PASP Plus Solar Array Parasitic Current Collection Flight Results

V. A. Davis and B. M. Gardner
Maxwell Technologies Systems Division

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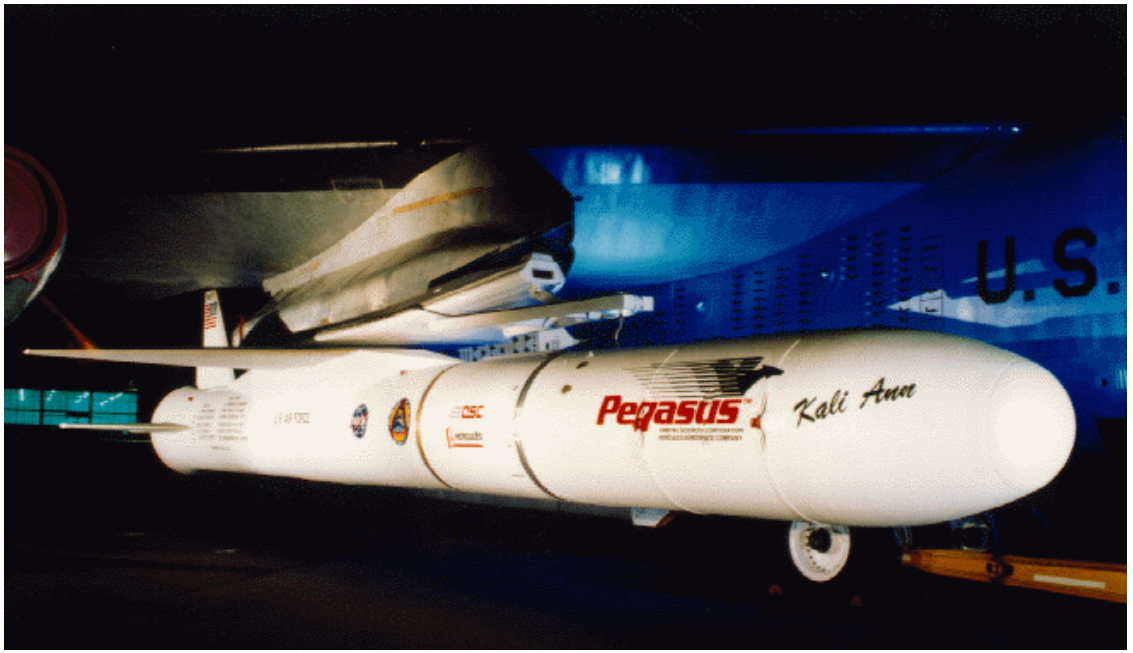
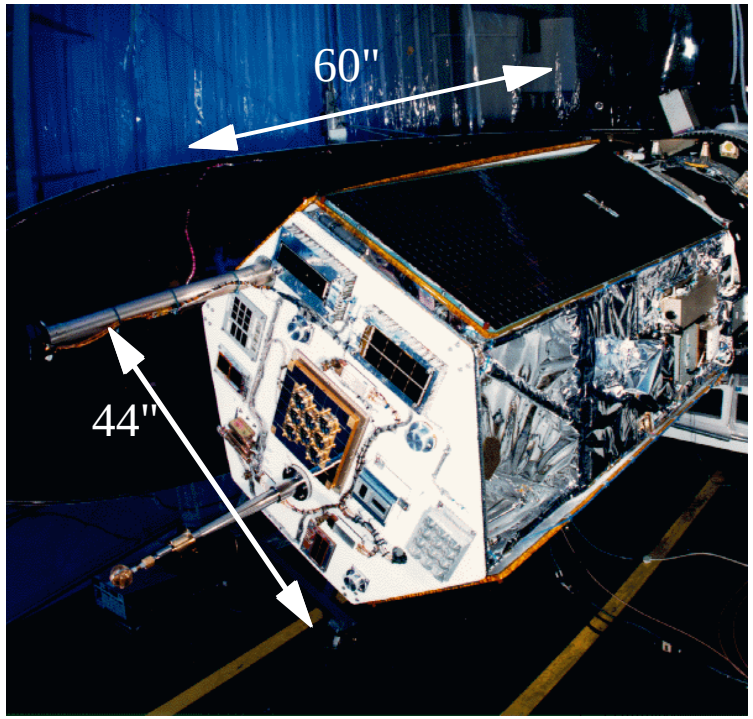
Overview

