SAFE SAMPLE ACQUISITION USING A TETHERED HARPOON. Joseph A. Nuth III[1], Donald C. Wegel[2] and Walter F. Smith[3], [1]NASA Goddard Space Flight Center, Solar System Exploration Division Code 690 Greenbelt MD 20771 USA (joseph.a.nuth@NASA.gov) [2]NASA Goddard Space Flight Center, Aerospace Flight Systems Code 592 Greenbelt MD 20771 USA (donald.c.wegel@nasa.gov) [3]NASA Goddard Space Flight Center, Flight Structures Code 544 Greenbelt MD 20771 USA (walter.f.smith@nasa.gov).

Introduction: Obtaining samples from a wide range of solar system bodies is the next major stage of planetary exploration. Samples can be used for scientific purposes such as tracing the origins and evolution of small bodies, or for more practical purposes such as in situ resource utilization or asteroid mining. In most cases the surface of the object to be sampled is both poorly characterized and potentially dangerous. For the OSIRIS-REx asteroid sample return mission the team spent a year characterizing the surface of the 492-meter diameter asteroid Bennu to insure that the region selected for sample collection is likely to have material that can be ingested by the TAGSAM sampler and is safe for space craft operations. There are a large number of other proposed sampling devices in development or under study, ranging from simple scoops and shovels to much more complex coring drills. Each of these devices has specific applications where the device in question will provide an adequate solution to the sampling problem at hand.

We present the development of an alternative sample acquisition system that can obtain samples from specific interesting regions, such as deep in the vents of an active comet or from a surface under the gondola of a balloon-borne explorer on Titan or Mars, where scoops and drills are impractical. A harpoon-based sample acquisition system provides a means to rapidly collect samples at distances defined by the length of the tether system employed to retrieve the collection vessel. Such systems do not require landing on the unknown surface of the body to be sampled or a means to hold the spacecraft to the surface in low-gravity environments. A harpoon-based sampling system can be used in very rough terrain where landing would be dangerous. The time to acquire a sample using a harpoon could range from seconds to minutes, depending on the range to the surface, and is therefore compatible with a slowly moving science platform.

Our team developed a harpoon-based Sample Acquisition System (SAS) for a comet surface sample return mission that eliminates or minimizes many of the risks associated with the sampling system employed by the OSIRIS-REx mission. The sampling technique is very robust, able to collect samples from both solid ice and from highly under dense regolith, requires very little pre-characterization of the region to be sampled and poses no risk to the spacecraft from the sampling operation. The SAS has been developed to TRL 5+ over the last several years using internal funding from GSFC. We will bring this system to TRL 6 for use on both cometary and asteroid targets by testing the system over a wide range of analog targets and in a flight-like configuration at the GSFC Tower Test Facility using a high-pressure-helium, gas-powered launcher.

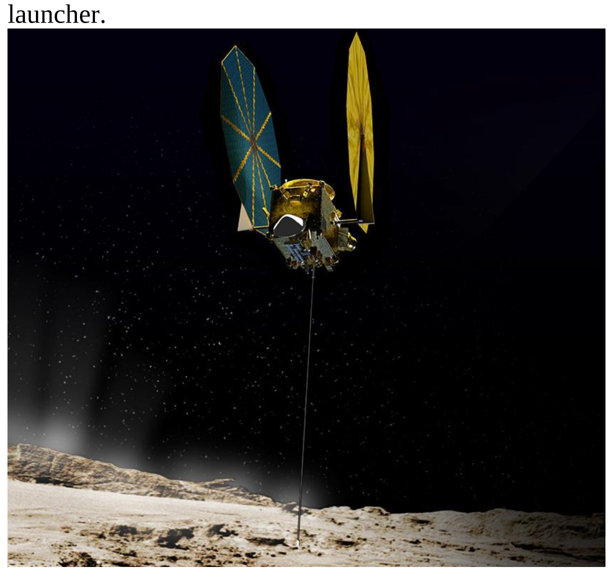

Figure 1. Deployment: SAS launch and sample collection at a comet.

System Characteristics: The SAS is the culmination of years of hardware development and testing at NASA's Goddard Space Flight Center. Sampling will be safely conducted in < 10 seconds, and without landing, using a tethered probe while the spacecraft remains up to 10 m above the surface. The SAS is designed to collect material down to depths of at least 10 cm, and possibly up to a meter in order to access primitive material that may be below the altered surface. The system will sample over an extensive range of surface strengths and local topographies, from snow to unconsolidated regolith and even solid icy material. The system has been tested in fine, powdered snow up to 2.5 MPa Foam Glass.

