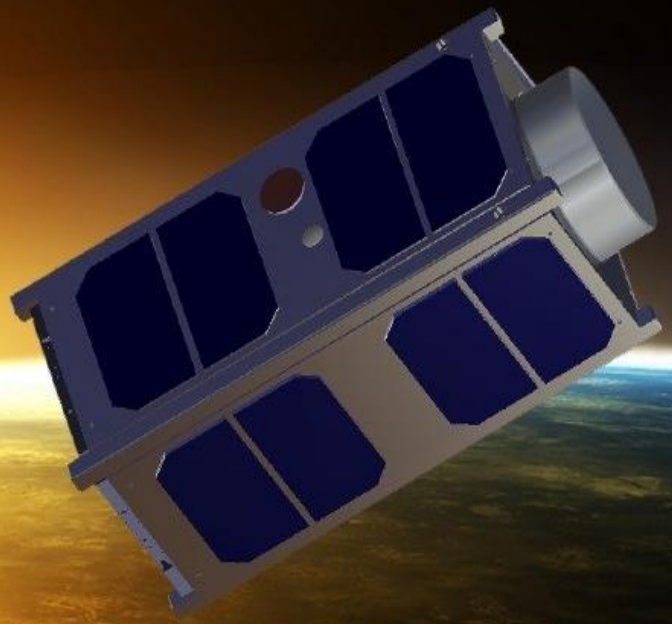
Certification of Lithium-ion Cells with Electrical Power Subsystem for CubeSat



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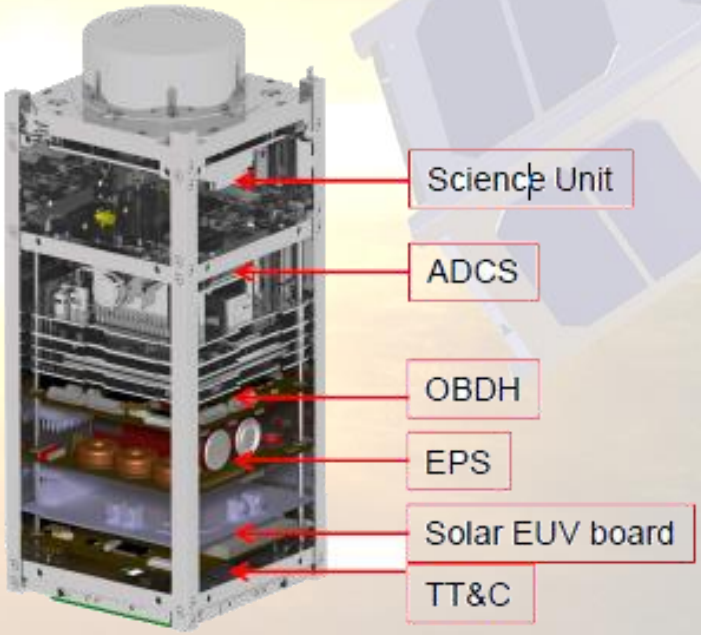
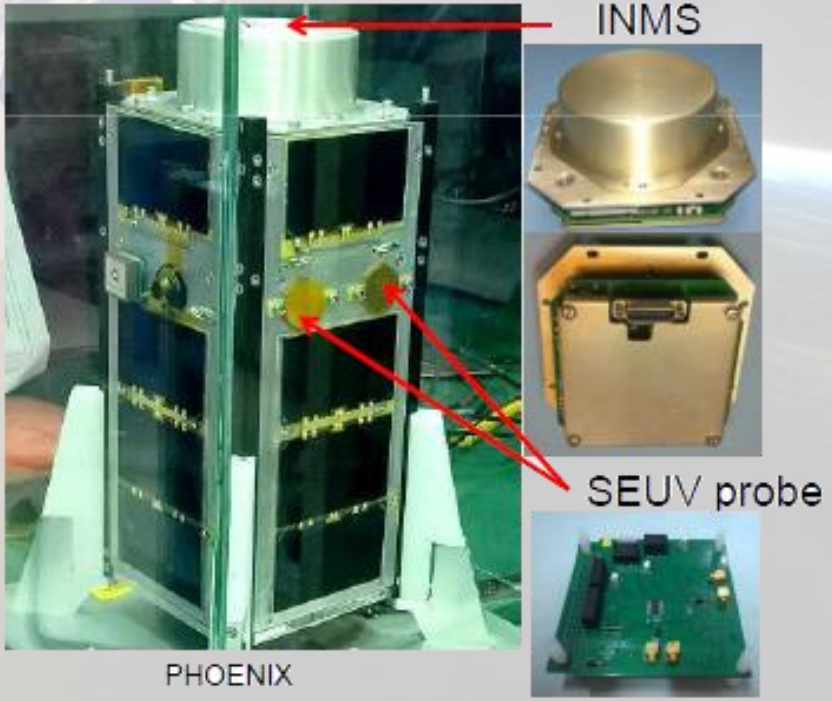
Introduction

- PHOENIX was developed at NCKU as a part of the QB50 mission in collaboration with Von Karman Institute (VKI), which aimed to be launched in December 2016.

