

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



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COMPUTED TOMOGRAPHY

Specialist's Factual Report

January 16, 2024

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A. ACCIDENT

Location: Pompano Beach, Florida
Date: August 28, 2023
Time: 0844 eastern daylight time
1244 coordinated universal time (UTC)
Helicopter: Eurocopter Deutschland GMBH EC135T1, N109BC

B. COMPUTED TOMOGRAPHY SPECIALIST

Specialist: John Flynn
National Transportation Safety Board
Washington D.C.

C. FUEL SHUT-OFF VALVE (FSOV)

The fuel shut-off valve (FSOV) is installed in the fuel line in sealed housings in the left and right side shell of the helicopter as shown in Figure 1. In the event of an engine fire, this valve can be closed to stop the flow of fuel from reaching the engine. The FSOVs are controlled electrically by the switches labeled EMER OFF SW 1 and EMER OFF SW 2, located in the warning unit and shown in Figure 2. The switches are push-to release switches. The valve is commanded to the "closed" position when the switches are pushed.

The FSOV consists of a direct current (DC) motor-operated ball type shut-off valve with position indication. Figure 3 shows the exterior of the FSOV. Figure 4 shows the electrical schematic for the FSOV. Figure 5 shows the helicopter electrical schematic for the FSOV. Microswitches provide indication when the valve is in the "open" state and in the "closed" state. The microswitches are shown in Figures 6 and 7.

When the valve is "open", microswitch 1 pin "C" and pin "NC" (normally closed) are connected and microswitch 2 pin "C" and pin "NO" (normally open) are connected. When the valve is "closed", microswitch 1 pin "C" and pin "NO" are connected and microswitch 2 pin "C" and pin "NC" are connected.

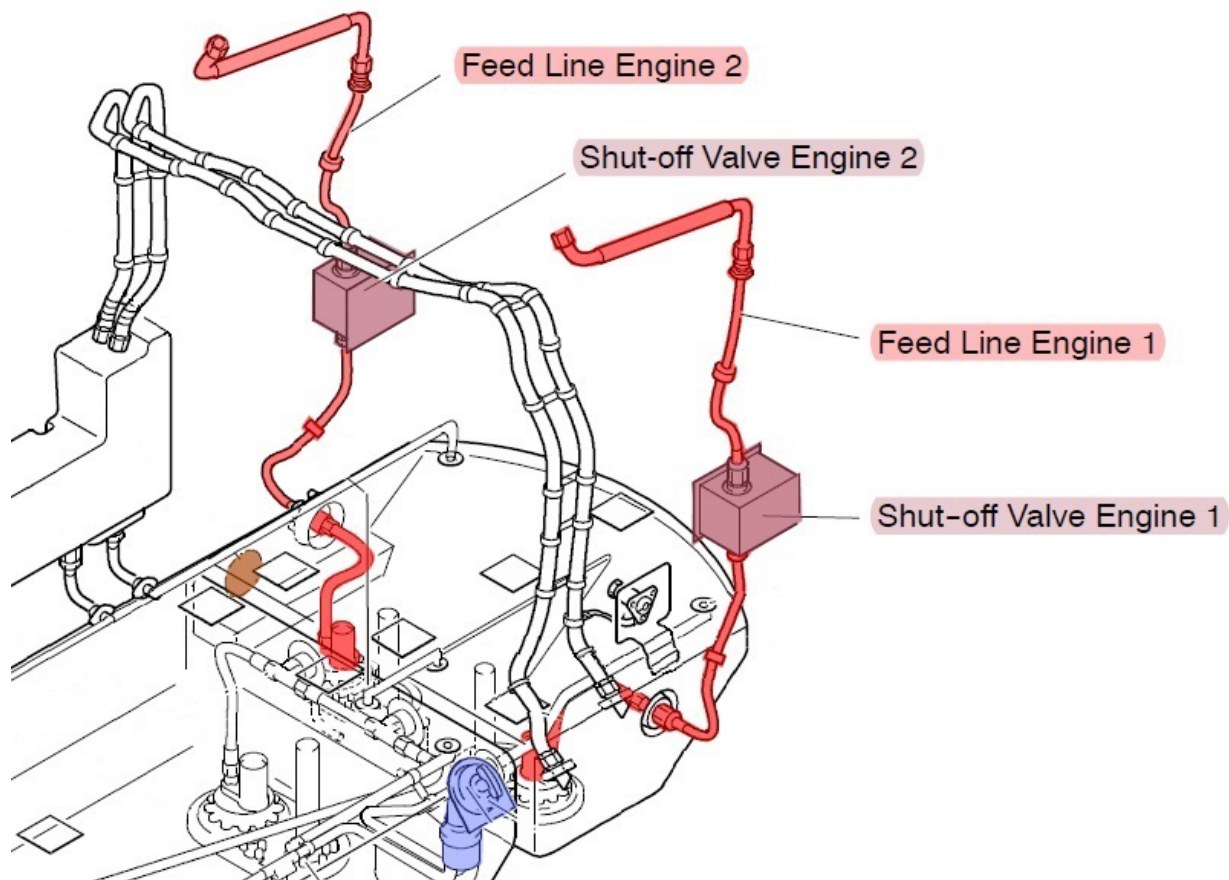


Figure 1. Drawing showing the location of the fuel shut-off valves in the helicopter. (Courtesy of Airbus.)

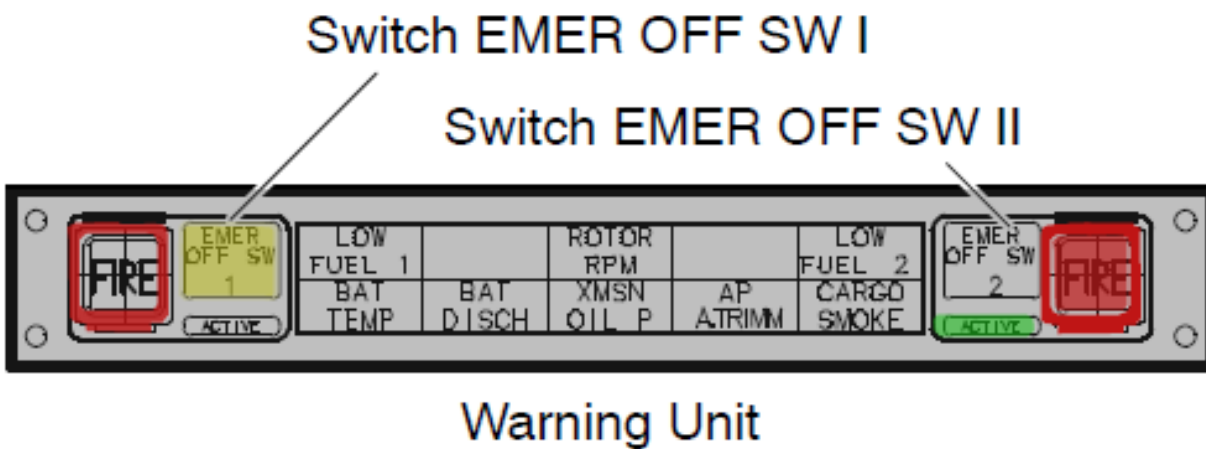


Figure 2. Image of warning unit showing the EMER OFF SW 1/2. (Courtesy of Airbus.)

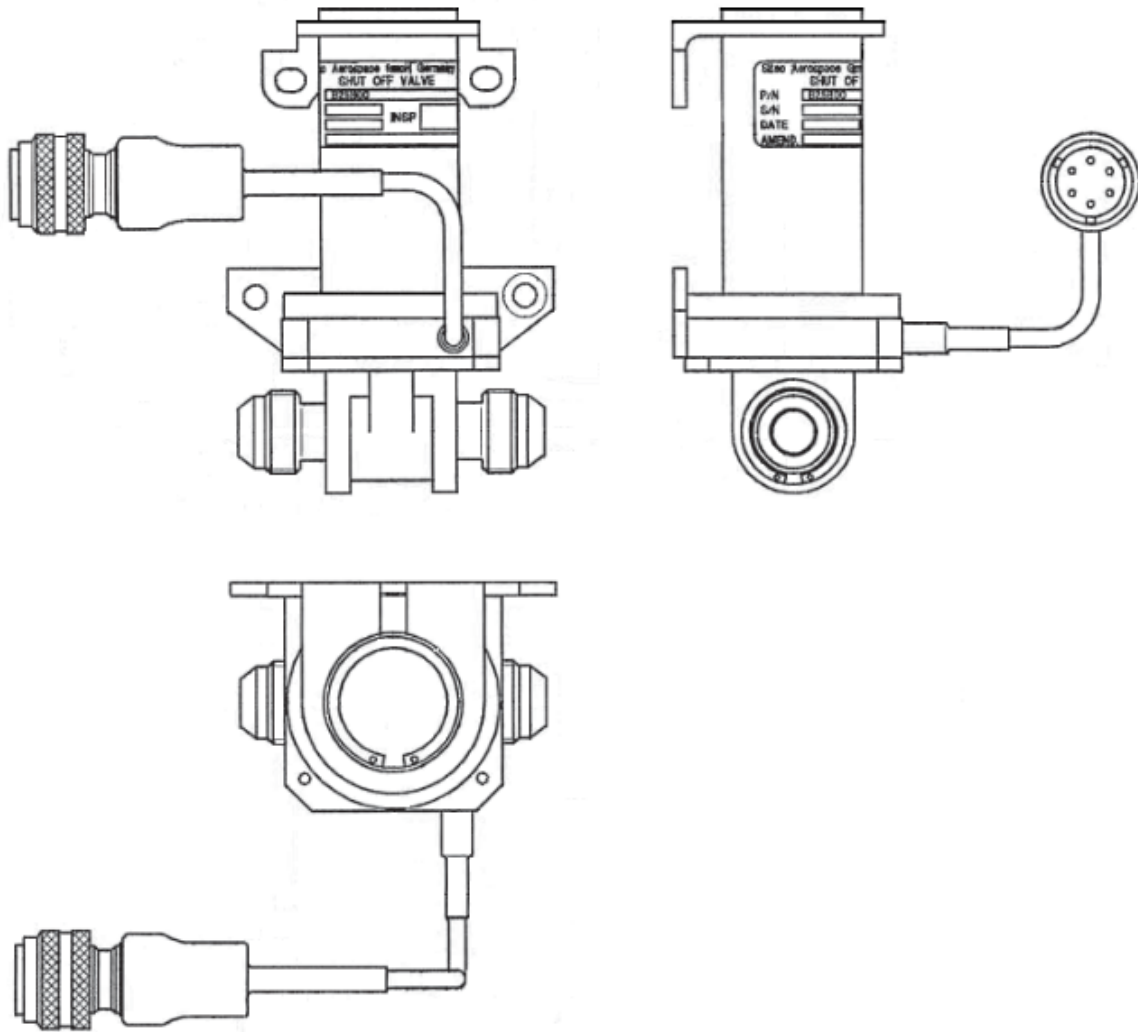


Figure 3. External view of the fuel shut-off valve. (Extract from Drawing B25600-01. Courtesy of Airbus.)

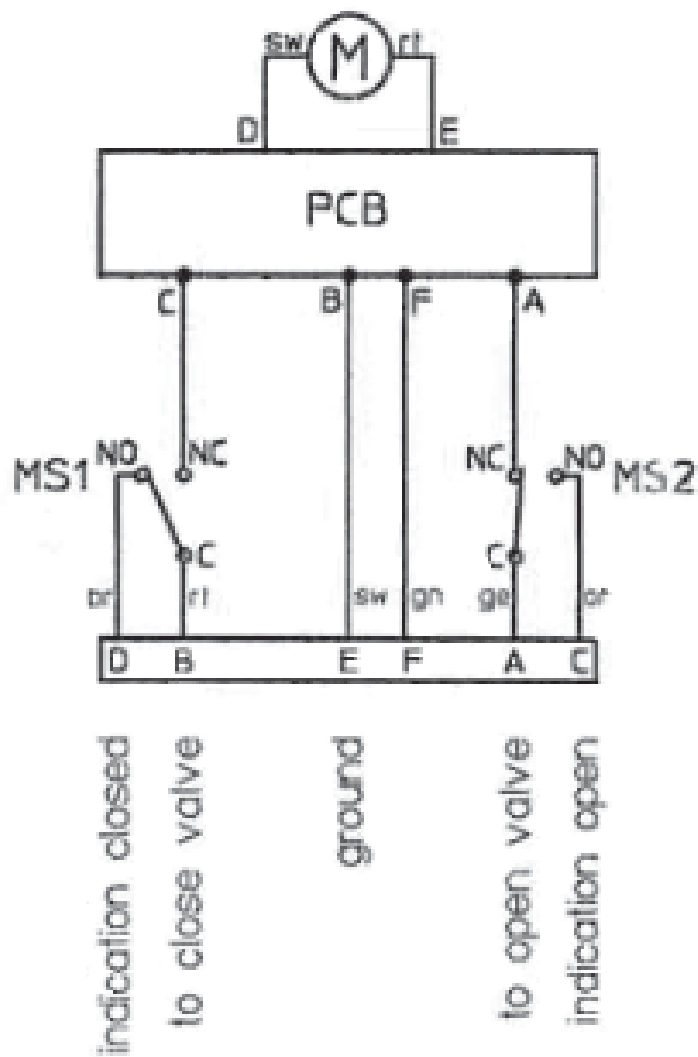


Figure 4. Electrical schematic of fuel shut-off valve. (Extract from Drawing B25600-01. Courtesy of Airbus.)

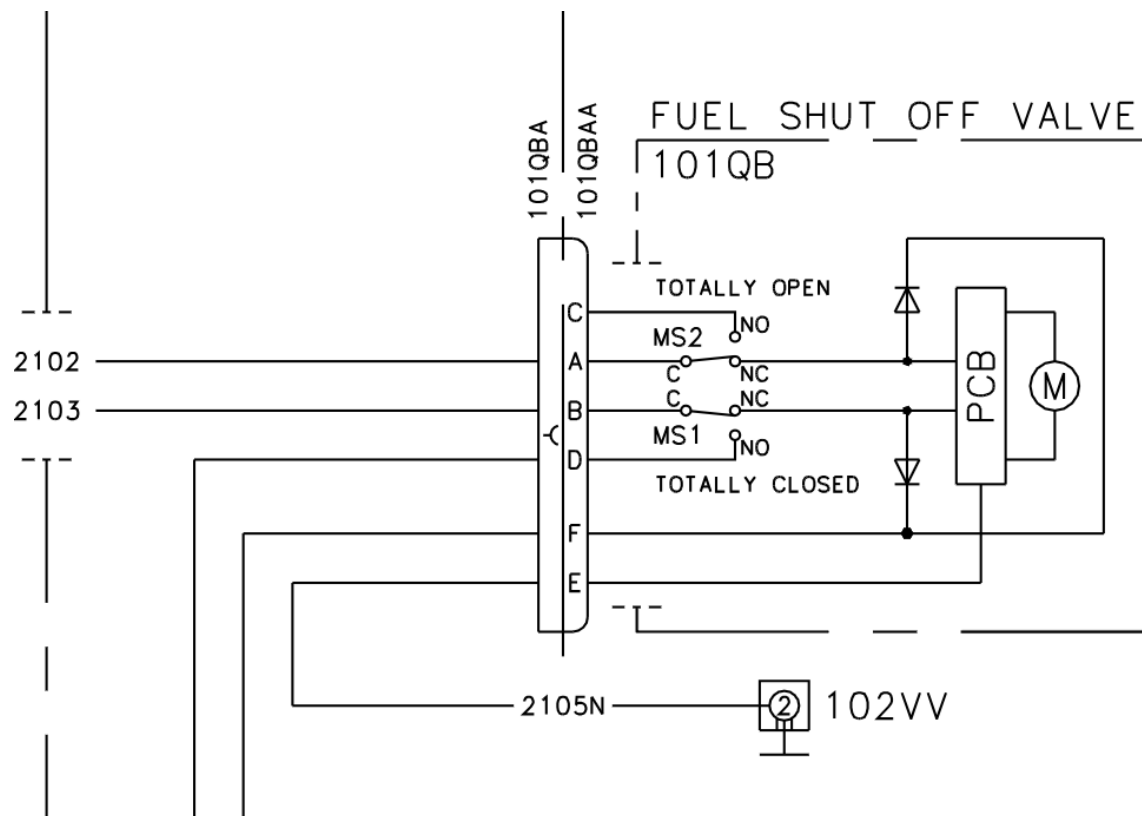


Figure 5. Portion of helicopter electrical schematic for the fuel shut-off valves. (Courtesy of Airbus.)

