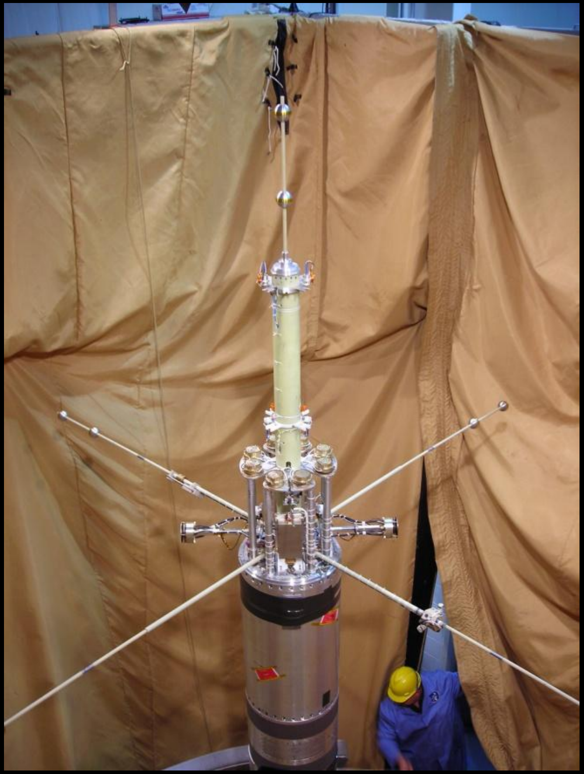
An Introduction to Sounding Rockets and Instrumentation



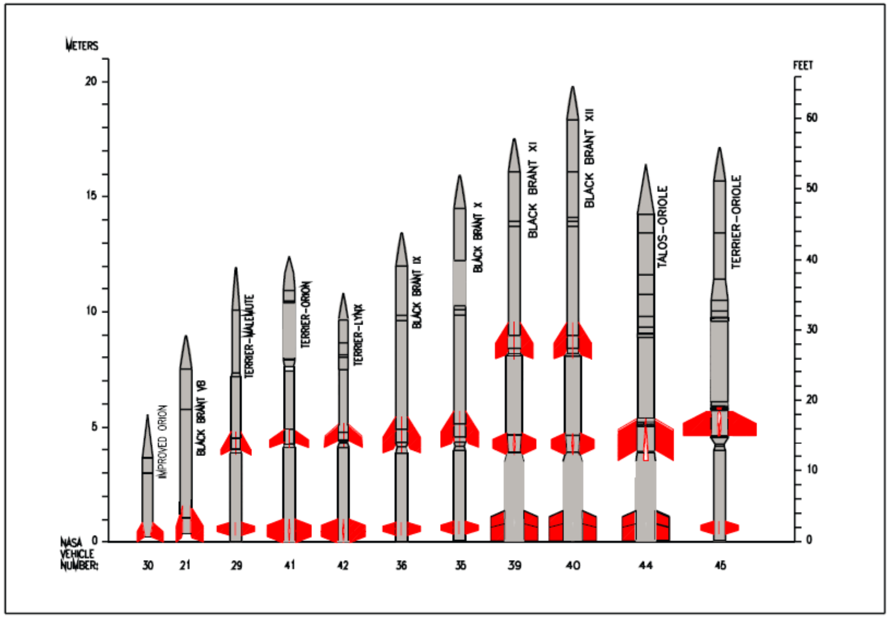
Stephen R. Kaeppler

University of Iowa

GEM/CEDAR Workshop - 26 June 2011

THE UNIVERSITY OF IOWA

Sounding Rocket Science



- *In-situ* observations of phenomena
  - Temporal/Spatial Issue
- Science with Rockets
  - Auroral Zone/Lower Magnetosphere
  - Ionosphere and Upper Atmosphere
  - Astronomy – Solar, X-ray, IR, Microgravity

- Altitudes: 0 – 1400 km
- Max Weight: 0-1600 lbs
- Flight Time: 0-1200 s
- Magnetically Aligned

