

Solar Array System Combined Environmental Effects Tests: Gateway Power and Propulsion Element

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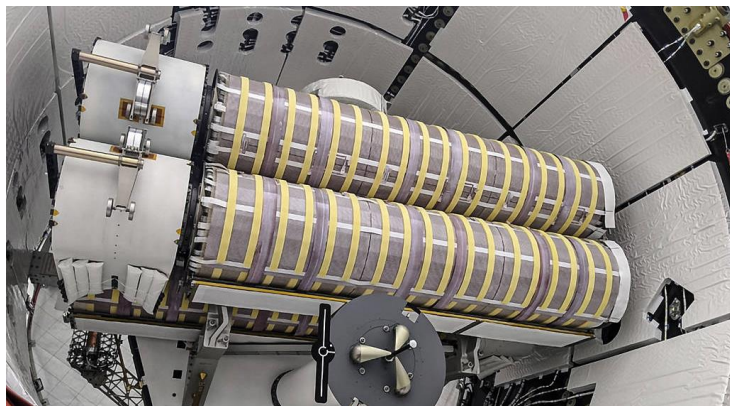
Bao Hoang

Maxar Space LLC



Background

- ❑ Maxar is developing advanced, lightweight, flexible Roll-out Solar Arrays (ROSA) for use on the Power & Propulsion Element (PPE) for Gateway
- ❑ Electric Orbit Raising (EOR) using Hall-Effect Thrusters
- ❑ Co-Manifested Vehicle (CMV) launch configuration PPE + HALO module
- ❑ Near Rectilinear Halo orbit (NRHO) planned for Gateway – moon centric, but Earth facing for nearly continuous communications



Credit: NASA/RedWire

**“iROSA”
International
Space
Station**

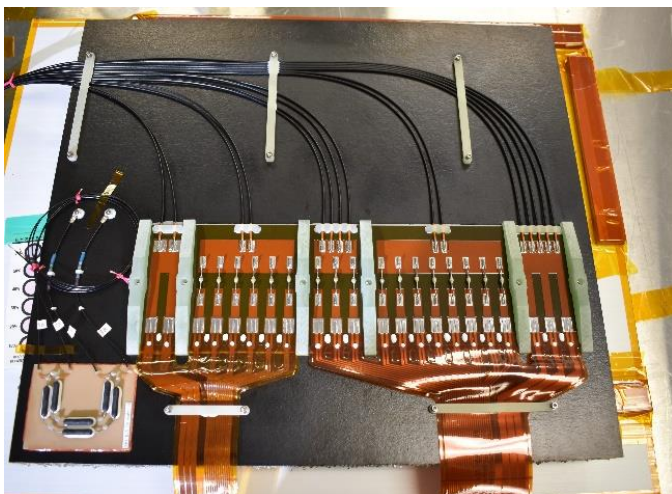


**Gateway
Power &
Propulsion
Element
“PPE”**

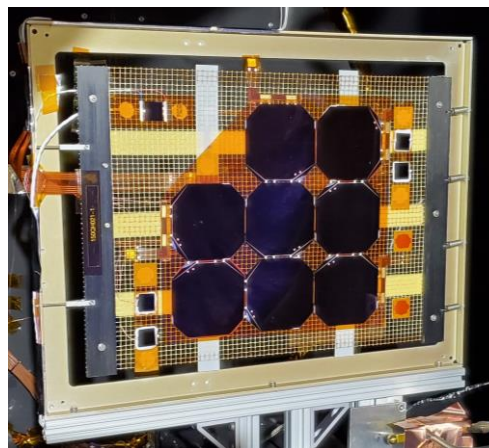
Test Coupons

- ❑ Design risk reduction through coupon testing
- ❑ 3 solar cell module coupons: Z4J cells with Qioptiq CMG coverglass with single layer MgF2 anti-reflective coating
- ❑ Diode Board: representing electrical current management at base of Photovoltaic Array (PVA) wing

