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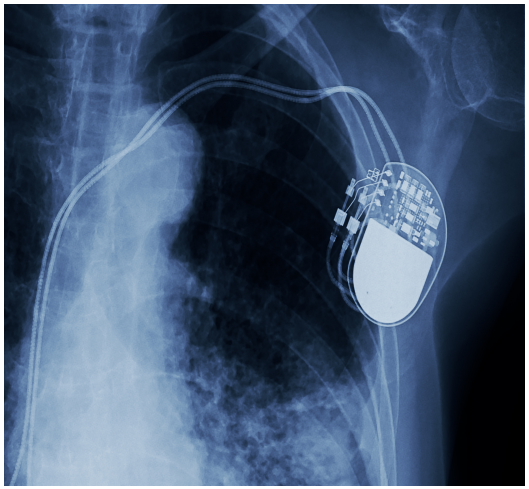
Updates of the Lithium-ion Space Chemistry, and COTS Testing

NASA Space Battery Workshop
Huntsville, AL
November 27-29th, 2018

Chad Deroy



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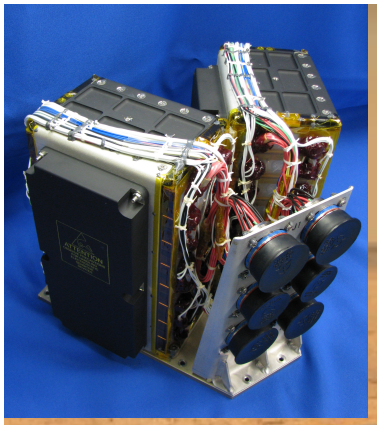
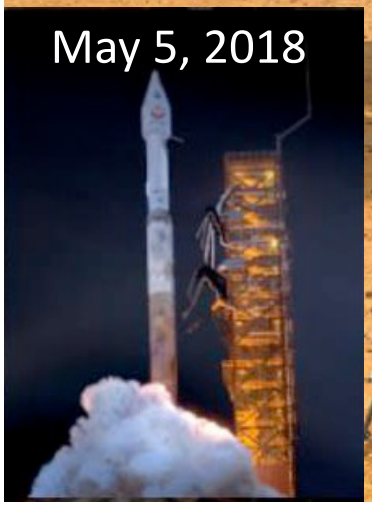
Congratulations InSight!!!!!

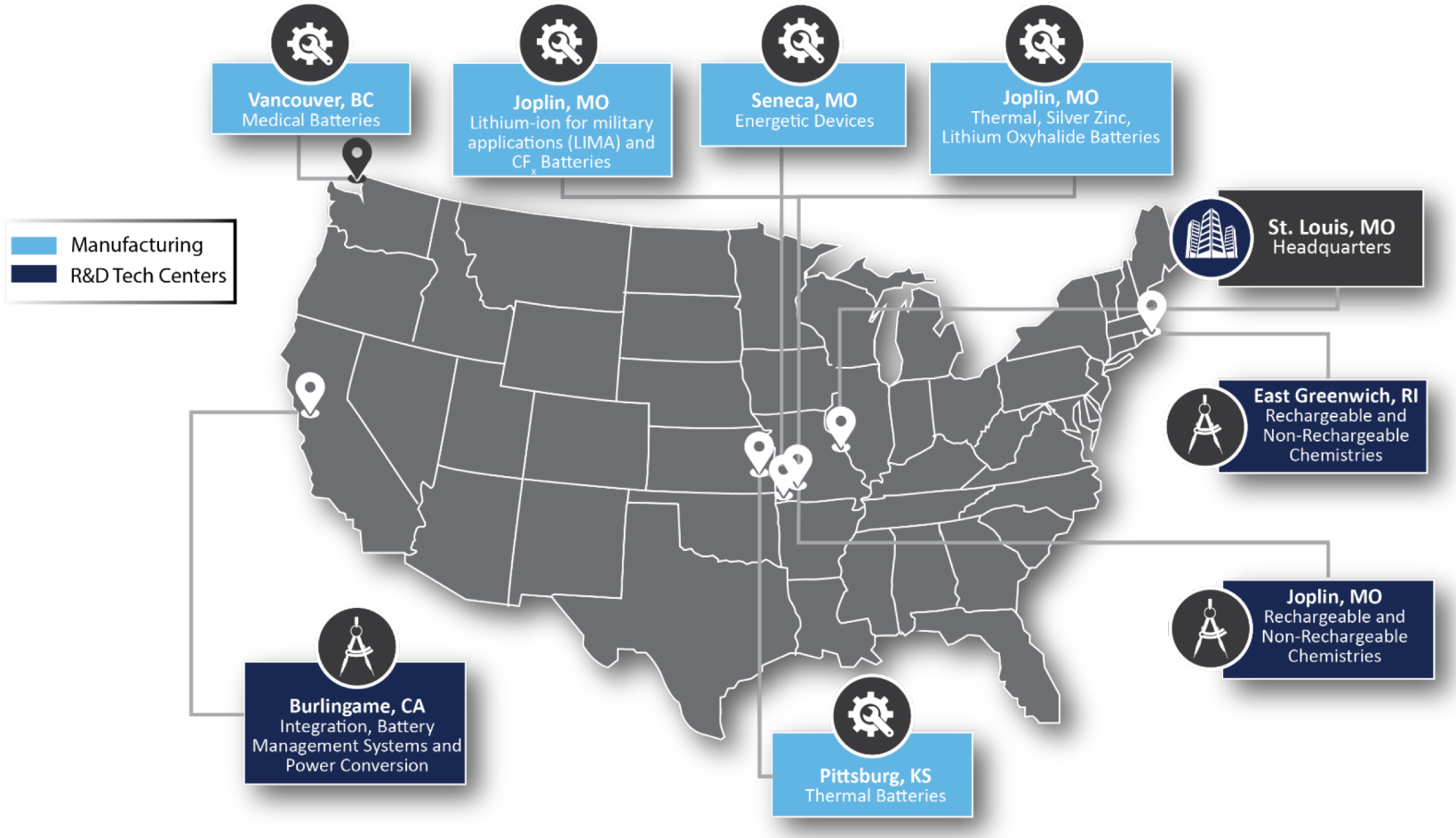


(2) 30 Ah, 28V with Balancing Electronics November 15, 2015



EaglePicher Provides Reliable, Flexible, Power and Energy Dense Solutions for High Technology Applications

Innovating, Investing and Growing



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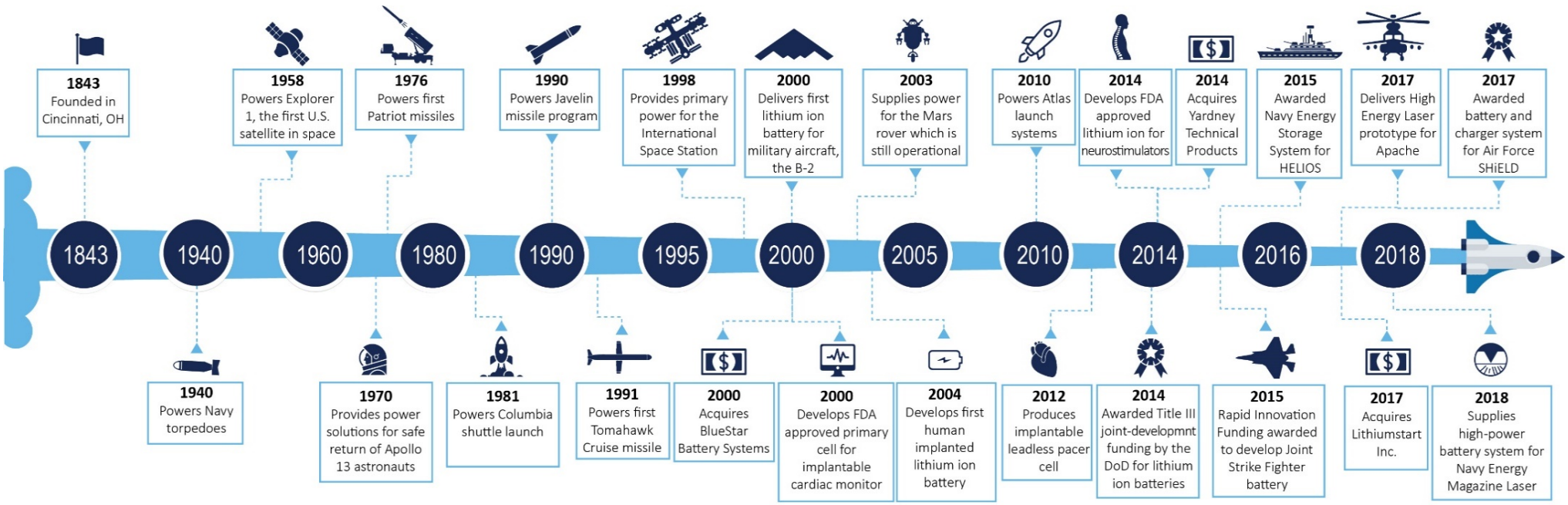
Heritage in Mission-Critical Applications



Serving Mission-Critical Aerospace, Defense, Aviation and Medical Battery Markets

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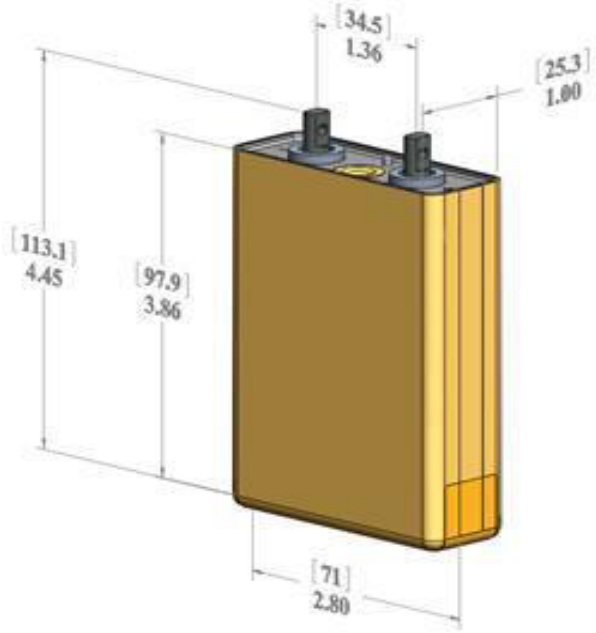
Life Testing Updates

