Engineering Design Impacts and Considerations for Satellite Sensors and Power Control

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***Abstract*—The following paper discusses the design considerations and their impacts on a satellite based I^2C sensor network. The considerations that were examined are the following: economic, environmental, sustainability, manufacturability, ethical, health and safety, social and political. These constraints were all taken into account on hardware selection and also software design decisions.

***Index Terms*— Design Considerations, Electra, I^2C Satellite sensors**

I. Introduction

A. Design Purpose

THE purpose of this design project is to provide a system to monitor and control the power being delivered to various key components aboard the Space Science and Engineering Lab's BarnacleSat, or CubeSat+, class satellite, Electra. In the event of a power problem, the sensor network must be able to detect the event, determine the severity of the problem, and disconnect the malfunctioning component from the satellite's power bus. Health information is also logged for later transmission to a ground station for analysis.

A satellite is confronted with different conditions while operating in orbit compared to functioning on a laboratory bench. One such concern is the flash memory module onboard the satellite receiving a charged particle strike while in orbit. This charged particle can cause the flash memory to latch-up which would result in a dangerous increase in current draw. Left unchecked, this current draw can destroy the flash memory, resulting in complete mission failure. Therefore, a reliable and accurate system is required to ensure a fault is detected and resolved quickly so that the memory can be reset without damage.

B. Electra Background

The mission of Electra will be to test the deorbiting capability of an electrodynamic tether to aid in slowing the accumulation of "space junk" in orbit around the Earth. The electrodynamic tether will drag through the Earth's magnetic field and decrease an orbiting object's total kinetic energy to bring it out of orbit more rapidly than if left alone. CubeSat class satellites are especially troublesome as they can remain in orbit for more than 25 years when placed in high orbits. Electra will be deployed from the upper stage of a booster carrying a primary payload and remain connected to the booster by a tether. High resolution GPS data will be collected to monitor the deployment of the tether and this data will be stored in the flash memory module to be transmitted to the ground for analysis. Protection of this data is vital to the success of the mission, which is the driving consideration for the sensor network.

II. Design Considerations and Impacts

Various constraints affect every design project and determine the base line requirements for a project to be considered successful. By taking these limitations into account before investing many design hours into a project, surprises such as component incompatibility or environmental failure can be avoided or at the very least mitigated. The following paragraphs discuss the constraints faced in designing the above described sensor network and power control system and how they affect the final design.

A. Economic

Due to the high costs of launching a satellite, construction costs should be kept as small as reasonably possible for a university funded project. Keeping the sensor network cost low leaves more funds available for more advanced equipment to carry out important science mission objectives. Using "off the self" parts facilitates this objective quite well. These parts are typically easy to obtain without any type of corporate contract, less expensive and available from various part vendors. The flash memory being used for file storage on the satellite led to the need for a power control system in addition to the sensor network. A higher quality, radiation hardened memory module was not feasible due to the high purchase price of such a module.

B. Environmental

The space environment in which the sensor network will ultimately be operating in requires special consideration in designing the system. The temperature range will be much larger than typical room temperature environments. The parts selected for the design were all capable of operating between -40°C and 85°C. This functional temperature range exceeded the expected temperatures of the predicted operating environment. Radiation hardened parts would be the most suitable components for the system, but due to high cost, low availability and the relatively low orbit of the satellite, they have been excluded. Due to the small inertial loads of the surface mount parts, vibration from the launch was not a concern. Noise produced by the rest of the system was not an initial concern. The goal for this design project did not involve final integration into the flight hardware, only a prototyped system. But, through testing as the project went on, certain I^2C communication line layouts were found to be problematic. This lead to the use of a parallel trace design which separated the data and address lines with power and ground traces.

C. Sustainability

The sensor network being designed must be able to function for a minimum of three months. In this three month period the network must reliably detect power faults and react correctly to prevent damage to key components. Regular maintenance will not be possible. Full reliability testing will not be possible due to time constraints and the lack of resources to fully simulate a space environment.

The final design of the project will also allow the use of more sensors with only minor hardware additions due to the constraints of I^2C hardware such as preset component addresses. The software design also left room for expansion by using a generic I^2C driver base and building around the driver for specific parts. Additional I^2C components could be easily added to the system at a later date. All decisions, reasoning and processes have been documented for later implementation by future projects.

D. Manufacturability

Future part availability for construction of the sensor network would be a concern if the system was being designed for large scale distribution. In the event of an unexpected mission failure, such as the launch vehicle not reaching orbit, rebuilding a functioning satellite in a short period of time provides an improved opportunity for a subsequent launch. This specific system will only be implemented for Electra and final part purchasing will be made as soon as the system is shown to fully comply with the required specifications. Three flight ready models will be constructed before launch to provide flight, backup and testing systems. Actual layout and circuit board designs were not taken into account in the early stages of the project. The initial goal of the project was to successfully demonstrate the hardware and software of the system on a development board. This allowed the design to be "dropped in" to the flight system once the rest of the subsystems, both hardware and software, were all completed and an entire flight computer could be constructed.

E. Ethical

High ethical engineering practices were used by all of the design team members throughout the entire design process. The possible international recognition of the project and in turn, the University, meant that the integrity of the entire project had to be maintained. Poor ethical decisions on a project of this scale could tarnish the reputation of both the Space Science and Engineering Laboratory and Montana State University.

F. Health and Safety

Following the current trend in the use of lead free parts, all selected components with lead free alternatives were chosen for the system.

G. Social

The Electra communication system uses the 70 cm amateur radio band. University projects that use this frequency band typically provide a simple telemetry beacon that amateur radio operators around the world can detect and decode either during the primary mission or during the satellite's end of life phase. This telemetry beacon is done as a "Thank you" to the amateur radio community for allowing student projects to occupy the band by providing a public signal that can be heard by an amateur radio operator around the world.. To make this telemetry beacon more user friendly, the sensor code on board the satellite had to convert the data into a clear text format that can easily be added to the comment field of an APRS beacon.

H. Political

Due to the possibility of launching Electra through a Russian based agency, export laws have to be considered in selecting parts. The companies manufacturing the components for the sensor network only require following applicable United States trade and export laws. These include not exporting components to embargoed nations such as Cuba and Syria. Proper US channels will be followed to export the satellite as a whole if and when a foreign agency is used for launch. ITAR regulations were considered in regards to the trade of arms between countries.

III. CONCLUSION

The above listed design considerations proved to be valuable in preparing to design the satellite sensor network. By taking all of these ideas into account before buying hardware or piecing together software, the group was able to avoid costly delays or surprises in the software design. This process made sure that the project was able to meet goals and deadlines in the first semester of work and also provided confidence in the remaining work to be done.

APPENDIX

A. Terms and Acronyms

APRS – Automatic Position Reporting System
APRS is a defined amateur radio packet format, usually used in conjunction with GPS systems to provide position reports over the amateur radio bands.

ITAR - International Traffic in Arms Regulations
ITAR controls the import and export of defense related materials and services. These regulations control the export of satellites to foreign countries for launch.

70 cm band –
The 70 cm frequency band of the amateur radio bands consists of frequencies between 420 MHz and 450 MHz.

BarnacleSat class –
A BarnacleSat class satellite is a larger version of a CubeSat class satellite (specifications can be found at http://cubesat.atl.calpoly.edu/) that is designed to fit into a RocketPod deployment system developed by Ecliptic Enterprises.

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