National Aeronautics and Space Administration

Diagnosing Potential Points of Failure in a Cubesat Power System

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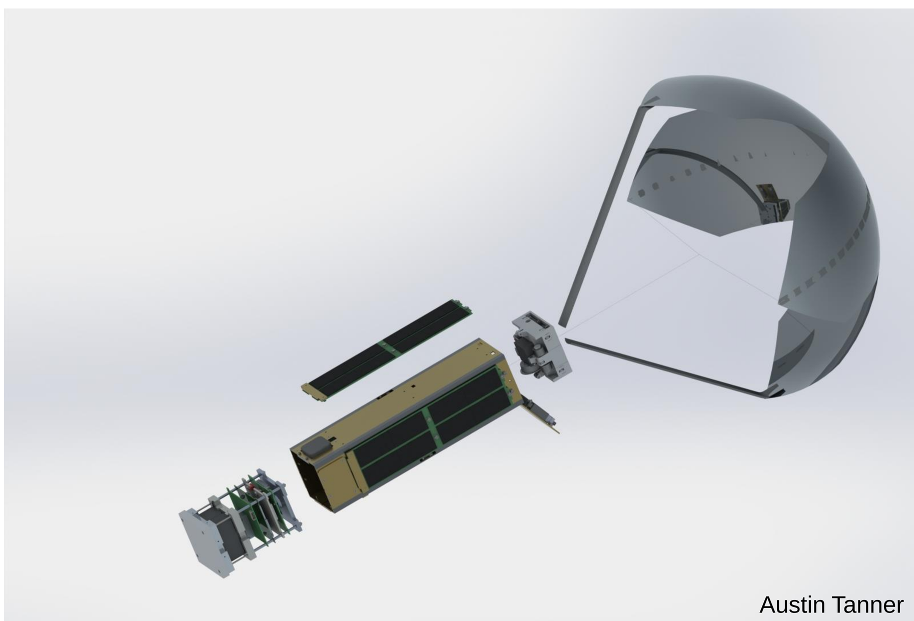
Introduction

TechEdSat 5 (TES5), a 3.5U Cubesat, was launched March 6, 2017 as a test of a drag device called an exo-brake. TES5 stopped sending telemetry 78 days after deployment, possibly due to an anomaly in the power system. Different portions of the system were developed at various times with minimal integration, so to pinpoint potential causes of the communications failure and increase the reliability of the power system, I compiled several schematics and datasheets into a comprehensive block diagram. The solar panels are a new design, so the updated power system has not been analyzed in detail, and telemetry points show unexpectedly high solar panel/battery bus voltages. The purpose of this project is to diagnose where and under what conditions a power system anomaly could occur and then to improve the reliability and flexibility of the system.

