A Comparison of In-Orbit Telemetry Data vs. Software Predicted Behaviour of ABSL Lithium-Ion Battery for NASA Lunar Reconnaissance Orbiter

NASA Space Battery Workshop

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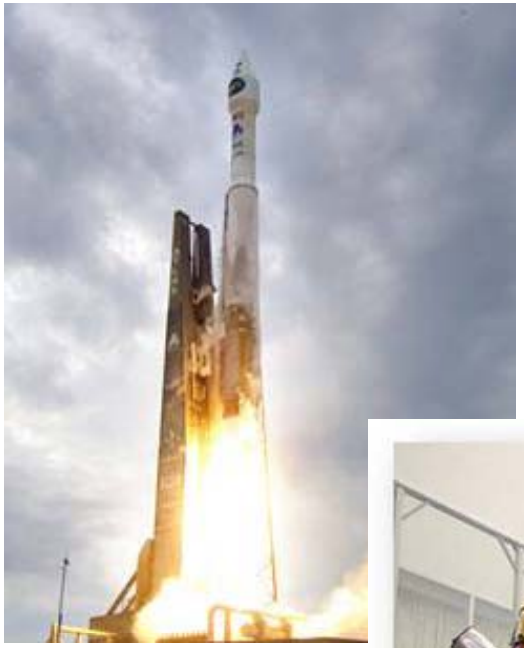
Agenda

- Objective
- LRO Mission Details
- Past Comparisons
- Software Tools
- ABSL Design Predictions
- Telemetry Data
- 2014 Prediction
- Conclusion



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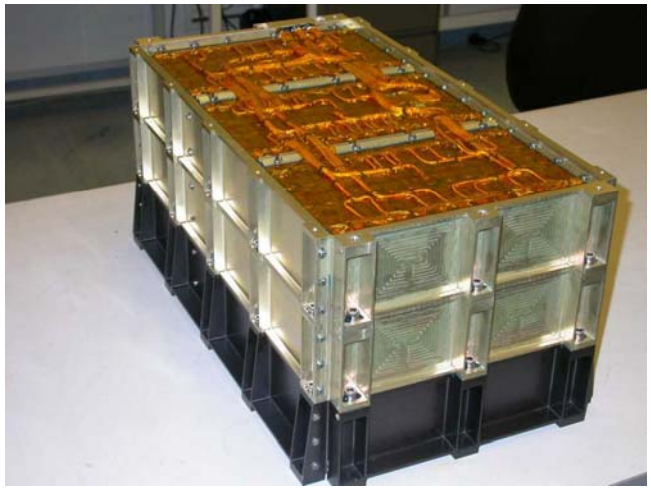
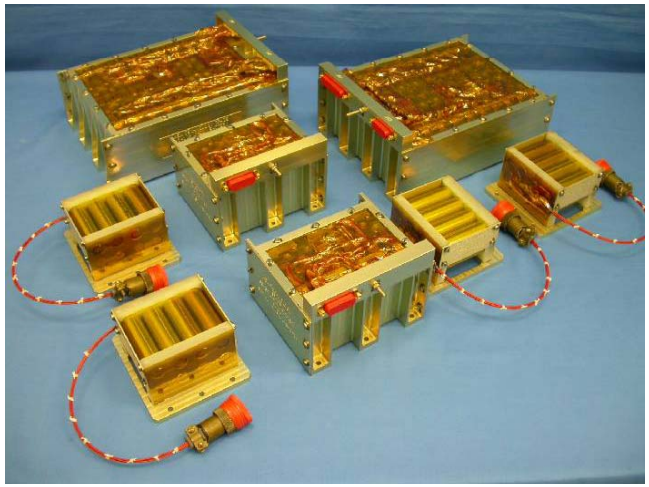
ABSL: Premier Space Li-ion Supplier

- Design, Engineering, Production, and testing Facilities in Colorado and the United Kingdom
- 70+ successfully launched spacecraft powered by ABSL Li-ion batteries
  - LEO, GEO, Interplanetary, Manned, Landers, LV
- Five ten year LEO orbit missions
- Worlds longest serving Li-ion battery in Space (PROBA) , 9 years in LEO
- > 33,000 cell years in-orbit operations without failure
- 30+ space qualified battery designs
  - 1.5Ah- 150Ah
  - 3.5V – 270V nominal voltage





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Objective

- Comparison of telemetry data vs. prediction
  - Was our prediction accurate?
  - How does battery health look compared to expectations?
  - Why is this important?
  - What does it mean for battery design?
- Validate new transient model for battery behavior
- Predict extended mission performance

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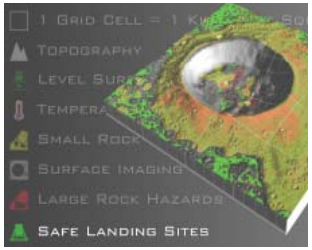
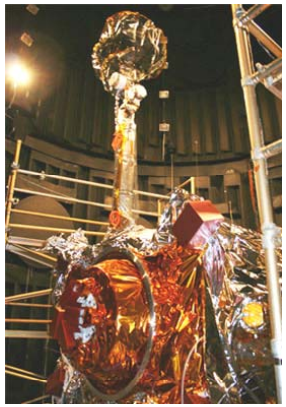
LRO Mission Overview

- **Mission**: first time back to Moon in a decade
- **Objective**: Finding safe landing sites, locate potential resources, characterize the radiation environment, and demonstrate new technology.
- **Payload**: The LRO payload, comprised of six instruments and one technology demonstration.
- **Orbit**: The spacecraft is in Lunar low polar orbit (31 miles).
- **Launch**: Launched June 18, 2009 on an Atlas V 401 rocket.
- **Battery**: 18 month specified mission life (March 2011)
- 2-4 Year discovery phase
- The mission is also carrying a secondary payload called Lunar Crater Observation and Sensing Satellite (LCROSS).





- **LRO/LCROSS Discovered water ice on Moon!**

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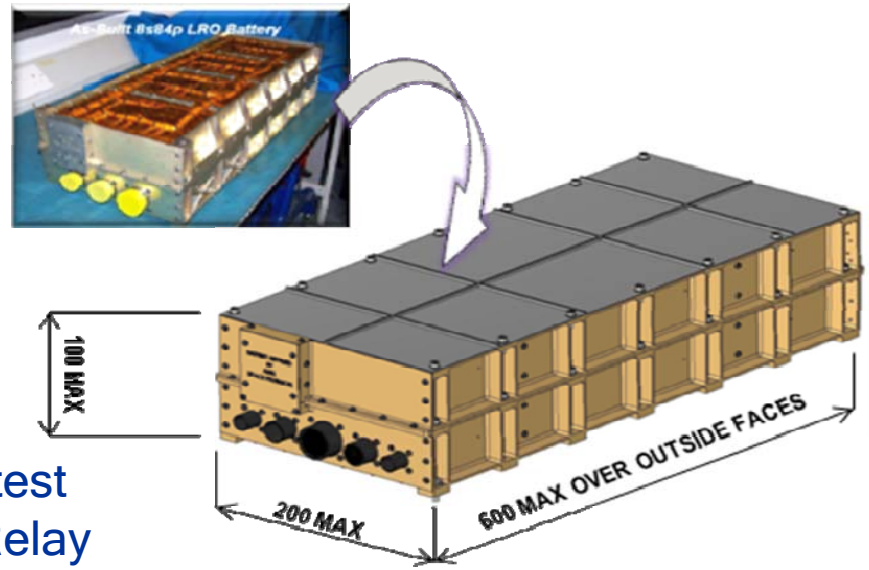
LRO Battery Design: Summary

