High Shock Modeling of Fuze Components

Presented to:

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Presented by:

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Overview

- Background
  - MEMS Safe and Arm
  - Purpose
  - DYSMAS
- Literature Search
- VHG Characterization
- Simulations
- Material Characterization Tests
  - Split Hopkinson Bar
  - 4-Point Bend Test
- Path Forward

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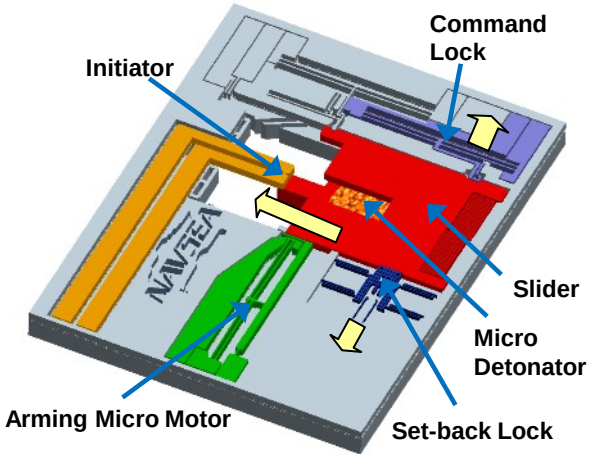
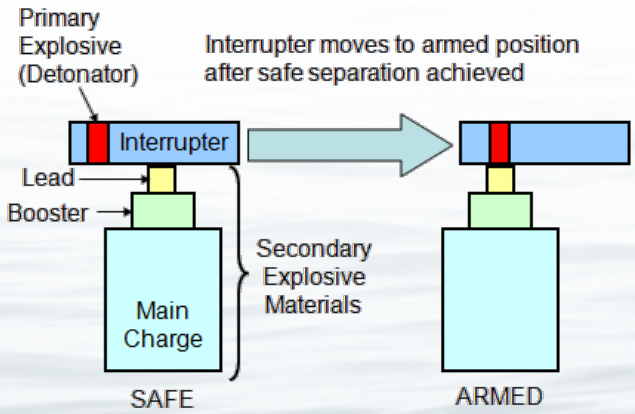
MEMS Safe and Arm

- Micro-Electro Mechanical Systems (MEMS)
  - Low cost, out-of-line safety, small volume, low power alternative to ESADs
- Naval Surface Warfare Center Indian Head Division (NSWC IHD)
  - Two decades of silicon/silicon-on-insulator (SOI) MEMS design, fabrication, packaging and testing experience
  - Class 10,000 clean room with explosive capability
- Commercial processes
  - Non-explosive components only
- Safety locks
  - Integrated mechanical structures, command actuated locking architecture
- Arming
  - Environmentally derived command architectures



Interrupted
- "Out-of-line" systems
- Electro-mechanical
- Pure mechanical



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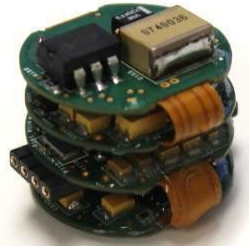
NSWC IHD Core Capabilities

- Electrical design and test
  - Electronic Safe Arm Devices (ESADs) and MEMS SADs
  - Sensing technologies, imbedded systems, RF design



- Initiation systems design and test
  - Micro-energetics, micro-firesets
  - Characterization (e.g., Photonic Doppler Velocimetry)

- Mechanical design and test
  - Fuze packaging
  - Full scale launch and impact testing (reverse impact available and explosive certified)
    - Guns up to 21” diameter
    - Speeds >2000 ft/s
  - MEMS
  - High G shock testing and survivability

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High Shock Modeling

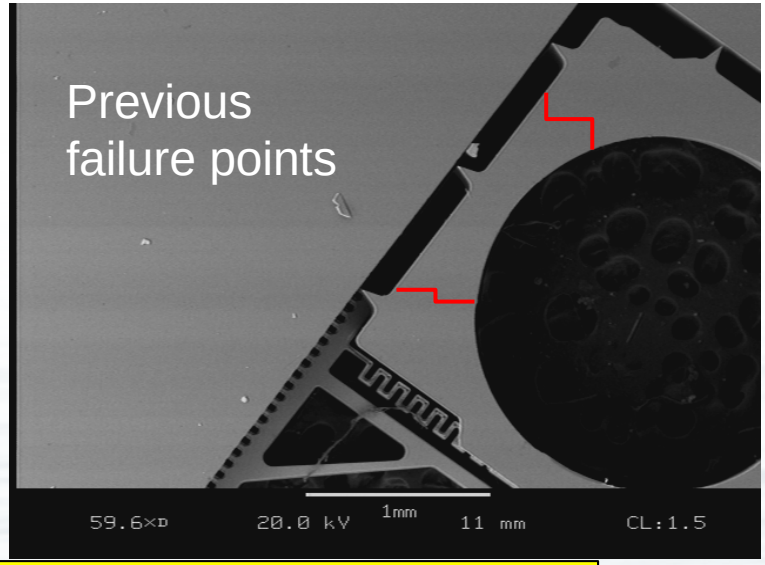
Objectives:

- Utilize modeling and simulation (M&S) to increase shock survivability of NSWC IHD MEMS fuze components
- Develop silicon material model for more accurate M&S at high strain rates using NSWC IHD MEMS S&A as testbed

Approach:

Gather silicon material models from literature/material characterization tests

Refine model and validate using experimental data from Very High G (VHG) testing



Current efforts funded through Joint Fuze Technology Program.

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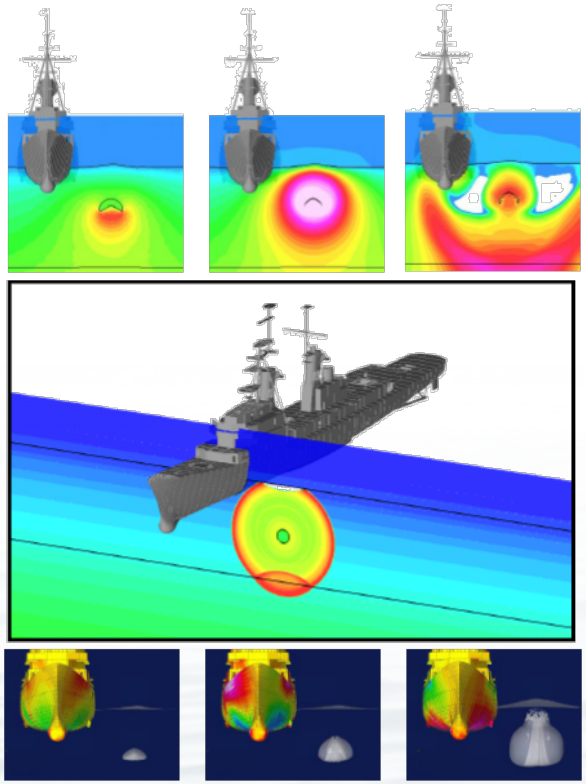
DYSMAS

- Dynamic System Mechanic Advanced Simulation (DYSMAS)
  - ParaDyn-explicit 3D-finite element code for solid and structural mechanics that is good for highly dynamic environments
  - Similar to other commercial codes such as ABAQUS, LS-Dyna
- Government owned
- Extensively validated for underwater detonations against various surface and submerged structures
  - Can run structural loading and analysis or fluid dynamics separately
- Co-developed between the United States and Germany