- Experiment Description
- Data Collection
- Flight Data
- Discussion



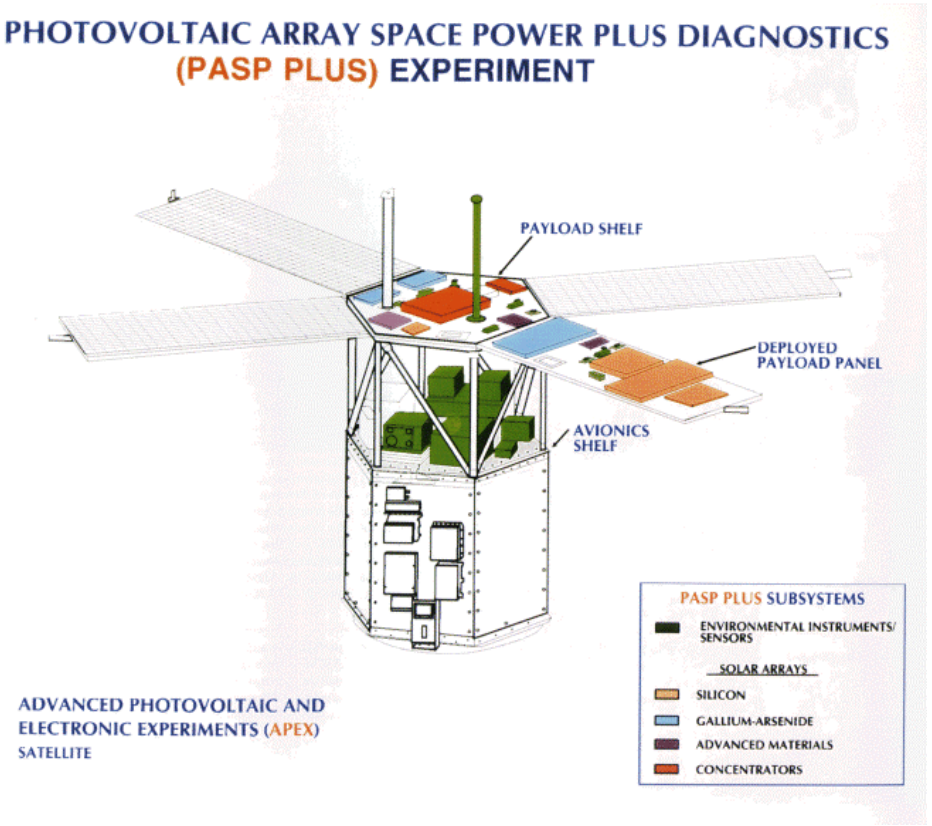
PASP Plus was Main Payload on APEX

- Launched August 94 on a Pegasus.
- 360 km by 2540 km, 70^{o} inclination.
- 3-axis stabilized within 0.5 degrees.
- Power from 36 V arrays.
- Body is covered with MLI with the conductive side out.
- Top panel, deployed panel, and backs of the solar arrays painted with 5 mil Z-93 (10^{12} ohm-m).
- Electron emitter
  20 mA of 100 eV electrons



Photovoltaic Array Space Power Plus Diagnostics

- Air Force Phillips Laboratory (PL/GPS)
- Array Measurements: August 1994 to August 1995.
- Investigate: negative potential arcing, parasitic current collection, long-term radiation damage.



