Joint Services Power Expo
ARPA-E BEEST & NSWC Crane

Advancing Power Systems Technology

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ARPA-E History

- America Competes Act establishes Advanced Research Projects Agency-Energy (ARPA-E) in 2007
- Funded $400M in 2009 by American Recovery and Reinvestment Act
- ARPA-E mission is to fund projects that will enhance the economic and energy security of the U.S., and ensure that the U.S. sustains a technological lead in developing and deploying advanced energy technologies
ARPA-E Principles

• Funding High Risk/High Reward R/D projects that may not otherwise be pursued due to high risk of failure
• Cross disciplinary approach using government labs, private industry and academia
• Selected performers will be funded with deliverables/milestones being actual power systems that can be measured for success against program metrics
ARPA-E Programs

- Innovative Materials & Processes for Advanced Carbon Capture Technologies (IMPACCT) Electrofuels
- Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS) Microgrid Technology
- Agile Delivery of Electrical Power Technology (ADEPT) Power Transmission / Control
- Building Energy Efficiency Through Innovative Thermodevices (BEET-IT)
- Batteries for Electrical Energy Storage in Transportation (BEEST) Advanced Power Systems
In line with the DoE / DoD overarching MoU of July 2010

BEEEST purpose is to develop and test new, next generation power systems and provide benefits to US Industry.

The Energy Power & Interconnect Technologies Division, Test & Evaluation Branch at Crane Division Naval Surface Warfare Center will work with ARPA-E and their performers to develop program specifics and independently verify/validate BEEEST test assets compared to actual test metrics.
ARPA-E BEEST
Metrics for Success

- **Specific Energy Density** – 400Wh/Kg
  - Cell Value @C/3
- **Volumetric Energy Density** – 600Wh/L
  - Cell Value @C/3
- **Volumetric Power Density** – 1200W/L
  - Cell 80% DOD, 30 Sec
- **Specific Power Density** – 800W/Kg
  - Cell 80% DOD, 30 Sec
- **Cycle Life**
  - 1000 @ 80% DOD
- **Temperature Tolerance**
  - -30C to 65C
- **Self Discharge**
  - < 15% / Month
- **Safety**
  - Over Charge, Heat, Crush
BEEST Performers

- MIT
- Fastcap
- Pellion
- Recapping Inc
- Inorganic Materials
- Planar Energy
- Missouri Institute of Tech
- Sion
- Arizona State University
- Envia
- Applied Materials
- Stanford University / Honda Support
- Polyplus
- ReVolt
- Eagle Picher
- BNL
- Max Power
- Nanolab
- A123
- Rutgers University
- NREL
- U of Florida/Florida Central
- U of Colorado Boulder
- UC SanDiego
- U of South Florida
- Penn State
BEEST Performer Ideas & Concepts

• All Electron Power System
• Solid State Power System
• Using Additional Valence Electrons
• Semi Solid and Fluidic Batteries
• Protonic Electrochemical Capacitors
• Lithium Air
• Sodium Power Systems
• Advanced Lithium Ion/Polymer
• And Others
Networking for Greatest Benefit

NSWC Crane Battery Connections

- DoD
- DoE
- EV / HEV Mfg
- Power Systems Mfg
- Public Institutions
- OGA
- R&D Labs
- AEROSPACE
Energy, Power & Interconnect Technologies Division Formal Charters

- NAVSEA Center of Excellence on Batteries
- Technical Direction Agent (TDA) for Standard Missile Batteries
- Cognizant Field Activity (CFA) for Aircraft Batteries
- TDA for Navy Special Warfare Batteries
- ISEA for Submarine Batteries
- MoU for Army Missile Command Batteries
- Interagency Agreement With FAA
- ISEA for SDV Batteries
- TDA for ASDS Batteries
- Interagency Agreement With DoE
Energy, Power & Interconnect Technologies Division Capabilities

