Electron-induced x-rays for remote potential sensing

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Motivation

- Knowledge of charge of one craft doesn't translate to nearby craft
  - Poses potential hazards in rendezvous
- General spacecraft charging interest
  - 30 kV observed at GEO
- Electrostatic debris remediation

Electrostatic tractor

- Proposed method to touchlessly re-orbit and detumble GEO debris
  - 10s of mN attractive force
- Control requires knowledge of charge on both bodies

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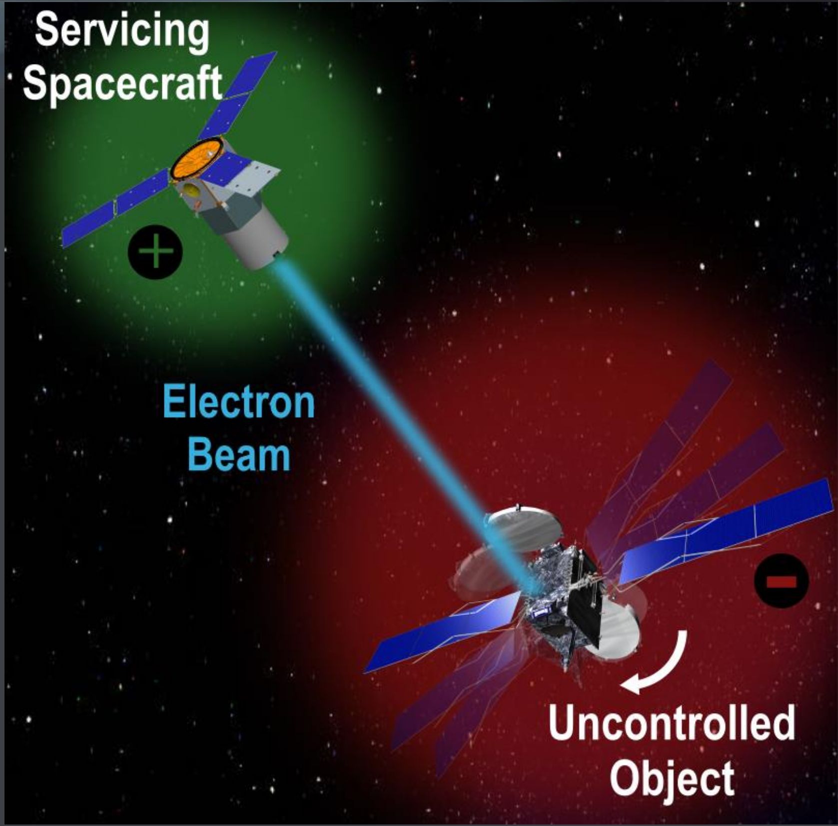
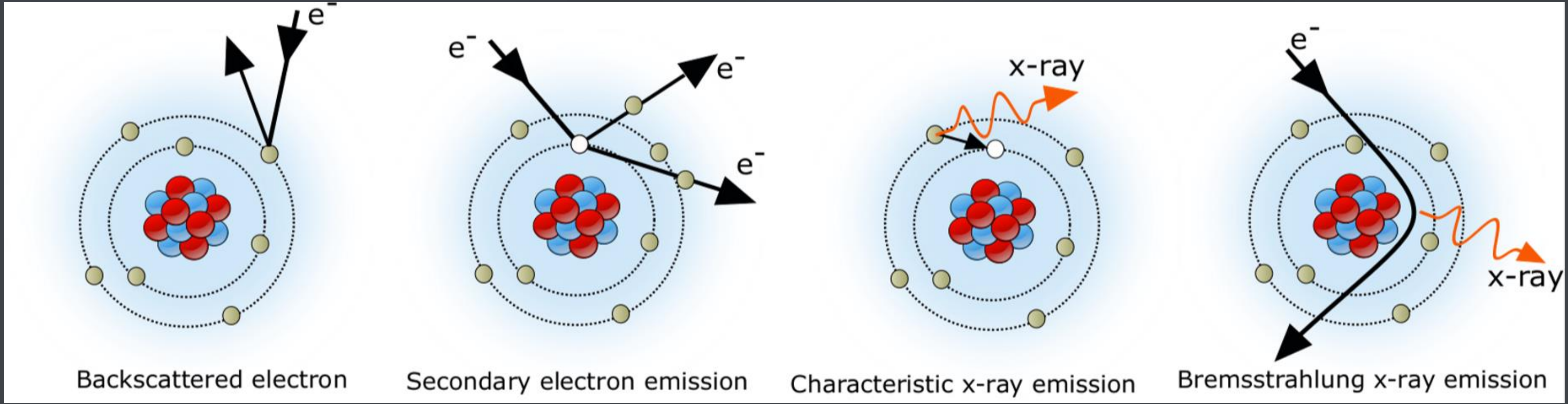


