Space Environmental Effects for Exploration

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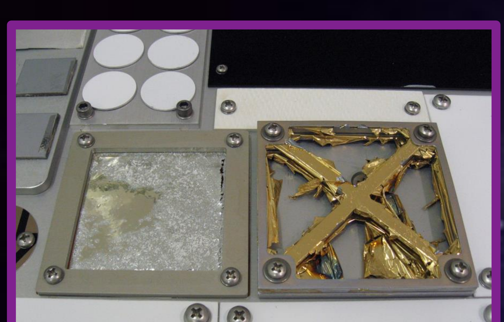
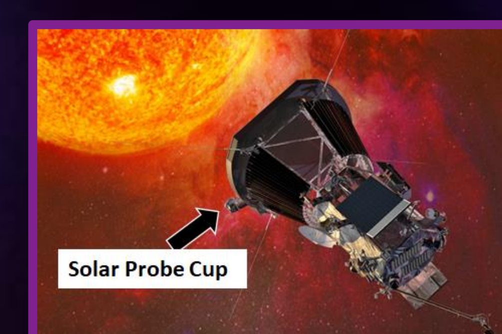
Who We Are

The Space Environmental Effects (SEE) Test and Analysis Team is part of EM41 (the Nonmetallic Materials and Space Environmental Effects Branch). Our team has decades of experience in the fields of Extreme Environments and Space Weather.

We enable a wide variety of missions and projects to meet their science and exploration objectives by proving materials and systems in relevant extreme environments.

- Capabilities include **individual** and **combined** effects utilizing **multiple unique test systems** for the most complete SEE test capability available in the world.
- MSFC's ability to test all effects in one location is critical for minimizing the handling of sensitive material coupons after environmental aging.
- Test systems can be rapidly adapted and reconfigured to customize tests to meet customers needs. Every test is different!
- The SEE Team provides space-flight technology development programs the ability to elevate their hardware to **TRL-6** "Qualification in a Relevant Environment".





A Few of the Projects We've Enabled

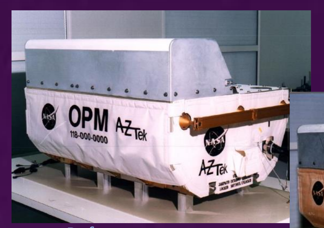
- Europa Clipper
  - Charging properties of coatings and cables
  - Instrument thermal and plasma calibration for potential Venus fly-by
- Europa Lander
  - Total ionizing dose (TID) to De-Orbit Stage materials, including live propellant
  - Radiation analysis for Planetary Protection
- ROSA (Roll Out Solar Array)
  - Space environment testing during development
- Parker Solar Probe
  - Validation of the Solar Probe Cup
- IXPE (Imaging X-Ray Polarimetry Explorer)
  - Contamination control for in-space optics
- Gateway PPE (Power & Propulsion Element)
  - Solar panel ESD testing
- Lunar GATR
  - Space environment for thermal coatings characterization
- Lunar THeRMiS – Survive the Night
  - Heat pipe high vacuum thermal cycling
- MISSE (Materials International Space Station Experiment)
  - Flight experiments and analysis
- ISS – Payloads & Safety Assessments
  - RPCM Hot Mate/De-Mate analysis, generating molten metal in a plasma
- E-Sail (Electric Sail)
  - First laboratory thrust measurements of a solar wind "sail"
- FPMU (Floating Potential Measurement Unit)
  - ISS plasma relative potential measurement device designed by our team members

Capabilities to Simulate All Space Environments

ULTRAVIOLET (UV) RADIATION

UV can change tensile properties of polymers and thermal properties of polymers, coatings, and optics. Increased effect in the presence of contamination/outgassing.

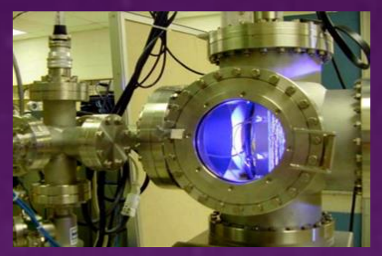
Two UV regions:
- Near ultraviolet radiation (NUV)- wavelength range 200 nm to 400 nm
- Vacuum ultraviolet radiation (VUV)- wavelength range 115 nm to 200 nm
- VUV is absorbed by atmosphere and only found in space

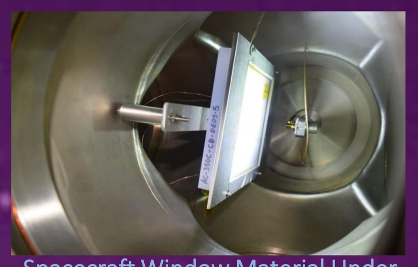


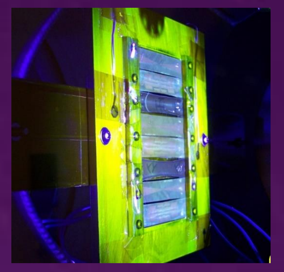
Before space exposure

After space exposure

MSFC has many test systems sources for exposing materials to NUV radiation, VUV radiation and combined NUV and VUV radiation. These tests range from a month (24/7) to over a year.

