Small Satellite Space Environment Effects Test Facility with Space Environment Effects Ground-testing Capabilities

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Space Environment Effects

The harsh space environment can modify materials and cause detrimental effects to satellites. If these modifications are severe enough, the spacecraft will not operate as designed or can fail altogether. In an ideal situation a full spacecraft would be tested in all applicable space environments over the mission lifetime [1]. This, however, is obviously not practical. 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.

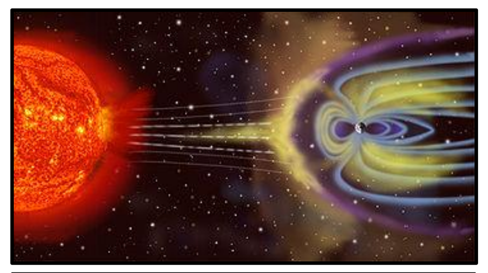


Fig. 1. Solar wind and Earth's magnetosphere structure.

Space Environment Characteristics

The Space Survivability Test (SST) chamber simulates several critical characteristics of the space environment: electron flux, ionizing radiation, photon flux, temperature and neutral gas environment. Figures 2 shows representative electron spectra for several common environments. The solar UV/Vis/NIR spectrum is shown in Fig. 3. The range of electron, ionizing radiation, and photon sources are shown above the environmental flux graphs. 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 ~60 K to ~450 K. This chamber does not yet simulate ions, plasma or atomic oxygen.

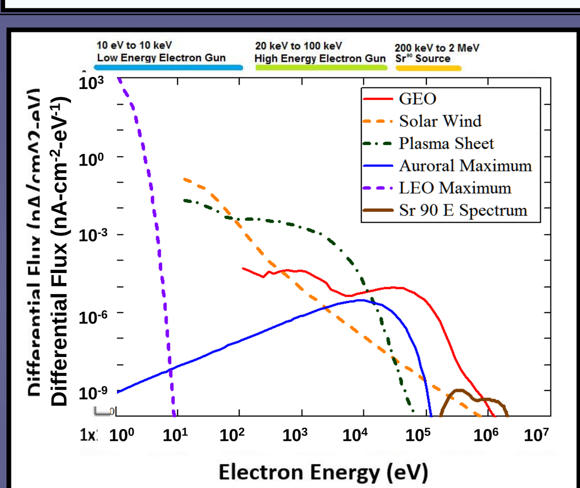


Fig. 2. Typical Space Electron Flux Spectra. Bars show source ranges.

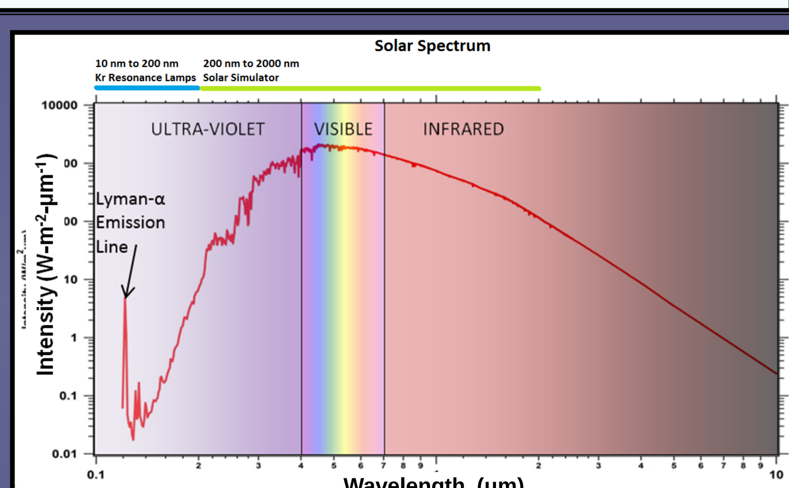


Fig. 3. Solar Electromagnetic Spectrum. Bars show source ranges.

