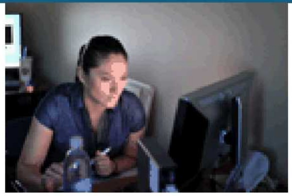
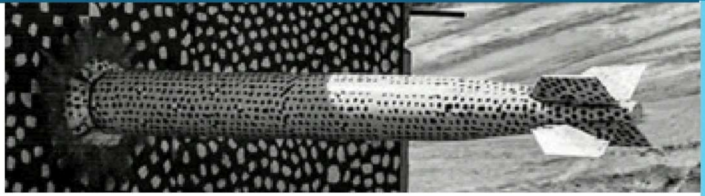
SAND2019-0845C

A Method for Determining Impact Force for Single and Tri Axis Resonant Plate Shock Simulations





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PRESENTED BY

Brian Ferri, Sandia National Laboratories

IMAC, 37

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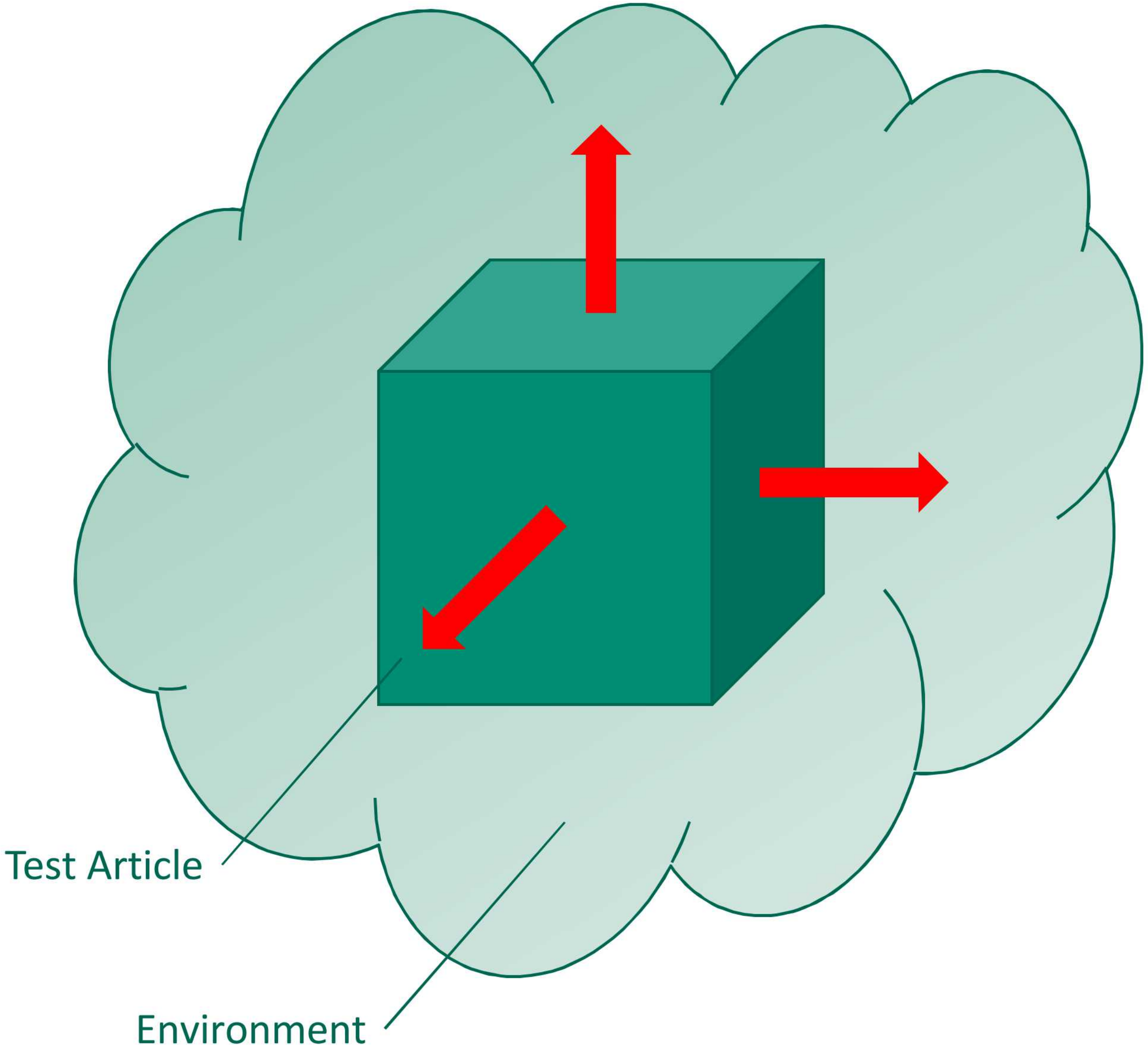
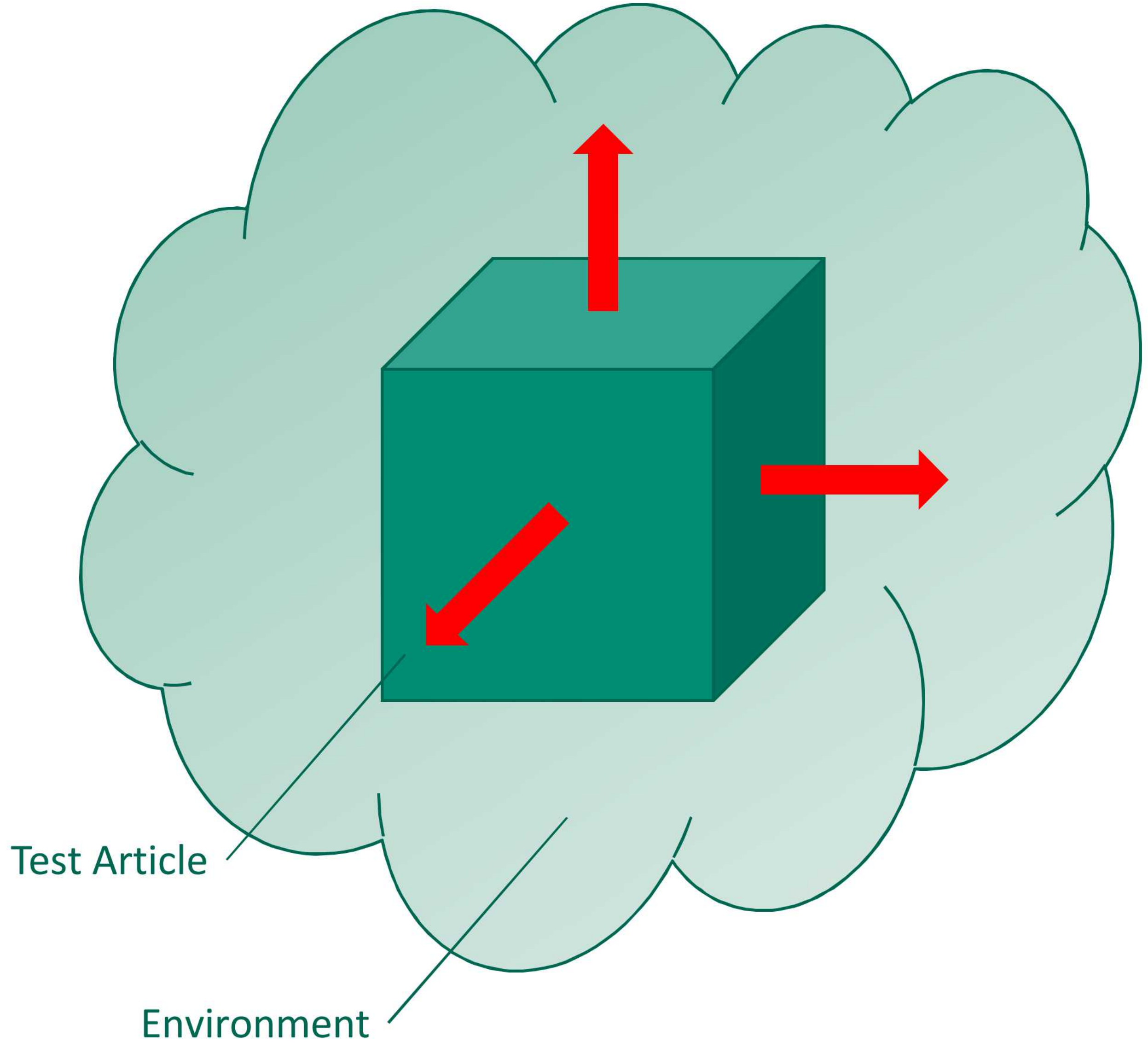
Component Testing

