New Data Resources
For Accelerating AI Research

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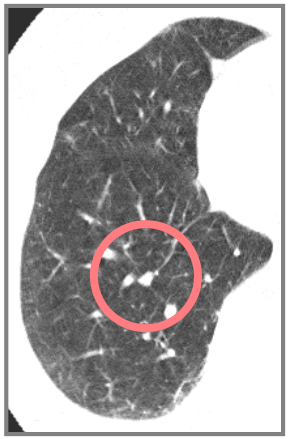
CT Lung Cancer Decision Support Landscape

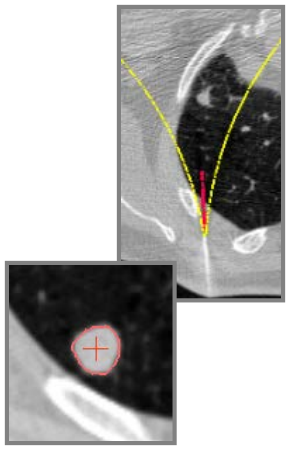
Pipeline

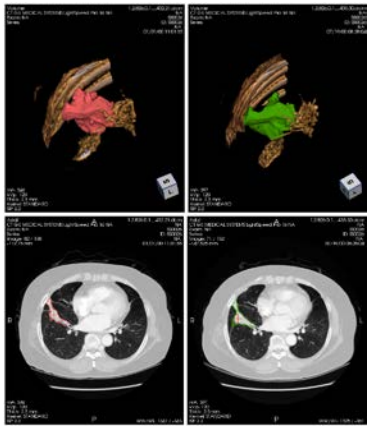
Individual Risk Assess, Δ, Monitor → Personalized Early Detection → Differential Diagnosis → Intervention & Therapy

Imaging Opportunities

Image+ Based Risk Analysis	Computer Aided Detection (CAD) + Δ Analysis	Δ Analysis & IG Biopsy	CAD + Δ Analysis

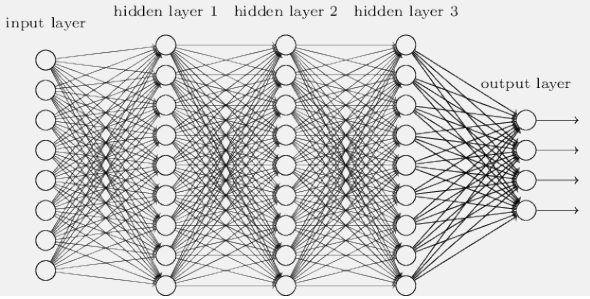






Deep Learning Challenges

1) What rules/methods/physics/equations did it learn?

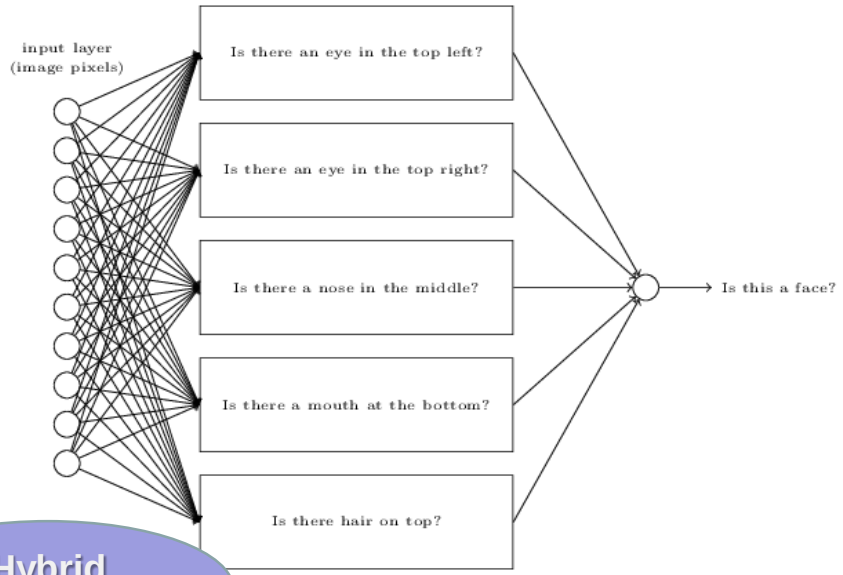


2) Massive representative & labeled datasets are continuously needed for training and validation

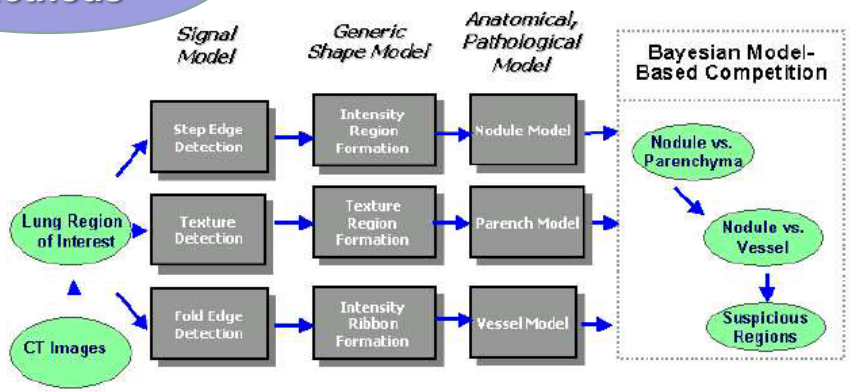
3) Image quality matters for many applications and it is changing faster than our ability to acquire large databases

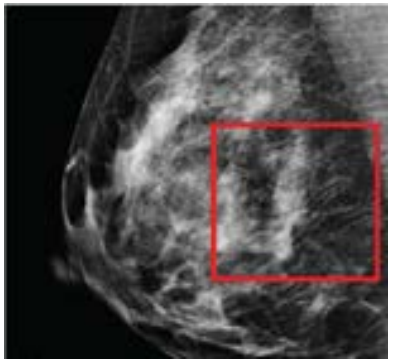
Deep Learning and Model-Based Algorithms

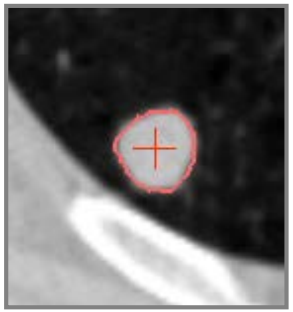
Known Models/Physics ..... Discovery

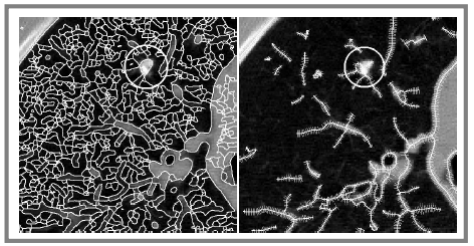


Hybrid Methods









Model-Based Detection of Lung Lesions in CT Exams, CARS 2003

Early Lung Imaging Confederation (ELIC) Project
A New Global Lung Imaging Research Resource

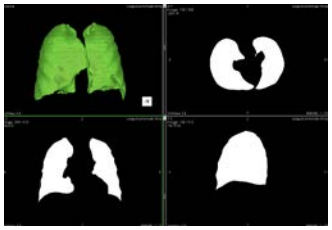
Problem: Many Promising CT Lung Cancer Screening Research Opportunities Including Artificial Intelligence/Deep Learning Require 10x to 100x Larger Datasets (e.g. $10^4 \longrightarrow 10^6$)

Solution: Create a New and Secure CT Lung Imaging Computing Environment That Removes Barriers to Site Participation and is Populated With De-Identified, High Quality Data

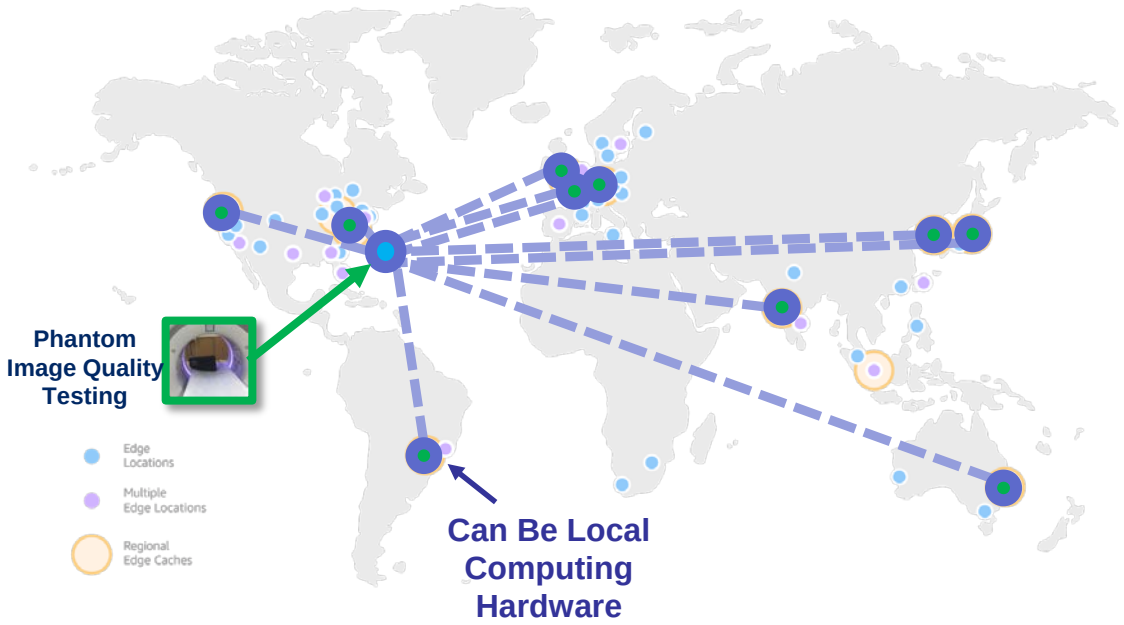
ELIC Live Demonstration
Using The Amazon Web Services (AWS) Cloud

Two Algorithms

Lung Volume



Lung Nodule Volume



Hub

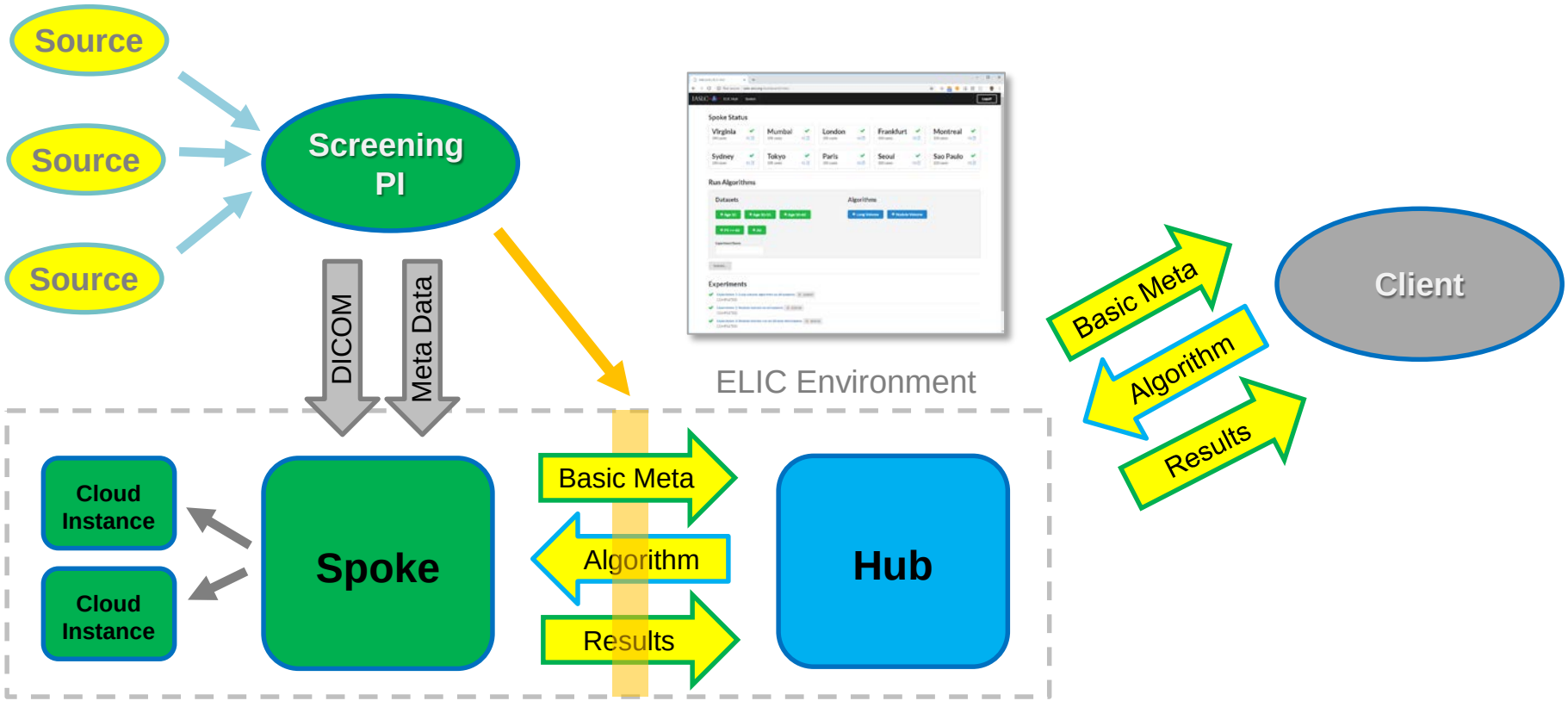
- Virginia, USA

Spokes

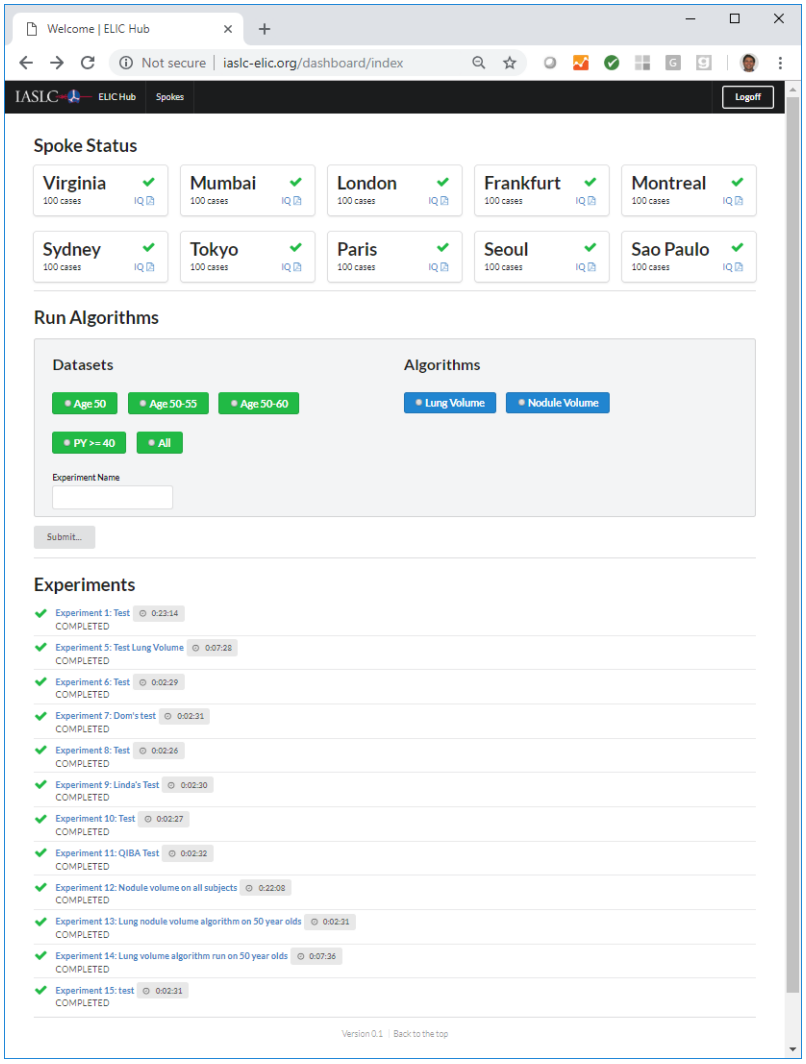
1. Virginia, USA
2. Mumbai, India
3. London, UK
4. Frankfurt, Germany
5. Montreal, Canada
6. Sydney, Australia
7. Tokyo, Japan
8. Paris, France
9. Seoul, South Korea
10. Sao Paulo, Brazil

