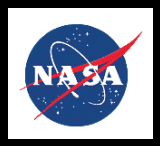
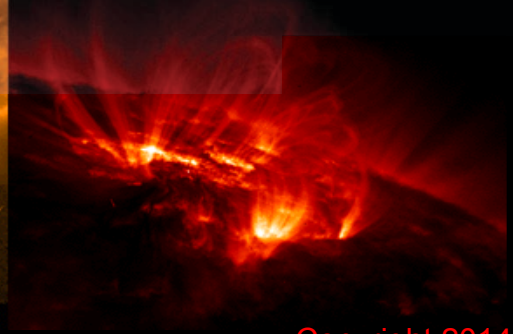


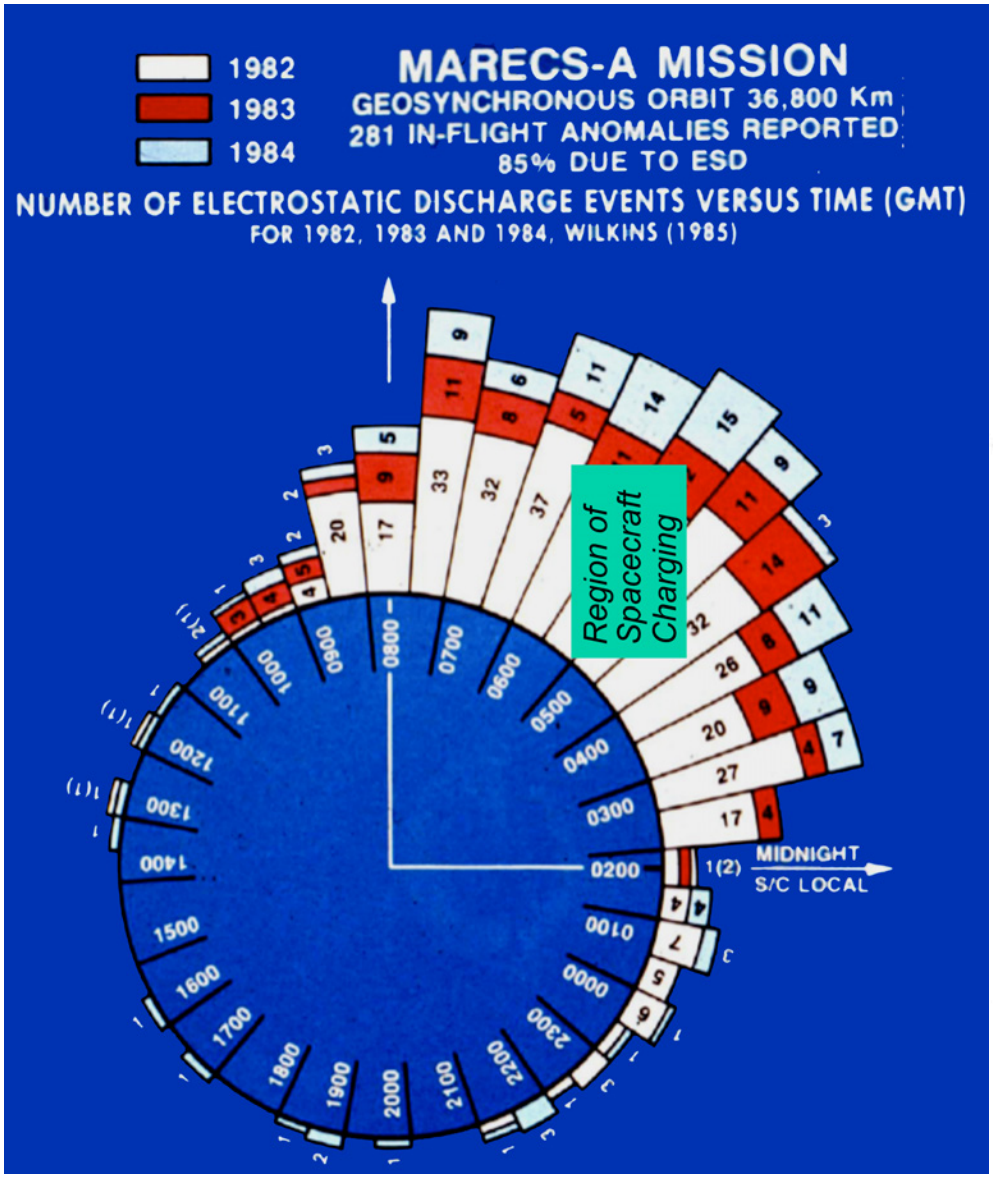
National Aeronautics and Space Administration
**Jet Propulsion Laboratory**
**California Institute of Technology**

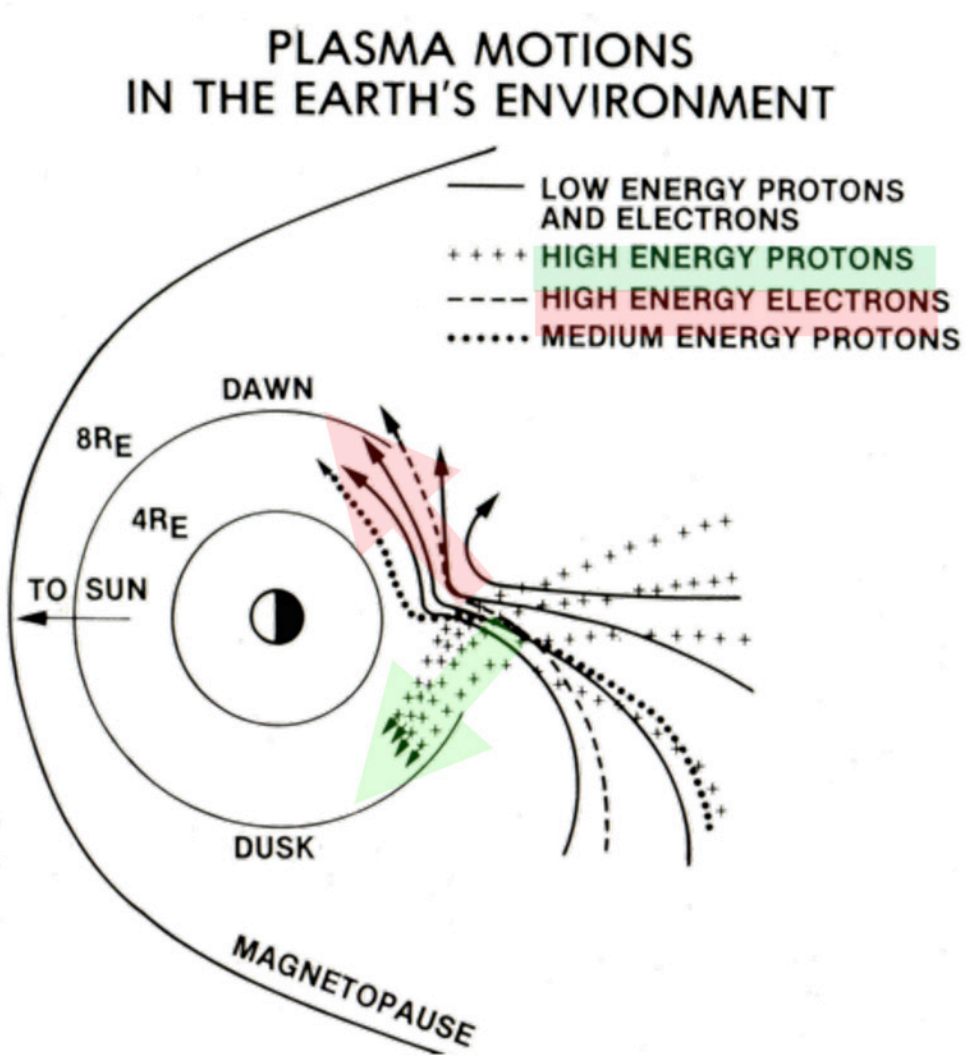
# *Spacecraft Charging Interactions*

Dr. Henry B. Garrett
Jet Propulsion Laboratory
California Institute of Technolgy
Pasadena, CA 91109