SEEM Space Environment Test Facility

Unique capabilities for simulating and testing potential environmental-induced modifications of small satellites, components, and materials are available at the Material Physics Group's (MPG) Space Environment Effects Materials (SEEM) test facility. Their new versatile ultrahigh vacuum Space Survivability Test (SST) chamber [2] is particularly well suited for cost-effective tests of multiple small scale materials samples over prolonged exposure to simulate critical environmental components including: the neutral gas atmosphere/vacuum, the far UV through near IR solar spectrum, electron plasma fluxes, and temperature. Testing is available for a 10 cm X 10 cm CubeSat face sample area (maximum sample area of 16 cm X 16 cm or 20 cm diameter), with exposure to within <5% uniformity at intensities for >5X accelerated testing. A Sr^{90} β-radiation source produces a high-energy (~200 keV to >2.5 MeV) spectrum similar to the GEO spectrum for testing of radiation damage, single event interrupts, and COTS parts [2]. 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].

Electron Flux

A high energy electron flood gun (A) (20 keV – 100 keV) provides ≤5 X 10^6 electrons/cm^2 (~1pA/cm^2 to 1 μA/cm^2) flux needed to simulate the solar wind and plasma sheet at more than the 100X cumulative electron flux. A low energy electron gun (A') (10 eV-10 keV) simulates higher flux conditions. Both have interchangeable electron filaments.

Ionizing Radiation

A 100 mCi encapsulated Sr^{90} radiation source (E') mimics high energy (~500 keV to 2.5 MeV) geostationary electron flux (see Fig. 2) [2].

Infrared/Visible/Ultraviolet Flux

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. Source uses a Xe discharge tube bulbs with >1 month lifetimes for long duration studies.

Far Ultraviolet Flux

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

Temperature

Temperature range from 60 K [4] to 450 K is maintained to ±2 K [3].

Vacuum

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

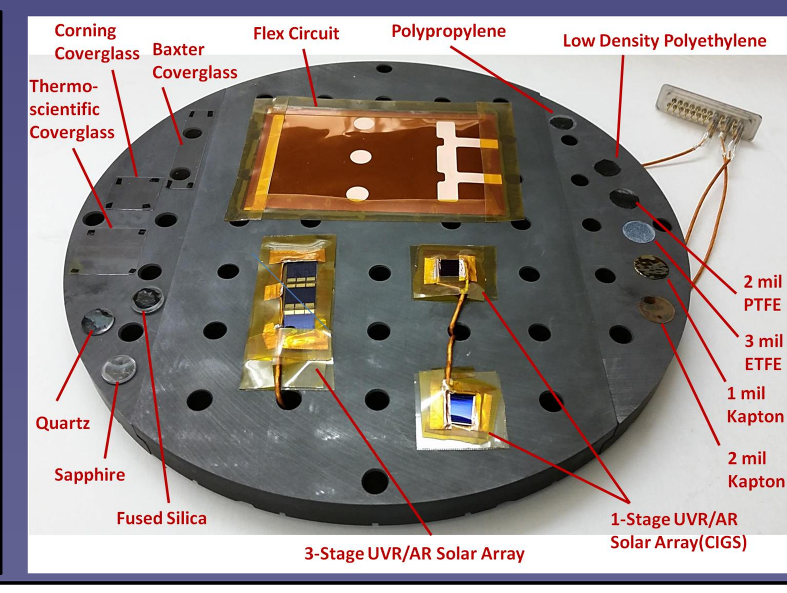
Overview

The Utah State University Materials Physics Group (MPG) and Space Dynamics Laboratory (SDL) have developed an extensive versatile and cost-effective test capability for verification and assessment of small satellites, system components, and spacecraft materials. The facilities can perform environmental testing, component characterization, system level hardware in-the-loop testing, and qualification testing to ensure that each element is functional, reliable, and working per its design. A wide array of tests related to typical CubeSats—including performance of solar arrays, electronics, sensor and memory components, radiation damage, basic communication responses, structural integrity, etc.—acquired at the SEEM and NOVA facilities are presented to demonstrate their combined test capabilities.