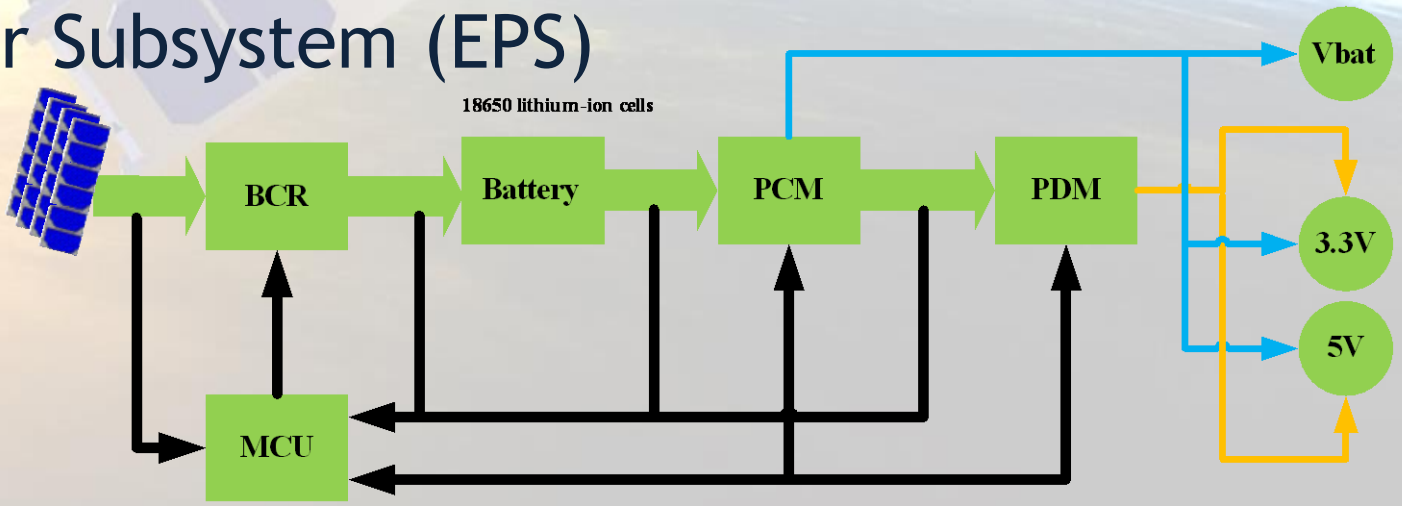




Introduction

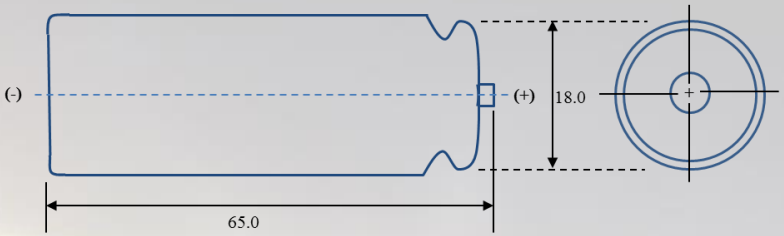
- CubeSat
  - Standardized nanosatellite
  - Cost effective and shorter development time
  - Commercial Off-The-Shelf (COTS) products available

- Electrical Power Subsystem (EPS)
  - Regulation
  - Storage
  - Distribution
  - Management



Introduction

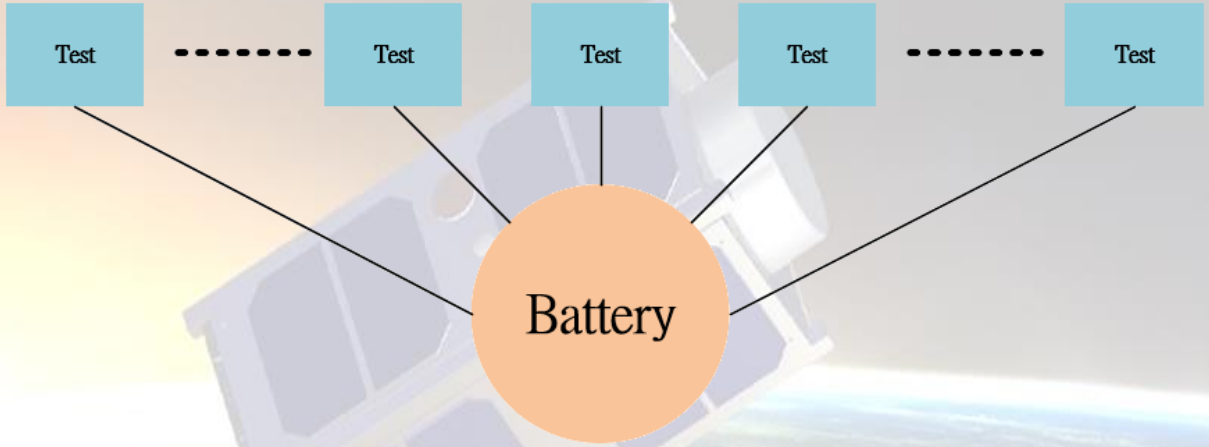
- Regulation ➔ Converter
  - Convert the voltage to the proper value
- Storage ➔ Battery
  - 18650 lithium-ion, pouch lithium-ion



