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Technologies, LLC
A VECTRA Company

Updates of the Next Generation Lithium-ion Space Chemistry, for improved Energy density and Improved Cycle Life

NASA Space Battery Workshop
Huntsville, AL
November 15th, 2016

E. Alex Buonanno

EaglePicher™ Technologies, LLC
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Next Generation Lithium-ion Prismatic Cells

NCP12-4 Cell

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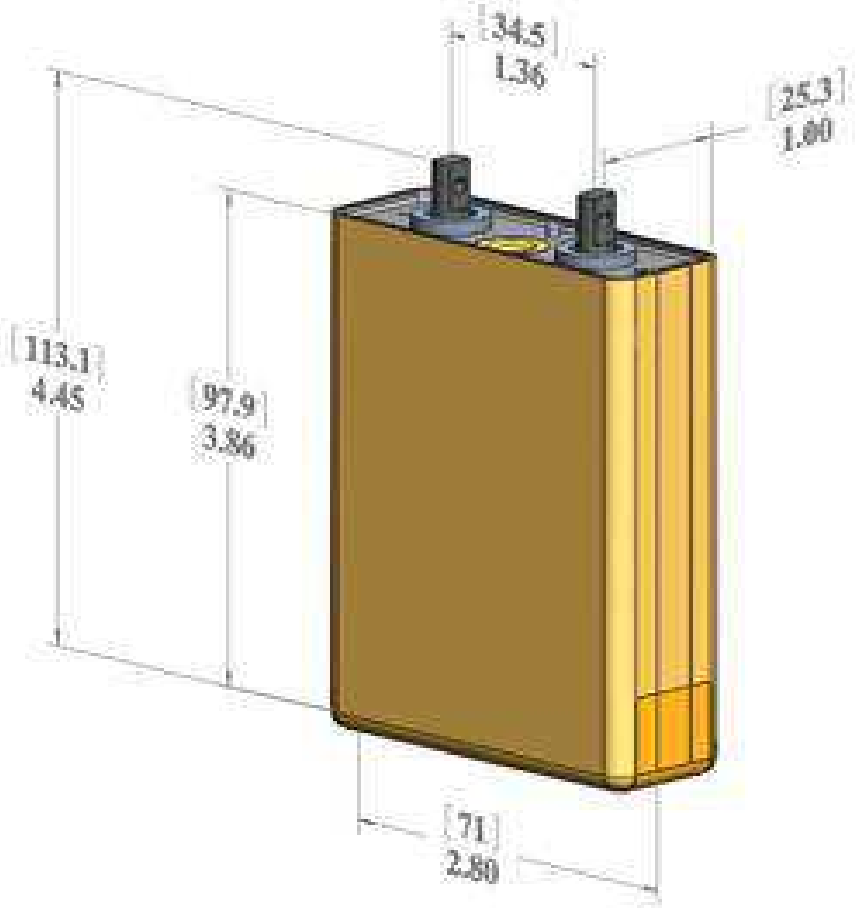
- NCP12-4 Design
  - NCA/Synthetic Graphite
  - 14.5 Ah BOL
  - 12 Ah Nameplate
- Physical Properties:
  - 456 grams
  - 4.45” Tall x 2.8” Wide x 1.0” Thick



NCP12-2 Flight Heritage: X-37B Space Plane

NCP43-4 Cell

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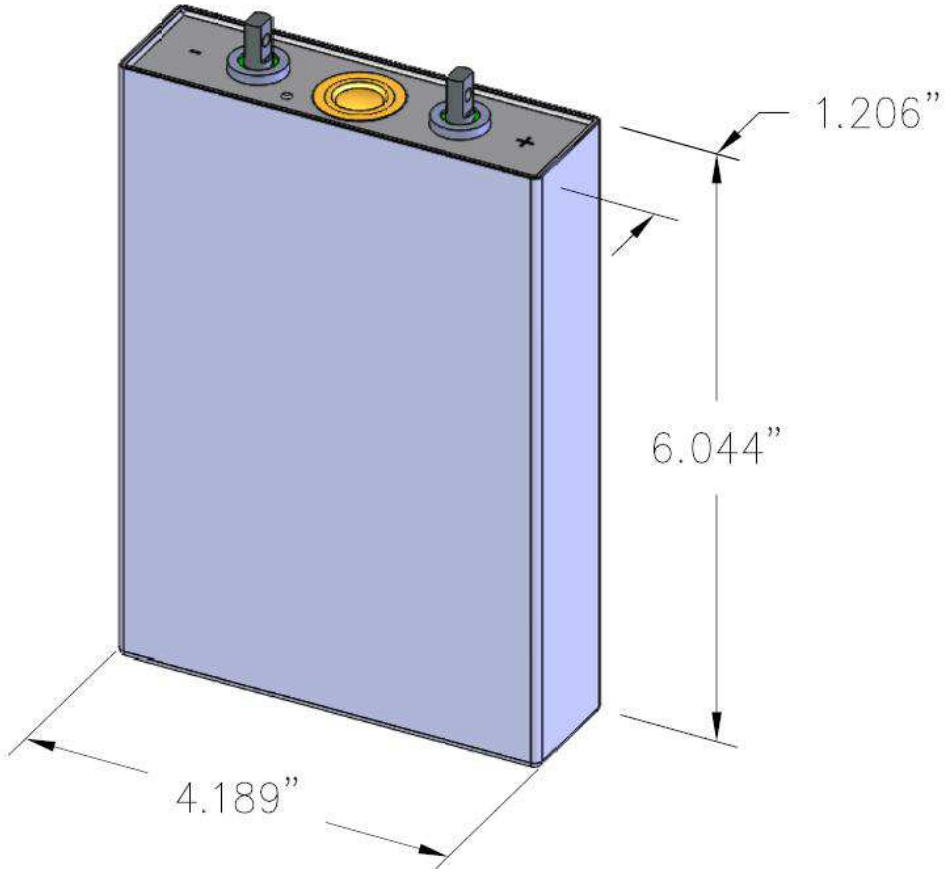
- NCP43-4 Design
  - NCA/Synthetic Graphite
  - 47 Ah BOL
  - 43 Ah Nameplate
- Physical Properties:
  - 1283 grams
  - 6.0” Tall x 4.2” Wide x 1.2” Thick



NCP43-2 Flight Heritage: ASTRO (Orbital Express), X-37B Space Plane

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NCP12-2 vs. NCP12-4

BOL Test; Discharge Capacity

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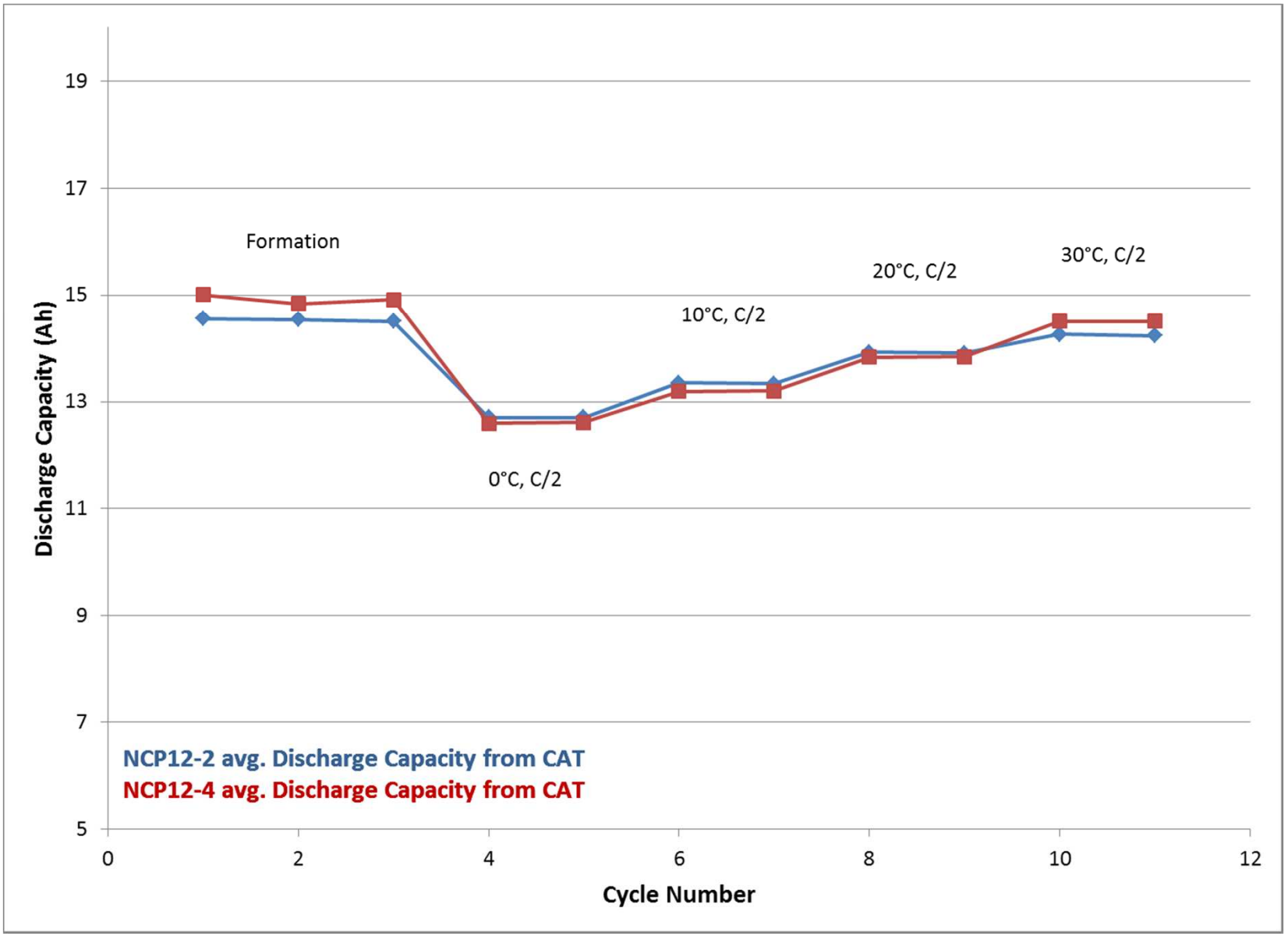