Relevant Background

Prior touchless sensing work

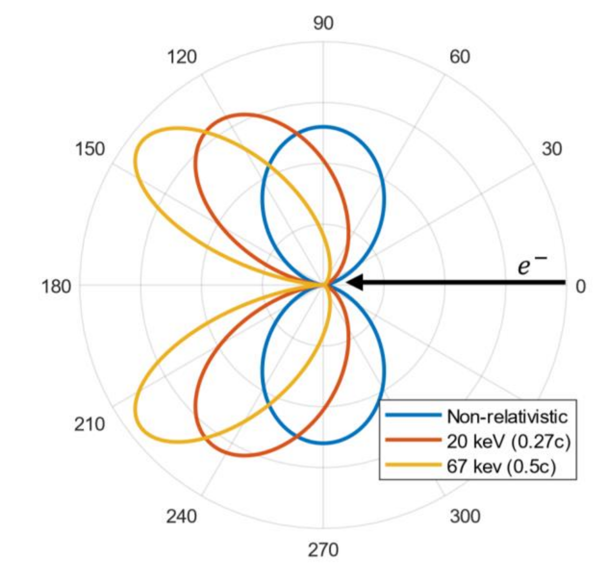
- Trek non-contacting voltmeters
  - Require mm separations
- Electron microscopy field has used bremsstrahlung x-rays and secondary electrons
  - Significant flight heritage for both electron energy analyzers and x-ray spectrometers

