A Comparison of ARTEMIS Data with the Lunar Plasma Design Environment for NASA Crewed Missions

Emily M. Willis, Heidi Fuqua Haviland, Joseph I. Minow, Victoria N. Coffey

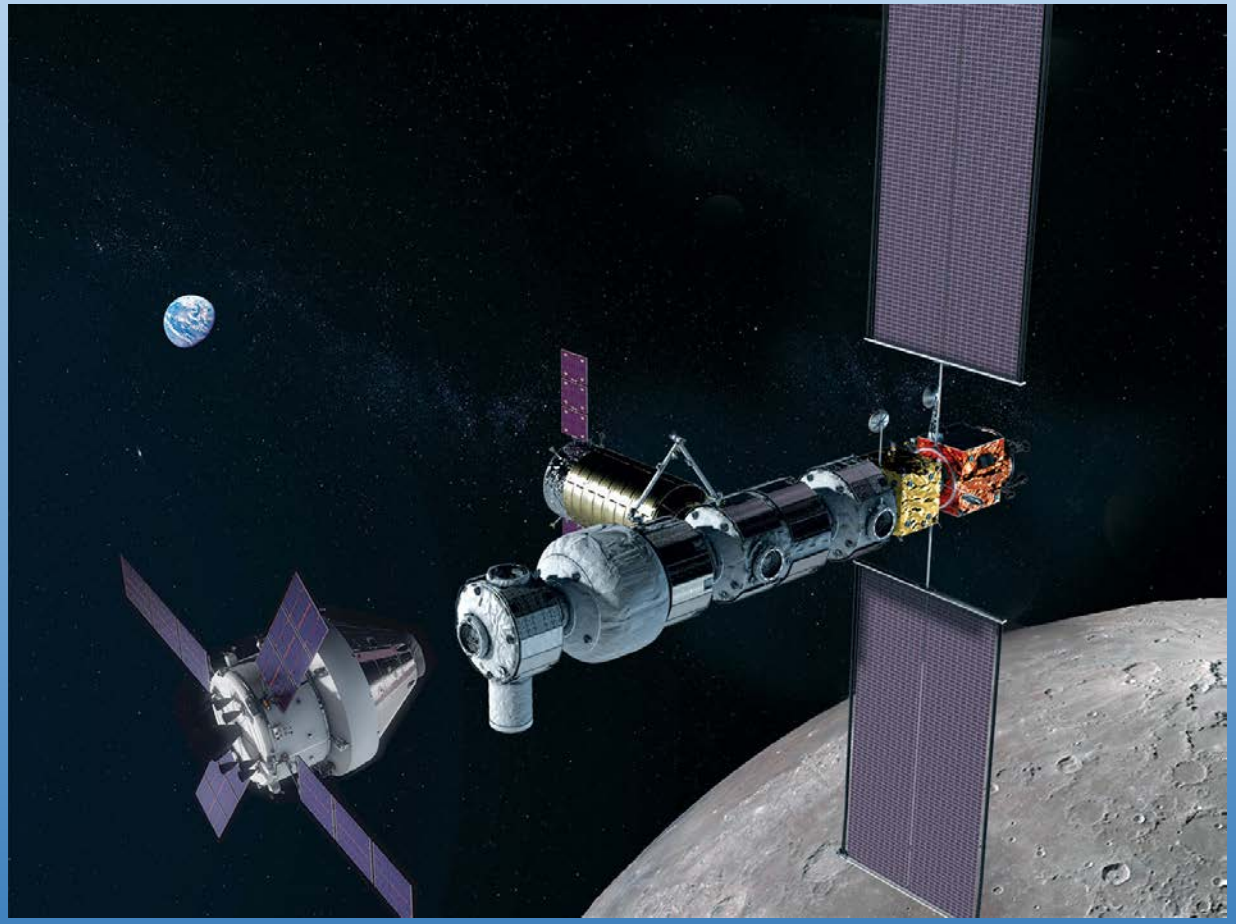
Overview

- Goal – Determine if the existing lunar plasma environment definition is sufficient for NASA's Gateway and Lander missions
- Method – Compare ARTEMIS data with the existing lunar plasma environment definition
- Results – Initial observations of ARTEMIS data show some differences with the existing definition, particularly in the lunar wake and locations in the magnetosphere
- Conclusion – A full statistical analysis of ARTEMIS data is needed in order to fully characterize the lunar environment

