MEPAG Goals

Overview and Process

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Chair

MEPAG Goals Committee

Dune field in Endurance Crater
http://marswatch.astro.cornell.edu/pancam_instrument/endurancedunes_new.html

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Flagstaff, AZ

Overview

- What is the MEPAG Goals Document?
- Who works on the Goals process?
- How was the Goals Document created?
- How does the document achieve community consensus?
- Content of the Goals document
- Example of Investigation reprioritization
- Plans for updates to Goals Document

MEPAG Goals Document is:

- A comprehensive list of the high level science goals, objectives, and investigations for Mars
- Valuable for guiding program implementation decisions
- Improved through periodic updates as new results from Mars are discovered
- A process for documenting community consensus

Goal document location: http://mepag.jpl.nasa.gov/reports/index.html

MEPAG Goals Document

- What it isn't:
  - Advocacy for any individual mission, instrument, measurement, or theory

Preview: Goals document

<u>Science Goals for Mars Exploration</u>

I. Determine if life ever arose on Mars
II. Understand the processes and history of climate on Mars
III. Determine the evolution of the surface and interior of Mars
IV. Prepare for human exploration

MEPAG does not prioritize <u>across</u> these four Goals, but does prioritize <u>within</u> Goals

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)

History of the Goals Document

- 2001 – The original MEPAG Goals Document was created
  - Drafted by the MEPAG Executive Committee with inputs from the community
  - Included sessions at MEPAG meetings dedicated to establishing consensus
- 2004 – First Major revisions
- 2005 – Minor Maintenance
- 2006 – Minor Maintenance
- 2008 – Major revision of Goals II & III
- 2009 – Update in work for Goals I & IV

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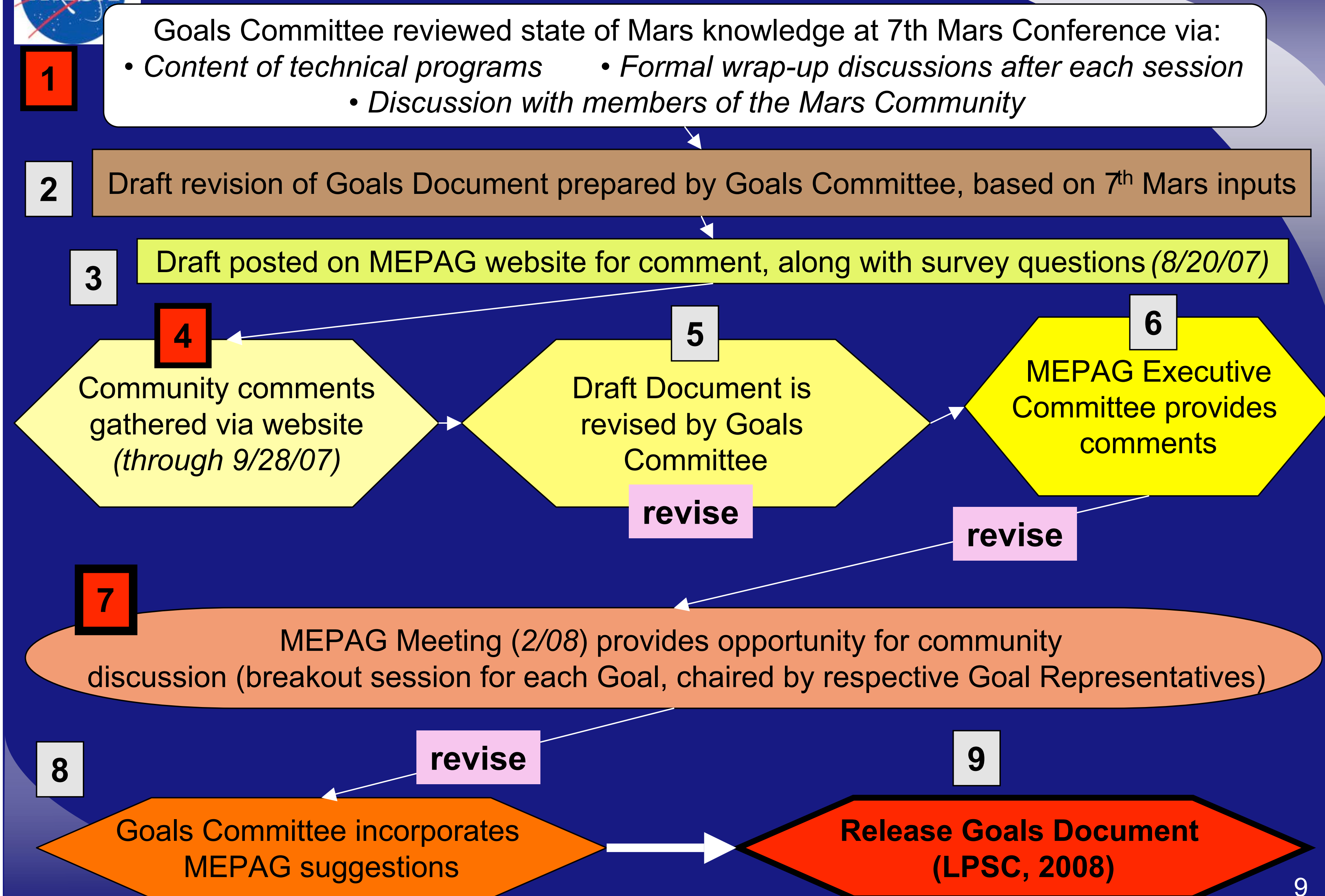
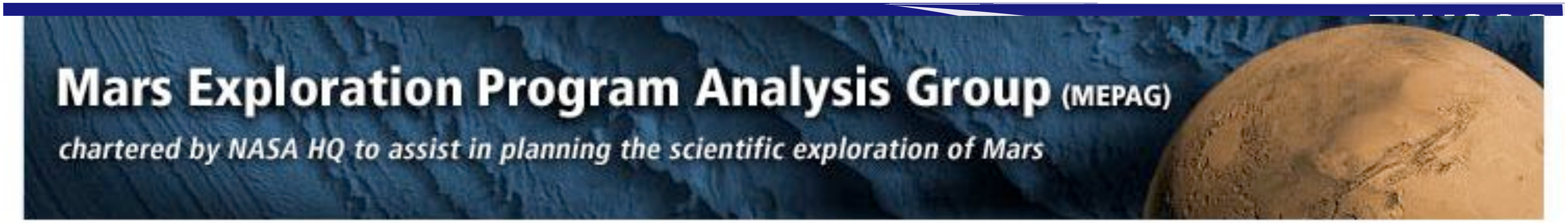
How does the Goal Document reach a "community consensus?"

