SAND2008-2684C

Pulsed Power Driver for Isentropic Compression Experiments

(SNL Future Designs)

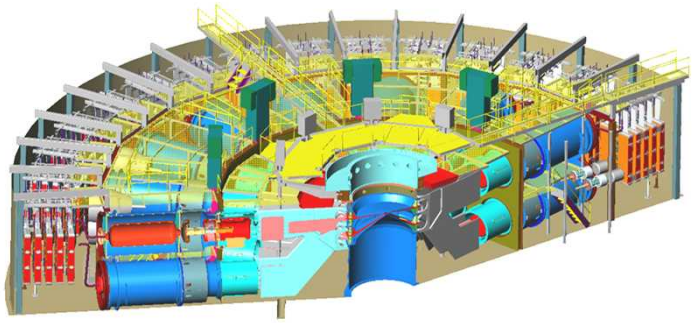
French DGA & US DOE meeting

April 24, 2008

Steve Glover

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

A Next Generation Compact ICE Driver will Provide Capability Beyond that Presently Available

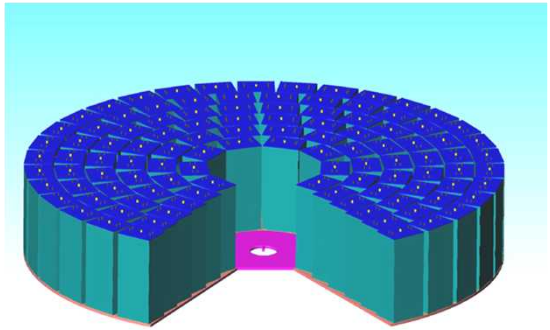


Z Machine

- > 20 MA
- > 4 Mbar
- pulse shaping 36 modules
  - 36 trigger points
  - 200-500 ns rise time
- ~ $100k per shot

Veloce Small Pulser

- 2.5 - 3 MA
- 70 kbar (20mm strip)
- limited shaping
- 500 ns rise time
- ~ $5k per shot



Next-Generation Small Pulser

- 4.5 - 5 MA
- 250 kbar (20mm strip)
- pulse shaping >200 modules
  - ~60 trigger points
  - 200-500 ns rise time
  - Tungsten to Polypropylene
  - ~ $5k per shot

Address physics issues in Sandia mission areas with lower cost and more flexibility than is possible on Z

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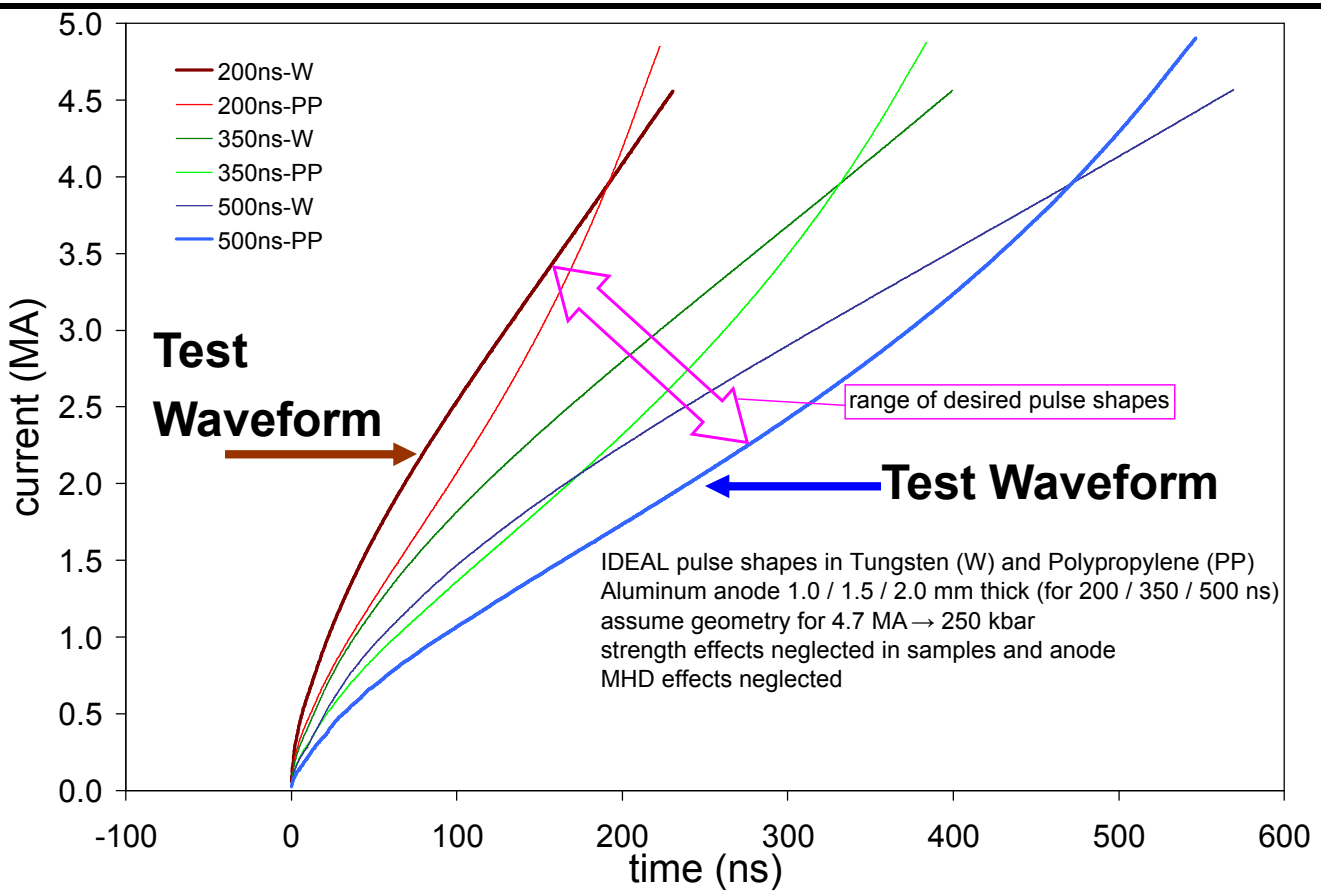
System Will Accommodate a Broad Range of Waveforms



Two waveforms were chosen to demonstrate the concept capabilities

- **200ns risetime optimized for Tungsten**
- **500ns risetime optimized for Polypropylene**

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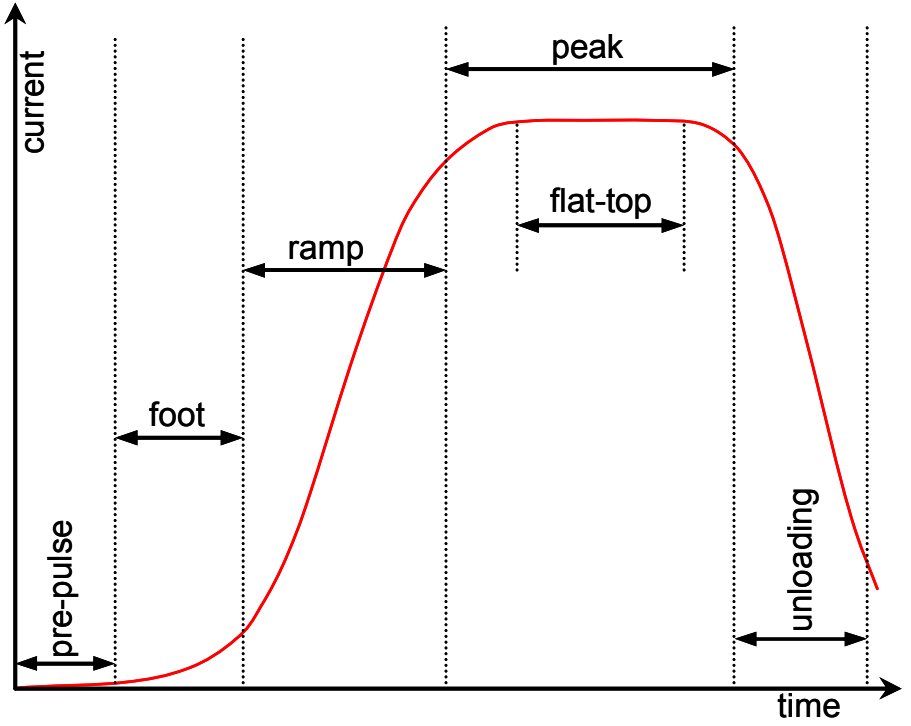
Design Criteria Developed in Close Collaboration with Users to Greatly Expand Performance

