# Shields-1 Technology Demonstration on ELaNaXIX


Dr. D. Laurence Thomsen III (1), Mark L. Jones (2), Stephen C. Bowen (2), William Girard (3) and Dr. James W. Cutler (4)

(1) NASA Langley Research Center, Advanced Materials and Processing Branch, 6A West Taylor Street, Hampton, VA 23681. Ph: 757-864-4211, Email: d.l.thomsen@nasa.gov.

(2) NASA Langley Research Center, Electronics Systems Branch, 5 N. Dryden Street, Hampton, VA 23681.

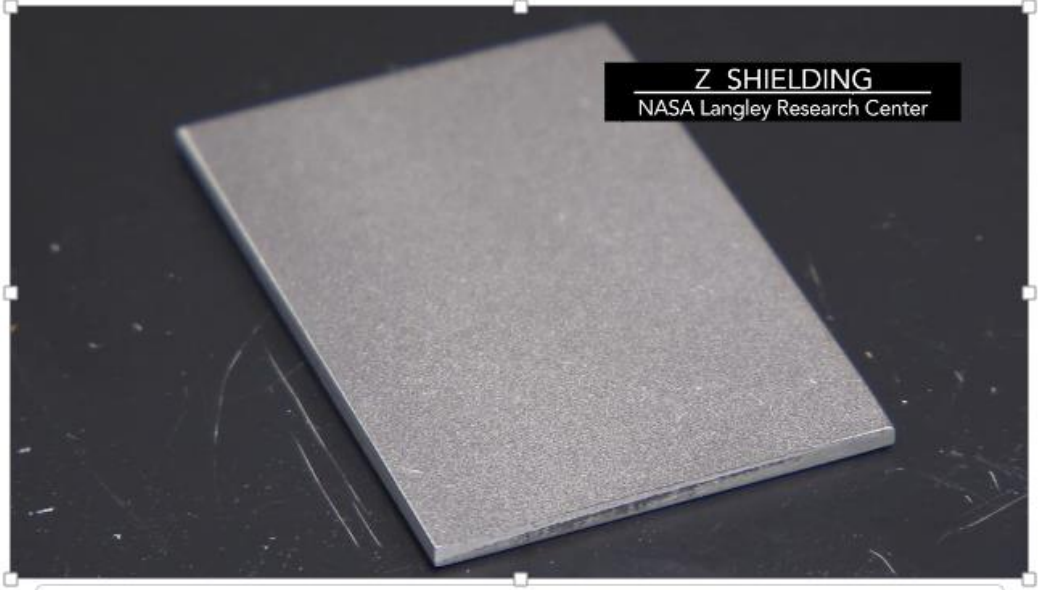
(3) Science and Technology Corp, NASA Langley Research Center, Metals Applications Technology Branch, Mail Stop 222B, Hampton, VA 23681

(4) Associate Professor, University of Michigan, Department of Aerospace Engineering 1320 Beal Avenue, 3013 FXB Building, Ann Arbor, MI 48109-2140.



