Mapping Water on Mars

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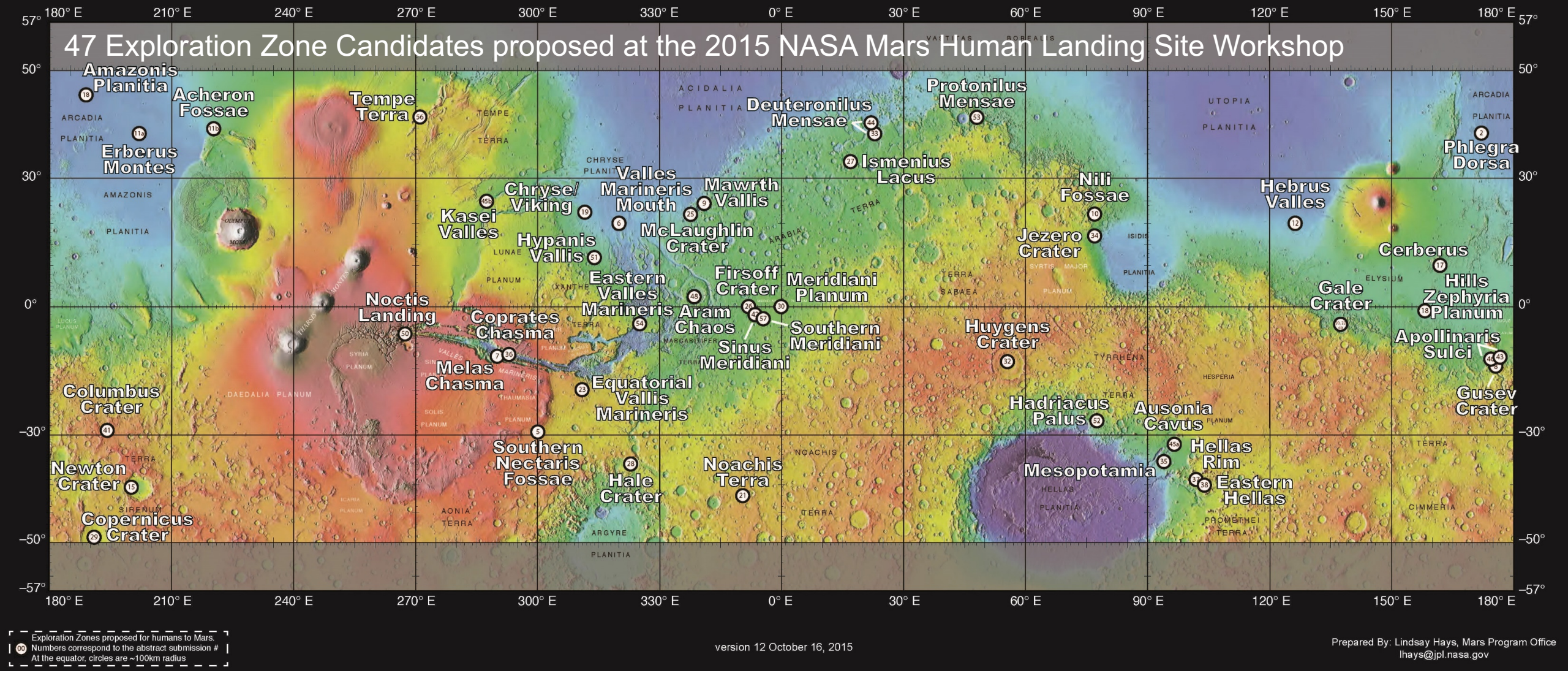
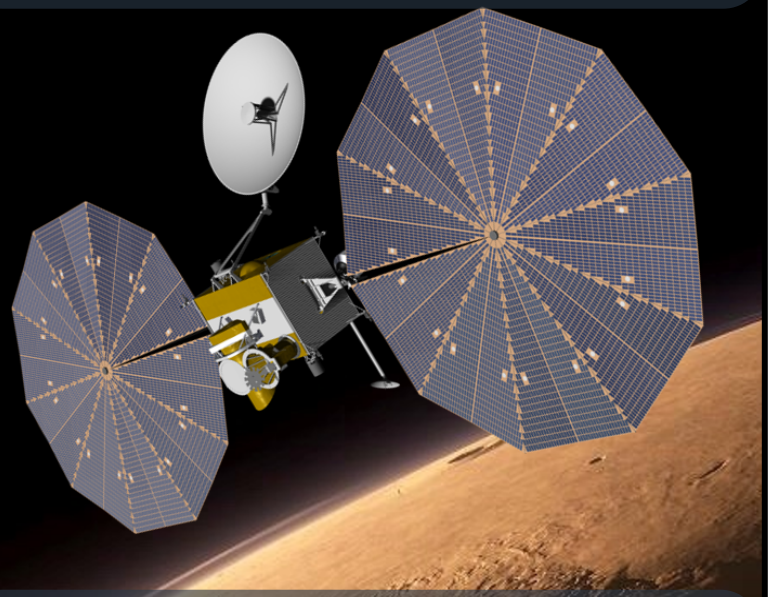
Humans to Mars Summit 2019 – ISRU Panel

