10-17-2014

# Space Effects Survivability Testing

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## Recommended Citation

Lisa Phillipps, JR Dennison, Kent Hartley, Robert H. Johnson, Justin Dekany and James S. Dyer, "Space Effects Survivability Testing," American Physical Society Four Corner Section Meeting, Utah Valley University, Orem, UT, October 17-18, 2014.

# Small Satellite Space Environments Effects Test Facility

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## Space Environment Effects

The space environment can modify materials and cause detrimental effects to satellites. Some of these effects are change in reflectivity and emissivity, which lead to changes in thermal, optical, and charging properties. If these are severe enough the spacecraft will not operate as designed. The key to predicting and mitigating these deleterious effects is the ability to accurately simulate space environment effects through long-duration, well-characterized testing in an accelerated, versatile laboratory environment.

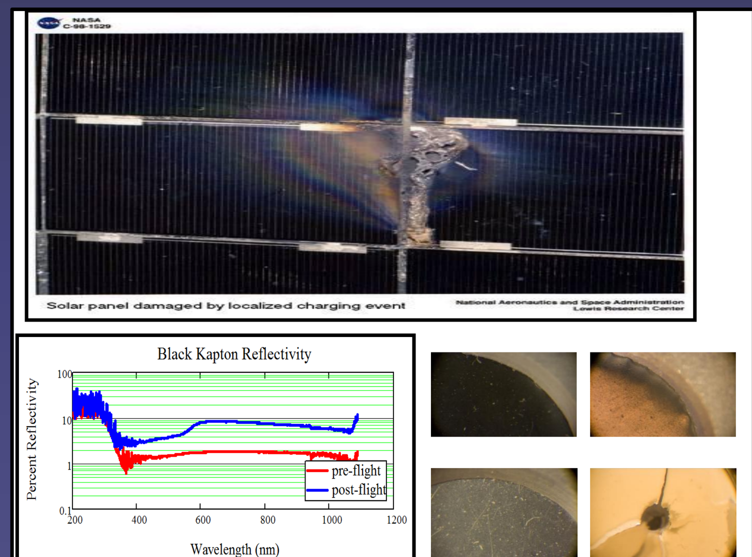
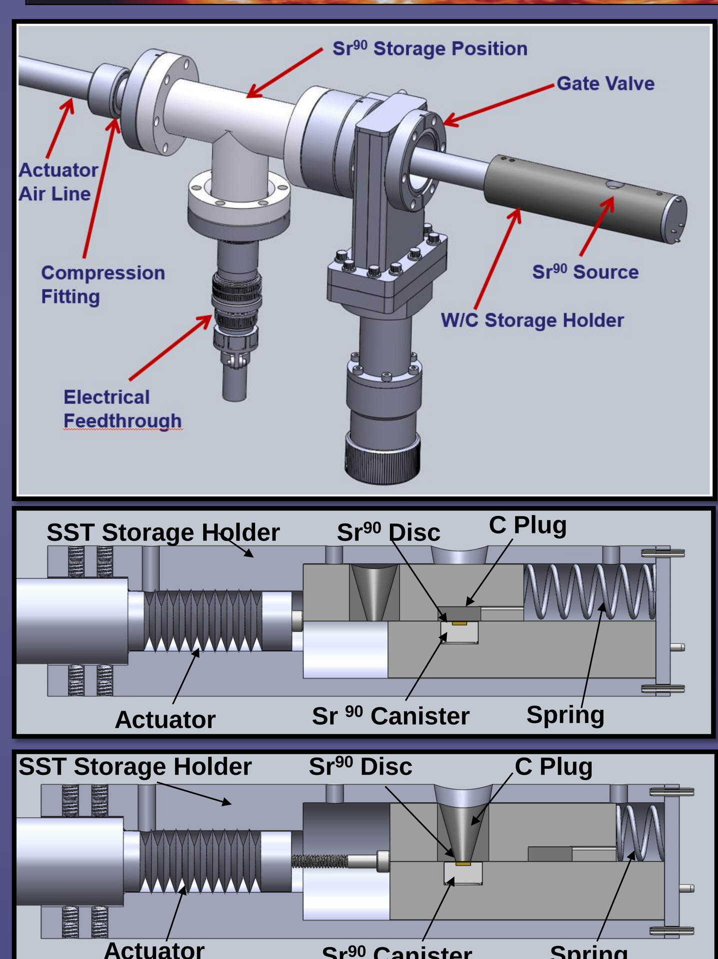



