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

November 6, 2015

Computed Tomography Specialist's Factual Report

WPR-15-IA-046

A. ACCIDENT

Operator:	Hawkeye Aviation Holdings Ltd
Location:	Palm Springs International Airport (PSP), Palm Springs, California
Date:	November 23, 2014
Time:	1052 pacific standard time
Vehicle:	Embraer EMB-505, C-GJOL

B. GROUP

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

C. SUMMARY

On November 23, 2014, about 1052 Pacific standard time, an Embraer EMB-505 airplane, C-GJOL, experienced an uncommanded severe yaw to the right immediately after takeoff from the Palm Springs International Airport (PSP), Palm Springs, California. Neither the airline transport pilot nor the 4 passengers on board were injured. The airplane, which was owned by a private individual, was operated by Hawkeye Aviation Holdings Ltd, Kelowna, British Columbia. Visual meteorological conditions prevailed for the planned cross-country flight, which was being operated in accordance with 14 Code of Federal Regulations Part 91. An instrument flight rules flight plan was in effect at the time of the event, with Springbank, British Columbia, the reported destination.

Radiographic studies were done from December 24, 2014 through March 23, 2015 in Chicago, Illinois to examine and document the internal configuration of the rudder gust lock actuator. The component was documented using computed tomography (CT) scans and was imaged using a total of 6,421 CT slices.

Review of the images indicated that the extend limit switch contacts were indicated to be in a different position during the standard focus scans as opposed to during the microfocus scans; high and medium density particles were found in various locations throughout the actuator; there was an indication of a discontinuity within one of the balls shown on the microfocus images; there were indications of two areas with distorted windings within the solenoid; there was material containing voids within the passages of the solenoid; and a high density particle was noted within the solenoid within the area of the piston to housing gap.

D. DETAILS OF THE INVESTIGATION

1.0 General

The rudder gust lock actuator was subjected to x-ray computed tomography (CT) scanning to document its internal condition. The scanning was conducted from December 24, 2014 to March 23, 2015. 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 CT system and the Actis 500/450 standard focus CT system.

For the CT scans, the component was loaded into the imaging unit and placed on a turntable. It 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 fan beam of x-rays, and the portion of the part imaged was adjusted slightly after each scan was completed until the entire assembly 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 a reconstruction algorithm.

The actuator was scanned using a total of 6,421 slices. The total size of the combined data sets was 50.26 Gb. The actuator was scanned multiple times with different

scanning protocols using both the microfocus imaging system and the standard focus imaging systems. The microfocus scans provided the best possible spatial resolution, but this type of imaging was constrained to a lower power level that resulted in streaking artifacts within the images. The standard focus scans used a higher power level (with a lower spatial resolution), but these higher power levels eliminated the streak artifacts and had an inherently higher contrast resolution. Target CT imaging using the microfocus system was used for selected areas to get the highest possible resolution. In addition, the entire part scans and the limit switch scans were re-reconstructed using different reconstruction parameters in an effort to highlight the low density components within the scans. The complete scan protocols are given in table 1.

Table 1
Scan Protocol

	Standard focus scan (entire part)	Microfocus target CT (limit switches)	Microfocus target CT (screw and ball)	Microfocus target CT (solenoid)
Number of slices	842	701	2101	1235
Voxel Size - X Direction (mm)	0.048	0.022	0.022	0.03
Voxel Size - Y Direction (mm)	0.048	0.022	0.022	0.03
Voxel Size - Z Direction (mm)	0.20	0.03	0.03	0.03
Image Projections per Revolution	1800	3600	3622	3600
Exposure time (ms)	111	285.58	285.58	285.58
Frames to Avg (frames per projection)	1	2	2	1
X-ray Source Voltage (kV)	225	222	222	223
X-ray Source Current (mA)	2.0	0.55	0.55	0.55
Source Filter Material	Brass	Brass	Brass	Brass
Source Filter Thickness (mm)	1	1	1	0.5
Image Matrix Size (pixels)	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 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 high 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.

The images of the actuator were examined for any signs of missing or damaged parts, contamination, obstructed passages 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 rudder gust lock actuator are shown in figures 1 through 42. Review of the images indicated:

1. The extend limit switch contacts appeared to be closed during the standard focus scans (see figure 6) and open during the microfocus scans (see figure 7). Whether this difference was due to an actual position change of the contacts or due to the resolution differences of the two scanning methods could not be determined;

2. The extend and retract limit switch plungers were extended different lengths (0.87 mm and 1.26 mm respectively) (see figure 10);

3. High and medium density particles were found in various locations throughout the actuator;

4. A low density indication within one of the extend limit switch screws was only visible in the standard focus scans and not the microfocus scans – this indication is consistent with the apparent low density area being a scanning artifact (see figures 13-15);

5. Indications of a crack in the ball screw that were noted in the standard focus scans were more completely resolved in the microfocus scans as the balls and groove located on the ball screw. However, there was an indication of a discontinuity within one of the balls shown on the microfocus images (see figures 19-26);

6. There were indications of two areas with distorted windings within the solenoid. Neither of these areas appeared to contain breaks in the windings, nor did either area contact the solenoid plunger (see figures 38-42);

7. Review of the solenoid images using enhanced contrast methods indicated that there was material containing voids within the passages of the solenoid (see figures 43-45);

8. A high density particle was noted within the solenoid within the area of the piston to housing gap (see figures 46 and 47).

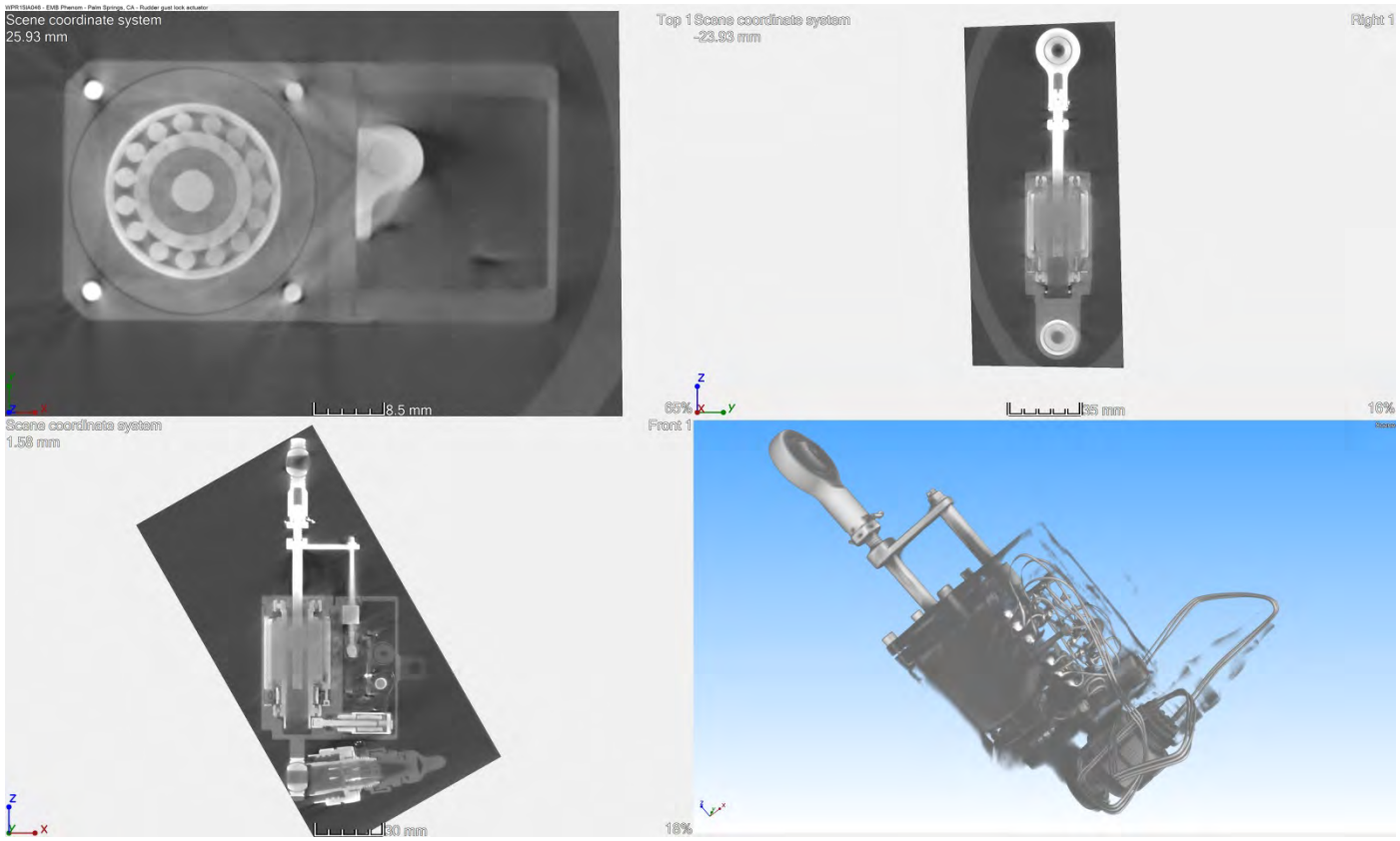

Figure 1
Rudder gust lock actuator – standard focus – Overall cross section centered on actuator

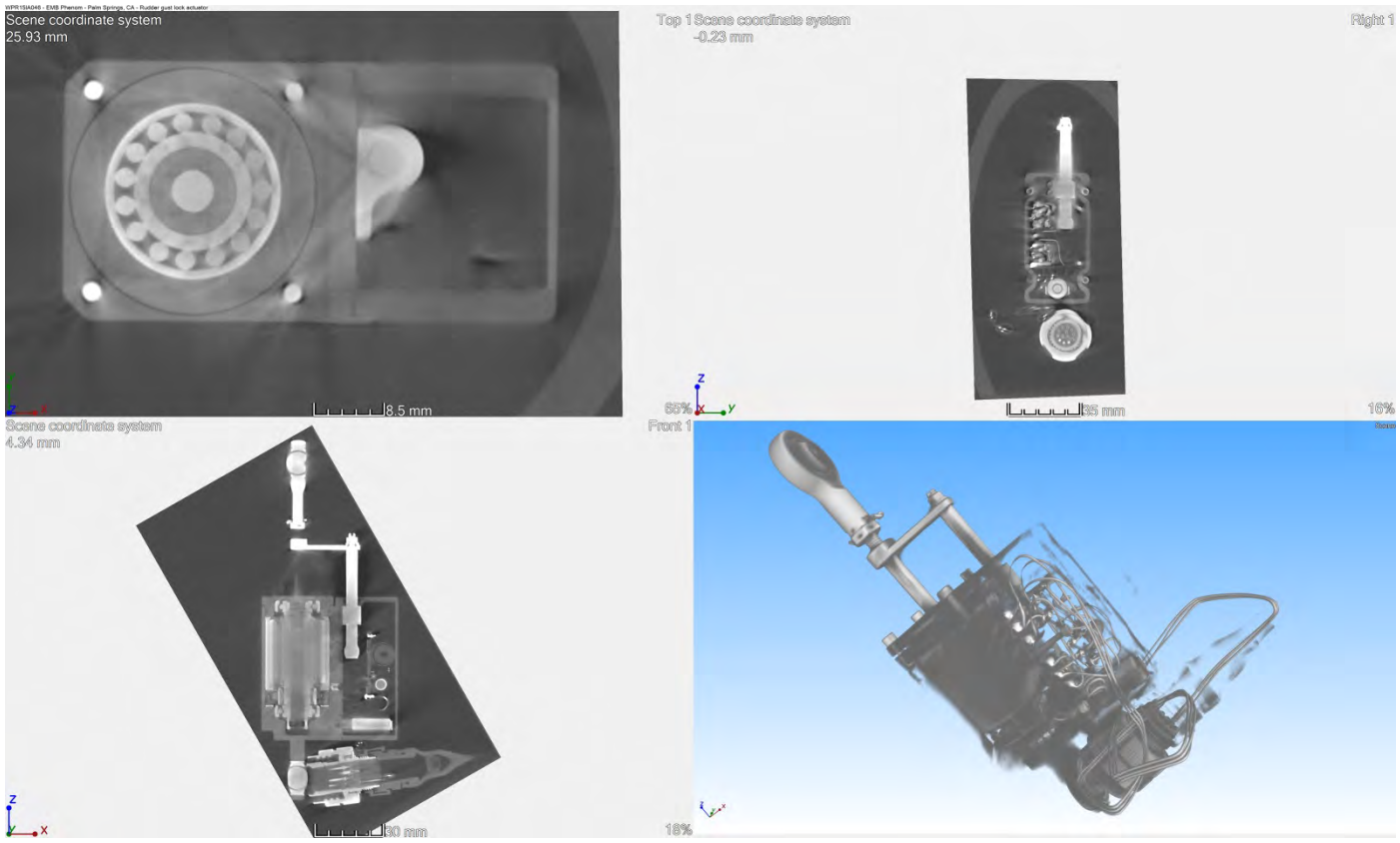

Figure 2
Rudder gust lock actuator – standard focus – Overall cross section centered on feedback piston

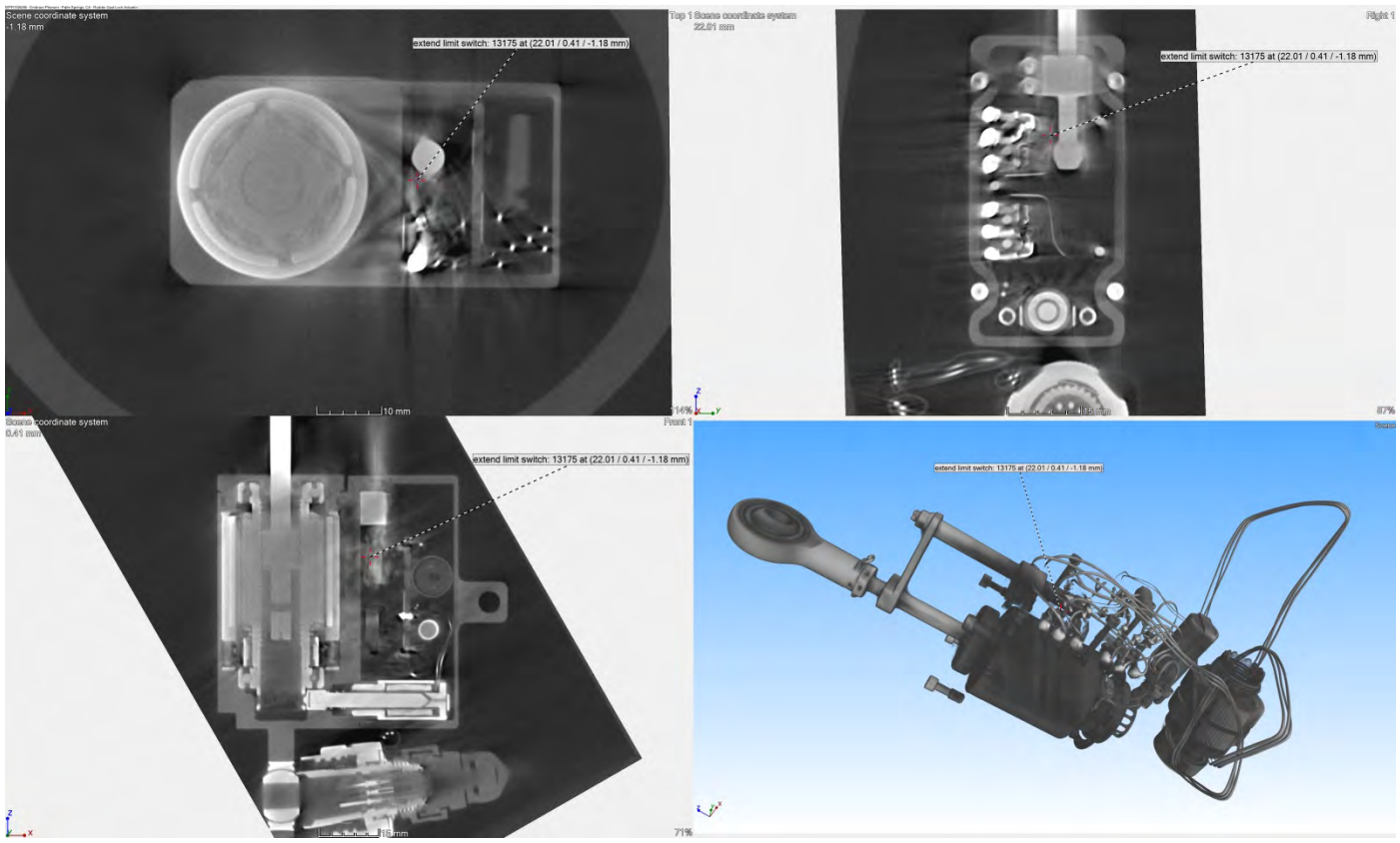

Figure 3
Rudder gust lock actuator – standard focus – extend limit switch location

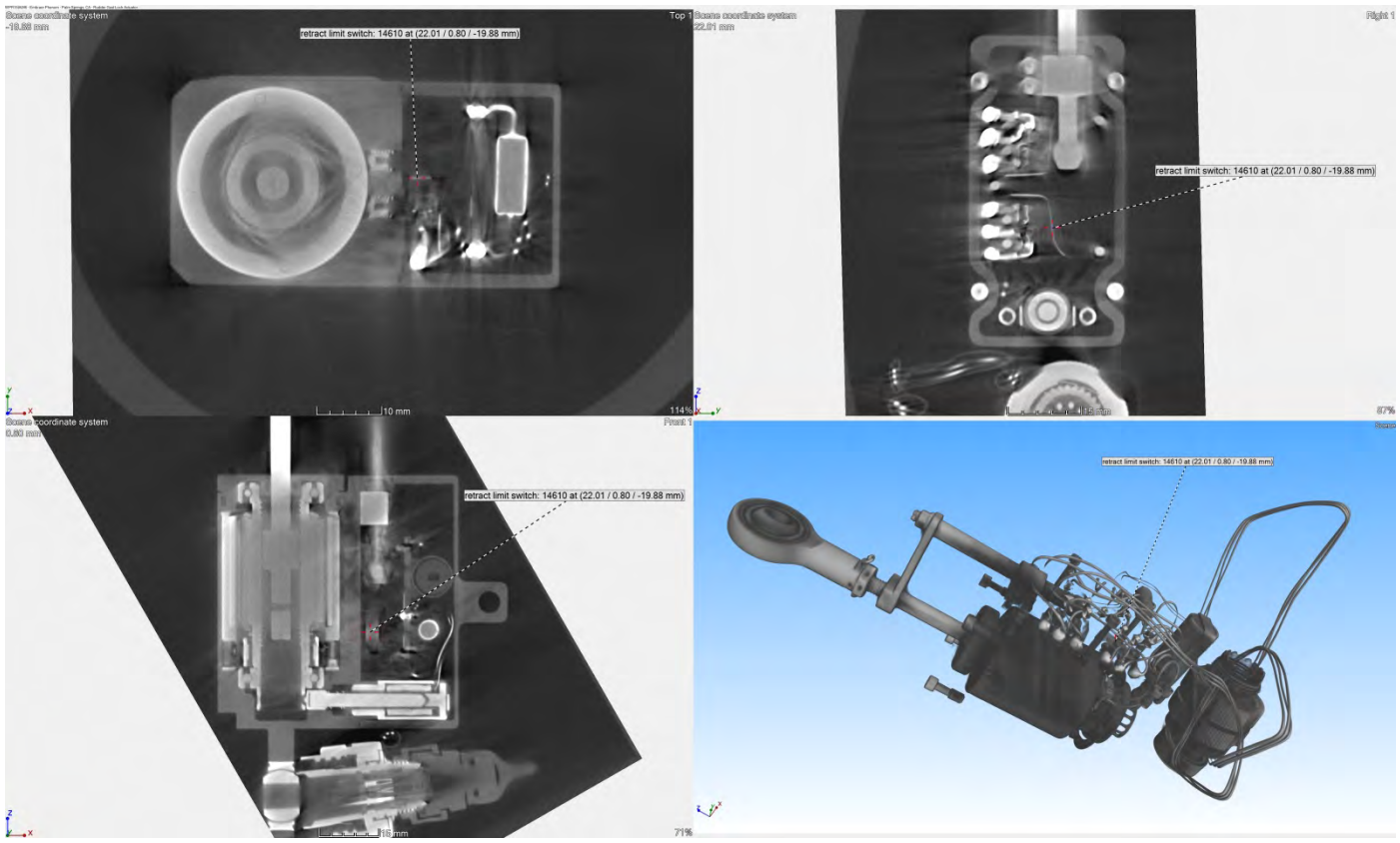

Figure 4
Rudder gust lock actuator – standard focus – retract limit switch location

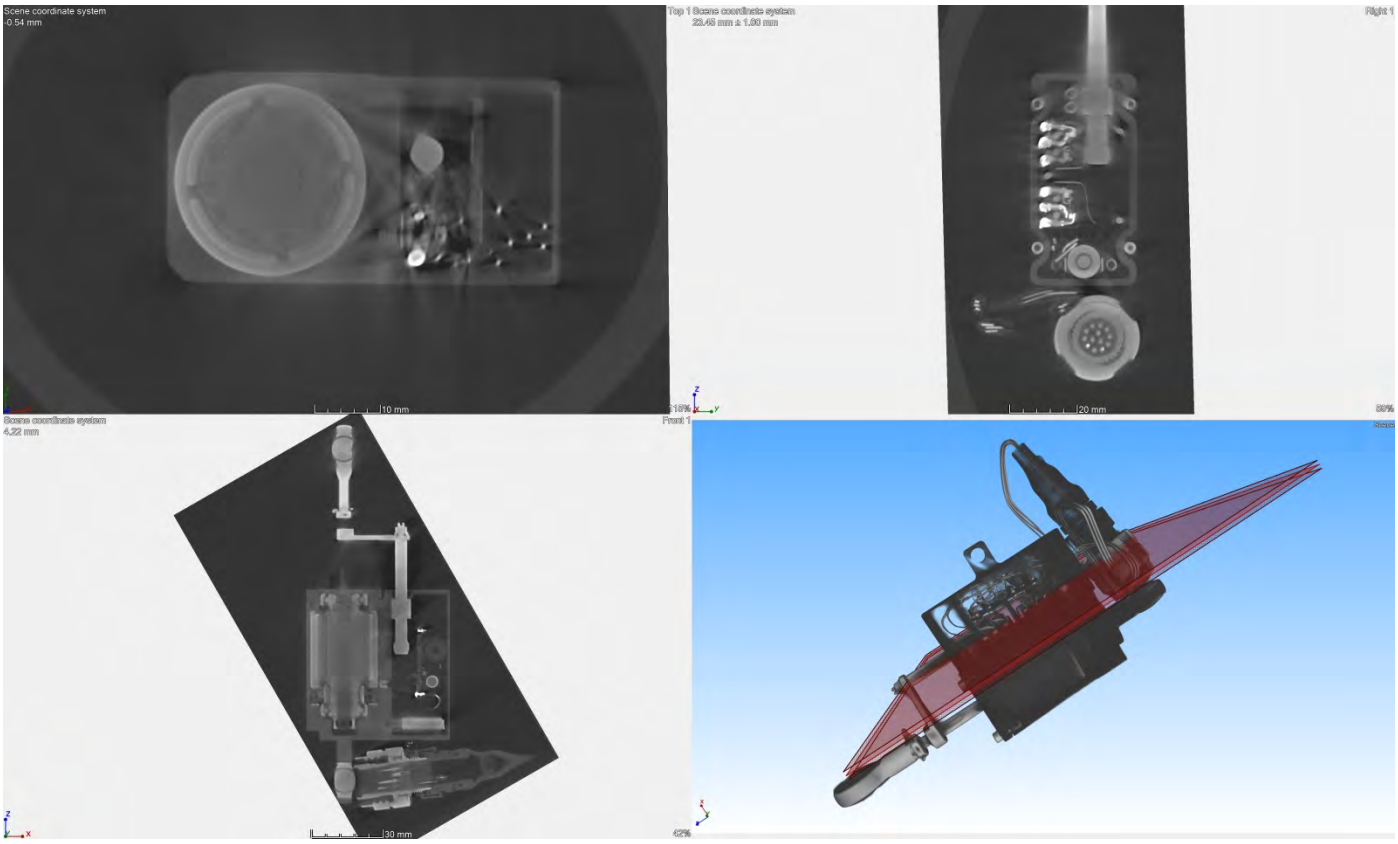

Figure 5
Rudder gust lock actuator – standard focus – extend and retract limit switches (upper right view shows multiple slices combined)