Design Criteria

- Programmable current pulse
  - Individual parts can be defined
    - Pre-pulse
    - Foot
    - Ramp
    - Flat-top
    - unloading
- 250kbar peak pressure
- Easy access to the load
- One shot per day minimum
- 1200 shots before maintenance



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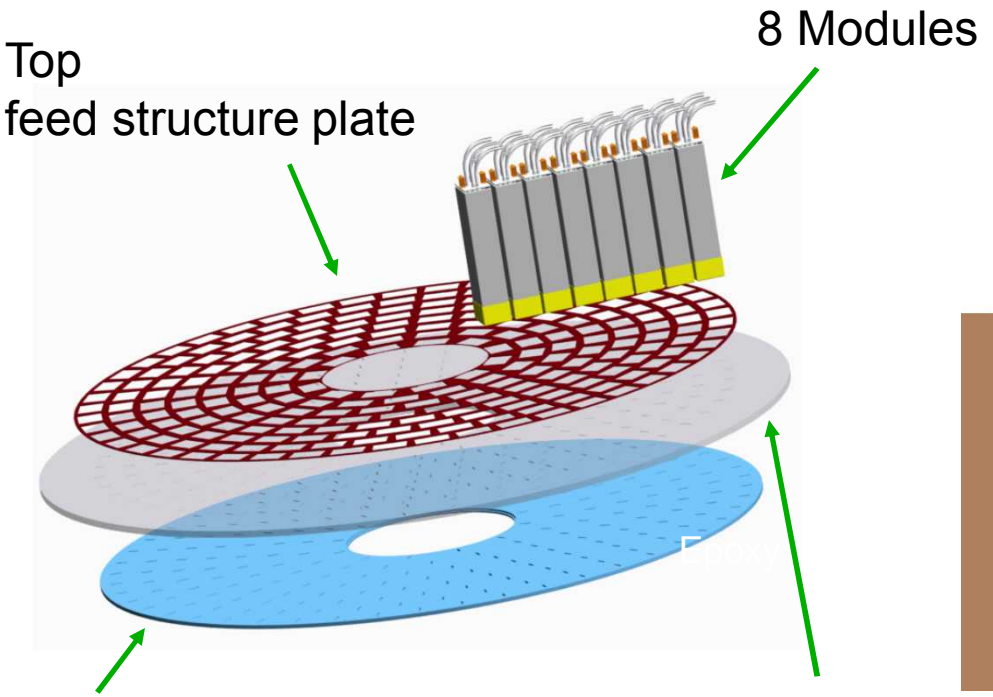
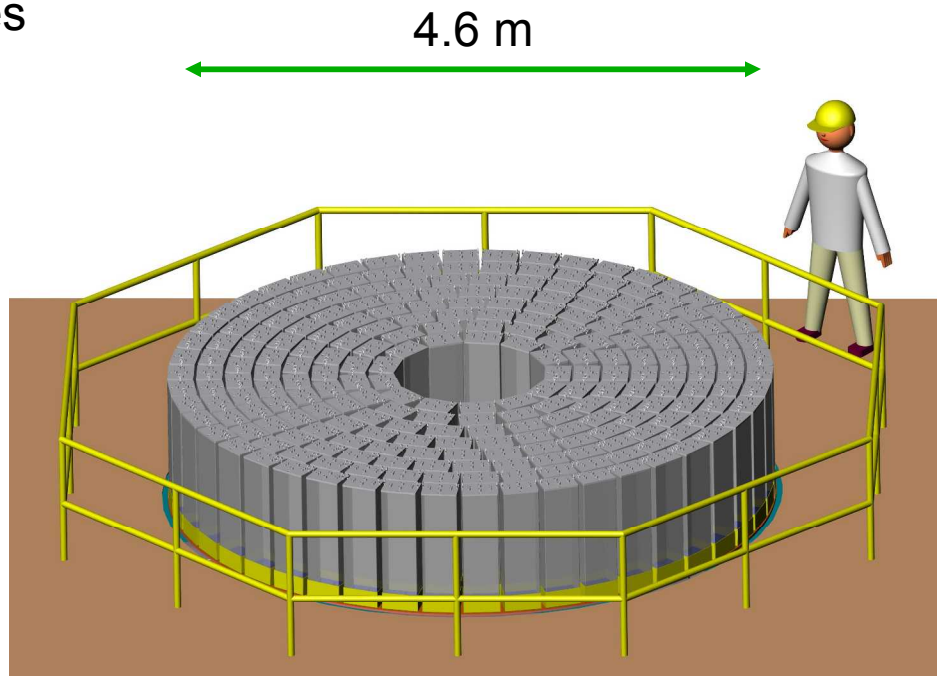
Modules Connect in Parallel to Form a Current Adder

- **Solid insulators in the feed structure help minimize impedance**
- **Gel insulator will mitigate tracking paths at the interface**
- **236 modules seat into the parallel plate feed structure to form the driver**
- **Modules will be triggered in groups of 4 resulting in 59 trigger points**





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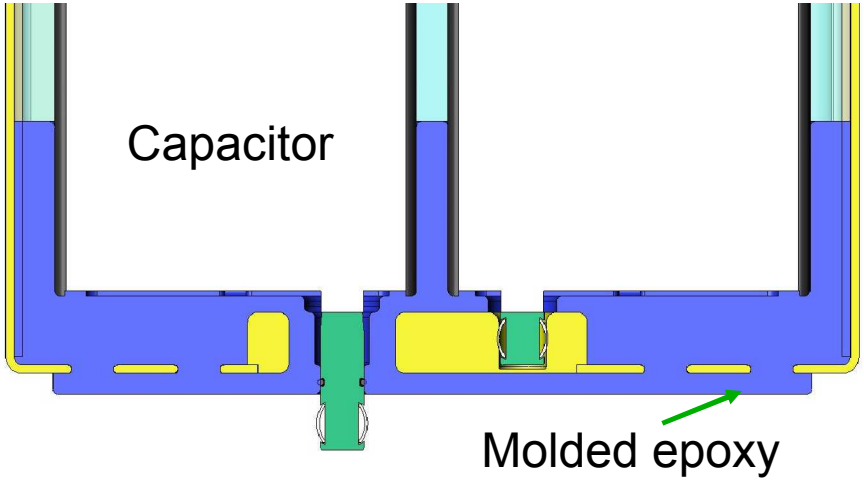
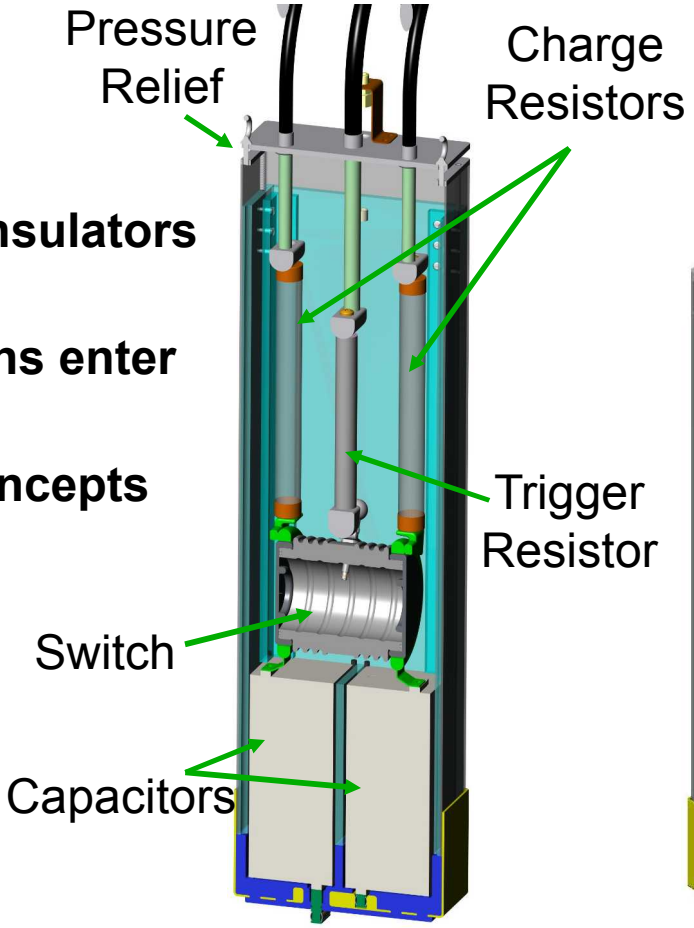
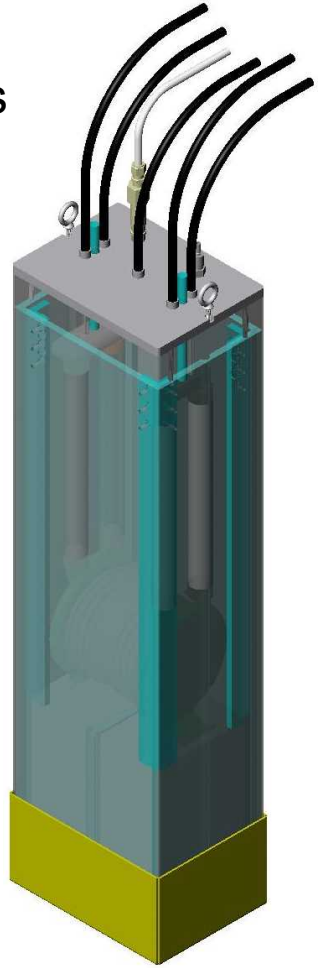
LTD-like Bricks are the Baseline System Building Blocks

