CubeSat Electrostatic Dust Analyzer (CEDA) for Measuring Electrostatic Dust Transport on Airless Bodies

X. Wang[1,2], Z. Sternovsky[1,2], M. Horányi[1,2], and Dust BUSTER Student Team[3];

[1]Laboratory for Atmospheric and Space Phsics, University of Colorado, Boulder, CO 80303, USA.
[2]NASA/SSERVI's Institute for Modeling Plasma, Atmospheres, and Cosmic Dust, Boulder, CO 80303, USA.
[3]Ann and H.J. Smead Aerospace Engineering Sciences, University of Colorado, Boulder, CO 80309, USA.

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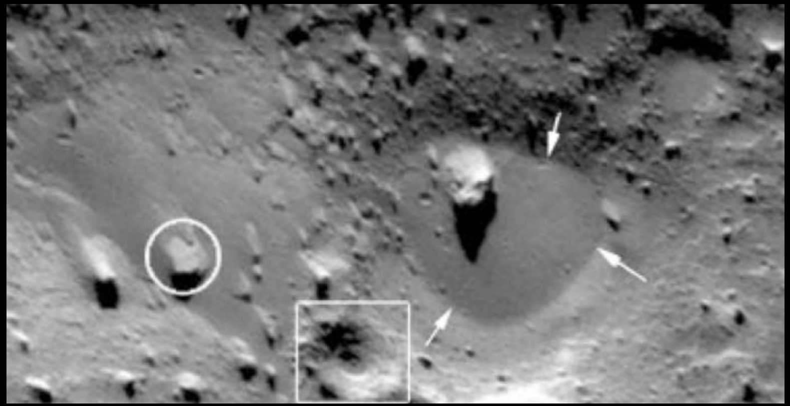
Science Motivation

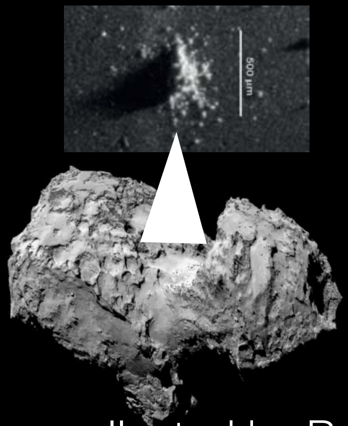
Examples of Observations Related to Electrostatic Dust Transport

Lunar Horizon Glow (Colwell et al., 2007)



Dust pond on asteroid Eros (Robinson et al., 2001)

The radial spokes in Saturn's rings (Mitchell et al., 2006)

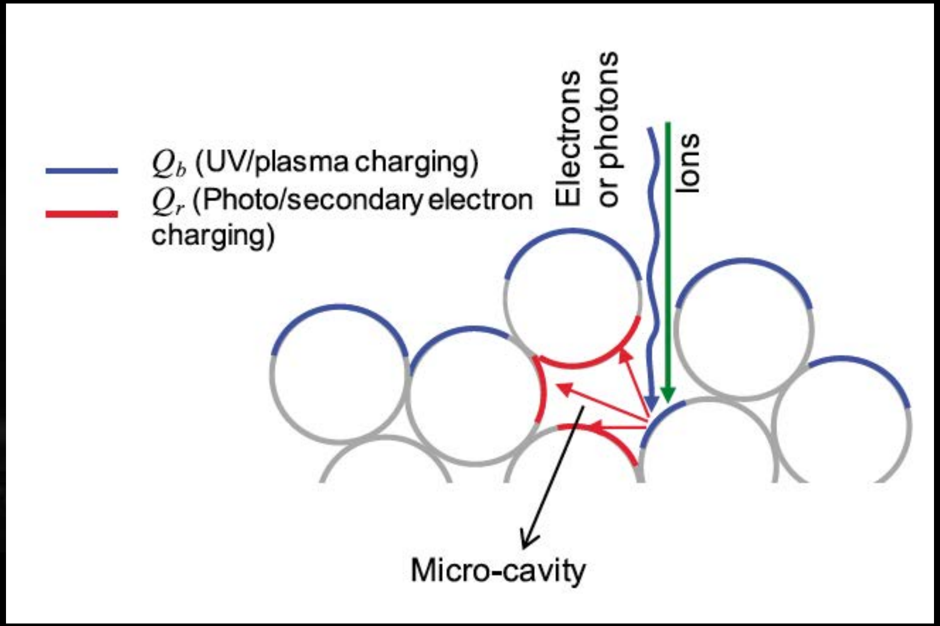


Dust particles collected by Rosetta from comet 67P (Schulz et al., 2015)

