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The Space Survivability Test Chamber

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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.

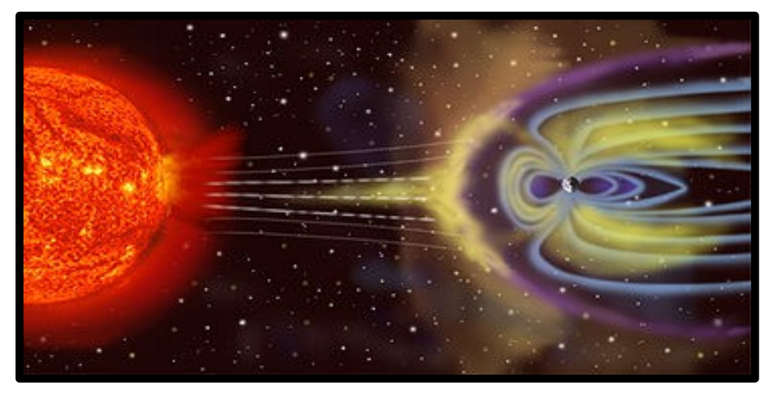
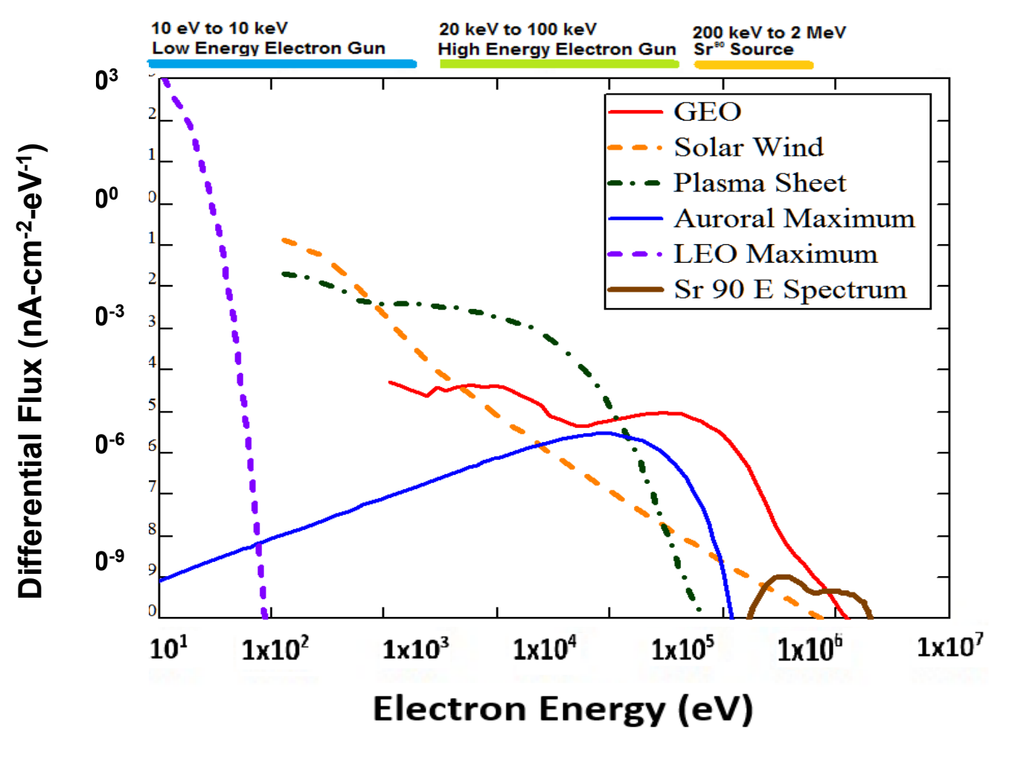


Fig. 1. Solar wind and Earth's magnetosphere structure.

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. Fig. 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. Table I shows typical ionizing dose level in various enviroments.



