MISSE-16 Overview

4th VOLTRON Meeting, February 22-24, 2023

Georgia Tech Research Institute

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Team

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DuPont de Nemours

- **Jainisha R. Shah and Sydney E. J. Collman**

Assurance Technology Corporation

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Timeline

May 2020
Proposal submitted to ISS NL

August 2020
Project started

July 2022
Launch from the Kennedy Space Center

August 2022
First data are taken

March 2023
Expected return on Earth

August 2023
End of the project

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Motivation

Thorough characterization of physical and chemical changes of heritage and novel spacecraft materials under true space exposure and ground-based space-simulated weather is important

- Establishing correlation factors between true space exposure and accelerate space weather experiments
- Enabling accurate prediction of on-orbit material performance based on laboratory-based testing
- Supporting material identification for space situational awareness

Materials International Space Station Experiment (MISSE) Flight Facility (MISSE-FF) is a perfect testbed to generate benchmark data for the efficiency validation of ground-based space weather simulation experiments

Approach

Phase I

MISSE-FF spectral analysis of flight samples

- Optical imaging of samples as a function of time in orbit

We are here

Phase II

Ground-based analysis of duplicate sets of flight samples

- Control samples characterization
- Preparation and characterization of flight duplicate samples

Done

Phase III

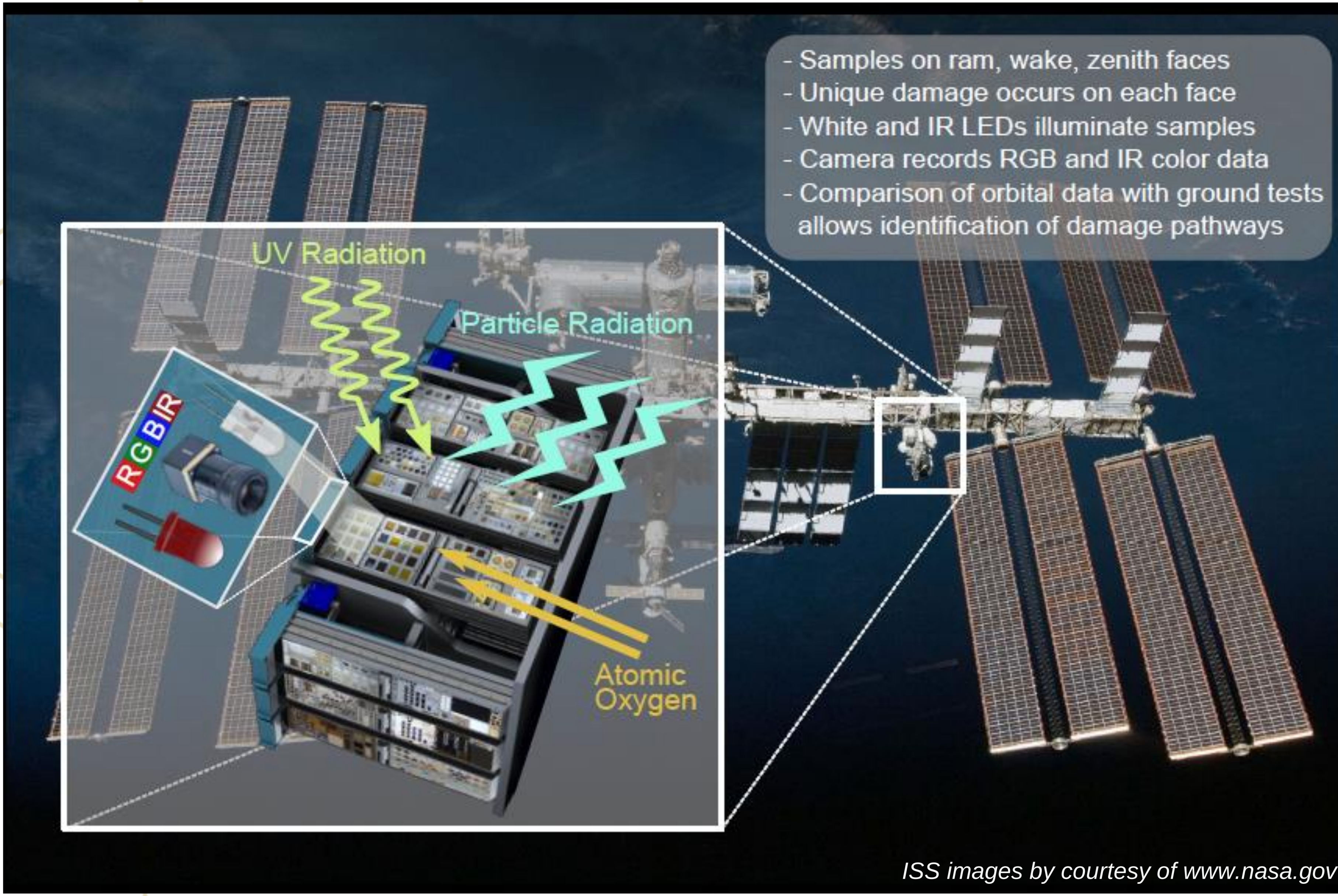
Post-flight analysis of the flight samples

- Comparison of control, flight-duplicate, and flight samples

2023 Work

Materials International Space Station Experiment (MISSE)

