DUst and plaSma environmenT survEyoR
(DUSTER)

X. Wang and DUSTER Team

Science Objectives

- DUSTER will develop a full picture of the dust and plasma environment around an Artemis landing site in the lunar south polar region
- DUSTER will characterize the **near-surface plasma**, **electrostatically lofted dust**, **micrometeoroid impacts**, and **dust ejecta generated during lander liftoff**
- DUSTER will provide crucial results to gauge the safety, ensure the success of future crewed/robotic missions, and enable a **sustained human presence** on the lunar surface

Science Objectives

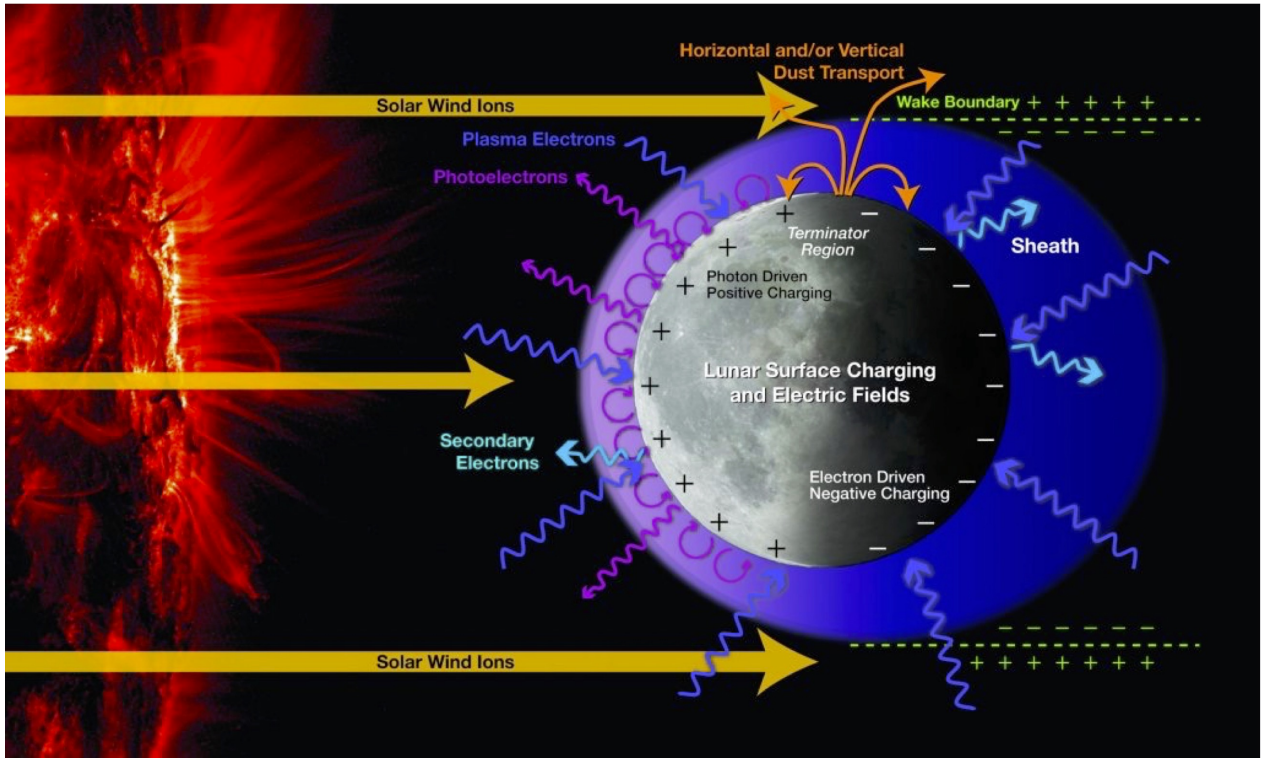
- Dust and Plasma Environment is critical for surface operations on the lunar surface, including **ISRU and related processes**

Jack Schmitt during Apollo 17

- Plasma charging may cause electrostatic discharge (ESD) hazard and dust mobilization
- Dust can cause clogging and wearing of mechanical joints and surfaces of ISRU equipment and facilities
- Dust can cover thermal radiator surfaces, causing failure of thermal management
- Dust can cover optical lenses, affecting ISRU processes relying on solar energy
- Dust can block solar panels, reducing power output

