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# Three-Dimensional Backscatter X-Ray Imaging

**In-Space Inspection Technology Workshop**

D. Clark Turner, PhD, CEO

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# Presentation Outline

- 3D Backscatter X-ray System
  - Approach
  - Phase I Results
  - Phase 2 Design and Results
- Miniaturization of X-ray Components
  - Design Issues
- Roadmap to Handheld BSCT

# Acknowledgements


- **NASA STTR # NNX11CC68C**
- **University of Utah – Scientific Computing Institute**
  - **Dr. Ross Whitaker**
  - **Dr. John Schreiner**
- **ARIBEX**
  - **Dr. Arturo Reyes**

# Backscatter CT

How do we get 3D images from single side inspection?

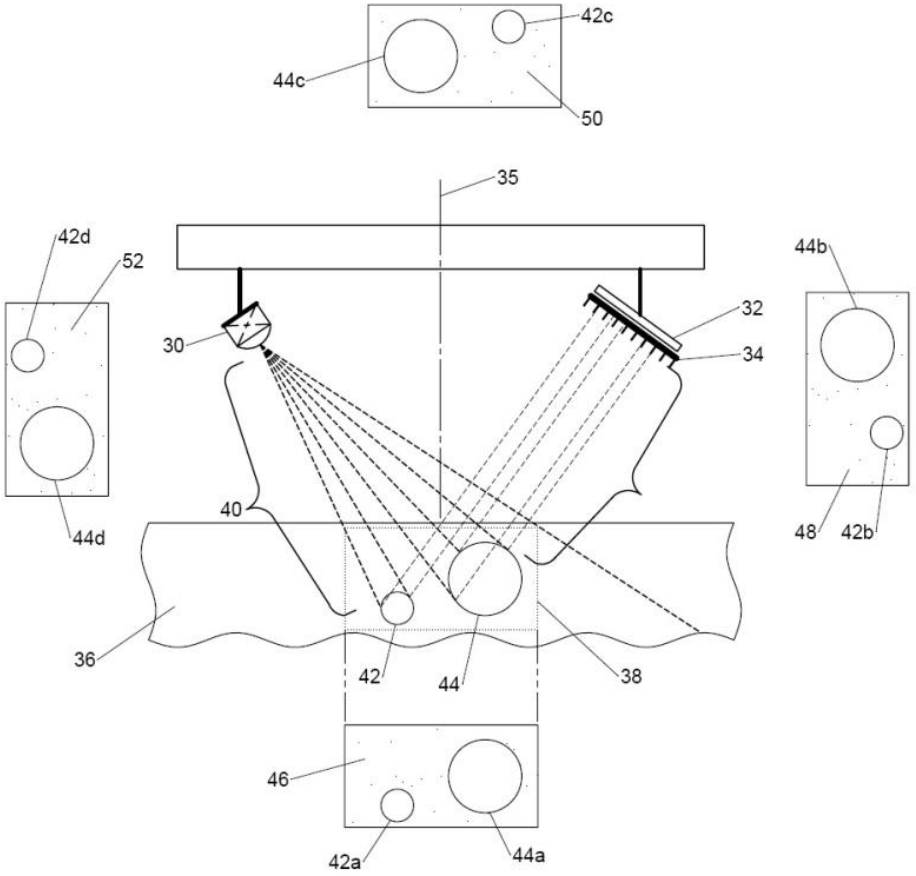
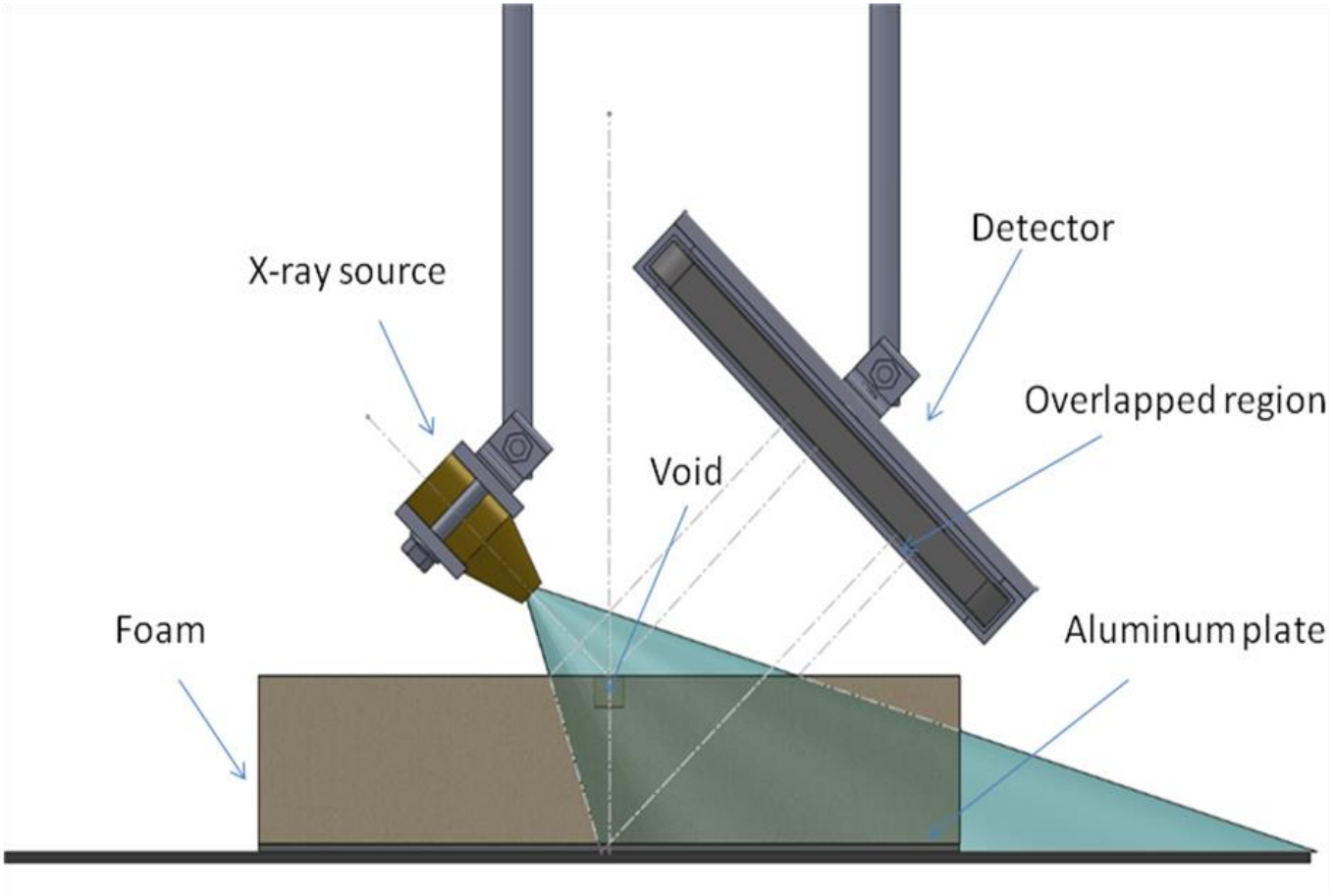



