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The Derivation of System Shock Responses for a Worst Case Road

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Background

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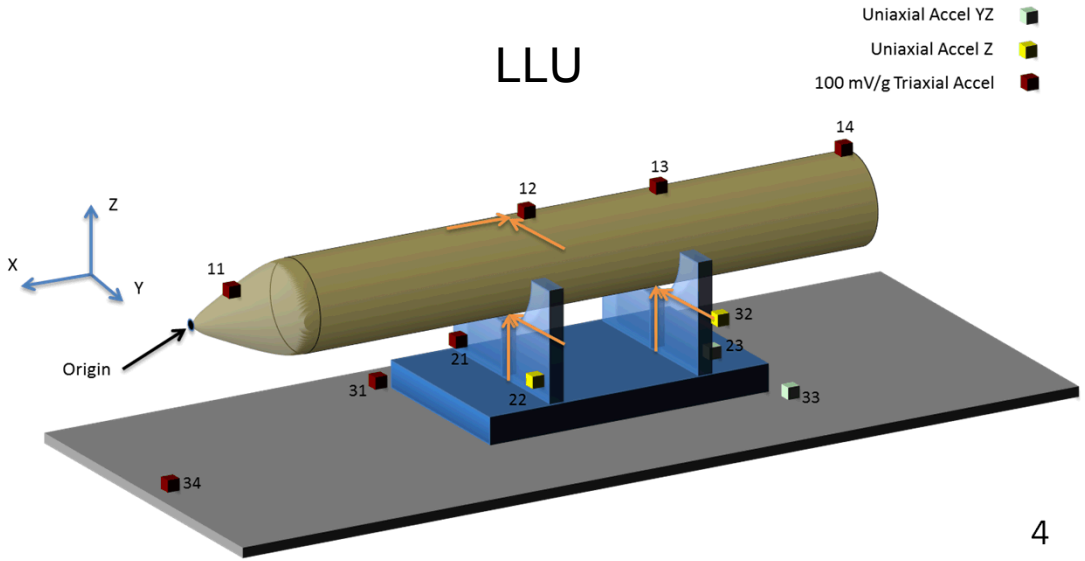
- Goal
  - Identify the worst case road shock for internal locations on a system
- Problem
  - Measuring the responses of a system to the worst case road shock would be expensive and time consuming
- Solution
  - Measure random vibration 6DOF responses and MIMO transmissibility response functions during live road tests
  - Use measured field data to predict 6DOF responses to a worst case road shock
  - Generate system level single axis test specifications that reproduce the predicted responses to the worst case road inputs
- Complimentary adaptation of paper presented last year for deriving worst case road vibration responses

Outline

- **Road Test**
- Determine Worst Case Road Responses
- Replicate Worst Case Road Responses in Laboratory

Road Test

- Collect data on a wide variety of road conditions
  - Measured data on several trucks (5-ton flatbed, tractor trailer)
  - 3 handling gear configurations
  - 4 road types measured in the Albuquerque, NM area (Interstate, rural highway, city streets, & dirt roads). Several records per road
- Measured response data on the truck bed, the base of the handling gear (shown with MDM low fidelity mass mock unit), and on the high fidelity mass simulator (LLU)



Road Environment Measurements

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- Data collected
  - 6 channels truck floor (1 X-dir, 2 Y-dir, 3 Z-dir)
  - 6 channels handling gear deck (1 X-dir, 2 Y-dir, 3 Z-dir)
  - 12 channels system responses (tri-ax at 4 locations)
- Relational information from data
  - 6 Degree-of-Freedom (DOF) Cross Spectral Density (CSD) at floor
  - MIMO Transmissibility Response Functions
    - Floor to handling gear deck
    - Floor to unit responses

Outline

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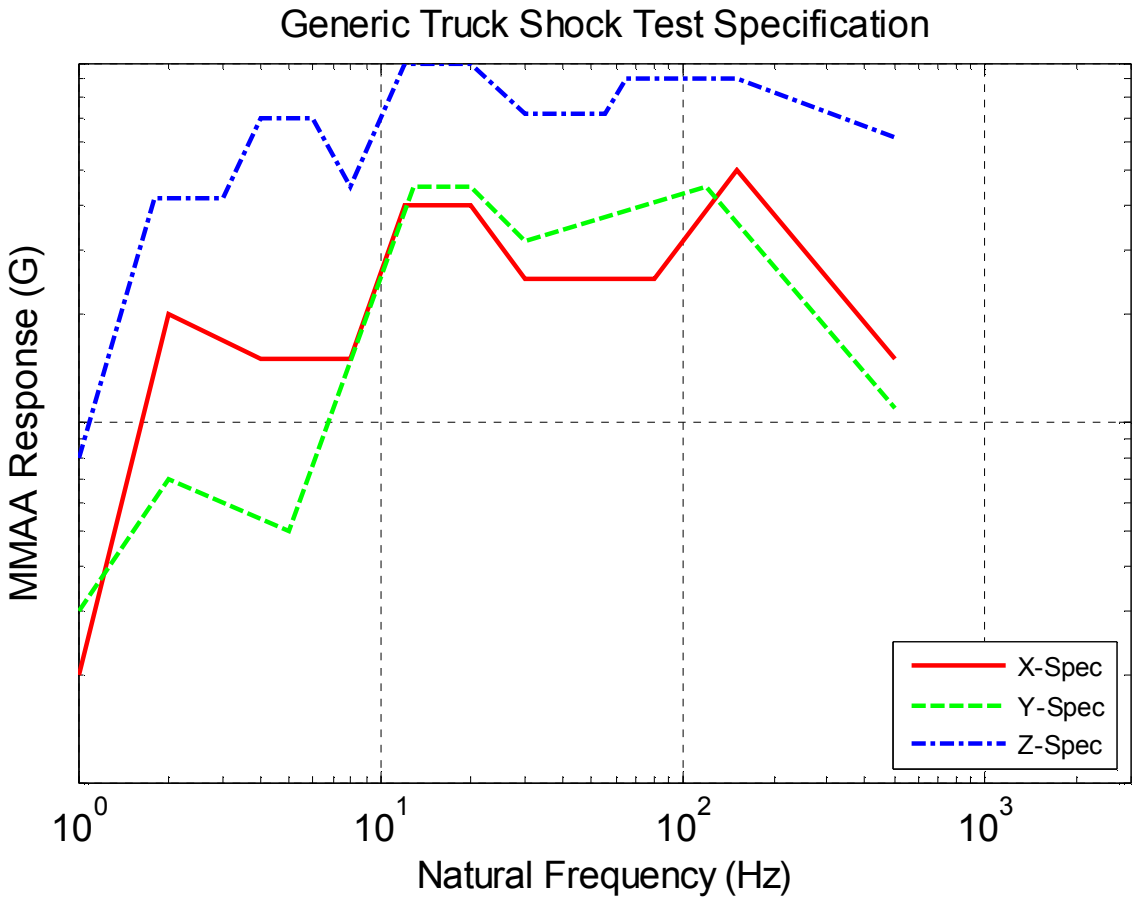
Worst Case Road Shock

