MEPAG GOALS 2015 - REVIEW COPY - high-level view. COMMENTS DUE BY FEB. 20 to mepagmeetingsqs@jpl.nasa.gov. *Objectives are in order of priority. Sub-objectives are listed in order of priority within the parent Objective. Investigations are listed in order of priority within the parent Sub-objective. Prioritization is based on criteria explained in text.*

Objectives	Sub-Objectives	Investigations	Cross-cutting w/i goal	Cross-cutting btwn goals
GOAL I: Determine whether life ever arose on Mars.				
A. Determine if paleoenvironments having high combined potential for prior habitability and preservation of biosignatures record evidence of **past life.**	**A1.** Characterize the prior habitability of paleoenvironments, with a focus on resolving former conditions and processes that influence the degree or nature of habitability in each paleoenvironment.	1. Establish overall geological context.		GIII: A1.1-6, A2.1-3, B2.3
		2. Constrain prior water availability with respect to duration, extent, and chemical activity.		GII: B1.1, C2.1-3; GIII: A1.1-2
		3. Constrain prior energy availability with respect to type (e.g., light, specific redox couples), chemical potential (e.g., Gibbs energy yield), and flux.		GIII: A1.2
		4. Constrain prior physicochemical environment, emphasizing temperature, pH, water activity, and chemical composition.		GIII: A1.2
		5. Constrain the abundance and characterize potential sources of bioessential elements.		GIII: A1.2
	A2. Assess the potential of conditions and processes to have influenced preservation or degradation of biosignatures and evidence of habitability, from deposition to time of observation. Identify specific paleoenvironmental deposits and subsequent geological conditions that have high potential to have preserved evidence of individual or multiple types of biosignatures.	1. Identify conditions and processes that aided preservation and/or degradation of complex organic compounds, focusing particularly on characterizing: redox changes and rates in surface and near-surface environments (including determination of the "burial depth" in regolith or rocks that may shield from ionizing radiation effects); the prevalence, extent, and type of metamorphism; and potential processes that influence isotopic or stereochemical information.		GIII: A1.1-3, B2.3
		2. Identify the conditions and processes that aided preservation and/or degradation of physical structures on micron to meter scales.		GIII: A1.1-3
		3. Characterize the conditions and processes that aided preservation and/or degradation of environmental imprints of metabolism, including blurring of chemical or mineralogical gradients and changes to stable isotopic composition and/or stereochemical configuration.		GIII: A1.2
	A3. Determine if ancient biosignatures are present.	1. Characterize organic chemistry, including (where possible) stable isotopic composition and stereochemical configuration. Characterize co-occurring concentrations of possible bioessential elements.		GIII: A1.2
		2. Test for the presence of possibly biogenic physical structures, from microscopic (micron-scale) to macroscopic (meter-scale), combining morphological, mineralogical, and chemical information where possible.		GIII: A1.2-3
		3. Test for the presence of the prior metabolic activity, including: stable isotopic composition of possible metabolic reactants and products (i.e. metabolites); mineral or other indicators of prior chemical gradients; localized concentrations or depletions of potential metabolites (e.g. biominerals); and evidence of catalysis in chemically sluggish systems.		GIII: A1.2
B. Determine if localities having high combined potential for modern habitability and biosignature presence host evidence of **extant life.**	**B1.** Characterize present habitability in modern environments, with a focus on resolving conditions and processes that enhance or diminish habitability.	1. Identify areas where liquid water (including brines) presently exists, with emphasis on reservoirs that are relatively extensive in space and time.		GII: A1.1, A3.3
		2. Identify areas where liquid water (including brines) may have existed at or near the surface in the relatively recent past including periods of significant different obliquity.		GIII: A3.3
		3. Establish general geological context (e.g., rock-hosted aquifer or sub-ice reservoir; host rock type).		
		4. Identify and constrain the magnitude of possible energy sources (e.g., water-rock reactions, ionizing and non-ionizing radiation) associated with occurrences of liquid water.		
		5. Assess the variation through time of physical and chemical conditions in such environments and potential processes responsible for observed variations. Of particular importance are temperature, pH, and fluid composition.		
		6. Identify possible supplies of bioessential elements to these environments.		

