Spacecraft Charging

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Outline

 Basics of spacecraft surface charging and Langmuir probes
 Overview of various sounding rocket programs undertaken at Utah State
 Data from SAL rocket flight. Triboelectric charging.
 FPMU data results and charging on ISS.
The spacecraft surface potential is a function of the net current flow to/from the spacecraft surface.
Current Collection I-V Curve

Ion Saturation region:
Ions attracted, electrons repelled

Electron Saturation region:
Electrons attracted, ions repelled

Floating Potential

Plasma Potential

Electron Retardation region
Different Surface Geometries

Swept current-voltage characteristics for different Langmuir probe geometries

Ion Saturation Region

- Voltage (V)
- Current (mA)

Electron Saturation Region

- Voltage (V)
- Current (mA)

Legend:
- Plate
- Cylinder
- Sphere

Vp = 0
$I_E(V) - [I_I(V) + I_{PH}(V) + I_{SE}(V) + I_{BSE}(V) + I_B(V)] = IT$

$I_E = $ Electron Current
$I_I = $ Ion Current
$I_{PH} = $ Photoelectron
$I_{SE} = $ Secondary Electron
$I_{BSE} = $ Back Scatter
$I_B = $ Beam/Ion thruster
Past Sounding Rocket Programs

**SAL**
- **Flight:** 19th Feb 1998, Puerto Rico 2009 LT
- **Study:** sporadic sodium layers

**EWINDS**
- **Four Sequential Rockets:** July 1, 2003, Wallops Island
- **Study:** descending sporadic-E layers

**EQUIS II**
- **Two Rocket Flights:** August 7th and 15th, 2004, Kwajalein Atoll
- **Study:** precursors to equatorial spread-F
Upcoming Sounding Rocket Programs

Tropical Storms Mission

Flight in Fall 2007
Wallops Island

Study mid-latitude spread-F caused by tropical weather systems
Sudden Atom Layer (SAL)

- Investigation of sporadic sodium layers
- Dust Detector
- Langmuir Fast Temperature Probe (FTP)
- Floating Potential Probes
- Swept Impedance Probe
- DC Langmuir Probe (DCP)
SAL Mission

- Max. Altitude: 115 Km
- 5 Km thick sodium layer peaking at 94 Km
- Positively charged dust layer just below the sodium layer at 92 Km
SAL Electron Density Profiles

Plasma Density Upleg

Plasma Density Downleg

Charged Dust Layer

Altitude (Km)

Density (cm$^{-3}$)
The Sporadic-E Layer

(a) DCP Instrument Malfunction?
(b) Shock wave related effect?
(c) Vehicle Surface Charging?
Reasons for low DCP response
(a) Instrument Malfunction?

DCP worked above and below the layer
Reasons for low DCP response

(b) Effect of shock wave

Ambient Neutral Density: 0.6E+20
Density reduction factor around the DCP section of the boom: 3
Reasons for low DCP response
(c) Vehicle Charging?
Reasons for low DCP response
(c) Vehicle Charging?

Triboelectric Charging:
When two metal surfaces come in contact with each other and then separate, the metal surface with lower work function gets charged positive and the other surface gets charged negative.

Work function: Aluminium: 4.2eV  Sodium: 2.36eV  ➔ Dust source of electron current

Dust is modeled as RAM current
Reasons for low DCP response
(c) Vehicle Charging

Observed Dataset

Triboelectric Charging Simulation Results
Floating Potential Measurement Unit
Floating Potential Measurement Unit

- Floating Potential Probe (FPP)
- Wide Langmuir Probe (WLP)
  - Sweep -20 to +80 volts
- Narrow Langmuir Probe (NLP)
  - Sweep -5 to +5 volts around Vf
- Plasma Impedance Probe (PIP)
- Electronics

Distance:
- 130 cm
- 150 cm
Floating Potential Measurement Unit

Photovoltaic Cell Gap Geometry

After Miktarian et. al. IAC World Space Congress 2002 Houston, Texas
Floating Potential Measurement

Unit

Eclipse Sun Eclipse Sun

Data Dropout

ISS Floating Potential from different instruments on 2006 Day 217
FPMU Calibration File SN 2

-Fp (volts)

01:00:00 02:00:00 03:00:00 04:00:00

Time