Space Environment Effects and Radiation Testing

Radiation testing of SparkFun Arduino Board COTS parts. In situ tests are run on parts during irradiation with simultaneous tests on identical control hardware. Periodic tests include:

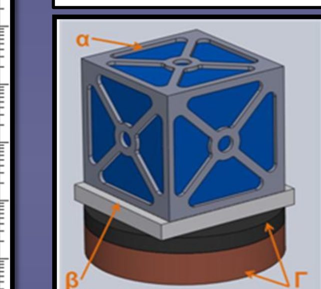
- CPU diagnostics relayed via USB connection.
- μSD card memory read/write tests.
- Bluetooth and WiFi communication.
- Sensor tests with fixed sources for reproducible, periodic, variable stimuli for magnetic Hall, temperature, photocell, IR, & acceleration sensors.



Degradation studies of common spacecraft materials (coverglass, quartz, sapphire, fused silica PI, LDPE, PTFE, ETFE).

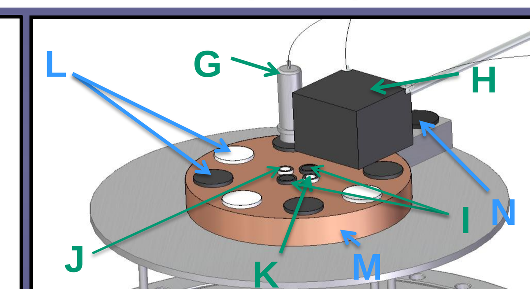
Pre- and post-irradiation characterization of optical transmission, conductivity, surface composition and morphology. fused silica,

In situ monitoring during irradiation of IV curves of flexible solar panels for CubeSats from Vanguard Space Technologies mounted on sample stage.



Sample Stages

(Above) 21 cm diameter sample stage (M) connected to 360° rotary feedthrough (S) to enhance flux uniformity by periodic rotation. The standard breadboard allows versatile sample configurations. (Left) 1U CubeSat mounted on sample stage. (Right) Stage with thermal control and linear translation stage with *in situ* characterization probes.



Space Survivability Test Chamber

Fig. 6. Cutaway View with Source Beams.

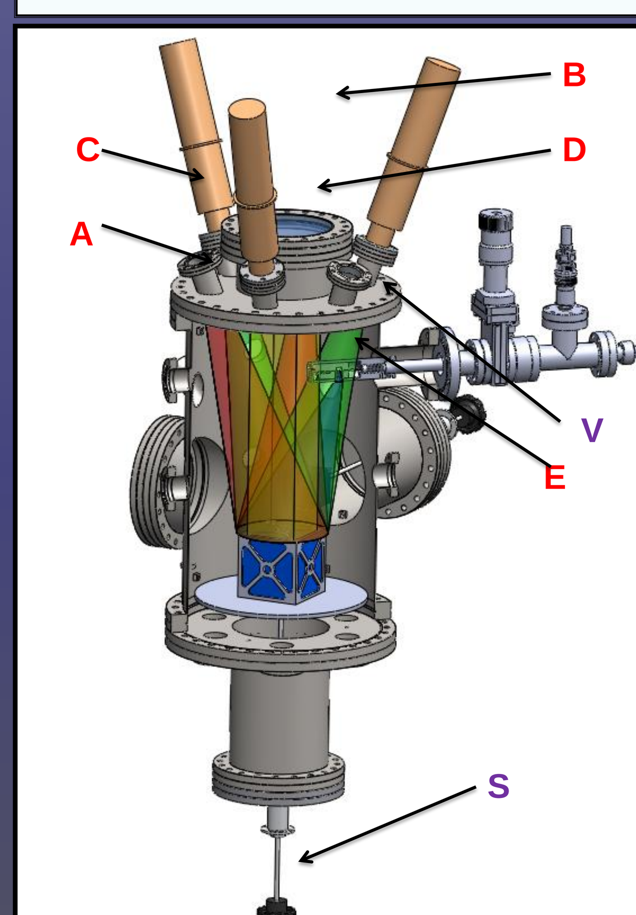


Fig. 7 SST Chamber.

