INFORMING THE SELECTION OF THE FIRST HUMAN LANDING SITE ON MARS – AN OVERVIEW OF NASA'S MARS WATER MAPPING PROJECTS.

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Introduction: In 2015, NASA began a series of studies to better understand the requirements for selecting a landing site for the first campaign of human missions to Mars. As part of this process, the concept of an "Exploration Zone" (EZ) was introduced, a 100km radius region on Mars that would contain a research station, landing and launch zones, power generation facilities, and scientific and in-situ resource regions of interest. The research station located within this EZ was intended to host multiple visiting crews, who would each perform their own program of scientific investigation and technology development and maturation.

To gain further input into the ideal location of a Mars EZ, the first Mars Human Landing Site/ Exploration Zone Workshop was held in October 2015, to gather input from the broader science and engineering communities. This resulted in 47 EZ site proposals, and the consensus that a better understanding of the distribution of water across Mars in its various naturally occurring forms was needed. It was widely recognized that water is a key resource needed for sustaining human life on Mars – besides supporting crew health and well-being, it can act as a feedstock for in-situ propellant production, a coolant for habitat and spacesuit thermal control, a medium for radiation shielding, and a key ingredient for in-situ food production.

As a consequence of this realization, NASA funded a series of studies to better characterize the type of data needed to characterize different forms of indigenous Martian water, as well as the type of extraction and processing systems that would be needed to produce water of a quality sufficient for use by future human crews. With a basic understanding of these data requirements established, NASA then sought to understand how these data might be obtained from existing Mars orbital datasets. This resulted in the Mars Water Mapping Projects – an ongoing series of NASA-funded studies aimed at fusing multiple existing orbital datasets to develop the current best possible global maps of Martian subsurface ice and hydrated minerals.

This paper presents an overview and status of the Mars Water Mapping Projects, and their context within NASA's broader Mars Human Landing Site Study.

Project Development: Following the October 2015 Mars Human Landing Site Workshop, NASA commissioned the Mars Water ISRU Planning (M-WIP) [1] and the Mining Water Ice on Mars [2] studies. These studies were motivated by the insight that defining the parameters by which water is to be searched and mapped is strongly dependent on the capability of the mining and processing technologies available to extract this water. The definition of these technologies themselves is also dependent on the natural state in which water might appear on Mars, as well as the rate at which water is needed. There is thus a three-way coupling between the type of water that is to be mapped, the technologies needed to extract this water, and the expected usage rate of this water. These studies aimed to better understand this relationship for different types of water on Mars. A key result from these studies was the identification and prioritization of the major types of data needed to characterize various forms of indigenous Martian water. Table 1 summarizes this result, indicating that most of the high-priority data needed can be obtained from orbital datasets.

Table 1: Highest Priority Measurements for Characterizing Major Types of Indigenous Martian Water (blue cells correspond to data that can be obtained from orbit, while green cells require in situ data) [1]

Type	#1	#2	#3
Ice and open pit	Thickness of overburden	Mechanical properties of overburden	Mechanical consistency of ore deposit
Ice and sub-surface	Mechanical consistency of ore deposit	*Thickness of overburden*	*Mechanical properties of overburden*
Hydrated sulfate	2D geometry/size of ore deposit	Mechanical consistency of ore deposit	Distance to processing plant

Based on this result, a workshop was held in conjunction with the 2016 AGU Fall Meeting. This workshop brought together a wide cross-section of experts from the Mars science and engineering communities to discuss various options in which existing Mars orbital datasets could be combined to yield new insights into the mapping of water on Mars. This resulted in the formulation of two types of mapping tasks. These were:

- Task A, which aims to develop techniques to map potential locations of subsurface ice within depths of 0-20m beneath the Martian surface, over a single 5-10° wide longitudinal swath from 0° to 60°N latitude. In addition, this task also involves the analysis of the relationship between surface properties (e.g. rockiness, albedo, etc.) to the depth and concentration of shallow ice, and how this relationship might affect the nature of the gradational boundary from regions of continuous ice, to discontinuous ice, through to regions of no ice. This project is planned to be experimental in nature, with the resultant map intended to be a proof-of-concept for the future potential development of a global map

- Task B, which requests the development of algorithms to partially automate the processing of existing orbiter hydrated mineral detections (i.e. spectral data) to determine the type of mineral detected and to estimate its concentration. Following this, the developed algorithms will be applied on a global scale to develop a global map of all existing near-surface hydrated mineral detections on Mars

These tasks were publicized in a Request for Proposals (RFP) released by NASA in early June 2017. Selections were made at the end of 2017 and in early 2018, and the projects commenced in March 2018.