The Ultimate Goal: Refining Constraints for Human Landing Site Selection



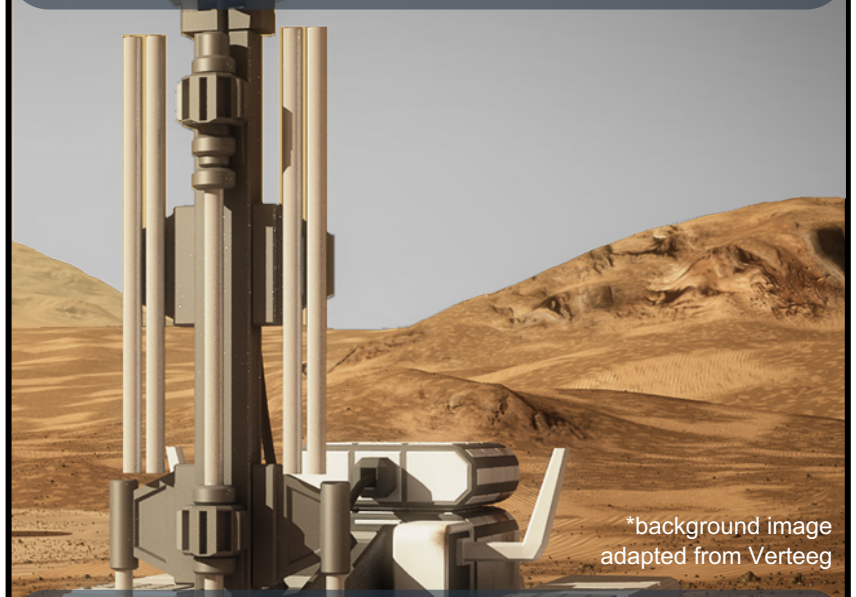
Why Map Water?

Informing Future Orbital Science / Reconnaissance



Provide targets and requirements for potential future orbiter mission(s) carrying new instruments to better characterize the distribution and depth of hydrated minerals and subsurface water ice deposits

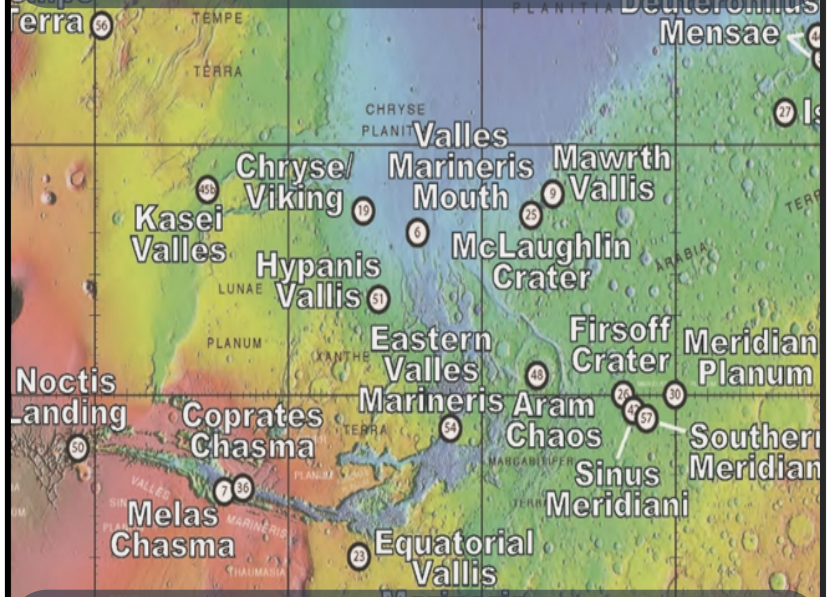
Guiding Future Surface Science / Reconnaissance



*background image adapted from Verteeg

Revealing landing site options for a potential future landed ground truthing mission that will validate orbital measurements and further characterize possible water feedstocks

Selecting Humans Landing Sites / Exploration Zones

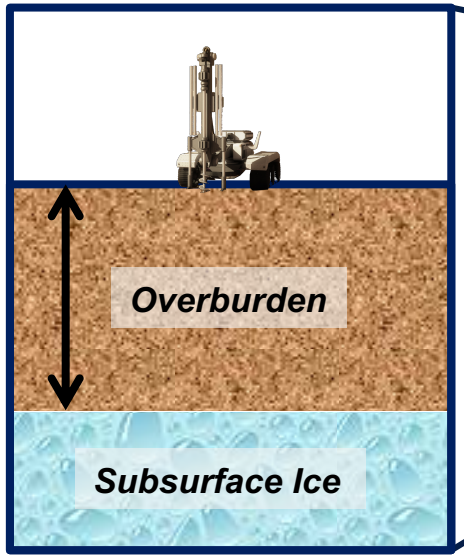


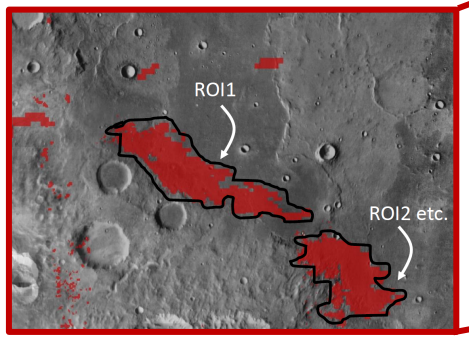
Supporting human landing site selection activities and ongoing architecture studies for future human surface systems

What do we need to know about Water ISRU Feedstocks?

Overview of Mars Water ISRU Planning (M-WIP) Study Results

The ranked value of information for assessing potential for engineering viability

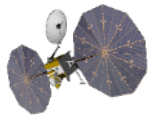




CASE	#1	#2	#3
A1 (Ice+open pit)	Thickness of overburden	Mechanical properties of overburden	Mechanical consistency of ore deposit
A2 (Ice+subsurface)	Mechanical consistency of ore deposit	*Thickness of overburden*	*Mechanical properties of overburden*
B (hydrated sulfate)	2D geometry/size of ore deposit	Mechanical consistency of ore deposit	Distance to processing plant
C (clay)	2D geometry/size of ore deposit	Mechanical consistency of ore deposit	Distance to processing plant
D (regolith)	Water concentration of ore deposit	Mechanical consistency of ore deposit	Chemical properties of ore deposit

Source: M-WIP (2016)

