NASA Future Magnetospheric Missions

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Future Magnetospheric Missions

Strategic Missions

- Radiation Belt Storm Probes (LWS/2011)
- Magnetospheric Multi-Scale (STP/2013)

PI Missions

- THEMIS (MIDEX/2006)
- MESSENGER (Disc/2011)
- Juno (NF/2014 or 2015)

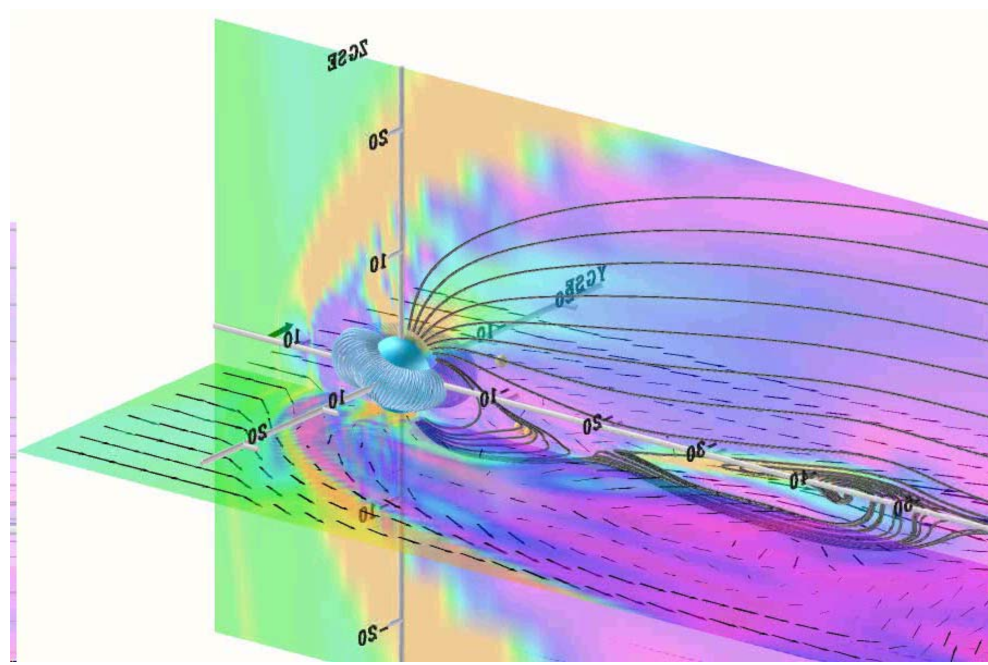
Sun-Solar System Connection Roadmap Missions

- GEospace Magnetospheric and Ionospheric Neutral Imager (GEMINI)
- Auroral Acceleration Multi-Probes (AAMP)
- Magnetospheric Constellation (MC)

THEMIS

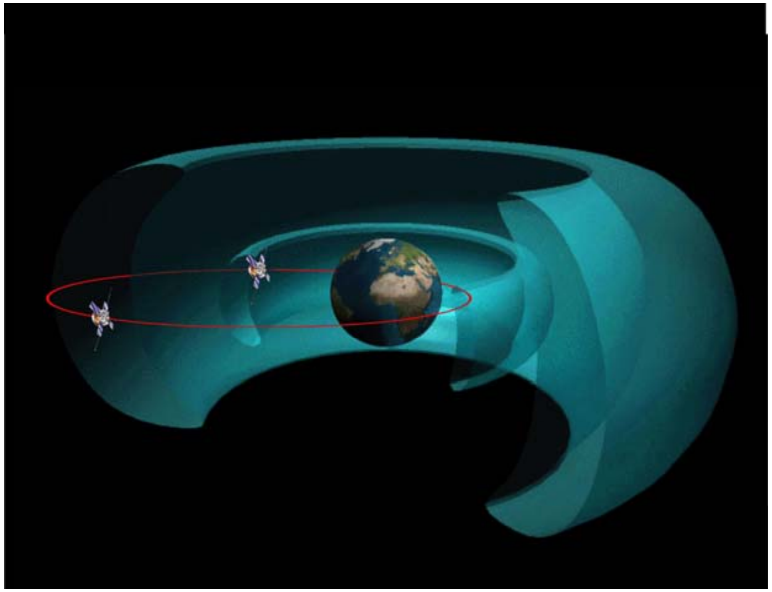
THEMIS: The When, where and how of magnetospheric substorms

- 5 identical probes, aligned capture 10 substorms/year
- In situ particles and fields at nightside (primary)
- Bonus: dayside and radiation belt science
- 130kg/sc wet
- Launch=2006
- Scales: 1-30R_E



Radiation Belt Storm Probes

Living With a Star
Radiation Belt Storm Probes (RBSP)



Science Objectives

- Characterize and understand the variability of energetic radiation belt ions and electrons by identifying and evaluating:
- Source
- Loss
- Transport mechanisms

Mission Description

- Two spacecraft in nearly identical, low-inclination (<18º, 12º goal), highly elliptical (500 km · 5.5 R_E) ‘chasing’ orbits distinguish spatial from temporal variations.