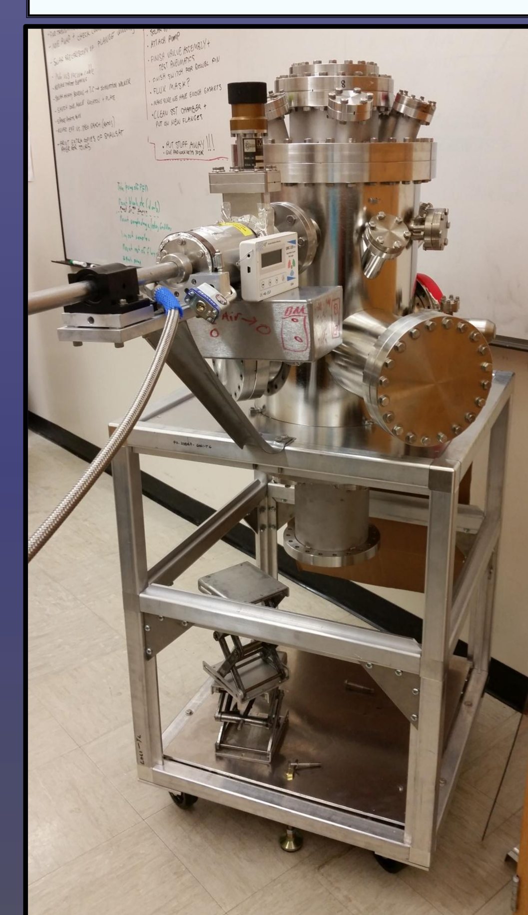
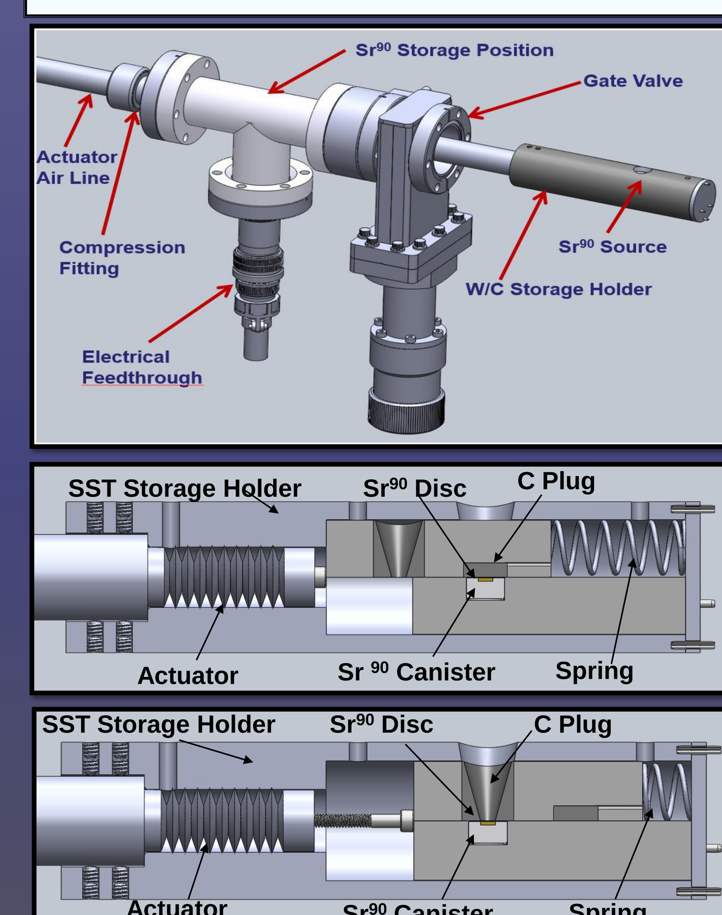


Fig. 8. Sr^{90} Ionizing Radiation Source.



