University of Colorado Boulder
Bioastronautics

Lunar Surface Assessment Tool (LSAT): A Simulation of Lunar Dust Dynamics for Risk Analysis

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HuLC
HUMAN LANDER CHALLENGE

Motivation and Solution Statement

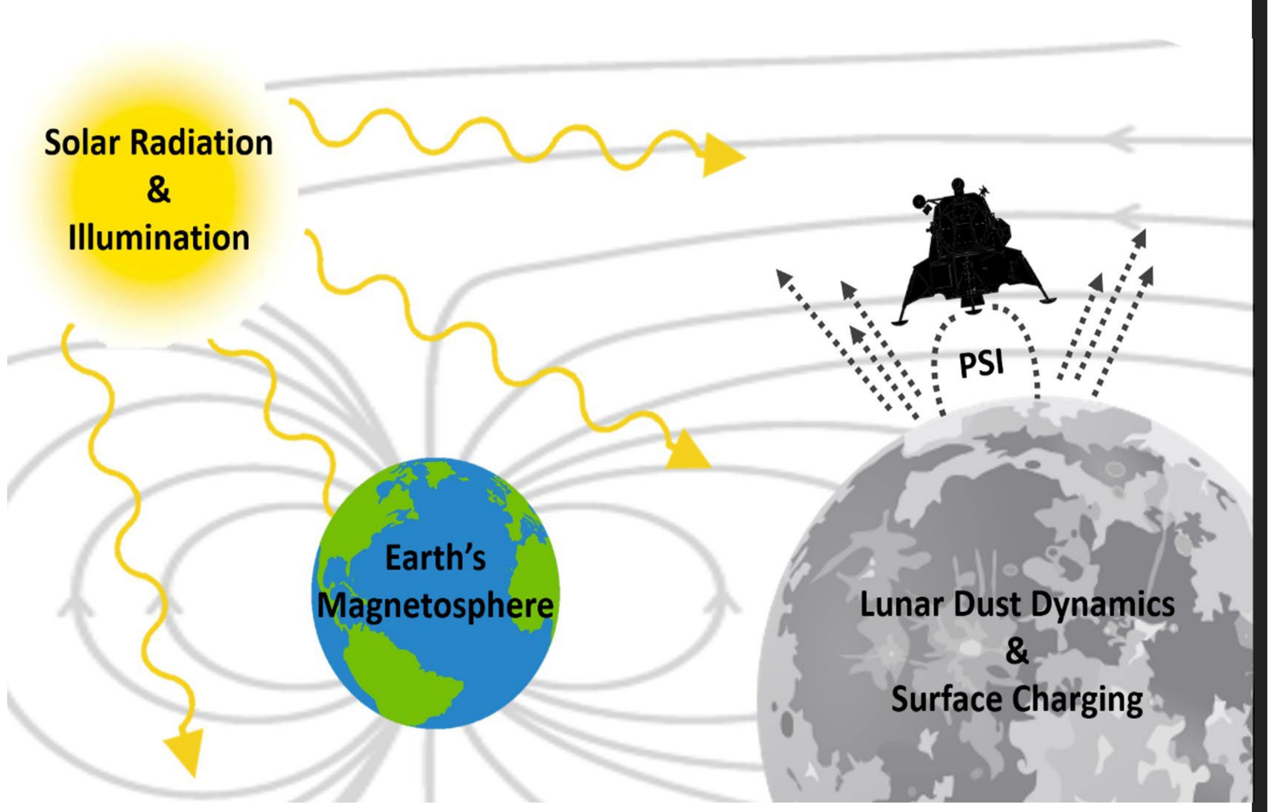
Plume-surface interactions (PSI) have large but mostly unknown effects on the lunar surface. Surface charging associated with the lunar environment cause dust lofting, posing risks to Extravehicular Activity (EVA) operations. Improved modeling techniques which consider the evolution of surface charging throughout a mission must be implemented to increase the understanding of these complex, dynamic systems.

