Electroluminescence Imaging:

A Quantitative Characterization Technique to Measure Dust Occlusion of Solar Cells

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Roselin Campos, Harry Yates, and Bran Tranter – *Maxar Space Systems*

Dust vs Solar Arrays

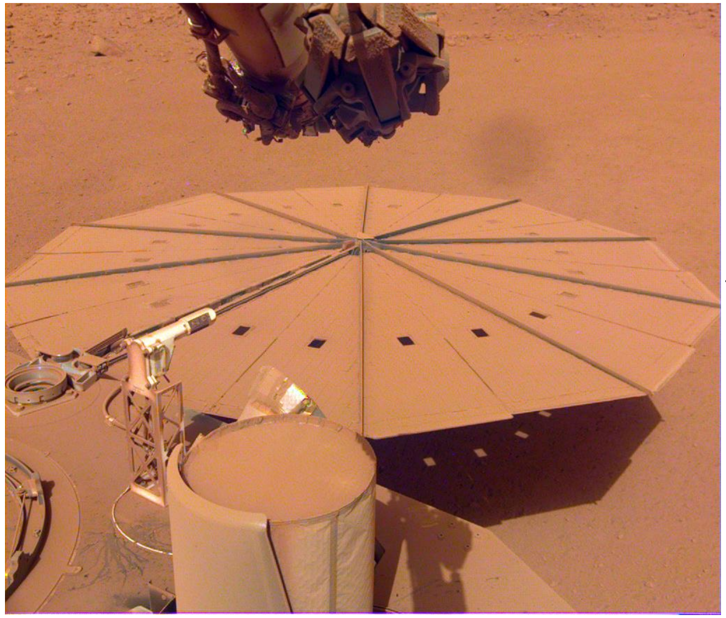
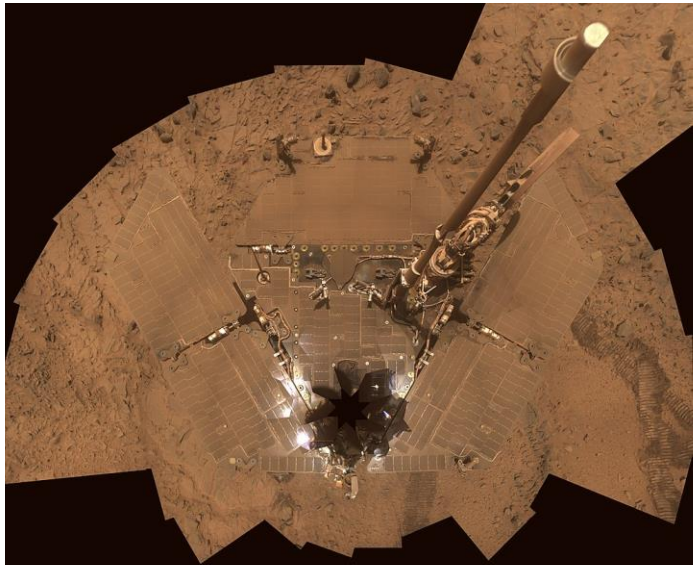


Image courtesy of NASA/JPL-Caltech

Mars Insight Lander

Image courtesy of NASA/JPL-Caltech/Cornell


Mars Spirit Rover (MER-A)

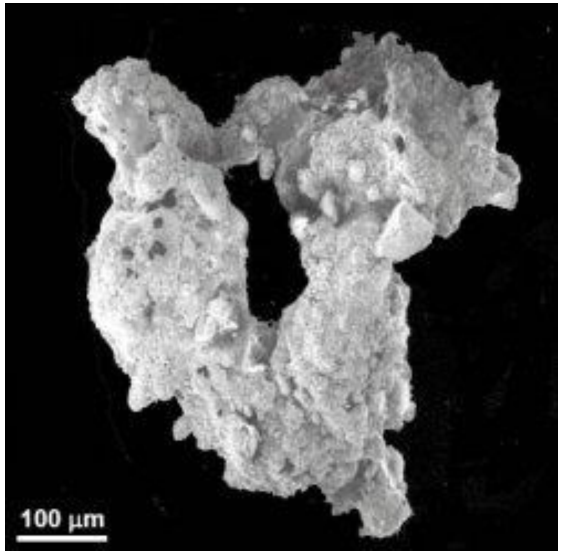
Image courtesy of David McKay, NASA/JSC


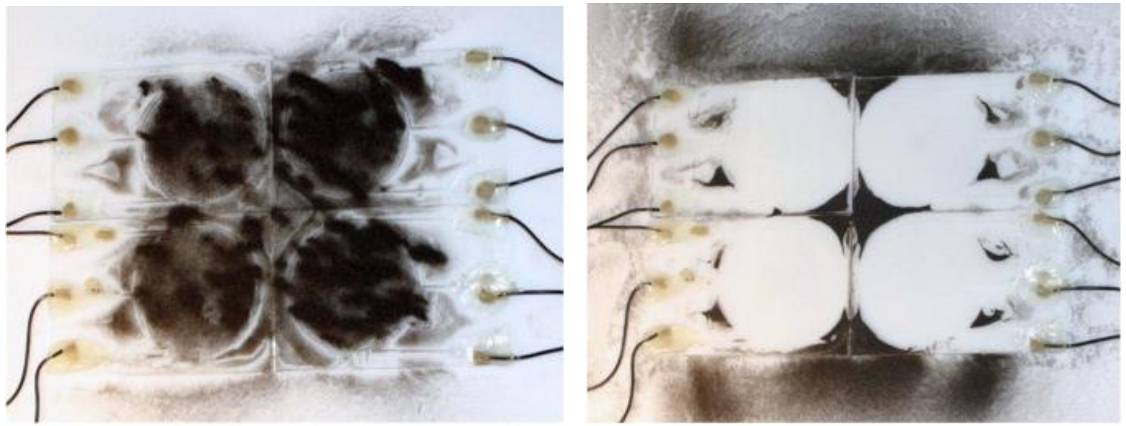
Image courtesy of NASA


- lunar dust sticks to exposed surfaces
- **dust adherence dominated by electrostatic forces**
- dust accumulation on arrays limits power
- no cleaning events like Martian arrays

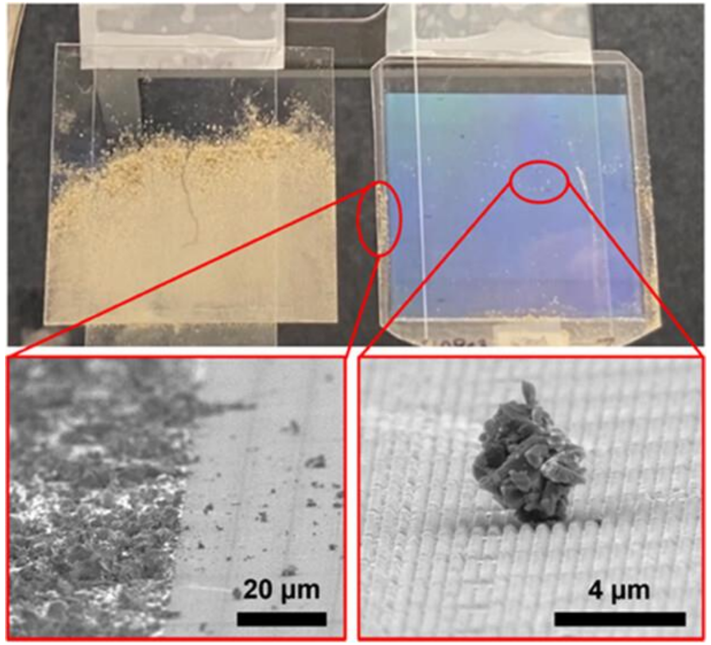
Dust mitigation is crucial for arrays on the lunar surface.

Dust Mitigation

Electrodynamic Dust Shield



C.I. Calle, et al, (2013, June 11-13). *Space Environmental Testing of the Electrodynamic Dust Shield Technology*. Annual Meeting of the Electrostatics Society of America, Cocoa Beach, FL, US.



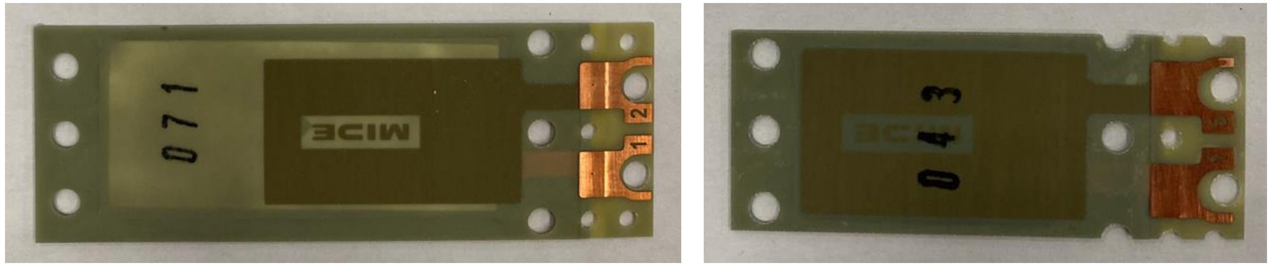
Large-Area Antidust Surfaces

Samuel S. Lee, et al., *Engineering Large-Area Antidust Surfaces by Harnessing Interparticle Forces, ACS Applied Materials & Interfaces*, 2023, *15* (10) ISSN 13678-13688 DOI: 10.1021/acsami.2c19211