- Worst case floor input shock specifications developed jointly by DOE and DOD based on a collection of trucks



Generate 6DOF Worst Case Shock Inputs on Floor

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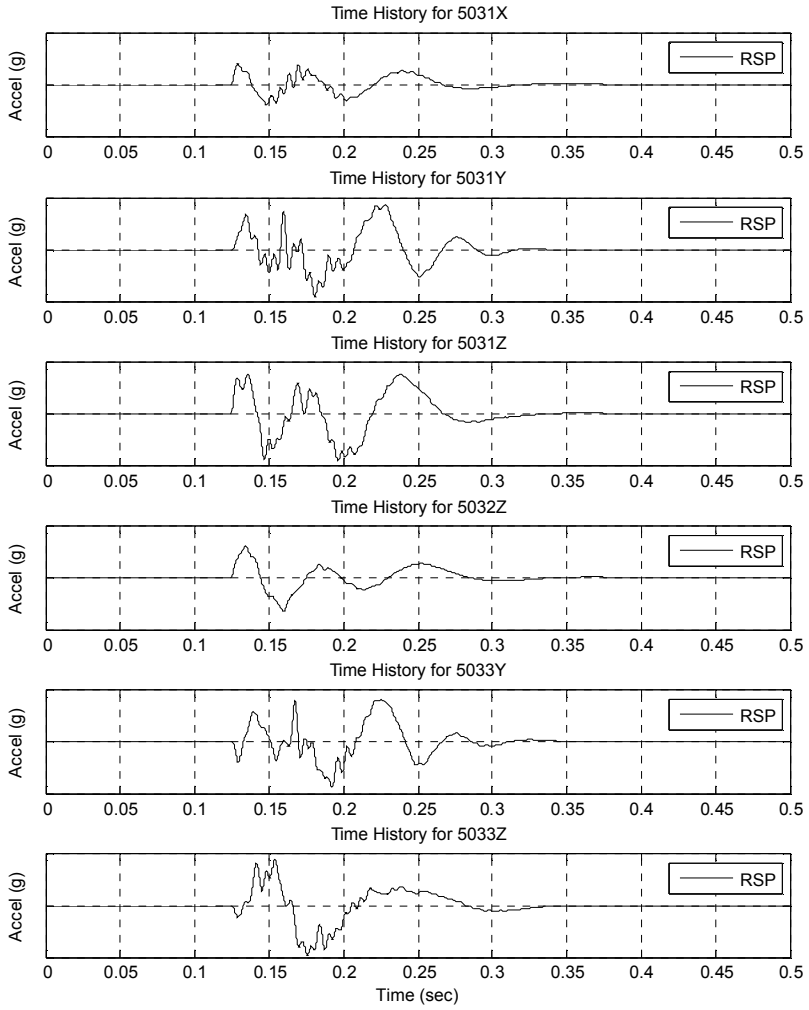
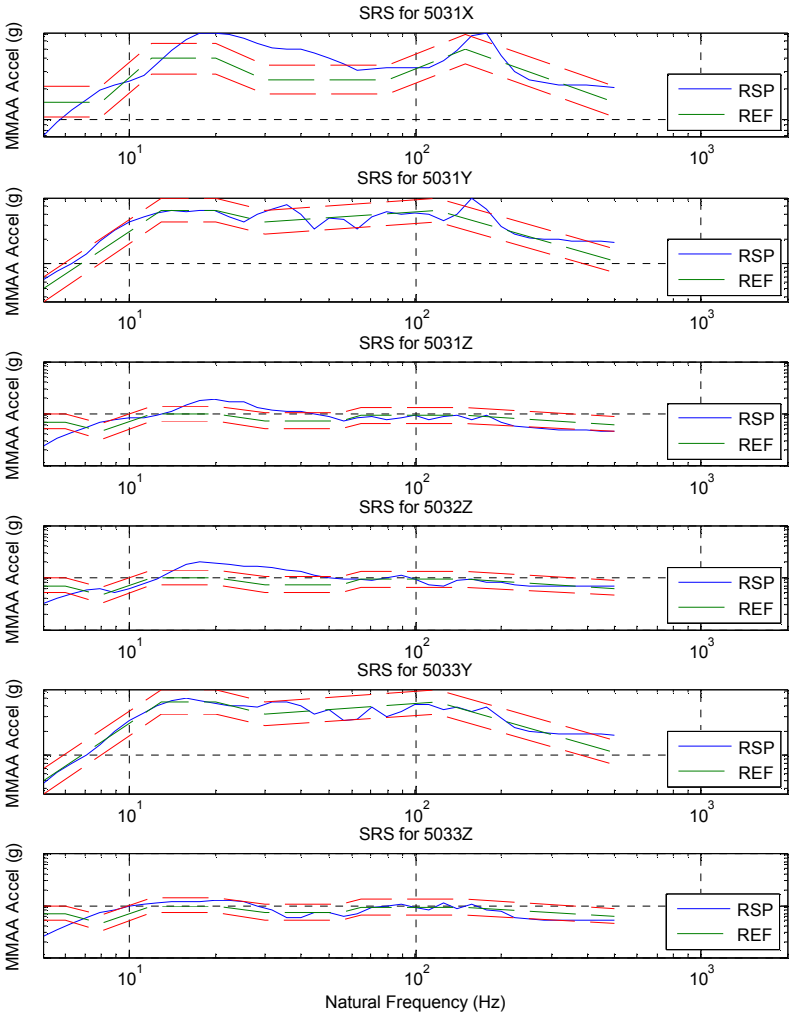
- Generate transient random inputs of test specification road shock for every road/truck/store configuration
  - Since transient random has full spectral content it will better leverage the phase relationships at all frequencies
- Use phase information in Cross Spectral Density (CSD) to correlate 6 DOF transient random inputs
  - First transient random has random phase, the phases for the other inputs are defined relative to first based on CSD
  - Generate 30 realizations
  - Select realization with smallest error