Updated Chemistries for Space application

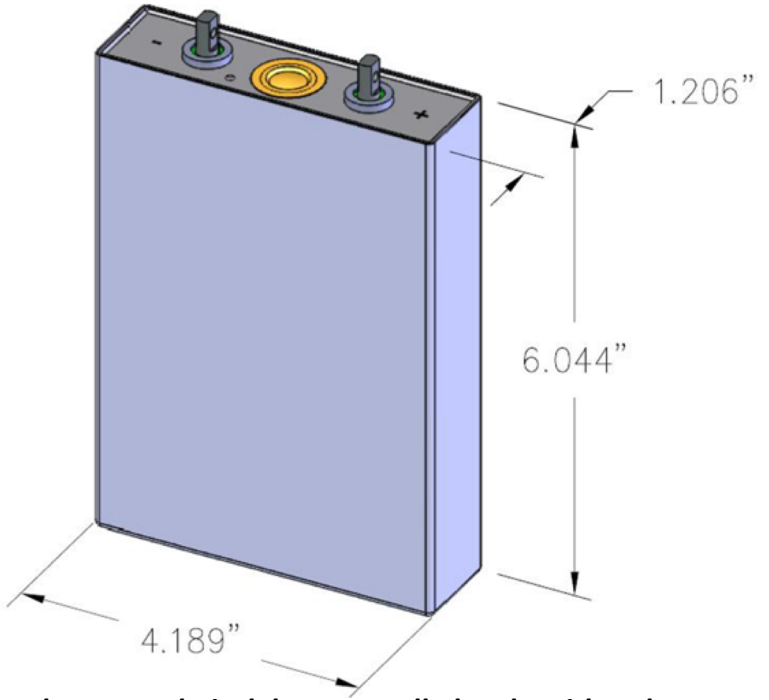
- NCP12-4 Design
  - NCA/Synthetic Graphite
  - 14.5 Ah BOL
  - 12 Ah Nameplate
- Physical Properties:
  - 456 grams
  - 4.45” Tall x 2.8” Wide x 1.0” Thick

Currently used for LEO Applications



- 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

Currently used for LEO Applications



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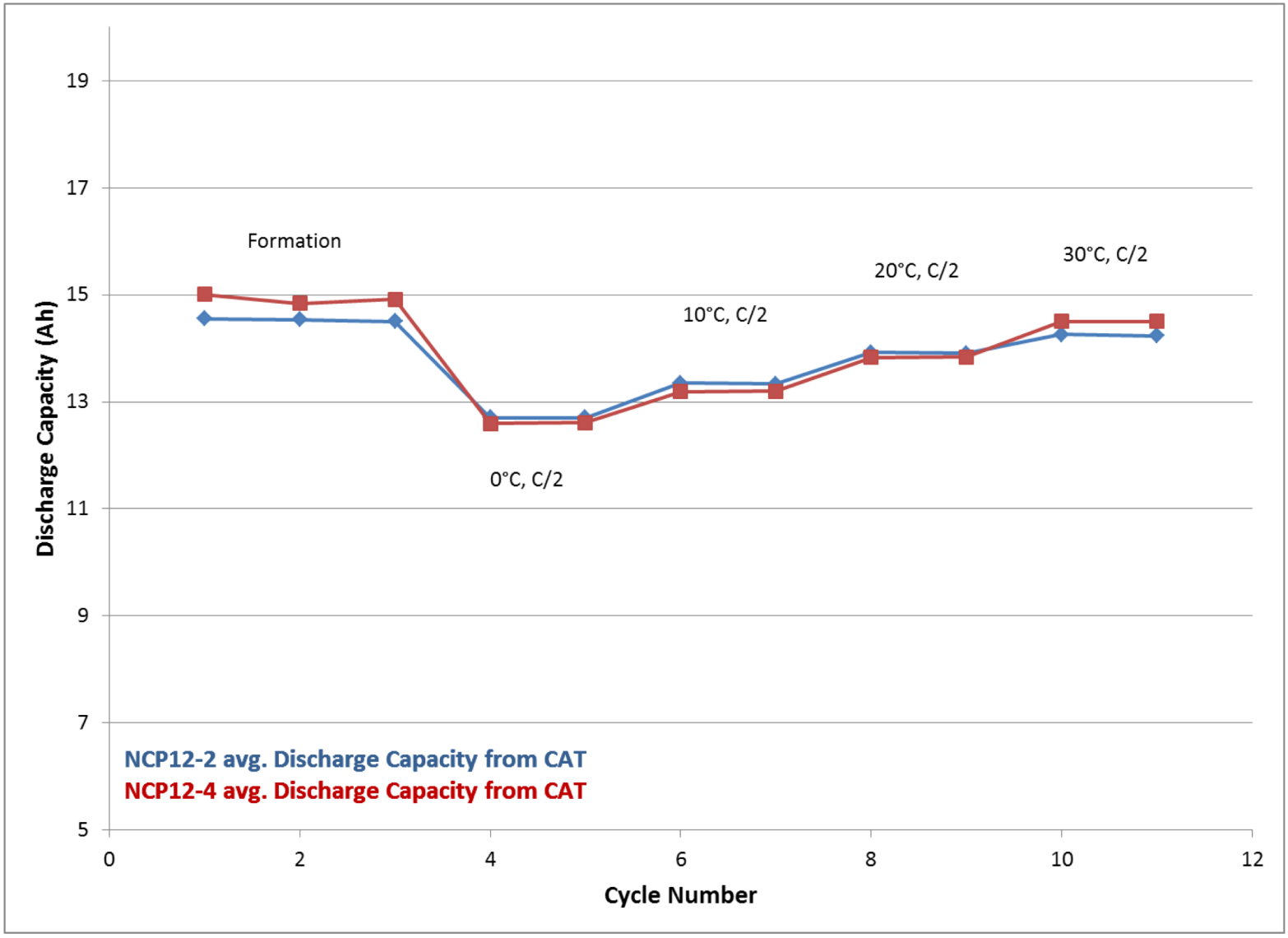
NCP12-4

BOL Test; Discharge Capacity



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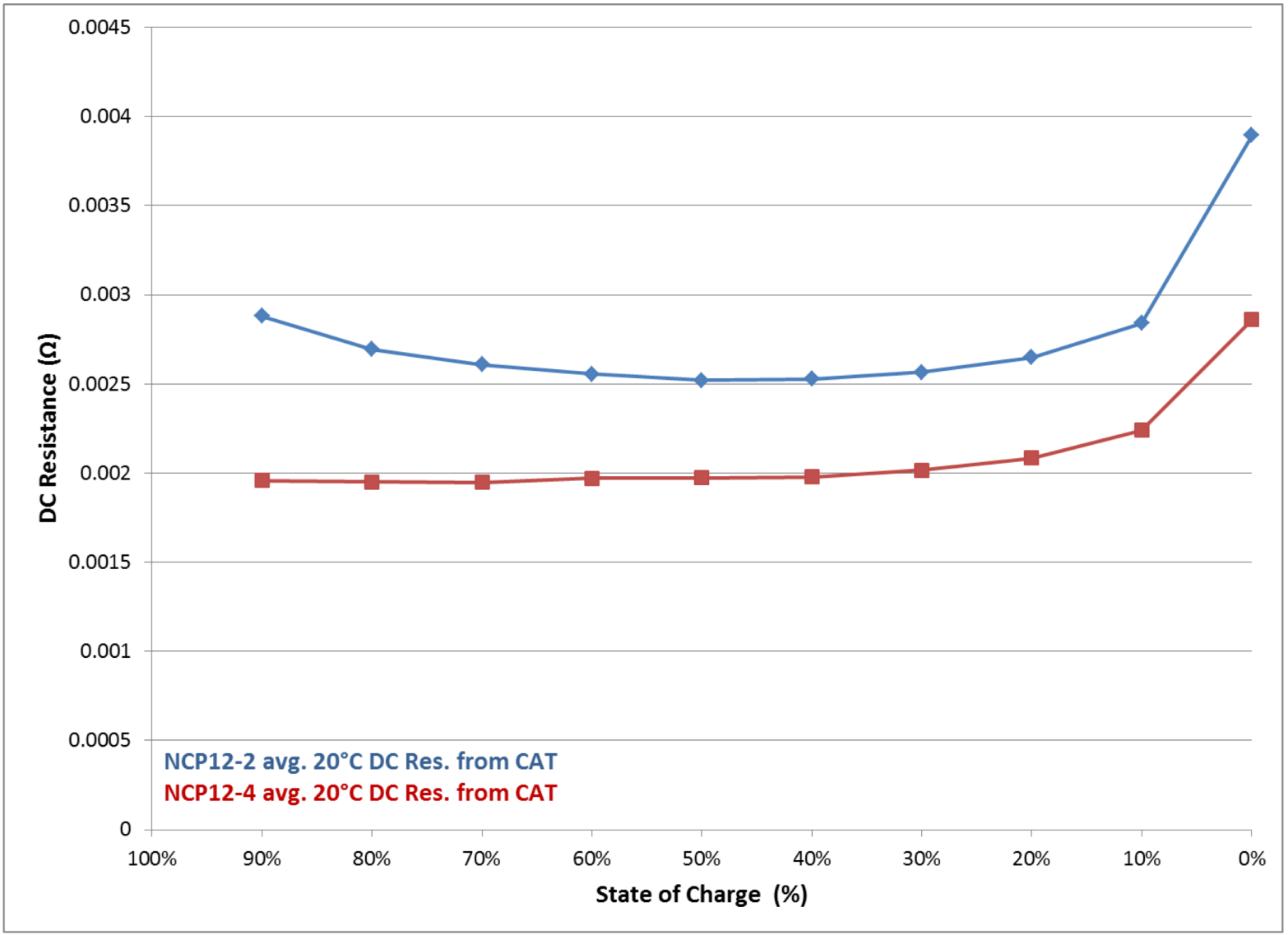
BOL Test; 20°C DC Resistance