- Real world mechanical environments
  - Multiple simultaneous loading directions
  - Multiple loading durations
  - Interaction with other environments/structures
- Real world test article response
  - Follows similar pattern to environments
    - Multiple simultaneous response directions
    - Multiple loading durations
    - Interaction with other structures/structures' responses
- Traditional testing
  - Isolate as many of these interactions as possible
    - 1 environment load (source and direction)



Three Axis Testing

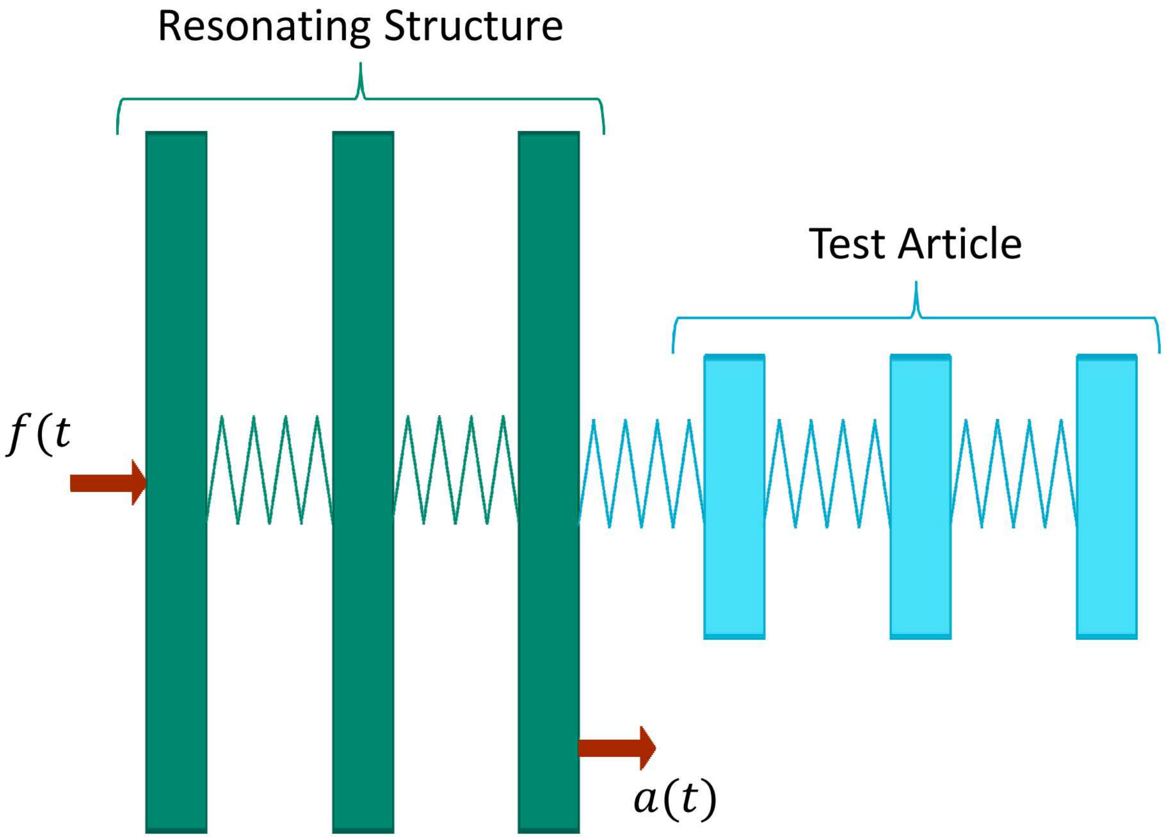
- Advantages
  - Fewer tests to qualify parts in 3 axis shock environments
  - Capture simultaneous loading effects
  - More representative of real-world environments



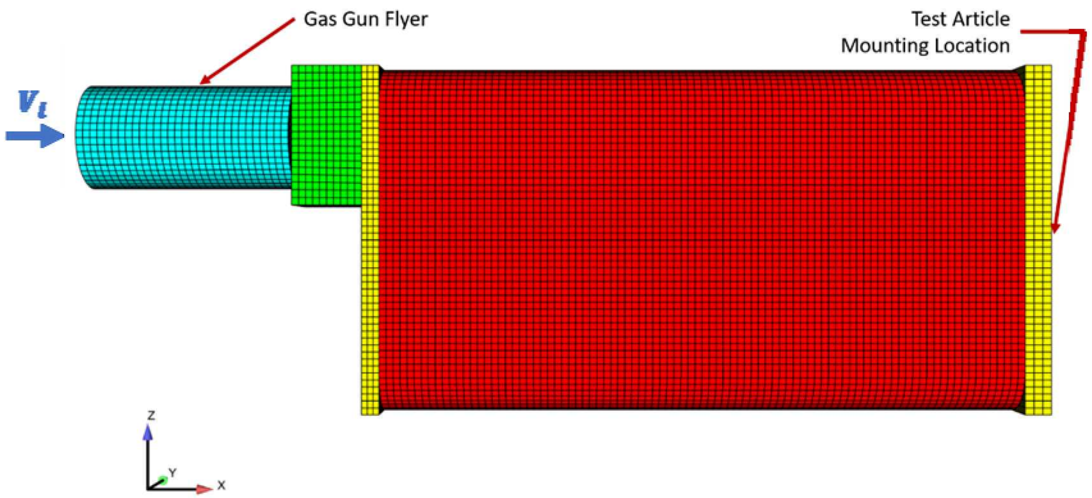
Three Axis Test Setup

Resonant Plate Shock Setup

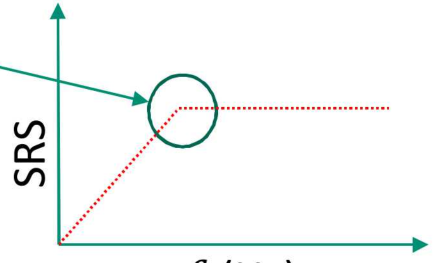
- $a(t)$ describes the "environment" for the test article
- An SRS calculation transforms $a(t)$ to the frequency domain
  - Specifications for environments are derived from the SRS
- The goal of designing tests is to "tune" $f(t)$ and the resonant structure to get the right $a(t)$
- Main focus here is getting the right $f(t)$