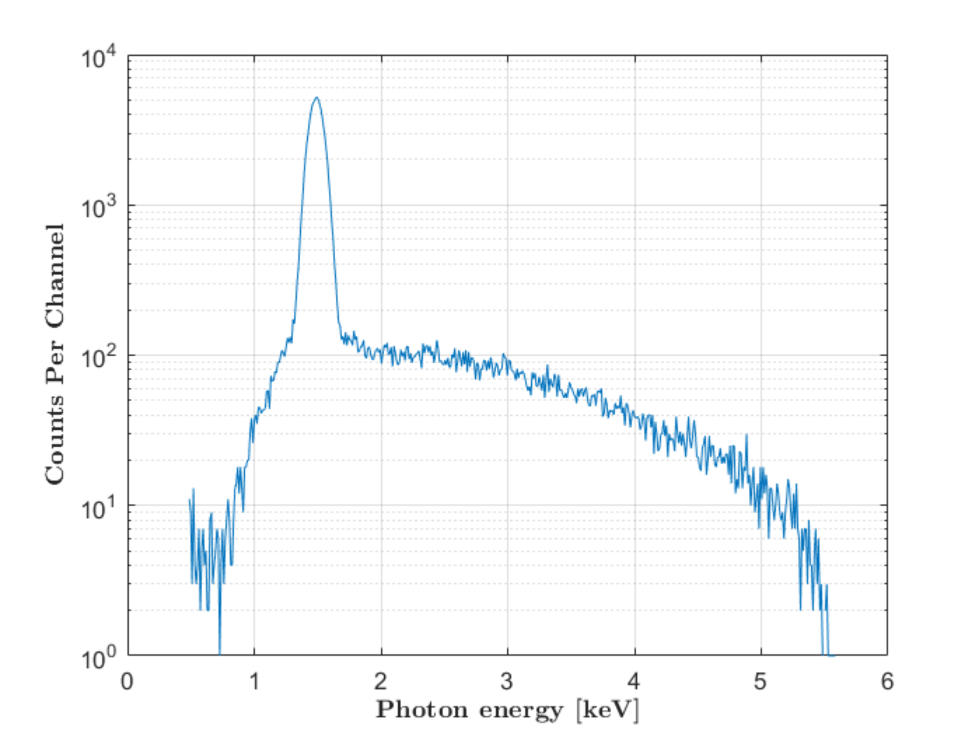
Electron-atom interactions



Bremsstrahlung

- Strong angular dependence
- S/N depends on angle

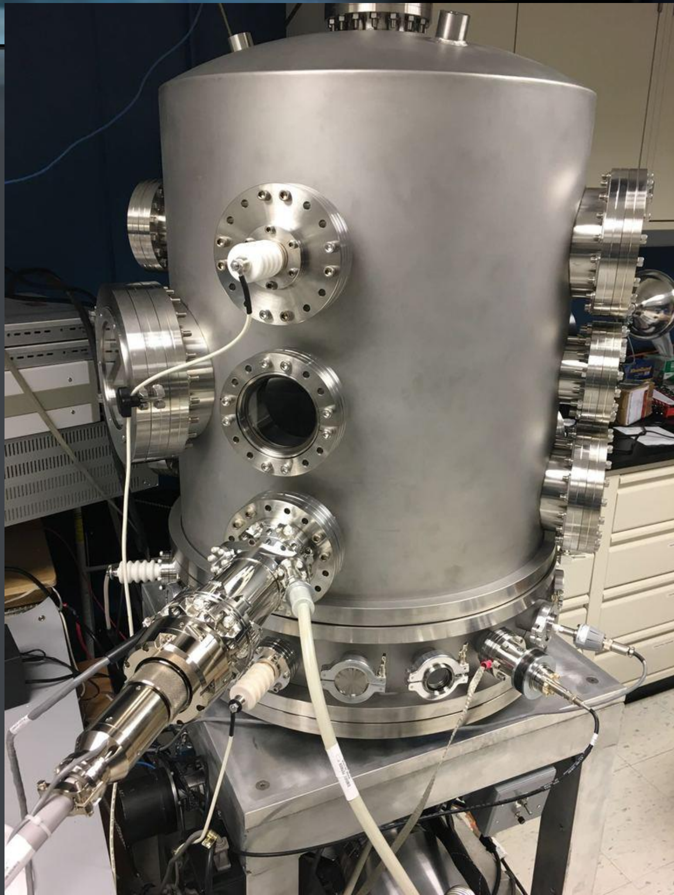




Experimental setup

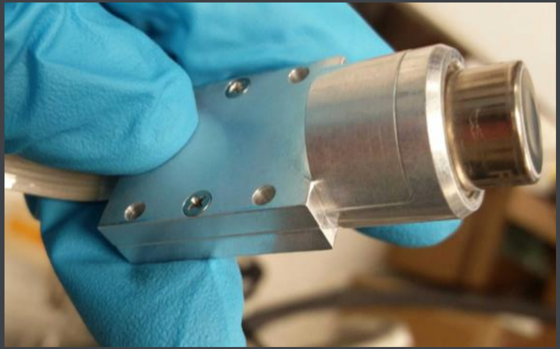
Experimental setup

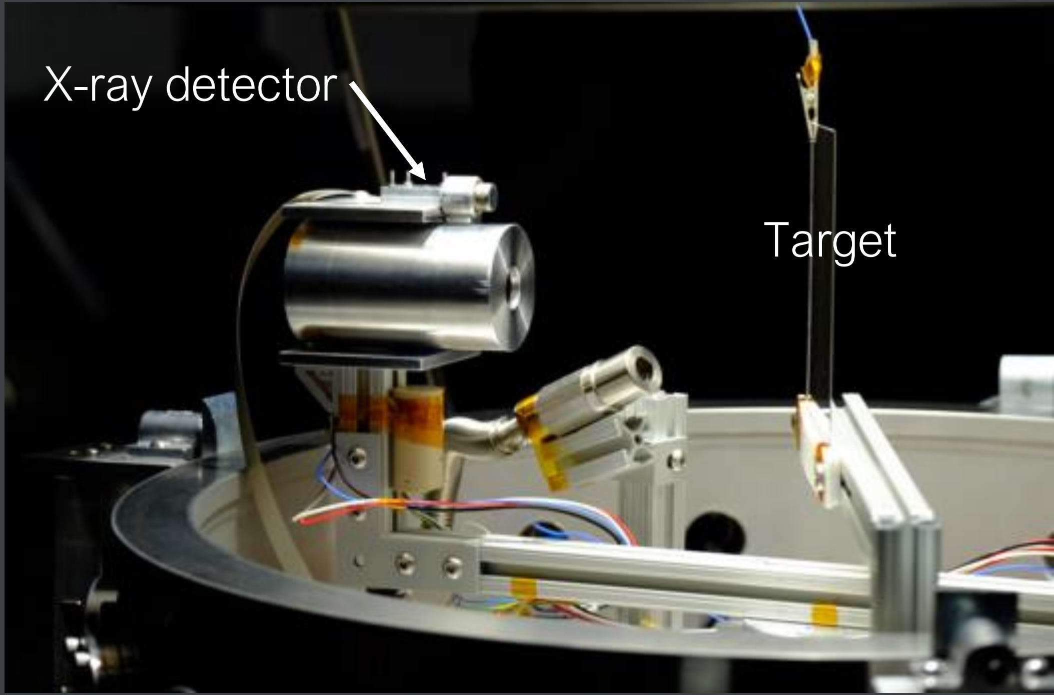
- Electrostatic Charging Laboratory for Interactions of Plasma and Spacecraft (ECLIPS)
  - Vacuum chamber, 10^{-6} Torr typical