Outline

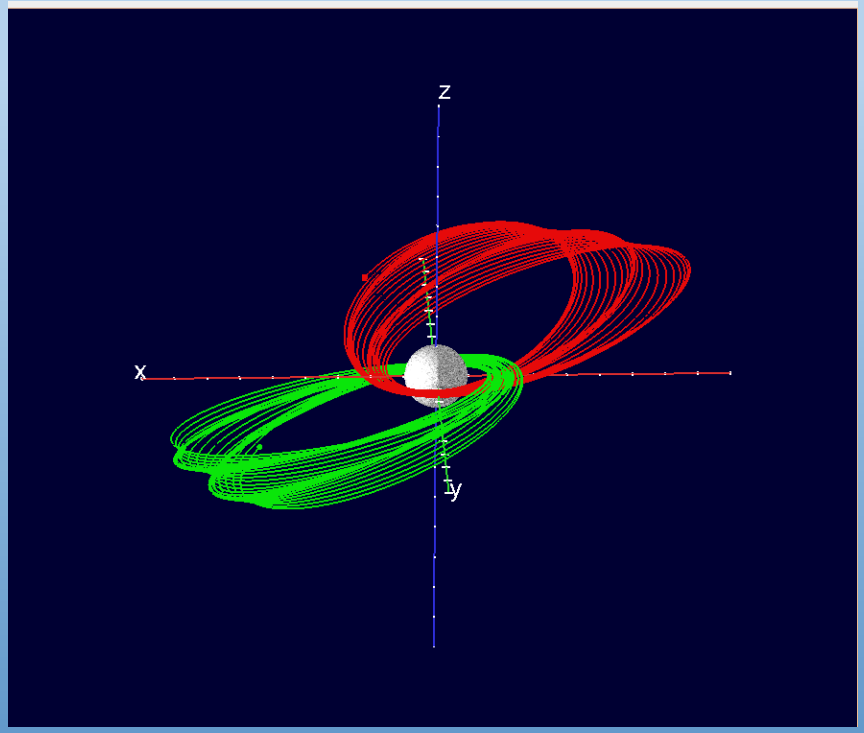
- Overview of NASA's Gateway, ARTEMIS, and Spacecraft Charging
- Existing Lunar Plasma Environment Definition
- ARTEMIS Data Comparison with DSNE
- Conclusions
- Forward work

NASA's Gateway[1]

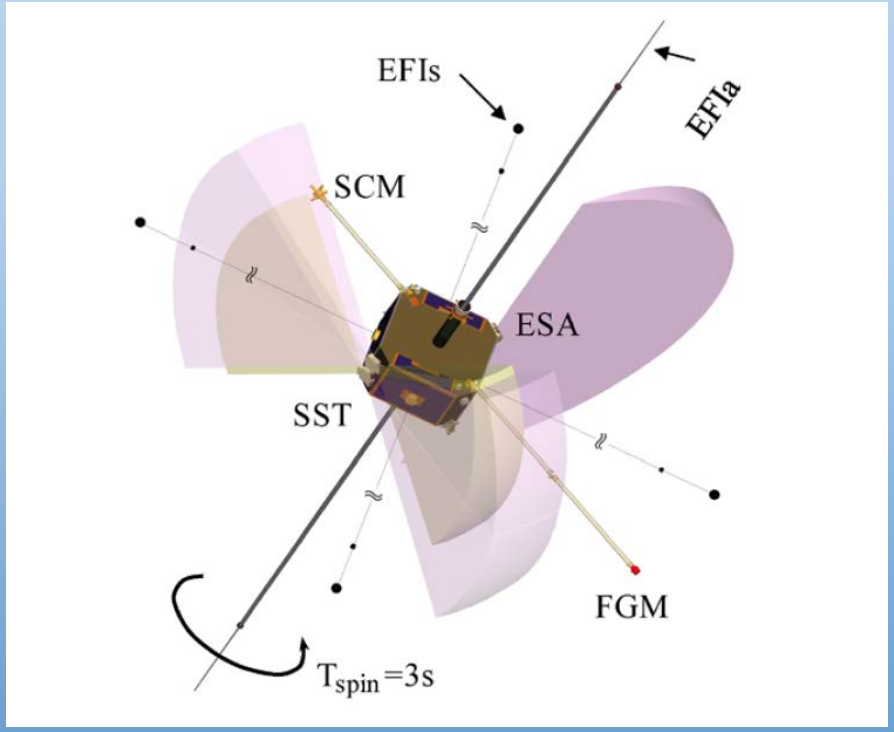


- Orbit: 2500km x 75000km Near Rectilinear Halo Orbit (NRHO) *(not final)*
- Elements: Power and Propulsion, Habitat, Docking, Visiting Vehicles (Orion), Solar Arrays
- Operations: Dockings, Maneuvers, EVAs, Solar Arrays