DYSMAS Version 7.7.00
Manual Dated: 18 Sep 2018

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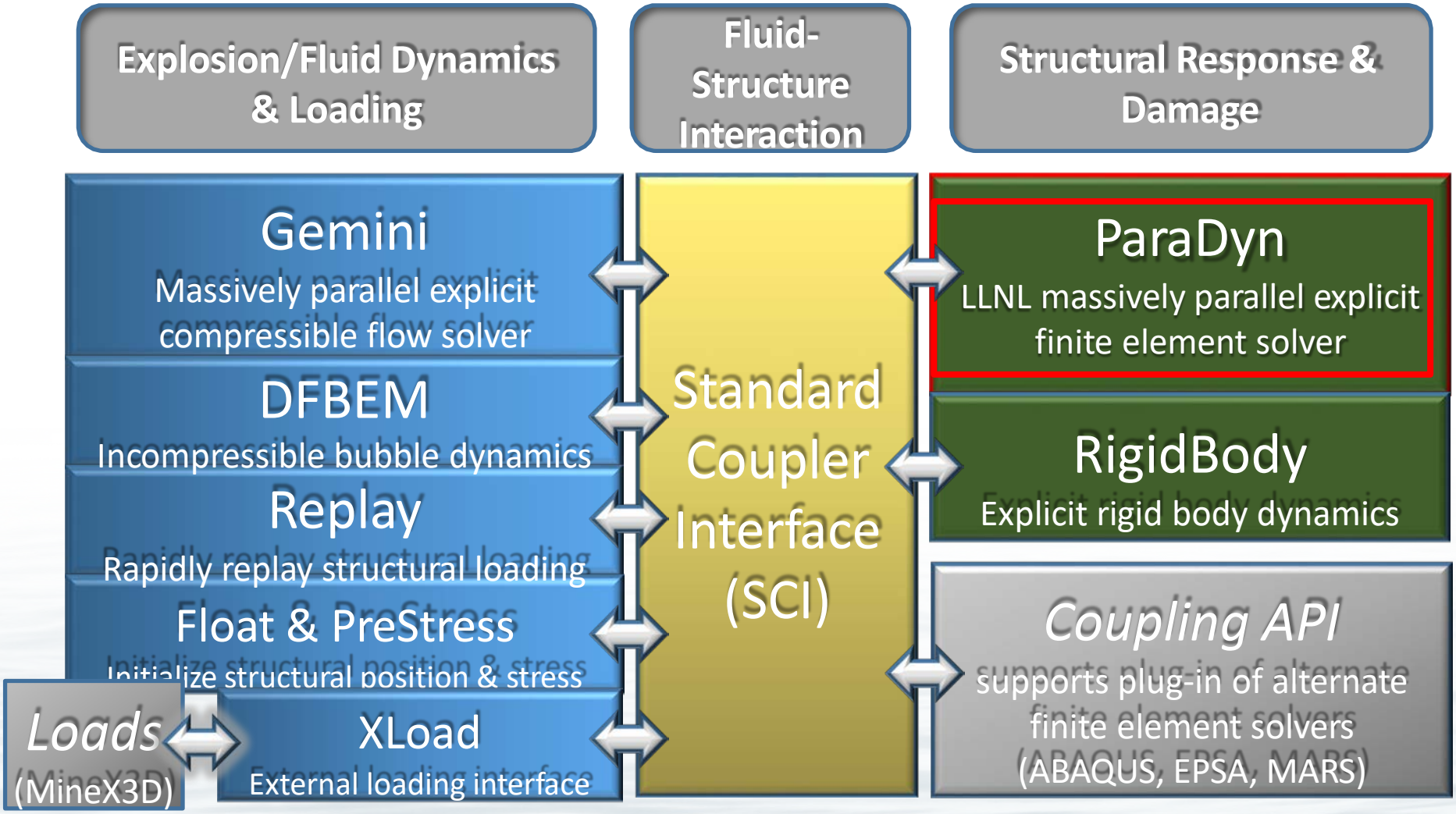
DYSMAS Architecture



