Roadmap for Advanced Firing/Detonation Systems (AF/DS) supports future stockpile needs

- Increased Surety
- Miniaturization/Increased System Functionality

Stockpile Firing Systems

Present → Future
Support Stockpile Life Extension Program

Micro-CDUs
Detonator Stronglinks
Direct Optical Initiation
Micro firing set

CDU Assembly
*Poco
SPRYTRON
*CAPACITOR
*FLAT CABLE

OPTICAL PACKAGE

LOW VOLTAGE BOARD

HIGH VOLTAGE BOARD

TRANSFORMER
Micro CDU firing set working prototype
Micro CDU - 0.23 in$^3$ - Working prototype
Neutron Initiators

Topics to be discussed

- Internal initiators
- External initiators
- Movie - An overview of neutron source technology
- Technology involved
- Evolution of neutron generator development
- Production
- Future systems
Basics of an Implosion Assembly (IA)
Neutron yield is dependent on ion source material and ion energy
Neutron multiplication rate
There are two fundamental reasons neutron sources are used in weapons

- Jump start the weapon
- Stabilizes the output
Alpha curve
Show Movie
Basics of how a neutron tube work

Picture of a neutron tube
Neutron generator using an explosive to electric (EET) power supply
Neutron generator using an electronic power supply
Implosion Assembly (IA) timing requirements
Neutron generations requirements over time
Neutron generator timing is affected by several factors

- System center time shift with temperature
- Neutron generator center time shift with temperature
- Neutron generator jitter
- Firing set jitter
- Weapon detonator jitter
- Neutron generator detonator jitter (explosive NG)
- Shift in electronic components (electronic NG)
Neutron generator "family" picture
SNL is now the production agency for neutron generators

- The targets will be loaded at LANL
- The first production requirement is for the W76 (2000)
  - MC4277 Neutron Tube
  - MC4380 Neutron Generator
- Future need for a small tube/generator for W80
  - FY2008? (P&PD 96-0)
  - Requires the small neutron tube, MC4300
  - MC4600 neutron generator
MC4380 Neutron generator
MC4300 Neutron Tube
Design evolution from the MC4300 neutron tube (W76) to the MC4600 neutron tube (future applications)
Power Systems

- Basic battery types
- Examples of non-thermal batteries
- Thermal battery applications
- Thermal battery operation
- Examples of thermal batteries
- Power supply design influences
- Battery performance
- Evolution of Battery Development
- Production
- Future Technology
Basic battery types

- Primary: not rechargeable
  - Active: power immediately available
  - Reserve: must be activated
- Secondary: rechargeable
- Nearly all nuclear weapon batteries are primary batteries
- Most weapon batteries are reserve batteries
Types of power sources in nuclear weapons

- Thermally activated
- Rechargeable - Ni/Cd
- Reserve - Zn/AgO
- Active - Li/SO$_2$
- Active and reserve - Li/SOCL$_2$
- RTG (fissionable heat source)
  - Radio isotropic Thermal electric Generator (RTG)
- Double-layer capacitor
Non thermal battery applications

- SA2039
Picture of a generic thermal battery
Picture of thermal battery cell

- Current
- Voltage
- Anode, cathode, electrolyte
- Thermal vs current handling requirements
Thermal batteries are used in many nuclear weapon applications

- RADARs
- Programmers
- Timer
- Firing sets
- Spin rocked motors
- Parachute deployment
- Telemetry
- Command disable
- Command enable
- Fin activation
What is a thermal battery?

- Thermal batteries are primary reserve batteries that employ inorganic salt electrolytes, which are nonconductive solids at ambient temperatures, and integral pyrotechnic materials scaled to supply sufficient thermal energy to melt the electrolyte.
Movie

- Thermal Battery Ignition
Thermal battery performance - voltage - with constant load
Thermal battery performance - current - with constant load
Calcium chromate performance
Lithium battery performance
Power supply design influences

- Reliability (0.995 - 0.997)
- Shelf life - Thermal battery > 25 years
- Ruggedness - W82 AFAP application
- Operating temperature
- Current density
- Pulse capability
- Voltage - determined by cell chemistry
Thermal batteries are mechanically and environmentally robust