Designed as a single stage Marx

- **Double ended capacitors reduce impedance**
- **A combination of solid and liquid insulators allow for compact design**
- **Charge, gas, and trigger connections enter from the top of the module**
- **Advanced switch and triggering concepts under development**







Modules are designed to mitigate fault hazards

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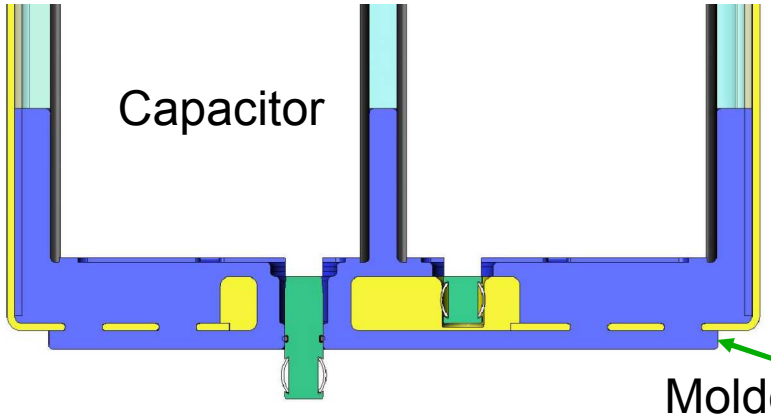
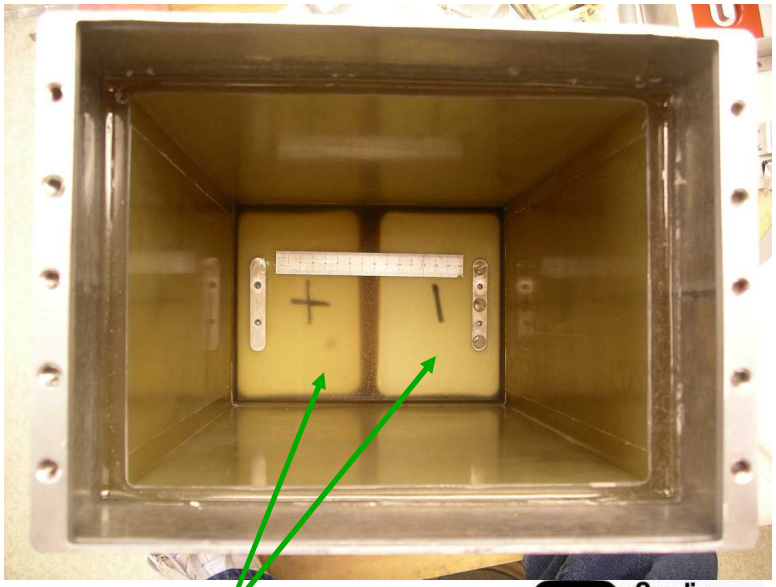
Potted Insulation Reduces Impedances and Increases Reliability

Process has been refined





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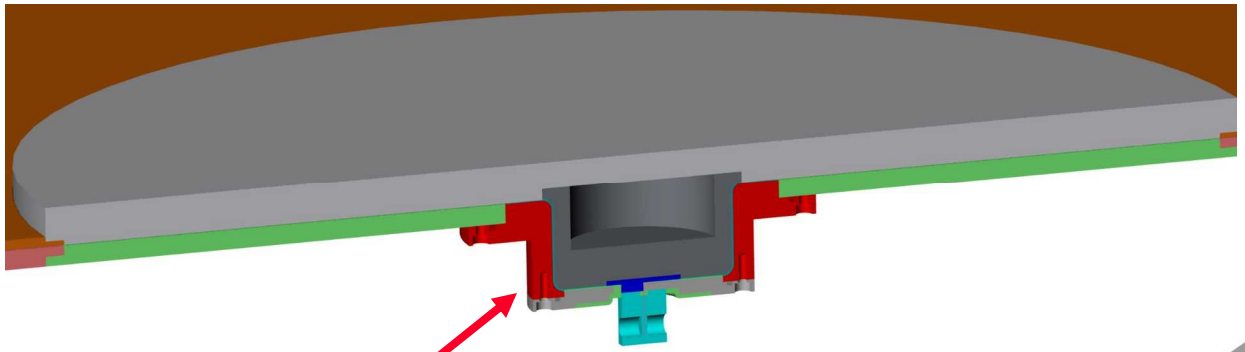
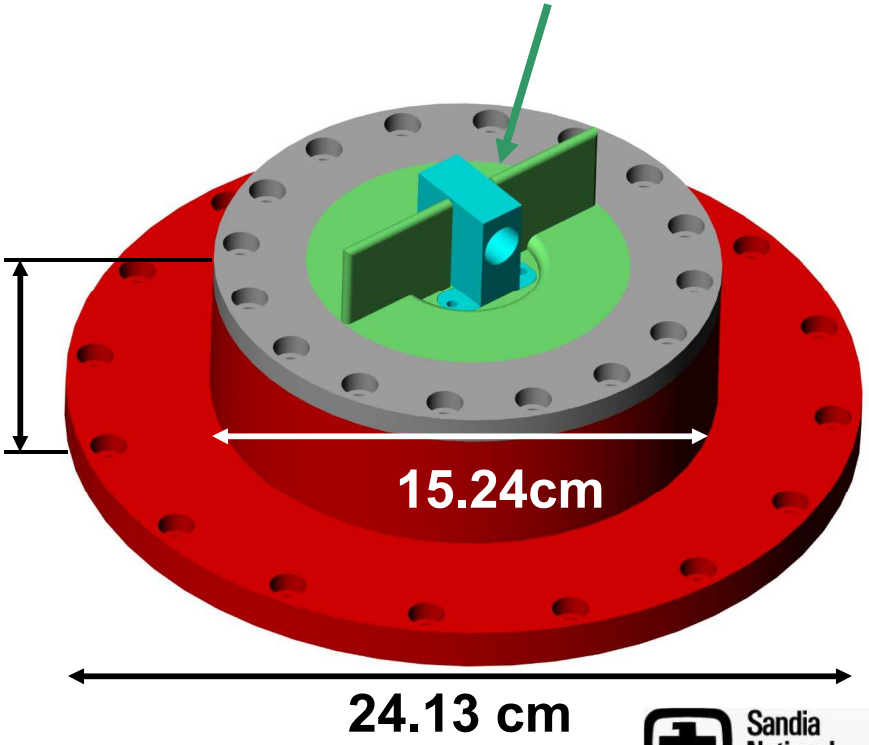
New Load Concept
Installs from the Bottom, Increases Pressure up to 20%