$$dB_{Error} = \frac{1}{N}\sum \left| 20 * \log\left(\frac{SRS_{TR}}{SRS_{Specification}}\right)\right|$$

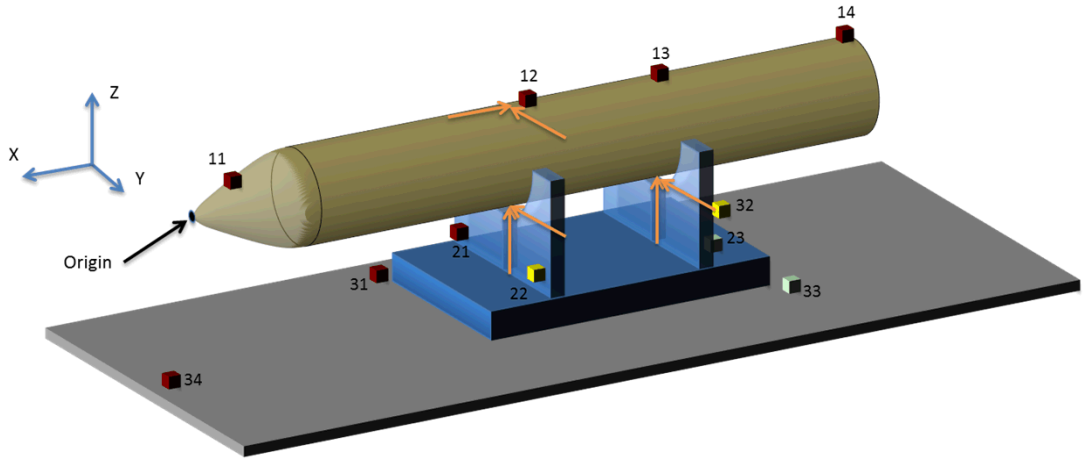
Typical Realization



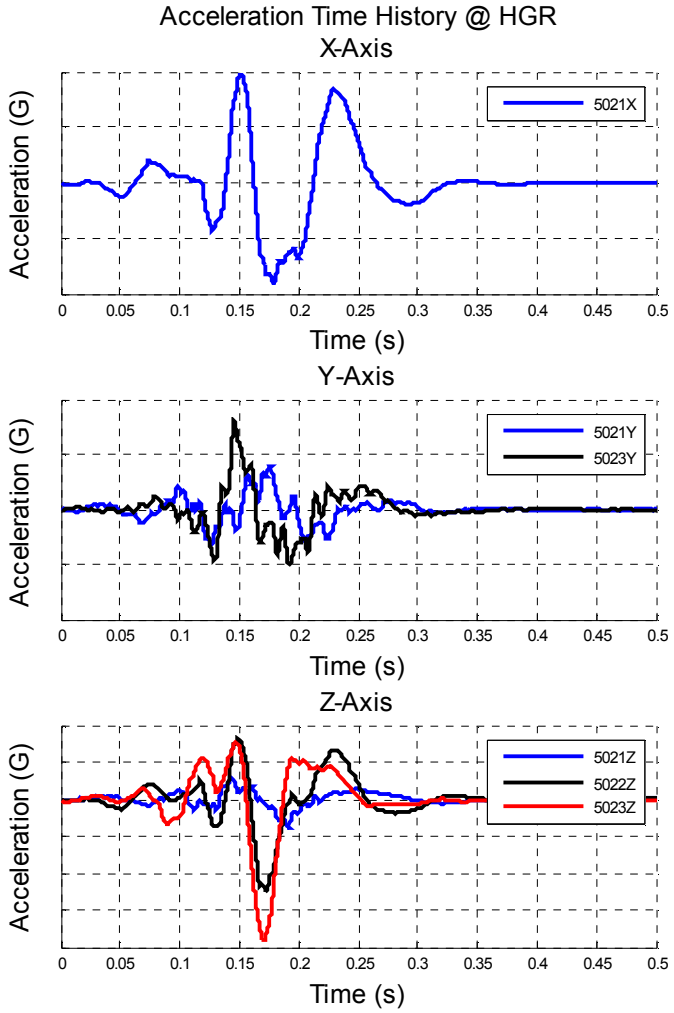


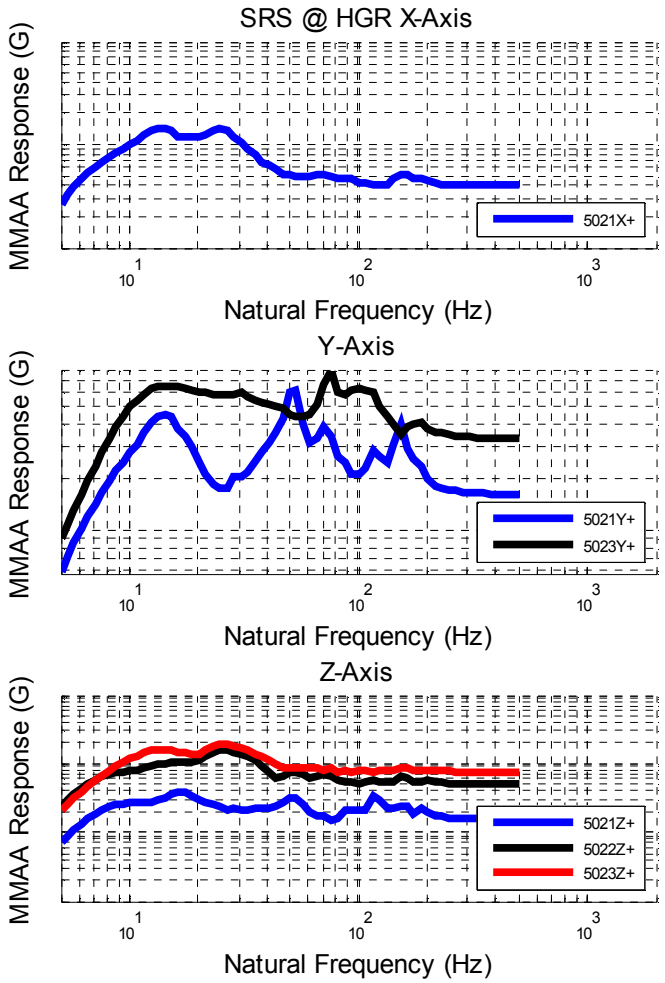
Worst Case Responses on Unit & Handling Gear

- Generate responses for worst case inputs for each road/truck/system configuration using convolution
  - Transfer functions from all road tests
  - Best set of transient random input time histories
  - Responses on unit and handling gear
  - Remove out of family responses