BOL Test; 20°C DC Resistance

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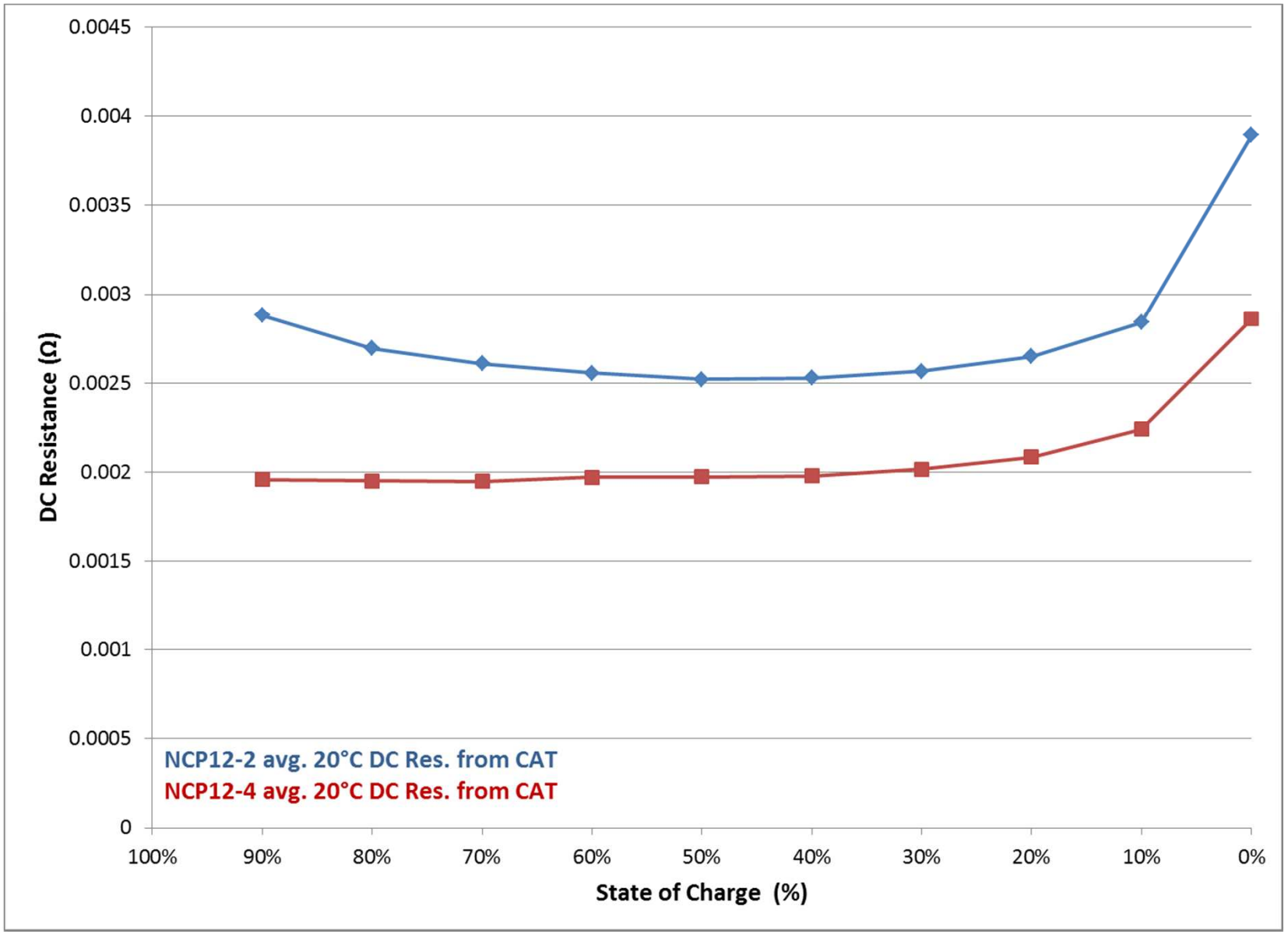

12Ah Life Cycling @30°C

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- The NCA chemistry NCP12-4 cells were placed on life cycling per LiTP-6245 that was previously run on the NCP12-2 NCO chemistry cells.
  - Per para. 5.1 Real-time life cycling at 30°C
    - 4320 cycles per round
      - 2.4 amp charge to 4.1Vdc, tapering for a total time of 55 min
      - 13 amp discharge for 4.5 min
      - Open Circuit rest for 30.5 min
    - Capacity and DC Resistance
      - Every 1000 Cycles

End-of-Discharge Voltage

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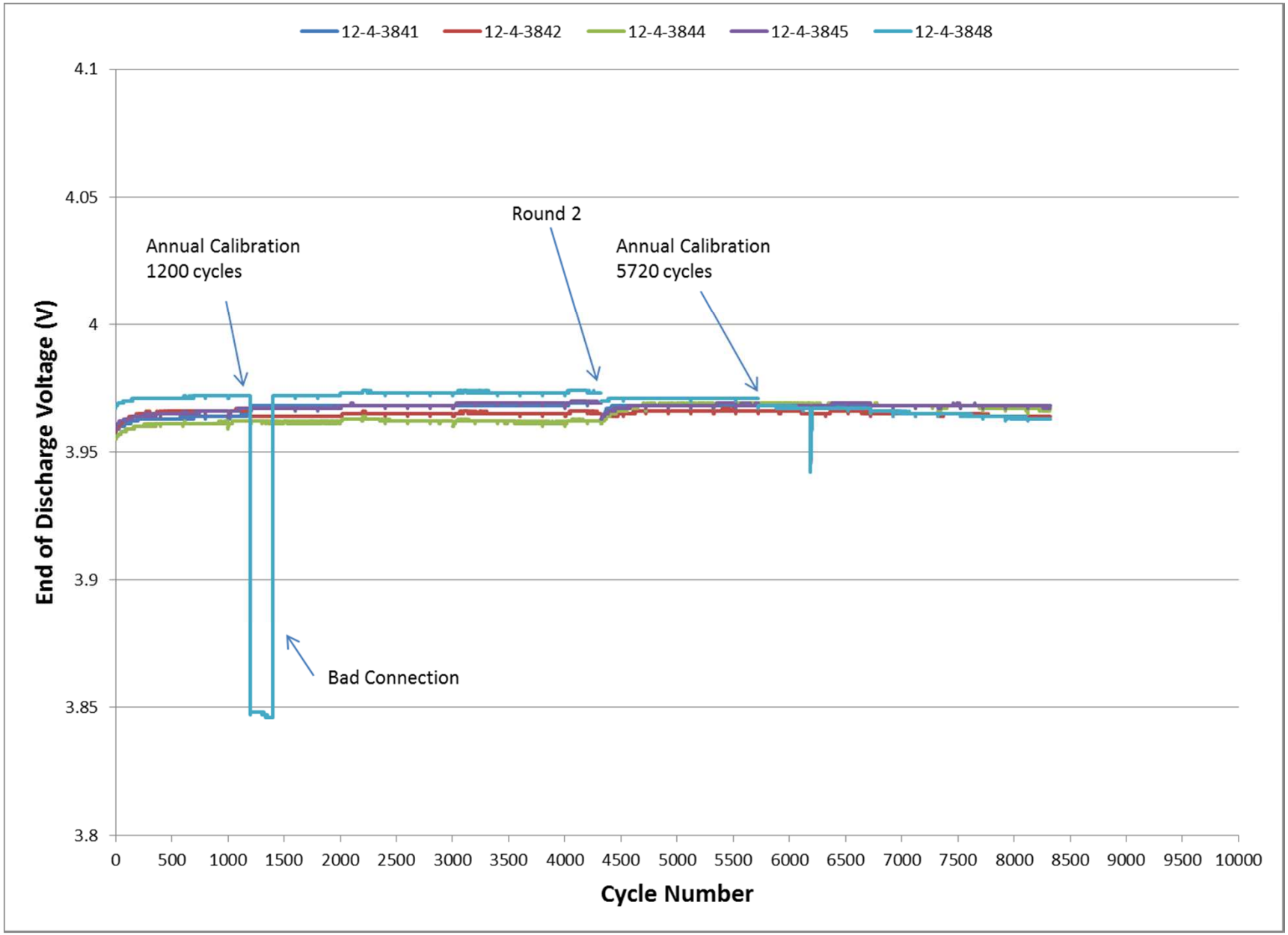

NCP12 Life Cycle Capacity Checks @30°C

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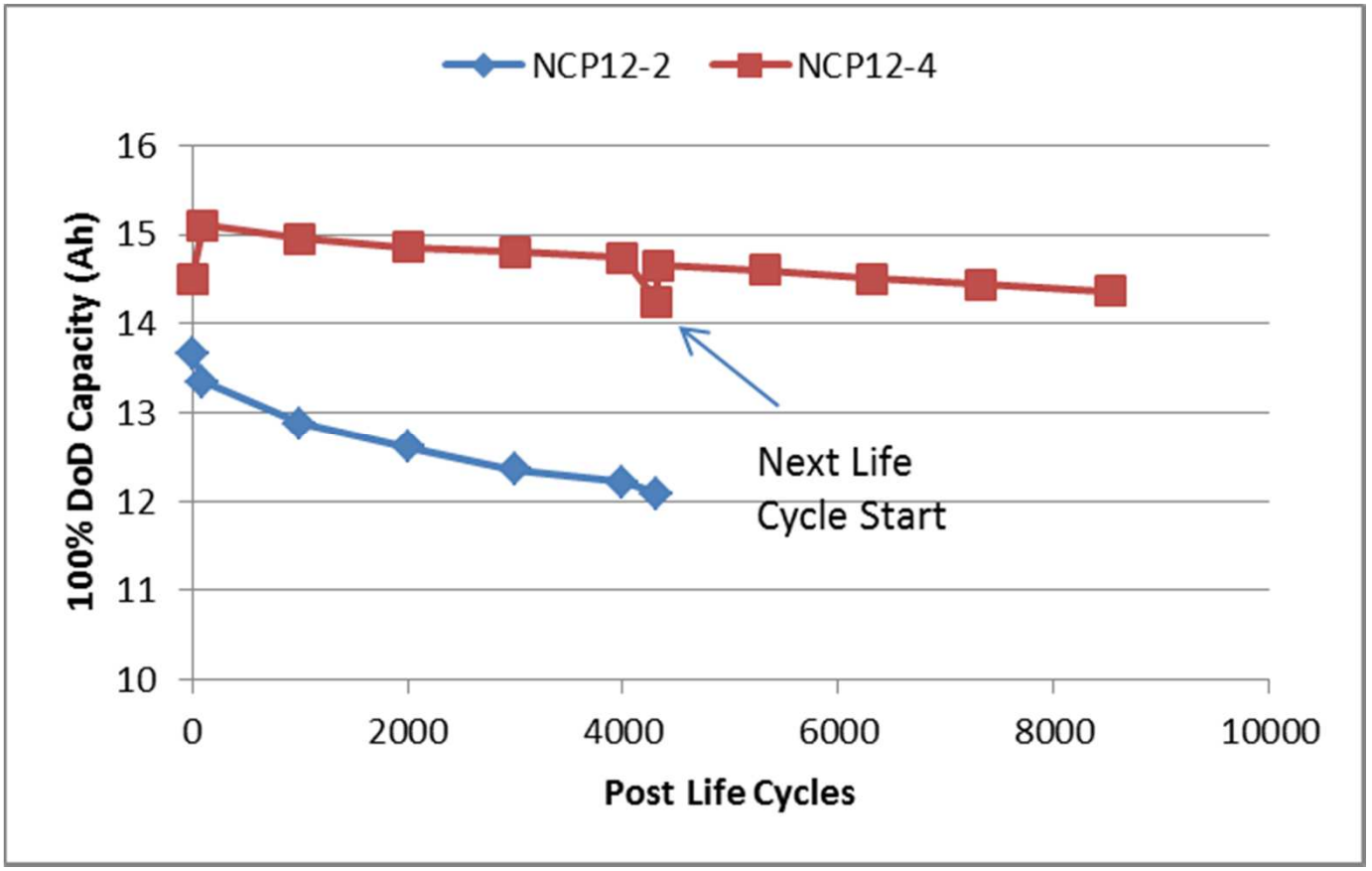