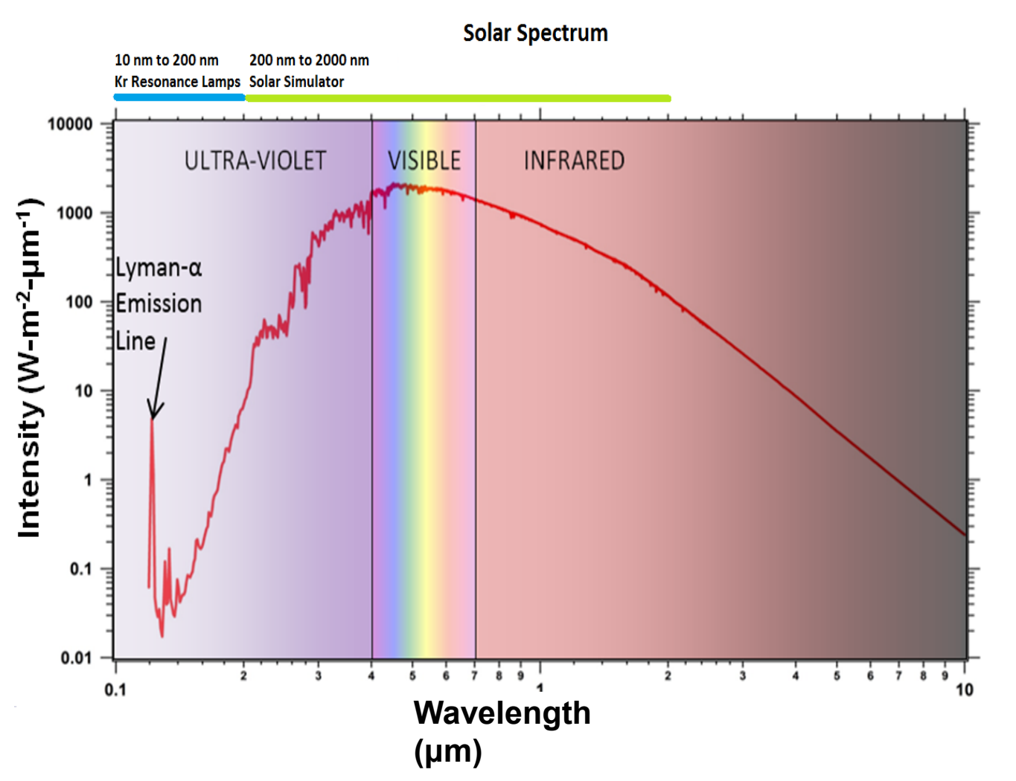


Fig. 2 (top left). Representative space electron flux spectra for geostationary earth orbit, solar wind at the mean earth orbital distance, plasma sheet environment, maximum aurora environment, and low earth orbit. The Sr^{90} source emission spectrum is also shown.
Fig. 3 (top right) AM0 Solar Electromagnetic Spectrum. Bars show source ranges.

Table I. Typical total ionizing dose levels in space environments (surface dose per year)

Orbit (Example)	Total Annual Dose	Primary Source
Earth Orbits (nearly all from trapped particles)		
LEO (ISS-Shuttle)	~ 2 krad	Protons
MEO	~ 100 krad	Protons and Electrons
GEO (GOES)	~ 10 krad	Electrons
Transfer (CRRES)	~ 50 krad	Protons and Electrons
Polar	~ 100 krad	Protons and Electrons
Planetary Orbits		
Mars (all from flares)		
Mars Surface	~ <1 krad	Heavy Particles
Orbit	~ 5 krad	Protons
Transit	~ 5 krad	Protons
Jovian (nearly all from trapped particles)		
Exploration Orbits	~ 100 krad to 100 Mrad	Electrons and Protons

Overview

The Utah State University Materials Physics Group (MPG) has developed an extensive versatile and cost-effective pre-launch 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 to demonstrate their test capabilities in a cost effective way.

