



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

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Proprietary Information

Approved by

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STS-133



Discovery is currently scheduled for launch on November 30th 2010 (tentative) and will be the first flight of the ABSL 18650NL cell and a first flight of the ABSL battery built in US!



Agenda



- Background to the ABS L 18650NL Cell
- Internally funded testing
- Customer funded work
- Conclusions



Background

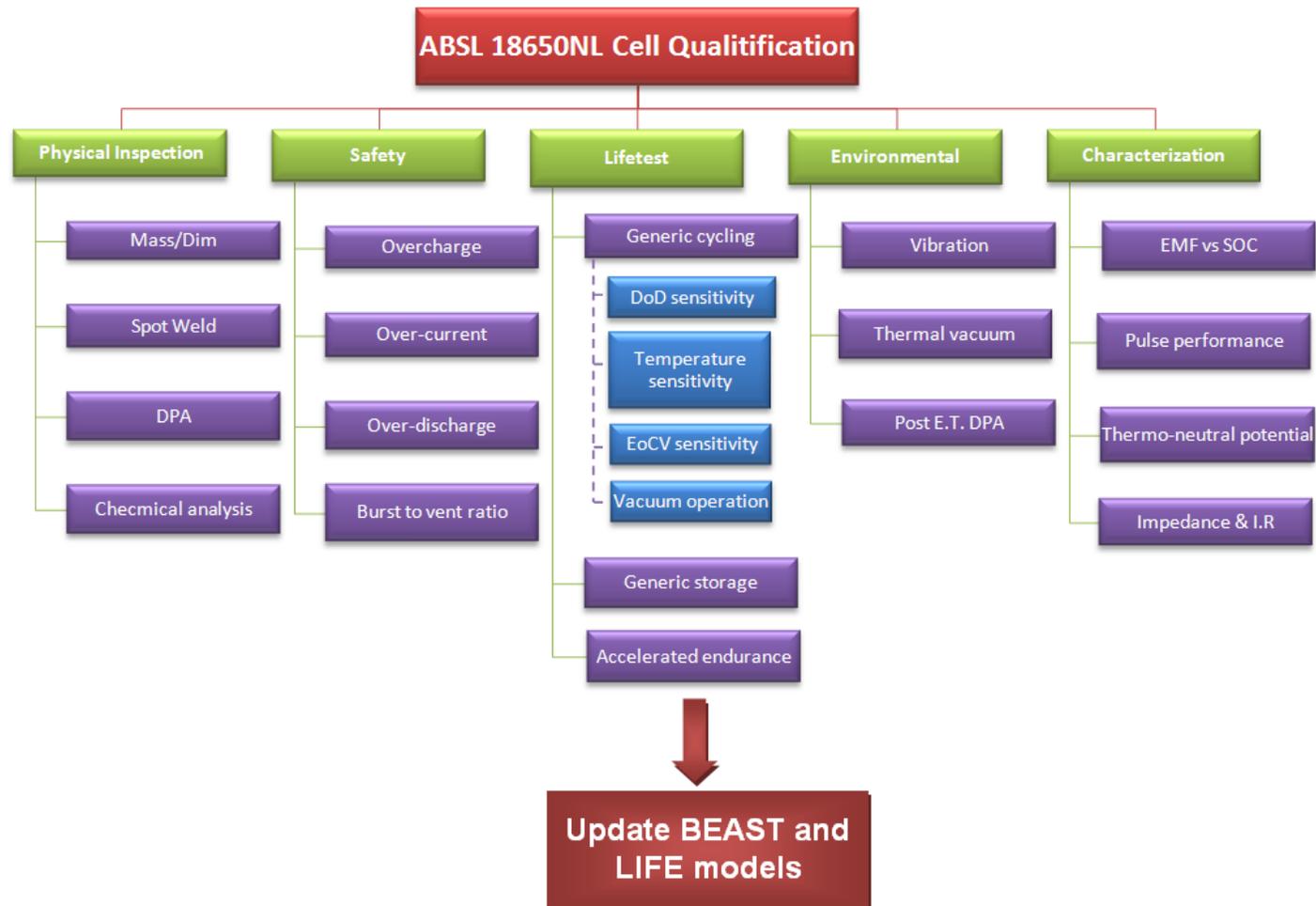
Background: ABSL Cell Suite



Cell	Energy Density	Attributes	Space Qualified	Space Proven	Space Application
ABSL18650NL	190 Wh/kg	High energy secondary cell	 *	 2010	High energy density
ABSL18650HC	130 Wh/kg	Excellent and Characterized 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

