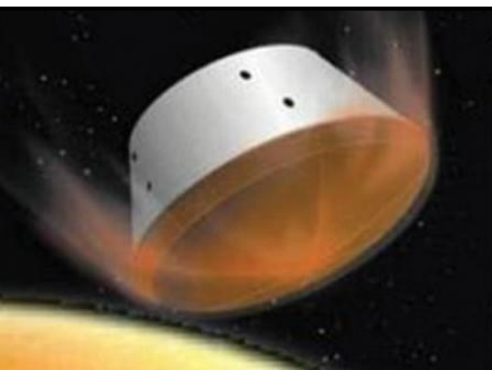
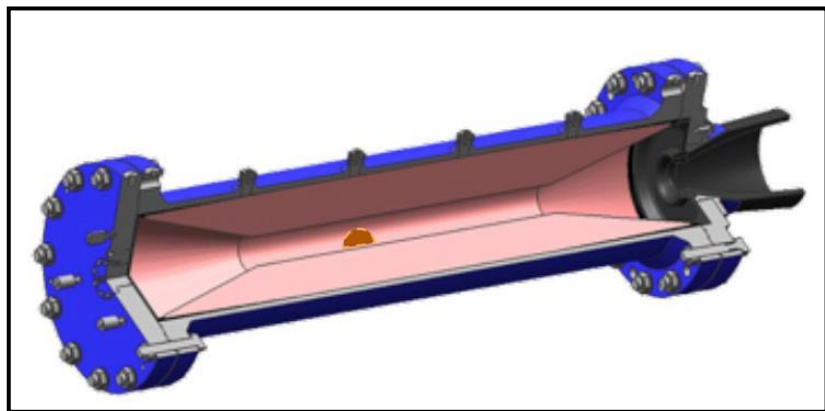
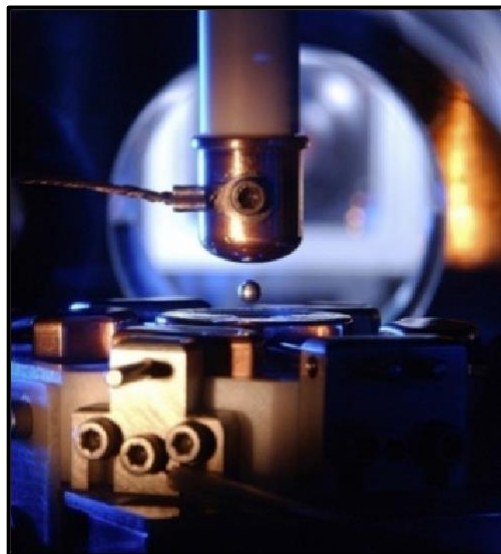


Marshall Space Flight Center

nonmetallic materials and space environmental effects branch



EM41 Nonmetallic Materials and Space Environmental Effects Branch

The EM41 Nonmetallic Materials and Space Environmental Effects Branch, provides research, technology, and engineering support for space exploration related nonmetallic materials, processes, and products along with a world class Space Environmental Effects (SEE) capability that provides exposure testing in simulated space environment conditions and a levitation laboratory for investigators studying high- temperature materials. EM41 supports, directs, and conducts nonmetallic material research and space environmental effects testing across the entire life-cycle of space exploration hardware, from lab-scale development to flight hardware.

EM41 is focused on material and process technologies associated with cryogenic insulation, paints, primers, coatings, adhesives, seals, ablators, thermal vacuum testing, large scale thermal protection system processing capabilities, graphites, carbon-carbons, ceramic matrix composites, solid and liquid rocket nozzles/extensions, solid rocket insulation, solid rocket propellant, and subscale solid rocket motor processing.

EM41 test facilities enable a wide range of individual and combined effects tests capabilities utilizing multiple unique test systems that offer the most complete SEE testing capability available. EM41's ability to test all effects in one location is critical to the goal of minimizing the handling of potentially sensitive material coupons. When combined with additional analytical capabilities for pre- and post-test evaluations, EM41 is a one-stop shop for material exposure testing and analysis. Extensive flight experiment experience bolsters this simulation and analysis capability with a comprehensive understanding of space environmental effects.

Nonmetallic Materials and Space Environmental Effects Branch Contacts

Ms. Alison Protz, Branch Chief
alison.protz@nasa.gov, 256-544-4234

Mr. Lee Allen, Assistant Branch Chief
lee.r.allen@nasa.gov, 256-544-4218



TPS Processing Robot



Cryogenic Propellant Storage
Tank Demonstration Article

Polymeric Materials Team

Team Lead – Currently Vacant

Thermal Protection System Development Facility

The Thermal Protection System (TPS) Development Facility was designed to develop environmentally compliant TPS materials and processes for current and future space programs. The TPS Development Facility is used to characterize materials and provide data on equipment and processing parameters to support large-scale TPS applications. The Facility provides the ability to apply primers, paints, and spray on foam insulation (SOFI) materials to large-scale test articles in various orientations. Current and future environmental, health, and safety issues, as well as product performance issues, will drive a continual utilization of this facility to maintain adequate TPS materials and processes for space vehicle applications.

The TPS Development Facility's key features include:

- 30- × 30- × 85-ft Class I Div I rated (able to utilize flammable materials) temperature and humidity controlled spray booth with associated heating, ventilation, and air conditioning (HVAC) equipment. Provides:
 - 20- × 27- × 70-ft hardware capability.
 - Temperature limits of 65 – 130 °F.
 - Temperature dependent relative humidity ranges of 5% – 75%.
- 9-axis Fanuc M710iC 70 robotic system (with tower and track).
- Two-part foam dispense system along with a nitrogen drum pressurization capability.
- Portable new delivery system (PNDS) two-part foam dispense system for manual sprays.
- Heated test panel holder (capable of holding six 2- × 2-ft test panels).
- Horizontal process tooling, vertical process tooling, and an associated TPS transporter.
- Data acquisition and remote viewing capability.
- Onsite cold-storage coolers required for processing of HFC-245fa based cryoinsulation materials.



