A SAMPLE ACQUISITION AND CACHING ARCHITECTURE APPLICABLE TO A MER-CLASS ROVER FOR MARS SAMPLE RETURN. Paul Backes, Paulo Younse, Tony Ganino. Jet Propulsion Laboratory, California Institute of Technology, Paul.G.Backes@jpl.nasa.gov

Introduction: The Mars Surface System Capabilities area challenge to enable sample acquisition and caching from a MER-class rover for a proposed Mars Sample Return caching mission could be achieved with the new Minimum Scale Sample Acquisition and Caching (MinSAC) architecture, as shown in Figure 1. The MinSAC architecture could enable a low cost caching mission, e.g. a MER-class rover on a MER-type landing system. It could also enable combining MSR mission phases such as landing a MER-class caching rover along with a Mars Ascent Vehicle on a pallet using an MSL-type landing system.

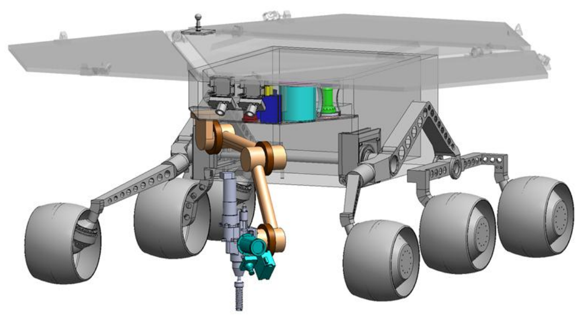

Figure 1: Sample Acquisition and Caching on a MER-class rover.

MinSAC Architecture: MinSAC is a variant of the IMSAH architecture and its primary features have been demonstrated with TRL 4 hardware performing end-to-end sample acquisition and caching [1]. The MinSAC architecture further eliminates actuators from the caching mechanism by using the robotic arm for sample tube transfer. Some key architectural features of the MinSAC architecture are listed below.

- A sample is acquired directly into its sample tube in the sampling tool bit.
- Bit changeout is used to transfer the sample to the caching element.
- Sample tubes are transferred between components of the caching element.
- Sample tube sealing is provided.
- The robotic arm provides position, orientation, and linear feed for the sampling tool and transfer of sample tubes for the caching element.

MinSAC Architecture Benefits: The MinSAC architecture improves upon past MSR sample acquisition and caching approaches in several ways. Acquiring core samples directly into sample tubes minimizes contamination and allows for handling only known geometry tubes rather than unpredictable and possibly broken and loose samples. Returning samples in tubes minimizes the size of the return cache canister through efficient packaging and small tube thickness. The number of actuators needed for sample acquisition and caching is minimized through the use of the robotic arm across multiple functions including: instrument placement; tool positioning, alignment, preload, and linear feed; bit changeout; and tube transfer. Use of sample tubes manipulated by the robotic arm enables hermetic sealing of sample tubes with minimal required volume for a sealing station.

Robotic Arm: The robotic arm (RA) has a turret which holds science instruments, the sampling tool, and the tube gripper, as shown in Figure 2. A six axis force-torque sensor is provided at the base of the turret.

Sample Acquisition: The sample acquisition tool has the following primary features:

- Sample tube in bit.
- Rotary percussion for coring.
- Linear spring for tool feed.
- Core breakoff.
- Sample retention.
- Bit changeout.

Rotary percussion in the coring tool enables coring in hard rocks with low preload and no stabilization tines. Experiments have shown that a preload of 30N is sufficient for coring with a rotary percussive coring tool. Core breakoff separates a core sample from its parent rock after coring and sample retention retains the sample in the bit. Bit changeout includes bit capture and bit release at the caching element. The sampling tool is mounted to the robotic arm turret on a pair of linear springs which are linear rails that constrain linear motion and have springs to apply preload and absorb percussive energy. An example sample acquisition tool is described in [2].

The robotic arm is used for bit position, alignment, preload, and linear feed. The sampling tool then does not need to have its own linear feed actuator. The force-torque sensor can detect side loads on a bit and the RA can realign the bit in the hole. Coring is accomplished in 1cm increments while the coring tool is preloaded and guided by the linear springs. The robotic arm brakes are engaged during the coring increment so no energy is consumed by the arm during coring increments. Before each coring increment the robotic arm realigns and preloads the coring tool in the hole.

