Mastering CT: Advanced Techniques in Practice

Episode 2 – Automating Workflows for X-ray CT

Wednesday, September 17 at 10 am CDT

Presenter: Angela Criswell

- *You will be muted during the workshop*
- *You can ask questions using the Q&A tool.*
- *You should hear music if your sound is working*

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Mastering CT: Advanced Techniques in Practice

Episode 2 – Automating Workflows for X-ray CT

Wednesday, September 17 at 10 am CDT

Presenter: Angela Criswell

We are starting now…

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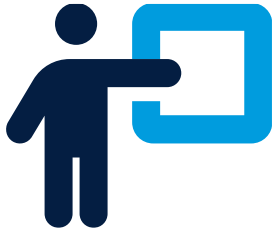
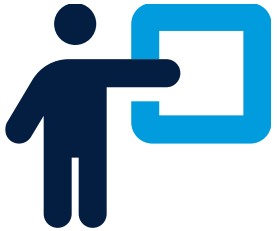


Presenter:
Angela Criswell



Co-presenter:
Ted Huang

Host:
Katelynn Stuchlik

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You can ask questions during the presentation. Please use the Q&A to ask questions.

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Recording will be available tomorrow.

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Automating Workflows for X-ray CT

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Microsoft stock

What you'll learn

1. Why repeatability matters
2. Automating CT scanning
3. Automating CT analysis

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Why repeatability matters

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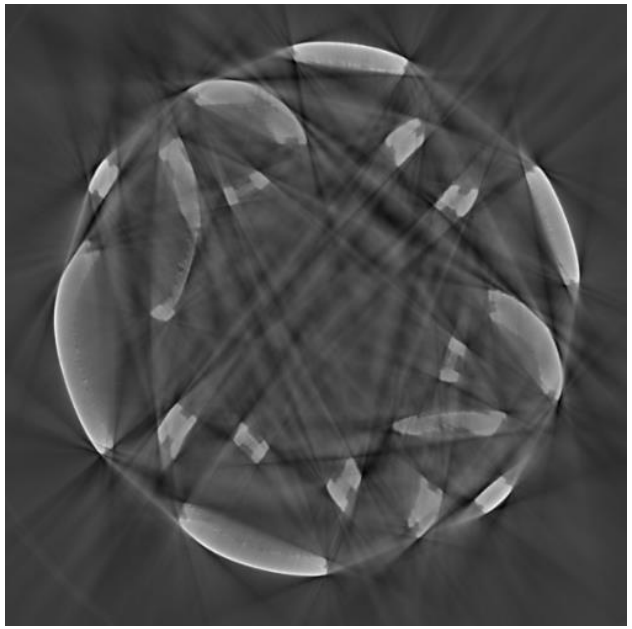
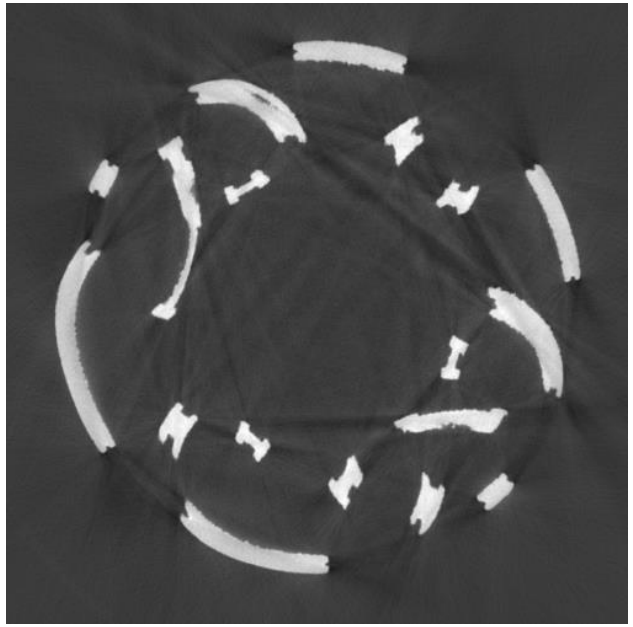
130 kV, no filter



200 kV, Sn filter



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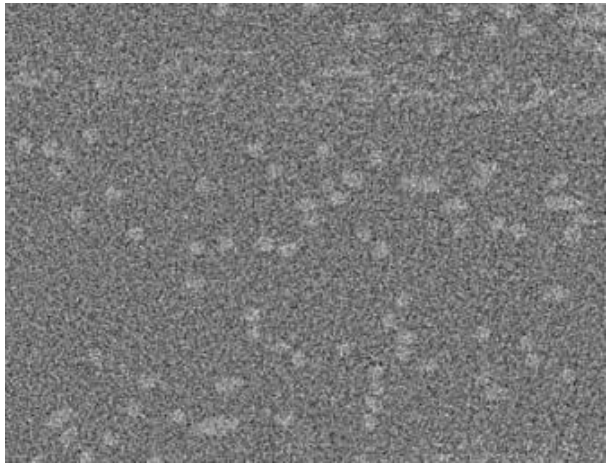
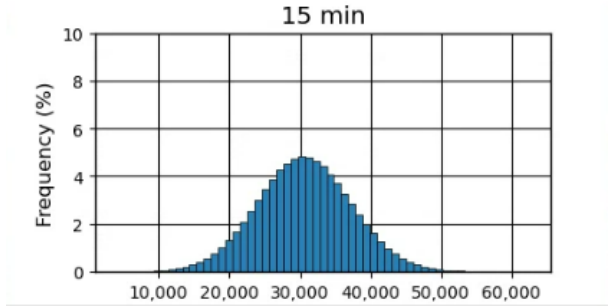
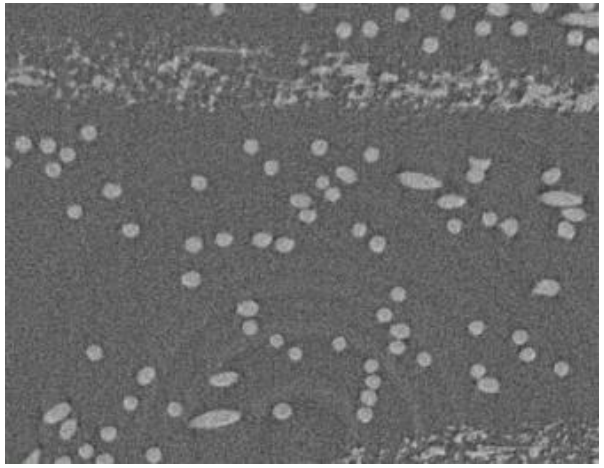
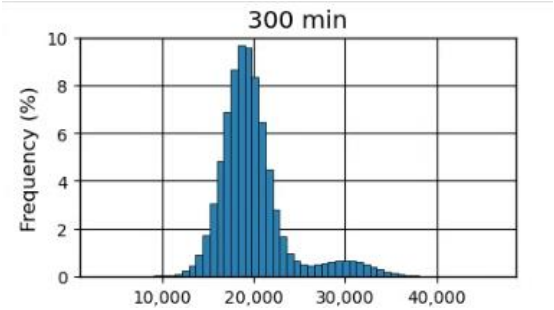
15 min





300 min





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Repeatable CT = Better CT

- Saves time and enables higher throughput
- Reduces errors and biases
- Improves data consistency across samples and batches

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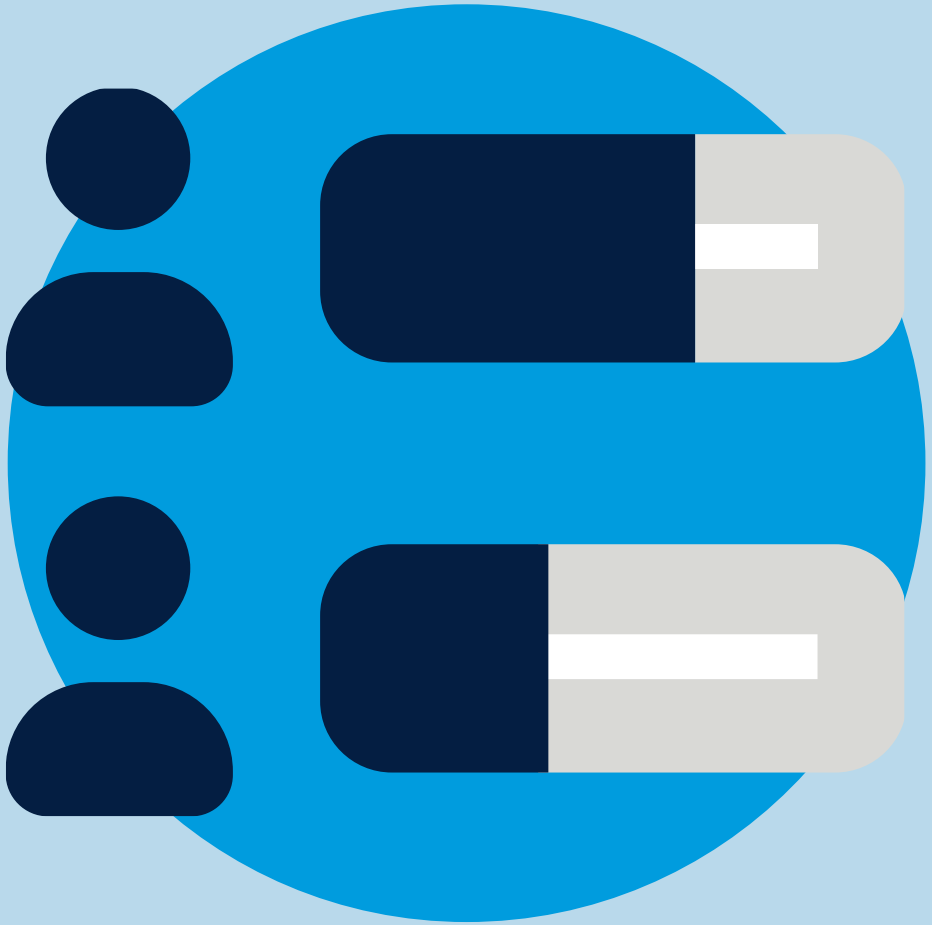
Polling Question

#1



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Automating CT scanning

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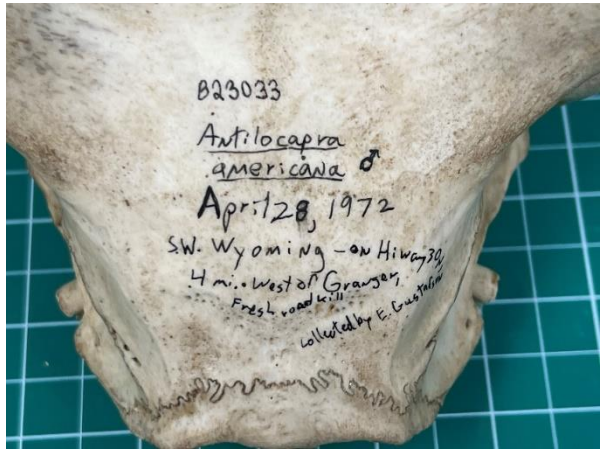
Sample labeling

- Take pictures of your sample!
- Utilize metadata



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Sample labeling

- Take a picture of your sample!
- Utilize metadata
- Integrate a label into your sample
  - Embossed labels for larger samples
  - Add label when 3D printing

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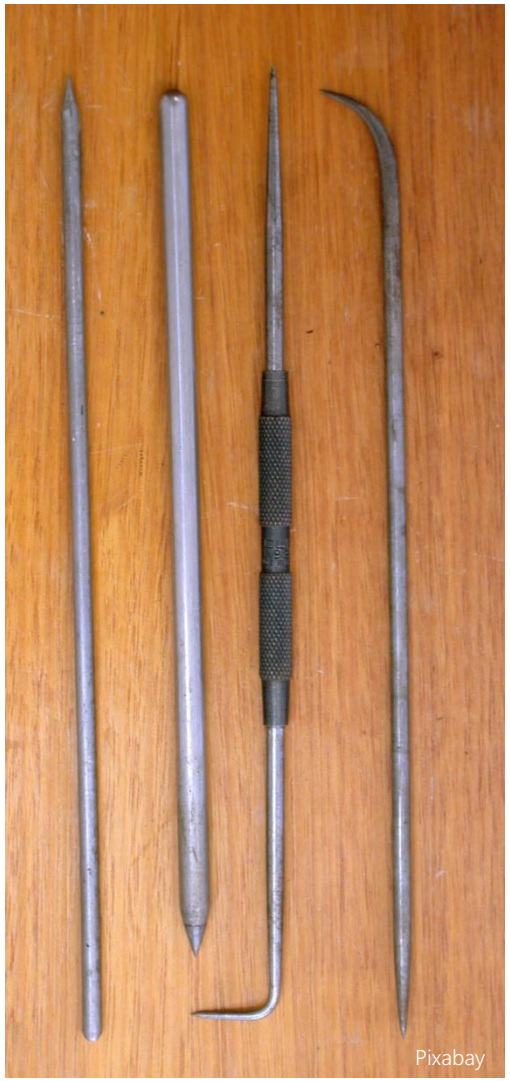
Sample labeling

- Take a picture of your sample!
- Utilize metadata
- Integrate a label into your sample
  - Embossed labels for larger samples
  - Add label when 3D printing
- Manually scribe samples
- Use a silver pen to label



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Sample holders and mounting

- Avoid sample movement

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Sample holders and mounting

- Avoid sample movement
- Use consistent, optimal orientation

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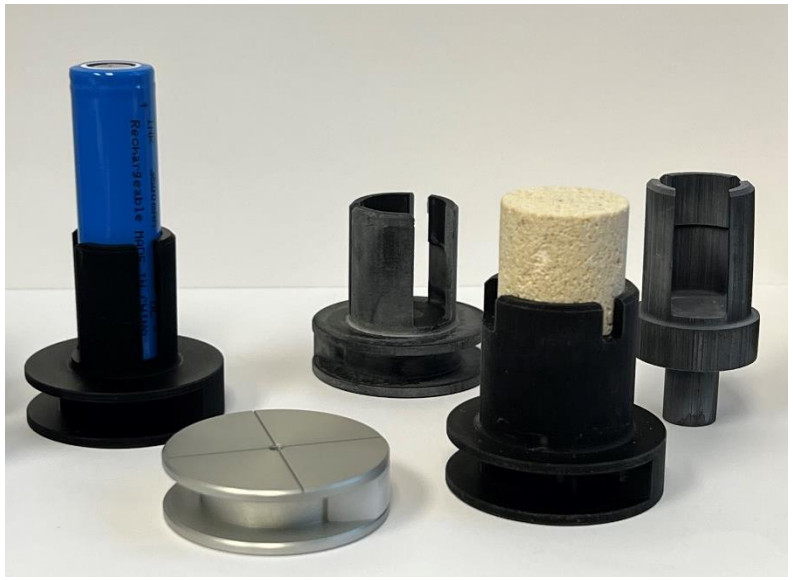
Sample holders and mounting

- Avoid sample movement
- Use consistent, optimal orientation
- Design and 3d print custom holders
  - Use an automatic sample changer



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Sample holders and mounting

- Avoid sample movement
- Use consistent, optimal orientation
- Design and 3d print custom holders
  - Use an automatic sample changer
- Stack samples
  - Straw, tube, or stackable containers

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Pixabay

Establish scan strategy & conditions

- What resolution do I need?
- What X-ray energy should I use?
- How long should I scan my sample?