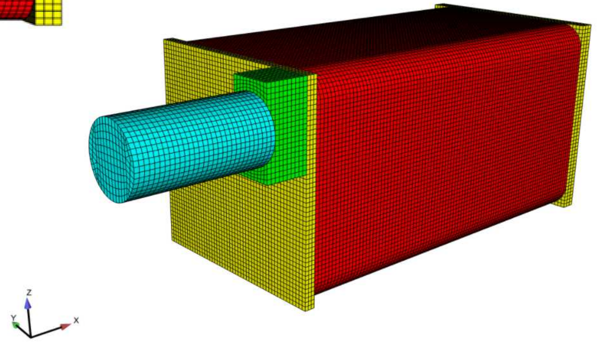


Resonant Structure

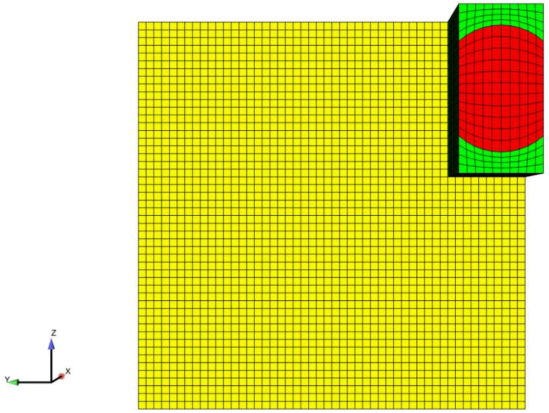


- Designed for specific fundamental resonance
- Hit with a projectile from an air cannon
- Impact location away from centerline x axis
  - Imparts a moment about z and y axis
  - Excites "non axial" modes to a higher degree
- Test article center mounted opposite end as impacting location





Iso View

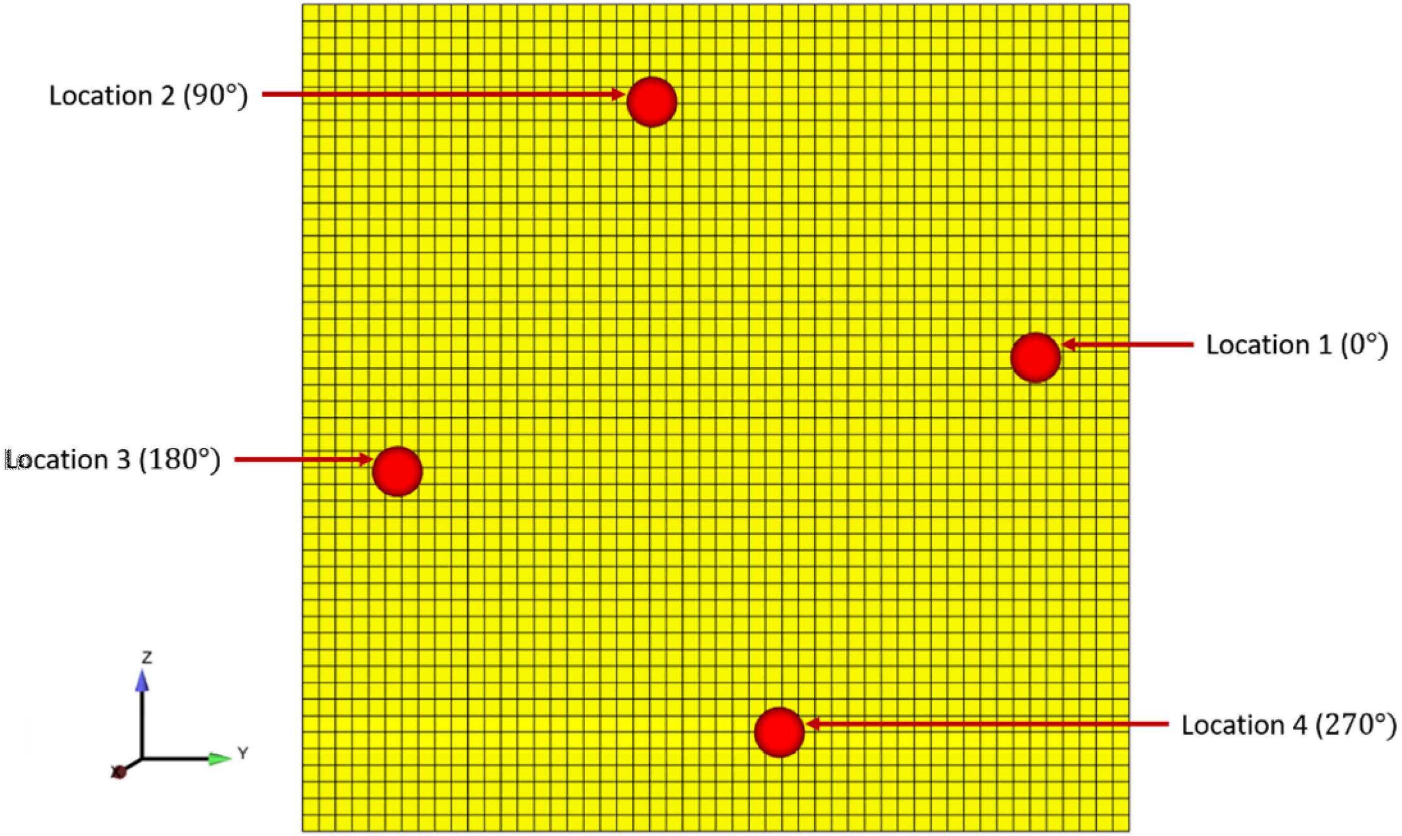


Impacting Side View

Measurement

- All tri-axis accelerometer locations away from centerline x axis
- Simulations set up use the same output locations to validate test quality
- Only output accelerations measured
  - Input acceleration/force was prohibitively difficult to measure in-situ*

*Input strain on impact block was measured in-situ. However, the strain response proved incapable of providing or validating input force.



Test Article Side View

Measurement

- All tri-axis accelerometer locations away from centerline x axis
- Simulations set up use the same output locations to validate test quality
- Only output accelerations measured
  - Input acceleration/force was prohibitively difficult to measure in-situ*