FIG. 2a

# System Characteristics

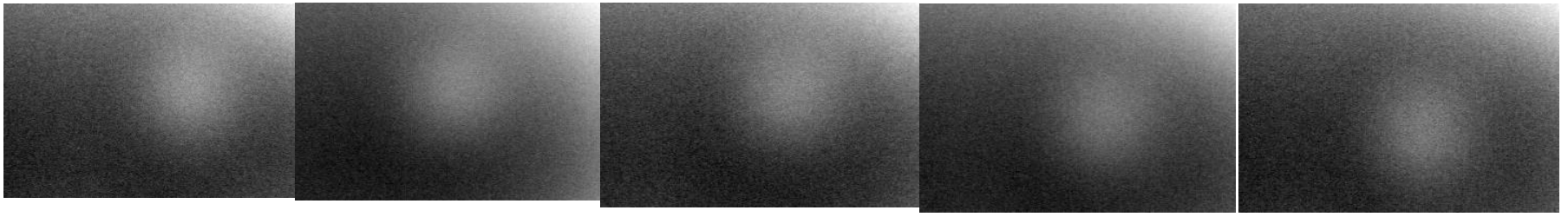
- Collimated “staring array” detector for 2D images
- A cone-beam x-ray source is used, allowing:
  - Simultaneous 2D image data collection
  - Large field of view
  - Reduce data collection time
- Rotationally movable system – Automated collection of 2D images 360$^{o}$ around the object to be imaged
- A 3D-processing computed tomography model

# Phase 1 Approach

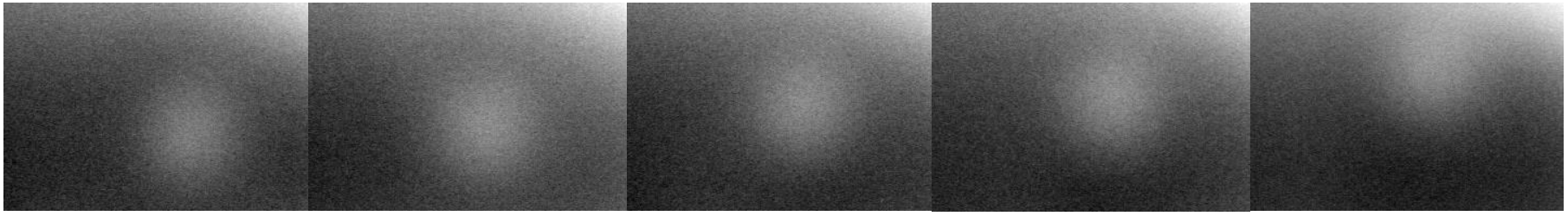


# Initial Results

Typical void-in-foam images taken with initial system setup



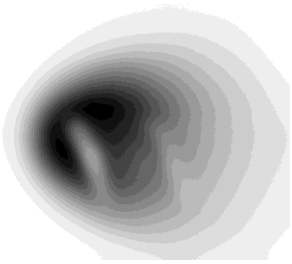
350º 310º 270º 230º 190º



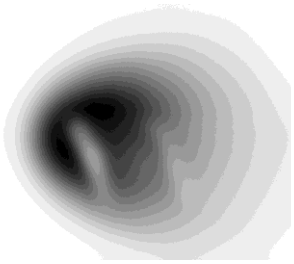
150º 110º 70º 30º 0º

# Initial Results

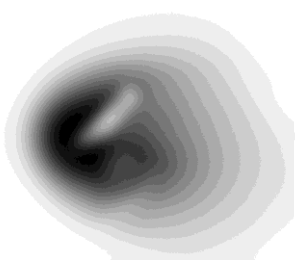
Multiples images of a void-in-acrylic with metallic objects using initial system setup



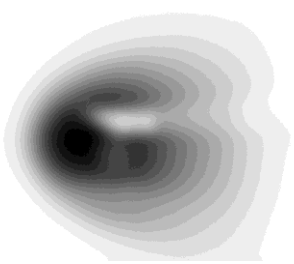
310º



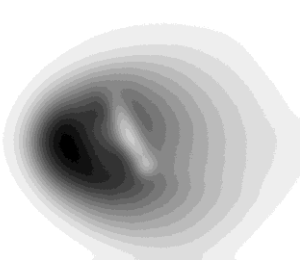
270º



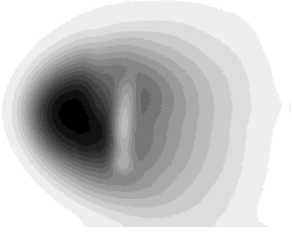
220º



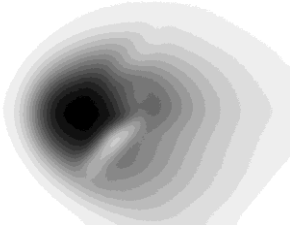
180º



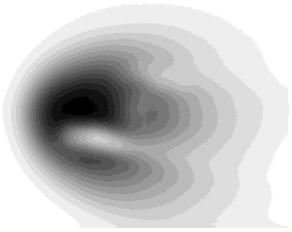
130º



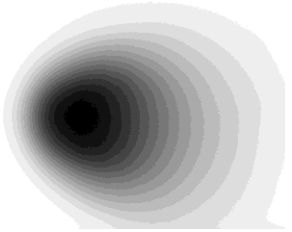
90º



40º



0º



Background at 0º

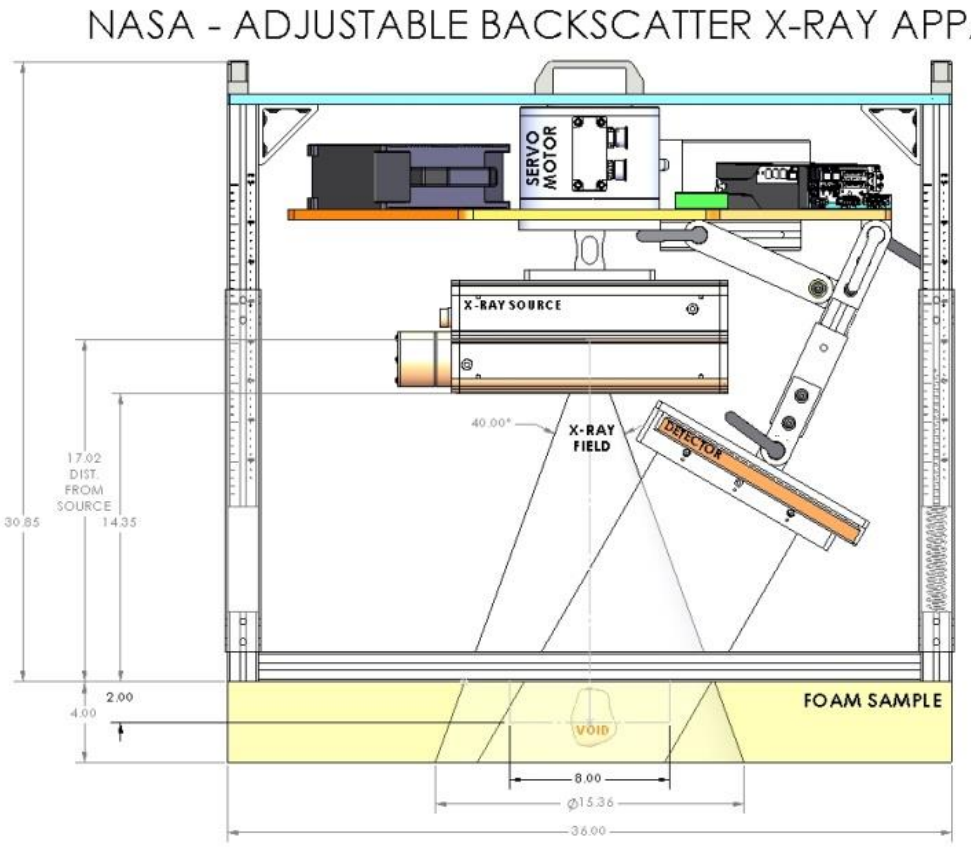
# Learnings for Phase 2

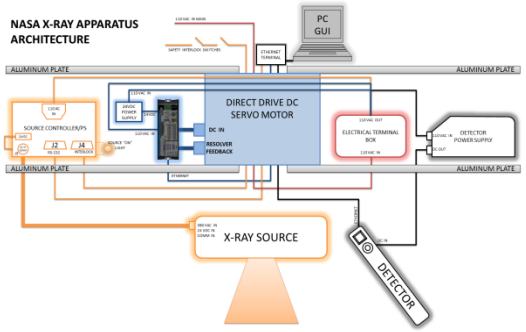
Improvements to initial system design:

- Brighter x-ray source
- Wider x-ray source cone beam
- A digital detector (instead of a Photostimulated Plate (PSP) used in the initial setup)
- Stacked collimator for better resolution
- System automation for use in a more realistic environment

# Phase 2 Design

## Prototype design



# Improved Resolution

- Stacked collimator grids

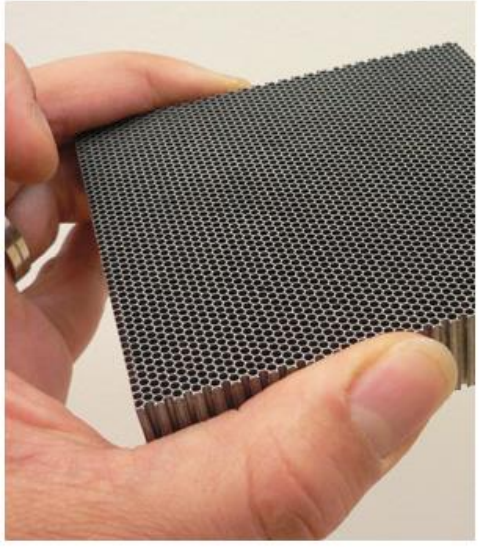
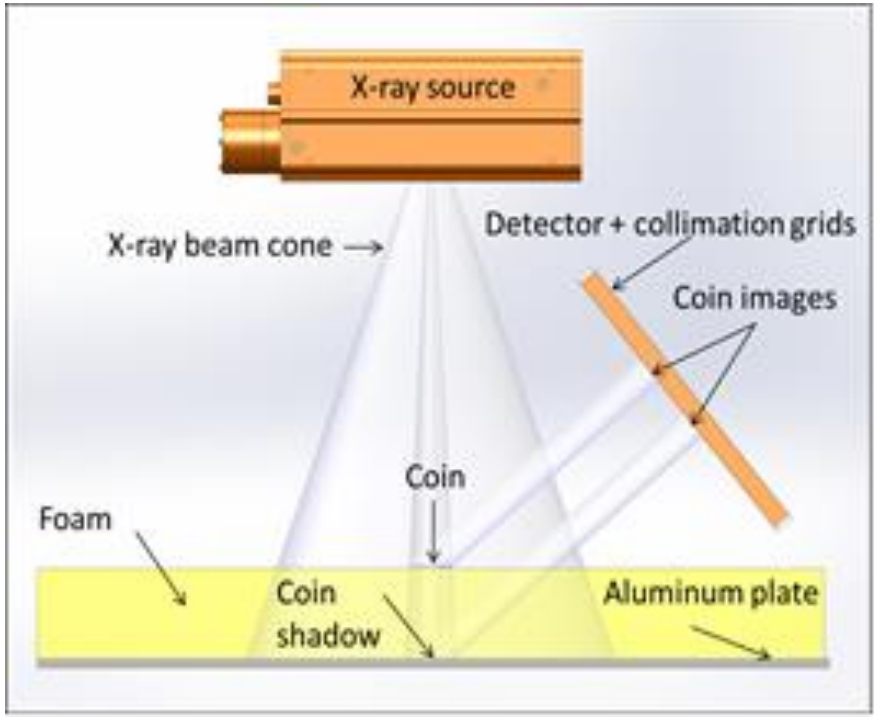
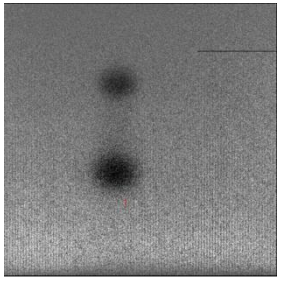


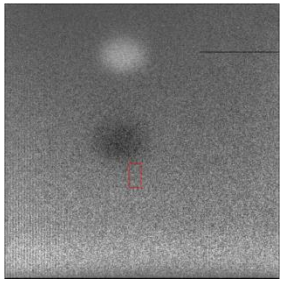
Photo courtesy Nuclear Fields, Inc.