TPS Processing Team



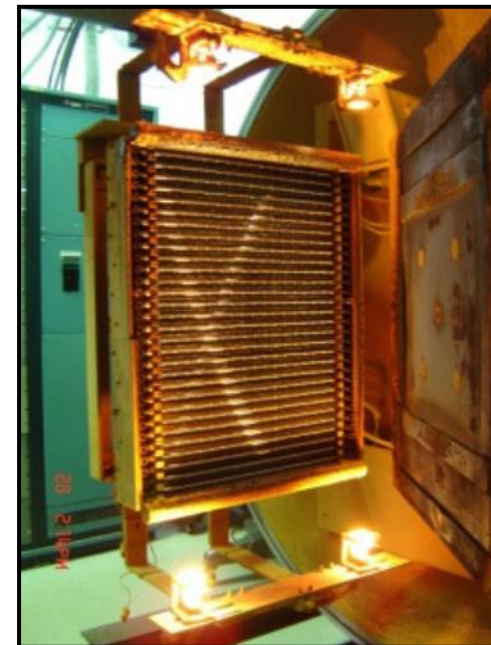
Thermal Vacuum Test Facility

Thermal Protection System Material Testing

EM41 has the ability to perform various TPS material characterization tests. Capabilities range from low fidelity in-process tests such as density, plug pull, and reactivity testing to higher fidelity thermal vacuum tests that expose TPS materials to vacuum levels and heating rates that mimic a launch vehicle's ascent through the atmosphere and into space. EM41 also has the facilities, equipment, and expertise to fabricate various TPS test specimens to American Society for Testing and Materials (ASTM) and other industry standards.

Specific related capabilities include:

- Pour foam testing capabilities with multiple foam molds available.
- Bonding lab with the ability to adhesively bond TPS materials.
- In-process testing including portable tensile (plug pull), density, and reactivity testing.
- FOAMAT foam reactivity test equipment.
- Machining equipment, cure ovens, and tooling for specimen preparation.
- Thermal Vacuum Test Facility:
 - Pressure profiling (0-10 mmHg).
 - Radiant heat profiling: Quartz lamps (90 kW) (20 Btu/ft² sec calorimeter sensors).
 - Data acquisition (50 scans/sec).



Thermal Vacuum Test Facility Lamp Bank

Coating and Adhesive Materials Development

EM41 has the ability to develop and apply a wide range of coatings and adhesives for space applications. Specific examples include:

- Electro-Static Dissipative (ESD) coatings to meet spacecraft hardware requirements
- Weather barrier coatings designed to protect cork-based thermal protection materials from severe heat, ultraviolet (UV) light, and moisture.
- Lightweight and low thermal conductivity coatings that provide excellent insulation capability for spacecraft applications.
- Adhesive material selection and bonding process development for highly unique space-related applications



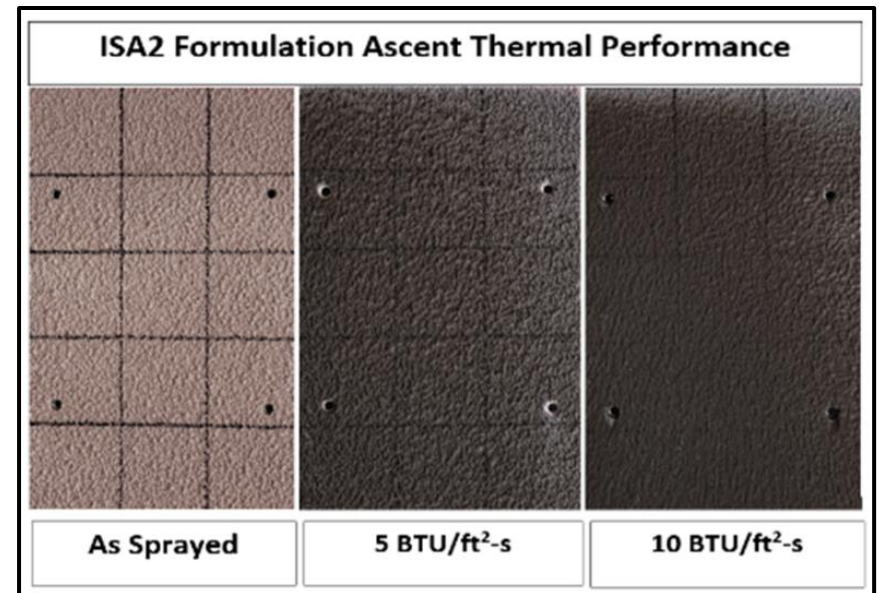
MSA with EM41-Developed Black Target and White (accreage) ESD Coatings Applied

Ablative Materials

EM41 conducts materials research and process development for ablative materials used on spacecraft hardware. Current ablative material systems range from standard sheet cork applications through more complex sprayable and hand-applicable ablators such as Marshall Convergent Coating (MCC-1) and RT 455 ablative compound.



Cross Section of MCC-1 Material. Nominal Thickness: 1/8 to 1/4 inch



Ablator Hot Gas Performance Results

Ceramics and Ablative Materials Team

Ms. Sarah Howse, Team Lead

sarah.a.howse@nasa.gov, 256-544-7418

Subscale Solid Rocket Motor Processing/Manufacturing

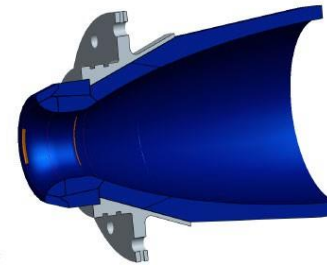
EM41 conducts subscale solid rocket motor material selection, testing, and processing. EM41 is leading the industry in developing alternative materials for solid rocket motor systems. EM41 maintains and operates a variety of capabilities that are used to verify the performance of new material and process options that help maintain environmental compliance and ensure mission success.