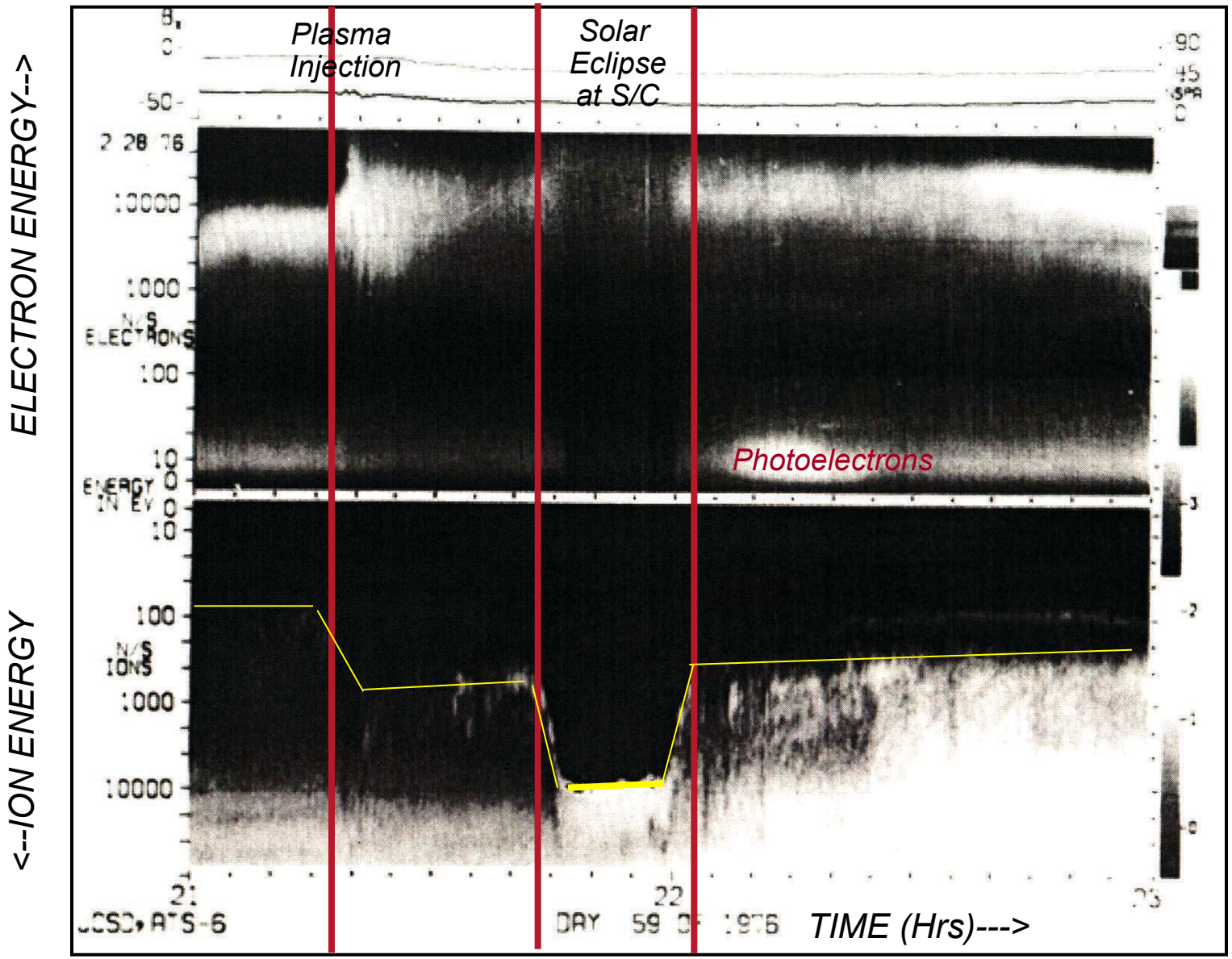


# Plasma Environment—Surface Charging

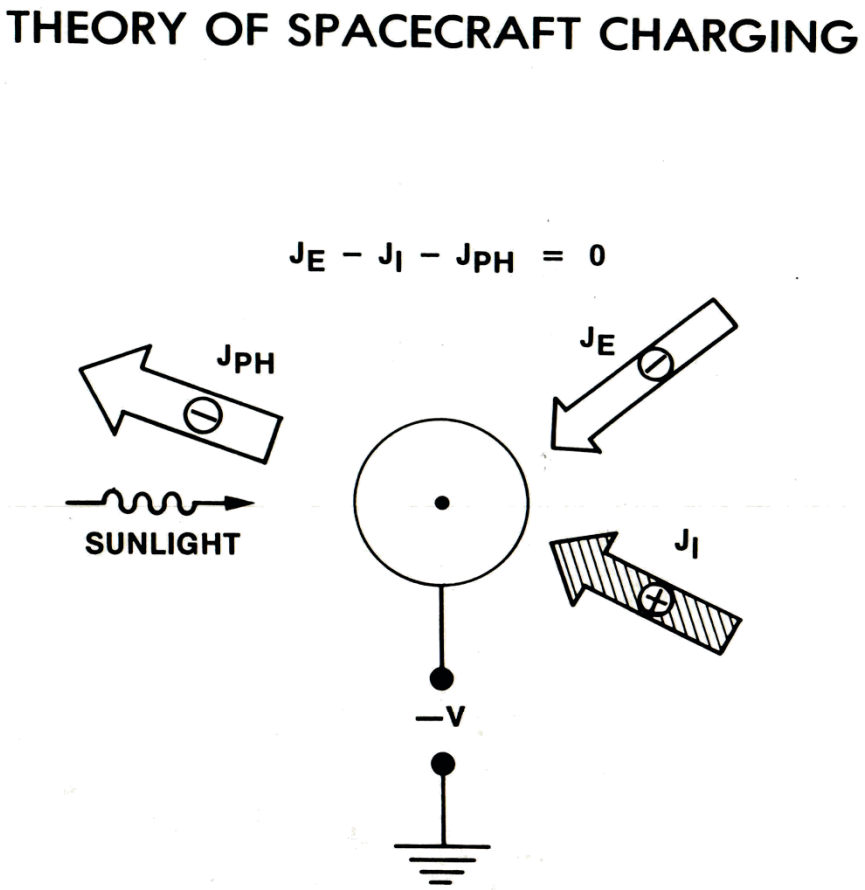


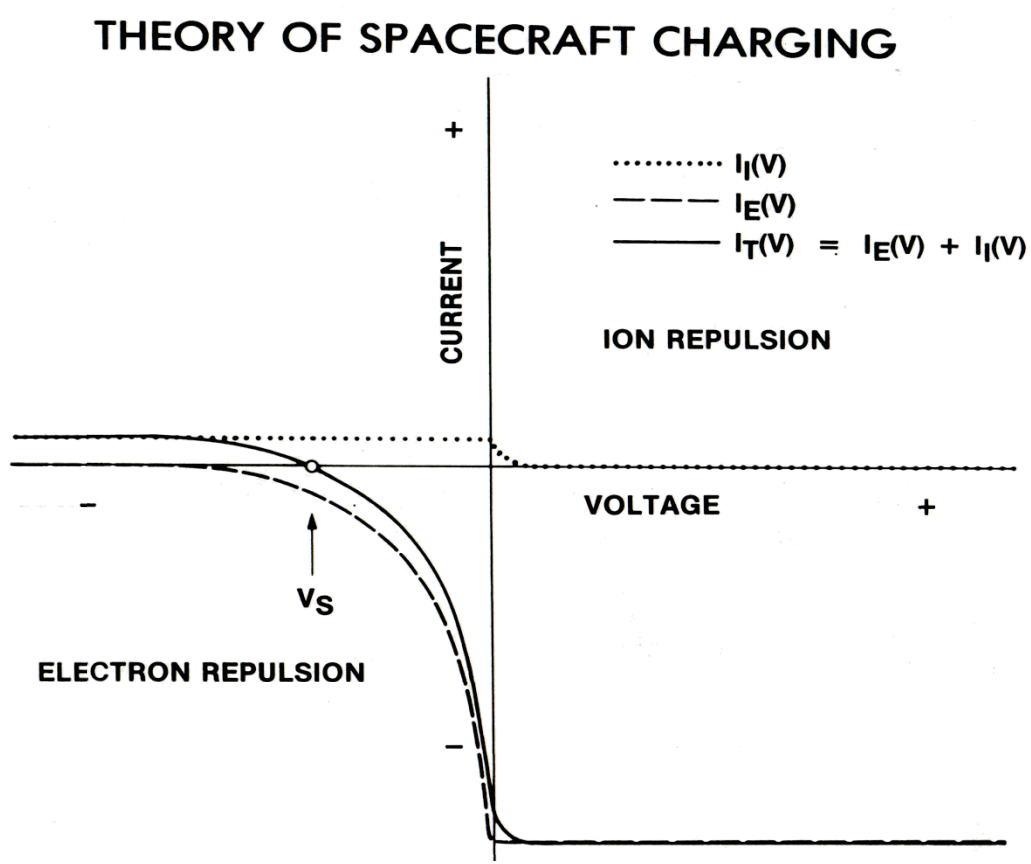



# ATS-6 Spectrogram of Geosynchronous Charging



# Theory of Spacecraft Charging: A Simple Picture …



# Theory of Spacecraft Charging: A Simple Example

**FOR A NEGATIVELY CHARGED SPACECRAFT:**

$$J_T(V) = J_{Io}\left(1 - \frac{qV}{KT_I}\right) - J_{eo}\left(e^{qV/KT_e}\right)$$