# Concept Results



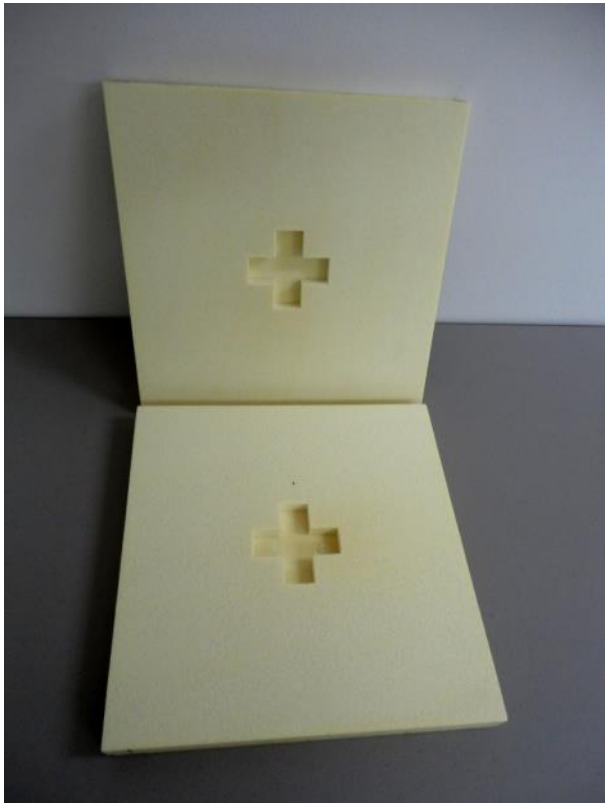



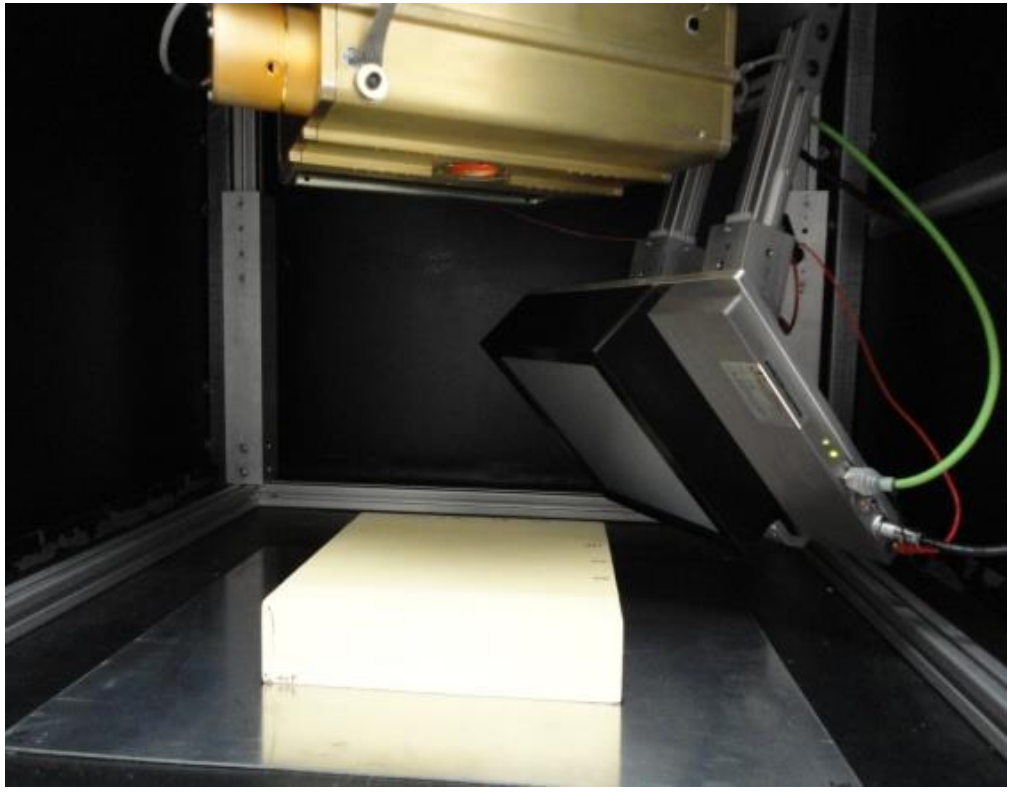
US Quarter coin



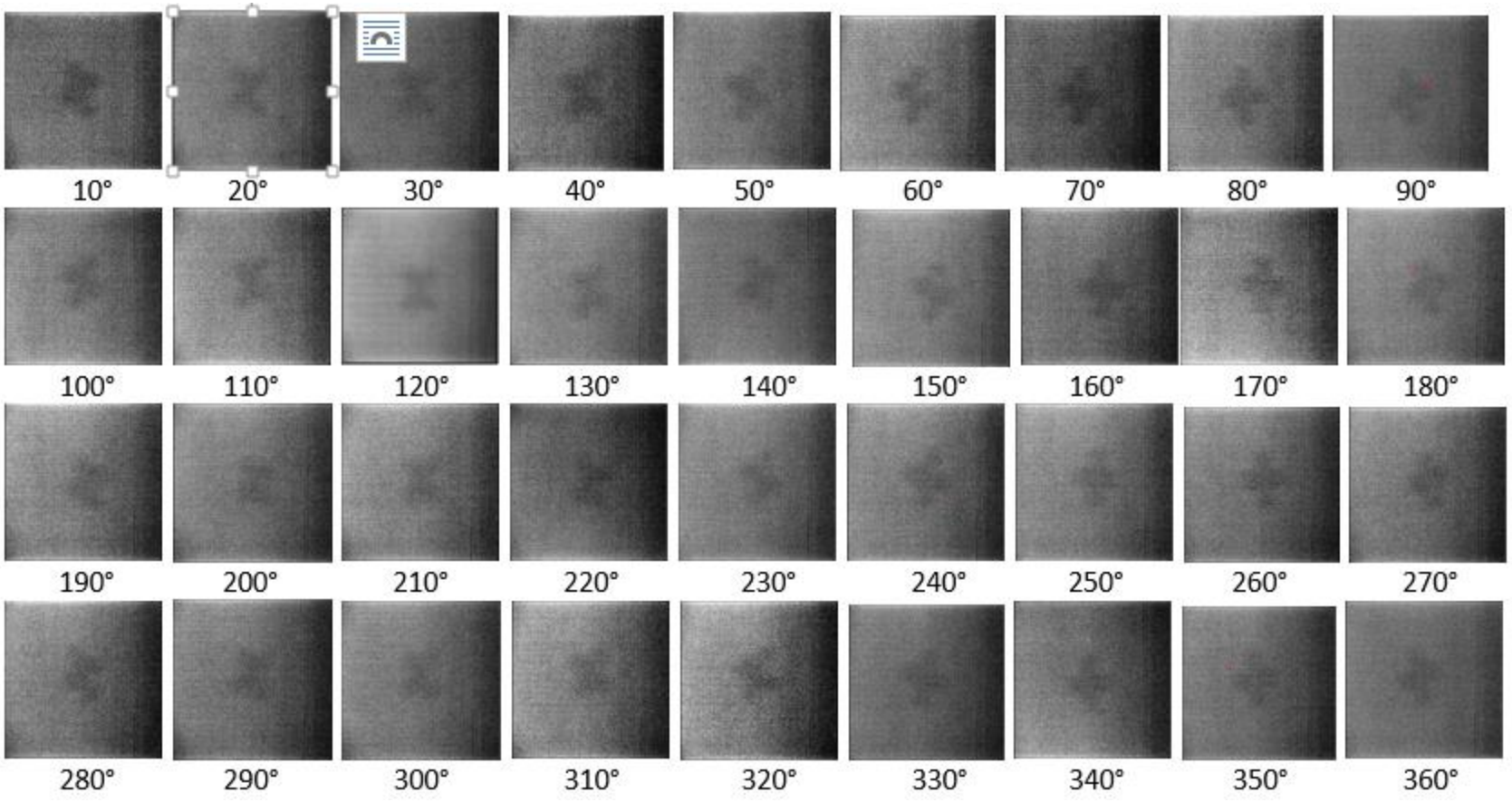
Aluminum “coin”

# Cross-void for System Validation





# 2D images of cross-void



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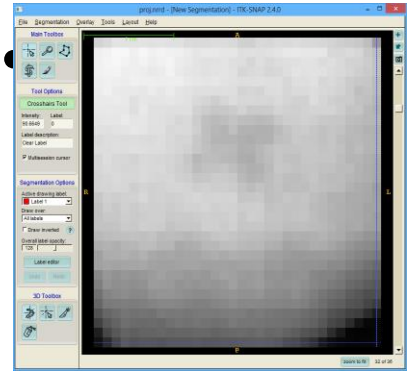
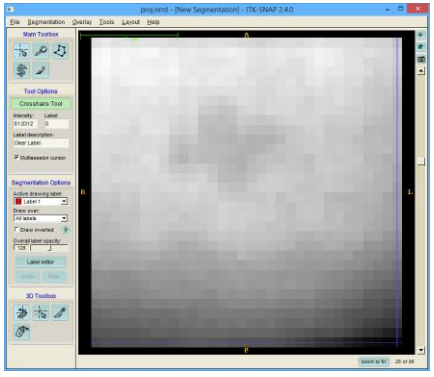
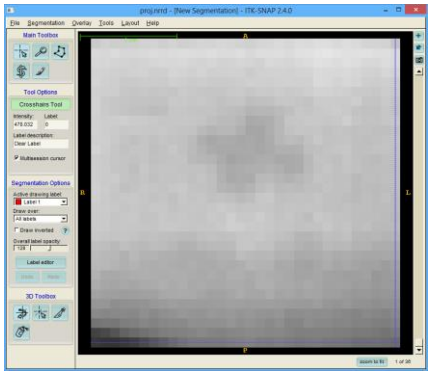
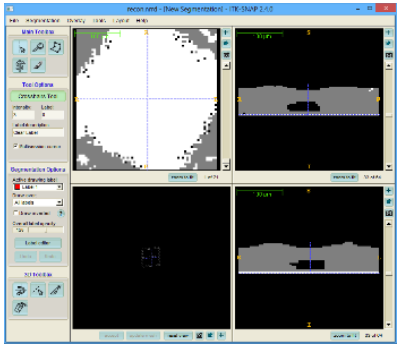
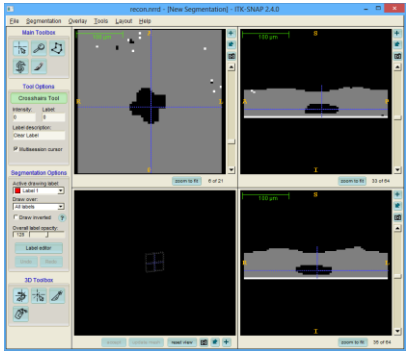
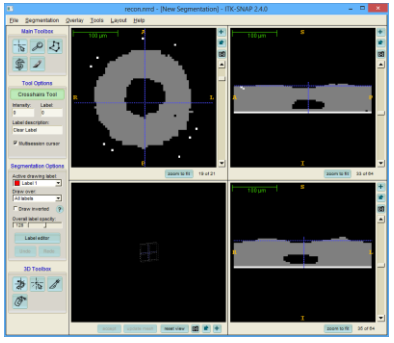
# Three different orientations to the cross-void

