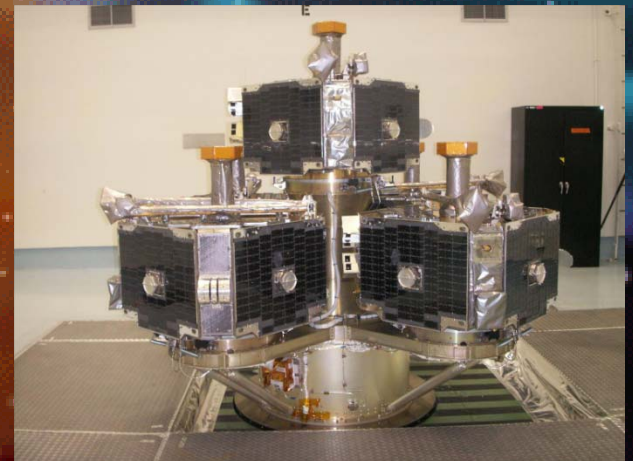
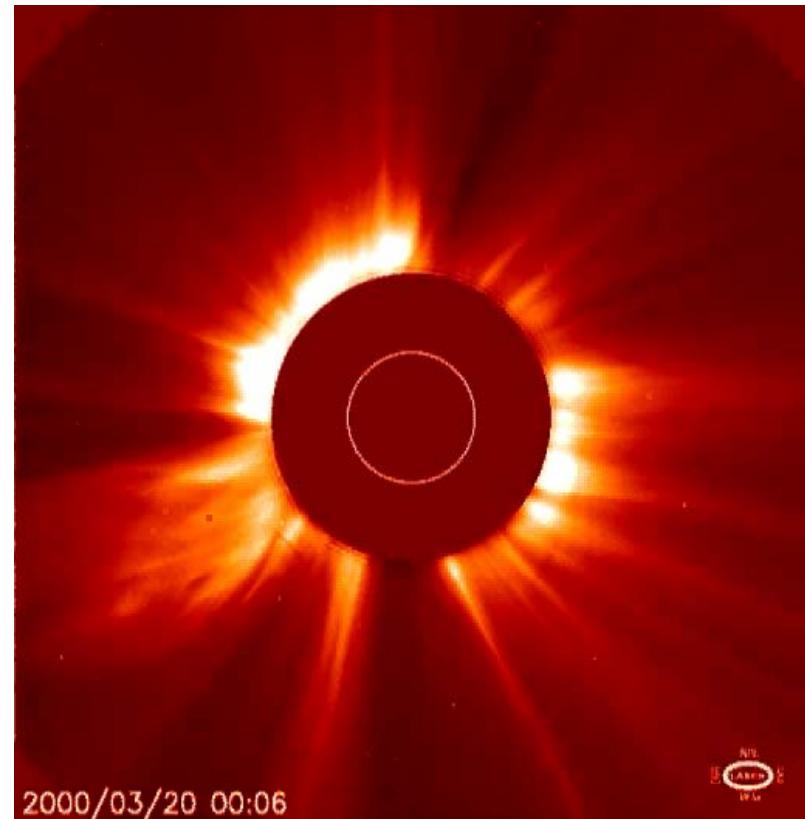


Magnetospheric constellations: The natural next step in heliophysics exploration

Vassilis Angelopoulos



The Earth's space environment is buffeted by the dynamic solar wind



The energy released can wreak havoc to satellites and ground systems, and endanger future space tourists



The Economic Real Estate

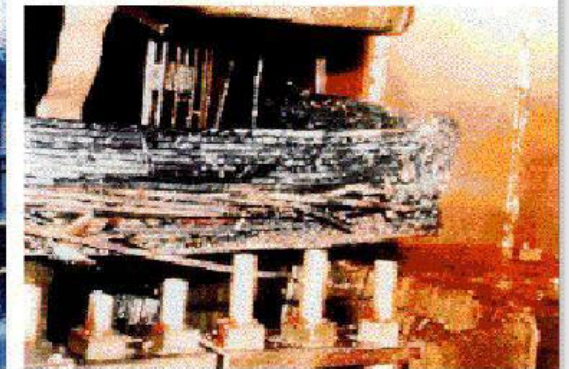
Location	Commercial	Military	Research	Total
LEO	273	94	70	437
MEO	19	101	12	132
GEO	308	51	8	367
Totals:	600	245	91	936

