The MEPAG Goals Document

Don Banfield, MEPAG Goals Committee Chair

Outline:

1. What is the MEPAG Goals Document?
2. Revision history/timeline
3. Overview of draft revisions

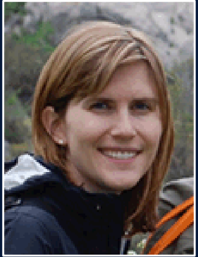
Goals Committee

Jen Stern
NASA
GSFC,
Goal 1

Alfonso
Davila
NASA
Ames,
Goal 1

Don Banfield
Cornell, Goals
Committee Chair

Briony Horgan
Purdue, Goal 3



Sarah Stewart Johnson
Georgetown, Goal 1

Becky Williams
PSI, Goal 3

Michelle Rucker
NASA JSC, Goal 4

David Brain
UC Boulder,
Goal 2

Robin Wordsworth
Harvard University, Goal 2

Jacob
Bleacher
NASA
GSFC/HQ,
Goal 4

Paul Niles
NASA
JSC,
Goal 4

MEPAG Goals Document

- Prioritizes **"flight"** measurements to achieve high priority Mars system science questions
- Periodically updated, in response to new discoveries and research directions

Mars Exploration Program Analysis Group (MEPAG)

Life	Climate	Geology	Human Exploration
			
I. Determine if Mars ever supported, or still supports life	II. Understand the processes and history of climate on Mars	III. Understand the origin and evolution of Mars as a geological system	IV. Prepare for human exploration

What has been the timeline for this revision?

- Initiated at 9th Mars Conference (July 2019)
- First Draft to public January 2020
- Feedback accepted via community telecon (Feb 10) & web-form (through Feb 14)
- Finalizing revision now.
- Release revision at LPSC 2020.
  - in time for Decadal Survey kickoff & influence white papers

Extent of Input

- 32 people joined our feedback telecon
- 25 sets of detailed comments via web-form
  - One from a group of 9 community members
- Lots of constructive comments and suggestions
- The MEPAG Goals Committee carefully considered **ALL** of the input and in most cases followed the comments given.

Integrating Across the MEPAG Goals to Understand Mars and Beyond

- We identify where Investigations contribute to others throughout.
  - e.g., polar science investigations touched on by all 4 goals.
- We examine MEPAG Goals in terms of MEPAG's "Big Questions" of Solar System Exploration
  - Ease integrating our work into the Decadal Survey

  - ➢ How do planetary surfaces, crust and interiors form and evolve?
  - ➢ How do climates and atmospheres change through time?
  - ➢ What are the pathways that lead to habitable environments across the solar system and the origin and evolution of life?
  - ➢ How is our solar system representative of planetary systems in general?
  - ➢ What is needed for humans to explore the Moon and Mars?

Mars Exploration Program Analysis Group (MEPAG)

Life	**I. Determine if Mars ever supported, or still supports, life.**	A. Search for evidence of life in environments that have a high potential for habitability and preservation of biosignatures. B. Assess the extent of abiotic organic chemical evolution.
Climate	**II. Understand the processes and history of climate on Mars.**	A. Characterize the state and controlling processes of the present-day climate of Mars under the current orbital configuration. B. Characterize the history and controlling processes of Mars' climate in the recent past, under different orbital configurations. C. Characterize Mars' ancient climate and underlying processes.
Geology	**III. Understand the origin and evolution of Mars as a geological system.**	A. Document the geologic record preserved in the crust and investigate the processes that have created and modified that record. B. Determine the structure, composition, and dynamics of the interior and how it has evolved. C. Determine the origin and geologic history of Mars' moons and implications for the evolution of Mars.
Human Exploration Source: MEPAG 2020, Penultimate Draft	**IV. Prepare for Human Exploration.**	A. Human landing with acceptable cost, risk and performance. B. Human surface exploration and EVA with acceptable cost, risk and performance. C. In Situ Resource Utilization (ISRU) of atmosphere and/or water with acceptable cost, risk and performance. D. Biological contamination and planetary protection protocols with acceptable cost, risk and performance. E. Human missions to Phobos or Deimos with acceptable cost, risk and performance.

