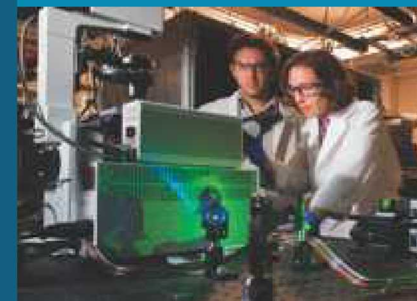
SAND2018-11905C

Design of a Resonant Plate Shock Test for Simultaneous Multi-Axis Excitation



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Sandia National Laboratories
Albuquerque, NM

Overview

Overview of resonant plate shock testing

Observations from traditional single-axis resonant plate testing

Finite element analysis of bare plate test

Finite element analysis of plate with a sample component

Experimental setup and results for a sample component

Conclusions

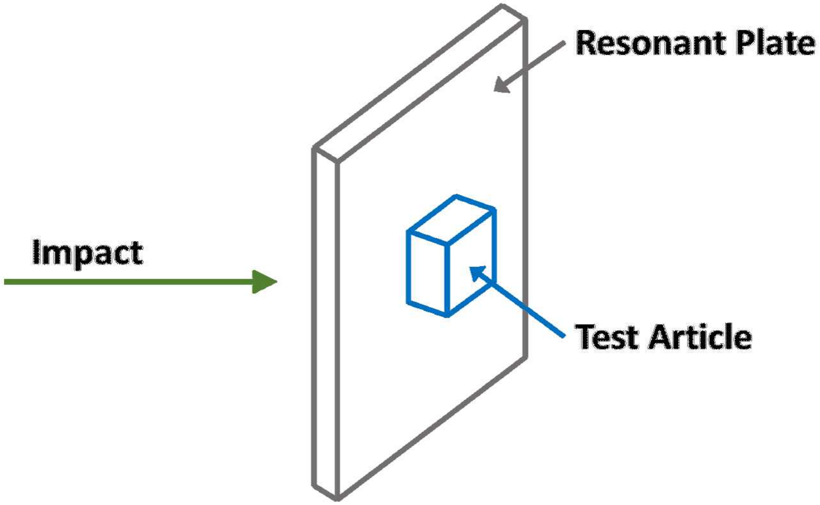
Overview of Resonant Plate Shock Testing

Resonant plate testing is an accepted method for simulating high-frequency pryoshock type environments at the component and subassembly level

Unit under test is typically mounted on the front center of the plate with a projectile impact at the rear center of the plate

Three shocks are typically applied to the unit under test—once in each of three mutually orthogonal axes

Exciting the same unit three times risks over-exposing the unit to shock energy, particularly apparent at higher frequencies due to the presence of cross-axis coupling



Observations from Single-Axis Resonant Plate Tests

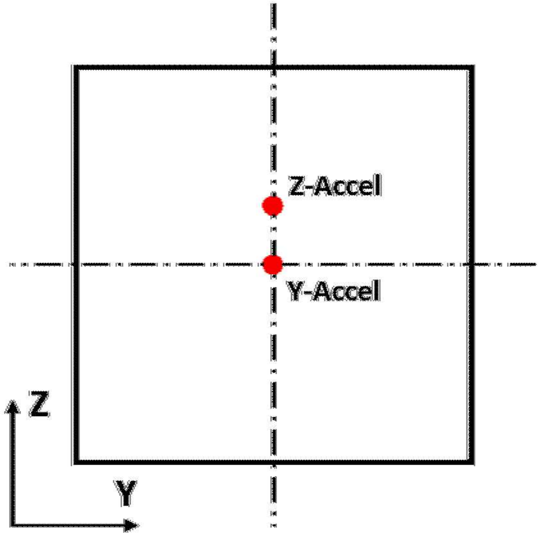
Off-axis response of plate is non-negligible at high-frequencies