Science Questions

Plasma Environment on the Moon



NASA

The Moon lacks a global magnetic field and has tenuous atmosphere

The Moon is covered by a layer of dust, called regolith

The lunar surface is charged due to direct exposure to solar wind plasma and UV radiation, which may cause

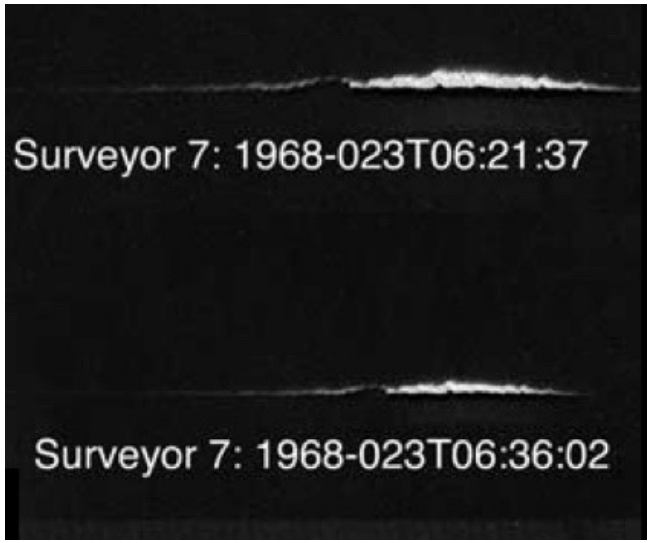
- Electrostatic discharge (ESD) hazard
- Dust hazard due to electrostatic charging and mobilization

SQ1: What is the surface plasma environment and its spatial and temporal variability in the lunar south polar region?

Science Questions

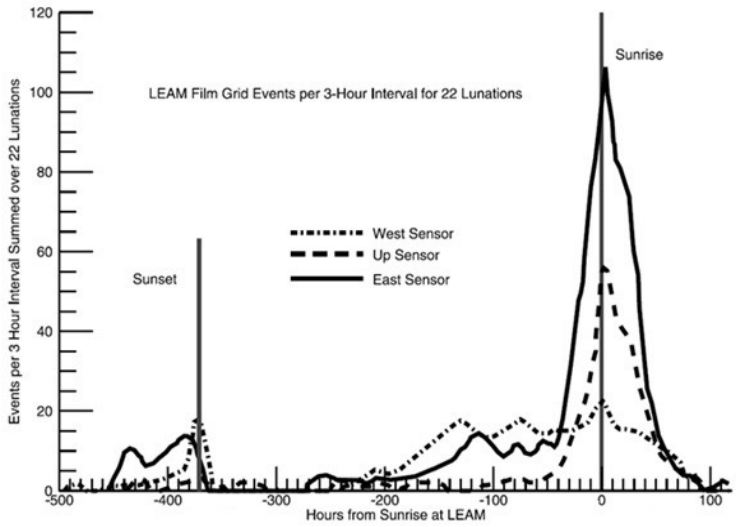
Longstanding Problem of Electrostatic Dust Lofting on the Moon

Lunar Horizon Glow (LHG)



