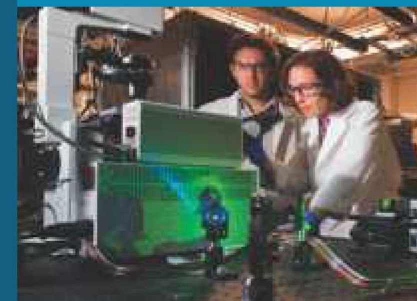
SAND2019-12507C

Defining Resonant Plate Shock Test Specifications in the Time Domain



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Albuquerque, NM

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Overview

Introduction and overview of resonant plate testing

Current SRS method for defining resonant plate test specifications

Review of sample data from two shock laboratories

Proposed time domain method for defining resonant plate test specifications

Understanding time domain variations in the shock

Potential problems with time domain specifications

Review of some recent test results

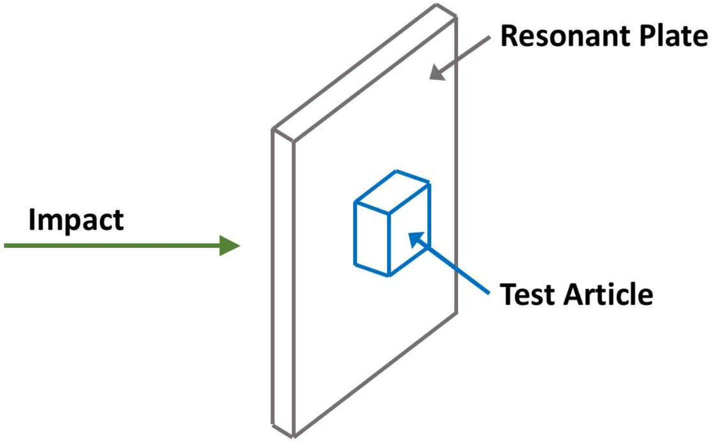
Conclusions

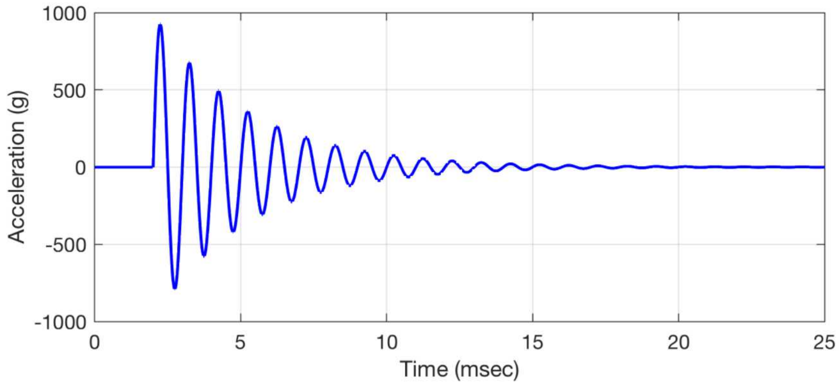
Introduction & Overview of Resonant Plate Testing

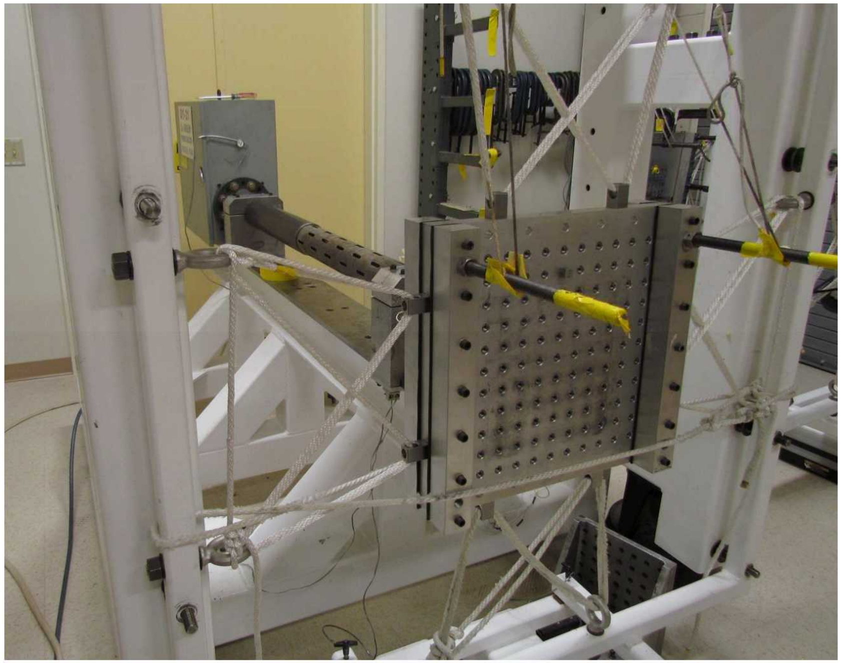
Resonant plate testing is commonly used to simulate pyroshock events in the test lab

