



Life Cycle Testing and Evaluation of Energy Storage Devices

Summer Ferreira, Wes Baca, Tom Hund and David Rose

September 28, 2012



*Exceptional
service
in the
national
interest*

The authors gratefully acknowledge the support of Dr. Imre Gyuk and the Department of Energy's Office of Electricity Delivery & Energy Reliability.



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Mission:

Provide reliable, independent, third party testing and verification of advanced energy technologies for cells to MW systems

Problem:

- Current testing methods are inconsistent and the results confusing
- Potential storage customers, i.e. utilities, without experience in storage, are reluctant consumers.

Approach:

Develop advances through:

- exploration of test protocols, through direct research and standards activities
- high precision testing

Provide ongoing:

- expertise in testing programs to customers
- verification of specific technologies

Providing reliable, independent, third party testing and verification of advanced energy technologies for cell to MW systems

Testing Capabilities Include:

Expertise to design test plans to fit technologies and their potential applications

Cell, Battery and Module Testing

- 14 channels from 36 V, 25 A to 72 V, 1000 A for battery to module-scale tests
- Over 125 channels; 0 V to 10 V, 3 A to 100+ A for cell tests
- Potentiostat/galvanostats for spectral impedance
- Multimeters, shunts and power supply for high precision testing
- Temperature chambers
- IR camera



72 V 1000 A Bitrode (2 Channels)



Energy Storage Test Pad (ESTP)

System Testing

- Scalable from 5 KW to 1 MW, 480 VAC, 3 phase
- 1 MW/1 MVAR load bank for either parallel microgrid, or series UPS operations
- Subcycle metering in feeder breakers for system identification and transient analysis

DOE Performance Protocol

- Working closely with PNNL, and have input from utility and manufacturing side



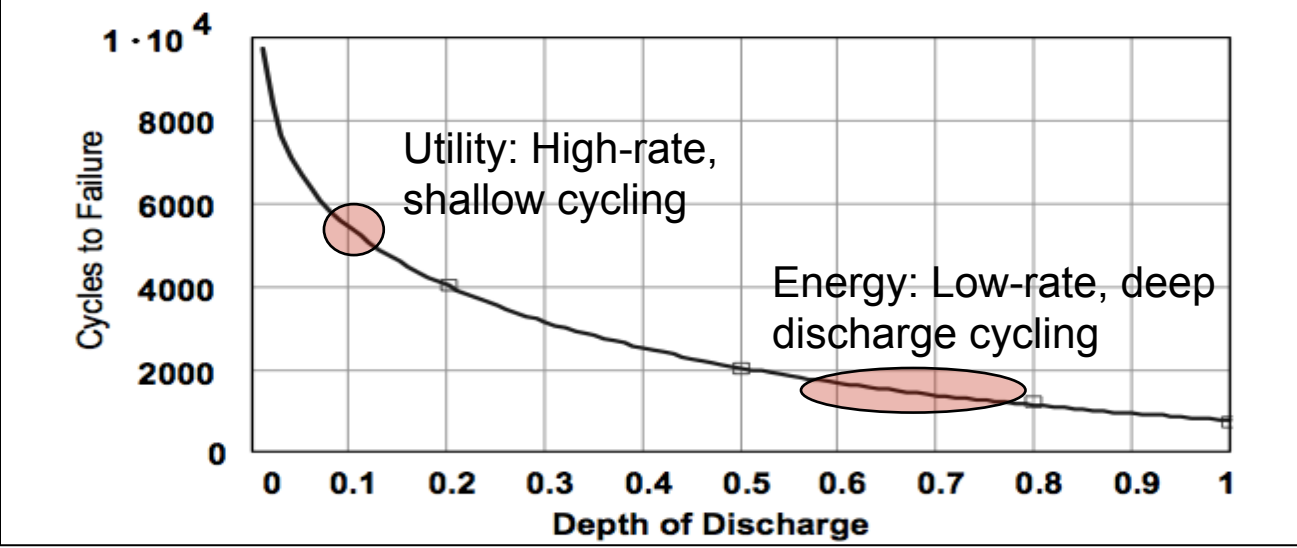
IEC

- CENELEC Workshop Agreement for Flow Batteries
- International Standard IEC 61427-2 Secondary Cells and batteries for renewable energy storage – Part 2: On-grid applications

