Sounding rockets for Canadian space research

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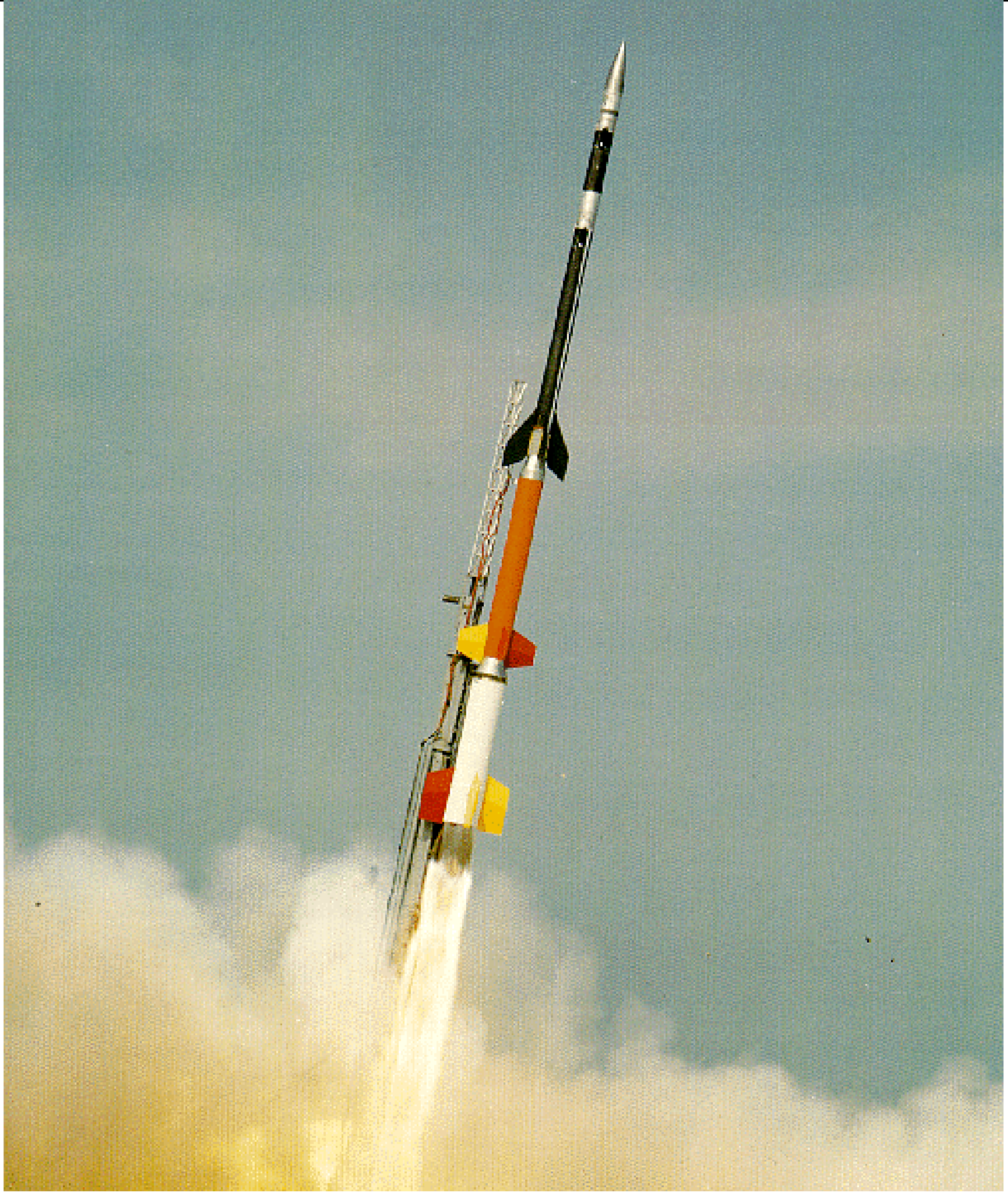
CSA Workshop on Suborbital Platforms and Nano Satellites, CSA/St-Hubert, 14 April 2010

James_CSA_Workshop_Rockets_eng.ppt



Talk outline

- Attractive features of sounding rockets.
- Illustrative examples.
- Programmatic considerations in Canada.

Tomorrow: Kotelko presentation of Magellan rocket capabilities

Features of Rocket Missions

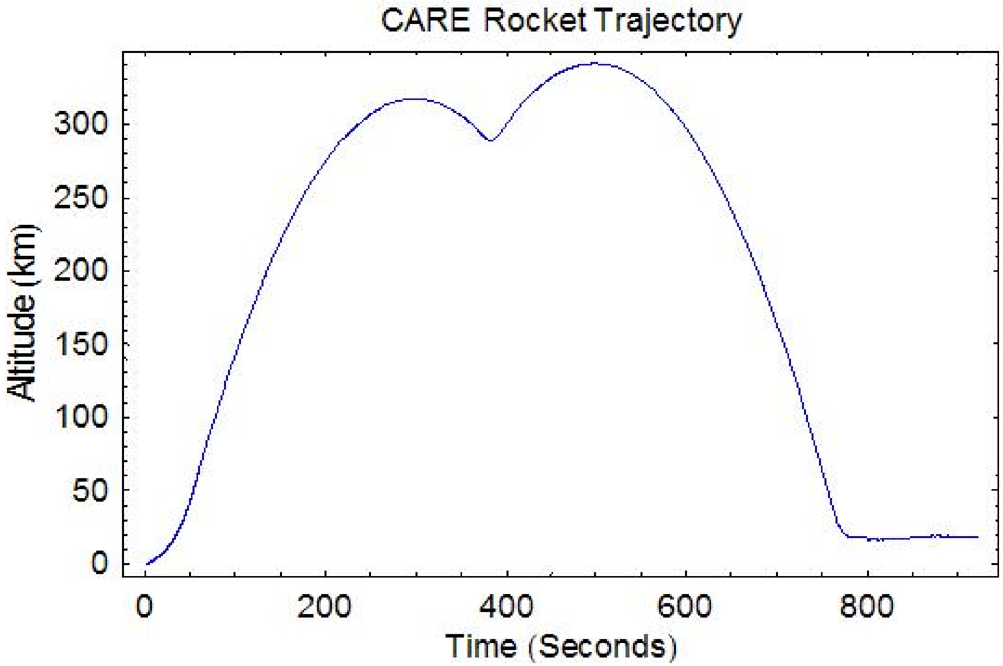
Range of disciplines: Aeronomy, Space Environment, Astronomy, Microgravity (in, from, **on**)

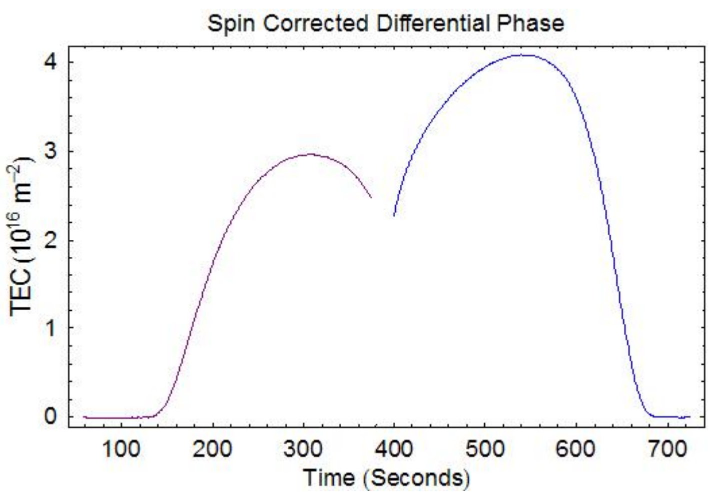
Turn around times smaller than for orbital missions

