EDS on the MOON!

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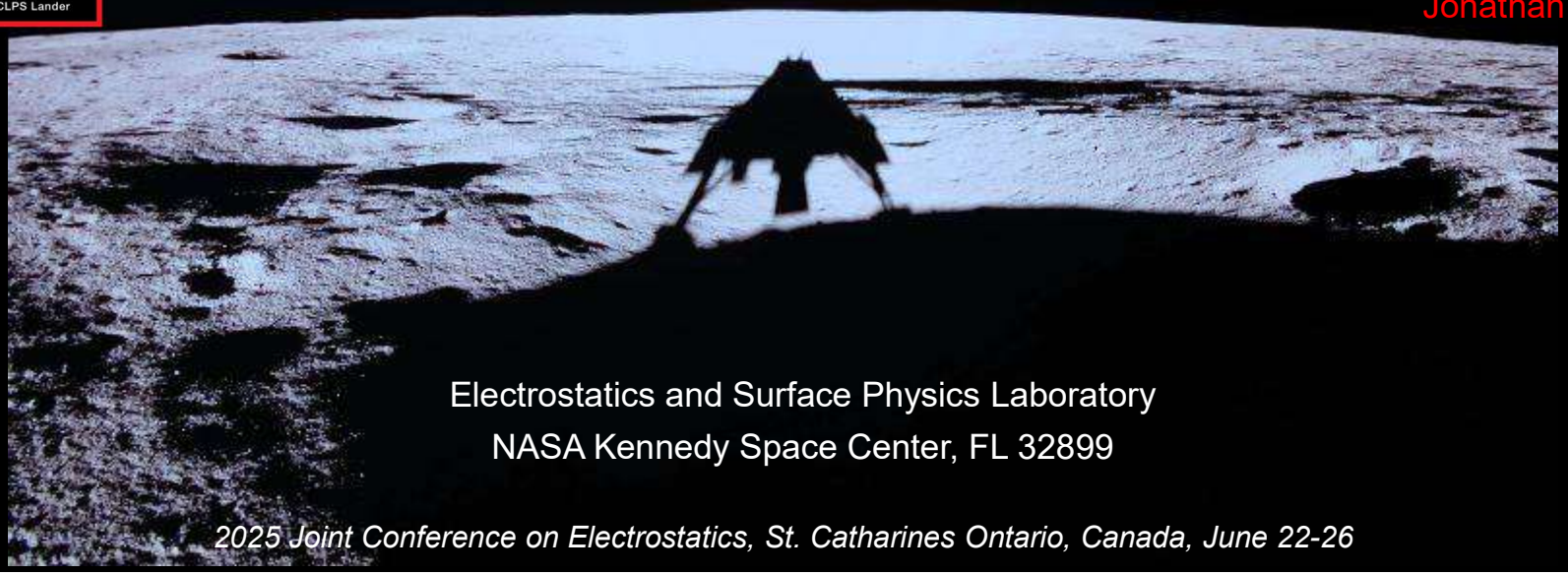
EDS

Electrodynamic Dust Shield on a CLPS Lander

FIREFLY AEROSPACE



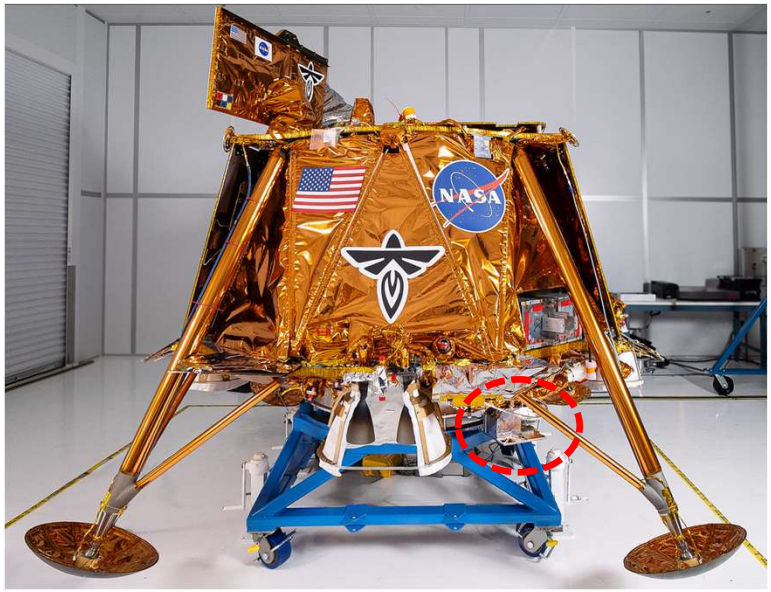
Electrostatics and Surface Physics Laboratory

