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

May 12, 2014

# Computed Tomography and Aircraft Systems Specialist's Factual Report

CEN-14-LA-127

## A. ACCIDENT

| | |
|---|---|
| Operator: | Mountain Aviation, Inc |
| Location: | Abraham Lincoln Capital Airport (SPI), Springfield, Illinois |
| Date: | January 31, 2014 |
| Time: | 1312 central standard time |
| Airplane: | Piaggio model P180, N700FE |

## B. GROUP

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

## C. SUMMARY

On January 31, 2014, at 1312 central standard time, a Piaggio model P180 airplane, N700FE, was substantially damaged when the landing gear collapsed during landing roll at Abraham Lincoln Capital Airport (SPI), Springfield, Illinois. The pilot, copilot, and 3 passengers were not injured. The airplane was registered to Peregrine Falcon, Inc. and operated by Mountain Aviation, Inc., under the provisions of 14 Code of Federal Regulations Part 91, while on an instrument flight rules flight plan. Day instrument meteorological conditions prevailed for the cross-country business flight, which departed Dane County Regional Airport (MSN), Madison, Wisconsin, at 1157.

The flight crew reported that before crossing the outer marker for the instrument approach to runway 4 they executed a missed approach because of an unsafe landing gear position indication. The flight crew successfully extended the landing gear after completing the emergency landing gear extension procedure. One of the steps of the emergency extension procedure was to select the hydraulic system to OFF. The landing gear was then hand-pumped into the down-and-locked position. Before landing, the flight crew reengaged the hydraulic system in an attempt to utilize power braking and nose-gear steering during the landing on a snow-covered runway. However, the pilot flying reported that during landing the wheel brakes were less effective than normal and the nose wheel steering was not functioning. He stated that the landing gear retracted without warning as the airplane approached normal taxi speed near the taxiway foxtrot turnoff.

Radiographic studies were done from February 14-28, 2014 in Chicago, Illinois to examine and document the internal configuration of the directional control valve (DCV), the emergency landing gear selector valve (ELGSV), and the hydraulic pump package assembly. These components were documented using computed tomography (CT) scans and were imaged using a total of 7,480 CT slices.

Review of the images showed that there was a high density particle in the DCV between the spool and the housing. There were no other particles noted in the DCV, filter, ELGSV, or hydraulic pump package. In addition, there were no damaged areas noted within these components.

A review of the hydraulic schematics was conducted and compared to the CT imaging results. The review documented the designed hydraulic flow paths in the hydraulic pump package.

## D. DETAILS OF THE INVESTIGATION

### 1.0 General

The directional control valve (DCV), the emergency landing gear selector valve (ELGSV), and the hydraulic pump package assembly were subjected to x-ray computed tomography (CT) scanning to document their internal conditions. The

scanning was conducted from February 14-28, 2014. The scans were performed by Varian Medical Systems, Inc (formerly Bio-Imaging Research, Inc. (BIR)) under the direction of the NTSB using a combination of the Varian Actis 500/225 microfocus and Actis 500/450 standard focus CT systems.

For the CT scans, the components were loaded into the imaging unit and placed on a turntable. They 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 (microfocus) or fan beam (standard focus) 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 captured 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 7,480 slices. The total size of the combined data sets was 58.35 Gb. The complete scan protocol for each component is given in table 1.

Table 1
Scan Protocol

| Component | DCV | Hydraulic Pump Package Filter | ELGSV (closed) | ELGSV (open) | Hydraulic Pump Package |
|---|---|---|---|---|---|
| Number of slices | 1473 | 2229 | 1549 | 1558 | 671 |
| Voxel Size - X Direction (mm) | 0.054 | 0.054 | 0.054 | 0.054 | 0.144 |
| Voxel Size - Y Direction (mm) | 0.054 | 0.054 | 0.054 | 0.054 | 0.144 |
| Voxel Size - Z Direction (mm) | 0.053 | 0.053 | 0.053 | 0.053 | 0.4 |
| Image Projections per Revolution | 2180 | 2180 | 2180 | 2180 | 1440 |
| Exposure time (ms) | 285.58 | 285.58 | 285.58 | 285.58 | 64 |
| Frames to Avg (frames per projection) | 2 | 2 | 2 | 2 | 1 |
| X-ray Source Voltage (kV) | 223 | 223 | 223 | 225 | 450 |
| X-ray Source Current (mA) | 0.6 | 0.6 | 0.6 | 0.6 | 2 |
| Source Filter Material | Brass | Brass | Brass | Brass | Brass |
| Source Filter Thickness (mm) | 1 | 1 | 1 | 1 | 2 |
| Image Matrix Size (pixels) | 2048 x 2048 | 2048 x 2048 | 2048 x 2048 | 2048 x 2048 | 2048 x 2048 |

Each data set of slice images was evaluated using the VGStudioMax software package to create a three-dimensional reconstructed image of the component. As part of the evaluation, some sections of the components were digitally removed to allow closer observation of interior parts. In the images, the high density areas are shown as brighter shades of gray and lower density areas are shown as darker shades of gray. The pointers shown in some of the images denote specific areas of interest within that 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

### 2.1 Directional Control Valve

The computed tomography (CT) results for the DCV are shown in figures 1 through 11. Review of the images showed that there was a particle located between one of the spool lands and the DCV housing. The particle was approximately 3 mm long.

A review of the hydraulic system schematics was conducted, and the hydraulic ports associated with the DCV were identified. The ports are labeled in figures 8-11. The review indicated that the position of the DCV spool was consistent with a position where the pressure port would be connected to the C1 port.

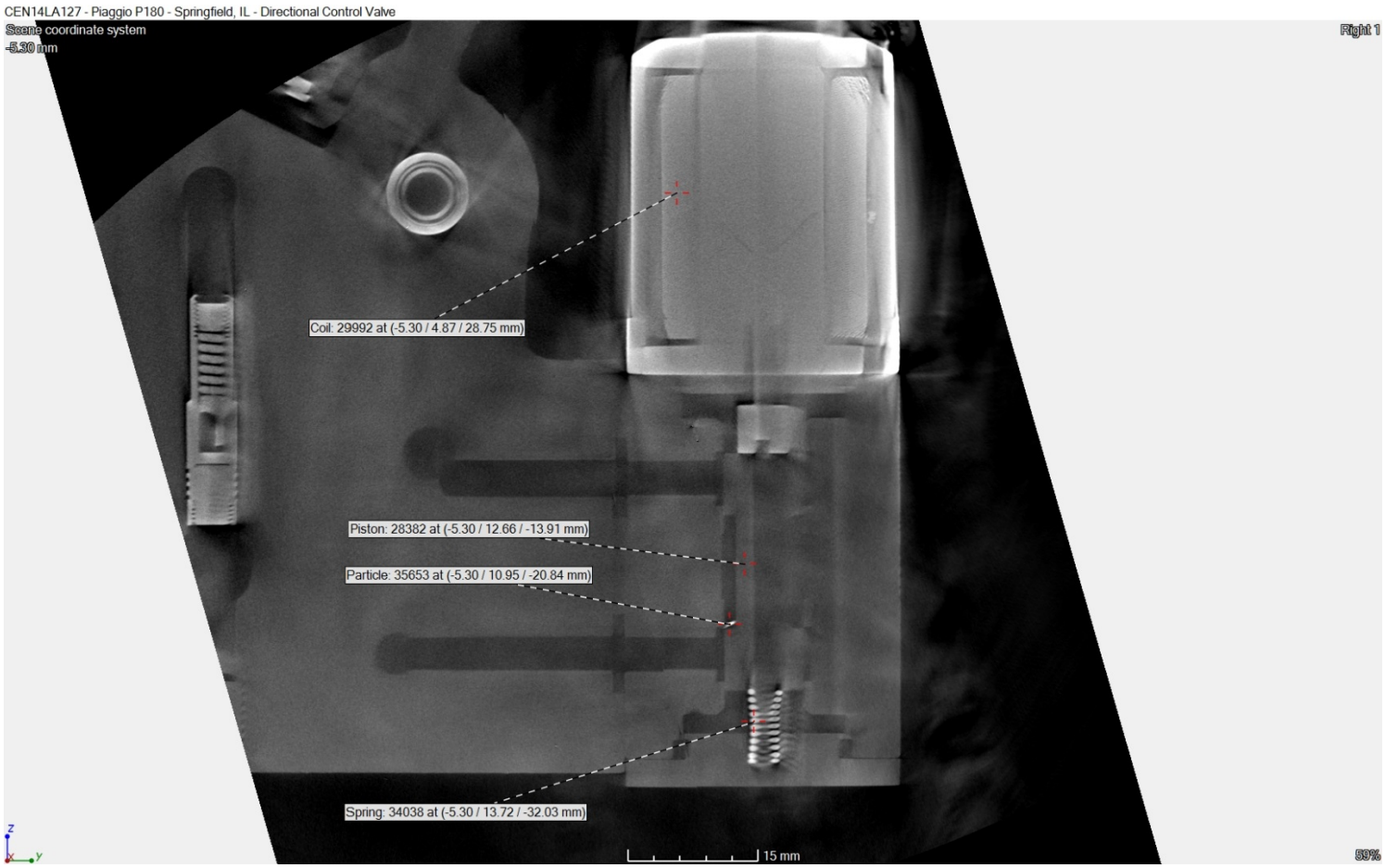


Figure 1
DCV – Overall view

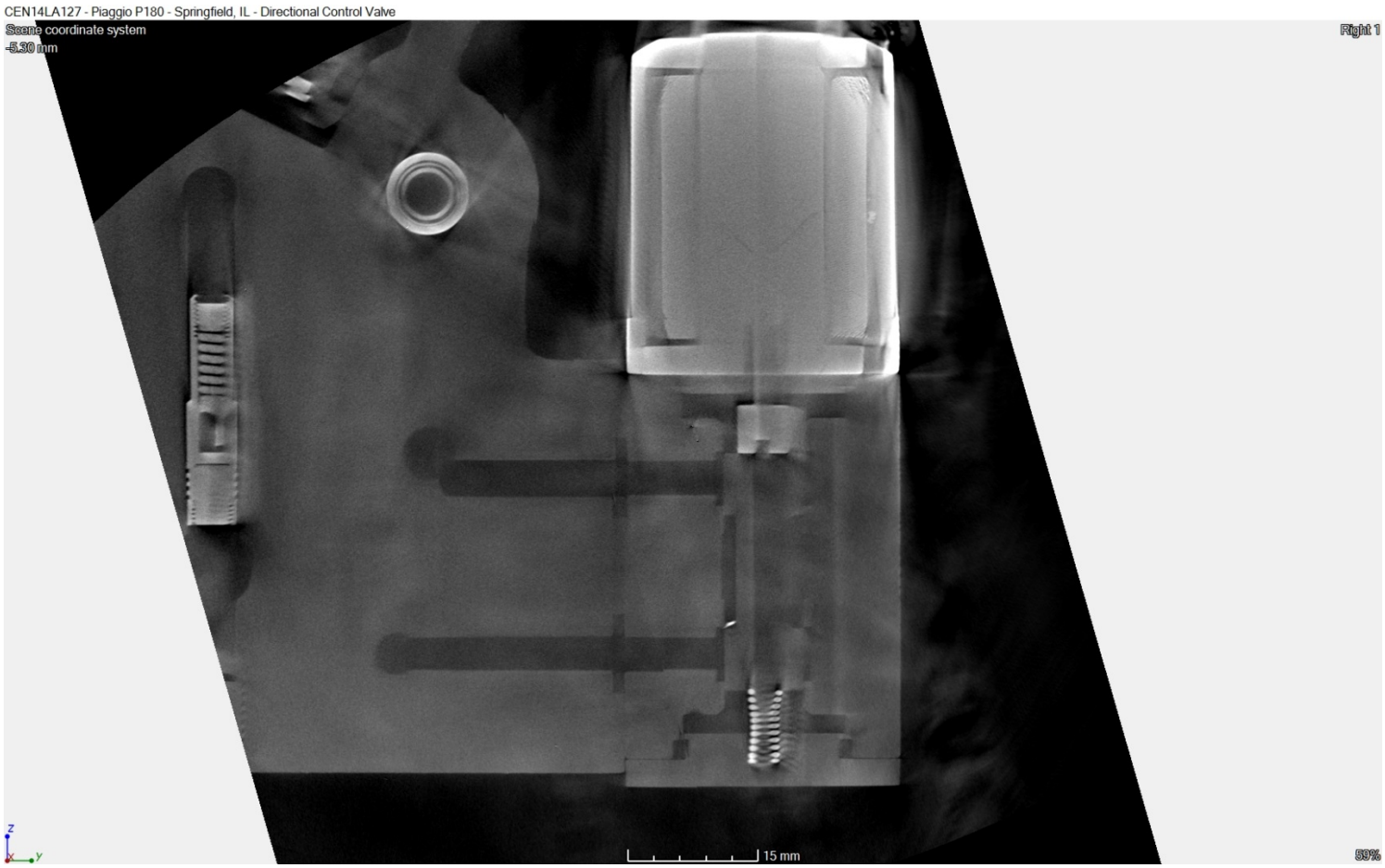


Figure 2
DCV – Overall view (without indicators)