**TYPICALLY AT GEOSYNCHRONOUS ORBIT:**

$$\frac{qV}{KT_I} \sim 0$$

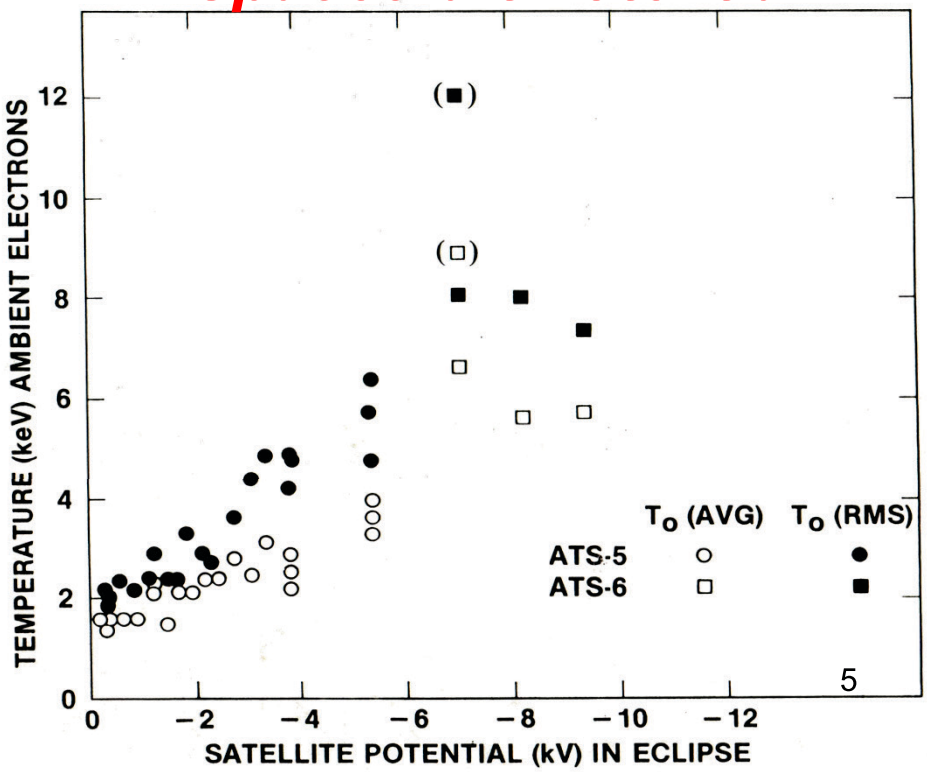
**FOR CURRENT BALANCE:**

$$J_T(V) = 0$$

**THIS IMPLIES:**

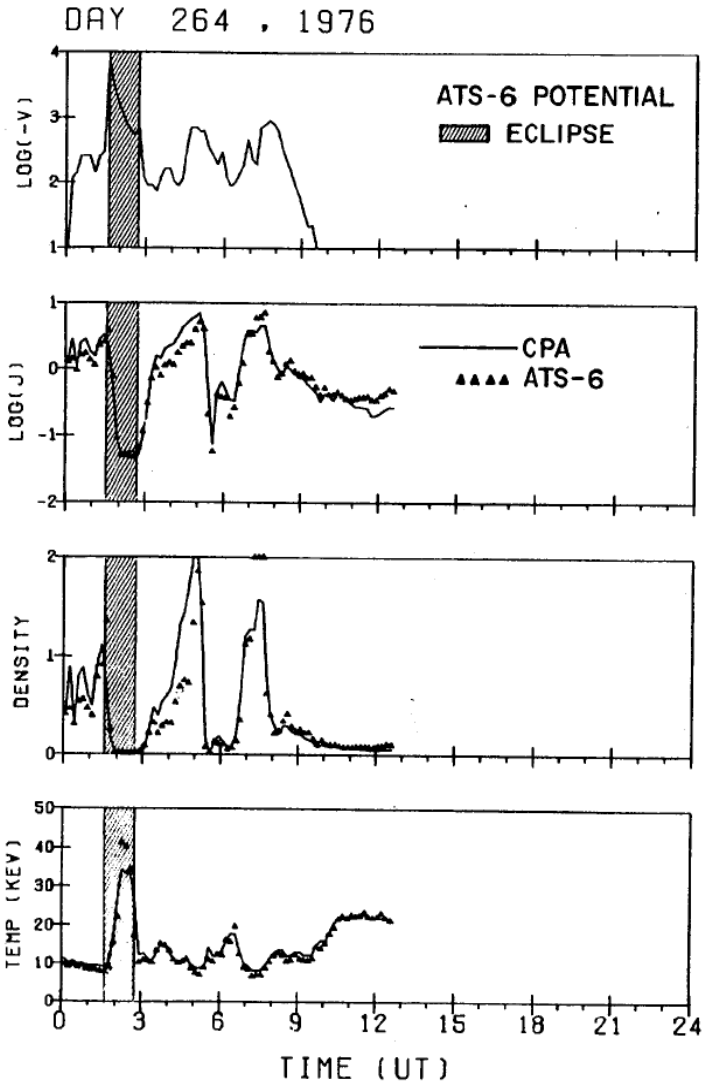
$$V = \frac{-KT_e}{q}\ln\left(\frac{J_{eo}}{J_{Io}}\right)$$