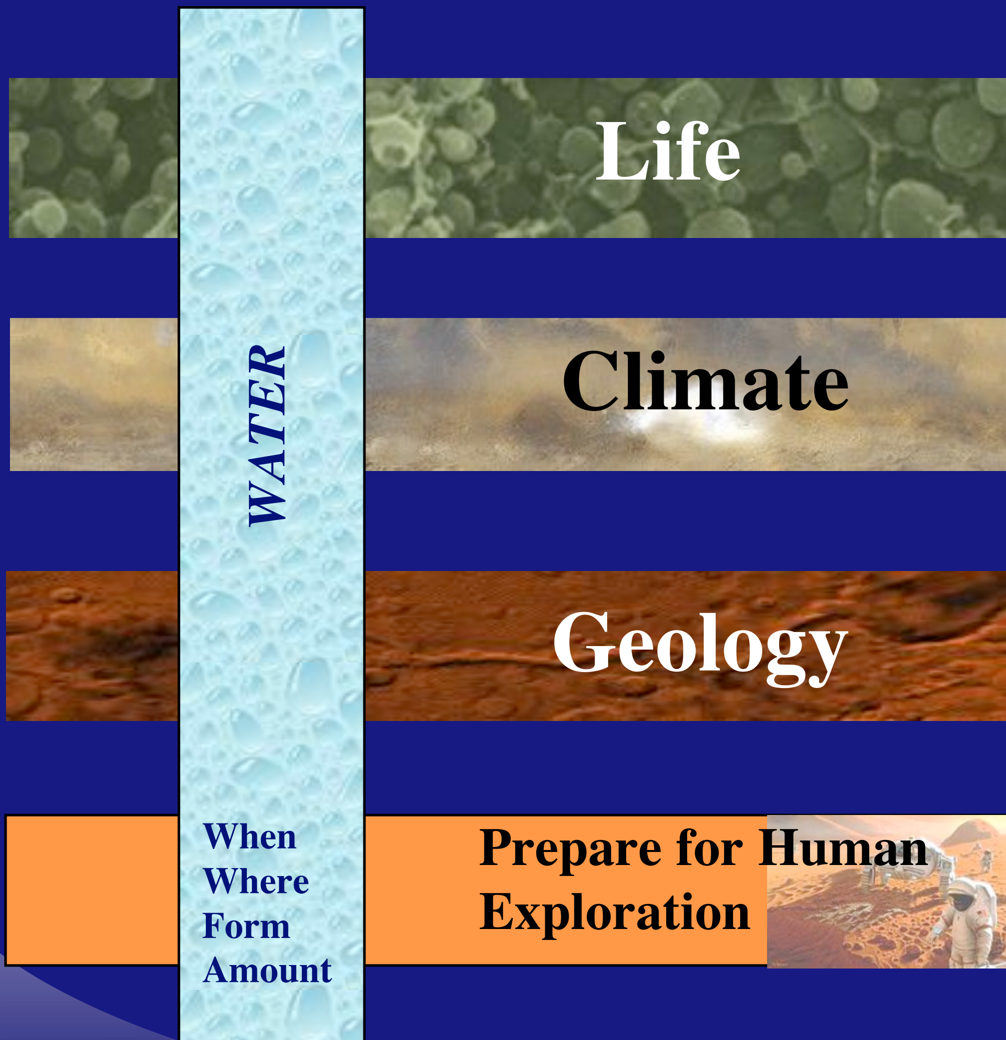
- The process is inclusive and open to the entire U.S. and international community
- The objectives and investigations focus on the high level scientific questions.
- Many opportunities exist for community input
  - Sub-groups often formed when document is updated
  - Revisions are circulated to the Mars community for comments and discussed in subgroups and/or in plenary sessions during MEPAG meetings
- See 2008 example (next page)

