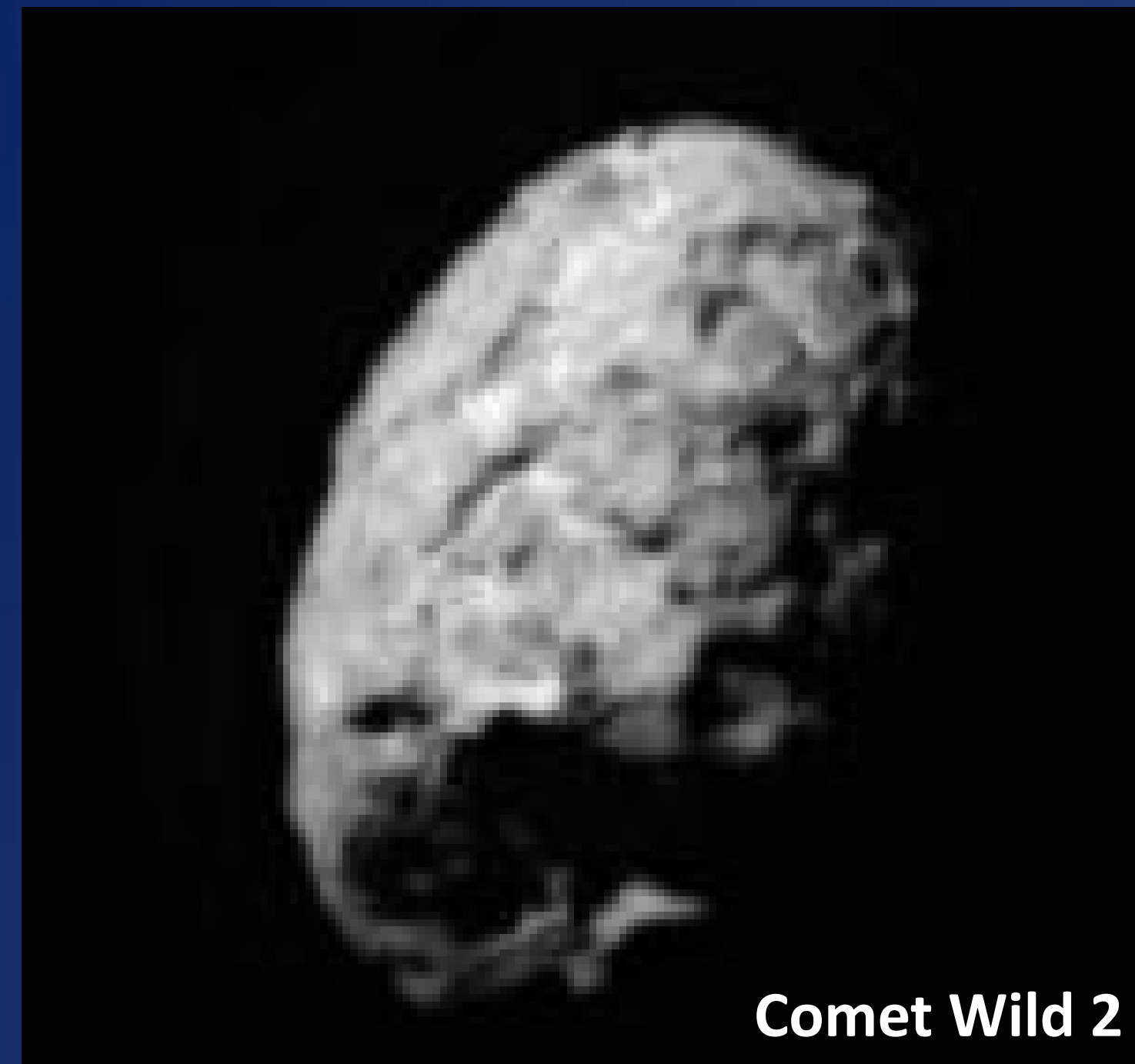