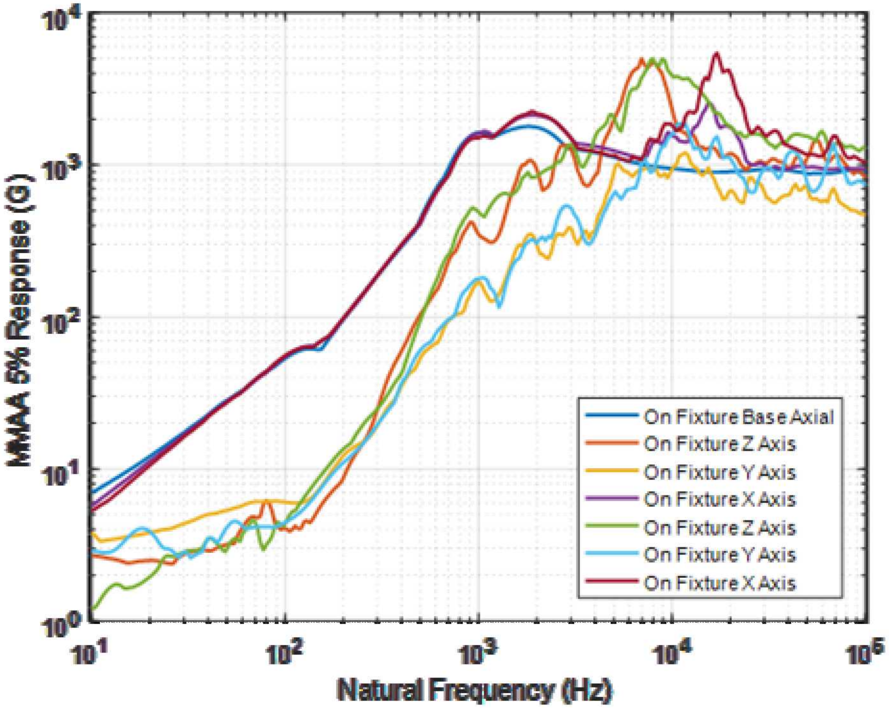
- Often of similar amplitude as the in-axis response

In the plot, the z-axis accelerometer has a z-direction offset from plate centerline while the y-axis accelerometer is on plate centerline

Offset results in significant off-axis response.

Can this be exploited to design a multi-axis test?





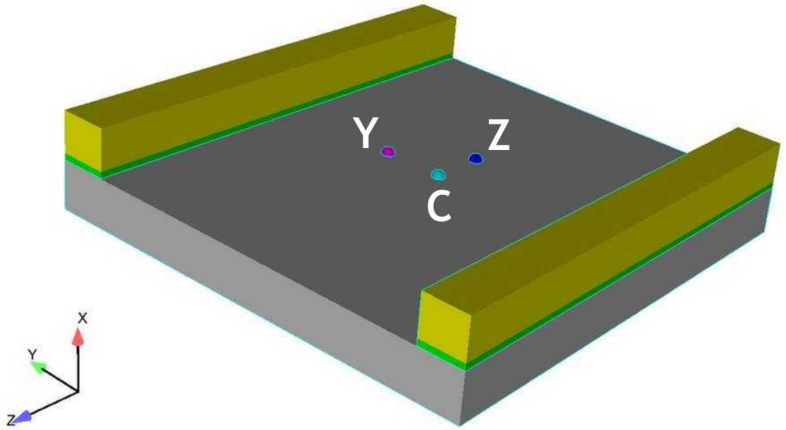
Simple Test Problem – 1kHz Plate

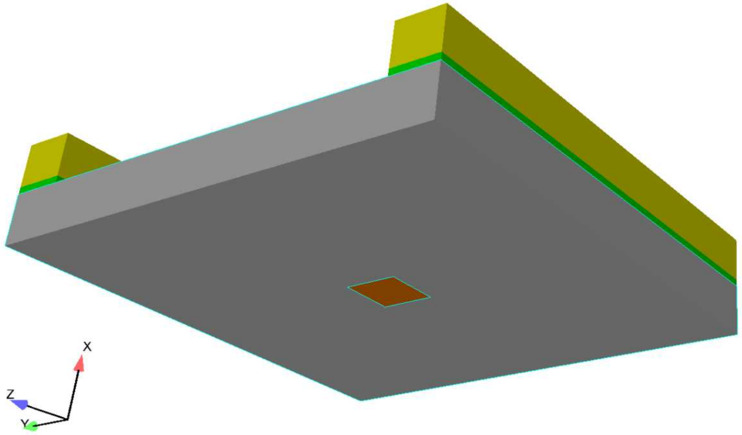
FEM of 1kHz resonant plate was created and impulse input applied

The response on the plate's opposite side was computed at three locations

- Center of plate
- Y-direction offset
- Z-direction offset

Can we intentionally amplify this cross-axis coupling to develop a multi-axis component shock test?

