INTERNATIONAL MARS ICE MAPPER MISSION: RECONNAISSANCE FOR THE HUMAN EXPLORATION OF MARS AND DECADAL-LEVEL SCIENCE. D. M. H. Baker[1], T. Haltigin[2], R. Davis[3], R. Mugnuolo[4], T. Usui[5], M. Kelley[3], M. A. Viotti[6]. [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771 (david.m.hollibaughbaker@nasa.gov), [2]Canadian Space Agency, [3]NASA Headquarters, [4]Agenzia Spatiale Italiana, [5]Japan Aerospace Exploration Agency, [6]Jet Propulsion Laboratory, California Institute of Technology.

Introduction: The International Mars Ice Mapper (I-MIM) mission concept is being developed by partner Agencies [Agenzia Spatiale Italiana (ASI), the Canadian Space Agency (CSA), the Japan Aerospace Exploration Agency (JAXA), and National Aeronautics and Space Administration (NASA)]. Its primary goal is to characterize adequate, accessible water-ice in the uppermost 0-10 m to meet future human exploration goals for Mars (*e.g.*, accessing the ice to understand the climate/geological history of Mars, identification of astrobiological targets, as well as *in situ* resource utilization) and to address high-priority science objectives associated with the planet's geology, climate, and habitability.

The anchor payload would be a polarimetric (hybrid-compact pol or "HCP") L-band (930 MHz) Synthetic Aperture Radar (SAR) provided by CSA that would operate in side-looking imaging and nadir sounding SAR modes at high RF bandwidth. Possible secondary payloads (e.g., visible wavelength camera, atmosphere/space weather sensors) under consideration may augment the baseline measurements of the SAR to address the mission objectives.

In September 2022, a Final Report of the I-MIM Measurement Definition Team (MDT) was released [1] describing how well the anchor payload meets the mission objectives and potential augmentations to enhance these measurements and increase scientific return. Here, we summarize the I-MIM mission objectives and measurements. We then present further details on the MDT findings, outline how the mission would provide significant advances toward Decadal Survey priority science questions, and demonstrate its fundamental importance in preparation for the human exploration of Mars.

Reconnaissance Objectives: The Agency partners have established three mission Reconnaissance Objectives (RO), where reconnaissance is defined as "what we need to know before humans go," as enabled by robotic spacecraft that address critical knowledge gaps related to the future human exploration of Mars:

RO-1: Location and Extent of Water Ice: Inventory the spatial distribution and depth-to-ice of water-ice resources in the near surface layer (top 0-10 m).

RO-2: Accessibility of Water Ice: Detect, characterize, and map surface/near-surface geotechnical properties (roughness, compactness) to provide a fundamental characterization of the accessibility of water-ice resources (e.g., engineering-level evaluation of the overburden for drilling/ISRU and the structural stability of the terrain for landing/launch, construction, trafficability, and other human-related surface operations).

RO-3: Candidate Human Landing Site Assessment: Provide detailed high-resolution maps of targeted areas of interest that: (1) have adequate (RO-1) and accessible (RO-2) water ice, (2) are as equatorward as possible, and (3) model the potential for human-led surface science and human-class landing and ascent, ISRU, and civil engineering.

Each of these Reconnaissance Objectives will drive measurement requirements within a defined Reconnaissance Zone (RZ). The RZ is the mid-to-low latitude, low elevation, terrain-favorable areas on Mars where human exploration is likely, defined by human-led science potential, in-situ resources, engineering constraints, civil engineering, and other factors. Ongoing related studies, such as the Subsurface Water Ice Mapping (SWIM) at Mars project, are working to improve definition and characterization of the RZ for subsurface ice deposits [2].

Maximizing Return on Investments: In addition to the primary Reconnaissance Goals, the Supplemental Value Goal of I-MIM is to provide high-value science opportunities and mission-support capabilities that serve reconnaissance, science, and engineering. On the basis of this goal, the Agency partners have established Supplemental Science Objectives (SSO) that maximize the use of the SAR anchor payload and Mission Support Objectives (MSO) that further maximize potential returns on investments:

SSO-1: Augmented Water Ice Inventory: Use the anchor payload (HCP SAR) to extend the detection, mapping, and inventory of shallow water ice to a near-global scale tied to priority climate/geology goals.

SSO-2: Reconnaissance/Science Investigations of Opportunity: Enable reconnaissance and science observations of opportunity aligned with high-priority, international, and multidisciplinary community goals (e.g., Martian climatology and geology, the volatile history of Mars, habitability, search for geologic structures for radiation protection, etc.).