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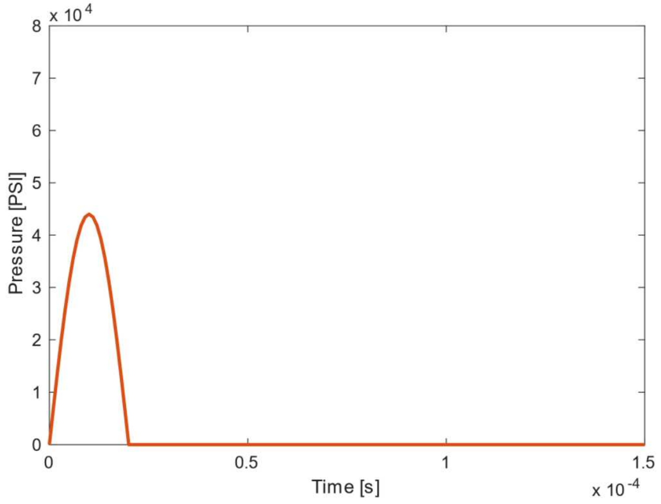
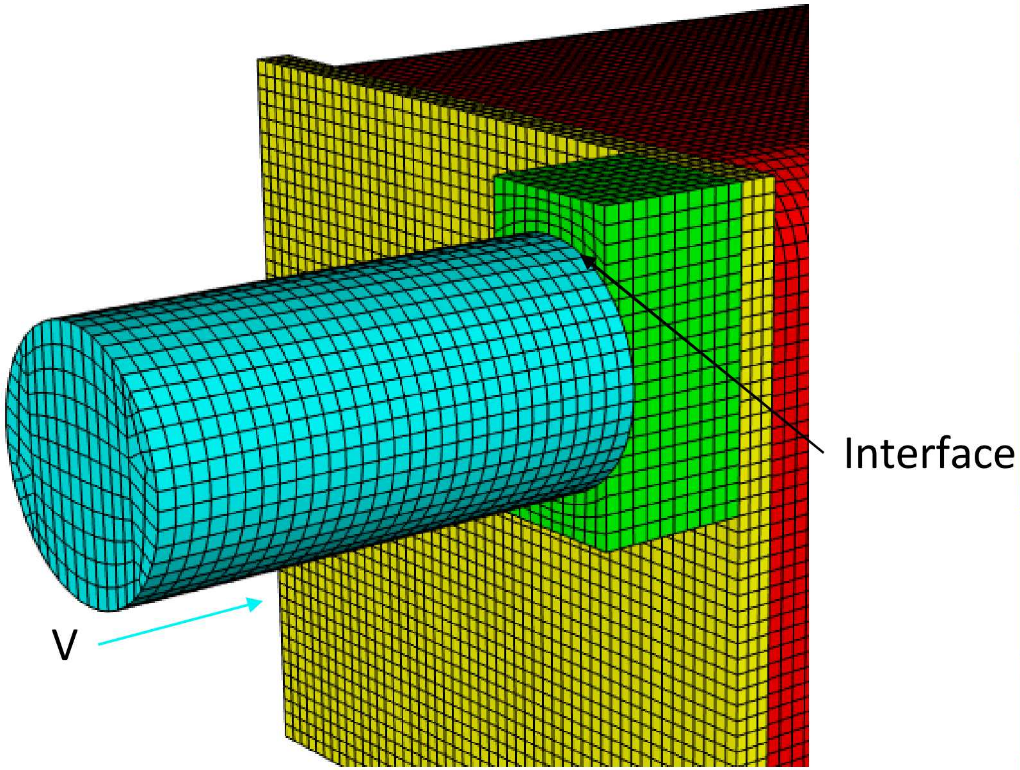


Theoretical Impulse

Simulating an Impact with Sierra Solid Mechanics

Simulation of Impact

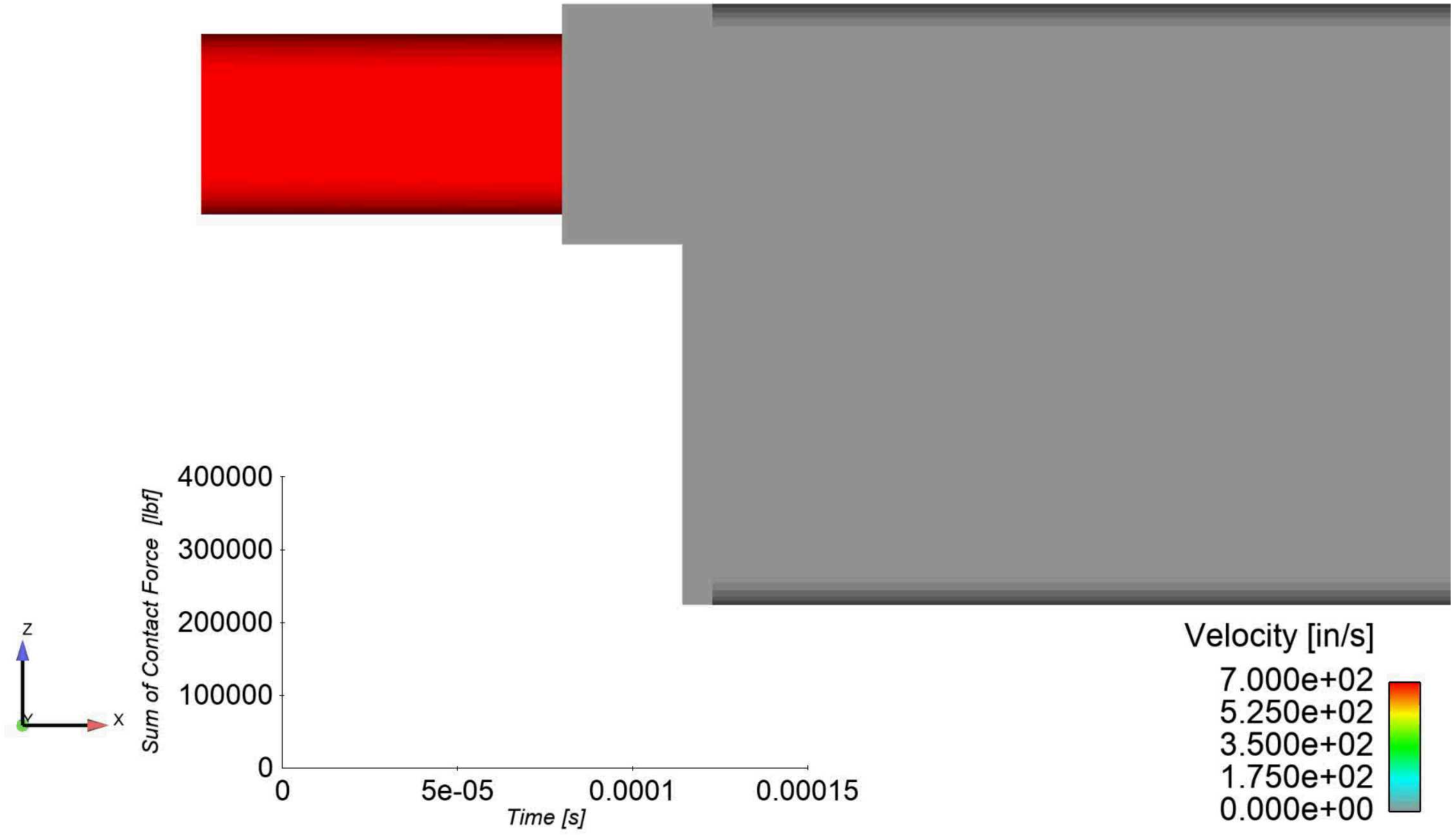
Known Inputs for Sierra Solid Mechanics	Outputs from Solid Mechanics
Velocity of Projectile	Contact Force at Interface
Material Properties (E, ρ)	



- Projectile cylinder to impacting block interface modelled as frictionless slip contact
- Rest of fixture interfaces are tied together or have coincident nodes

Simulation of Impact

- Sum of contact force shows trapezoid shape as a function of time
- Pressure function is found by dividing by contact patch area



