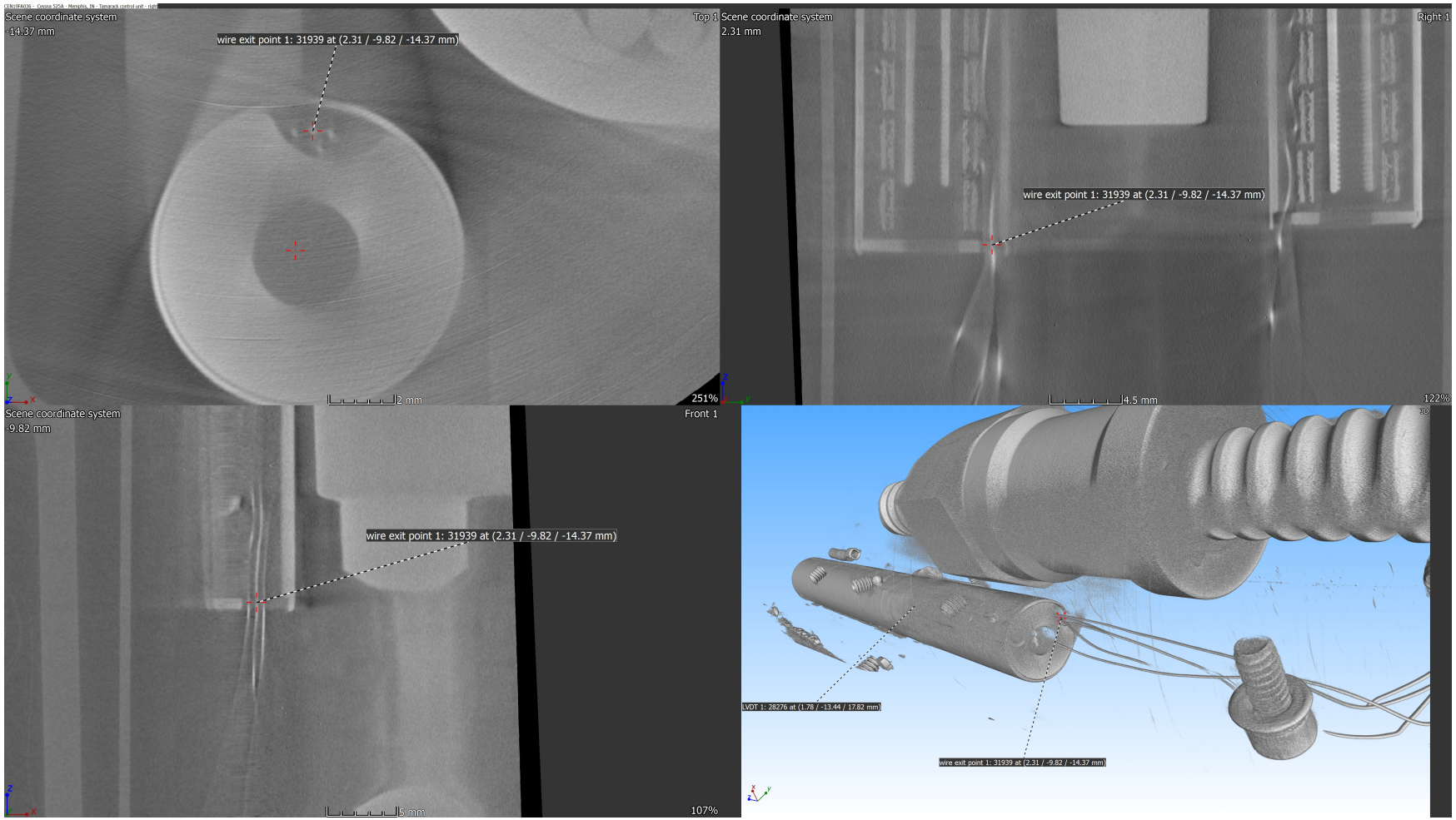


Figure 92
Right TACS control unit – target CT – wire exit point 1



Figure 93
Right TACS control unit – target CT – wire exit point 2

