Mars Cross-Cutting Themes Within the Solar System Exploration Decadal Survey

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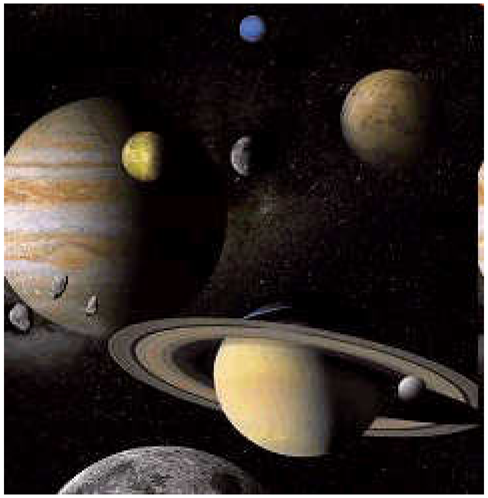
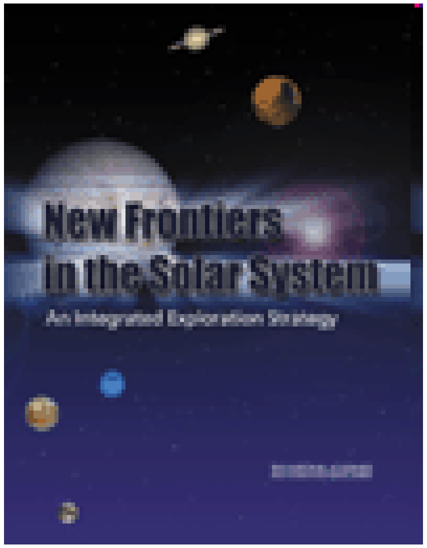


March 3, 2009

Assignment

1) MEPAG Goals Committee was tasked with comparing 2003 Decadal Survey (DS) cross-cutting themes and current MEPAG Goals
   - Discuss how MEPAG Goals/Objectives/Investigations fall within DS themes in the context of planetary exploration
   - Identify any MEPAG Goals/Objectives/Investigations that do not map well to cross-cutting themes
   - Suggest new cross-cutting themes if needed



2) White paper (3-5 pp.) prepared by June 1
   - For dissemination to DS integration panel and subpanels

2003 DS Cross-cutting Themes (and sub-themes)

-- from *"New Frontiers in the Solar System: An Integrated Exploration Strategy"*, National Research Council, 2003; *http://www.nap.edu/catalog.php?record_id=10432*

1) The First Billion Years of Solar System History

1. What processes marked the initial stages of planet and satellite formation?

2. How long did it take the gas giant Jupiter to form, and how was the formation of the ice giants (Uranus and Neptune) different from that of Jupiter and its gas giant sibling, Saturn?

3. How did the impactor flux decay during the solar system's youth, and in what way(s) did this decline influence the timing of life's emergence on Earth?

2) Volatiles and Organics: The Stuff of Life

4. What is the history of volatile compounds, especially water, across the solar system?
5. What is the nature of organic material in the solar system and how has this matter evolved?
6. What global mechanisms affect the evolution of volatiles on planetary bodies?

2003 DS Cross-cutting Themes (cont'd)

3) The Origin and Evolution of Habitable Worlds

7. What planetary processes are responsible for generating and sustaining habitable worlds, and where are the habitable zones in the solar system?

8. Does (or did) life exist beyond Earth?

9. Why have the terrestrial planets differed so dramatically in their evolutions?

10. What hazards do solar system objects present to Earth's biosphere?

4) Processes: How Planetary Systems Work

11. How do the processes that shape the contemporary character of planetary bodies operate and interact?

12. What does the solar system tell us about the development and evolution of extrasolar planetary systems, and vice versa?

2009 Goals Committee Members

- Jeff Johnson (USGS), Chair
- Goal I: Life
  - Tori Hoehler (NASA Ames)
  - Frances Westall (CNRS, France)
- Goal II: Climate
  - Scot Rafkin (SwRI)
  - Paul Withers (Boston Univ.)
- Goal III: Geology
  - Vicky Hamilton (SwRI)
  - Jeff Plescia (APL/JHU)
- Goal IV: Human Exploration
  - Abhi Tripathi (JSC)
  - Darlene Lim (NASA Ames)

- 2002-2003 Mars Panel Themes

http://www7.nationalacademies.org/ssb/2003ssedecadal_presentation.pdf

What is the Potential of Mars as an Abode of Life?

