Posters

Materials Physics

9-9-2017

CubeSat Space Environments Effects Studied in the Space Survivability Test Chamber

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Recommended Citation

Alex Souvall, Gregory Wilson, Ben Russon, Katie Gamaunt, and JR Dennison, "CubeSat Space Environments Effects Studied in the Space Survivability Test Chamber," USU Fall Undergraduate Research Orientation, Logan, UT, September 9, 2016.

The Space Survivability Test Chamber

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Utah State University Materials Physics Group

Overview

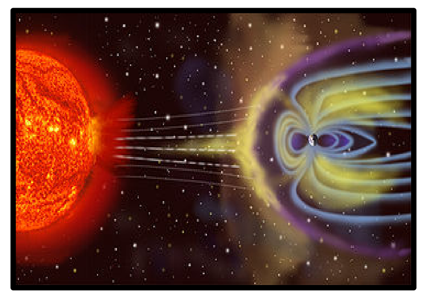


Fig. 1. Solar wind and Earth's magnetosphere structure.

The Space Survivability Test Chamber (SST) provides an extensive, versatile, and cost-effective system for pre-launch verification and assessment of small satellites, system components, and spacecraft materials. A *UNSGC Faculty Research Infrastructure Grant* was awarded a for the purpose of making improvements to enhance and extend the capabilities of the SST. Since the SST was brought online in August 2016, several externally funded projects have been completed and collaborative projects with The University of Tsukuba (Japan) and Logan High School (Utah). Many more projects are forthcoming and the capabilities of the SST continue to be improved and developed for the future.

Space Environment Effects

The harsh space environment can modify materials and cause detrimental effects to satellites. To predict and mitigate these deleterious effects, ideally a full spacecraft would be tested in all applicable space environments [1]. Because this is not practical, the ability to accurately simulate space environment effects through long-duration, well-characterized testing in an accelerated, versatile laboratory environment becomes key.

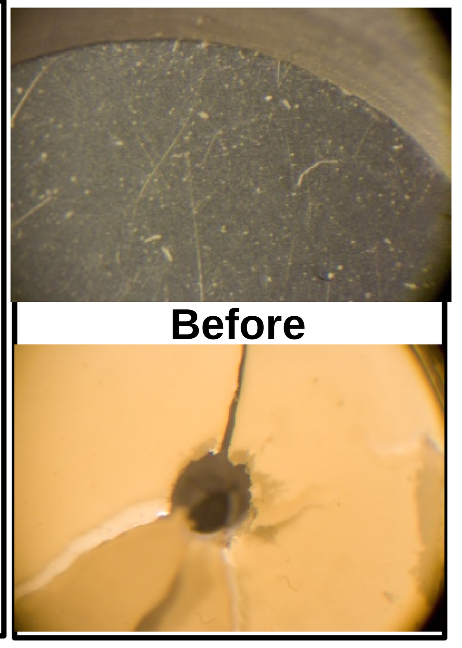


Fig. 2 . Vapor Deposited Aluminum (VDA) coated Mylar sample exposed to LEO for 18 months outside the ISS. Atomic oxygen erode the Al, VUV radiation discolored the Mylar, and a micrometeriod impacted the brittle polymer.

Simulated Space Environments

The SST chamber simulates several critical characteristics of the space environment: electron flux, ionizing radiation, photon flux, temperature and neutral gas environment. Fig. 3 show representative electron spectral fluxes for several common environments and the solar UV/Vis/NIR. The energy range of electron, ionizing radiation, and photon sources are shown above these graphs.