MISSE-16 Overview



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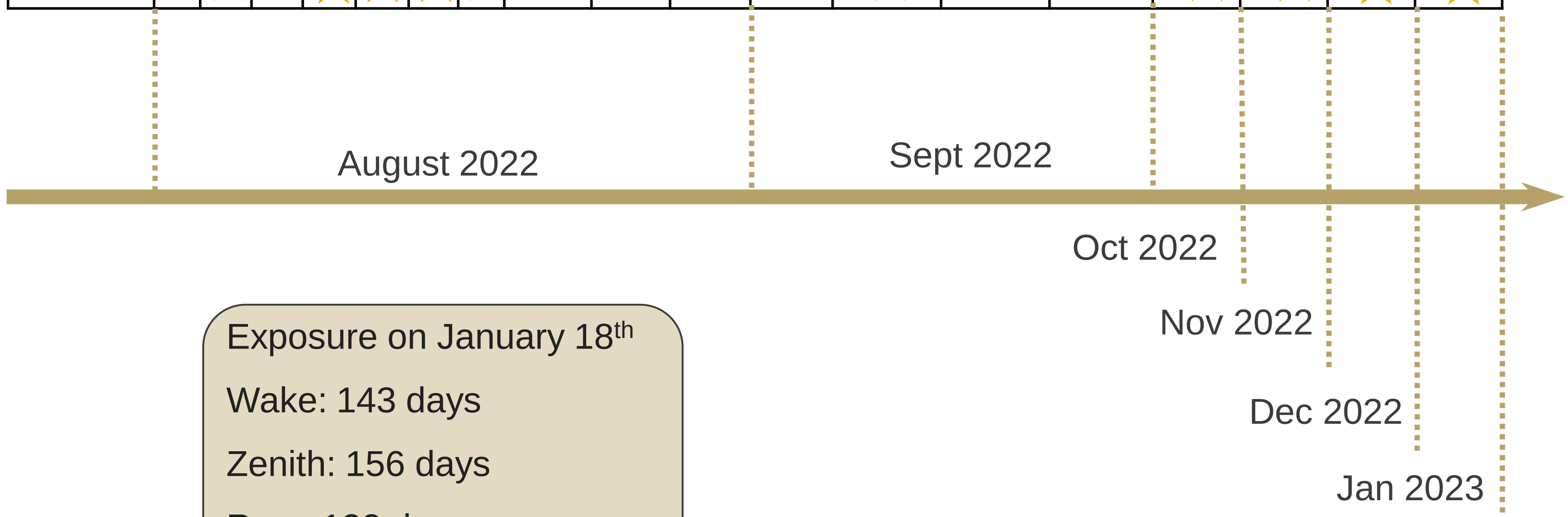
Orbital Experiment Measurement Cadence

MISSE-16 Mission Duration

	M1										M2				M3	M4	M5	M6
	W1							W2	W3	W4	W1	W2	W3	W4				
	1	2	3	4	5	6	7											
Ram	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★
Wake	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★
Zenith	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★



Exposure on January 18th

Wake: 143 days

Zenith: 156 days

Ram: 133 days

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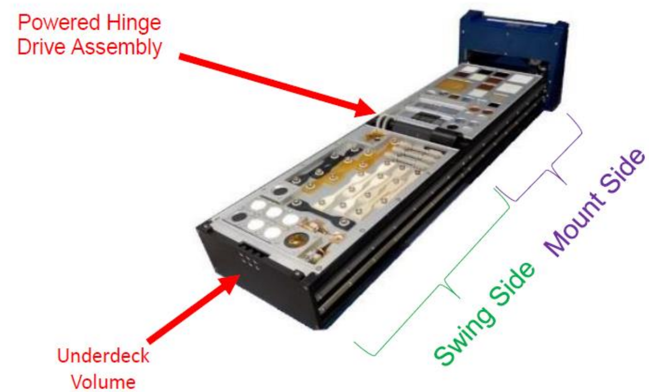
MISSE-16 Materials

	Material	Type	
1	Kapton® CR	PI/ PMDA	Corona-resistant; shielding of sensitive equipment
2	Kapton® CS		Thermoformable; component of next-gen space solar cells
3	Kapton® WS		High thermal stability; alternative for traditional PI film in MLI blankets
4	Kapton® XC		Electrically conductive; space charge mitigation
5	Kapton® TF		Thermoformable; candidate for small satellite parts manufacturing
6	DR9		Novel material in PI family
7	Kapton® HN		"Golden standard" of space industry
8	Economyplate™ Carbon Fiber	CFRP	Used in construction of present-day LEO satellites
9	G-10/FR4 Glass Epoxy	GFRP	
10	Zenite®	LCP	Flexible LCP antennas and LCP-based circuits molded to available spacecraft areas
11	Melinex® 454	PET	Candidates for improved MLI reflectivity and durability
12	Mylar® M021		
13	CORIN®XLS	POSS	Optical signature characterization for orbital debris and operational RSO
14	Thermalbright®N		
15	Alumina	Alum. Oxide	Optical standard

