Plasma Interactions and Effects for Large Systems

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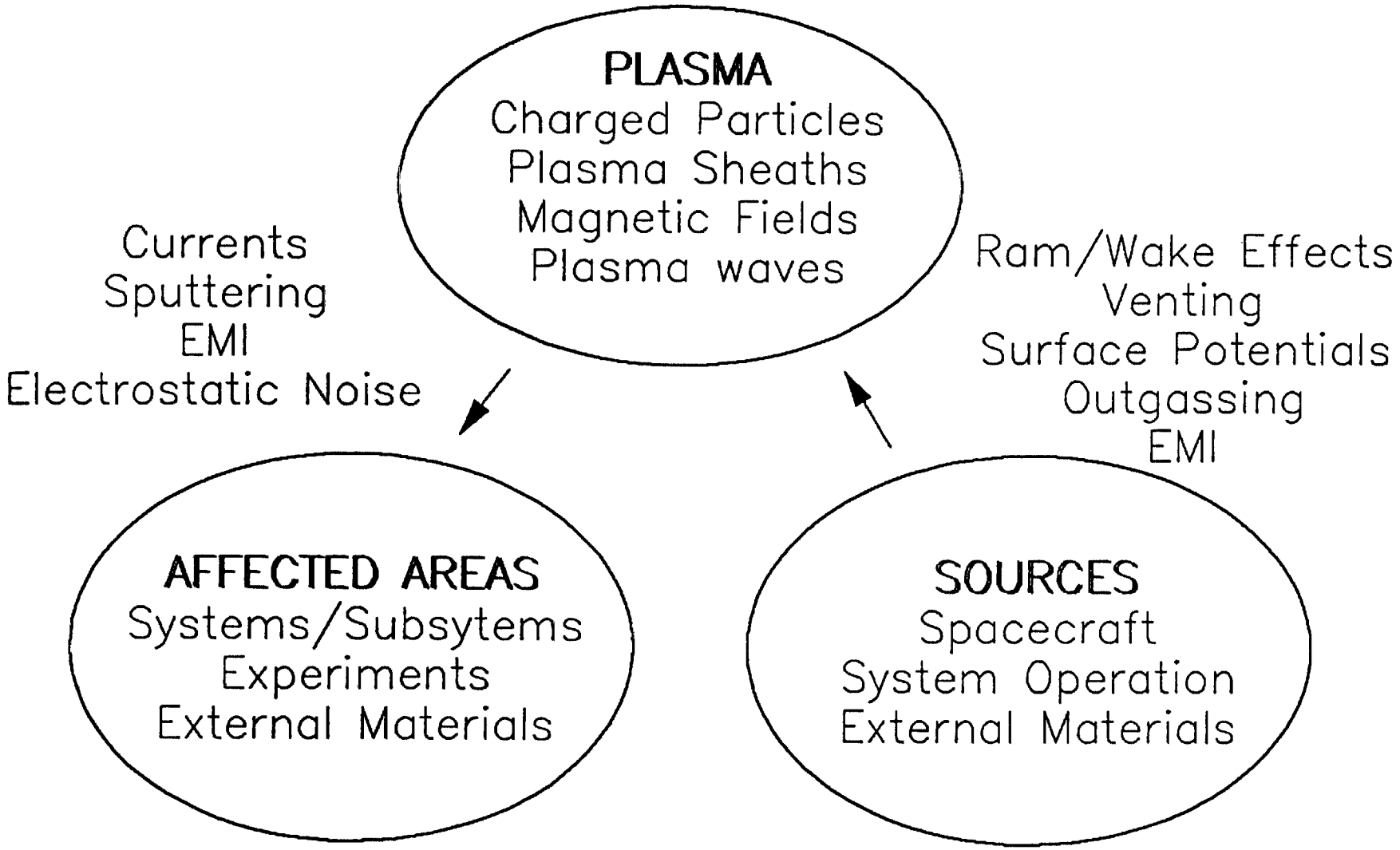
PLASMA–SPACECRAFT INTERACTIONS



PLASMA ISSUES

Plasma tends to 'ground' surfaces.
Charging not as severe an issue. Fewer high energy charged particles than in GEO. (Except in Polar orbits)

But:
Current Collection is now an issue.
(Currents through structure, instrumentation)

Discharges on exposed, High Voltage Surfaces.