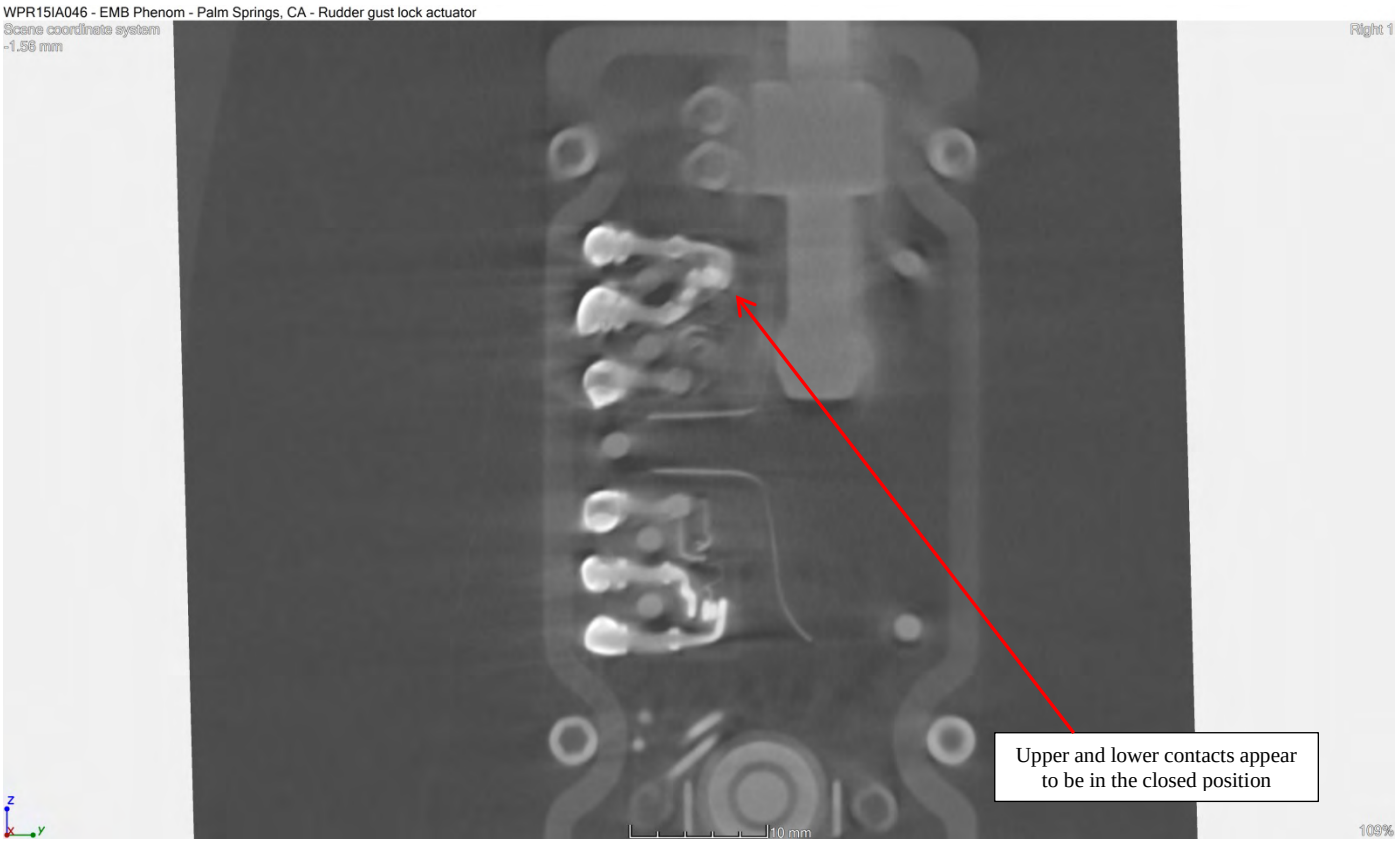

Figure 6
Rudder gust lock actuator – standard focus – limit switches close up view (note that the extend limit switch contacts (lower and upper) appear to be closed)

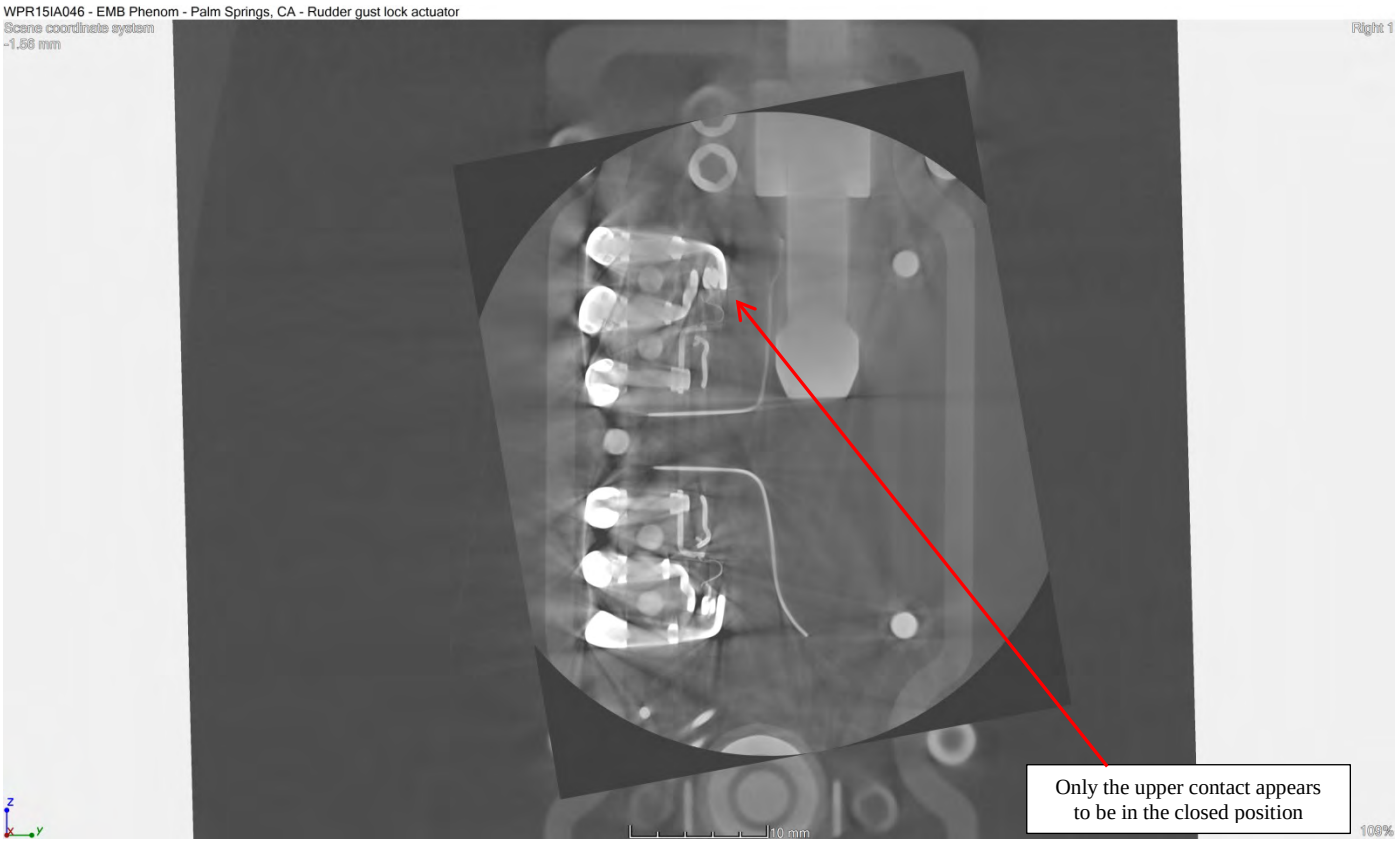

Figure 7
Rudder gust lock actuator – standard focus – limit switches close up view with microfocus view overlaid (note that the extend limit switch lower contact appears to be open)

Figure 8
Rudder gust lock actuator – microfocus – extend limit switch contact point

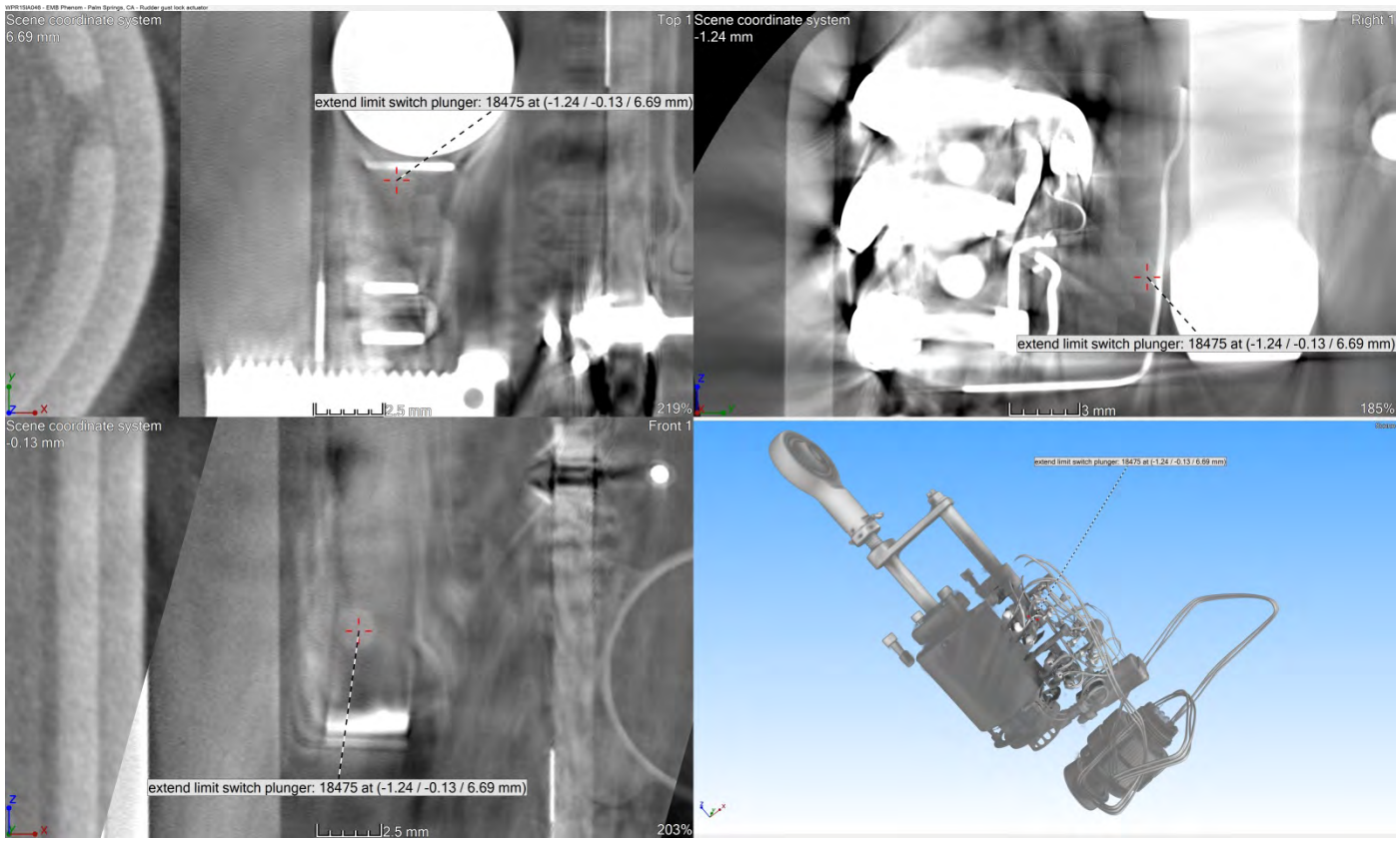

Figure 9
Rudder gust lock actuator – microfocus (re-reconstructed to enhance low density objects) – extend limit switch plunger

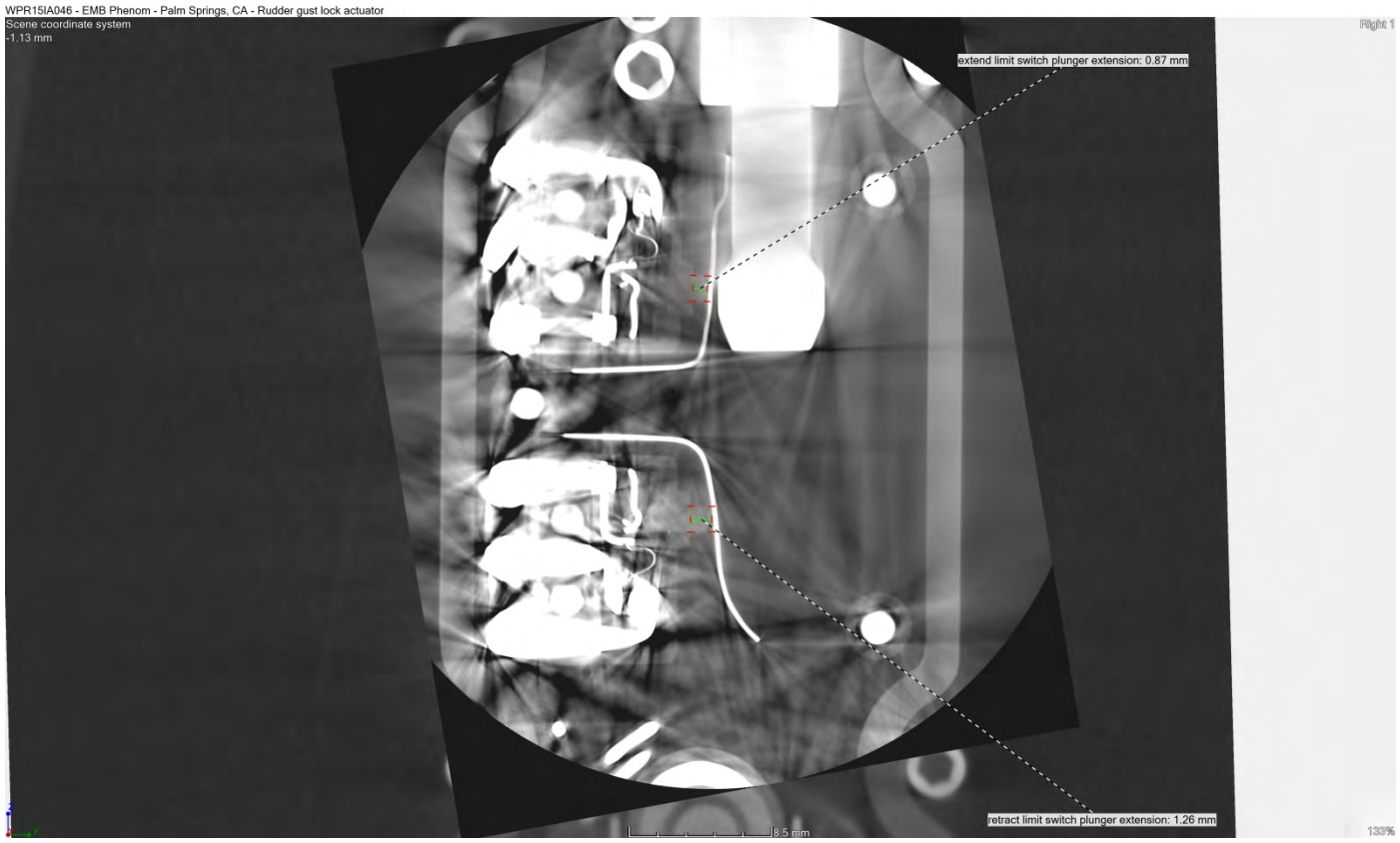

Figure 10
Rudder gust lock actuator – microfocus (re-reconstructed to enhance low density objects) – extend and retract limit switch plunger extension distances