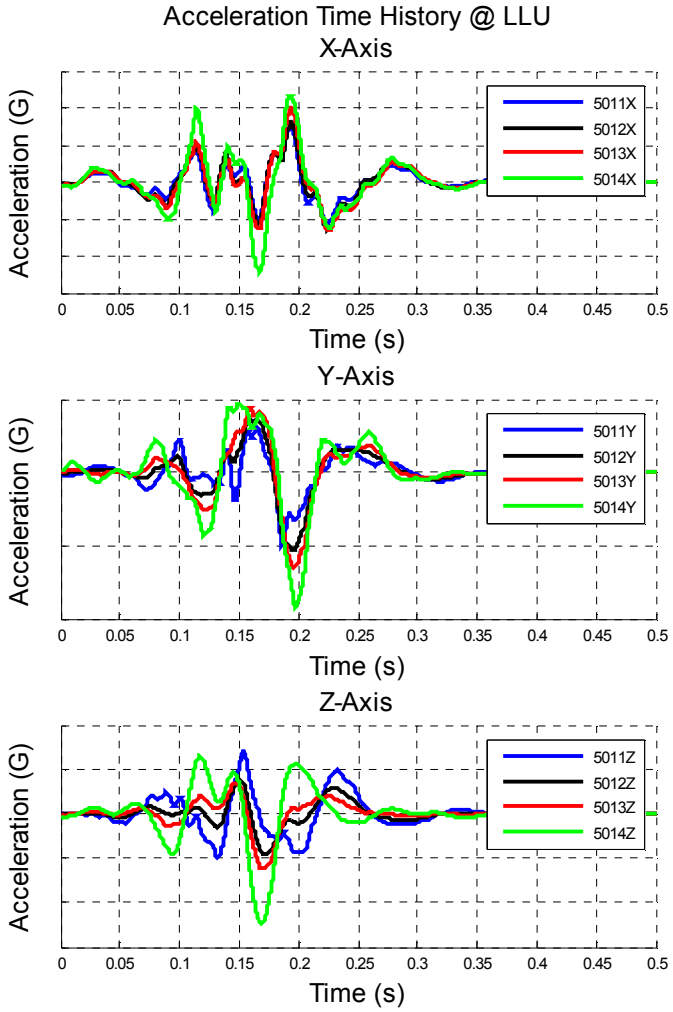


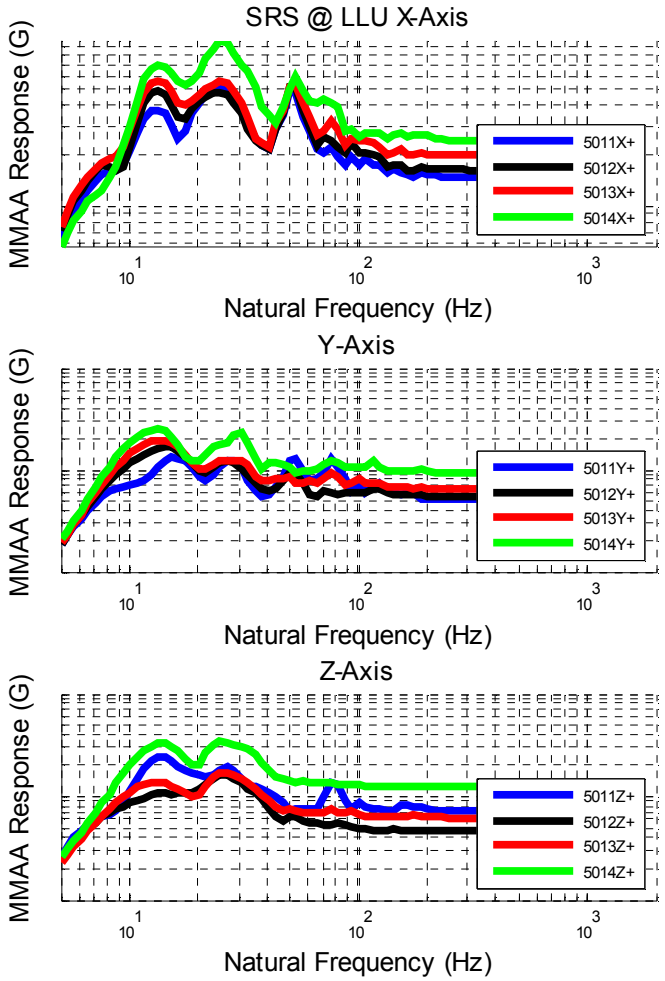
Worst Case Responses on Handling Gear Interface