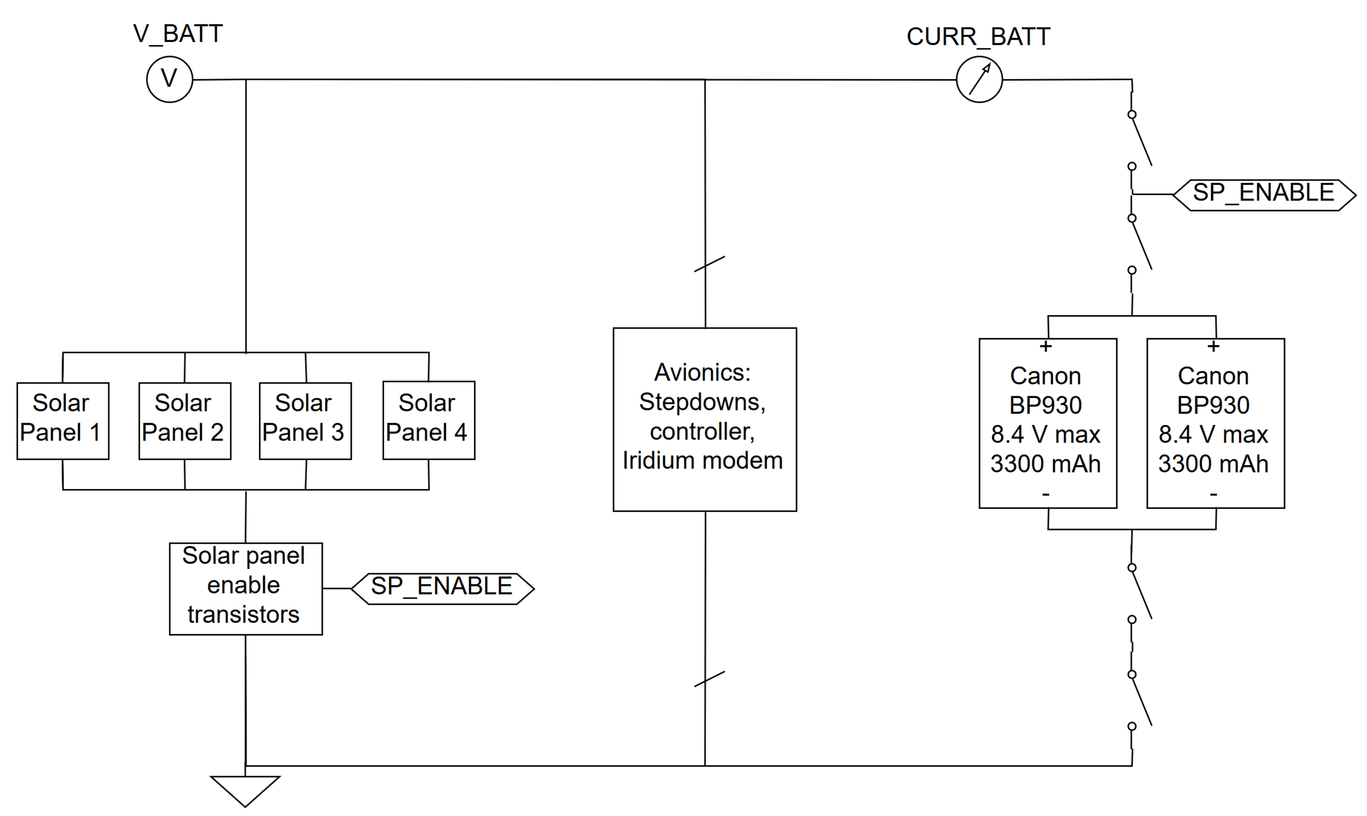


Austin Tanner

Objectives

- Compile existing power system documentation into readable and up to date diagrams
- Identify potential causes of the anomaly
- Perform laboratory testing of the power system, particularly the solar panels and batteries
- Recommend and design power system improvements, including implementing a battery State of Charge (SOC) algorithm

TechEdSat 5 Power System



There is one solar panel on each side of the Cubesat; up to two may be illuminated at a given time. For simplicity, it is assumed that one panel is fully illuminated. When the TechEdSat is deployed from the ISS, the switches on the right close, enabling the solar panels and batteries to power the avionics. There are two batteries in parallel, each with a built in protection circuit. The avionics consist of several voltage regulators for powering various payloads and an Iridium modem for sending telemetry and receiving commands; these are controlled by a microcontroller which also measures voltages and temperature.