GOAL: investigate vibromechanical dust removal for flexible arrays

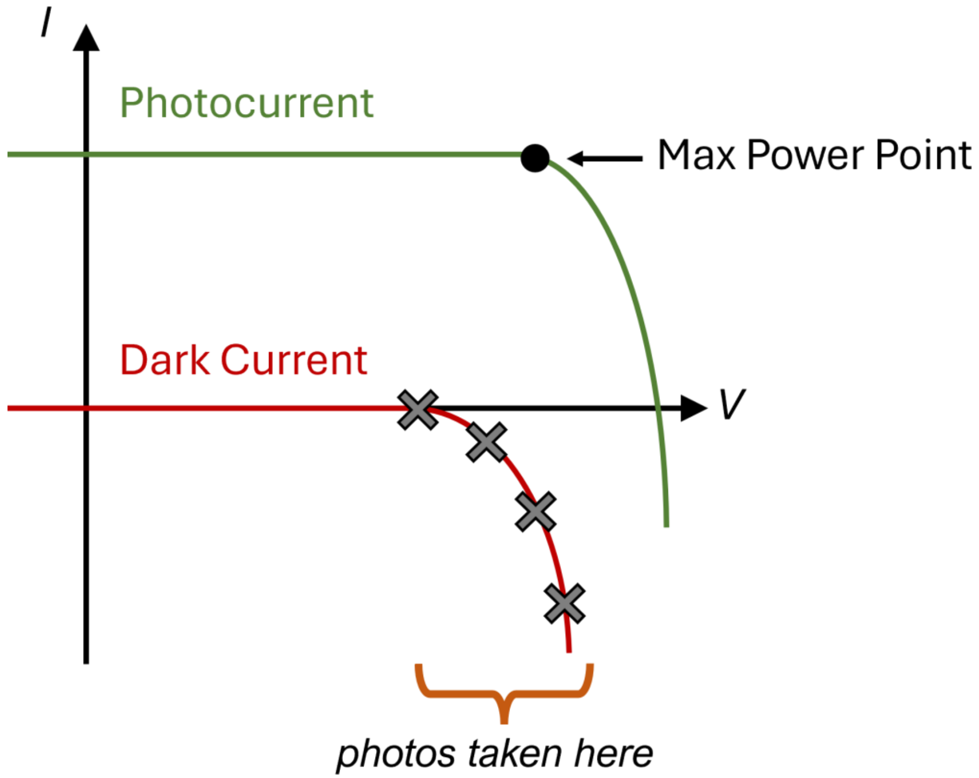
- Flexible arrays present the opportunity for a unique, simple dust mitigation strategy: vibration
- Piezoelectric motor converts electricity into a bending movement
- Frequencies being tested:
  - Small piezo resonant frequency: 150Hz
  - Large piezo resonant frequency: 433Hz
  - Frequency sweep: 1Hz – 500Hz

