Shields-1, A SmallSat Radiation Shielding Technology Demonstration

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Overview

Desired Orbits

<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>
</tr>
<tr>
<td></td>
<td>240-200,000 km</td>
</tr>
<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>
</tr>
<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 $\mu$dosimeters.
- Reduces technology development schedule and associated costs by collective testing in a relevant space environment.
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.
Spacecraft Overview with Experiments

Shields-1

**Mass:** 6.6 kg
**Cube Size:** 3U

**System**

**CubeSat Vault Electronics**
- TRL Advancement: 4-5. Partner: M&K, AstroDev
  - Redesigned board layout to fit in the inner CubeSat vault form factor.

**Battery System**
- Partner: M&K, AstroDev
  - Pair lithium ion cells provide power during eclipse periods and high power operational modes. The batteries provide 9000 mAh at 6.4V.

**Electrical Power System**
- Partner: M&K, AstroDev
  - The EPS regulates power from the solar panel and outputs three bus voltages: 3.0V, 5.0V, 6.4V. 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-ion radio provides nefexx communication in the UHF band.

**Z-Grade Radiation Shielding Vault**
- TRL Advancement: 3-4. Partner: NASA Langley Research Center
  - Radiation shielding using Atomic Number 26 Grade Technology for enhanced electron shielding performance with reduced volume benefits for small satellite applications.

**Flight Software**
  - The flight software, written in C, provides primary spacecraft operational capability and runs on the flight computer. It gathers telemetry, monitors health, and provides commands, both in real time from the ground and scheduled for a later time. The software has flown in various forms on RAX, MObid, and GRIPEX.

**Electrostatic Discharge Cleaned CubeSat Solar Panels**
- TRL Advancement: 4-5. Partner: Vanguard Space Technologies, Inc. SBIR Commercial Readiness Program
  - CubeSat Solar Panels designed for extreme radiation environments.

**Antenna Array**
- The ISID 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 capture. The antenna system has been designed for maximum compatibility with existing G075 CubeSat components.

**Ground Systems**

- Proposed Ground Link Station: Wallops Island
  - 18 Meter UHF parabolic dish: 1801 MHz, VHF, and 402 MHz D/L, Government Frequency Licenses committed 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.

**Research**

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

**Dosimeters**
- 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 “Daisy” Mission, LRO, M150E-7B.

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

**Charge Dissipation Film**
- TRL Advancement: 3-4. Partner: LUNA Innovations, Inc.
  - Charge dissipation film designed for extreme external charging environments, developed through the NASA OTTO Phase I proposal award NNX11A078P and Phase II.

**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: 3-9, 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**
- 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**
- TRL Advancement: 4-8, Partner: Vanguard Space Technologies, Inc., SBIR Commercial Readiness Program
- CubeSat Solar Panels designed for extreme radiation environments.

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**Ground Systems**
- Proposed Ground InK station
- Wallis Island

**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.

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

**Charge Dissipation Film**
- TRL Advancement: 3-9, Partner: LUNA Innovations Inc.
- LUNA XP-GD-B is a charge dissipation film designed for extreme internal charging environments, developed through the NASA OTRI Phase I proposal award NNX11O63P and Phase II.
Shields-1


- **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 output, voltage, and temperature.
  - **Flight Computer and Communications**
    - Partners: 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-ion radio provides half-duplex communication in the UHF band.
  - **Z-Grade Radiation Shielding Vault**
    - TRL: Advancement: 3-6, Partners: 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 3D dosimeters.
  - **μDosimeters**
    - TRL Level: 9
    - 3D 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 "Dea" Mission, LRO, MGS-E7B.
  - **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** (schedule)
    - TRL: Advancement: 3-6, Partner: LUNA Innovations, Inc.
    - LUNA XP-CoD-B is a charge dissipation film designed for extreme internal charging environments, developed through the NASA STTR Phase I proposal award NNX11C029P and Phase II.

- **Ground Systems**
  - Proposed Ground Link Station
    - Wallops Island

- **Mission Operations**
  - Flight Mission Support Center
    - NASA Langley Research Center
    - Overall operations center for launch support, early orbit and payload activation, anomaly resolution, data capture and down link, payload health and monitoring.
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”.

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<th>Expected Resistance</th>
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<td>Thickness 0.0025 cm</td>
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**Charge Dissipation Film Experiment**

Charge Dissipation Film

Positive Electrode

Negative Electrode

Fiber Circuit board or isolation surface

Thermal Sensor

Analog to Digital Convertor

Current Source

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”.

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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.
Acknowledgements

- R. Bryant (LaRC)
- M. Cooney,
- M. Jones,
- N. Miller
- B. Seufzer
- V. Stewart
- K. Somervill
- H. Soto
- S. Thibeault
- A. Thornton
- J.M. Lauenstein (GSFC)
- C. Marshall
- A. Simon
- H. Garrett (JPL)
- N Green
- I. Jun
- B. Blake (Aerospace Corp.)
- B. Crain
- A. Goff (Luna Innovations)
- S. Princiotto (Teledyne)
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