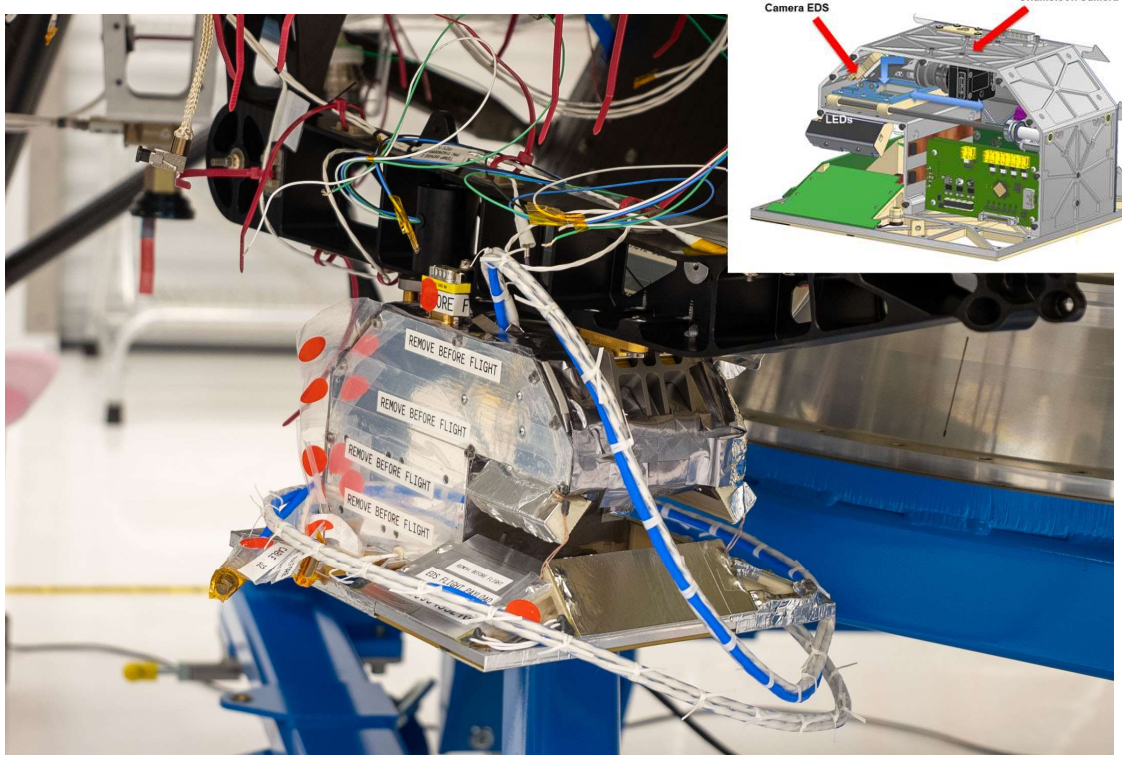
NASA Kennedy Space Center, FL 32899

2025 Joint Conference on Electrostatics, St. Catharines Ontario, Canada, June 22-26

Firefly Aerospace

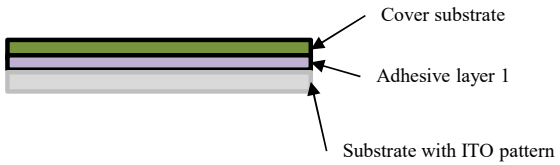
- The Blue Ghost mission from Firefly Aerospace successfully landed on the moon (Mare Crisium) on March 2, 2025 at 2:34 CST.
- The EDS was one of 10 payloads deployed on the lunar surface.
- It was the first successful commercial landing on the moon.
- Blue Ghost then completed more than 14 days of surface operations (346 hours of daylight) and just over 5 hours of operations into the lunar night. This achievement marks the longest commercial operations on the Moon to date.
- All the 10 payloads were successful!

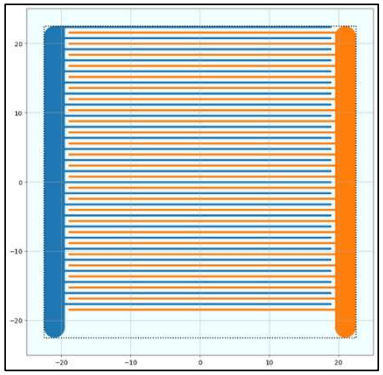


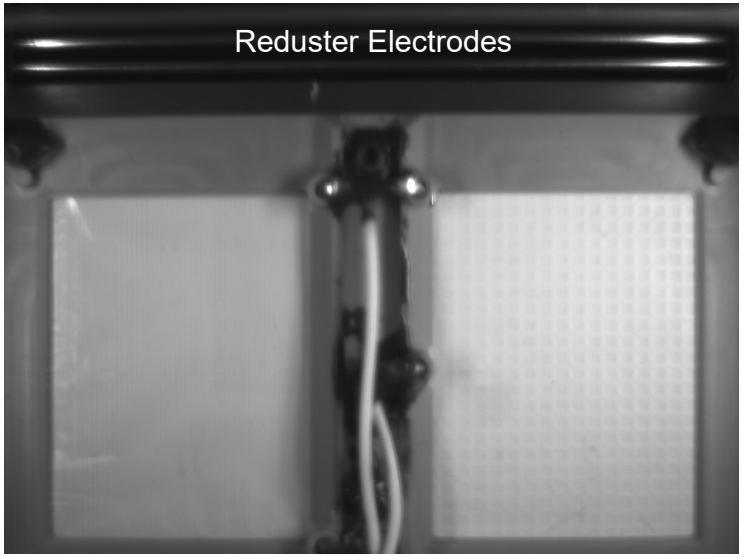


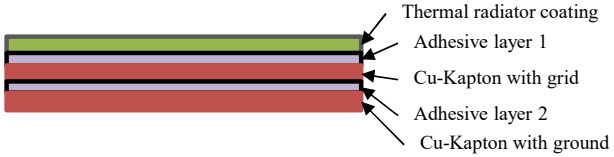
EDSs in Transit

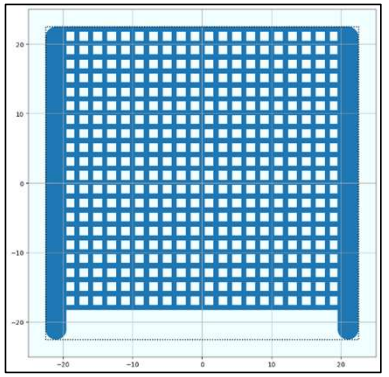
Clear images of the two EDS's during transit health check (~45 days)