Specific related capabilities include:

- The Plasma Torch Test Facility (PTTF) — an internationally unique ablation test facility used for material screening that offers reliable, statistically proven data at a fraction of the cost of subscale motors or other test beds. The PTTF simulates the erosive flow found in solid rocket motor plumes and exposes various sized samples to a variable heat load and particle content impingement in order to measure the material's ablation performance.

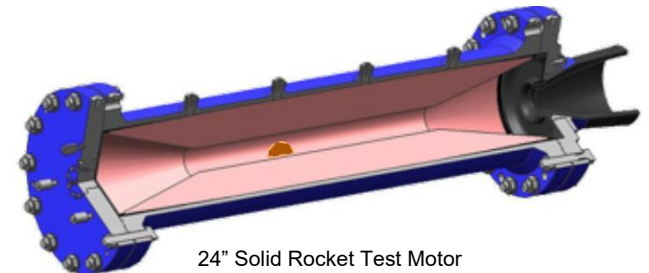


Plasma Torch Test Facility



Solid Fuel Torch

- Solid Fuel Torch (SFT) — a mid-range subscale test motor that can expose multiple materials to solid rocket motor environments. SFTs offer customizable test sections, close to 60 second fire times, and real time erosion data collection.
- 24" Solid Rocket Test Motor (SRTM) — a larger subscale test motor that provides qualification level thermal erosion performance data typically required prior to full-scale solid rocket motor system implementation. SRTMs can be used to evaluate nozzle and insulation test configurations.



24" Solid Rocket Test Motor

X-37 C-C Ruddervator Subcomponent



X-37 C-C Ruddervator

X-37 C-C Flaperon



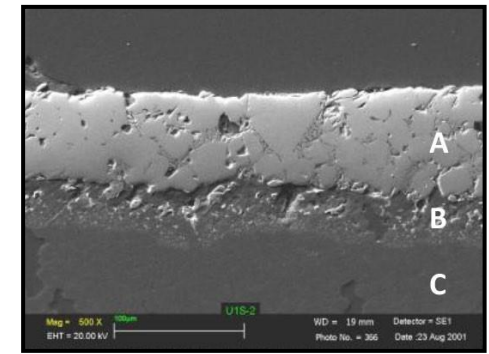
Carbon-Carbon, Ceramic Matrix Composite, and Thermal Protection System Materials Development

EM41 conducts materials research associated with the development of carbon-carbon (C-C), ceramic matrix composite (CMC), and TPS materials. The branch has been heavily involved in the use of C-C for moderate-to-large liquid rocket engines (J-2X, RL10C-3, etc.) and winged hypersonic vehicles (X-37, X-43, DARPA concepts), and the development of CMCs for various applications, including the Orion Launch Abort System (LAS) and hypersonic vehicles. The branch works to promote the use of C-C and CMC materials for both propulsive (nozzles, thrusters, and throats) and non-propulsive (structural, aerodynamic, and TPS) functions.

Additionally, EM41 is involved in the development of coated graphite and C-C for various high temperature applications, such as nuclear thermal propulsion fuel elements, rocket nozzles, and hypersonic components. EM41 has in-house capabilities that include heat-treatment furnaces and a very high temperature induction furnace facility optimized for coating and joining process development—useful for technology development such as ceramic reaction-sintered coatings for Hyper-X leading edge components (see photo).



C/C-SiC threaded component examined under scanning electron microscopy (SEM) as part of postflight test hardware assessment for Orion LAS.



Hyper-X Mach 10 vehicle development specimen, featuring (A) ceramic coating (B) non-porous graded transition region, and (C) C-C substrate.

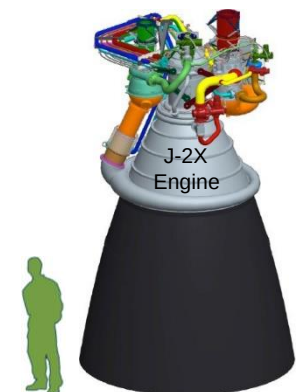
Specific related capabilities include:

- Various ovens and furnaces (capable of 760–1,700°C operating temperatures).
- Astro high-temperature furnace (2,500°C, 4-in diameter × 6-in hot zone).
- Ajax Tocco induction furnace facility (2,600°C, 2.8-in diameter × 6-in hotzone).



Hot structure components and aeroshells for hypersonic vehicles:

- Carbon-Carbon
- CMC's such as Carbon/Silicon-Carbide (C-SiC)





Rubber Mill



Rubber Calendar

Rubber Development Laboratory

Using the Rubber Development Laboratory, EM41 conducts reformulation research and development on a variety of rubber materials. Six pound mixes allow for rapid mixing, milling, and testing of candidate rubbers for a variety of applications at low expense in order to down-select formulations for larger scale mixing and testing. Rubber mixed in the Rubber Development Laboratory in small batches has chemical, mechanical, and thermal properties comparable to those of established formulations mixed on a large scale, making it an excellent sub-scale test-bed for formulation development. Any desired constituent of a rubber formulation can be varied in amount, or be substituted with a different material, giving a wide variety of formulation possibilities.

