MEPAG Goals Document, 2018, supplemental summary table.

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Objectives are listed 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 within main document. The list of cross-cutting Investigations is intended to assist with seeing interdependencies, etc., but may not be complete.

Objectives	Sub-objectives	Investigations	Cross-cutting	
			w/i goal	btwn goals
GOAL I: Determine if Mars ever supported life.				
A. Determine if environments having high potential for prior habitability & preservation of biosignatures contain evidence of past life.	**A1.** Identify environments that were habitable in the past, & characterize conditions & processes that may have influenced the degree or nature of habitability therein.	1. Establish overall geological context.		GIII: A1, A2
		2. Constrain prior water availability with respect to duration, extent, & chemical activity.		GII: B3, C2; GIII: A1.1-2, A1.4
		3. Constrain prior energy availability with respect to type (e.g., light, specific redox couples), chemical potential (e.g., Gibbs energy yield), & flux.		GIII: A1.2
		4. Constrain prior physicochemical conditions, emphasizing temperature, pH, water activity, & chemical composition.		GIII: A1.2
		5. Constrain the abundance & characterize potential sources of bioessential elements.		GIII: A1.2
	A2. Assess the potential of conditions & processes to have influenced preservation or degradation of biosignatures & evidence of habitability, from the time of formation to the time of observation. Identify specific deposits & subsequent geological conditions that have high potential to have preserved individual or multiple types of biosignatures.	1. Identify conditions & processes that would have aided preservation and/or degradation of complex organic compounds, focusing particularly on characterizing: redox changes & rates in surface & near-surface environments; the prevalence, extent, & type of metamorphism; & potential processes that influence isotopic or stereochemical information.		GIII: A1, A3
		2. Identify the conditions & processes that would have aided preservation and/or degradation of physical structures on micron to meter scales.		GIII: A1, A3
		3. Characterize the conditions & processes that would have aided preservation and/or degradation of environmental imprints of metabolism, including blurring of chemical or mineralogical gradients & changes to stable isotopic composition and/or stereochemical configuration.		GIII: A1, A3
	A3. Determine if biosignatures of a prior ecosystem are present.	1. Characterize organic chemistry, including (where possible) stable isotopic composition & 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, & chemical information where possible.		GIII: A1.2-3
		3. Test for the presence of prior metabolic activity, including: stable isotopic composition of possible metabolic reactants & products (i.e. metabolites); mineral or other indicators of prior chemical gradients; localized concentrations or depletions of potential metabolites (e.g. biominerals); & evidence of catalysis in chemically sluggish systems.		GIII: A1.2
B. Determine if environments with high potential for current habitability & expression of biosignatures contain evidence of extant life.	**B1.** Identify environments that are presently habitable, & characterize conditions & processes that may influence the nature or degree of habitability therein.	1. Identify areas where liquid water (including brines) presently exists, with emphasis on reservoirs that are relatively extensive in space & time.		GIII: A1.1, A4.3; GIV: D1.1
		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.		GII:B3; GIII: A4.1, A4.3
		3. Establish general geological context (such as rock-hosted aquifer or sub-ice reservoir; host rock type).		
		4. Identify & constrain the magnitude of possible energy sources (e.g., water-rock reactions, ionizing & non-ionizing radiation) associated with occurrences of liquid water.		
		5. Assess the variation through time of physical & chemical conditions, (particularly temperature, pH, & fluid composition) in such environments & potential processes responsible for observed variations.		
		6. Identify possible supplies of bioessential elements to these environments.		

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

GOAL II: Understand the processes & history of climate on Mars.