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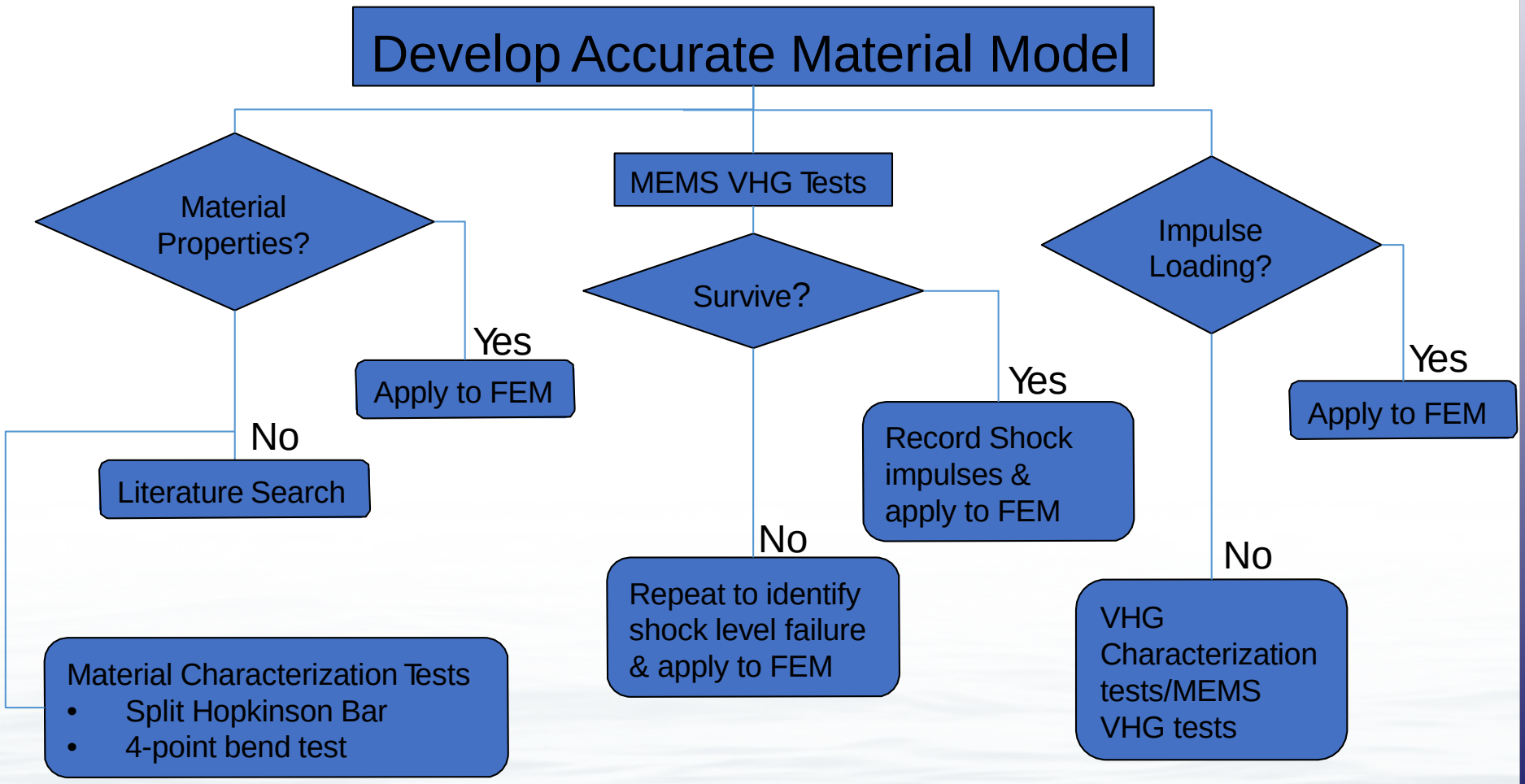
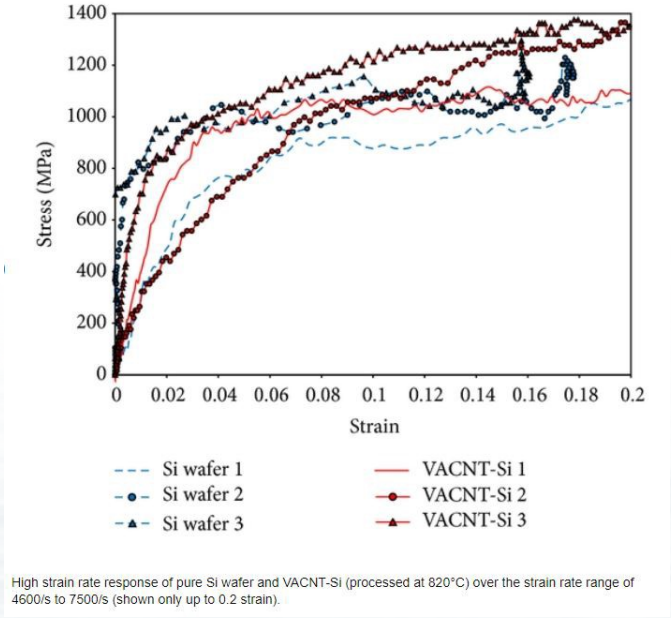
Process Flow

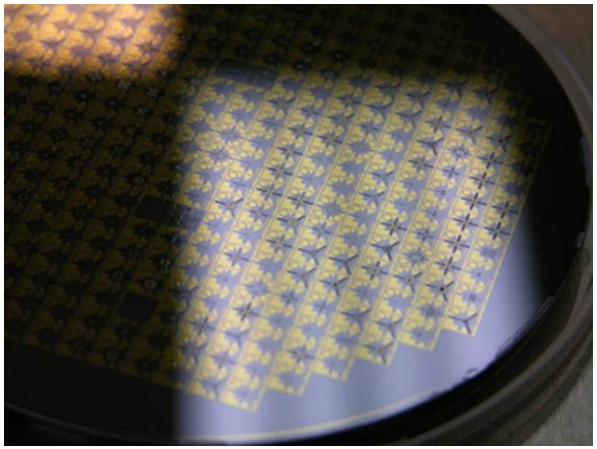


Literature Search

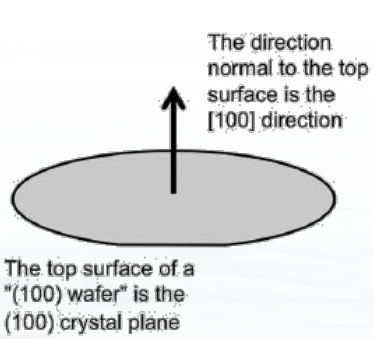
- Cubic symmetric anisotropic material
  - Single crystal wafers
  - Plane orientation
  - x & y-direction planes <110>

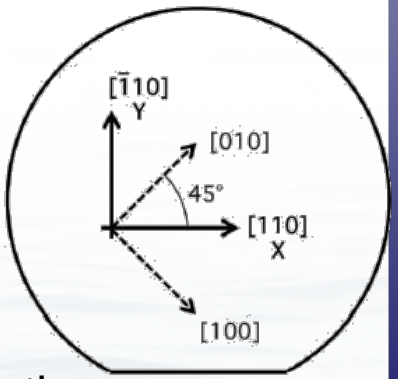


High strain rate response of pure Si wafer and VACNT-Si (processed at 820°C) over the strain rate range of 4600/s to 7500/s (shown only up to 0.2 strain).