ELIC Live Demonstration Spoke Locations Do Not Indicate ELIC Future Plans

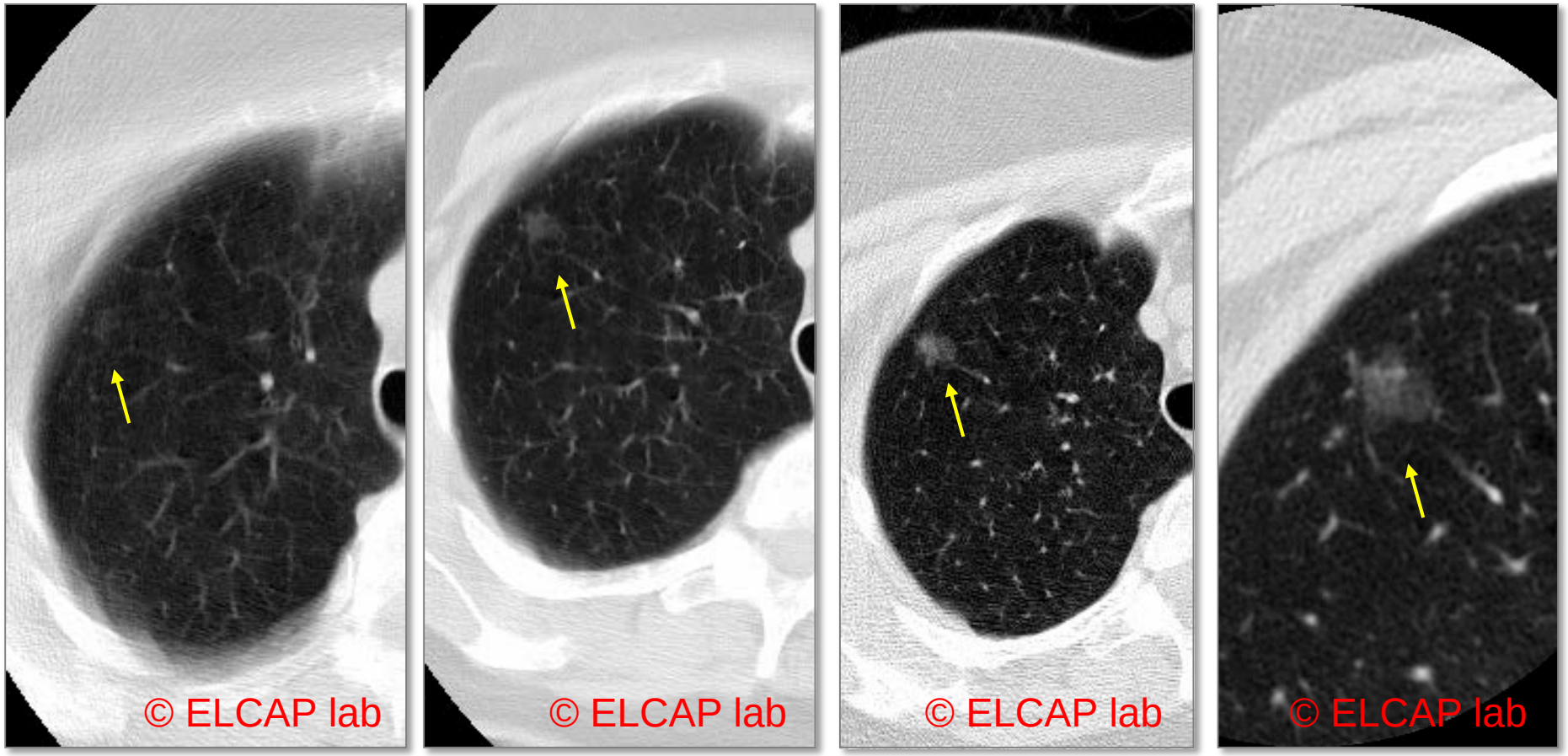
ELIC Stakeholder Participation Overview



ELIC Demonstration @ iaslc-elic.org



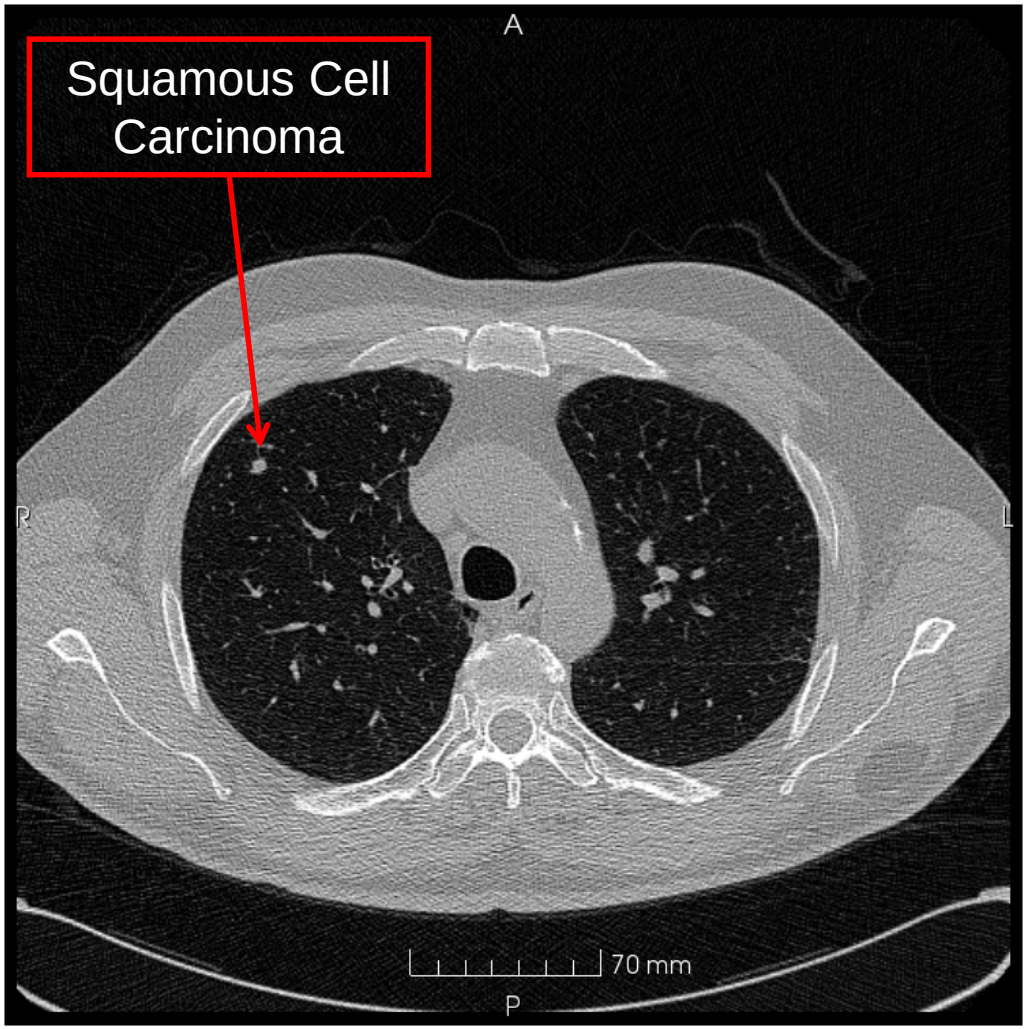
CT Image Quality



10.0 mm **5.0 mm** **2.5 mm** **1.25 mm**

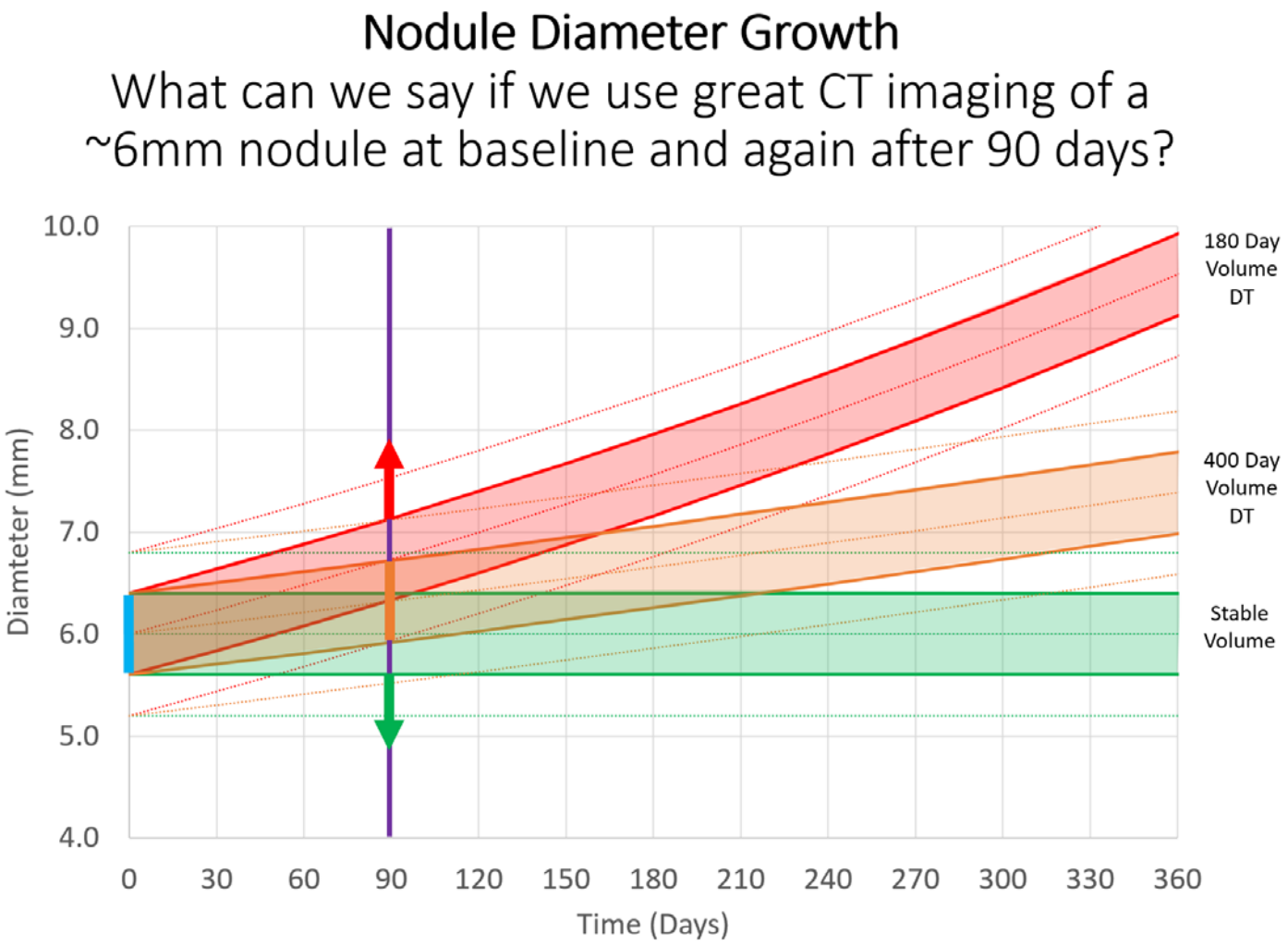
[Dr. David Yankelevitz, Mount Sinai]

Follow-Up Measurement of Small Lung Nodules



[Dr. Javier Zulueta, University of Navarra]

Precision Follow-up Time



2010: Roche ABIGAIL Study

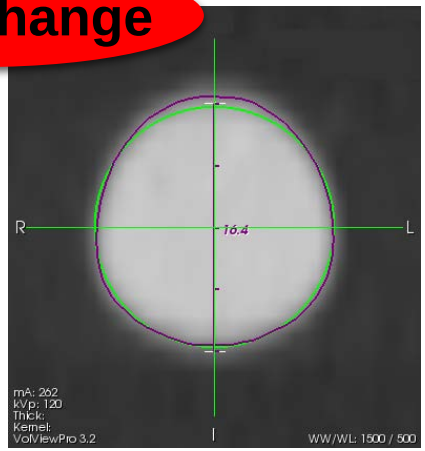
Model A
Site 1

+44% Change

1654 mm^3 2379 mm^3

Model A
Site 2

+33% Change

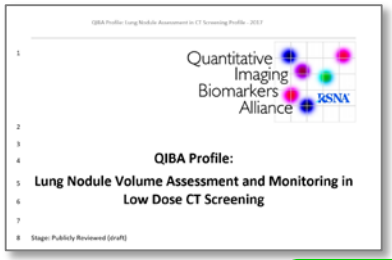


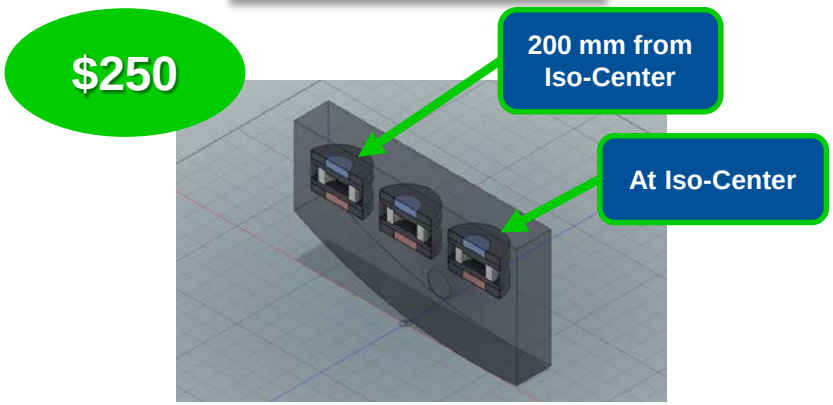
1601 mm^3 2127 mm^3

JMI 2016

CTLX1 Phantom

The First Image Quality Phantom To Measure The Full CT Scanner Field of View

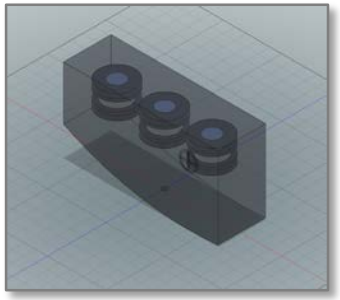


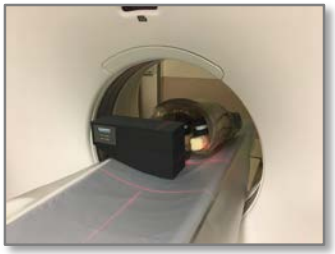


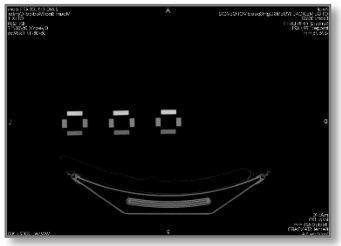
This Ellipsoid Represents The Smallest Size Lung Nodule That a CT Lung Cancer Screening Site Needs To Be Able To Reliably Measure