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- How big is my sample?
- What are the feature sizes inside my sample?

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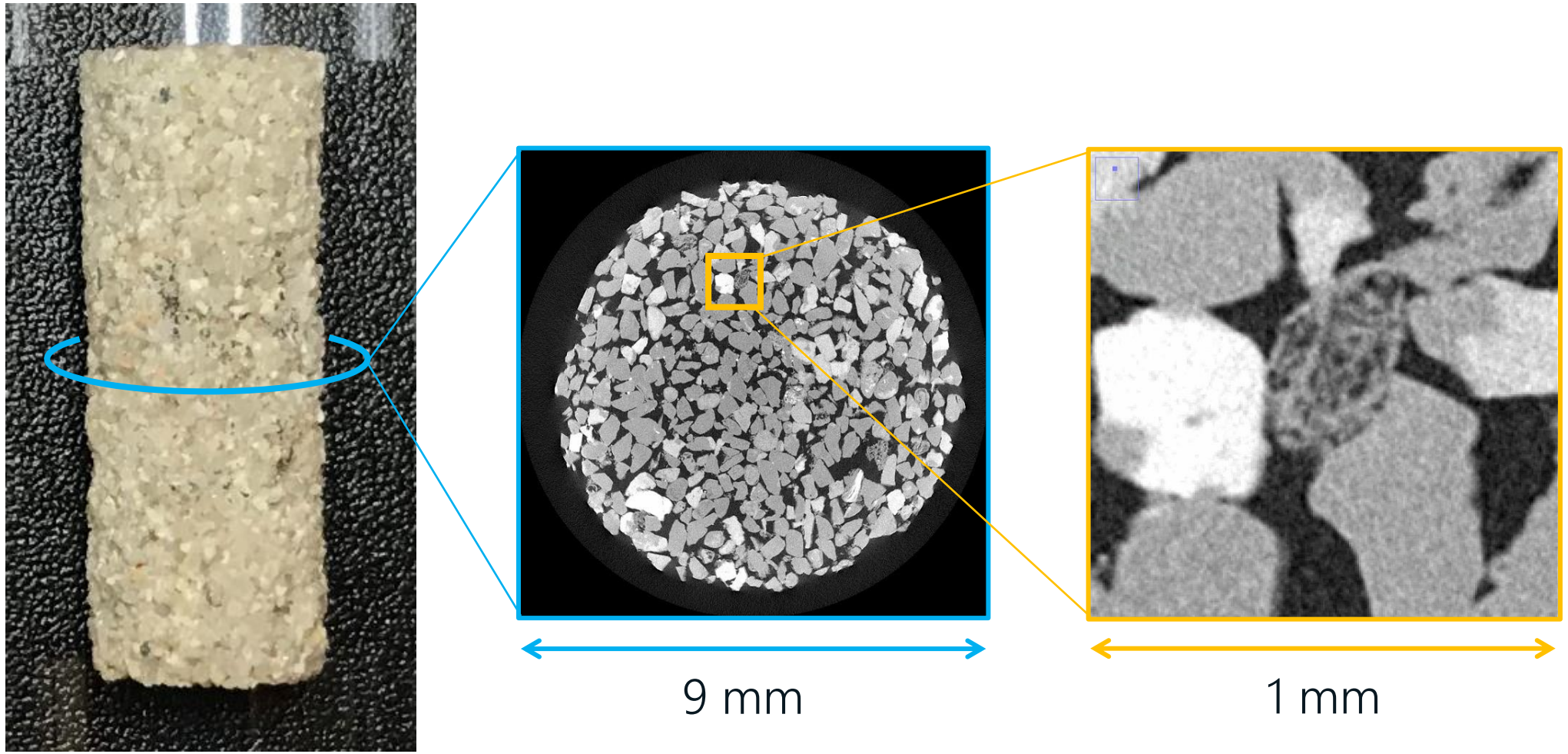
Sandstone



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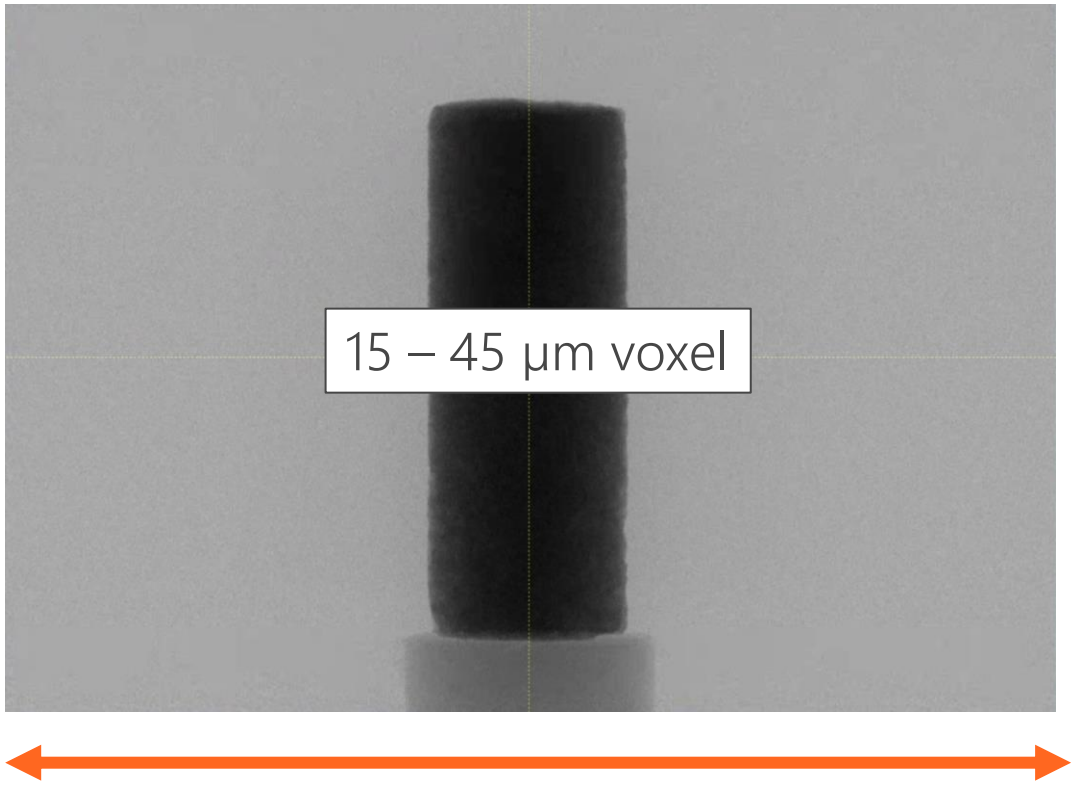
$$voxel\ size \sim \frac{FOV}{3000} - \frac{FOV}{1000}$$



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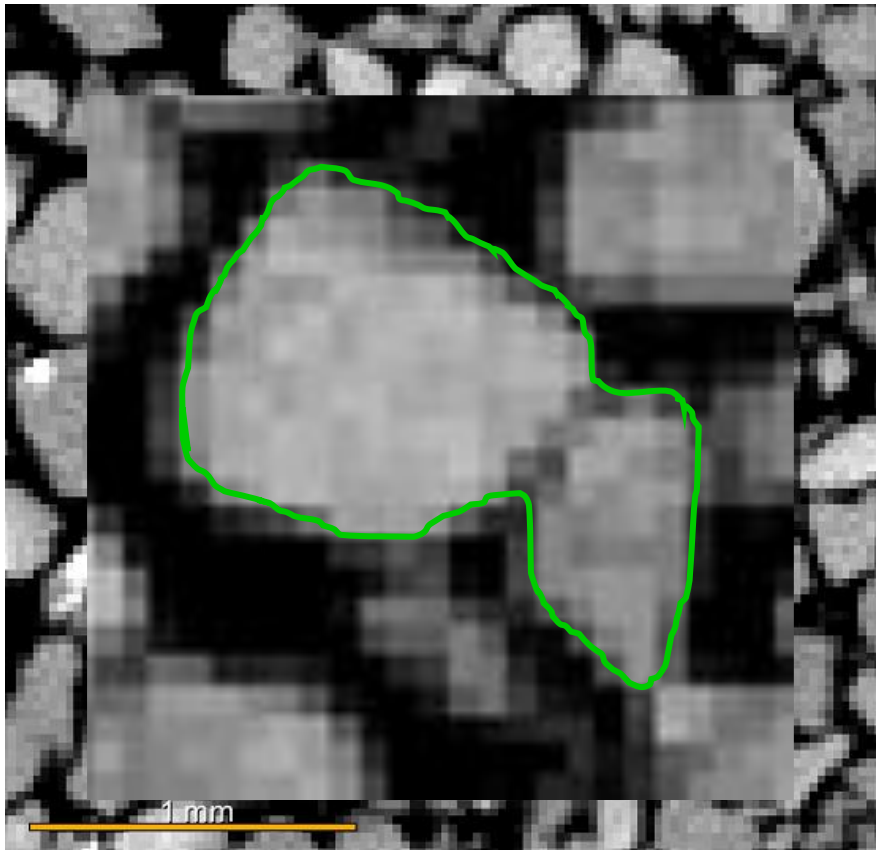

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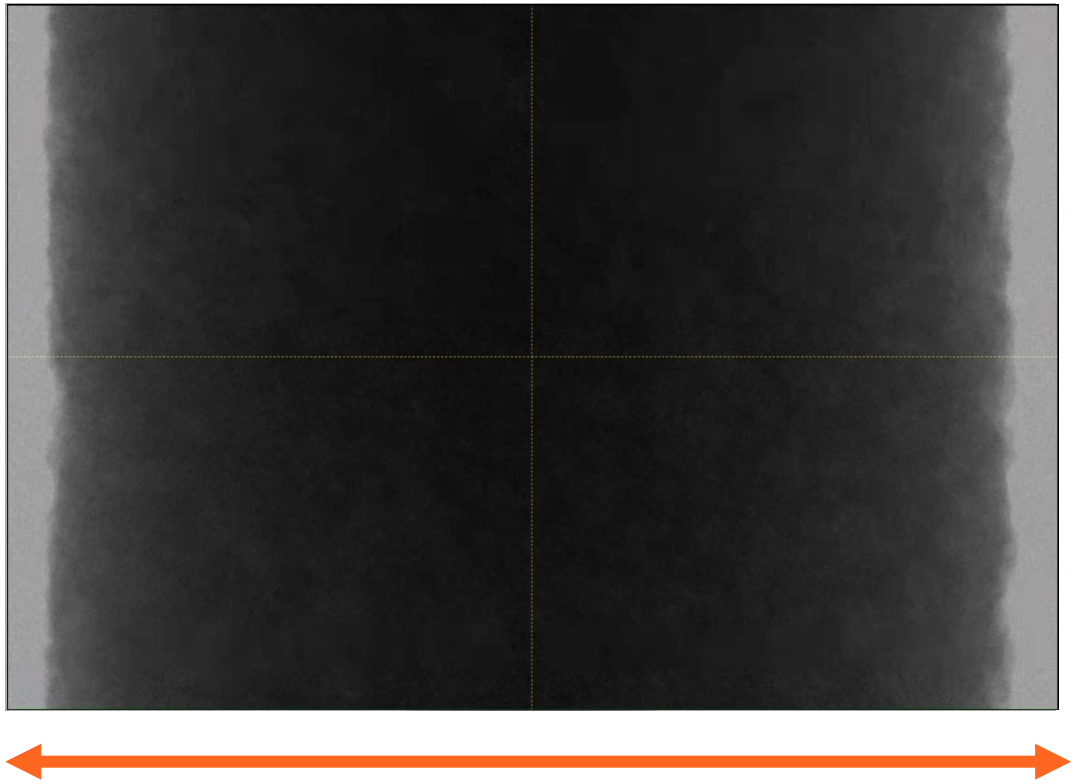
Sandstone



10 mm FOV

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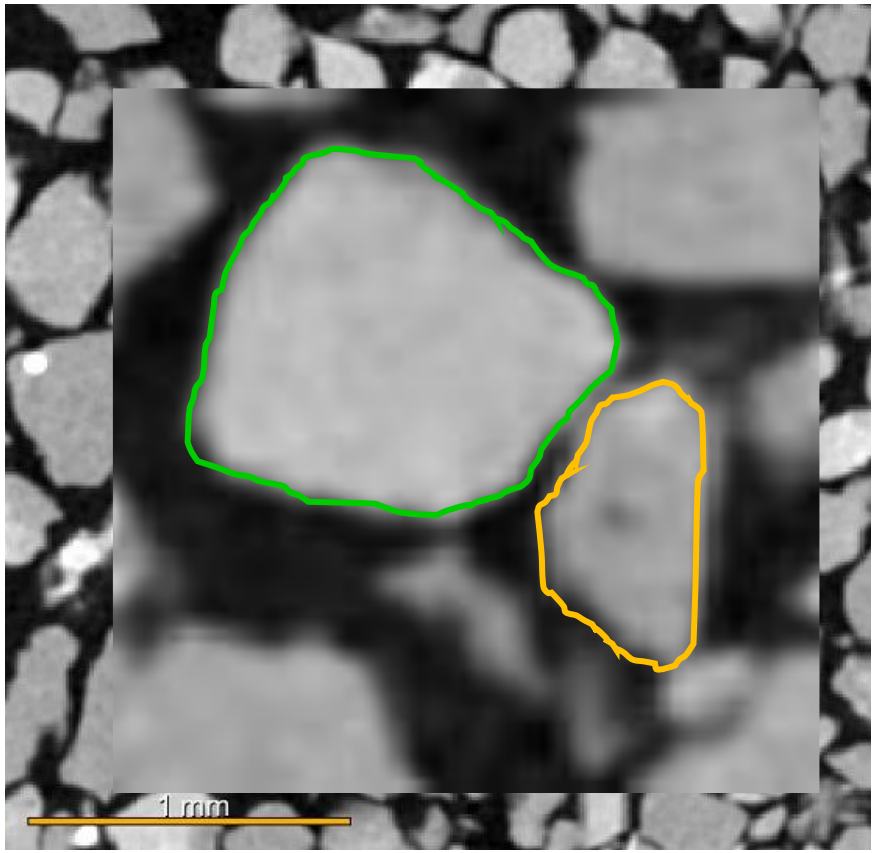

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- How big is my sample?
- What are the feature sizes inside my sample?