Specific related capabilities include:

- Mark 3 LTE Moisture Analyzer for measuring the percent moisture of powders, fibers, cured rubber, green rubber, and other materials using a predetermined heating recipe and weight loss measurements.
- Plasma Torch Test Facility (PTTF) for thermal and ablation testing of cured rubber insulation specimens. The PTTF successfully simulates mission environments via high-temperature plasma jets that provide thermal and erosive testing of flight materials and screening of new materials.
- Press cure capabilities for curing rubber samples.
- Autoclave cure capabilities for curing rubber samples and parts.
- Mechanical testing to determine mechanical properties of cured rubber (via internal MSFC providers).
- Analysis of cured rubber via SEM/EDS, Raman spectroscopy, and other chemistry methods (via internal MSFC and external providers).



Rubber Mixer

Automated Cleaning Facility (Waterblast)

The Automated Cleaning Facility (ACF), sometimes referred to as Waterblast or Hydroblast Facility, is home to a high-pressure water stripping system that allows stripping of hard to remove adhesives, paint systems, and even cladding and chromate conversion coatings. This process supports projects like the Space Launch System (SLS) by providing test coupon cleaning, de-painting, motor case cleaning, and hydro-proof pressure testing.

This facility also houses a fully integrated robot and turntable; two high pressure waterjet pumps which operate at pressures of 20,000-36,000 PSIG; and a Nitrojet 5000 System which has operational pressures of 1000 – 55,000 PSIG and is utilized in water-free stripping, precision cutting and cleaning, and cryogenic pressure testing.



6 Degree-of-Freedom Robot Used for Automated Cleaning

Space Environmental Effects Team

Ms. Mary Nehls, Team Lead
mary.nehls@nasa.gov, 256-544-6578

Planetary Protection

As NASA develops landers to touch down on the surface of potentially life-supporting planets and moons, EM41 has established a Planetary Protection (PP) capability within the Space Environmental Effects Team. PP has a goal of preventing the accidental transportation of Earth's microbes and resulting contamination of extraterrestrial moons and planets, and preventing the potential reverse contamination of the Earth-Moon system with samples from other planetary bodies.

To support PP efforts, EM41/SEE has a fully functional Biosafety Level (BSL) 2 microbiology lab capable of performing a wide variety of PP-specific and microbiological assays. Current lab research activities are centered on understanding the inherent antimicrobial effects of solid rocket motor materials and processes and operational environments, as well as maturing the use of cryogenic milling as an assay technique for composite materials. Future areas of interest include understanding how combined space environmental effects (cold vacuum, UV, ionizing radiation, atomic oxygen, etc.) can be used for their antimicrobial effects.



Tardigrade – A common microorganism resistant to standard decontamination techniques



Pelletron Accelerator

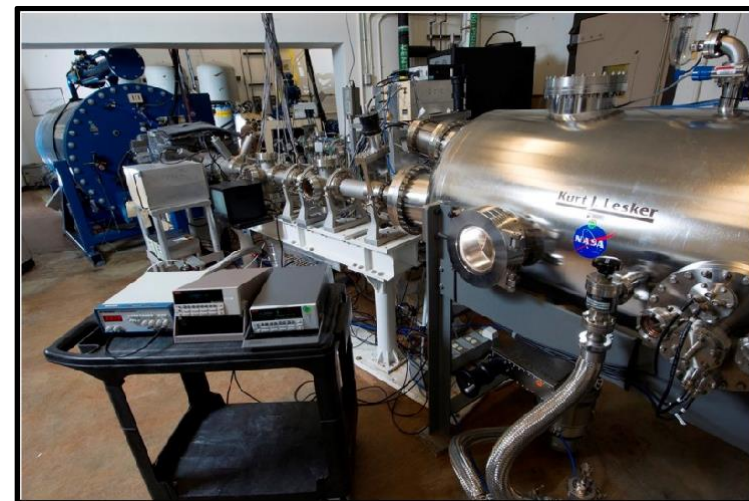
Charged Particle Radiation Exposure

Charged particle radiation includes protons and electrons with a wide range of energies. Spacecraft operating in the Van Allen belts are, for example, exposed to much greater radiation levels than those in low Earth orbit. Charged particle radiation, along with ultraviolet radiation can cause cross-linking (hardening) and chain scission (weakening) of polymers, darkening and color center formation in windows and optics.

MSFC radiation test systems cover a wide energy range of protons, electrons, and ions to simulate space environment exposures. Multiple sources which can be used individually or in combination provide a broad capability to cover individual customer needs. Materials can be exposed to a combination of particles and particle energies sequentially or simultaneously to reveal any synergistic effects. Fluences can be tailored to simulate a specific exposure at a defined environment or to allow comparison testing of different materials at the same exposure. Low energy sources and a Strontium-90 source comprise a unique capability in deep dielectric charging evaluation under ambient to cryogenic temperature exposure conditions.

Specific related capabilities include:

- Pelletron Accelerator-Based Combined Environmental Effects Facility:
 - Low Energy Electrons (1 keV– 100 keV)
 - High Energy Electrons (100 keV– 2.5 MeV)
 - Protons (40 keV– 700 keV)
 - Vacuum Ultraviolet Radiation (VUV) (115 nm– 165 nm)
 - 16-inch square exposure area
- Solar Wind Test Facility:
 - Low Energy Electrons (1 keV– 100 keV)
 - Low Energy Protons (1 keV– 20 keV)
 - Vacuum Ultraviolet Radiation (VUV) (115 nm– 165 nm)
 - Near Ultraviolet Radiation (NUV) (230 nm– 500 nm)
 - Solar Simulator
 - 12-inch square exposure area
- Strontium-90 Source:
 - Simulates L2 electron spectrum
 - Beta spectrum emitter up to 2 MeV
 - 100 mCurie activity
- Other Electron and Proton Sources can be adapted to various vacuum chambers for customized test setups:
 - Low Energy Electrons (1 keV– 100 keV)
 - Low Energy Protons (1 keV– 30 keV)