- **Fundamental CT Image Properties**
  - 3D Resolution:
    - 3D PSF Ellipsoid Volume <= 1.5mm^3
  - 3D Resolution Aspect:
    - PSF Z/X <= 2.0
  - Linearity Bias:
    - Air and Acrylic Bias < 35 HU
  - Image Noise:
    - Acrylic Noise <= 50 HU SD
  - Kernel Edge Enhancement:
    - Air to Delrin Enhancement <= 5%
  - 3D Spatial Warping:
    - Delrin Cylinder RMSE <= 0.3 mm
- **Lung Nodule Volume Change Performance**
  - Verifies That Image Quality Meets or Exceeds The QIBA CT Lung Nodule Profile Volume Change Measurement Recommendations

RSNA/QIBA Conformance Certification Pilot Project Using Cloud-Based Computing Services



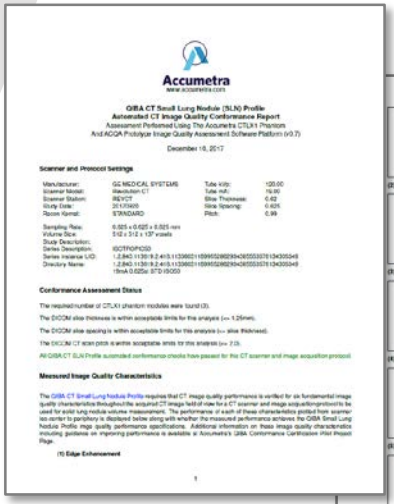


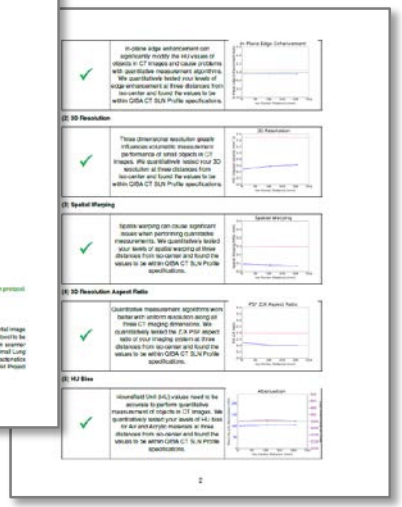


http://accumetra.com

Email

Upload

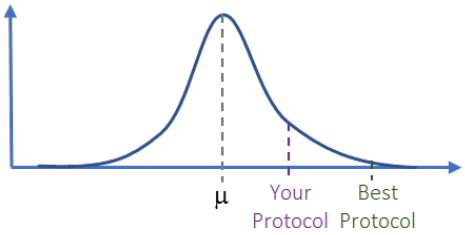




Optimize

+ Performance Prediction

Check Each Time Scanner or Protocol Changes and Once Per Year



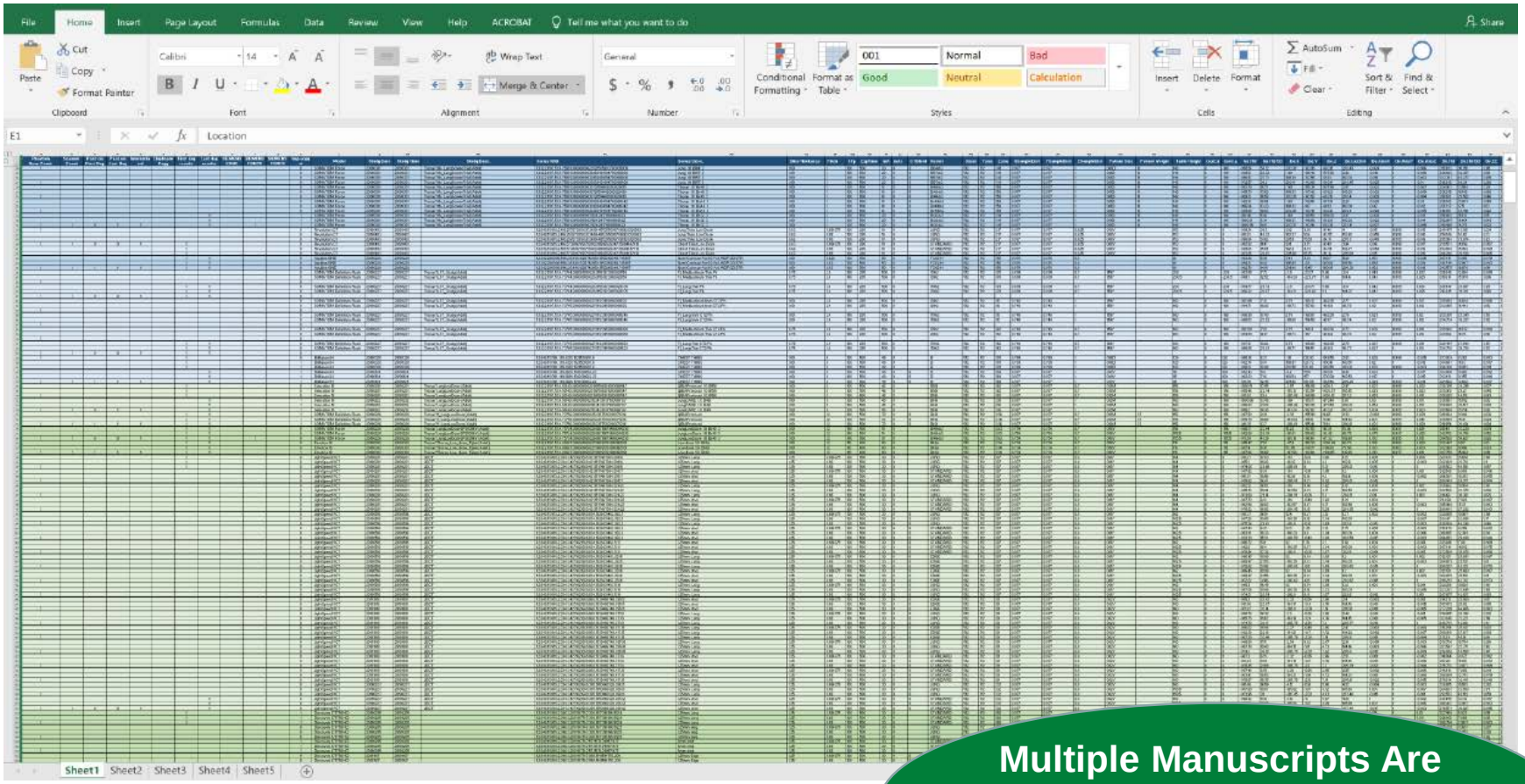
International CT Image Quality Monitoring

Many Thanks to the Prevent Cancer Foundation

> 700 CTLX1 Scans Received

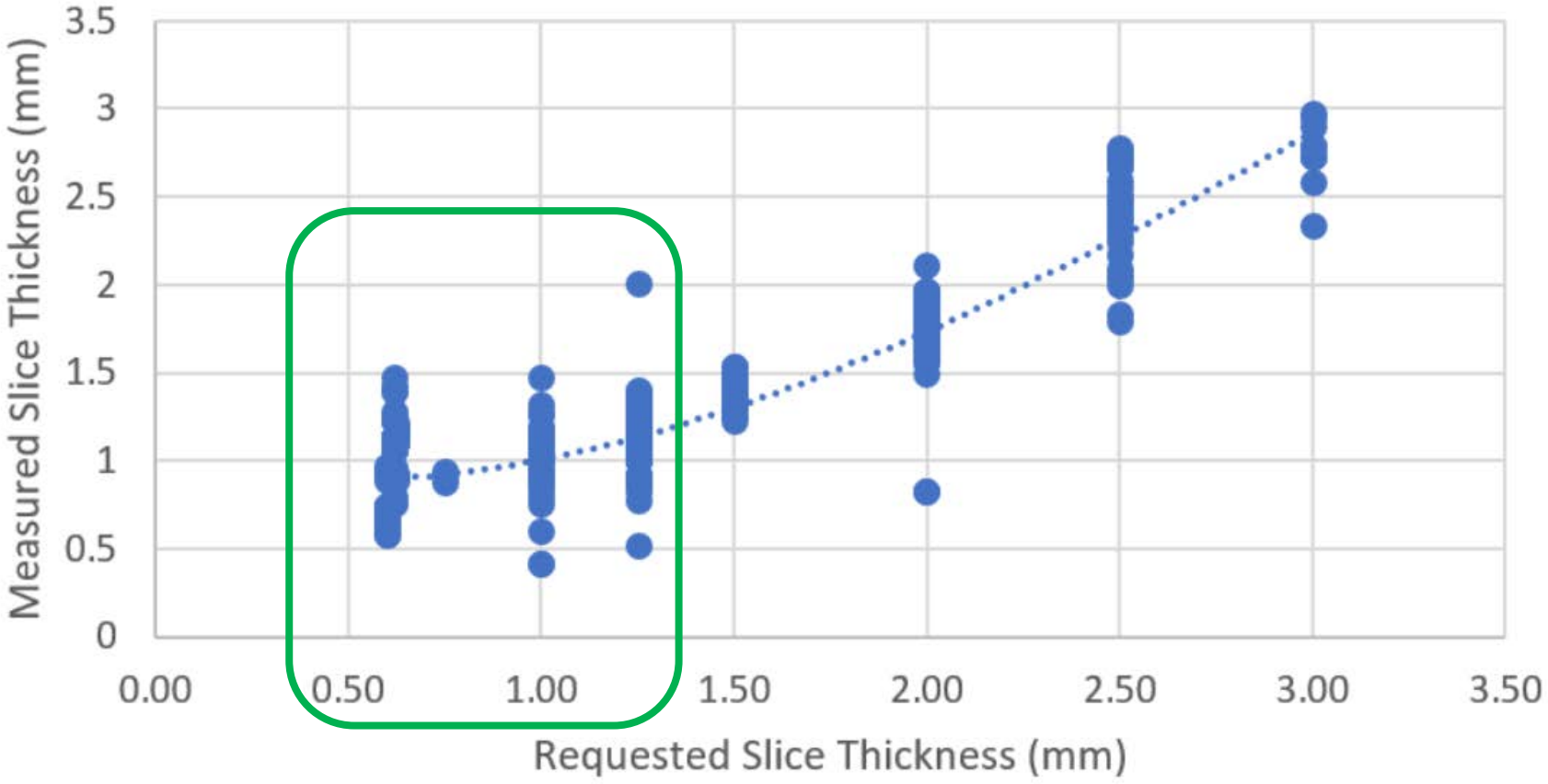
89 CTLX1 Phantoms Shipped As Of 04/04/2019

Large and Growing CT Image Quality Database



Multiple Manuscripts Are Now Being Prepared For Publication

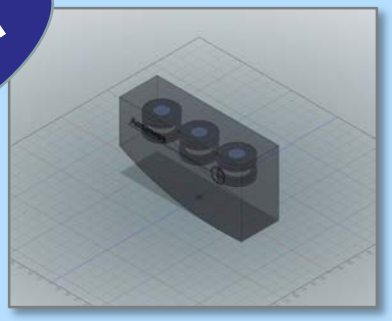
Requested vs Observed Slice Thickness



Cloud-Based and Task-Specific Image Quality Monitoring

CTLX1 Phantom

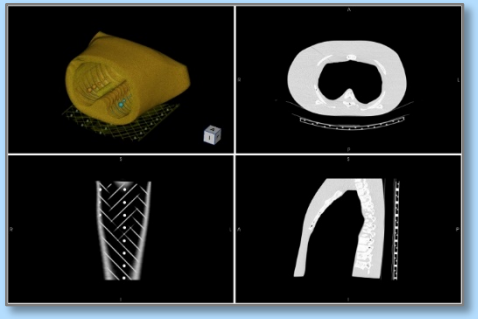
5 min



Protocol Optimization

CT Table Phantom

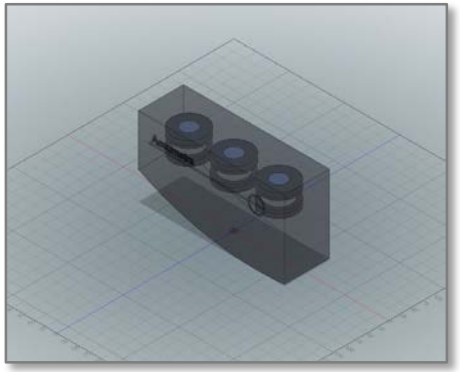
0 min



Real-Time Continuous

Opportunity For AI

Careful Monitoring and Optimization of CT Image Quality Will Help Build and Maintain Better AI Systems:



1. Efficiently Eliminate Low Quality CT Scans
2. Provide New Opportunities For AI Methods To Detect New Features
3. Help ID Protocol & Scanner Changes That Can Influence/Lower AI Results

Summary

- **Early Lung Imaging Confederation**
  - **A First ELIC Environment Software Has Been Created & Tested That Is Designed To Support Store/Compute on Millions of Cases Using The Cloud.**
  - **Early Testing of the ELIC Environment With Two Open Source CT Lung Measurement Algorithms Provided a Proof of Concept.**
  - **The ELIC Environment Has the Potential to Accelerate & Improve Artificial Intelligence Lung Cancer Research and Method Development.**
- **CT Image Quality Monitoring and Control**
  - **CT Image Quality is Clinical Task Dependent and Fundamentally Influences the Performance of All Computational Methods Including AI Methods.**
  - **Without CT Image Quality Control, Many Image Quality Changes Are Happening Without AI Algorithm Investigator Understanding.**
  - **Global Image Quality Control Has Been Set Up For Low Dose CT Lung Screening.**
  - **RSNA's QIBA Conformance Certification Is Now Providing Tools and Services.**
  - **Adding Fundamental CT Image Quality Data To a Deep Learning System Is a Near Term Opportunity.**