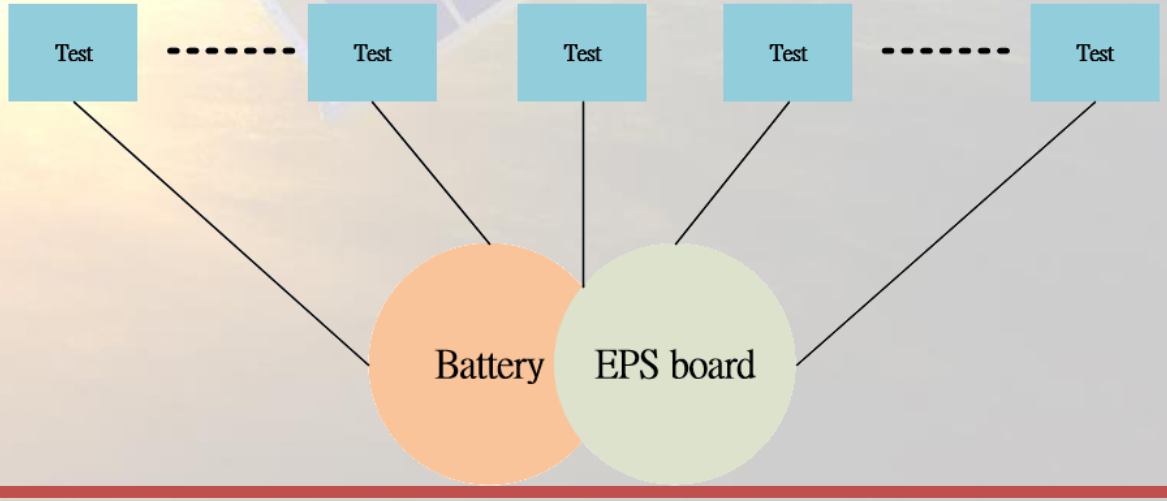
- Management
  - Heater => avoid the battery working on the low temperature
  - MPPT => control the PWM of converters to increase the power
  - Sensor => measure the temperature, voltage, and current
  - Communication => send data to OBC (On Board Computer)
  - Protection => prevent from abnormal scenarios

Introduction

- Normal battery test ➔ the serial tests for battery



- NASA safety battery test ➔ the serial tests for battery and EPS board



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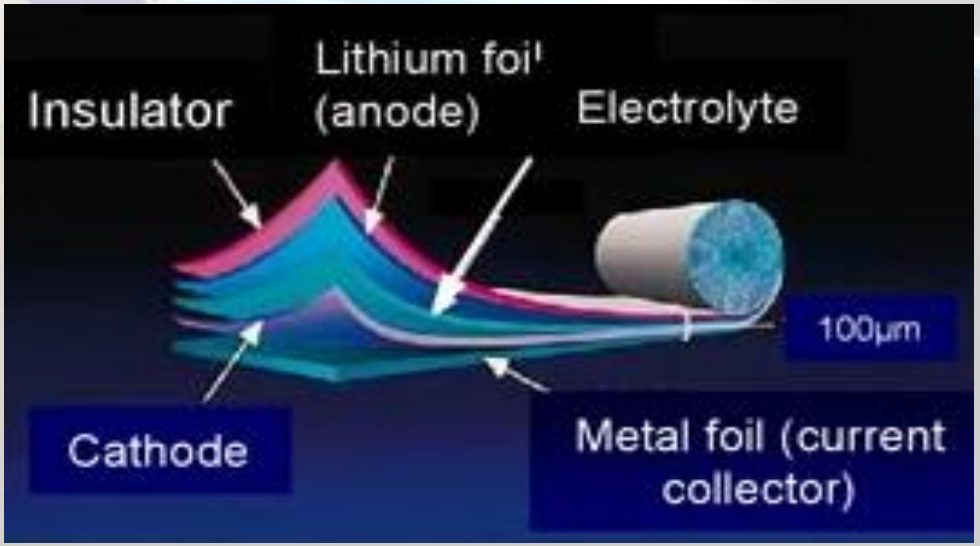
Battery safety issue

