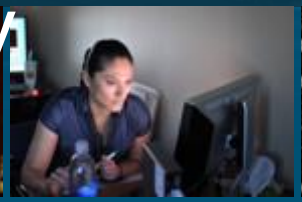
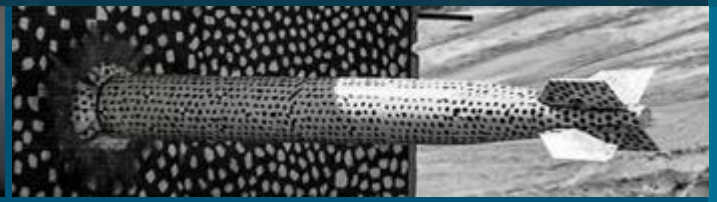
Material Identification and Classification using Machine Learning Techniques with Hyperspectral Computed Tomography





PRESENTED BY

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So What? Who Cares?

- **Space:** enhanced material evaluation capability in industrial, security, and other general non-destructive testing applications
  - Motivation: materials differ in appearance and contrast based on incident photon energy
  - Dual energy CT leverages this to provide more information about an object
- **Problems:**
  - Requires two separate acquisitions
  - The selected energy ranges may not provide sufficient contrast
  - Materials may be indistinguishable
- **Solution:** Hyperspectral Computed Tomography
  - >100 images simultaneously acquired corresponding to unique energy bins between 0 and 300 KeV
- **Results:**
  - Distinguishes different types of explosive simulants