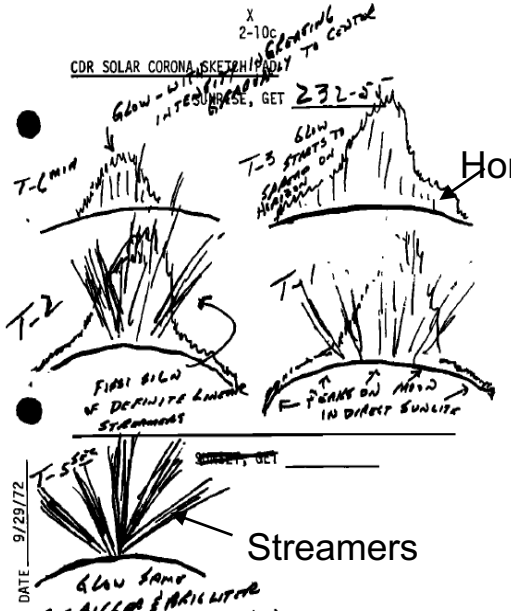
NASA

Dust Detections by LEAM across Terminator



Berg et al., 1976

High-altitude LHG and Streamers

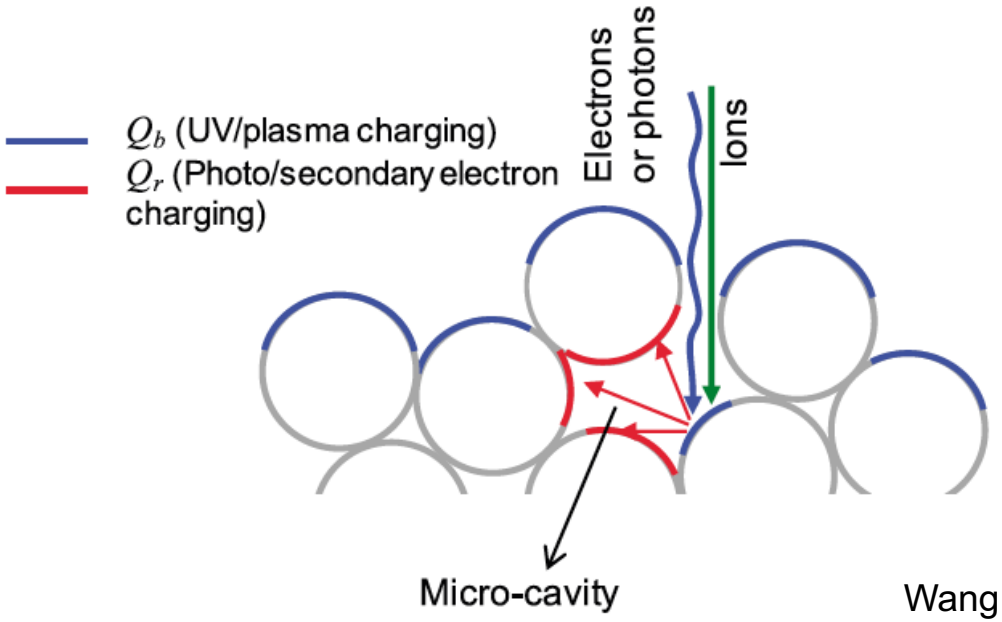


McCoy and Criswell, 1974

To date, no direct measurements can confirm electrostatic dust lofting on the lunar surface. **DUSTER will give an ultimate answer for this more than five-decade old problem.**

Science Questions

Patched Charge Model (PCM)



Electrostatic dust lofting in lab experiments

Wang et al., GRL, 2016

- Photo- or secondary electrons are absorbed within microcavities and collected by the surrounding particles, resulting in large negative charges on their surfaces.
- Coulomb repulsive forces between these negatively charged particles cause them to be lofted.

SQ2: What are the size, charge, velocity distributions, and flux of electrostatically lofted dust and its spatial and temporal variability in the lunar south polar region?

Science Questions

Micrometeoroid Impacts

- Measured by LADEE – LDEX in an equatorial obit; however, impacts near polar regions yet to be investigated
- Micrometeoroid impacts **alter the geotechnical processes** through comminution and/or agglutination
  - Comminution: reduction of solid materials into smaller particles
  - Agglutination: clumping of particles
- Micrometeoroid impacts **cause damage and degradation on exposed surfaces**

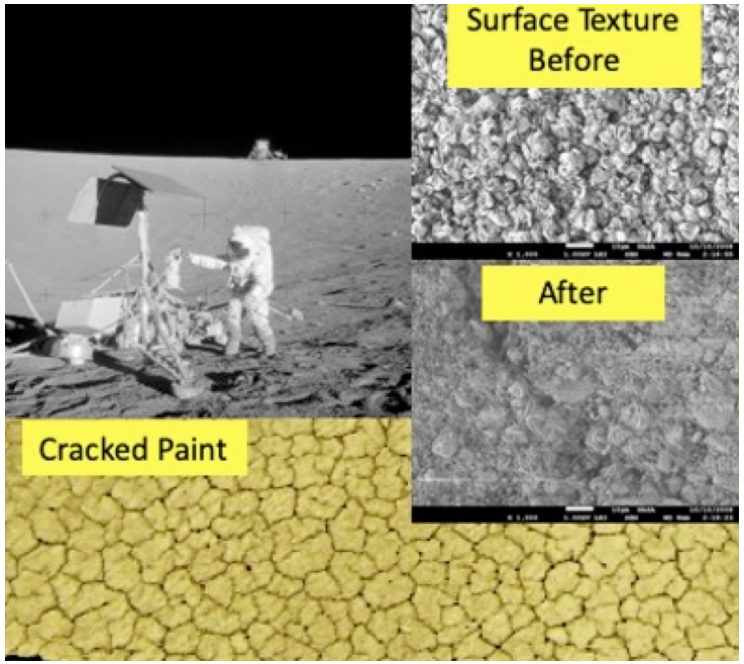
SQ3: What is the flux of micrometeoroid impacts in the lunar south polar region?

