Power System Testing and Verification for a Space Camera System With 18650 Batteries

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Abstract

CubeSat functionality is often limited by not only volume but also power. As such, there have been multiple advances in devices to store energy with higher energy density. 18650 Lithium-Ion Cells are a common battery used for low current draw use cases, making them an economical and approachable candidate as primary batteries for powering this type of small spacecraft. However, it is known that the performance and efficiency will vary according to different environmental conditions, in particular, temperature--requiring thorough testing of the batteries at extreme conditions. This project will explore environmental tests to verify a power system based on 18650 batteries for a mission duration and to rate them for human spaceflight. The main tests that were conducted included discharge tests at various temperatures, cyclic testing corresponding to the environment in which the batteries will be used, and maximum discharge testing. From this performance, data is collected on the battery's performance at a range of temperatures, discharge rates, and environmental conditions.

Figure 1: LLAMAS Flight Unit Render

Introduction/Background

- Space Technologies Laboratory (STL) developing stereoscopic camera system for Polaris Dawn mission called LLAMAS, including two 23.5Mpx RGB cameras, infrared camera, radiation dosimeter, and NVIDIA Jetson TX2 onboard computer.
- Custom power system needed for unique geometry: Panasonic/Sanyo NCR18650GA Li-Ion cells selected.
- Testing of batteries is required to ensure safety of human crew and performance meets required duration of mission.
- LLAMAS project aims to validate 18650 cells as primary batteries for short-duration human spaceflight.
- Primary safety concern: thermal runaway due to uncontrolled exothermic reactions.

Testing Summary

Thermally Controlled Discharge Testing

- Discharge tests conducted at 4A and 1A across temperatures from -20°C to 10°C.
- DS18B20 thermocouple monitored temperatures.
- Humidity monitored with DHT22 sensor to prevent condensation.
- Evaluated discharge performance and recovery from voltage sag.

Environmental Testing

- Four batteries tested, two as controls and two exposed to environmental conditions.
- Cycling phase for all batteries followed by functional baseline check consisting of discharge, charge, and internal resistance measurements
- Vibration to Falcon 9 specifications, Thermal cycles to battery temperature limits ± 20°F, Vacuum to NASA standards of 1×10^{-4}.

Maximum Discharge Testing

- Two batteries discharged from 4.2V to 2.5V at 10A using Arbin LB21024 tested, highest rated discharge capacity.
- Temperature of each battery tracked with two DS18B20 thermocouples linked to Raspberry Pi.
- Test aimed to understand voltage sag, heat generation for high discharge rates, and risk of thermal runaway.

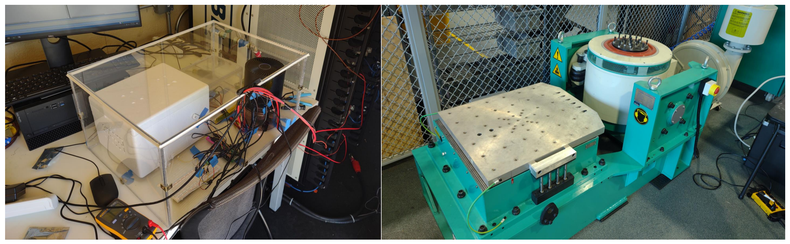
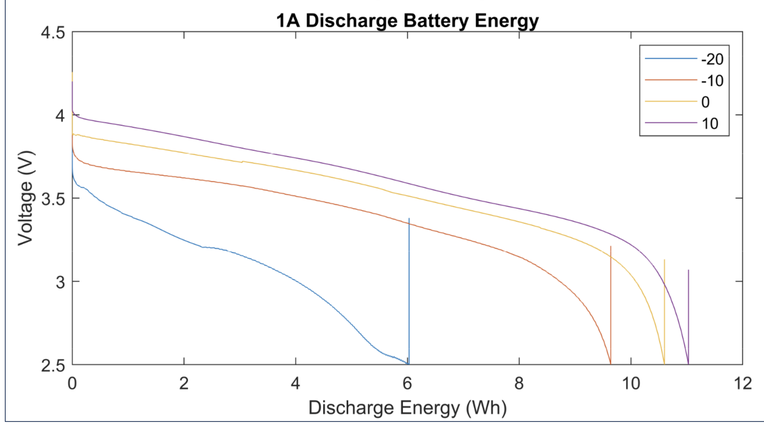


Figure 2: Thermally Controlled Discharge Test Setup (Left) and Vibration Table (Right)

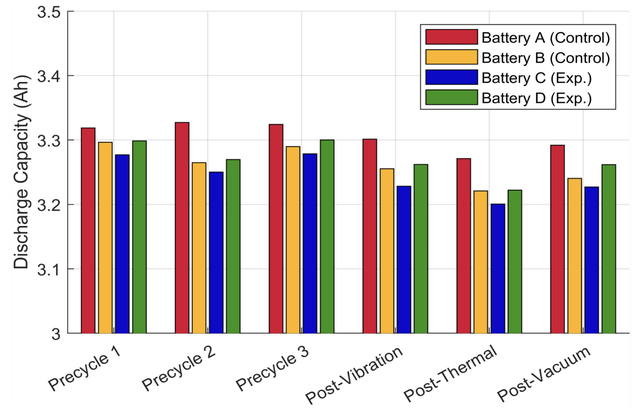
Results

Thermally Controlled Discharge Testing



Results cont.

Environmental Testing



Maximum Discharge Testing