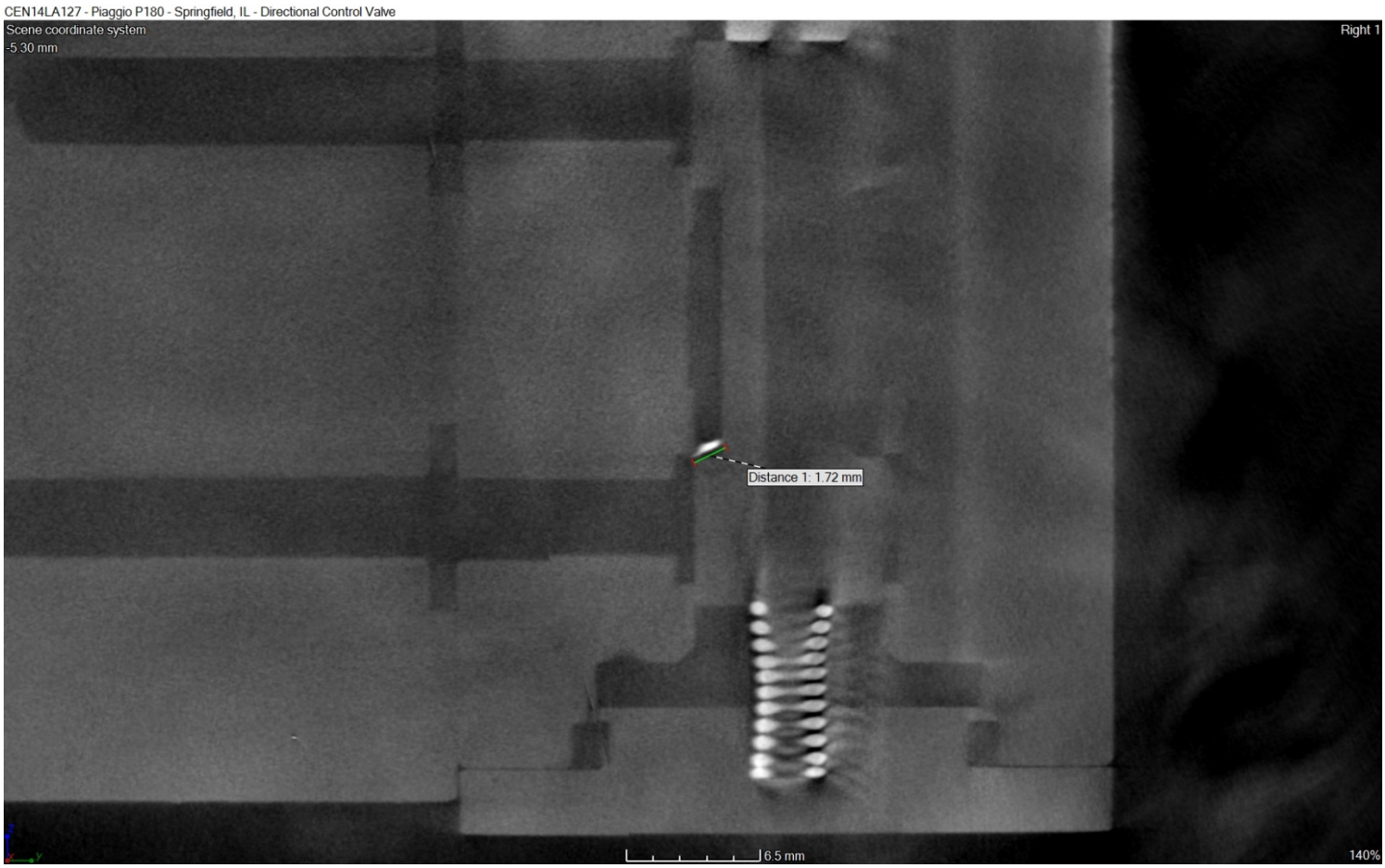


Figure 3
DCV – Particle between DCV spool land and housing

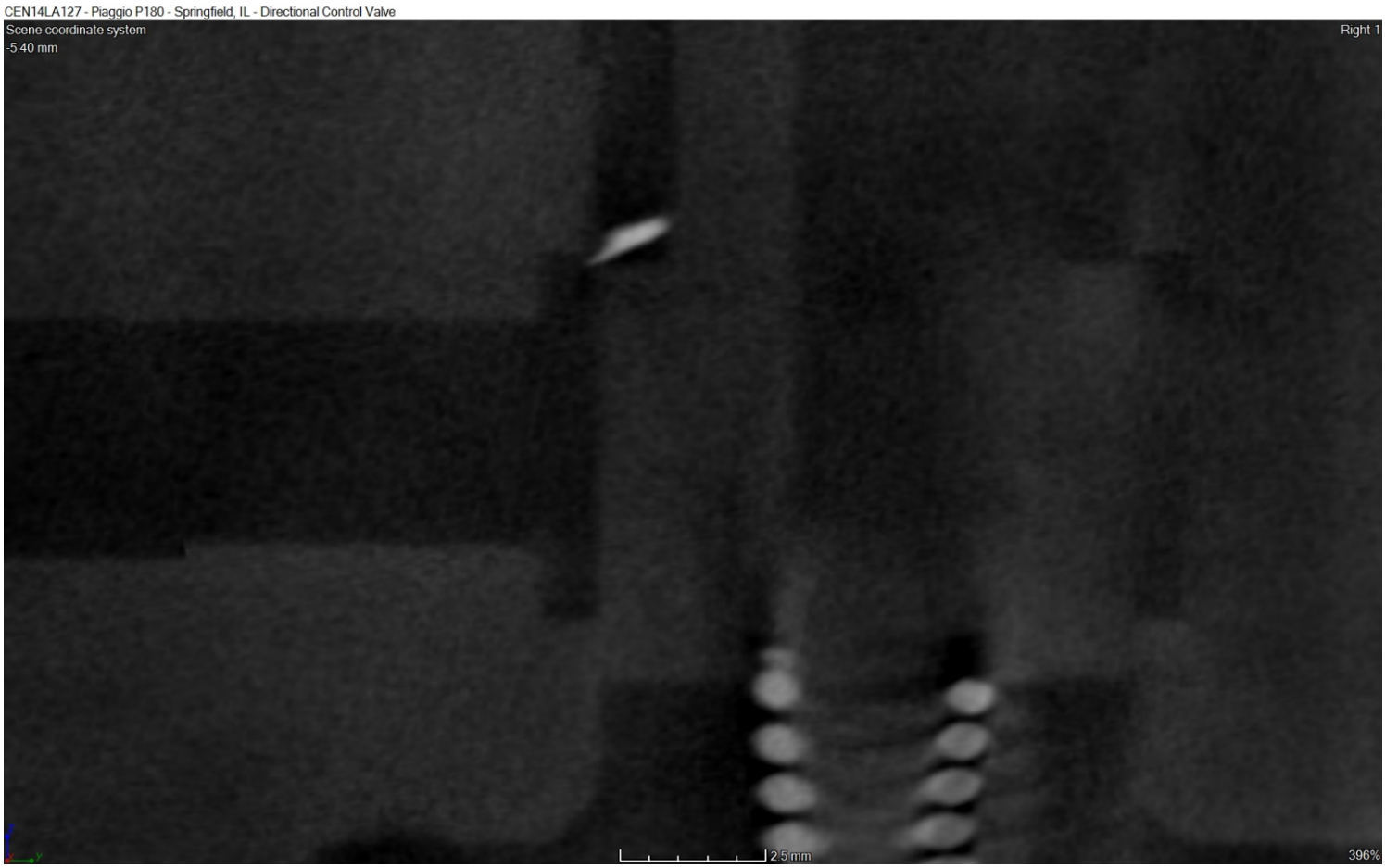


Figure 4
DCV – Particle between DCV spool land and housing (close up)

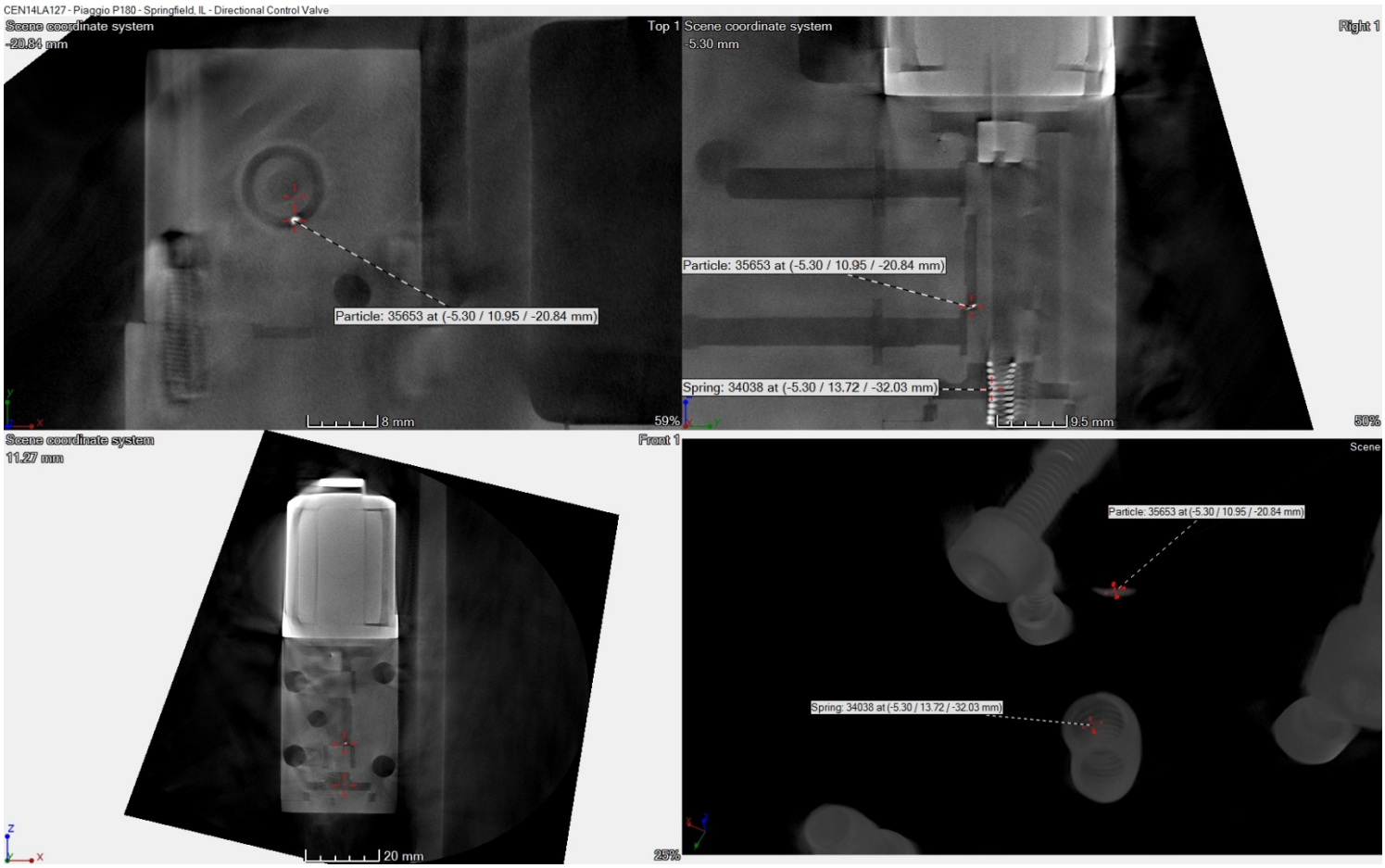


Figure 5
DCV – Particle between DCV spool land and housing oriented to show the maximum length of the particle

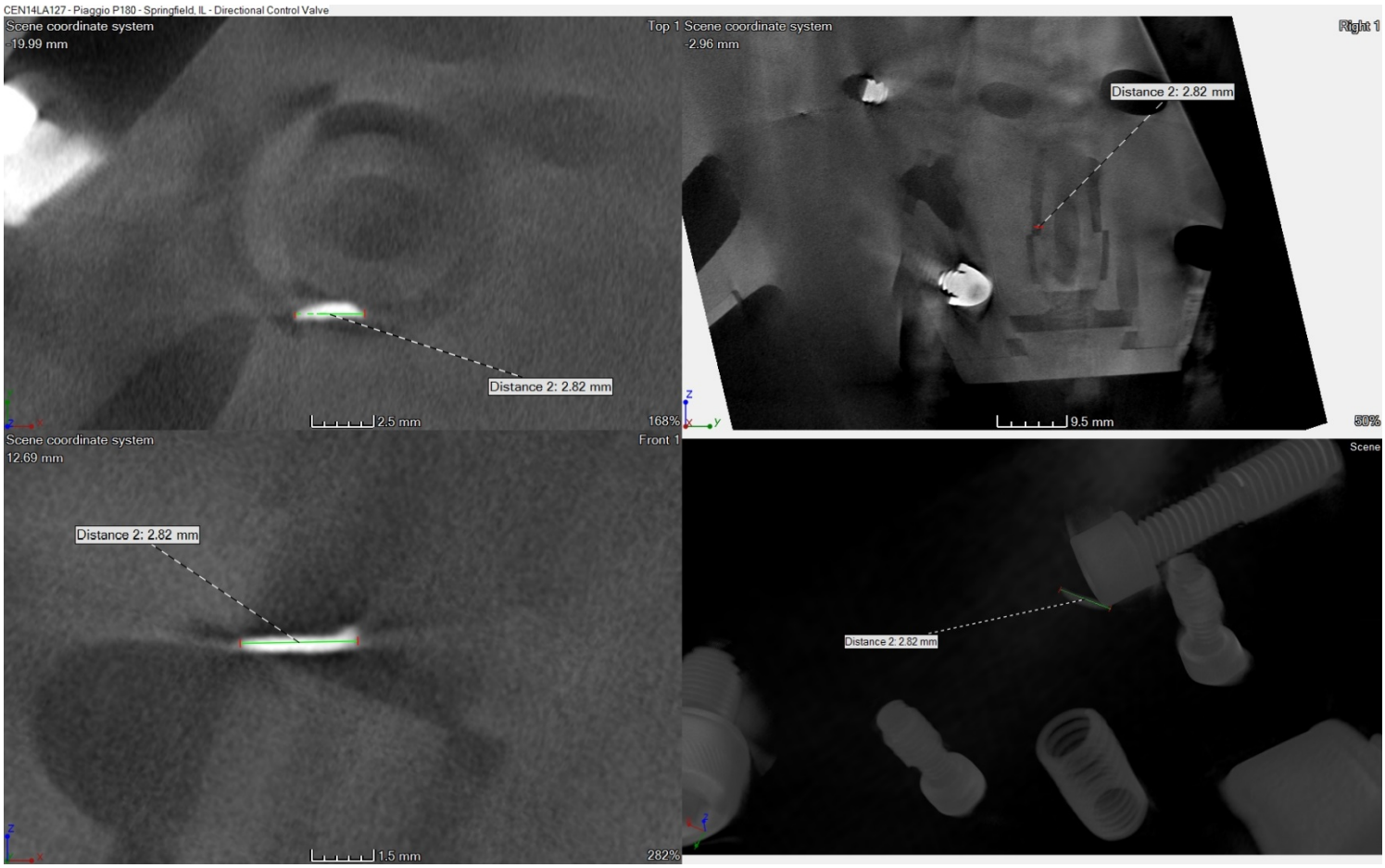


Figure 6
DCV – Particle between DCV spool land and housing oriented to show the maximum length of the particle (close up)