- What is my sample composed of?
- What X-ray energy should I use?

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But first…

$$I_{measured} = I_{incident}\, e^{-\mu t}$$

Attenuation coefficient

Object thickness

$$\mu \propto \frac{\rho Z^4}{E^3}$$

- $\propto$ Density (ρ)
- $\propto$ Atomic number (Z)
- $\propto \frac{1}{\text{X-ray energy } (E)}$

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But first…

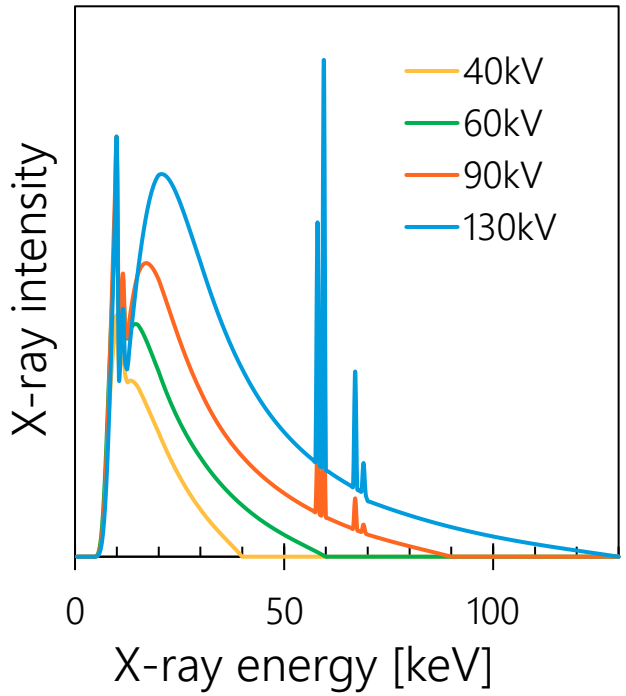
kV

voltage current

$$W = kV \times \mu A$$

X-ray power

keV



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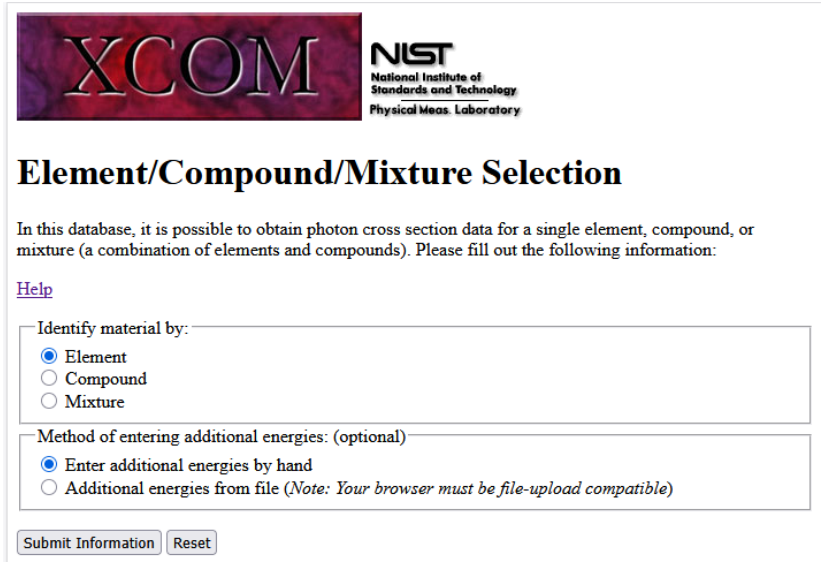
What is your sample composition?

- Choose optimal kV
  - Calculate attenuation (μ) for your material(s) vs. keV



https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html

TEXAS Geosciences

MUCALC

UTCT

Hanna, R.D., Ketcham, R.A., 2017. *Geochemistry* 77, 547–572.

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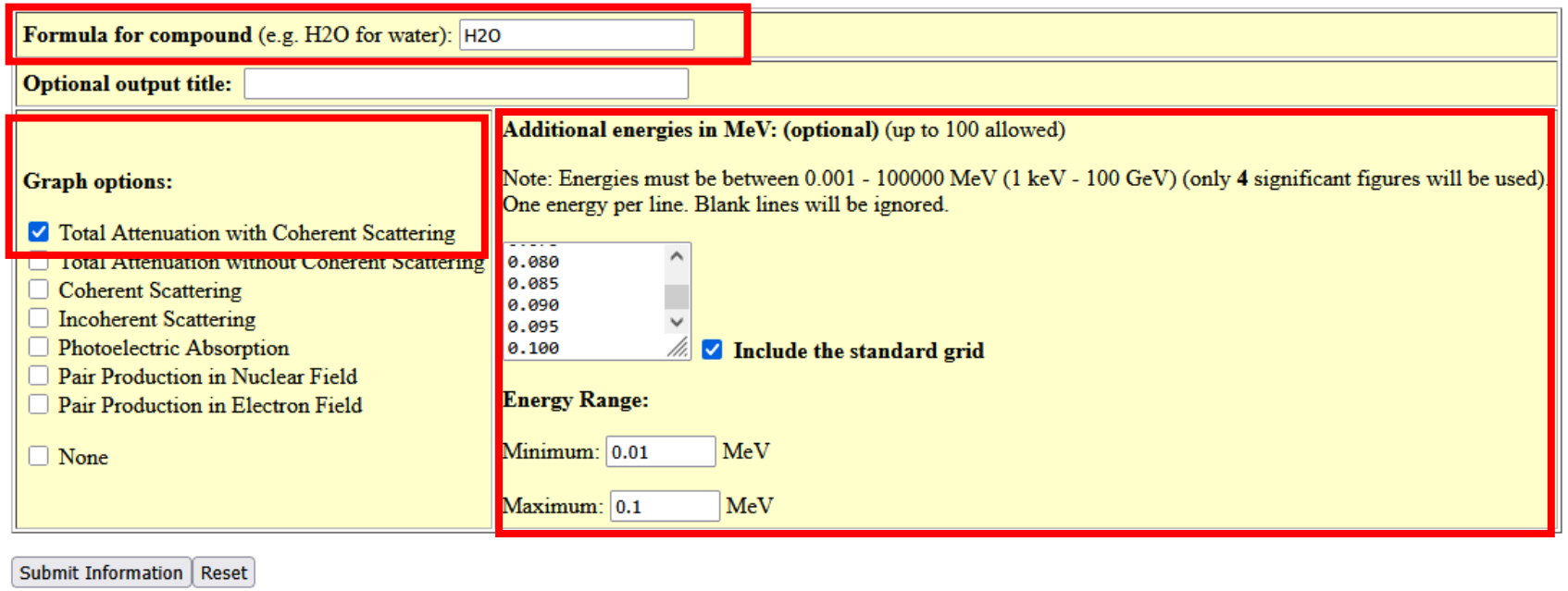

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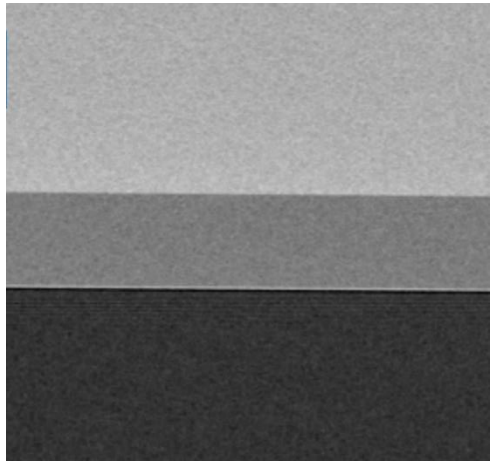

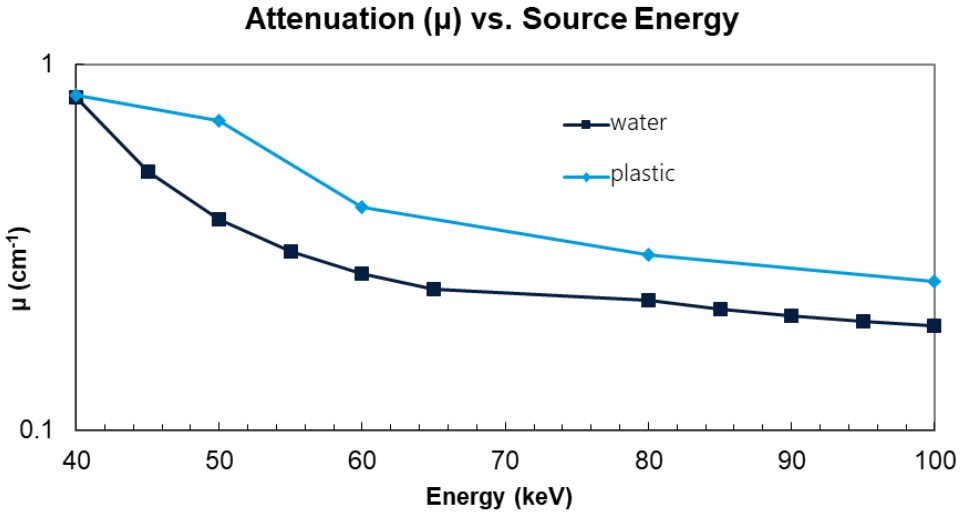

Plot prepared using MuCalc: Hanna, R.D., Ketcham, R.A., 2017. *Geochemistry* 77, 547–572.
and attenuation data from XCOM: https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html

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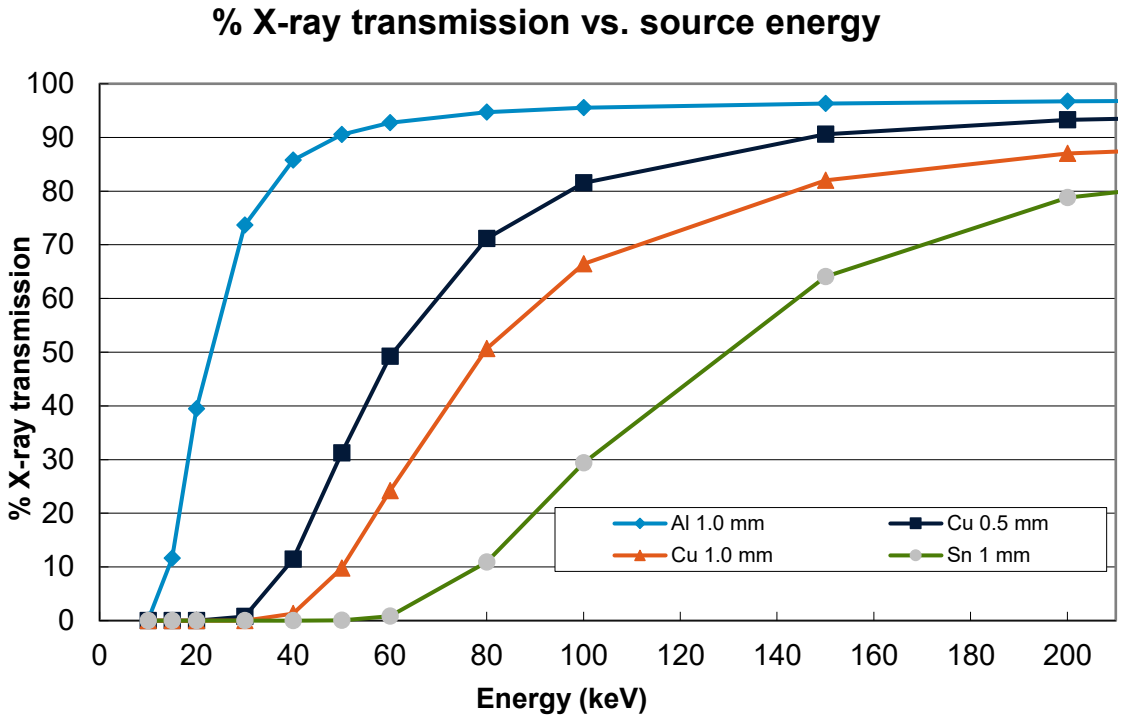
What is your sample composition?

- Choose optimal kV
- Choose optimal filter
  - Calculate average keV for filters



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and attenuation data from XCOM: https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html

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- How big is my sample?
- What are the feature sizes inside my sample?

- What is my sample composed of?
- What X-ray energy should I use?

- How long should I scan my sample?
- How will I assess image quality?

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How will you assess CT image quality?