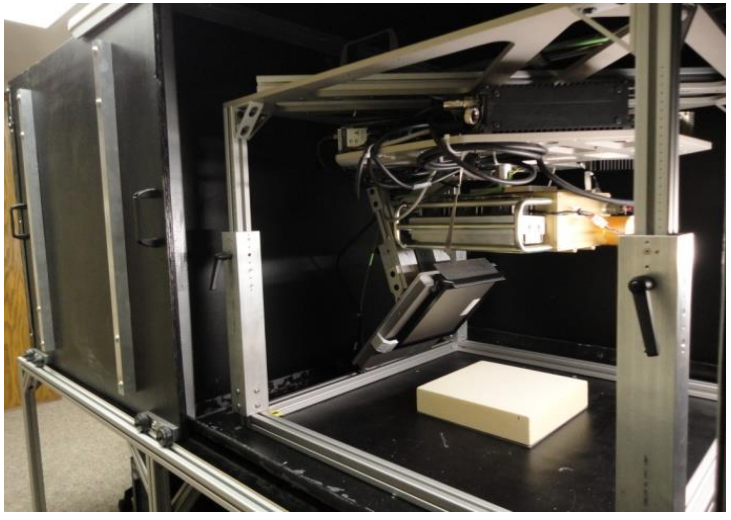




Reconstructions at various planes in sample

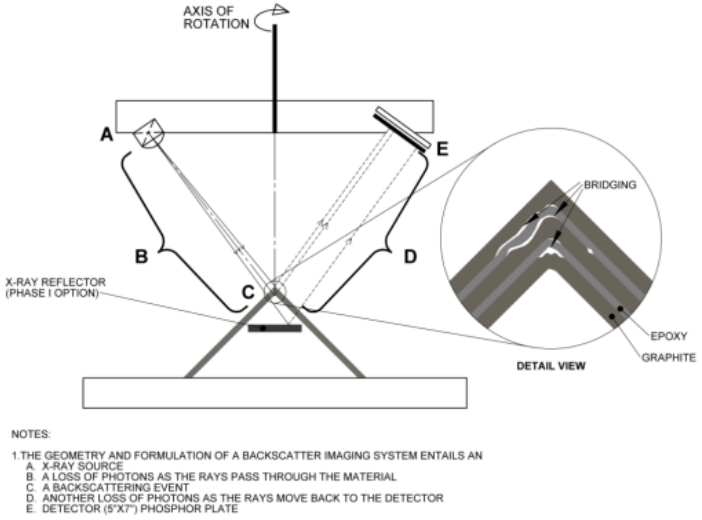
# 3D Backscatter CT Imaging

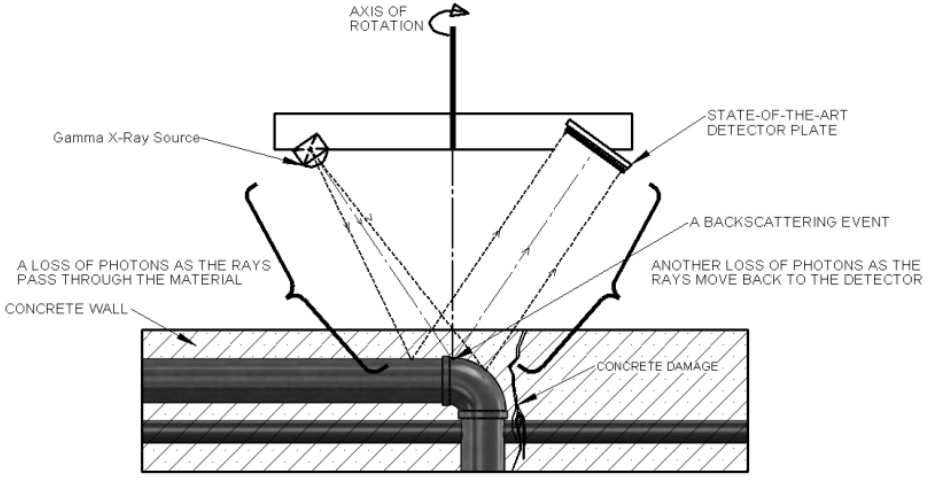
- System architecture developed
- 3D reconstruction algorithms
- Prototype delivered to NASA 9/2013
- Three (3) patent applications
- Next Steps
  - Improvements in hardware
  - Improvements in software
  - Need Phase 3 funding



# OTHER APPLICATIONS

- **Composite Materials**
- **Cargo Inspection**
- **NDT and explosive detection**
- **Construction and Related Industries**



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# Can We Make it Handheld?

To meet the size requirement for a Handheld Backscatter CT system (BSCT) we need:

- Small, lightweight detectors
- Focusing optics for large field of view
- Compact, light-weight x-ray sources

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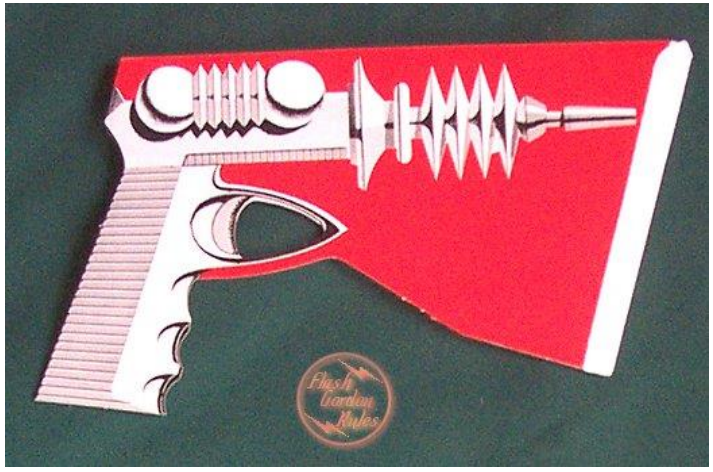
# Yesterday's science fiction


