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Author: Mr. Pierluigi Vergari
Politecnico di Torino, Italy

Mr. Matteo De Matteis
Politecnico di Torino, Italy
Dr. Marco Quadrelli
Jet Propulsion Laboratory - California Institute of Technology, United States
Dr. Richard Blomquist
Jet Propulsion Laboratory - California Institute of Technology, United States
Dr. Federico Rossi
Jet Propulsion Laboratory - California Institute of Technology, United States
Mr. Riccardo Apa
Politecnico di Torino, Italy
Mr. Stefano Aliberti
Politecnico di Torino, Italy
Prof. Marcello Romano
Politecnico di Torino, Italy

MODELING AND ANALYSIS OF TETHERED SYSTEM DYNAMICS FOR VENUS AEROBOTS AND TOWED PROBES

Abstract

Venus, the Earth's nearest planetary neighbor, hides information that could help us better understand Earth and exoplanets. Despite sharing similarities with Earth, Venus has transformed into an inferno-like world, making it a subject of intensified scientific interest. The Venus wind and atmospheric patterns are also poorly known. NASA's Jet Propulsion Laboratory is developing missions to explore and survive the planet's extreme temperature and atmospheric pressure. One of the most promising approaches to studying the Venusian atmosphere and its surface is using an autonomous scientific balloon, also called "aerobot," which could navigate the atmosphere using buoyancy force to maintain a certain altitude (around 52 km), where temperatures and pressures are comparable to Earth's. Modeling and control of the dynamics of such a balloon is critical to support architecture design for such a mission. This research shows how an efficient and user-friendly simulator could be extremely helpful in capturing and testing various systems architectures with different purposes. The simulator has implemented two different modeling approaches involving tether dynamics, particularly the lumped mass and the DeNOC (Decoupled Natural Orthogonal Matrix). In addition, a stochastic wind model was implemented. The simulator is also able to reproduce and analyze the behavior of towed atmospheric probes and assess their ability to change the trajectory of the entire system by exploiting the presence of aerodynamic forces acting on the towed body, which could be trailing at kilometers of distance below the balloon. Using the simulator, we demonstrate the feasibility of tracking and manipulating the trajectory of a towed body using a micro aerial vehicle capable of flying autonomously. This approach allows the collection of samples from Venus's hot and high-pressure surface and their return to the lofting system. The simulator is crucial for evaluating system architectures and understanding the entire flight chain dynamics, encompassing balloons, tethers, and towed bodies. Future studies will explore balloon and body aerodynamics in more detail, focusing on

controlling the aerobot trajectory using aerodynamic forces on towed bodies.