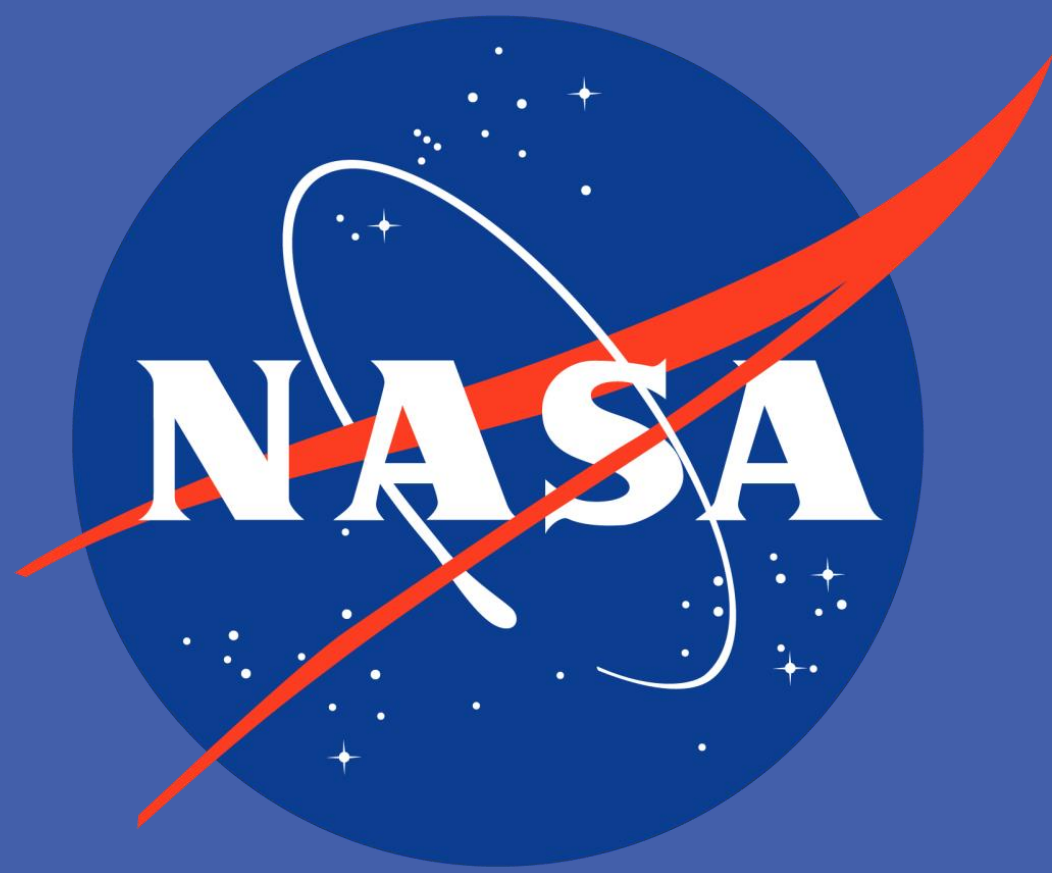




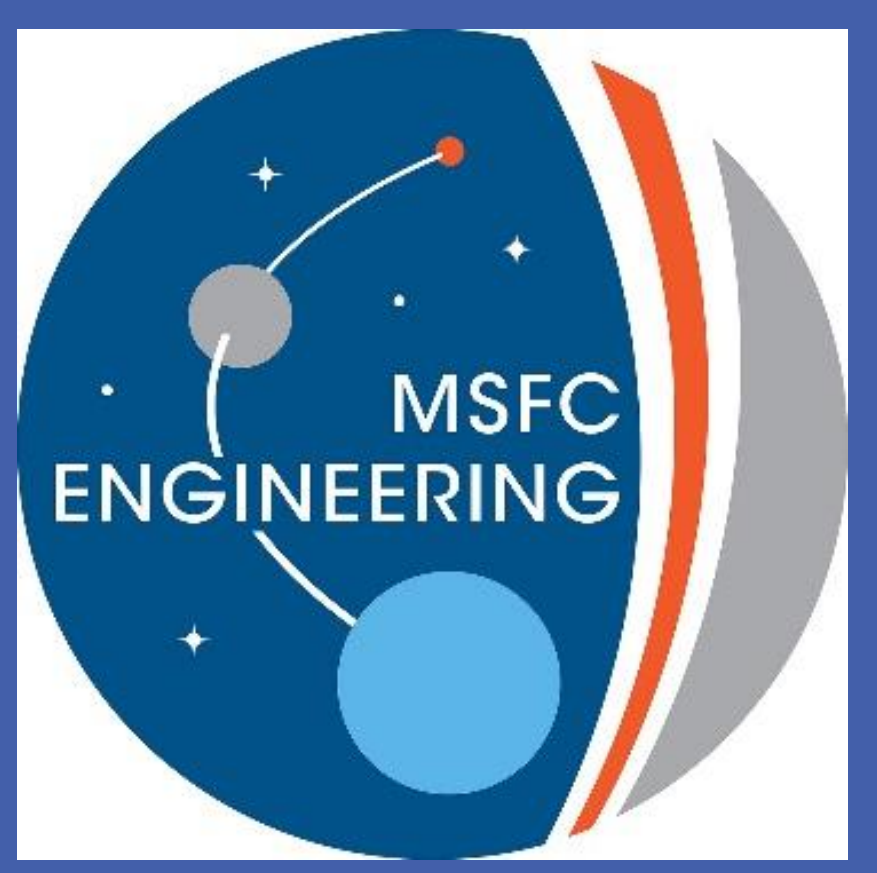
Internal Electrostatic Discharge Testing of Inert Solid Rocket Motor Materials

Todd A. Schneider¹, Jason A. Vaughn¹, Erin G. Hayward¹, Brandon S. Phillips¹, Kenneth H. Wright, Jr.², and Jason C. Reynolds³

¹NASA, Marshall Space Flight Center, Huntsville, AL 35812, USA (email: todd.schneider@nasa.gov)

²Universities Space Research Association (USRA), Science and Technology Institute, Huntsville, AL 35805, USA