Water, Atmosphere, and Climate

Planetary Structure & Evolution

2008 MEPAG Goals Document Review

I. GOAL: DETERMINE IF LIFE EVER AROSE ON MARS

A. Objective: Assess the past and present habitability of Mars

B. Objective: Characterize Carbon Cycling in its Geochemical Context

C. Objective: Assess whether life is or was present on Mars

 Goal document (2008) location: *http://mepag.jpl.nasa.gov/reports/index.html*

2008 MEPAG Goals Document

II. GOAL: UNDERSTANDING THE PROCESSES AND HISTORY OF CLIMATE ON MARS

A. Objective: Characterize Mars' Atmosphere, *Present* Climate, and Climate Processes Under Current Orbital Configuration

B. Objective: Characterize Mars' *Recent* Climate History and Climate Processes Under Different Orbital Configurations

C. Objective: Characterize Mars' *Ancient* Climate and Climate Processes

2008 MEPAG Goals Document

III. GOAL: DETERMINE THE EVOLUTION OF THE SURFACE AND INTERIOR OF MARS

A. Objective: Determine the nature/evolution of geologic processes that have created/modified the Martian crust

B. Objective: Characterize the structure, composition, dynamics, and evolution of Mars' interior

C. Objective: Understand the origin, evolution, composition and structure of Phobos and Deimos

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IV. GOAL: PREPARE FOR HUMAN EXPLORATION

A. Objective. Obtain knowledge of Mars to design/implement human missions with acceptable cost, risk and performance

B. Objective. Conduct risk and/or cost reduction technology and infrastructure demonstrations in transit to, at, or on the surface of Mars

C. Objective. Characterize the State and Processes of the Martian Atmosphere of Critical Importance for the Safe Operation of Both Robotic and Human Spacecraft

Discussion Highlights to date

- *Goal I (Life):*
  - All Goal I Objectives/Investigations can be mapped into DS cross-cutting themes.
    - Some mismatch with DS sub-themes, but water and carbon are matched well.
    - If previous DS themes survive it is likely that the top-level themes will be maintained rather than the sub-theme questions
      - Habitability is a key aspect of the "life"-oriented themes that should be maintained

Discussion Highlights to date

- *Goal II (Climate):*
  - All Goal II Objectives/Investigations map into DS themes of “Volatiles/Organics” and “Origin/Evolution”
  - Only *Ancient* climate Objective maps into “First Billion Years” DS theme
  - Possible new cross-cutting theme: How/why climates change
    - This is a primary question in earth science, but what perspectives can planetary science bring?
    - Too exclusionary to bodies without atmospheres

Discussion Highlights to date

- *Goal III (Geology):*
  - Most Goal III Objectives/Investigations can be mapped into DS cross-cutting themes.
  - Interior studies not necessarily as well tied to "Volatiles/Organics" or "Evolution of Habitable Worlds" DS themes as to "Planetary Processes" theme

Discussion Highlights to date

- *Goal IV (Prepare for Exploration):*
  - Can effectively map all the *science-related* Objectives/Investigations into DS themes, but not the *engineering-related* Objectives/investigations
    - Noted that DS is intended to focus SMD science activities, not exploration arena (ESMD)
  - Consider new theme idea: *Safe, Efficient, Productive Scientific Exploration*
    - Cross-cutting between at least Moon and Mars
    - Could also encompass "Planetary protection" to bring in outer planets
  - Need to update Goal IV with inputs from upcoming Design Reference Architecture 5.0

Questions from Discussions

•Does “First billion years” imply disk accretion or planetary evolution?

– mismatch between theme and sub-themes

• How should the “Planetary Processes” DS theme be interpreted?

•Are “Volatiles/Organics“ and “Origin/Evolution“ really two themes?

• What is the importance of Phobos/Deimos studies to the Mars Exploration Program and/or in context of DS?

• Will all Mars science have to fit within the DS themes?

