SMALL BODY IN-SITU MULTI-PROBE MASS ESTIMATION EXPERIMENT (SIMMEE). J. Atchison[1], R. Mitch[1], C. Apland[1], L. Kee[1], [1]Johns Hopkins University Applied Physics Laboratory (11100 Johns Hopkins Road, Laurel, MD, 20723-6099, Justin.Atchison@jhuapl).

Introduction: We explore a concept and instrument for improving our ability to resolve the mass of asteroids and comets during flybys or orbital phases. In this concept, called OpGrav, a host spacecraft releases a group of small white spheres, which it then tracks using an on-board telescope. The spheres, called probes, are deployed such that they pass very near to the small body, and their trajectories are measurably perturbed by the body's gravity. The spacecraft-mounted camera determines the relative measurements of the probes, including right ascension and declination angles with respect to the host spacecraft using background stars. These measurements are then processed on the ground and used to estimate the body's mass. These measurements have the advantages of a high signal-to-noise ratio and a high resolution, owing to the short distance between the host spacecraft to the spheres and the spheres to the body. They are also diverse and numerous, since multiple probes can be deployed to different relative geometries. These benefits enable the accurate determination of mass for bodies that are too small to study using typical ground-based radiometric tracking.

Applicability: The concept is evaluated in a modeling and simulation environment, which includes high-fidelity acceleration models for the small body's gravity, planetary gravity, and solar radiation pressure. The simulation results show meaningful performance during typical flyby scenarios (many kilometers per second) for asteroids as small as 1 kilometer in diameter. Current radiometric techniques require much more massive asteroids, even for missions that are willing to have their spacecraft come very close to the small bodies of interest. The population distribution of asteroid sizes follows a power-law (a larger number of asteroids at smaller sizes). Therefore, this technique greatly increases the number of asteroids that we can collect meaningful scientific gravity information on.

Operations: This approach also enables a greater degree of operational flexibility. Accurate estimation of the small body's mass requires that the host spacecraft pass close enough to the body that the gravitational tug (scaling to first order as the inverse of the distance squared) causes a measureable change in the host's trajectory. In OpGrav, the close approach requirement is instead fulfilled by the probes, and the mass is estimated by tracking their motion in time. There is an additional mission constraint of probe tracking, but this is a benign constraint because there is no requirement of probe tracking during the close approach phase of the small body flyby. Tracking is required for a short period of time following probe deployment (several hours) to fit out initial probe positions and velocities, and an amount of time post-flyby (up to several days) to fit out their perturbed states.

Hardware Design Drivers: The simulations indicate that the measurement success is highly dependent on the deployment accuracy of the hardware (how well one can aim the probe's deployment) and post-deployment knowledge (how well can one determine what the probe's deployment velocity and timing was). The deployment accuracy is important because it determines how close the probe can pass by the body in addition to the observational geometry. Post-deployment knowledge is important because it bounds the estimation problem's *a-priori* uncertainty.

These effects drive the hardware design, requiring an accurate dispenser with a means of measuring the deployment velocity. The hardware implementation of this concept is called the Small Body In-Situ Multi-Probe Mass Estimation Experiment (SIMMEE), and it is being developed on a NASA Innovative Advanced Concepts (NIAC) grant.

Hardware Design: The instrument consists of a dispenser, a probe, and a sabot (Figures 1 and 2). The sabot houses the probe inside the dispenser. The probe is designed to fold compactly into a thick disc. Doing so allows more probes to be stored in a given volume. The probes and sabots are loaded into independent dispenser bays. The bays contain a precompressed spring, which when released via a pin-puller, dispenses the sabot/probe assembly at a predetermined rate of up to 5 m/s. The spring system is designed to accommodate long mission lifetimes (5+ years) while under compression.

The probe deployment state is measured using an LED emitter and detector pair, which is positioned to protrude outside the dispenser. The detector's output is measured to record when the sabot breaks the optical path, and the duration of the blockage. Given a known sabot diameter, this gives an estimate of the deployment speed to within 1 mm/s (1 sigma).

