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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
effects are severe enough, the spacecraft will not operate as designed. The key to predicting and mitigating these
detrimental effects is the ability to accurately simulate space environment effects through long-duration, well-characterized testing in an experimental, versatile laboratory environment.

**Radiation Testing**

![Image](image_url)

**Experimental Test Chamber Design**

![Image](image_url)

**Space Environment Characteristics**

The Space Survivability chamber simulates several critical characteristics of the solar environment, including solar flux, electrons, particle, temperature and neutral gas environment. Figure 7 shows representative electron spectra for several common environments: the run of the chambers, two electron guns, and SRM source are shown. The solar UV/VIS/NIR spectrum is shown in Figure 9; source includes a standard solar simulator (~200 nm to 2000 nm) and Kr resonance source to mimic the H Lyman-alpha emission at ~121 nm. Samples can be exposed to a vacuum or controlled neutral gas environment down to ~10^{-8} Torr. Temperature can be maintained for prolonged durations (~100 – 1000 K) to ~400 K. This chamber does not yet simulate ions, plasma or atomic oxygen.

**Simulation Chamber for Space Environment Survivability Testing of Small Satellites**

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**Abstract**

A versatile space environment 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 deletions or catastrophic failures over the duration of space missions. This is increasingly important as small satellite programs have longer mission lifetimes, expand to more harsh environments (such as polar or geosynchronous orbit), 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 material samples. The facility simulates critical environmental components including the neutral gas atmosphere [altrhhigh vacuum (10^{-6} Pa) to ambient], the FUV/VIS/NIR solar spectrum (120 nm to 2000 nm), electron plasma fluxes (10^{4} e^{-} / cm^{2} / s) and temperatures (100 K to 450 K). 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 are discharge tube source has a 200 nm to 2000 nm range, with up to four small intense light sources of a CubeSat face. For ultraviolet (FUV) radiation is provided by Kx discharge light source, with a primary emission lines at 124 nm and 117 nm and up to four small UV intensity. This provides an adequate substitution for the solar FUV spectrum, which is dominated by the ultraviolet hydrogen Lyman emissions line at 121.6 nm. An electron flood gun provides a uniform, stable, low-energy, monochromatic (~20 eV to ~15 keV) electron flux of <1 pa-cm^{2} > 1 pa-cm^{2} over the CubeSat face. A second medium-energy (~20 keV to ~100 keV), low-exchange energy source uses filament-free photomultiplier. A SRM radiation source produces a high-energy (~50 keV to 1.2 MeV) spectrum similar to the geomagnetic spectrum; intensities of ~50% of the geomagnetic spectrum are possible. Electron and photon fluxes are continuously monitored during the sample exposure cycle, using standard Faraday cups and photodiode detectors. All of the electromagnetic and electron radiation sources maintain uniform exposure to within ~5% over CubeSat. 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 x-ray calibration standards in the previous radiative environment. Samples can be mounted in the main chamber on single-axis radiation high-temperature or cryostat stages; alternatively, the modular design allows the sources to rotate relatively with a larger chamber with a 5-axis rotation/translation stage that can position five faces of a CubeSat relative to the incident beams.

**Figure 1** Cutaway View of Beam Trajectories. **Figure 2** Vertical Cutaway with CubeSat. **Figure 3** Physical Chamber.

**Experimental Test Chamber Design**

![Image](image_url)

**Legend of Components**

<table>
<thead>
<tr>
<th>Radiation Sources</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron Gun</td>
<td>UV/VIS/NIR Solar Simulator</td>
</tr>
<tr>
<td>CUV Krystal Discharge Lamp</td>
<td>FUV Plasma Zero Filter Set</td>
</tr>
<tr>
<td>Air Mass Zero</td>
<td>E Flux</td>
</tr>
</tbody>
</table>

**Legend of Components**

- **Source**
  - Electron Gun
  - UV/VIS/NIR Solar Simulator
  - CUV Krystal Discharge Lamp
  - FUV Plasma Zero Filter Set

- **Emission**
  - Emission: 10-4 e-/cm^2/s

- **Flux**
  - Flux: 1-100 keV

- **Temperatures**
  - Temperature: 100-500 K

- **Materials**
  - Materials: Aluminum, Stainless Steel, Copper, Glass

- **Logic**
  - Logic: Single- or Dual-Beam

**Legend of Components**

<table>
<thead>
<tr>
<th>Chamber Components</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryogenic Vacuum Chamber</td>
<td>UV/VIS/NIR Solar Simulator</td>
</tr>
<tr>
<td>Electron Gun</td>
<td>Faraday Cup-Electron Flux Monitor</td>
</tr>
<tr>
<td>Air Mass Zero</td>
<td>Platinum Resistance Temperature Probe</td>
</tr>
</tbody>
</table>

**Legend of Components**

<table>
<thead>
<tr>
<th>Sample Carrousel</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samples</td>
<td>Sample Carrousel</td>
</tr>
<tr>
<td>Reflectivity/Emissivity Calibration</td>
<td>Standards</td>
</tr>
<tr>
<td>Resistance Heaters</td>
<td>Cryogenic Reservoir</td>
</tr>
</tbody>
</table>

**Legend of Components**

<table>
<thead>
<tr>
<th>Instrumentation (Not Shown)</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Acquisition System</td>
<td>Temperature Controller</td>
</tr>
</tbody>
</table>
| Electron Gun | Colorimeter
| UV/VIS/NIR Solar Simulator Controller | Reflectometry Source |
| Spectrometers and Reflectivity Source |

**Acknowledgements/References**


**Infrared/Visible/LiHdustroduktlu ultraviolet Flux:** A commercial Class AAA solar simulator (UV/VIS/NIR) provides a low-energy electron flux (>1 MeV) with a solar flux distribution that can be continuously modified for 100 to 2000 nm. The electron gun was custom built at USU after work by Sweatman [2004].

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