	B2. Assess the potential of specific diagenetic conditions and processes to affect the preservation and/or degradation of signatures of extant life.	1. Evaluate the physicochemical conditions and processes of actual surface regolith or rock environments in terms of their potential for preserving or degrading biosignatures, and the effects of these conditions and processes on specific types of potential biosignatures.		
		2. Evaluate the potential rate of physical degradation from wind abrasion, dust storms, dust devils, and frost action.		GII: A4.1; GIII: A3.2
		3. Evaluate the physicochemical conditions and processes at depth in regolith, ice, or rock environments in terms of their potential for preservingor degrading biosignatures.		
	B3. Determine if biosignatures of an extant ecosystem are present.	1. Test for the presence of ongoing metabolism, in the form of rapid catalysis of chemically sluggish reactions, stable isotopic fractionation, and/or strong chemical gradients, or potential biogenic gases, which could migrate from habitable deep subsurface environments to surface environments.		
		2. Characterize organic chemistry and co-occurring concentrations of bioessential elements, including stable isotopic composition and stereochemistry. Analyses might include but should not be limited to known molecular markers of terrestrial life, such as membrane lipids, proteins, nucleic acid polymers, and complex carbohydrates.		
		3. Test for the presence of organic and mineral structures or assemblages that might be associated with life. Seek evidence of mineral transformations bearing evidence of biological catalysis (e.g., depletion of possibly bio-essential elements in mineral surfaces).		GIII: A1.3

GOAL II: Understanding 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, under the current orbital configuration.	**A1.** Constrain the processes that control the present distributions of dust, water, and carbon dioxide in the lower atmosphere, at daily, seasonal and multi-annual timescales.	1. Measure the state and variability of the atmosphere from turbulent scales to global scales.	A1.2, A1.3, A4.1	GI: B1.1; GIV: 1A
		2. Characterize dust, water vapor, and clouds in the lower atmosphere.	A1.1, A1.3, A4.1, A3.4	GIV: 4A
		3. Measure the forcings that control the dynamics and thermal structure of the lower atmosphere.	A1.1, A1.2, A4.1	
	A2. Constrain the processes that control the dynamics and thermal structure of the upper atmosphere and surrounding plasma environment.	1. Measure the spatial distribution of aerosols, neutral species, and ionized species in the upper atmosphere.	A2.2, A2.3, A2..4, C1.1, C1.2	GIV: 1A
		2. Measure velocities of neutral and ionized species in the upper atmosphere.	A2.1, A2.2, A2.4, C1.1, C1.2	
		3. Measure temperatures of neutral and ionized species in the upper atmosphere.	A2.1, A2.2, A2.4, C1.1, C1.2	
		4. Measure the forcings that control the dynamics and thermal structure of the upper atmosphere.	A2.1, A2.2, A2.3	
	A3. Constrain the processes that control the chemical composition of the atmosphere and surrounding plasma environment.	1. Map spatial and temporal variations in the column abundances of species that play important roles in atmospheric chemistry or are transport tracers.	A1.1, A3.2, A3.3, A3.4	
		2. Measure globally the vertical profiles of key chemical species.	A1.1, A3.1, A3.3, A3.4	
		3. Determine the significance of heterogeneous chemical reactions (i.e., those involving atmospheric gases and solid bodies such as aerosols or surface materials) for the chemical composition of the atmosphere.	A3.1, A3.2, A3.4	
		4. Measure key electrochemical species.	A1.2, A3.1, A3.2, A3.3	GIV: 4A
	A4. Constrain the processes by which volatiles and dust exchange between surface and atmospheric reservoirs.	1. Measure the turbulent fluxes of dust and volatiles between surface and atmospheric reservoirs.	A1.1, A1.2, A1.3, A3.4	GI: B2.2; GIII: A3.2, A3.3
		2. Determine how the exchange of volatiles and dust between surface and atmospheric reservoirs has affected the present distribution of surface and subsurface ice.	A4.1	GIII: A3.2, A3.3
		3. Determine how the exchange of volatiles and dust between surface and atmospheric reservoirs has affected the Polar Layered Deposits (PLD).	A4.1, A4.2, B1.1, B2.1	GIII: A1.4

