9-25-2010

Comparison of Flight and Ground Tests of Environmental Degradation of MISSE-6 SUSpECS Materials

JR Dennison
Utah State Univesity

John Prebola
Aerospace Testing Alliance, Arnold Air Force Base

Amberly Evans Jensen
Utah State University

Joshua L. Hodges
Utah Sate University

Recommended Citation

Dennison, JR; Prebola, John; Evans Jensen, Amberly; and Hodges, Joshua L., "Comparison of Flight and Ground Tests of Environmental Degradation of MISSE-6 SUSpECS Materials" (2010). 11th Spacecraft Charging Conference. *Conference Proceedings.* Paper 24.
https://digitalcommons.usu.edu/mp_conf/24

Comparison of Flight and Ground Tests of Environmental Degradation of MISSE-6 *SUSpECS* Materials

JR Dennison, John Prebola†, Amberly Evans*, Danielle Fullmer*, and Joshua L. Hodges**

* USU Materials Physics Group
Utah State University, Logan, Utah 84322-4415
Phone: (859) 559-3302, FAX: (435) 797-2492, E-mail: JR.Dennison@usu.edu

† *Aerospace Testing Alliance*
Arnold Air Force Base, TN, 37389
Phone: (931) 454-4997, E-mail: John.Prebola@arnold.af.mil

UtahStateUniversity MATERIALS PHYSICS GROUP

11th Spacecraft CHARGING Technology Conference

Pre- and Post-Flight Comparisons

Optical microscopy and normal specular reflectance of pre- and post flight samples are compared to assess on–flight degradation.

Before After Before After Before After
Black Kapton Aquadag Kapton, HN

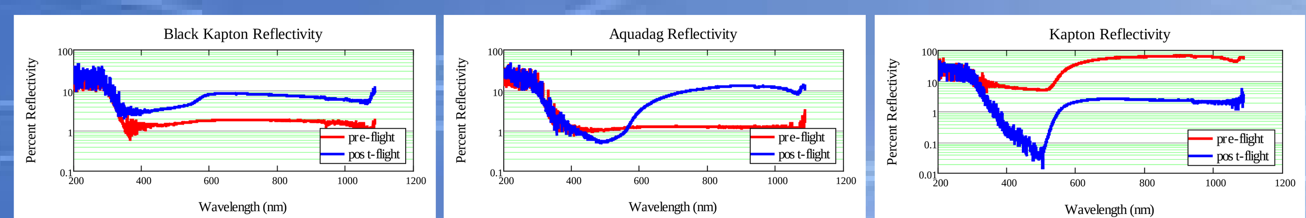
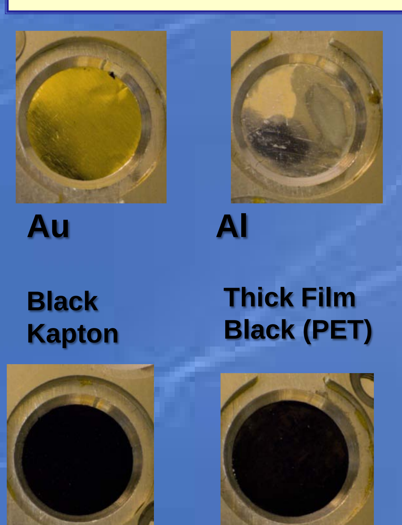


Figure 1. Photographs and UV/VIS/NIR spectra comparing pre- and post-flight samples from SUSpECS II with ram exposure (Black Kapton 100XC, Acquadag, Kapton HN & Ag coated Mylar) and from SUSpECS III with wake exposure (Ag). Note the apparent micrometeoroid impact and the full AO oxidation of the Ag of the Ag coated Mylar sample.

