

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

February 7, 2019

Computed Tomography Specialist's Factual Report

ERA17FA135

A. ACCIDENT

Location: Marietta, Georgia
Date: March 24, 2017
Time: 1924 eastern daylight time
Airplane: Textron Aviation Citation 500, N8DX

B. GROUP

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

C. SUMMARY

On March 24, 2017, at 1924 eastern daylight time, a Cessna 500, N8DX, collided with terrain in a residential neighborhood near Marietta, Georgia. The private pilot, and sole occupant, was fatally injured. There were no ground injuries. The airplane was destroyed by the impact and post-impact fire. The airplane was registered to Shelter Charter Services Inc and operated as a 14 Code of Federal Regulations Part 91 business flight. Visual meteorological conditions existed near the accident site at the time of the accident and the flight was operated on an instrument flight rules flight plan. The flight originated from Cincinnati Airport - Lunken Field (LUK), Cincinnati, Ohio, about 1812, and was destined for Fulton County Airport-Brown Field (FTY), Atlanta, Georgia.

The internal configuration of isolation transformers from the autopilot roll and pitch channels from the accident aircraft and exemplar isolation transformers were documented using radiographic images that were collected from July 5, 2017 to September 13, 2018 in Chicago, Illinois and Livermore, CA. A total of 38,670 computed tomography (CT) slice images were examined, processed, and analyzed by the NTSB to evaluate the components.

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

- the attachment points and routing of the lead and coil wires associated with each pin of the roll and pitch transformers appeared to be different (figures 1-3);
- there was possible wire damage noted in the microfocus scans associated with the coil wire from pin 1 of the roll transformer (figures 4-7);
- the attachment points and routing of the lead and coil wires associated with each pin of the Duncan Aviation unairworthy transformer appeared to be different (figure 8);
- there was possible wire damage noted in the microfocus scans associated with pin 6 of the Duncan Aviation unairworthy transformer – the coil wire appearance varied when pressure on pin 6 was applied and removed (figures 9-13);
- the LLNL scans did not show any indications of wire damage in the coil wires associated with pins 1, 3, 4, and 6 of the roll transformer (example images showing the area of interest shown in figures 6 and 7 as well as the complete coil wire length of pin 1's coil wire are shown in figures 14 and 15);
- the LLNL scans showed additional details regarding the coil wire for pin 1 of the roll transformer (figures 16 – 18);
- the LLNL scans indicated several areas within the roll transformer which included high density particles, medium density particles, medium density areas, and voids (figures 19 – 33);
- initial LLNL scans indicated anomalous areas of the coil wire associated with pin 6 of the Duncan Aviation unairworthy transformer. These areas were imaged further at LLNL with high resolution scans, and these scans confirmed the anomalies were not artifacts. This confirmation indicated that the lower

resolution LLNL scans were adequate for finding anomalous areas within the coil wires (figures 34-39).

D. DETAILS OF THE INVESTIGATION

1.0 General

The CT scanning work for this investigation was conducted in three phases.

During phase one, digital radiographs and target CT images were acquired of the isolation transformers located on the pitch and roll channel circuit card assemblies (CCA's) using Varex Imaging Corporation's microfocus CT machine. CT scans of an exemplar transformer provided by Honeywell as well as two additional isolation transformers provided by Duncan Aviation were also acquired. The phase one CT work was conducted at Varex from July 5-28, 2017.

After the phase one CT scans, the CCA's and the Duncan Aviation transformers were sent to Honeywell for additional testing under the direction of the NTSB. The testing activities at Honeywell determined that, when finger pressure was applied to pin 6 of one of the Duncan Aviation transformers (labeled as "unairworthy"), an open circuit was created within that transformer. Following this testing, the isolation transformers were removed from the CCA's and sent back to Varex for additional CT scanning.

During phase two CT scanning, the roll channel isolation transformer and the Duncan Aviation unairworthy transformer were scanned using target CT. Target CT scans of the Duncan Aviation transformer were acquired both with and without pressure applied to pin 6. Following the target CT scans of the Duncan Aviation transformer, scans using a similar CT imaging protocol were conducted on the roll channel isolation transformer. The phase two CT work was conducted at Varex from September 8 – October 10, 2017.

During the phase three CT scanning, the roll channel isolation transformer and the Duncan Aviation transformer were sent to Lawrence Livermore National Laboratory (LLNL) for specialized CT scanning. The LLNL facility has a nanofocus CT machine which is capable of higher resolution images than the microfocus CT machine used previously at Varex. The roll channel isolation transformer and the Duncan Aviation transformer were both scanned multiple times covering multiple regions of interest within each transformer. At LLNL, attempts to duplicate the open circuit condition by applying pressure to pin 6 of the Duncan Aviation transformer were unsuccessful. The phase three work was conducted at LLNL from June 12 to September 13, 2018.

The scans were performed by Varex using the Varex Actis 500/225 microfocus CT system, and by Lawrence Livermore National Laboratory using the Zeiss Xradia 510 Versa x-ray microscope under the direction of the NTSB.

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 part¹. 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.

Each component was subjected to more than one scan, as required, to provide different types of information in each data set. The target CT scans used the microfocus x-ray source to scan a limited region of interest within the component. This scanning setup allowed for increased resolution within that region of interest.

Combining all three scanning phases, the components were scanned using a total of 38,670 slices, and the total size of the combined data sets was approximately 269 Gb. Many of the CT scans conducted during this evaluation produced images that were superseded in quality by subsequent images. As a result, only the most relevant images are provided in this report. The scan protocols for selected scanning work are given in table 1. The digital radiograph and CT axial slice images were provided by Varex and LLNL to the NTSB where they were examined, processed, and analyzed to evaluate the components.

¹ For the LLNL scans, the Zeiss Xradia 510 Versa x-ray microscope used a slightly different internal architecture. After the x-rays penetrated the component, they were then converted to visible light by a scintillator and then the visible light information was optically magnified prior to being sensed by the detector. The detector information was then processed to create cross sectional CT slice images.

Table 1
Scan Protocols

Component	Roll and pitch transformers – on PCB	Roll transformer – off PCB	Duncan Aviation unairworthy transformer – overall	Duncan Aviation unairworthy transformer – target CT	Roll transformer – target CT	LLNL – Roll transformer - overall scan	LLNL – Roll and Duncan Aviation transformers – target CT	LLNL – Duncan Aviation transformer – high res CT
Number of slices	1877	1588	1668	1991	2433	1213	14022	2928
Voxel Size - X Direction (mm)	0.020	0.007	0.007	0.005	0.005	0.013	0.00196	0.00094
Voxel Size - Y Direction (mm)	0.020	0.007	0.007	0.005	0.005	0.013	0.00196	0.00094
Voxel Size - Z Direction (mm)	0.020	0.007	0.007	0.005	0.005	0.013	0.00196	0.00094
Source to Detector Distance (mm)	1042.37	1042.37	1042.37	1042.37	1042.37	80.0 with 0.4x optical magnification	36.0 with 4x optical magnification	39.0 with 20x optical magnification
Source to Object Distance (mm)	106.21	59.289	39.095	29.02	29.02	30.0	21.0	27.0
Image Projections per Revolution	1800	1800	1800	1800	1800	1201	1201	651
Exposure time (ms)	285.58	285.58	285.58	285.58	285.58	2500	14000	40000 with 2x2 binning
Frames to Avg (frames per projection)	3	3	3	3	3	1	1	1
X-ray Source Voltage (kV)	220	160	160	160	160	160	160	160
X-ray Source Current (mA)	0.490	0.200	0.200	0.200	0.200	0.062	0.062	0.072
Source Filter Thickness (mm)	2	0.25	0.25	0.5	0.25	HE3	HE3	HE1
Source Filter Material	Brass	Brass	Brass	Brass	Brass	NA	NA	NA
Image Matrix Size	2048 x 2048	2048 x 2048	2048 x 2048	2048 x 2048	2048 x 2048	2048 x 2048	2048 x 2048	2048 x 2048

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

into orthogonal slice images and a three-dimensional reconstructed image of the component. As part of the evaluation, some sections of the components were digitally removed or rendered transparent to allow closer observation of interior parts. In the images, the 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.

In some images, curved structures were “virtually unrolled” using the software. This process required the identification of a path for the software to use when unrolling the data set, and it resulted in a non-planar structure being “unrolled” to show a non-planar 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 39. Review of the images indicated that, when the scans were conducted, the following items were noted:

- the attachment points and routing of the lead and coil wires associated with each pin of the roll and pitch transformers appeared to be different (figures 1-3);
- there was possible wire damage noted in the microfocus scans associated with the coil wire from pin 1 of the roll transformer (figures 4-7);
- the attachment points and routing of the lead and coil wires associated with each pin of the Duncan Aviation unairworthy transformer appeared to be different (figure 8);
- there was possible wire damage noted in the microfocus scans associated with pin 6 of the Duncan Aviation unairworthy transformer – the coil wire appearance varied when pressure on pin 6 was applied and removed (figures 9-13);
- the LLNL scans did not show any indications of wire damage in the coil wires associated with pins 1, 3, 4, and 6 of the roll transformer (example images showing the area of interest shown in figures 6 and 7 as well as the complete coil wire length of pin 1’s coil wire are shown in figures 14 and 15);
- the LLNL scans showed additional details regarding the coil wire for pin 1 of the roll transformer (figures 16 – 18);
- the LLNL scans indicated several areas within the roll transformer which included high density particles, medium density particles, medium density areas, and voids (figures 19 – 33);
- initial LLNL scans indicated anomalous areas of the coil wire associated with pin 6 of the Duncan Aviation unairworthy transformer. These areas were imaged further at LLNL with high resolution scans, and these scans confirmed

the anomalies were not artifacts. This confirmation indicated that the lower resolution LLNL scans were adequate for finding anomalous areas within the coil wires (figures 34-39).

