PLANETARY OBJECT GEOPHYSICAL OBSERVER (POGO): A NEW APPROACH TO SMALL BODY LANDED SCIENCE.

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Introduction: The exploration of small bodies, including asteroids, comets, and small planetary satellites, has progressed beyond the stages of purely flyby and orbital studies (e.g., by *Galileo*, *Deep Space 1*, *Cassini*, *NEAR*) to include acquisition of contact science measurements and of samples for return to Earth. Detailed measurements of elemental and mineralogic abundances, isotopic abundances, and the abundances and forms of carbon and volatiles are required to address fundamental questions about the origins and geologic evolutions of small bodies [e.g., 1,2,3]. Thus, collecting a comprehensive set of composional measurements is a high priority for future exploration of small bodies. *Rosetta* included several types of *in situ* compositional measurement, whereas *Stardust*, *Hayabusa*, *Hayabusa 2*, and *OSIRIS-REx* each have the objective of returning some amount of sample to Earth.

A landed package provides a means of obtaining a comprehensive suite of compositional measurements for a mission where cost or mission design precludes return of sample to Earth. A first-order technical challenge is deployment and stability of this package on a body with mill-g or smaller graviational acceleration. We address this technical challenge with a lander concept that fits within the cost envelope of NASA *Discovery* or *New Frontiers* missions, the Planetary Object Geophysical Observer, or POGO (Fig. 1). This development was begun under IR&D funding at APL, and was selected for a 2-year development under NASA's Homesteader program. POGO is targeted for maturation to TRL 6 by Sep. 2017.

POGO Overview: POGO is designed for ballistic emplacement on a target body from 3 km or more in altitude, to survive landing at 5 m/s terminal velocity, and to achieve its core objectives from any landed orientation. No tethering system is required to hold POGO to its target body. The package is tablet-shaped with rounded edges, designed to come to rest on either of two flat faces after bouncing to rest (Fig. 1).

The science instrumentation is chosen to provide a comprehensive investigation of abundances of 20 key major and minor elements that are diagnostic of the origin, provenance, and evolution of primitive, carbonaceous compositions, using a gamma-ray spectrometer (GRS) and an alpha particle X-ray spectrometer (APXS). The GRS uses a low-mass scintillator design developed and matured to TRL 6 under APL IR&D funding [4]. Deploying GRS to the surface, for several days of operation, yields several times larger signal than the threshold for meaningful compositional measurements from orbital altitude (≥10 days inside 1 body radius altitude from the surface [5]). APXS uses the design of the *Rosetta* APXS [6] except with an alternate door mechanism that is operated electrically. Its stimulation of X-ray emissions by a ^{244}Cm source avoids the dependence on solar flares for measurements of many elements by passive X-ray spectroscopy, and enables X-ray spectroscopy to be employed beyond the asteroid belt using only hours-long measurement baselines. GRS is omnidirectional and a single sensor is located inside the lander. One APXS is included on each of the two flat faces of POGO.

POGO's structure is build around a Ti cage that withstands landing shock. The cage houses avionics boards, and encloses upward- and downward-pointed APXS sensors and a voice coil that provides mobility. Power comes from primary batteries outside the cage that support 5 days of landed operation. Communication with the carrier spacecraft is by a UHF antenna.

Concept of Operations: The carrier spacecraft deploys POGO at altitude, and POGO free falls to the asteroid surface. Bouncing is expected, and after several bounces POGO comes to rest on a flat face. A preprogrammed measurement sequence is initiated once motion stops. GRS data collection is initiated, and a 24-hr APXS integration is begun. As data are collected and stored, they are transmitted on a repeating loop to the carrier spacecraft which remains in orbit. After 24 hrs of operation the voice coil is energized, the reaction causes POGO to "hop" a distance of meters or more depending on the target body's gravity and regolith properties, and the measurement sequence is repeated. Hops are initiated every 24 hrs to ascertain composition heterogeneity of the target body.