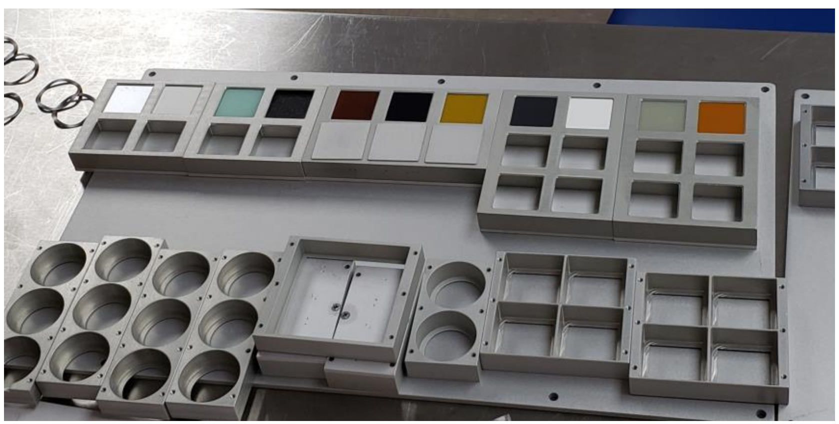
MISSE-16 Materials

Mount

Swing



Photo/image credit: Aegis Aerospace



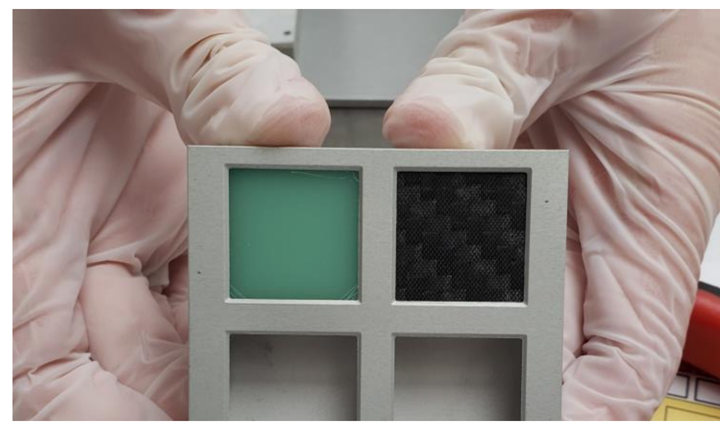


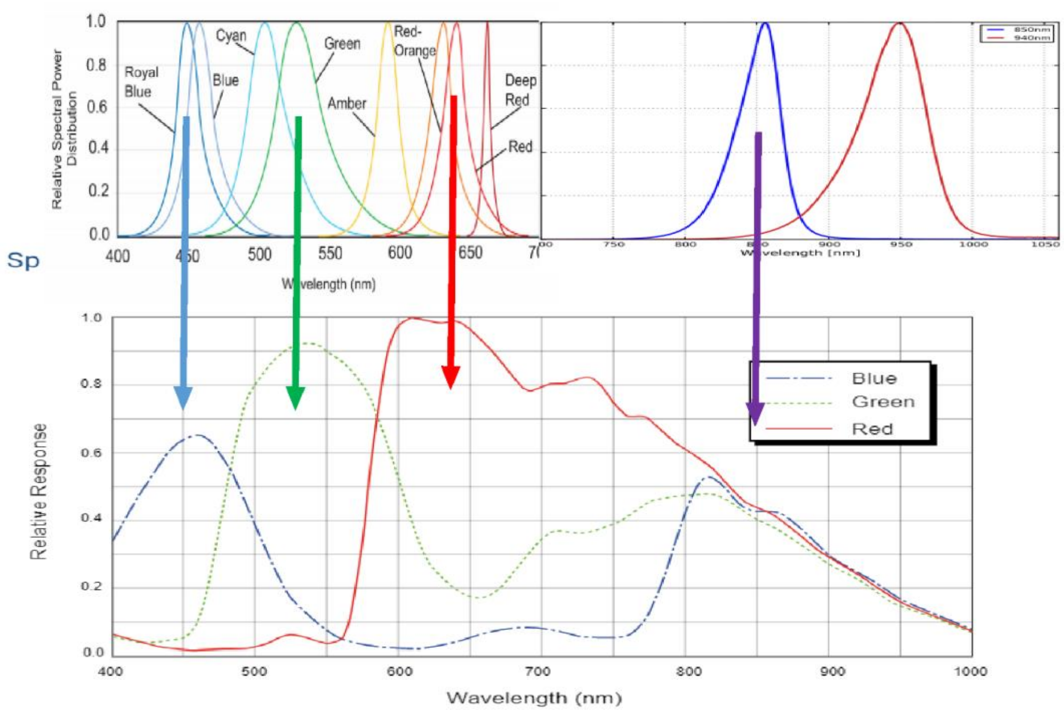
Image credit: NASA/JSC

MISSE-FF Camera Board Integration

Lights

Camera

Photo credit: AFRL



https://www.baslerweb.com/en/products/cameras/area-scan-cameras/ace/aca2440-20gc/

Basler daA1600-60uc camera with IR LED illumination that provides broad illumination ranges in IR region

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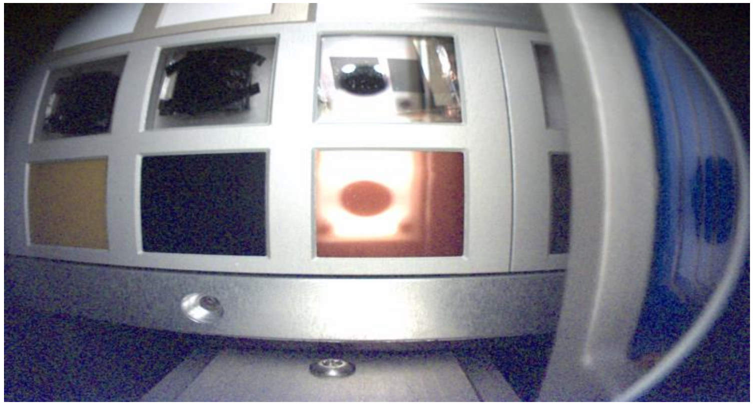
MISSE-FF Camera Board Integration

Camera board assembly



Sample image delivered by the Basler daA1600 camera

Image credit: AFRL

MISSE-16 Launch and MSC Installation


Photo credit: NASA

MISSE-16 Science Carriers (MSCs) were installed on the MISSE-FF on 31 July - 2 August 2022 with support from the Canada Space Agency ISS Robotic Systems Team

