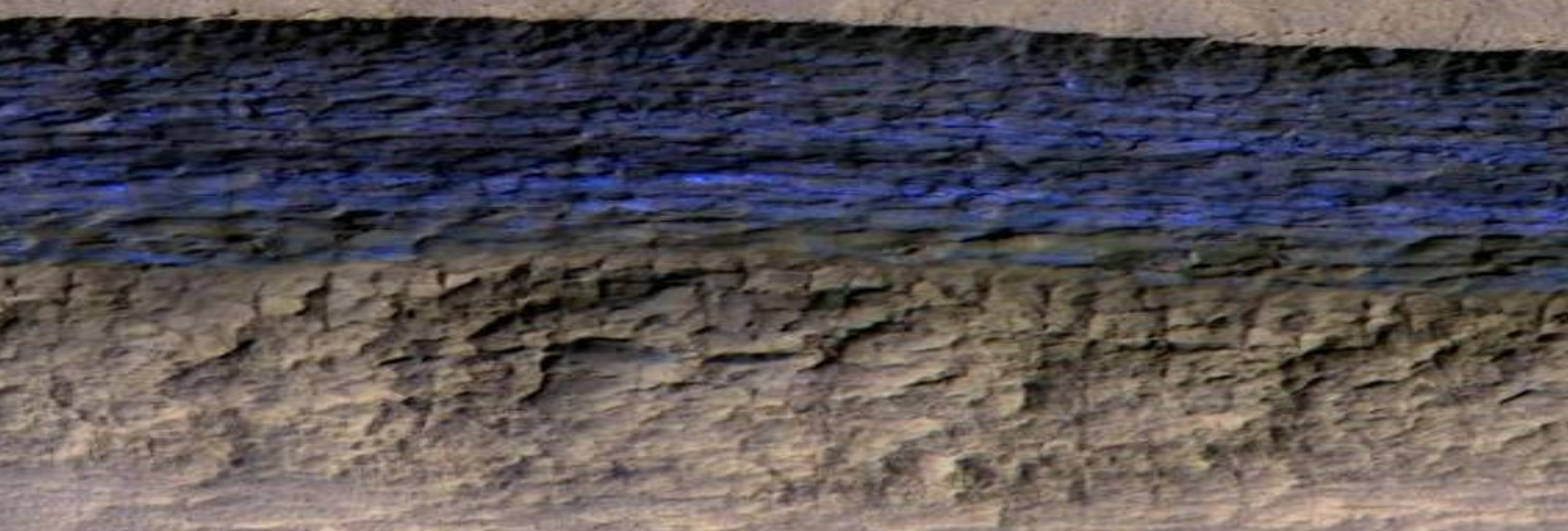
Reconnaissance and Emerging Strategies to Enable Human Exploration of Mars



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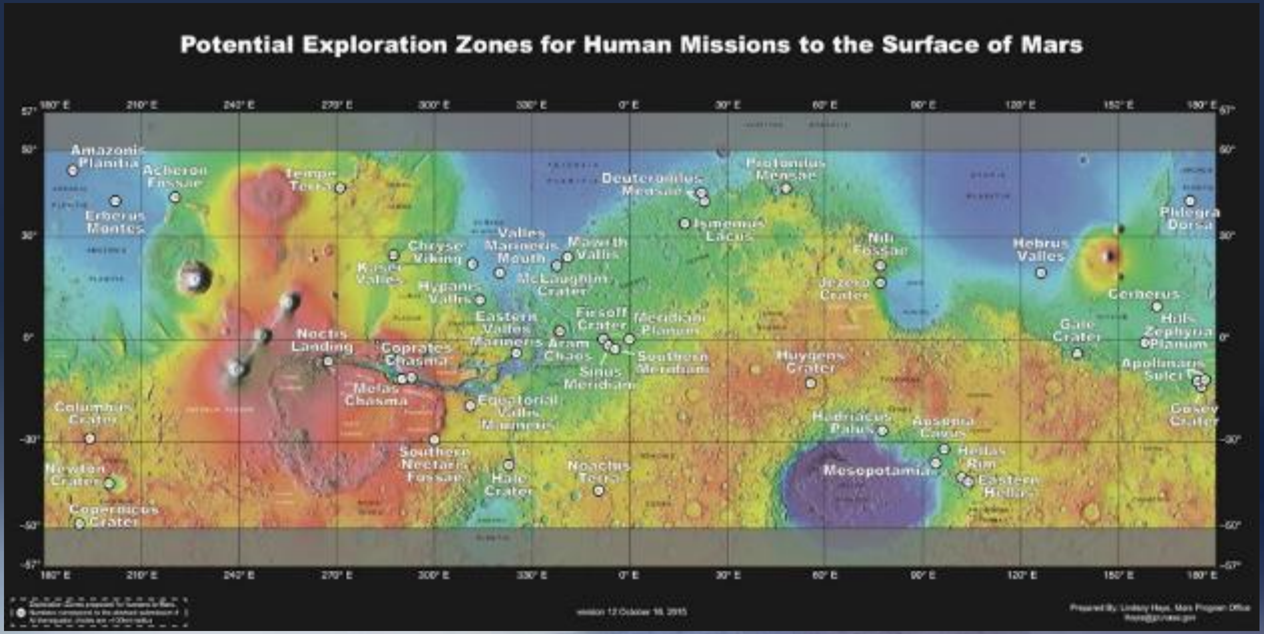
Outline

