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ANALYSIS OF BALLOON AND SAIL SYSTEM TRAJECTORIES WITHIN EXTRA-TERRESTRIAL ATMOSPHERES

Abstract

Balloon systems have been proposed for use exploring the atmospheres of extra-terrestrial bodies on several missions to date. The system concept was demonstrated by the aerostats aboard the Vega 1 and 2 missions sent to explore Venus. Such systems glean propulsion from the winds, and at present are unable to travel in a direction perpendicular to the direction of the wind, limiting their exploration capabilities. As such, a system capable of modifying the system trajectory by traveling in a direction perpendicular to the direction of the wind is desired to increase exploration potential as well as to perform tasks such as maintaining latitude.

A balloon and sail system which can use wind velocity and density gradients to produce a guiding force perpendicular to the velocity of the wind is discussed. Such a system is passive in nature and requires little power for actuation and control. At the 67th IAC in 2016, it was demonstrated that such a system is capable of generating guiding velocities of several meters per second within the Venusian atmosphere. Furthermore, such a system was shown to be able to utilize wind to achieve sufficient system control for the majority of the latitudes on Venus.

This work builds on previous results and demonstrates the effect of the control velocity by viewing the trajectories taken by the planetary balloon systems subjected to the guiding velocities. First, a description of the system model is given. Next, for the atmospheres of Venus and Titan, trajectory control is demonstrated for various sail parameters, such as sail size and mass. Such control is shown by the ability to achieve various latitudes of interest for a given flight duration. These latitudes are chosen based on geographic features, such as mountain ranges on Venus and lakes on Titan. Finally, a bang-bang controller is added to the model to demonstrate control of the system for maintaining and changing latitudes. A brief discussion regarding the control law of the system is also provided.