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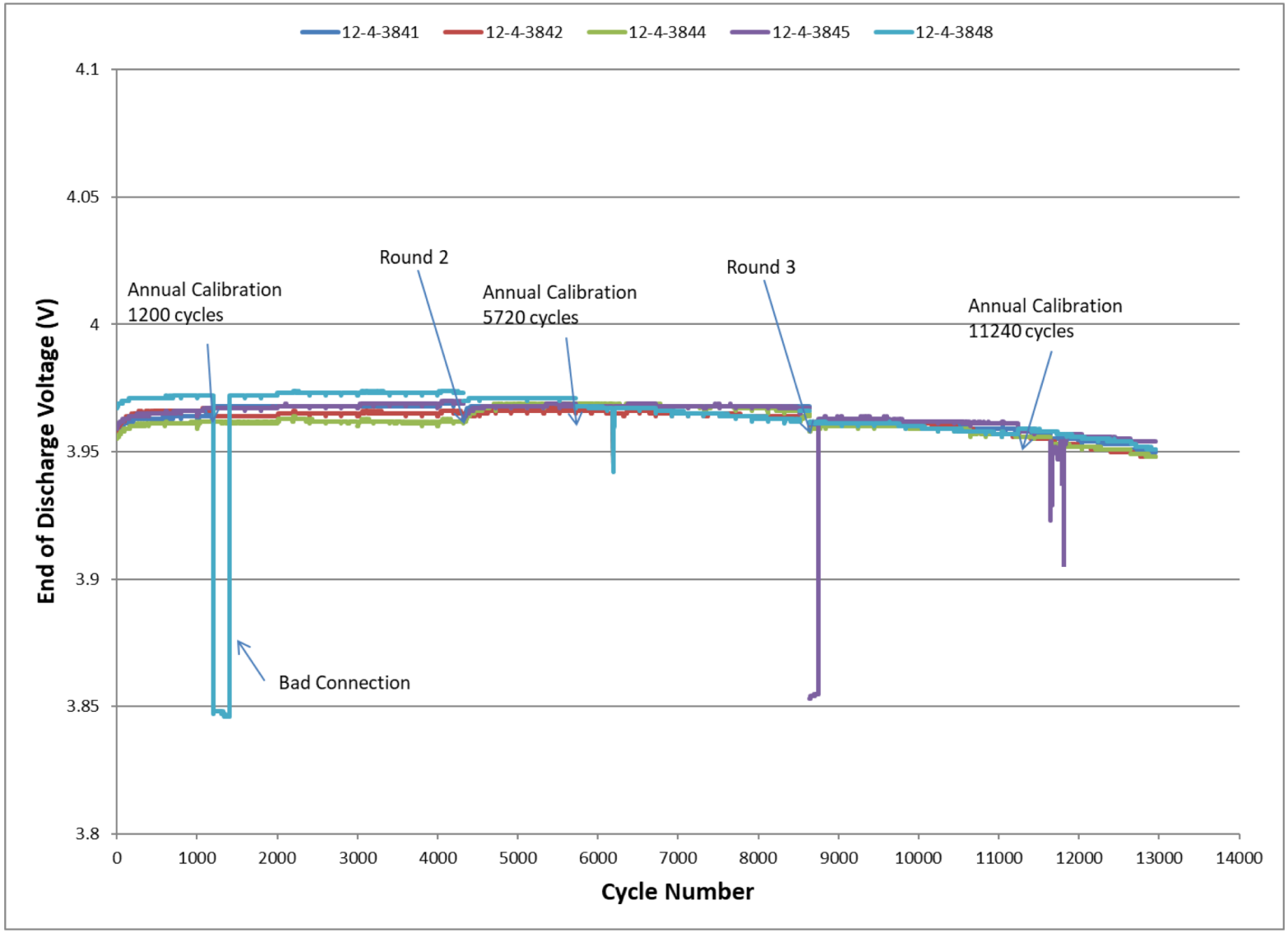
12AH LIFE CYCLING @30°C

- 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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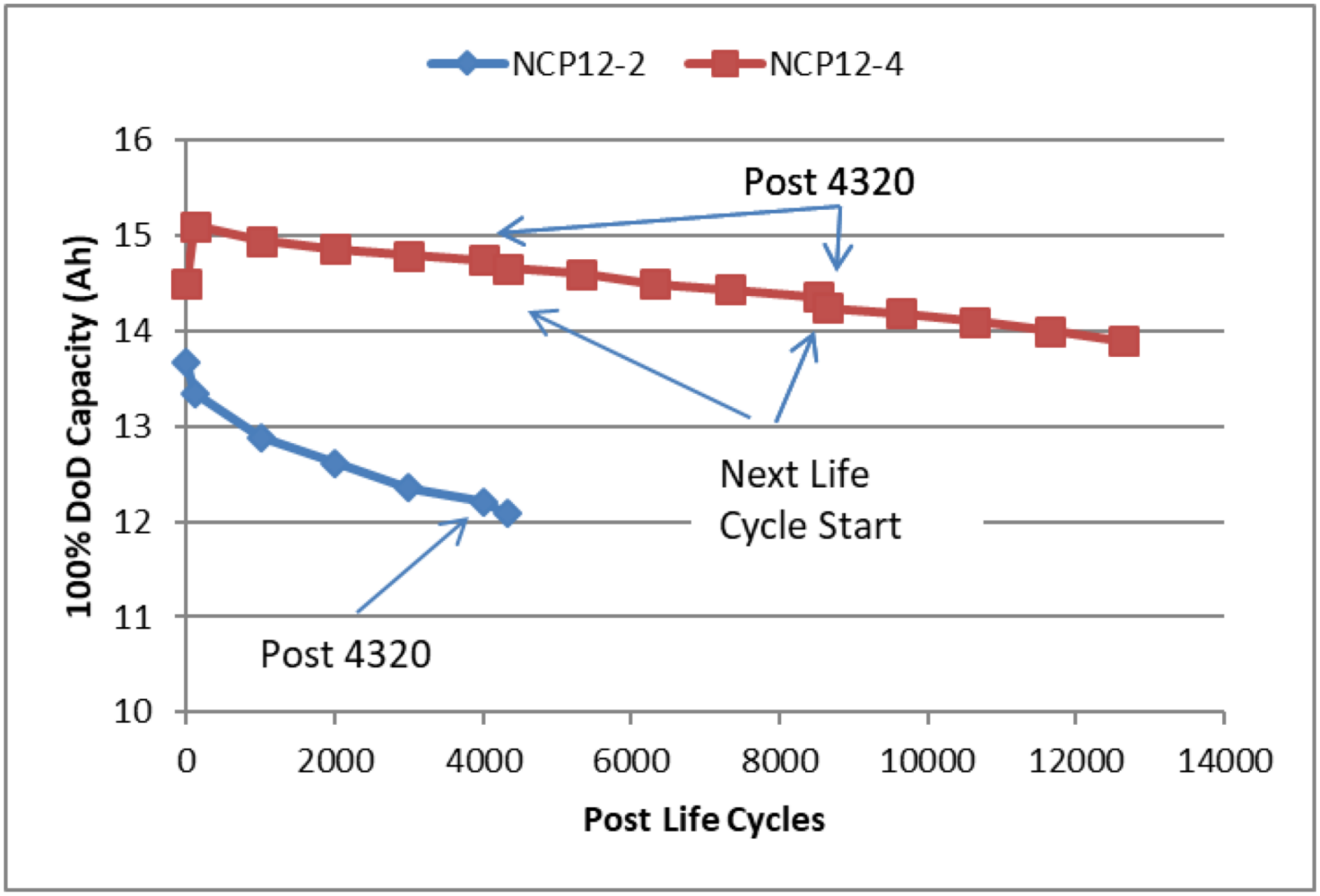
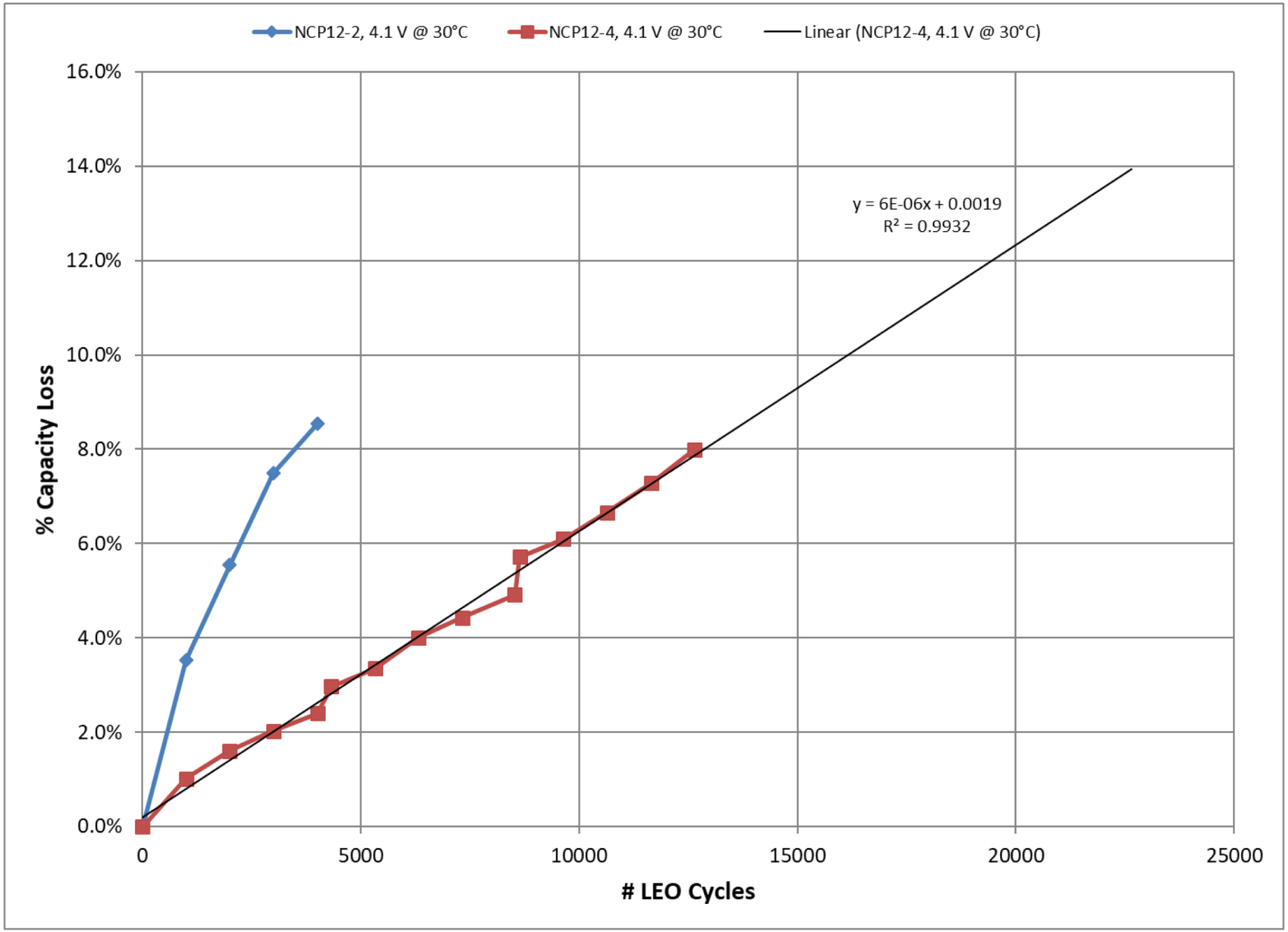
NCP12 Life Cycle Capacity Checks @30°C



