NSWC Crane Nickel-Zinc Testing and Evaluation

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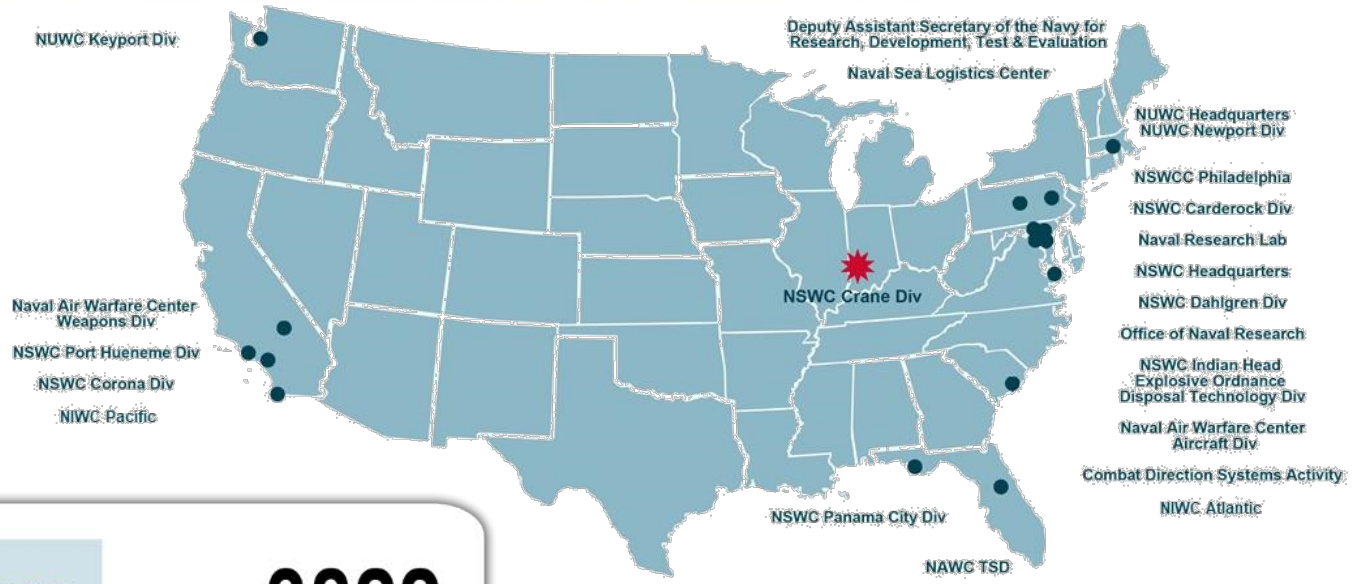

QUICK FACTS

$3.024B Economic Impact

1 MISSION

3822 NSWC Crane Employees

3 MISSION AREAS


Strategic Missions


Expeditionary Warfare


Electronic Warfare

65% Scientists, Engineers, & Technicians

141 Doctorate
720 Masters
1,819 Bachelors

Aggressive RESEARCH, DEVELOPMENT, TEST & EVALUATION for Reliable Real World Solutions

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POWER AND ENERGY DIVISION




- **Battery Technology In-Service Engineering and Testing**
- **Requirements Development, Design, Prototyping and Limited Mfg.**
- **Test and Evaluation**
- **Safety Certification**
- **Technology Evaluation and Insertion**
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The **Power & Energy Systems Division** is a technology leader providing expertise for electrochemical power systems, power management systems, electronic interconnect technology products (printed circuit boards and printed wiring assemblies), and alternative energy systems.

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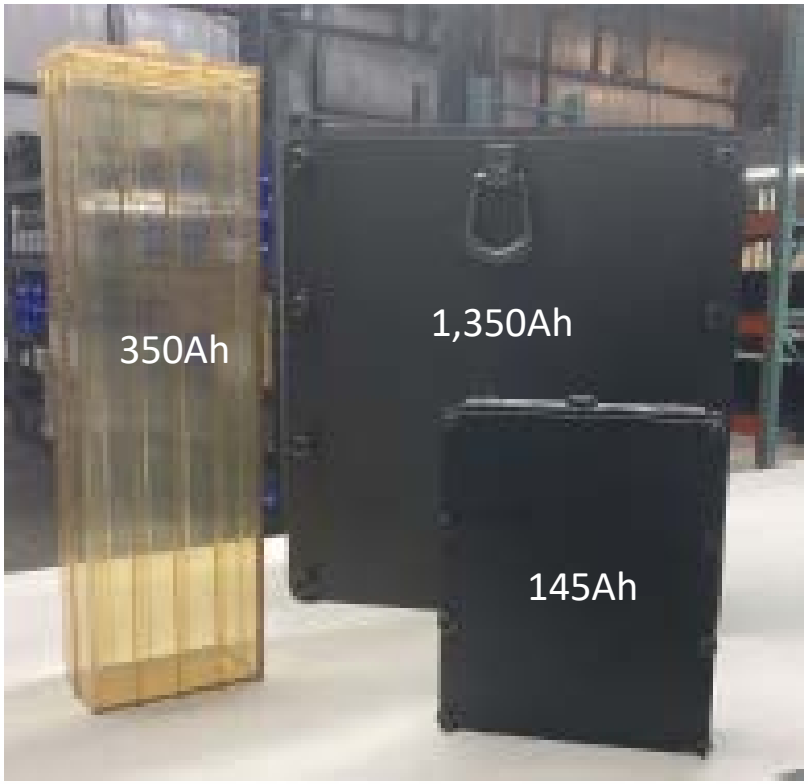
Æsir Technologies, Inc.