Mars Exploration Program Analysis Group (MEPAG)

I. Determine if Mars ever supported, or still supports, life

A. Search for evidence of life in environments that have a high potential for habitability and preservation of biosignatures.

A1. Determine if signatures of life are present in environments affected by liquid water
A2. Investigate the nature and duration of habitability near the surface and in the deep subsurface.
A3. Assess the preservation potential of biosignatures near the surface and with depth

B. Assess the extent of abiotic organic chemical evolution.

B1. Constrain atmospheric and crustal inventories of carbon (particularly organic molecules) and other biologically important elements over time
B2. Constrain the surface, atmosphere, and subsurface processes through which organic molecules could have formed and evolved over martian history

II. Understand the processes and history of climate on Mars

A. Characterize the state and controlling processes of the present-day climate of Mars under the current orbital configuration.

A1. Lower atmosphere dust, water, CO_2 cycles
A2. Volatiles/dust exchange with surface
A3. Chemistry of atmosphere and surface
A4. Upper atmosphere/magnetosphere state & controlling processes

B. Characterize the history and controlling processes of Mars' climate in the recent past, under different orbital configurations.

B1. Determine recent climate record in polar region
B2. Determine recent climate record in low- and mid-latitudes
B3. Recent past atmospheric composition

C. Characterize Mars' ancient climate and underlying processes.

C1. Determine changes in atmospheric composition and mass through time
C2. find and interpret surface records of past climates

III. Understand the origin and evolution of Mars as a geological system

A. Document the geologic record preserved in the crust and investigate the processes that have created and modified that record.

A1. Characterize past and present water and other volatile reservoirs
A2. Document the geologic record in sediments
A3. Constrain ancient environmental transitions
A4. Determine the construction and modification of the crust

B. Determine the structure, composition, and dynamics of the interior and how it has evolved.

B1. Crust-mantle interactions
B2. accretion, differentiation and thermal evolution

C. Determine the origin and geologic history of Mars' moons and implications for the evolution of Mars.

C1. Origin of moons
C2. Impactor flux

IV. Prepare for human exploration

A. Human landing with acceptable cost, risk and performance.

A1. Atmospheric state affecting orbital capture and EDL for human missions
A2. Orbital debris environment
A3. Landing-site & environmental characteristics for safe landing

B. Human surface exploration and EVA with acceptable cost, risk, and performance.

B1. Surface radiation and dust hazards
B2. Impact of dust on hardware
B3. Dust storm risks
B4. Identify landing-site hazards

C. ISRU of atmosphere and/or water with acceptable cost, risk, and performance.

C1. ISRU resilience to varying environmental conditions
C2. Characterize water resources for ISRU for long-term human needs

D. Biological contamination and planetary protection protocols with acceptable cost, risk, and performance.

D1. Definition of "special regions" in the exploration zone
D2. Crew risk of martian biohazards
D3. Earth risk of martian biohazards
D4. Astrobiological baseline of landing site prior to human arrival
D5. Survivability of terrestrial organisms at Mars

E. Human missions to Phobos or Deimos with acceptable cost, risk, and performance.

E1. Geology to define science objectives, operations planning and resources
E2. Surface and orbital conditions for proximity operations

Source: MEPAG 2020, Penultimate Draft

Changes in Current Draft from 2018 version

Goal I (Life):

- Modified title to capture the possibility of ancient and modern life
- Removed distinction between extinct and extant life
  - Un-needed distinction, implementation strategy de-emphasized
- Objective IA. Search for evidence of life in environments that have a high potential for habitability and preservation of biosignatures.
  - i.e., merging extinct and extant Objectives from prior versions
- Objective IB. Assess the extent of abiotic organic chemical evolution
  - Balances IA., examining abiotic origins of organics

Changes in Current Draft from 2018 version

Goal II (Climate):

- Shortened & updated prose
- Re-prioritized sub-Objectives:
  - Reflecting MAVEN's advances and a renewed focus on polar science