  - Spectral information can be integrated into machine learning pipeline for above 90% accuracy in separating similar materials
- **TRL:** 4
  - Technology has demonstrated competence in a wide variety of NDT applications
  - Limitations: long acquisition times, slow production pipeline, bulky, and limited FOV
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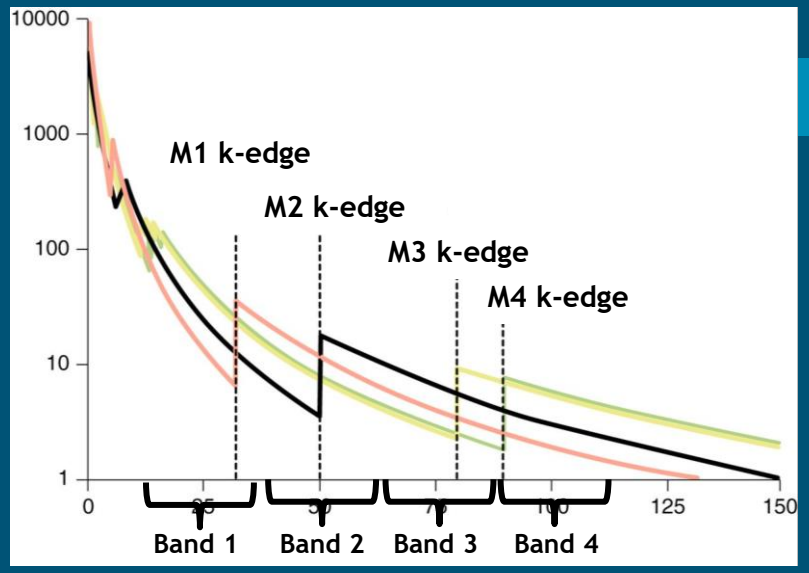
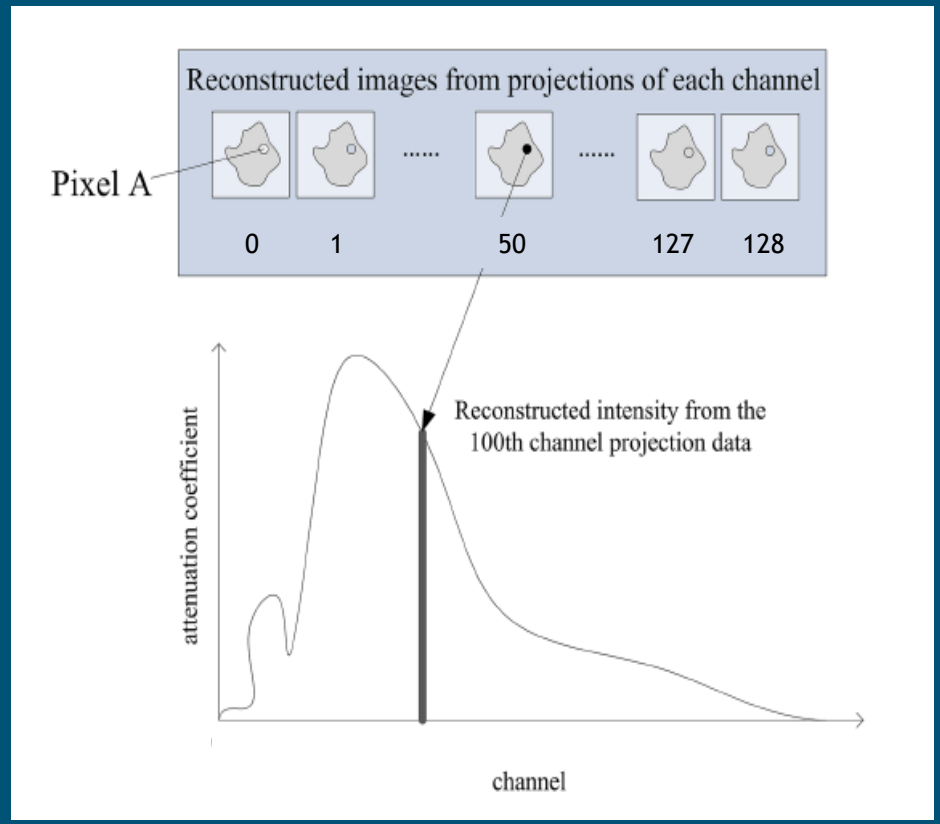
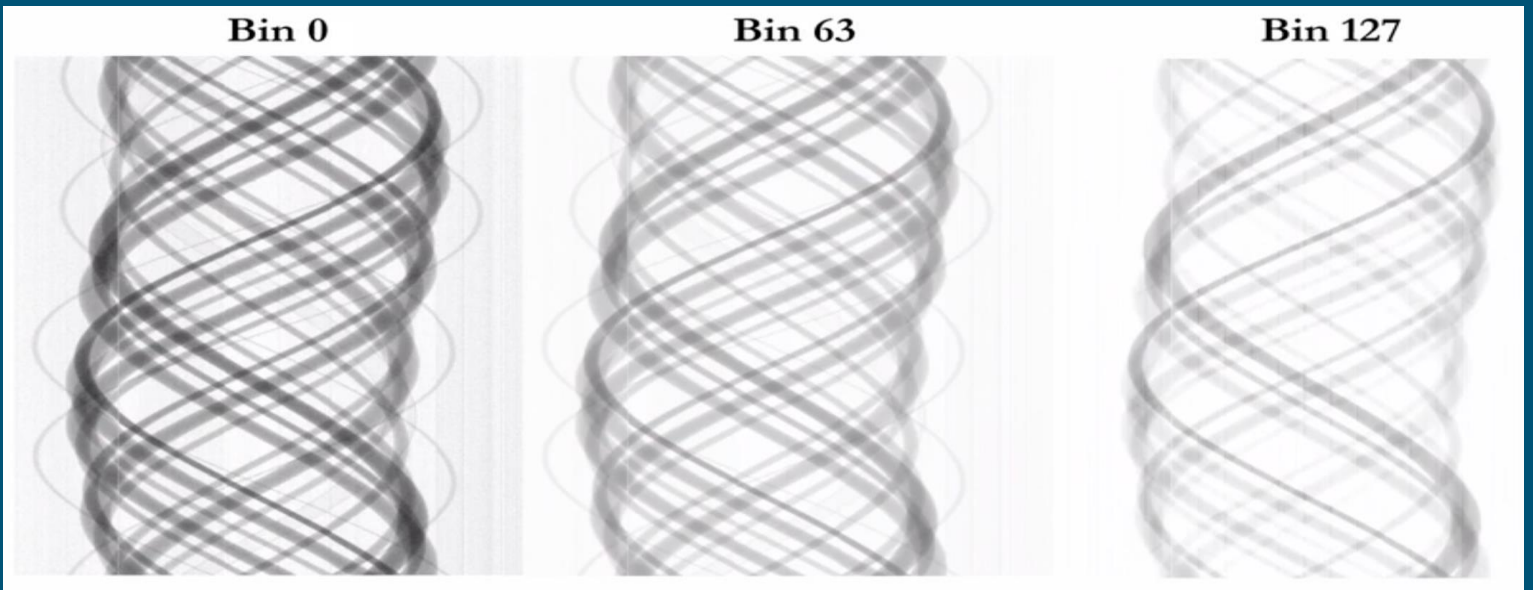
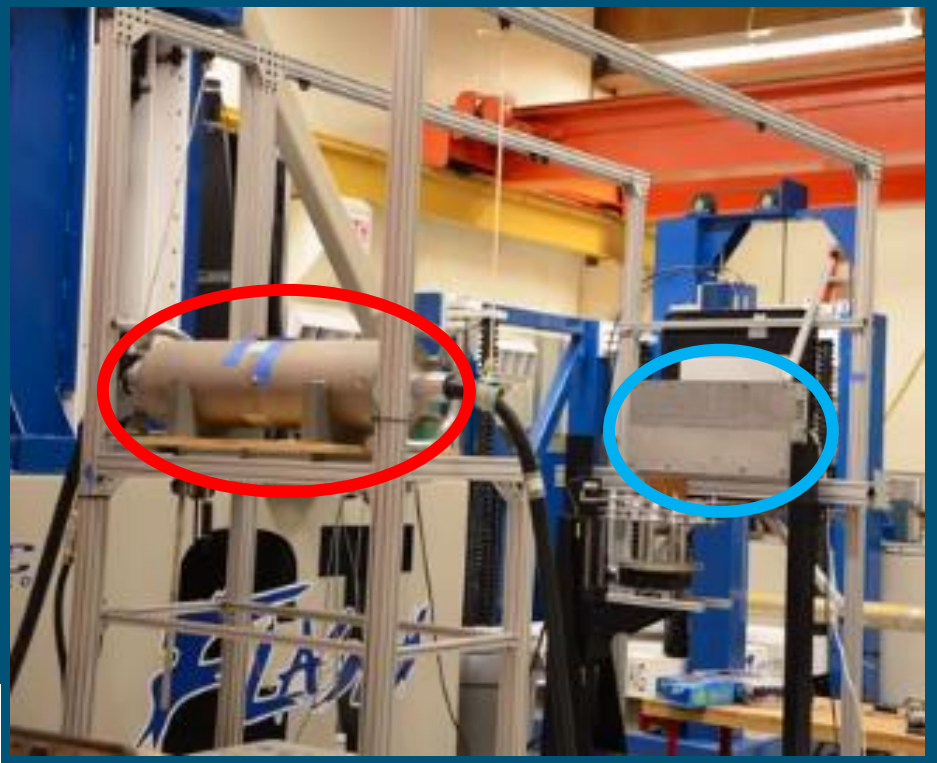