ZAF/ÆSIR NIZN EVALUATION

- Many benefits of NiZn – Safety and Performance are important for submarine app.
- Evaluating ZAF/Æsir small-format designs for performance and characterization
- Evaluations include OCL, Float Only, Rate Characterization, and Safety Testing
- Continuing work with Æsir on cell design optimization, safety and performance testing, and scaling to mid-and-large-format cells
- Finalizing requirements, design, and large-format prototypes – engaged with NAVSEA PMS-450, SUB 073, and SEA 05Z in development/integration



Æsir Coating Line

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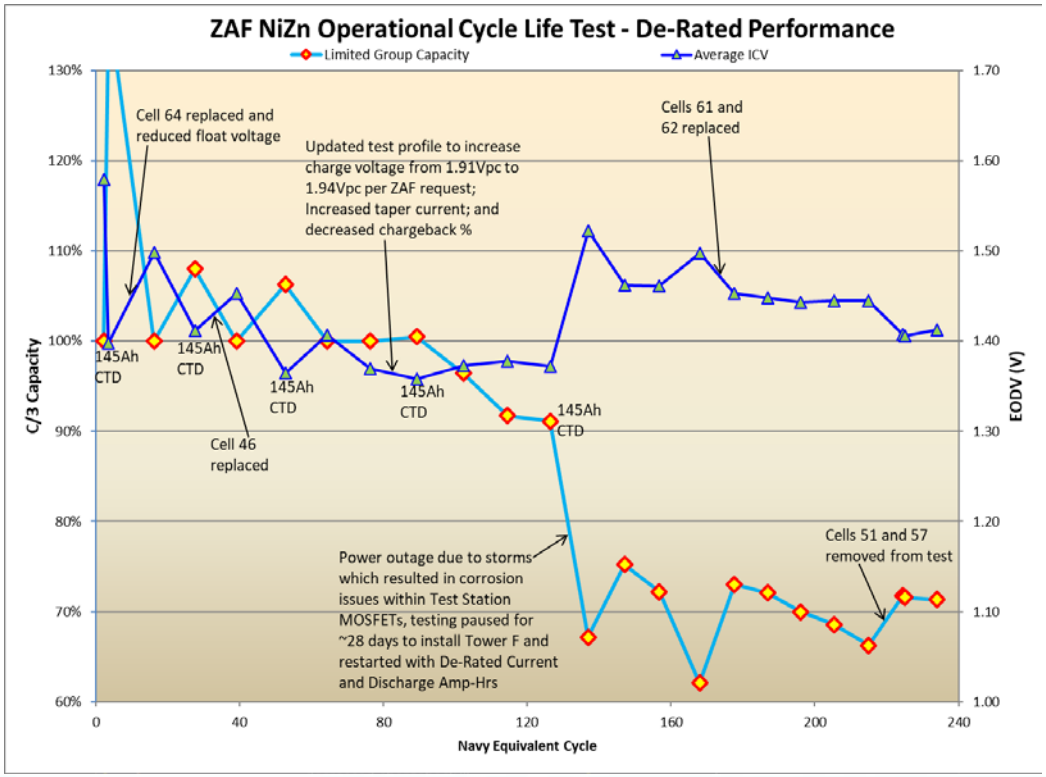
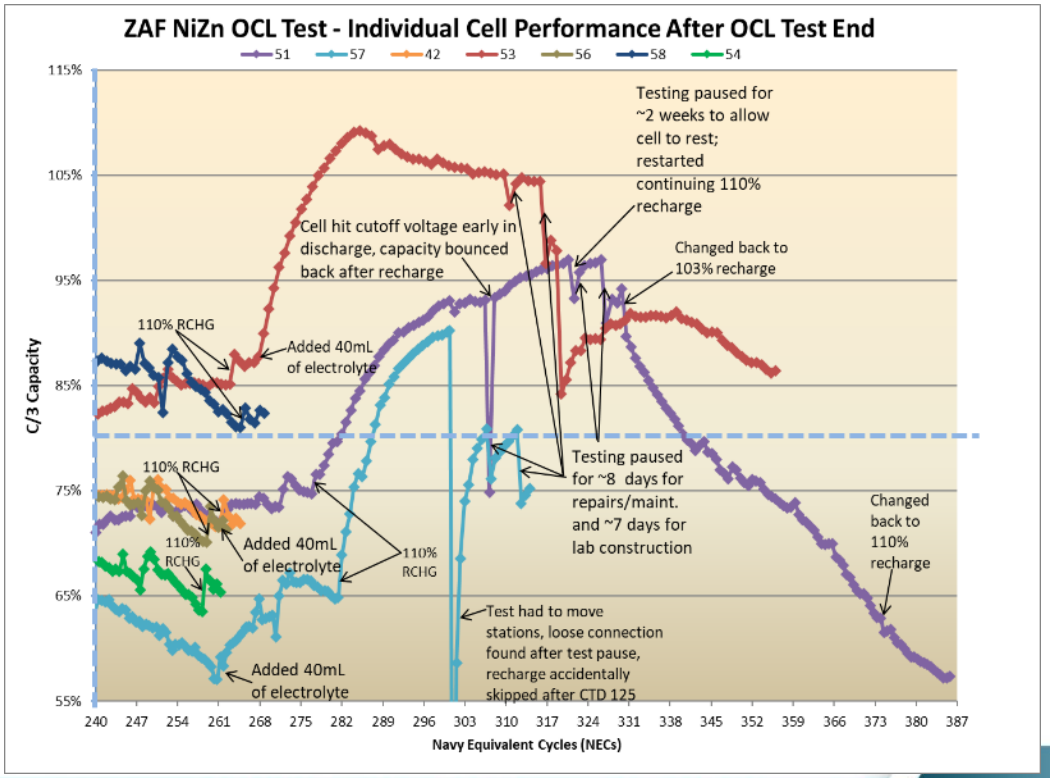
ÆSIR OCL 1 TEST

- OCL 1 ran for 2.5 years as 10 cell circuit; further cycling on individual cells
- Determine performance of cells through modified OCL profile
- Modified test profile through float voltage and changes in charge operation
- No shorts or zinc migration found during cell dissections throughout all tests
- Several cells showed 80% – 100% capacity performance after removal
- Multiple OCL tests being run with variations of test profile & cell connections