MEPAG Goals Document (2008) Revision Process Flowchart





Mars Goals



Understand the potential for life elsewhere in the Universe

Characterize the present and past climate and climate processes

Understand the geological processes affecting Mars' interior, crust, and surface

Develop knowledge & technology necessary for eventual human exploration

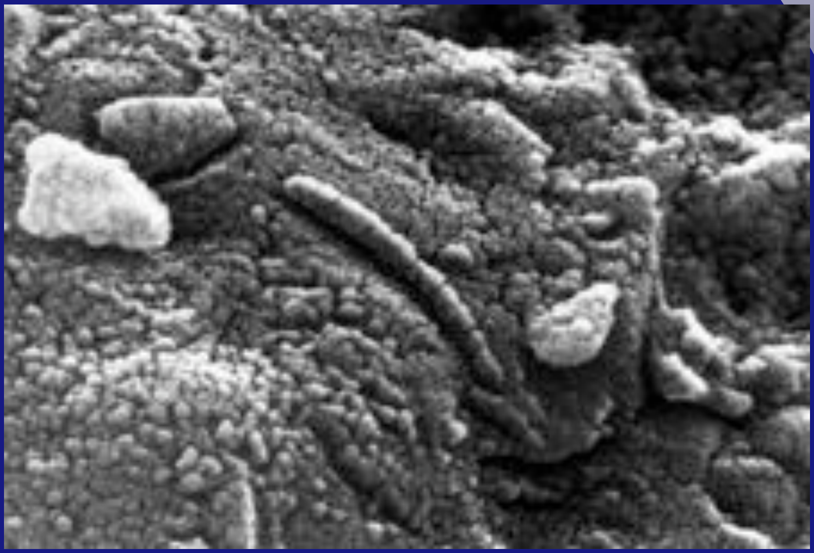
MEPAG 4-Tiered Hierarchy

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

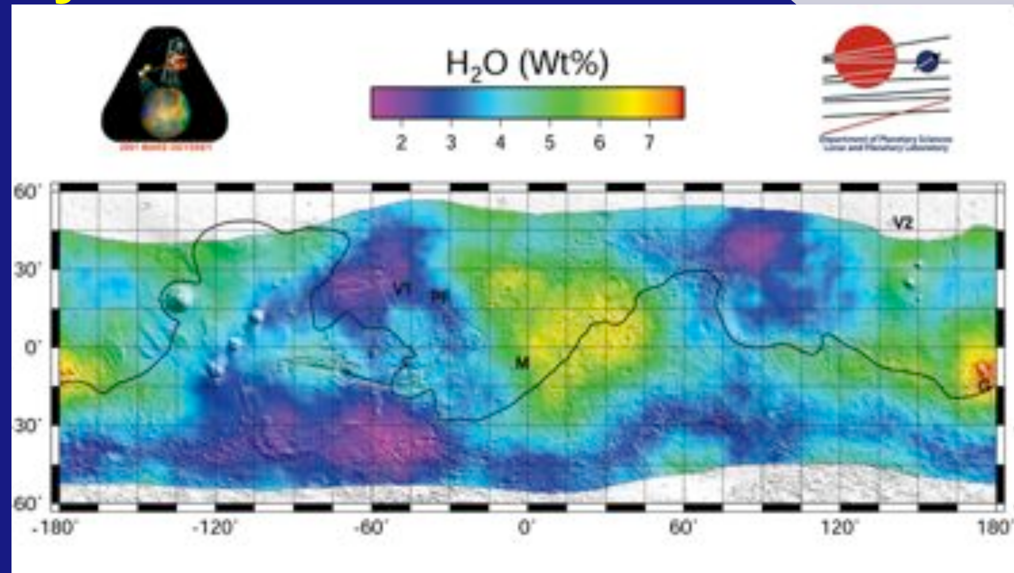


High-resolution scanning electron microscope image showing an unusual tube-like structural form that is less than 1/100th the width of a human hair in size found in meteorite ALH84001. NASA image.

I.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 the geological history of water on Mars, and model the processes that have caused water to move from one reservoir to another.



Concentration estimates of equivalent-weight water found in the regions around the equator of Mars. Map is based upon gamma ray data collected for the element hydrogen. Regions of high hydrogen concentration are shown in red while regions of low hydrogen concentration are shown in blue. Hydrogen may be in the form of hydrated minerals or buried ice deposits.
http://grs.lpl.arizona.edu/latestresults.jsp

3. Investigation: Identify and characterize phases containing C, H, N, O, P and S, including minerals, ices, and gases, and the fluxes of these elements between phases.