Unit under test is typically attached to the plate front and the plate is excited by striking the rear of the plate with a hammer or projectile

Excitation should be a two-sided oscillating response similar to a decaying sinusoid



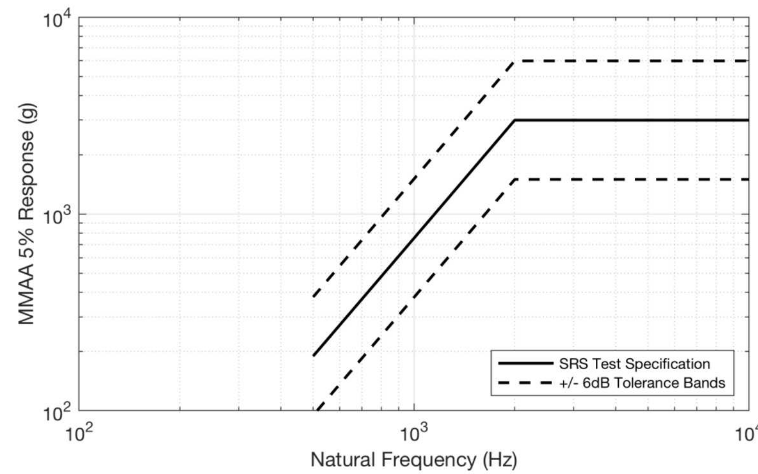




Resonant Plate Test Specifications

Resonant plate test specifications are typically defined by a simple, three-point SRS and standard tolerance bounds

- Knee frequency is the plate frequency
- Low-frequency slope is typically 12 dB/octave
- High-frequency point is about a decade above the knee



In contrast, nearly every other shock test type is defined by physical parameters

- Velocity change and shock duration
- Peak acceleration and shock duration
- Hammer drop height
- Explosive charge stand-off distance
- Impact velocity or drop height

While almost all shocks are analyzed with SRS, very few are defined by SRS

Motivation for the Change – Are These the Same?

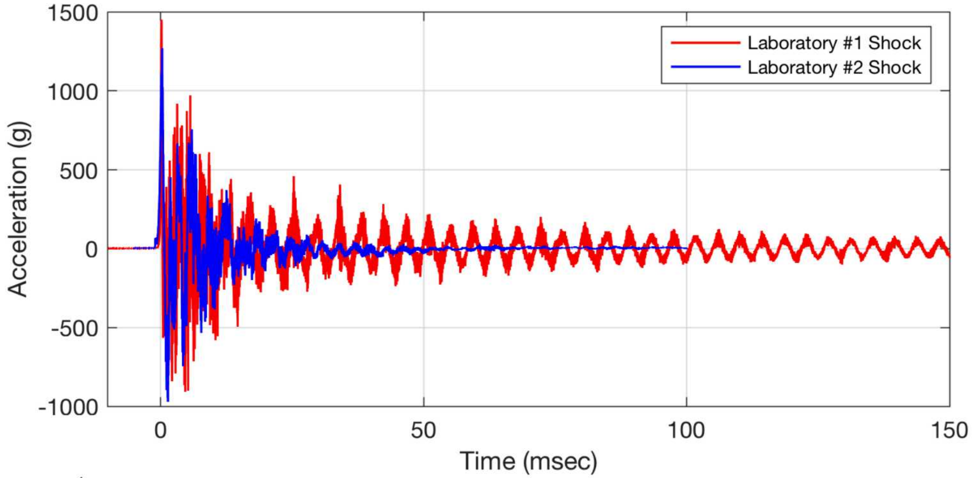
Same SRS shock test specification performed at two different laboratories

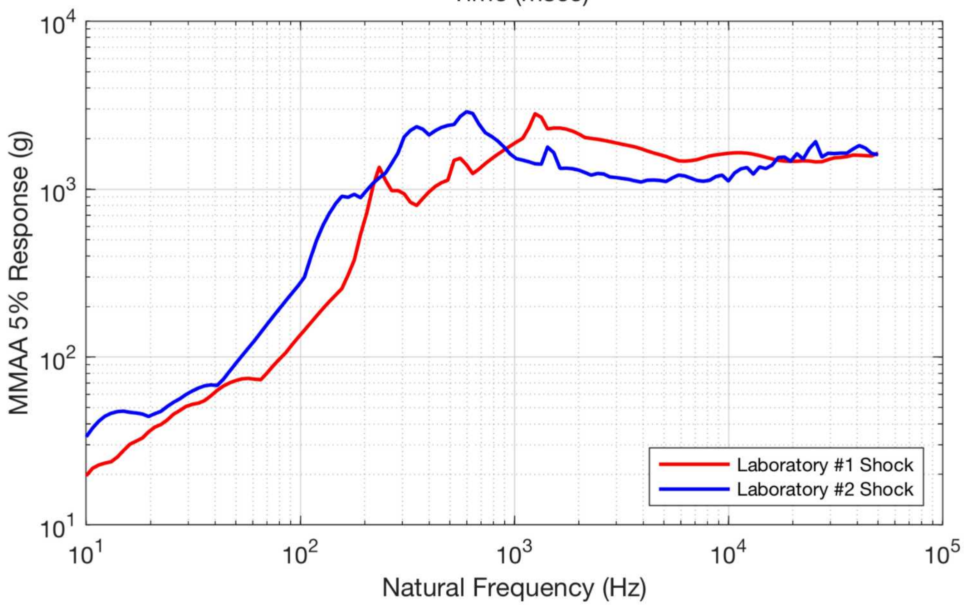
- Both laboratories are well respected and competent
- Time history responses are drastically different