Science Questions

Dust ejecta generated during lander landing/liftoff

- Dust ejecta from vehicle's landing/liftoff can travel as fast as 2 km/s
- These ejecta can damage nearby equipment or habitats

Dust ejected by lander engine plume during IM-1 mission (CLPS)

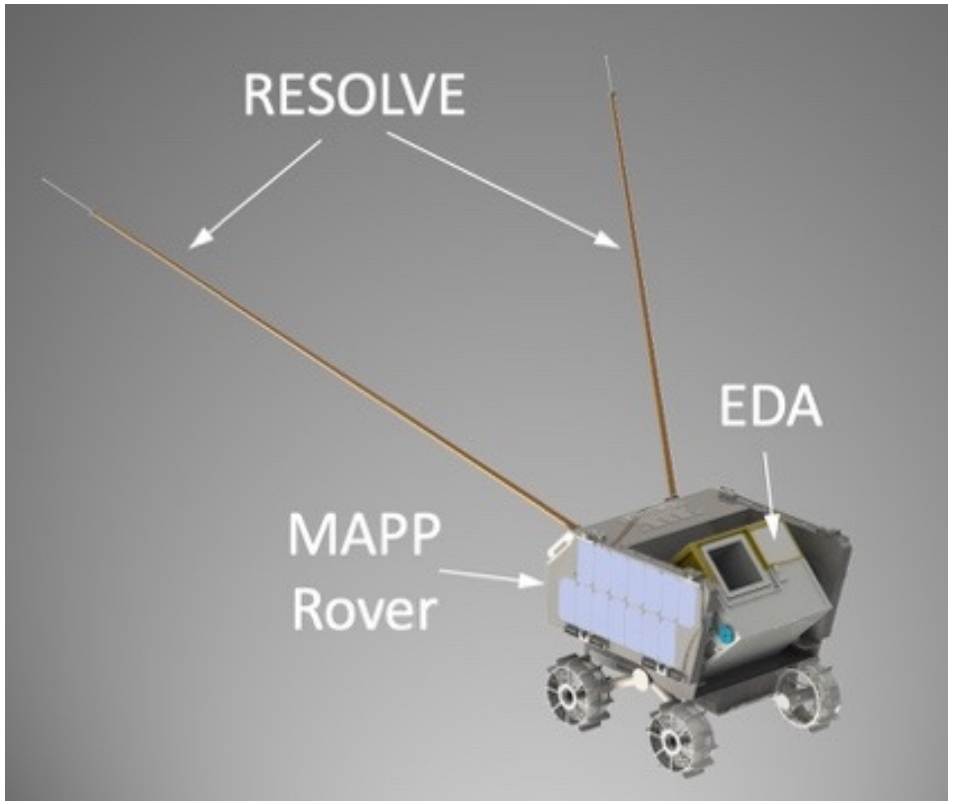


Sandblasting/cracking damage on Surveyor 3 from Apollo12 landing plume ejecta

(Immer et al., 2011)

SQ4: What is the flux of dust ejecta generated during lander liftoff?