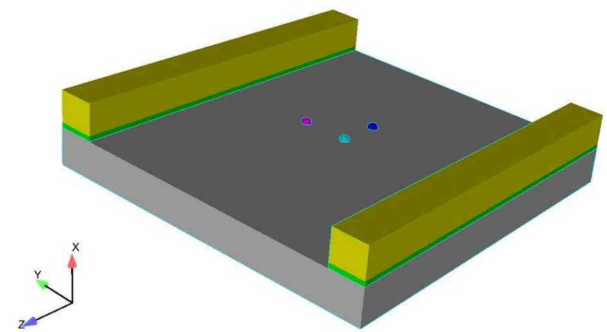


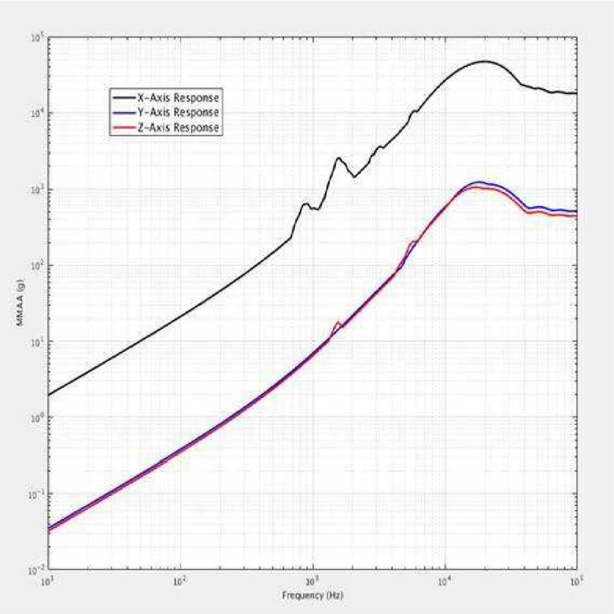


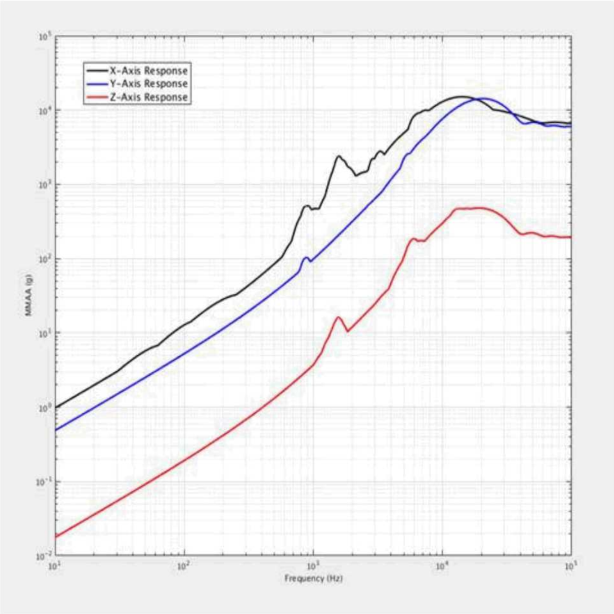
Response SRS Plots – Simple Test Problem

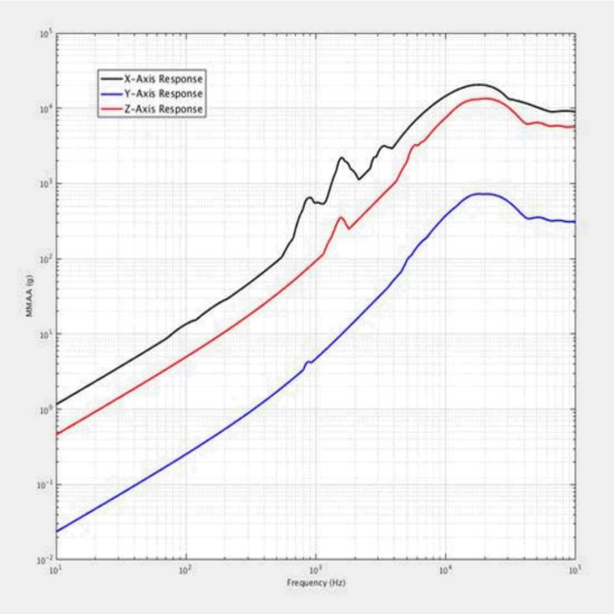
The response at the center shows very low off-axis responses