NCP12 Capacity Loss Comparison



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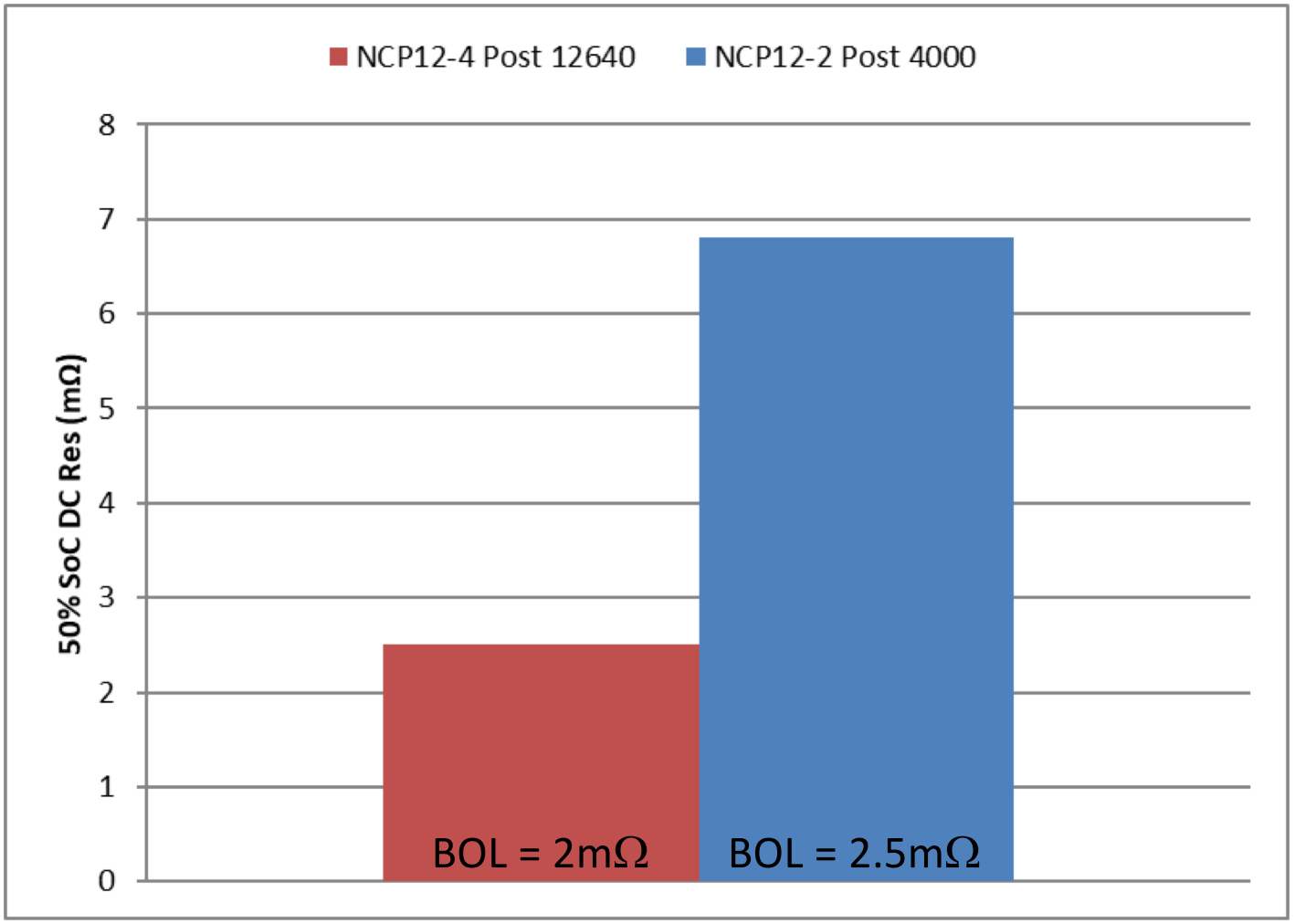
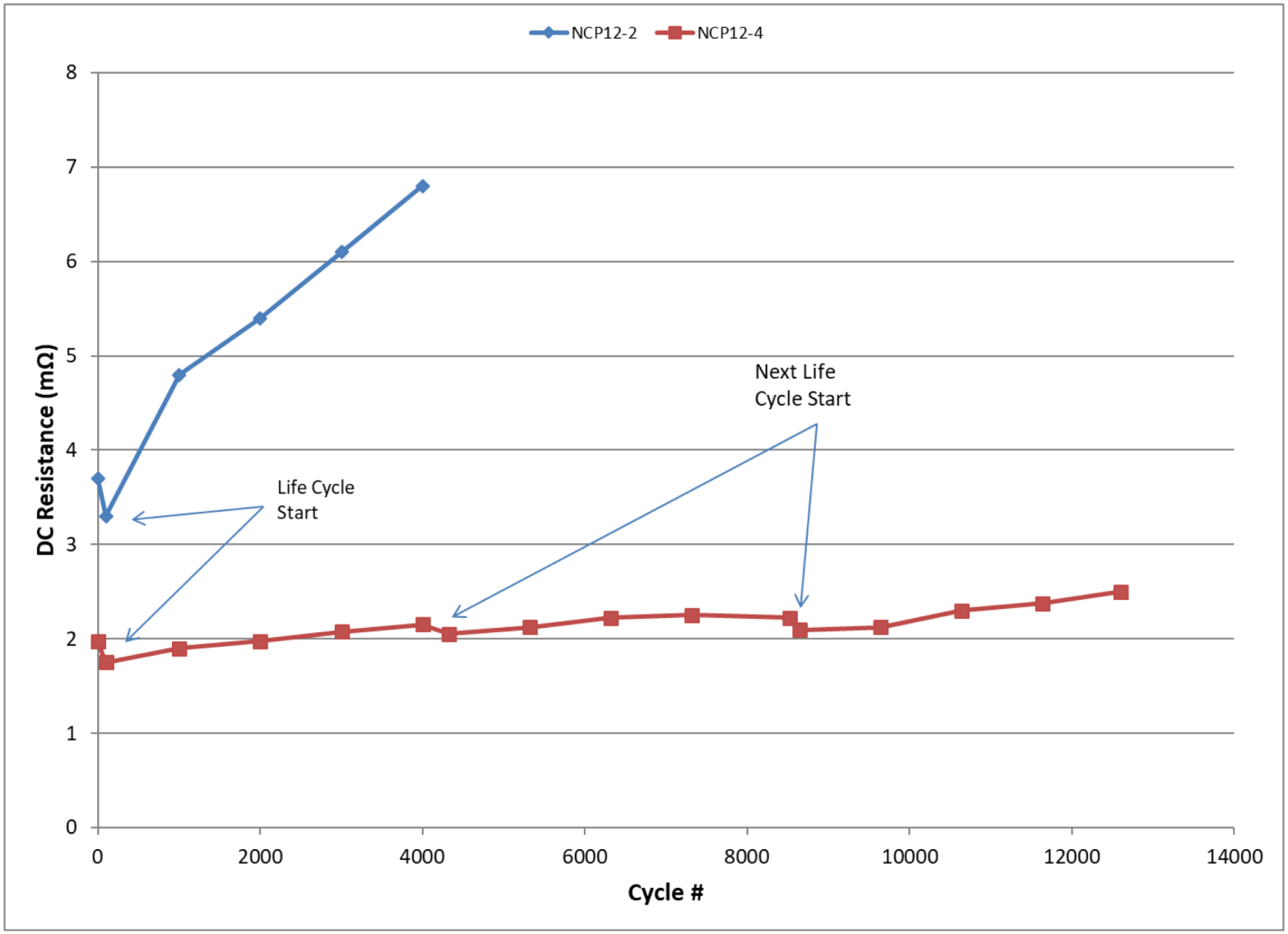
Life Cycle 50% SoC DC Res. @30°C