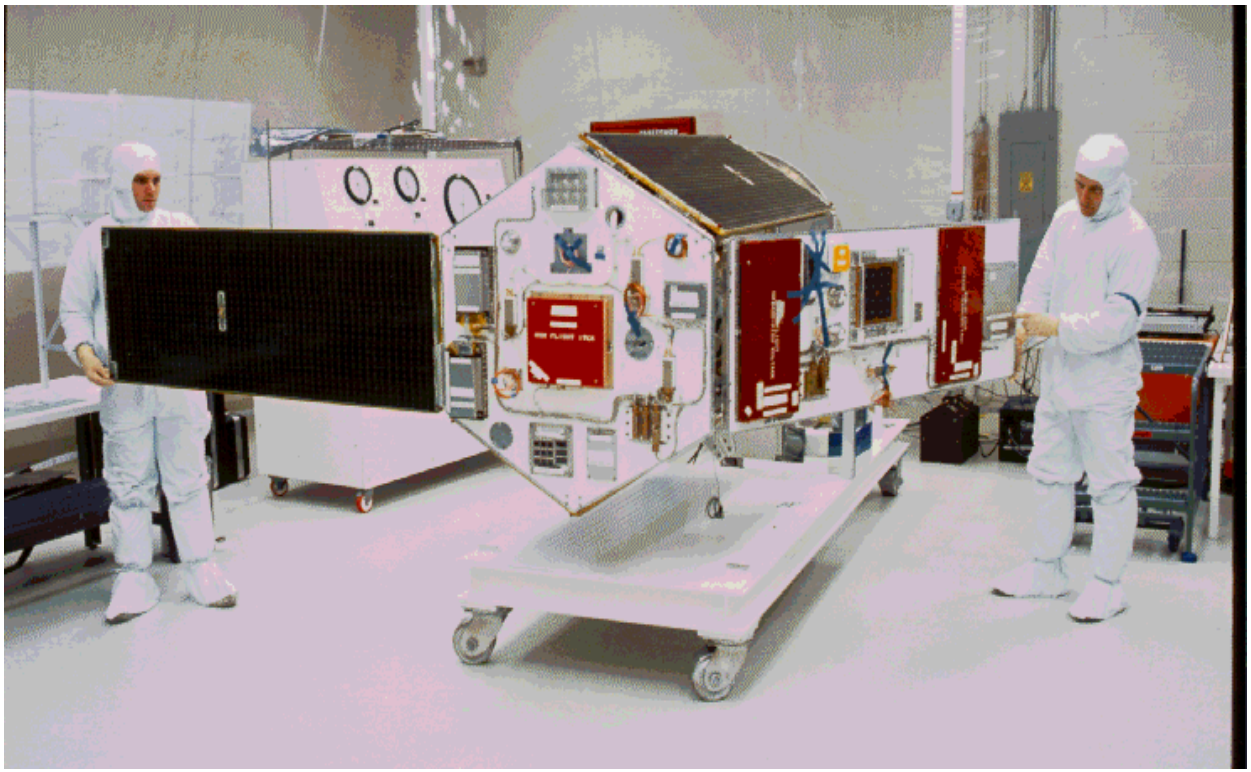
Environment Instruments

- Sun sensor to orient arrays with respect to sun.
- Langmuir probe.
  - **10^{-10} to 10^{-4} A of electrons, 10^{9} to 10^{12} m^{-3}, 0.06 to 0.43 eV**
  - **SENPOT: a potential sensor that assures that the probe will sweep the correct voltage range.**
- Transient pulse monitor.
  - 4 electric field sensors—minimum detectable field of 5 V/m
  - 1 current sensor on high voltage power supply
- Electrostatic analyzer.
  - 30 eV to 30 keV in 20 steps, electrons and ions within a 15 degree cone
  - (30, 44, 64, 95, 139, 204, 300, 440,...)
- Dosimeter.
- Contamination monitors.
- Magnotometer.

Solar Array Measurements

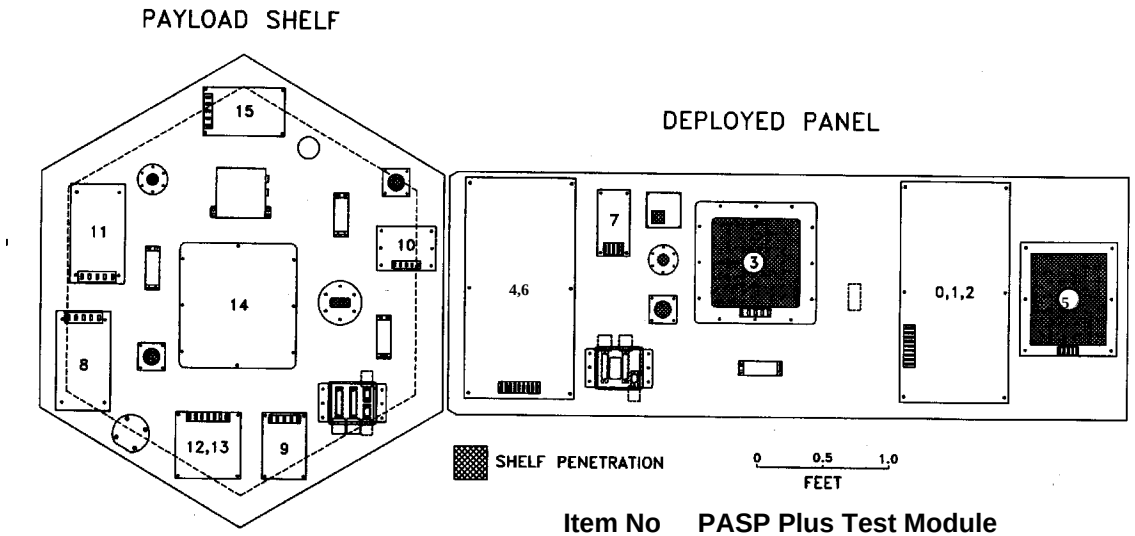
- 12 Types of solar arrays.
- 8 Types of solar arrays tested at high voltages.
  - Conventional, GaAs/Ge, Wrap-Thru interconnects, and 2 concentrators.
- Each test array can be biased from 50 V to 500 V positive and negative.
- Procedure
  - IV curve by varying the resistance value for radiation damage investigation.
  - Apply a fixed bias to solar array while monitoring the current or TPM.
  - IV curve.
- Leakage current measured from 0.2 μA to 20 mA.