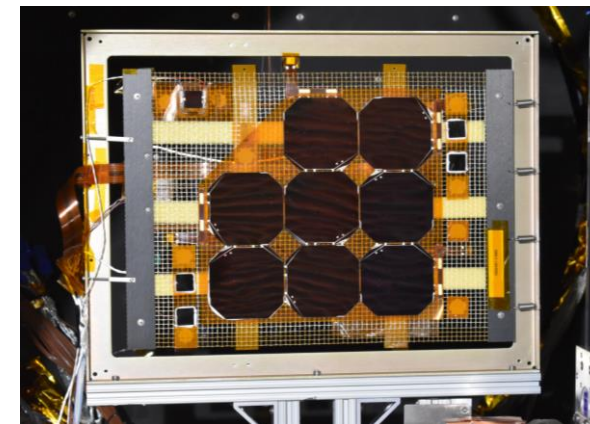
Diode Board



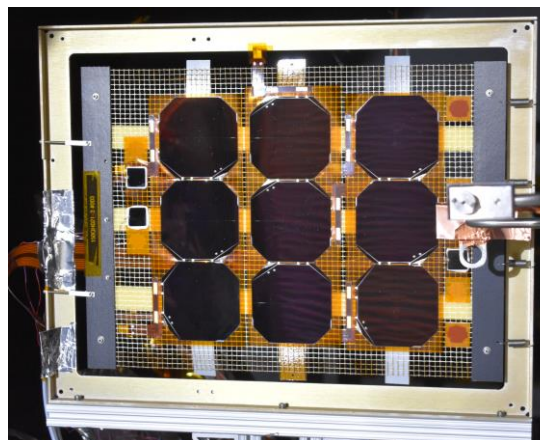
CE-1



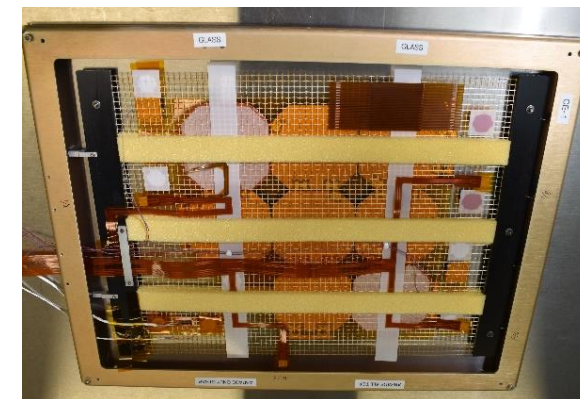
CE-2



CE-4



Back



Picture Credits: NASA/MSFC/Todd Schneider

Space Environments and Diagnostics

EOR = Electric Orbit Raising

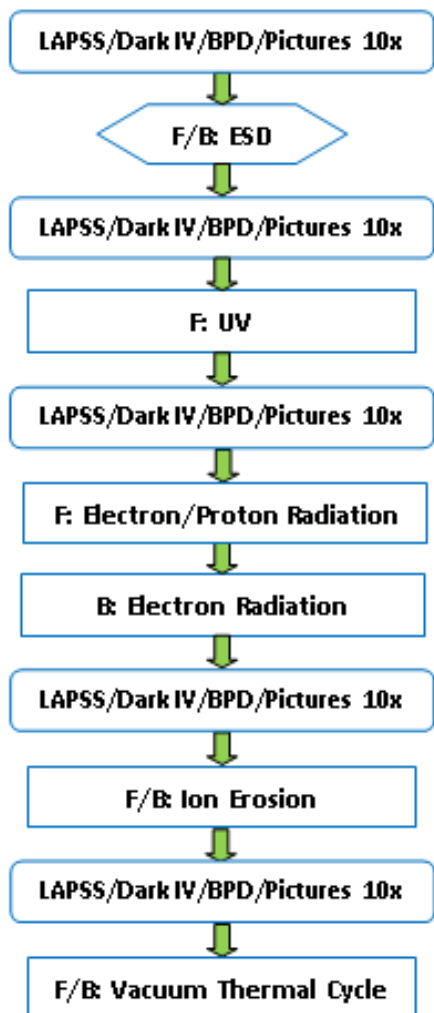
Cumulative Space Environment Exposure after each mission phase			
Type	EOR	EOR+5y	EOR+15y
UV radiation in Equivalent Sun Hours (Front)	667	1333	2000
1 MeV electrons in 10^{14} #/cm ² (Front & Back)	6.24	8.4	12.1
40-50 keV protons in 10^{15} #/cm ² (F&B)	2.0	4.6	9.8
580 eV xenon ions in 10^{19} #/cm ² cells (F&B)	1.35	1.4	1.5
580 eV xenon ions in 10^{18} #/cm ² diode board (F)	8.43	8.75	9.37
vacuum thermal cycling at +100 C to -183 C (F&B)	268	318	418
electrostatic discharge (ESD) # arcs (F only):	12*	18	24

* Includes 6 arcs at BOL

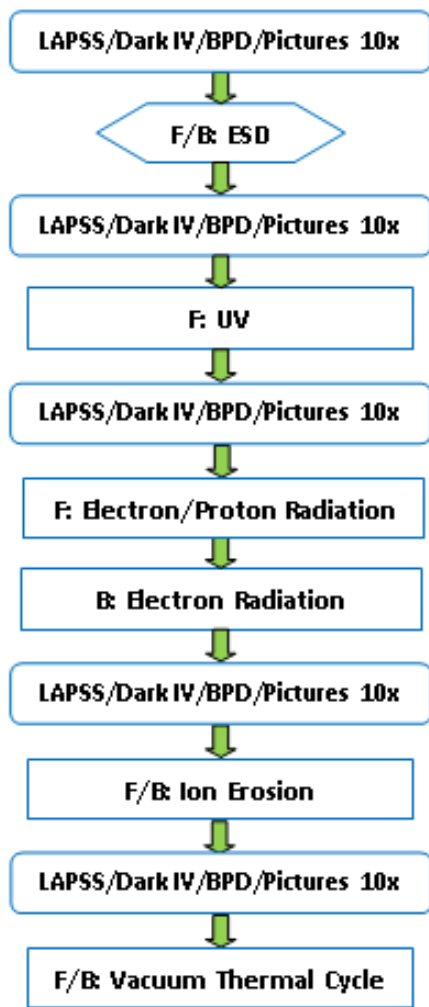
- ❑ Diagnostics are preformed at Beginning of Life (BOL) and after each environment: 10x magnification picture, Large Area Pulsed Solar Simulator (LAPSS), Dark I-V, Bypass Diode, Forward Bias (FB) and Reverse Bias (RB) of each component of diode board

