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MINING REQUIREMENTS FOR ASTEROID ORE EXTRACTION

Abstract

This paper outlines methods that may be used to estimate the energy and time requirements to extract a desired mass of mineral resources from an asteroid's regolith using surface mining techniques. Water is a highly valued mineral to extract from asteroids, as it has many uses as a propellant, and in life-support systems. Water may be present in asteroids in the form of subsurface water-ice, or in hydrated minerals containing OH compounds. Hydrated minerals are found in high concentrations in chondrite meteorites, indicating they may be present in the regolith of C-type near-Earth asteroids. Subsurface ice is thought to be present in many main-belt asteroids, permeating a fraction of the pores of the regolith. Ice above a minimum depth sublimates and is lost to space, with the depth-to-ice receding over time. To analyse the mining requirements, geological models of the theoretical spatial distribution of the mineral densities are generated from analytical expressions in spherical coordinates. The asteroid parent body is modelled as a sphere with a given diameter. Ice density is modelled as a function of depth. Hydrated mineral density is modelled as a separable function of both depth, and latitude. The ore containing the mineral deposit is to be extracted using open-pit mining. The mass and volume of ore required to be extracted is estimated from volume integrals of the density function in spherical coordinates, with constraints placed on the slope of the mine pit. This volume may be used to estimate the total energy and time requirements to extract a desired mass of mineral. To consider the mining operations, an ore block body model is generated to represent discrete blocks of unit volume. We solve the constrained ultimate pit limit problem to determine the optimal set of blocks to be extracted. We then solve the open-pit block-sequencing problem to determine the optimal sequence to remove these blocks.