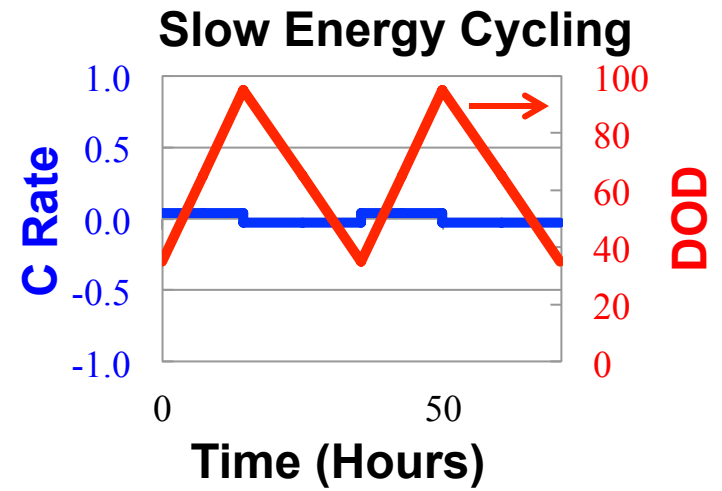
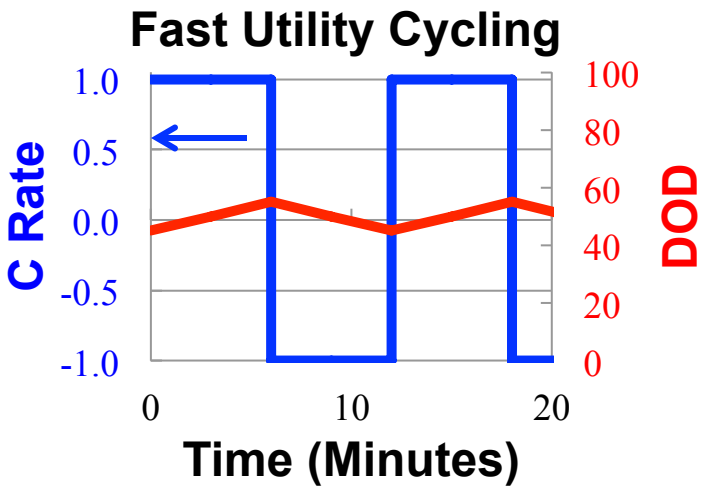


Last Peer Review saw repeated calls for standard language and testing, with definitions. In response standards development has been a large priority in the past year