³The University of Alabama at Birmingham, Birmingham, AL 35233, USA



Introduction

Europa Lander Mission

- To place a spacecraft on the surface of Jupiter's moon Europa

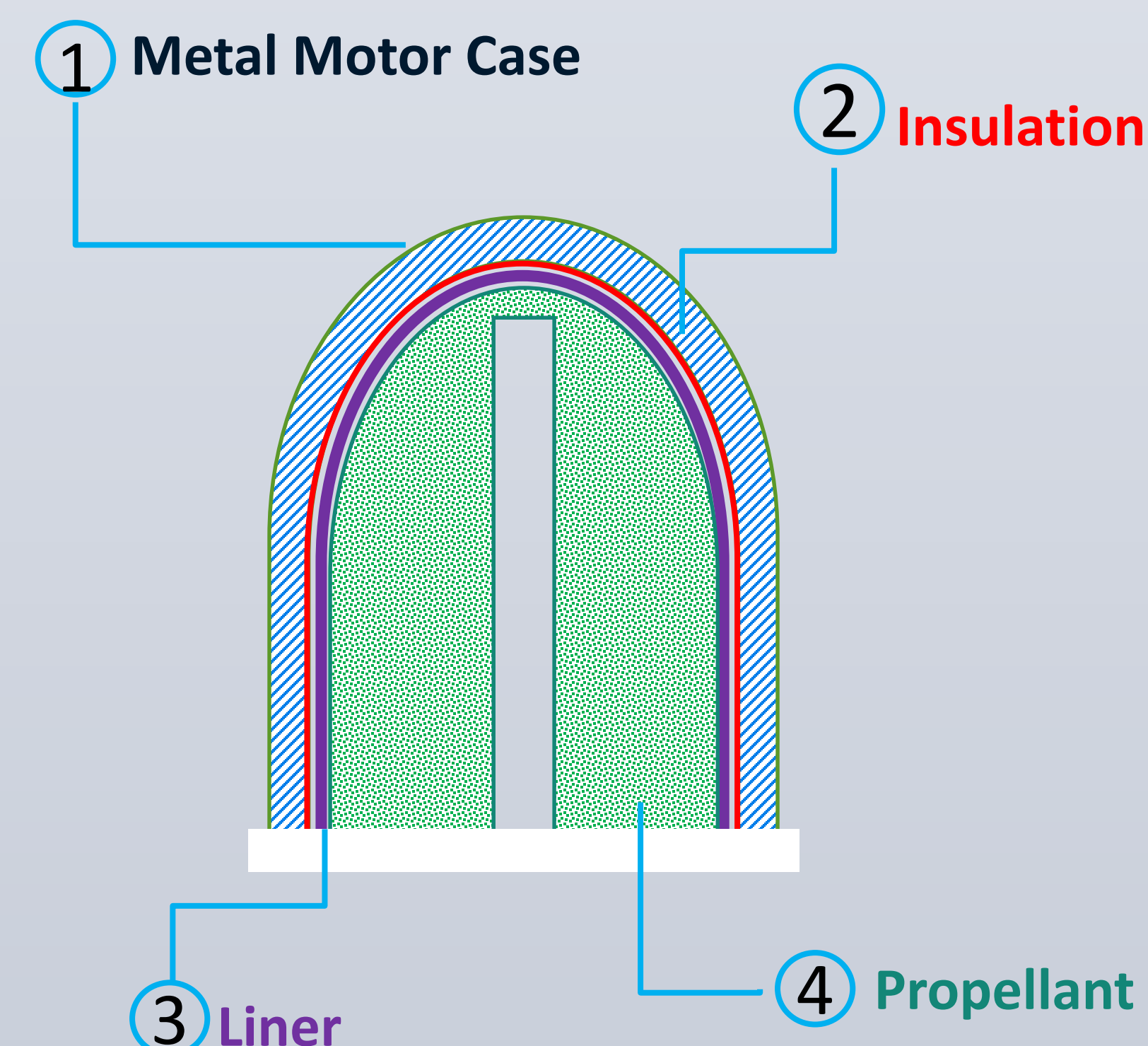
The Jupiter (Jovian) Environment is characterized by high radiation levels

- Including a spectrum of high energy charged particles

A successful mission to Europa requires verification through analysis and test that all elements of the spacecraft will survive the space environment

- Radiation dose issues
- Material charging concerns

Solid Rocket Motor for the De-Orbit Stage (DOS)