Test and Diagnostic Sequence

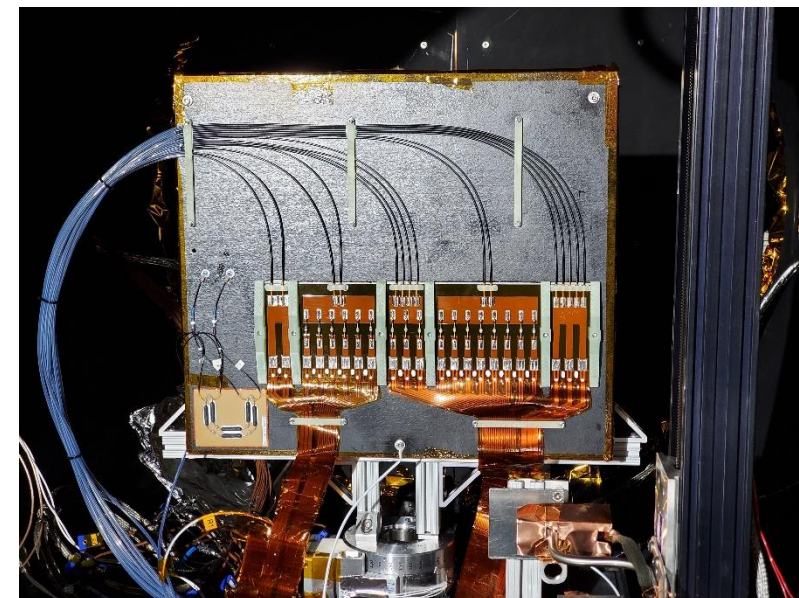
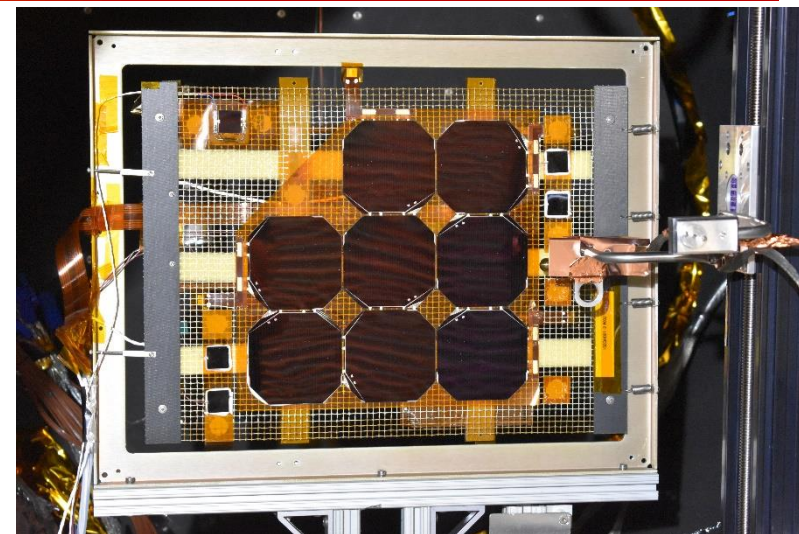
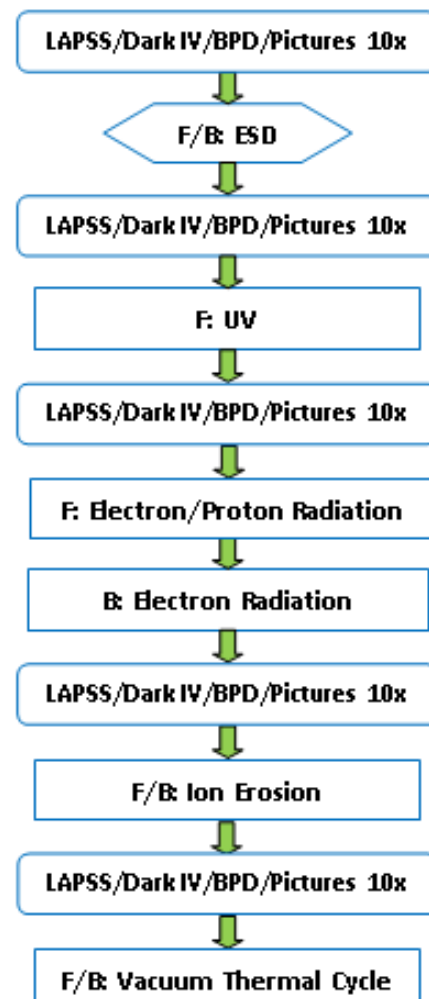
BOL-EOR



EOR + 5-year

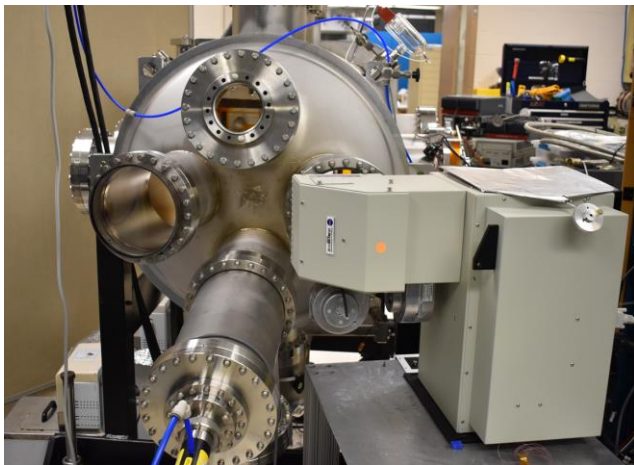


EOR + 15-year



MSFC Environment Test Chambers

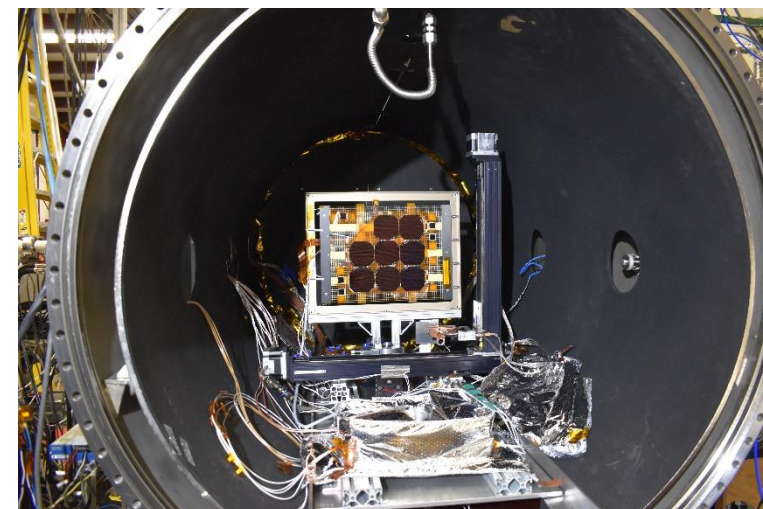
UV Test Chamber



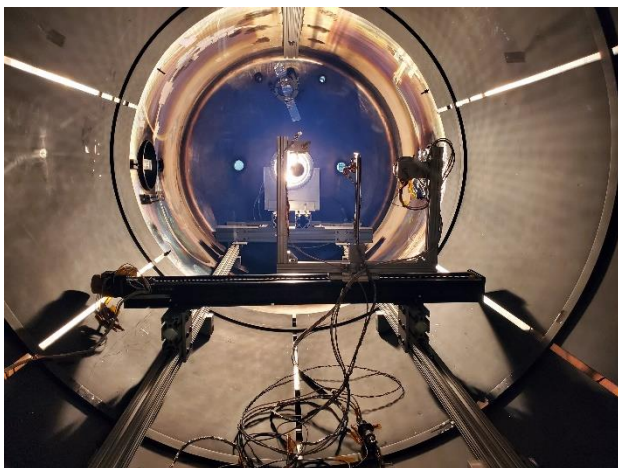
Accelerator Lab: Electron and Proton Radiation