- Water and the Human Landing Sites Study (HLS2)
- Mars Subsurface Ice and Hydrated Mineral Maps
- Potentially Needed Future Missions from the International Mars Exploration Working Group (IMEWG)
- Growing Awareness of Potential Need for Civil Engineering
- Mars Exploration Planning Analysis Group Science Goal IV: Prepare for Human Exploration

Water and the Human Landing Sites Study (HLS2)

- Four Major Questions:
  - Is it really there?
  - Can you really produce it economically?
  - How much water do you need?
  - If the feedstock drives location, what does that mean for landing, launching to go home, and living there?



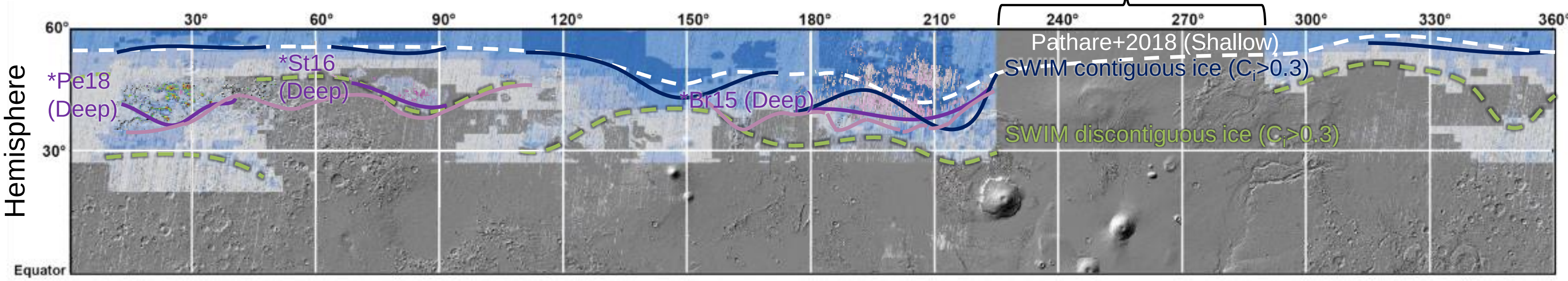
This effort is a joint Human Exploration and Operations Mission Directorate (HEOMD) / Science Mission Directorate (SMD) study

Subsurface Ice Maps
Pushing the Ice-Boundary Line Equatorward

Datasets used: MONS, TES, THEMIS, SHARAD, Geomorphology (imagery and elevation data)

Region not mapped due to high elevation (not landable by human-class vehicles)

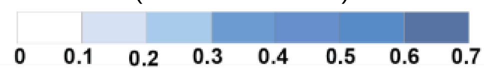
Northern Hemisphere



Legend

- Prior shallow (<1 m) ice from neutrons
- SWIM contiguous ice consistency >0.3
- SWIM discontiguous ice consistency >0.3
- Previously published deep (>15m) ice southern boundary
- SWIM detected deep (>15m) ice southern boundary

Ice Consistency (C_i)
(0-5m from Surface)