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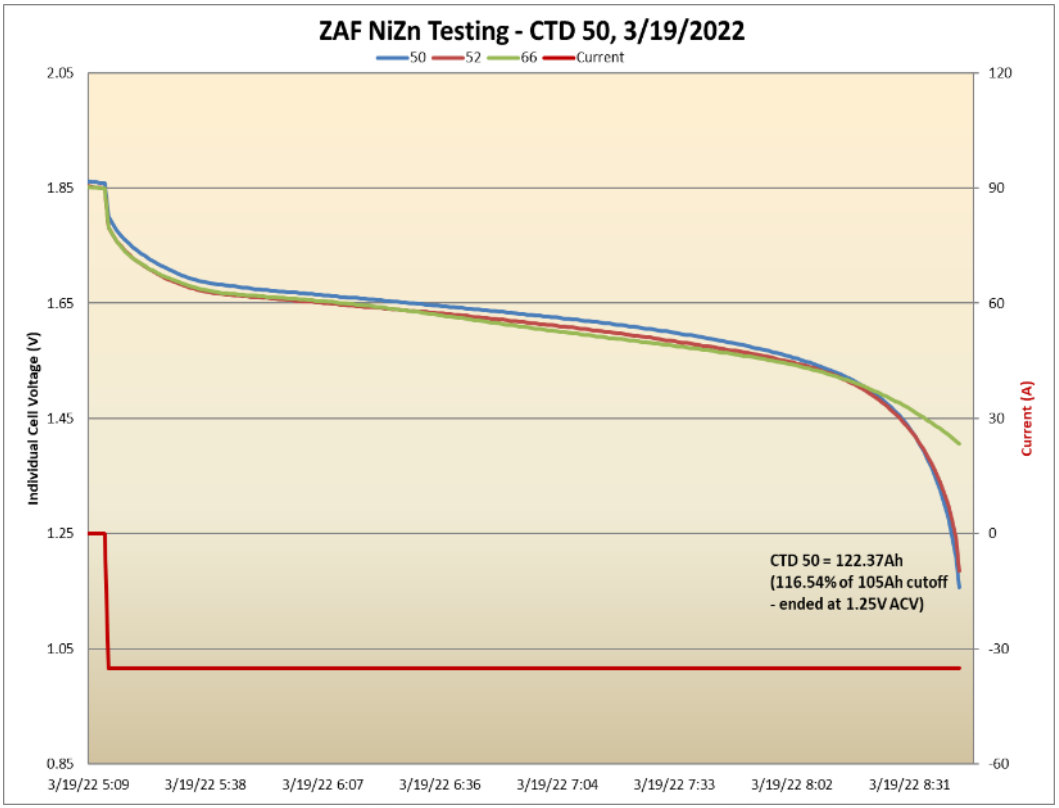
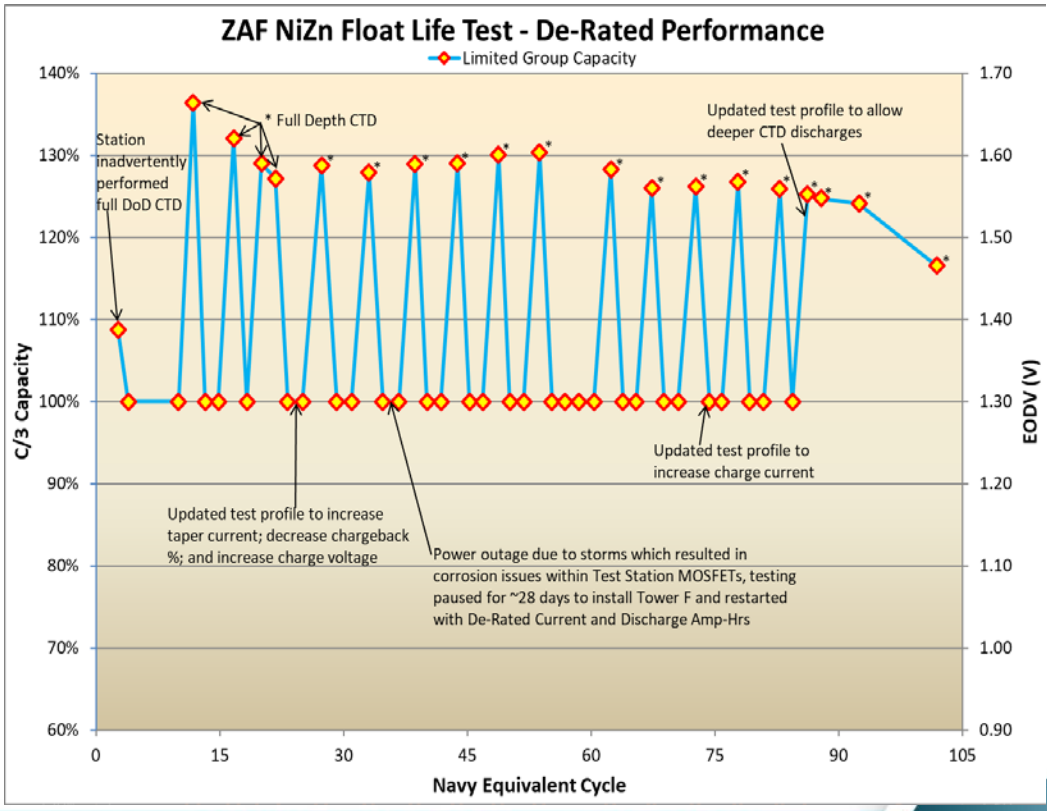
ÆSIR FLOAT TEST

- Determine performance through float only profile with monthly discharges
- Status: Test recently ended – 4 years on test / 103 Navy Equivalent Cycles (NECs)
- Occasional full depth of discharge cycling performance >100%
- Continued >100% performance – 50 Capacity Test Discharges (CTD) and 49 months of float cycling
- Demonstrates NiZn cells operate well on float – dissections revealed dry cells