PASP Plus



- Miriad of photographs of arrays and cells.
- Before launch, many cells peeled up from backing.

Experiment Layout



Item No	PASP Plus Test Module	Item No	Instrument
0, 1, 2	Si Standard	18, 19, 20 ,21	TPM E-field Sensors
3	Si Wrap-Thru (Space Station)	23	LP Boom & Sensor
5	Thin Si (2 mil), APSA	27	PASP Sun Sensor
4,6	GaAs on Ge, 3.5 mil	30, 31	Quartz Crystal Microbalances
7	AlGaAs/GaAs	32, 33, 34	Calorimeters
8	GaAs on Ge, 7 mil, Wrap-Thru		
9	Amorphous Si		
10	InP		
11	GaAs on Ge, 7 mil		
12,13	GaAs/CuInSe2		
14	GaAs Mini-Cassegrainian		
15	GaAs/GaSb Mini-Dome		

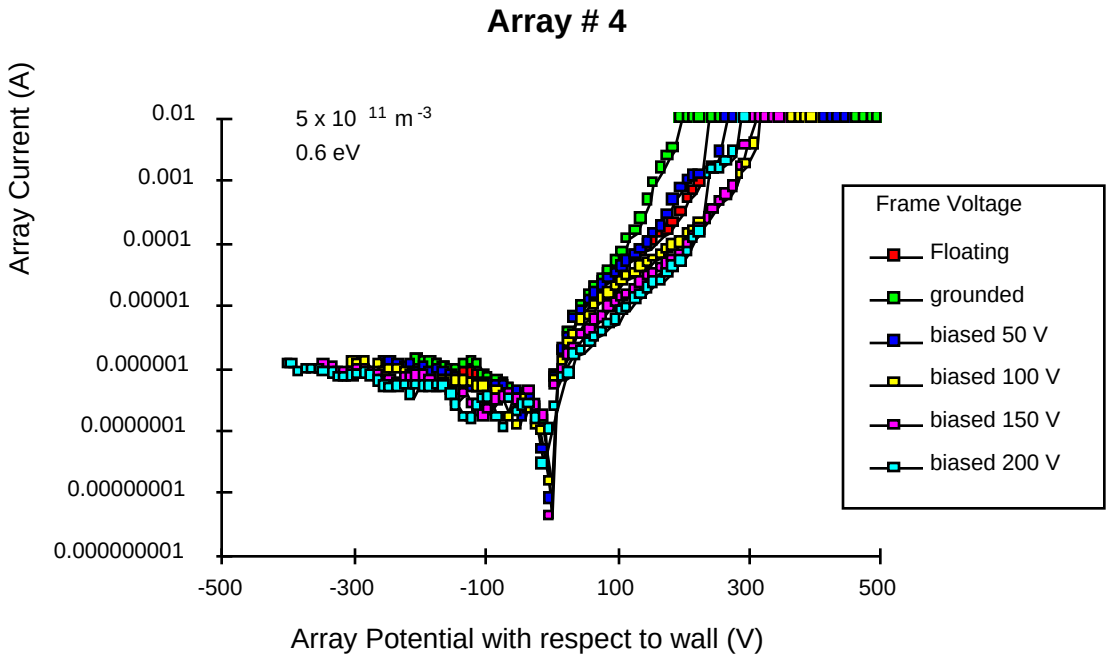
PHOTOS

PASP Plus Biasable Solar Arrays

