Teaching K-12 Particle Physics as an Advocate: A Personal Journey into Radio Wave Science and Technology Research

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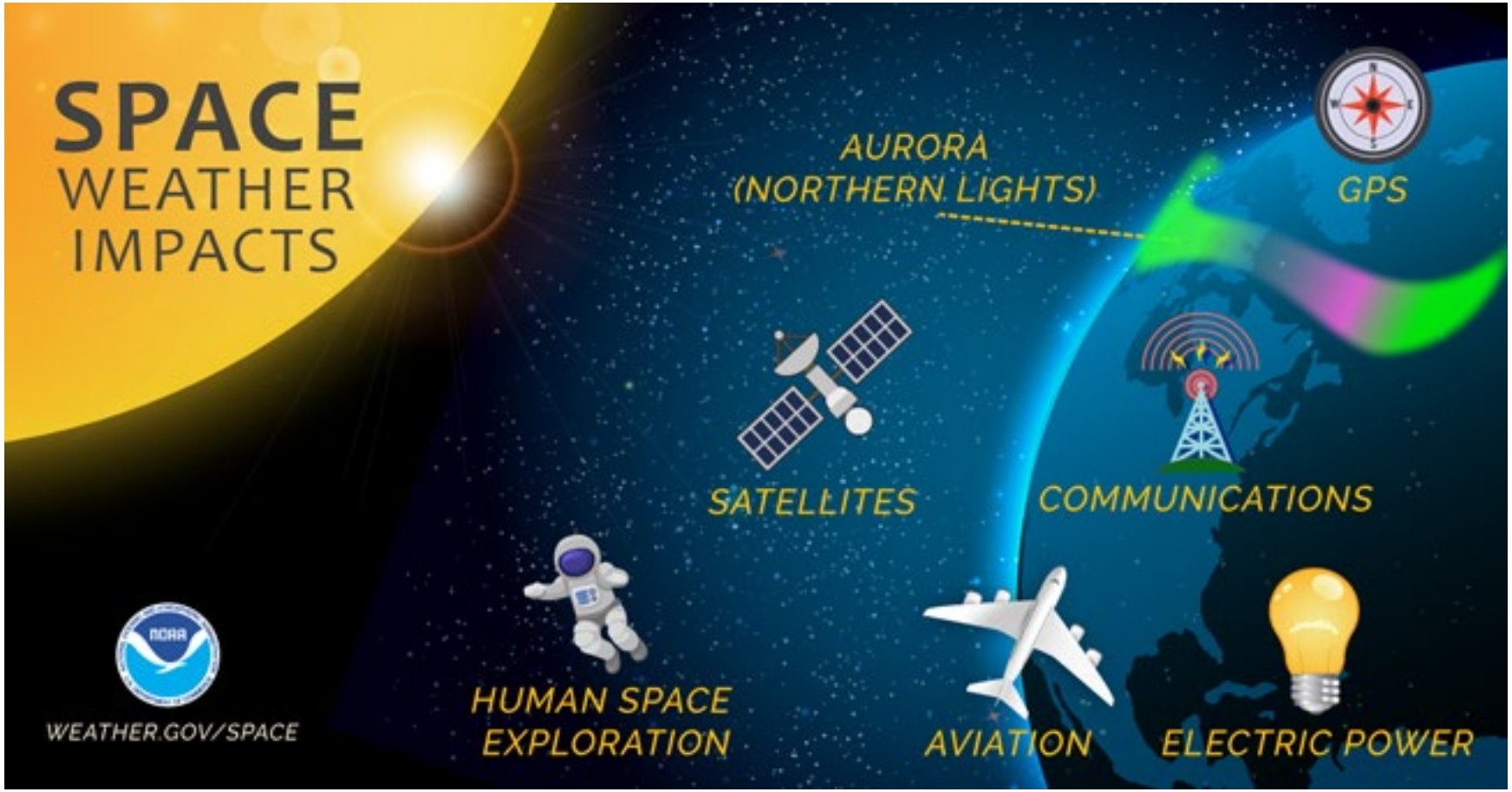
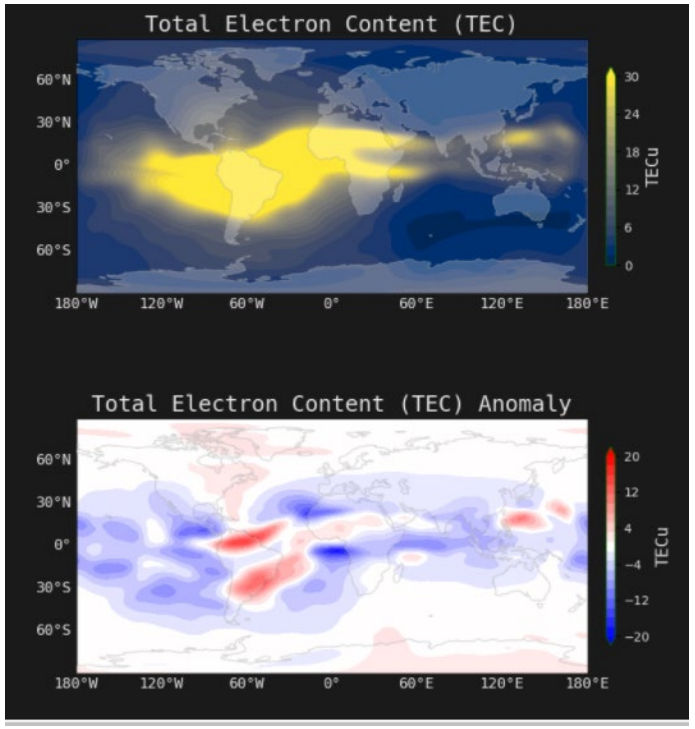
The sun is the main source of space weather.