Recent Laboratory Experiments

Exposure to UV and plasma

New “Patched Charge Model”



Wang et al., GRL, 2016; Schwan et al., GRL, 2017

- Dust particles that form microcavities can attain large negative charges from the collection of photo- or secondary electrons emitted by their neighboring particles.
- The repulsive force between two adjacent negatively charged dust particles causes their lofting and mobilization.

Science Objectives

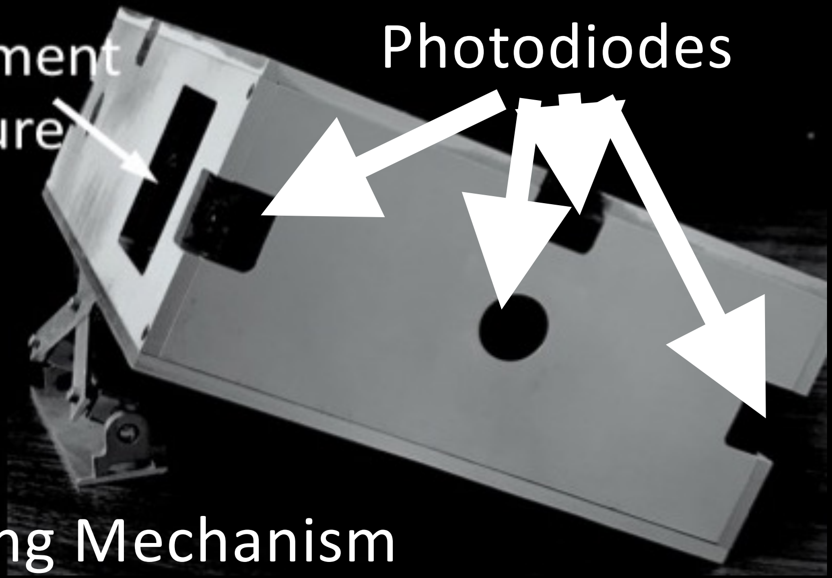
- Explore and characterize electrostatically lofted dust on the surface of asteroids, the Moon or other airless bodies in order to find ground truth of this universal phenomenon and to understand its role in the surface evolution of these airless bodies.
- Evaluate potential hazards posed by electrostatically lofted dust for future robotic or human exploration on these bodies.

Measurement Parameters

To measure the **charge, velocity, mass**, and flux of electrostatically lofted dust particles on the surface of an asteroid, the Moon or other airless bodies.

- The charge, velocity and mass identifies and characterizes lofted dust particles. The velocity is a unique parameter to discriminate electrostatically lofted dust (< 100 m/s) from other space dust (100 – a few km/s).
- The flux determines the efficiency of the electrostatic dust transport mechanism in surface processes.

CEDA Overview



Specifications

- 6U (10 cm x 20 cm x 30 cm)
  - Mass Estimate: < 10 kg
  - Power Estimate: < 10 W
- Dust analyzer module (2U).
- Sun sensors: determine the sun position.
- Tilting Mechanism: raise the cubesat on the anti-solar side for optimized field-of-view (FOV).
- Doors: prevent solar wind & solar UV as well as stirred-up dust during landing from entering the dust analyzer.
- Solar panels are folded during landing to avoid stirred-up dust deposition and opened after settling down.