Potting allows for lower impedance more robust design

Can height allows room for diagnostics



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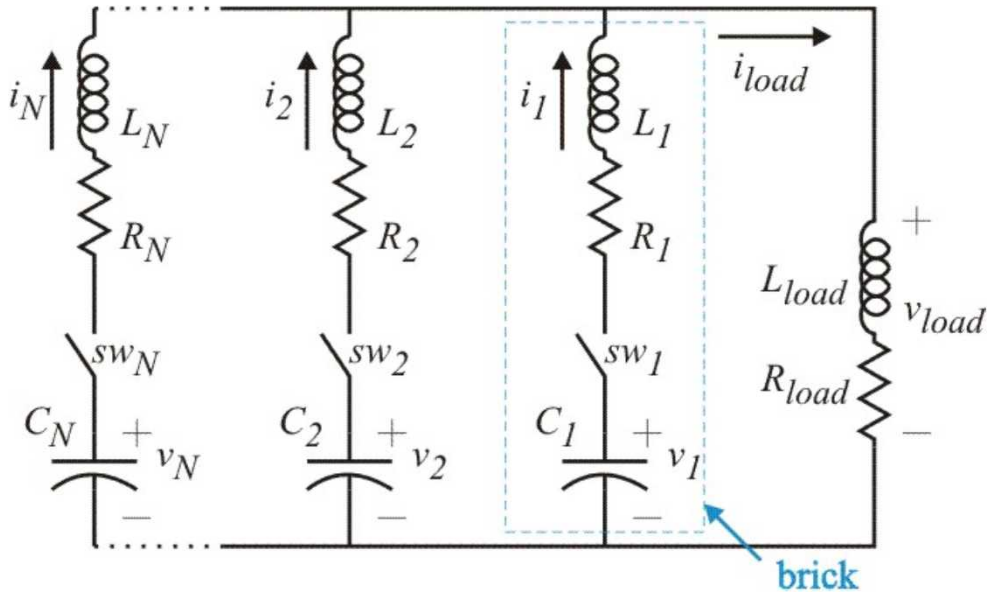
Many Independently Triggered Switches Allow Current Shaping

- Many parallel circuit branches improve current shaping
- Switches triggered in groups of 4 (4x59=236 modules)
- Genetic optimization handles the large number of variables
- Exponential loading effects drive the system size
- Varying switch voltages require known switch performance



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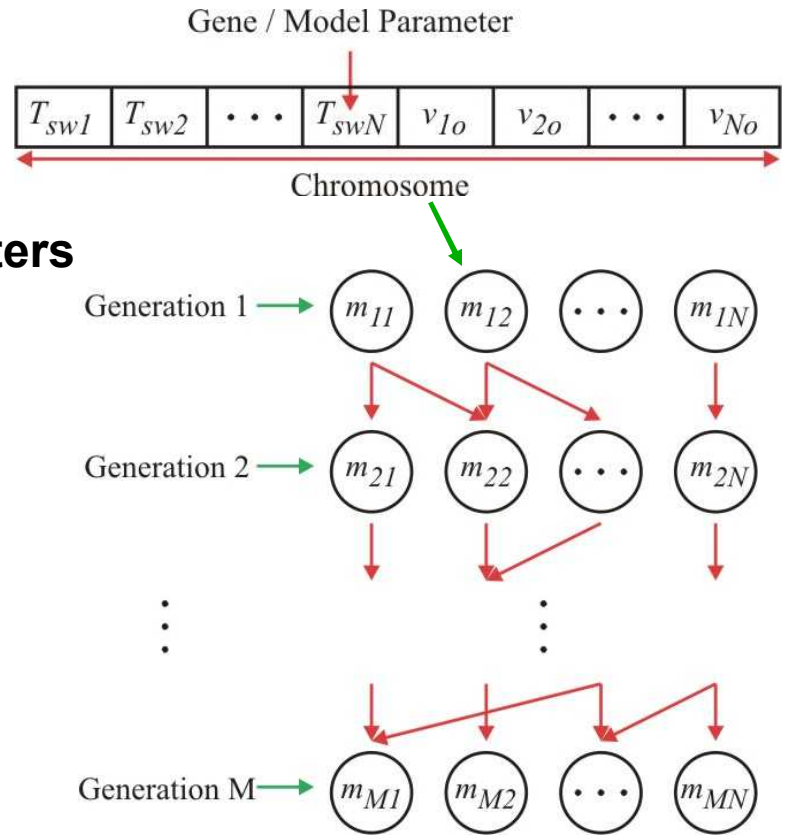
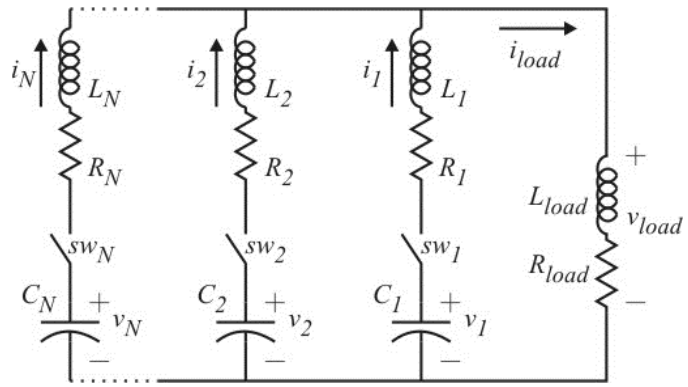
Genetic Optimization Addresses Complexity of System Programming

- **Advantages**
  - Handles large numbers of variables
  - Works with continuous and discontinuous components
  - Doesn't require derivative information
  - Optimizes to a user defined fitness function
- **Based on natural selection processes**
  - Mating, Mutation, Elitism
- **Models can contain fixed and variable parameters**
  - Fixed parameters: R's, L's, etc
  - Variable parameters: Defined in each gene
- **Genes defined by parameters to be searched**
- **Each generation consists of N models**
- **Optimizations run for M generations**





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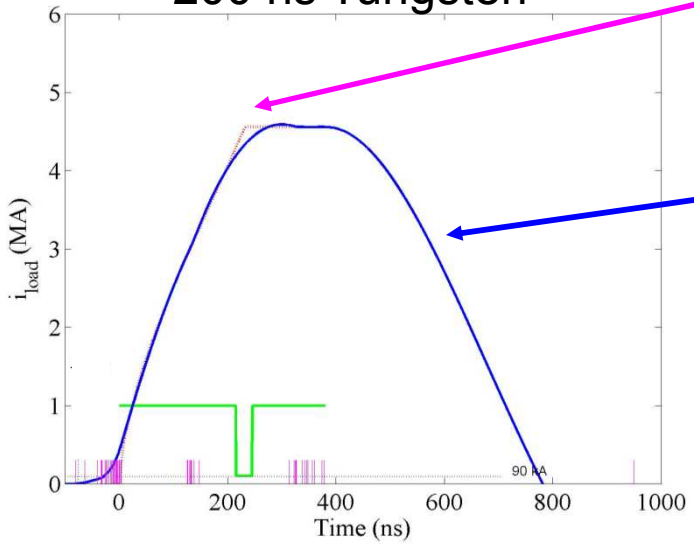
Waveforms Obtained from Optimization Must Have Low Ripple