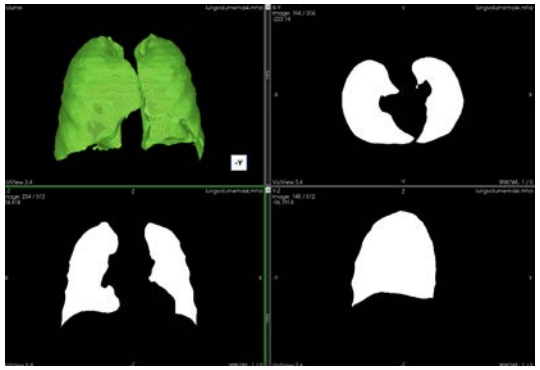
Thank You

Extra Slides

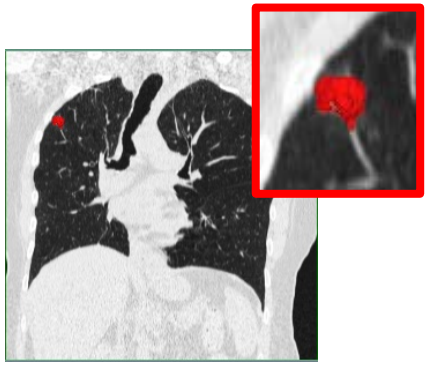
2018 ELIC Pilot Project (3 months)

- Create a First Version of the ELIC Hub and Spoke Environment
- Run ELIC on the Amazon Cloud With 10 Global Spokes Each Providing 100 De-identified CT Lung Images (N = 1,000)
- Develop and Run Two Open Source Lung Measurement Algorithms
- Perform a Live ELIC Demo at the 19th WCLC (Toronto, 9/22) Showing Running of Computational Experiments at 10 ELIC Spokes
- Demonstrate That Prospective CT Image Quality Can Be Monitored and Optimized With the RSNA/QIBA CT Small Lung Nodule Profile
- Distribute All Code Developed as Free and Open Source Software – Global Sites Can Contribute To Software Development

Lung Volume



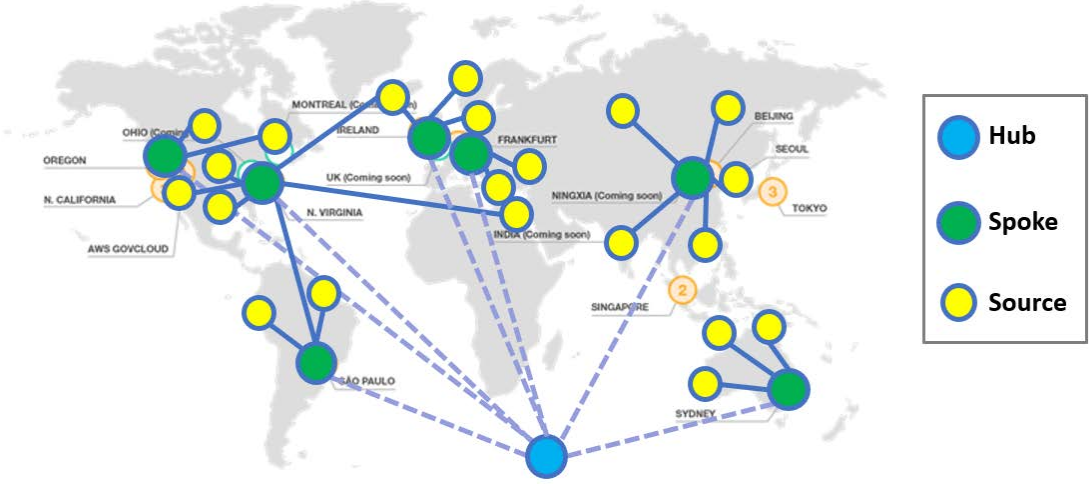
Lung Nodule Volume



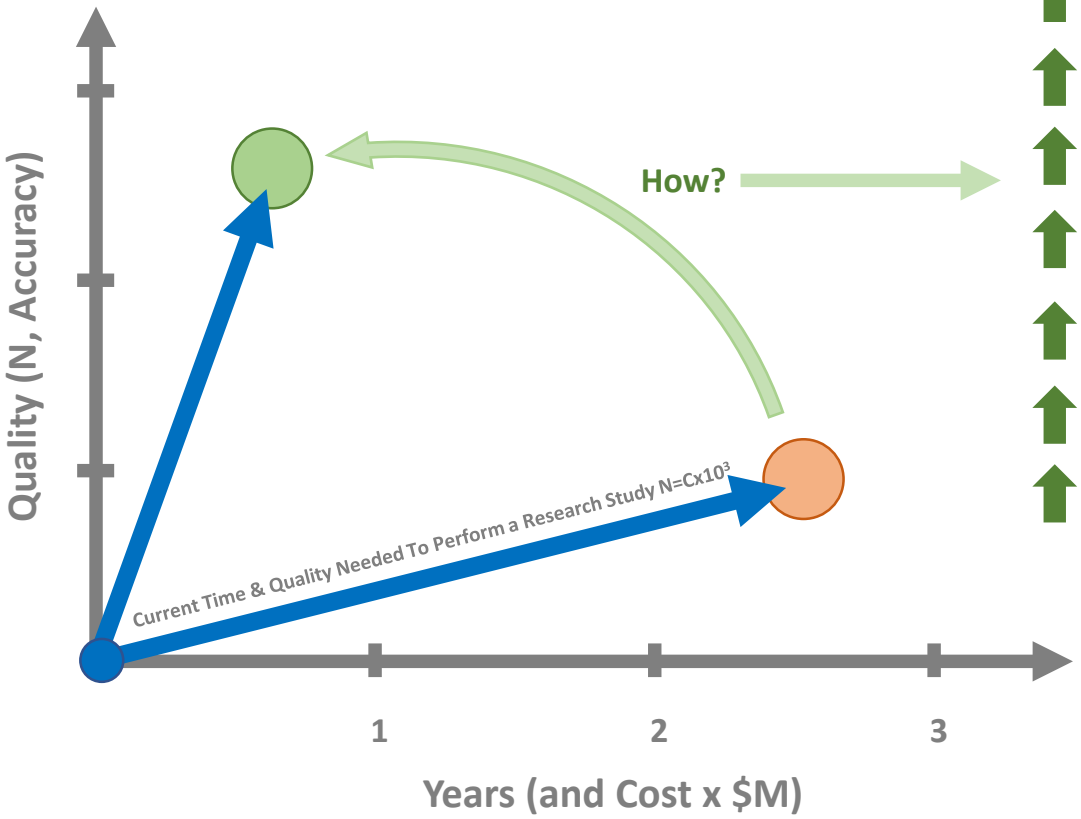
Early Lung Imaging Confederation (ELIC) Project
A New Global Lung Imaging Research Resource

Critical Requirements:

- Keep CT Image Data Locally and Send Algorithms To Spokes To Perform Analysis
- Make Setup and Secure Running of Spokes Automated, Easy, and Efficient
- Have Strong Governance and Pre-Established Data Use Agreements
- Leverage The Latest Computing Resources & Best Practices (Cloud, Open Source, …)
- Provide CT Image Quality Monitoring and Optimization Tools To Ensure High Quality Data



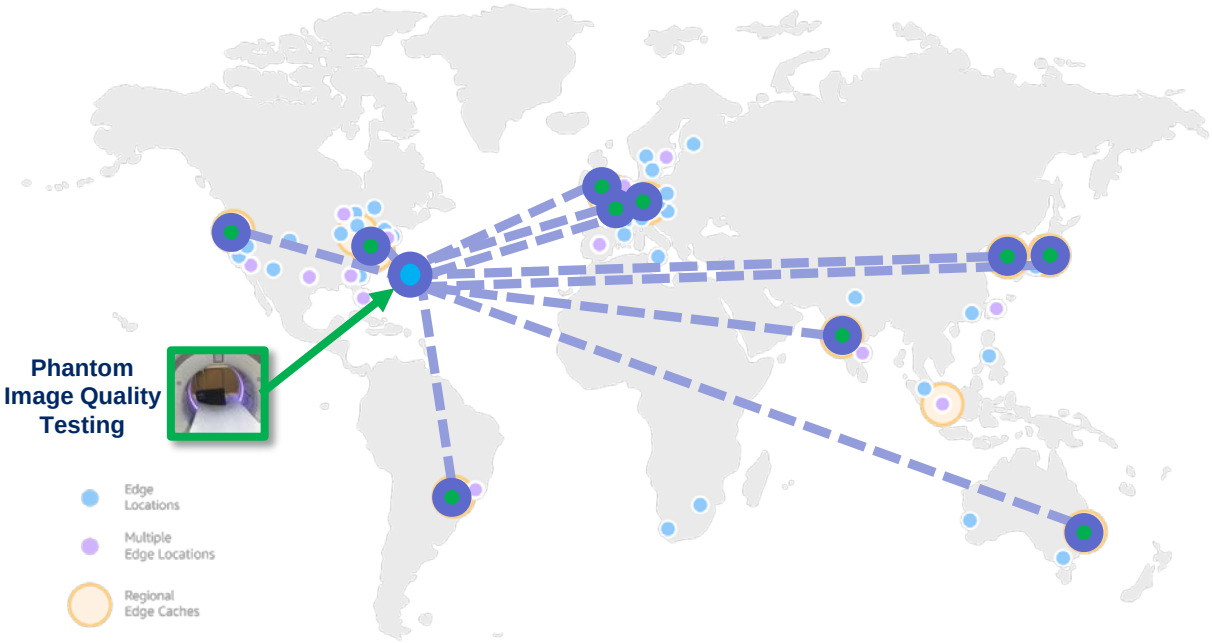
Early Lung Imaging Confederation (ELIC): Improving The Time, Cost, & Quality of Computational Studies



- Scale To Support N > 10^6 Cases
- Standardized Data Representation
- New Computing Tech (e.g. Cloud)
- Pre-Established Data Use Terms
- Strong, Fair Global Governance
- Easy To Use GUI For PIs and Clients
- Improved Quality (Image, Accuracy)

When Fully Deployed, ELIC Will Allow Global Research Studies To Be Performed in Days/Weeks Vs Years

ELIC Environment



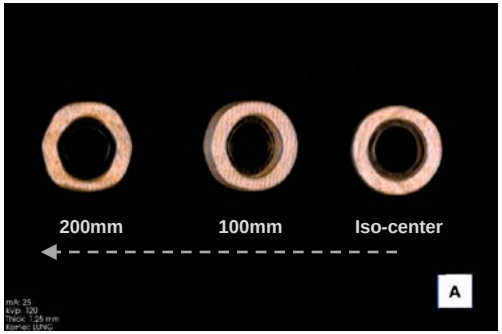
Opportunities

- Global Research Studies
- Regional Analyses
- Artificial Intelligence
- Technology Surveillance
- Global Quality Monitoring

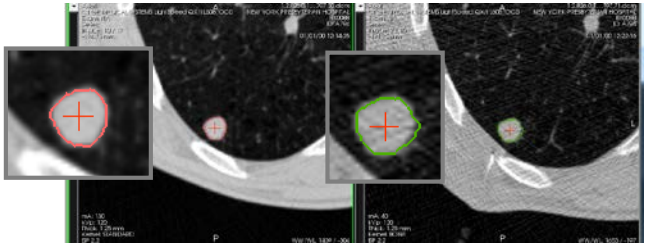
The ELIC Architecture Is Designed To Efficiently Support Storage and Analysis of Millions of Subjects

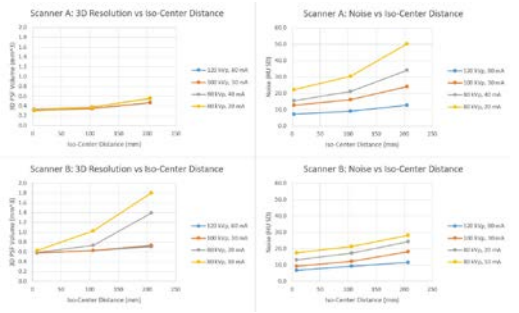
Quality of Lung Nodule Measurements: What Have We Learned Over The Last 15 years?

- While studies have shown great results, major quality issues persist & impact small (6-10mm) lung nodule measurements:
  - CT Image quality can greatly degrade in the periphery
  - 3D spatial warping can give the appearance of +- 40% Δ (JMI 2016)
  - Some recon kernels can bias HU values by > 50 HU
  - Lowering dose can result in resolution losses of > 200%
  - Many institutions continue to use thick slices
  - Difficult to determine if a segmentation is “good enough”
  - …



- CT imaging technology is constantly changing
  - Scanner geometries and detectors
  - “Standard” reconstruction kernels
  - Iterative reconstruction algorithms
  - New AI-based measurement methods
  - Measurement equipment is being replaced/repaired and protocols are changing across lung nodule follow-ups
  - …





We need to constantly measure and monitor CT acquisition and measurement equipment

Solution: QIBA CT Small Lung Nodule Profile
+ Conformance Phantom & Online Software

Quantitative Imaging Biomarkers Alliance

RSNA

2

3

4 **QIBA Profile:**

5 **Lung Nodule Volume Assessment and Monitoring in**

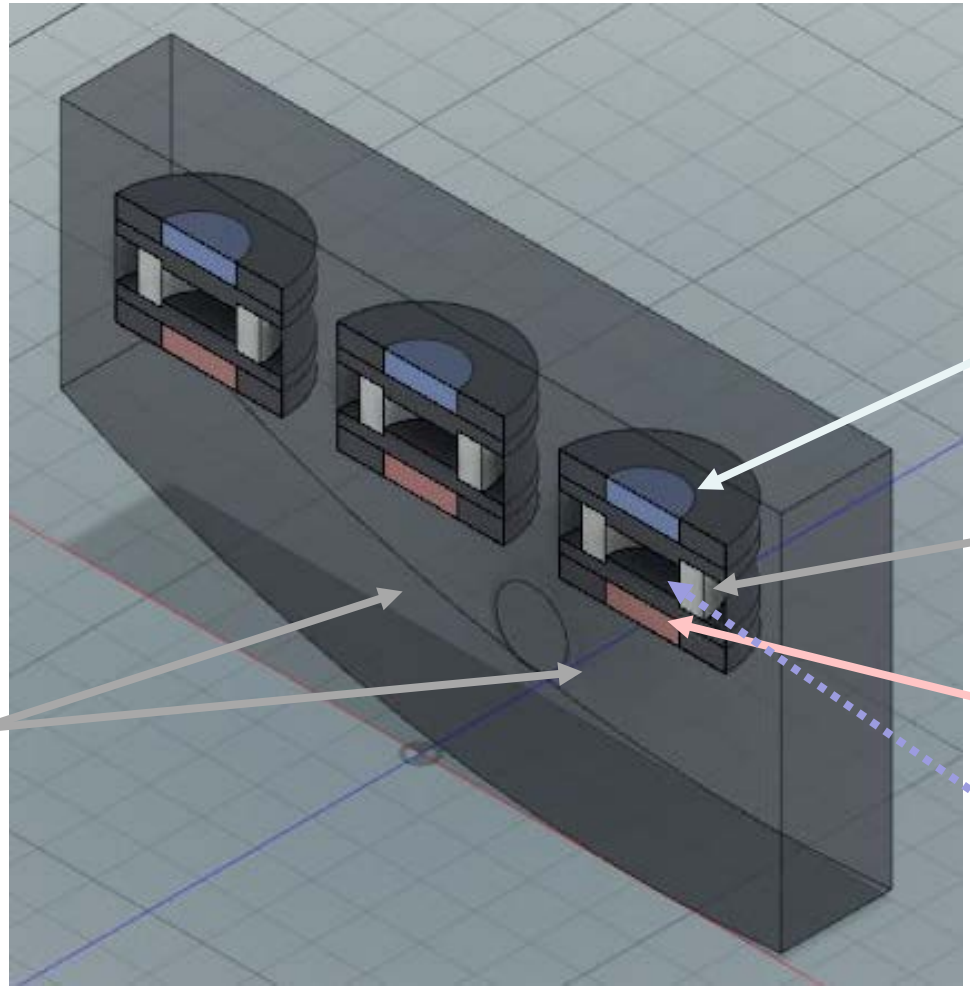
6 **Low Dose CT Screening**

7

8 Stage: Publicly Reviewed (draft)

QIBA Small Lung Nodule Phantom

First CT Image Quality Phantom To Measure From Iso-Center to Periphery



Room For Other Compartments

Teflon (~950 HU) Cylinder

Delrin (~340 HU) Concentric Cyl

Acrylic (~120 HU) Cylinder

Air (-1000 HU)