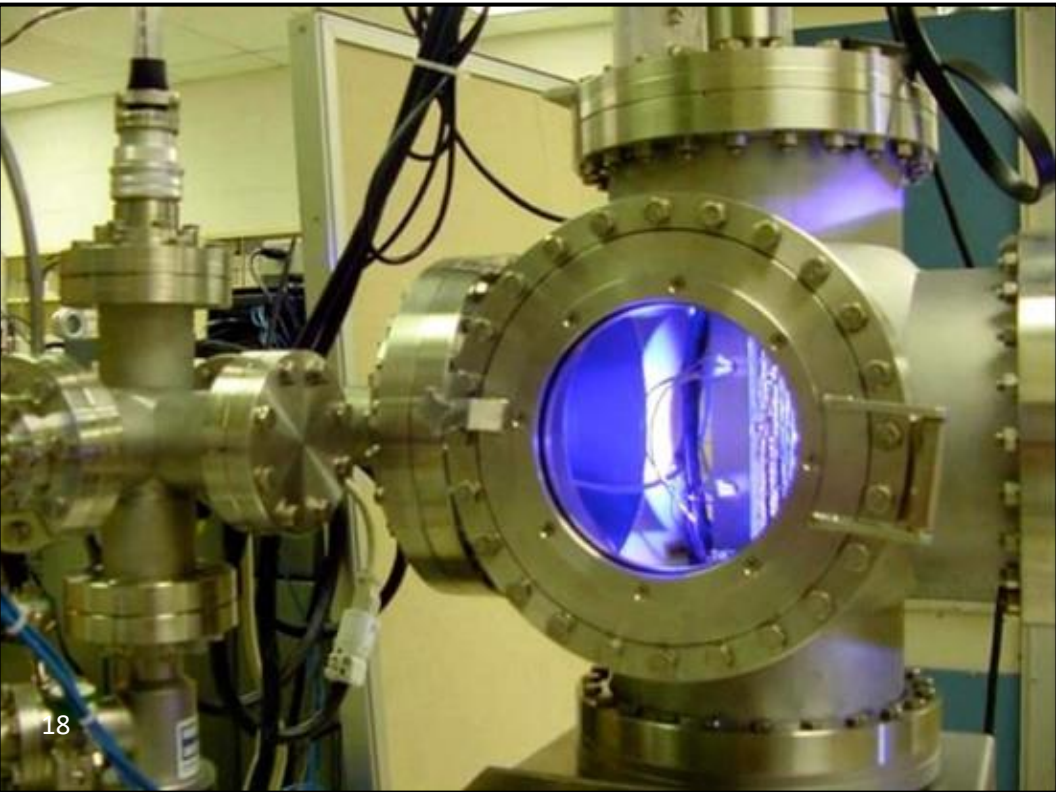


Pelletron Accelerator

Ultraviolet Radiation (UV) Exposure

Ultraviolet radiation, along with charged particle radiation can cause cross-linking (hardening) and chain scission (weakening) of polymers, darkening and color center formation in windows and optics. Ultraviolet radiation is typically split into two regions by wavelength, near ultraviolet radiation (NUV) and vacuum ultraviolet radiation (VUV). Vacuum ultraviolet radiation is the UV wavelengths that are absorbed by the air and is only present in space. Multiple vacuum chambers are available for UV exposure of a wide range of sample and component sizes. Synergistic effects are also studied in conjunction with other space exposure effects. Outgassing and contamination testing with and without UV allow for photo-deposition studies.

UV Exposure Chamber



Specific related capabilities include:

- X-25 Solar Simulator:
 - Three X-25 Solar Simulators with 2.5 kW Xenon arc lamps
 - Output spectrum of lamp is 250 nm to 2200 nm
 - Intensity ranges from 1 to 3 Equivalent Suns (ES) at AM0 over a 13-inch beam spot
 - X-25 intensity can reach up to 10 ES at AM0 over a 4-inch beam spot
- Enhanced Near Ultraviolet Radiation:
 - Two enhanced NUV systems with 1 kW Hg-Xenon lamps to accentuate the UV output
 - Majority of lamp spectral output over the range of 230 nm to 500 nm
 - Intensity ranges from 2 ES to 5 ES over an 8-inch spot diameter
- Combined NUV/VUV:
 - Unique test facility combining the illumination of a Vacuum Ultraviolet (VUV) source with an enhanced Near-UV (NUV) source
 - VUV radiation covers the wavelength range of 115 nm to 165 nm
 - NUV radiation covers the wavelength range of 230 nm to 500 nm
 - The NUV source has an intensity of 3 ES over a 6-inch diameter spot and the VUV source has an intensity of 5 ES over the same 6-inch spot
- High Intensity Solar Environment Test (HISSET):
 - Combines the elements of the solar wind environment with a high intensity, high power solar radiation source
 - The High Intensity Solar Simulator (HISS) is capable of producing intensity ranging from 10 ES over a 2-foot beam spot size to 600 ES over an 4-inch spot beam
 - Simulated solar wind environment of combined Low Energy Electrons (1 keV– 100 keV), Protons (1 keV– 30 keV), NUV and VUV
 - This facility can also be used for evaluating high temperature materials and components at temperatures exceeding 1,000 °C



Atomic Oxygen Beam Facility

Atomic Oxygen (AO) Exposure

On orbit, atomic oxygen is produced when ultraviolet radiation reacts with molecular oxygen in the upper atmosphere. Currently only found in low Earth orbit, between 100 and 1,000 km altitude, AO oxidizes metals, especially silver and osmium. AO reacts strongly with any material containing carbon, nitrogen, sulfur, and hydrogen bonds of 5 eV bond energy or less, meaning that most polymers react and erode away and ceramic coatings can be bleached. Polymers containing fluorine, such as Teflon, react synergistically, where the reactivity to AO increases with longer exposure to ultraviolet radiation. EM41's Atomic Oxygen Beam Facility (AOBF) was developed to expose samples to neutral atomic oxygen atoms with a kinetic energy of 5 eV to simulate the effects of spacecraft flying through the low Earth orbit (LEO) neutral environment.