4. Investigation: Determine the array of potential energy sources available on Mars to sustain biological processes.

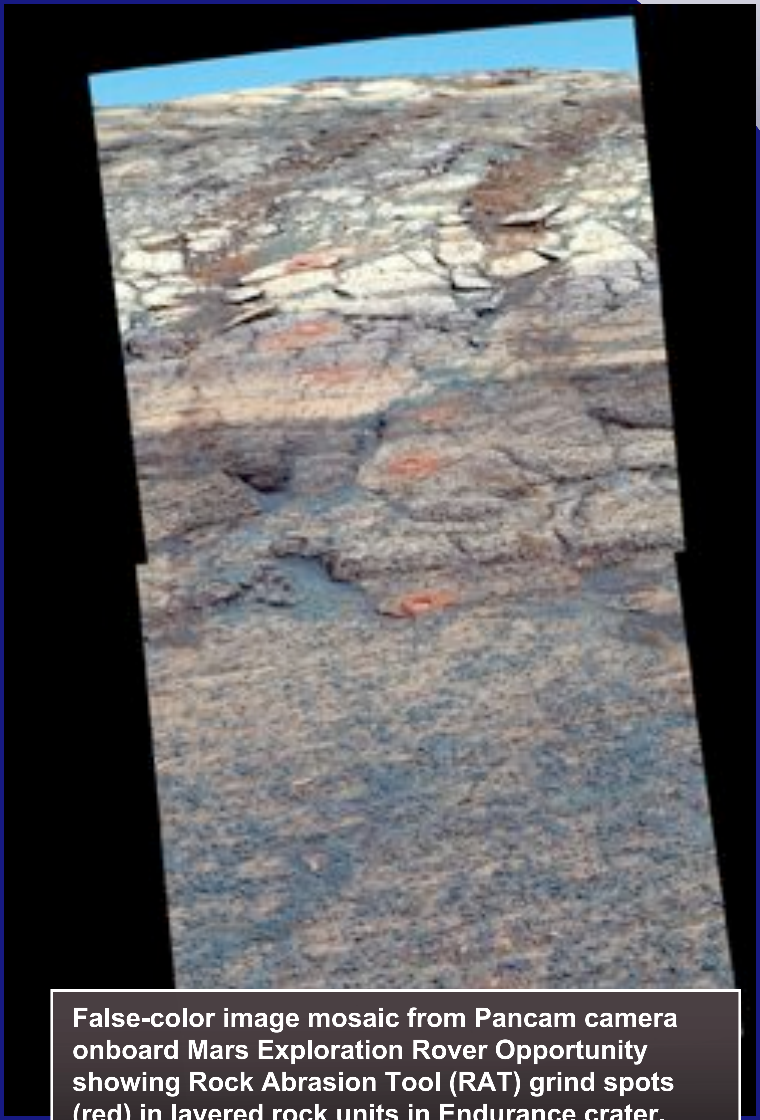
I.B. Objective: Characterize Carbon Cycling in its Geochemical Context

1. Investigation: Determine the distribution and composition of organic carbon on Mars.

2. Investigation: Characterize the distribution and composition of inorganic carbon reservoirs on Mars through time.

3. Investigation: Characterize links between C and H, N, O, P, and S.

4. Investigation: Characterize the preservation of reduced compounds on the near-surface through time.



False-color image mosaic from Pancam camera onboard Mars Exploration Rover Opportunity showing Rock Abrasion Tool (RAT) grind spots (red) in layered rock units in Endurance crater. http://marswatch.astro.cornell.edu/pancam_instrument/173B_P2401.html

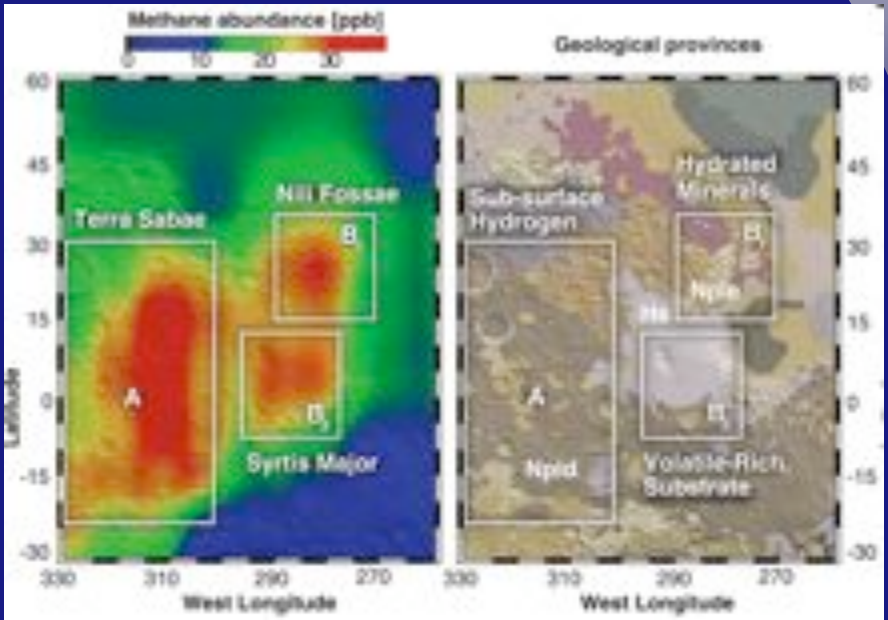
I.C. Objective: Assess whether life is or was present on Mars

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.



