POWER REGULATION AND DISTRIBUTION SYSTEM

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ABSTRACT

This paper consists of the process and research that has undergone in the Leonidas Nanosatellite project. The team has accomplished many things in the short time we were together and has shown in the increasing help and interest we are getting from outside companies. The team allowed me to handle the power subsystem of the satellite, which has gone under many transformations. At the beginning of the semester I couldn't tell you a thing about a power subsystem and now I have gained much knowledge from my research.

INTRODUCTION

In January 2006 the LEONIDAS Mission Concept Study Team (LMCST) was established by Professor Lloyd French to develop a satellite concept report that demonstrates Hawaii capabilities to produce a low Earth orbit mission. This was completed in the summer of 2006. Starting the fall semester 2006, the LMCST prepared for the mission proposal for the Air Force Office of Scientific Research (AFOSR) University Nanosat Program. Upon the completion of this proposal the LMCST prepared for a Jet Propulsion Laboratory (JPL) presentation. Now that these are completed, the next goal for the LMCST is to prepare for the JPL Preliminary Design Review (PDR) in the spring semester of 2007.

My main priority while working with Professor Lloyd French will be to continue to the work that the LMSCT began in spring of 2006 and to ensure that the LMCST doesn't fall behind because of my lack of work. My next step is to begin preparing for the JPL PDR.

The basis of the JPL PDR will come from the JPL presentation done in the fall of 2006. In the PDR, the LMCST was given the opportunity to present their own subsystem to a group of engineers from JPL. Here the LMCST was shown the true meaning of how to present in the professional carrier. The team was asked questions on the spot and needed to react without looking up the answers in their notes. It is expected that the JPL PDR will be more intense. The engineers from JPL will be less forgiving for some of the mistakes we presented in our first meeting. They will want us to show how we are going to spend their money and if we are capable enough to complete a mission from design to launch. I believe that the LMCST is capable of completing a mission from design to launch and will earn the respect of JPL.

METHODS

My main focus for this semester will consist of the completion of the power subsystem requirements and prepare for the JPL PDR. I will complete the analysis needed to gain a better understanding of the actions of the power subsystem. To do this I will find and answer my most updated list of system requirements:

- Orbital Requirements
- Orientation Stability
- Grounding
- Shunt Requirements
- Charging time
- Operational Requirements
- Battery Life
- Power Quality
- Transient Response
- Temperature Requirements
- Integration and Testing Requirements
- Interface
- Transmission Requirements
- Regulation Requirements
- Photovoltaic Life
- Noise Control

Over the entire time of doing this research, I've learned so much about satellites, the power subsystem, and my peers that work along side of me. The knowledge and experience I'm getting from all this research and teachings from our mentor Lloyd, could never be matched in the classroom. If you asked me two semesters ago, what the power distribution and regulation unit on a satellite looked like, I probably couldn't tell you. Ask me now and I would tell you that the Power Generation and Distribution subsystem will provide the power necessary for the nanosatellite's electronic components. Power regulation is mainly made up of battery charge and discharge converters, a shunt resistor, and a mode controller that talks to the bus voltage error signal.

Power is generated with 28.3% efficiency Ultra Triple Junction (UTJ) Solar Cells, manufactured by Spectrolab, Inc. Seven of the eight sides of the nanosatellite will be mounted with these solar cells measuring 22 cm by 50 cm. This will provide about 100 W of continuous power. From the solar cells the power will pass through the PRU (Power Regulator Unit), provided by Crisa. This PRU could provide for a 40 Volt bus, our bus will be running on 3, 5, +-12, and 28V. A series of controllers will check the system, including the Lithium Ion batteries (100 Wh), to see if it should enter any of four the error modes: shunt mode, charge cut-back mode, discharge mode, and PRU bypass mode. Here is a short list of modes and the power they will require:

- Check - Varies
- Standby - 14.8 W
- Charge - 14.8 W
- Communication - 50.36 W
- Payload - 42.36 W to 47.36 W
- Maneuver - 41.36 W

These modes are ways to control the power input and output in the system. For example, when in shunt mode the solar cells will pass the power they receive through shunt resistors (NHR NHS 2-T220 T221), manufactured by Riedon, and excess power is dissipated out as heat from the satellite. The Power Distribution Unit (PDU) will power the subsystems directly. The PDU will ensure that all loads are powered through switches and fuses. The fuses are to protect the power system from errors in the user equipment. The PDU will be hooked up to the back of the power subsystem tray (nearest to the interface board), so that the other loads can be connected to the power without much wiring.

