Addressing Material Challenges for the Europa Clipper Mission

Presented by
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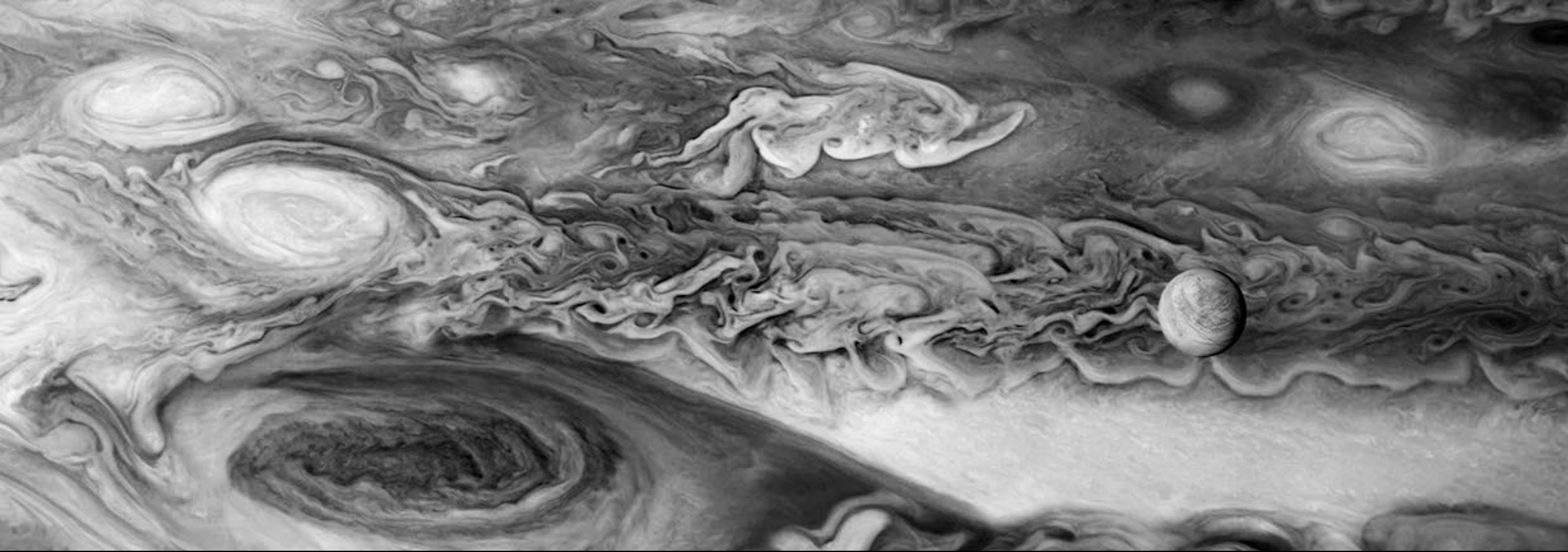

Contributors

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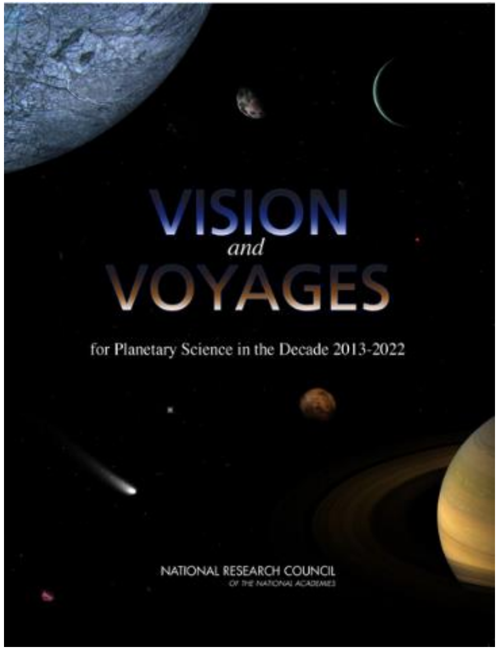
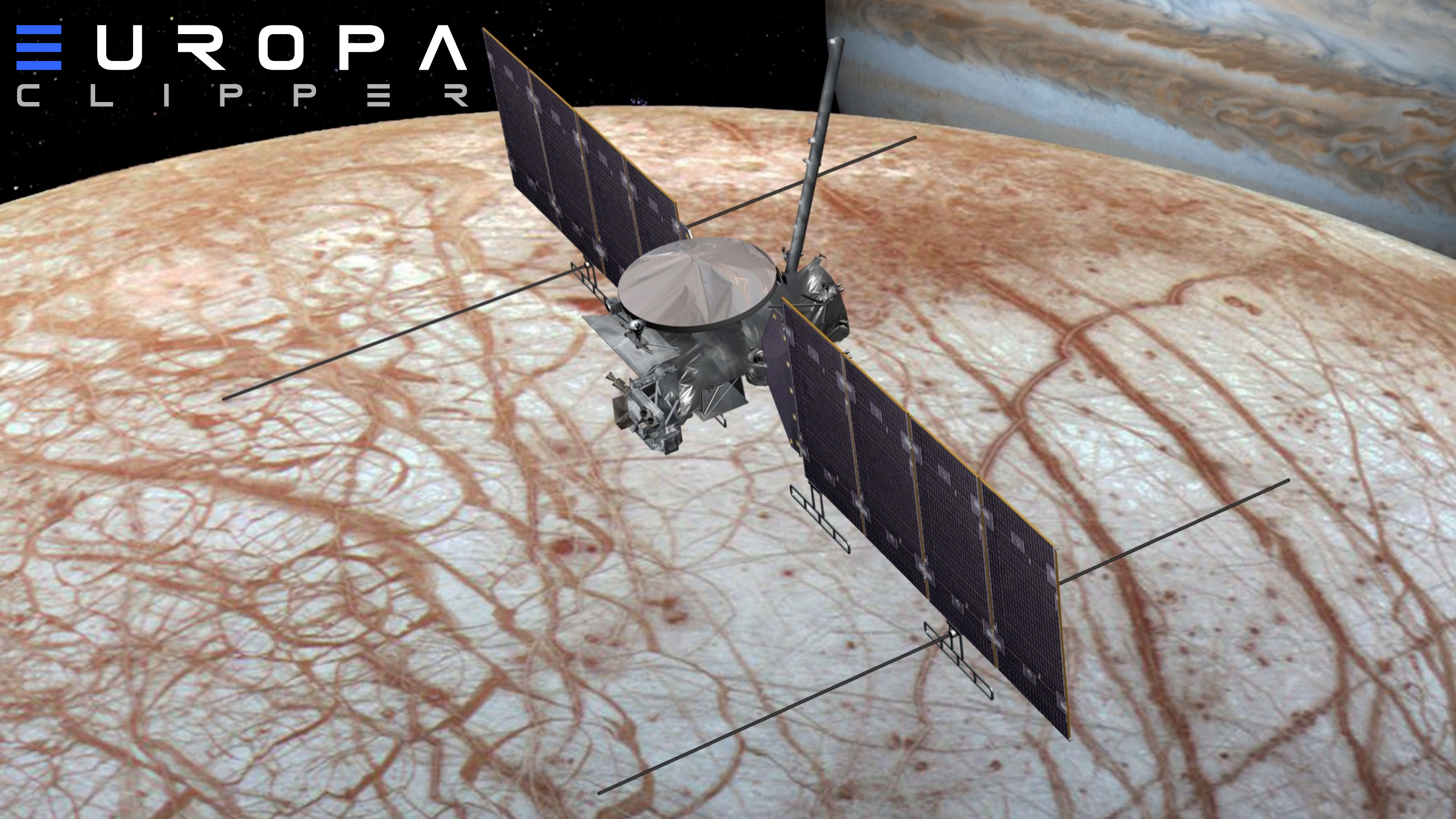
EUROPA CLIPPER

Europa



From the 2013-2022 Visions and Voyages for Planetary Science report,

"…Jupiter's icy moon Europa. This moon, with its probable vast subsurface ocean sandwiched between a potentially active silicate interior and a highly dynamic surface ice shell, offers one of the most promising extraterrestrial habitable environments in our solar system…"