- Ease of segmentation/surface determination
- Signal-to-Noise ratio (SNR)
- Contrast-to-Noise ratio (CNR)

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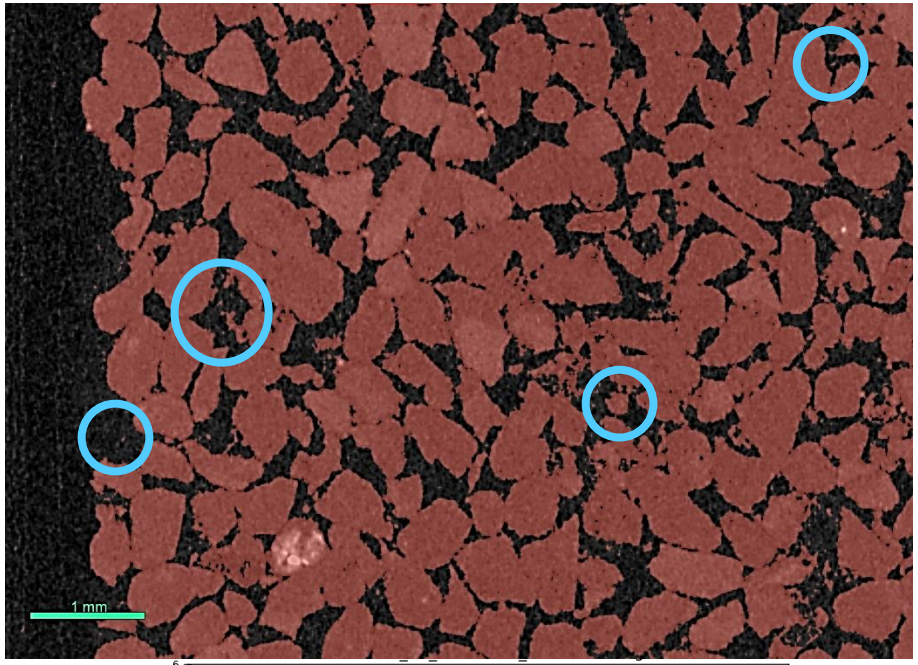
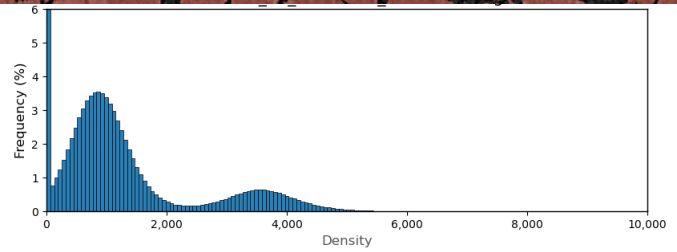
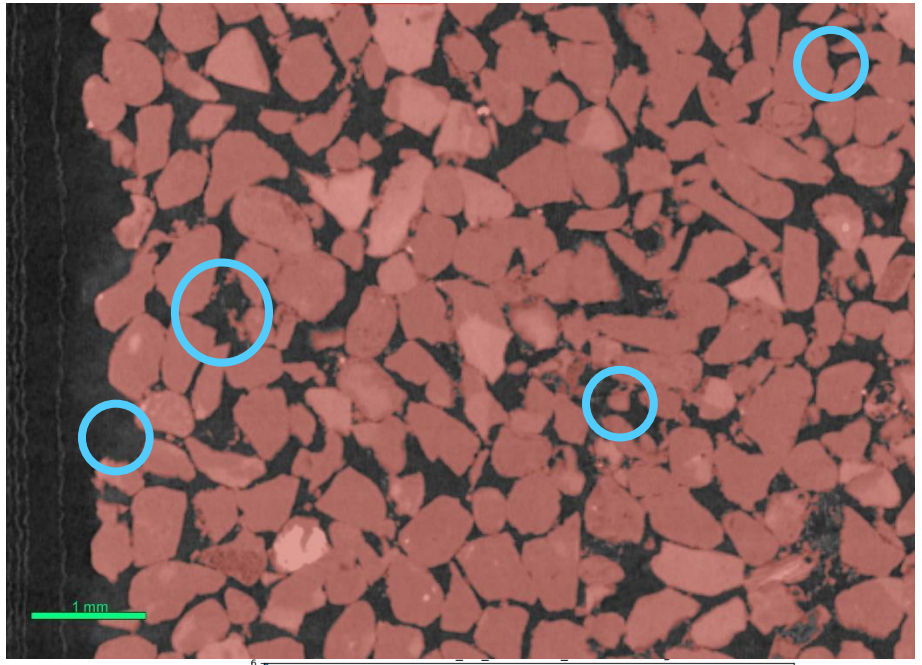
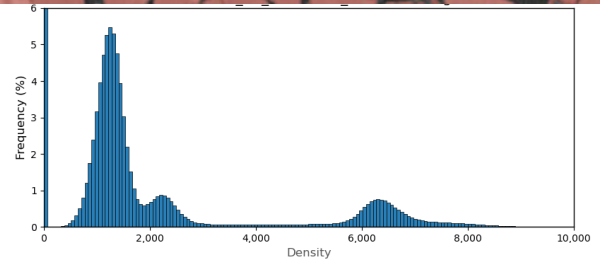
Ease of segmentation/surface determination









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SNR / CNR

$$SNR = \frac{Signal}{Noise} = \frac{\mu_1}{\sigma_2}$$

$$CNR = \frac{Contrast}{Noise} = \frac{|\mu_1 - \mu_2|}{\sigma_2}$$

μ- mean intensity
σ- std dev intensity

- SNR is related to attenuation
- CNR compares attenuation between materials

du Plessis, A., Tshibalanganda, M., le Roux, S.G., **2020**. *Mater. Today Commun.* 22, 100792.
Rodríguez-Sánchez, Á., *Thompson, A., Körner, L., Brierley, N., Leach, R.*, **2020**. *Precision Engineering* 66, 382–391.

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SNR / CNR

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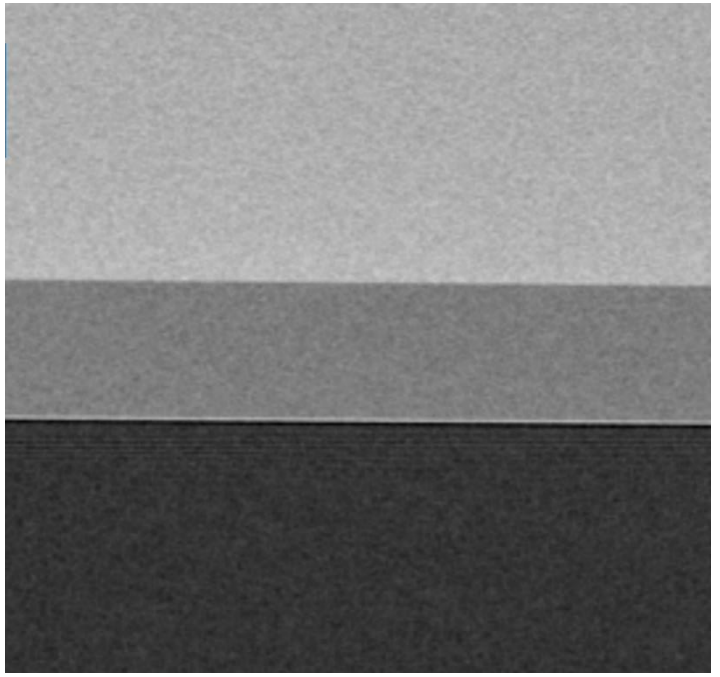

CT scans at 3 X-ray energies
- 50 kV
- 90 kV
- 130 kV

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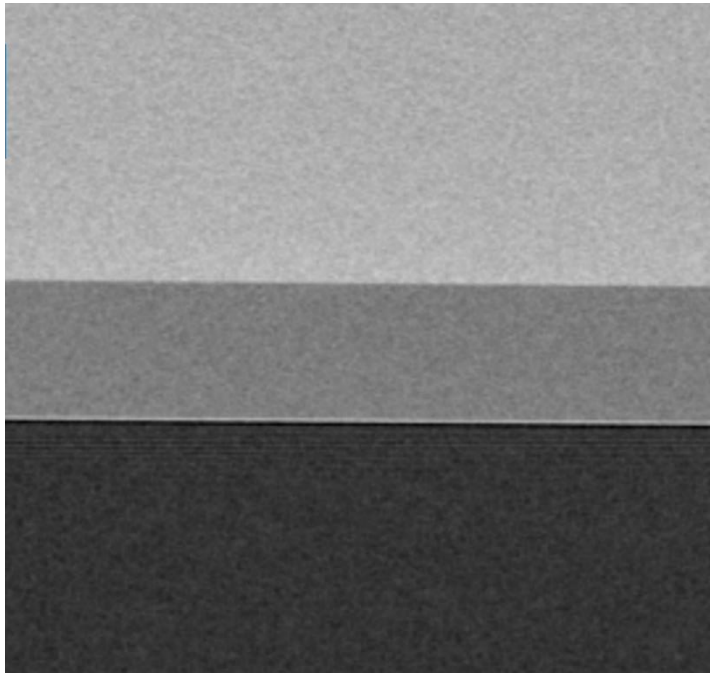
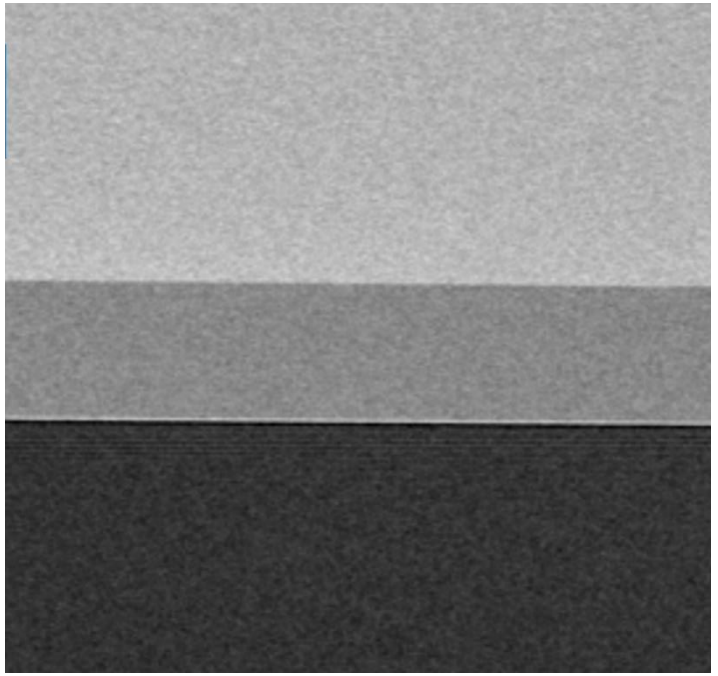
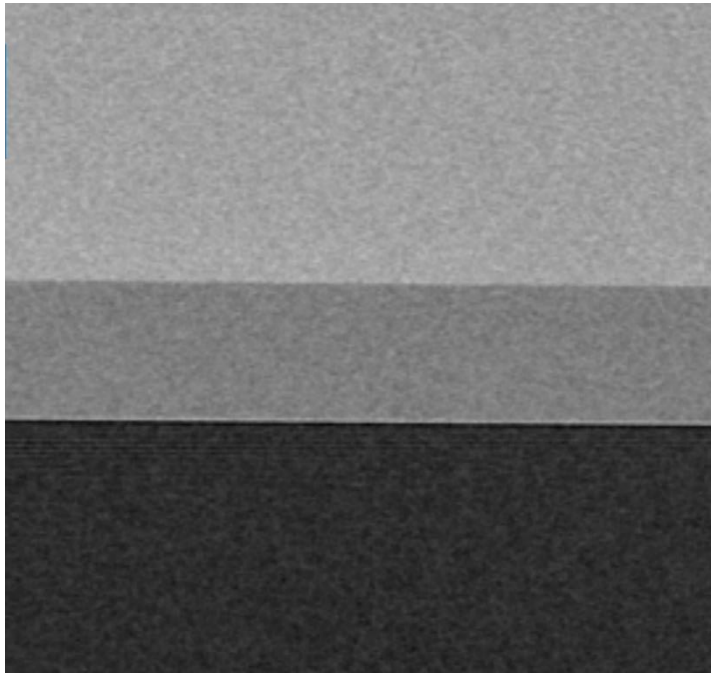
SNR / CNR



50 kV, 160 µA



90 kV, 88 µA



130 kV, 61 µA

8 W for all scans

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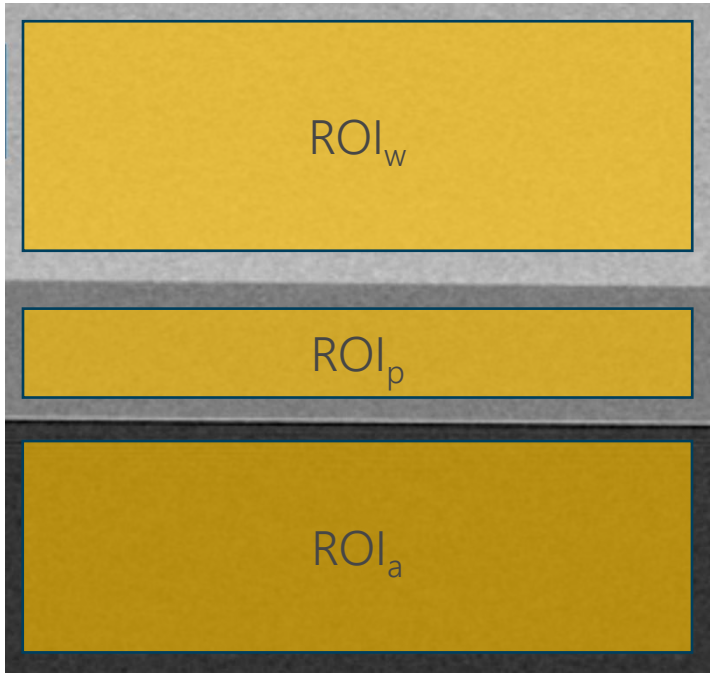
SNR / CNR