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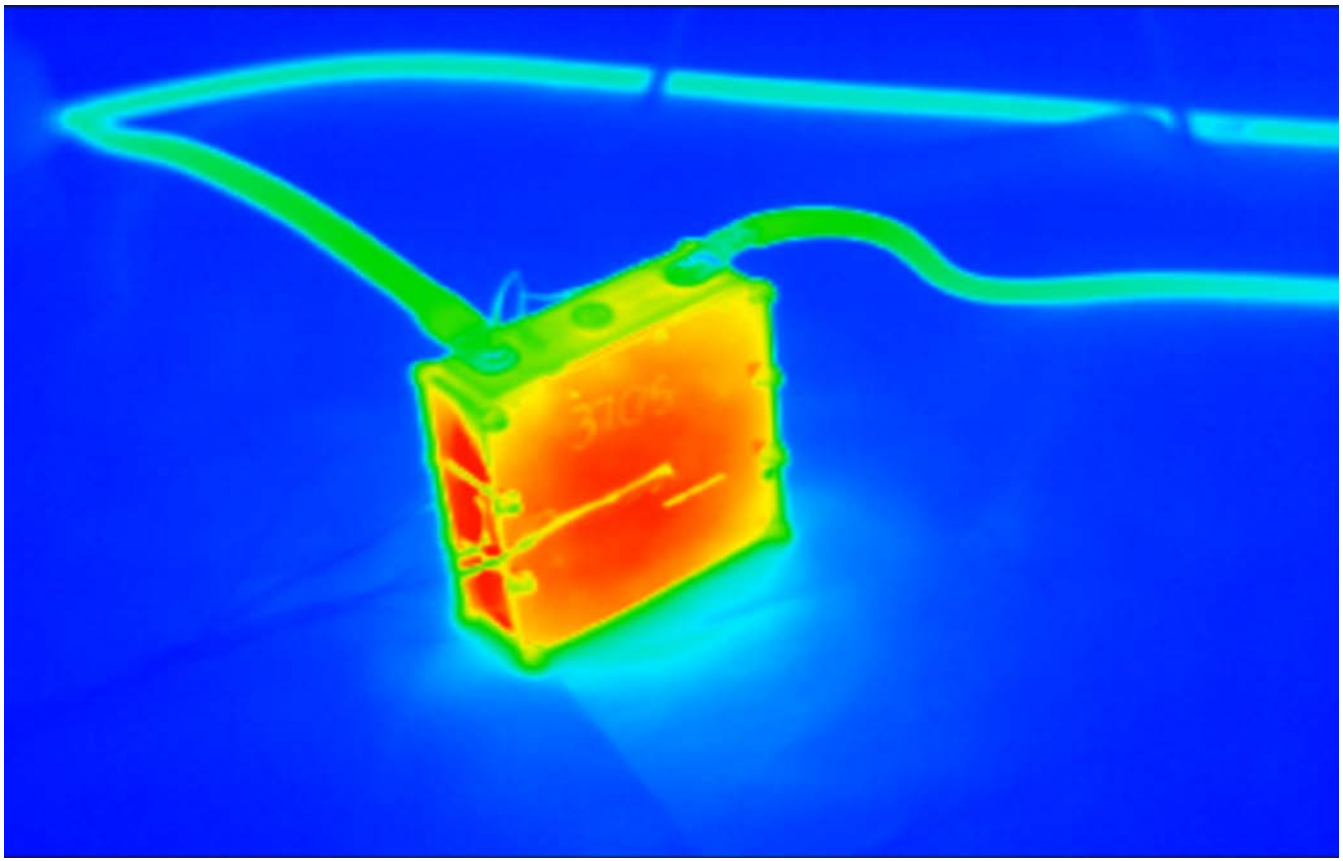
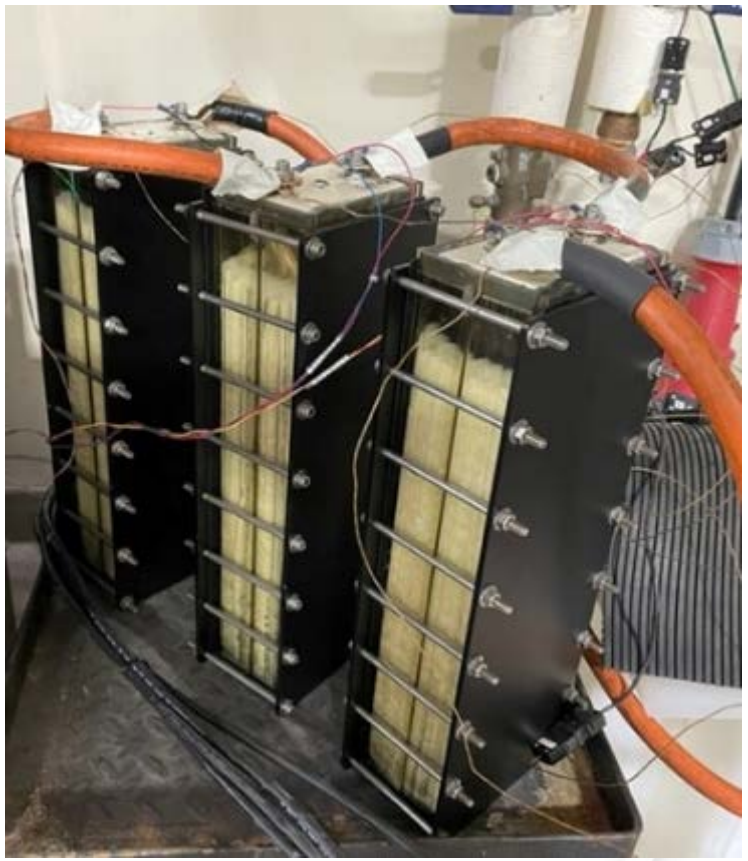
NIZN SAP PROJECTS

- Project 1 – NiZn cells for further Submarine Performance Testing – Completed Nail Penetration, Short Circuit, Overcharge (Safety Testing); OCL 4 ongoing testing in progress
- Project 2 – Prototype small-format NiZn cells for Design Optimization Testing – ongoing OCL testing in progress for design variant groups (x5)
- Project 3 – Prototype design analysis for a scaled NiZn cell (350Ah) – Characterization Testing Completed and OCL 4 Testing in progress