The y- and z-offset locations show y- and z-axis responses of similar magnitude to the x-axis response at the plate center







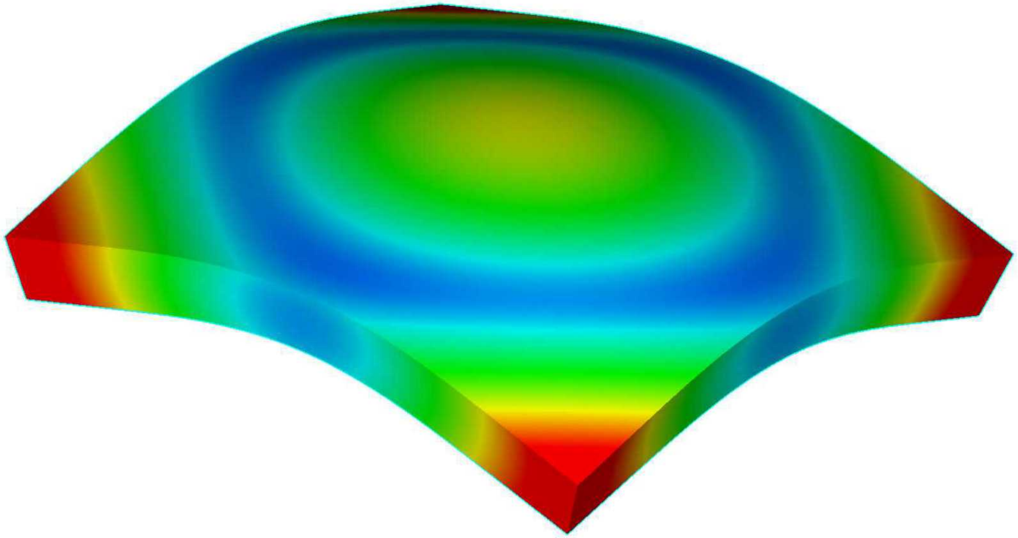


Key Modes – Plate Bending Modes

Plate bending modes are key to developing three-axis response

Because test article is located on plate's top surface, bending about the neutral axis produces an $R \times \theta$ response where R is half the plate thickness and θ is the plate rotation

- θ is a function of the distance from the plate's center



Real Component Example

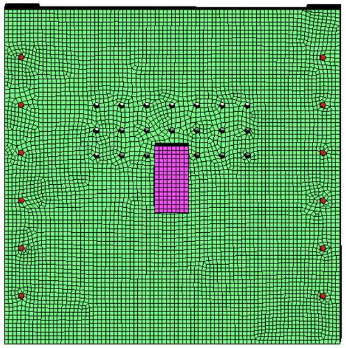
Component requires three-axis shock for qualification

- Component must continuously function through the shock event
- Component life is short with insufficient time to perform three separate tests

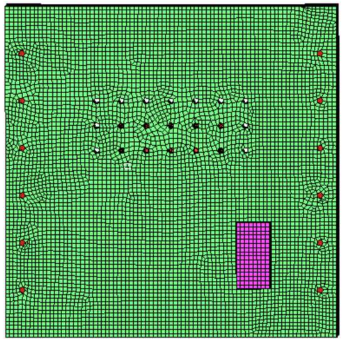
Analyzed two cases using FEM

- Impact location centered on plate back face
- Impact location offset five inches in both y- and z-direction