PCF Grant International Sites

Canada

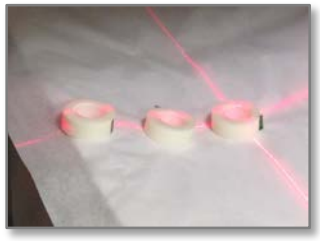
China

Italy

Poland

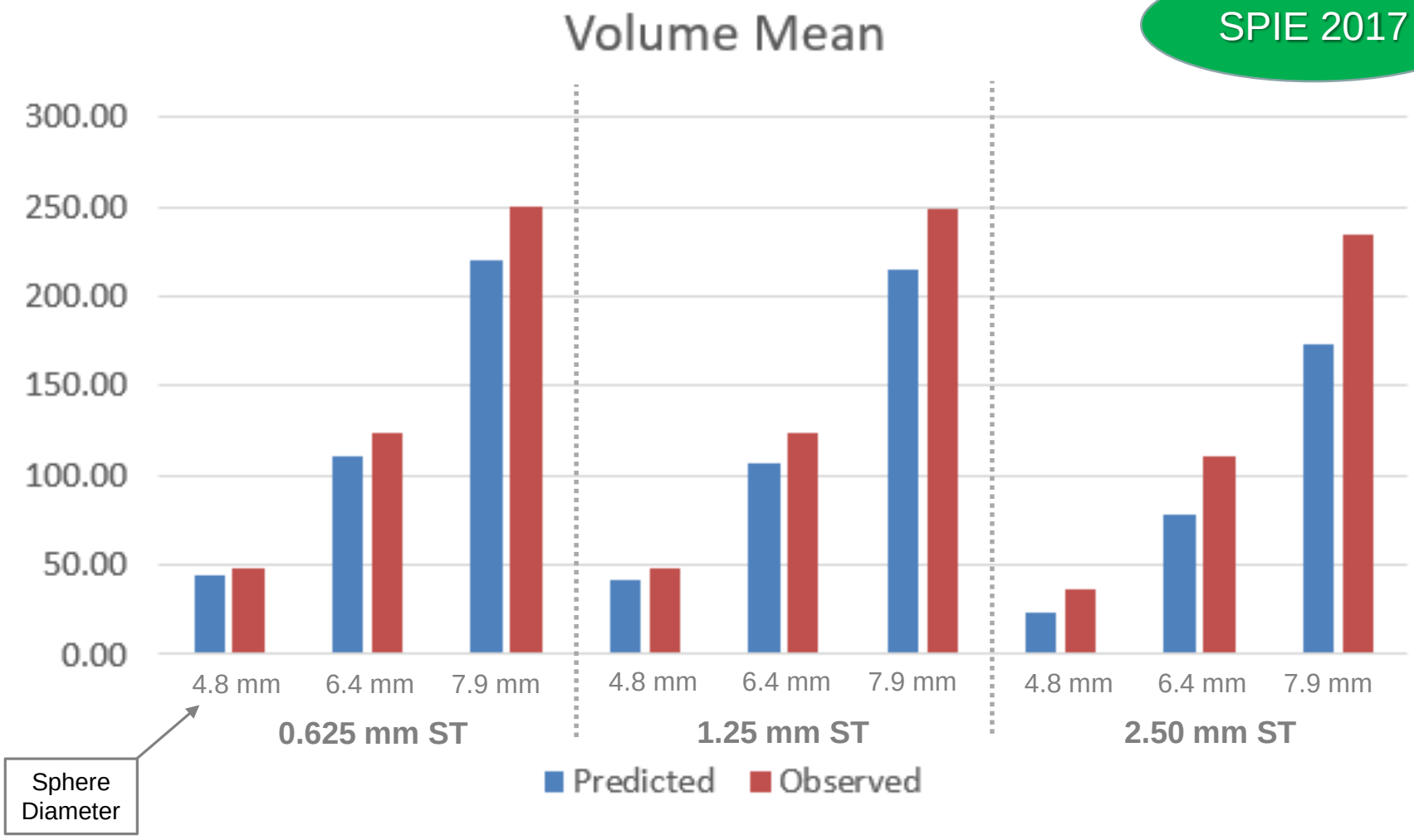
Validation Study: Predicted vs Measured

- CT Scanner
  - GE LightSpeed VCT
- Scan Protocol
  - Lung screening protocol with standard kernel, 0.625, 1.25, and 2.5mm slice thickness and spacing
- Objects
  - 1 scan of 3 rolls of 3M Scotch Tape ¾ x 1000 inch
  - 10 scans of Teflon spheres inside low density foam inside an anthropomorphic chest phantom, phantom was moved slightly each time
- Analysis
  - Automated analysis of scotch tape scan including estimated volume measurement performance
  - Independent algorithm for the detection and volume measurement of spheres
- Comparison
  - Plot predicted volume performance vs actual measurements



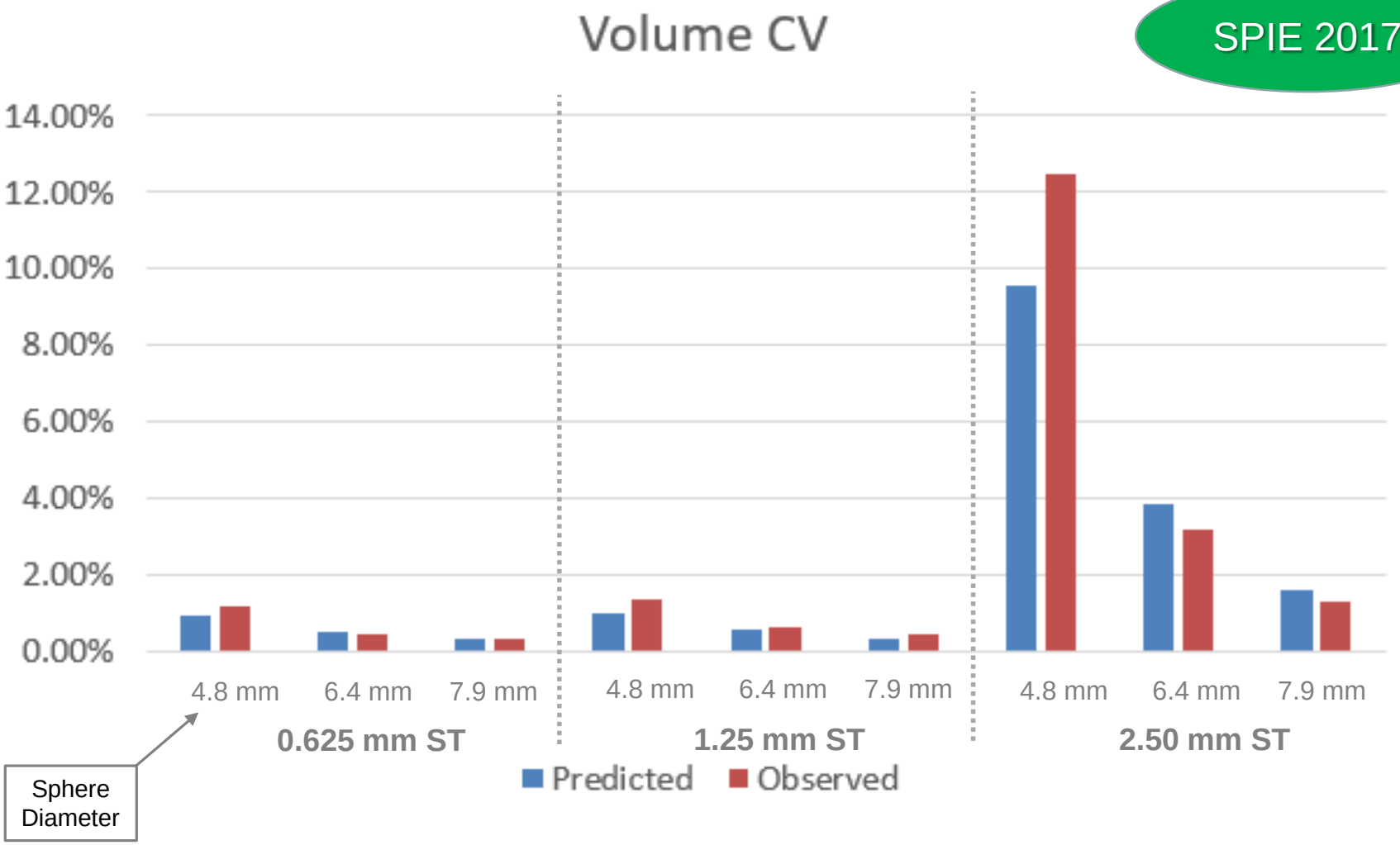
Predicted vs Observed Sphere Volume

SPIE 2017



Predicted vs Observed Sphere Volume

SPIE 2017



Prevent Cancer Foundation International Grant

RSNA/QIBA & Accumetra received PCF grant to globally improve image quality for CT lung cancer screening.

- Project ran from 8/2017 to 2/2019
- Major project goals:
  1. Set up an additional cloud-based CT image quality phantom analysis service in Frankfurt, Germany
  2. Manufacture and distribute >= 40 phantoms to international sites.
  3. Estimate improvement in small lung nodule volume measurement performance and publish 2 papers (1 clinical, 1 technical)

Frankfurt Cloud Analysis Server Setup January 2018

42 CTLX1 Phantoms Globally Distributed By December 2018

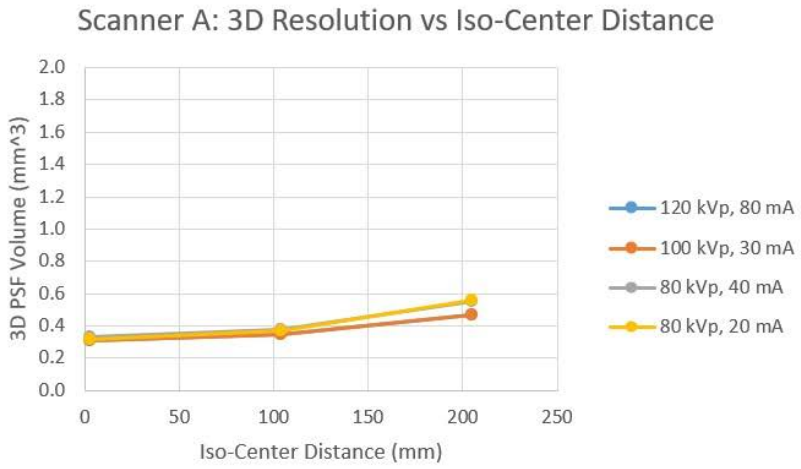
34 International CT Scanners Tested
10 (27%) Passed on 1st Day
21 (63%) Passed on Last Day

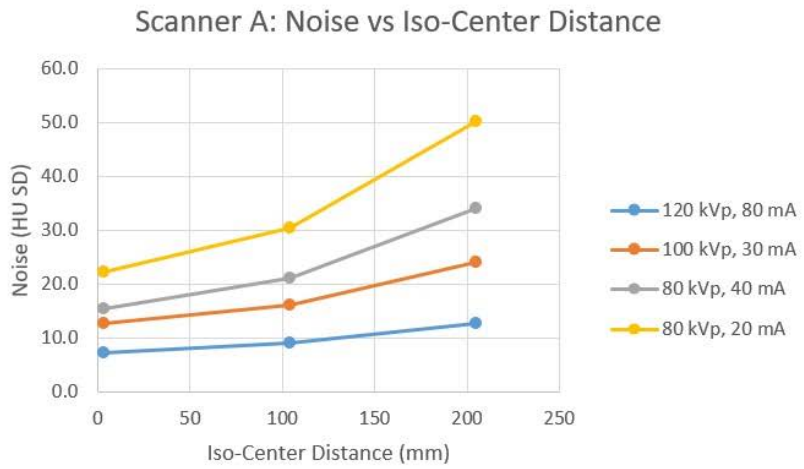
Set Up The First Global CT Image Quality Monitoring and Optimization System For CT Lung Cancer Screening

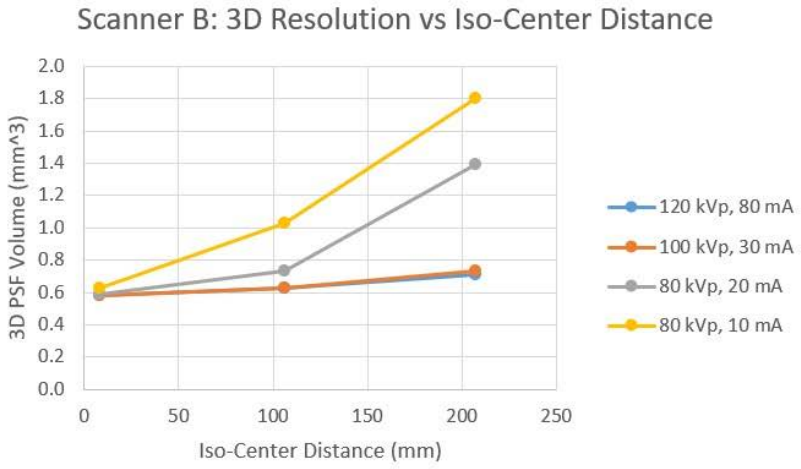
PCF International Grant Phantom Distribution

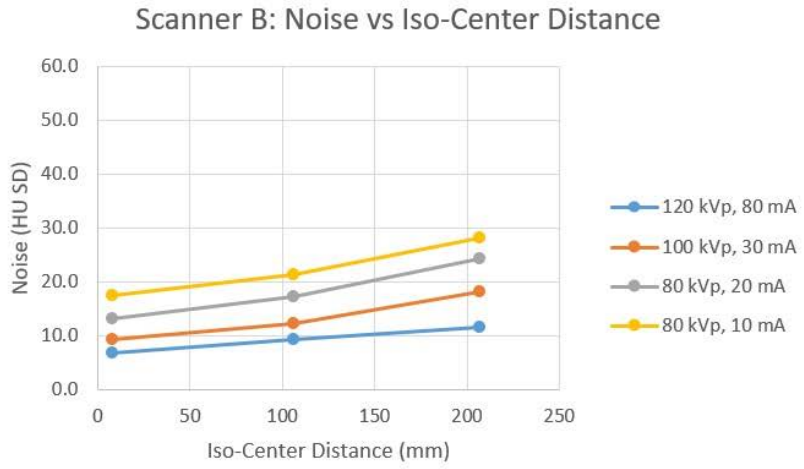
Count	Country	Number of Phantoms
1	Australia	6
2	China	10
3	Canada	7
4	Hong Kong	2
5	Italy	2
6	Israel	3
7	Japan	1
8	Netherlands	3
9	Poland	1
10	Spain	3
11	United Kingdom	4
	Total # Phantoms	42

