A FEASIBILITY STUDY ON THE CHARACTERIZATION OF THE INTERNAL STRUCTURE OF SMALL NEOs WITH SMALL SPACECRAFT. C. Church[1] and R. Fevig[1], [1]Department of Space Studies, University of North Dakota, 4149 University Avenue Stop 9008, Grand Forks, ND 58202.

Introduction: There are more than 9000 known Near-Earth Objects (NEO) and more are continually being discovered. The majority of these are small asteroids less than 1 kilometer in diameter. Despite their numbers, little is known about the internal structure of these objects. Many are considered "rubble piles" while others may be shattered bodies, or even monoliths. Ground-based observations of NEO are not suited for extensive studies of the internal structure of these objects. Detailed information regarding the internal structure of an NEO requires in situ observations.

This work addresses methods that can be used to characterize the internal structure of small NEOs through in situ measurements using small spacecraft. Because of the complex gravity fields associated with these small bodies, it is questionable whether techniques that have been successfully applied to larger targets are applicable to small NEOs. For this study, the objects being considered are roughly 500 m and smaller.

Two indirect methods of sensing the internal structure of an NEO are being considered. The first method tracks a single spacecraft in orbit around a small NEO, while the second method tracks the relative separation between two spacecraft as they orbit the NEO. The data generated from each of these methods is used to map the object's gravity field. Variations in the object's gravity field result from a non-uniform mass distribution within the object, and are therefore related to the internal structure of the object. The question this work will answer is whether or not either of these methods is capable of resolving variations in a small NEO's gravity field to the extent that it can be used to back out the internal structure of the object. Each of these techniques has been successfully demonstrated on past missions including NEAR, GRACE, and GRAIL. However, in each of these cases, the subject was significantly larger then the objects being considered for this work

Method: AGI's Satellite Tool Kit (STK) software is being used to model the orbits of small spacecraft in close proximity to NEOs, and is producing simulated data for each method being considered. STK's High Precision Orbit Propagator (HPOP) is being used to numerically integrate the equations of motion, which include the perturbations caused by solar radiation pressure (SRP) and gravitational interactions with other major solar system bodies. The inclusion of these effects will serve as the noise in the simulated data.

Asteroid 25143 Itokawa is currently being used as the central body for developing this STK simulation. The basic shape model being used is a triaxial ellipsoid with dimensions 0.27405 km x 0.1561 km x 0.13755 km. These values were calculated from the overall dimensions of 0.5481 km x 0.3122 km x 0.2751 km [1]. The rotational period for Itokawa is 12.132 hours according to ephemeris data available from JPL horizons [2]. The gravity model includes the spherical harmonic coefficients to degree and order 4 have been calculated in [1]. Figure 1 shows three screen shots from a preliminary simulation that was run to test this software. It shows the relatively rapid divergence of two nearly identical orbits.

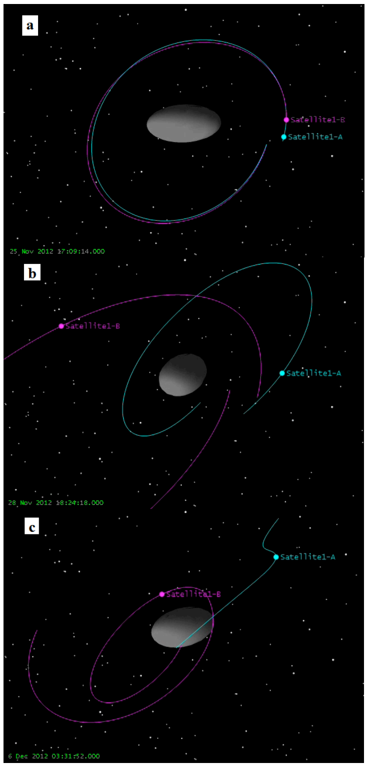

Figure 1 – Three screenshots which show the rapid divergence of two spacecraft orbits in close proximity to a rotating model of 25143 Itokawa. (a) Initial configuration showing two spacecraft in the same orbit in close proximity to one another. (b) Approximately 73 hours later both orbits have diverged significantly. (c) Approximately 250 hours later one of the spacecraft has escaped the system.

Using the data described above, numerous simulations using a variety of orbital parameters will be run. From these, data commensurate with each of the techniques being considered will be generated. These data will then be used to estimate the gravity coefficients for the simulated NEOs using software provided by the Space Geodetic Application Group at NASA Goddard. A comparison between the estimated gravity coefficients and the published values used to create the simulation [1] will be used to validate the simulation's output. Upon validation of the output, the capabilities and requirements for each method will be analyzed and compared to simulated tracking data to determine if flight proven payload elements are capable of attaining the required gravity-field resolution.

The results of this analysis will provide an estimate of the quality of gravity field measurements that can be obtained by a small spacecraft in close proximity to an NEO. This will inform requirements for an NEO assessment mission. By comparing these requirements to the capabilities of existing technology, conclusions can be made about whether the techniques considered are useful for small NEOs.

Preliminary Results: Currently, the simulation has been developed in STK and initial data has demonstrated expected behavior of the orbiting spacecraft (ref. Figure 1). Execution of several scenarios with varying initial conditions has resulted in different outcomes over identical time intervals. These results are promising. Additional data will be collected and analyzed using the method described above. Furthermore, at the time of this abstract we are assessing two software packages, which will provide gravity coefficients from both types of mission scenarios, single and dual spacecraft. We expect to have incorporated gravity modeling software into our analyses by conference time, and will report on the same.

References: [1] Scheeres, D. J., Broschart S., Ostro S., J., & Benner, L.,A. (2004) AIAA 2004-4864. [2] JPL HORIZON System, telnet://horizons.jpl.nasa.gov:6775.