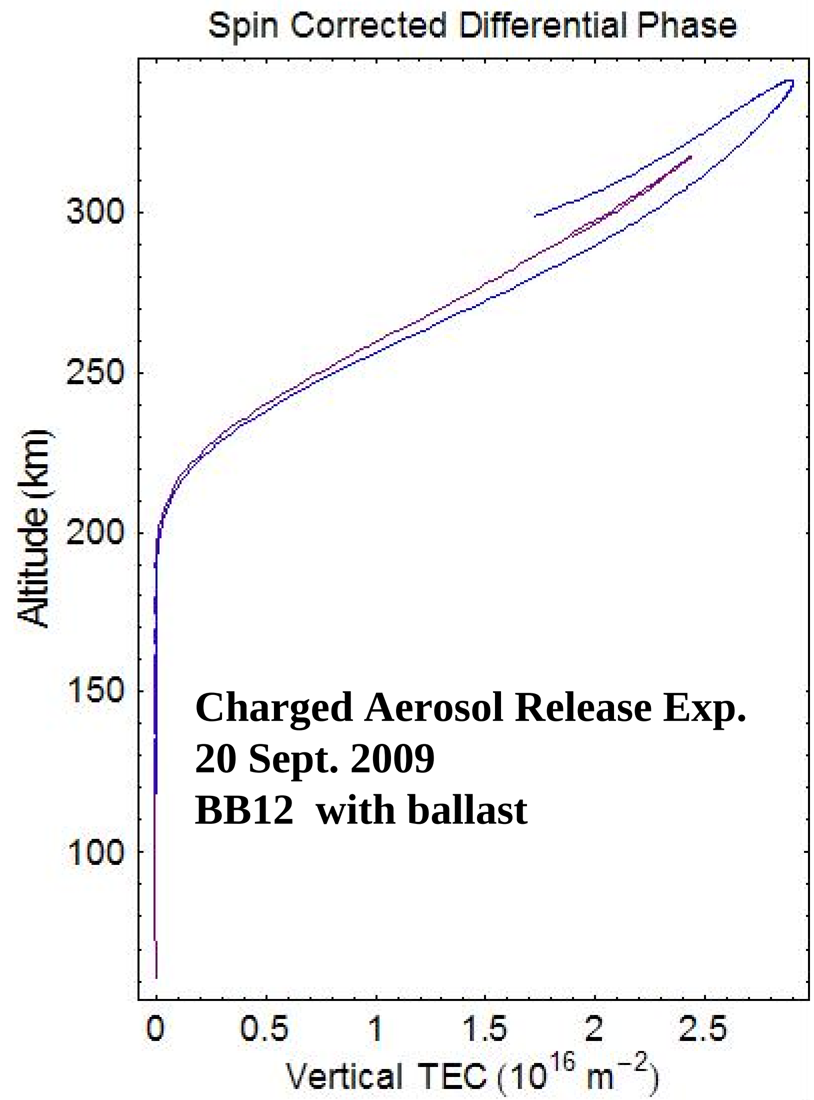
Focussed, specific research objectives.

Parabolic trajectories, nearly vertical legs, "hover". (CARE)

CARE I Rocket TEC from NWRA Receiver at Chesapeake, VA







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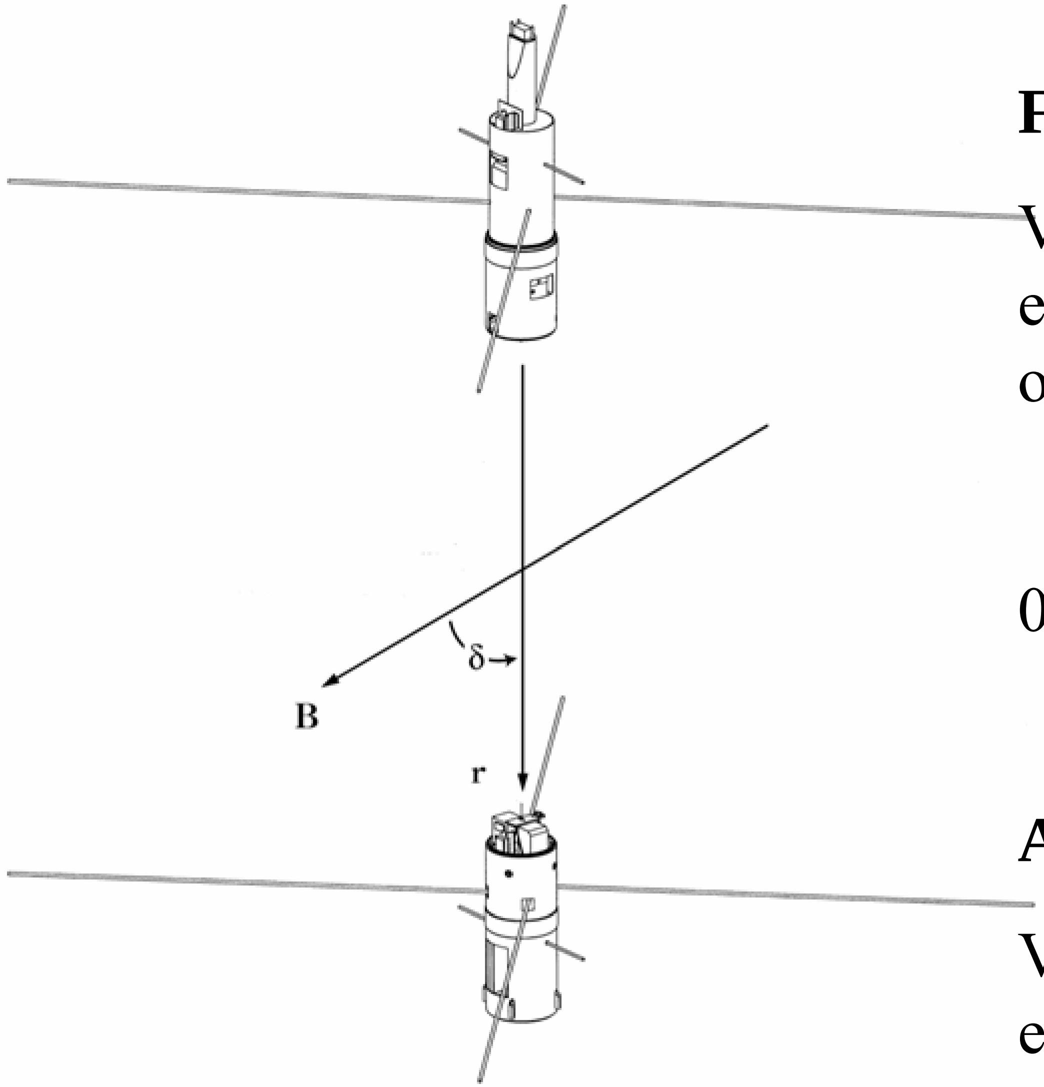
Overall time in space is brief (5-20 min) but fruitful if carefully designed. (OEDIPUS C)