- Total Satellite Fleet (ca Dec, 2004)..... ~ 936
- Total hardware + launch cost..... ~ \$ 230 billion
- GEO Transponder Capacity..... ~ 6,800
- GEO industry annual revenue..... \$ 87 billion
- LEO + MEO satellite annual revenue..... \$ 10 billion
- Satellite Industry annual revenue..... \$ 225 billion



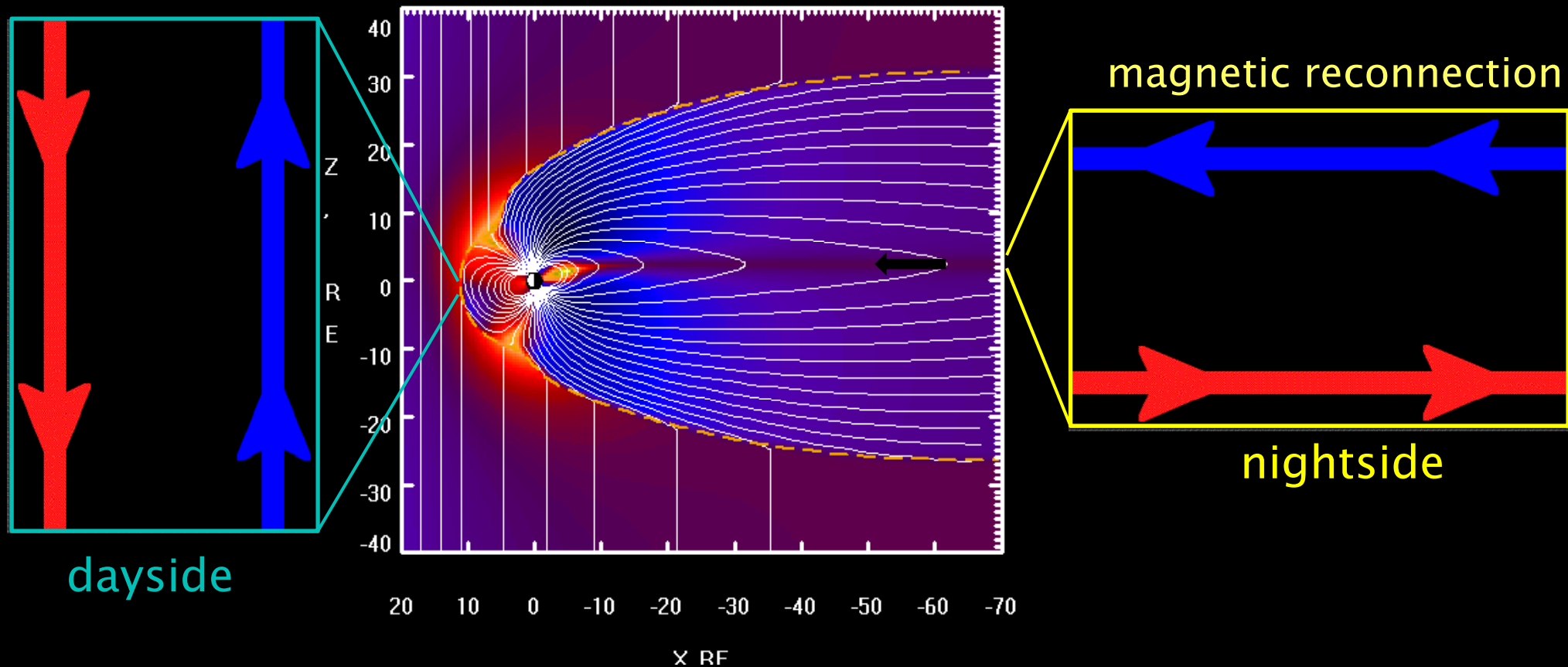
**PJM Public Service
Step Up Transformer**

Severe internal damage caused by the space storm of 13 March, 1989.



A large space storm in 1989 caused currents which damaged this transformer and shut off power for six million people for nine hours.

