MEPAG Goals Document, 2020 / Supplemental Hierarchical Summary Table

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All goals are of equal priority. Prioritization within objectives, sub-objectives, and investigations are explained within main document and is not necessarily related to listing order.

Objectives	Sub-objectives	Investigations
GOAL 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 activity.	1. Search for chemical signatures of life in surface or subsurface environments that have a high potential for modern/past habitability and preservation of biosignatures.
		2. Search for physical structures or assemblages that might be associated with life in surface or subsurface environments that have a high potential for modern/past habitability and preservation of biosignatures.
		3. Test for evidence of physiological activity in surface or subsurface environments that have a high potential for modern habitability.
	A2. Investigate the nature and duration of habitability near the surface and in the deep subsurface.	1. Constrain the availability of liquid water with respect to duration, extent, and chemical activity.
		2. Identify and constrain the magnitude of possible energy sources, chemical potential and flux, and how they change with depth.
		3. Characterize the physical and chemical environment, particularly with respect to parameters that affect the stability of organic covalent bonds.
		4. Constrain the abundance and characterize potential sources of bioessential elements.
		5. Provide overall geologic context.
	A3. Assess the preservation potential of biosignatures near the surface and with depth.	1. Evaluate conditions and processes that would have aided preservation and/or degradation of complex organic compounds as a function of depth, such as aqueous, thermal, and barometric diagenesischemical and biological oxidationor radiolytic ionization.
		2. Evaluate the conditions and processes that would have aided preservation and/or degradation of physical structures on micron to meter scales and as a function of depth, such as physical destruction by mechanical fragmentation, abrasion, and dissolutionand protection by minerals (i.e., inclusions, surface bonding, grain boundaries).
		3. Evaluate the conditions and processes that would have aided preservation and/or degradation of environmental imprints of active metabolism near the surface and as a function of depth, such as chemical alteration or dilution.
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.	1. Characterize the inventory and abundance of organics on the martian surface and subsurface, including macromolecular organic carbon, as a function of exposure time/age.
		2. Characterize the atmospheric reservoirs of carbon and their variation over time.
		3. Constrain the abiotic cycling (between atmosphere and crustal reservoirs) of bioessential elements on ancient and modern Mars.
		4. Characterize bulk carbon in the martian mantle and crust through investigations of martian meteorites.
	B2. Constrain the surface, atmosphere, and subsurface processes through which organic molecules could have formed and evolved over martian history.	1. Investigate atmospheric processes (e.g. photolysis, impact shock heating) that could potentially create and transform organics.
		2. Investigate the role of ionizing radiation in organic synthesis and destruction and how it changes with depth.
		3. Investigate surface and subsurface processes, such as mineral catalysis, that play a role in organic evolution.
		4. Investigate the role of subsurface processes (e.g. hydrothermalism, serpentinization) in driving organic evolution.

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GOAL 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.** Characterize the dynamics, thermal structure, and distributions of dust, water, and carbon dioxide in the lower atmosphere.	1. Characterize the dynamical and thermal state of the lower atmosphere and their controlling processes on local to global scales.
		2. Measure water and carbon dioxide (clouds and vapor) and dust distributions in the lower atmosphere and determine their fluxes between polar, low-latitude, and atmospheric reservoirs.
	A2. Constrain the processes by which volatiles and dust exchange between surface and atmospheric reservoirs.	1. Characterize the fluxes and sources of dust and volatiles between surface and atmospheric reservoirs.
		2. Determine how the processes exchanging volatiles and dust between surface and atmospheric reservoirs affect the present distribution and short-term variability of surface and subsurface water and CO_2 ice.
	A3. Characterize the chemistry of the atmosphere and surface.	1. Measure the global average vertical profiles of key gaseous chemical species in the atmosphere and identify controlling processes.
		2. Measure spatial and temporal variations of species that play important roles in atmospheric chemistry or are transport tracers and constrain sources and sinks.
		3. Determine the significance of heterogeneous reactions and electrochemical effects for the chemical composition of the atmosphere.