Radiation Dose and Resolution

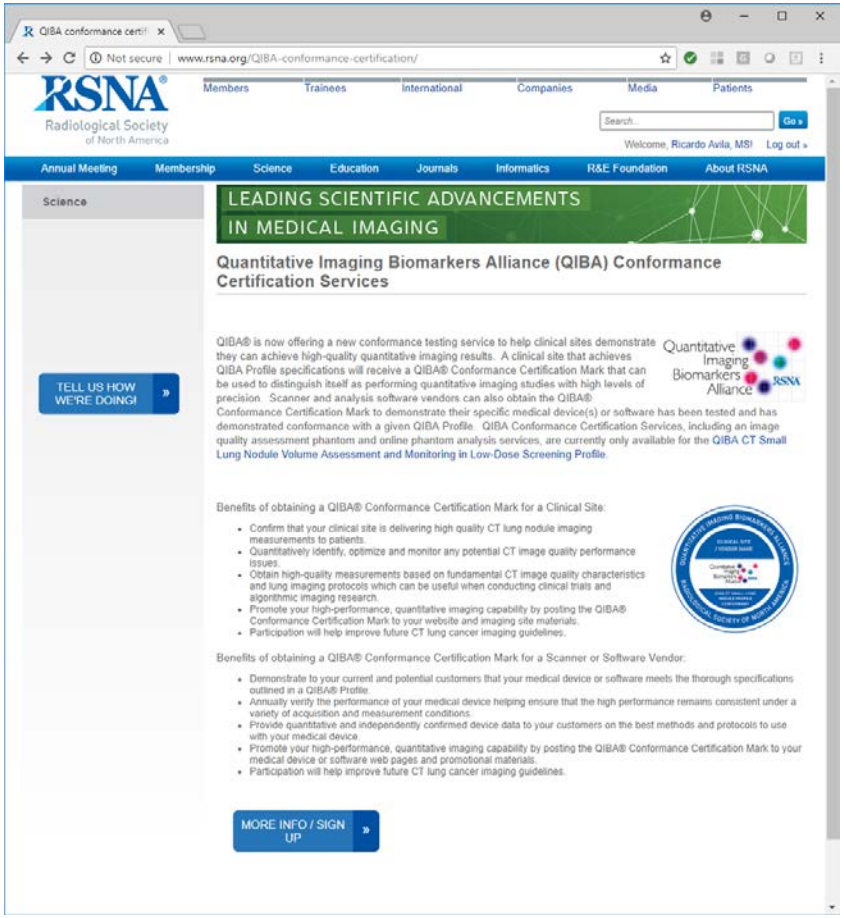


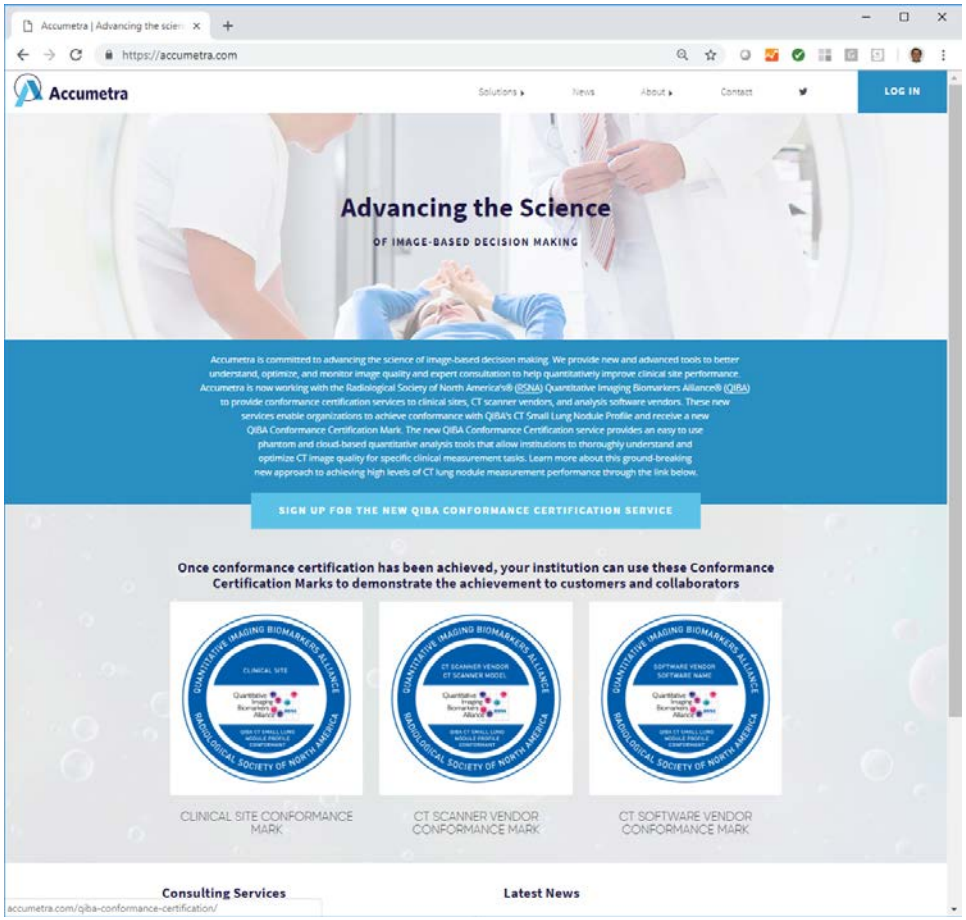




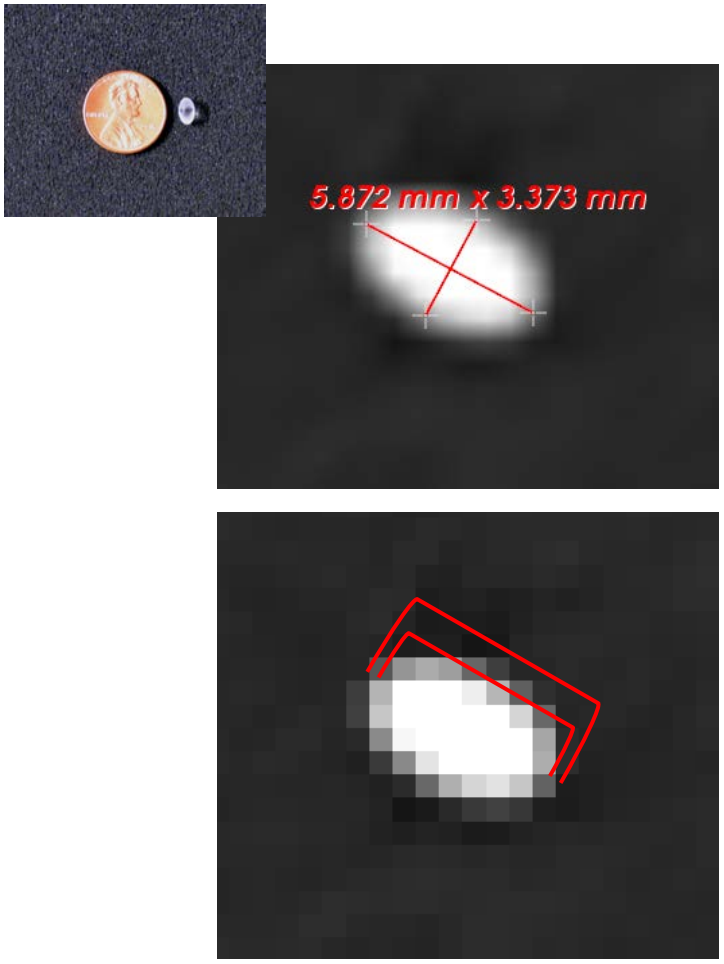


RSNA/QIBA Conformance Certification





Small Lung Nodule Measurement



For a 6.0 x 3.6 x 3.6 mm Lung Nodule:

We are working with axial CT images with a maximum nodule diameter of between 6 and 9 pixels

+1mm Max Diameter Increase

Nodule Diameter	Diameter Change %	Volume Change %
6.0	17%	59%
7.0	14%	49%
8.0	13%	42%
9.0	11%	37%
10.0	10%	33%

If This Is TRULY a +1.0 mm Max Diameter Increase Over 6 Months, This Is a > 250% Volume Increase Over A Year

(640% for 3m)

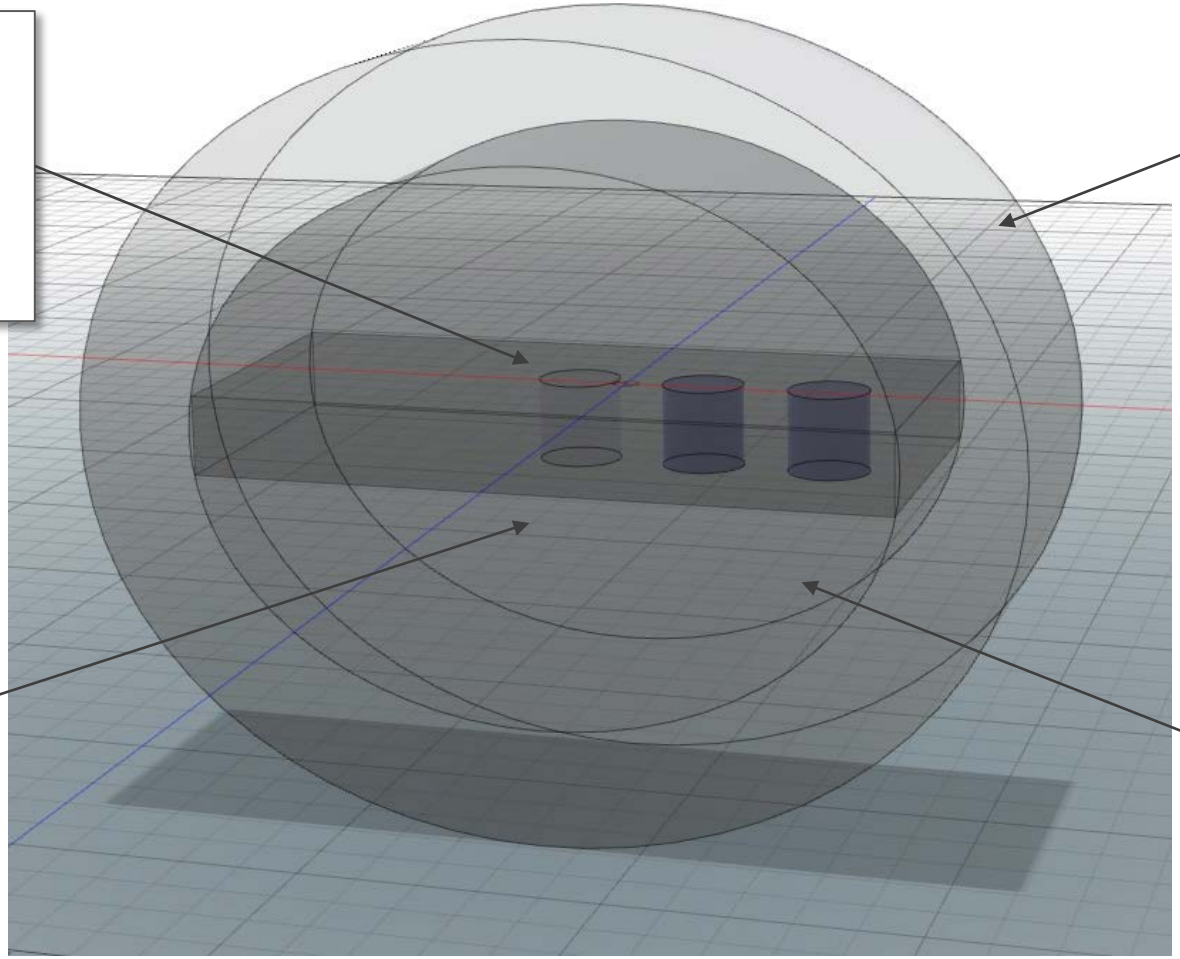
Numerous CT Image Quality Issues Can Bias This Measurement

Use of Precise and Quality Controlled Quantitative Image Measurement Tools Is Critical