Before After Before After
Ag Mylar with micrometeoroid impact

Charge-Induced Contamination Study

This comparison focuses on six sets of four identical samples [Au, Al, carbon-loaded polyimide (Dupont Black Kapton 100XC), and carbon-loaded polyester (Sheldahl Thick Film Black)]. Two sample sets were located on the top and bottom tiers of a three-tiered sample panel designed to provide variable atomic oxygen and UV exposure. The four other sample sets were located on the wake side sample panel, with sets biased for the duration of the flight at 0 VDC, +5 VDC, -5 VDC, and -15 VDC, respectively. The biased sample configuration was designed to approximate typical conditions of materials subject to spacecraft charging. Positively charged components will typically charge to only a few volts positive. By contrast, negatively charged materials can charge to large voltages. Biases of -5 V and -15 V were chosen as representative of modest and more extreme negative charging.



Effects of Evolving Contamination on Charging

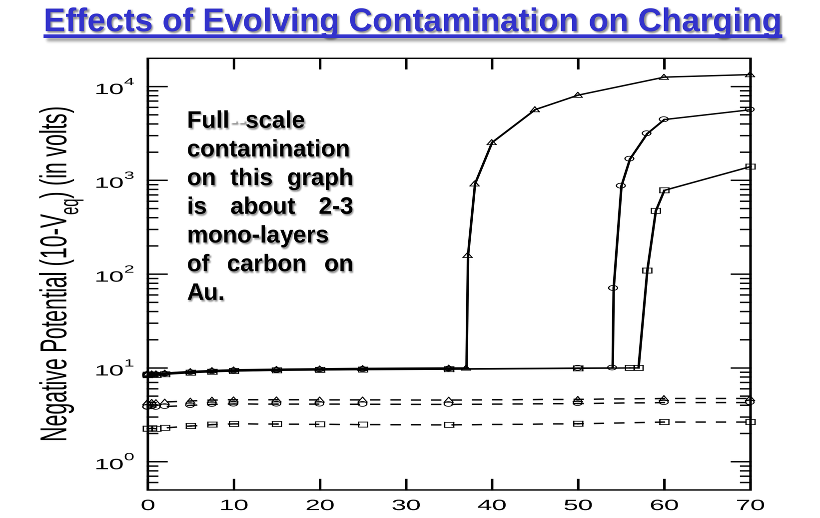
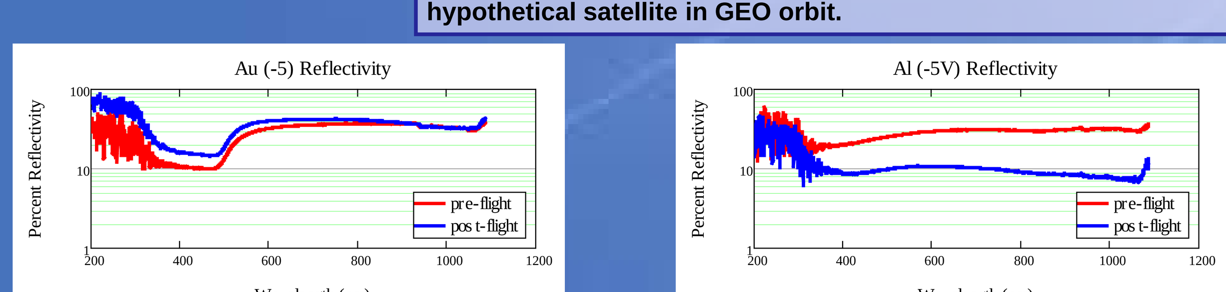


Figure 2. Photographs an reflectance spectra of -5 V charge samples with wake exposure on SUSpECS I.

USU studies have shown that very thin layers of contamination—even a few monolayers—can potentially cause significant changes in electron emission properties that can dramatically affect satellite. charging The graph at left shows the differential charging of clean Au and carbon-contaminated Au surfaces on a hypothetical satellite in GEO orbit.



Future Work

Work on analysis of the effects of space environment exposure on the 168 samples has only begun. Measurements of optical and electron microscopy, reflectivity, FTIR, emissivity, mass loss, electron-, ion- and photon-induced electron emission, photoyield, AES, photoemission, and variable angle UV/VIS/NIR reflectivity will continue. Work will also progress in collaboration with the AEDC space simulation facility to understand the origins of these effects and quantify their impacts.