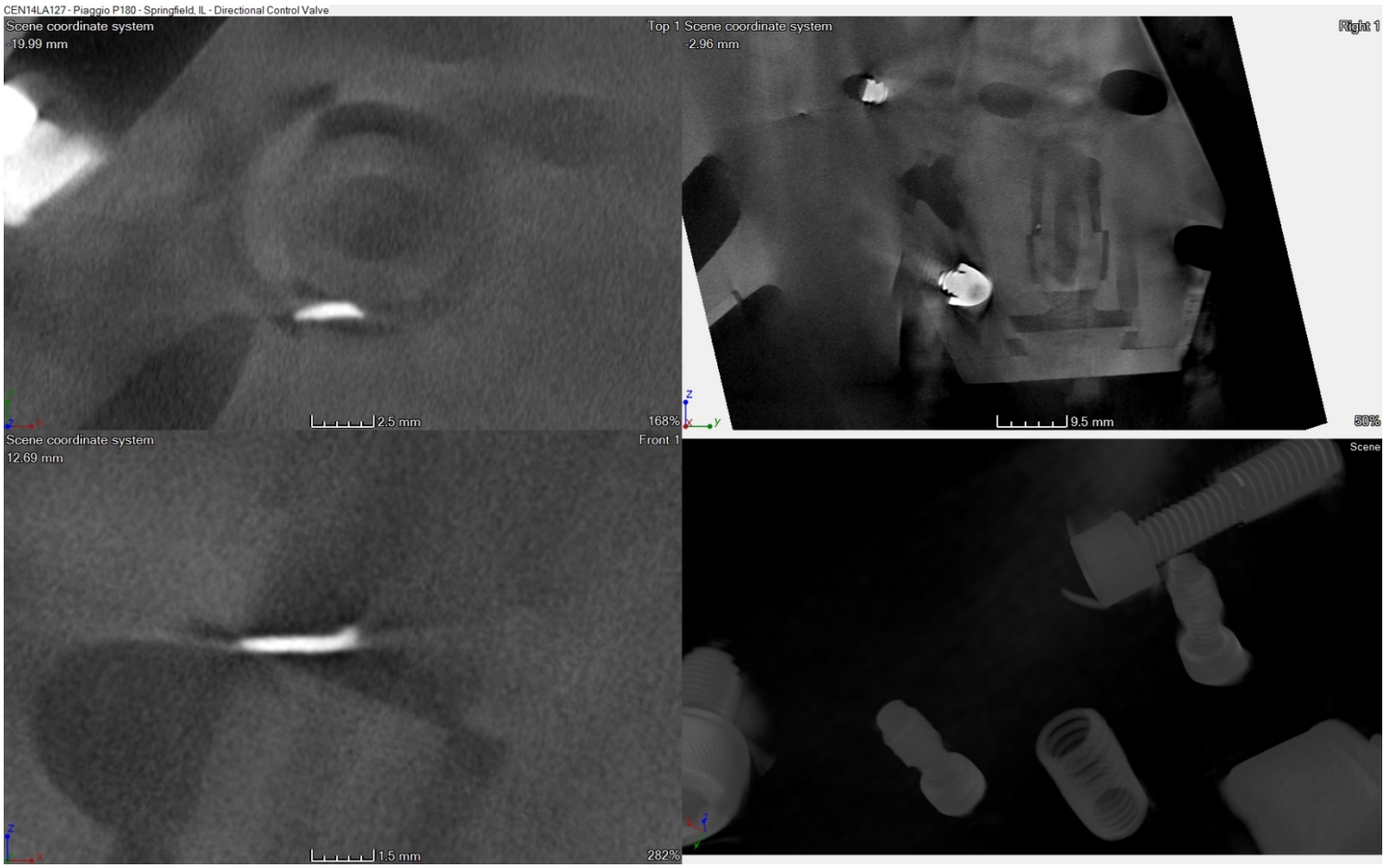


Figure 7
DCV – Particle between DCV spool land and housing oriented to show the maximum length of the particle (close up without indicators)

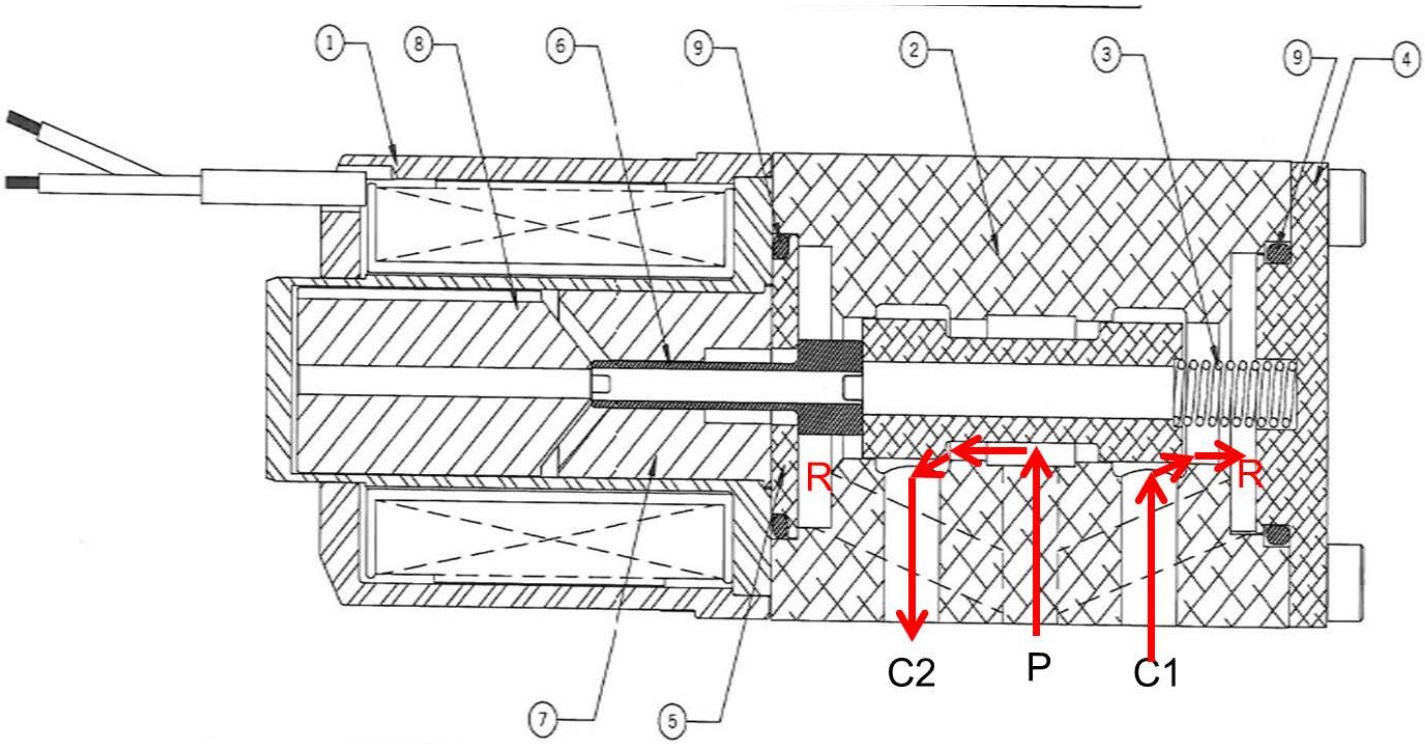


Figure 8
Assembly drawing of the DCV showing the pressure port (P), control ports (C1, C2), and return ports (R). The arrows indicate the designed flow paths through the DCV when the solenoid is in the de-energized (gear down) position.

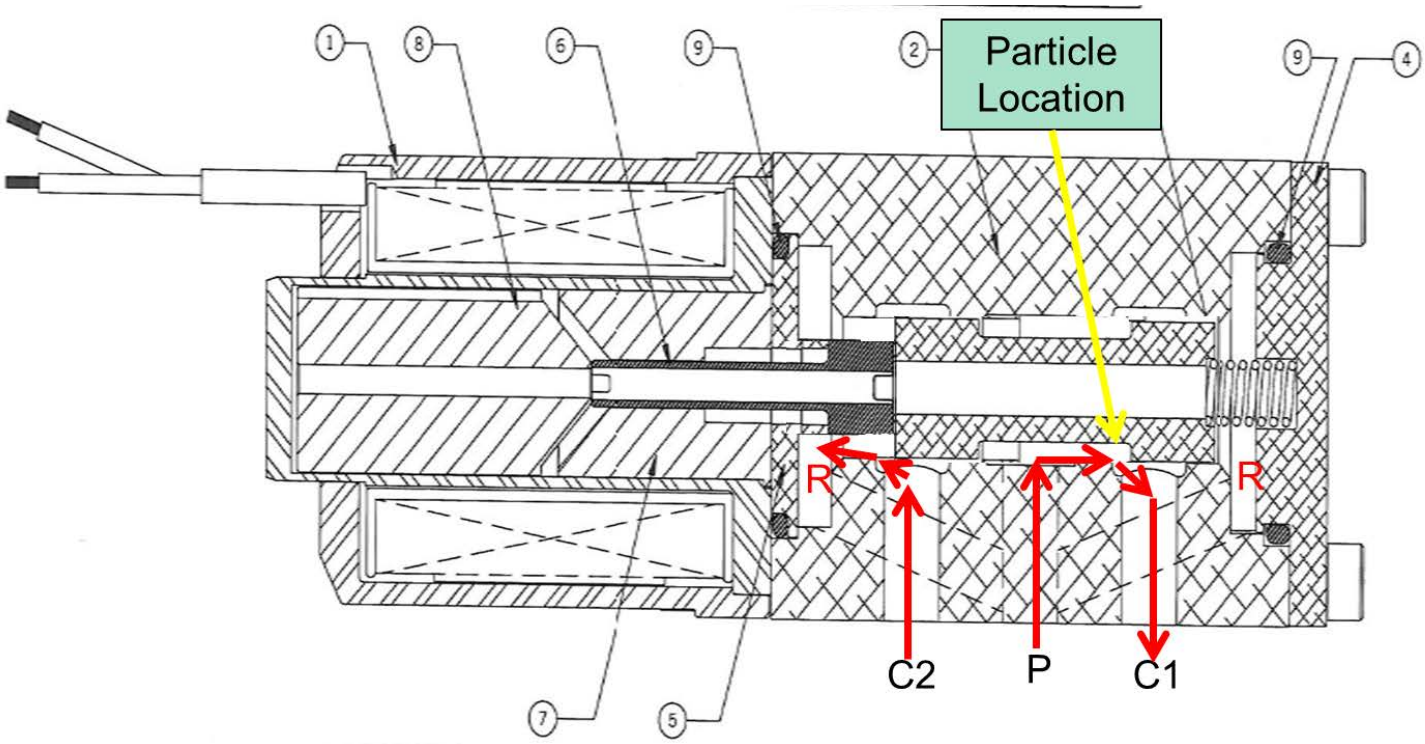


Figure 9
Assembly drawing of the DCV showing the pressure port (P), control ports (C1, C2), and return ports (R). The arrows indicate the designed flow paths through the DCV when the solenoid is in the energized (gear up) position.