Space Survivability Test Chamber

The Space Survivability Test (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. A Sr^{90} β-radiation source produces a high-energy 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') (~200 keV to >2.5 MeV) 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 4X 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.

Space Survivability Test Chamber

Fig. 6. Cutaway View with Source Beams.

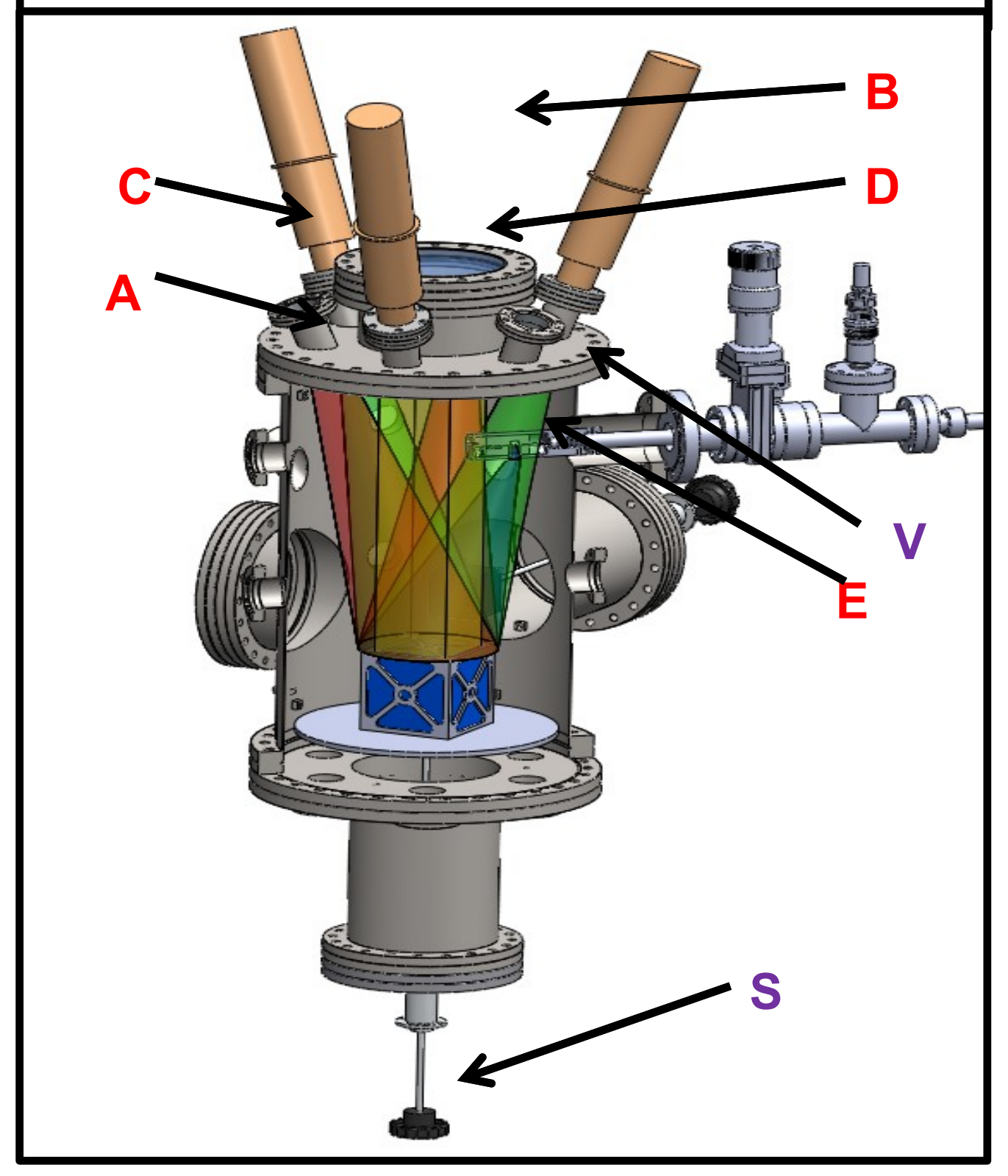


Fig. 7 SST Chamber.