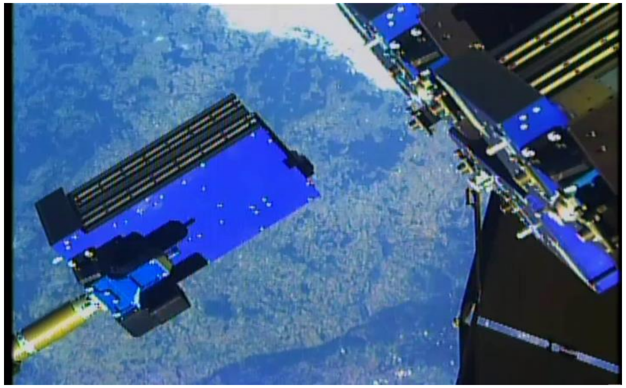
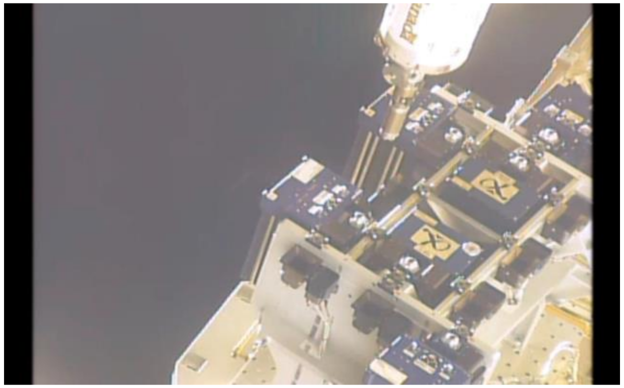
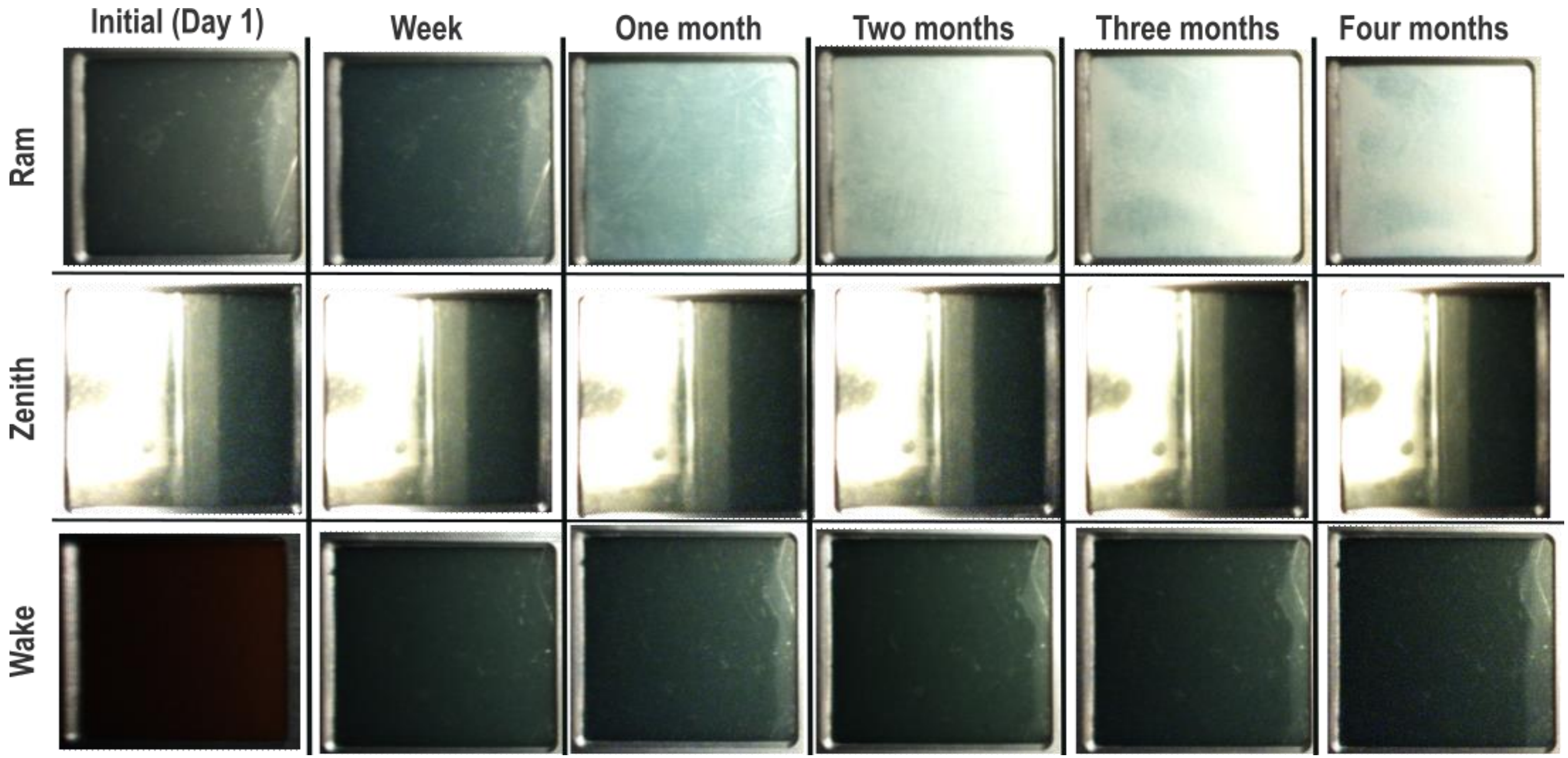



Photo credit: NASA

News Articles
Launch https://spacenews.com/spacex-launches-cargo-dragon-mission-to-iss/
Docking https://spaceflightnow.com/2022/07/16/spacex-crs-25-iss-docking/