Obvious difference in exposure

Both tests meet the SRS specification within tolerance

- They are assumed to be equivalent





	Laboratory #1	Laboratory #2
Max Acceleration	1450 g	1270 g
Pulse Duration	89.2 msec	20.4 msec
SRS dB Error	-0.65 dB	0.43 dB

Motivation for the Change – Are They Really Equivalent?

Peak acceleration is comparable

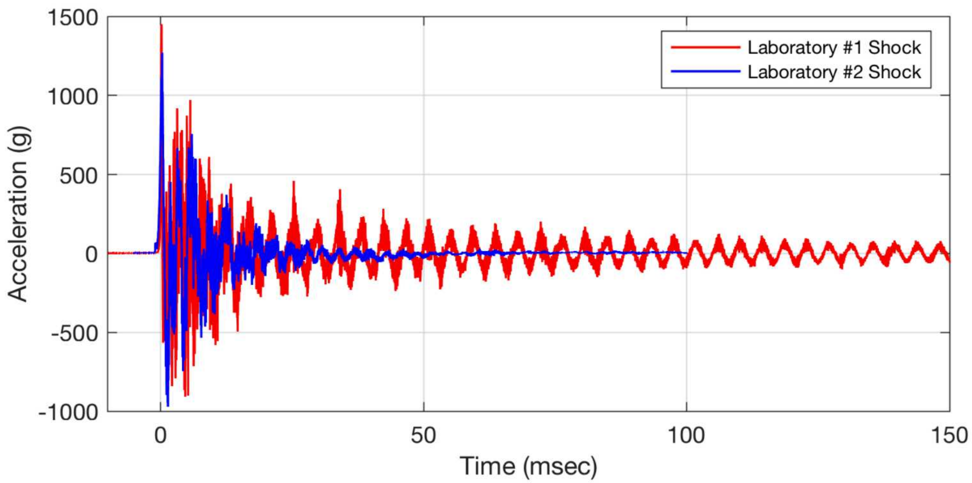
- Peak strain should also be comparable

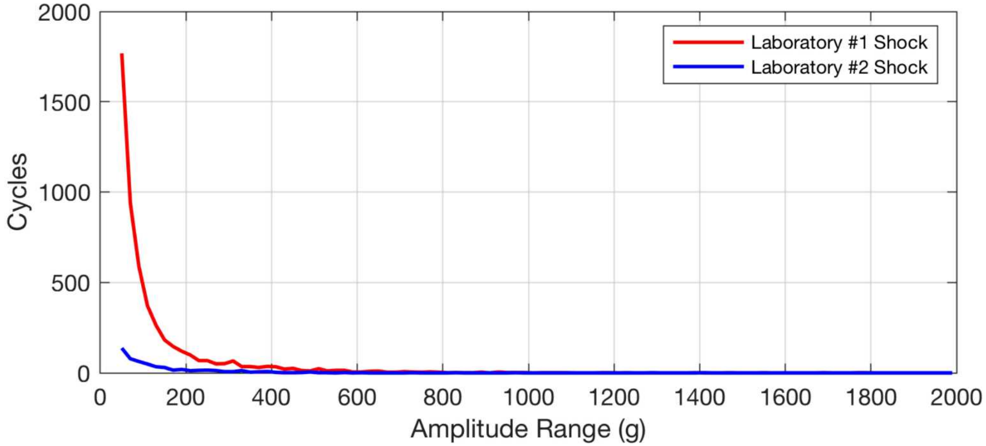
Rain-flow analysis used to estimate the number of applied strain cycles

Significant difference in the number of high-strain exposure cycles between the two exposures

- Difference in fatigue damage

Acceleration	Lab 1 Exposure
800g +	About Equal
400g	+30 cycles
200g	+100 cycles
100g	+420 cycles
50g	+1600 cycles