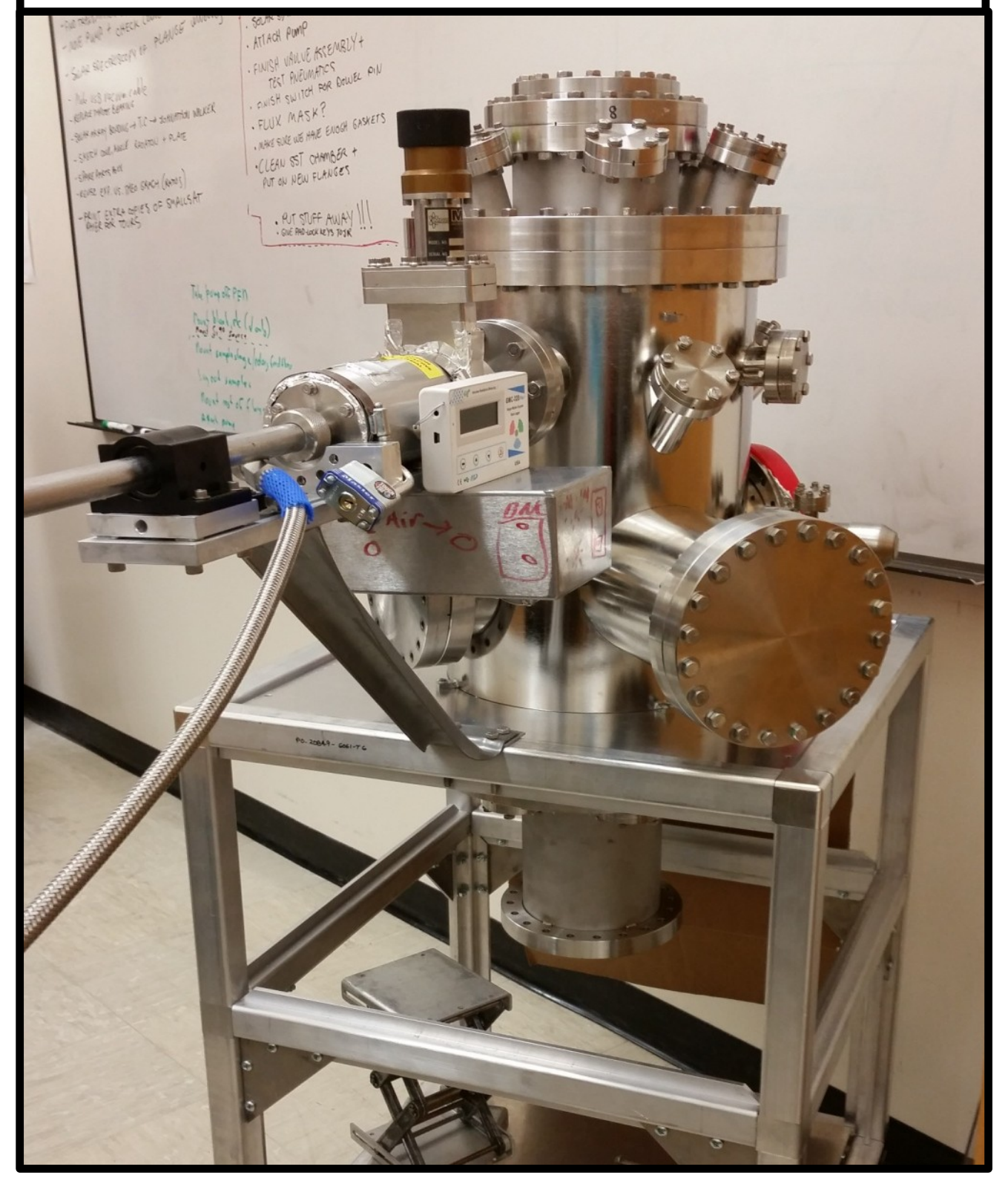
