# Shields-1, A SmallSat Radiation Shielding Technology Demonstration

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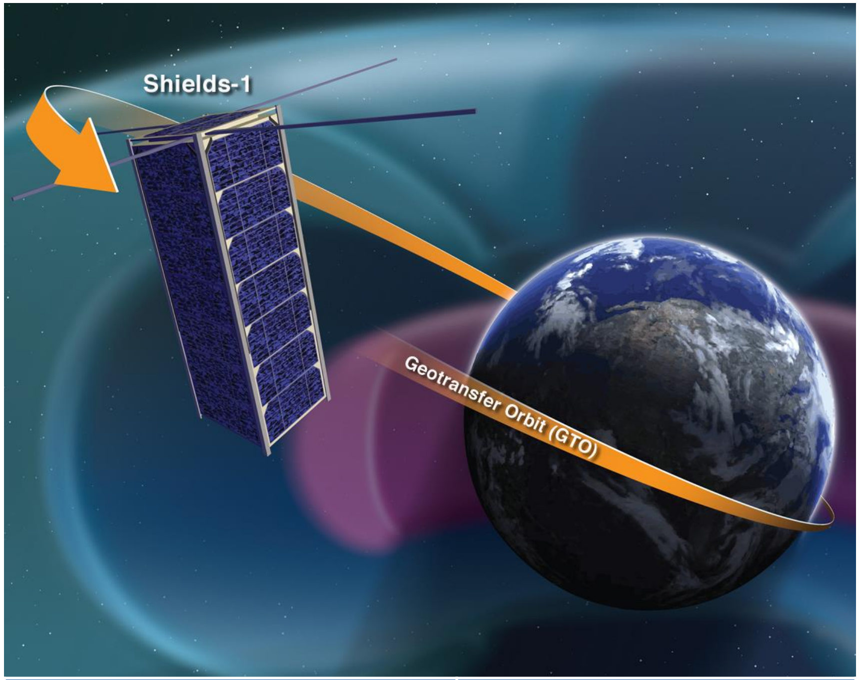
# Overview




| Desired Orbits | | Acceptable Orbit Ranges |
|---|---|---|
| Altitude (GTO/HEO) | 350-37,500 km | 240-200,000 km |
| Inclination | 0-23 deg | 0-90 deg |
| Altitude (Polar LEO) | 450-800 km | 400-1000 km |
| Inclination | 80-110 deg | 70-120 deg |

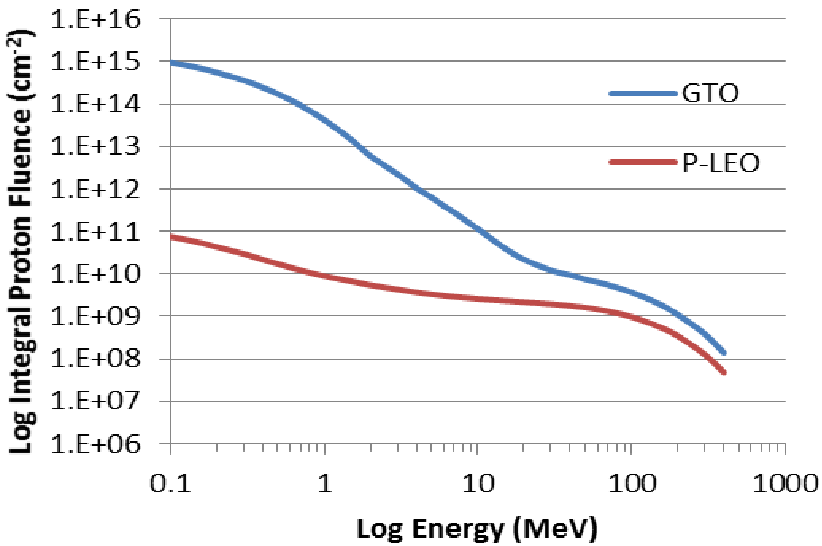
## Highlights

- **Extends typical CubeSat missions from 3 months to years with an atomic number (Z)-grade vault.**
- **Demonstrates a Charge Dissipation Film designed for extreme charging environments.**
- **Develops and demonstrates a one-piece (Z)-grade radiation protection for electron radiation environments.**
- **Matures innovative μdosimeters.**
- **Reduces technology development schedule and associated costs by collective testing in a relevant space environment.**

