Linear Attenuation Coefficient Drift in the Micro-Computed Tomography (MCT) System at LLNL

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INTRODUCTION

The goal of the Livermore Explosives Detection Program (LEDP) is to optimally utilize computed tomography to detect an expanding range of explosive threats all while minimizing the number of false alarms.

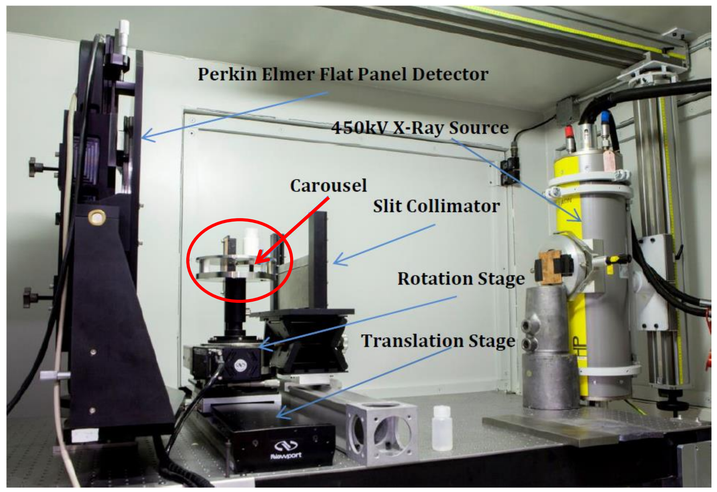
LEDP has created a database utilizing dual energy computed tomography (DECT) with detailed information on the x-ray properties of explosives threats and nonthreats.

These data help the transportation security administration (TSA) and scanner manufacturers develop performance standards for screening checked and carry-on baggage.

MV3D Dual Energy CT from L-3

SYSTEM DESIGN

The LEDP micro-computed tomography (MCT) system designed to determine x-ray signatures of explosives

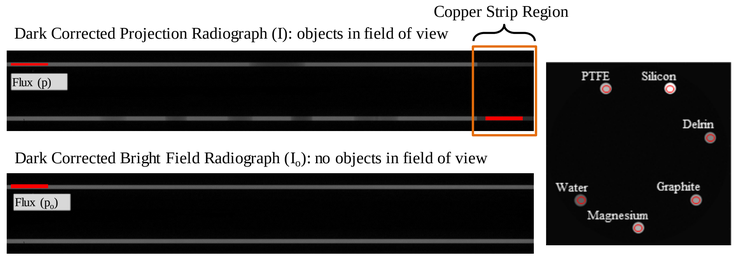


A set of references is used to asses system stability:

Reference Materials:
1. Graphite
2. Polyoxymethylene (Delrin)
3. Water
4. Polytetrafluoroethylene (PTFE)
5. Magnesium
6. Silicon

DATA PROCESSING

Several steps are in place during radiograph processing to minimize errors



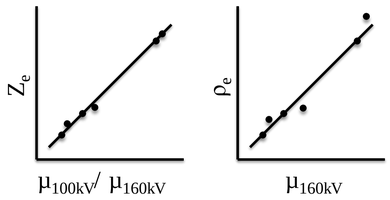
$$\text{Attenuation Radiograph} = -\ln\left(\frac{I}{I_o}\frac{p_0}{p}\right)$$

DECT is used to determine Z_e and ρ_e

At least two data sets are collected.
Differences between protocols are listed below.

Configuration	Voltage (kV)	Current (mA)	Detector Integration Time (ms)	Filtration
1	160	9.35	700	2mm Al + 2mm Cu
2	100	7.5	267	2mm Al

Objective: Determine properties of a specimen of interest by measuring the linear attenuation coefficient (μ) of references and specimen at two x-ray source energies.