Pros and Limitations of Rockets

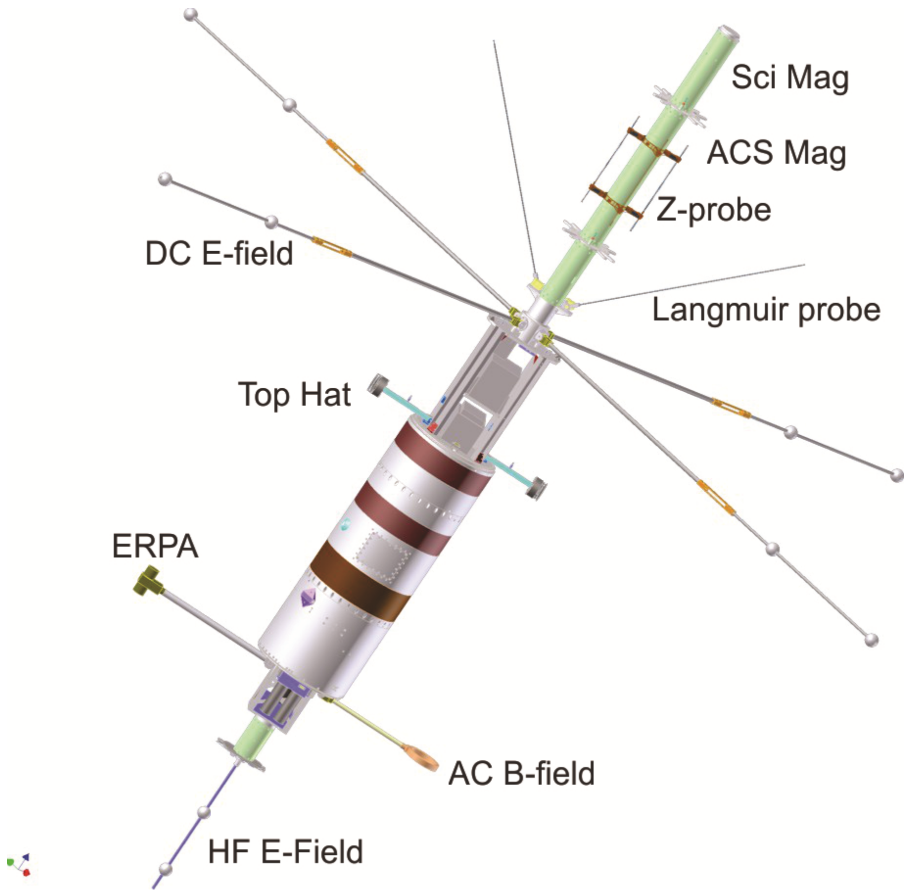
Pros

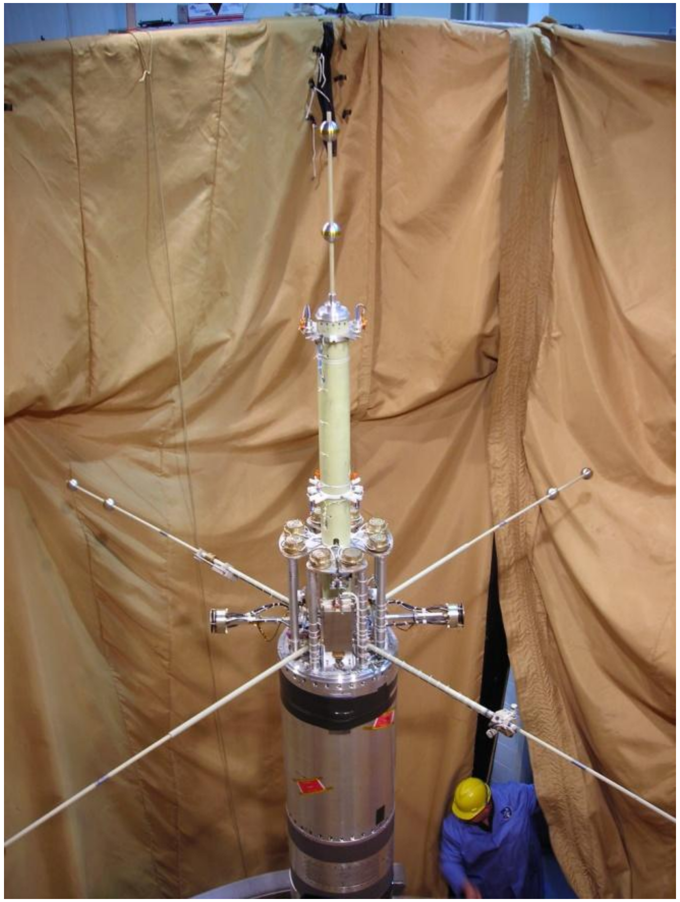
- Lots of science possibilities
  - Access to low altitude
- Fast turn around of data
- Relatively inexpensive
- Test-bed for PIs to test new instruments
  - Flight Heritage
- Training ground for PIs & graduate students
  - Instrumentation/data analysis