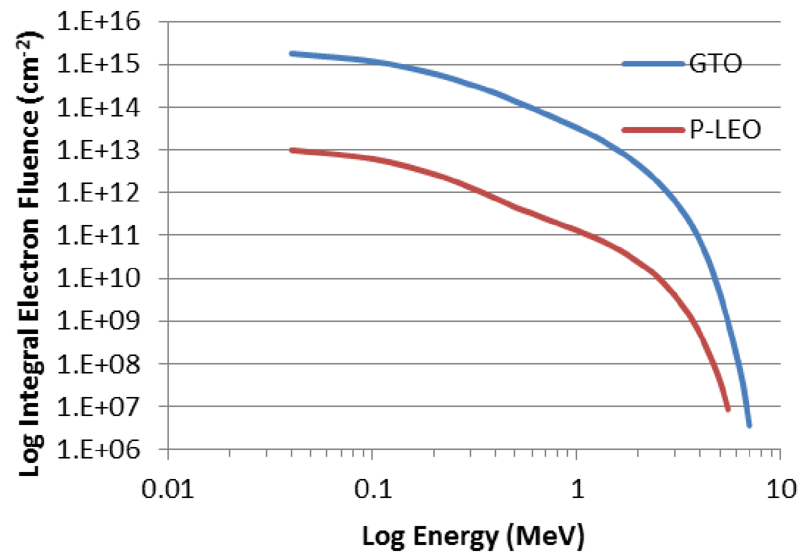
# Space Environment:  GTO and Polar-LEO

*SPENVIS: AP8min-AE8 Max Model for GTO and Polar LEO, ELaNa III satellite environment particle fluence.*

Proton fluence for a year




Electron fluence for a year




- Proton fluence in GTO at energies greater than 30 MeV have approximately a factor of 10 larger fluence than in Polar-LEO.
- Electron fluence in GTO a factor of 100 higher when compared to Polar-LEO for energies below 5 MeV.