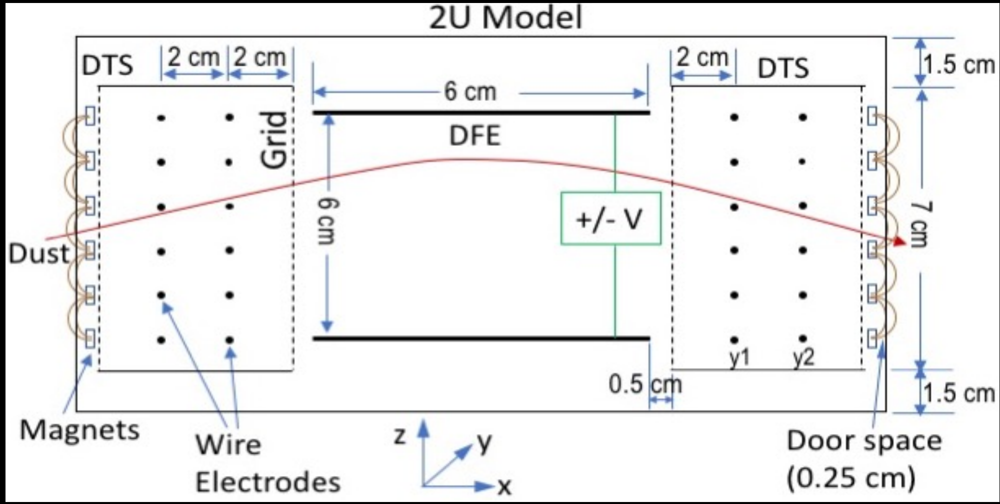
CEDA Deployment

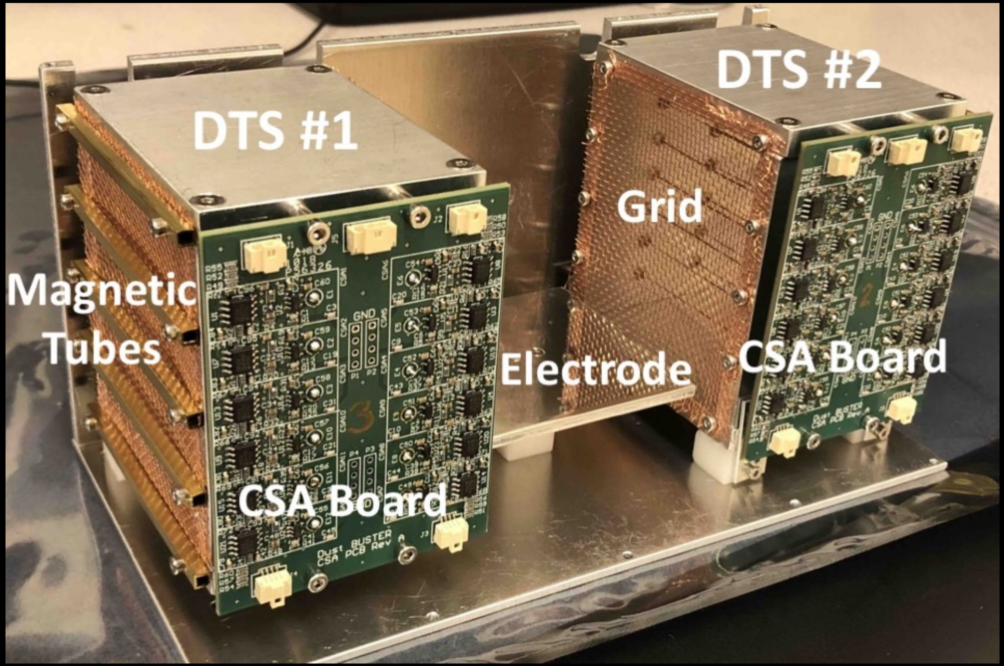
- On asteroids: hard landing after the deployment from a mother SC.
- On the Moon: deployed by a lander or astronauts.
- The mother SC provides the communication relay and/or power.

Deployment Sequence

1) Determine the sun position.
2) Tilt the cubesat on the anti-solar side to a desired angle 45 ± 20 degrees.
3) Open the door on the same side for dust collection.
4) Open the solar panels.

