THE RELEVANCE OF MARS SAMPLES TO PLANNING FOR POTENTIAL FUTURE IN-SITU RESOURCE UTILIZATION.

iMOST Team (J. Kleinhenz[1], D. W. Beaty, D. Boucher, M. Dixon, P. B. Niles, R. M. Wheeler, M. P. Zorzano, F. Altieri, Y. Amelin, E. Ammannito, M. Anand, L. G. Benning, J. L. Bishop, L. E. Borg, J. R. Brucato, H. Busemann, K. A. Campbell, B. L. Carrier, A. D. Czaja, V. Debaille, D. J. Des Marais, B. L. Ehlmann, J. D. Farmer, D. C. Fernandez-Remolar, J. Fogarty, D. P. Glavin, Y. S. Goreva, M. M. Grady, L. J. Hallis, A. D. Harrington, E. M. Hausrath, C. D. K. Herd, B. Horgan, M. Humayun, T. Kleine, N. Mangold, R. Mackelprang, L. E. Mayhew, F. M. McCubbin, J. T. McCoy, S. M. McLennan, H. Y. McSween, D. E. Moser, F. Moynier, J. F. Mustard, G. G. Ori, F. Raulin, P. Rettberg, M. A. Rucker, N. Schmitz, E. Sefton-Nash, M. A. Sephton, R. Shaheen, D. L. Shuster, S. S. Siljestrom, C. L. Smith, J. A. Spry, A. Steele, T. D. Swindle, I. L. ten Kate, N. J. Tosca, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, F. Westall, J. Zipfel.) [1]NASA Glenn Research Center, 21000 Brookpark Rd. MS: 86-8 Cleveland, Ohio, USA 44135.

Introduction: Considerable recent planning has focused on the potential importance of Mars *in-situ* resources to support future human missions. While atmospheric CO_2 provides a source of oxygen [1], the regolith 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* processes would require definition of the resources to influence equipment design and resource budgeting. Exploration via orbital and landed surveys as well as technical demonstrations would be necessary. Mars sample return could play a key role in supporting this planning, especially when considering possible long-term human presence.

The goal of the International MSR Objectives & Samples Team (iMOST) is to define the objectives that could be met using returned martian samples, and identify the types of samples needed to meet those objectives. In-Situ Resource Utilization (ISRU) is one of the six iMOST objectives, and this document summarizes the needs specified therein.

ISRU Objectives: The primary surface resource of interest for Mars ISRU is water. (Although the presence of subsurface ice deposits [6] is of great interest to ISRU, the candidate landing sites for Mars 2020 were chosen in part to avoid near-surface ice, due to planetary protection concerns.) The amount and form of water in Mars surface material will heavily impact potential production processes. Therefore the first two ISRU-related objectives of studying Mars samples on Earth would be to; 1) Determine the concentration of water, its mineralogical basis, and its variation, and to identify contaminants that may negatively impact either production or end-use processes. Some of these contaminants (e.g. perchlorates) may also be usable resources; 2) Characterize the physical and thermophysical properties of martian surface materials to influence the design of possible ISRU surface systems and to develop high-fidelity regolith simulants for engineering test beds 3) The third ISRU-related objective focuses on assessing the presence and quantity of any elements/minerals (especially water-soluble attributes) that are essential for plant growth, as well as elements/minerals that can be toxic to plants and/or a microbiome.

The final ISRU-related 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.

Recommended Samples: We have identified five samples that would be useful for meeting ISRU objectives. Three samples could be used to fulfill ISRU objectives 1 and 2. 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, and 3) a core sample of sedimentary rock that displays the strongest signature of hydration in the landing zone. Two additional samples to fulfill the agriculture objective are: 4) a sample of sand-sized basaltic dune material, and 5) a sample of bright fine-grained dune material. Two optional samples would be an ore-rich sample of opportunity, and an airborne dust sample for filtration concerns.

References: [1] Drake, B.G. (2009), NASA-SP-2009-566; [2]Abbud-Madrid,et.al.(2016), http://mepag.nasa.gov/reports/Mars_Water_ISRU_Study.pptx [3] Wheeler, R.M. (2004), Acta Hort. 642, ISHS 2004.[4]Kleinhenz, J.E. and Paz, A., (2017), AIAA SciTech Forum. AIAA-2017-0423 [5] Jakus, Adam E. et al. (2017). Scientific Reports 7, Article number: 44931. [6] Dundas, C. et. al. (2018), Science, 359: 199-201.