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THE PITHIA MISSION: A CASE STUDY OF THE THEMIS ASTEROID FAMILY IN EXPLORING SUSTAINABLE PROSPECTING AND MINING OF WATER ICE IN SOLAR SYSTEM ASTEROIDS

Abstract

Space missions in the future will look to satisfy the needs not only of industries on Earth, but also the needs of extended deep space missions and even solar system colonies. Critical to in-situ resource utilization (ISRU), one of the biggest commodities in deep space is water ice. A limited deep-space resource and catalyst for valuable extraterrestrial life, there is a need for sustainable approaches to prospecting and mining; and unlike geologically active icy moons, ice can be extracted from asteroids with a negligible risk of forward contamination of extraterrestrial life. Besides being critical for ISRU, understanding the distribution of water in our solar system will improve our understanding of its origins, and shed insight on the distribution of other natural resources. It will help with characterizing other star systems, while also informing our search for extraterrestrial life in our solar system and beyond.

In this paper, we discuss non-invasive methods to determine the extent to which water-ice is available for mining on large asteroids. We conduct a case study of 24 Themis, the largest member of the Themis asteroid family; a large, C-type carbonaceous asteroid with significant surface ice coverage located in the outer main belt. We explore the use of direct observation methods to evaluate current theories about its origin, which suggest it is the remnant icy core of a larger protoplanet that fractured into the Themis family of asteroids today. Characterizing 24 Themis and other Themistian asteroids will allow us to reconstruct this precursor protoplanet and provide valuable scientific information about our primordial solar system. We also explore various sustainable ISRU solutions, depending on the different ice distributions that may be observed.

Our proposed mission, Protoplanetary-theory Investigation of Themistian Icy Asteroids (PIThIA), comprises a solar electric propulsion (SEP) satellite featuring a lightweight instrument suite designed for studying large asteroids like 24 Themis. PIThIA would utilize visual data, spectroscopy and monostatic radar technology to characterize 24 Themis and model its distribution of ice. Mission continuation to explore the remainder of the Themis family belt is studied, as well as the adaptability of the design in targeting other asteroid systems. In our report, we simulate a polar orbit of 24 Themis and two phases of operations at different altitudes using the NASA GMAT software, providing a framework for future prospecting and mining missions which will pave the way for sustainable resource utilization in deep space.