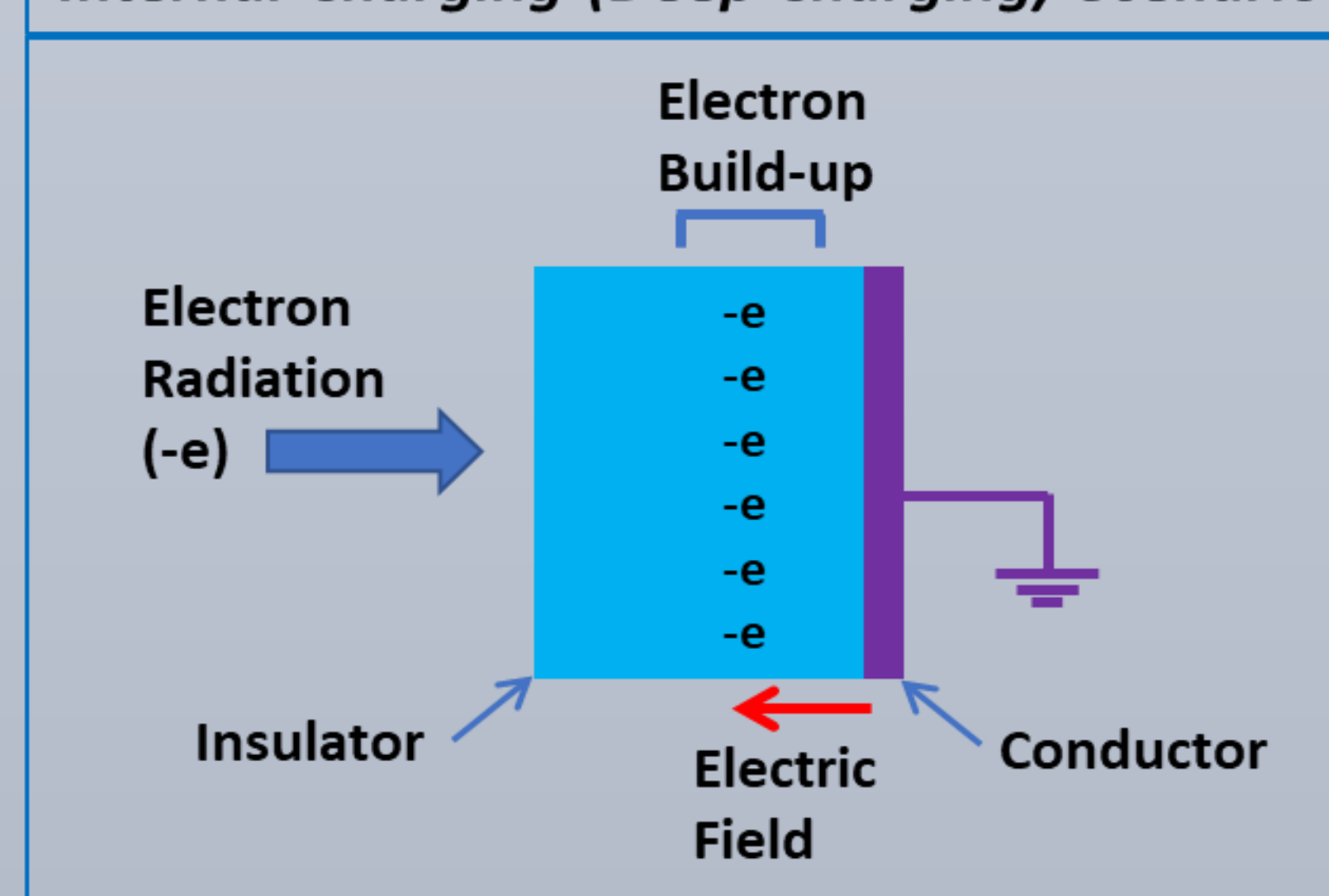


Cross-Section of Typical Solid Rocket Motor Layout

Internal Electrostatic Discharge (iESD)

Arcing occurs when the electric field, created by the build-up of electrons in a region of the material, exceeds the dielectric strength of the material.

Internal Charging (Deep Charging) Scenario



iESD Test Plan

Conduct tests in MSFC's Combined Environmental Effects Facility using high-energy Pelletron accelerator

All iESD tests require high energy electrons (> 0.8 MeV) to penetrate deep into the sample

- Scattering foil creates large diameter electron beam to uniformly cover sample area up to 16 inch (40 cm) diameter beam spot

Expose inert solid rocket motor materials to high energy electrons and measure the arc frequency, arc current magnitude, and duration

- Measure iESD activity by monitoring sample mounting plate current
 - Ground sample mounting plate externally through 50-ohm high-frequency load

iESD Test Summary

Silica-Filled EPDM Insulation

Most sensitive to generating iESD of the four sample types tested

Date	Sample under Test	Energy (MeV)	Flux (nA/cm ²)	Average time between arcs
10/25/2018	Silica-Filled EPDM	1	0.1	900 sec/1 arc = 900 sec/arc
		1	0.25	900 sec/6 arcs = 150 sec/arc
		1	0.5	900 sec/16 arcs = 56.3 sec/arc
		1	1	2038 sec/200 arcs = 10.2 sec/arc
10/29/2018	Silica-Filled EPDM	1	0.1	3600 sec/12 arcs = 300 sec/arc
		1	0.25	1560 sec/14 arcs = 111.4 sec/arc
		1	0.5	6170 sec/84 arcs = 73.5 sec/arc

Total fluence after both days = 5.26×10^{13} e-/cm² => 3 Mrads
(Mission Requirement: 3 Mrads)