Limitations

- One shot, difficult to do continuous studies on phenomena
  - statistical studies
- Temporal/spatial issue in observations
- Limited launch locations
- Constrained by launch conditions
- Increased risk of failures
  - Lower Cost

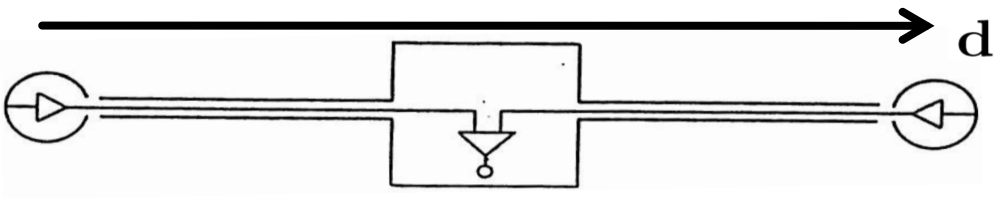
A Brief introduction to Instrumentation on Auroral Payloads



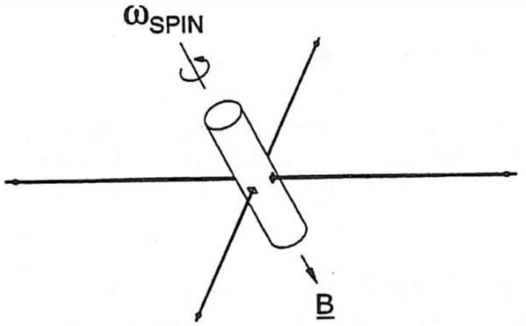


Techniques/Instruments presented common to auroral missions, but also overlap with many satellites

DC Electric Fields: Double Probes



$$\Delta\Phi = -\mathbf{E} \cdot \mathbf{d}$$



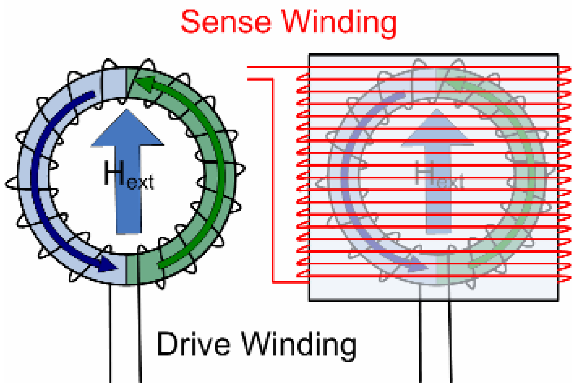
Operation: DC electric field measured through observed voltage (ΔΦ) and distance (**d**) between probes ("Voltmeter")
Parameters: Perpendicular DC electric fields, electron density (AC – cutoffs), spacecraft potential (charging)
Typical Measured Value: 0-500 mV/m, (50 mV/m in 50000 nT = 1 km/s flow)
Freq. Range: **DC:** 0 – 5 KHz, **HF:** 0-5 MHz