ARTEMIS^2



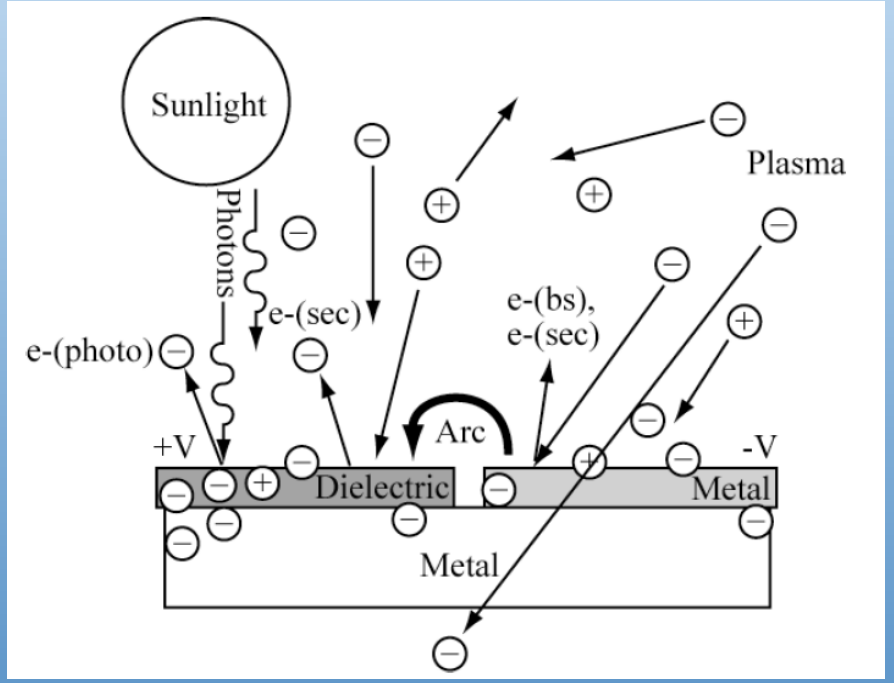
- Orbit:
  - 26 hour period
  - Lunar wake crossings from a wide range of altitudes.
  - Equatorial
  - 100km x 19,000km



- Instruments
  - Electric Field Instruments
  - Fluxgate Magnetometer
  - Search Coil Magnetometer
  - Axial and Spin Plane Electric Field Sensors
  - Solid State Telescope
  - Electrostatic Analyzer

Spacecraft Charging[3]

- The amount of charge collection to surfaces depends on:
  - Ambient plasma
  - Photoemission
  - Secondary electron emission
  - Backscattering
- Material dependent, design dependent
- Photoemission and secondary electron emission are significant contributors in cislunar space



The Moon
"a fundamental physics laboratory" [4]

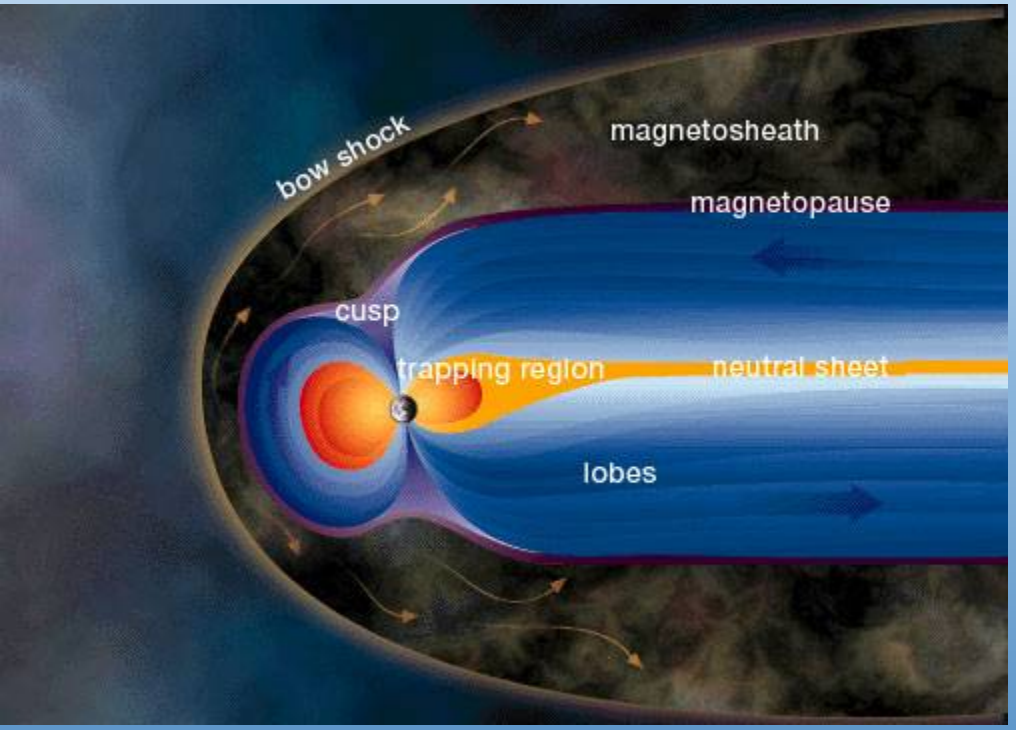


Image Credit: CCMC web

- No significant atmosphere
  - Weak surface boundary exosphere
- No significant global magnetic field
  - Regions of crustal magnetism
- Solar Wind (73% of orbit)[5]
  - IMF inductive effects
  - Wake
  - Downstream diamagnetic currents
- Magnetosheath (14% of orbit)[5]
  - Plasma dominated by exosphere
- Magnetotail (13% of orbit)[5]
  - Plasma Sheet interactions and magnetic reconnection.