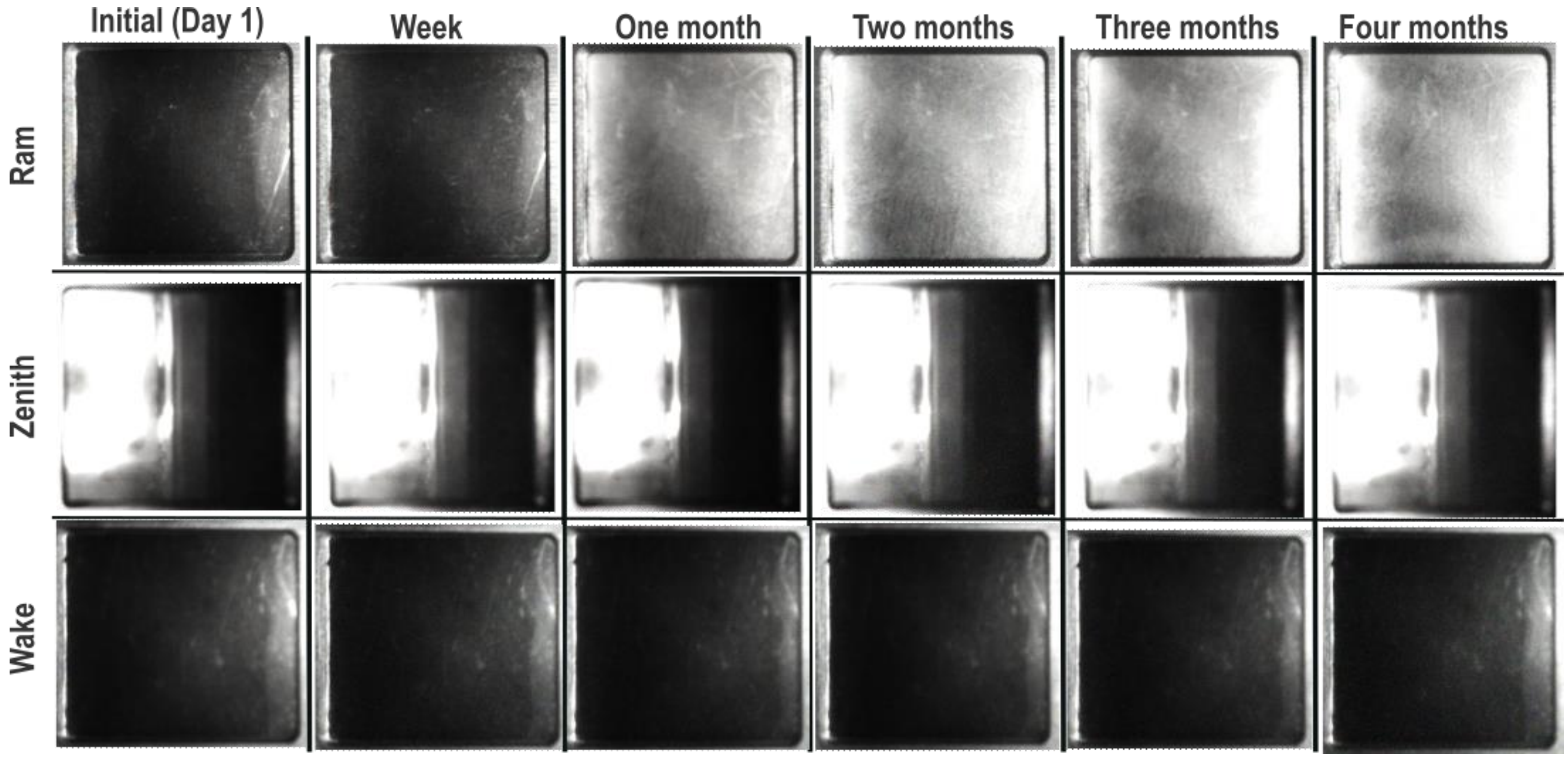
Representative Orbital Data (Visible)



Visible images of Kapton® CS on Ram, Zenith, and Wake ISS faces

Photo/image credit: Aegis Aerospace

Representative Orbital Data (IR)