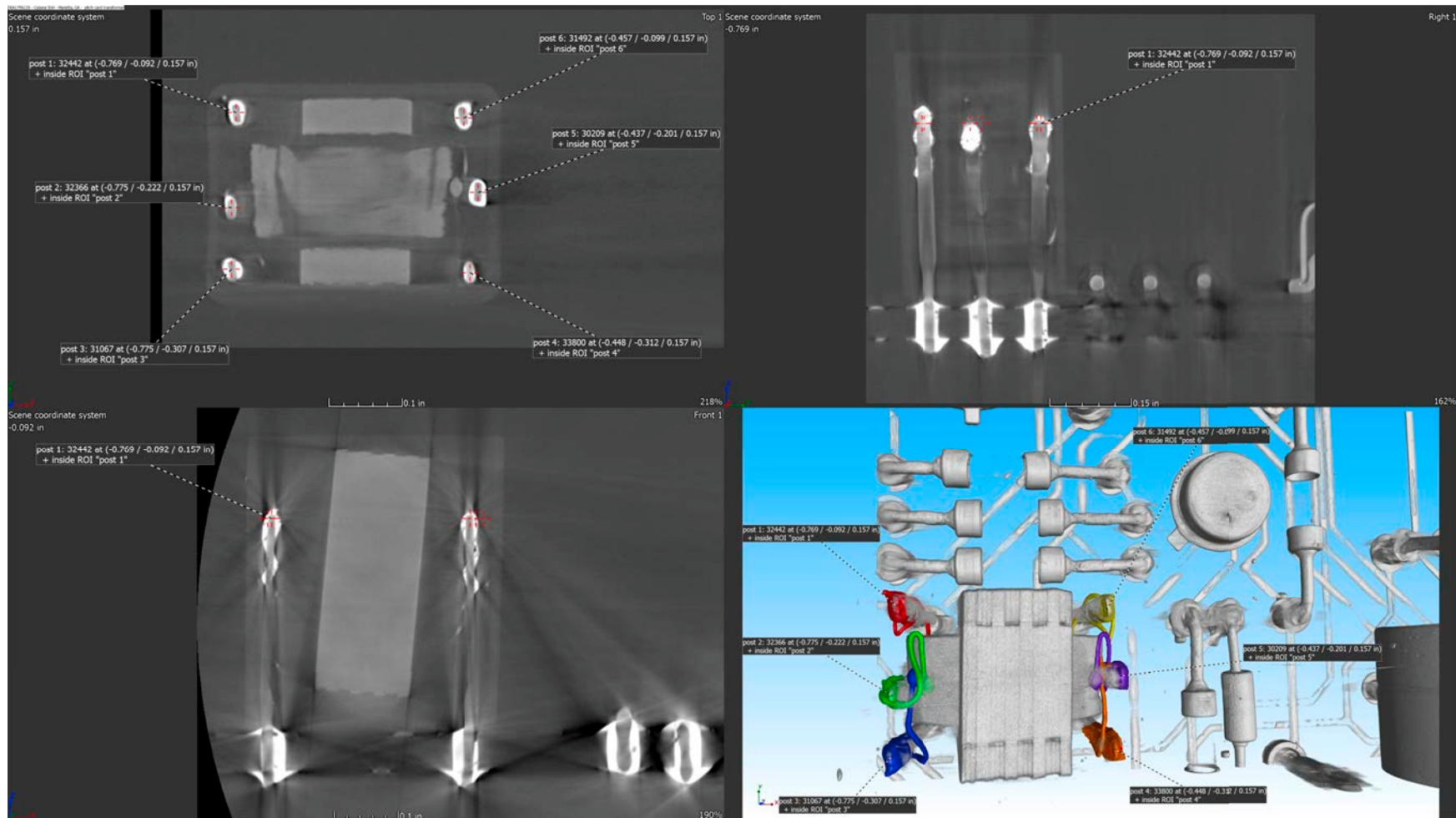


Figure 1
Pitch transformer on printed circuit board – overall view

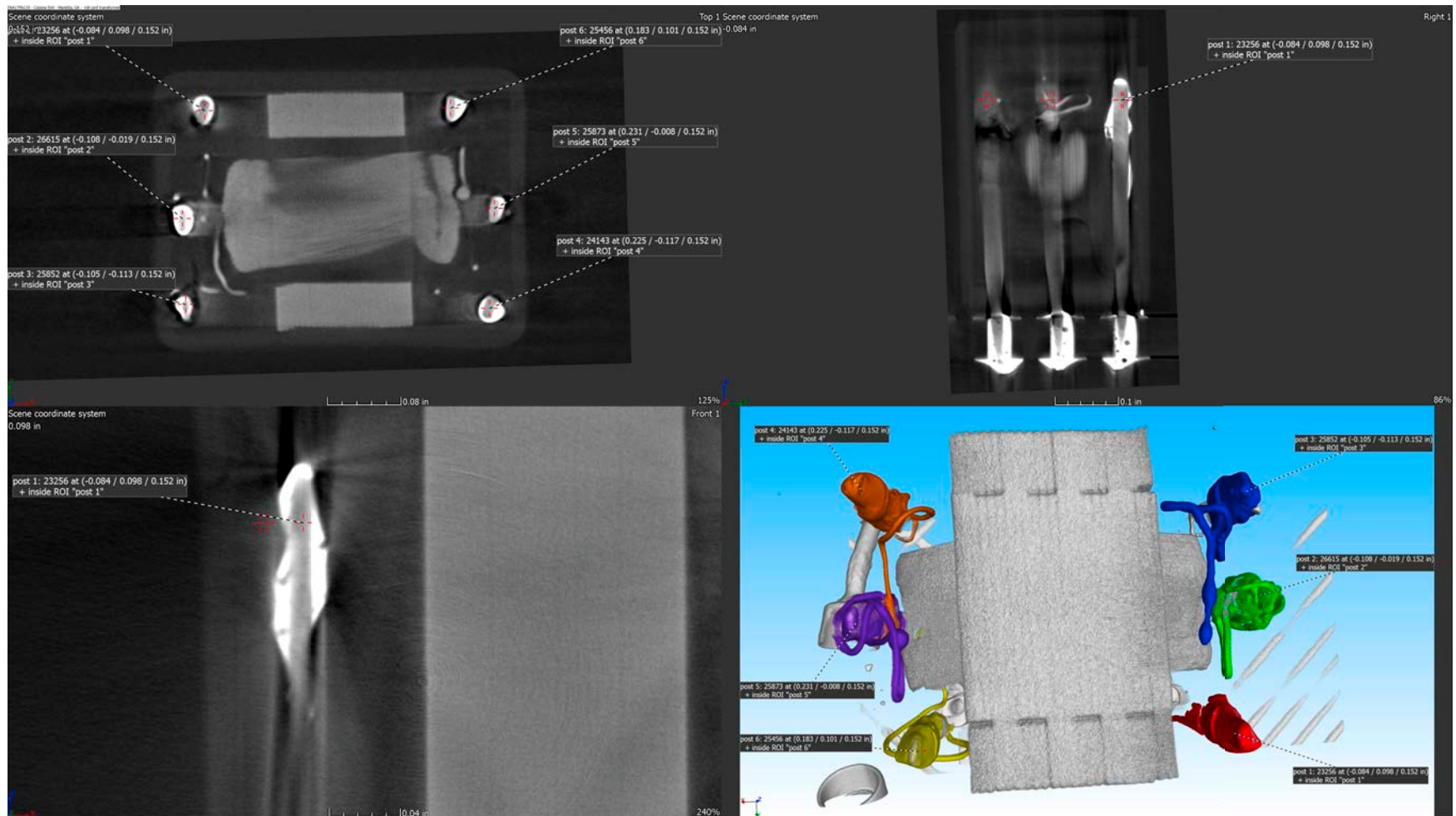


Figure 2
Roll transformer on printed circuit board – overall view

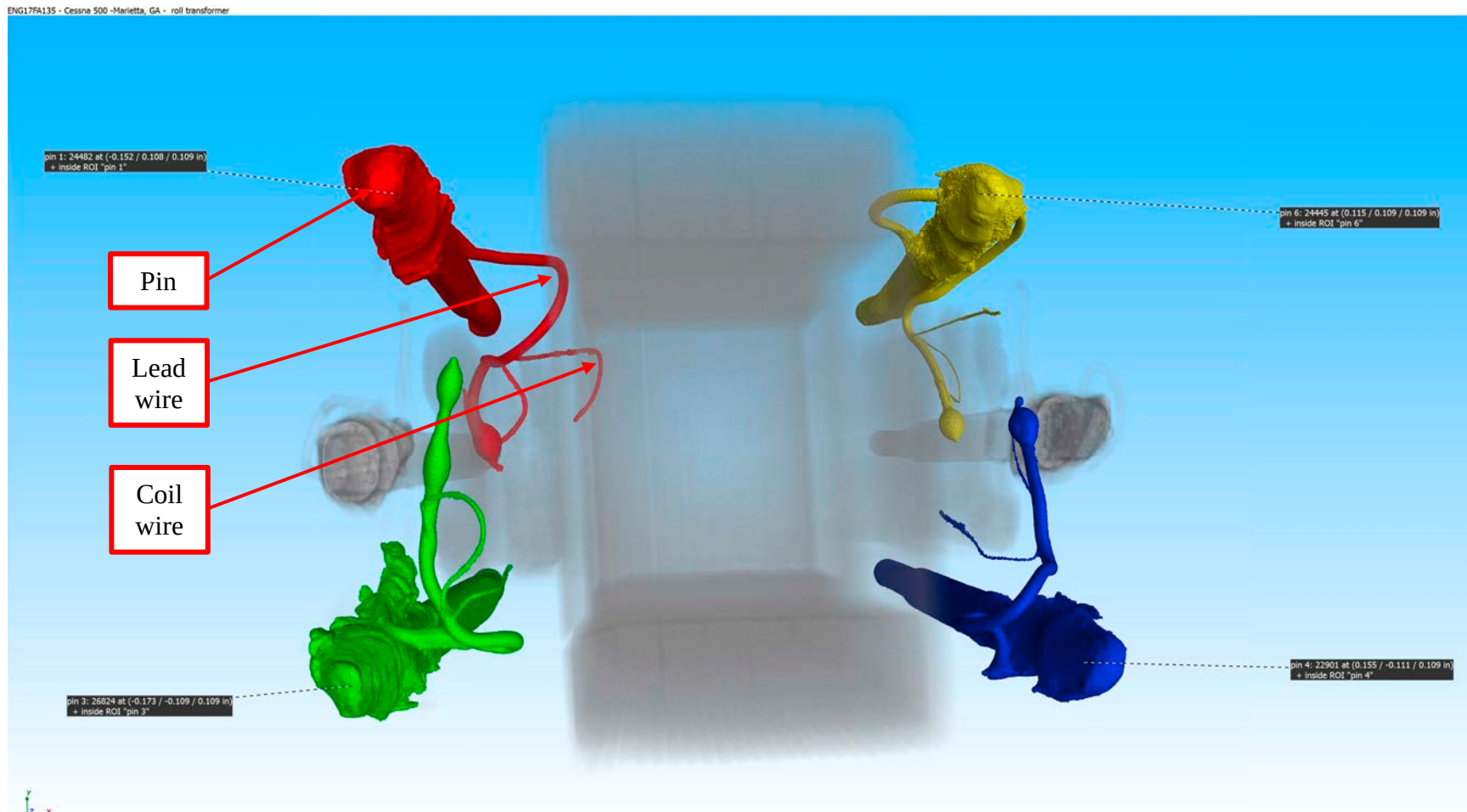


Figure 3
Roll transformer – overall view – 3D

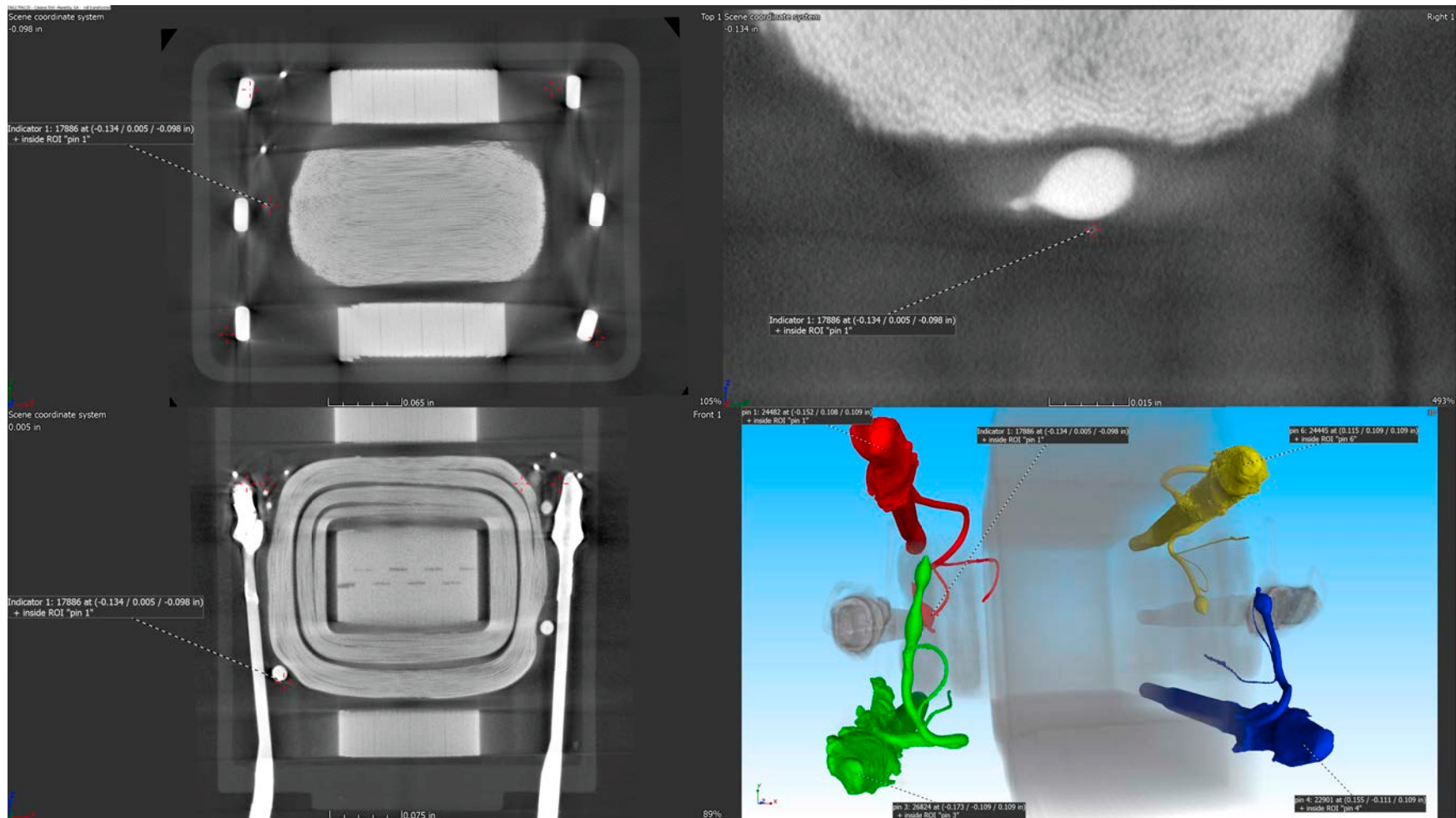


Figure 4
Roll transformer – possible wire damage associated with pin 1 – top view

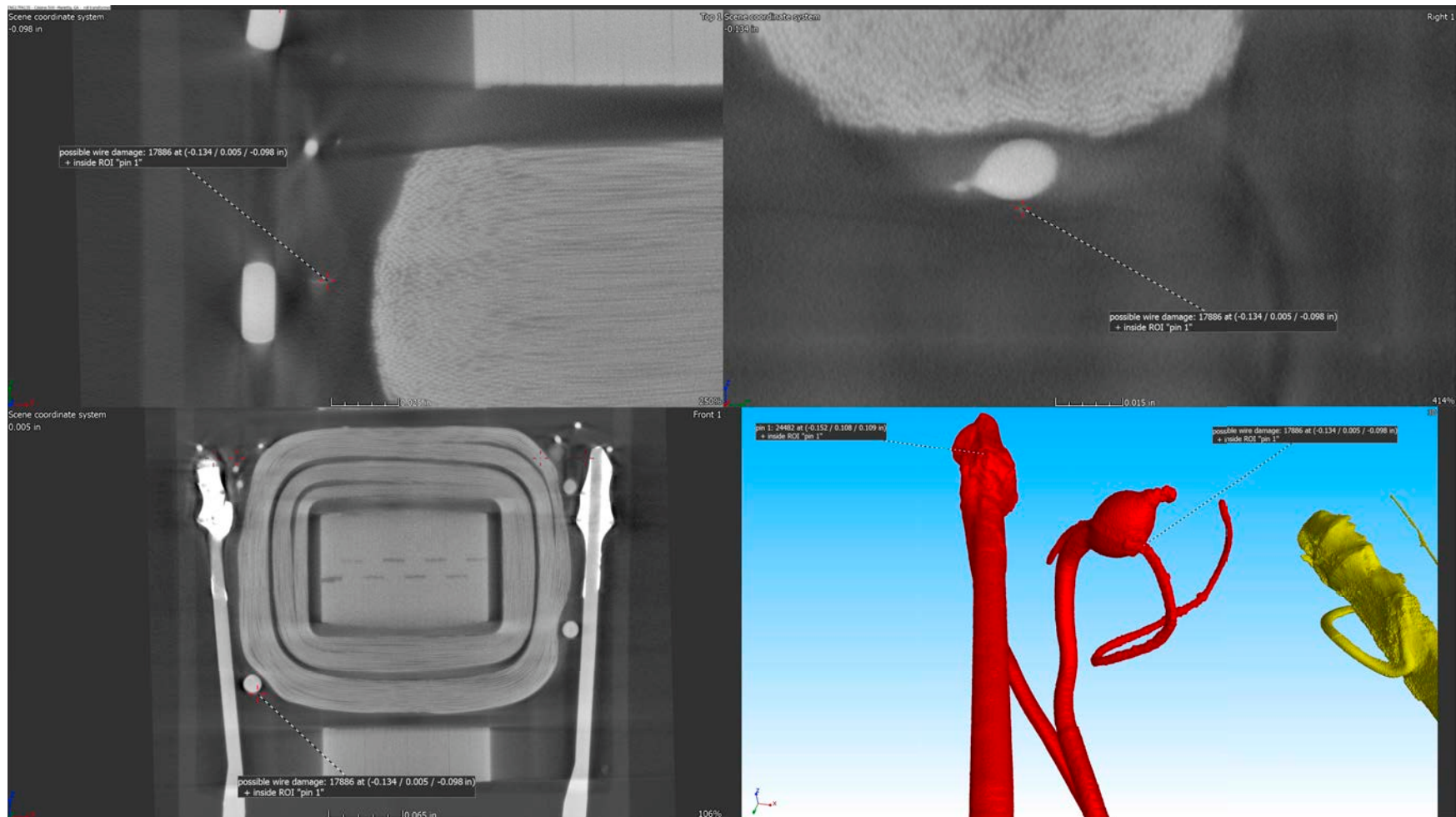


Figure 5
Roll transformer – possible wire damage – view 2

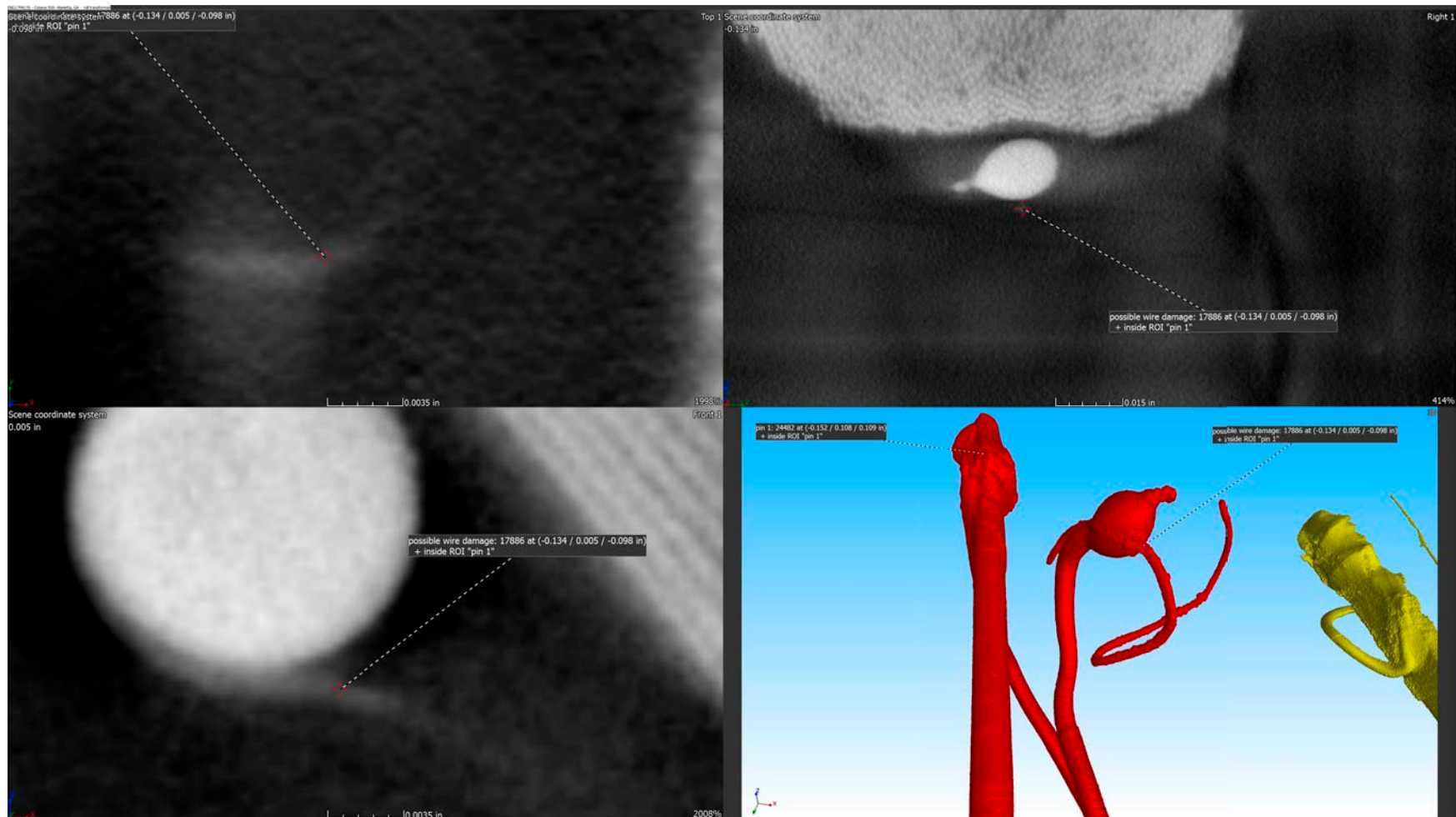


Figure 6
Roll transformer – possible wire damage – close up view

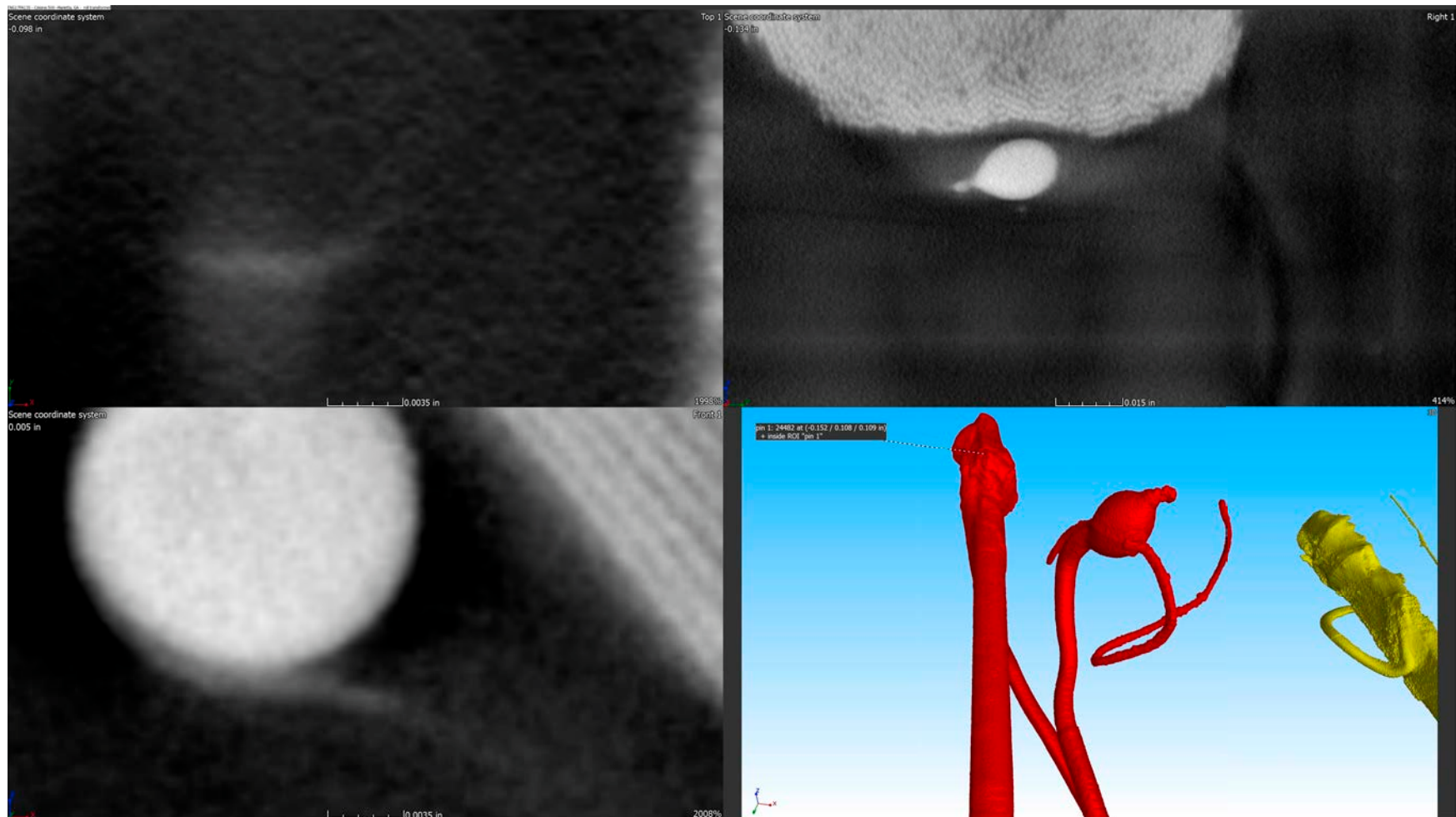


Figure 7
Roll transformer – possible wire damage – close up view without indicators