  - Electron gun (0-30 keV)
  - Range of high voltage feedthrough, 5x high voltage power supplies
  - VUV light
  - 3 axis translation stage ($\hat{\theta}, \hat{r}$ directions done, $\hat{z}$ pending)
  - Ion gun (awaiting install)



Experimental setup

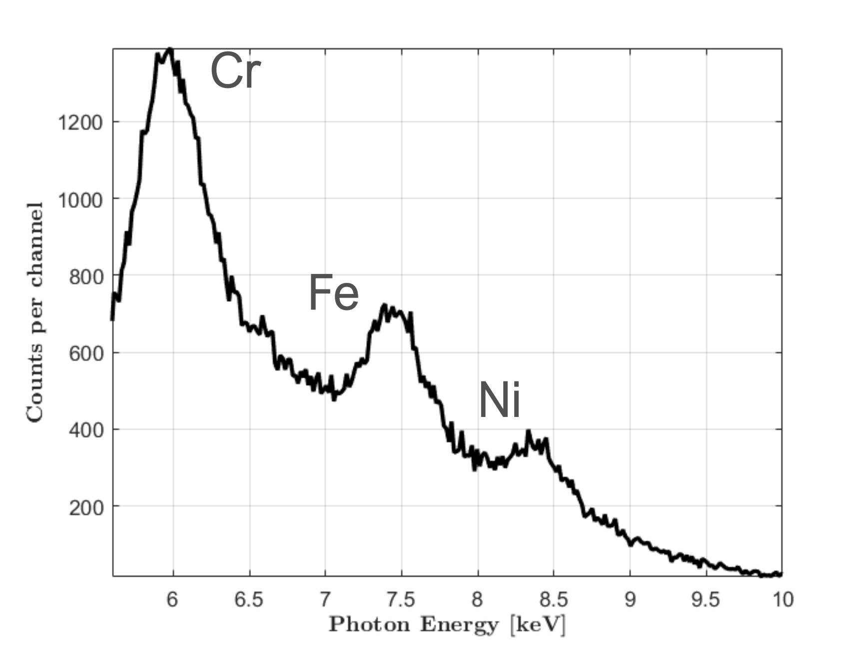
- X-ray detector commercially sourced
  - X123 Si-PIN from Amptek
  - FWHM 120 eV at 5.9 keV
  - Integrated thermoelectric cooling
  - Spaceflight heritage