OEDIPUS C right after separation



Forward subpayload has

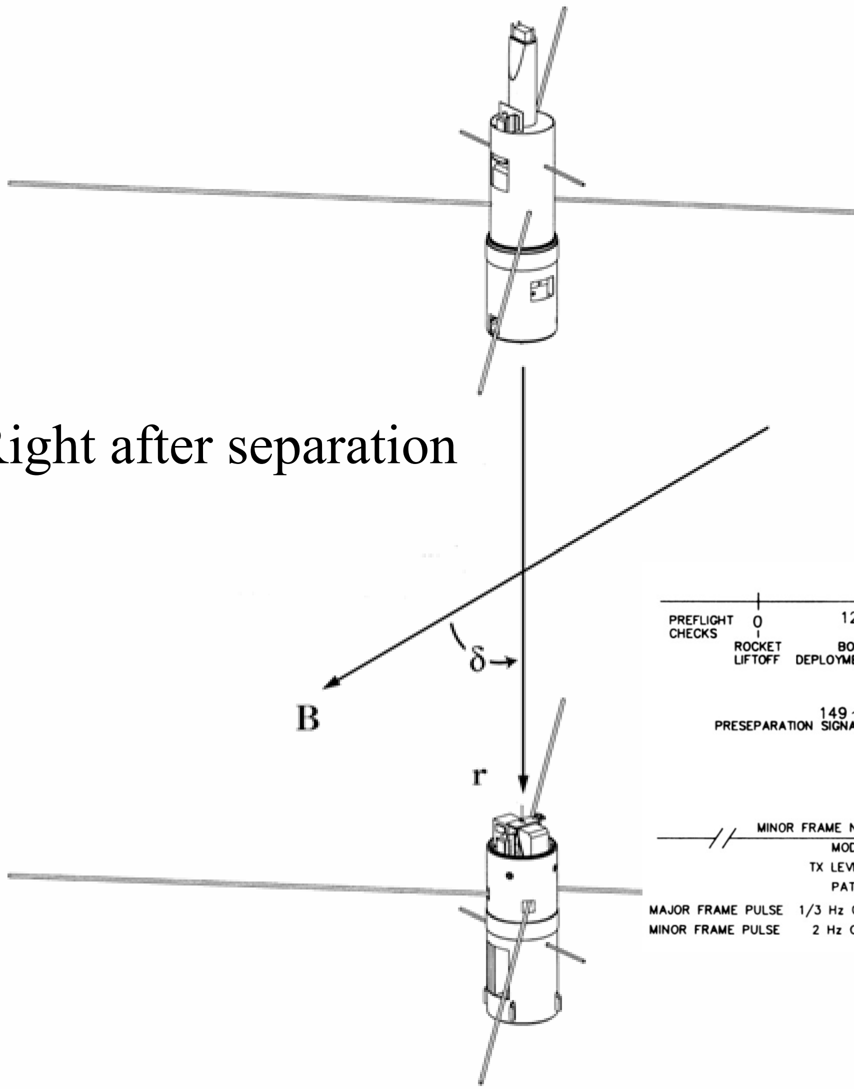
VLF-HF exciter (HEX), energetic-particle and other instruments.

$0.2° < \delta < 5°$.

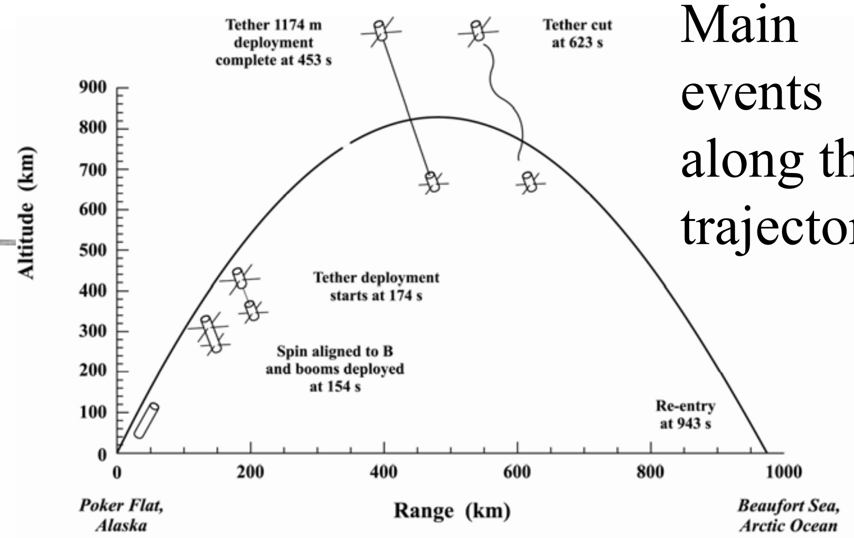
Aft subpayload has

VLF-HF receiver (REX), energetic-particle and other instruments.

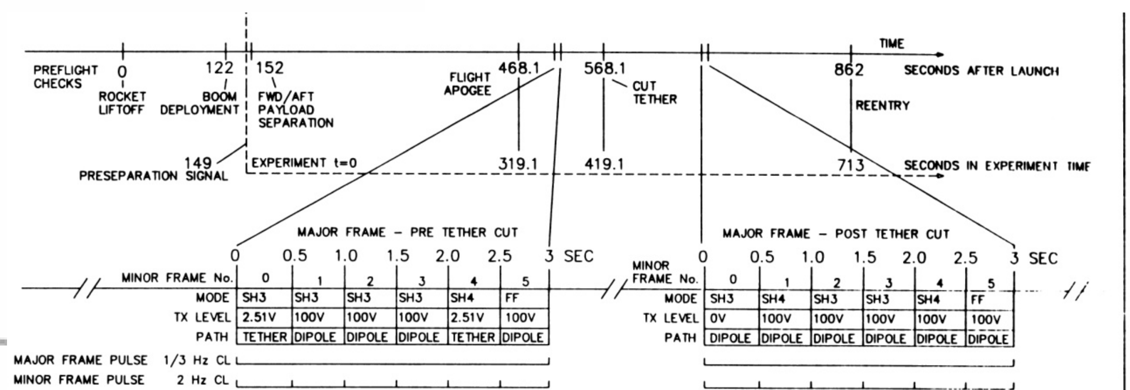
OEDIPUS C



Right after separation



Main events along the trajectory



Three-second duty cycle

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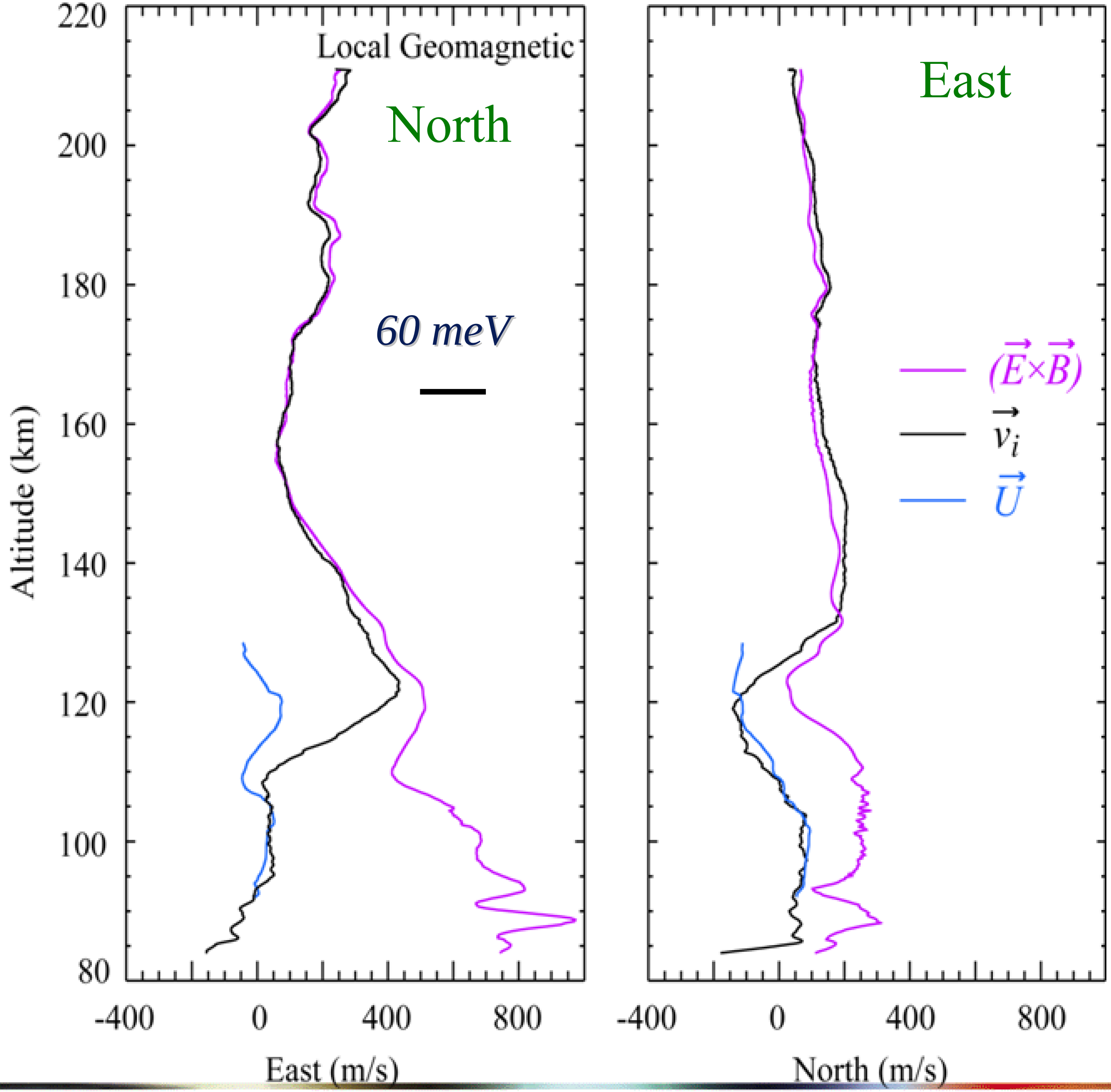
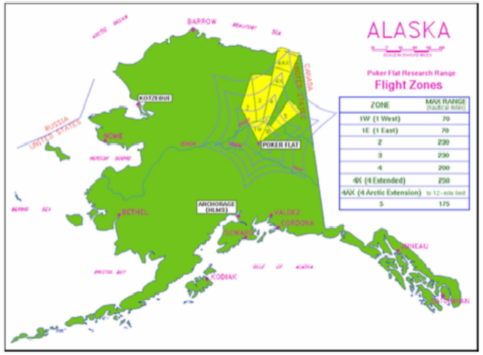
Sole access to important regions of space : Mesosphere to the lower ionosphere. (Joule II)