- Safety is the basic requirement for all the systems which are demanded to protect themselves and not to interfere others.
- Pressure varying
  - Structural deformation
  - Electrolyte leakage
- Vibration
  - Deformation
  - Elements separation
  - Internal short



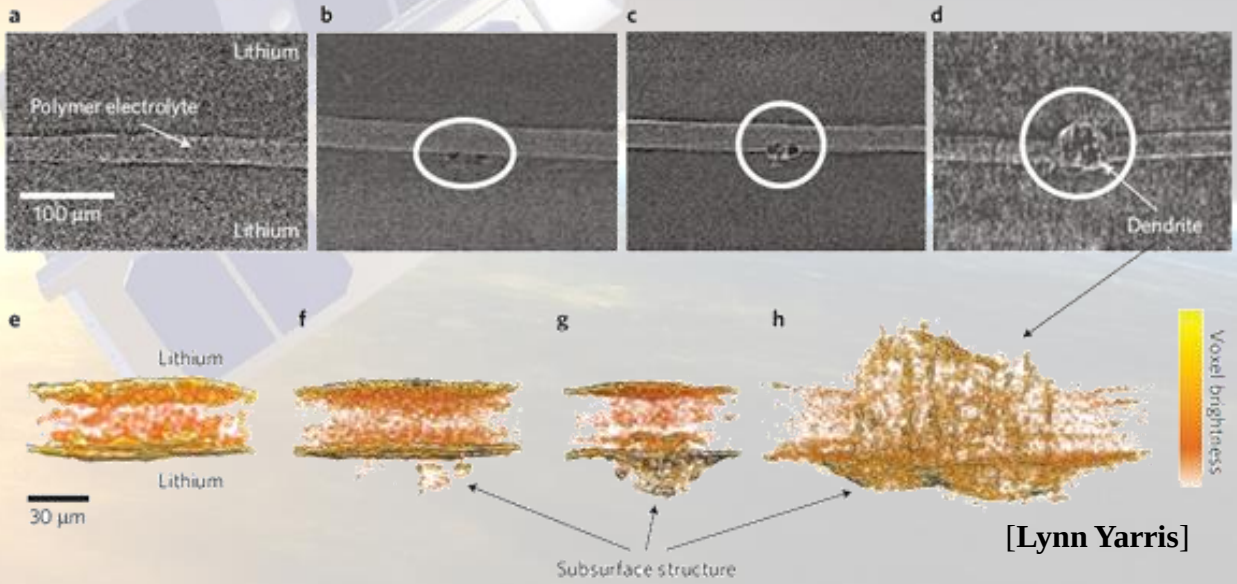
[Kenneth J. Wynne]

Battery safety issue

- Internal short

1. Cumulate a large amount of dendrites

   voltage, current, charge/discharge rate or temperature beyond the tolerances



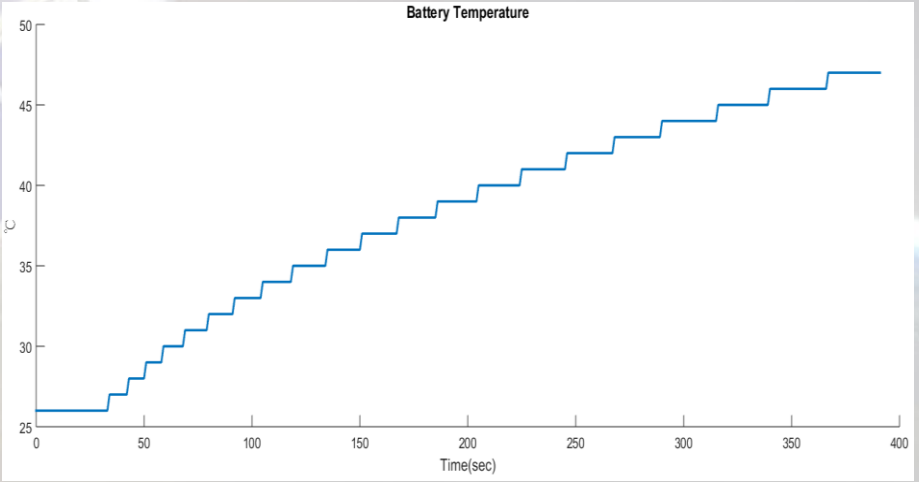
[Lynn Yarris]

2. Lax manufacturing process

   metal particle, burr etc.