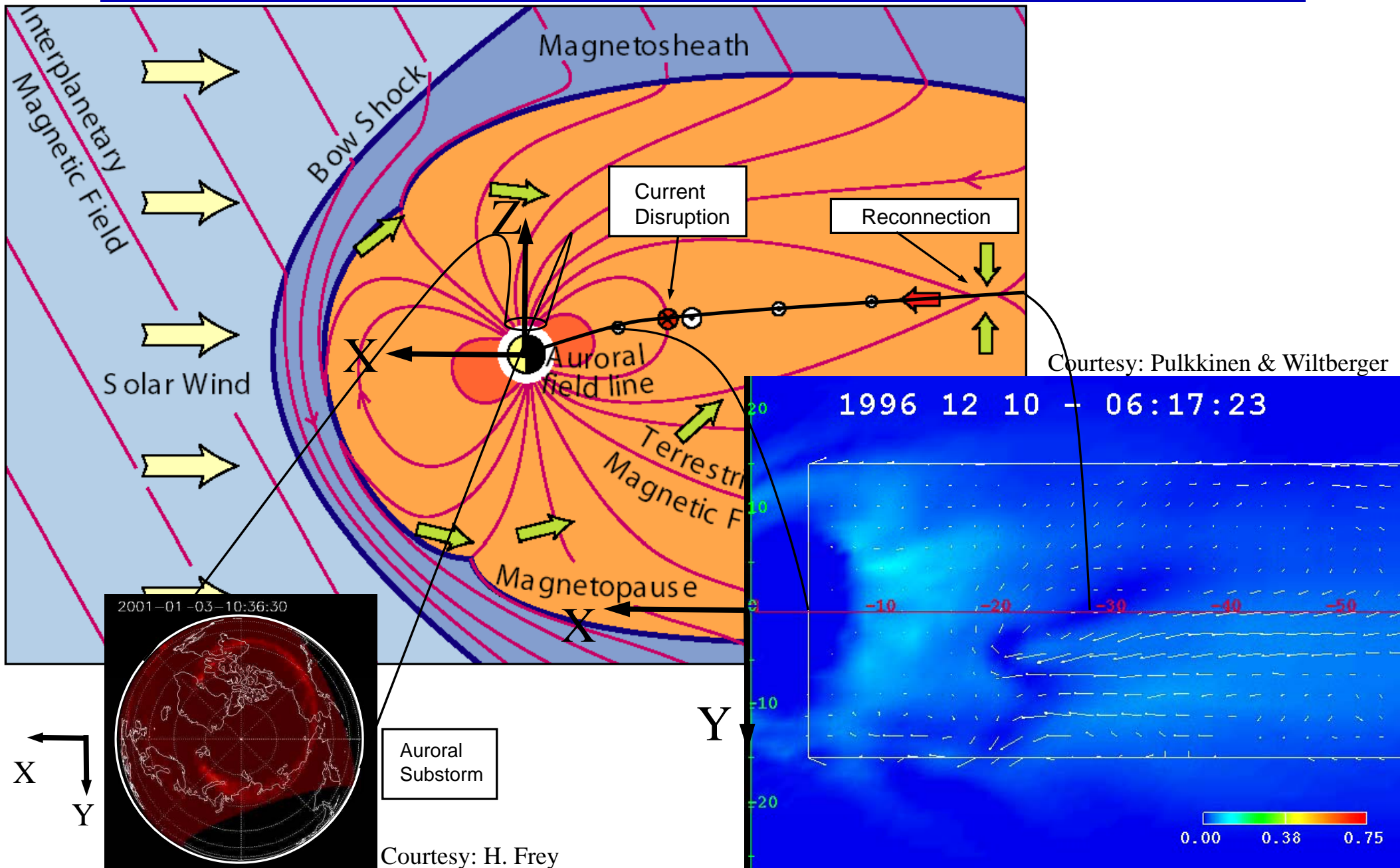
Penetration of solar wind energy



- About 10% of solar wind energy enters magnetosphere due to dayside magnetic reconnection.
- Nightside reconnection jets plasma toward Earth

The solar wind energy circulation is bursty.