Purple: Data can be measured from orbit

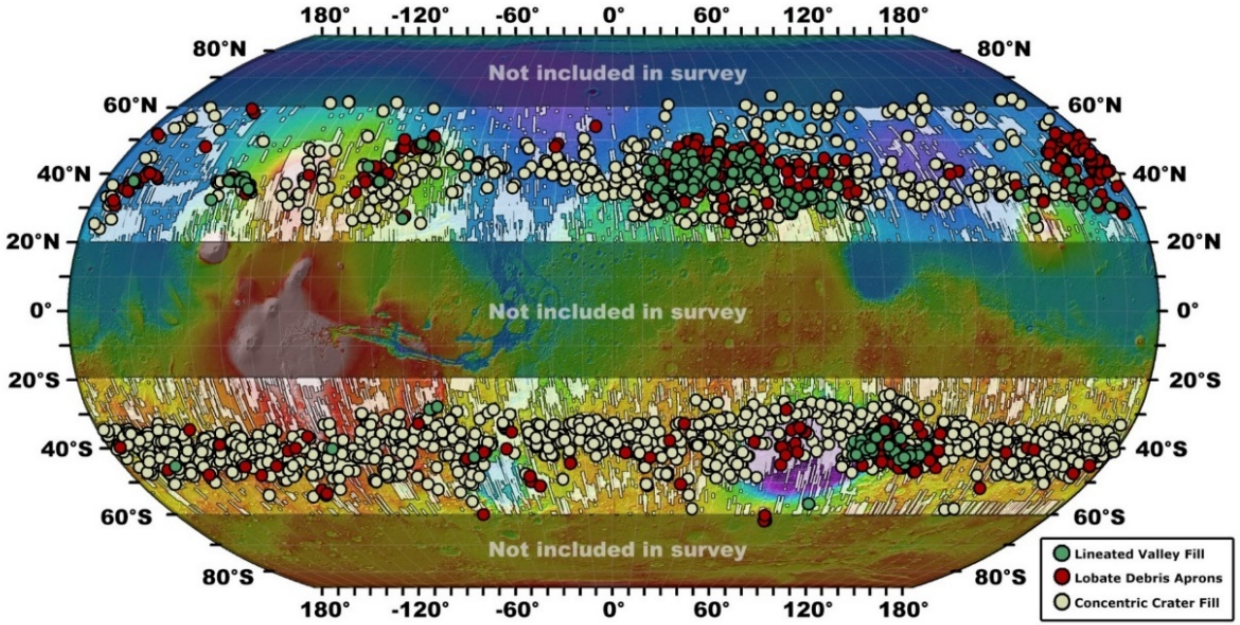


Green: Data needs to be measured on the ground, *in situ*

Previous State of the Art in Water Mapping

Subsurface Ice

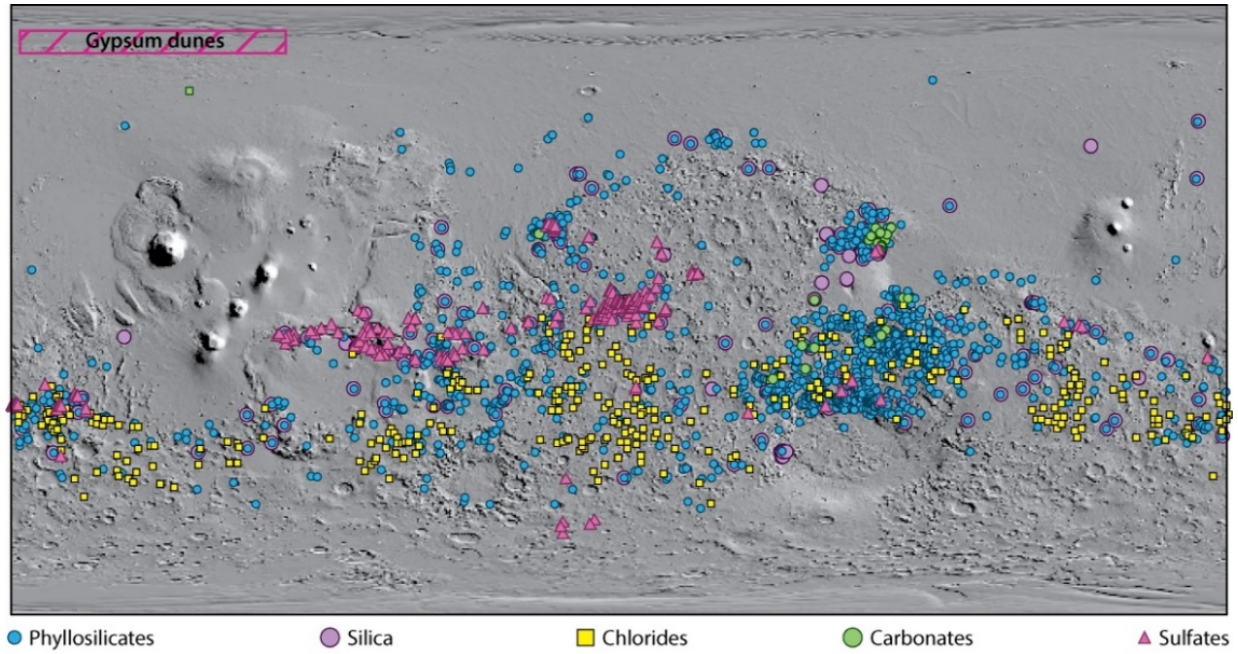
Survey of locations with geomorphological features that are indicative of subsurface ice



From: Dickson et al., 2012

Hydrated Minerals

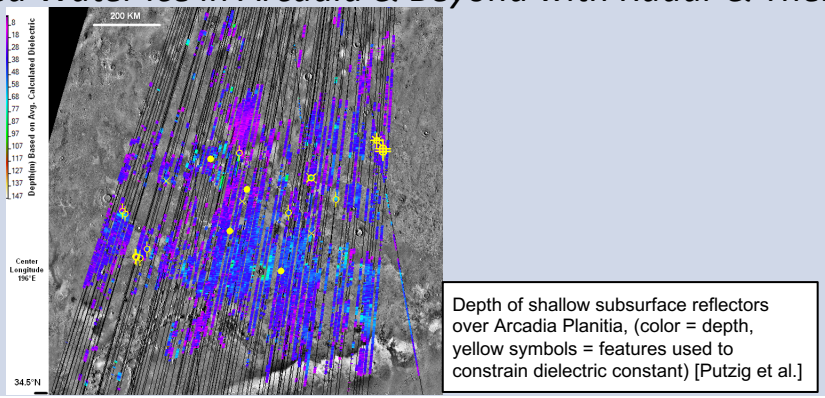
Survey of detections of spectral signatures of major classes of hydrated minerals