Measurement Strategy

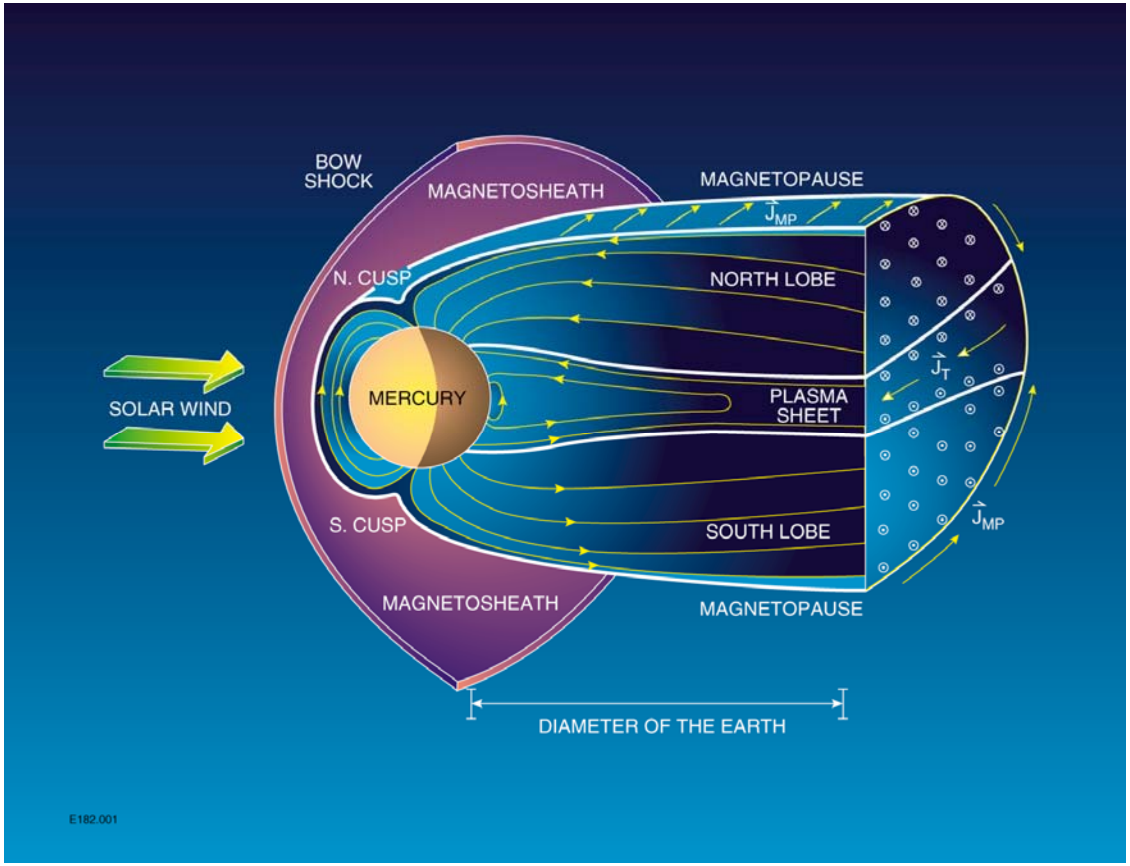
- Measure temporal variations and radial profiles of energetic charged particles, electric and magnetic fields in response to varying solar wind conditions
- Simultaneous two-point measurements discriminate between temporal and spatial phenomena, distinguish local acceleration from radial transport.
- Evolving spacecraft orbits provide observations over a wide range of radial and azimuthal separations.
- An integral part of the LWS program: simultaneous LWS I-T Storm Probe observations define the ionosphere-thermosphere response.
- Correlative studies with other ground-based and spacecraft assets

Enabling and Enhancing Technologies

- Enabling technology development in high-rad avionics
- Enhancing technology to reduce spacecraft cost for multiple spacecraft investigations