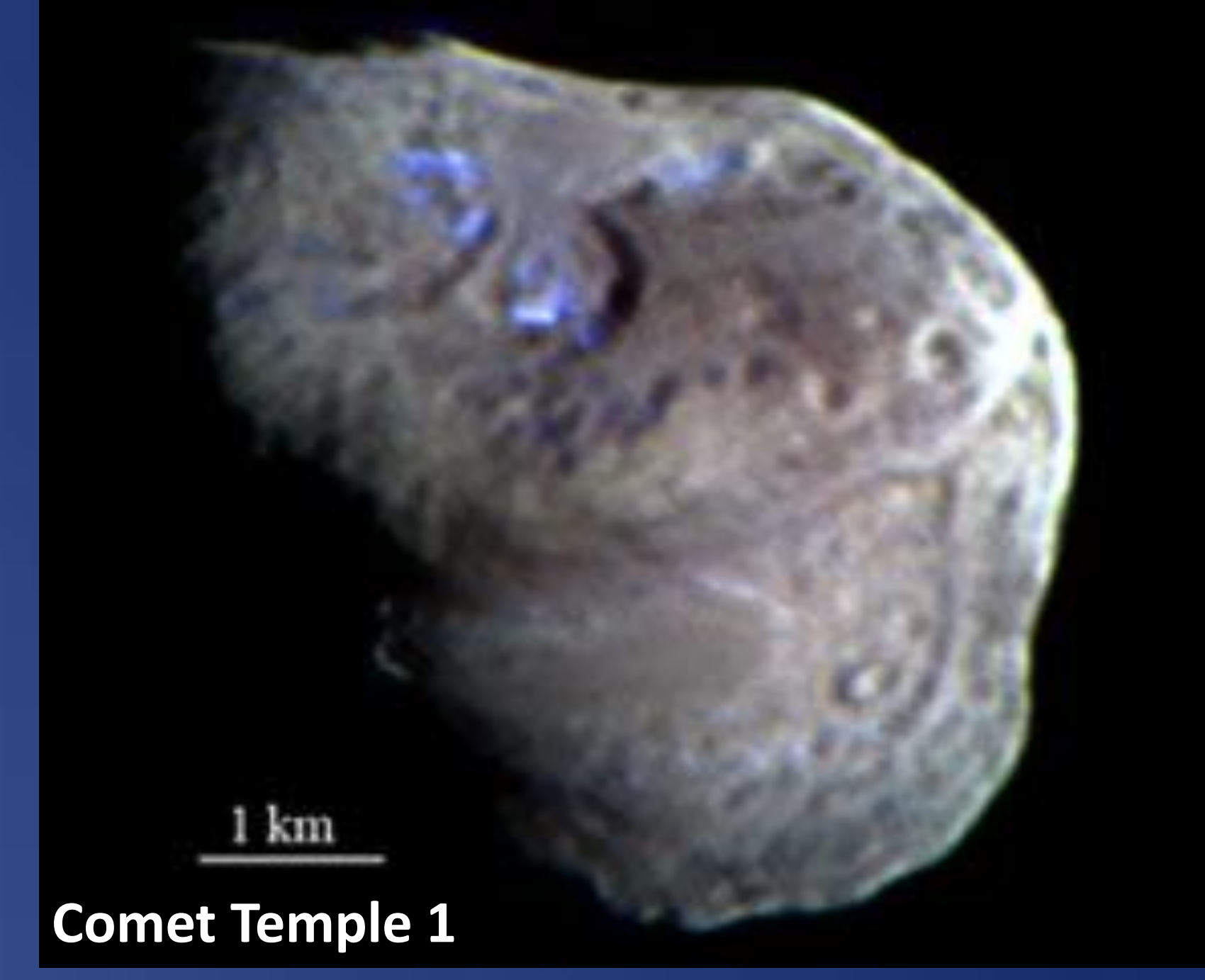