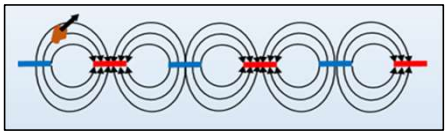






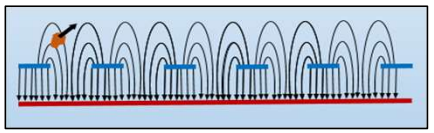


side view



Glass
2-D EDS

Thermal Radiator EDS
(ThermalBright ®)
3-D EDS



side view

Deployment

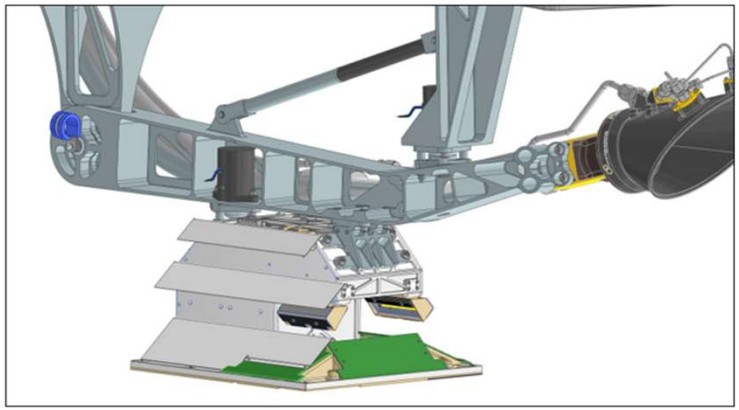
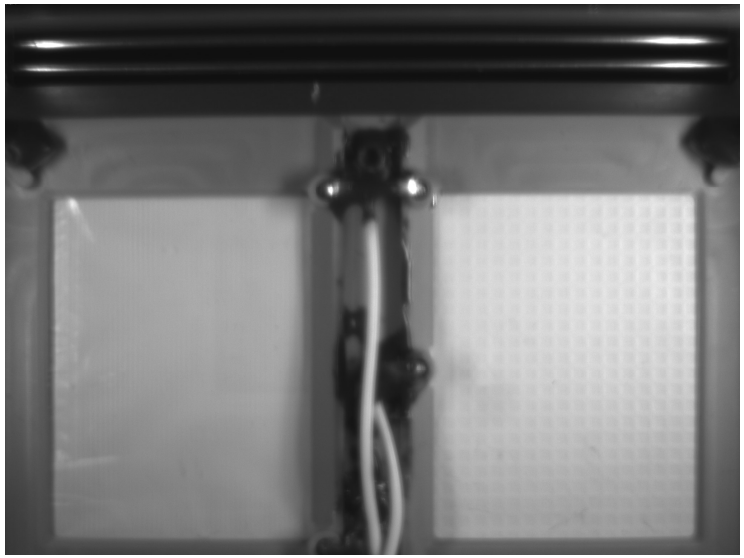


Image credit: SCALPSS (LaRC)

- **The Surface Access Arm was deployed approximately 10 hours after landing.**
- **The EDS was deployed shortly after that.**

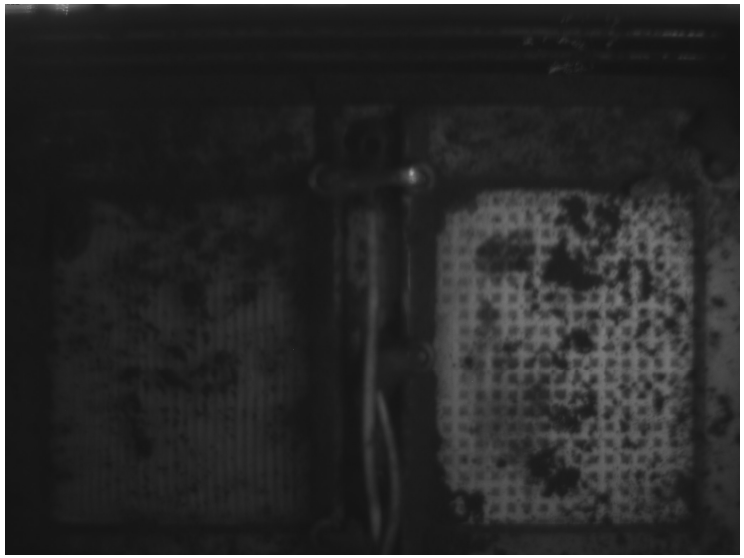
Dirty EDSs!