– Concern regarding potential exclusionary nature of the “extrasolar planetary systems” aspect of “Planetary Processes” DS theme….

Outline of White Paper

- *Executive Summary (0.5 pp.)*
- *Introduction (0.25 pp.)*
- *Background (0.25 pp.)*
- *Discussion (0.5 to 1 pp. each)*
  - *The First Billion Years*
  - *Volatiles and Organics: The Stuff of Life*
  - *Origin and Evolution of Habitable Planets*
  - *Planetary Processes*
- *Summary (0.5 pp.)*

Any comments welcome—forward to Charles Budney:
charles.j.budney@jpl.nasa.gov

Revision of the Goals Document

- 2008 MEPAG Goals Document
  - Completed September, 2008
    - Except for Goal IV
      - Goal IV awaiting release of Design Reference Architecture (DRA) 5.0
        - » 50-slide Powerpoint presentation released this week by HQ
        - » Update from Abhi Tripathi
  - Desire to update Goal I and II to include better defined priorities with respect to atmospheric methane

2008 MEPAG Goals Document Review

I. GOAL: DETERMINE IF LIFE EVER AROSE ON MARS

A. Objective: Assess the past and present habitability of Mars

1. Investigation: Establish the current distribution of water in all its forms on Mars.
2. Investigation: Determine and model the geological history of water on Mars.
3. Investigation: Identify and characterize materials containing C, H, O, N, P and S.
4. Investigation: Determine the potential energy sources available on Mars to sustain biological processes.

B. Objective: Characterize Carbon Cycling in its Geochemical Context

1. Investigation: Determine the distribution and composition of organic carbon on Mars.
2. Investigation: Characterize the spatial and temporal distribution and composition of inorganic carbon reservoirs on Mars.
3. Investigation: Characterize links between C and H, O, N, P, and S.
4. Investigation: Characterize the temporal preservation of reduced near-surface compounds.

C. Objective: Assess whether life is or was present on Mars

1. Investigation: Characterize complex organics.
2. Investigation: Characterize the spatial distribution of chemical and/or isotopic signatures.
3. Investigation: Characterize the morphology or morphological distribution of mineralogical signatures.
4. Investigation: Identify temporal chemical variations requiring life.

 Goal document (2008) location: *http://mepag.jpl.nasa.gov/reports/index.html*

II. GOAL: UNDERSTANDING THE PROCESSES AND HISTORY OF CLIMATE ON MARS

A. Objective: Characterize Mars' Atmosphere, *Present* Climate, and Climate Processes Under Current Orbital Configuration

1. Investigation: Determine processes controlling present distributions of water, CO_2, and dust in the upper and lower atmospheres.

2. Investigation: Determine the production/loss, reaction rates, and global 3-dimensional distributions of key photochemical species and their interaction with the surface.

3. Investigation: Understand how volatiles and dust exchange between surface and atmospheric reservoirs, including the mass and energy balance. Determine how this exchange has affected the present distribution of surface and subsurface ice as well as the Polar Layered Deposits (PLD).

4. Investigation: Search for microclimates.

B. Objective: Characterize Mars' *Recent* Climate History and Climate Processes Under Different Orbital Configurations

1. Investigation: Determine how the stable isotopic, noble gas, and trace gas composition of the Martian atmosphere has evolved over obliquity cycles to its present state.

2. Investigation: Determine the chronology, including absolute ages, of compositional variability, and determine the record of recent climatic change that are expressed in the stratigraphy of the PLD.

3. Investigation: Relate low latitude terrain softening and periglacial features to past climate eras.

C. Objective: Characterize Mars' *Ancient* Climate and Climate Processes

1. Investigation: Determine the rates of escape of key species from the Martian atmosphere, their correlation with seasonal and solar variability, the influence of remnant crustal magnetic fields, and their connection with lower atmosphere phenomenon.

2. Investigation: Find physical and chemical records of past climates.

3. Investigation: Determine how the stable isotopic, noble gas, and trace gas composition of the Martian atmosphere has evolved through time from the ancient climate state.