CTLX2 Phantom

Will Contain 3 Small Modules Similar To The CTLX1

+ Outer Channel To Add Varying Amounts Of Water



+ An Additional Access Port

+ Additional Components Including Some Spheres and Ellipsoids

Table Phantom Scanning

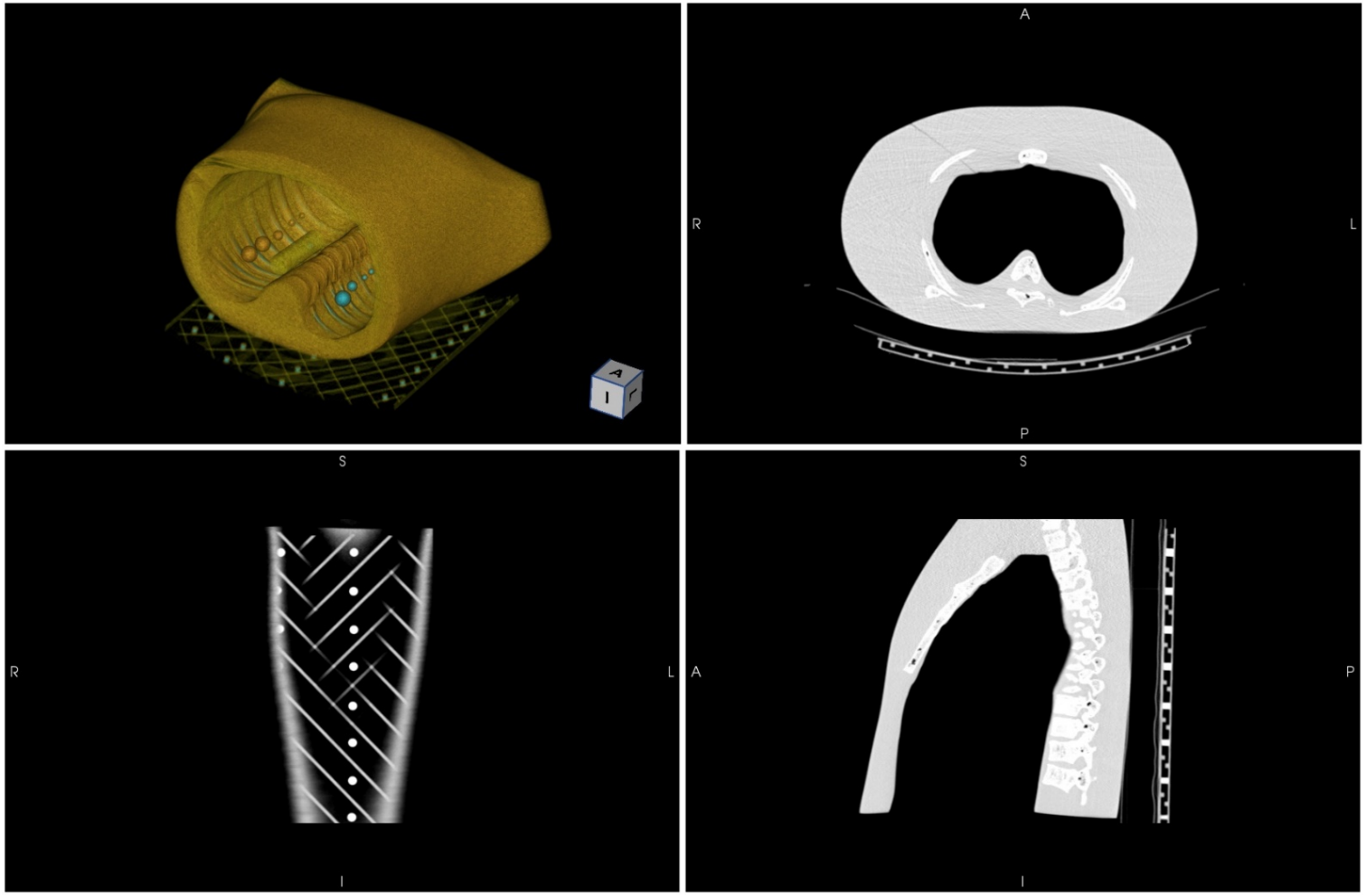


Table Phantom Scanning

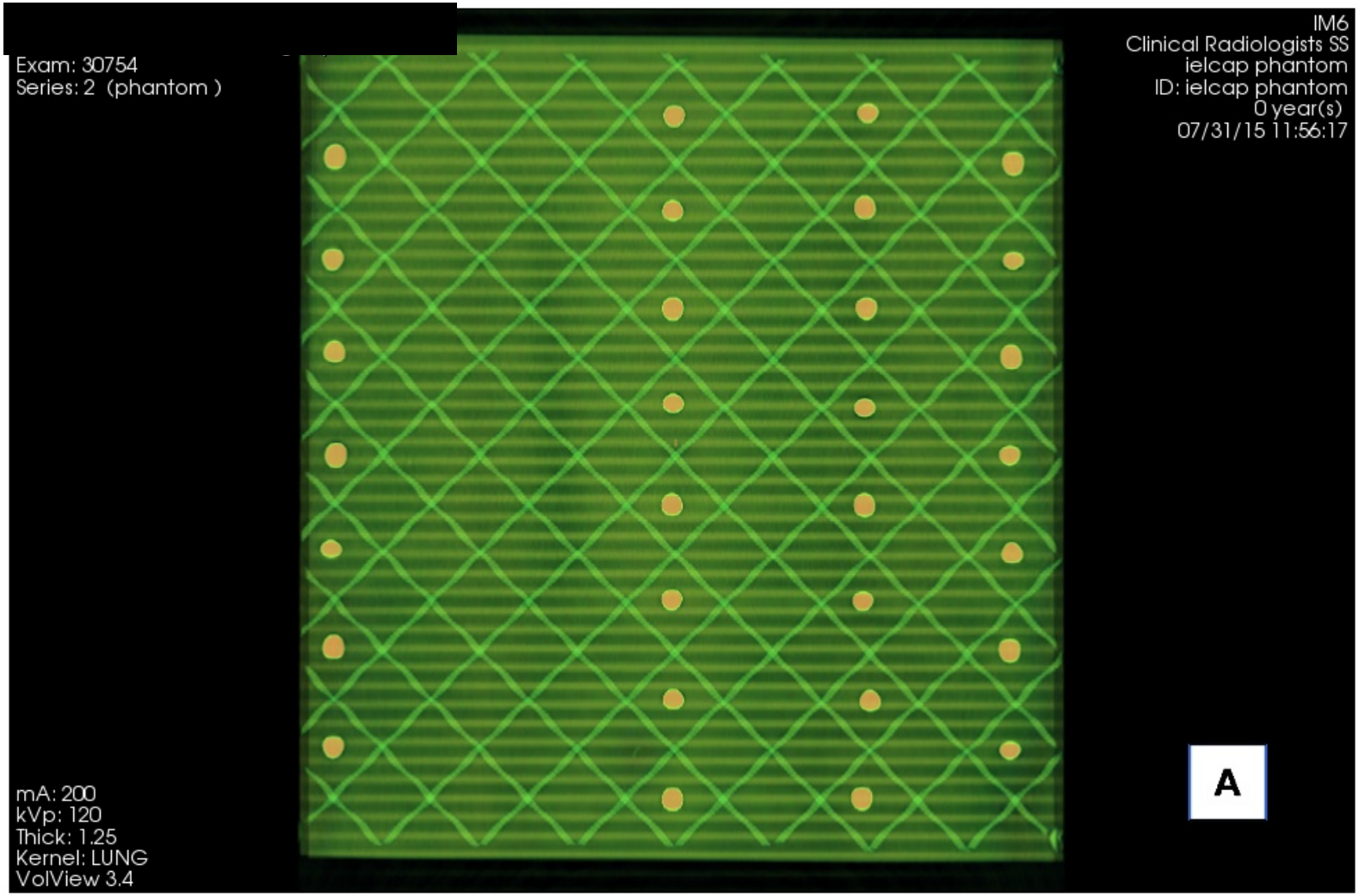
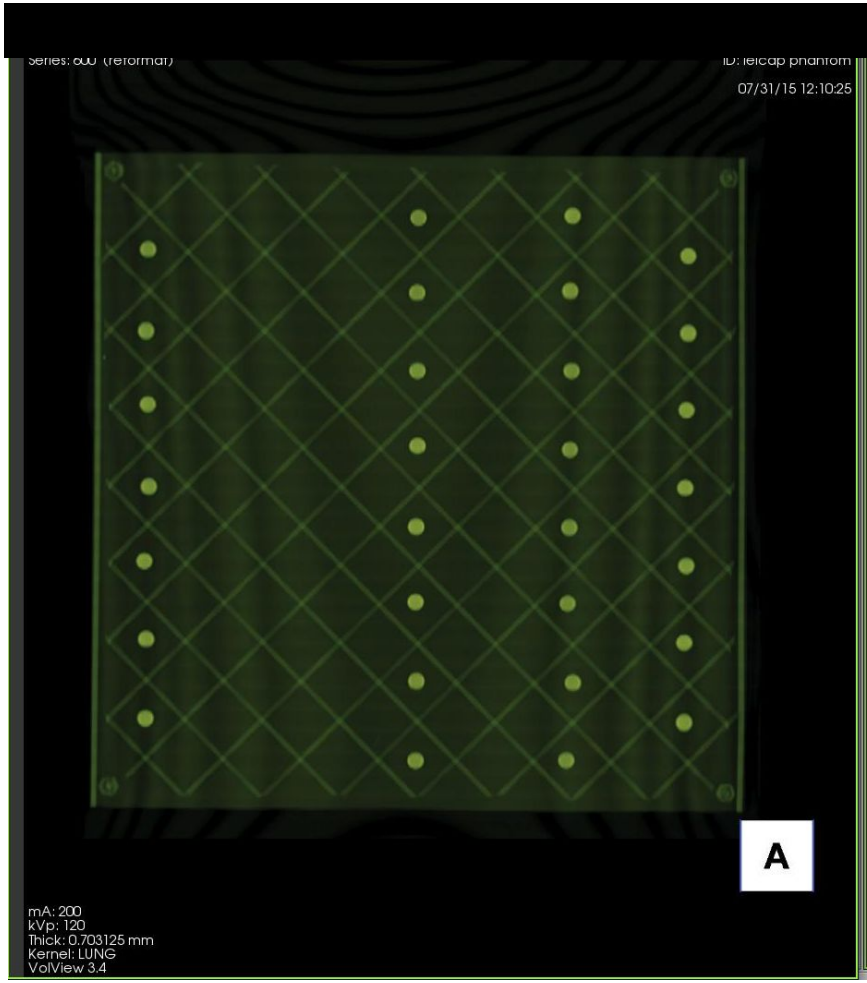
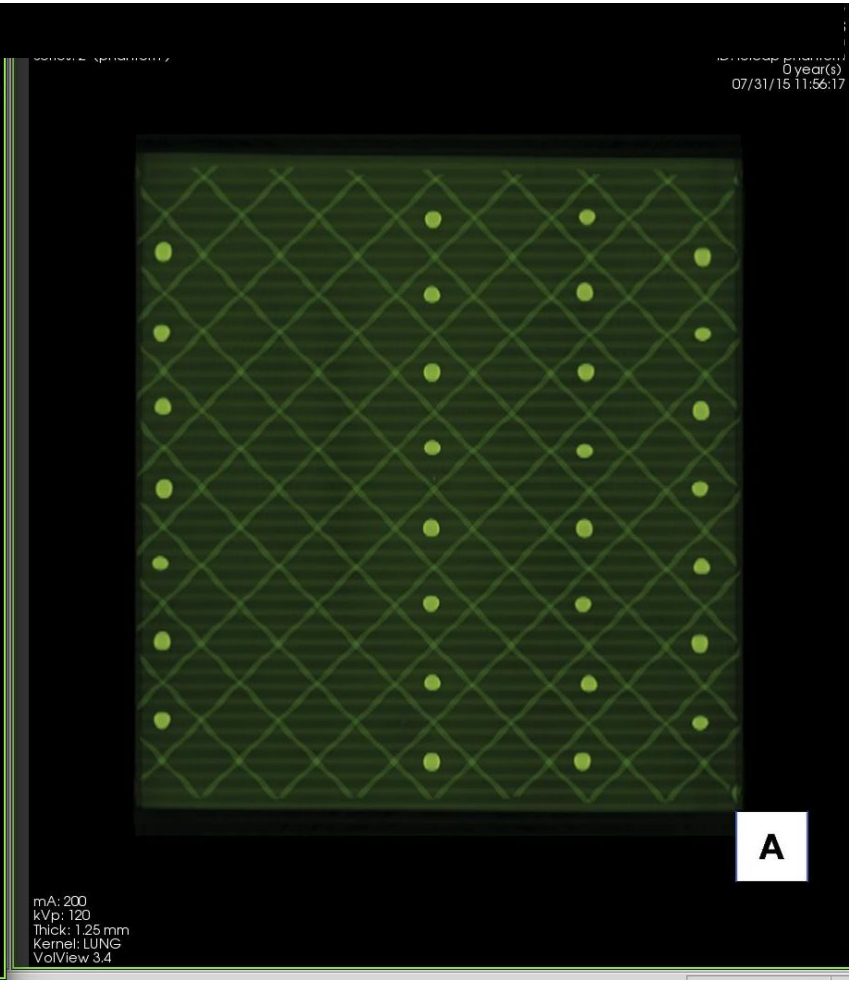