Transit images



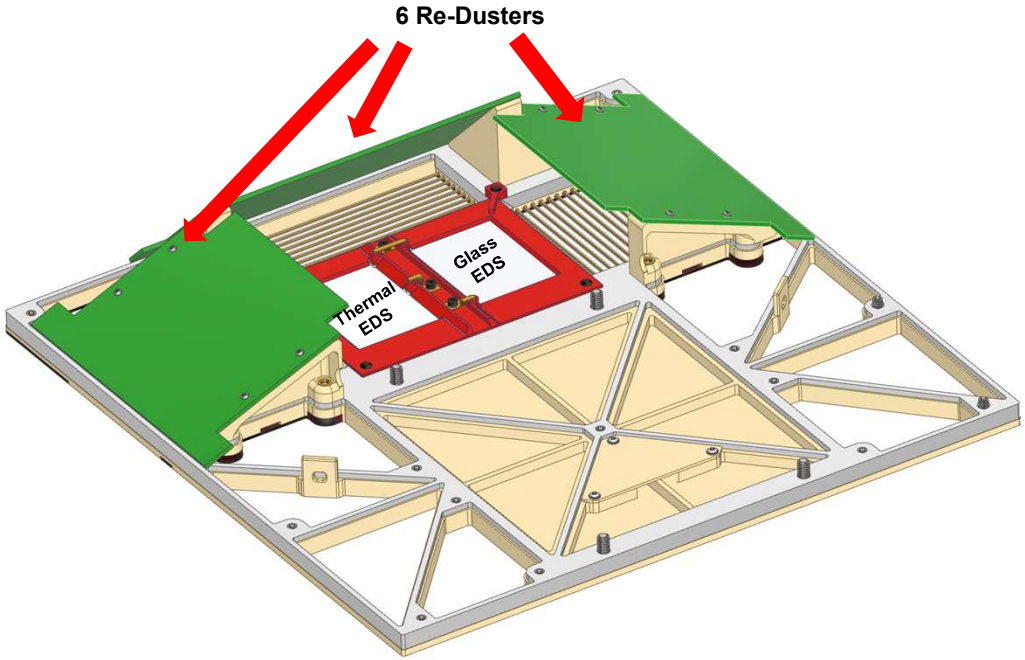
- No dust loading
- Working LEDs
- 45 days in space

Landing images



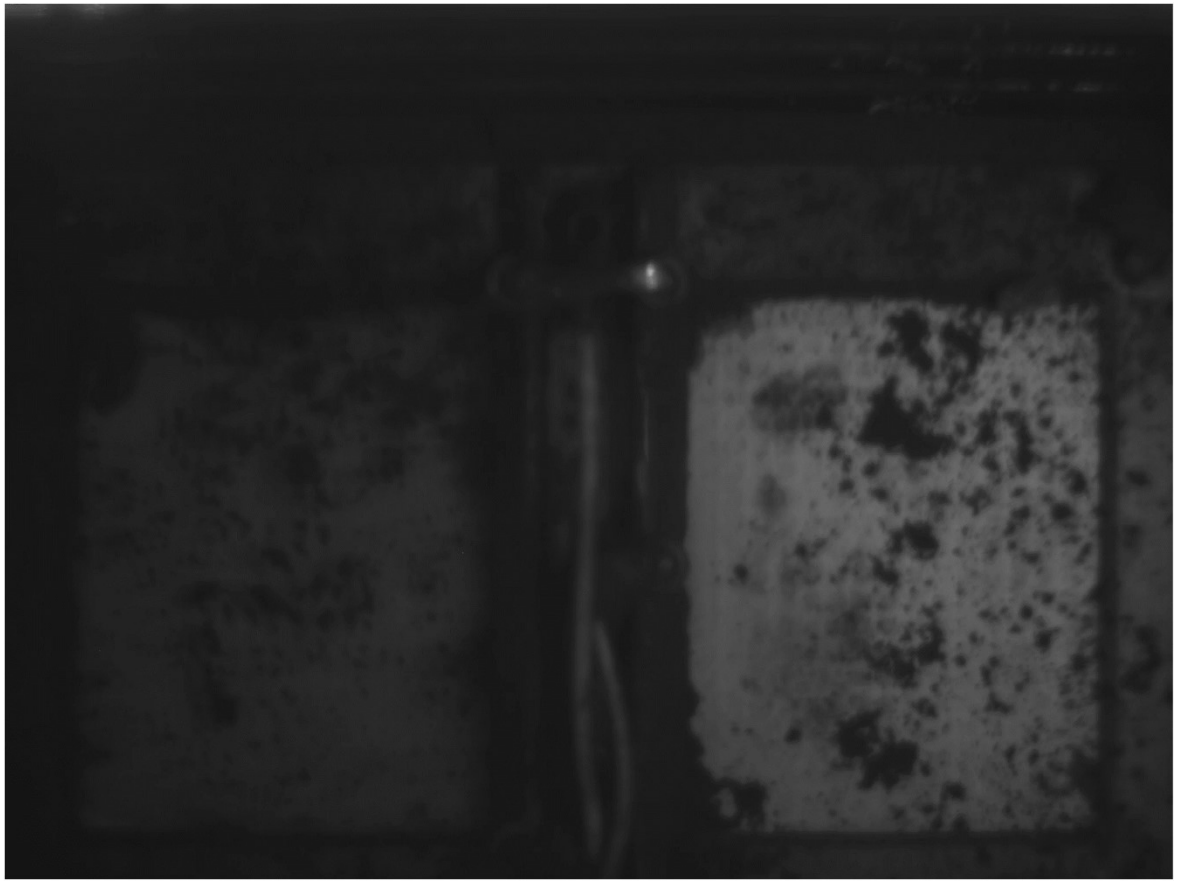
- Significant dust loading
- Loss of LED on the left
- Flight constraints did not allow us to operate on time

Reduster on the Moon!



The 6 Reduster EDS's allow dust from the surface to be lifted through the spaces between EDS rods and then deflected onto the two Footpad EDSs.

