SEC Roadmap Community Forum (3/4-6/02)

Magnetospheric Subpanel Breakout Session -

1. What science do I want to accomplish in the next 25 years?

Tim Eastman – We've worked at: system as a system; boundaries in detail; microphysics in detail. What is the linkage between microphysics, mesophysics, to macrophysics?

Jim Green - *Understand and validate the science objectives in the STP line, but we should focus our views and perspectives of LWS.*

Chuck Goodrich - *What are the questions from former Roadmap?*

Dick McEntire - *STP is science-based research line of the physics of Sun-Earth Connections. LWS is targeted science program that focuses on relevance to life and society.*

Eastman - How is the magnetotail fed and how does it circulate?

Goodrich - Coupling between near-Earth tail and ionosphere? Auroral zone mapping and coupling to magnetospher is a hole in our global understanding)

Green - Dynamics and evolution of substorm and what is the mechanism of substorm onset? Understand energy storage and release.

Brian Anderson - Acceleration region still needs work in the coupling between ionosphere and magnetosphere.

McEntire - Comparative magnetospheres tests universality of models and theories developed from Earth observation

Howard Singer- Puzzles remain about how information is transported and communicated throughout the magnetosphere (a applied to general issue of coupling), how it changes, and what directions the potential feedbacks work. "Who" drives "who"?

Don Mitchell - Ring current physics remains a question.

Tony Lui - Non-MHD (kinetic) regions and their dynamics remain mysteries – understanding basic physics and identifying critical regions (e.g., auroral region, inner magnetosphere, current sheet disruption)

Anderson - What is net effect of underlying physical processes and how does the system behave at a whole across spectrum (cross-scale coupling – macroscale/microscale, physics coupling – kinetic/fluid).

Goodrich - Need relevant observations to test microscale (local) theories in the same way that we've done at fluid lev

Steve Christon - *We'll have a magnetospheric constellation but will we have a coordinated, concurrent ionospheric constellation?*

Shin Ohtani - Need to quantify the values and failings of MHD codes.

Ramona Kessel- Dayside boundary layers (m'pause and bow shock) remain an open issue because we've lacked multipoin measurements – can't assess signficance of microscale processes without the global view.

McEntire - *Multipoint measurements are imperative to test MHD/kinetic models (enabling "technology") – we can't understand until we can predict with a model.*

Kazue Takahashi- Dayside phenomenon (upstream, bow shock, magnetosheath, m'pause) need to be resolved at Alfven tran time and many points in order to understand their genesis and subsequent evolution to feed the magnetosphere.

Eastman - *Theory/model and observation closure demonstrates a sophistication of our discipline. We can quantitati test our understanding. We should support the strong connections that now exist in our field.*

Green - *We've been lulled into the notion that solar wind (and auroral and ENA imaging) monitors will be availa but we need these to understand the global context.*

Howard - *Data assimilation is a technology development area that is imperative for all of our missions.*

Mona - Multiple solar wind monitors may be important for magnetospheric physics. What is the variability of the near-Earth solar wind and how does it impact interactions with the magnetosphere? How lumpy is the sol wind?

Steve - With a constellation you will have some spacecraft in the solar wind some of the time, but we'll still need set of monitors.

Mona - *Visualization of data and models in three-dimensions (and time-varying!) is critical and the value of this PR should not be undersold. More modeling…more imaging.*

Bob -	Monitoring is a "dirty word" → but long-term observations is essential
Dick -	LWS may be a more suitable place for "monitoring"
Chuck -	We should note that L1 is important to us in a way that may not be in heliospheric circles.
Shri Kanekal -	Particle energization to MeV energies is a fundamental question that will probably not be solved in recent years.
Steve -	Sample geomagnetic field globally – update IGRF – especially in auroral regions.
Tom Moore -	Models have not kept up with observations in the area of the ionosphere. We need a better 3D ionosphere model that is dynamically coupled into magnetospheric modeling.
Joe Borovsky -	Flows are turbulent in solar wind, magnetosheath, magnetosphere, and possibly the ionsphere.. We need t quantify the significance of turbulence and the impact it may have on transport.
Brian -	Foreshock dynamics modifies the solar wind (preconditions) and needs better understanding.
Jim Green -	Ionospheric input in the magnetosphere (e.g., plasmasphere) is not understood. Plasmaspheric "fingers" a "tails" not understood in terms of current models.
Shin -	Monitoring is important, but we motivate it by showing how critical it is to the science (could be consider "debilitating" influence).
Bob -	Magnetospheric response to a magnetic storm – observations are not consistent with present models. Wh happening to the cold plasma response during storms?
Karen Sigsbee-	Storms, substorms, SMC's – how is the magnetosphere driven or responding to solar wind inputs?
Ron Oliverson -	Solar System Enterprise Roadmap does NOT emphasize (or nearly mention) magnetospheres of planets. must continue to support it if there is any chance for continued chances for future missions.
Steve -	Mercury should be included in our planetary support for comparative magnetospheres.
Chuck -	Getting accurate solar wind measurements is a basic requirement for global models.
Craig Pollock -	Structure in the solar wind – can be either radial or transverse – which is most important, do we need both Spatial? Temporal? Both?
Chuck -	MHD satellite comparisons had some cross-wind variations in order to make the observations and data ag Can have a huge leveraging factor in the code predictions.
Mona -	Need to explore 3D structure to understand them.
Don Mitchell -	Note: Largest-scale solar wind structures are the most geoeffective (CME's).
Tim -	