# Today's Reality

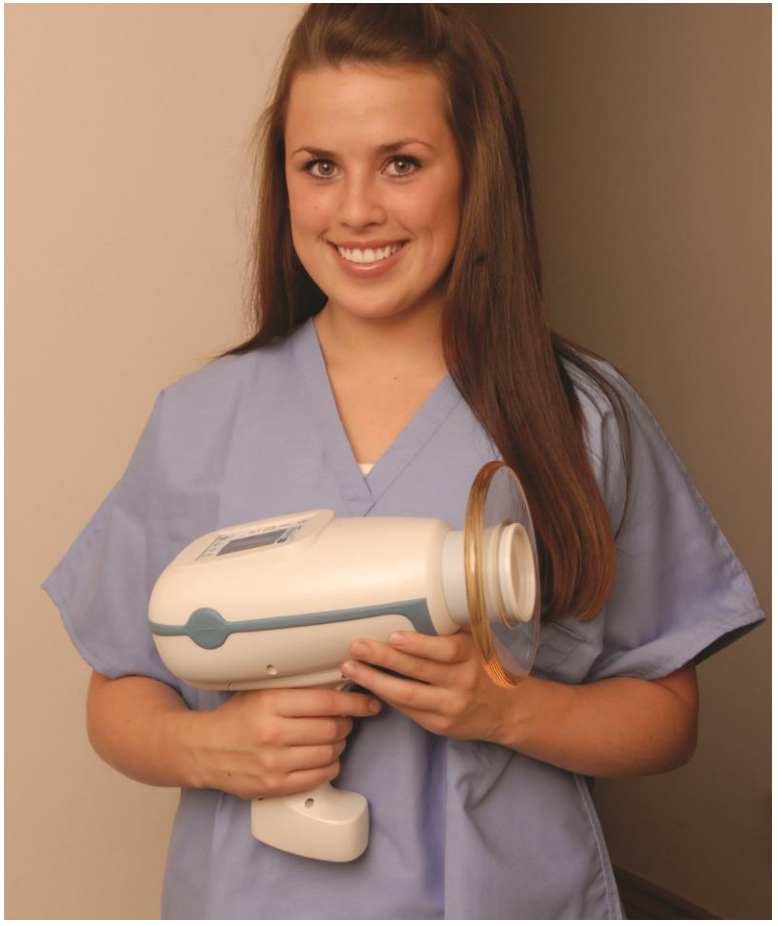

Handheld XRF analyzers

- Lead in toys
- Metals and Mineralogy
- Scrap metal sorting
- ROHS/WHEE compliance

# Handheld Imaging

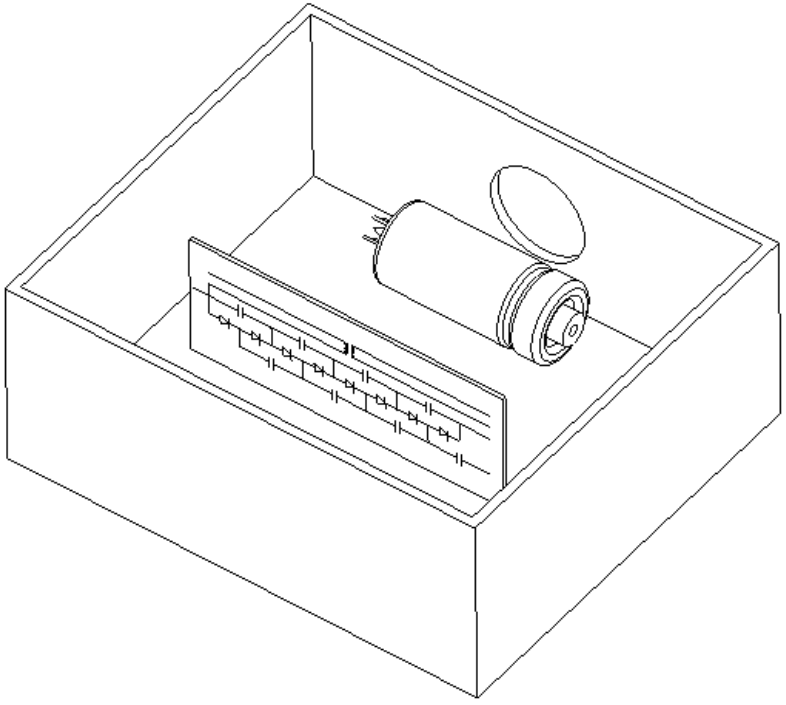
ARIBEX NOMAD Pro

- Intra-oral x-ray imaging
- Weight reduced to 5.5 lbs
- mA increased to 2.5mA



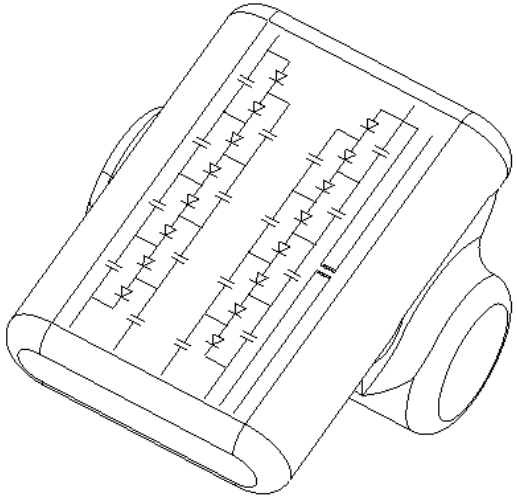
# Prior Art

- Oil-filled enclosure
- Lead-foil shielding
- Problems –
  - Weight
  - Leaks
  - Maintenance