Fig. 5. (Top) Damaged solar panel due to spacecraft charging. (Bottom) Photographs and UV/VIS/NIR spectra comparing pre- and post-flight samples from SUSpECS II [Dennison]: (Top Right) Black Kapton. Bottom Right) Ag coated Mylar with micrometeroid impact.

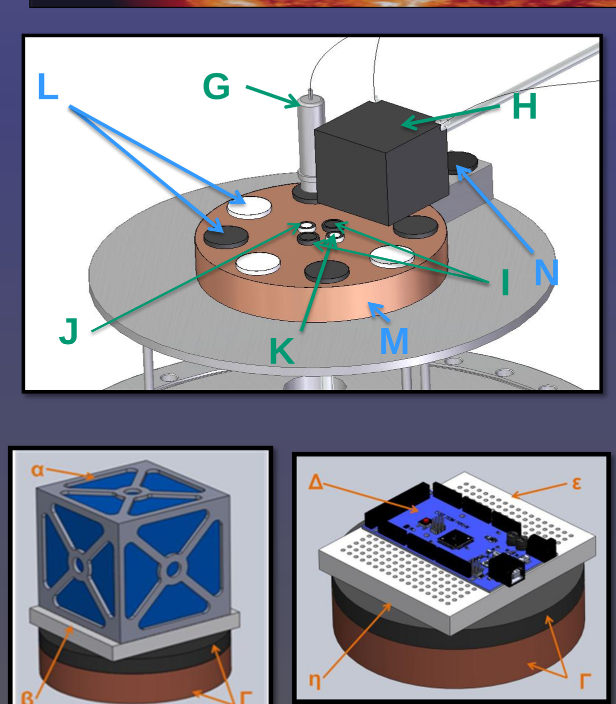
## Radiation Testing




<u>$Sr^{90}$ Radiation Source</u>- The 100 mCi encapsulated radiation source mimics high energy (~500 keV to 2.5 MeV) geostationary electron flux. A pneumatic actuator controls the position of source's C and W shielding materials to expose samples or shield materials to $Sr^{90}$ beta radiation. A spring returns the shielding material to its safe position which covers the source. Assembly is contained in a stainless steel storage holder. This self-contained, portable radiation assembly is compatible with several different stand alone vacuum chamber.

Fig. 6. (Top) $Sr^{90}$ Source Assembly. (Middle) View in $Sr^{90}$ Radiation Storage. (Bottom) View in $Sr^{90}$ Radiation Exposure.

## Versatile Sample Holder Design




<u>Sample Stage</u>- Sample stage (M) connected to 355º rotary feedthrough (S) to position samples under probe translation stage (T) and enhance flux uniformity by periodic rotation. Sample stage shown has six 2.5 cm diameter samples (L) plus flux sensors (I ,J ,K); alternate configurations have up to one 10 cm diameter sample. Uniform temperature over ~100 K to 450 K controlled using attached cryogenic reservoir (P) and resistance heaters (O). Large thermal mass helps maintain stable thermal.

Fig. 7. (Top) View of Sample Carousel and Probe Translation Stage. (Left) View of CubeSat test fixture. (Right) View of COTS test fixture

## Acknowledgements/References

• Dennison, J R, "Charge-Enhanced Contamination and Environmental Degradation of MISSE-6 SUSpECS Materials," IEEE Transactions on Plasma Science, February 2012, Vol. 40

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Scan code to access accompanying paper and references, as well as other USU MPG articles.