MSO-1: Complementary Payloads for Reconnaissance, Science, and Engineering: Consider additional payloads, rideshares, extended operations, and leverage of capabilities for future human and robotic Mars missions.

L-Band SAR Measurements to Meet Reconnaissance and Supplemental Science Objectives: I-MIM's L-band polarimetric SAR instrument was chosen on the basis of over 20 years of studies and proposals by the science community and Agency partners that support the desire for an orbital active microwave instrument to interrogate the martian surface and subsurface [e.g., 3]. The baseline design choices for the L-band SAR were made to optimize the retrieval of the properties of accessible subsurface water ice deposits and its overburden within the top 10 m.

The L-band center frequency at 930 MHz allows interrogation of the subsurface to >6 m depth with vertical resolution (in sounder mode) of < 1 m depending on the physical properties of top-layer and subsurface materials. The hybrid, compact polarimetric design allows for the determination of the four essential Stokes parameters for distinguishing between scattering regimes and to measure the polarimetric signatures of subsurface ice (e.g., the coherent backscatter opposition effect or CBOE for thick ice layers).

The different SAR imaging and nadir sounding modes provide complementary measurements to further characterize subsurface electrical and physical properties. For example, the sounding mode would be able to identify the vertical and horizontal extent of subsurface interfaces due to layers of overburden and ice in targeted regions that may be suggested by a strong polarimetric response in the side-looking SAR imaging products.

Measurement Definition Team: A Measurement Definition Team (MDT)—competitively assembled in 2021 and representing 10 countries and diversity across gender, career stage, and discipline—was tasked by the Agency partners to: (1) define the core measurements and payload required to achieve the ROs; (2) suggest augmentations in the form of science investigations and hardware that may be included, and; (3) develop a model concept of operations based on the findings of Tasks 1 and 2.

As described in its Final Report [1], the MDT demonstrated that the baseline mission, consisting of a single instrument (a Synthetic Aperture Radar / sounder centered at 930 MHz), would largely satisfy all of the ROs and would provide ample opportunity to conduct high-priority science investigations. Should complementary payloads (e.g., lower frequency radar sounder and/or high-resolution stereo-imager) be included, the reconnaissance and science return of the mission would be greatly augmented. The MDT lists the following summary of findings [1]:

- An I-MIM mission will provide a new way to observe Mars, and will acquire essential information to enable human exploration.
- The mission's capabilities provide an opportunity to accomplish unique new science covering a broad range of international science priorities in addition to the primary goal of reconnaissance for human missions.
- Additional instruments could expand the capabilities of I-MIM to undertake high-priority science investigations and fill any gaps in meeting reconnaissance objectives.
- The primary reconnaissance goal can be accomplished in a nominal mission lasting one Mars year. The reconnaissance and science objectives would greatly benefit from an enhancement of data downlink capabilities.
- The Agency partners should continue to pursue development of the I-MIM mission as a key element in the future exploration of Mars.

Traceability to Decadal Survey Priorities: The results of the I-MIIM MDT report respond clearly to the recommendations of the Planetary Science and Astrobiology Decadal Survey 2023–2032 [4]:

"The development of the goals and measurement requirements for missions addressing both science and human exploration interests should be developed to meet the objectives of both communities," (p. 22-12) and;

"NASA should consider an ice-mapping mission that prepares for [In Situ Resource Utilization] by humans and addresses the priority climate science questions at Mars related to near-surface ice." (p. 22-12)

Further, the I-MIM mission would provide foundational and complementary data products needed for a Mars Life Explorer (MLE) medium-class mission that was prioritized in the Decadal Survey. Crucially, I-MIM would help to address the issue of an aging orbital infrastructure at Mars to enable the next generation of decadal-level scientific investigations of the planet.

References: [1] I-MIM MDT Final Report (2022) 239 pp., online: https://science.nasa.gov/researchers/ice-mapper-measurement-definition-team. [2] Morgan, G.A. et al. (2021) *Nature Astronomy* 5, 230–236. [3] MEPAG NEX-SAG Report (2015), http://mepag.nasa.gov/reports.cfm (see also BAAS 43, March 2021 updated version of NEX-SAG: https://doi.org/10.3847/25c2cfeb.da7b0e6a). [4] National Academies of Sciences, Engineering, and Medicine (2022) Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032. https://doi.org/10.17226/26522.