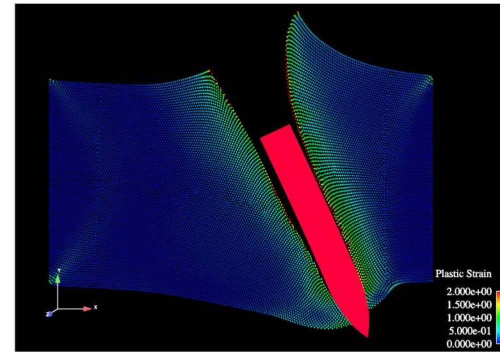
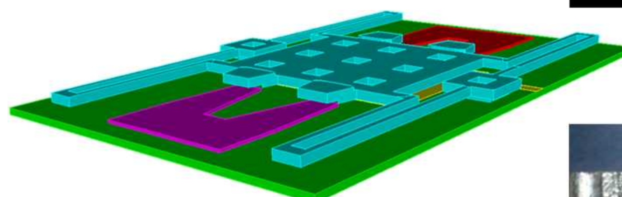
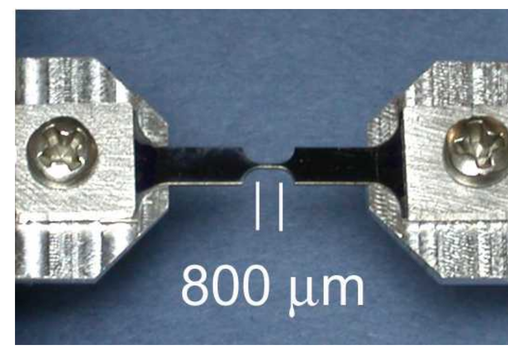
SAND2007-0420C

Solid/Material Mechanics and Structural Dynamics Discipline



ESRF External Panel Review
January 15, 2007





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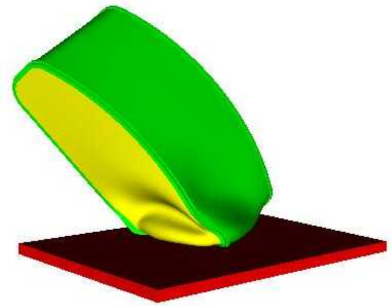
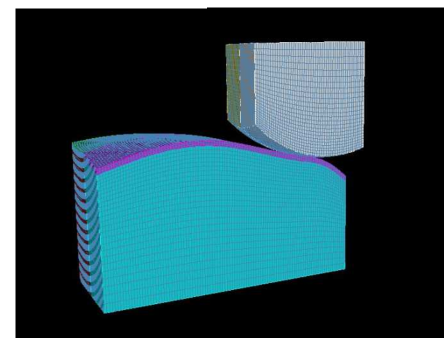
Solid/Materials Mechanics and Structural Dynamics

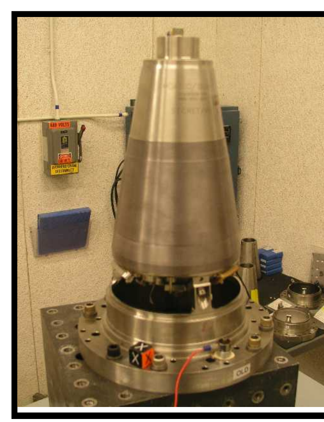


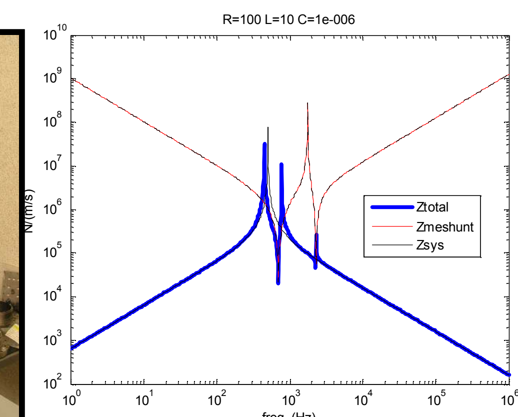
Objectives:

Develop and enhance capabilities in materials and structures modeling, computational algorithms and experimental diagnostic and experimental discovery methodologies to

- provide validated modeling and simulation technologies to resolve stockpile issues
- enable predictive modeling and simulation
- address solid/materials mechanics & structural dynamics issues in emerging technological areas