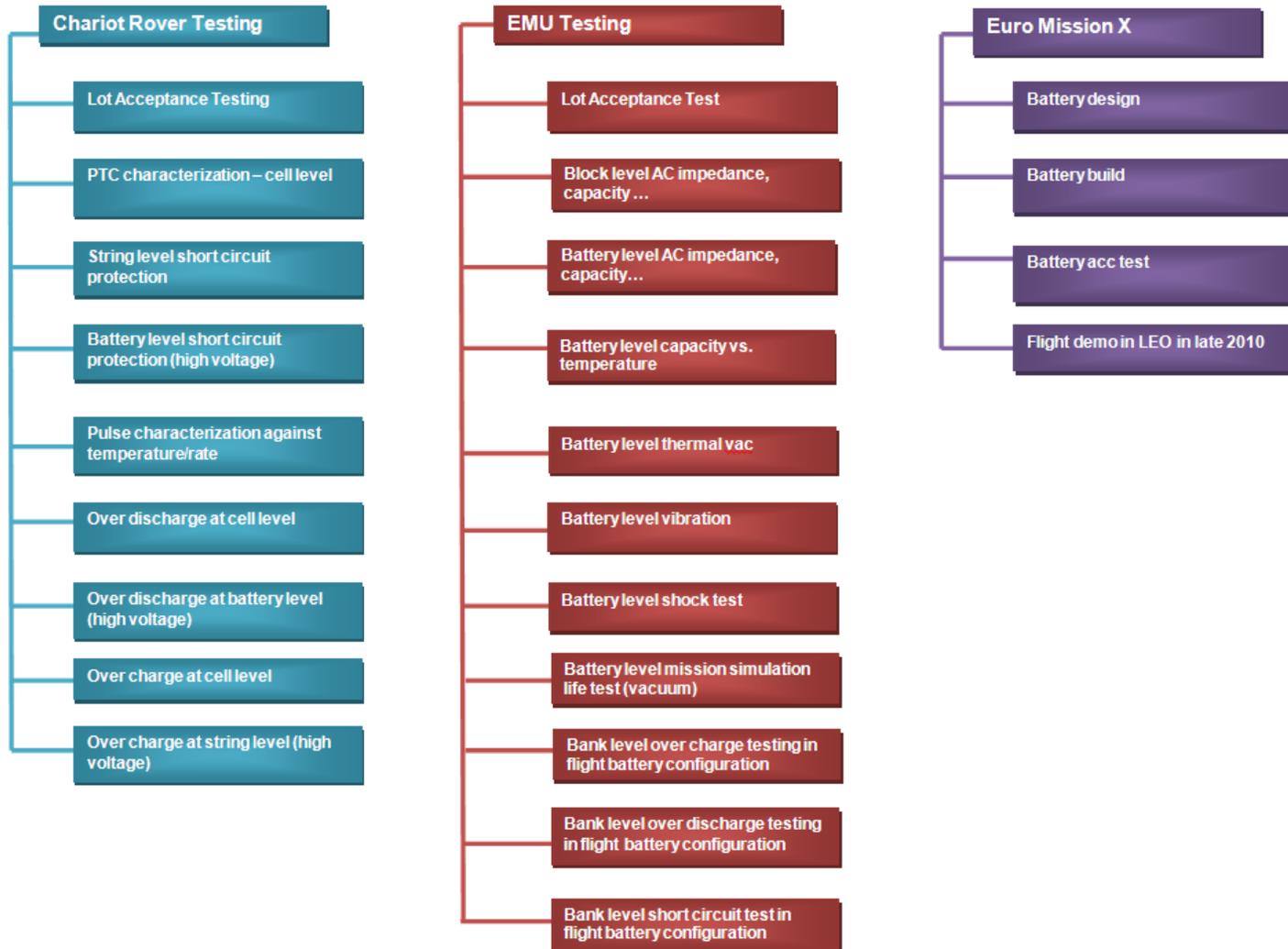
*For specific space missions

18650NL ABSL Funded Cell Testing



Under internal investment, ABSL has performed its typical suite of tests for space qualification on the ABSL 18650NL