## Plasma Temperature vs Spacecraft Potential

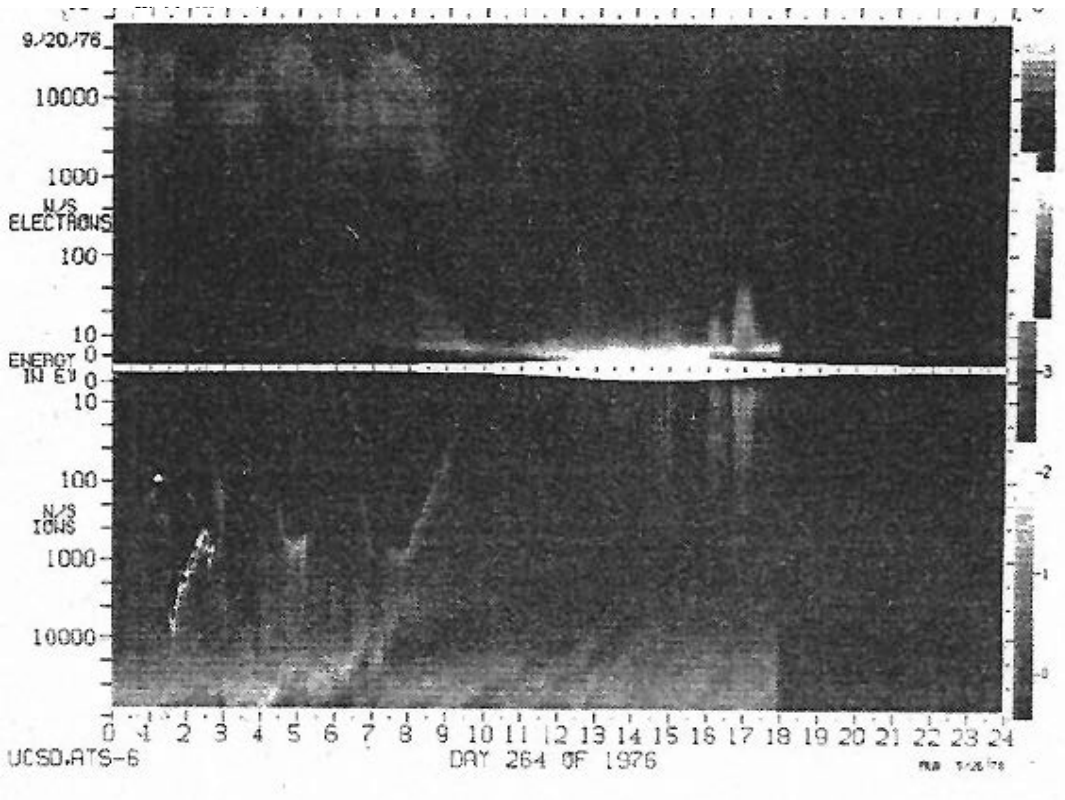


# Electron Current versus Spacecraft Potential

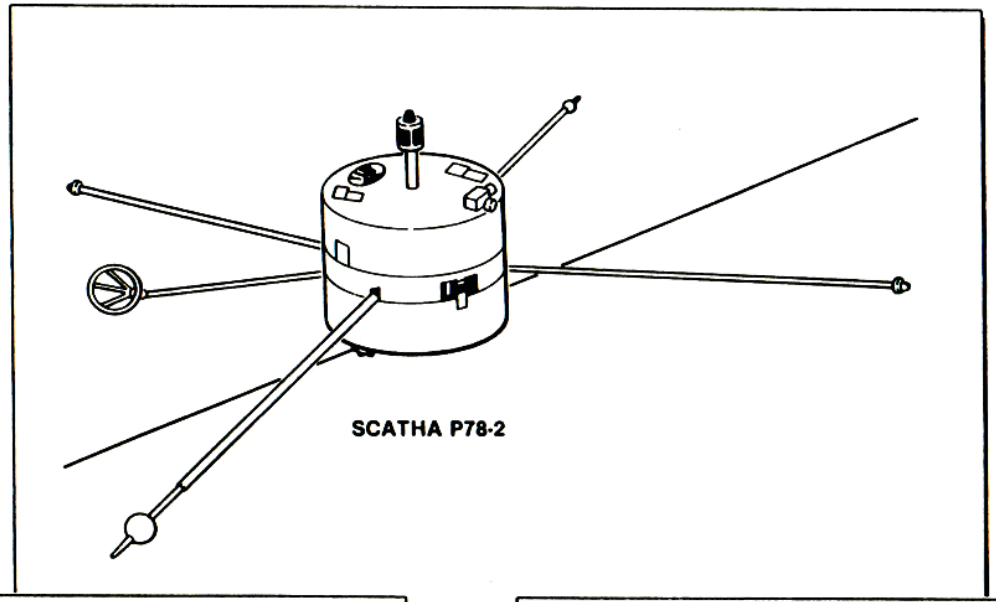
30-95 KeV ELECTRON DATA

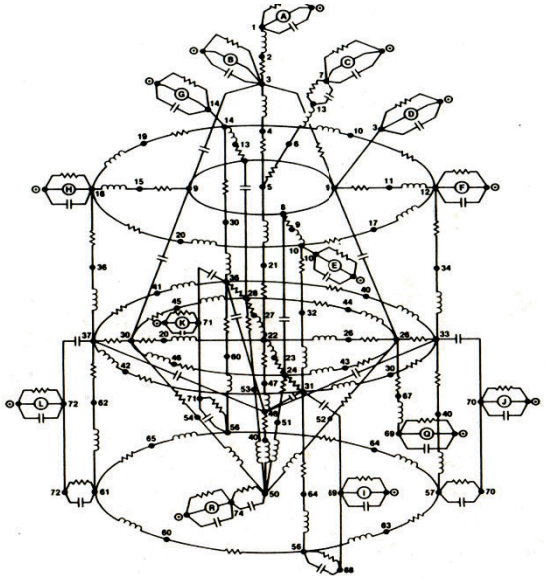


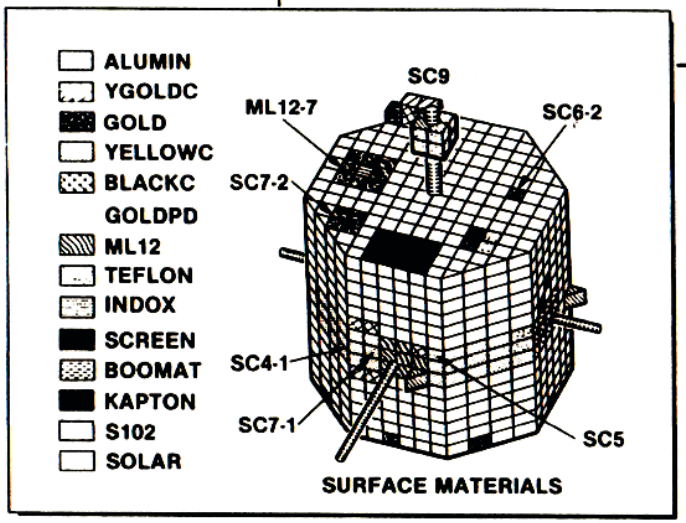

ATS-6 SPECTROGRAM

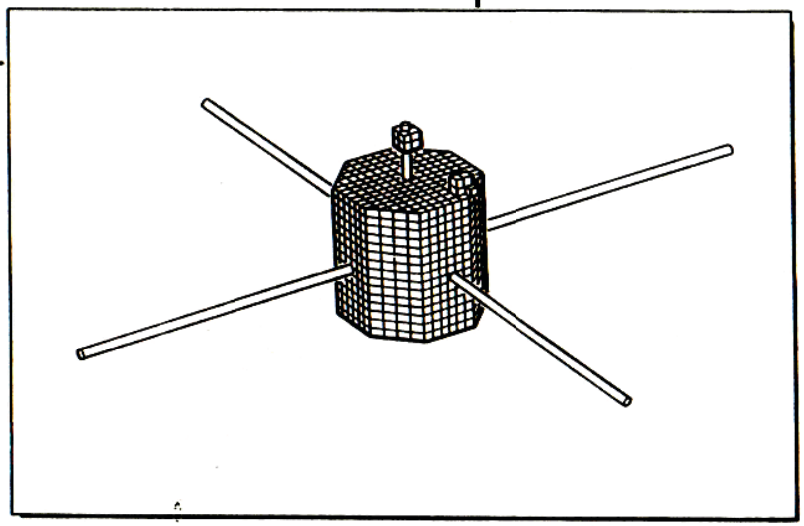


# NASCAP Spacecraft Charging Code: Differential Potentials

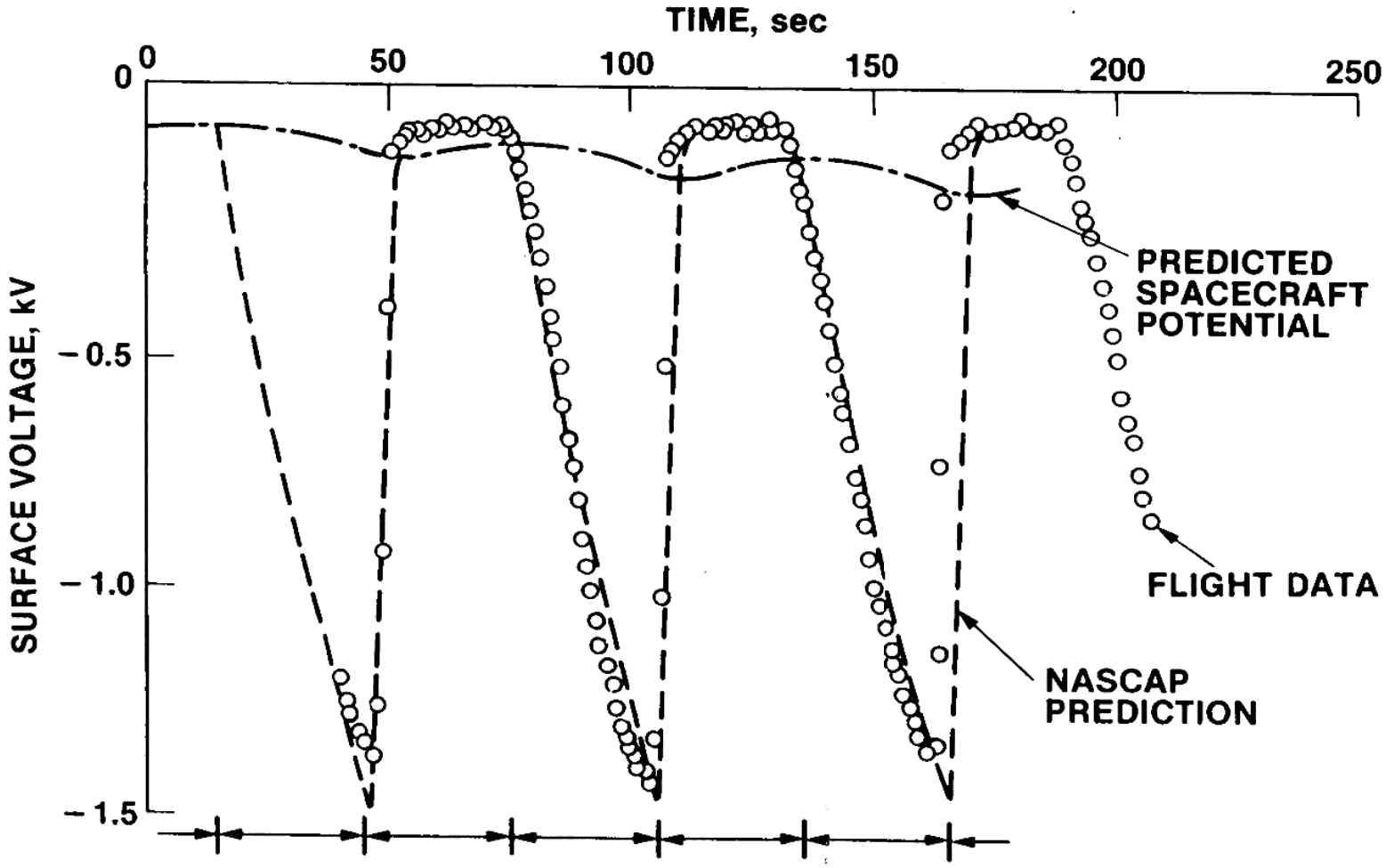


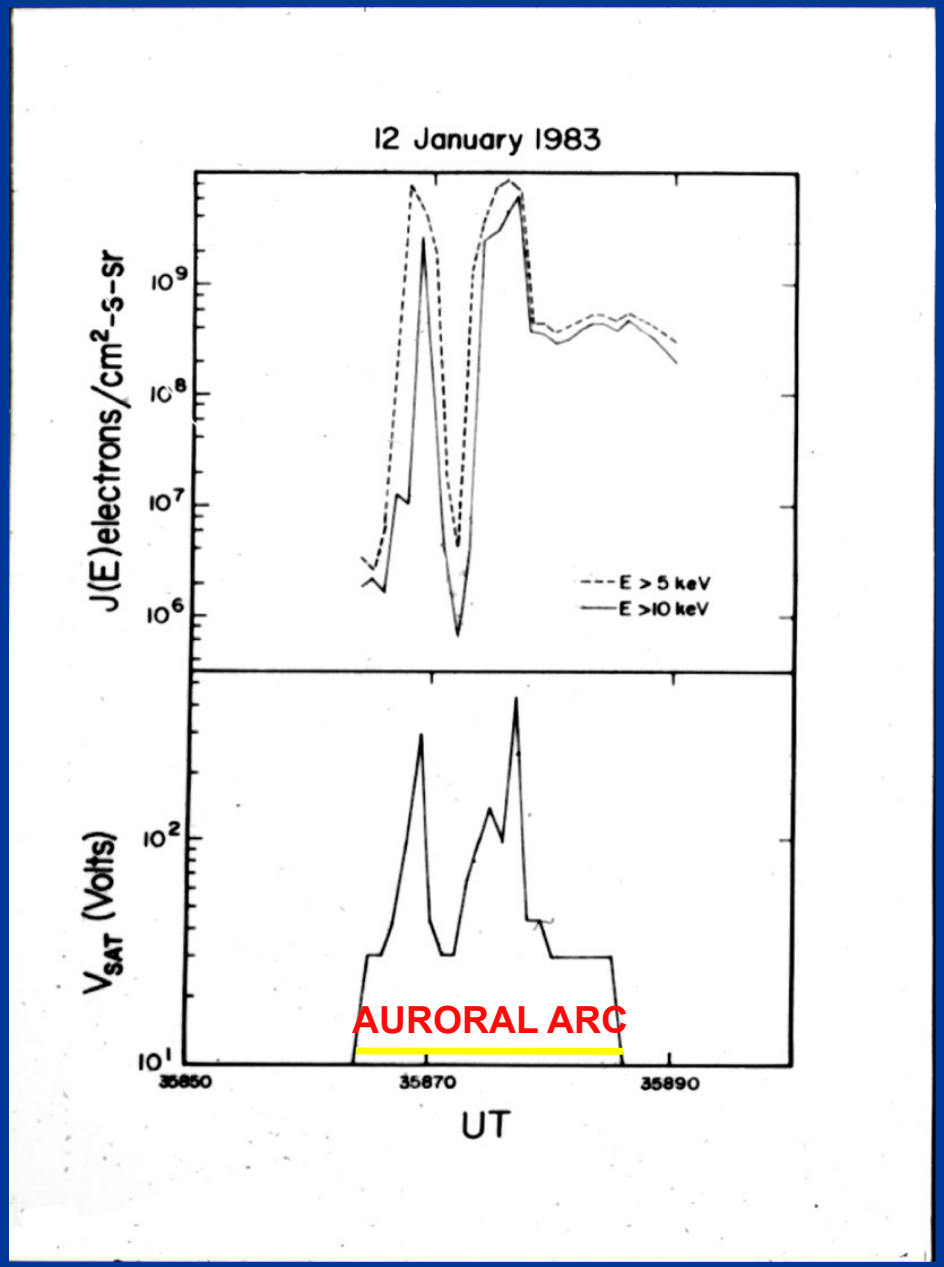


# Differential Potentials on SCATHA as Predicted by NASACP

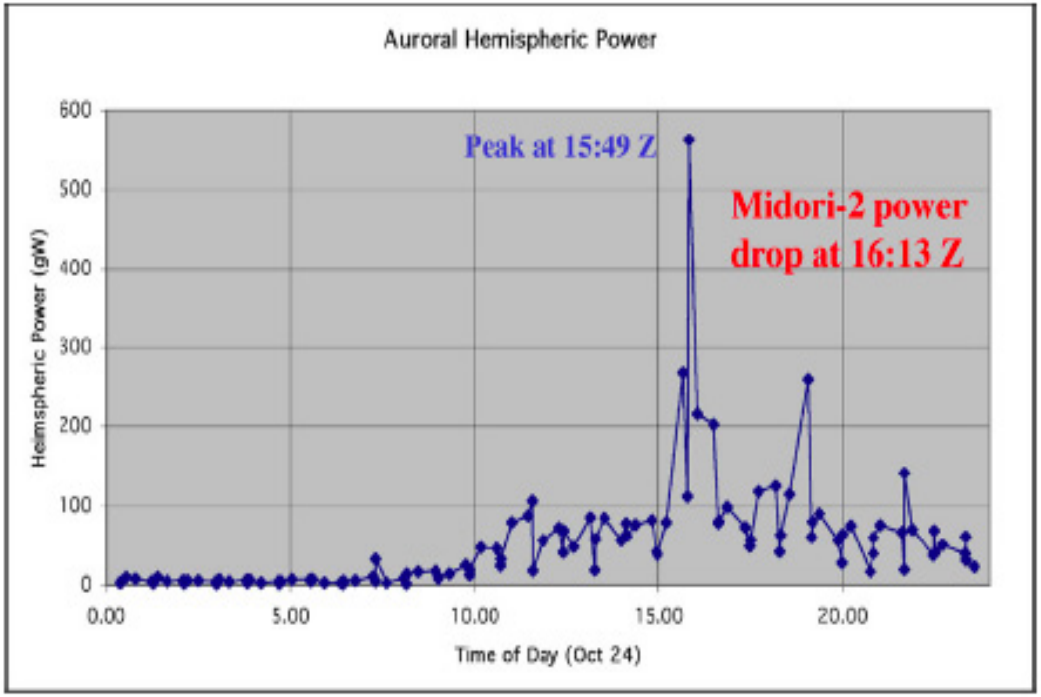


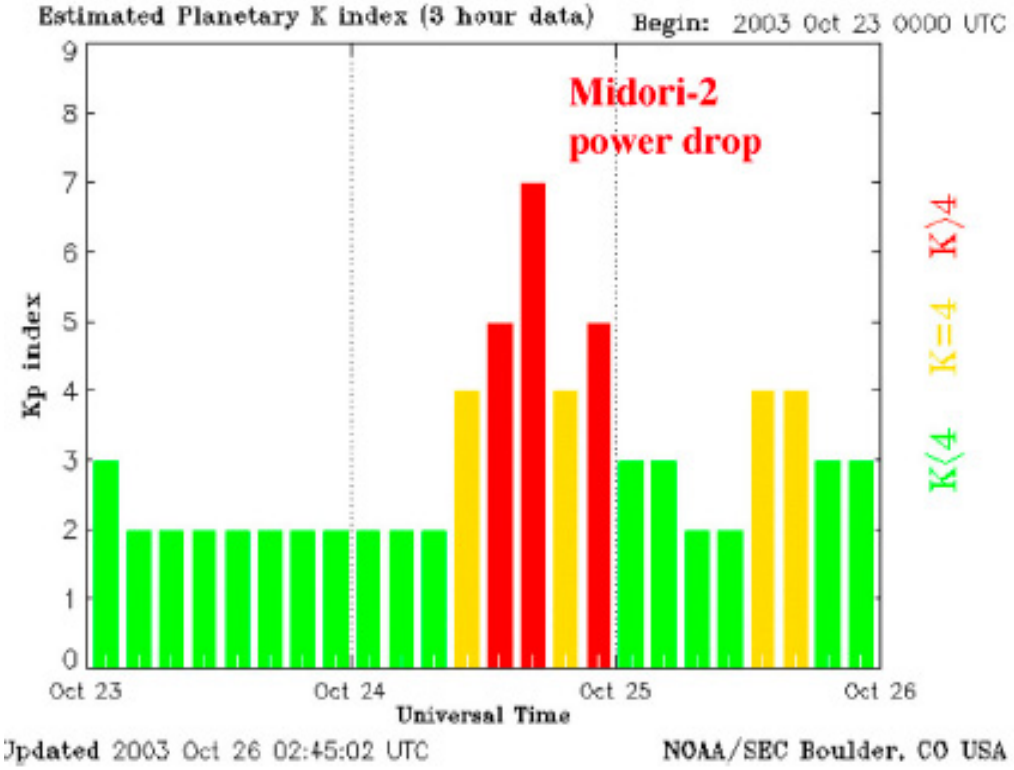