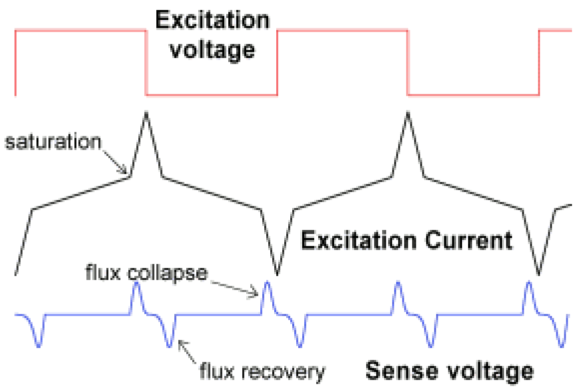
1. Gains and offsets: residual spin or coning, perpendicular cross calibration
2. Sheath effects/Spacecraft charging, probe coupling issues
3. **E** = **-V_{sc} x B** Correction

Kelly M.C., 2009 (Book – Appendix A); Gurnett, 1998 (Measurement Techniques)

Image: Gurnett, 1998 and Pfaff, 1996

DC Magnetic Field: Fluxgate Magnetometer





$$\Delta\Phi = nA\frac{\partial \mathbf{B}}{\partial t}$$

Operation: AC current drives core into oscillating saturation. During changing of magnetic flux (gating) a voltage is induced at $2f_o$ in sensing coil. Feedback loop in sense coil designed to null the induced field giving direction and magnitude of B-field.

Parameters: 3-D vector DC magnetic fields, currents

Typical Measured Value: 5000 – 60000 nT , **Residuals** 500 nT

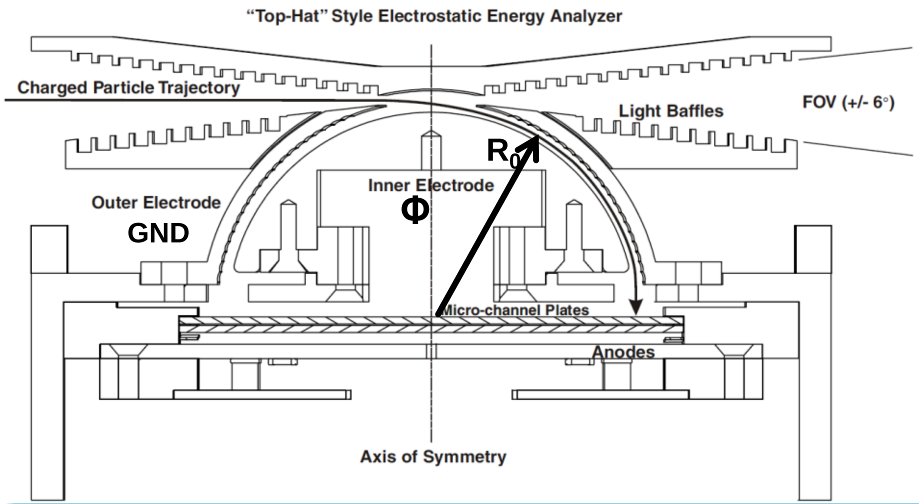
Freq. Range: 0 – 10 Hz; **Resolution:** 1-10 nT

1. Gains and offsets: residual spin or coning, perpendicular cross calibration
2. Slower response time, harmonic noise, temperature, must be calibrated

Kivelson and Russell, 1995 (p. 448); Primdahl, 1979; Acuna and Pellerin, 1969

Image: http://www.invasens.co.uk/Fluxgate20Wave.gif; http://www3.imperial.ac.uk/pls/portallive/docs/1/19371697.PNG

Electron and Ion Flux: Electrostatic Analyzers



$$\mathbf{F} = q\frac{\Delta\Phi}{\Delta r} = \frac{mv^2}{r_0}$$

$$W(eV) = \frac{e\Delta\Phi r_0}{2\Delta r}$$

Operation: Electron/ion guided if energy of particle matches the electric field created between the inner and outter electrode. Particles that strike microchannel plates are integrated over for a time interval (1 ms).

