SimBRS: A University/Industry Consortium Focused on Simulation Based Solutions for Ground Vehicles

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Why simulation?

- Emergence of high-performance computing has created a third mode of scientific investigation for discovering new knowledge.
  - Theoretical analysis
  - Physical experimentation
  - Computational simulation
- Simulation provides:
  - Efficient exploration of novel approaches to satisfying a design constraint
  - Linking of sub-systems to explore design trade offs
  - Optimization at the component level
  - Risk reduction

Why simulation?

- "… there is overwhelming concurrence that simulation is key to achieving progress in engineering and science in the foreseeable future."
  - NSF Blue Ribbon Panel on Simulation-Based Engineering Science, May 2006
- "In the swiftly changing and increasingly competitive global marketplace, innovative design solutions and short product development cycles that rely on integrated product development teams armed with computationally based design, engineering analysis, and manufacturing tools are what give the nation its competitive edge."
  - Integrated Computational Materials Engineering: A Transformational Discipline for Improved Competitiveness and National Security, NRC, 2008.

- The Simulation Based Reliability and Safety (SimBRS) Program is focused on supporting the warfighter by developing advanced M&S tools for improving the reliability and safety of ground vehicle systems.
- This is accomplished by:
  - Working through a consortium of university and industry partners
  - Leveraging unique M&S capabilities and HPC resources available at TARDEC and SimBRS consortium members

- The challenge in any simulation based research program is to be able to have data and observations from sensors that can be used to verify and validate models (physics or empirical based) of the system being simulated.
- SimBRS researchers characterize the ground vehicles, their surrounding environments, threats, and warfighters and the interactions amongst these subsystems with a network of *in situ* sensors and laboratory measurements.
- The modelers use the resulting trend data and flow depictions to understand the underlying processes and build computational models of the vehicle system, interactions between protective devices and warfighters, and other systems contributing to safety and reliability.

- Over time, researchers will refine these models and assimilate them with real-time observations to predict failures of components and overall safety and reliability of the integrated system of vehicle and warfighter.

- Partners (original)
  - HBM nCode
  - Lawrence Technological University
  - Mississippi State University (lead)
  - University of Alaska Fairbanks
  - University of Notre Dame
  - Western Michigan University
- New Partners
  - Caelynx LLC
  - PTC
  - Ricardo Inc.

Research Thrusts

- Multi-Scale, multi-physics modeling for vehicle dynamics and structural reliability, durability, and survivability
- Warfighter based simulations for survivability
- Validation, verification, and accreditation of models and simulations
- System Integration and Optimization: Hybrid technologies
- Simulation of fluid-structure interactions

- New computational design methodologies for topologically controlled crashworthiness design synthesis for improved soldier survivability subject to nonlinear transient loadings and blast loadings. (ND)
- The development of multi-scale nano-composite simulations for multi-scale material design. (ND)
- Coupled computer-aided-engineering (CAE) simulation methodologies and high strain rate material characterization to evaluate explosive blast and fragmented shrapnel effects on ground vehicle structures. (MSU)

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SimBRS

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MODELING AND SIMULATION, TESTING AND VALIDATION

- Parametric study related to side curtain air bag interaction with an out-of-position occupant (crash test dummy) simulating a crash event. (MSU)
- Improve the fidelity of human behavior modeling and visualization in the TARDEC Ground Vehicle Simulation Lab. (MSU)
- Develop and characterize the mechanical behavior of biomimetic gel material for use as surrogate human tissue. (ND)

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MSTV
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- Improved techniques for vehicle prognostic/diagnostic data acquisition, analysis, and storage. (HBM nCode)
- State-of-the-art computer tools for use in modeling and simulation to advance the prediction of ground vehicle reliability and safety in extreme operating environments. (WMU)
- Enhancing test capabilities for vehicle armor and vehicle sub-systems. (LTU)

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- Focus on OBVP
- Improving the power density associated with the converter/inverter for engine driven applications
- Investigating modifications to both vehicle, speed controller, and power converter to facilitate mobile, “on the go” applications for OBVP, and
- Developing and evaluating non-belt-driven advanced electromechanical energy conversion subsystems to achieve up to engine-limited power levels from the vehicle. (MSU)

Research Thrusts

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- **Simulation of fluid-structure interactions**

- Blast wave-structure interaction problems and their resulting loading on occupants using state-of-the-art gas dynamics and material dynamic response simulation tools. Computationally efficient prediction tools will be developed to provide physics-based analysis tools that can be used in design optimization. (WMU)