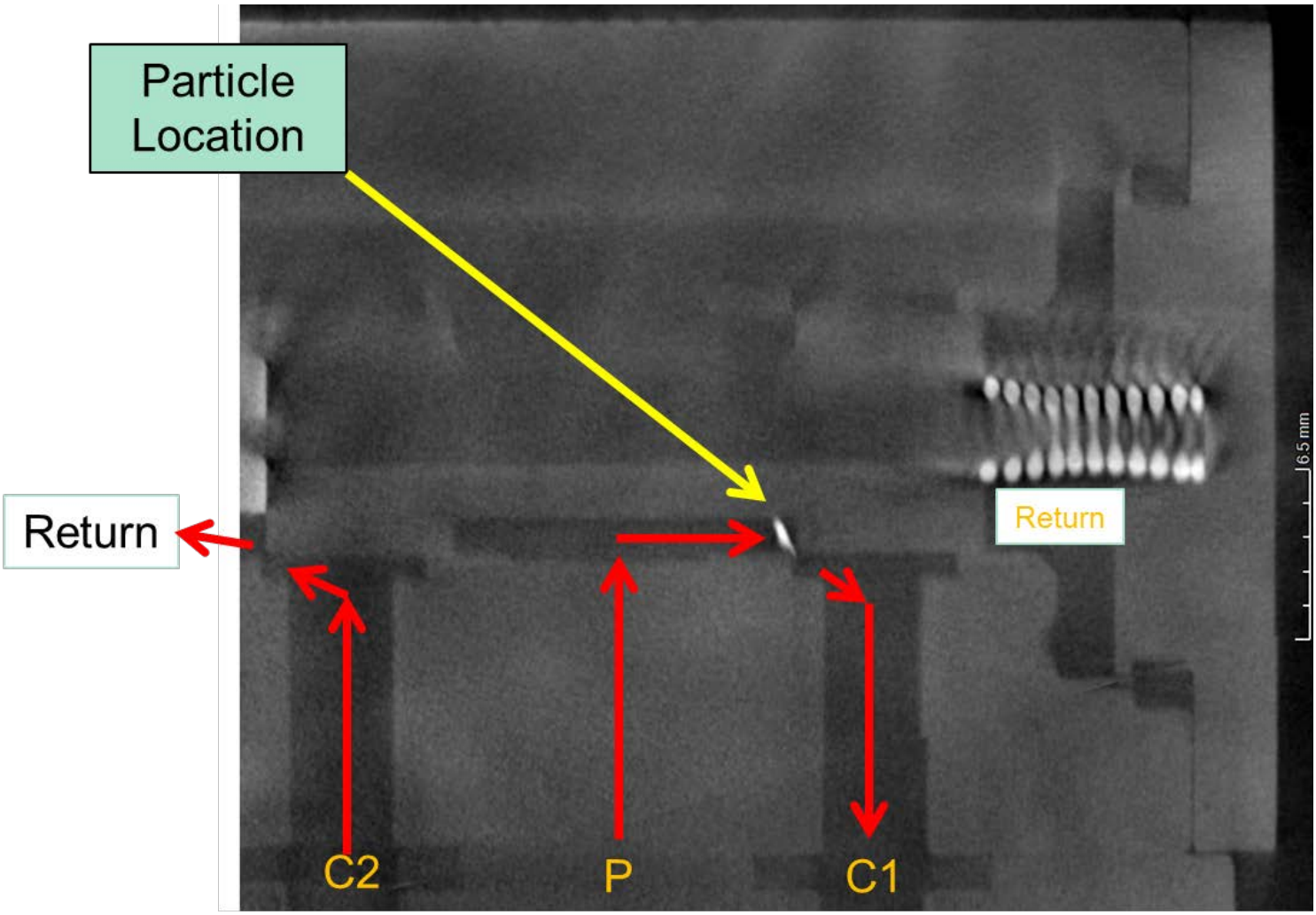


Figure 10
Close up CT image of the DCV showing the pressure port (P), control ports (C1, C2), and return ports (Return). The arrows indicate the designed flow paths through the DCV in the "as-imaged" condition.

Note: the pressure port (P) is not in the same plane as the other ports, so the actual port was not shown in this image. The "P" symbol and associated arrow show the location of the port in relation to the control ports.

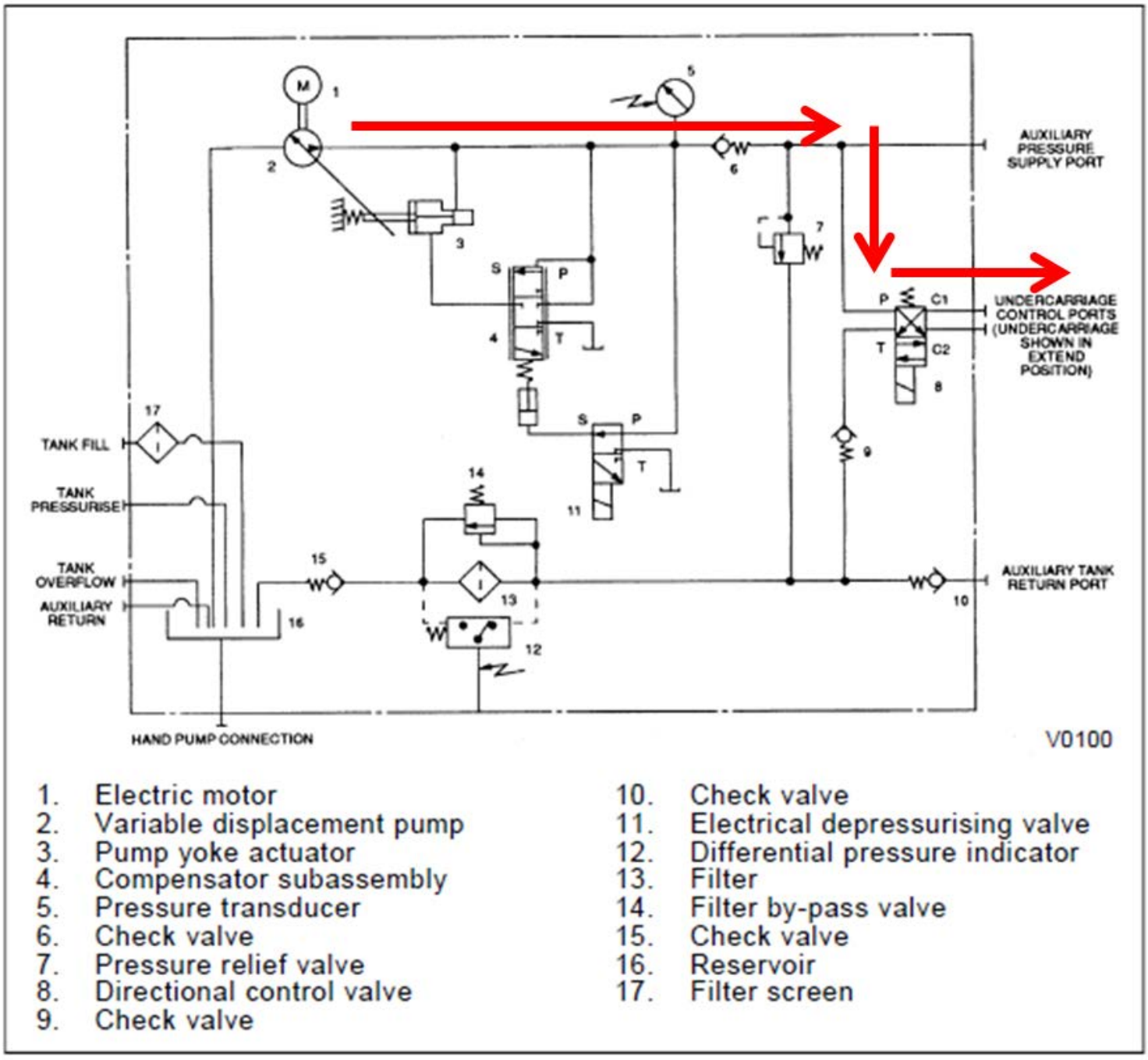


Figure 11
Hydraulic schematic of the hydraulic pump package showing the components within the unit including the DCV (8), the variable displacement pump (2), filter (13), and check valve (6). The arrows indicate the designed flow paths through the DCV when the solenoid is in the de-energized (gear down) position.

## 2.2 Hydraulic Pump Package Filter

The computed tomography (CT) results for the hydraulic pump package filter are shown in figures 12 and 13. Review of the images did not show any radiographic indications of high density particles in the filter.

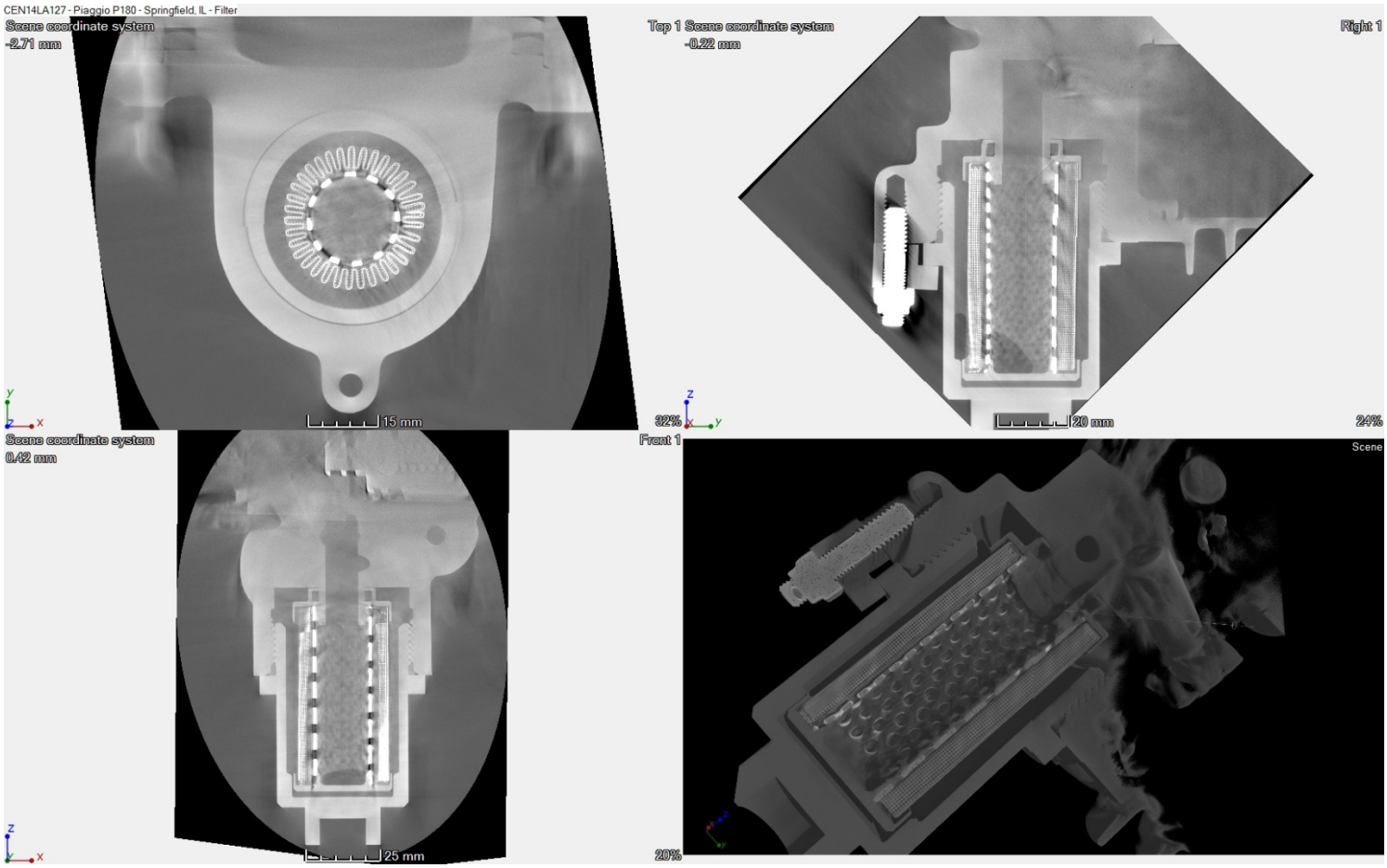


Figure 12
Hydraulic Pump Package Filter – Overall view

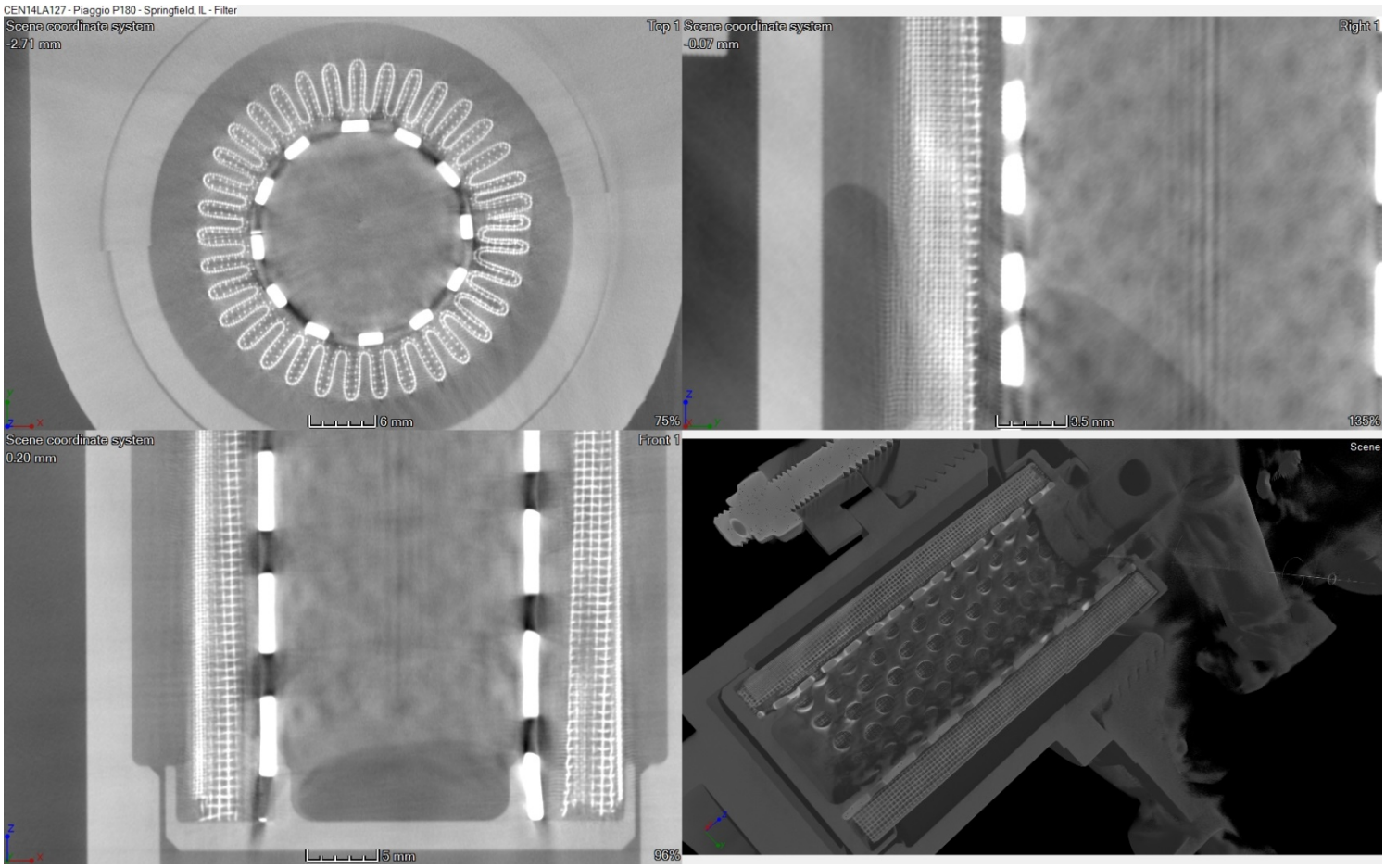


Figure 13
Hydraulic Pump Package Filter – Close up view showing multiple filter layers

## 2.3 Emergency Landing Gear Selector Valve

The computed tomography (CT) results for the ELGSV are shown in figures 14 through 18. Both the open and closed positions were imaged. Review of the images did not show any radiographic indications of high density particles in the valve, and the path for the valve spool did not appear to have any obstructions that would prevent the spool from moving to either the open or closed positions.