From Ehlmann and Edwards (2014)

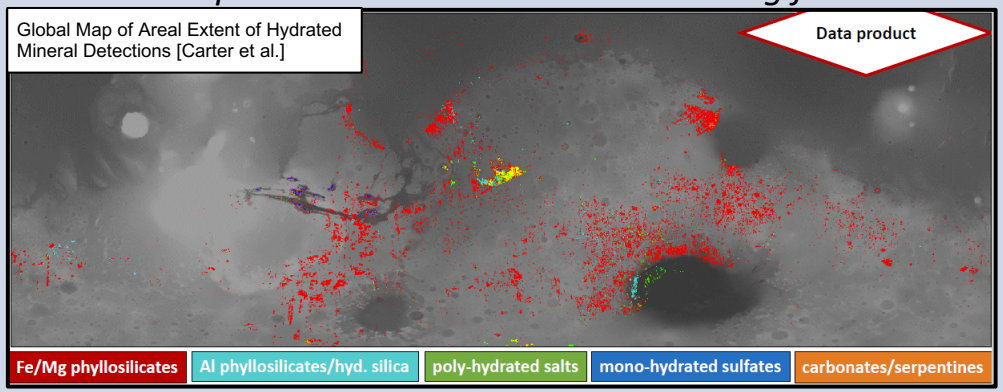
Mars Water Mapping Project Teams

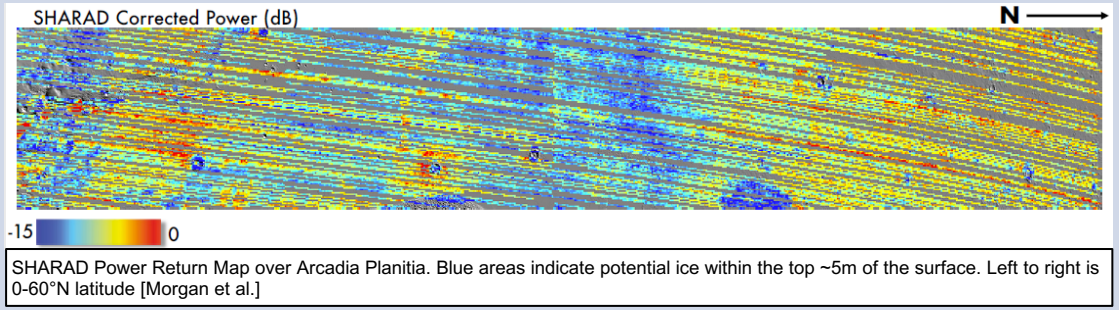
	Task A – Subsurface Ice Mapping	Task B – Hydrated Minerals Mapping
Team 1	**Putzig et al. (PSI)** *Mapping Buried Water Ice in Arcadia & Beyond with Radar & Thermal Data*	**Carter et al. (Paris-Sud Univ.)** *A Global Aqueous Mineral Abundance Catalog for Mars*
Team 2	**Morgan et al. (PSI)** *Local Subsurface Ice Mapping Through the Integration of SHARAD Derived Data Products with Other Datasets*	**Seelos et al. (APL)** *CRISM-Derived Global Map of Hydrated Mineral Bearing Units*



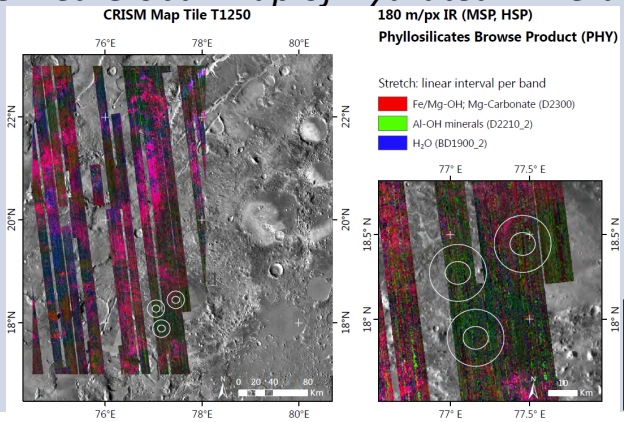
Depth of shallow subsurface reflectors over Arcadia Planitia, (color = depth, yellow symbols = features used to constrain dielectric constant) [Putzig et al.]

Merged into a Joint Project in August 2018





SHARAD Power Return Map over Arcadia Planitia. Blue areas indicate potential ice within the top ~5m of the surface. Left to right is 0-60°N latitude [Morgan et al.]



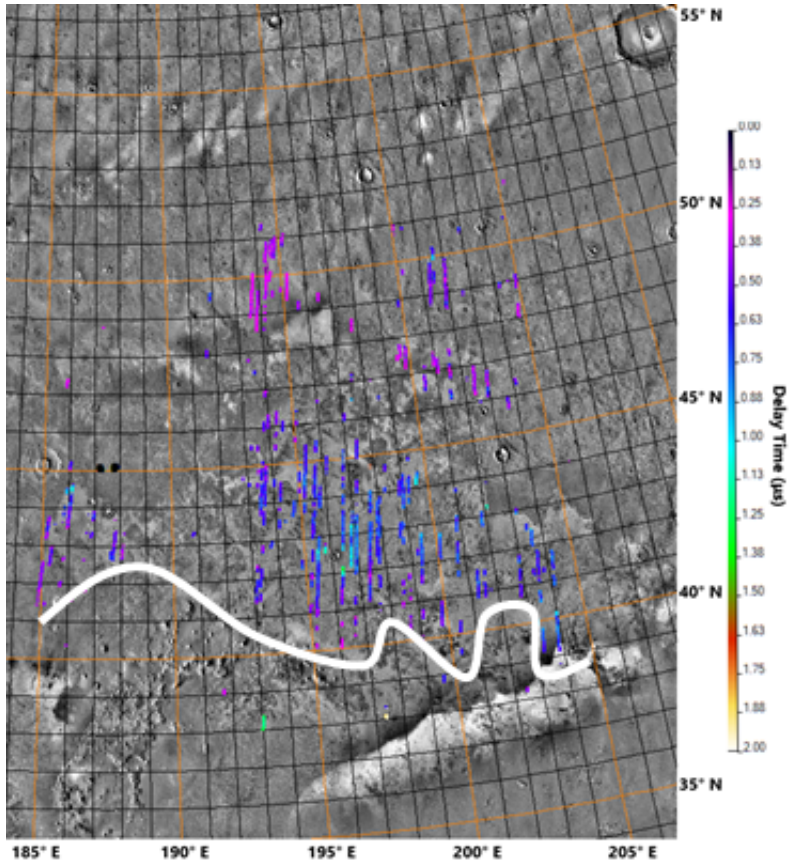
Map of two types of hydrated minerals and bound water over the Mars 2020 Nili Site Candidates [Seelos et al.]