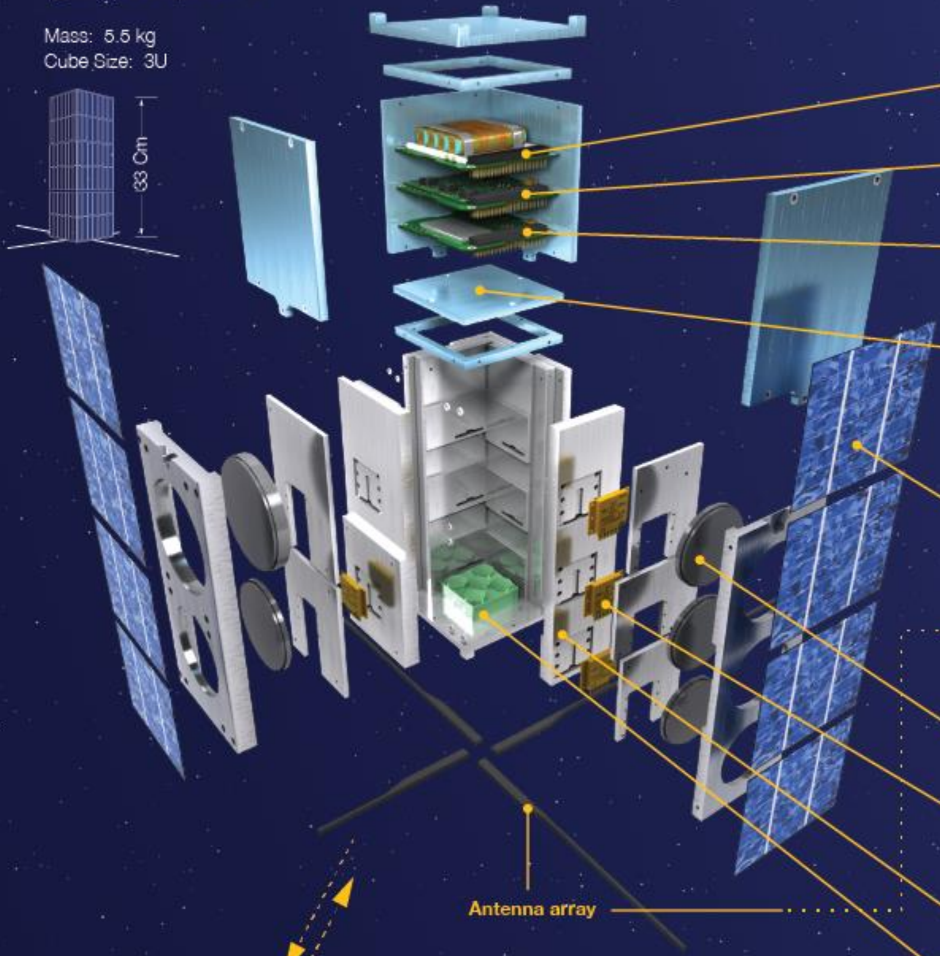
# Three Experiments

- **Vault Electronics**
  - **To measure total ionizing dose (TID) over time and monitor system electronics performance.**
- **Charge Dissipation Film Resistance**
  - **Measure the resistance over time**
- **Atomic Number (Z)-Grade Radiation Shielding**
  - **To measure total ionizing dose of Z-grade radiation shielding and compare to baseline aluminum for at least 3 samples each.**

# Spacecraft Overview with Experiments

## Shields-1

Mass: 5.5 kg
Cube Size: 3U




Excerpt: Shields-1 Brochure, NASA NP-2015-04-608-LaRC

### System

Low risk (green) · Med risk (yellow) · High risk (red)

**CubeSat Vault Electronics** (green)
TRL Advancement: 4-6, Partner: MXL, AstroDev
Redesigned board layout to fit in the inner CubeSat vault form factor.

**Battery system** (green)
Partners: MXL, AstroDev
Four lithium ion cells provide power during eclipse periods and high power operational modes. The batteries provide 6800 mAh at 8.4V.

**Electrical power system** (green)
Partners: MXL, AstroDev
The EPS regulates power from the solar panel and outputs three bus voltages: 3.3V, 5.0V, 8.4V. Telemetry systems monitor currents, voltages, and temperatures.

**Flight computer and Communications** (green)
Partner: AstroDev
The Flight Computer provides telemetry collection and command control capabilities. It interfaces to various sensors around the spacecraft, controls the payload, and logs data to dual, redundant SD card systems. A lithium-1 radio provides half duplex communication in the UHF band.

**Z-Grade Radiation Shielding Vault** (yellow)
TRL Advancement: 3-6, Partners: NASA Langley Research Center
Radiation shielding using Atomic Number (Z) Grade Technology for enhanced electron shielding performance with reduced volume benefits for small satellite applications.

**Flight Software** (green)
TRL Advancement: 7-9, Partners: MXL, AstroDev
The flight software, written in C, provides primary spacecraft operational capability and runs on the flight computer. It gathers telemetry, monitors health, and processes commands, both in real time from the ground and scheduled for a later time. The software has flown in various forms on RAX, MCubed, and GRIFEX.

**Electrostatic Discharge Cleaned CubeSat Solar Panels** (yellow)
TRL Advancement: 4-8, Partner: Vanguard Space Technologies, Inc. SBIR Commercial Readiness Program
CubeSat Solar Panels designed for extreme radiation environments.

**Antenna array** (green)
The ISIS deployable antenna system contains up to four tape spring antennas of up to 55 cm length. The system can accommodate up to four monopole antennas, which deploy from the system after orbit insertion. The antenna system has been designed for maximum compatibility with existing COTS CubeSat components.

### Research

**Work Research Payload** (yellow)
Experimental Radiation Shielding: Experimental Z-grade or baseline shielding with varying areal densities in front of the µdosimeters.