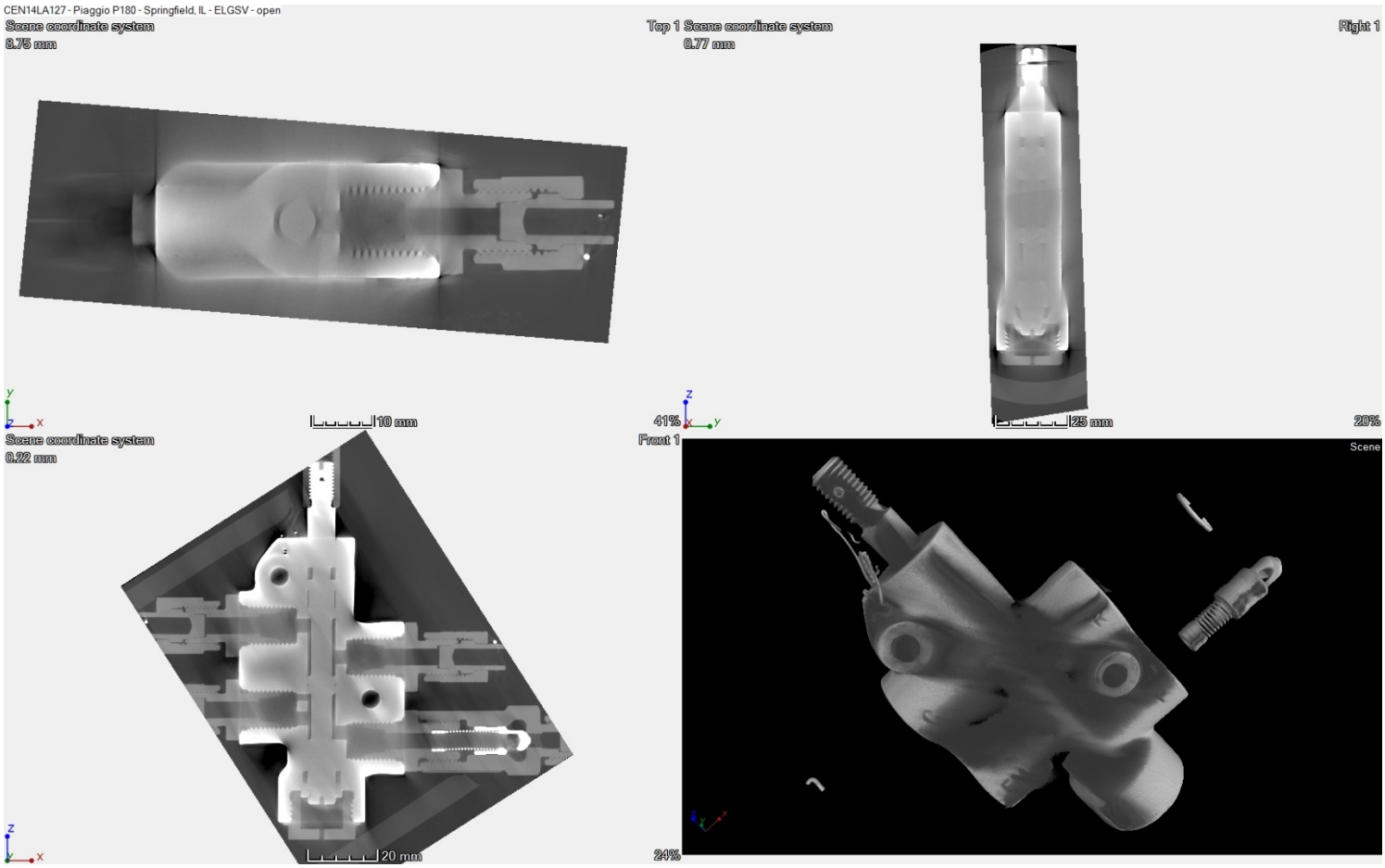


Figure 14
ELGSV – Open Position – Overall view

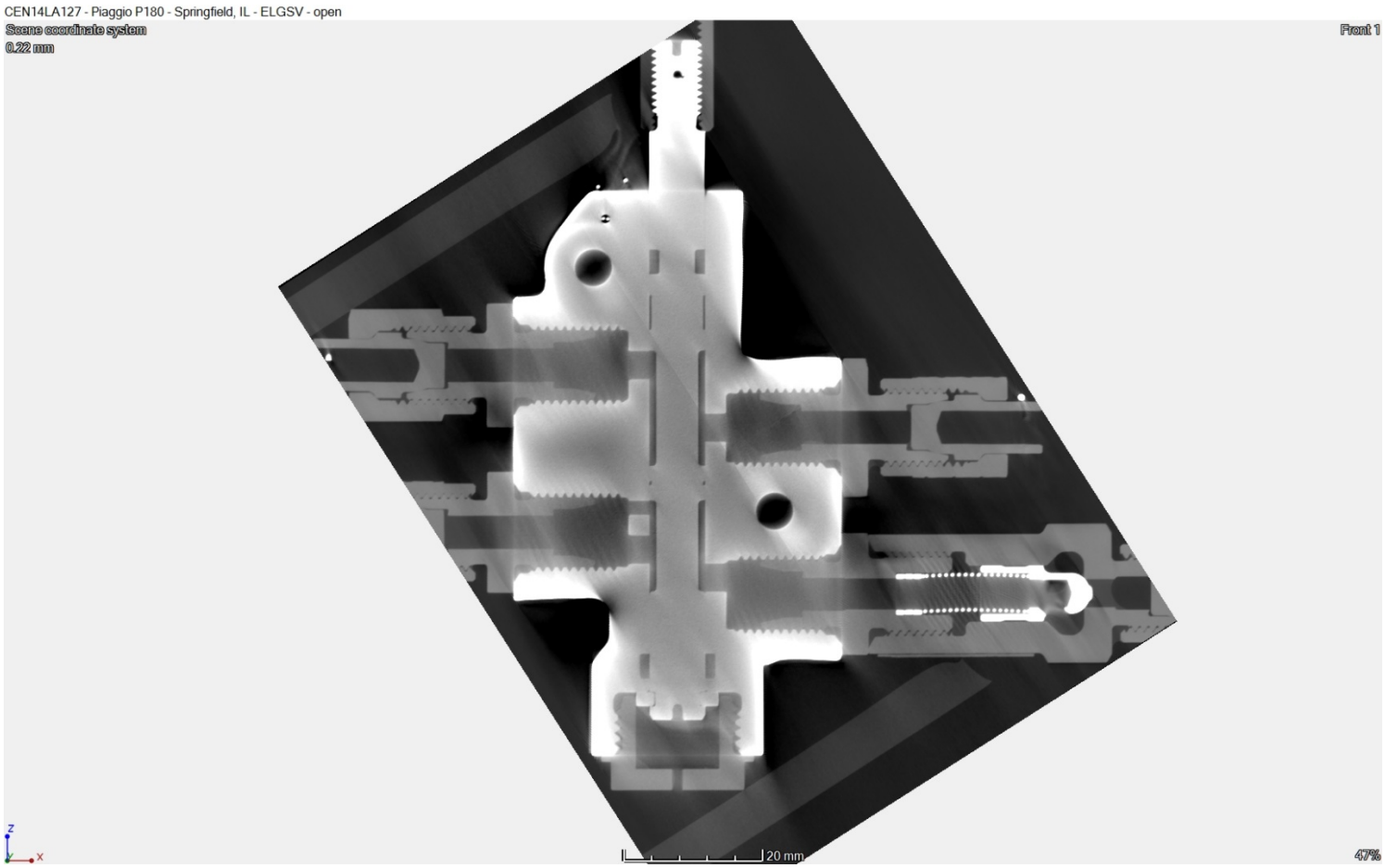


Figure 15
ELGSV – Open Position – Close up view

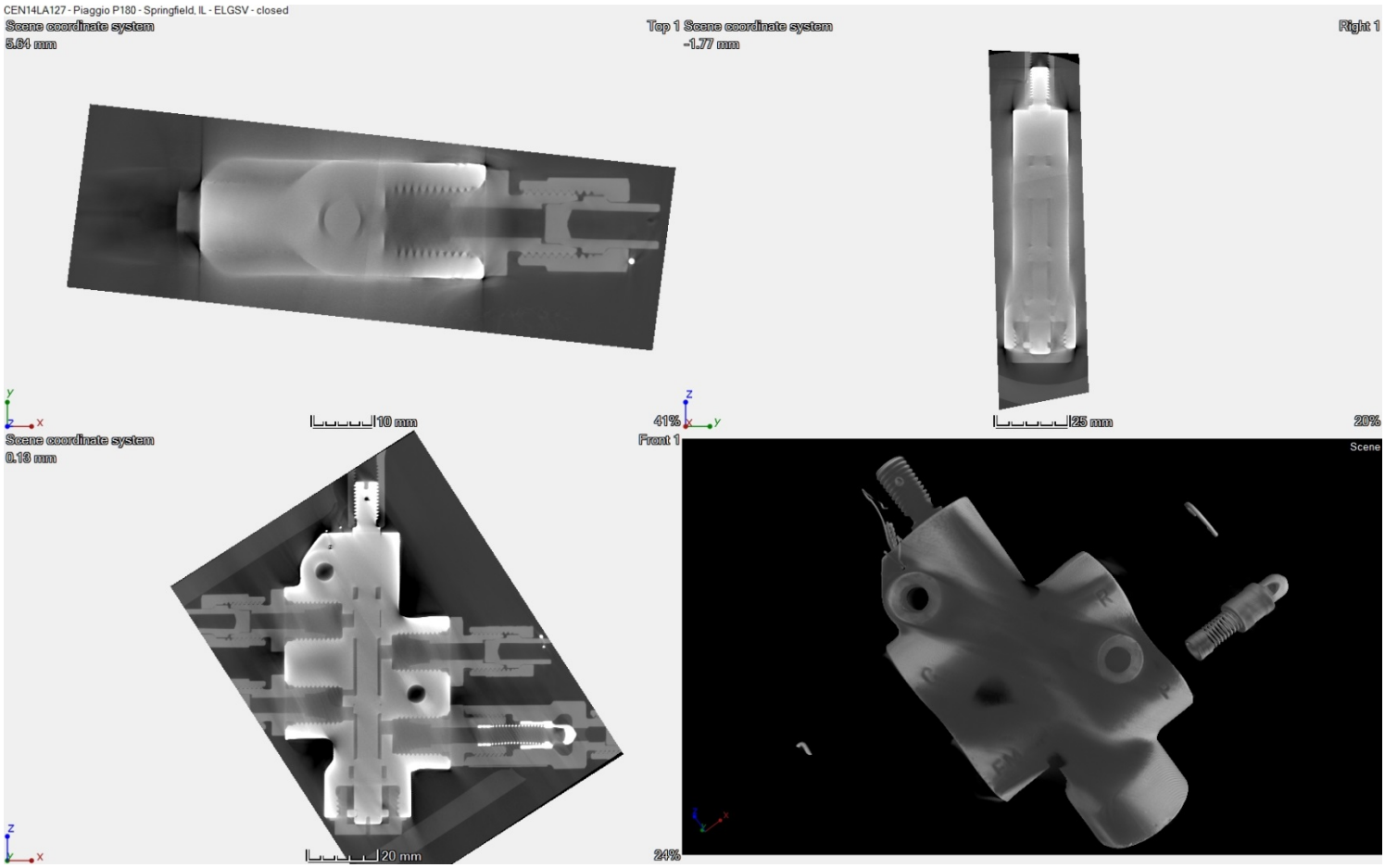


Figure 16
ELGSV – Closed Position – Overall view

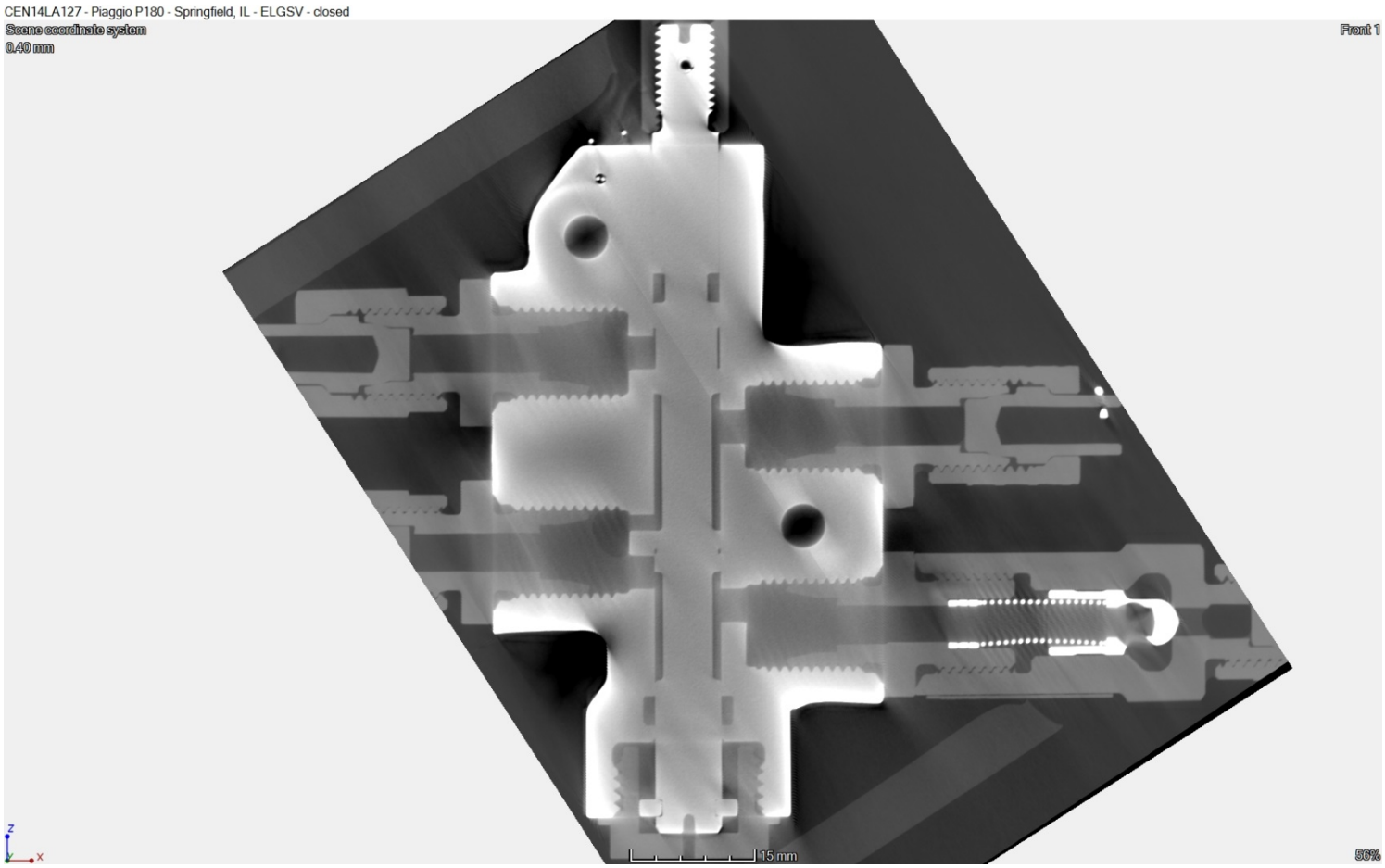


Figure 17
ELGSV – Closed Position – Close up view

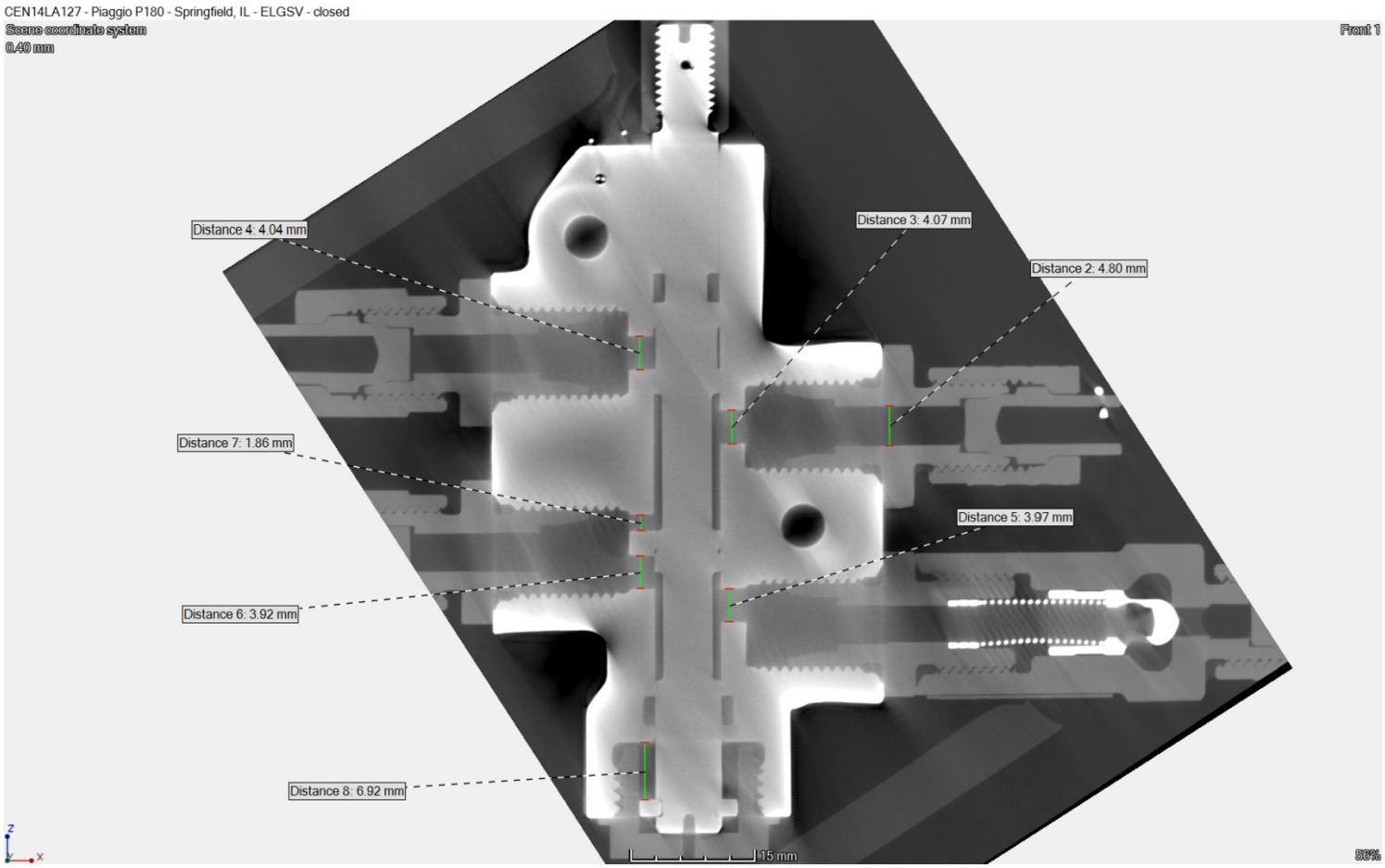


Figure 18
ELGSV – Closed Position – Close up view with port diameters noted

## 2.4 Hydraulic Pump Package

The computed tomography (CT) results for the hydraulic pump package are shown in figures 19 through 27. Review of the images did not show any radiographic indications of high density particles other than the particle in the DCV. The hydraulic flow paths within the pump package were digitally marked. Pressure was colored red, return was colored yellow, C1 was colored blue, and C2 was colored green.

