Development of the Terrestrial Planet Finder Coronagraph Membrane V-Grooves

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Abstract

The Terrestrial Planet Finder (TPF) mission will study all aspects of planets outside our solar system: from their formation and development in disks of dust and gas around newly forming stars to the presence and features of those planets orbiting the nearest stars; from the numbers at various sizes and places to their suitability as an abode for life [1]. The Terrestrial Planet Finder Coronagraph is a potential architecture under developing at Jet Propulsion Laboratory for this mission. Figures 1 to 3 show the TPF Coronagraph in both packaged and deployed configurations.

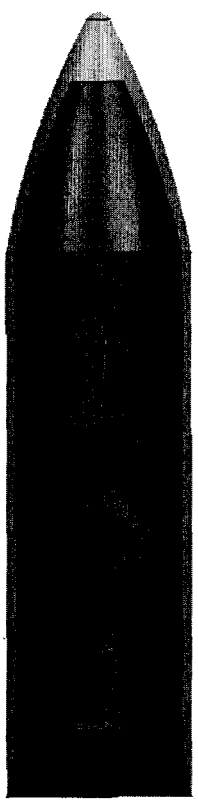

Figure 1. Stowed Configuration in Delta IV-H Fairing

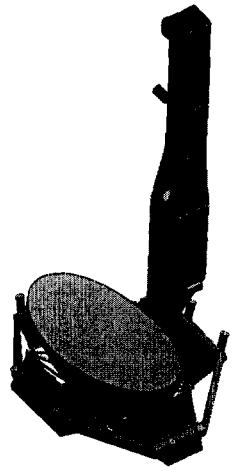

Figure 2. Coronagraph Is Deployed and V-Groove Sunshield Is Packaged

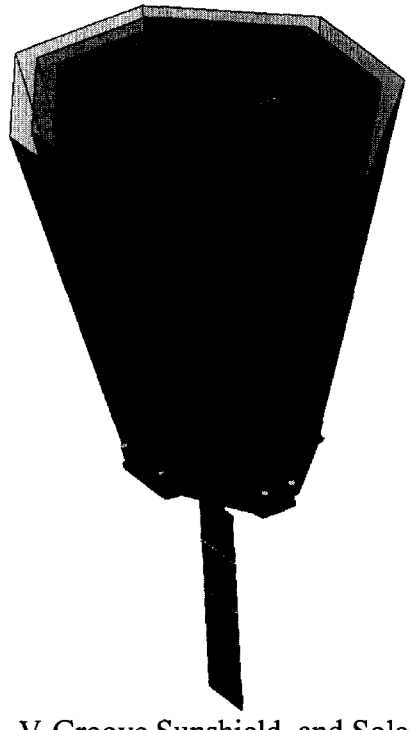

Figure 3. Coronagraph, V-Groove Sunshield, and Solar Panel Are All Deployed

To control the coronagraph's thermal environment, a novel V-groove sunshield, which serves as both a thermal shield and as a light baffle, has been developed. The sunshield is composed of six layers of cone-shaped thin-membranes as shown in figure 4. The diameter of the most inner V-groove is 6.5 meters and the height of all V-grooves is 11.5 meters. The thickness of the membrane is 2-mil. Major components include: 1) membranes to serve as the shield, 2) catenary systems that stretch the membranes to give them stiffness, 3) booms which deploy the membranes and provide structural rigidity, and 4) tensioning cables to apply hoop stress to the sunshield. Significant design tradeoffs include the dynamic characteristics of the sunshield, it's packaging volume, and on-orbit deployment.