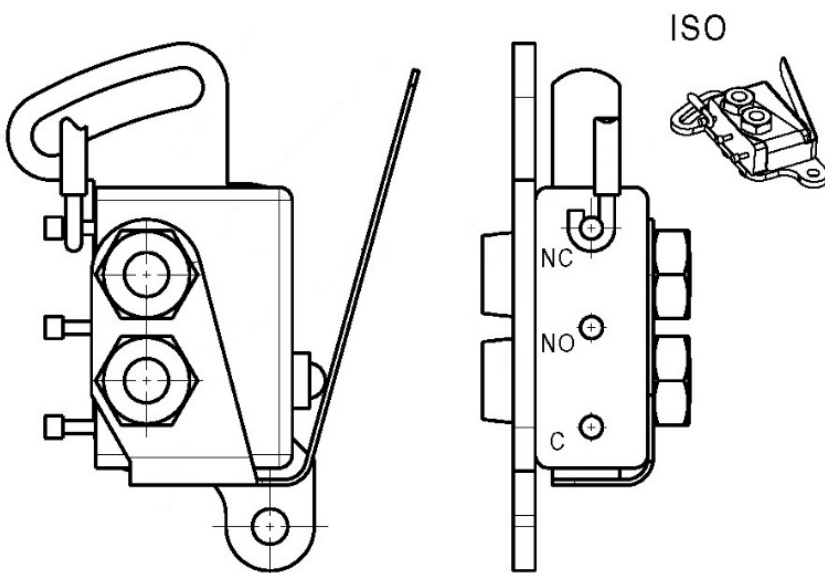


Figure 6. External view of microswitch 1. (Extract from Drawing B25140. Courtesy of Airbus.)

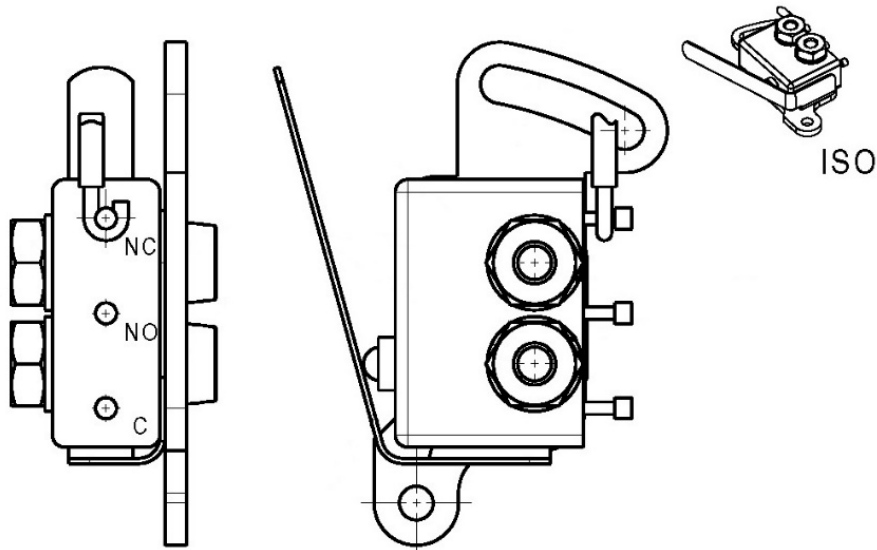


Figure 7. External view of microswitch 2. (Extract from Drawing B25150. Courtesy of Airbus.)

D. DETAILS OF THE INVESTIGATION

1.0 General

The engine 1 FSOV from the accident helicopter was subjected to x-ray radiograph and computed tomography (CT) scanning to document the ball valve position and the condition of the internal components. The scanning was conducted from September 22, 2023 to October 24, 2023, in Chicago, Illinois by Varex Imaging, Inc under the direction of the NTSB using the Actis 225/500 microfocus CT system.

For the CT scans, the component was loaded into the imaging unit and placed on a turntable. The component was 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 component was scanned using a total of 3,177 slices, and the total size of the combined data sets was approximately 20.42 GB. The complete scan protocols are given in table 1. The digital radiograph and CT axial slice images were provided by Varex Imaging to the NTSB where they were examined, processed, and analyzed to evaluate the component.

Table 1. Scan Protocol

CT System	225 kV	225 kV (microfocus)
Area scanned	Whole part	Top of motor to the ball valve
Number of Slices	1276	1901
Voxel ¹ Size - X Direction (millimeter(mm))	0.08	0.04
Voxel Size - Y Direction (mm)	0.08	0.04
Voxel Size - Z Direction (mm)	0.08	0.0426
Image Projections per Revolution	2160	2520
Exposure Time (milliseconds)	285.6	285.6
Frames to Avg (frames per projection)	2	3
X-ray Source Voltage (kilovolts)	223	222
X-ray Source Current (mA) (microfocus system)	580	570
Source Filter Thickness (mm)	1	1
Source Filter Material	copper	copper
CT Matrix Size (voxels, x, y, z)	1536x1536	2048x2048

The data sets of slice images were examined, processed, and analyzed by the NTSB using the VGStudioMax software package to convert the axial slice data into orthogonal slice images and a three-dimensional reconstructed image of the component. As part of the evaluation, some sections of the components were digitally removed or rendered transparent to allow closer observation of interior parts. In all the images, the higher density areas were shown as brighter shades of gray and lower density areas were shown as darker shades of gray. Each 2-D quadrant within the images shows a scale at the bottom of that quadrant - note that the scales in each quadrant may be different. The pointers shown in some of the images denote specific areas of interest within that image. The numbers associated with the pointer are the gray value at the pointer location and the three positional coordinates of the pointer.

The images of the component were examined for any signs of failed or broken parts. Specific results (including example images) are presented in subsequent sections of this report.

2.0 Computed Tomography Results

The CT results for the engine 1 fuel shut-off valve are shown in Figures 8 through 38. Images from the 225 kV data are labeled "225 kV" while images from the 225 kV microfocus data are labeled "Microfocus 225 kV". Review of the images determined that, when the scans were conducted, the following indications were noted:

1. The ball valve was in the open position (Figure 9).

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

2. The pins of the electrical connector were seated properly. (Figures 10 - 18)
3. The helicopter wire for pin C was not present, as designed. (Figures 5 and 15)
4. The wires from the electrical connector to their terminations in the valve were intact and matched the electrical schematic. (Figures 19, 22, 23, 25, 26, 27, and 29).
5. Microswitch 1 was in the open position (contact between contacts "C" and "NC". Microswitch 2 was in the "closed" position (contact between contacts "C" and "NO". (Figure 21)
6. The drivetrain was intact with no anomalies observed (Figures 32 - 38)

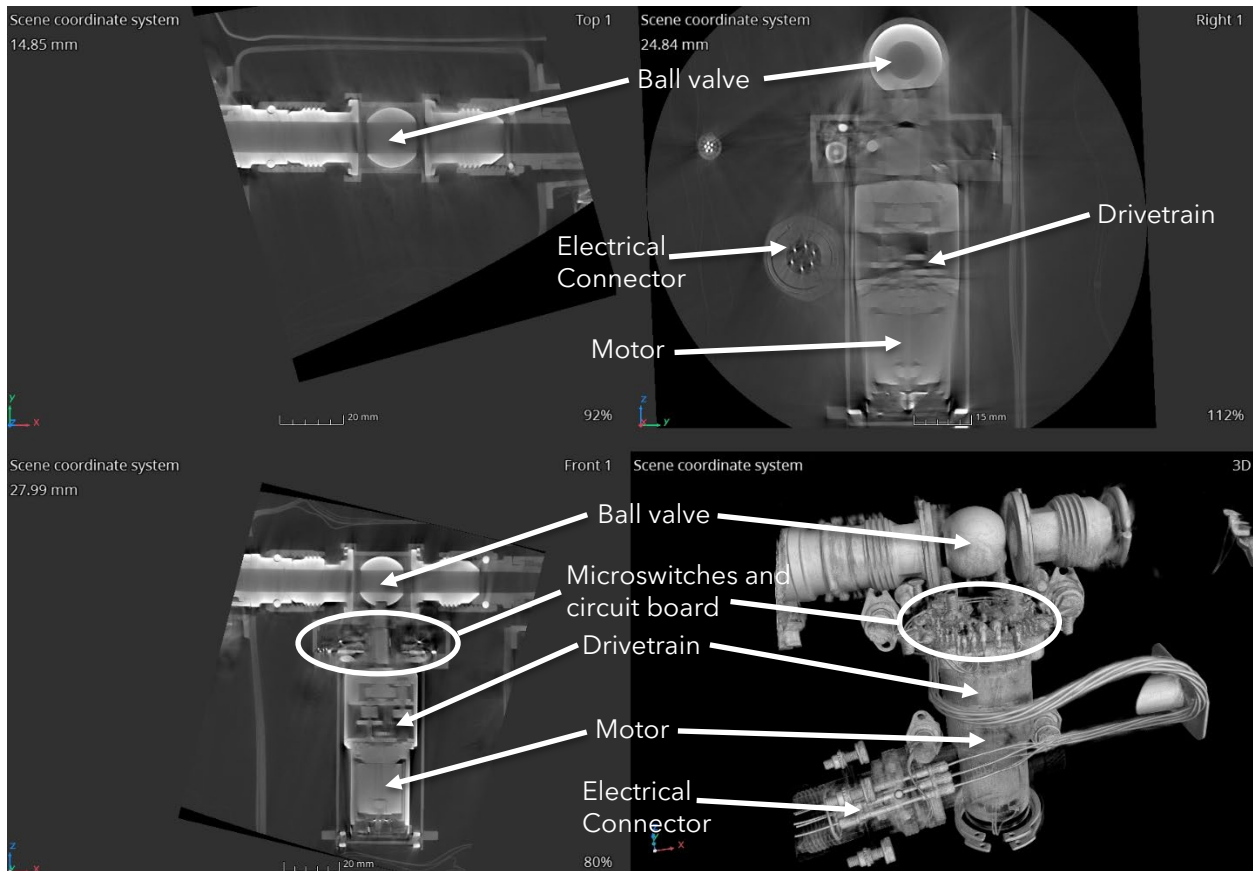


Figure 8. Fuel shut-off valve - overview. (225 kV)

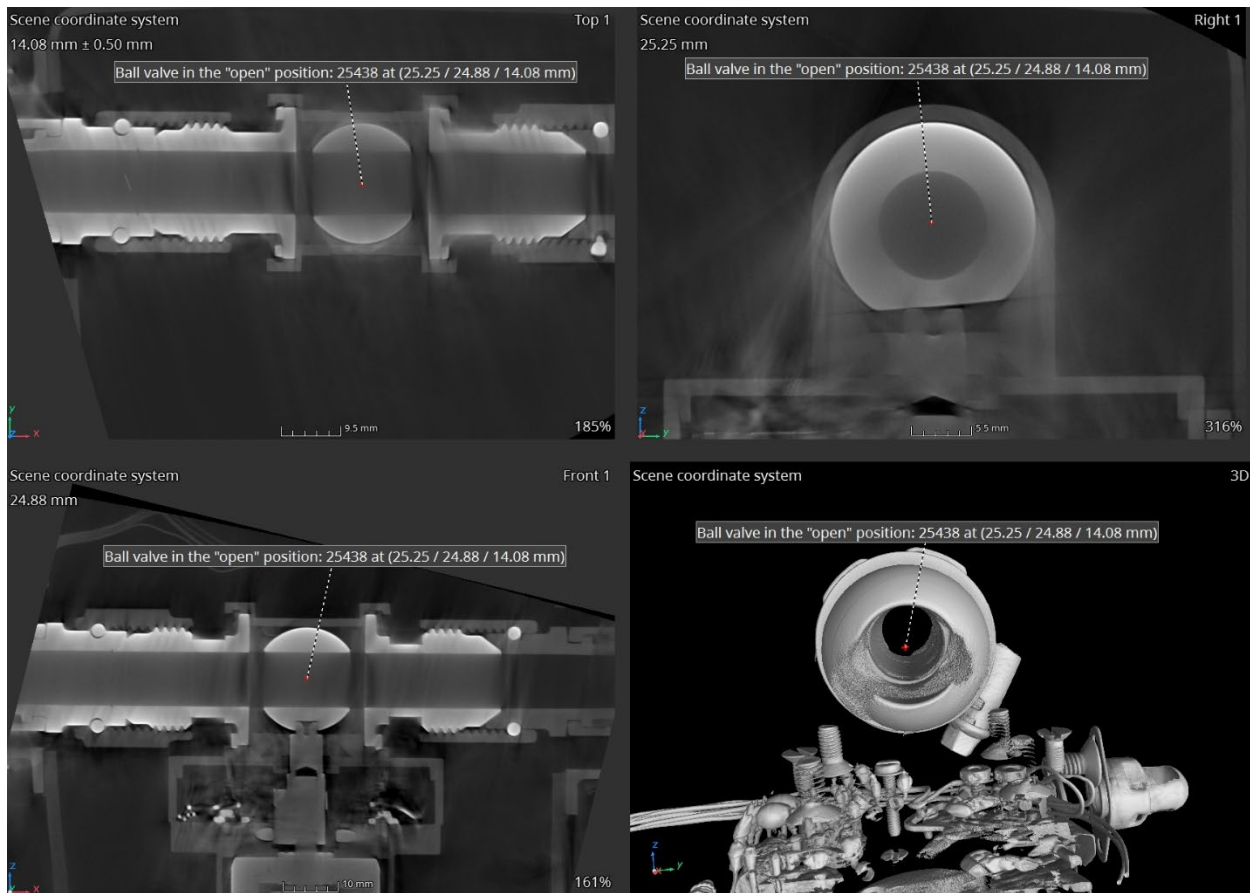


Figure 9. Fuel shut-off valve - showing "open" ball valve. (225 kV)

