Results from the Ice and Climate Evolution Science Analysis Group (ICE-SAG)

LPSC 2019 #2035

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Charter

MEPAG chartered ICE-SAG to identify:

- Compelling science objectives addressable within the decade 2023-2032 and traceable to MEPAG Science Goals (Life, Climate, Geoscience, Prep. for Human Explorers)
- Measurements required to address the objectives
- Techniques needed to make these measurements
- Technology investments to develop these techniques
- Mission approaches to address the science objectives and make the required measurements. Types and classes:
  - orbiters, landers, drillers, rovers, networks
  - small spacecraft, Discovery, New Frontiers, Flagship

ICE-SAG Membership

Table 1. 22 members from 13 institutions covering a broad range of relevant expertise

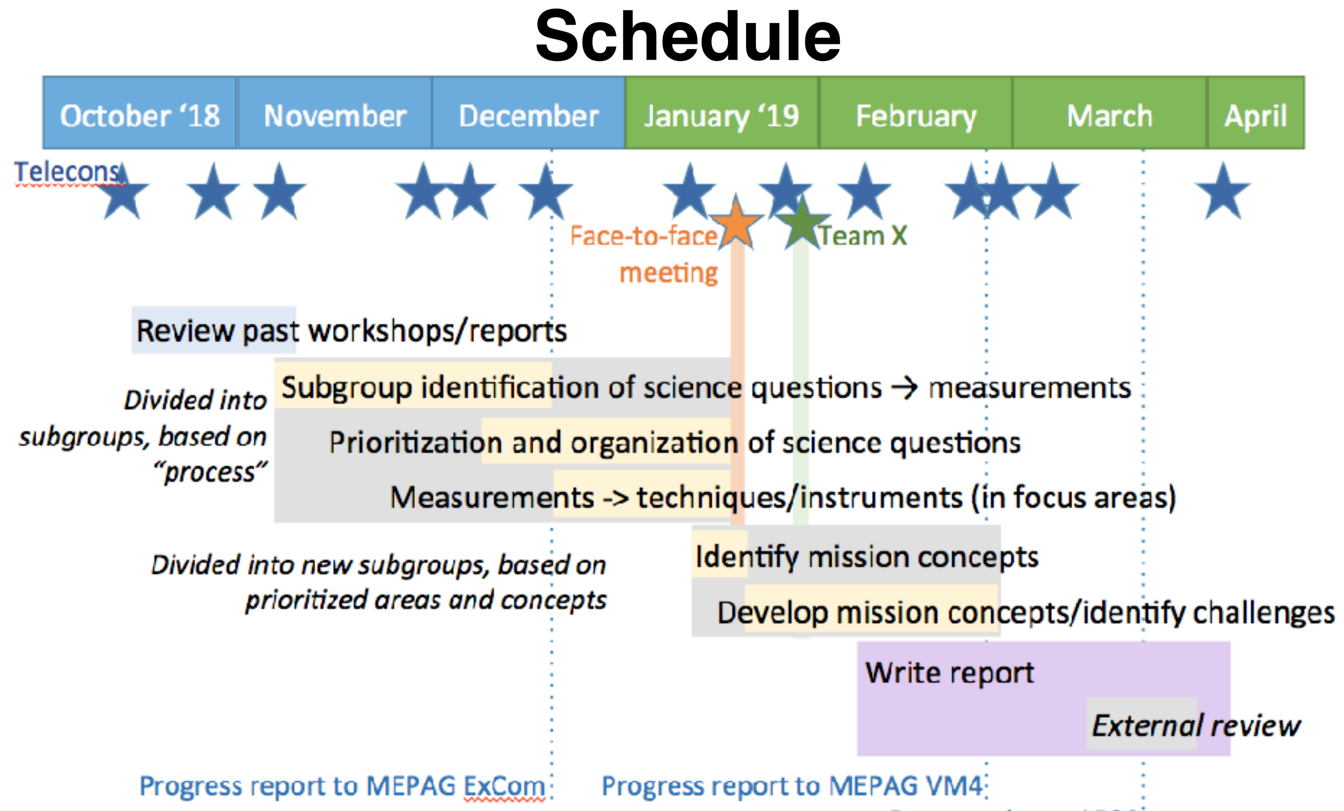
NAME	INSTITUTION	MARS SCIENCE EXPERTISE
Than Putzig (Co-Chair)	Planetary Science Inst.	subsurface, thermal properties, resources
Serina Diniega (Co-Chair)	Jet Propulsion Lab.	surface activity, geomorphology
Shane Byrne	University of Arizona	polar caps and layered deposits
Wendy Calvin	Univ. Nevada - Reno	polar caps and layered deposits
Colin Dundas	US Geological Survey	subsurface ice, surface activity, geomorphology
Lori Fenton	SETI Institute	aeolian, climate
Paul Hayne	University of Colorado	atmosphere
David Hollibaugh Baker	NASA - Goddard	subsurface ice
Jack Holt	University of Arizona	subsurface ice
Christine Hvidberg	Univ. of Copenhagen	polar caps and layered deposits, ice drilling
Melinda Kahre	NASA - Ames	climate modeling
Michael Mischna	Jet Propulsion Lab.	climate modeling
Gareth Morgan	Planetary Science Inst.	volcanism, periglacial, radar, field
Dorothy Oehler	Planetary Science Inst.	astrobiology, resources
Anya Portyankina	University of Colorado	surface ice, CO_2 ice lab
Deanne Rogers	Stonybrook University	surface mineralogy
Hanna Sizemore	Planetary Science Inst.	subsurface ice, volatile transfer in regolith lab
Isaac Smith	PSI + York University	polar layered deposits, subsurface ice, climate
Alejandro Soto	Southwest Res. Inst.	climate
Leslie Tamppari	Jet Propulsion Lab.	atmosphere
Timothy Titus	US Geological Survey	climate, surface activity
Chris Webster	Jet Propulsion Lab.	isotopic records