Science Instruments



DUSTER Instruments:

- Electrostatic Dust Analyzer (EDA)
- RElaxation SOunder and differentiaL VoltagE (RESOLVE)

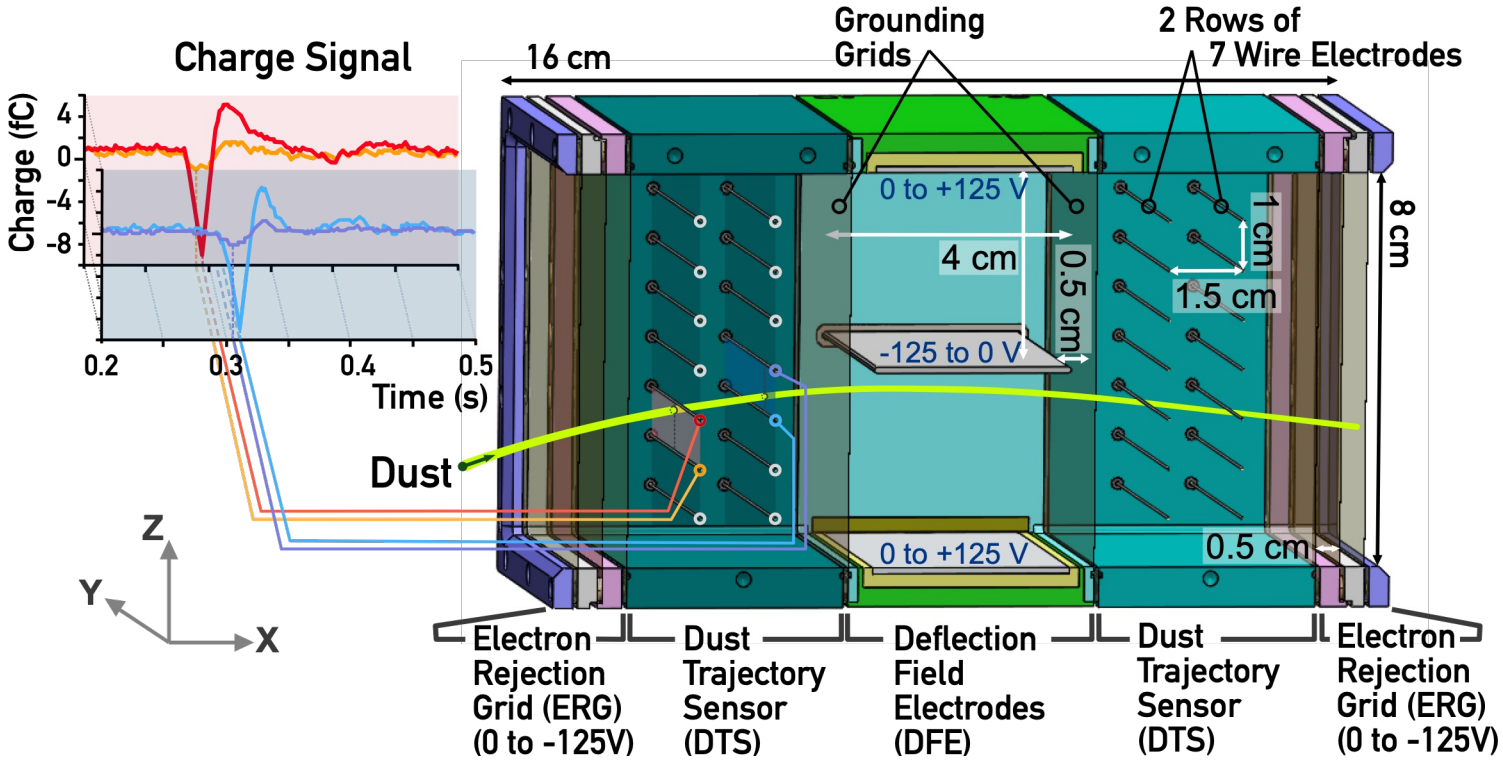
Accommodated on the Mobile Autonomous Prospecting Platform (MAPP) rover.

- EDA measures electrostatically lofted dust
- RESOLVE measures plasma density, micrometeoroid impacts, and high-speed ejecta generated during lander liftoff.

DUSTER will be deployed by an astronaut, then drive and operate by ground command to explore different areas around the landing site.