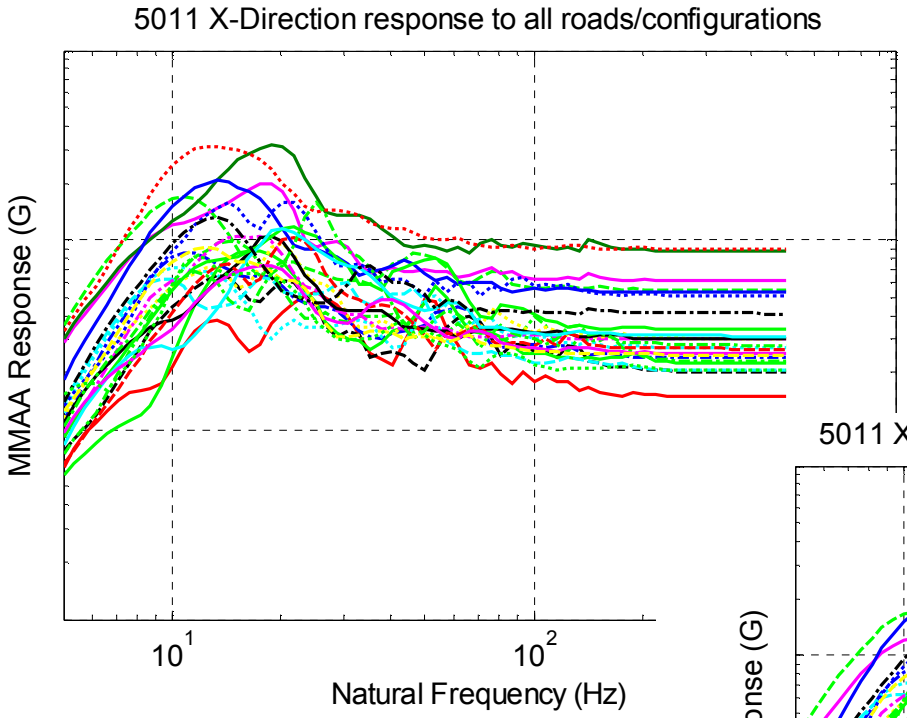


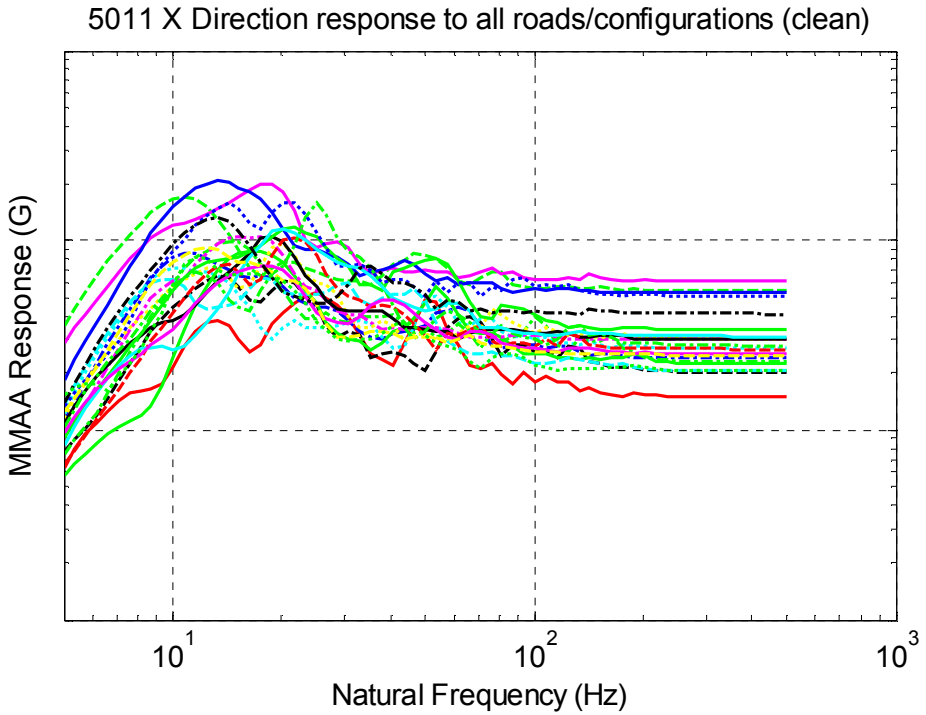
Worst Case Responses on Unit



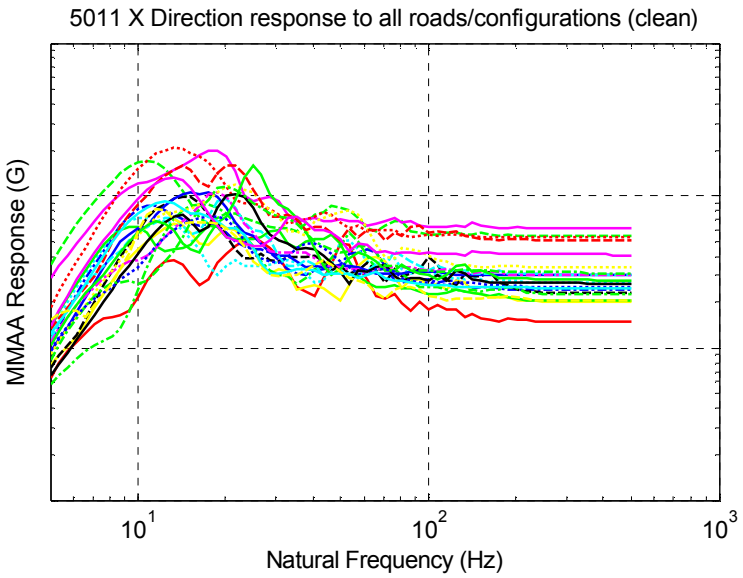


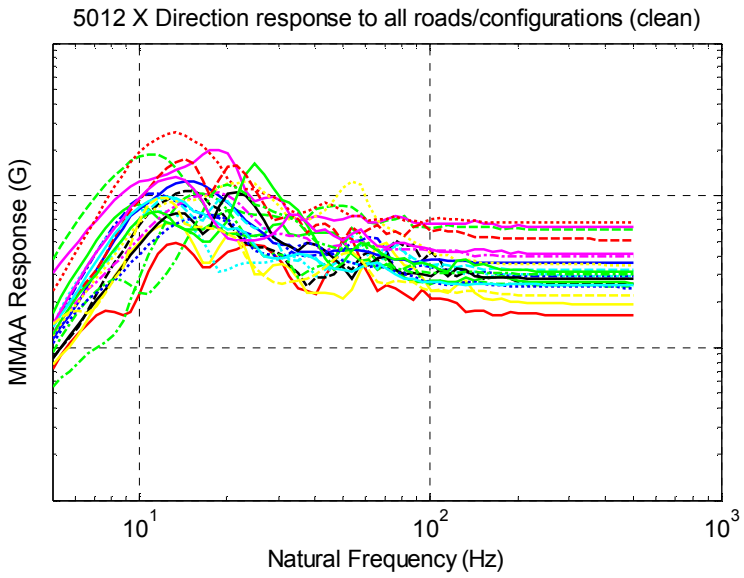
Remove Out of Family Responses