B. Characterize the history of Mars' climate in the recent past, and the underlying processes, under different orbital configurations.	**B1.** Determine how the chemical composition and mass of the atmosphere has changed in the recent past.	1. Measure isotopic composition of gases trapped in the Polar Layered Deposits (PLD) and near-surface ice.	A4.2, A4.3, B2.1	GI: A1.2; GIII: A2.1
	B2. Determine the record of the recent past that is expressed in geological features of the polar regions.	1. Map the ice and dust layers of the Polar Layered Deposits (PLD) and determine the absolute ages of the layers.	B1.1	GIII: A1.4, A2.1
	B3. Determine the record of the climate of the recent past that is expressed in geological features of low- and mid-latitudes.	1. Identify and map the location and extent of glacial and peri-glacial features and quantify the depth to any remnant glacial ice.	B2.1	GIII: A2.2
C. Characterize Mars' ancient climate and underlying processes.	**C1.** Determine present escape rates of key species and constrain the processes that control them.	1. Measure spatial and temporal variations in the escape rates of key species.	A2.1, A2.2, A2.3, A2.4	
		2. Measure the forcings that drive escape processes.	A2.1, A2.2, A2.3, A2.4	
	C2. Find physical and chemical records of past climates and factors that affect climate.	1. Determine the atmospheric environment required by observed geochemical and geophysical features.	A2.1, A2.3, A2.4	GI: A1.2; GIII: A3.1
		2. Identify the extent of any oceans or large lakes and determine the absolute ages of associated features.	A2.1, A2.2, A2.4	GI: A1.2; GIII: A3.1
		3. Determine boundary conditions necessary for climate modeling, including topography, state of polar caps, and state of the magnetic field.	A2.1, A2.2, A2.3	GI: A1.2; GIII: A3.1
	C3. Determine how the chemical composition and mass of the atmosphere have evolved from the ancient past to the present.	1. Measure absolute ages of trapped gases.		GIII: A2.1

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

A. Document the geologic record preserved in the crust and interpret the processes that have created it.	**A1.** Identify and characterize past and present geologic environments and processes relevant to the crust.	1:. Determine the role of water and other processes in the sediment cycle.	A2.3	GI: A1.1-2, A2.1-2, B1.1-2, B2.2; GII: C2.2
		2. Identify the geochemical and mineralogic constituents of crustal materials and the processes that have altered them.	feeds into all of A1	GI: A1.1-5, A2.1-3, A3.1-3, B1.5-6; GII: C2.1
		3. Characterize the textural and morphologic features of rocks and outcrops.	A2.3	GI: A1.1, A2.1-2, A3.2, B3.3
		4. Identify ice-related processes and characterize how they have modified the Martian surface.	A2.3	GI: A1.1; GII: B2.1
		5. Document the surface manifestations of igneous processes and their evolution through time.	A1.2, A2.3, B2.1, A4.1	G1: A1.1
		6. Evaluate the effect of large- and small-scale impacts on the nature and evolution of the Martian crust.		GI: A1.1
	A2. Determine the relative and absolute ages of geologic units and events through Martian history.	1. Quantitatively constrain the absolute ages of the surface and accessible crustal layers.	A1	GI: A1.1
		2. Assess the characteristics of Martian craters and document their distribution.	A1	GI: A1.1
		3. Identify and characterize the distribution, nature, and age relationships of rocks, faults, strata, and other geologic features, i.e., geologic mapping.	A1, A3, B1.3	GI: A1.1
	A3. Constrain the magnitude, nature, timing and origin of past planet-wide climate change.	1. Identify paleoclimate indicators in the geologic record and estimate their timing and duration.	A1, A2	
		2. Characterize surface-atmosphere interactions as recorded by aeolian, glacial/periglacial, fluvial, chemical and mechanical erosion, cratering and other processes.	A1, B1.1	GI: B2.2; GII: B3
		3. Determine the present state, 3-dimensional distribution, and cycling of water on Mars including the cryosphere and possible deep aquifers	A1.1, B1.1	GI: B1.1, B1.2; GII: A1.2
B. Determine the structure, composition, and dynamics of the Martian interior and how it has	**B1.** Identify and evaluate manifestations of crust-mantle interactions.	1. Determine the types, nature, abundance and interaction of volatiles in the mantle and crust.	A3	
		2. Seek evidence of plate tectonics and metamorphic activity, and measure modern tectonic activity.		
	B2. Quantitatively constrain the age and processes	1. Characterize the structure and dynamics of the interior.		

