La Jument: Student Created CubeSat for Remote Sensing and Software Testing

USC Space Engineering Research Center

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1. Mission

La Jument is USC's 4th CubeSat mission built in partnership with Lockheed Martin to carry their payload to Low Earth Orbit (LEO). USC's primary research goal for this project is creating a transmission system between the student run ground station at USC's campus and the spacecraft in orbit.

2. Power System

The electrical power system (EPS) supplies power to all system spacecraft as well as regulating the charging of the battery system via its 4 BCRs. The spacecraft's battery system provides 26.6 W-hrs and a total of 7 solar panels (4 deployable & 3 fixed) provide 22W in full sun. Power is centrally controlled and distributed across three major lines.

Power Line	Voltage	Current Limit
VBATT	7.8 V	4.2 A
5 V Line	5 V	1.2 A
3.3 V Line	3.3 V	1 A

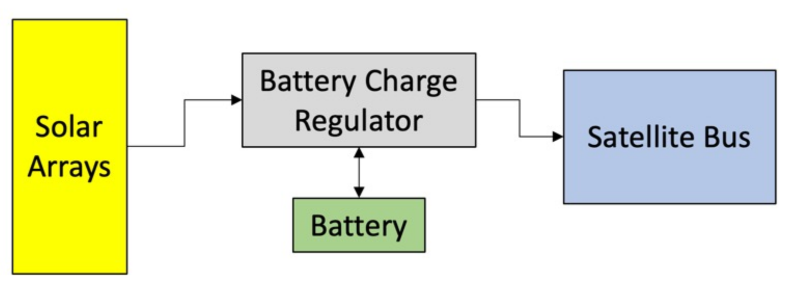


Figure 1: Simplified Power System Layout

3. Attitude Determination/Control

The spacecraft is 3-axis stabilized and utilizes a SERC-designed control software for attitude determination and control. The software controls an MAI-200 with three reaction wheels and three torque rods, three single-axis gyros, and a Sinclair sun sensor. The control system executes its modes of operation in a domino-like sequence while also utilizing a B-dot controller to minimize power consumption in de-tumbling mode.