Kevlar-Filled EPDM Insulation

iESD not detected until flux raised to 2 nA/cm²

Date	Sample under Test	Energy (MeV)	Flux (nA/cm ²)	Average time between arcs
11/1/2018	Kevlar-Filled EPDM	1	0.1	No arcs in 3600 sec
		1	0.25	No arcs in 3600 sec
		1	0.5	No arcs in 2100 sec
		1	1	No arcs in 1200 sec
		1	2	1260 sec/ 21 arcs = 60 sec/arc
		1	5	600 sec/40 arcs = 15 sec/arc
11/2/2018	Kevlar-Filled EPDM	1	1	No arcs in 1200 sec
		1	2	1800 sec/12 arcs = 150 sec/arc
		1	3	1800 sec/35 arcs = 51.5 sec/arc

Total fluence after both days = 1.21×10^{14} e-/cm² => 6.9 Mrads
Mission Requirement: 3 Mrads

Liner

iESD detection threshold at 2 nA/cm²

Date	Sample under Test	Energy (MeV)	Flux (nA/cm ²)	Average time between arcs
11/8/2018	Liner (HTPB)	0.8	0.1	No arcs in 1800 sec
		0.8	0.25	No arcs in 1800 sec
		0.8	0.5	No arcs in 1800 sec
		0.8	1	No arcs in 1800 sec
		0.8	2	1800 sec/1 arc
		0.8	3	1800 sec/1 arc
		0.8	4	1800 sec/4 arcs = 450 sec/arc
		0.8	5	1800 sec/2 arcs = 900 sec/arc
		0.8	5.5	900 sec/2 arcs = 450 sec/arc

