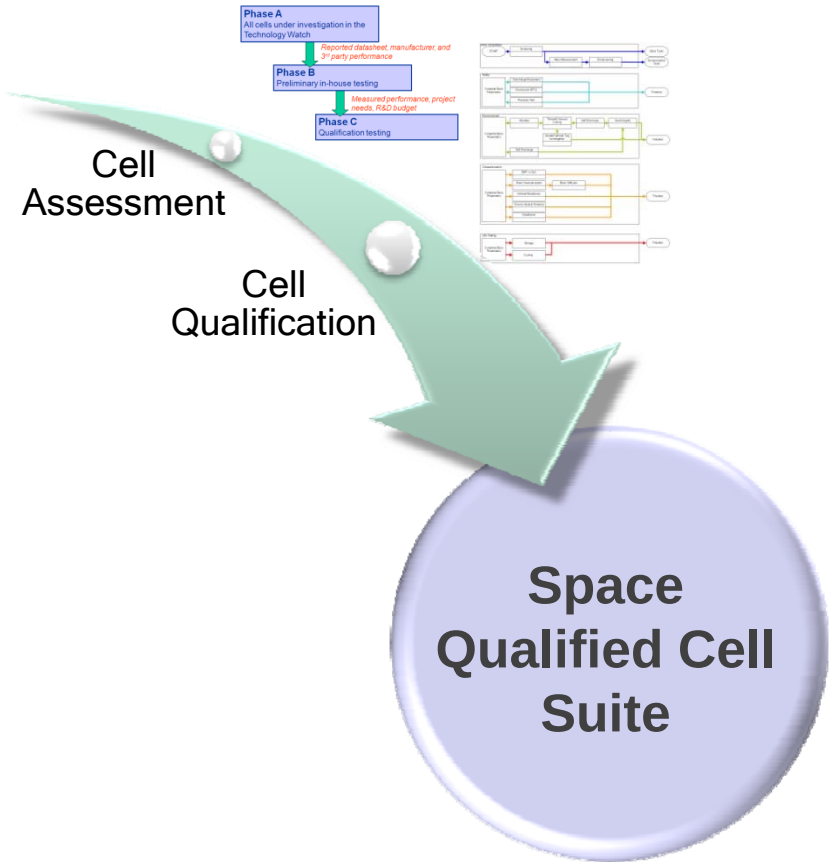
# Progress on the Space Qualification of the High Energy ABSL 18650NL Cell

*Jeremy Neubauer, Hannah Alcock, Naseer Ahmed, Chris Pearson*

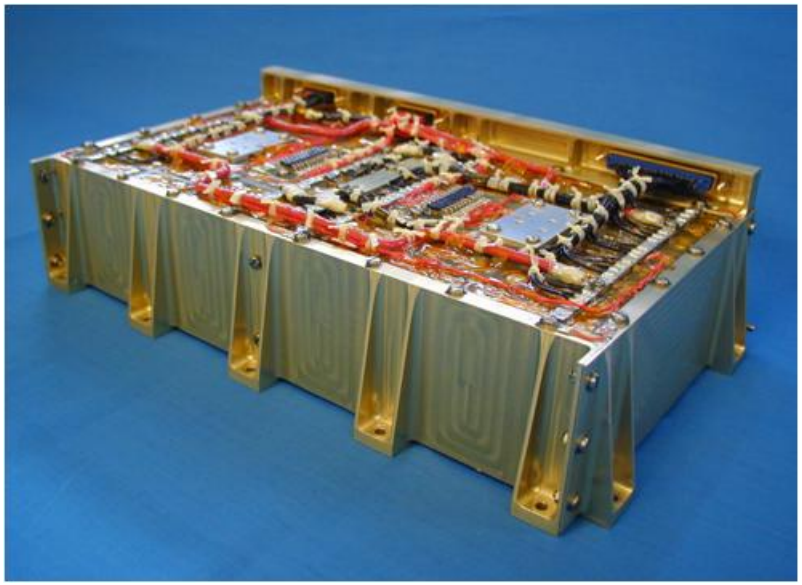
# Building a Cell Suite



# ABSL Cell Suite

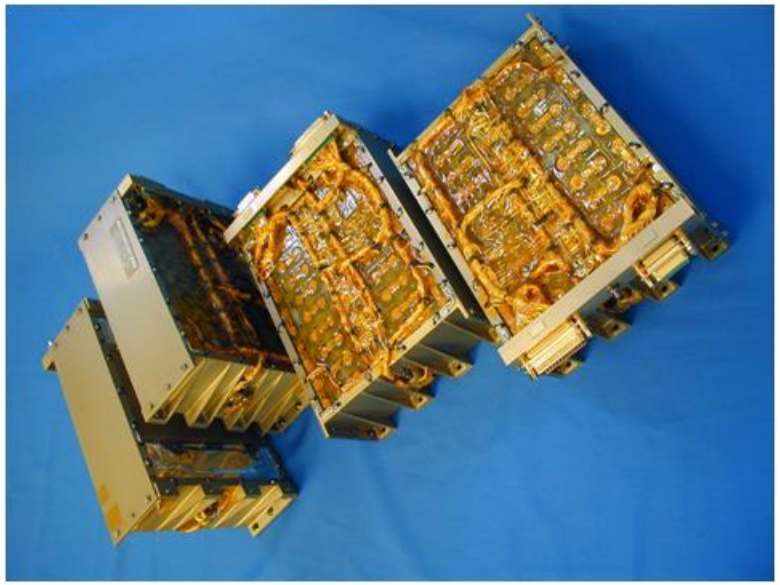
| Cell | Energy Density | Attributes | Space Qualified | Space Proven | Space Application |
|---|---|---|---|---|---|
| ABSL18650NL | 190 Wh/kg | High energy secondary cell | 2009 | 2010 | High Energy |
| ABSL18650HC | 130 Wh/kg | Excellent and Characterised Cycle Life |  |  | All space programs |
| ABSL18650HR | 100 Wh/kg | Very high current delivery >10 C |  |  | High Power |
| ABSL33111PR | 450 Wh/kg | High energy and structural integrity |  |  | Primary batteries |
| ABSL 26650HC | 120 Wh/kg | Excellent cycle life |  |  | Retired |