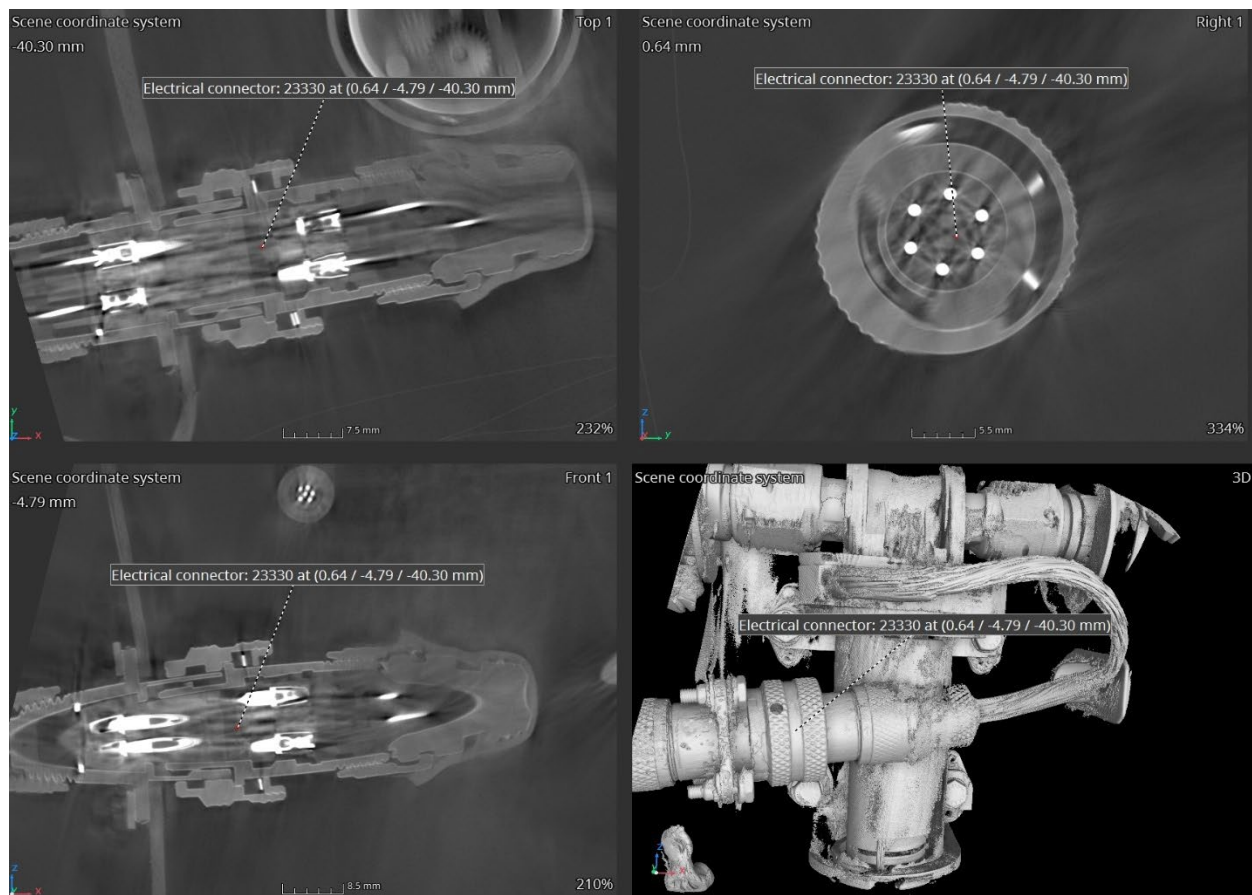


Figure 10. Fuel shut-off valve – electrical connector. (225 kV)

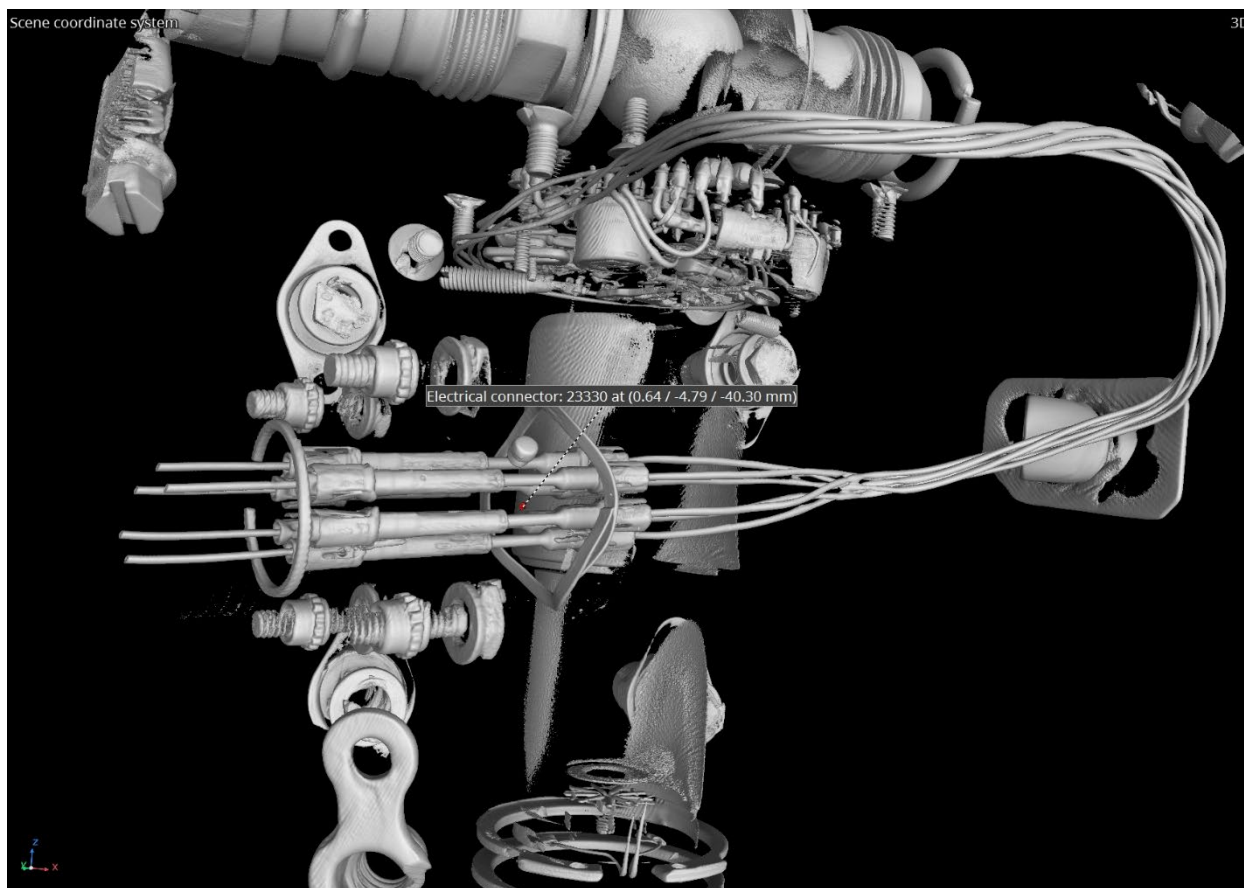


Figure 11. Fuel shut-off valve – electrical connector with connector material digitally removed. (225 kV)

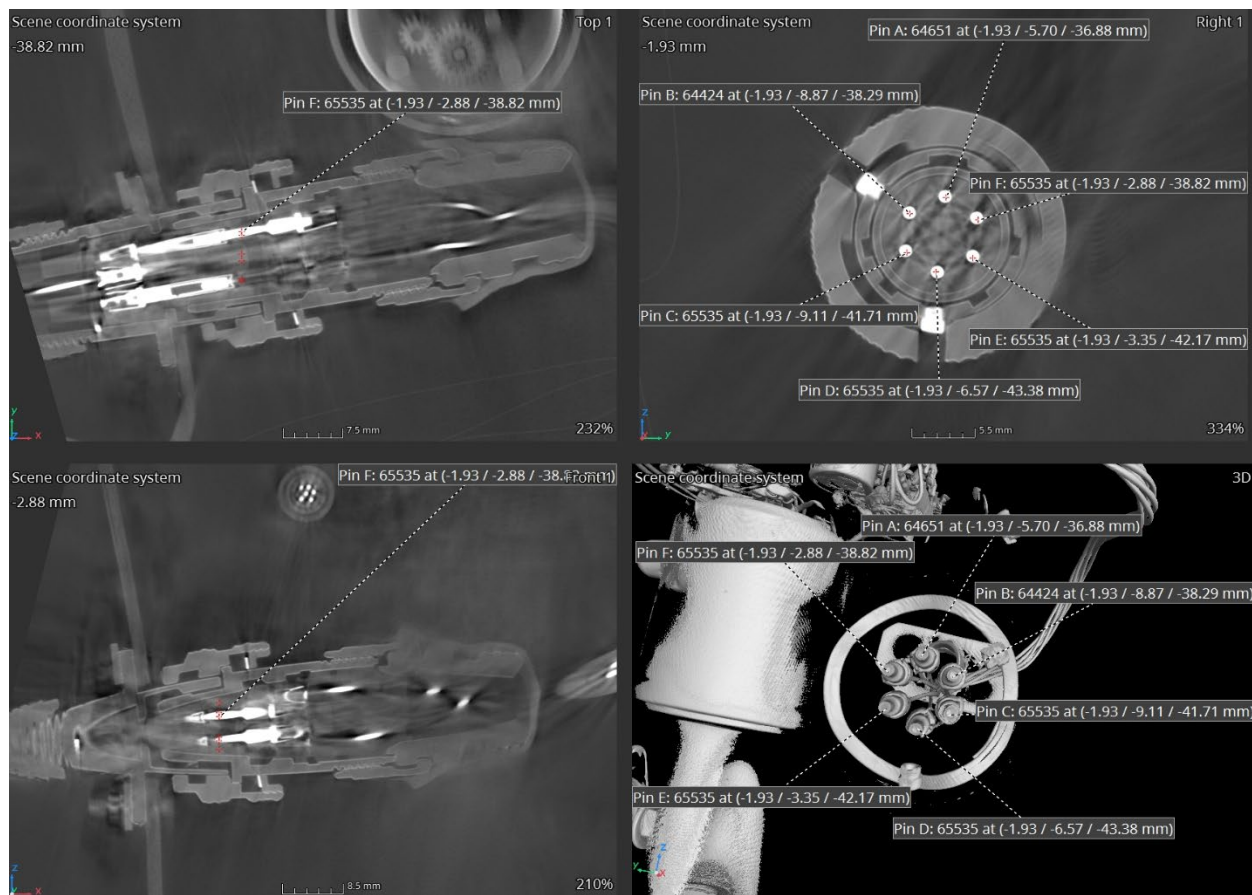


Figure 12. Fuel shut-off valve – electrical connector with pins labeled. (225 kV)

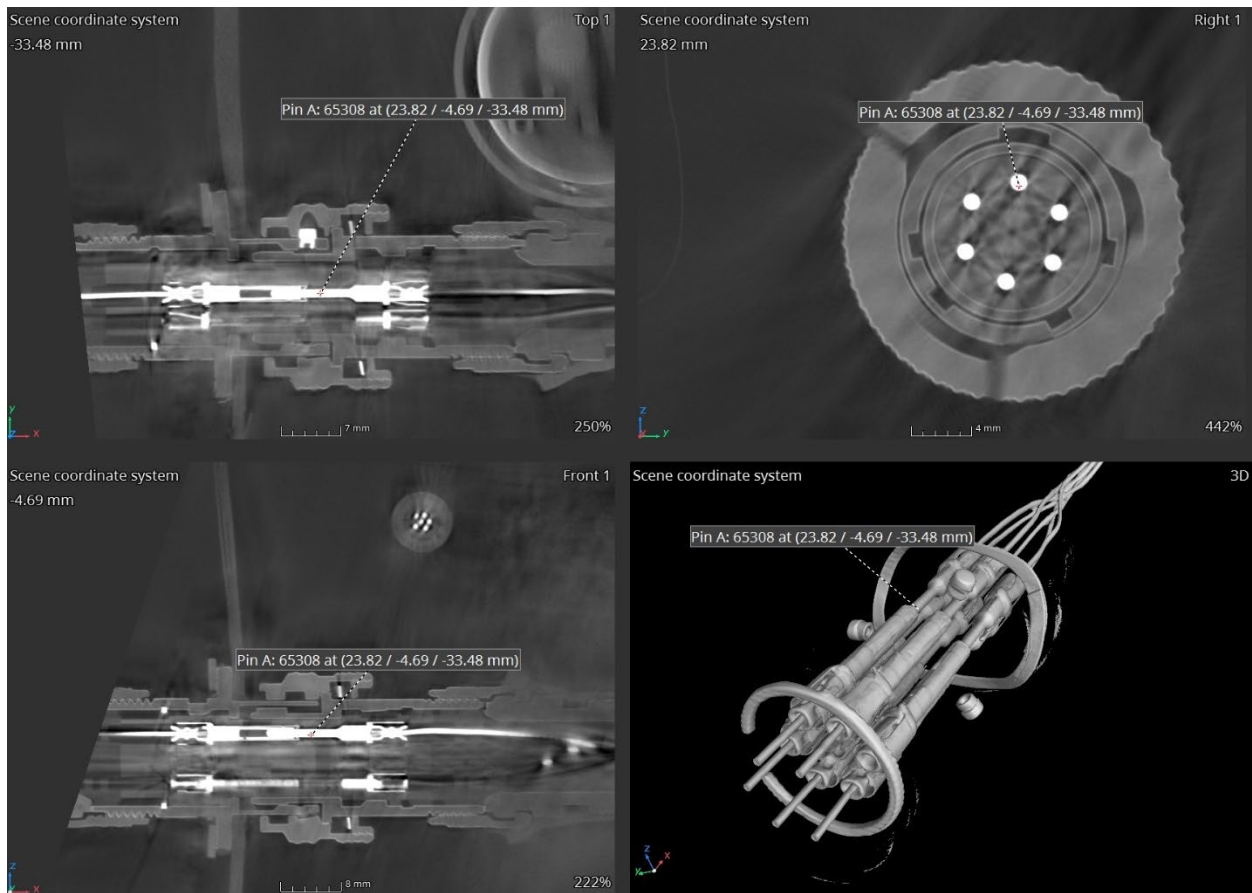


Figure 13. Fuel shut-off valve - electrical connector - pin A. (225 kV)

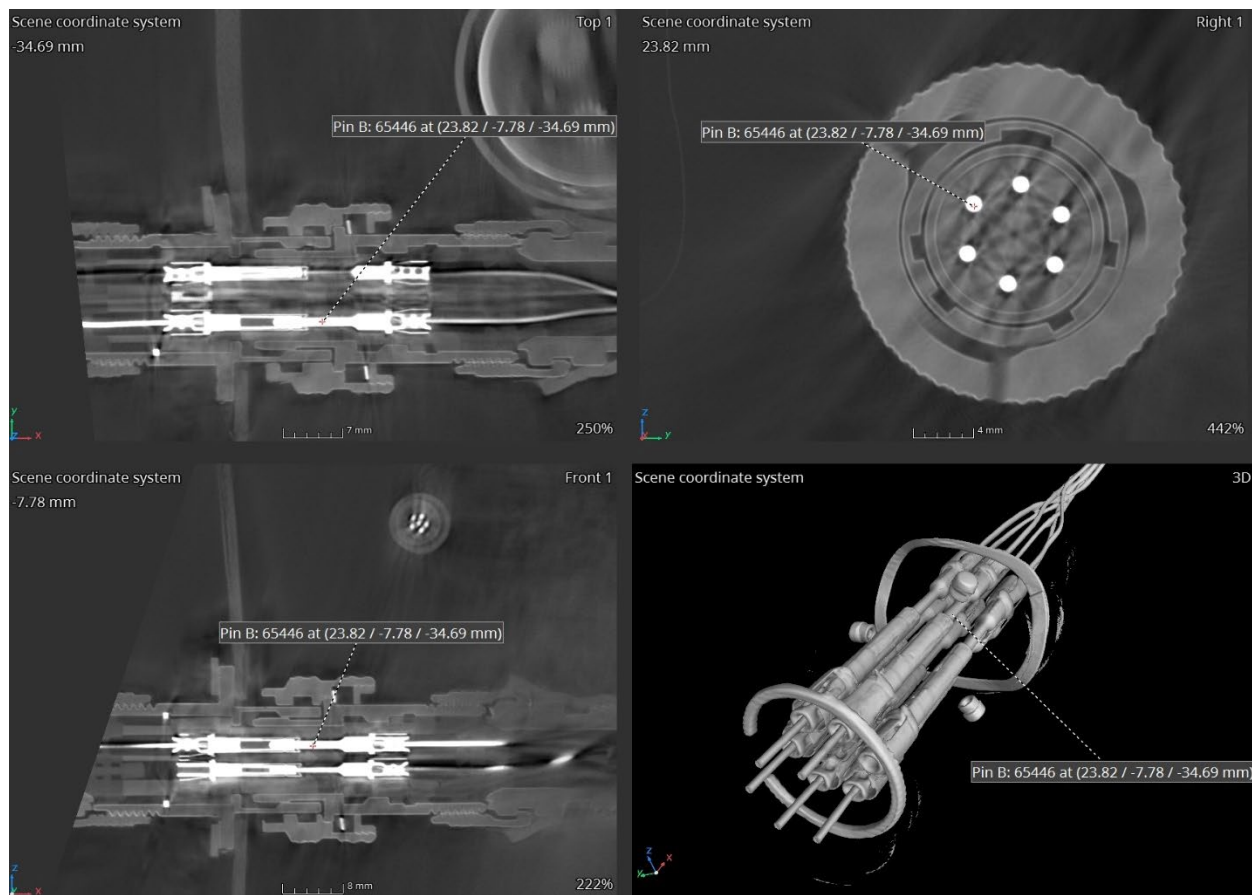


Figure 14. Fuel shut-off valve – electrical connector – pin B. (225 kV)