**µDosimeters** (green)
TRL Level: 9
µdosimeters tested in inner and outer proton belts with varying shielding areal densities.
Space heritage from previous missions: AeroCube 6, MARS, Van Allen Probes, Rapid Pathfinder "Deal" Mission, LRO, MISSE-7B.

**Back Shield Panels** (yellow)
Shielding behind the µdosimeters to create a back slab. Most radiation will enter through the front Z-grade experimental sample or baseline shield.

**Charge Dissipation Film** (red) (schedule)
TRL Advancement: 3-6, Partner: LUNA Innovations, Inc.
LUNA XP-CD-B is a charge dissipation film designed for extreme internal charging environments, developed through the NASA STTR Phase I proposal award NNX11CI29P and Phase III.

### Ground Systems

**Proposed Ground link station** (green)
Wallops Island
18 Meter UHF parabolic dish: 401 MHz U/L and 402 MHz D/L, Government Frequency License submitted in the first half of FY2014.

### Mission Operations

**Flight Mission Support Center** (green)
NASA Langley Research Center
Special operations center for launch support, early orbit and payload activation, anomaly resolution, data capture and down link, payload health and monitoring.

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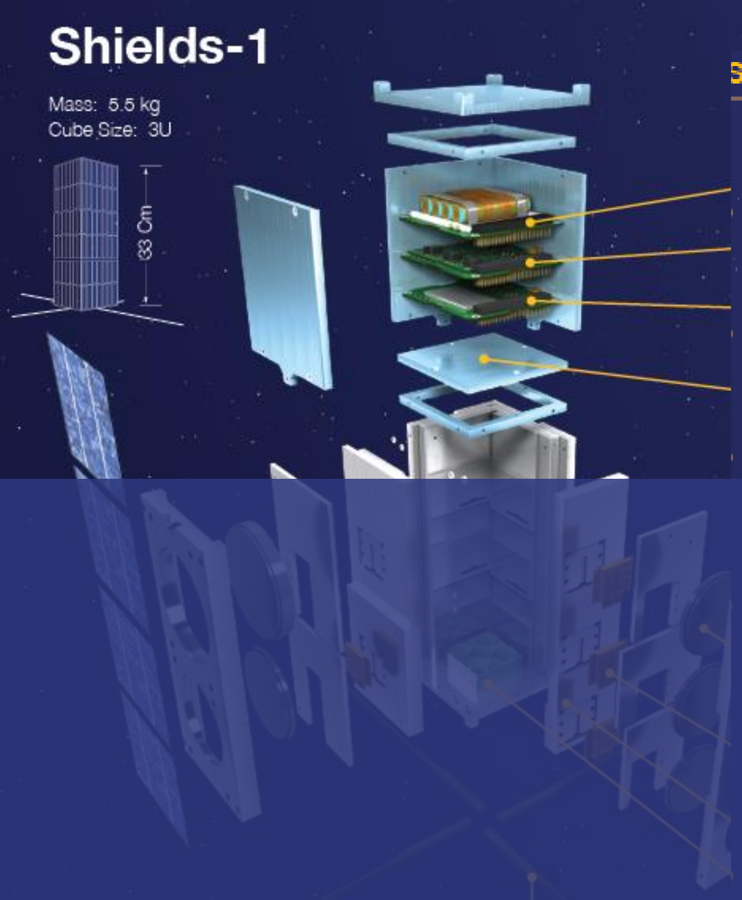