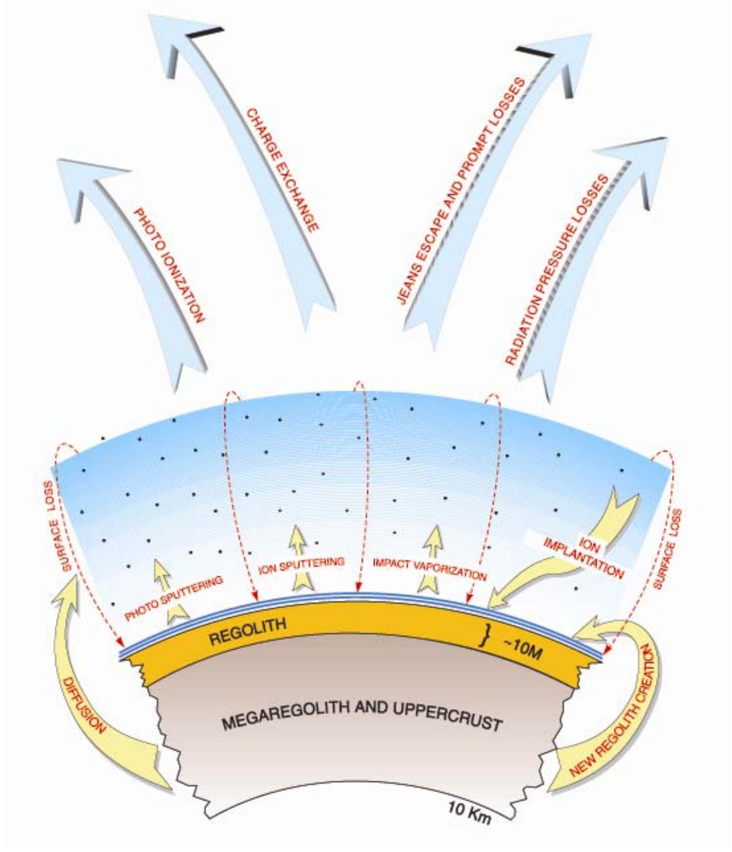
MESSENGER

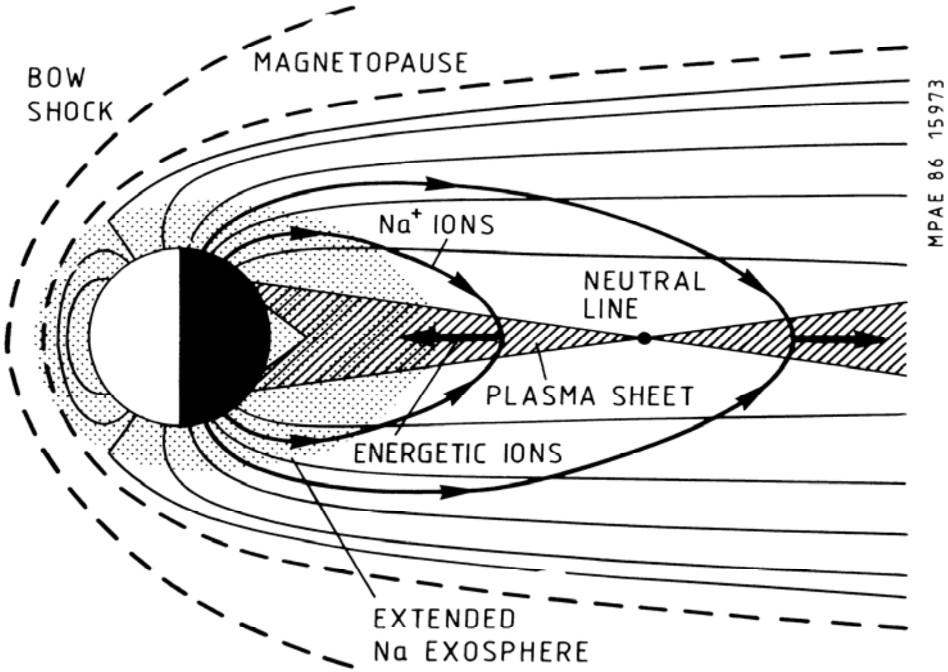
Mercury's Magnetosphere



- Not even dipole term well-resolved by Mariner 10 data.
- Competing hypotheses for the internal field predict different field geometries.
- Internal field can be separated from external field by repeated orbital measurements.
- Mercury's magnetosphere provides an important comparison to that of Earth.