Specific related capabilities include:

- Atomic Oxygen Beam Facility (AOBF)
 - 5 eV Neutral Beam
 - 10^{16} AO atoms/cm²sec
 - Concurrent VUV Radiation (130nm)

Plasma Exposure

EM41's plasma exposure and test systems have been developed for studying material conductivity, arc characterization, and high voltage system interactions with plasma and plasma generation and coupling to spacecraft systems including electrodynamic tethers. These systems can simulate natural environments such as low Earth orbit (LEO), geosynchronous Earth orbit (GEO) and polar orbit plasma conditions as well as man-made environments such as high density electric propulsion thruster plumes and plasma contactor systems.

The interaction of spacecraft systems with plasma environments can result in surface charging and arcing. This is particularly true of solar array systems which have been shown to be susceptible to Electro-Static Discharge (ESD) events. The need for testing system designs for materials and component ESD susceptibility is critical especially when approaching degraded end-of-life (EOL) conditions. In combination with other SEE test systems, a complete space environment exposure can be simulated to determine plasma effects on already aged material samples.

Specific related capabilities include:

- Low Earth Orbit (LEO) Testing
 - Electron Temperature Range (0.1 eV – 0.5 eV)
 - Plasma Density Range (10⁴ – 10⁶/cm³)
 - Monitored by Langmuir and emissive probes
- Geosynchronous Earth Orbit (GEO) Testing
 - Electron energies (1 keV– 100 keV)
 - Fluxes from 1 nA– 10 nA
 - Proton energies (1 keV– 30 keV)
- Electric Propulsion/Thruster Plume Testing
 - Argon and Xenon ions
 - Energy range from 100 eV to 1000eV
 - Current density from 5 nA/cm² to 10 mA/cm²

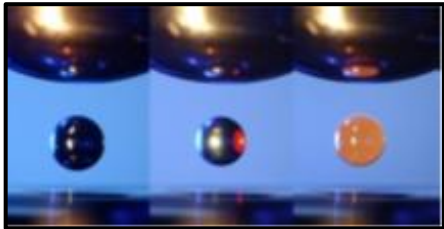
Plasma Exposure Testing



Electrostatic Levitation Laboratory

EM41's Electrostatic Levitation (ESL) Laboratory is a unique facility for investigators studying high-temperature materials. The laboratory boasts two levitators in which samples can be levitated, heated, rotated, melted, undercooled, and resolidified, all without the interference of a container or data-gathering instrumentation, and where many challenging gravitational effects are minimized. A high-temperature emissivity measurement system complements the levitation studies.

This exceptional suite of testing capabilities plays a prominent role in many ground-breaking research programs studying refractory metals, super alloys, ceramics, glasses, oxides, elemental metals, and binary and tertiary alloys. Such research has already led to the development of advanced high-temperature materials for aerospace applications (better rocket engine nozzles, radiator panels, and habitat surfaces), improved medical and industrial optics, metallic glasses that are stronger than steel, and materials with memory.



Levitated samples
inside the Main
Electrostatic Levitator

Main Electrostatic Levitator



HiTEMS Unit

Specific related capabilities include:

- Main Electrostatic Levitator
 - Sample size limited to 1–3 mm (0.039–0.12 in.) diameter
 - Sample mass is limited to ~15–80 mg (0.0005–0.003 oz)
 - Atmosphere capabilities include vacuum levels of 10–7 torr range and neutral gases: ≤ 5 atm
 - Heating capability is provided by a focused, steerable 200-Watt laser
 - Instrumentation includes a pyrometer, infrared camera, oxygen partial pressure control system, quenching system, magnetic rotation device with controlled sample spin (up to 30,000 Hz), and multiple high-speed cameras
- Portable Electrostatic Levitator (used for research in other facilities where additional capabilities, e.g., x-ray beam, are already in place)
 - Sample size limited to 1–3 mm (0.039–0.12 in.) diameter
 - Sample mass limited to ~15–80 mg (0.0005–0.003 oz)
 - Vacuum levels of 10–7 torr range
 - Heating capability is provided by a focused, 60 or 100 Watt laser
 - Instrumentation includes a pyrometer, infrared camera, and multiple high-speed cameras
- High-Temperature Emissivity Measurement System (HiTEMS)
 - Sample size limited to 9.5×9.5 mm (0.375×0.375 in.)
 - Vacuum levels of 10–7 torr range
 - Heating range is 827K – 3,000K (600 °C – 2,700 °C)

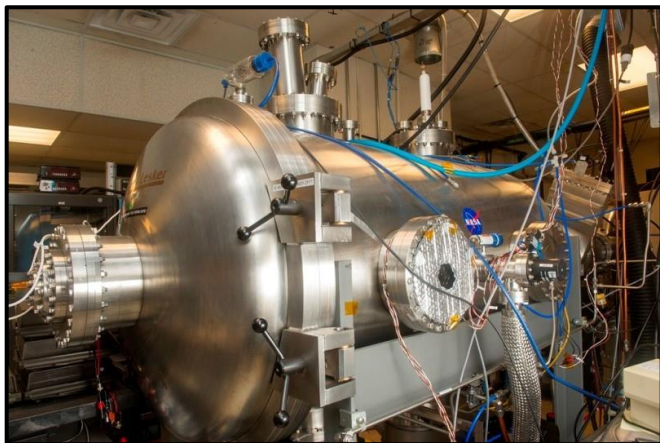
Planetary and Extraterrestrial Environments

EM41's Lunar Environments Test System (LETS) is the first and only operational test system available to examine the lunar surface environment including dust/regolith effects. LETS was designed to address the effect of the lunar environment on materials and systems as well as to enable study of the effect of lunar dust charging on materials and mechanisms. By combining expertise in electrostatic charging, solar wind simulation, and radiation technology, MSFC created a charged dust environment with a thermal control system to simulate the correct thermal environment that closely emulates the lunar surface environment as well as a lunar regolith handling system that is both vacuum and cryogenic compatible. The modular nature of the design allows this system to be transitioned on demand to examine other extraterrestrial surface environments such as that of a Near Earth Object or Mars.