- GSFC Capacity = 104 Ah GSFC
- Voltage Range = 24V to 33.6V
- Operating Temperature = 10 to 30 degrees C
- Survival temperature = 0 to 40 degrees C

- 672 ABSL 18650 HC Cells
- 8s x 84p
- Seven 8s12p bricks
- Mass = 35 kg
- Width = 280x680x170mm (WxLxH)



- Modular double deck modular construction
- Connector Interface: Power, Flight, ground test
- Telemetry: Battery Voltage, Temperature, Relay operation
- Integral Dual Relay Units

LRO has enabled other missions such as GPM (312 Ah system)

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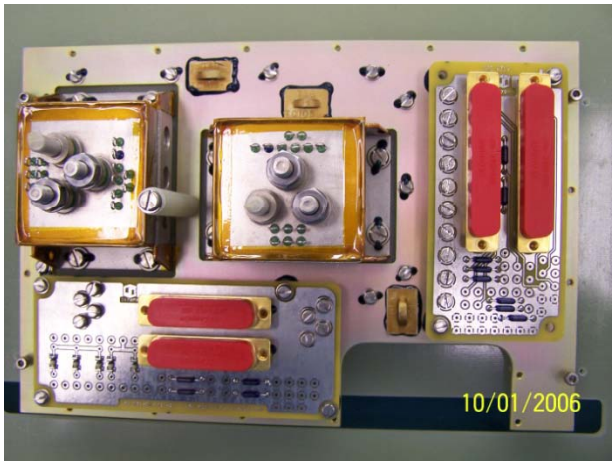
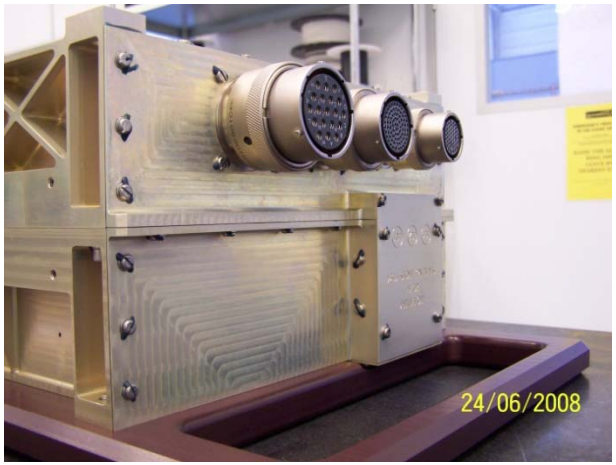
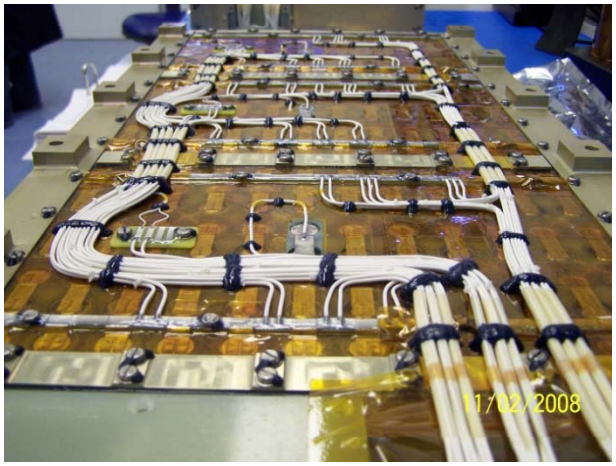
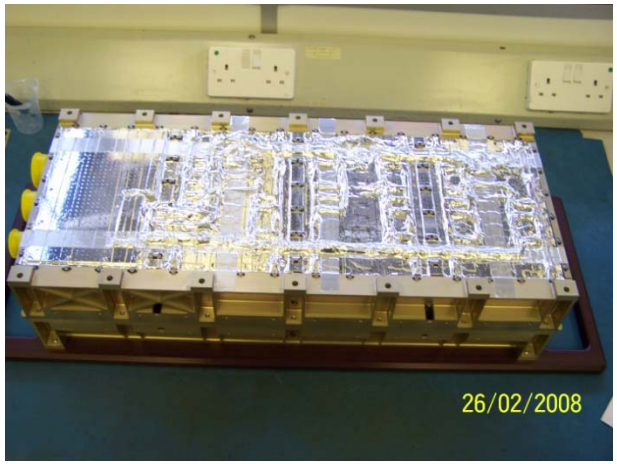
LRO Battery Design Features









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Previous Comparisons

- PROBA
  - Longest Li-ion battery in Orbit
  - launched Oct. 2001
- MEX
  - First Li-ion battery to Mars
  - Launched June 2003
- Predictions validated with in-orbit telemetry data
- Well publicized missions
  - Space Power Workshop 2003, 2005
  - European Space Power Conference, 2005
  - NASA Battery Workshop, 2006
  - IAA symposium on Small Satellites for Earth Observation, 2007
- Used predictions and in orbit correlation to verify extended mission life

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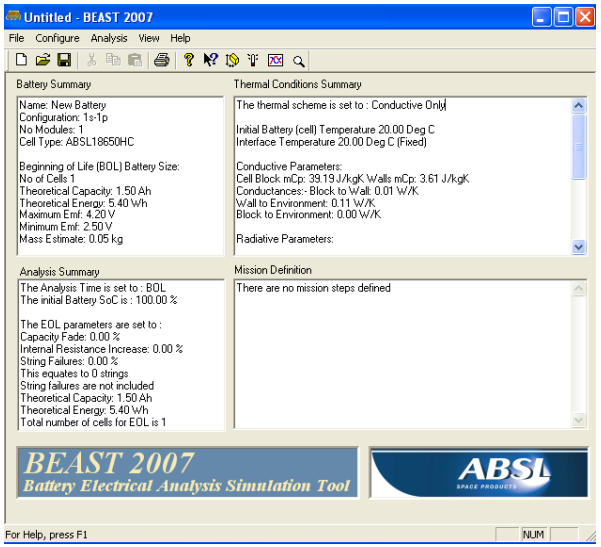
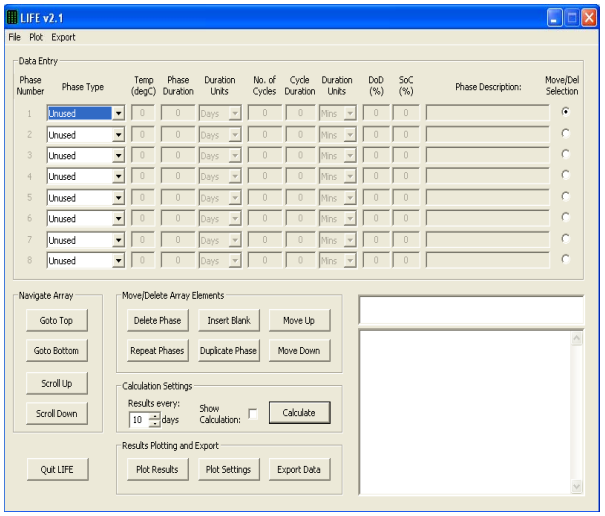
BEAST & LIFE