# Rapid Sample Retrieval System (RaSaRS) for Comet Nucleus Sample Return

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Comet Wild 2



Comet Temple 1

## Projectile-based Sample Acquisition System

We are developing fundamental technologies for a Projectile-based Sample Acquisition System (SAS) that can be used to obtain samples from 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, locations where scoops and drills are impractical. A projectile-based sample acquisition system provides a means to rapidly collect samples at distances defined by the length of the tether retrieval system. The tether in this case is highly specialized and designed to act flexibly during launch, but become stiff upon retrieval. This design allows sample retrieval in situations and locations most other concepts cannot access. Our system will not require landing on the surface to be sampled or a means to hold the Lander to the surface. The time required to collect a sample using a projectile could be quite brief (ranging from seconds to minutes), and is therefore compatible with a slowly moving science platform.

We have developed a 3<sup>rd</sup> generation sample collecting projectile that can rapidly collect samples from targets of varying densities. The prototype is made up of an outer harpoon sheath and an inner sample cartridge (Figure 1-3). The sheath protects the sample cartridge from the forces imparted during launch and impact. It also contains the tip geometry that allows optimized penetration and flukes (not shown) that help control its penetration. The sample cartridge contains the mechanisms that allow sample capture, coupling/decoupling from the sheath, and sensors that will detect temperature and acceleration among other data. After the projectile is fired, penetrates, and captures a sample, the sample cartridge will be retrieved, leaving the outer sheath behind. This has several benefits that include the ability to create a tunnel that is larger than the sample cartridge, which allows sample collection with less likelihood of jamming; It also allows us to leave behind sensors in the target which can be used in many interesting ways.