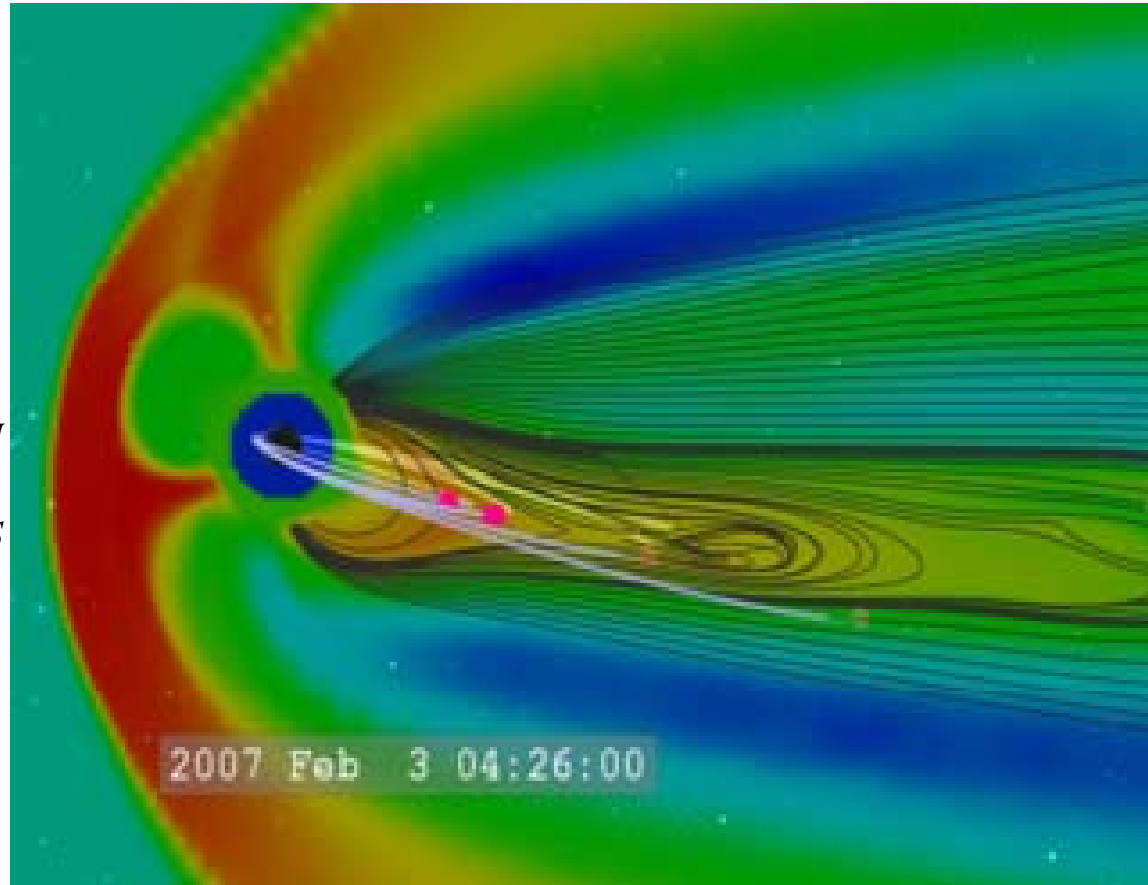
Understanding burst physics and interactions is key to understanding space weather.



