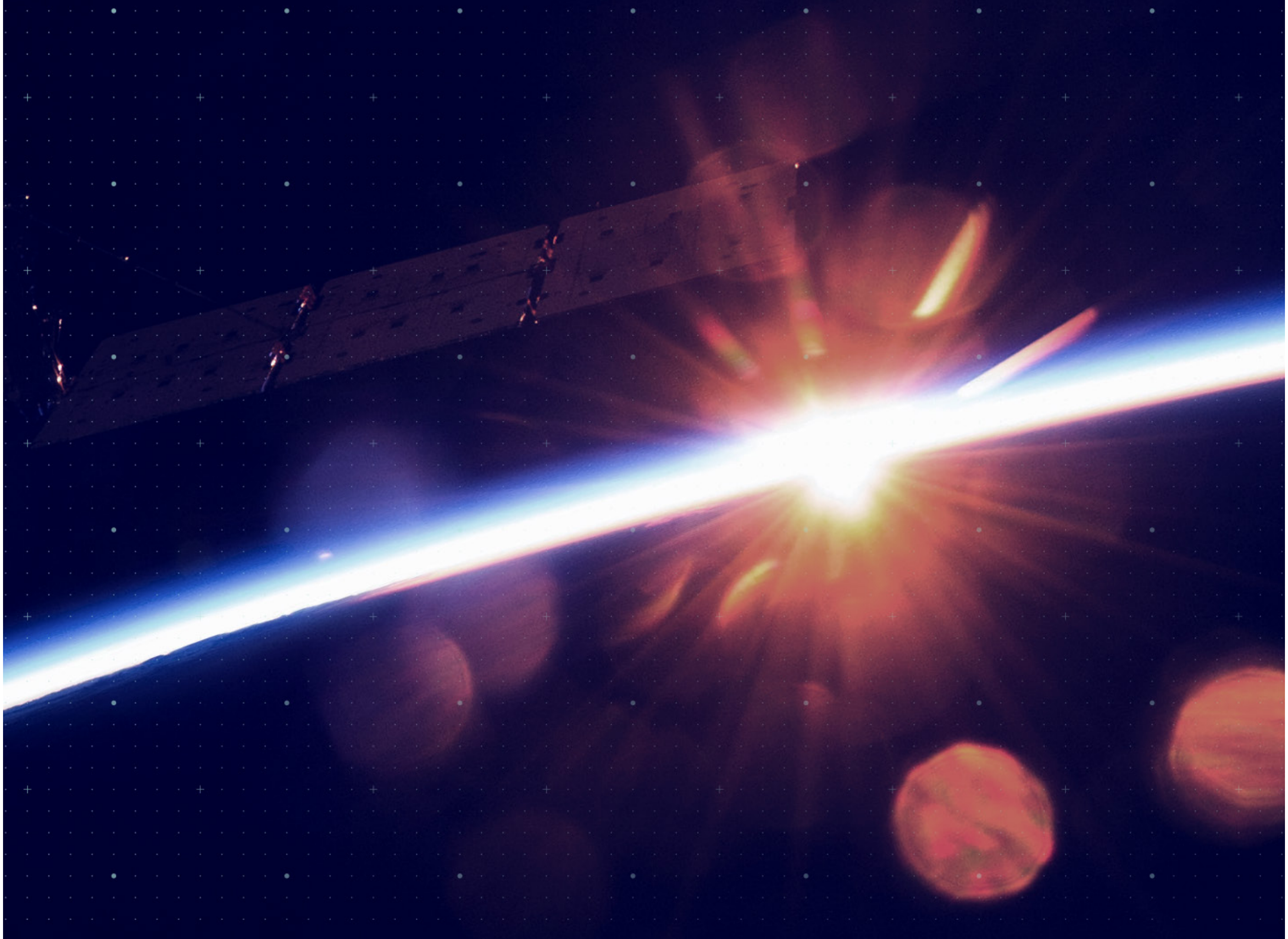
BATTERY REQUIREMENT



HYPER GIANT INDUSTRIES

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1. INTRODUCTION

This document describes the acceptance/screening tests required for Lithium-Ion cells and battery packs (which are to be flown) to determine if they are acceptable for flight to the International Space Station (ISS). The requirements stated in this document are based on JSC EP-WI-032 Statement of Work: Engineering Evaluation, Qualification and Flight Acceptance Tests for Lithium-ion Cells and Battery Packs for Small Satellite Systems.