Specific related capabilities include:

- Lunar Environments Test System (LETS):
 - Cryogenic pumped vacuum chamber (10–7 Torr)
 - Large quantity regolith handling container with 75 kg lunar simulant
 - Two sources for charging regolith
 - Deuterium Lamp (115 nm– 165 nm)
 - Low Energy Electron Source (1 keV– 100 keV)
 - Low Energy Proton Source (1 keV– 10 keV)
 - Quartz lamps for sample heating
 - Trek Probe for charge measurements
 - Neutral plasma source to discharge charged regolith
 - Particle Image Velocimeter (PIV)

Lunar Environments Test System



Flight Experiments

- Materials flight experiment experience over the past 30 years including development, operation, and analysis has contributed to MSFC's engineering expertise and ability to accurately simulate the space environment. These flight exposures help to verify ground based test system comparisons to flight environments and yield invaluable information on large variety of spacecraft materials.
- Long Duration Exposure Facility (LDEF)
- Optical Properties Monitor (OPM)
- Passive Optical Sample Assembly-I (POSA)
- Materials on International Space Station Experiment (MISSE)
- Floating Potential Measurement Unit (FPMU)
- Space Portable SpectroReflectometer (SPSR)

MISSE-2



MISSE-6A and -6B



LDEF

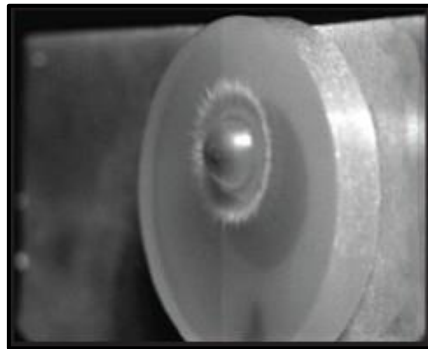


Impact Testing Facility (ITF)

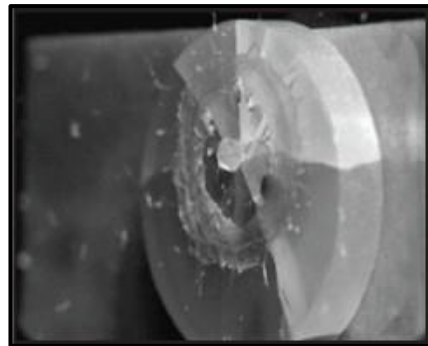
The ITF is one of NASA's premiere impact test facilities for materials science with gas, powder, and a two-stage light gas gun that can accommodate a wide range of projectile and target options. These systems allow scientists and engineers to simulate impacts ranging from rain to micrometeoroids and orbital debris in order to evaluate materials and components for flight and ground-based systems. Impact testing can be combined with other space environmental effects exposures to better evaluate the impact susceptibility of a material already degraded by the space environment. Testing can be accomplished in three general areas of interest: hypervelocity impact testing, ballistic impact testing, and weather encounter testing.

For velocities above those possible with physical test systems, smooth particle hydrodynamic code (SPHC) simulation and modeling support is available to evaluate one-, two-, or three-dimensional impacts on any material for which a specified set of properties is known.

Hydrometeor Impact Gun



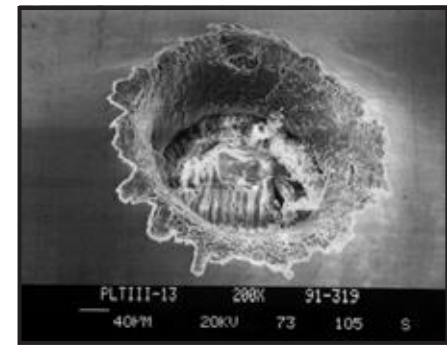
Polymeric bead impacting sensor window



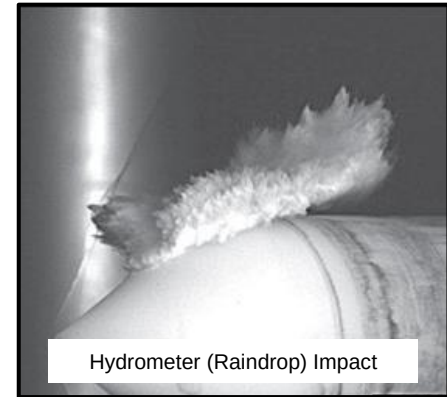
Post Impact Damage

Specific related capabilities include:

- Hypervelocity Impact Testing
 - Micro Light Gas Gun
 - Exploding Wire Gun
- Ballistic Impact Testing
 - Large Ballistic Gun
 - Small Ballistic Gun
 - Microballistic Powder Gun
 - Microballistic Gas Gun
- Weather Encounter Testing
 - Hydrometeor Impact Gun
 - Single-Particle/Multiparticle Impact Gun