Figure 15. Fuel shut-off valve – electrical connector – pin C. (225 kV)

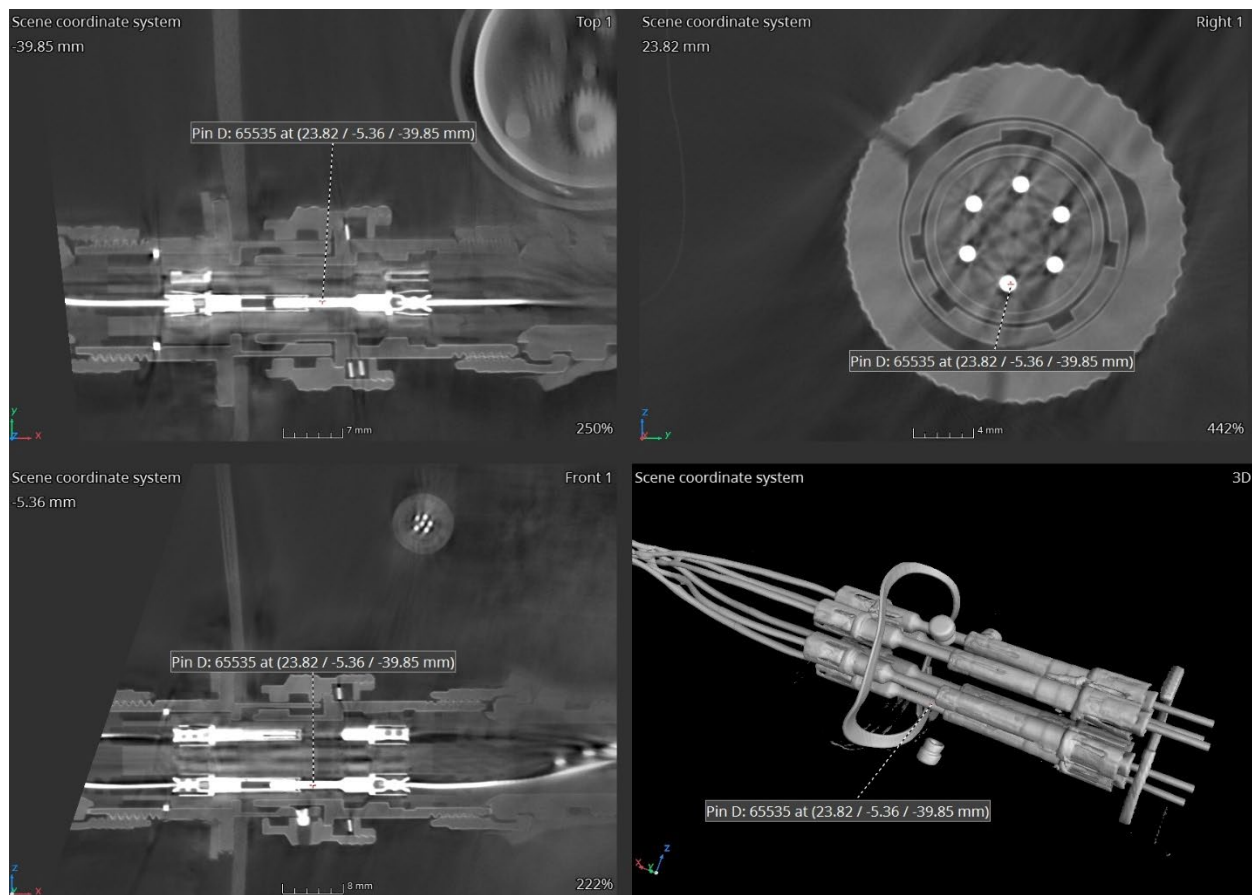


Figure 16. Fuel shut-off valve – electrical connector – pin D. (225 kV)



Figure 17. Fuel shut-off valve - electrical connector - pin E. (225 kV)

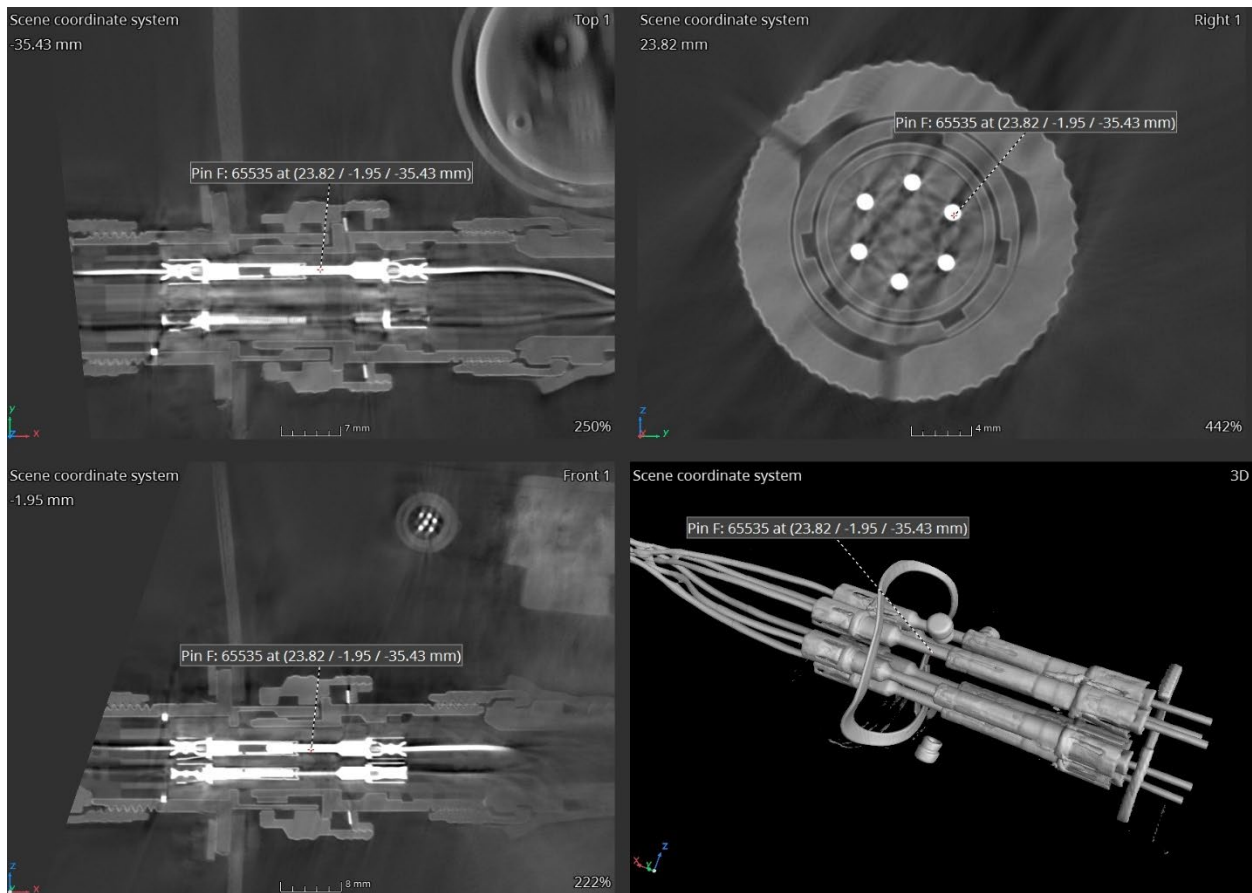


Figure 18. Fuel shut-off valve – electrical connector – pin F. (225 kV)

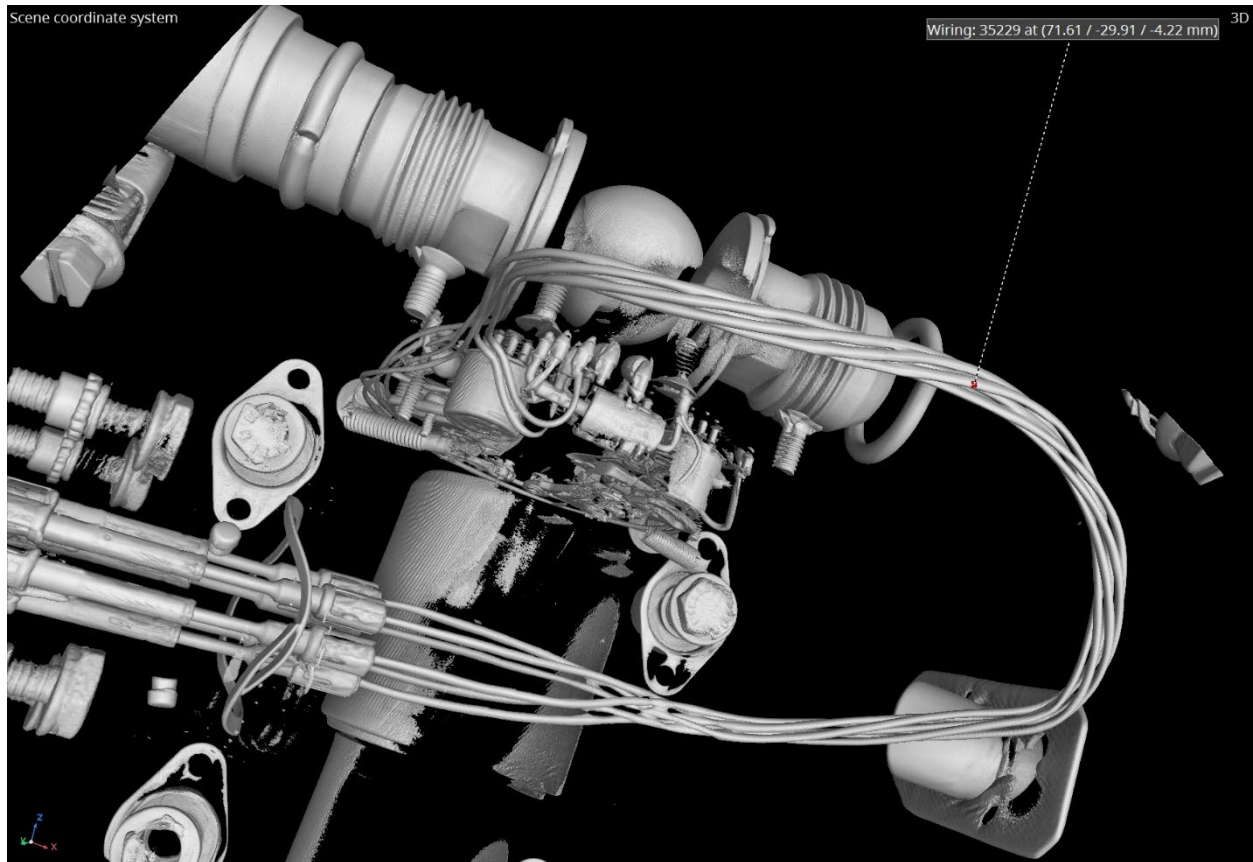


Figure 19. Fuel shut-off valve - wiring. (225 kV)

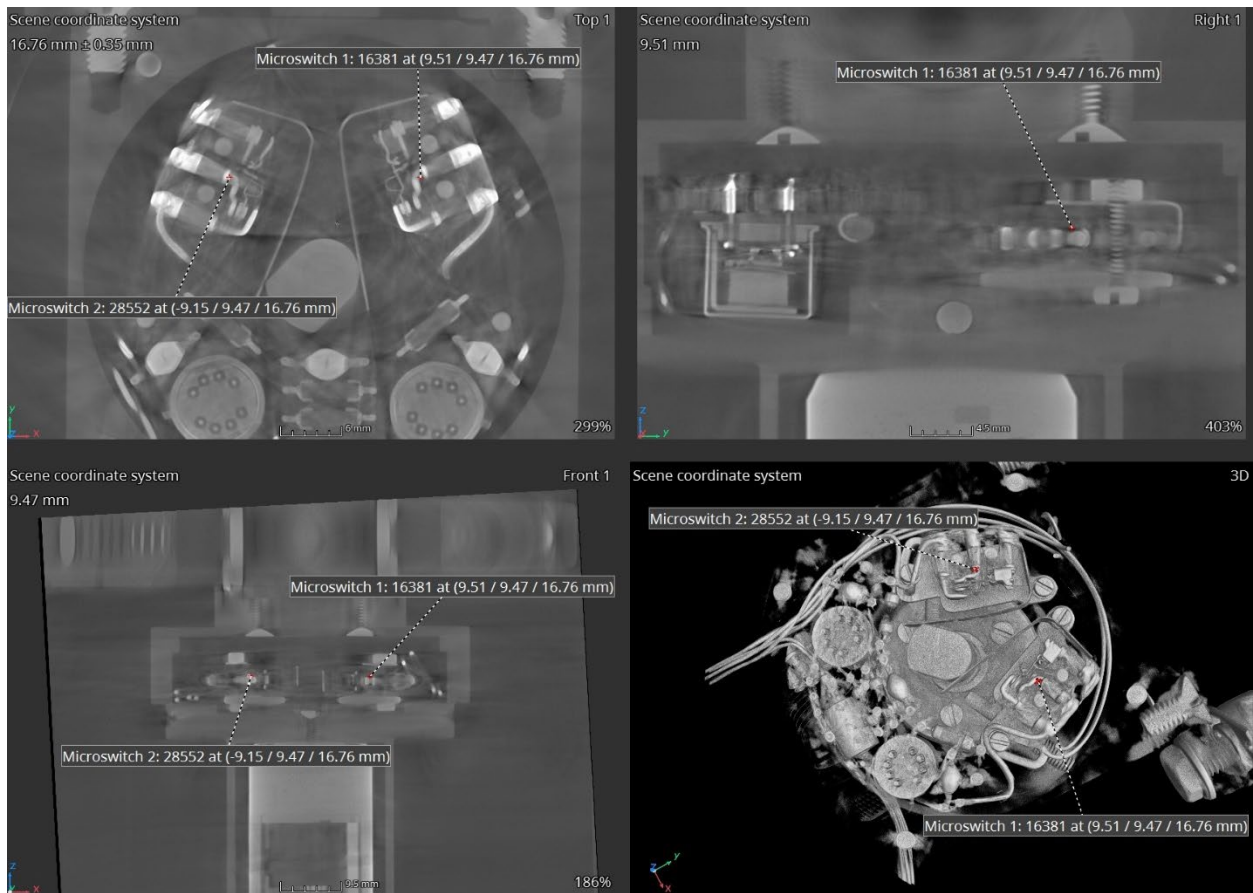


Figure 20. Fuel shut-off valve – microswitches. (Microfocus 225 kV)