Naturally occurring space radiation is always with us. It occurs when atoms, ions, or subatomic particles are accelerated to high velocity by processes such as solar particle events from the Sun. Disrupted propagation of radio signals emitted by satellites, disruptions in telecommunications, GPS position, aviation, and sometimes Earth's ground electric power. Analyses of historical blackout events in the United States indicate that even short blackouts, which occur several times during a year in the United States, sum up to an annual economic loss between $104B and $164 B.



NOAA. The TEC in the ionosphere is modified by changing solar Extreme Ultra-Violet radiation, geomagnetic storms, and the atmospheric waves that propagate up from the lower atmosphere. The propagation of radio waves is affected by the ionosphere.

Global Ionosphere: The Total Electron Content (TEC) is the total number of electrons present along a path between a radio transmitter and receiver. Radio waves are affected by the presence of electrons.



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- The first of its kind coupled Whole Atmosphere Model and Ionosphere Plasmasphere Electrodynamics Model (WAM-IPE Model) is now part of the Space Weather Prediction Center's (SWPC) suite of forecast tools and has expanded space weather forecasts

- The Total Electron Content (TEC) is the total number of electrons present along a path between a radio transmitter and receiver. Radio waves are affected by the presence of electrons. The more electrons in the path of the radio wave, the more the radio signal will be affected. For ground to satellite communication and satellite navigation, TEC is a good parameter to monitor for possible space weather impacts.