SmallSat Conference Workshop, 6 August 2017

# LaRC Z-Shielding Increases CubeSat Mission Lifetimes



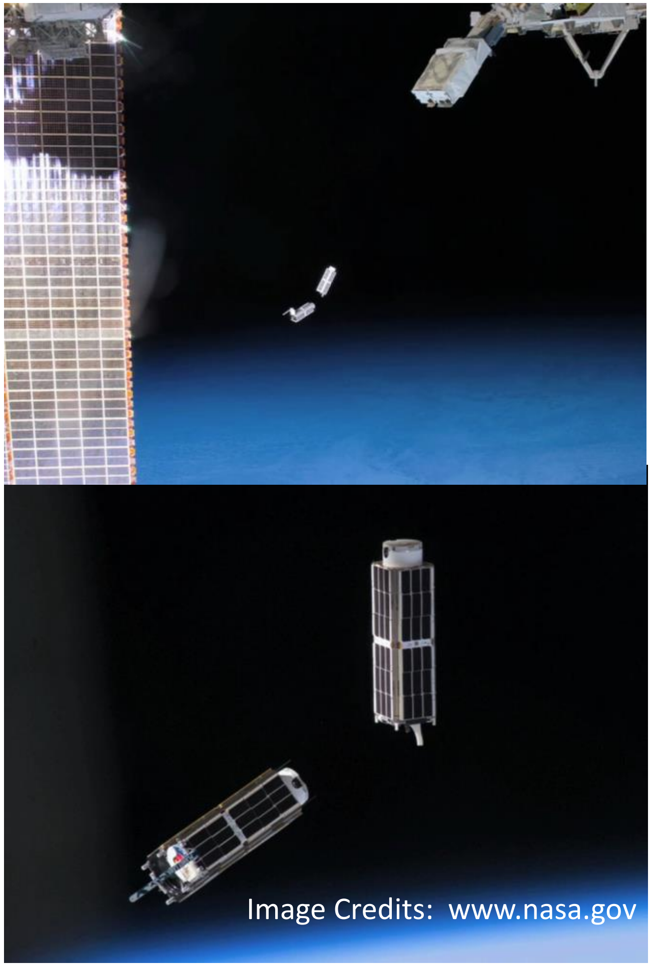

NASA Tech-Transfer web releases of LaRC Z-Shielding

*Z-shielding pitch:*
https://www.youtube.com/watch?v=oHA8j5bpFcU&t=21s
*Webinar:* https://www.youtube.com/watch?v=RrqDocGqawQ
https://techgatewire.larc.nasa.gov/2017/01/26/radiation-protection-material-webinar/

- **Extends typical CubeSat missions from 3 months to years**
- **A 100x reduction of total ionizing dose and removal of internal charging effects**.
- **Increases return on investment**

# CubeSat Market: $0.5B-1B over 3yrs

- over 1700 small satellites forecasted for 2017-2023 (www.spaceworksforecast.com)
- Over 500 over next 3 yrs into polar low earth orbit (PLEO) (www.spaceworksforecast.com)
- Typical CubeSats costs $1-2M (https://esto.nasa.gov/techval_space.html)
- CubeSat value at risk: <u>$0.5-1B in the next three years alone</u>



# Shielding is not common today

- Cube Sat missions have been short, mostly experimental
- There are size and material constraints in the "standard" Cubesat packaging
- Mostly in low, short-lived orbits, such as deployed from ISS
- The actual satellites have been viewed as "disposable"

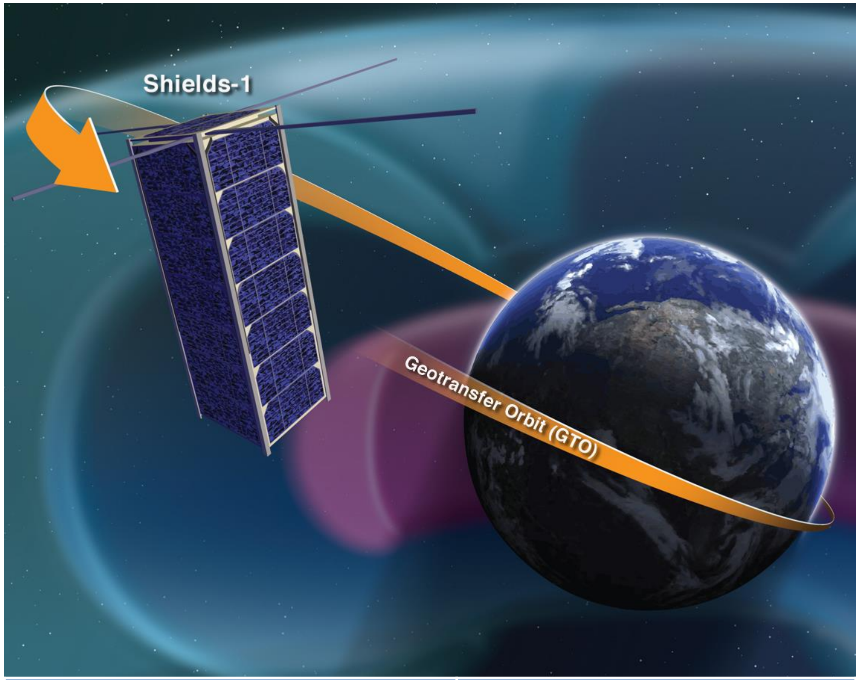
# But that can and will change quickly

- The satellites themselves are now more capable
- Higher orbits are now available
- Longer orbit life calls for longer functional life for the satellite
- Shielding now matters

# Solution:  Z-Shields

- **Predicted Life 3+ years depending on Shielding Areal Densities**
- **100x or greater performance increase**
- **$1M CubeSat on-Orbit:  $0.5 million/month (2 month lifetime)**
- **CubeSat with Z-Shields limited only by orbit lifetime (2-6 yrs typical LEO)**