Overarching Science Themes from Decadal Surve y Panel:

1. Creation and Annihilation of Magnetic Fields - reconnection
2. Magnetospheres as Shields and Accelerators – deflection of solar wind and trapping and creation of energetic particle
3. Magnetospheres as Complex, Coupled Systems – complex internal flows and fields, 3D time-dependent, spatially-structured system, coupled to varying solar wind, regions internally coupled, and processes coupled across size scale and processes.

Recommendations:

- The deeper physical understanding of fundamental plasma processes, such as particle acceleration, magnetic reconnection, and the role of turbulence, is at the core of present and future space exploration. We therefore strongly endorse the planned **Magnetospheric Multiscale Mission**.
- For predictive purposes we need to understand the scale sizes of solar wind structure that power the Earth's magnetosphere. For that purpose we need **multi-spacecraft (solar wind) missions** with separations of tenths of AU survey these structures in the neighborhood of 1 AU.
- To understand the dynamics of the coupled magnetospheric system and of space weather we need to have arrays of instruments in space as well as on the ground, in analogy to ground weather stations. Thus a **Magnetospheric Constellation** of up to 100 spacecraft is most highly recommended.
- To understand the complex interaction between the solar wind and the polar ionosphere we need to establish the long awaited Relocatable Atmospheric Observatory at high latitudes. This facility could be enhanced with many possible space missions such as a **Stereo Imager or a Polesitter auroral imager**.
- In order to understand finally the energization of the radiation belts we **need to obtain radial swaths of the particle and field environment** simultaneously at different local times and do so under different geomagnetic conditions to s how and why particle populations intensify and decay.
- In the planetary interactions area we must fly particles and fields instruments on both Discovery-class and major missions to understand the solar wind and magnetospheric interactions of these complex systems and their effects on planetary atmospheres. Missions to study **atmospheric loss from the Venus and Mars**, the occurrence of **lightning Venus and Jupiter**, the **dynamics of the Mercury magnetosphere** and the joint **control of jovian aurora by Io an the solar wind** are examples of the many missions that could contribute to our understanding of planetary magnetospheres.

Working Draft of 12 Science Questions from the SEC Roadmap Magnetospheric Subpanel

Fundamental Space Science Processes (2) – for example, reconnection, turbulence, particle acceleration a plasma interactions with gas, dust (maybe etc.)

- for example, reconnection (creation and annihilation of magnetic fields), currents, turbulence, particle acceleration and plasma interactions with g dust (maybe etc.)
- How do micro-, meso-, and macro-scale physics link in the magnetosphere and how is informatio transported, fed back, and communicated, both throughout the system and across size scales? Wh is the net effect of underlying microscopic physical processes to the system as a whole, and, how global conditions control localized physics?
- Why is there turbulence in magnetospheric and solar wind plasmas and how does it affect large-s flow? What is the significance of turbulence in the solar wind, magnetosheath, magnetosphere, a ionosphere to transport within and through geospace?

How do fundamental space processes control large-scale Plasma Dynamics and Energy Conversion Processes within the magnetosphere(3)

- Why does the magnetosphere have different convective modes (SMCs, storms, substorms), what determines the details of circulation, and how do the modes relate either directly or indirectly to solar wind inputs?
- Coupling between and within magnetospheric regions
- How is energy stored and released explosively in the magnetotail during substorms? What is the mechanism of substorm onset – what are the dynamics and evolution of a substorm? "What caus substorm?"
- How does the magnetosphere produce highly energetic particles? How are ring current and radiat belt particles energized, transported, and lost during magnetic storms? Where do MeV electrons come from?