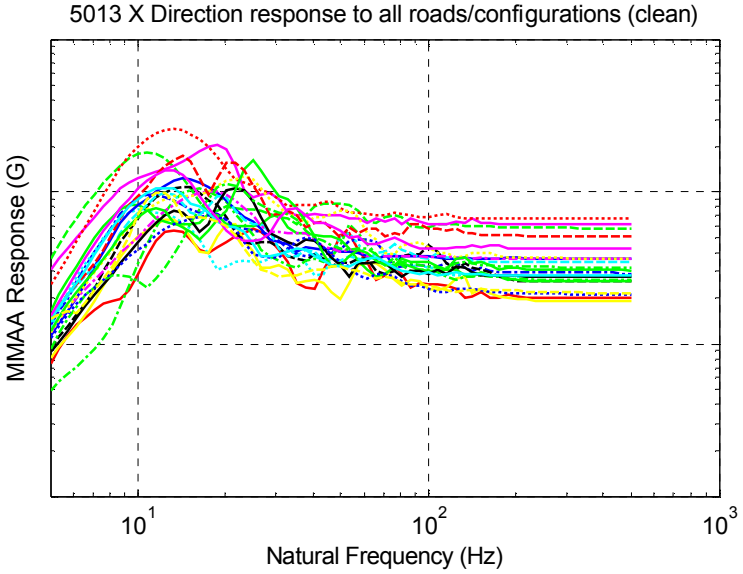


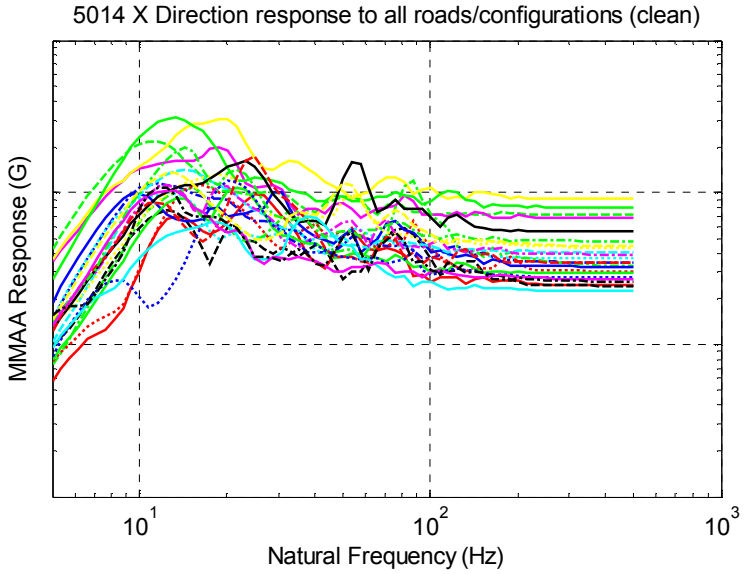


All Responses on Unit









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Develop System Level Laboratory Test Inputs

