SAMPLE COLLECTION FROM PLANETARY SURFACES Andrew F. Cheng[1], Carlé M. Pieters[2], Scott L. Murchie[1]; [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD; [2]Brown University, Providence, RI.

Abstract. Prototype planetary surface sample collectors that enable a small robotic spacecraft or vehicle to sample rock or regolith surfaces have been designed and trested at APL. Technical requirements for the sample collector include small size and mass, minimum power, operability in near vacuum and microgravity, and minimal alteration and contamination of the sample. Our prototype unit weighs about 2 kg and obtains 35 g samples from solid basalt rock or loose sand, using a pyrotechnic gas generator to propel a coring tube into the surface. This concept of operation is similar to that of side-wall samplers used in terrestrial drilling operations. Multiple samplers will be accommodated to obtain samples from different parts of the target body. Possible applications under active study include low cost sample return missions to small bodies, possibly in the NASA Discovery Program, and sample acquisition by a small rover on Mars or the Moon leading to in situ analysis or Earth return. We will discuss science requirements and implications for sample collection techniques. We will also summarize successful test results from our sample collector development program which is supported by the NASA Planetary Instrument Definition and Development Program.

Introduction. Key scientific objectives of the NASA planetary exploration program can be achieved only by means of sample return missions from planetary surfaces. The scientific importance of sample return is widely recognized for planets, satellites, and small bodies [1-4]. Laboratory analyses of returned samples promise tremendous advances in our understanding of the origins, evolution, and geologic history of specific planetary bodies. Some critical analyses, such as absolute age determinations, can be performed only on returned samples in terrestrial laboratories. The scientific value of sample return is greatly enhanced if the geologic context of the samples is determined with appropriate remote sensing and/or analytical instrumentation. Specific choices for the scope and focus of a mission depend on cost and technical constraints as well as the nature of the target body. Here we address general implications of science requirements for sample collection. Our challenge is to acquire bulk samples from unknown rock or regolith surfaces, while maximizing science return and minimizing cost, risk, and complexity. We present a technical approach to sample collection that uses a pyrotechnic device to fire a hardened steel sampling tube into the target surface.

Science Requirements of Sampling Device. The principal requirements can be stated simply as: to obtain a scientifically meaningful quantity of material, to minimize contamination with foreign materials, and to minimize alteration of physical or chemical state. Each of these has important implications for sample collection.

sample size - Experience with meteorites indicates that samples of at least 10 g mass will support hundreds of quantitative analyses, many of which are non-destructive. Much smaller samples, down to a mm or less in diameter, limit the number and type of analytical measurements that can be performed. Mm-sized samples, even from regolith, might not be representative unless sufficient numbers are acquired. Especially on small bodies, a regolith might not be well-mixed on such small scales. We plan for a minimum sample size of 10 g from any single site.

contamination - Two types of potential contamination during sampling are identified: one from the spacecraft (including the sample collector), and one from the target body itself (i. e., mixing of samples collected at different sites). Both types of contamination should be minimized, but contamination at some small level is unavoidable and cost and complexity must also be minimized. The level of effort to avoid contamination should also be consistent with the mode of curation - lunar samples are not kept at low temperature or in hard vacuum. Contamination from spacecraft/sample collector material is most troublesome if it creates problems of interpretation in quantitative analyses of samples. This is especially problematic if the contaminant is itself poorly characterized, as would be the case for thruster and pyrotechnic propellant residues. Thus, during sample acquisition, in no case should a bipropellant or solid rocket thruster be fired close to a surface to be sampled, and samples must be isolated from pyrotechnic propellant residues. Another potential source of contamination is mechanical damage to the sample collector, particularly from sampling hard materials, that could create fragments from the collector mechanism. Our experience in sampling solid basalt and reinforced concrete targets indicates that macroscopic fragments that may break off and mix with the sample can be readily identified. This is not necessarily a problem if sampler fragments are well known a priori. It is thus desirable to minimize the number of different materials that potentially contact the sample. Since steel tools and containers are presently used for sample dividing, handling and curation in any case, we use only steel in the sample collector and require that it be well characterized in composition. Finally, no mixing of samples obtained from different sites should be allowed, even though such mixing inevitably occurs as a natural process on the target body itself. We design each sampler for single use (one sample in each collector). The multiple mount that will accommodate a number of sample collectors will also have separate cover mechanisms to seal off each sample after acquisition.

alteration - Heating of the sample, which can alter both its physical and chemical state, should be minimized. For an impact coring system, such as the present sampler, this requirement drives us to minimize the impact velocity consistent with achieving adequate penetration and minimizing the total mass and recoil impulse. Impact speeds of ~100 m/s are used in the present system which is designed for rock and regolith sampling. We have therefore concentrated on "warm" sample returns (>-50C) for the present work. Although it is also desirable to preserve physical and textural properties of the target surface, such as stratigraphy, some disturbance is inevitable associated with the sampling process even for loose regolith. The present impact coring system operated into basalt and concrete targets produces a broad range of particle sizes in the extracted sample, from cm-size (for concrete, both chunks of matrix and single or fragmented quartz pebbles) down to fine powder.