Abstract

The effects of prolonged exposure to the LEO space environment and charge-enhanced contamination on optical, thermal, and electron emission and transport properties of common spacecraft materials has been investigated by comparing pre- and post-flight characterization measurements. The State of Utah Space Environment & Contamination Study (SUSpECS) deployed in March 2008 on board the Materials International Space Station Experiment (MISSE-6) payload, was exposed for ~18 months on the exterior of the International Space Station (ISS), before retrieval in September 2009. A total of 165 samples were mounted on three separate SUSpECS panels on the ram and wake sides on the ISS. Electron-, ion-, and photon-induced electron emission yield curves, crossover energies and emission spectra, resistivity, dielectric strength, optical and electron microscopy, UV/VIS/NIR reflection spectroscopy, and emissivity were tested for pre-flight SUSpECS samples in their pristine conditions.

MISSE Objectives

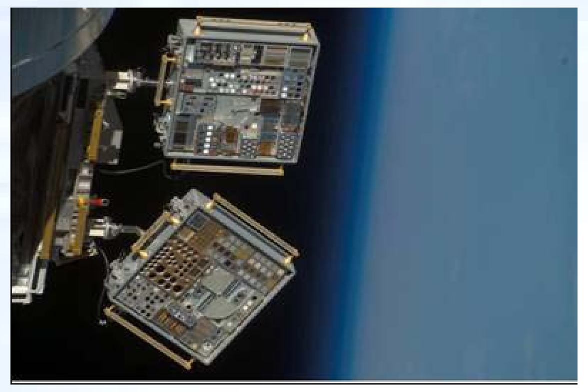
The purpose of MISSE is to characterize the performance of new prospective spacecraft materials when subjected to the synergistic effects of the space environment.

MISSE-6 Time Table

1/05	Sample selection completed
12/05	PEC's completed and tested for flight readiness
3/2008	Launch on Space Shuttle ISS-123
9/2009	Return of samples from space

Launch

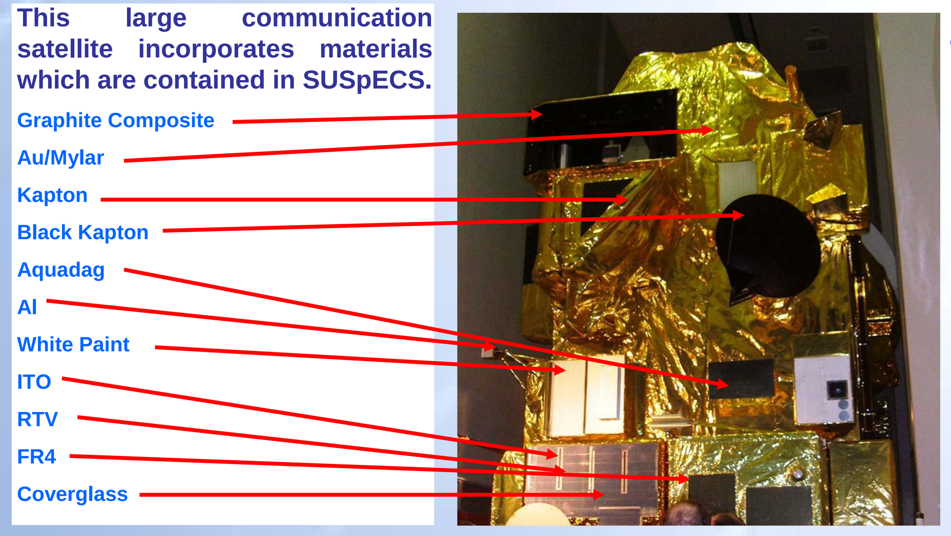
Deployment



Retrieval

SUSpECS Test Samples and Mounting

This large communication satellite incorporates materials which are contained in SUSpECS.



