THE UNIVERSITY OF HAWAII CUBESAT: STUDENT PROJECTS IN SATELLITE TECHNOLOGY

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ABSTRACT

The University of Hawaii CubeSat project is the largest multi-disciplinary project at the College of Engineering, involving over 50 mechanical, electrical, and civil engineering undergraduates. The preliminary thermal and structural analyses have been completed by the mechanical engineers. The CubeSat’s electrical subsystems have been designed by electrical engineering students: the satellite is powered by GaAs solar cells, in conjunction with lithium-ion batteries; communications are done in the 70-cm band, with modified commercial-off-the-shelf components; a commercially available core module will serve as the satellite’s flight processor; the payloads of the CubeSat include a high-frequency active antenna, thermal sensors, and a passive stabilization system. Civil engineering students are designing and constructing an antenna mounting structure for the ground station.

INTRODUCTION

Small satellites can accomplish many of the same functions of their larger counterparts at a fraction of the cost and design time, making them excellent for remote sensing, quick-response science missions, ad hoc communication networks, component evaluation, and technology demonstrations. As a result, there has been an explosion in the amount of small-satellite projects. Indeed, many United States government agencies, including the Defense Advanced Research Projects Agency and the Jet Propulsion Laboratory, in addition to companies such as the Aerospace Corporation and TRW, are all working on small-satellite projects [1]-[4].

Capitalizing on this new interest, Professor Robert Twiggs of Stanford University’s Space Systems Development Laboratory developed the CubeSat program to expose students to the various aspects of small-satellite design, manufacture, and operation [5]. Design constraints include a mass no greater than 1 kg and a maximum volume of 1000 cm³ (Fig. 1).

The University of Hawaii’s CubeSat program, now in its first year, is the largest project ever undertaken by a multidisciplinary group of engineering students in the university’s history, with over 50 undergraduate students and nine faculty advisors. Furthermore, all of the engineering fields at the University of Hawaii are represented on its CubeSat team. Electrical engineers are designing, fabricating, and testing the necessary electronic subsystems of the satellite. Mechanical engineers are simulating the
thermal conditions the CubeSat will experience, as well as analyzing and testing structural components. Even civil engineers are involved; they are in charge of the design and construction of the ground-station antenna structure. While this is very demanding on the students that are involved, since they are all at the undergraduate level, the educational value is tremendous, as the students accomplish tasks usually reserved for graduate students.

Fig. 1. The housing of the University of Hawaii’s CubeSat picosatellite, donated by One Stop Satellite Solutions [6]. It measures 10 cm on each side, and has a mass of 318 grams.

SATELLITE BUS

The satellite subsystems that are essential for operation form the satellite bus. This includes the power, communications, and structural systems, along with the satellite’s onboard data processing unit. The teams that form the University of Hawaii CubeSat project are organized with these subsystems in mind.

The Mechanical Structures and Analysis (MSA) team is responsible for the thermal, thermal stress, and dynamic modeling of the CubeSat. The thermal conditions of the CubeSat will be simulated using a hybrid resistance-capacitance model (the system is analogous to a resistor-capacitor circuit). In addition, the MSA team is in charge of design and fabrication of all the mechanical support structures needed for the satellite, based upon vibration and thermal stress simulation and testing.

The Power Generation and Distribution (PGD) team supplies the power for the CubeSat’s electronic components. Power is generated with 21% efficiency gallium arsenide solar cells. Each side of the CubeSat has two solar cells, measuring 6.9 cm by 4.0 cm, mounted on it. This provides about 1 W of continuous power. The solar cells charge lithium-ion batteries, rated at 5600 mA-hours. The batteries are used during the eclipse periods of the satellite orbit (when the satellite passes over the dark side of the Earth), or when the power demand exceeds the output of the solar cells. The PGD team is also designing and fabricating a regulation/switching network to provide power to the CubeSat subsystems, a battery charging circuit, and a gas gauge for telemetry.
The Tracking, Telemetry, and Command (TTC) team is responsible for the communication link between the satellite and ground station. The satellite transceiver system consists of a terminal node controller (TNC), commercial-off-the-shelf handheld radio, and an antenna. Data from the CubeSat's CPU is sent to the TNC [7], which encodes the data using amplitude frequency shift keying and the AX.25 amateur radio protocol. The packets are then broadcast in the 70-cm UHF band using a modified Yaesu VX-1R handheld transceiver, which in turn is connected to a dual monopole antenna that provides an approximate omnidirectional radiation pattern.