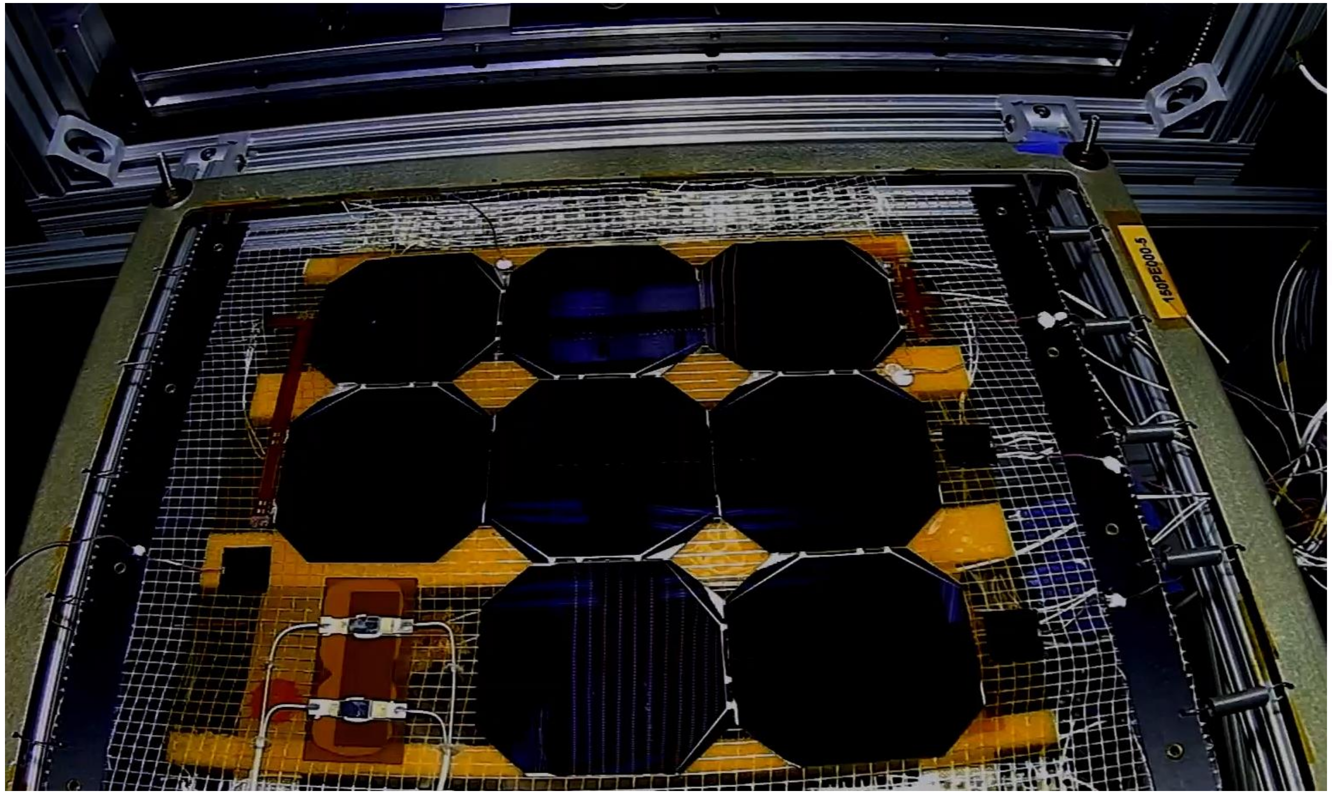
Image courtesy of Maxar



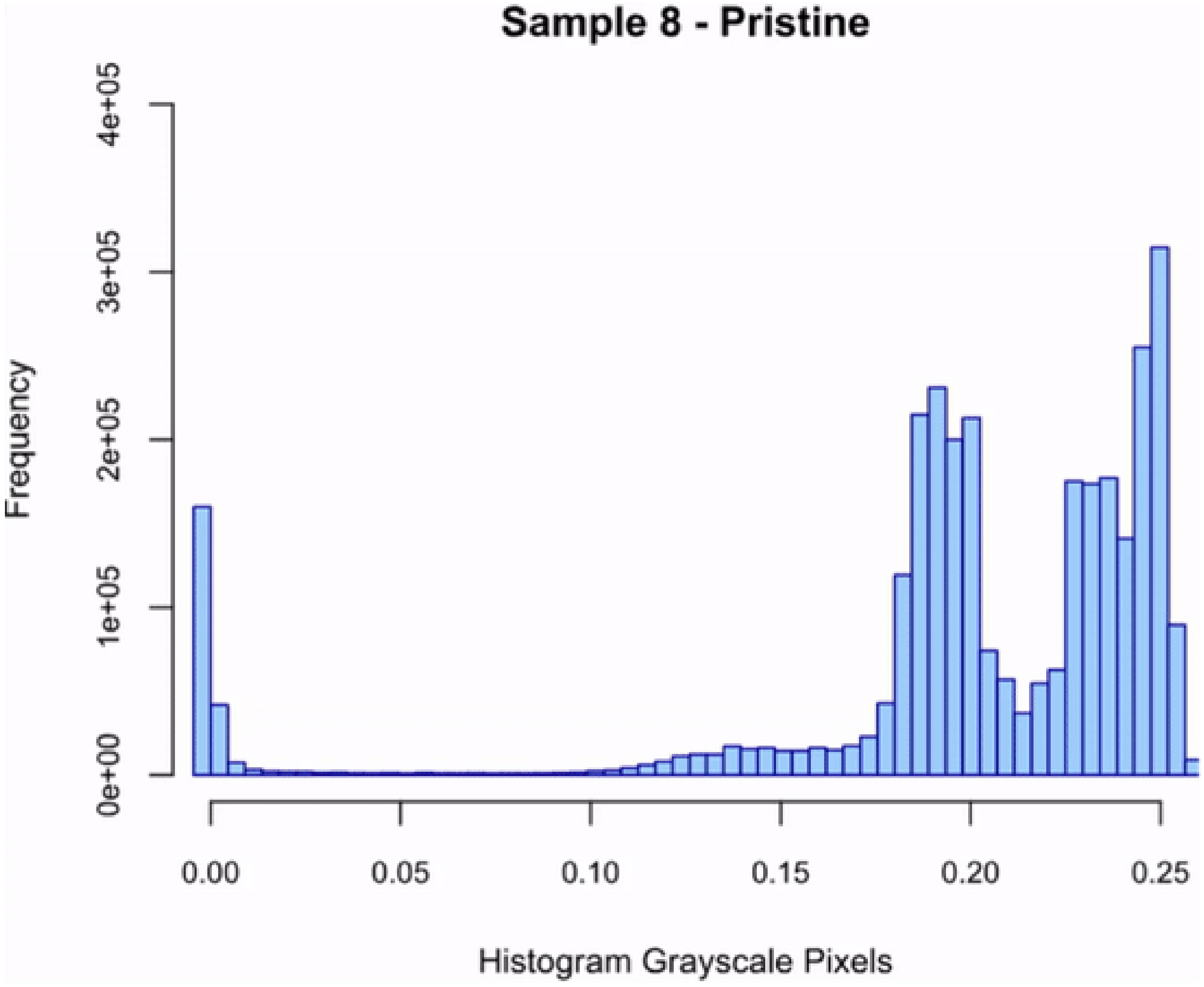
Electroluminescence Imaging

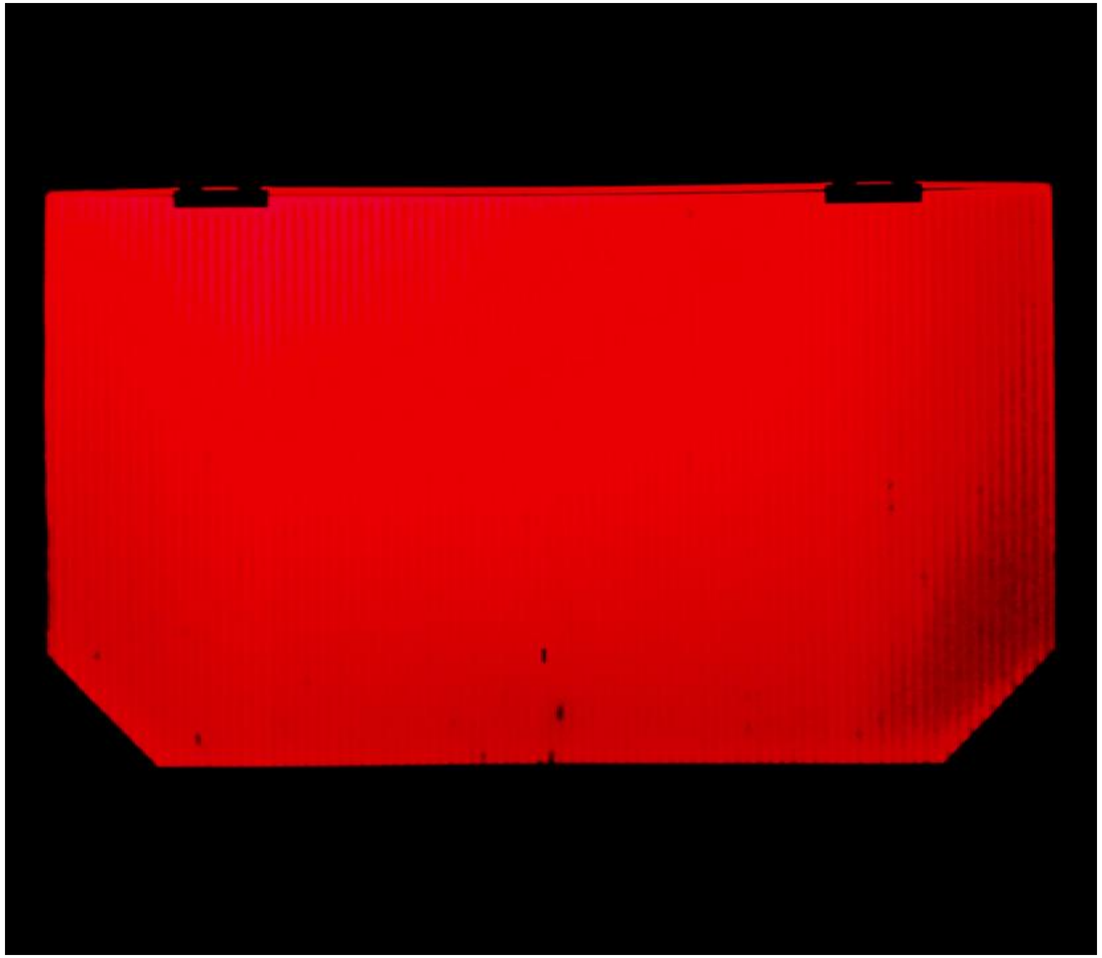
forward bias solar cell → solar cell emits light





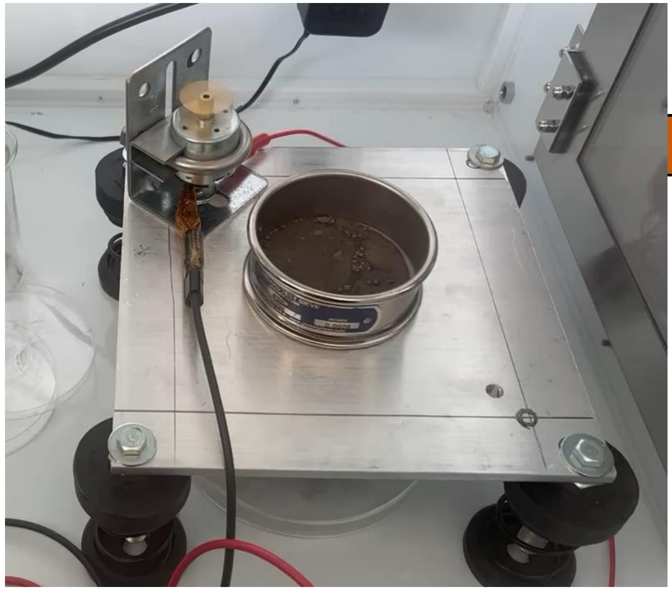
Electroluminescence Imaging

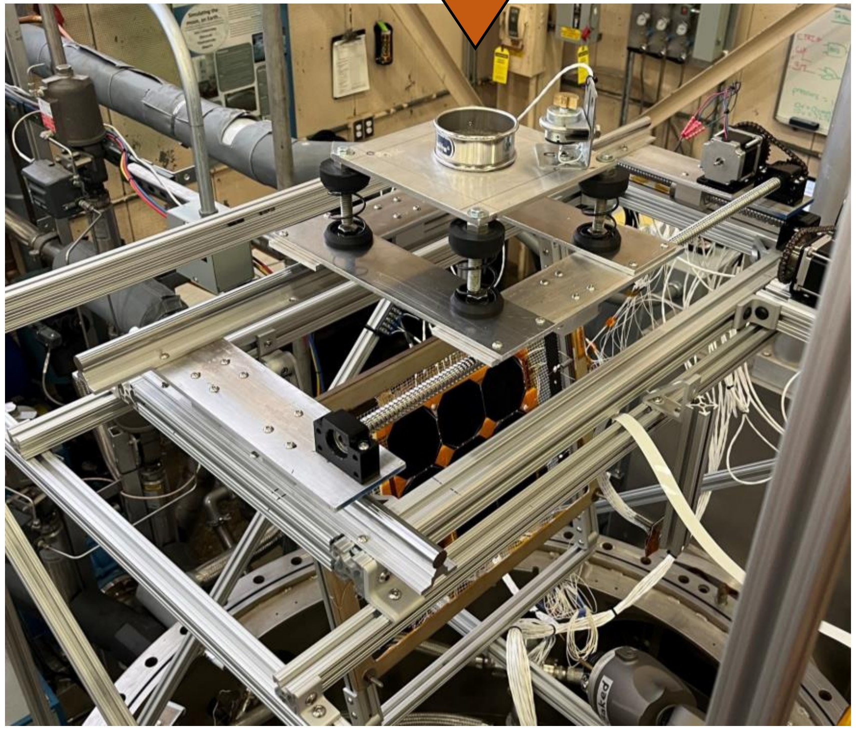




Dust Deposition System

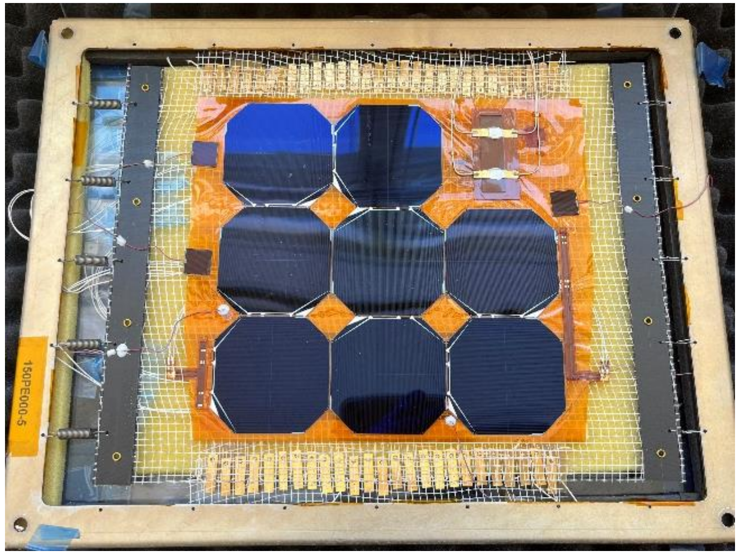
- vibration motor excites a simulant-loaded mechanical sieve
- designed to **raster** and **deposit dust** over full test article area





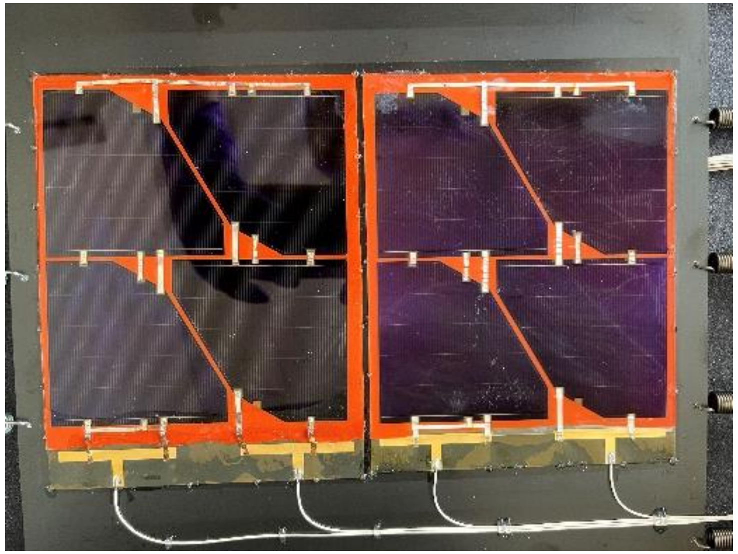
Test Articles

Coupon 1 – ROSA (ZTJ)