Focus: This research focuses on the key implementation challenges, including a practical concept-of-operations that is consistent with deep space missions. It also evaluates the instrument hardware implementation for the probes and their dispenser, including a test campaign to increase its technology readiness.

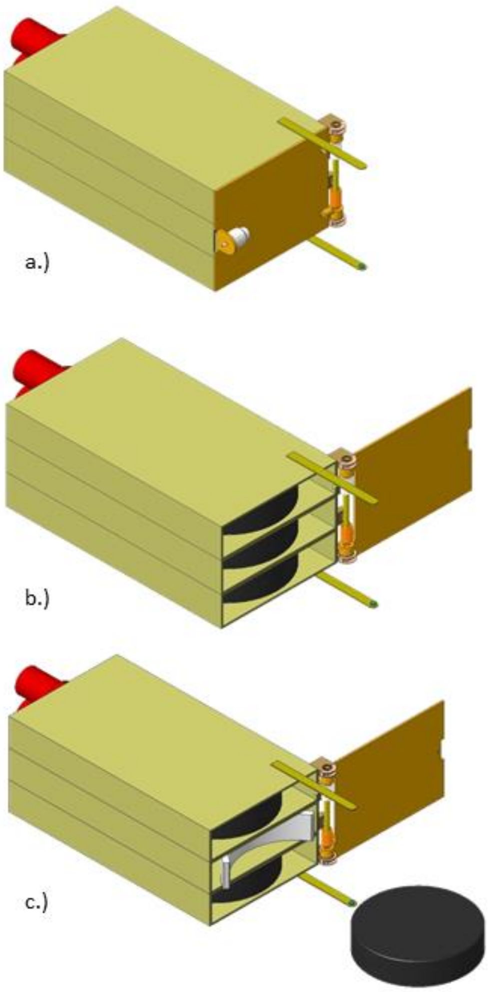

Figure 1: a.) The dispenser assembly is housed inside a single door. b.) The door opens with a pin-puller. c.) The probes are dispensed from independent slots, each of which contains a spring. The two protruding arms contain a LED emitter/detector pair used for velocity and timing measurement.

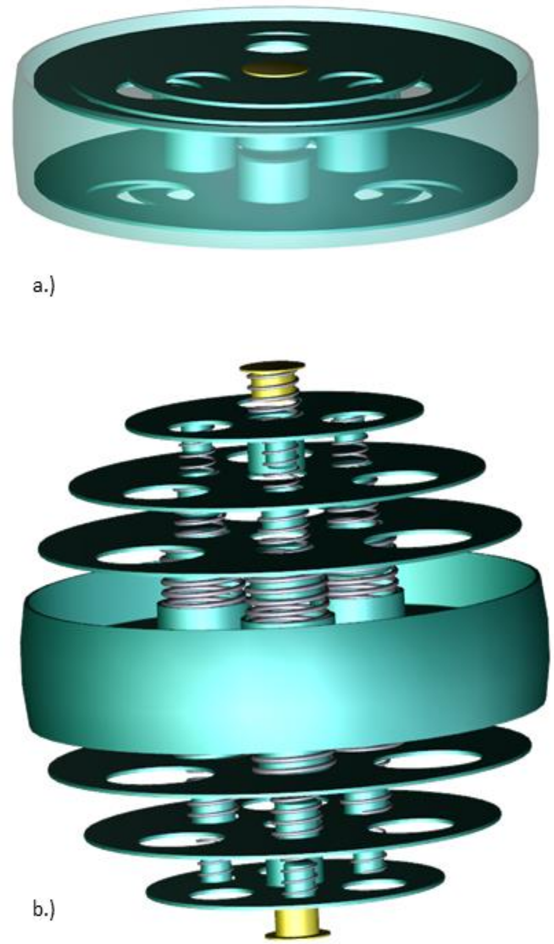

Figure 2: a.) The probe folds compactly into a thick disk. b.) The probe unfolds into a spherical shape using a set of springs. Dissimilar metals prevent stiction during the long mission life. The structure (as shown) is covered with white Beta-cloth for long-range detection in visible bands.