	A4. Characterize the state and controlling processes of the upper atmosphere and magnetosphere.	1. Characterize the mechanisms for vertical transport of energy, volatiles, and dust between the lower atmosphere and the upper atmosphere.
		2. Characterize the spatial distribution, variability, and dynamics of neutral species, ionized species, and aerosols in the upper atmosphere and magnetosphere.
		3. Characterize the thermal state and its variability of the upper atmosphere under the full range of present-day driving conditions.
B. Characterize the history and controlling processes of Mars' climate in the recent past, under different orbital configurations.	**B1.** Determine the climate record of the recent past that is expressed in geomorphic, geological, glaciological, and mineralogical features of the polar regions.	1. Determine how orbital parameters, atmospheric processes, and surface processes influence layer formation and properties in the polar regions.
		2. Determine the vertical and horizontal variations of composition and physical properties of the materials forming the Polar Layered Deposits (PLD).
		3. Determine the absolute ages of the layers of the Polar Layered Deposits (PLD).
	B2. Determine the record of the climate of the recent past that is expressed in geomorphic, geological, glaciological, and mineralogical features of low- and mid-latitudes.	1. Characterize the locations, composition, and structure of low and mid-latitude ice and volatile reservoirs at the surface and near-surface.
		2. Determine the conditions under which low- and mid-latitude volatile reservoirs accumulated and persisted until the present day, and ascertain their relative and absolute ages.
	B3. Determine how the chemical composition and mass of the atmosphere has changed in the recent past.	1. Determine how and when the buried CO2 ice reservoirs at the south pole formed.
		2. Measure the composition of gases trapped in the Polar Layered Deposits (PLD) and near-surface ice.
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.	1. Measure the composition and absolute ages of trapped gases.
		2. Characterize mineral and volatile deposits to determine crustal sinks of key atmospheric species.
		3. Determine sources of gases to the atmosphere over time by characterizing rates of volcanism, crustal alteration, and bolide impact delivery.
		4. Determine the rates of atmospheric escape over geologic time.
	C2. Find and interpret surface records of past climates and factors that affect climate.	1. Constrain the ancient water cycle by determining the spatial extent, age, duration, and formation conditions of ancient water-related features.
		2. Characterize the ancient climate via modeling and constrain key model boundary conditions.
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GOAL 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.** Identify and characterize past and present water and other volatile reservoirs.	1. Determine the modern extent and volume of liquid water and hydrous minerals within the crust.
		2. Identify the geologic evidence for the location, volume, and timing of ancient water reservoirs.
		3. Determine the subsurface structure and age of the Polar Layered Deposits (PLD) and identify links to climate.
		4. Determine how the vertical and lateral distribution of surface ice and ground ice has changed over time.
		5. Determine the role of volatiles in modern dynamic surface processes, correlate with records of recent climate change, and link to past processes and landforms.
	A2. Document the geologic record preserved in sediments and sedimentary deposits.	1. Constrain the location, volume, timing, and duration of past hydrologic cycles that contributed to the sedimentary and geomorphic record.
		2. Constrain the location, composition and timing of diagenesis of sedimentary deposits and other types of subsurface alteration.
		3. Identify the intervals of the sedimentary record conducive to habitability and biosignature preservation.
		4. Determine the sources and fluxes of modern aeolian sediments.
		5. Determine the origin and timing of dust genesis, lofting mechanisms, and circulation pathways.
	A3. Constrain the magnitude, nature, timing, and origin of ancient environmental transitions.	1. Link geologic evidence for local environmental transitions to global-scale planetary evolution.
		2. Determine the relative and absolute age, durations, and intermittency of ancient environmental transitions.
		3. Document the nature and diversity of ancient environments and their implications for surface temperature, geochemistry, and aridity.
		4. Determine the history and fate of sulfur and carbon throughout the Mars system.
	A4. Determine the nature and timing of construction and modification of the crust.	1. Determine the absolute and relative ages of geologic units and events through martian history.
		2. Link the petrogenesis of martian meteorites and returned samples to the geologic evolution of the planet.
		3. Characterize modern surface processes and their rates of change, and assess their origin.