Dust Analyzer Module





Instrument Specifications

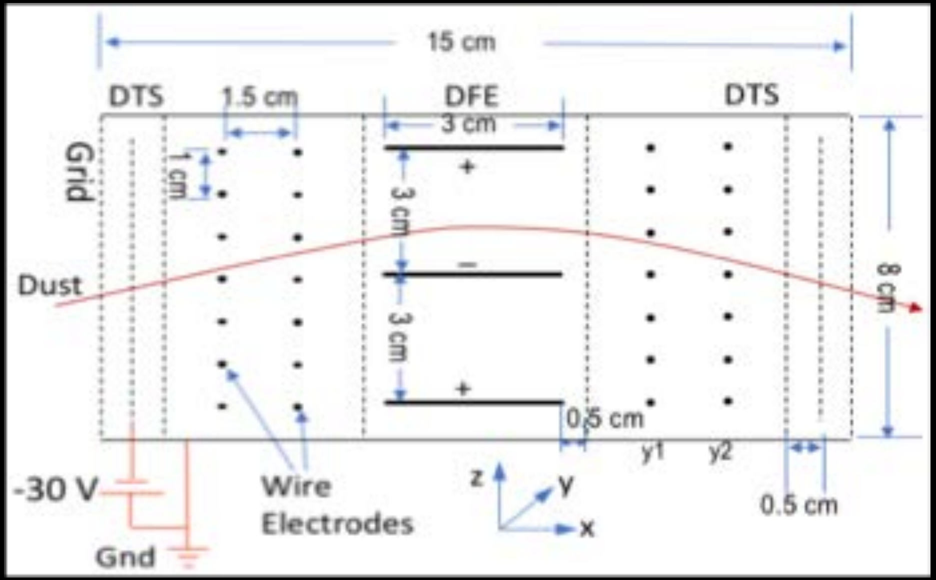
- 2U (10 cm x 10 cm x 20 cm)
- Charge sensitivity: 2 x 10^3 electrons
- Q/M range: 2 – 20 x 10^{-4} C/kg
- Velocity range: 0.01 – 10 m/s

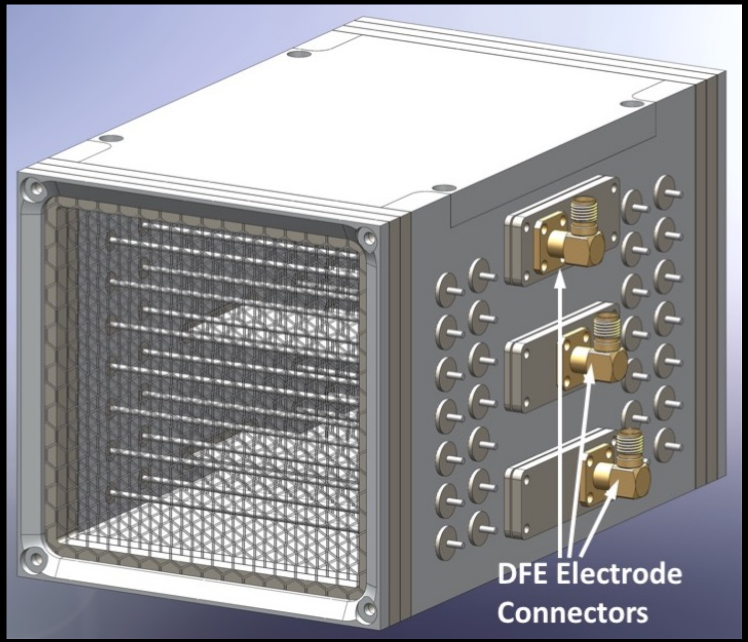
DTS (Dust Trajectory Sensor): The wire-electrodes measure the ***charge*** induced by a dust particle passing through. The dust trajectory is reconstructed by two wire-electrode planes to determine the ***velocity***.

