STRATEGIES FOR PROSPECTING AND EXTRACTING WATER ON MARS FOR LONG-TERM HUMAN EXPLORATION.

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Changing the Paradigm of Human Exploration: Since the Apollo era, human spaceflight missions have operated under a paradigm of supplying all required consumable resources from Earth. Materials such as propellant, oxygen, and water have traditionally been shipped along with crew and other cargo to destinations such as the Moon and the International Space Station. However, the use of local resources to produce consumables that the crew needs to carry out the mission, known as in-situ resource utilization or ISRU, can be an enabling factor for human exploration missions beyond low-Earth orbit. ISRU can help reduce the overall consumable mass sent from Earth to support human crews, significantly reducing mission cost and risk while enabling long-term or permanent habitation of other solar system bodies.

Water on Mars: The horizon goal for human space exploration is a crewed mission to the surface of Mars in the 2030s [1]. Sending humans to the Martian surface will enable real-time sample acquisition and analysis using sophisticated instruments, allowing for an adaptable exploration campaign that can dramatically increase science return compared to orbiter and robotic lander missions. Current studies conducted by NASA as part of the Evolvable Mars Campaign are considering a 500-day mission on the Martian surface [2]. The use of ISRU will be vital to support the crew in long-duration mission scenarios such as these and to enable permanent settlement.

One of the most critical resources for a human crew is water. Besides its use for human consumption, water can be used to produce oxygen for the crew as well as propellant for a Mars ascent vehicle and other surface systems. It can also be used for crew hygiene, food production, and radiation shielding. Because of the immense versatility of water as a resource, the extraction and use of water from the surface of Mars can play a key role in the development of human mission architectures to the surface of the red planet.

Current data obtained from orbital spacecraft and landed rovers has indicated the presence of a significant quantity of water at or beneath the Martian surface, as seen in Figure 1 [3]. Water on Mars is expected to be present in various forms, including subsurface glaciers, hydrated minerals, and trapped in regolith [4].

Goal and Scope of Work: To date, work has been performed by NASA at a conceptual level to classify the water reserves present on Mars and to design systems to prospect for and extract water [4].

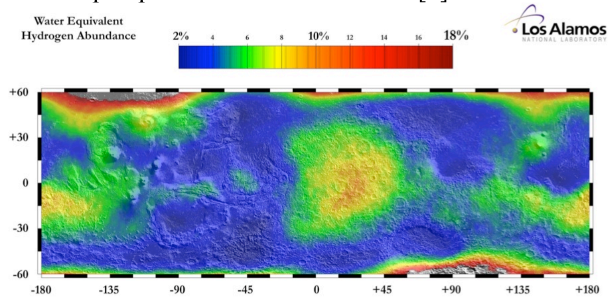

Figure 1: Water Equivalent Hydrogen Abundances on Mars [3].

The goal of the work proposed in this abstract is to expand upon the results of previous studies. We aim to develop a specific set of criteria to classify water reserves on Mars, and to design water prospecting and extraction systems for various human landing sites using a requirements-driven framework. Specific steps to achieve this goal are as follows:

- Identify a representative amount of water needed for human missions to the Martian surface
- Study analog infrastructures for prospecting and extracting resources on Earth, including the mining and petroleum industries
- Classify water reserves and quantify environmental characteristics of potential human landing sites and exploration zones
- Design water prospecting and extraction systems based on the water reserves and environmental characteristics of each site

Each of these steps is explained in greater detail in the following sections.

Water Usage: Water can be used by a crew of astronauts in several different ways, including: crew hydration, food and beverage rehydration, personal hygiene, medical usage, EVA usage, oxygen production, radiation shielding for both a surface habitat and nuclear fission power systems, and propellant production. To gain an understanding of the mass of water required for a human Mars mission, parametric models of each of these usage types will be developed based on the number of crew and duration of the mission. A minimum and maximum use case will be identified to constrain the quantity of water needed.

Water usage can also be classified to better understand its impacts on mission architectures. We propose to classify types of water usage as enabling vs. enhancing, fixed vs. variable, and recyclable vs. non-recyclable. A metric of marginal water per capita will be produced, identifying how much additional water is needed to support one additional crew member.