Neutral and Charged Particle Coupling

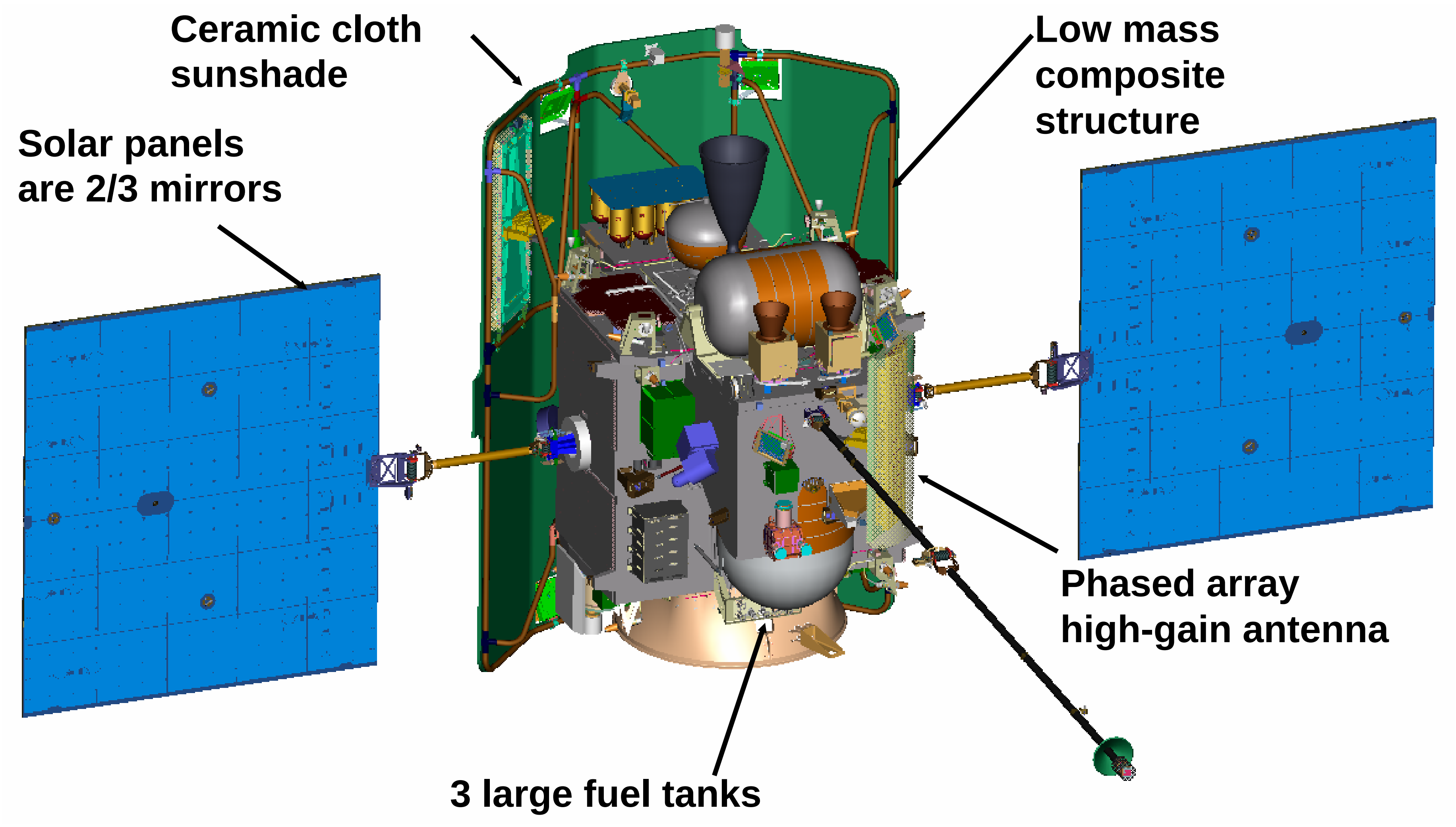




Killen et al. [2001]

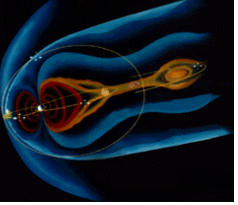
Ip [1986]

Spacecraft



Ceramic cloth
sunshade
Low mass
composite
structure
Solar panels
are 2/3 mirrors
Phased array
high-gain antenna
3 large fuel tanks

MMS



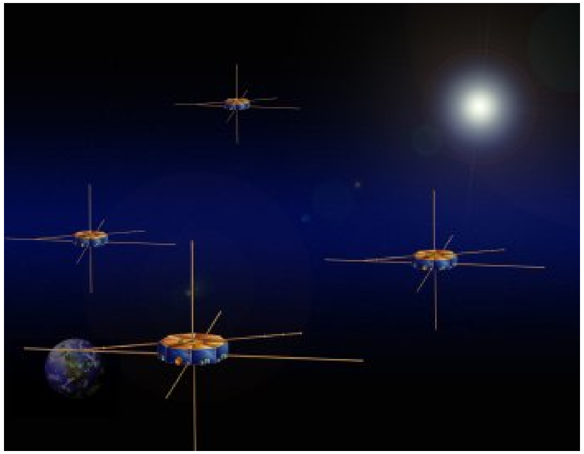
Project Description: Magnetospheric MultiScale (MMS)

Mission Objectives: 2-yr mission to explore and understand the fundamental plasma physics processes of magnetic reconnection on the micro- and mesoscale in the Earth's magnetosphere.

Organizations: GSFC: Project Management, Systems Engineering, Mission Ops
SwRI: SMART Instrument Science Suite (PI – James Burch)

Mission Description:

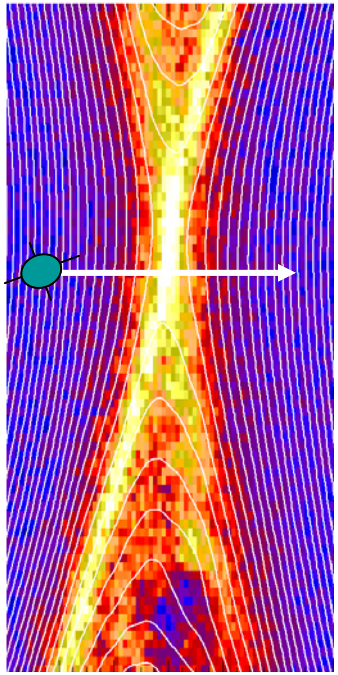
- 4 spin-stabilized spacecrafts
- 4 suites of identical instruments: electric field, energetic particles, fast plasma, hot plasma & magnetometers
- Inter-spacecraft ranging system
- Tetrahedron constellation formation during periods of interest
- 3 mission orbit phases (elliptical: perigee 1.2 R_E)
  - Phase 1 apogee 12 R_E 9 months
  - Phase 2 apogee 12-25 R_E 3 months
  - Phase 3 apogee 31 R_E 11 months (perigee 12 R_E)
- Observatory resources (conceptual)
  - Mass ~300kg
  - Power ~130W
  - Data rate ~2Gbit/day
  - Dimensions ~2m across flats ~0.9m high