How does the magnetosphere respond to the solar wind and how does the magnetosphere couple with oth regions? Magnetospheric Coupling to Other Regions (4)

- How significant is ionospheric plasma to magnetospheric dynamics, particularly during storms an substorms? How and why is ionospheric outflow driven?
- How do the magnetosphere and ionosphere couple? How does the auroral zone map and couple the magnetosphere? How do processes in acceleration regions affect the coupling?
- How do the dayside boundary layers (foreshock, bow shock, magnetosheath, magnetopause, etc.) modify the solar wind and interplanetary magnetic field and how do these changes affect their coupling to the magnetosphere?
- What structures in the solar wind are of importance to magnetospheric coupling? (Note to self: 3D time dependent, turbulent, etc.)

How important are the various processes occurring in the Earth's and planetary magnetospheres t other planetary magnetospheres and to solar system evolution? astrophysical systems? Comparati Planetology (3)

How fundamental are the various processes occurring in the Earth's and planetary magnetospheres to sol system evolution?

- What is the difference between Earth's magnetosphere and other planetary magnetospheres?

- What role do planetary magnetospheres play in the evolution of atmospheres and life?
- What is the relevance of fundamental processes occurring in Earth's magnetosphere to astrophysi plasmas? How universal are the processes occurring in Earth's and other planetary magnetosphe to astrophysical plasmas?

Overarching Theme: (= "Roadmap Objectives")

What are the relevant fundamental processes, how do they operate within the magnetosphere, how does the magnetosphere then behave as a complex, coupled system, and finally, how can these concepts be applied to other astrophysical systems?

- What are the relevant fundamental processes operating within the magnetosphere a what controls where and when they dominate?
- How do fundamental space processes control large-scale plasma dynamics and ener conversion processes within the magnetosphere?
- How does the magnetosphere respond to the solar wind and how does the magnetosphere couple with other regions (solar wind, magnetosheath, ionosphere)?
- Test the predictive understanding of magnetospheric processes at other planets, expand the parameter space, and determine: "how important are the various process to solar system evolution?"

Note: List of 12 questions shown before were our "Research Focus Areas." They map into the four above themes.

2. **<u>What missions are going to allow me to accomplish that science</u>?**

Recapitulation of five themes:

A. What are the relevant fundamental processes operating within the magnetosphere ar what controls where and when they dominate? **? maps directly to our proposed Science Objective #7a.a, 7a.b**

B. How do fundamental space processes control large-scale plasma dynamics and ener conversion processes within the magnetosphere? **? maps directly to our propose Science Objective #7b.c**

C. How does the magnetosphere respond to the solar wind and how does the magnetosphere couple with other regions (solar wind, magnetosheath, ionosphere)? **maps directly to our proposed Science Objective #7b.d**

D. What elements of which processes do we need to understand in order to predict thos changes in the space environment most relevant to life and society? **? maps direct to our proposed Science Objectives #7c.c, 8**

E. Which magnetospheric processes have universal application to other planetary and astrophysical plasmas? Test the predictive understanding of magnetospheric proces at other planets, expand the parameter space, and determine: "how important are the various processes to solar system evolution?" **? maps directly to our proposed Science Objectives #7a.d, 3.d, and 5**

Consensus View of Mission Time Ordering Within Different Categories from Magnetospheric Roadmap Community

"Solar-Terrestrial Probe" Candidates

- **Magnetospheric MultiScale Mission – detailed studies of microphysics at boundary layers (reconnection, turbulence, and particle acceleration)**

***Status*:** **AO soon**
***Where in queue*:** **Currently STP #4**
***Target launch*:** **2008 (near term)**
- **Primary Theme - A**
- **Secondary Theme – B and C**

- **Magnetospheric Constellation Mission – manifestations of microscale physics and its consequences and signficance to dynamics and energy conversion on the global scale**

***Status*:** **Study Team report released in 2001, instrument technology development program underway**
***Where in queue*:** **Currently STP #6**
***Target launch*:** **2012 (intermediate term)**
***Quad chart responsibility*:** **Tom Moore/Harlan Spence**
- **Primary Theme - A and B**
- **Secondary Theme – C**

Science Questions – How does the dynamic magnetotail control energy flow?
- ***What processes control magnetotail structure and dynamics?***
- ***How do magnetotail dynamics respond to extrinsic conditions as well as to inter instabilities?***
- ***How do physical processes and regions couple over the hierarchy of scales?***

Dynamics –
- Are there states approximating equilibria of the magnetotail?
- Does the magnetotail fluctuate strongly even when the solar wind is steady?
- How do these fluctuations depend on the pressure, speed, magnetization, and fluctuati of the solar wind?
- What is the nature of global magnetotail reconfigurations?
- How do magnetotail dynamics accelerate and transport energetic particles?