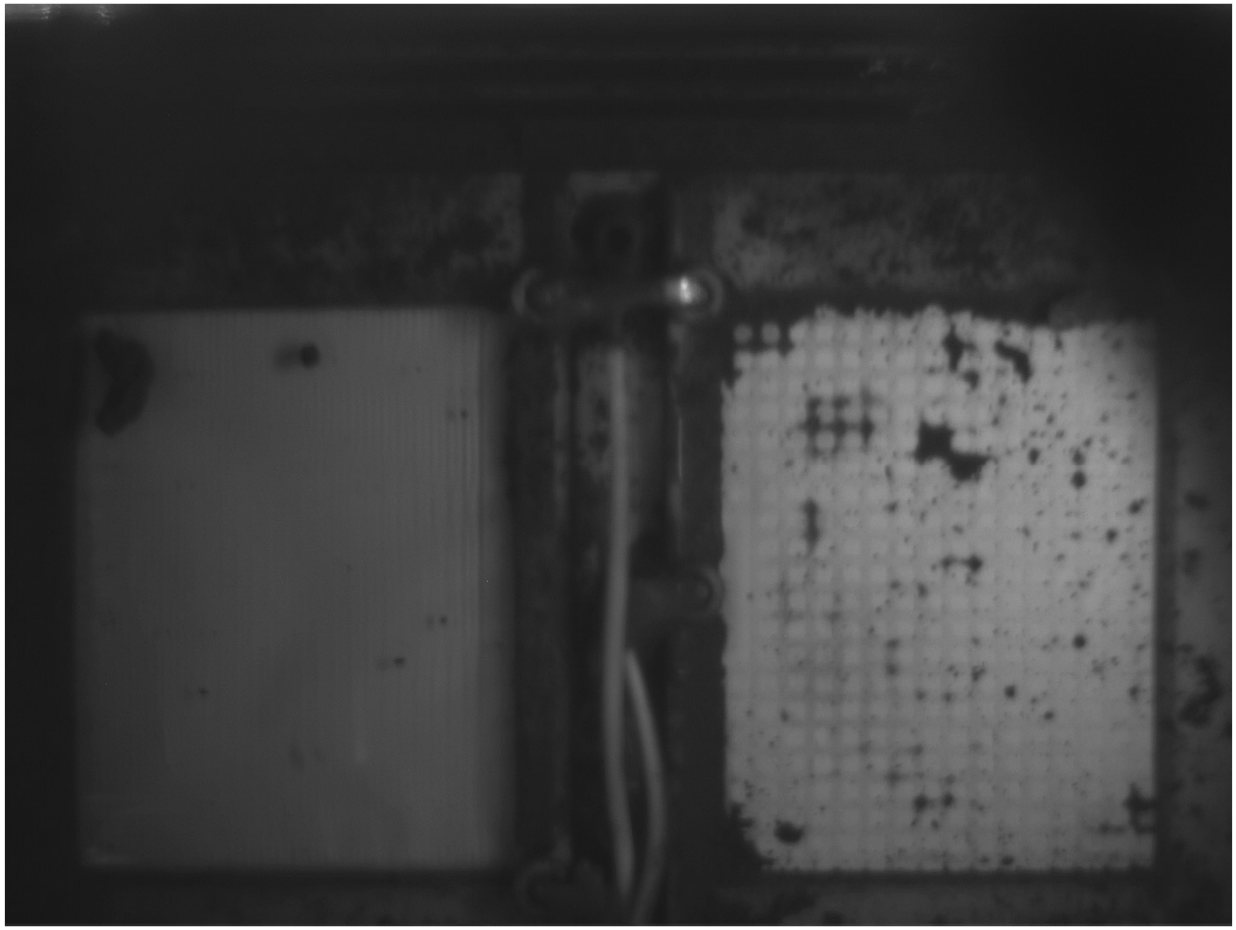
Reduster in action!



Successful tests on the Reduster shows the ability of the EDS to lift and apply dust to a given location without the use of gases, fluids, moving parts or vibration mechanisms.

EDS working!

These are the first videos of the EDS working on the lunar surface!



We have shown that the EDS can remove lunar dust in lunar conditions.

Both types of EDS's shown dust removal.

Image Analysis

The clearing efficiency is then defined as the summed values of the post-EDS image verse the summed value of a clean image.

- Clearing Efficiency Percentage (CEP): $CEP = \frac{\sum p_{b/a}}{\sum p_c}$

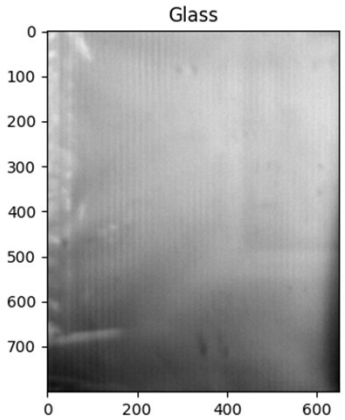
- p_a is a pixel value *after* EDS clearing.
- P_b is a pixel value *before* EDS clearing.
- P_c is an estimated *clean* pixel value.
- ***The estimate is a CEP = 82.1% (radiator), 96.6% (glass).***

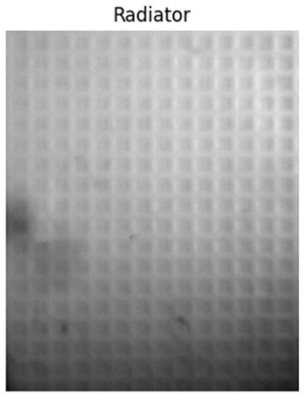
The mass removed is estimated from residual image.