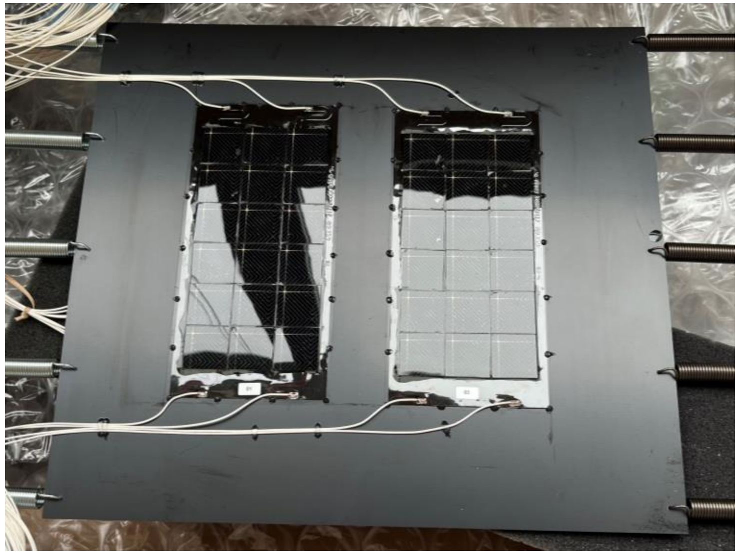
- Rocket Lab ZTJ cells
- bonded to flexible mesh
- 4 piezos on back

Coupon 2 – MicroLink IMM



- MicroLink IMM cells
- bonded to black Kapton-coated glass fiber composite
- 4 piezos on back

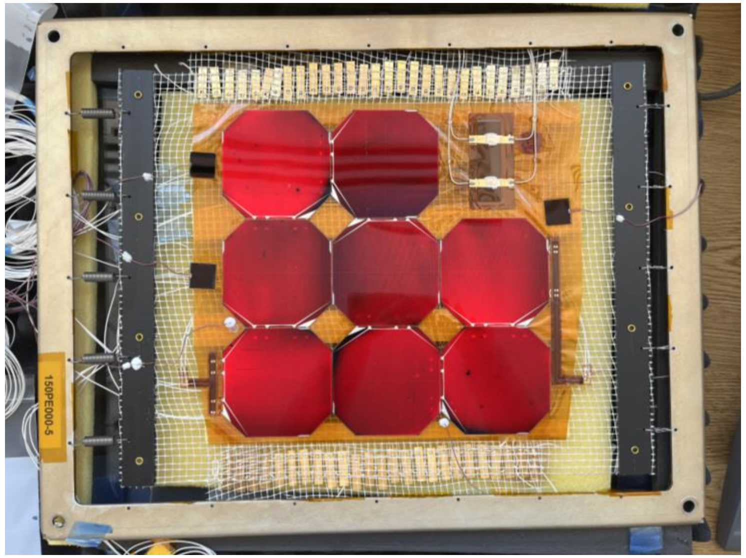
Coupon 3 – mPower Si



- mPower Silicon cells
- bonded to black Kapton-coated glass fiber composite
- 4 piezos on back

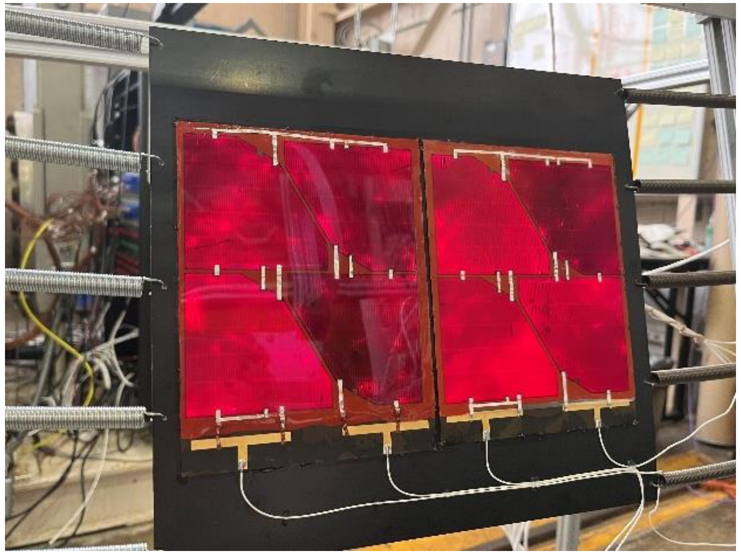
Test Articles - EL

Coupon 1 – ROSA (ZTJ)



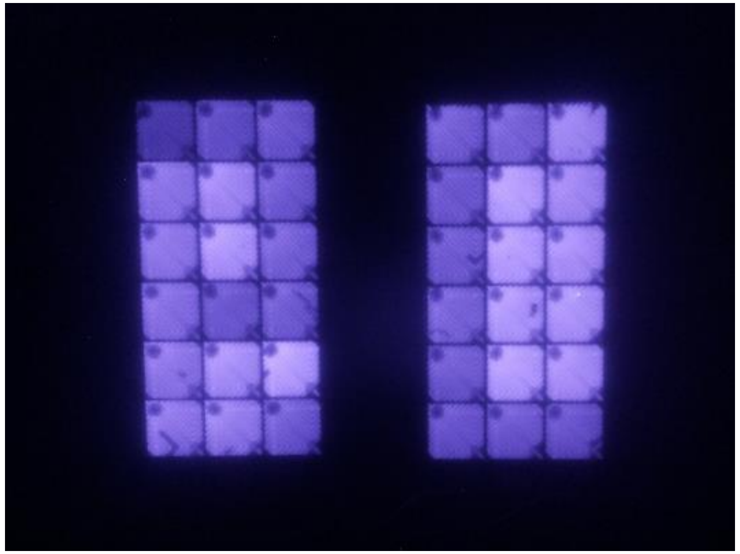
- Sol Aero ZTJ cells
- bonded to flexible mesh
- 4 piezos on back

Coupon 2 – MicroLink IMM



- MicroLink IMM cells
- bonded to black Kapton-coated glass fiber composite
- 4 piezos on back

Coupon 3 – mPower Si

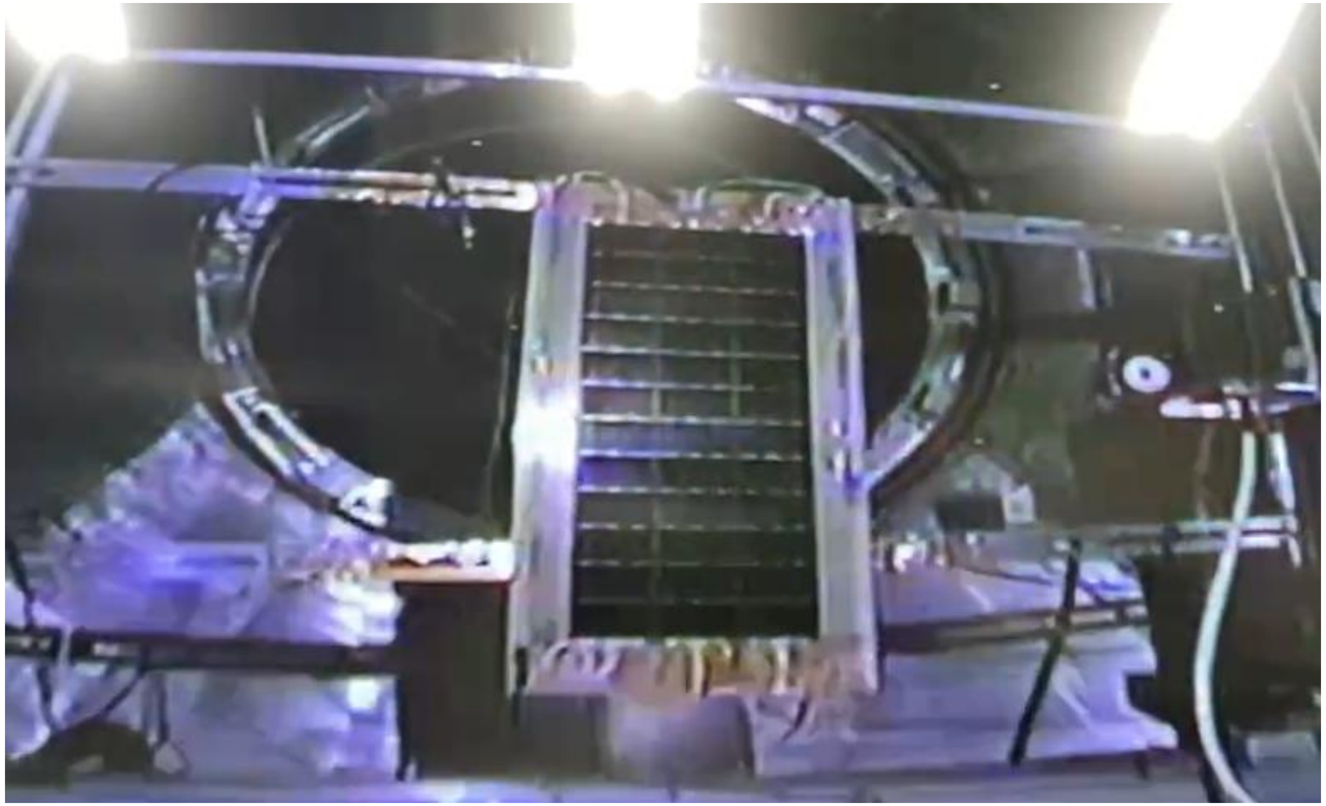


- mPower Silicon cells
- bonded to black Kapton-coated glass fiber composite
- 4 piezos on back