Cycling protocols employed in testing

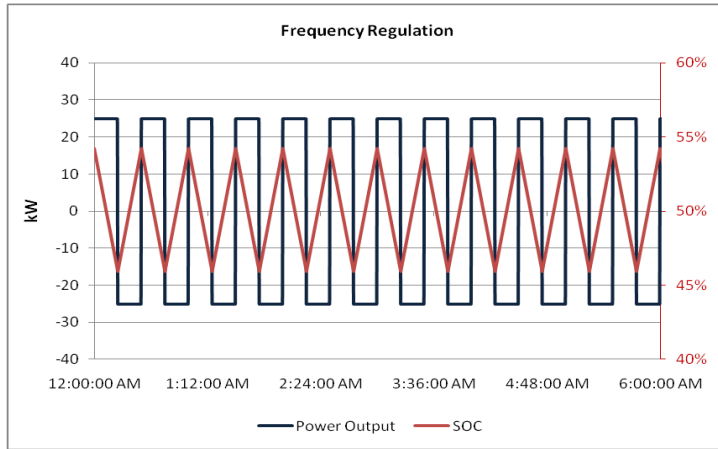


VRLA Life cycle data *S. Drouilhet, B.L. Johnson, 1997 NREL*

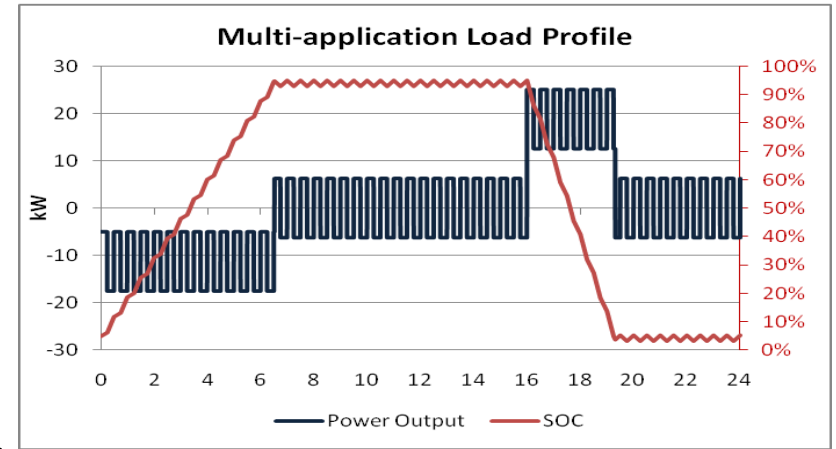


Waveform Testing

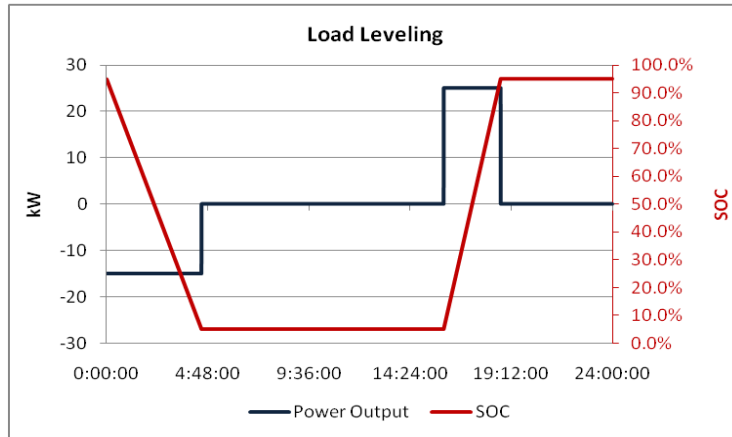
State of the Art: Frequency Regulation



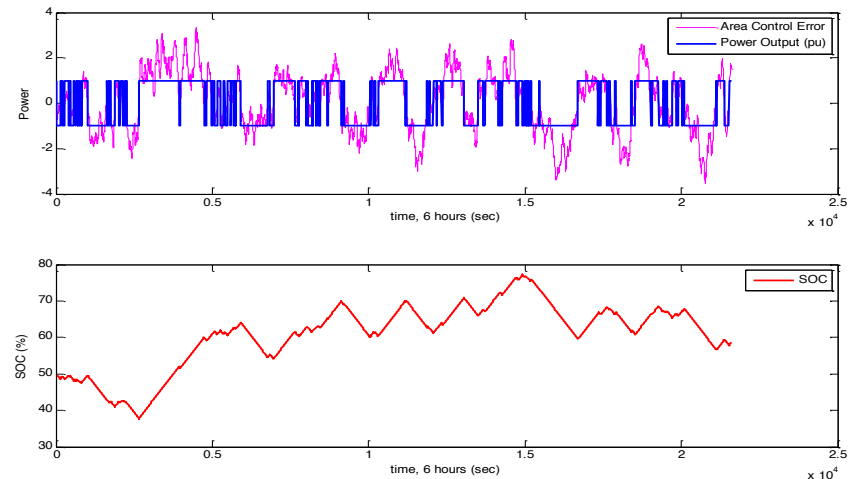
Stacked Applications: Working with KEMA



State of the Art: Load Leveling



Stochastic Application Modeling:



Future Projects

CUNY: Ni-Zn Flow battery modules August 2013



AllCell: Test Program under consideration



Encell: Testing anticipated February 2012



Altairnano: Generation II 13 Ah cells; Generation III 14 Ah



LiFe Batt: Cost share agreement for testing new generation



3rd party testing open to researchers and
manufacturers in FY 2013

Summary of completed testing activities



East Penn

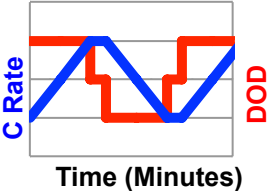
East Penn Ultrabattery® Module
20,347 5% PSOC utility cycles
422 Days and 229 PV deep discharge cycles