A. Characterize the state of the present climate of Mars' atmosphere & surrounding plasma environment, & the underlying processes, under the current orbital configuration.	**A1.** Constrain the processes that control the present distributions of dust, water, & carbon dioxide in the lower atmosphere, at daily, seasonal & multi-annual timescales.	1. Measure the state & variability of the lower atmosphere from turbulent scales to global scales.	A1.2-3, A4.1	GIV: A1, B1
		2: Characterize dust & other aerosols, water vapor & carbon dioxide & their clouds in the lower atmosphere.	A1.1, A1.3, A3.4, A4.1	GIII: A1.6; GIV: A1.2, B1.1
		3: Measure the forcings that control the dynamics & thermal structure of the lower atmosphere	A1.1-2, A4.1	
	A2. Constrain the processes that control the dynamics & thermal structure of the upper atmosphere & surrounding plasma environment.	1. Measure the spatial distribution of aerosols, neutral species, & ionized species in the upper atmosphere.	A2.2-4, C3	GIV: A1.2, B1.1
		2. Measure temperatures of neutral & ionized species in the upper atmosphere.	A2.1, A2.3-4, C3	
		3. Measure the forcings that control the dynamics & thermal structure of the upper atmosphere.	A2.1-2, A2.4, C3	
		4. Measure velocities of neutral & ionized species in the upper atmosphere.	A2.1-3, C3.2	
	A3. Constrain the processes that control the chemical composition of the atmosphere & surrounding plasma environment.	1. Measure globally the vertical profiles of key chemical species.	A1.1, A3.2-4	
		2. Map spatial & temporal variations in the column abundances of species (listed) that play important roles in atmospheric chemistry or are transport tracers.	A1.1, A3.1, A3.2-4	
		3. Determine the significance of heterogeneous chemical reactions (i.e., those involving atmospheric gases & solid bodies such as aerosols or surface materials) for the chemical composition of the atmosphere.	A3.1-2, A3.4	
		4. Measure key electrochemical species.	A1.2, A3.1-3	GIV: A1.2
	A4. Constrain the processes by which volatiles & dust exchange between surface & atmospheric reservoirs.	1. Characterize the fluxes & sources of dust & volatiles between surface & atmospheric reservoirs.	A1.1-3, A3.4, A4.3	GI: B2.2; GIII: A1.4, A1.6, A4.3
		2. Determine how the processes exchanging volatiles & dust between surface & atmospheric reservoirs have affected the present horiz. & vert. distrib. of surface & subsurface water & CO2 ice.	A4.1, A4.3, B1.2	GIII: A1.4, A3, A4.2
		3. Determine the energy & mass balance of the surface volatile reservoir over relevant timescales, & characterize their fluxes.	A4.1-2, B1.1, B2	GIII: A1.4, A3, A4.2
B. Characterize the history of Mars' climate in the recent past, & the underlying processes, under	**B1.** Determine how the chemical composition & mass of the atmosphere has changed in the recent past.	1. Measure isotopic composition of gases trapped in the Polar Layered Deposits (PLD) & near-surface ice.	A4.2-3, B2	GI: A1.2; GIII: A2
		2. Determine how & when the buried CO2 ice reservoirs at the south pole formed.	A4	GIII: A1.4

different orbital configurations.	**B2.** Determine the climate record of the recent past that is expressed in geological, glaciological, & mineralogical features of the polar regions.	1. Determine the vertical & horizontal variations of composition & physical properties of the materials forming the PLD.	B1.1, B2.2	GIII: A1.4, A1.6
		2. Determine the absolute ages of the layers of the PLD.	B1.1, B2.1, B2.3-4	GIII: A1.6
		3. Determine which atmospheric & surface processes are recorded during layer formation.	B2.1-2	GIII: A1.4, A3
		4. Constrain Mars' polar & global climate history by characterizing & interpreting the relationships between orbitally forced climate parameters & the layer properties of the PLD.	A4, B1.1, B2.1-3	GIII: A1.4, A4.1
	B3. Determine the record of the climate of the recent past that is expressed in geological & mineralogical features of low- & mid-latitudes.	1. Characterize the locations, composition, & structure of low & mid-latitude ice & volatile reservoirs at the surface & near-surface.		GIII: A1.4, A4.1
		2. Determine the conditions under which low- & mid-latitude volatile reservoirs accumulated & persisted until the present day, & ascertain their relative & absolute ages.	A4, B2.3	GIII: A1.4, A2
C. Characterize Mars' ancient climate & underlying processes.	**C1.** Determine how the chemical composition & mass of the atmosphere have evolved from the ancient past to the present.	1. Measure the composition & absolute ages of trapped gases in rocks.		GIII: A2.1
	C2. Find & interpret physical & chemical records of past climates & factors that affect climate.	1. Determine the atmospheric environment required by observed geochemical & geophysical features.		GI: A1.2, B1.2; GIII: A4.1
		2. Identify the extent of any oceans or large lakes & determine the absolute ages of associated features.		GI: A1.2, B1.2; GIII: A4
		3. Determine boundary conditions necessary for climate modeling, including topography, state of polar caps, & state of the magnetic field.	A4.3	GI: A1.2; GIII: A2.3, A4, B2.3
	C3. Determine present escape rates of key species & constrain the processes that control them.	1. Measure spatial & temporal variations in the escape rates of key species.	A2	
		2. Measure the forcings that drive escape processes.	A2	
GOAL III: Understand the origin & evolution of Mars as a geological system.				