Total fluence = 2.08×10^{14} e-/cm² => 4.09 Mrads
Requirement: 3 Mrads

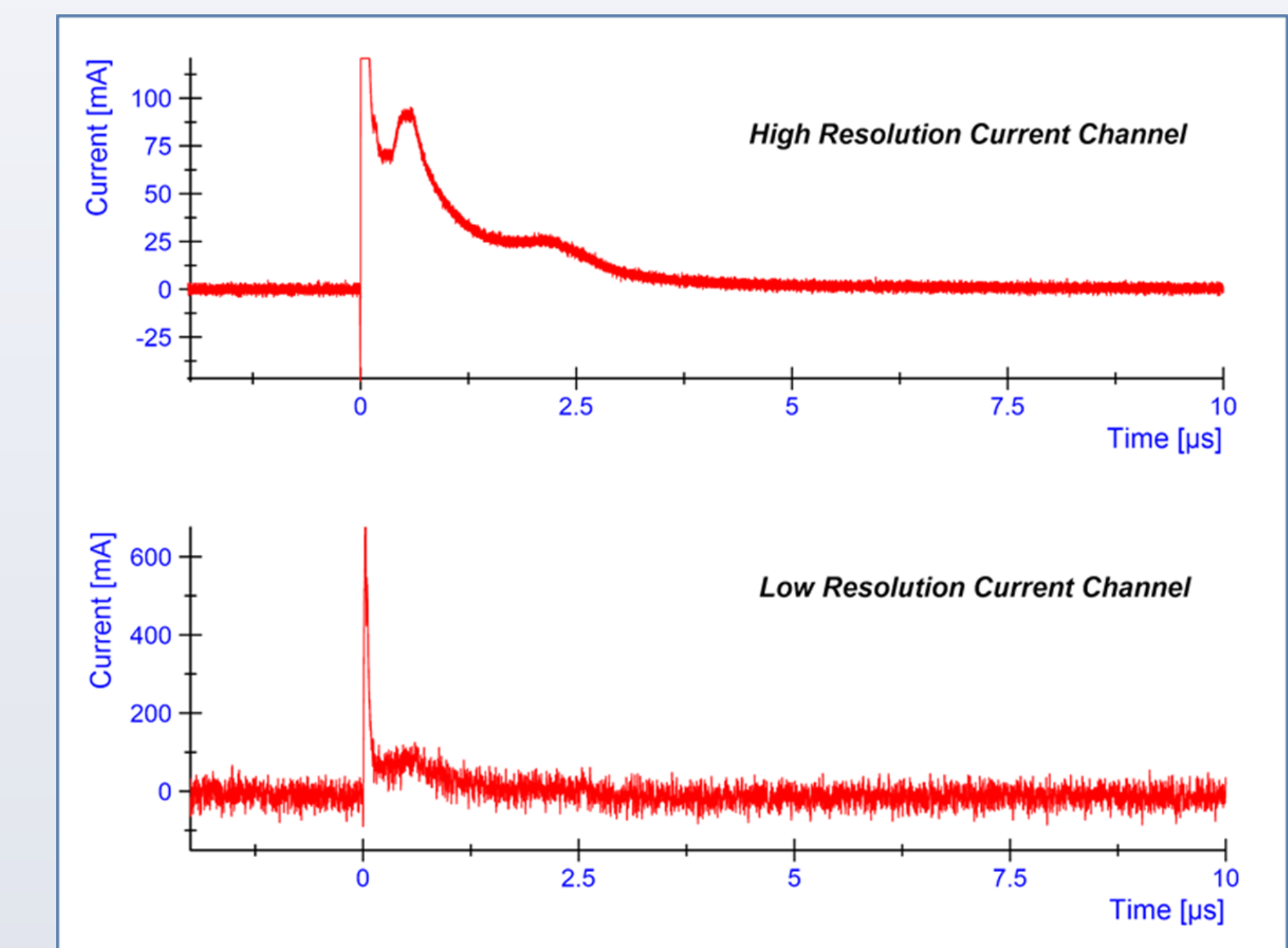
Inert Propellant

Highly resistant to iESD generation

Date	Sample under Test	Energy (MeV)	Flux (nA/cm ²)	Average time between arcs
11/5/2018	Inert Propellant	2.4	0.1	No arcs in 2580 sec
		2.4	0.2	No arcs in 1800 sec
		2.4	0.5	No arcs in 1800 sec
		2.4	1	No arcs in 1800 sec