NCP12 Capacity Loss Comparison

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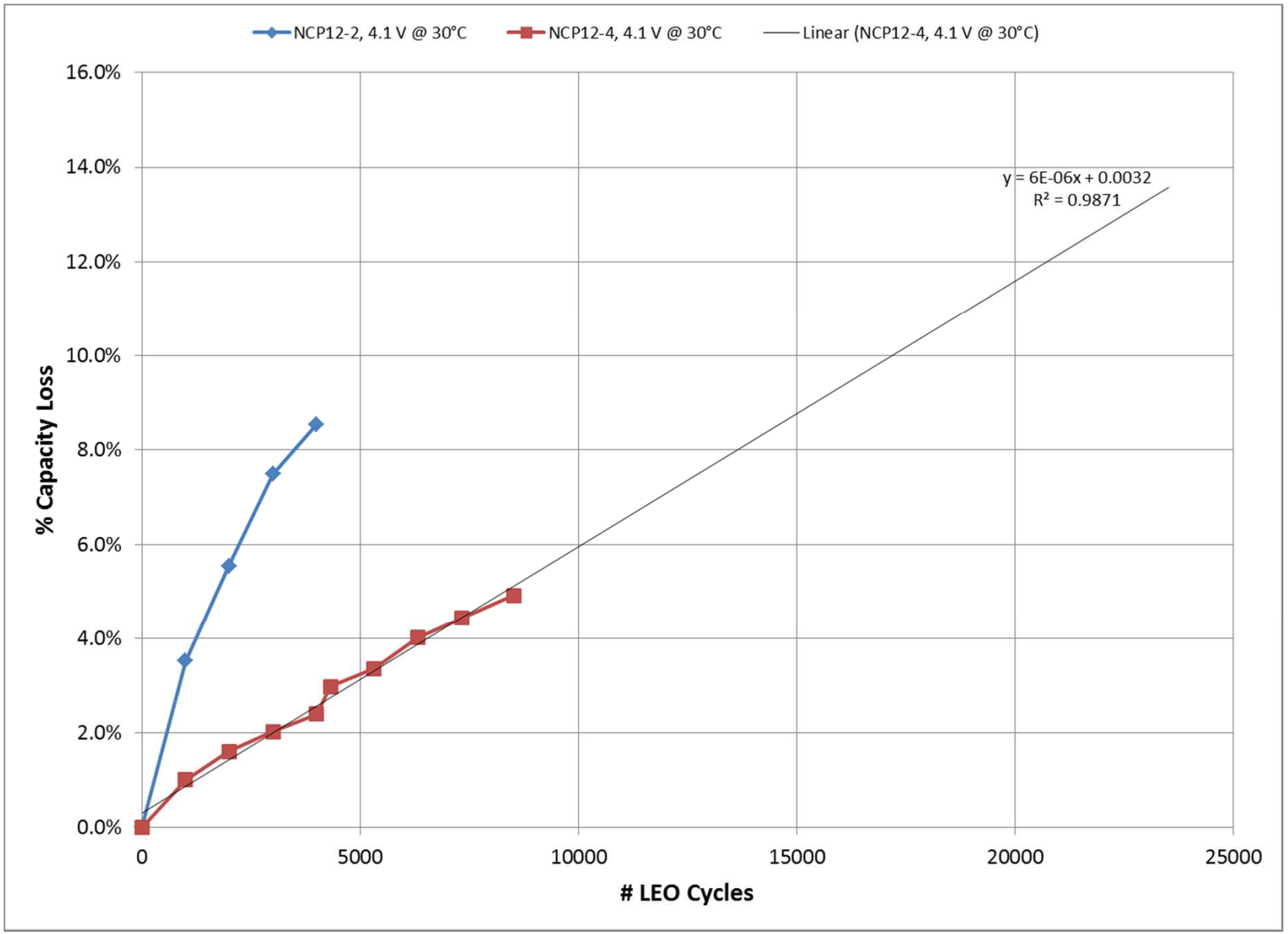
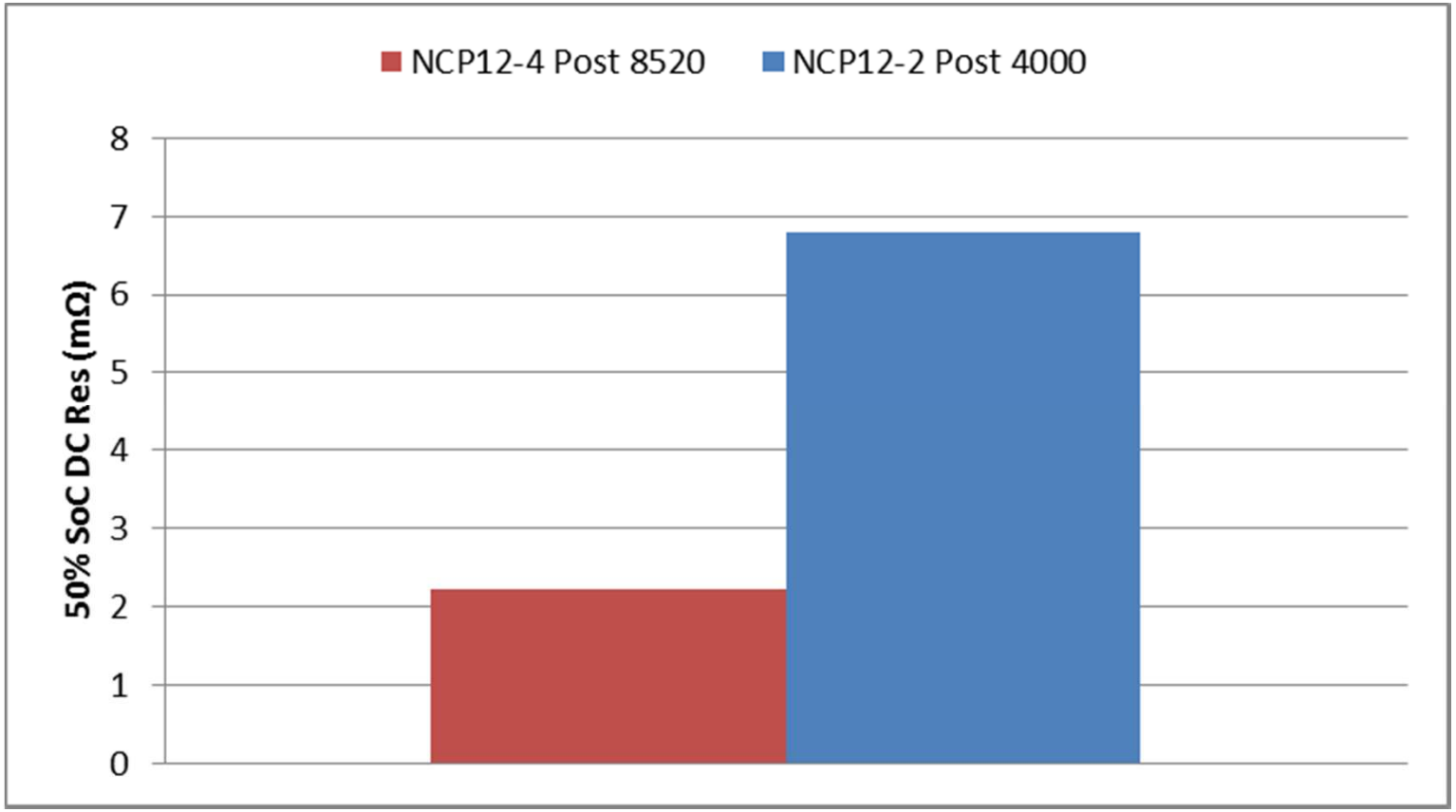


Life Cycle 50% SoC DC Res. @30°C



NCP12 DC Resistance Comparison

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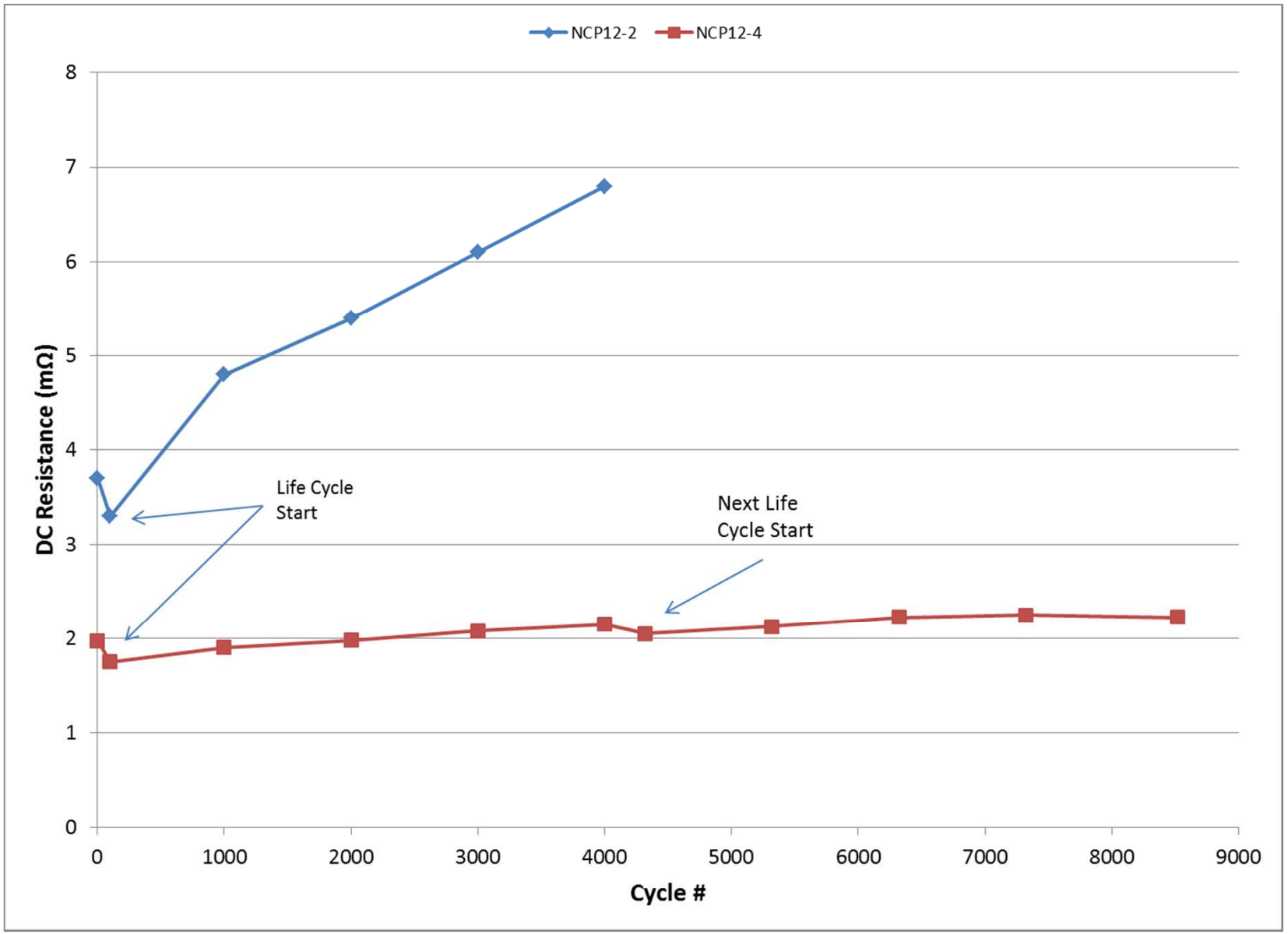