# Motivation



HC Based Battery

- 2 x 8s16p
- 1382Wh, 28V
- 13.0kg

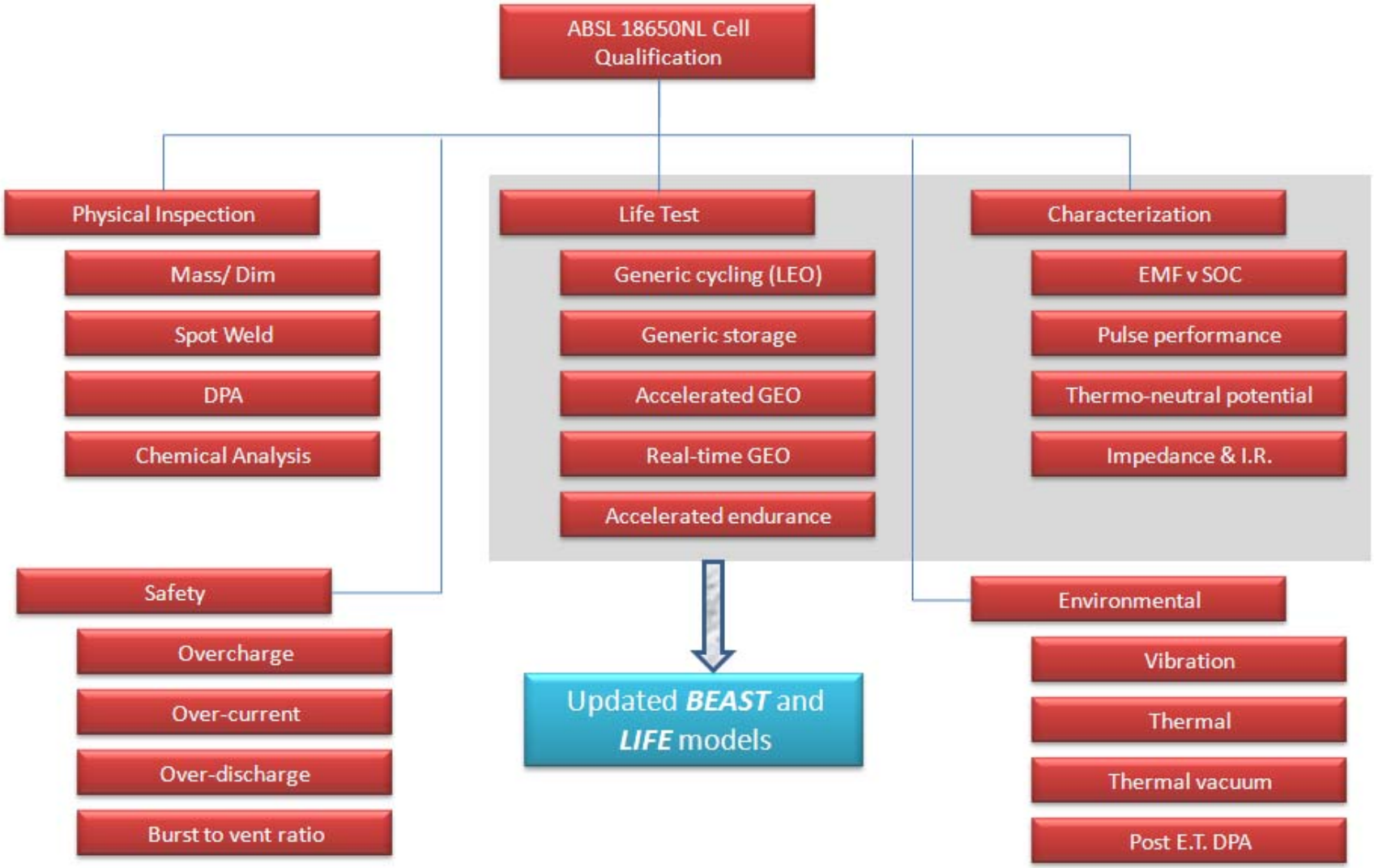


NL Based Battery

- 2 x 8s10p
- 1398Wh, 28V
- 9.0kg

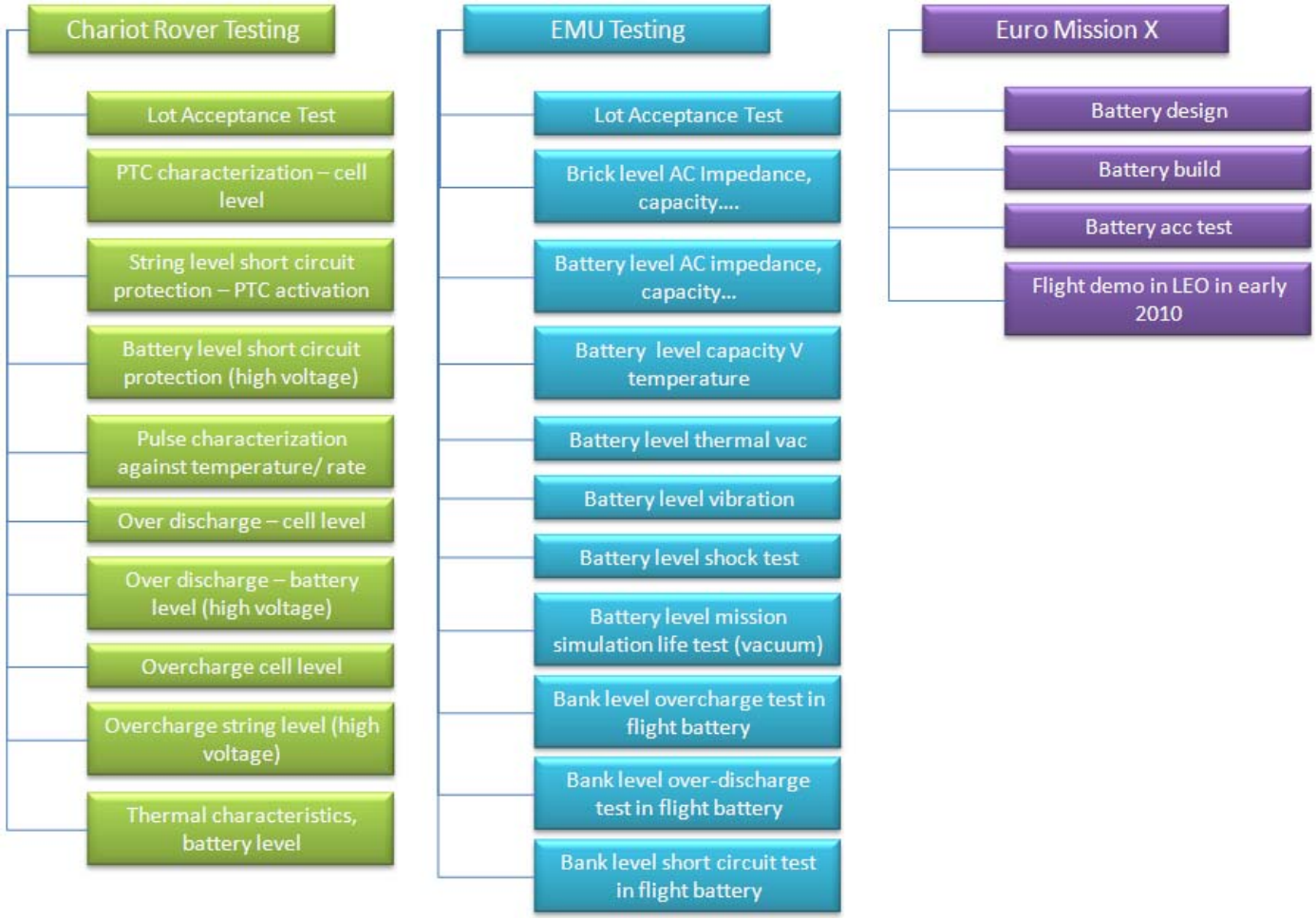
Equivalent batteries, roughly a 25% mass decrease