Regions where methane appears notably localized in northern summer (A, B1, and B2) and their relationship to mineralogical and geomorphological domains. (left) Observations of methane near the Syrtis Major volcanic district. (right) Geologic map superimposed on the topographic shaded relief from the Mars Orbiter Laser Altimeter.

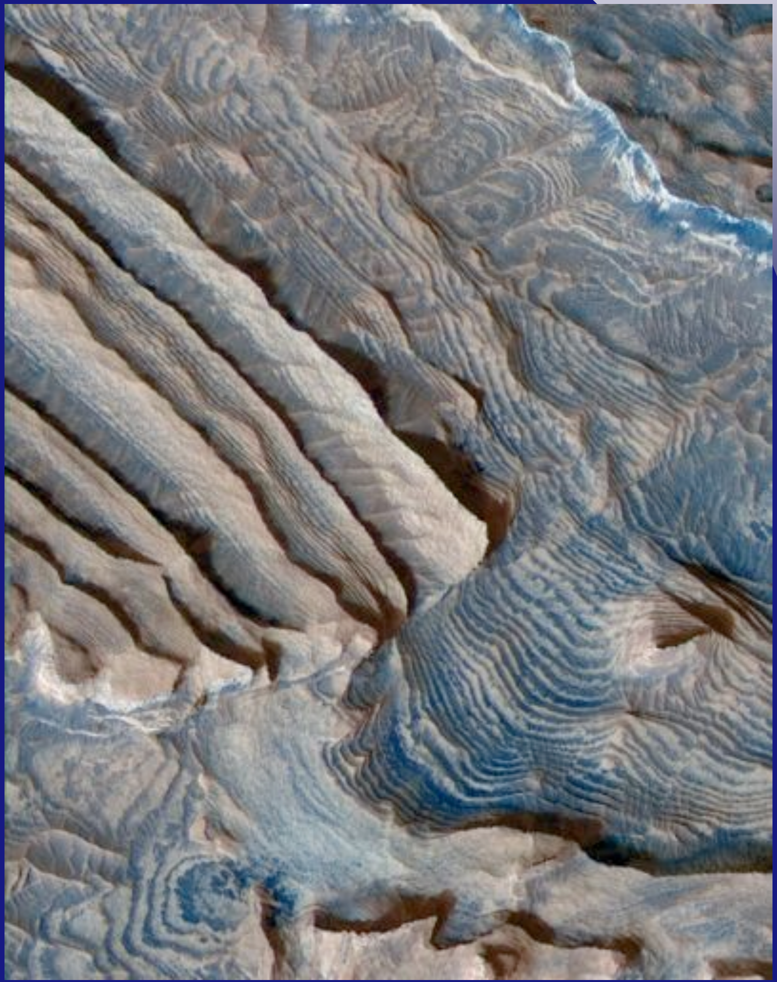
Mumma, M. et al., Strong Release of Methane on Mars in Northern Summer 2003, Science 323 (5917), 1041. [DOI: 10.1126/science.1165243]

II. GOAL: UNDERSTANDING THE PROCESSES AND HISTORY OF CLIMATE

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



Rhythmic bedding in sedimentary bedrock within Becquerel crater on Mars in HiRISE false-color image. View covers an area about 1.15 km, with individual layers ~3.6 meters thick.
http://photojournal.jpl.nasa.gov/catalog/PIA11443

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

1. Investigation: Determine the processes controlling the present distributions of water, carbon dioxide, and dust by determining the short- and long-term trends (daily, seasonal and solar cycle) in the present climate. Determine the present state of the upper atmosphere (neutral/plasma) structure and dynamics; quantify the processes that link the Mars lower and upper atmospheres.

2. Investigation: Determine the production/loss, reaction rates, and global 3-dimensional distributions of key photochemical species (e.g., O_3, H_2O, CO, OH, CH_4, SO_2), the electric field and key electrochemical species (e.g., H2O2), and the interaction of these chemical species with surface materials.

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.

II.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.

False-color image from HiRISE image PSP_001738_2670 of the north polar layered deposits. Some of the color variations may be caused by small amounts of water frost on the surface, or they may be due to variations in dust composition within the layered deposits.
http://photojournal.jpl.nasa.gov/catalog/PIA10003

II.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 (e.g., dust storms). From these observations, quantify the relative importance of processes that control the solar wind interaction with the Mars upper atmosphere in order to establish the magnitude of associated volatile escape rates.