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NCP43-2 vs. NCP43-4

BOL Test; Discharge Capacity

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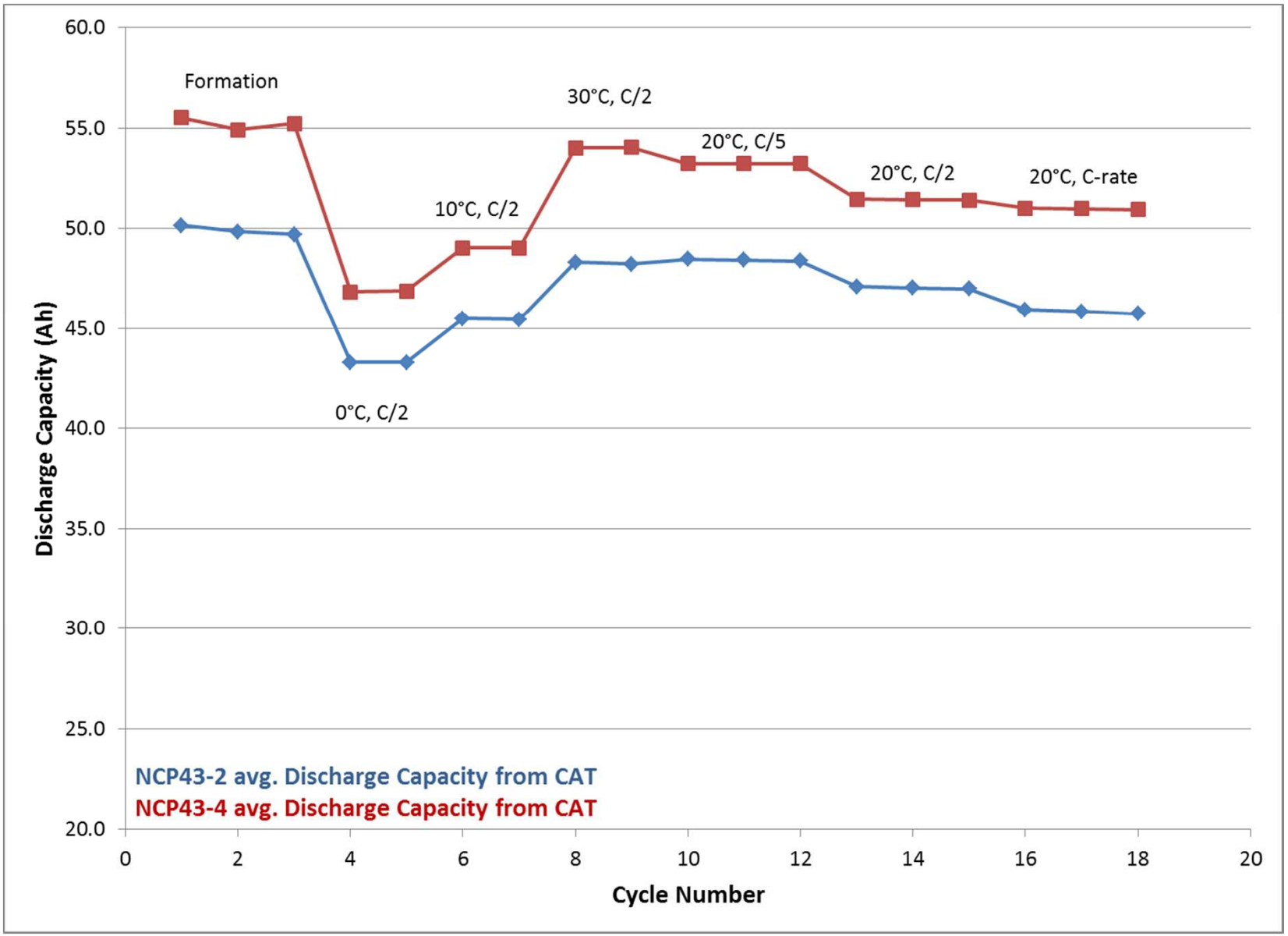

NCP43-4 BOL Test; 20°C DC Resistance

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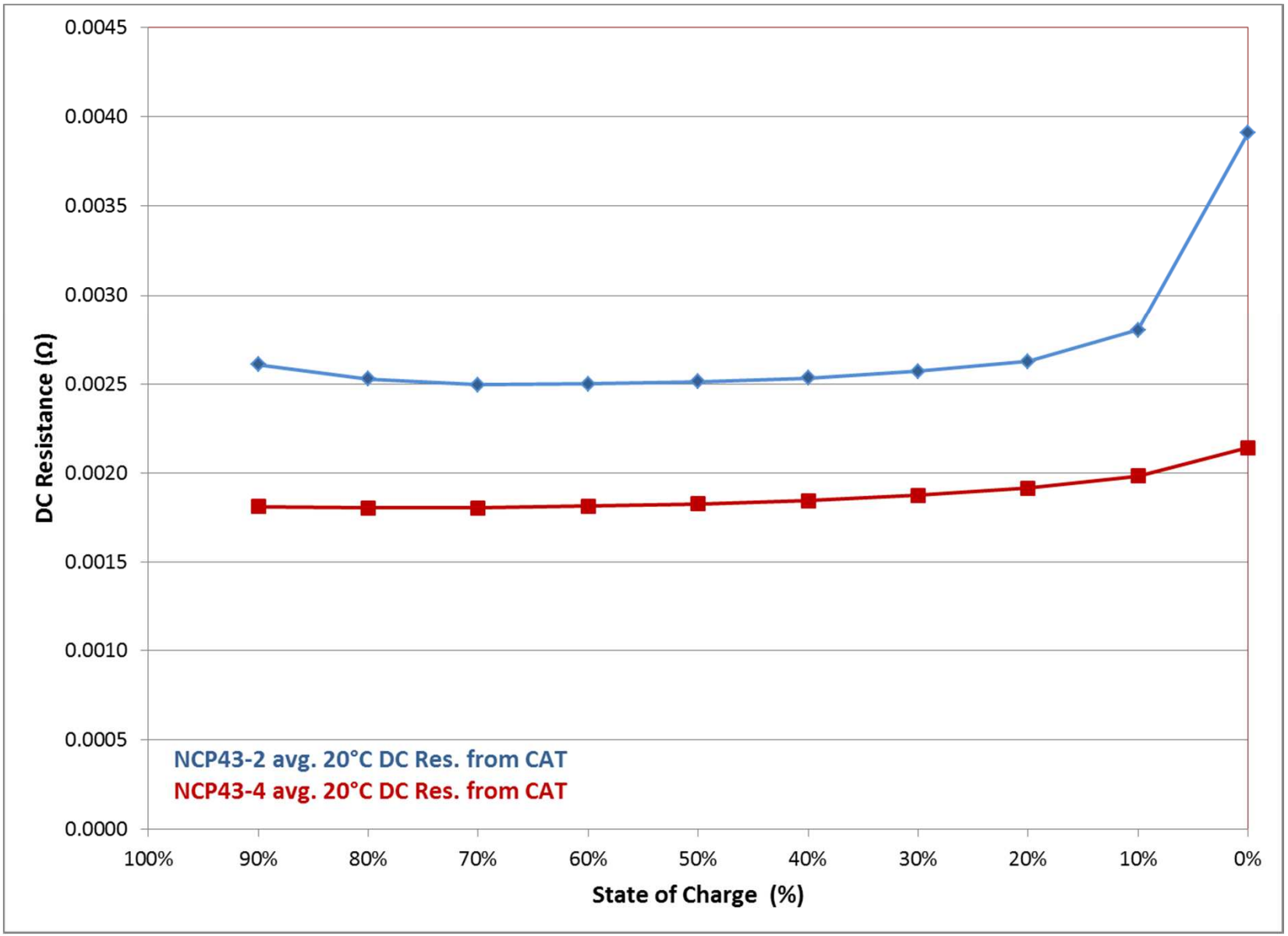

43Ah Life Cycling @30°C

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- The NCA chemistry NCP43-4 cells were placed on life cycling per LiTP-6245 that was previously run on the NCP43-2 NCO chemistry cells.
  - Per para. 5.3 Real-time life cycling at 30°C
    - 4320 cycles per round
      - 11.0 amp charge to 4.1Vdc, tapering for a total time of 53.3 min
      - 14.0 amp discharge for 36.7 min
    - Capacity and DC Resistance
      - Every 1000 Cycles