Lunar Surface Assessment Tool (LSAT):

Holistic, mission-specific lunar surface simulation incorporating:

- Topography and illumination
- Mission timing
- Human Landing System (HLS) landing operations and charge
- Dust dynamics

The simulation can be used to **assess the potential risks to crew, vehicle, and surface assets over a lunar mission.**

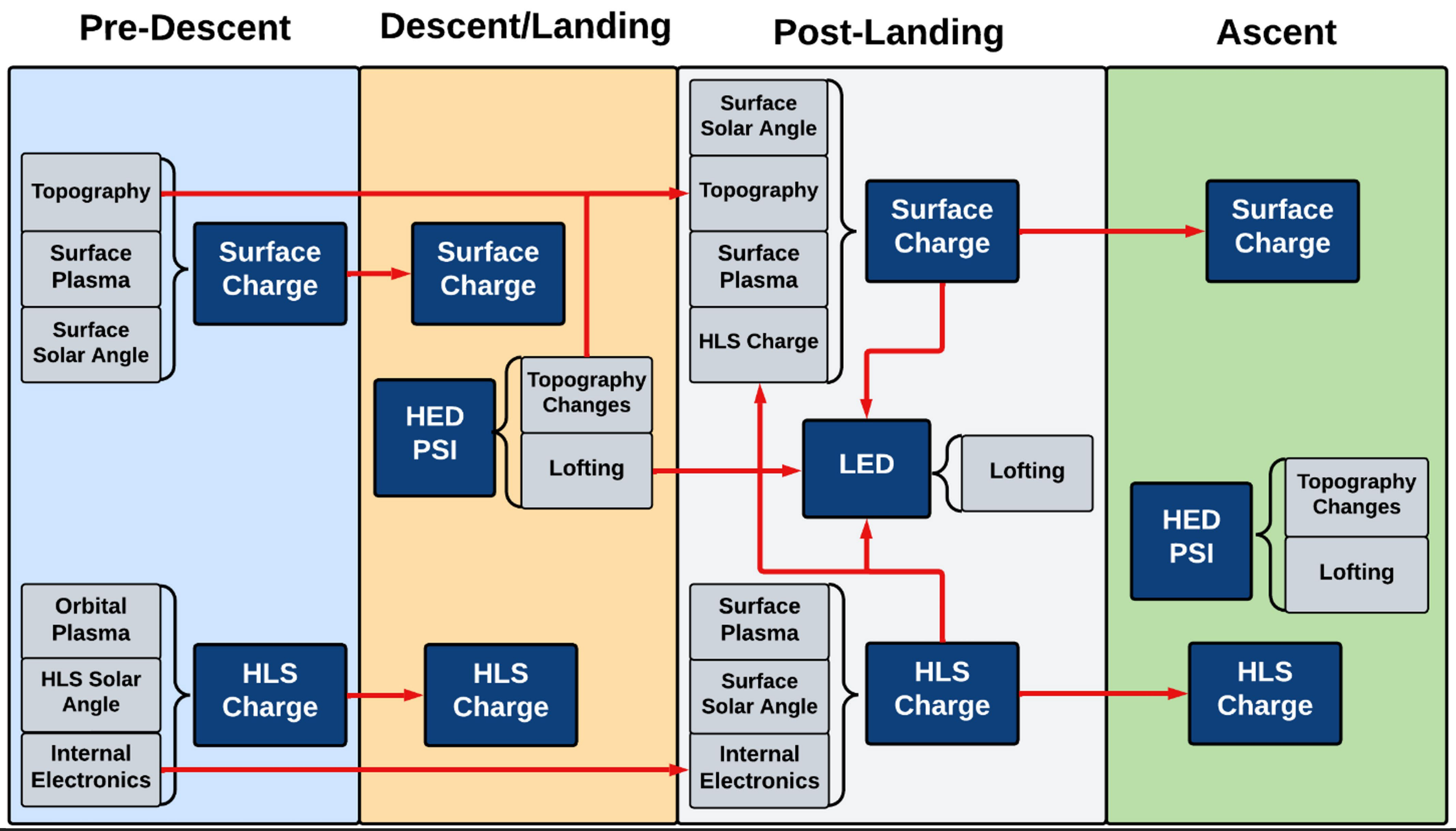


Modeling Methodology

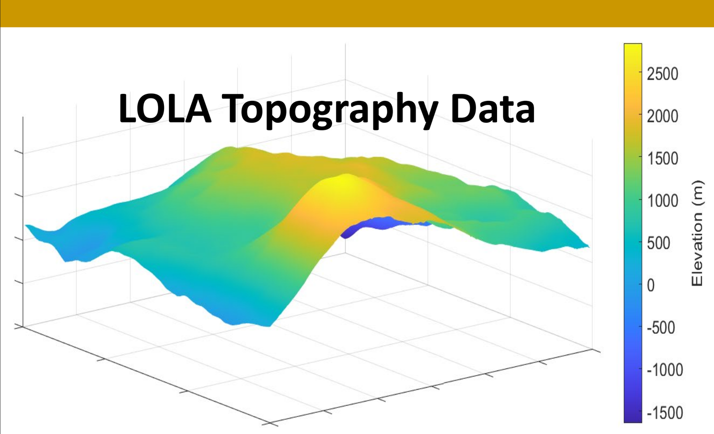
LSAT will determine lunar surface charge, HLS charge, and topographical changes over the various mission phases, informed by the following parameters and models:

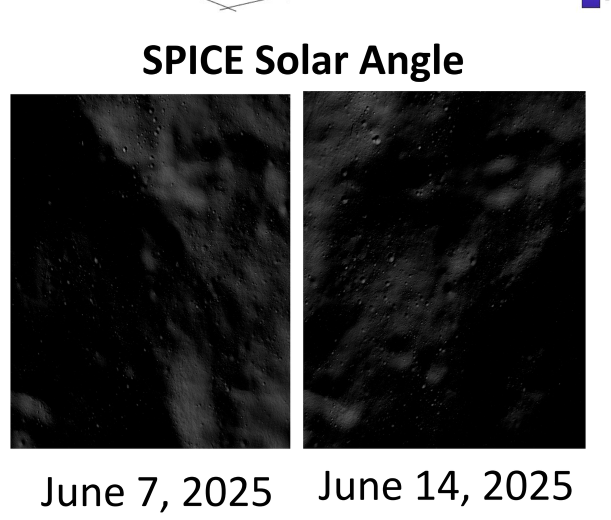
- Lunar surface & orbit plasma environments