NCP12 DC Resistance Comparison



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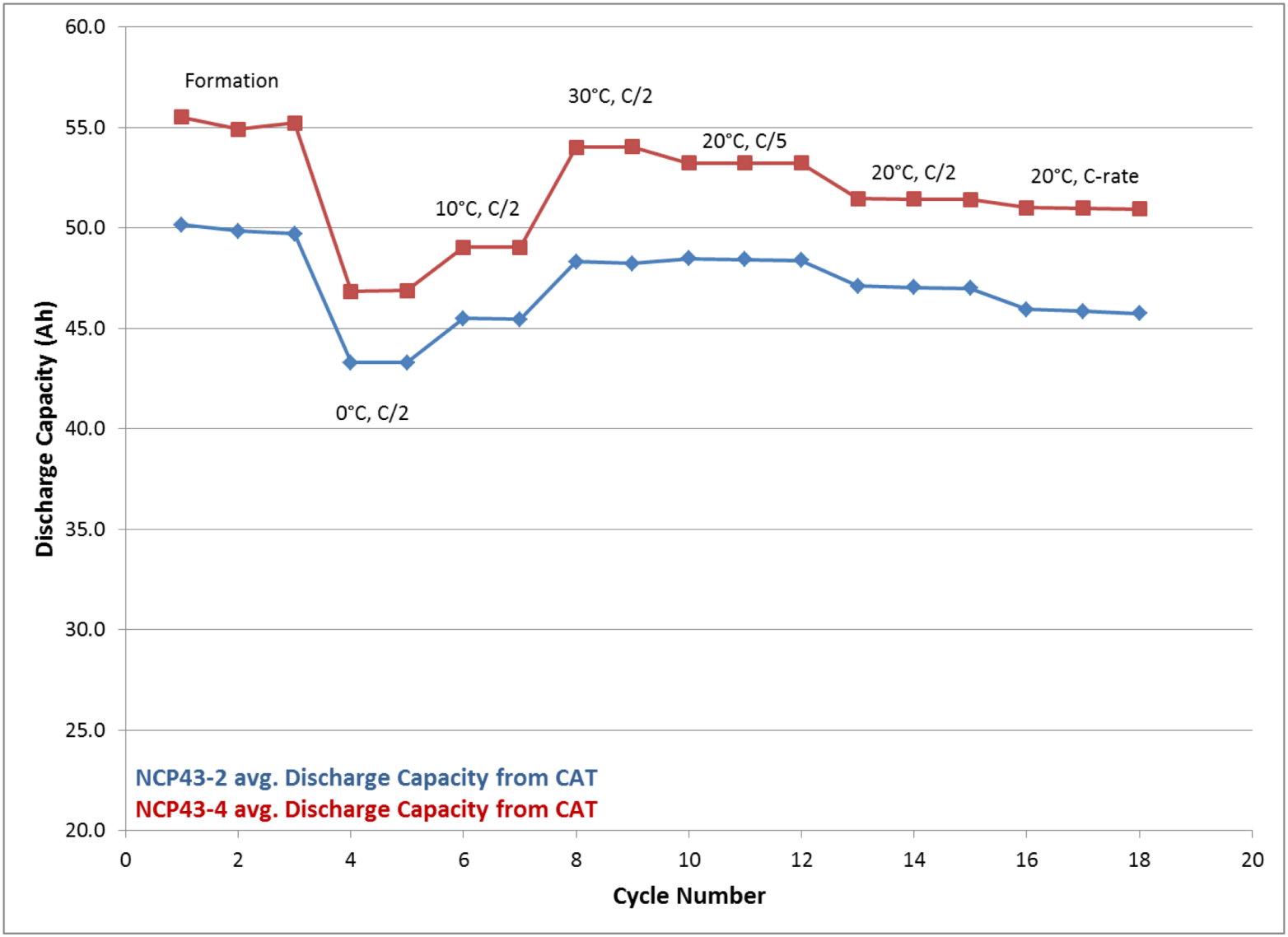
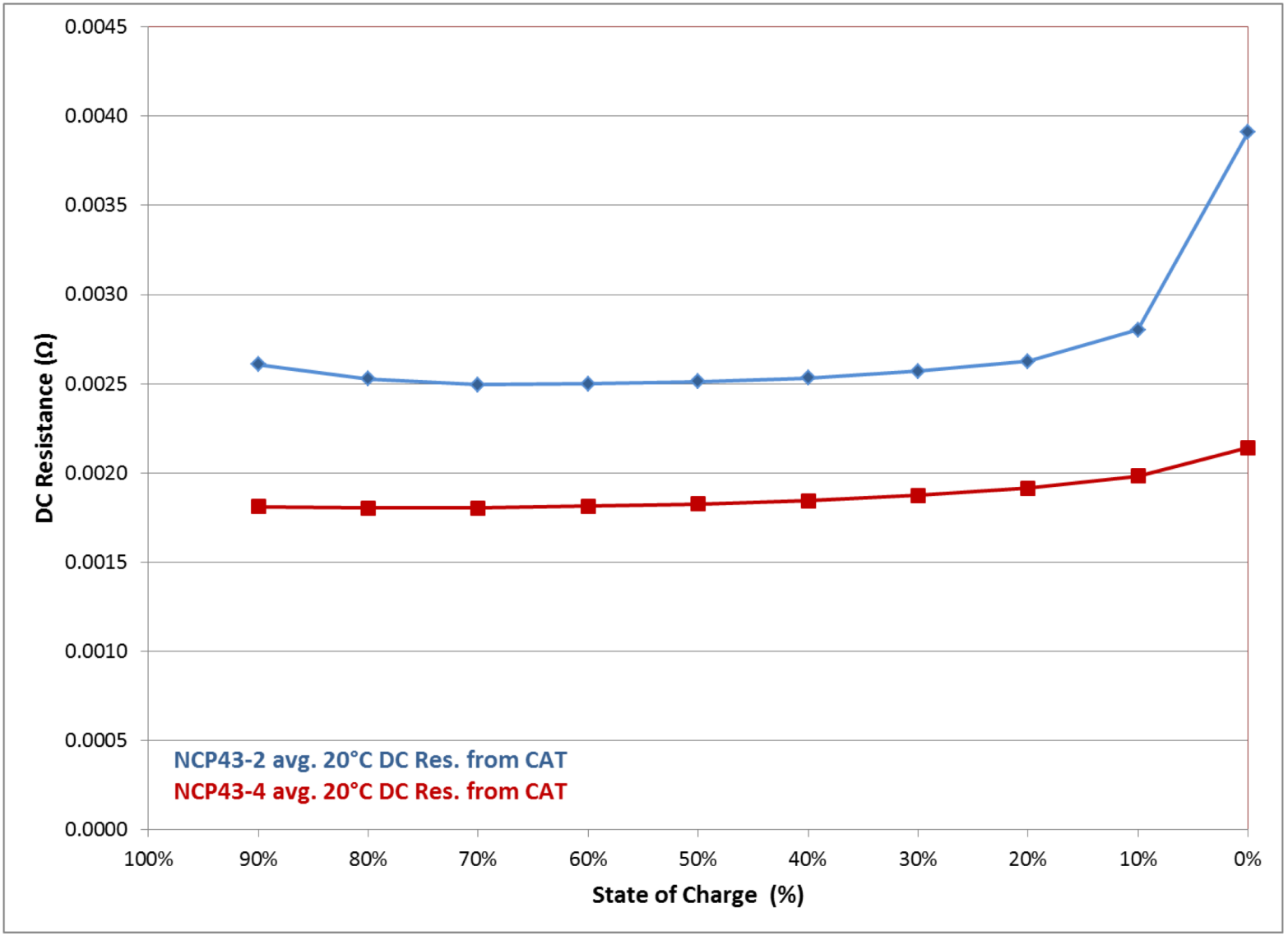
NCP43-4