## Abstract

A versatile space environments test facility has been designed and built to study the effects on small satellites and system components. Testing for potentially environmental-induced modifications of small satellites is critical to avoid possible deleterious or catastrophic effects over the duration of space missions. This is increasingly more important as small satellite programs have longer mission lifetimes, expand to more harsh environments (such as polar or geosynchronous orbits), make more diverse and sensitive measurements, minimize shielding to reduce mass, and utilize more compact and sensitive electronics (often including untested off-the-shelf components). Our vacuum chamber is particularly well suited for cost-effective, long-duration tests of modifications due to exposure to simulated space environment conditions for CubeSats, system components, and small scale materials samples. The facility simulates critical environmental components including the neutral gas atmosphere, the FUV/UV/VIS/NIR solar spectrum, electron plasma fluxes, and temperature. The UV/VIS/NIR solar spectrum is simulated using an external class AAA Solar Simulator source, with standard Air Mass Zero (AM0) filters to shape the incident radiation spectrum. This Xe arc discharge tube source has up to four Suns light intensity over a CubeSat face. Far ultraviolet (FUV) radiation is provided by Kr discharge line sources, with a primary emission lines at 124 nm and 117 nm and up to four Suns intensity. An electron flood gun provides a uniform, stable, low-energy, monoenergetic (~20 eV to ~15 keV) electron flux over the CubeSat surface. A second medium-energy (~20 keV to ~100 keV), low-flux electron source uses filament-free photoemission. A $Sr^{90}$ β radiation source produces a high-energy spectrum similar to the geosynchronous spectrum; intensities of >5X the geosynchronous spectrum are possible. A stable, uniform temperature range from 100 K to 450 K is achieved using a cryogenic reservoir and resistance heaters with standard PID controllers. An automated data acquisition system periodically monitors and records the environmental conditions, sample photographs, UV/VIS/NIR reflectivity, IR absorptivity/emissivity, and surface voltage over the CubeSat face and *in situ* calibration standards in the main chamber during the sample exposure cycle. The modular design allows the sources to mate separately with a larger chamber with a 5-axis rotation/translation stage that can position five faces of a CubeSat relative to the incident beams.

## Experimental Test Chamber Design

Fig. 1 Cutaway View with Source Beams.

