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# DYNAMICS AND CONTROL OF A PARAGLIDER FOR PLANETARY EXPLORATION

**Abstract**

Paragliders represent a light, low cost, space efficient means for autonomous transportation. They can be used for accurate delivering of payloads using inexpensive guidance and control modules. If equipped with proper sensor, it is possible to use paragliders for scientific observation during flight, such as chemical, thermal, meteorological, or biological analyses of the atmosphere. Aerial remote sensing of the surface can also be carried out, obtaining high-resolution imaging, measurements of seismic activity, and more generally collecting data on dangerous or inaccessible areas.

Since they are inexpensive, light and versatile, they are interesting for planetary exploration, in particular if Mars, Venus, Titan and the Outer Planets are considered. However, the atmosphere of the planets can be a hostile environment. A correct model accounting for the presence of winds, gradient of temperature and of atmosphere density has to be developed for a proper mission analysis.

The aim of the proposed paper is to study the behavior of a paraglider system flying through the atmosphere of a planet. A parametric analysis can be carried out, in order to verify the feasibility of such a space transportation mean for different planets. In particular, atmosphere density is a key parameter in the analysis since it directly influences aerodynamic forces (lift and drag) and moments (rolling, pitching, yawing), and apparent forces and torques exerted on the system. The dynamics is nonlinear and a complete analysis has to be carried out to prevent instability and design the canopy's geometry and structure accordingly.

A model that can simulate the flight of the paraglider, conceived as a parafoil and payload multibody system, is developed. In particular, nine degrees of freedom are considered to describe the inertial position of the system and the attitude of the parafoil and of the payload separately. The dynamic response to the atmospheric environment can be analyzed to determine the geometrical and aerodynamic characteristics of the canopy that provide stability in free flight. If the environment results suitable for paraglider use, existing control laws and path planning strategies can be implemented and tested for typical missions, such as payload delivery or visual servoing of the planetary surface.