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

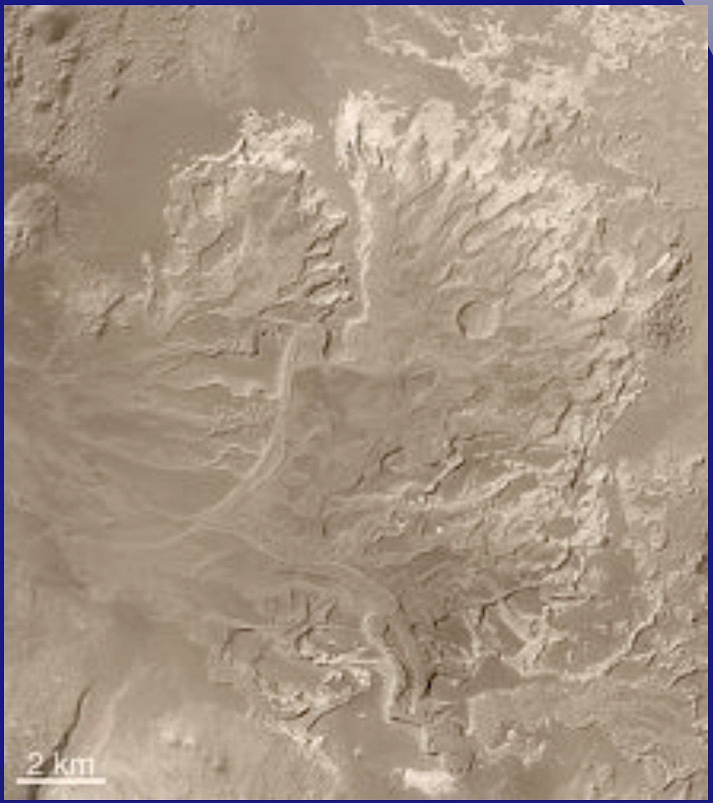
3. Investigation: Determine how the stable isotopic, noble gas, and trace gas composition of the Martian atmosphere has evolved through time from the ancient climate state.

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

A. Objective: Determine the nature and evolution of the geologic processes that have created and 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



http://www.msss.com/mars_images/moc/2005/09/20/eberswalde/

MOC2-1225a: Mosaic of MOC images of Eberswalde delta.

III.A Objective: Determine the nature and evolution of the geologic processes that have created and 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/laucustrine, 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: Explore potential hydrothermal environments.

5. Investigation: Evaluate igneous processes and their evolution through time

III.A Objective: Determine the nature and evolution of the geologic processes that have created and modified the Martian crust (cont'd)

6. Investigation: Characterize surface-atmosphere interactions on Mars, as recorded by aeolian, glacial/periglacial, fluvial, chemical and mechanical erosion, cratering and other processes.

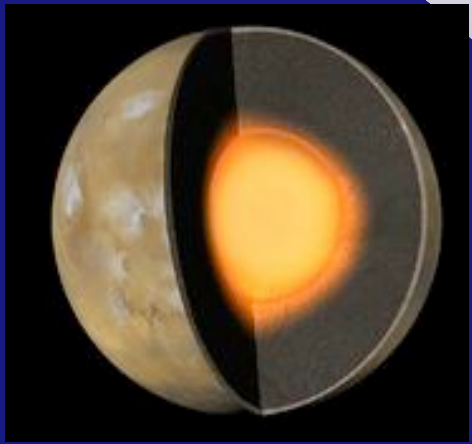
7. Investigation: Determine the tectonic history and large-scale vertical and horizontal structure of the crust, including present activity. This includes, for example, the structure and origin of hemispheric dichotomy.

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/origin of crustal magnetization.

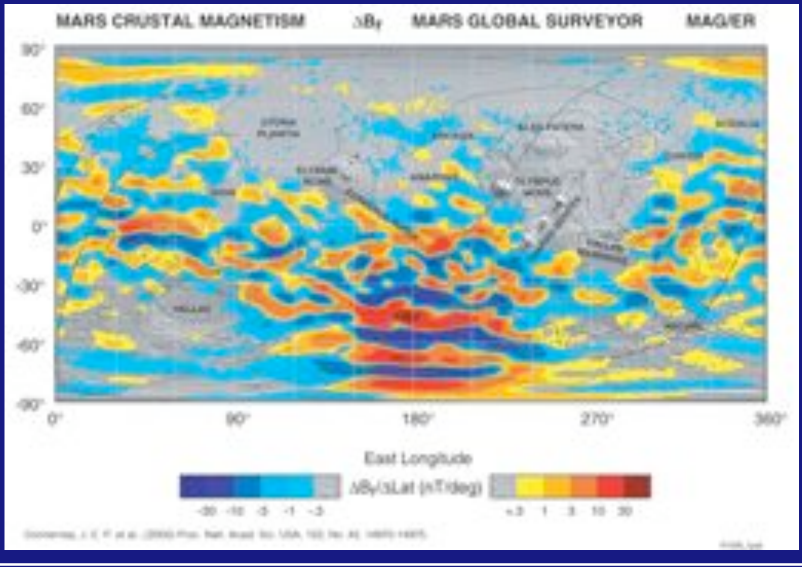
10. Investigation: Evaluate the effect of large-scale impacts on the evolution of the Martian crust.