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- Laboratory test configuration hard bolts the handling gear base to the shaker interface
  - Boundary conditions don't match field
    - Different location on handling gear
    - No chocks in laboratory configuration
  - Single axis inputs
- Develop the optimum laboratory input to match unit responses to the worst case road
  - Minimum frequency of test specification of 10Hz to be compatible with laboratory shakers

Steps for deriving the responses to a laboratory input

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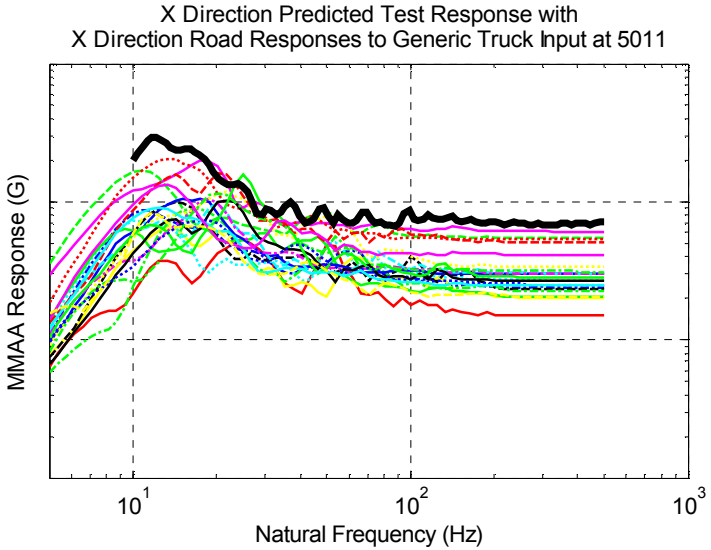
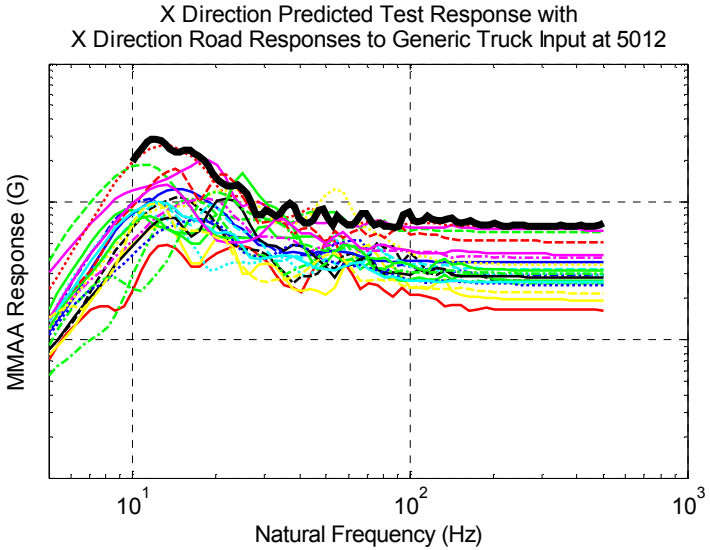
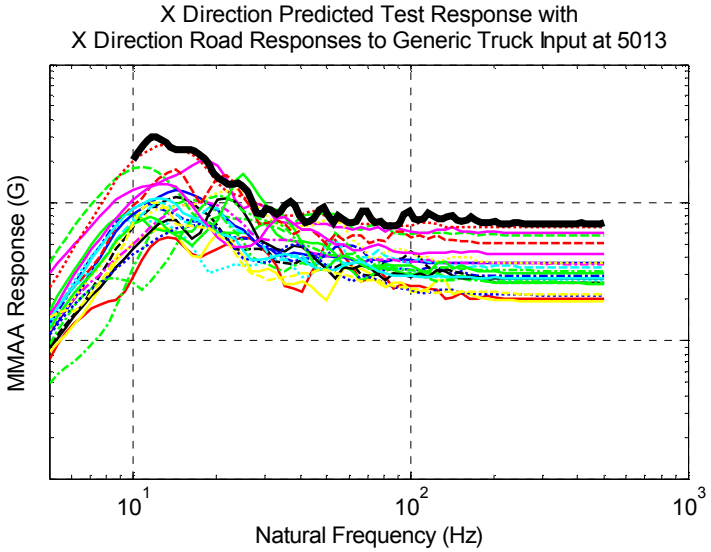
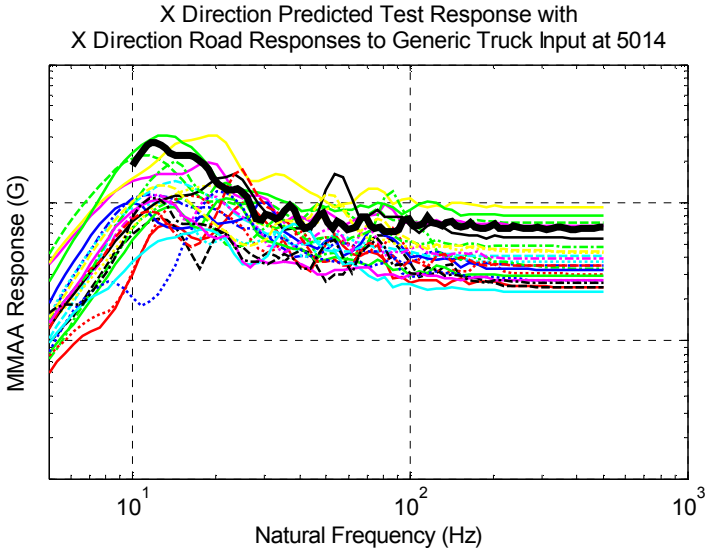
- Use envelope of in-axis worst case shock responses at handling gear from all roads to develop preliminary laboratory test inputs (straight line SRS with decayed sine implementation)
- Convolve decayed sine time history with transmissibility response functions from laboratory mass mock scoping tests to find responses on unit from inputs.
- Compare laboratory and predicted worst case responses as a measure of the realism of the laboratory specifications
  - Iterate to optimize inputs
  - Best match for 3 of 4 locations