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III. GOAL: DETERMINE THE EVOLUTION OF THE SURFACE AND INTERIOR OF MARS

A. Objective: Determine the nature/evolution of geologic processes that have created/modified the Martian crust

1. Investigation: Determine the formation and modification processes of the major geologic units and surface regolith as reflected in their primary and alteration mineralogies.
2. Investigation: Evaluate volcanic, fluvial/lacustrine, hydrothermal, and polar erosion and sedimentation processes that modified the Martian landscape over time.
3. Investigation: Constrain the absolute ages of major Martian crustal geologic processes, including sedimentation, diagenesis, volcanism/plutonism, regolith formation, hydrothermal alteration, weathering, and the cratering rate.
4. Investigation: Hydrothermal environments.
5. Investigation: Evaluate igneous processes and their evolution through time.
6. Investigation: Characterize surface-atmosphere interactions on Mars, as recorded by aeolian, glacial/periglacial, fluvial, chemical and mechanical erosion, cratering and other processes.
7. Investigation: Determine the tectonic history and large-scale vertical and horizontal structure of the crust, including present activity. This includes, for example, the structure and origin of hemispheric dichotomy.
8. Investigation: Determine the present state, 3-dimensional distribution, and cycling of water on Mars including the cryosphere and possible deep aquifers.
9. Investigation: Determine the nature of crustal magnetization and its origin.
10. Investigation: Evaluate the effect of large-scale impacts on the evolution of the Martian crust.

B. Objective: Characterize the structure, composition, dynamics, and evolution of Mars' interior

1. Investigation: Characterize the structure and dynamics of the interior.
2. Investigation: Determine the origin and history of the magnetic field.
3. Investigation: Determine the chemical and thermal evolution of the planet.

C. Objective: Understand the origin, evolution, composition and structure of Phobos and Deimos

1. Investigation: Determine the origin of Phobos and Deimos.
2. Investigation: Determine the composition of Phobos and Deimos.
3. Investigation: Understand the internal structure of Phobos and Deimos.

2008 MEPAG Goals Document

IV. GOAL: PREPARE FOR HUMAN EXPLORATION

A. Objective. Obtain knowledge of Mars to design/implement human mission with acceptable cost, risk and performance

1A. Investigation. Characterize potentially damaging particulates.
1B. Investigation. Determine the atmospheric fluid variations from ground to >90 km that affect EDL.
1C. Investigation. Determine if each Martian site to be visited by humans is free of biohazards.
1D. Investigation. Characterize potential sources of water to support In Situ Resource Utilization for human missions.
2. Investigation. Determine the possible toxic effects of Martian dust on humans.
3. Investigation. Assess atmospheric electricity conditions that may affect human occupation.
4. Investigation. Determine the processes by which terrestrial microbial life, or its remains, is dispersed/destroyed on Mars.
5. Investigation. Characterize in detail the ionizing radiation environment at the Martian surface.
6. Investigation. Determine traction/cohesion in Martian regolith (with emphasis on trafficability hazards).
7. Investigation. Determine the meteorological properties of dust storms that affect human occupation and EVA.

B. Objective. Conduct risk and/or cost reduction technology and infrastructure demonstrations in transit to, at, or on the surface of Mars

1A. Demonstration. Conduct a series of three aerocapture flight demonstrations:
1B. Demonstration. Conduct a series of three in-situ resource utilization technology demonstrations:
1C. Demonstration. Demonstrate an end-to-end system for soft, pinpoint Mars landing with 10 m to 100 m accuracy
2A. Demonstration. Demonstrate continuous and redundant *in situ* communications/navigation infrastructure; Deploy in full-up Precursor Test Mission.
2B. Demonstration. Investigate long-term material degradation over times comparable to human mission operations.
3. Demonstration. Develop and demonstrate accurate, robust and autonomous Mars approach navigation.

C. Objective. Characterize the State and Processes of the Martian Atmosphere of Critical Importance for the Safe Operation of Both Robotic and Human Spacecraft

1. Investigation: Understand the thermal and dynamical behavior of the planetary boundary layer.
2. Investigation: Understand and monitor the behavior of the lower atmosphere (0-80km) on synoptic scales.
3. Investigation: Determine the atmospheric mass density and its variation over the 80 to 200 km altitude range.
4. Investigation: Determine the atmospheric mass density and its variations at altitudes above 200 km.