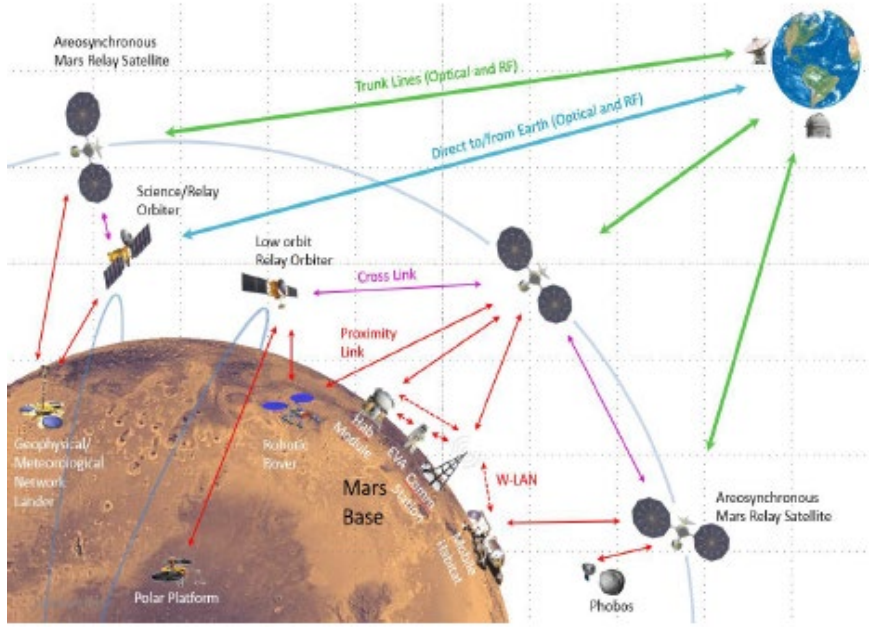
Introduction—Instructional Context

Standards documents (NGSS Lead States, 2013)	Scientists	Teachers	Students
To apply, explore, and learn science concepts such as developing models, analyzing data and constructing explanations.	To decipher and evaluate data for sensemaking and pattern interpretations: "The Evidence"	Teachers often present science as disconnected facts, algorithms and definitions (Roth & Garnier, 2006).	Students rather than memorizing the ideas of others (Sandoval, et al., 2014)—have students directly challenge the perception that science is made up of final form ideas.
Science as not being made up of final form ideas (NRC, 2012).	Scientists continuously refine and revise explanations of the natural world.		Student work aligns with the work of scientists who are continuously refining and revising explanations of the natural world