EUROPA
CLIPPER

Europa Clipper Mission

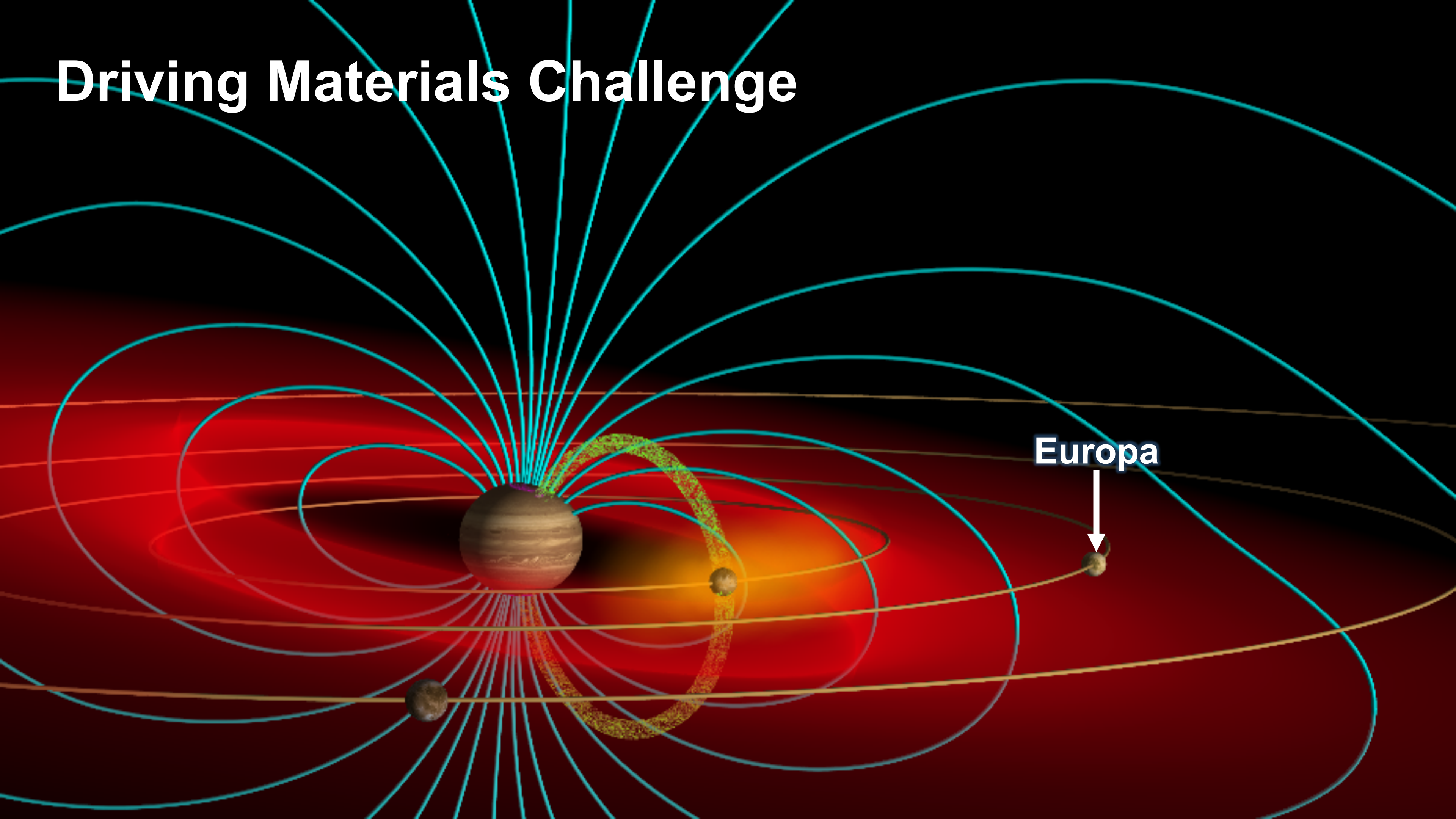
Flyby Mission

- 40-45 Flybys enables nearly global coverage over ~3 years
- 14 day orbit allows for downlink and recharge
- No Europa Orbit Insertion
- Minimizes time in the high radiation environment

Science Payload – 9 instruments

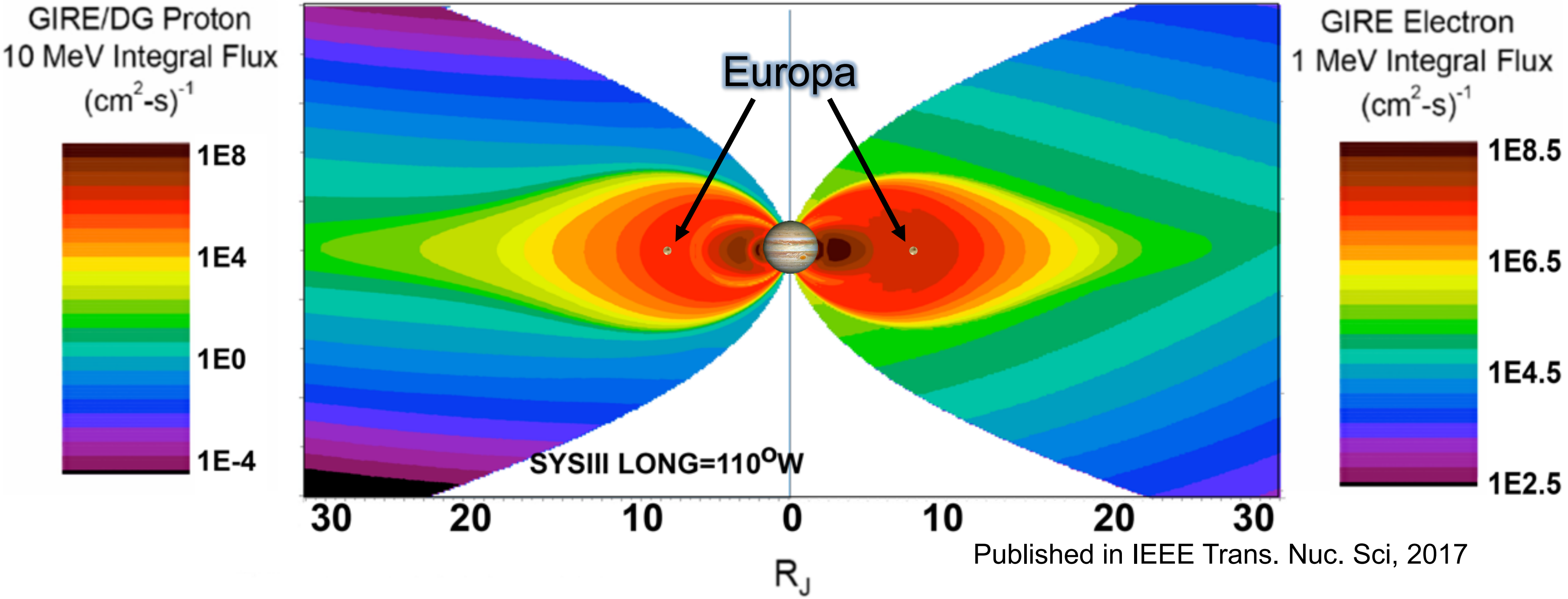
- High resolution cameras and spectrometers
- Ice penetrating radar
- Magnetometer
- Thermal Imager

Driving Materials Challenge



Driving Materials Challenge

Radiation



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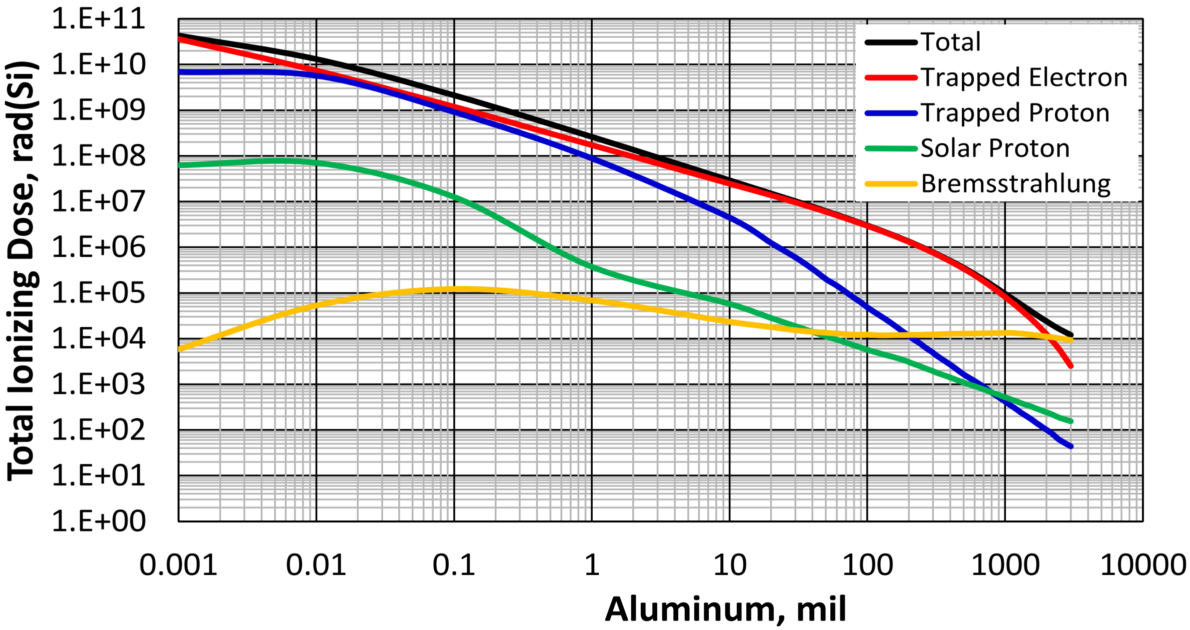
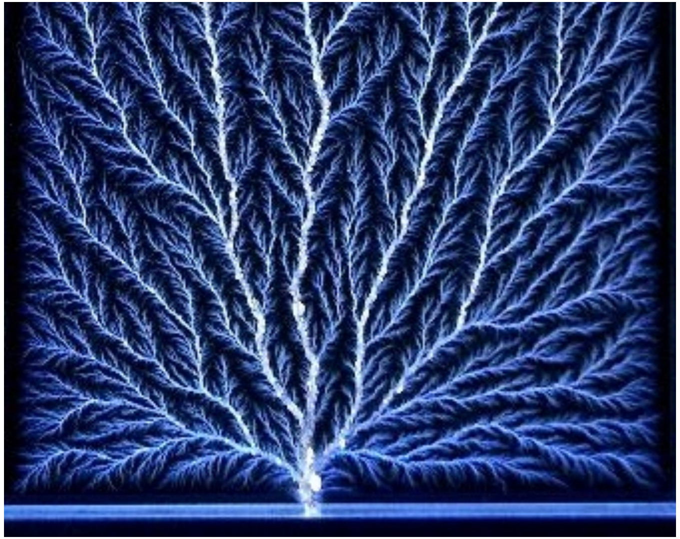
Driving Materials Challenge