# Cell Qualification Sampling

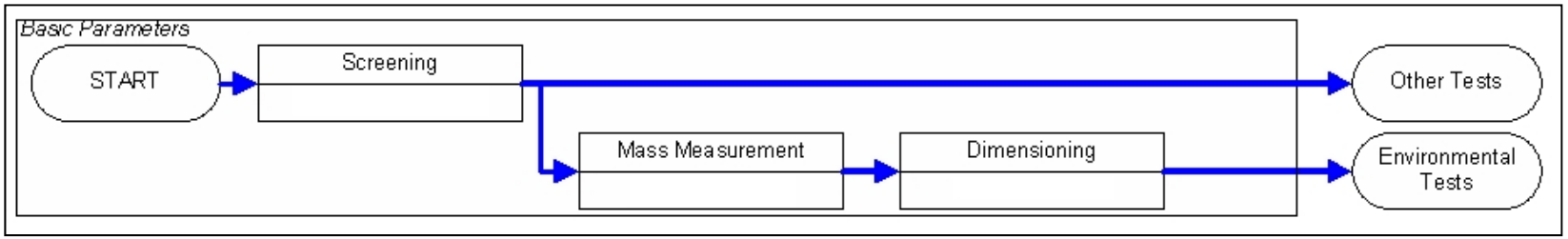


# Past Programmatic Work

- Processed >10,000 cells to date from 3 different batches
- 5 custom batteries designed and built using this cell



# Cell Qualification: Basic Parameters

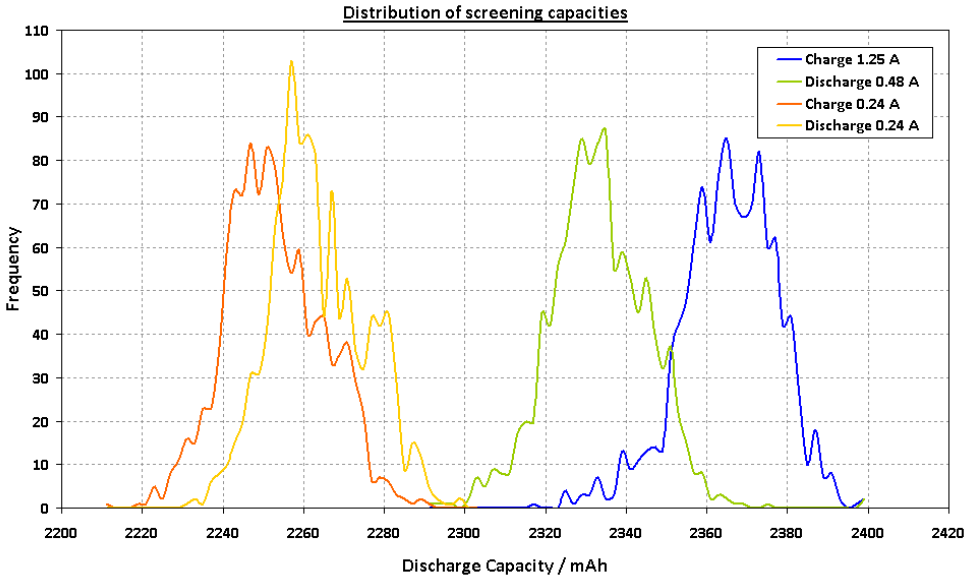



*Simplified test flow; actual qualification processes vary*

- Enables selection of suitable cells for testing
- Evaluates the basic build quality and consistency

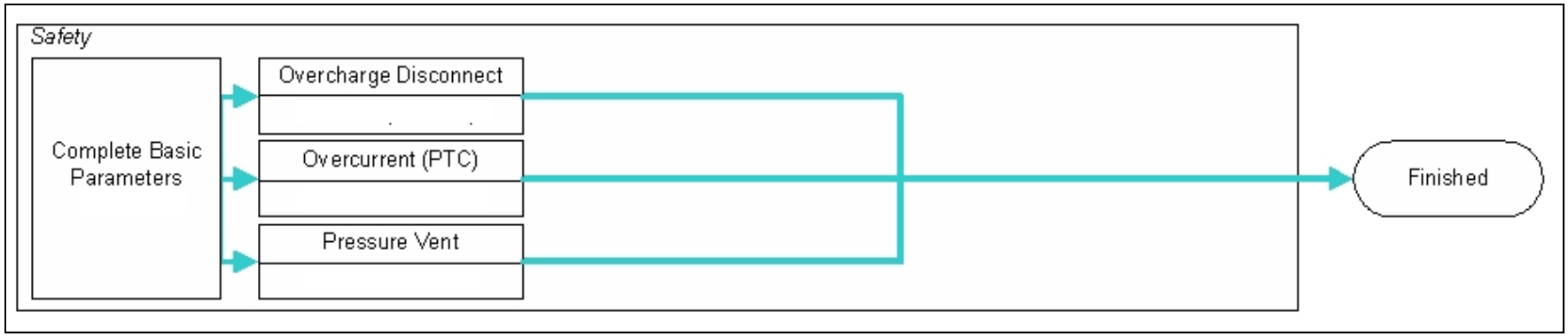
# Cell Qualification: Basic Parameters

- Screening of all cells to the manufacturer's specifications and to an ABSL standard.
- Mass and dimensional screening compared to manufacturers specification.
- Overall consistency very similar to that of the ABSL 18650HC




| | Average | Standard Deviation |
|---|---|---|
| **Mass / g** | 45.97 | 0.088 (0.19 %) |
| **Length / mm** | 64.4 | 0.013 (0.02 %) |
| **Width (Top) / mm** | 17.9 | 0.007 (0.04 %) |
| **Width (Bottom) / mm** | 17.9 | 0.006 (0.03 %) |

