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PLANETARY EXPLORATION USING CUBESAT DEPLOYED SAILPLANES

Abstract

Exploration of terrestrial planets such as Mars are conducted using orbiters, landers and rovers. Cameras and instruments onboard orbiters have enabled global mapping of Mars at low spatial resolution. Landers and rovers such as the Mars Science Laboratory (MSL) carry state-of-the-art laboratories to characterize small localized areas. This leaves a critical gap in exploration capabilities: mapping regions in the hundreds of kilometers range. The use of aircraft such as the proposed Mars Sailplane offers a new low-cost pathway to fill in this critical gap in exploration capabilities. The Mars Sailplane concept would be a secondary payload deployed during Entry, Descent and Landing (EDL) of a MSL-class vehicle. These are packaged into 12U/24kg CubeSats, occupying some of the 190 kg of available ballast. Sailplanes extend inflatable-wings to soar without power limitations by exploiting atmospheric features such as thermal updrafts for static soaring, and wind gradients for dynamic soaring. Such flight patterns have been proven effective on Earth and demonstrated similarities between Earth and Mars show strong potential for a long-lasting airborne science platform on Mars. The maneuverability of sailplanes offers distinct advantages over other exploration vehicles: they provide continuous reconnaissance images of areas of interest from multiple viewpoints and altitudes, achieving higher pixel-scale resolutions than orbital assets and enabling exploration capabilities over rugged terrain such as Valles Marineris, steep crater walls and the Martian highlands that remain inaccessible for the foreseeable future due to current EDL technology limitations. In this paper, we extend our work on CubeSat-sized sailplanes with detailed design studies of different aircraft configurations and payloads, identifying generalized design principles for autonomous sailplane-based surface reconnaissance and science applications. We analyze the potential science instruments that can be added impart from cameras and thermal imagers. We further analyze potential wing deployment technologies, including conventional inflatables with hardened membranes, use of composite inflatables, and quick-setting foam. We perform detailed modeling of the Martian atmosphere and possible flight patterns at Jerezo crater using the Mars Regional Atmospheric Modeling System (MRAMS) to provides realistic atmospheric conditions at the landing site for NASA's 2020 rover. We revisit the feasibility of the Mars Sailplane concept, comparing it to previously proposed solutions, and identifying pathways to build laboratory prototypes for high-altitude Earth based testing. Finally, our work will analyze the implications of this technology for exploring other planetary bodies with atmospheres, including Venus and Titan.