Floating Potential of Spacecraft.
(What should be used for reference ground?)
rapid fluctuations may induce structure currents

Electrostatic Noise. (Ram/Wake, venting, thruster firing)
Plasma supports wave propagation
Magnetic Field Guides waves

Multi-purpose vehicle.
When will systems/users interfere with each other?

Design Guidelines exist for Geo environment but not for LEO

NASA TP2361 Purvis, et al. (1984)

GEO Environment: low charge density, high energy particles

GEO Issues: Dielectric Charging, Arcing

GEO Recommendations: Maximize dielectric Conductivity, conductors must be grounded

PLASMA CHARACTERISTICS
(200 - 800 km altitude along equator)

day density: 10^5 to 10^6 #/cm^3

Temperature
electrons: 1000 to 2500 K (0.1-0.2 eV)
ions: 700 to 1900 K
Debye length ~ 0.5 cm
Thermal Current Flux
electrons: 0.004 A/m^2 ions: 2×10^{-5} A/m^2

night density: 10^4 to 5×10^4 #/cm^3

Temperature
electrons: 900 to 1100 K (0.1 eV)
ions: 700 to 1100 K
Debye length ~ 2 cm
Thermal Current Flux
electrons: 2×10^{-4} A/m^2 ions: 2×10^{-5} A/m^2

Magnetic Field: 2 to 4 $\times 10^{-5}$ tesla

Magnetic Field (vxB•l)

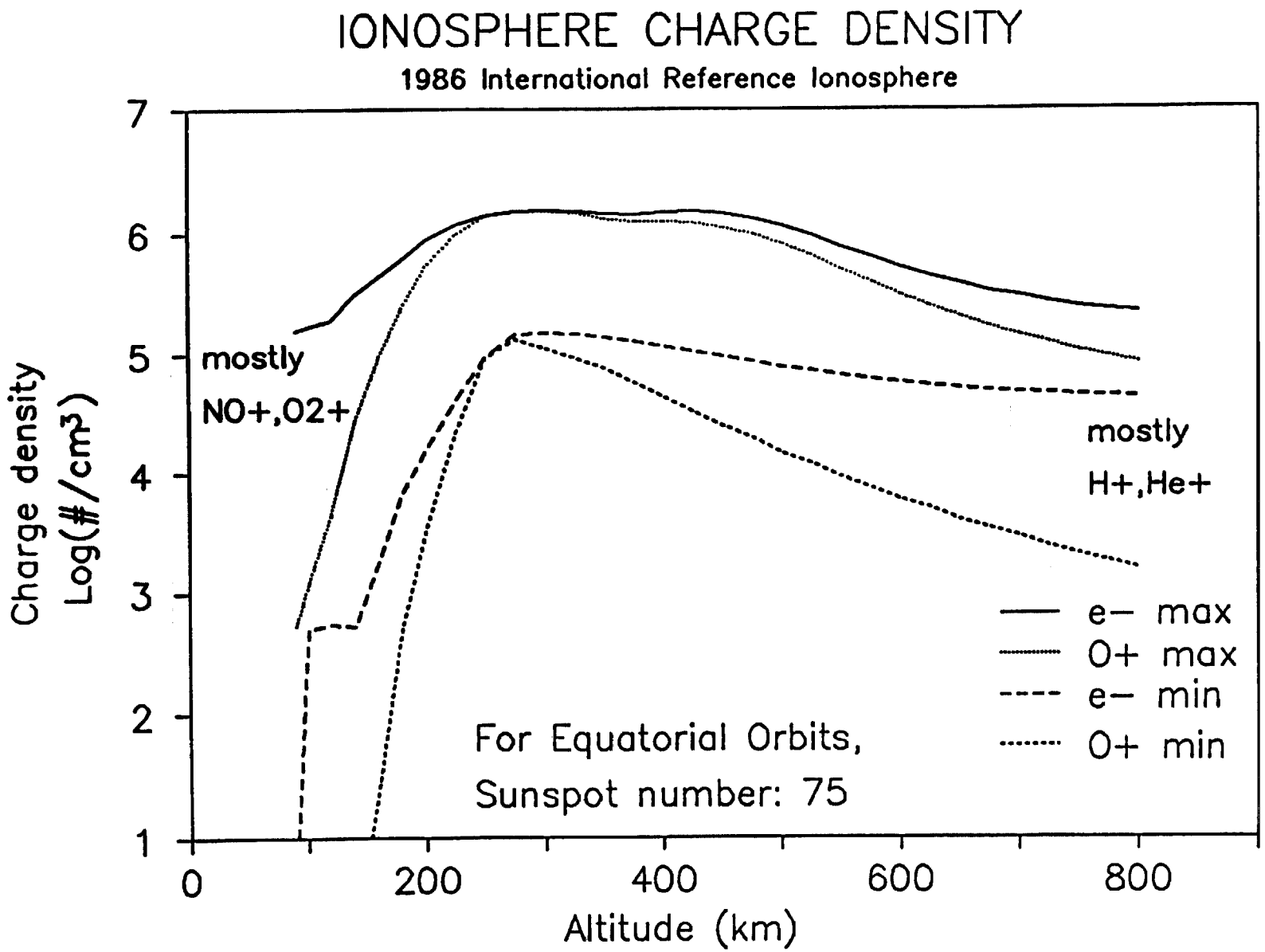
at 400 km: |B|=3.4E-5 tesla (an approximate high field)
20 deg dip angle