Short Circuit Test



Mid-Format OCL Test

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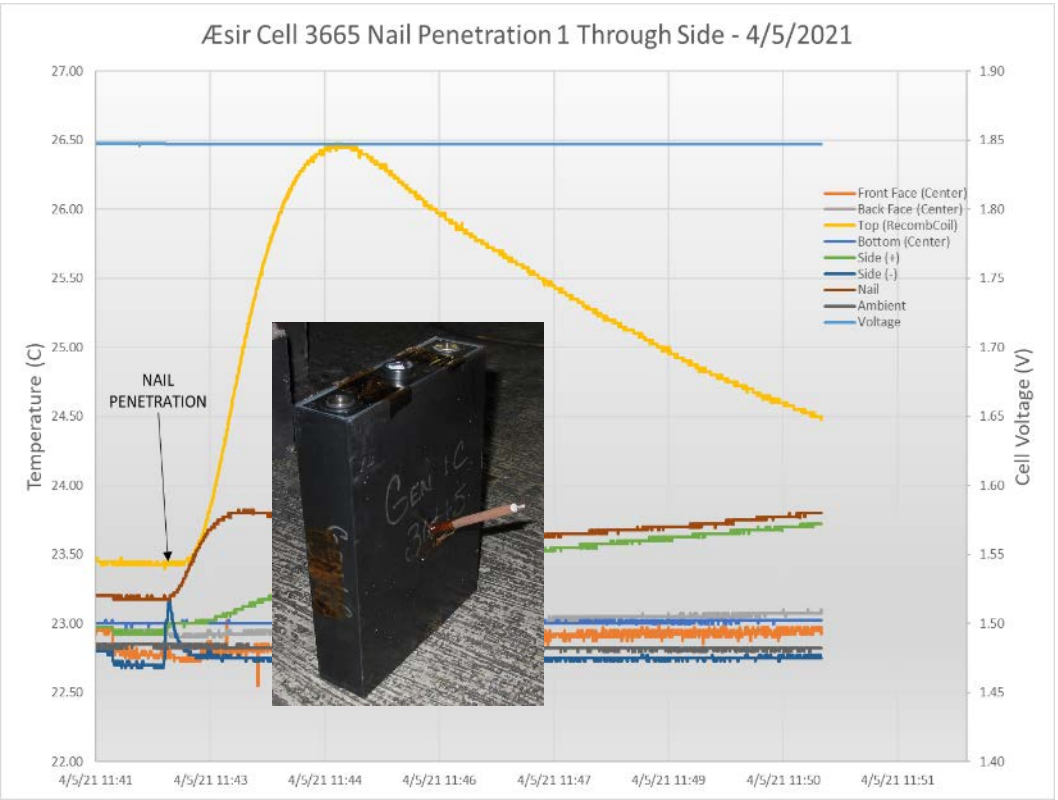
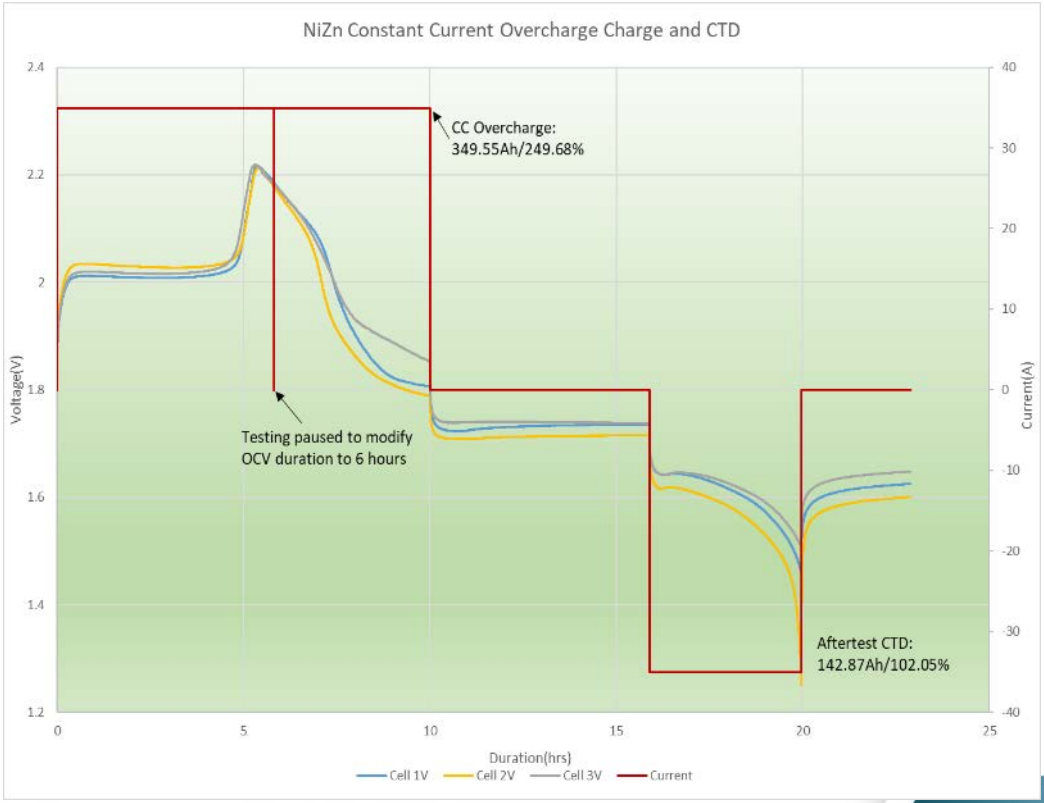
SAFETY TESTING SUMMARY

- Four nail penetration tests completed – no aggressive discharging events in any of the tests – 3/4 nail penetrations remained at healthy Open Circuit Voltage (OCV) 48hrs+
- Short Circuit testing current was -1045A and then tapered down while cell slowly discharged (minimum was 1010A) – 3/3 tests all with same results
- Constant Voltage (CV) Overcharge – two cells vented liquid electrolyte 40+ hrs
  - Approximately 1349Ah (964%) were charged throughout four CV holds
- Constant Current (CC) Overcharge – 350Ahs (250%) charged; all three cells vented