- Lunar surface topography
- Solar illumination angle
- Regolith High Energy Dynamics (HED), from PSI
- Regolith Low Energy Dynamics (LED)

Integration of these models requires both temporal and spatial synchronization of parameters to ensure stable simulations.



Component Model Selection



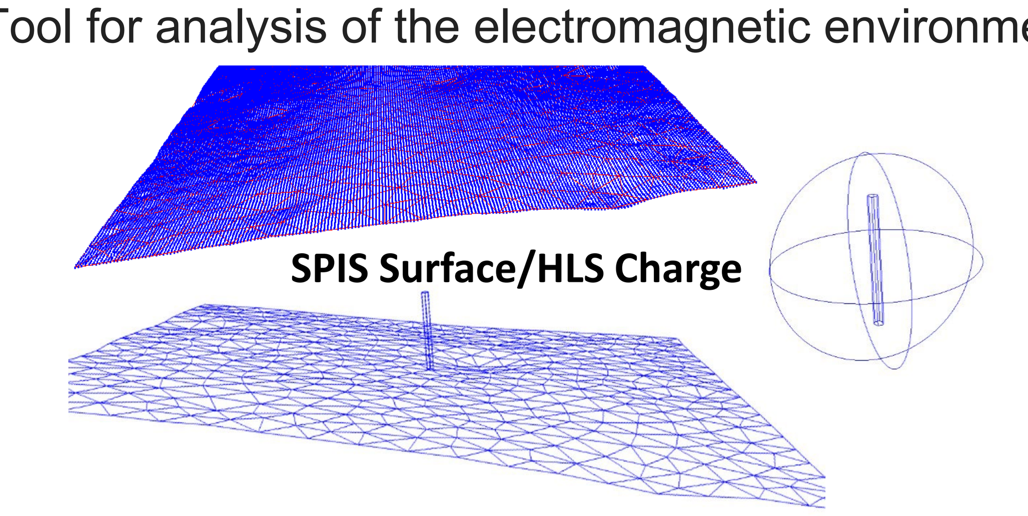


Topography and Surface Solar Angle

- Lunar Orbiter Laser Altimeter (LOLA)[1]
  - Provides data for digital elevation models
- Spacecraft, Planet, Instrument, C-Matrix, Event information system (SPICE)[2]
  - Simulates astrodynamics of Moon-Sun-Earth system
  - Generates solar angle and lunar position in the magnetosphere