Old II.A	New II.A
A. Characterize the state of the present climate of Mars' atmosphere and surrounding plasma environment, and the underlying processes.	**A. Characterize the state and controlling processes of the present-day climate of Mars under the current orbital configuration.**
A1. Lower atmosphere dust, water, CO2 cycles	A1. Lower atmosphere dust, water, CO2 cycles
A2. Upper atmosphere dynamics/thermal structure	A2. Volatiles/dust exchange with surface
A3. Present atmospheric composition	A3. Chemistry of atmosphere and surface
A4. Volatiles/dust exchange with surface	A4. Upper atmosphere dynamics/thermal structure

Changes in Current Draft from 2018 version

Goal II (Climate):

Old II.B

B. Characterize the history of Mars' climate in the recent past, and the underlying processes, under different orbital configurations.

B1. Recent past atmospheric composition
B2. Determine recent climate record in polar region
B3. Determine recent climate record in low- and mid-latitudes

New II.B

B. Characterize the history and controlling processes of Mars' climate in the recent past, under different orbital configurations.

B1. Determine recent climate record in polar region
B2. Determine recent climate record in low- and mid-latitudes
B3. Recent past atmospheric composition

Old II.C

C. Characterize Mars' ancient climate and underlying processes.

C1. Ancient atmosphere composition
C2. Paleoclimate reconstruction
C3. Volatile escape rates

New II.C

C. Characterize Mars' ancient climate and underlying processes.

C1. Determine how the chemical composition and mass of the atmosphere have evolved from the ancient past to the present.
C2. Find and interpret surface records of past climates and factors that affect climate.

Changes in Current Draft from 2018 version

Goal III (Geology):

- Major Update Objective IIIA (Geologic Record) to focus on specific, actionable strategic knowledge gaps
  - Organized around four interrelated themes
    - Past and present water & volatile reservoirs
    - Sediments and sedimentary deposits
    - Environmental transitions
    - Construction & modification of crust
  - Two new Investigations
    - History of sulfur & carbon
    - Link martian meteorites and returned samples to Mars' geologic evolution
  - Identified possible impact of Mars sample return throughout, but also identified areas where additional data/missions are critical

Mars … (MEPAG)