- Simulation tools to size battery and predict performance
- BEAST - Battery Electrical Analysis Simulation Tool
  - Short term performance
- LIFE - Lithium Ion Fade Evaluator
  - Long term battery health
- Developed with over a decade of life test data
- Validated with telemetry data





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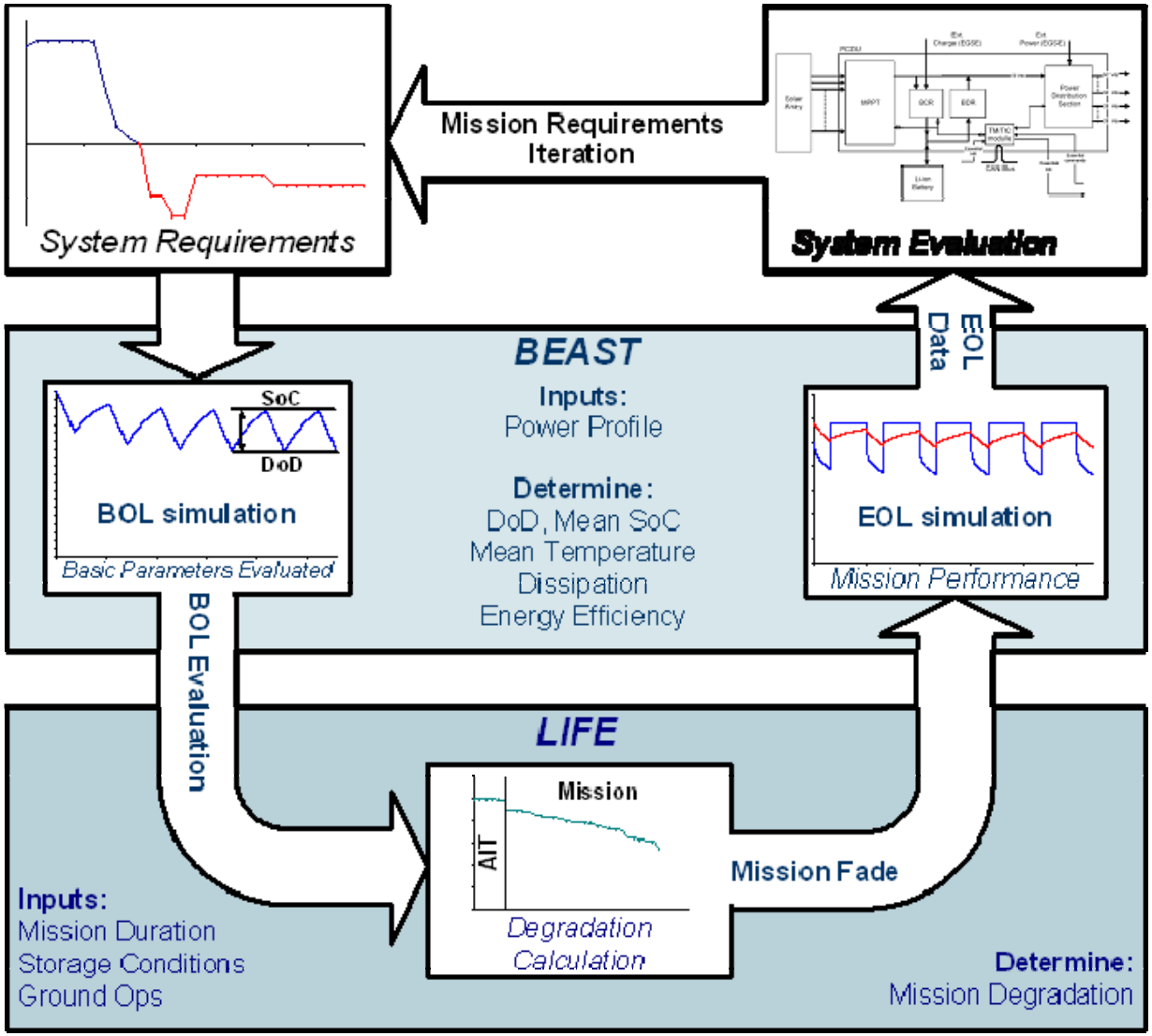
Battery Design



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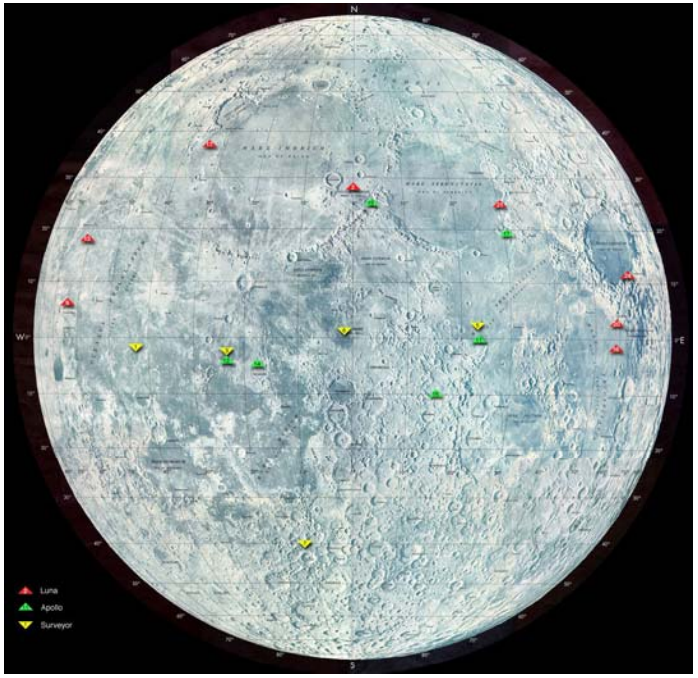
Data Correlations

- Original Predictions for BOL, EOL
- Thermal Vacuum Test
- 2009 (90 days from Launch)
- 2010 (1 year + 90 days from Launch)
- 2014 EOL Prediction



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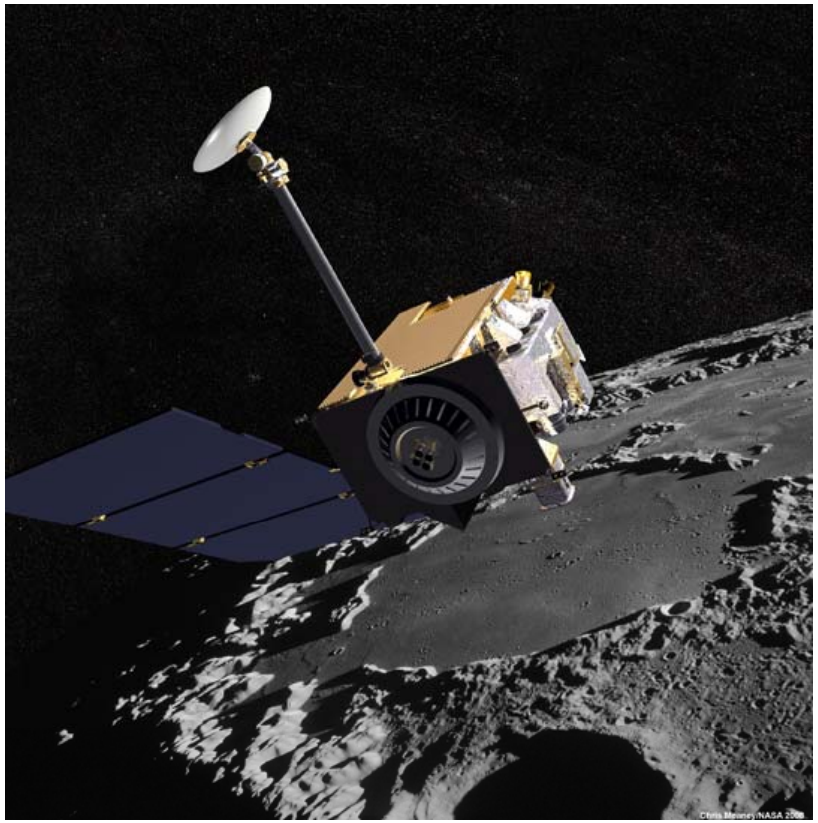
BEAST and LIFE Predictions