18650NL Past Program Based Testing

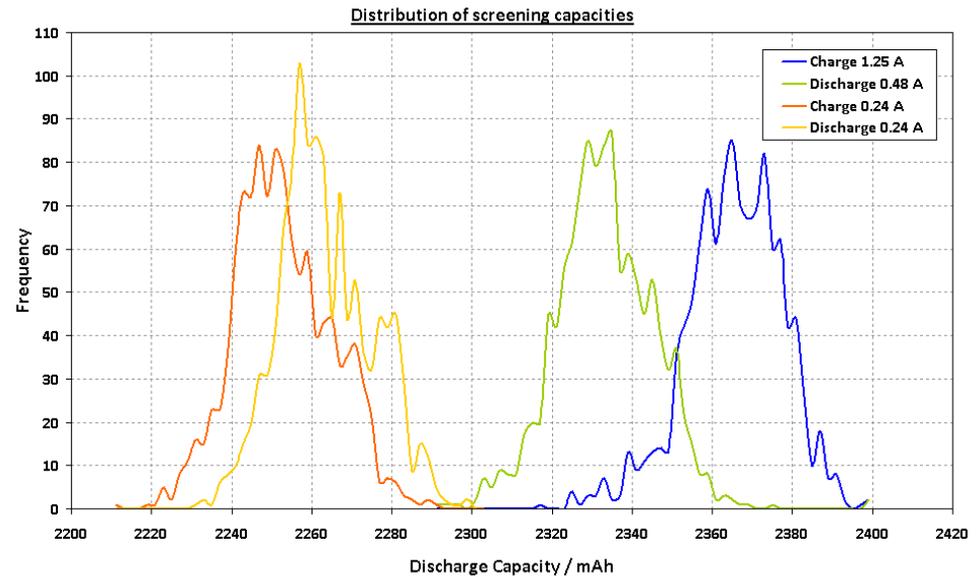


18650NL ABS L Funded Testing (more info on request)

18650NL 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.

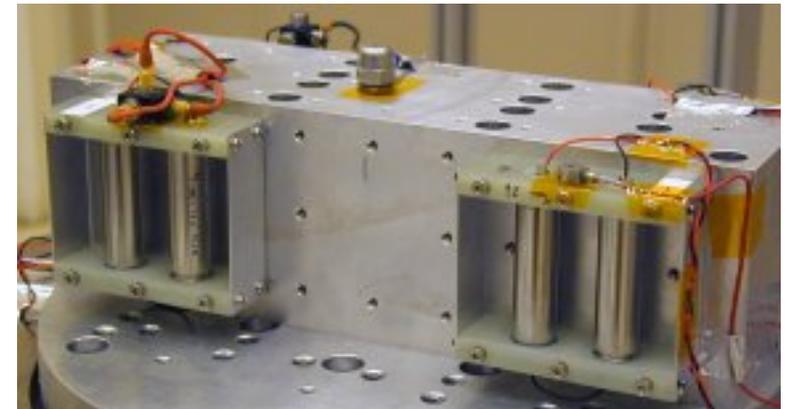
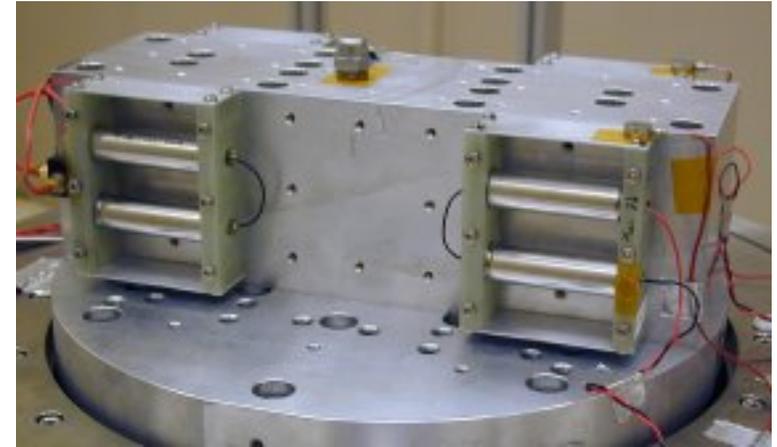