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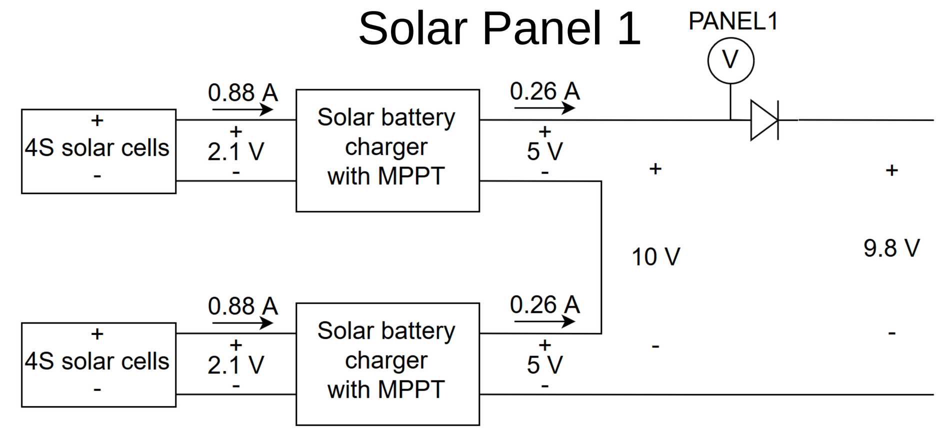
Potential Problems