Test Facilities: VF-20

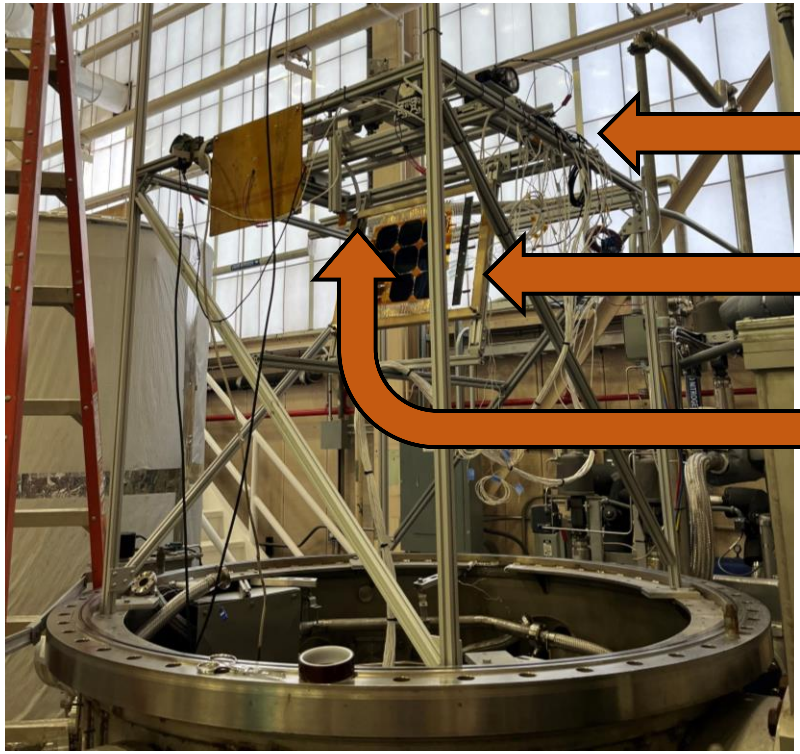
- Spacecraft charging investigations
- Derive surface charging range for testing in VF-13
- Testing done for **GEO conditions** (worst-case scenario for the lunar surface)

Slow motion capture, 0.25x speed



Test Facilities: VF-13

- VF-13 houses the dust deposition system, solar array test coupon, and EL imaging hardware for testing in vacuum
- System has a slow roughing pump to minimize simulant pluming in the e-1/-2 torr range
- HV supply simulates surface charge buildup on array