JOULE-II Downleg Jan. 2007



Sangalli et al., JGR, 2009

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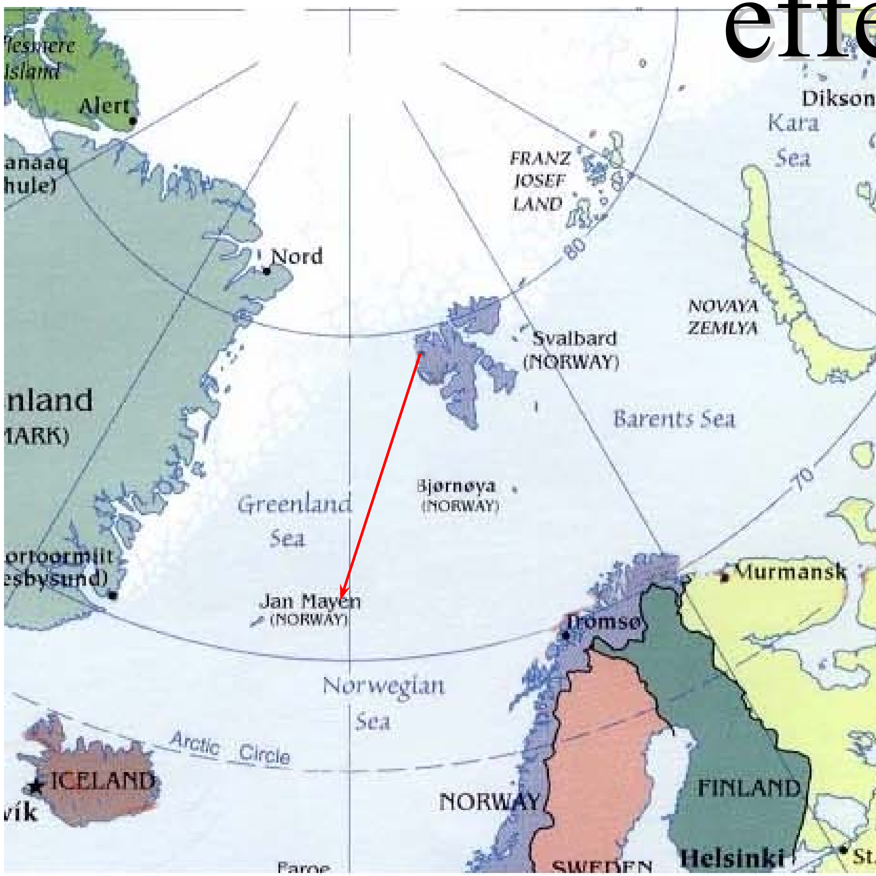
Microgravity missions: Minutes of free-fall without interference, noise.

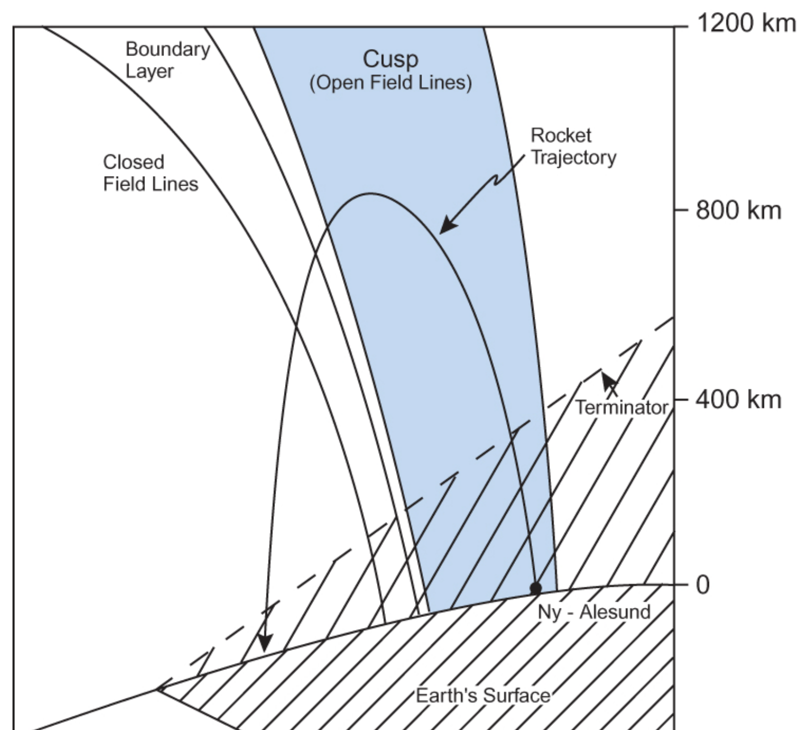
Features of Sounding Rockets, cont'd

- Optical obs. of astronom., solar, and planetary sources can be made of radiation at wavelengths absorbed by the lower atmosphere. (GEMINI, ACTIVE)
- Ability to fly relatively large payload (~500 kg) masses on inexpensive vehicles. (CSAR, GEMINI)
- Ability to use the Earth's limb as an occulting disk to observe astronomical sources close to the Sun.
- Aim at specific geophysical targets such as the aurora, equatorial electrojet, noctilucent clouds, polar wind (Cusp)

