Mars Sample Return Objectives Relevant to Future In-Situ Resource Utilization:. J. E. Kleinhenz[1], D.W. Beaty[2], D. Boucher[3], M. Dixon[4], P. B. Niles[5], R. M. Wheeler[6], and M. P. Zorzano[7], [1]NASA Glenn Research Center 21000 Brookpark Rd. Cleveland, OH 44135 julie.e.kleinhenz@nasa.gov, [2]NASA Jet Propulsion Laboratory, [3]Deltion Innovations, [4]University of Guelph, [5]NASA Johnson Space Center, [6]NASA Kennedy Space Center, and [7]Centro de Astrobiología (INTA-CSIC), and Luleå University of Technology.

Introduction: The goal of the International Mars Sample Return (MSR) Objective/Samples Team (iMOST) is to define the MSR objectives for the Mars 2020 mission, and identify the specific types of samples needed to meet those objectives. Seven top level objectives have been identified (Table.1). While most of the objectives address scientific topics, iMOST specifically addresses exploration goals in objective 6 and 7. Notably to this community is the latter, Objective 7; In-Situ Resource Utilization.

Mars Sample Return Proposed Objectives		
Objective	**Shorthand**	**Full Statement of Objective**
1	***Geological environment(s)***	Interpret in detail the primary geologic processes that formed and modified the pre-Amazonian geologic record.
2	***Life***	Assess and interpret the biological potential of Mars
3	***Geochronology***	Determine the evolutionary timeline of Mars, including calibrating the crater chronology time scale.
4	***Volatiles***	Constrain the inventory of martian volatiles as a function of geologic time, and determine the ways in which these volatiles have interacted with Mars as a geologic system.
5	***Planetary-scale geology***	Reconstruct the history of Mars as a planet, elucidating those processes that have affected the origin and modification of the crust, mantle and core
6	***Environmental hazards***	Understand and quantify the potential martian environmental hazards to future human exploration
7	***ISRU***	Evaluate the type and distribution of in-situ resources to support potential future Mars Exploration

Table 1: A list of the top level objects for Mars Sample Return as defined in the iMOST study.

Considerable recent planning has focused on the potential importance of Mars *in-situ* resources to support future human missions. While the atmospheric CO_2 provides a source of oxygen [1], the regolith itself offers other potential resources [2]. The most significant surface asset is water, which could be used for propellant generation [3], life support, habitat sustainment, and agriculture [4]. In regard to the latter, the regolith could also provide a source of nutrients to supplement terrestrial fertilizers and/or act as a substrate to buffer plant roots. Local material could also be used as feedstock for construction, including for structures, roads, and additive manufacturing [5]. Native salts (e.g. perchlorates or chlorides) in the Martian regolith could be used as water absorbents for closed loop life support systems or for capture of the limited atmospheric water.

Any of these in-situ utilization processes require definition of the resources to influence equipment design and resource budgeting. Prospecting via orbital and landed surveys as well as technical demonstrations are necessary and sufficient for initial ISRU planning and technology development. However, sample return will play a certain role in supporting this planning, including ground-truthing of orbital surveys and providing a more comprehensive picture of the available resources and their properties. When considering long term human presence this information becomes more critical to site selection, architecture decisions, and hardware design. Likewise, detailed assays of a returned sample may identify other resources and/or utilization potential not yet considered.

ISRU Objectives: Four investigation strategies were identified to meet ISRU goals for a Mars sample return. These strategies are defined in Table 2. It is important to note that carrying out these strategies would not be enough to complete the objective of evaluating the potential for successful martian ISRU operations. Substantial in-situ exploration is also required. For example, sample analysis alone can give highly precise and accurate estimates of concentration/quality, but it cannot be used to estimate quantity. Thus, these strategies are necessary but not sufficient to complete the larger objective, at least for certain resources of interest.