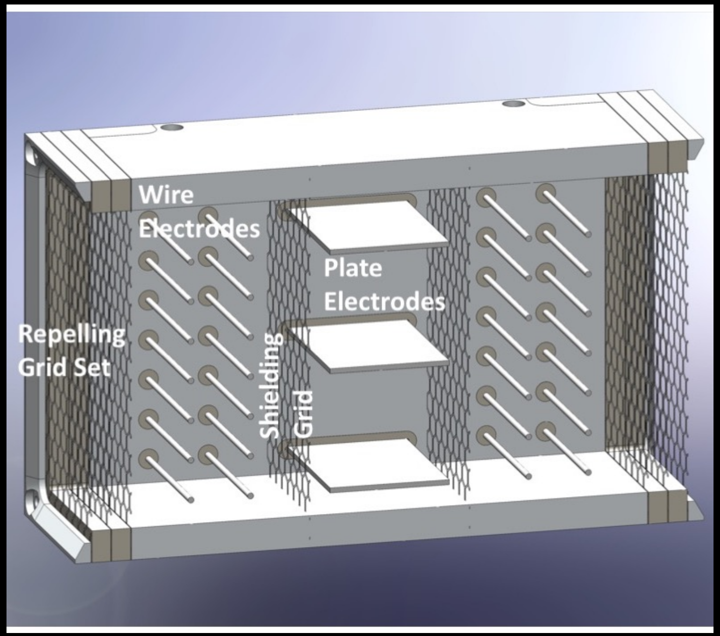
DFE (Deflection Field Electrodes): The voltage applied across two electrodes deflects a charged dust particle to determine its charge-to-mass ratio (Q/M). The ***mass*** is then calculated, given the measured charge.

Magnet tubes are used to deflect electrons while allow dust particles to pass.