Our challenge is to describe the environment in a way that is useful for spacecraft design.

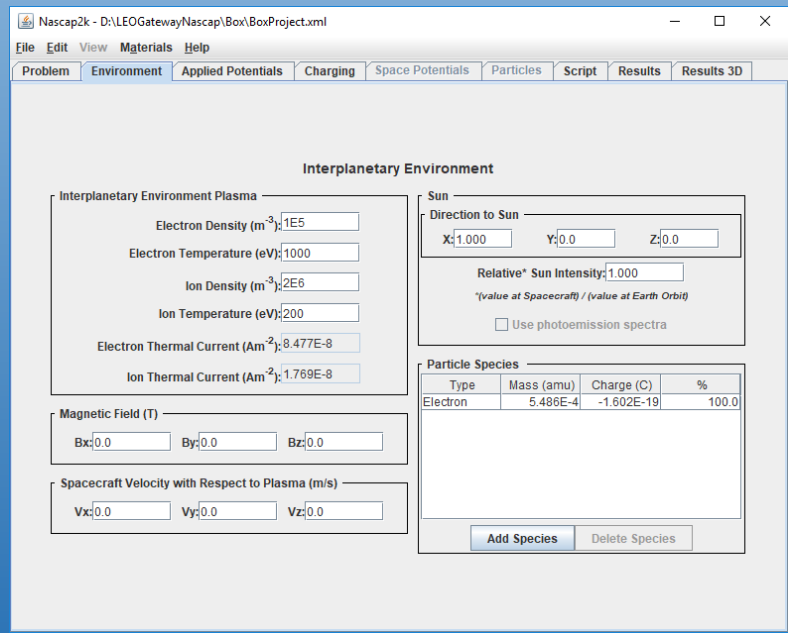
Existing DSNE Environment[5]

Table 3.3.3.4-1. Interplanetary Environment Plasma Parameters

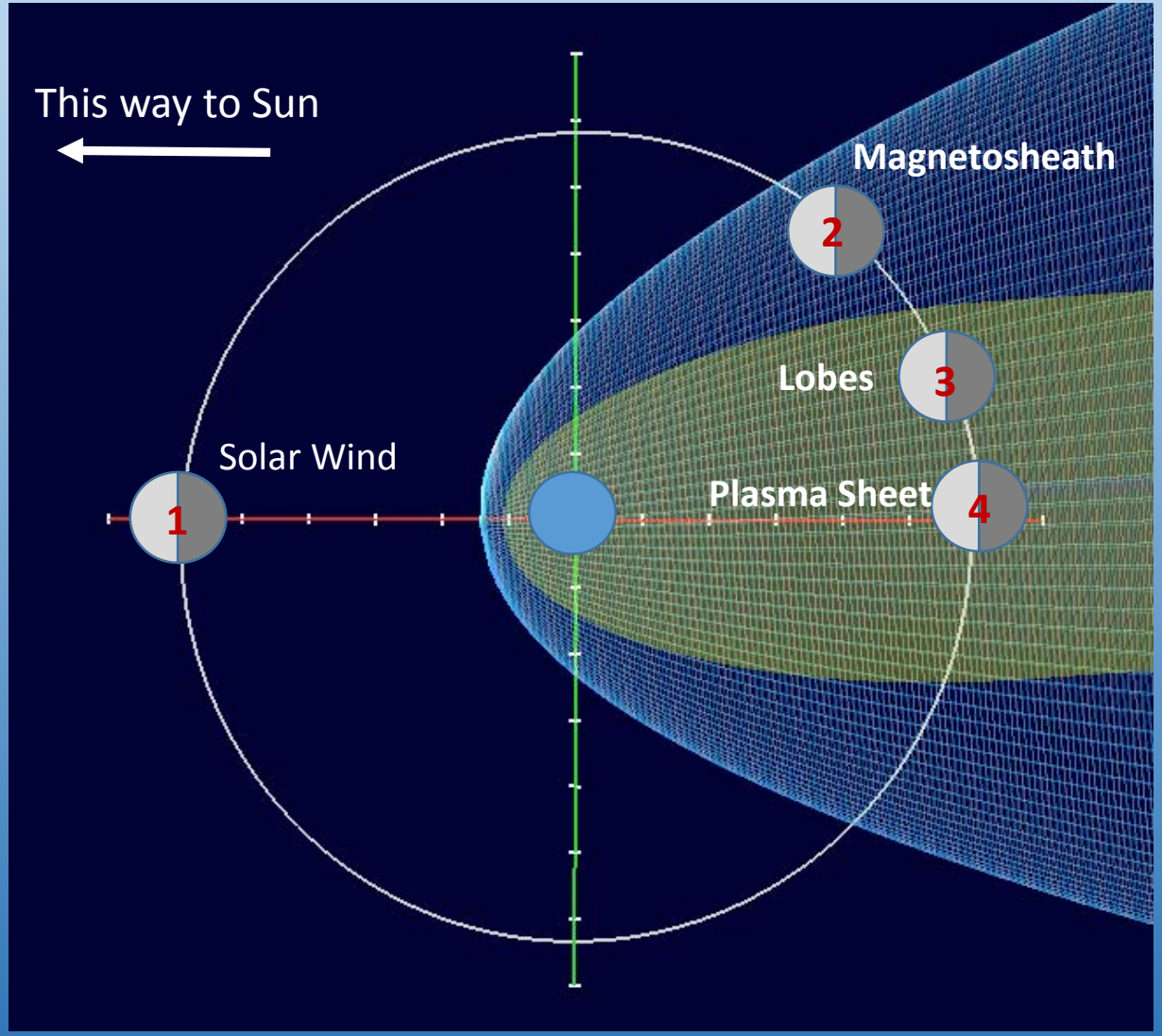
	Electron Density	Electron Temperature	Ion Velocity	Ion Density	Ion Temperature
	m^{-3}	eV	km/s	m^{-3}	eV
Magnetosheath / magnetotail	10^6 - 10^8	10-2000	400-1000	10^6 - 10^8	10-10,000
Solar Wind	10^5 - 10^8	12	400-1000	10^5 - 10^8	50