A. Document the geologic record preserved in the crust & investigate the processes that have created & modified that record.	**A1.** Identify & characterize past & present geologic environments & processes relevant to the crust.	1. Determine the role of water & other processes in the sediment cycle.	A2.3	GI: A1.1-2, A2, B1.1-2; GII: C2.2
		2. Identify the geochemical & mineralogic constituents of crustal materials & the processes that have altered them.	A1.1, A1.3-7	GI: A, B1.5-6; GII: C2.1
		3. Characterize the textural & morphologic features of rocks & outcrops.	A2.3	GI: A1.1, A2.1-2, A3.2, B3.3
		4. Identify ice-related processes & characterize when & how they have modified the Martian surface.	A2.3, A3	GI: A1.1; GII: A4.2, B3
		5. Document the surface manifestations of igneous processes & their evolution through time.	A1.2, A2.3, B2.1, A4.1	GI: A1.1
		6. Determine the processes that create dust & distribute it around the planet, identify its sources, & fully characterize its composition & properties.	A3	GI: B2.2; GII: A4.1; GIV: B7.3
		7. Evaluate the effect of large- & small-scale impacts on the nature & evolution of the Martian crust & establish their production rates.	A2.2, A3	GI: A1.1
	A2. Determine the absolute & relative ages of geologic units & events through Martian history.	1. Quantitatively constrain the absolute ages of the surface & accessible crustal layers.	A1	GII: C1.1
		2. Assess the characteristics of Martian craters & document their distribution.	A1	
		3. Identify & characterize the distribution, nature, & age relationships of rocks, faults, strata, & other geologic features, via comprehensive & topical geologic mapping.	A1, A4	GI: A1.1
	A3. Identify & characterize processes that are actively shaping the present-day surface of Mars.	1. Identify present-day changes within the rocky or icy surfaces of Mars, & estimate past & present rates of change.		
		2. Determine relevant surface & atmospheric environmental conditions and/or processes that cause observable surficial changes over diurnal, seasonal, & multi-annual timescales.	A1	GII: A1.1, A4.1-2
		3. Extend the evolving knowledge of active surface processes to other locations on the planet & backward in time.	A1	
	A4. Constrain the magnitude, nature, timing, & origin of past planet-	1. Identify paleoclimate indicators in the geologic record & estimate the climate timing & duration.	A1, A2	

	wide climate change.	2. Characterize surface-atmosphere interactions as recorded by aeolian, glacial/periglacial, fluvial, lacustrine, chemical & mechanical erosion, cratering & other processes.	A1, B1.1	GI: B2.2; GII: B2, B3
		3. Determine the present state, 3-dimensional distribution, & cycling of water on Mars including the cryosphere & possible deep aquifers.	A1.1, B1.1	GI: B1.1-2; GII: A1.2, A4.2, B3.2; GIV: D1.1
B. Determine the structure, composition, & dynamics of the Martian interior & how it has evolved.	**B1.** Identify & evaluate manifestations of crust-mantle interactions.	1. Determine the types, nature, abundance & interaction of volatiles in the mantle & crust.	A1.4	GII: B1.2, B3.2
		2. Seek evidence of plate tectonics-style activity & metamorphic activity, & measure modern tectonic activity.		
	B2. Quantitatively constrain the age & processes of accretion, differentiation, & thermal evolution of Mars.	1. Characterize the structure & dynamics of the interior.		