Simulate coupled fluid-structure interactions

- Coupling methodologies with Loci/CHEM
  - Loose ("two-way") coupling and decoupled ("one-way") with in-house CSD software
  - Decoupled ("one-way") with commercial CSD software (LS-DYNA)
    - Underlying assumption is that response time for solid is much slower than the time of the fluid interaction with the solid
- Interdisciplinary Data Transfer
  - Conservative load and moment transfer and work done during transient simulations
  - Several non-overlapping schemes being tested (node-projection, quadrature-projection, common-refinement)
  - Many existing algorithms were developed for aerodynamics applications – not blast waves

Blast-structure interaction simulations

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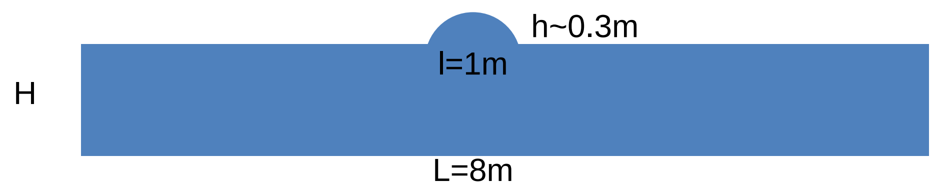
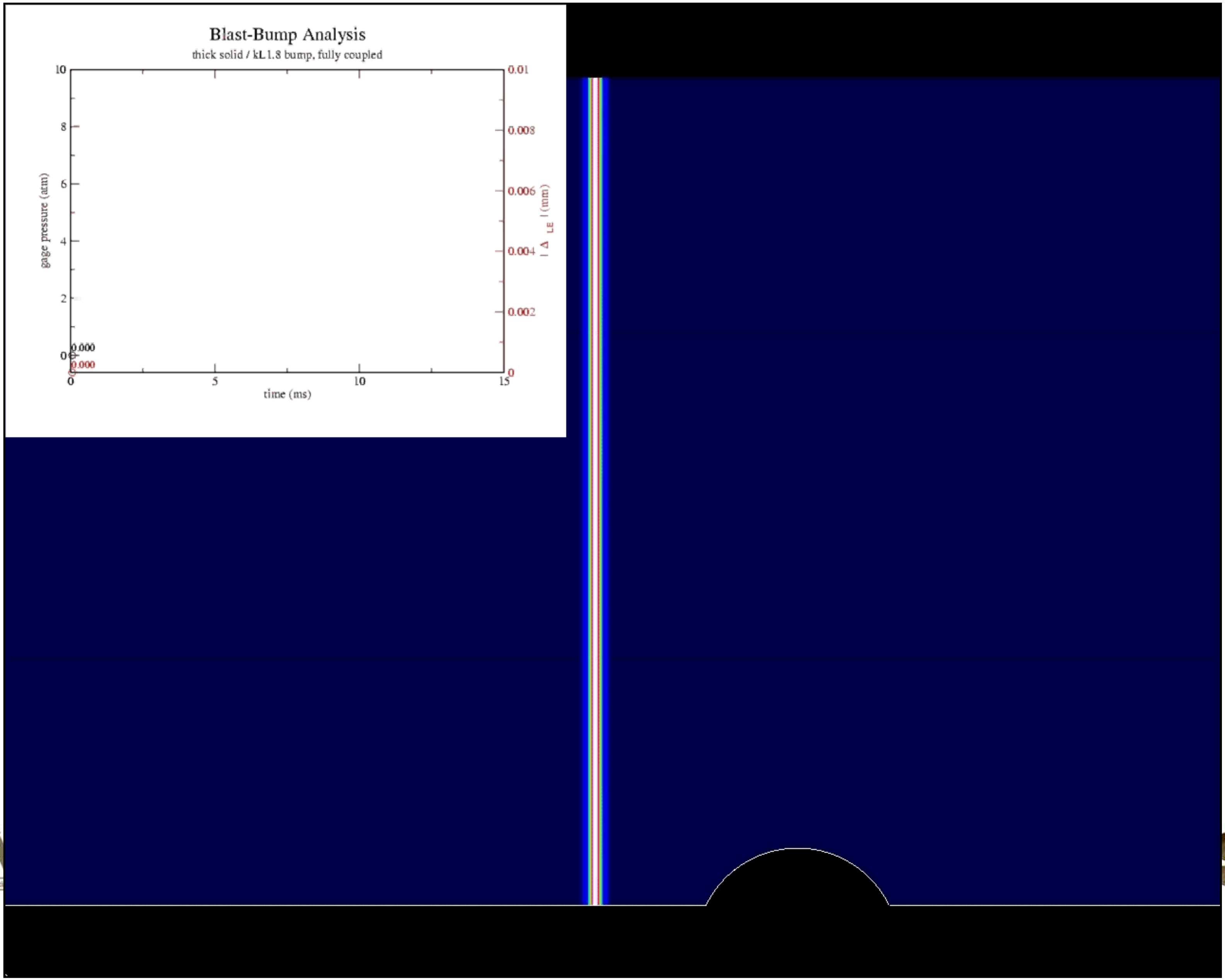
- Blast-wave interacting with an elastic bump
  - Assess accuracy of interdisciplinary transfer algorithms
  - “Thick Solid” (L/H=2) vs. “Thin Solid” (L/H=50) response to blast-wave loading and influence of coupling methodology