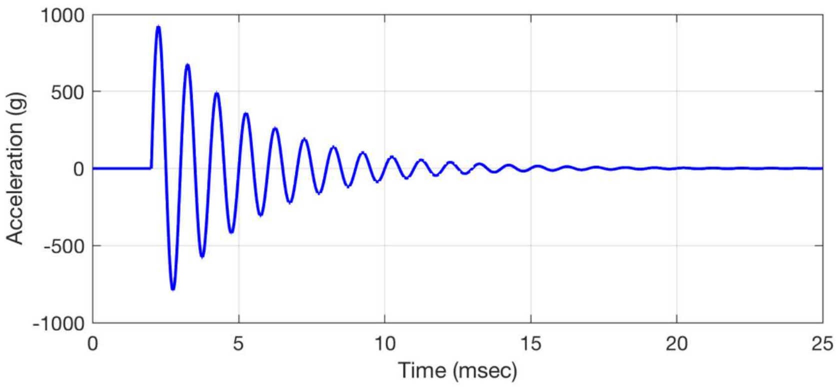
New Resonant Plate Test Specification Method

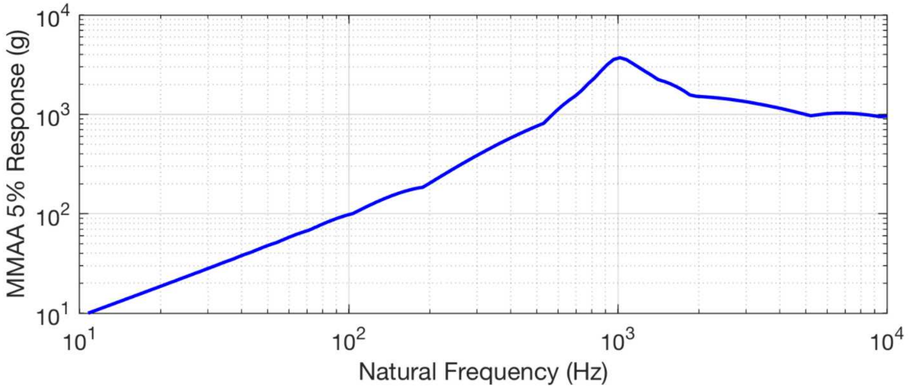
Would like to consider moving away from an SRS definition for resonant plate shock test specifications to a time-domain test specification method

Many researchers have suggested adding temporal requirements to the SRS specification
- Usually temporal moments or shock pulse duration

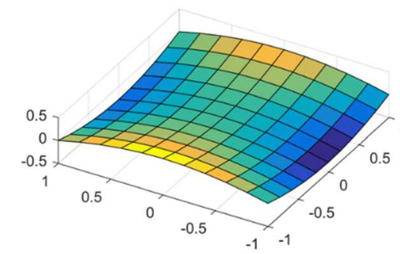
Proposing to replace the SRS specification with a temporal-only test specification based on three parameters:
- Resonant plate frequency
- Positive and negative peak accelerations
- Shock pulse duration

Undoubtably the SRS will continue to be calculated for comparison





Frequency Tolerances



Resonant plate frequency is nominally defined by the physical size of the plate and its material properties

$$f_i = \frac{\lambda_i^2}{2\pi l^2}\sqrt{\frac{Et^3}{12\gamma(1-\nu^2)}}$$

Actual response frequency is influenced by:

- Test fixture mass and stiffness
- Unit under test mass and stiffness
- Mass and stiffness of additional items added to the plate (damping bars, weights, etc.)

Unreasonable to ask shock lab to perform a modal test for every shock test executed

- Need to allow reasonable latitude to accommodate test fixture installation

Can verify requirement post-test with Fourier transform

Peak Acceleration Tolerances

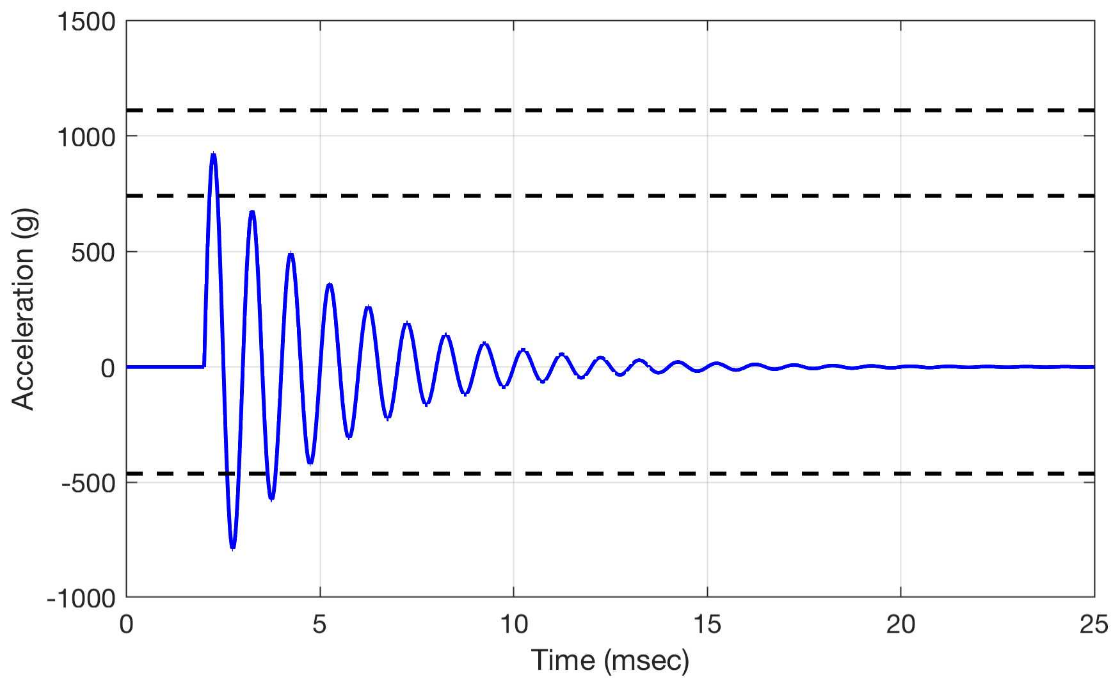
Maximum peak amplitude within some defined tolerance range