	Average	Standard Deviation
Mass [g]	45.97	0.088 (0.19 %)
Length [mm]	64.4	0.013 (0.02 %)
Width (Top) [mm]	17.9	0.007 (0.04 %)
Width (Bottom) [mm]	17.9	0.006 (0.03 %)

18650NL Environmental Testing: Cell Level



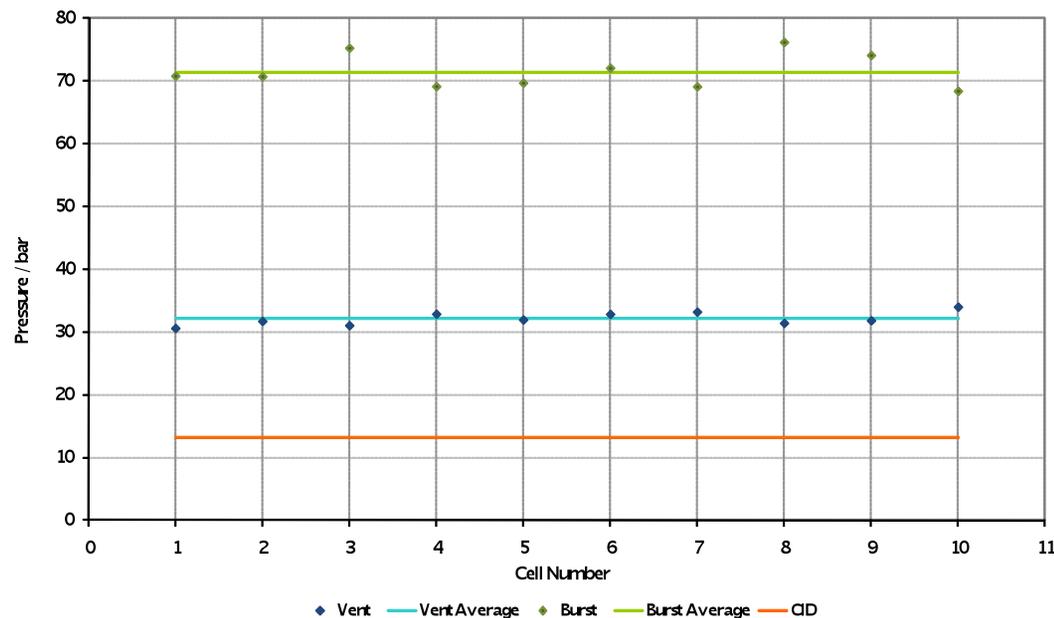
- Cells subjected to >45 grms random vibration, 20 g sine sweeps representative of installed loading
- Subsequent testing and DPA showed the tested cells passed without any signs of mechanical damage
- Cells have also been subjected to up to 5 MRad radiation exposure and there is no indication of performance impact; longer term life tests planned.



18650NL Burst - Vent Testing



- Measured activation pressure of the designed 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



18650NL Cell Level Life Cycle Testing



Cycling

		Temperature (°C)					Duration	
		0	10	20	30	40	60	Time/cycle (mins)
DoD (%)	2			✓				6
	5			✓				15
	10	✓	✓	✓ ¹		✓		30
	15			✓				45
	20	✓ ^{1,2}	✓	✓ ^{1,2,3}	✓ ^{1,2}	✓		60
	30			✓				90
	40	✓		✓ ¹		✓		120
	60	✓	✓	✓ ²	✓	✓		180
	70			✓				210
	80			✓				240
100			✓				300	