Lunar Exospheric Radio Communications

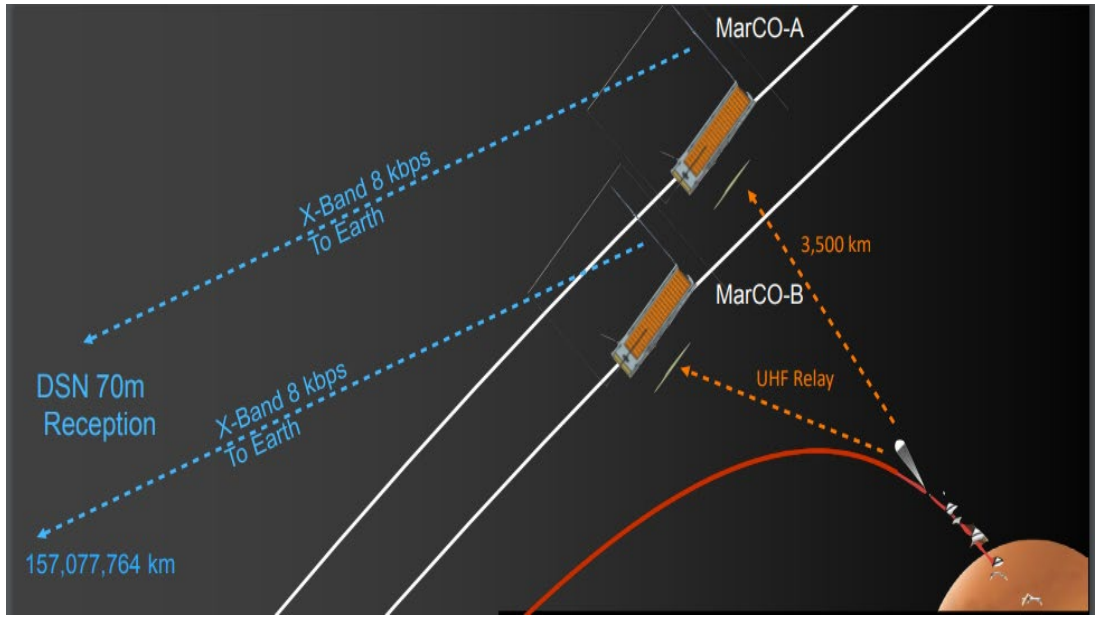
Example1---November 26, 2018

Notional Mars Architecture



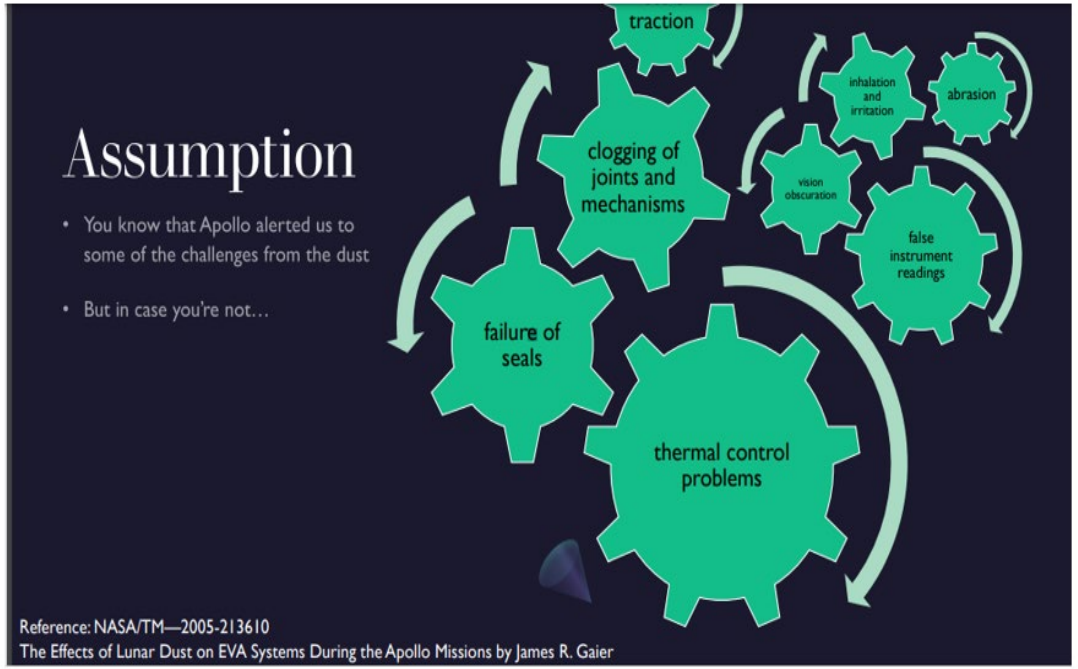
Notional Mars Architecture

Cubesats on MartianMissions



Examples of dust-related damage of mechanisms per Apollo 17 de-briefing reports.

Mission	Problem
Apollo 12	Lock buttons of the equipment conveyor very hard to manipulate because of the dust accumulation in the moving parts
Apollo 15	Camera drive mechanisms got jammed with dust and prevented it from working
Apollo 16	Battery cover of radiator jammed because of dust accumulation in the mechanism
Apollo 17	Some of the moving components of the geopallet got stuck after the second EVA; the angle adjustment of some geological tools (scoop and rake) got fixed in one position which could not be changed anymore; multiple components attached to the rover jammed because of the dust exposure (e.g. bag holders, pallet locks)

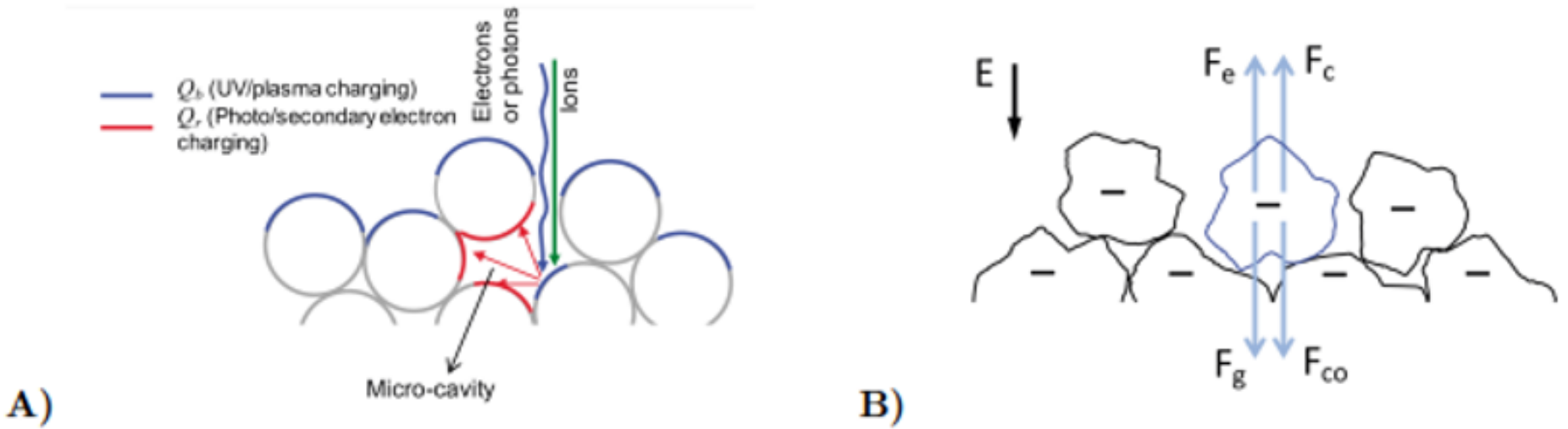


Dust particles lifted from the surface of the regolith and levitating, immersed in the interstellar or interplanetary plasma, are electrically charged and, therefore, are associated with the plasma through electric and magnetic fields