Subsurface Ice-Mapping Preliminary Results (1/2)

A pilot study performed by the SWIM team over the Arcadia Planitia region improved the previous state of the art by:

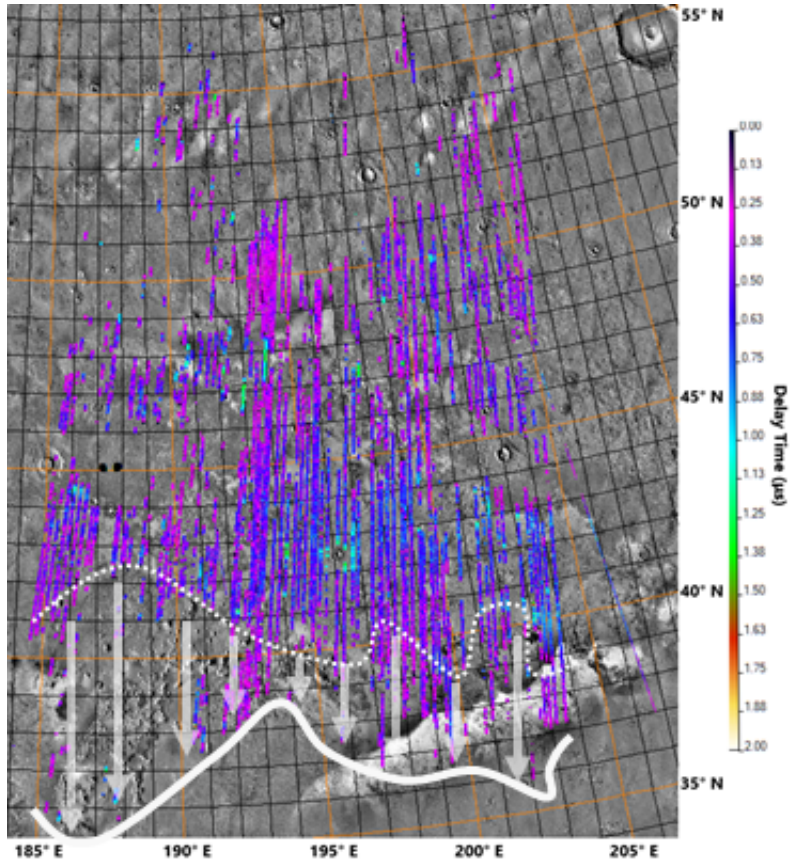
1. Extending reflector mapping coverage over region
2. Detecting more equatorward ice at ~35.6°N (compared to ~39°N previously)
   - Eases thermal design requirements landed ice exploration missions
3. Incorporating 19 additional topographic features to better refine the dielectric constant and hence estimate of material composition
   - Updated results indicate a larger fraction of non-ice material in the subsurface

Previous state of the art over Arcadia Planitia: Bramson et al. 2015



SWIM Project:

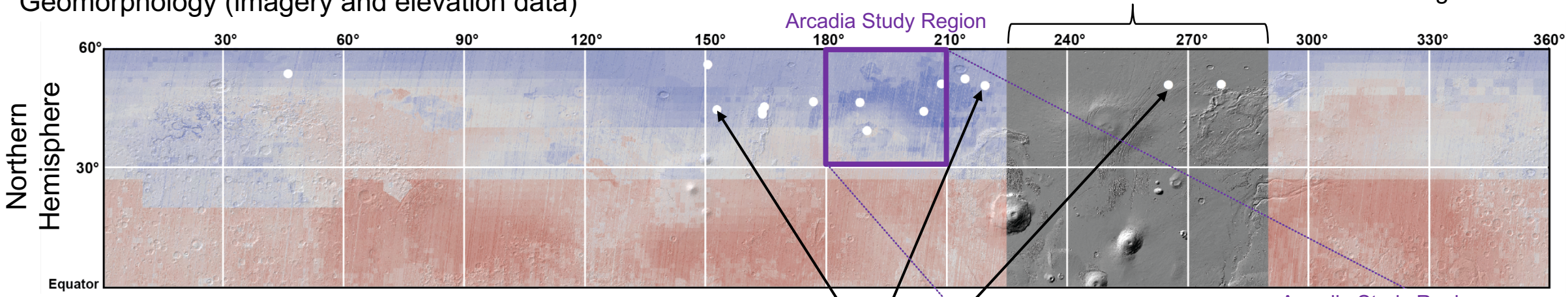
- Increased coverage
- Refined dielectric constants (material composition)
- More-equatorward detections



Subsurface Ice-Mapping Preliminary Results (2/2)

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

Region not mapped due to high elevation (not landable by a human class lander and hence not a human landing site candidate)

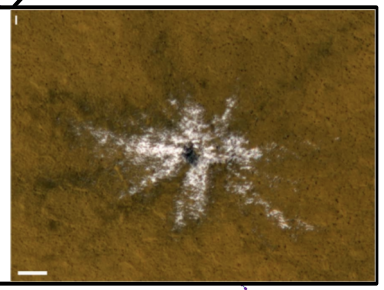


Ice Consistency
(0-100m from Surface)

