SAMPLE COLLECTION FROM SMALL AIRLESS BODIES: EXAMINATION OF TEMPERATURE CONSTRAINTS FOR THE TGIP SAMPLE COLLECTOR FOR THE HERA NEAR-EARTH ASTEROID SAMPLE RETURN MISSION.

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Introduction: There have been a number of missions that have explored the solar system with cameras and other instruments but profound questions remain that can only be addressed through the analysis of returned samples. However, due to lack of appropriate technology, high cost, and high risk, sample return has only recently become a feasible part of robotic solar system exploration. One specific objective of the President's new vision is that robotic exploration of the solar system should enhance human exploration as it discovers and understands the the solar system, and searches for life and resources [1]. Missions to small bodies, asteroids and comets, will partially fill the huge technological void between missions to the Moon and missions to Mars. However, such missions must be low cost and inherently simple, so they can be applied routinely to many missions. Sample return from asteroids, comets, Mars, and Jupiter's moons will be an important and natural part of the human exploration of space effort. Here we describe the collector designed for the Hera Near-Earth Asteroid Sample Return Mission. We have built a small prototype for preliminary evaluation, but expect the final collector to gather ~100 g of sample of dust grains to centimeter sized clasts on each application to the surface of the asteroid.

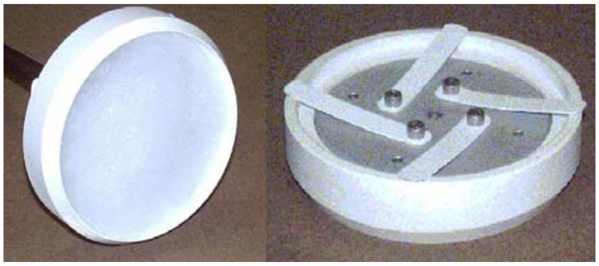

Fig. 1. a) (Left) Laboratory prototype version of the TGIP loaded with silicone grease. b) (Right) Backside of the TGIP collector. Springs and retractable outer ring are visible.

Design of the Sample Collector. The sample collector for this mission was designed as a simple and passive device. The touch-and-go-impregnable-pad (TGIP) prototype collector is 12 cm in diameter and 2 cm deep, the flight version being larger, and consists of springs and a retractable ring (Fig. 1). One centimeter of collection substrate (Dow Corning Vacuum Grease) is evenly housed inside the retractable ring. The retractable ring allows for the collection substrate to be pushed down into the sample being collected, which permits large fragments to be collected. The sample is retracted back into the ring which allows for protection during stowage in the sample return cansister after the collection sequence.

Collection Environment. The collector must be successful in a variety of adverse conditions associated with space. In particular, the collector must remain efficient at the temperatures associated with near-Earth asteroids. Estimating the temperature on near-Earth asteroids is difficult due to a number of circumstances (i.e., varying topography). However, the dominating variable is the asteroid's distance from the sun. We used an equilibrium temperature calculation (assuming a black body) [2] to estimate the temperature of the subsolar (warmest) point of the asteroids, which is sufficient for the experiments conducted here. Equilibrium temperatures were calculated for each of the asteroids deemed potential mission targets by Sears et al. in 2003 [3]. Due to the taxonomic classes being unknown for many of the near-Earth asteroids, the case where each asteroid was assumed to be S, C, and M were calculated. Average bond albedos and emissivities were used for each of the asteroid classes [4]. The calculation of equilibrium temperatures for these asteroids shows that the temperature varies by ~7°C at most, all else being equal. The temperature range between asteroids located at 0.8 AU to 1.5 AU is between 36°C and -43°C.

Experimental Methods: The experiment was set up to explore the effect of this range of temperatures on the collector and to determine the range of temperatures over which the collector would be effective. The simulated asteroid regolith was made up of a sand-gravel blend consisting of 60 weight percent (300-425 μm grains) sand and 40 weight percent gravel (≤1 cm in size). The TGIP was loaded with 1cm (100 g) of collection substrate and then weighed. Regolith samples and the collector were stored at -75°C, -50°C, -25°C, 23°C, 65°C, and 105°C until thermocouples placed in the grease and sample were stable for 30 minutes. Sample regolith was placed on the laboratory bench and the collecter was pushed into the mock regolith by hand using constant ~40 ± 8 N force. The TGIP was then weighed to determine the amount of sample that was collected. Temperature fluctuation experiments were done on two of the -75°C sample. In these experiments, the collector was allowed to warm to room temperature after the initial trial collection and made to take another sample to determine if the collector would recover its room temperature collection efficiency.