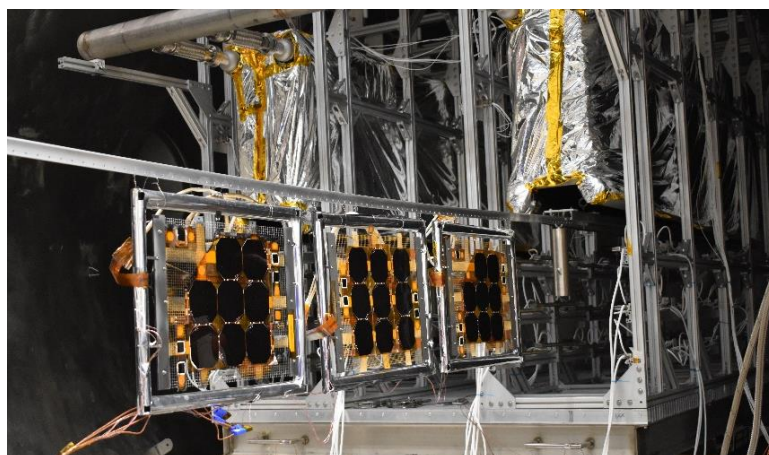
ESD Chamber: interior view



Ion Erosion Chamber: interior view

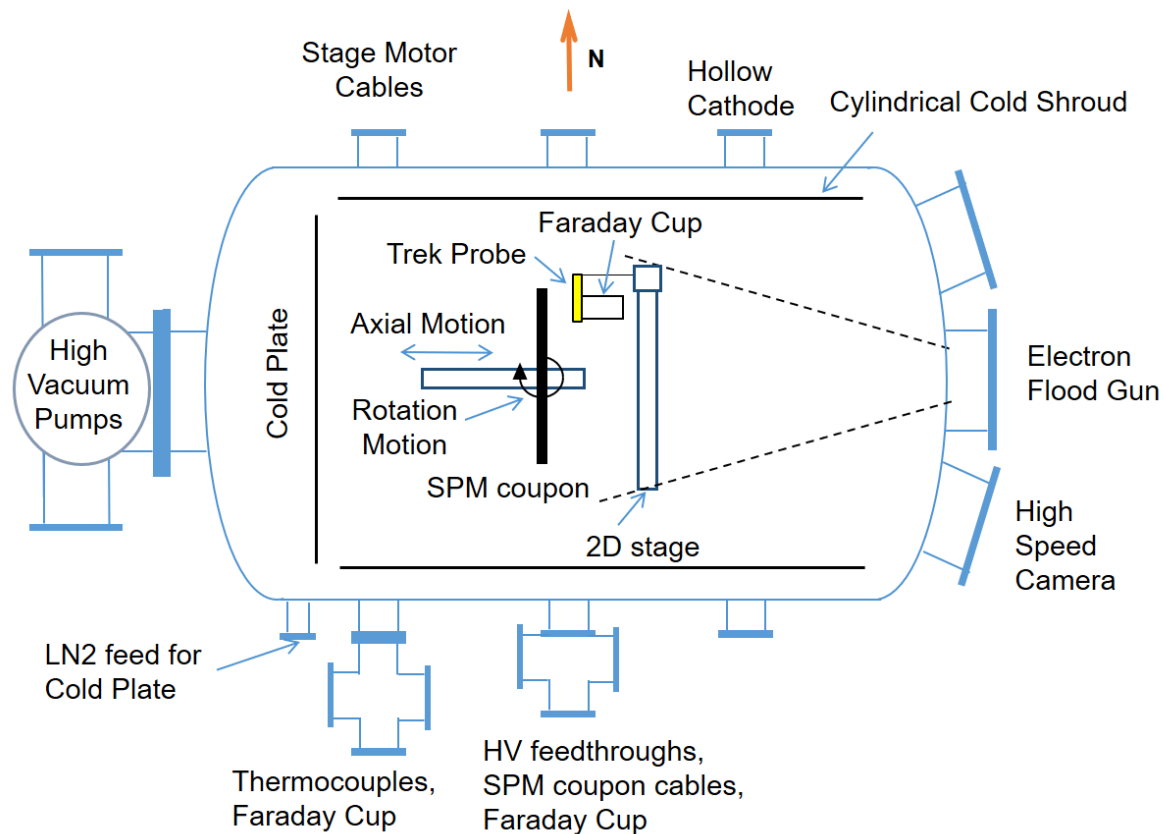


T/V chamber: interior view

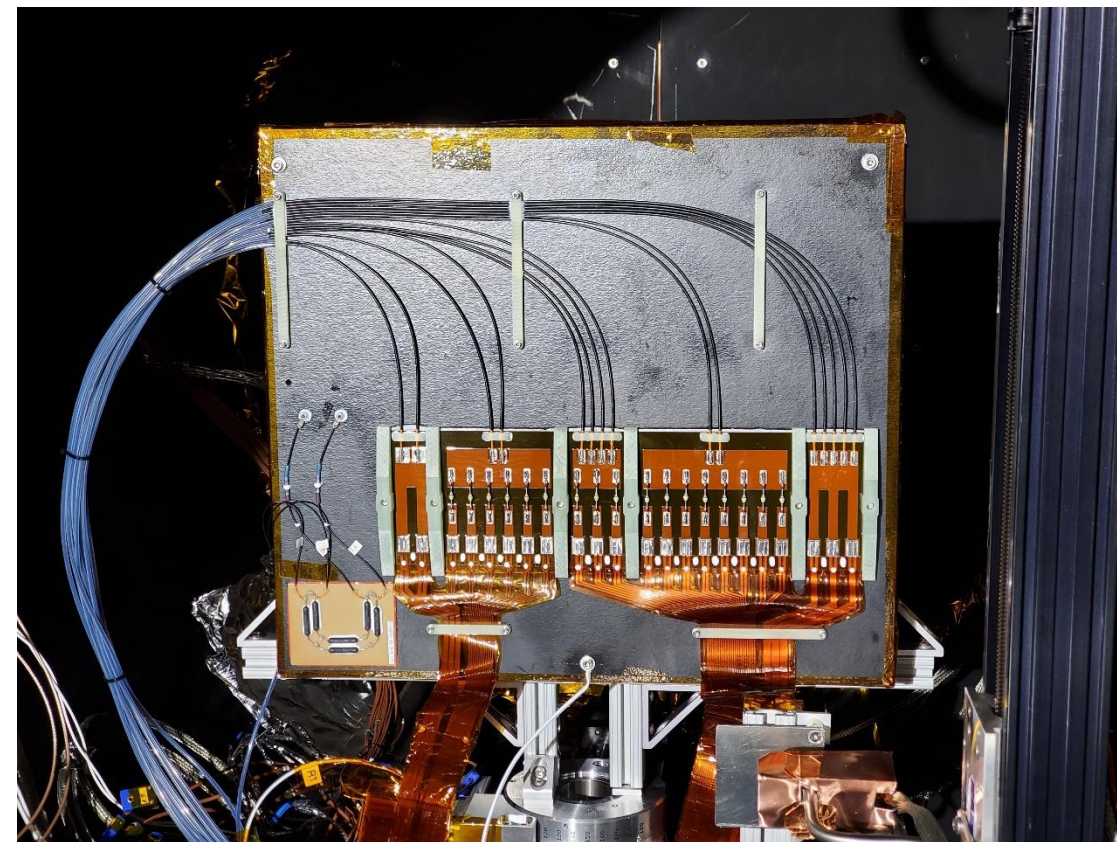


Picture credits: NASA/Todd Schneider

MSFC Electrostatic Discharge (ESD) Test Chamber



Diode Board in ESD Chamber



Picture credit: NASA/ Todd Schneider

New chamber allows upgraded capability: (1) colder (old -65C, new -110C); (2) rotation allows front and back testing in single pump-down; (3) Buffered high-speed camera to capture arc picture