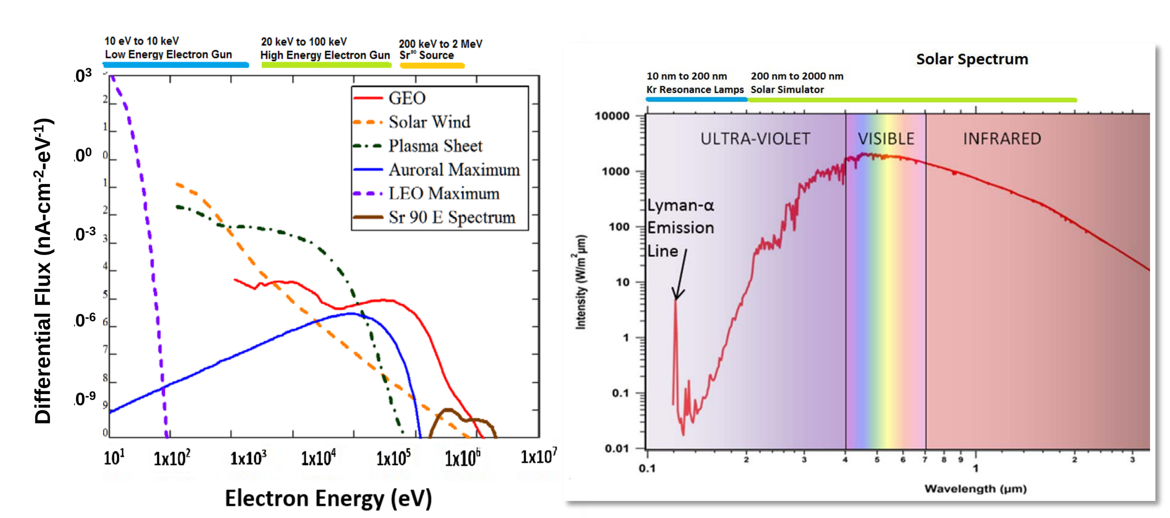


Fig. 3 (Left). Representative space electron flux spectra for geostationary earth orbit, solar wind at the mean earth orbital distance, plasma sheet environment, maximum aurora environment, and low earth orbit. (Right) UV/Vis/NIR solar spectrum. Energy ranges for electron and photon sources and the Sr^{90} beta radiation source are also shown.

SST Space Environmental Effects Projects

Telecommunications Component Viability

High frequency RF antenna dielectric components used on telecommunications satellites were tested in orbital conditions. Electrostatic discharge events induced by β-radiation were monitored and characterized using video and current monitoring to identify the frequency, location, and magnitude of discharges. Effect of temperature (~10 ºC to 60 ºC) on discharge characteristics was tested over a full orbital cycles of several days. *Funded by ViaSat.*

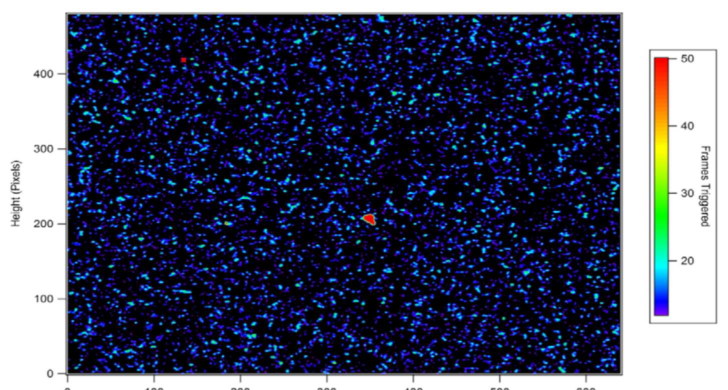


Fig. 4. Video Discharge Monitoring Output

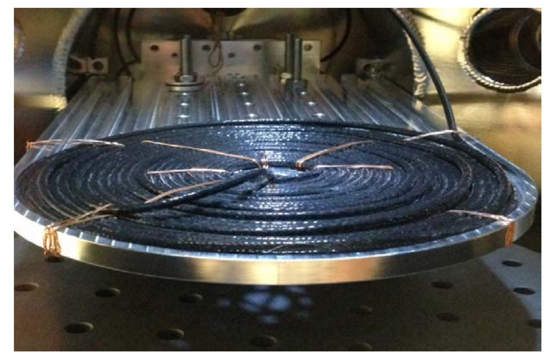


Fig. 5. Cabling Under Testing in SST

Mission Lifetime Survivability of Space Grade Electronic Components

High performance RF communications cabling underwent accelerated testing simulating the duration of a full multi-year mission. *In-Situ* permittivity characterization was performed to understand the long-term cumulative effects of β-radiation on cable properties including frequency response and power loss. Additionally, electrostatic discharge was monitored and characterized using video and current monitoring. This provided understanding of charge accumulation and discharge induced by β-radiation within the samples. *Funded by TimesMicrowave.*

Microcontroller Radiation Hardening

Microcontrollers are essential satellite components, but radiation hardened electronics can be prohibitively expensive for CubeSat missions. Testing of economical Commercial-Off-The-Shelf (COTS) electronic components is necessary to determine their viability for replacing radiation hardened electronics. Tests showed that the Arduino ceased to function properly functioning after ~250 Gy exposure.