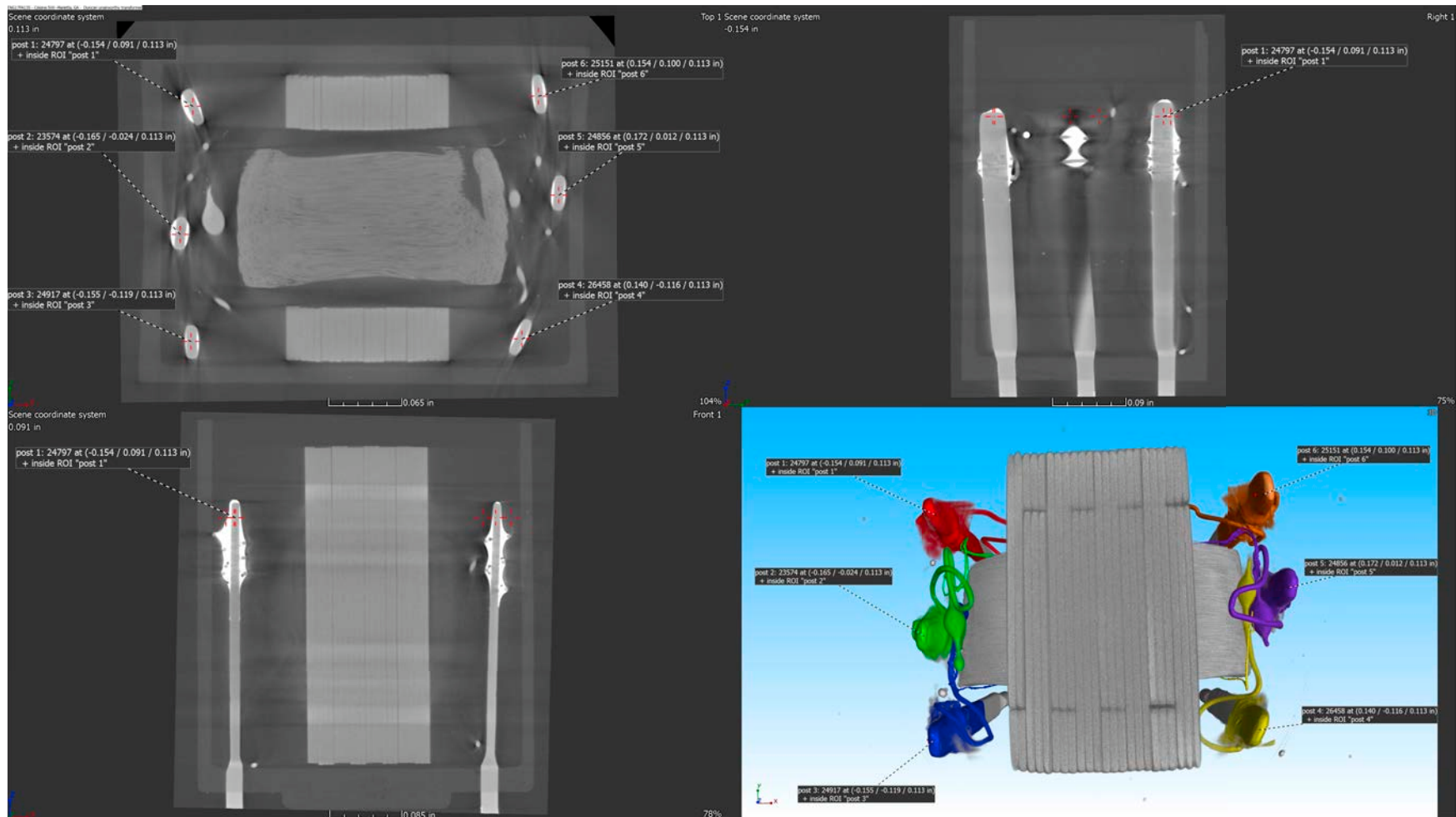


Figure 8
Duncan Aviation unairworthy transformer – overall view

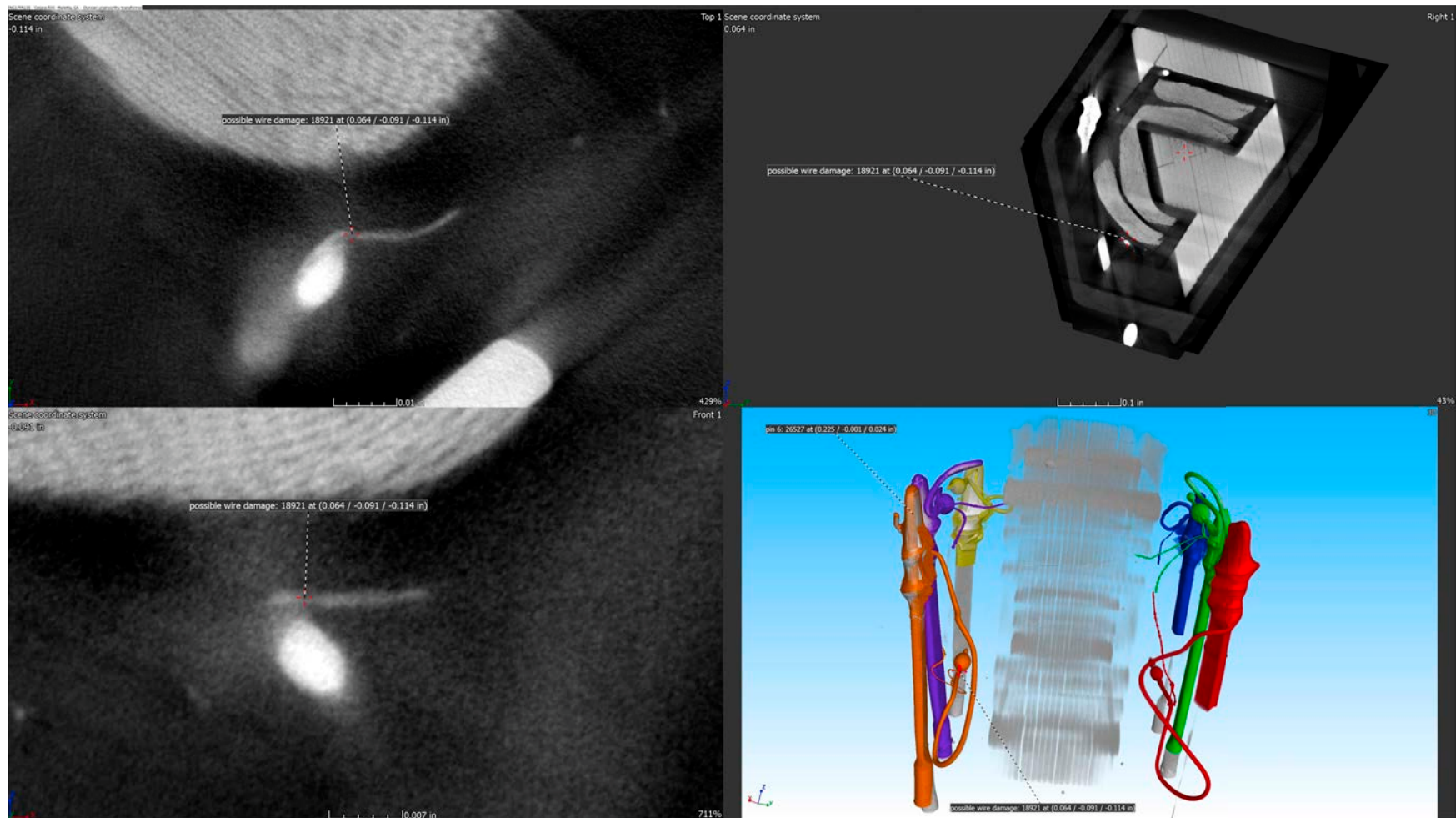


Figure 9
Duncan Aviation unairworthy transformer – with pressure applied to pin 6 – possible wire damage - overall view

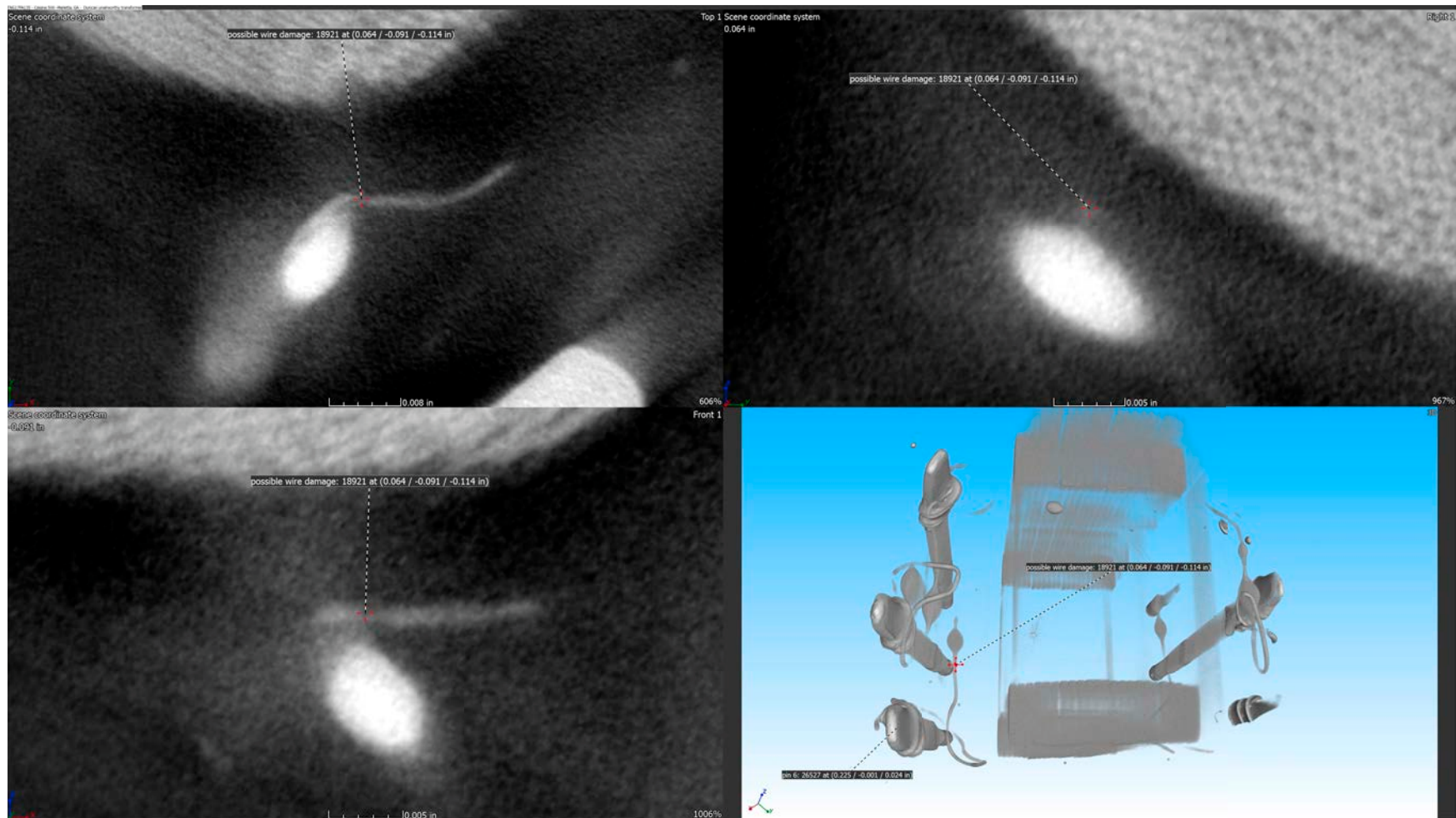


Figure 10
Duncan Aviation unairworthy transformer – with pressure applied to pin 6 – possible wire damage - overall view 2

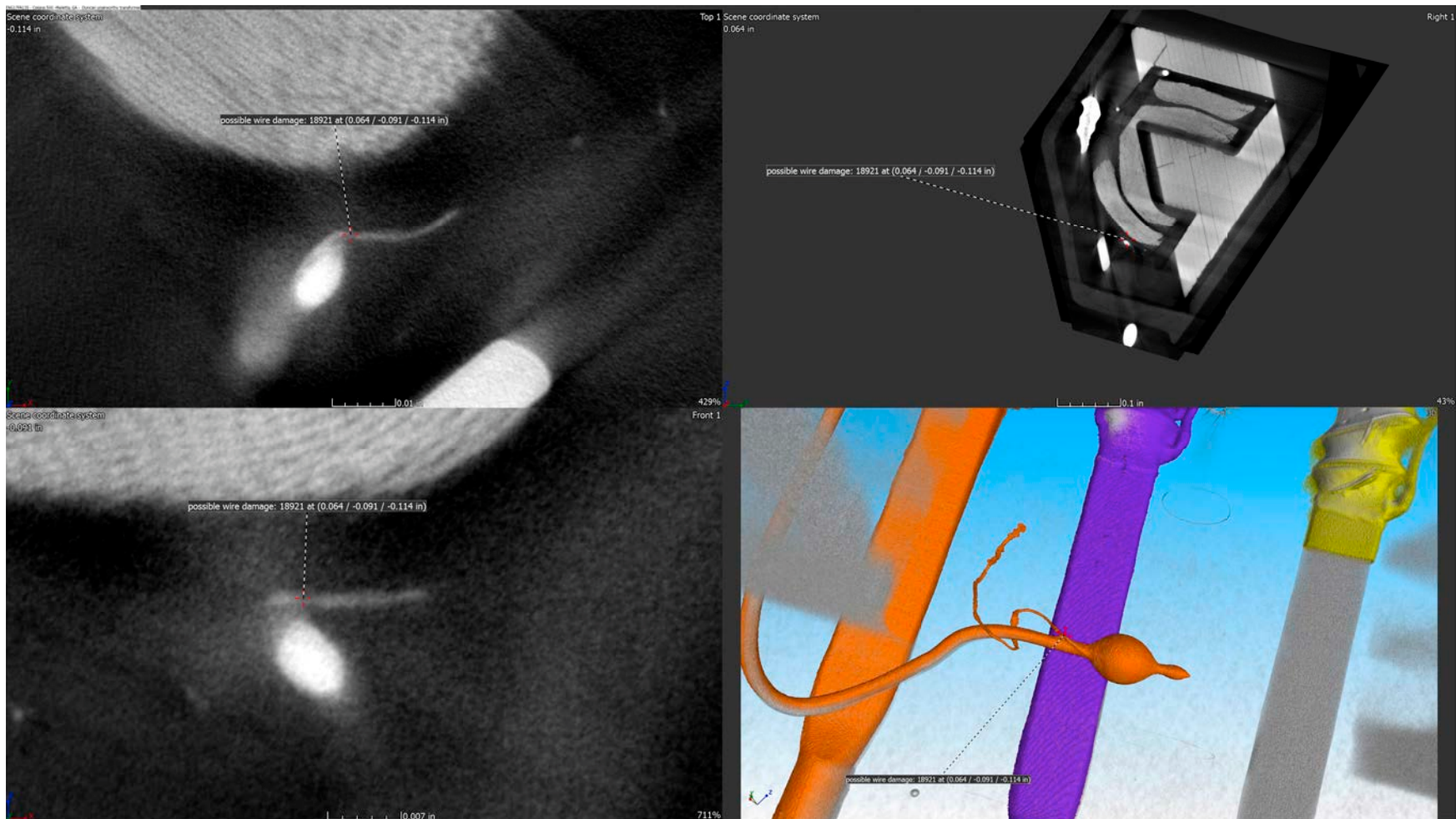


Figure 11
Duncan Aviation unairworthy transformer – with pressure applied to pin 6 – possible wire damage - overall view 3

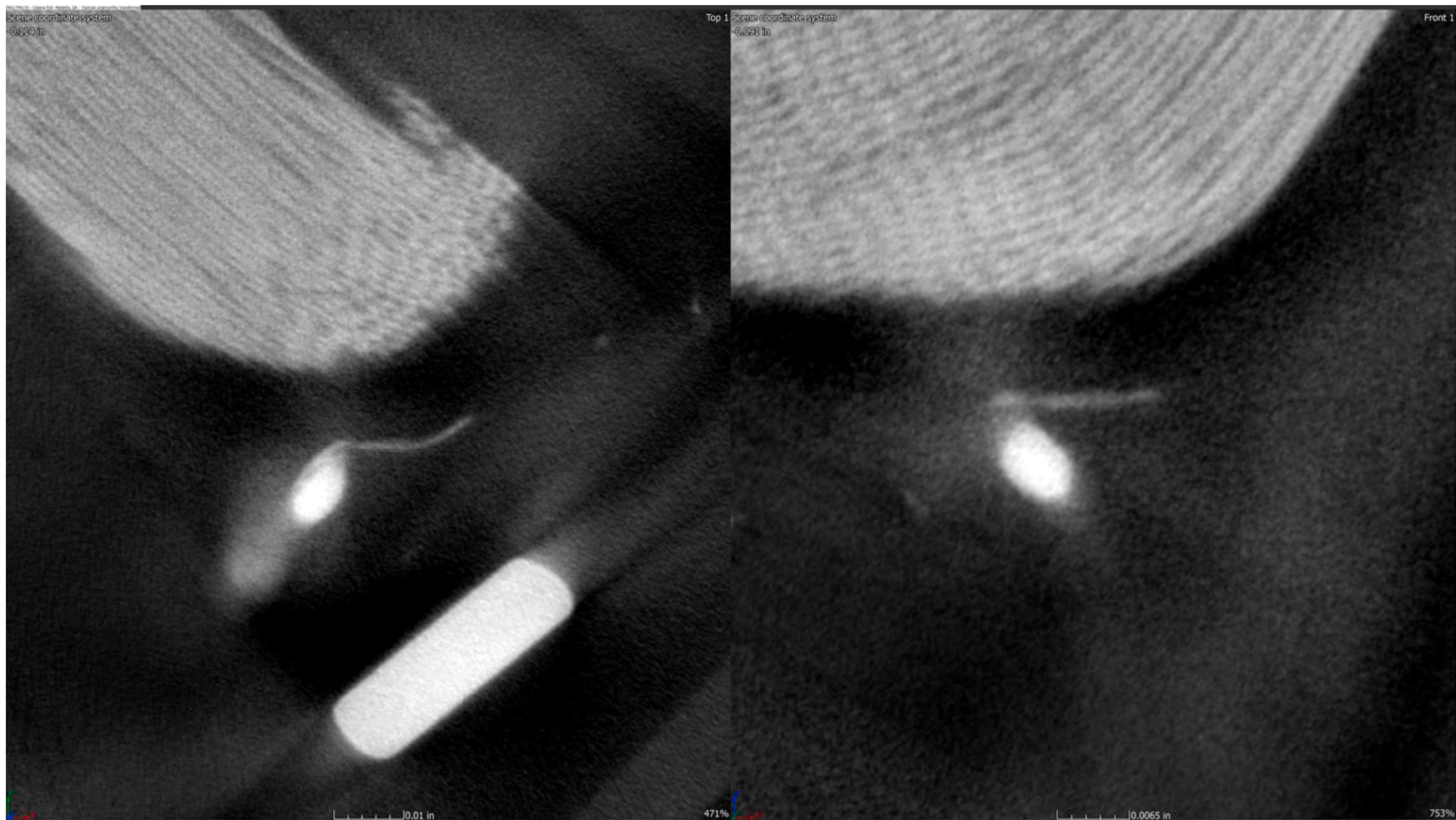


Figure 12
Duncan Aviation unairworthy transformer – with pressure applied to pin 6 – possible wire damage – close up view

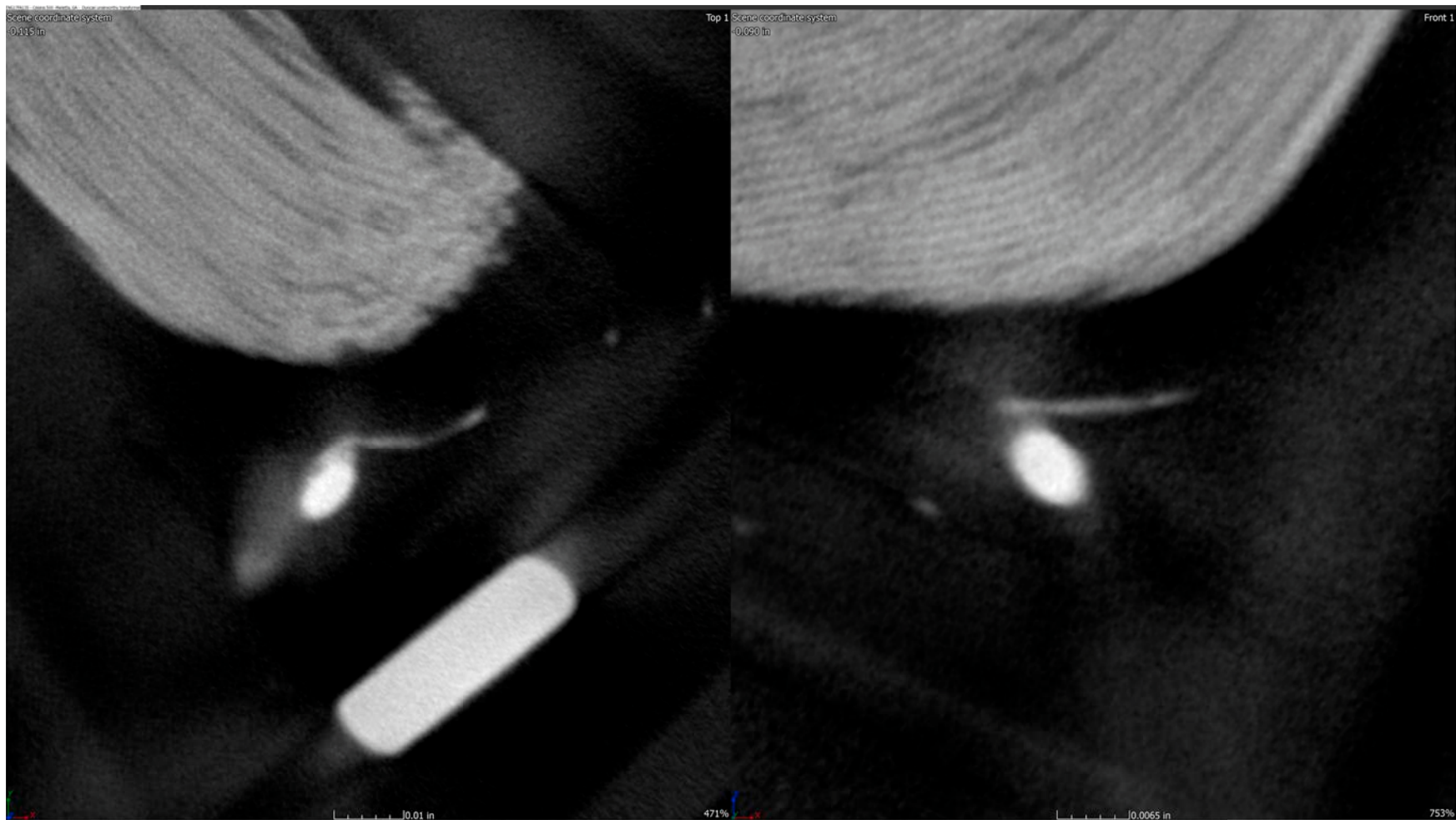


Figure 13
Duncan Aviation unairworthy transformer – with no pressure applied to pin 6 – possible wire damage – close up view