Battery safety issue

- Overcharge
  - Increase temperature
  - Decomposes the electrolyte into the Li_2CO_3
  - Increase impedance
  - Reduce capacity

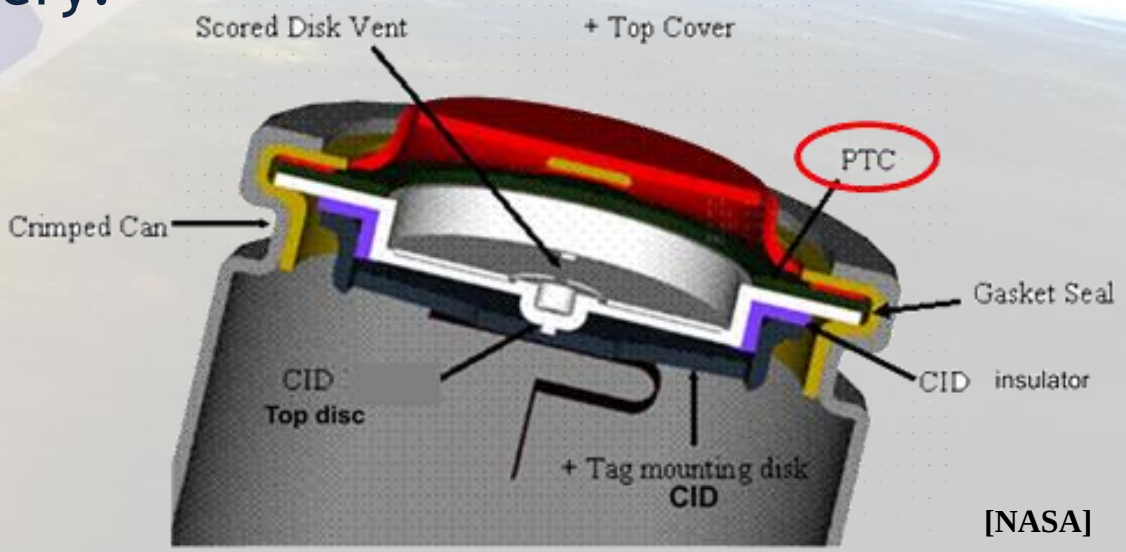


- Overdischarge
  - Reduce the capacity by the irreversible reaction

$$LiCoO_2 + Li^+ + e^- \rightarrow Li_2O + CoO$$

Battery safety issue

- External short
  - High Current
  - High temperature
  - Even though the battery possesses the PTC (Positive Temperature Coefficient) switch, the enormous current harms the circuit and battery.



[NASA]

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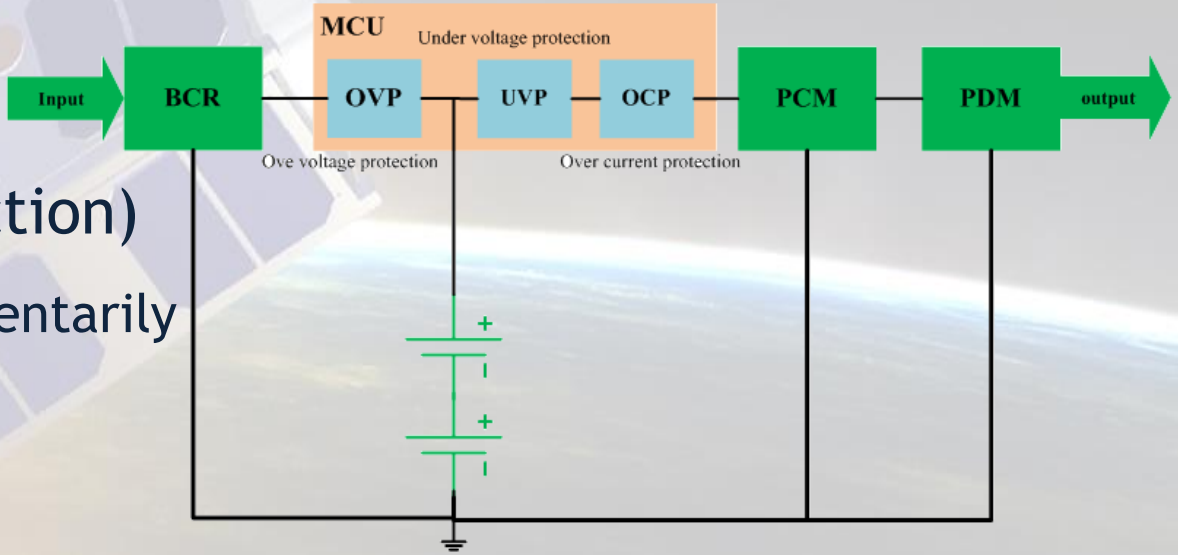
EPS protection mechanism

- OVP (Over Voltage Protection)
  - Maintain the maximum voltage and diminish the charged current



- OCP (Over Current Protection)
  - Shunt down the system momentarily

- UVP (Under Voltage Protection)
  - Switch off the system until the voltage recovery to minimum