- Original simulation
  - Used to size battery
- 113 minute orbit
- 48 minute eclipse
- 14% DOD
- 18 month mission (6880 cycles)

- 80% DOD during lunar eclipse drives battery size
- EODV specified for only 30V
- Planned extension



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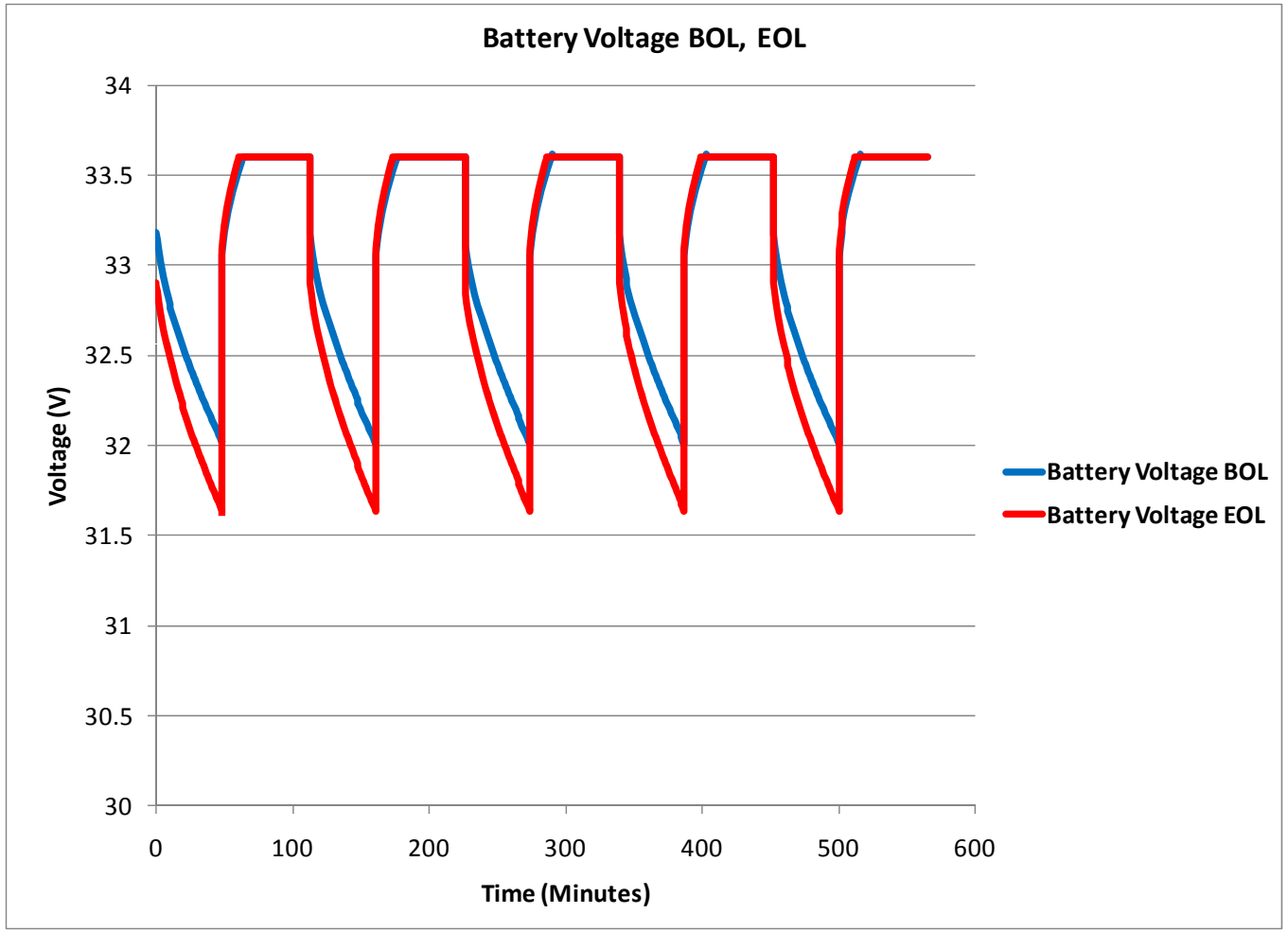
Voltage Prediction BOL, EOL



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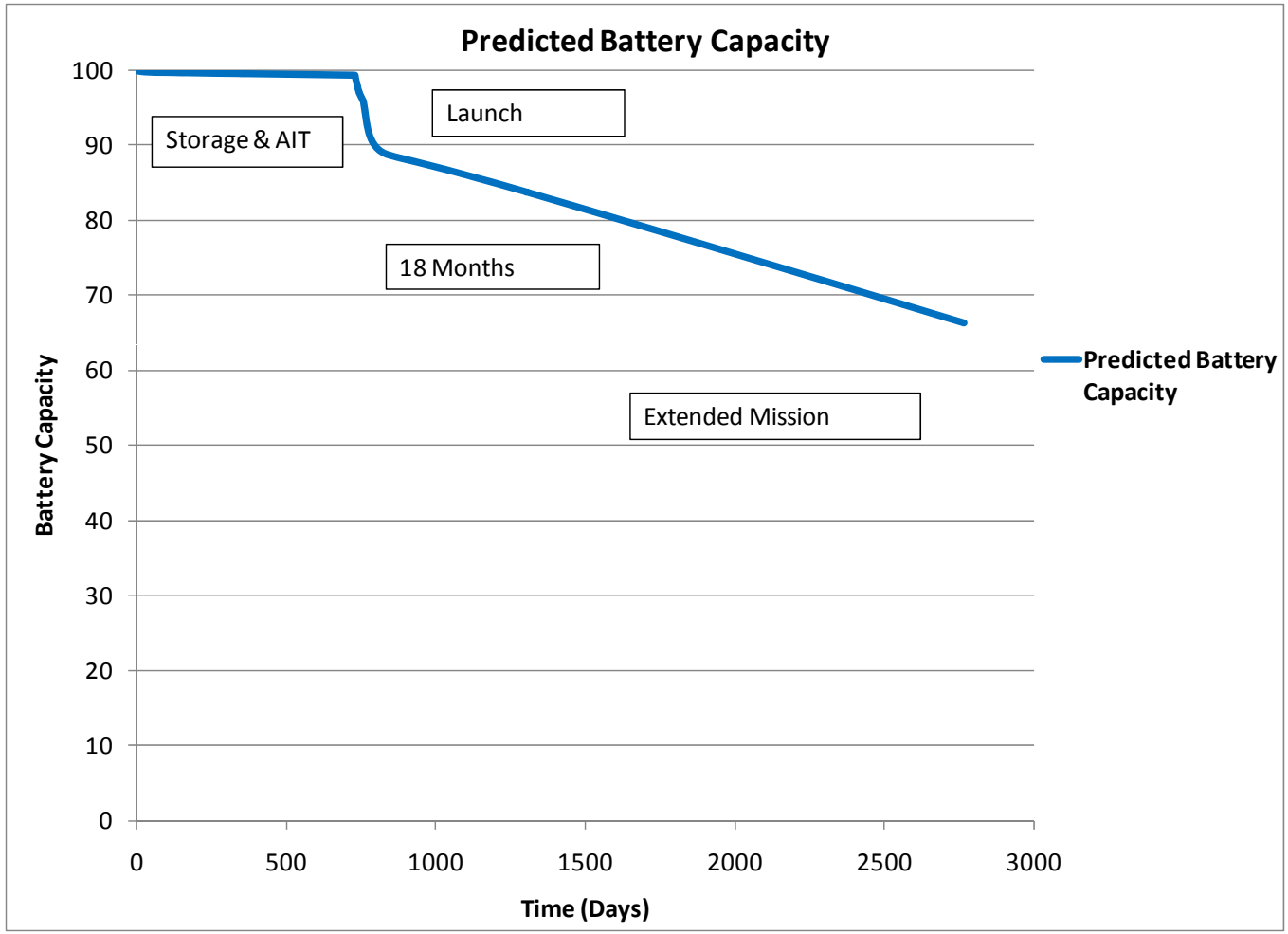
LIFE Prediction