Parameters: Precipitating auroral ion/electron differential flux, plasma distribution functions (Lyons, 1984)

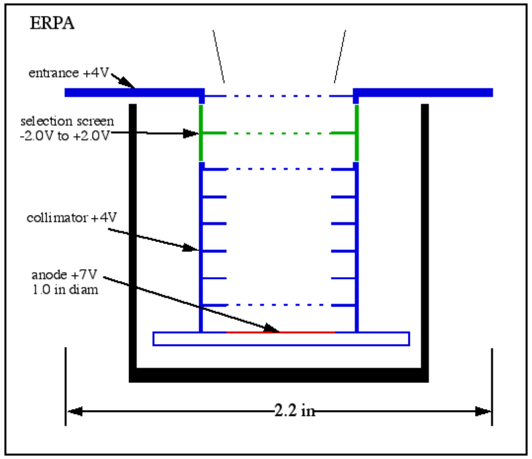
Typical Measured Value: $10^6 - 10^{11}$ (eV*#)/(cm^2 * ster * s* eV)

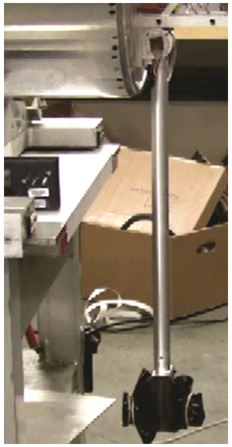
Energy Range:100 eV – 15 KeV in 50 ms sweeps; **Pitch Angle Range:** 0-180^o

Photo-effects, high voltage, sensitivity and cross contamination between counters

Carlson et al, 1983; Carlson and McFadden, 1998 (Measurement Techniques)

Electron and Ion Flux: Retarding Potential Analyzer



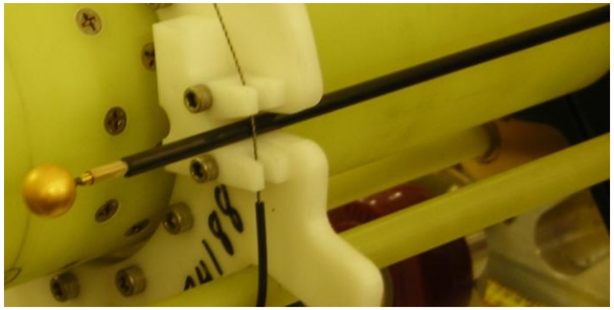


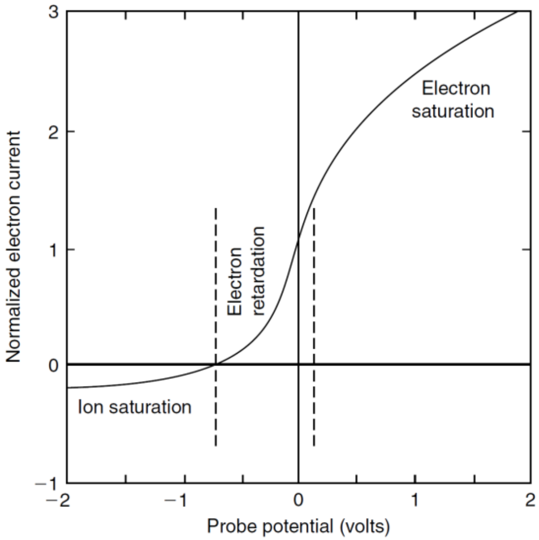
Operation: Swept potential set by selector screen to reject particles below a certain energy, all other particles counted. Current is collected on anode and measured through via low noise electronics.
Parameters: Cold electron/ion distributions (background), background temperature, plasma potential, currents
Typical Measured Value: 10-50 nA**,** 10-50 nA/eV, **Energy Range**: 0-30 eV

Spacecraft charging/sheath effects, very large count rates, field of view

Kelly M.C., 2009 (Book – Appendix A); Heelis and Hanson, 1998 (Measurement Techiques)