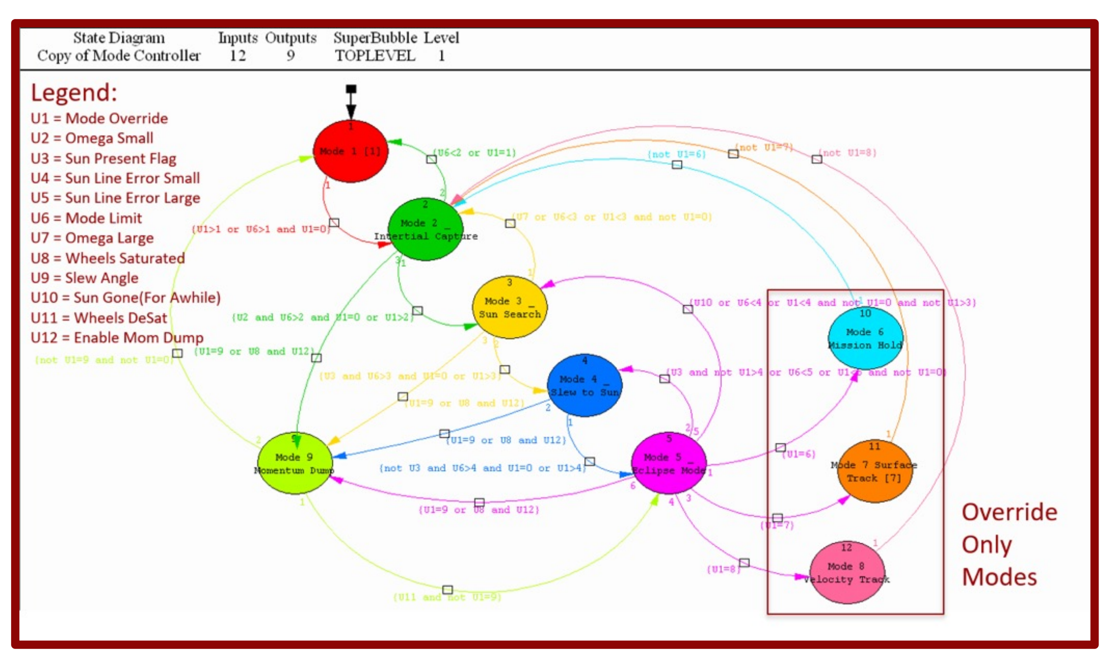
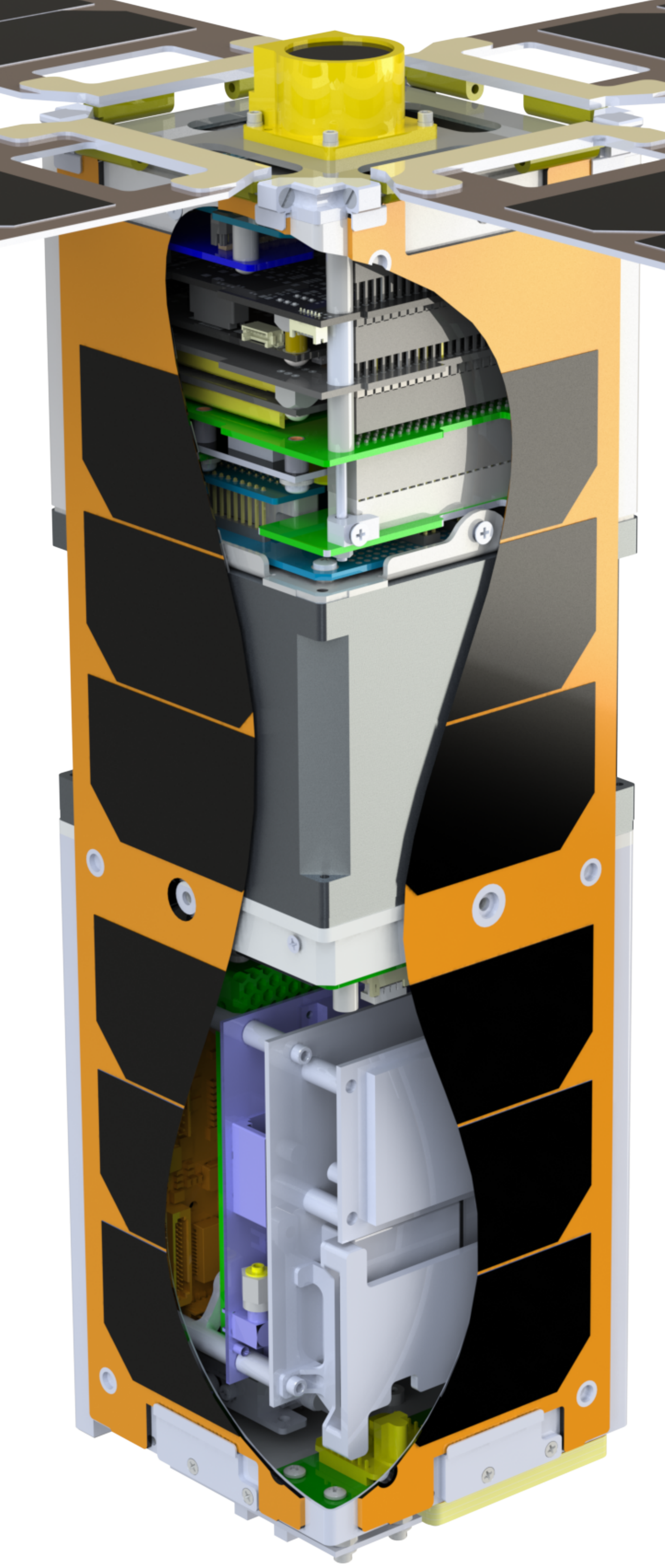


Figure 2: La Jument control system state diagram detailing transitions between different modes of operation



4. System Power Budget

La Jument operates on a 2-in-series, 3-in-parallel battery system to support the spacecraft's power needs when the solar arrays are not able to provide power during certain scenarios. The spacecraft's operations are limited by the depth of discharge experienced by the system during one discharge cycle. Much of the charge drained from the batteries is caused by the spacecraft facing away from the sun to take and process images. The spacecraft is unable to recharge the batteries during this time and can only do so when reorienting itself towards the sun.

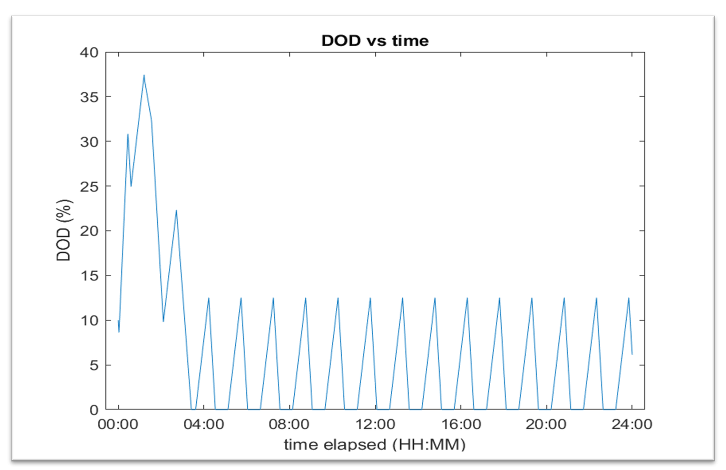


Figure 3: Current estimates for the depth of discharge cycles for a typical day in the life of the satellite. The batteries are discharging as the line increases and charging when the line decreases

5. Typical Day in The Life

A typical "Day in the Life" of La Jument is as follows: from the ground station, a series of commands are uploaded to spacecraft that instructs where in the orbit to begin an image capturing process along with the sequence of modes required capture the image. When the satellite approaches its target, it switches from an idle mode to a slewing mode in which the spacecraft turns the imaging payload towards the target. Once the image is captured, the spacecraft slews into its original orientation where it will process the collected data in order to transmit back down to the ground station.