System

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**Electrical power system** ■ (Low risk)
Partners: MXL, AstroDev
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**Flight computer and Communications** ■ (Low risk)
Partner: AstroDev
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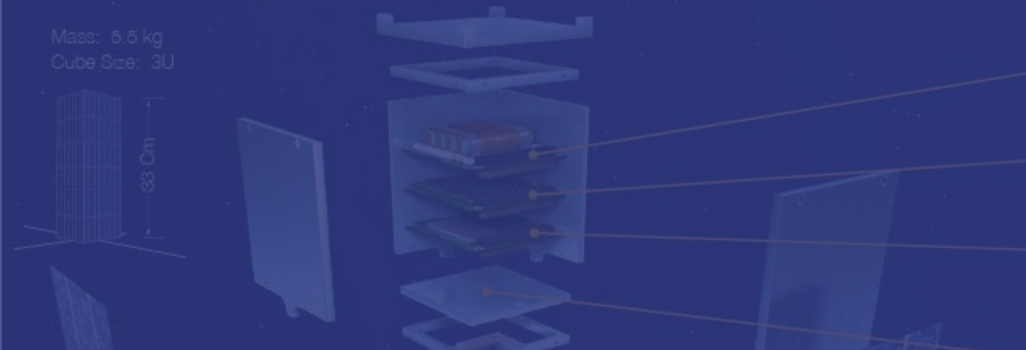


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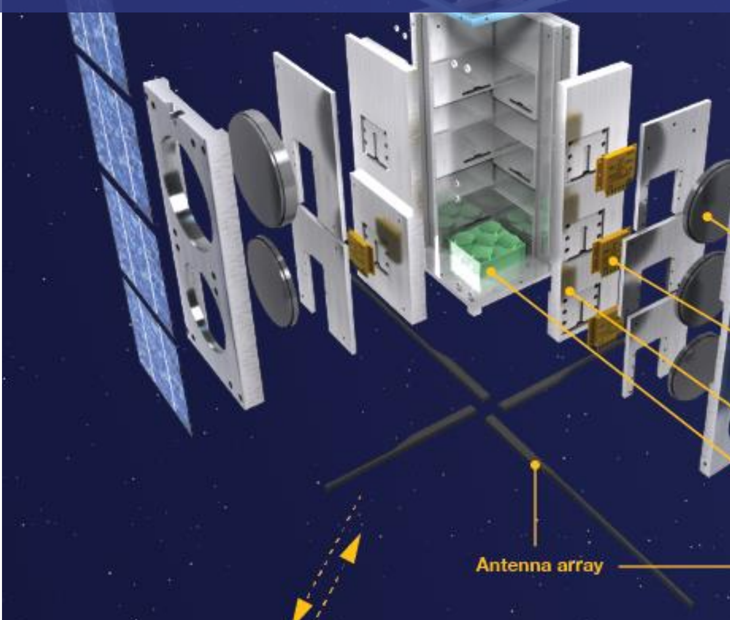