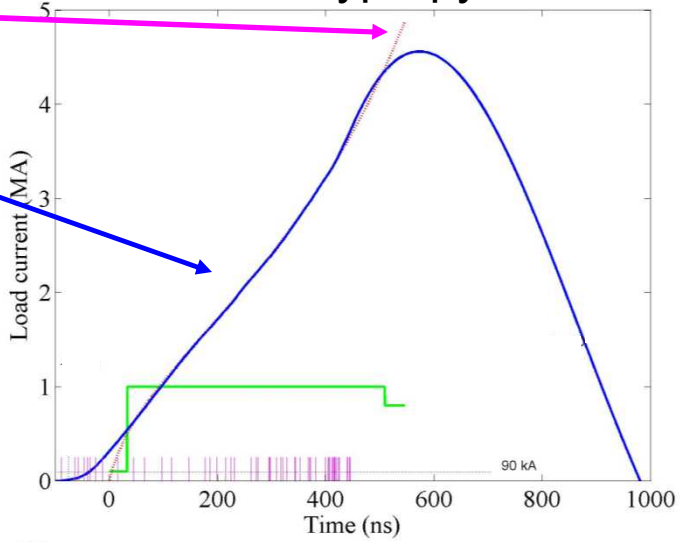
200 ns Tungsten

Ideal current shape

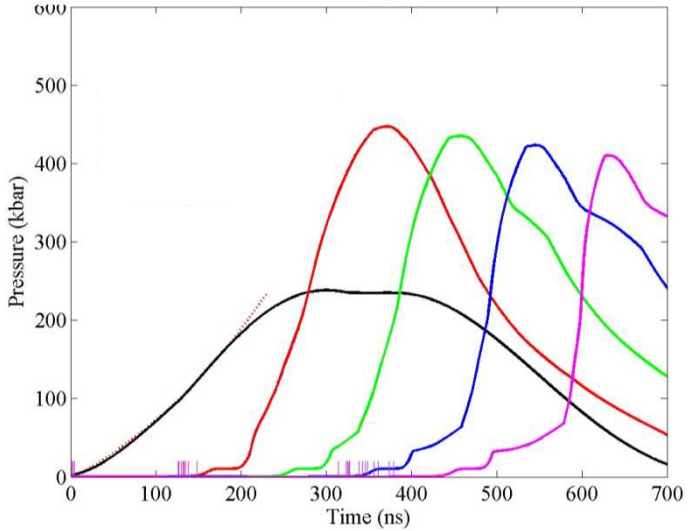
500 ns Polypropylene



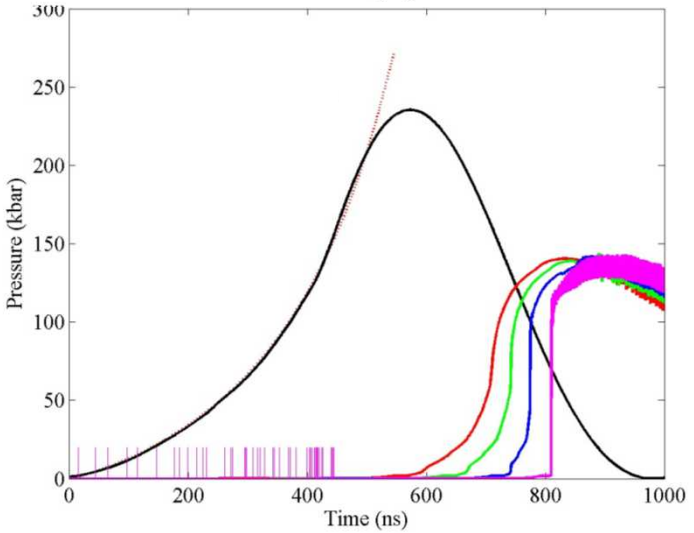
Simulated Driver current



These waveforms are simulations

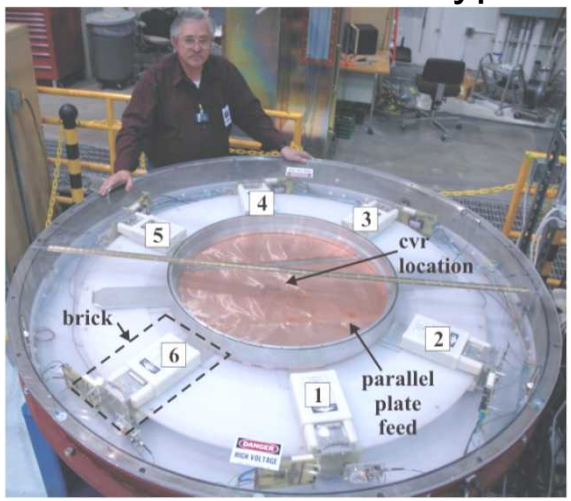


Pressure waveforms

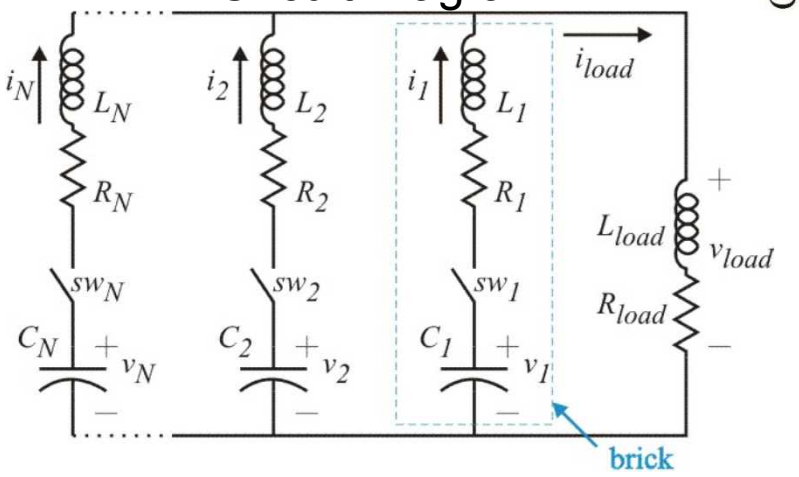


System Characterization and Pulse Shaping have been Demonstrated with Scaled Down System

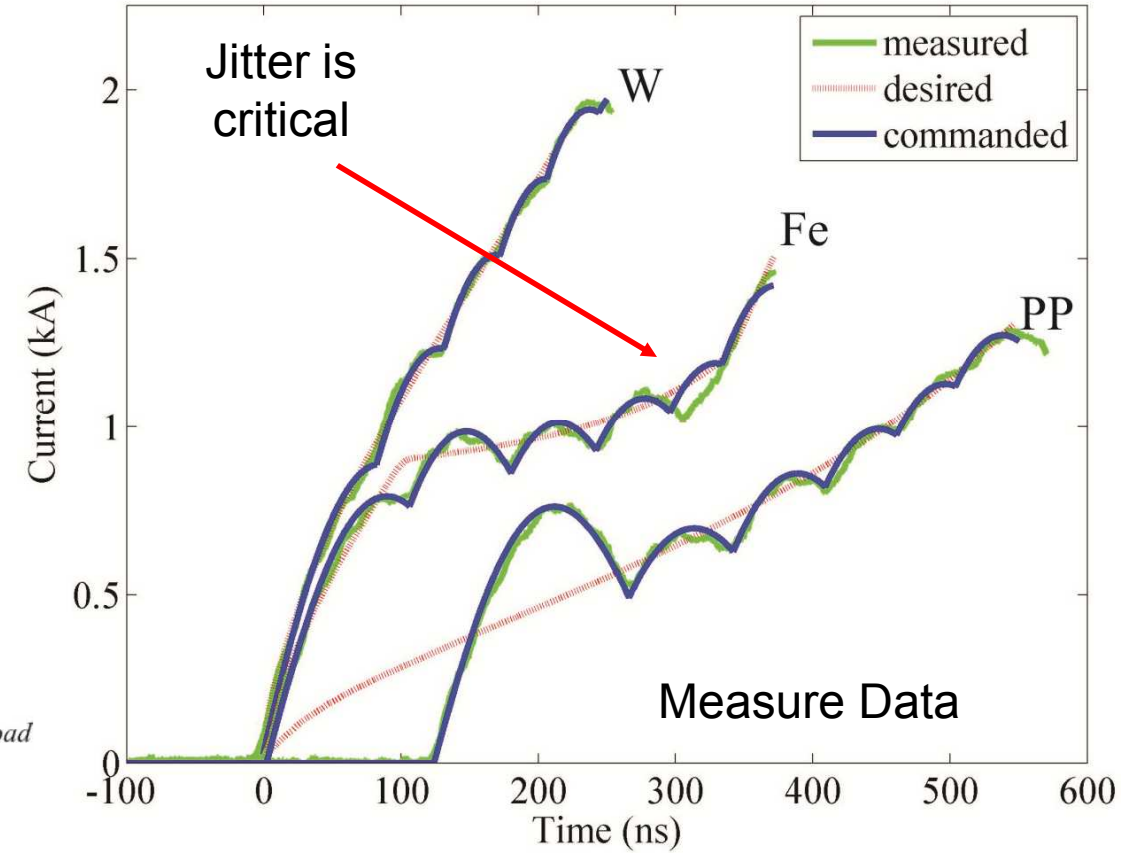
Current Adder Prototype



Circuit Diagram



Genetic Optimization determined trigger times and charge voltages.