		4. Constrain the effect of impact processes on the martian crust and determine the martian crater production rate now and in the past.
		5. Determine the surface manifestation of volcanic processes through time and their implications for surface conditions.
		6. Constrain the petrology/petrogenesis of igneous rocks over time.
		7. Develop a planet-wide model of Mars evolution through global and regional mapping efforts.
B. Determine the structure, composition, and dynamics of the interior and how it has evolved.	**B1.** Identify and evaluate manifestations of crust-mantle interactions.	1. Determine the types, nature, abundance, and interaction of volatiles in the mantle and crust, and establish links to changes in climate and volcanism over time.
		2. Seek evidence of plate tectonics-style activity and metamorphic activity, and measure modern tectonic activity.
	B2. Quantitatively constrain the age and processes of accretion, differentiation, and thermal evolution of Mars.	1. Characterize the structure and dynamics of the interior.
		2. Measure the thermal state and heat flow of the martian interior.
		3. Determine the origin and history of the magnetic field.
C. Determine the origin and geologic history of Mars' moons and implications for the evolution of Mars.	**C1.** Constrain the origin of Mars' moons based on their surface and interior characteristics.	1. Determine the thermal, physical, and compositional properties of rock and regolith on the moons.
		2. Interpret the geologic history of the moons, by identification of geologic units and the relationship(s) between them.
		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- versus macroporosity).
	C2. Determine the material and impactor flux within the Mars neighborhood, throughout martian history, as recorded on Mars'	1. Understand the flux of impactors in the martian system, as observed outside the martian atmosphere.
		2. Measure the character and rate of material exchange between Mars and the two moons.
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GOAL IV: Prepare for human exploration.

A. Obtain knowledge of Mars sufficient to design and implement human landing at the designated human landing site with acceptable cost, risk and performance.	**A1.** Determine the aspects of the atmospheric state that affect orbital capture and EDL for human scale missions to Mars.	1. At all local times, make long-term (>5 Mars years) observations of the global atmospheric temperature field (both the climatology and the weather variability) from the surface to an altitude ~80 km with ~5 km vertical resolution and a horizontal resolution of <300 km.
		2. At all local times, make long-term (>5 Mars years) global measurements of the vertical profile of aerosols (dust and water ice) between the surface and >60 km with a vertical resolution ≤5 km and a horizontal resolution of <300 km. These observations should include the optical properties, particle sizes, and number densities.
		3. Make long-term (>5 martian years) observations of global winds and wind direction with a precision ≤5 m/s at all local times from 15 km to an altitude >60 km. The global coverage would need observations with a vertical resolution of ≤5 km and a horizontal resolution of ≤300 km. The record needs to include a planetary scale dust event.
	A2. Characterize the orbital debris environment around Mars with regard to future human exploration infrastructure.	1. Develop and fly an experiment capable of measuring or constraining the primary meteoroid environment around Mars for particles in the threat regime (>0.1 mm).
	A3. Assess landing-site characteristics and environment related to safe landing of human-scale landers.	1. Characterize selected potential landing sites to sufficient resolution to detect and identify hazards to landing human scale systems.
		2. Determine physical and mechanical properties and structure (including particle shape and size distribution), cohesion, gas permeability, and the chemistry and mineralogy of the regolith, including ice contents.
		3. Profile the near-surface winds (<15 km altitude) with a precision ≤2 m/s in representative locales (e.g., plains, up/down wind of topography, canyons), simultaneous with the global wind observations. The boundary layer winds would need a vertical resolution of ≤1 km and a horizontal resolution of ≤100 m. The surface winds would be needed on an hourly basis throughout the diurnal cycle. During the daytime (when there is a strongly convective mixed layer), high-frequency wind sampling would be necessary.
B. Obtain knowledge of Mars sufficient to design and implement human surface exploration and EVA	**B1.** 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. Conduct measurements of neutrons with directionality (energy range from <10 keV to >100 MeV).
		2. Measure the charged particle spectra, neutral particle spectra, and absorbed dose at the martian surface throughout the ~11 year solar cycle (from solar maximum to solar minimum) to characterize "extreme conditions" (particle spectra from solar maximum and minimum, as well as representative "extreme" solar energetic particle (SEP) events), and from one solar cycle to the next.