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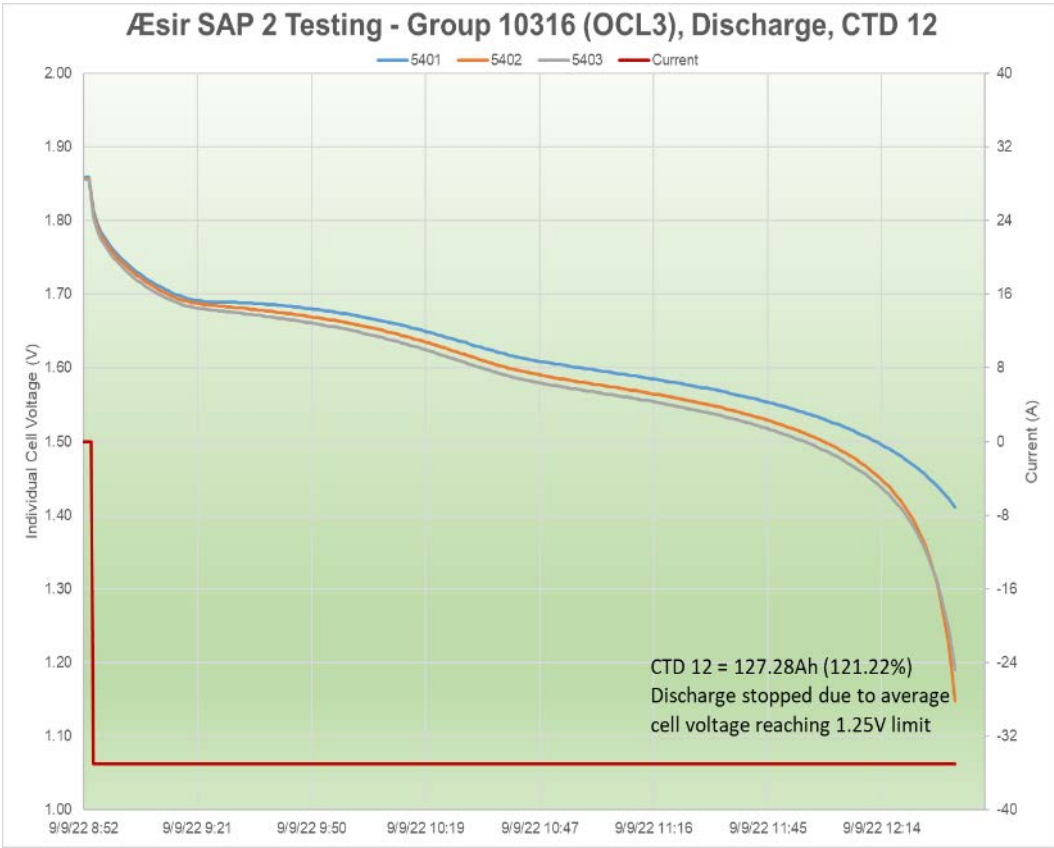
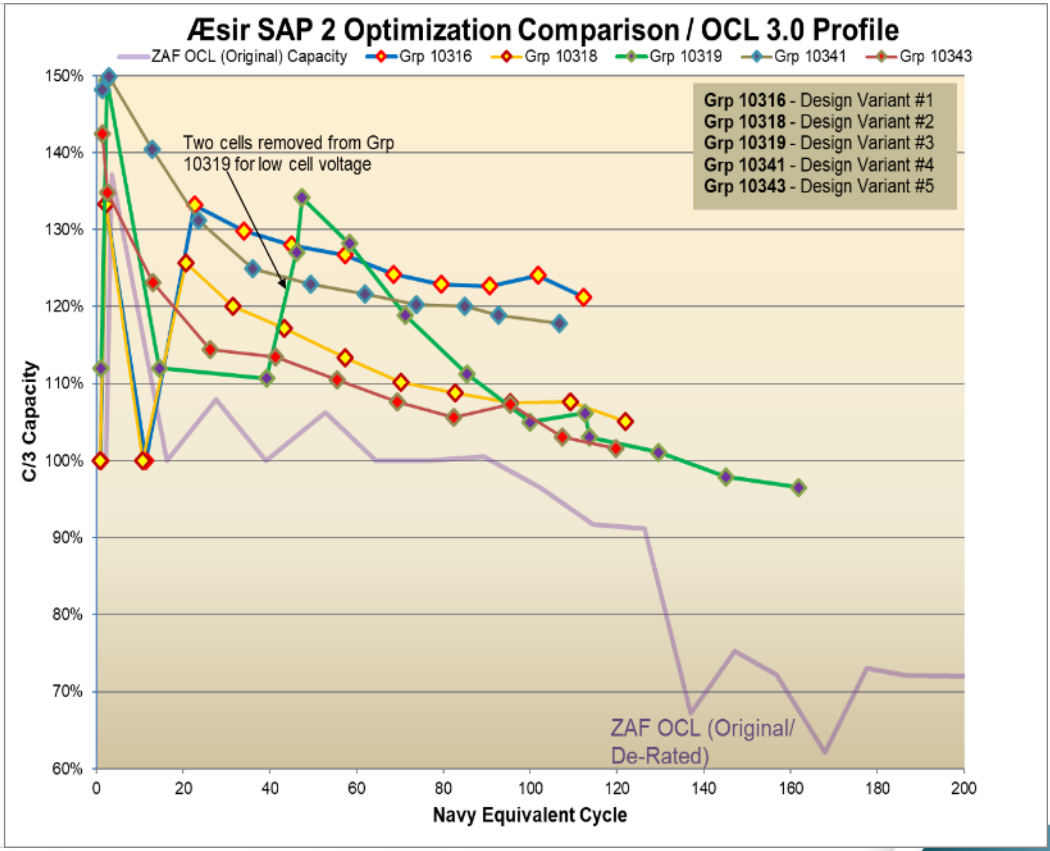
ÆSIR DESIGN OPTIMIZATION

- **Purpose: Evaluate design changes to anode, separator, cathode, active material, current collector tab length, and formulation for submarine application**
- **5 groups of 3 small-format cells, each with one design change, operating on OCL profile**
- **Continued cycling to gauge design changes / affect on sub-specific cycling profiles**
- **Benefit Navy designs and technology improvements going forward**





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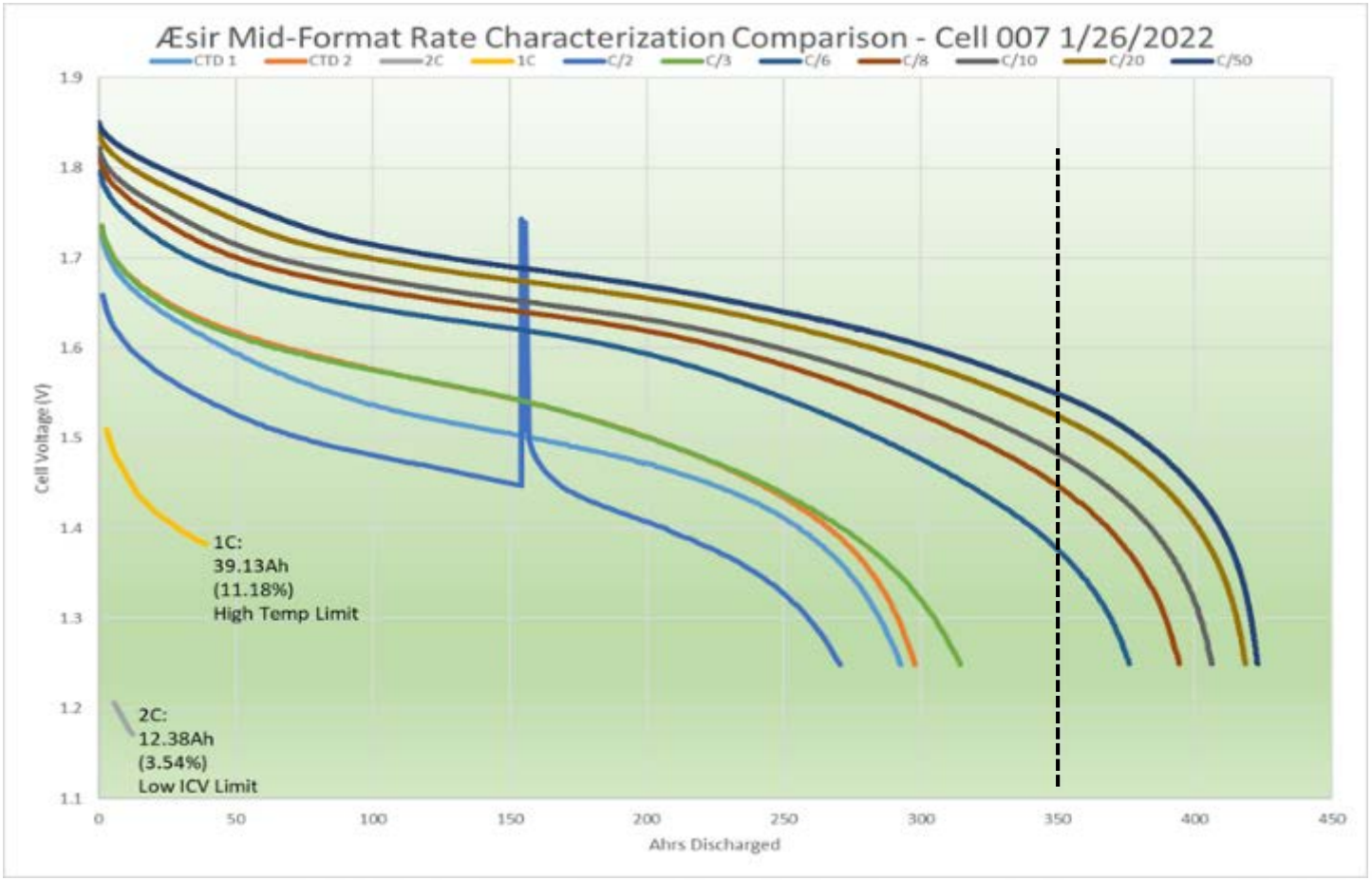
NIZN SAP 3 – MID-FORMAT