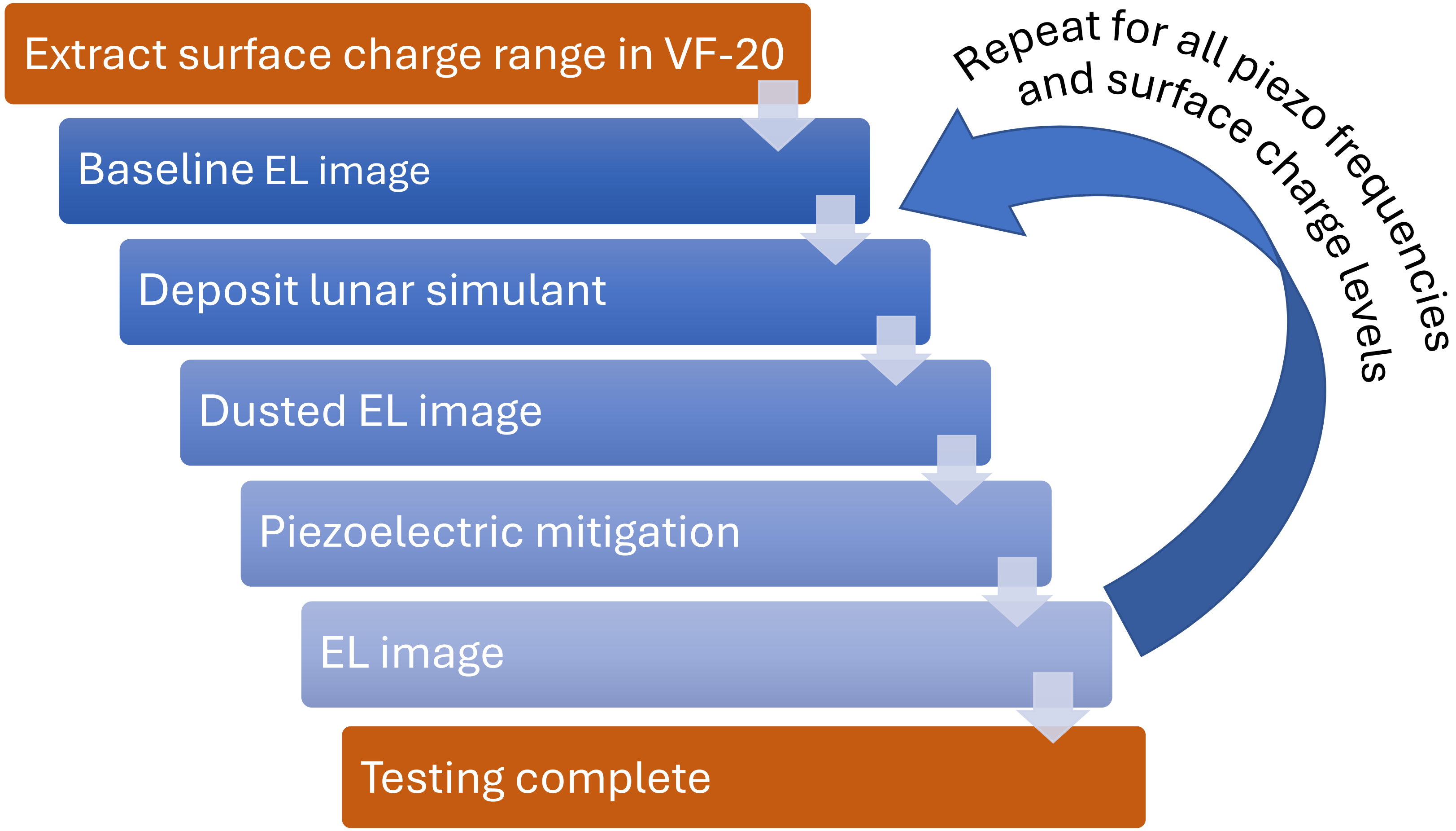


dust deposition system

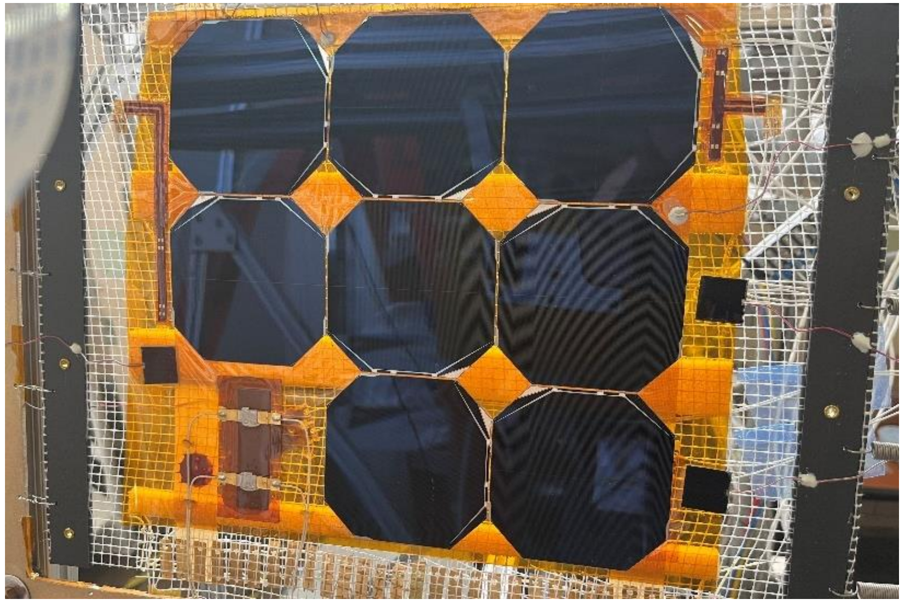
test coupon

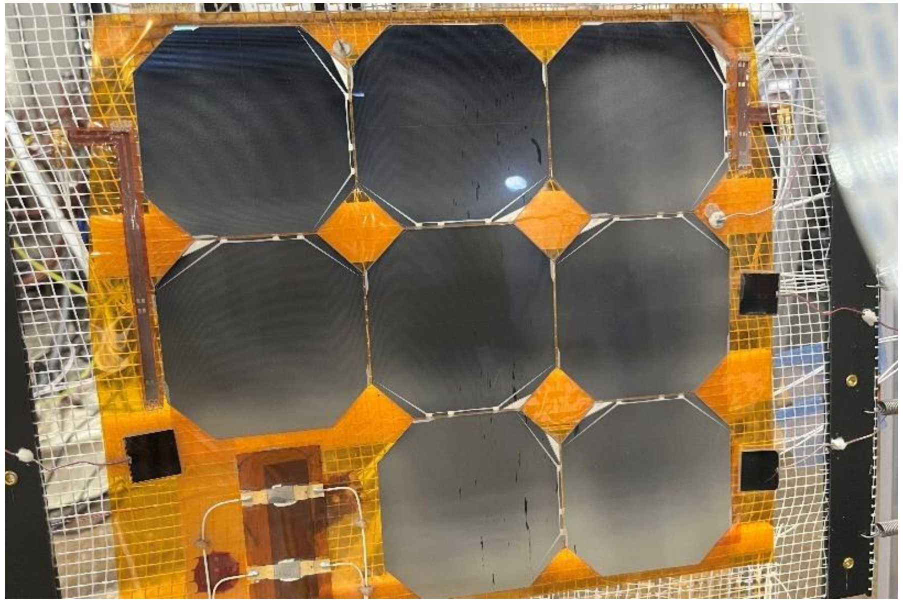
Raspberry Pi camera

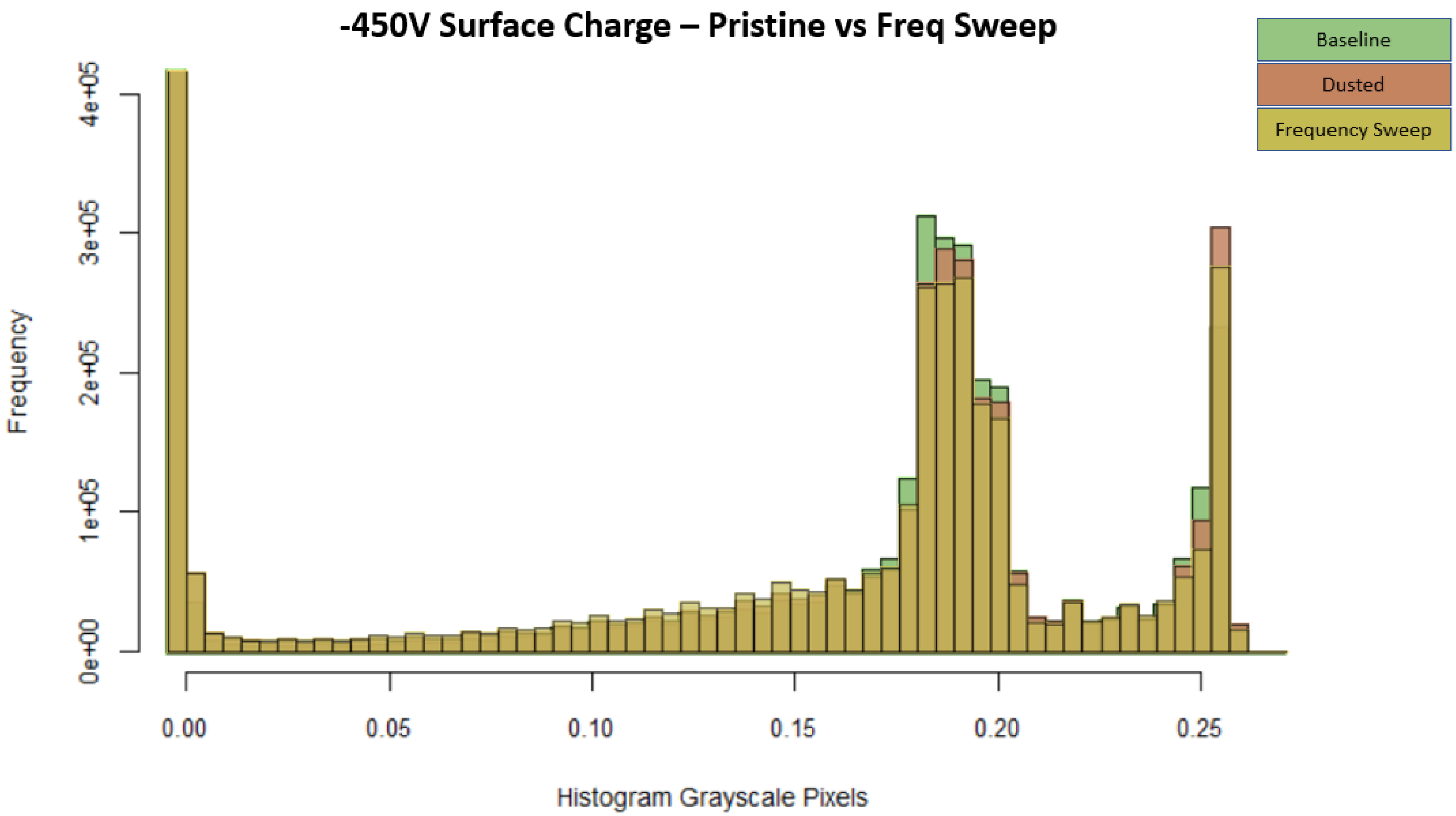
Test Overview



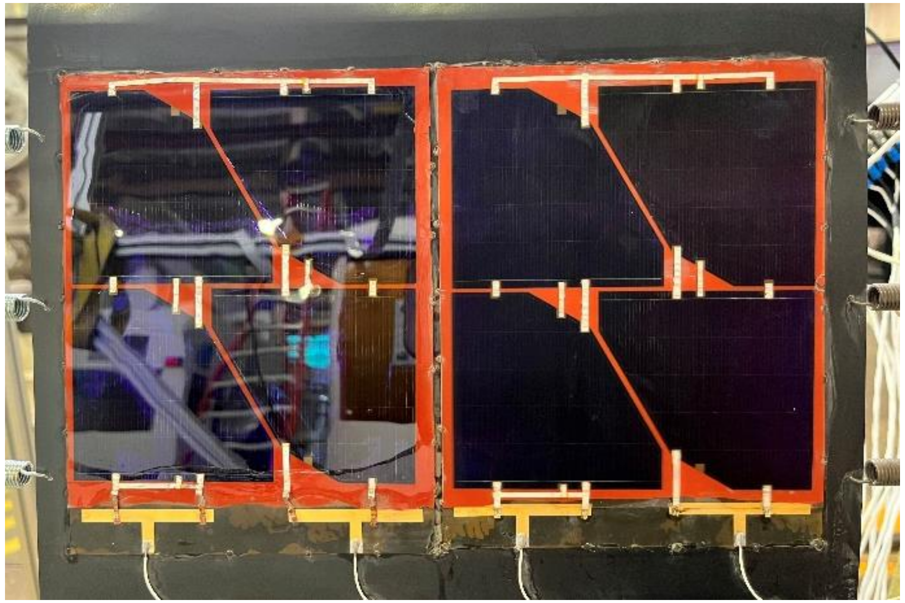
Coupon 1 Result

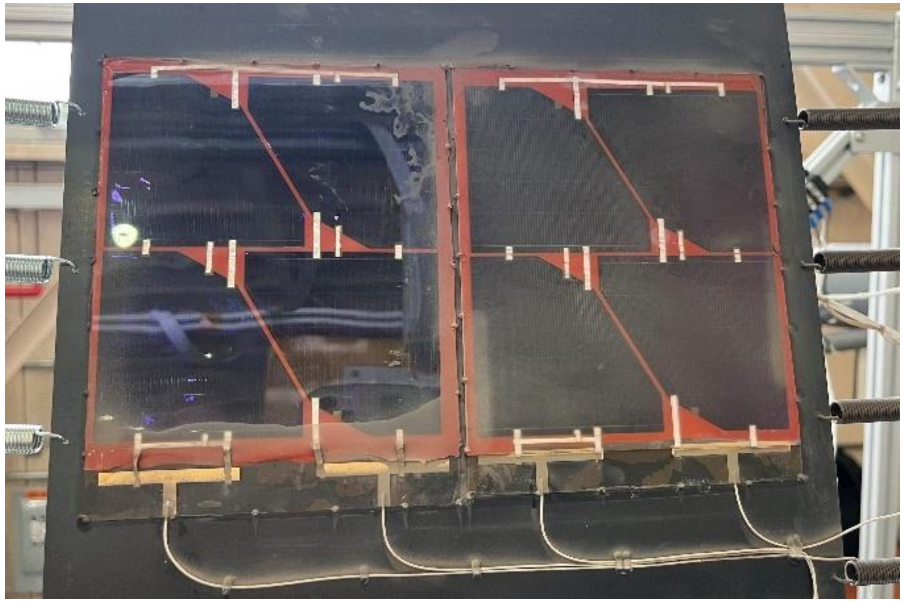


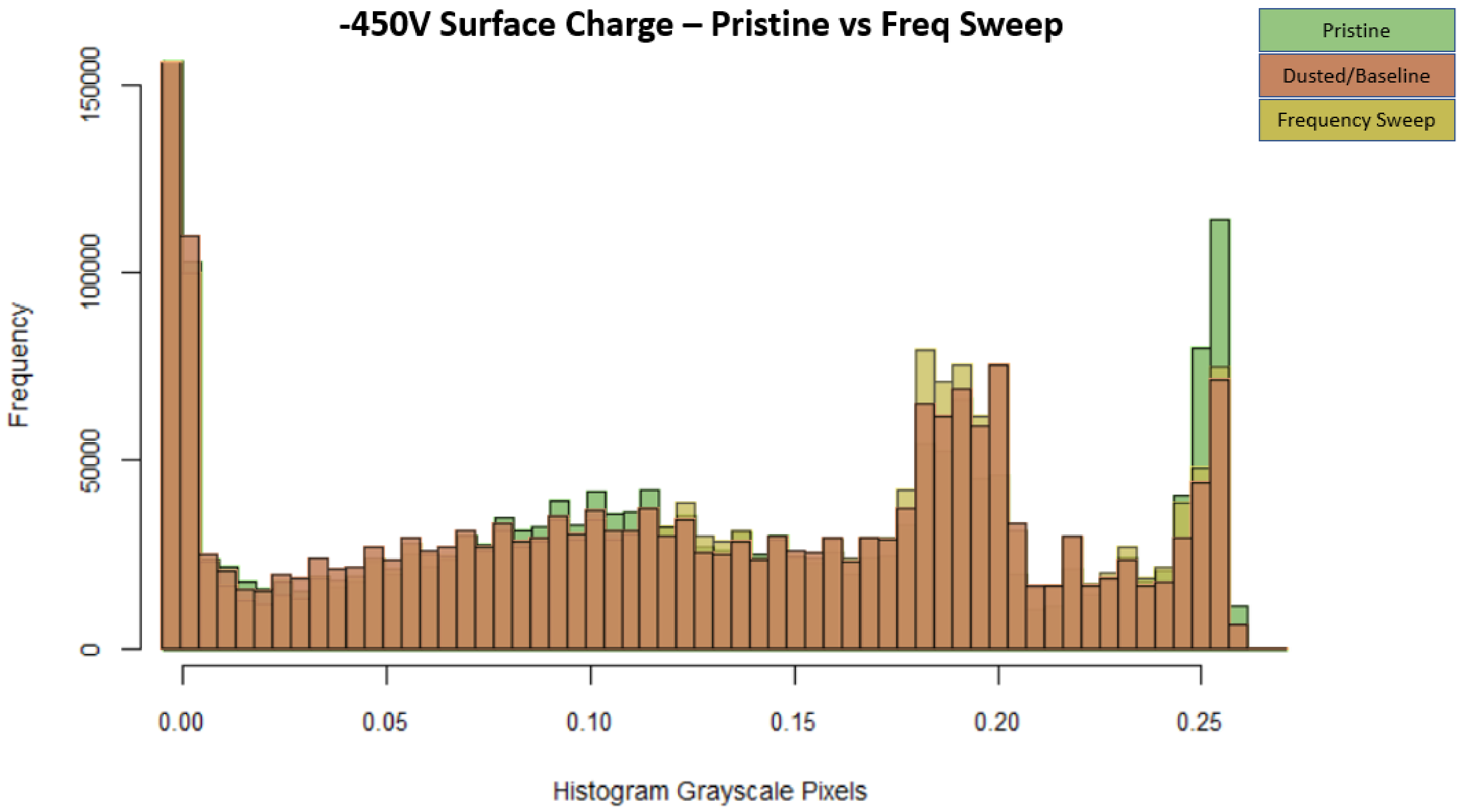




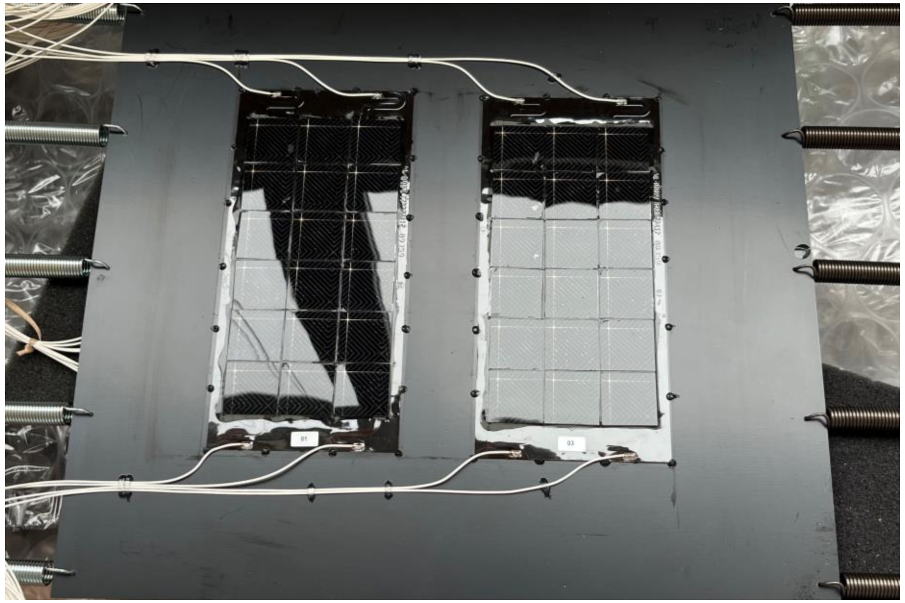
Coupon 2 Result

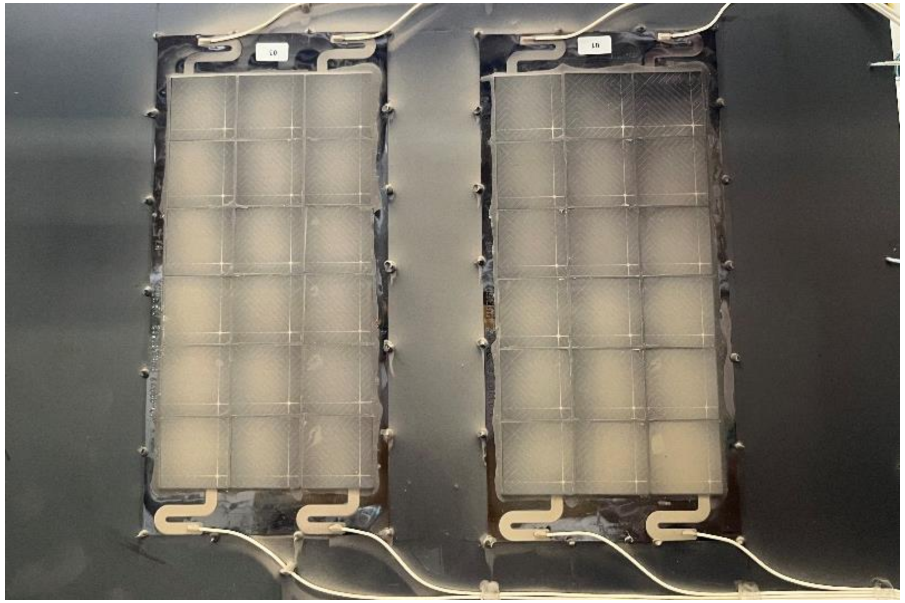


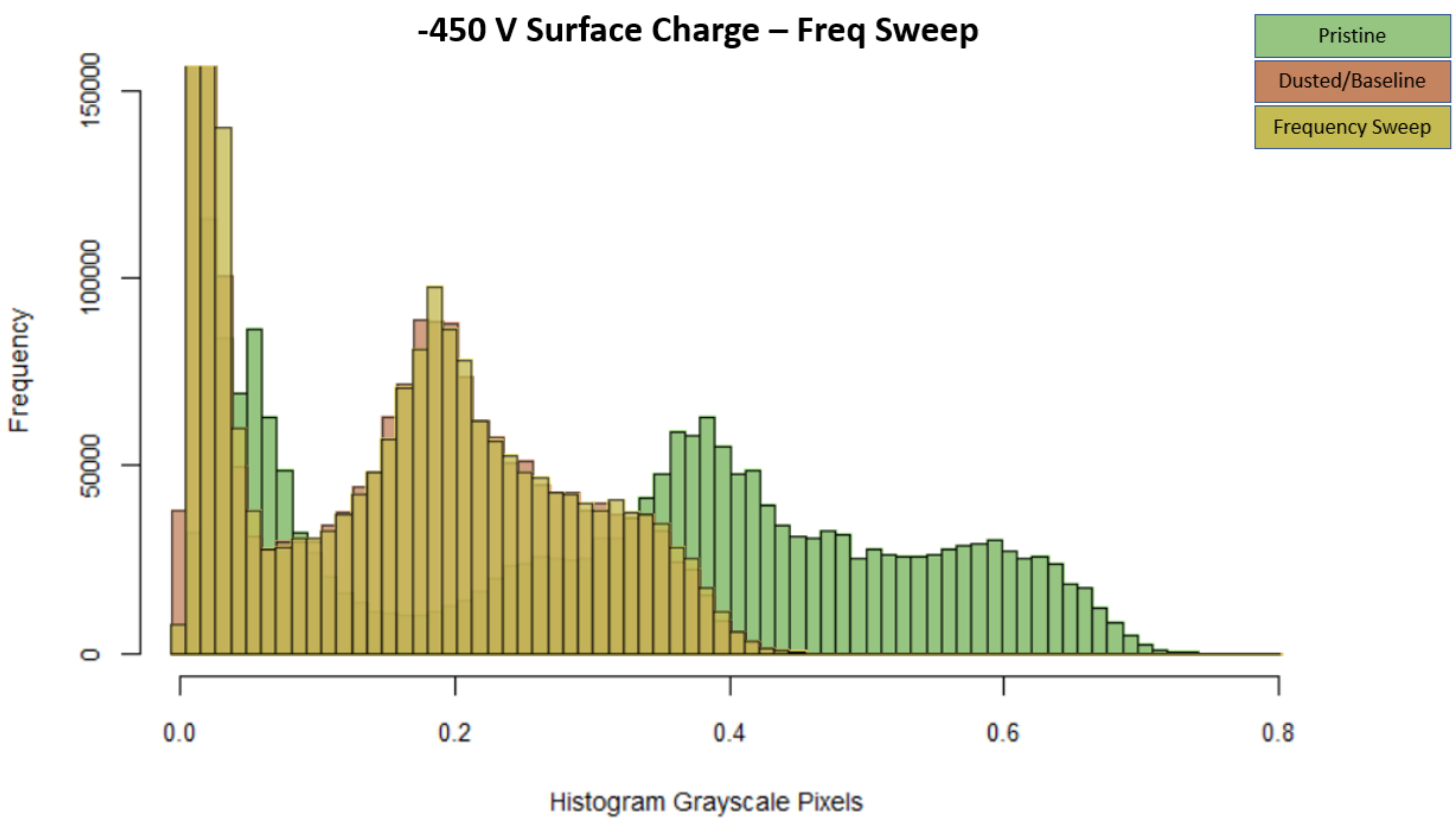




Coupon 3 Result







Lessons Learned

Sieve Size Matters

- smaller mesh sizes not compatible with vacuum deposition

EL Imaging Scalability

- EL is highly sensitive on the cell level
- array architecture differences and camera limitations hinder EL scalability (for now)

Adhesion Depends on Charge

- at ambient, water drives adhesion
- in vacuum, limited dust sticking to array under zero bias
- tribocharging insufficient

Simulant Preparation

- un-baked simulant experiences major clumping in vacuum
- hot plate bakeout is not suitable

Potential Forward Work

- Expand upon testing with additional variables:
  - temperature
  - array tilt
  - simulant charging mechanism
  - simulant type
- Test additional coupons and vary:
  - cell technology
  - substrate
  - **dust mitigation technology → linear actuators**
- Test compatible technologies (i.e., radiator with thermal imaging)
- **Investigate impact of dust grain size/type on cell performance**

Acknowledgements

- NASA STMD: Game Changing Development Program
  - *DMFlex ACO – 20 – 20 ACO Final – 0020*
- GRC Project Managers: **Erica Montbach** and **Jenna Fothergill**
- Solar cell providers:

REDWIRE

DragonSCALES™

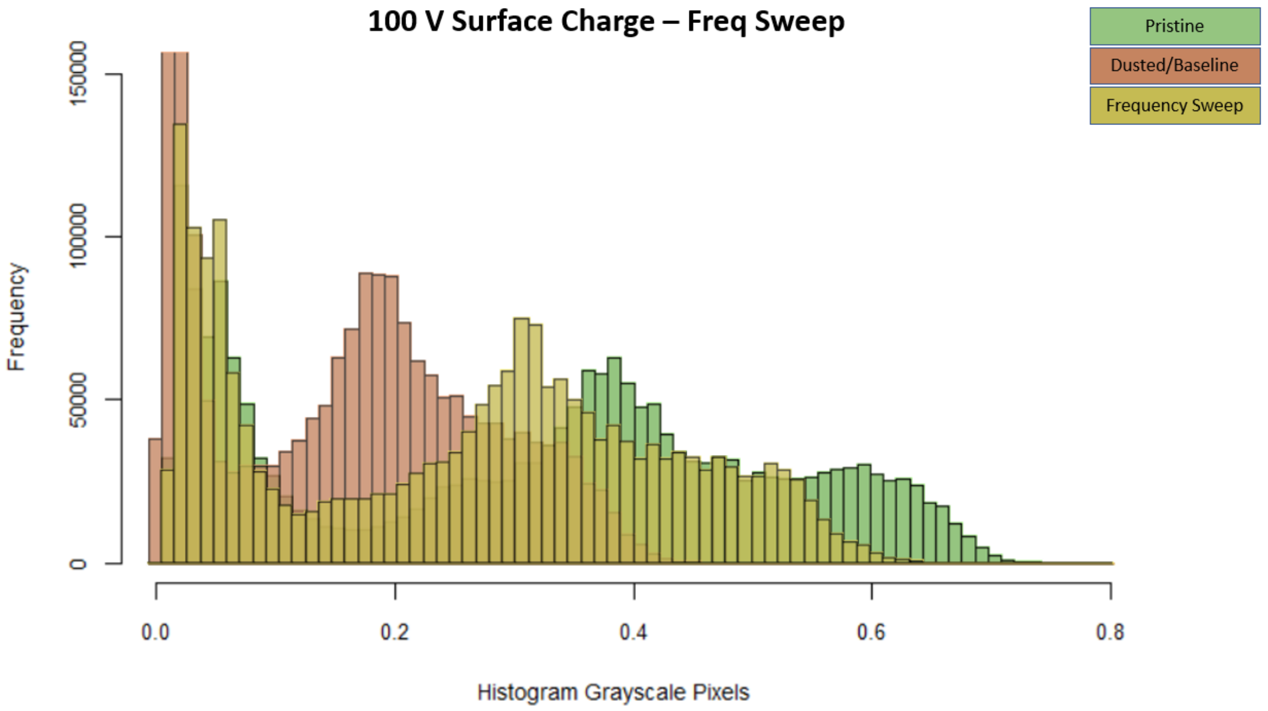
MicroLink Devices, Inc.

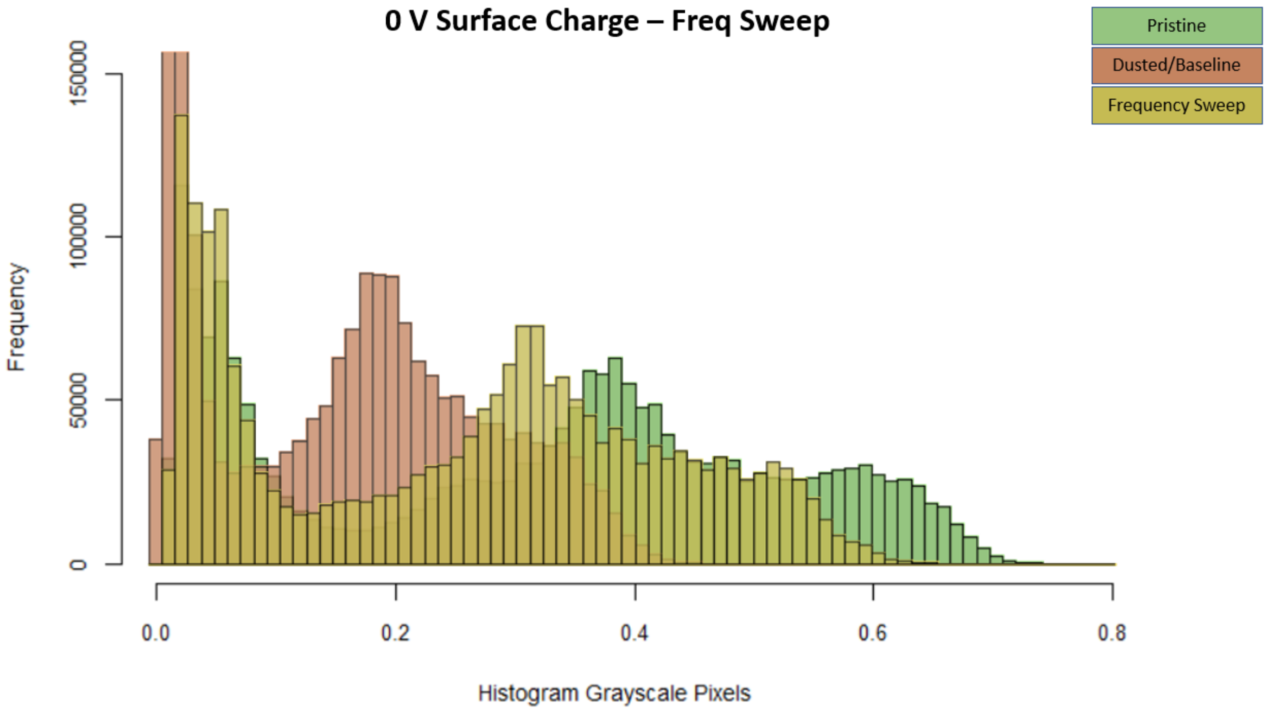
mPower TECHNOLOGY

Questions?

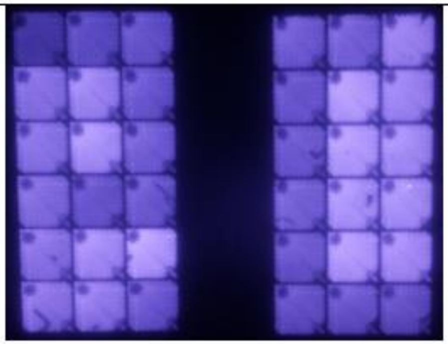
backup slides

Silicon's Brief Recovery

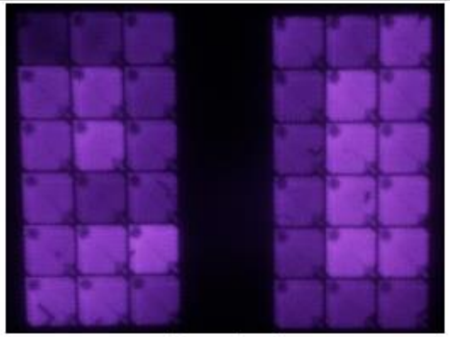




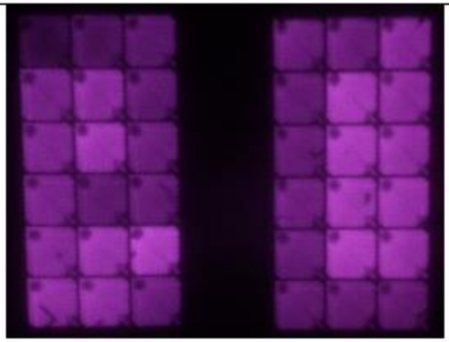
Silicon's Brief Recovery



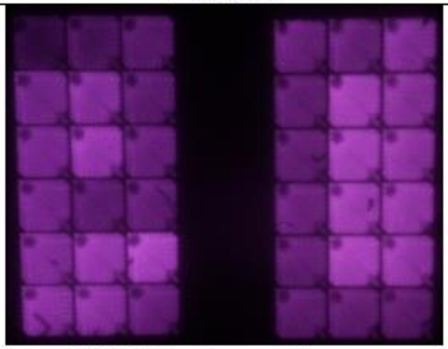
Pristine



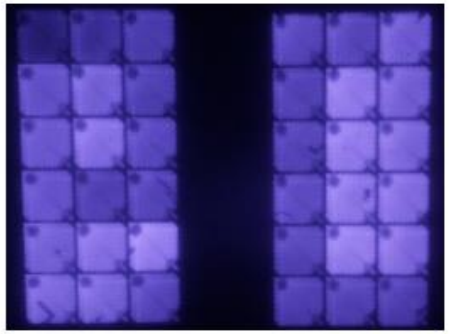
Dusted



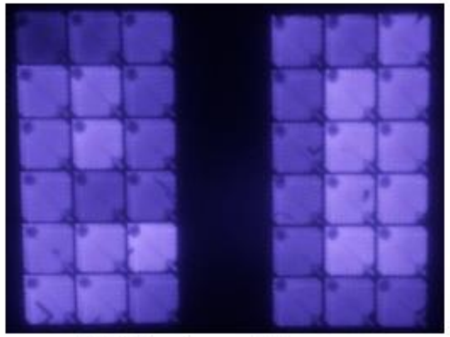
450V Surface Charge



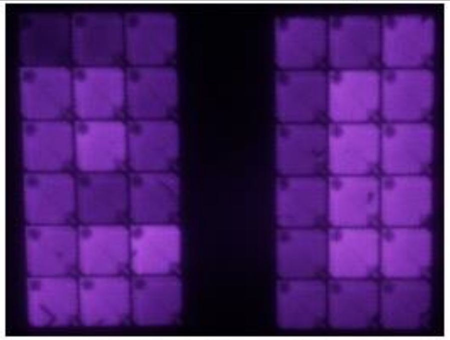
250V Surface Charge



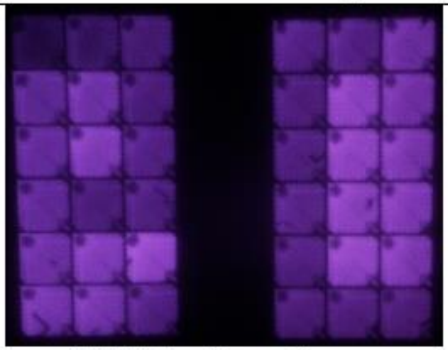
100V Surface Charge



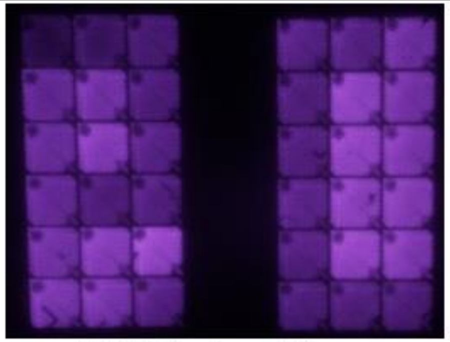
0V Surface Charge



-100V Surface Charge



-250V Surface Charge



-450V Surface Charge

Dust Deposition