# Z-Shielding Technology Development

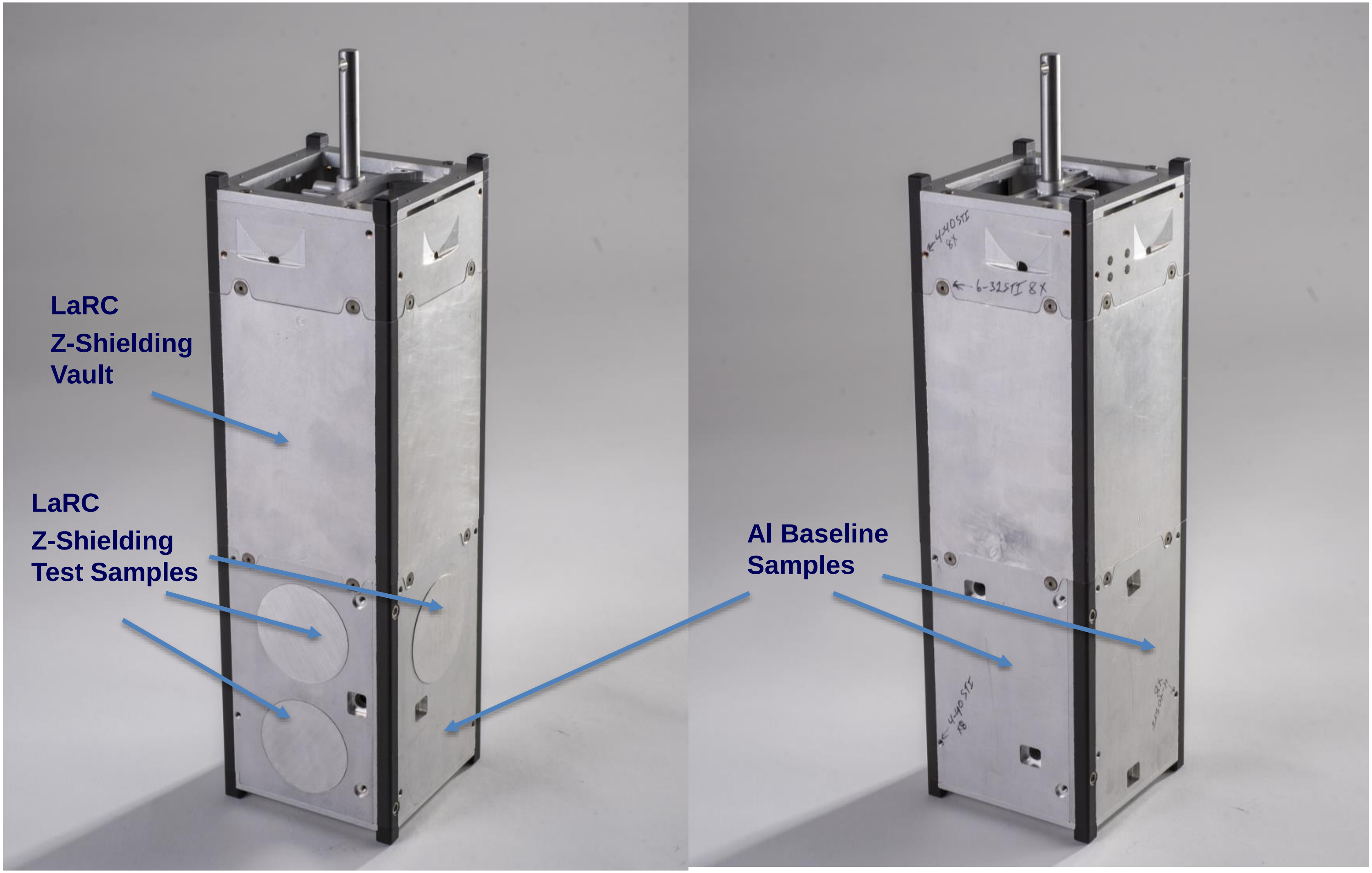



| Desired Orbits | | Acceptable Orbit Ranges |
|---|---|---|
| Altitude (GTO/HEO) | 350-37,500 km | 240-200,000 km |
| Inclination | 0-23 deg | 0-90 deg |
| Altitude (Polar LEO) | 450-800 km | 400-1000 km |
| Inclination | 80-110 deg | 70-120 deg |