# Cell Qualification: Safety



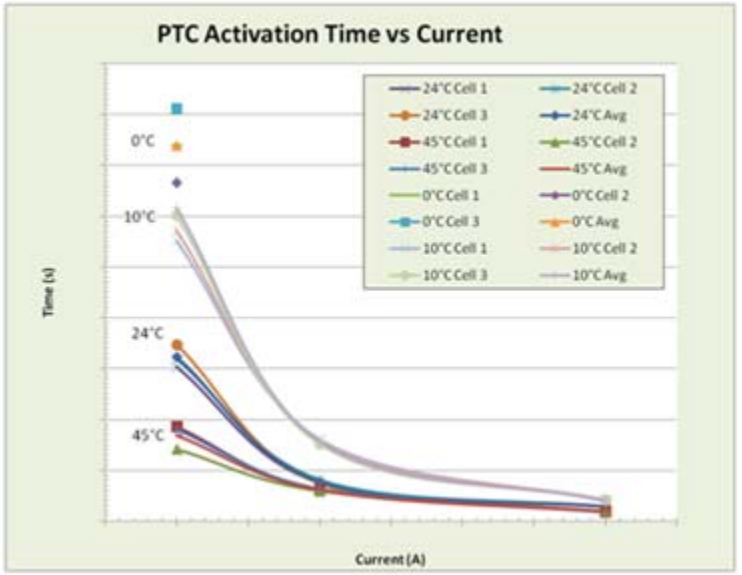

*Simplified test flow; actual qualification processes vary*

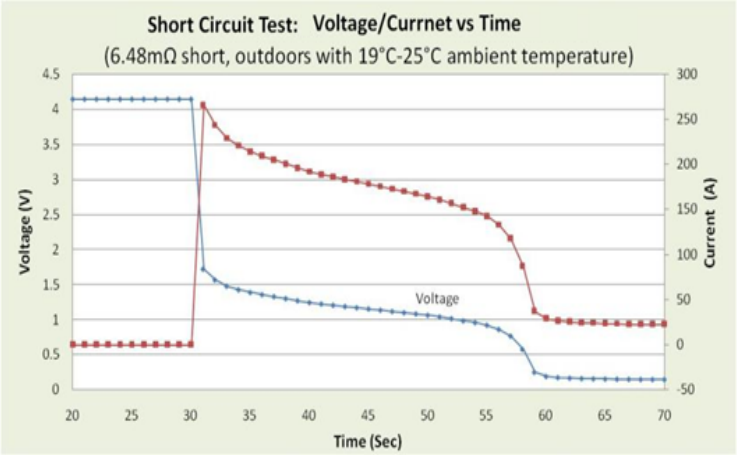
- Evaluates cells under off-nominal and abusive conditions

# Over-Current Testing

- Cell Level:
  - Activation characterization completed from 0 to 45 deg C
  - Additional testing down to -20 deg C also completed

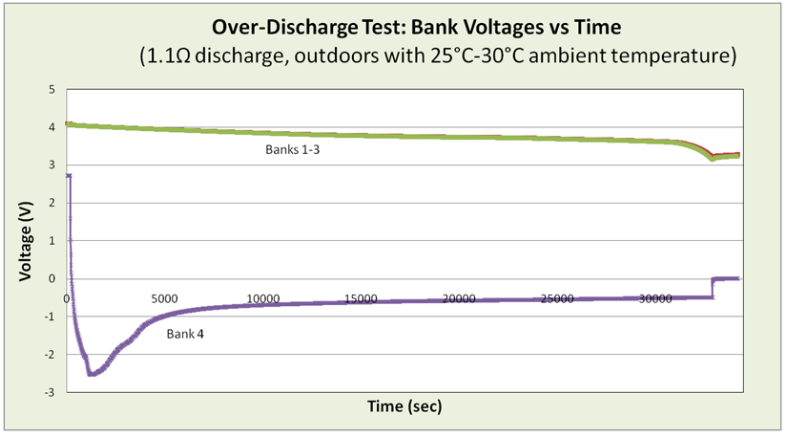
- Battery Level:
  - String level testing up to 20s / 84 V test showed safe PTC activation without failure
  - Multiple battery level short circuit tests with inrush currents up to ~300 A all show safe fault handling

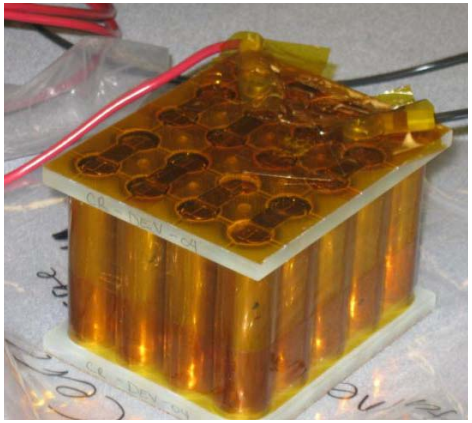


# Over-Discharge Testing

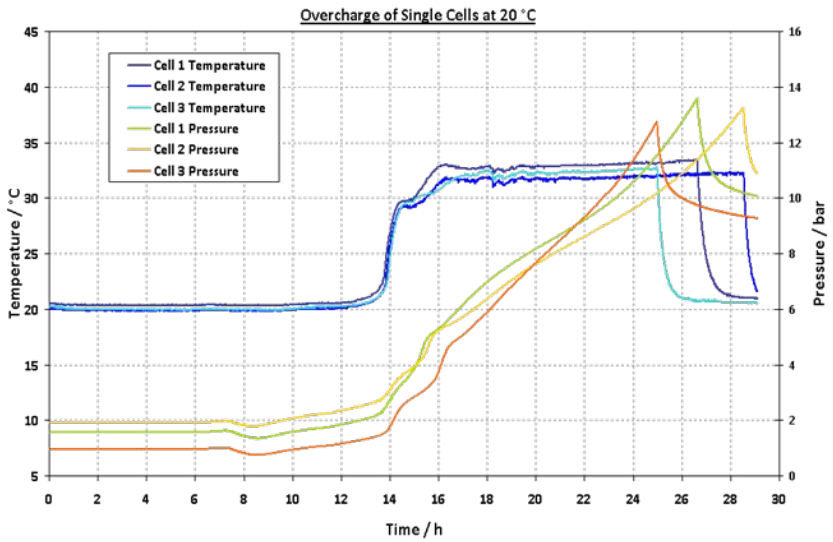
- Cell Level
  - Single cells over-discharged well into reversal without event
- Battery Level
  - Imbalanced 5s battery was cycled without event.
  - Imbalanced 20s string was cycled without event.
  - Full scale 80s4p module discharged to ~28 V without event