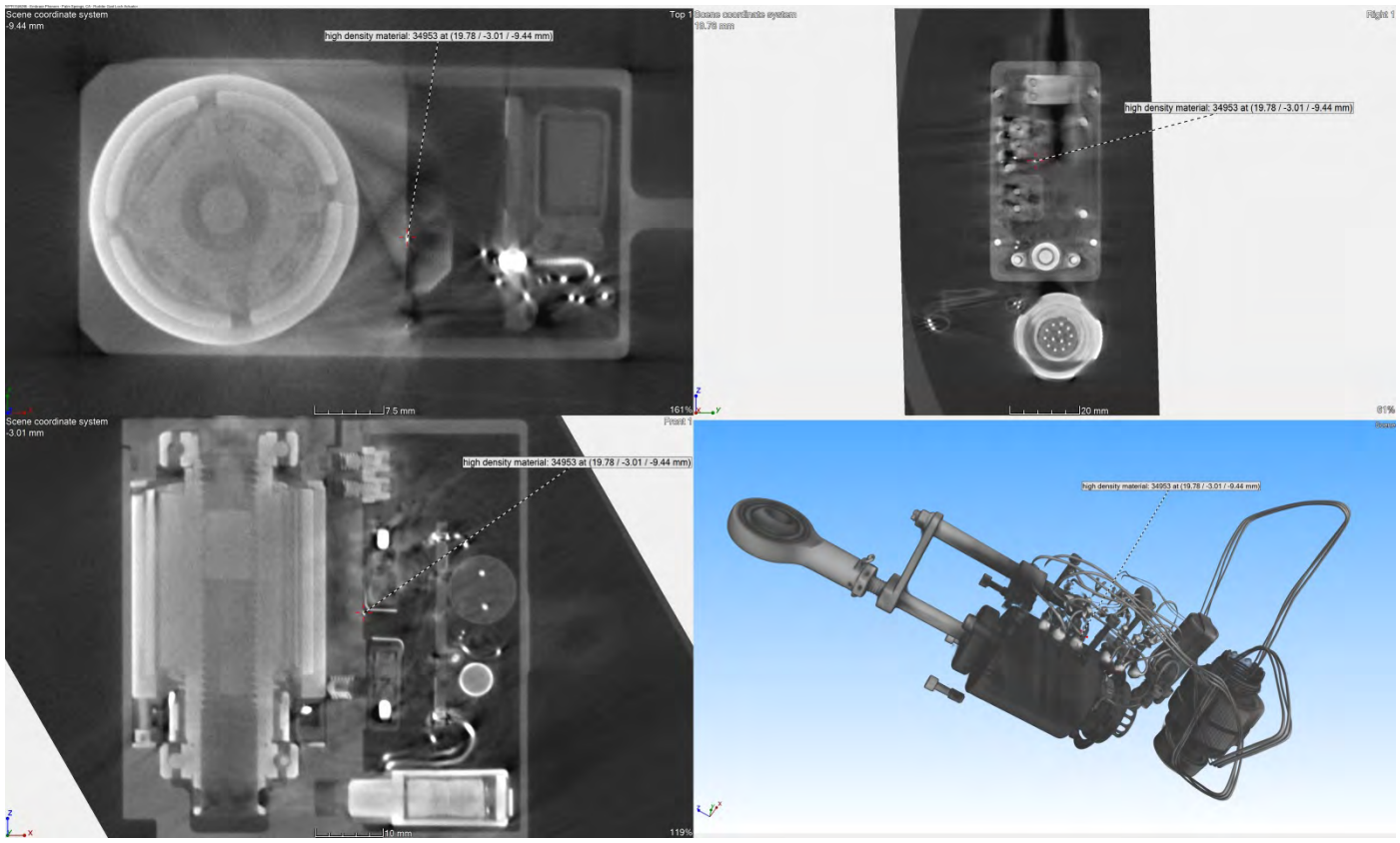

Figure 11
Rudder gust lock actuator – standard focus – high density particle

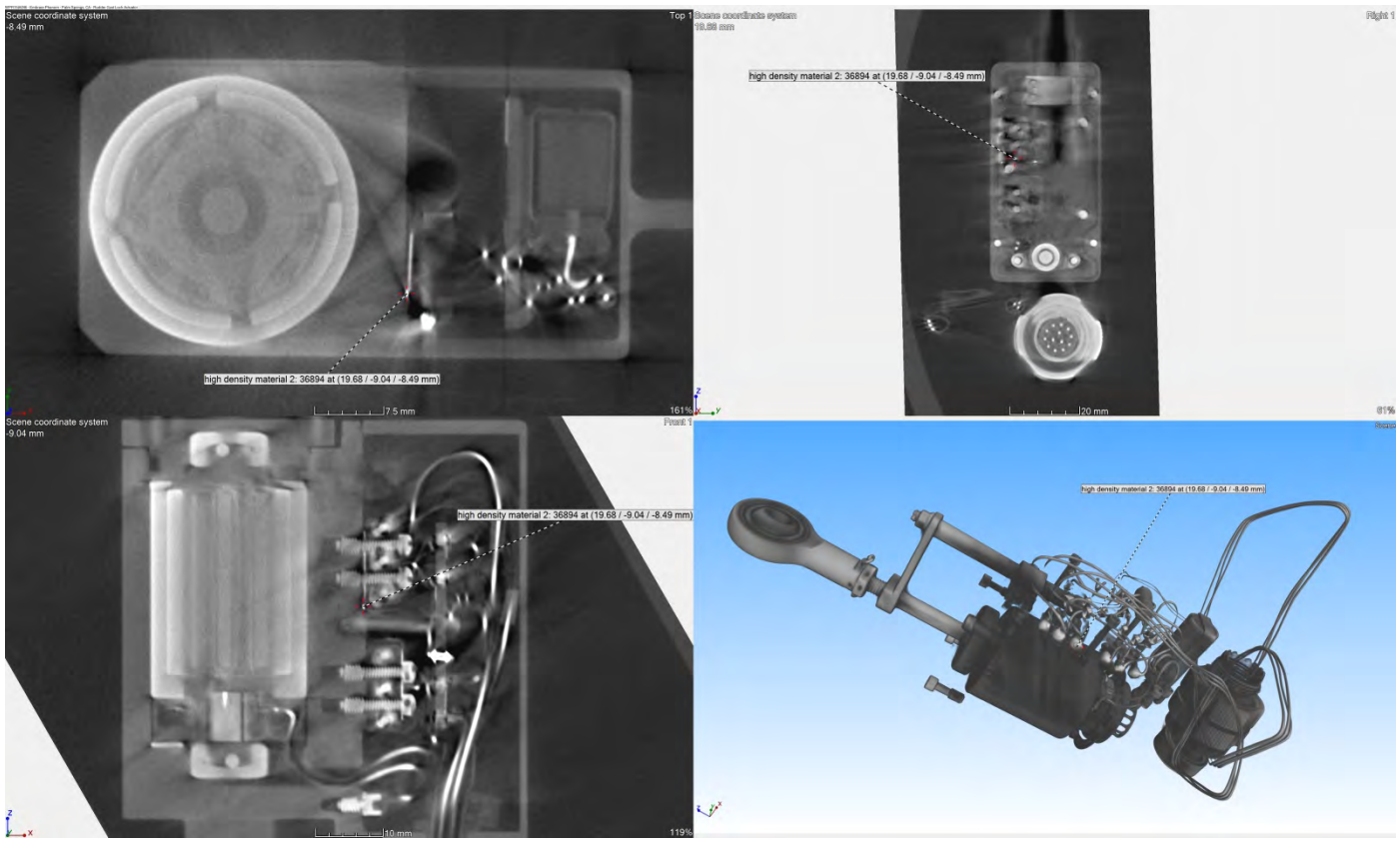

Figure 12
Rudder gust lock actuator – standard focus – high density particle 2

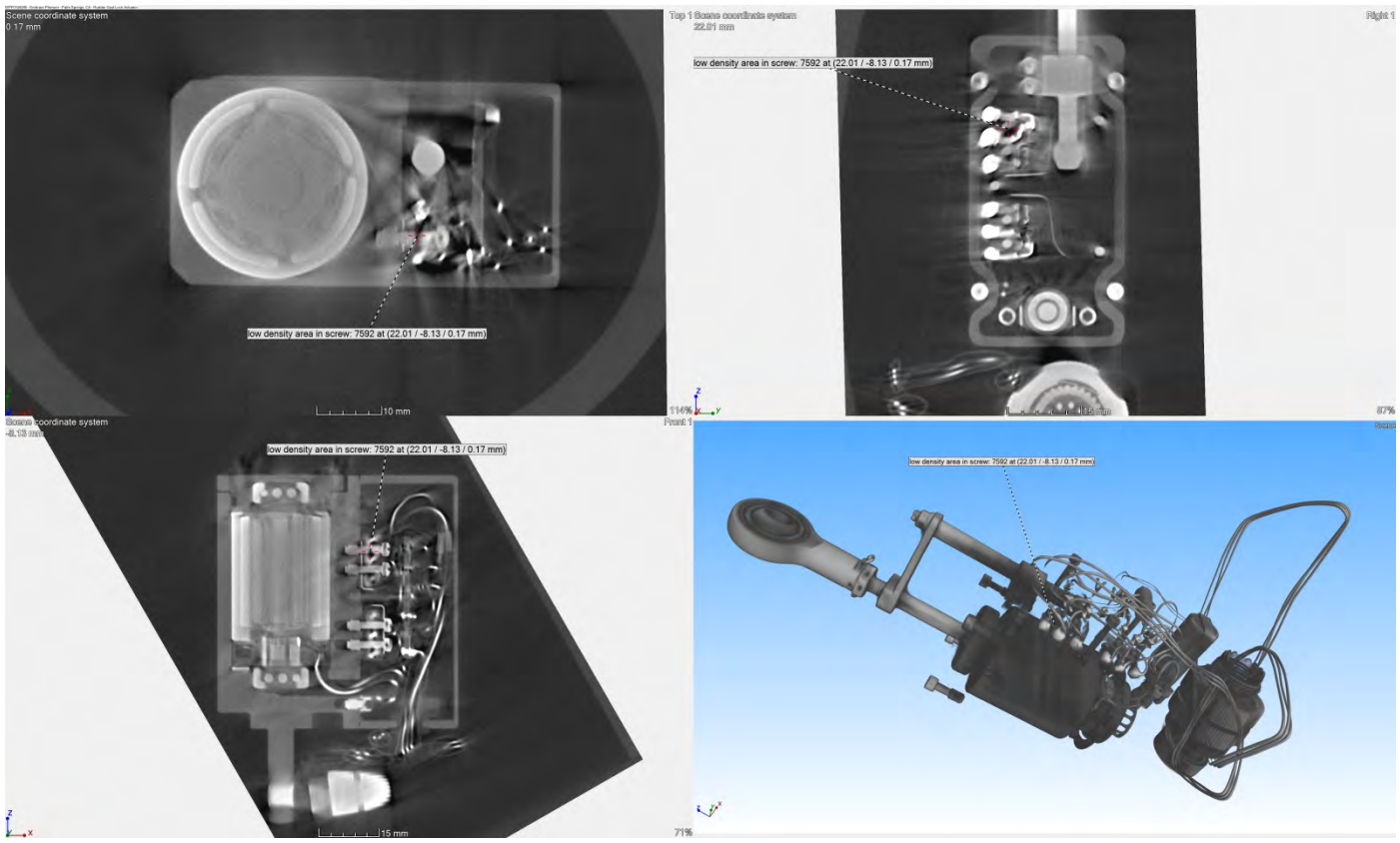

Figure 13
Rudder gust lock actuator – standard focus – low density area in screw

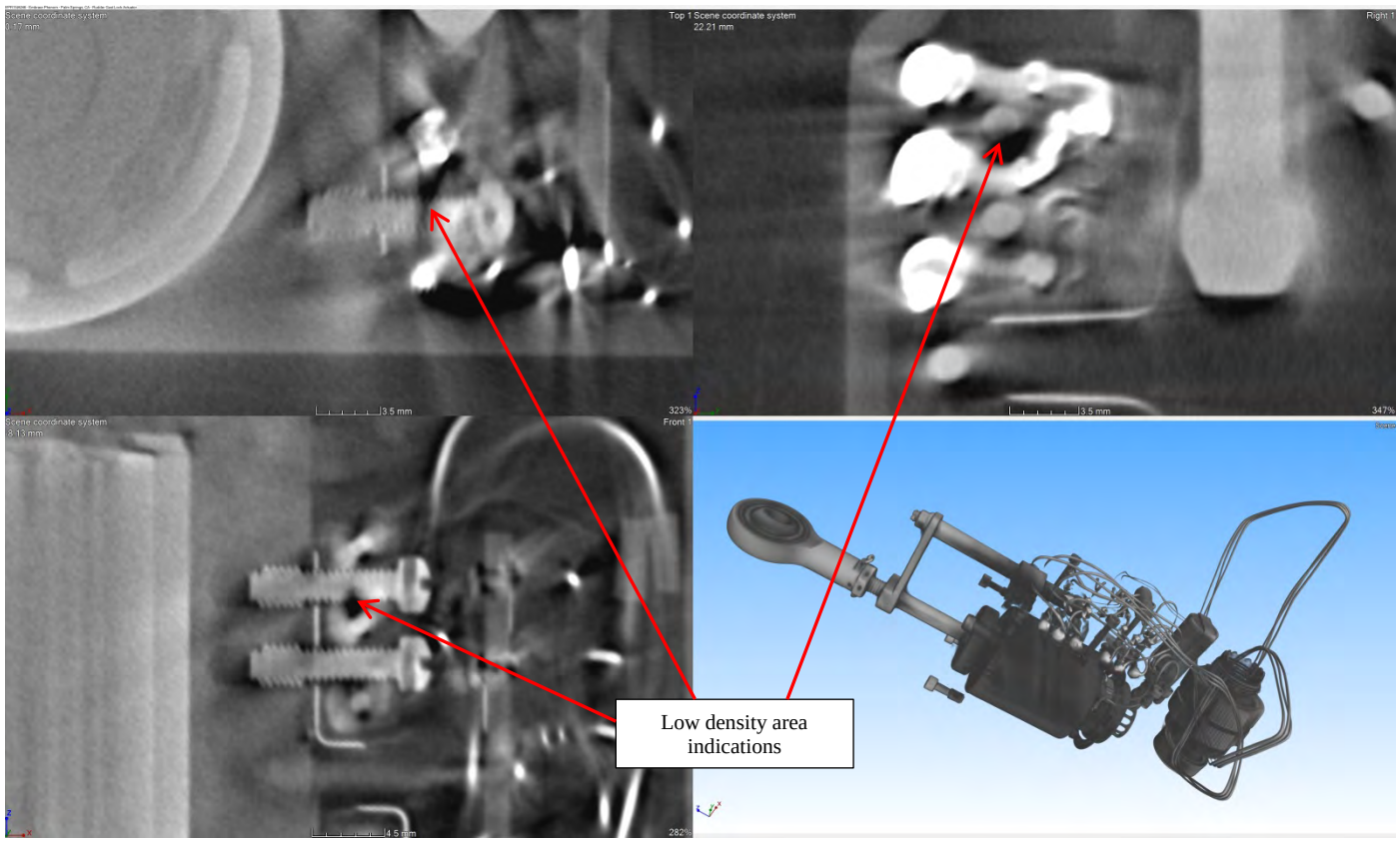

Figure 14
Rudder gust lock actuator – standard focus – low density area in screw close up view

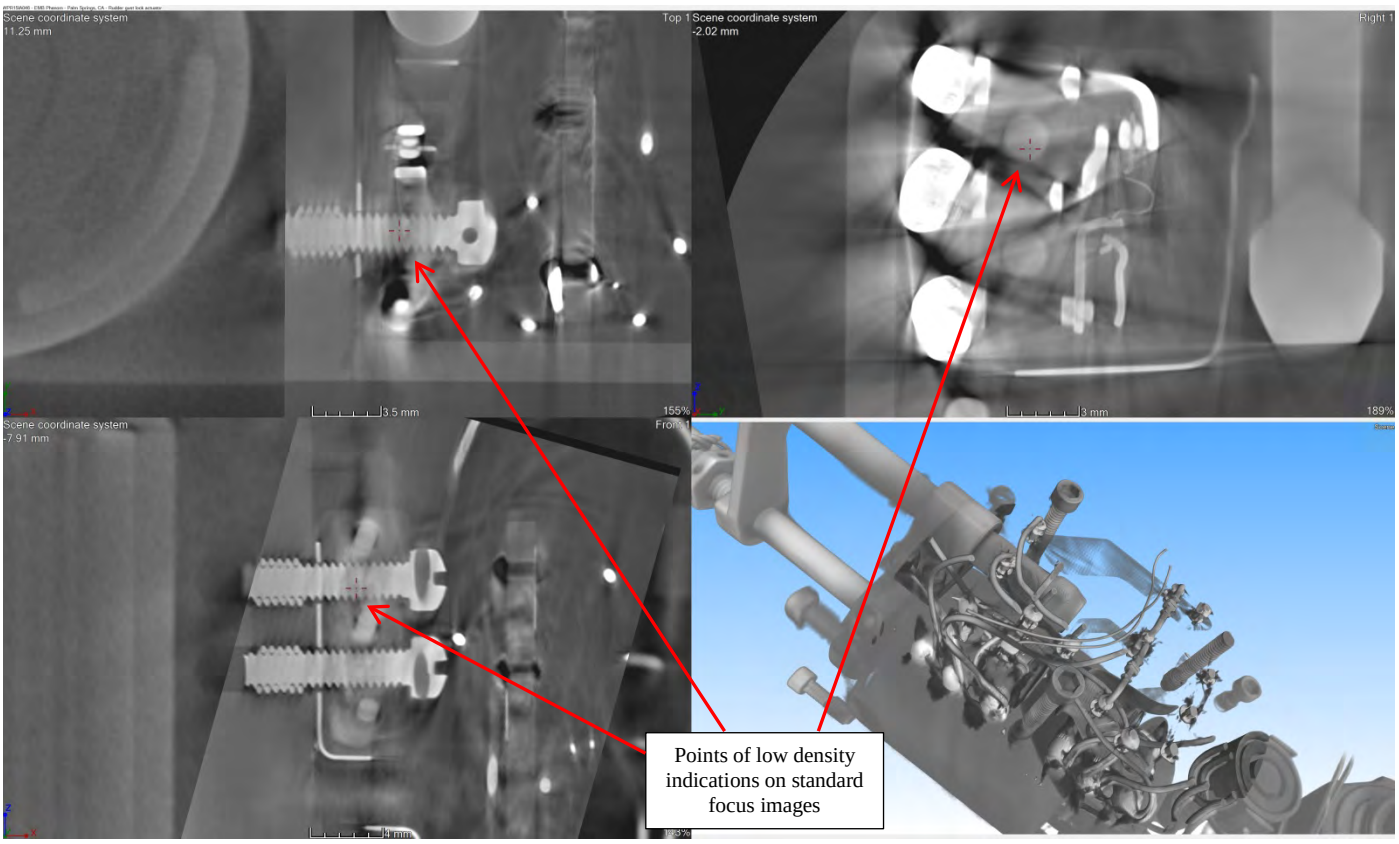

Figure 15
Rudder gust lock actuator – microfocus – low density area in screw close up view (low density area indicated in standard focus images is no longer present)

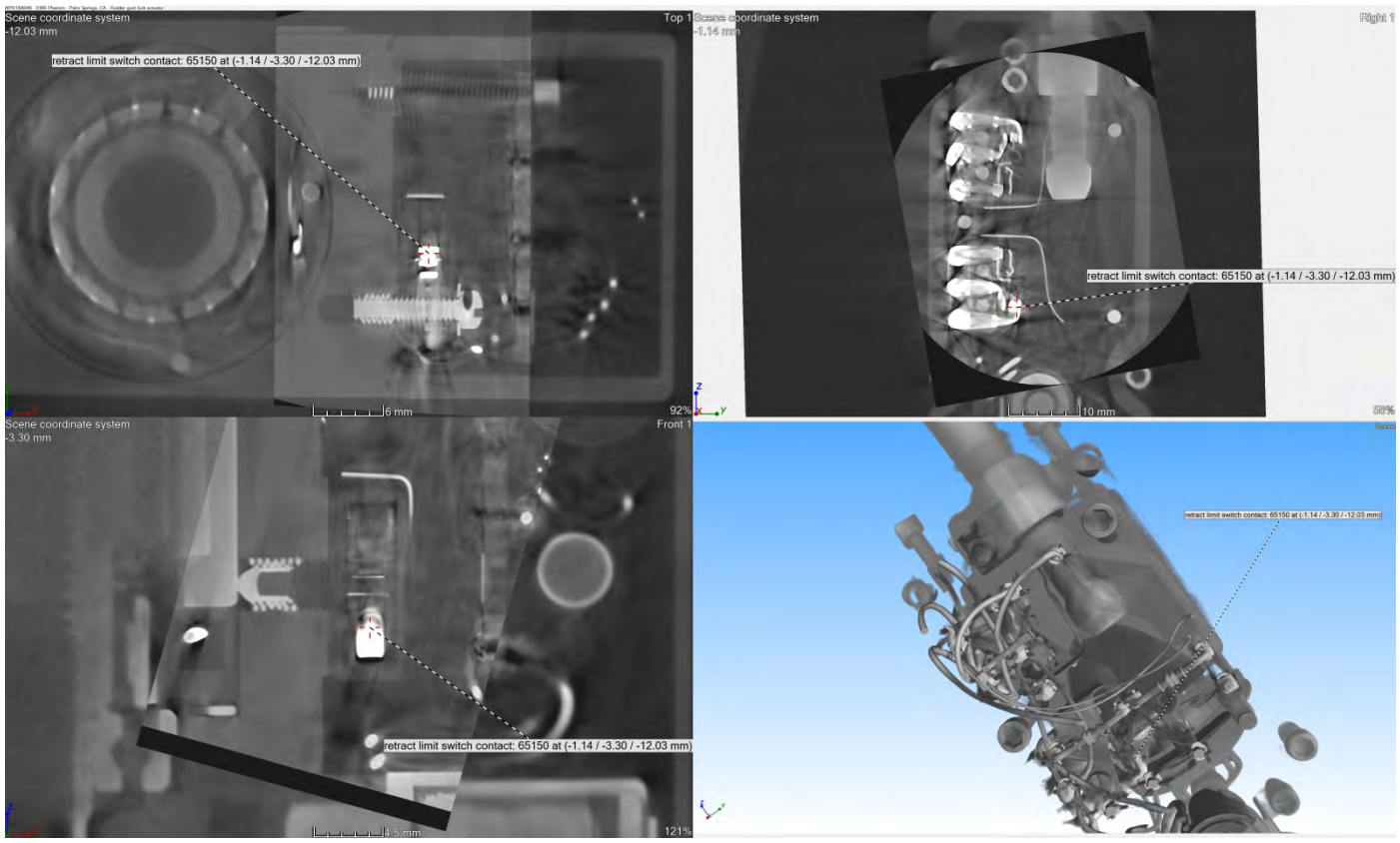

Figure 16
Rudder gust lock actuator – microfocus – retract limit switch contact point

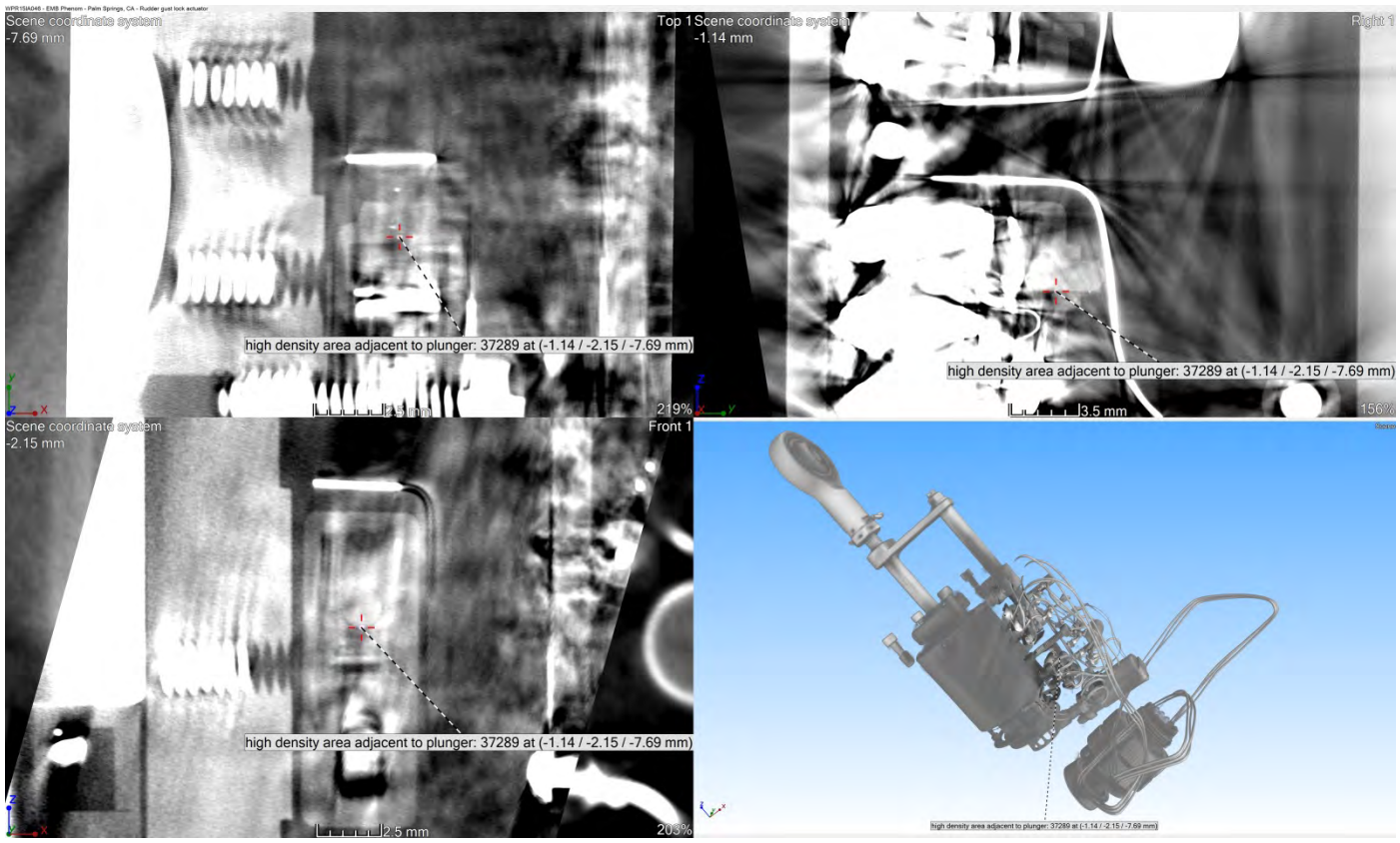

Figure 17
Rudder gust lock actuator – microfocus (re-reconstructed to enhance low density objects) – high density area adjacent to retract limit switch plunger