Earth Analogs: All of the materials we use in our daily lives can be considered the end result of 'ISRU' on Earth. In particular, the mining and petroleum industries have employed and refined methods of identifying, classifying, and extracting resource reserves for centuries. Studying how these industries classify resource reserves and investigate and extract mineral ore and oil deposits can provide valuable insight into how such a process might be carried out on another planet such as Mars.

Reserves at Landing Sites and Exploration Zones: The first human landing site workshop identified nearly 50 potential landing sites and exploration zones that could be selected for the first human missions to Mars, shown in Figure 2 [5]. In order to accurately design surface systems to prospect for and extract water at these locations, the water reserves at each site must be classified and the environmental factors of each site must be quantified. Water reserves at each site will be classified according to a specific set of criteria based on resource availability (demonstrated, inferred, speculative) and feedstock type (glaciers, hydrated minerals, regolith). Environmental characteristics including average slope, rock distribution, temperature range, elevation, and availability of sunlight, will be quantified for each site.

Prospecting and Extraction Systems: A detailed understanding of the water reserves and environmental characteristics of a landing site can help identify whether the site has the potential for water ISRU, and if additional prospecting is necessary to provide greater knowledge of available reserves. If a site contains sufficiently demonstrated reserves, this information can drive the design of optimal extraction and processing systems to minimize overall mass and power. Several systems will be designed to support water prospecting and extraction needs at selected landing sites. This will provide a more detailed, quantitative, and practical approach to planning human Mars exploration missions utilizing water ISRU.

References:

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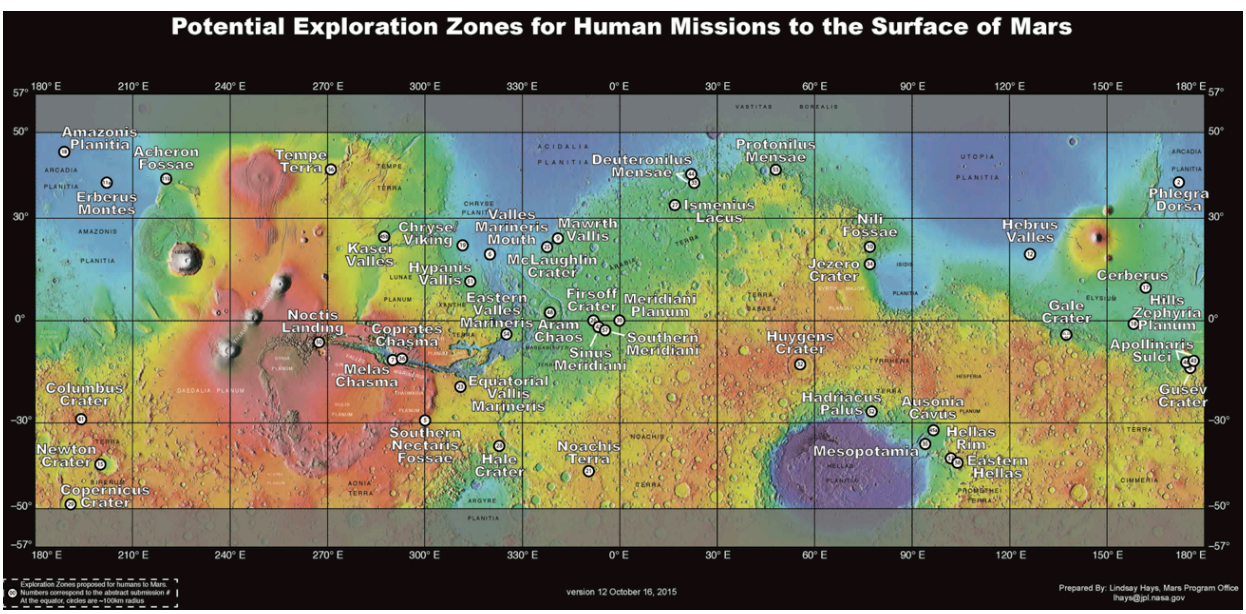

Figure 2: Proposed Landing Sites and Exploration Zones for Human Mars Missions [5].