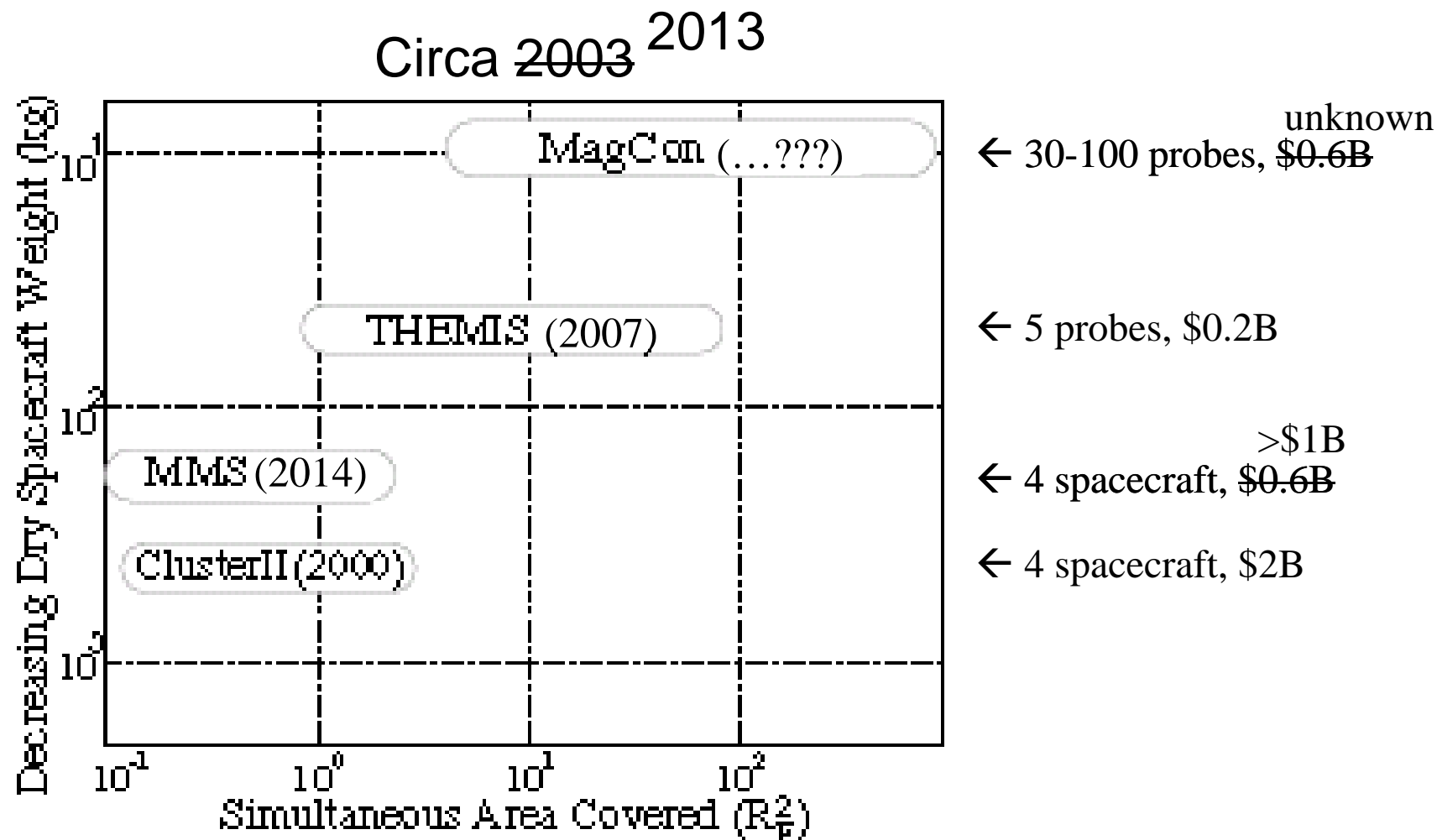
THEMIS: a constellation pathfinder with focused objectives

Addressed Substorm Onset Science (c. 2007): Probe Alignments and Ground Conjunctions

