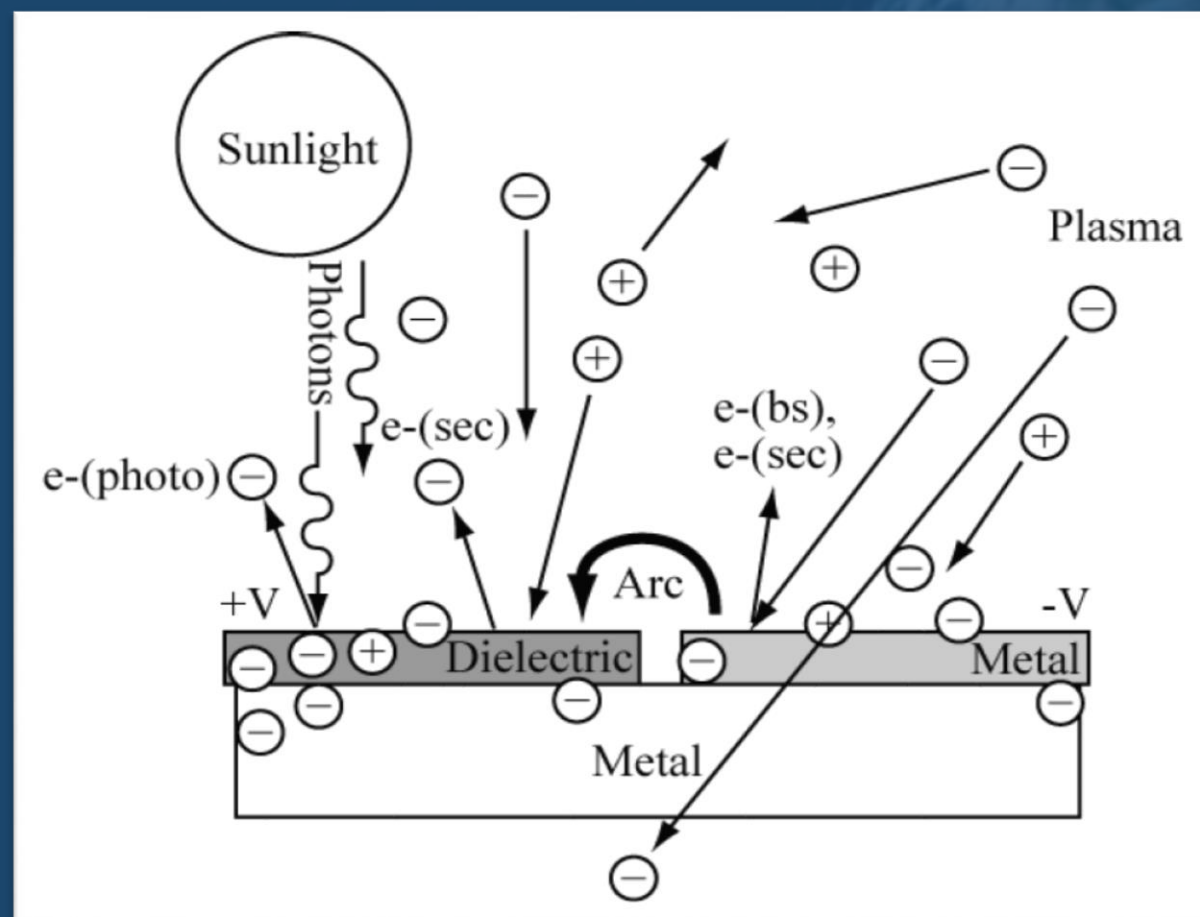


Abstract

As spacecraft travel through plasma, spacecraft surfaces become charged by the collection of charged particles. This process is referred to as Surface Charging. These charges can be detrimental to the vehicle's electronic subsystems as they present a threat of electrostatic discharge (ESD) to onboard circuitry. The process of Surface Charging is complex and is affected by many elements. The charging of each surface is unique. The potential of an individual surface is dependent upon many variables including but not limited to the surface's geometry, material and its location. Each surface also has unique interactions with the surrounding plasma. Other factors that play large roles in the charging process is the density and temperature of plasma ions and electrons. Using Nascap-2k, a model of the Freja satellite has been constructed, and its auroral plasma environment has been imitated to simulate surface charging characteristics. The charging process of the Freja satellite has been modeled iteratively with incremental changes in both the Maxwellian electron temperature (eV) as well as the Gaussian electron energy (eV). This study provides an analysis of the sensitivity between spacecraft surface charging and these two primary variables of electron differential flux.