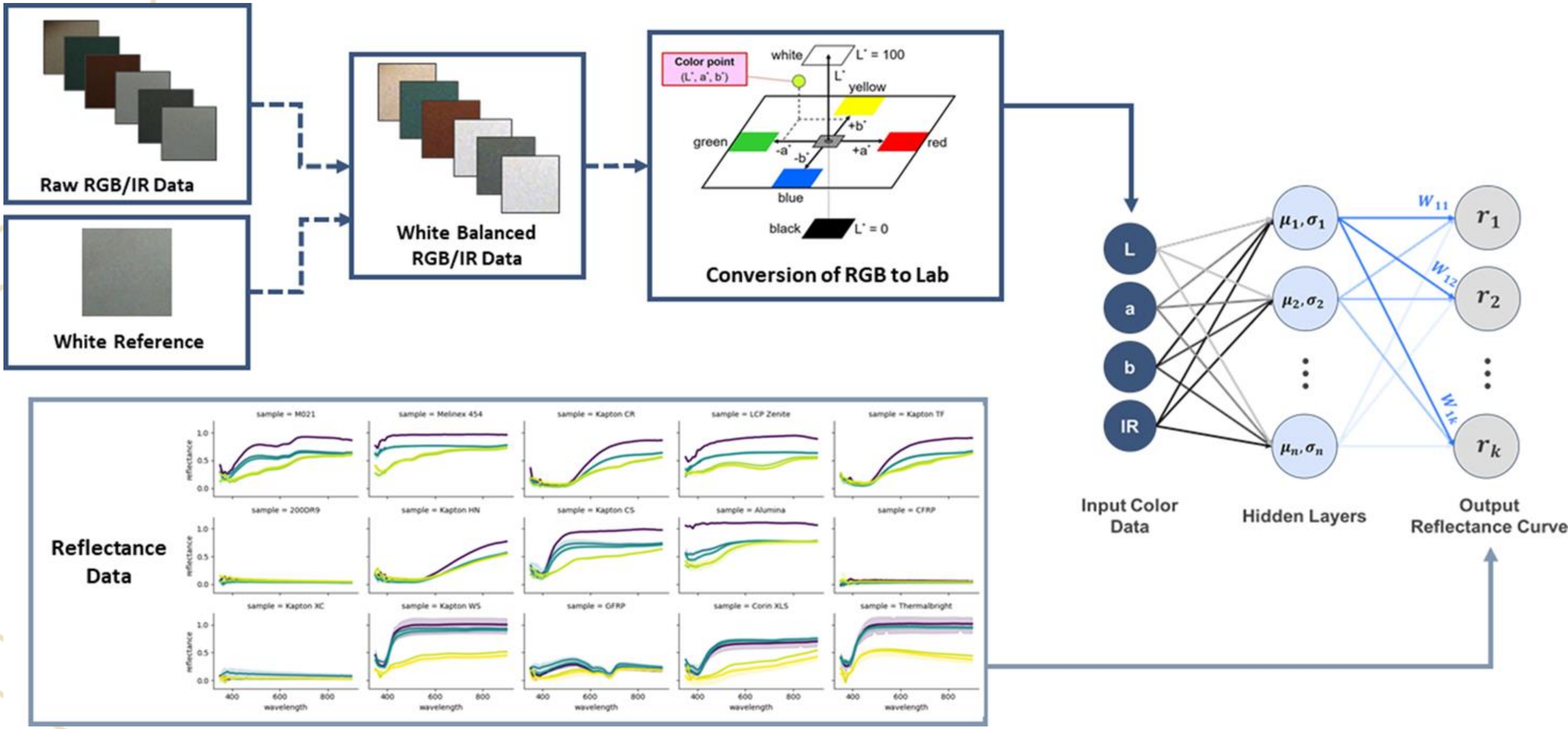


IR images of Kapton® CS on Ram, Zenith, and Wake ISS faces

Photo/image credit: Aegis Aerospace

Spectral Analysis of MISSE-16 Flight Samples

Machine Learning Approach



- The ML Algorithm gives an estimated reflectance spectrum for each taken image
- Spectral characterization from a camera is an under-constrained problem since it involves mapping from a low dimensional space (RGB/IR pixel counts) to a high dimensional space (reflectance as a function of wavelength)
- Utilized ML approach uses a radial basis function (RBF) network

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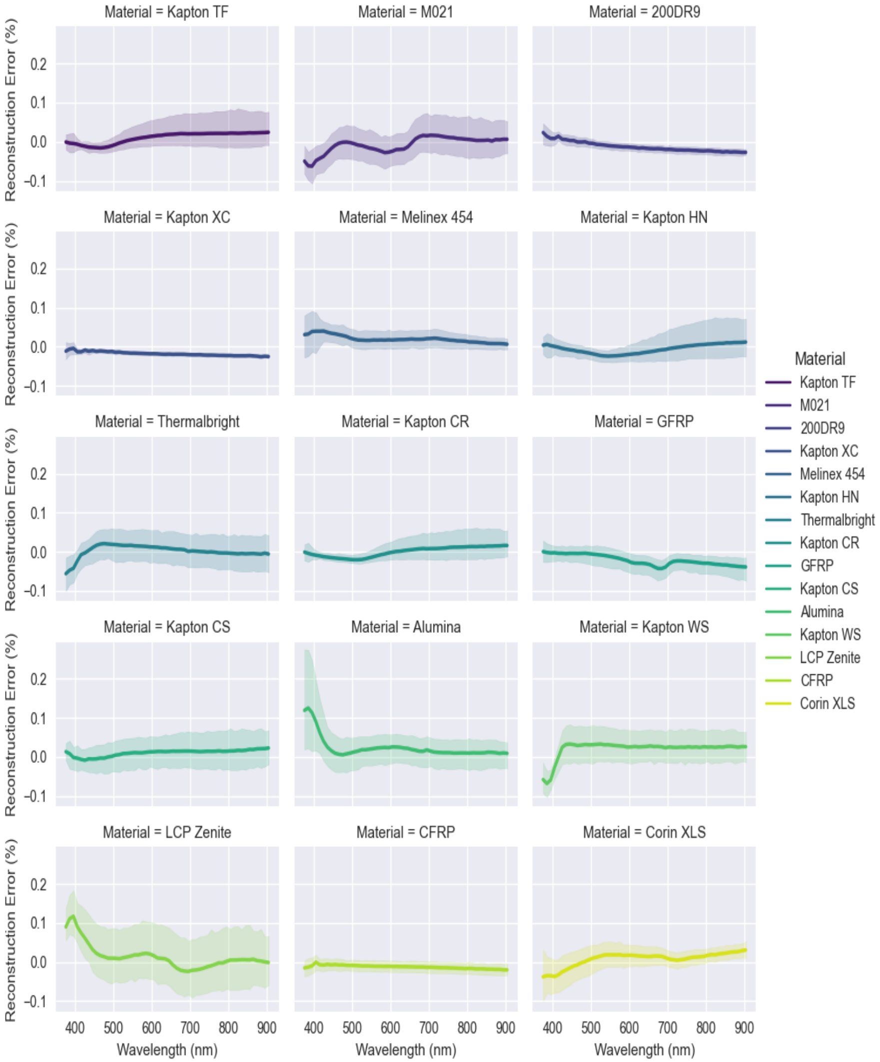
Model Validation

- Model was trained on 140 samples of color (L*a*b* and IR) and spectral information
- Validation was done on approximately 70 samples of color (L*a*b* and IR) and spectral information. There was a 2/1 split in the training and validation datasets respectively
- Dark lines represent mean reconstruction error and transparent bars represent the spread of the error
- Model is able to retrieve the spectrum to within 10% error for the majority of samples across wavelengths 350nm to 900nm
- Lowest overall error is near the green (500nm) and red (650nm) wavelength regions and highest overall error occur in the blue (400nm) region.