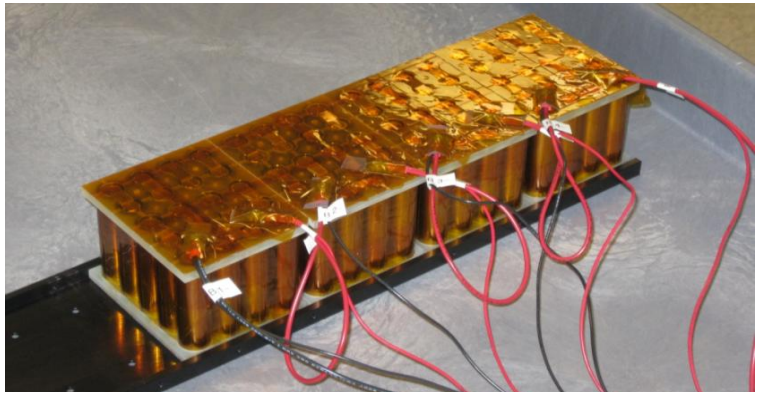



# Over-Charge Testing

- Cell Level
  - Cell level testing at multiple rates and temperatures showed no venting / flame / explosion

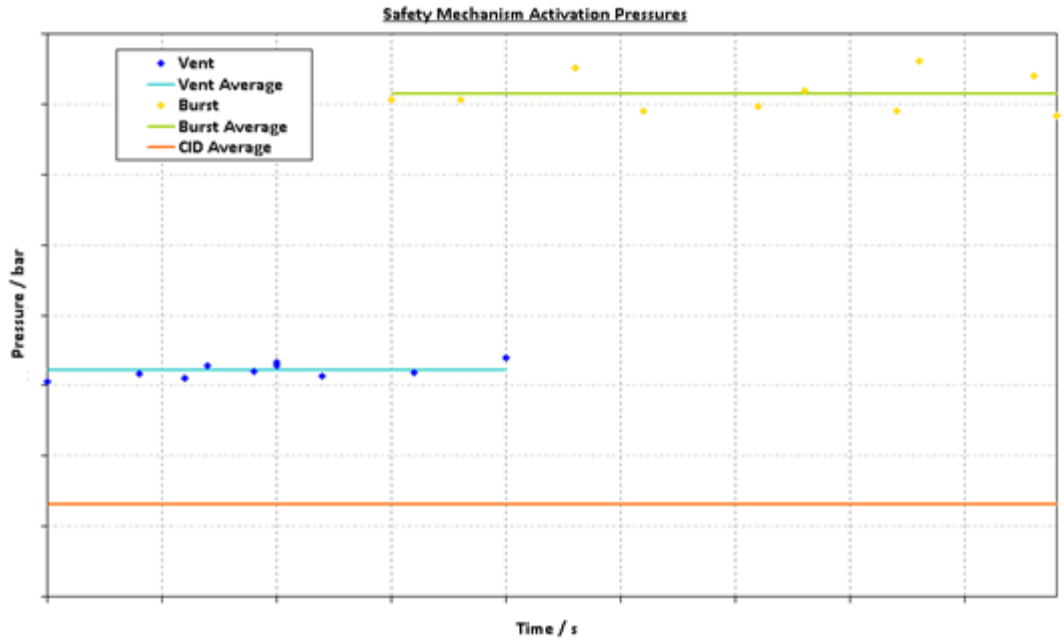



- Battery Level:
  - 5s battery overcharged at low rate resulted in safe shutdown without venting / flame / explosion
  - 80s string overcharged at C/2 resulted in safe shutdown without venting / flame / explosion or high voltage failure mode

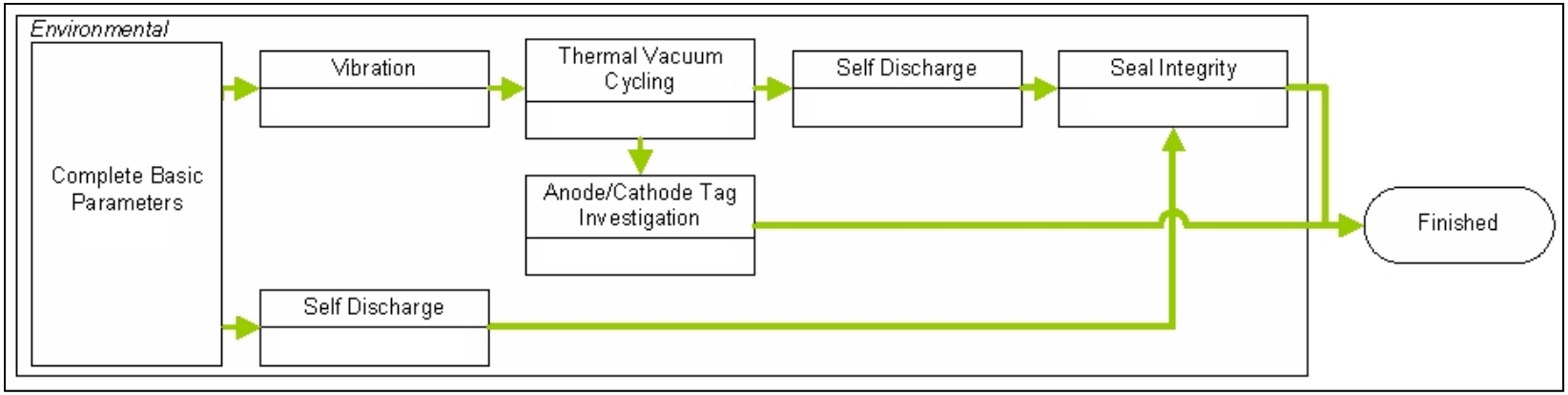


# Burst – Vent Testing

- Measured activation pressure of the designed in vent to ensure safe and consistent operation
- Deactivated vent and measured burst pressure as well
- Comparisons of CID, Vent, and Burst pressures show safe margins between the three events are consistently delivered



# Cell Qualification: Environmental




*Simplified test flow; actual qualification processes vary*

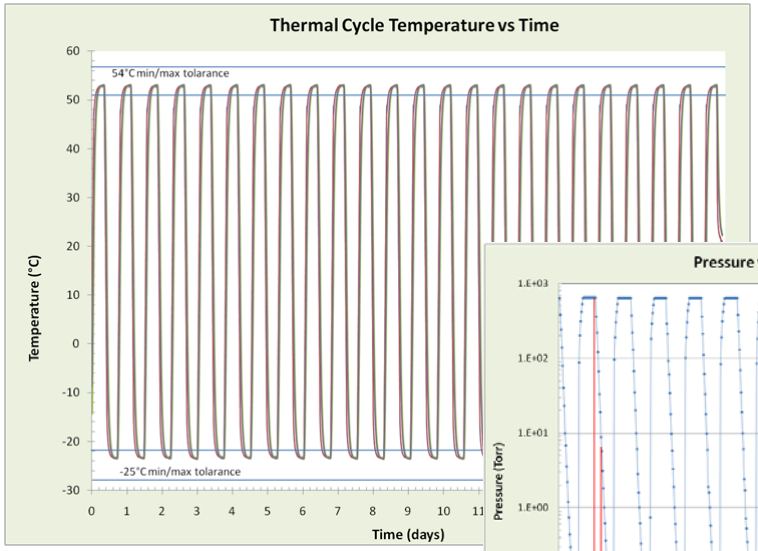
- Evaluates cells under launch and in-orbit conditions