Table 3.3.3.5-1. Lunar Wake Plasma Parameters

	N_e/N_{eo}	T_e/T_{eo}	N_i/N_e	T_i/T_e
Wake 150°	0.005	7.6	0.1-1	0.01-1
Wake 180°	0.003	4.5	0.1-1	0.01-1

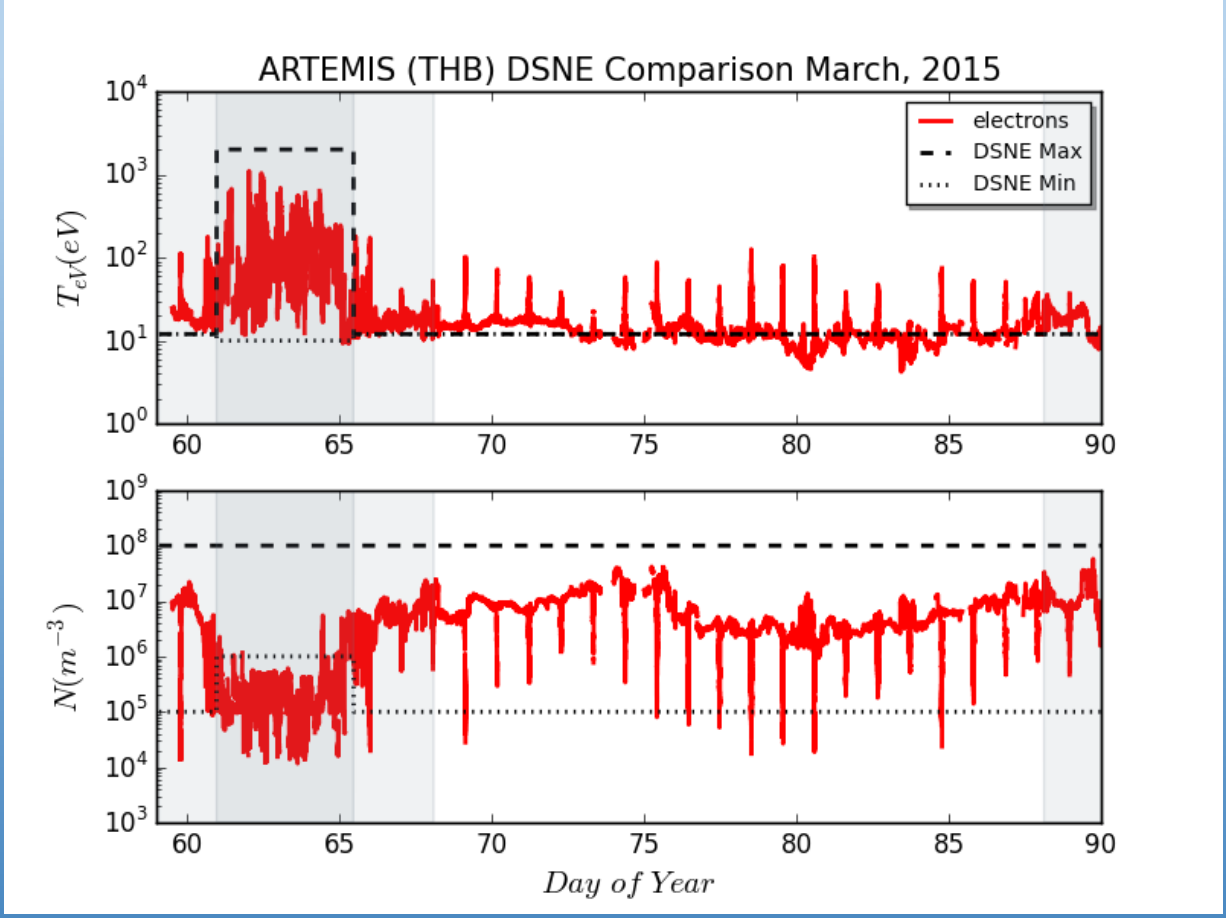