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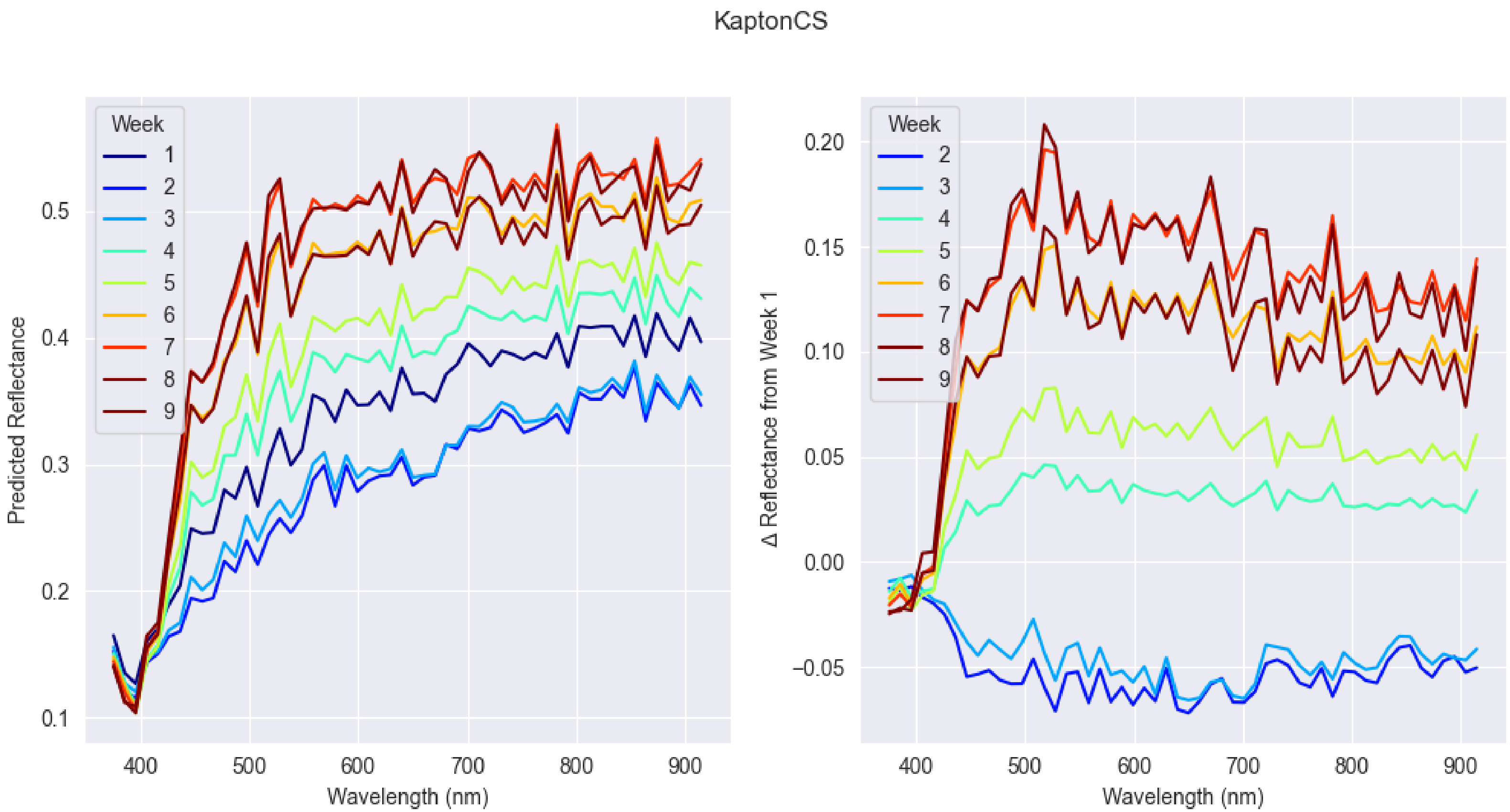
- Data were preprocessed using empirical line method alignment for white balancing prior to feeding it to the ML model



Reflectance curves extracted from the visible RAM images of Kapton® CS

Material Characterization of MISSE-16 Flight Duplicate Samples

Weathering Facilities

Electron and VUV Exposure

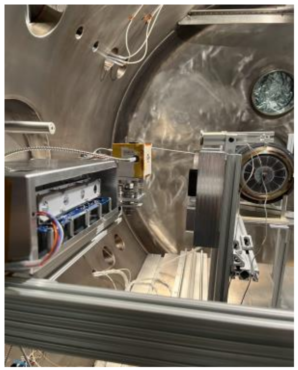
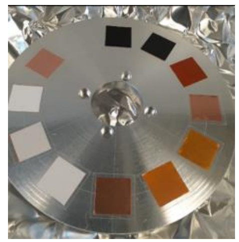
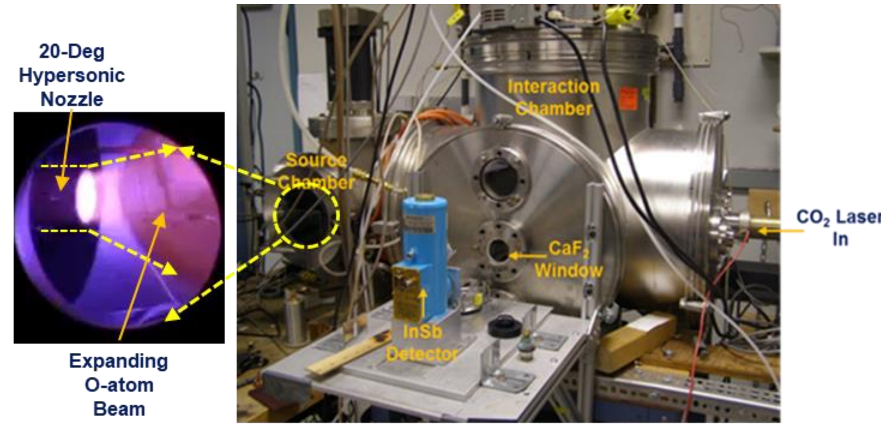




Image credit: AFRL

- Materials may be irradiated with high-energy electrons (up to 100 keV) and/or exposed to VUV particles
- *In situ* directional hemispherical reflectance (DHR), surface potential decay (SPD), and Fourier-Transform Infrared (FTRI) spectral measurements capabilities

AO Exposure



U.S. Patent 4,894,511, Foreign Patent

Image credit: PSI

- Targeted peak fluence of 2 x 10^{20} O/cm^2
- 8 km/s O-atom beam generated in high vacuum chamber with pulsed laser discharge
- AO beam is a neutral atom beam with a ~1% O+ ion content