orbit velocity: 7.67 km/s

E = v x B => .26 V/m

Space Station Dimensions (approximate):
length: 110 m (10 V) (20 degree dip angle)
height (across solar arrays): 70 m (18 V , 0 deg. dip)

Chemical interactions with ions may be important.
Structure currents induced.
Plasma currents radiate noise.


IONOSPHERE CHARGE DENSITY
1986 International Reference Ionosphere
Charge density
Log(#/cm³)
7
6
5
4
3
2
1
0
200
400
600
800
Altitude (km)
mostly
NO+,O2+
mostly
H+,He+
e− max
O+ max
e− min
O+ min
For Equatorial Orbits,
Sunspot number: 75

SPACECRAFT FLOATING POTENTIAL

Steady State when:
ion current = electron current

This is achieved locally by charging a few kT negative to reduce the thermal electron current.

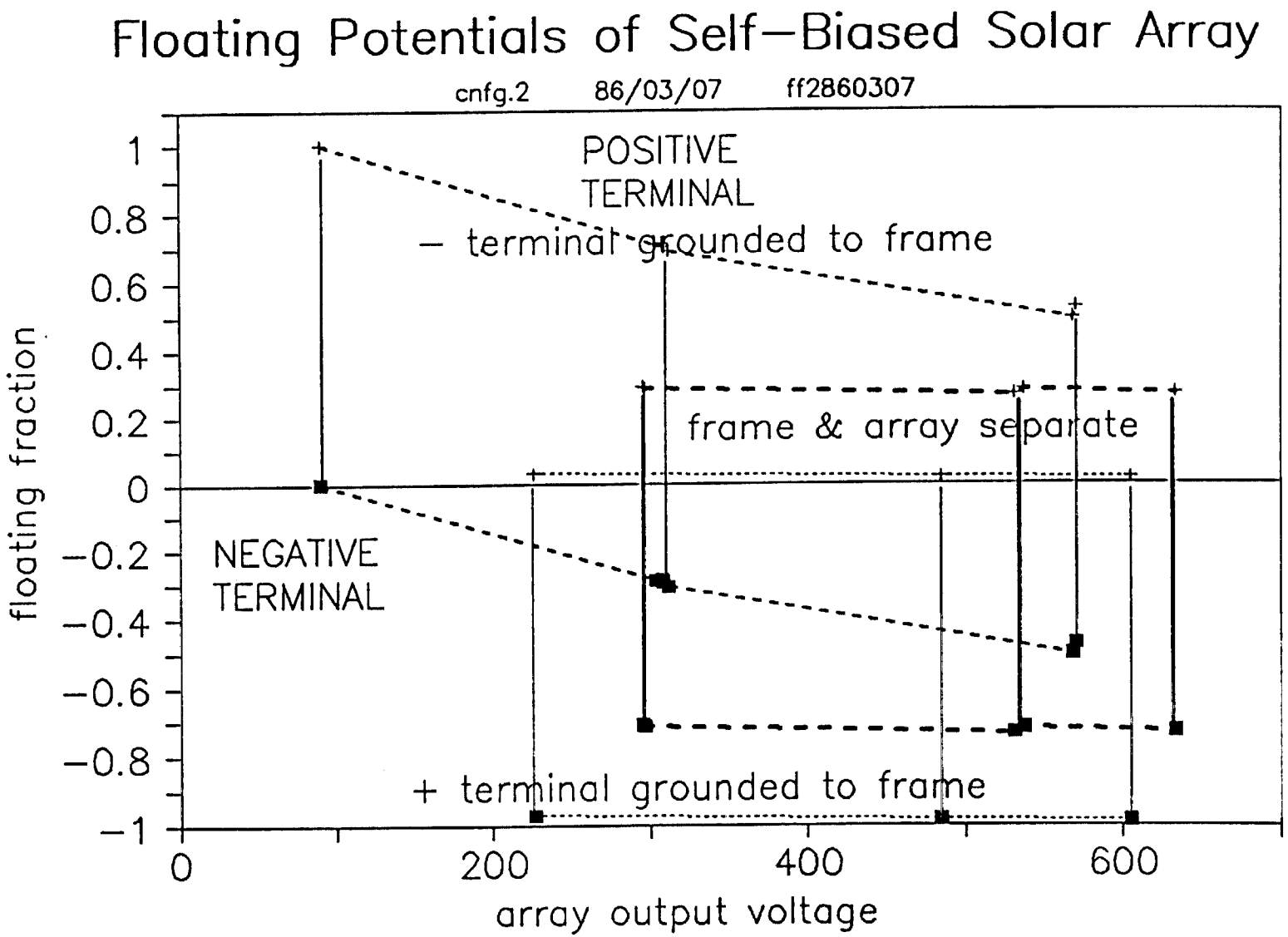
<u>Biased systems</u> (exposed conductors)