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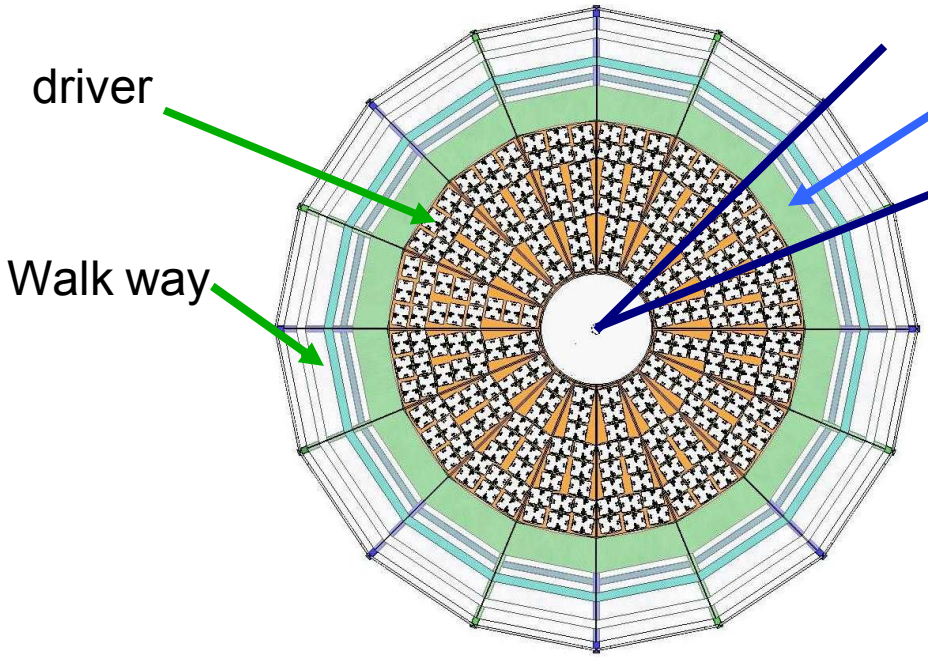
Detailed Models of the Full System Have been Created by SNL and L3

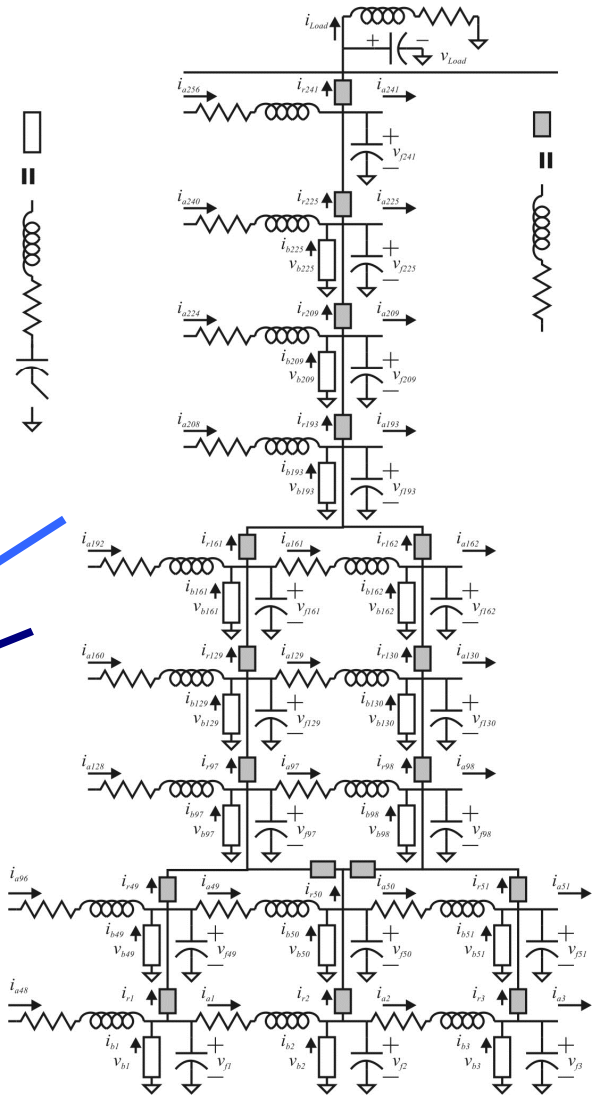
SNL's model is based in Matlab

- **State equation model**
- **Constructed using Tee circuit representation**

L3's model is based in TL

- **Transmission line based model**





One section of the SNL model

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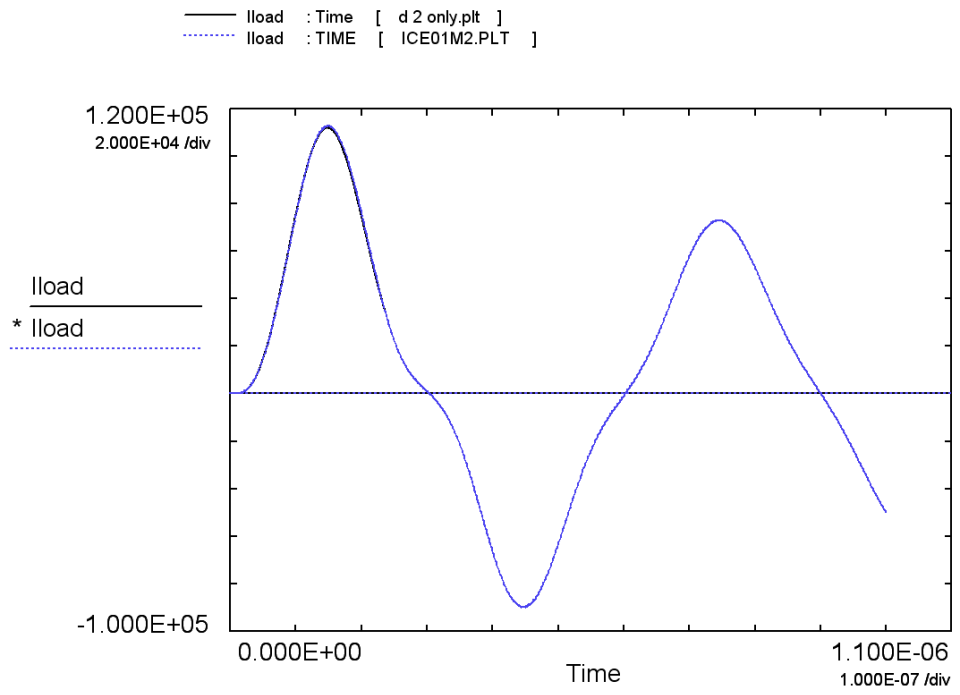
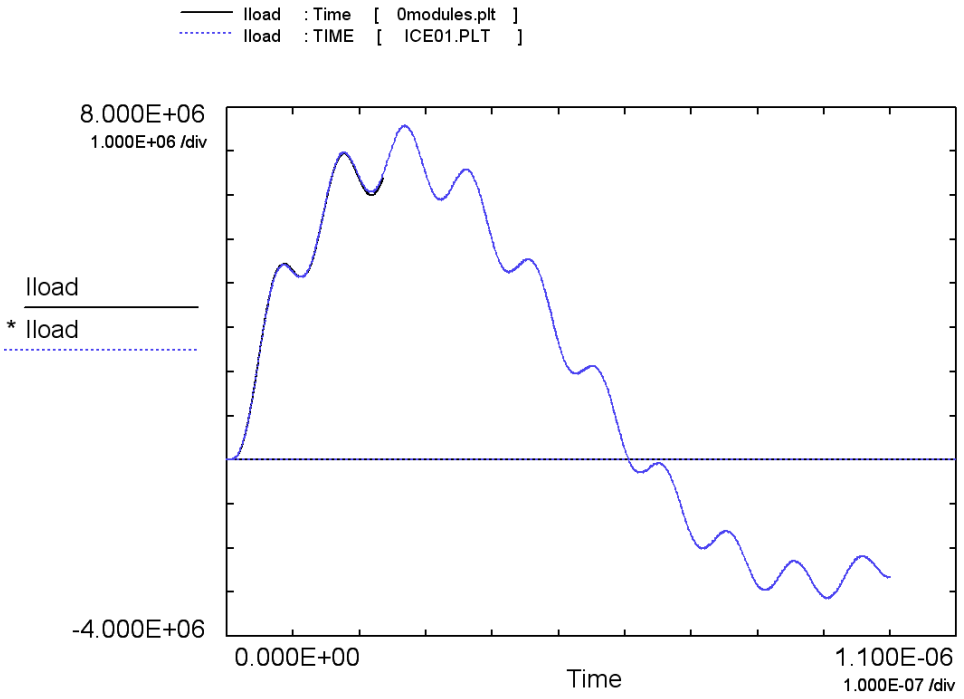
Detailed Models of the Full System Match Well

