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RESOURCE MODELLING AND SIMULATION OF ASTEROID OREBODIES FOR OFF-EARTH MINING

Abstract

Observational data of near-Earth objects suggests that most asteroids are rubble piles – aggregates of boulders, rocks and regolith held together by weak gravitational and surface forces acting between the constituent particles. Scientific studies of the dynamics and formation processes of rubble pile asteroids often make use of large-scale N-body discrete element methods (DEM) or smoothed particle hydrodynamics (SPH) simulations involving millions of particles. While these simulations provide accurate modelling of the dynamics, they are computationally intensive, requiring the use of supercomputers and many hours to run. On the other hand, simulations of spacecraft operations in the vicinity of asteroids often use simplified models where the asteroid body is represented as a constant density polyhedron defined by a shape model and bulk geological properties. This paper details the development of a software package containing tools for generating 3D resource models of asteroid orebodies for the use in the planning and simulation of operations involved in off-Earth mining and mineral extraction. The package uses a combination of the two modelling approaches based on varying levels of detail for different types of operations. Orbital operations are modelled using a constant density polyhedral model, with the option of including large boulders to simulate gravity perturbations due to mass concentrations. Surface operations make use of detailed DEM simulations in a restricted area of operation surrounding the spacecraft, with a constant density model outside this area. Mining operations add additional large-scale granular physics simulations of the regolith directly surrounding the points of contact between the asteroid and mining equipment. This modelling approach is designed to provide a balance between numerical accuracy and computation time, with the aim to allow rapid simulation of spacecraft operations and off-Earth mining processes without the need for large-scale computational facilities or long runtimes.