III.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.

Magnetic field observed by Mars Global Surveyor. Pixels colored according to median value of the filtered radial magnetic field component. shaded MOLA topography relief map provides context. http://mgs-mager.gsfc.nasa.gov/publications/pnas_102_42_connerney/

III.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.

Phobos imaged by combining data from HiRISE's blue/green, red, and near-infrared channels. Materials near the rim of Stickney appear bluer than the rest of Phobos. http://hirise.lpl.arizona.edu/phobos.php

IV. GOAL: PREPARE FOR HUMAN EXPLORATION

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

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

C. Objective. Characterize the state and processes of the <u>martian atmosphere</u> of critical importance for the safe operation of both <u>robotic and human</u> spacecraft

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

1A. Investigation. Characterize the particulates that could be transported to hardware and infrastructure through the air (including both natural aeolian dust and other materials that could be raised from the Martian regolith by ground operations), and that could affect engineering performance and in situ lifetime.

1B. Investigation. Determine the atmospheric fluid variations from ground to >90 km that affect EDL (Entry, Descent, Landing) and TAO (Takeoff/Ascent to Orbit) including both ambient conditions and dust storms.

1C. Investigation. Determine if each Martian site to be visited by humans is free, to within acceptable risk standards, of biohazards that may have adverse effects on humans and other terrestrial species. Sampling into the subsurface for this investigation must extend to the maximum depth to which the human mission might come into contact with Martian material.

1D. Investigation. Characterize potential sources of water to support In Situ Resource Utilization (ISRU) for eventual human missions.

IV.A Objective. Obtain knowledge of Mars sufficient to design and implement a human mission with acceptable cost, risk and performance (cont'd)

2. Investigation. Determine the possible toxic effects of Martian dust on humans.

3. Investigation. Assess atmospheric electricity conditions that may affect TAO (Takeoff/Ascent to Orbit) and human occupation.

4. Investigation. Determine the processes by which terrestrial microbial life, or its remains, is dispersed and/or destroyed on Mars (including within ISRU-related water deposits), the rates and scale of these processes, and the potential impact on future scientific investigations.

5. Investigation. Characterize in detail the ionizing radiation environment at the Martian surface, distinguishing contributions from the energetic charged particles that penetrate the atmosphere, secondary neutrons produced in the atmosphere, and secondary charged particles and neutrons produced in the regolith.

IV.A Objective. Obtain knowledge of Mars sufficient to design and implement a human mission with acceptable cost, risk and performance (cont'd)

6. Investigation. Determine traction/cohesion in Martian regolith (with emphasis on trafficability hazards, such as dust pockets and dunes) throughout planned landing sites; where possible, feed findings into surface asset design requirements.

7. Investigation. Determine the meteorological properties of dust storms at ground level that affect human occupation and EVA.

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

USGS science for a changing world

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 using systems characteristics that are representative of Mars human exploration systems. (Mid)

2A. Demonstration. Demonstrate continuous and redundant in situ communications/navigation infrastructure (Early). Deploy in full-up Precursor Test Mission (Late).

2B. Demonstration. Investigate long-term material degradation over times comparable to human mission operations. (Mid)

3. Demonstration. Develop and demonstrate accurate, robust and autonomous Mars approach navigation. (Mid)

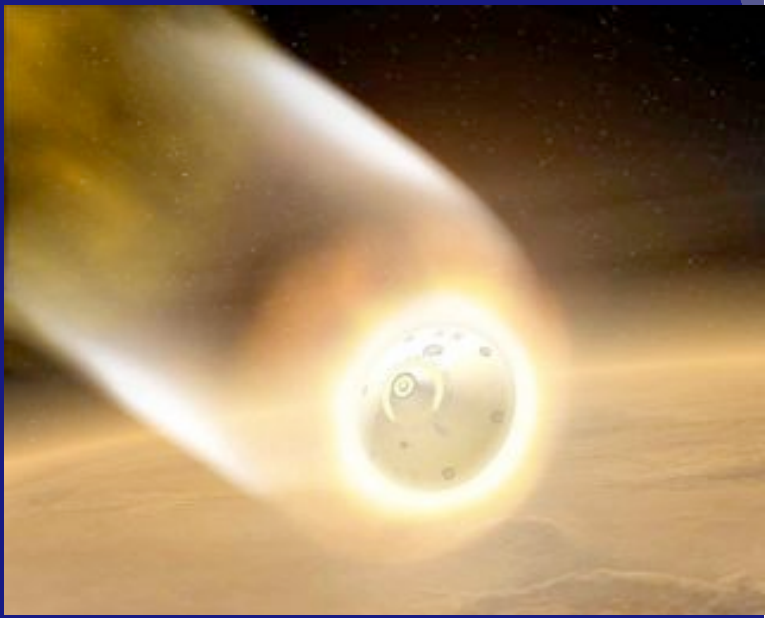
IV.C Objective. Characterize the state and processes of the martian atmosphere of critical importance for the safe operation of both robotic and human spacecraft

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.