ICE-SAG Contributors

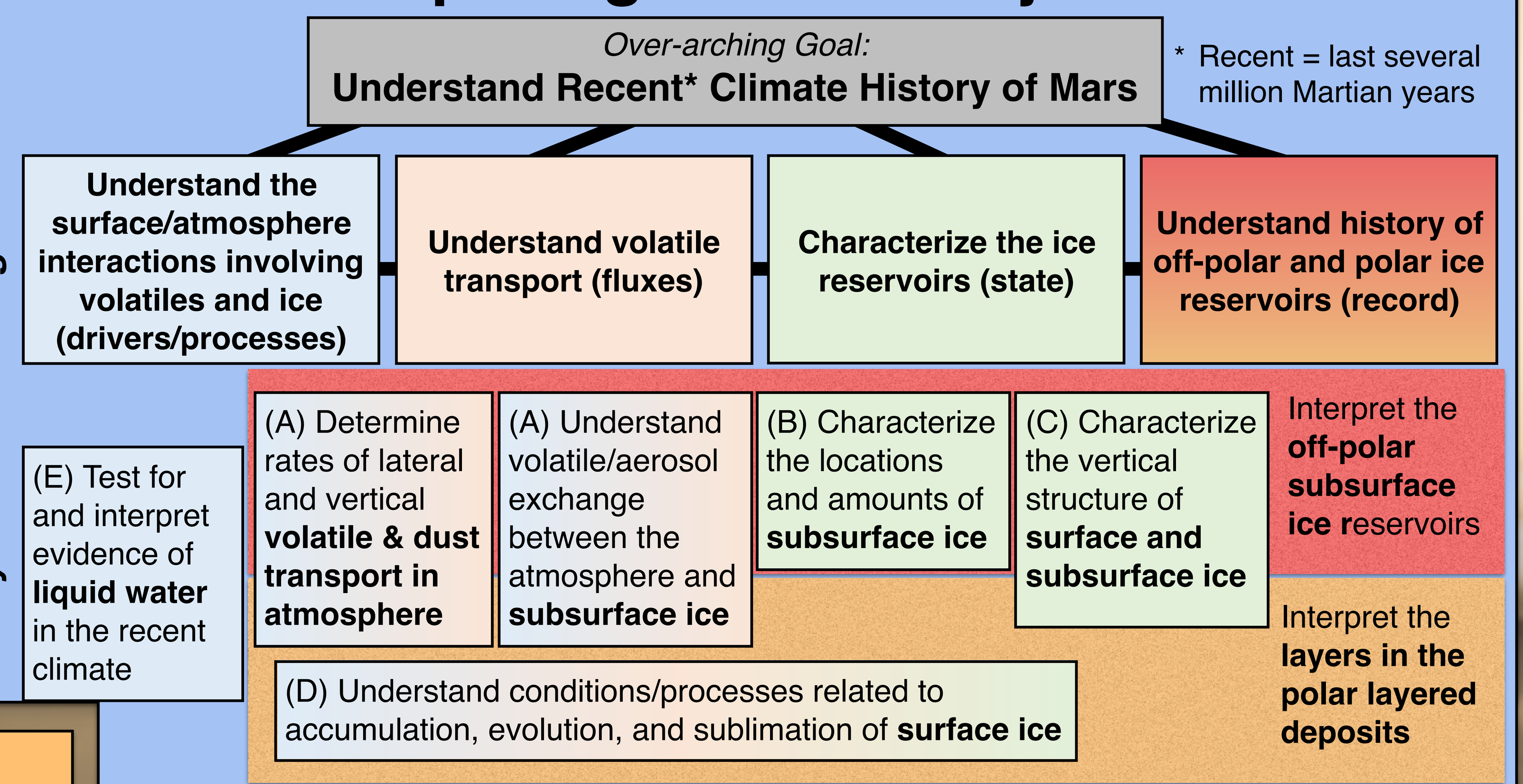
Table 2. ICE-SAG sought inputs from internal* and external participants in a related SAG and recent workshops (green background) and from 11 external relevant subject-matter experts.