Silicon Wafer





Orientation

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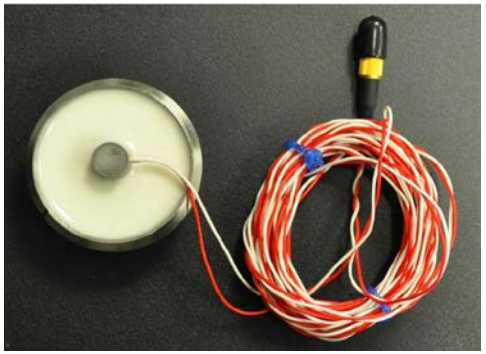
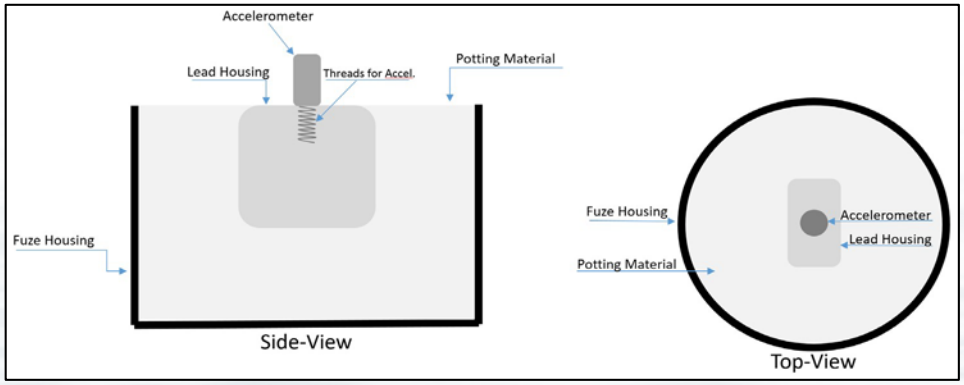
VHG Characterization

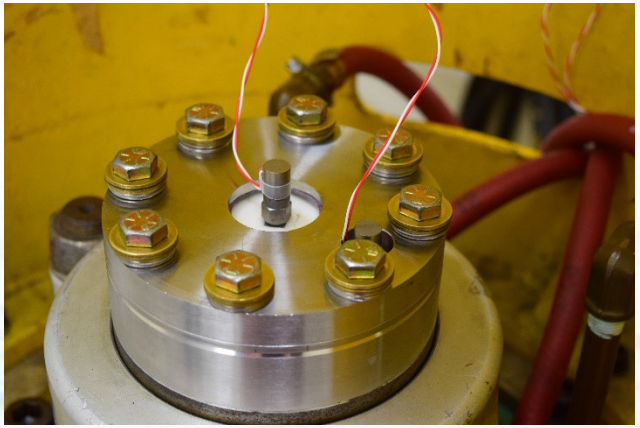
- Potted accelerometer to characterize high G loading
- Captured VHG loading(s) and applied to model



Potted Accelerometer



Cross-section view Top view



Test Setup

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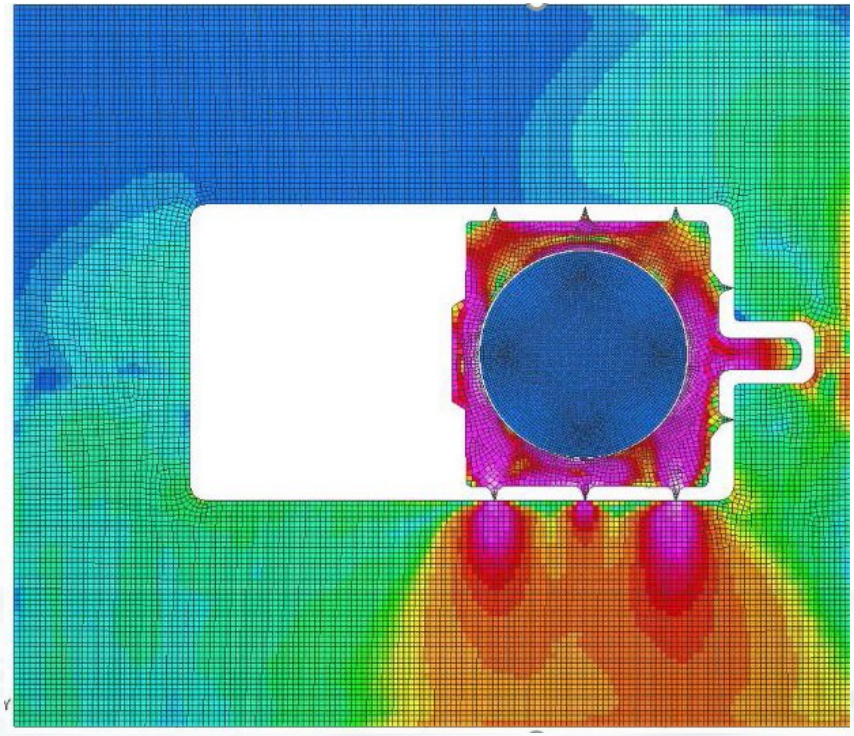
Initial Simulations