Single module triggered



All modules triggered together



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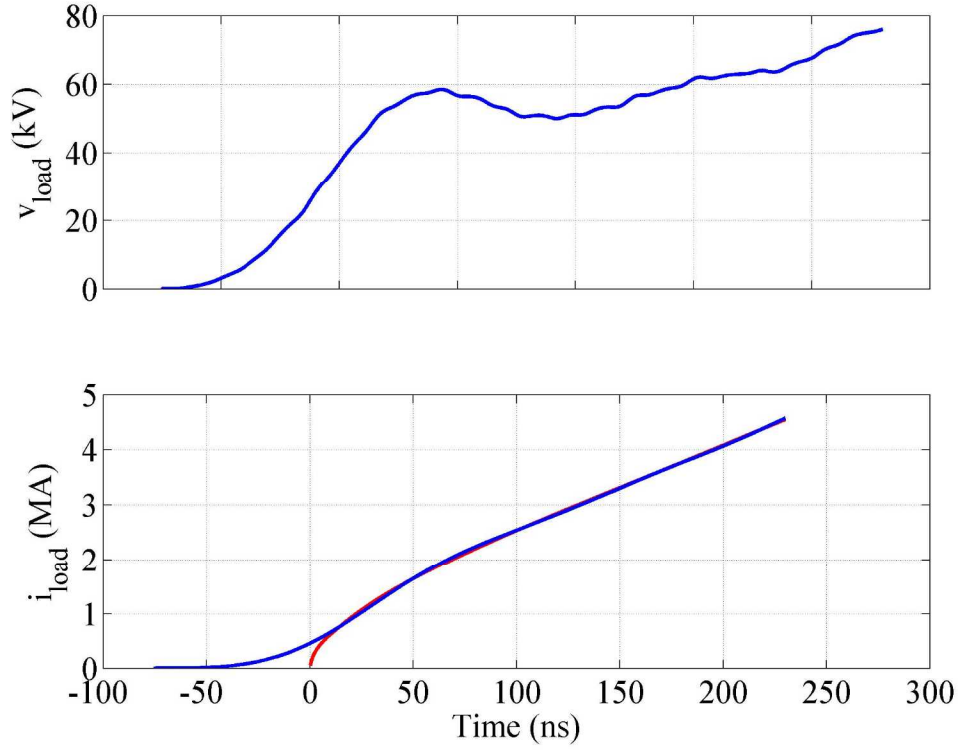
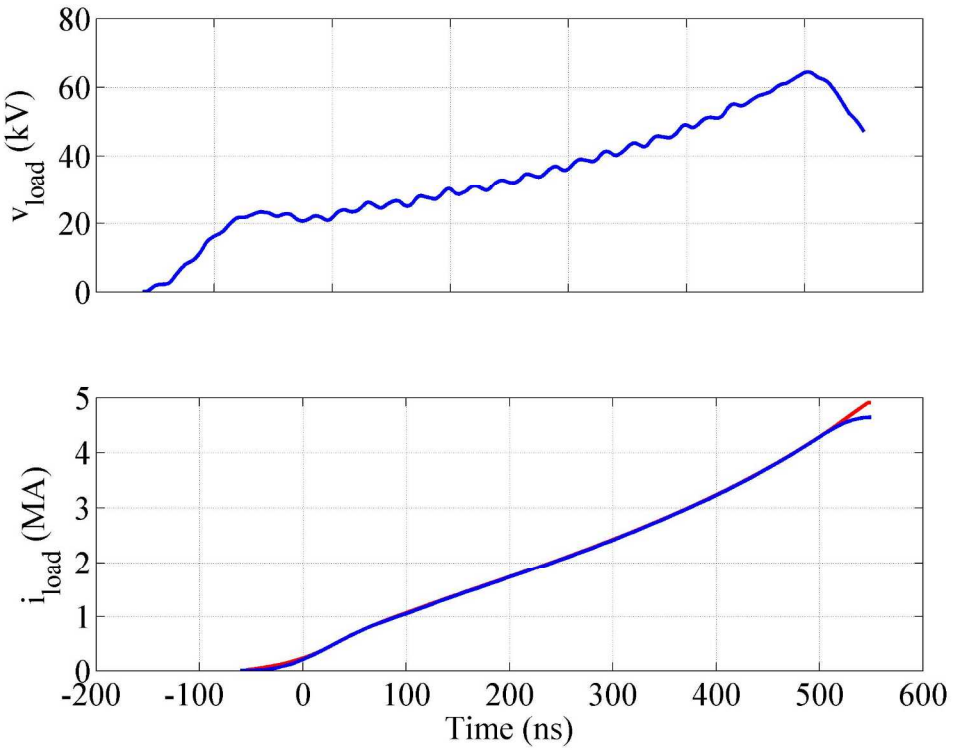
Optimized Simulations Approach Ideal Current Shapes

Optimized current for tungsten



Optimized current for polypropylene



Red trace is the target current

Blue trace is the simulated current

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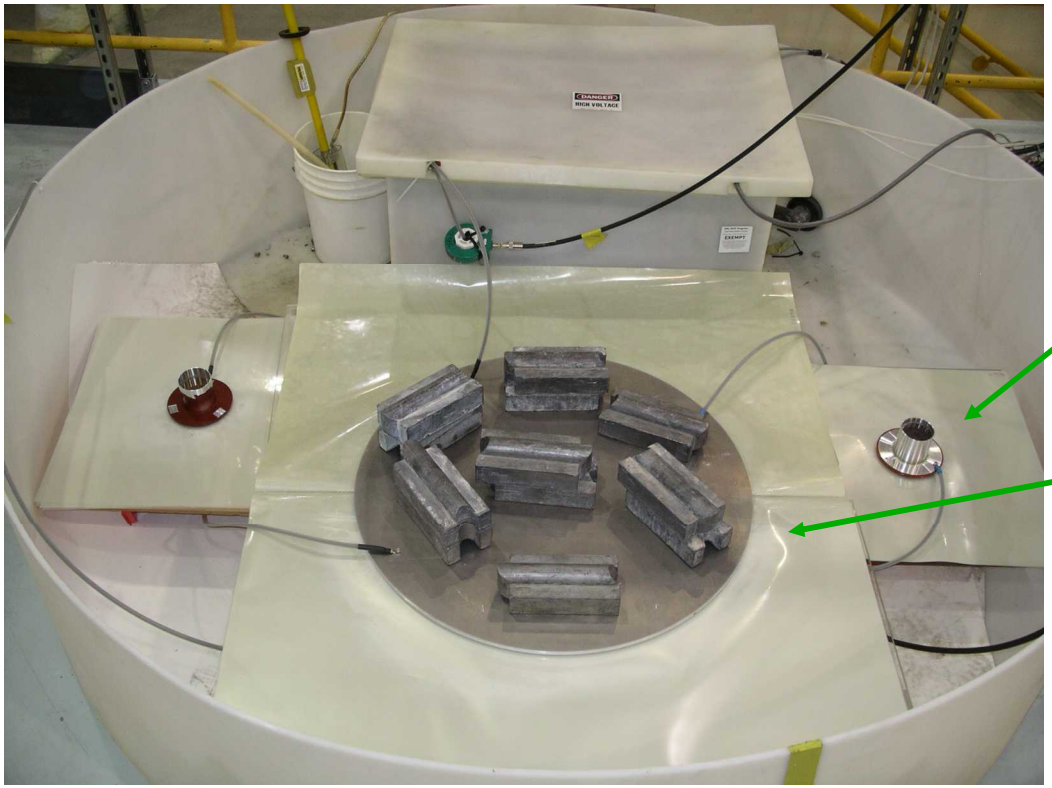
Voltage Hold off is being Tested in the Insulation and Interface Test-bed

Insulation and Interface test-bed

- **Operational**
- **Evaluating**
  - **insulator design in the feed structure**
  - **module – feed structure interface for voltage hold off**