Radiation

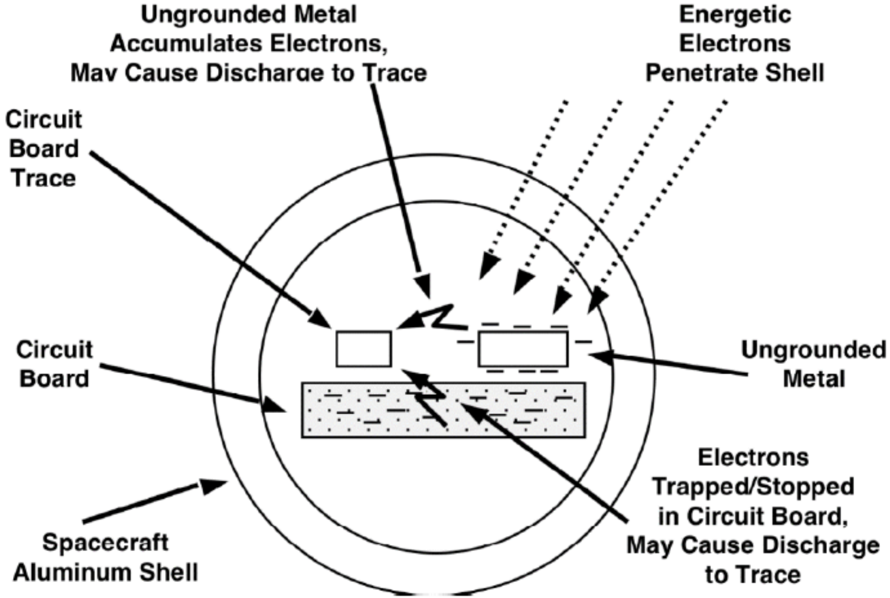


Driving Materials Challenge

Radiation



Credit: capturedlightening.com



From NASA-HDBK-4002A
Mitigating in-Space Charging Effects – a Guideline
Hank Garrett and Al Whittlesey

Driving Materials Challenge

Thermal Environment

Europa Hardware	Temperature, °C	
	min	max
Spacecraft		
Telecom Subsystem	-230	125
GNC Subsystem	-150	125
Power Subsystem	-35	70
Avionics Subsystem	-35	70
Radiation Monitoring Subsystem	-35	75
Thermal Subsystem	-105	400
Propulsion Subsystem	-47	55
Mechanical Subsystem	-200	135
Solar Array Assembly	-240	135
Payload		
EIS	-75	70
E-Themis	-75	70
Europa UVS	-75	50
ICEMAG	-165	105
MASPEX	-35	70
MISE	-35	70
PIMS	-55	70
REASON	-240	120
SUDA	-35	70
Temp Extremes	**-240**	**400**

Driving Materials Challenge

Planetary Protection

	3-Order Reduction				4-Order Reduction		6-Order Reduction	
	Surface			Encap	Surface	Encap	Surface	Encap
	Dry	Ambient	Uncontrolled					
T (C)	D (hours)							
110	19.42	33.56	97.12	-	140.91	704.56	-	-
116	10.06	15.58	50.30	74.65	116.53	582.64	-	-
125	3.75	4.93	18.75	18.75	88.58	442.88	265.73	1328.63
150	0.28	0.28	1.43	1.43	8.08	40.42	24.25	121.27
200	0.01	0.01	0.05	0.05	0.07	0.34	0.20	1.01

Materials Testing

- Electrical Connectors
- Adhesives
- UV / Electron / Proton Tests
- Thermal Control Coatings

Electrical Connectors

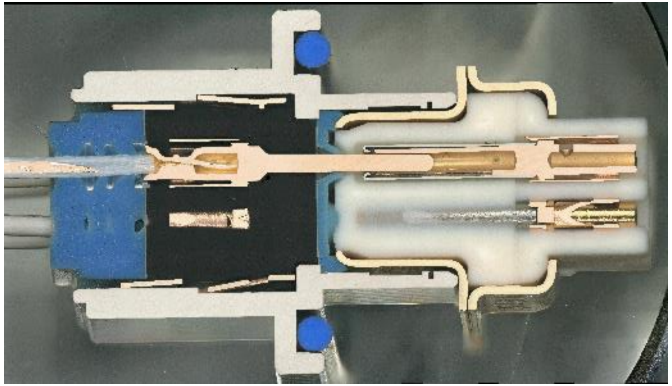
Overview

- Aerospace connectors and harness materials for potential Clipper applications are exposed to Clipper level radiation and thermal environment to assess performance with the following:
  - Planetary Protection (PP) Protocol
  - Internal Electrostatic Discharge (iESD)
  - Total Ionizing Dose (TID)
  - Thermal cycling

Electrical Connectors

iESD testing

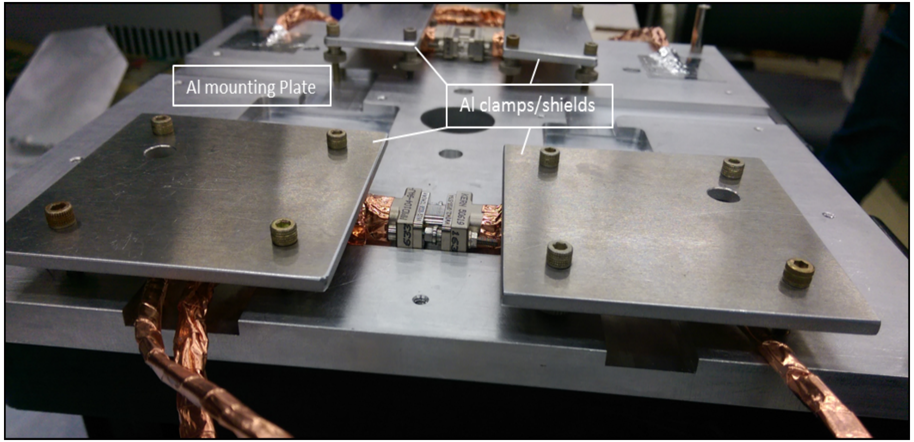
- Internal Electrostatic Discharge (iESD) testing summary
  - Electron beam exposure conducted at JPL Dynamitron facility
  - Mated connector pairs tested
  - 4x flux condition relative to the Europa iESD design environment
  - Discharge detection through monitoring of connector pins using oscilloscopes

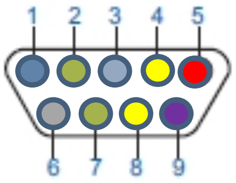


Electrical Connectors

iESD testing

Connector Mated Pair for iESD testing



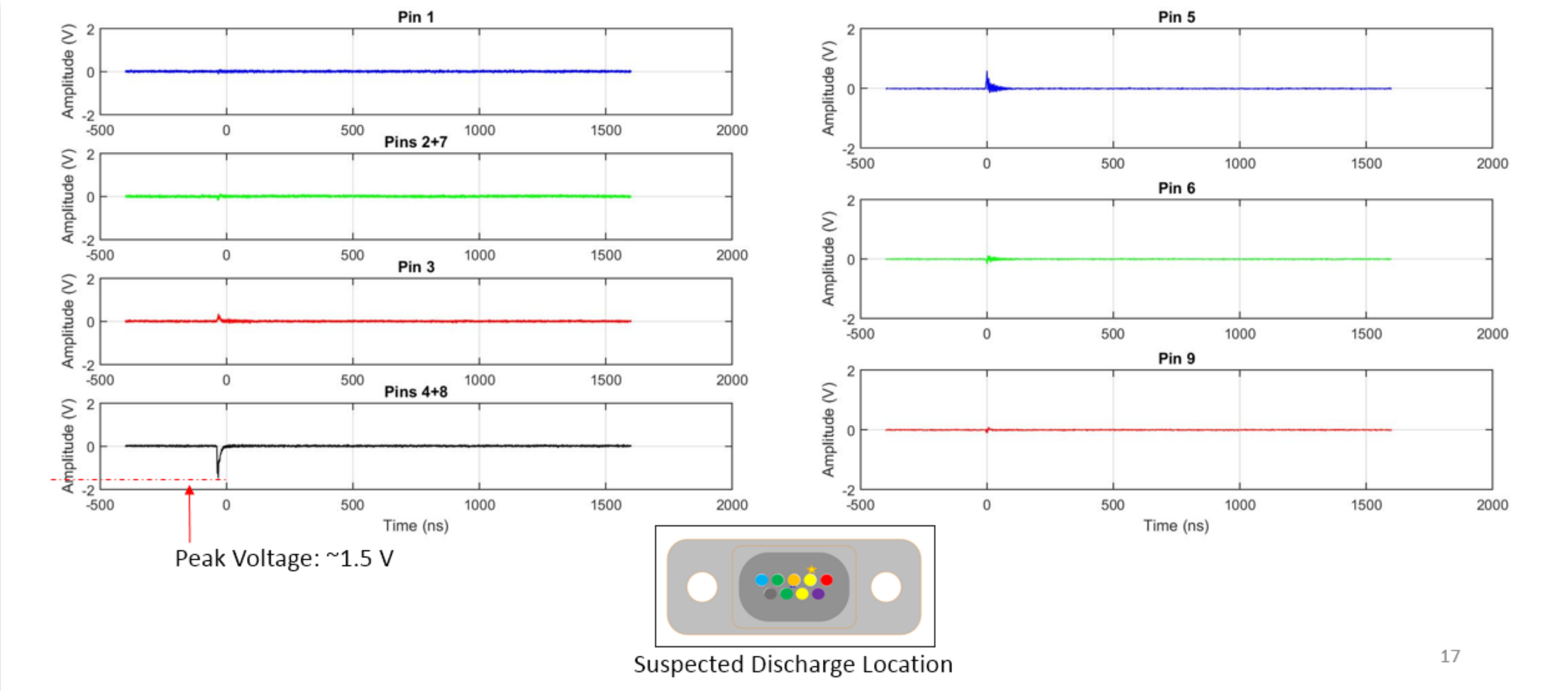


9 Contacts

- CH1 – 1 pin
- CH2 – 2 pins
- CH3 – 1 pin
- CH4 – 2 pins
- CH5 – 1 pin
- CH6 – 1 pin
- CH7 – 1 pin