Surface Charging Background

Atmospheric plasma is a gas consisting of charged electrons and ions that are traveling in an omnidirectional manner¹. These charged particles collect on spacecraft surfaces creating electric currents. Electric current is also created when the incoming of electrons and ions cause the outgoing of ions and electrons away from the surface. These ejected particles are known as secondary ions, secondary electrons and backscattered electrons.



Positive Current (+)	Negative Current (-)
Incident Ions	Incident Electrons
Secondary Electrons	Secondary Ions
Backscattered Electrons	
Photoelectron Emissions	

Table 1. Potentials of current contributions of charged particle interactions.

Figure 1. Illustration of plasma interactions.¹

It is the summation of these collective currents that provides the total current of each surface.²

$$I_T = I_i + I_{se} + I_{be} + I_{ph} - I_e - I_{si} \quad (1)$$

When the summation equals zero, there is equilibrium among the currents and no further charging is occurring.² It is the balance of these electric currents that is the cornerstone of the surface charging process.²

$$\sum I_k = I_T = 0 \quad (2)$$

Parameters of the Plasma Environment

The variables of electron differential flux make up the parameters of Nascap's adjustable auroral environment tab as shown in figure 2. These parameters have been broken into four contributing components, Low Energy, Maxwellian, Gaussian, and Power Law. It is by modifying these parameters that a simulated environment has been created in which to model Freja's charging events. The variables at the focus of this study have been Maxwellian temperature (θ_{max}) and Gaussian energy (E_{gauss}).

$$Flux(E) = \sqrt{\frac{e}{2\pi\theta m_e}} \frac{E}{\theta} n \exp\left(-\frac{E}{\theta}\right) + \pi\delta_{max} E \exp\left(-\frac{E}{\theta_{max}}\right) + \pi\delta_{gauss} E \exp\left(-\left(\frac{E_{gauss}-E}{\Delta}\right)^2\right) + \pi\delta_{power} E^{-\alpha} \quad (3)$$

where δ_{max} is the coefficient of the Maxwellian component, δ_{gauss} and δ_{power} are the coefficients of the Gaussian and Power Law components respectively, e is the charge of the electron, m_e is the mass of the electron, α is the exponent of the Power Law component, Δ is the width of the Gaussian component and n is the density of the Low Energy component.³ Also, while θ is the temperature of the low energy plasma, θ_{max} is the temperature of the high energy plasma and is a more influential variable of the flux as the ambient plasma in an auroral environment has high energy particles.³