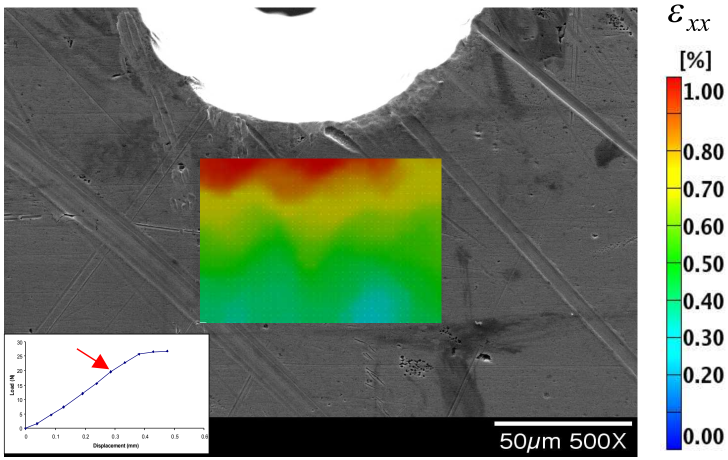




Drivers:

* DSW problems * ASC requirements
* MESA needs
* Emerging National and corporate technology issues and concerns

Solid Mechanics



SEM DIC strain mapping

Near Term Objectives:

- Develop methods to deal with fracture and large deformation problems
    - Implement large deformation methods capable of modeling failure
    - Implement multiscale capabilities to support failure modeling, model refinement, and material scale issues
- Support MEMS technological needs
- Invest in improved efficiency methods

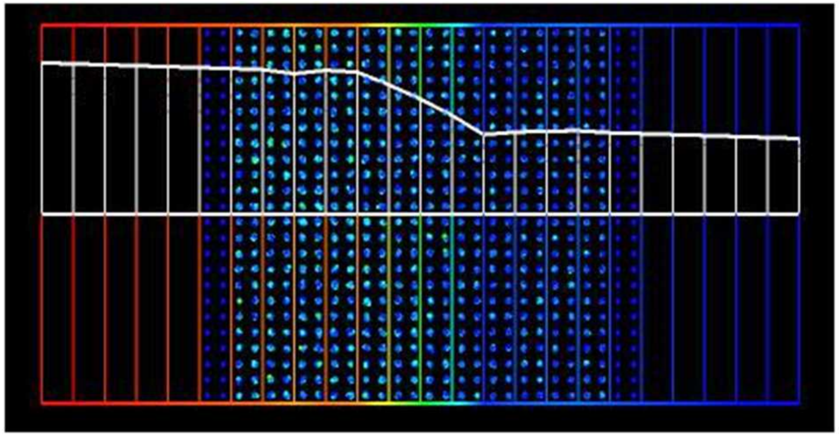
Current State:

- Capable of modeling systems with moderately large deformations (without failure)
- Meshless methods, nonlocal methods, and cohesive zone models have been studied
- Robust methods that can model post-failure behavior need development
- Multiscale capability needed
- Need robust methods that can model general very large deformation/strains without causing numerical problems

Gaps:

- Explore and Implement Meshless Methods
- Explore/develop multiscale methods
- Explore other methods (Xfem, VETFEM for added capabilities and enhanced DtoA capabilities?)
- Support code efficiency enhancements

Concurrent Atom-Continuum Coupling



Objectives:

- Simulation of physically representative systems with atomic detail using a consistent atomic-continuum paradigm.
- To enhance molecular dynamics with missing physics from finite element and vice versa
- To free MD from restriction such as periodic bcs and rectangular domains via coupling with FE

DP Applications: simulation of complex, localized processes, e.g. cracking, spot welding.

Non NW Business Opportunities: evaluation of nano-structures and systems.