Compared to drilling techniques for sample acquisition [e.g., 5], impact coring as in the present device has several advantages. Heating of sample is generally not a concern for impact coring, although it is a potentially serious problem for drilling, especially into hard and/or cohesive surfaces. Other advantages of impact coring are that it requires only a pyrotechnic firing pulse, does not require anchoring of the vehicle even in microgravity, and operates within milliseconds. Drilling requires high sustained power input, may require anchoring of the vehicle, and may require a long time for sample acquisition. However, drill cores can better preserve stratigraphy and can be obtained from greater depth. The present impact corer is designed for shallow penetration (up to several cm).

Test Results. - We have performed 21 test firings of prototype sampling devices as of December 1995. These tests have validated technical approaches for the following components:

• launcher that accommodates a pyrotechnic gas generator and propels a penetrator into the surface;

• hollow core penetrator that can obtain samples from targets as hard as solid basalt rock while maintaining the ability to sample loose regolith;

• sample retention system within the open-ended, hollow core penetrator that essentially eliminates loss of sample after penetration due to extraction from the target surface. The penetrator has no moving parts and no mechanism to close off the end of the coring tube immediately after sampling. A sample retention device, in the form of a custom-designed steel brush, is included within the coring tube to hinder the escape of powdered sample upon extraction from the target.

Two versions of the sampler have been prototyped and tested at APL, a 'large' sampler that weighs about 2 kg and a 'miniature' rock chipper that weighs about 200 g. The latest version of the large sampler obtained a *70 gram sample from hardened, steel-reinforced concrete*. With an earlier version of the penetrator tip design, it also extracted ~35 gram samples from a solid basalt rock and from loose sand with no binder. The 'miniature' rock chipper has demonstrated the ability to remove the weathering rind from a solid basalt rock [6]. The successful implementation of large and small versions of the device demonstrates that we can scale the basic design up or down in size in order to optimize the characteristics for a particular mission. An interior ballistics simulation code has been developed for this purpose, to calculate the penetrator velocity versus time, given thermophysical properties of the propellant and mechanical parameters of the launcher and penetrator. We will report on results of instrumented tests to measure impact velocities and shock loads.

safe and reliable operation - No catastrophic failures have occurred to date, and a single launcher (for the 2 kg sampler) has been fired successfully 11 times without appreciable degradation.

sampling of rock or regolith surfaces - A single mechanical design, embodying pyrotechnic gas generator, penetrator and launcher, has been shown in test firings to obtain samples of sufficient size from either rock or regolith surfaces. The capability of a single device to sample surfaces over a wide range of mechanical strength and cohesiveness is important, because mechanical properties of target surfaces may be unknown, as in the case of small bodies, and because a low cost spacecraft or vehicle may not be able to assure that only regolith (say) be sampled.

sample retention - The sample retention device was tested by firing the sampler vertically downward into a target and measuring sample mass after allowing material to fall out of the coring tube after extraction. The sampler with the steel brush system successfully acquired *and retained a 29 g sample against 1 g acceleration*.

scientifically valid sample - While the prototype sample collector has been designed to meet all of the science requirements outlined here, we consider it desirable to validate the sampling technique by undertaking quantitative analyses of test specimens actually obtained by the sampler. Preliminary plans for such tests will be discussed.

References. [1] Drake, M., W. Boynton, and D. Blanchard (1987). The Case for Planetary Sample Return Missions 1: Origin of the Solar System, *EOS 68*, 105-109. [2] Gooding, J., M.H. Carr, C. McKay (1989) The Case for Planetary Sample Return 2: History of Mars. *EOS 70*, 745-755. [3] Ryder, G., P. Spudis, and G. J. Taylor (1989) The Case for Planetary Sample Return Missions 3: Origin and Evolution of the Moon and its Environment, *EOS 70*, 1495-1509. [4] Swindle, T., J. Lewis, and L. McFadden, (1991) The Case for Planetary Sample Return Missions 4: Near Earth Asteroids and the History of Planetary Formation. *EOS 72*, 473-480. [5] Allton, J. A. (1989) Catalog of Apollo Lunar Surface Geological Sampling Tools and Containers, NASA/Johnson Space Center report JSC-23454. [6] Cheng, A. F. (1994), Rock Chipping Facility, in *Mars Surveyor Science Objectives and Measurements Requirements Workshop* (D. J. McCleese et al. eds.), pp. 32-33, JPL Tech. Rpt. D12017, JPL, Pasadena, CA.