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Author: Mr. Wei Han
Politecnico di Torino, Italy

Dr. Manuel Carreño Ruiz
Politecnico di Torino, Italy
Prof. Domenic D'Ambrosio
Politecnico di Torino, Italy

ANALYSIS OF DESIGN CONCEPTS FOR MARS UNMANNED AERIAL VEHICLES

Abstract

Mars is recognized as the most habitable planet in our solar system after Earth, and its exploration holds significant meaning, both in scientific discovery and in future human exploration and settlement. Inspired by the success of Ingenuity Mars Helicopter, recent attention has turned to utilizing aerial vehicles for Mars exploration. Aerial vehicles offer a unique advantage in mobility when exploring Mars, as they can bypass the complex terrain of the Martian surface and have the potential to achieve high speeds, thereby offering the opportunity to explore vast areas. In this paper, we study the Mars atmosphere and investigate various previous design concepts for Mars Unmanned Aerial Vehicle (UAV) based on different approaches. We justify their configurations by considering various constraints that impact design, including low-pressure, low-density, dusty, and radiative atmosphere on Mars, as well as limitations related to packaging, aeroshell volume, deployment, and vertical take-off and landing (VTOL). Additionally, the low-Reynolds number aerodynamics is a significant consideration in selecting configurations. The requirements for potential missions, including necessary payload, scientific instruments, and flight endurance are considered. We analyze and compare different power supply methods in terms of their mass, specific energy, flight endurance, working environment, and environmental impact. Based on these investigations, we summarize the suitable aerodynamic features for the Mars UAV. Three typical concepts based on different flight approaches including fixed-wing, rotary-wing, and flapping-wing configurations are compared and their feasibility to different application scenarios is summarized. After analyzing previous research on Mars UAV concepts, we propose a new preliminary conceptual design for a reusable, long-endurance fixed-wing Mars exploration UAV. This UAV is designed to collect samples from specific sites and collaborate with rovers in analyzing samples, or potentially serve as the basis for future sample return missions. The combination of the reusability requirement and the fixed-wing configuration on Mars necessitates VTOL capabilities. To address the challenge of VTOL, high-efficiency optimized rotors under Mars' atmospheric conditions are employed. An aerodynamic analysis aimed at verifying the performance of a VTOL system under Mars conditions is carried out, as it is a critical aspect of the multiple-flight Mars UAV.