Artist's Rendering

EDA Instrument and Measurements



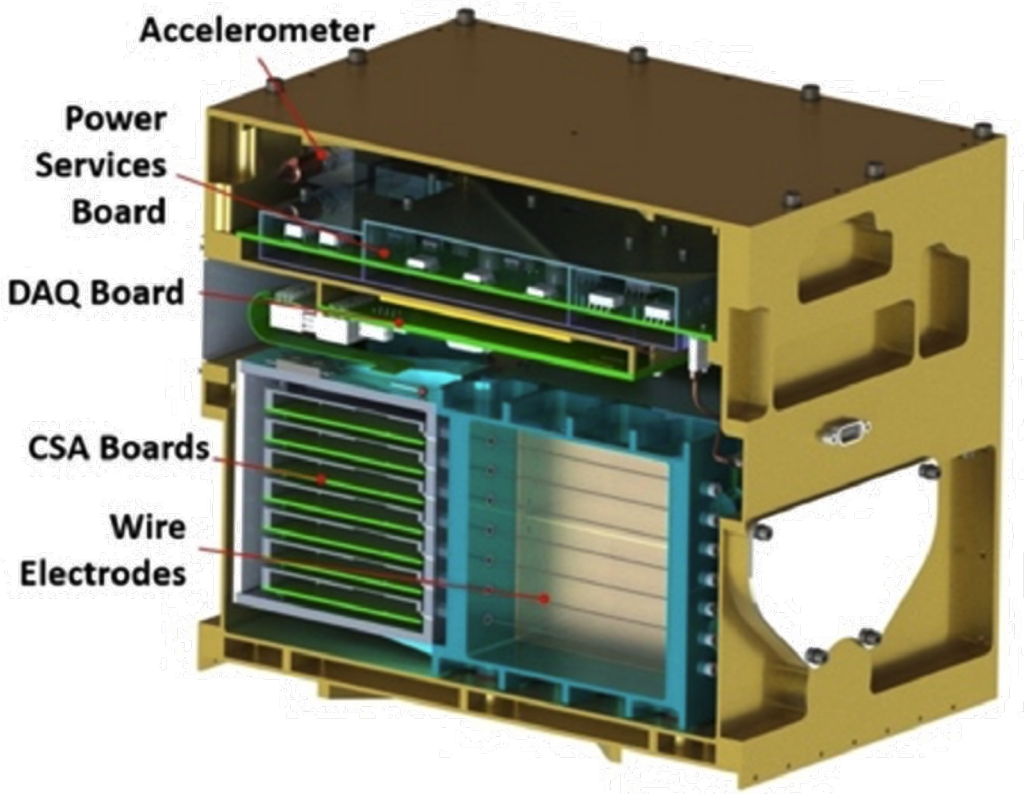
Dust size accuracy	1 < r < 20 μm 15%
Velocity accuracy	0.8 < v < 20 m/s 15%
Charge accuracy polarity	1.2 < Q < 64 fC 20% positive/negative
Flux accuracy cadence	0 < F < 1.7 particles cm^{-2} s^{-1} 20% continuous
FOV	54° (for size meas.) 135° (for flux meas.)

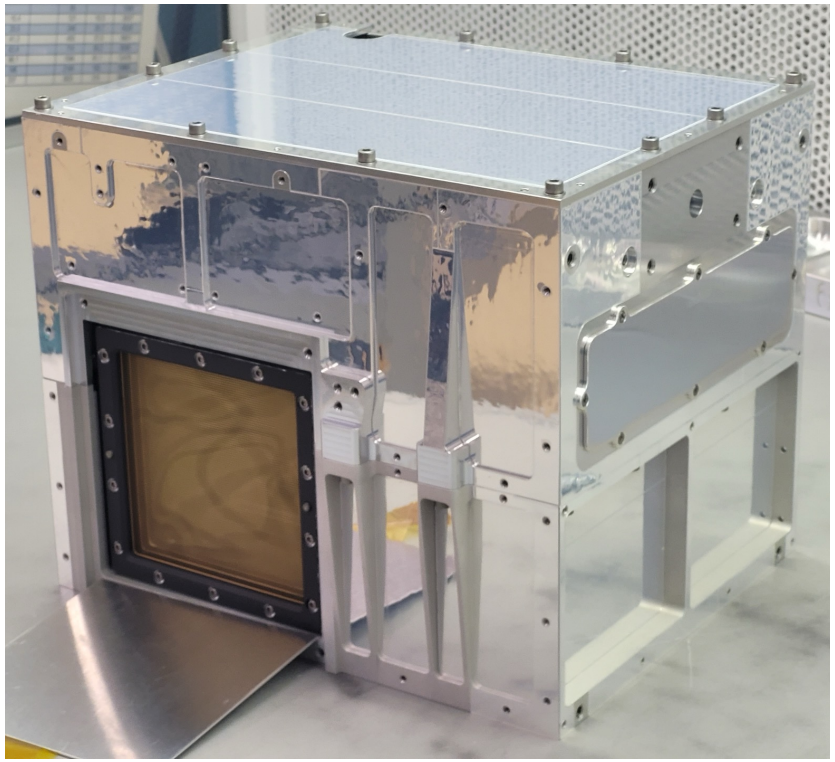
When a charged dust particle enters through the EDA sensor, it is detected through induced charges on the wire-electrodes in two DTS:

- **Charge** is measured from the total induced charges on all wire-electrodes in a DTS
- **Velocity** is determined from the time shift of the charge signals between the two wire-electrode arrays.
- **Mass (and size)** is derived from the trajectory deflection by DFE.

Wang et al., PSJ, 2024

EDA Instrument and Measurements





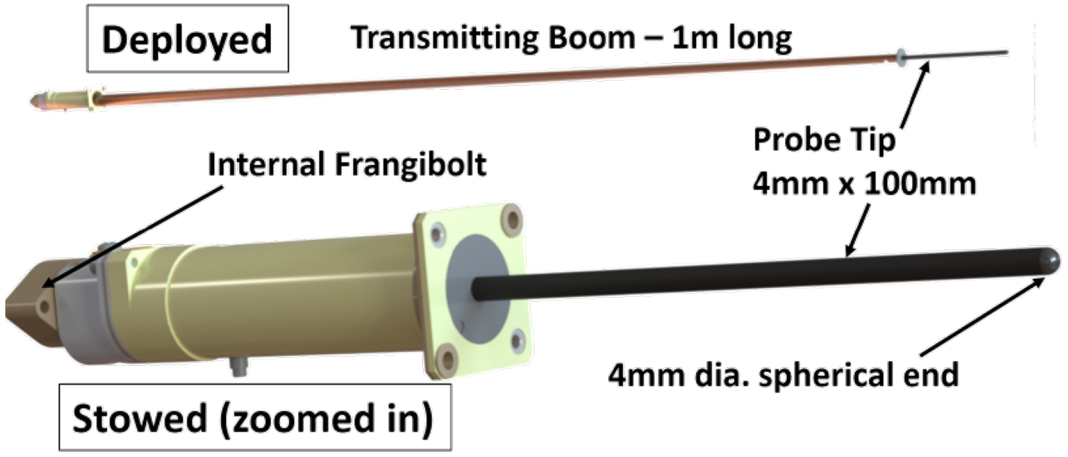
EDA TRL 6 Model

Power: 7W
Mass: 5.5 kg
Volume: 21.6 cm x 17 cm x 17.9 cm

Wang et al., PSJ, 2024

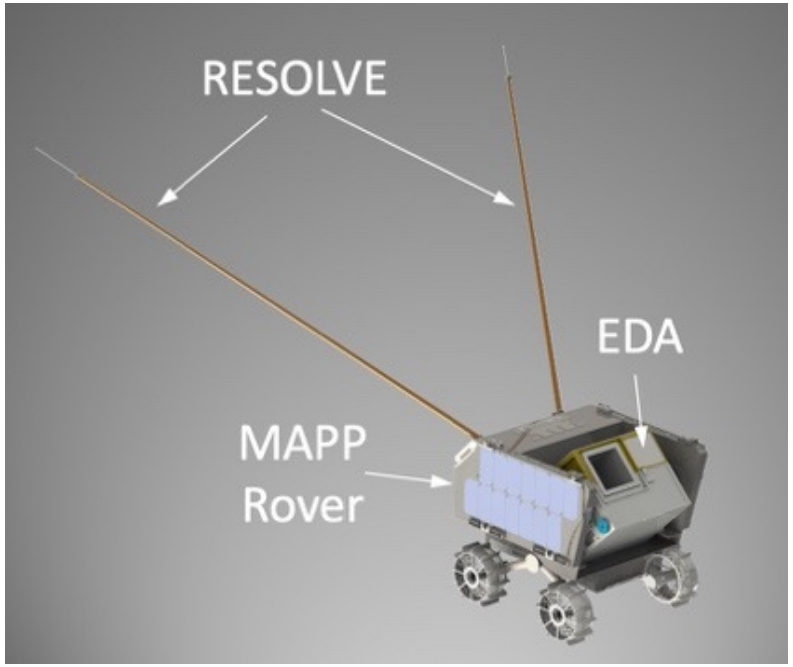
RESOLVE Instrument

- Characterize the average electron density over a volume via plasma relaxation sounding
  - The two booms drive electric field to excite the plasma with broadband frequencies
  - The two tips at the end of the booms listen to the resonance frequency that determines the electron density
- Detect high-speed micrometeoroid impacts and dust ejecta during lander liftoff from plasma plumes generated from impact ionization on the surface of the rover or nearby regolith



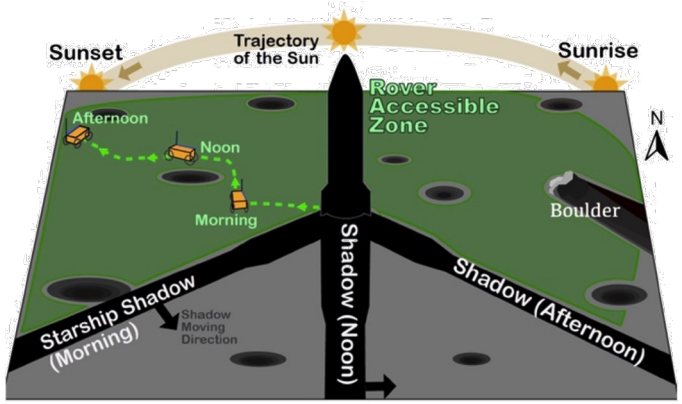
Electron density	$10 < n < 2000$ cm^{-3}
accuracy	1%
cadence	0.1 s
Impact rate	$0 < J < 10^7$ hits m^{-2} s^{-1}
accuracy	<10% false detection