Locations of Interest

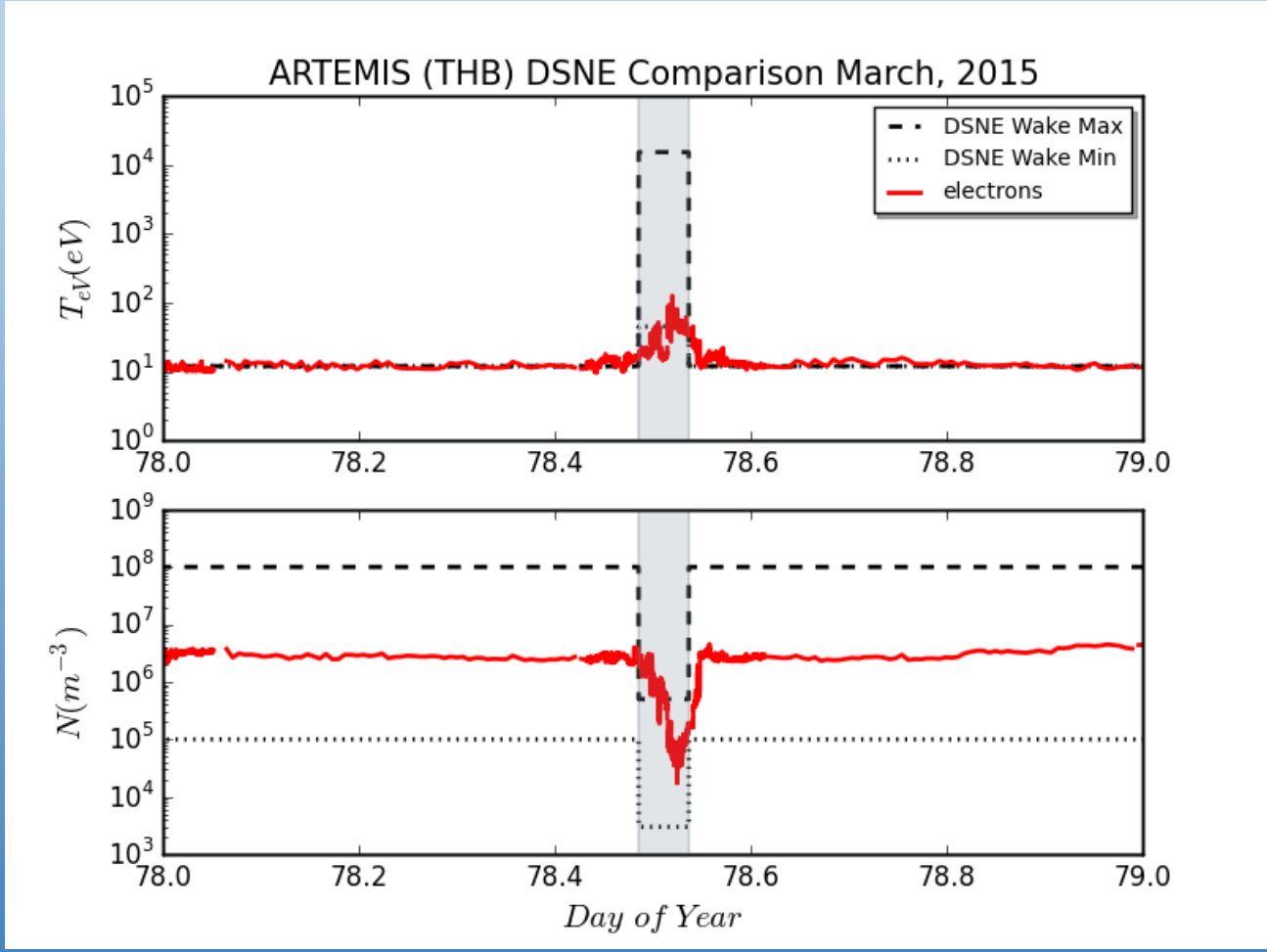


- High Altitude
  - Sun Side
  - Dark Side
- Low Altitude
  - Sun Side
  - Dark Side
- Surface
  - Sun Side
  - Dark Side