Electrical Connectors

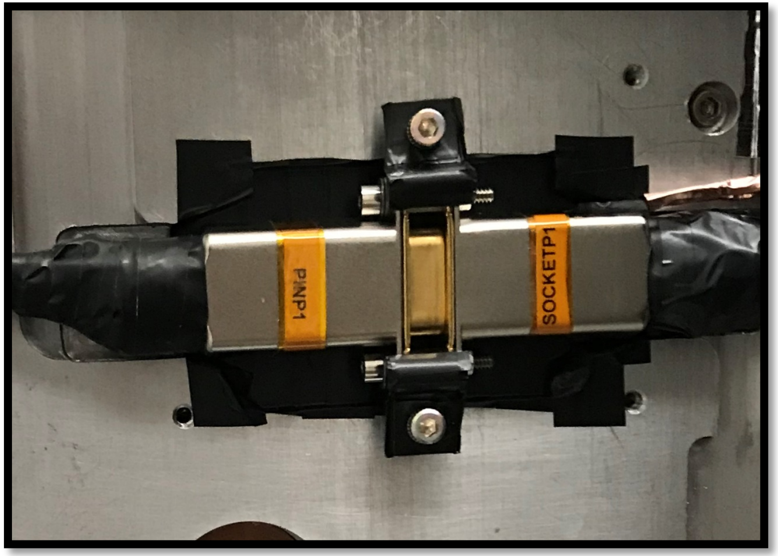
iESD testing



Electrical Connectors

iESD testing

- Summary of iESD test status
  - Dsubs Connectors
    - Small Dsub – completed at -75C
      - Safe interface with HBM Class 3 rated electronics
    - Large Dsub – completed at -75C
      - Safe interface with HBM Class 3 rated electronics

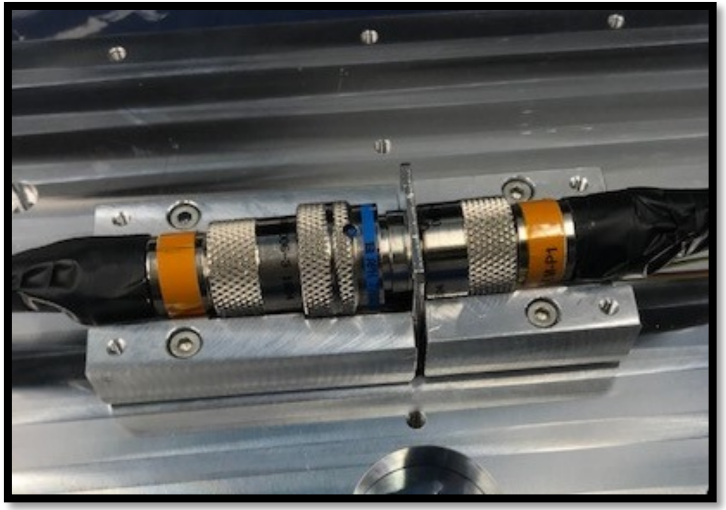


Dsub Mated Pair

Electrical Connectors

iESD testing

- Summary of iESD test status
  - Circular D38999
    - Small heritage circular – completed at -75C
      - Safe interface with HBM Class 1A rated electronics
    - Large heritage circular – completed at -75C
      - Safe interface with HBM Class 1C rated electronics

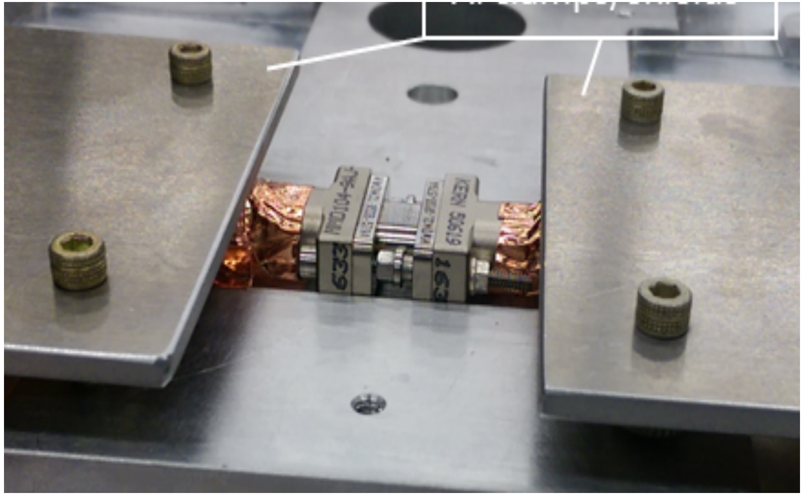


Heritage Circular Mated Pair

Electrical Connectors

iESD testing

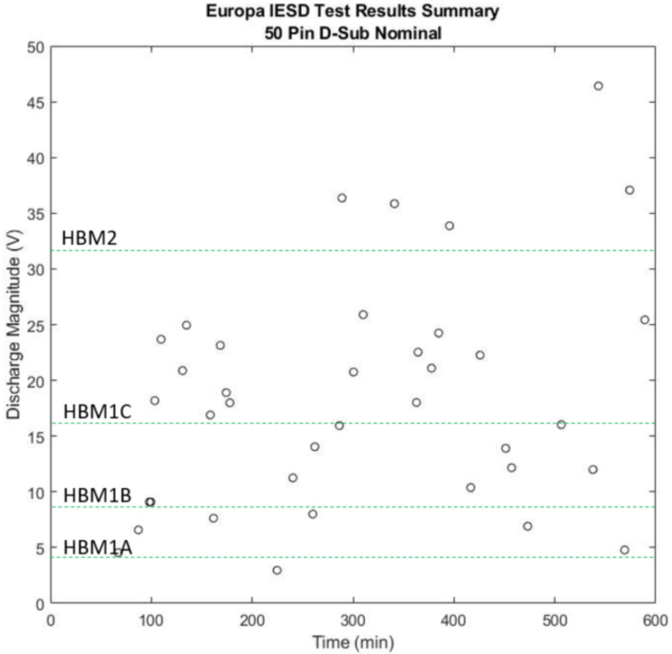
- Summary of iESD test status
  - Micro-D connectors
    - Small Micro-D – completed at -167C
      - Safe interface with HBM Class 1A rated electronics
    - Large Micro-D – completed at -155C
      - Safe interface with HBM Class 1A rated electronics