BOL Test; Discharge Capacity



BOL Test; 20°C DC Resistance

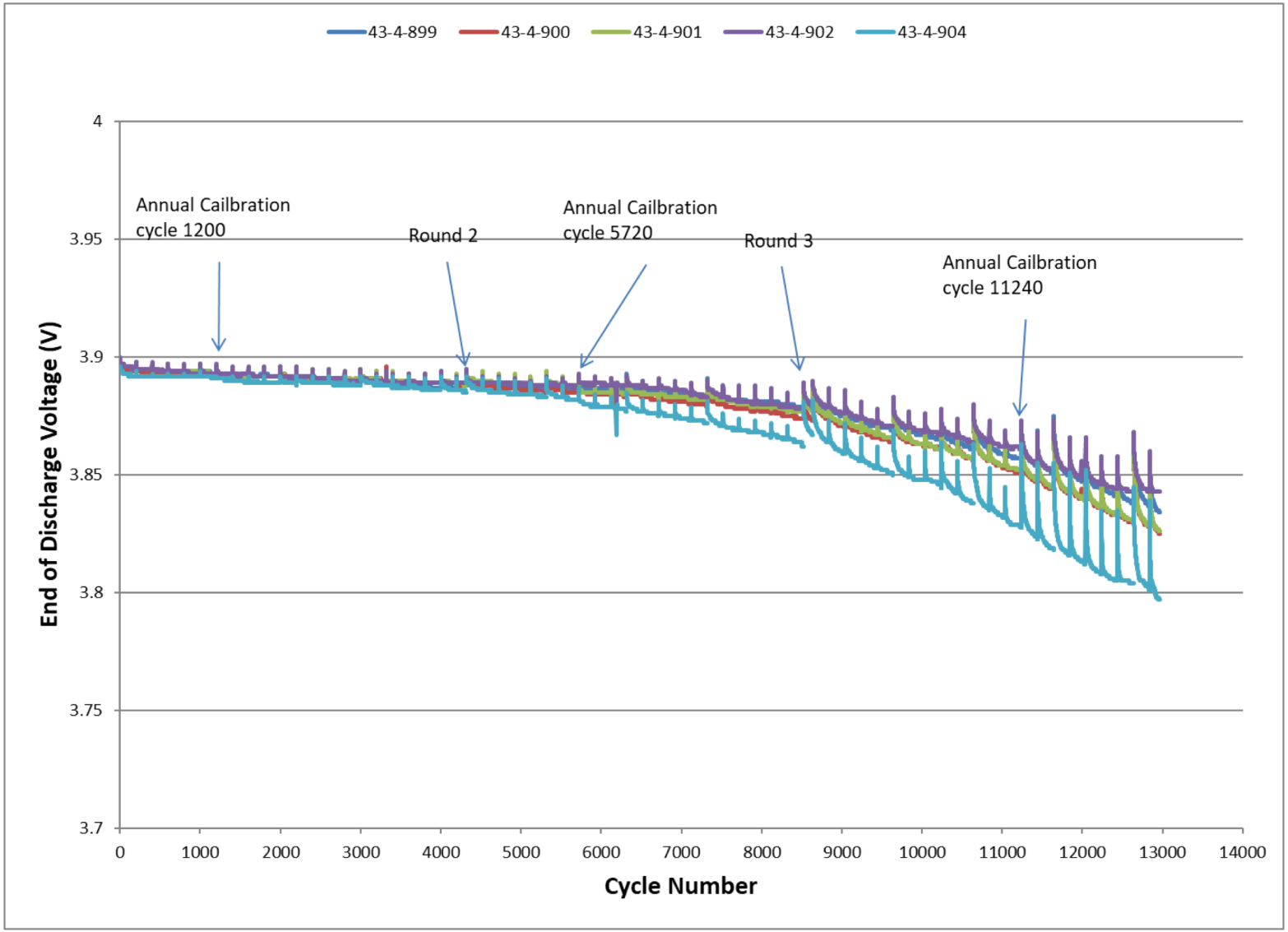


EAGLEPICHER TECHNOLOGIES

43AH LIFE CYCLING @30°C

- 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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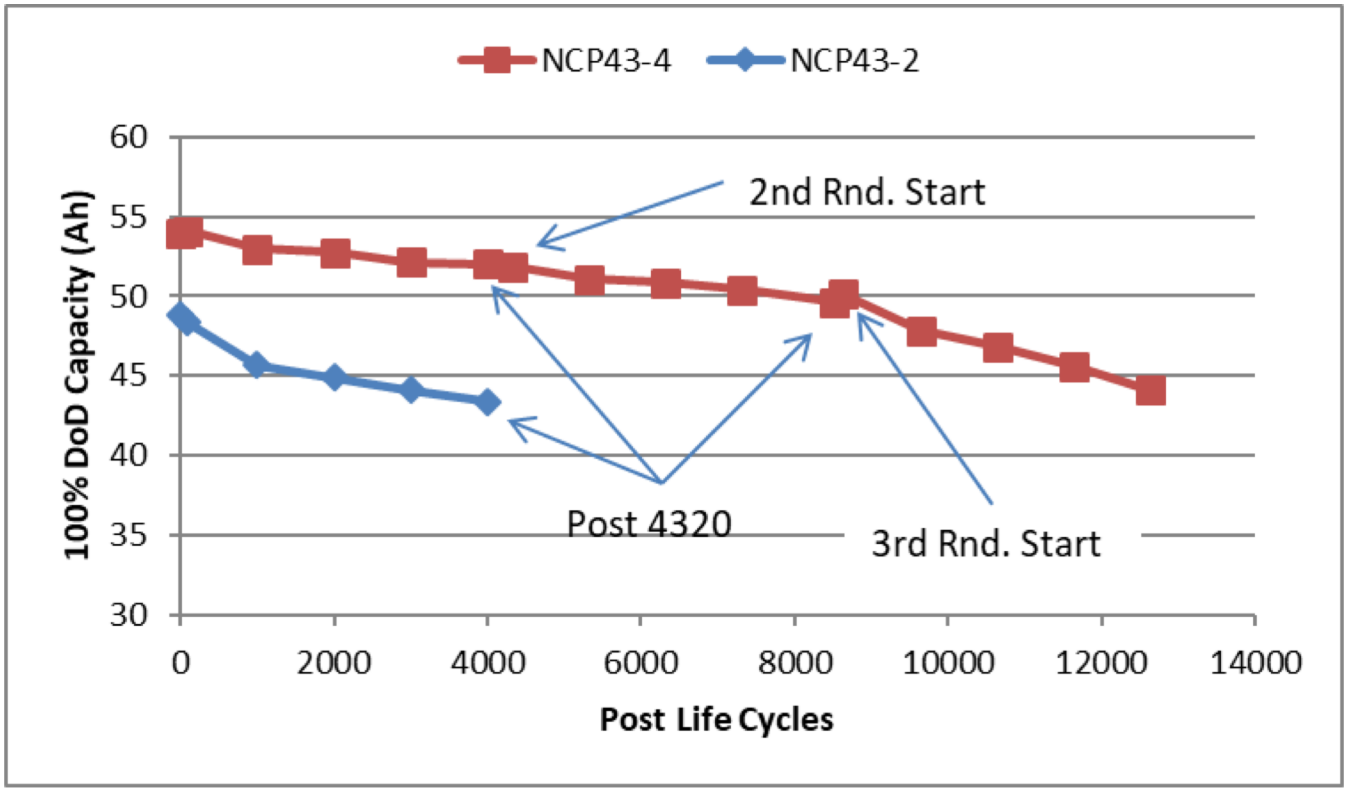
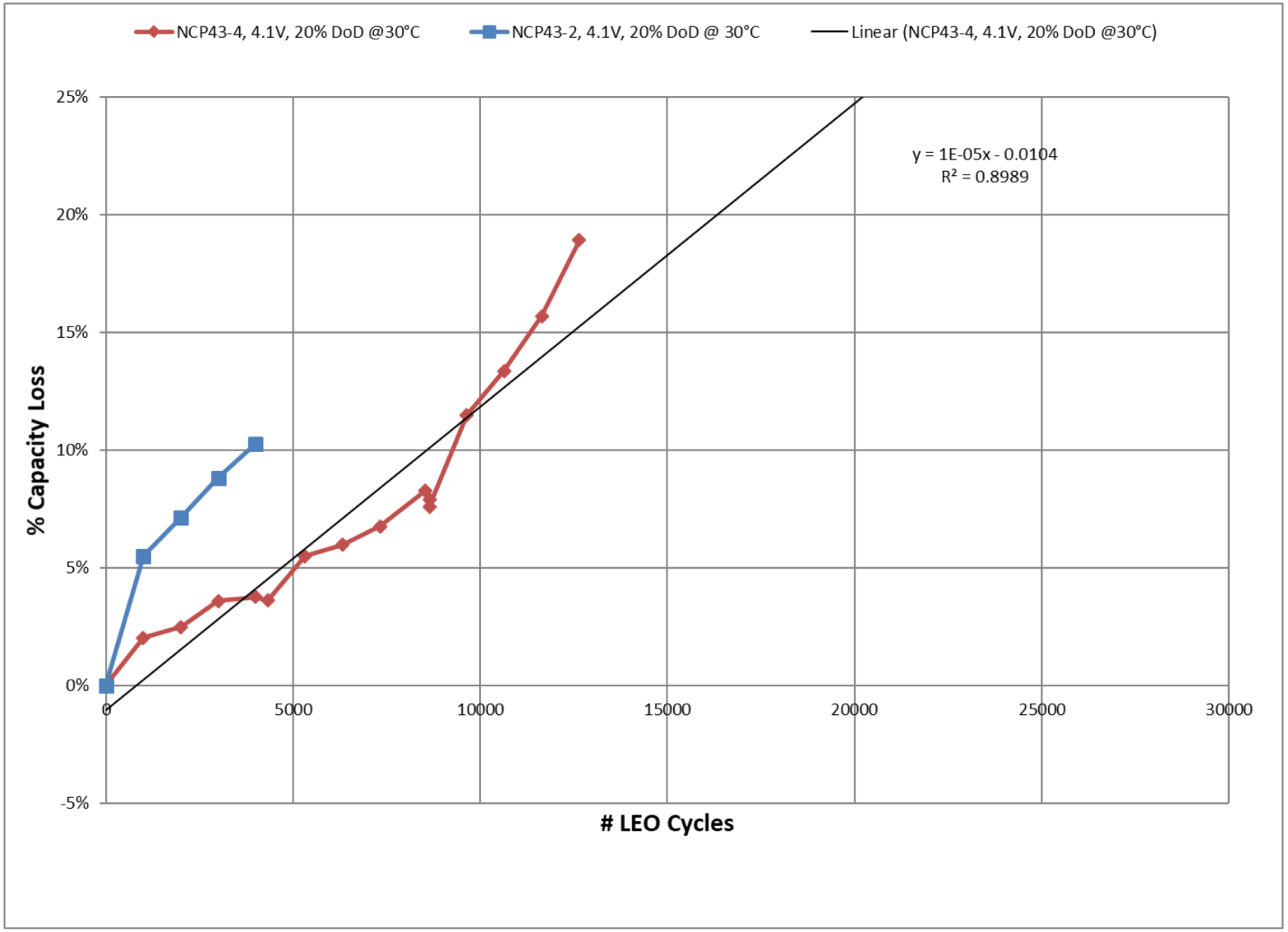
NCP43 Life Cycle Capacity Checks @30°C



