Building an Asteroid Sampler: Preliminary Design and Testing. Thomas D. Dougan and Dr. Larry Roe, Mechanical Engineering, University of Arkansas, Fayetteville, AR 72701

Introduction: Due to inadequate success of *in-situ* scientific space missions a new mission is being proposed to retrieve dust from an asteroid and bring it back to earth. The proposed mission is very similar to the recent NEAR mission and is tentatively named "Hera". Hera will use the same spacecraft as the NEAR mission, while taking samples from three near earth asteroids. The current plan is to take three samples from each asteroid with the target sample size being approximately 300 grams for each sample. Detailed information on the Hera mission can be found at http://www.uark.edu/hera.

The most important piece of new engineering is the sampler mechanism. This mechanism will have to be reliable under many conditions and is subject to the following constraints:

1) The sampler cannot pose any danger to the spacecraft.
2) The sampler will have to work within a large temperature range.
3) The sampler must work in vacuum and at microgravity.
4) The sampler must be very, very reliable and return samples of adequate size.
5) The sampler must be resistant to the stress of exiting the atmosphere.
6) To minimize maneuvering needs and maximize the safety of the ship, the sampler must work quickly when in contact with the surface.
7) The sampler must use as little electricity as possible.

During the preliminary design phases many ideas were proposed. Proposed sampler mechanisms ranged from simple clamshell-type designs to auger-type designs, and even a ballistic design that blows debris off the asteroid and collects it in a sample container. Honeybee Robotics built a prototype of a design to be tested, consisting of two counter-rotating blades that pushed samples into a sample container. However, the design did not perform adequately under a microgravity test. Lockheed Martin Astronautics suggested a design with an auger bit on it. One of the main concerns with designs of this type is mechanical failure: if a blade or bit gets jammed or broken the mission will be a failure.

Analysis of an adhesive design: One of the most intriguing and promising designs is an adhesive sampler, primarily due to its simplicity. The sampling mechanism can be made reliably with current engineering methods. and can be made to work in a variety of conditions. One of the limitations of an adhesive design is that it has been used very sparsely on a commercial level. Two of the most common occurrences of this design in use today are lint rollers and sticky floor mats to remove dust from shoes. Another limitation of this design is that it has a limited sampling depth and will only pull from the surface of an asteroid. Since we do not know what the core of asteroids are made of, designing a sampler to return a core sample would be very difficult and hard to test. Thanks to the recent NEAR mission we have close up images of an asteroid and we can see that the asteroid is covered with dust. Information on the NEAR mission and its results can be found at http://near.jhuapl.edu/. Most of the scientists working on this mission agree that retrieving any type of sample from an asteroid will provide an immense amount of information to the scientific community. They also agree having a successful mission is more important than retrieving a core sample

Adhesives have been studied and used for bonding for well over half of a century [1]. A wide variety of information on adhesives can be found, but the amount and availability of useful information for space specific applications is very limited. Currently adhesives are not tested or developed for application at very low pressure and at low temperatures as previously there has been no need for this information. So, choosing an adhesive for this design is a difficult task requiring a lot of testing.

Currently there are 5 common types [1] of adhesives available, each with pros and cons: 2-part, 1-part, hot melt, pressure sensitive, and Ultraviolet cured. After careful deliberation, the first choice for an adhesive is the pressure sensitive adhesive (PSA) category. This will make the sampling mechanism as simple as possible. However, finding a PSA that will work under these conditions is not an easy task and will require much testing. Obviously the most important criteria in choosing an adhesive is finding one that works reliably and effectively under as many situations as possible.

Evolution of sampler mechanisms: From a design engineering standpoint, simpler is better. The fewer the things that can break the less chance there is of something breaking. The simplest design available is a flat round sampling pad (Figure 1). This will provide a very simple sampling mechanism and easy storage. This sampler has limitations because of size. This simple design does not provide a lot of surface area for the size. So, if the dust on the asteroid is very small, a pad of approximately half of a meter across will be needed to retrieve a sample of 300 grams. (Table 1) This could make the sampler prohibitively large and current sample container designs may not work with this large of a sampler. For this experiment a 12.7 cm adhesive pad (3M® 444PC) was pressed into an asteroid simulant with the pressure of 5-10 lb. for approximately 1-2 seconds.

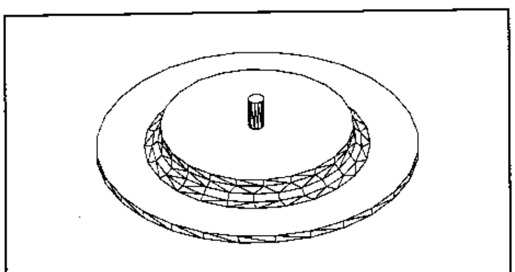

Figure 1 - Flat plate adhesive pad

One of the problems with this design is the limited surface area. That can be resolved by changing from a flat plate to a plate with cones protruding from it. This can increase the surface area by more than thirty percent thus giving the pad a smaller diameter. Another problem with this design is its inability to pick up a large rock that could be picked up, but not able to fit into a sample container. Presumably, the mission will be setup to ensure a proper site will be chosen to so that the sampler will have as flat a surface as possible to sample from. If that is not the case, however, other problems could occur causing the sampler to not retrieve a full sample.

Table 1 - Test 1 of flat round sampling pad

Sample	Area of Sampler (cm^2)	Sand (300-5000 μm) Sample Size (g)	Diameter req'd for 300g (cm)
1	126.68	16.71	53.81
2	126.68	19.07	50.37
3	126.68	17.34	52.83
AVG	126.68	17.707	52.28

An improved design that better handles some of the deficiencies of the flat sampling pad is a cylindrical sampling pad (Figure 2) that rolls along the surface of the asteroid similar to a lint roller. This will allow for more surface area in a smaller container. The mechanism will be slightly more complex because it has to be rolled along the surface. This design will also increase surface contact time slightly. Around the roller, a blade can be fitted at a nominal distance to remove any sample pieces that are larger than will fit inside the holding container. This design allows for more flexibility within the parameters because the length and diameter determine the surface area of the adhesive section of the sampler. Table 2 shows how the test roller type sampler worked under normal conditions. The tester had a 5.08 cm diameter and was 17.78 cm long.

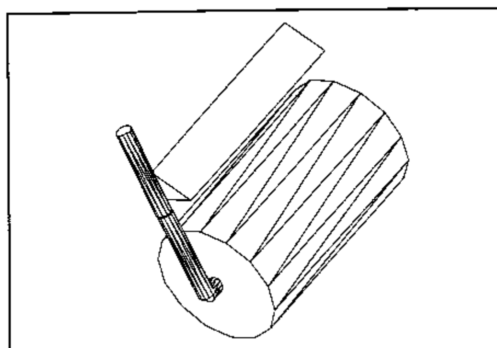

Figure 2 - Roller type design with blade

Table 2 - Test 1 of roller type sampling pad

Sample	Area of Sampler (cm^2)	Sand (300-5000 μm) Sample Size (g)
1	283.76	34.84
2	283.76	46.24
3	283.76	38.15
AVG	283.76	39.743

Currently: The adhesives that seem most suited for this application are acrylate adhesives. Two adhesives that are manufactured by 3M®, the 444PC and 950, have promising futures. The ability to find an adhesive that will fit the design parameters is a difficult and imperative task. The testing of adhesives and design of sampler mechanisms is still ongoing and continues to show progress and ingenuity. All options will be explored thoroughly and a definite solution will be found.

References: [1] Irving Skeist Ph.D. (1990) *Handbook of Adhesive, 2-38, [2]*