- Dust particles lifted from the surface of the regolith and levitating, immersed in the interstellar or interplanetary plasma.
- Electrically charged and, associated with the plasma through electric and magnetic fields.
- Dust can be considered as a collection of isolated particles (“dust-in-plasma”)

- Plasma containing charged dust particles referred to as a “dust plasma”, has properties determined by the ratio of three characteristic length scales: dust grain size a, Debye length, and dust density.
- Dust plasma medium includes plasma flows, secondary particles, photoelectrons, levitating dust particles of regolith, as well as the extremely rarefied atmosphere of the Moon.
- A collisionless exosphere of the Moon, which can extend to several hundred kilometers above the surface

Lunar charging environment: The lunar surface is subject to the solar wind plasma, and ultraviolet and soft x-ray radiation that can vary over the course of a lunar day.



Patched Charge Model (A) A schematic illustration of the Patched Charge Model proposed by Wang et al., 2016. Regolith grains are charged through the collection of photo/secondary electrons induced by Solar UV and plasma within regolith micro-cavities. (B) Gravity and the cohesive force resist the plasma sheath and coulomb forces as charges build up.

Why do we care about the plasma environment?

Charging governed by current balance

$$I_E(V) - \left[I_I(V) + I_{PH}(V) + I_{Secondary}(V)\right] = I_T$$

V = spacecraft surface potential relative to plasma

I_E = incident electron current

I_I = incident ion current

I_{PH} = photoelectric current

$I_{Secondary}$ = electron currents from secondaries, other sources

I_T = total current to spacecraft

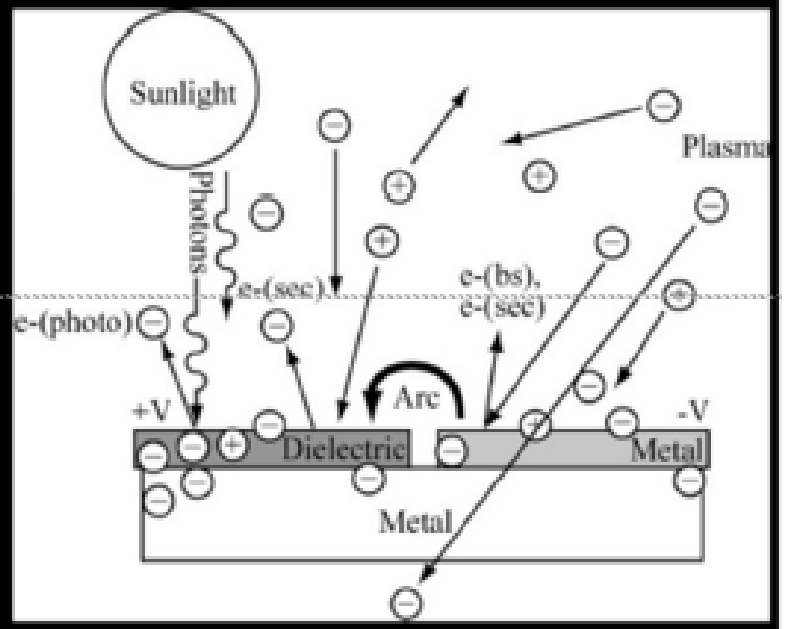
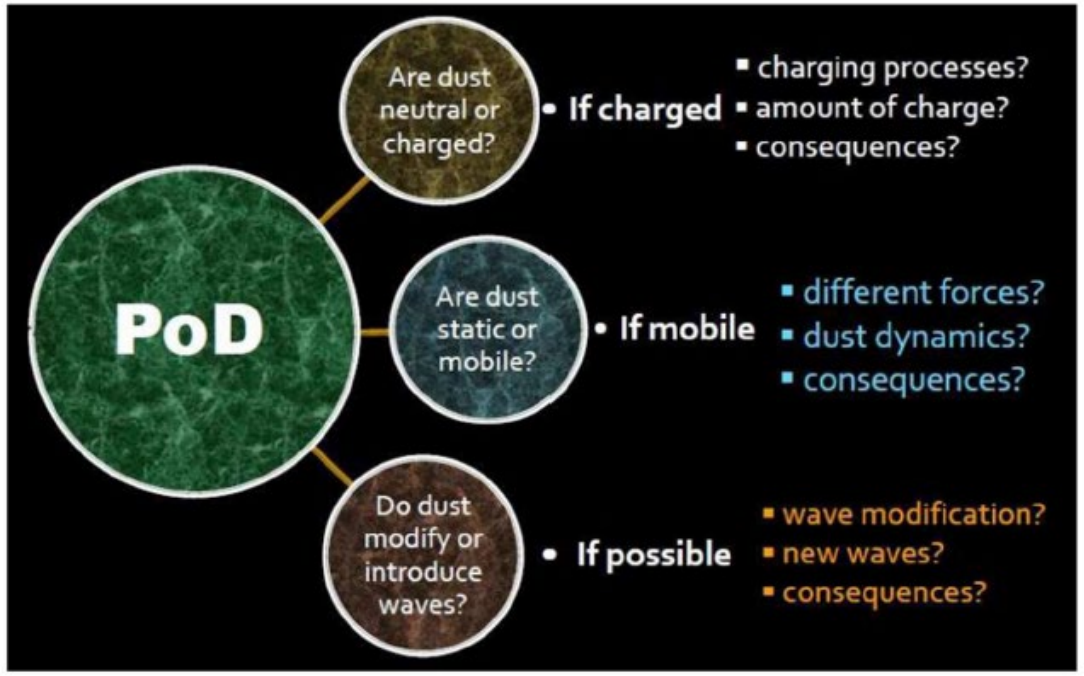
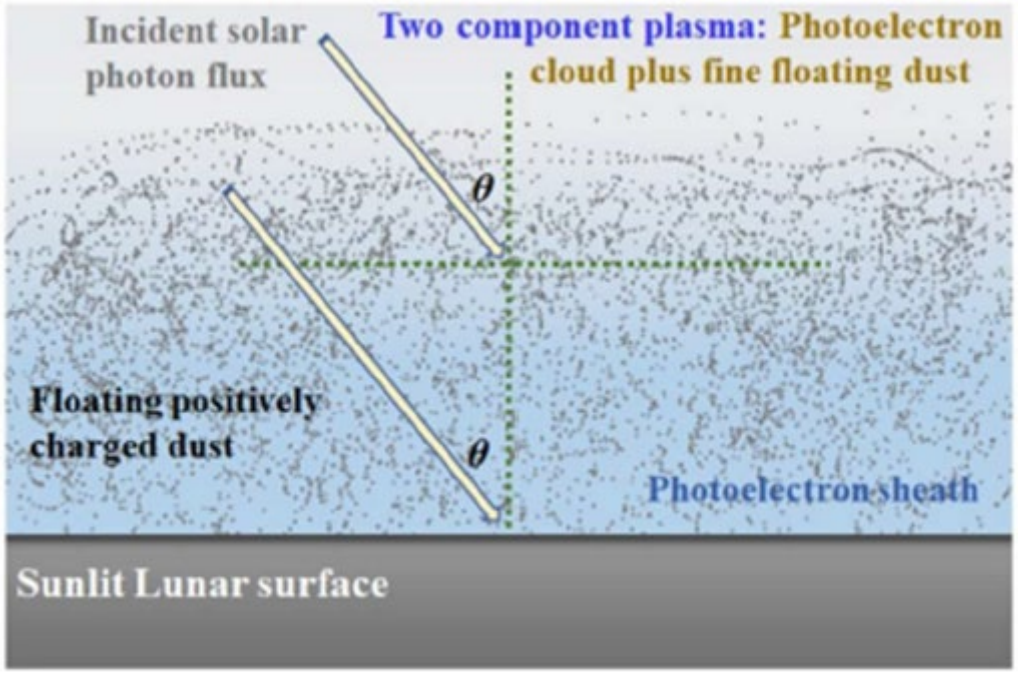