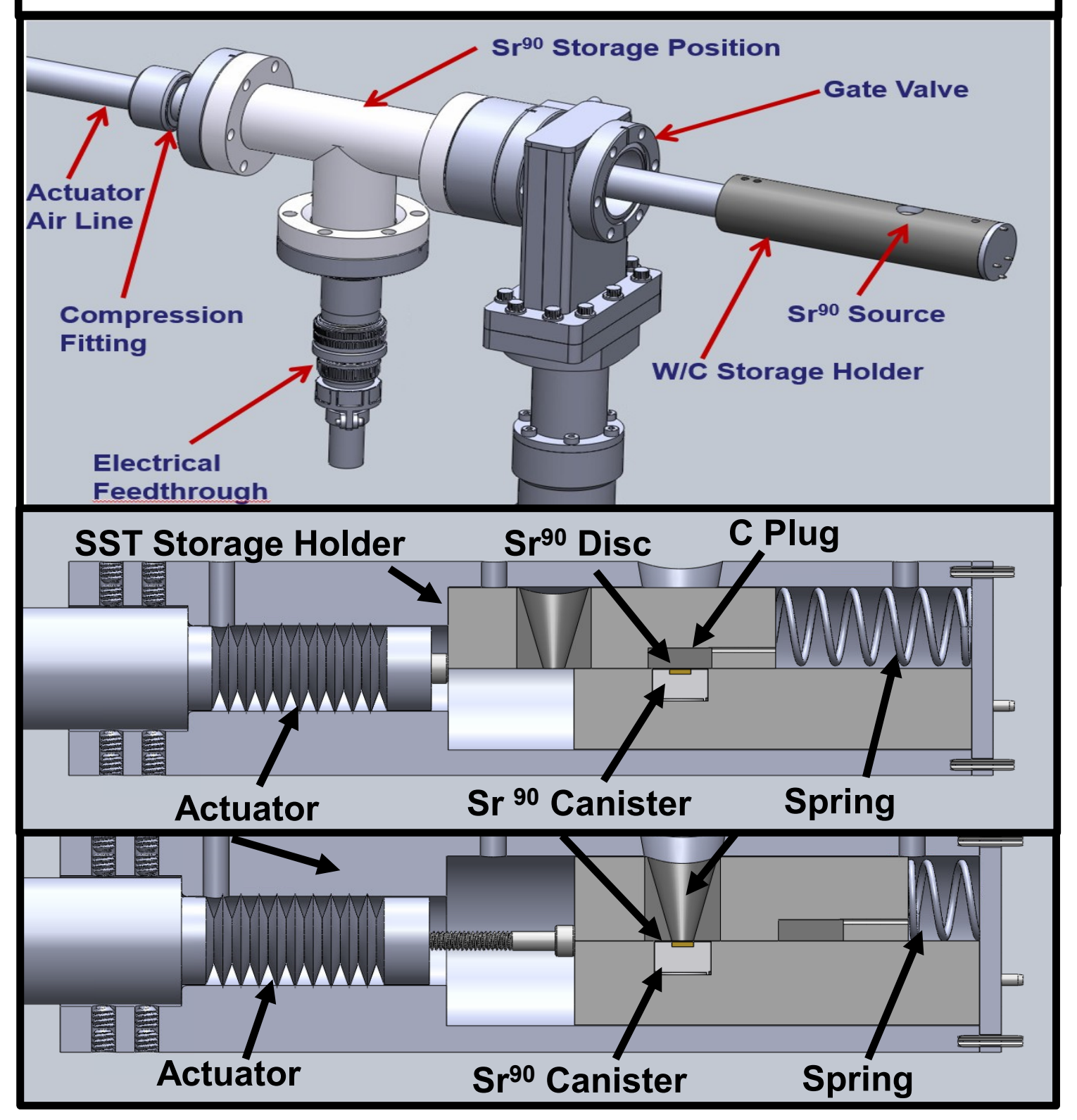