Diode Board ESD Test Circuit

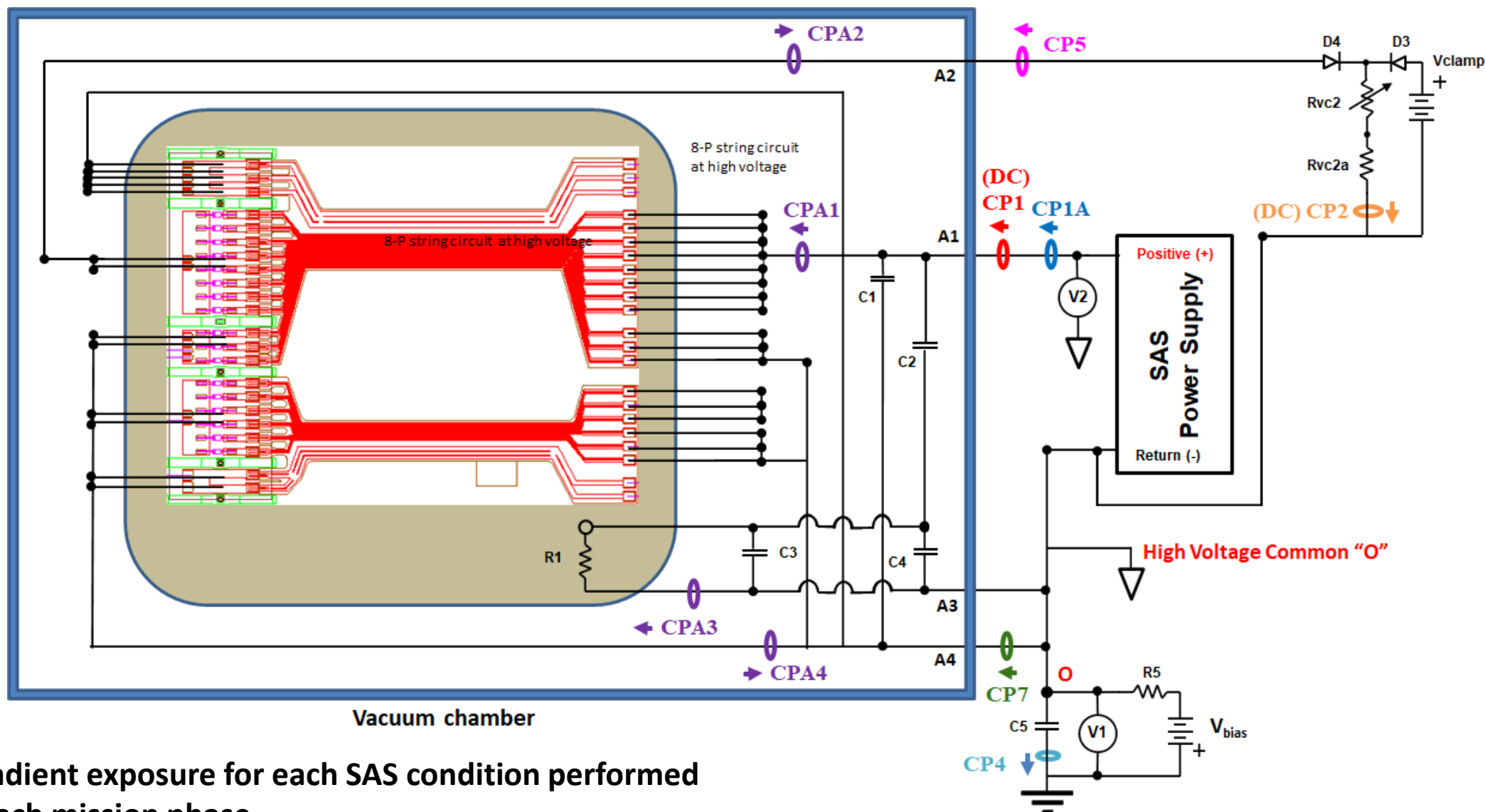
ESD Test Conditions

SAS

100V, 6.9A

100V, 8.3A

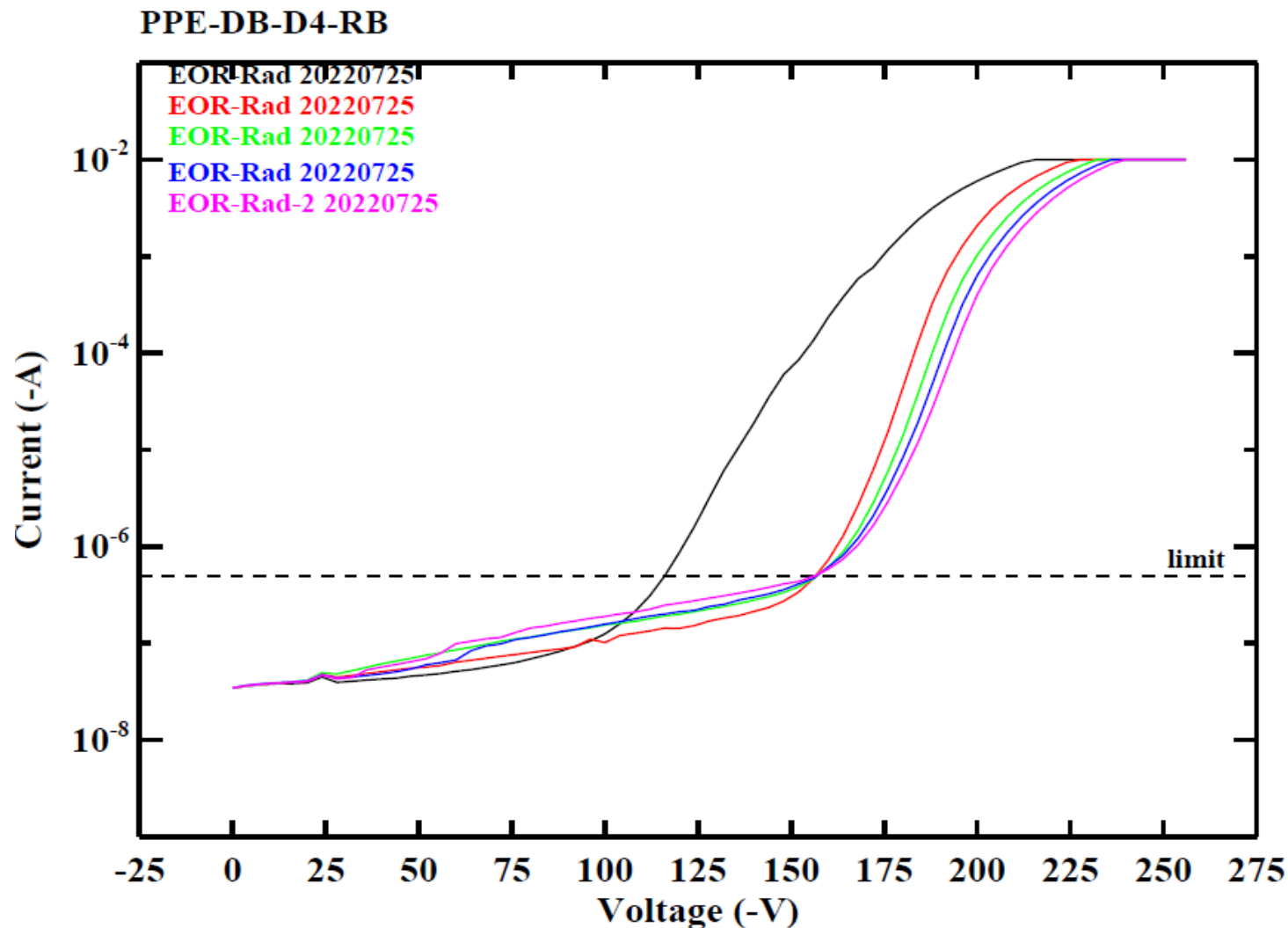
120V, 6.9A