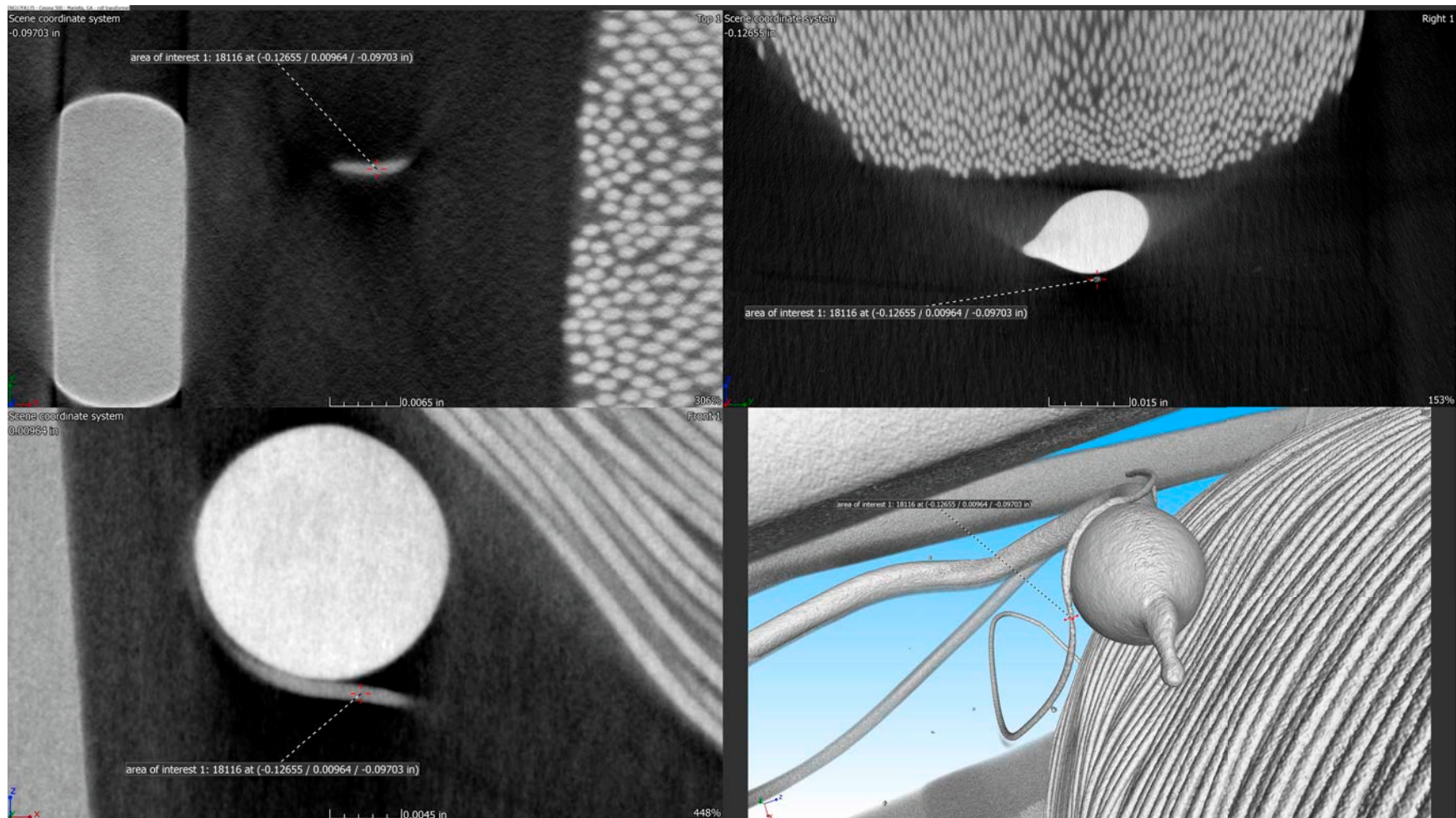


Figure 14
Roll transformer – LLNL scans - possible wire damage area noted in figures 6 and 7 – close up view

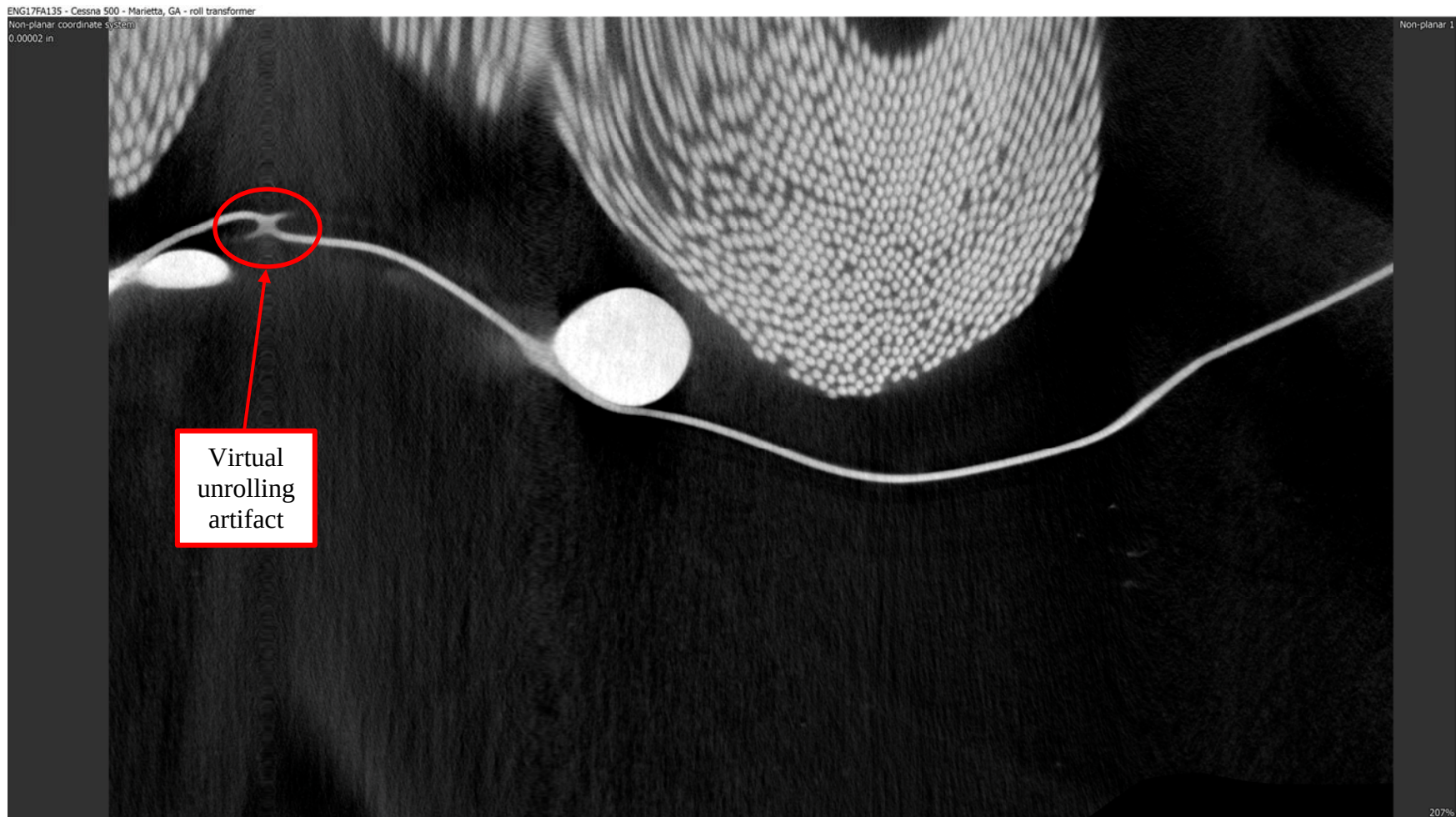


Figure 15
Roll transformer – LLNL scans – coil wire for pin 1 – virtually unrolled

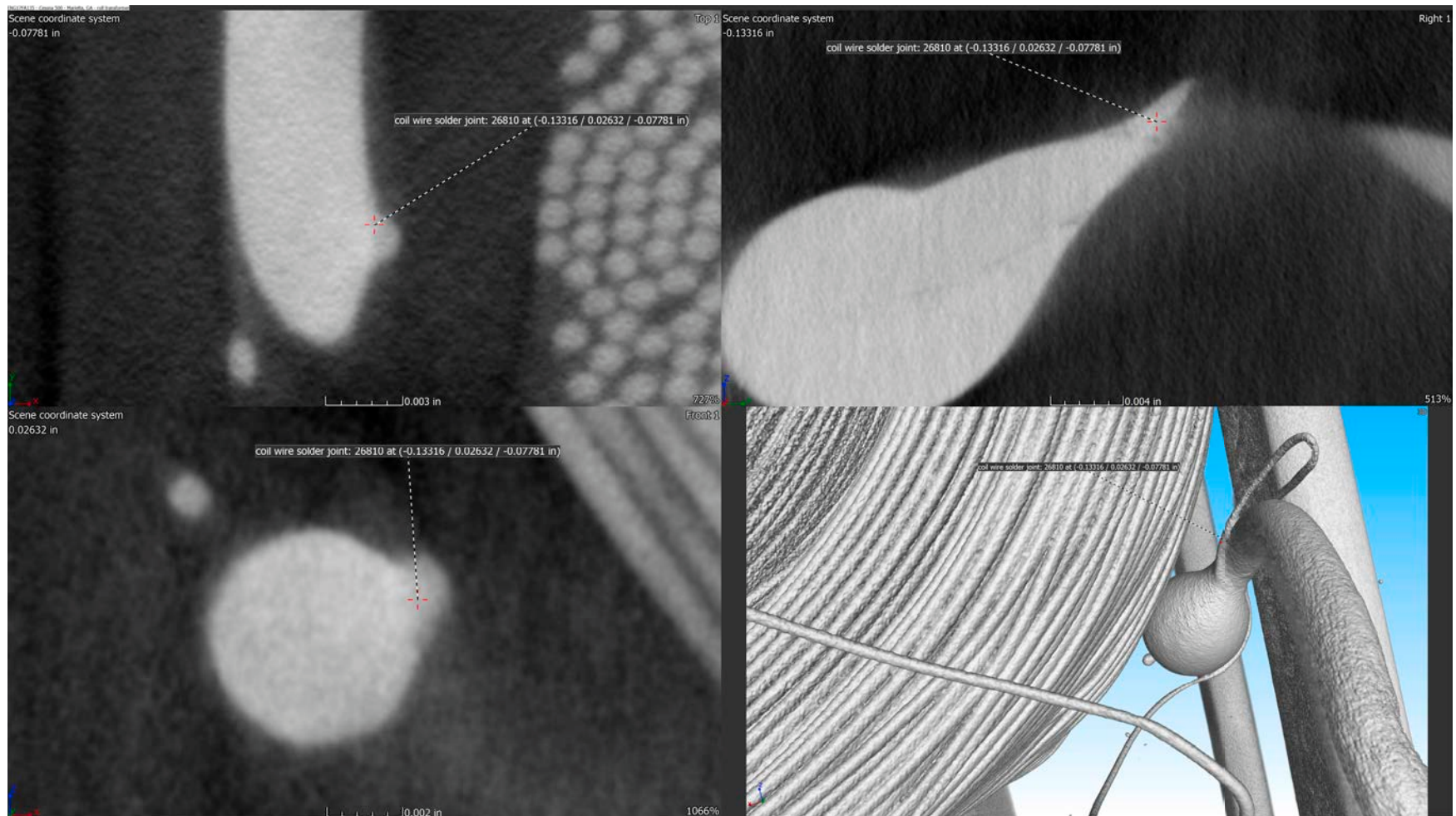


Figure 16
Roll transformer – LLNL scans – lead wire to coil wire solder contact

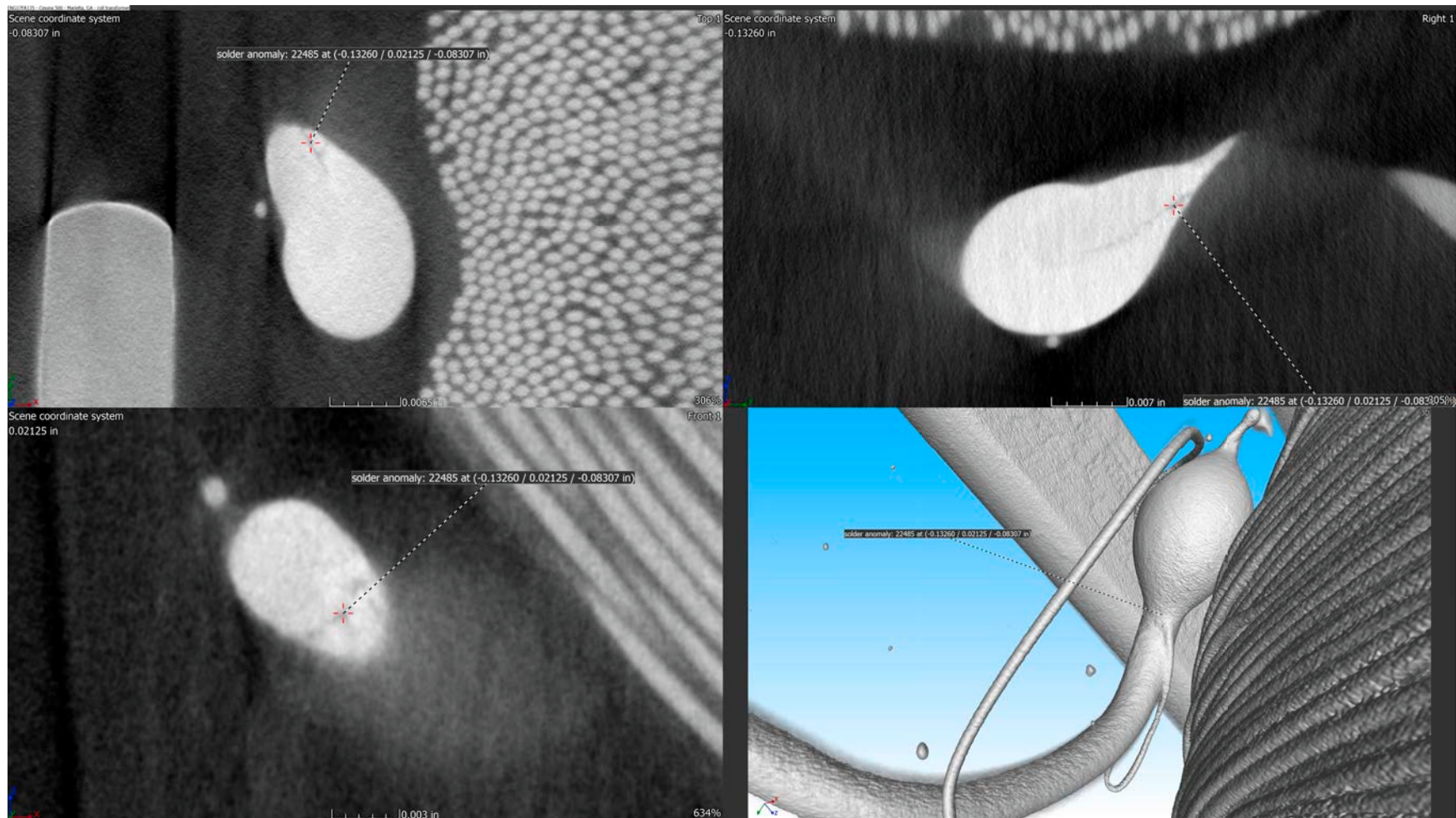


Figure 17
Roll transformer – LLNL scans – lead wire to coil wire solder joint – anomaly area