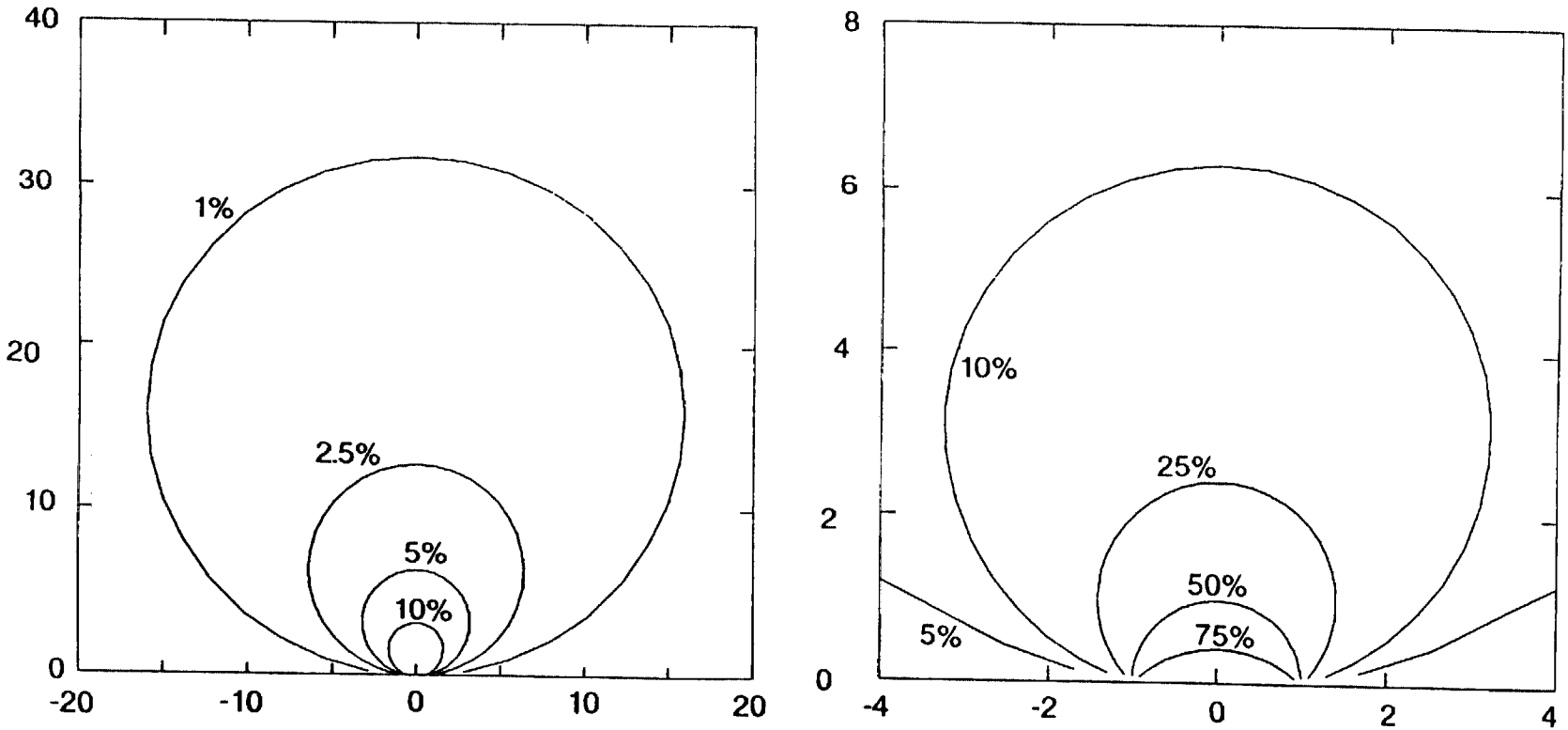
If Positive and Negative ends are widely separated the system floats mostly negative so that:

$A_{-\ sheath} * J_{ion} = A_{+\ sheath} * J_{e-}$ (thin sheath approximation)

