ASTEROID MINING AND IN-SITU RESOURCE UTILIZATION

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Introduction: Like many space exploration missions, cost is a determining factor. Transportation alone imposes a cost of $10,000 per kilogram for the entire mission making it simply not profitable or attractive to potential investors. A potential near-instantaneous solution would be to develop an asteroid mining economy developing of a human-commercial market. It is suggested that this scenario will create the economic and technological opportunities not available today. Future manned missions would require the use of native material and energy on celestial objects to support future human and robotic explorations. The process of collecting and processing usable native material is known as in-situ resource utilization (ISRU). Currently, space travelling requires missions to carry life necessities such as air, food, water and habitable volume and shielding needed to sustain crew trips from Earth to interplanetary destinations. [1] The possibility of a mission depends on the deduced market value from commercial sale of the product. Engineering choices are identified; a matrix of mineralogy, product and process choices can be developed. [2] One major consideration in the process of obtaining energy and life supporting materials from the lunar surface is the identification and excavation of raw material. [3] Lunar soil is produced primarily by meteorite impacts on the surface. This process caused for mineral fragmentation with composition consisting of miscellaneous glasses, agglutinates and basaltic and brecciated lithic fragments. The natural specific gravity of lunar soil is said to be between the values of 2.90 and 3.24. [4] Professor Xiangwu Zeng and his team at the NASA Glenn Research Center have developed a design calculation model to determine the excavation force based on basic principles of soil mechanics. Simulants with the properties of Apollo Regolith were used: the JSC1a fines, JSC1a very fines and the JSC1a. A hydrometer test was used to determine particle size. This test is based on Stoke's Equation. Unlike traditional models, the Zeng model takes into account the ability to handle acceleration of the tool blade while other models assume constant velocity. It is also able to calculate passive earth pressure. [6] The model is based on the principles of basic soil mechanics and the parameters can be determined by soil tests. These include horizontal and vertical acceleration, soil blade friction angel and external friction angel. A relationship between the total excavation force, the passive earth pressure components and the side friction and the above variables are drawn.

These principles are likely to be applied to a broad parameter aside from lunar conditions including asteroid environments. These failed planetesimals have varying composition including volatile-rich elements to metallic bodies with high concentrations of rare elements such as iron, nickel, platinum, gold, silver and other useful rare metals for human use and consumption. Due to the inherent difficulty of asteroid mining given the current level of technologies, governments and companies has not been considering asteroid mining as a feasible solution to depleting natural research on Earth. Cost analysis have shown that a cost for a future mission to return 500-ton asteroid to low earth orbit would be in the range of $2.6 billion USD which does not include the initial capital costs for infrastructure and technological development and testing [7]. Challenges include difficulty in categorization and identification of mineral deposits, infrastructure development to develop, refine and transport processed materials back to earth [7] as examples. Significant advances in robotic technology will be part of the equation to overcoming such challenges.

Conclusion: The results find the Zeng model have high dependence on soil cohesion and therefore forms a linear relationship with the amount of excavation force needed for ISRU. The results will deviate from the actual lunar specimen as simulants were used for the experiments. The use of real samples may give a more accurate understanding of soil properties and experimental results. Although this investigatory tool can be used on a broad basis including under asteroid conditions, current technology is still being developed to bring down the massive initial capital costs down for asteroid mining to becoming a reality. There are many challenges as outlined above that needs to be considered and resolved to making asteroid mining a feasible solution.

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