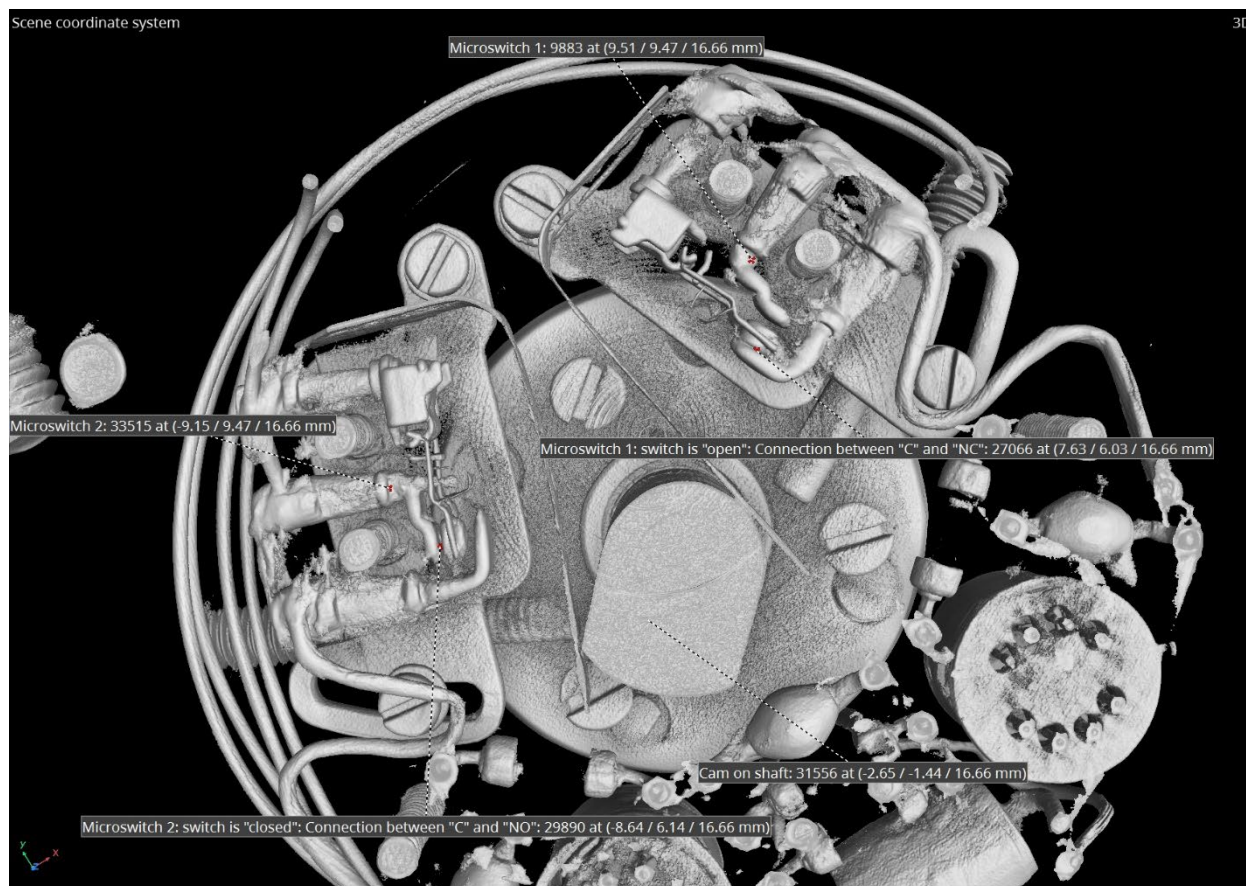


Figure 21. Fuel shut-off valve – microswitches. (Microfocus 225 kV)

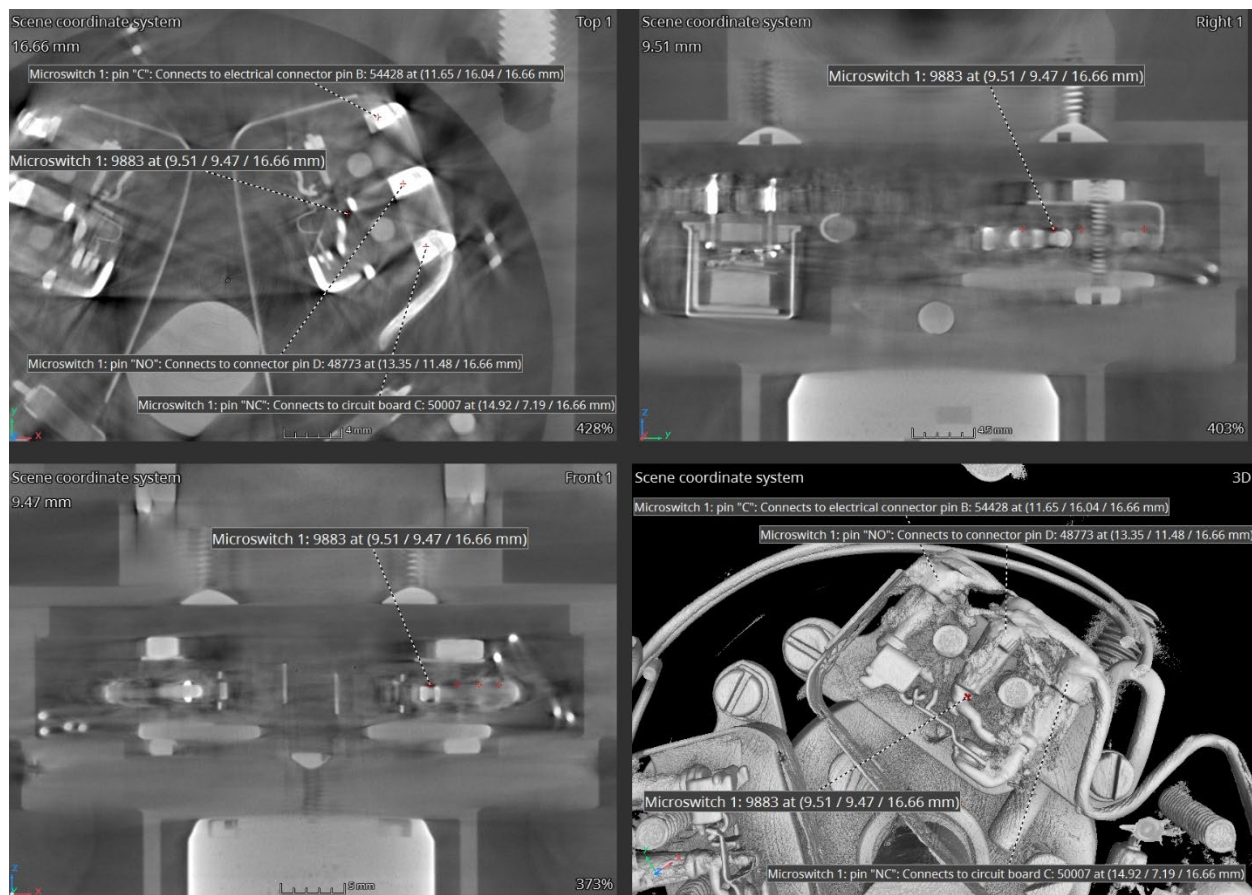


Figure 22. Fuel shut-off valve – microswitch 1. (Microfocus 225 kV)

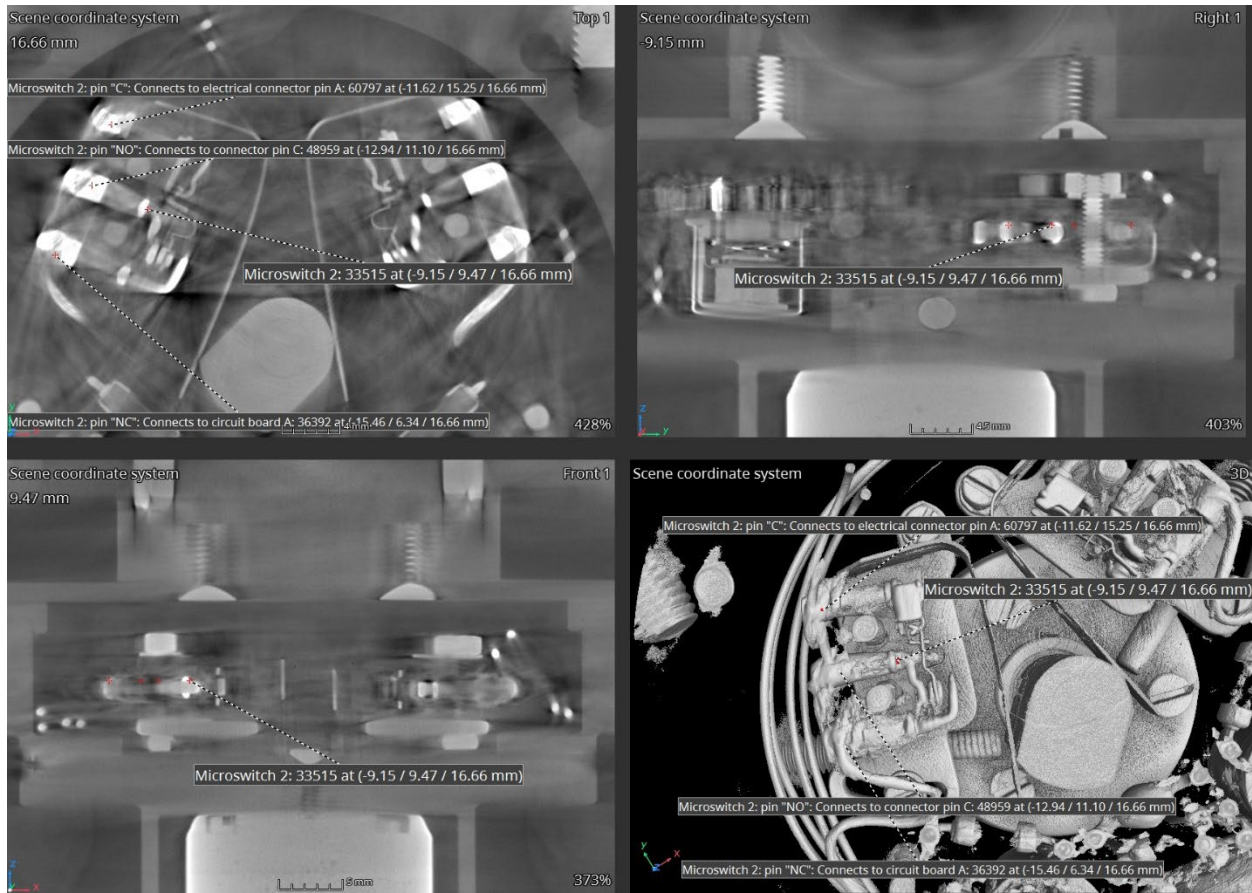


Figure 23. Fuel shut-off valve – microswitch 2. (Microfocus 225 kV)

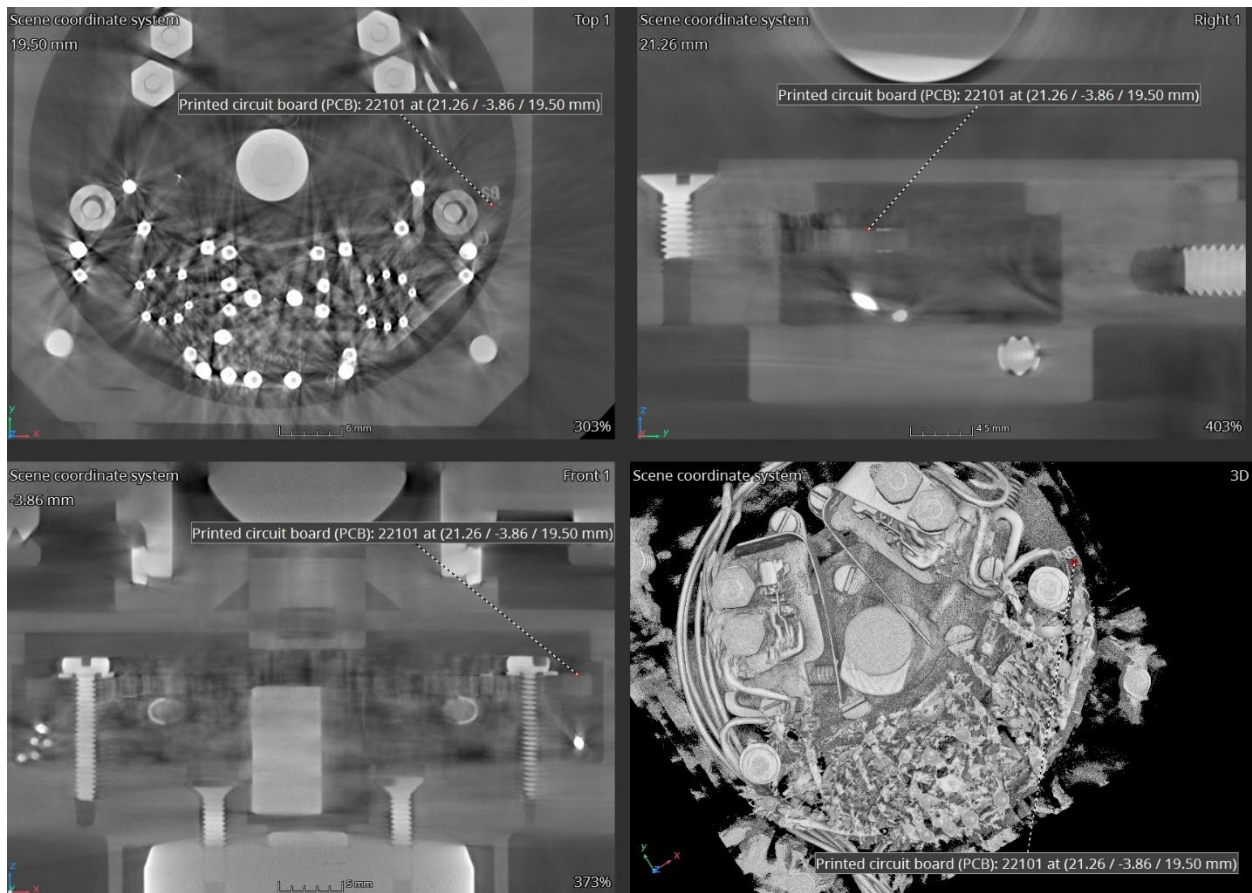


Figure 24. Fuel shut-off valve – printed circuit board (PCB). (Microfocus 225 kV)

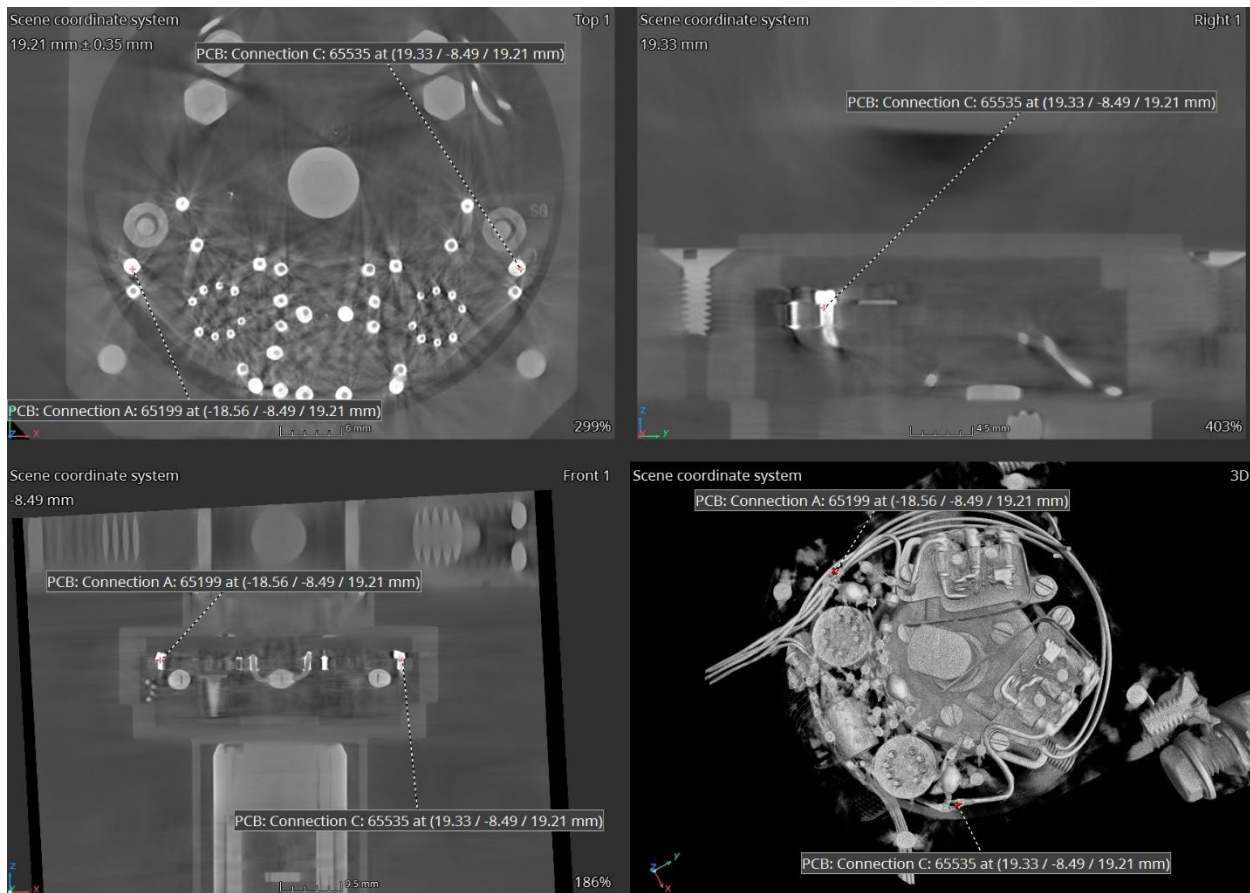


Figure 25. Fuel shut-off valve – PCB “A” and “C” terminations from microswitches. (225 kV)