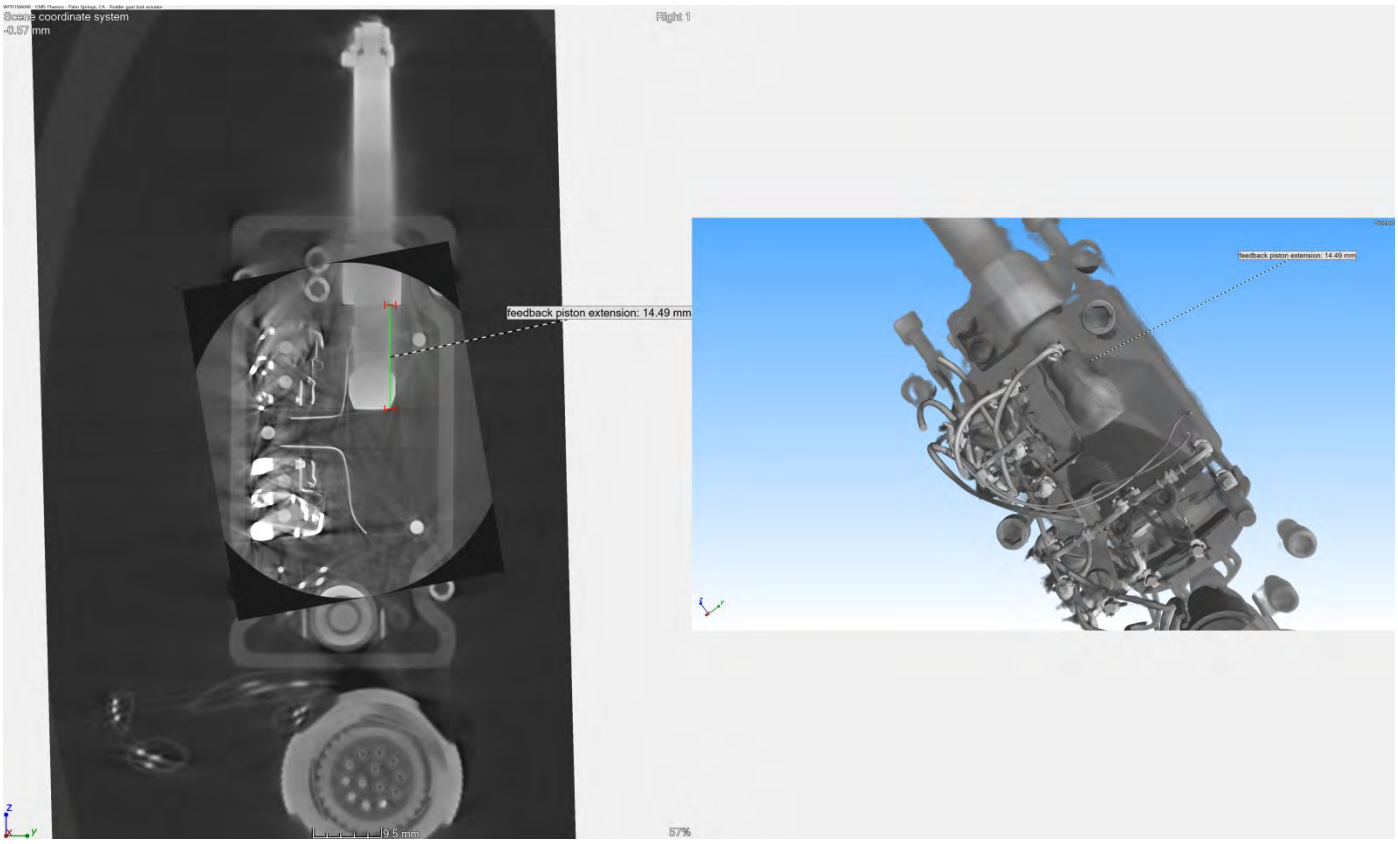

Figure 18
Rudder gust lock actuator – standard focus with microfocus view overlaid – feedback piston extension dimension

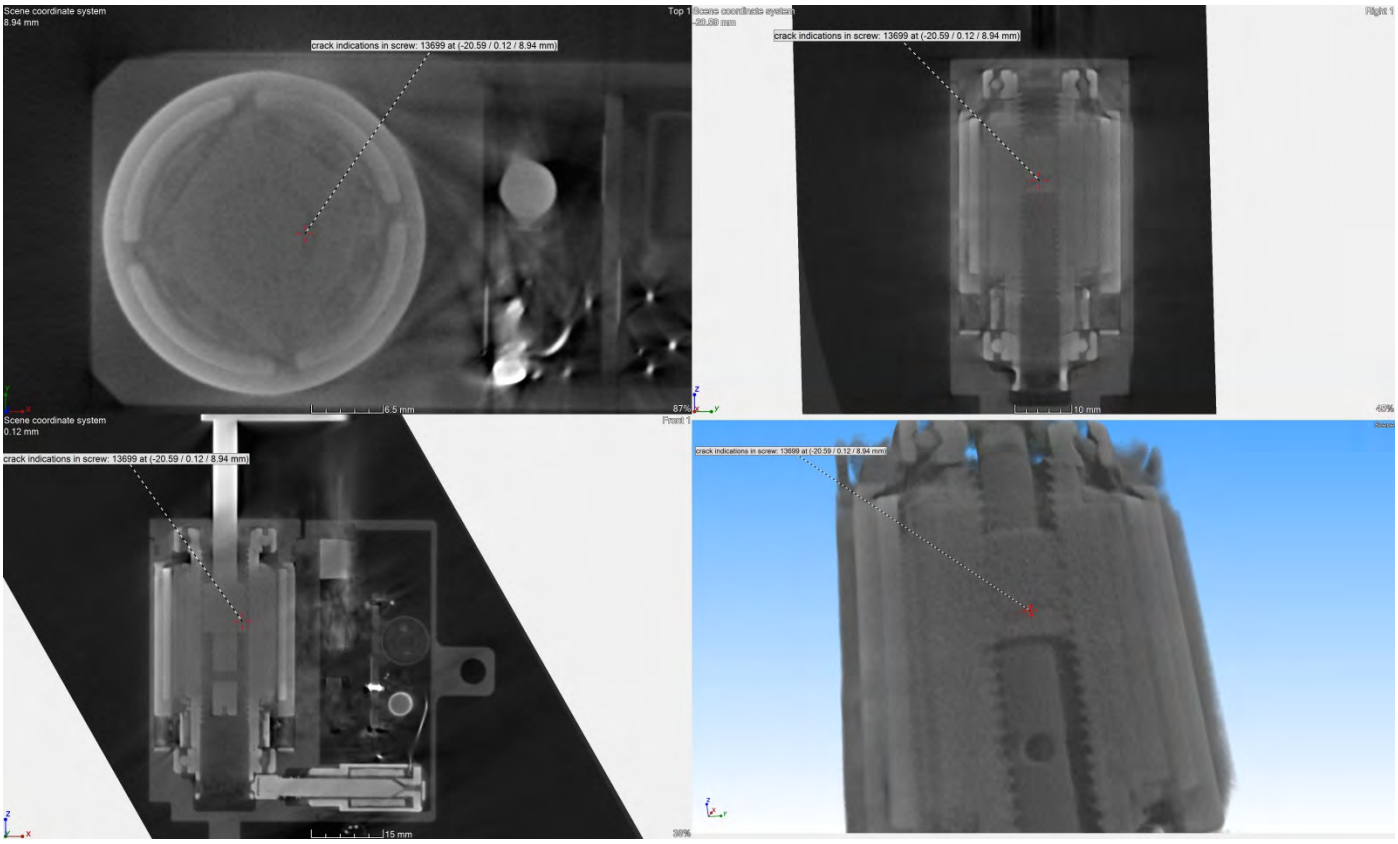

Figure 19
Rudder gust lock actuator – standard focus – crack indication in screw ball area

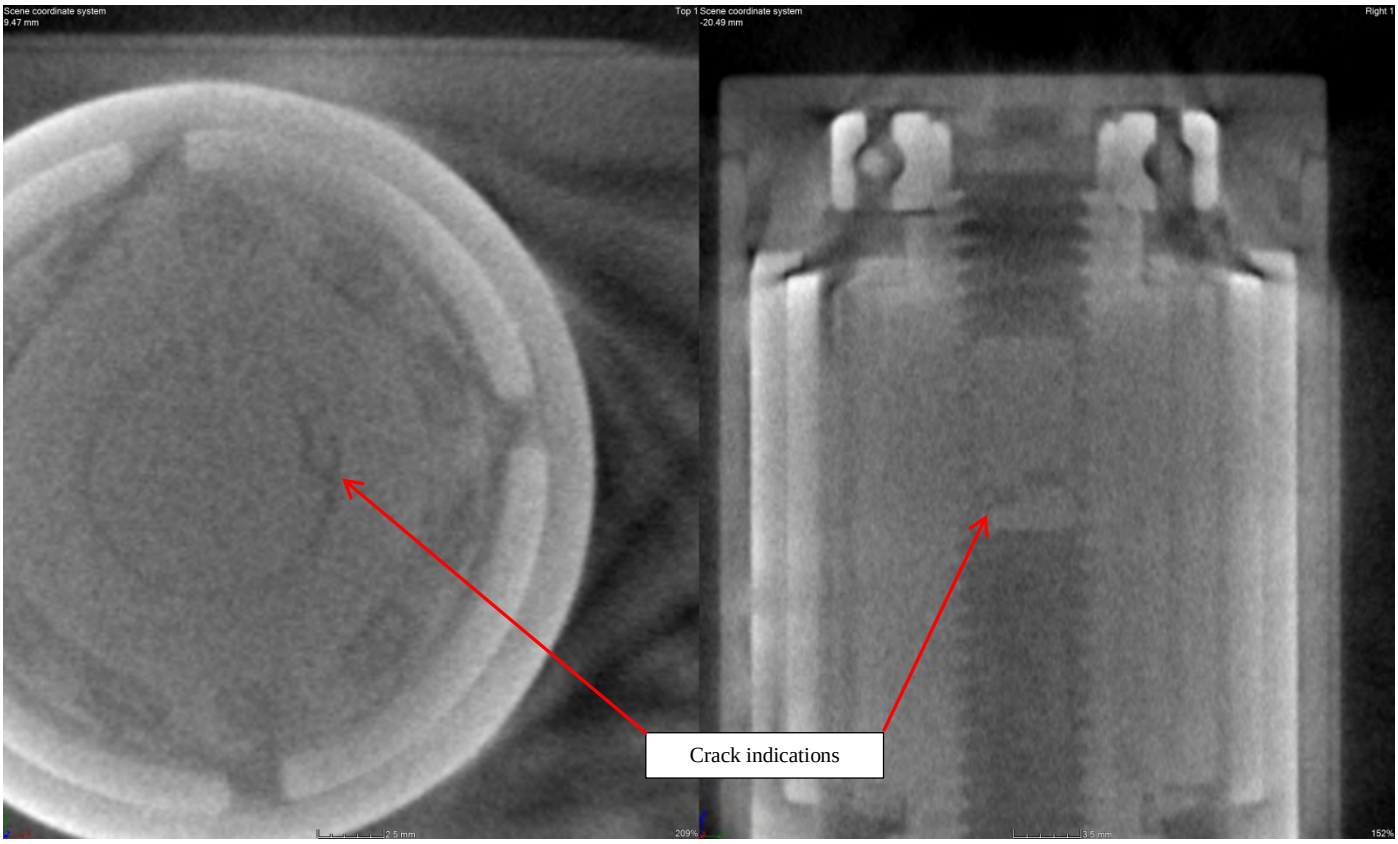

Figure 20
Rudder gust lock actuator – standard focus – crack indication in screw ball area close up view

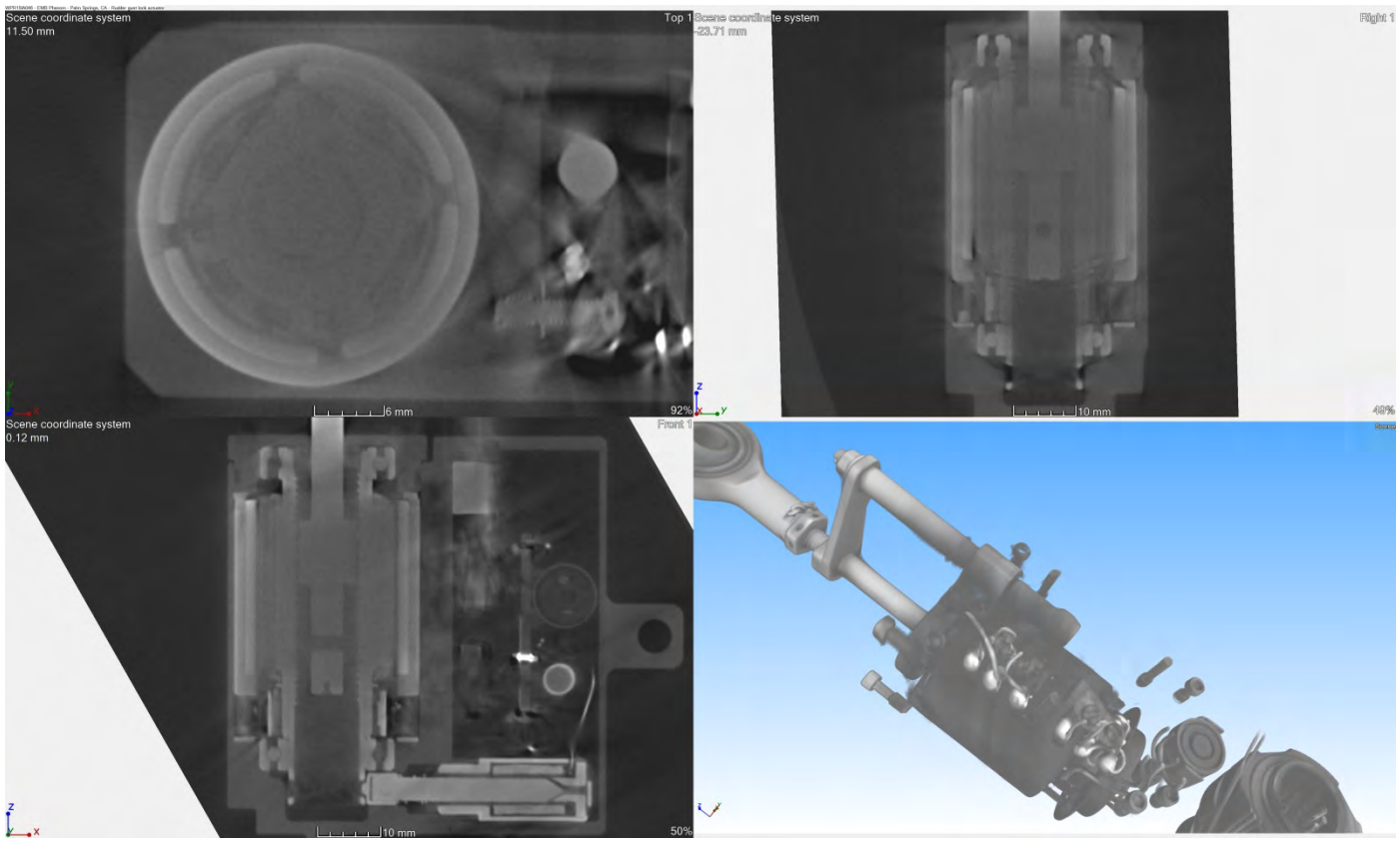

Figure 21
Rudder gust lock actuator – standard focus – overall motor and screw ball cross section

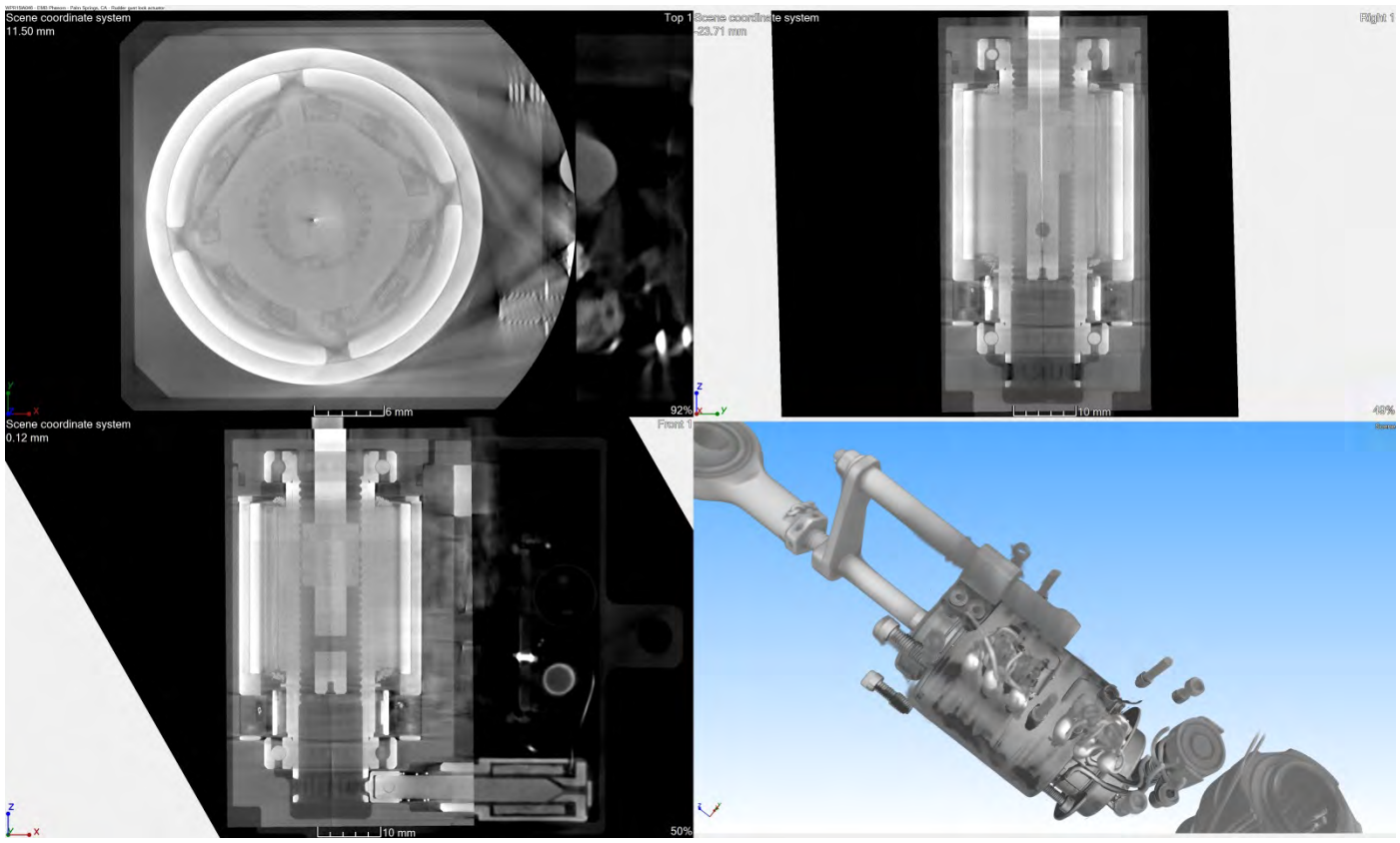

Figure 22
Rudder gust lock actuator – standard focus with microfocus view overlaid – overall motor and screw ball cross section

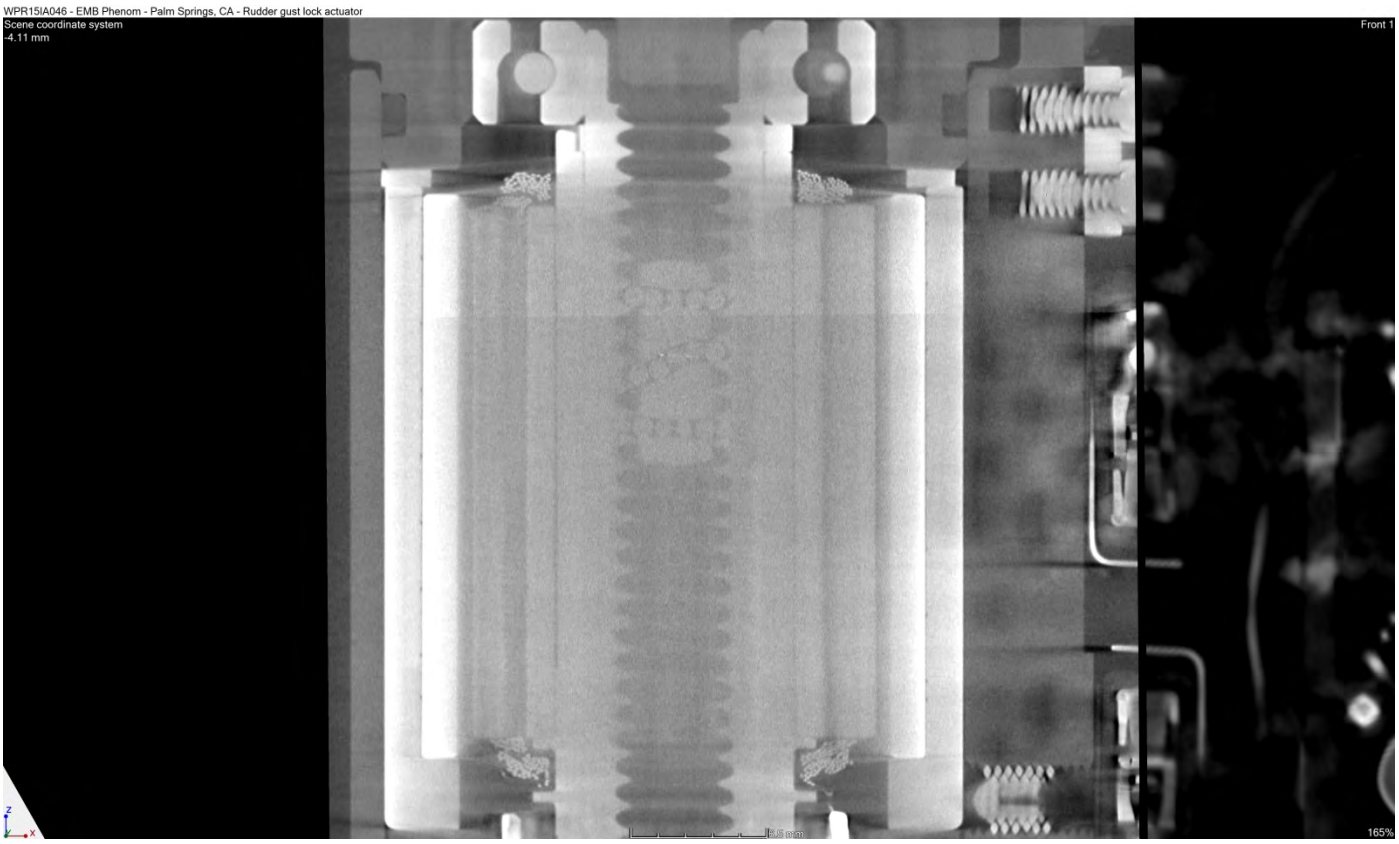

Figure 23
Rudder gust lock actuator – standard focus with microfocus view overlaid – ball screw close up view

