Shields-1, A SmallSat Radiation Shielding Technology Demonstration

D. Laurence Thomsen III
NASA Langley Research Center, Advanced Materials and Processing Branch, 6A West Taylor Street, Hampton, VA 23681; 757-864-4211, d.l.thomsen@nasa.gov

Wousik Kim
Jet Propulsion Laboratory, Mission Environments Group, 4800 Oak Grove Drive, MS 122-107, Pasadena, CA 91109-8099; 818-354-7884, wousik.kim@jpl.nasa.gov

James W. Cutler
University of Michigan, Department of Aerospace Engineering 1320 Beal Avenue, 3013 FXB Building, Ann Arbor, MI 48109-2140, 734-615-7238, jwcutler@umich.edu
Overview

<table>
<thead>
<tr>
<th>Desired Orbits</th>
<th>Acceptable Orbit Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (GTO/HEO)</td>
<td>350-37,500 km</td>
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<tr>
<td></td>
<td>240-200,000 km</td>
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<tr>
<td>Inclination</td>
<td>0-23 deg</td>
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<tr>
<td></td>
<td>0-90 deg</td>
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<tr>
<td>Altitude (Polar LEO)</td>
<td>450-800 km</td>
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<tr>
<td></td>
<td>400-1000 km</td>
</tr>
<tr>
<td>Inclination</td>
<td>80-110 deg</td>
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<tr>
<td></td>
<td>70-120 deg</td>
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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 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.
**Shields-1**

- **Mass:** 0.5 kg
- **Cube Size:** 3U

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**System**

- **CubeSat Vault Electronics**
  - TRL Advancement: 4-8, Partner: MXL, AstroDev
  - Redesigned board layout to fit in the inner CubeSat vault form factor.

- **Battery System**
  - Partner: MXL, AstroDev
  - Five lithium ion cells provide power during eclipse periods and high power operational modes. The batteries provide 9000 mAh at 5.4 V.

- **Electrical Power System**
  - Partner: MXL, AstroDev
  - The EPS regulates power from the solar panel and outputs three bus voltages: 3.0 V, 5.0 V, 6.4 V. Telemetry systems monitor currents, voltages, and temperatures.

- **Flight Computer and Communications**
  - 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 near real-time communication in the UHF band.

- **Z-Grade Radiation Shielding Vault**
  - TRL Advancement: 3-4, Partner: NASA Langley Research Center
  - Radiation shielding using Atomic Number 25 Grade Technology for enhanced electron shielding performance with reduced volume benefits for small satellite applications.

- **Flight Software**
  - 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, MOLI and, and GRIPEX.

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

- **Antenna Array**
  - The 195 deployable antenna system contains up to four tape spring antennas of up to 65 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 GOES CubeSat components.

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**Research**

- **Work Research Payload**
  - Experimental Radiation Shielding: Experimental Z-grade or baseline shielding with varying shield densities in front of the photometers.

- **EDosimeters**
  - TRL Level: 3
  - Dosimeters tested in inner and outer proton belts with varying shielding area densities.
  - Space heritage from previous missions: AeroCube 8, MARS, Van Allen Probes, Rapid Pathfinder “Dea” Mission, LR2, MIMSA-7B.

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

- **Charge Dissipation Film**
  - TRL Advancement: 3-8, Partner: LUNA Innovations, Inc.
  - LUNA XP-CC-6 is a charge dissipation film designed for extreme internal charging environments, developed through the NASA GTP Phase I proposal award NN011125P and Phase III.
Spacecraft Overview with Experiments

**Shields-1**

**System**

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

- **Battery system**
  - Partners: MXL, AstroDev
  - Four lithium ion cells provide power during eclipse periods and high power operational modes. The batteries provide 8800 mAh at 8.4V.

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

- **Flight computer and Communications**
  - 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**
  - TRL Advancement: 3-8, 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**
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  - TRL Advancement: 4-8, Partner: Vanguard Space Technologies, IBIR Commercial Readiness Program
  - CubeSat Solar Panels designed for extreme radiation environments.

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**Ground Systems**

- Proposed Ground In-Orbit Station
- Wallops Island
- 18 Meter UHF parabolic dish: 401 MHz UPL and 402 MHz DPL, Government Frequency License submitted in the first half of FY2014.

**Mission Operations**

- Flight Mission Support Center
- 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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**Back Shield Panels**

- Shielding behind the picoimeters to create a back shield. Most radiation will enter through the front Z-grade experimental sample or backside shield.

**Charge Dissipation Film**

- TRL Advancement: 3-8, Partner: LUNA Innovations Inc.
- LUNA XP-DD-8 is a charge dissipation film designed for extreme external charging environments, developed through the NASA OTPP Phase I proposal award NNK11OISP and Phase II.
Spacecraft Overview with Experiments


Shields-1
- Mass: 3.6 kg
- Cube Size: 3U

System
- CubeSat Vault Electronics
  - TRL: Advancement: 4-5; Partner: MKL, AstroDev
  - Redesigned board layout to fit in the inner CubeSat vault form factor.
- Battery System
  - Partners: MKL, AstroDev
  - Four lithium ion cells provide power during eclipse periods and high power operational modes. The batteries provide 8800 mAh at 8.4V.
- Electrical Power System
  - Partners: MKL, AstroDev
  - The EPS regulates power from the solar panel and outputs three bus voltages: 3.0V, 5.0V, 8.4V. Telemetry systems monitor currents, voltages, and temperatures.
- Flight Computer and Communications
  - 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
  - TRL: Advancement: 3-5; Partner: NASA Langley Research Center
  - Radiation shielding using Atomic Number, on Grade Technology, for enhanced electron shielding performance with reduced volume benefits for small satellite applications.

Research
- Work Research Payload
  - Experimental Radiation Shielding: Experimental Z-grade or baseline shielding with varying areal densities in front of the dosimeters.
- μDosimeters
  - TRL Level: 9
  - Dosimeters 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
  - Shielding behind the dosimeters to create a back slab. Most radiation will enter through the front Z-grade experimental sample or baseline shield.
- Charge Dissipation Film
  - TRL: Advancement: 3-5; Partner: LUNA Innovations, Inc.
  - LUNA XP-C0-B is a charge dissipation film designed for extreme internal charging environments, developed through the NASA STTR Phase I proposal award NNX11C129P and Phase II.

Ground Systems
- Proposed Ground Link Station
  - Wallops Island

Mission Operations
- Flight Mission Support Center
  - NASA Langley Research Center
  - Ground operations center for launch support, early orbit and payload activation, anomaly resolution, data capture and down link, payload health and monitoring.
- Charge Dissipation Film
  - TRL: Advancement: 3-5; Partner: LUNA Innovations, Inc.
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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
• 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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