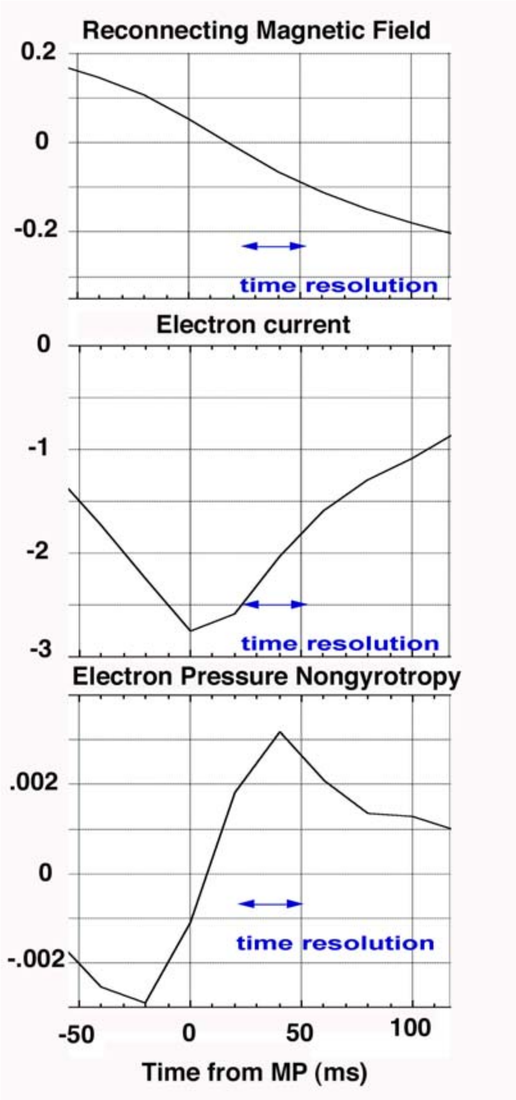


Launch: To be launched from KSC on a Delta II (heavy), 7/13
Web Site: stp.gsfc.nasa.gov

Resolving the reconnection layer

- The general basis for SMART time resolution is the assumption of a magnetopause reconnection layer with n = 10 cm^{-3}, B = 30 nT, and boundary velocity = 20 km/s.
- Simulation results show that 30-ms resolution for the electrons is sufficient to resolve electron pressure and currents, along with their gradients through the boundary.
- Fields measurements need to have higher resolutions of ~1 ms.





30 ms time resolution for electron distributions is required in reconnection layer.

Testing Reconnection Physics Models

What kinetic processes cause magnetic reconnection?

↓

Does particle inertia control the structure of the diffusion region?