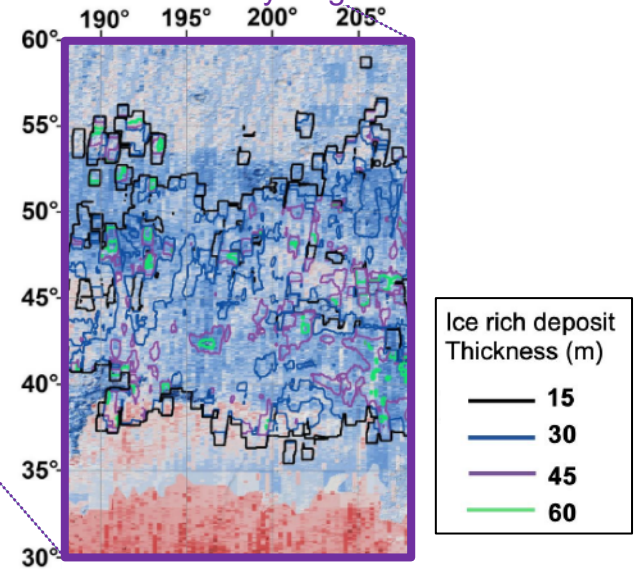
Multiple datasets show indications of ice within 0-100m of surface

Multiple datasets show indications of no ice within 0-100m of surface

White dots = Fresh ice exposing impacts mapped by Dundas et al. [2014] showing good agreement between this map and observed data



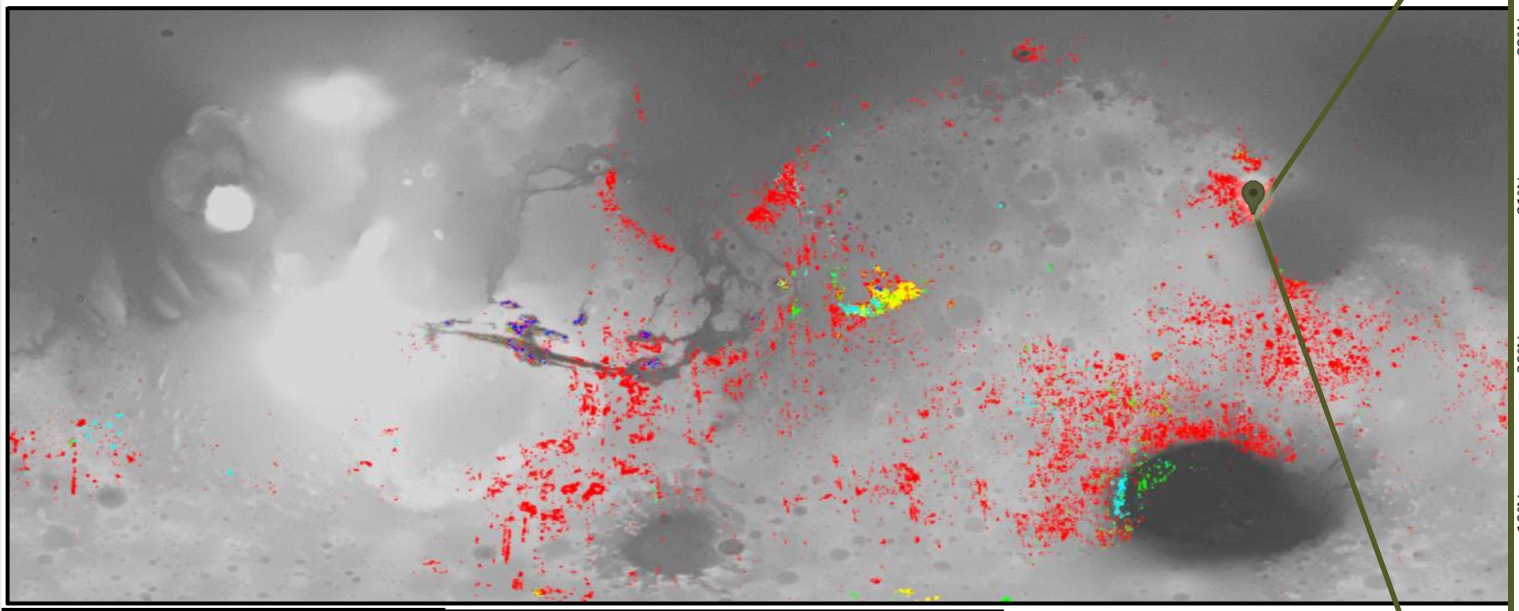
Arcadia Study Region



Map of boundaries of thickness of ice-rich deposits over the Arcadia study region, indicating a subsurface ice-rich deposit of 15-60m thickness throughout the region

