Results to Date for the Mars Science Laboratory Sample Acquisition, Sample Processing and Handling System (SA/SPaH). R. C. Anderson[1], L. W. Beegle[1], J. Hurowitz[1], D. Limonadi[1], L. Jandura[1], J. Melko[1], C. C. Seybold[1], M. Robinson[1], K. S. Edgett[2], R. A. Yingst[3], M. E. Minitti[4], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr. Pasadena Ca, 91109. Robert.C.Anderson@jpl.nasa.gov, [2]Malin Space Science Systems, San Diego, CA, USA; [3]Planetary Science Institute, Tucson, AZ, USA; [4]Applied Physics Laboratory, Laurel, MD, USA;

Introduction: The Mars Science Laboratory Mission (MSL) consists of a rover and a scientific payload designed to identify and assess the habitability, geological, and environmental histories of Gale crater. Unraveling the geologic history of this region and providing an assessment of present and past habitability requires an evaluation of the physical and chemical characteristics of the landing site; this includes providing an in-depth examination of the chemical and physical properties of Martian materials. The MSL Sample Acquisition, Processing, and Handling (SA/SPaH) subsystem is designed to acquire interior rock and soil samples from Martian surface materials and then process these samples into fine particles that are distributed to the onboard analytical science payload [1]. Figure 1 represents the layout of the instruments on the arm turret.

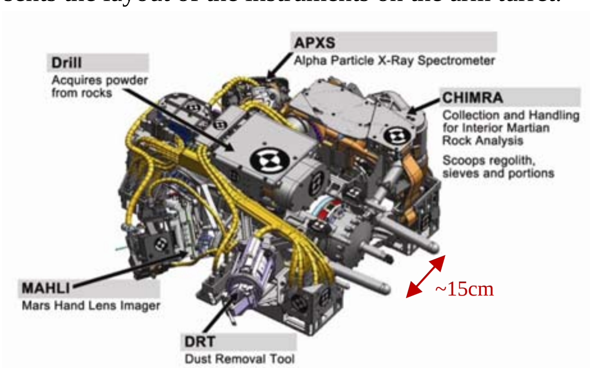

Fig. 1: Turret instruments and hardware components.

Components of the SA/SPaH system: SA/SPaH is a highly mechanized system that contains 17 actuated degrees-of-freedom designed to produce samples in the form required for the rover's analytical laboratory instruments, SAM and CheMin. Samples can be collected two ways, via drilling or scooping, and moved throughout the system with the help of vibration and gravity. SA/SPaH relies on a 2.3-meter Robot Arm (RA), that is designed to place and hold the turret-mounted devices and instruments (weighing about 30 kilograms) on 1) direct contact on rock and regolith targets in its primary workspace, 2) rover-mounted hardware (Observation Tray, Organic Check Material, SAM and CheMin instrument funnels, spare drill bit boxes), as well as 3) manipulate the turret-mounted sample processing hardware for sieving and delivery.

The drill, called the Powder Acquisition Drill System (PADS), is designed to penetrate to a maximum depth of 6.5 cm in rocks [2] and to produce rock powder that can be sieved to an appropriate size range for use by the onboard analytical instruments (< 150μm for CheMin and SAM, or < 1 mm for SAM). The diameter of drilled holes is 1.6 cm diameter. After the sampling operation is completed the sample is then transferred to the Collection and Handling for In-situ Martian Rock Analysis (CHIMRA) for sieving and delivery of sample aliquots (called "portions").

CHIMRA is the processing device that sieves and portions the samples acquired from the drill and scoop into aliquots, which are subsequently transferred to the analytical instruments [3]. Material collected by PADS moves through a Sample Transfer Tube, which connects CHIMRA to PADS. Regolith is collected by a scoop, which is attached to CHIMRA. Once a sample is in CHIMRA, processing takes place by moving the turret using gravity and vibration to move the powder through various chambers, labyrinths, and sieves.

During development, sample-to-sample cross-contamination was perceived to be a problem for CHIMRA. Therefore, the internal sieves were intentionally mounted to mechanisms (called " thwackers") that provide impact shock into each sieve and the interior surfaces to clear them of sample material. This "thwacking" minimizes cross-contamination and mitigates any potential clogging of sieves throughout the mission life.

Science Operations with SA/SPaH on Mars: Here we present an overview of operations that have occurred to date using the SA/SPaH arm and tools.

APXS and MAHLI investigations. The first scientific use of the arm was to explore the rock feature known as Jake Matijevic on Sol 46-47. This was the first time that the MAHLI and APXS instruments were used in concert to investigate a martian sample (**Fig. 2**). APXS and MAHLI have subsequently been used together to investigate other rock and soil targets in detail; the results of those investigations are detailed elsewhere.