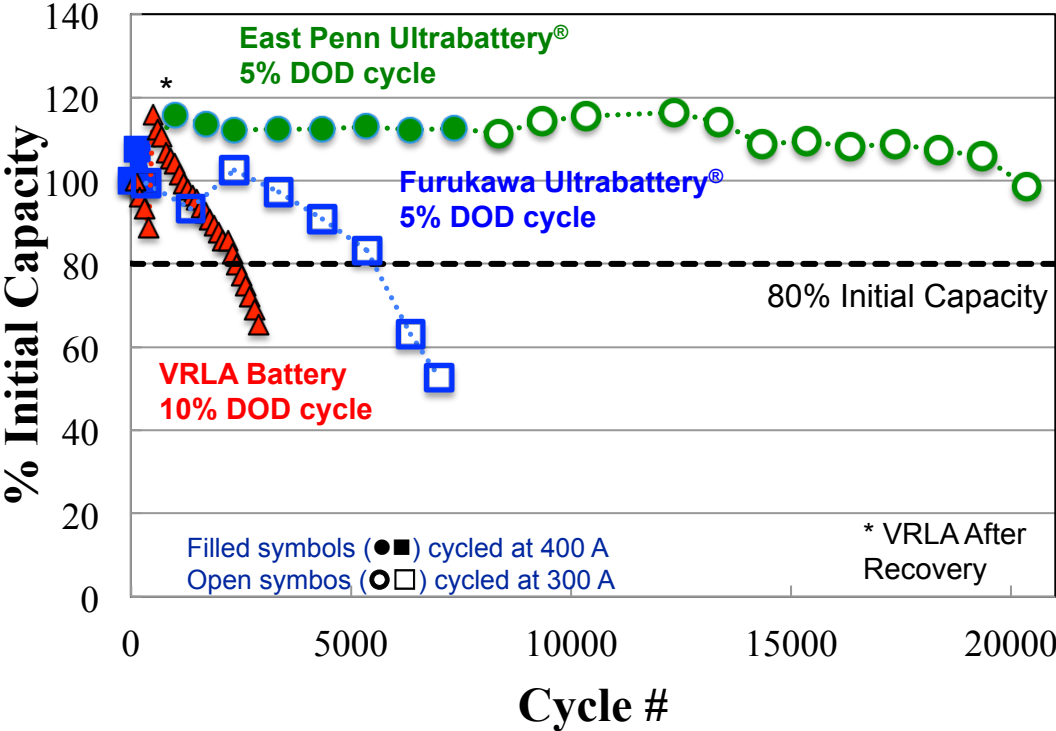
Furukawa

Furukawa Ultrabattery® Module
7,012 5% PSOC utility cycles
498 Days and 280 PV deep discharge cycles

Ultrabattery[®] performs much longer than VRLA



PSOC Utility Cycling

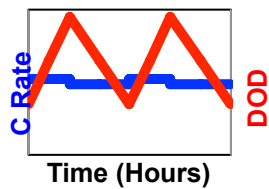
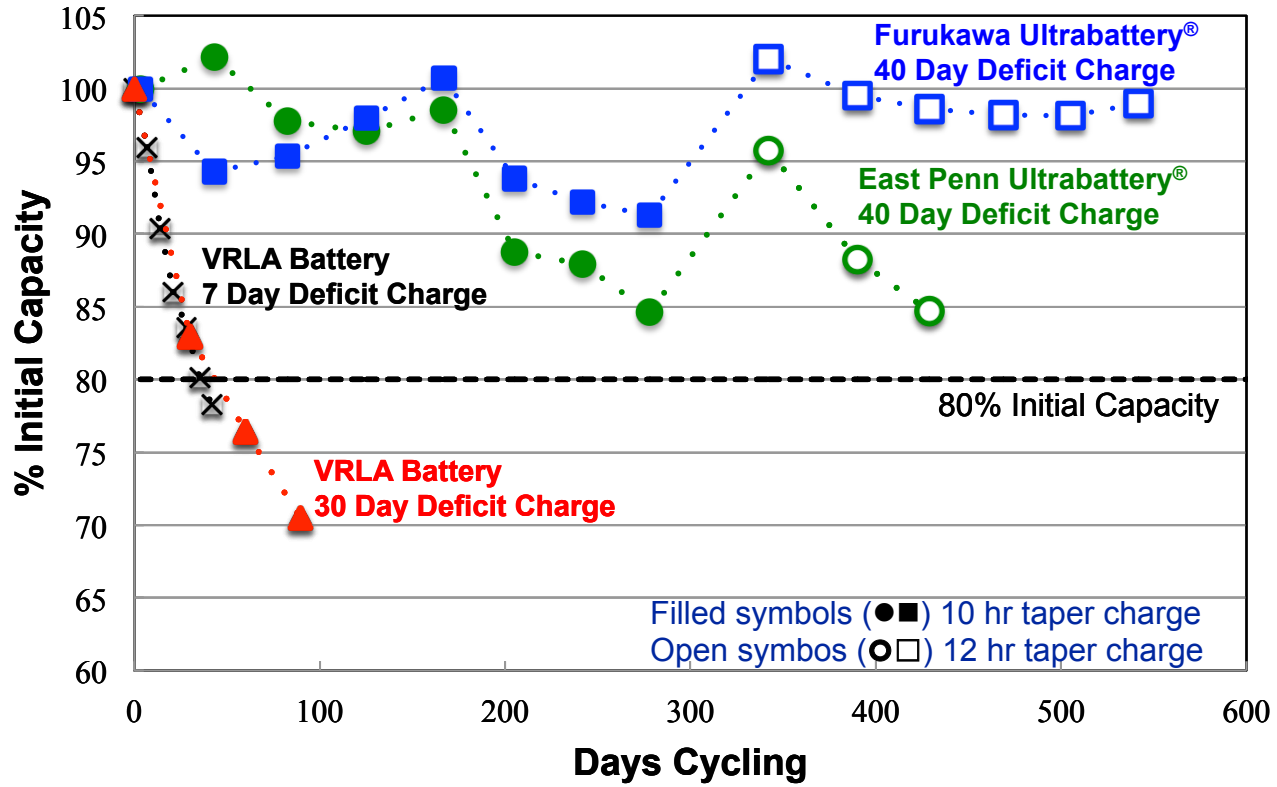