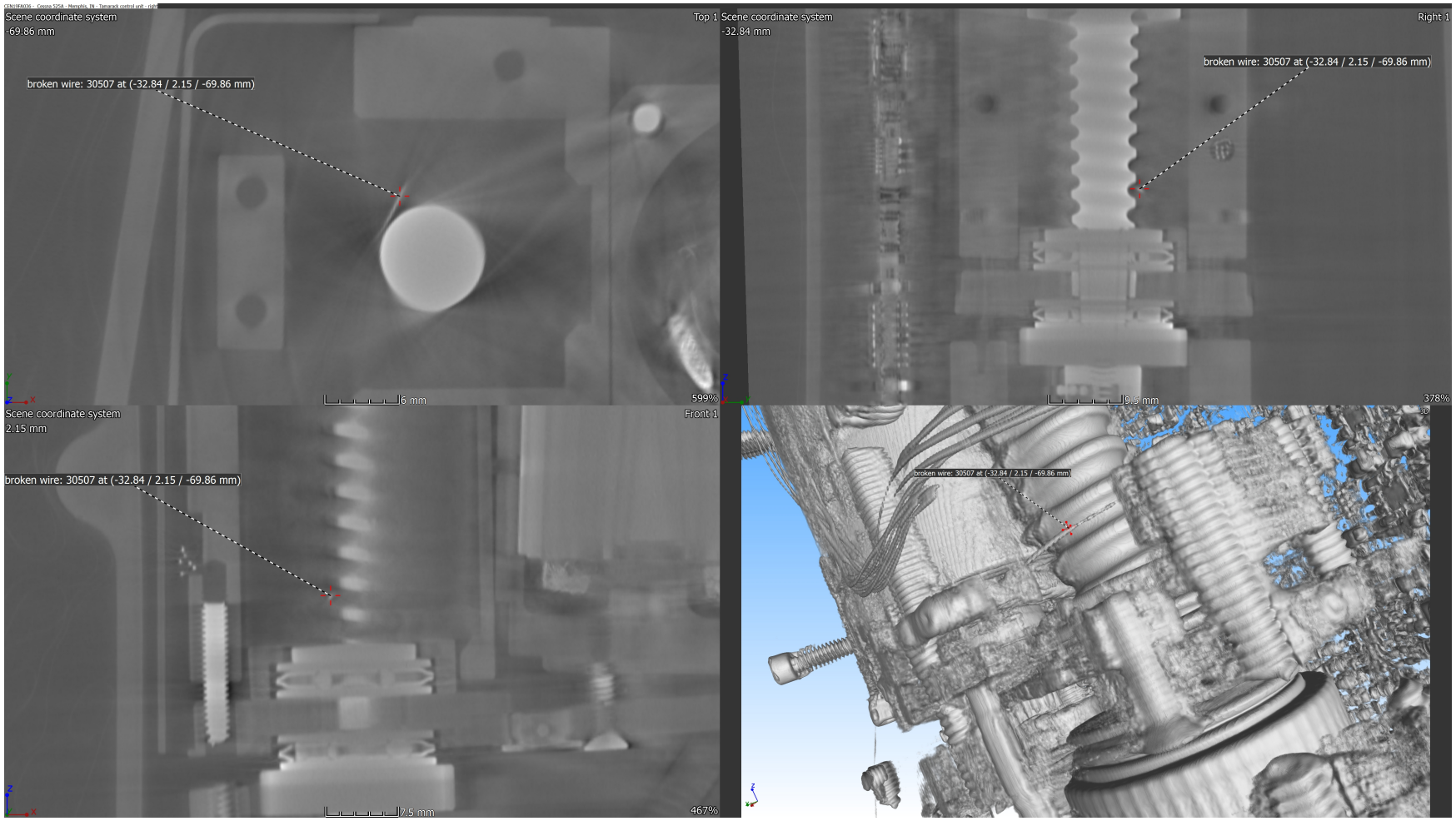


Figure 94
Right TACS control unit – target CT – broken wire

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