UNIVERSAL TOOL SUITE FOR PLANETARY AND SMALL BODY SAMPLING.
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Introduction: Given the current budgetary constraints and NASA's goal of reformulating the Mars Exploration Program to be responsive to both the Decadal Survey as well as the President's challenge of sending humans to Mars, it would seem critical to develop technologies and tools that can be used to satisfy both SMD and HEOMD needs across a wide range of potential Mars missions, [1]. In the latest version of the "Mars Science Goals, Objectives, Investigations, and Priorities", the MEPAG Goals Committee has identified several major areas of scientific knowledge as well as human exploration needs that should be addressed in future planned missions, [2]. Within the goals identified, it is apparent that there is a need for further development of autonomous planetary sampling capabilities in order to identify: 1) if life ever arose on mars, 2) how the surface and interior of Mars has evolved over time, and 3) the engineering boundary conditions necessary to define the Martian exploration environment to effectively implement human missions within programmatic constraints. In addition, the Strategic Knowledge Gaps (SKGs) identified by HEOMD, which references the pertinent investigations and measurements identified by MEPAG, clearly demonstrate the need for Martian surface sampling in order to reduce the risks and/or concerns associated with biohazards, In-Situ Resource Utilization (ISRU), and to a lesser extent toxic dust, [3].

Problem Statement: In order to satisfy the MEPAG goals and the SKG's identified above, it would be envisioned that several low mass and compact landed platforms utilizing some type of autonomous planetary sampling tool would be required. Previous drilling and sample collection systems have been highly mission specific and driven by a top-down approach to requirement generation (e.g. MSL Drill). This top-down approach, although possibly effective for conventional payload subsystems, is highly constraining to sampling subsystems due to the design space complexity that results from the myriad of stakeholders, see Figure 1. In addition, the problem is confounded by the fact the sampling subsystem is considered part of the mission payload and is often lumped together with science instruments during the mission Pre-Phase A development cycle. In doing so, the sampling subsystem is effectively put on a similar development path as the mission instruments which typically have a significantly less complex design space. The result is a significant cost upper levied on the project by the sampling subsystem due to both a highly constrained design environment and a very short development cycle.

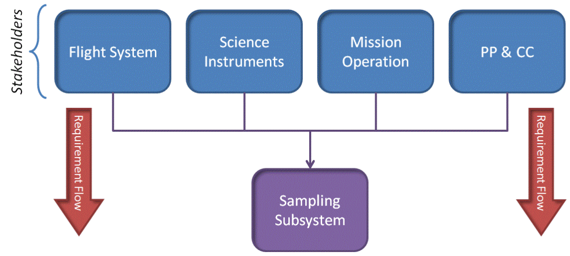

Figure 1. Top down approach to requirement flow as related to sampling systems.

In addition sampling systems, and sampling tools in particular, are designed against a rock test suite whose properties and characteristics are inherently variable in nature. This variability results in significant upfront cost and development testing using hardware with flight-like functionality , see Figure 2, to define tool capability needs vs. science objectives. This same rock variability also results in a challenging and costly V&V and characterization program of the subsequent flight hardware in order to fully identify the flight hardware's performance and functional constraints in a relevant environment, see Figure3, [4], [5], and [6].

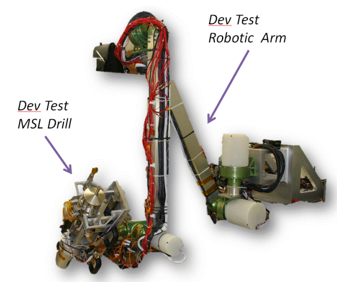

Figure 2. MSL Drill Developmental Test Setup

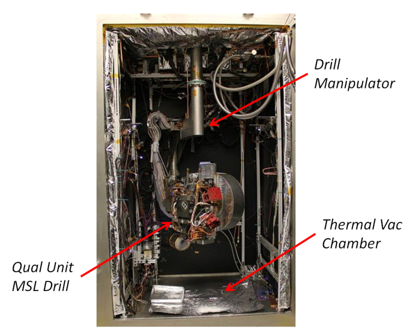

Figure 3. MSL Drill Qualification Test Setup

Objective Statement/Technology Development: In order to resolve the problem of ill-defined requirement generation and allow the project to better manage cost and schedule, there is a need for a balance between the previous top-down only approach and a bottoms-up approach, see Figure 4. Taking a balanced approach will preserve the top-down capability of the project to maintain an efficient overview at the higher levels while permitting the subsystem a degree of flexibility to work within a complex design space by managing stakeholder expectations and needs very early within a projects lifecycle.