Although the UH CubeSat communicates in half-duplex mode exclusively at the 70-cm band, the ground station is equipped with both UHF and VHF antennas in anticipation of future satellite missions and collaborations with other universities. The two assembled antennas are placed on a rotator and mounted on a support structure designed and built by the Antenna Support and Mounting (ASM) team, consisting of UH civil engineering students. The rotator is interfaced with Nova Tracking software on a Windows-based PC platform via an external control box. The completed ground station will be capable of finding the position of objects in space based upon their Keplerian elements, and tracking the object during its geometrically calculated window of communication in real time.

The Data and Command Handling (DCH) team is responsible for the microprocessors and other on-board digital support circuitry. Automated tasks are run by a Rabbit Semiconductors microprocessor. In addition, the TTC and Analog/Digital Sensors teams have programmable integrated circuit (PIC) chips to aid the Rabbit processors in data routing and handling throughout the satellite. Should the main CPU fail, the PICs can function as back-up processors.
MISSION PAYLOADS

The University of Hawaii’s CubeSat is able to accommodate three separate payloads, despite the 1-kg weight limit. The main payload consists of an experimental high-frequency active antenna. Other experiments include thermal sensors, and a passive stabilization system.

Current CubeSat communication systems operate in the VHF/UHF range, which may not be able to accommodate future, data-intensive CubeSat missions such as the lunar and Mars missions in 2006-2007 [8]. With this need in mind, the UH CubeSat is developing a 5.8-GHz active antenna [9], [10] that provides high-frequency communications, facilitating faster data transmission rates. This type of active antenna, known as a grid oscillator, uses an efficient power-combining scheme packaged in a compact, low-profile structure that can be mounted on the side of a cube (Fig. 4). Compared to conventional CubeSat antennas, grid oscillators do not require deployment, are tolerant to single-point failures, and facilitate long-link communications at microwave frequencies – important advantages in satellite design, and necessary design features for future CubeSat missions.

Fig. 4. A prototype active antenna, consisting of an array of transistors directly embedded into a planar radiating structure.

The Analog/Digital Sensors team (ADS) is designing and fabricating a thermal sensor system. The onboard Maxim MAX6633 thermal sensors will be used to better understand the type of environment that the CubeSat will experience when in orbit and to verify the thermal simulations of the MSA team. The thermal sensors are connected to a PIC16F872 microcontroller, which handles the A/D conversion of the sensor data, and sends the data to the main CPU for transmission to the ground station (Fig. 5).

Fig. 5. Block diagram of the ADS subsystem.

The Science (SCI) team is designing the CubeSat’s passive stabilization system consisting of magnets and hysteresis rods. The most important benefits of having such a system on board would be improved power generation (solar cells work more efficiently
if the spin of the satellite is reduced) and aiming the active antenna towards the Earth. The neodymium-iron-boron magnets align the CubeSat with the Earth’s magnetic field, while the nickel-iron alloy hysteresis rods reduce the satellite’s spin.

**FUTURE DIRECTION**

The launch date of the University of Hawaii CubeSat is tentatively scheduled for March 2004. To meet this deadline, fabrication and testing of subsystem components will continue throughout the year. System integration will take place beginning early 2003.

This project does not end with the completion of the current CubeSat. Future CubeSat missions have already been discussed. In addition, the future may hold possibilities for collaboration with other universities. This synergy of ideas and information will ensure that CubeSat projects will challenge students for years to come.

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**REFERENCES**