Storage

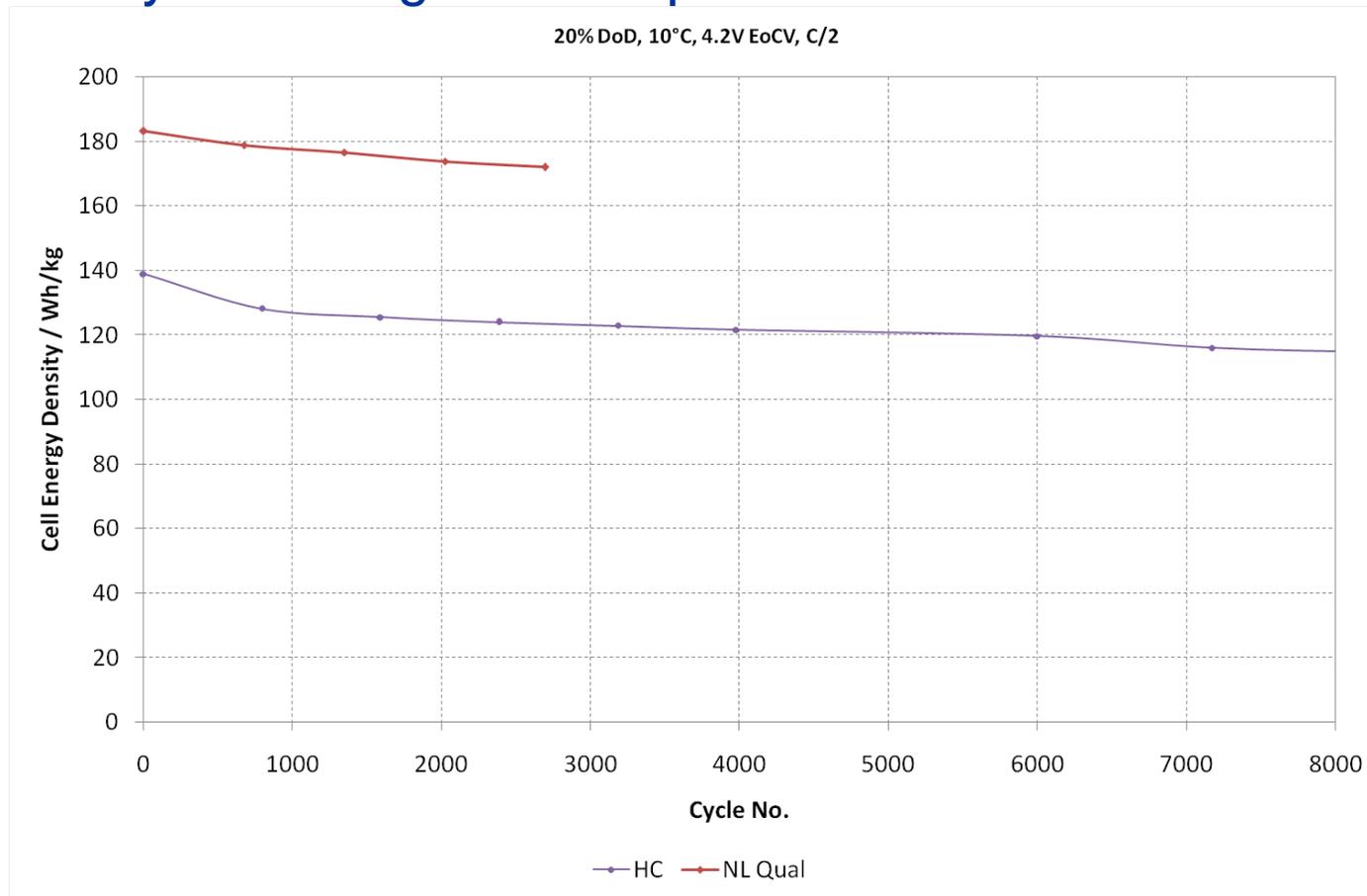
		Temperature (°C)		
		0	20	40
SoC (%)	25	✓	✓	✓
	50	✓	✓	✓
	75	✓	✓	✓
	100	✓	✓ ³	✓

Notes: 1 = EoCV, 2 = Rate, 3 = Vacuum

18650NL Cell Level Life Cycle Testing



- Life cycle testing and comparison to HC cell:



- 20% DoD
- 10°C
- 4.2V EoCV
- C/2

Early test data is extremely encouraging with the NL fade similar to that of the HC indicating potential for long cycle life

18650NL Customer Funded Work (more info on request)

18650NL: ABSL Projects



Extravehicular Mobility Unit



- 17.5V system
- 38.4Ah capacity
- 190Wh/kg cell
- 12EM, 1QM, 34FM bricks and 18FM batteries built



Chariot Rover



- 270V system
- 20kWh energy
- 190Wh/kg cell
- System built and delivered



18650NL: EMU Program



- 16p5s Topology
- Cell brick designed to be integrated into an existing NASA housing
- Acceptance testing completed on both the cell bricks and the integrated batteries
- Environmental testing completed on battery assemblies



18650NL: Chariot Rover Program



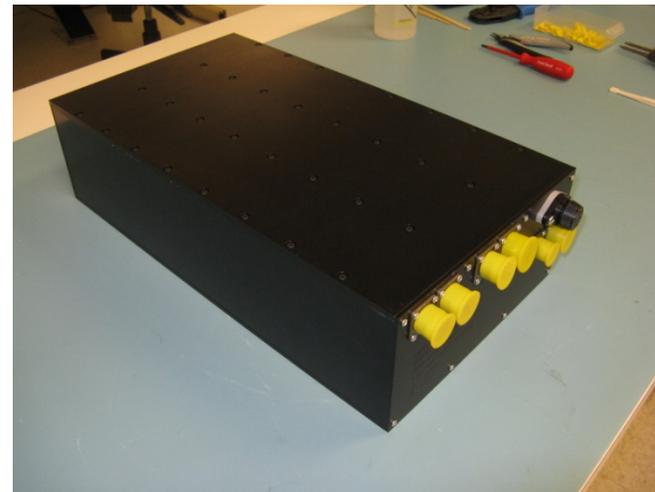
- Designed, manufactured and delivered 7 modules in 9 months
- Modular design used to break up 80s1p strings into 20s1p blocks
- 3 different block designs required to fit into existing envelope defined by NASA
- Each module designed as an independent 80s4p battery



18650NL: Chariot Rover Program



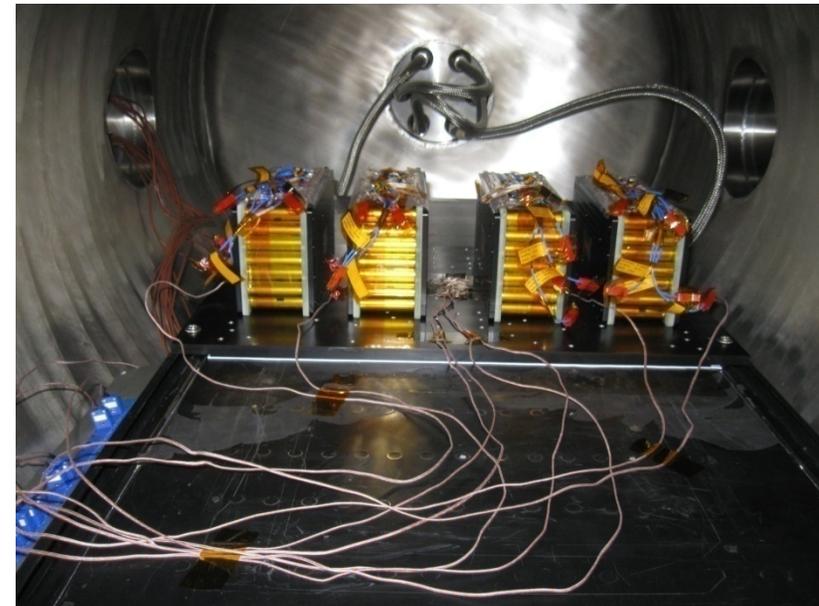
- Arming plugs incorporated to reduce voltage to reduce maximum voltage to 84V when not in use
- 7 modules connected in parallel to obtain required capacity
- Every string incorporates voltage monitoring for each 20s1p block



