Paper ID: 94677
student

23rd IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE (D4)
Innovative Concepts and Technologies (1)

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TRANSFORMATIONAL TECHNOLOGIES FOR FUTURE SPACE EXPLORATION AND RESOURCE UTILIZATION

Abstract

Space exploration's future depends on the creation of ground-breaking technology and long-term, impactful tactics. In order to facilitate deep-space missions, space-based infrastructure, and sustainable extraterrestrial resource exploitation over the next 20 to 30 years, this article examines transformational system concepts. This paper highlights important technological developments that have the potential to completely transform robotic and human space exploration by combining sophisticated propulsion systems, AI-driven autonomy, and in-situ resource utilization (ISRU). Three primary categories of innovation are examined: (1) Early-stage concepts requiring theoretical and laboratory validation, (2) Technologies that have undergone initial experimental testing but need further demonstration, and (3) Cross-cutting advancements that merge multiple breakthroughs to establish new mission capabilities. Key areas of focus include nuclear and solar-electric propulsion for interstellar precursor missions, autonomous robotic systems for deep-space exploration, and lunar resource processing for sustaining long-duration missions. The potential of these technologies to improve mission sustainability and cost effectiveness is assessed in this study using system-level feasibility studies, prototype testing, and computer simulations. According to preliminary findings, integrating this cutting-edge technology can greatly increase mission success rates and lessen reliance on resources from Earth. This article offers a strategic roadmap for developing space technologies that will support short- and medium-term missions and help define the future of interstellar travel, in line with the goals of the 23rd IAA Symposium on Visions and Strategies for the Future. By guaranteeing that poorer spacefaring nations can take part in and profit from future lunar and deep-space activities, the findings support international efforts to create a sustainable and cooperative space economy.