NCP43-4 End-of-Discharge Voltage

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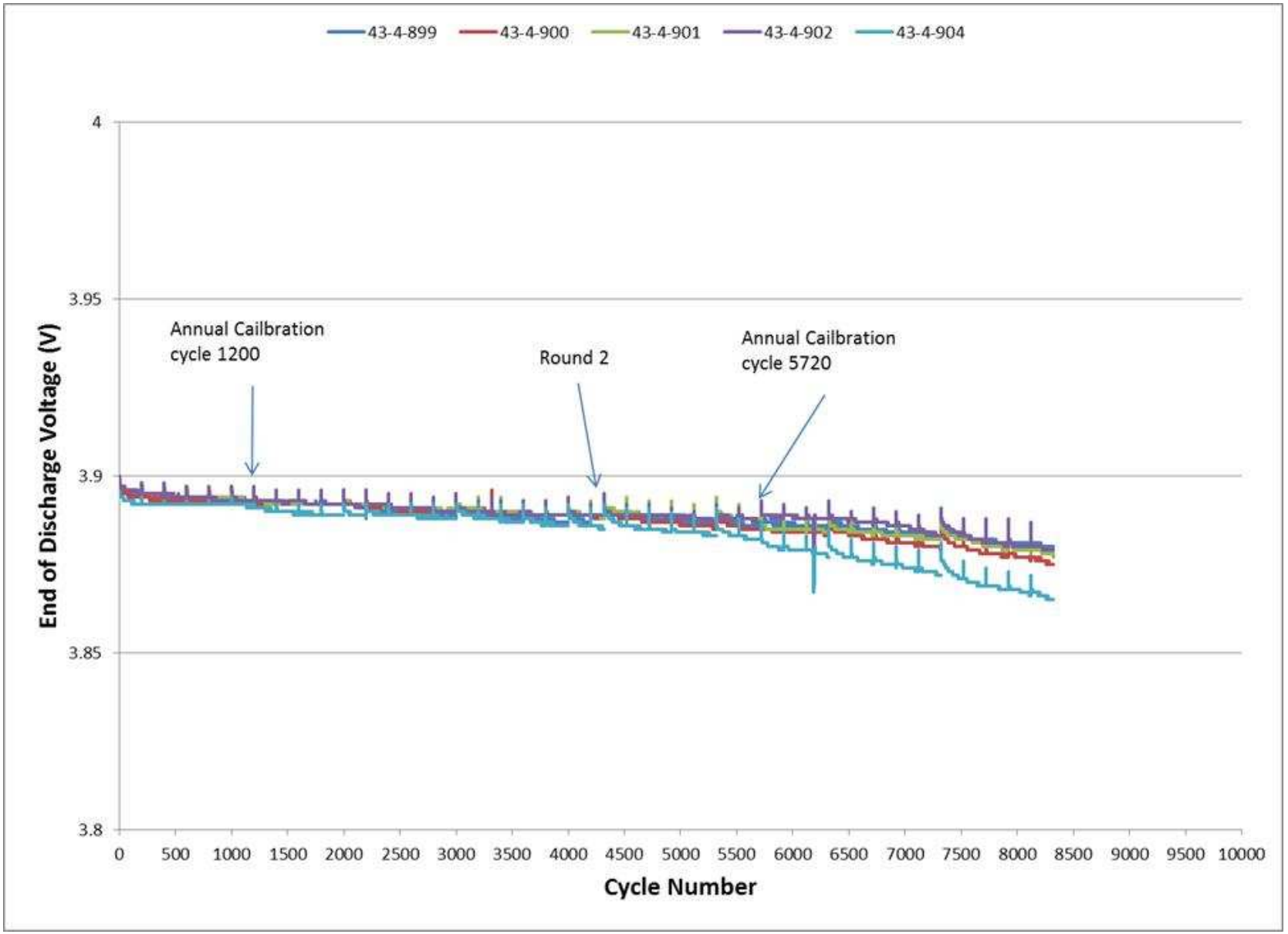

NCP43 Life Cycle Capacity Checks @30°C

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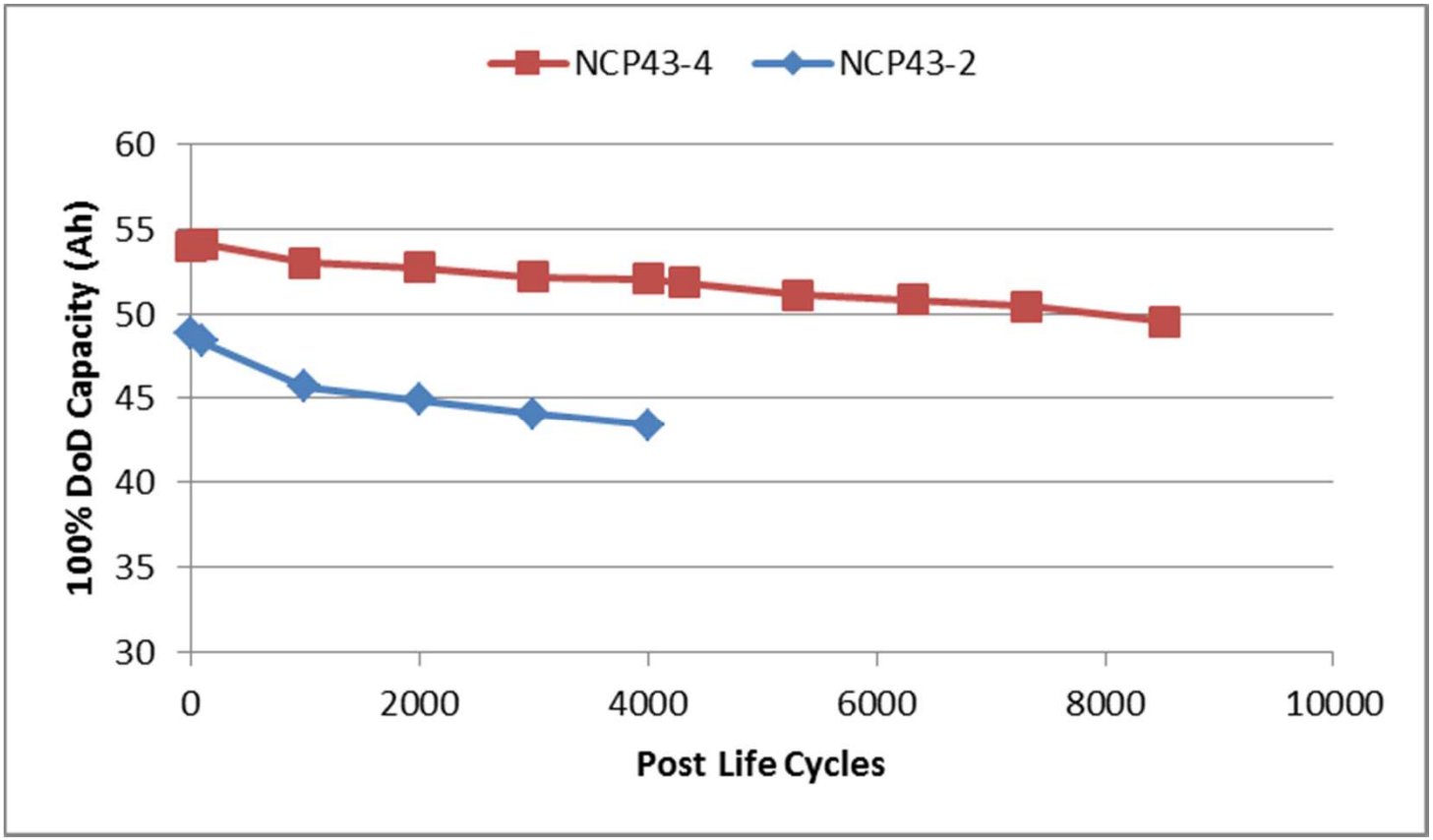

NCP43 Capacity Loss Comparison

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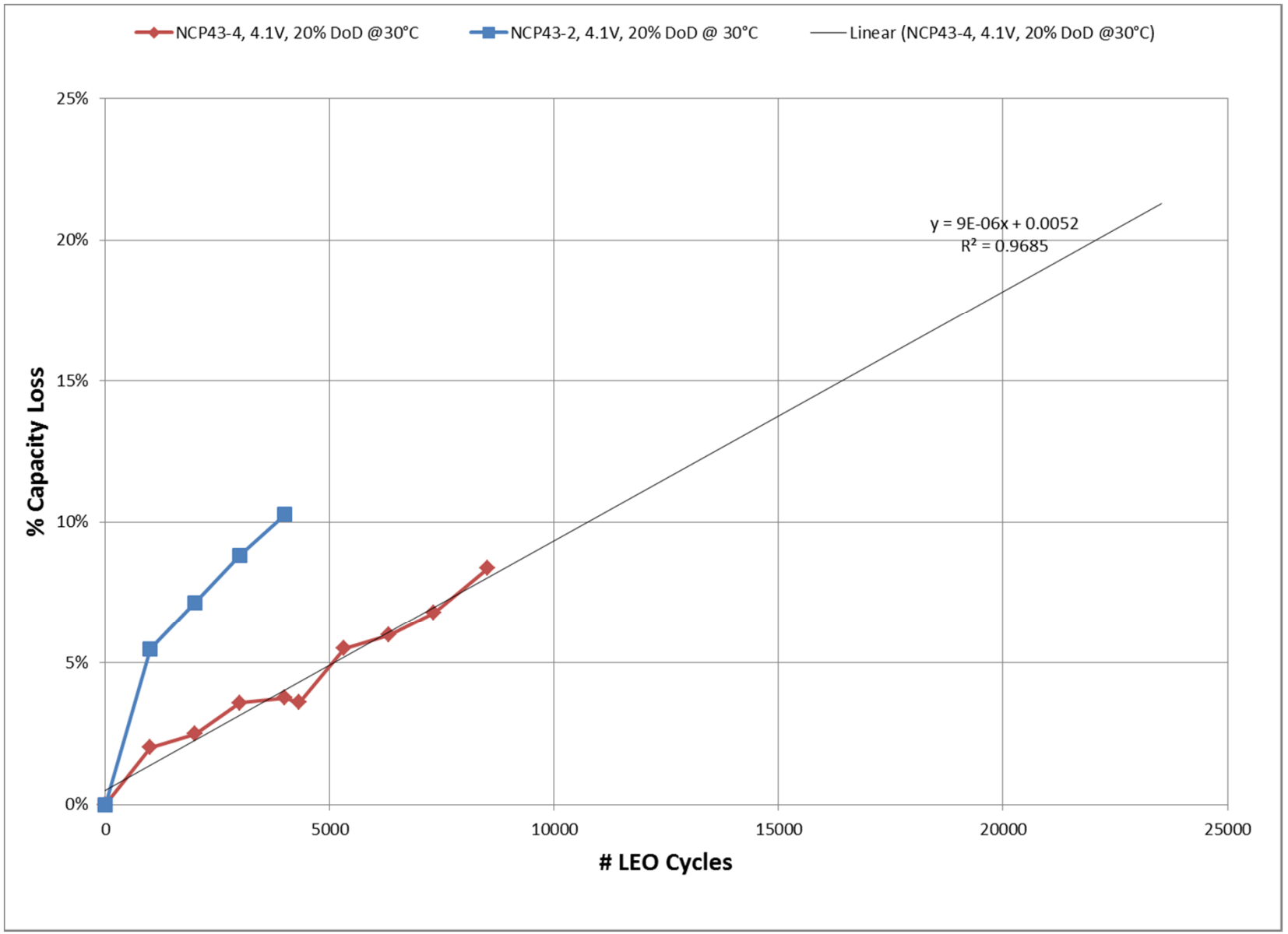
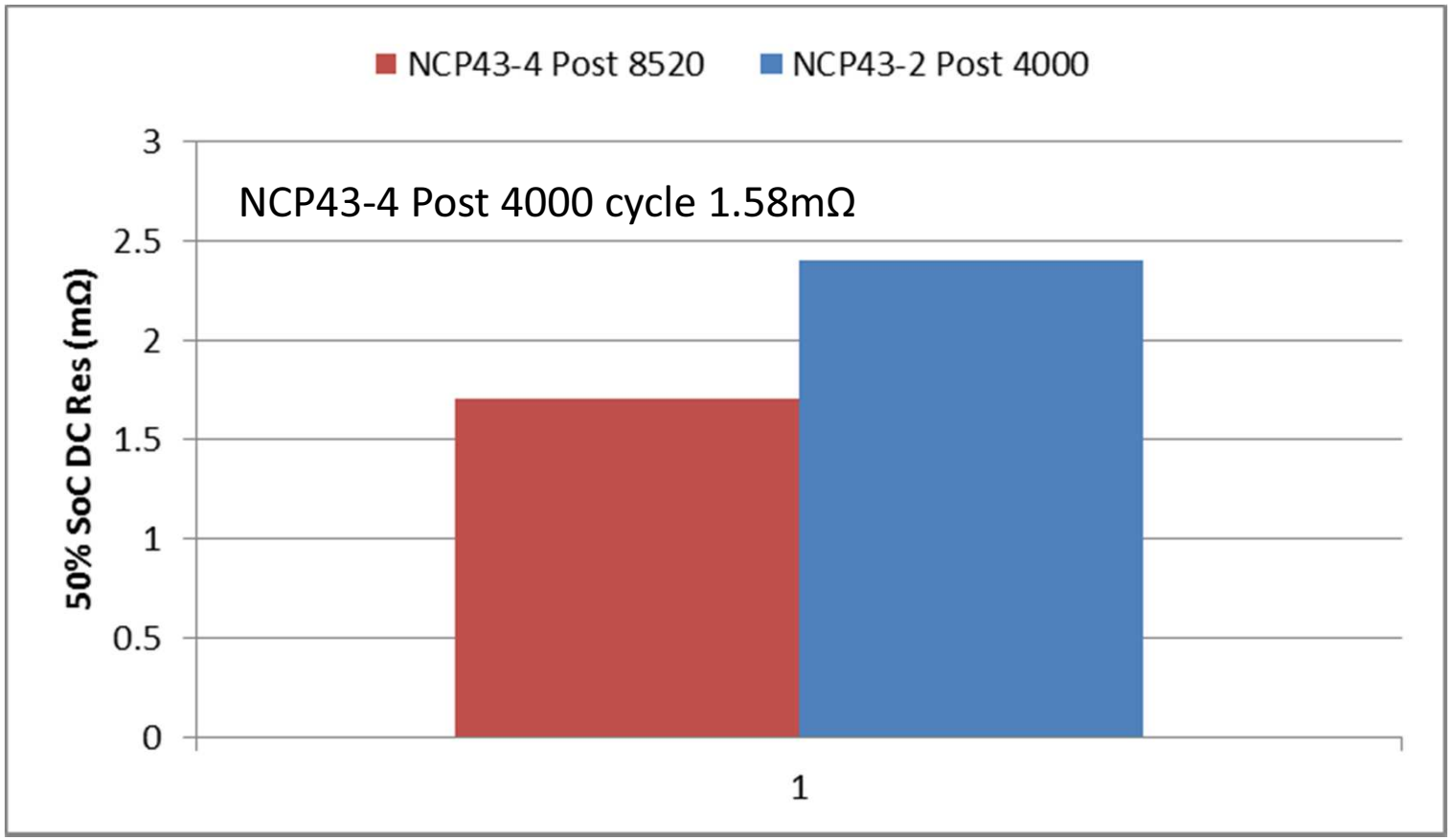