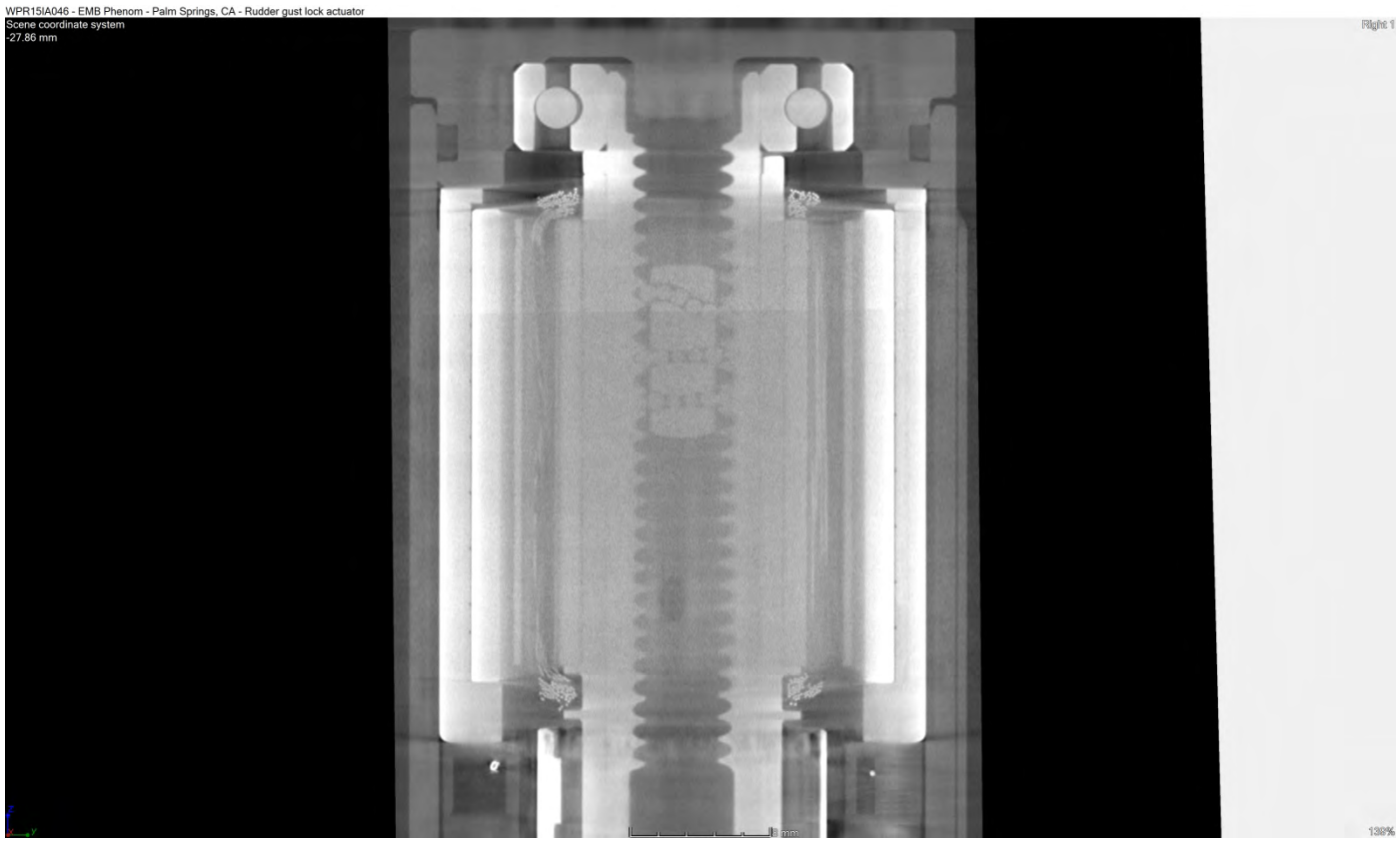

Figure 24
Rudder gust lock actuator – microfocus – ball screw close up view 2

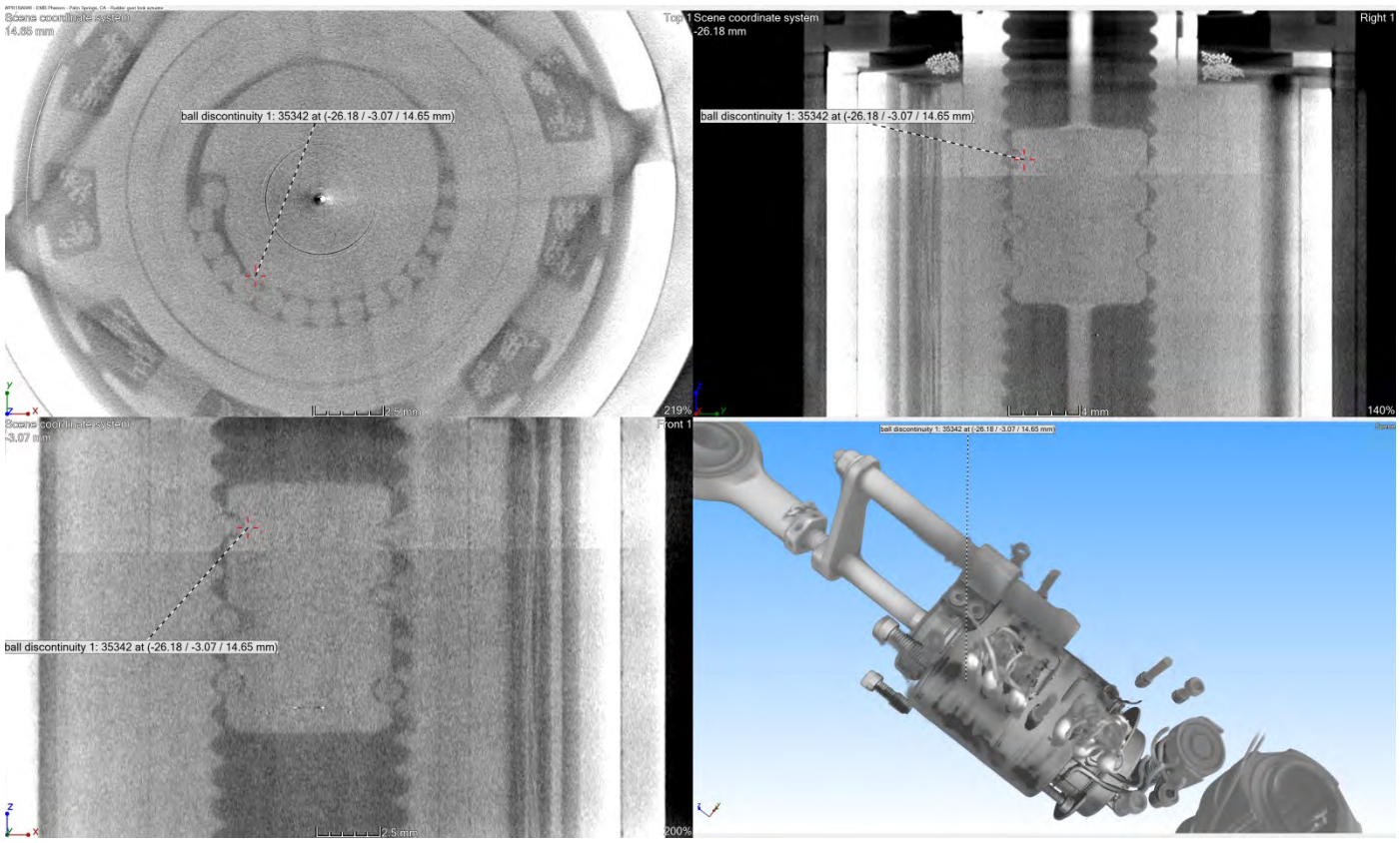

Figure 25
Rudder gust lock actuator – microfocus – ball screw showing possible ball discontinuity

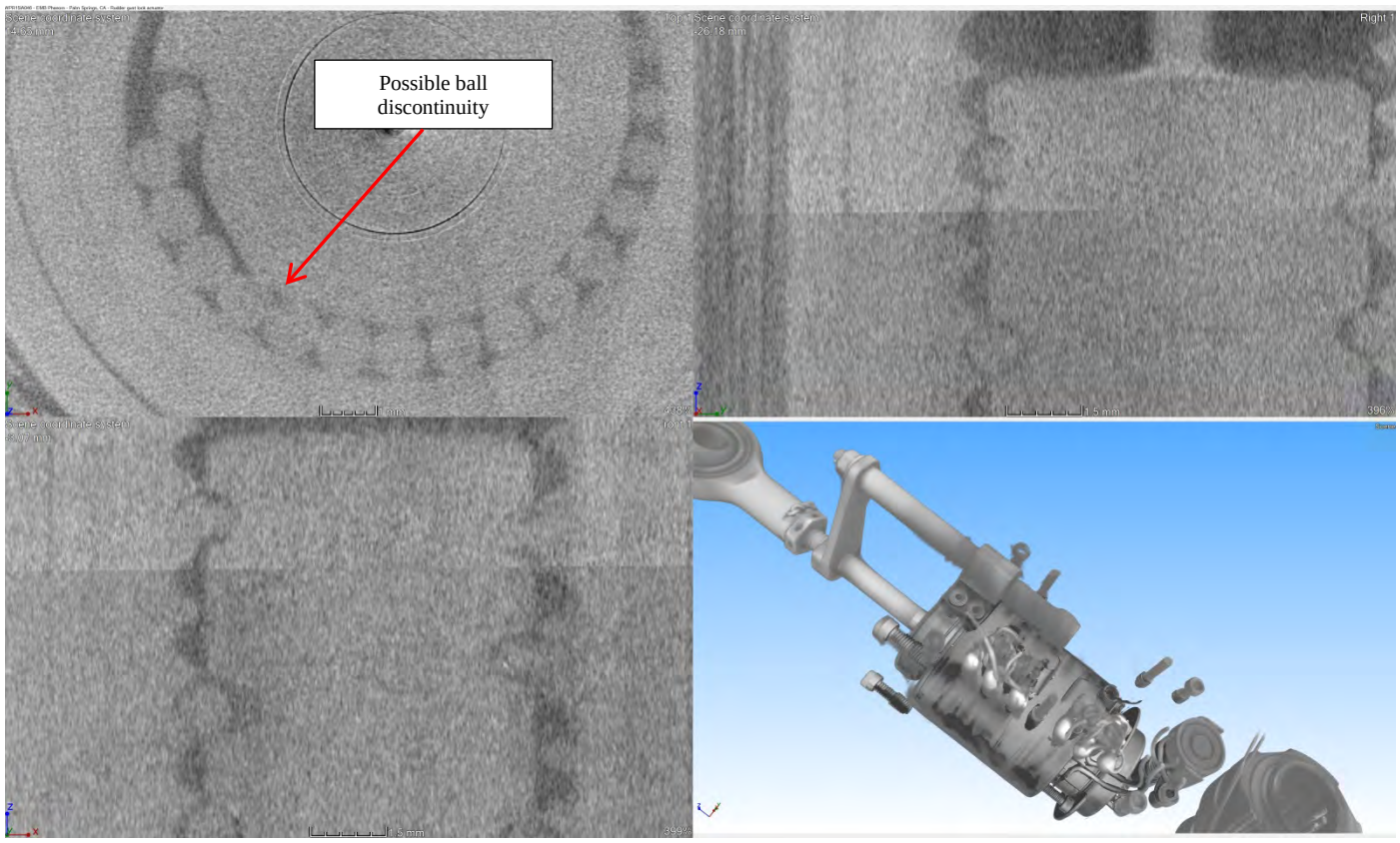

Figure 26
Rudder gust lock actuator – microfocus – ball screw showing possible ball discontinuity close up view

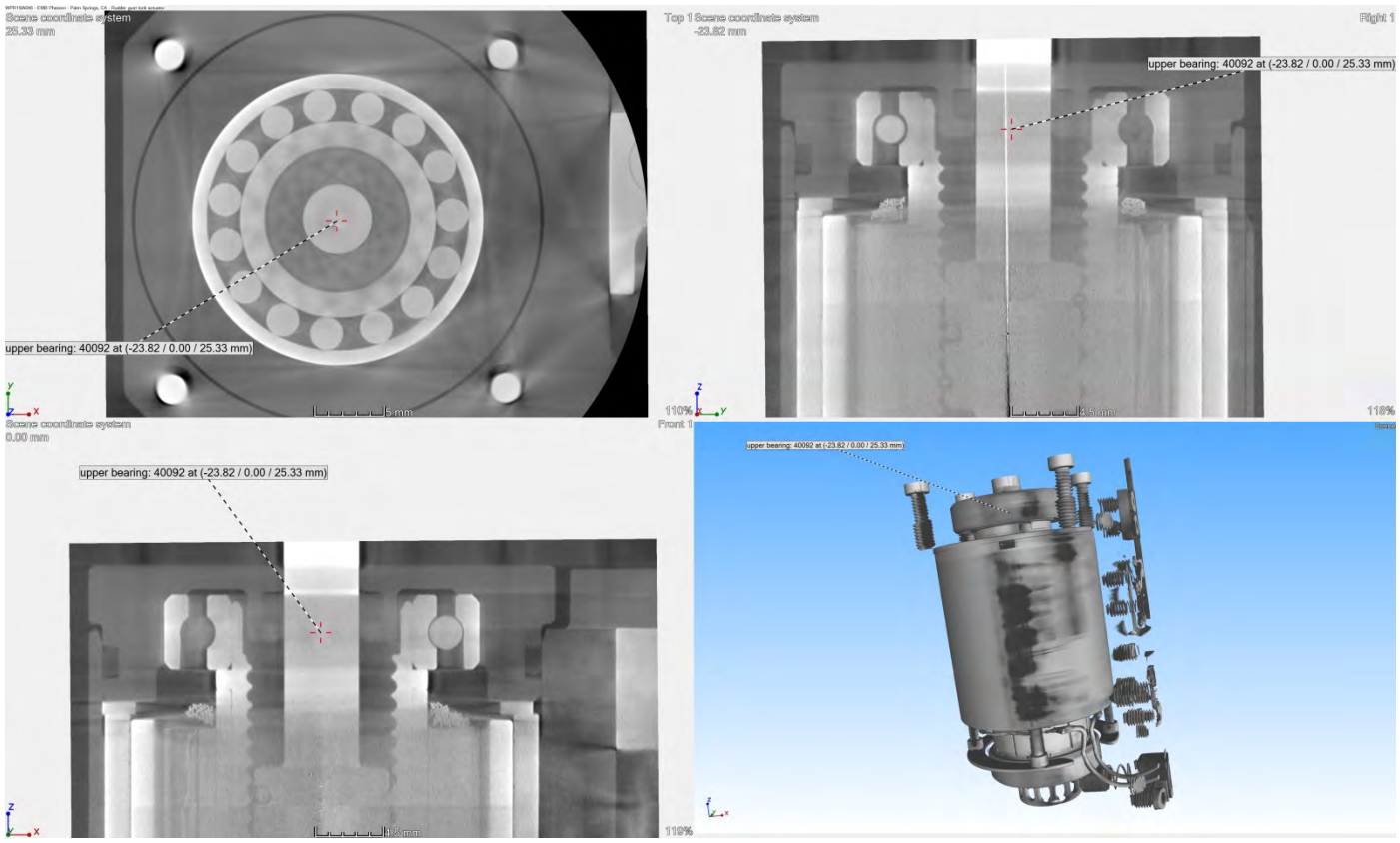

Figure 27
Rudder gust lock actuator – microfocus – upper bearing

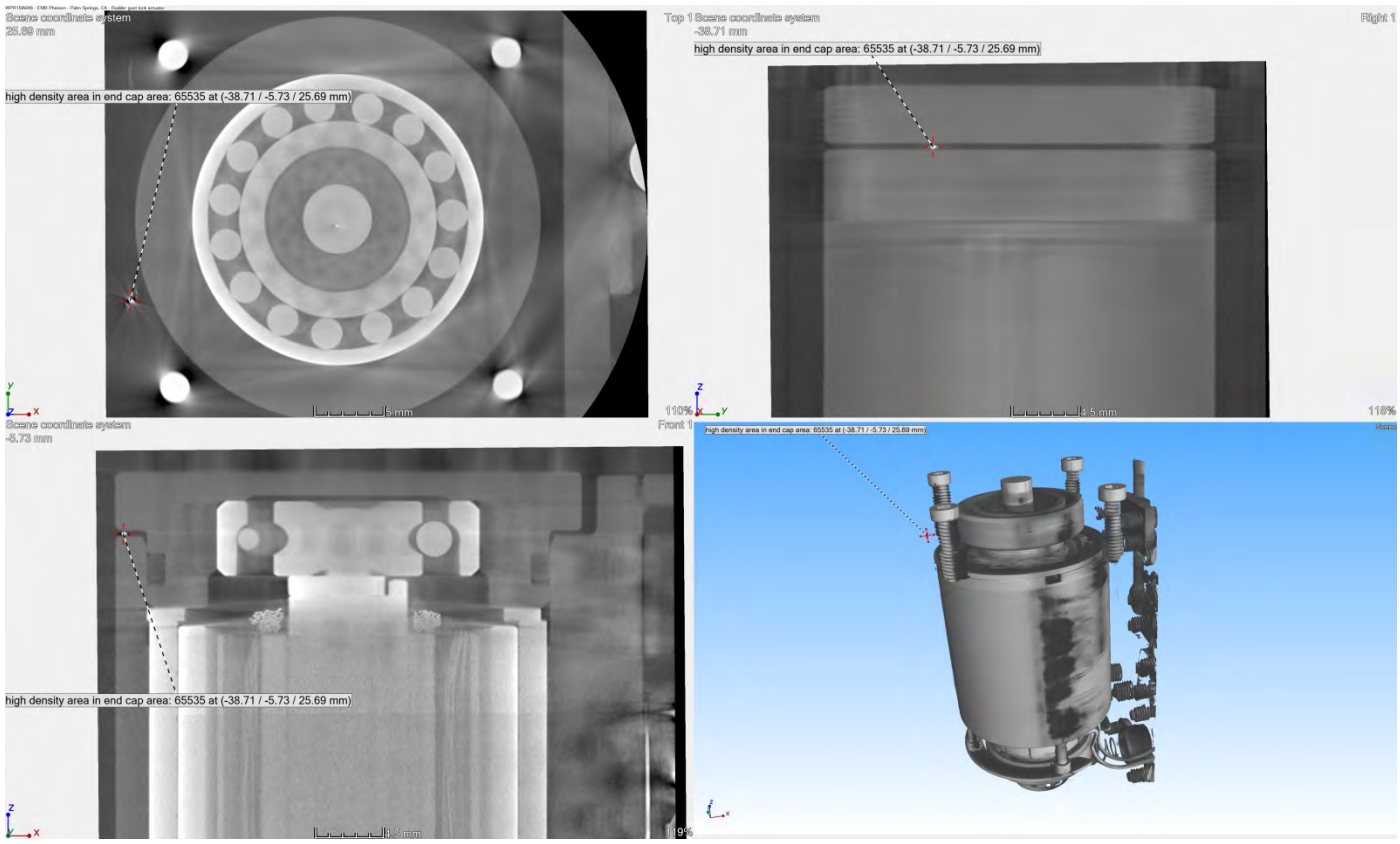

Figure 28
Rudder gust lock actuator – microfocus – high density particle in end cap area