Later in the semester I went into greater depth with some of the components. First I started with the solar cells and decided to work UTJ cells. The dimensions of these cells would be 0.5 meters by 0.22 meters and weigh about 76 mg, this is for each cell. The satellite would consist of about 7 cells, working on where we can put more. For our limited surfaces area and mission life, these cells will help the team reach peak output for power. The cells have a beginning of life (BOL) average efficiency of about 28% and end of life (EOL) average efficiency of about 24%. From this I can make some quick calculations:

- BOL power output
  - Power @28.3%x1,367 W/m2(average solar illumination intensity) = 386.86 W/m2
  - Power of Sat : 386 W/m2 x .114 m2 = 44 W per panel
  - Peak Power output of solar panels (ideal 3 panels) = 106.225 W

- EOL (5 year lifetime) power output
  - Power @24.3% = 332.181 W/m2
  - Power of Sat = 37.9 W per panel
  - Peak Power output of solar panels = 91.499 W

This shows us that at the beginning of our mission, the solar panels will be putting out a peak power of 106 Watts to charge the batteries. If our mission was to last 5 years, the solar cells would only put out about 91 Watts of power.

The next component I went and did more research on was the secondary battery for our satellite. Secondary battery just stands for a battery that is able to recharge, while primary batteries cannot be charged. I decided to go with a rechargeable Lithium-ion MP 176065 battery from Saft Batteries. These batteries were perfect because they are fairly small and would fit perfectly anywhere on the satellite. Also they have a good Watt hour per kg ratio and have a long life cycle. They put out a 26 Watt hour and only weigh about 150 grams. The charge rate at which we will be charging will be at four amps. This will take about 3 to 4 hours to charge a battery because of the PRU I chose can only charge at 4 amps. We are not exactly sure how many batteries we will be using yet, but we came up with a number of batteries we would need in a total failure of Solar Cells and be able to stay alive for 12 hours and we would need 16 batteries. So that isn't that bad, and I would still be under my weight budget.

Along with the secondary batteries and the solar cells, I looked into a PRU unit from CRISA. Here, I found something that helps me meet some of my system requirements. CRISA calls it a HESC 104, but that's short for high efficiency and smart charging vehicle power supply. It is very small in size and mass and I might use more than one, so it makes it very volatile. It can have an input voltage of 6 to 40 Volts. The main thing that sold me though was that it was able to support the different voltages I stated in my requirements; 3, 5, +12, and -12. Depending on what voltages the other subsystems need, will determine how many HESC 104 boards I will need.

Problems will come up everyday in the life of research. The biggest problem and the one thing that I've learned over and over, was during my research. Every time I answered one question, it leads me to at least three new questions. At times this was frustrating, but it leads to a better understanding of my subsystem. Right now I have no real problems with my design of the subsystem, mainly because I have nothing to test right now. The buying and testing of the components comes next semester, which will be exciting. Another problem is just in the communication of the team. We have a hard time of meeting together, to integrate what we have to see if it fits. This happens once a month and this is where a lot of things go wrong or don't seem to fit. Next semester, the team needs to meet TOGETHER more, thus we can move along faster.

CONCLUSION

In all, I've learned so much about satellites and the power subsystem especially, this semester. The experience I have received out of this project is priceless. I have done multiple presentations and a PDR with real companies. I have co-authored a proposal and a concept study which was published (waiting on the results of the proposal to the Air Force). I have received much practice in technical writing and extensive research that will help me in the furthering of my education. This project did take a lot of commitment and time, but I would not have traded that for anything. This project only seems to grow. My research will continue for as long as this project gets funded. Our projected launch date is in 2009. I can't wait to begin again next semester.

By continuing to work with Professor Lloyd French I hope to attain added knowledge of the mission design process, have a great knowledge of the power subsystem to be able to support to our satellite. I hope to also help the team when the help is needed because the work will grow as the mission gets more and more close to the JPL PDR. The team has also grown from 4 undergraduate students to eight undergraduate students and one graduate student. These new team mates will need the help to catch up to the rest of the team and for the team to move forward. I am currently still in the process of completing my system requirements. I hope to reach a point in my research, in which when asked a question by the group of engineers from JPL during the PDR, I will be able to answer with no confusion and no hesitation. I will be ready for this design review.

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