NCP43 Capacity Loss Comparison



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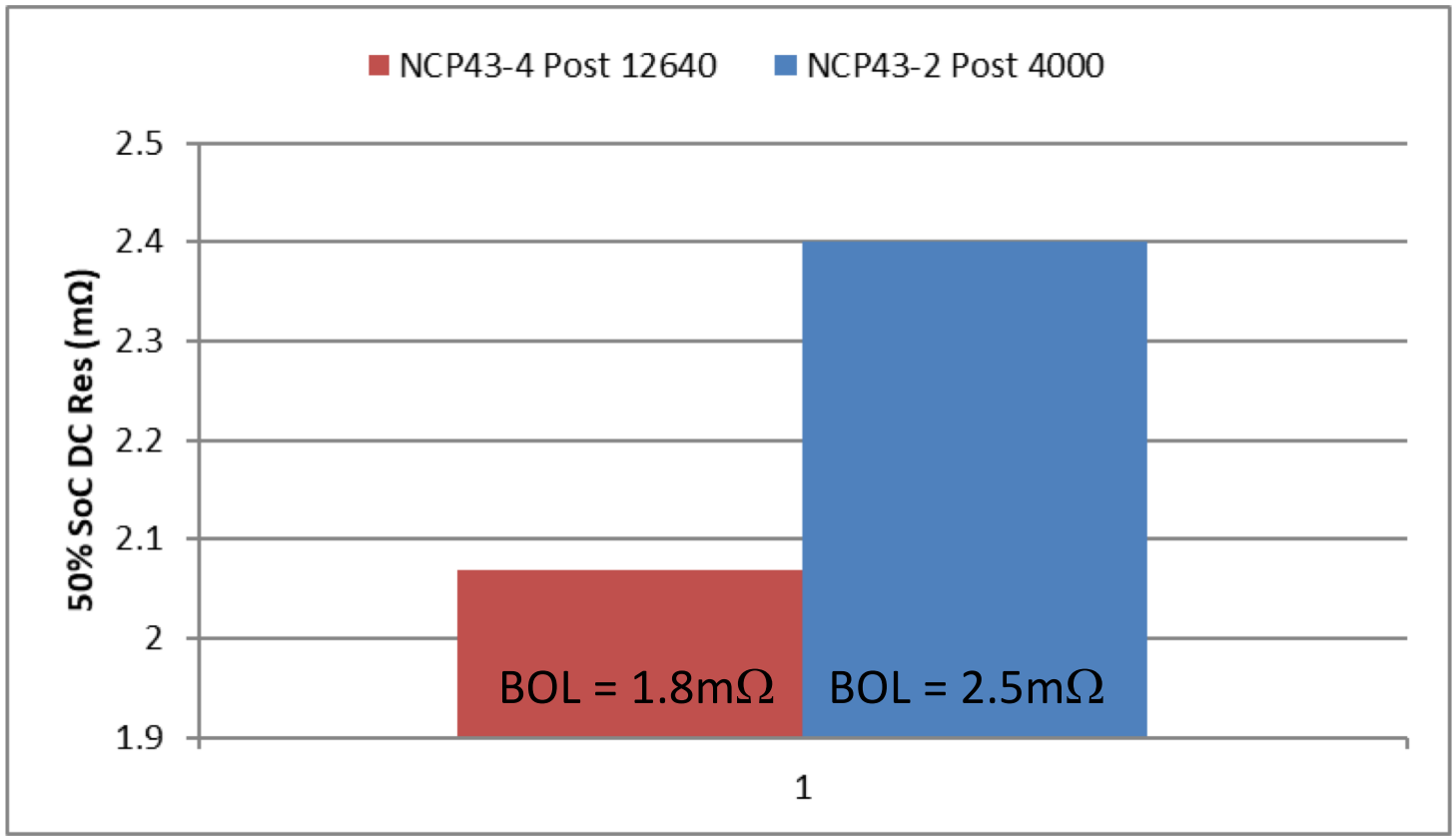
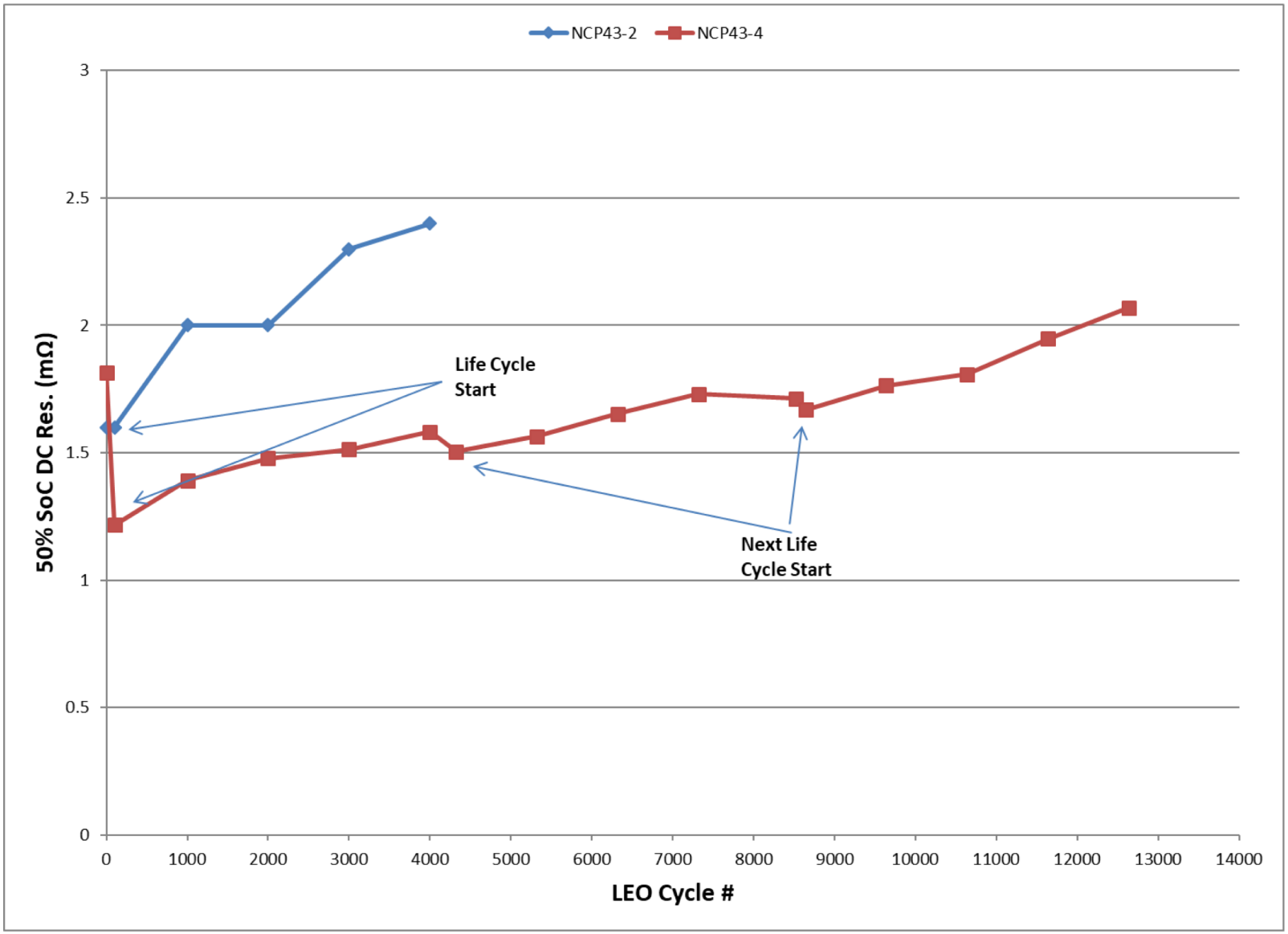
Life Cycle 50% SoC DC Res. @30°C



NCP43-4 DC Resistance Comparison



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COTS Cell Evaluations

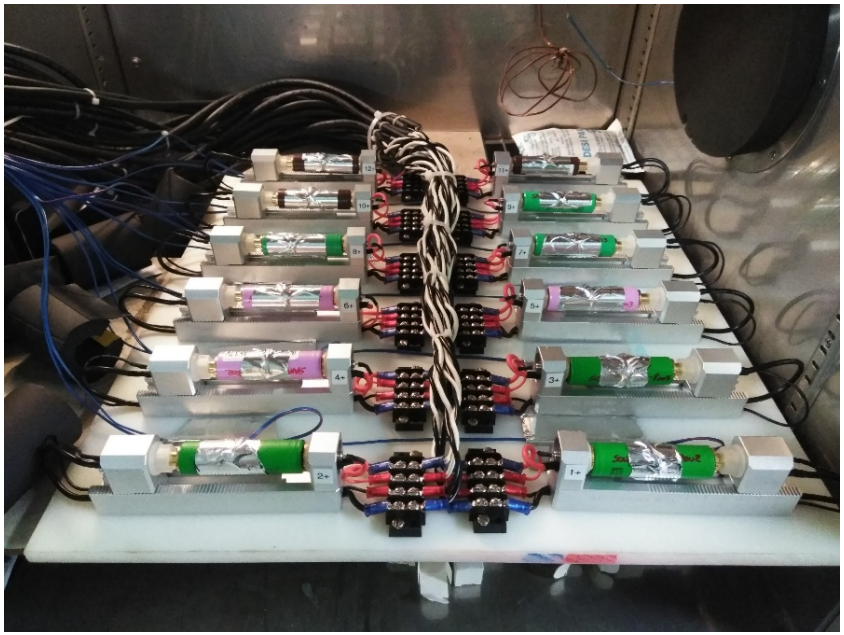
COTS EVALUATION- TEST PLAN

- CAT Tests (All Cells)
  - Use (or determine) the 1C rated capacity for C rate calculation
    - * 50% SOC should be half of the rated capacity at 1C/25°C
  - Use datasheet to select operating voltage range
  - Low Rate Continuous
    - Continuous 25°C
      - » C/5 Charge, C/5 Discharge 3 cycles, 72hr stand
      - » C/5 Charge, C/2 Discharge with DCR at 100% and ~50% SOC* (at 1hr)
      - » C/5 Charge, 1C Discharge
      - » C/5 Charge, 5C Discharge
      - » C/5 Charge, ~20A Discharge
    - Continuous 0°C
      - » C/5 Charge, C/5 Discharge 3 cycles
      - » C/5 Charge, C/2 Discharge with DCR at 100% and ~50% SOC* (at 1hr)
      - » C/5 Charge, 1C Discharge
      - » C/5 Charge, 5C Discharge
      - » C/5 Charge, ~20A Discharge
    - Continuous -20°C
      - » C/5 Charge, C/5 Discharge 3 cycles
      - » C/5 Charge, C/2 Discharge with DCR at 100% and ~50% SOC* (at 1hr)
      - » C/5 Charge, 1C Discharge
      - » C/5 Charge, 5C Discharge.
      - » C/5 Charge, ~20A Discharge

COTS EVALUATION- TEST PLAN CONT.