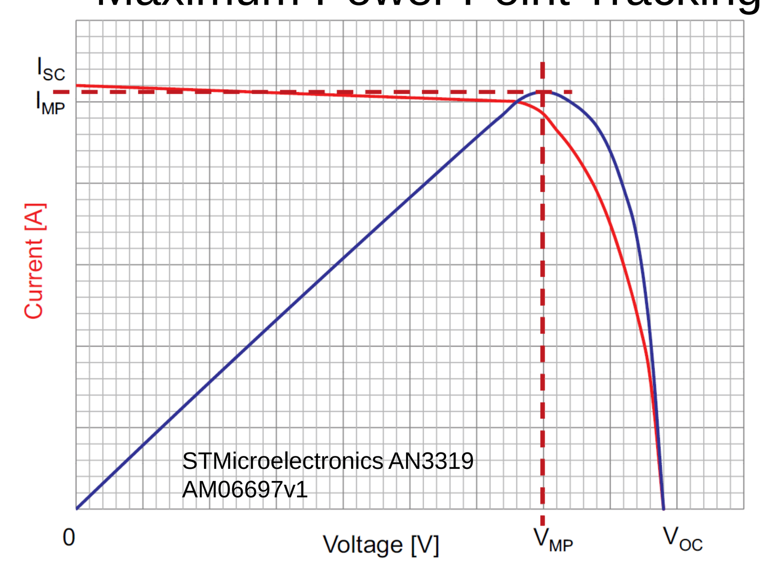
Solar Panels

Solar Panel 1

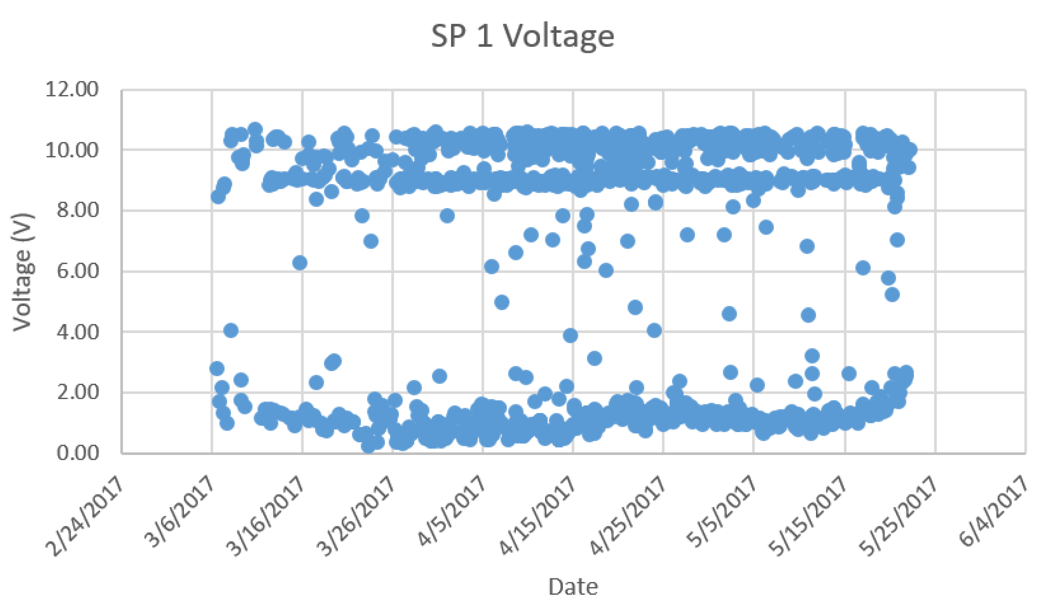


Custom solar cells:
Efficiency = 18.49%
V_{OC} = 0.6188 V
I_{SC} = 0.9471 A
V_{MP} = 0.5224 V
I_{MP} = 0.8798 A
P_{MP} = 0.4597 W

Maximum Power Point Tracking



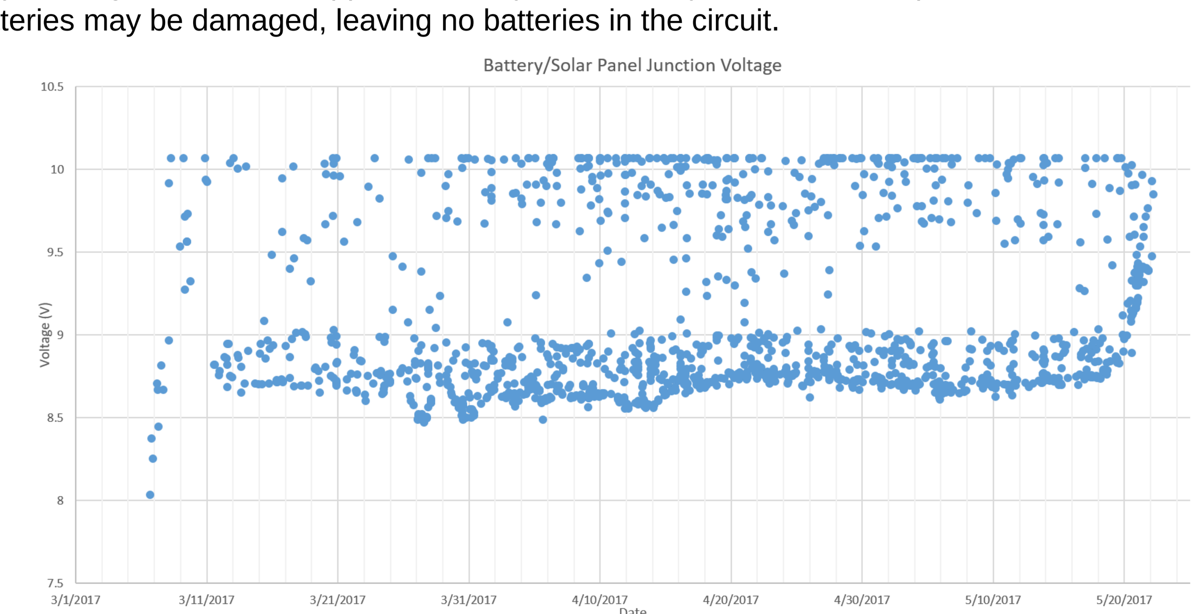
The inductor used for the switching step-up converter circuit in the battery charger circuit was not rated for the current generated in the solar cells and it had a high resistance, dissipating nearly 15% of the power generated. This may have caused the charger to behave inconsistently, explaining why the panels sometimes output only 9 V and sometimes more than 10 V.



Mitigation: A properly rated inductor with a much smaller series resistance was chosen for future TechEdSat solar panels.