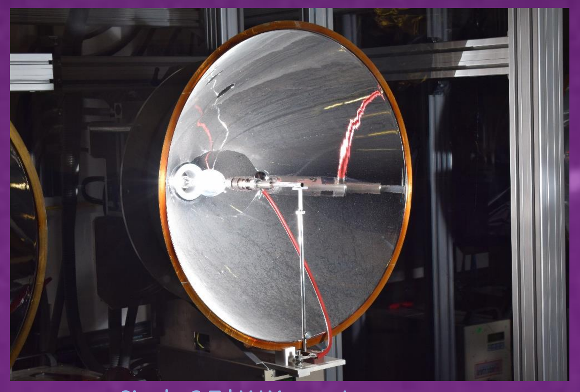

Typical MSFC UV Test Facility

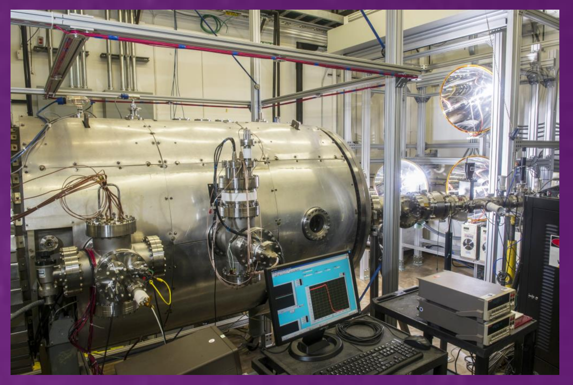

Spacecraft Window Material Under Test


Polymeric Material Under Test

SOLAR PHOTON RADIATION INCLUDING UV

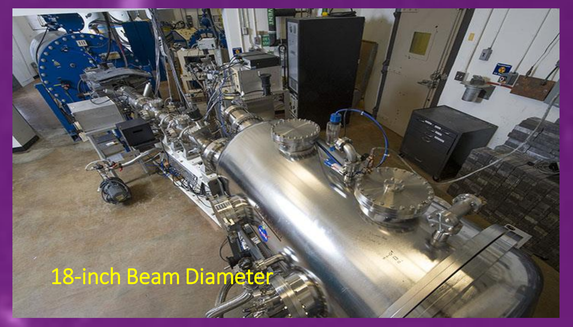
High Intensity Solar Environment Testbed (HISET)
- Able to produce intensity from 1 equivalent sun over a 2-foot beam spot to 600 equivalent suns over a 4-inch beam spot
  - 1 equivalent Sun is the illumination in earth orbit, compared to about 2 equivalent Suns at Venus and about 0.4 equivalent Suns at Mars
- Able to simulate the effects of spacecraft flying towards the sun


Single 6.7 kW Xenon Lamp


HISET has Three 6.7 kW Xenon Lamps

IONIZING RADIATION: PARTICLE (ELECTRON + PROTON), X-RAY

- Charged particle radiation occurs naturally in space – GCR, SPE, SW
- While we typically think of radiation being harmful to humans or causing single event effects in electronics, radiation can also damage materials.
- Exposure to radiation can embrittle polymers through cross-linking or chain-scission. It also degrades solar array performance.

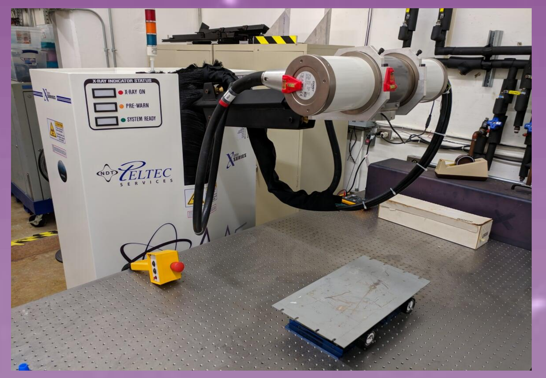


Top View of Target Chamber


Side View of Pelletron beam line

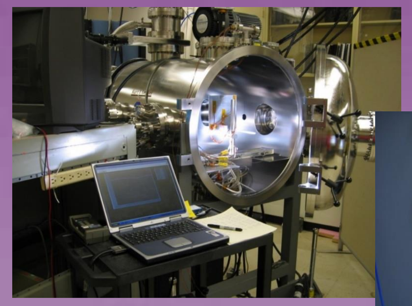
- Two Pelletron particle accelerators provide higher energy particles:
  - <= 2.5 MeV electrons (spot/beam)
  - <= 700 keV protons (square/raster)
- Both beam lines converge in single chamber
- Single energy at a time, but can vary to do different profiles
- Cryogenic capability
- Test Types: total ionizing dose (TID), iESD