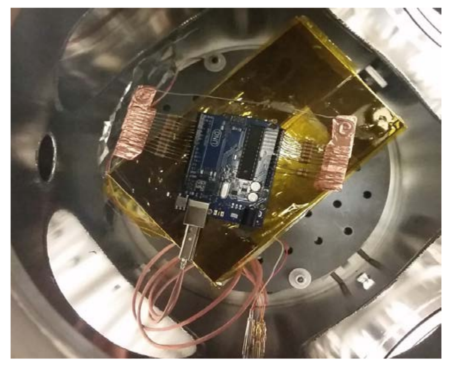


Figure 6. Arduino inside the SST

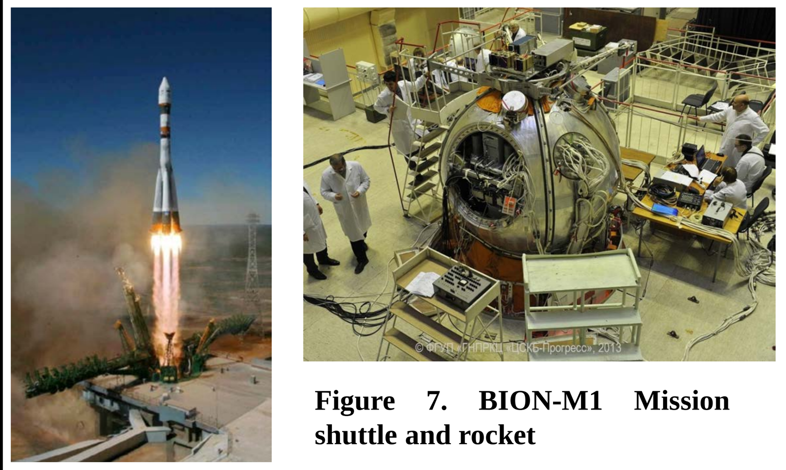


Figure 7. BION-M1 Mission shuttle and rocket

Viability of Plant Growth in Space

Radish seeds flown on the Russian BION-M1 mission were observed by Logan High School students to have faster germination rates than control, ground based radish seeds. Seeds were tested in the SST to test if radiation was the cause of this change in germination rate. A biological test chamber, designed by University Tsukuba students, housed the seeds in a controlled atmosphere for safe testing in the SST vacuum. *Partial funding through the USUStars Gear Up Program.*

Space Environment Effects on Muscle and Skeletal Cells

In-Vitro tests of muscles cells irradiated in the SST and biological test chamber have been. The effects of radiation on muscle cells will progress work in cardiovascular disease and degenerative tissue risks from space radiation. *A collaborative follow-on 2017 UNSGC Infrastructure award will support further development of the physiological effects of ionizing radiation.*

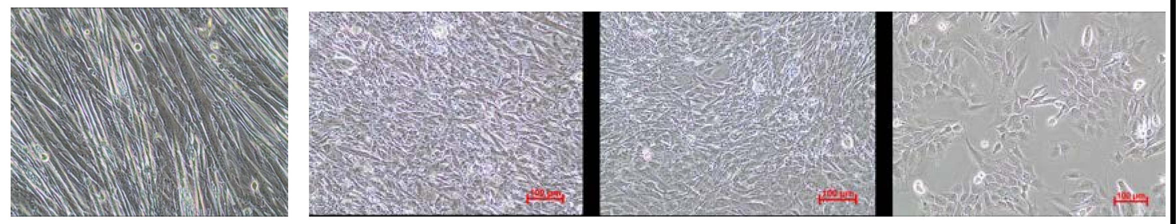


Figure 8. Mouse muscle cells before irradiation (far left), and after irradiation (left: 10 Gy, mid: 20 Gy, Right: 50 Gy)

Projects On The Horizon

Future proposed projects cover a wide array of scientific fields; these include:

Communications Satellite Component Testing

- VUV degradation of antennas and thermal control coatings. *Proprietary funding.*

Spacecraft Materials Testing

- Radiation induced conductivity (RIC) of perovskite dielectric materials by total ionizing dose (TID). *Funding pending from Sandia National Labs.*
- Effects of radiation on conductivity and permittivity of space polymers for NASA Europa Mission. *Funding pending from NASA* Jet Propulsion Lab.

Radiation Damage of Spaceflight Electronic Components

- β radiation TID effects on electronic components. *Funding pending from Space Dynamics Lab & Space Flight Industries.*

Testing of New Spacecraft Propulsion Engineering Designs

- Equipment to be flown on a Terrier Malamute rocket to test hybrid thruster designs. *Proposed by USU Engineering Department in conjuncture with a NASA Undergraduate Student Instrument Project (USIP).*

SST Chamber Capabilities

The SST chamber [2] is a high vacuum system particularly well suited for cost-effective tests of multiple small scale materials samples over prolonged exposure to simulate critical environmental components. Exposure is uniform to within <5% at intensities for >5X accelerated testing. An automated data acquisition system periodically records real-time environmental conditions—and *in situ* monitoring of key satellite/component/sample performance metrics and characterization of material properties and calibration standards—during the sample exposure cycle [5].