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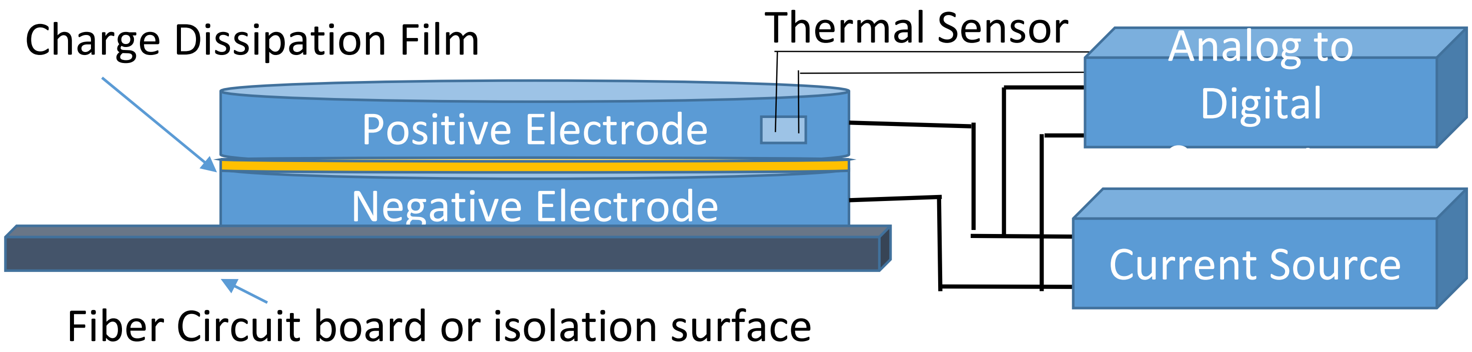
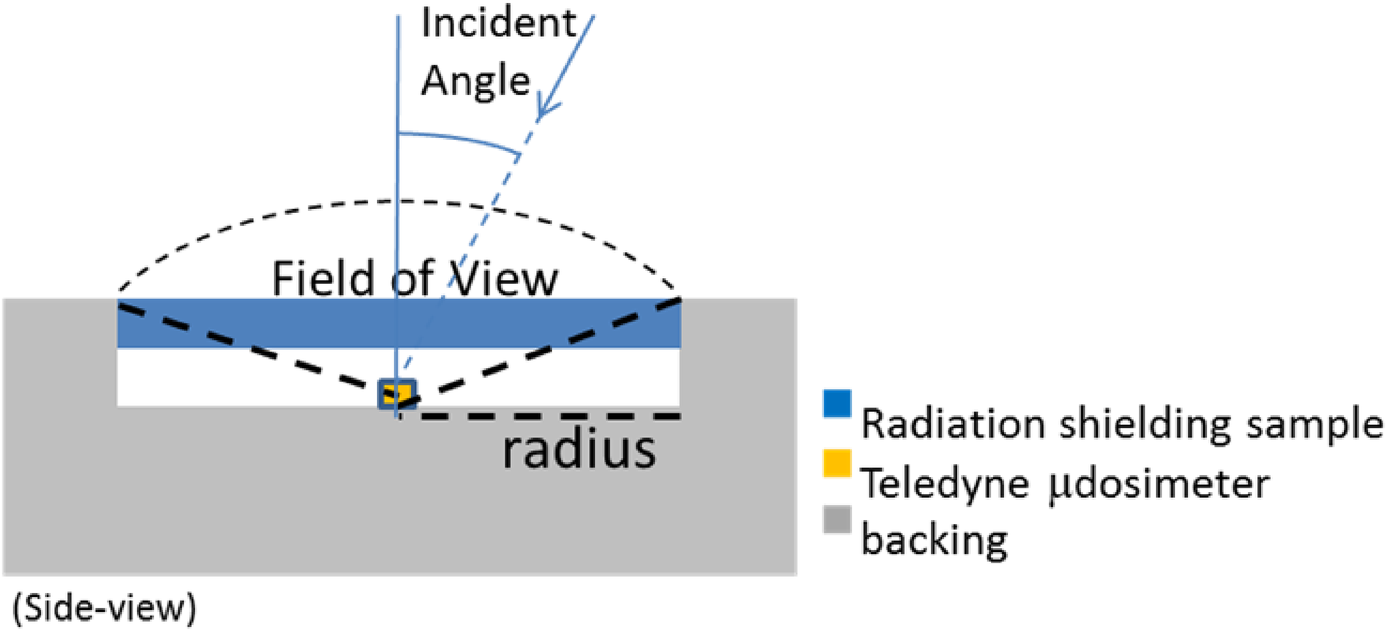
# Charge Dissipation Film Experiment




| LUNA XP-CD-B Volume Resistivity | Specimen Dimensions | Expected Resistance |
|---|---|---|
| 4.7 x 10e$^9$ ohm cm at 25°C | Area 5 $cm^2$ | 2.3 MOhm |
| | Thickness 0.0025 cm | |