18650NL Environmental Testing: Battery Level



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



18650NL Over-Current Testing

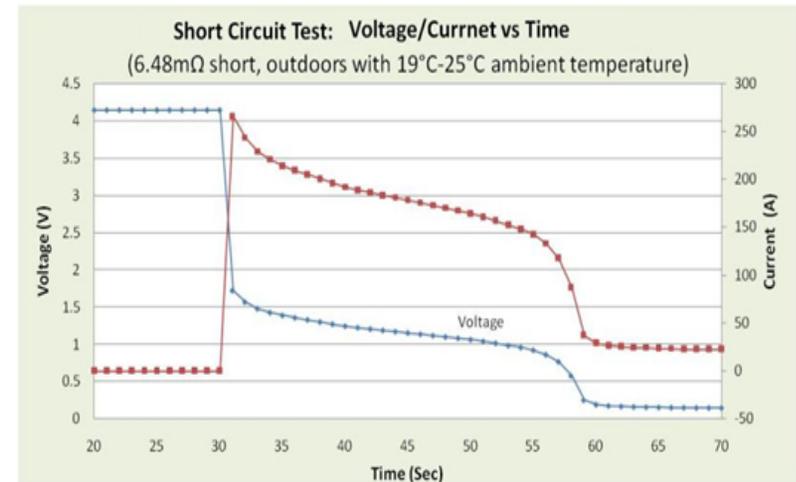
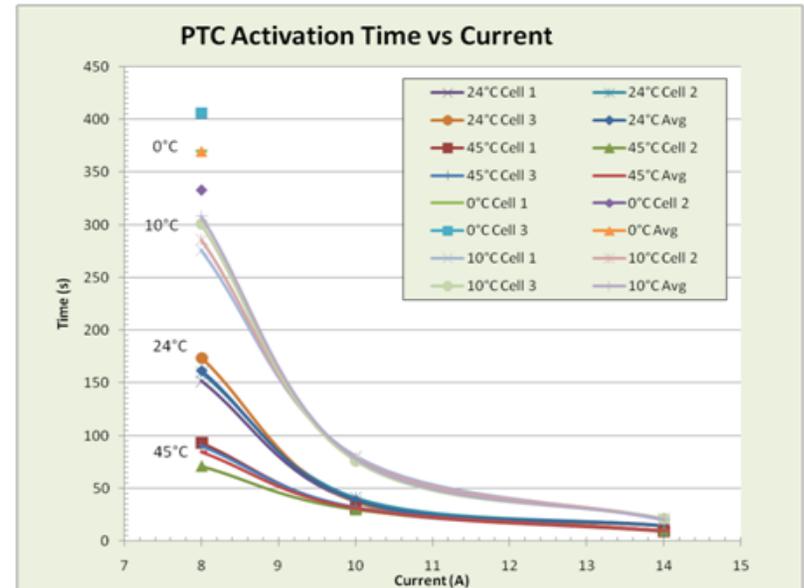


- **Cell Level:**

- PTC activation characterization completed from 0 to 45 deg C
- PTC additional testing down to -20 deg C also completed

- **Battery Level:**

- String level high current discharge testing showed safe block behavior without failure
- Short circuit tests with inrush currents up to ~300 A all show safe fault handling



18650NL Over-Discharge Testing

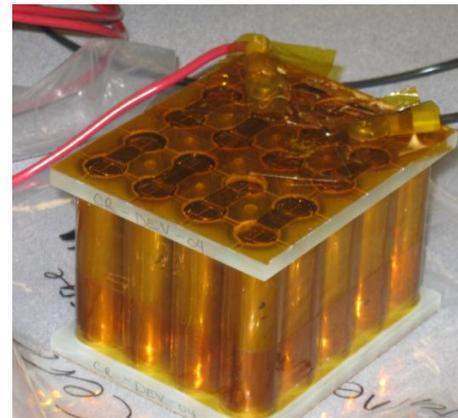
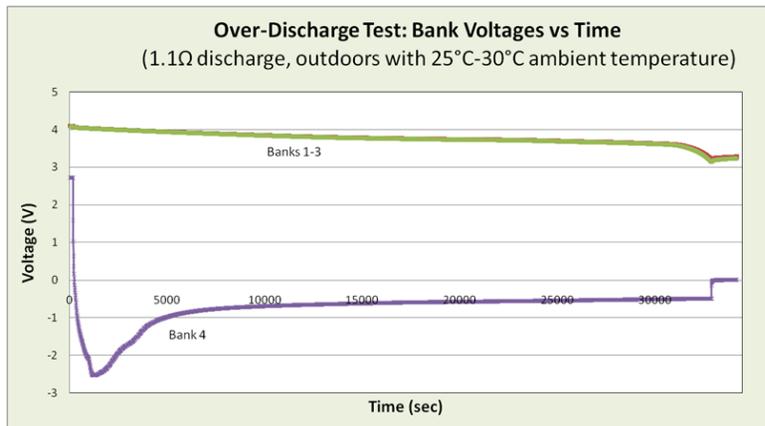


