SAMPLE COLLECTION AND HANDLING DESIGNS FOR DIVERSE PLANETARY SURFACES. E. B. Bierhaus[1], M. Yant[1], R. Dubisher[1], D. Wurts[1], M. Thomas[1], J. Taylor[1], J. Songer[1], B. C. Clark[1], and T. Vu[1], [1]Lockheed Martin (12257 S. Wadsworth Blvd. Littleton, CO 80125-8504).

Introduction: We have advanced multiple types of planetary sampling systems, and here discuss: (1) a capable, compact percussive-coring system, and (2) a bulk regolith device derived from TAGSAM, suitable for smaller samples or multiple, discrete samples. Both types are relevant for sample collection from a wide variety of planetary surfaces (see subsequent discussion). The collected sample is available to science payloads for in-situ analysis, or for sample return and subsequent analysis in terrestrial research facilities – and sample curation.

Some of the most profound questions regarding the formation and evolution of planetary systems involve direct measurement of composition [1] via (e.g.) mass spectrometry, realized via in-situ sample analysis, sample return, and in-situ resource utilization (ISRU) for long-duration robotic and human exploration. A necessary step for instruments that ingest or otherwise directly interact with the material (vs. remote sensing) is to collect, and in some cases, pre-process the material. There are physical and dynamical interfaces between the sampling system and host spacecraft that have major impacts on the overall design, architecture, and operations of a mission. Our experience [2-3] established the importance of a systems-level approach to the design of a sampling system, and the value of concurrent design for the spacecraft and the sampling system.

Environmental factors, instruments, and science requirements: Planetary surfaces span a wide range of material properties (e.g. regolith derived from volcanism on terrestrial planets, small-body regolith with a variety of compositions and grain sizes, icy satellites), temperature ranges (driven by distance from the Sun and rotation rates), and surface gravities. Different instruments require different sample types (gas, rock, sieved regolith) and / or different sample volumes. As a result, no one sampling system will address all possible scenarios. On the other hand, certain sampling designs are inherently more adaptable and scalable to account for these factors. The designs described here are the results of trades that considered a range of sampling techniques, and the relative functionality of the sampling systems for different surfaces and instruments.

Coring system: Our design is a percussive coring system, capable of collecting material from hard, competent surfaces or strengthless, granular regolith (Fig 1). The core design provides multiple advantages: the form-factor supports the inclusion of multiple cores in a single sample-collection system, enabling collection of multiple samples from multiple locations; the ability to control depth provides a deterministic volume; and the core preserves stratigraphy.

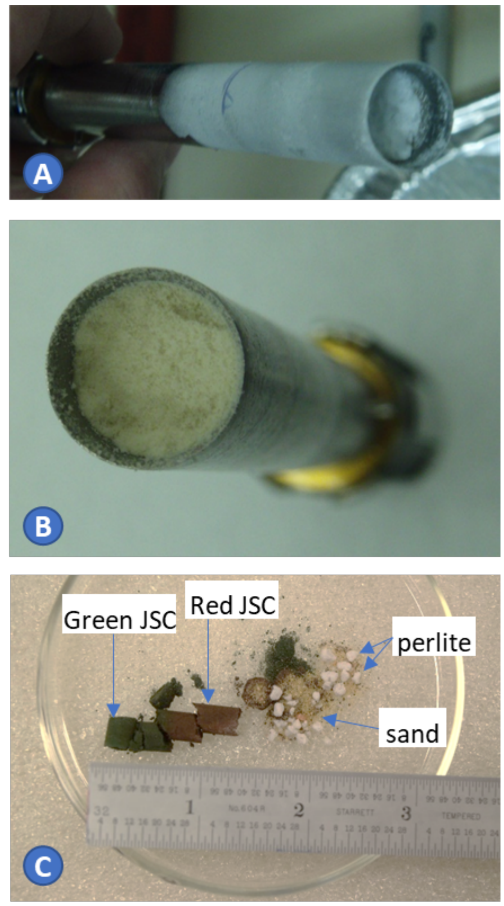

Figure 1. Example collections of the coring device. (A) very cold (-136 deg C) ice. (B) a multi-MPa porous foam. (C) a layered target of different granular materials; note the preservation of stratigraphy (from JSC-1A dyed green at the bottom to perlite at the top).