Results: Figure 2 shows the results of the experiments. The mass collected generally increased linearly over the entire temperature range. At -75°C, the mass recovered by collector was only ~13% of that at room temperature, clearly showing decreased efficieny as temperature decreased. Figure 2 shows a more constant trend of the amount of sample collected at temperatures above 25°C. The black squares in Fig. 2 symbolize the temperature fluctuation recovery experiments. These data show that the grease recovered its ability to collect sample to at least 80% of its initial room temperature capacity. The ability of the collection substrate to collect samples was not significantly reduced by the low temperature excursion. The best conditions for the TGIP appear to be above 0°C.

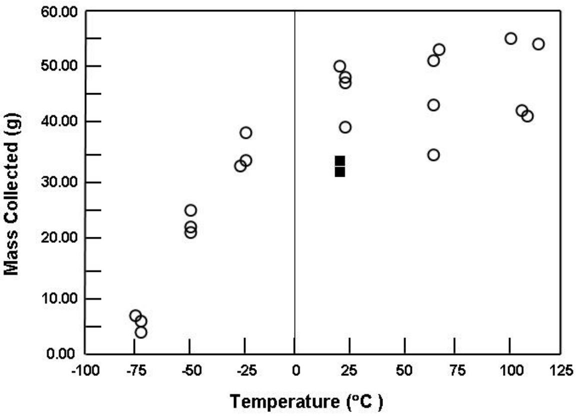

Fig. 2. Temperature dependence on the amount of sample collected by the prototype TGIP. The two overlapping black squares represent temperature fluxuation recovery experiments.

Discussion: We suspect that the changes in collection efficiency are related to the rigidity of the springs on the collector and the increasing viscosity of the grease at low temperatures. Both of these recovered after low temperature excursions. The scatter in the mass collected at higher temperatures can be attributable to the "flow" of the collection substrate at higher temperatures, to slight differences in force applied to the TGIP during the collection process, and to heterogeneity of the surface. Despite some hard-to-control variables in these experiments, the results clearly show that over a very wide range of temperatures conceivably found on near-Earth asteroids, the TGIP collector maintains a high collection efficiency. A scientifically significant mass would be collected even if the coldest temperatures experienced by the TGIP in our experiments were encountered on the asteroid. The collection substrate does not lose its collection abilities by temporary excursions to low temperatures so that storage during flight is not a problem. Temperature at the time of collection is what matters and optimum performance of the TGIP appears to be at or above 0°C. Most scenarios for asteroid sample collection require operations on the sun-asteroid line where temperatures will be highest, but otherwise battery or chemically powered heaters could be placed inside collection substrate.

Conclusions: Equilibrium calculations have shown that near-Earth asteroids have expected temperatures in the range of -43°C to 36°C. It was found that the mass of sample collected by the TGIP increased nearly linearly to 23°C and then leveled off to between 45 g and 55 g per collection at higher temperatures. Temperature fluctuation recovery experiments were performed which concluded that the collection substrate does not lose its ability to collect sample after being frozen and then thawed. These experiments have shown that the TGIP sample collector can operate effiecienty at temperatures expected on near-Earth asteroids.

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References: [1] *Vision for Space Exploration* (2004)*http://www1.nasa.gov/pdf/55583main_vision_space_exploration2.pdf* [2] Lewis J. S. (1995) *Physics and Chemistry of the Solar System.* Academic Press, London, 223-224. [3] Sears D. W. G. et al. (2003) *LPS XXXIV*, Abstract #1047. [4] Cox, A. N. (ed.) (2000) *Allen's Astrophysical Quantities*, 4th edition. Hamilton Printing Company, Rensselaer, NY.