Statements of Investigation Strategy	
Objective 7	
ISRU	Evaluate the type and distribution of in-situ resources to support potential future Mars Exploration
Invest. 7A	Determine the concentration, mineralogic basis, and variation of water in martian surface materials and identify associated chemical constituents that may negatively impact potential end-use processes of this water.
Invest. 7B	Characterize the physical and thermophysical properties of martian surface materials to influence the design of potential future ISRU surface systems and to develop high-fidelity simulant material for use in ISRU engineering test beds.
Invest. 7C	Indentify components in martian granular material that may be beneficial or detrimental to its use for in-situ agriculture.
Invest. 7D	Contingent on discovering significant concentrations of natural metallic resources, characterize the source materials to enable predictions of where and how such deposits may be concentrated on Mars.

Table 2: The investigation strategies defined under the iMOST ISRU objective. Each investigation also includes a list measurements and the set of samples needed to achieve them.

The first investigation,7A, addresses the primary surface resource of interest for Mars ISRU; water. Although the presence of subsurface ice deposits [6] is of great interest to ISRU, the current Mars 2020 landing sites are with 19°N of the equator, where ice is not present. Therefore the iMOST sample objectives do not encompass ice samples. The investigation strategies thus focus on hydrated near-surface material contained in regolith or rock. The amount and form of water in Mars surface material will heavily impact potential production processes. Thus the first measurement goal of 7A is to identify hydrated minerals, and their hydration state in both regolith and rock samples. The samples will be also used to characterize the water release profile with temperature and to identify the by-products released during that process. By-products of particular interest are chlorides and perchlorates which are a potential contaminants for water use (propellant production, life support), but are a potentially useful resource for closed loop life support applications.

The selection of technologies and techniques used to acquire and process the surface material will be highly dependent on the material properties themselves. Characterization of the physical and thermophysical properties of the surface material, as identified in investigation 7B, enables advanced model refinement to influence engineering design. Along with the information from 7A, this property information also allows for the generation of high fidelity simulant materials for use in hardware test programs. In addition to measuring these properties for both regolith and rock samples, investigation 7B also addresses potential construction applications for the surface material (building/shielding material, additive manufacturing) and calls out a 'desired' measurement of the fine, or dust, component of the regolith for filtration concerns.

The third ISRU investigation, 7C, addresses potential agricultural applications of the surface material. Performing a basic elemental analysis and more traditional "soils" type analyses on regolith samples would be invaluable for understanding the needs of future of Martian agriculture. Of particular interest for measurement are minerals that have high concentrations of fertilizer elements such as Nitrogen, Potassium, and Phosphorus. These could either be extracted from the regolith to augment earth substrates or as a basis for an agriculture soil itself. Identifying harmful compounds, particularly those that are water soluble, is also a critical measurement. These include transition metals such as Zinc, Copper as well as Sodium, and water soluble Aluminum.

The final ISRU objective is to identify and characterize high value metallic resources. The potential presence of ore deposits would be of value both for ISRU and economic considerations. However, this type of collection would be considered a 'sample of opportunity'; not specifically sought out, but if encountered should be considered worthy of a sample return. Note that a sample of this type would also necessitate information regarding the surrounding ore body. Ore-forming processes on Earth happen when certain elements are segregated from others, typically either by differential transport or precipitation mechanisms. Once these mechanisms are understood, it may be possible to predict the location, grade, and mechanical consistency of natural concentrations of such deposits.

Recommended Samples: When considering all the ISRU needs, we have identified five samples that would provide the relevant information. Three samples could be used to simultaneously fulfil ISRU investigation strategies 7A and 7B. These are 1) a "typical" surface sample, representative of abundant loose material, 2) a subsurface regolith sample from the same location that is isolated from diurnal heat cycling (thus may retain a higher water content), and 3) a core sample of sedimentary rock that displays the strongest signature of hydration in the landing zone. These samples are intended to bound a range water-bearing materials. Two additional samples that can fulfill the agriculture objective 7C are: 4) a sample of sand-sized basaltic dune material, and 5) a sample of bright fine-grained dune material. Earth based basaltic soils have proven fertile, making similar Mars material a good candidate. Meanwhile, the in-situ analysis of fine grained 'bright' material has shown signatures of promising nutrients such a nitrogen. An ore-rich 'sample of opportunity' to meet investigation 7D is listed as an optional, desired sample. An additional desired sample, listed in 7B, is an airborne dust sample for filtration concerns. This is not required since this information may be adequately obtained from other samples or instruments.

References:

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