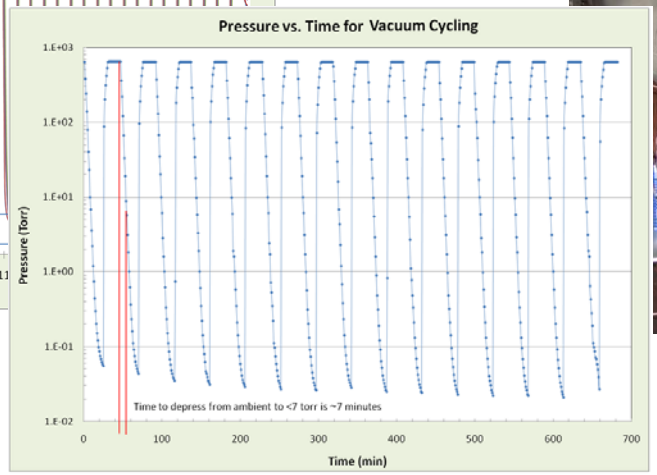
# Environmental: Cell Level

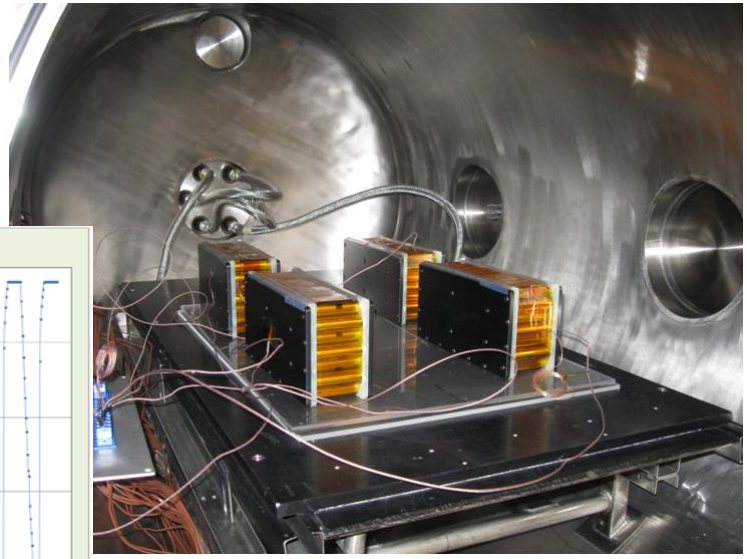
- Cells subjected to high level random vibration and sine sweeps representative of installed loading
- Followed by vacuum and thermal cycling from –30 to +80 deg C with RGA leak detection
- Subsequent testing and DPA showed the tested cells passed without any signs of environment induced failure.
- Cells have also been subjected to up to 5 MRad radiation exposure and are currently undergoing subsequent life cycling to assess effects thereof; higher dosage (20 MRad) testing to follow

# Environmental: Battery Level

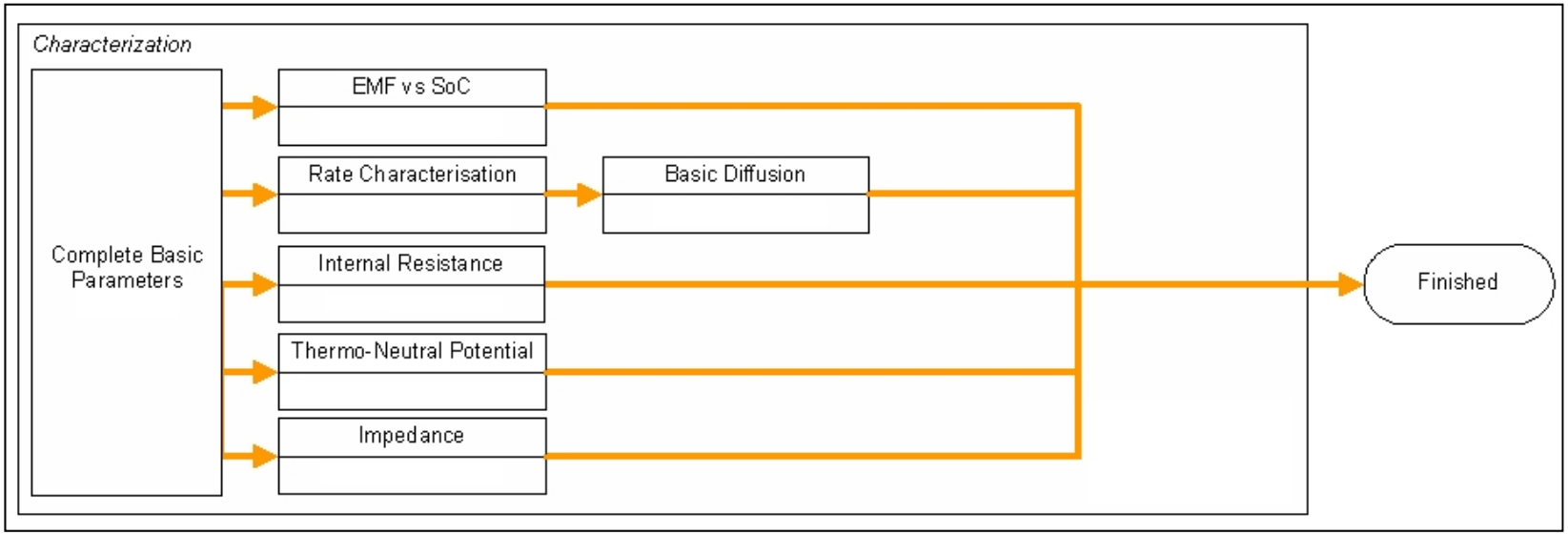
- Thermal cycling from -25 to +54 deg C
- 3 day, +35 deg C vacuum dwell and vacuum cycling
- Random vibration up to 9.89 $g_{rms}$ and shock to 20 g