Cross-Cutting Themes

- **Follow the Water (2000)**
  - Provided means to simultaneously approach multiple Goals and Objectives
- **Understand Mars as a System (2004)**
  - Origin and interconnectivity of diversity of Mars
- **Seek Habitable Environments (2008)**
  - Variety of ancient/modern settings capable of supporting life

Investigation reprioritization example
Goal III. Objective A: Geologic Processes

2006 III.A Investigations

1) 3D water cycling
2) Fluvial/sedimentary processes
3) Absolute ages
4) Igneous processes
5) Surface-atmosphere interaction
6) Crustal evolution/alteration
7) Tectonics
8) Hydrothermal processes
9) Regolith evolution/alteration
10) Magnetism
11) Impacts

2008 III.A Investigations

1) Formation/alteration geol. units
2) Volcanic/fluvial/lacustrine
3) Absolute ages
4) Hydrothermal processes
5) Igneous processes
6) Surface-atmosphere interaction
7) Tectonics
8) 3D water cycling
9) Magnetism
10) Impacts

Ongoing work: 2009-2010

- Goal I updates: Westall/Hoehler organizing revision
  - Desire to re-address objectives and investigations with respect to water
  - Expect new draft on MEPAG website this month
    - Community will have opportunity to provide feedback
  - Objective B (Carbon) “reabsorbed” into Habitability and Life objectives
    - Not a “demotion” of carbon – which retains high priority, particularly in the Life objective
    - Intent is to remove current redundancies and more clearly demonstrate the connection between specific carbon investigations and broader scientific objectives

Ongoing work:

- Goal I updates
  - Objective A: Assess the habitability of Mars through time, at local and planetary scales
    - Emphasizes habitability investigations as a means of prioritizing sites for life detection efforts
  - Objective B: Assess whether life is or was present on Mars
    - Emphasizes the search for traces of past and extant life in terms of analysis of an ensemble of biomarkers
    - N.B.: Objective B has highest priority, but some Objective A investigations seen as prerequisite or guiding
    - Objectives should be pursued concurrently to the extent possible

Ongoing work: Goal IV updates

- MEPAG and Tripathi/Lim organizing small Science Analysis Group (SAG) to prepare revised Goal IV
  - Release of “Design Reference Architecture 5.0”
  - http://www.nasa.gov/exploration/library/esmd_documents.html
- SAG scheduled to start ~Oct.1
  - Finish in time for next MEPAG meeting (March ‘10)
  - Allows input from the Review of U.S. Human Space Flight Plans panel (Augustine Commission) report due soon
  - Will be requesting membership for SAG

Summary: 2008 Scientific Objectives for the Exploration of Mars

Life

Sequential

- Assess past and present habitability potential of Mars
- Characterize carbon cycling in its geochemical context (including its origin and distribution)
- Test for life (identify and determine the spatial distribution of biosignatures)

Climate

Higher priority

- Characterize the atmosphere and present climate and processes under current orbital configuration
- Characterize Mars' recent climate history/processes under different orbital configurations
- Characterize Mars' ancient climate and climate processes

Geology

Higher priority

- Determine the nature and evolution of the geologic processes that have created and modified the martian crust and surface
- Characterize the structure, composition, dynamics, and evolution of the martian interior

Preparation

Equal priority

- Obtain knowledge of Mars sufficient to design and implement a human mission with acceptable cost, risk and performance
- Conduct risk and/or cost reduction technology and infrastructure demonstrations in transit to, at, or on the surface of Mars.

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Summary: 2006 Scientific Objectives for the Exploration of Mars

Life

Sequential

- Assess past and present habitability potential of Mars
- Characterize carbon cycling in its geochemical context (including its origin and distribution)
- Test for life (identify and determine the spatial distribution of biosignatures)

Climate

Higher priority

- Characterize the atmosphere and present climate and processes
- Characterize Mars' ancient climate and climate processes.
- Atmospheric state and processes of critical importance for the safe operation of spacecraft

Geology

Higher priority

- Determine the nature and evolution of the geologic processes that have created and modified the martian crust and surface
- Characterize the structure, composition, dynamics, and evolution of the martian interior

Preparation

Equal priority

- Obtain knowledge of Mars sufficient to design and implement a human mission with acceptable cost, risk and performance
- Conduct risk and/or cost reduction technology and infrastructure demonstrations in transit to, at, or on the surface of Mars. .

MEPAG 4-Tiered Hierarchy

2006 Status

N = 4

N = 10

N = 55

Not enumerated