evolved.	of accretion, differentiation and thermal evolution of Mars.	2. Measure the thermal state and heat flow of the Martian interior.		
		3. Determine the origin and history of the magnetic field.		GI: A1.1, A2.1
C. Determine the manifestations of Mars' evolution as recorded by its moons.	**C1.** Constrain the planetesimal density and type within the Mars neighborhood during Mars formation, as implied by the origin of the Mars moons.	1. Interpret geologic history of the moon, by identification of geologic units and relationship between them (time-order, weathering, etc.).		GIV: C1
		2. Determine composition of rock and regolith on the moons, including elemental and mineralogical compositions.	depends on C1.1, C2.1, C2.2	GIV: C1
		3. Characterize the interior structure of the moons to determine the reason for their bulk density and the source of density variations within the moon (e.g., micro- vs. macroporosity).	C2.2	GIV: C1.3
	C2. Determine the material and impactor flux within the Mars neighborhood, throughout Mars' history, as recorded on the Mars moons.	1. Measure the character and rate of material exchange between Mars and the two moons.	feeds into C1.1, C1.2	GIV: A2.1
		2. Understand the flux of impactors in the Martian system, as observed outside the Martian atmosphere.	C1.1, A2.2	

GOAL IV: Prepare for human exploration.

A. Obtain knowledge of Mars sufficient to design and implement a human mission to Mars orbit with acceptable cost, risk and performance.	**A1.** Determine the aspects of the atmospheric state that affect aerocapture and aerobreaking for human-scale missions at Mars.	1. Long-term observations of the global atmospheric temperature field at all local times from the surface to an altitude >80 km.		
		2. Global measurements of the vertical profile of aerosols (dust and water ice) at all local times between the surface and >60 km.		
		3. Long-term observations of global winds and wind direction at all local times from 15 km to an altitude > 60 km.		
	A2. Determine the orbital particulate environment in high Mars orbit that may impact the delivery of cargo and crew to the Martian system.	1 . Determine spatial variation in size-frequency distribution of Phobos/ Deimos ejecta particles in Mars orbit.		GIII: C2.1
B.Obtain knowledge of Mars sufficient to design and implement a human mission to the Martian surface with acceptable cost, risk and performance.	**B1.** Determine the aspects of the atmospheric state that affect Entry Design and Landing (EDL) design, or atmospheric electricity that may pose a risk to ascent vehicles, ground systems and human explorers.	1. Create a long-term dust activity climatology.		
		2. Characterize the seasonal cycle, the diurnal cycle (including tidal phenomena) in seasonal pressure and quantify the weather perturbations (especially due to dust storms).		
		3. Simultaneous with the global wind observations, profile the near-surface winds (< 15 km) in representative regions.		
		4. Generate temperature or density profiles between the surface and 20 km.		
		5. Characterize and correlate atmospheric electricity, surface meteorological, and dust measurements.		
		6. Determine if higher frequency (AC) electric fields are present between the surface and the ionosphere.		
		7. Determine the electrical conductivity of the Martian atmosphere.		
	B2. Determine if the Martian environments to be contacted by humans are free of biohazards that might have adverse effects on the crew that might be directly exposed while on Mars, and on other terrestrial species if uncontained Martian material would be returned to Earth.	1. Determine if extant life is widely present in the Martian near-surface regolith, and if the air-borne dust is a mechanism for its transport. If life is present, assess whether it is a biohazard.		
	B3. Determine the Martian environmental niches that meet the definition of "Special Region."	1. Map the distribution of both naturally occurring special regions, and regions with the potential for s/c induced special regions, as defined by COSPAR5.		
	B4. Characterize the particulates that could be transported to hardware and infrastructure through the air (including natural aeolian dust and other materials that could be raised from the Martian	1. Determine the electrical conductivity of the ground.		
		2. Measure the magnitude and dynamics of any quasi-DC electric fields that may be present in the atmosphere as a result of dust transport or other processes.		
		3. Determine the charge on individual dust grains.		