NAME	INSTITUTION	TOPIC
Rich Zurek & Bruce Campbell	JPL & Smithsonian	2015 Next Mars Orbiter (NEX-SAG) report [1]
Portyankina*/Dundas*/Mischna*/Oehler*		2018 Late Mars workshop
Smith*	PSI + York University	2016 Mars Polar Science conference [2] 2018 Amazonian Climate workshop
Vlada Stamenkovic	Jet Propulsion Lab.	2018 KISS MarsX Subsurface workshop
Hayne, Byrne, Smith*		2017 KISS North Polar Science workshop
Kris Zacny	Honeybee Robotics	Subsurface access concepts
Tyler Jones	University of Colorado	Terrestrial isotopic records in ice
Franck Montmessin	LATMOS, IPSL	Martian isotopic records in atmosphere/ice
Jen Eigenbrode	NASA - Ames	Astrobiology investigations in ice
Lisa Pratt & Andy Spry	NASA PP Office	Planetary Protections concerns
Don Banfield & Chris Eckert	Cornell Univ. & MIT	Wind-generated power concept
Don Banfield	Cornell University	InSight meteorological measurements
Mike Hecht	Mass. Inst. Technology	Heated drill concept
Ryan Stephan	NASA - PESTO	Planned NASA technology development

Schedule



Compelling Science Objectives



ICE-SAG began by compiling a list of questions concerning ice and recent climate science, spanning all areas—see graphic below. We defined ***Categories*** (top row above) to organize our questions.

Cross-cutting and repeated questions defined ***Priority Areas A-E*** (colored by categories) to address in the next decade. Priorities A-D feed into interpreting the history ice reservoirs—polar (orange box), non-polar (red box), or both.

Collectively, our ***Mission Concepts*** address all priority areas.