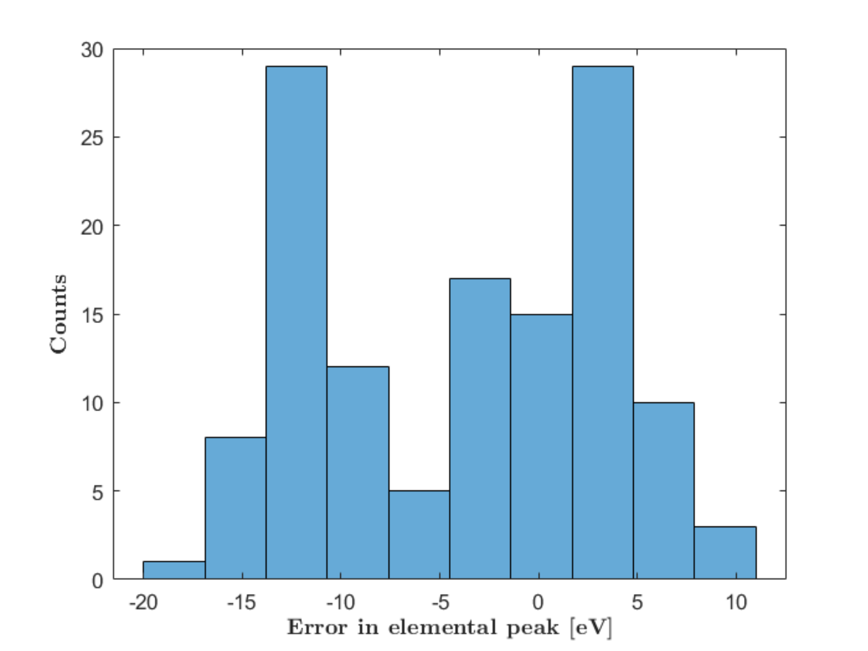


Experimental results

Detector characterization



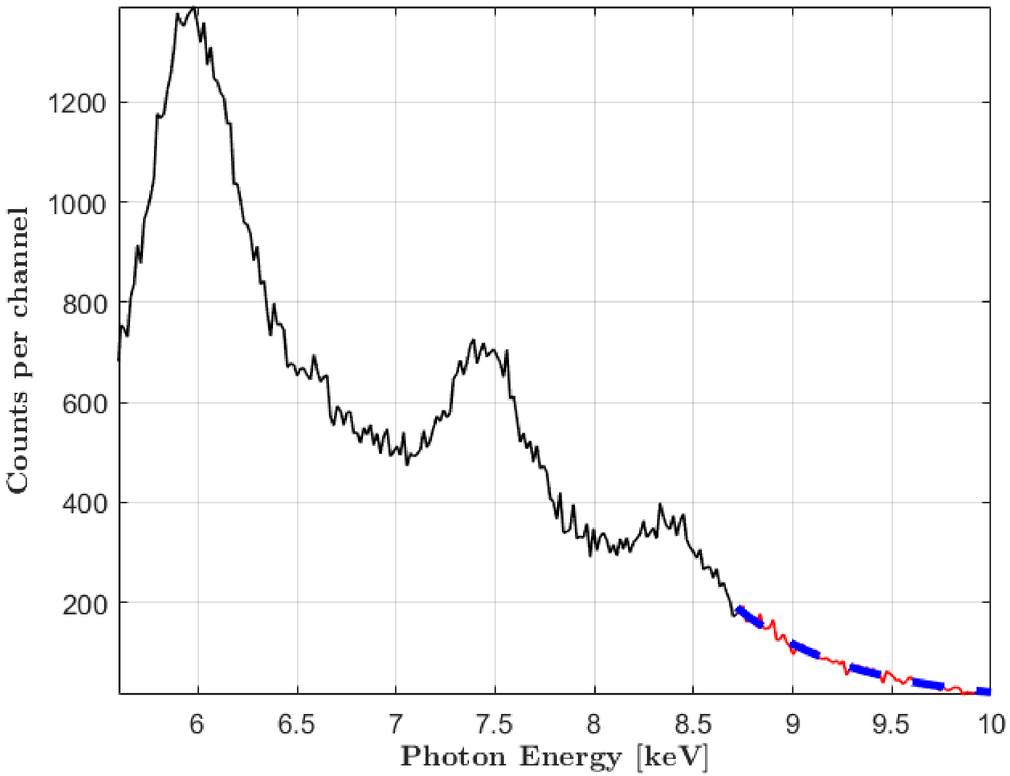
Inconel target, 10 keV beam



Change in characteristic peak energies over 2 hours

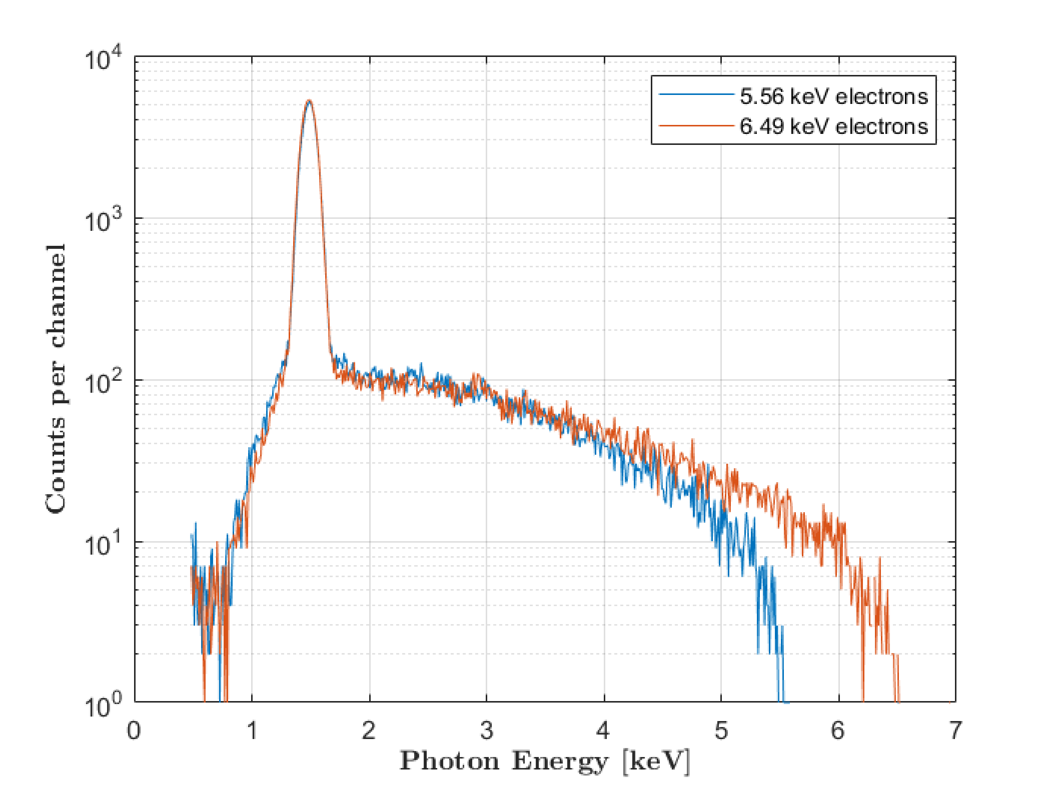