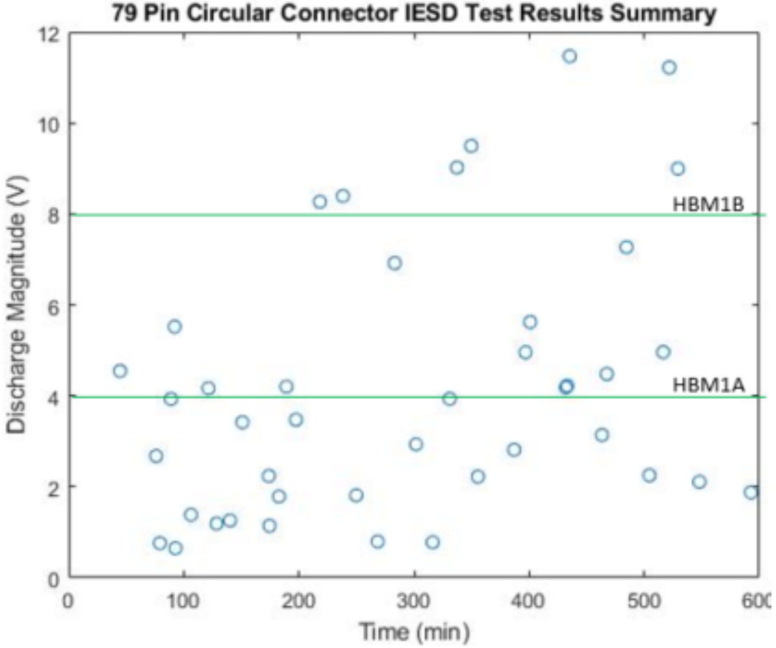


Micro-D Mated Pair

Electrical Connectors

iESD testing



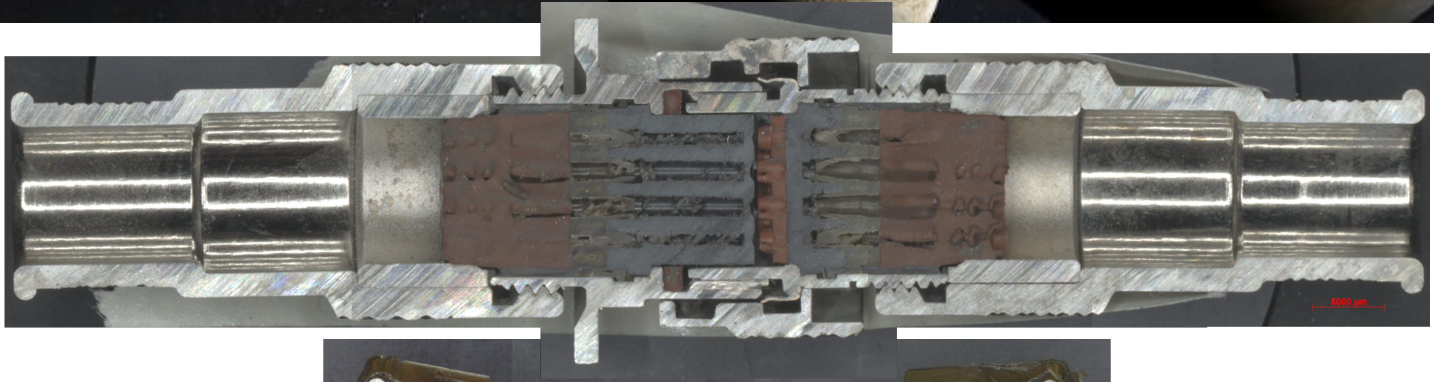


Electrical Connectors

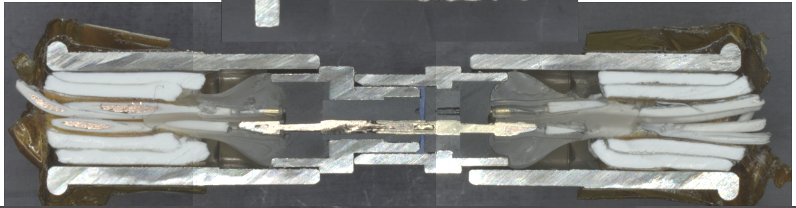
iESD testing

Circular

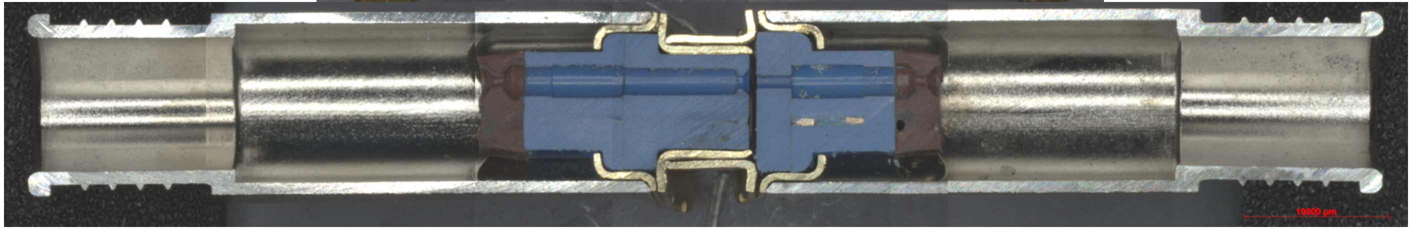
Circular



Micro D



D-sub



Electrical Connectors

Testing status

- Candidate connectors and harness materials for Clipper external vault applications are exposed to Clipper radiation and thermal environment to assess the following:
  - Planetary Protection (PP) Protocol
  - Internal Electrostatic Discharge (iESD)
    - Follow-up testing being conducted
  - Total Ionizing Dose (TID) exposure
  - Thermal cycling

Connector Harness Materials identification And control

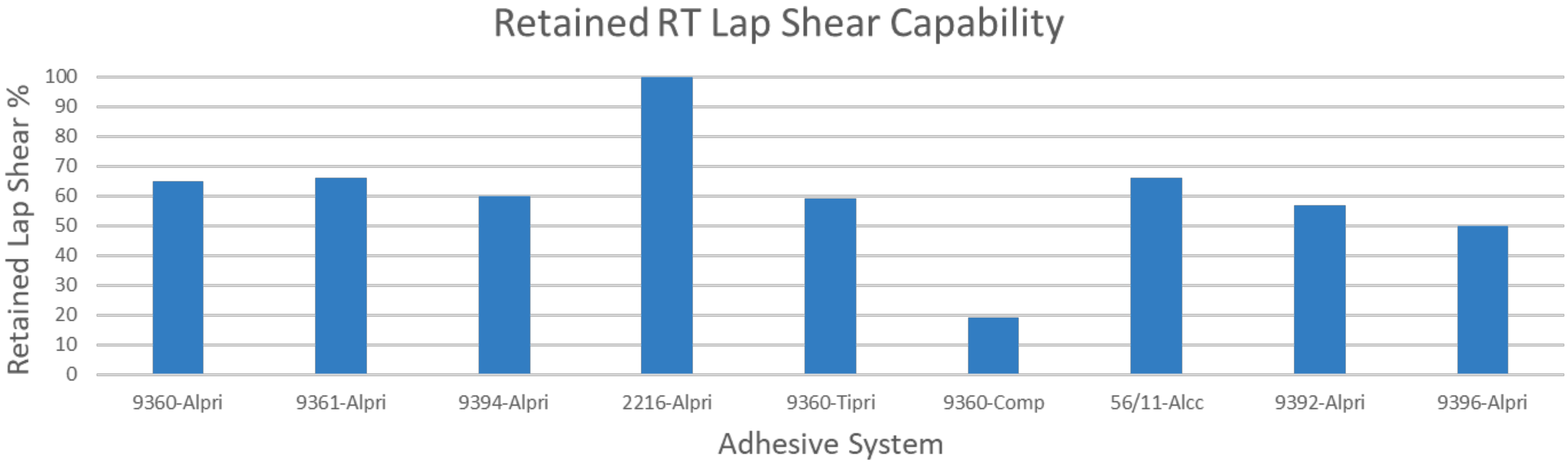
Adhesives

Overview

- Aerospace adhesive materials for Clipper external radiation vault applications are evaluated after exposure to Clipper radiation and thermal environment
- Radiation exposures
    - From 40 Mrad to 100 Mrad
- Thermal cycle extremes:
        - Relatively benign: -35C to 75C
        - Extreme: Ambient to 195 C followed by Ambient to -230 C

Adhesives

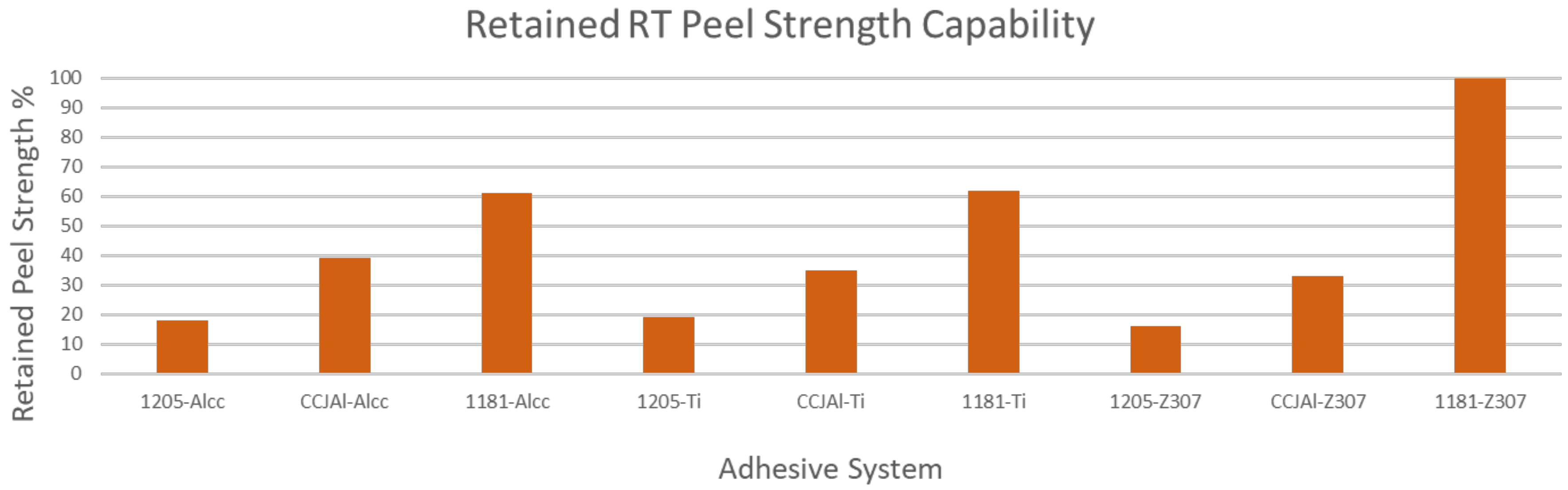
After extreme radiation and thermal cycle



Epoxy adhesives degrade after exposure to extreme rad dose but many still demonstrate structural capability

Adhesives

After moderate radiation and thermal cycle



Some acrylic tape adhesives degrade significantly after exposure to moderate rad dose but others still demonstrate adequate capability for non-structural applications

Adhesives

Test Status

- ***Work to go***
  - Testing tape adhesive systems in extreme environments
  - Structural epoxy adhesive system testing after radiation at cold temperatures

UV / Electron / Proton Tests

Clipper Mission Simulation

- External surface materials on Europa Clipper Spacecraft will be exposed to very large doses of radiation
- Examples of surface materials and possible radiation effects
  - Thermal control coatings – increase in absorption, cracking, delamination
  - Multilayer insulation (MLI) – increase in thermo-optical properties, curling, shredding, decomposition
  - Exposed optics and coatings – darkening, crazing, loss in transmission
  - Solar cell coverglass materials – see above
  - Metallics – generally unaffected except at extremely high radiation dose
- Candidate materials were exposed to simulated Europa Clipper Mission radiation and evaluated thermo-optical property effects