Centered Impact



Offset Impact

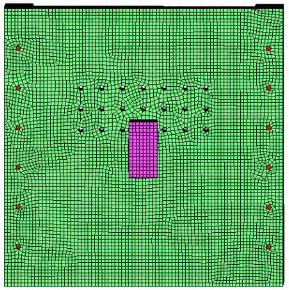


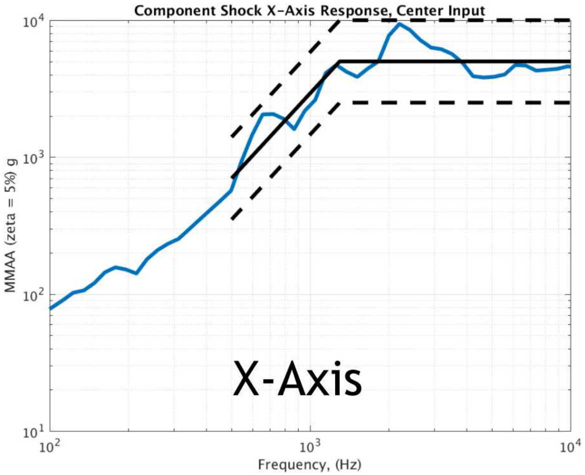
Centered Impact Results

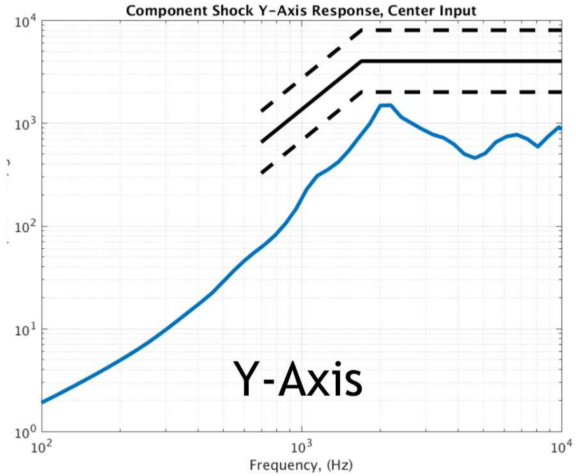
FEM predictions for impulse centered on back face of 1 kHz plate

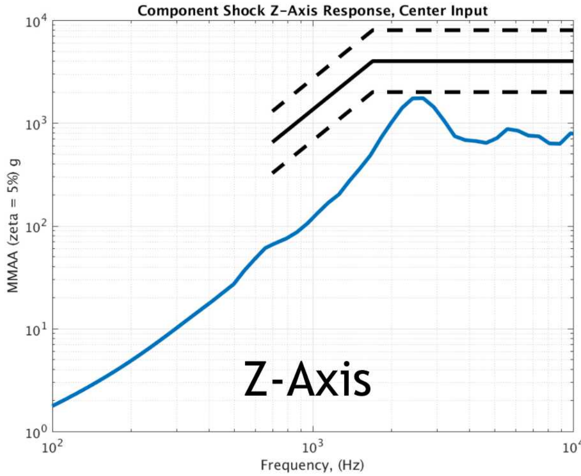
Predictions show component meets test specification in x-axis (direction of impulse) but response is below specification in y- and z-axes