Cusp rocket: Polar wind cause & effect

14 December 2002





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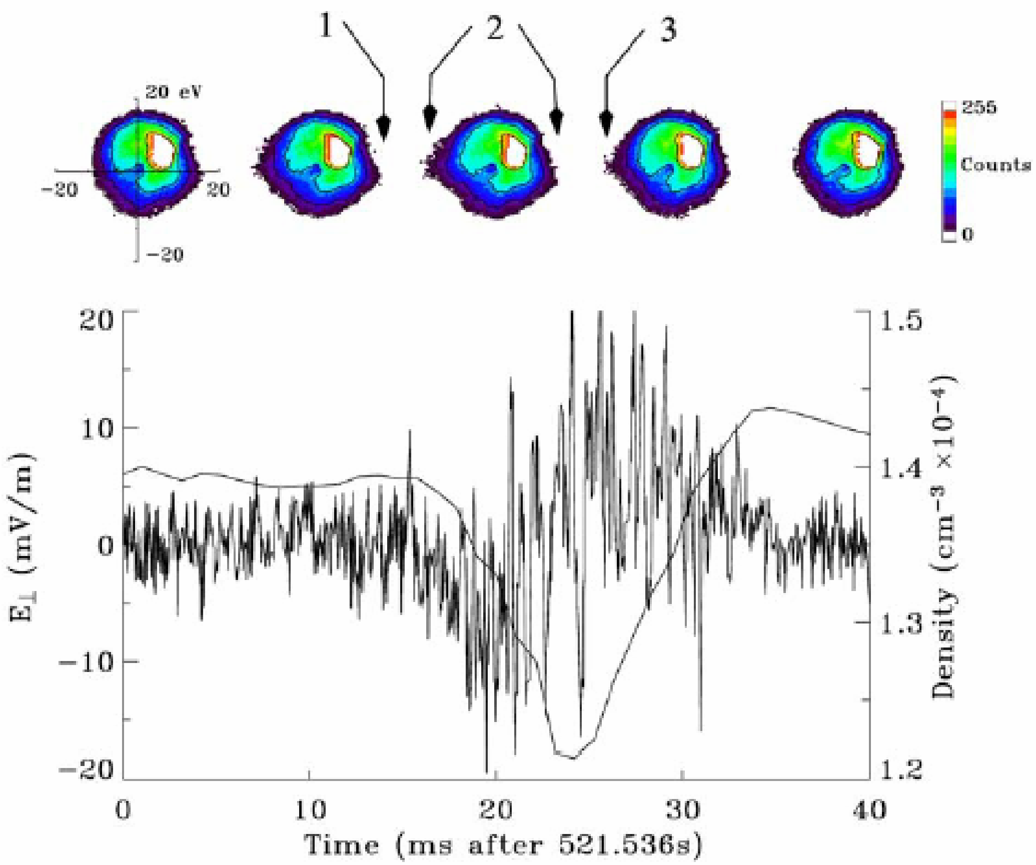
- Access to remote geophysical sites and southern hemisphere astronomical objects. (Eclipse studies, 1970; Cape Parry dayside aurora, 1974)
- Slow vehicle speed with respect to the ambient medium, slower than orbiting satellites, yields better resolution of structure. (GEODESIC)

Lower Hybrid Solitary Structures in Topside Ionosphere



- LHSS signatures
  - Density depletion
  - TAI and/or BB VLF noise
- GEODESIC rocket, 980 km (Burchill 2004)
- Low-energy ion distributions
  - 11 ms/13 m resolution
  - T ~ 0.2 eV (rammed O^+ ions)
  - Heated ions at several eV
- Observed density cavity
  - ~15% depletion
  - Temp. extent: ~10 ms

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- Slow vehicle speed with respect to the ambient medium, slower than orbiting satellites, yields better resolution of structure. (GEODESIC)
- Ability to fly simultaneous rockets along different trajectories, e.g., with different apogees, flight azimuths ; or a series of rockets along the same trajectory whose conditions are changing with time (Eclipse studies, 1970).

Eclipse studies with rockets at different times and radio partial reflection

Track change in A_X/A_O as moon shadow moves through trajectory

628 J. S. Belrose, D. B. Ross and A. G. McNamara

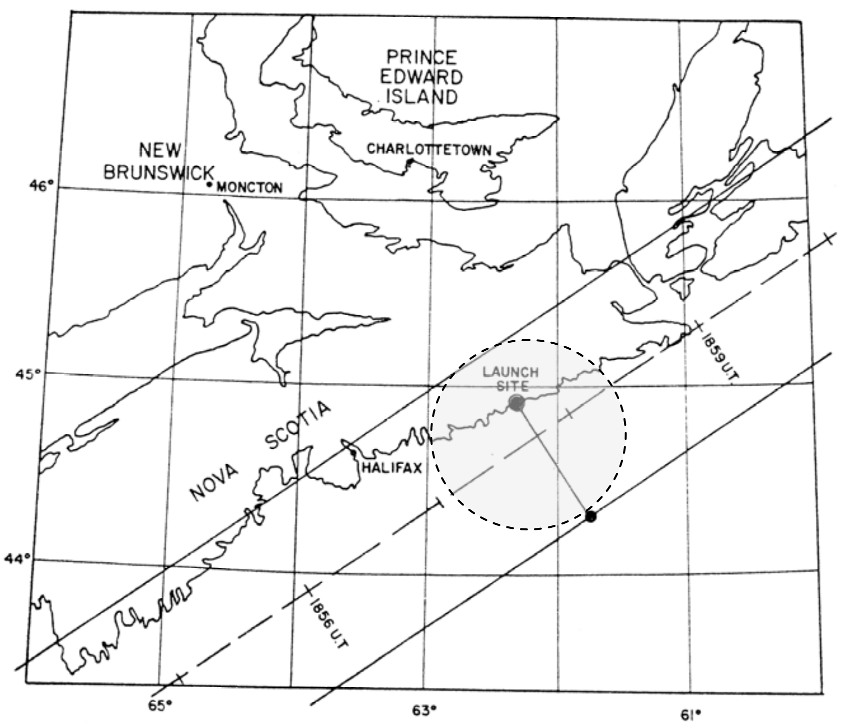
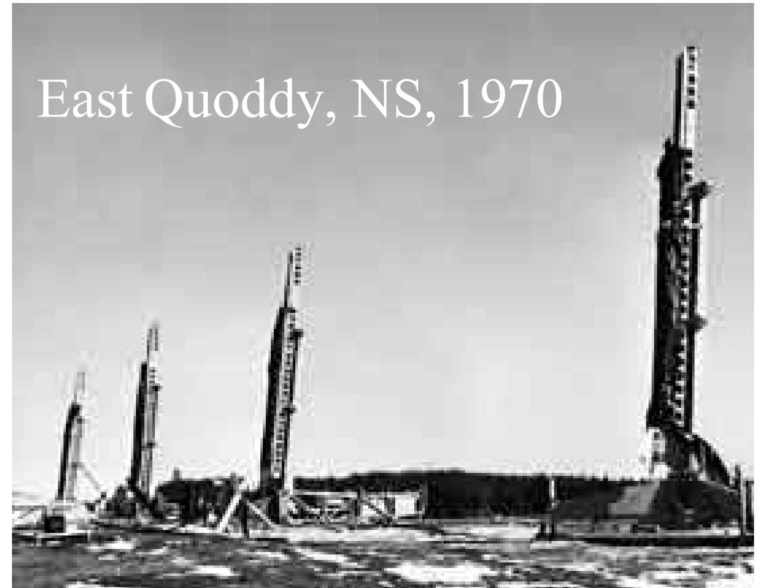
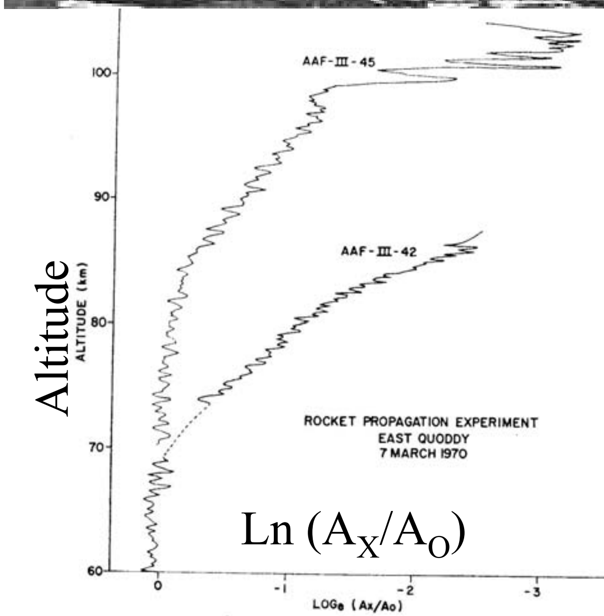


Fig. 1. Map showing the location of the launch site at East Quoddy and the path of totality at 100 km for the eclipse of 7 March 1970. The rocket launch and impact points are marked.





