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Spacecraft Charging in the Lunar Plasma Environment: An Analysis of the Gateway Mission

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ABSTRACT

In space, mission vehicles and astronauts are subject to many dangers. One is exposure to plasma, which drives a buildup of charge on spacecraft surfaces. This voltage is dangerous, due to unwanted discharges which threaten astronauts, materials, and components. Each space environment has different plasma properties; lunar orbit is characterized by the lack of a protective magnetic field and periodic transit through Earth's magnetotail. An engineering model of the lunar plasma environment is developed / implemented in Nascap-2k, and evaluations of spacecraft charging on the Gateway Mission are discussed.

THE GATEWAY

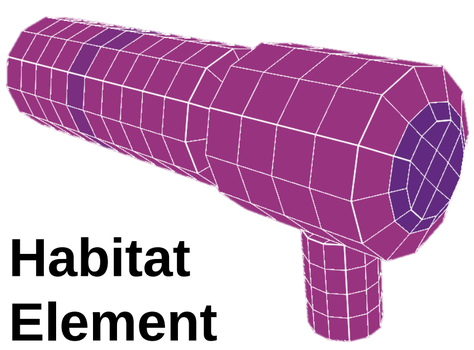
- Gateway Mission launches 2022-27
- Supports lunar / interplanetary exploration
- International effort with crew of four
- Near-Rectilinear Halo Orbit about the moon
- Transit through Earth's magnetotail

	Boundary Layer		Magnetosheath		Plasma Sheet		Solar Wind High Speed	
	Inter-planetary	Geo	Inter-planetary	Geo	Inter-planetary	Geo	Inter-planetary	Geo
ρ (m^{-3})	7.326×10^{4}		6.64×10^{5}		2.428×10^{4}		266.3	
T_e (eV)	156.7	156.7	290.9	290.9	1316	1316	78.28	78.28
v_i (m/s)	5.4×10^{4}		4×10^{5}		2×10^{5}		7.02×10^{5}	
E_i (eV)	15.22		835.3		208.8		2573	
ρ_e (m^{-3})		7.326×10^{4}		6.64×10^{5}		2.428×10^{4}		266.3
ρ_i (m^{-3})		6.684×10^{4}		6.06×10^{5}		2.215×10^{4}		50
T_i (eV)		111.6		920		995.7		10
I_e (A/m^2)	2.458×10^{-8}	2.458×10^{-8}	3.036×10^{-7}	3.036×10^{-7}	2.361×10^{-8}	2.361×10^{-8}	6.316×10^{-11}	6.316×10^{-11}
I_i (A/m^2)	6.338×10^{-10}	4.416×10^{-10}	4.255×10^{-8}	1.15×10^{-8}	7.779×10^{-10}	4.372×10^{-10}	2.995×10^{-11}	9.891×10^{-14}
Charging time	300 sec.	300 sec	1000 sec	300 sec	1000 sec	300 sec	1000 sec	300 sec

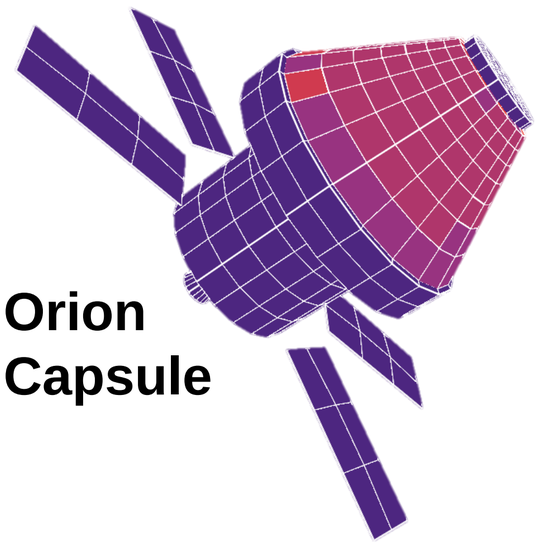
Local Plasma Environments

METHODOLOGY

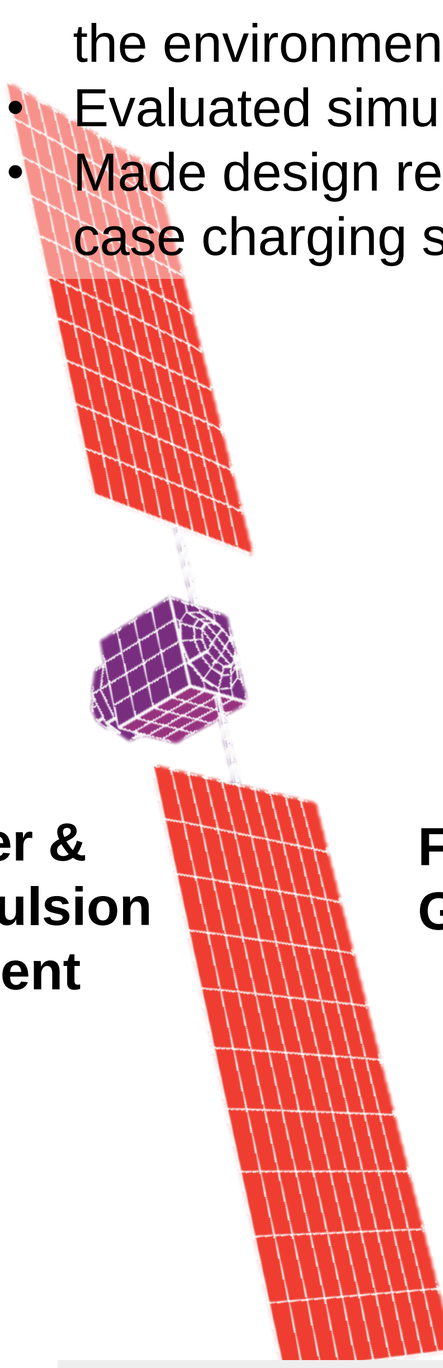
- Conducted meta-study to determine plasma characteristics
- Created Plasma Model for NASA Charging Analyzer Program (NASCAP)
- Constructed Gateway models and simulated in the environment
- Evaluated simulations for dangerous conditions
- Made design recommendations based on worst case charging scenarios