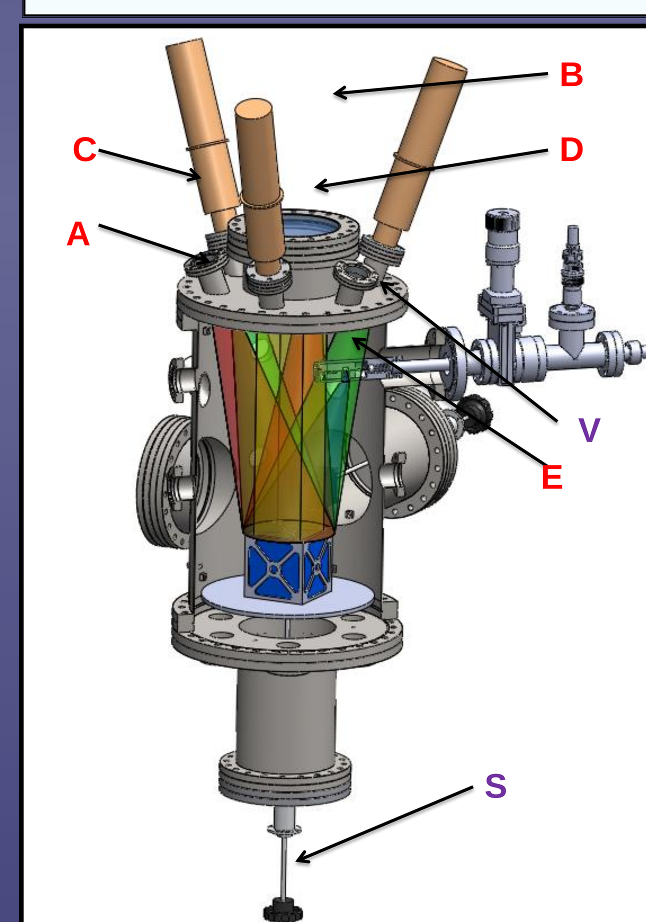



Fig. 2 Vertical Cutaway with CubeSat

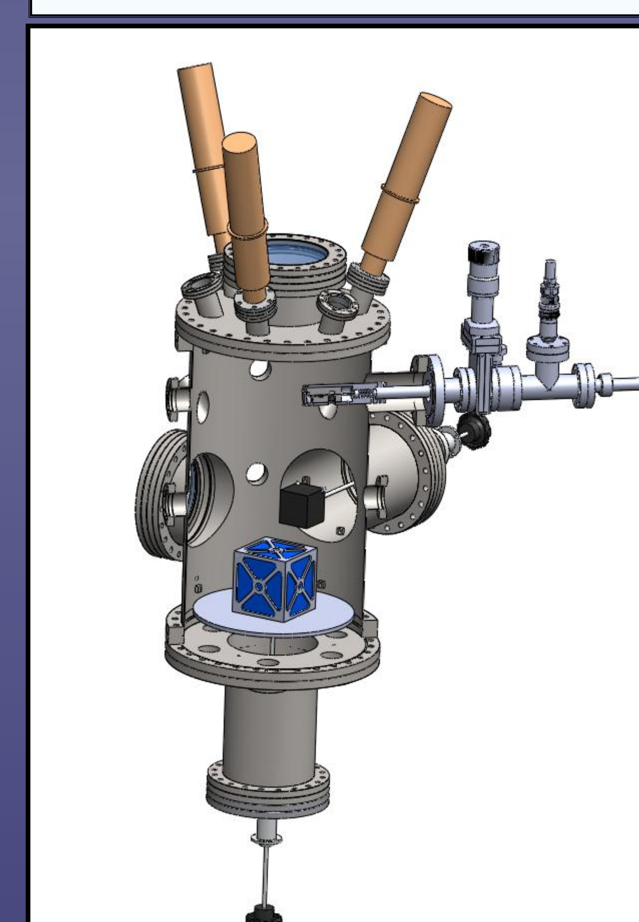


Fig. 3 Assembled Chamber

### Radiation Sources
- A Electron Gun
- B UV/VIS/NIR Solar Simulator
- C FUV Krypton Discharge Lamps
- D Air Mass Zero Filter Set
- E Flux Mask

### Analysis Components
- F UV/VIS/IR Reflectivity Spectrometers
- G IR Emissivity Probe
- H Integrating Sphere
- I Photodiodes–UV/VIS/IR Flux Monitor
- J Faraday Cup–Electron Flux Monitor
- K Platinum Resistance Temperature Probe

### Chamber Components
- Q Cryogen Vacuum Feedthough
- R Electrical Vacuum Feedthrough
- S Sample Rotational Vacuum Feedthrough
- T Probe Translational Vacuum Feedthrough
- U Sapphire UV/VIS Viewport
- V MgF UV Viewport
- W Turbomolecular/Mech . Vacuum Pump
- X Ion Vacuum Pump
- Y Ion/Convectron Pressure Gauges
- Z Residual Gas Species

### Chamber Components
- α CubeSat
- β CubeSat Test Fixture
- Γ Radiation Shielding
- Δ COTS Electronics
- ε Rad Hard Breadboard
- η COTS Text Fixture
- Θ Electron Gun

### Sample Carousel
- L Samples
- M Rotating Sample Carousel
- N Reflectivity/Emissivity Calib. Standards
- O Resistance Heaters
- P Cryogen Reservoir

### Instrumentation (Not Shown)
- Data Acquisition System
- Temperature Controller
- Electron Gun Controller
- UV/VIS/NIR Solar Simulator Controller
- FUV Kr Resonance Lamp Controller
- Spectrometers and Reflectivity Source