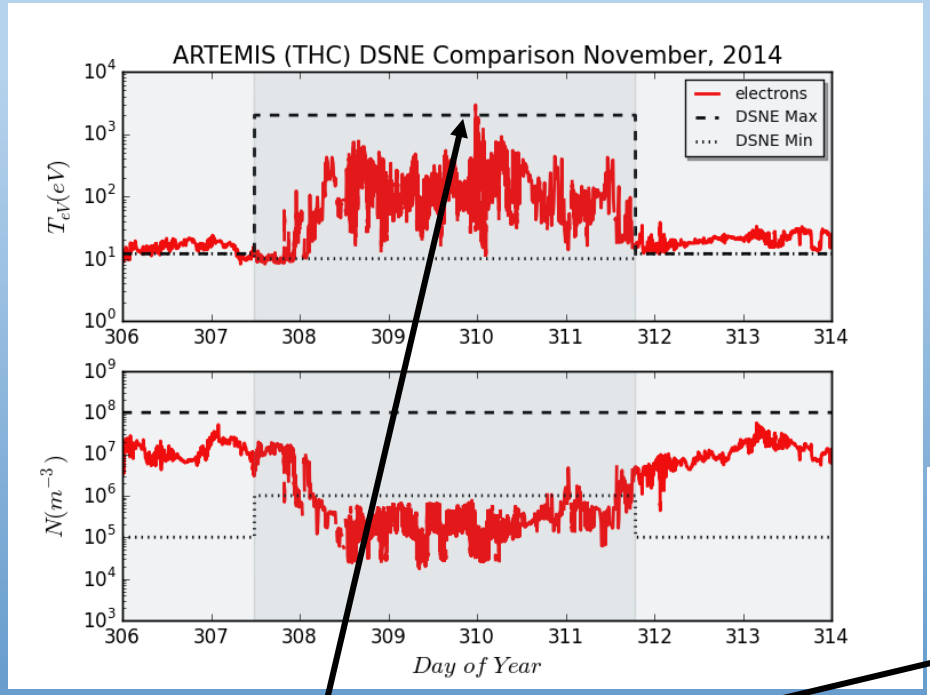
ARTEMIS Electron Data



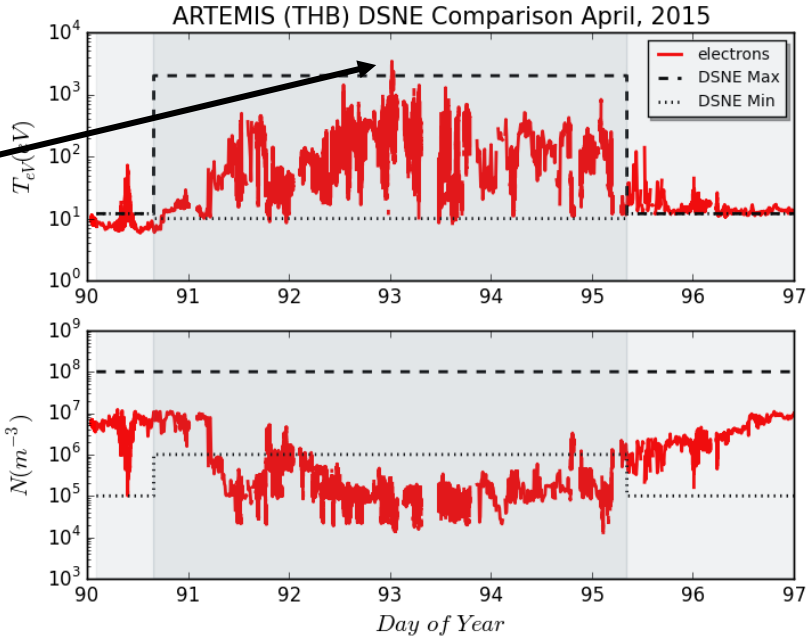
ARTEMIS Lunar Wake Crossing



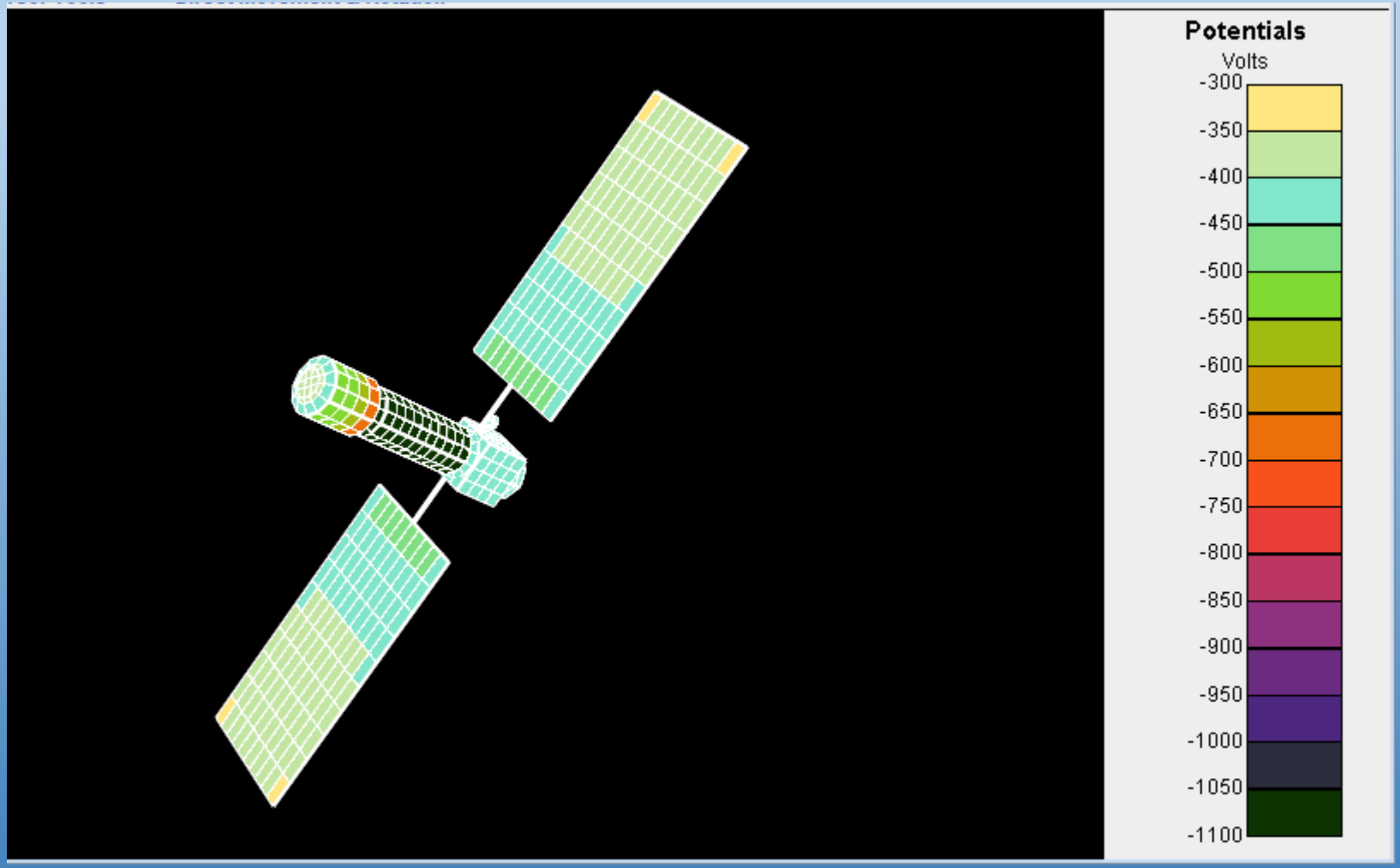
Examples of Higher Electron Energy



approximately 3000 eV



Charging Analysis



Representative spacecraft in lunar orbit with dielectric and conductive surfaces
Model Credit: Gwyer Sinclair, MSFC EV44 Summer Intern

Conclusions

- A statistical analysis of all ARTEMIS data is needed to fully characterize the lunar plasma environment for Gateway and Lander missions.
  - Average conditions
  - Extreme conditions
  - Range of altitudes

- Initial data observations show some disagreement with existing lunar plasma definition.
  - Lower density in the magnetosphere
  - Electron energy tends to stay below 2000 eV
  - High wake temperatures were not observed

References

[1] “Lunar Gateway.” www.nasa.gov/mission_pages/station/main/index.html, National Aeronautics and Space Administration.

[2] Angelopoulos, Vassilis. "The ARTEMIS mission." The ARTEMIS mission. Springer, New York, NY, 2010. 3-25.

[3] "NASA-HDBK-4002A: Mitigating in space charging effects—A guideline." nrts.nasa.gov. National Aeronautics and Space Administration

[4] Halekas, J. S., et al. "New views of the lunar plasma environment." Planetary and Space Science 59.14 (2011): 1681-1694.

[5] “Cross-Program Design Specification for Natural Environments (DSNE).” nrts.nasa.gov. National Aeronautics and Space Administration, Marshall Space Flight Center.