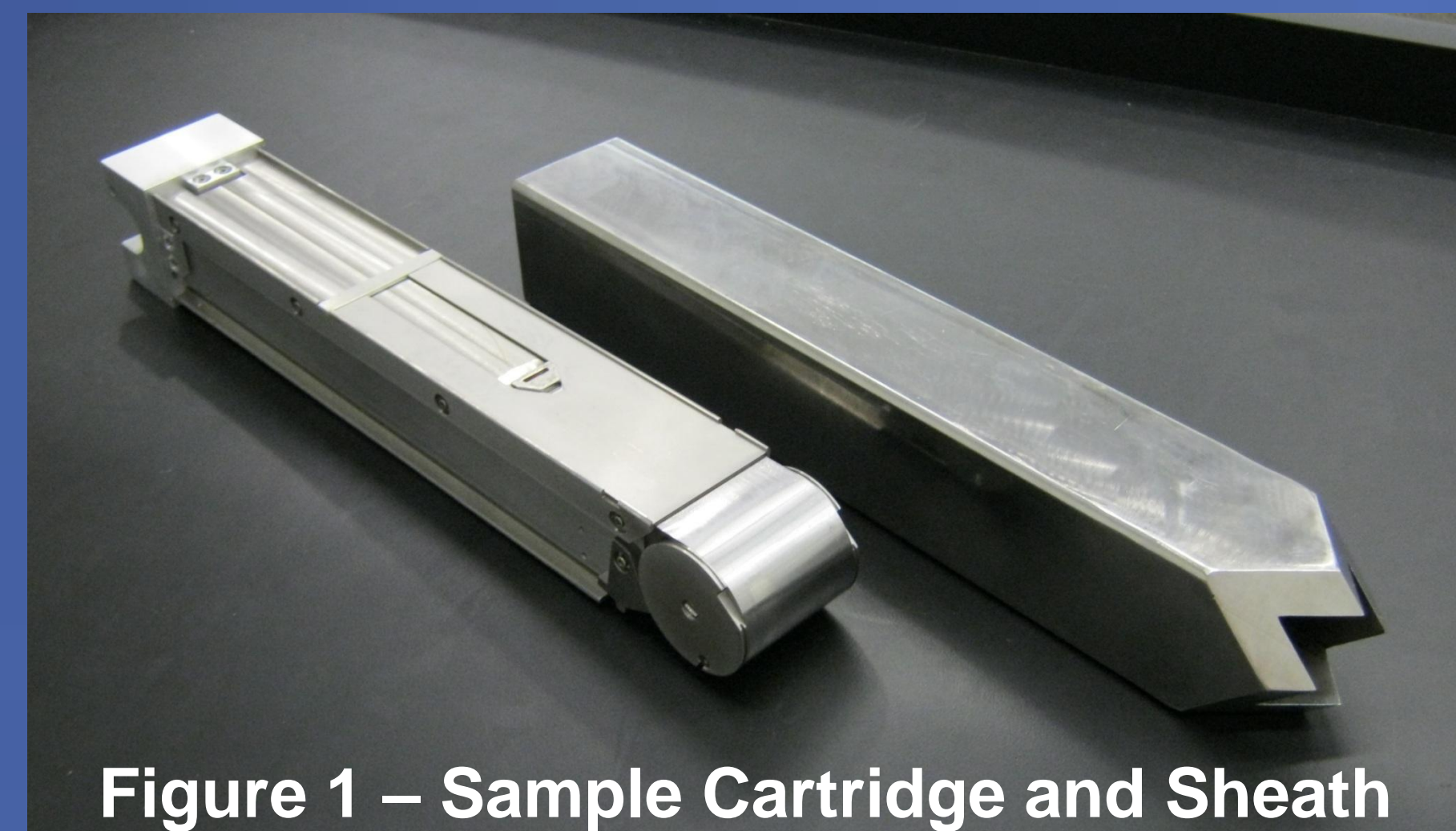


Figure 1 – Sample Cartridge and Sheath

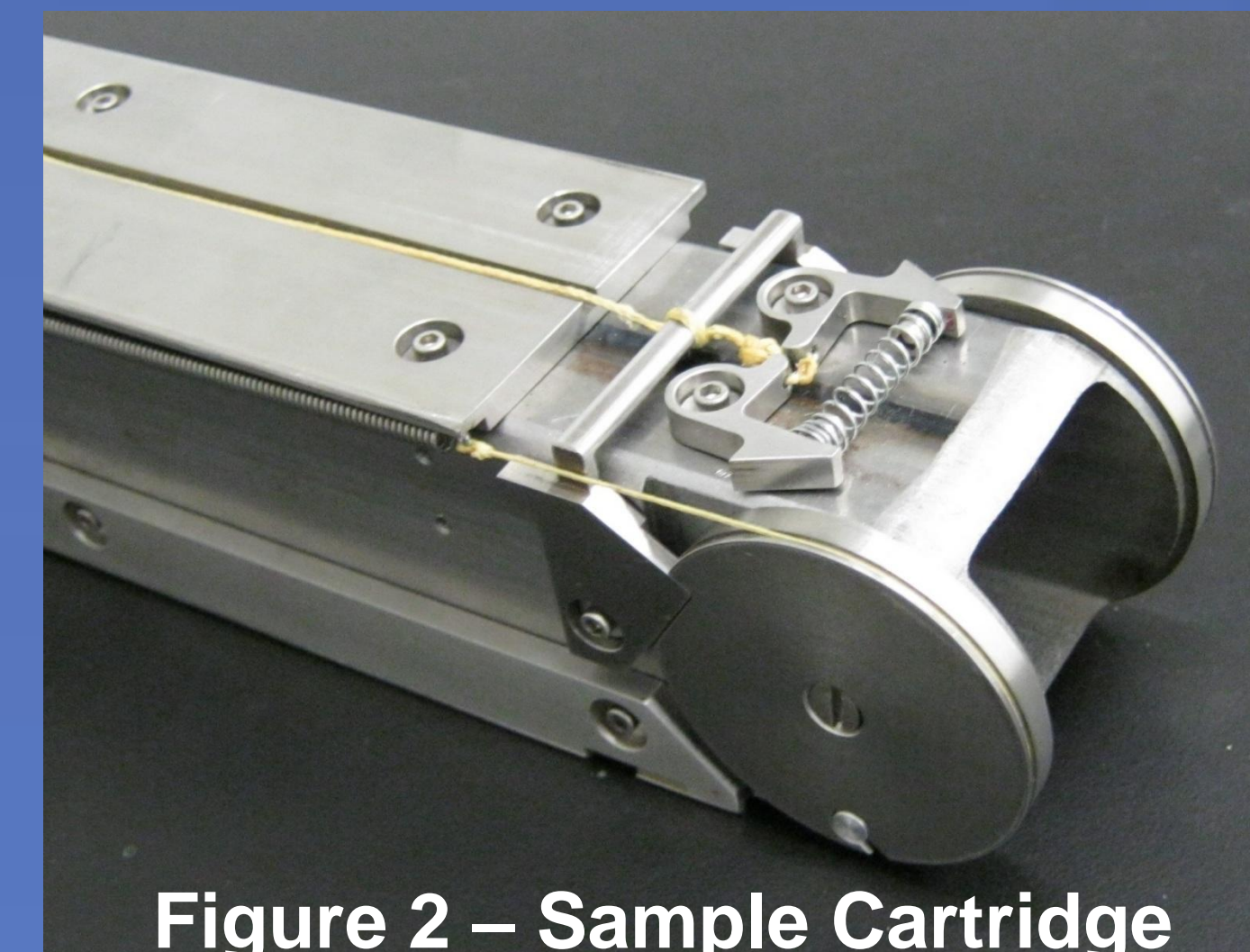


Figure 2 – Sample Cartridge



Figure 3 – Sheath



Figure 4 – Ballista Test Bed



Figure 5 - Projectile Tower Test Facility (TTF)

The ballista test bed has been relocated to the top platform of the Tower Test Facility (TTF) at the Goddard Geophysical and Astronomical Observatory (GGAO). The facility is comprised of a 20' tall concrete tower, with a steel I-beam exoskeleton. When the construction of this facility is complete, we will have the capability to study longer range projectile based sample acquisition systems along with tether dynamics, payout, and retrieval methodology, which will allow Goddard to be a leader in the development of sample retrieval instruments.

