Spy Sat

Intermittent imaging of ground target location via stabilized camera system.

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1.0 Mission Statements

To build a camera stabilization system that would use information gathered from solar and magnetic sensors to image a target ground location and to verify success by choosing distinctive targets.

2.0 Mission Requirements and Description

The system must reliably function at extremely low temperatures and atmospheric pressures and weigh no more than 1.5 kg. Facilitating aiming required minimization of payload rotation. For aiming, the payload must track its own pitch, roll, yaw, and position. After calculating an aiming vector, the payload needs to point the camera at the target location. The system also required a non-volatile storage medium to record data. In a NASA scenario, the system would require a real-time communications system as well.

3.0 Payload Design

We constructed the fuselage of our satellite with half-inch insulation with an R rating of three. The structure is shaped like an elongated hexagon with a tail attached to the back. Mounting the balloon support cable slightly ahead of the center of gravity encouraged the payload to point into the wind. We strung the support cable through a fiberglass golf club shaft with a pair of roller blade bearings mounted on either end to minimize wear on the cord.

Our imaging system was comprised of a Logitech web camera. We selected it because it only weighed fifty-five grams and came with a self-contained set of servos that are capable of 180 degrees of motion along the azimuth and 60 degrees elevation. We mounted the camera in a box constructed of lightweight aircraft plywood that we then attached to the underside of the satellite.

Two zones required heating: a well-protected, internal zone with most of the electronics, and an external zone with the camera. We used two ten-ohm resistors in parallel and a one-ohm resistor in series to produce 11.6 watts of heat for the camera. This allowed us to heat the camera continuously for up to eighty-five minutes. Our internal heating system is comprised of eighteen one-ohm two-watt resistors. We used a mechanical thermostat that would close the circuit when the temperature dropped below zero Celsius and open the
circuit when the temperature rose above ten degrees Celsius. Our internal heater is capable of producing 15.7 watts of power for 77 minutes.

The GPS we chose for the payload is the Garmin 18 PC (RS-232). It is reliable, inexpensive, and works above 18km altitude.

The yaw and pitch portion of the orientation system consisted of Honeywell products. We used the HMC 1051Z one axis magneto-resistive sensor and the HMC 1052 two-axis magneto-resistive sensor. Combining the two magnetic sensors at right angles allowed us to calculate the direction of the magnetic field, thus establishing one of our orientation vectors. We used an IRF-7509 dual channel MOSFET power transistor to create a set reset circuit for the magnetometers. This prevents a memory build up within the sensor. We amplified the signal with two LM324N quad-channel op amps. This brought the signal within the functional range of the analog to digital converter on our single board computer.

Our payload power supply consisted of four 7.2-volt 2.4 amp/hour lithium-ion batteries. Two were used to power the electronics and two were used to power the heaters. To ensure constant power to our electrical components, we used several voltage regulators. The amplifiers required a twelve-volt power source, and all other components required a five-volt power source.

To generate the second vector required for orientation, we constructed a solar tracker. We built it with four .5V at .3A solar panels mounted in pairs along the x and y axis of the payload. We encased the panels in black foam insulation to block ambient radiation, and mounted them at a thirty-degree elevation from the payload itself. We used the voltage difference between the panels to calculate the roll of the satellite.

The single board computer (SBC) integrates components and stores information. The SBC receives data from environmental sensors, orientation sensors, GPS; communicates via 802.11b (WiFi); and stores data on non-volatile, solid-state memory (a "flash" drive). Many DemoSat projects choose simple microcontrollers (such as a PIC or Stamp) as computers. It was not feasible to use a microcontroller because of the processing demands of image compression and complexity of the USB interfaces necessary for data storage, 802.11b communication, and image acquisition. PPCC choose the Technologic Systems TS-7250 SBC which features a 200MHz ARM CPU, 32MB RAM, 2 USB ports, 2 RS-232 ports, 5+8
channels ADC, 20 lines DIO, and a low power consumption of 375mA at 5VDC. The SBC comes standard with the Debian Linux 3.0 operating system, which was used and provided a robust development platform.

The software written for the SBC consisted of several modular, function-oriented components: ADC daemon; ADC, GPS, and system loggers; image logic and logger; web server; and automated downloaded. All new software was written in C++ for portability and performance, and use of existing, generic software accelerated development. The multithreaded ADC daemon is a service that via efficient UNIX sockets provides simplified access to the SBC's two ADCs, and ensures that only one read is allowed per ADC. The ADC logger records ADC data into an SQLite database. The system logger records the general system information, such as CPU load, and communications information, such as bytes of data transmitted. Working in conjunction with the automated downloaded, the web server component provided access to all stored data via the ubiquitous hyper-text transfer protocol (HTTP). Designed for the ground station, the automated downloader downloads data from the DemoSat to the ground and then removes that data from the DemoSat. The image logic and logger system was the most complex software written. It initializes the camera and pulls orientation and location data from other software. Then it cycles through a list of image targets and calculates an aiming vector for each target. The targets are giving priority by ordering them from last acquired to more recently acquired. If a target is in range, the image software system aims the camera using builtin servos; then, the image system copies the image into memory, compresses it with lossless PNG compression, and records it to the filesystem.

Some components were not fully developed. Because a critical component of the communications system was shipped late and did not arrive until two days before launch, the communication components (web server and automated downloader) were not written. Because of difficulty in establishing orientation sensors, the aiming system was never tested, though nearly fully written as software. Because of an unanticipated lack of manpower, no environmental sensors were purchased, electronically integrated, or used.
4.0 Student Involvement

Chris designed the sensors, electronics, and payload. He developed the orientation mathematics and constructed the sensors and payload body.

Andrew programmed the SBC.

Jason conducted research for the project, developed some of the mathematics, and assisted in the design, construction, and assembly of various components and the payload body.

Dan constructed the frame that we used to mount the camera in the payload, and assisted with the assembly of various systems.

Matt designed and assembled the heating system. He also assisted with the construction of various payload components.

Drew assisted with the final construction and launch of the payload.

5.0 Testing Results

We tested the functionality of our camera in low temperatures with the use of dry ice and concluded that it would function normally at negative 20-30 degrees Celsius. We used a fan to test the satellite fuselage to establish that our satellite would always face into the wind. Our most extensive tests, however, concerned the various electronic components. We spent a significant amount of time testing various materials and configurations for the solar tracker. Our selection of the black foam insulation as a cover for the solar panels is a result of this work.

6.0 Mission Results

Due to the failure of our storage medium, we do not have any information on the results of our flight. We are still investigating the cause of failure.

7.0 Conclusions

We are unsure what caused the USB memory device to fail. We have determined that the single board computer is fully functional and the fault lies elsewhere. We do not know if the failure was caused by defective hardware, the violence of the decent, or static discharge.
8.0 Potential Follow-on Work

We would like to follow up on our mission by completing the missing systems and re launching our payload.

9.0 Benefits to NASA and Scientific Community

Our solar tracker will prove useful in the further exploration of the solar system. Celestial navigation is the only practical method of orientation in outer space. Our targeting equation will also be useful for communication between spacecraft orbiting the Earth. It will allow precise point to point transmission of data with a minimum waste of transmission power. A similar imaging system could be used to map the Earth or another celestial body.