MICRO-PENETROMETER SCIENCE INSTRUMENT FOR SMALL BODIES. V. Hernandez[1], S. Schwartz[1], E. Asphaug[1], and J. Thangavelautham[1], [1]Space and Terresterial Robotic Exploration (SpaceTREx) Laboratory, School of Earth and Space Exploration, Arizona State University, 781 E. Terrace Mall, Tempe, AZ, 85287, jekan@asu.edu.

Introduction: Asteroids and comets hold tantalizing clues to the formation history of our Solar System as well as to the origins life. They are also potential sources for water and off-world resources. Asteroids and comets range enormously in size and surface properties, and it is important to determine the specific environment in advance to ensure a safe landing and to conduct in-situ exploration, resource exploitation or for near-Earth object (NEO) hazard mitigation. Images of asteroids, even those at very high resolution such as those taken of Itokawa by the Hayabusa spacecraft [1], can give clues to the surface properties and composition, but due to various complex deposition and layering processes, some of this data can be deceiving given our current limited understanding. Use of an instrument to physically interact with an asteroid or cometary surface and obtain its hardness and other physical properties can provide valuable insight for landing, risk assessment, or for in-situ resource extraction.

Penetrometer: A suitable instrument to perform this task is a micro-penetrometer. A penetrometer was flown on the Cassini Huygens probe to estimate the surface hardness of Titan [2]. Percusive penetrometers are in development for lunar surface missions [3]. A micro-penetrometer is an instrument that consists of a rod with a conical tip that is pushed into regolith. The rod is mounted with force sensors. By pushing the rod into the regolith and measuring the reactive forces, it may be possible to determine the granularity, the porosity, the hardness, and the chemical composition of the top layers of the asteroid surface. In our present work, we are developing a penetrometer that would fit into a 1U CubeSat body. The penetrometer could be pushed into place using linear actuators that can be readily space-qualified.

Asteroid Missions: An important advantage of the penetrometer as a science instrument for a small (~0.1–1 km diameter) asteroid mission is that it can be used in touch and go exploration, where a spacecraft has brief encounters with an asteroid surface (Fig. 1), but due to the very low gravity, does not land. Touch and go operations, demonstrated in the Hayabusa mission [1] and to be used by OSIRIS-REx and Hayabusa-2 sample return missions, require low-delta V and limits risk when the surface properties of an asteroid are unknown. Repeated touch and go operations can enable sampling of the asteroid surface to determine relative hardness and distribution of surface material.

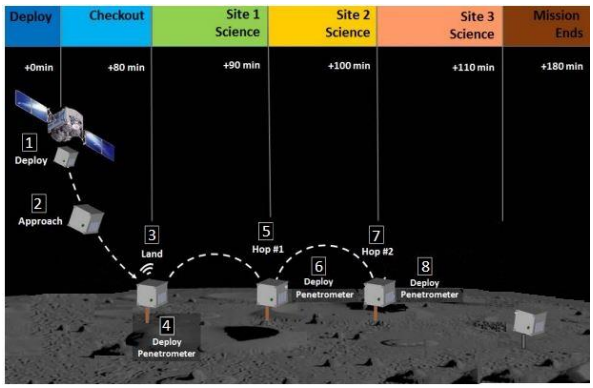

Figure 1: Penetrometers can be used on low-cost NanoSat sized asteroid surface explorers to obtain readings of hardness, porosity and granularity. This data can be used to reduce risk of landing a large spacecraft.

The data obtained from a penetrometer are not readily obtained from imagers, due to surface ambiguity (e.g. porous crusts, aggregate clods, etc.) and will allow for an assessment of surface properties prior to more ambitious engagement with the surface. In this work, we propose use of a penetrometer for a touch and go microsatellite mission to an asteroid and for use on nanosat-sized asteroid surface explorers. Microsat missions offer the possibility of getting to an asteroid, performing touch and go operations and obtaining samples. Nanosat sized surface explorers can be sent by the tens or hundreds to image the surface and characterize surface properties. These surface explorers would hop, roll and fly over the asteroid. In both cases, a penetrometer would be an important instrument that would complement the capabilities of onboard imagers and spectrometers.

Prototype Development: A prototype penetrometer is being built in our laboratory (Fig. 2) and is being used to characterize the properties of fine to coarse grain material and soft rock (Fig. 3). Next steps include testing the penetrometer on asteroid simulant.

Figure 2: Penetrometer Prototype.

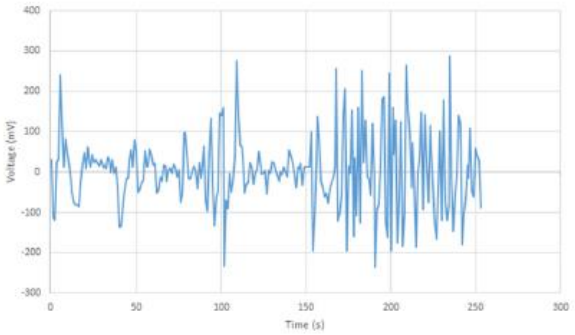

Figure 3: Preliminary readings of a penetrometer tested using sand and gravel mixture.

Deployment shown in Fig. 1 includes repeated touch and go attempts with small delta-V to keep the spacecraft engaged at the point of contact of the penetrometer. These results will be compared against computer simulations and conventional hardness testing of materials. Our laboratory development paves the way for further refinement of the instrument and flight qualification aboard an Asteroid science laboratory such as AOSAT [4], in preparation for an asteroid surface mission.

References: [1] Fujiwara A. et al. (2006) Science 312, 1330–1334. [2] Zarnecki J. et al. (2005) Nature 438, 792–795. [3] Bar-Cohen Y. and Zacny C. (2009) Extraterresterial Drilling and Excavation, 400–410. [4] Asphaug E. and Thangavelautham J. (2014) 45th LPSC, 2306.