Experiments and Modeling at Mesoscale

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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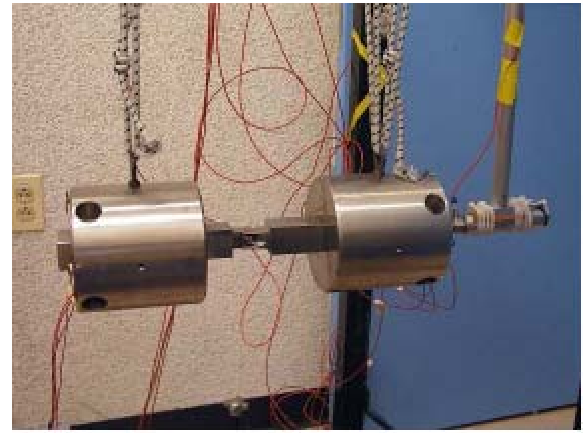
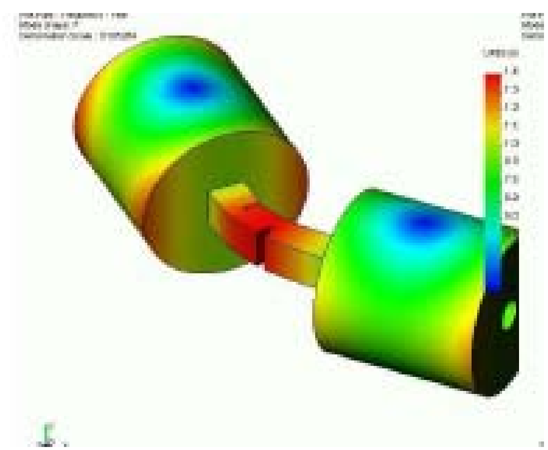
Ultimate Goal

- **To develop predictive simulations of full-up systems, including energy dissipating mechanisms, such as bolted joints**
  - Meaningful predictions of system response to realistic loads
  - “Before-built” predictions to guide design decisions
  - Predict response and margin to un-testable environments





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Ultimate Goal Cont.

- Discovery and validation experiments
  - Give intuition to the modeler
- Long-term: Compile a database of experimental data to use in future model development and validation
  - Make use of experimental data and theories to explain that data.
  - Primary focus thus far: Interfaces with bolted joints
    - Majority of work with single joints in shear

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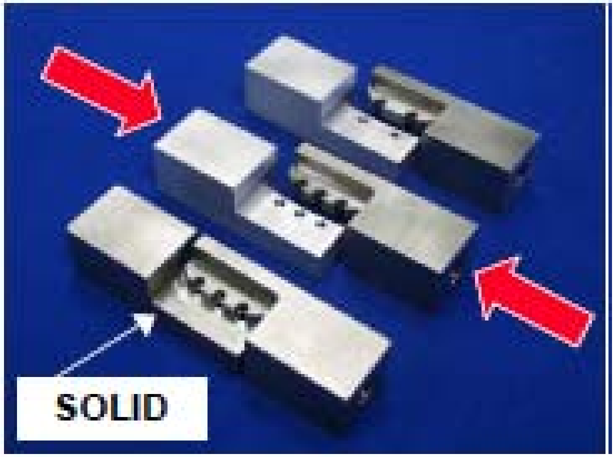
Where Do We Go From Here?

- **Many energy-dissipating mechanisms**
  - **Bolted, threaded, tape joints…**
  - **Foam**
  - **Interfaces**
- **Considered the major contributors to response of systems**
  - **Determined that bolted joints were a major contributor**
  - **Expand our understanding in more complex geometries and environments**
  - **Also determined that “top-down” or “hybrid” approaches may lead to more predictive models**

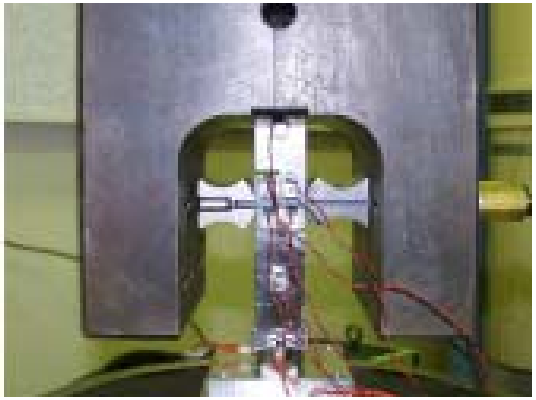


How Do We Get There?

- To gain insight into the behavior of real bolted joints in full-up systems during realistic environments:
  - Variety of inputs
    - Complex shock waveform, random vibration
  - Multiple joints
    - Bolt rings, flange joints, etc.
  - Combination Loading
    - Past work has focused on joints in shear. Real loading includes bending, etc.
  - Explore “top-down” and “hybrid” approaches
    - Empirical approaches to subsystem damping
  - Variability and Uncertainty

Predictive Capabilities

- **Repeatability and Variability Experiments (Mike Starr)**
  - A phenomenologically-based analysis to capture variability intrinsic to the assembled lap joint structure due to interface surface features and interface misalignment.
  - Examine sample-to-sample variation and assembly-to-assembly variation of the same sample
  - Experimental results will be compared to computational ones (Adagio FE model)
  - Random and shock inputs will also be included for future model validation



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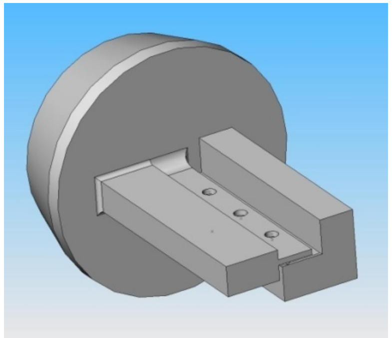
Predictive Capabilities

- **Non-dimensional relationship for predictive modeling (Mike Starr)**
  - Non-dimensional parameter study indicates a relationship between ratios of key joint characteristics (i.e. cyclic load amplitude/clamping load) and dissipation
  - Tailored variability study to consider the cyclic load/clamping load ratio
  - Will expand to vary thickness and contact area of the lap specimens
  - If verified experimentally, would develop set of key parameters to populate a model for unique joints without the need for extensive experimentation or simulation

Multiple Joints/Shock Loading

- **Bolt Rings, Multi-Joint (Mike Jew)**
  - Study dissipation in shock
  - Several different configurations,
    - Multiple bolts in one lap joint (Tab)
    - Multiple single lap joints in one assembly ("layer cake")
    - Bolt ring configuration (24 bolts around circumference
    - Different materials-steel, aluminum
    - Top-down modeling



Tab (serial)

Layer Cake

Combination Loading

- **Previously, the majority of work has focused on joints in shear**
  - Actual environments include more complex loading (bending, torsion, etc.)
  - Choosing from the following
    - Big Mass Device with offset mass to provide moment with axial shear
    - Big Mass Device with a static moment from a cable
    - 6-DOF system to provide combined loads
    - Use piezo-washers to provide time-varying bolt loads to lap joint

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