Landing energy determination

- Use counts from high-energy bins
- Curve fit
- Root find on that curve



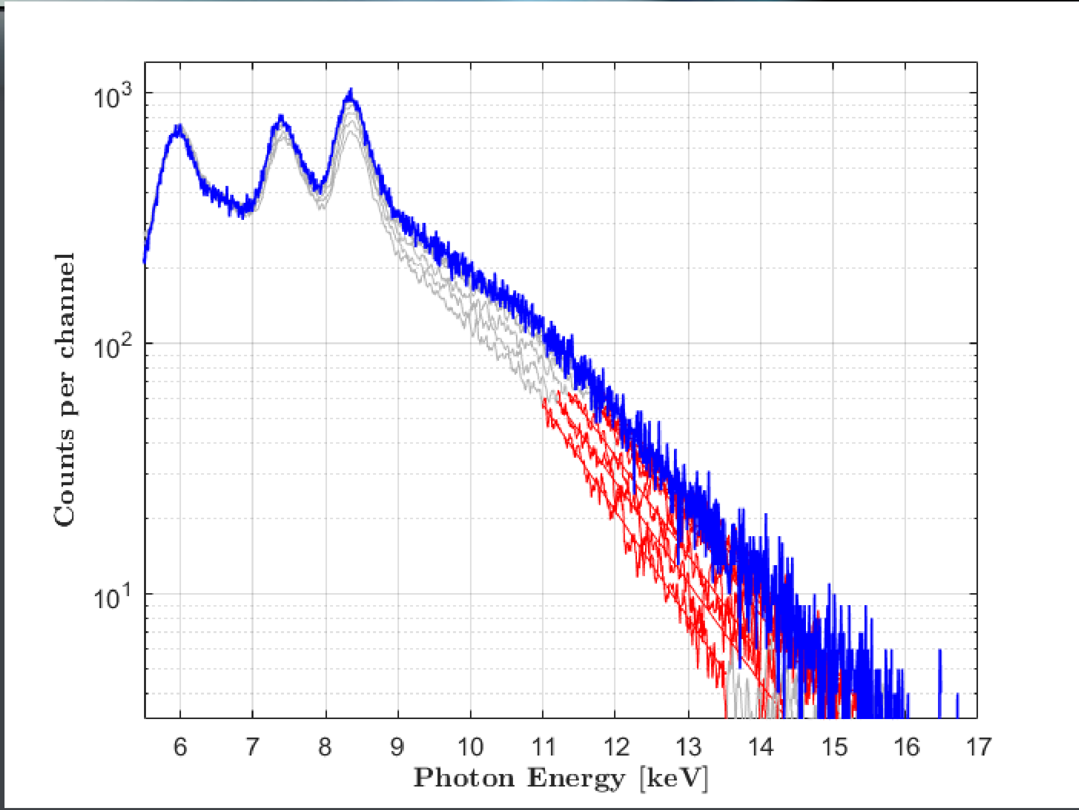
Initial results

- Aluminum target, varying beam energy
- Found landing energy to <50 eV
- Aluminum peak resolved to <15 eV