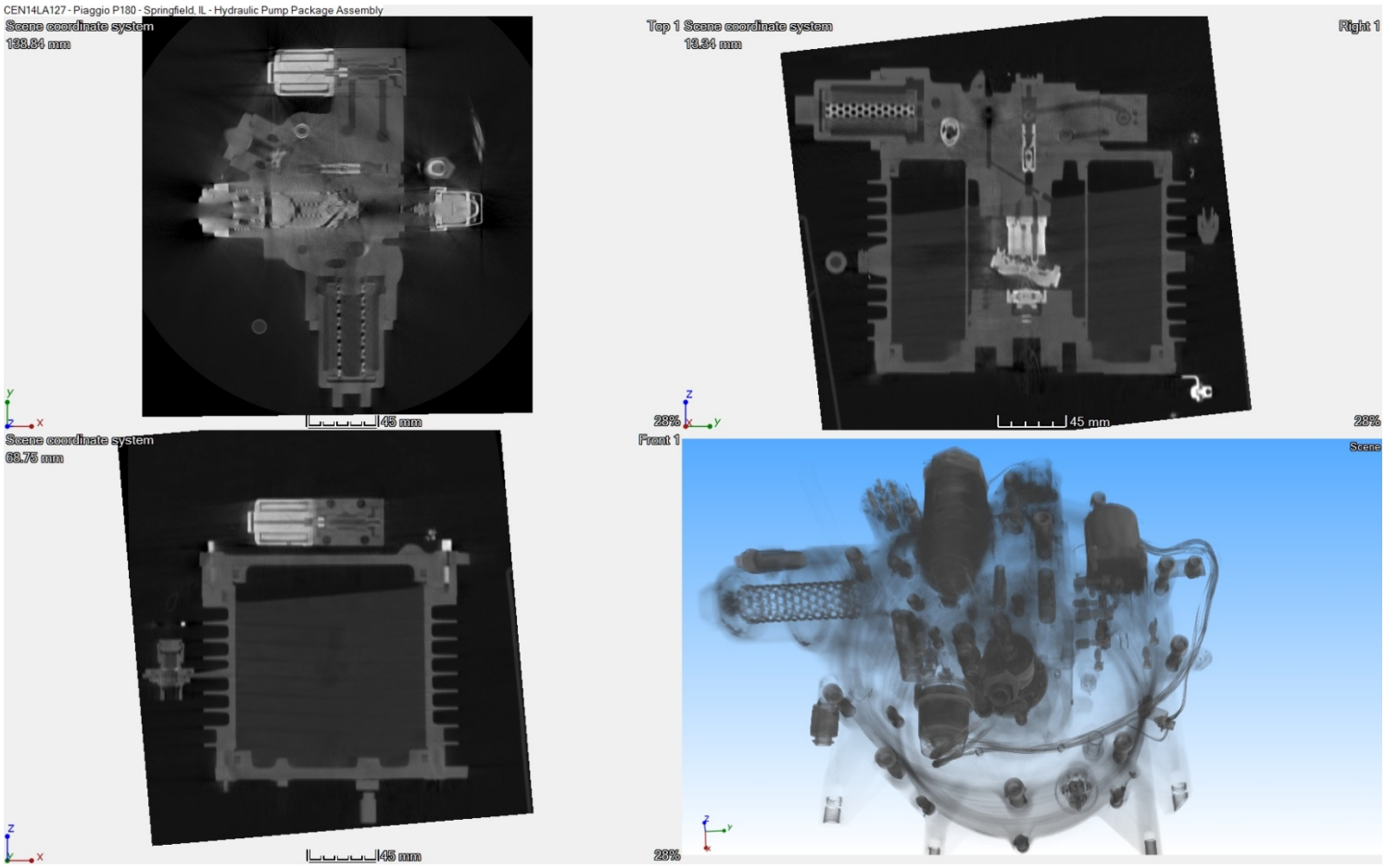


Figure 19
Hydraulic Pump Package – Overall view through DCV

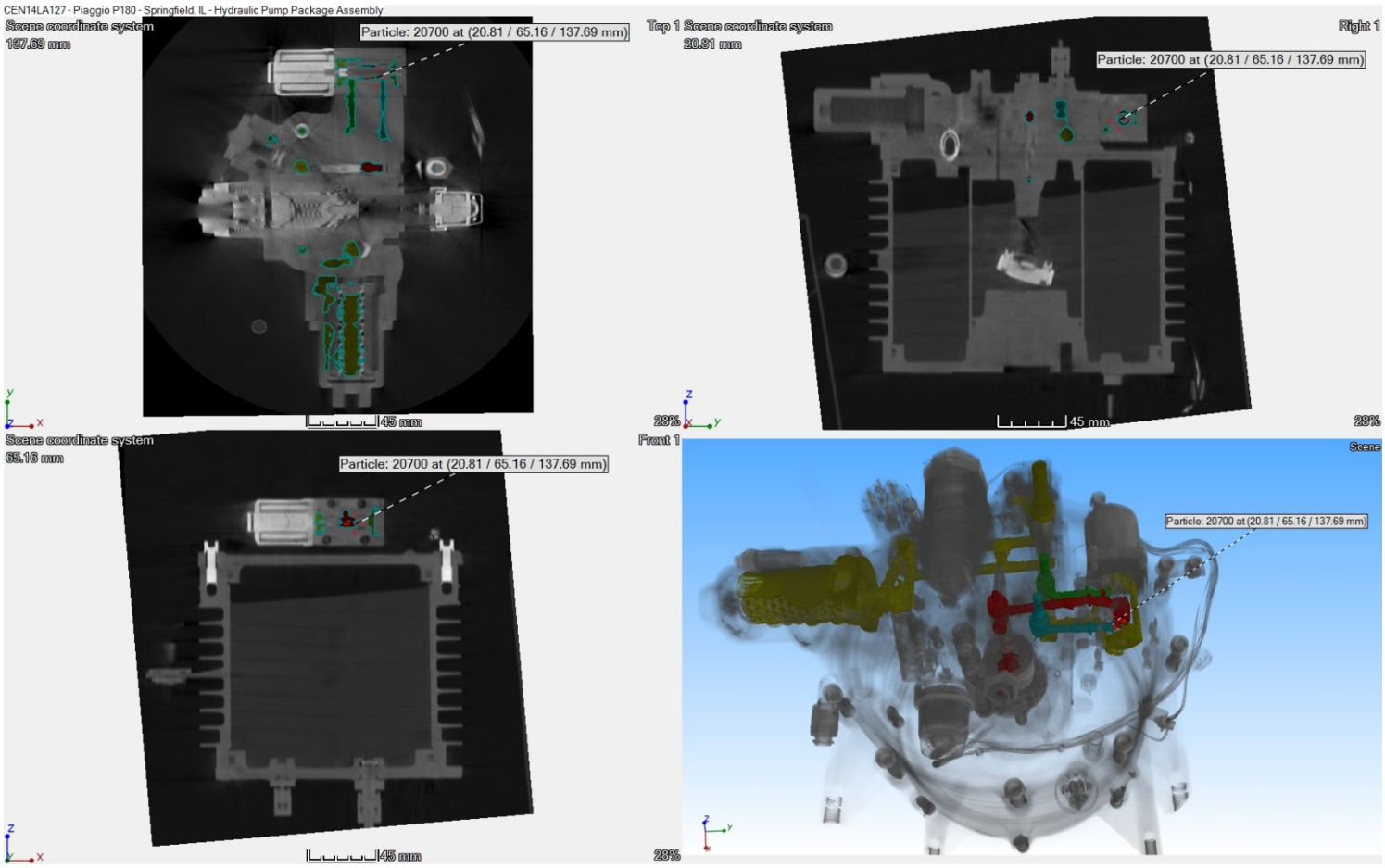


Figure 20
Hydraulic Pump Package – Overall view showing particle location in DCV

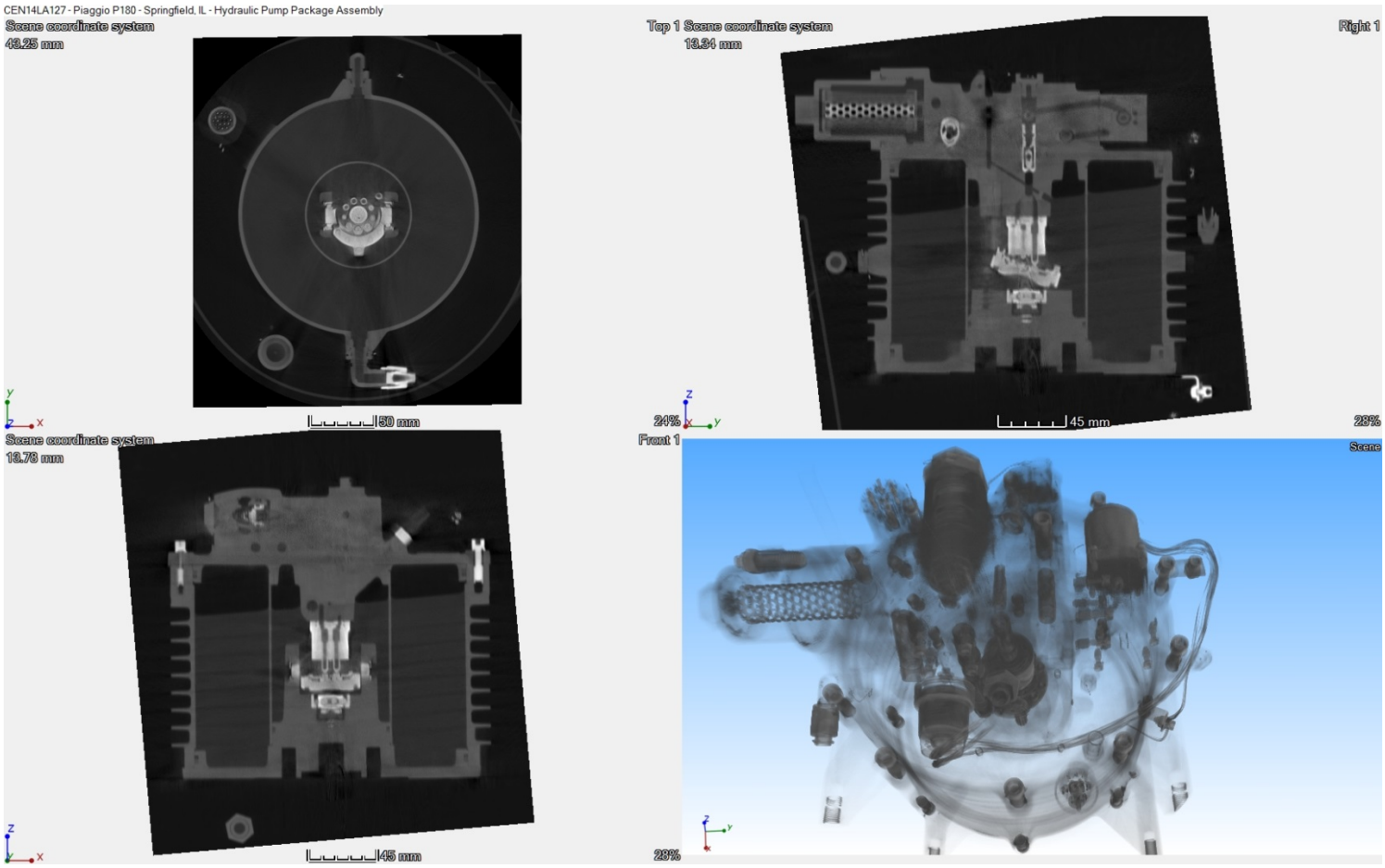


Figure 21
Hydraulic Pump Package – Cross section through pump

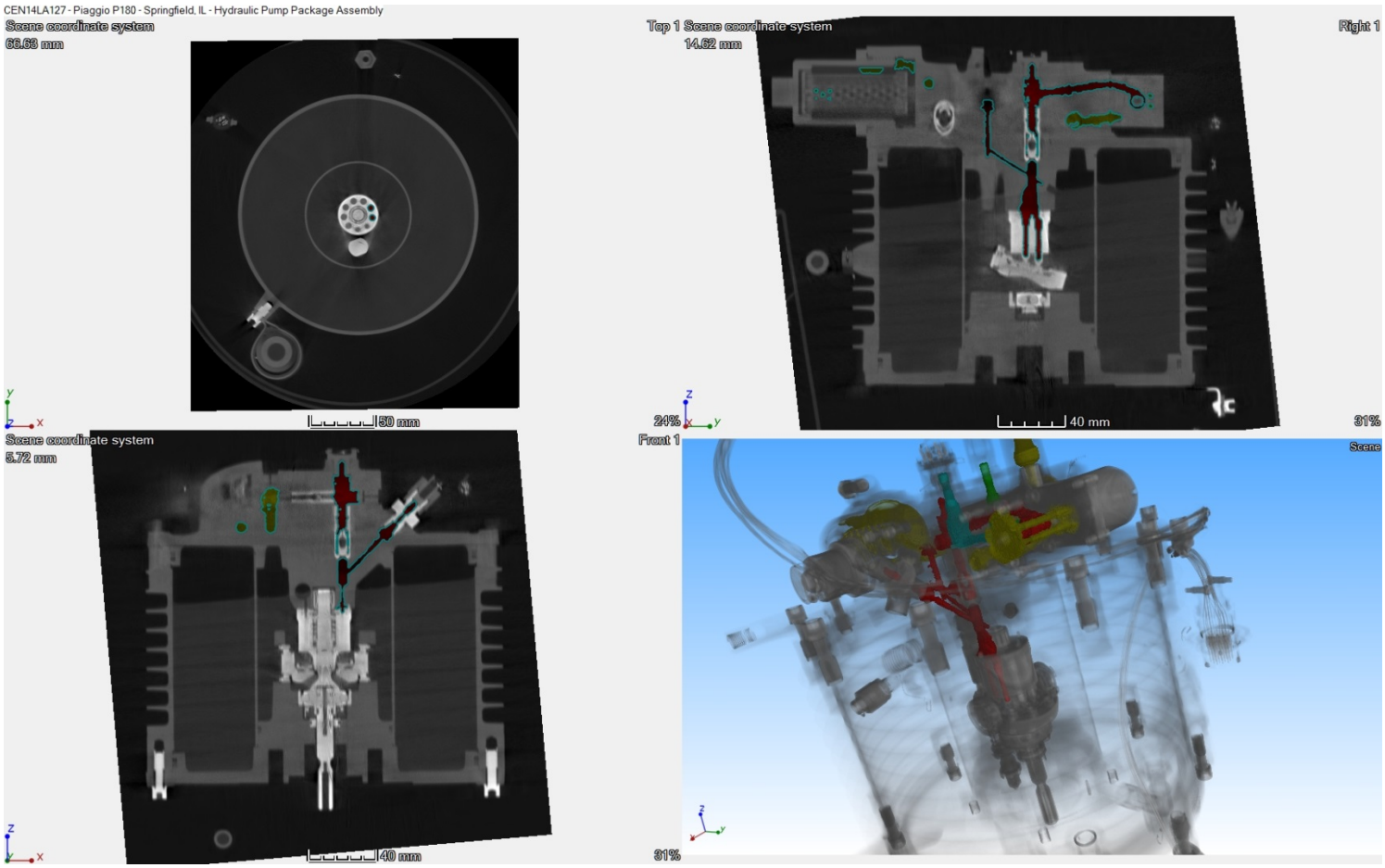


Figure 22