- ±20% tolerance bands shown here

Return acceleration greater than some defined percentage of specification maximum

- > 50% of the specification shown here

Tolerance limits shown here suggestions to be investigated, not definitive limits



Peak acceleration to fall within defined band

Peak return acceleration to exceed defined limit

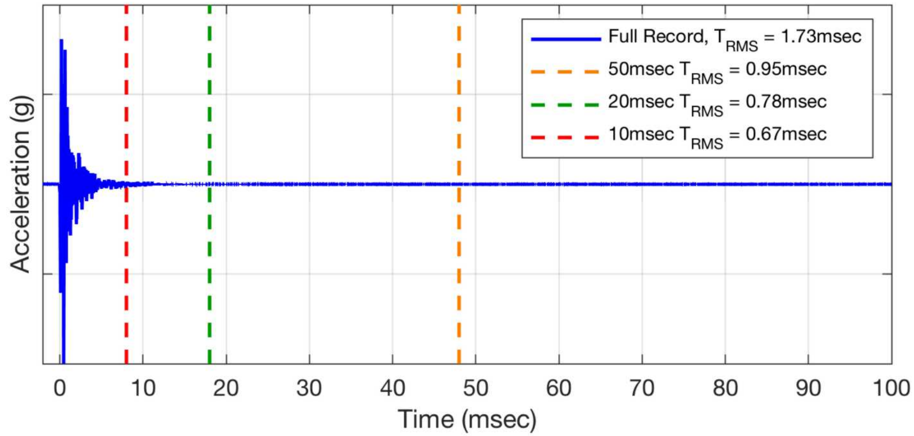
Shock Pulse Duration Tolerances

Shock duration is surprisingly difficult to define
- Analytical models are very clean since shock starts and ends at zero
- Measured test data is more complex since shock starts and ends in the noise floor

MIL-STD-810H is not exactly helping us out with this one
- The overall shock duration, T_e, is the "duration from the time the signal rises above the noise floor until the perceived termination of the shock."
- Difficult to write an algorithm against the user's perception

Temporal moments are affected by the signal length
- Additional noise floor data can significantly alter RMS duration calculation
- RMS duration requirement can always be satisfied by changing the processed signal length

10% amplitude duration method
- Used for drop table shocks
- Unaffected by record length
- May be impacted by signal noise or subsequent impacts



Monte-Carlo Variations of the Ideal Response

Need to understand how variations in the time history impact the SRS

- Need to quantify time history variations with likely SRS dB error

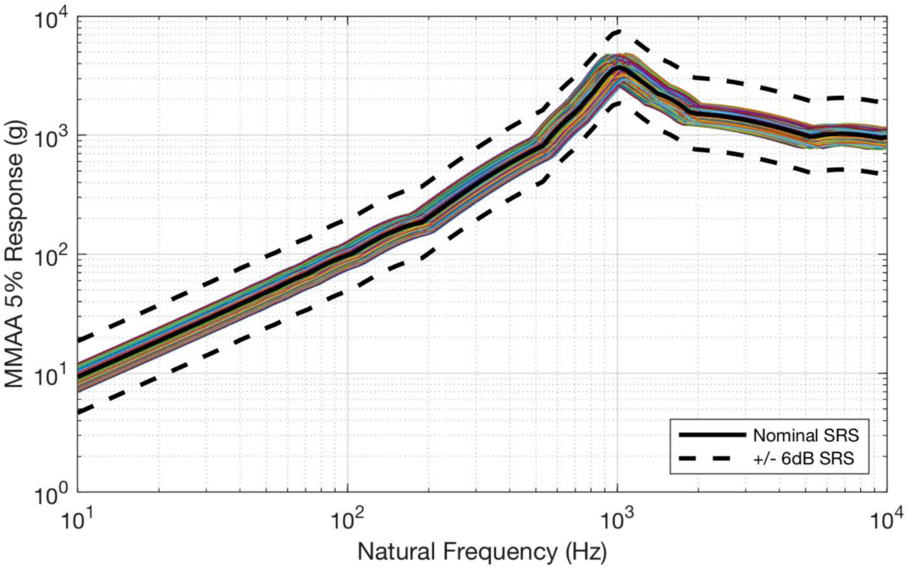
Monte-Carlo simulation of 1,000 decaying sinusoids uniformly varying frequency, amplitude, and decay rate