Responses –
- Are magnetotail flow vortices generated spontaneously or in response to solar wind disturbances?
- Is the occurrence of kink, ballooning, tearing and/or reconnection instabilities determi by magnetotail boundary conditions?
- Are fast Earthward flows and associated currents the same disturbances that form and release plasmoids, and are they triggered by specific solar wind variations?
- Is particle acceleration triggered or enhanced by solar wind discontinuity effects on magnetotail dynamics?

Connections –

- Does the plasma sheet collapse from the inside out (rarefactively), or the outside in (compressively)?
- How are observed ionospheric current systems and auroral expansions connected to plasma flows, particle acceleration, and plasma injections?
- How are disturbances communicated within the magnetosphere?
- What is the horizon of magnetotail predictability at present and can it be extended with improved knowledge of initial and boundary conditions?

- **Auroral MultiScale Mission – Ultimate electrodynamic coupling between magnetosphere an ionosphere**

  ***Status*:** **Possible new STP mission – upgrade from several MIDEX-cla concepts**
  Where in queue: **New**
  Target launch: **2014 (intermediate term)**
  Quad chart responsibility: **Brian Anderson/Barry Mauk**
  - **Primary Theme – A and C**
  - **Secondary Theme – B**

- **Geospace System Response Imager– global, multipoint, multispecies, multispectral imaging the aurora and magnetosphere**

  ***Status*:** **Modification of old concept from earlier Roadmaps with infusion of new elements from MIDEX-class mission concepts**
  ***Where in queue*:** **New revision**
  ***Target launch*:** **Long term (>2016)**
  ***Quad chart responsibility*:** **Don Mitchell/Craig Pollock**
  - **Primary Theme – B and C**
  - **Secondary Theme – A**

- **Magnetosphere-Ionosphere Observatory– geosynchronous cluster with electron gun to map ionosphere**

  ***Status*:** **New STP concept from MIDEX-class mission concept**
  ***Where in queue*:** **New**
  ***Target launch*:** **Long term (>2016)**
  ***Quad chart responsibility*:** **Joe Borovsky/Craig Pollock**
  - **Primary Theme – A, B, C (or some subset that was still under discussion)**
  - **Secondary Theme –**

- **Inner Magnetospheric Constellation – RBM provides LWS focused needs, but IMC is an imperative for doing basic research on non-radiation belt inner magnetospheric physics (i.e., plasmasphere)**

  ***Status*:** **Revised STP mission in light of LWS/RBM mission**
  ***Where in queue*:** **In previous Roadmap**
  ***Target launch*:** **Long term (>2016)**
  ***Quad chart responsibility*:** **Geoff Reeves/Michael Hesse**

- **Primary Theme – A and B**
- **Secondary Theme – C**

- **<u>Dayside Boundary Constellation</u> - mission to explore the consequences and significance of microscopic processes occurring in the dayside boundary layers to overall energy transfe to the magnetosphere**

  ***Status*: STP mission from earlier Roadmap**
  ***Where in queue*: In previous Roadmap**
  ***Target launch*: Long term (>2016)**
  ***Quad chart responsibility*: David Sibeck/Harlan Spence**
  - **Primary Theme – A, B, and C**
  - **Secondary Theme – C**

"Living With a Star" Candidates

- **LWS Geospace** (see IMC discussion above) - *Reeves*

  ***Status*:** **STP mission from earlier Roadmap, LWS study team in place**
  ***Where in queue*:** **In previous Roadmap**
  ***Target launch*:** **Near term**
  ***Quad chart responsibility*:** **Nicky Fox/Barry Mauk**
  - **Primary Theme – A and D**
  - **Secondary Theme – B**

Furthermore, we the magnetospheric community, **endorse a robust magnetospheric contribution to the measurements provided by such notional missions** as:

- ***Solar Sentinal/Geostorms*** *– we need to know the solar wind boundary conditions, not only at a point, but also how these quantities vary over the cross-section of the magnetosphere*

  Interface person: Howard Singer
  - *Primary Theme – C and D*
  - *SecondaryTheme – A*

- ***Ionospheric Mappers*** *– we need to know the inner conducting boundary of the magnetosphere a how the two couple dynamically*

  Interface person: Chuck Goodrich
  - *Primary Theme – C and D*
  - *Secondary Theme – A*

Planetary Magnetospheric Mission Candidates ("Frontier" Probes, Discovery+?)