If Positive and Negative ends are close together compared to thermal sheath thickness, the average potential over the biased area is a few kT negative.

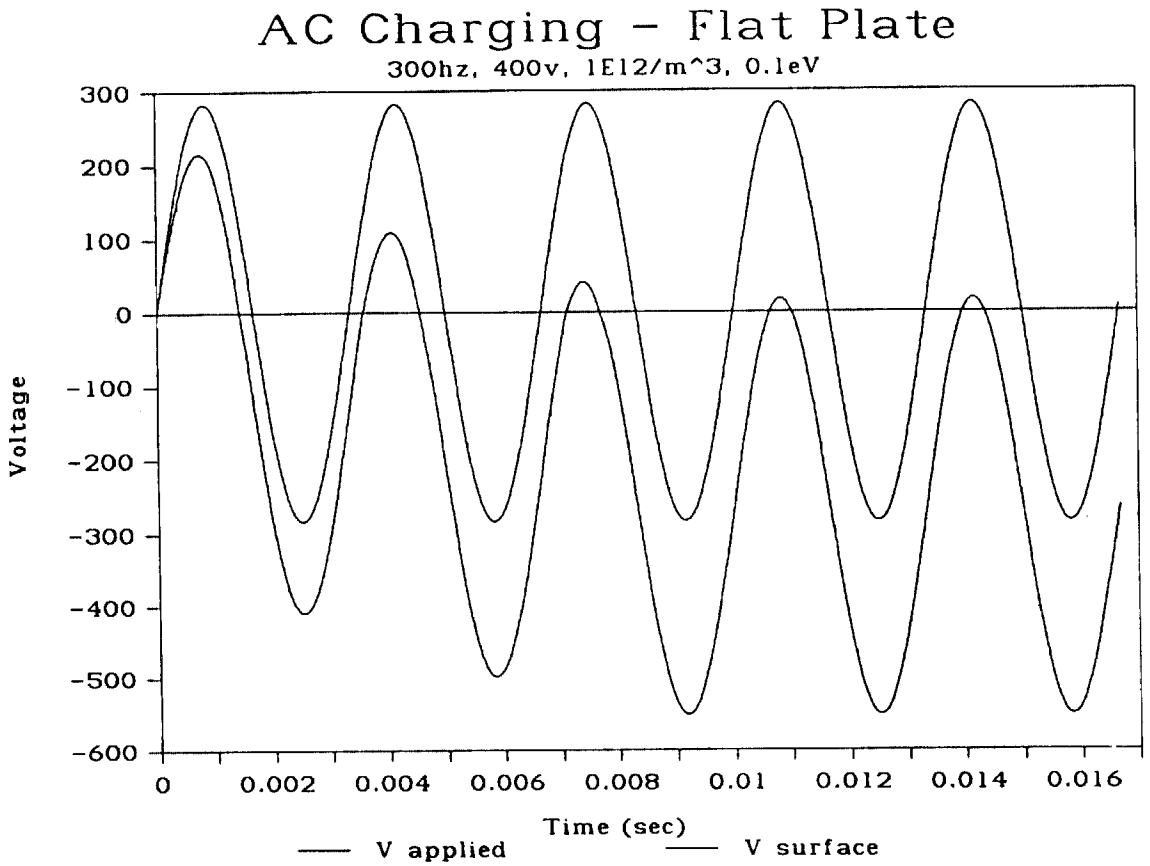
Large Areas of exposed conductor will determine the Floating Potential for the system.