Roll transformer – LLNL scans – coil wire on solder connection

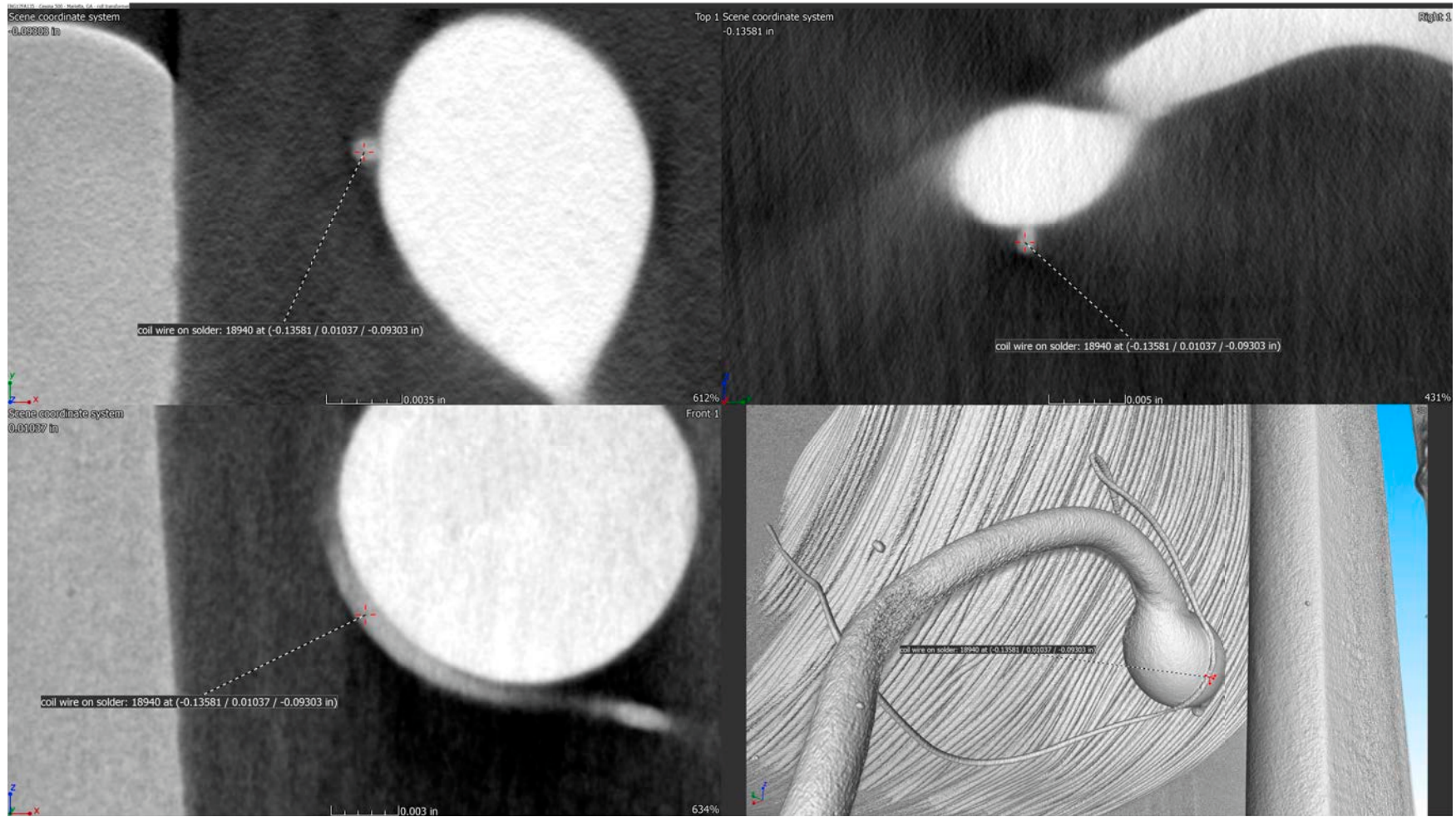


Figure 18
Roll transformer – LLNL scans – coil wire on solder connection

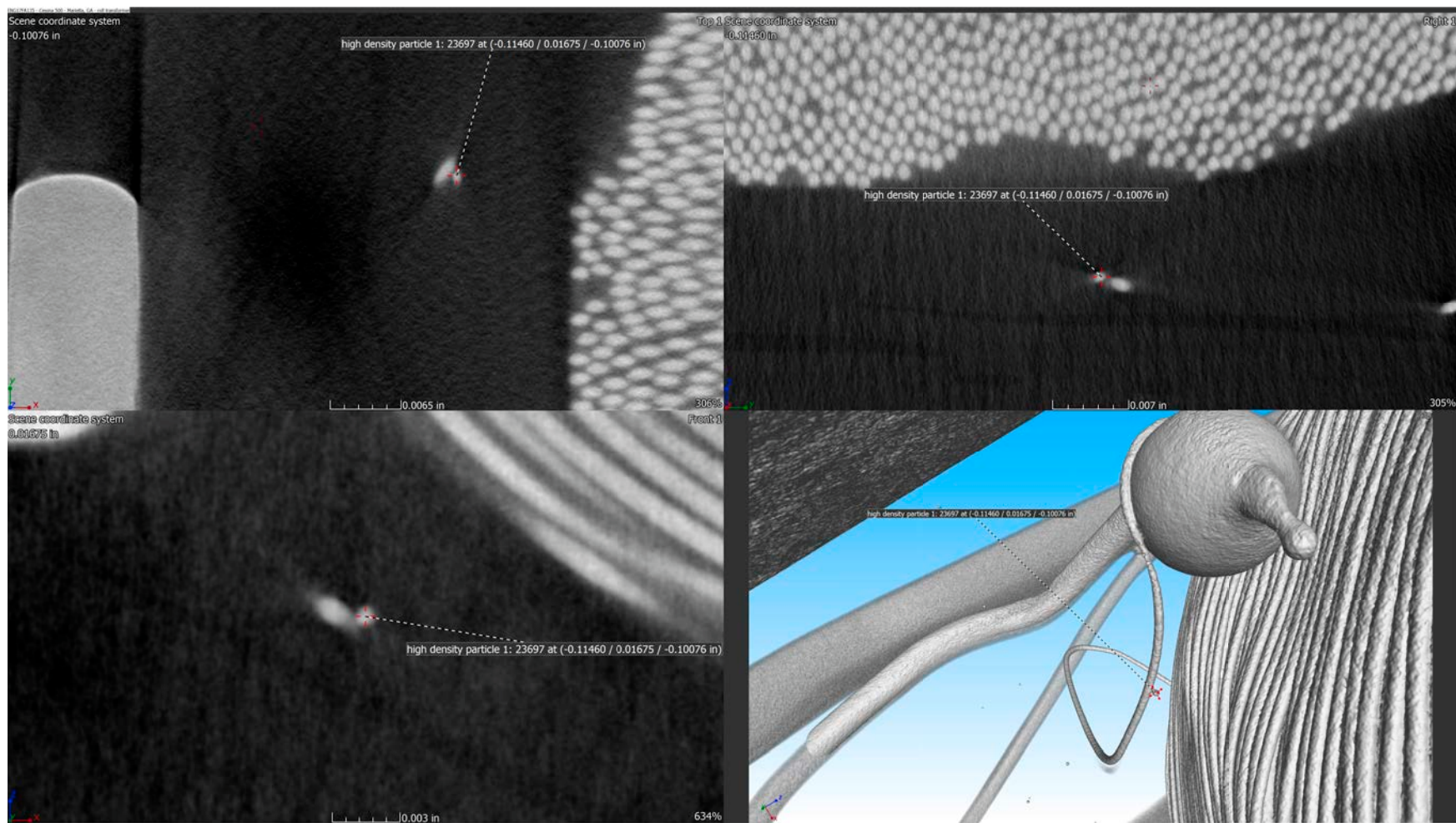


Figure 19
Roll transformer – LLNL scans – high density particle

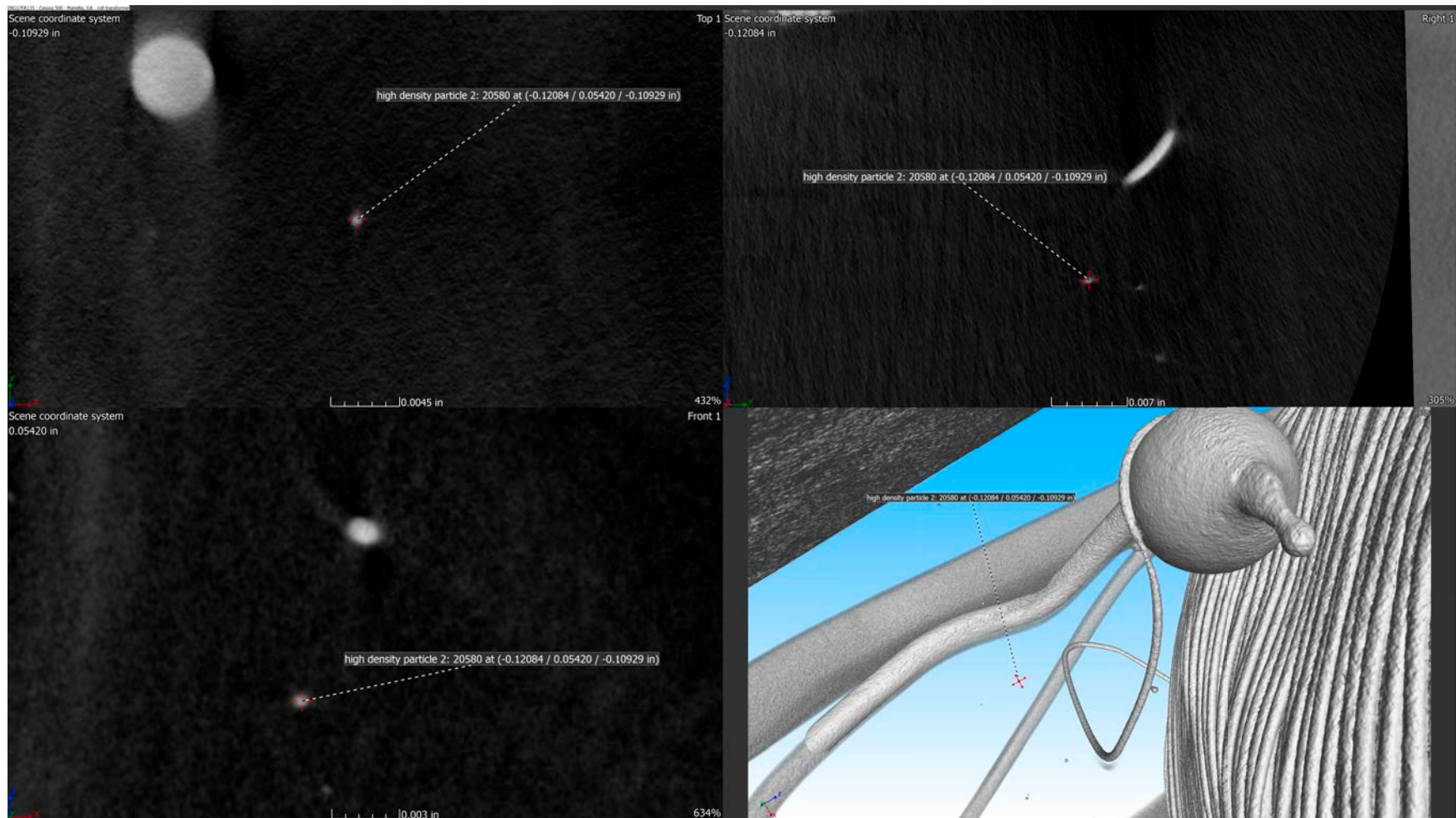


Figure 20
Roll transformer – LLNL scans – high density particle 2

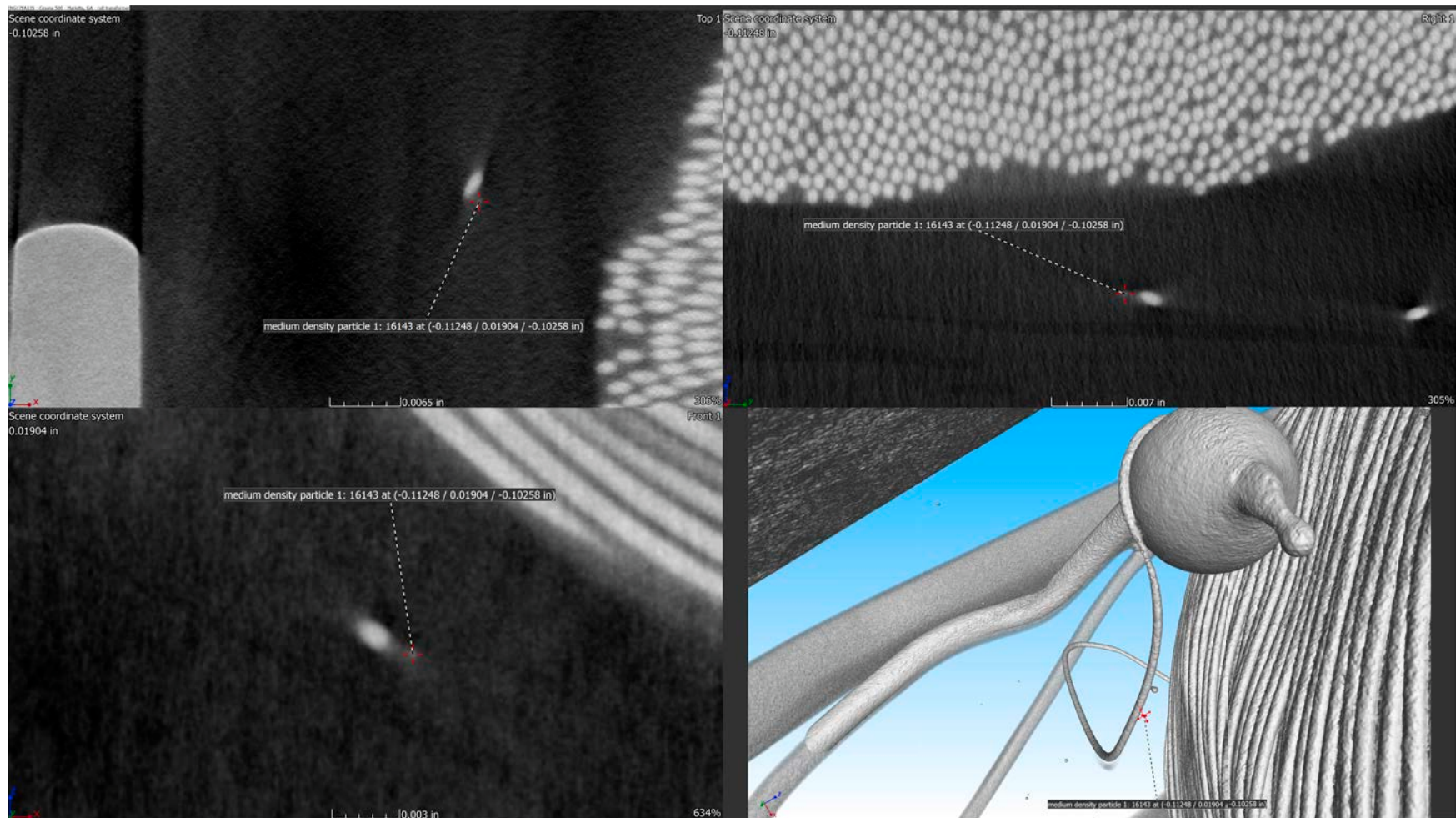


Figure 21
Roll transformer – LLNL scans – medium density particle

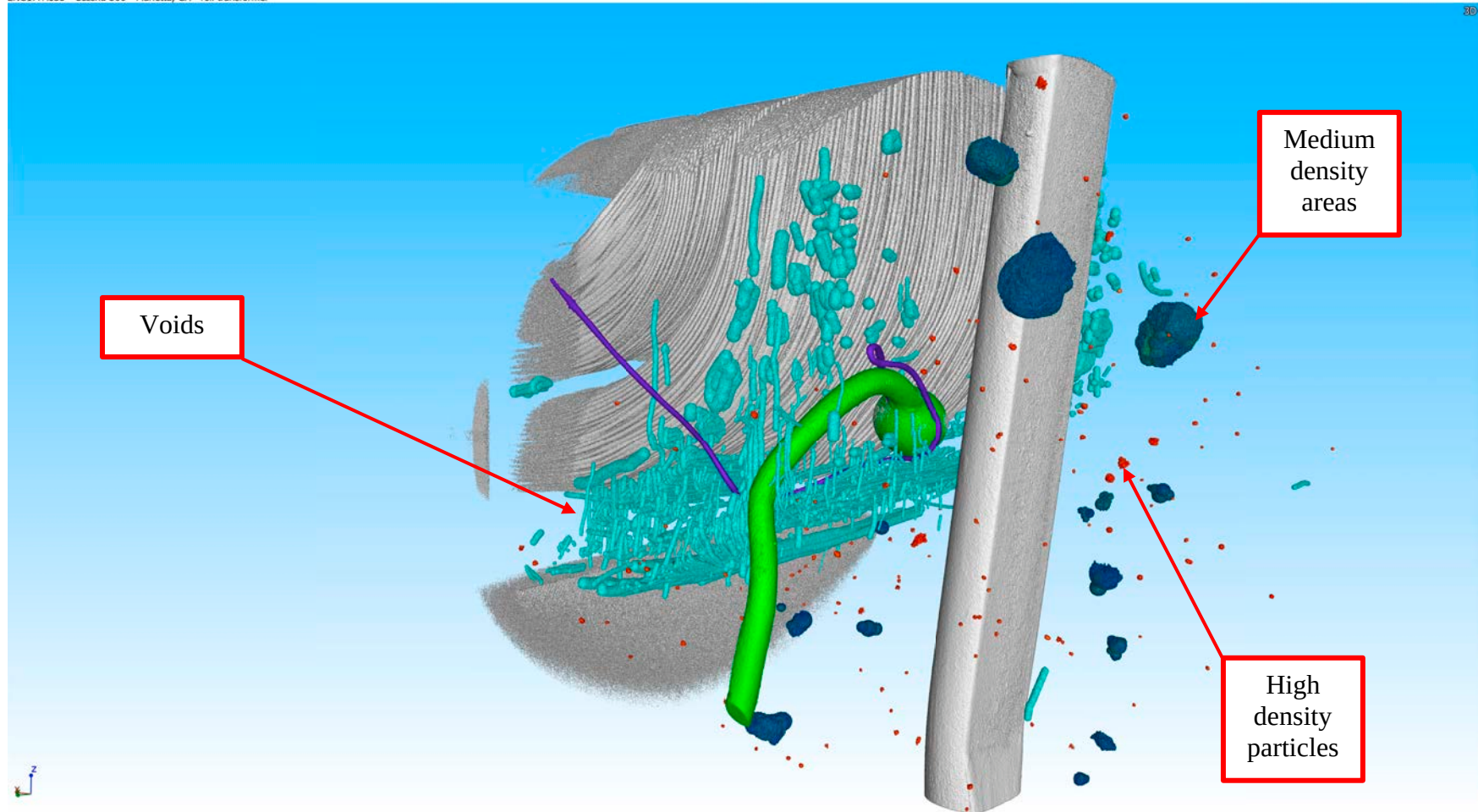


Figure 22
Roll transformer – LLNL scans – voids, high density particles, and medium density areas