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Characterization Measurements

Material		Characterization Technique/Responsible Party										
		Surface morphology			Optical measurements					Charge Transport		Vis/IR camera
		DSLR	SEM	AFM	R %	T %	BRDF	FTIR	DHR	ASTM	SPD	Images
1	Kapton® CR											
2	Kapton® CS											
3	Kapton® WS											
4	Kapton® XC											
5	Kapton® TF											
6	Kapton® HN											
7	DR9											
8	CFRP											
9	GFRP											
10	Zenite®											
11	Melinex® 454											
12	Mylar® MO21											
13	CORIN®XLS											
14	Thermalbright®N											

NASA JSC GTRI SCICL (AFRL)

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Characterization Measurements

Measurements = 14 x 11 x 4

Materials

Techniques

Conditions
- Pristine
- E-irradiated
- AO – exposed
- VUV - exposed

- Single-layer films were prepared and characterized
- AFM measurements were repeated at least 5 times per sample
- Measurements were often repeated for verification

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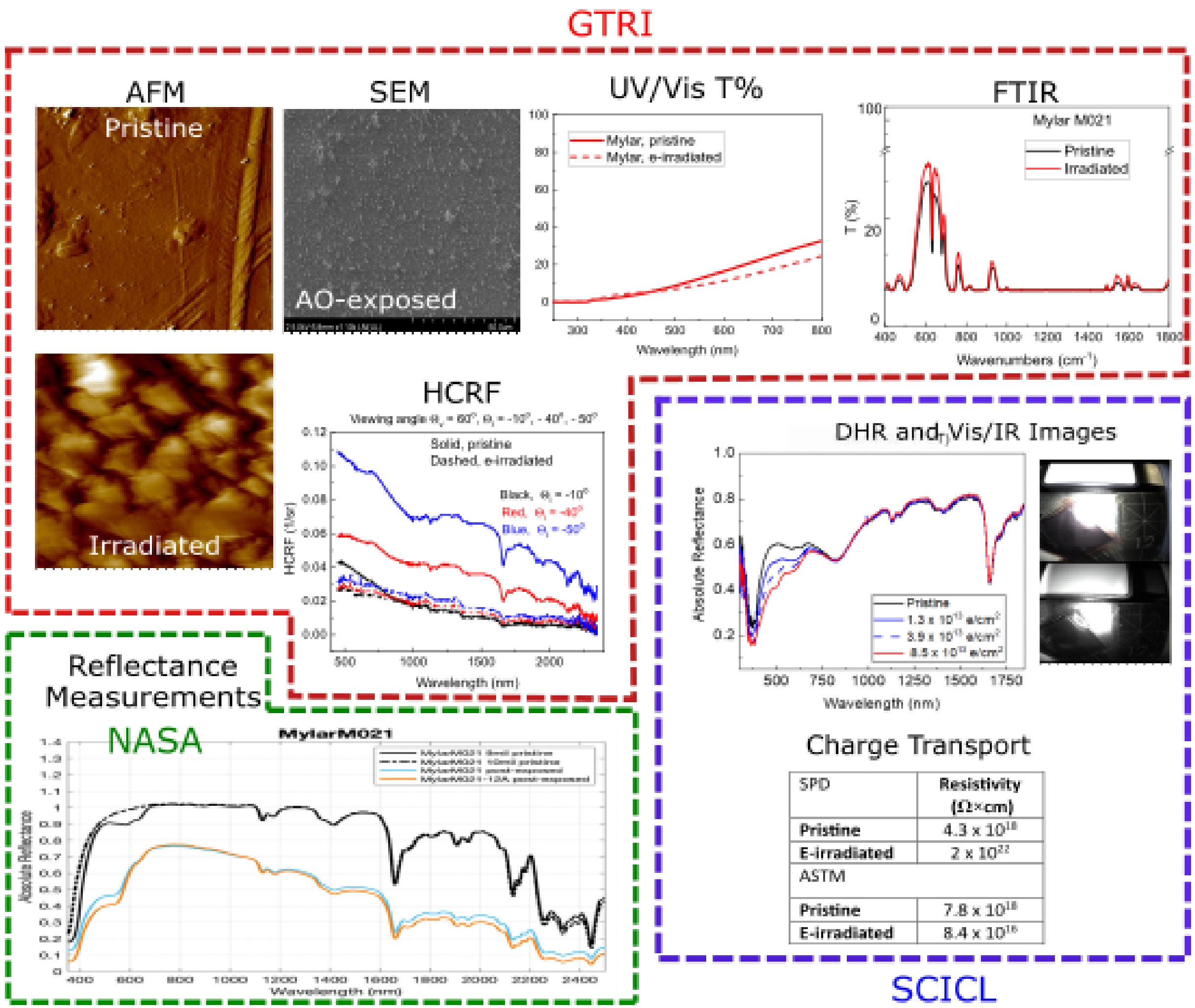
Representative Characterization Results



SPD	Resistivity (Ω×cm)
Pristine	4.3×10^{18}
E-irradiated	2×10^{22}
ASTM	
Pristine	7.8×10^{18}
E-irradiated	8.4×10^{16}

Material's representative characterization portfolio of Mylar M021

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Summary and Future Work

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In the project's framework:

- Finish analysis of orbital images
- Subject flown materials to the same characterization protocol as flight-duplicates
- Compare results obtained from the flight duplicates and flown materials
- Make findings available to the research community

Future projects:

- Expand characterization portfolio to mechanical and chemical analysis
- Work with ISS NL to launch the mechanical testing experiment
- Organize all the measured data into the database
- Investigate combined exposure approach (e/VUV, e/VUV/AO, e/T, VUV/T..)
- Expand to different material types, such as Kevlar or PEDOT
- Broaden our collaborative network

Thank you!