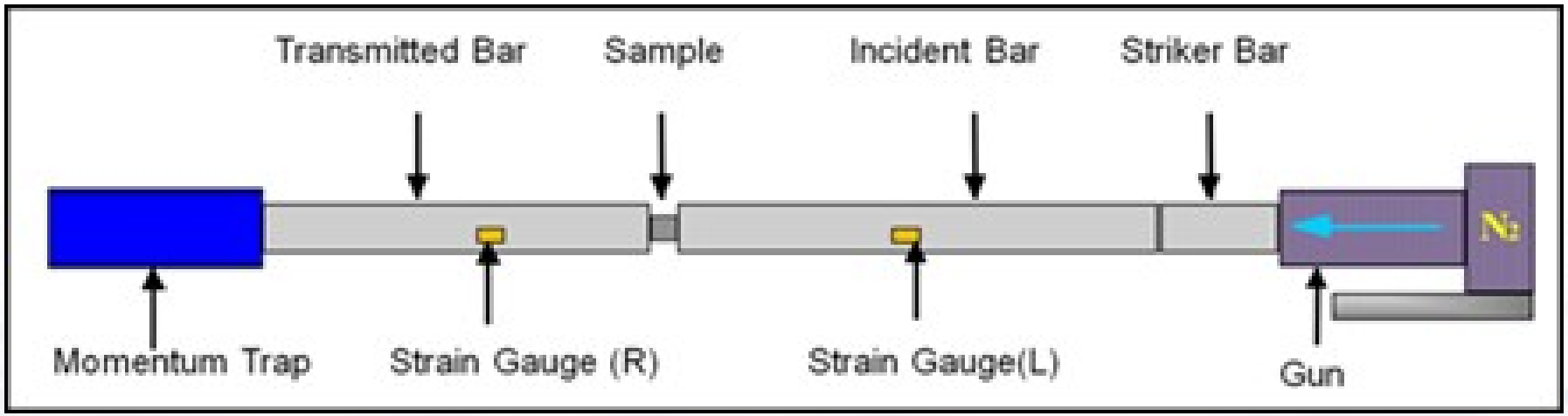
- High stress concentrations consistent with damage found
- Orthotropic elastic material model
  - No failure
  - No crack propagation