Furukawa Ultrabattery[®] operated at elevated temperatures, likely leading to thermally activated degradation

East Penn Ultrabattery[®] ran for more than 20,000 cycles without recovering the battery

Ultrabatteries[®] also perform much longer in energy applications than VRLA

PV Hybrid Cycle-Life Test



Even at 40 day deficit charge, Ultrabatteries[®] have performance far surpassing traditional VRLA batteries even with as low as a 7 day deficit charge (without recovery by taper charge).

Ongoing testing activities

Cell Level Testing



East Penn Advanced
Battery Cells
(D. Enos 10:50 AM Thur.)



A photograph of a white, rectangular battery cell with the 'altairnano' logo printed on it.

Altairnano Lithium-titanate oxide cells
40,000 10% PSOC



A photograph of a green, rectangular battery cell with terminals on top.

International Battery
Li-FePO₄ Cells
20,000+ 10% PSOC

Module Level Testing

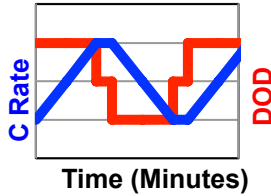
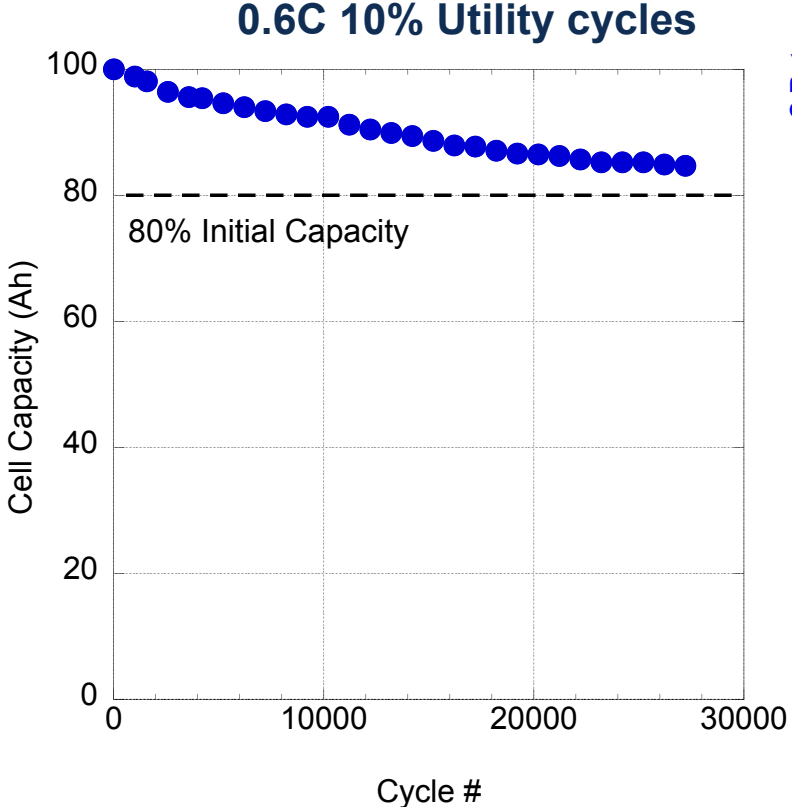