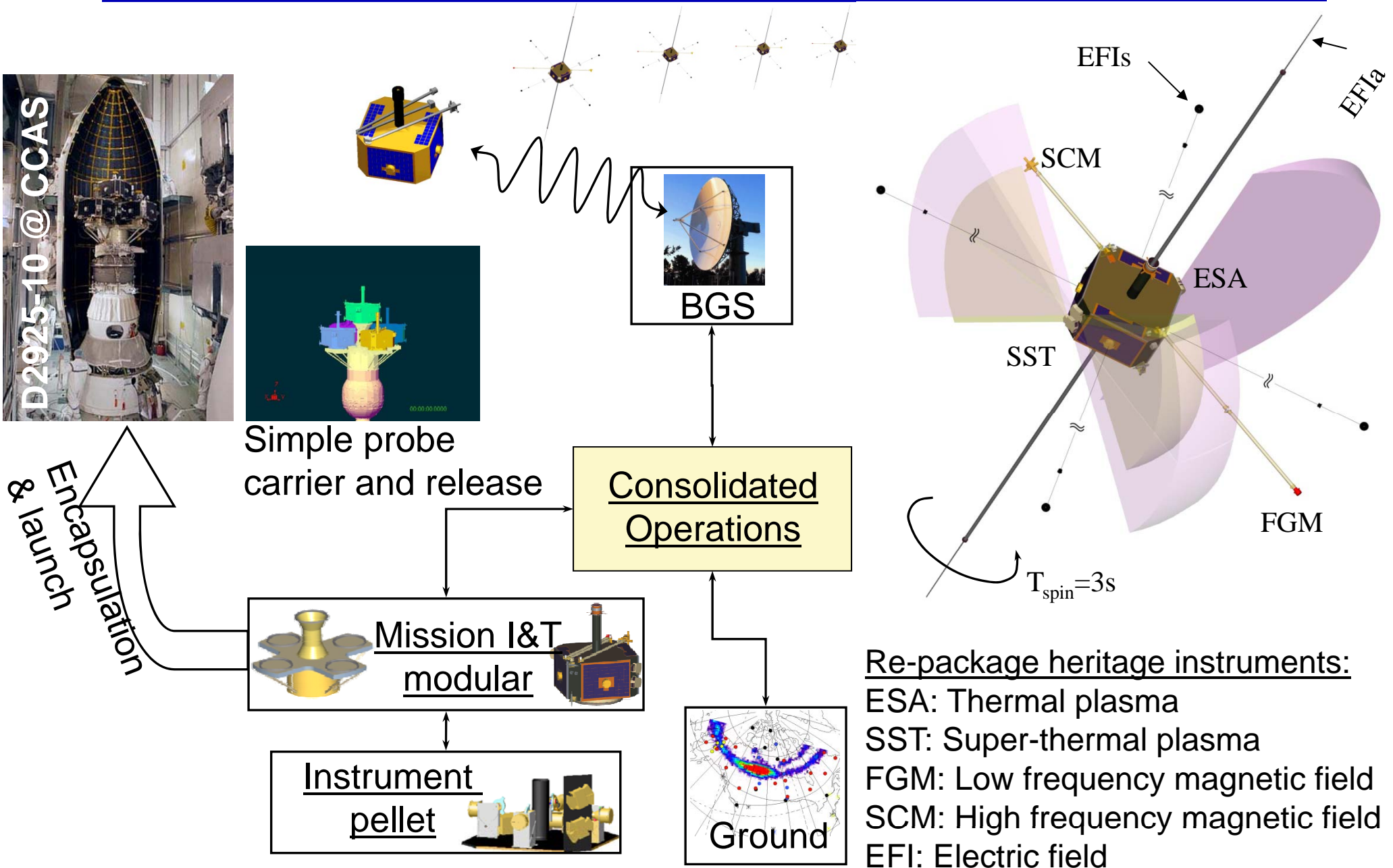
Simulation: J. Raeder, UNH
Visualization: Tom Bridgman,
GSFC/SVS



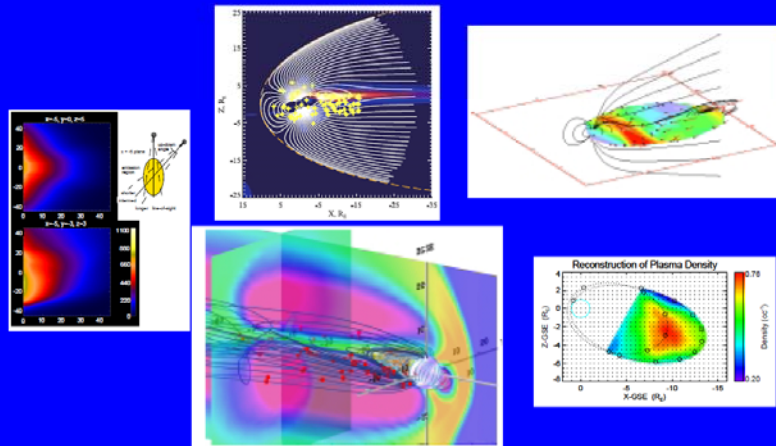
Current Missions and Relation to Magnetospheric Constellation