Fig. 8. Sr^{90} Ionizing Radiation Source.



Radiation Sources
- A High Energy Electron Gun
- A' Low Energy Electron Gun
- B UV/VIS/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 Prob

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

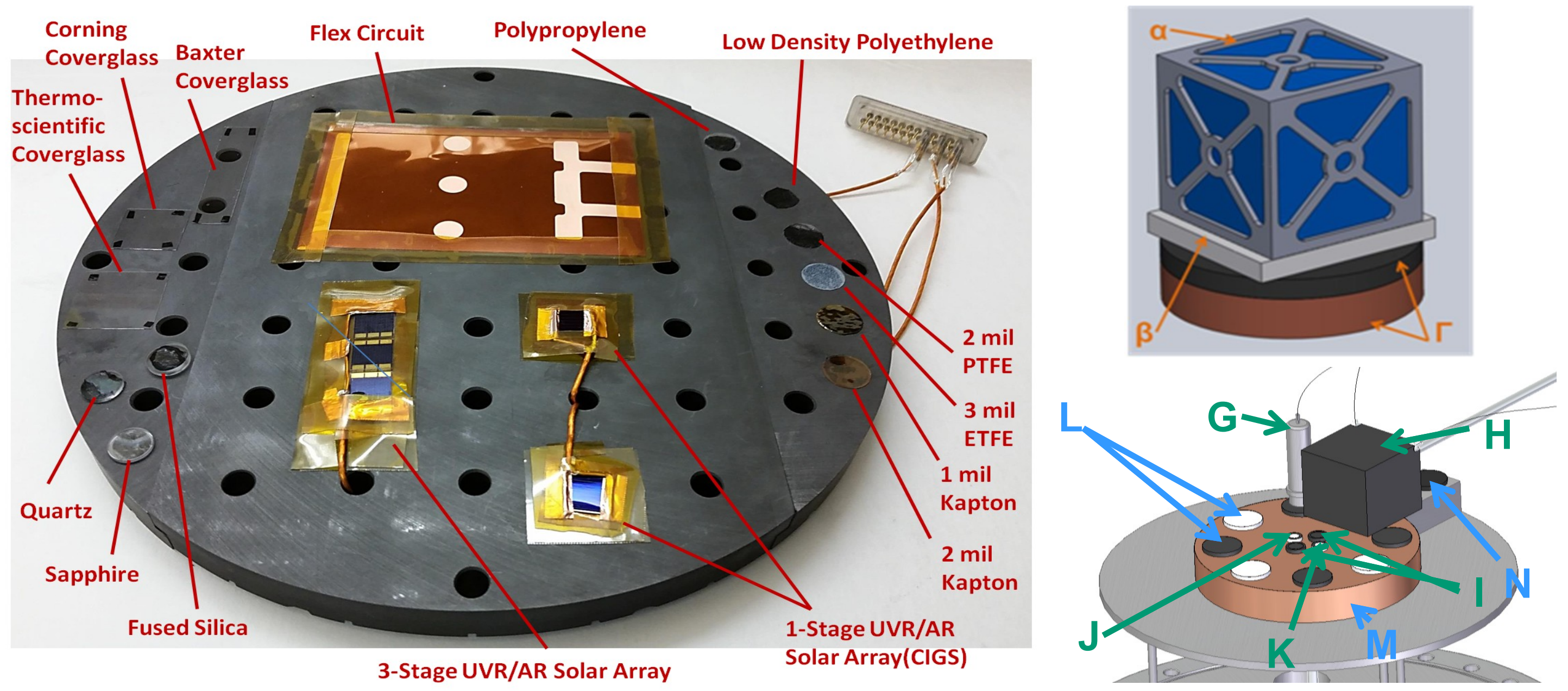
Chamber Components
- α CubeSat
- β CubeSat Test Fixture
- Γ Radiation Shielding
- Δ COTS Electronics
- ε Rad Hard Breadboard
- η COTS Text Fixture
- Θ Electron Gun