RedFlow 10kWh Zn-Br flow battery
module and system
(D. Rose)

International battery cell at 27K+ cycles



International battery Li-ion FePO₄ large format prismatic 160 Ah cells



0.6C Utility PSOC cycle
10% SOC cycles at 100 A

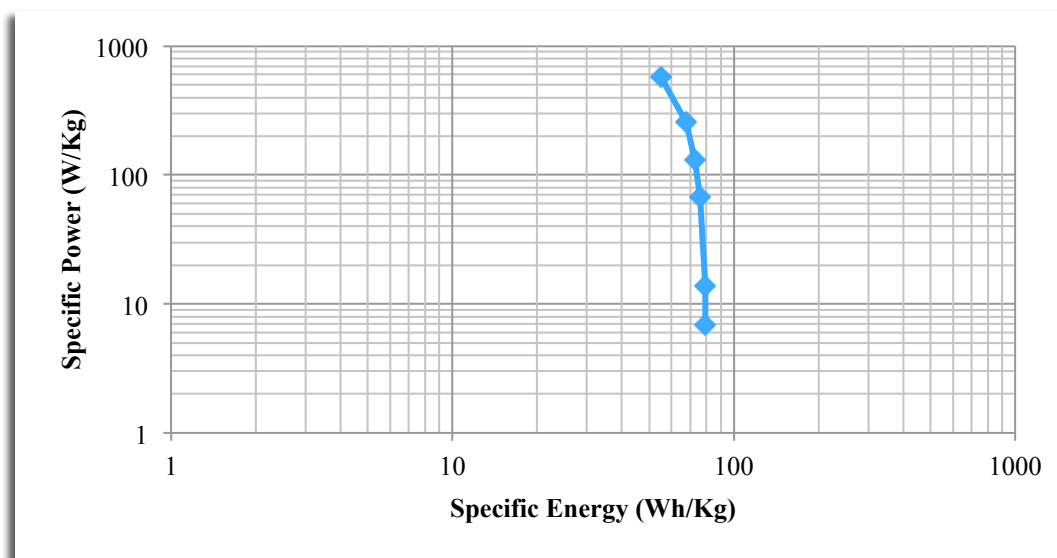
15% capacity loss after 27,000+ cycles

Altairnano Characterization

	Average	Standard Deviation
Capacity (Ah)	12.58	0.06
Voc (V)	2.531	0.006
R ($\mu\Omega$)	2642	147
Mass (kg)	0.367	0.001
3 Month Self Discharge	4.825%	0.025%