↓ ***Test***

$$\vec{E}_R = -\frac{1}{n_e e}\nabla\cdot\mathbf{P}_e$$

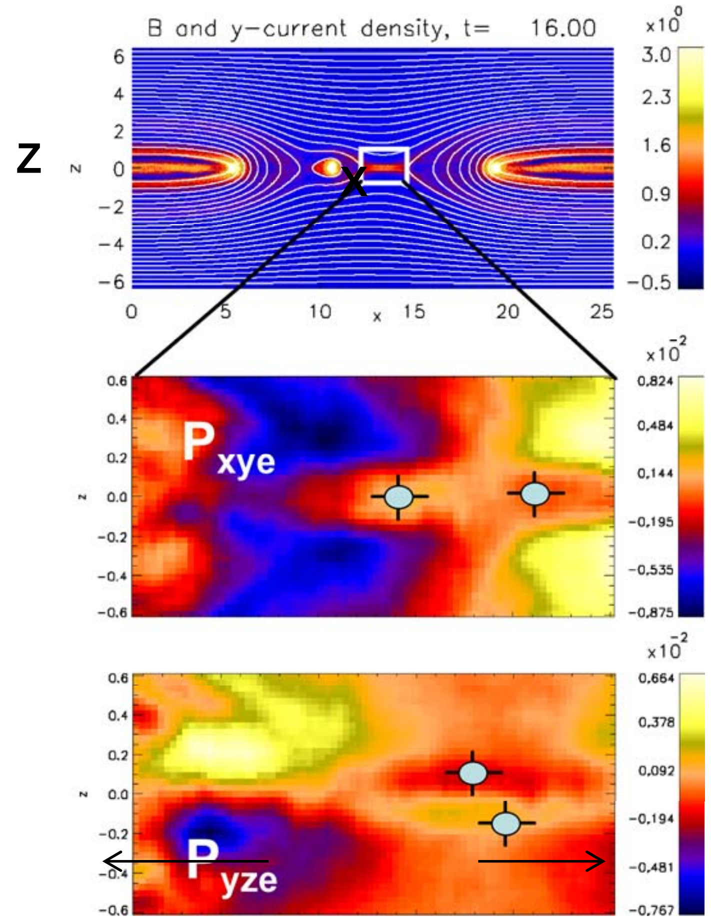
↓

Measure electron pressure gradients and compare to double-probe data

↓ ***If lose 1 s/c***

Orient plane of remaining 3 s/c in plane of reconnecting magnetic field

Y Current Density



Juno

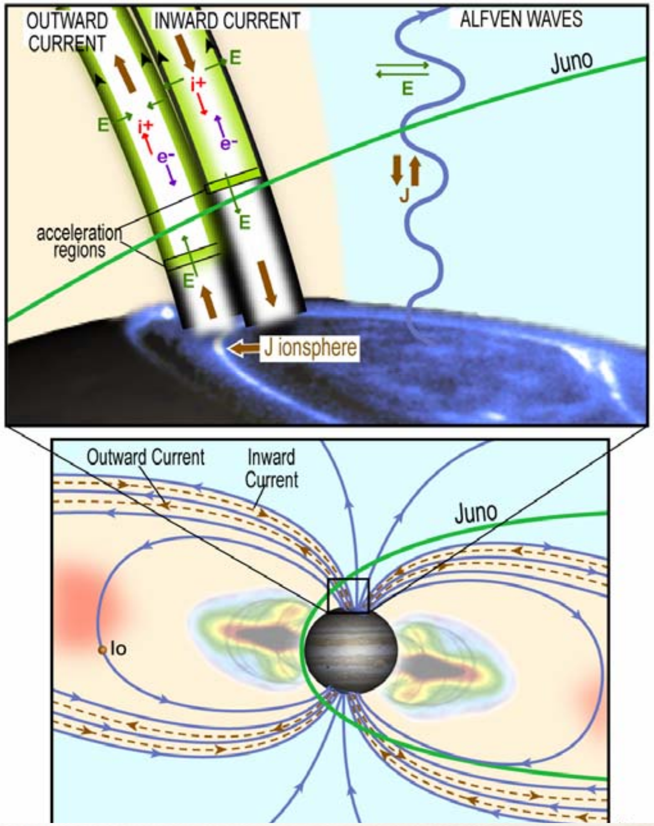
Juno: Polar Magnetosphere Exploration

Juno passes directly through auroral field lines

Measures particles precipitating into atmosphere creating aurora

Plasma/radio waves reveal processes responsible for particle acceleration

UV images provides context



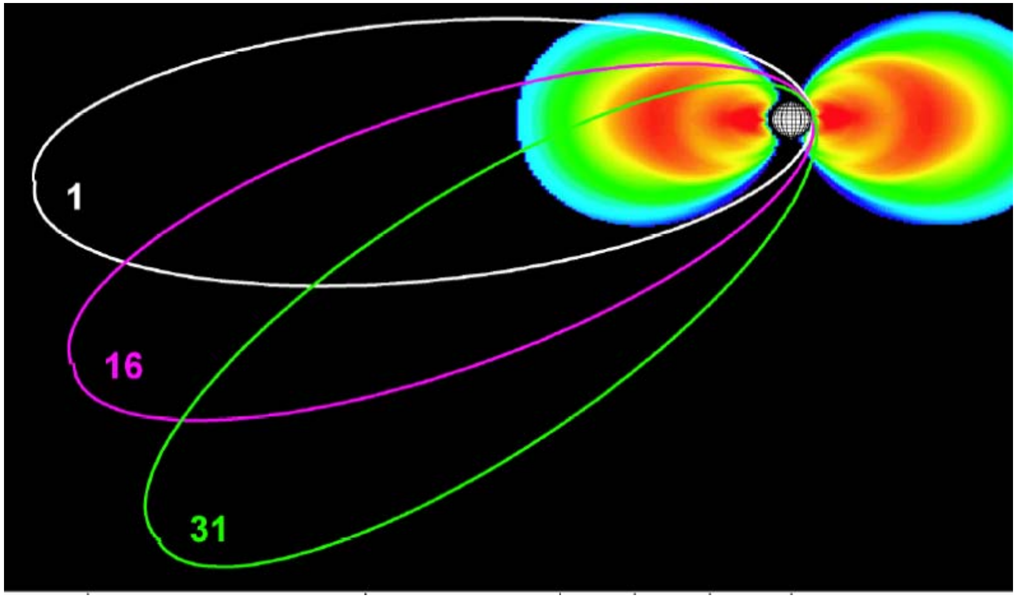
Juno Mission Design

Launch: June 2009 or July 2010

5 year cruise

Baseline mission:

- 32 polar orbits
- Perijove ~5000 km
- 11 day period
- Spinner
- Solar-powered



Science Objectives:

- Origin of Jupiter
- Interior Structure
- Atmosphere Composition & Dynamics
- Polar Magnetosphere

Sun-Solar System Connection

2006 Roadmap

Sun-Solar System Connection Framework

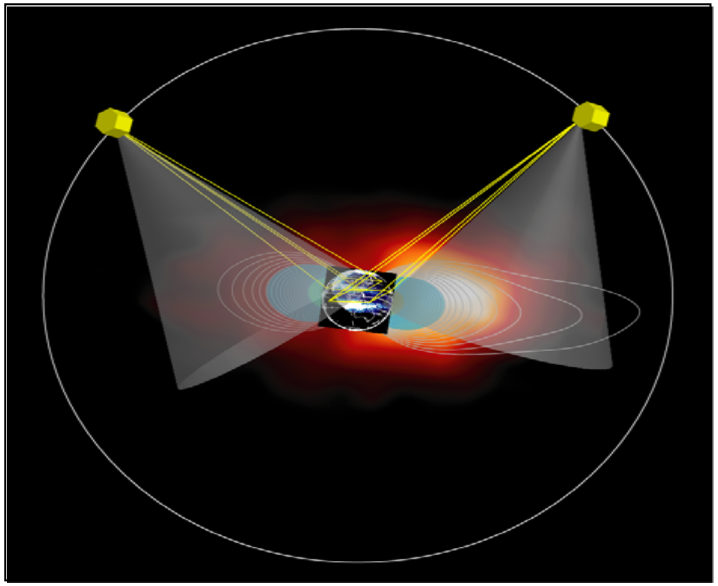
Science Questions

Science	Goals	Implementation	Achievements	Impacts
Defined through interaction with broad science community xplore the Sun-arth System to nderstand the un and its ffects on Earth, he solar system, nd the space nvironmental onditions that vill be experi-nced by human xplorers; and lemonstrate echnologies that an improve uture opera-ional systems	Open the Frontier to Space Environment Prediction Understand the Nature of Our Home in Space Safeguard the Journey of Exploration	• Systemically explore processes and domains using regular, cost-effective mission sets • Plan strategic missions for critical scientific exploration and for space weather understanding • Select low-cost Explorer opportunity missions for fast response as knowledge changes • Seek additional resources for flagship missions and partnerships • Utilize low-cost extended missions to gain solar systems scale understand-ing - SSSC Great Observatory "sensor web" • Enhance supporting programs for research & analysis, LCAS, E/PO, an technology • Disseminate data for environmental modeling via distributed Virtual Observatories	Scientific Understanding of the Sun, Heliosphere and Planetary Environments as a Single Connected System ↕ Sun-Solar System Dynamic Models and Information Products ↕ Operational Space Weather Prediction Models and Systems	• New Knowledge • Safe and Productive Space Operations • Space Weather Mitigation • Decision Support Tools • Future Scientists, Engineers & Informed Public

NASA and partner producers of SSSC science information

Users of SSSC science information

GEospace Magnetospheric and Ionospheric Neutral Imager (GEMINI)



Enabling Technology Development

- No "enabling" technology required

Measurement Strategy

- Two high altitude spacecraft with global ENA and EUV imaging of the magnetosphere, and high resolution global spectroscopic FUV imaging of the I-T system
- Ground radar measurements coordinated with space-based sensors

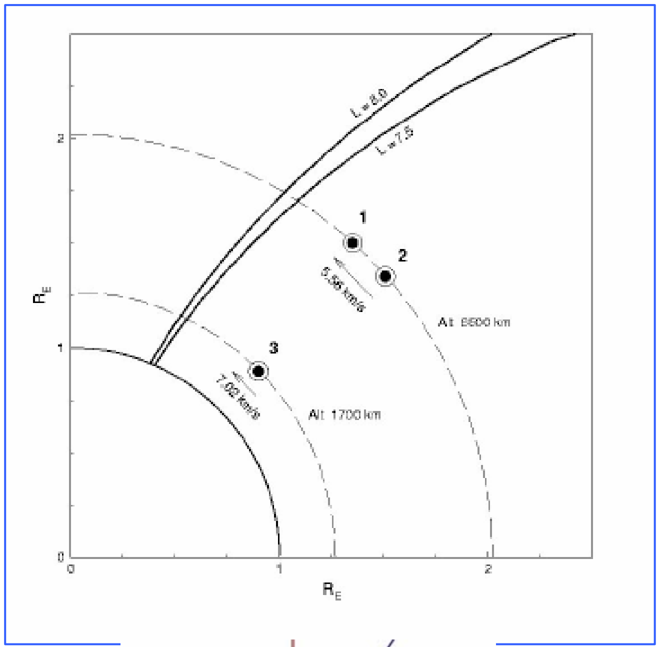
Science Objectives

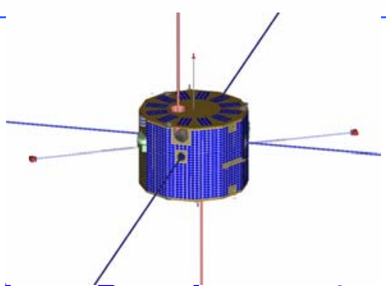
- Determine dynamic coupling between ionosphere and Magnetosphere
- Determine how magnetospheric energy is dissipated in the Ionosphere-Thermosphere (I-T) system
- Determine the important feedback mechanisms from the I-T system to the magnetosphere
- Determine global magnetospheric dynamics