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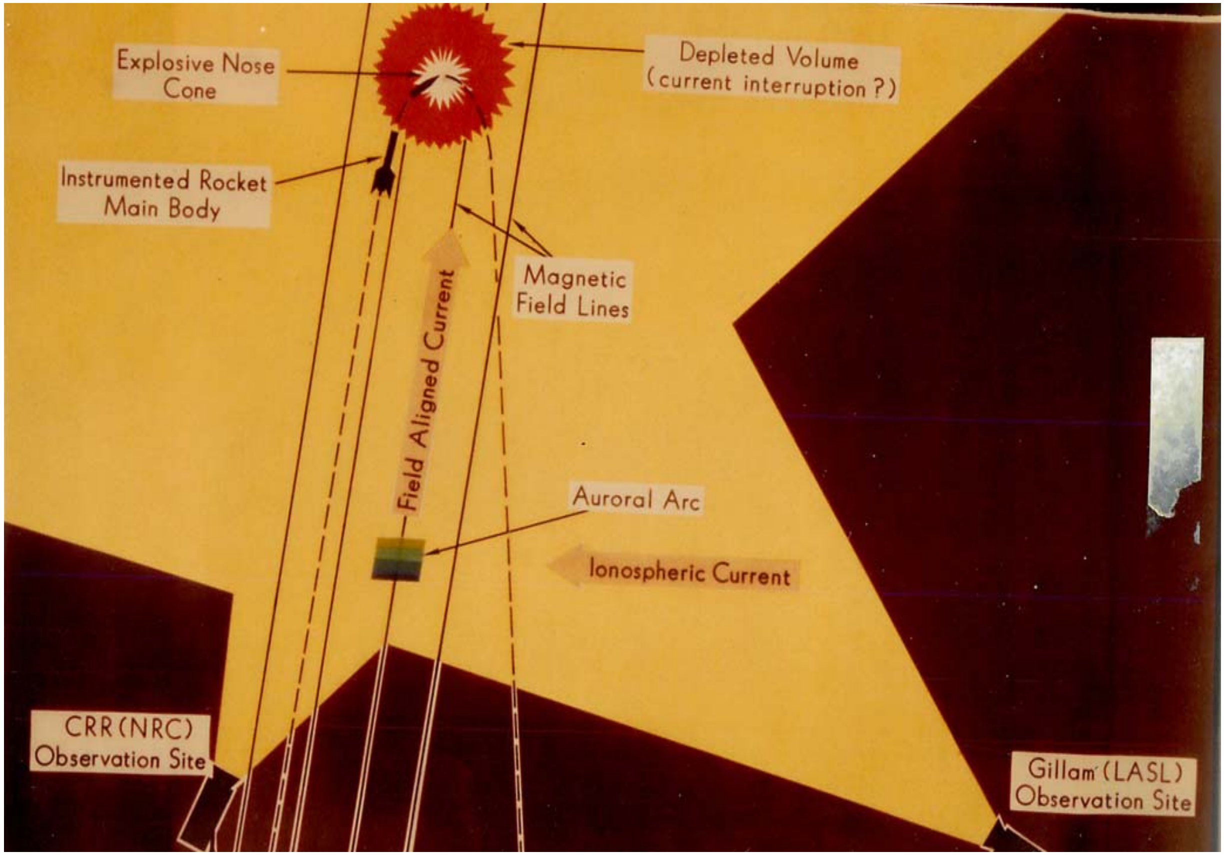
- Ability to fly simultaneous rockets along different trajectories, e.g., with different apogees, flight azimuths (Eclipse studies, 1970).
- Free-flying sub-payloads from a single launch at small separations. (OEDIPUS)
- Exploits possibilities in active experiments (Waterhole, CARE, OEDIPUS) .

Project Waterhole 1981-1984: The Concept …



Release water vapor into F-region above aurora

H_2O^+ and CO_2^+ ions dissociatively recombine to produce ion hole: "Waterhole"

Reduce ionospheric conductivity and disrupt auroral current system and …

Project Waterhole 1981-1984: The Science …

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 86, NO. A7, PAGES 5601–5613, JULY 1, 1981

Observations of Particle Precipitation, Electric Field, and Optical Morphology of an Artificially Perturbed Auroral Arc: Project Waterhole

A. W. YAU, B. A. WHALEN, AND F. CREUTZBERG

Herzberg Institute of Astrophysics, National Research Council of Canada

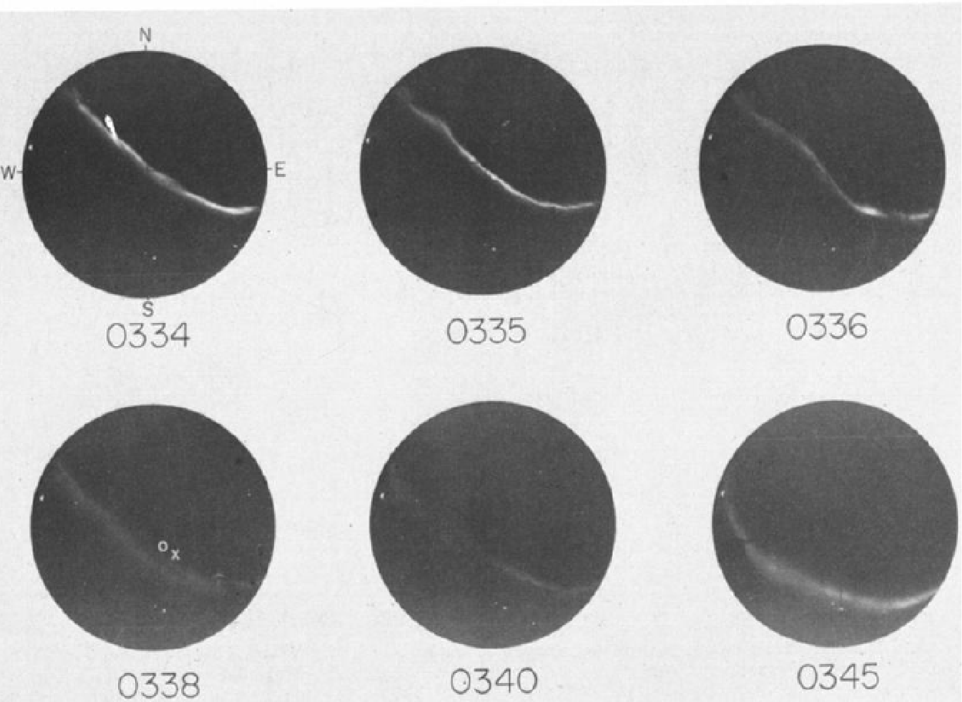


Fig. 11. ASC images of the auroral arc from 0334 to 0345. All frames were taken with 3-s exposure. Visibility thre
d of images is about 15 kR. The cross and the circle in the frame at 0338 denote the release point and its projection dc
100 km, respectively.