Depth to Base of Ice (m)
Derived from SWIM Radar Analysis

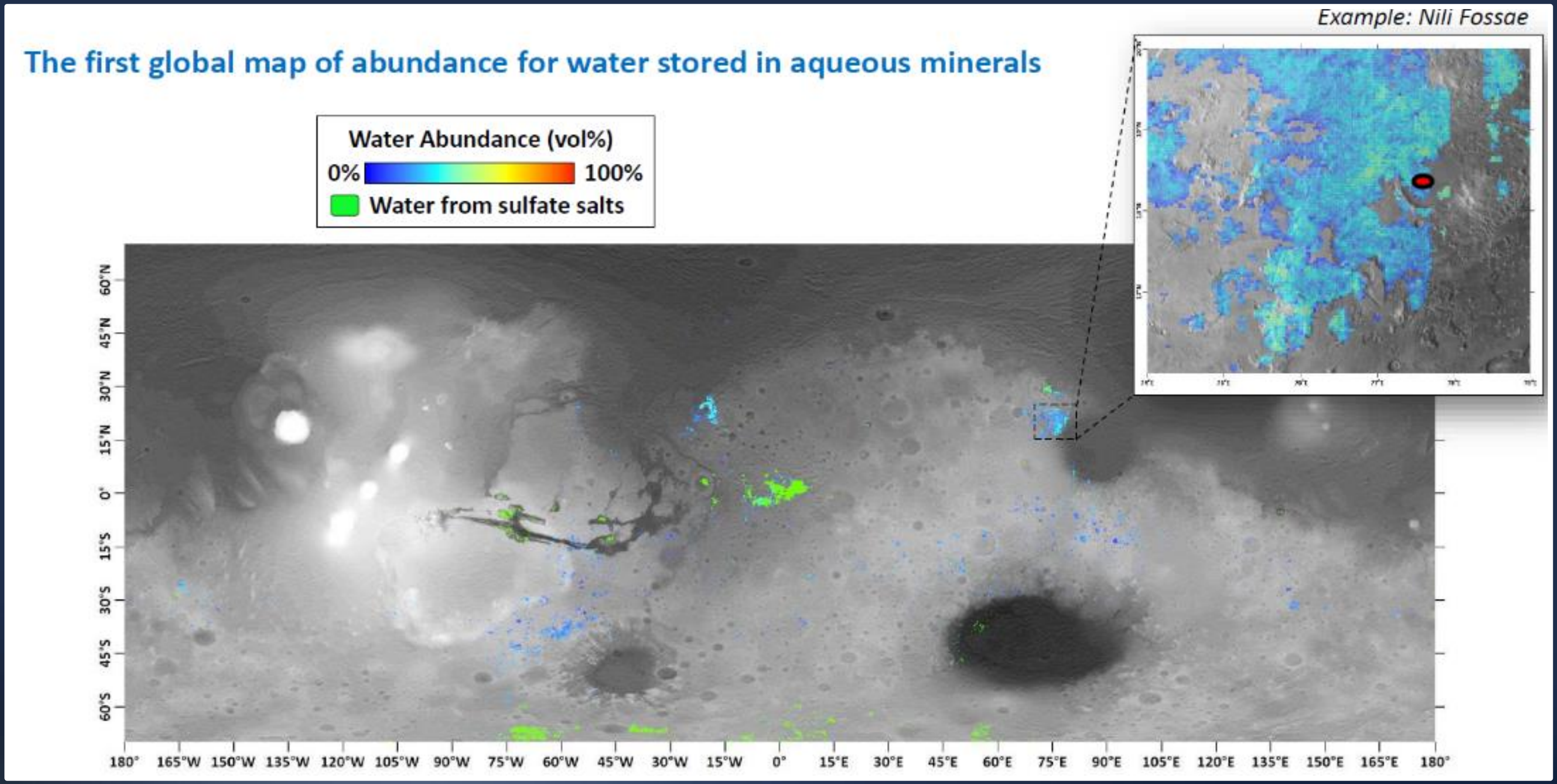
The SWIM Project has:

- Detected more **equatorward contiguous and discontiguous shallow** (<5 m) **ice** than previously found across the Northern Hemisphere
- Increased radar reflector coverage across the Northern Hemisphere, detecting more **equatorward deep ice**, and improving estimates of material composition

*Pe18: Peterson et al. 2018; St16: Stuurman et al. 2016; Br15: Bramson et al. 2015

Next Steps: Currently evaluating potential extension activities to this project that will increase coverage to the Southern Hemisphere and incorporate additional, improved mapping techniques.