Batteries

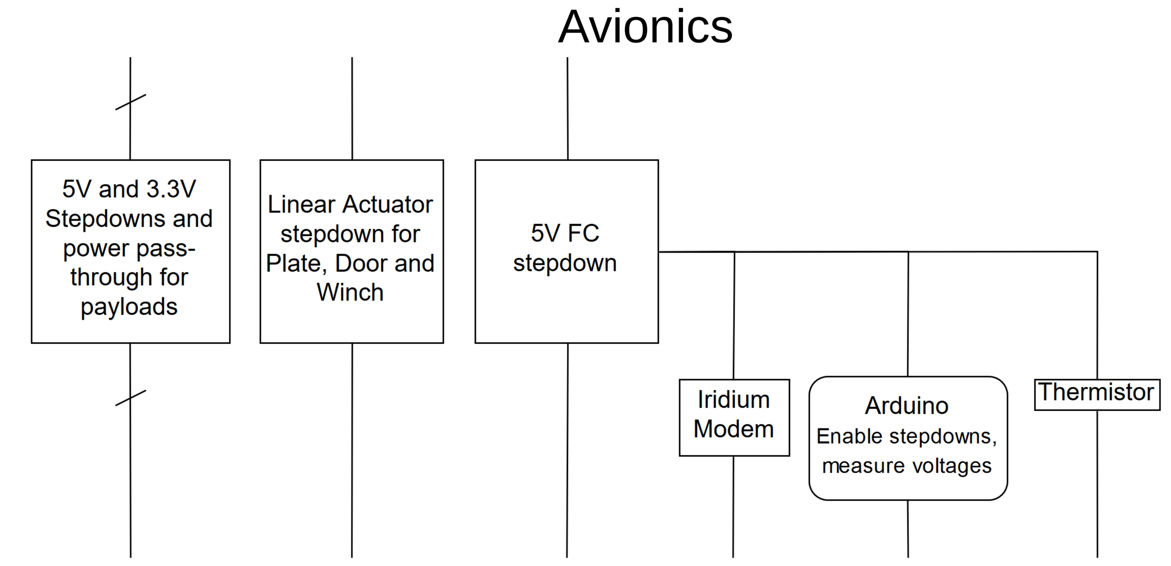
The batteries are rated for 8.4 V at full charge and the protection circuit is activated if the voltage crosses a set threshold value. Frequently charging beyond 8.4 V may have caused one or both batteries to fail. Overcharging stresses the cells, and can lead to activation of the built-in current interrupt device or possibly venting. Shorts can happen internally or externally. If either of the protection circuits fail to operate the batteries may be damaged, leaving no batteries in the circuit.



Mitigation: Future TechEdSat solar panels will output a lower voltage. Isolator diodes may be added.

Component Failure

Avionics

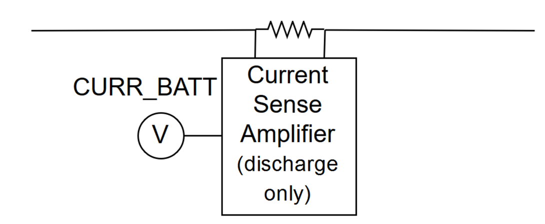


Telemetry would stop if any of the Arduino, Iridium or 5 V FC stepdown failed, but these are known to be relatively reliable. An antenna or transmitter or solder joint could have failed, but there is little evidence for this.

Mitigation: Temperature ratings and radiation performance were reviewed. Software was examined for memory leaks. Components on future TechEdSats will undergo thermal vacuum burn-in.

Limited Current Sensing

Ammeter Circuit (CURR_BATT)



The only current measurement on TES5 is the discharge current from the battery. The current that charges the battery is not known, nor is the current supplied by the solar panels or the current consumed by the avionics. It would have been useful to see battery charge current in determining the source of the power system anomaly.

Mitigation: Circuitry is being designed to enable bidirectional current measurement in two locations.

Next Steps

- Test the power system: log voltages and currents over a period of days
- Test batteries: simulate TES5 charge and discharge cycles to observe how or if failure occurs
- Add the ability to sense both battery charge and discharge current as well as load current or solar panel current
- Integrate algorithm developed by the SHARP Lab which estimates State of Charge and Remaining Useful Life of the battery

References

Jeevarajan, J., Darcy, E., Hoffman, W., Crewed Space Vehicle Battery Safety Requirements, NASA Johnson Space Center, JSC-20793, April 2006

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