Hydraulic Pump Package – Cross section through pressure hydraulic path

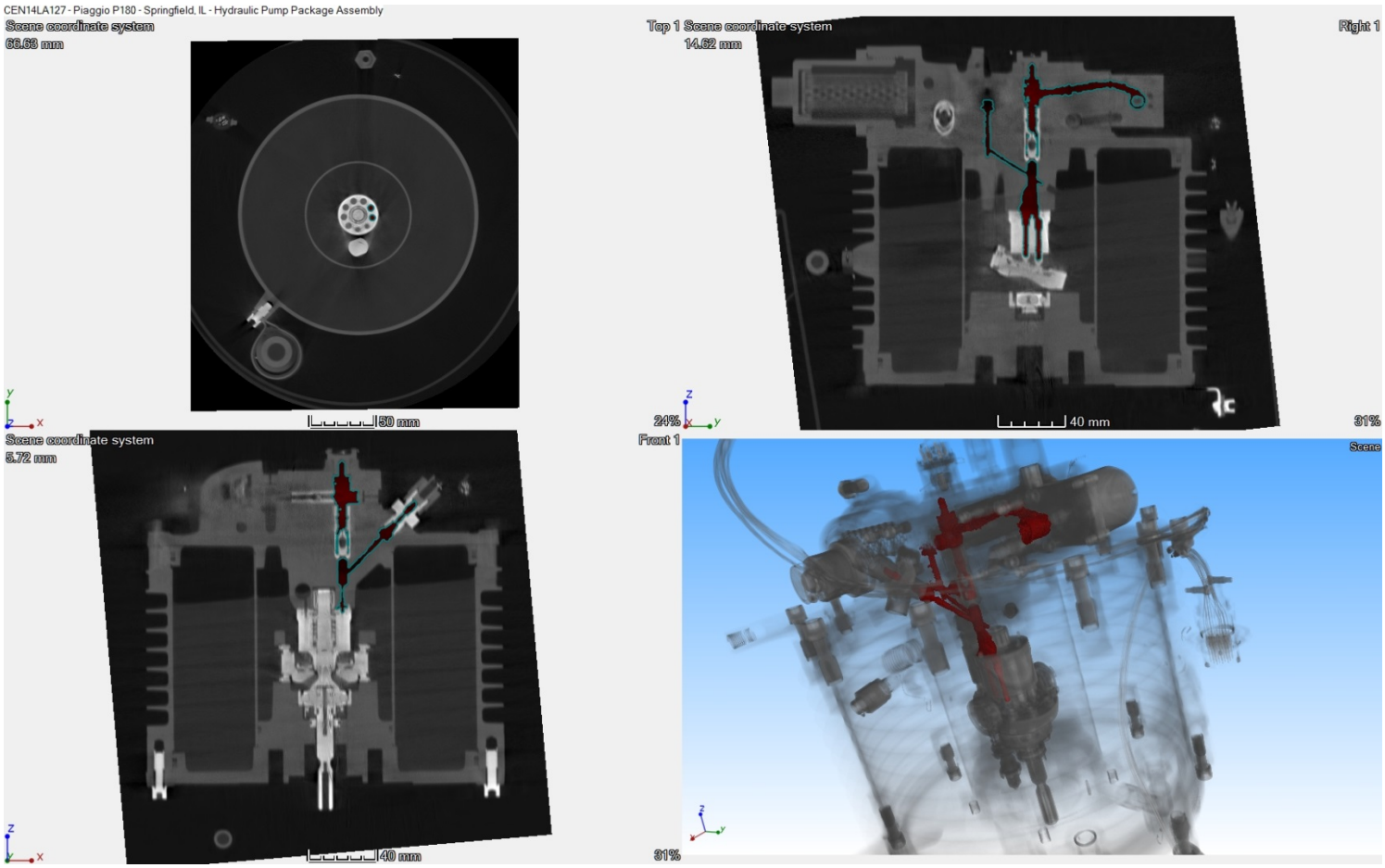


Figure 23
Hydraulic Pump Package – Cross section through pressure hydraulic path (isolated)

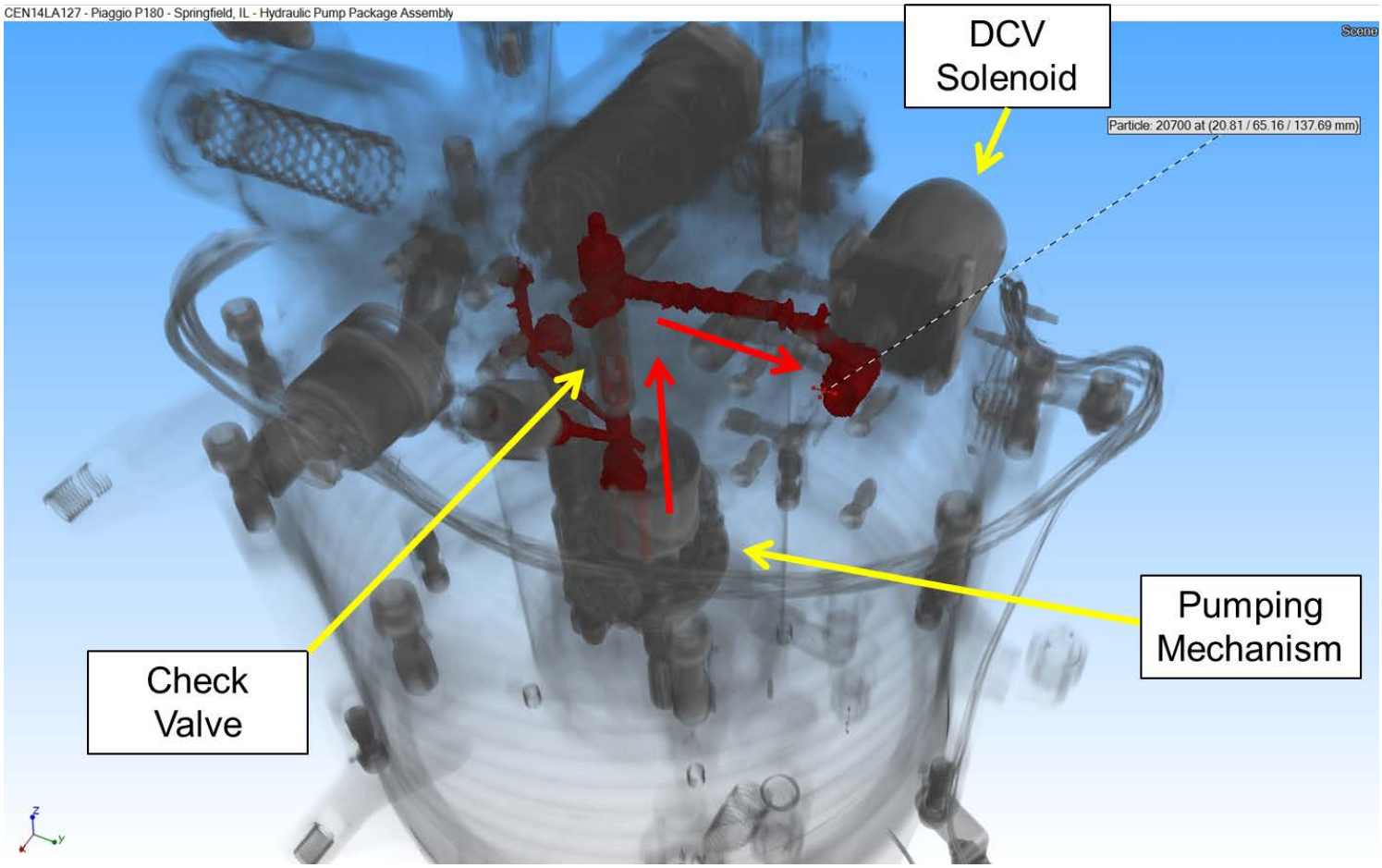


Figure 24
Hydraulic Pump Package – Three dimensional view showing isolated pressure hydraulic path. The arrows show the designed hydraulic flow path from the pumping mechanism to the DCV.