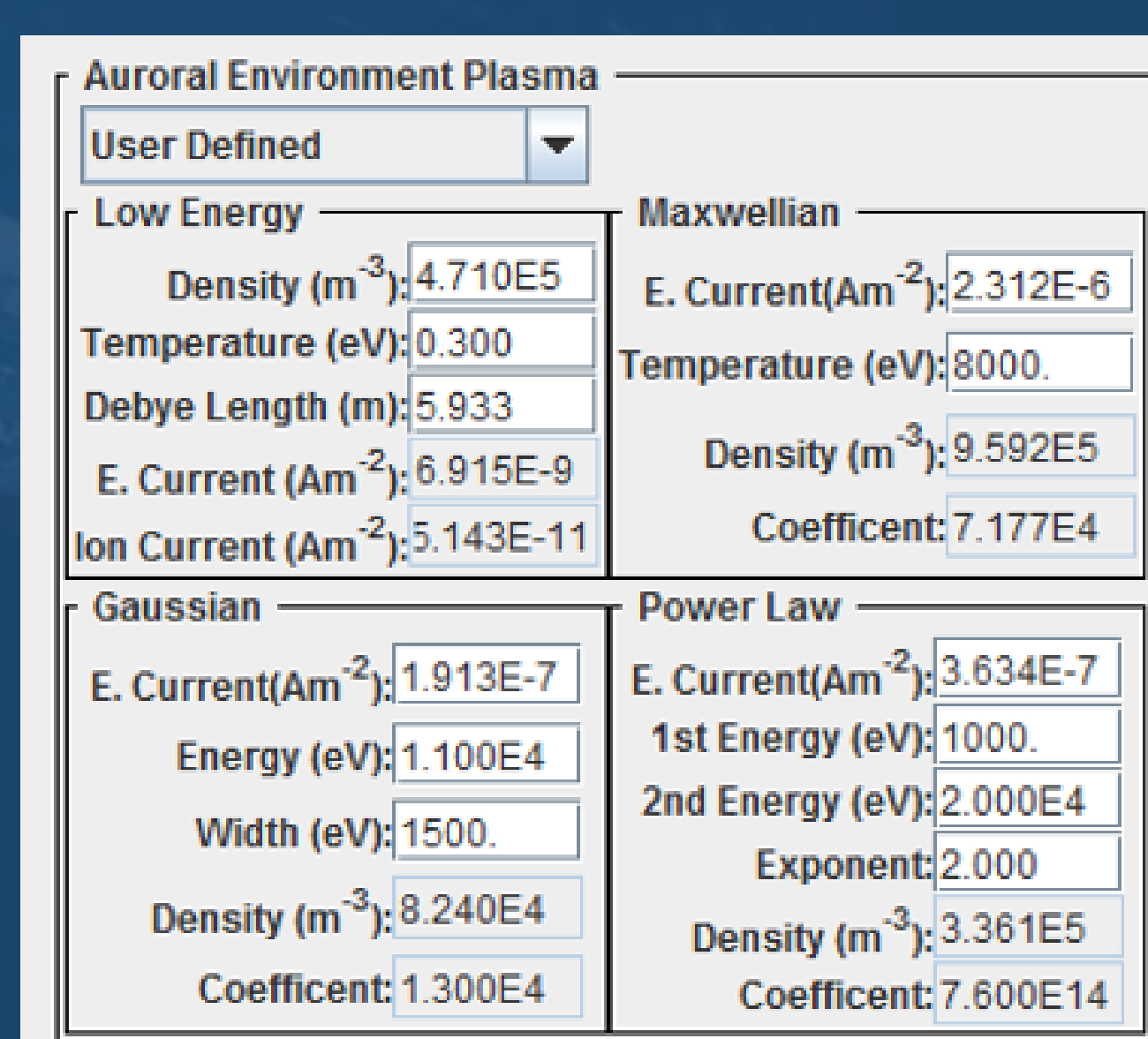


Figure 2. Nascap Auroral Environment Parameters Tab

Charging Simulations

Nascap computes and portrays surface potentials for charging analysis. With an initial severe-case plasma environment defined, Freja charging events were simulated iteratively with incremental changes in both the Maxwellian electron temperature (eV) as well as the Gaussian electron energy (eV). The resulting differential potentials (V) were recorded.