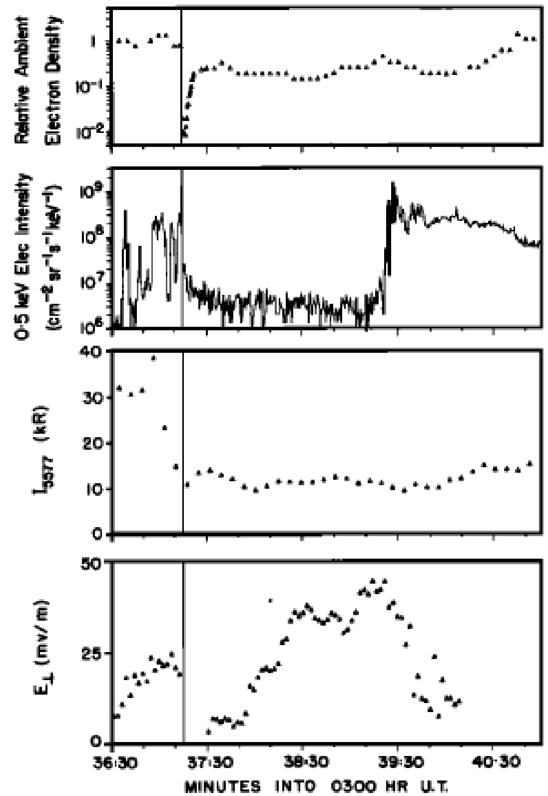


Fig. 13. Summary plot of in situ particle and field, and ground-based photometric measurements. (From top to bottom) Relative

Ionospheric depletion ⇒ auroral current disruption ⇒ auroral dimming

Validating New Instruments and Developing New Technology

- Low-cost testbed for new scientific techniques and instrumentation.
- Innovative technology 'proto-typed' for orbital assignments.

Sounding Rocket		Satellite	
Mission	Instrument	Mission	Instrument
GEODESIC, Joule, Cusp	SII, SEI	Swarm	EFI
		C/e-POP	SEI
ACTIVE S-520	TPA	Planet-B	TPA
	GPS	C/e-POP	GAP
	TSA	C/e-POP	IRM
	POSSEX	ODIN	OSIRIS

Education, training, capacity building

Examples: students (being) educated and trained through some stages of a sounding rocket mission led by D. Knudsen:

- S. Franchuk on OEDIPUS C
- J. Burchill on GEODESIC (now at U. Calgary)
- B. Bock
- L. Sangalli on Joule II (now at RMC)
- B. Archer on Joule - II
- R. Kabirzadeh on GEODESIC

Low-cost Access to Space

Canadian payload development costs.

Limited telemetry and tracking required.

Project management and payloads construction
in one central location.

Commonality of rockets, payloads, and sub-systems
flown more than once.

Costs of recoverable payload can be spread out over missions.

Lower design risk is acceptable.

Project costs to CSA of Canadian science payloads developed at Bristol

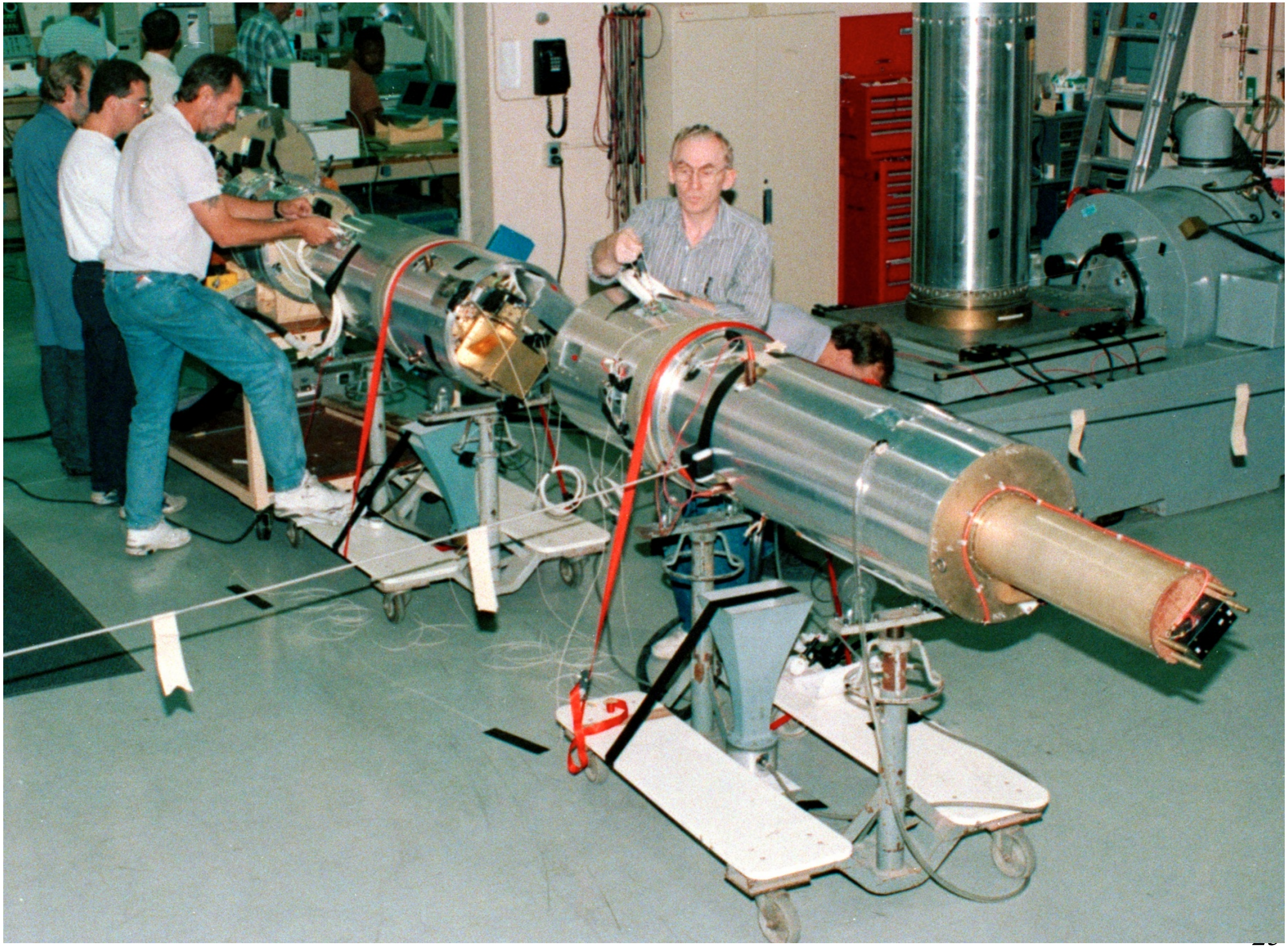
• OEDIPUS A	\$3 M	1989
• CSAR-1		1992
• GEMINI	\$6 M	1994
• CSAR-2	\$4 M	1994
• OEDIPUS C	\$7 M	1995
• ACTIVE		1998
• GEODESIC	\$4 M	2000

CPI-current/CPI-1995 = 116./88. = 1.31

Programmatic considerations in Canada

- Last seven payloads were sophisticated and expensive.
  - Better value in instruments for foreign launch?
  - Better synergism on focussed missions?
  - Can students have meaningful participation ?
  - What are PA/QA norms for $M payloads?
- What capacity does CSA want built?
- Last Bristol sci. payload was GEODESIC, 2000
  - Magellan intends to maintain rocket expertise.