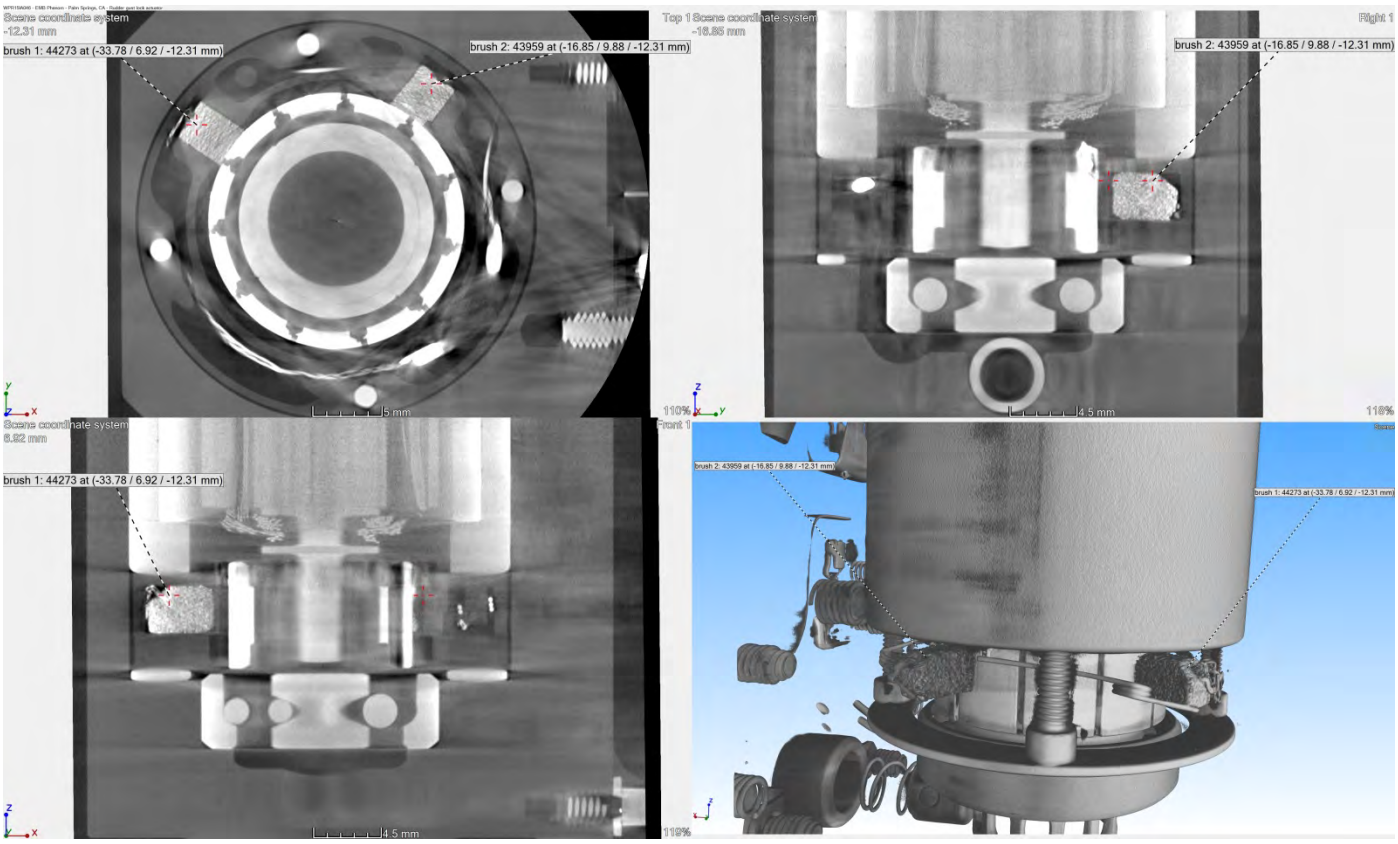

Figure 29
Rudder gust lock actuator – microfocus – motor brushes overall view

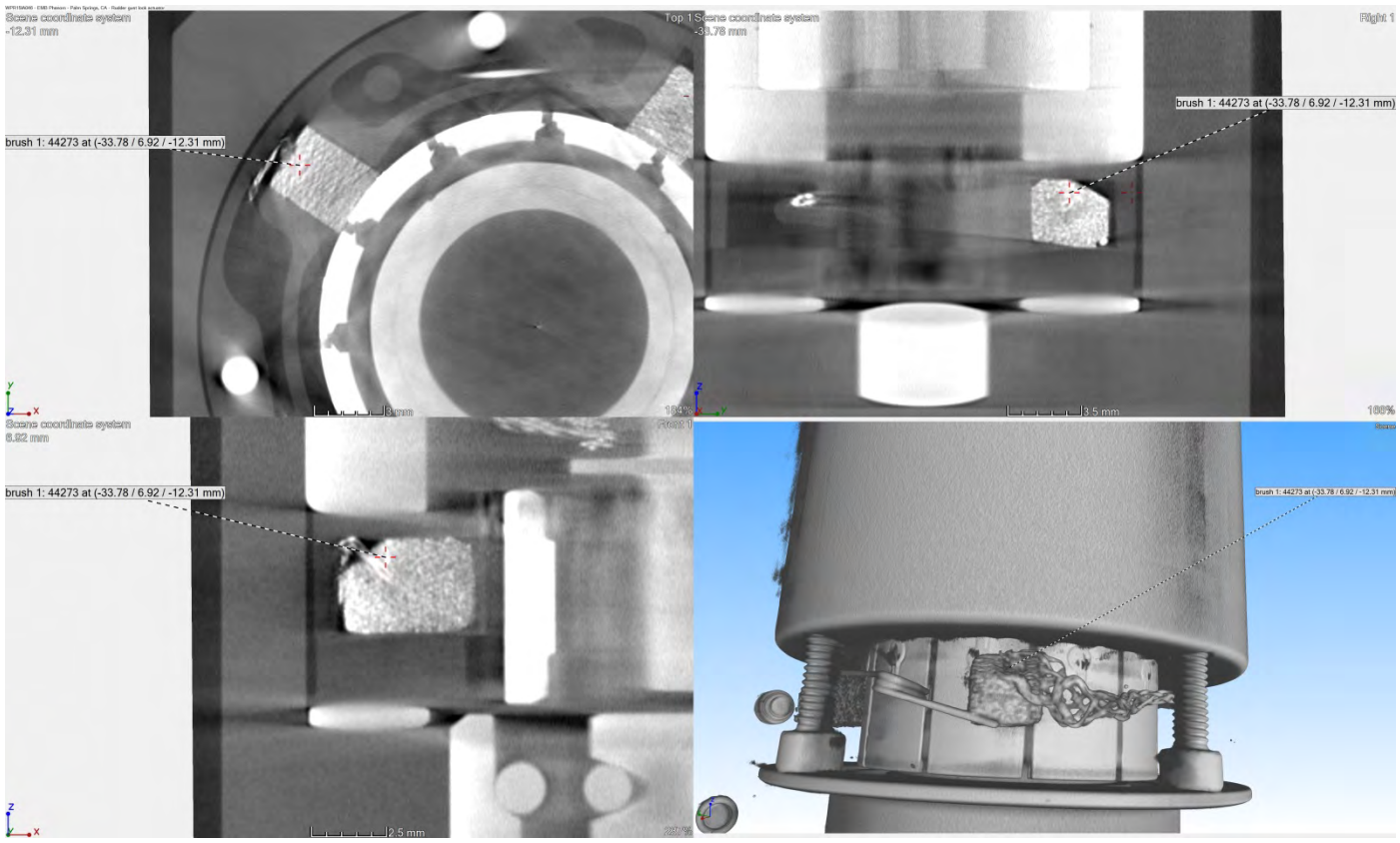

Figure 30
Rudder gust lock actuator – microfocus – motor brush 1

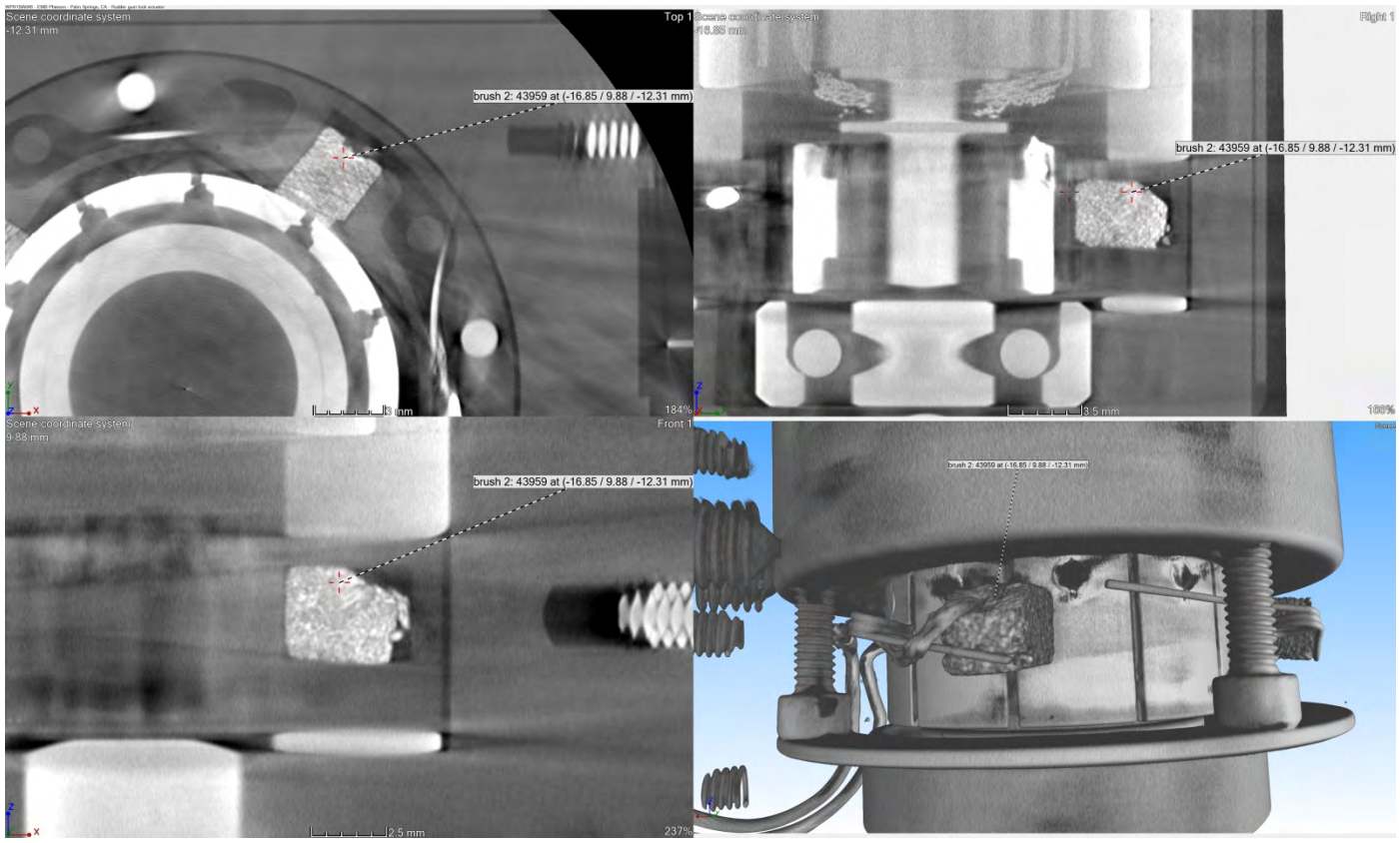

Figure 31
Rudder gust lock actuator – microfocus – motor brush 2

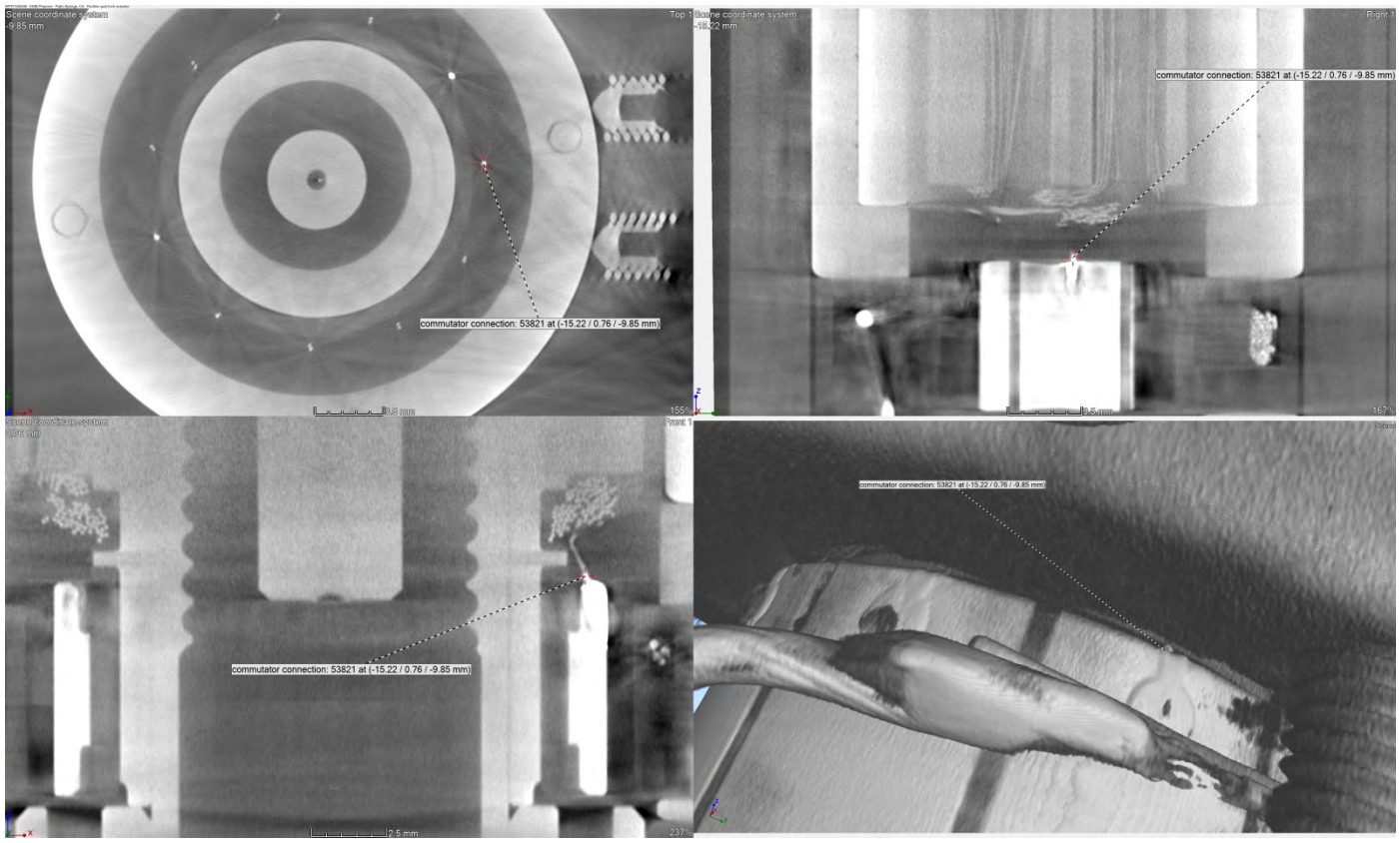

Figure 32
Rudder gust lock actuator – microfocus – commutator connection

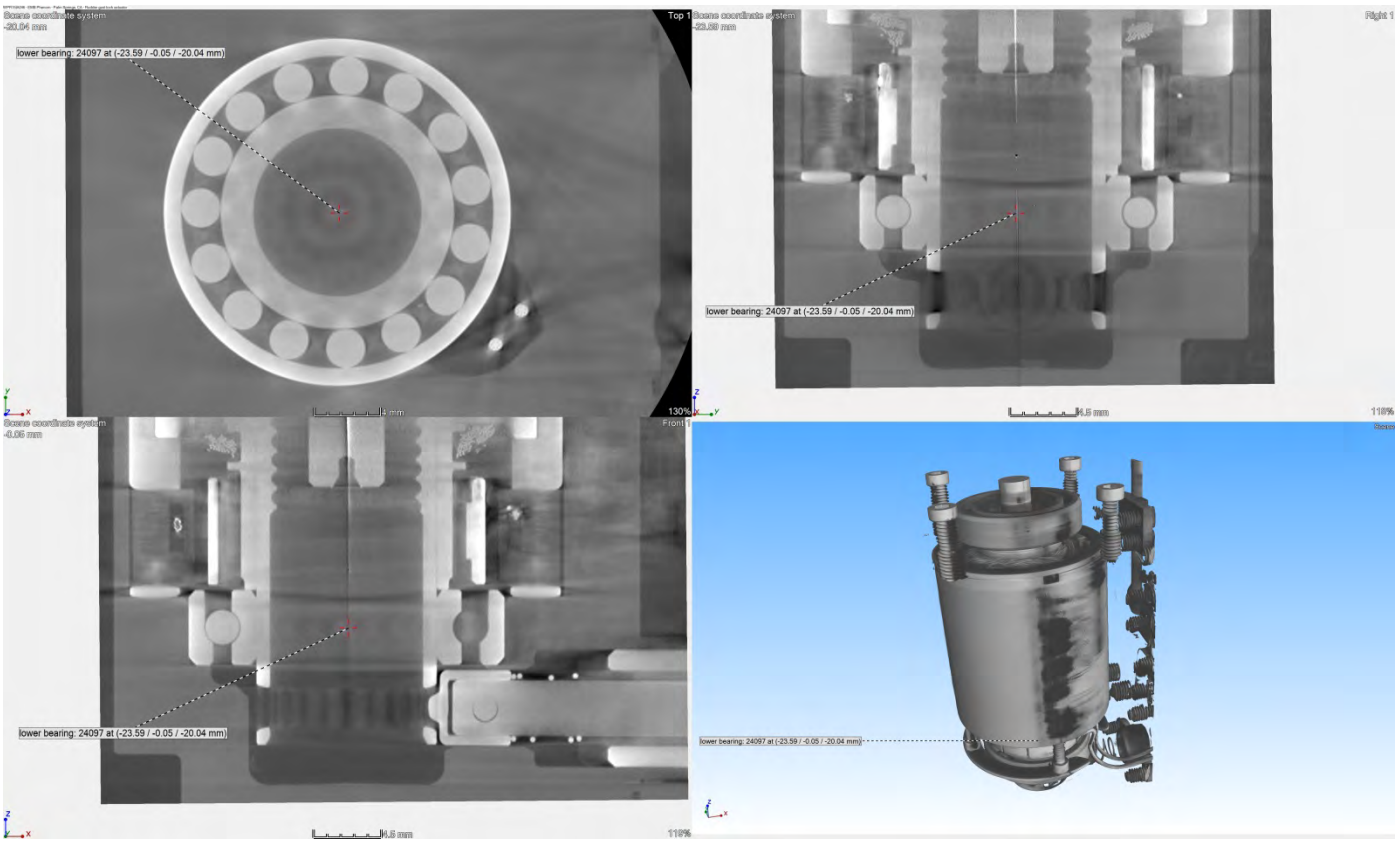

Figure 33
Rudder gust lock actuator – microfocus – lower bearing

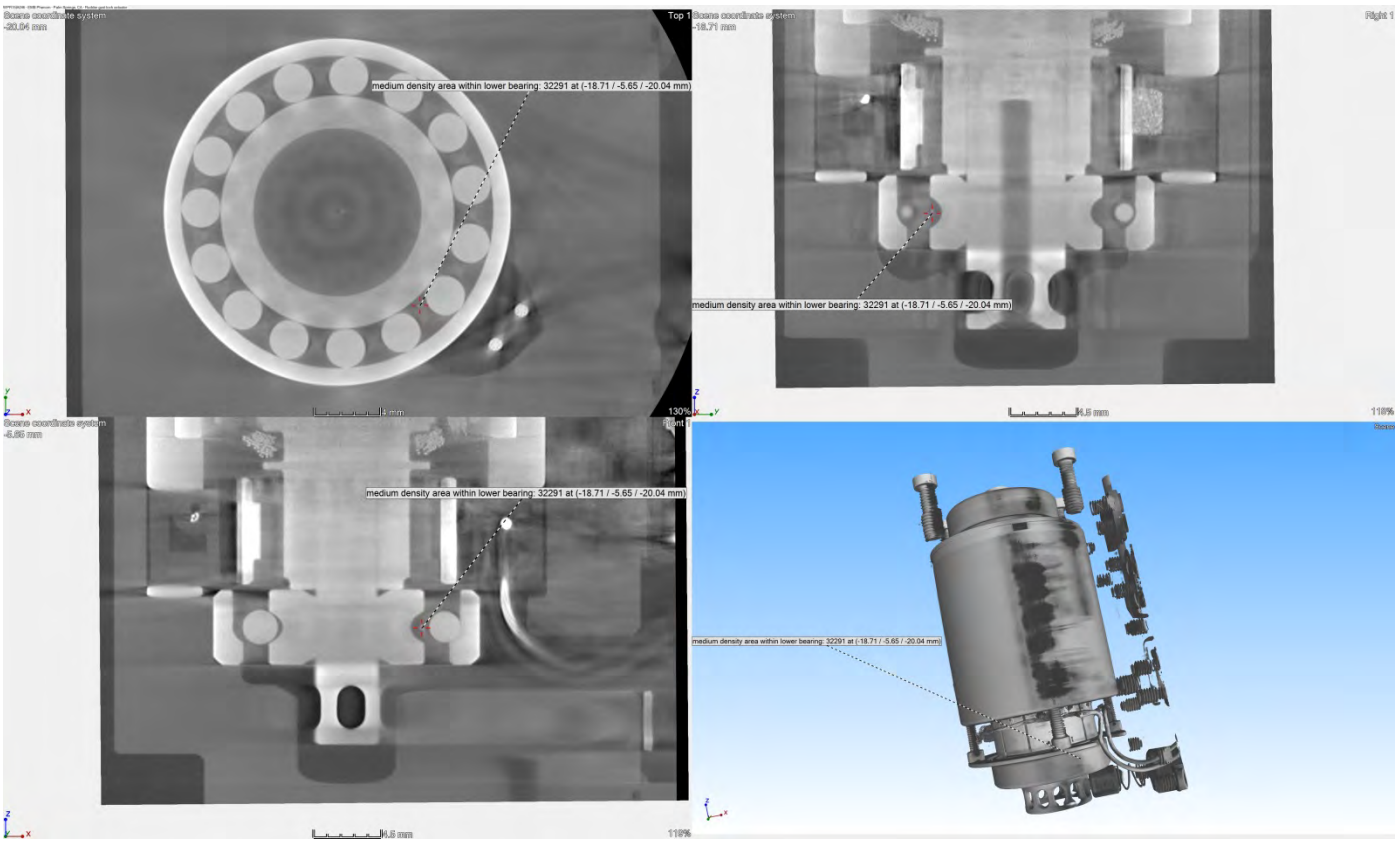

Figure 34
Rudder gust lock actuator – microfocus – medium density area within the lower bearing

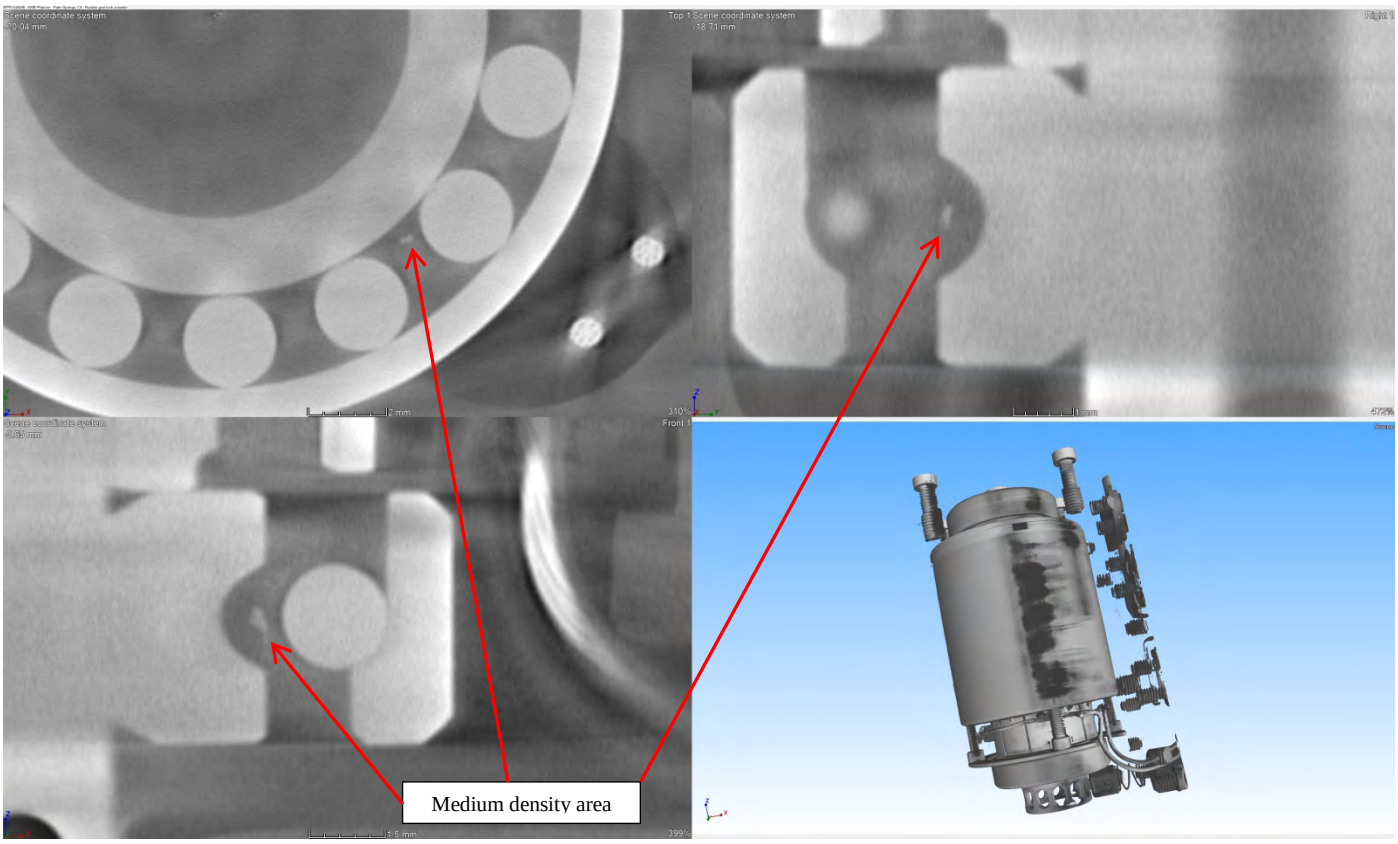

Figure 35
Rudder gust lock actuator – microfocus – medium density area within the lower bearing close up view