# DMSP Low Altitude Spacecraft Charging




# *Auroral Effects on JPL Ops, Oct. 24, 2003*

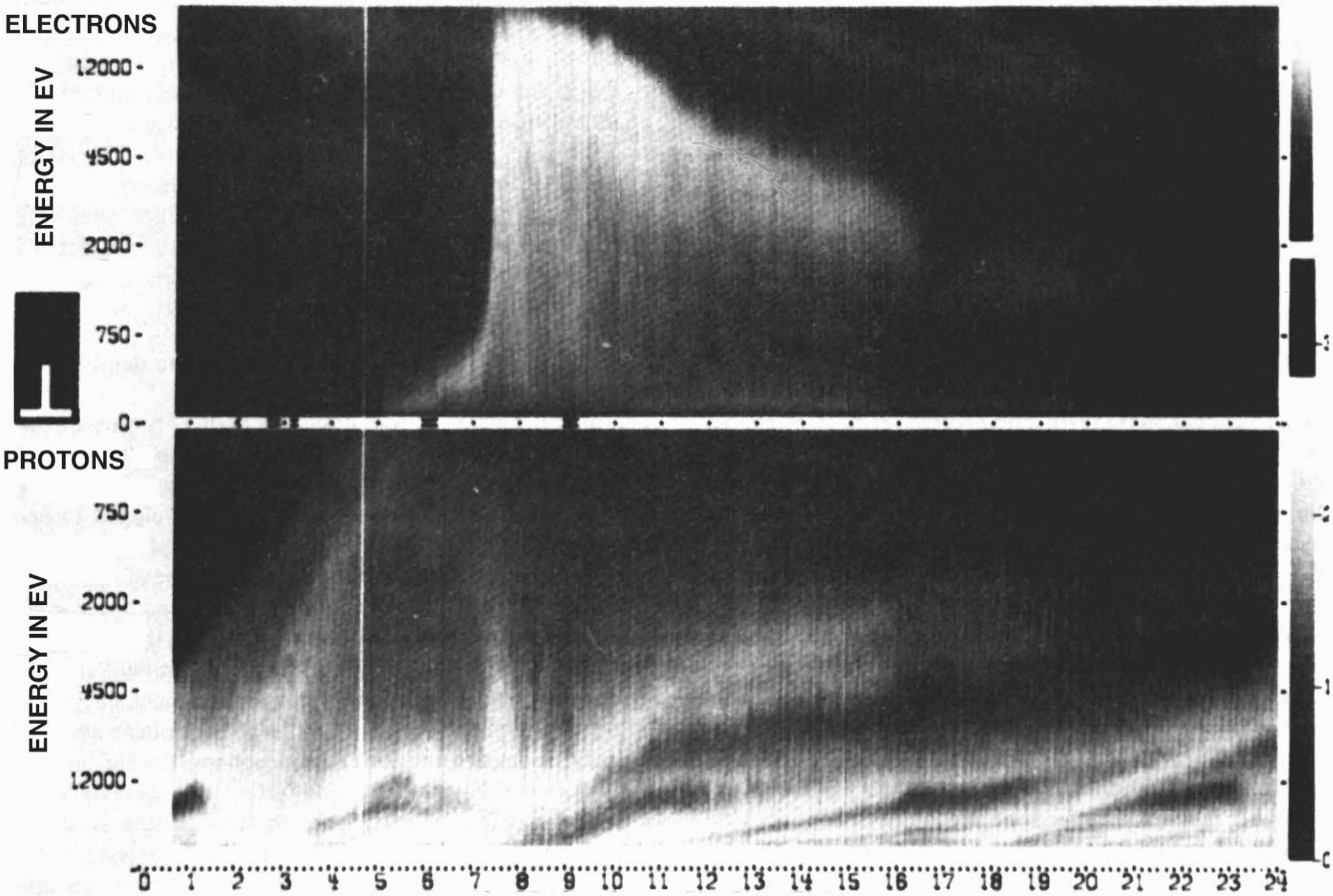
## Lessons Learned: Geophysical Indices Critical to Rapid Anomaly Resolution for JPL Missions



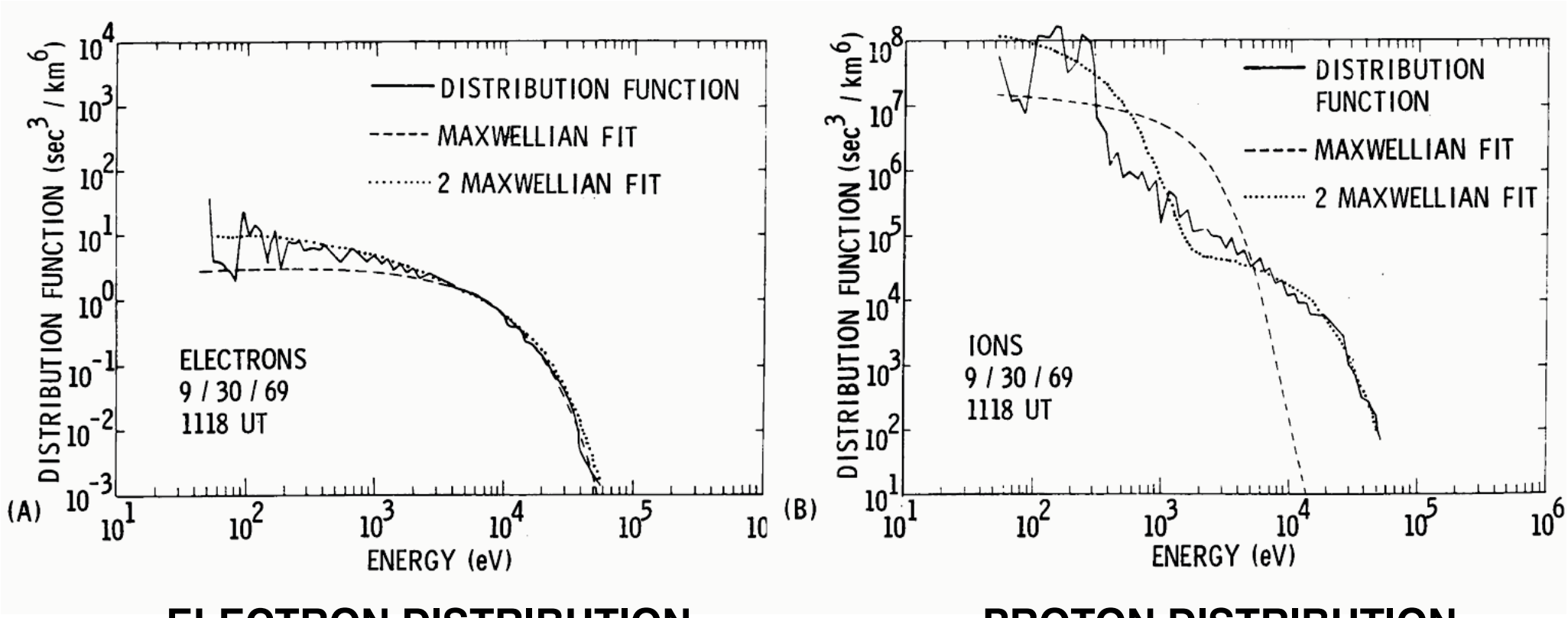




**Oct 24: ADEOS-Midori-2 (JPL SeaWinds Instrument) Failed. Attributed to Spacecraft Surface Charging**

# Space Weather: Spectrogram



# Electron and Proton Geo Plasma Distribution Functions




**ELECTRON DISTRIBUTION** **PROTON DISTRIBUTION**

# Two Maxwellian Approach to Charging Environment

## TWO MAXWELLIAN DISTRIBUTION FUNCTION

