IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

Author: Mr. Michael Biselx
Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, michael.biselx@epfl.ch

Mr. Vincent Roggli
Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, vincent.roggli@epfl.ch
Mr. Florentin Fellay
Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, florentin.fellay@epfl.ch

ENVELOPE, PROPULSION AND NAVIGATION FOR A MARTIAN EXPLORATION AIRSHIP

Abstract

Current Mars exploration mainly falls into two categories: global survey from orbit, or localized ground-level studies using rovers or landers. Mid-level regional studies would require an exploration vehicle capable of covering long distances. This could be fulfilled by an airship with significant flight autonomy, able to gather scientific data on large, currently unreachable areas of the Martian surface. The possible use of such an airship to explore low-altitude, rugged areas such as the steeper slopes of Valles Marineris was assessed in a preliminary feasibility study presented at GLEX 2021. The presented airship consisted of a hydrogen-filled envelope with a diameter of around 45 meters, and would be capable of carrying a hyperspectral camera of 10 kg.

This paper follows up on the aforementioned feasibility study by investigating the enabling technologies for such a mission, with a particular focus on envelope design, propulsion system choice and navigation / communication strategies.

The low-density, cold Martian atmosphere and its strong winds pose considerable challenges for the design of a lighter-than-air platform. In this paper, we explore these environmental challenges on the basis of the Mars Climate Database. First, the daily thermodynamic cycles of the lifting gas are simulated using a convective-radiative heat transfer model of the airship. The constraints imposed on the envelope geometry and materials by these cycles are then discussed and a case is made for the use of a ballast inner balloon for both lifting gas pressure and vertical control. Next, horizontal control is investigated in a trade-off study of different types of propulsion technologies. A preliminary design of the propeller propulsion system is established using blade element momentum theory and computational fluid dynamics. Using the power requirements for the propulsion system, a power budget for the airship's main subsystems is set up and used to dimension its solar cell array and on-board batteries. Then, the governing equations of the motion dynamics are used to create a numerical simulation, and some recommendations for the navigation and communications equipment are made. Finally, from a systems engineering perspective, a refined mass budget for the 900 kg airship is presented, as well as a preliminary concept of operations.

The results obtained show that the proposed Martian airship is not only feasible, but even a promising platform to bridge the gap between top-down global surveying and localized exploration.