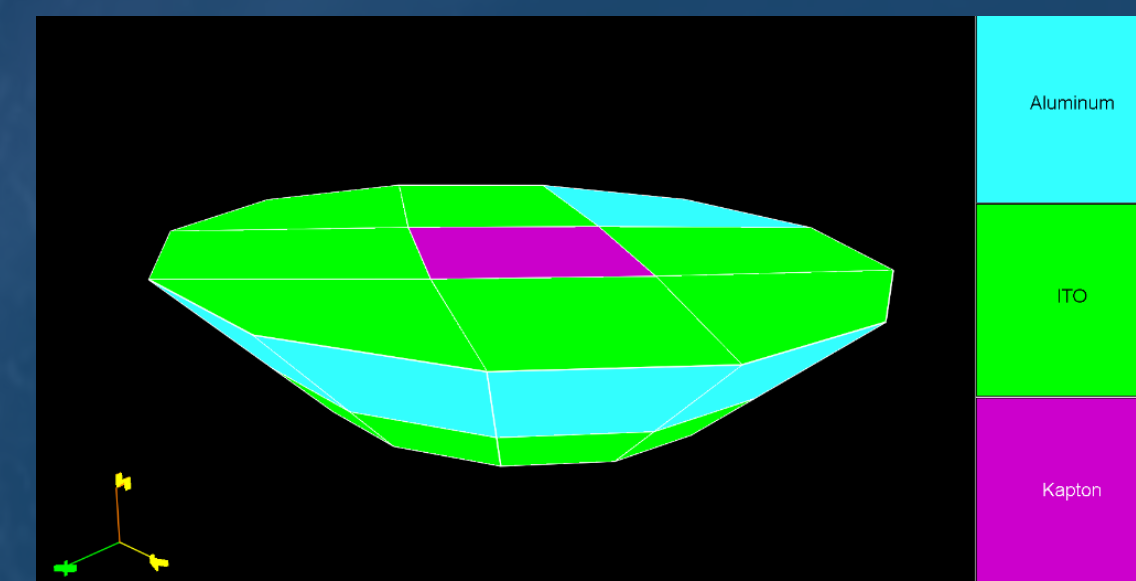


Figure 3. A simplified model of the Freja satellite.

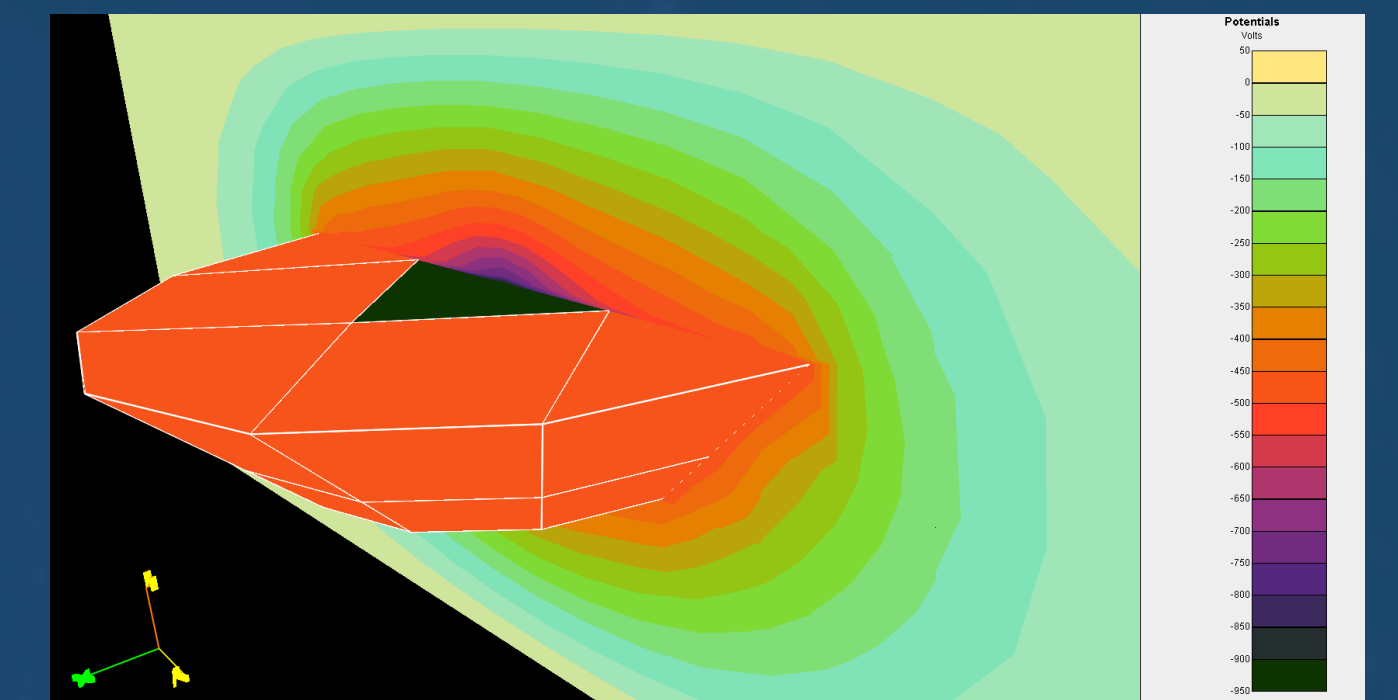


Figure 4. Contours of the potentials surrounding the satellite after a simulation.

Data

Throughout this study, Differential Potential is defined as the difference between the spacecraft's maximum potential and its minimum potential. The graphs below plot the spacecraft's Differential Potential values against the corresponding independent variable.