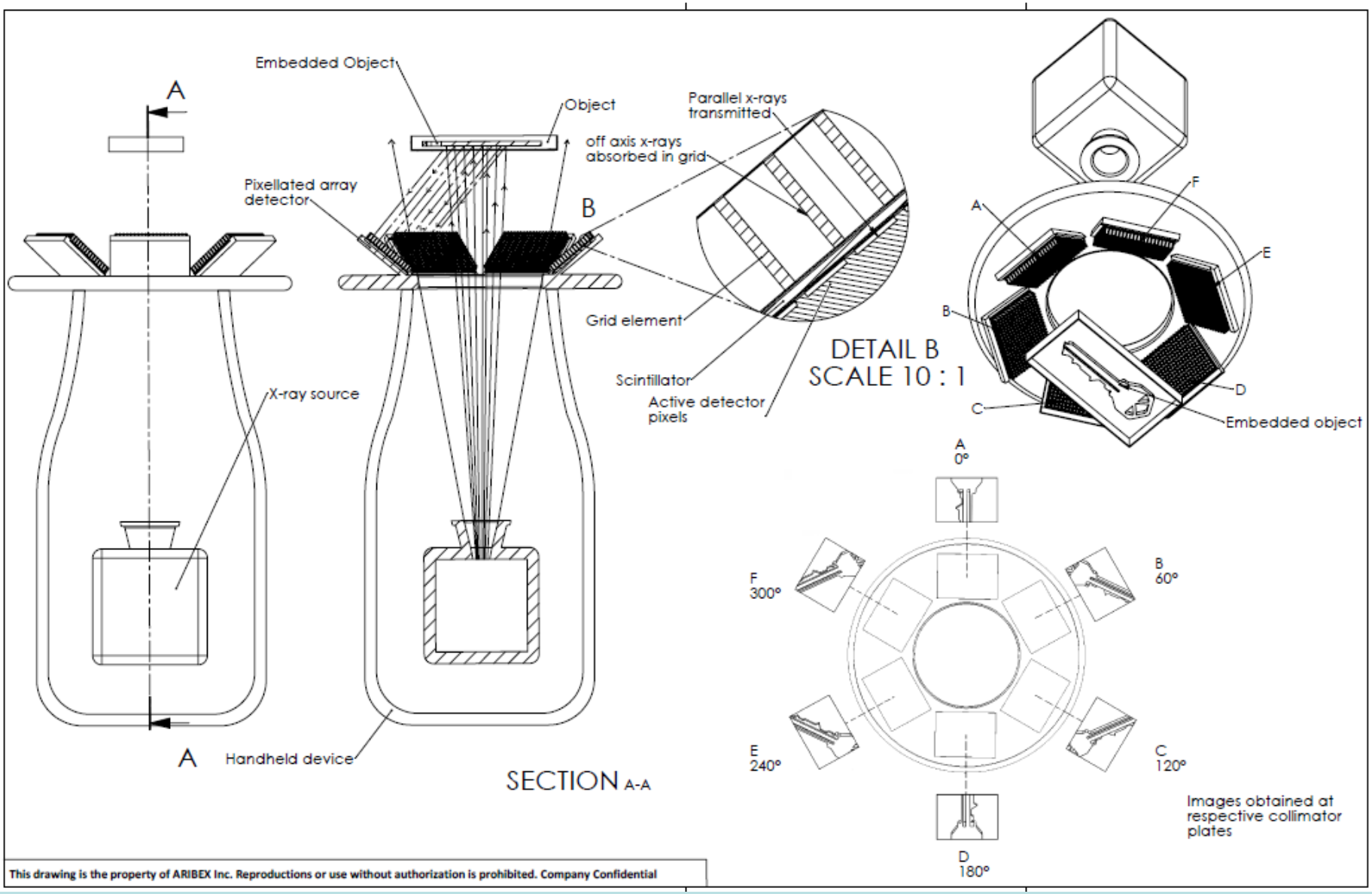


# Aribex Innovations

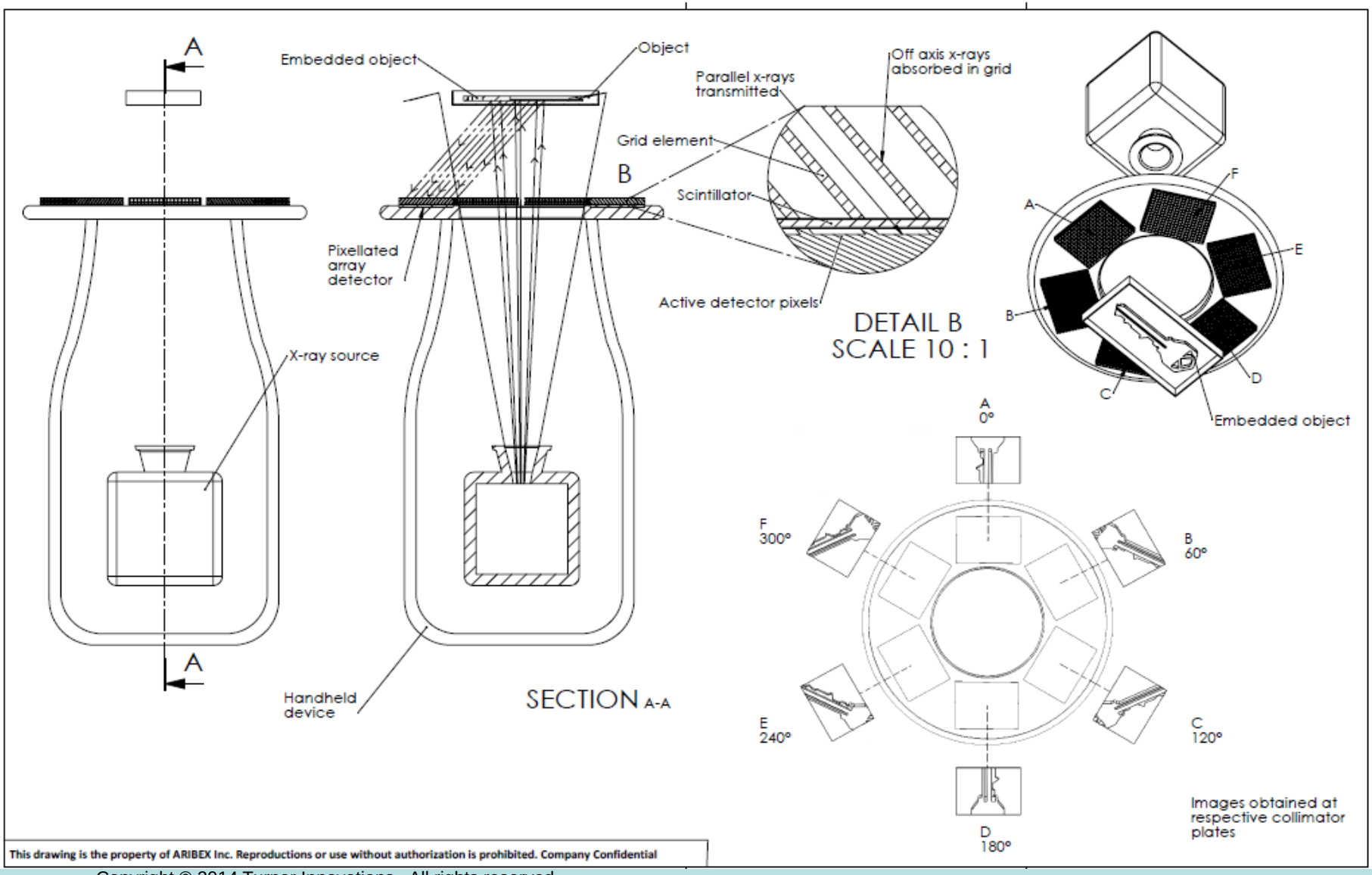
- Split high-voltage
  - Only have to hold off ½ voltage
  - +/- 30kV
- Silicone Potting
- “Secret Sauce”
  - Shielding – High Z material ***in*** the silicone
- <3 lbs in HVPS/Tube module