Centered Impact



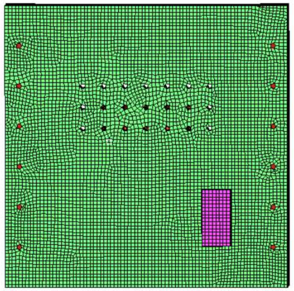






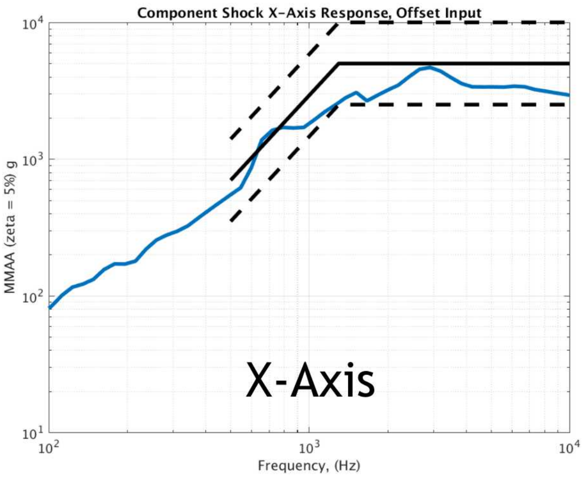
Offset Impact Results

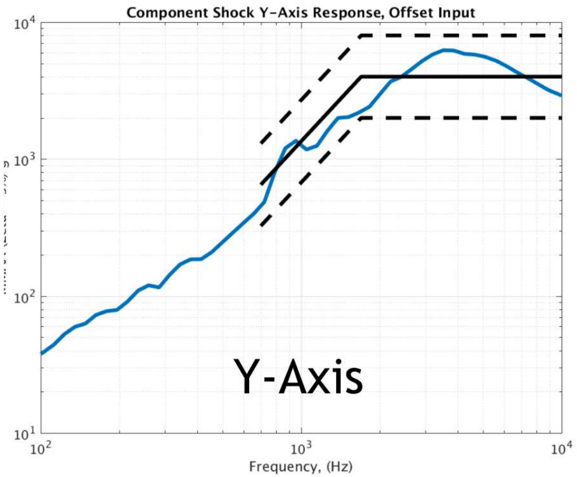
Offset Impact

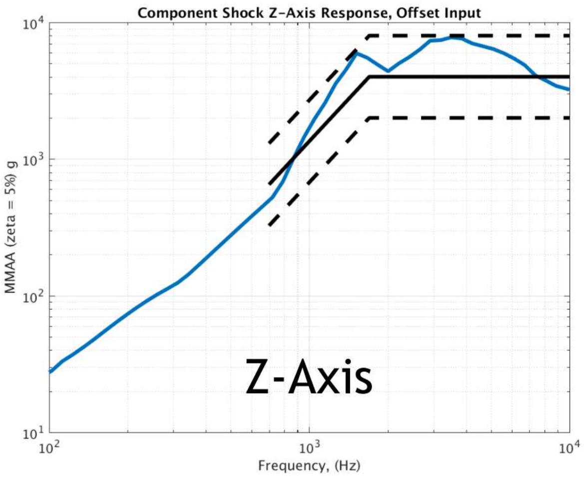


FEM predictions for impulse offset by five inches in both y- and z-directions
- Roughly 50% higher impulse needed for offset impact versus centered impact
- No free energy, plate must be hit harder

Predictions show component response close to meeting test specifications
- Responses generally within acceptable test tolerance bounds



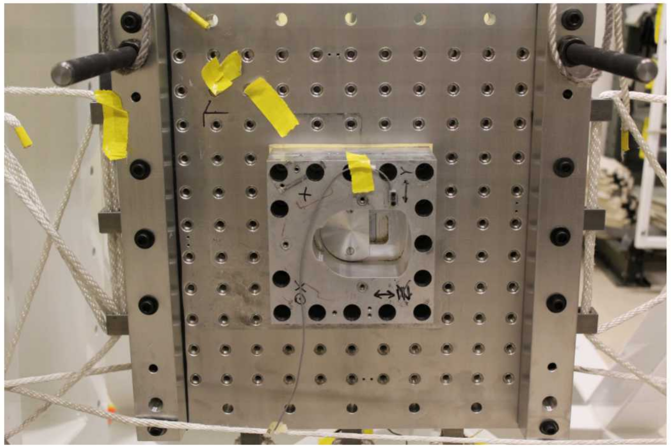




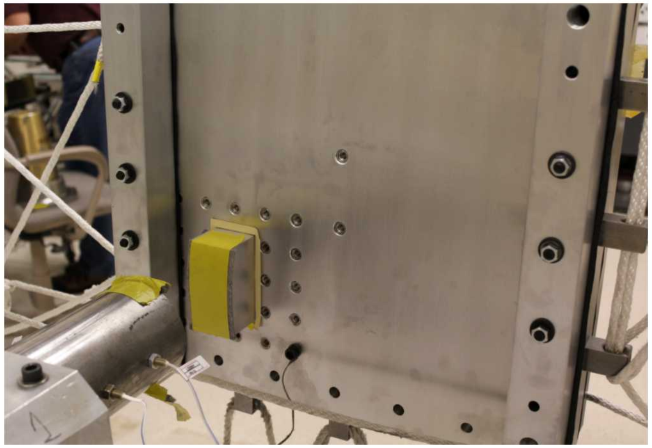
Experimental Test Setup

Shock lab starts with analysis driven design and determines air gun pressure and impact programmer configuration