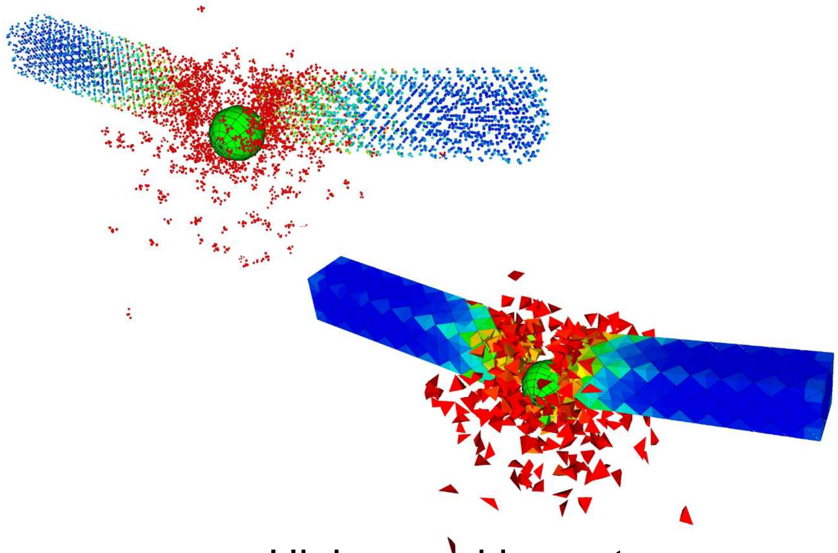
Team:

R.Jones(8776,PI), C. Kimmer (8774), G. Wagner(8775, LDRD leverage)

Approach:

- Concurrent two way coupling is achieved via a full overlay of the FE mesh with appropriate governing equations being blended in the transition region between MD and non-MD domains
- Consistent continuum-scale surrogate models are used in the non-MD regions and efficient filtering is used to pass information between scales

Meshless Methods for Failure Modeling



High-speed impact

Objectives:

- Develop a new computational mechanics methodology to model structural failure including fragmentation and penetration.
- Method should be convergent and efficient.

DP Applications:

•response of weapons systems to normal and abnormal environments
•VA (DoD, NRC, DHS, satellite shielding)

Approach:

- Pure Lagrangian explicit dynamics
- Discretization of structures using arbitrary polyhedral elements.
- Nodal shape functions defined using reproducing-kernel-particle method
- Discrete intercell fracture
- Dynamic insertion of cohesive intercell forces during fracture

Deliverables:

- Demonstrated computational methodology for modeling pervasive failure
- Integration with existing FEA technology
- Sand report, journal article

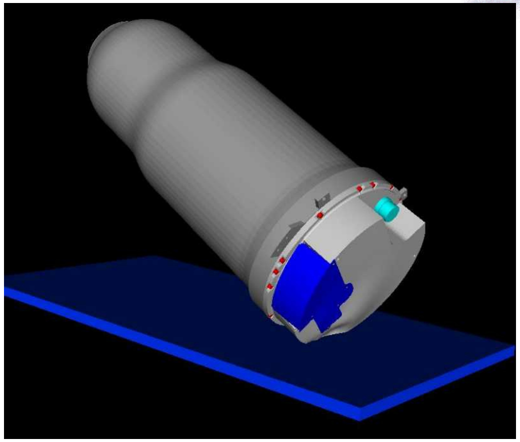
Team Members:

J. Bishop (PI), 1525

Collaboration:

M. Rashid (UC Davis)

Materials Mechanics



Current State:

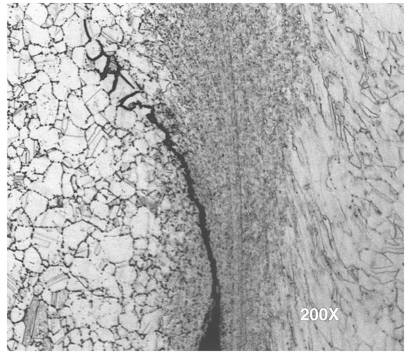
- Model development largely limited to metals - soft material capability needs development
- Mostly phenomenological models capable of data fitting but not prediction
- Can model fracture and failure initiation well but not growth/propagation
- Although some progresses have been made, post-failure calculations for most models are still mesh size dependent
- Need aging and environmental effect models
- Some coupled-physics capabilities exist that need to be strengthened and expanded
- Applications at ever shrinking size scales demand multi-scale and generalized continuum capabilities where only rudimentary models exist

Near Term Objectives/Gaps:

- Improved soft material capabilities - polymers, composites, tissues…
  - Gap: composites, foams
- Advanced predictive post-failure modeling and simulation: mesh-size independence, fracture growth/propagation,…
  - Gap: fracture propagation modeling with embedded length scales
- Design, fabrication, performance and reliability evaluation for miniaturized systems
  - Gap: general continuum theories, interface mechanics, multi-scale capability, coupled physics
- Improved aging and environmental effect models
  - Gap: hydrogen embrittlement, fatigue

Hydrogen Embrittlement

GTS reservoir



Weld crack

Goal:

To develop a continuum material model that will couple the mechanical response of materials with presence of hydrogen resulting in the capability of predicting embrittlement, aging and life.