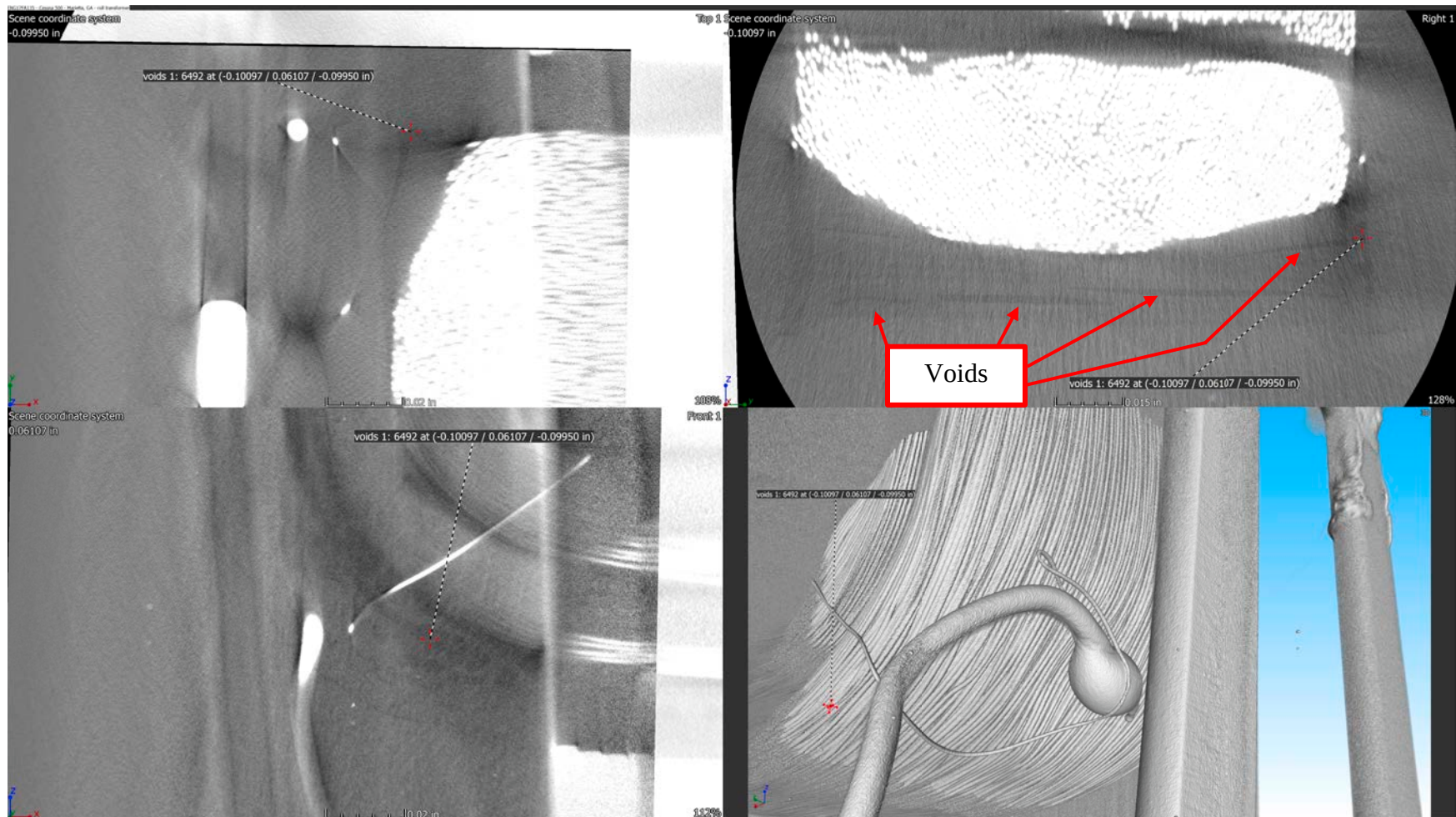


Figure 23
Roll transformer – LLNL scans – resin voids 1

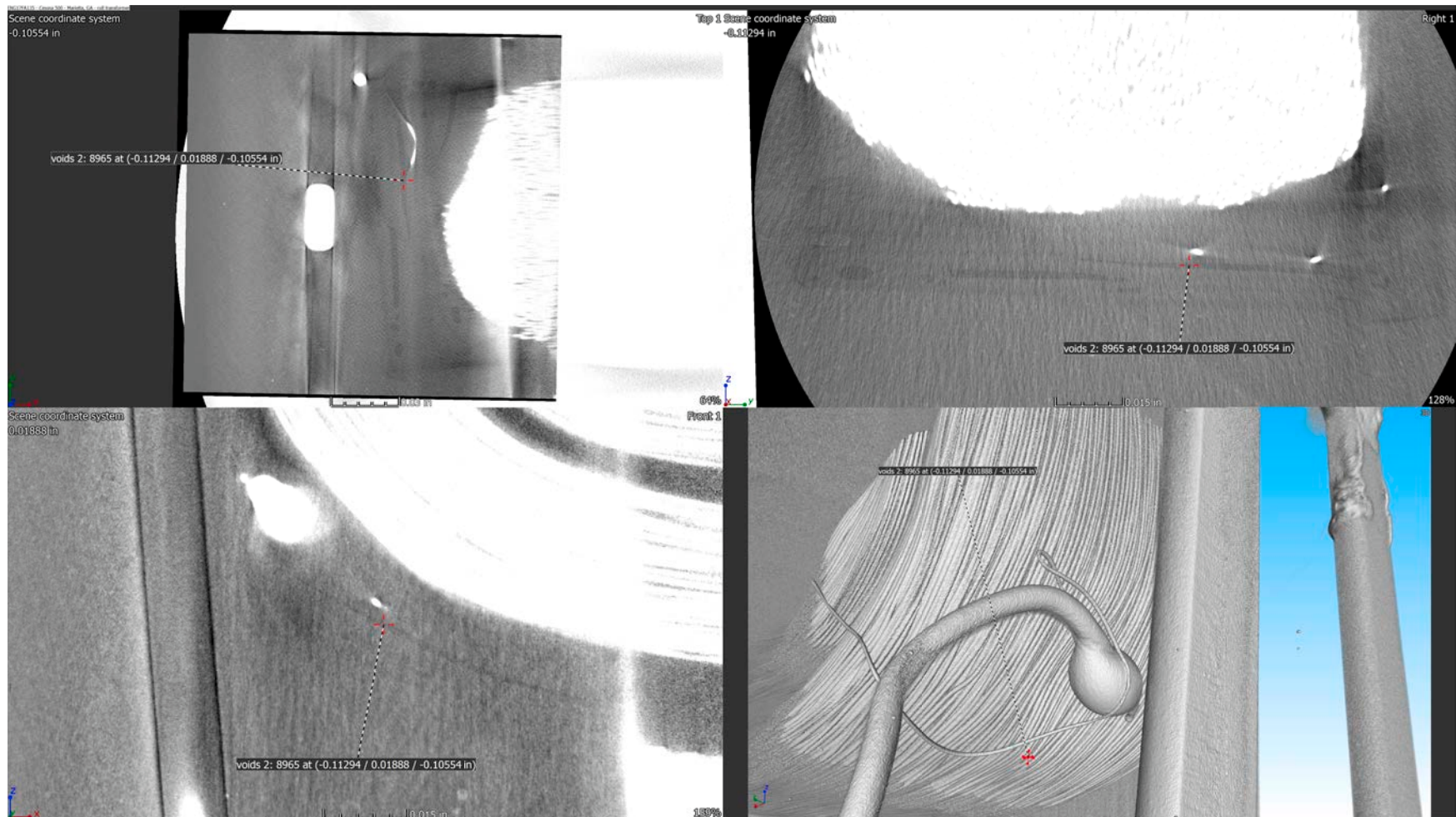


Figure 24
Roll transformer – LLNL scans – resin voids 2

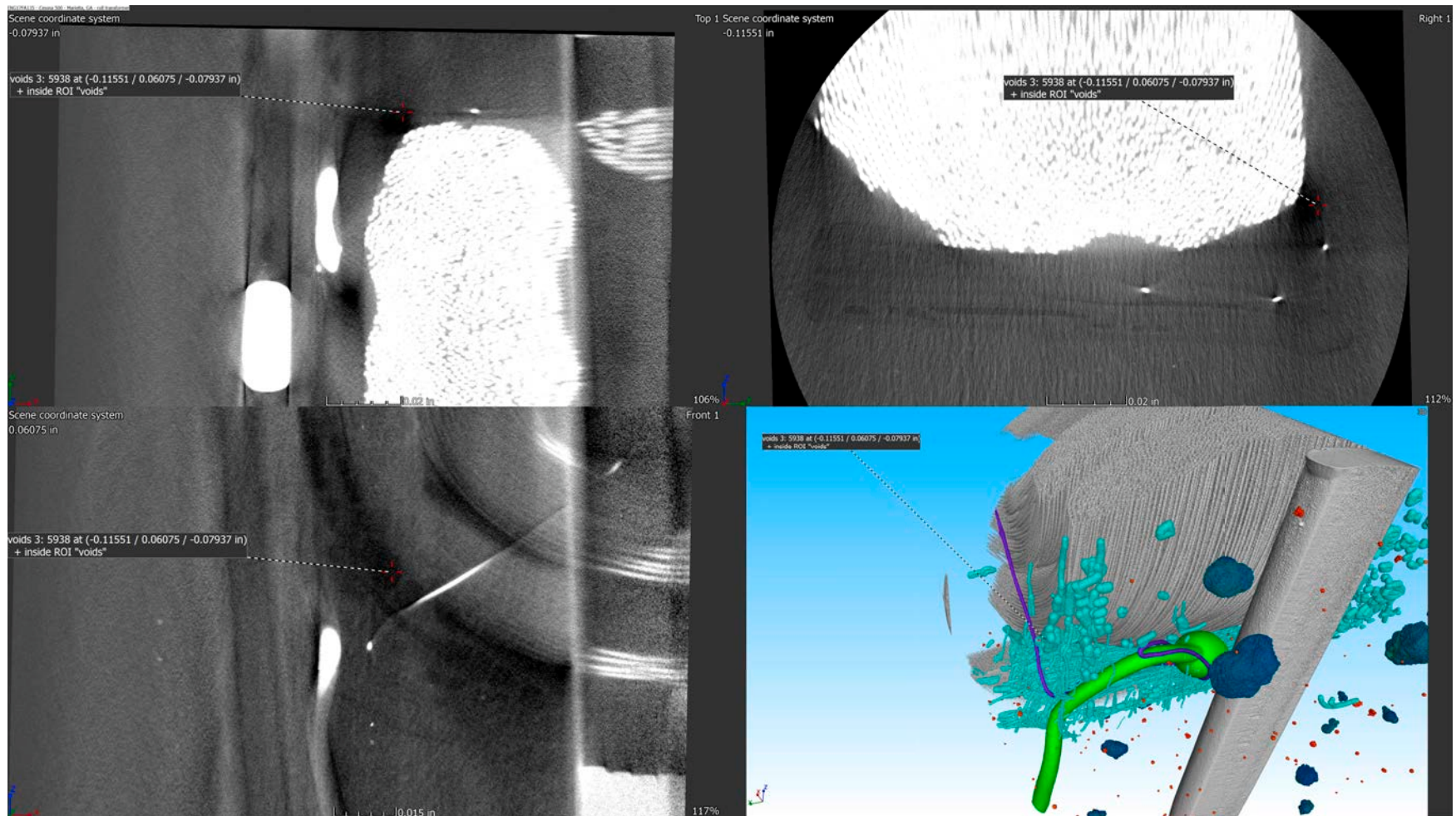


Figure 25
Roll transformer – LLNL scans – resin voids 3

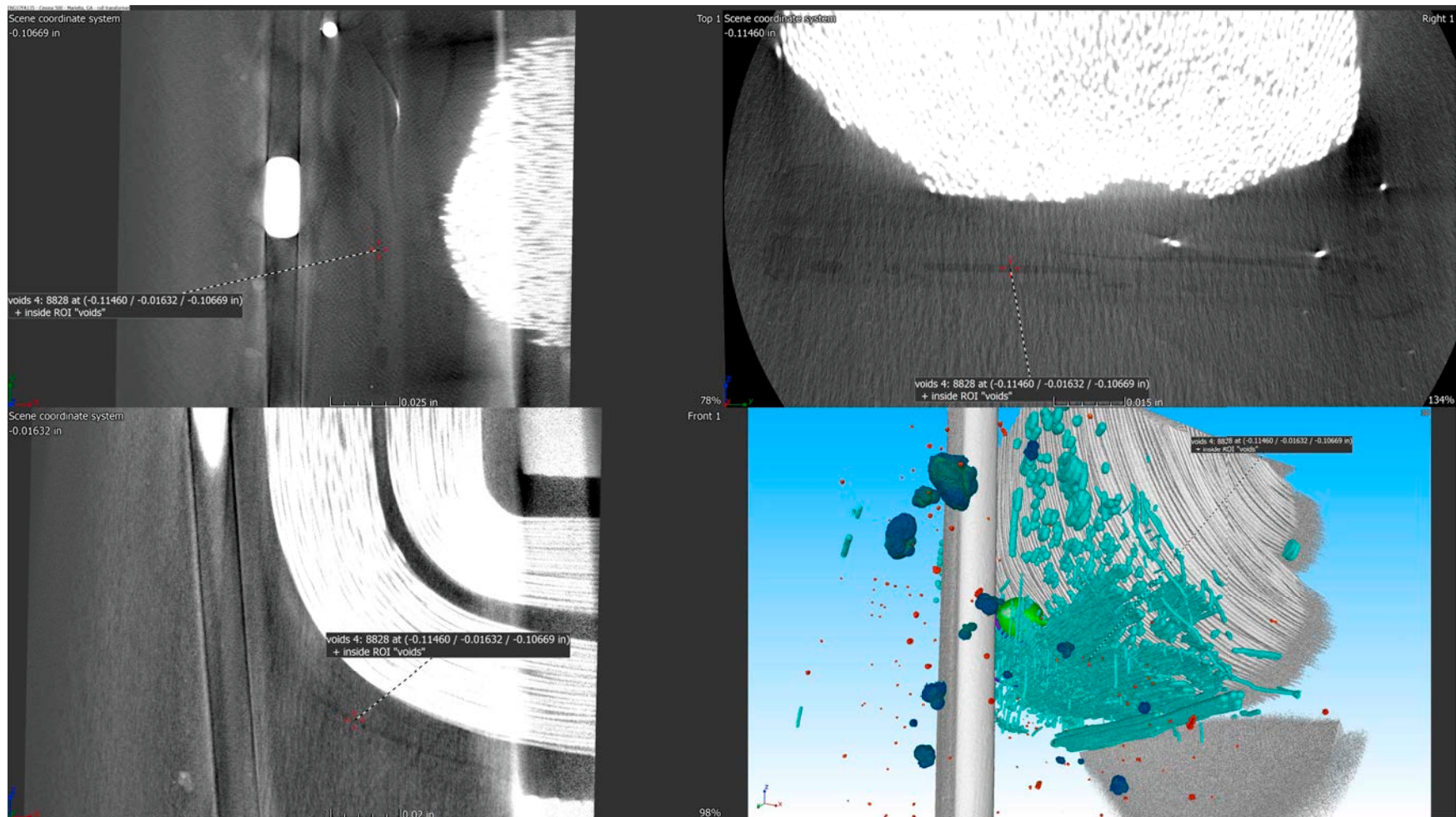


Figure 26
Roll transformer – LLNL scans – resin voids 4

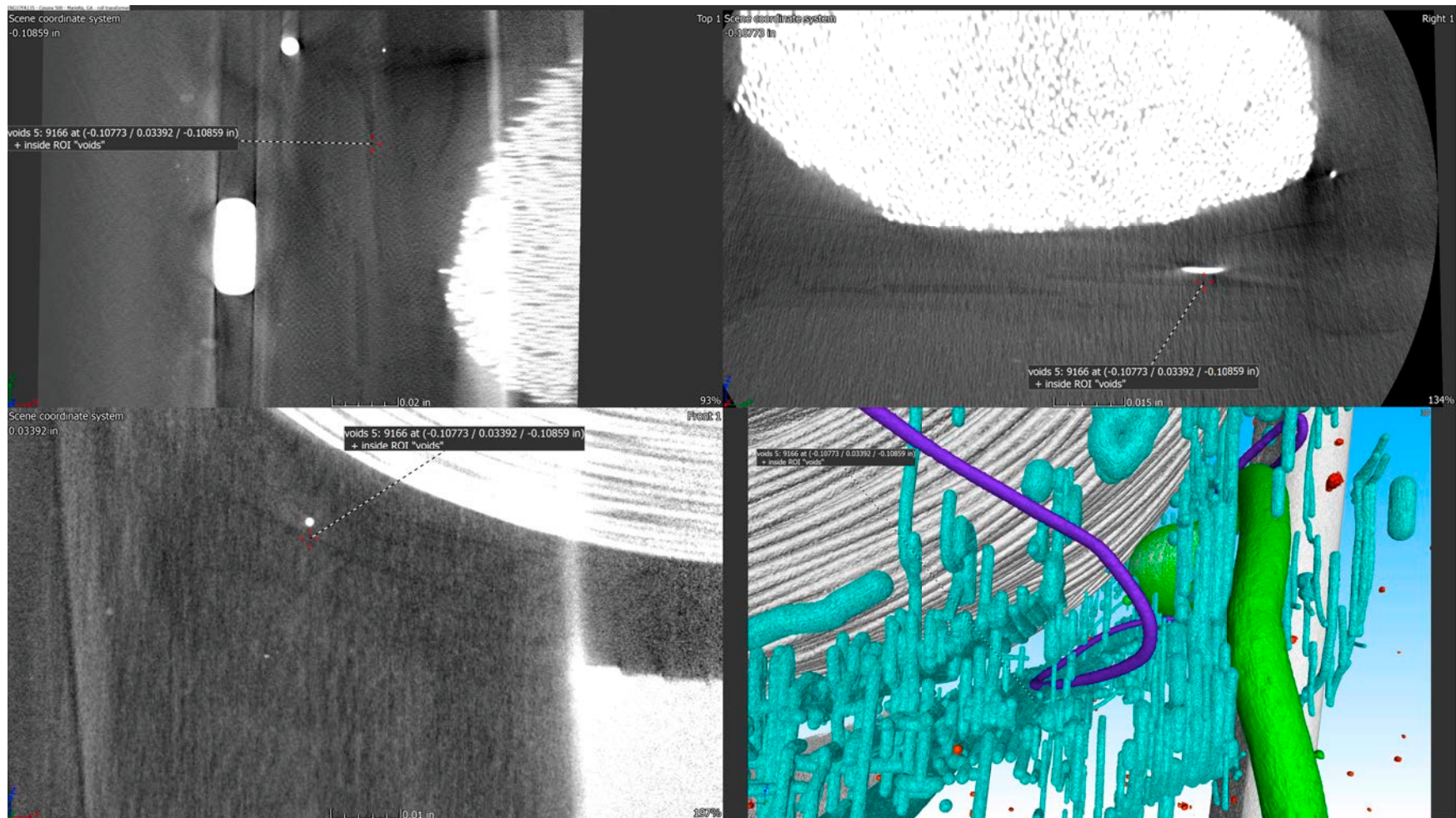


Figure 27
Roll transformer – LLNL scans – resin voids 5

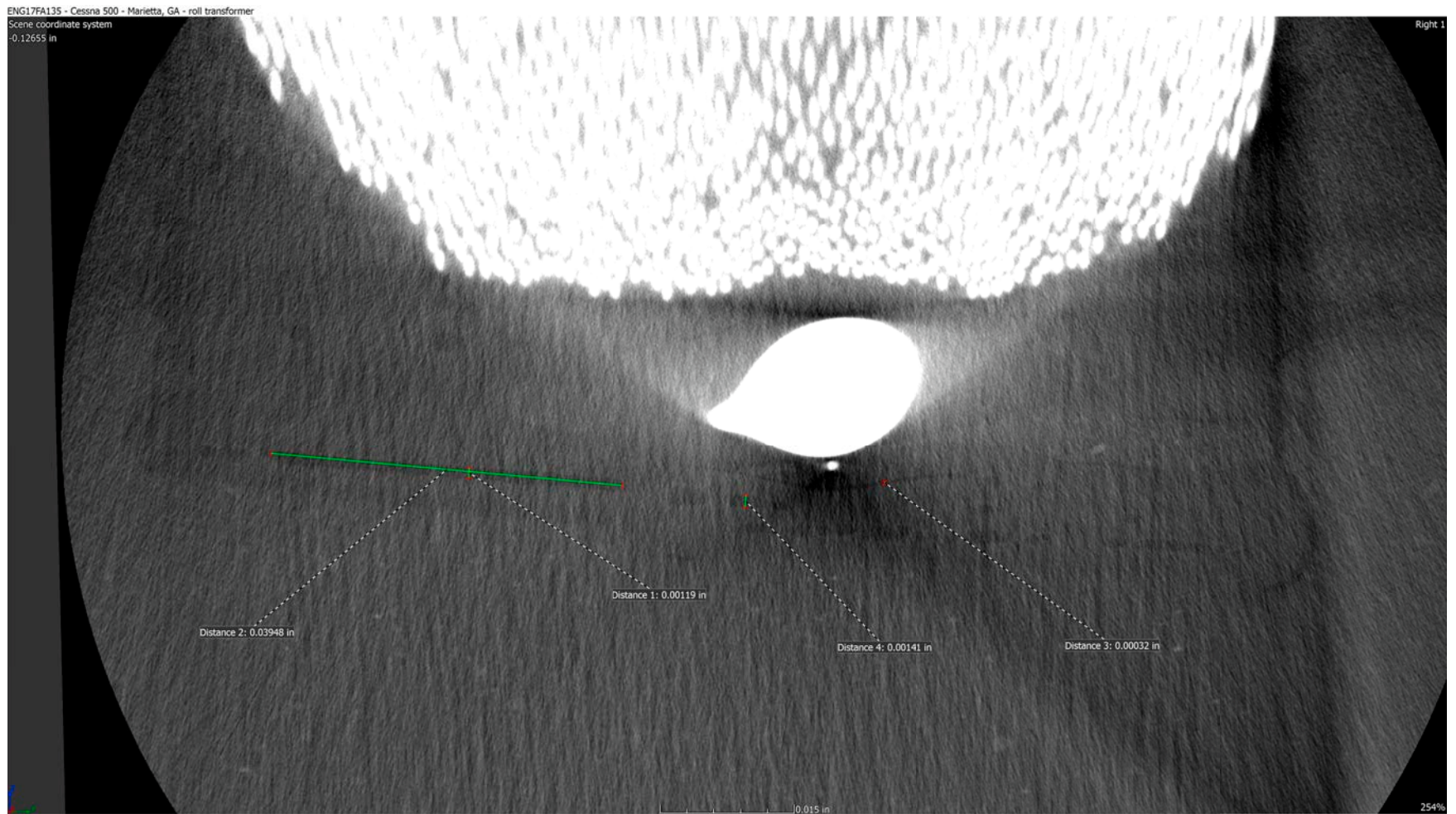


Figure 28
Roll transformer – LLNL scans – resin voids dimensions 1

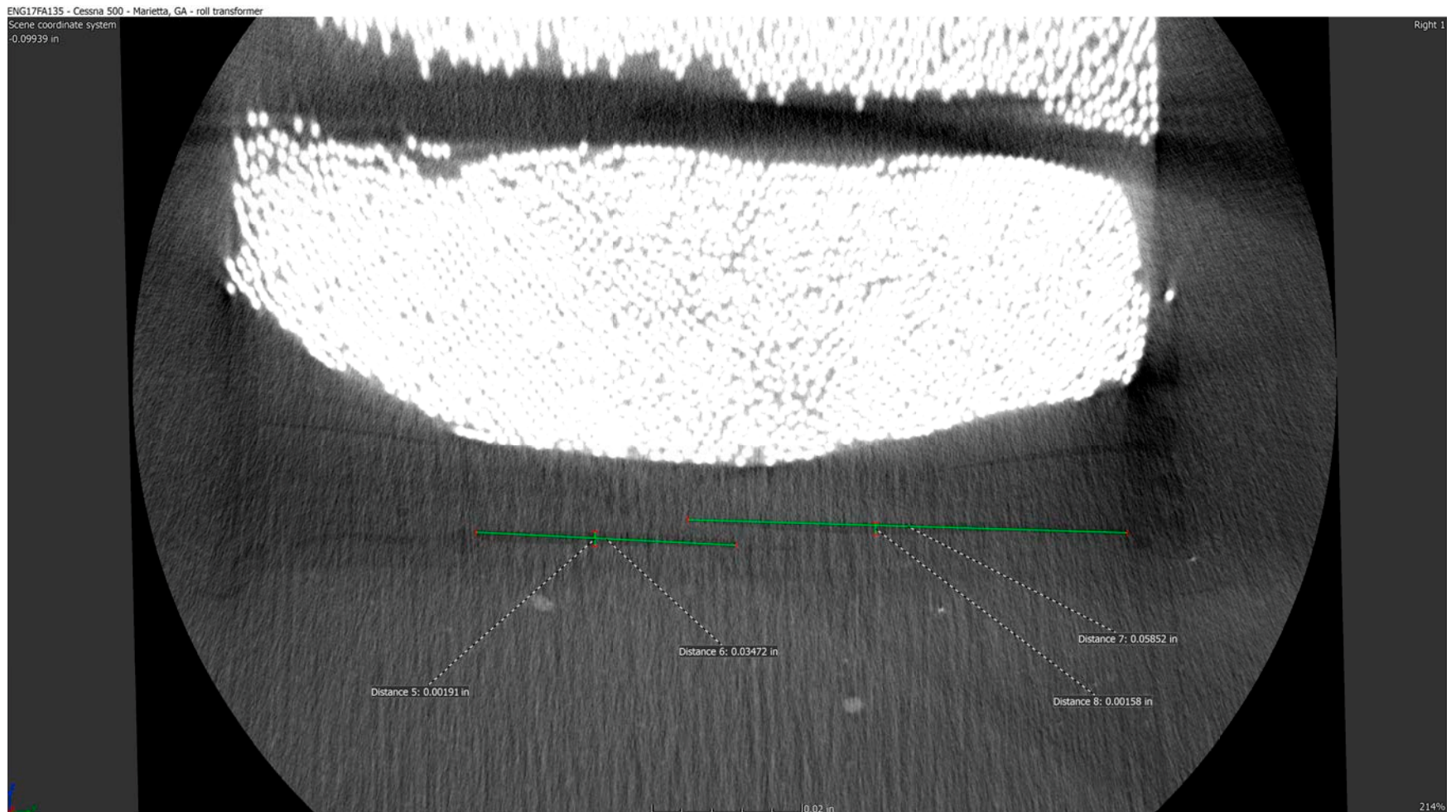


Figure 29