2020 Version	Links to 2018 Version				
A1.1 Determine the modern extent & volume of liquid water & hydrous minerals within the crust.	A1.4	A1.2	A4.1	A4.3	
A1.1 Identify the geologic evidence for the location, volume, & timing of ancient water reservoirs	A1.1	A1.3	A4.2		
A1.3 Determine the subsurface structure & age of the polar layered deposits, & identify links to climate.	A1.4	A3.1	A4.1	A4.2	A4.3
A1.4 Determine how the vertical & lateral distribution of surface ice & ground ice has changed over time.	A1.4	A3.3	A4.2		
A1.5 Determine the role of volatiles in modern dynamic surface processes, correlate with records of recent climate change, & link to past processes & landforms.	A1.1	A1.4	A3.1	A3.3	
A2.1 Constrain the location, volume, timing, & duration of past hydrologic cycles that contributed to the sedimentary & geomorphic record.	A1.1	A4.3			
A2.2 Constrain the location, composition & timing of diagenesis of sedimentary deposits & other types of subsurface alteration.	A1.2	A1.3			
A2.3 Identify the intervals of the sedimentary record conducive to habitability & biosignature preservation.	A1.1	A1.3	A4.1		
A2.4 Determine the sources & fluxes of modern aeolian sediments.	A1.1	A3.1	A3.3		
A2.5 Determine the origin & timing of dust genesis, lofting mechanisms, & circulation pathways.	A1.6	A3.1			
A3.1 Link geologic evidence for local environmental transitions to global-scale planetary evolution.	A1.1	A4.1			
A3.2 Determine the relative & absolute age, durations, & periodicity of ancient environmental transitions.	A4.1				
A3.3 Document the nature & diversity of ancient environments & their implications for surface temperature, geochemistry, & aridity.	A1.1	A1.3			
A3.4 Determine the history & fate of sulfur & carbon throughout the Mars system.	New				
A4.1 Determine the absolute & relative ages of geologic units & events through martian history.	A4.5				
A4.2 Constrain the effect of impact processes on the martian crust & determine the martian crater production rate now & in the past	A1.7	A2.2	A3.1		
A4.3 Link the petrogenesis of martian meteorites & returned samples to the geologic evolution of the planet.	New				
A4.4 Constrain the petrology/petrogenesis of igneous rocks over time.	A1.3	A1.5			
A4.5 Determine the surface manifestation of volcanic processes through time & their implications for surface conditions.	A1.3				
A4.6 Develop a planet-wide model of Mars evolution through global & regional mapping efforts.	A1.2	A1.3	A2.3		
B1.1 Determine the types, nature, abundance & interaction of volatiles in the mantle & crust, & establish links to changes in climate & volcanism over time.	B1.1				
B1.2 Seek evidence of plate tectonics-style activity & metamorphic activity, & measure	B1.2				
B2.1 Characterize the structure & dynamics of the interior.	B2.1				
B2.2 Measure the thermal state & heat flow of the martian interior.	B2.2				
B2.3 Determine the origin & history of the magnetic field.	B2.3				
C1.1 Determine the thermal, physical, & compositional properties of rock & regolith on the moons.	C1.1				
C1.2 Interpret the geologic history of the moons, by identification of geologic units & the relationship(s) between them.	C1.2				
C1.3 Characterize the interior structure of the moons to determine the reason for their bulk density & the source of density variations within the moon (e.g., micro- vs. macroporosity).	C1.3				
C2.1 Understand the flux of impactors in the martian system, as observed outside the martian atmosphere.	C2.1				
C2.2 Measure the character & rate of material exchange between Mars & the two moons.	C2.2				

Changes in Current Draft from 2018 version

Goal IV:

- Significant re-structuring: Architecture agnostic
  - Graceful to evolving Human Mars Exploration Plans
- Atmospheric knowledge requirements modified based on the ongoing development of supersonic retro-propulsion
- Clarification of Planetary Protection related objectives
  - One new objective to establish astrobiological baseline before human presence
- Importance of dust storm knowledge for landing and operations

Mars Exploration Program Analysis Group (MEPAG)

I. Determine if Mars ever supported, or still supports, life	**A. Search for evidence of life in environments that have a high potential for habitability and preservation of biosignatures.** A1. Determine if signatures of life are present in environments affected by liquid water A2. Investigate the nature and duration of habitability near the surface and in the deep subsurface. A3. Assess the preservation potential of biosignatures near the surface and with depth	**B. Assess the extent of abiotic organic chemical evolution.** B1. Constrain atmospheric and crustal inventories of carbon (particularly organic molecules) and other biologically important elements over time B2. Constrain the surface, atmosphere, and subsurface processes through which organic molecules could have formed and evolved over martian history			
II. Understand the processes and history of climate on Mars	**A. Characterize the state and controlling processes of the present-day climate of Mars under the current orbital configuration.** A1. Lower atmosphere dust, water, CO_2 cycles A2. Volatiles/dust exchange with surface A3. Chemistry of atmosphere and surface A4. Upper atmosphere/magnetosphere state & controlling processes	**B. Characterize the history and controlling processes of Mars' climate in the recent past, under different orbital configurations.** B1. Determine recent climate record in polar region B2. Determine recent climate record in low- and mid-latitudes B3. Recent past atmospheric composition	**C. Characterize Mars' ancient climate and underlying processes.** C1. Determine changes in atmospheric composition and mass through time C2. find and interpret surface records of past climates		
III. Understand the origin and evolution of Mars as a geological system	**A. Document the geologic record preserved in the crust and investigate the processes that have created and modified that record.** A1. Characterize past and present water and other volatile reservoirs A2. Document the geologic record in sediments A3. Constrain ancient environmental transitions A4. Determine the construction and modification of the crust	**B. Determine the structure, composition, and dynamics of the interior and how it has evolved.** B1. Crust-mantle interactions B2. accretion, differentiation and thermal evolution	**C. Determine the origin and geologic history of Mars' moons and implications for the evolution of Mars.** C1. Origin of moons C2. Impactor flux		
IV. Prepare for human exploration Source: MEPAG 2020, Penultimate Draft	**A. Human landing with acceptable cost, risk and performance.** A1. Atmospheric state affecting orbital capture and EDL for human missions A2. Orbital debris environment A3. Landing-site & environmental characteristics for safe landing	**B. Human surface exploration and EVA with acceptable cost, risk, and performance.** B1. Surface radiation and dust hazards B2. Impact of dust on hardware B3. Dust storm risks B4. Identify landing-site hazards	**C. ISRU of atmosphere and/or water with acceptable cost, risk, and performance.** C1. ISRU resilience to varying environmental conditions C2. Characterize water resources for ISRU for long-term human needs	**D. Biological contamination and planetary protection protocols with acceptable cost, risk, and performance.** D1. Definition of "special regions" in the exploration zone D2. Crew risk of martian biohazards D3. Earth risk of martian biohazards D4. Astrobiological baseline of landing site prior to human arrival D5. Survivability of terrestrial organisms at Mars	**E. Human missions to Phobos or Deimos with acceptable cost, risk, and performance.** E1. Geology to define science objectives, operations planning and resources E2. Surface and orbital conditions for proximity operations

