SAND2015-8400C

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Development of a Single Input Multiple Output (SIMO) Input Derivation Algorithm for Oscillatory Decaying Shocks

86th Shock and Vibration Symposium
October 5 – 8, 2015

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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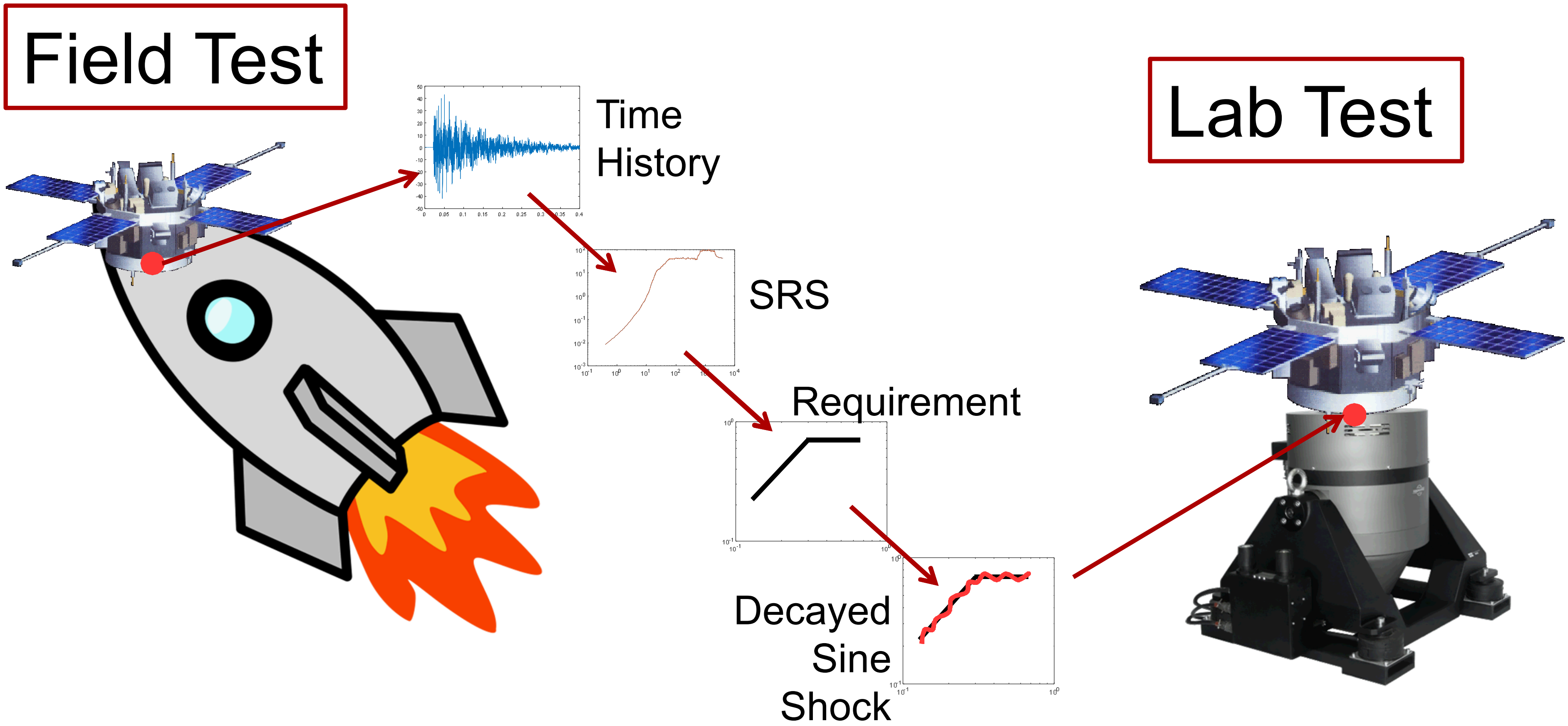
Acknowledgments

- Coauthor
  - Jack Reid, Jerry Cap, Dr. Vit Babuska
- Code Development & Validation
  - Jack Reid
- Technical Discussion & Analysis
  - David Smallwood
- Management
  - Scott Klenke

Traditional Laboratory Shaker Shock



The shaker can match the defined input - but either no attempt is made to match the other response locations to their field responses or it is done manually