Dust Analyzer Module



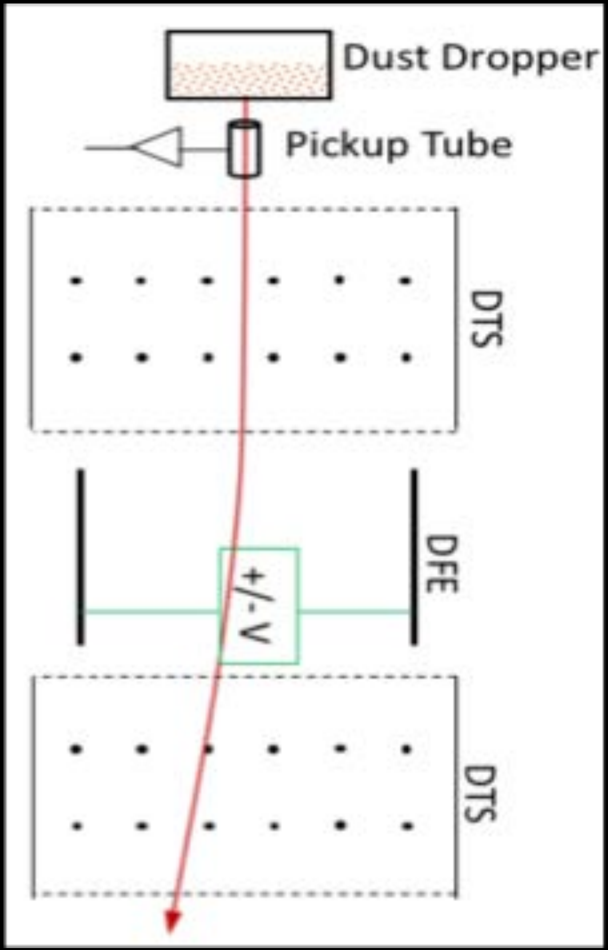


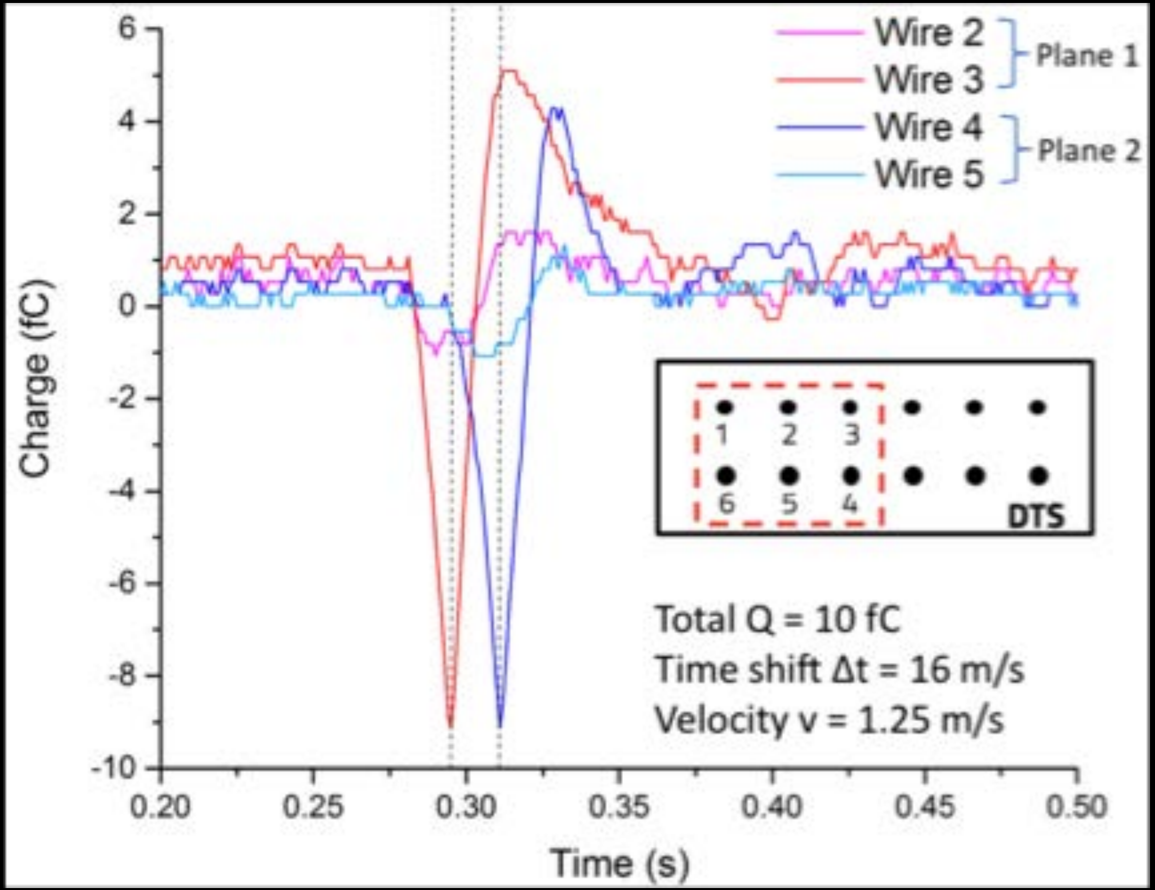


Alternative Design: Electrostatic Repelling Grids (Dust speed: 0.3 – 20 m/s)

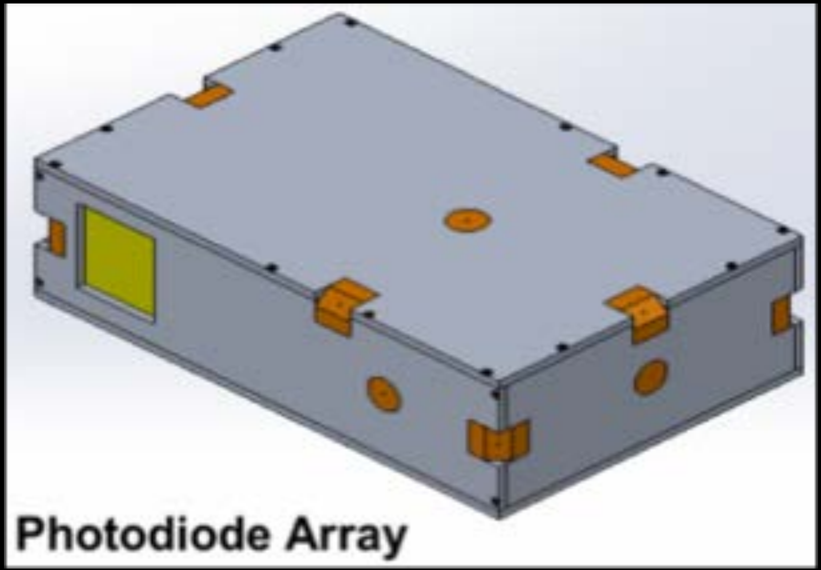
- The repelling voltage is larger enough to stop electrons while allows charged dust to pass through without losing any energy