Overview of Selected Projects: In total, four teams were selected as a result of the RFP process – two to complete each mapping task. The intent of selecting two teams per task was to provide an avenue for cross-checking each team's results, thereby increasing confidence in the the overall products. This section summarizes the approaches adopted by each team for their mapping project.

Task A (Subsurface Ice) Team 1 – Nathaniel Putzig et al. (PSI). Putzig's team is using SHARAD, TES, THEMIS, and other data to produce maps of subsurface ice and associated surface properties. They will apply advanced processing originally developed for Cassini RADAR to map all SHARAD subsurface-ice detections across the Arcadia swath, characterize physical heterogeneity (lateral mixtures, shallow layering) of regions with potential near-surface ice using maps of seasonal daytime and nighttime apparent thermal inertia (ATI) generated from TES data, and combine the latter with ATI maps generated from THEMIS data for improved lateral resolution in select areas. The combination of these datasets has the potential to detect ice within ~3 to 20 m of the surface, a depth not resolved with conventional SHARAD processing.

Task A (Subsurface Ice) Team 2 – Gareth Morgan (PSI). Dr. Morgan will be developing a new experimental technique to detect subsurface ice, based on isolating Fresnel reflectivity measurements collected by SHARAD and MARSIS by correcting for surface roughness. Supporting this detection technique will be HiRISE, CTX, and THEMIS day- and night-time data. Moreover, to build confidence in the detection capabilities of this technique, it will be validated against in-situ data taken by the Phoenix lander at its Green Valley landing site.

Task B (Hydrated Minerals) Team 1 – John Carter et al. (Paris Sud University). John Carter et al. will build upon their existing MOCCAS project, which aimed to systematically map all hydrated mineral detections on Mars, using a combination of CRISM and OMEGA datasets. For this project, they will extend the capabilities of the tools developed in this previous project to develop a global (60°S to 60°N latitude), spectrally discriminated catalog of all hydrated mineral detections. In addition, they will use radiative transfer modeling to derive the modal mineralogy for all hydrated mineral deposits identified on Mars. The resolution of their global map is expected to be approximately 300m/pixel.

Task B (Hydrated Minerals) Team 2 – Frank Seelos et al. (APL). Dr. Seelos and his team will build upon previously developed CRISM multispectral survey data processing procedures to construct a global map of the areal extent of hydrated mineral deposits and their associated spectral parameters. The data processing workflow includes corrections for atmospheric effects which moderate the appearance of spectral features diagnostic of hydrated surface mineralogy, and the radiometric reconciliation of the constituent observations to ensure that the spectral parameterizations are self-consistent throughout the data set. In addition, for each significant hydrated mineral detection, the team will record spectral parameter distributions to quantify the detection uncertainty and provide reference spectra that sample the cleanest hydrated mineral exposures.

Future Outlook: Results and mapping products generated from these projects are expected by March 2019. It is hoped that these will provide sufficient data to constrain the latitude band by which the first EZ site might be selected. In addition to narrowing the range of options for EZ site selection, this constraint has significant implications on the mission system architecture, such as driving the selection of the power system, defining thermal requirements, and driving the requirements of the descent and ascent vehicle that transports crew to and from a deep space transit vehicle waiting in Martian orbit. The resultant mapping products are planned to be distributed across the broader community, where they will support future studies that will form the basis of a second Mars Human Landing Site Selection workshop, currently planned for mid to late 2019.

References: [1] Abbud-Madrid, A. et al. (2016), Report of the Mars Water In-Situ Resource Utilization (ISRU) Planning (M-WIP) Study; 90 p, posted April, 2016 at http://mepag.nasa.gov/reports.cfm. [2] Hoffman, S. et al. (2016), Mining" Water Ice on Mars; 88 p, NASA Internal Report