Roll transformer – LLNL scans – resin voids dimensions 2

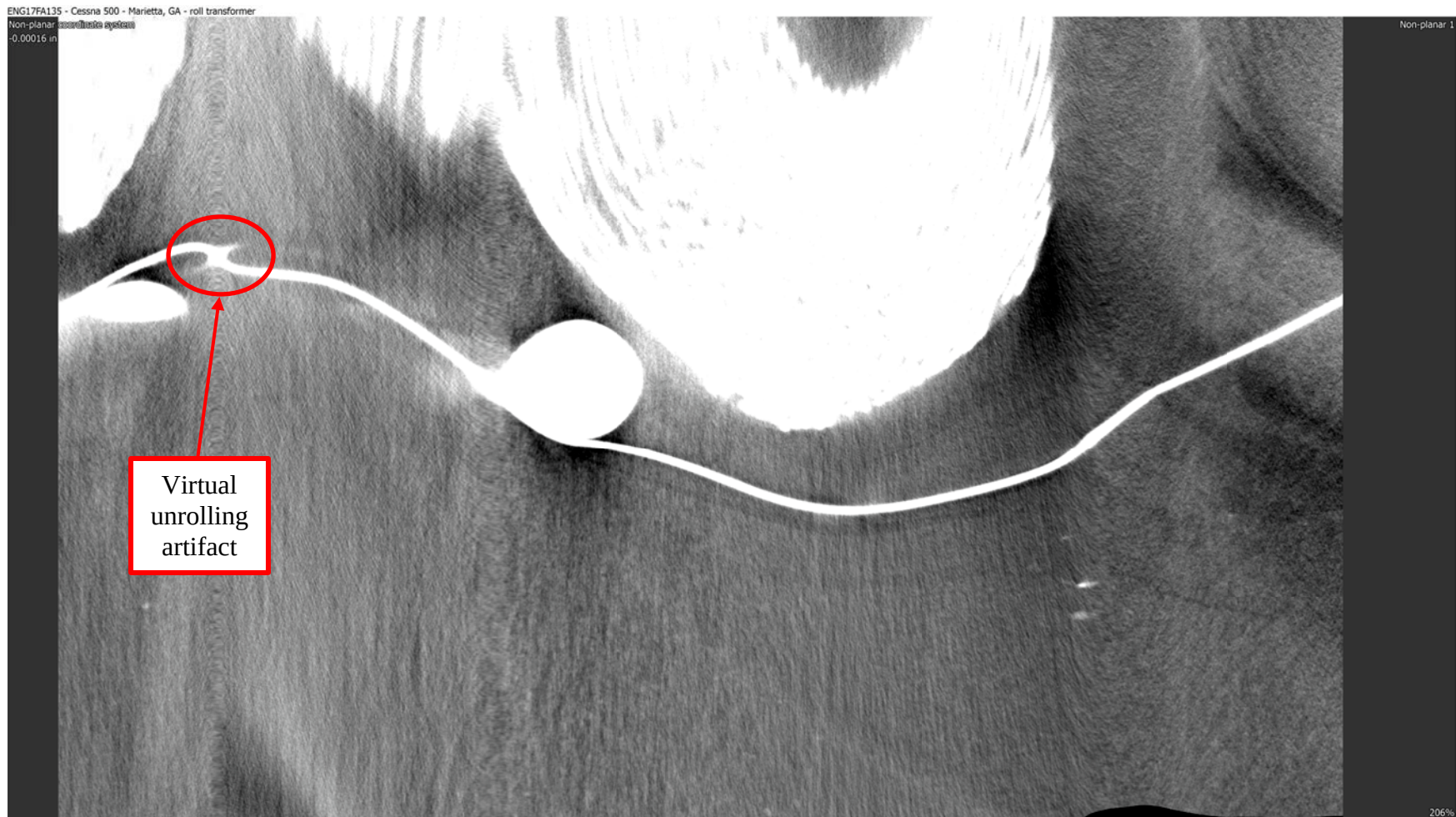


Figure 30
Roll transformer – LLNL scans – coil wire virtually unrolled with voids

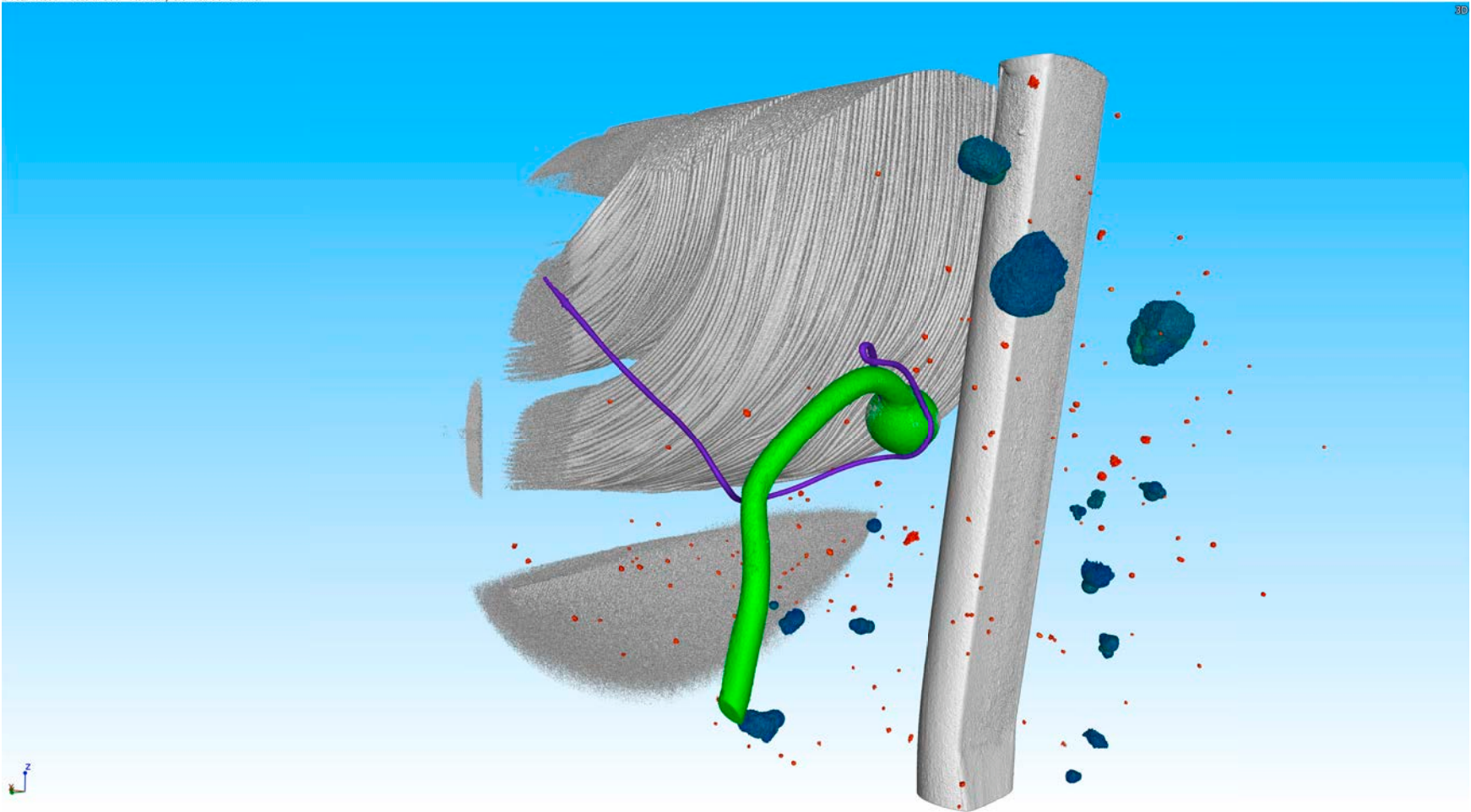


Figure 31
Roll transformer – LLNL scans – overall view – medium density areas

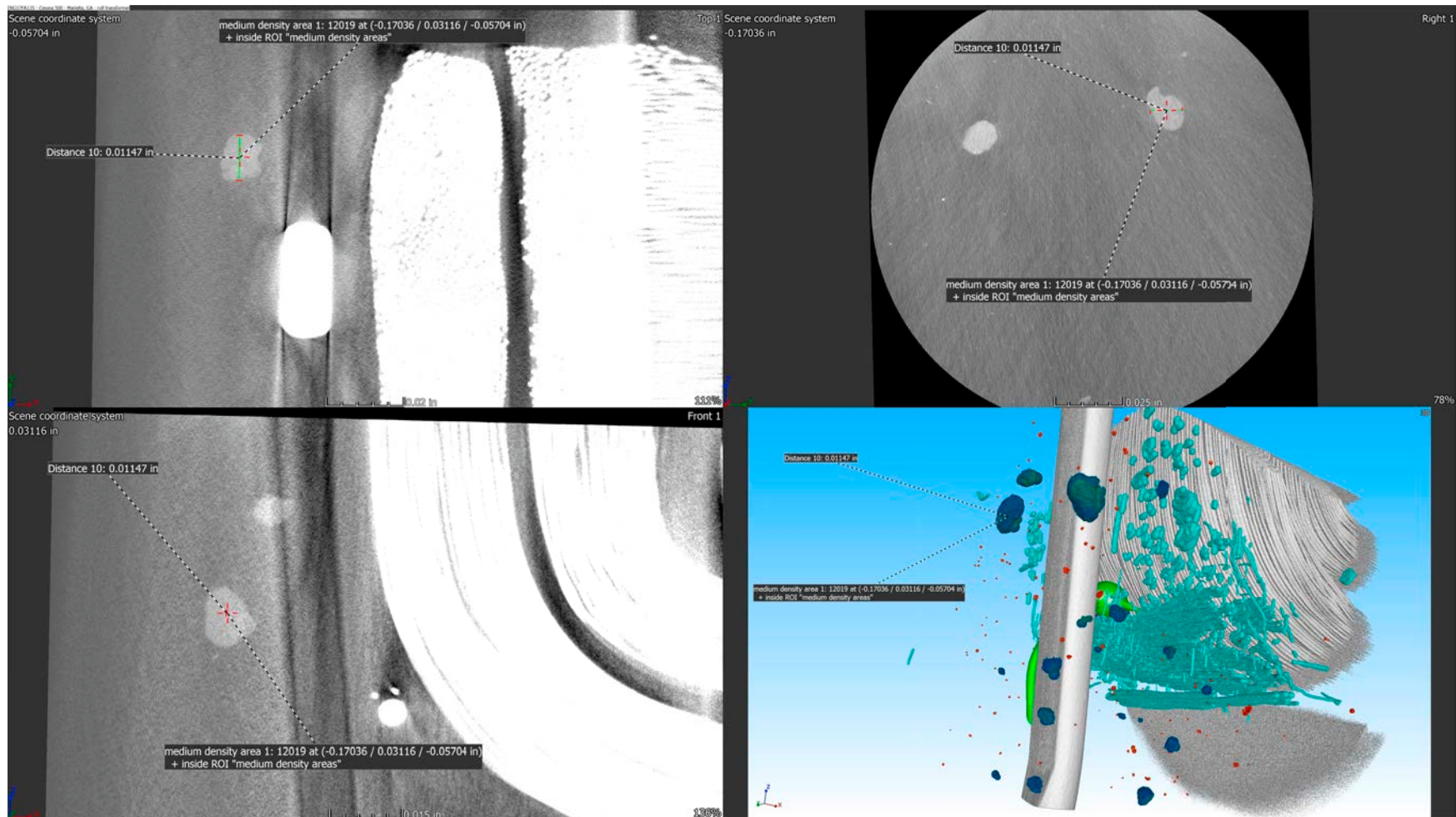


Figure 32
Roll transformer – LLNL scans – medium density area 1 with dimension

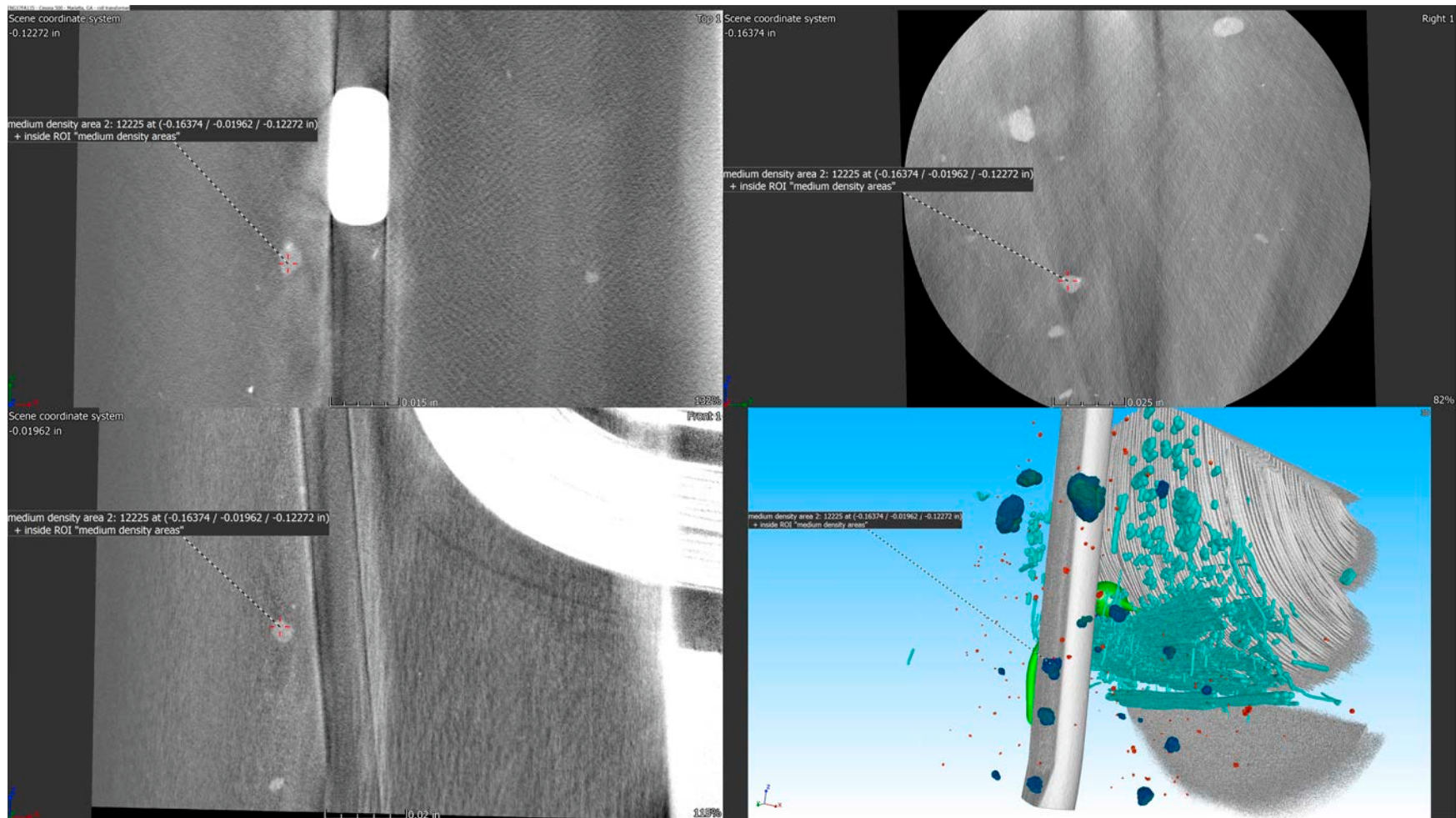


Figure 33
Roll transformer – LLNL scans – medium density area 2

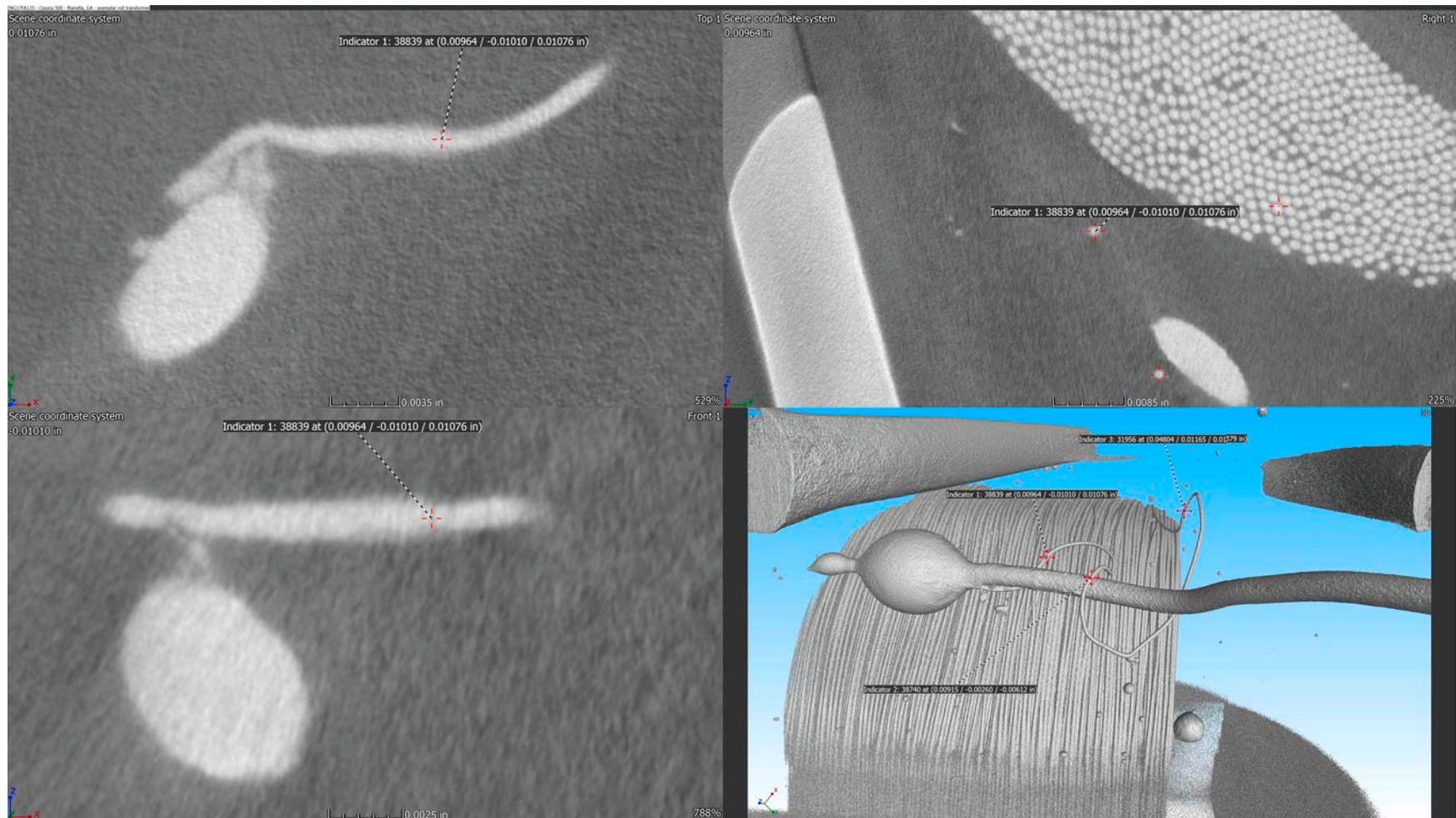


Figure 34
Duncan Aviation unairworthy transformer – LLNL scans – wire anomaly area 1