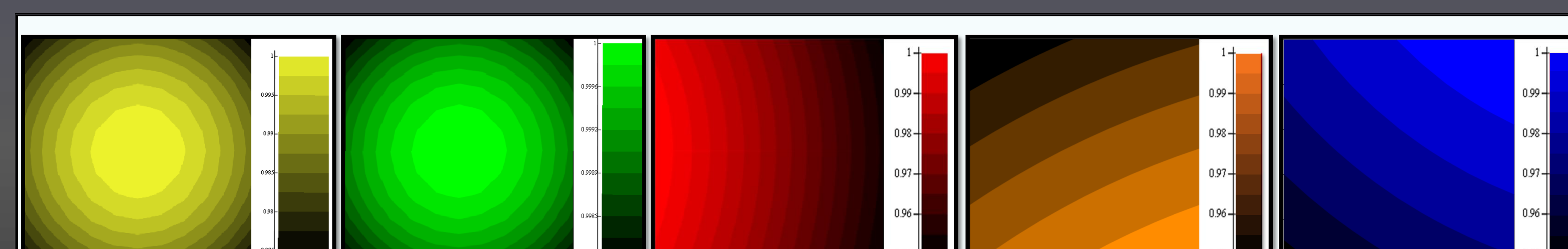
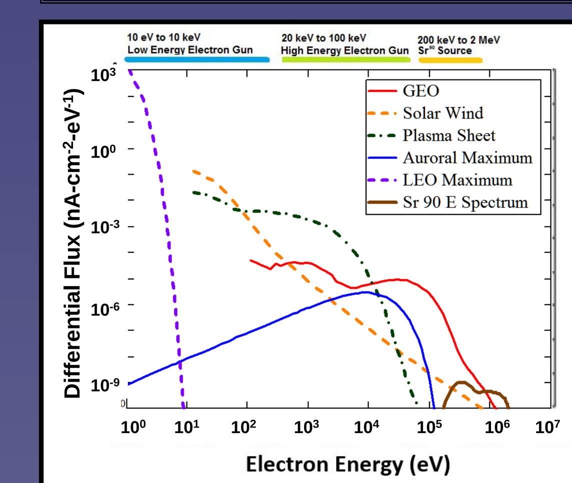
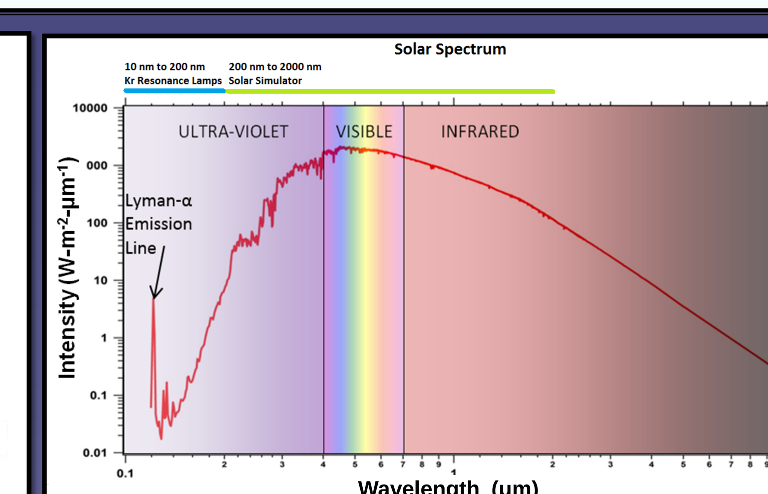



Fig. 4. Contour plots of exposure intensity on sample surface: (a) UVA/VIS/NIR light. (b) UVF light. (c) High Energy Electron Beam. (d) Low Energy Electron Beam. (e) $Sr^{90}$ Radiation. Variation in relative intensity is shown by the color scales at right.

## Space Environment Characteristics

The Space Survivability chamber simulates several critical characteristics of the space environment: electron flux, photon flux, temperature and neutral gas environment. Figure 8 shows representative electron spectra for several common environments; the ran of the chambers, two electron guns, and $Sr^{90}$ source are shown. The solar UV/Vis/NIR spectrum is shown in Figure 10; source includes a standard solar simulator (~200 nm to 2000 nm) and Kr resonance source to mimic the H Lyman α emission at 121.6 nm. Samples are in a low density particle environment, using a vacuum or controlled neutral gas environment down to ~$10^{-6}$ Pa. Temperature can be maintained for prolonged testing from ~100 K to ~450 K. This chamber does not yet simulate ions, plasma or atomic oxygen.