Material Characterization Tests

Split Hopkinson Bar

- Obtains high stress-strain rate



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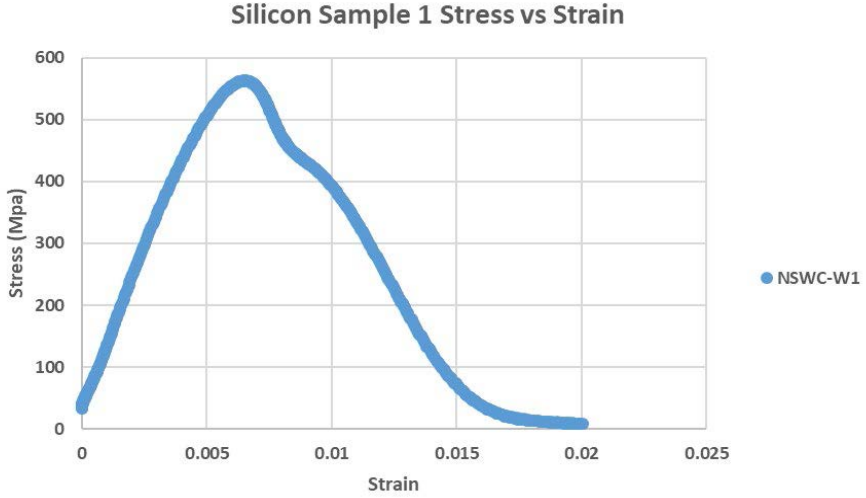
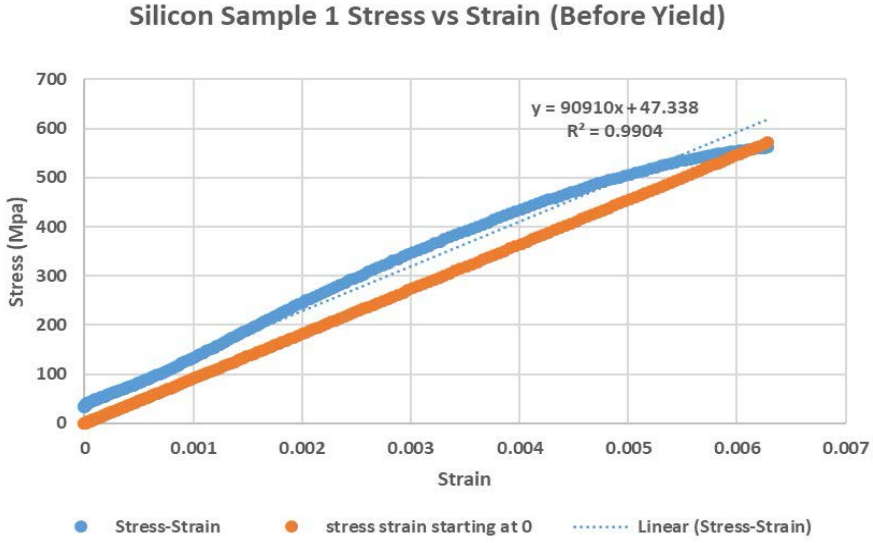
Material Characterization Tests



Split Hopkinson bar data



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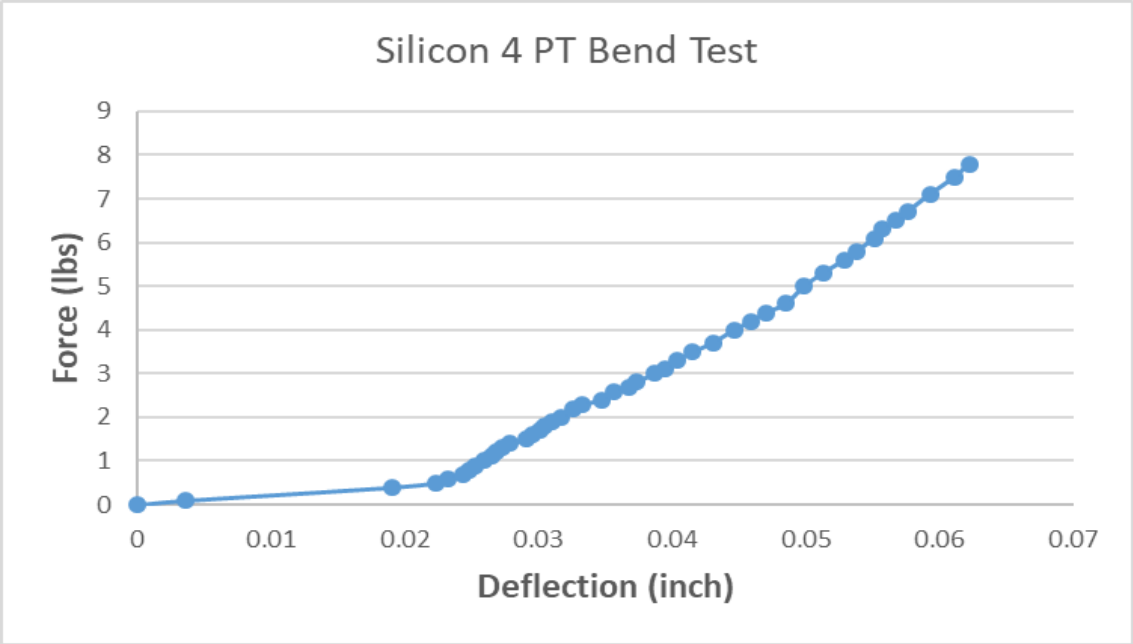
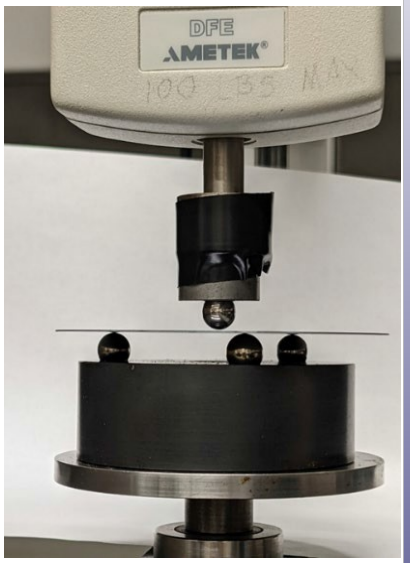
Material Characterization Tests