Simulation of Impact

- Sum of contact force shows trapezoid shape as a function of time
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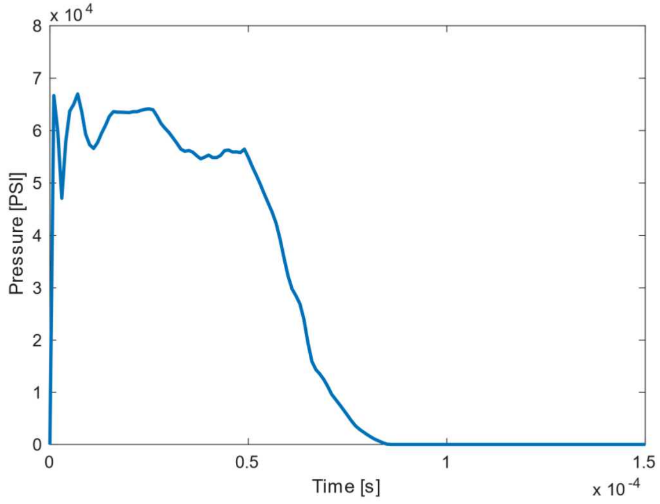
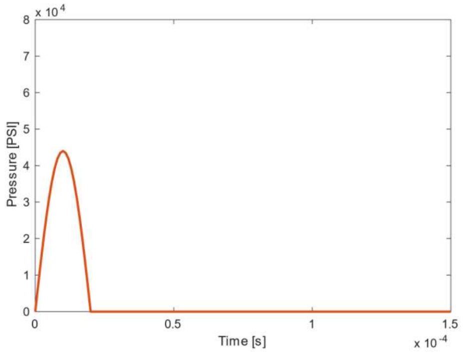


Simulated Pressure

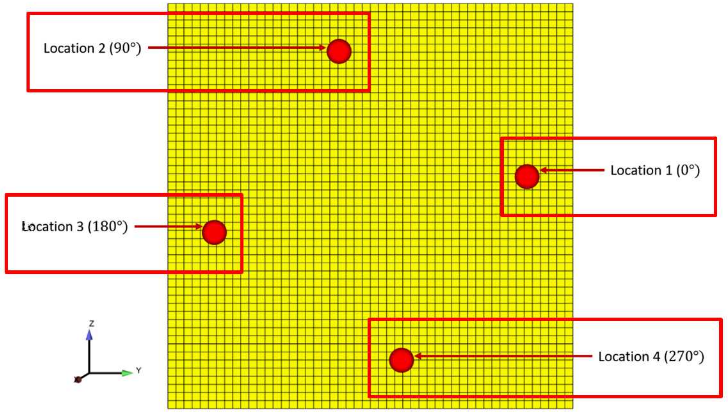


Theoretical Pressure

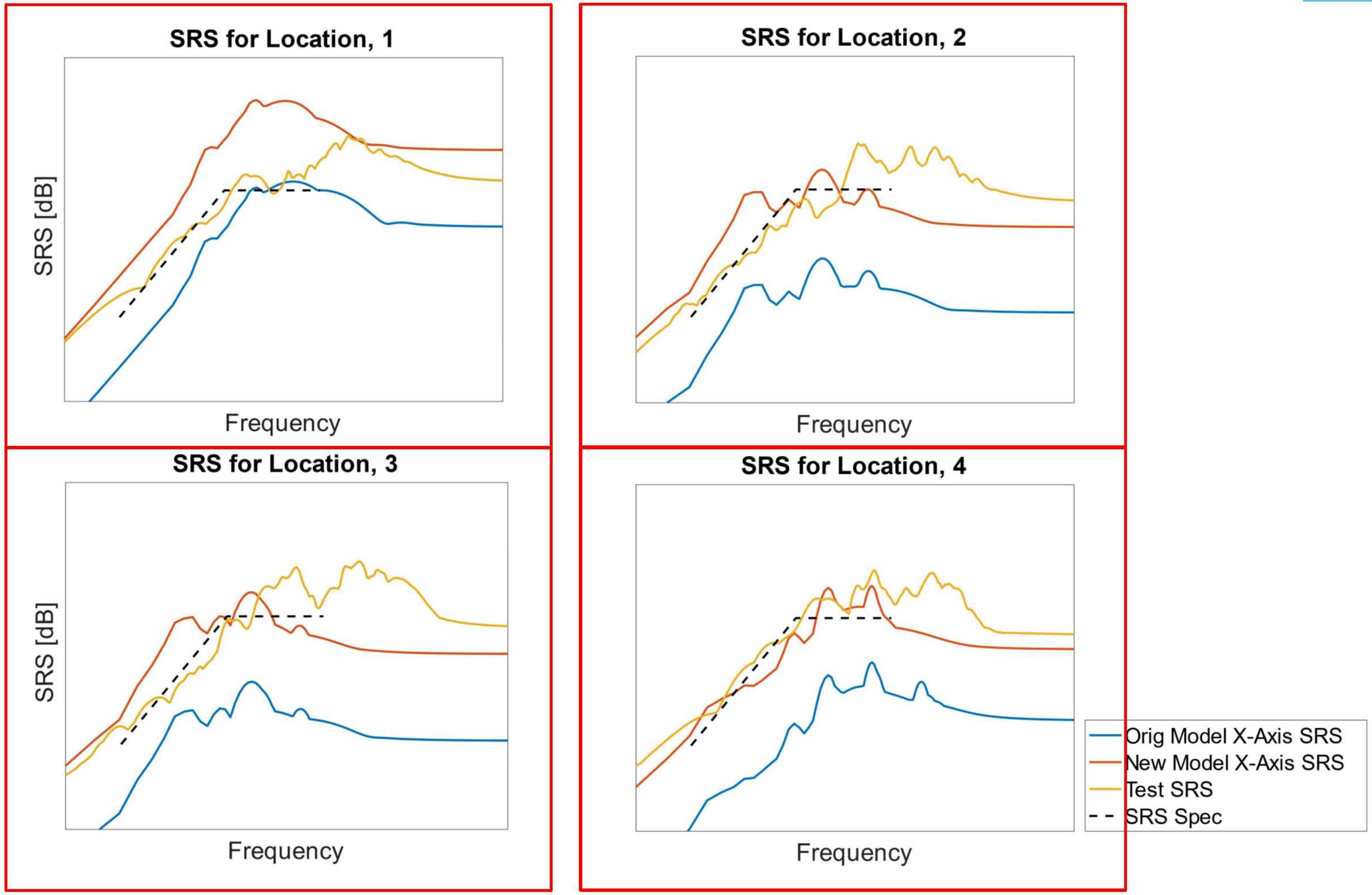
Simulated Impulse	Theoretical Impulse
20.93 lb*s	3.19 lb*s