Sum of Decayed Sinusoids Shaker Shock

- Convenient to describe shock time history as sum of decayed sines
- Sine tones are described by amplitude, frequency, decay, and delay
- Frequency, decay, and delay are predefined by user based on the characteristics of the shock
- Amplitude is optimized to match reference SRS

$$\sum_{i=1}^{N} A_i e^{-\lambda_i w_i t} \sin(w_i t + \phi_i)$$

Smallwood's Optimization Algorithm

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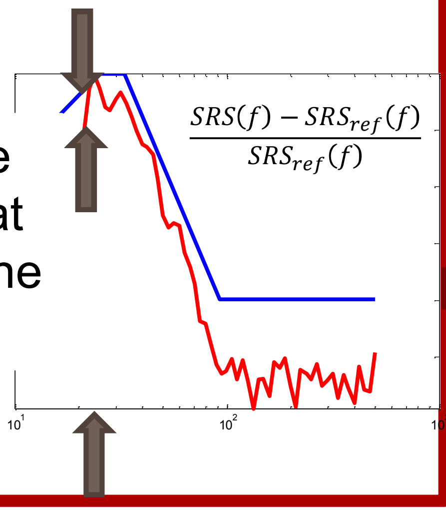
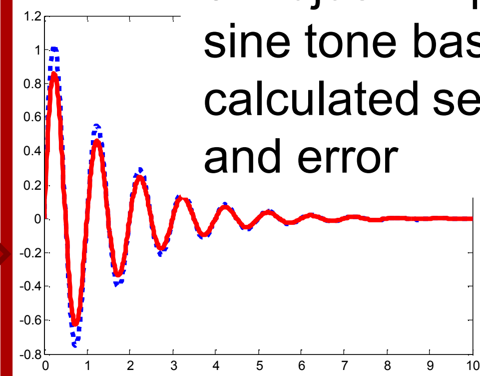
1. Make a guess of the sine tone amplitudes

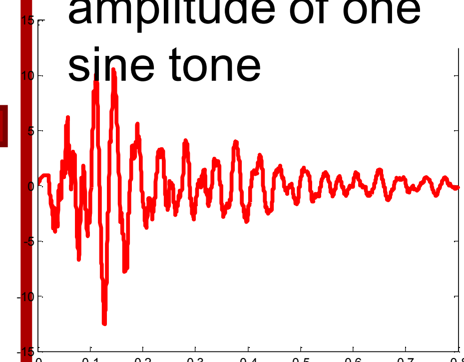
2. Calculate SRS error at first sine tone frequency



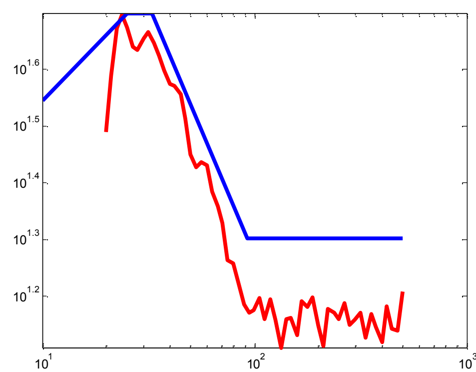
3. Adjust Amplitude of sine tone based on calculated sensitivity and error