4-Point Bend Test

- Measures load and deflection

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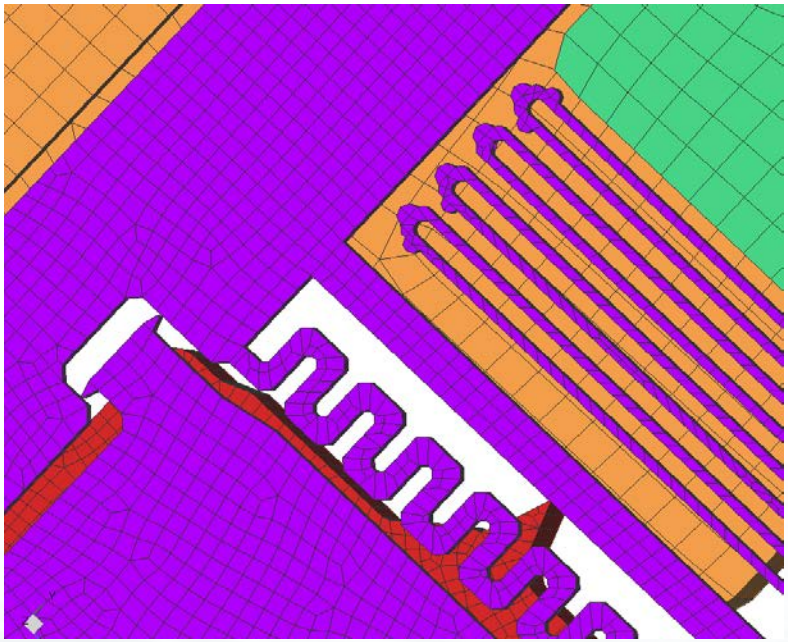
Summary

- Material Properties
  - Literature search
  - Split Hopkinson bar
  - 4-point bend test
- M&S
  - ParaDyn within DYSMAS code
  - No failure as of yet
- Testing
  - VHG



Increased # of elements to better capture effects

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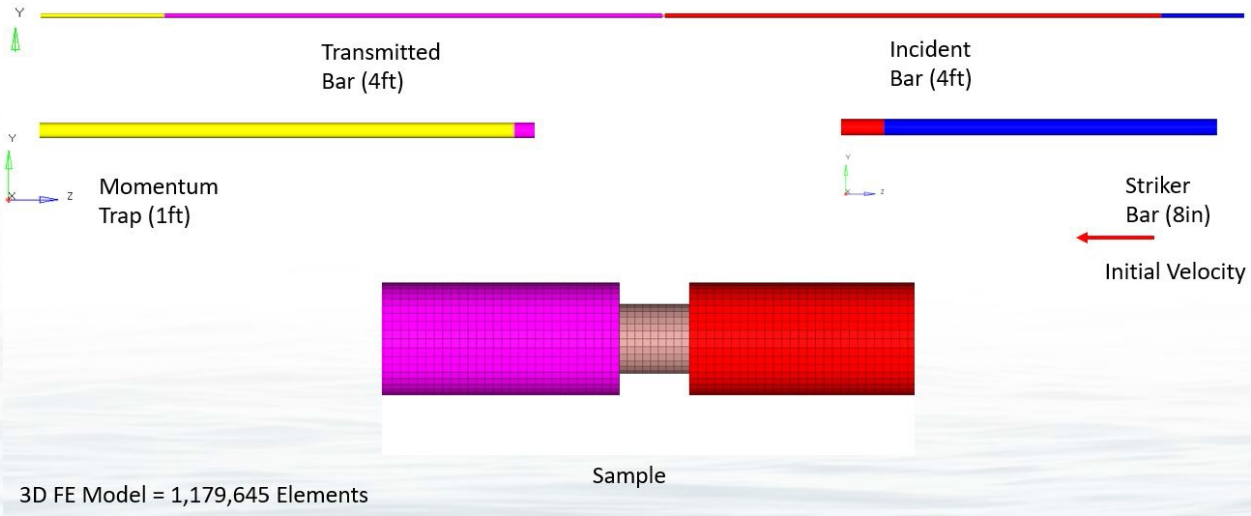
Path Forward

- Fabricate test chips for high-g testing
- Model split Hopkinson bar test and compare to experimental
- Identify failure loading for MEMS S&A
- Capture failure loading and impart on model
  - Compare and refine/update FEM



FEM of Split Hopkinson Bar

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Questions?