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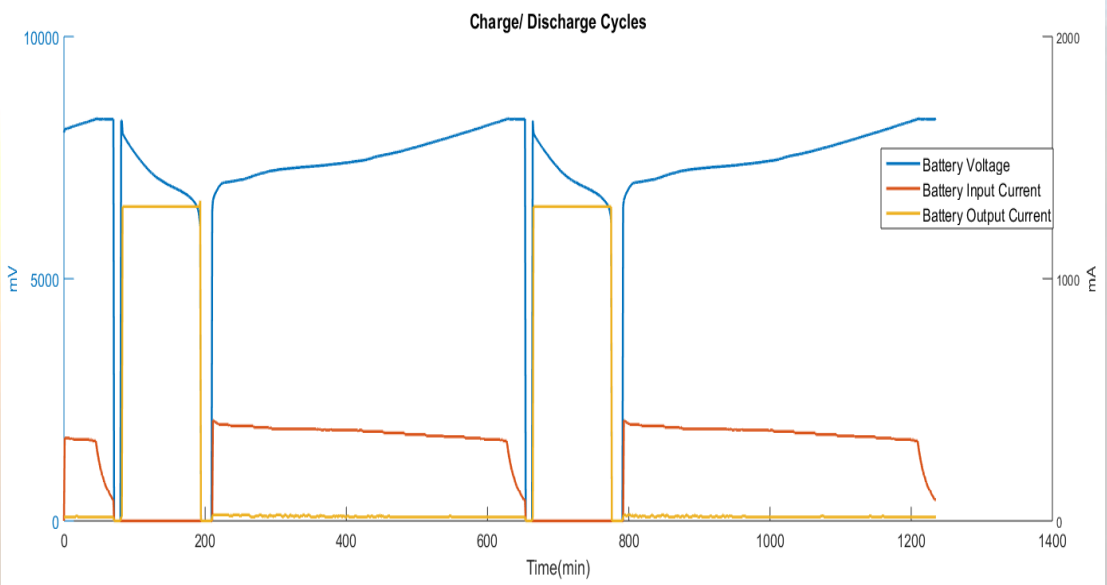
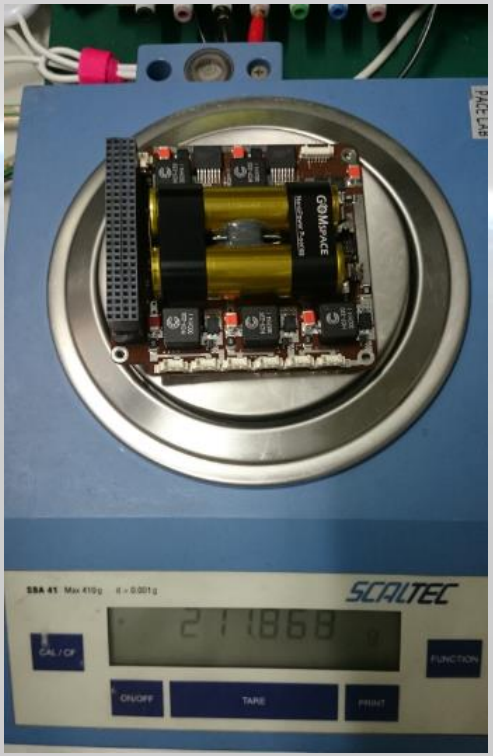
Experiments

- The test procedures and configurations for certification of PHOENIX , which are applicable to other CubeSats with a little adjustment.
  - EPS board senses the temperature, voltage, and current
  - Communicate with EPS board and OBC via I^2C
  - The storage of data and the logic decision through the OBC

Experiments

- Physical and electrochemical characteristics
  - Prior to simulate any adverse scenario, the parameters including the dimension, weight and capacity ought to be checked in order to build the basic aspect.
- Electrical cycling characteristics
  - Order: charge, discharge, charge, discharge, and charge