Figure 9. SST Chamber

Electron Radiation

A high energy (~10-80 keV) and three lower energy (~10 eV to 5 keV) electron guns provide high electron fluxes.

Ionizing Radiation

A 100 mCi encapsulated Sr^{90} β-radiation source (~200 keV to >2.5 MeV) mimics high energy (~500 keV to 2.5 MeV) geostationary electron flux [2].

Infrared/Visible/Ultraviolet Flux

A commercial Class AAA solar simulator provides NIR/Vis/UVA/UVB electromagnetic radiation (from 200 nm to 1700 nm) at up to 4 times sun equivalent intensity.

Far Ultraviolet Flux

Kr resonance lamps provide FUV radiation flux (ranging from 10 to 200 nm) at 4X sun equivalent intensity. Kr bulbs have ~3 month lifetimes for long duration studies.

Temperature Control

Temperature range from 60 K [4] to 450 K is maintained to ±2 K [3]. This is achieved through cartridge heaters, and chilled fluid pumped through a cold plate.

Controlled Atmosphere and Vacuum

Ultrahigh vacuum chamber allows for pressures $<10^{-7}$ Pa to simulate LEO.

Video Discharge Monitoring

Using custom developed software, live video capture and processing of electrostatic discharge events allows for visual identification of discharge location and frequency.

Flexible Sample Mounting

A rotating graphite carousel, ensures uniform irradiation and allows for custom mounting of samples. Or a flange mounted fixture allows for electrostatic discharge testing. Radiation source to sample distance is adjustable.

Biological Testing

Biological samples, which are vacuum incompatible, can use a custom designed chamber with controlled atmosphere and temperature.

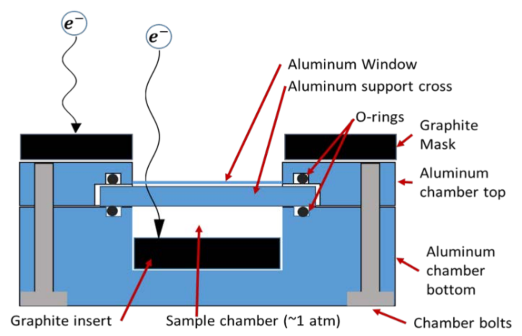
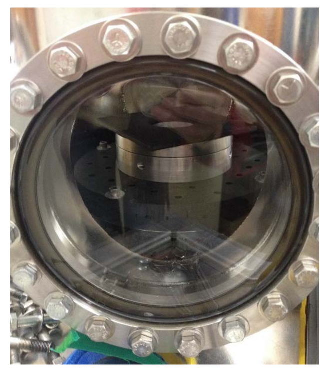
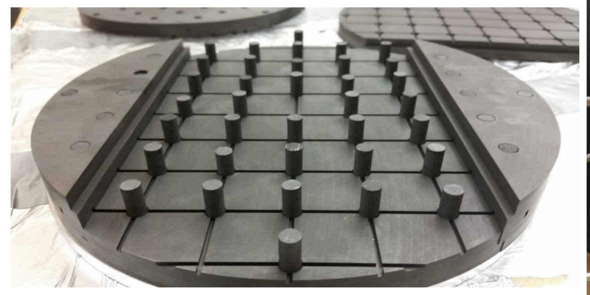


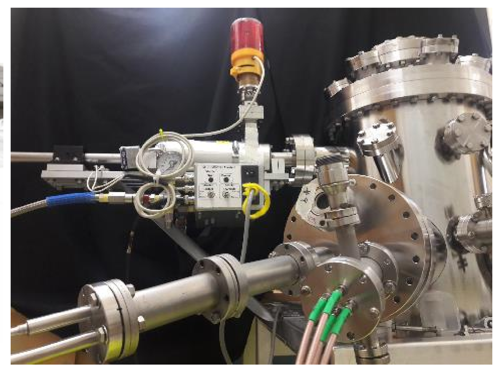
Figure 10. Biological Testing Chamber



SST Biological Test Chamber



Radiation Absorbent Sample Mount



Custom Designed SST Sr^{90} Radiation Source

Acknowledgments and References

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