Solution

- MultiX Detector:
  - Energy-resolved X-ray detector
  - 128 channels
  - 300 keV maximum energy detection
- FOV: images objects up to half meter wide and 9 meters tall
- System has been acquiring data as of May 2017
- Initial test:
  - Image phantom in circular orientation with polychromatic source between 0 and 250 keV



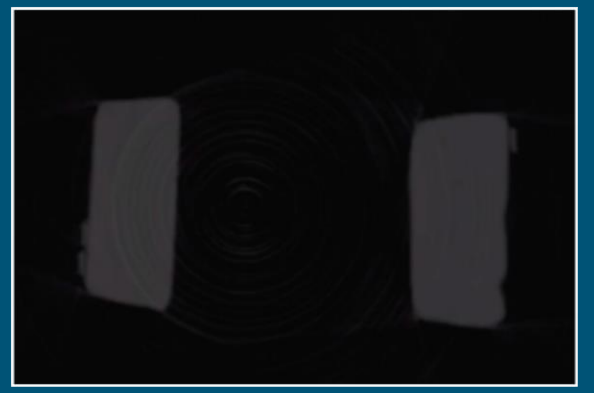


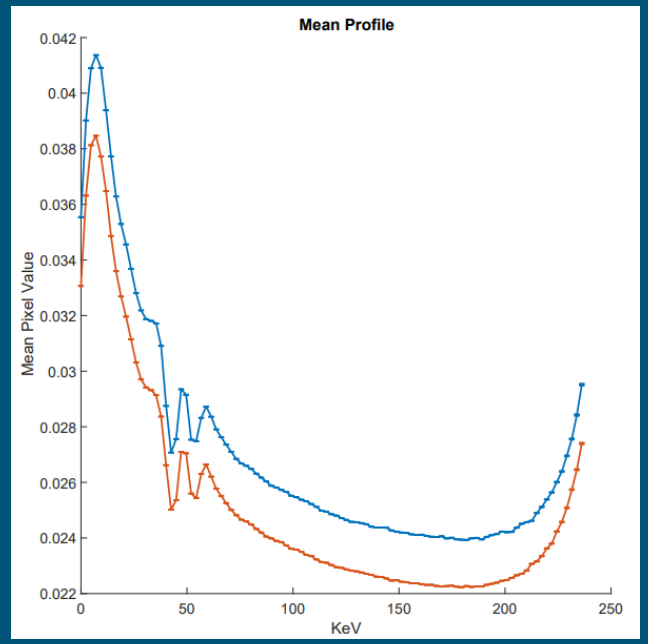
- **Scatter/pulse pile-up**
- **Charge sharing**
- **Other sources of non-linearities**

Results

- Two 1 pound block of explosive simulant
  - Very similar composition

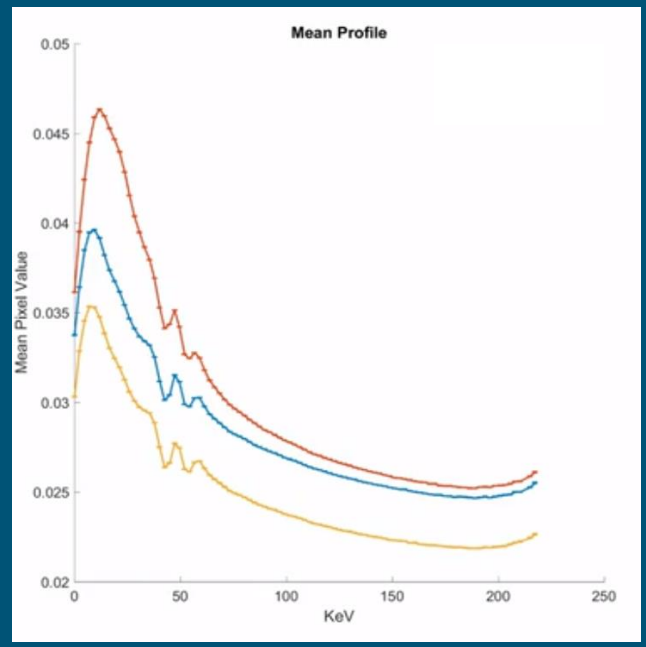
116 keV energy bin





- Three 1-inch diameter cylinders of explosive simulants
  - Very similar composition