		2. Measure the thermal state & heat flow of the Martian interior.		
		3. Determine the origin & 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 & type within the Mars neighborhood during Mars formation, as implied by the origin of the Mars moons.	1. Interpret the geologic history of the moons, by identification of geologic units & relationship(s) between them (time-order, weathering, etc.).	C1.2	
		2. Determine composition of rock & regolith on the moons, including elemental & mineralogical compositions.	C1.1, C2.1-2	
		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).	C2.2	
	C2. Determine the material & impactor flux within the Mars neighborhood, throughout Mars' history, as recorded on the Mars moons.	1. Measure the character & rate of material exchange between Mars & the two moons.	C1.1-2	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 & implement a human mission to Mars orbit with acceptable cost, risk, & performance.	**A1.** Determine the aspects of the atmospheric state that affect aerocapture & aerobreaking for human-scale missions at Mars.	1. At all local times, make long-term (> 5 Mars years) observations of the global atmospheric temperature field from the surface to ~80 km.	B1.2	GII: A1.1, A1.3, A2.2-3
		2. At all local times, make long-term global measurements of the vertical profile of aerosols between the surface & >60 km.	B1.1	GII: A1.2, A2.1
		3. Make long-term observations of global winds & wind direction at all local times over altitudes 15 to >60 km, & including a planetary scale dust event.	B1.4	GII: A1.3
	A2. Determine the orbital particulate environment in high Mars orbit that may impact the delivery of cargo & 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 & implement a human mission to the Martian surface with acceptable cost, risk, & performance.	**B1.** Determine the aspects of the atmospheric state that affect Entry, Descent, & Landing (EDL) design, or atmospheric electricity that may pose a risk to ascent vehicles, ground systems, & human explorers.	1. Globally monitor the dust & aerosol activity, especially large dust events, to create a long-term dust activity climatology (> 10 Mars years) capturing the frequence of all events & defining the duration, horizontal extent, & evolution of extreme events.	A1.2	GII: A1.2, A4.1; GIII: A1.6
		2. Monitor surface pressure & near surface meterology over various temporal scales (diurnal, seasonal, annual), & if possible in more than one locale.	A1.1	GII: A1
		3. Make temperature & aerosol profile obs. under dusty conditions (including w/i the core of a global dust storm) from the surface to 20 km (40 km in a great dust storm) with a vert. res. of <5 km.	A1.1-2, B1.1	GII: A4.1; GIII: A1.6
		4. Profile the near-surface winds (<15 km) in representative regions (e.g., plains, up/down wind of topography, canyons), simultaneous with the global wind observations.	A1.3	GII: A1.3
		5. Obtain temperature or profiles from all landed missions between the surface & 20 km.		
		6. Combine the characterization of atmospheric electricity with surface meteorological & dust measurements to correlate electric forces & their causative meteorological source for more than 1 Martian year, both in dust devils & large dust storms.		GII: A1.2, A3.4

	B2. Determine if the Martian environments to be contacted by humans are free, to within acceptable risk standards, of biohazards that might have adverse effects on the crew that might be directly exposed while on Mars, & 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, & if the air-borne dust is a mechanism for its transport. If life is present, assess whether it is a biohazard.		GI: B3
	B3. Determine the Martian environmental niches that meet the definition of "Special Region."	1. Map the distribution of both naturally occurring Special Regions, & regions with the potential for spacecraft-induced Special Regions, as defined by COSPAR5.		GI: B1.1-2; GII: B3.1; GIII: A1.1-2, A1.4, A4.3
	B4. Understand the resilience of atmospheric In Situ Resource Utilization (ISRU) processing systems to variations in Martian near-surface environmental conditions.	1. Test ISRU atmospheric processing system to measure resilience with respect to dust & other environmental challenge performance parameters that are critical to the design of a full-scale system.		