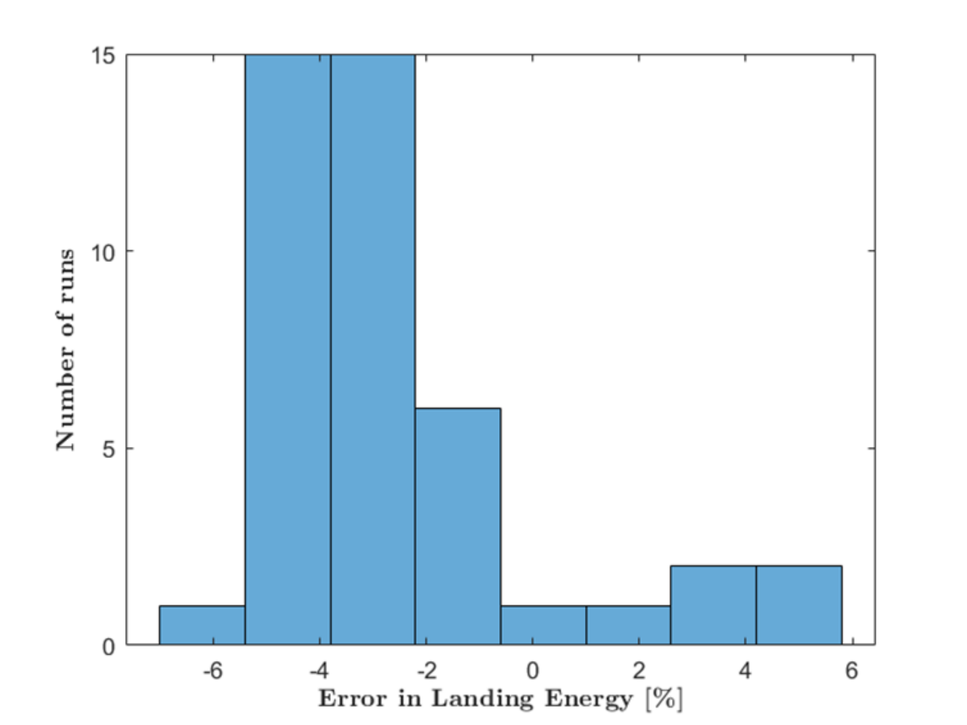
Initial results

- Example collection run with constant electron beam energy, charging plate



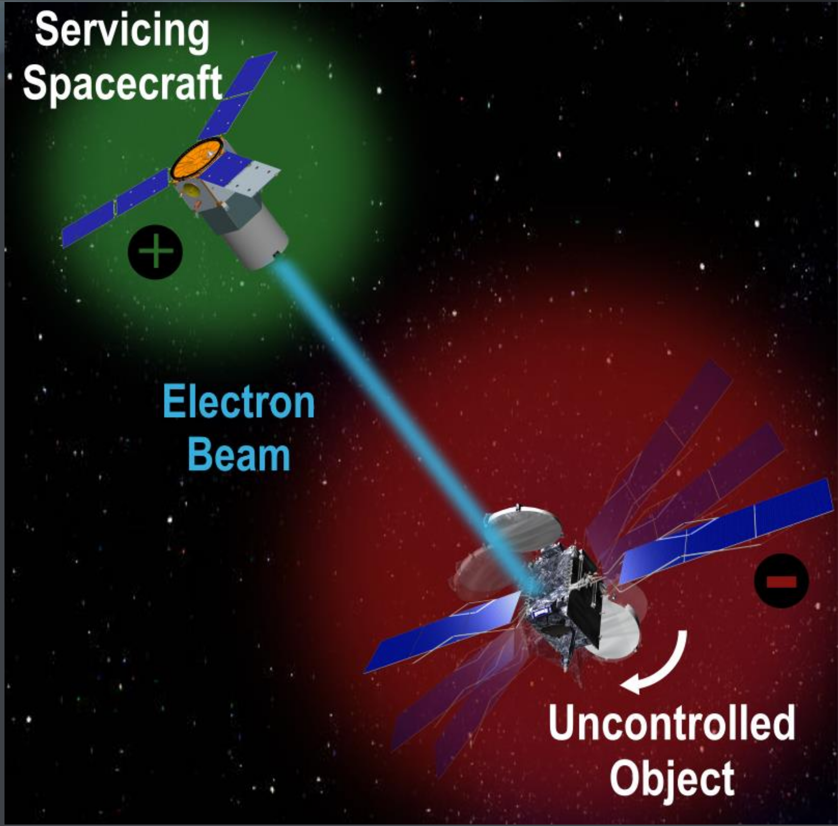
Initial results

- Constant beam parameters
- Varying angle
- Highest error runs first set conducted
- Resolution reduced from earlier runs
  - Higher temperature, lower peaking time



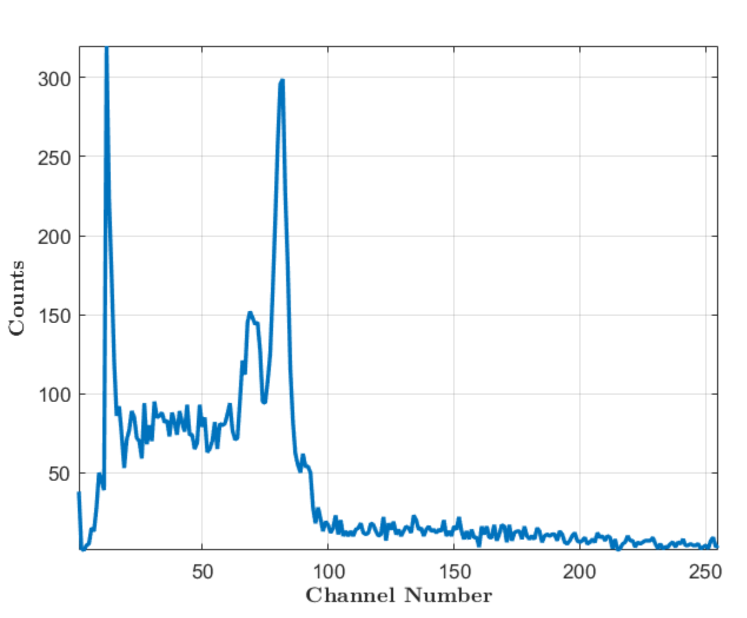
Conclusions

- Promising experimental results
- Sufficient resolution for Tractor concept



Next steps

- Vary targets
  - More complicated geometries
  - Additional materials
- Landing Energy resolution characterization
  - Function of angle, detector parameters
- Use environmental electrons instead of electron beam
  - Apply to flight data, look at lunar surface charging



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