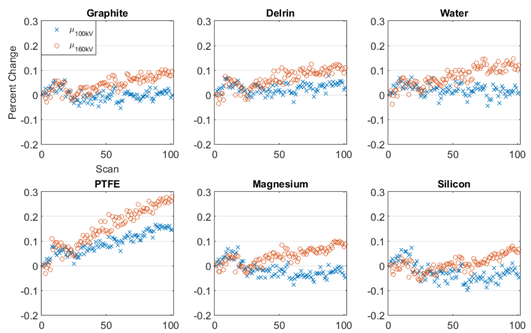
Use references to determine calibration line relating effective atomic number (Z_e) to μ_{100kV}/μ_{160kV} and the electron density (ρ_e) to μ_{160kV}

We have developed a dual energy decomposition method

CONCERN

The problem is maintaining the accuracy and precision of a DECT over a span of years

After about 100 scans, we observe that μ_{160kV} exceeds or approaches 0.1%, the threshold for allowable variation, for all references.

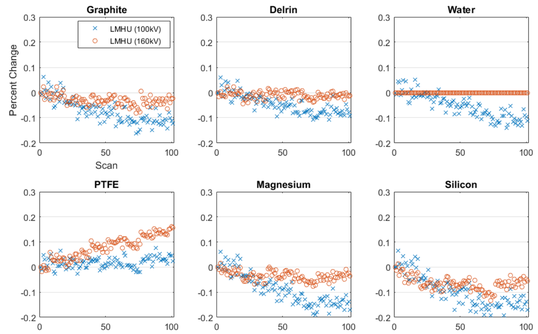


- Scans were taken during the period of November 2014 to March 2015.
- Percent change is measured from the first recorded scan
- Parameter of interest shown in legend

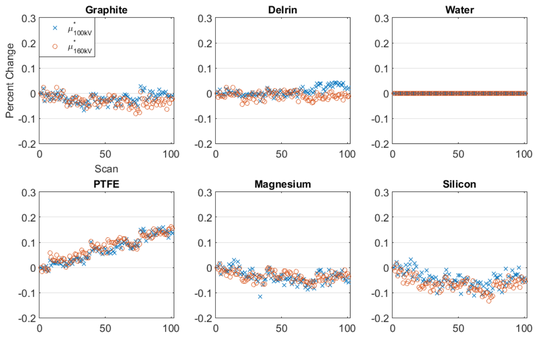
$$Percent\ Change\ of\ \mu = \frac{\mu - \mu_o}{\mu_o} x100\%$$

SOLUTION 1: NORMALIZATION

The current normalization method uses the μ of water at 160 kV to normalize both the 100 kV and 160 kV data to create Livermore Modified Hounsfield Units (LMHU).

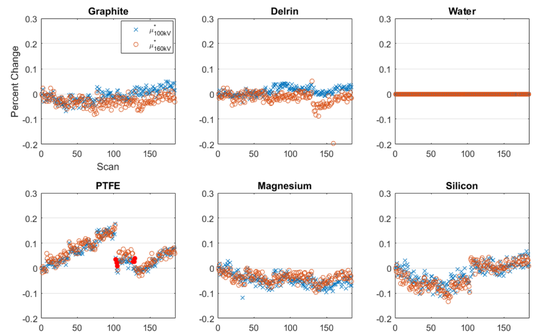


After normalizing by one reference (e.g. water) at the corresponding energy, we see more consistent behavior between 100kV and 160kV.



SOLUTION 2: RADIATION EFFECTS

After normalization by water, PTFE demonstrates a unique trend compared to the other references suggestive of radiation damage



CONCLUSION

1. Normalizing the 160 kV and 100 kV μ data by the μ of water at the corresponding energy significantly compensates for drift.

2. It appears that PTFE undergoes radiation damage that alters μ. A promising alternative to PTFE is FEP, a material that has the same effective atomic number (Z_e) and electron density (ρ_e) as PTFE, but is 10 times more radiation resistant.

3. Other causes of drift and potential solutions:
   - Examine methods to probe spectral changes from source and detector.
     - External spectrum monitor
     - Temperature
   - Possible radiation degradation of other references
     - Replacement of references

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