Life Cycle 50% SoC DC Res. @30°C



NCP43-4 DC Resistance Comparison

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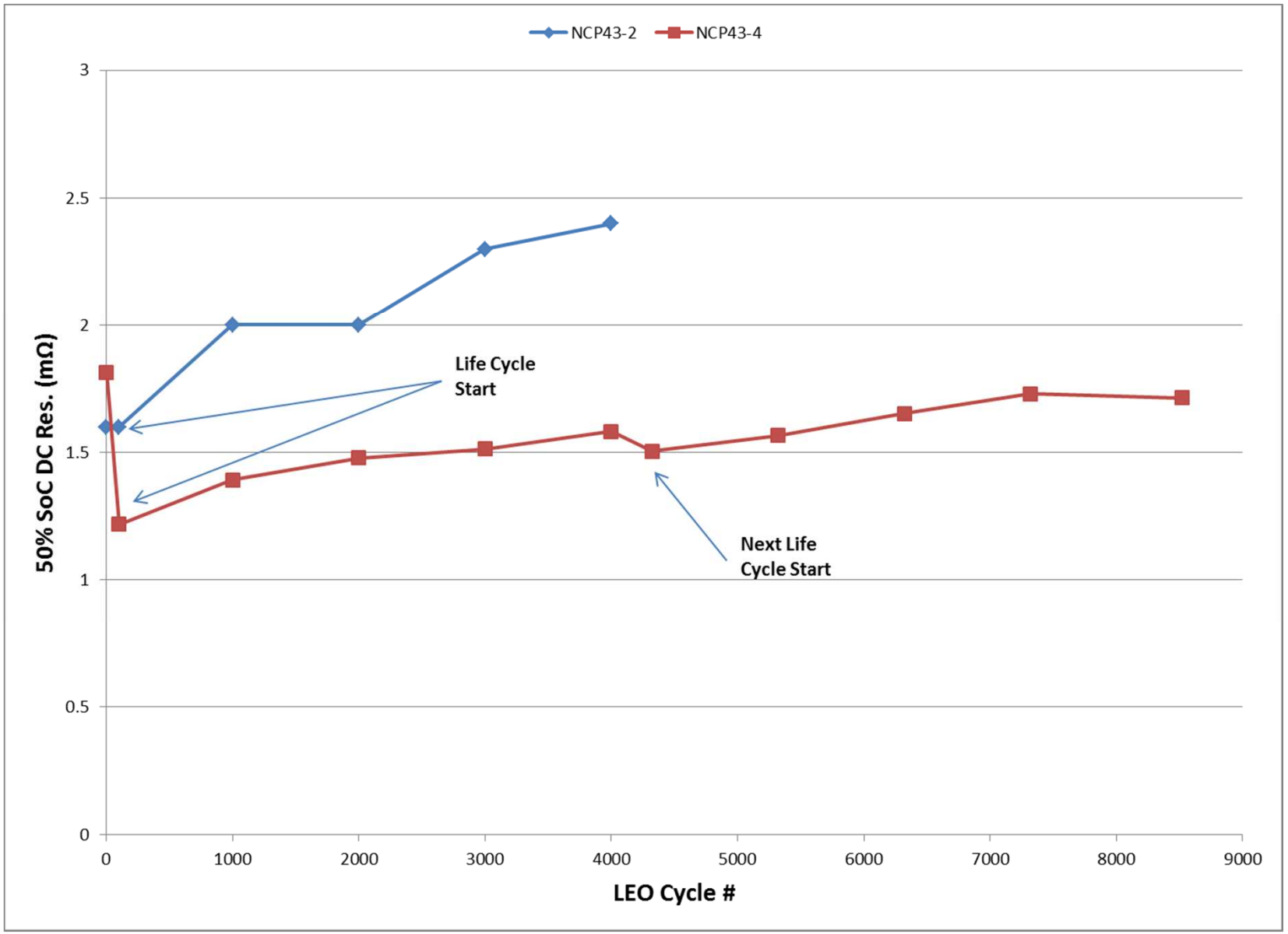

Comparison of Life Cycles NCP25-5

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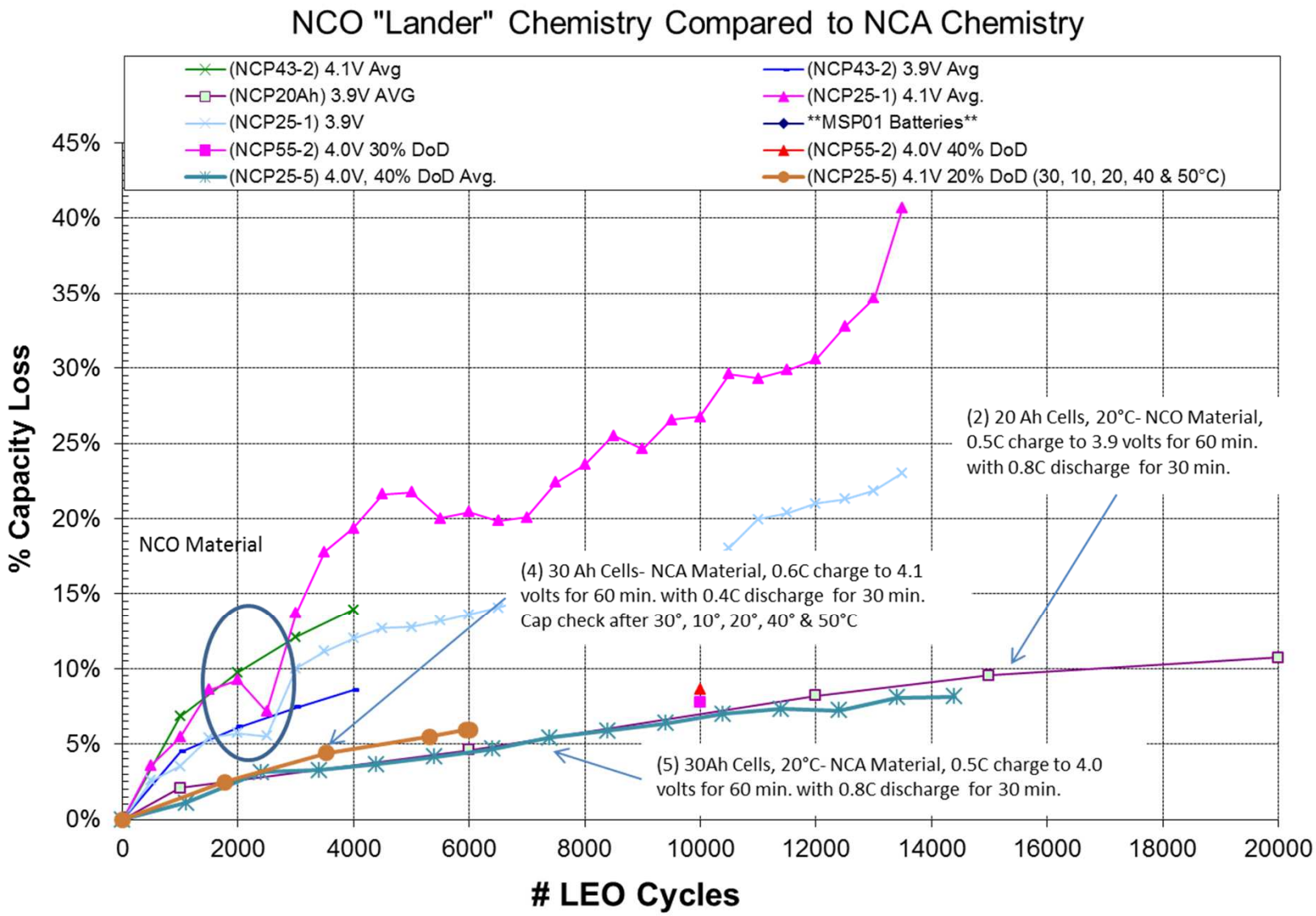