3-hour Normal Gradient exposure for each SAS condition performed at BOL and after each mission phase

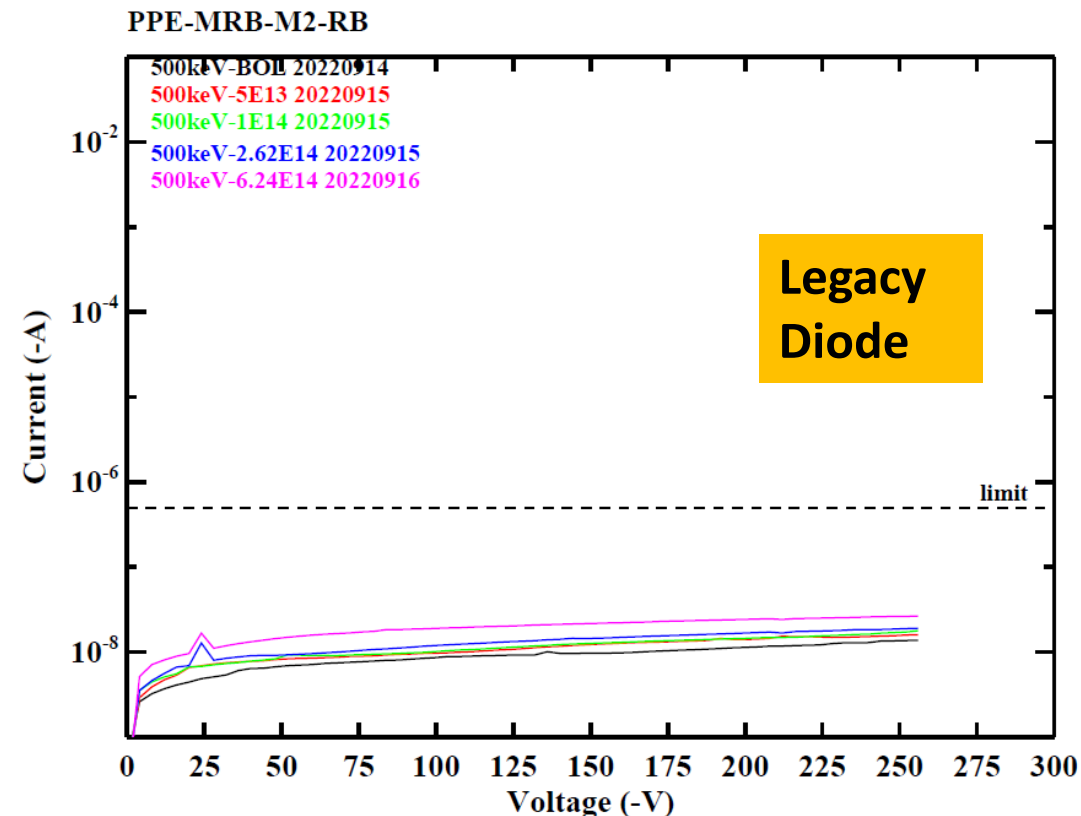
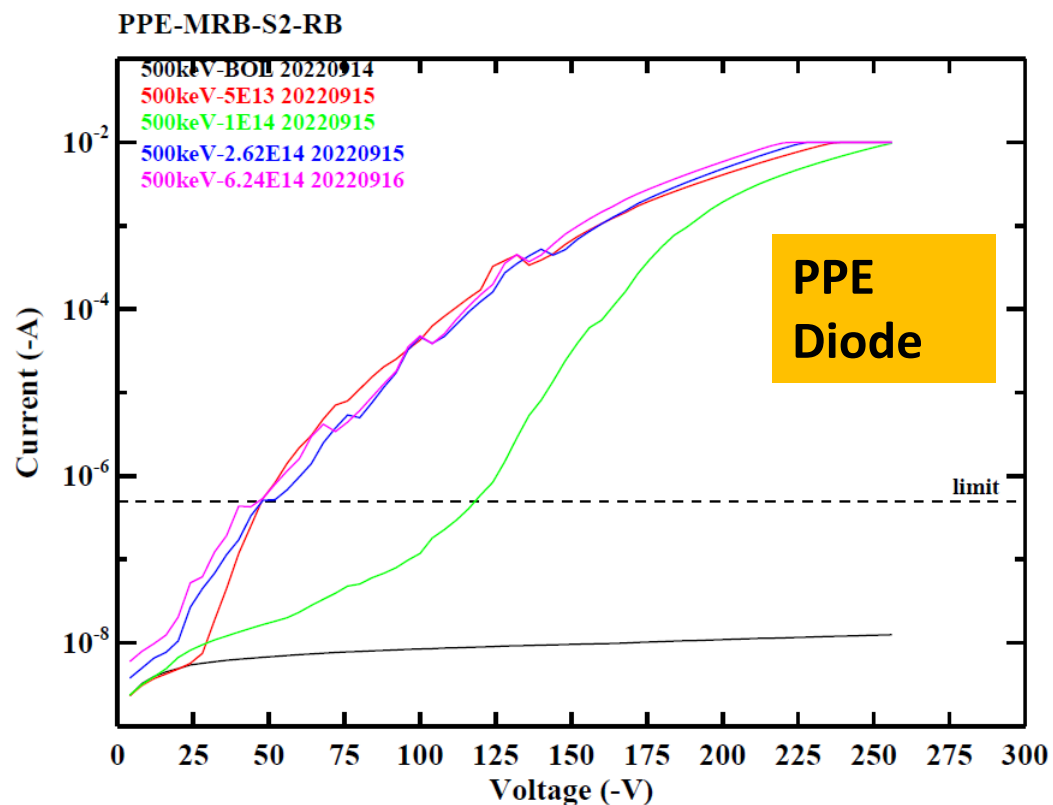
Diode Board – Post Lunar Transit (EOR) Radiation