- Mid-Format prototypes were scale-up effort prior to full scale-up to sub size cells
- Mid-Format Characterization testing performed early 2021
- OCL testing started early 2021 and
- C/6, C/8, C/10, C/20, and C/50 discharges between 108% and 120%+



Mid/Small-Format Cells

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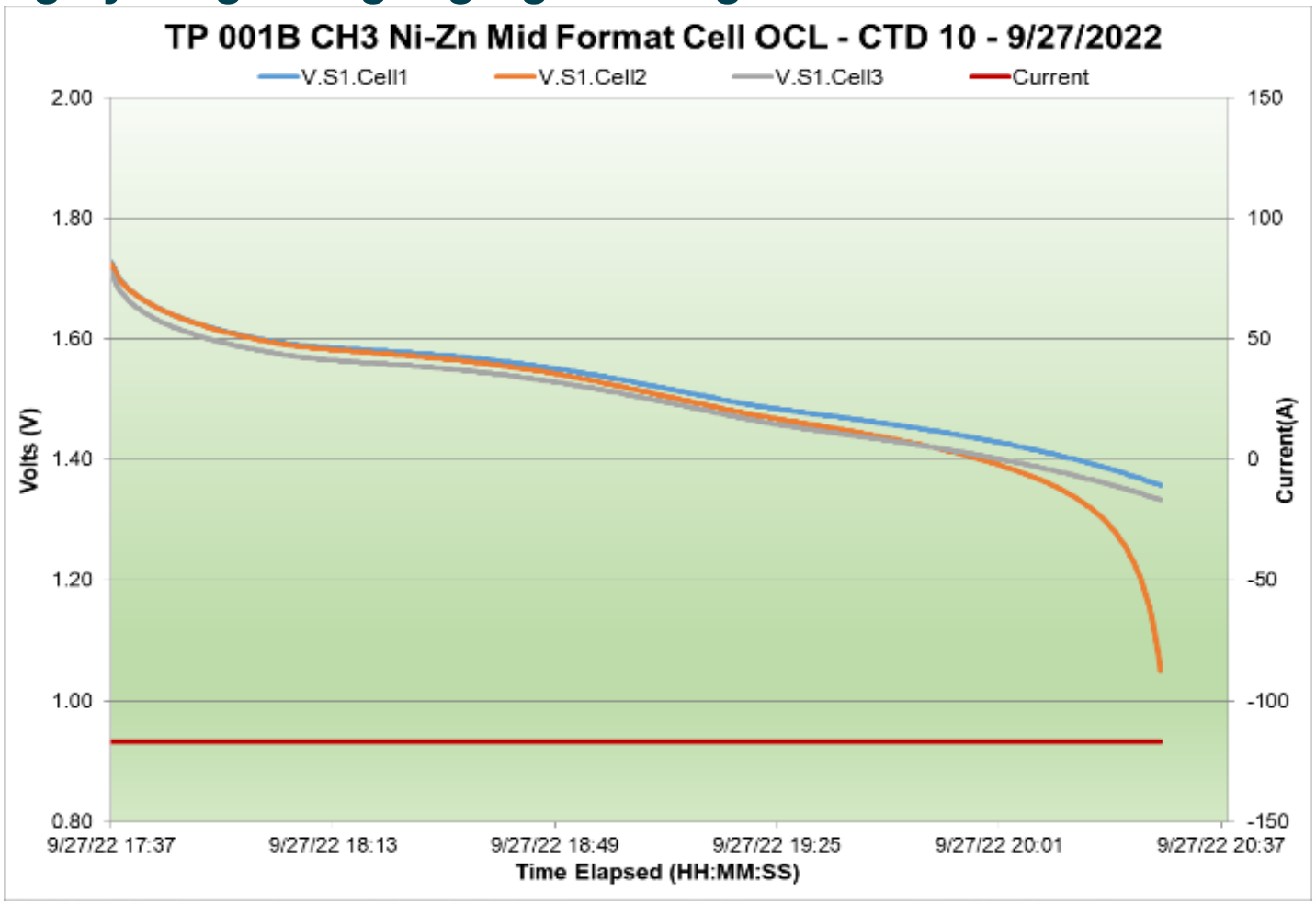
MID-FORMAT OCL

- Mid-Format OCL testing is 3 cells in series
- Will cycle for 2 years to gauge long-term performance
- Currently at 220+ cycles of targeted 700 cycles (~100% capacity)
- Continuing cycling and gauging recharge characteristics for future designs