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Battery Designs with Next Generation Cells

Space Batteries and Cells-Now Utilizing NCA

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- Batteries Delivered 28 Volt, 30Ah
  - 28 Volt, 29Ah (End of charge voltage, 32.0 volts)
  - 120 Volt, 30Ah
  - 28 Volt, 12Ah
- Upcoming Deliveries
  - 28 Volt 43Ah
- Cells for CubeSat and SmallSat applications
  - LiAD7BM-1, 6Ah
  - NCP12-4, 12Ah

28V -12Ah Battery Design

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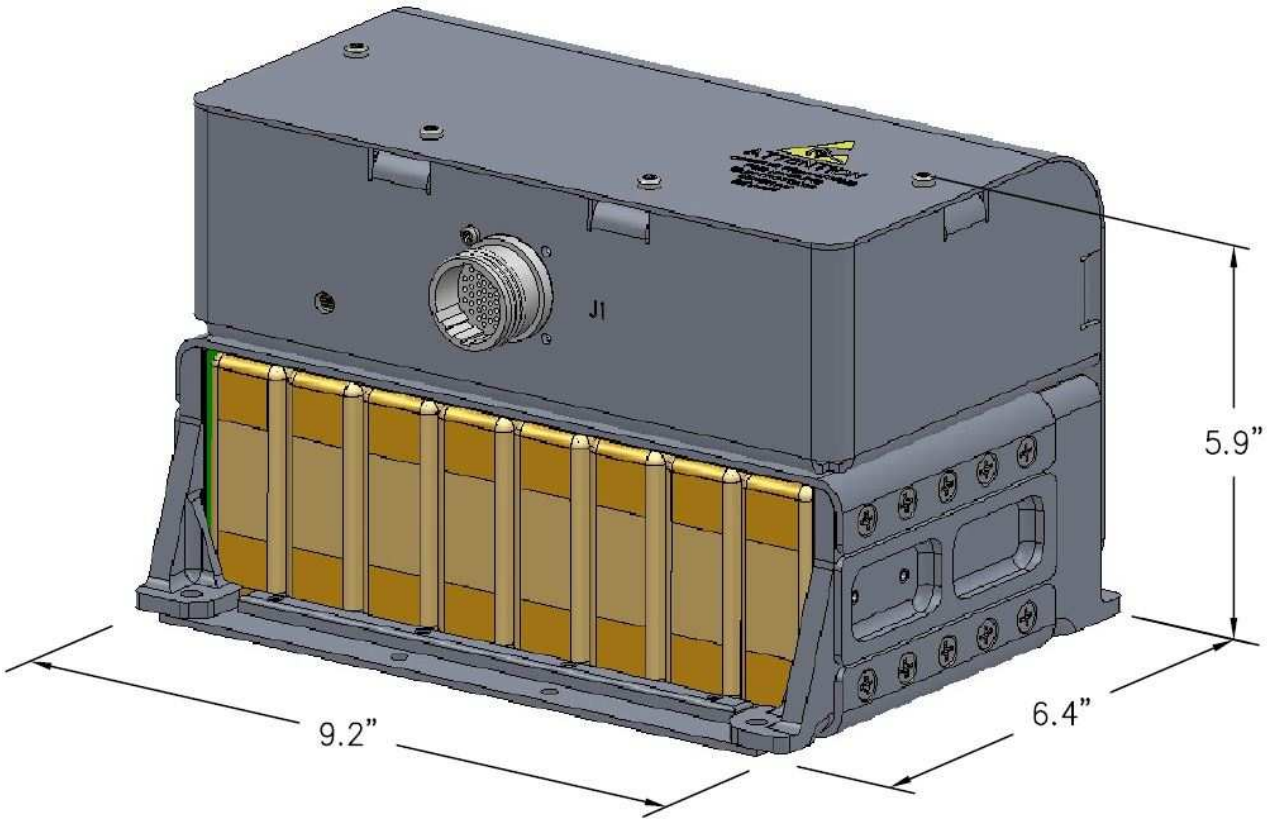

Key Design Requirements

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Voltage (nominal)	*28 Volts*
Capacity	*12 Ah*
Chemistry	*Lithium-ion*
Weight	*<6.3 kg*
Natural Frequency	*>200 Hz*
AC Impedance	*<100 mΩ*
Cell Equalization (internal to battery)	*4.0V ±3.7%*
Cell Over-Voltage Signal	*>4.3V ±1.5%*

28V -30Ah Battery Design

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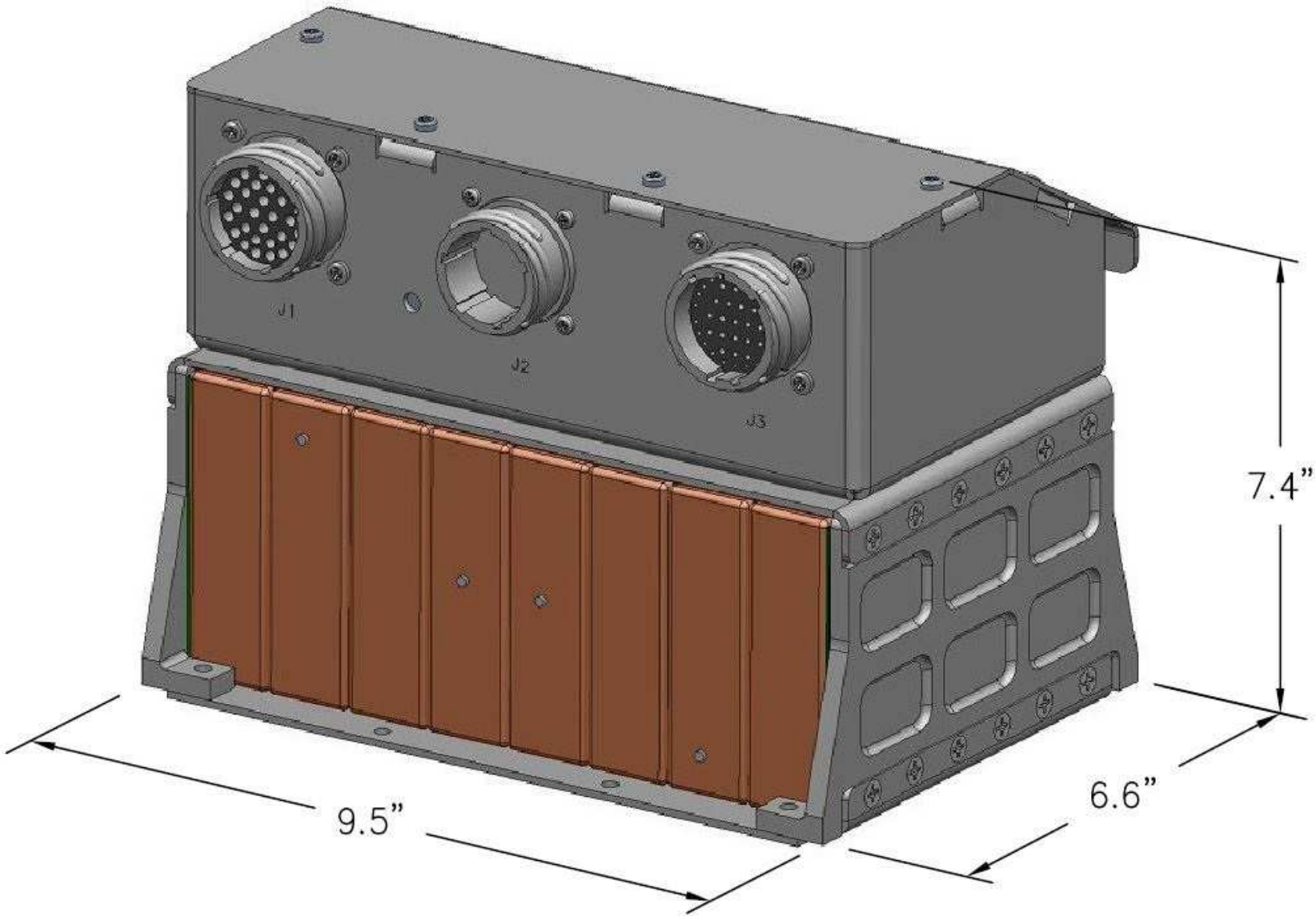

Key Design Requirements

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Voltage (nominal)	*28 Volts*
Capacity	*>30 Ah*
Chemistry	*Lithium-ion*
Weight	*<10.6kg*
Emissivity	*≥0.80*
Natural Frequency	*>50 Hz*
Thermal Gradient	*≤4°C*
AC Impedance	*<30 mΩ @ 50% SoC*
Cell Equalization	*4.10V ±3.7%*
Over-Voltage Signal	*>4.3V ±3.7%*

Next Generation Chemistry advantage

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- Batteries with Space Mission Heritage
  - Stay within Volume envelope.
  - Keep BMS design, on-craft or, internal to battery
  - Keep Electrical interface
  - Standardized interface, mechanical and electrical

28V -29 Ah Space Battery Update

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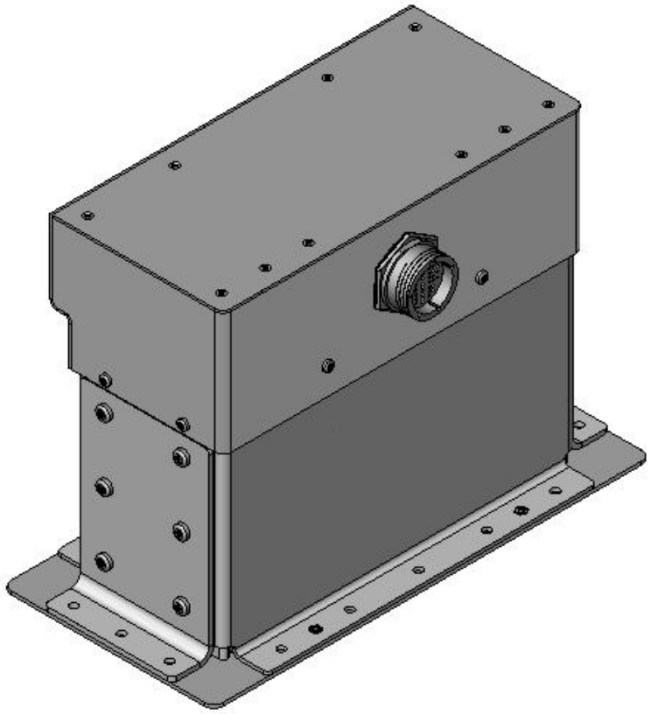
LP31500- 28V 29Ah Battery*