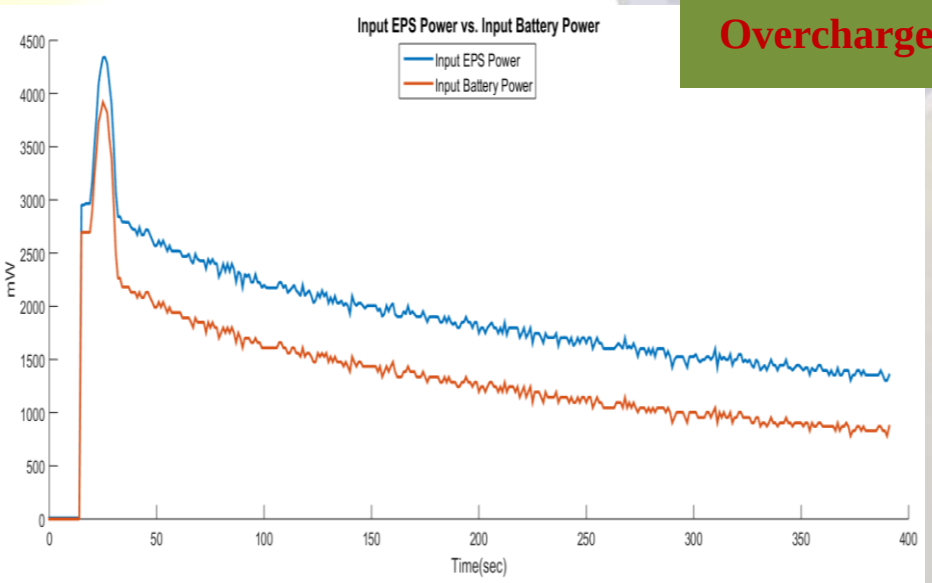




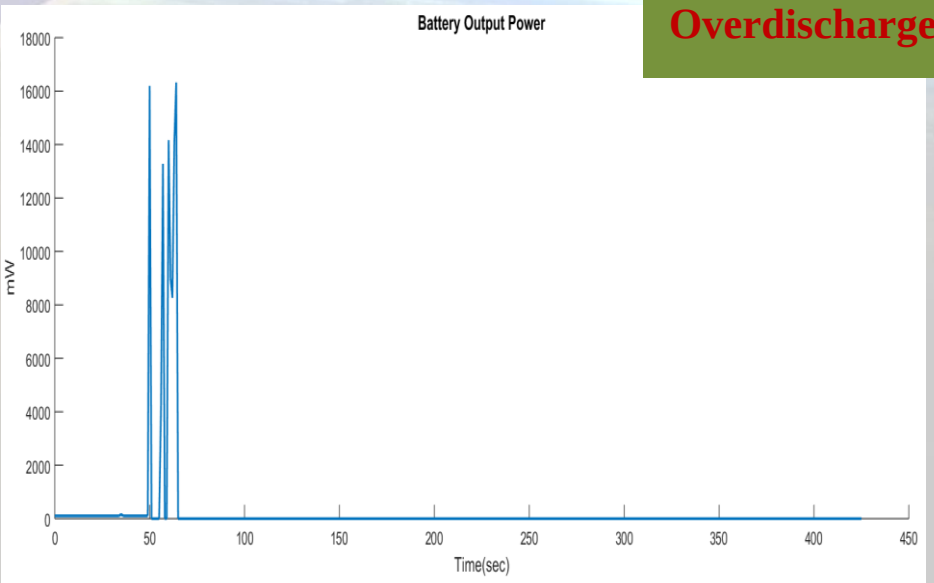
Experiments

- Overcharge/overdischarge
  - ***Active OVP in overcharge scenario***
  - ***Trigger UVP in overdischarge condition***
  - Recovery to normal operation after OVP or UVP trigger
  - Record the change of capacity