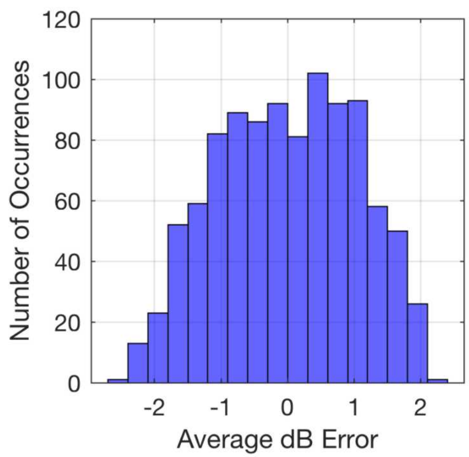
- ±10% on frequency
- ±20% on amplitude
- ±20% on damping ratio

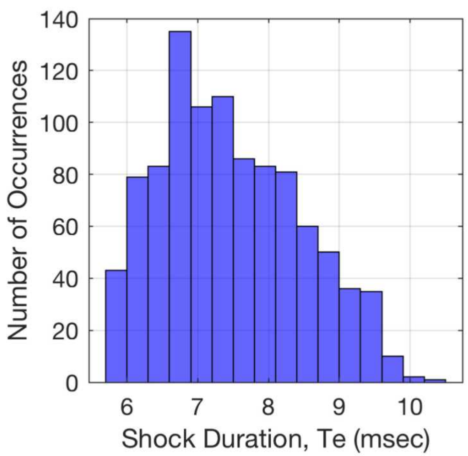
All SRS results were generally within ±2 dB of the ideal response

Nominal shock duration was 7.3 msec

- 10% amplitude duration calculation
- Low of 5.7 msec
- High of 10.3 msec







Increased Variations of the Ideal Response

Monte-Carlo analysis repeated with increased variation limits

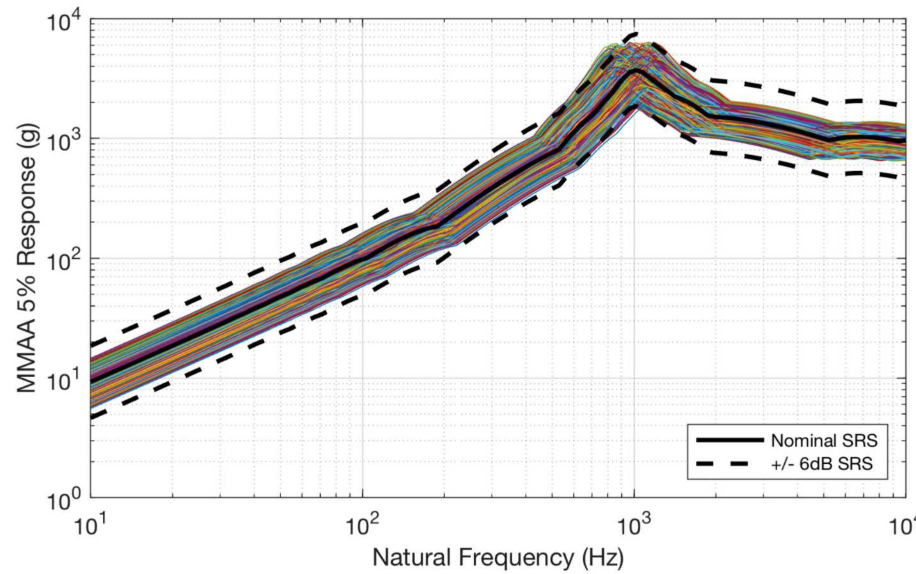
- ±20% on frequency
- ±30% on amplitude
- ±50% on damping ratio

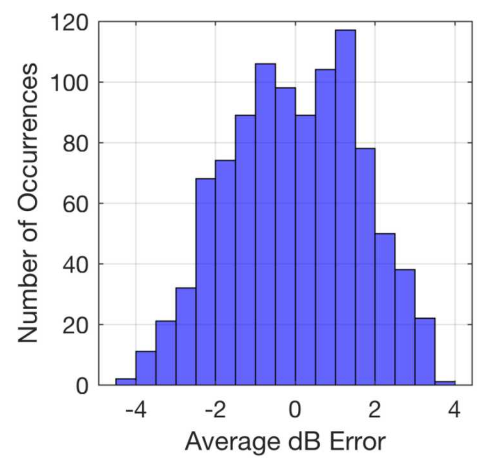
All SRS results were generally within ±4 dB of the ideal response