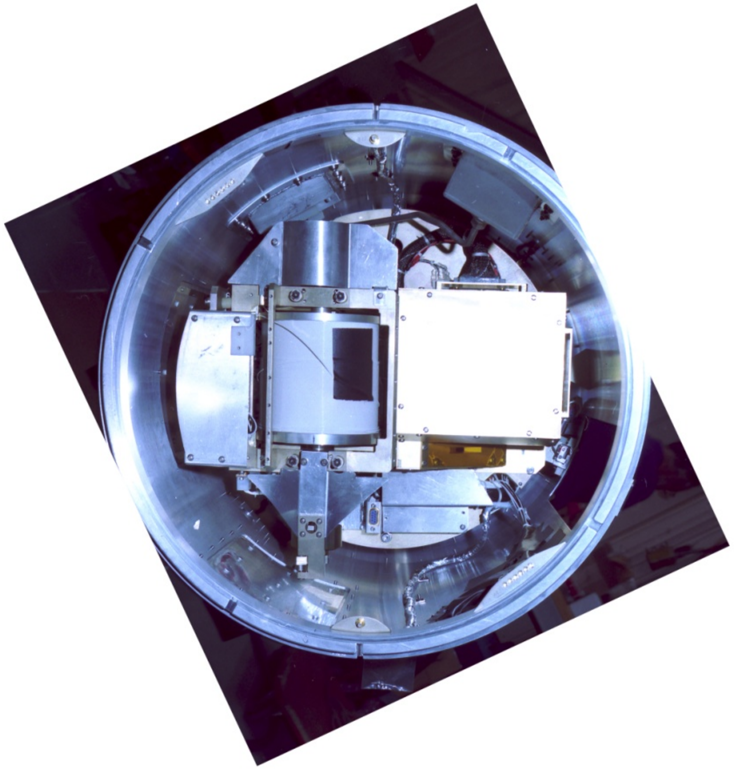
OEDIPUS-C double payload under test at BAL in 1995



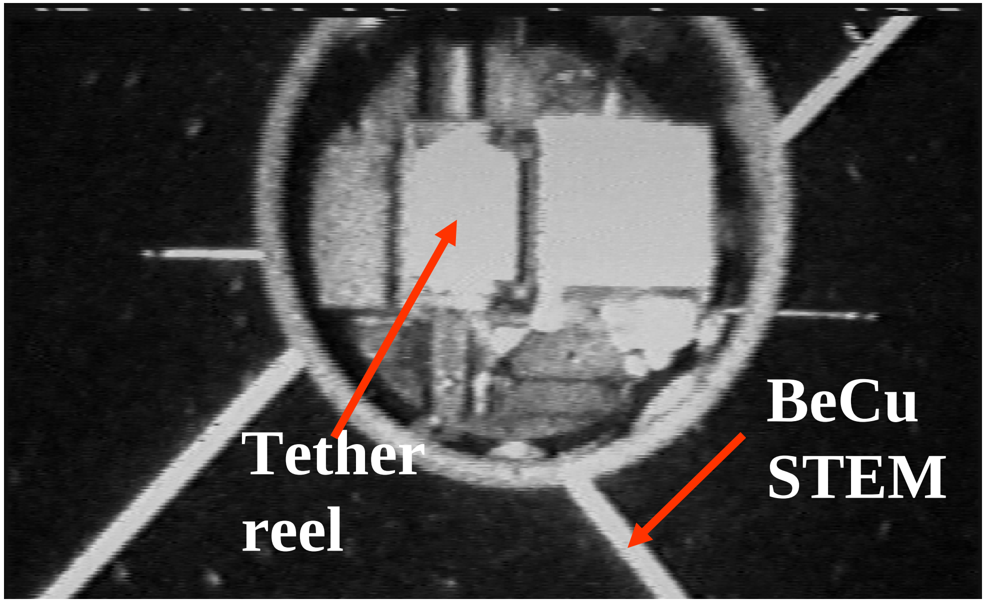
Principal Points

- 1) Sounding rockets continue to offer a rich variety of unique experiments.
- 2) Community needs to understand the program imperatives of the 2010 CSA budget.
- 3) Community needs to think about personnel required for this kind of science.

OEDIPUS-C forward subpayload, back end.

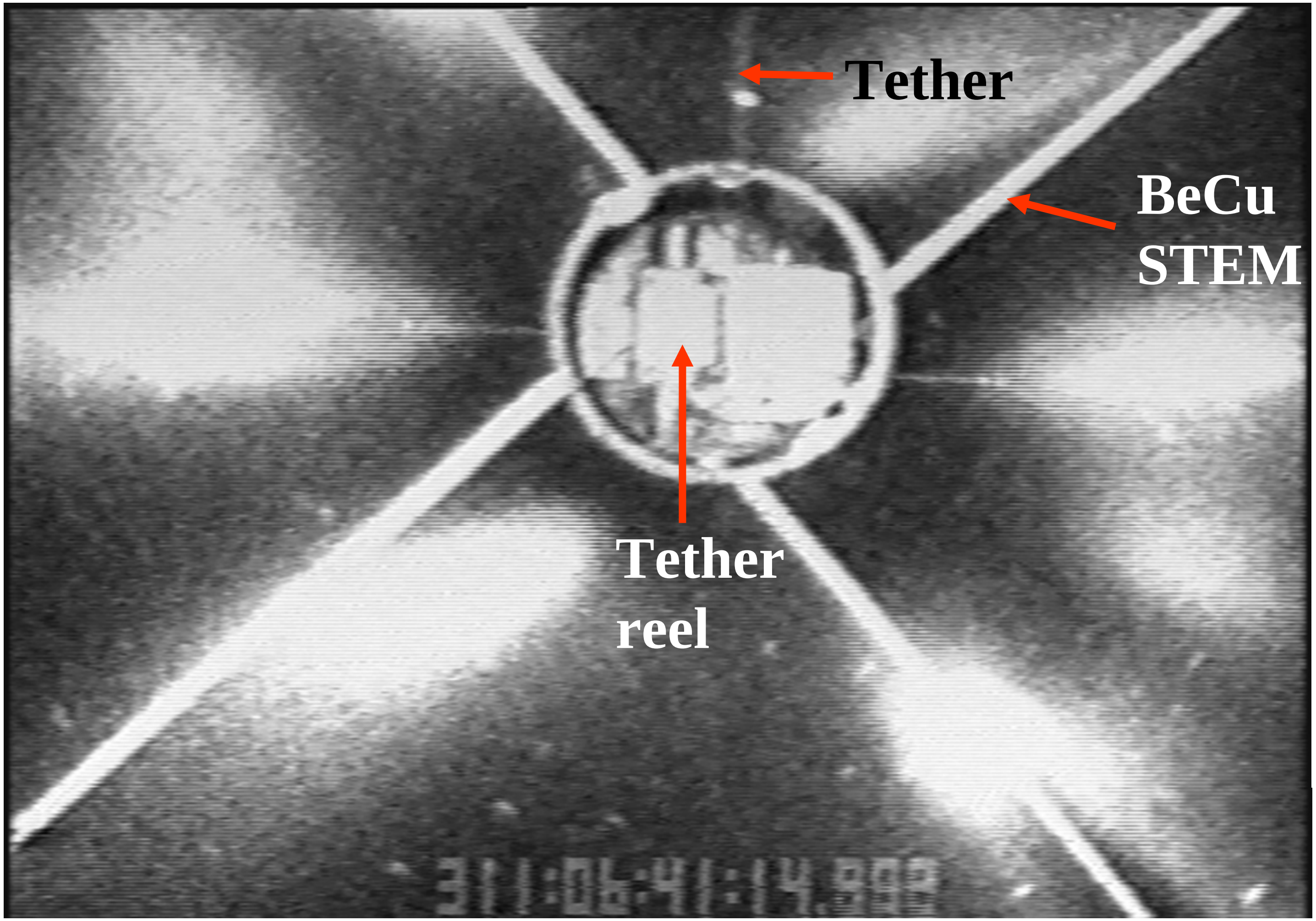


On the bench



Flight movie, +1 s after separation

OEDIPUS-C movie, +3 s



Luminosity results from electron impact on Ar atoms from thruster on forward subpayload.

First 30 s after OEDIPUS-C separation