$$F_2(v) = \left(\frac{m}{2\pi}\right)^{3/2}\left[\frac{n_1}{(KT_1)^{3/2}}e^{\left(\frac{-mv^2}{2KT_1}\right)} + \frac{n_2}{(KT_2)^{3/2}}e^{\left(\frac{-mv^2}{2KT_2}\right)}\right]$$

## TWO MAXWELLIAN PLASMA MOMENTS

**NUMBER DENSITY:**

$$M_1 = n_1 + n_2$$

**NUMBER FLUX:**

$$M_2 = \frac{n_1}{2\pi}\left(\frac{2KT_1}{\pi m}\right)^{1/2} + \frac{n_2}{2\pi}\left(\frac{2KT_2}{\pi m}\right)^{1/2}$$

**ENERGY DENSITY:**

$$M_3 = \frac{3}{2}n_1KT_1 + \frac{3}{2}n_2KT_2$$

**ENERGY FLUX:**

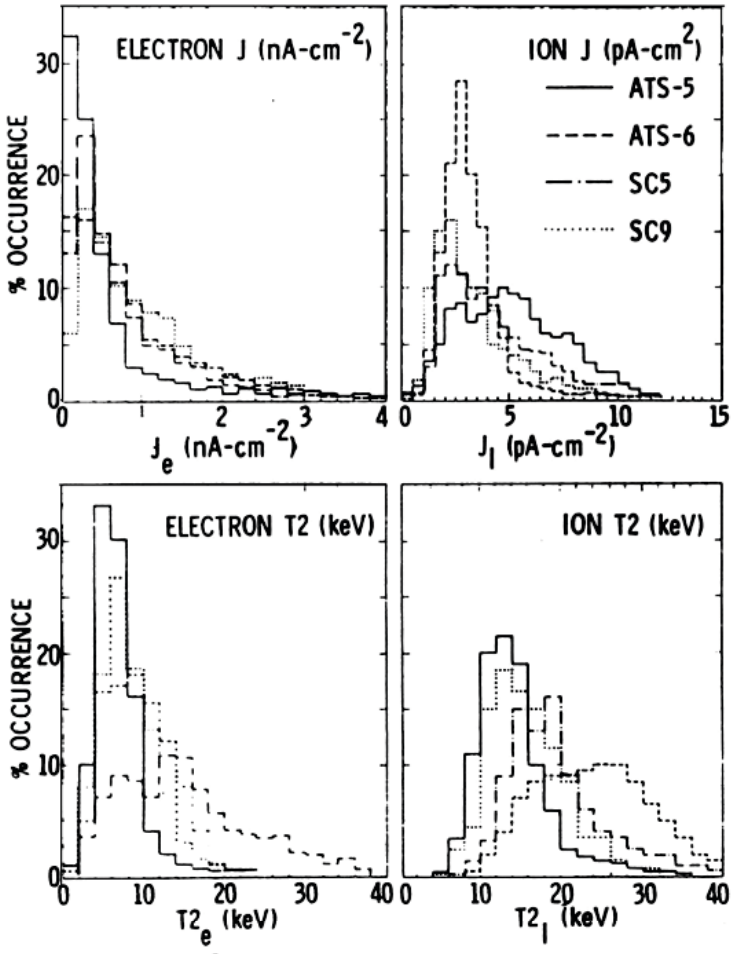
$$M_4 = \frac{n_1 m}{2\pi}\left(\frac{2KT_1}{\pi m}\right)^{3/2} + \frac{n_2 m}{2\pi}\left(\frac{2KT_2}{\pi m}\right)^{3/2}$$