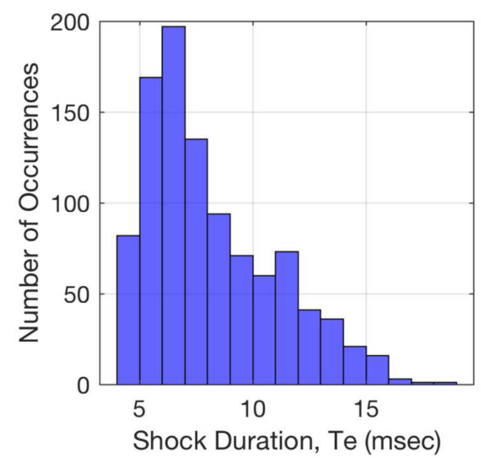
- A –4 dB test would not be acceptable but it helps to understand the problem bounds

Nominal shock duration was 7.3 msec

- Low of 4.1 msec
- High of 18.4 msec







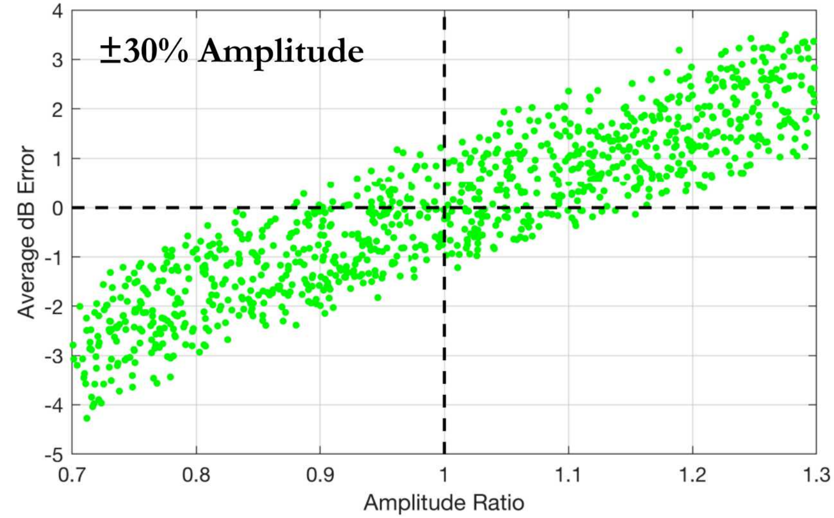
Allowable Response Variations

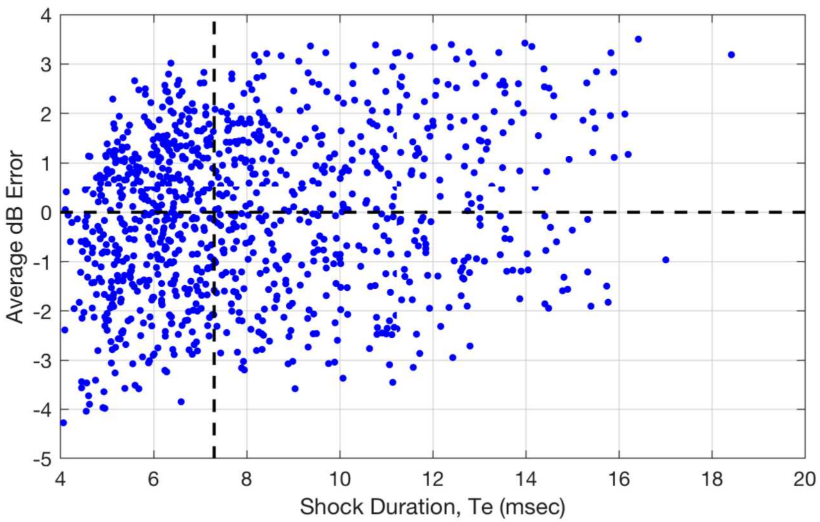
Monte-Carlo simulations help to quantify range of acceptable responses

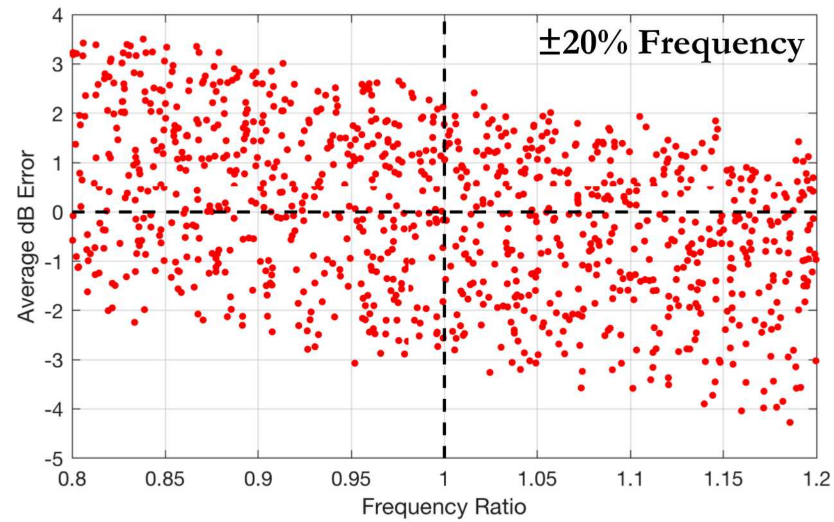
Amplitude variation is fairly linear with error