Backup Slides

Mars Exploration Program Analysis Group (MEPAG)

Goal	A	B	C	D
I. Determine if Mars ever supported life	**A. Determine if environments having high potential for prior habitability and preservation of biosignatures contain evidence of past life.** A1. Past habitable zones A2. Conditions that influenced preservation/ degradation, and identify regions of high preservation potential A3. Presence of biosignatures from prior ecosystems	**B. Determine if environments with high potential for current habitability and expression of biosignatures contain evidence of extant life.** B1. Environments that are presently habitable B2. Conditions that affect the expression/degradation of extant life B3. Presence of biosignatures of an extant ecosystem		
II. Understand the processes and history of climate on Mars	**A. Characterize the state of the present climate of Mars' atmosphere and surrounding plasma environment, and the underlying processes.** A1. Lower atmosphere dust, water, CO2 cycles A2. Upper atmosphere dynamics/thermal structure A3. Present atmospheric composition A4. Volatiles/dust exchange with surface	**B. Characterize the history of Mars' climate in the recent past, and the underlying processes, under different orbital configurations.** B1. Recent past atmospheric composition B2. Determine recent climate record in polar region B3. Determine recent climate record in low- and mid-latitudes	**C. Characterize Mars' ancient climate and underlying processes.** C1. Ancient atmosphere composition C2. paleoclimate reconstruction C3. Volatile escape rates	
III. Understand the origin and evolution of Mars as a geological system	**A. Document the geologic record preserved in the crust and investigate the processes that have created and modified that record.** A1. Water, ice, volcanic geomorphologies A2. Geologic unit age dating A3. Present-day active surface modifying processes A4. Climate change in geological record	**B. Determine the structure, composition, and dynamics of the Martian interior and how it has evolved.** B1. Mantle-crust interactions B2. Interior structure	**C. Determine the manifestations of Mars' evolution as recorded by its moons.** C1. Phobos and Deimos geology C2. Impactor flux	
IV. Prepare for human exploration Source: MEPAG 2018	**A. Human mission to Mars orbit with acceptable cost, risk, and performance.** A1. Aerocapture and aerobraking investigations A2. Orbital particulate environment	**B. Human mission to the Martian surface with acceptable cost, risk, and performance.** B1. Atmospheric dynamics - EDL B2. Biohazard assessment B3. Identify special regions B4. ISRU tech demo B5. Identify landing-site hazards B6. Surface radiation and dust hazards B7. Impact of dust on hardware	**C. Human mission to the surface of Phobos or Deimos with acceptable cost, risk, and performance.** C1. Phobos and Deimos science C2. Moon science	**D. Sustained human presence with acceptable cost, risk, and performance.** D1. Extractable water resources