Mission Description *(Near/Intermediate/Far Term)*

- **Mission Design**
  - 2 high altitude spacecraft in $8R_e$ circular near-polar orbit
  - Ground-based radar network covers 30° to 90° north and south latitudes
  - 2 year mission life
- **Flight System Concept**
  - 2 separate Pegasus –class launches
  - 3-axis stabilized platforms
  - xx m/s ⊗V
  - 0.01° (control), 0.02° (knowledge)
- **Payload**
  - Payload: 79 kg, 48 W, 110 kbps (avg.)
  - 3 FUV, 1 EUV, 1 ENA Imaging instruments per S/C, nadir pointing with yaw about nadir
  - ~ 10 ground radar installations with 2 antennas each

Auroral Acceleration Multi-Probes (AAMP)





Science Objectives

•**To understand the electrodynamic connection between Earth's ionosphere and magnetosphere**

What structures accomplish the connection?
What is the electrical impedance and how is it established?
What is the role of ionospheric feedback?
How does magnetospheric dynamics affect the coupling?

Mission Description

- **Example Mission Design**
  - Delta II Launch of 3 spacecraft into a 600 km x 6000 km, 90 deg. inclination.
  - Separate spacecraft in true anomaly.
  - 2 year mission lifetime
- **Flight System Concept**
  - Spinning solar powered spacecraft
  - Payload: Fields and Particles+ Imaging (71 kg/43 W)

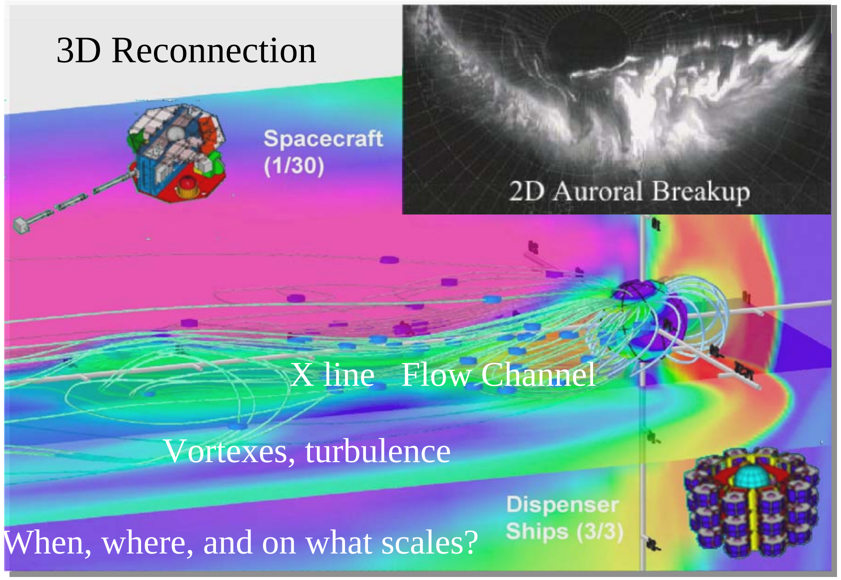
Measurement Strategy

•Measure j: B & precision attitude (0.02° maximum error)
Measure ⟩: DC E-field, particle distribution, || B necessary
Distinguish waves, static structures: <10 ⌠sec timing
Identify kinetic processes via established signatures

Technology Development

- Low Mass/Power Instrumentation

Magnetospheric Constellation (MC) Mission



More info:
http://stp.gsfc.nasa.gov/missions/mc/mc.htm

Enabling Technology Development

- None

Technology Requirements

- ST-5 design-experience base
- Fabrication, assembly and testing techniques from Iridium, GPS, other commercial, DoD constellations

Science Objectives

- Determine how the magnetosphere stores, processes, and releases energy from the solar wind interaction:

How does the magnetotail behave?

How are particles injected to form the radiation belts?

How does the magnetopause respond to the solar wind?

Mission Description

- Constellation of 30-36 ST-5 class s/c
- 15˚ inclination, nested orbits
- Apogees from 7-27 R_E, ΔV = 814 m/s
- Per s/c: 20 kg, 15 W, 1 kbps, 1˚ pointing

Measurement Strategy

- Synoptic vector measurements of magnetic field, plasma flow & energetic particles
- Mean spacecraft separation: 2 R_E
- Time resolution: 10 sec
- Mission targets are plasma sheet and low latitude magnetopause

All Three NMP/ST-5 Spacecraft in I&T

Launch will be February 28, 2006!!

Summary

The new measurements to be collected over the next 10 years will enable great strides in our understanding of magnetospheric physics and the ability to forecast space storms.