- *40% DoD LEO Life Cycling @ 20°C*
  - » *Characterization Cycles @20°C (4.1 V to 3.0V)*
    - » C/5 Charge, C/5 Discharge (3 cycles)
    - » C/5 Charge, C/2 Discharge with DCR at 10% increments until 0% SoC
  - Start LEO Cycle
    - » C/5 to 4.0V tapered to C/10
  - LEO Cycles
    - » 0.8C Discharge for 30 minutes
    - » C/2 Charge for 60 minutes tapering current to 4.0V
    - » Repeat the LEO discharge/charge cycling in 200 cycles have completed
    - » Once 1000 LEO cycles have completed repeat *Characterization Cycles*
    - » Continue LEO cycling and *Characterization Cycles until…?*
- *HOLD cells here until any mission specific testing is considered.*
- Cell DPA, Document Construction

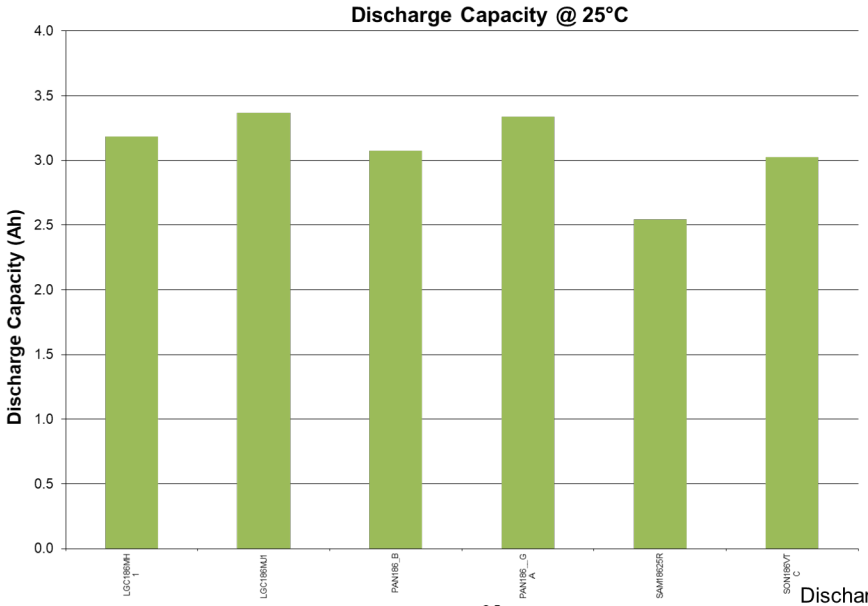
SETUP FOR COTS EVALUATION

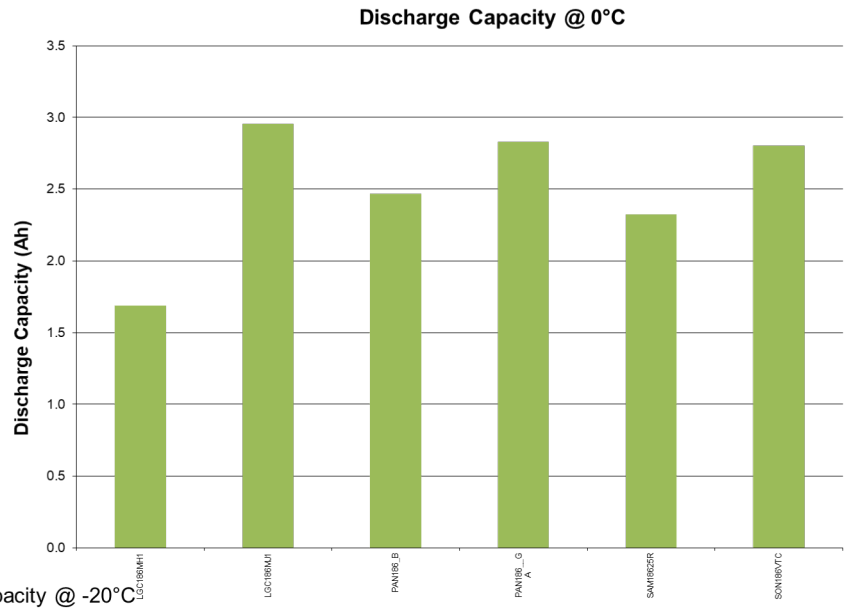


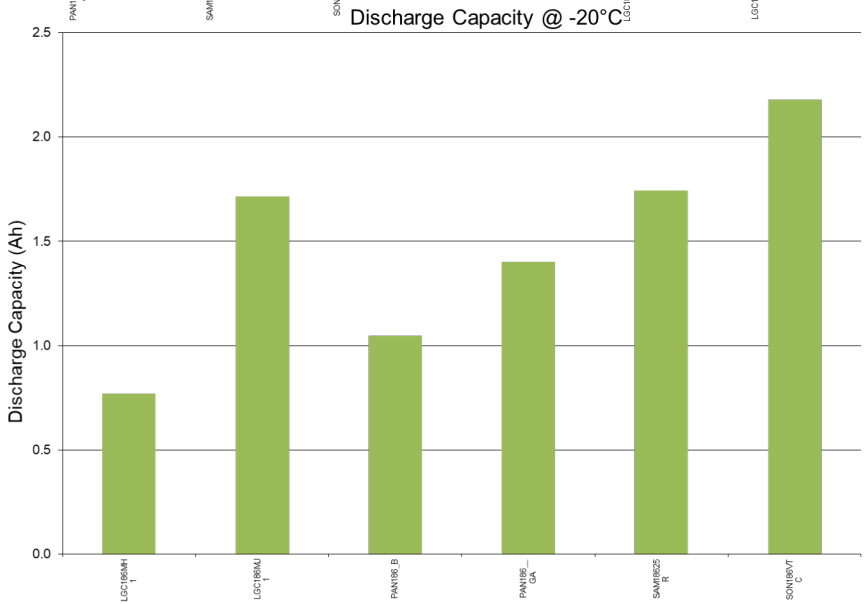
12-cell test fixture

Foam Insulation

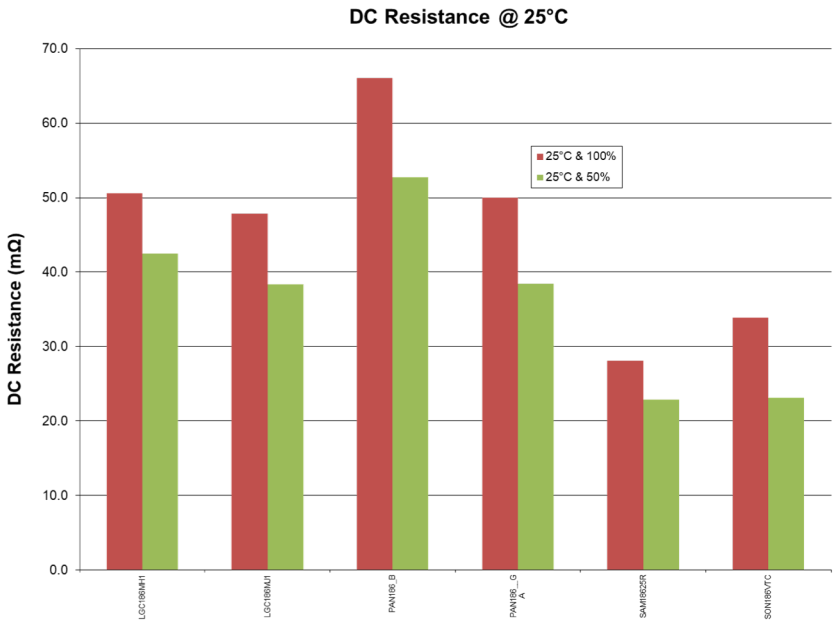
CAPACITIES @ VARIOUS °C

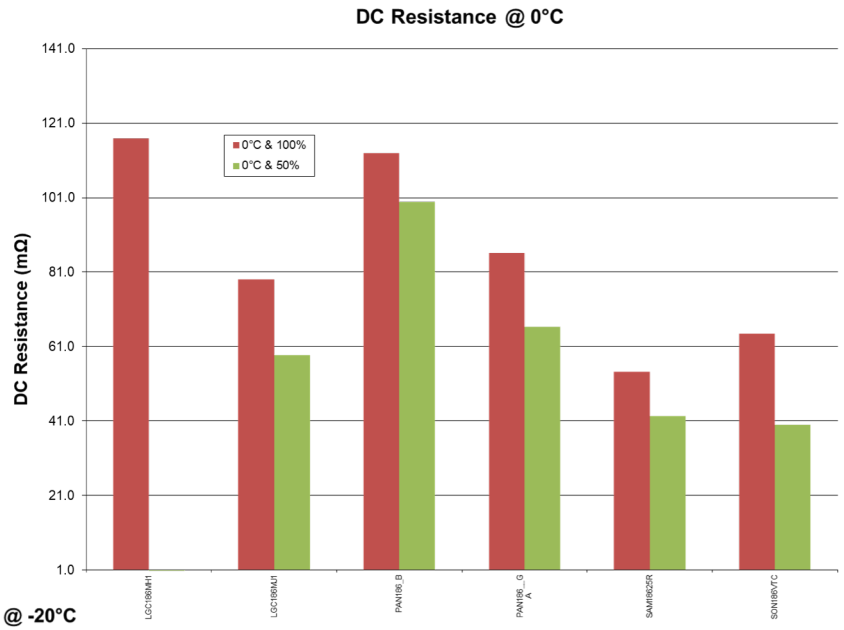


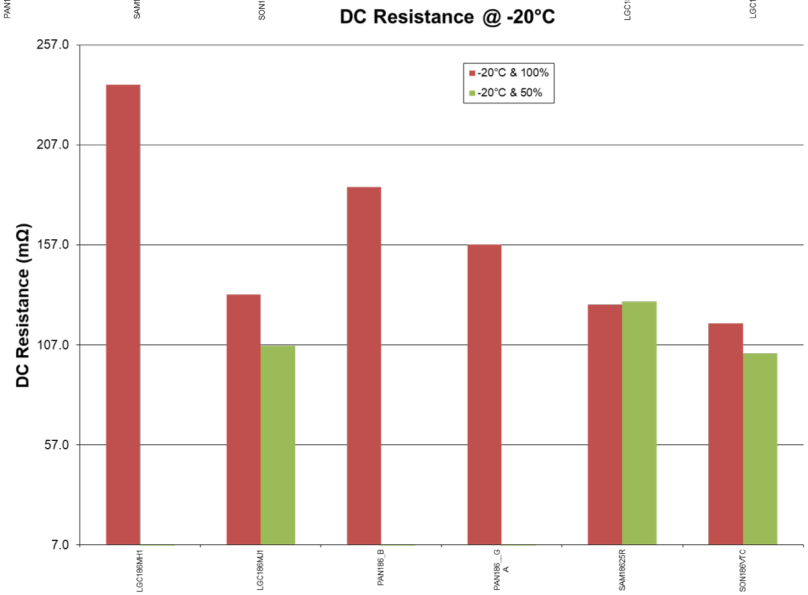




DC RESISTANCE @ VARIOUS °C







ONGOING AND FUTURE WORK

- 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.
- COTS solutions are being developed for certain applications.

Thank You

Thanks to all the employees at EaglePicher




To learn more visit www.eaglepicher.com.

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