PLEASE NOTE: All of these were in the last Roadmap. We did not get "Frontier Missions" last ti and we've been told we won't get them this time, but we need to keep stressing the importance of t science if we ever want to have them go forward!

- ***Messenger/Beppi-Colombo*** - *(need to endorse Messenger and comment that follow-ons are alre being planned – Beppi-Colombo) – Jim Slavin/Michael Hesse*
  - ***Primary – C and D***
  - ***Secondary – A and B***
- **Jupiter Polar Orbiter** – *Fran Bagenal/Barry Mauk*
  - **Primary – C and D**
  - **Secondary – B**
- **Venus/Mars Aeronomy** – *Janet Luhmann/Harlan Spence*
  - **Primary – C and D**
  - **Secondary –**
- **Io Electrodynamics** – *Chuck Carlson/Harlan Spence*
  - **Primary – C and D**
  - **Secondary – A**
- **Neptune Orbiter** – *Chris Russell/Harlan Spence*
  - **Primary – C and D**
  - **Secondary – A and B**

Remote sensing is important! Imaging is important!

3. What technologies will I need to perform these missions?

Technology Issues Important for Magnetospheric Missions:

- Solar sails
- Nanosatellites
- Autonomy
- Robust/reliable spacecraft
- High-data rate communications
- Low power electronics
- Propulsion

Moreover, we need robust and advanced investments into these technologies in order to realize virtually of the above missions.

Global
Remote-Sensing
Experiments:
Beholding
Our
Wonderful
SKY

4. What science results will educators and the general public be interested in?

EPO Concepts Relevant to Magnetospheric Missions:

- Magnetic fields
- Electric fields
- Complex, coupled systems
- Natural hazards
- Natural environment
- Natural cycles (substorms, storms)
- Radiation
- Charged particles
- Nano-satellites
- Crossing different scale sizes
- Atmosphere
- Orbits
- "Seeing the invisible"
- Space

Paul Kintner's LWS Roadmap Presentation on 3/6/02

LWS Priorities – see Nicky Fox's poster
SAT team met first in 2000 – blessed by HQ
GMDT met three times, set priorities, discussed missions

GMDT Charge –

- review and apply to geospace the science and user objectives, priorities and justifications defined by NASA HQ and LWS SAT
- Derive and priorities measurement requirements
- Develop approaches and a set of candidate flight elements that fulfill
- Identify accommodation requirements for
- Keep in the box
- Set priorities

Practical Task to be Performed -

- Examine output of SAT
- Map the output into general objectives and science issues
- Prioritize based on convolution of
  - Withbroe priorities
  - Space weather effect significance
  - Potential for making progress in science understanding
- Create missions

Possible Geospace Network -

- Radiation Belts
  - Simultaneous range of L shells, full solar cycle, possibly GTO, big/little brother
- Low Earth Orbit
  - In-situ ionosphere, thermosphere, SEPs, polar cap, SAA, multi-point
- Geosynch or (Eccentric) Polar Orbit
  - Global imaging: auroral, O/N_2, N_e^2, ENA

Complementary Measurements/Missions

- Radiation Belts
- LANL, GOES, GPS
- Ionosphere/Thermosphere

Polar Orbiting
DMSP, POES, NPOESS, MTOP
Equatorial Orbiting
C/NOFS, CINDI
GPS Occultation
COSMIC, NPOESS, C/NOFS, SBIRS-L
Ground Based-Radar, GPS chains, Ionosondes, etc.

MOUs are important to realize all the partnering needed for LWS.

SDO – 2007-12
Geospace - 2008 (low altitude) and 2010 (high altitude)

RFA 3.d
Determine how magnetospheres and stellar inputs affect the evolution of planetary atmospheres

RFA 5 – refocused part of 3a AND 3d
Determine the effectiveness of magnetic fields in shedding angular momentum by solar system bodies
Explore the role of planetary magnetic shielding in establishing such diverse atmospheres at Earth, Mars, and Venus

RFA 7a.d
Determine the behavior of fundamental plasma processes in diverse solar system environments?

RFA 7b.d

Already costed

Ready to go : **MMS**
Costed, already in queue: MC

Please cost!

AMS: MIDEX+
The new and improved GSRI (SMILE+)
JPO: Discovery+
(IMC then MIO as resources permit)

Don’t need costing this time:

DBC

Already being costed elsewhere:

LWS/RBM