SPADE: A ROCK CRUSHING AND SAMPLE HANDLING SYSTEM DEVELOPED FOR MARS MISSIONS.

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Access to the interior of rocks on Mars is an important goal for understanding Mars' petrology and geologic history. The spectral signature of the potentially diverse mineralogy of rocks on Mars is veiled by the ubiquitous dust and may be further hidden by weathered rind. We have developed a rock crusher and sample distribution system under the auspices of NASA's PIDDP program. We call it the "SPADE": the Sample Processing and Distribution Experiment. Its purpose is to access the interiors of rocks on Mars and prepare samples for analysis by a suite of *in situ* instruments.

The system, shown in Figure 1, consists of a rock crusher, which produces rock fragments and fines, a sample sorting system for separating fragments and fines, a sample wheel with bins for fragments and fines that moves the rock products to *in situ* instruments for inspection and analysis, and sweepers for cleaning the products off the wheel. There are no specific consumables that will limit the lifetime of the crusher and wheel other than eventual wear and tear on the gears.

The sequence starts with the introduction of a rock into the crusher. The size of a rock to be crushed is determined by the size of the crusher and separation of the crusher walls. The rotary action of the crusher walls cracks the rock and works the pieces down further into the crusher. The separation of the plates at the bottom determines the largest fragment size. The size of the system can be scaled up or down to meet the science requirements of the mission, and volume and mass constraints.

The typical amount of time to crush a rock is about an hour. The time to crush a specific rock is determined by the size and type of the rock. This crusher can be run from a 9V battery, thus power requirements are minimal.

The rock crusher products are fragments and fines. These are separated by a vibrating sieve into two adjacent bins. The size of the fines is determined by the sieve holes and thus is selectable. An LED is used to sense when the bins are full. When a bin is full the sample wheel autonomously rotates to position the next pair of bins under the rock crusher.

The fines and fragments in the sample wheel are rotated to inspection instruments such as microscopic imagers, spectrometers, or other *in situ* instruments that are used to do close-up examination. This enables a scientific triage that can allow a science team to select certain specific desirable samples for further experiments, by single-use analysis instruments such as ovens or chemical experiments. Sweepers clean out the bins, either dumping samples back on the ground or pushing them into the next stage analysis instruments, or storing them in cache.

We have run the SPADE with a set of 10 standard igneous and sedimentary rocks that are potential Mars analogs. The size distribution of product is measured for each case. Figure 2 shows a histogram of product from a basalt rock.

Our goal is to develop this system to the point that it is ready to incorporate in a Mars surface mission such as the Mars Science Laboratory (MSL), although it can be sized for a smaller mission. Our development effort is proving out the system functionality, risks are being identified and retired through design evolution, and options will be available for features such as the size of the system.

Figure 1. The rock crusher, sample carousel, and sweepers. Fines and fragments are sorted into adjacent bins.

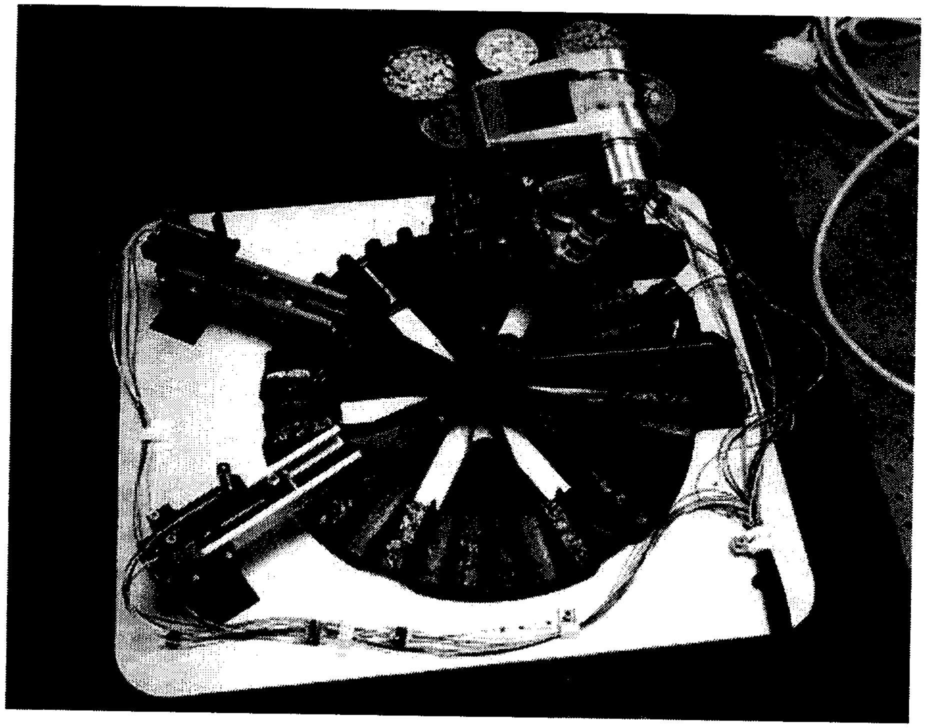

Figure 2. Sample product from rock crusher