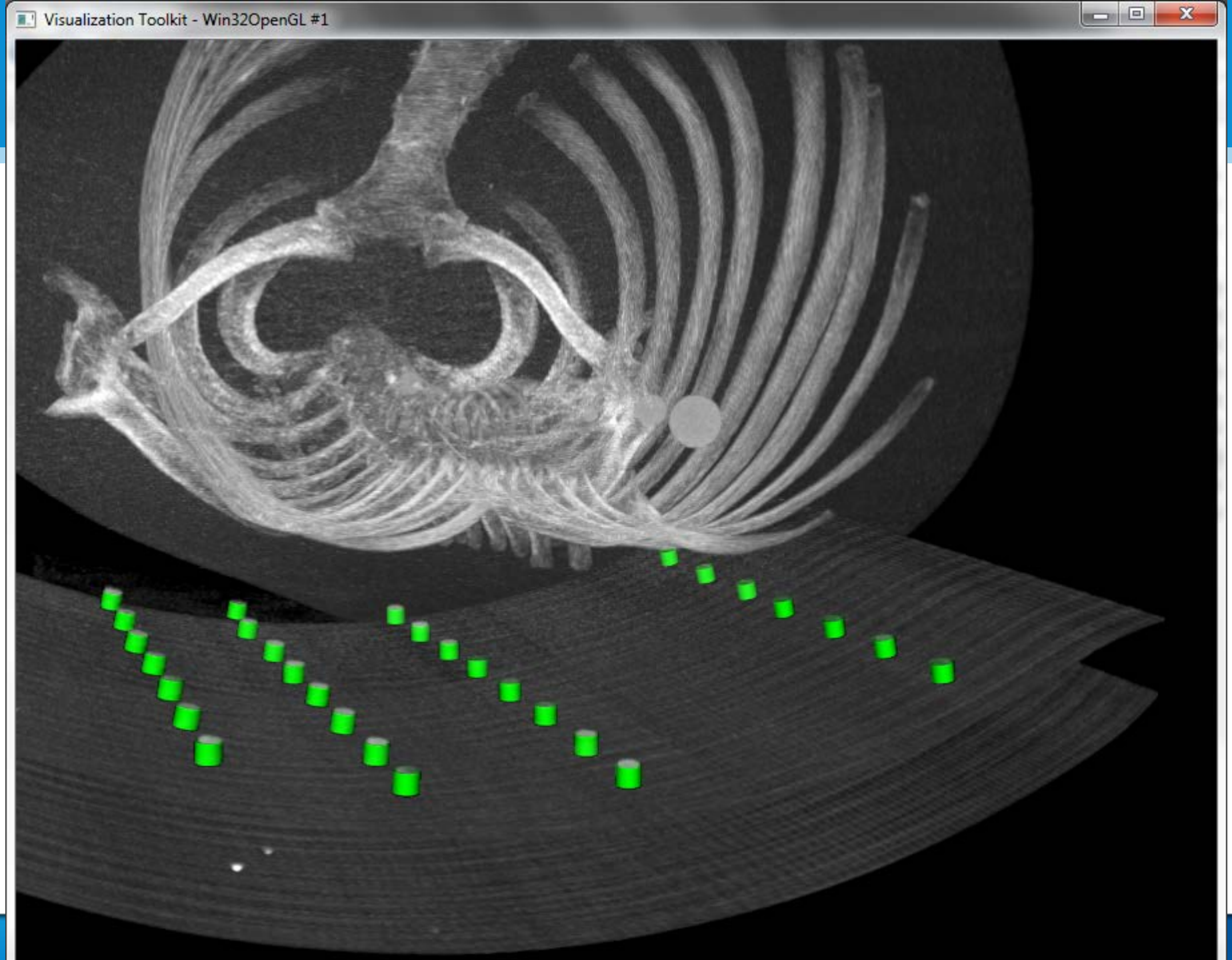
Table Phantom Scanning

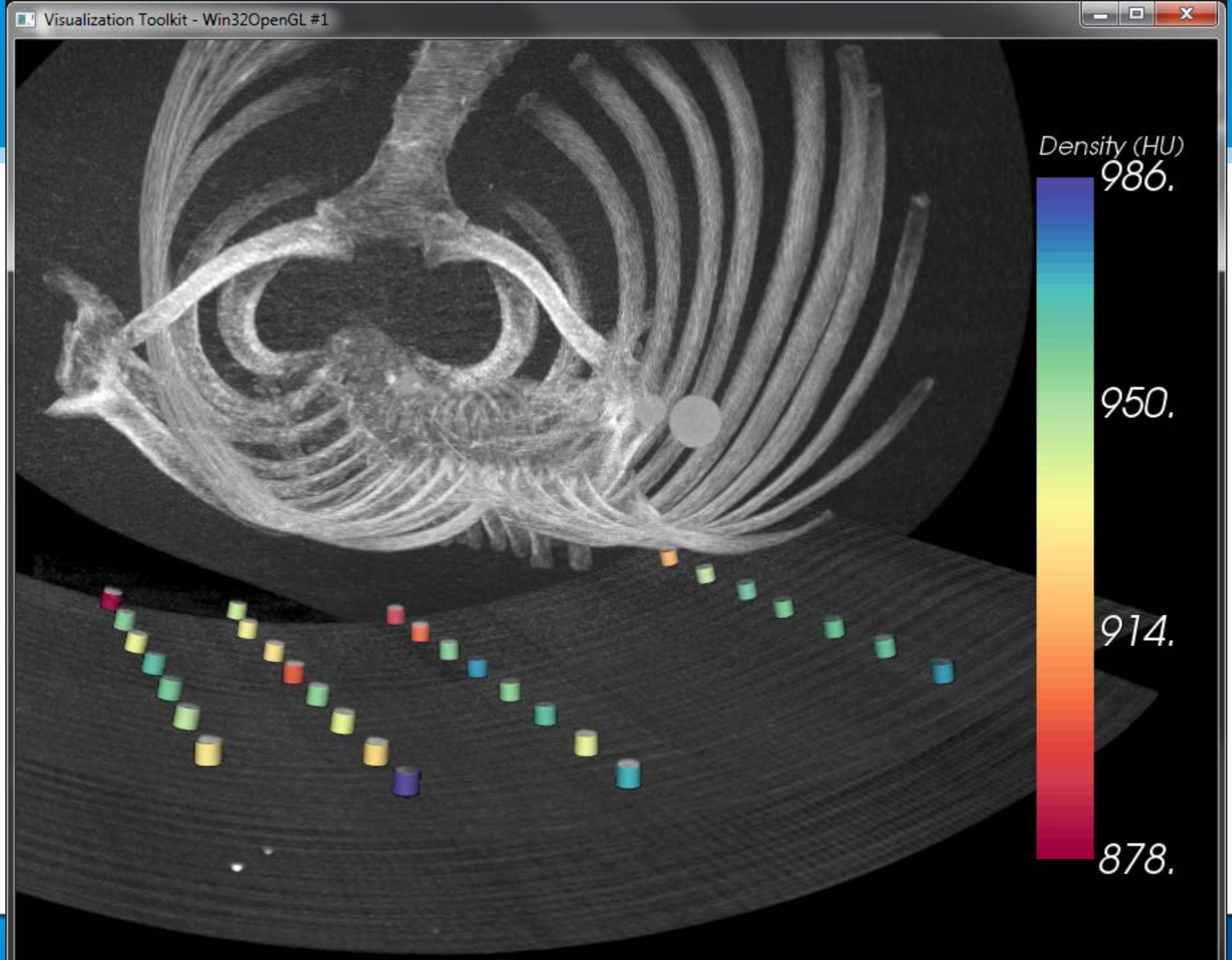


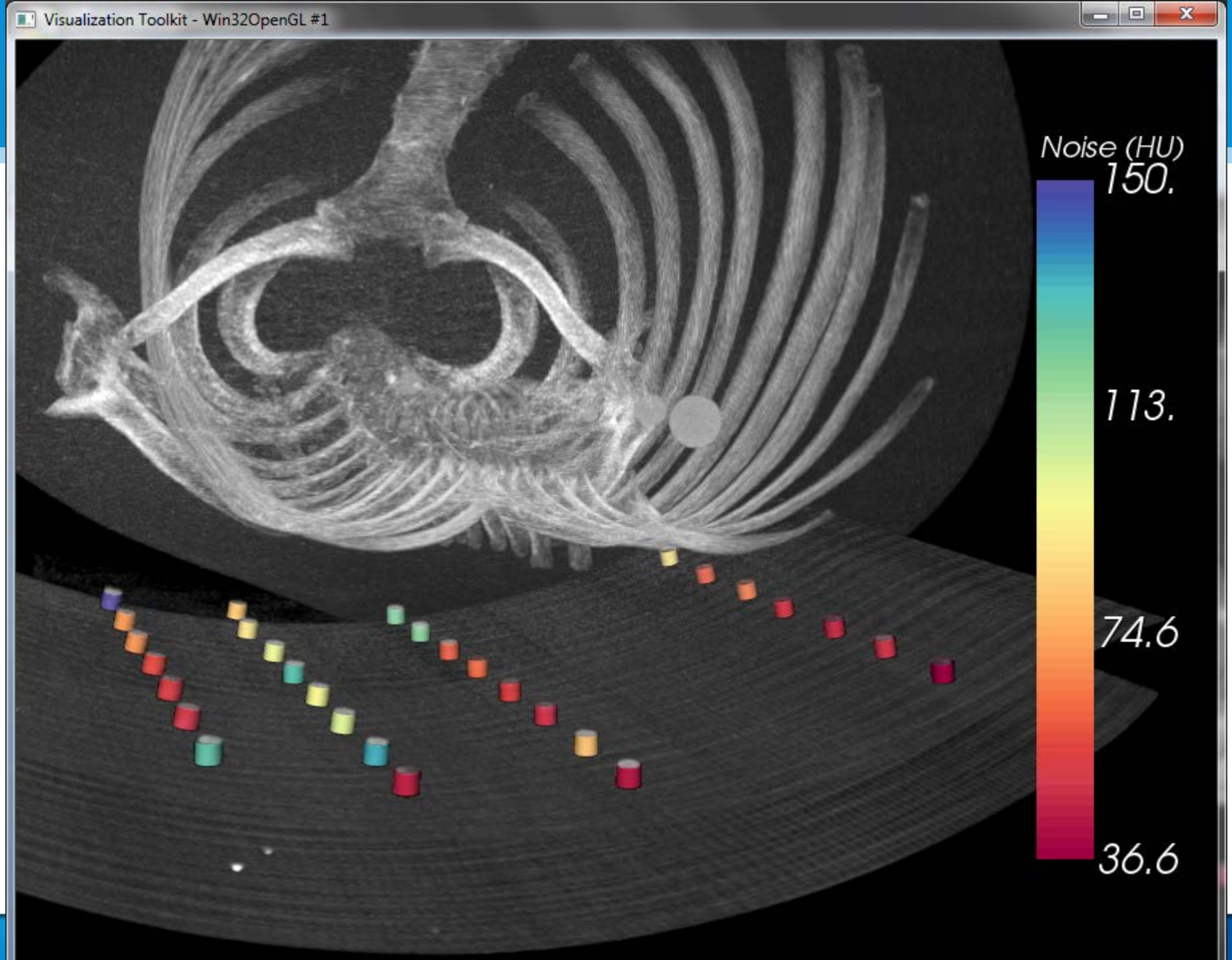
Step & Shoot Acquisition

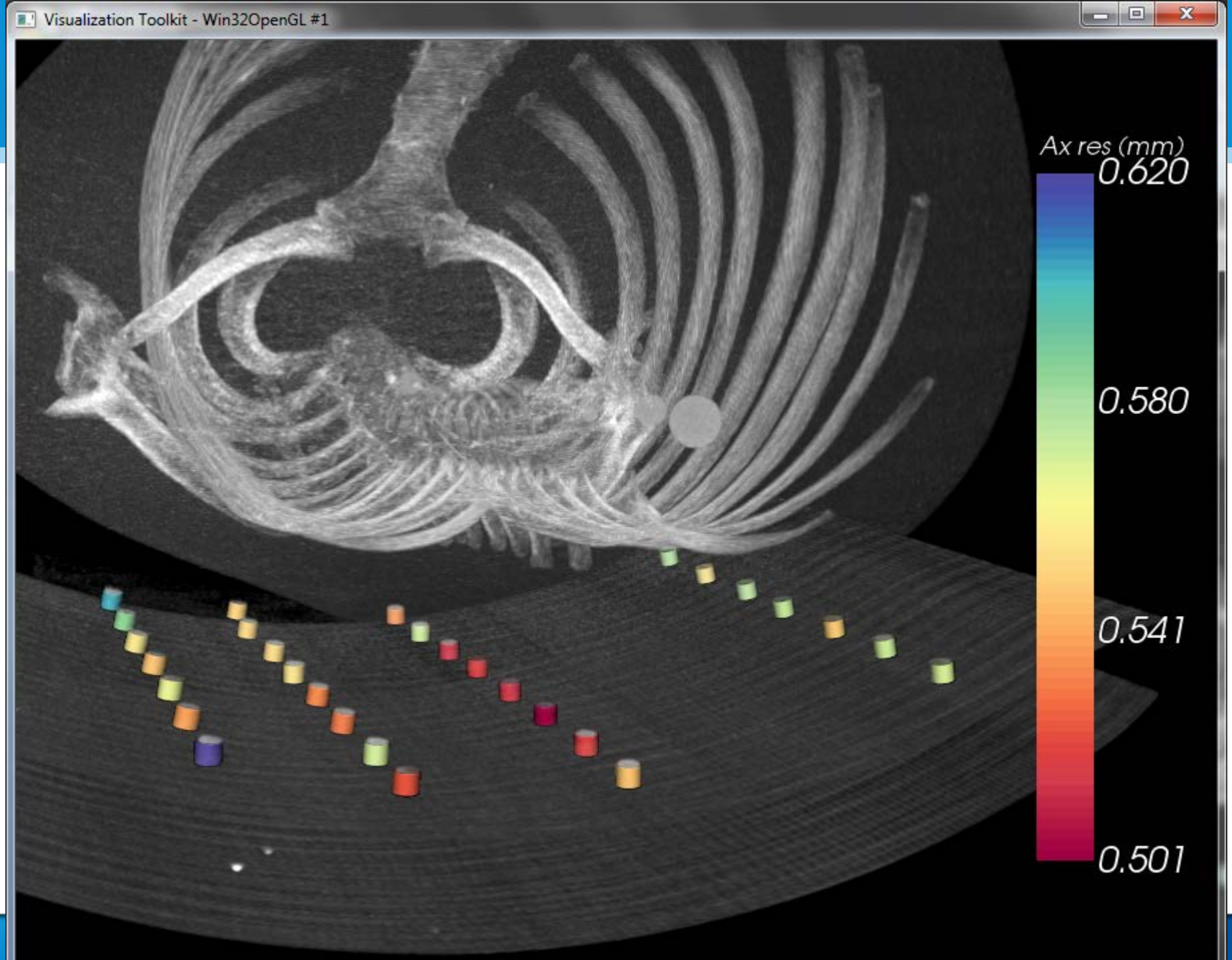


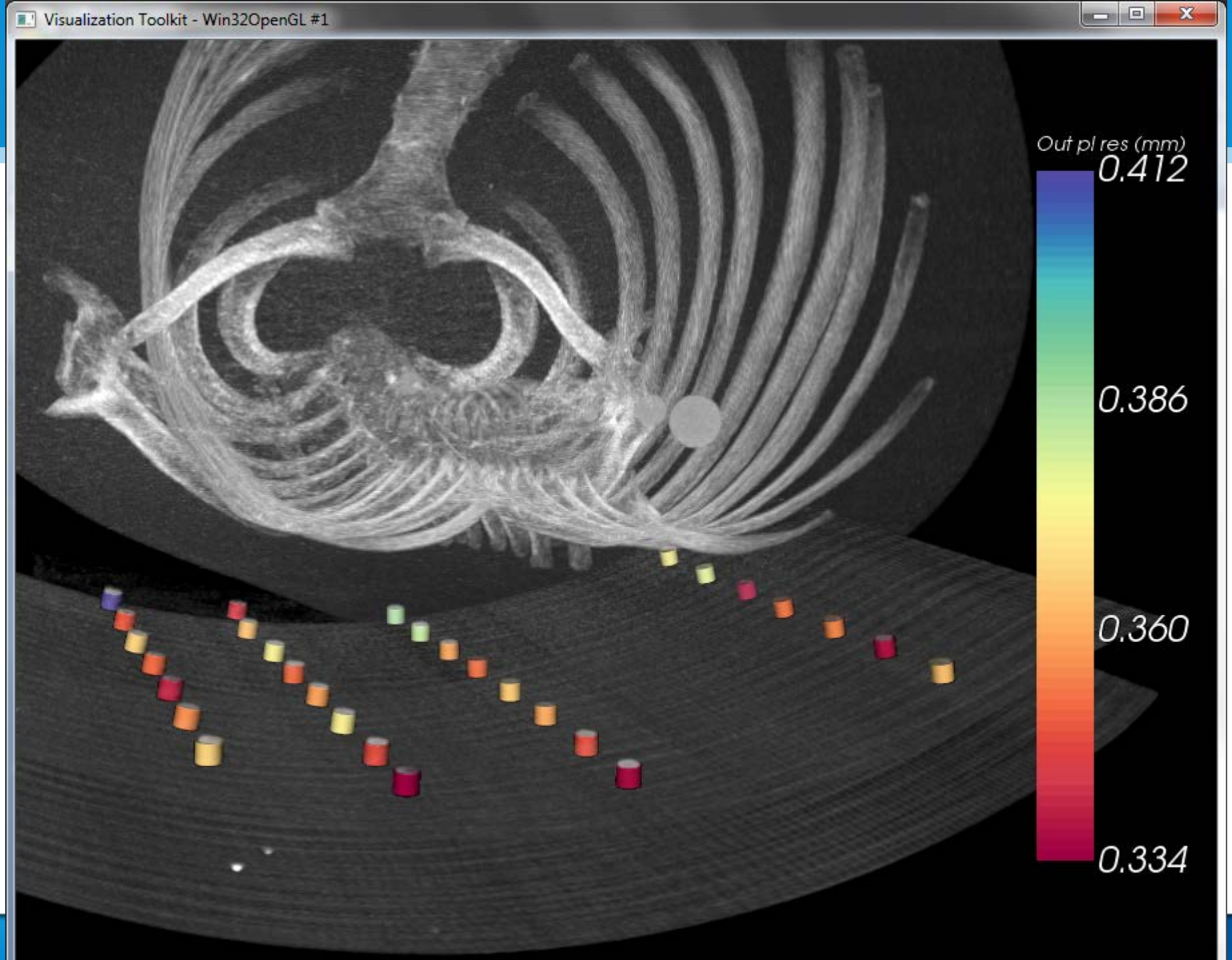
Helical Acquisition


Visualization Toolkit - Win32OpenGL #1


Visualization Toolkit - Win32OpenGL #1
Density (HU)
986.
950.
914.
878.


Visualization Toolkit - Win32OpenGL #1
Noise (HU)
150.
113.
74.6
36.6


Visualization Toolkit - Win32OpenGL #1
Ax res (mm)
0.620
0.580
0.541
0.501


Visualization Toolkit - Win32OpenGL #1
Out pl res (mm)
0.412
0.386
0.360
0.334