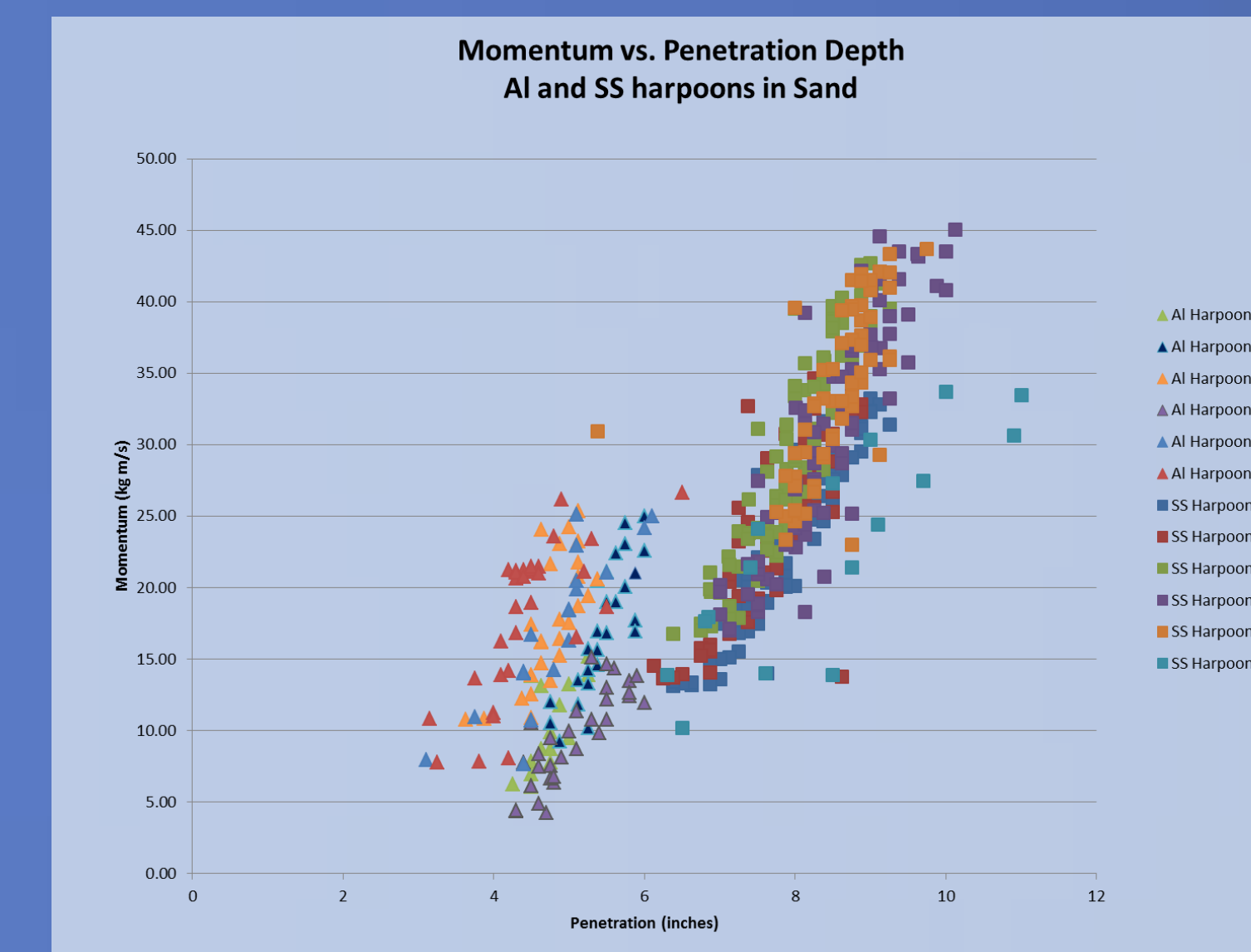


Figure 6 – Momentum vs Penetration  
This graph clearly shows how momentum dominates a projectile's penetration.

After a sample retrieving projectile (SaRP) is fired and has captured a sample, the next challenge is retrieving the inner sample cartridge back to the spacecraft and stowing it in the return capsule. Conceptually a tether system, telescoping boom, or robotic arm can be used for the back end of the retrieval system. Along with the development of the TTF, we are researching the best combinations of these methods through design studies, which leverage Goddard's engineering experience in mechanisms and robotics.

In order to study different projectile designs and correlate the amount of energy required to penetrate different materials to specific depths, a test bed was designed and built to collect this data. Conceptually, the actual mission will use a cannon to fire the sample collecting harpoons, but we developed a safer alternative for laboratory use that does not use explosives. (See Figure 4.) A ballista, or large cross bow, allows us to correlate imparted energy with penetration depth.

After studying the fundamental behavior of hollow projectiles we learned which design aspects were most effective in the penetration of low to medium density target materials. We tested projectiles with a range of different characteristics including cross sections, mass, material, and tip geometry. The data we collected clearly shows that a projectile's momentum is the most important aspect in terms of penetration, while the tip geometry is not nearly as important as expected. We studied the momentum required for sample collecting projectiles to penetrate specific depths in well-characterized media such as sand, pea gravel, vermiculite, organic kernel, and rock salt. Our experimental results have led us to design projectiles that are not light weighted and instead made of high density, high strength, high hardness materials. (See Figure 1-3.) This conclusion is corroborated by research done by William W. Anderson and published in the Journal of Geophysical Research [1]. The effect of cross section is straight forward; larger cross sections require more energy and are less effective in penetration. However, this fact must be balanced with the need to package required mechanisms, motors, and sensors into exceedingly small volumes. We have prototyped some of the mechanisms (Figure 2) involved in sample capture and cartridge coupling and studied their effectiveness.

Originally, the concept was to land on the surface of the comet or asteroid before firing a sample retrieving projectile, however the information gathered from OSIRIS –Rex studies has concluded it is necessary to limit the spacecraft's proximity to the comet due to the large and delicate solar arrays needed for such a mission. This has led us to design a SAS that is capable of firing and collecting a sample from greater distances and therefore manage tether dynamics, payout, and retrieval in a more challenging environment. The TTF (figure 5) will allow us to study these issues, gain confidence with tether behavior, and design a robust SAS. Although we have studied high speed footage of simple tether behavior and matched our analytical models to these tests, it is important to conduct increasingly realistic tests on a series of more sophisticated retrieval systems.



## Sample Acquisition System (SAS) X-Section, Firing and Retrieval Sequence