Figure from NASA-HDBK-4002

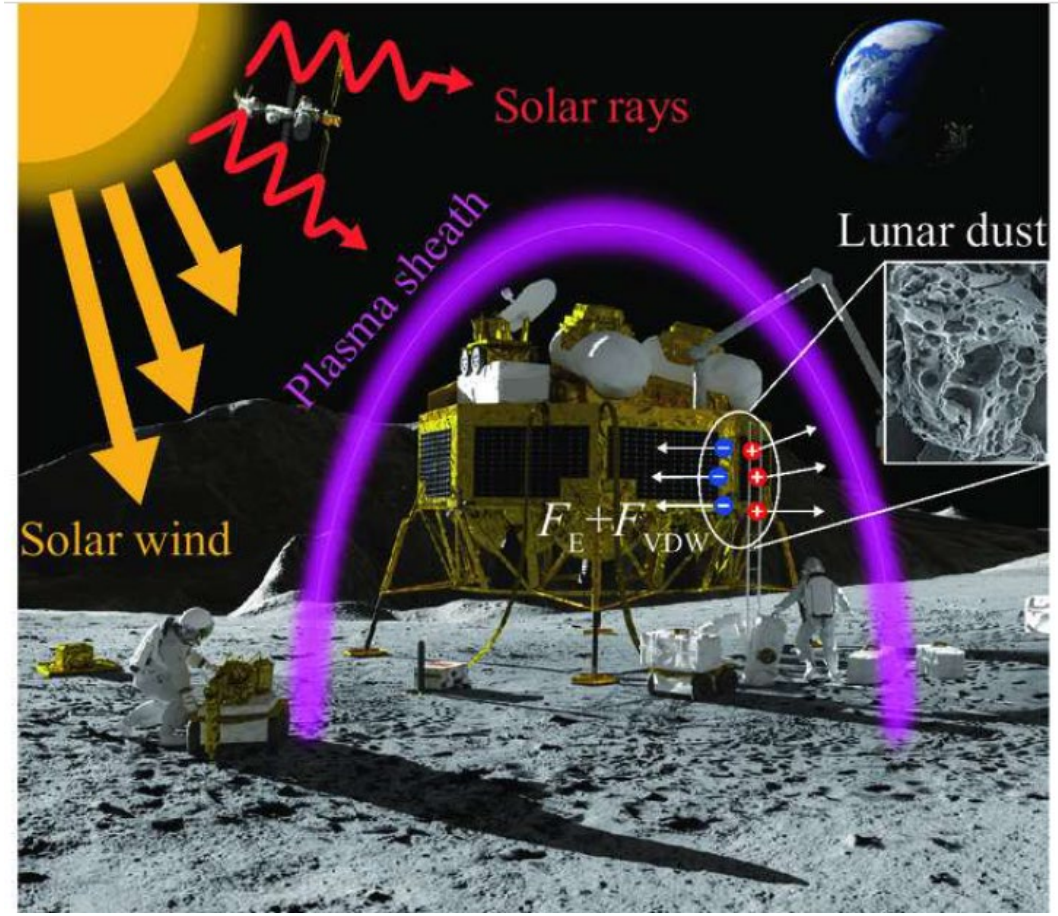
The physics of “dust-in-plasma” (PoD)

The photoelectron sheath and floating fine positively charged dust particles constitute a two-component dusty plasma in the sunlit lunar regolith’s vicinity.





When lunar dust does enter inside the plasma sheath, Das et al. (2016) [3] explained the ion drag force and neutral drag force caused by the plasma are negligibly smaller than the electrostatic force. Therefore, charged particles interact with the spacecraft within the confines of the plasma sheath, while the interaction between dust with plasma, neglected.