Our several hundred lab tests span a range of material types. Results presented here include a variety of water ice types, including a very cold (-136 deg C) ice (Fig 1A), a type of foam that simultaneously provides porosity and high material strength (a mechanical construction that may be possible for outer-solar system surfaces, Fig 1B), and combinations of granular materials (Fig 1C). The same core was used to collect these samples by adjusting parameters that control the percussive action of the core.

CO_2 ice has ~half the cutting strength of water ice [4], meaning CO_2 collection is enveloped by our water ice testing. Thus this capability is relevant for a variety of cold surfaces that have different abundances of ice materials.

In addition to the applicability to a range of planetary surfaces, the core design is scalable: it is possible to change the diameter or depth target of the coring system, enabling different aspect ratios of the collected sample, or different collection volumes. The core design is also straightforward to clean for contamination control and planetary protection requirements, continuing the capability implemented for TAGSAM [5].

Targeted regolith collection: We leverage experience from our TAGSAM design for a smaller form factor device that collects targeted volumes of regolith. Like TAGSAM, pressurized gas mobilizes the regolith into a collection volume. Revisions for this design include the option to present the collected material to a science instrument (Figure 2), and a smaller form factor to support multiple, discrete collections that preserve distinct samples.

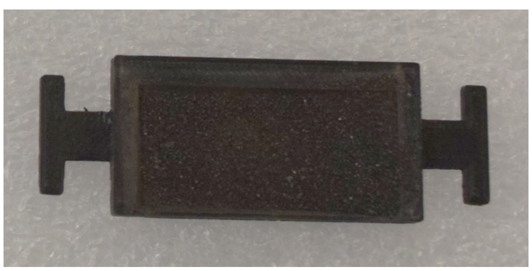

Figure 2. Example of a regolith sample (JSC-1A lunar simulant) collected and prepared for in-situ analysis.

Testing in a vacuum chamber and with JSC-1A lunar regolith simulant (Figure 2) demonstrates the capability to collect a specific volume and even surface, supporting ease of direct examination to one or more in-situ instruments.

Other capabilities and ongoing activities: In addition to the techniques shown here, we have developed other capabilities that address other sample collection or ISRU needs, including: rapid, bulk regolith collection with a definable maximum particle size; and the ability to access sub-surface materials.

We continue to advance the design and implementation of these capabilities. The LM Denver campus hosts multiple labs that support environmental testing (i.e. control the environmental pressure and temperature) and characterization of samples. Figure 3 provides examples of the test facilities: Fig 3A is a vacuum chamber that supports low-pressure and vacuum collection testing with regolith simulants (i.e. a "dirty vacuum chamber"); Fig 3B is in-house strength testing of ice samples. This work is done with support of spacecraft subsystem and subject-matter experts (e.g. planetary protection) to analyze specific environmental conditions on collection performance not just at the sampling level, but at the flight-system level, ensuring straight-forward integration with spacecraft designs.

The ability of the coring system to collect a range of material strengths make it suitable for surfaces that include granular regolith (e.g. the terrestrial planets, the surfaces of small bodies), as well as surfaces that have material strength (e.g. icy moons). The targeted regolith collector is intended for collecting loose material, with the capability to collect specific quantities and provide controlled viewing geometries for in-situ instruments. Either capability could also be part of a sample-return mission.

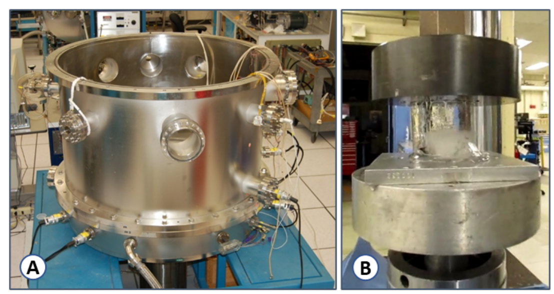

Figure 3. Example experimental facilities used in testing. (A) Vacuum chamber that supports collection tests. (B) Strength evaluation of ice sample.

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