4. Calculate new time history with adjusted amplitude of one sine tone



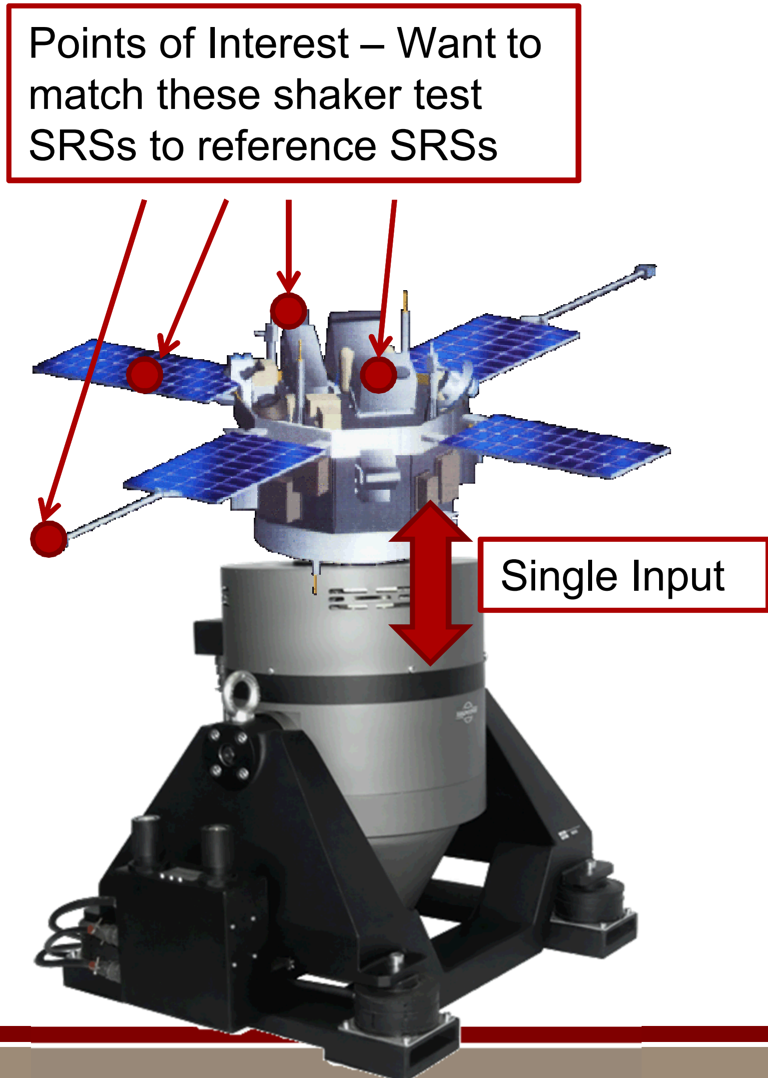
5. Calculate new SRS



6. Compute the error at the sine tone frequency – if within tolerance then move to the next sine tone

The algorithm steps through from the lowest frequency sine tone to the highest frequency sine tone

Single Input Multiple Output Shock



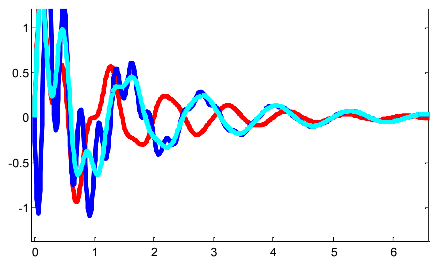
Objective – Find an input that will suitably match the response points of interest to their reference SRSs

Recognize that single axis input cannot exactly match multiple responses except as a weighted average

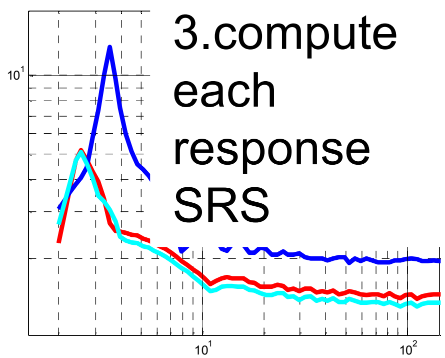
Single Input Multiple Output Shock

1. Make a guess of the sine tone amplitudes

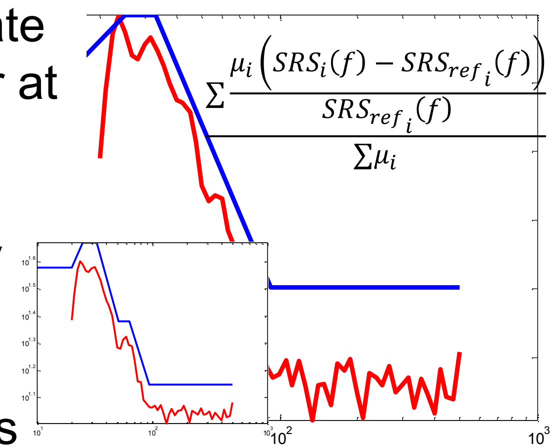
2. Convolve the input with each response transfer function to obtain response time history



3.compute each response SRS

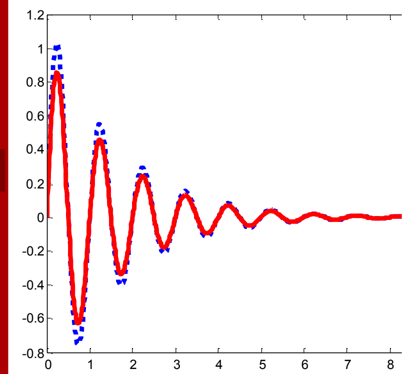


4. Calculate SRS error at first sine tone frequency based on assigned weightings



$$\frac{\sum \frac{\mu_i \left(SRS_i(f) - SRS_{ref_i}(f) \right)}{SRS_{ref_i}(f)}}{\sum \mu_i}$$