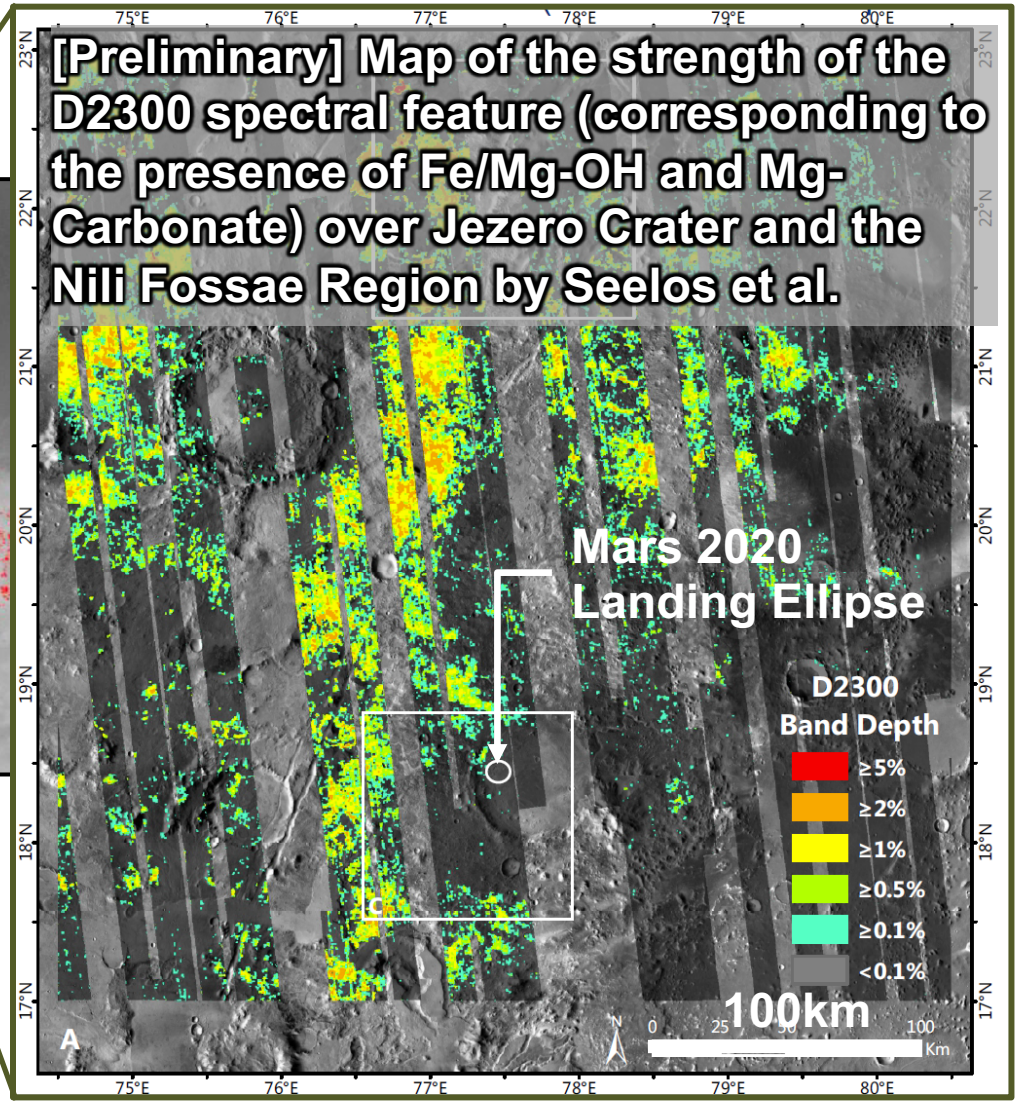
Hydrated Minerals Mapping Preliminary Results

[Preliminary] Global map of mineral detections compiled from the entire OMEGA dataset by Carter et al.



Fe/Mg phyllosilicates | Al phyllosilicates/hyd. silica | poly-hydrated salts

mono-hydrated sulfates | carbonates/serpentines | Sulfates + clays



Next Steps

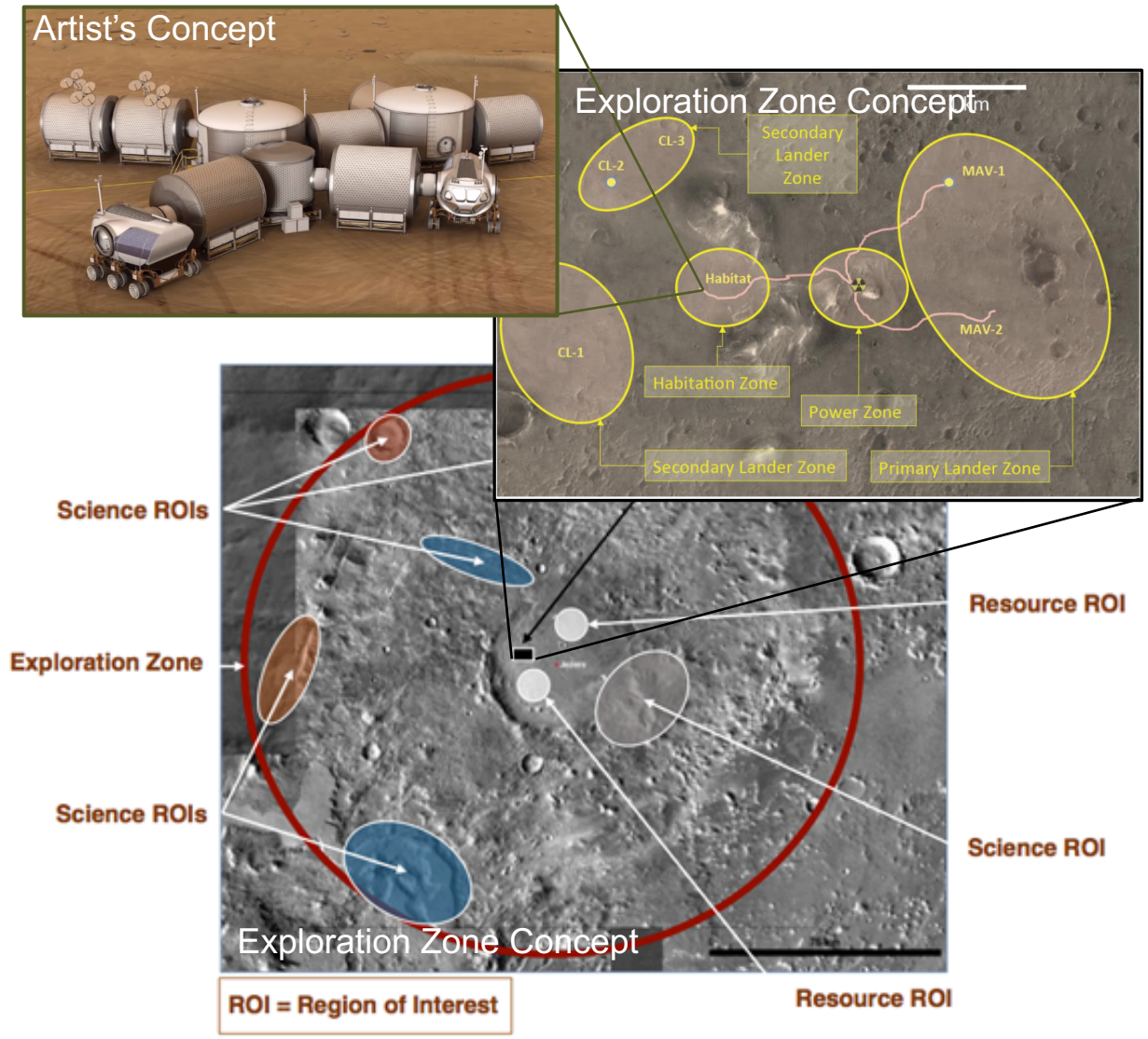
- Northern Hemisphere Subsurface Ice Maps and materials available at: https://swim.psi.edu
  - Currently evaluating potential extension activities to this project that will increase coverage to the Southern Hemisphere and incorporate additional, improved mapping techniques
- Global Hydrated Minerals Maps to be publicly released by mid-2019
- Future studies based on new knowledge revealed by these water mapping projects are currently being considered. Examples of possible follow-on studies/activities include:
  - A potential update to the Mars Water ISRU Planning (M-WIP) Study to better characterize the operational complexity of ISRU equipment required to extract water from feedstocks identified by these maps
  - A potential second Mars human landing site selection workshop to solicit feedback from the broader community on suitable landing sites given the new insights provided by these water maps