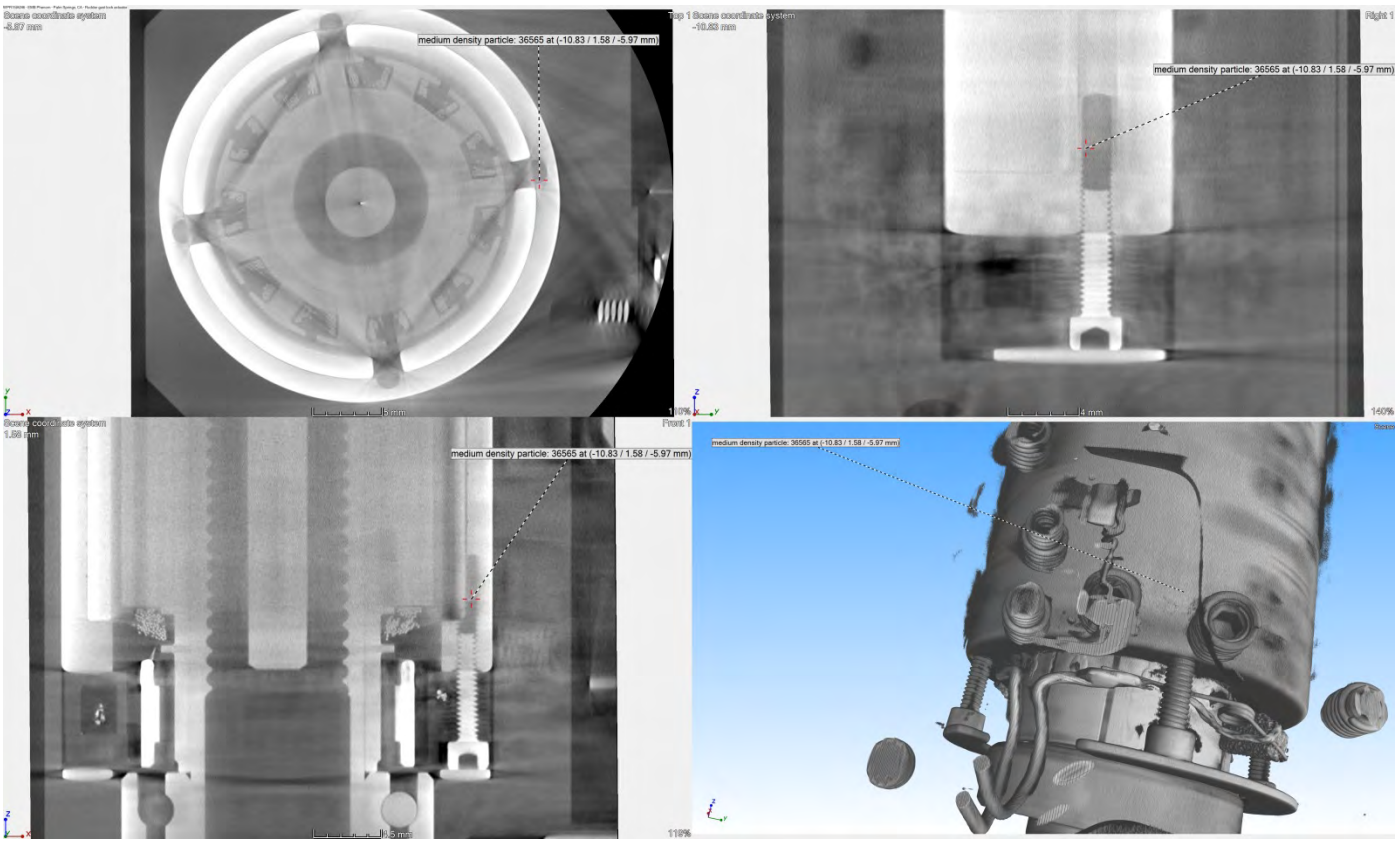

Figure 36
Rudder gust lock actuator – microfocus – medium density particle in housing

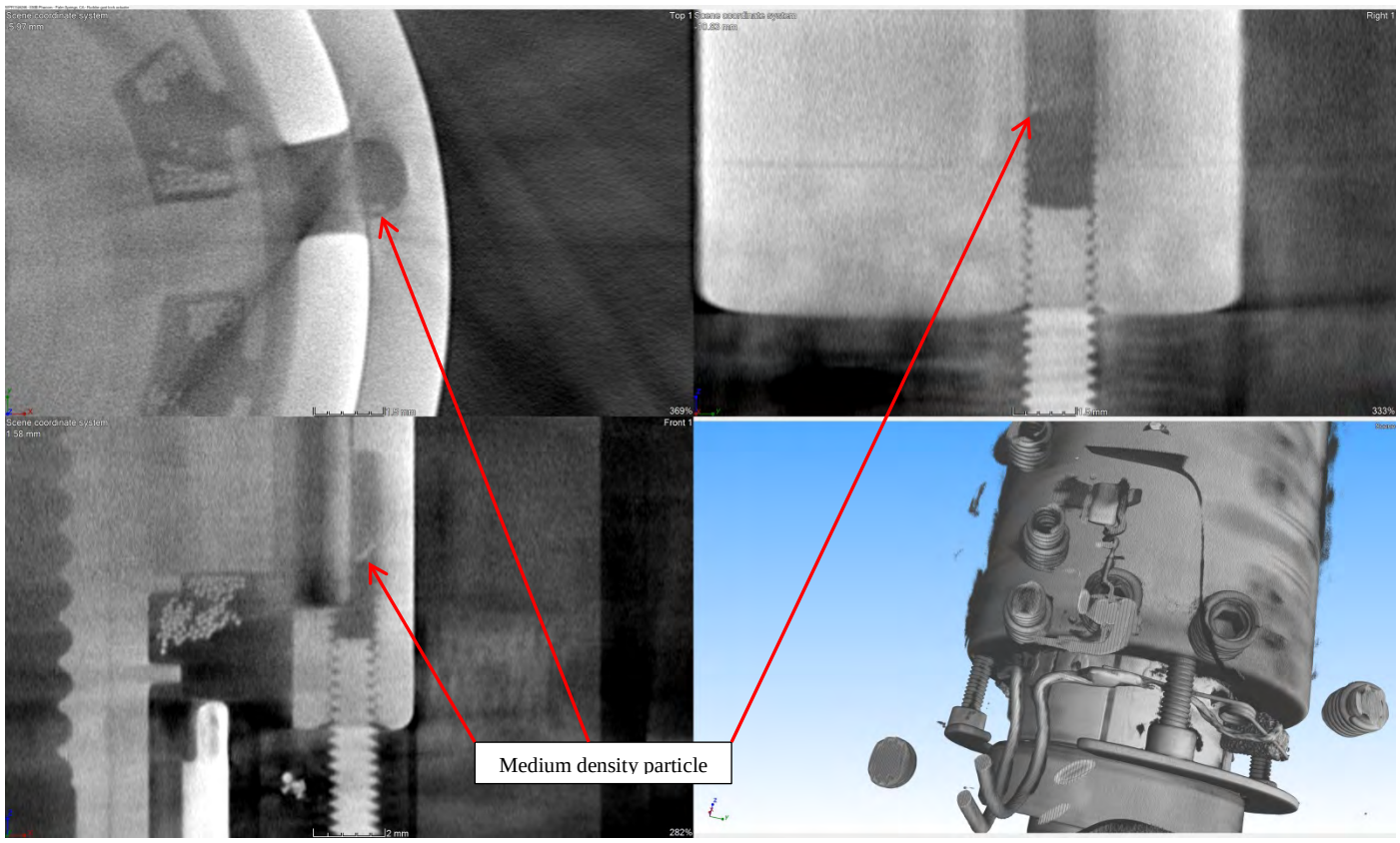

Figure 37
Rudder gust lock actuator – microfocus – medium density particle in housing close up view

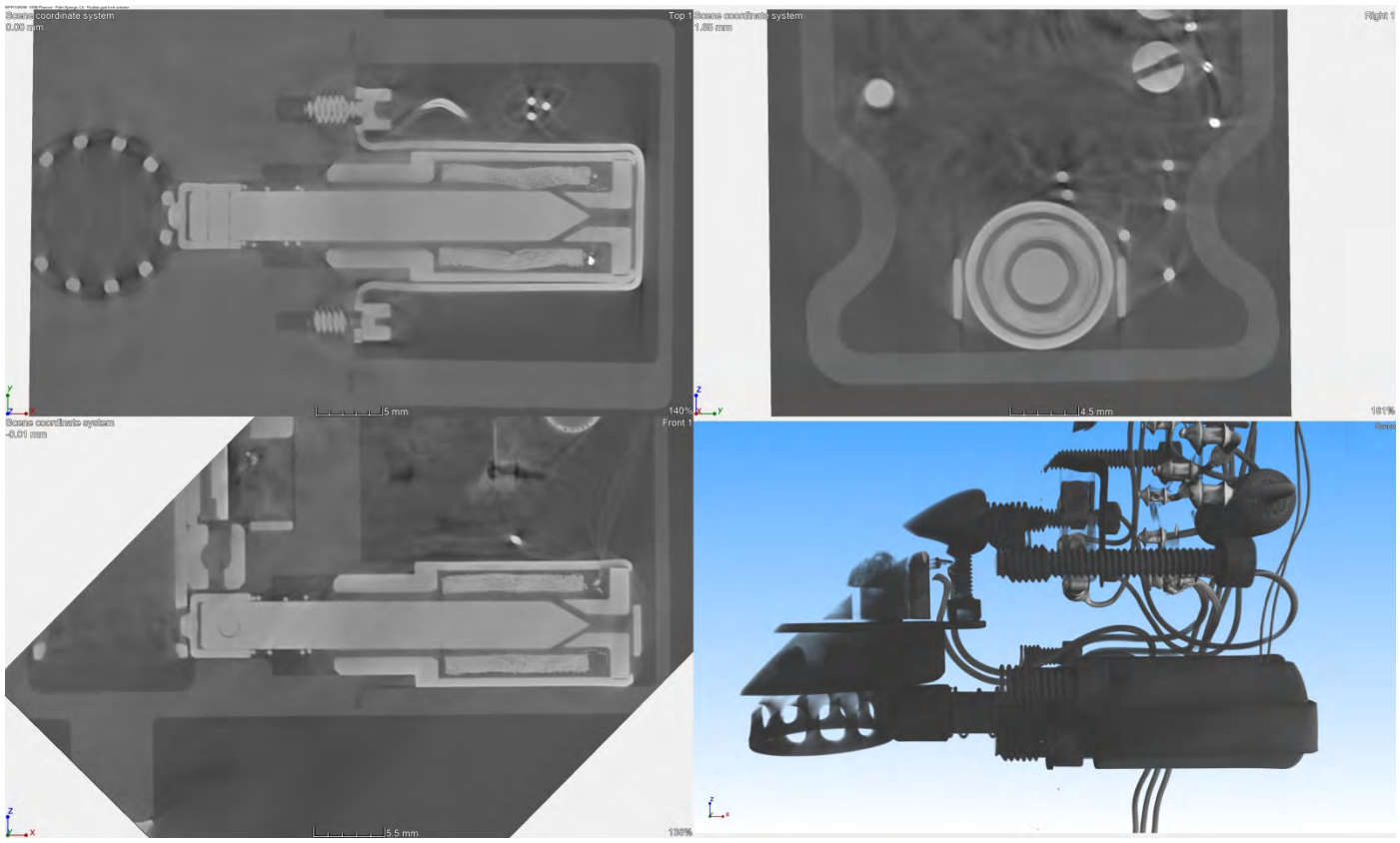

Figure 38
Rudder gust lock actuator – microfocus – solenoid overall cross section

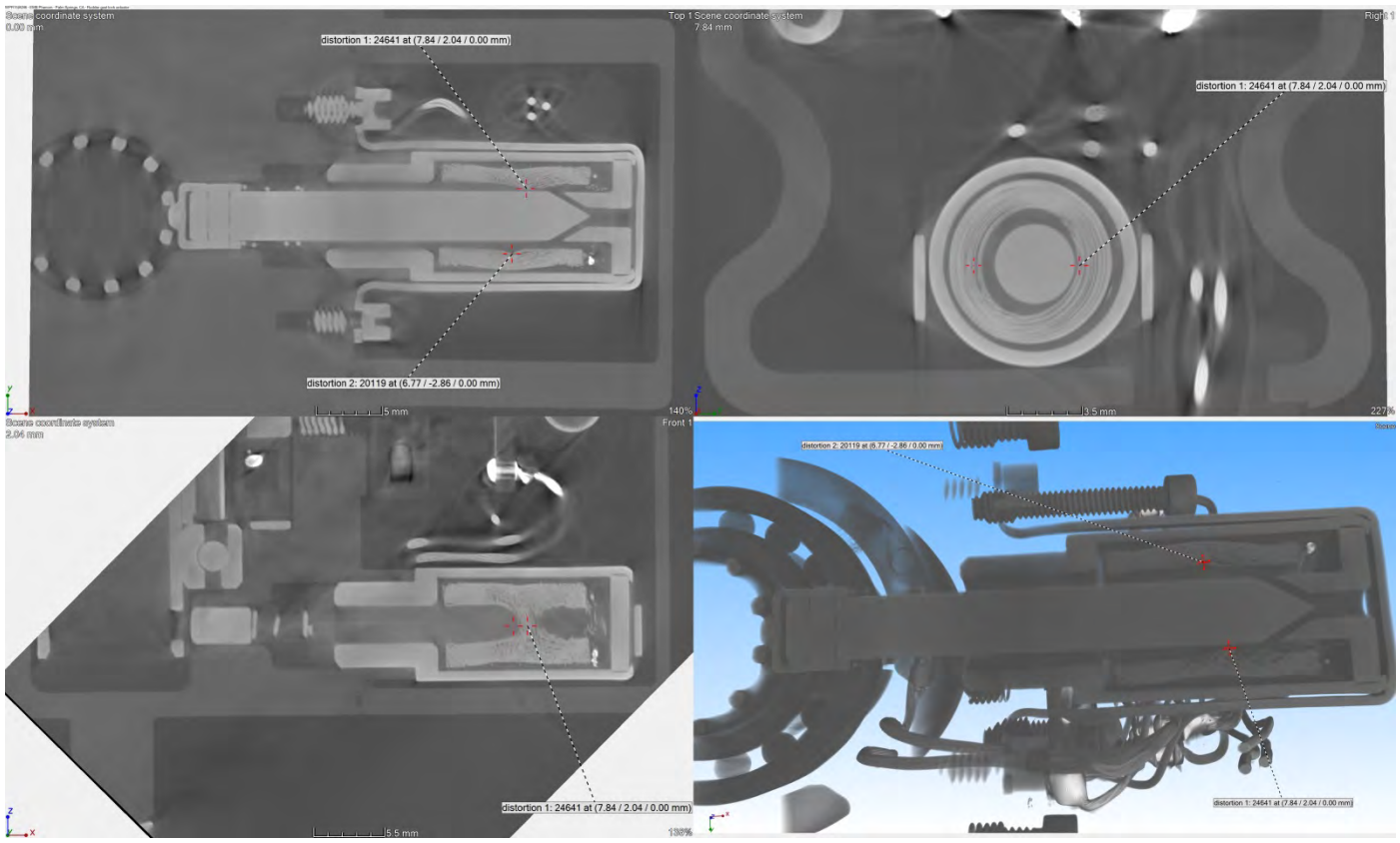

Figure 39
Rudder gust lock actuator – microfocus – solenoid overall cross section showing winding distortions 1 and 2

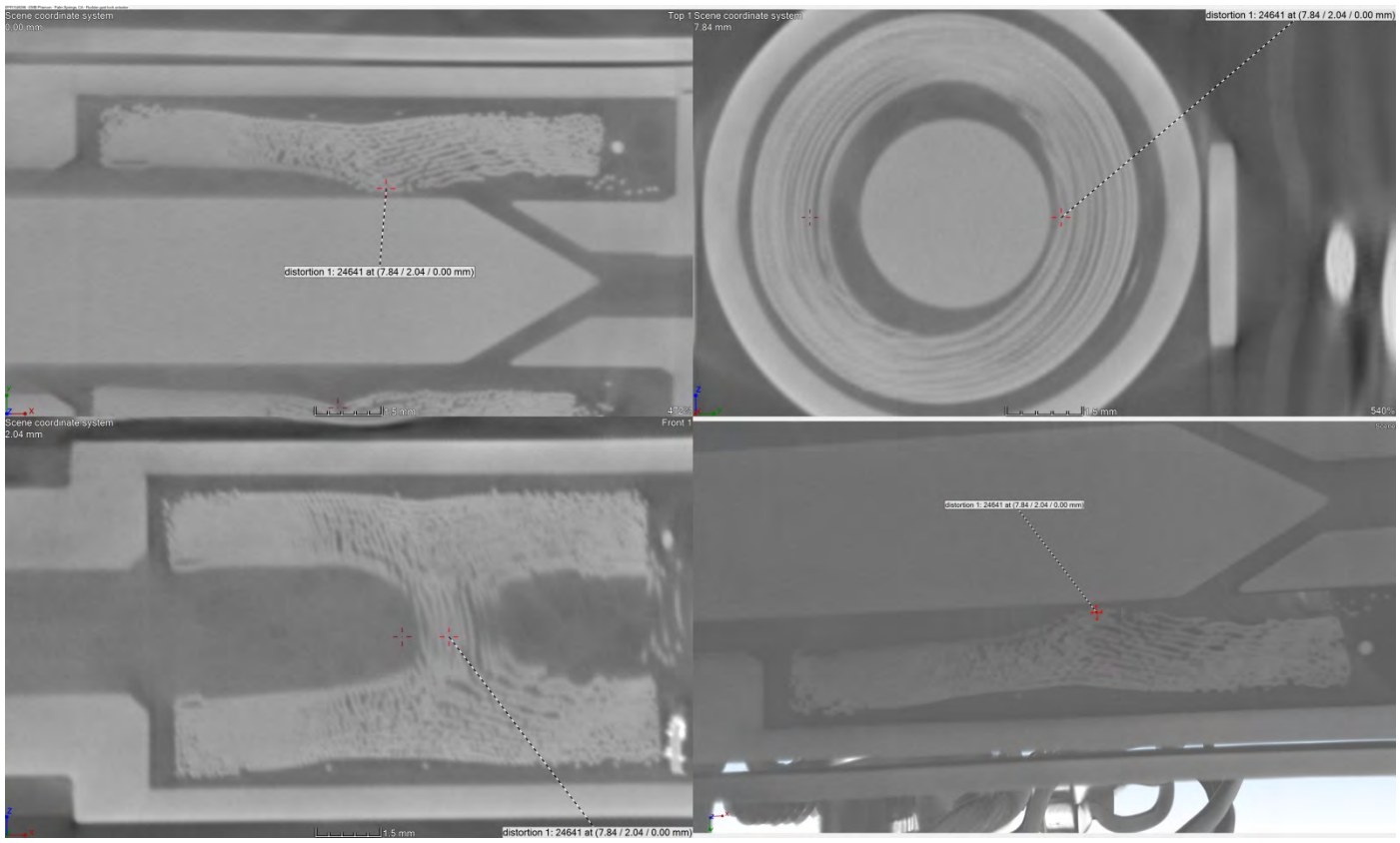

Figure 40
Rudder gust lock actuator – microfocus – solenoid showing winding distortion 1 close up view

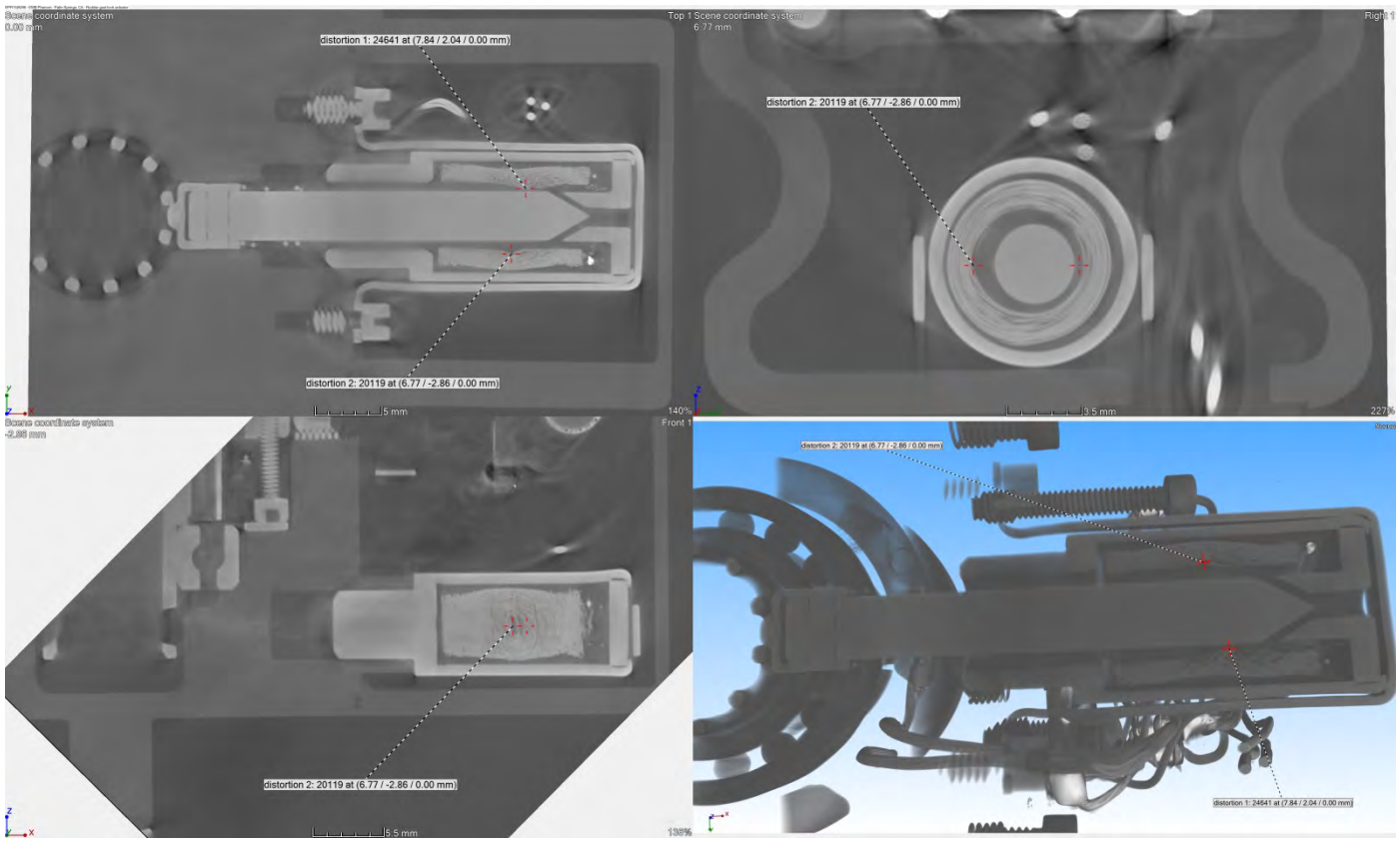

Figure 41
Rudder gust lock actuator – microfocus – solenoid overall cross section showing winding distortion 2