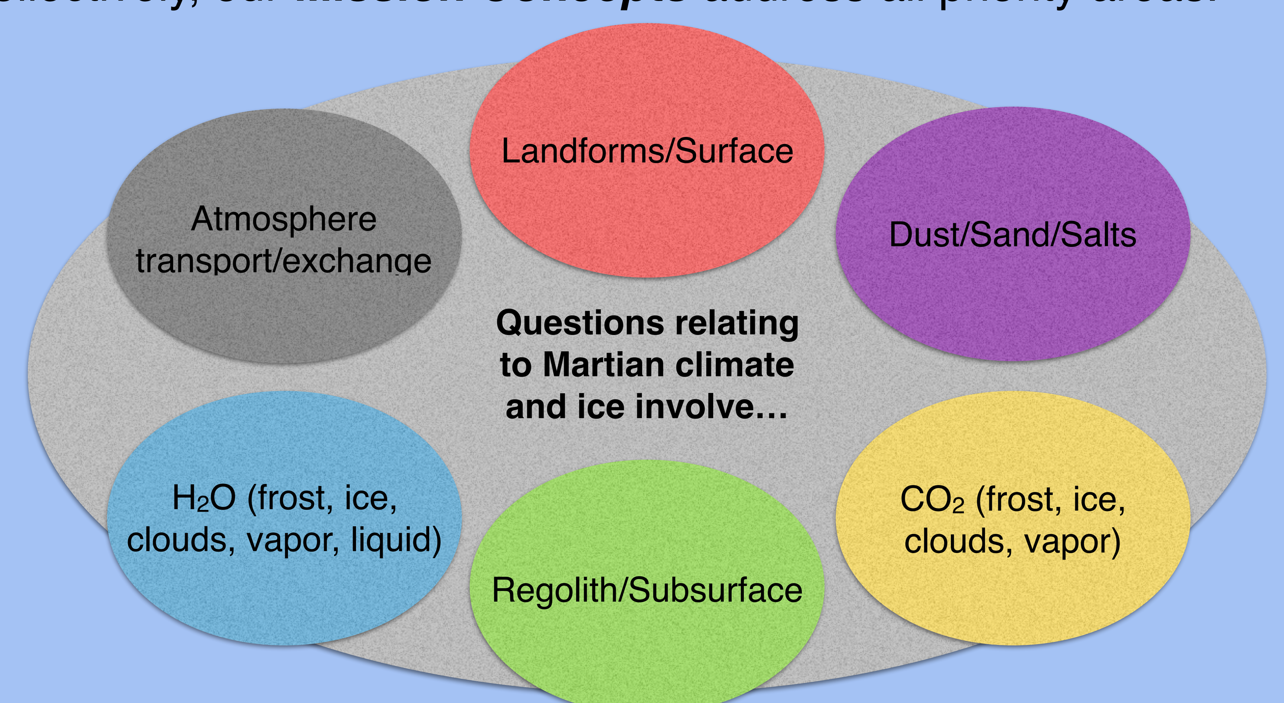


Table of Contents for Draft Report

Figure 2.1.1. (Left) HRSC mosaic of the NRC with circular area required for a MER-sized landing ellipse of unknown orientation. (Right) example of NRC surface where light/dark patches are ~20 m across.

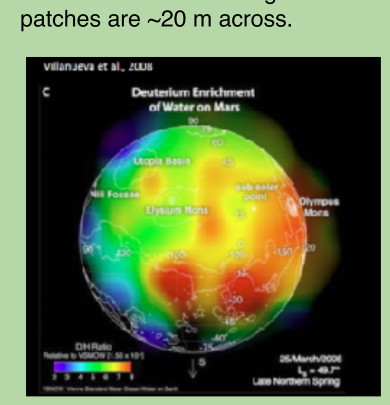


Figure 2.4. Map of Martian D/H ratio in water vapor from Earth telescopic observations [3], now being observed from Mars orbit in detail by the ExoMars Trace Gas Orbiter [4].

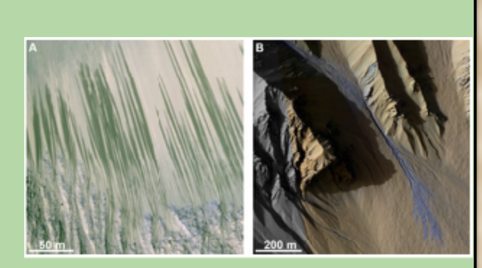


Figure 2.4.3. Active surface features observed by HiRISE. A) Recurring Slope Lineae (ESP_027802_1685). B) New gully flow with lobate deposits (ESP_020661_1440).

Figure 3.2.3. Fine layers and a textural change in ice-rich material exposed in a steep scarp near 57S (HiRISE enhanced-color ESP_057321_1220).