Sample Sources

- Wide array of common spacecraft materials (see left).
- Basic materials and key contaminants of ISS solar arrays and structure.
- Materials from CRRES satellite designed to study environment-induced charging and arching.
- Materials used in Floating Potential Measurement Unit (FPMU) plasma probe for ISS.
- Critical thermal control and optical materials for SDL GIFTS payloads.
- Composite and ceramic materials of the ATK Thermal Protection Systems (TPS) and the ATK Lightweight Structure Systems (LSS) .
- James Web Space Telescope Insulator Sample Charging Tests.
- Solar Probe Mission Heat Shield Insulator Samples tests.

USU Electron Emission/Resistivity Samples

Au [R,WB], Al [R,WB], 316 SS [R,W*], Au/Ni on Cu [R,W*]
Dupont Black Kapton [R,WB], Sheldahl Thick Film Black [R,WBI, Aquadag [R,W*], PI-Kapton [R,W], PET-Mylar [R,W], PTFE-Teflon [R,W]
FR4 [R,W], DC93-900 RTV on Cu [R,W]
CeO_2-doped glass solar cell cover slips [R,W], Al_2O_3-Alumina [R,W]
Anodized Al (Cr) [R*,W], Anodized Al (S) [R*,W]
Cu [R*,W*], Graphitic amorphous carbon [R*,W*]
Nylon [R*,W*], Kevlar [R*,W*l, ITO on Kapton [R*,W*], SiO_2 [R*,W*]
UV-coated CCO_2-doped solar cell cover slips [R*,W*]
CV-1147 RTV on Cu [R*,W*]

Charge-enhanced Contamination Samples

Au [R,WB], Al [R,WB], Dupont Black Kapton [R,WB]
Sheldahl Thick Film Black [R,WB]

CRRES Samples

PI-Kapton [R,W], PET-Mylar [RW], PTFE-Teflon [R,W]
FR4 [R,W], Al_2O_3-Alumina [R,W], SiO_2 [R*,W*]

ISS Samples

Au [R,WB], Al [R,WB], 316 SS [R,W*], Dupont Black Kapton [R,WB], PI-Kapton [R,W], DC93-900 RTV on Cu [R,Wl, Al_2O_3-Alumina [R,W]
CeO_2-doped glass solar cell cover slips [R,W]
Anodized Al (Cr), [R*,W], Anodized Al (S), [R*,W]
UV-coated CeO_2-doped solar cell cover slips [R*,W*]
CV-1147 RTV on Cu [R*,W*l

ATK and USU Space Dynamics Lab Composite Samples

COIC S400 COIC S200H and COIC S300 Nonoxide Ceramic-Metal Composites [W]
SDL/GIFTS Reinforced Carbon Nono-fiber/RS-3 Cyanate Ester Composite [W]
SDL PTFE [RWB]

Solar Probe Mission (JHU/APL) Samples

Plasma sprayed Al2O3 on Carbon/Carbon Composite [W]
Al2O3 [W[, Pyrolytic Boron Nitride on Carbon/Carbon Composite [W]
Pyrolytic Boron Nitride [W], Barium Zirconium Phosphate [W],
Carbon/Carbon Composite [W]

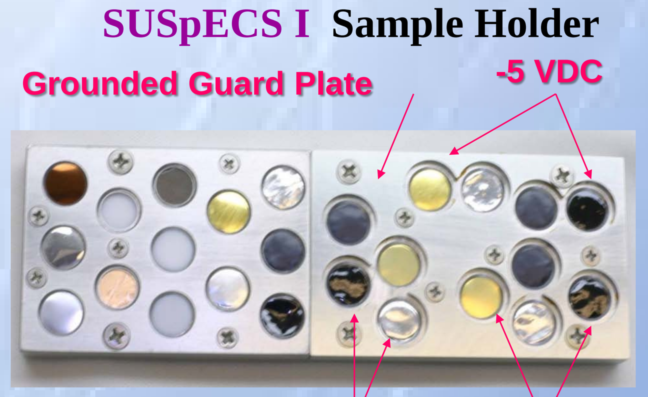
JWST Samples

PTFE [W], Kapton HN [W]. Tefzel [W], Hytrel [W] Kapron XC100 [W], Kapton E [W][R,WB],