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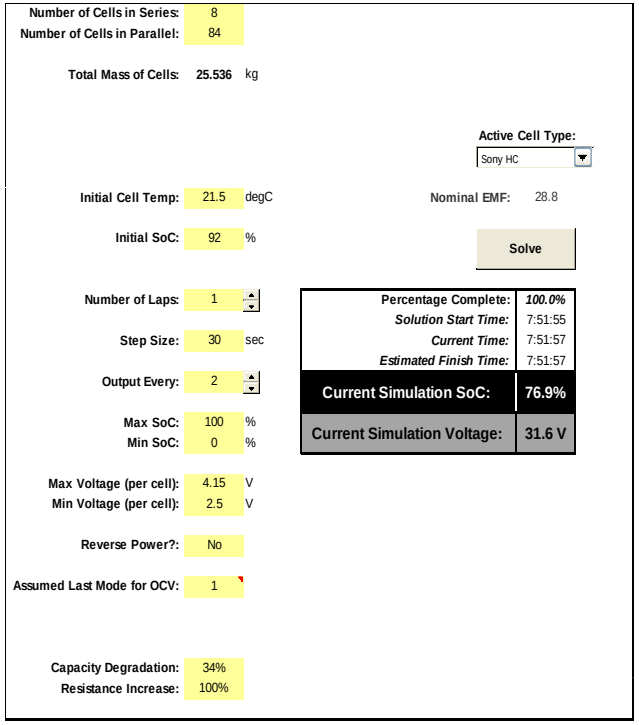
Modeling Advancements

- ABSL working in collaboration with ESA on multiple battery simulation models
- Updated with improved transient response
  - Models electrochemical properties of battery
- Updates for reduced end of charge voltage
- More accurate BEAST and LIFE predictions



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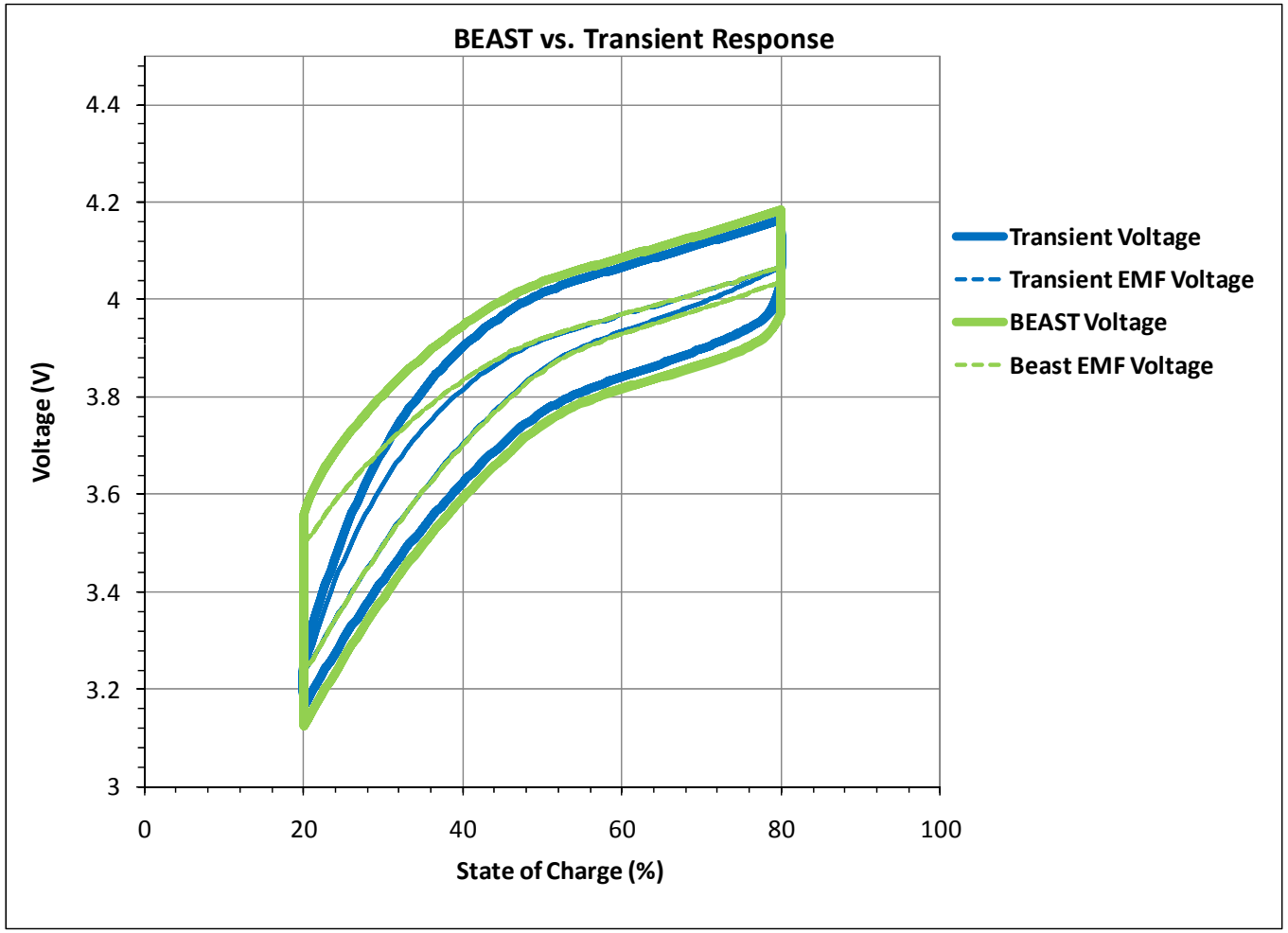
BEAST vs. Transient Response