Operation Concept: The spacecraft commands the launch of the SAS at ~10 m. The Launcher accelerates the Sample Acquisition Retrieval Projectile (SARP) to penetrate >10 cm into the regolith. (Figure 1) The SARP Outer Sheath bears the impact forces and breaks up material for ingestion. Under-dense material is compressed to fill the sample cartridge. The SARP comes to rest through comet resistance, retraction system braking, or both. (Figure 2)

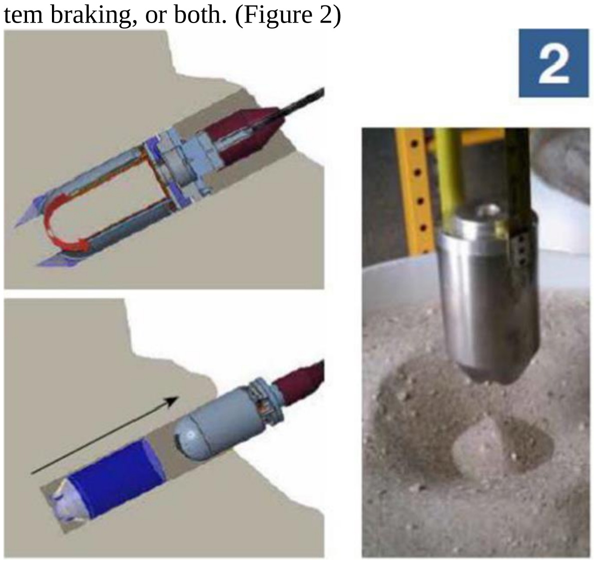

Figure 2. Acquisition: SARP penetrates & captures regolith (top). Outer sheath decouples and inner sheath returns to spacecraft (bottom). Testing the SARP in the Tower Test Facility (right).

The SARP door closes and decouples (T=1–2 s). A timer closes the Cartridge door, cutting through material and fully encapsulating the sample. Another timer separates the Outer Sheath from the Inner Sheath, providing a well-understood friction force for removal.

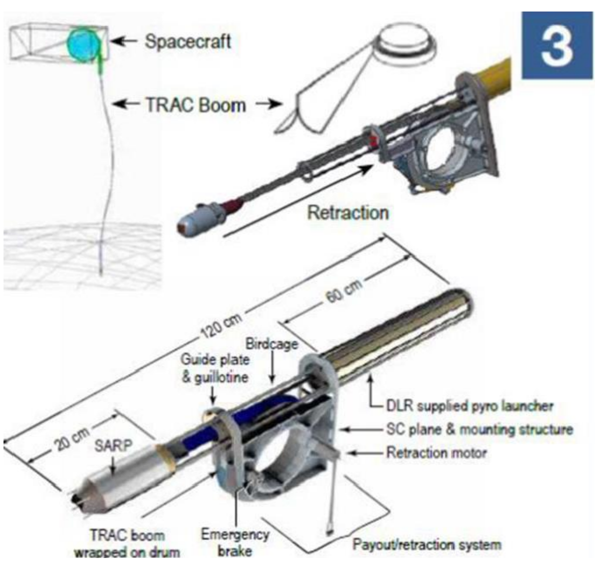

Figure 3. SARP is retracted to the spacecraft.

The Retraction System controls the SARP return to the end of the Launcher to avoid buckling. The SARP is mechanically grounded at the end of the Launcher. The ADAMS model (inset, Figure 3) was used to analytically verify buckling margins.

Figure 4. SARP Rotation to expose Robot interface

A final timer actuates the flip hinge, rotating the Cartridge and Inner Sheath away from the TRAC boom decoupler plate and exposing the clean interface to the robotic arm (Figure 4).

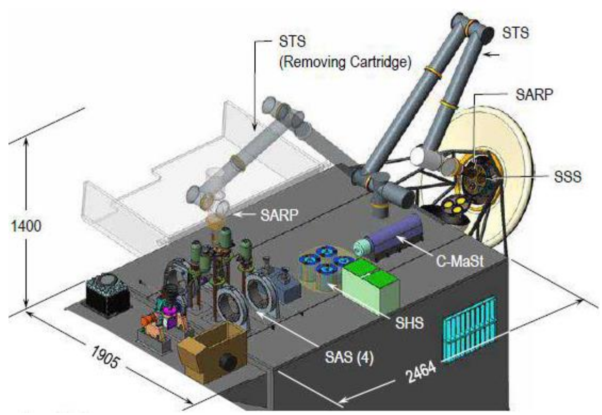

Figure 5. Robot Arm (RA) collects sample cannister from retracted SARP and takes it to the Sample Handling System (SHS).

A ground-commanded sequence takes a set of inspection images. Once downlinked and reviewed, a ground-commanded sequence has the RA grasp the KINEE interface and remove the SARP from the Inner Sheath. The STS is robust to multiple failures. A ground-commanded sequence continues by moving the SARP to the SHS (and later to the SSS after devolatilization [shown]). The RA releases the SARP once torque feedback verifies SHS (SSS) insertion. A final ground-commanded sequence takes a set of inspection images and returns the RA to the home position.