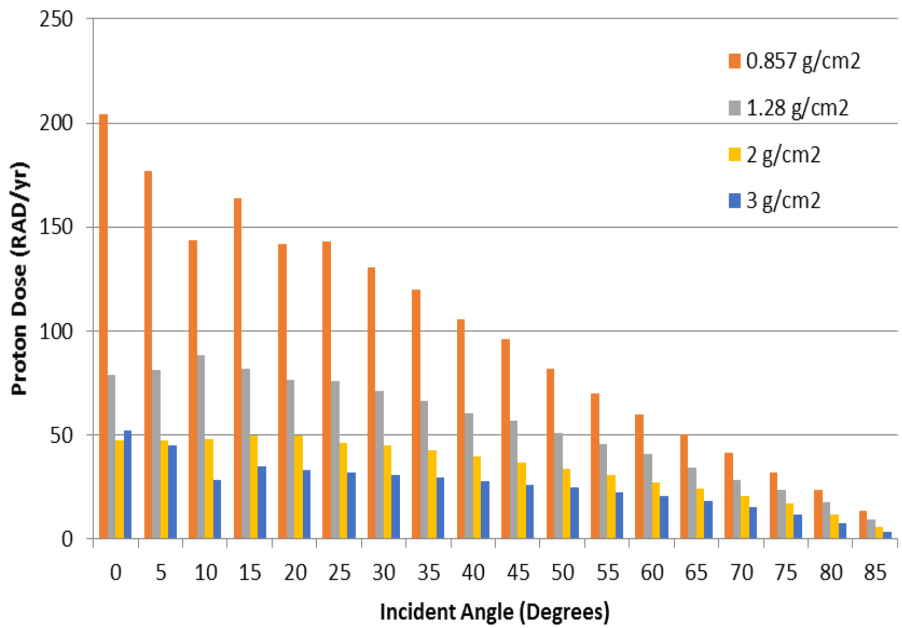
Measure Resistance of a known thickness and area charge dissipation Film, using an approach in ASTM 257-14, “Standard Test Methods for DC Resistance or Conductance of Insulating Materials”.

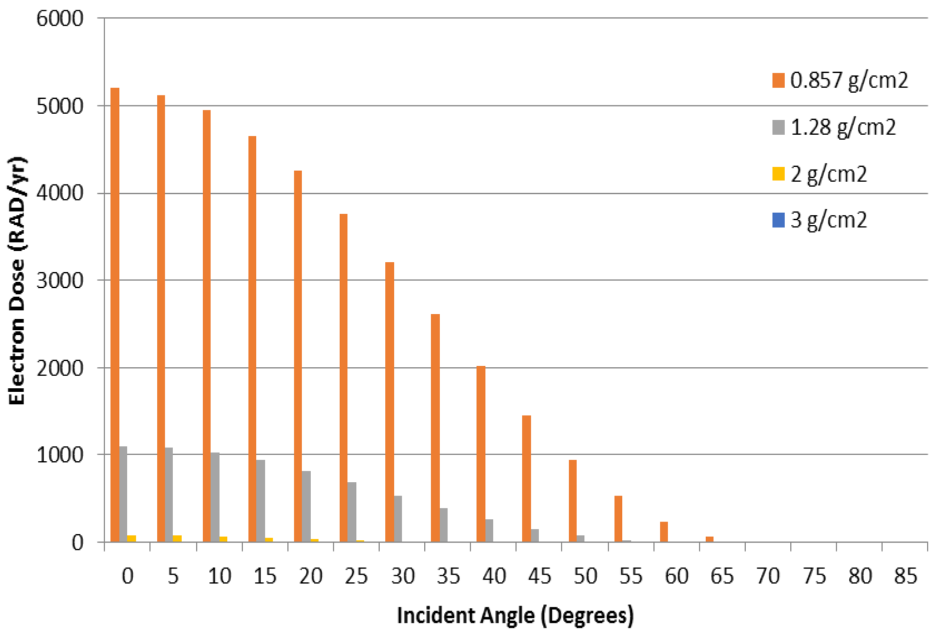
# Radiation Shielding Experiment




- Infinite slab, geometry approximation
- >95% incident radiation through shielding sample
- Large sample field of views, thick backing