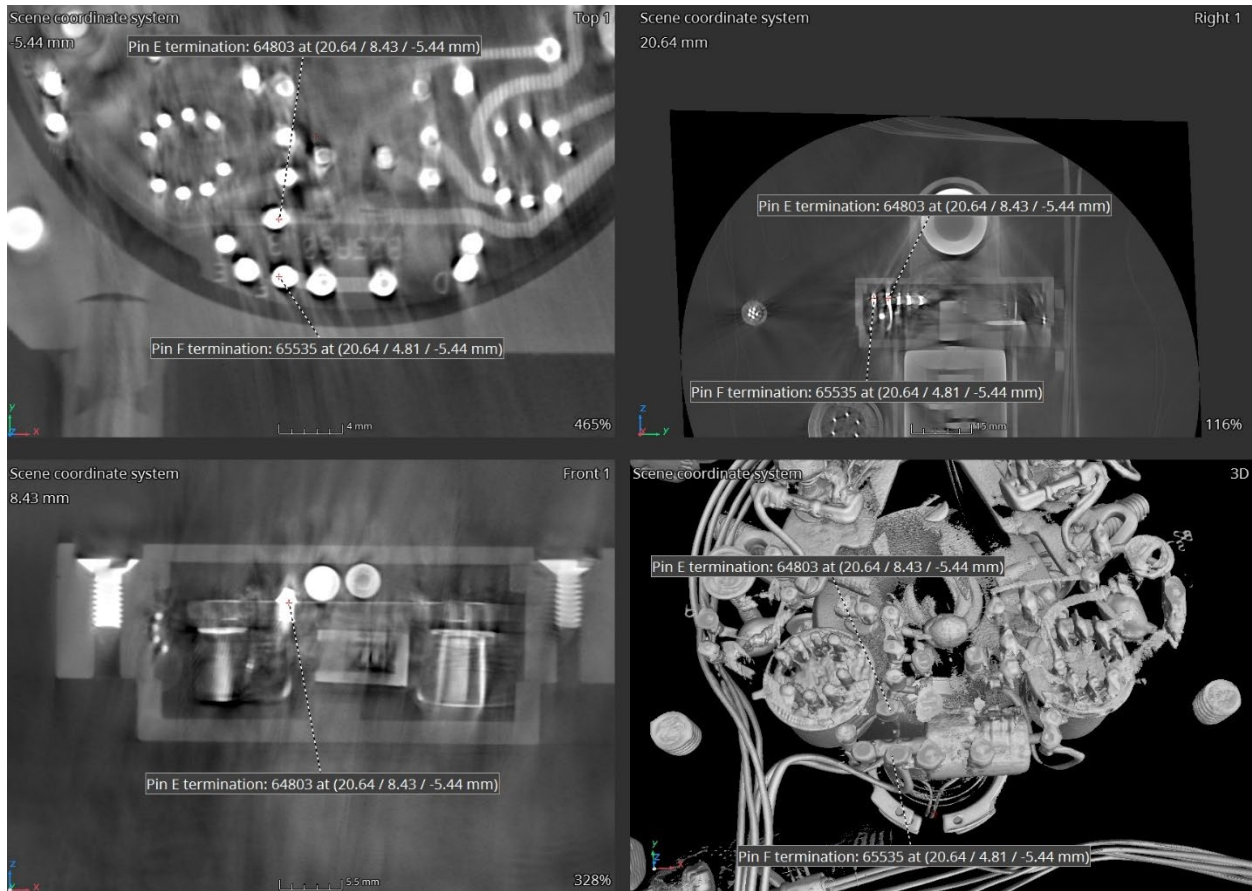


Figure 26. Fuel shut-off valve - PCB "B" and "F" terminations from electrical connector pins E and F. (Microfocus 225 kV)

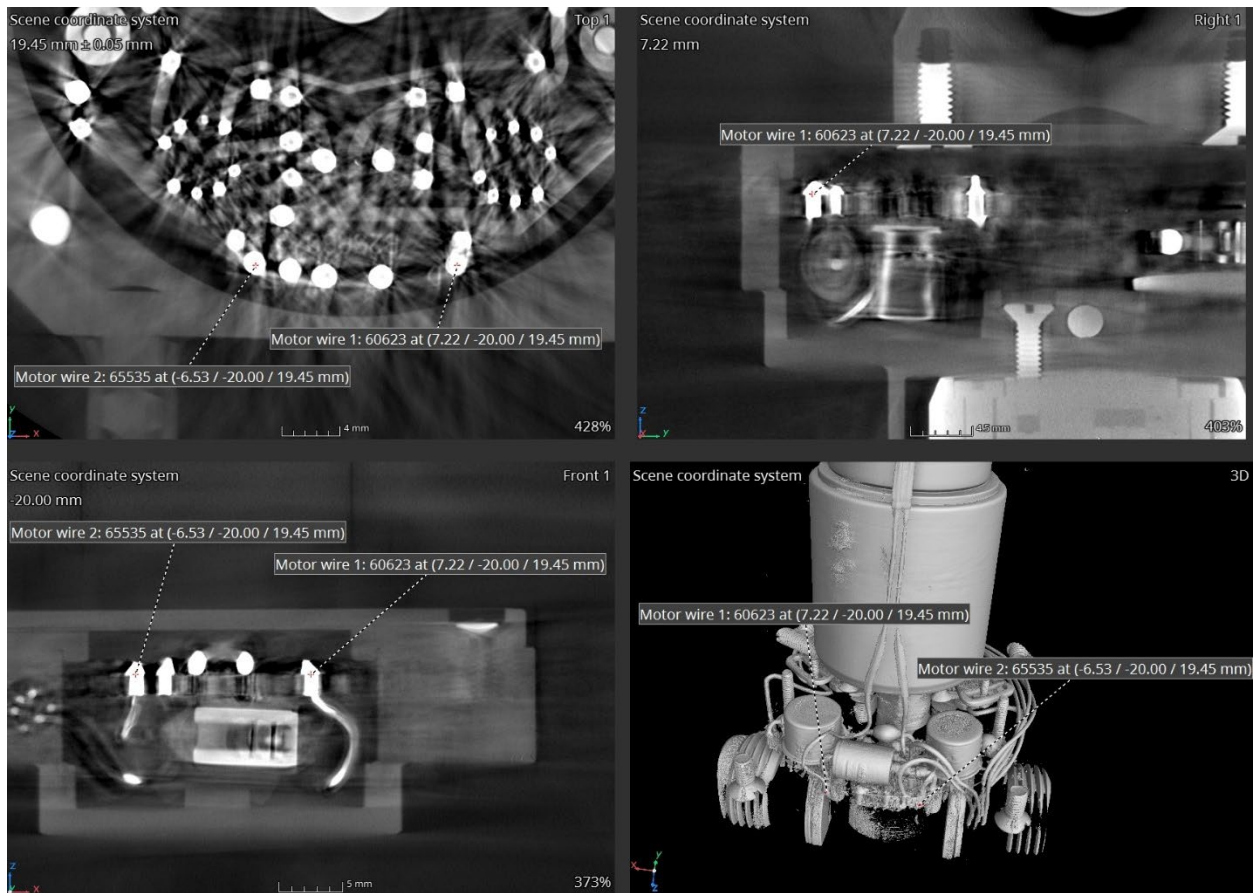


Figure 27. Fuel shut-off valve - PCB "D" and "E" connections to motor wires. (Microfocus 225 kV)

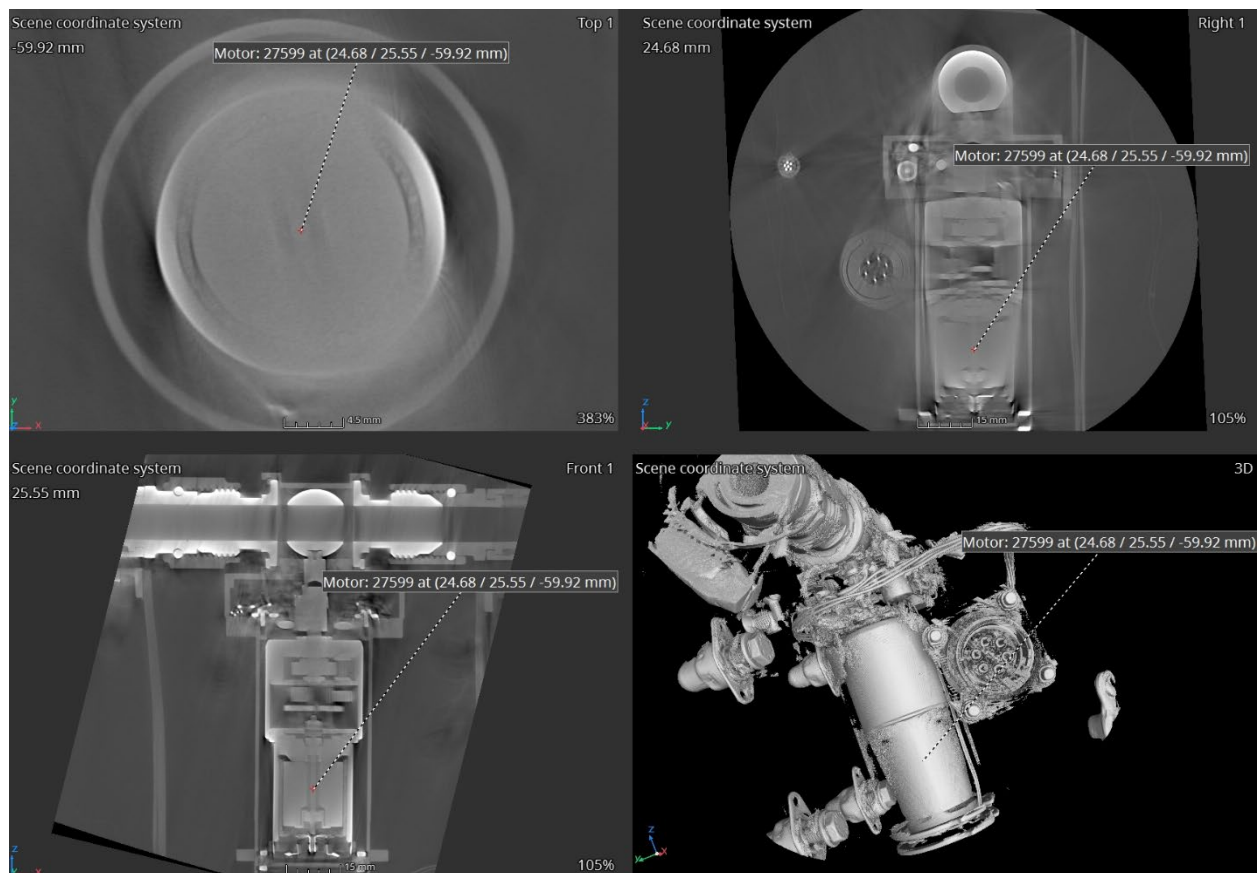


Figure 28. Fuel shut-off valve – motor. (225 kV)

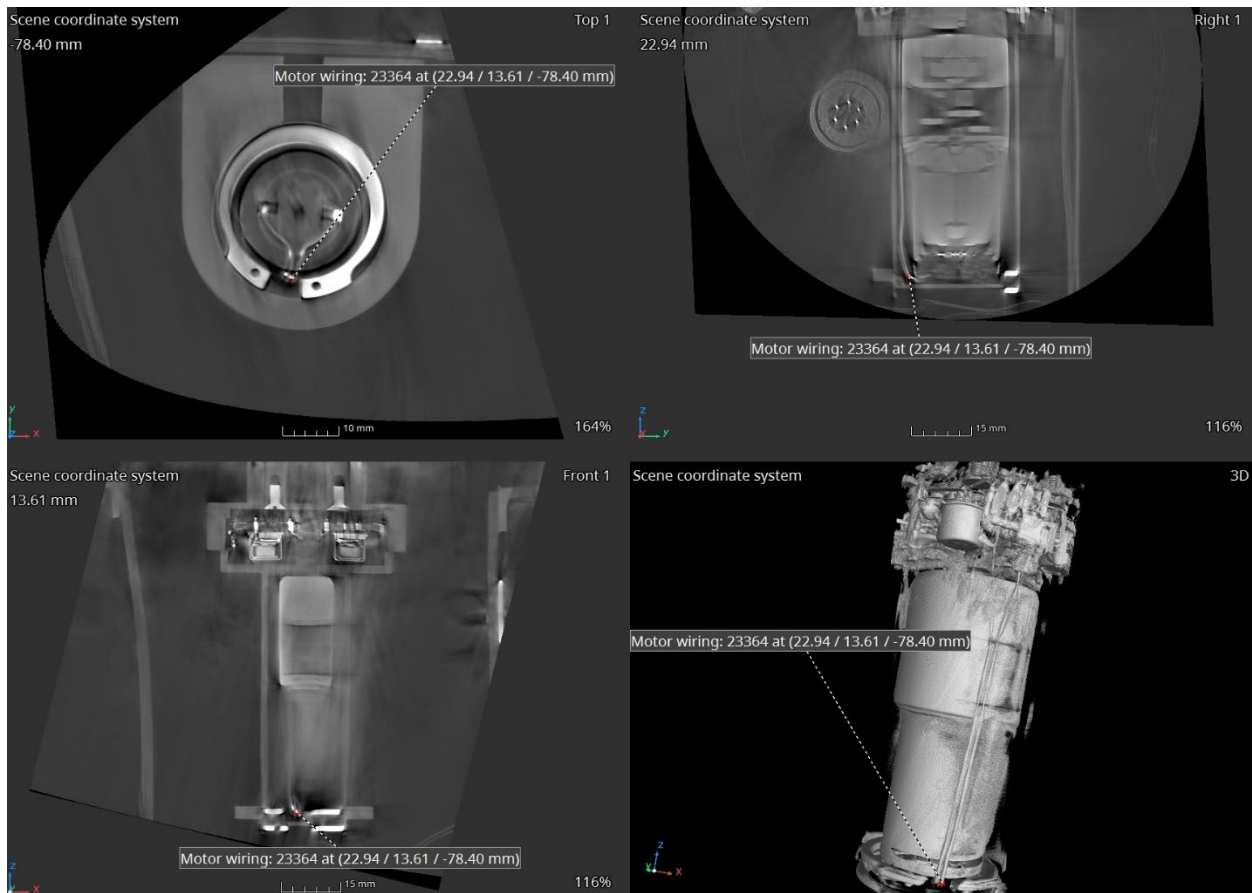


Figure 29. Fuel shut-off valve - motor wiring. (225 kV)