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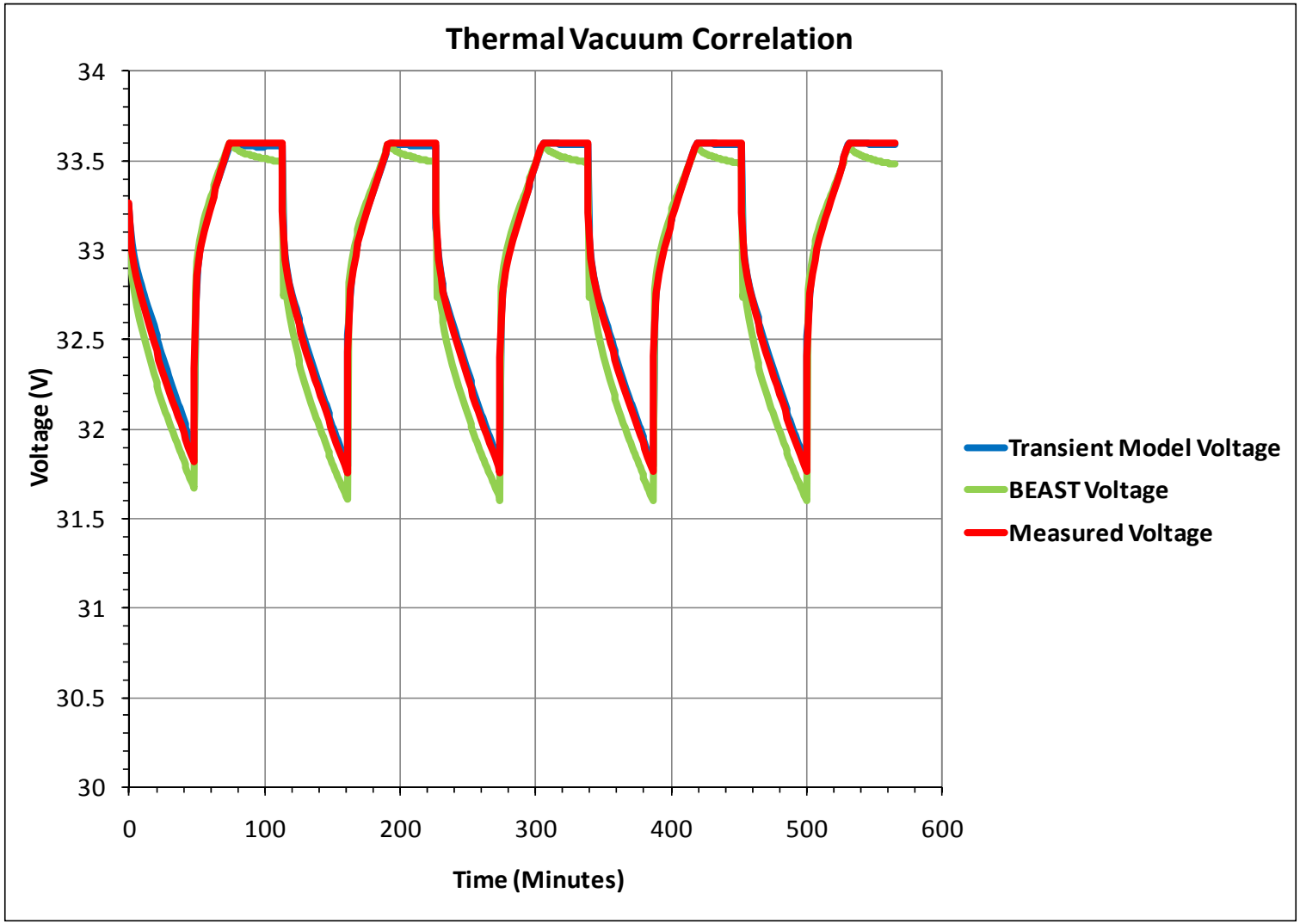
Thermal Vacuum Data



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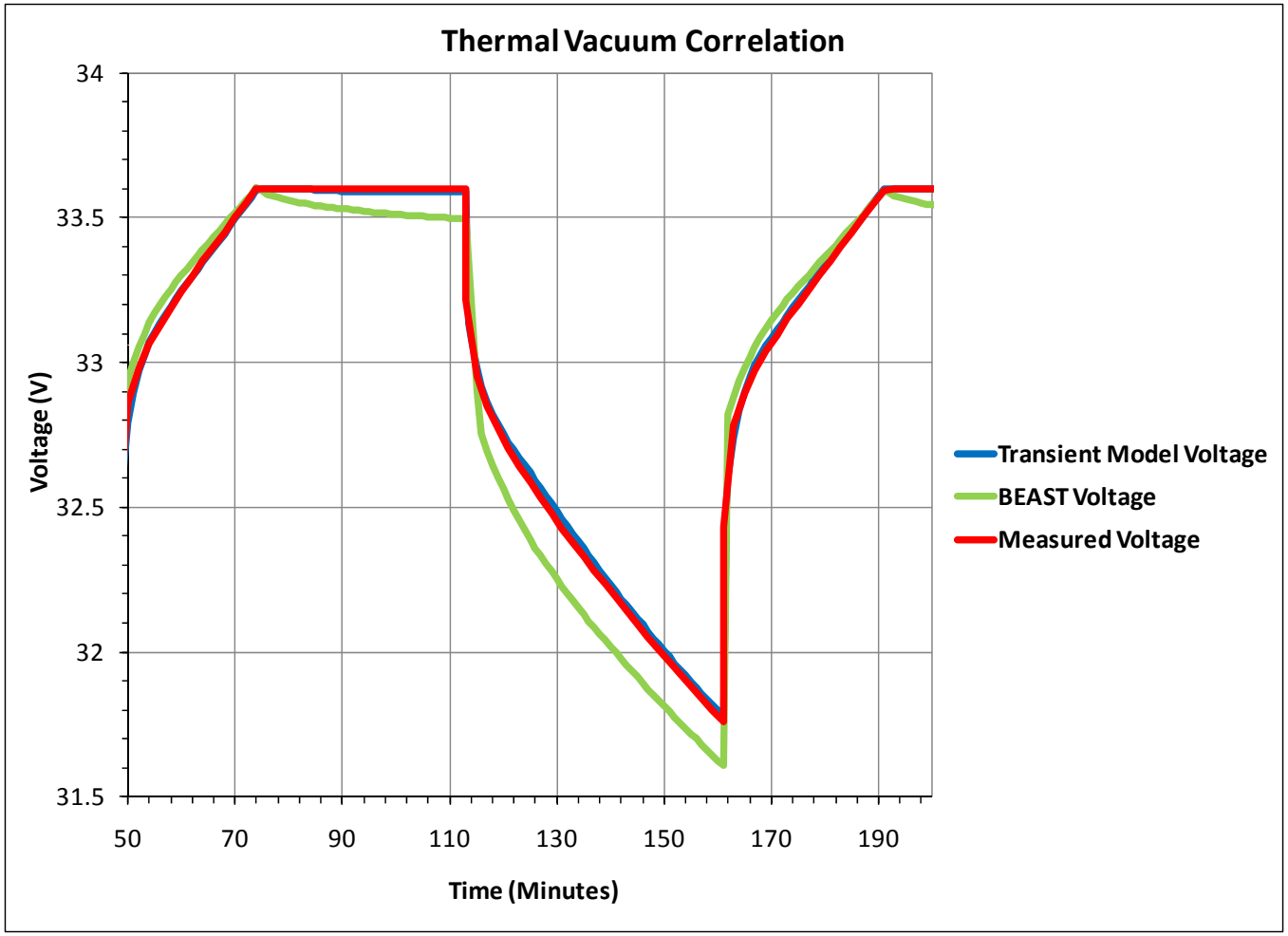
Zoom View