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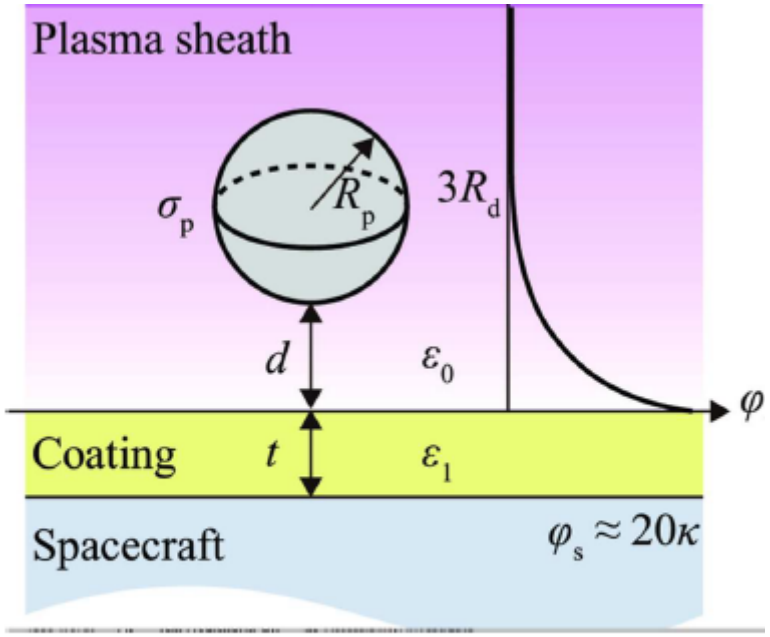
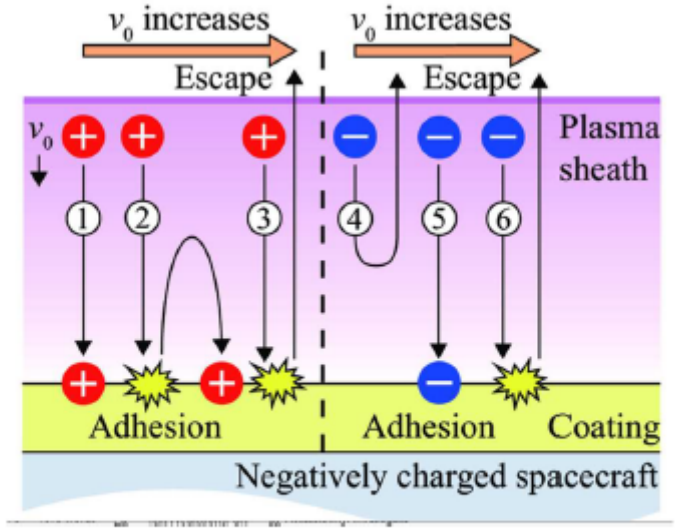


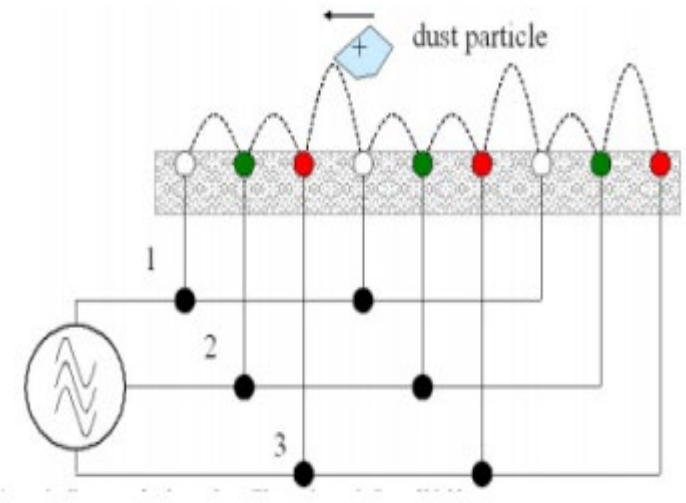
Geometric representation of a charged dust particle positioned above



4. Diagram illustrating that the adhesion and escape trajectories of positively and negatively charged particles interacted with negative spacecraft potential.

A novel combination of active and passive technologies integrated into the hardware surface to alleviate dust contamination.

- Leveraging two specific technologies, the Electrodynamics Dust Shield (EDS) active technology and Work Function Matching Coating (WFM) passive technology
- Developed by NASA for rigid surfaces, a new high performance materials such as the Carbon Nanotube (CNT) flexible fibers to develop a spacesuit-integrated dust cleaning system.



Conclusion

- Research Journalism posits an engaged science teacher within a community where knowledge-sharing is valued independent of age, background, or competency.
- Visual models provide a scaffolding platform for interpreting data and observing data patterns (with modifiers provided by atmosphere/ magnetosphere and material science substitutes).
- System reliability models processes, disruptive patterns prompts further science forecasting threshold limits per Alert Warnings (Total Electron Counts).
- Uncertain problem domains require methods for characterization.

Thank you

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