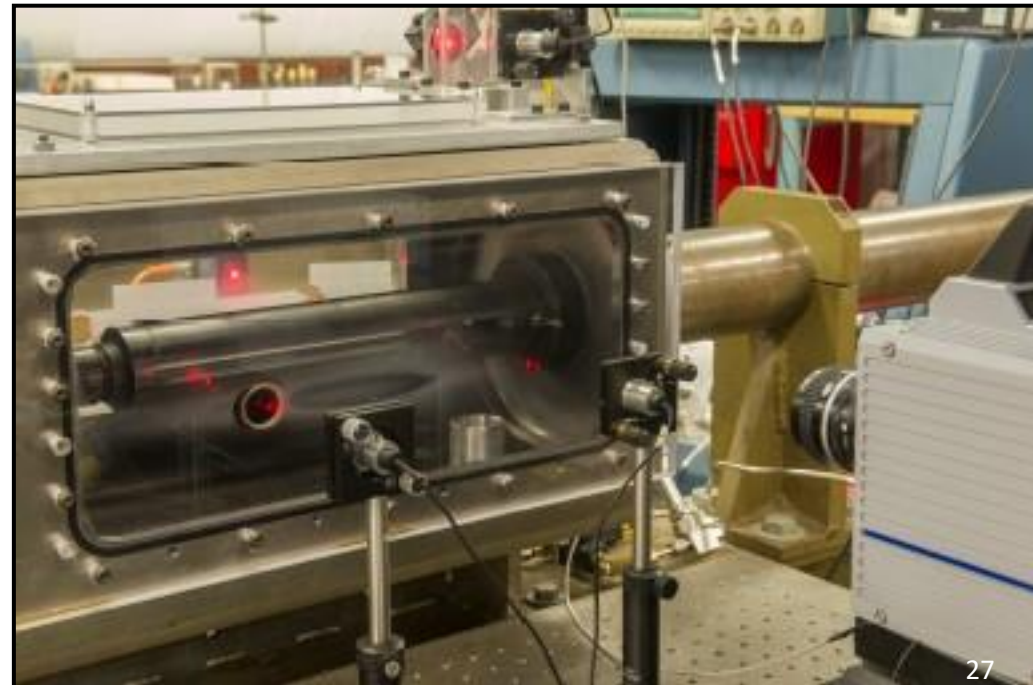


Micrometeoroid / Space Debris Impact



Hydrometeor (Raindrop) Impact

Hydrometeor Impact Gun



Additional Capabilities

Capability	Description/Features	Location
Walk-in Environmental Chamber	- Temperature range capability: -30°F to 185°F - Humidity range capability: 10 to 95% RH - Interior workspace: 141.125" width x 129.5" depth x 94.625" height	4707
Programmable Horizontal Tape Wrapper	- Used to fabricate ablative nozzle components and liners 3-axis movement with 60" swing - Variable speed control of all axis - Programmable controls for roller pressure, application speed, heating, and cooling - Capable of operating with various material types and widths - Capable of machining operations on non-cured materials 5-ton overhead crane for loading/unloading	4707
Thermal Protection System (TPS) Specimen Preparation	Specialized facility for milling, cutting, drilling, sanding, and bonding TPS materials	4707
Ascent Recession Analysis Measurement	Post test analysis of TPS mass loss and thermally effected areas due to ascent recession	4602
Ultracapacitor Ceramic Powder Milling	- Programmable vibratory mill with three dimensional agitation - Micro-mill capable of extreme, high yield particle size reduction (<50nm) and homogenization	4602
Particle Size Analysis	- Microtrac Bluewave with range from 0.01 – 2800 microns 780 nm, 405 nm lasers - Wet and dry measurement capability - Detailed statistical reporting	4602
Outgassing Measurement Capabilities	- Tests of materials per ASTM E595 and E1559 - Thermal quartz crystal microbalances are utilized for monitoring outgassing deposition rates on cryogenic to ambient temperature surfaces	4711
Coatings Development Lab	- Specialized facility for developing, improving and characterizing polymer coatings - Spray applications and specimen preparation - Dry film properties characterization and measurement	4602
Adhesive Bonding and Preparation	- Mixing of adhesive components in climate control environments - Elevated and room temperature capabilities - Isolated silicone bonding areas to reduce contamination - Specimen preparation per ASTM D1002, ASTM C297	4707 4602

Additional Capabilities

Capability	Description/Features	Location
Vertical Processing Fixture	- Turntable and support structure used for process development - Weight limit: 13,000 lbs. @ 5 rpm, 6,000 lbs. @ 10 rpm 20' diameter turntable bed - NEPA Class I Div I rated (can be used with flammable materials) - Integrated ducting for article heating	Mobile
Horizontal Processing Fixture	- Horizontal rolling support structure used for process development - Weight limit: 10,000 lbs. @ 10 rpm - Roll rings designed for 18' diameter hardware - Roll ring-to-roll ring distance can vary from 131.88" to 24' (requires structural plug) - NEPA Class I Div I rated (can be used with flammable materials) - Separate process air stinger cart mates for internal heating of test articles	Mobile
Transporter	- Multifunction flatbed transporter - Weight limit: 50,000 lbs. - Deck dimensions: 26' long x 18' wide - Maximum speed: 0.8 mph - Maximum range: three to four miles on single battery charge - Steer functions include regular 2 wheel steer, crab left, crab right, lateral travel, and rotate on center	Mobile
Coordinate Measurement Machine (CMM) Capability	3-D part inspection and measurement - FaroArm® Platinum 12' arm has single point repeatability of 0.029" and volumetric accuracy of ± 0.0041" - FaroArm® Platinum 10' arm has single point repeatability of 0.020" and volumetric accuracy of ± 0.0029" along with a laser line probe accessory - Faro Laser Tracker	4707
Analytical Capabilities	- Thermo-optical properties measurements - Reflectance measurements (VUV – visible) - Transmission – UV/visible/NIR - Microscopy 10x – 100x - Resistivity - Hi-pot - Fourier Transform Infrared Spectroscopy (FTIR) - X-Ray Fluorescence - High-speed digital photography	4711

National Aeronautics and Space Administration

George C. Marshall Space Flight Center

Huntsville, AL 35812

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