Match Road Responses with Test Responses

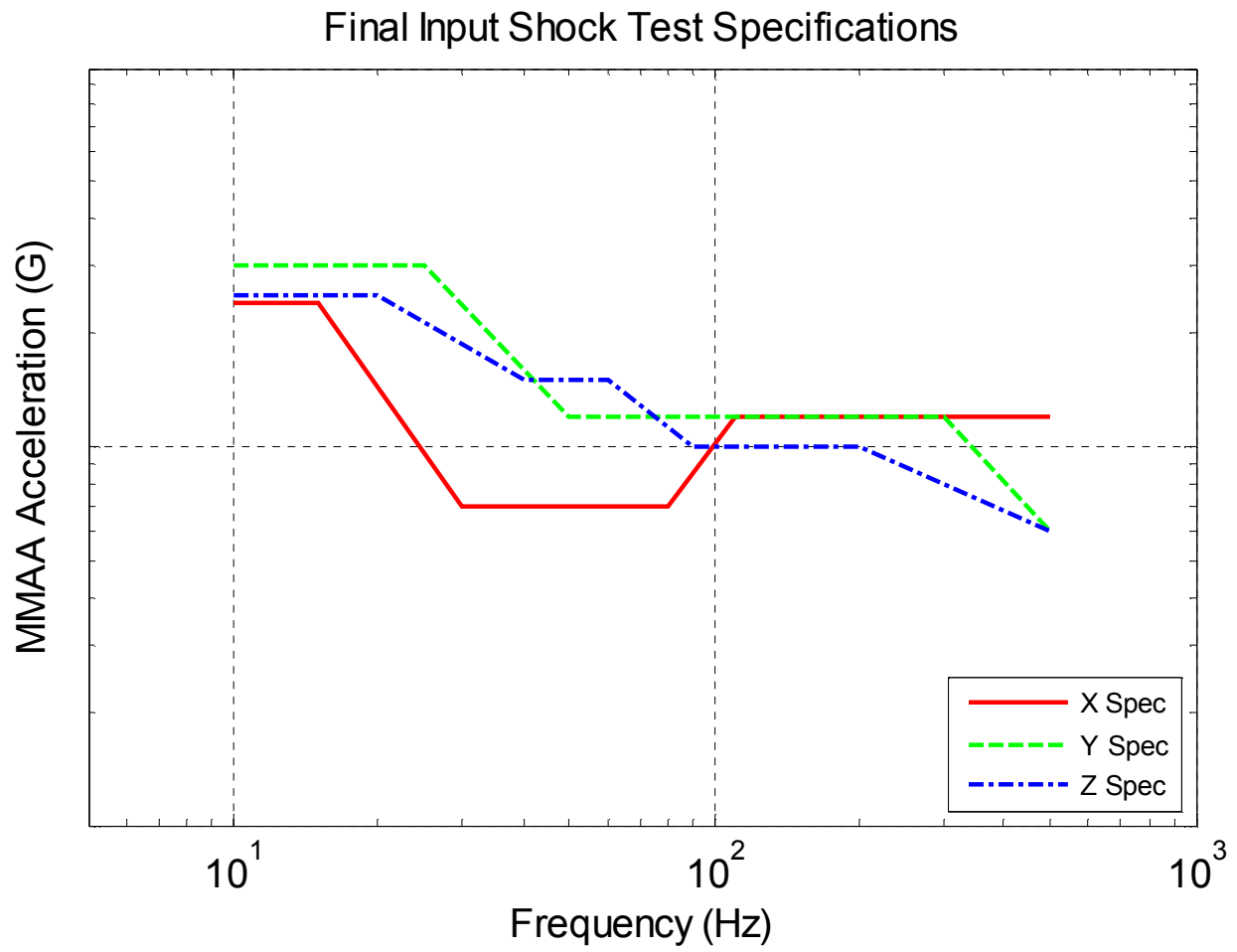








Final Single Axis Test Inputs to Handling Gear



Summary

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- Process
  - Road Test
  - Worst Case Road Responses
  - Replicate Worst Case Road Responses in Laboratory

- We have developed a methodology for deriving 6 DOF system responses to the worst case road shocks
- We have developed a methodology for deriving a laboratory test that produces the predicted worst case road responses
- Responses from internal components can now be determined from the laboratory test

References

- Follow on to talk from last year “The Derivation of System Responses for a Mil-Standard Road” Mr. Jerome Cap, Ms. Melissa C’ de Baca, & Mr. Troy Skousen (Sandia National Laboratories)