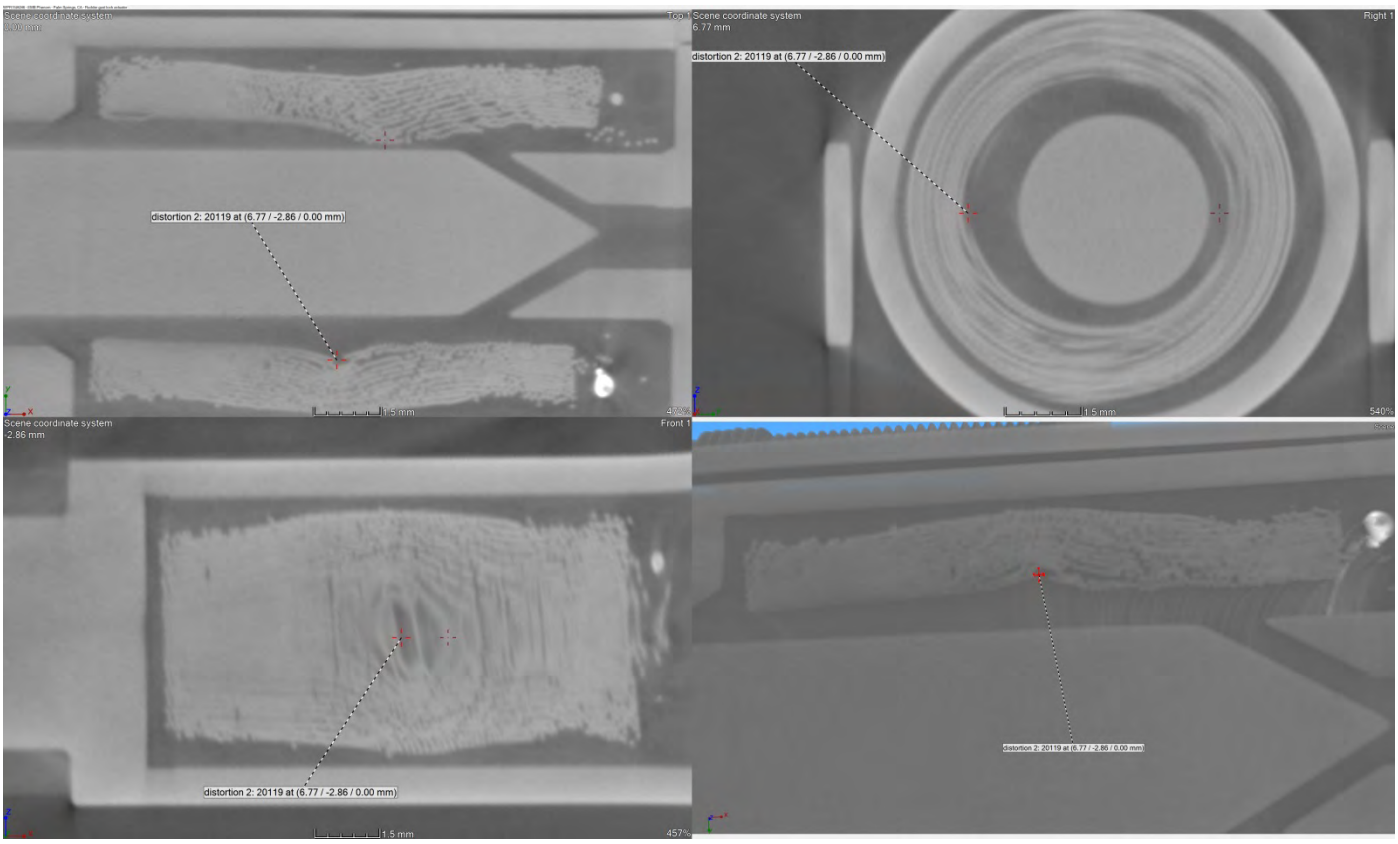

Figure 42
Rudder gust lock actuator – microfocus – solenoid showing winding distortion 2 close up view

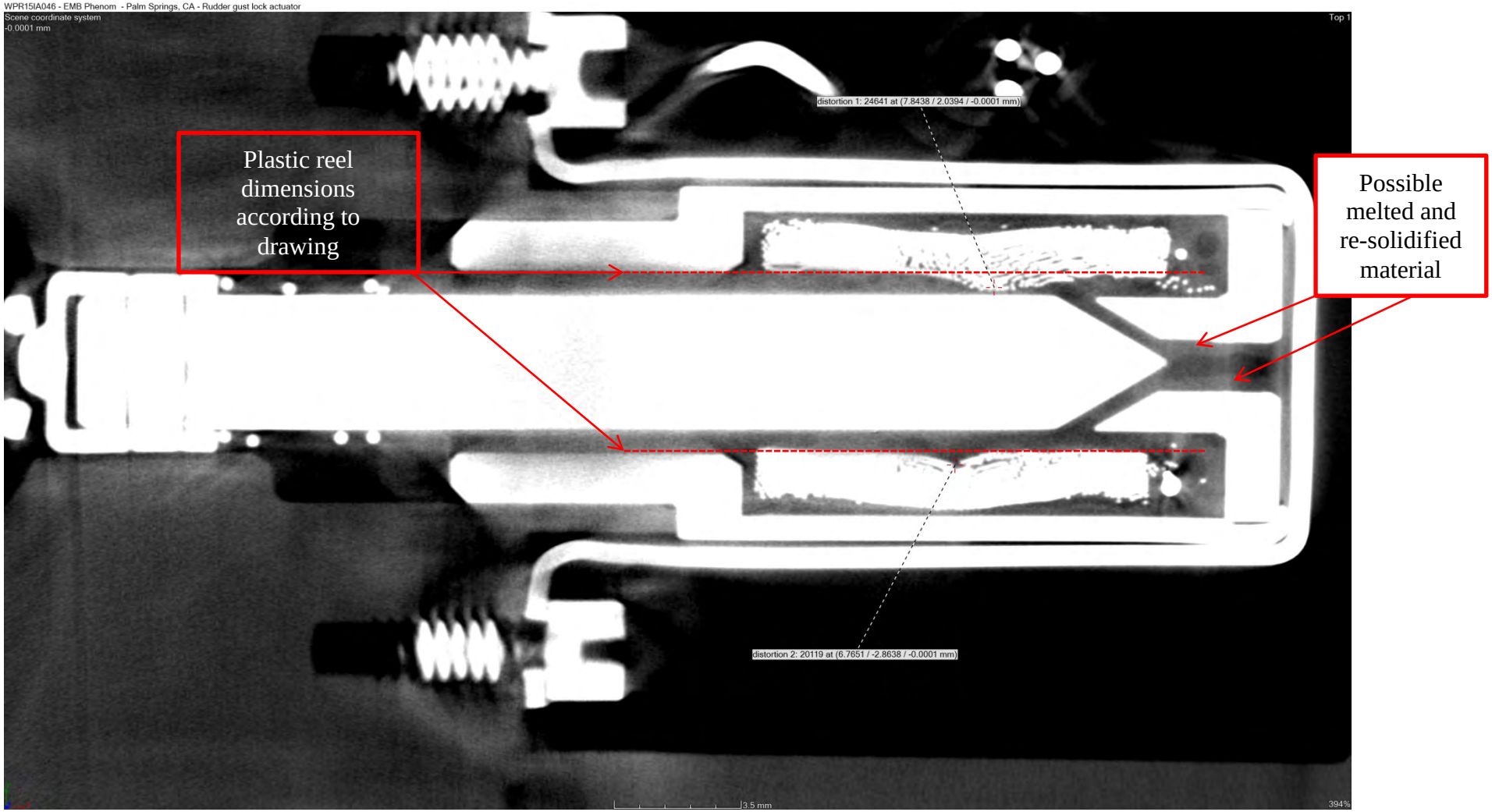

Figure 43

Rudder gust lock actuator – enhanced contrast microfocus – solenoid showing winding distortions 1 and 2, the plastic reel dimensions according to the drawing, and possible melted and re-solidified material

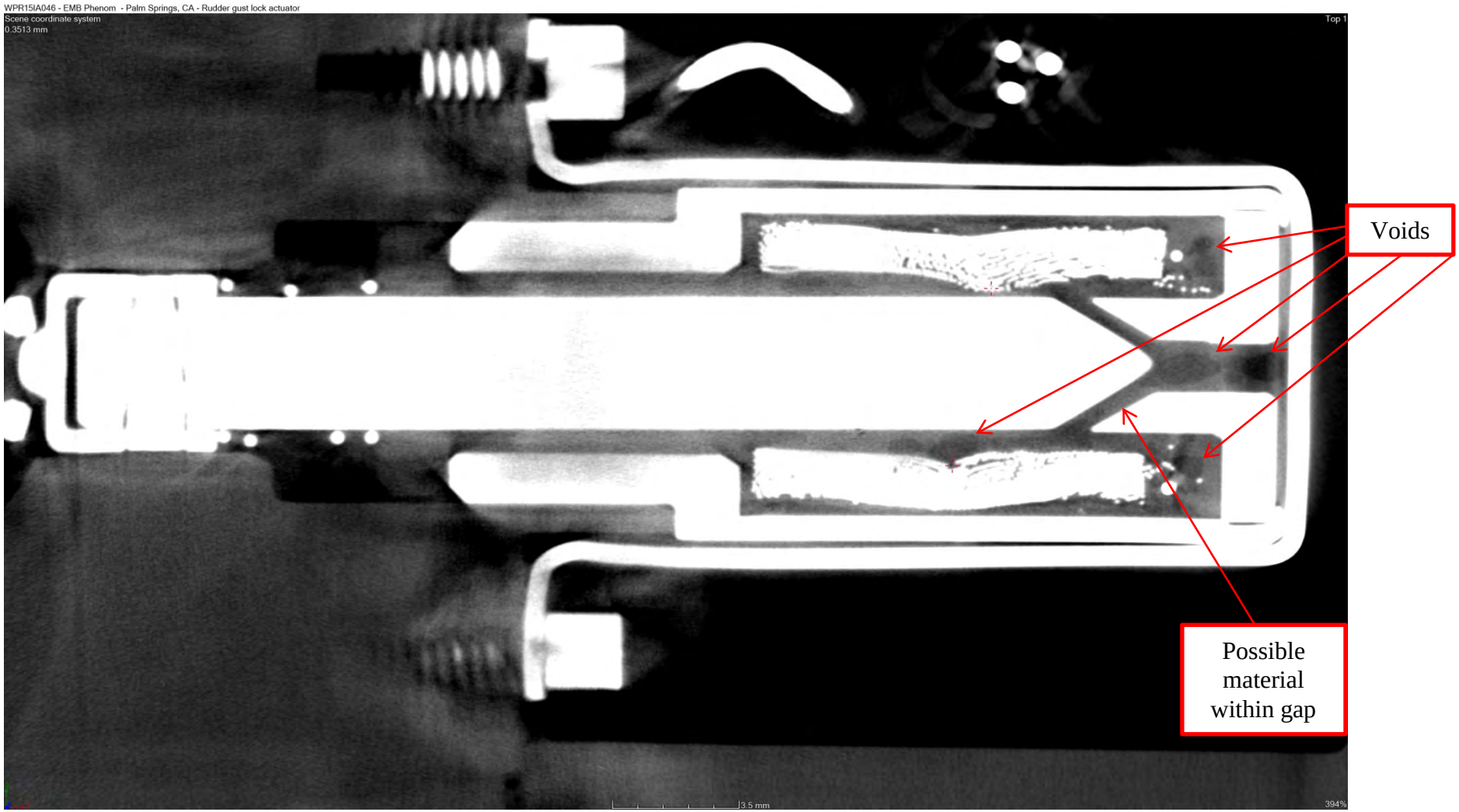

Figure 44

Rudder gust lock actuator – enhanced contrast microfocus – solenoid showing possible material within the solenoid gaps along with voids in those areas

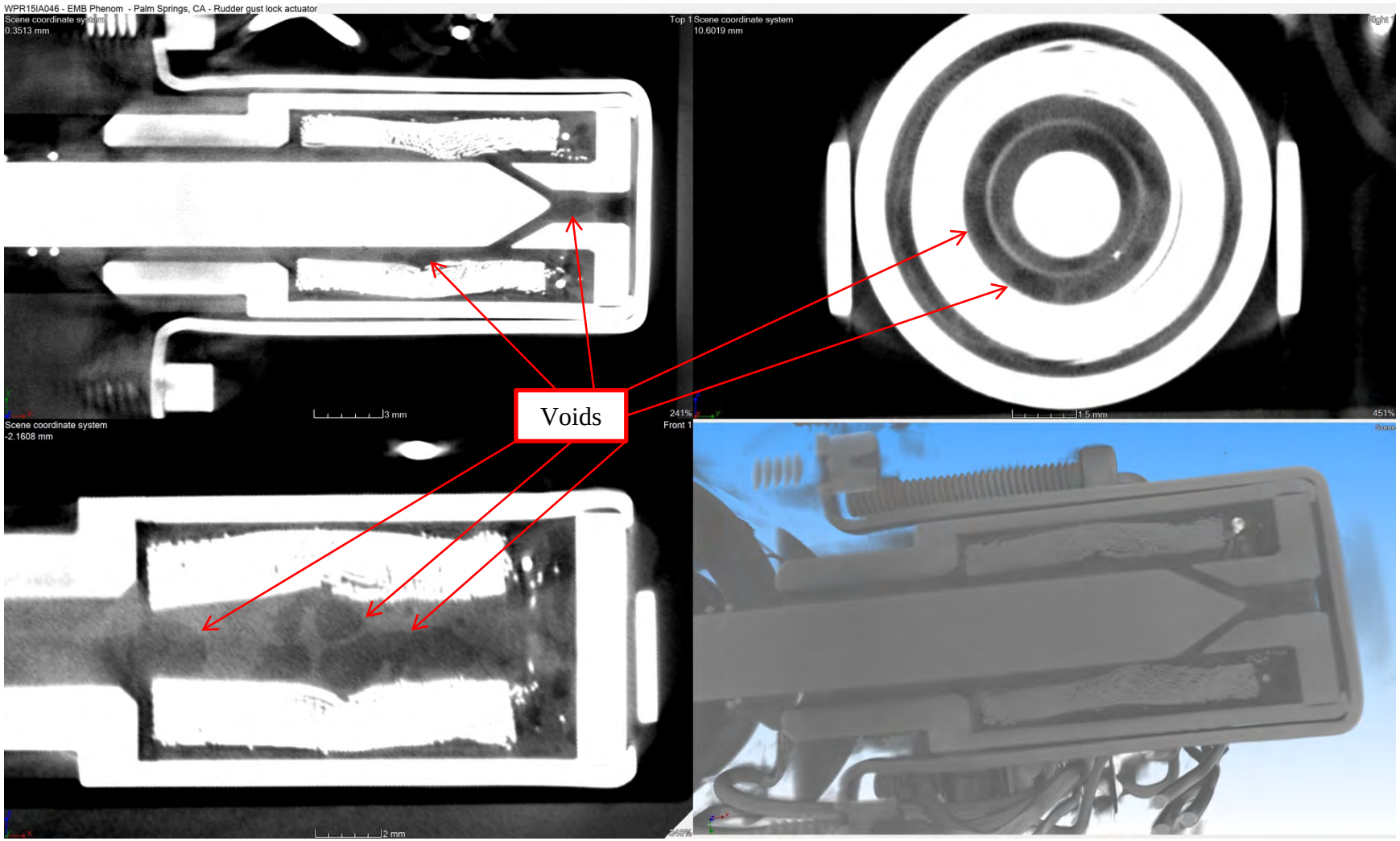

Figure 45

Rudder gust lock actuator – enhanced contrast microfocus – solenoid showing possible material and voids in areas between the solenoid windings and piston

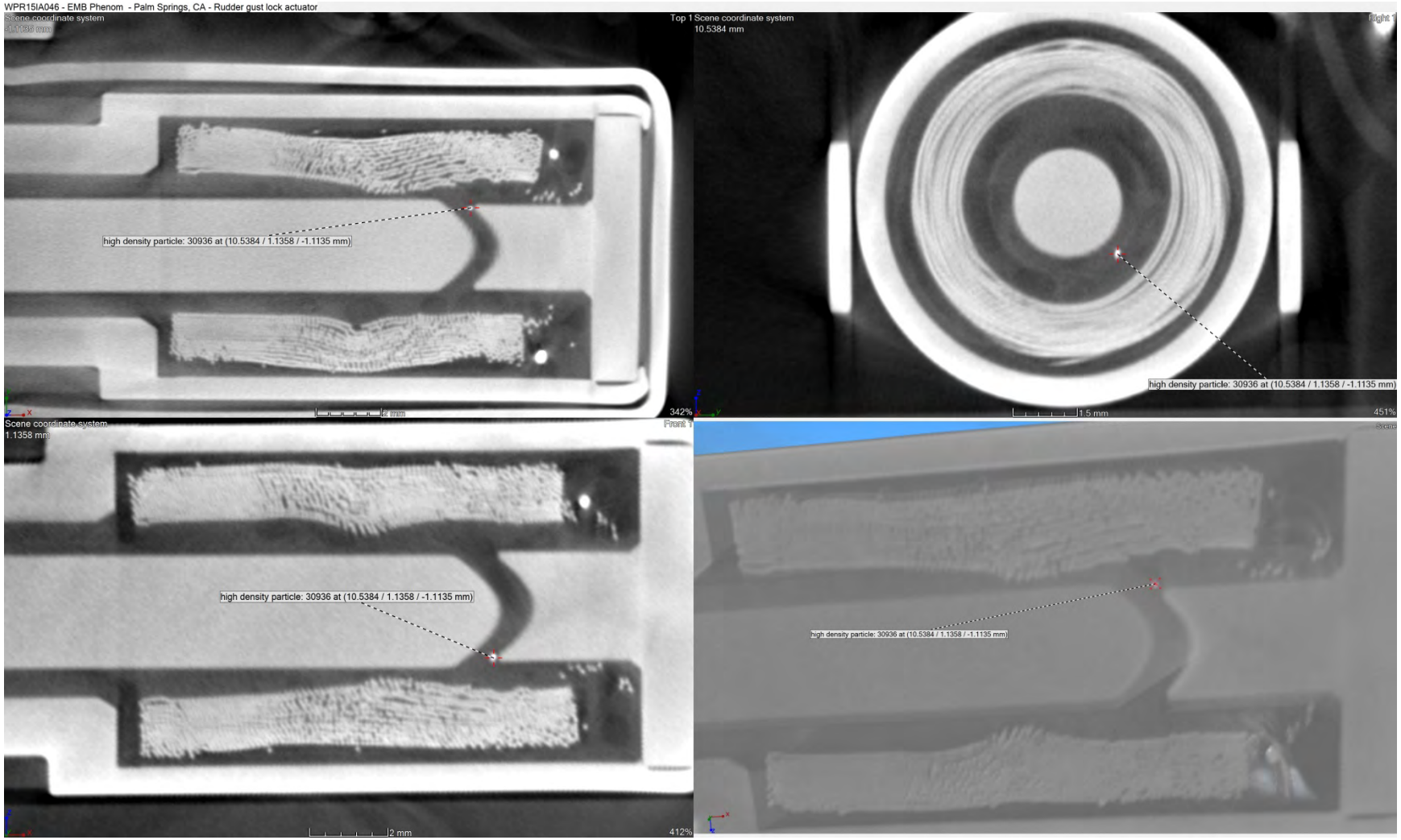

Figure 46

Rudder gust lock actuator – enhanced contrast microfocus – solenoid showing high density particle

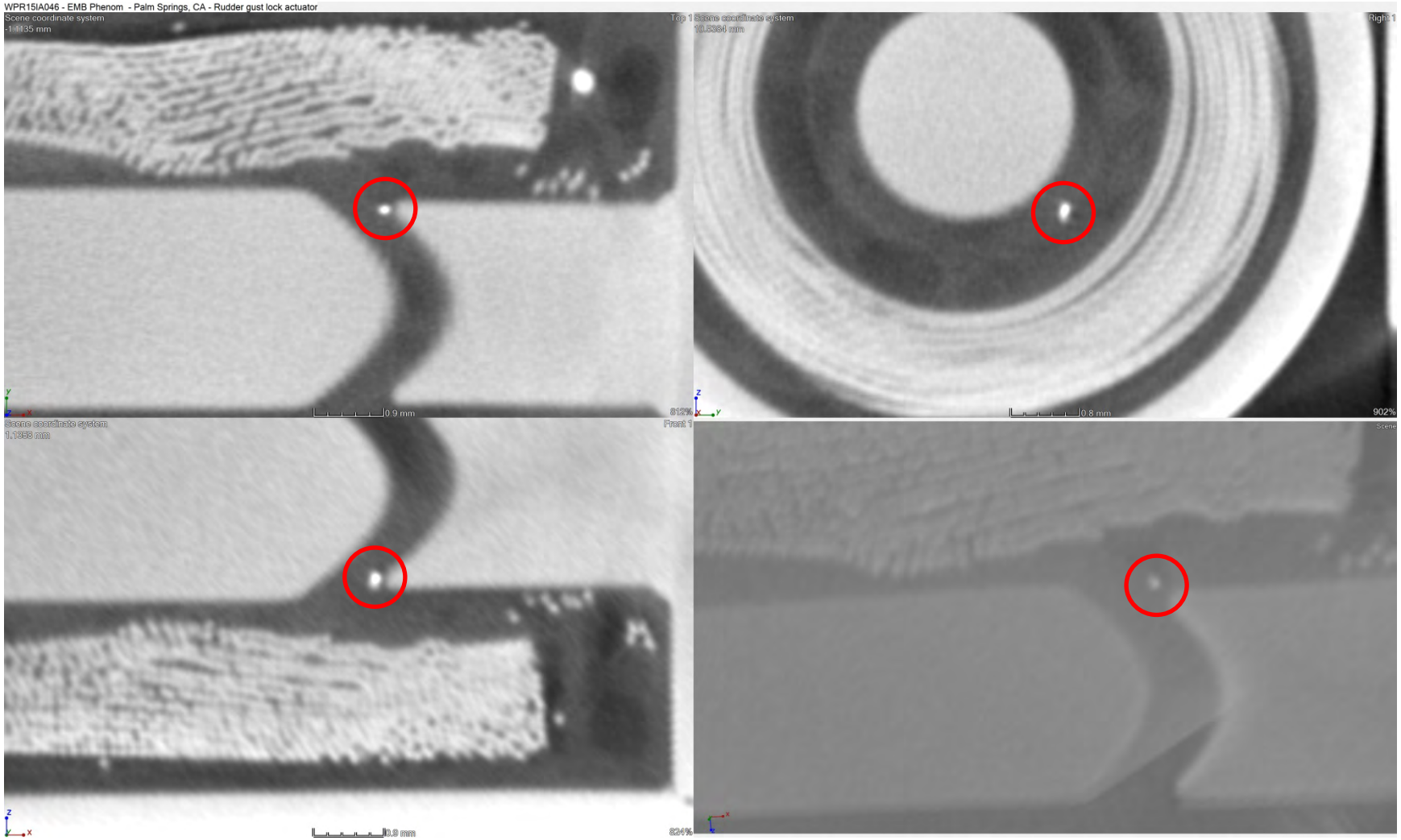

Figure 47

Rudder gust lock actuator – enhanced contrast microfocus – solenoid showing a close up view of the high density particle

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