Global Hydrated Mineral Water Abundance Map



From: Carter et al., IAS Paris-Sud University

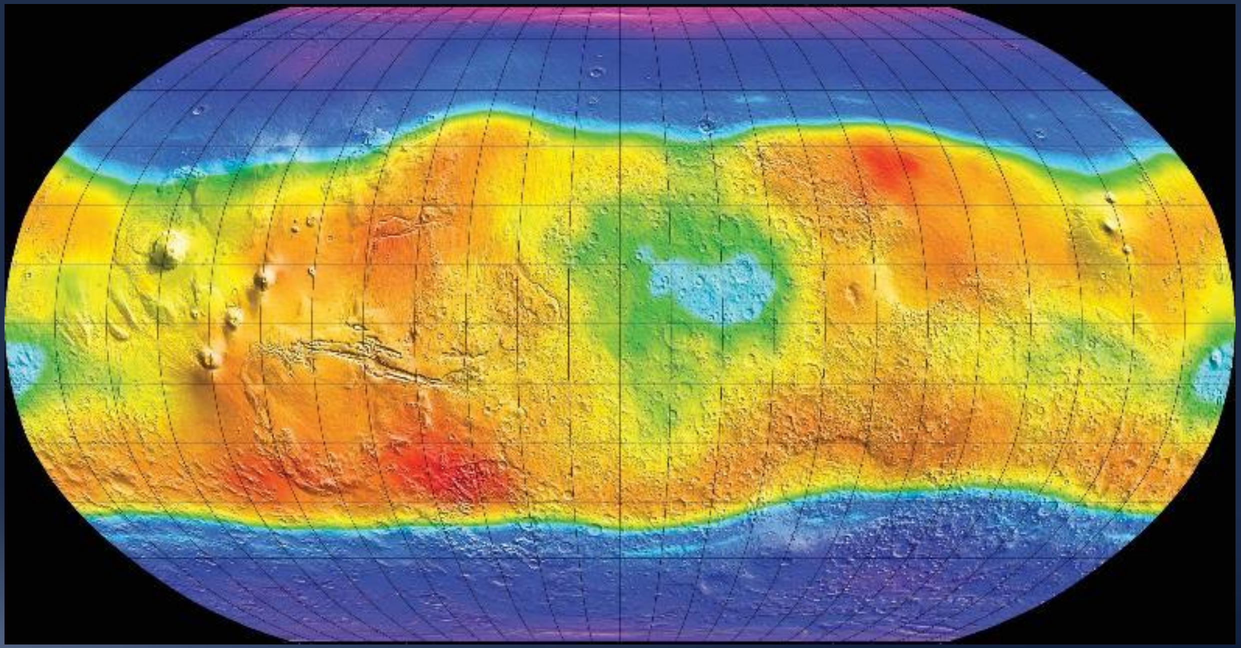
Next Steps: Future studies based on new knew knowledge revealed by these mapping projects are currently being considered, including a potential update to the M-WIP Study and a potential second Mars human landing site selection workshop.

MARS

Potentially Needed Future Missions

From International Mars Exploration Working Group

- Mars Sample Return
  - Accomplish Decadal Science Priorities
  - In addition, MSR is probably needed to confirm the mechanical properties of the regolith/dust (abrasiveness, oxidizing potential particle size, etc.), how it will interact with surface systems (e.g., suits, rovers, habitats, etc.), and potential human health hazards (toxicity, respiratory, potential extant life, etc.)
- Water Recon
  - Identify near surface ice
  - Assess Potential of Hydrated Minerals
  - Ground Truthing
  - Ease of access
- Special Regions Drill
  - Search for life
  - Characterize the water
    - For ISRU
    - For potential human use
- Next-Gen Weather Capabilities (Orbital and Surface)
  - Density Profiles
    - (EDL)
  - Winds Aloft
  - Potential Microbial Transport
- Improved Communications
  - Increased data rate



Growing Awareness of Potential Need for Civil Engineering on the Moon and Mars

- Landing large spacecraft on loose regolith in a low gravity environment has the potential to disturb huge plumes of rock and dust posing a threat to any mission infrastructure nearby

- There is growing awareness that civil engineering efforts may be needed to create landing pads and/or roads
- Understanding these challenges requires a more in-depth understanding of the overburden at potential human landing sites

MARS

MEPAG Science Goal IV: Prepare for Human Exploration

MEPAG Goals Document, 2018, supplemental summary table.

This document and the main text can be downloaded from: http://mepag.nasa.gov/reports.cfm?expand=science. If citing information, please reference the main document.

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 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.		

MARS

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