ABSTRACT

The attitude dynamics and stability of a solar sail spacecraft during deployment are of great interest since the deployment process itself has a large effect on the overall long-term stability and control of the vehicle. Solar sailcraft dynamics are very complex and nonlinear due to the highly flexible sail membrane, modal interactions among sail components, and contributions from multibody dynamics. In order to advance the Technology Readiness Level (TRL) it is critical that static and dynamic stability of the sailcraft be ensured, with or without active control, during all phases of its operation including the deployment process.

To model these dynamics, equations of motion governing the deployment of a solar sail are developed and the stability of the predicted motion is evaluated. For this purpose, an expression is derived to calculate the principal moments of inertia as the solar sail is deployed. A typical 40 m x 40 m square solar sailcraft is considered with a center of mass vs. center of pressure (cm/cp) offset of 0.25% of the sail edge length, boom deployment rate of 2.5 cm/s, and maximum incident solar radiation pressure force density of 8.33x10^{-6} N/m². The dynamic simulations show that the sailcraft exhibits an exponential decay in the spin rate about its roll axis (perpendicular to the sail membrane). This behavior is accompanied by an increase in the pointing error of the sail membrane normal vector (i.e., thrust vector). Variations in the baseline parameters given above will alter the final pointing error. It is shown that uncertainty in the cm/cp offset produces the most severe increase in the pointing error. Adjustment of the boom deployment rate (and thus, the total time required for deployment) also significantly affects the pointing error induced by the deployment process. It is observed that the final pointing attitude error in most cases is significantly larger than the typical sailcraft specification of ±1 deg misalignment of the thrust vector. The capabilities of the attitude control system and the deployment parameters (e.g., initial spin rate, boom/sail deployment rate, and initial pointing attitude) must then be optimized to assure satisfactory deployment.

Friday, April 21, 2006
2:15 p.m., CAMP
Refreshments will be at 2:00 p.m.