

FIREBIRD Proposal - 2010 MSU Space Physics REU

SIMULATION OF THE PRECISE SEPARATION OF A TWO-NANOSATELLITE SYSTEM USING DIFFERENTIAL DRAG AND PASSIVE ATTITUDE STABILIZATION VIA MAGNETIC HYSTERESIS

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1 Goals

I am planning on writing a program to numerically determine the low-earth-orbits and attitudes of the two satellites of FIREBIRD with a variety of modified structural conditions. The main program would determine at least three important details about the FIREBIRD mission:

1. The time it takes the satellites to reach a maximum separation distance between them, double back upon themselves, and to reach that distance in the opposite direction, given a certain difference in mass between them and initial separation speed.
 - A slight difference in mass between the satellites leads to a different ballistic coefficient.
 - The different ballistics of the satellite lead to differential drag between them in a low-earth-orbit with atmospheric drag forces.
 - Differential drag will cause the leading satellite to lose its initial separation speed with respect to the lagging satellite; the separation distance between them will then reverse and close, and the leading satellite will eventually lag behind until a separation distance is achieved in the opposite nature.
 - Given a mass difference between the satellites, the mission duration can be effectively increased without changing the original separation velocity.
2. The time it takes the attitude of each satellite to stabilize, given the structural design of the bar magnets within FIREBIRD.
 - The satellites each have passive attitude control, where they shift their attitude to line their bar magnets up with Earth's magnetic field.
 - Engineers use materials with magnetic hysteresis to provide forces which dampen out natural oscillatory attitude movements and eventually stabilize the attitudes.

3. The effect of having the satellites separate along a vector that points in a different direction from their center-of-mass velocity vector, or separate at a very different speed than the one planned.
 - Having the satellites separate in a direction that is different from direction the two satellites are traveling before separation could drastically change each satellites individual orbits and the mission duration.
 - Having the satellites separate at a different speed could drastically change the mission duration.
 - The project requires a test to see how much error can be introduced into the separation velocity vector before mission failure.

2 Programming Outline

1. The program shall be written in MATLAB.
2. Loops should be replaced with vectors as much as possible, to improve program efficiency.
3. Numerical evaluation should use a fourth-order Runge-Kutta method to increase accuracy.
4. The program shall utilize geodetic Newton's Laws of gravity.
 - The earth shall be assumed to be an ellipse, using the J2 Earth gravitational harmonics.
 - The numerical evaluation of physics equations should use Earth-Centric-Inertial Cartesian coordinates.
5. The program should be as accurate as possible over the simulation time.
 - The numerical step size should be no larger than 3-5 seconds.
6. The atmospheric drag associated with LEO must be accurately accounted for.
 - The atmospheric density must be represented by the NRLMSISE-00 Atmospheric Model at each step.
 - The geodetic location of the satellite in orbit must be known at each step.
 - The satellite surface area through time must be accurately represented, determined by its attitude with respect to its velocity vector.
7. The attitude of the satellite must be known at each step.
 - The attitude is controlled by passive attitude control; the Earth's magnetic field must be represented by the IGRF Geomagnetic Model.
 - The attitude is stabilized through magnetic hysteresis; the physics must be understood and the errors from any simplifying assumptions must be negligible.