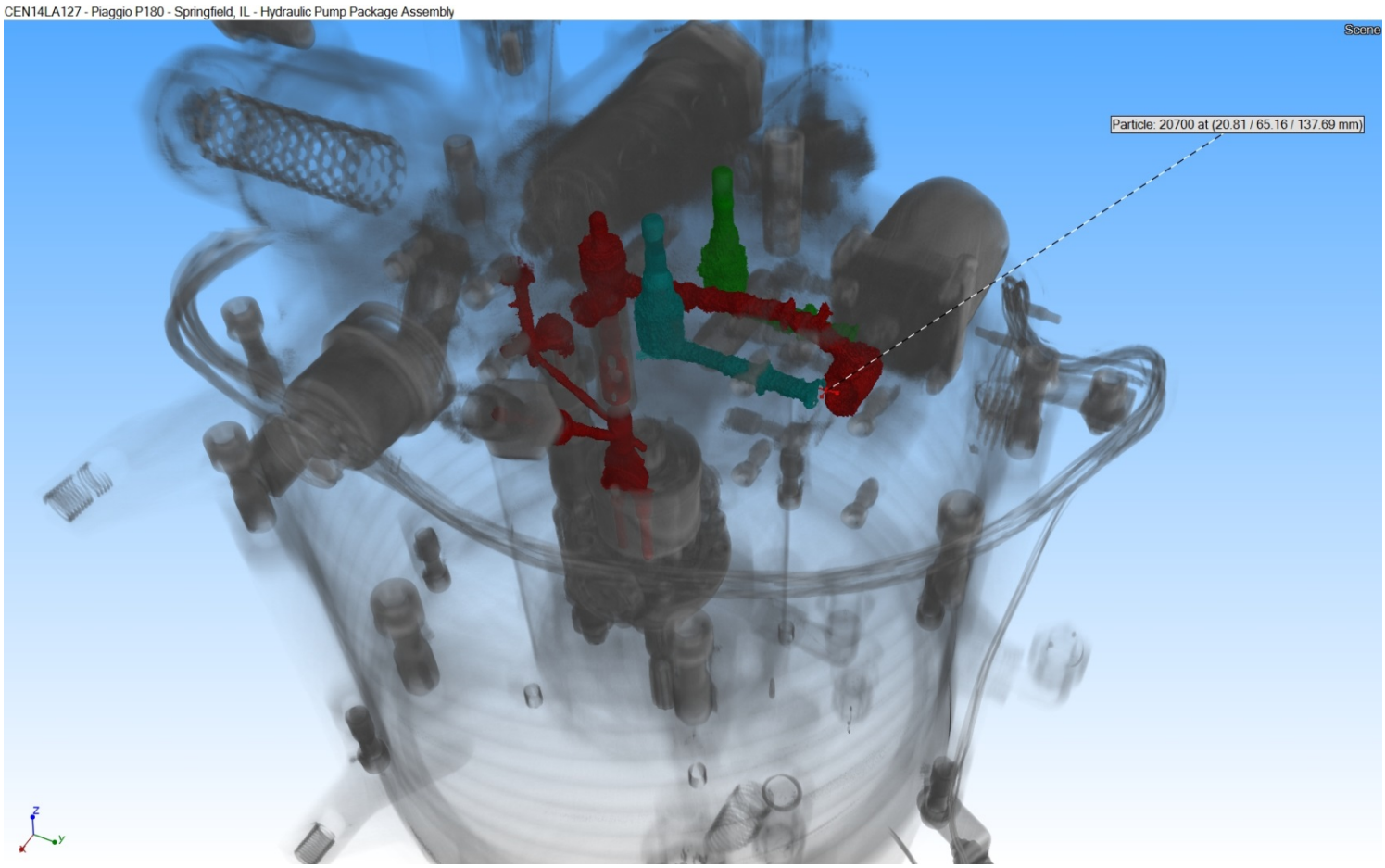


Figure 25
Hydraulic Pump Package – Three dimensional view showing pressure (red), C1 (blue), and C2 (green) hydraulic paths

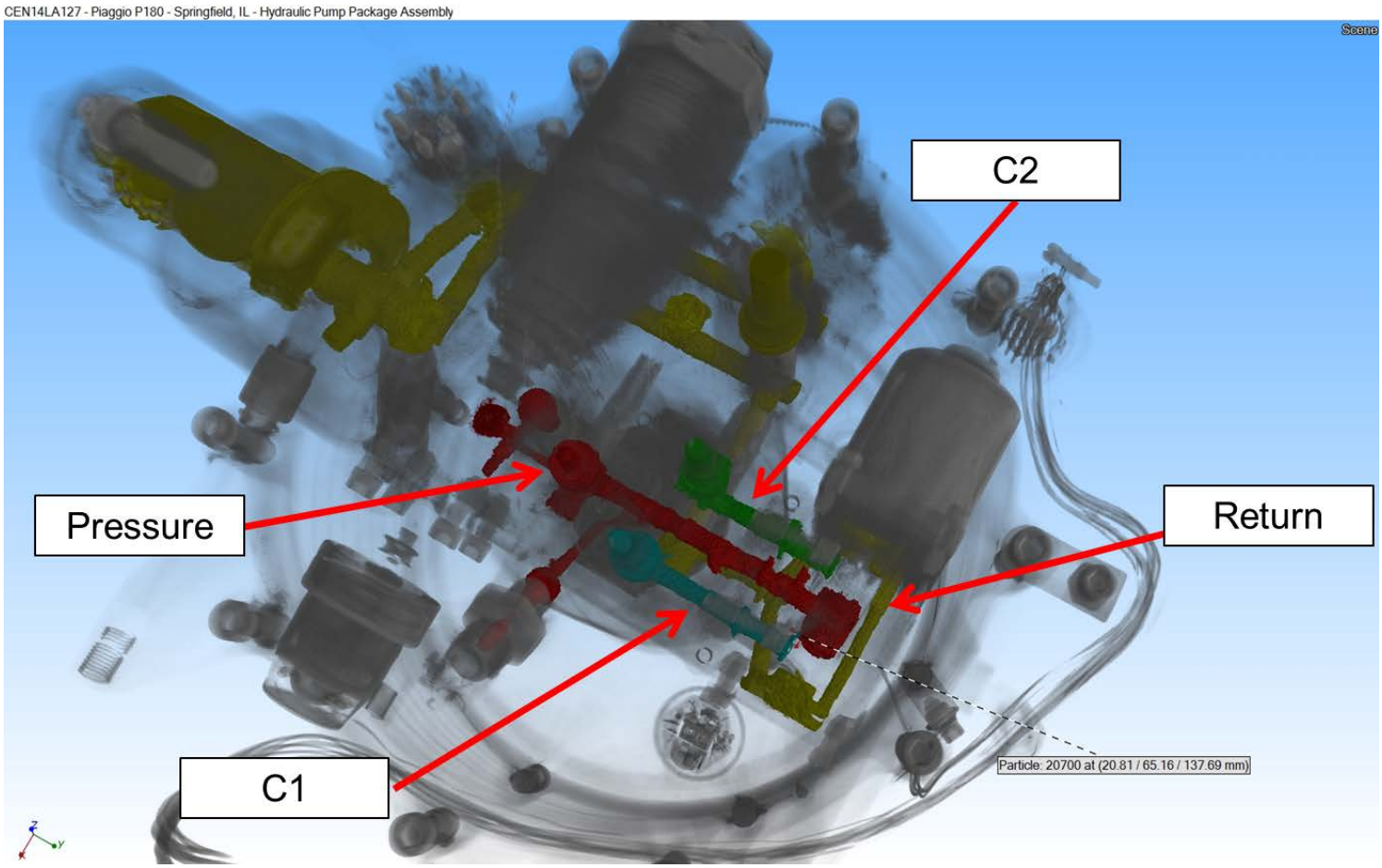


Figure 26
Hydraulic Pump Package – Three dimensional view showing pressure (red), C1 (blue), C2 (green), and return (yellow) hydraulic paths

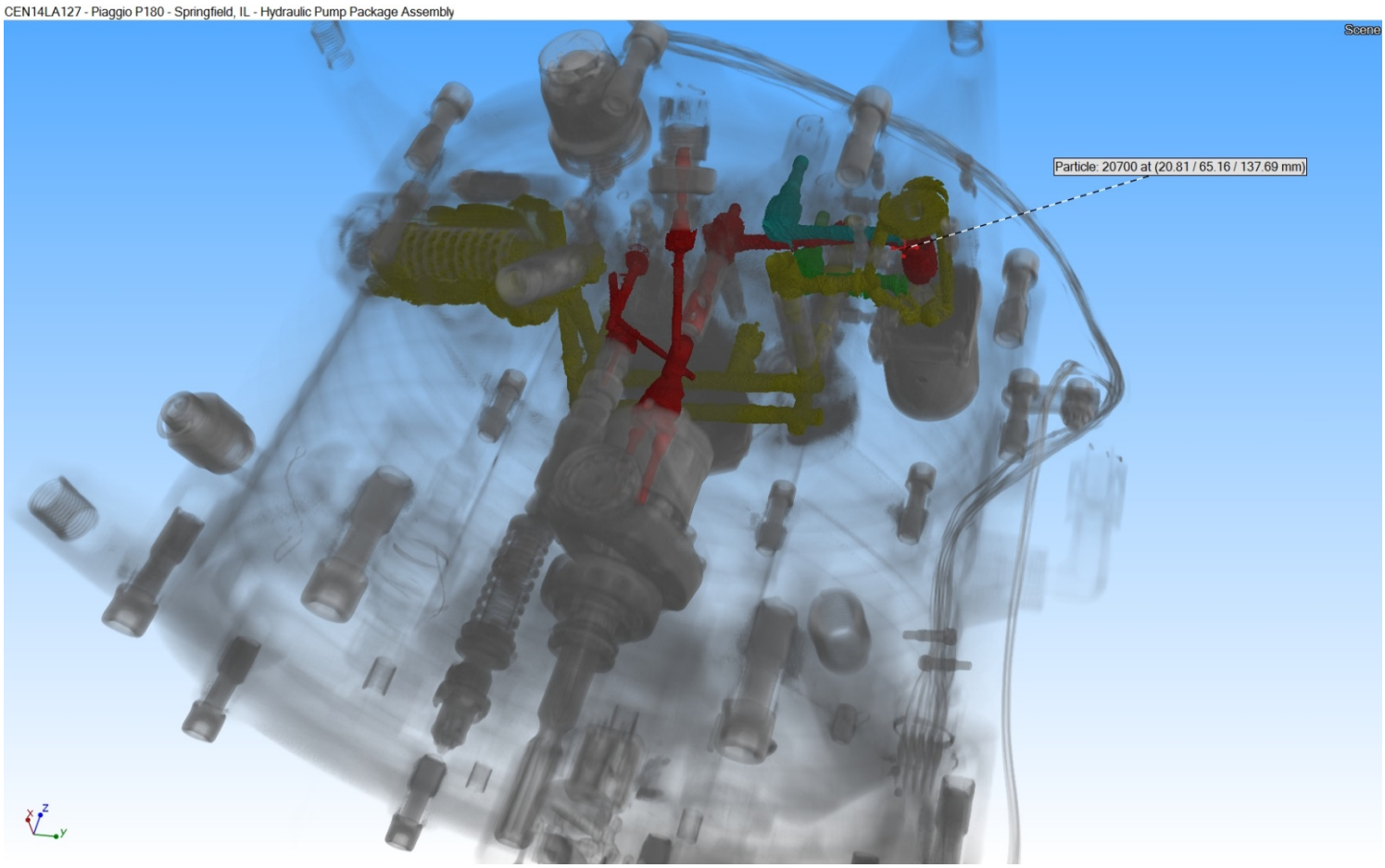


Figure 27
Hydraulic Pump Package – Three dimensional view showing pressure (red), C1 (blue), C2 (green), and return (yellow) hydraulic paths (from below)

Scott Warren
Lead Aerospace Engineer - Aircraft Systems
(Computed Tomography Specialist)