- ❑ With Test fluence from table in page 4:
 - All 15 diodes showed leakage current in reverse bias
- ❑ Review of radiation transport analysis
 - Test/PPE = 7.1
 - Test/max GEO = 4.5
 - Goal: Test to envelope both PPE & GEO



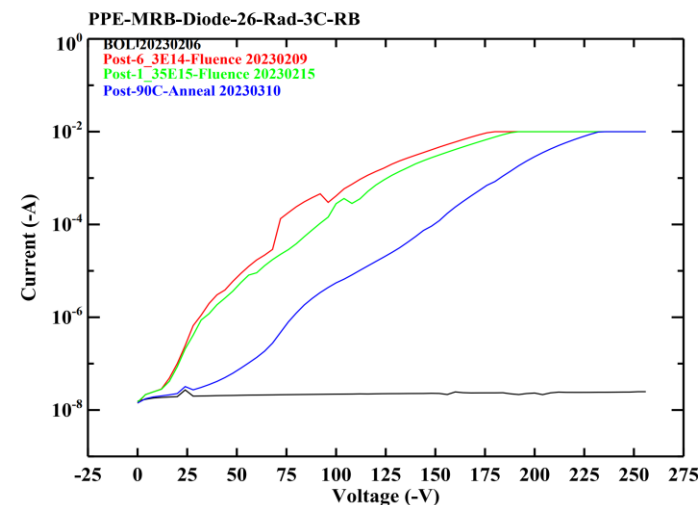
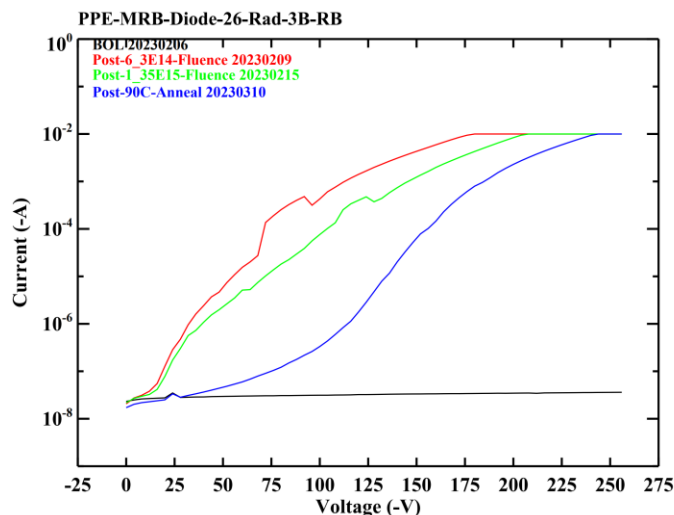
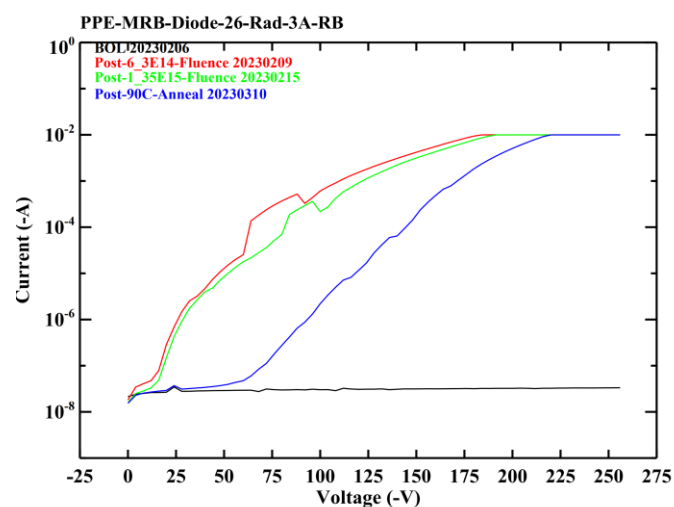
Diode Board: Impact of Test Results