- Example of the W82 AFAP MC3714 environmental requirements
  - Spin: 18,000 rpm
  - Setback acceleration: 17,000 g's, 10 ms
  - Angular acceleration: 40,000 rad/sec\(^2\)
  - Ramming shock: 440 g, 1.83 ms, haversine
  - Rebound acceleration: 4000 g's 0.3 ms
The three dimensional design space for batteries is volume, performance, and life.
Picture showing thermal battery performance versus size
## Typical thermal battery performance

Values based on Li(Si)/FeS$_2$ system

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Active Life (sec)</th>
<th>Min Volts (v)</th>
<th>Current Density (mA/cm$^2$)</th>
<th>Specific Power (W/Kg)</th>
<th>Volume (cc)</th>
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</thead>
<tbody>
<tr>
<td>Pulse</td>
<td>0.050</td>
<td>17.5</td>
<td>7500</td>
<td>8000</td>
<td>10</td>
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<tr>
<td>Pulse</td>
<td>5</td>
<td>26</td>
<td>1000</td>
<td>1700</td>
<td>10</td>
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<tr>
<td>Power</td>
<td>200</td>
<td>12</td>
<td>1800</td>
<td>740</td>
<td>1640</td>
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<tr>
<td>Power</td>
<td>60</td>
<td>25</td>
<td>300</td>
<td>260</td>
<td>137</td>
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<tr>
<td>Power</td>
<td>120</td>
<td>26</td>
<td>120</td>
<td>80</td>
<td>360</td>
</tr>
<tr>
<td>Power</td>
<td>1200</td>
<td>26</td>
<td>100</td>
<td>80</td>
<td>320</td>
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<tr>
<td>Long Life</td>
<td>4500</td>
<td>13</td>
<td>55</td>
<td>18</td>
<td>320</td>
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</tbody>
</table>
Examples of batteries used in the US nuclear weapons program

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Technology</th>
<th>Cell Voltage</th>
<th>Approx. Date</th>
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<tbody>
<tr>
<td>Little Boy</td>
<td>Lead Acid</td>
<td>2.0 volts</td>
<td>1945</td>
</tr>
<tr>
<td>Fat Man</td>
<td>Lead Acid</td>
<td>2.0 volts</td>
<td>1945</td>
</tr>
<tr>
<td>MK4,5,6,7</td>
<td>Nickel-Cadmium</td>
<td>1.2 volts</td>
<td>1953</td>
</tr>
<tr>
<td>MK15</td>
<td>Thermal CA-CaCrO₄</td>
<td>2.5 volts</td>
<td>1955</td>
</tr>
<tr>
<td>W62</td>
<td>Silver-Zinc</td>
<td>1.8 volts</td>
<td>1970</td>
</tr>
<tr>
<td>W70</td>
<td>Thermal Li/FeS₂</td>
<td>1.9 volts</td>
<td>1973</td>
</tr>
<tr>
<td>B83</td>
<td>Thermal Li/CoS₂</td>
<td>1.8 volts</td>
<td>1980's</td>
</tr>
</tbody>
</table>
W76 thermal battery
MC2936 thermal battery
Battery production is currently taking place at three production agencies (PAs)

- **Eagle Pitcher**
  - The primary PA which resulted from the nonnuclear reconfiguration study

- **SNL**
  - The backup site for production which resulted from the nonnuclear reconfiguration study

- **Enser Corporation - Private Corporation**
  - Recently formed out of Martin Marietta Specialty Components, Inc. (GEND, Pinellas Plant)
Battery production is at a low level

<table>
<thead>
<tr>
<th>Company</th>
<th>Nomenclature</th>
<th>Type</th>
<th>Application</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>Eagle Pitcher</td>
<td>SA3562</td>
<td>Zn/AgO</td>
<td>JTA</td>
<td>~ 2 Dozen</td>
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<tr>
<td>MC3471A</td>
<td>Thermal</td>
<td></td>
<td>B61</td>
<td>300-400</td>
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<td>MC2736A</td>
<td>Thermal</td>
<td></td>
<td>JTA</td>
<td>~ 2 Dozen</td>
</tr>
<tr>
<td>Enser</td>
<td>MC3323A</td>
<td>Thermal</td>
<td>W80 JTA</td>
<td>~ 2 Dozen</td>
</tr>
<tr>
<td>SNL</td>
<td>MC4152</td>
<td>Thermal</td>
<td>B61 Common JTA</td>
<td>~ 2 Dozen</td>
</tr>
</tbody>
</table>
Aerogel and a heater may increase battery output without increasing volume