		2.4	2	No arcs in 1800 sec
		2.4	5	No arcs in 1980 sec
		2.4	10	3600 sec/1 arc
11/6/2018	Inert Propellant	2.4	15 +/- 2	1200 sec/4 arcs = 300 sec/arc

Total fluence after both days = 5.45×10^{14} e-/cm² => 8.54 Mrads
Mission Requirement: 3 Mrads

SF-EPDM Waveform



Summary

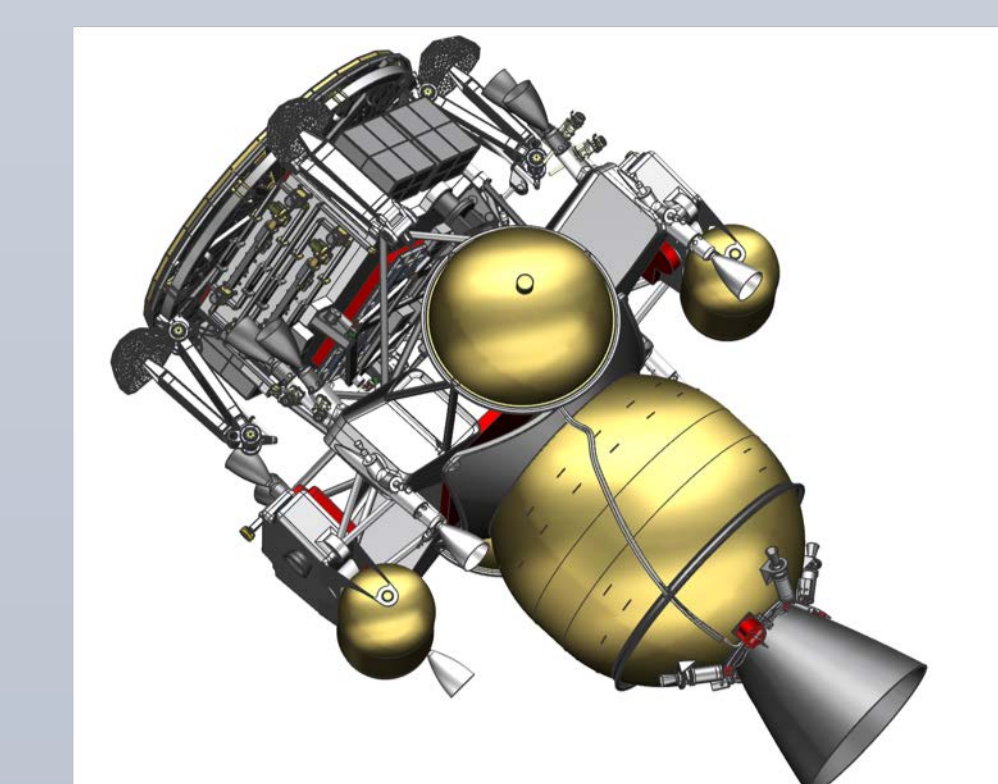
Missions to the Jovian environment are challenging due to the high radiation levels.