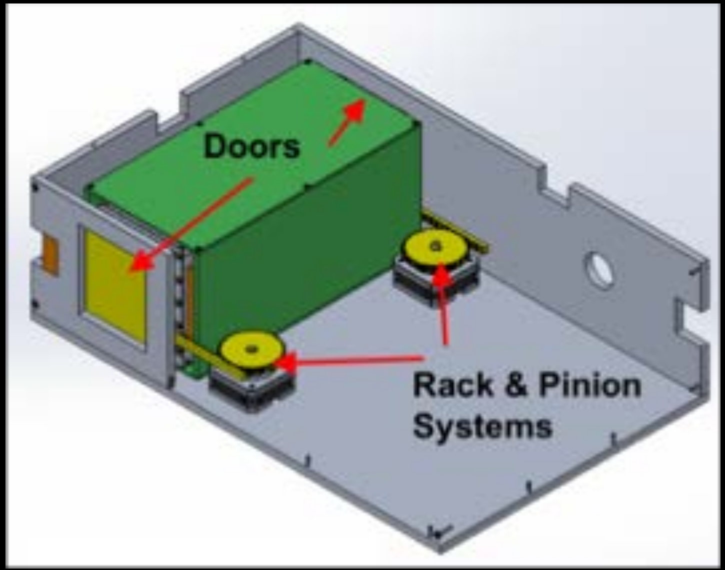
Testing Results (Dust Analyzer Module)

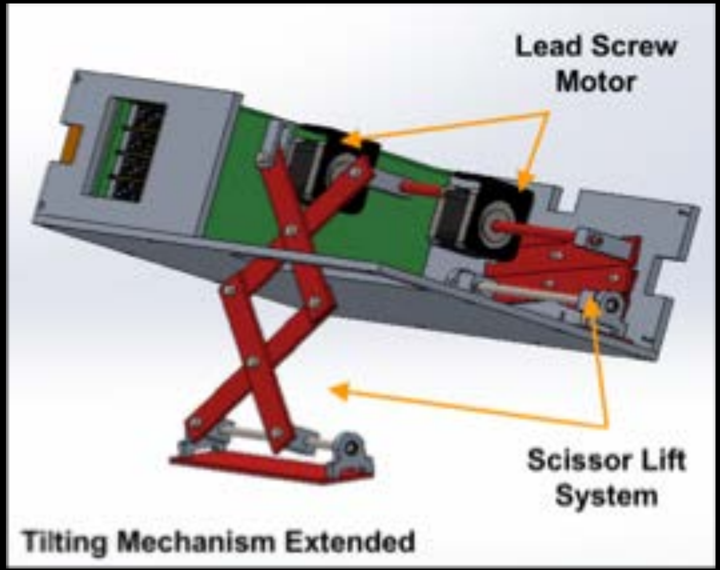




Autonomous Repositioning System (ARS)







13 photodiodes to cover entire sky (± 2 deg accuracy)

Sliding Door Mechanism

Scissor Lift Tilting Mechanism (45 deg. ± 2 deg accuracy)

Summary

We have developed and demonstrated a 6U cubesat dust instrument for measuring electrostatically lofted dust on the surfaces of airless bodies in order to understand how this mechanism plays a role in surface processes.

The instrument includes a 2U dust analyzer module and an ARS subsystem for positioning the instrument for optimized measurement.

The instrument can be modified to fit missions to different targets.