2. SCOPE

The purpose/scope of this cell/battery acceptance testing is to screen the flight items wherever possible to discover indications of defects or design that may become a hazard to the ISS or Crew. The acceptance criteria documented herein is applicable to all uses of Lithium cells/batteries for CubeSats and MicroSat-Class satellites where the battery energy level is less than 80w-hr/kg. The criteria also applies to battery applications for internal and external deployer systems but does not apply to designs that are charged or discharged while a hazard potential is present to the ISS or Crew.

For battery applications where the energy level is above 80w-hr/kg additional criteria are imposed and discussed in Appendix A of this document.

3. DEFINITIONS AND ACRONYMS

Terms/Acronyms	Definition
Battery	A single or set of cells either in series or parallel to give ideal voltage/current rating.
C	The discharge rate that is equal to the capacity of the battery in amp-hours divided by 1 hour.
Cell	A single lithium-ion cell.
DPA	Destructive Physical Analysis.
OCV	Open Circuit Voltage.
TR	Thermal Runaway.

4. REQUIRED TEST PROCEDURES – PHYSICAL AND ELECTROCHEMICAL CHARACTERISTICS

4.1 RECORD AS MUCH OF THE FOLLOWING DATA POSSIBLE FOR EACH CELL/BATTERY TO BE FLOWN

- Manufacturer
- Cell model number
- Date code
- Cell/Battery Specifications
- Cell Chemistry
- Electrolyte type

Note 1: For the procedures outlined in this document, all test values (temperature included) must be recorded for each corresponding cell/battery pack. Serialize all cells/batteries before testing. Pictures should be taken throughout the testing process. Cells/batteries under test should not be left in a completely discharged state between tests.

Note 2: All acceptance testing and data recording is to be completed for the flight cells/battery including any spares except for the over charge and over discharge testing as noted below since these tests may be damaging to flight cells.

4.2 VISUAL INSPECTION (PERFORMED ON FLIGHT CELLS/BATTERY)

Inspect cells/batteries for any deformations such as scrapes, bulges, or dents. Record all findings.

4.3 MEASUREMENTS OF PHYSICAL PROPERTIES (PERFORMED ON FLIGHT CELLS/BATTERY)

a. The length, width, and height need to be measured and recorded. Length, width, and height are defined as the following:

   ▹ Length: The horizontal length of the battery with the serial number upright.
   ▹ Width: The vertical length of the battery with the serial number upright.
   ▹ Height: The smallest dimension.

   Measurements should be recorded with 0.1mm precision.

b. Record the mass of each cell/battery with 0.1g precision.

4.4 ELECTROCHEMICAL CHARACTERISTICS (PERFORMED ON FLIGHT CELLS/BATTERY)

a. Measurement of Open Circuit Voltage (fully charged cell/battery)

Measure the Open Circuit Voltage (OCV) on the flight cells/battery using a multimeter and record the value for each of the cells/ batteries. Measurements should be recorded with 0.1 V precision.

b. Measurement of Closed Circuit Voltage

Ensure that the flight cell/battery is at least charged to 4.0V before proceeding. After setting up the programmable load to a constant current of 1.875A, load the battery and wait for 30 seconds before recording the Closed Circuit Voltage.

c. Open Circuit Voltage (OCV) 14 day test (performed on flight cells/battery)

Discharge each cell at constant voltage to the minimum allowable voltage specified by the manufacturer's data sheet and terminate the discharge when current tapers below C/100. Record the OCV at discharge termination for each cell. Rest cells for 14 days while monitoring (checking) the OCV for each cell on days 1,3,7,10 and 14. Cells with declining voltages >2.0mV shall be rejected.

5. CHARGE CYCLING DATA PROCEDURES (PERFORMED ON FLIGHT CELLS/BATTERY)

The Charge Cycling Data Procedures include the following cycles in this order: Charge, Discharge, Charge, Discharge, and Charge. Record relevant data for all of these cycles. The temperatures for these cycles should also be recorded and a 10-minute rest period should be provided between charge and discharge.

a. Charge the flight cells/batteries to 4.2V using a current of C/2. Then hold the batteries at a constant 4.2V until the current drops below 50mA.
b. Discharge the flight battery pack at a rate of C/2 until the voltage drops to 3.0V.
c. Repeat charge cycling procedures until cycling is complete.