SUSpECS I Sample Holder

Wake Side

- 13 Grounded Samples
- 12 Biased Samples: for 3 sets of 4 samples with low current biases for charge-enhanced contamination studies.
- 6 Concealed samples



Sample Holders

- Holder area 5 cm x 15 cm
- 9 mm diameter exposed sample area

SUSpECS II Sample Holder

Ram Side

- 25 Exposed samples on each of 3 tiers for varying AO and UV exposure.
- 23 Concealed samples

SUSpECS III Sample Holder

Wake Side

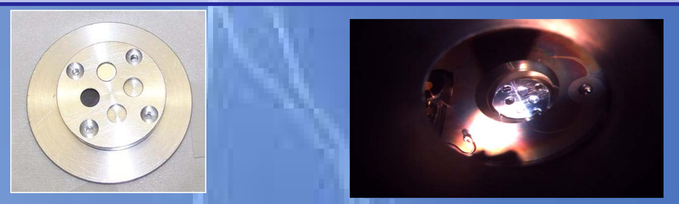
- 25 Grounded Samples
- 10 Concealed samples

Space Environment Simulation at ADEC

The second comparison reported here focused on four materials [carbon-loaded polyimide, polyester (Dupont Mylar), Al_2O_3 (sapphire), and SiO_2 (quartz)] that showed some of the most pronounced environmentally–induced changes in optical properties. Samples of each material on the wake and 3-tiered sample panels were exposed to a complex environment during the flight. Identical witness samples were also exposed to a simulated subset of the environment in the Characterization of Combined Orbital Surface Effects (CCOSE) space environment test chamber at the USAF Arnold Engineering Development Center to mimic the space exposure profile. The primary optical characterization methods employed for the comparison were UV/VIS/NIR and FTIR transmission of the sapphire and quartz and UV/VIS/NIR reflectance of the polyimide and polyester. Comparison of pre-flight, post-flight, and simulated exposure samples served two primary purposes: to investigate the validity of simulated environmental testing methods and to help distinguish the effects of specific components of the complex space environment that samples were simultaneously exposed to during the flight.

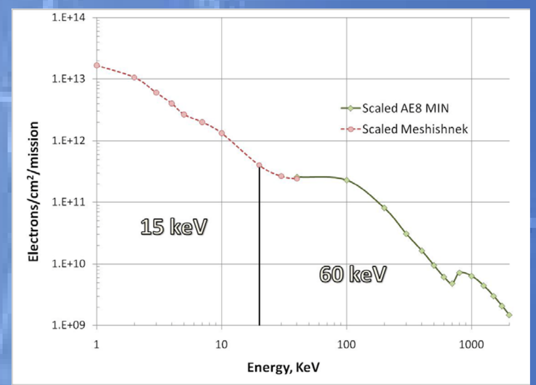
Analysis of constraints limited the selection of samples to those on SUSpECS II wake panel, primarily due to a maintenance overhaul of the CCOSE atomic oxygen source. In order to verify that all samples did not change in the same way, such as all darkening or all having no change, wake-side samples were selected which exhibited a variety of optical property changes on orbit. The final list was as follows: Mylar for having highly varying optical properties, Black Kapton for minor change, and quartz and sapphire for no change. These samples are shown in the Figures at right.

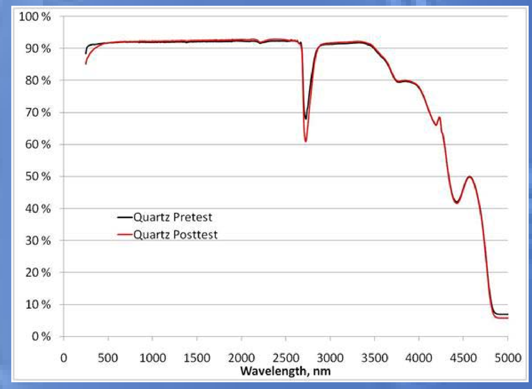
Figures Above. Ground test sample materials. Figures Below Custom Quad sample Holder. Figure Below. Ground Simulation division of the mission spectrum.



