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THE CERES HUMAN EXPLORATION AND TRANSIT ARCHITECTURE (CHEATA): A MISSION ARCHITECTURE FOR SMALL BODIES EXPLORATION

Abstract

The Ceres Human Exploration and Transit Architecture (CHEATA) is a conceptual mission developed by MIT, to enable human exploration of Ceres and other small bodies in the asteroid belt. These small bodies present tempting targets for future human exploration, providing insight into the evolution of our solar system, potentially containing environments of interest to astrobiologists, and acting as water- and mineral-rich stepping stones for outer solar system exploration.

Minimizing radiation exposure and mission duration while maximizing surface science on Ceres were the driving critical requirements considered for this mission concept. Key elements of the design include (1) an active high-temperature superconducting magnet system (HTS), complemented by a passive high-density polyethylene system, to mitigate crew exposure to galactic cosmic radiation and solar energetic particle events, (2) a bimodal nuclear thermal propulsion (NTP) system that utilizes liquid hydrogen and a reusable CERMET core , and (3) a low gravity hopping vehicle using vacuum retro-propulsion and LOX/Methane propellant, taking advantage of the low gravity environment for regional exploration and surface operations on Ceres. A transit habitat vehicle is assembled in cislunar space and used to ferry astronauts to Ceres orbit. The study also details breakdowns of the human countermeasures employed to address the effects of microgravity and isolation.

The CHEATA mission concept was initially presented at the IEEE Aerospace Conference in 2022 (cited in this paper). The mission architecture has been updated to now include the design of additional spacecraft and habitation subsystems. These include the design of an Environmental Control and Life Support System, including net oxygen and water recovery estimates, a deep space communication system, and the design of a thermal management and protection system for both the crew compartment and the NTP system. Further refinements to the mission concept include the inclusion of zero boil-off technology for the Liquid Hydrogen tanks, an improved design for the Ceres hopper, the design of the HTS assembly and deployment mechanism, and a consideration of exploration medical capabilities to support the mission crew. A detailed technology development plan and launch manifest maps the timeline of this mission over an 16-year period with initial technology development completed from 2035 to 2043, to ensure a landing at Ceres in 2050 and return to Earth by 2051. Several additional mission scenarios have also been included,

targeting other small bodies in the solar system such as the Saturn moon of Rhea and the small body Vesta.