The current Europa Lander Mission design utilizes a solid rocket motor to provide the high thrust needed for the de-orbit stage.

The use of electrically insulating materials in the construction of a solid rocket motor raised concerns about the possible generation of internal Electrostatic Discharge (iESD) events and potential damage to materials leading to diminished motor performance.

A series of evaluation tests of inert solid rocket motor materials at the Marshall Space Flight Center indicated minimal susceptibility to iESD generation – particularly compared to the predicted flux levels in the Jovian environment.

Future iESD evaluation tests will focus on external de-orbit stage components which will be exposed to higher flux levels due to minimal shielding.



Artist Rendering of Europa Lander with DOS
Image Credit: NASA JPL-Caltech

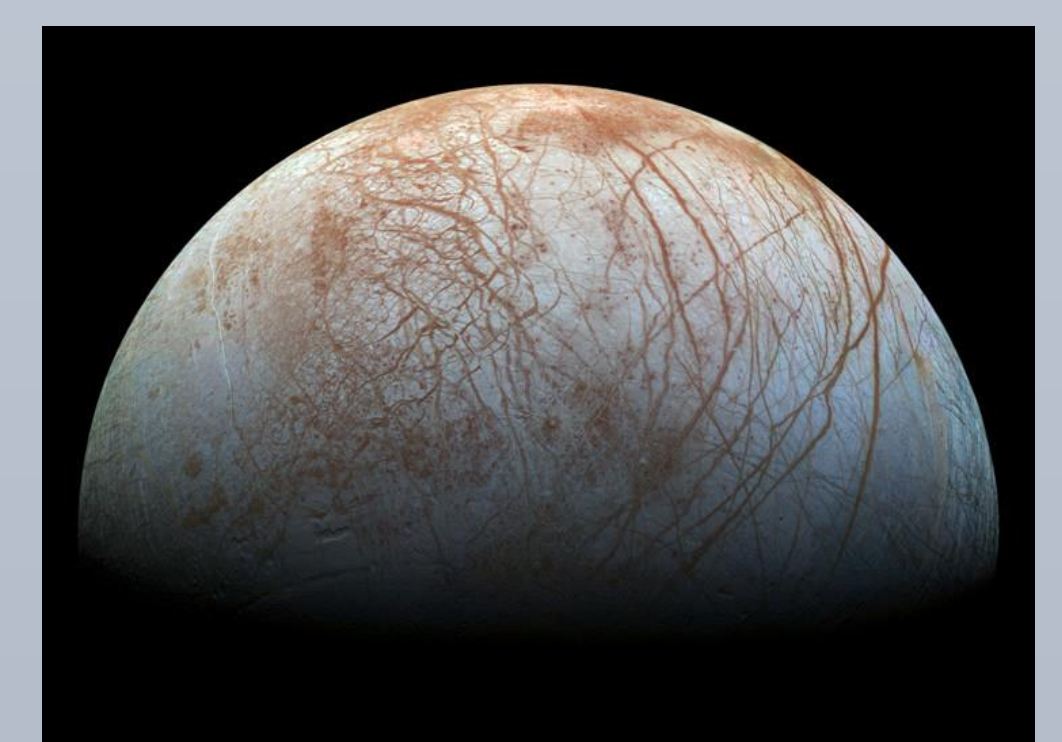


Image Credit: NASA JPL-Caltech