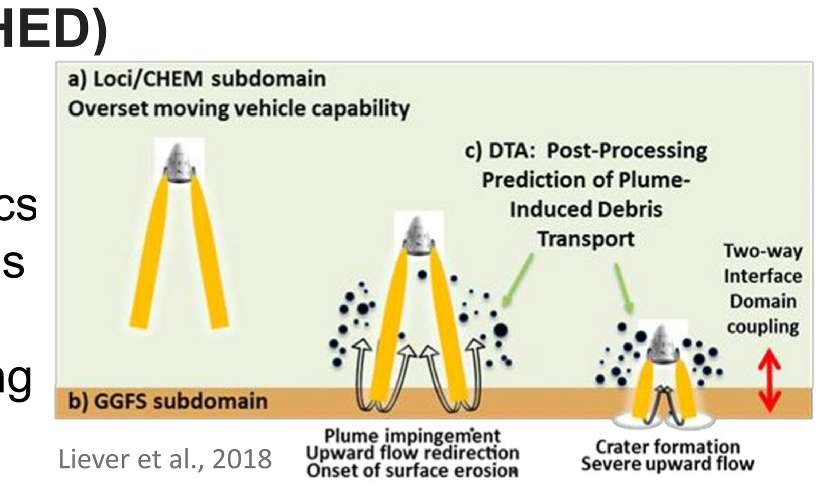
Surface Charging

- Spacecraft Plasma Interaction Software (SPIS)[3]
- Simulates surface charging of lunar surface topography and HLS
- Uses Dirichlet and Robin boundary conditions for sheath and pre-sheath conditions
- Tool for analysis of the electromagnetic environment

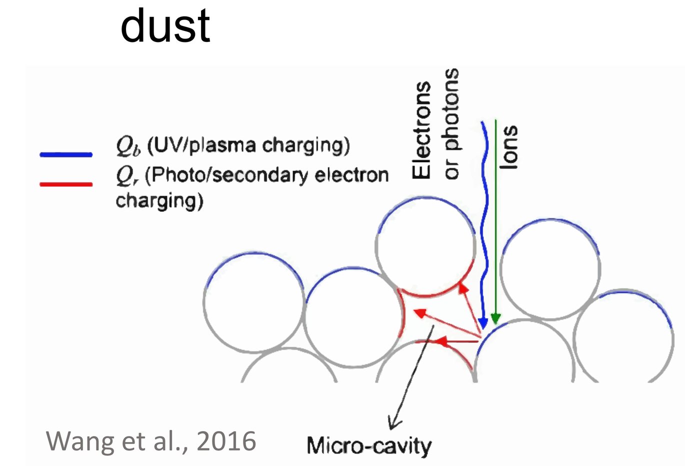


High Energy Dynamics (HED)

- Gas-Granular Flow Solver (GGFS), Loci/CHEM Computational Fluid Dynamics and Debris Transport Analysis (DTA)[4,5]
- Simulates cratering and lofting dust



Liever et al., 2018



Wang et al., 2016

Low Energy Dynamics (LED)

Patched charge model[6]

Considerations for dust grain morphology, grain size, charge, grain initial velocity/position, and plasma environment

Experimental Validation

Goal: Validate HED (sandblasting and cratering) and LED (lofting and 3D particle size distribution) models.

Experimental Details

- Simulate the lunar environment in a Thermal Vacuum (TVAC).
- Ion thruster charges the dust and generates a plasma environment
- Thruster plume → Cold nitrogen gas
- High speed cameras analyze particle HED & LED

Increases our fundamental understanding of ejecta dynamics in a charged environment

Risk Analysis

Models assess the time-dependent likelihood & consequence of risks associated with ejecta.

