PAYLOAD DESIGN FOR A MICROSATELLITE

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ABSTRACT

Conventional satellites are extremely large, highly expensive, and may take several years to design and build. Microsatellites have the potential to reduce cost and risk when compared to conventional satellites. The main purpose of the LEONIDAS project is to prove that the University of Hawaii has the capabilities to design, build, test, launch, and operate a microsatellite. The payload subsystem is the heart of the microsatellite and consists of all the different hardware and software on the satellite that is used to satisfy the mission objectives. The payload subsystem will consist of four different instruments. An imager system will be used to test the satellite's capability to house a camera and will take pictures of Hawaii in the ultraviolet, visible, and infrared spectrum. A retro directive antenna designed by the University of Hawaii and a GPS unit provided by SSTL will test the satellite's capability to demonstrate new technologies. The satellite will also house health monitoring software provided by JPL/AMES.

INTRODUCTION

Currently, conventional satellites are extremely large, highly expensive, and may take several years to design and build. Not to mention each satellite is as unique as its mission. These factors are causing NASA to push toward the use of microsatellites. Microsatellites have the potential to reduce cost and risk when compared to conventional satellites.

First of all, a microsatellite can reduce cost by cutting down the design and integration and testing time since the satellite will be less complex. The manufacturing may also be reduced since the satellite will be smaller and therefore require fewer materials. Second, a microsatellite can reduce operations cost, since a smaller, less complex satellite should take less people to manage and operate it. Third, a microsatellite could reduce launch cost by requiring the use of a smaller rocket. Fourth, once a “cookie cutter” microsatellite has been design long-term costs will be reduced.

A microsatellite can also be used to test new technologies and therefore reduce risk. As missions become progressively more daring, and thus more difficult, more advanced capabilities are needed. While an emerging technology may seem promising and likely to provide the technical capabilities NASA requires, it may also present an unacceptable risk to any exploration mission using it for the first time in space. However, before new, untried technologies are used for the first time on complex exploration missions, engineers and scientists want to make sure they will operate well, and safely, in the hazardous environment of space.

The main purpose of the LEONIDAS project is to prove that the University of Hawaii has the capabilities to design, build, test, launch, and operate a microsatellite. Proving these capabilities will lead to many new opportunities within the aerospace industry. The success of the LEONIDAS project could lead to partnerships with NASA and could push the University of Hawaii to start its own aerospace program.
The payload subsystem is the heart of the microsatellite and determines many of the capabilities and limitations of the mission. The payload consists of all the different hardware and software on the satellite that is used to satisfy the mission objectives. The main purpose for the other subsystems of the satellite is to keep the payload subsystem happy and healthy.

**DESIGN**

In order to determine the design of the payload subsystem mission requirements need to be formulated. To satisfy our mission objectives the satellite will have to function at a 400 km orbit, a 92.6 minute orbital period, and a ground track speed of 7.2 km/s. The payloads must perform with a pointing accuracy of ±0.5°, determined by the capabilities of the Attitude Determination and Control subsystem. The payloads must also have a total mass of less than 2.2 kg and a total power consumption of less than 8 W. The satellite will house four different instruments: an imager system, GPS unit, retro directive antenna, and health monitoring software package.

The objective of the imager system is to test whether the microsatellite has the capabilities to house a camera. The imager system must successfully take a picture of Hawaii in the ultraviolet, visible, and infrared spectrums. The same model camera (Sony XCD) will be used for each spectrum. Using the same model camera will ease the process of testing and integration. At a certain orbital position, the satellite command and data handling system will trigger the imager to take five pictures to insure that a successful image is taken.

Each image will be processed onboard the camera and will be sent to the C&DH system via a firewire interface. The advantage of using a firewire interface is the quick transfer rate and the elimination of a separate power interface. The data volume was calculated by multiplying the pixels and the pixel depth. The specifications for the cameras are given in table 1.