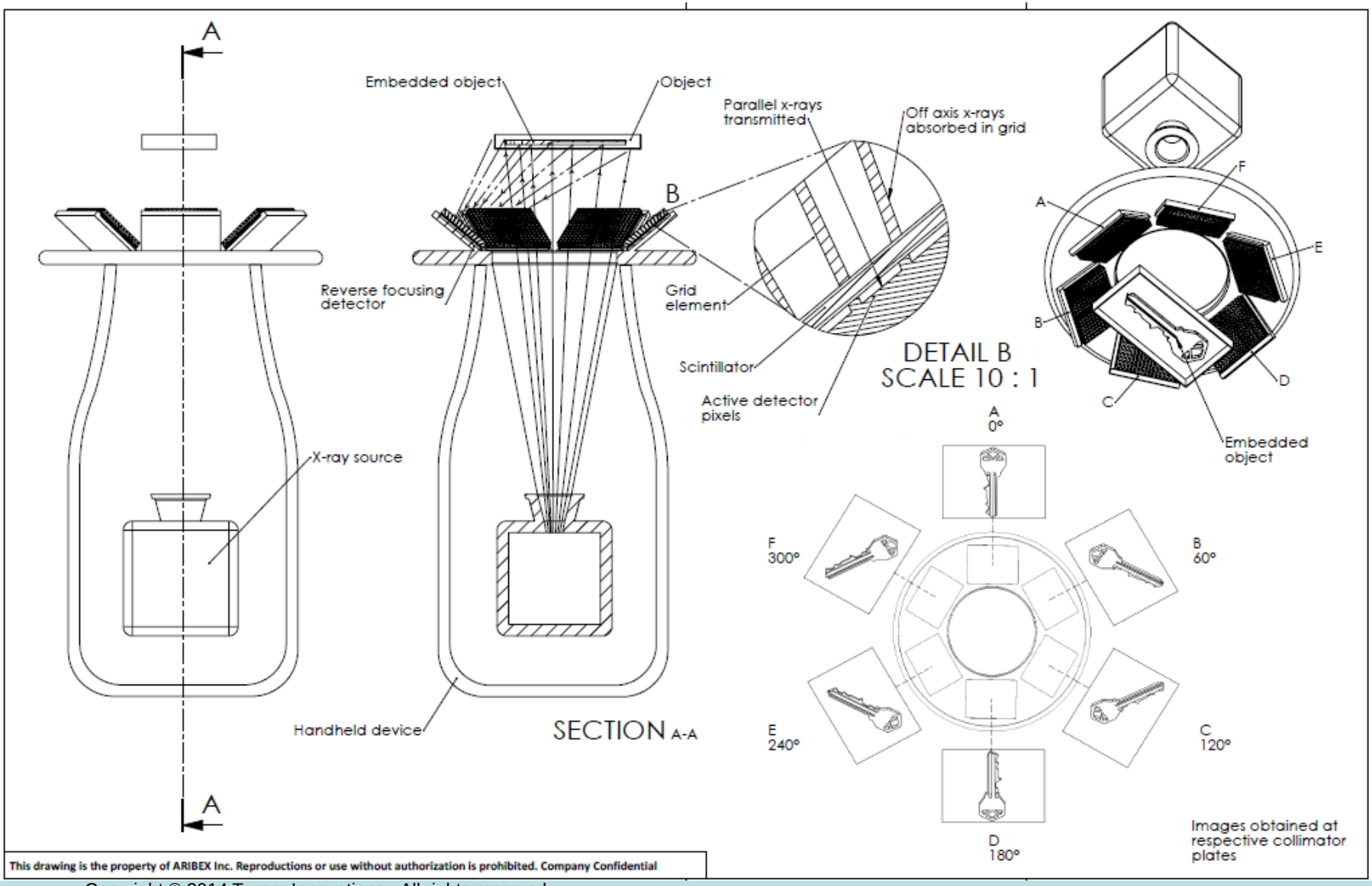
# Handheld BSCT – Concept 1



# Handheld BSCT – Concept 2

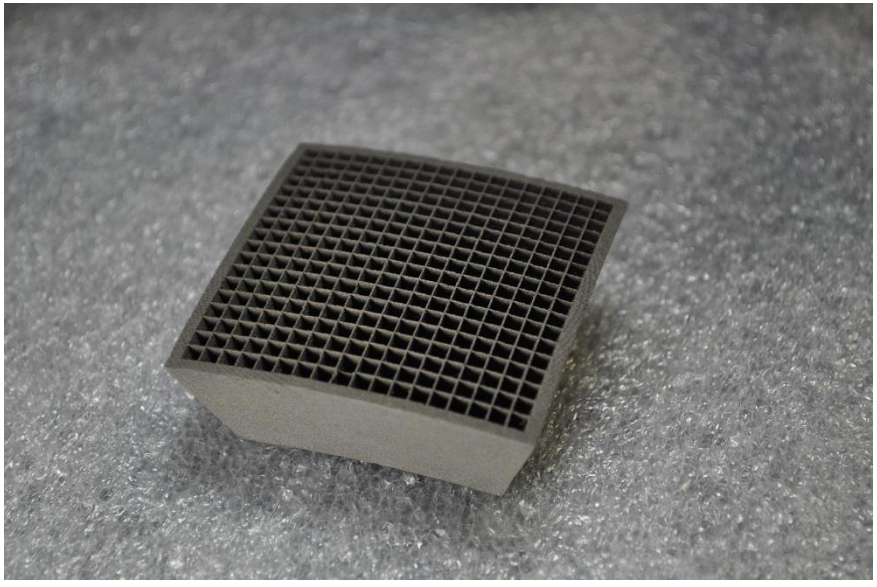


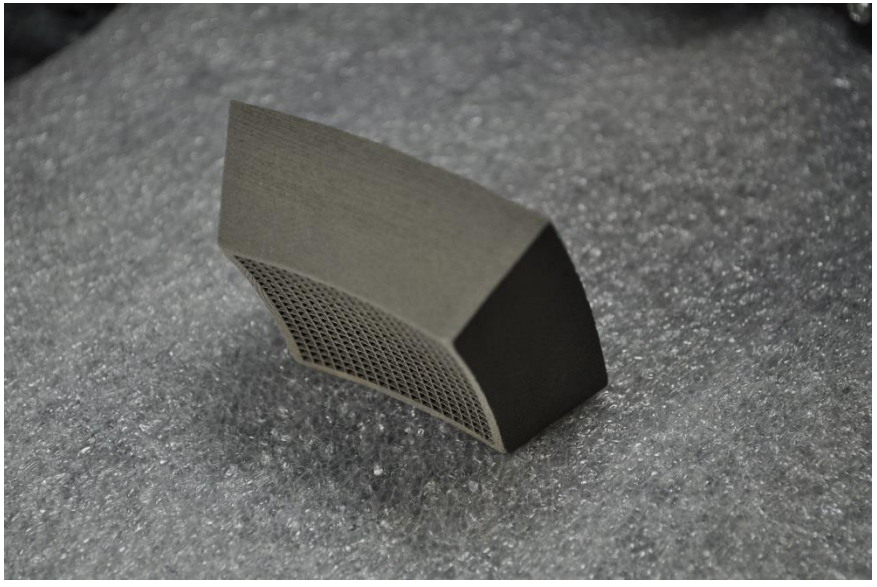
# Handheld BSCT – Concept 3



# Focusing Optics

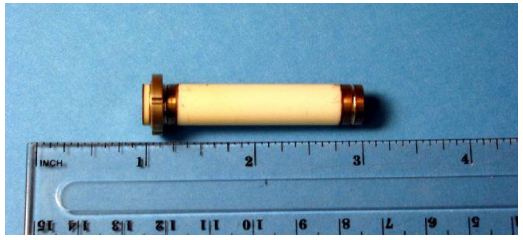
3D printed tungsten collimator grids





Photos courtesy of Radiation Protection Technologies

# How Do We Get There? – Alt. 1



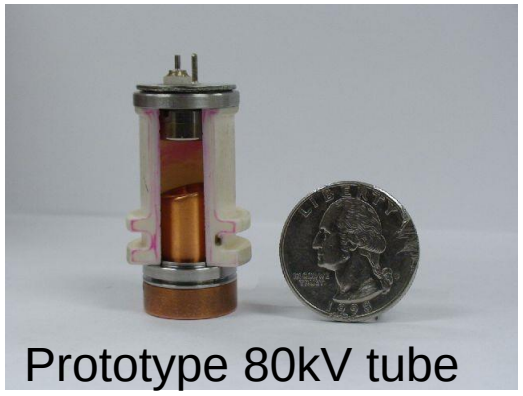
Prototype 120kV tube & HVPS

Photos Courtesy xxxxxx, Inc.
- Confidential -

## End-Window Design

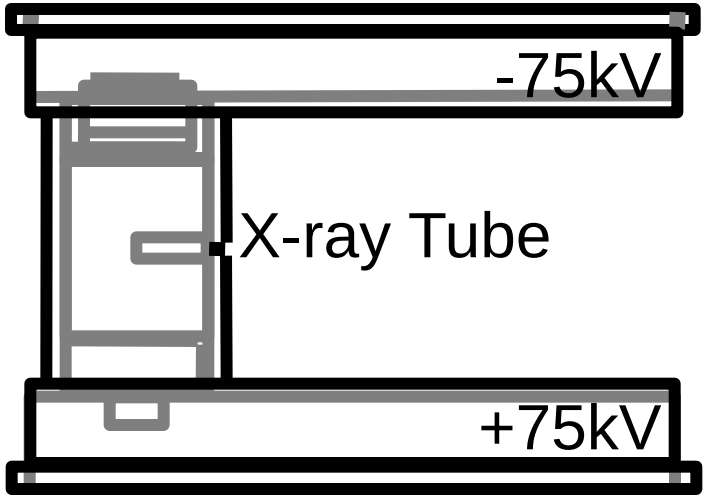
- Advantages
  - More compact size
  - – Grounded anode
- – Disadvantages
  - – Max current unknown??
  - – Filament isolation??

# How Do We Get There? – Alt. 2



Prototype 80kV tube

Photo Courtesy xxxxxx, Inc.
- Confidential -




Split high-voltage concept

## Split High-Voltage Design

- Advantages
  - More mass in tube anode
    - Better heat conduction
  - Max. 75kV HV standoff
  - Internal radiation shield
- Disadvantages
  - 2 power supplies – Cost
  - Slightly heavier
  - Hard to get heat out

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# Summary

- Preliminary results show good promise for Backscatter CT systems
- Miniaturization of other x-ray modalities has already occurred.
- Proposed Roadmap for Handheld Backscatter CT (BSCT) through source, detector, and optics miniaturization

# Thank You!

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