Applications:

Exposure to high pressure tritium in GTS reservoir results in material degradation over time which has led to post-weld cracking

Approach:

Develop dislocation based plasticity model including hydrogen dislocation interaction in mechanical response as well as transport. Hydrogen dependent cohesive zone model developed for modeling crack growth.

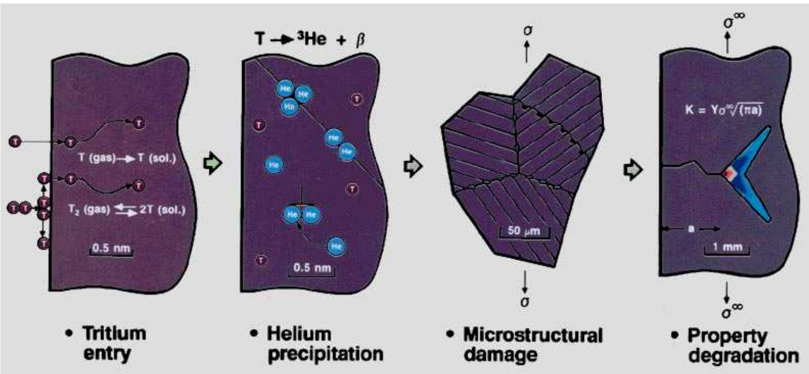
PI: Doug Bammann, 8776

Colloborators: Petros Sofronis,Univ. Illinois

Project Leveraging:

GTS material modeling, MST - H2 experiments (Someday), ESRF hydrogen experiments (Antoun)

Hydrogen-Deformation Interactions



Objectives:

- Develop a fundamental understanding of the presence of hydrogen on the mechanical behavior of storage materials.
- Characterize storage materials with varying levels of hydrogen to enable physics-based model development.

DP Applications: GTS stockpile

Non-DP Applications: Hydrogen storage and delivery (pipeline) applications

Approach:

- Use existing mechanics-based experimental methodology for determining material model plasticity parameters.
- Extend/develop new methodology in an attempt to separate or elucidate hydrogen effects.
- Correlate material microstructure (as a function of hydrogen presence) with material properties and ductile fracture processes.

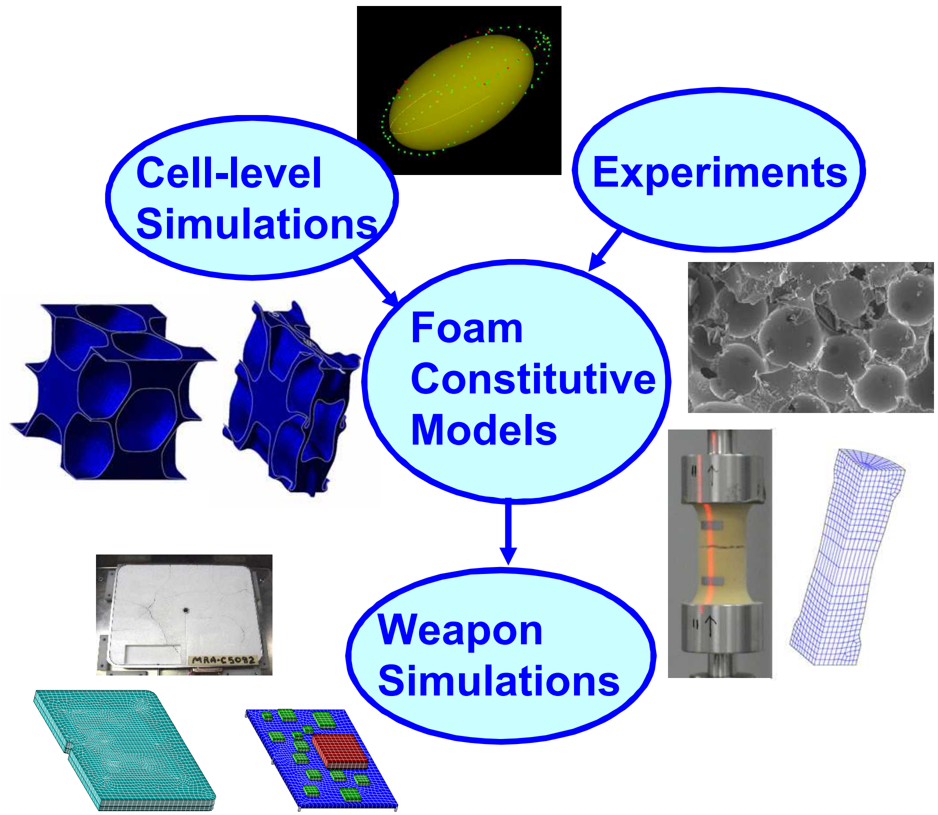
Team Members:

B. Antoun, 8776
J. Korellis, 8776

Collaborators:

B. Somerday, 8772
D. Bammann, 8776
P. Sofronis, U. of Illinois

Foam Constitutive Models



DP Applications	Foams Used
B61 nose crush	PMDI20, PMDI50
W80-3, W76-1 LEP	REF308, RSF200
	PMDI
W76 Container	FR3712, TF-5070

Approach: Use complementary experiments and numerical tools to study foam failure and develop constitutive models for DP foams.

Team Members:

Mike Neilsen, 1526
Bill Scherzinger, 1524
Andy Kraynik, 1514

Collaborators:

Wei-Yang Lu, 8776
Prof. Triantafyllidis, Univ. of Michigan

Objective: Develop constitutive models for foams used in weapons for packaging.

Structural Dynamics

Current State:

- Some Strengths
  - ➢ Sustained excellence in linear structural dynamics
  - ➢ Sustained research in interface mechanics is feeding into model development and validation for jointed structures
  - ➢ Nationally recognized leaders in sub-discipline
- Challenges
  - ➢ Use of nonlinear models for traditionally linear analysis
  - ➢ Need innovation with testing technology, data processing
  - ➢ Structural Acoustics is leading edge but needs visibility
  - ➢ Creating predictive models of aging systems

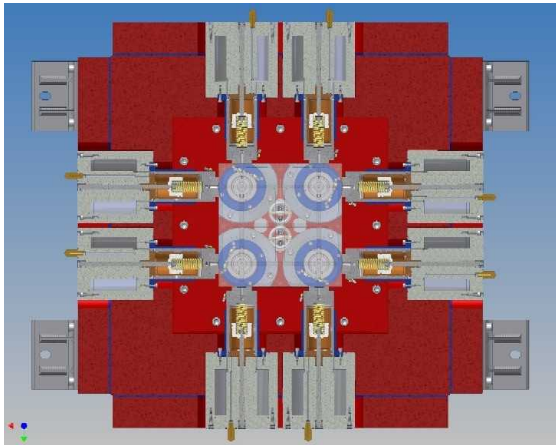
Desired Near Term State:

- Structural-acoustics analysis for bombs, JTA flight tests
  - Pyroshock analysis (Coupled hydrodynamic-structural dynamic analysis)
- Environmental load characterization for Reentry, Impulse, blast, TMS/TSR
- Multi-physics analysis capabilities for microsystems (fluid-structural)
- Enhanced BC and load control for validation experiemnts
- Coupled microsystems model validation
- Robust identification and characterization of moderately nonlinear structures through mid-frequency
- Viable approach to weapon condition monitoring and health assessment

Gaps:

- Random field analysis techniques
- Efficient structural acoustics characterization
- Data processing, analysis, characterization of moderately non-linear system
- Multi-physics analysis capability for microsystem response
- Wireless embedded sensing
- Validation Testing
- Test set-up and data processing to visualization

Experimental 6-DOF Vibration and Shock Capability



12-actuators generate forces and moments to fully control (or constrain) selected DOF's

Objectives:

- Develop and deploy new experimental 6-DOF vibration and shock simulation and model validation capability
- Provide experimental test bed to investigate methodologies for specification of 6-DOF environments and assessment of conservatism and damage potential

DP Application:

DP Weapons component development and qualification, ISE, MEMS, Model validation

Approach:

- Investigate the performance envelopes of the 6-dof shaker/control system.
- Develop methodology for specification and quantification of 6-DOF environments
- Investigate dynamic responses of specially designed test structures to tailored 6-DOF environments