• Over 2000 Work Years experience

• ~ 153 Personnel

• ~ 60% are Engineers and Scientists; 6 PhD’s

• Unbiased Independent Test Lab

• Established Government / Industry Team

• NOSSA Technical Agent for lithium battery safety.
## Electrochemistry Experience

### Battery Types

<table>
<thead>
<tr>
<th>Alkaline (Sealed/Vented)</th>
<th>Lithium (Reserve/Active)</th>
<th>Thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum-Oxygen (Air)</td>
<td>Carbon Monofluoride</td>
<td>Calcium/Calcium Chromate</td>
</tr>
<tr>
<td>Cadmium-Oxygen (Air)</td>
<td>Copper (II) Oxide</td>
<td>Calcium/Potassium Dichromate</td>
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<tr>
<td>Carbon-Zinc</td>
<td>Copper Sulfide</td>
<td>Lithium Iron/Iron Disulfide</td>
</tr>
<tr>
<td>Mercury-Cadmium</td>
<td>Iodine</td>
<td>Lithium Aluminum/Iron Disulfide</td>
</tr>
<tr>
<td>Mercury-Zinc</td>
<td>Ion</td>
<td>Lithium Silicon/Iron Disulfide</td>
</tr>
<tr>
<td>Nickel-Zinc</td>
<td>Iron Disulfide</td>
<td>Lithium Silicon/Cobalt Disulfide</td>
</tr>
<tr>
<td>Nickel-Iron</td>
<td>Oxyhalide</td>
<td>Magnesium/Vanadium Pentoxide</td>
</tr>
<tr>
<td>Nickel-Cadmium</td>
<td>Polymer</td>
<td>Other</td>
</tr>
<tr>
<td>Nickel-Hydrogen</td>
<td>Sulfur Dioxide</td>
<td>Absorbed Electrolyte</td>
</tr>
<tr>
<td>Nickel-Metal Hydride</td>
<td>Sulfuryl Chloride</td>
<td>Antimony Grid</td>
</tr>
<tr>
<td>Silver-Zinc</td>
<td>Thionyl Chloride</td>
<td>Calcium Grid</td>
</tr>
<tr>
<td>Silver-Cadmium</td>
<td>Vanadium Pentoxide</td>
<td>Gel Electrolyte</td>
</tr>
<tr>
<td>Silver-Hydrogen</td>
<td></td>
<td>Flooded Electrolyte</td>
</tr>
<tr>
<td>Silver-Metal Hydride</td>
<td></td>
<td>Pure Lead Grid</td>
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<tr>
<td>Silver-Iron</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc-Manganese Dioxide</td>
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<td></td>
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<tr>
<td>Zinc-Oxygen (Air)</td>
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</tr>
</tbody>
</table>

### Other

- Seawater
- Ammonium
- Sodium-Sulfur

### Capacity Ranges

**0.03 to Tens of Thousands of Ah**

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Equipment & Facilities Capabilities

- 21 Custom Test Control Systems
- 27 COTS Test Systems (Arbin, Bitrode Maccor PEC, TSC, EDA)
- Electronic Loads and Power Supplies up to 80 KW (240Vdc/300A; 120Vdc/600A)
- Full Environmental Test Capabilities
- Unlimited Abuse and Safety Test Capabilities
- Dissection and Materials Analysis Capabilities
- Unique High Energy Battery Test Facility
- Remote Ordnance Test Range
- Remote Underwater Test Range
Equipment & Facilities Capabilities

Nail Penetration

Shock & Vibration

Temp, Altitude & Humidity

Gas & Pressure

Acceleration

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Conclusion

• The NSWC Crane Division, Energy Power & Interconnect Technologies Division is proud and eager to be part of this new and exciting DoE ARPA-E technology advancement initiative

• ARPA-E Director:
  – With the energy concerns of today, the Country cannot afford for this initiative to fail…..
  – The success of ARPA-E BEEST will change the way we all live.
Contact Information

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