- ☐ The impacts of leakage:
 - 1.0 mA leakage will result in loss of 0.1 W/string, or 8W for an 8P circuit
 - 10 mA leakage will result in loss of 1 W/string, or 8W for an 8P circuit
- ☐ Current leakage would only occur if the affected string is either shorted to ground or mostly shadowed
- ☐ PPE telemetry would not be able to detect such small changes in current output
- ☐ Need further testing to quantify whether observed leakage is acceptable



Radiation of Additional Flight Diodes

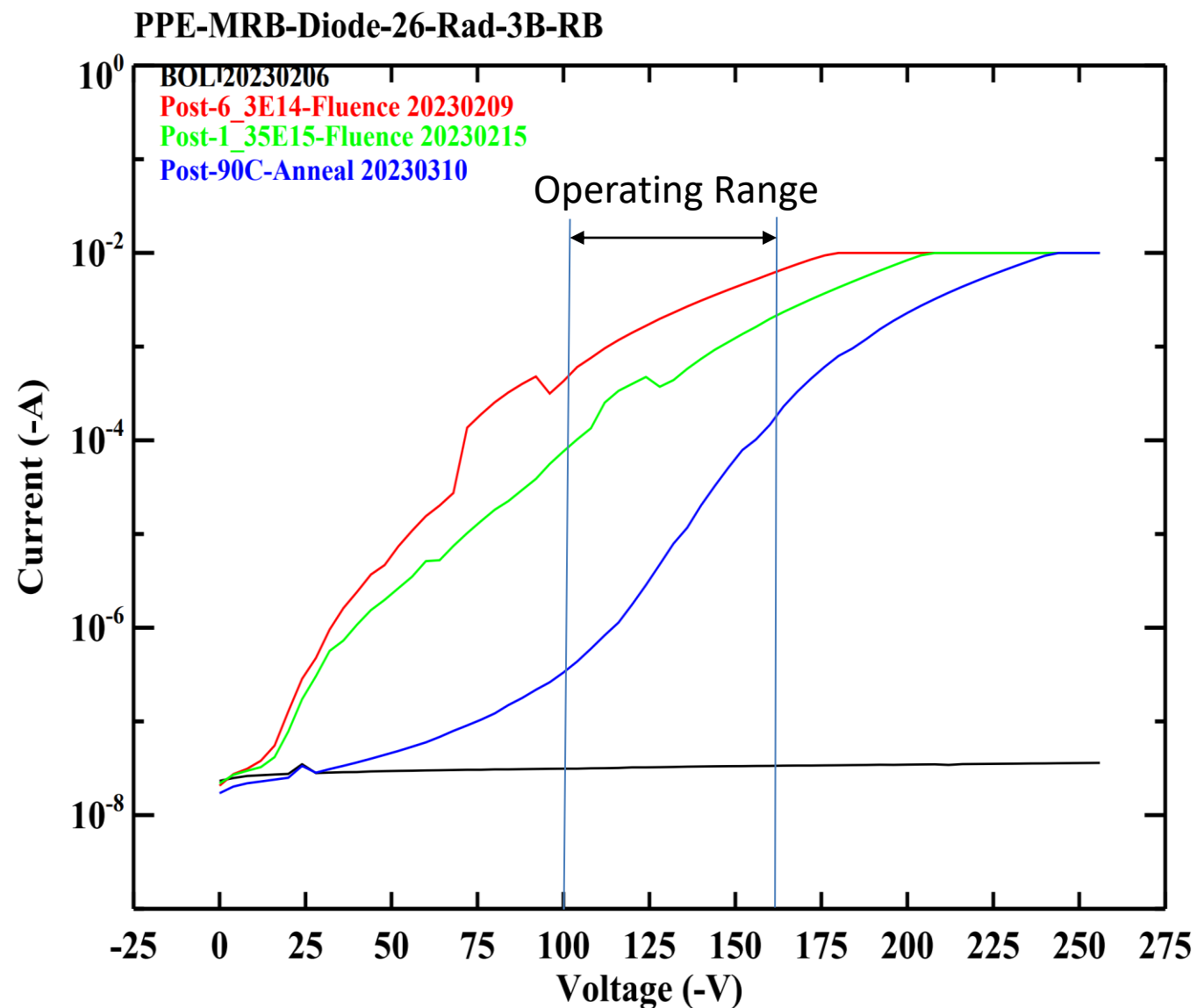
- ❑ 29 additional diodes were tested to give sample size of 44 - a statistically significant sample size of irradiated diodes
 - Diodes tested to 1-MeV electrons: $1.35\text{E}15 \text{ \#/cm}^2$
 - Post radiation, all diodes annealed at $+90^\circ\text{C}$ in ambient pressure for 24 hours
 - Elevated diode temperature would occur in flight
- ❑ Ref. Mil S 19500J, Table IX for Lot Tolerance Percent Defective: A sample size of 45 would have a maximum defect rate of 5% at 90% confidence level



Like the 15 diodes from the test coupon, the 29 additional diodes have similar reverse leakage signatures. Diode leakage decreased with temperature anneal

Radiation of Additional Flight Diodes

- ❑ Summary of 44 diode leakage results post radiation (99.9% CL, averages + 6σ)
 - -100V: 0.94 mA max leakage
 - -160V: 12.5 mA max leakage
- Failure investigation demonstrates, with a statistically significant sample size, that observed diode leakage is acceptable



Summary

- ❑ PPE solar array risk reduction test schedule update
 - All solar cell module coupons have completed EOR + 5-year cumulative environments testing
 - CE1, CE2, and CE4 have completed the EOR + 15-year UV cumulative exposure
 - Diode board beginning EOR + 5-year ESD test
- ❑ Completion of test program expected Spring 2024



Credit: NASA