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**Electrical Power System for an OPEN Hardware CubeSat**

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Introduction
The OpenOrbiter program at the University of North Dakota is developing a complete set of CubeSat hardware and software (see [1]) to facilitate the development of a 1-U CubeSat (10 cm x 10 cm x 10 cm, 1.33 kg spacecraft) with a parts cost of less than $5,000 [2].

In order to supply all spacecraft subsystems with power, an electrical power system (EPS) has been implemented. The EPS generates power using multiple solar panels and regulates it to provide continuous levels of power to all of the subsystems of the spacecraft. The EPS has a crucial role in the spacecraft and thus has been and is being developed and tested with extreme care.

Power Requirements
Several requirements drive the design of the satellite’s EPS. It must be capable of supplying power at 3.3V, 5V, 9V, and 12V, based on subsystem requirements and prospective future uses. It must also be able to automatically restart in case of an electrical failure. It must contain and use photovoltaic solar arrays as power inputs. Finally, it must include an onboard microprocessor which will be connected to the Raspberry Pi primary flight computer using GPIO pins. The microcontroller and flight computer communicate using the I2C protocol. The subsystem must also conform to the OPEN board sizing and interconnection specifications [1].

Electrical Power System Overview
A block diagram of the EPS is shown in Figure 1. As indicated, the EPS consists of three blocks (generation, storage and power management and distribution). It supplies power services (at different voltages) to multiple component subsystems including the onboard computing, communications, propulsion (if present, OpenOrbiter I doesn’t include this), altitude control and payload systems.

Role of the Electrical Power System
The EPS acts as an interface between the collecting and storing systems for power and all of the electrical systems of the CubeSat. The primary power source is solar energy. The EPS uses solar power directly when this power source is available. The EPS is also responsible for charging and monitoring the change of the spacecraft’s batteries and triggering power conservation activities if the level of overall power falls below a preset level.

The EPS also performs ongoing health assessment of the battery and electrical buses. These tasks are performed by routines running on the onboard EPS microcontroller. This microcontroller collects and processes data from the multiple subsystems and buses of the spacecraft and makes power system decisions, based on the data it collects.

Conclusions & Future Work
The team has studied the interactions and interconnections of systems within the OPEN CubeSat Framework as a SoS. The EPS, in particular, was considered as it is a SoS within the spacecraft SoS and has high interconnectivity with other subsystems. Through this, the benefits of SoS-style design for CubeSat systems has been demonstrated.

Future work will focus on the analysis of a CubeSat SoS within a larger spacecraft cluster SoS. Analysis of other CubeSat systems in a SoS context is also planned.

The EPS as a System of Systems (SoS)
The SoS approach facilitates concurrent development of systems making it an attractive approach for CubeSats. In the context of designing OPEN, where the design is supposed to be component-based, such that others can replace, remove, and/or alter components to suit their own mission needs, the SoS approach takes on an even greater level of value.

The EPS, on its own, can be thought of as a system of systems (SoS) within the CubeSat [3]. The systems comprising the EPS are: the power generation block (PGB), the power storage block (PSB), and the power management and distribution block (PMDB) which includes EPS onboard microcontroller. The EPS performs many functions autonomously in order to compensate for possible issues with the primary flight computer and maximize survivability of the spacecraft. The EPS acts on its own, in this and other regards to serve the needs of other systems, as is typical of a directed SoS.

References