Paper ID: 85796
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IAF SPACE EXPLORATION SYMPOSIUM (A3)
Mars Exploration – missions current and future (3A)

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SYSTEMATIC SELECTION OF THE NEXT GENERATION MARTIAN ROTORCRAFT CONFIGURATIONS

Abstract

This paper proposes a new design study of the reusable next-generation Martian drone based on aerodynamic parametric analysis of battery-electric rotary VTOL aircraft configurations. Mars offers a few design challenges for a rotorcraft, mainly because its atmospheric density is about 100 times lower, and the speed of sound is about 32% lower than that of Earth. Therefore, the rotors operate at extremely low Reynolds numbers, but at higher Mach numbers because of the higher tip speed required, imposing severe constraints on the rotor design and heat evacuation mechanism of the propulsion system during flight. NASA's Ingenuity has overcome most challenges for flying a rotating wing aerobot on Mars by landing and flying 72 times on the planet since the year 2021. However, the design of the helicopter has limitations such that it lacks endurance, range, and science payload capacity due to its small size and elementary design. These limitations reduce its ability to perform science exploration missions that would require long-distance flights, higher scientific payload, a sophisticated communication system, or a powerful propulsion system for high-altitude flights. Enhancing the Ingenuity Helicopter could entail augmenting its size or integrating fixed wings into its configuration, aiming to extend endurance, payload capacity and accommodate more solar panels. Proposing more ambitious requirements involves the development of new rotorcraft designs within practical constraints, particularly adhering to a maximum available aeroshell diameter of 4.5 meters. Accommodating a larger craft may require separate transport, packaging with a smaller ground spacecraft, or an inventive folding mechanism within the aeroshell. Thus, a comprehensive parametric study of rotorcraft configurations becomes essential to definitively assess the overall advantage of larger or winged Martian rotorcraft and identify optimal configurations for further pursuit. We have developed a conceptual framework rooted in simplified momentum theory that enables a comprehensive parametric study of diverse Martian rotorcraft configurations, including overlapping rotors. This analysis offered estimations for power requirements during hover, vertical climb, and forward flight, facilitating insightful trade-off assessments concerning power consumption, rotor size, and aircraft mass. Consequently, the preliminary aerobot design is grounded in theoretical rationale. In this paper, we aim to extend this analytical research by coupling it with numerical aerodynamic analysis and provide a conclusive package with the pros and cons of various configurations based on the full flight regimes' power consumption. We are confident that these analyses would benefit Martian aerobot researchers, expediting trade-off analyses and accelerating decision-making in selecting optimal designs.