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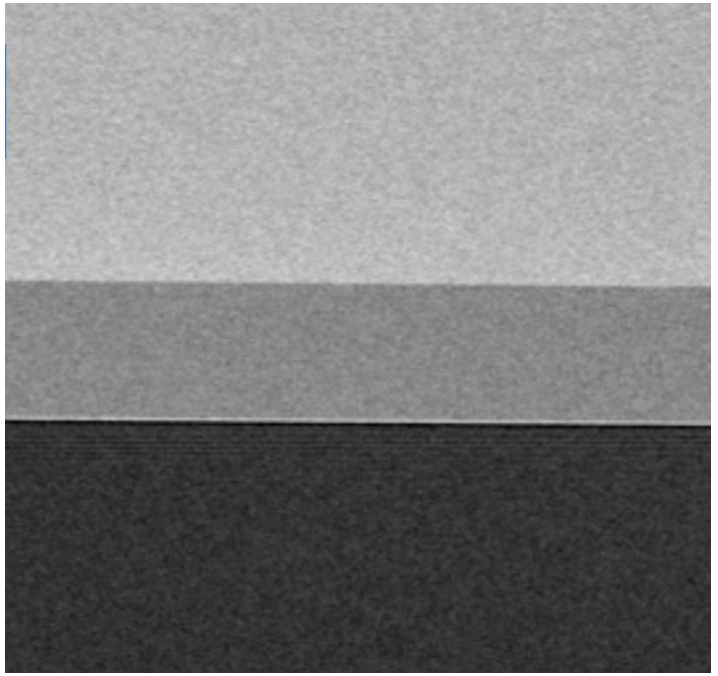

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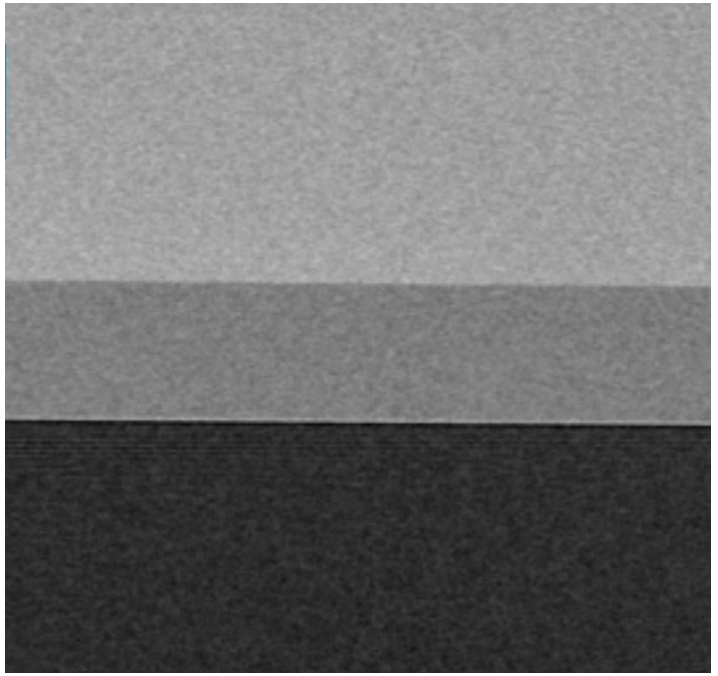

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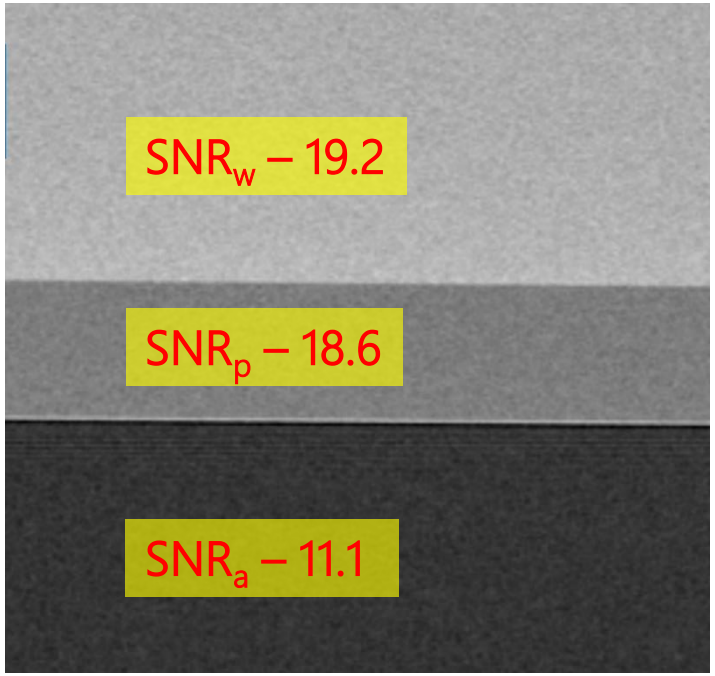
SNR / CNR



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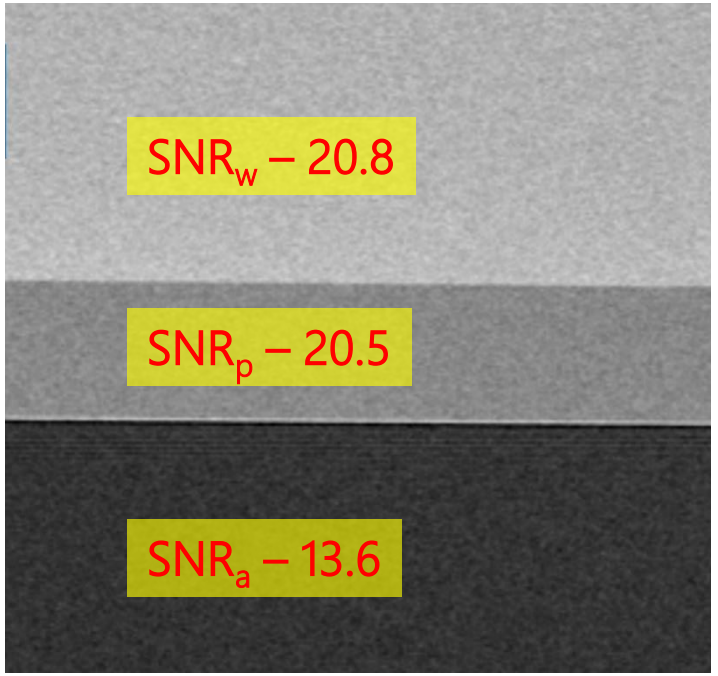
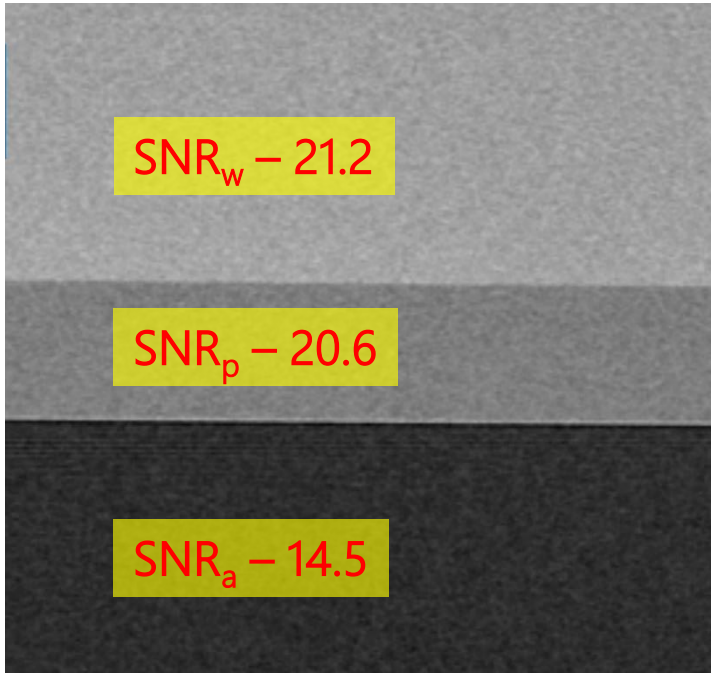


90 kV, 88 µA



130 kV, 61 µA

8 W for all scans

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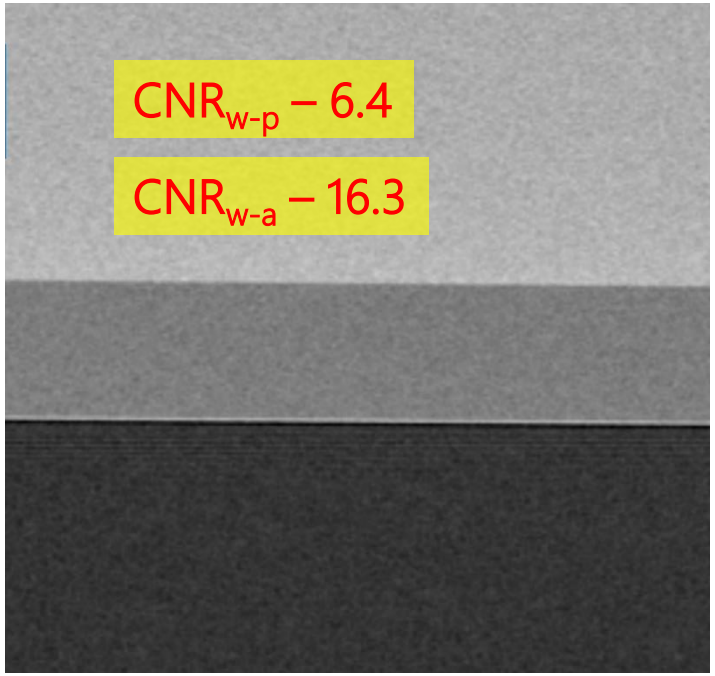
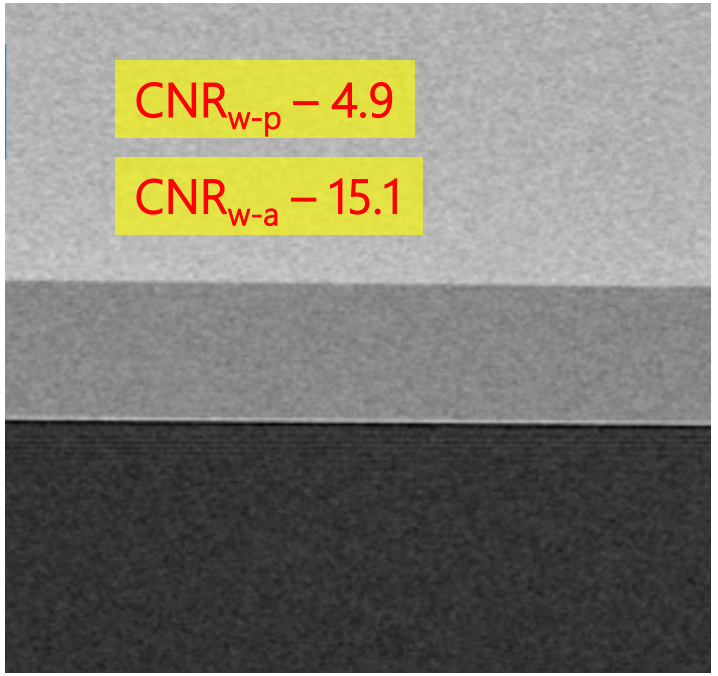
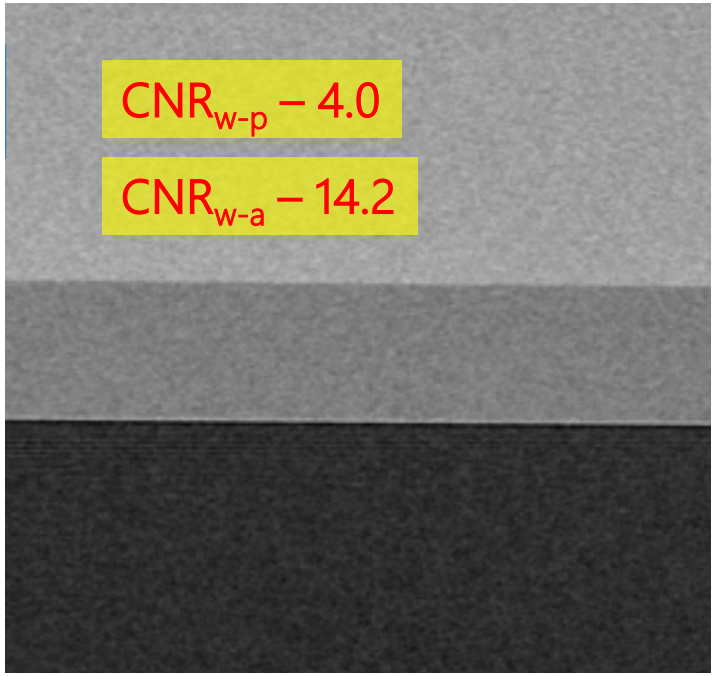
SNR / CNR



50 kV, 160 µA



90 kV, 88 µA



130 kV, 61 µA

8 W for all scans

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How long should I scan my sample?