Overcharge

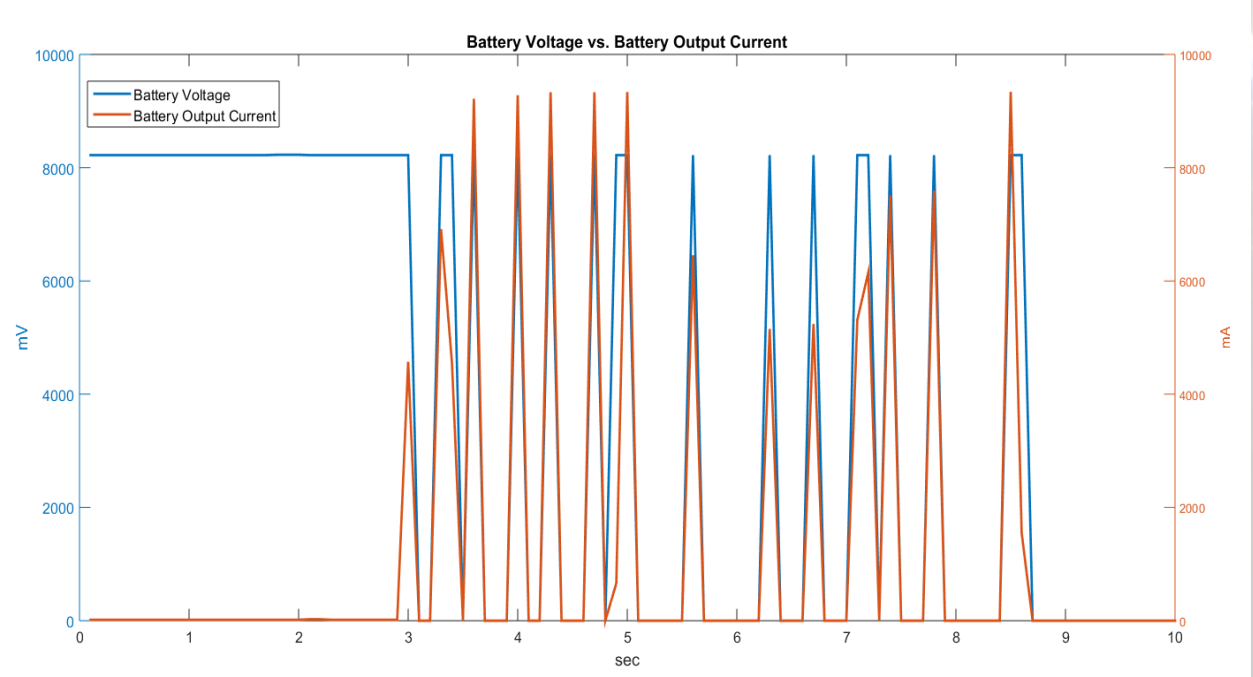


Overdischarge



Experiments

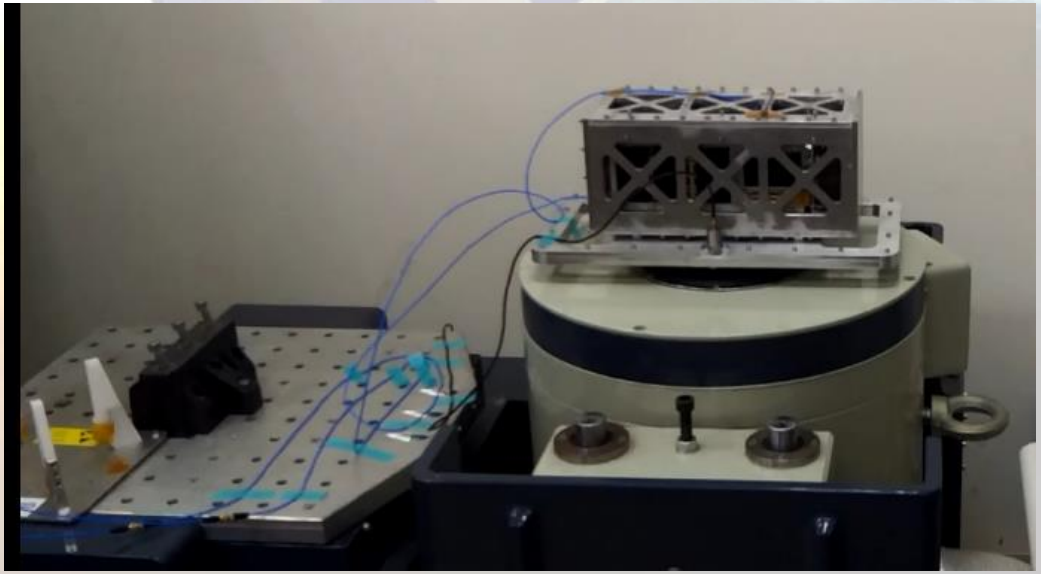
- External battery short
  - ***Verify OCP function for 10 secs***
  - Reset the system after OCP trigger
  - Record the variation of capacity



Experiments

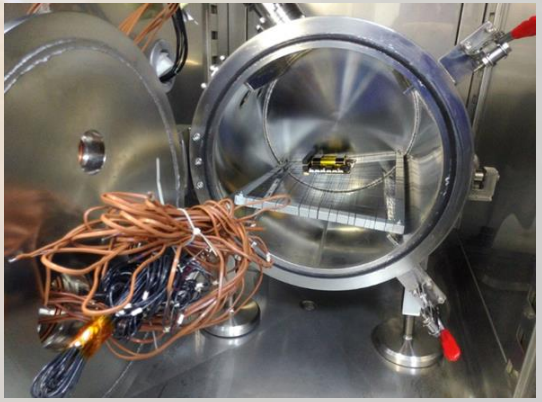
➢ Vibration test

- ***The purpose is to verify that the EPS board and battery could withstand violent vibration***
- The OCV which is recorded before test and after each axis of vibration could not surpass 0.1% change
- The change of capacity must be less than 5% before and after vibration test



Experiments

- Vacuum test
  - ***The purpose is to validate the EPS board and battery can endure the pressure variation***
  - Inspect whether any deformation, bulge, and leakage
  - The change of mass should be less than 0.1%
  - The OCV which is recorded before test and after each axis of vibration could not surpass 0.1% change
  - The change of capacity must be less than 5% before and after vibration test



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Conclusion

- Through the series of tests, PHOENIX's battery had been certified to meet the safety requirements as established by NASA and NanoRack.
- It presents the combination of EPS board and lithium-ion battery for testing and certifying all safety requirements.
- Those data could be used to predict the power behavior of EPS via the DoD (Depth of Discharge) or SoC (State of Charge).

Thank you for your attention!!

Questions?