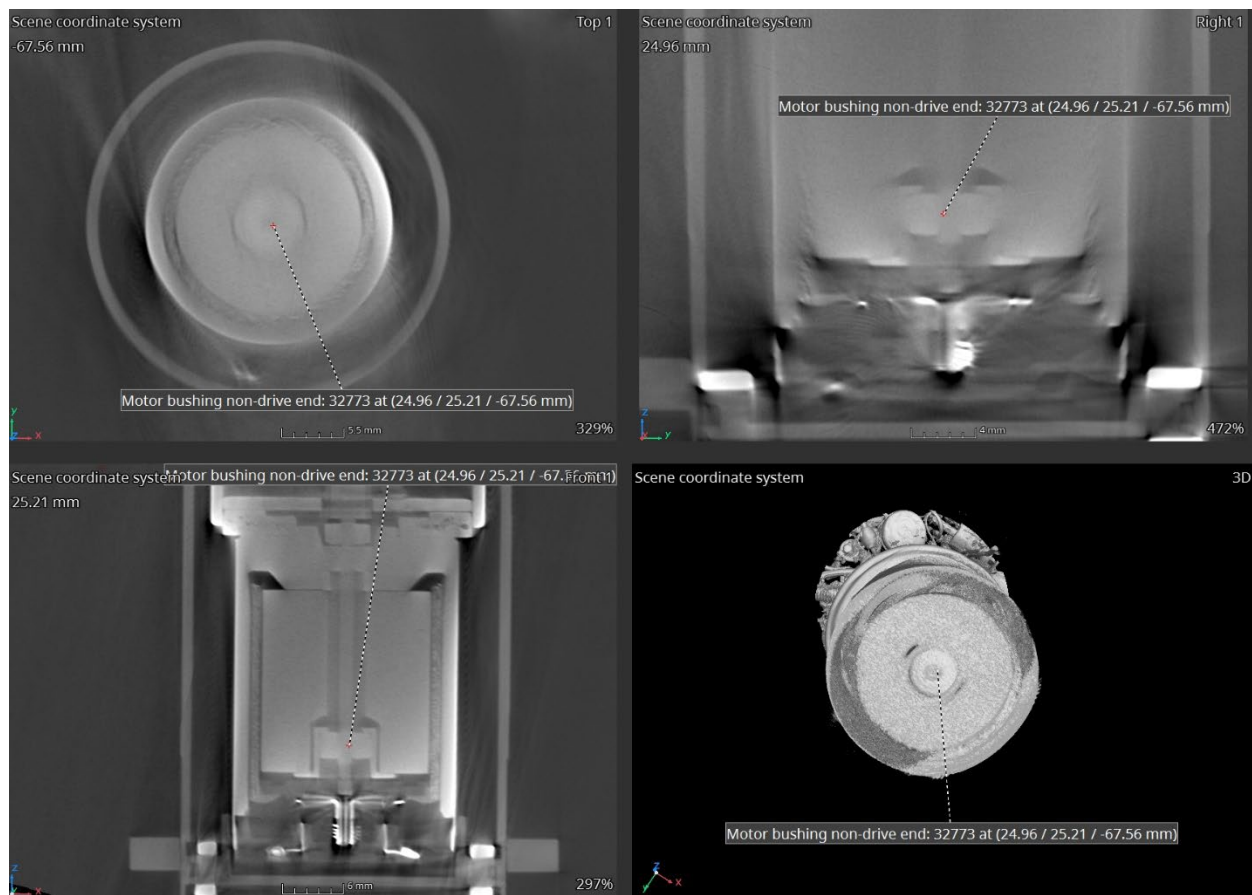


Figure 30. Fuel shut-off valve - motor bushing non-drive end. (225 kV)

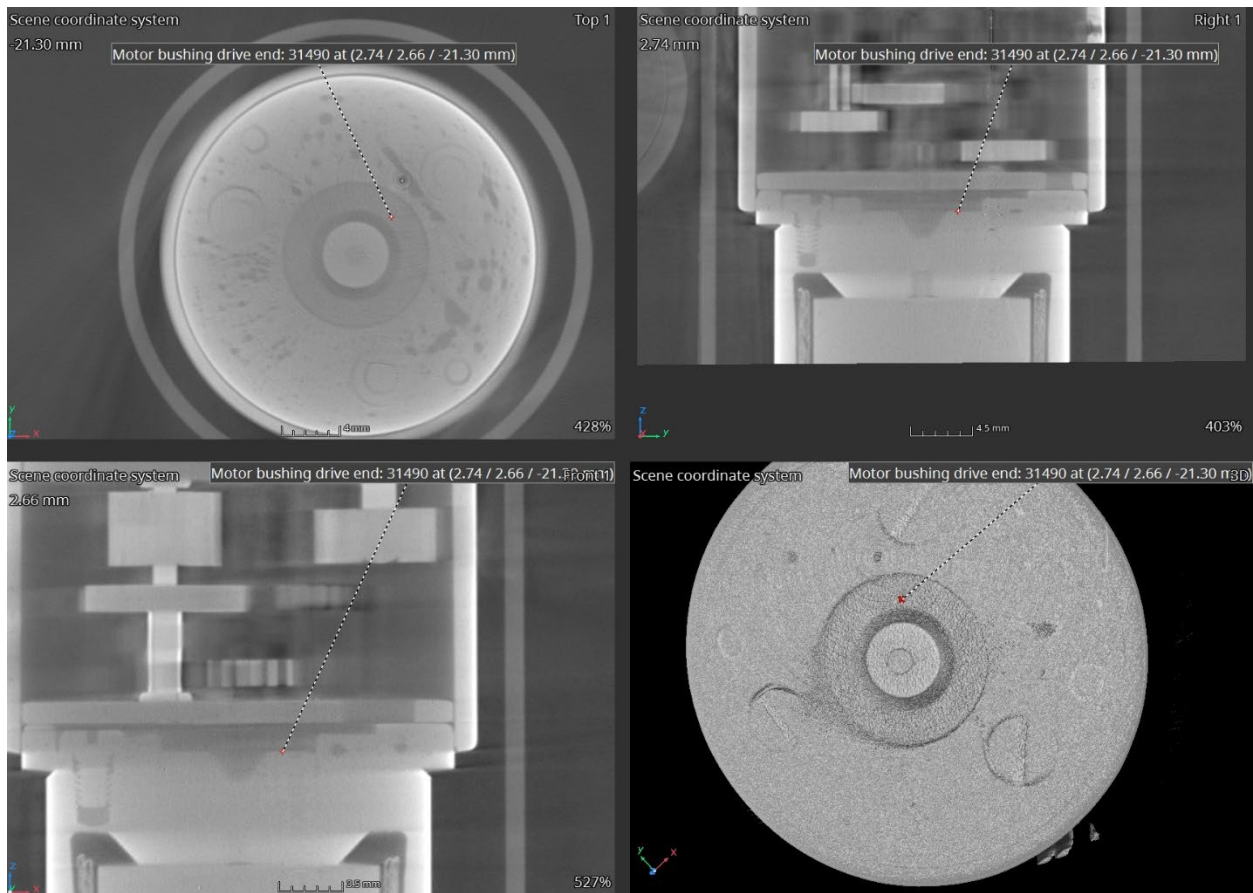


Figure 31. Fuel shut-off valve - motor bushing drive end. (Microfocus 225 kV)

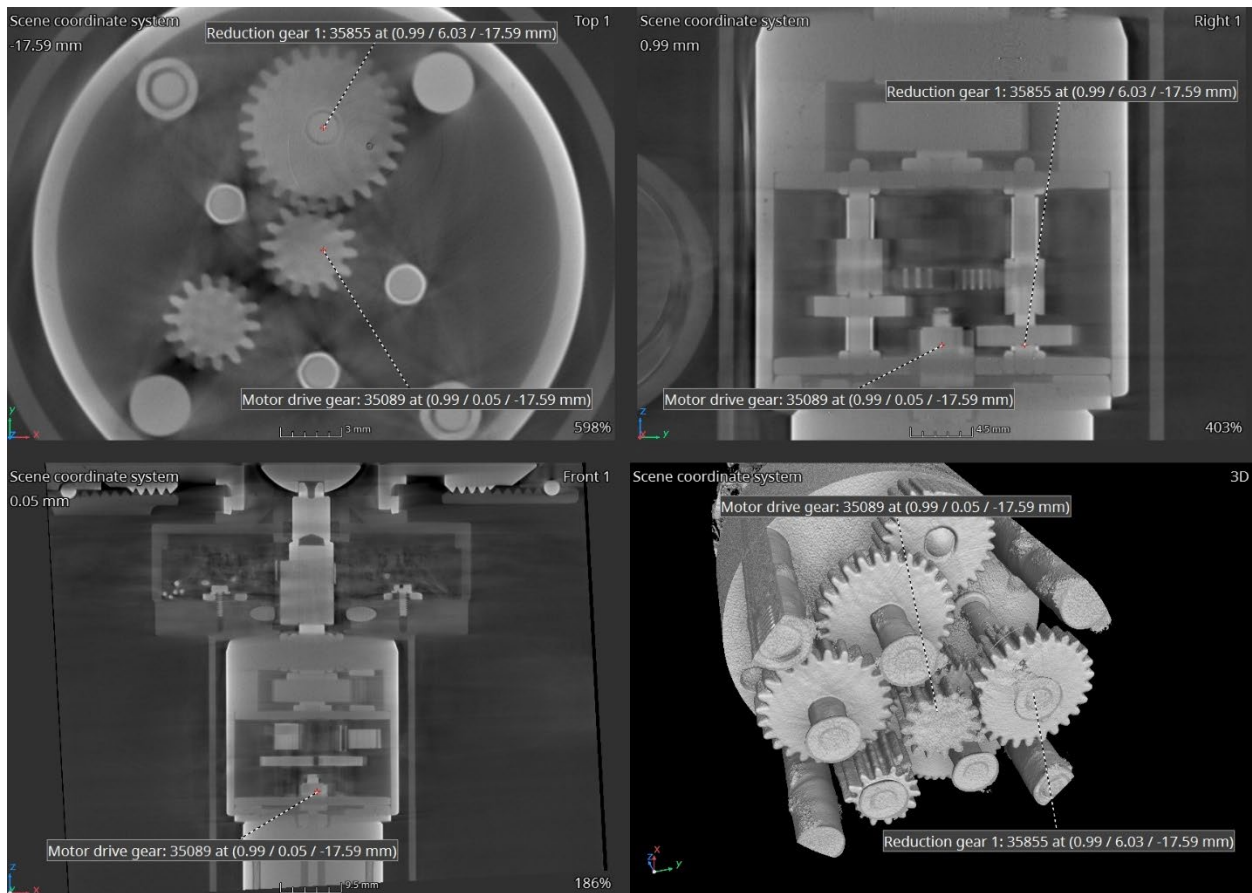


Figure 32. Fuel shut-off valve - motor drive gear and reduction gear 1. (Microfocus 225 kV)

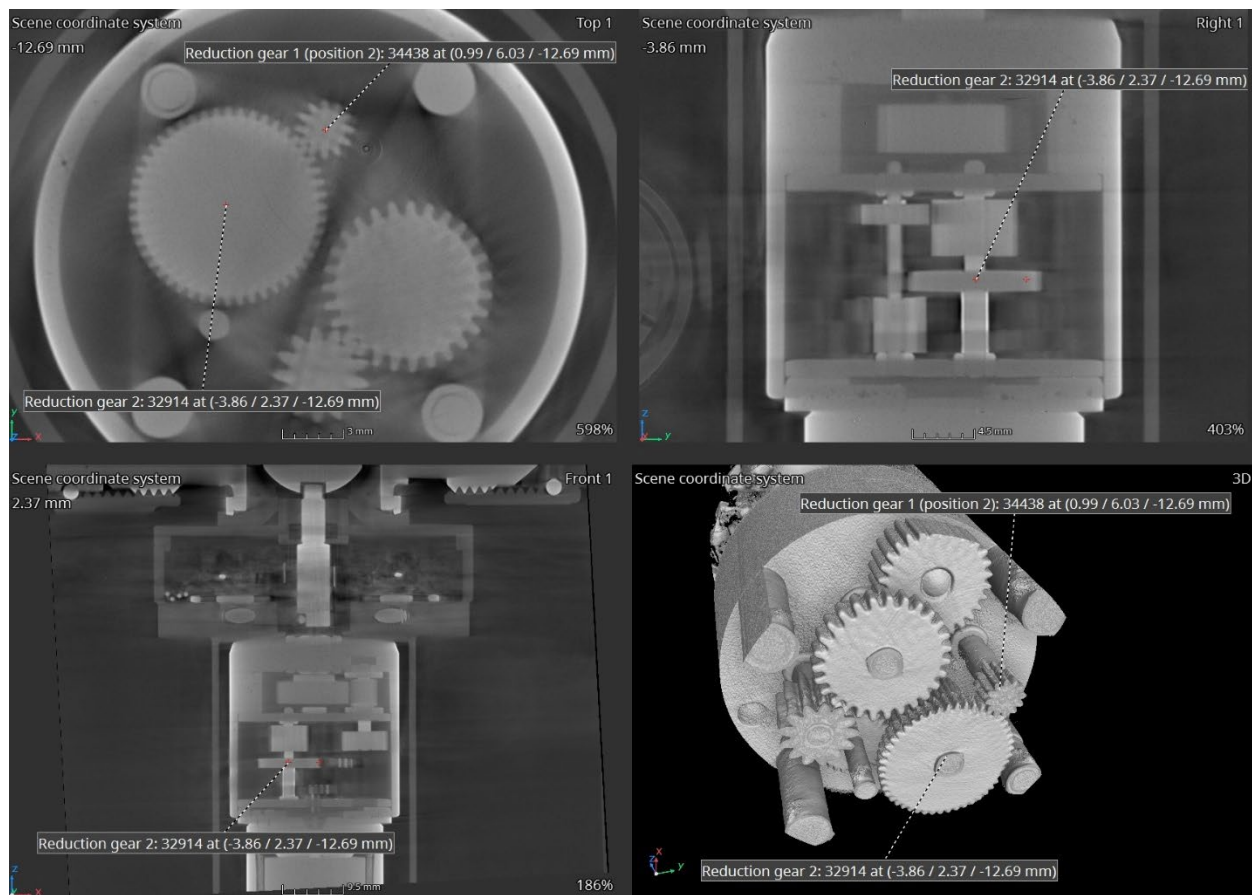


Figure 33. Fuel shut-off valve - reduction gears 1 and 2. (Microfocus 225 kV)

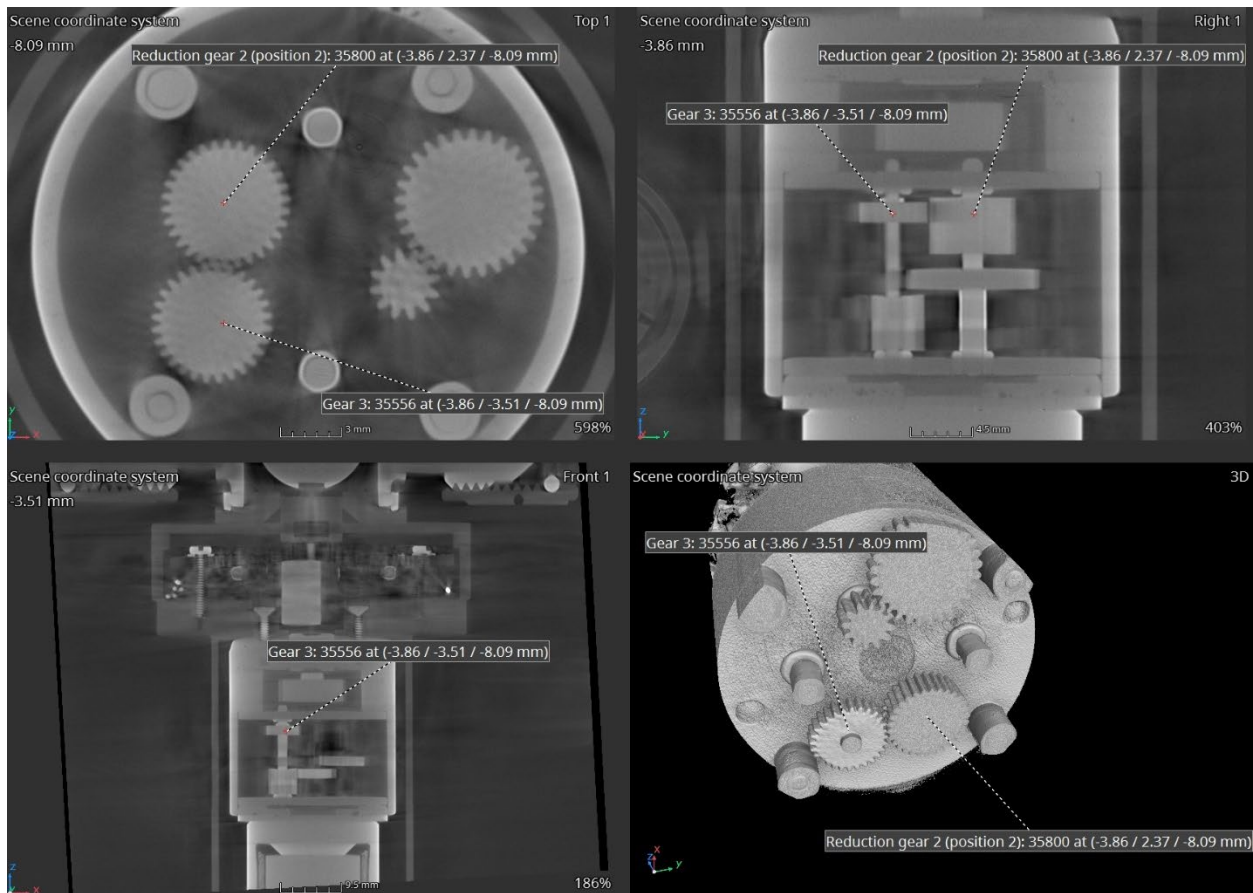


Figure 34. Fuel shut-off valve – reduction gear 2 and gear 3. (Microfocus 225 kV)