on Mars with acceptable cost, risk and performance.		3. Assay for chemicals with known toxic effect on humans in samples containing dust-sized particles that could be ingested. Of particular interest is a returned sample of surface regolith that contains airfall dust, and a returned sample of regolith from as great a depth as might be affected by surface operations associated with human activity (EVA, driving, mining, etc.).
		4. Analyze the shapes of martian dust grains with a grain size distribution (1-500 microns) sufficient to assess their possible impact on human soft tissue (especially eyes and lungs).
	B2. Characterize the surface particulates that could affect engineering performance and lifetime of hardware and infrastructure.	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 (especially chemistry of relevance to predicting corrosion effects), of samples of regolith from a depth as large as might be affected by human surface operations.
	B3. Assess the climatological risk of dust storm activity in the human exploration zone at least one year in advance of landing and operations.	1. Globally monitor the dust and aerosol activity continuously and simultaneously at multiple locations across the globe, especially during large dust events, to create a long-term dust activity climatology (>10 Mars years) capturing the frequency of all events (including small ones) and defining the duration, horizontal extent, and evolution of extreme events.
		2. Monitor surface pressure and near surface (below 10 km altitude) meteorology over various temporal scales (diurnal, seasonal, annual), and if possible in more than one locale.
		3. Collect temperature and aerosol profile observations even under dusty conditions (including within the core of a global dust storm) from the surface to 20 km (50-80 km in a global dust storm) with a vertical resolution of <5 km.
	B4. Assess landing-site characteristics and environment related to safe operations and trafficability within the possible area to be accessed by elements of a human mission.	1. Characterize selected potential landing sites to sufficient resolution to detect and characterize hazards to trafficability at the scale of the relevant systems.
		2. Determine physical and mechanical properties and structure (including particle shape and size distribution), cohesion, gas permeability, and chemistry and mineralogy of the regolith, including ice contents.
		3. Combine the characterization of atmospheric electricity with surface meteorological and dust measurements to correlate electric forces and their causative meteorological source for more than 1 Mars year, both in dust devils and large dust storms.
C. Obtain knowledge of Mars sufficient to design and implement In Situ Resource Utilization of atmosphere and/or water on Mars with acceptable cost, risk and performance.	**C1.** 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 and other environmental challenge performance parameters that are critical to the design of a full-scale system.
	C2. 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.
		2. Prepare high spatial resolution maps of one equatorial site with water bound in regolith materials and one mid to high latitude site with water ice at or within a few meters of the surface that include the information needed to design and operate an extraction and processing system with adequate cost, risk, and performance.
		3. Measure the energy required to excavate/drill and extract water from the H-bearing material, either shallow water ice or hydrated minerals as appropriate for the resource.
D. Obtain knowledge of Mars sufficient to design and implement biological contamination and planetary protection protocols to enable human exploration of Mars with acceptable cost, risk and performance.	**D1.** Determine the martian environmental niches that meet the definition of "Special Region" at the human landing site and inside of the exploration zone.	1. Identify the locations and characteristics of naturally occurring Special Regions, and regions with the potential for spacecraft-induced Special Regions.
	D2. 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.	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.
	D3. Determine if martian materials or humans exposed to the martian environment are free, within acceptable risk standards, of biohazards that might have adverse effects on the terrestrial environment and species if returned to Earth.	1. Determine the viability of terrestrial organisms when exposed to martian material under Earth-like conditions.
	D4. Determine the astrobiological baseline of the human landing site prior to human arrival.	1. Determine characteristics of the Mars atmosphere, surface, and sub-surface environments that constitute the astrobiological baseline of the landing site prior to the introduction of terrestrial bio-material.
	D5. Determine the survivability of terrestrial organisms exposed to martian surface conditions to better characterize the risks of	1. Determine the extent to which bio-material released by human exploration activities can be transported by wind and air-borne dust.

	forward contamination to the martian environment.	2. Determine the survivability of terrestrial organisms released at the surface under martian surface conditions and micro-environments created by human exploration elements.
E. Obtain knowledge of Mars sufficient to design and implement a human mission to the surface of either Phobos or Deimos with acceptable cost, risk, and performance.	**E1.** Understand the geological, compositional, and geophysical properties of Phobos and/or Deimos sufficient to establish specific scientific objectives, operations planning, and any potentially available resources.	1. Determine the elemental and mineralogical composition as well as the physical and thermal properties of the surface and near sub-surface of Phobos and Deimos.
		2. Identify geologic units, their value for science and exploration, and their potential for future in situ resource utilization (ISRU) operations.
		3. Determine the gravitational field to a sufficiently high degree and order to make inferences regarding the internal structure and mass concentrations of Phobos and Deimos.
	E2. Understand the conditions at the surface and in the low orbital environment for the martian satellites sufficiently well so as to be able to design an operations plan, including close proximity and surface interactions.	1. Measure and characterize the physical properties and structure of regolith on Phobos and Deimos.
		2. Determine the gravitational field to a sufficiently high degree to be able to carry out proximity orbital operations and rendezvous.
		3. Measure the electrostatic charge and plasma fields near the surface of Phobos and Deimos.
		4. Measure the surface and subsurface temperature regime of Phobos and Deimos to constrain the range of thermal environments of these moons.