No.	Type and Size of Cells	Number of Cells	Adhesive Thickness (mil)	Coverglass Thickness (mil)	Gap (mil)	Overhang (mil)	Interconnect Type
1,2	Silicon, 2x4 cm, 8 mil	20, 60	1	6+1	60	1	exposed
3	Silicon, 8x8 cm, 8 mil	4	0	5	32	3.5	wrap-thru
4,6	GaAs/Ge, 4x4 cm, 3.5 mil	20, 12	5	4+2	40	5	exposed
8	GaAs/Ge, 4x4 cm, 7 mil	4	5	6+3	40	0	wrap-thru
11	GaAs/Ge, 4x4 cm, 7 mil	8	5	6+3	40	0	exposed
5	Silicon, APSA, 2.6x5.1 cm, 2.5 mil	12	1	2+1	50	1	exposed
14	GaAs, Mini-Cassegrainian						
15	GaAs/GaSb, Mini-Dome Concentrator						

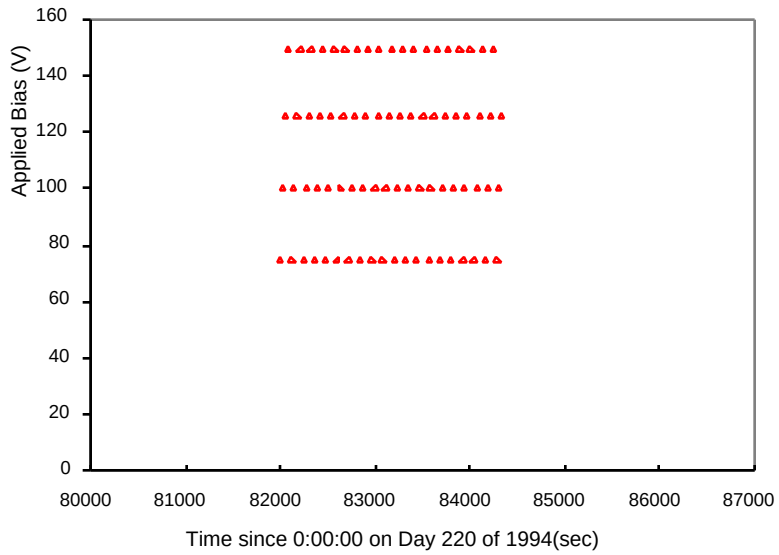
Preflight Laboratory Tests at NASA/LeRC

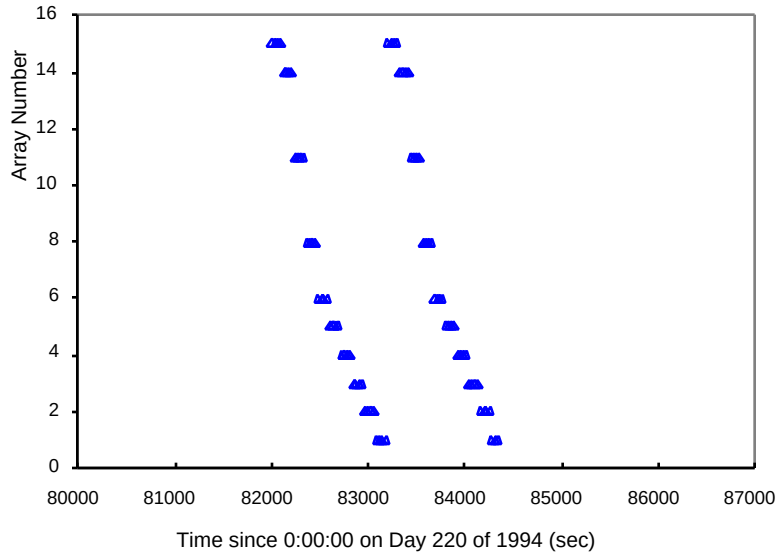
- Two slightly different chamber conditions.
- One set of sweeps per array.
- Frame floating, grounded or biased.
- Densities higher than typical flight.