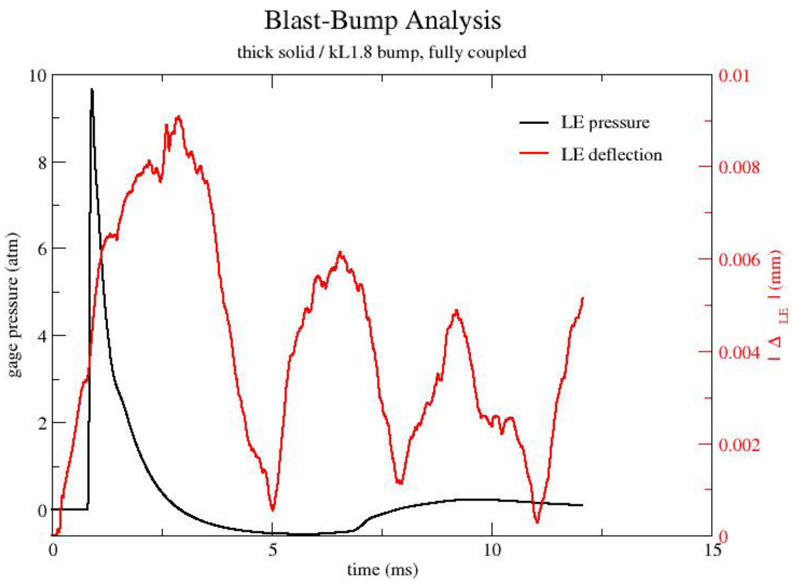


- Blast-wave interacting with a metallic plate
  - Blast-wave loading and influence of coupling methodologies (in-house software)
  - One-way coupling with commercial software

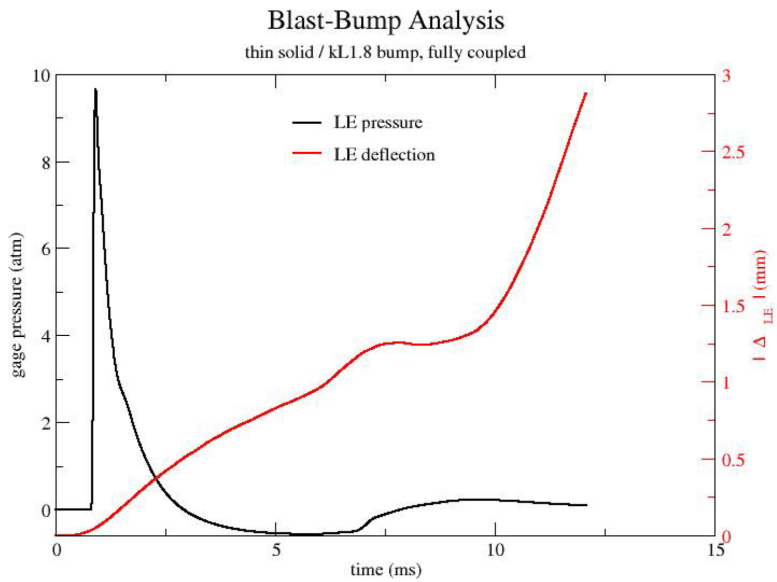
Results


Blast-Bump Analysis
thick solid / kL1.8 bump, fully coupled
gage pressure (atm)
time (ms)
| Δ LE | (mm)
0.000
0.000
0
5
10
15
2
4
6
8
10
0.002
0.004
0.006
0.008
0.01

Results



"Thick Solid" (L/H=2)
localized response



"Thin Solid" (L/H=50)
global response

Conclusions

- The challenge for the SimBRS team is to establish an approach based on the capacity of measured data and simulations to support decision-making by the Army in establishing policies and management solutions for current and future ground vehicles.
- This decision-making is driven by systematically relating appropriate results from measurements and applied research in engineering and science. In turn, basic research and technology developments in areas such as materials science and energy enable applied research.
- The relationship among basic research and development, applied research, and operational solutions is dynamic and iterative and requires a systematic approach to bridge the gaps between the research and operational domains.