	regolith by ground operations), and that could affect engineering performance and in situ lifetime.	4. Analyze regolith and surface aeolian fines (dust), with a priority placed on the characterization of the electrical and thermal conductivity, triboelectric and photoemission properties, and chemistry.	B5.1	
		5. Regolith particle shape and size distribution.		
		6. Determine the chemistry and mineralogy of the regolith, including ice contents (extended beyond Gale Crater).		
	B5. Understand the resilience of atmospheric ISRU processing systems to variations in martian near-surface environmental conditions.	1. Analyze regolith and surface aeolian fines (dust), with a priority placed on the characterization of the electrical and thermal conductivity, triboelectric and photoemission properties, and chemistry.	B4.2	
		2. Determine the column abundance and size-frequency distribution of dust particles in the Martian atmosphere.		
		3. Detemine the potential effects of trace gas within the martian atmosphere on atmospheric ISRU.		
		4. Test ISRU atmospheric processing system to measure resilience, with respect to dust and other environmental challenges.		
	B6. Assess landing site-related hazards, including those related both to safe landing and safe operations (includng trafficability) within the possible area to be accessed by elements of a human mission.	1. Determine regolith physical properties and structure, including surface bearing strength; presence of significant heterogeneities or subsurface features of layering; and an index of shear strength.		
		2. Measure gas permeability of the regolith .		
		3. Detect and characterize hazards to both landing and trafficability at the scale of the relevant landed systems.		
		4. Determine traction/cohesion in Martian regolith throughout planned landing sites.		
		5. Determine vertical variation of in situ regolith density within the upper 30 cm.		
	B7. Assess risks to crew health and performance by (1) characterizing in detail the ionizing radiation environment at the Martian surface and (2) determining the possible toxic effects of Martian dust on humans.	1. Measure neutrons with directionality.		
		2. Simultaneous with surface measurements, measure energy spectra in solar energetic particle events from orbit.		
		3. Identify charged particles and their energies at the surface.		
		4. Assay for chemicals with known toxic effect on humans.		
		5. Fully characterize soluble ion distributions, reactions that occur upon humidification and released volatiles from samples from the surface and a depth that may be affected by human surface operations.		
		6. Analyze the shapes of Martian dust grains to assess their possible impact on human soft tissue.		
C. Obtain knowledge of Mars sufficient to design and implement a human mission to the surface of either Phobos or Deimos (P/D) with acceptable cost, risk and performance.	**C1.** Understand the geological, compositional and geophysical properties of P/D sufficient to establish specific scientific objectives, operations planning, and any potentially available resources.	1. Determine the elemental and mineralogical composition of the surface and near sub-surface ofP/D.		GIII: C1
		2. Identify geologic units for science and exploration and materials for future in situ resource utilization operations.		GIII: C1.1, C1.2
		3. Determine the first-order subsurface attributes of Phobos and Deimos.		GIII: C1.3
	C2. Understand the conditions at the surface and the low orbital environment for P/D sufficiently to be able to design an operations plan (including close proximity and surface interactions).	1. Measure the electrostatic charge and plasma fields near the surface ofP/D.		
		2. Determine the gravitational field to a sufficiently high degree to be able to carry out proximity orbital operations.		
		3. Measure and characterize the physical properties and structure of regolith on P/D.		GIII: C1.1
		4. Measure the surface and subsurface temperature regime of P/D to constrain the range of thermal environments of these moons.		
D. Obtain knowledge of Mars sufficient to design and implement sustained human presence at the martian surface with acceptable cost, risk and performance.	**D1.** Characterize potentially extractable water resources to support In Situ Resource Utilization (ISRU) for long-term human needs.	1. Generate high spatial resolution maps of mineral composition and abundance.		
		2. Generate high spatial resolution maps of subsurface ice depth and concentration.		
		3. Measure the energy required to excavate/drill the H-bearing material.		
		4. Measure the energy required to extract water from the H-bearing material.		
		5. Measure the energy required to excavate/drill the H-bearing material.		
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