The primary constituents of the ISS orbit are vacuum, solar, atomic oxygen, protons and electrons. Of these, CCOSE could replicate all but the atomic oxygen. For the other components, the environment could be replicated if on-orbit data were available. Fortunately, the equivalent sun hour (ESH) estimates were provided by the Boeing ISS Thermal Analysis group. Utah State provided the temperature time history data from NASA. NASA had Boeing-supplied Lithium Fluoride (LiF) thermoluminescent dosimeters (TLDs) radiation detectors located behind some of the samples on the MISSE-6 mission. These detectors output total radiation dose measurements.

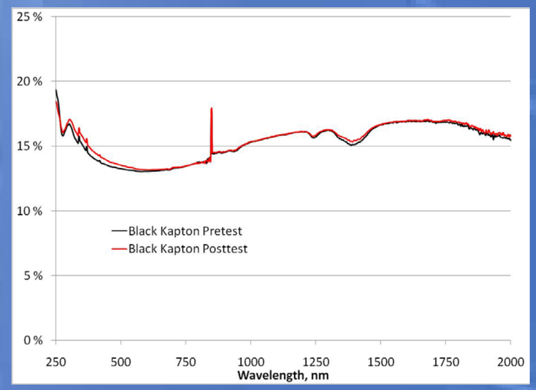
In order to properly set the CCOSE electron source, the CCOSE test profile was to divide up the electron spectrum and map it to the electron gun output. Due to the monoenergetic nature of the electron gun output, two different beam energies were selected to represent the full particle spectrum. (Figure-Top Right). A monoenergetic beam of 15 keV electrons was run to simulate the lower portion of the spectrum while a 60 keV beam was used for the upper. This resulted in a run time of 129 hrs of 15 keV and 39 hrs of 60 keV.

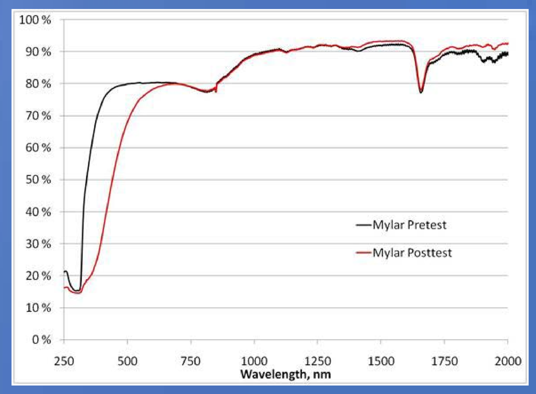




Pre-test reflectance and transmittance measurements were performed at atmospheric conditions using both a Jasco UV-VIS-NIR spectrometer and a Bruker FTIR spectrometer. Post-test reflectance and transmittance measurements were also performed with these instruments. The following results are based on initial assessment of the data and will be reviewed in greater detail in a future publication. The initial analysis follows the trend of the MISSE-6 SUSPeCS samples.

- As stated earlier, quartz and sapphire were selected for their resistance to any change. The figure at right shows the transmission measurements made before and after testing. Minimal changes were observed in the UV region with these samples but appeared primarily unchanged.
- Black Kapton had some small changes on the orbital samples but had little change in the ground test (Figure-Middle Right). This was likely due to interaction with AO on orbit and lack of AO in the ground test.
- The most noticeable change in both the flight and ground samples occurred on the aluminized Mylar (Figure-Bottom Right). Most of the loss appears within the visible region from 300 to 700 nm. This change was likely due to vacuum ultraviolet radiation severing the polymer bonds, but may have been enhanced by the electron beam as other researchers have found degradation in Mylar under energetic electron bombardment.





Acknowledgements

Research was supported by funding from USU Space Dynamics Laboratory, Johns Hopkins Applied Physics Laboratory and a Utah State University Undergraduate Research and Creative Opportunities grant. A special thanks to the USU Get-Away-Special Team for there critical roll in the design and construction of SUSpECS.