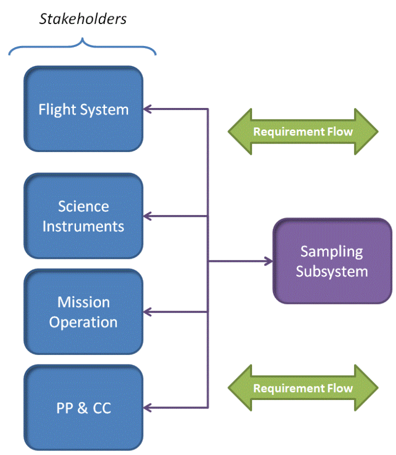

Figure 4. A balanced approach to requirement generation as related to sampling systems

In order to make this balanced approach work within future mission programmatic constraints it would be necessary that each subsequent mission's sampling subsystem is not starting from a clean slate so to speak. As such, it would seem prudent to develop a universal or baseline suite of sampling tools for use on low mass compact landed platforms and characterized against a variety of constraints and science capabilities, see Figure 5. In doing so, each subsequent sampling mission would be in a position to better:

- Provide a starting point for mission definition and process development early within the project lifecycle
- Provide a starting point to assess and trade current capabilities versus presumed stakeholder needs
- Provide acceptable and relevant constraints when instrument AO's are released
- Provide for a reduced sampling system development cycle as the fundamental sampling tool capabilities vs. science objectives will have been well characterized
- Provide ample time to test and characterize each sampling system during subsystem V&V activities

It is important to emphasis that the intent of the tool suite is to not develop a suite of "ready-to-fly" tools, which would be cost prohibitive, and may not fully capture subsequent sampling subsystem flight constraints and science goals. Rather, the effort will provide a starting point for subsequent missions to better inform the project management and relevant stakeholders of expected and realistic capabilities and limitations (allowing for better management of cost and schedule) as well as allow for a more appropriate development lifecycle than sampling mission in the past.

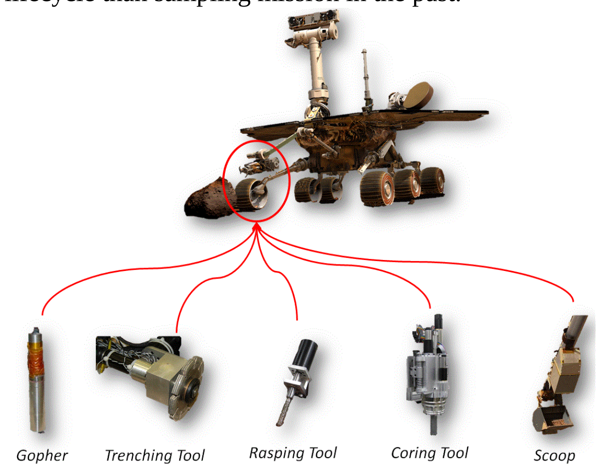

Figure 5. Example baseline sample suite for use on low mass compact landed platforms

Challenge Area: Challenge Area 1, Near Term Instrumentation and Investigation Approaches - interrogating the shallow subsurface of Mars from the surface via subsurface and excavation tools.

References: [1] Author National Research Council (2011) *Planetary Decadal Survey*, ES1–ES8. [2] Author MEPAG Goals Committee (2010), "Mars Scientific Goals, Objectives, Investigations, and Priorities." *MEPAG*. [3] Author M. J. Wargo (2012) "Strategic Knowledge Gaps." *MEPAG*. [4] Author A. B. Okon (2010) "Mars Science Laboratory Drill." *Aerospace Mechanism Symposium*. [5] Author L. Jandura (2010) "MSL SASPaH: Subsystem Design and Test Challenges." *40th Aerospace Mechanism Symposium*. [6] Author L. Jandura (2012) "Results from Functional Testing of the MSL SASPaH Subsystem." *Earth and Space Conference*.