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System Requirements Document

March 7, 2002

1. Program Overview

Prof. J. M. Longuski of Purdue University has developed a two-burn thrusting method to eliminate the angular momentum bias resulting from unknown thruster (or center of mass) offset in axially thrusting-spinning spacecraft. This document describes the requirements for a small satellite that shall be designed to test the effectiveness of the two-burn scheme with the presence of an exaggerated thruster (or c.m.) offset. The experiment shall also include a secondary mission using a small separate SRM to test the trapezoidal thrust profile for velocity precision pointing (US patent No: 6,332,592 B1), also developed at Purdue by Longuski et al. The SRM used for this secondary objective shall also cause the orbital decay during the experiment for de-orbiting of the spacecraft.

Interplanetary missions, and HEO missions that require large ΔV's during orbit transfers are most likely to benefit from this demonstration, where small pointing errors cause large costs in attitude corrections.

Although this mission shall be designed for LEO, due to cost considerations and limited range of launch possibilities as a university satellite, the results obtained from this demonstration is expected to justify the effectiveness of the two-burn and trapezoidal thrusting schemes.

2. Mission Design

The mission for this study shall be to establish a low Earth orbit while maintaining flexibility in launch options and using proven technology. The spacecraft shall be designed to perform various pointing error correction techniques and transmit the data collected to the Purdue University ground station. The orbit shall have an inclination capable of direct communication with the Purdue ground station. The orbit shall have a minimum of 3 passes for communication each day.

3. Launch Vehicle

The satellite shall be designed to fit any launch vehicle available (i.e. Delta, Shuttle Hitchhiker, Pegasus/OSP, and Minotaur), as a secondary payload. Due to the varying constraints of the different launch vehicles, the satellite shall be designed for the maximum allowable case. The Delta rocket imposes the greatest limits on the spacecraft dimensions, while the Pegasus will impose the largest structural constraints.

The spacecraft shall have maximum dimensions of 30 cm X 30 cm X 35 cm and maximum mass of 40 kg, so the spacecraft shall fit in the Delta launch vehicle as a secondary payload.

4. Mission Life

The satellite shall be designed for a one-week life in orbit. The experiments will take approximately three days, allowing for a redundancy of four days.

5. Propulsion

The satellite shall have a cold gas thruster capable of providing the thrust profiles required to perform a test of the single and two burn maneuver. The total velocity change for the cold gas thruster shall be 6 m/s. The satellite shall also have a solid rocket motor to de-orbit the spacecraft and that is capable of providing the thrust profile required to perform the trapezoidal burn maneuver. The total velocity change for the solid rocket motor shall be 50 m/s. The cold gas and solid rocket motors shall provide approximately 1 Newton of thrust to perform the burn maneuvers. Two separate SRMs shall be attached to the side of the spacecraft to provide the initial spin-up of the spacecraft. The total velocity change for the spin-up thrusters is 0.5 m/s.

6. Attitude Determination & Control

The spacecraft shall have multiple sun sensors for precise attitude determination. The angular velocities shall be determined by rate gyros. The sun sensors shall be used in conjunction with gyros for reference correction. Accelerometers shall be used to detect acceleration changes of the spacecraft, which shall be used to determine the velocity history of the spacecraft during the experiments. The spacecraft shall spin about the maximum moment of inertia axis at a rate of 20 rpm (this spin rate has no significance). Two small solid thrusters that are placed about the spin axis shall provide the initial spin in case that the launch vehicle is incapable of providing it.

The spacecraft shall not have an active attitude control system aside from the axially placed main cold-gas thruster (along the spin axis) and the SRM on the opposite face. Due to energy damping induced by flexible antennas, any nutation caused by the offset thrusters shall decay passively in a short time (maximum 1-2 hours), causing the spacecraft to spin only about the maximum MOI axis (intended spin axis).

7. Power

The power requirement for the spacecraft shall have a maximum peak power requirement of 40 watts. The power shall be provided by primary D-cells with an operating voltage of 24 volts. The batteries' state of charge shall be monitored throughout the mission.

8. Thermal Control

The thermal control system shall have a thermal margin of 5°, meaning that temperatures of 5° higher than the lower temperature limit and 5° below the upper temperature limit will be maintained. (The temperature limits shall be determined as the equipment is selected.) Coating or insulating their outer surfaces shall control temperature of compartments, and conventional electronic equipment. Gyros shall be placed in insulated compartments with active electrical heaters to carefully control temperature. The need for additional heaters shall be determined as specific temperature limits are specified.

9. Telecommunications and Data Handling

The goal shall be to use the ground station available at Purdue University, through a direct downlink from the spacecraft. Commands shall be uplinked to the spacecraft via a terminal node controller, which shall format the data for transmission. The primary use of the downlink shall be to transmit the attitude data, temperatures of different subsystems, and battery state of charge to the ground station during each pass. The uplink frequency shall be in the two-meter wavelength band (~150 MHz), and the downlink frequency shall be in the 70-centimeter wavelength band (~440 MHz). The exact frequencies shall be as allotted. The transmitter, receiver, and terminal node controller shall use existing, off-the-shelf technology. Communications shall use the A.X. 25 amateur radio protocol to package and transmit the data at a rate of 1200 bits per second. The antennae shall utilize two pairs of monopole antennae (one pair for transmit and one pair for receive), which shall be mounted on opposing corners of the spacecraft.

The data handling shall use a processor, a data module, several analog-to-digital converters, a decoder, and a digital databus. The data shall be buffered in the memory module as the experiments are performed and then, upon ground command, downlinked data to the Purdue University ground station.

10. Structures

A prime requirement for the structure is that it shall be designed to withstand dynamic loads present during testing, launch phases, and zero gravity environment. The main bulk of the structure shall consist of a durable, lightweight, cheap material that is relatively easy to manufacture. The structural component will also have to withstand axial and lateral frequencies of 35Hz and 18Hz respectively, in order to have a successful mission.