- Longer scans with higher X-ray intensity are better
  - Increase the X-ray intensity
  - Increase the exposure time per projection
  - Increase the number of projections
- Consider motion correction for very long scans

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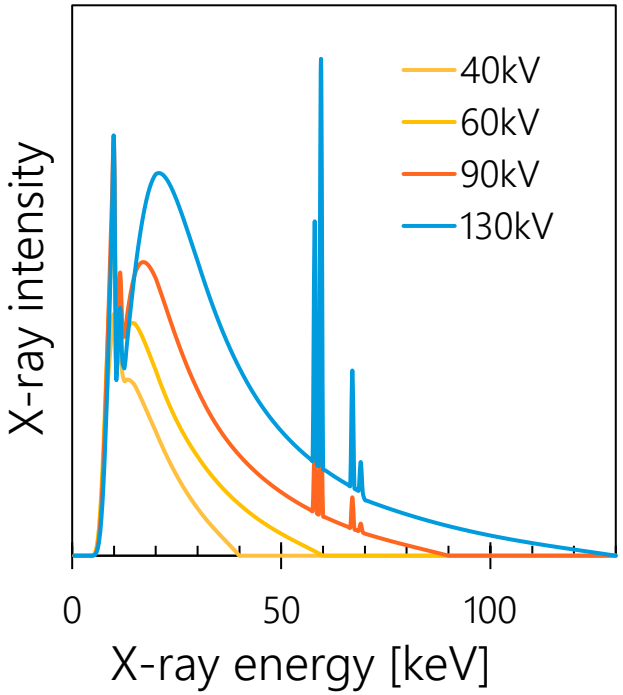
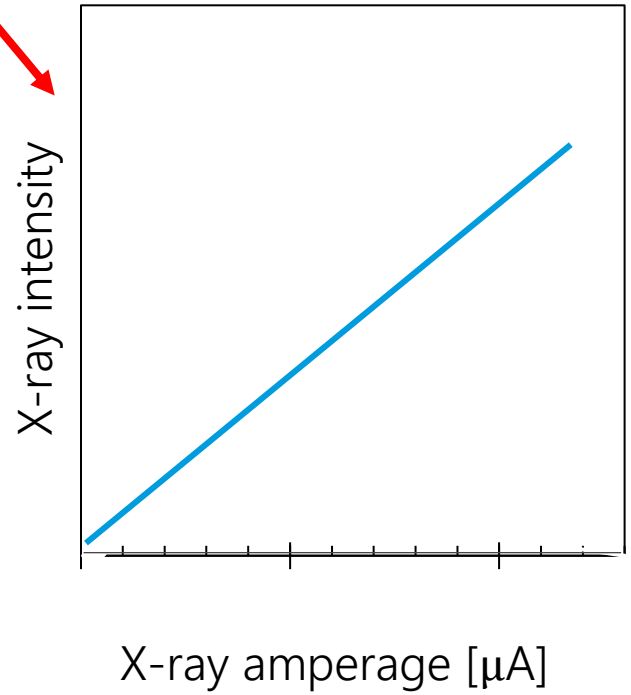
$$W = kV \times \mu A$$





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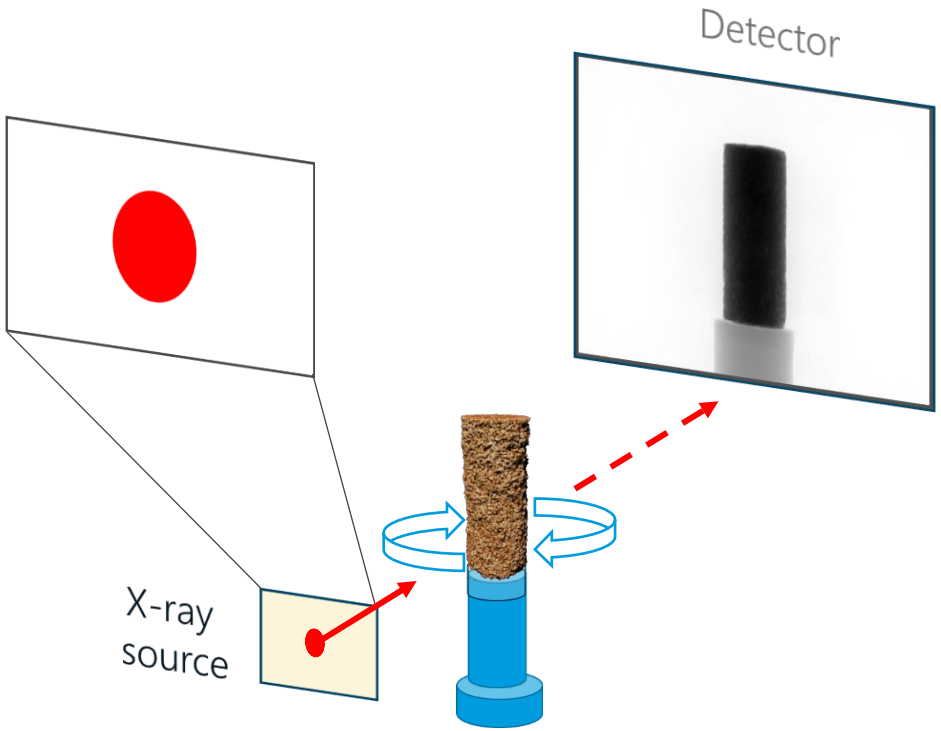
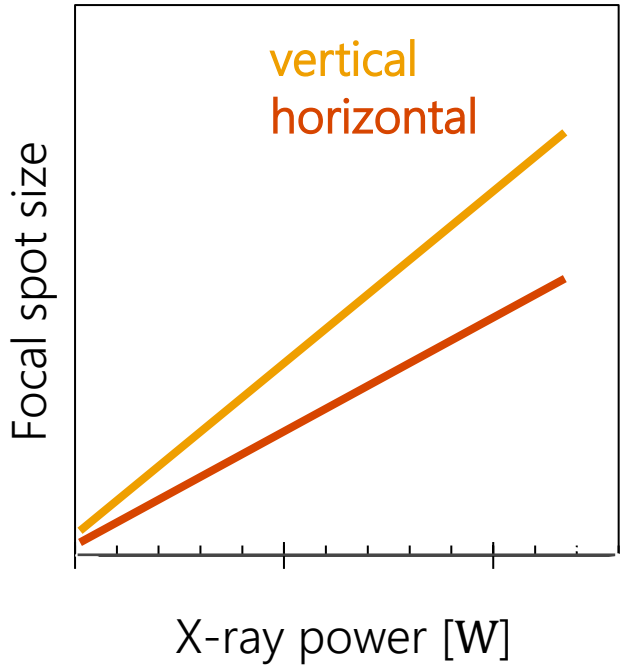
Changing the X-ray current changes the X-ray focal spot size





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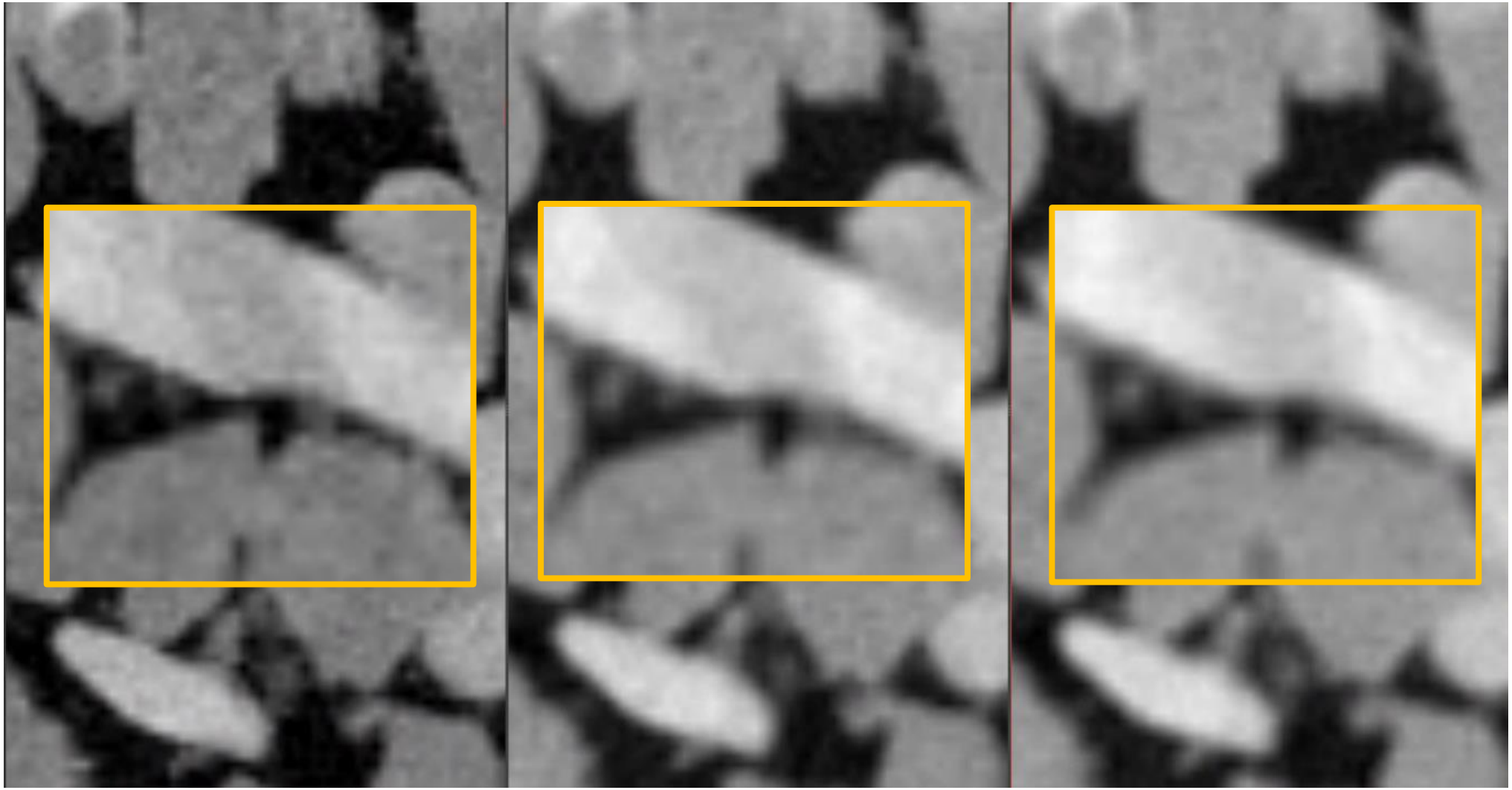

8 W 16 W 24 W

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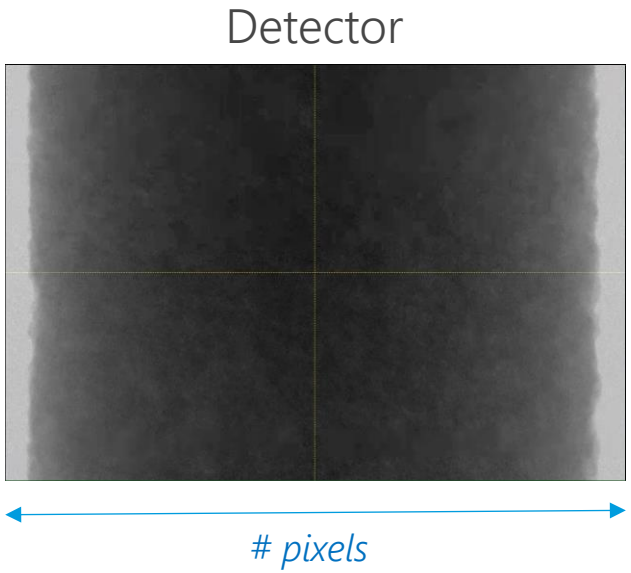
So, what about the number of projections??



The ideal # of projections is

# of horizontal pixels * 1.5

For a detector with 2000 pixels,
3000 projections is estimated to be ideal

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Automated CT scan workflow

1. Establish sample labeling and mounting
2. Determine scan parameters from CT scans of a small set of samples
3. Create scan recipes and reuse for all samples
   - Collect data for the full sample
   - Collect higher resolution data for ROIs
4. Reconstruct CT scans with same settings
5. Backup scans along with any metadata
   - Sample info, scan info (FOV, voxel size, X-ray settings, etc.)

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Questions?

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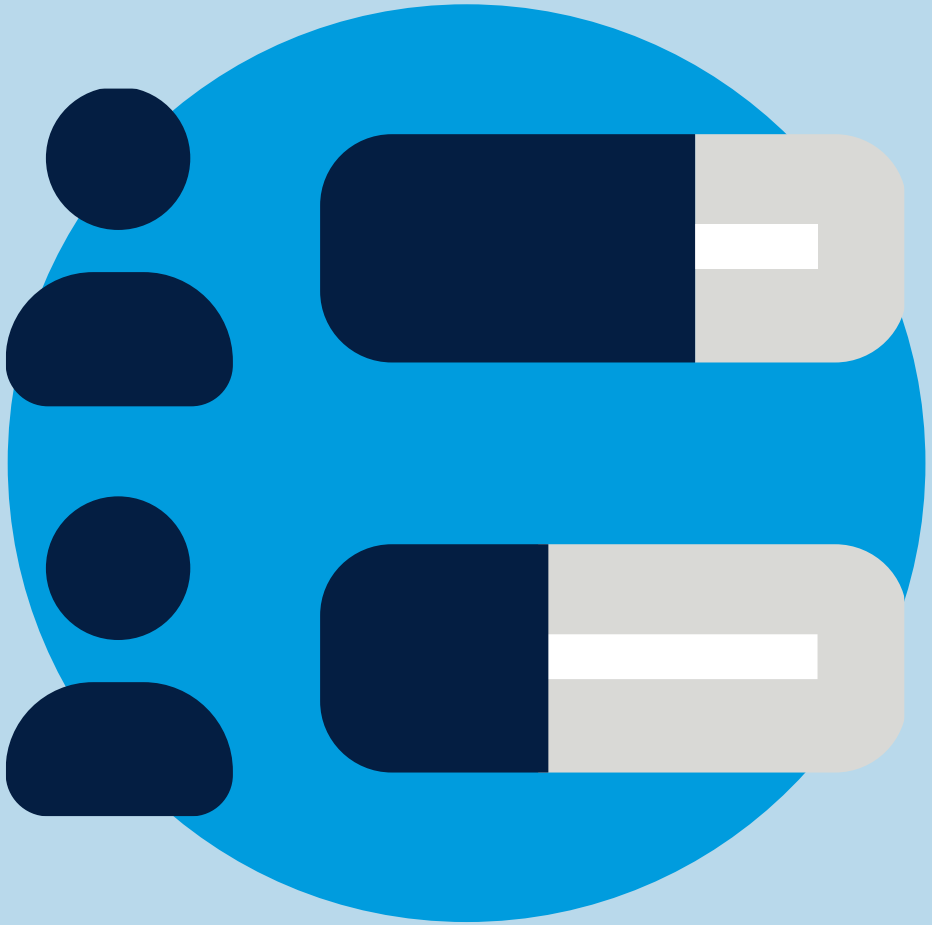
Polling Question