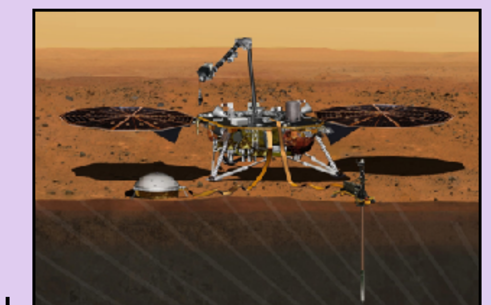
Mission Concepts

ICE-SAG discussed mission concepts addressing key questions over a range of mission sizes. Here, we present concepts that could fit within NASA's New Frontiers class and considerations for larger and smaller missions. JPL's Team X assisted with improved cost assessments for several aspects of these missions.

Ordering does not imply any prioritization of the mission concepts.

New Frontiers Class Concepts

NF1: Investigate polar layered structure and formation
- Examine interaction of the current climate with the surface and layering within the upper meter
- Lander with atmospheric and material properties instruments, drill or bistatic GPR for subsurface investigation



Artist's rendition of InSight with seismometer and heat probe deployed (NASA /JPL-Caltech).

NF2: Assess deposition & sublimation of seasonal polar frost layer
- Monitor transport of volatiles and dust and the seasonal evolution of surface ices
- Lander with atmospheric and surface properties instruments for assessing conditions throughout the polar night

NF3: Measure key atmospheric parameters from surface to 80 km
- Monitor temperature, pressure, wind, water vapor, and aerosol abundance over annual & diurnal cycles
- Orbiter with solar-electric propulsion, optionally paired with landed met stations

Artist's rendition of MRO over the south polar region (NASA/JPL/Corby Waste).

NF4: Catalog and characterize the north polar layered deposits
- Traverse and sample outcropping layers & their conditions within a polar trough
- Rover with material properties instruments and a met station

NF5: Investigate mid-latitude ice vertical structure & exchange
- Assess boundary-layer meteorology, subsurface ice reservoirs, and volatile exchange between ice, regolith, and atmosphere
- Lander with atmospheric and material properties instruments, a ~1-m drill, and radar or electromagnetic sounding

NF6: Map global near-surface ice, stratigraphy, changes
- Determine stratigraphy to depths of 1-100 m at ~1-m vertical resolution, map surface composition and topography at ~20-m lateral and ~1-m vertical resolutions, quantify surface changes
- Orbiter with InSAR, radar sounder, spectral and thermal imagers

Other Concepts

Flagship missions can be realized by supplementing or merging the New Frontiers concepts. Discovery or smaller missions can be realized by scaling down the New Frontiers concepts.

ICE-SAG considered separate small missions with specific goals:
- Landers for Investigating Gullies and Recurring Slope Lineae
- Lander to Assess North Polar Residual Cap and Atmosphere

More Information

The ICE-SAG report is in review, with completion slated for April 2019. The final report will be posted on the MEPAG website.

ICE-SAG's presentation for MEPAG Virtual Meeting 4 on Feb. 25, 2019 is available at: http://mepag.jpl.nasa.gov.

References

[1] NEX-SAG, 2015. Report from the Next Orbiter Science Analysis Group. http://mepag.nasa.gov/reports.cfm.
[2] Smith et al., 2017. 6th Int'l Conf. Mars Polar Sci. Expl.: Conference summary and five top questions. Icarus 308, 2-14, doi:10.1016/j.icarus.2017.06.027. [3] Villanueva et al., 2008. Mapping the D/H of water on Mars using high-resolution spectroscopy. 3rd Int'l Wkshp on the Mars Atmosphere: Modeling and Observations. Abs. 9109.
[4] Vandaele et al. 2018. NOMAD, an integrated suite of three spectrometers for the ExoMars trace gas mission. Spac. Sci. Rev. 214, doi:10.1007/s11214-018-0517-2.

Acknowledgements

ICE-SAG thanks our subject-matter experts, JPL's Team X, other external contributors, and our reviewers, and we are grateful to PSI, Kimberly Foote (PSI), and Barbara Saltzberg (JPL) for hosting and supporting our January 2019 meeting in Tucson.