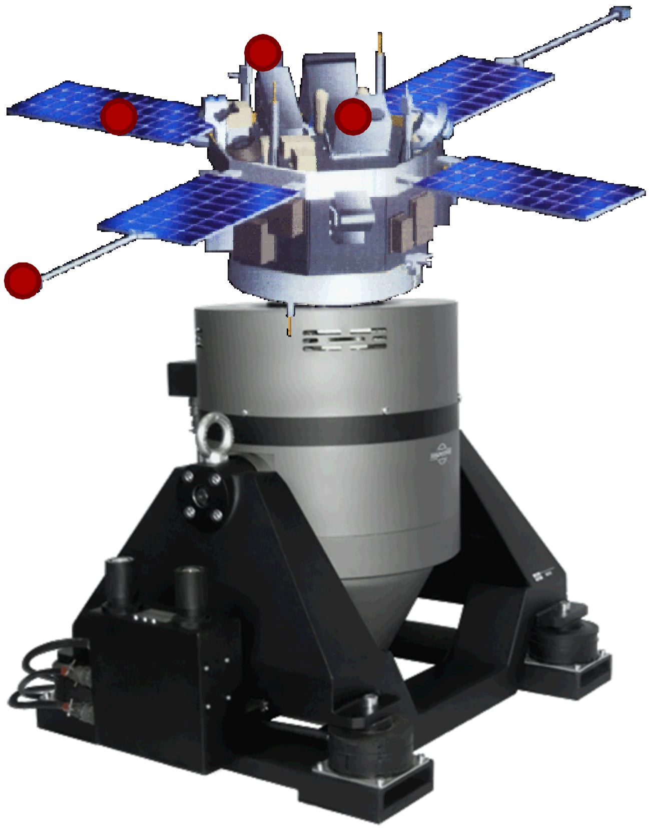
5. Adjust Amplitude of sine tone based on calculated sensitivity and error



If error is within tolerance, go to next frequency

Weightings of Target SRSs

- Error function allows for the weighting of each response error (0,1)
- If one response location (target SRS) is more critical then unequal weightings may be better
- Weightings could be developed further to include
  - Prioritizing the minimization of the largest error rather than minimizing the average error
  - Response limited weighting scheme - Allow the 1 response SRS to be equal or less than the target SRS while the other response SRSs are all less than their targets



Test Case 1: Coupled System

Drive toy problem with experimental input

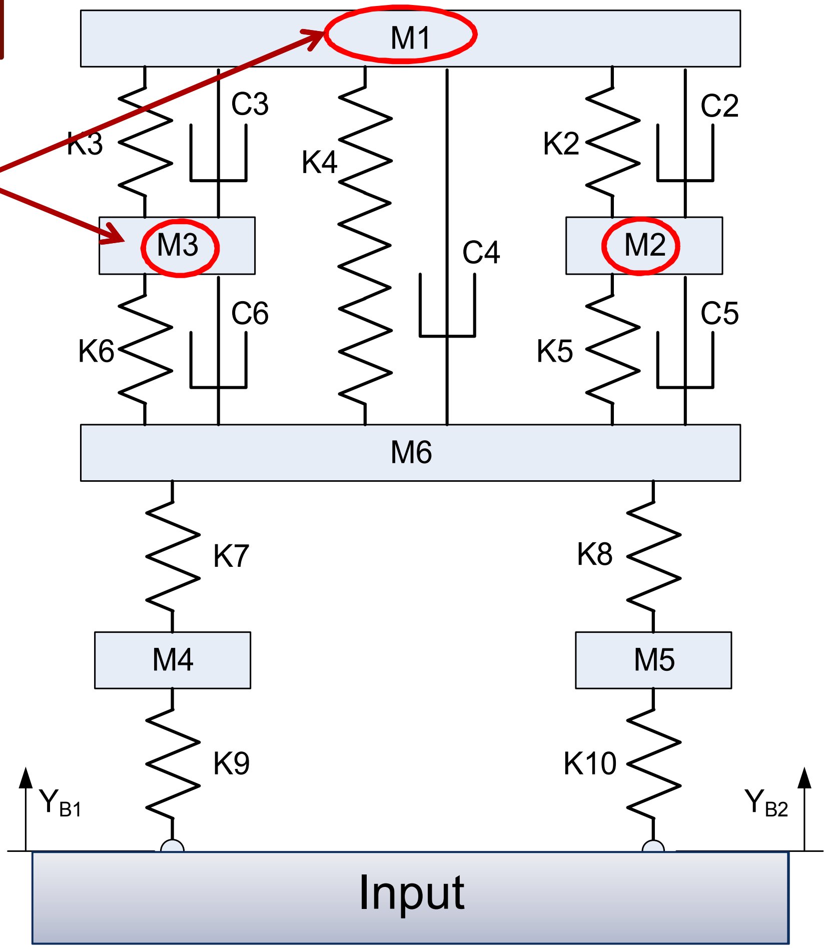
Calculate response at points of interest