- The image is normalized and inverted, i.e., to ensure regolith is recorded as a higher pixel value.
- Mass removed is estimated from: $\Delta m = \omega^2 \rho x \frac{\sum p_{b/a}}{\sum p_c}$
- ω is the pixel scale.
- x is the assumed depth of the regolith.
- ρ is the density of a regolith particle (~3 g/cm^3).
- ***The estimate is a mass removal of 30 mg (radiator), 39 mg (glass).***

Image Analysis – “Clean”

During transit both LEDs functioned properly





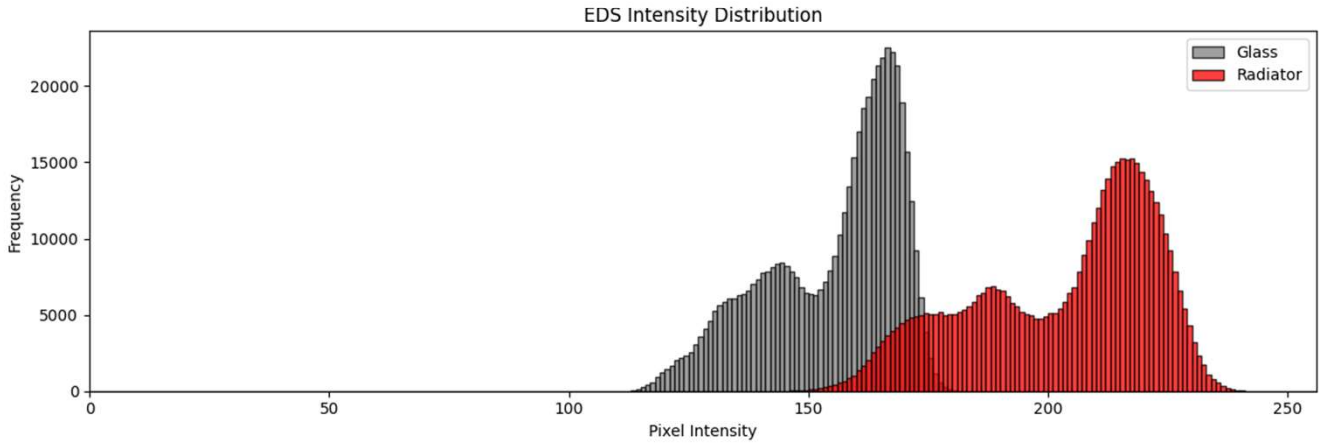


Image Analysis - Radiator

Due to the loss of the LED, a “clean’ pixel was defined as the “bright spot” on the Post-landing pic.