- Analysis predictions require understanding of programmer choice and its effect on impulse period
- Programmer choice dependent on plate frequency, test article response, and test specification levels



Calibration Setup

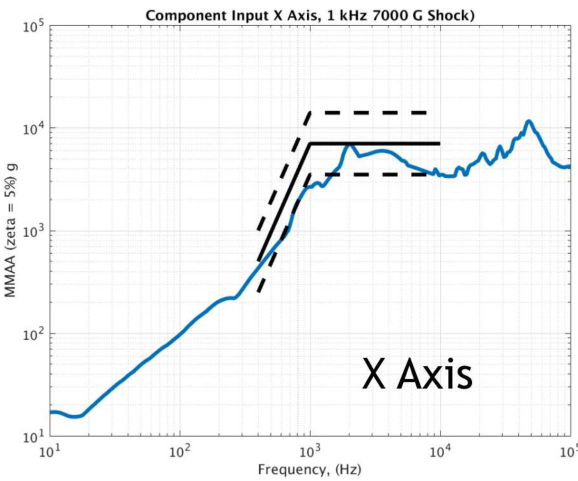


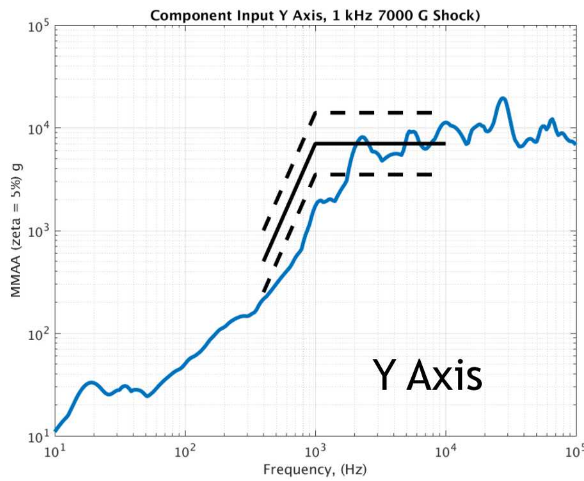
Impact Block Location

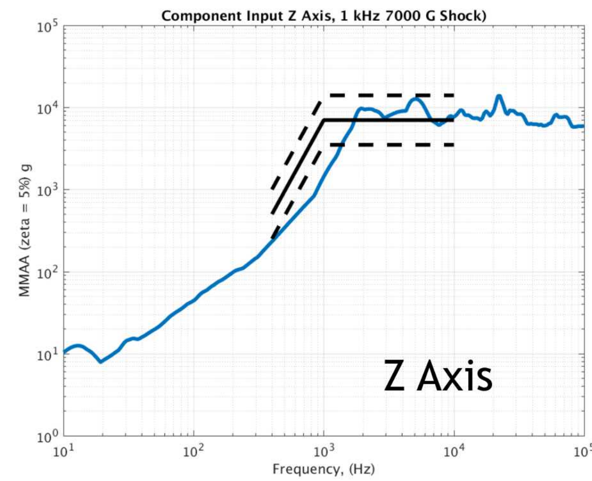
Experimental Test Results

Calibration shots under spec below 1500 Hz, programmer configuration requires additional adjustment

- Test results follow same trends as analysis predictions







Development of Test Quality Metric

Single axis resonant plate test acceptance requirement is

- Response within ±6dB over 80% of the specification frequency range
- Response within ±9dB over the entire frequency range
- Response must be greater than −1dB on the average dB error

Have been comparing three-axis test response to the single axis specifications but this does not account for phasing differences between the excitations

As plate motion is extremely complex, would like to understand if there is a better way to specify a three-axis test

- Potential to look at time history parameters (amplitude and duration) in addition to or instead of the SRS

Conclusions & Future Work

Multi-axis component shock testing on the resonant plate developed using offset impact and component positioning

Capability developed with finite element analysis and refined with laboratory testing

Can achieve SRS match in multiple axes with one test

Much work remains to be done before this becomes a production capability

- Need to ensure that equivalent damage mechanisms are being excited
- Need to quantify shock gradient across the plate
- Need to understand differences between plate vibration and rigid body motion