## GEOSYNCHRONOUS PLASMA MODEL

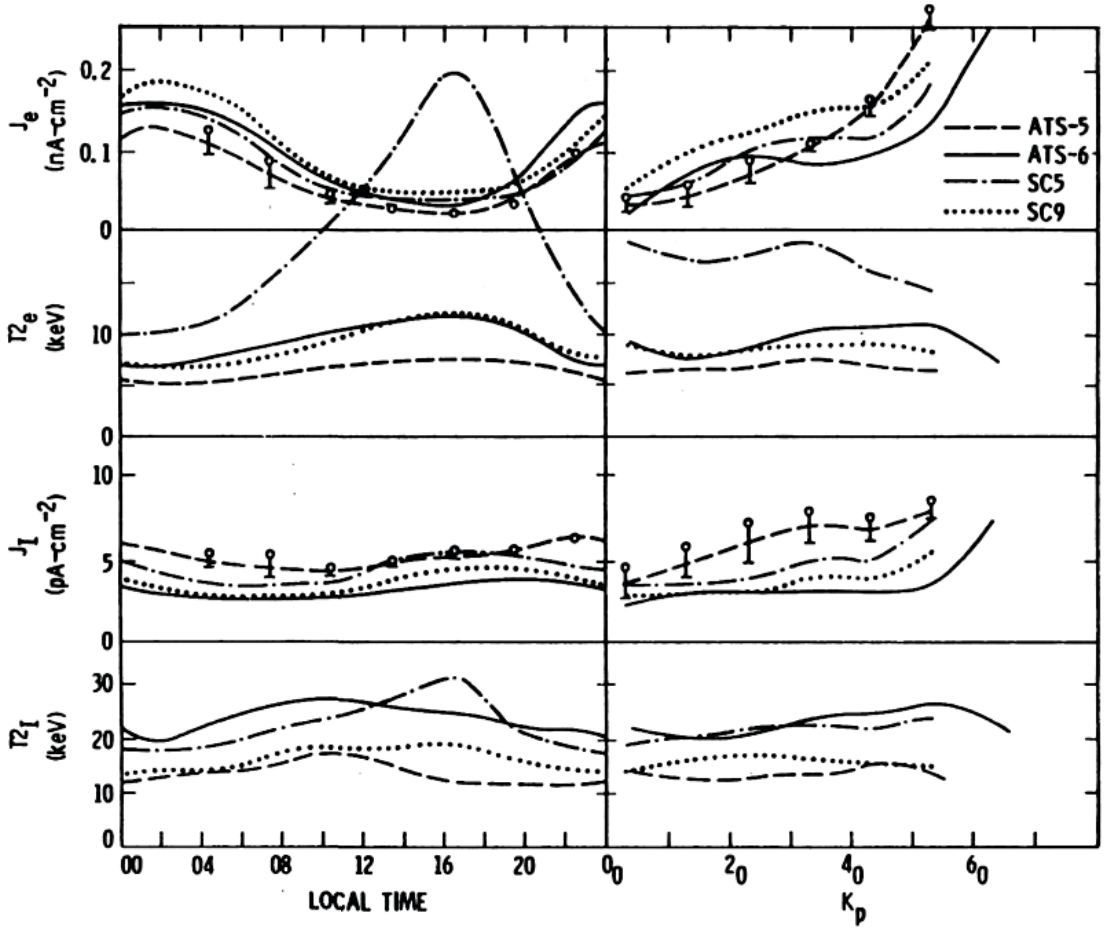
$$M_i(A_p, LT) = (a + bA_p)\{c + d\cos[2\pi(LT - e)/24] + f\cos[4\pi(LT - g)/24]\}$$