Applied Bias and Array Number for 117 Minute Period

- **2 Minute Measurement Sequence for each array**
- For 4 Bias Values $\begin{cases} 7\ \text{secs} : \text{Density Measurements \& IV Curves} \\ 23\ \text{secs} : 23\ \text{Current Measurements at Fixed Bias} \end{cases}$





Plasma Density and Current Measurements for Same 117 Minute Period

- Plasma density varies during orbit.
- Current higher during biasing of more exposed and larger arrays.
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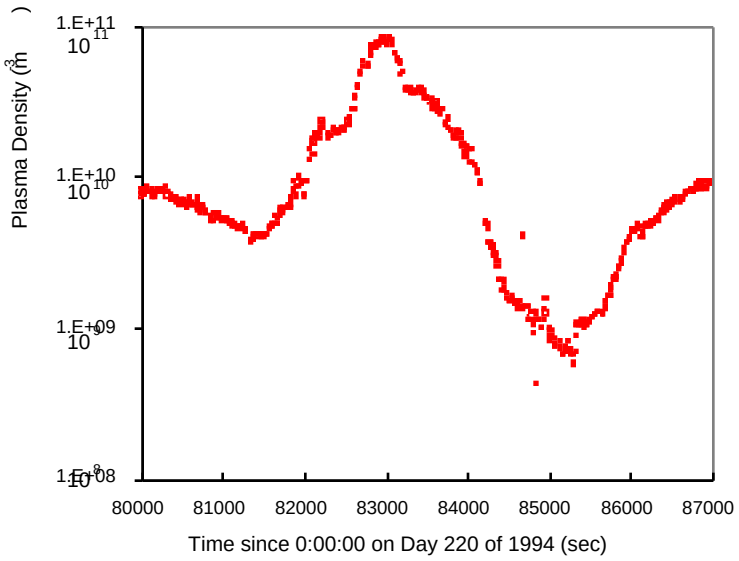
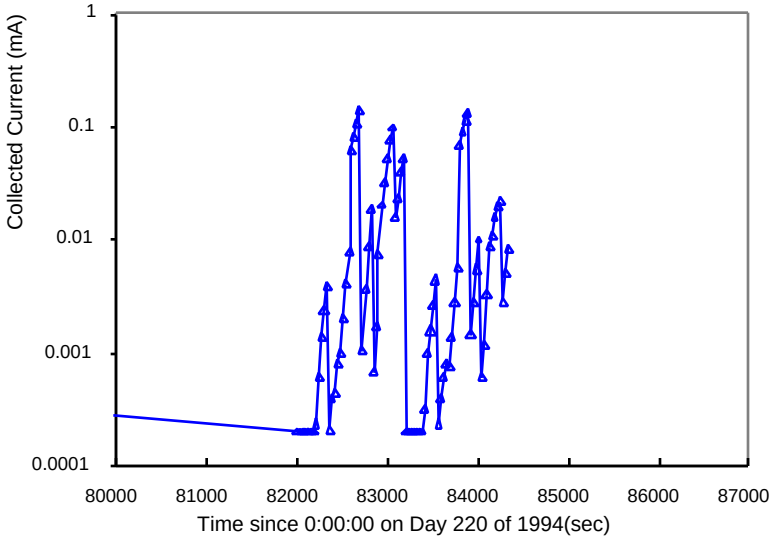