UV / Electron / Proton Tests

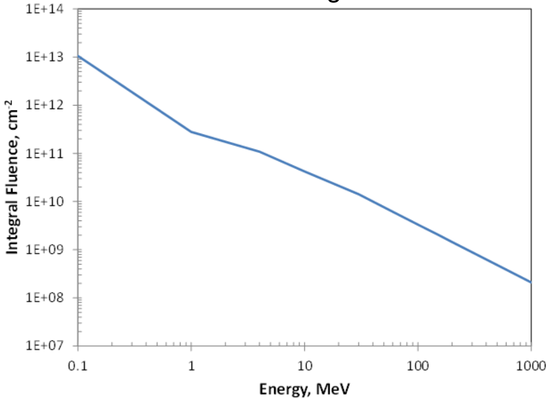
Material Candidates

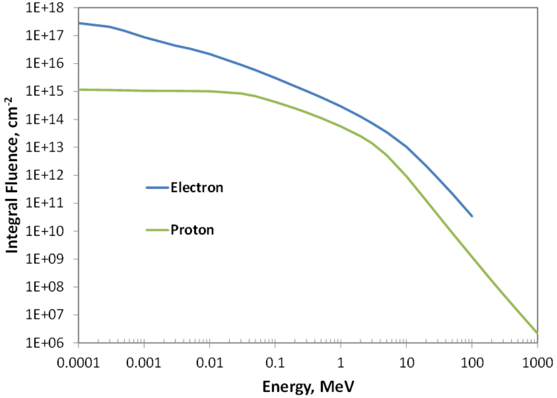
Candidates		Description	In-situ Measurement
Thermal Control Coatings	AZ-2100IECW	White Inorganic "Conductive" Coating	x
	S13GP:6N/LO-1 [1]	White Organic Coating	x
	Z-93C55	White Inorganic "Conductive" Coating	x
	AZ-2000IECW	White Inorganic "Conductive" Coating	x
	Z-93P [1]	White Inorganic Coating	x
	Aeroglaze Z307	Black Organic "Conductive" Coating	
	MH21:6NC/LO	Black Organic "Conductive" Coating	
	MH21:6N/LO	Black Organic Coating	
	MH55ICP	Black Inorganic "Conductive" Coating	
Cover Glass	12 mil coverglass/AR/ITO	coverglass	x
	8 mil coverglass/AR	coverglass	x
	20 mil coverglass/AR/ITO	coverglass	x
	20 mil coverglass/AR	coverglass	x
	17 mil coverglass/AR	coverglass	x
MLI Materials	Coated Black Kapton	Coated carbon loaded PI	x
	Black Kapton	Carbon loaded PI	x
	Embossed Aluminized Kapton	Double side aluminized PI	
	White coated Kapton	White “Conductive” coated PI	x

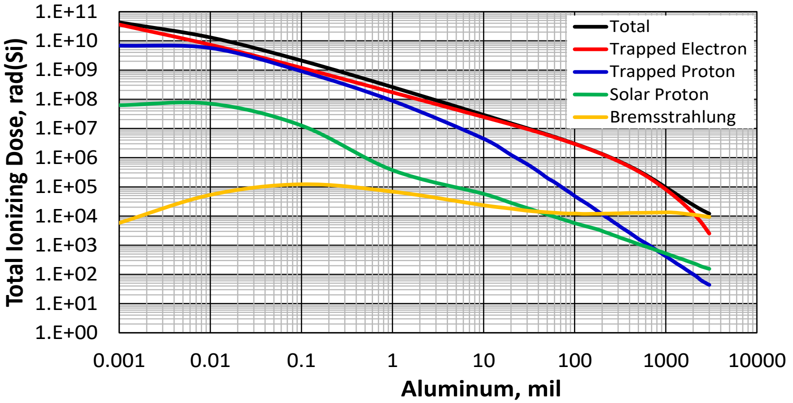
UV / Electron / Proton Tests

Clipper Mission Simulation

- Mission Environments
  - Interplanetary space environment
  - Jovian tour







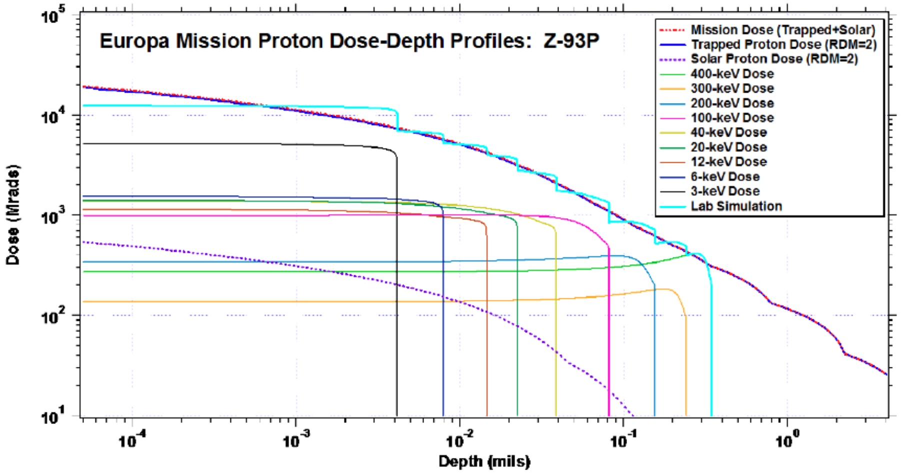
UV / Electron / Proton Tests

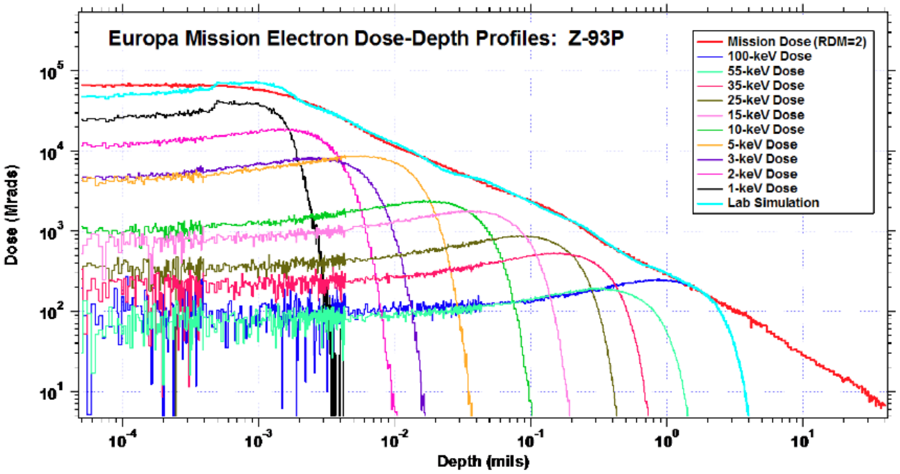
Clipper Mission Simulation

- Environment Simulation
  - Interplanetary space environment
    - Protons concurrent with broadband and vacuum-UV illumination
    - 4500 ESH
  - Jovian tour
    - Mission energy deposition as a function of depth (dose-depth) profile calculated for 4 representative candidate materials
    - A series of mono-energetic charged particles fluences were used to simulate the calculated mission dose
    - Scaling employed so that the net contribution in the materials would match electron or proton mission dose-depth
  - Radiation Design Factor of 2 was applied for charged particle fluences

UV / Electron / Proton Tests

Environment Simulation





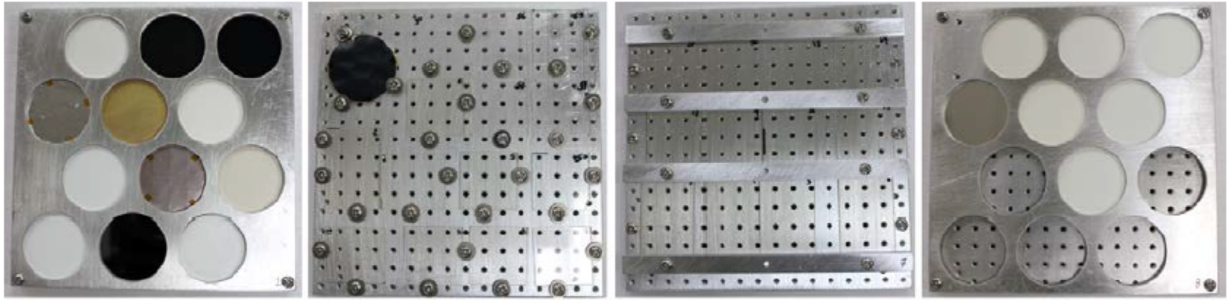
UV / Electron / Proton Tests

Environmental Simulation

- Simulation Facilities – Aerospace Corporation
  - Mid-Energy Proton Exposures
    - Aerospace's Low-Energy Accelerator Facility (LEAF)
    - Used to simulate a portion of the energy deposition in the test materials
    - Ex-situ measurements
  - UV/Low-Energy Electron/Proton Exposures
    - Aerospace's Research and Development of Radiation Deposition (R2D2)
    - Broadband solar and Vacuum UV radiation
    - Low to mid-energy electrons
    - Low to mid-energy protons
    - Auxiliary measurement chamber for in-situ optical property measurements (solar absorptance and transmittance)