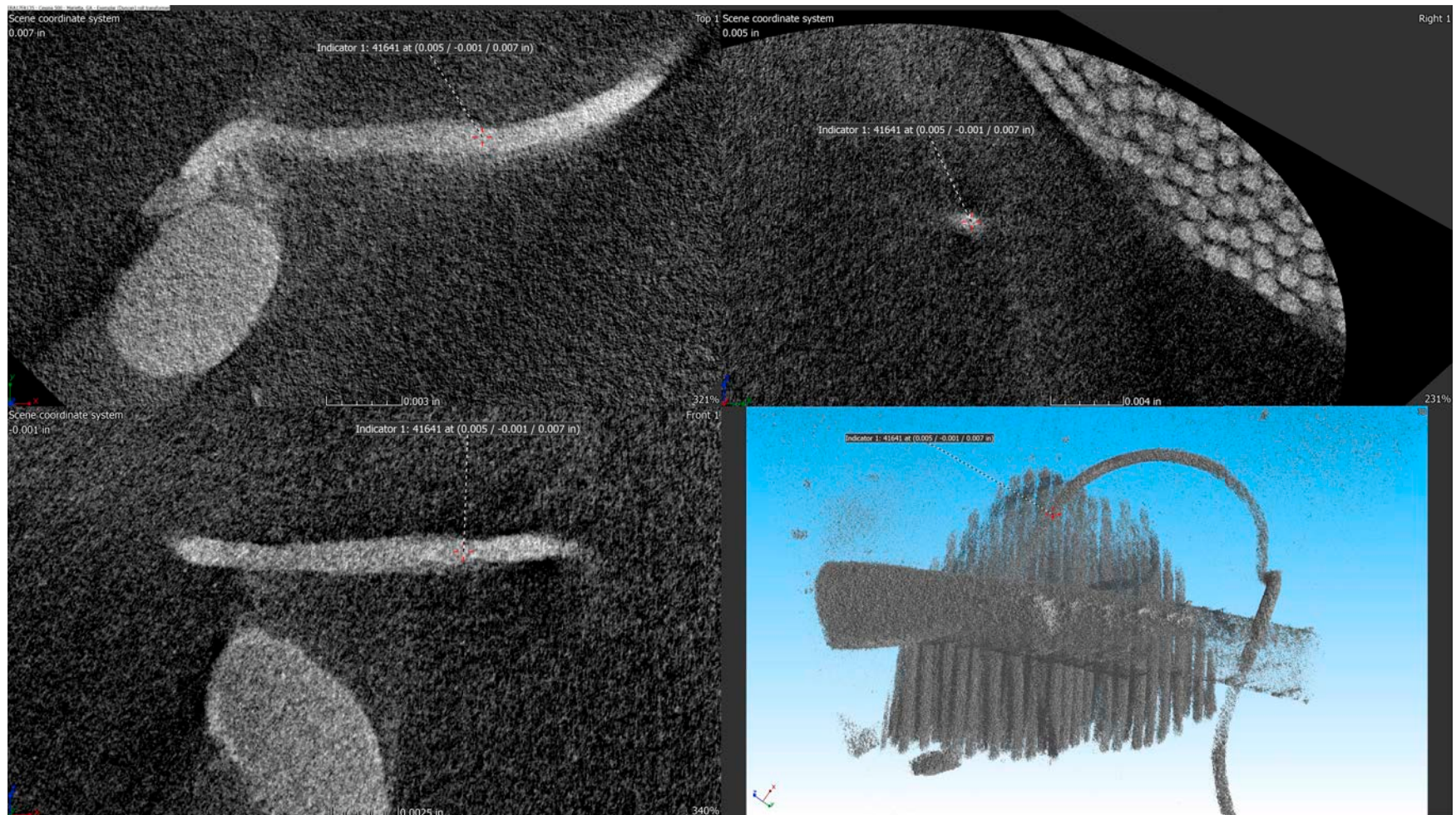


Figure 35
Duncan Aviation unairworthy transformer – LLNL scans – wire anomaly area 1 – high resolution view

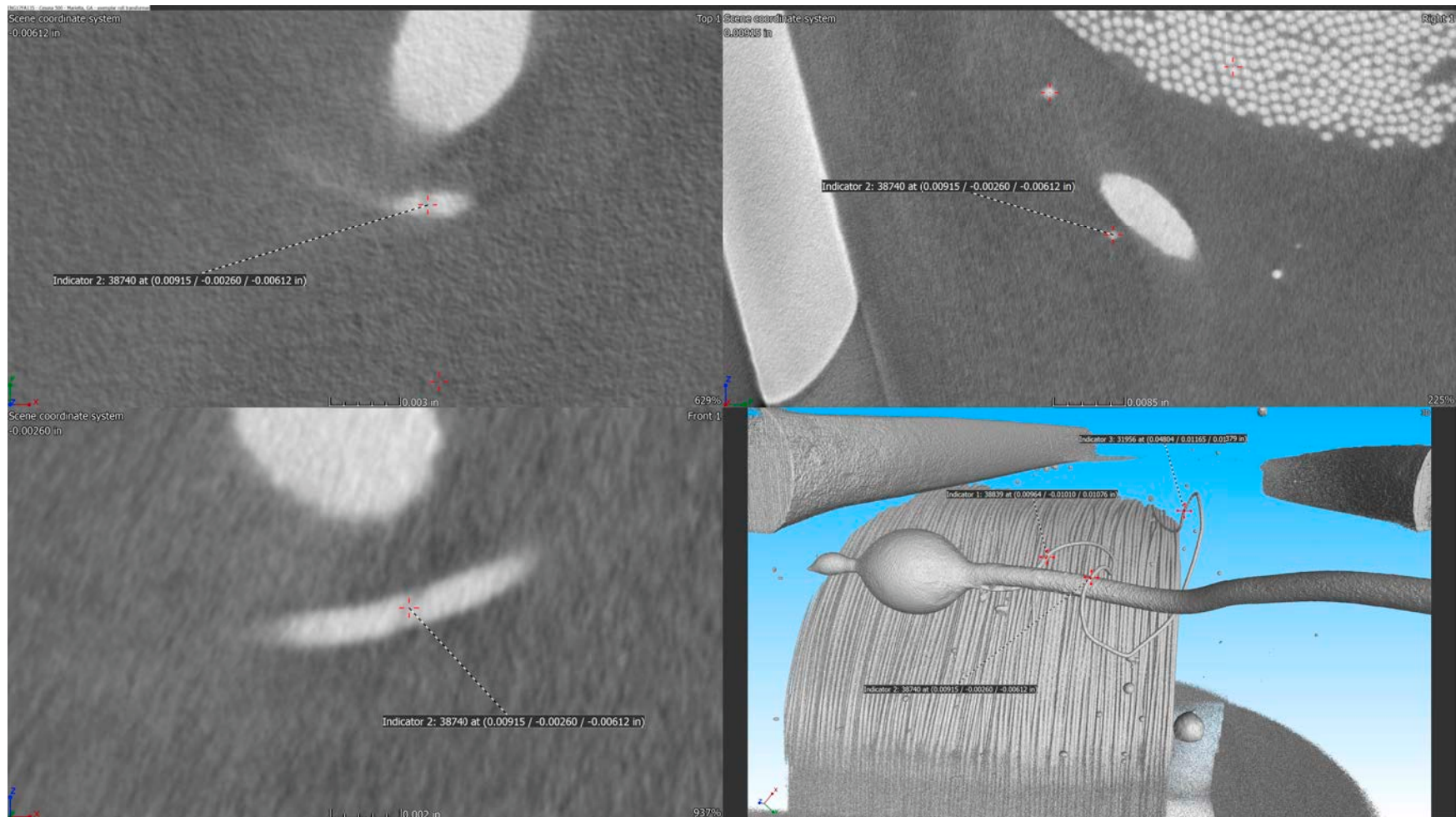


Figure 36
Duncan Aviation unairworthy transformer – LLNL scans – wire anomaly area 2

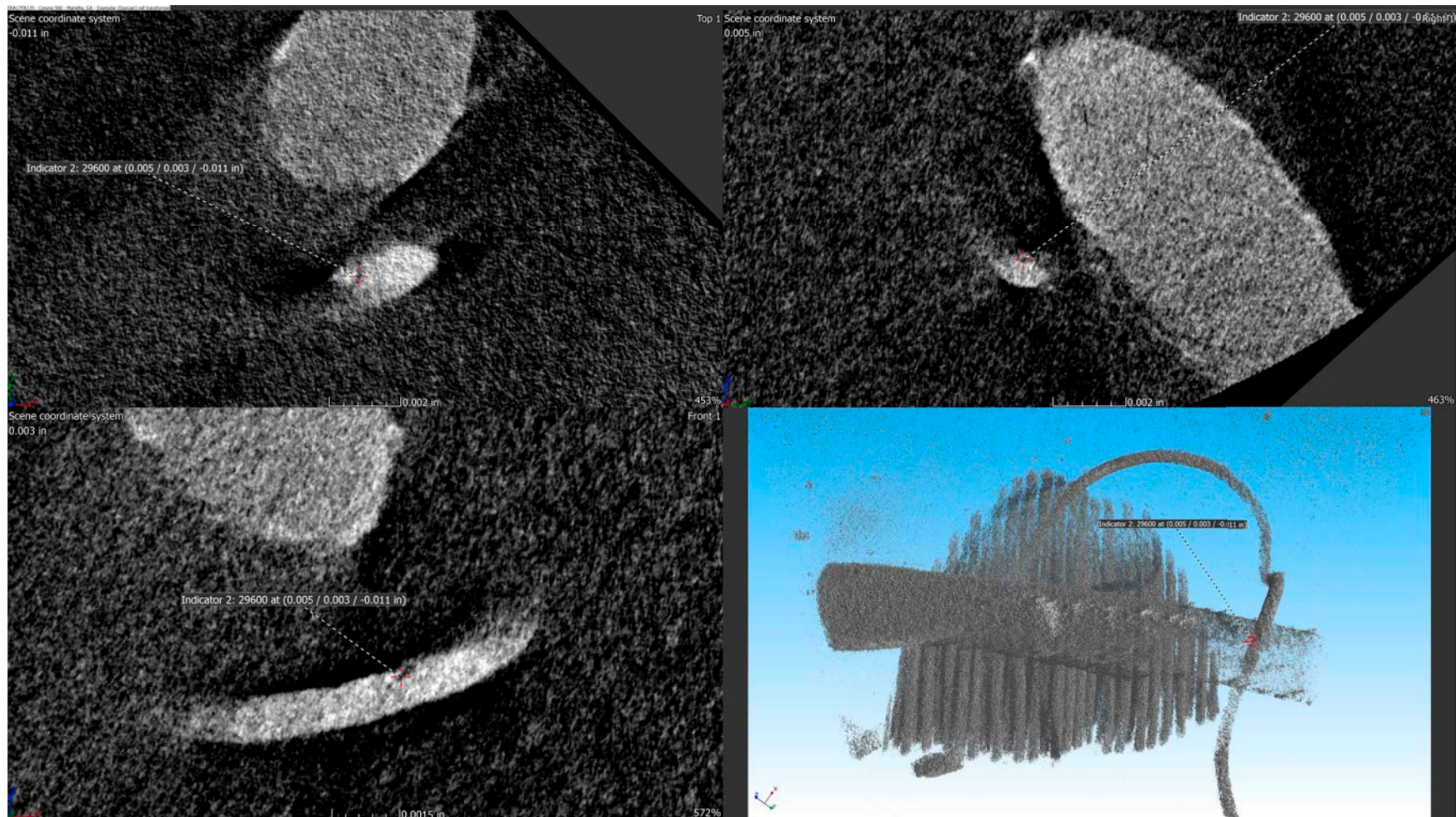


Figure 37
Duncan Aviation unairworthy transformer – LLNL scans – wire anomaly area 2 – high resolution view

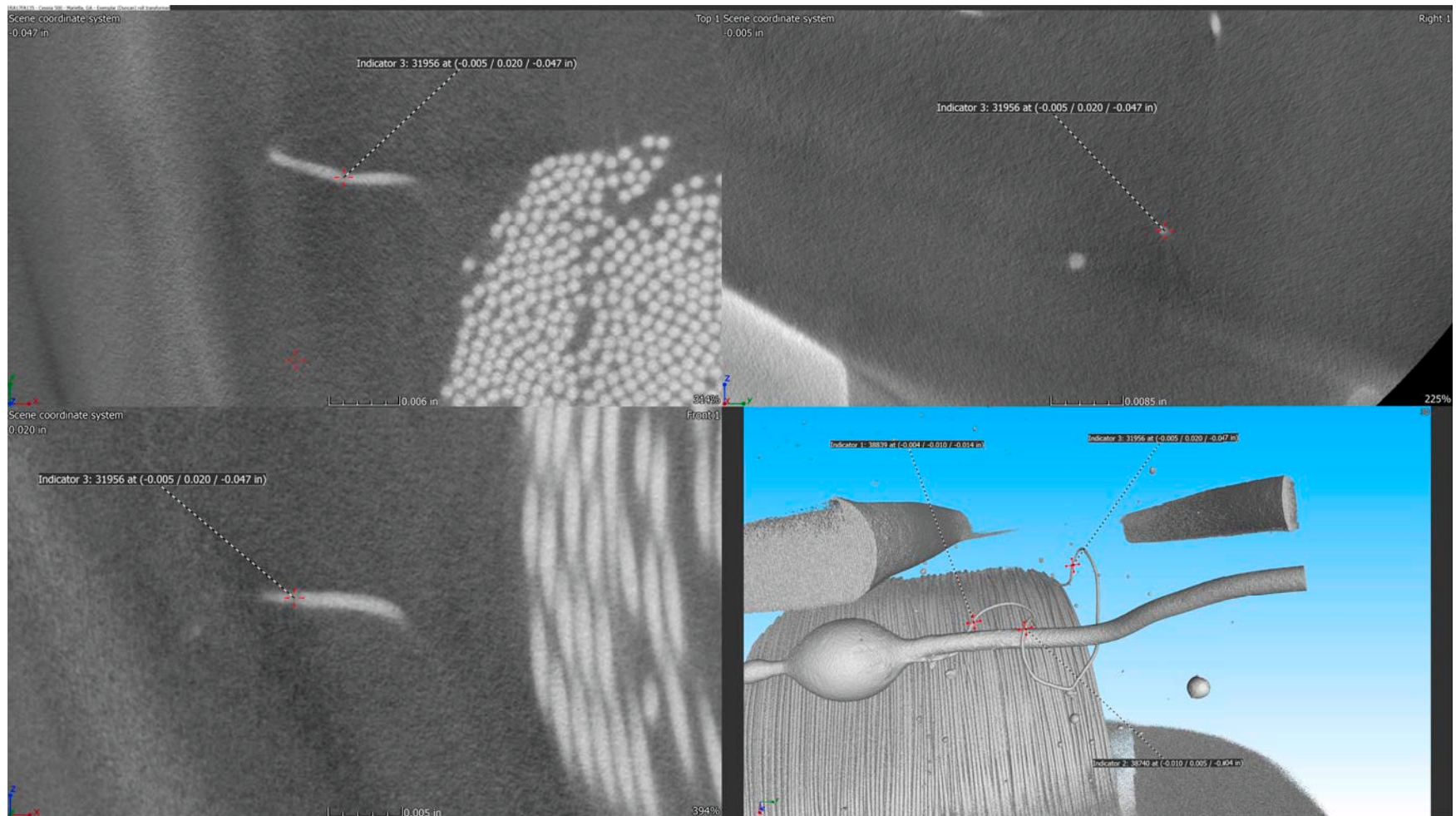


Figure 38
Duncan Aviation unairworthy transformer – LLNL scans – wire anomaly area 3

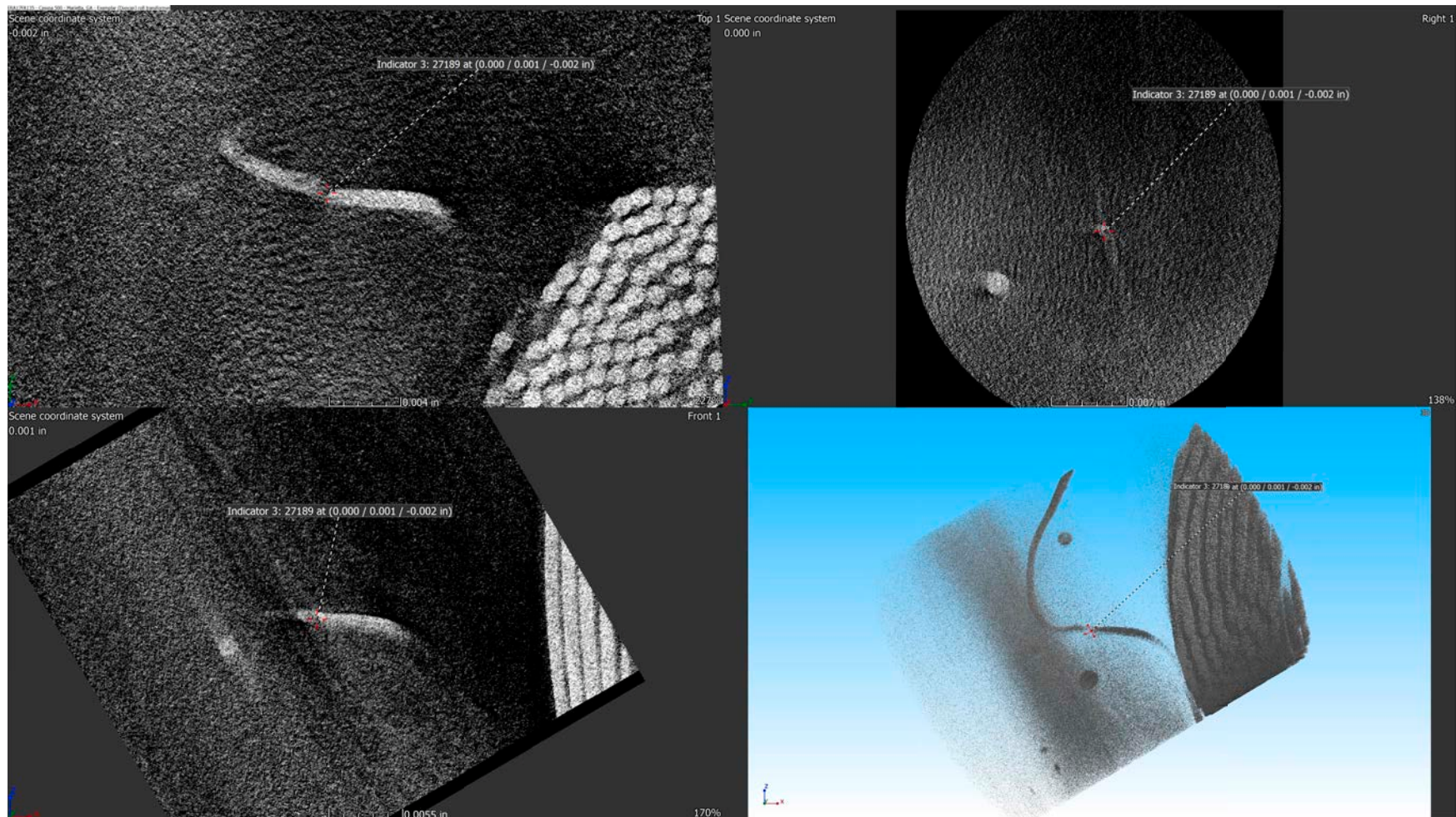


Figure 39
Duncan Aviation unairworthy transformer – LLNL scans – wire anomaly area 3 – high resolution view

Scott Warren
Lead Aerospace Engineer
(Computed Tomography Specialist)