# Cell Qualification: Characterization

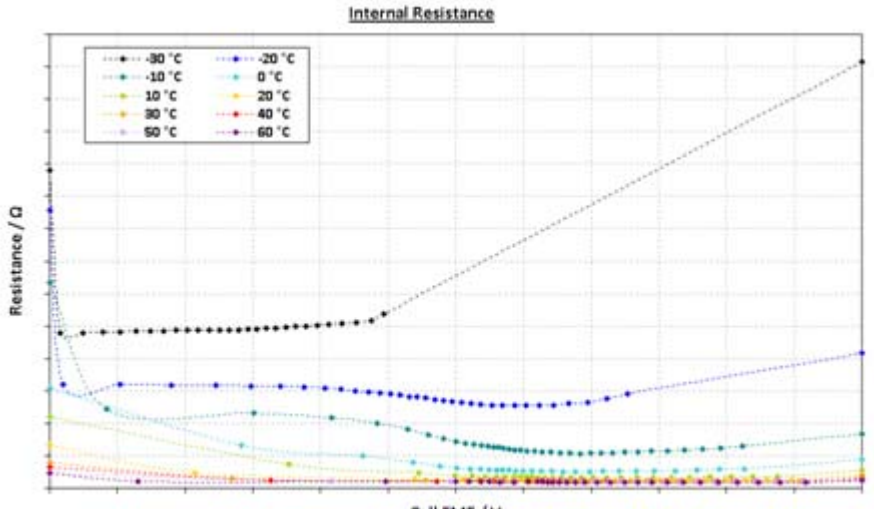


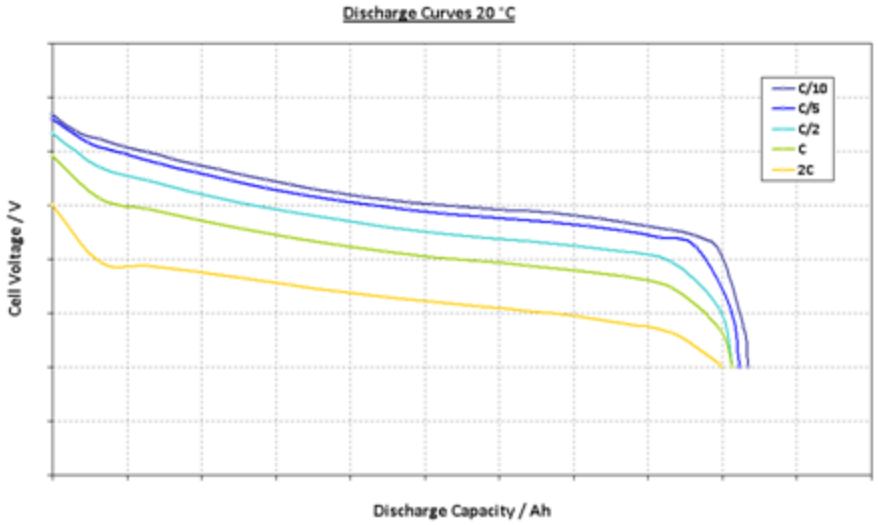

*Simplified test flow; actual qualification processes vary*

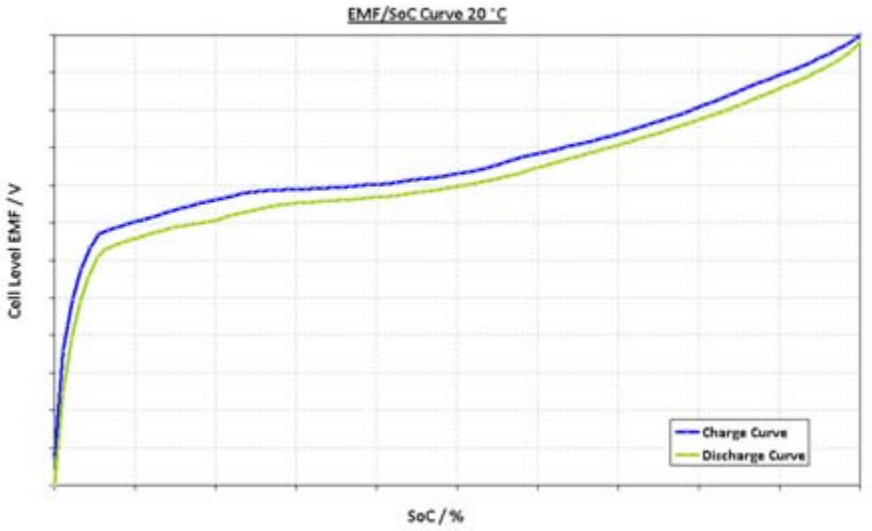
- Produces the data required to model the cell's performance using ABSL's in-house analysis tools BEAST and BATS.

# Characterization

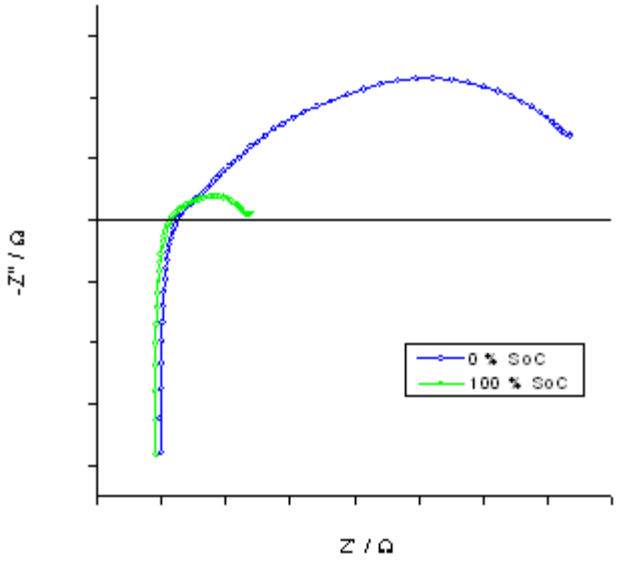
- Extensive cell characterization testing includes EMF vs SOC, internal resistance, rate and temperature sensitivity...