- Cell Level

- 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 deep discharged to ~28 V without event ($200V \leq \text{Battery Voltage} \leq 336V$)



18650NL Over-Charge Testing

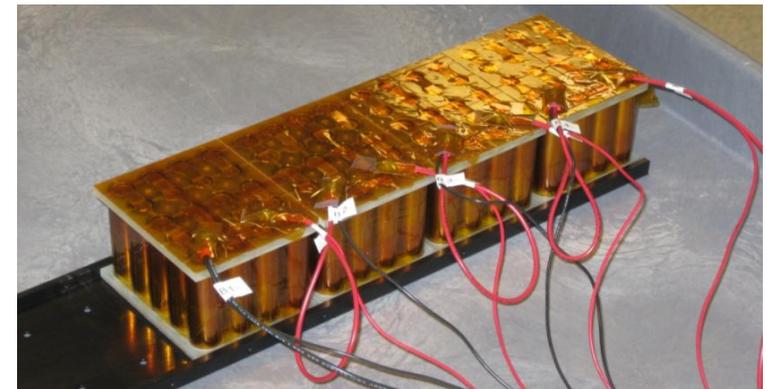
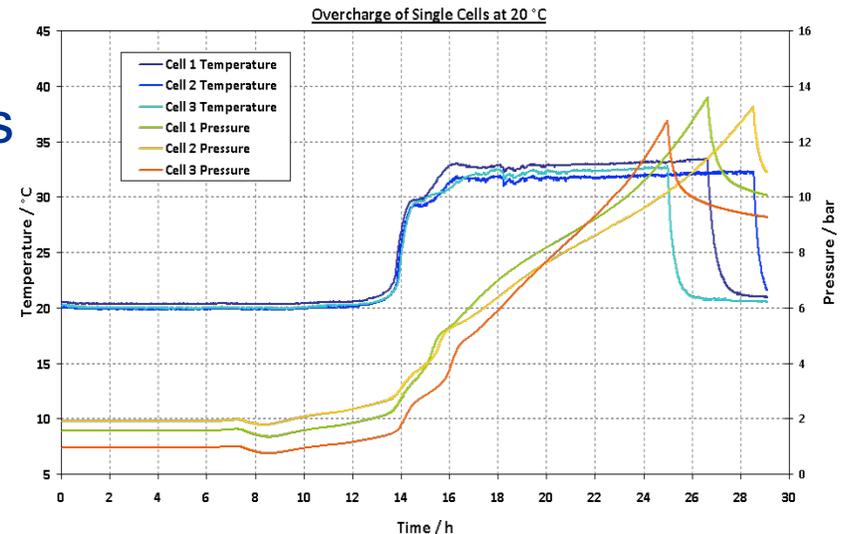


- **Cell Level**

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

- **Battery Level:**

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



Conclusions



- ABSL has completed qualification to employ NL cell in a specific spaceflight configuration.
- ABSL continues to expand the qualification program to prove the NL cell for any generic space mission.
- ABSL has built and delivered battery hardware for three programs using the ABSL 18650NL cell
- Life test data is being accrued on the ABSL 18650NL cell to support longer and longer missions; current results look very promising
- ABSL is looking for new customers to fly the 190Wh/kg cell.



ABS L would like to thank Eric Darcy and Sam Russell from NASA JSC for their support.