# Geosynchronous 2 Maxwellian Statistics

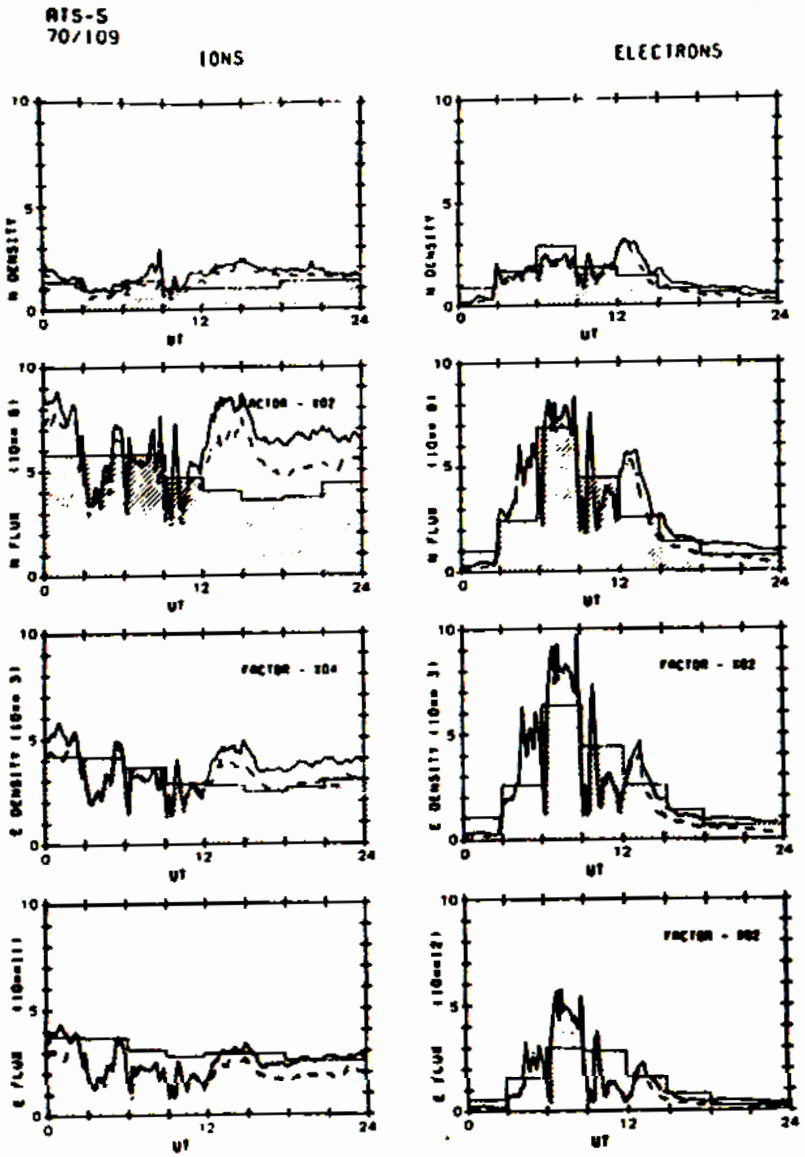
## STATISTICAL DISTRIBUTIONS OF KEY GEOSYNCHRONOUS PARAMETERS

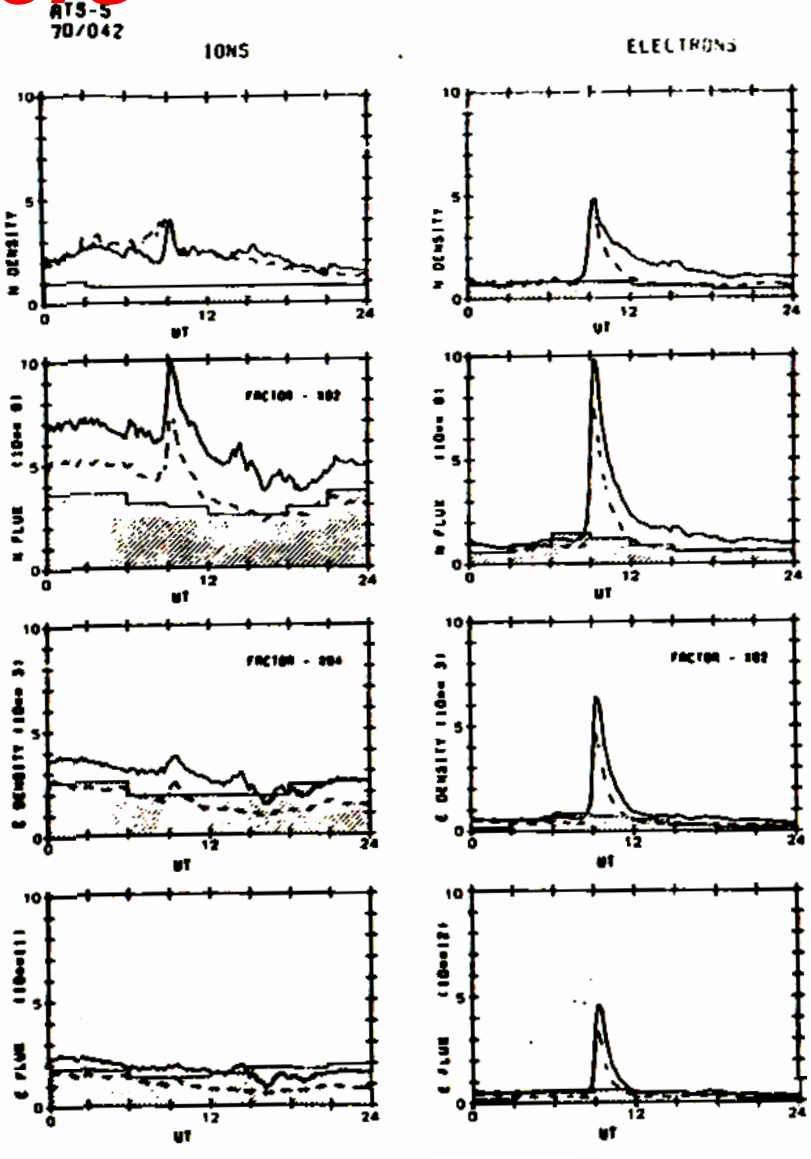



## LOCAL TIME/Kp VARIATIONS FOR KEY GEOSYNCHRONOUS PLASMA PARAMETERS



# Modeled (Kp, LT) vs Observed Geo Plasma Parameters

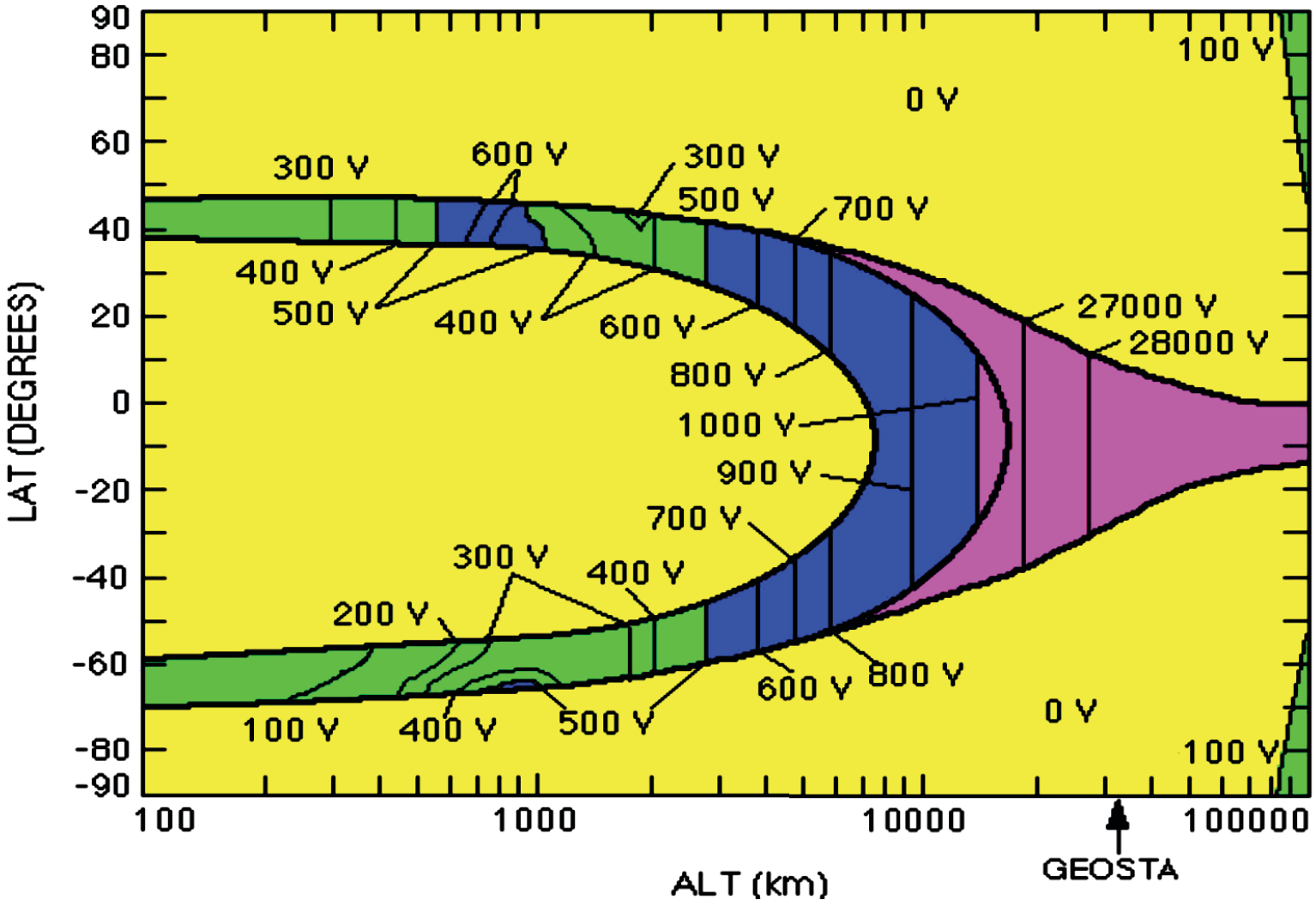


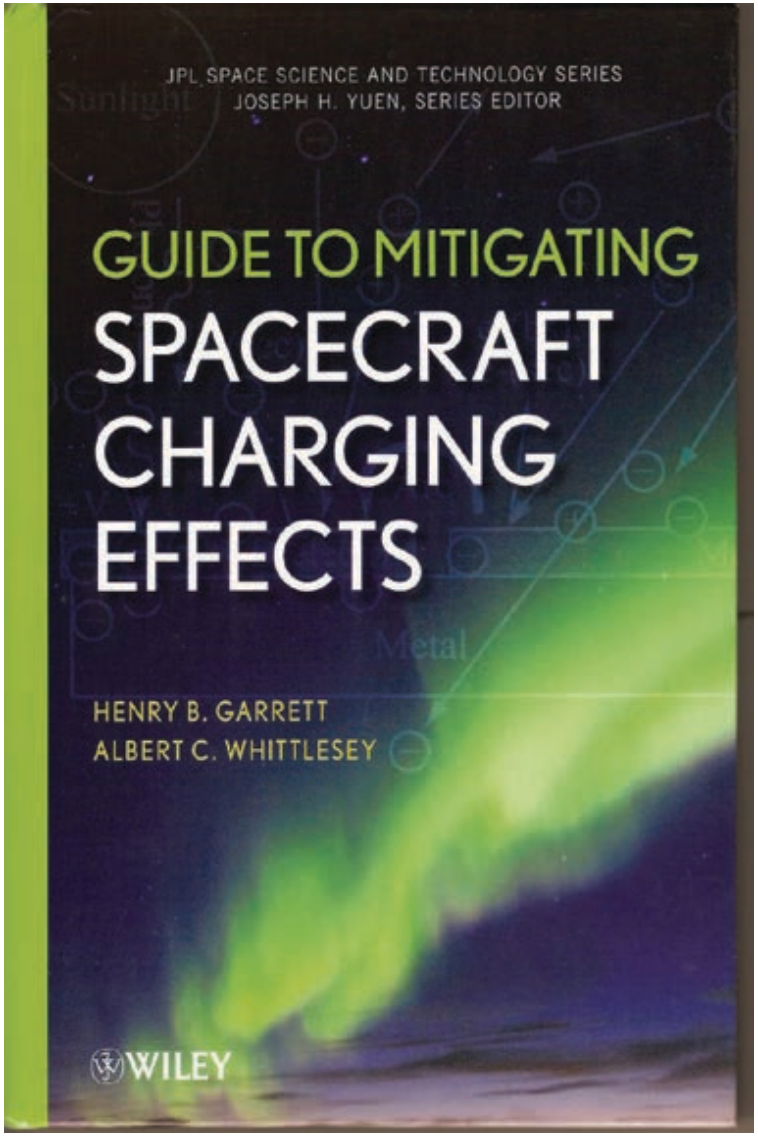
# Summary:

- Surface Charging comes in 2 forms:
  - "Absolute" or "Spacecraft to Plasma Ground"
  - "Differential Charging" between surfaces
- Absolute Charging (10-30 KV) roughly proportional to the ambient electron current once a threshold temperature (~2-3 KV) is exceeded→Need Te and Je estimates
- Differential Charging is very spacecraft configuration dependent (spinner vs 3-axis, shadowed surfaces, surface properties, etc.)
- Absolute Charging can have little effect but indicative of possible high levels of Differential Charging
- Differential Charging source of arc discharges ($\Delta V<100$ V?)
- Space Weather Forecasting useful for Absolute Charging but need spacecraft modeling (NASCAP-2K) for Differential Charging

# Worst Case Surface Potentials for Earth Environment in the Absence of Sunlight (Evans et al., 1989)



# Recommended Guide to Spacecraft Charging




**Title: Guide to Mitigating Spacecraft Charging Effects**

**Authors: Henry B. Garrett and Albert C. Whittlesey**

**Publisher: Wiley, 2012**

**ISBN: 978-1-118-18645-9**

# BACKUP VIEWGRAPHS

# "Analog" Model of Geo Orbit Environment