

Nano Rover Solar Sail Dynamic Simulation

Abstract

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The Nano-Rover Solar Sail is a concept being investigated at JPL for the deployment of small rovers that may be used for extra-terrestrial exploration. The Solar Sail is comprised of rings with progressively smaller diameters such that the entire sail can be folded and stored in a very compact form. The rings are arranged in the form of "fronds" attached to a spine. The prototype sail will have six principal spines emanating in a hexagonal array from a central hub. Each spine has secondary spines attached on either side with fronds containing rings. The full sail will have over 4000 rings. When deployed, the fronds fan out from the central hub and the spines to form an array extending about 25m in diameter.

A demonstration model with 52 rings is planned for use in proof of concept studies on a suitable platform such as the KC-135 or the space shuttle. This model comprises a single spine with two sets of four fronds attached to either side of rings on the spine. The spine has four rings of 9-in diameter. Each frond has six rings. The diameters of the rings on the frond decrease progressively by 1/16 each.

Each ring is made of a stainless steel tube 0.012-in OD and 0.006-in ID, and butt welded to the adjacent ring. The torsion induced in the rings by twisting them to the folded position provides the spring stiffness that propels the sail during deployment. Each ring has a central aluminized Kapton membrane 0.00025-in thick. From the open or deployed position, the rings fold on top of one another and eventually on to the spine ring in "jelly roll" fashion. The spine rings are then folded in "accordion" fashion. The demonstration model extends to approximately 100-in by 60-in when deployed.

This paper discusses a dynamic simulation of the Nano Rover Solar Sail deployment using ADAMS. An ADAMS model was constructed of the 52-Ring Solar Sail Demonstration unit. A dynamic simulation was performed with the model. A 6-Ring trial model was also built and used for guidance in developing the 52-Ring model. The simulation showed that the unit deploys as intended and gave valuable information on deployment times as well as insight into the deployment dynamics. The difference between the deployment of a sail that is anchored at one point and a sail that is free in space was demonstrated. The sequence of deployment was illustrated. The effect of air damping was quantified in tests on a 6-Ring model at JPL, and the variation of deployment time with air damping was evaluated. Parametric studies with different values of the friction between the rings and membranes showed that this is not a sensitive parameter.

Details of the model and simulation results are presented. The presentation will include a video showing the deployment of the sail.

A future effort is planned to investigate the feasibility of a dynamic simulation of the full 4000+-Ring sail. The present effort showed that this simulation will push the capabilities of ADAMS to the limit, both in the effort to build the model, and in terms of the computer resources required to run the simulation. Therefore, the next task will initially investigate methods to automate model building and to set up the simulation for optimal resource utilization. If these efforts establish the practicality of a dynamic simulation of the prototype sail, a dynamic simulation of the full 4000+-Ring sail will be undertaken.

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