Results from Sierra Structural Dynamics

X Axis SRS



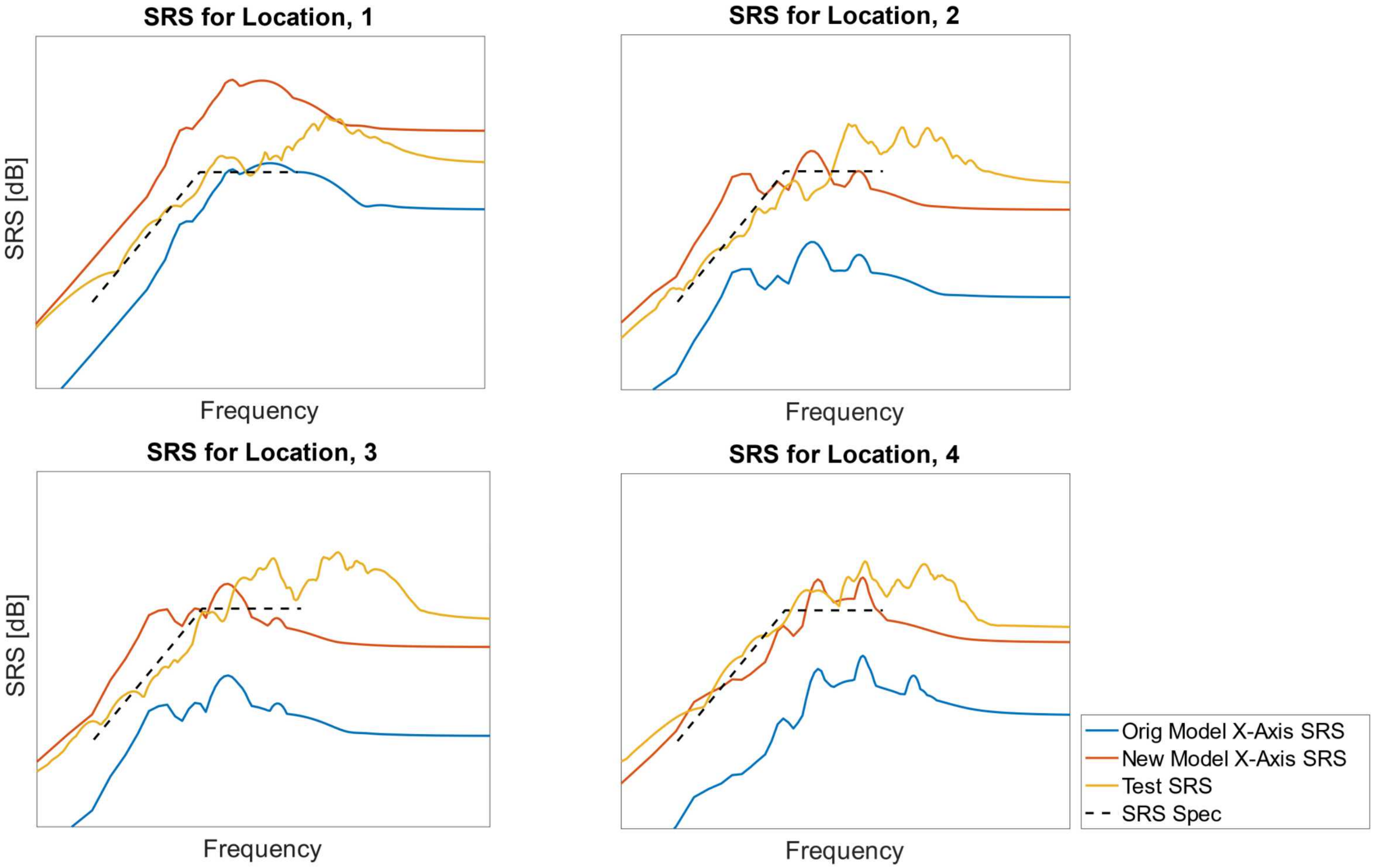
Location 2 (90°)
Location 1 (0°)
Location 3 (180°)
Location 4 (270°)



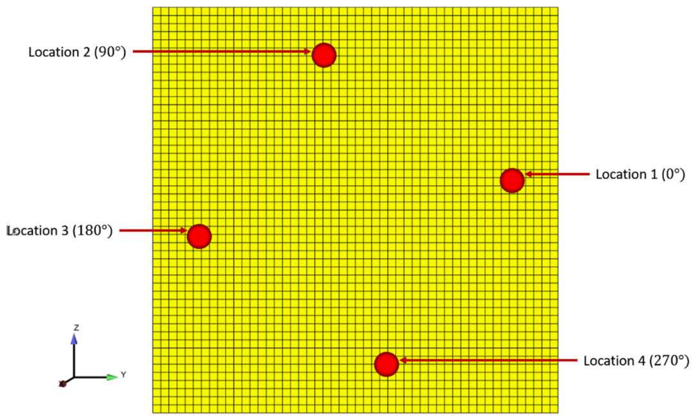
SRS for Location, 1
SRS for Location, 2
SRS for Location, 3
SRS for Location, 4
SRS [dB]
Frequency
Orig Model X-Axis SRS
New Model X-Axis SRS
Test SRS
SRS Spec

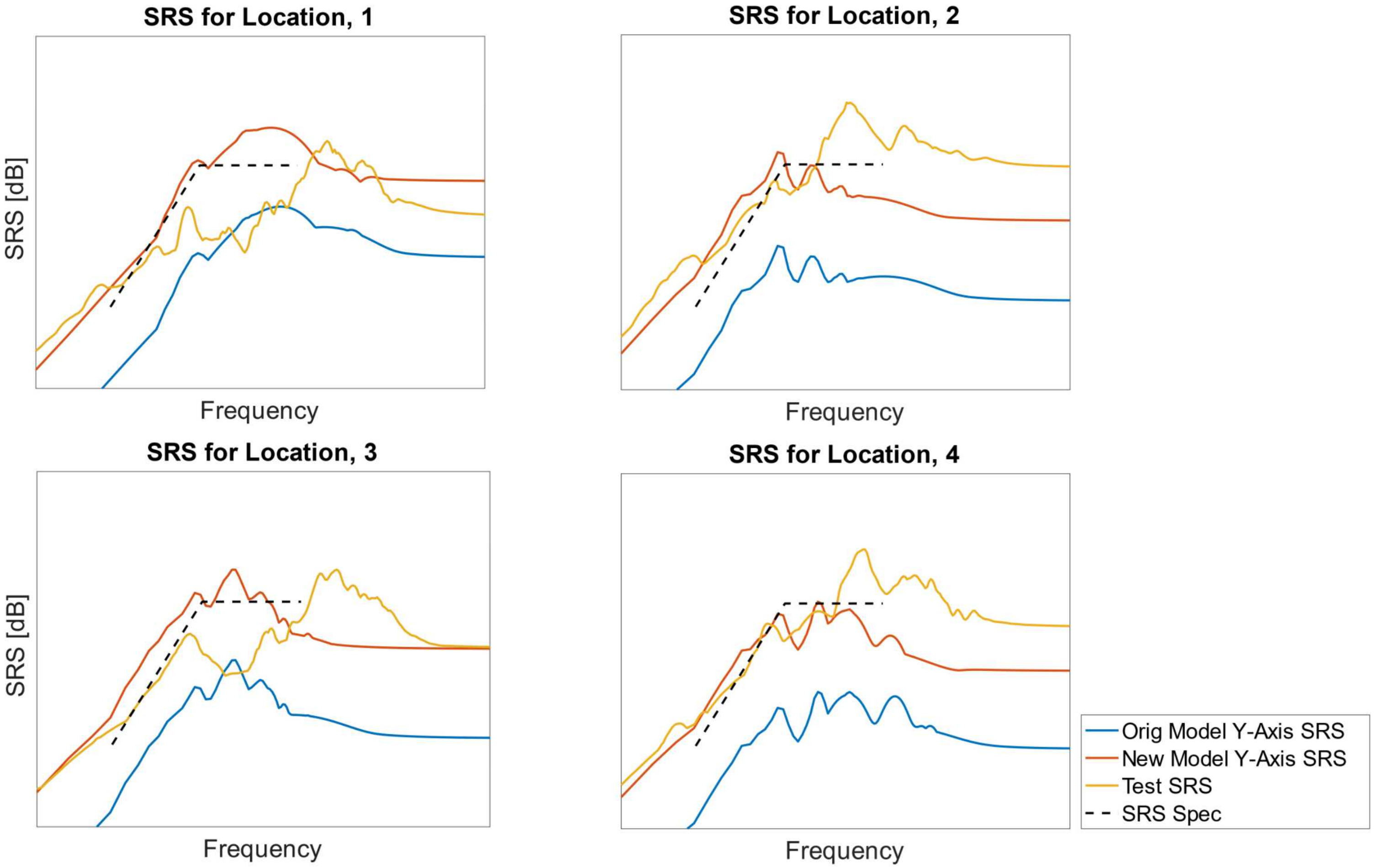
X Axis SRS

- X Axis SRS shows a large decrease in average error between theoretical and modelled pressure input
- Response frequency shift unnoticeable between two inputs
- Consistent difference in amplitude between both model responses