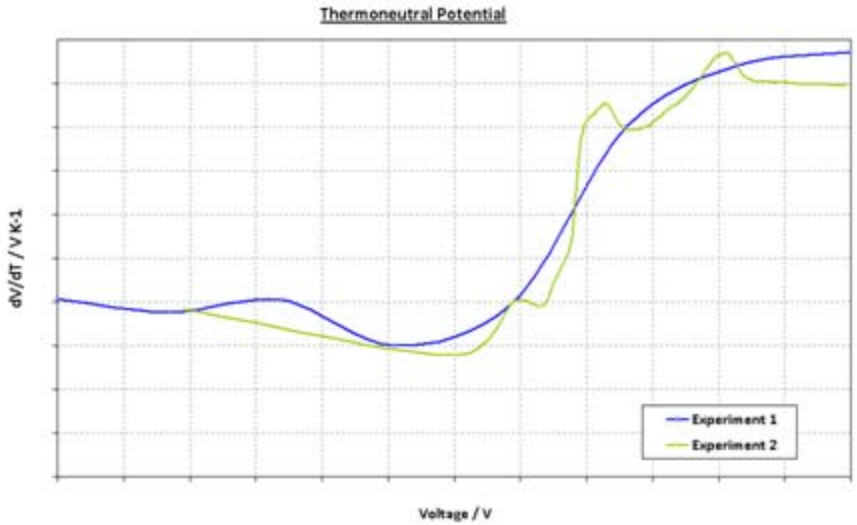


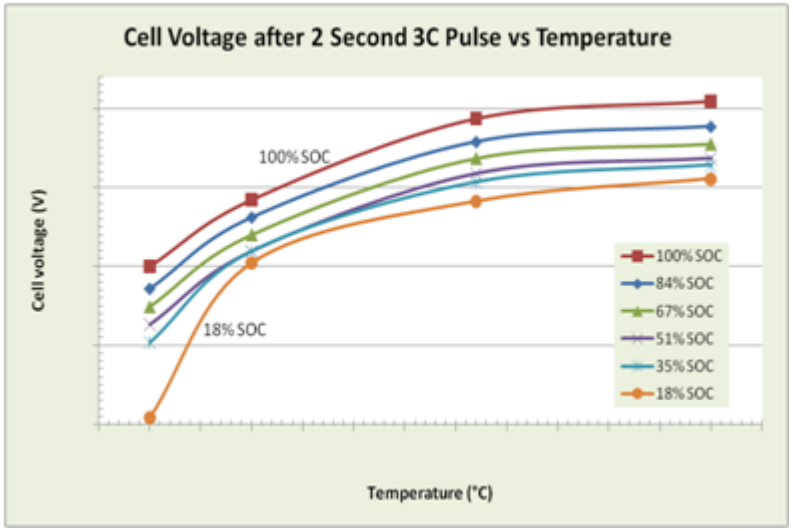



# Characterization

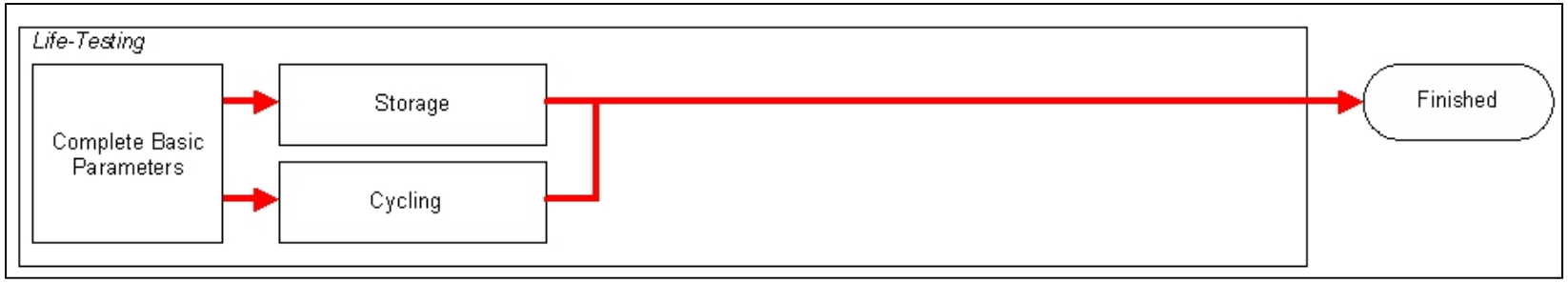



- … AC impedance, thermoneutral potential, pulse performance, and more!

# Cell Qualification: Endurance




*Simplified test flow; actual qualification processes vary*

- Produces the data required to model the cell's degradation (resistance increase, fade, etc.) over long time periods. Involves a suite of storage and cycling tests on individual cells together with modules.
- Resultant data will be incorporated into LIFE, ABSL's long term degradation analysis software

# Cell Level Cycle Testing

- 12 different cycle charge / discharge periods
- 11 different DODs from 2 to 100%
- 6 different temperatures from 0 to 60 deg C
- 5 different rates from C/4 to 1C
- 4 different EOCVs from 3.90 to 4.20 V
- Both vacuum and ambient pressure environments

- *More total cases than you can shake a stick at!*

# Cell Level Storage Testing

- 5 different SOC levels from ~10% to 100%
- 3 different temperatures from 0 to 40 deg C
- Both vacuum and ambient pressure environments

# Battery Level Cycle Testing

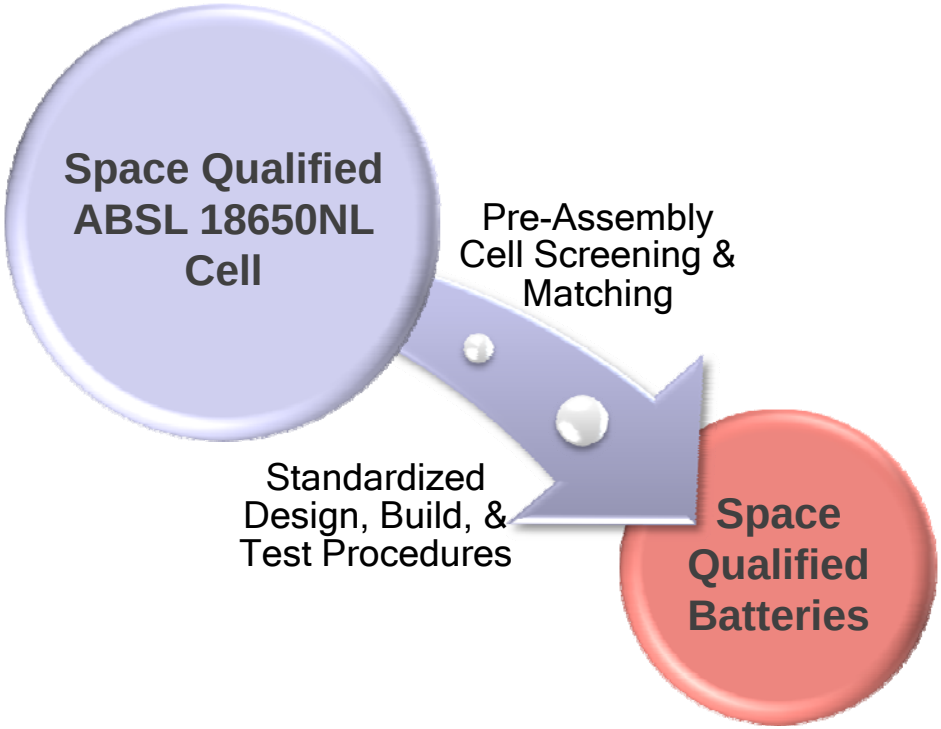
- Accelerated GEO profile with an 8s4p battery
- Real-Time GEO profile with an 8s4p battery
- Real-Time LEO profile with an 8s4p battery and variable EOCV management

# Current Status

- A few short term tests still remain to be completed, expected to be finished before 2010
- Long term tests (cycling, storage, radiation) will all begin prior to 2010 and continue as necessary

# Moving Forward

- Once qualified, the NL cell will be marketed for space applications
- ABSL's standard architecture will be employed with minimal modifications
- First LEO flight expected in early 2010
- First manned flight expected summer / fall 2010



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