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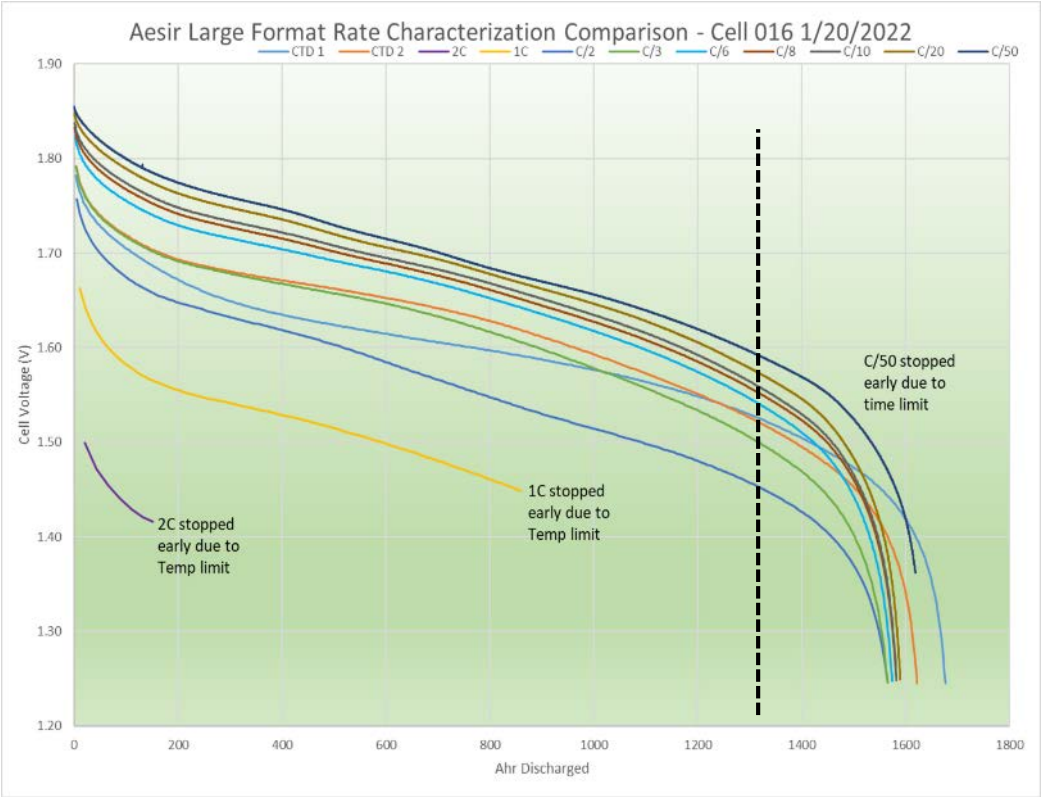
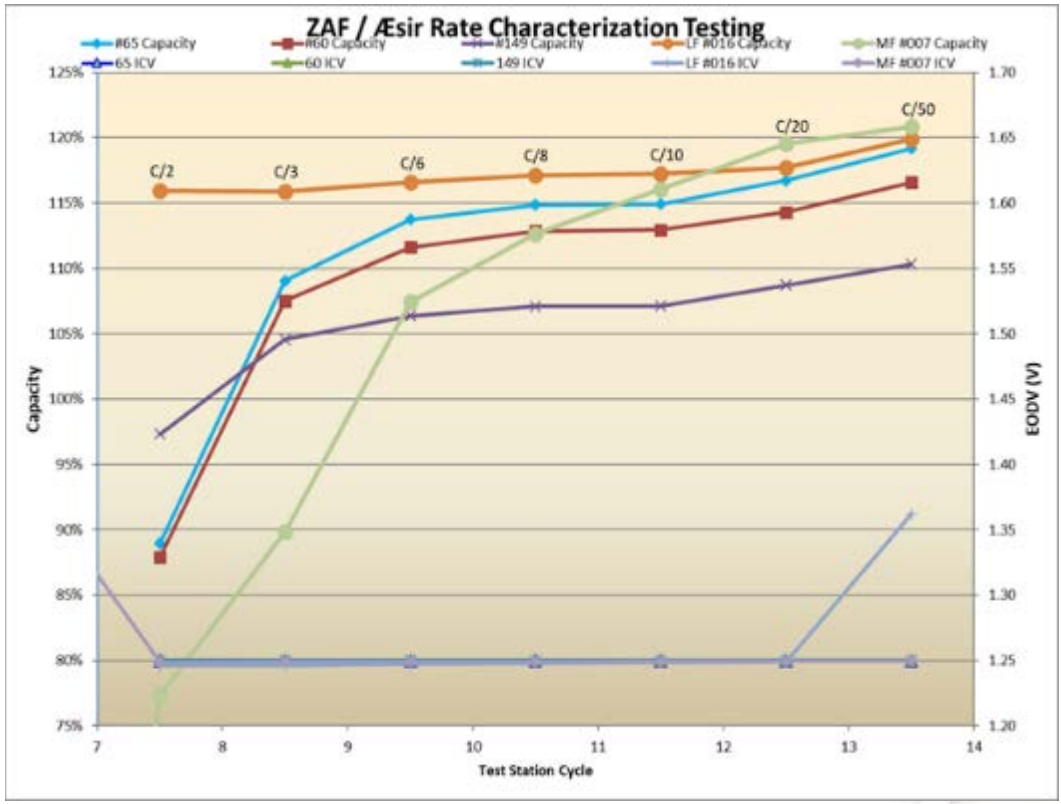
NIZN MANTECH EFFORT

- Kickoff meeting May 2020 – Deliverable of 12 large-format (1,350Ah) prototype cells received at NSWC Crane September 2021
- Check-in cycling, initial testing, rate characterization completed in 2022
- 2C and 1C discharges – hit high temperature limits and ended early – future designs will have higher discharge capability
- C/2 through C/50 between 116% to 120%+





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MANTECH OCL

- Long-term performance cycling (OCL 4) started February 2022 – 8 Cells in Series
- Will cycle for 2 years to gauge long-term performance
- Currently at 220+ cycles of targeted 700 cycles (~90% capacity)
- Fine-tuning charge operations to find optimal charge profile for larger cells/circuit
- Future designs developed based on lessons learned and updated requirements

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NEXT STEPS

- Submarine MSB NiZn – Continued small, mid, large-format testing
  - Continuing collaboration with foreign Navies, Crane testing, and evaluations of manufacturing and performance variables for cell size and geometry trade-offs to feed future designs
  - Crane purchasing dedicated NiZn test equipment for further NiZn Optimization, Performance Testing, System Level Design/Development
- Other applications – looking to investigate NiZn solution for PRM vehicle
- Starting feasibility testing in FY23

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THANK YOU

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