Tolerance of Landed Orientations: The tolerance of POGO to operation on a realistic asteroidal surface was evaluated using the techniques of Ernst et al. [7]. In a Monte Carlo simulation, an asteroidal surface was simulated by extrapolating Eros' block size-frequency distribution to smaller sizes, using hemispherical caps as proxies for boulders. Starting with POGO in an random orientation, a model of the spacecraft is lowered onto the surface in a random location until it comes to rest on 3 points (Fig. 3). Over 100,000 simulated landings, 99% have the downward-pointed APXS coming to rest with its aperture within the required 10-cm line-of-sight distance to rock or soil for high signal-to-noise ratio measurements.

Technology Development Strategy: POGO has been funded through the NASA New Frontiers Homesteader grant to perform various risk reduction tasks. We are performing relevant environment testing of a fully integrated system, and updates to the mobility mechanism, radio frequency communications (RF) subsystem, and structural design to increase hop distances and communications range to the carrier spacecraft and reduce landing loads on the structure. The new RF design was completed, with the antenna moving from the rim to the top and bottom plates of POGO to ensure communication through dust and better attachment to POGO. The structural analysis has been completed, and the mechanical design was updated to reflect higher loads during landing. The top and bottom plate material is in the process of being selected, with Nomex, aluminum honeycomb, and foam being strong candidates. We perfomed drop tests to 6 m/s that are informing the selection. We are setting up life tests for a variety of battery chemistries, and preparing for Zero-G weightless flight testing in November 2016.

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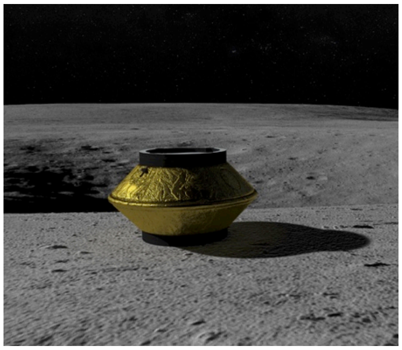

Figure 1. Artist's conception of POGO at rest on the surface of a target asteroidal body.

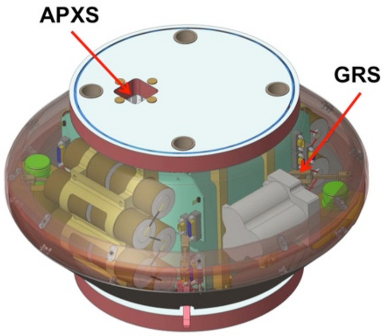

Figure 2. CAD rendering of POGO design with the outer shell and thermal blanket transparent, showing the locations of the GRS and APXS.

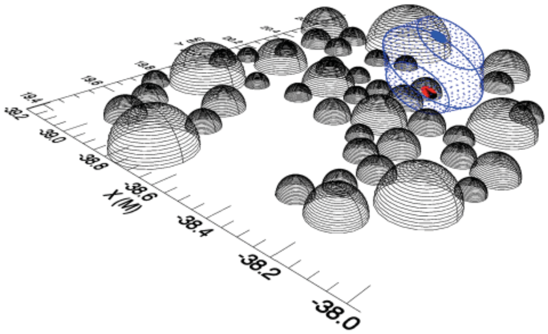

Figure 3. CAD rendering of POGO (in blue) at rest in a block field on its target body, showing the location of the APXS aperture (in red).

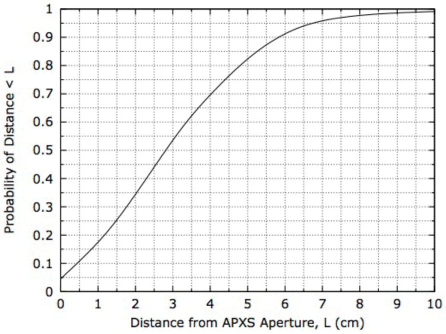

Figure 4. Cumulative probability of the APXS aperture being within a given working distance, over 100,000 trials of a Monte Carlo simulation.