UV / Electron / Proton Tests

LEAF Sample Plates

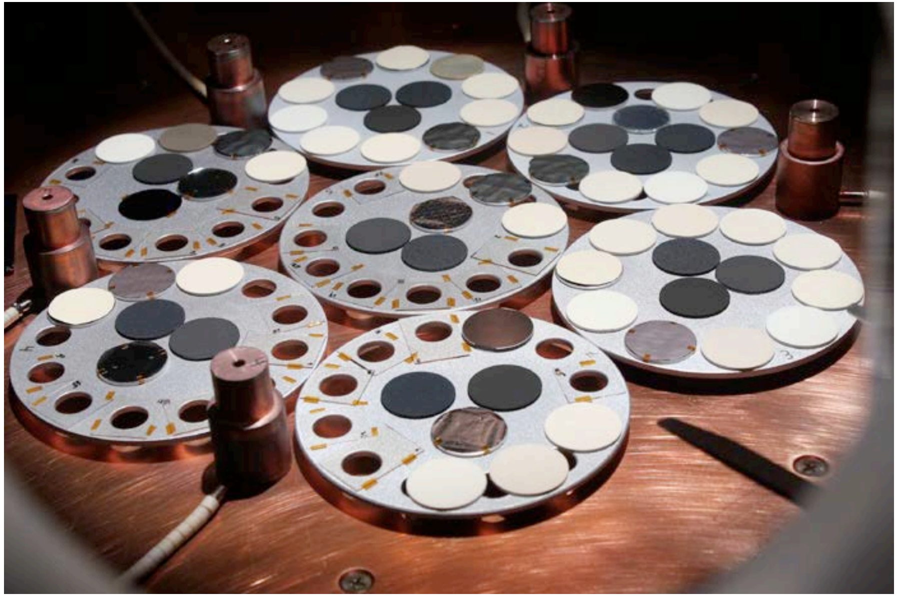


Group B

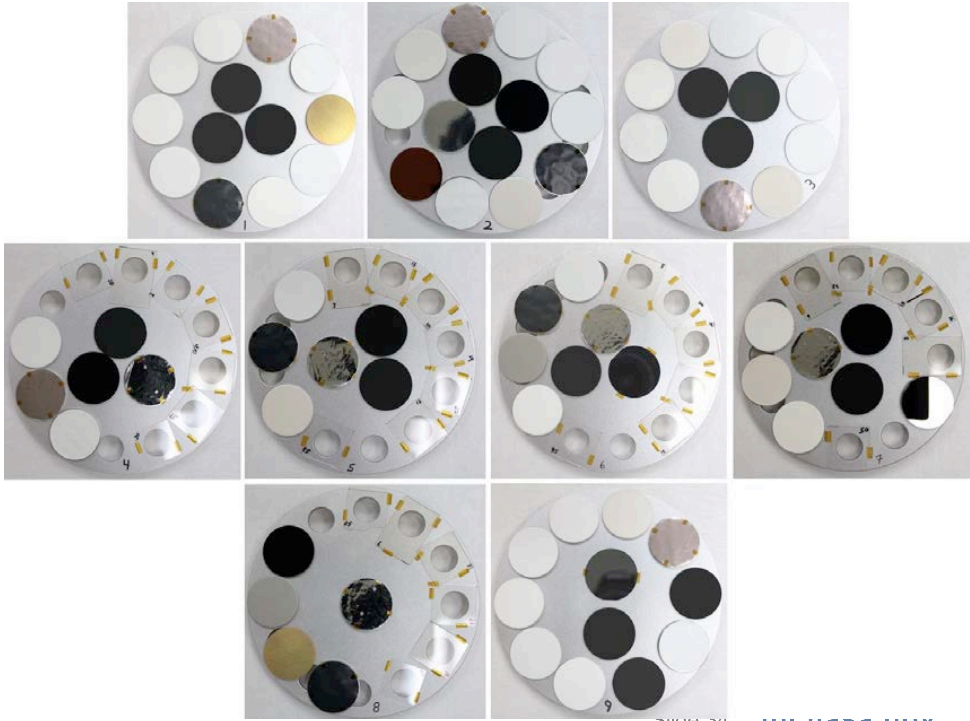
Group A

UV / Electron / Proton Tests

R2D2 Sample Plates

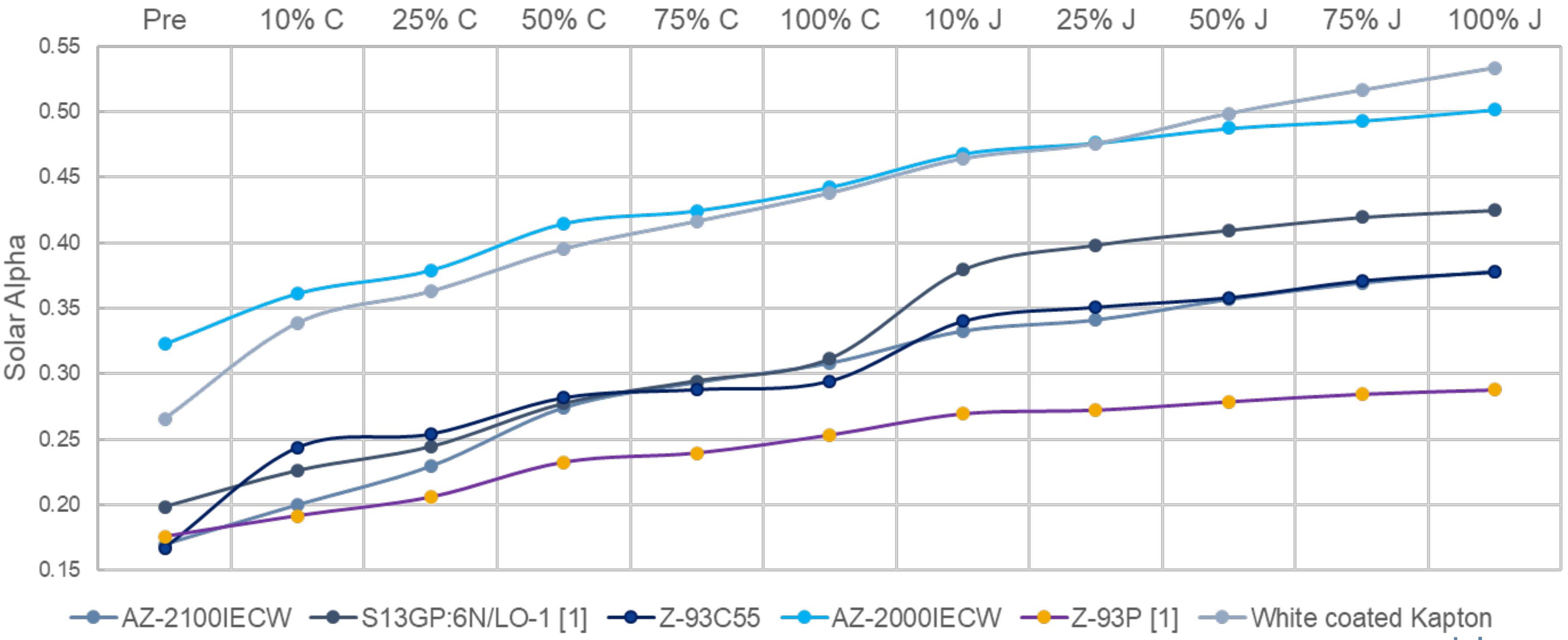


Sample plates mounted inside R2D2



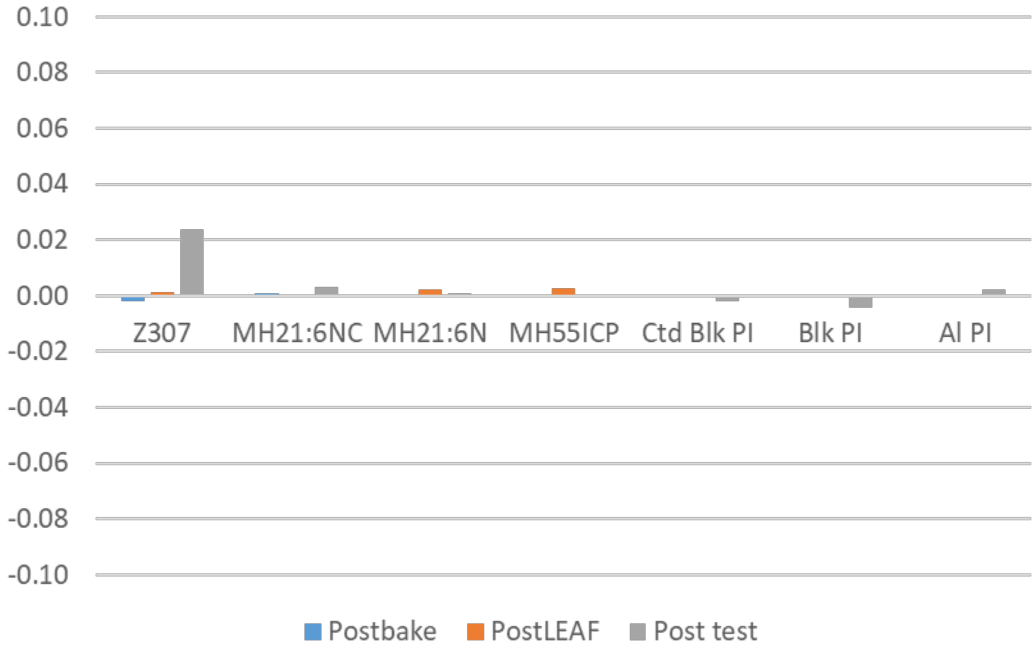
UV / Electron / Proton Tests

In-Situ Solar Absorptance Changes



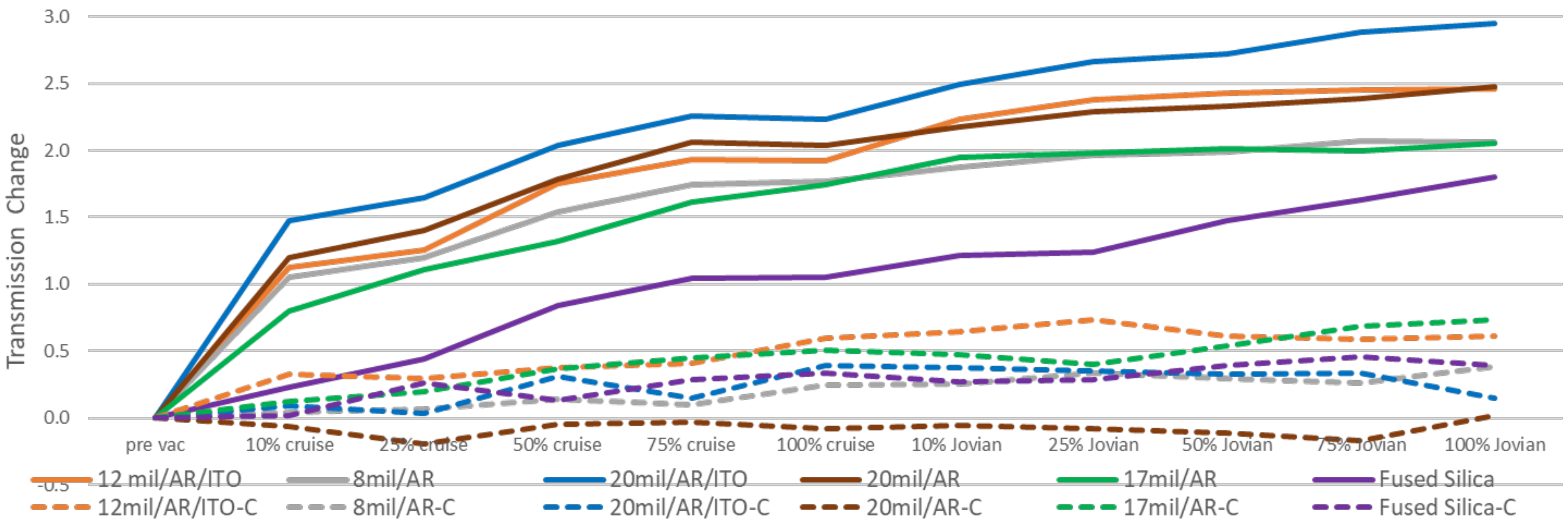
UV / Electron / Proton Tests

IR Emissivity Changes



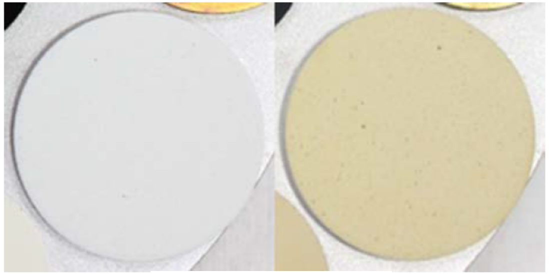
UV / Electron / Proton Tests

Percent changes in coverglass transmission

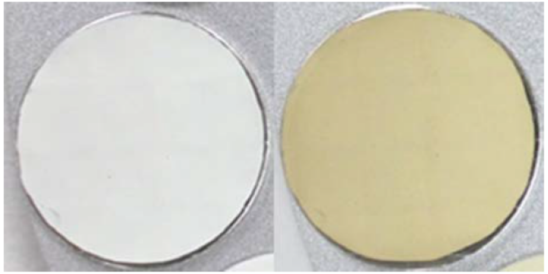


UV / Electron / Proton Tests

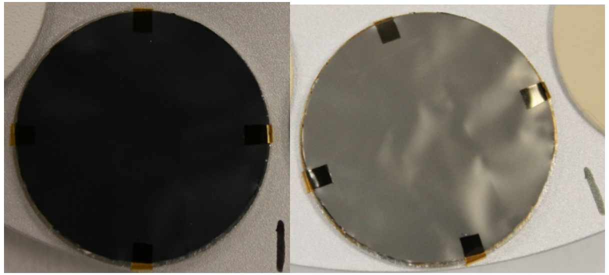
Noteworthy visual changes



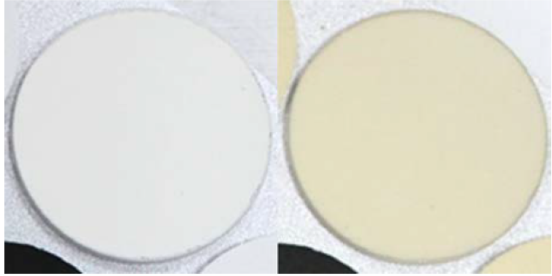
S13GP:6N/LO-1



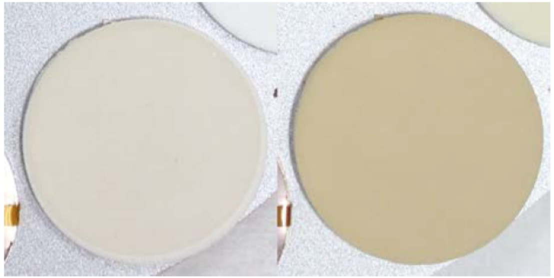
White coated Kapton



Black Kapton



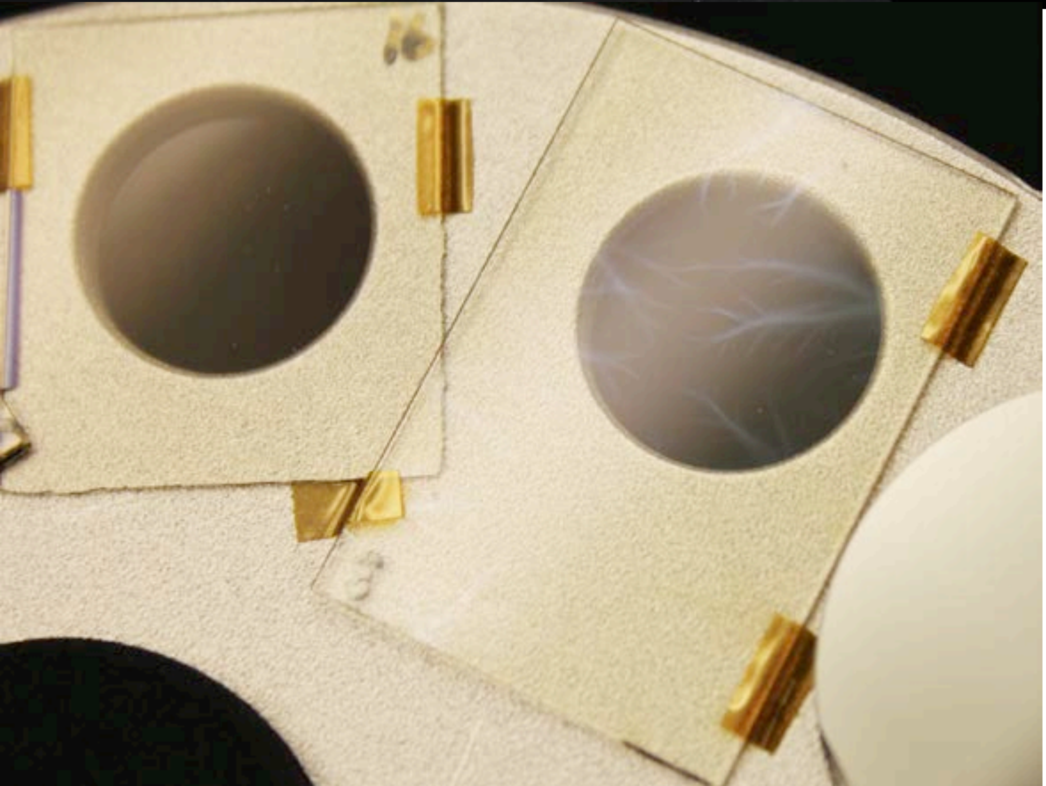
Z93C55



AZ2000IECW

UV / Electron / Proton Tests