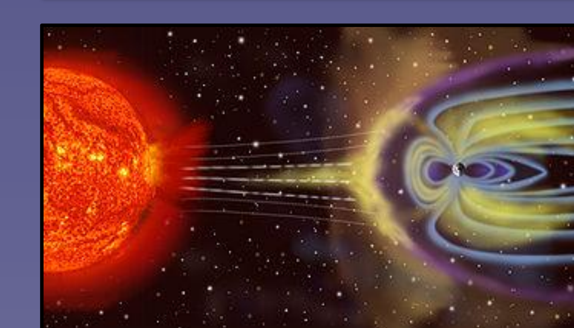



Fig. 8. (Top Left) Typical Space Electron Flux Spectra [Larsen]. Bars show source ranges.

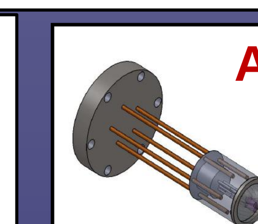
Fig. 9. (Bottom Left) Solar wind and Earth's magneto-sphere structure.

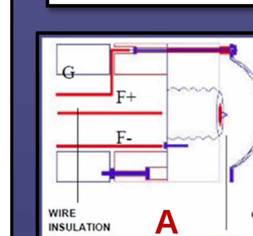
Fig. 10. (Top Right) Solar Electromagnetic Spectrum. Bars show source ranges.

## Space Simulation Capabilities

Versatile ultrahigh vacuum test chamber provides controlled temperature and vacuum environment with stable, uniform, long-duration electron and UV/VIS/NIR fluxes at up to 4 times sun equivalent intensities for accelerated testing for a sample area of 8 cm by 8 cm. Particularly well suited for cost-effective tests of multiple small scale materials samples over prolonged exposure.

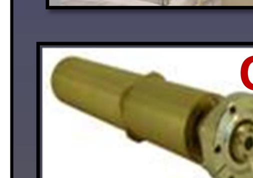
<u>Electron Flux</u>—Electron flood guns (A) provide ≤5·$10^6$ electrons/$cm^2$ (~1pA/$cm^2$ to 1 μA/$cm^2$) flux needed to simulate the solar wind at more than the 100X cumulative electron flux. Mono-energetic energy range is ~0.05 to 15.00±0.01 keV. Gun provides a >98% uniform flux distribution over the full sample area, with "hot swappable" filaments for continuous exposure over the entire long duration testing. The electron gun was custom designed at USU after work by Swaminathan [2004].



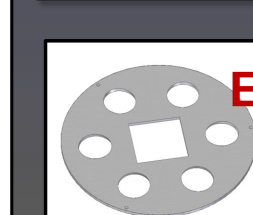




<u>Infrared/Visible/Ultraviolet Flux</u>- A commercial Class AAA solar simulator (B) provides NIR/VIS/UVA/UVB electromagnetic radiation (from 200 nm to 1700 nm) at up to 4 times sun equivalent intensity for accelerated testing over an area of 80mmX80mm. Source uses a Xe discharge tube, parabolic reflector, collimating lens, and standard Air Mass Zero filters (D) to match the incident radiation spectrum to the solar spectrum. Xe bulbs have >1 month lifetimes for long duration studies.


<u>Far Ultraviolet Flux</u>- The Kr resonance lamps (C) provide FUV radiation flux (ranging from 10 to 200 nm) at 4 times sun equivalent intensity. Three lamps oriented 120º apart provide >98% flux uniformity. Lamp's emission lines reproduce the H Lymann-α line (121.6 nm) that dominates the solar FUV spectrum. Kr bulbs have ~3 month lifetimes for long duration studies.




<u>Flux Mask</u>-Flux mask (E) located near the chamber's top ports restricts the flux boundaries to the sample stage, limiting equipment exposure and reducing scattering to accommodate uniform exposure. Can be readily modified for different sample geometries.




<u>View Ports</u>- Solar simulator UV/VIS/NIR light passes through sapphire viewport (U). Krypton source FUV light passes through a Magnesium Fluoride window (V) . Additional viewports allow visual inspection.


<u>Vacuum</u>—Chamber uses standard mechanical and turbomolecular pumps (X) for roughing and an ion pump (Y) for continuous maintenance-free operation (base pressure <$10^{-7}$ Pa).

<u>Temperature</u>---A temperature range from 100 K to 450 K is maintained to ±2 K by a standard PID temperature controller, using a cryogenic reservoir (Q) and resistance heaters (P) attached to a large thermal mass sample stage (M).