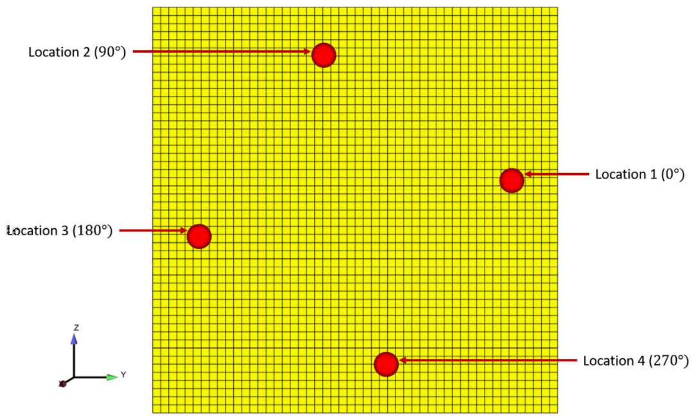


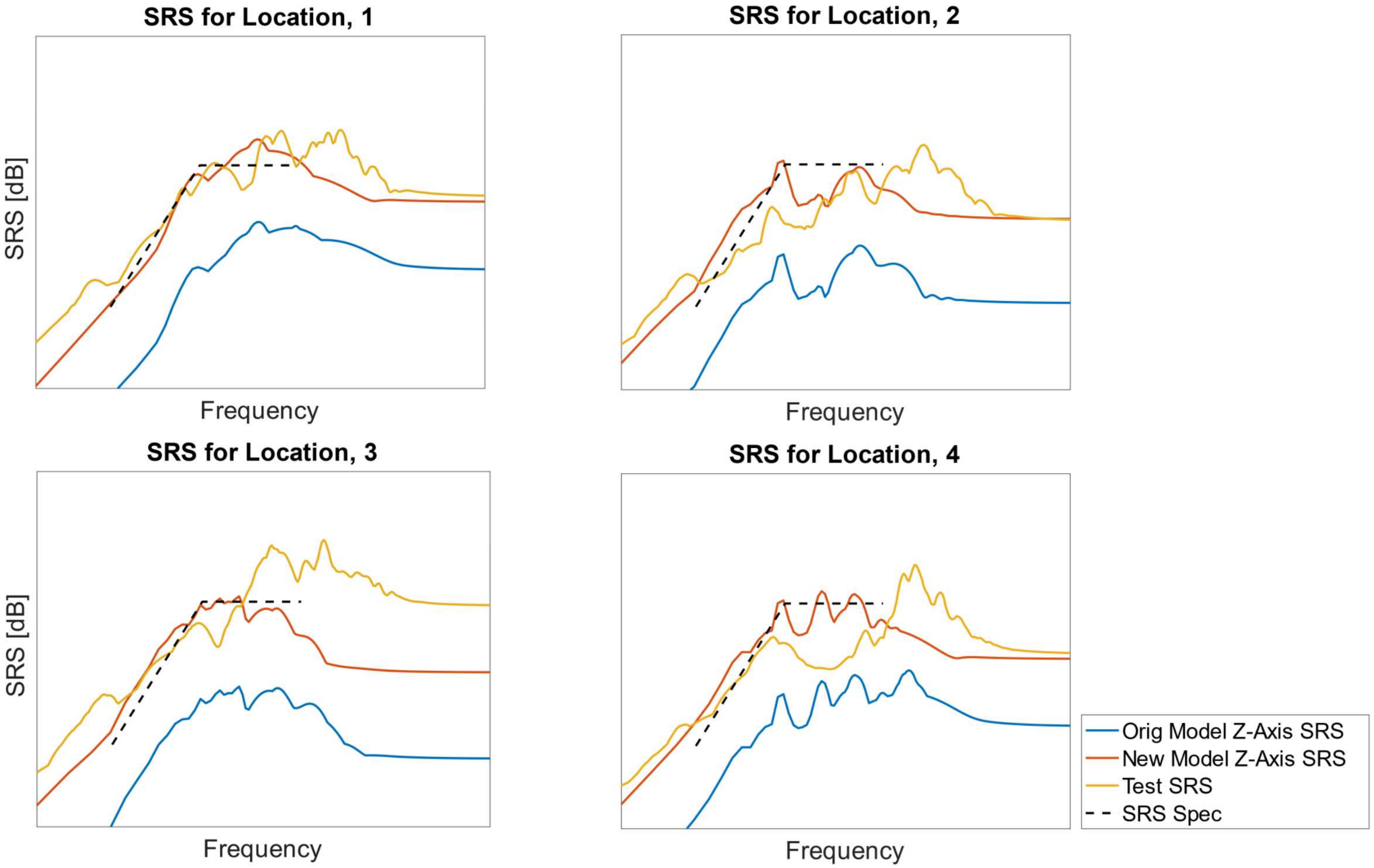
Y Axis SRS


Location 2 (90°)
Location 1 (0°)
Location 3 (180°)
Location 4 (270°)
Z
Y


SRS for Location, 1
SRS for Location, 2
SRS for Location, 3
SRS for Location, 4
SRS [dB]
Frequency
Orig Model Y-Axis SRS
New Model Y-Axis SRS
Test SRS
SRS Spec

Z Axis SRS


Location 2 (90°)
Location 1 (0°)
Location 3 (180°)
Location 4 (270°)
Z
Y


SRS for Location, 1
SRS for Location, 2
SRS for Location, 3
SRS for Location, 4
SRS [dB]
Frequency
Orig Model Z-Axis SRS
New Model Z-Axis SRS
Test SRS
SRS Spec

Next Steps

- Work being done to characterize other test methods including added programming materials
  - Explicit contact method can be repeated to include the effect of programming material on the shape of the temporal input function
  - Effect on output SRS can also be observed

Thank You

Questions?

Acknowledgements to:

David Weigand – Project Leader and Technical Direction

Bill Bonahoom – Hardware Development and Test Engineer

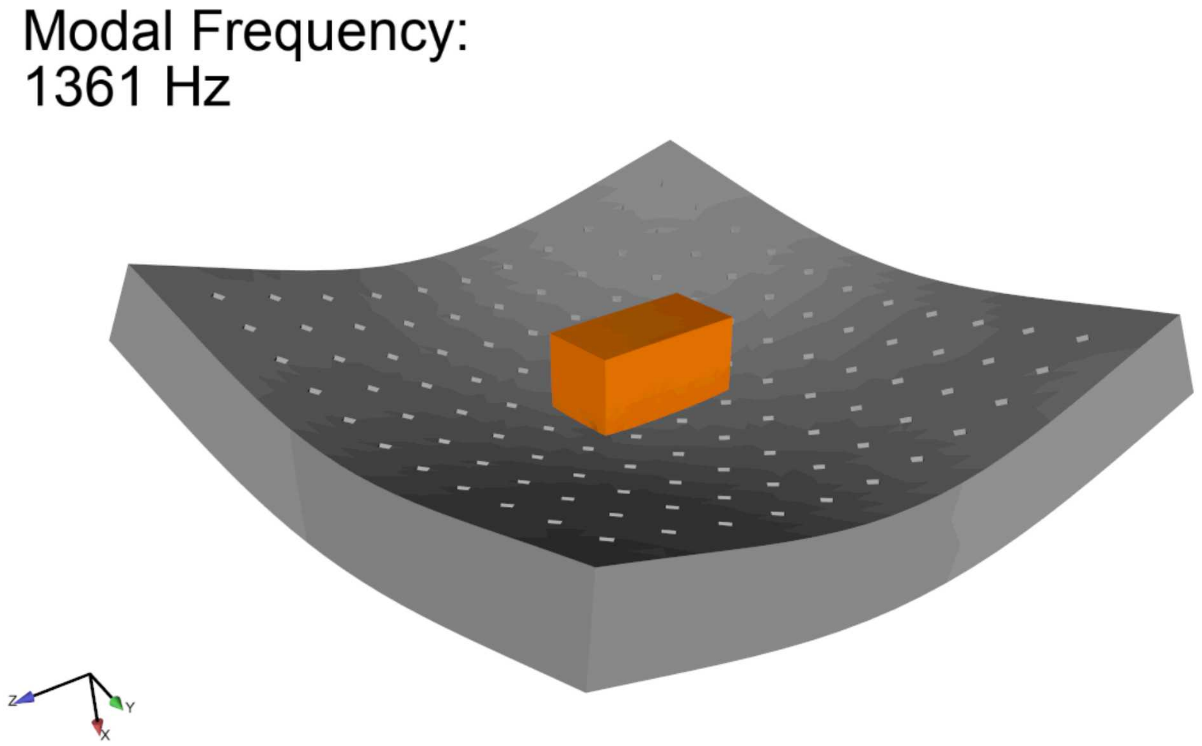
Mikhail Mesh – Technical Consultant

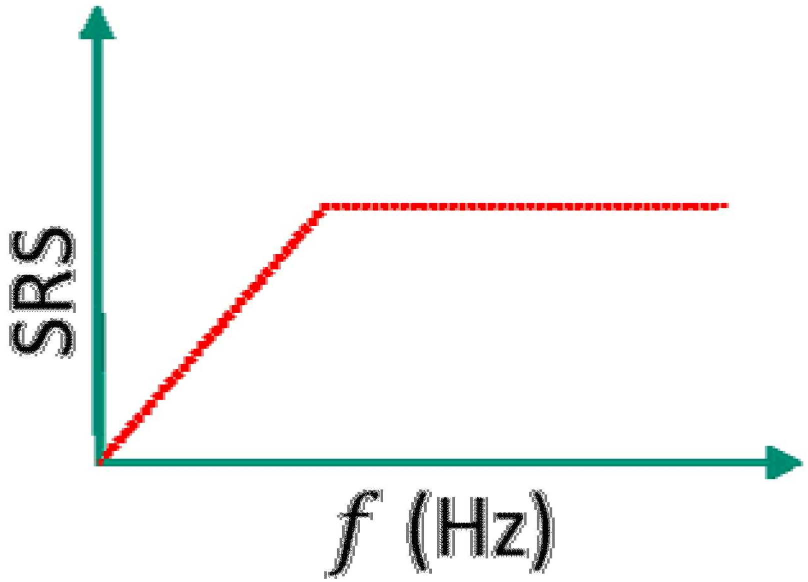
Matt Spletzer – Resonant Fixture Test Engineer

Additional Slides

Using a resonant "plate" instead

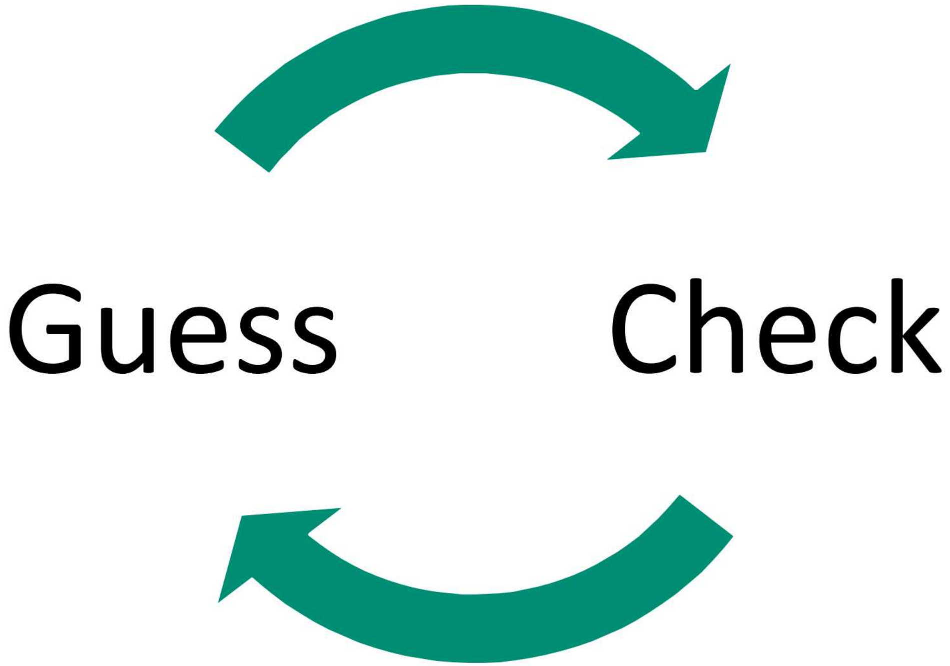
- Plate design works same as pedestal, but may not need prior simulation for general response characterization
- Same process for coming up with input shape can be used





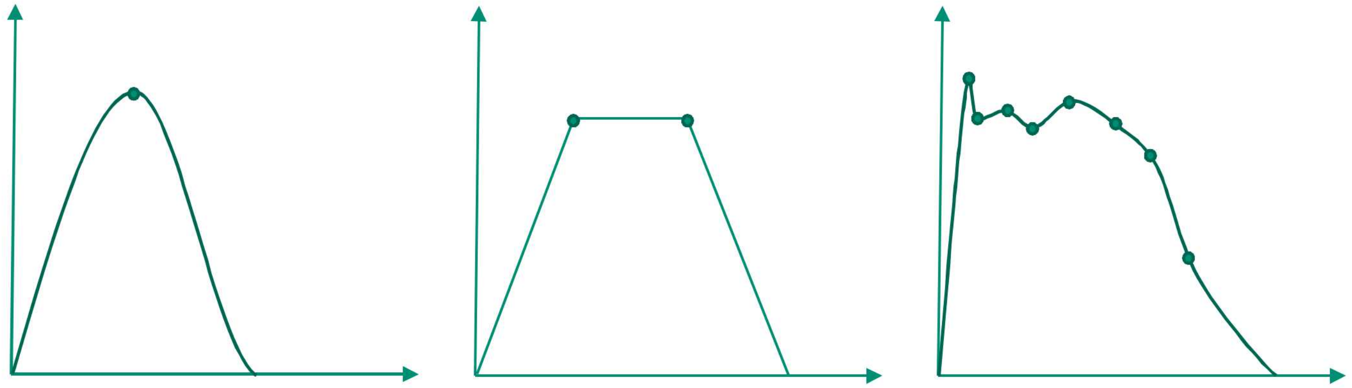
How to create inverse problem

- Come up with initial guess for forward problem
- Use guess to evaluate error
- Use error to inform a better initial guess
- Iterate to minimize error



Problem for this case

- Come up with a temporal shape for load function using discrete number of control points
  - Would have to know shape before setting up inverse problem



Additional Graphics

Other Graphics