A Novel Excavator for Asteroid Mining Context

Korbin Hansen, Siva Muniyasamy, Dr Jekan Thanga

Space and Terrestrial Robotic Exploration (SpaceTREx) Laboratory,
Department of Aerospace and Mechanical Engineering, University of Arizona

Asteroid mining is a promising means to facilitate the in-space production of propellants and precious metals. As developing the space economy will enrich Earth and expand humanity's reach, there is a push to make asteroid mining technologies more feasible. In this paper, several continuous mining tools are physically tested to inform the design of an optimized, scalable, asteroid-specific excavator. These tools are designed to meet the unprecedented challenges posed by the asteroid surface environment—microgravity, where even minute reaction forces can translate to a loss of stability or scatter regolith to escape velocity; lack of cohesion, making it difficult to remain secure while mining; and (relatively) large grain sizes, which may obstruct machinery. Bucket wheel and pulse elevator designs are considered. Bucket wheels have been incorporated into the most technologically mature Lunar mining vehicles, such as NASA's ISRU Pilot Excavator. Bucket wheels provide a solid foundation for an asteroid-specific excavator, though fundamental redesigns are necessary. A pulse elevator employs a vibrating assemblage of scoops to vertically translate granular materials, such as low-cohesion asteroid regolith. Testing these excavators necessitates the development of a simulant that is mechanically analogous to asteroid surface conditions. When the constraint of affordability is applied, the resulting simulants are to be composed of shredded foam particles. By employing multiple sieves, simulants of varying average grain sizes can be developed in parallel. Since foam particles will not precisely match asteroid surface conditions, each batch of simulant will be mechanically tested for cohesion, angle of internal friction, density, and porosity such that scaling factors can be obtained. As Bennu is the most thoroughly examined rubble pile asteroid—courtesy of the OSIRIS-REx mission—it will be considered representative of asteroid surface conditions for comparison. Next, 3D-printed prototype excavators are tested for each grain size configuration—the test beds will read horizontal cutting force, vertical resistive force, deployment angle of extended components, electric power consumption, and filling efficiency. Resolved force data is compared to the weight and resulting friction generated by the excavator if it was placed on Bennu. Deployment angle will be fed into computer simulations to determine the handling characteristics of the bucket wheel in the irregular terrain native to asteroids. Electric power consumption and filling efficiency will be used to determine the energy required to mine a set mass of regolith, which is critical information for top-level systems engineering or economic analysis.