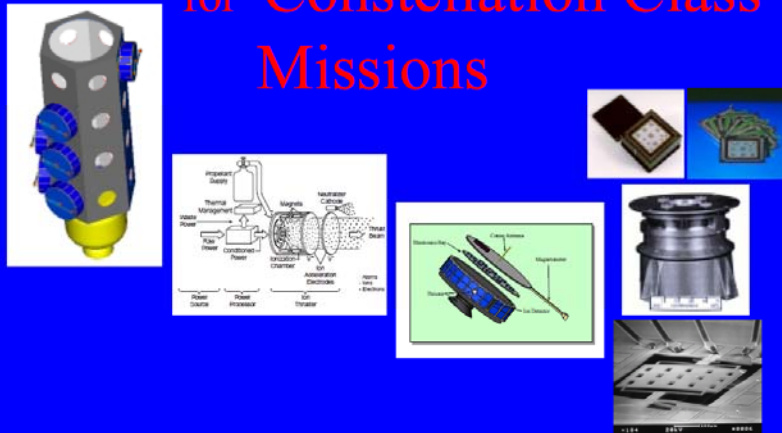
Mission success relied on high-heritage instruments.
Allowed attention to manufacturability for risk reduction



Exploration in the next ten years: Constellation class missions to understand global consequences of local activations



Science Closure and Enabling Technologies for Constellation Class Missions

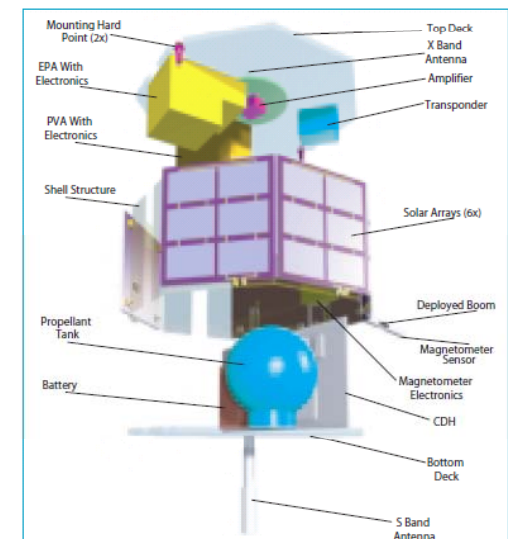
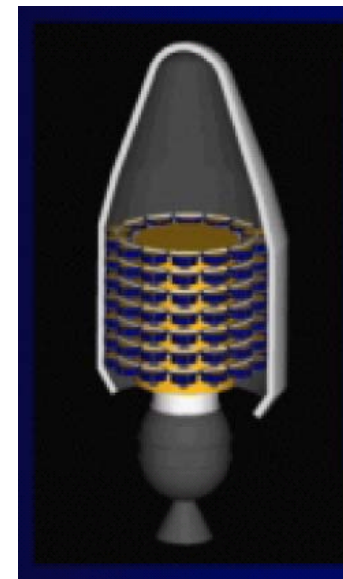
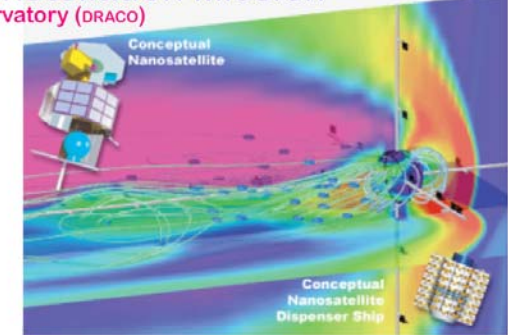


V. Angelopoulos and P. V. Panetta, Editors
UCB, 1998

The Magnetospheric Constellation Mission

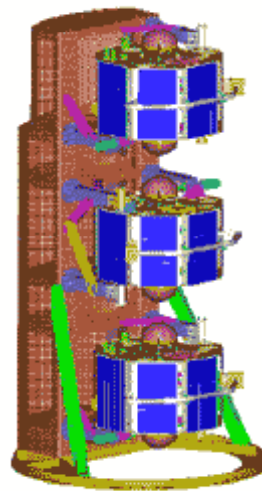
Dynamic Response and Coupling Observatory (DRACO)

- How does the magnetotail control energy flow?
- What processes control magnetotail structure and dynamics?
- How do the physical processes and regions couple over the hierarchy of scales?

