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ASTEROID MINING: ECONOMIC FEASIBILITY AND TECHNOLOGICAL CHALLENGES

Abstract

Asteroids, remnants of the early solar system, present a vast reservoir of untapped resources, comprising rocks, metals, and ice. Ranging from meter-sized entities to proto-planets of country-scale proportions, these celestial bodies are distributed across the asteroid belt and Kuiper belt, with numerous others traversing independently between planets. With growing feasibility in space travel, attention has shifted towards exploring the potential economic benefits of harnessing resources from asteroids. Notably, even smaller metallic asteroids possess immense value, potentially containing trillions worth of industrial and precious metals such as platinum, while larger asteroids, exemplified by 16 Psyche, could satisfy the world's metal demands for millions of years through abundant iron-nickel deposits. Current market valuations indicate that the rare raw materials alone could be worth quadrillions of dollars. Despite the promise of asteroid mining, significant hurdles remain, chiefly the prohibitive costs associated with space travel. Traditional rocket propulsion systems, reliant on expensive fuel, make mining ventures economically unviable. One proposed solution involves transitioning from conventional rockets to electric spaceships, leveraging electrical rocket engines that, while not suitable for Earth departure, demonstrate efficiency in deep space travel. The reduction in fuel requirements enhances cost-effectiveness, laying the groundwork for the initial phases of asteroid mining missions. Upon securing an electric asteroid-mining spaceship, the next challenge involves selecting and reaching the target asteroid. While successful space probe missions have already visited and sampled asteroids, the focus remains on near-Earth asteroids for their proximity, facilitating easier and more cost-efficient missions. The journey itself involves manipulating the asteroid's trajectory through precise thruster maneuvers and utilizing the Moon's gravitational pull to establish a stable orbit around Earth. The mining process begins with stabilizing the asteroid and initiating resource extraction. Innovative space-based mining and processing equipment, utilizing giant mirrors to concentrate sunlight for rock heating, break down asteroid material into gravel and dust. Advanced centrifuges separate valuable dense elements from lighter ones. Even with a modest extraction rate, a fraction of the asteroid's mass yields several times more precious metals compared to terrestrial mining. The challenge now turns to transporting the extracted metals back to Earth. Options include reusable rockets or 3D-printed, heat-shielded capsules for secure re-entry and ocean drop-off, providing cost-effective and efficient means of delivering the acquired resources. As the pursuit of asteroid mining advances, addressing these challenges will be pivotal in unlocking the vast economic potential inherent in these celestial bodies.