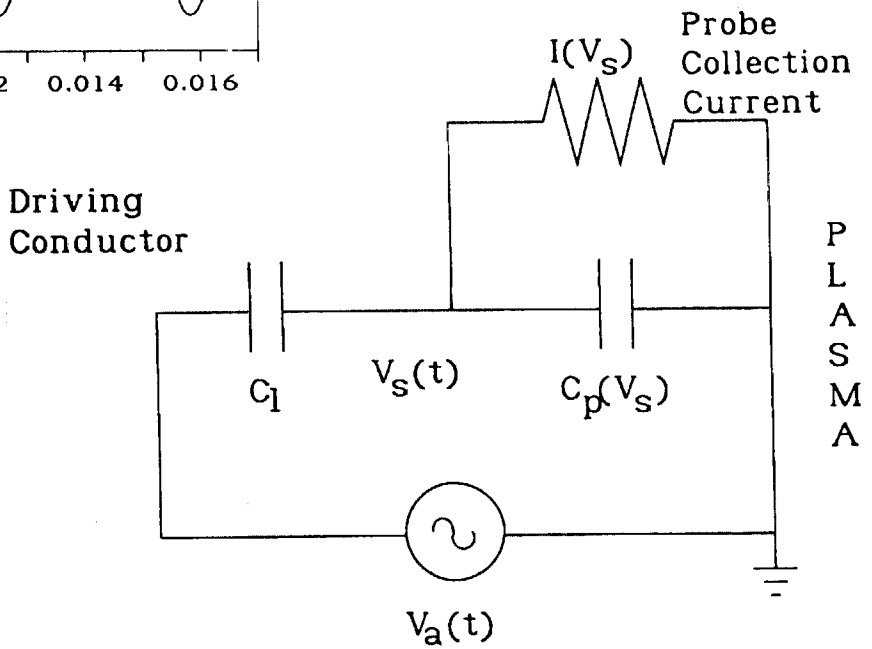

Floating Potentials of Self–Biased Solar Array
cnfg.2 86/03/07 ff2860307
POSITIVE
TERMINAL
– terminal grounded to frame
frame & array separate
NEGATIVE
TERMINAL
+ terminal grounded to frame
floating fraction
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
0
200
400
600
array output voltage



Electric Potential Contours for a biased slit

Solutions to LaPlace's Eqn. (i.e. no Plasma)





Conclusions

- GEO requirements are not directly applicable to LEO
- Environment Issues for Operating on Large Spacecraft
  - EMI levels
  - v×B·l induced voltage offset
  - Fluctuations of S/C ground relative to plasma
- Environment Issues for external payload design
  - Current Collection from Plasma
  - Discharges
  - EMI radiation
  - Sputtering