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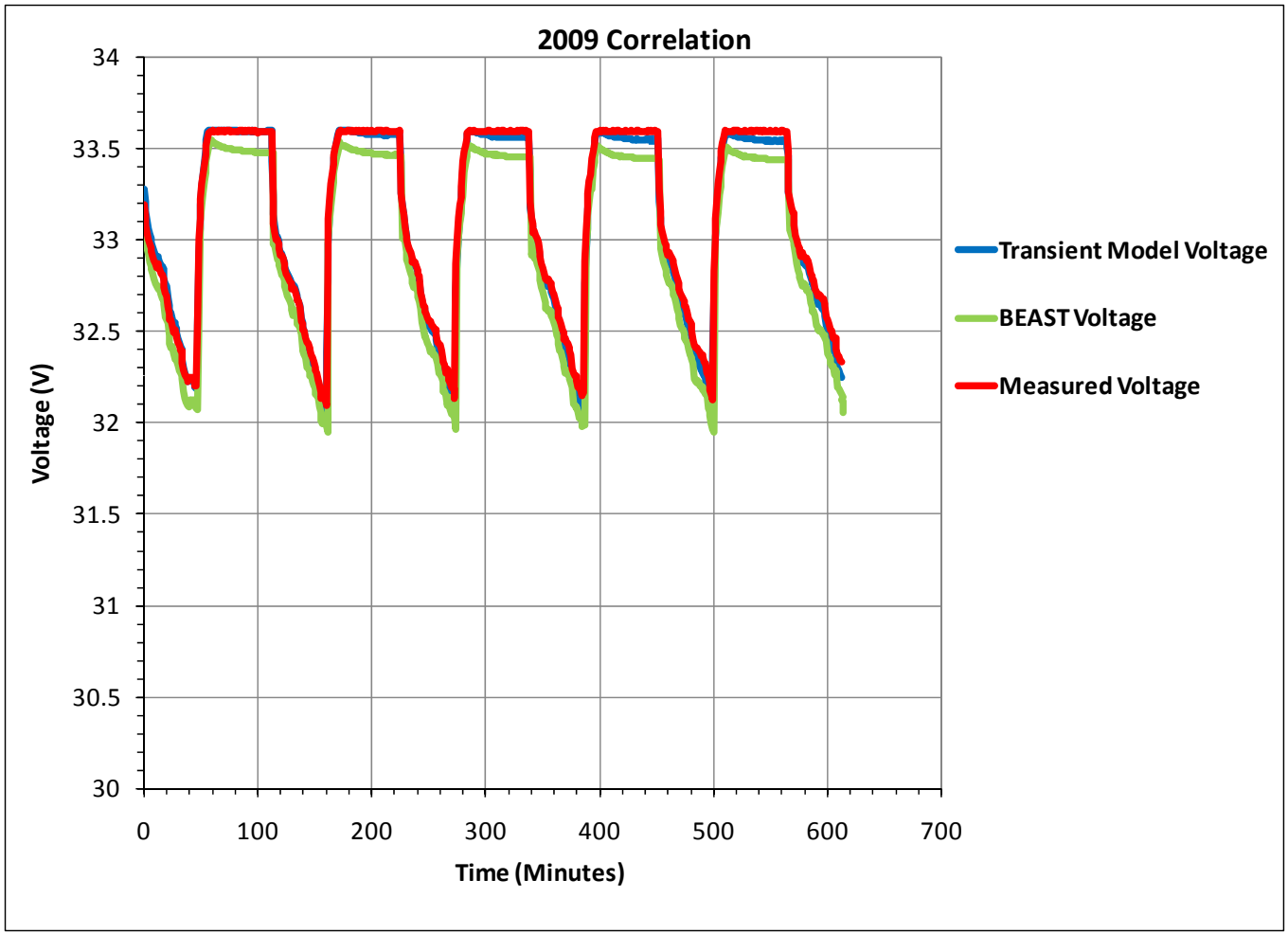
2009 Telemetry Data



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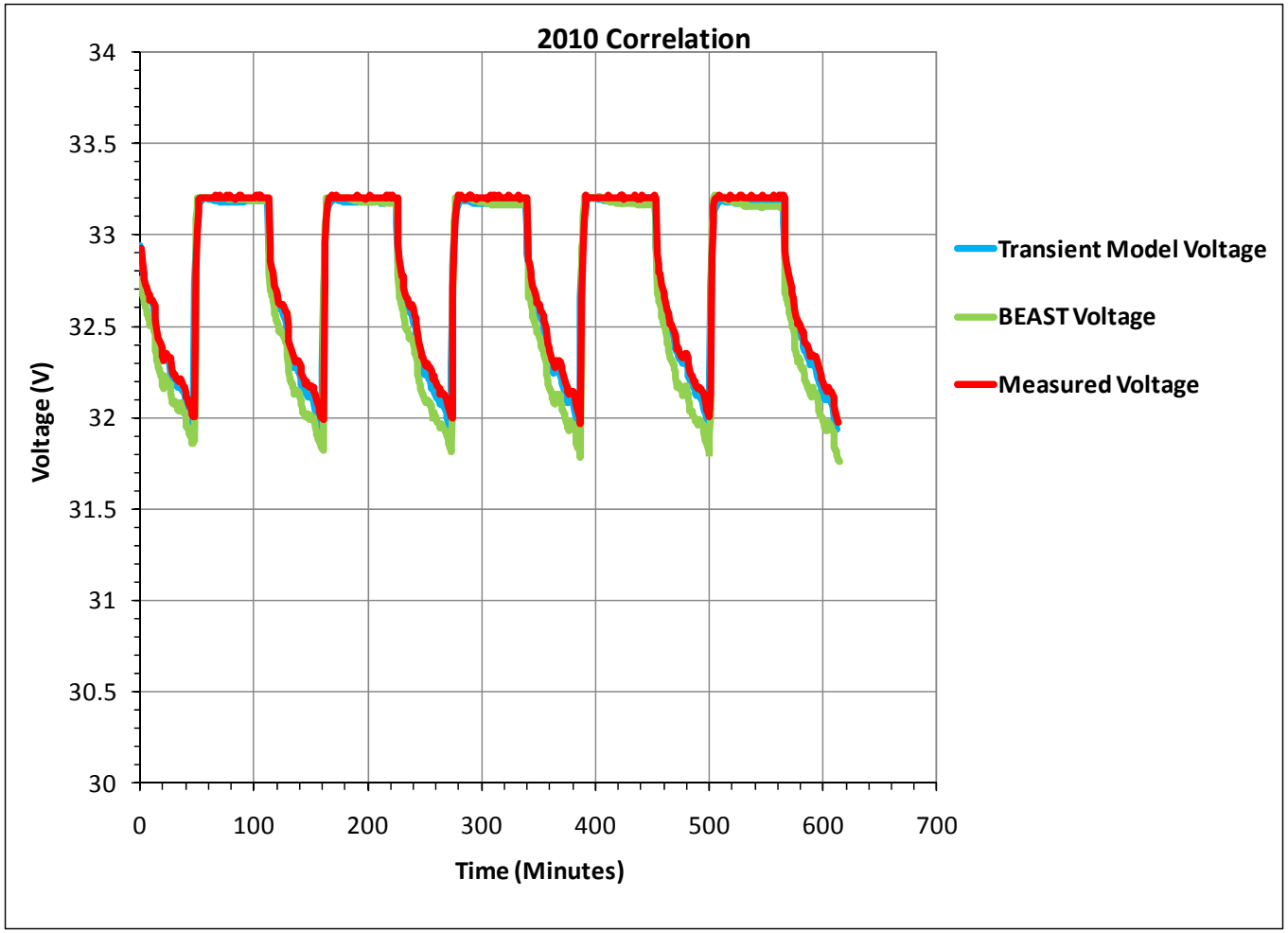
2010 Telemetry Data