#2



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Automating CT analysis

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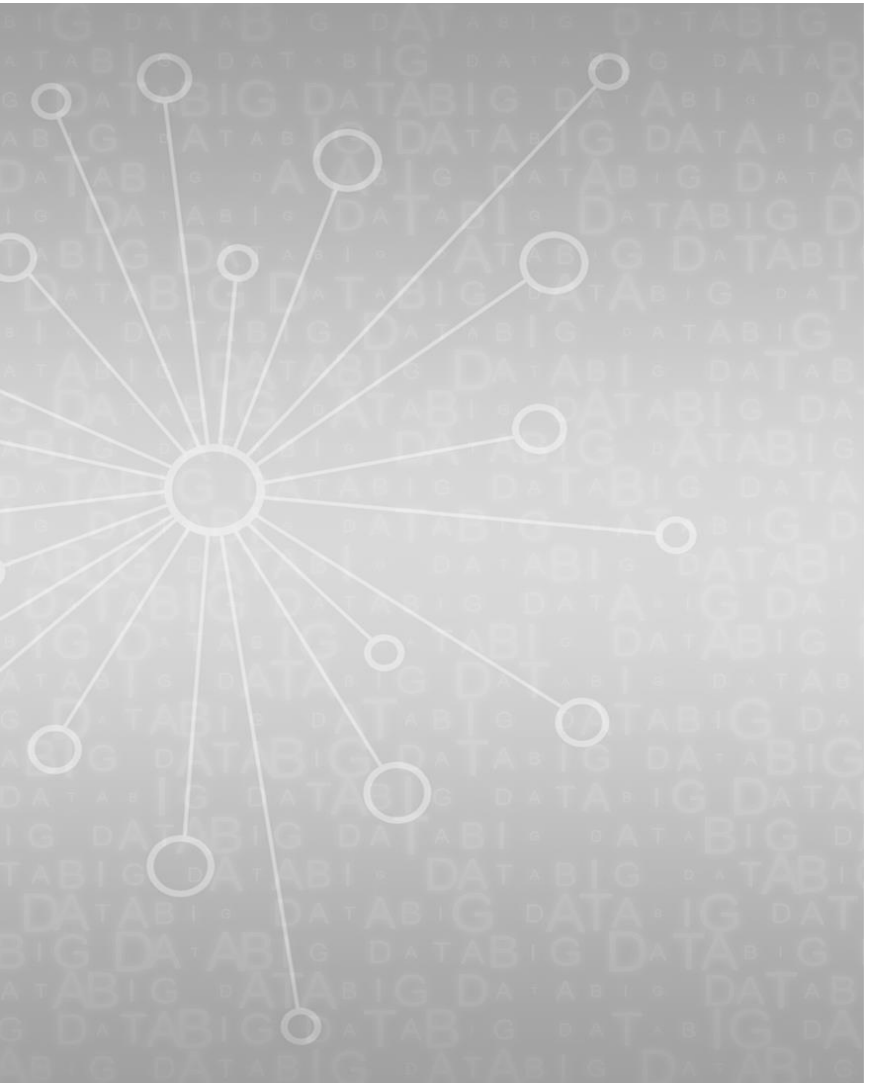

Automating CT data processing

- Speeds up analysis dramatically
- Reduces operator-to-operator variation
- Enables batch comparison
- Frees scientists for higher-level interpretation
- *Even automating a few repeated steps can help a lot*

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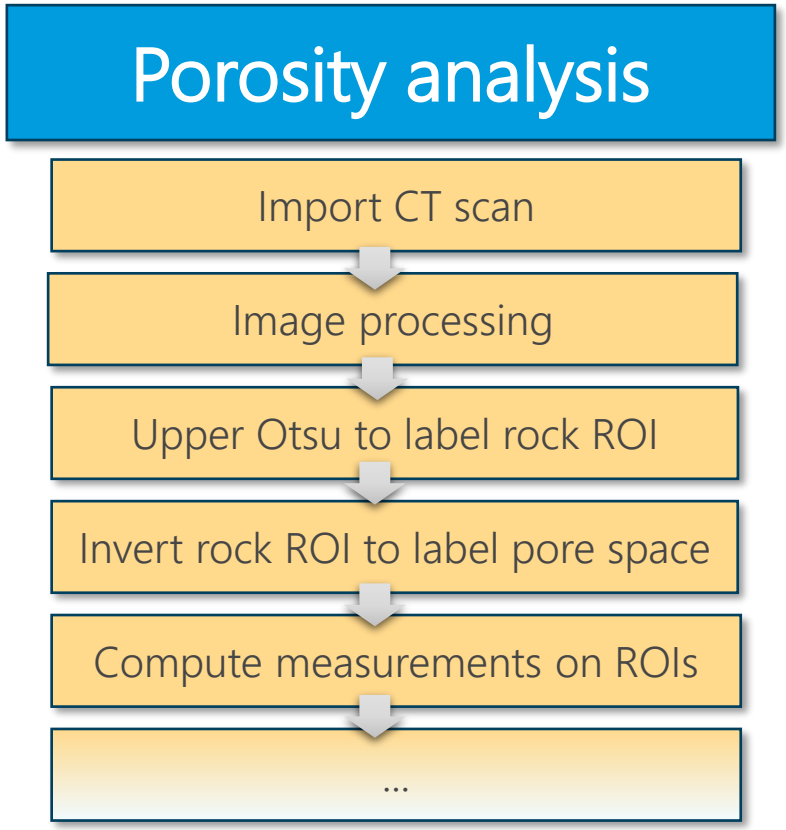
Determine the essential steps of your analysis workflow

- Data corrections?
  - Normalize intensity?
  - Image processing/denoising?
- Segmentation
  - Otsu binarization?
  - Machine/deep learning
- Quantitative analysis
  - Volume %
  - Area, surface area, sphericity
- Simulations



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Software tools that provide for automation

Dragonfly 3D World

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Typical automation mechanisms

- Creating macros
  - Records actions performed via the UI
- Running macros
  - ‘Play' macros on loaded datasets
  - Batch processing of multiple data sets

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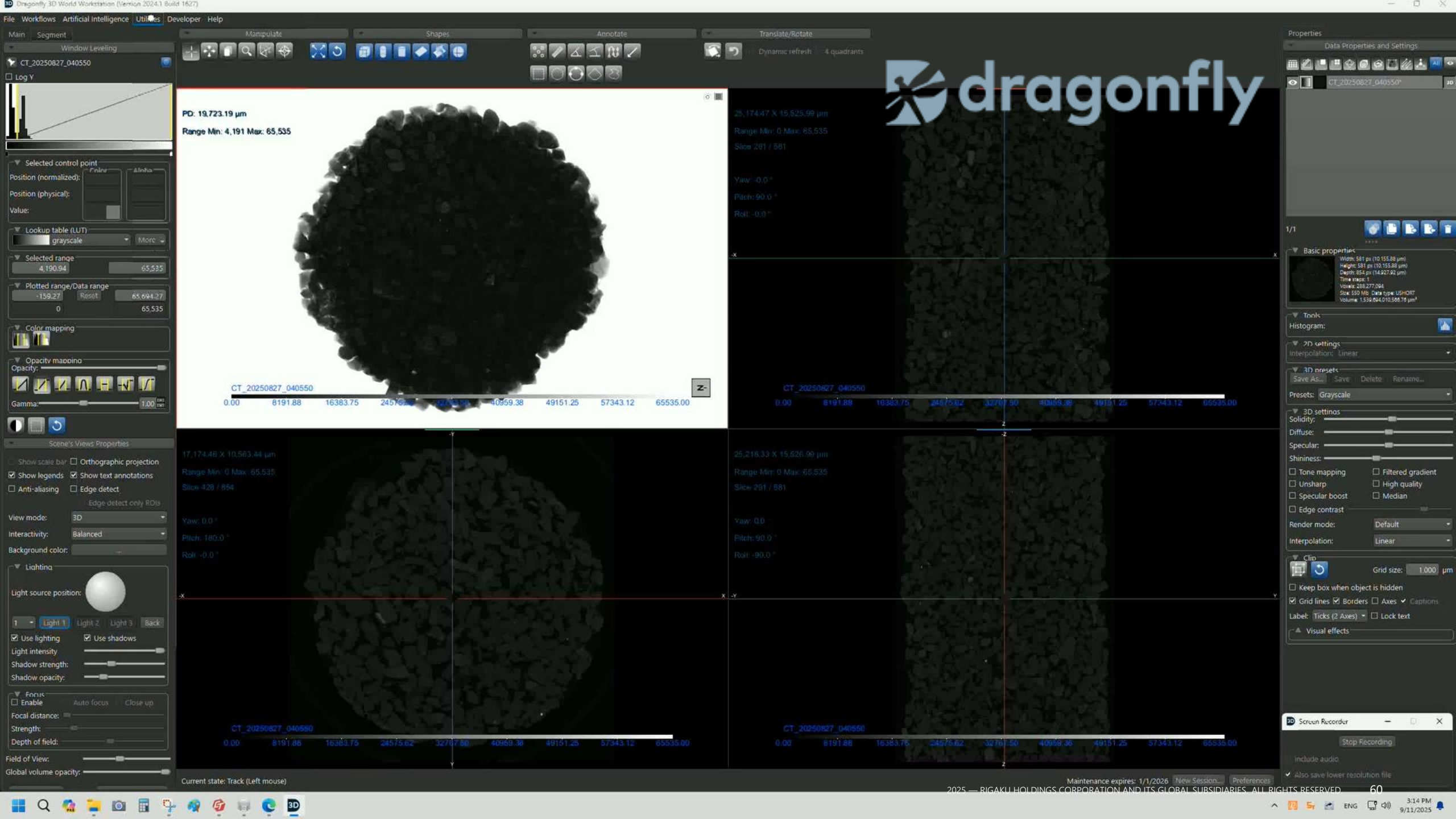