6. Uplink/Downlink Message Structure

La Jument requires dynamically sized packets to be sent to/from the spacecraft and more diverse kinds of data to be transmitted down to the ground. This is challenging, particularly for a spacecraft with no network stack and limited resources. A custom layered protocol and high-level messaging interface was therefore developed to help with these challenges. By wrapping transmission data inside a USC message before sending it to the transceiver, which tacks on a checksum, we were able to provide the flexibility required of data transmission, while maintaining the appropriate separation of concerns.

	Name	Description	Size (Bytes)	Data Type
Header	Project ID	Unique project identifier, identifying this message as belonging to this project	6	Char
	Message ID	Unique identifier for each message	2	UShort
	Message Type ID	Identifies the type of data that is contained within this message	2	Ushort
	Data Length	Length of data section in bytes	2	Ushort
Body	Data	Data to be processed	Variable (Max 221)	Char
Footer	CRC	Cyclic Redundancy Check. For data validation.	2	Ushort

Table 1: La Jument Uplink Command Message Definition

7. Battery Lot Testing

La Jument has required the use of battery testing to further ensure the batteries can handle the depth of discharge requirements. The batteries are hooked up to a load while connected to an Arduino that continuously measures the voltage of the circuits and calculates average current, C rating, capacitance, average voltage loss per second, and run time for each battery tested. Using the capacitance and C rating an excel document is then used to calculate an expected run time for comparison. The batteries with the longer calculated run time would last the longest under load making them top candidates for the La Jument mission.

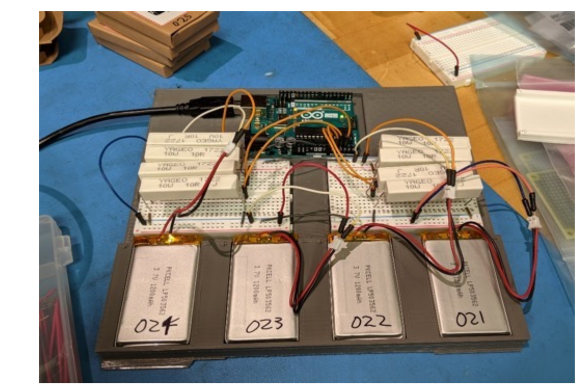


Figure 4: Battery Lot Testing Circuit

8. Far-field Testing

To test the function of the onboard StenSat beacon and GomSpace transceiver, a Mobile Radio Testing Unit (MRTU) was built. This unit houses the beacon and transceiver in a clean box to prevent ESD, with a port to connect the beacon to be controlled by an Odroid XU4, which is operated by using an ethernet cable to SSH into it. Far Field testing will be done at Griffith Observatory since it offers a straight line-of-sight to the USC ground station.

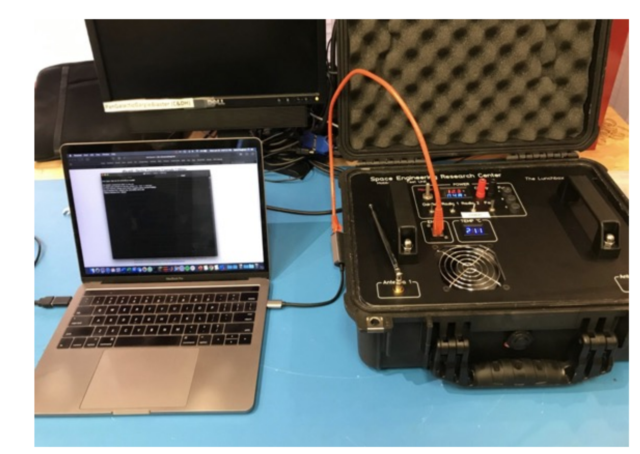


Figure 5: Mobile Radio Test Unit (MRTU) nicknamed "The Lunchbox", next to a laptop sending commands to the unit

9. Conclusion

This project has allowed students to collaborate with engineers in the aerospace industry while supervised in a university research environment. Part of the mission required students to design individual and integrated test systems to validate hardware/software performances. Despite hardware shortages and pandemic restrictions, detailed procedures and protocols allowed students to complete tasks efficiently within the set deadlines.

Acknowledgments

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