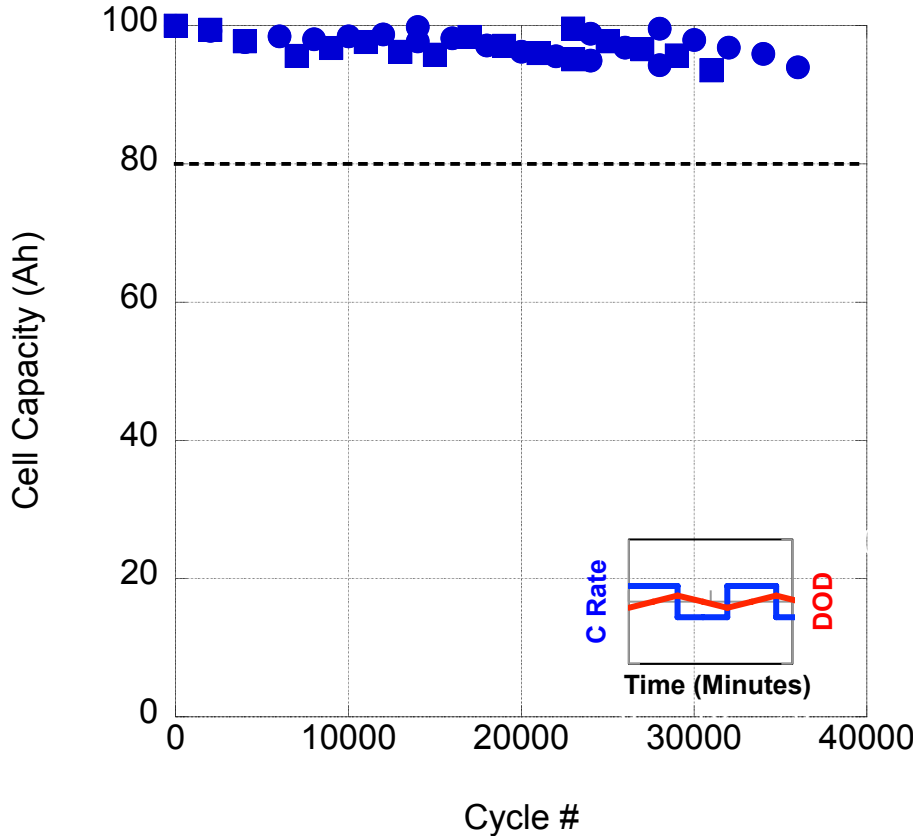


Lithium-titanate oxide cells



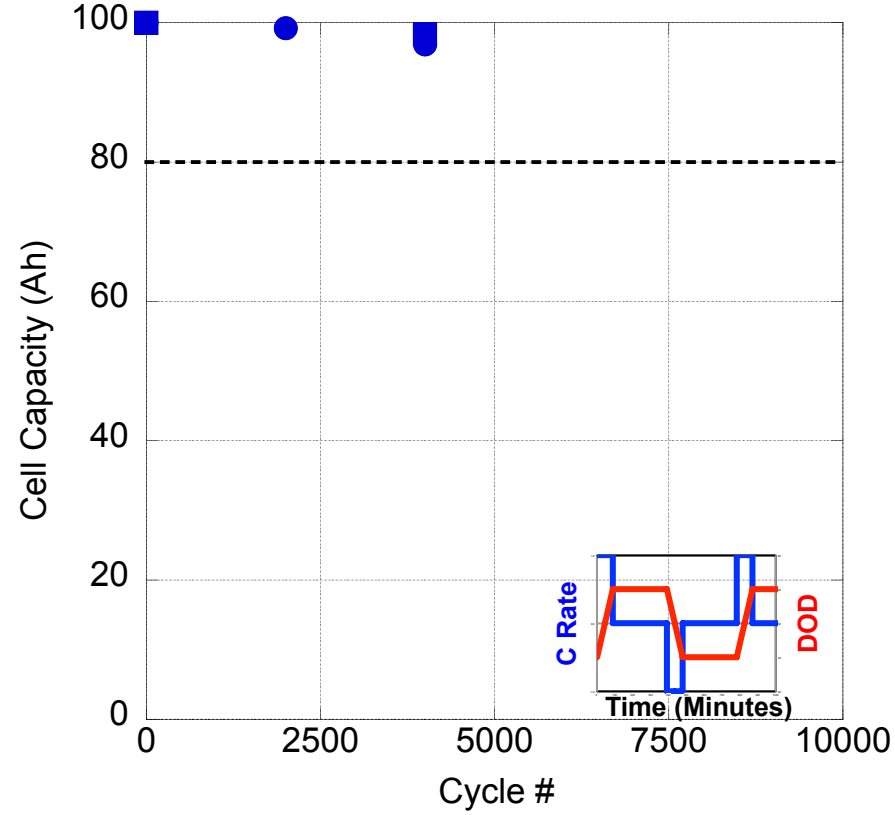
Altairnano Cycle-Life

2C 10% Utility cycles without rests



94% of initial capacity after 36K 10% PSOC utility 2C cycles without rests

4C 10% Utility cycles with rests



97.6% of initial capacity after 4,000 10% PSOC utility 4C cycles

Summary/conclusions to date

- Current advanced batteries are completing over 10,000 10% cycles with little loss in capacity, currently at over 40,000 cycles for Altairnano.
- Anticipate longer testing to reach EOL so we are exploring testing paths. More aggressive tests, and varied protocols including stacked testing under investigation.
- Participation in standards activities is becoming a priority; as we heard at last Peer Review a recurring call for standard language and testing.

Contact Information:

To take advantage of Sandia testing services or consultation:

Summer Ferreira: srferre@sandia.gov

Advanced Power Sources R&D

Manager Thomas Wunsch tfwunsc@sandia.gov

With grateful acknowledgment of Dr. Imre Gyuk for support of storage testing