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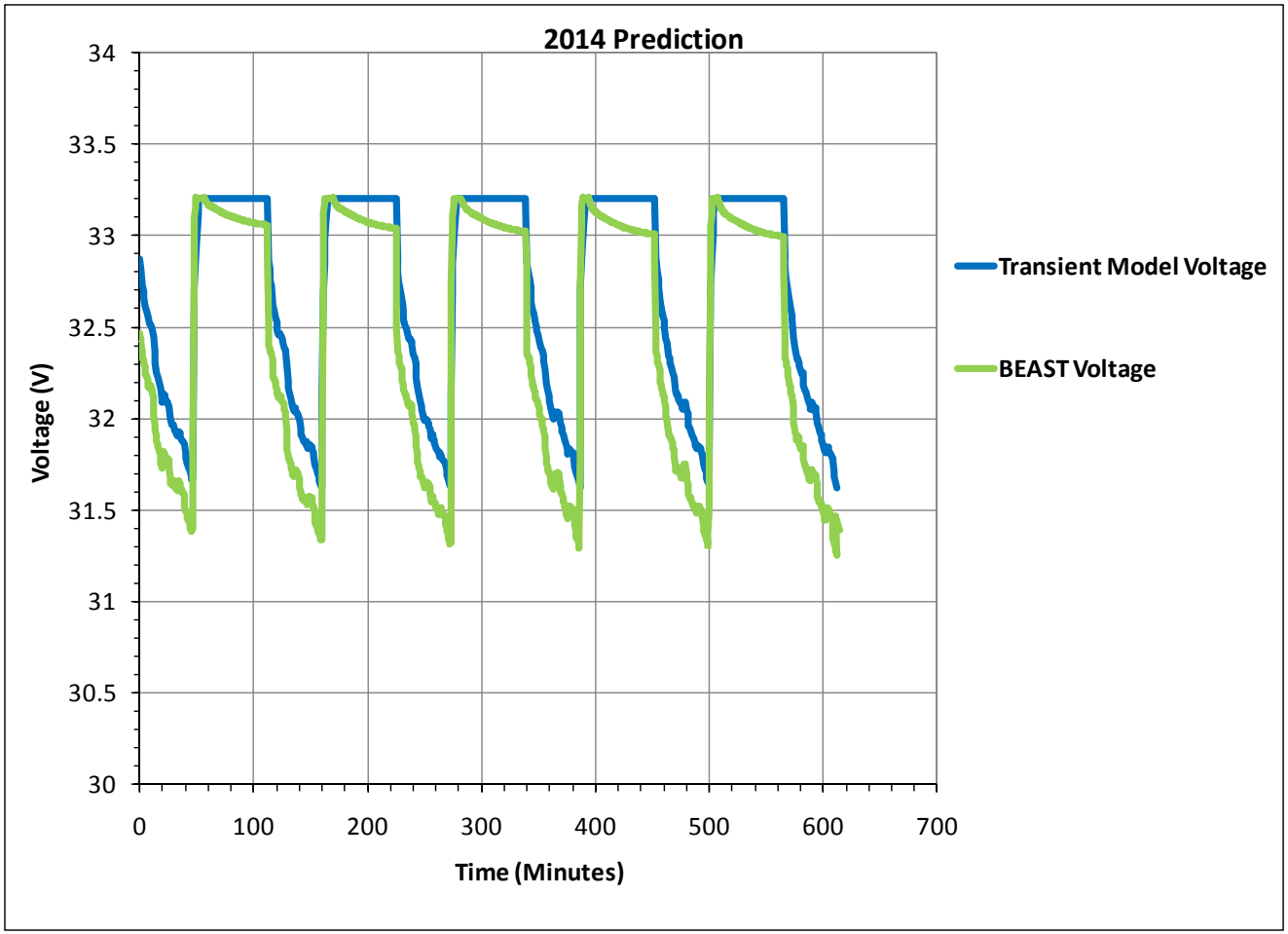
2014 EOL Prediction



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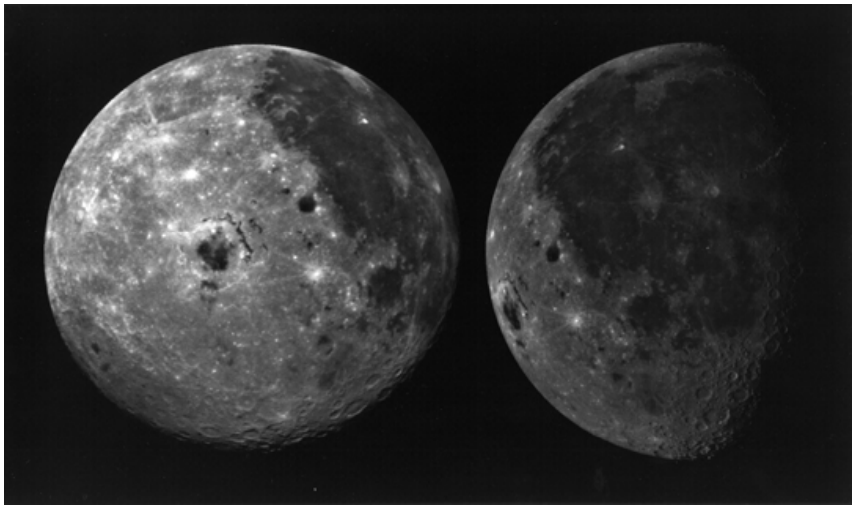
Conclusions

- ABSL's BEAST and LIFE software can create detailed performance predictions throughout mission life
- Telemetry data correlate well with predicted battery behavior
- ABSL continues to refine modeling software for better accuracy
- Transient models more accurately predict battery behavior



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Conclusions, cont.

- Greater modeling accuracy allows for…
  - Proving the ability to extend missions
  - Optimize battery size, footprint and mass
  - Optimize battery performance
  - Planning and training to deal with system level anomalies
  - Less design contingency requirements

- ABSL Proven Li-ion battery supplier for high performance batteries
- ABSL space qualified batteries capable of many years of mission life

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Acknowledgements

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- Carl Thwaite, Dave Curzon, ABSL Ltd.

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