Outputs can be used to inform trade study variables, weights, and criteria for landing sites.

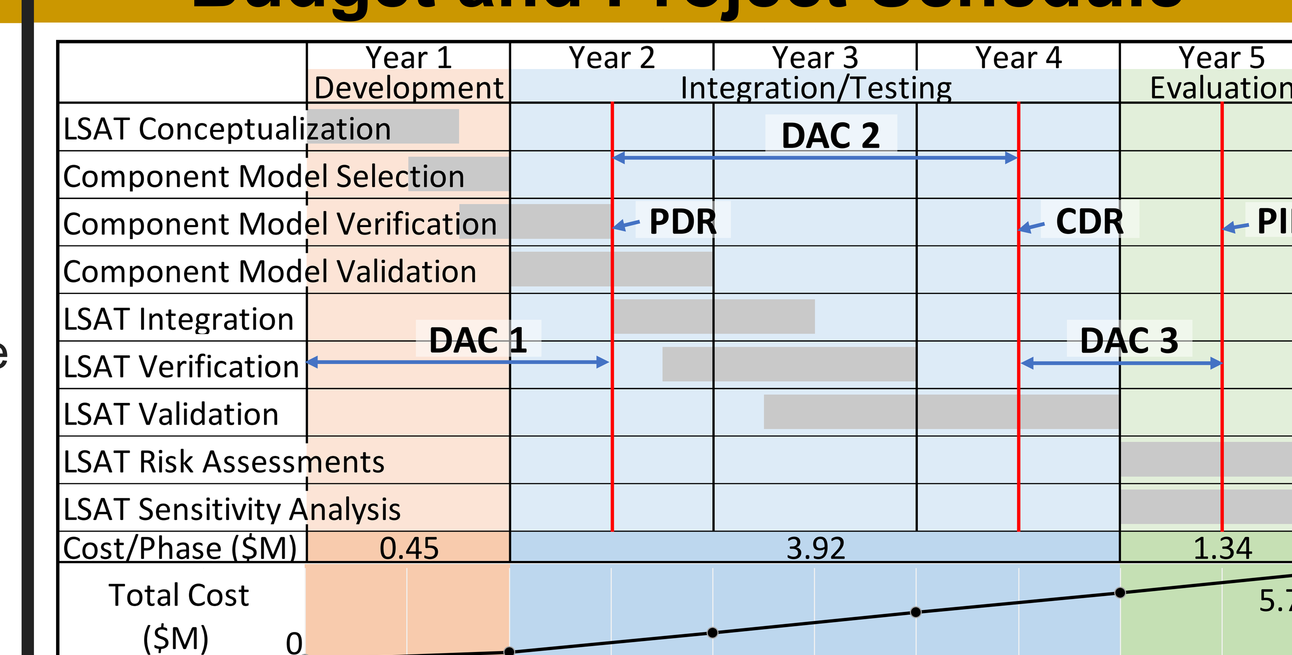
Eval. Criteria	Reasoning
Lofted dust size distribution	Lofted dust risks include degradation of materials, system, and crew health.
Dust settling time	Dust settling times may affect EVA missions.
Topographic changes	Cratering & erosion from rocket plume may change local topography.
Vehicle ejecta damage	Kinetic energy, velocity, and impact angles of the debris particle may result in risk to the vehicle.
Electrostatic potential	Electric potential differences between the vehicle, surface, and crew may pose safety risks.
Arcing risk	Dust lofted during descent may increase the risk of arcing.

Principal Outcomes

LSAT results in the following outcomes:

1. Novel understanding of the impacts of foreign bodies on the lunar surface
2. Thorough prediction of lunar PSI on a macro-scale and a micro-scale
3. Assessment of the time and activity-dependent likelihood and consequence of risks associated with lunar PSI
4. Pathway to a high-fidelity risk analysis for the purpose of mitigating and managing the impacts of lunar PSI.
5. Innovative, systems-level tool that can be implemented in the next 5 years.

Budget and Project Schedule



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