Utilizing the NCP25-1 Cell with NCO Chemistry

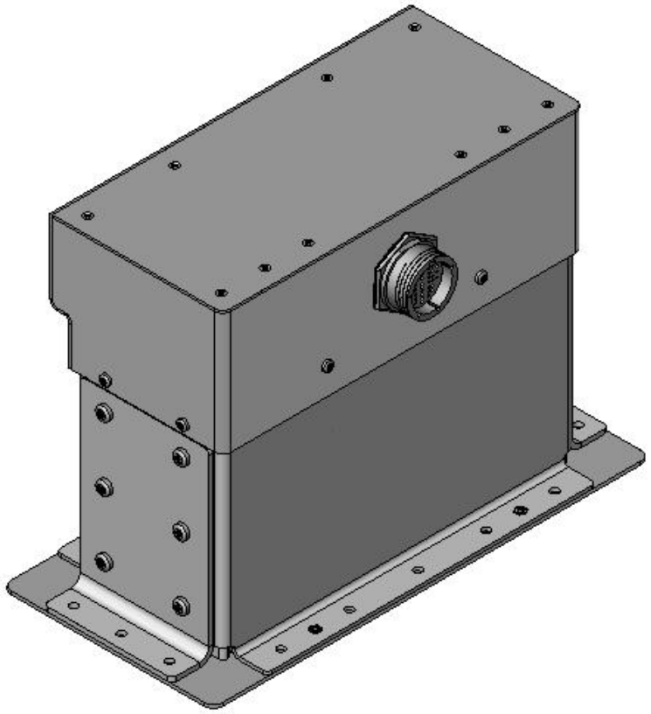
- 8s 1p Configuration
- 11.865”L X 5.750”W X 8.473”H
- Mass ≈9.9Kg



LP32300- 28V 29Ah Battery*

Utilizing the NCP25-5 Cell with NCA Chemistry

- 8s 1p Configuration
- 11.865”L X 5.750”W X 8.473”H
- Mass ≈10.4Kg



*Nameplate capacity with end of charge voltage 32.0V

28V, 29Ah Battery, NCO vs. NCA

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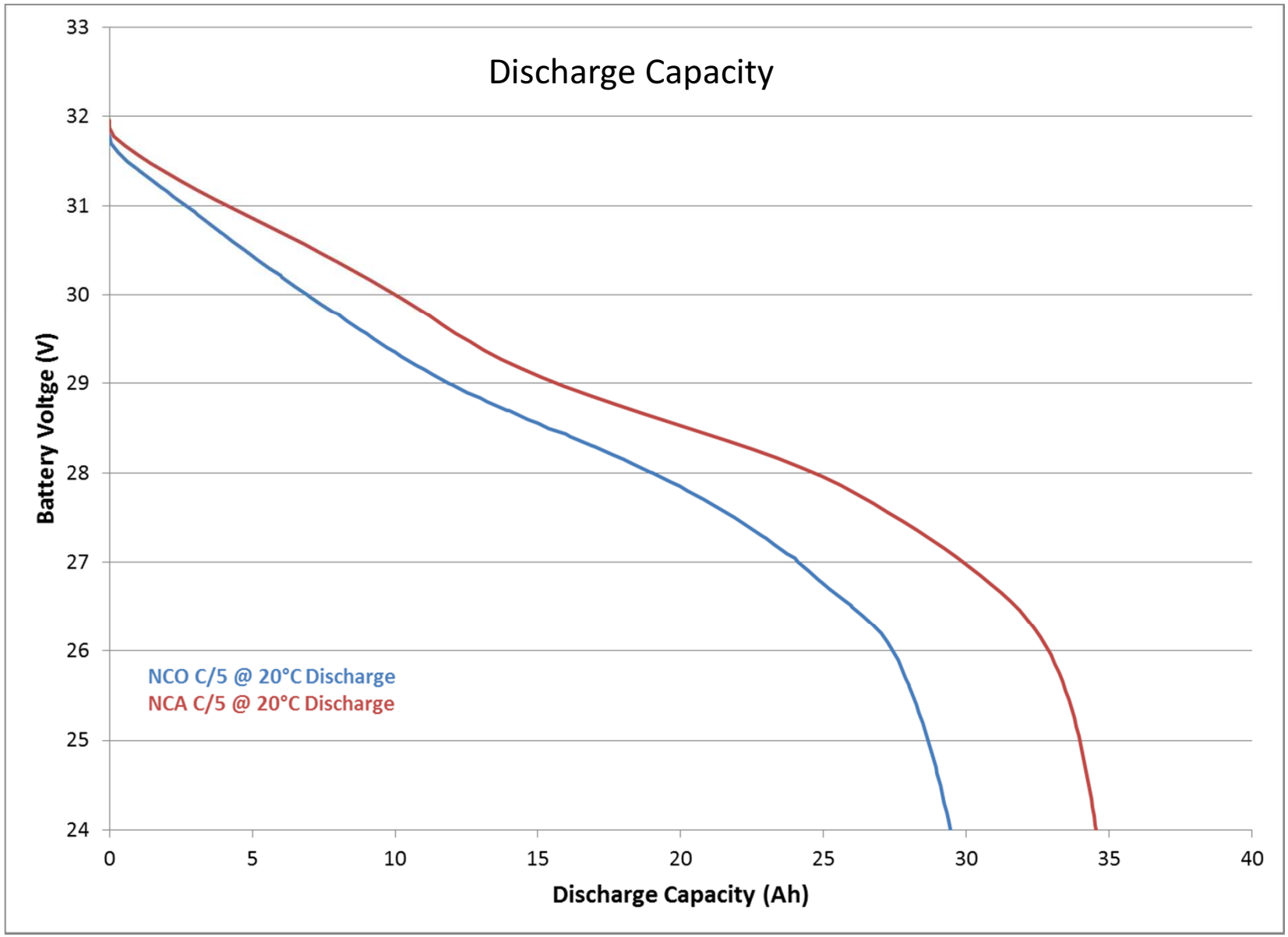

28V, 29Ah Battery, NCO vs. NCA

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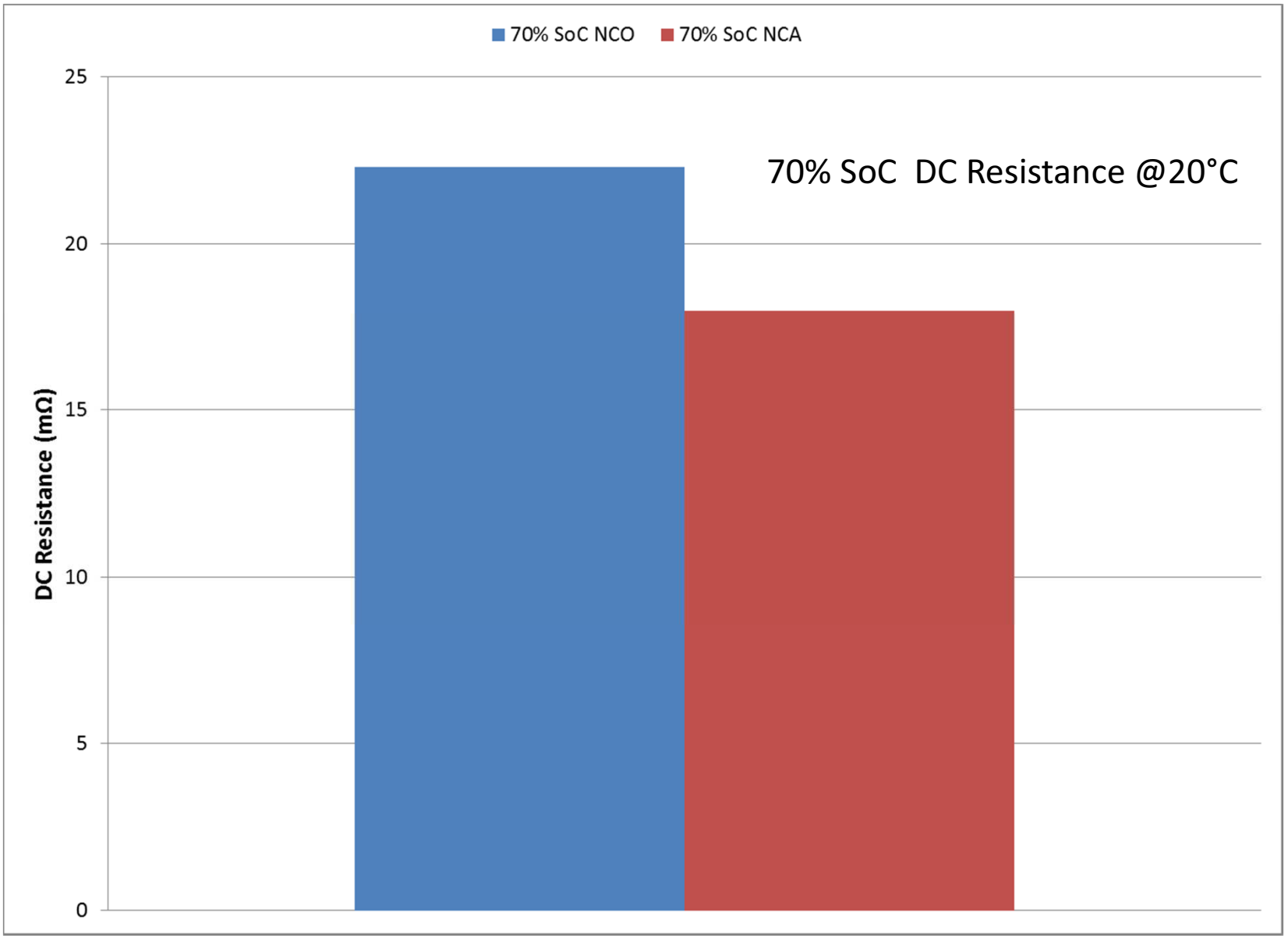

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Conclusions

- Next Generation of Lithium-ion Space Chemistry for these prismatic cell designs yields improvements
  - Increased BOL capacity
  - Decreased capacity loss over life
  - Reduction of 3-times in impedance growth, following LEO cycling
  - Physical dimensions allow for Off-the-shelf designs, utilizing this chemistry, gaining improvements for the next generation of space vehicle.

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Acknowledgments

Chad Deroy
Dr. Rob Gitzendanner