United States Naval Academy Small Satellite Program

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Abstract

This paper describes the United States Naval Academy's (USNA) Small Satellite Program. The program actively pursues flight opportunities for miniature satellites designed, constructed, tested, and commanded or controlled by Midshipmen. The Small Satellite Program provides funds for component purchase and construction, travel in support of testing and integration, coordination with DoD/NASA laboratories or universities for collaborative projects, and guides USNA Midshipmen through the DoD Space Experiment Review Board (SERB) flight selection process.

The satellite development process is a multi-semester effort requiring the contributions of Midshipmen from several consecutive graduating classes. Senior students in our Aerospace Design course initiate the process in the spring semester with identification of the mission and determination of requirements, followed by development of the conceptual design. Students in subsequent classes will take the satellite through feasibility study, final design, construction, testing, and launch platform integration. Each spring, students in the design class begin the process anew with a new satellite concept, so that new projects are germinating to take the place of those that are coming to completion and awaiting launch.

USNA-1 is a simple communications satellite designed to provide a space-based node to the Amateur Position Reporting System (APRS). Conceived by R. Bruninga of the USNA Satellite Ground Station (SGS), and operating in the amateur radio band, it will receive position and identification data from amateur radio operators participating in APRS, and them rebroadcast that data to the USNA SGS for integration into the APRS database.

I. Introduction

Historically, the senior-level spacecraft design course for aerospace engineering majors following the astronautics track at the United States Naval Academy (USNA) has been a traditional conceptual design project. While requiring the students to design and integrate a space mission, the course did not give the students a chance to build, test, or operate a spacecraft. Our USNA Small Satellite program addresses those shortcomings, plus it is a great motivator for our students. The first spacecraft in our program, USNA-1, is a small communications satellite that can be accessed by the USNA SGS, other educational institutions, and amateur radio operators.

USNA-1 is designed to fly as a secondary payload on a launch obtained through the DoD Space Experiments Review Board (SERB); therefore, the design must be robust enough to operate in a variety of orbits and survive the launch environment presented by a variety of launch vehicles. Potential orbits include low-Earth, sun-synchronous, geostationary transfer, and geostationary. Since geostationary transfer orbit (GTO) represents the most stressful environment in term of radiation and variable path length, we chose GTO for our baseline. Potential launch vehicles include the space shuttle and numerous expendable launch vehicles. We designed the structure to survive a wide range of acoustic and acceleration environments described in Table 1.

Table 1. Launch Vehicle Environment

Axial Acoustic Frequency	Lateral Acoustic Frequency	Axial Acceleration	Lateral Acceleration
Hz	Hz	G's	G's
35	18	6.7	5.9

Finally, the spacecraft must operate in the amateur radio-frequency band. We chose 145.81 MHz for the uplink and downlink frequencies.

II. USNA-1 Design.

Our mission concept for USNA-1 calls for a simple lightweight design. For these reasons, our design does not include a propulsion system or an attitude control system. The main elements of the spacecraft design include the payload (a communications package), electrical power, thermal control, and the structure. USNA-1 has a mass of 10 kg and is a cube – 25.4 cm on a side.

Communications

The communications package on USNA-1 acts as a digital repeater for package communications and also provides subsystem telemetry to the ground station.   The basic components are four 48.26 cm whip antennas, a transceiver, and a terminal node controller (TNC). Since we designed the spacecraft with no attitude control system, the antennas must be omni-directional. Using a transmitter power of 500mW, a data rate of 1200 bps, and a nominal orbit altitude of 800 km, our energy-per-bit to noise-density ratio is about 30 dB. We are investigating options for mounting the antennas for easy storage during launch and deployment after separation from the launch vehicle.

USNA-1 will operate in the amateur satellite frequency band – 145.81 MHz. Onboard hardware includes a TT175 VHF Transceiver and a Kantronics KPC-3+ terminal node controller (TNC). Both the transceiver and TNC operate at 12 volts. The transceiver requires three watts of power in the receive mode and the TNC requires approximately 0.2 watts of power.

Electrical Power

The requirement for the electrical power system for USNA-1 is 3.45 watts of power and a 12-volts bus. We also require a 5-volt voltage regulator for voltage conversion. Body-mounted solar cells and D-cell batteries provide electrical power. Since the spacecraft does not have attitude control, enough power from a single side must be adequate to power the spacecraft. We are testing various COT, terrestrial solar cells and batteries for use on USNA-1.

Structure

The basic structure of USNA-1 is a 25.4x25.4x25.4 cm aluminum cube and must support a total spacecraft mass of 10 kg. An aluminum shelf supports and separate components within the spacecraft. The structure design must support the spacecraft in a variety of launch environments, since we don't know the launch vehicle. The structure mass accounts for approximately 40% (4 kg) of the spacecraft mass.

Thermal Design

Design requirements for the thermal control system calls for a temperature range of 0^o to 30^o C in a variety of environments using passive thermal control.[1] The biggest unknown is eclipse duration because we don't know our final mission orbit. Assuming a 600-km circular orbit and assuming the spacecraft is covered with solar cells, our maximum and minimum steady- state temperatures are approximately 0^o and -120^o C well below our requirements. We need further analysis and testing to determine transient temperatures and the effects of using thermal insulation.

III. Future Work

Future work for this mission includes developing and completing a test plan for the spacecraft and finalizing our launch plans. While we are completing our plans for USNA-1 we are beginning plans for USNA-2. Seniors in our Spring '00 Spacecraft Design class will complete the conceptual design for this mission. We are currently investigating a technology demonstration using a satellite-cell phone for communications. We also plan on carrying a digital camera and a GPS receiver.

Bibliography:

Larson, Wiley and James Wertz, *Space Mission Analysis and Design, 3rd Edition,* 1999, McGraw-Hill, New York. Pg. 430.

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Daryl G. Boden is Professor and Director of Astronautics in the Aerospace Engineering Department at the United States Naval Academy in Annapolis, MD. Dr. Boden received his B.S. degree in Aerospace Engineering for the University of Colorado in 1972, his M.S. degree in Astronautical Engineering for the Air Force Institute of Technology in 1979, and his Ph.D. in Aeronautical and Astronautical Engineering from the University of Illinois in 1986.