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

Space Environment Effects and Radiation Testing

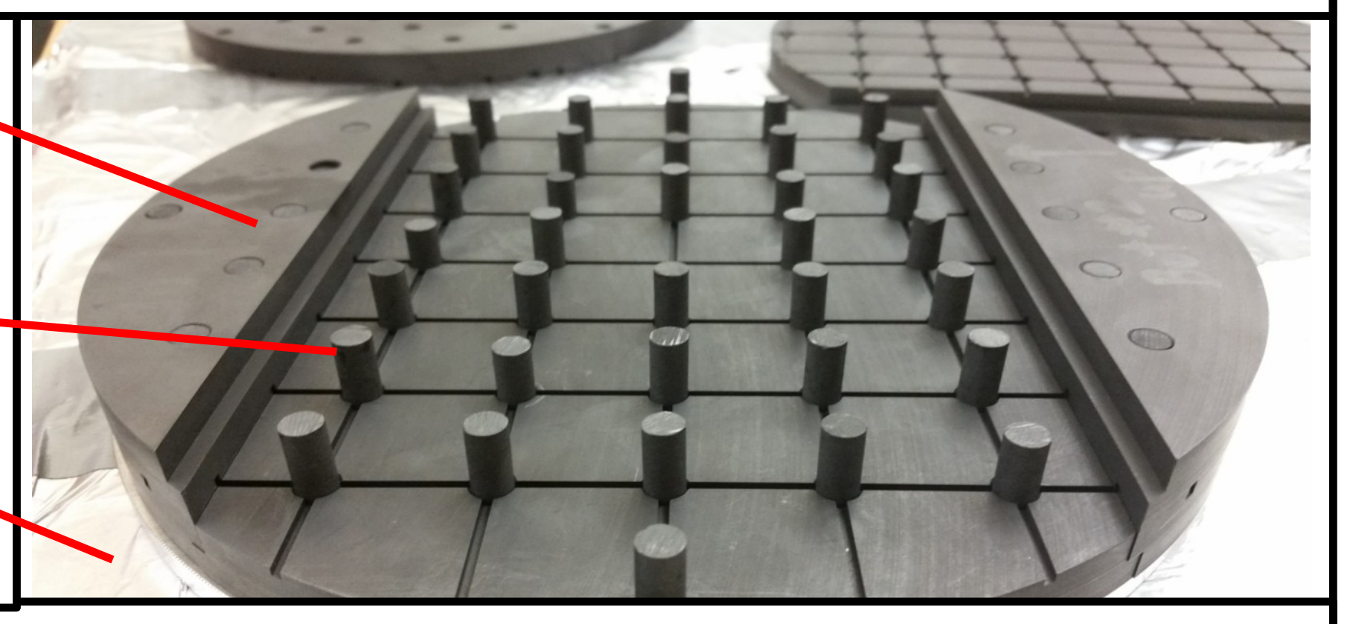
Sample Stages

(Below Left) 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. (Below Right) 1U CubeSat mounted on sample stage. (Bottom Right) Stage with thermal control and linear translation stage with *in situ* characterization probes.



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 as shown on the left side of the sample stage (Above Left).

- •Channeled Graphite Bilayer (inhibits beta radiation from leaving SST chamber)
- •Graphite Plugs
- •Stainless Steel substrate (inhibits Bremsstrahlung x-rays)



Radiation testing

With the flexibility of the sample stage numerous tests can be acomplished. Current tests include:

- •Radiation testing of SparkFun Arduino Board COTS parts with in situ tests as well as simultaneous tests on identical control hardware.
  - -CPU diagnostics relayed via USB connection.
  - -Micro SD 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.
- •Radiation testing of flexible solar panels for CubeSats from Vanguard Space Technologies with in situ IV measurments to determine efficiency loss as a function of radiation dose.

Acknowledgments and References

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