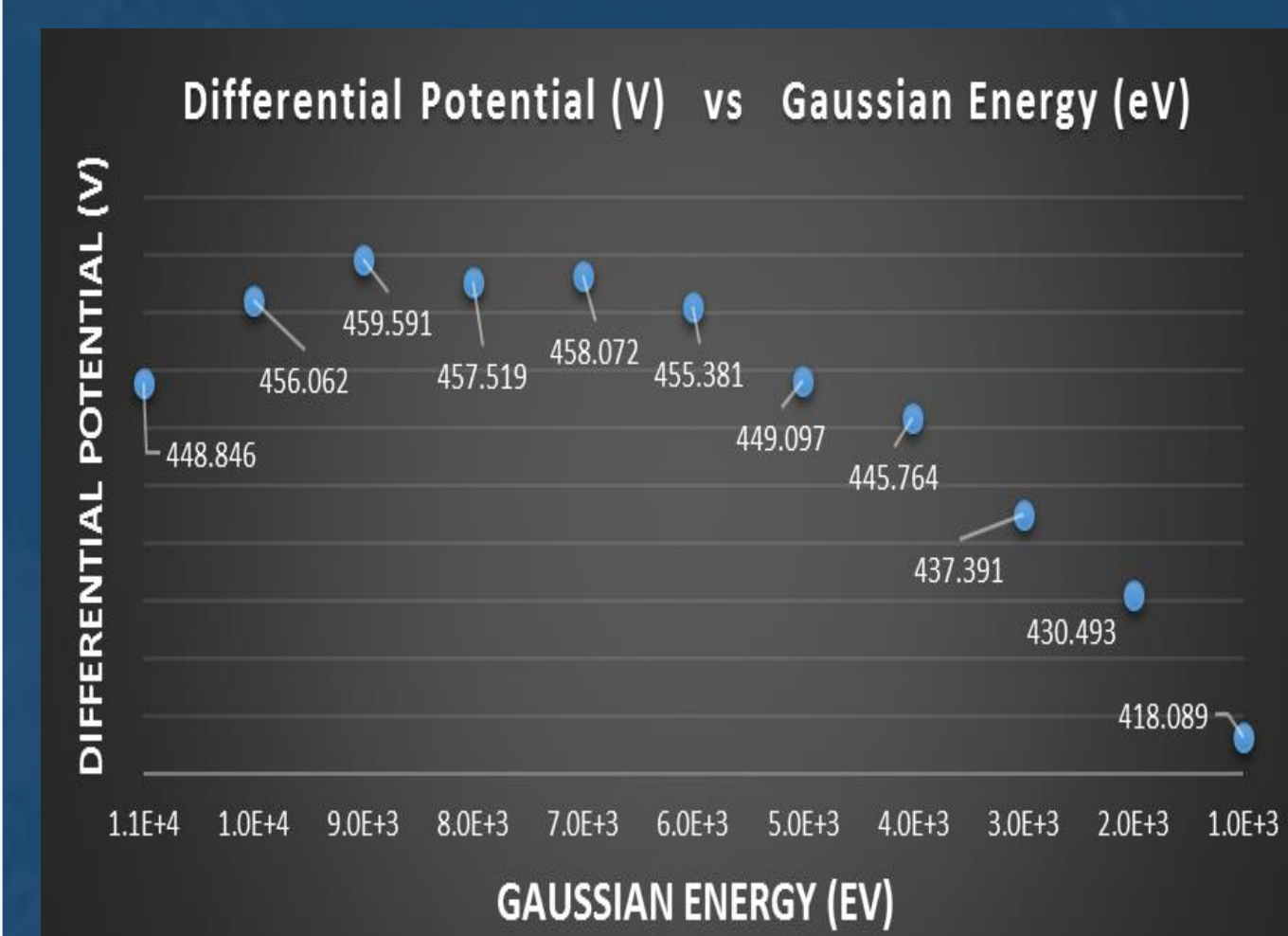


Figure 5. Gaussian energy from 1.1×10^4 (eV) to 1.0×10^3 (eV)