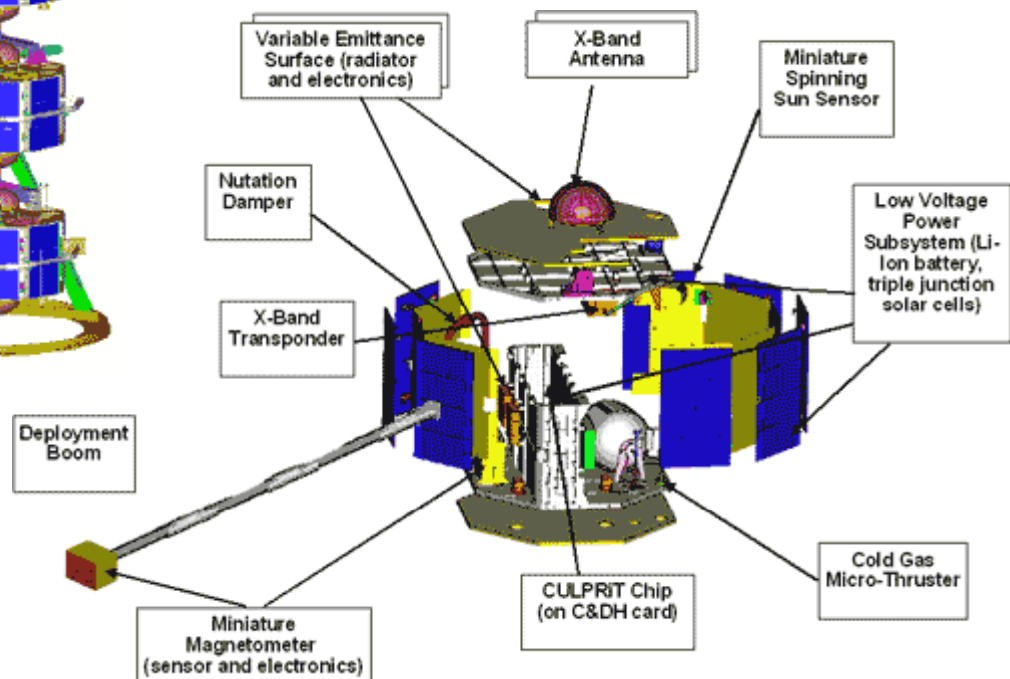


Space Technology 5 (New Millennium)

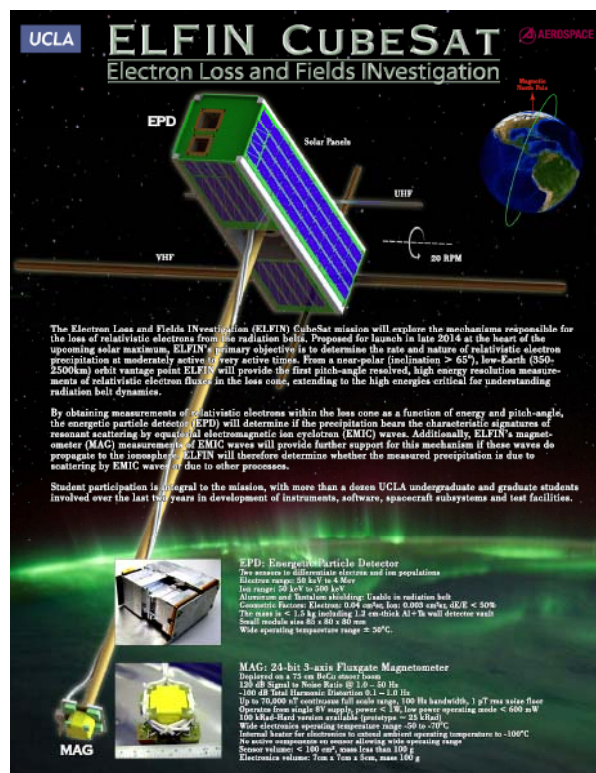
Proposed 1999, approved 2002, launched 2006, Center: GSFC



- Constellation pathfinder
- 22 kg ea., d~50cm
- 7 new technologies
- Costs escalated due to LV



CubeSats break traditional models, enabling low-risk constellation development



1. Flight-validation as part of major program reduces risk.
2. Packaging and testing efficiencies into a “science-craft” also necessitate an integrated team – recipe for success.
3. Evolution in system design with flight-testing allows progressive increase in system robustness.
4. Risk posture very strong: no single-point failure.
5. Reconfigurability enables very high science return
6. Progressive buildup of full constellation in pieces enables a Heliophysics Constellation Observatory:

Ionosphere + Radiation Belts + Magnetosphere + Solar Wind.