	B5. Assess landing site-related hazards, including those related to safe landing & safe operations (including trafficability) within the possible area to be accessed by elements of a human mission.	1. Image selected potential landing sites to sufficient resolution to detect & characterize hazards to both landing & trafficability at the scale of the relevant landed systems.		
		2. Determine regolith physical properties & structure, gas permeability of the regolith & the chemistry & mineralogy of the regolith, including ice contents.		GII: A4.2; GIII: A1
	B6. Assess risks to crew health & performance by characterizing in detail the ionizing radiation environment at the Martian surface & determining the possible toxic effects of Martian dust on humans.	1. Measure neutrons with directionality.		
		2. Measure the charged particle spectra, neutral particle spectra, & absorbed dose at the martian surface throughout the solar cycle, & over more than one solar cycle.		
		3. Assay for chemicals with known toxic effect on humans, particularly oxidizing species, in samples containing dust-sized particles that could be ingested.		
		4. Fully characterize soluble ion concentrations, & chemical reactions that occur upon humidification.		
		5. Analyze the shapes of Martian dust grains to assess their possible impact on human soft tissue.		
	B7. Characterize the particulates that could be transported to hardware & infrastructure through the air (including natural aeolian dust & other materials that could be raised from the Martian regolith by ground operations), & that could affect engineering performance & in situ lifetime.	1. Analyze regolith & surface aeolian fines, with a priority placed on the characterization of the electrical & thermal conductivity, triboelectric & photoemission properties, & chemistry of samples of regolith from depths that might be reached by human surface operations.		
		2. Determine the electrical conductivity of the ground, measure the magnitude & dynamics of any quasi-DC electric fields, & determine the charge on individual dust grains.		
		3. Determine the column abundance & size-frequency distribution, resolved at less than scale height, of dust particles in the Martian atmosphere.		GII: A4.1; GIII: A1.6
C. Obtain knowledge of Mars sufficient to design & implement a human mission to the surface of either Phobos or Deimos (P/D) with acceptable cost, risk, & performance.	**C1.** Understand the geological, compositional, & geophysical properties of P/D sufficient to establish specific scientific objectives, operations planning, & any potentially available resources.	1. Determine the elemental & mineralogical composition of the surface & near-surface of P/D.		GIII: C1
		2. Identify geologic units for science & exploration & materials for future ISRU operations.		GIII: C1.1-2
		3. Determine the gravitational field to a sufficiently high degree & order to make inferences regarding the internal structure & mass concentrations of P/D.		GIII: C1.3
	C2. Understand the conditions at the surface & the low orbital environment for P/D sufficiently well so as to be able to design an operations plan, including close proximity & surface interactions.	1. Measure & characterize the physical properties & structure of regolith on P/D.		
		2. Determine the gravitational field to a sufficiently high degree to be able to carry out proximity orbital operations.		
		3.Measure the electrostatic charge & plasma fields near the surface of P/D.		GIII: C1.1
		4. Measure the surface & subsurface temperature regime of P/D to constrain the range of thermal environments of these moons.		
D. Obtain knowledge of Mars sufficient to design & implement sustained human presence at the Martian surface with acceptable cost, risk, & performance.	**D1.** Characterize potentially extractable water resources to support ISRU for long-term human needs.	1. Identify a set of candidate water resource deposits that have the potential to be relevant for future human exploration.		GII: B3.1
		2. Prepare high spatial resolution maps of at least one high-priority water resource deposit, that include the information needed to design & operate an extraction & processing system with adequate cost, risk, & performance.		
		3. Measure the energy required to excavate/drill & extract water the H-bearing material from either shallow water ice or hydrated minerals as appropriate for the resource.		