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PARAMETRIC ANALYSIS OF ROTARY VTOL AEROBOT DESIGN CONFIGURATIONS TO FLY ON TITAN

Abstract

This paper proposes a conceptual design study of the reusable Titanian drone based on aerodynamic parametric analysis of rotary VTOL aircraft configurations. Titan, Saturn's moon, shares similarities with Earth and Mars in various fields like hydrology, sedimentology, and weather, offering valuable insights into universal processes and the formation of life. Huygens probe is the only spacecraft that explored the surface of Titan (2005), but some variants of unmanned aerial vehicles such as hot air balloons, winged and rotary-wing aircrafts have been proposed by researchers as the most attractive choice for some obvious reasons. Titan offers a few aerodynamic advantages for rotorcraft design, mainly because its atmospheric density is about 4.4 times higher, and the surface gravity acceleration is about 7 times lower than that of Earth. Moreover, the kinematic viscosity is 12 times lower, leading the rotors to operate comparatively at higher Reynolds numbers on Titan. This implies that the power required to fly a vehicle of a given mass on Titan will be significantly lower than on Earth. However, the speed of sound is 1.7 times lower on Titan, meaning if the rotors are spun at a higher rate the blades' tip speed can reach transonic Mach number quickly, though this can be considered as not to be the driving factor in the design. Operating on Titan presents some challenges due to its cryogenic conditions, which impose significant constraints on materials, lubricants, and vibration isolation for operations. The low solar flux on Titan makes radioisotope power systems the most viable option for long-term spacecraft, albeit with added weight. NASA's Dragonfly, a coaxial quadrotor robot scheduled for launch in 2028, represents a significant advancement in Titan exploration. Nevertheless, the next generation of Titanian rotorcrafts face more ambitious requirements, necessitating the development of new designs within practical constraints. A comprehensive parametric study of rotorcraft configurations is essential to assess advantages and identify optimal designs. Through simplified momentum models, we have gathered estimates on power consumption for various rotorcraft configurations, including hover and vertical climb power. Initial sizing of battery-electric aircraft has also been conducted, with further analysis planned for forward flight power consumption. We aim to provide a conclusive assessment of different configurations based on power consumption across various flight regimes, informing the selection of the most optimized design for specific missions. Ultimately, these analyses aim to aid Titanian aerobot designers in making informed decisions based on theoretical estimates.