Electron Density: Langmuir Probes





$$I = \frac{1}{4} n_e e A \overline{v}$$

$$n_e = n_0 exp\left(\frac{e\Phi_p}{kT}\right)$$

Operation: Voltage swept or fixed, density is determined based in I-V characteristic of Langmuir probe. Three Regions: Electron/Ion Saturation, Electron Retardation
Parameters: Electron density, electron temperature, plasma potential
Typical Measured Value: $10^4 – 10^7$ cm^{-3}

Dependent on many assumptions to get a density (e.g. Mozer, 1979): spacecraft charging/sheath effects, probe size, plasma magnetization

Schott, 1968; Hutchinson, 2002; M.C. Kelly, 2009 (Appendix A); Chen, 2006

Image: Kelly, M.C., 2009 – Appendix A

Other Techniques

- Chemical release
  - Neutral wind studies/auroral studies
- Electron density
  - Impedance Probes
- AC B-field (EM Waves)
  - Search coils, Rogowski Coil
- Photometers/Imagers
  - Rees, 1963, RENU Mission 2010
- Neutral particle detectors
  - Time of flight style detectors

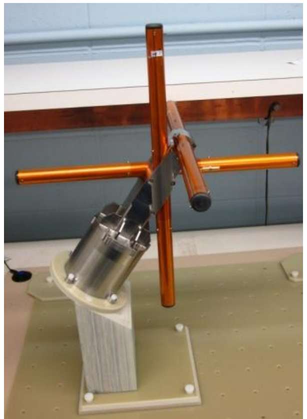
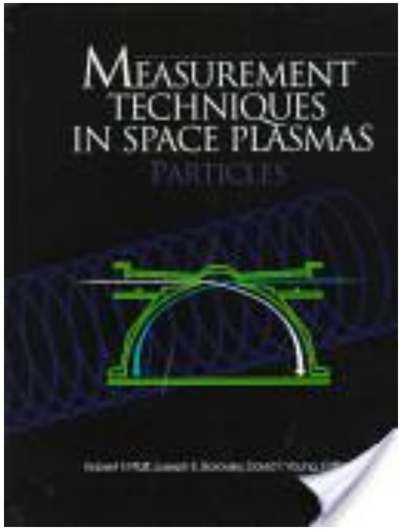
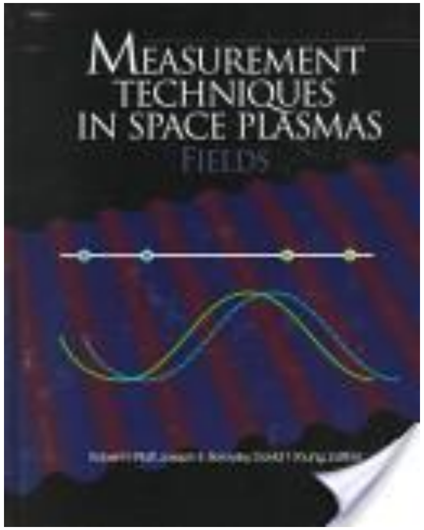
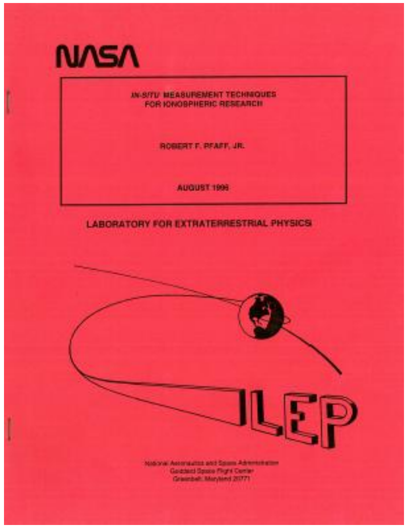


Image: Craig Heinselman: http://heinselslug.smugmug.com/

Summary/References







- Sounding rocket science, advantageous and limitations of sounding rocket science
- Terse introduction to a variety of instruments/techniques commonly used on sounding rocket (satellite) missions including some resources
- More extensive review of a variety of instruments/techniques in Kelly, 2009 and sources therein, along with books listed above.

Thank you!