Insulator penetration evaluation

Insulator joint evaluation

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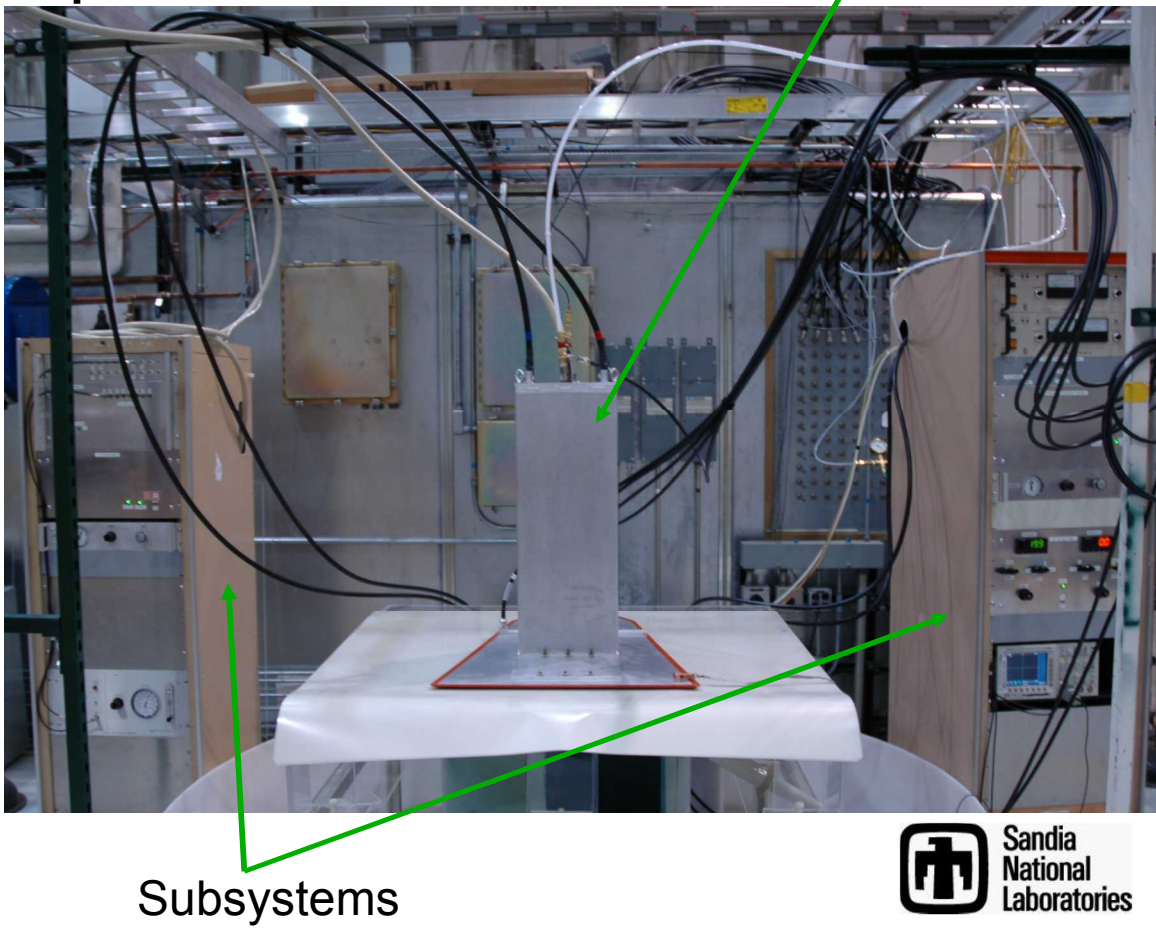
SubSystem Design is being Evaluated in the Single Module Test-bed

Single Module test-bed

- **Operational**
  - **first sets of data are being acquired now**
- **Evaluating**
  - **control system design**
  - **charge and dump system**
  - **pressure system**
  - **trigger system**
  - **module operation**
  - **current connection**



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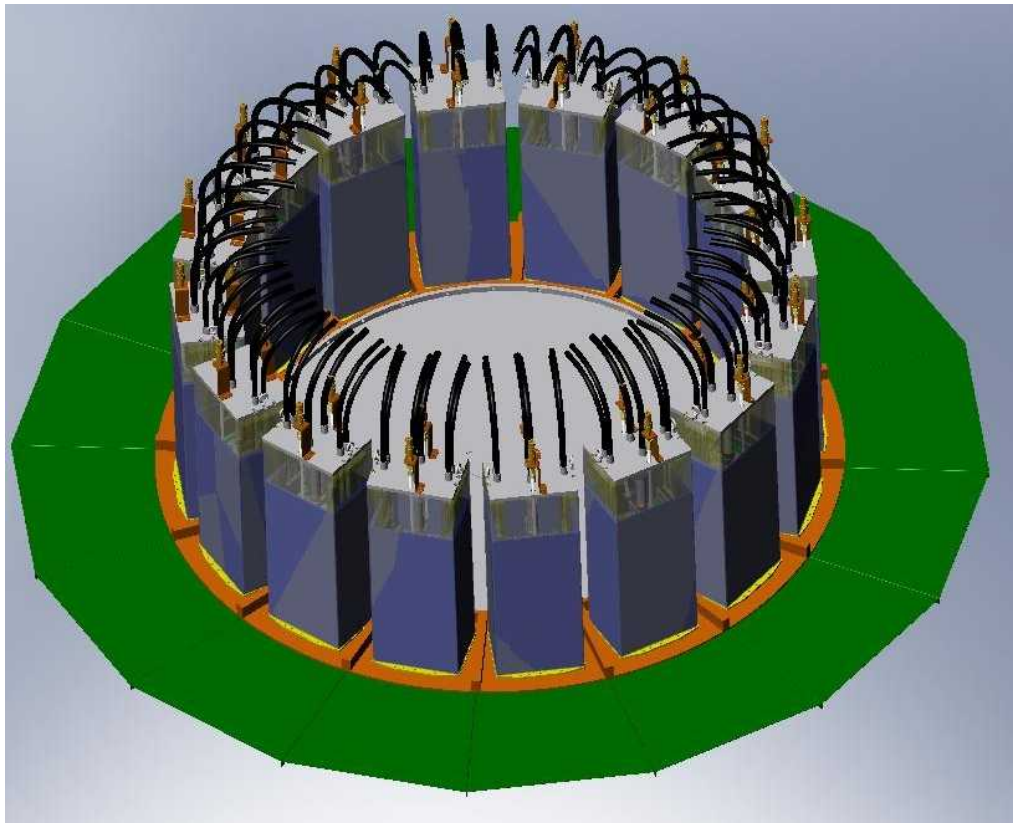
Final Verification of the System Design will Occur in a Multi-module Test-bed

Multi-module test-bed

- **Will be constructed this year**
- **Evaluation**
  - **scaled version of the full system design**
    - **voltage hold off of insulators**
    - **current connections**
    - **control system**
    - **diagnostics**
    - **model calibration**



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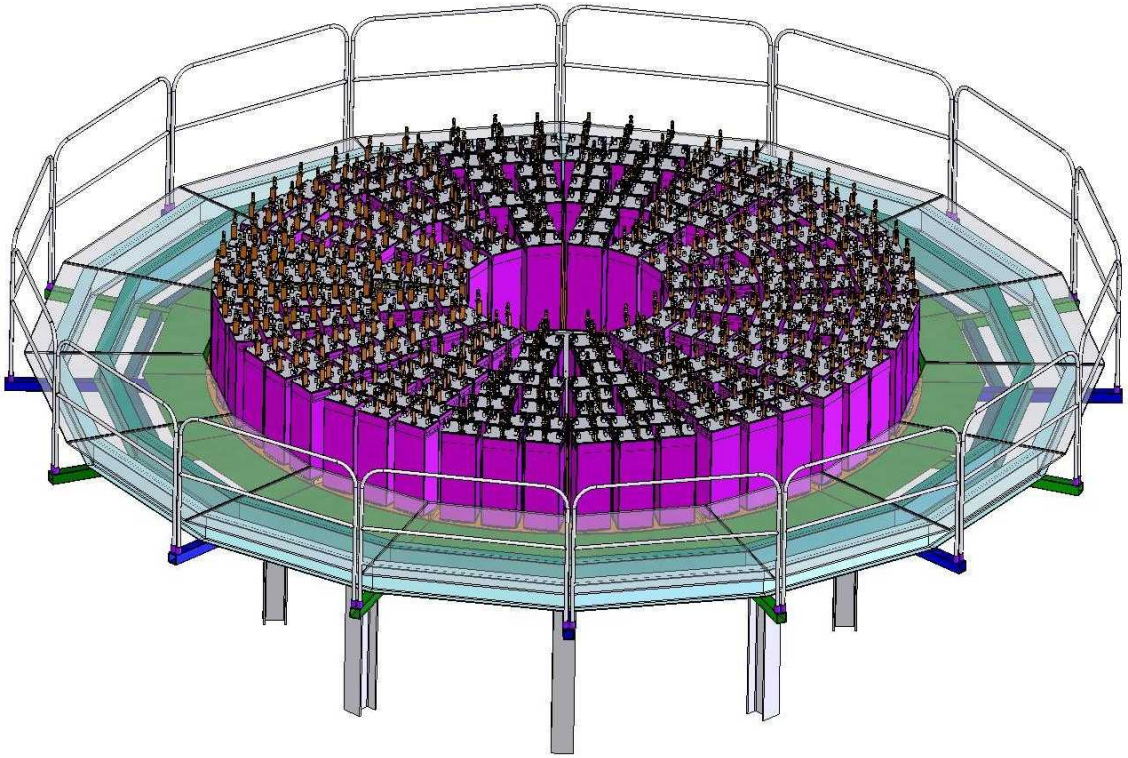
In Conclusion

- System modeling indicates that high levels of pulse shaping will be feasible
- Extensive testing will continue through the fiscal year
- Targeting the end of the fiscal year for a complete system design
- Construction is expected to occur in 2009.



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