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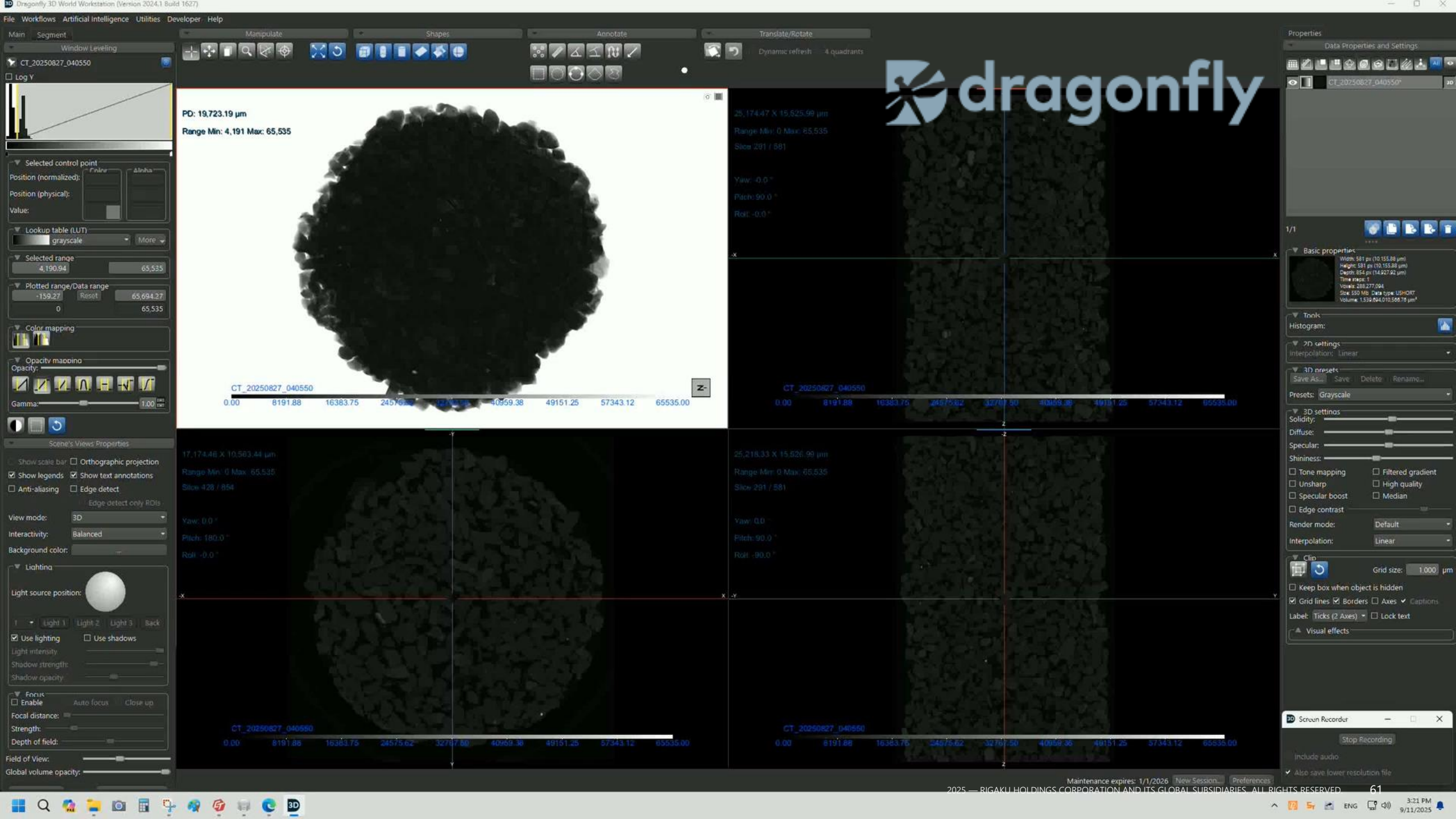
Dragonfly 3D World Workstation (Version 2024.1 Build 1627)
File Workflows Artificial Intelligence Utilities Developer Help
Main Segment
Manipulate
Shapes
Annotate
Translate/Rotate
Dynamic refresh
4 quadrants
Properties
Data Properties and Settings
dragonfly
Window Leveling
CT_20250827_040550
Log Y
Selected control point
Position (normalized):
Position (physical):
Value:
Color
Alpha
Lookup table (LUT)
grayscale
More
Selected range
4,190.94
65,535
Plotted range/Data range
-159.27
Reset
65,694.27
0
65,535
Color mapping
Opacity mapping
Opacity:
Gamma:
1.00
Scene's Views Properties
Show scale bar
Orthographic projection
Show legends
Show text annotations
Anti-aliasing
Edge detect
Edge detect only ROIs
View mode:
3D
Interactivity:
Balanced
Background color:
Lighting
Light source position:
Light 1
Light 2
Light 3
Back
Use lighting
Use shadows
Light intensity
Shadow strength:
Shadow opacity
Focus
Enable
Auto focus
Close up
Focal distance:
Strength:
Depth of field:
Field of View:
Global volume opacity:
PD: 19,723.19 µm
Range Min: 4,191 Max: 65,535
CT_20250827_040550
0.00
8191.88
16383.75
24575.62
32767.50
40959.38
49151.25
57343.12
65535.00
Z-
25,174.47 X 15,525.99 µm
Range Min: 0 Max: 65,535
Slice 291 / 581
Yaw: -0.0 °
Pitch: 90.0 °
Roll: -0.0 °
17,174.48 X 10,583.44 µm
Range Min: 0 Max: 65,535
Slice 428 / 854
Yaw: 0.0 °
Pitch: 180.0 °
Roll: -0.0 °
25,218.33 X 15,526.99 µm
Range Min: 0 Max: 65,535
Slice 291 / 581
Yaw: 0.0 °
Pitch: 90.0 °
Roll: -90.0 °
1/1
Basic properties
Tools
Histogram:
2D settings
Interpolation: Linear
3D presets
Save As...
Save
Delete
Rename...
Presets: Grayscale
3D settings
Solidity:
Diffuse:
Specular:
Shininess:
Tone mapping
Filtered gradient
Unsharp
High quality
Specular boost
Median
Edge contrast
Render mode:
Default
Interpolation:
Linear
Clip
Grid size:
1.000
µm
Keep box when object is hidden
Grid lines
Borders
Axes
Captions
Label:
Ticks (2 Axes)
Lock text
Visual effects
Screen Recorder
Stop Recording
Include audio
Also save lower resolution file
Maintenance expires: 1/1/2026
New Session...
Preferences
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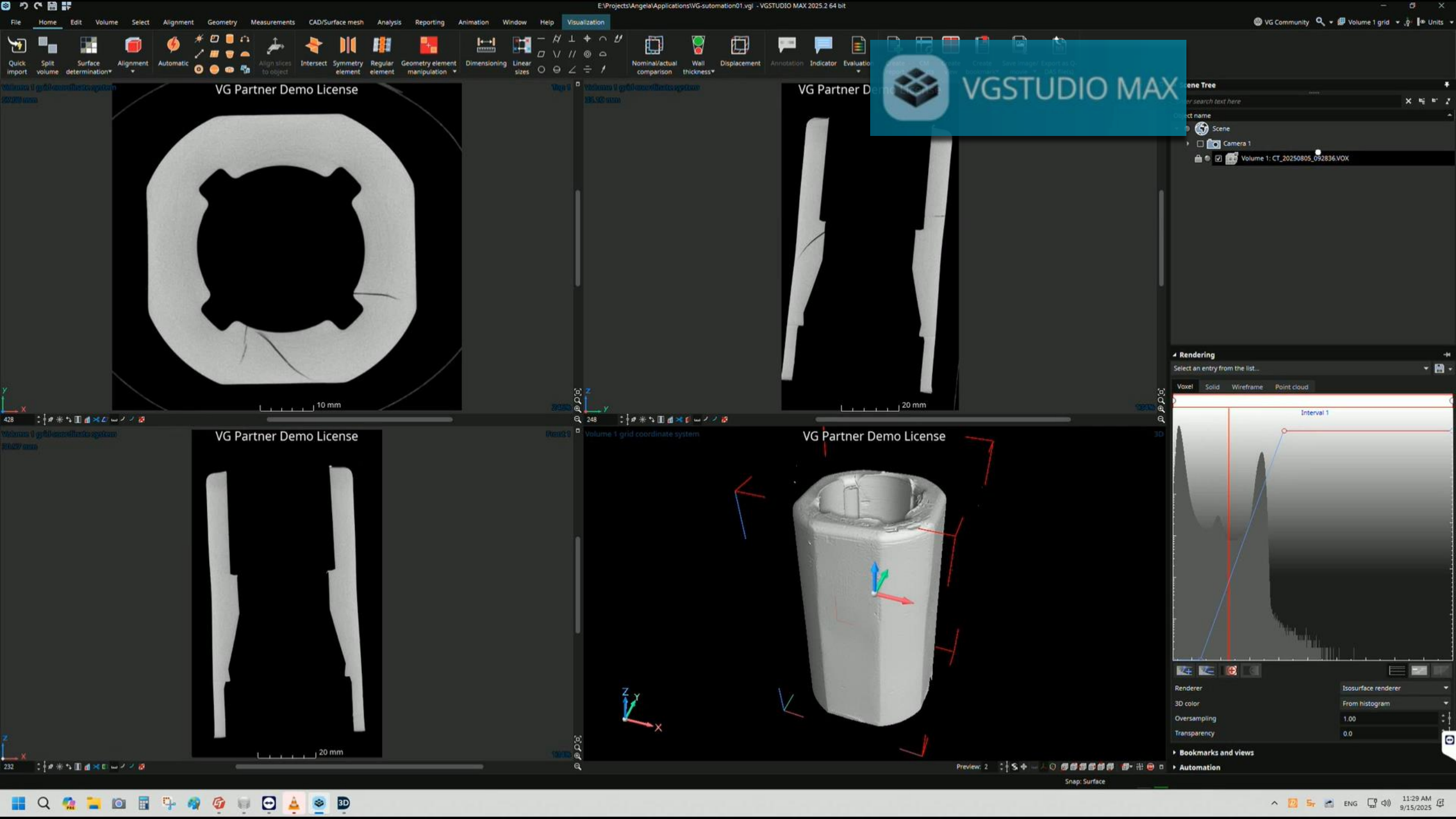
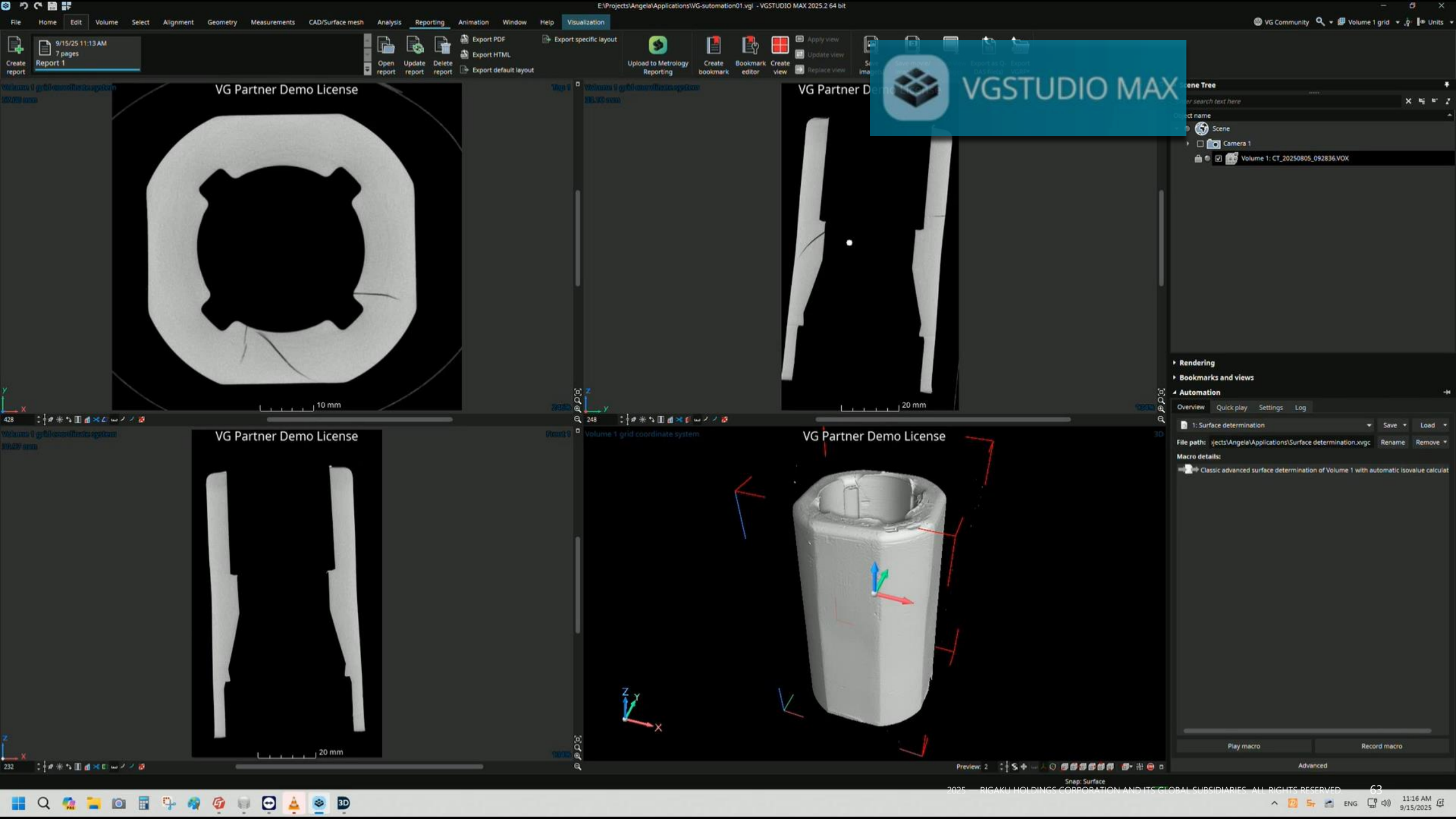
61
ENG
3:21 PM
9/11/2025


E:\Projects\Angela\Applications\VG-sutomation01.vgl - VGSTUDIO MAX 2025.2 64 bit
File
Home
Edit
Volume
Select
Alignment
Geometry
Measurements
CAD/Surface mesh
Analysis
Reporting
Animation
Window
Help
Visualization
VG Community
Volume 1 grid
Units
Quick import
Split volume
Surface determination
Alignment
Automatic
Align slices to object
Intersect
Symmetry element
Regular element
Geometry element manipulation
Dimensioning
Linear sizes
Nominal/actual comparison
Wall thickness
Displacement
Annotation
Indicator
Evaluation
VGSTUDIO MAX
VG Partner Demo License
10 mm
VG Partner Demo License
20 mm
VG Partner Demo License
20 mm
VG Partner Demo License
Volume 1 grid coordinate system
Scene Tree
Scene
Camera 1
Volume 1: CT_20250805_092836.VOX
Rendering
Select an entry from the list...
Voxel
Solid
Wireframe
Point cloud
Interval 1
Renderer
Isosurface renderer
3D color
From histogram
Oversampling
1.00
Transparency
0.0
Bookmarks and views
Automation
Preview: 2
Snap: Surface
ENG
11:29 AM
9/15/2025



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  - Batch processing of multiple data sets
- Macro recommendations
  - One macro with many steps
  - Many macros to create
- Customization
  - Scripting with Python

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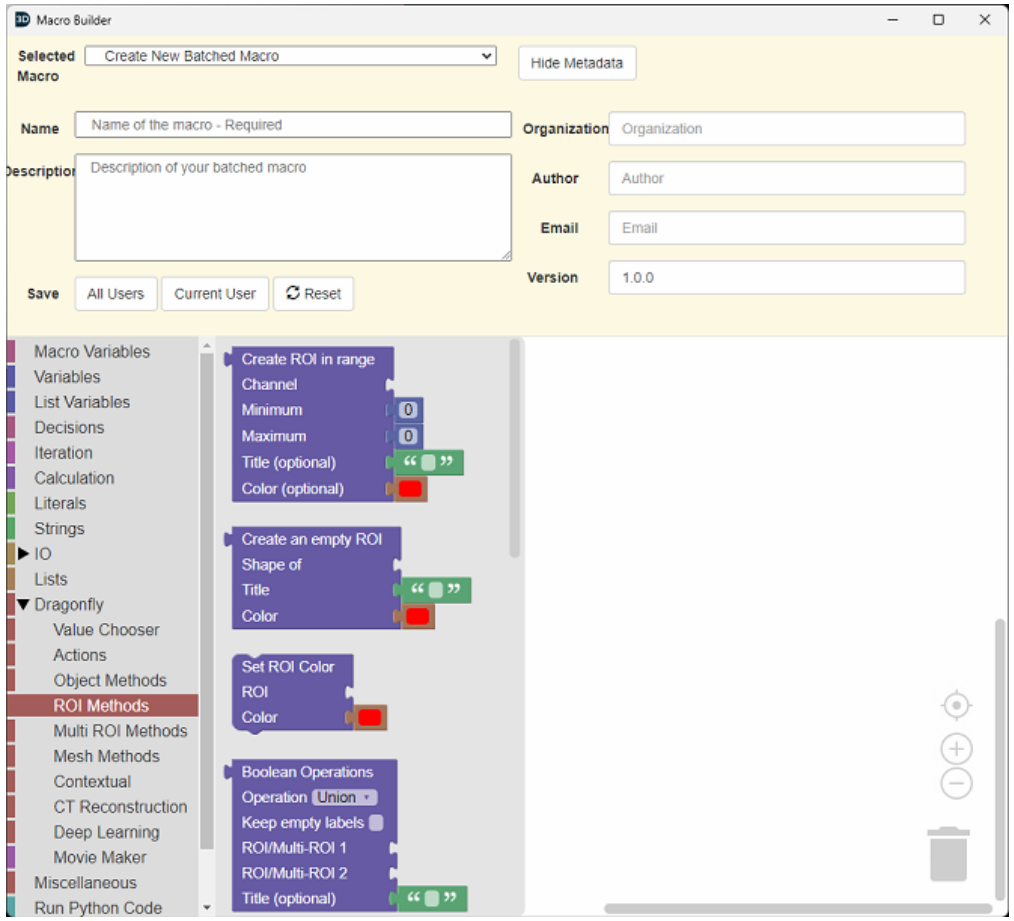
  - One macro with many steps
  - Many macros to create
- Customization
  - Scripting with Python
  - Visual programing with Scratch (*Dragonfly*)



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Microsoft stock

You just learned

1. Why repeatability matters
2. Automating CT scanning
3. Automating CT analysis

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Questions?

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We'll follow up with your questions.

Recording will be available tomorrow.

Register for webinar.

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Mastering CT: Advanced Techniques in Practice

Episode 3 – 4D Structure Study with X-ray Computed Tomography

Wednesday, October 15 at 10 am CDT

Presenter: Ted Huang

Don't forget to register for the next episode!

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