6. CELL OVERCHARGE PROCEDURES (FOR ACCEPTANCE/SCREENING)

Note: Over charge tests to be performed on non-flight cell only in order to establish protection characteristics.

a. Overcharge cells/batteries to 5.0V with a current of 1C.
b. Record the voltage at which the battery protection activates to the charging circuit.
c. Discharge the cells/batteries at a rate of C/5 and record the voltage at which protection circuit closes the circuit.
d. Complete a charge/discharge cycle as specified in Section 4 and record the capacity.

7. CELL OVERDISCHARGE PROCEDURES (FOR ACCEPTANCE/SCREENING)

Note: Over discharge tests to be performed on non-flight cell only to establish protection characteristics.

a. Overdischarge the cells/batteries at a rate of 1C to 0V.
b. Record the voltage at which the protection circuit opens.
c. Charge the pack at rate of C/5 and record the voltage at which the protection features reset.
d. Complete a charge/discharge cycle as specified in Section 4 and record the capacity.

8. CIRCUIT SCHEMATIC ANALYSIS

Provide the protection circuitry schematic and a description of how it works including operating parameters and set points.

9. VIBRATION TEST PROCEDURE (PERFORMED ON FLIGHT CELLS/BATTERY)

Note: This test may be performed separately or with the battery installed in the satellite during satellite structural vibration testing as long as these test levels are enveloped and the battery can be inspected and/or performance health checked after the test.

Record the OCV for each flight cell/ battery before vibration testing and between each axis of vibration. Vibration testing should follow the spectrum as specified in Table 1 for one minute on each axis.

Table 2 Vibration Testing Spectrum

Frequency (Hz)	ASD (G2/Hz)	dB/OCT	Grms
20.00	0.028800	*	*
40.00	0.028800	0.00	0.76
70.00	0.072000	4.93	1.43
700.00	0.072000	0.00	6.89
2000.00	0.018720	-3.86	9.65

Discharge/charge/discharge cycle each flight cell/battery after the vibration tests and record the capacity. The pass/fail criteria requires that there shall be less than 0.1% change in the OCV and less than 5% change in capacity before and after vibration tests and throughout the remainder of the test procedures.

10. VACUUM TEST PROCEDURE (PERFORMED ON FLIGHT CELLS/BATTERY)

a. The length, width, and height need to be measured before beginning this test. Length, width, and height are specified in Section 3.2-a. Measurements should be recorded with 0.1mm precision.

b. Obtain and record the mass of each cell/battery. Measurements should be recorded with 0.1g precision.

c. Measure the voltage of all cells/ batteries and record the values. If any batteries are not fully charged, charge before continuing.

d. Place fully charged batteries into the vacuum chamber at atmospheric pressure and pull vacuum at approximately 8 psi/minute. Maintain vacuum (approximately 0.1 psia) for 6 hours. Re-pressurize the chamber to ambient at a rate of 9 psi/minute.

e. Visually inspect the batteries for leaks, deformations, or bulges. Record any findings.

f. Obtain measurements of the length, width, and height of the post-vacuum tested batteries.

g. Obtain and record the mass of each cell/ battery. The pass/ fail criteria requires that there is less than 0.1% change in mass.

h. Discharge/ charge/ discharge cycle the cells/ batteries and record the capacity. The pass/ fail criteria requires that there shall be less than 0.1% change in the OCV and less than 5% change in the capacity before and after vacuum testing.

11. REPORTING

Prepare a Battery Acceptance Test Report to document the acceptability of the cells/ battery to be flown. Include all of the above data including test set-up details and all results. Additionally, include any photos that accurately display the test activity. The report should be signed/approved by the appropriate program authority.

APPENDIX A

BATTERY SYSTEMS THAT EXCEED 80w-hr/kg

Large capacity battery systems may present extreme hazard to the ISS or Crew. Systems that have energy capacity above 80w-hr/kg necessitate additional requirements to reduce or control this hazard level. Options listed below are to be considered for these designs.

- Wherever possible, designs above 80w-hr/kg should be divided into smaller battery enclosures each of which below 80w-hr/kg. The enclosures shall be physically separated to preclude any thermal runaway event in one enclosure from propagating to other enclosures. Thermal runaway testing will not be required for enclosures having less than 80w-hr/kg.
- Where designs are above 80w-hr/kg in a single non-isolated enclosure, design feature must include appropriate options to preclude cell-to-cell propagation. Examples are given, but not limited to, those listed below.
    - Cell isolation such that a TR event will not propagate to from cell to cell. This option must be supported by test results.
    - Overall cell state of charge reduced to preclude any TR event. This option must be supported by test results.
    - Other designs which preclude a TR event will be considered on a case-by-case basis.