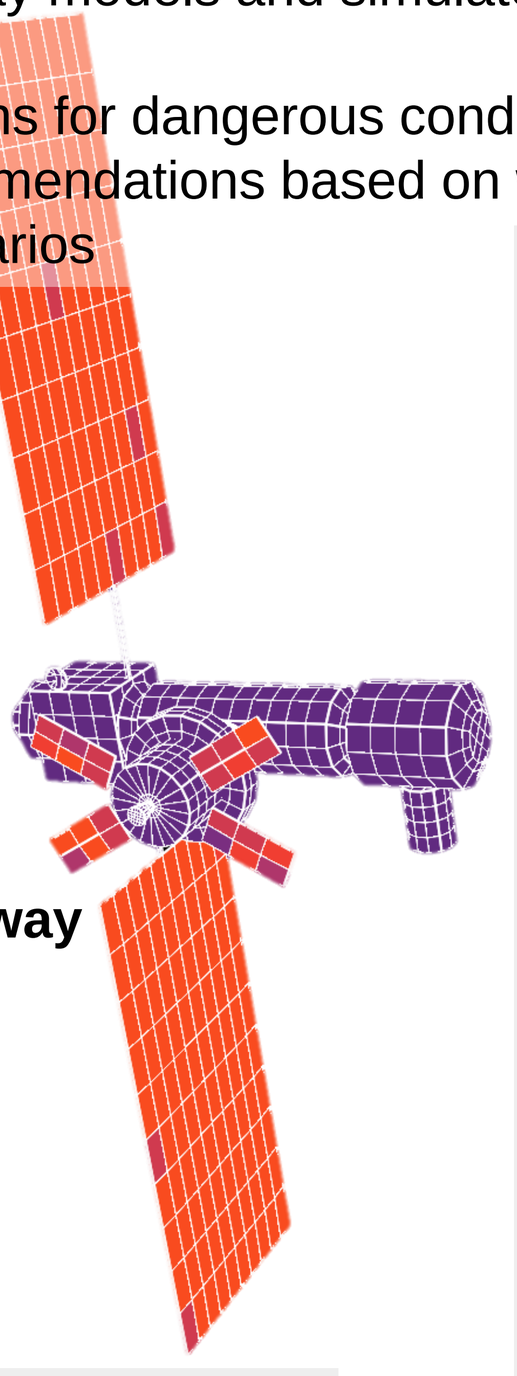
Habitat Element



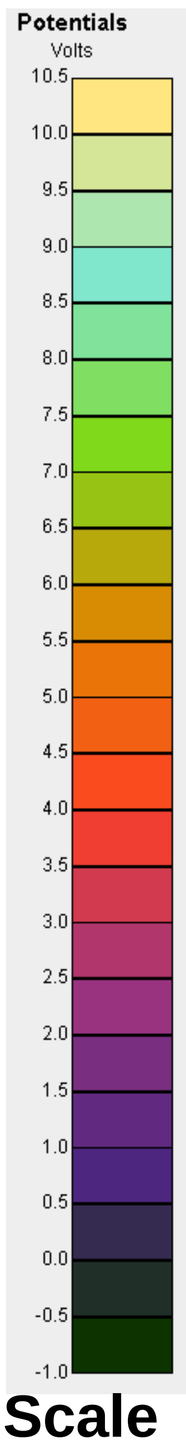
Orion Capsule



Power & Propulsion Element



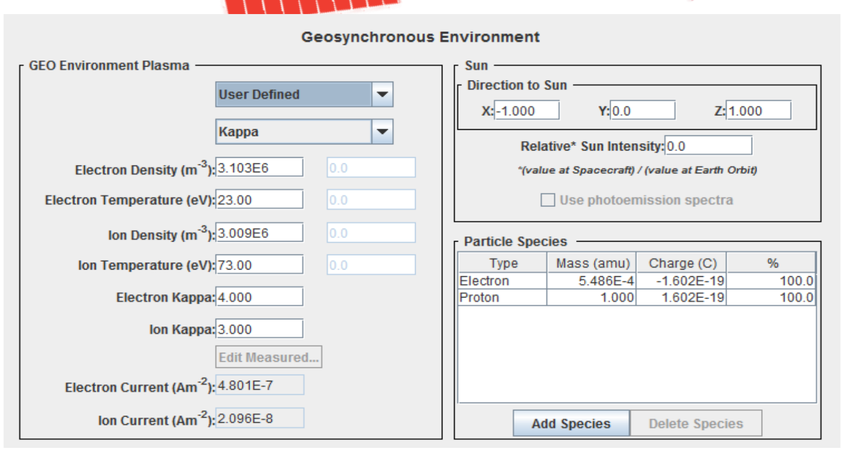
Full Gateway



Scale

CONCLUSIONS

- Gateway components developed dangerous voltage in solar storm conditions (> 50 V diff.)
- Worst charge is developed in eclipse during magnetosheath transit
- Overall worst environment is, however, geosynchronous Earth orbit.
- Gateway should utilize high-resistance contact points to prevent electrostatic discharge
- Astronauts should avoid EVA during charging events



Environment Parameters

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NASA