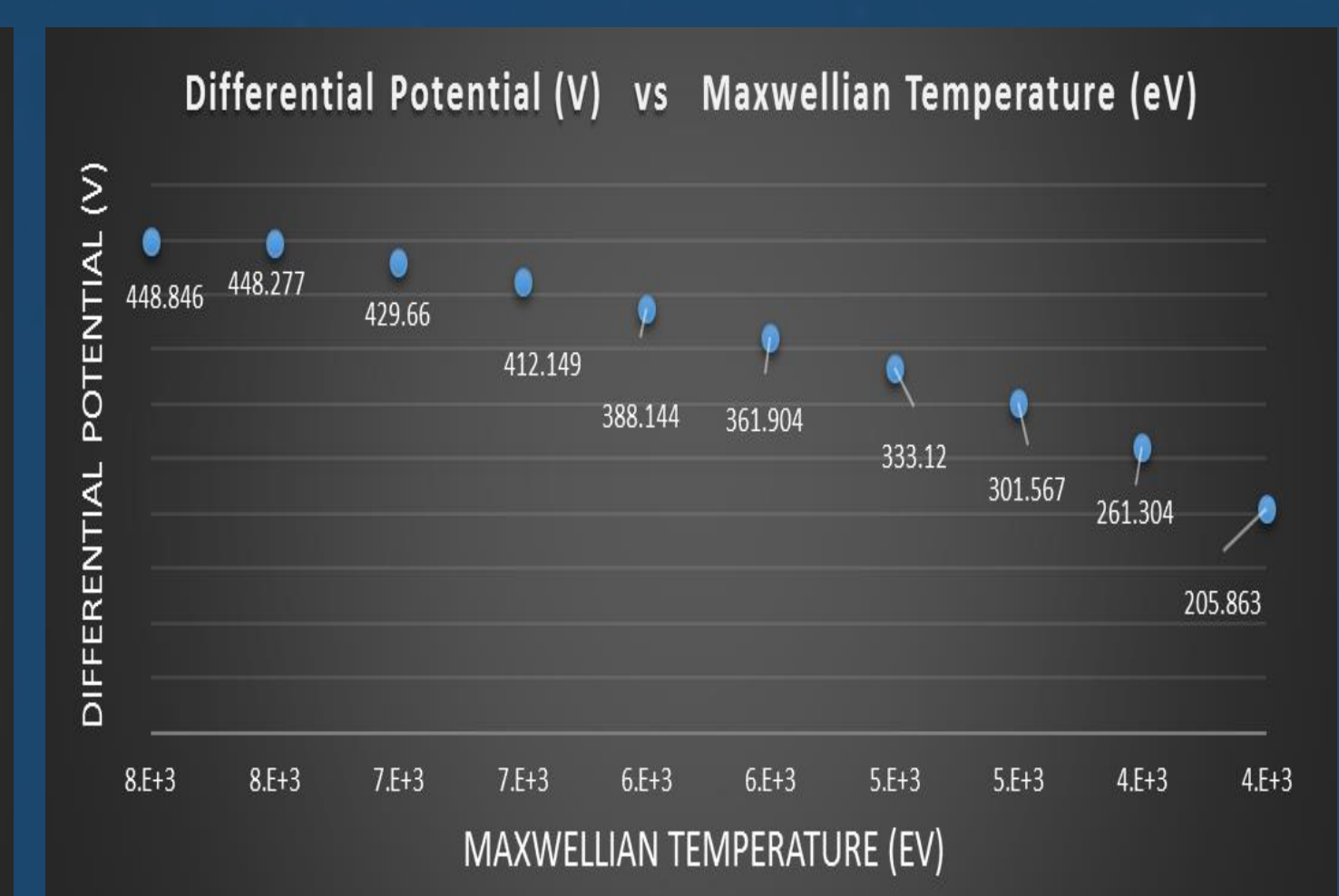


Figure 6. Maxwellian temperature from 8.0×10^3 (eV) to 3.5×10^3 (eV)

Analysis

- Changes in Maxwellian temperature correspond with differential potential values in a linear fashion.
- Gaussian energy (eV) appears to have a non-linear relationship with differential potentials.

Both Gaussian energy and Maxwellian temperature prove to be significant factors in the surface charging process. More research needs to be conducted to better understand the relationship between these variables and the Differential Potentials of spacecraft surfaces.

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