cadence	continuous

Power: 0.5W
Mass: 2.5 kg
Volume: 1 m boom (2x)
10 cm tip (2x)

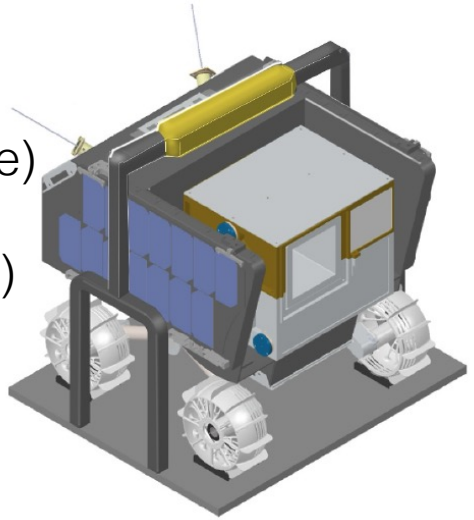


ConOps Overview

- Designed for a 1-crew, 1-handed carry
- Once DUSTER is placed on the lunar surface, an astronaut will flip a switch to power on DUSTER from its internal batteries
- During the surface mission, DUSTER will measure the dust and plasma environment from the disturbed landing area and progressively move towards more pristine regions
  - Communicate with HLS via WiFi
  - Can communicate over S-Band to an orbiting relay satellite after HLS departs
- Baseline investigation: 6-7 days
- Extended investigation: up to 14 days (w/ relay satellite available)
  - Measure dust ejecta from lander liftoff
  - Measure dust lofting across terminator (Lunar Horizon Glow)



Cartoon showing that DUSTER will drive away from HLS during the Lunar day



DUSTER on the Handling Interface Plate 39cm (W) x 38cm (D) x 50cm (H)

Cartoon image showing a 1-hand carry

Stowed Volume: 39cm (W) x 38cm (D) x 50cm (H)
Mass: 24 kg
Internally Powered (30W to 48W)
Data Rate: 180 kbps (avg), 712 kbps (peak)
Temp Range: -40C to +80C

To the Moon

Questions?