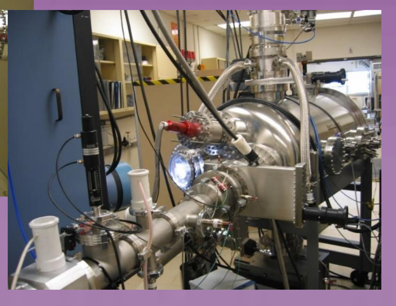
X-Ray Source
- The MSFC x-ray system for radiation effects provides materials with mission predicted total ionizing dose (TID)
- Spot size varies as inverse of dose rate (<= Mrad/hr)
- More penetrating than particles; no charging



320 kV X-Ray Source

Lower Energy Particles
- Low Energy Electrons (1 keV – 100 keV)
- Low Energy Protons (1 keV – 30 keV)
- Ultraviolet Radiation (VUV & NUV)
- 12-inch Diameter Exposure Area

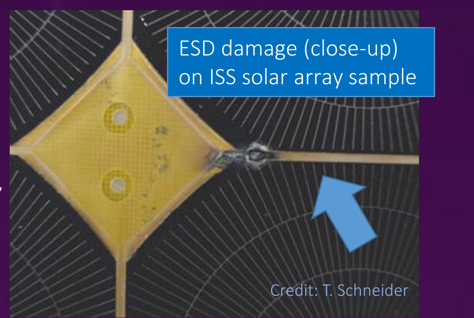




MSFC has a unique capability to irradiate explosive materials, such as Solid Rocket Motor live propellant and initiators.

SPACECRAFT CHARGING, ARCING & ESD TESTING

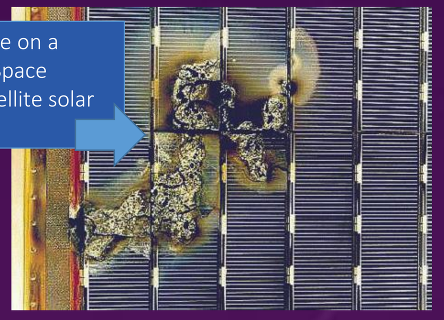
- ElectroStatic Discharges (ESD) can occur when charge build-up and potential differences occur within or across a system
  - Different & non-conductive materials
  - Varying illumination conditions
  - Tribocharging – lunar rovers
- A poor design can lead to an ESD event that can permanently damage the system, via property changes or complete loss of function



Credit: T. Schneider


Clear Window Sample (on a black mat) Before Radiation Exposure


Clear Window Sample (on a black mat) After Radiation Exposure



Credit: ESA

MSFC frequently tests systems, materials, & coatings for arcing & ESD generation

REGOLITH SIMULANT TESTING

Lunar Environment Test System (LETS)
- Fully functional test system for studying the effects of the lunar surface environment on materials and systems as well as enabling the study of the effect of lunar dust charging on materials and mechanisms.

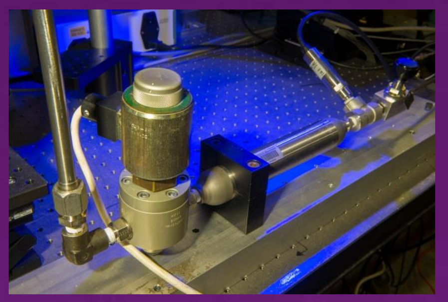
IMPACT TESTING

Hypervelocity Impact Range Micro-Light Gas Gun (MLGG)

- Velocity Range: 0.3 – 7.5 km/s
- Bore size .22 caliber (0.223 in.) diameter
- Target chamber approx. 1 ft. wide x 2ft. long
- Projectile Types include but are not limited to: Al, glass, polymers, ceramics
- Sample heating to 5000 K

Hypervelocity impact testing is often performed in combination with other SEE exposures to evaluate combined effects.

Microballistic Gas Gun/ Sand Gun

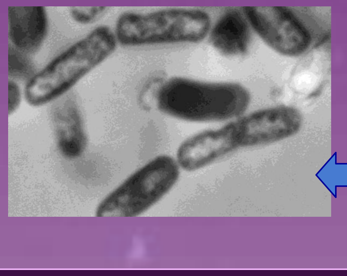


- Velocity: Up to 3,000 ft/s (Mach 2.76)
- Projectile Diameter: 2-4 mm
- Target Size: 51 x 51 mm (2x2 in.) up to full-scale hardware
- Research focused
- High Speed Digital Video
- Working on conversion to shoot regolith simulant

PLANETARY PROTECTION


Tardigrade

- Current NASA projects include landers to touchdown on the surface of potentially life-supporting planets and moons.
- Planetary protection is the required prevention of accidental transportation of Earth's microbes to these environments.
- In addition to traditional interplanetary spacecraft decontamination operations, EM41 is investigating new techniques for biological burden reduction.
- Studies are focusing on solid rocket propulsion systems and the innate antimicrobial capacity of both the chemical agents within the motor and of the assembly and operational environments.


Bacilli on Propellant Sample

EXTREME TEMPERATURES

- **Cryogenic** temperatures down to -180 C
  - Liquid nitrogen or cold gas
  - Shrouds and cold plates available for many chambers
- **Hot** temperatures
  - Quartz lamps, Kapton heaters
- Bakeouts, thermal cycling, deep space/solar profiles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