## Highlights

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

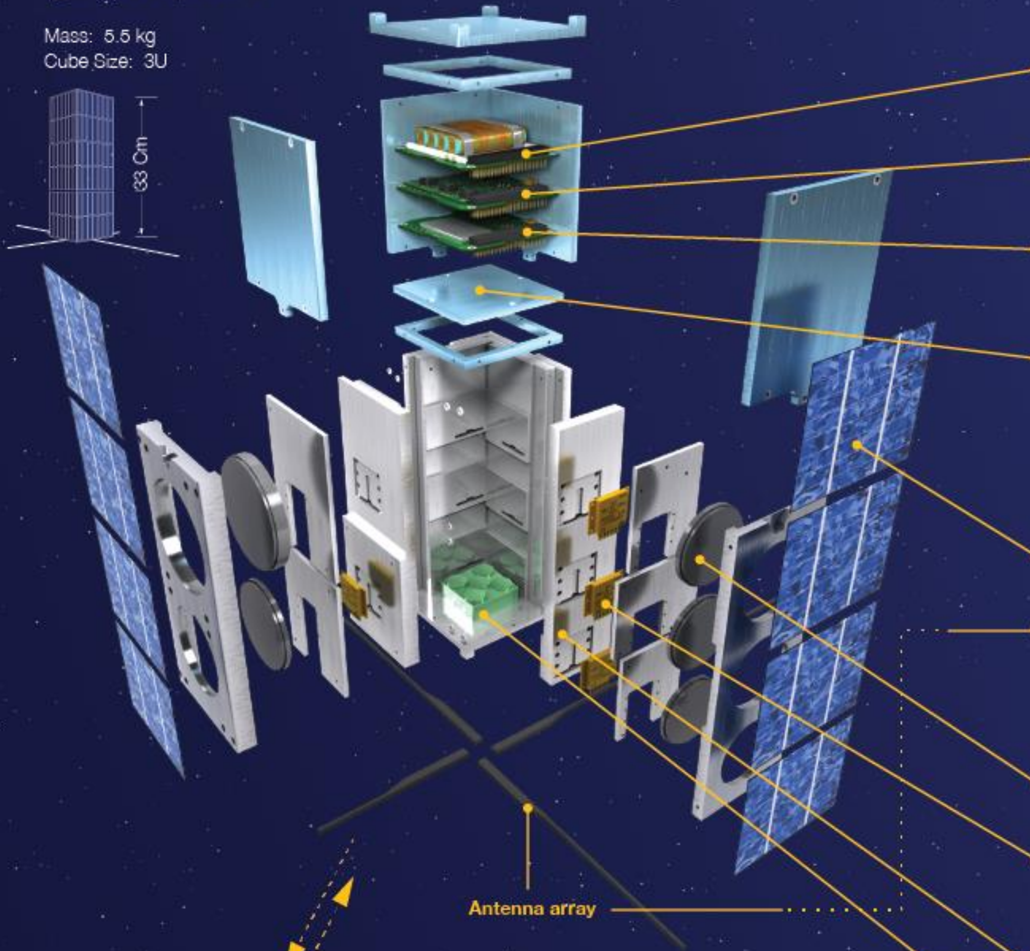
# Shields-1:  2 Orientations



# 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 ■ Med risk ■ High risk ■

**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 6800 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 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: 3-6, 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** ■
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.

**Antenna array** ■
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** ■
Experimental Radiation Shielding: Experimental Z-grade or baseline shielding with varying areal densities in front of the µdosimeters.

**µDosimeters** ■
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** ■
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** ■ (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** ■
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** ■
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.

# Total Ionizing Dose (TID) Environment

**Polar- LEO:**

- **Orbit: 102° inclination, 775 km apogee, 458 km perigee**
- **ELaNa III[1] CubeSat environment: AUBIESAT-1, RAX-2, DICE, Explorer, M-Cubed/COVE.**
- **TID environment Shielddose-2 calculation[2]: 5.0 kRad/yr total dose, 0.5 g/cm2 Al**
  - *0.5 g/cm2 ~ 0.078 in Al the typical Al Structure thickness for the CubeSat standard form factor*
  - *Commercial parts Hardness levels[3]: 2-10 Krad*
  - *Radiation Design Margin[4] of 2*

Adding shielding to commercial CubeSats reduces risk for premature failures due to total ionizing dose

1. http://www.nasa.gov/pdf/627975main_65121-2011-CA000-NPP_CubeSat_Factsheet_FINAL.pdf
2. SPENVIS, Shielddose-2 calculation, AP8min-AE8 Max Model Environment.
3. NASA PD-ED-1258, "Space Radiation Effects on Electronic Components in Low-Earth Orbit, April 1996
4. NASA PD-ED-1260, "Radiation Design Margin Requirement", May 1996.

# Compelling Value Proposition

- Cube Sat average cost delivered to orbit is $1-2M
- Unshielded satellites fail within weeks or months
- Material Cost to add shielding is $5K or less
- For only the cost of shielding the life of the satellite is extended beyond the life of the orbit
- Why not?

# Acknowledgements


- Robert Bryant (LaRC)
- Thomas Burns (LaRC)
- Sankara Sankaran (LaRC AMA)
- Kevin Somervill (LaRC)
- Raymond Lueg (LaRC AMA)

# Questions?