116 keV energy bin

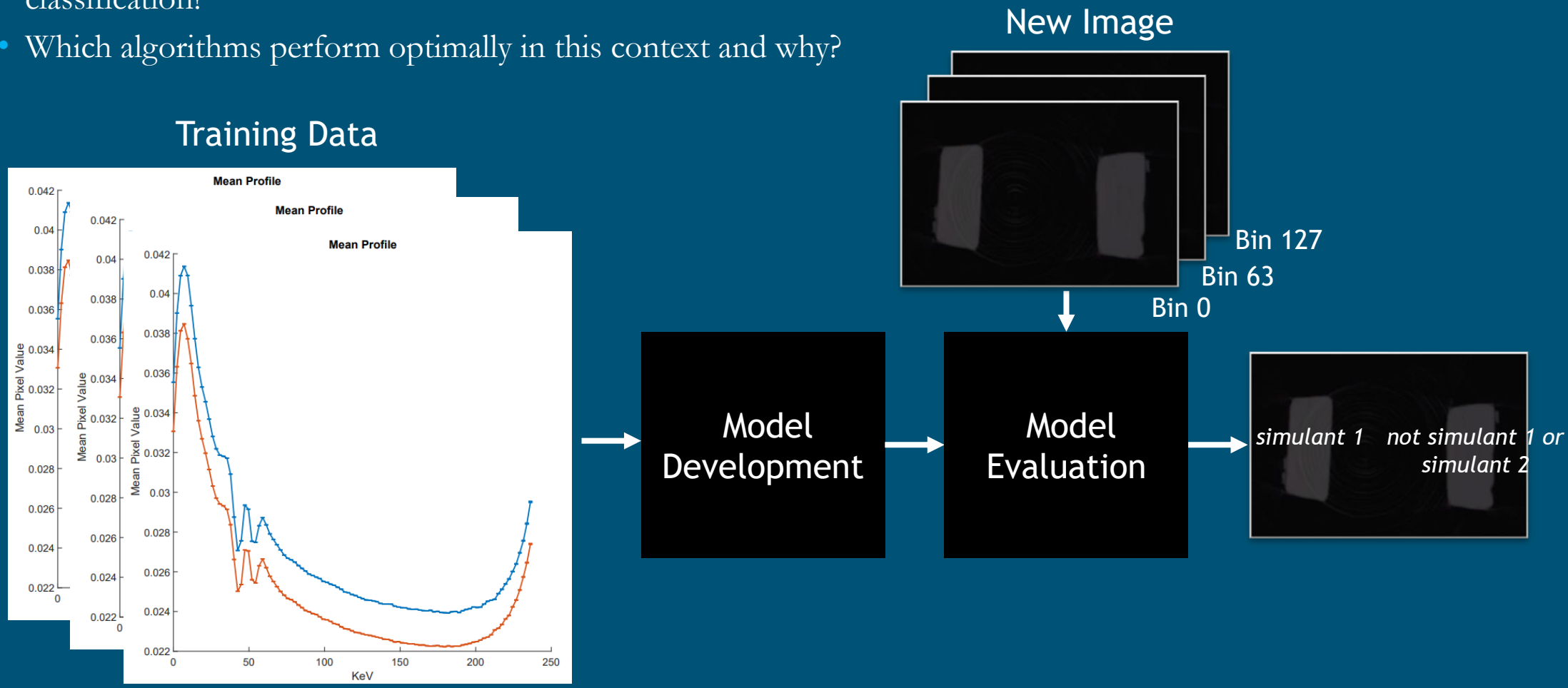


Materials with similar composition can be quantitatively separated using energy-dependent attenuation waveforms from spectral CT system[1]

1. Jimenez, Edward S., et al. "Leveraging multi-channel x-ray detector technology to improve quality metrics for industrial and security applications." *Radiation Detectors in Medicine, Industry, and National Security XVIII*. Vol. 10393. International Society for Optics and Photonics, 2017.