Noteworthy visual changes



Coverglass

AR only - coated coverglass (right)
AR/ITO-coated coverglass (left)

Thermal Control Coatings

Overview

- Thermal Control Coating Evaluations
  - Optical Property Effects
  - Total Ionizing Dose Radiation and thermal cycling survivability
  - Electrostatic Discharge evaluation
- Candidates
  - White organic and inorganic, electrically dissipative, low absorptivity coatings
  - Black organic and inorganic, electrically dissipative, high emissivity coatings

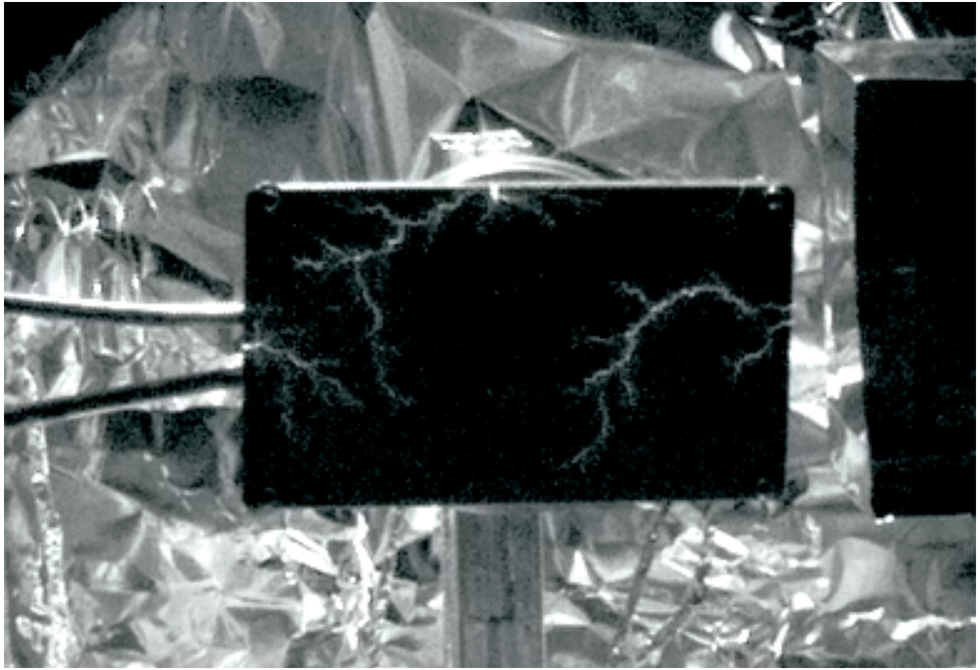
Thermal Control Coatings

Status

- Optical Property Effects
  - See previous section
- TID Radiation and thermal cycling survivability – in progress
  - Subject select coatings to 2x TID radiation and encompass expected thermal cycling
  - Evaluate survivability using adhesion tests
- ESD evaluation – in progress
  - Conduct discharge testing

Thermal Control Coatings

ESD testing



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