Frequency variation is less sensitive to error although there is an apparent trend

Pulse duration does not indicate a very clear trend although the extremes should be avoided



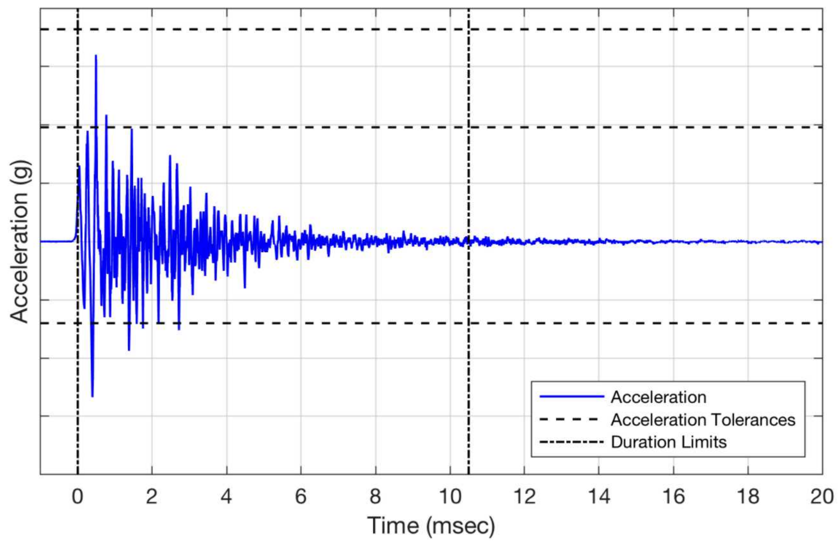




Recent Test Results

Recent test series performed at Sandia National Laboratories Mechanical Shock Laboratory used time-domain shock specifications

Three test series performed on two different resonant plates and one resonant fixture



Tolerances used for this test series were:

- ±30% on shock amplitude
- ±20% on frequency
- +50% on shock duration
- Acceleration data low-pass filtered at 100kHz

Calibrations shocks used to tune specifications

- First test series required 14 calibration shots
- Second test series required 9 calibration shots
- Final series required 4 calibration shots
- Calibration requirements similar to an SRS specification

Potential Problems with New Method

Acceleration signal must be filtered to remove accelerometer resonance

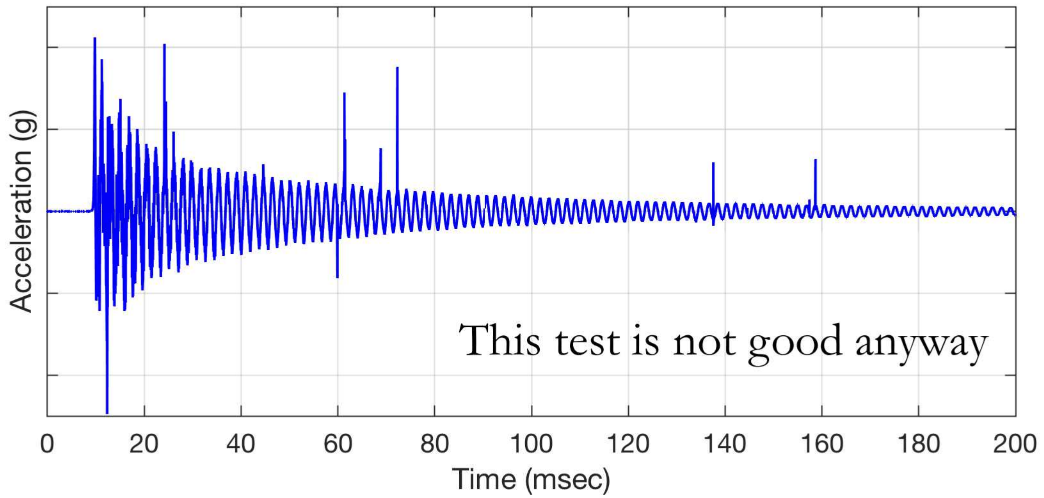
- Typical undamped piezoresistive accelerometers have resonances ≫ 100 kHz
- Damped piezoresistive accelerometers have resonances around or slightly below 100 kHz

Need a consistent definition of faired peak amplitude that does not remove acceleration content of concern

- Cannot change the filter frequency until you get the desired result

Secondary impacts or part damage will often present as a pulse duration failure

- Test may have been good but measure response fails duration check



Conclusion

It is possible to specify a resonant plate test without an SRS

It is possible to control resonant plate shock pulse duration with appropriate damping material on the plate

Calibration requirements for a time-domain specification are similar to those for an SRS specification

More work is required to identify the best combination of test specification parameters that will be widely accepted