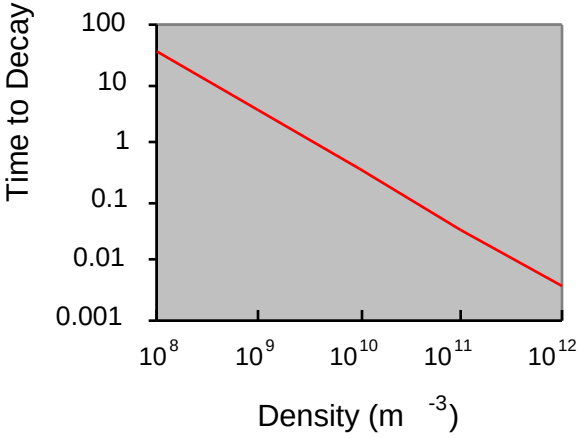


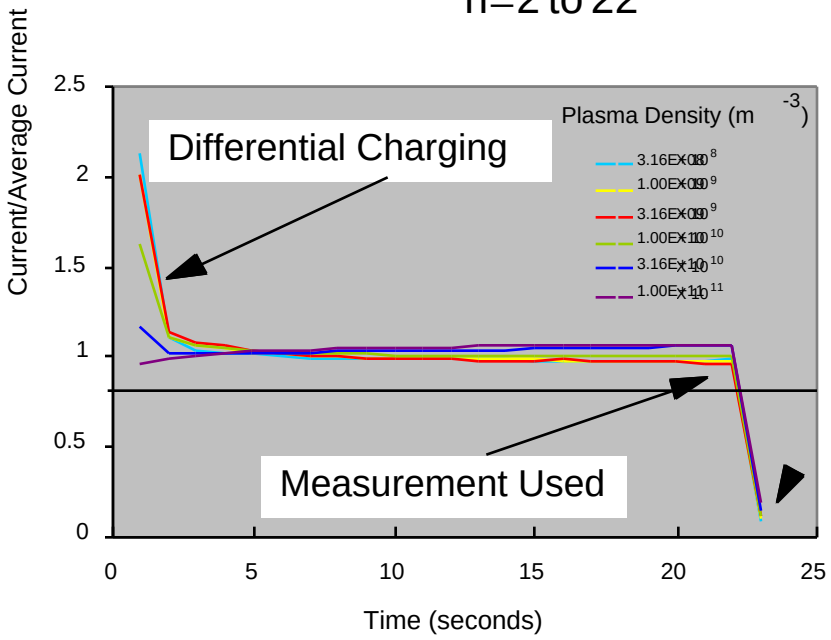
Variation Within a Measurement

- Time scale of differential charging across the cover glass depends on density. We can estimate the decay time.

$$\tau = \frac{(\phi_{cell} + 2\theta)\kappa\varepsilon_o}{\Delta(j_{th} - j_{collected})}$$

$$Ratio_i^j = \frac{I_i^j}{\sum_{n=2\ to\ 22} I_n^j}$$





Unknown Origin

Collecting Area as a Function of Cell Bias and Plasma Density

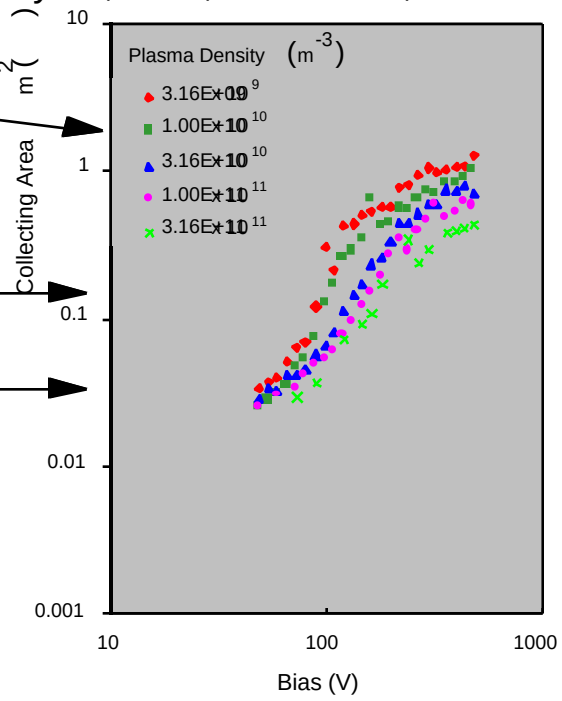
$$\text{CollectingArea}\left(m^2\right) = \frac{\text{LeakageCurrent}}{\text{ThermalCurrentDensity}} = \frac{\text{LeakageCurrent}(A)}{2.68\times10^{-14}\,\text{Dens}\left(m^{-3}\right)\sqrt{\text{Temp}(eV)}}$$

Near 1.5 m^2, electron current exceeds ram ion current to uncharged APEX ⇨ APEX charges