Radiation Sources
- A High Energy Electron Gun
- A' Low Energy Electron Gun
- B UV/NIS/NIR Solar Simulator
- C FUV Kapton Discharge Lamps
- D Air Mass Zero Filter Set
- E Flux Mask
- E' Sr^{90} Radiation Source

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

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

Chamber Components
- Q Cryogen Vacuum Feedthrough
- 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 Analyzer

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

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

NOVA Small Satellite Test Facility

Complimentary testing at SDL's Nano-Satellite Operation Verification and Assessment (NOVA) test facility provides comprehensive testing capabilities and expertise for characterization and verification of subsystem and system performance of small satellites up to 10 kg [6]. Hardware-in-the-loop (HWIL) system testing enables test and verification of system interfaces, algorithms and flight software. Component test stations provide for a high fidelity HWIL model. NOVA's component test capabilities include:

Dynamic Magnetic Field Environment Testing

- A magnetic test cell for torquer coils and magnetometers uses a 3-axis Helmholtz cage with a field that can be rotated in real time using closed-loop control to within 10 nanoTesla. The 2-meter cage provides a 60-cm working volume. Dual NIST-traceable differential magnetometers provide accurate results.
- A zero-gauss chamber is available for magnetometer calibration and determination of CubeSat magnetic dipole moment.

High Resolution Mass and Moment of Inertia Testing

- Amass properties test cell features load cells and kinematic mounts to obtain the measurements needed to verify and refine the calculations from the CAD models, and to statically balance the spacecraft. Mass can be measured within 2 grams (3σ) and center of gravity to within 1 mm (3σ).
- A patent-pending moment-of-inertia (MOI) table provides a simple, low-cost, but accurate means of determining spacecraft inertia.

Attitude Control Systems Speed, Jitter, and Torque Measurements

- A reaction wheel test cell accurately measures wheel speed using 400 MHz sampling, analytically derives the torque, and enables characterization of wheel jitter.
- A Sun simulator with two-axis precision control enables Sun sensor system characterization and performance assessment.

Solar Array Testing

- A solar array simulator and battery/charger simulator replicate on-orbit power to enable testing of algorithms, controls and interfaces.
- The solar panel test cell provides a continuous AM0 light source to verify the power output of the solar arrays to a class BBA (IEC 60904-9). A NIST-traceable pyranometer is used to measure the light intensity in the target area.

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For additional information visit the SDL SmallSat Exhibit: Booth 11-12

Fig. 9. NOVA Lab's ADCS test bed and Power Testing stations.

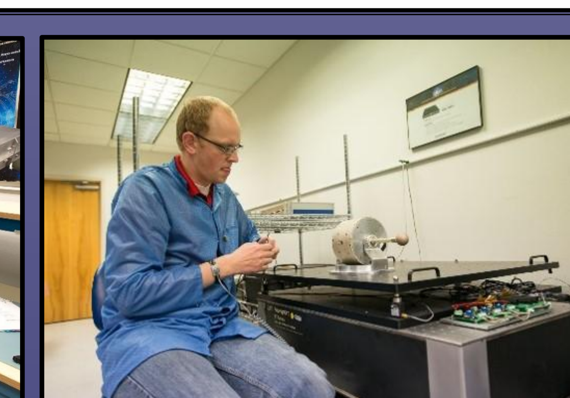

Fig. 10. Auroral Spatial Structures Probe (ASSP) subpayload undergoing mass properties testing.

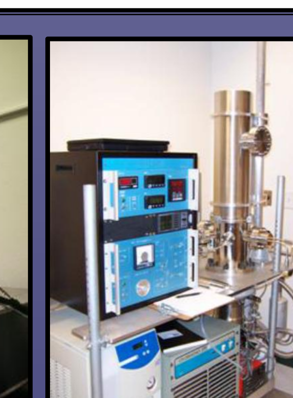

Fig. 11. SDL ASTM E595 Outgassing test chamber for %TML and %CVCM measurements.

Additional SDL environmental test small satellite facilities include:

Thermal Testing

Vacuum and inert gas test chambers for thermal cycling and swing characterization, vacuum bakeout , and thermal space simulation.

Outgassing Testing

Outgassing measurement capabilities for screening new materials.

Vibration Testing

Vibration table capable of a suite of sinusoidal and random vibration profiles to simulate environments seen on launch vehicles.

Chemistry Group Lead: Jim Dyer (435) 713-3545 Jim.Dyer@sdl.usu.edu

Acknowledgments, References & Tours

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6) Ben Iannotta, "NOVA: Bright New Star for CubeSat Testing," Aerospace America, 24-26, June 2012.

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SEEM Test Facility Tours
Wednesday 8/12/15 17:00
Thursday 8/13/15 14:00