Mars Exploration Program Analysis Group (MEPAG)

I. Determine if Mars ever supported, or still supports, life

A. Search for evidence of life in environments that have a high potential for habitability and preservation of biosignatures.
A1. Determine if signatures of life are present in environments affected by liquid water
A2. Investigate the nature and duration of habitability near the surface and in the deep subsurface.
A3. Assess the preservation potential of biosignatures near the surface and with depth

B. Assess the extent of abiotic organic chemical evolution.
B1. Constrain atmospheric and crustal inventories of carbon (particularly organic molecules) and other biologically important elements over time
B2. Constrain the surface, atmosphere, and subsurface processes through which organic molecules could have formed and evolved over martian history

II. Understand the processes and history of climate on Mars

A. Characterize the state and controlling processes of the present-day climate of Mars under the current orbital configuration.
A1. Lower atmosphere dust, water, CO2 cycles
A2. Volatiles/dust exchange with surface
A3. Chemistry of atmosphere and surface
A4. Upper atmosphere/magnetosphere state & controlling processes

B. Characterize the history and controlling processes of Mars' climate in the recent past, under different orbital configurations.
B1. Determine recent climate record in polar region
B2. Determine recent climate record in low- and mid-latitudes
B3. Recent past atmospheric composition

C. Characterize Mars' ancient climate and underlying processes.
C1. Determine changes in atmospheric composition and mass through time
C2. find and interpret surface records of past climates

III. Understand the origin and evolution of Mars as a geological system

A. Document the geologic record preserved in the crust and investigate the processes that have created and modified that record.
A1. Characterize past and present water and other volatile reservoirs
A2. Document the geologic record in sediments
A3. Constrain ancient environmental transitions
A4. Determine the construction and modification of the crust

B. Determine the structure, composition, and dynamics of the interior and how it has evolved.
B1. Crust-mantle interactions
B2. accretion, differentiation and thermal evolution

C. Determine the origin and geologic history of Mars' moons and implications for the evolution of Mars.
C1. Origin of moons
C2. Impactor flux

IV. Prepare for human exploration

A. Human landing with acceptable cost, risk and performance.
A1. Atmospheric state affecting orbital capture and EDL for human missions
A2. Orbital debris environment
A3. Landing-site & environmental characteristics for safe landing

B. Human surface exploration and EVA with acceptable cost, risk, and performance.
B1. Surface radiation and dust hazards
B2. Impact of dust on hardware
B3. Dust storm risks
B4. Identify landing-site hazards

C. ISRU of atmosphere and/or water with acceptable cost, risk, and performance.
C1. ISRU resilience to varying environmental conditions
C2. Characterize water resources for ISRU for long-term human needs

D. Biological contamination and planetary protection protocols with acceptable cost, risk, and performance.
D1. Definition of "special regions" in the exploration zone
D2. Crew risk of martian biohazards
D3. Earth risk of martian biohazards
D4. Astrobiological baseline of landing site prior to human arrival
D5. Survivability of terrestrial organisms at Mars

E. Human missions to Phobos or Deimos with acceptable cost, risk, and performance.
E1. Geology to define science objectives, operations planning and resources
E2. Surface and orbital conditions for proximity operations

Source: MEPAG 2020, Penultimate Draft

Extant & Extinct Life

- The discovery of evidence of life on Mars would be paradigm-shifting
  - MEPAG Goal 1 recognizes and stresses the importance of searching for evidence of life (extant/ancient) for the Mars exploration program
- To address Goal 1, as written, no strategy (extant/ancient) is a priori better than the other
  - Although one result might be more impactful than the other
- Recent workshop identified caves, salts, ice & deep-subsurface as of significant interest to search for evidence of extant life.
  - Search for evidence of life needs to be justified by habitability and bio-signature preservation. The habitability bar set in the document is ‘empirical evidence of liquid water activity’. Does such evidence exist for any of those environments?