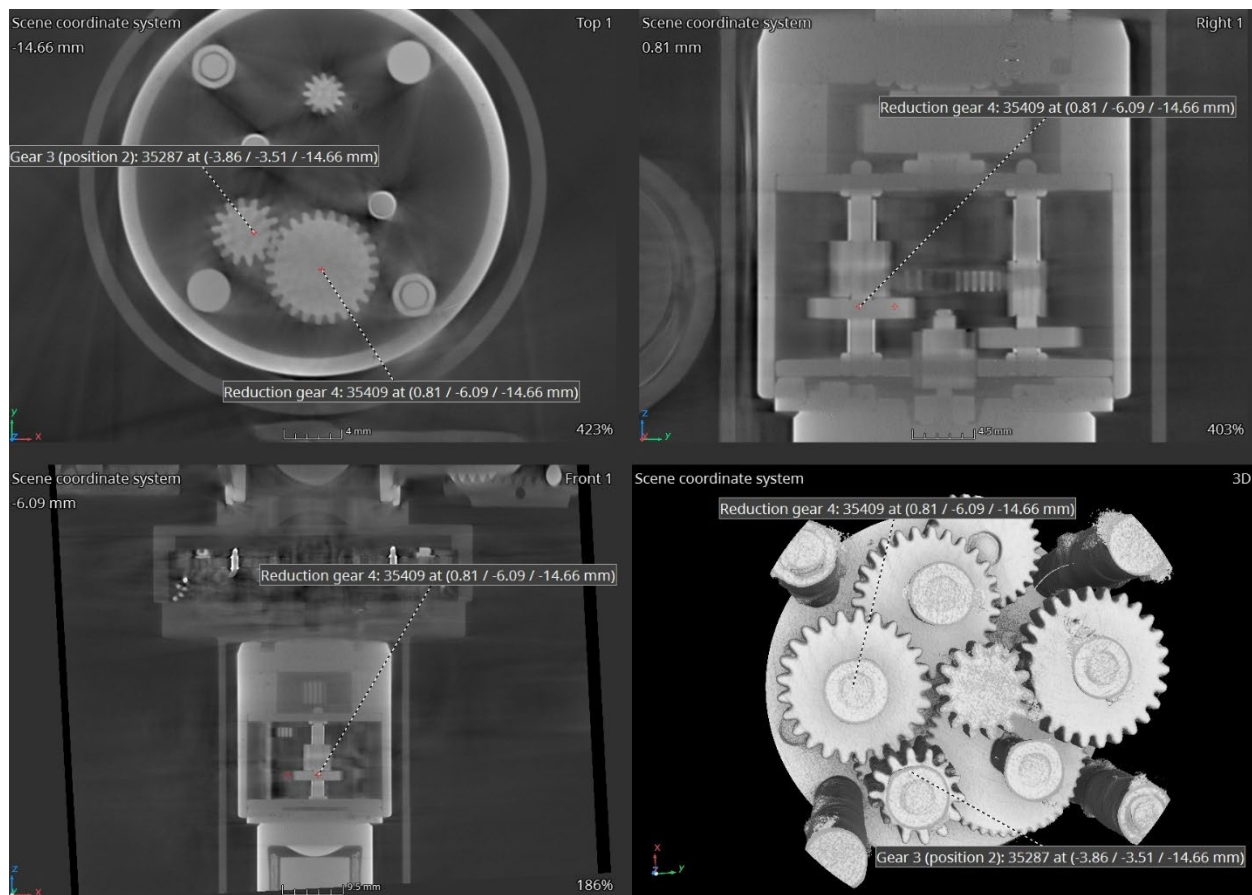


Figure 35. Fuel shut-off valve – gear 3 and reduction gear 4. (Microfocus 225 kV)

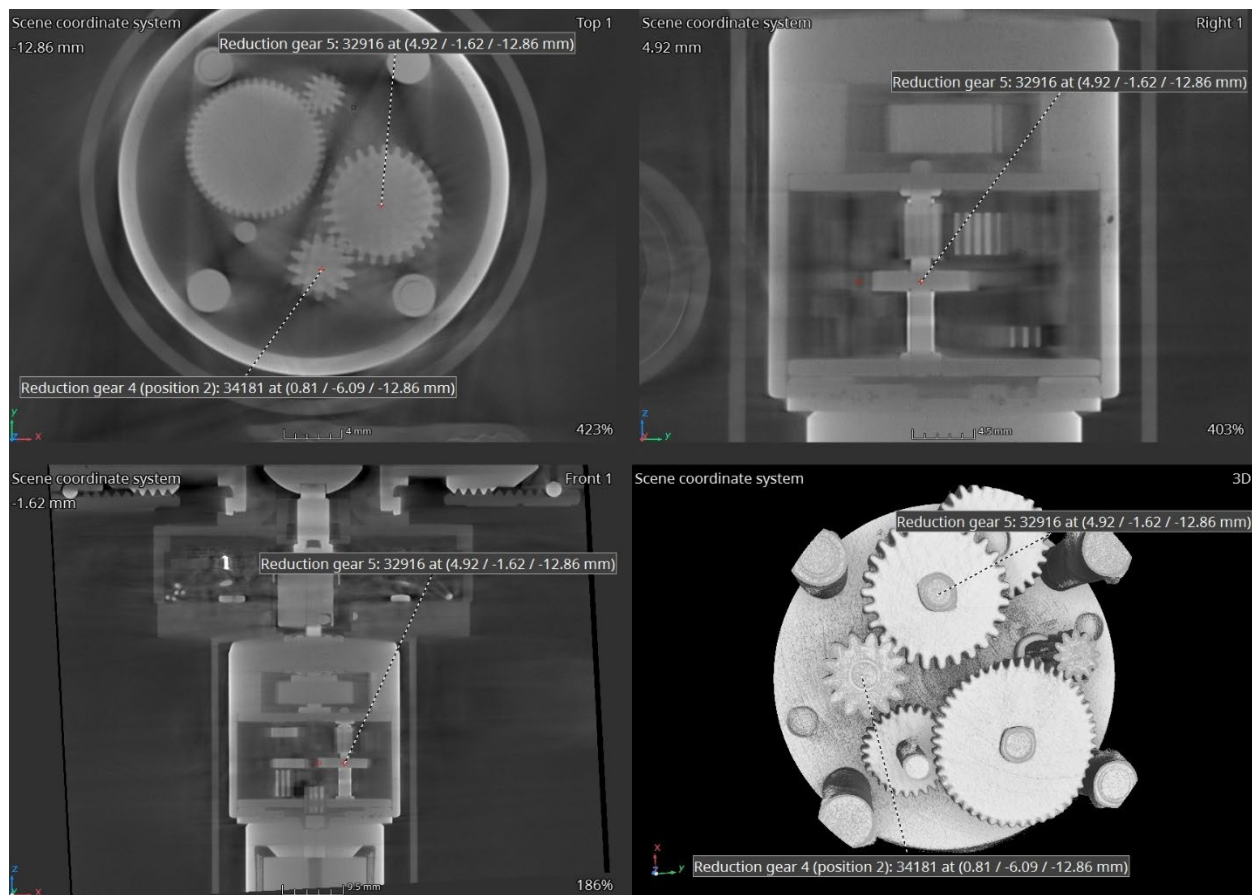


Figure 36. Fuel shut-off valve – reduction gears 4 and 5. (Microfocus 225 kV)

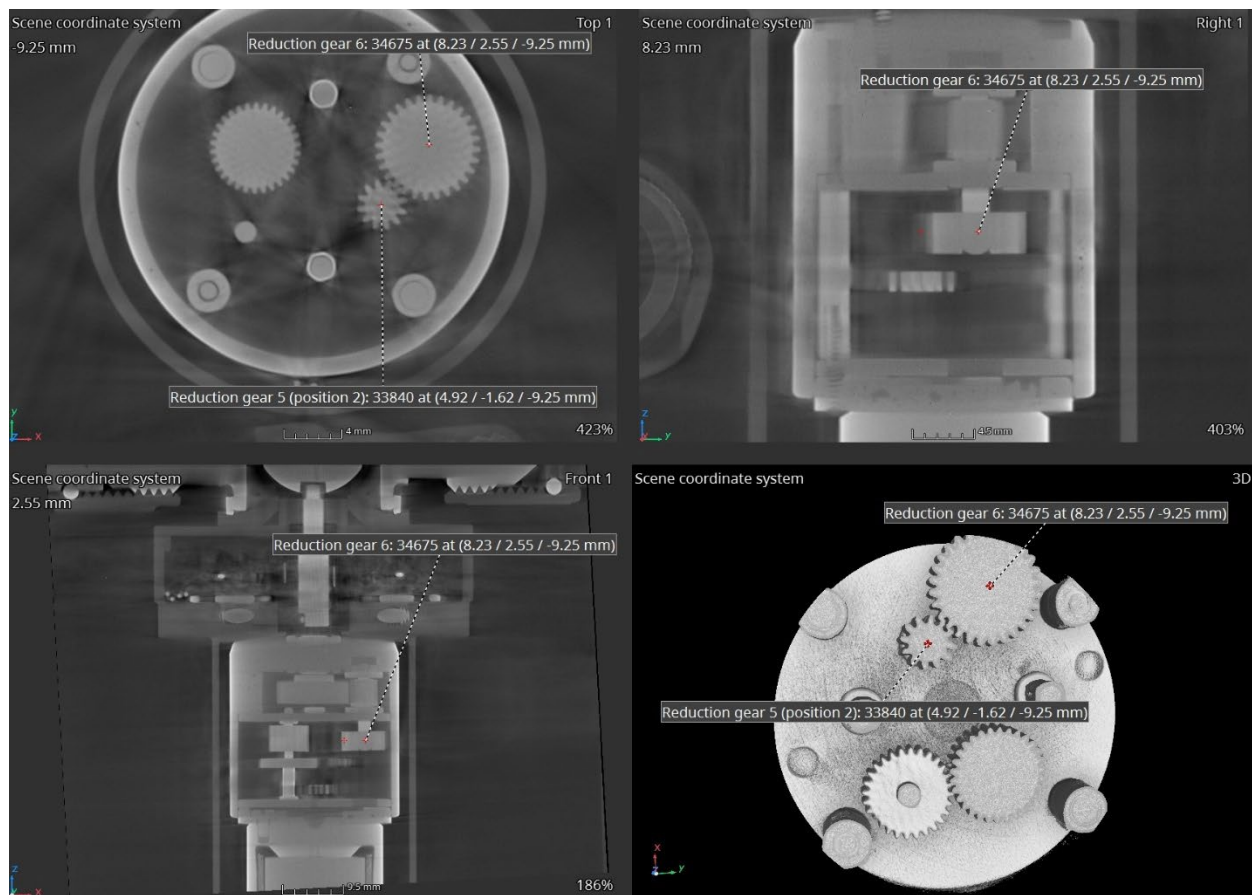


Figure 37. Fuel shut-off valve - reduction gears 5 and 6. (Microfocus 225 kV)

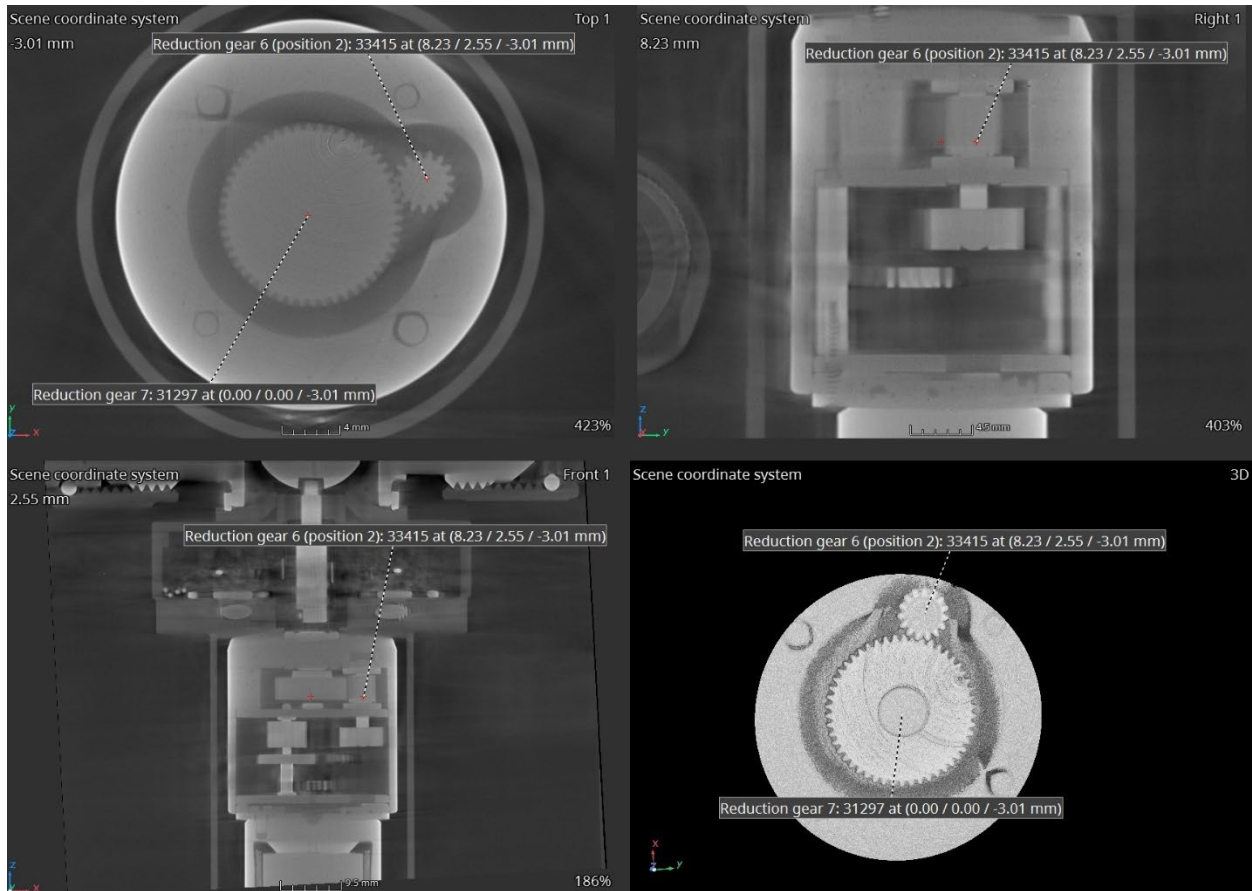


Figure 38. Fuel shut-off valve – reduction gears 6 and 7. (Microfocus 225 kV)

Submitted by:

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