Thank You!

Backup

Exploration Zone – Working Definition

- 100km radius site at latitude band: ±50°
- Contains:
  - **Habitation Site**: Flat, stable terrain for emplacement of infrastructure, located ≤5km from landing site location
  - **Landing Site(s):** Flat, stable terrain, low rockiness, clear over length scales greater than landing ellipse
  - **Resource Regions of Interest**
    - One or more potential near-surface (≤3m) water resource feedstocks in a form that is minable by highly automated systems, and located within ~1-3km of ISRU processing and power infrastructure. Total extractable water should be ~100MT (supports ~5 missions)
    - Show potential for minable metal/silicon resources, mainly Fe, Al, and Si, located within ~1-2m of the surface
  - **Science Regions of Interest**
    - Related to Astrobiology, Atmospheric Science, and Geoscience

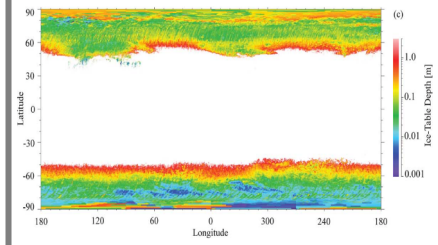


Previous Methods used to Detect Martian Ice

1960-1990s

Theory + Thermal (TES) data predicts likely ice in high (>50°) latitudes of Mars

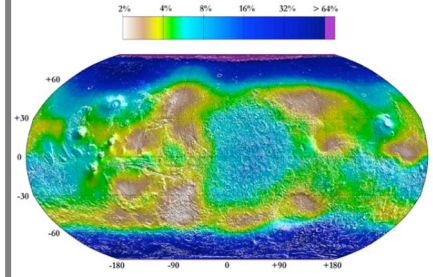
Detection Depth:
Top mm-cm



Early 2000s

Neutron Spectrometer (MONS) data finds clear indications of hydrogen in the form of water ice in the same regions

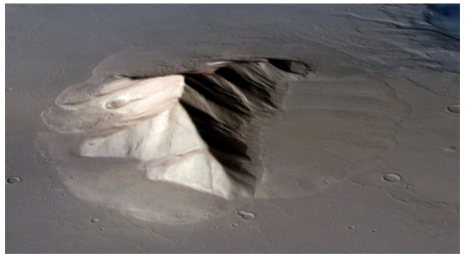
Detection Depth:
Top ~1m



Since Early 2000s

Geomorphological analysis of glacial and non-glacial features captured by high resolution imagers HRSC and HiRISE show evidence of ice in the mid-latitudes

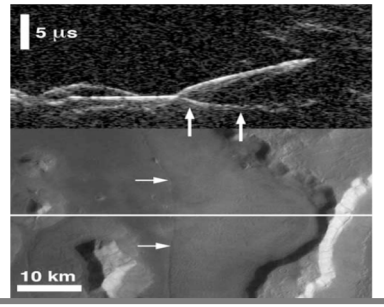
Detection Depth:
Top 1-100s meters



Since 2008

Shallow Radar (SHARAD) Time Delay Data detects subsurface water ice layers over high latitude glacial features and some mid-latitude non-glacial features

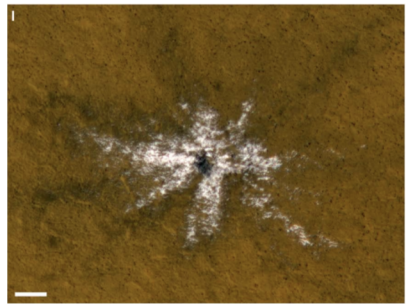
Detection Depth:
~20 to 100s meters detection of base of subsurface reflector



Since 2009

High Resolution Images (HiRISE) detect fresh ice-exposing craters, sometimes at lower latitudes

Detection Depth:
Top ~10m



Subsurface Water Ice Mapping (SWIM) Project

Comprehensive effort to map subsurface ice on Mars by:

- Improving previous mapping techniques used to detect ice across depths of millimeters to 100 meters
- Contributing three new ice detection techniques
  - Measuring ***SHARAD surface power return*** to infer ice presence within the top 5m
  - State-of-the-art ***super-resolution processing*** techniques that increase data resolution of radar data to a level that can potentially resolve the top of the ice layer
  - The ***"split-chirp" sub-band processing*** technique that measures material loss properties, thereby constraining bulk composition
- Extending coverage of existing mapping techniques to cover the entire Northern Hemisphere of Mars
- Combining results from all ice detection methods into a single measure of "ice consistency" over each pixel of an integrated map