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AEROSPACE PROPULSION FOR SUPRA-KÁRMÁN AND SUB-KÁRMÁN FLIGHTS: APPLICATIONS ON MARS, THE MOON, AND THE SPACE ERA.

Abstract

The exploration of propulsion systems for supra-Kármán and sub-Kármán flights represents a critical challenge in the space age, particularly in the context of interplanetary exploration. This work aims to analyze and compare propulsion technologies suitable for these flight regimes, with a focus on their applicability in extraterrestrial environments such as Mars and the Moon. The study is motivated by the success of the Ingenuity drone, which achieved the first powered flight on Mars, demonstrating the feasibility of rotor-based propulsion in thin atmospheres. On Mars, where the atmosphere is only 1% as dense as Earth's, lightweight electric propulsion systems powered by solar energy have proven effective for short-duration flights. In contrast, the Moon's lack of atmosphere necessitates alternative approaches, such as rocket-based propulsion or ion engines, which do not rely on aerodynamic forces.

This work also explores advanced propulsion technologies, including hybrid systems, and solar-electric propulsion, which could revolutionize space exploration by offering greater efficiency, sustainability, and adaptability to diverse environments. The primary objective of this study is to evaluate the performance, energy requirements, and environmental adaptability of these propulsion systems, providing a comprehensive roadmap for their integration into future missions. By comparing the advantages and limitations of each technology, this research seeks to identify the most promising solutions for enabling long-term exploration and colonization efforts on Mars, the Moon, and beyond.

The findings highlight the importance of innovation in propulsion systems to overcome the technical and economic challenges of interplanetary exploration. Furthermore, this study emphasizes the role of propulsion technologies in ensuring the sustainability of space activities, particularly in the context of resource utilization and mission longevity. The integration of advanced propulsion systems adapted to different environments could pave the way for a new era of space exploration, characterized by increased mission flexibility, reduced costs, and a stronger human presence in space.

This work includes that the development of efficient and versatile propulsion systems is essential for achieving the goals of the emerging space age, including the exploration of distant celestial bodies and the establishment of sustainable extraterrestrial habitats. By addressing the unique challenges of propulsion in both atmospheric and vacuum environments, this research contributes to the advancement of technologies that will define the future of space exploration. Additionally, the study underscores the need for international collaboration and investment in research and development to accelerate the implementation of these technologies.