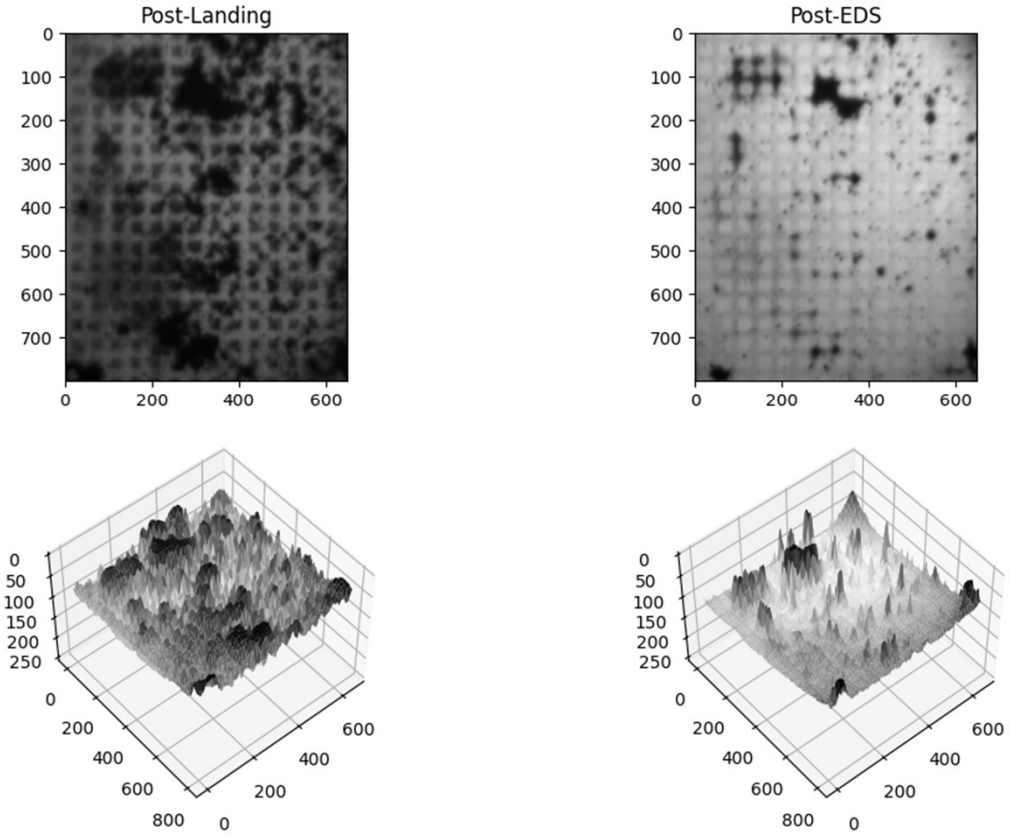
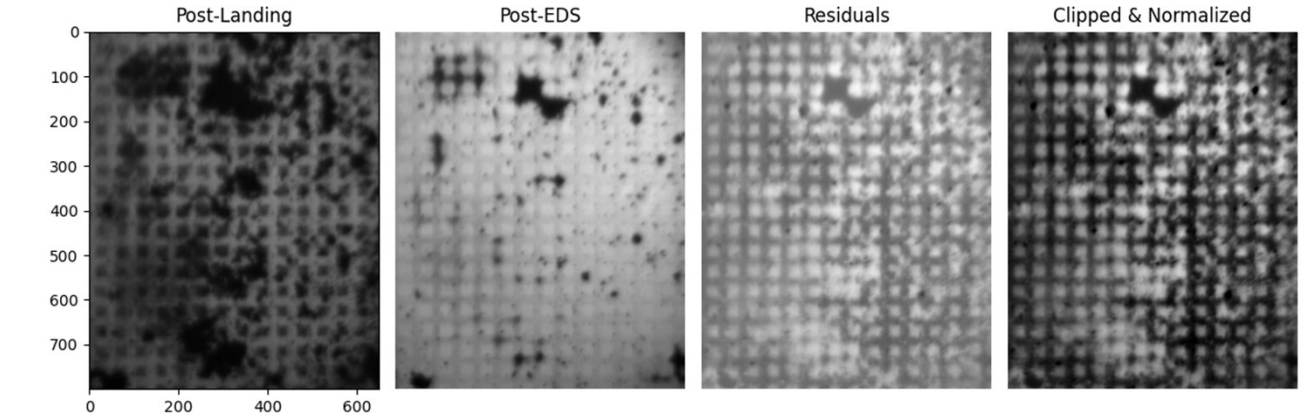
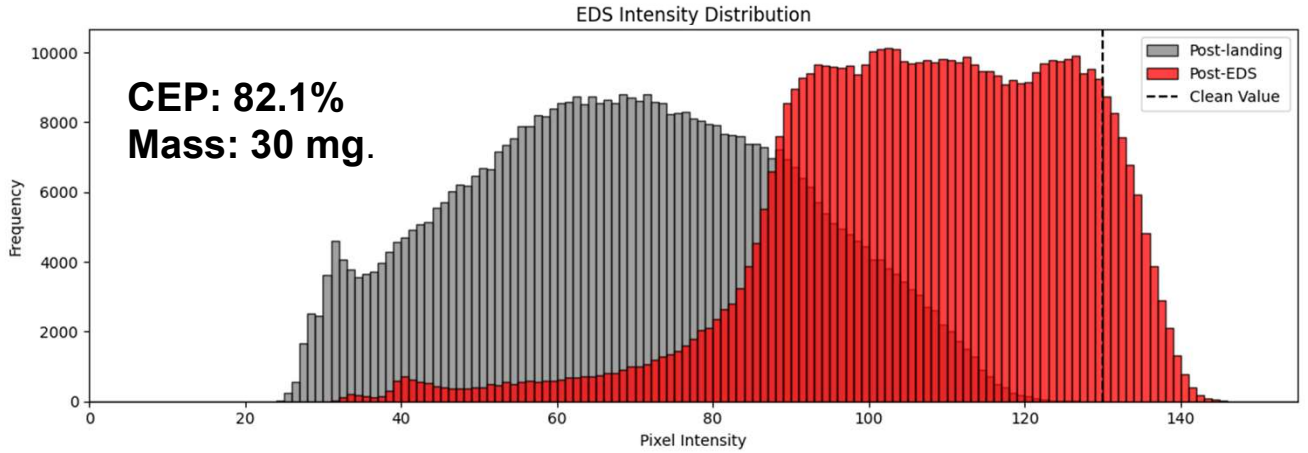


Image Analysis - Radiator

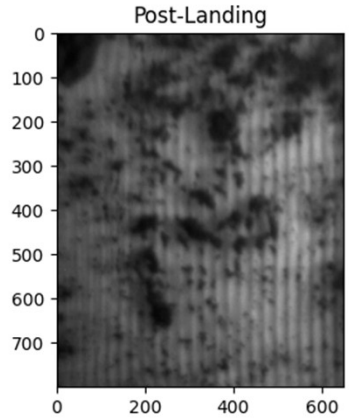


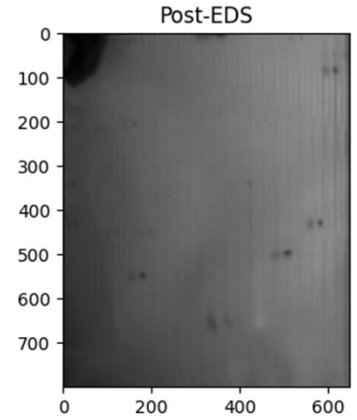


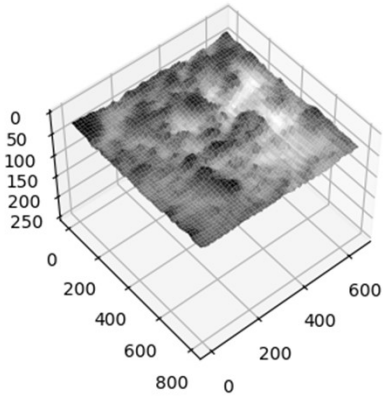
The Residuals are the subtraction of the post-landing and post-EDS images.

