PROBLEM SET #5

TO: PROF. DAVID MILLER, PROF. JOHN KEESEE, AND MS. MARILYN GOOD

FROM: SEUNG CHUNG AND ANNA SILBOVITZ

SUBJECT: PROBLEM SET #5 (STRUCTURE, ACS, AND PROPULSION)

DATE: 6/21/2004

MOTIVATION

With greater demand for high-resolution images and the technological infeasibility of manufacturing and launching larger aperture optics, many missions are turning to interferometry as an alternative high-resolution imagery technique. One of the interesting aspects of a single spacecraft interferometry, as opposed to the use of formation-flying multiple spacecraft, is the trade off between acquiring higher-resolution images with a long spacecraft vs. shorter spacecraft that is less affected by the gravity gradient torque disturbance. (Though in general, if the structure is perfectly symmetric, the gravity gradient torque disturbance does not exist, with an offset in the center of the gravity, the gravity gradient torque disturbance will be an important factor.) While higher-resolution images may be desirable from the perspective of the science objective, a lighter spacecraft (i.e. shorter spacecraft with smaller effective aperture) may be more desirable from mass perspective. That is, a spacecraft with large effective aperture will be highly affected by the gravity gradient due to the long length of the spacecraft. With greater torque disturbance, larger reaction wheels are necessary to counter act the torque disturbance. In addition, the size of the reaction wheels as well as the size of the propulsion system used for momentum dumping will greatly depend on the frequency of momentum dumping. As such, a good balance among the design of the three subsystems (structure, attitude control, and propulsion) is necessary to produce high-resolution images with low mass spacecraft.

PROBLEM STATEMENT

Optimize the design of a satellite so that it has high-resolution imaging capability but with minimal mass spacecraft. Mass of the outer satellite, the reaction wheels, and the propulsion system should be considered. For a given satellite length, find the gravity gradient disturbance, the reaction wheels needed to compensate, and the propulsion system necessary for momentum dumping at a given rate. By performing trending analysis, find trade-offs between satellite size, and the reaction wheels and the propulsion system associated with the momentum dumping frequency. Note that the focus of this problem is not to design a high fidelity model of the subsystems, but rather to analyze the dependencies among the three aspects of the satellite system.

APPROACH

A tool using MATLAB will evaluate the three subsystems. The satellite will be modeled as a cylinder with an offset center of gravity. The user will input a length for the cylinder, the location of the center of gravity, the radius of orbit, the mission lifetime, and the frequency of momentum dumping. First, by using a fixed material for the satellite structure, the mass and angular momentum of the structure will be found. Next, the worst-case gravity gradient torque, due to the length of the structure, will be found. From this torque, the necessary momentum storage for the reaction wheels and their mass will be found. Finally, using the momentum from the reaction wheels, the mission lifetime, and the frequency at which momentum should be dumped, the necessary mass of the propellant and propulsion system can be found. To limit the complexity of the problem, maneuvers other than what is necessary to compensate the gravity gradient torque disturbance will not be considered. Furthermore, the propulsion system design will be fixed to a monopropellant system to simplify the problem.