# Aluminum (Al) Incidence Angle Dependence on Total Ionizing Dose (TID)

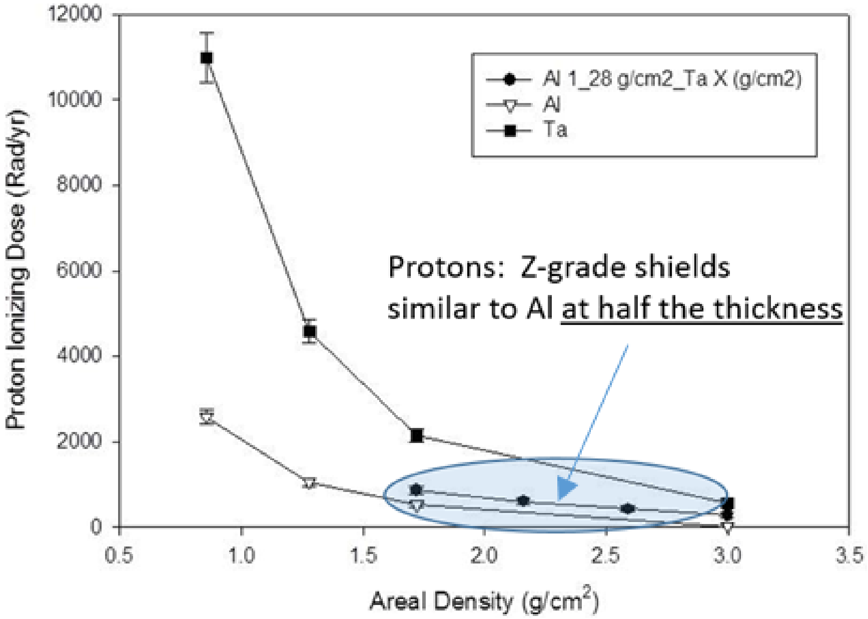


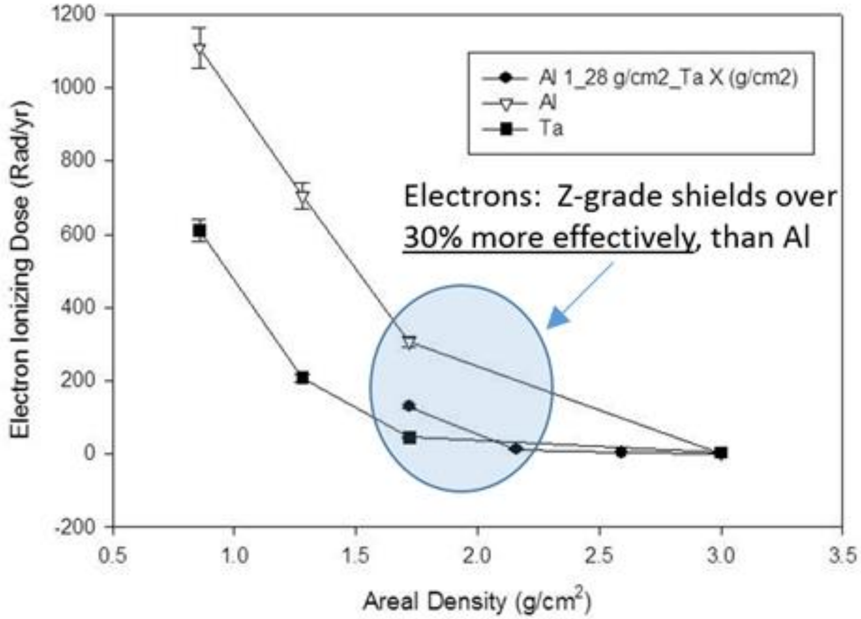

- Incident angle dependence used to determine shielding FOV slab diameters.
- In order to receive greater than 95% of the proton radiation through a shielding slab the incident angles need to be at least 75 degrees.
- No electrons contribute to dose from incident angles greater than 70 degrees.

# Expected Dose Results for Various Shielding Areal Densities in GTO

Proton Dose




Electron Dose




Aluminum/ Tantalum Z-Grade Shielding Samples (Al_Ta)
Baseline: Aluminum (Al) and Tantalum (Ta)

# Conclusion

- **Addition of Z-Grade Shielding into CubeSat missions offer reduction of TID on sensitive electronics.**
- **Lifetimes of TID sensitive electronic devices are increased**
- **Internal charging effects are greatly reduced.**
- **Shields-1 technology development of the Z-grade radiation shielding and charge dissipation film enable future missions with the acquired space heritage.**

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