Each image will have a ground resolution of 100x100 km. The field of view for the imager system was calculated using the 400 km orbit and the required ground resolution. The field of view for the imager system is approximately 14.0°. Lenses were chosen to match the field of view and the specifications are also given in table 1.
The GPS unit will test the satellites capabilities to perform technology demonstrations and will be provided by the Surrey Satellite Technology Ltd. (SSTL). The GPS unit is a spacecraft orbit determination sub-system designed specifically for small low earth orbiting satellites. This unit provides GPS standard time, position and velocity in a compact unit. The GPS unit also supports multiple antennas to improve visibility under changing orientations and attitude determination.

The GPS unit works by receiving and decoding the L-Band signals from four or more GPS satellites and, through ranging techniques, is able to calculate the position of the spacecraft to an accuracy of better than 20 meters and determine accurate velocity and time. The carrier phases measured from multiple antennas can be used interferometrically to determine the attitude of the spacecraft. The GPS unit and its specifications are shown in Table 2.
The GPS unit must accurately obtain orbital and altitude information. Measurements will be taken every 18.5 minutes during the test orbit. These measurements will be sent to the C&DH system via an RS-232 interface. The attenuation of the GPS signal may also be used for atmospheric data. In order to perform successfully the GPS must meet the performance requirements that are given in Table 3.

<table>
<thead>
<tr>
<th></th>
<th>Typical (95%)</th>
<th>Max (90%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbital Position (3-D)</td>
<td>10 m</td>
<td>20 m</td>
</tr>
<tr>
<td>Orbital Velocity (3-D)</td>
<td>0.15 m/s</td>
<td>0.25 m/s</td>
</tr>
<tr>
<td>Time</td>
<td>0.5 µs</td>
<td>1 µs</td>
</tr>
<tr>
<td>Time to First Fix (cold)</td>
<td>200 s</td>
<td>350 s</td>
</tr>
<tr>
<td>Time to First Fix (warm)</td>
<td>50 s</td>
<td>90 s</td>
</tr>
<tr>
<td>Attitude Determination</td>
<td>0.5 – 1 °</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Table 3: GPS Performance Requirements

For attitude determination, configuration of antennas is important. Four antennas are required for accurate attitude determination and each antenna will have to be placed two meters apart. Either all four antennas will be positioned on one side pointing spaceward or three antennas will be positioned on one side and one antenna on the opposite side pointing spaceward. The two configurations are shown in figure 1.
Originally the satellite was supposed to house an active antenna developed at the University of Hawaii by Dr. Wayne Shiroma’s. However, Dr. Shiroma and his students are currently in the process of redesigning the active antenna. The new retro directive antenna will be able to locate and communicate with other satellites. Since the antenna is still being designed no other information is available at this time.

JPL and AMES research center will be providing us with an autonomous spacecraft control and health monitoring software package. This software will be a part of the C&DH system and will demonstrate the following benefits:

- Low cost and flexible modeling, allowing health management algorithms to be tailored to the C&DH as it is developed and refined
- Ability to rapidly and safely update health models, providing the capability to improve health management with learned flight behavior
- On-board detection and isolation of C&DH errors and anomalies, greatly reducing operations overhead and risk to the microsatellite
- A flexible microsatellite operations concept that reduces costs, improves the cost predictability, enhances reliability, and enhances microsatellite capability.

CONCLUSION

There is still a great deal of work that needs next to be done next semester before the design for the payload subsystem is complete. I need to work with Dr. Shiroma’s students in order to understand how their new retro directive antenna will work. Then I will need to take the specifications of the antenna and make sure that the fit within requirements of the subsystem and meet the mission objectives of the satellite. I will also need to work with JPL and AMES research center to insure that the health monitoring software can be implemented in our satellite. Once I have the design for the antenna and the software I will need to perform an iterative analysis on the subsystem as a whole. Part of this analysis will be to calculate the data rates of the instruments to make sure that they fit within the specifications of the C&DH system. In order for the analysis to be complete, I will need to make sure that all the instruments meet the payload requirements, can satisfy the mission objectives, and are able to interact with the other subsystems in the satellite. After the analysis is finished, my subsystem will be ready for the critical design review in April.

REFERENCES