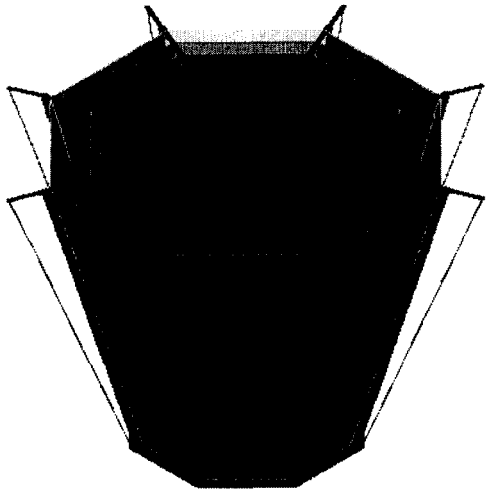

Figure 4. A V-Groove Sunshield System

A representative two-dimensional approximation (shown in figure 5) has been used for the preliminary design analysis of the system. If the membranes are held under tension, all booms must support compression loads. In addition, tensioned cables are used to minimize the moments applied to the lightweight booms and to provide radial forces which will apply the hoop stress to the catenary systems.

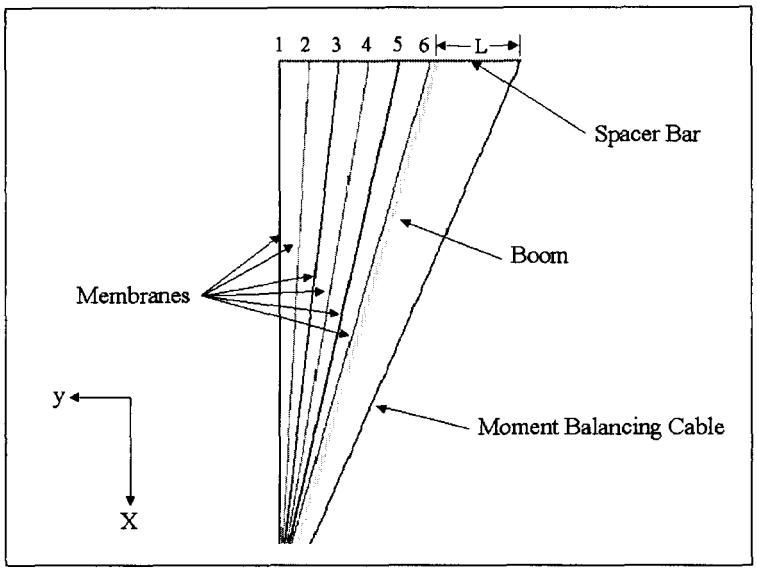

Figure 5. Orientations Of The Boom, Membranes, And Moment Balancing Cable

This paper will discuss the sunshield's design including its in-space deployment. The catenary design [2] will also be shown. Trade studies of different locations and orientations of the moment balancing cable will then be presented. Boom loads will be calculated and potential boom candidates for this application will also be discussed [3-7]. Preliminary results for these calculations indicate rigidized inflatable or mechanically

deployed booms will be competitive. Dynamic characteristics of the V-groove sunshield system will be analyzed and discussed.

References:

1. http://planetquest.jpl.nasa.gov/TPF/tpf_index.html
2. H. Fang, M. Lou, L. Hsia, P. Leung, "Catenary Systems for Membrane Structures," AIAA 2001-1342, 42nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference and Exhibit, Seattle, WA, 16-19 April 2001
3. M. Lou, H. Fang, and L. Hsia, "Self- Rigidizable Space Inflatable Boom", AIAA Journal of Spacecraft and Rockets, Vol. 39, No.5, pp. 682-690, 2002
4. C. Hazelton, K. Gall, E. R. Abrahamson, R. J. Denis, M. Lake, "Development of a Prototype Elastic Memory Composite STEM for Large Space Structures", AIAA 2003-1977, 44th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference and Exhibit, Norfolk, Virginia, April 2003
5. E. J. Simburger, et al., "Development, Design, and Testing of Powersphere Multifunctional Ultraviolet-Rigidizable Inflatable Structures", AIAA 2003-1897, 44th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference and Exhibit, Norfolk, Virginia, April 2003
6. Charles R. Sandy, "Next Generation Space Telescope Inflatable Sunshield Development", IEEE 0-7803-5846-5, 2000
7. http://www.aec-able.com/Booms/ablebooms.html