Team Members:

Dan Gregory, 1521
Brian Resor, 1521
Ron Coleman, 1521
Jerry Cap, 1523

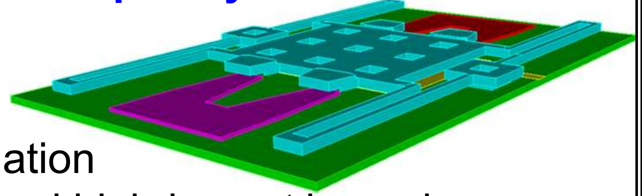
Collaborators:

David Smallwood, Retired Sandian

RF MEMS: Synergistic Experimentation and Simulation Solve Switch Bouncing Problem

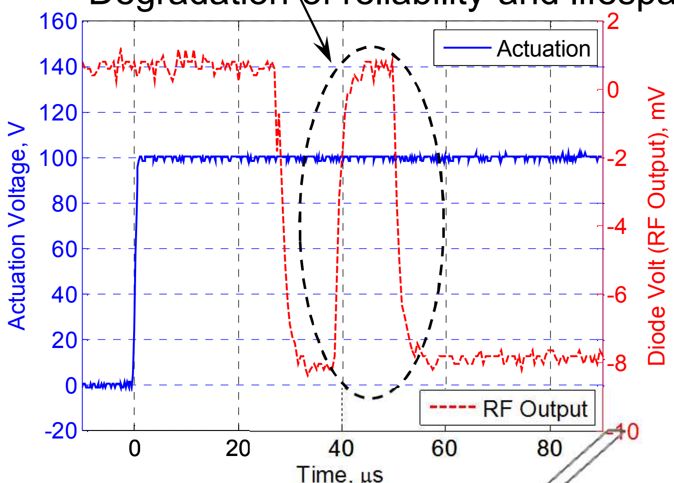
Sandia Radio-Frequency MEMS Switch

143 µm wide
6.5 µm thick

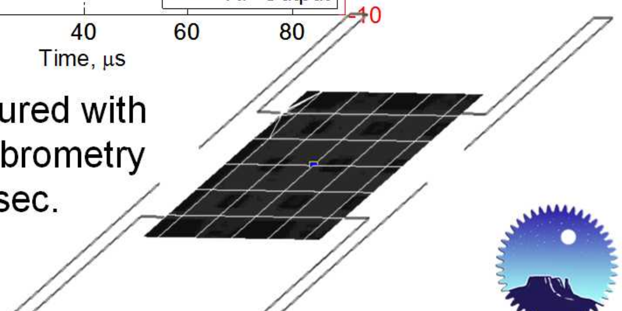


Original actuation scheme caused high-impact bouncing.

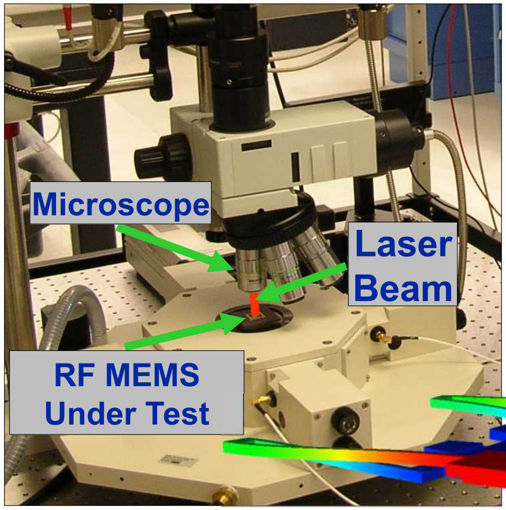
- Interruption of signal
- Degradation of reliability and lifespan.



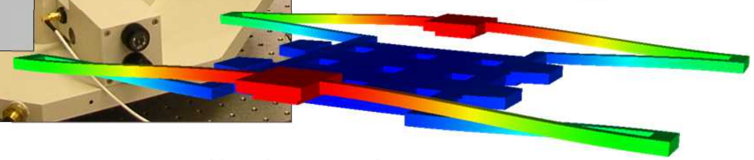
Bouncing measured with laser Doppler vibrometry at 5M samples/sec.



Synergistic Solution



Laser Doppler Vibrometry and High-fidelity, 3D Multi-physics FEA



- Computed waveform eliminates bounce.
- Switching time reduced by 81%.