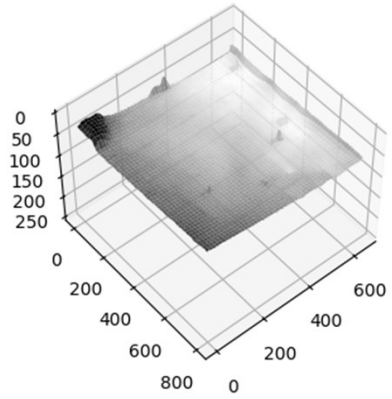
That image was then clipped and used as the normalized value to estimate the clearing efficiency

Image Analysis – Glass



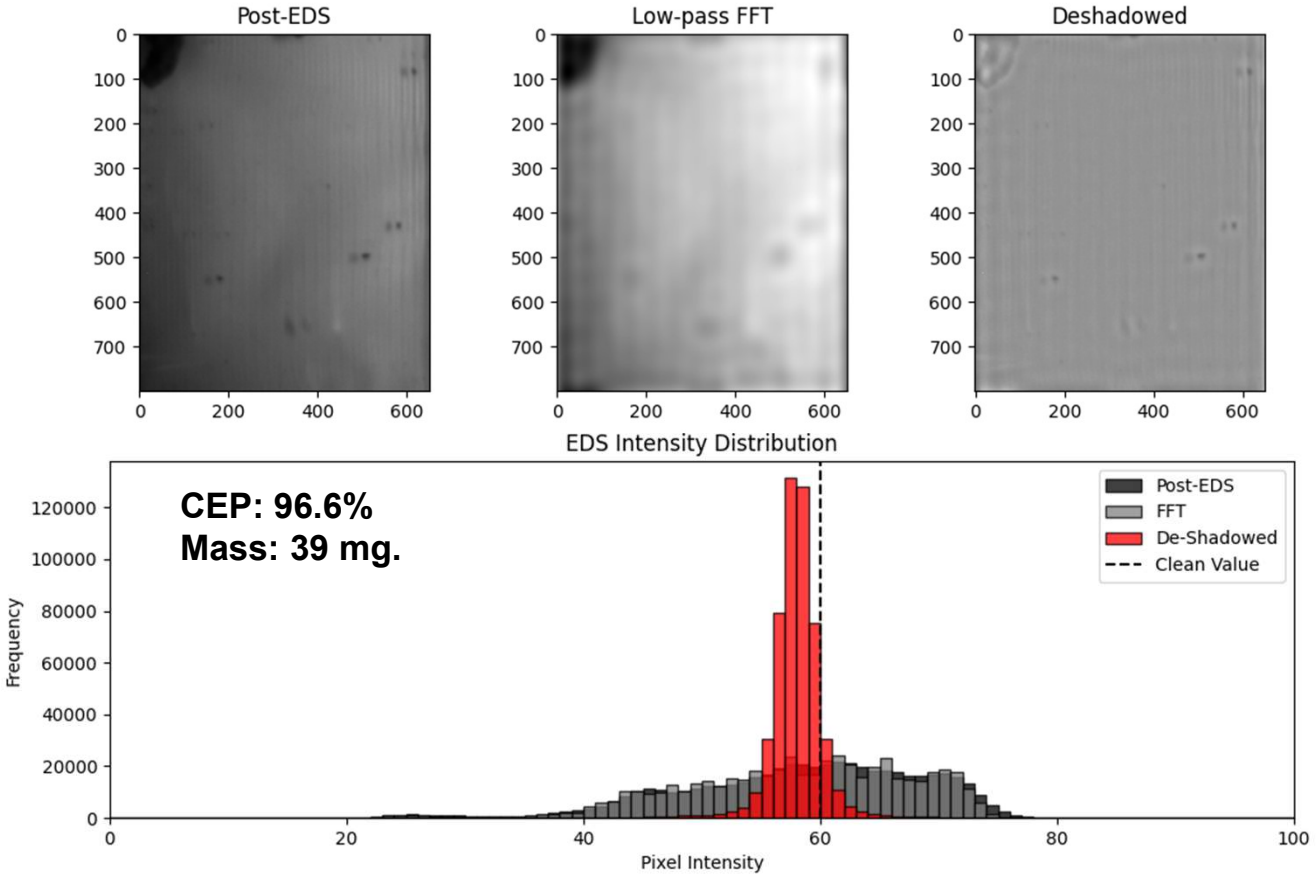






- The shadow model is created using a Fast Fourier Transform with a given kernal size to suppress small features and highlight largescale features (low-pass filter).
- The shadow model is then used as a “flat-field” to remove shadows from the post-EDS glass image. The model is normalized and divided into the post-EDS image.

Image Analysis – Glass



The EDS Team!

PI: Dr. Charles Buhler, NASA KSC

Co-PI: Dr. Joseph Toth, NASA KSC

Team: NASA KSC and LaRC

- Dr. Krystal Acosta, Ops Lead / Payload Operator
- Chris Forney, Software / Payload Operator
- Jonathan Hsu, Software Co-Lead / Payload Operator
- Lexis Mazerski, Electrical Lead
- Dr. Aaron Olson, Mechanical / Payload Operator
- James Phillips, Software Lead / Payload Operator
- Jerry Wang, Testing Lead
- Troy Toon, Systems Engineer
- Jeffrey Dyas, Systems Engineer
- Melissa Young, Thermal Lead
- Michael Baron, Mechanical Analysis
- Marty Grashik, Chief Engineer
- Alexis Hongamen, Project Management
- Jennifer Wilson, Project Management