Paper ID: 77776

IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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UNFOLDING METHODS OF A TWO ORDERS OF MAGNITUDE MECHANICAL VOLUME REDUCED SPHEROID TUMBLEWEED MOBILE IMPACTOR

Abstract

Despite the increasing interest in planetary exploration, the cost of space missions remains largely inaccessible to the research community. Team Tumbleweed aims to address this issue by developing a low-cost Mars mission based on a swarm of wind-driven mobile impactors. One of the main development challenges is the volume and size restrictions imposed by current launchers. They severely limit the maximum size of the swarm due to the large volume taken up by the spheroid Tumbleweed Rovers, which are approximately five meters in diameter.

To solve this, the structure of a Tumbleweed Rover must be foldable, which reduces overall mission mass and volume to guarantee compatibility with current launch vehicles and decreases mission costs. The volume-efficient folding structure for wind-driven mobile impactors, presented in this paper, is designed to unfold during atmospheric entry, providing the necessary drag and impact resistance in order to land on Mars. Such a landing procedure presents fewer risks by landing on the Martian surface at terminal velocity, thereby removing the need for complex control sequences. The same structure also functions as the locomotion system, a control mechanism for the trajectory of the rover, and a framework for the deployment of the payload instruments into the operational configuration. The main design challenges of this system relate to the unfolding procedure, structural integrity, and the transition between mobile and stationary states.

In this paper, we focus on the Tumbleweed Rover's unfolding mechanism, which consists of a flexible carbon-fiber structure with a spring-loaded deployment system. We use several structural analysis tools to size the structure, and iteratively develop the unfolding system through a series of prototypes. We then validate our design against its key requirements of unfolding, structural integrity, control, and deployment of payload instruments with a sub-scale prototype, along with a series of lab and field tests.

We show that the structure is suited to absorb the landing impact while retaining structural integrity for the duration of the mission. Additionally, we practically show the feasibility of transporting the Tumbleweed Rover swarm on a single launch by folding the structure into a flat disk shape with a diameter reduction of 80%. We successfully test the innovative mid-air unfolding sequence in lab conditions, demonstrating the feasibility of this critical aspect of Tumbleweed Missions. Lastly, the ability of the structure to withstand rolling loads while controlling the rover's trajectory through repeated stopping is shown in field tests.