Scoop Sample: The first solid sample acquired and processed on Mars (**Fig. 3**) with the SA/SPaH hardware was regolith from an eolian drift that had accumulated in the lee of a number of large rocks surround-

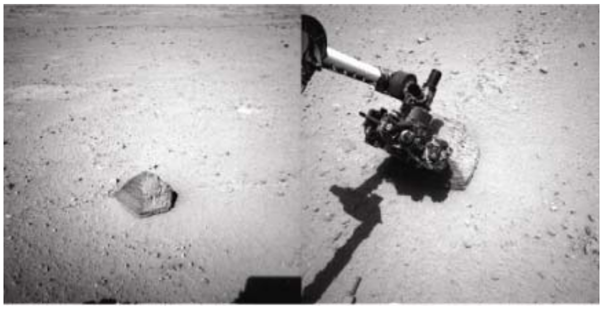

Fig. 2: Navigation camera images of the rock target Jake Matijevic. Image at right shows the arm with APXS placed on the rock.

ing a semi-circular depression (possibly a small, degraded impact crater – called Rocknest). Rocknest was chosen for first-time sample acquisition because it was thought to have properties: (1) broadly representative of basaltic-liked deposit investigated at other landing sites on Mars, and thus of high scientific interest; (2) similar to regolith simulants used in terrestrial testbeds, and thus unlikely to present unexpected difficulties for the hardware; (3) that make it ideal for removal of any residual terrestrial organic carbon-bearing compounds that might be adhering to the internal surfaces of CHIMRA [4].

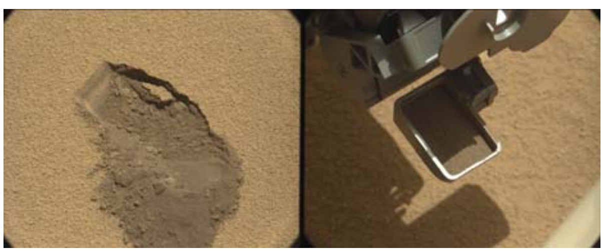

Fig. 3: MastCam images of the Rocknest drift after acquisition of the first scoop and sample in the scoop.

Scoop Sample Triage: In order to confirm our suspicions regarding the nature (physical, chemical, mineralogical) of the Rocknest soil and to ensure optimal sample delivery performance, a significant triage investigation was conducted, involving the concerted use of multiple instruments and hardware components. The rover wheel was used to scuff the Rocknest drift and subsequent engineering camera, Mastcam, and MAHLI images were used to ensure (1) that the depth of the deposit was sufficient to avoid scraping the scoop against bedrock underlying the deposit; (2) the deposit contained a sufficient amount of particles <150 μm to pass the CHIMRA sieve; (3) that the material was not significantly cohesive and/or cemented (i.e., that it would behave as a dry, cohensionless powder in CHIMRA), and 4) contained no underlying pebbles. Additional information on the physical properties of the material were obtained by imaging sample portions dropped on the MSL observation tray. Information on the chemistry of the deposit was collected using the APXS and ChemCam instruments. Finally, wind sensors in the REMS instrument package were used to determine the optimal time of day (i.e., low velocity winds from the desired direction) to perform sample dropoff to instruments.

SA/SPaH Decontamination: To ensure that the sampling hardware would not contaminate Martian samples with residual terrestrial organic carbon bearing compounds, a particular concern for the SAM instrument suite, the SA/SPaH hardware was "cleaned" on Mars. This was accomplished by collecting three separate scoop samples and using a specially designed set of arm and turret motion sequences that brought the acquired samples into contact with the interior surfaces of CHIMRA and vibrated the sample against those surfaces, effectively"stripping" any residue off the walls. Each of the three samples was then ejected from CHIMRA. After each cleaning activity, the entire system was imaged to determine amount of material present, the amount that passed through the sieve, and the effectiveness of sample ejection (**Fig. 4**). We note that swab samples collected from the internal surfaces of CHIMRA prior to launch were analyzed by FT-IR and pyrolysis GC-MS and showed exceptionally low levels of residual carbon contamination [5]. This data, combined with models of the efficacy of the vibration cleaning procedure executed on Mars [4], indicate that CHIMRA is not a likely source of terrestrial organic carbon contamination. In total, five scoops were collected from the Rocknest drift, four of which were successfully processed by CHIMRA and one of which was discarded. All SA/SPaH hardware components behaved as expected and sample delivery to the MSL instrument payload was completely successful.

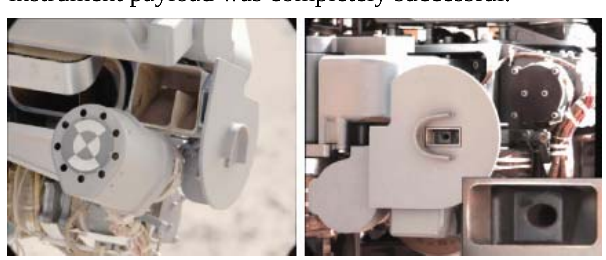

Fig. 4: MastCam images of CHIMRA internal surfaces.

References: [1] R. C. Anderson et al., *Space Sci. Rev.*, (2012) DOI 10.10077/s11214-012-9898-9. [2] L. Jandura, in *Proc. 40th AMS.* [3] A. Okon, in *Proc. 40th AMS.* [4] M. S. Anderson et al., Rev. Sci. Inst. (2012) doi: 10.1063/1.4757861. [5] Eigenbrode et al., in 44th LPSC.