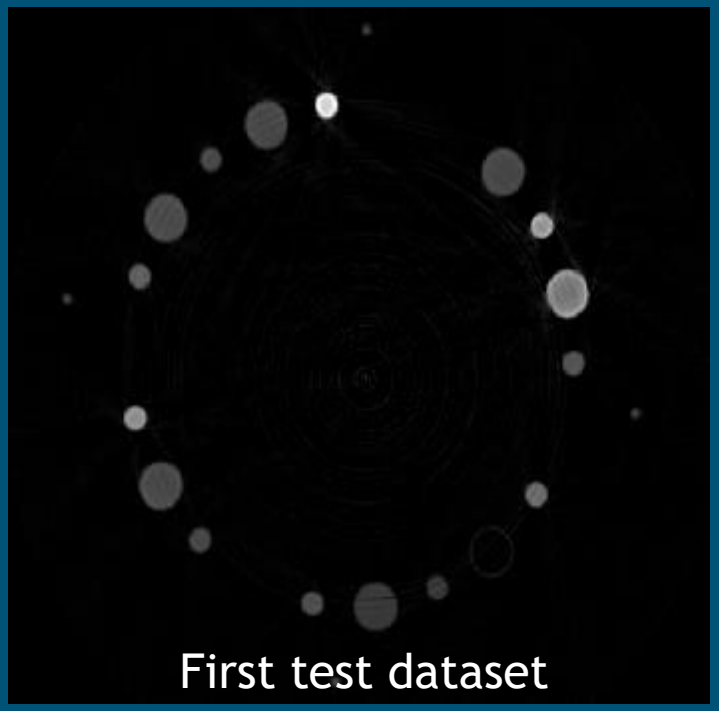
Results

- The utility of machine and deep learning techniques for understanding quantitative spectral CT information has been investigated
  - Given training/reference data for various materials, can algorithms be developed for automated material classification?
  - Which algorithms perform optimally in this context and why?

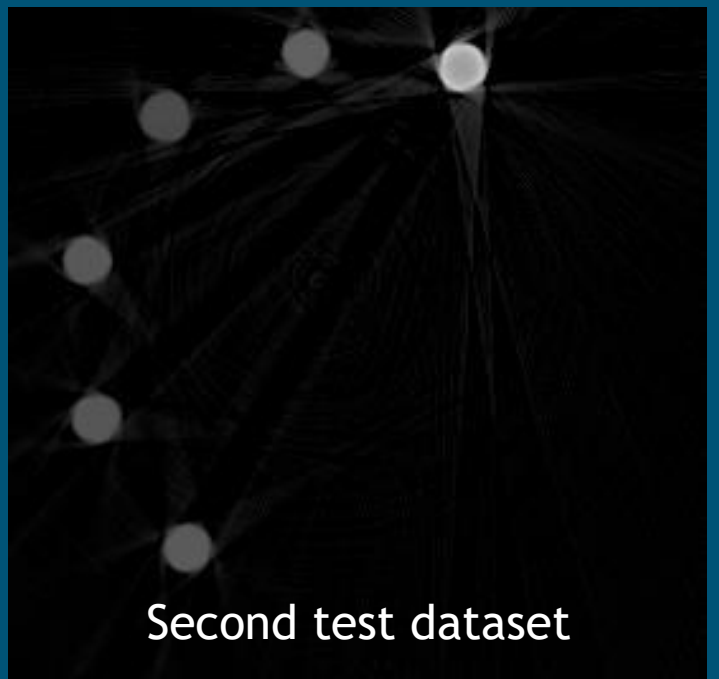


Results

- All ML algorithms trained with pixel-by-pixel spectral attenuation waveforms for different materials
  - Training dataset comprised of only two example scans
- 17 cylindrical samples in circular orientation
  - 128 images reconstructed for energy bins uniformly spaced up to 250 keV
  - Variety of materials: empty polyethylene bottle, Nylatron, Delrin, SAE 30 motor oil, acrylic, nylon, two samples of water (one ionized, one tap), teflon, polyethylene, soft-drink Pepsi, lexan, diet soft-drink Coke, aluminum, magnesium, salt, and phenolic
  - Can separate each of these materials with **above 90% accuracy**
- 6 cylindrical ceramic samples in circular orientation: zirconia, alumnia, alumina-bisque, aluminum silicate, high temperature glass-mica, and glass-mica
  - Can separate all materials with **above 90% accuracy**



First test dataset



Second test dataset

TRL

- TRL: 4
  - Advantages:
    - Distinguishes similar and dissimilar objects with very high accuracy and in an automated fashion
  - Limitations:
    - (1) Can currently only image small objects half meter wide and 9 meters tall
    - (2) Bulky
    - (3) Relatively long acquisition times
    - (4) Warrants a direct comparison with dual energy CT

Contact me

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Thank you!