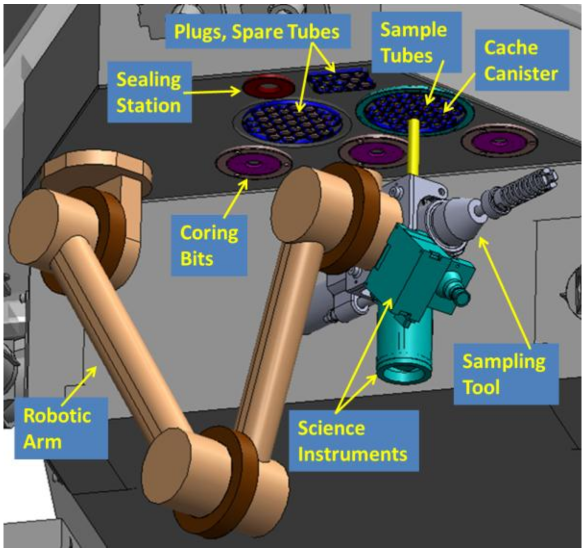

Figure 2: Caching components.

Caching: The caching element includes bits in bit chambers, a cache canister, sample tubes, tube plugs, and a sealing station as shown in Figure 2. Empty sample tubes are stored in the cache canister. Tube plugs and spare sample tubes are stored outside of the sample canister. Multiple bits are provided in bit chambers, allowing for redundancy in case a bit wears out and the option to provide different types of bits, such as an abrading bit and a specialized regolith bit. Mechanical and hermetic sealing of sample tubes for the architecture have been demonstrated [3]. The end-to-end sample acquisition and caching process is listed below.

1. Robotic arm (RA) positions tube gripper (on the turret) at an empty sample tube and tube is grasped and removed.
2. Sample tube is inserted into a bit and released.
3. RA positions sample acquisition tool (SAT) at the bit and bit is attached to the SAT.
4. RA deploys SAT to surface and sample is acquired into the sample tube in the bit.
5. RA transfers bit to bit chamber and releases bit in bit chamber.
6. RA positions tube gripper at tube in bit and tube is grasped and removed from bit.
7. RA positions tube at a plug in caching element and pushes tube up which inserts plug in tube.
8. RA transfers tube to sealing station where tube is pushed up against sealing head element which pushes plug into contact with sample, enabling containment and measurement of the sample. Sealing head engages hermetic sealing process which seals the sample tube.
9. RA transfers sealed sample tube to cache canister and inserts sample tube in cache canister.

The Cache: The cache includes a cache canister with samples sealed in sample tubes. This volumetrically efficient packaging method maximizes the amount of returned sample, as shown by the example 19 sample cache canister in Figure 3. Returning more samples requires only the volume assocated with the additional sample tubes. For core samples 2.7g/cc, 6cm long and 1cm diameter, a 31 sample cache is estimated to have dimensions 9cm diameter by 10cm tall with total mass of 1.1 kg including 393g of samples. The cache could be released by a mechanical lever allowing for the robotic arm to release and place the cache on the ground or for a robotic arm on a subsequent mission's rover to release the cache if needed.

Figure 3: Example sample cache canister.

Fitting in a MER-class Rover: Figure 4 shows the system within the stowed volume for the case where the system is landed in a MER-style airbag lander.

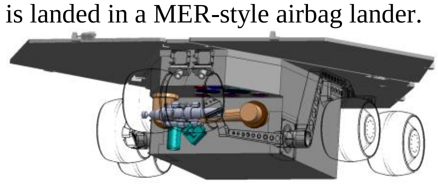

Figure 4: Stowed in a MER landing volume.

References:

[1] Backes, P., Aldrich, J., Zarzhitsky, D., Klein, K., Younse, P., "Demonstration of Autonomous Coring and Caching for a Mars Sample Return Campaign Concept," IEEE Aerospace Conference, paper #1480, March 2012. [2] Klein, K., Badescu, M., Haddad, N., Shiraishi, L., Walkemeyer, P., "Development and Testing of a Rotary Percussive Sample Acquisition Tool," IEEE Aerospace Conference, March 2012. [3] Younse, P., de Alwis, T., Backes, P., Trebi-Ollennu, A., "Sample Sealing Approaches for Mars Sample Return Caching," IEEE Aerospace Conference, March 2012.