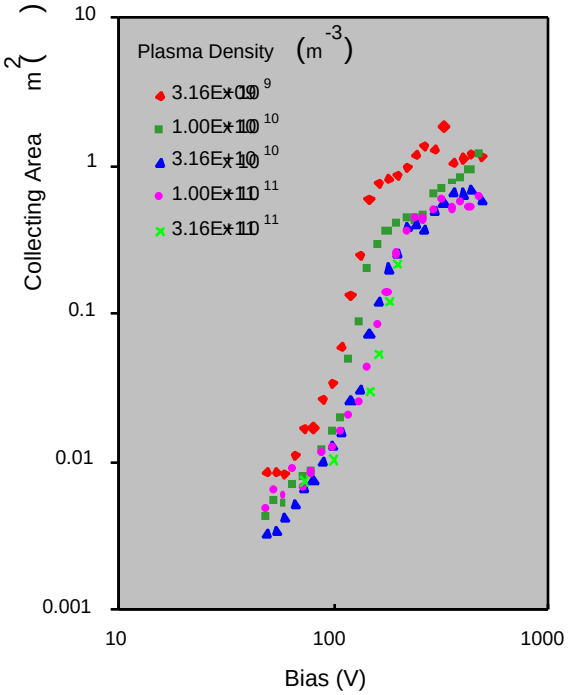
Panel Area = 0.129 m^2

Array Area = 0.032 m^2

Array #1, Ram, Emitter Off, All Data



Array #4, Ram, Emitter Off, All Data



Density Measurement Complications

- Algorithm for Langmuir probe had difficulties at higher densities.
- During electron gun operations APEX slightly positive.
- SENPOT was not configured to measure positive potentials, so Langmuir probe sweep was not adjusted to accomodate.
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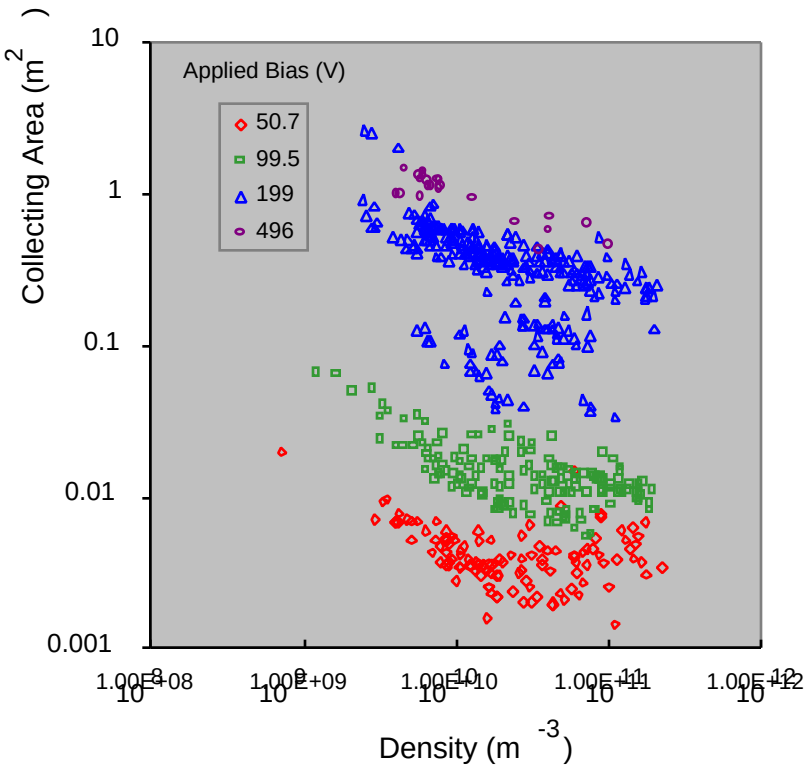
Scatter in Flight Data

Possible Sources of Scatter

- Measurement of Plasma Density and Temperature (20%)
- APEX Floating Potential
- Insulator Potentials(negligible)
- Surface Properties with Time (sorting by time does not reduce scatter)
- Plasma Constituents
- Attitude (sorting by angle does not reduce scatter)
- Unstable/Bistable Nature of Snapover Other Parameters



Summary

- Large amount of excellent data collected.
- We understand general characteristics of the data.
  - Snapover gives steep increase in current with increasing bias.
  - Charging of spacecraft body attenuates this rapid rise.
- Amount of scatter between measurements made under the (apparently) same circumstances is not understood.
- Left with as many questions as answers.

More Controlled Conditions give More Definitive Results

- Simple geometry test samples.
- Selection of arrays with varying area.
- Selection of cells with varying overhang, gap, etc.
- Large array areas to minimize edge effects.
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- Larger range of voltage settings and sweeps up and down to give potential dependency.
- Long dwell times to give dependency on density and other environmental conditions.
- Laboratory tests done under anticipated flight conditions.
- Orbit with repeatable flight orientations.
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