Calculate Target SRS

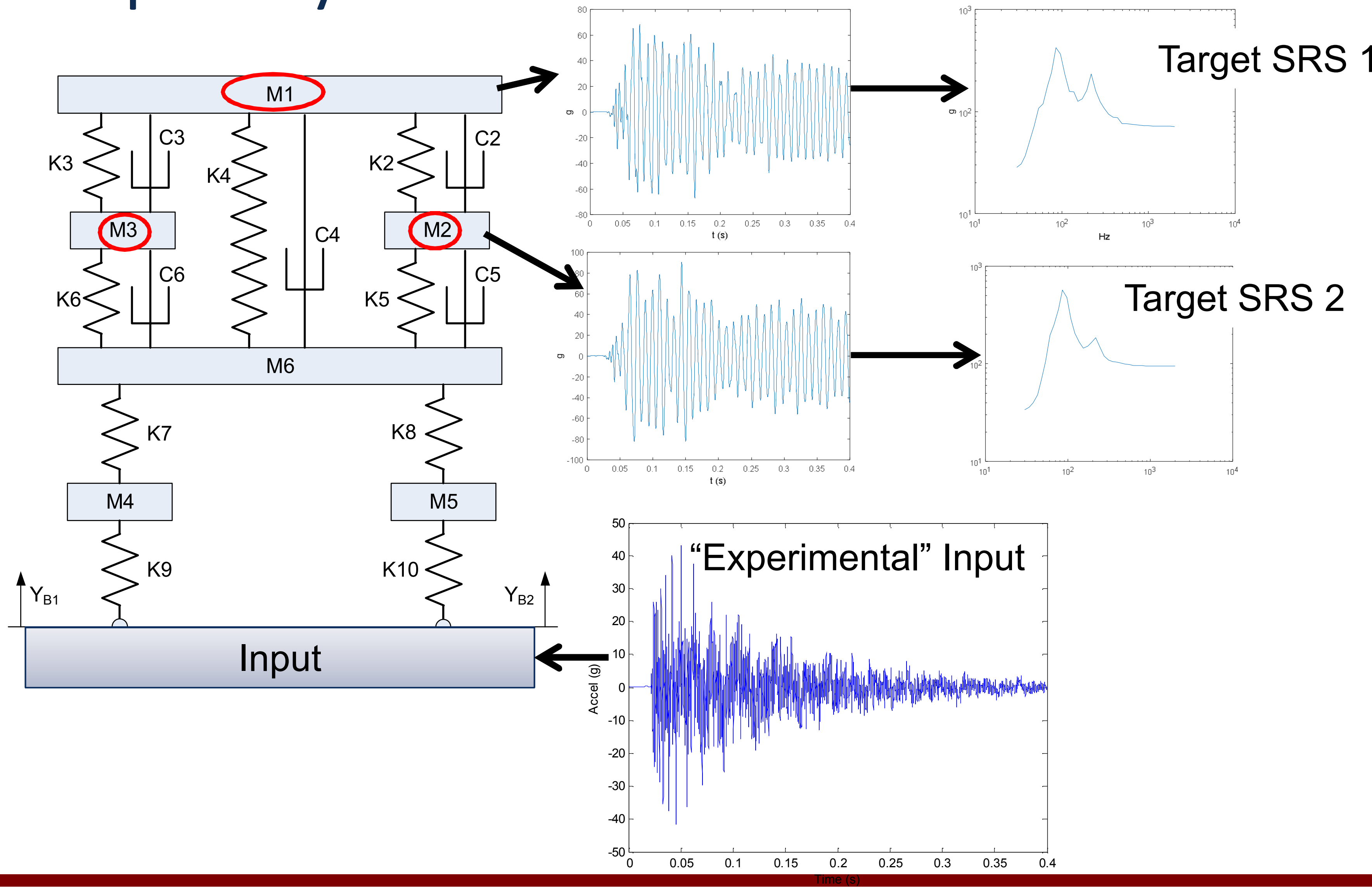
Use SIMO algorithm to compute input and predicted SRSs at points of interest

Do the predicted SRSs match the target SRSs?

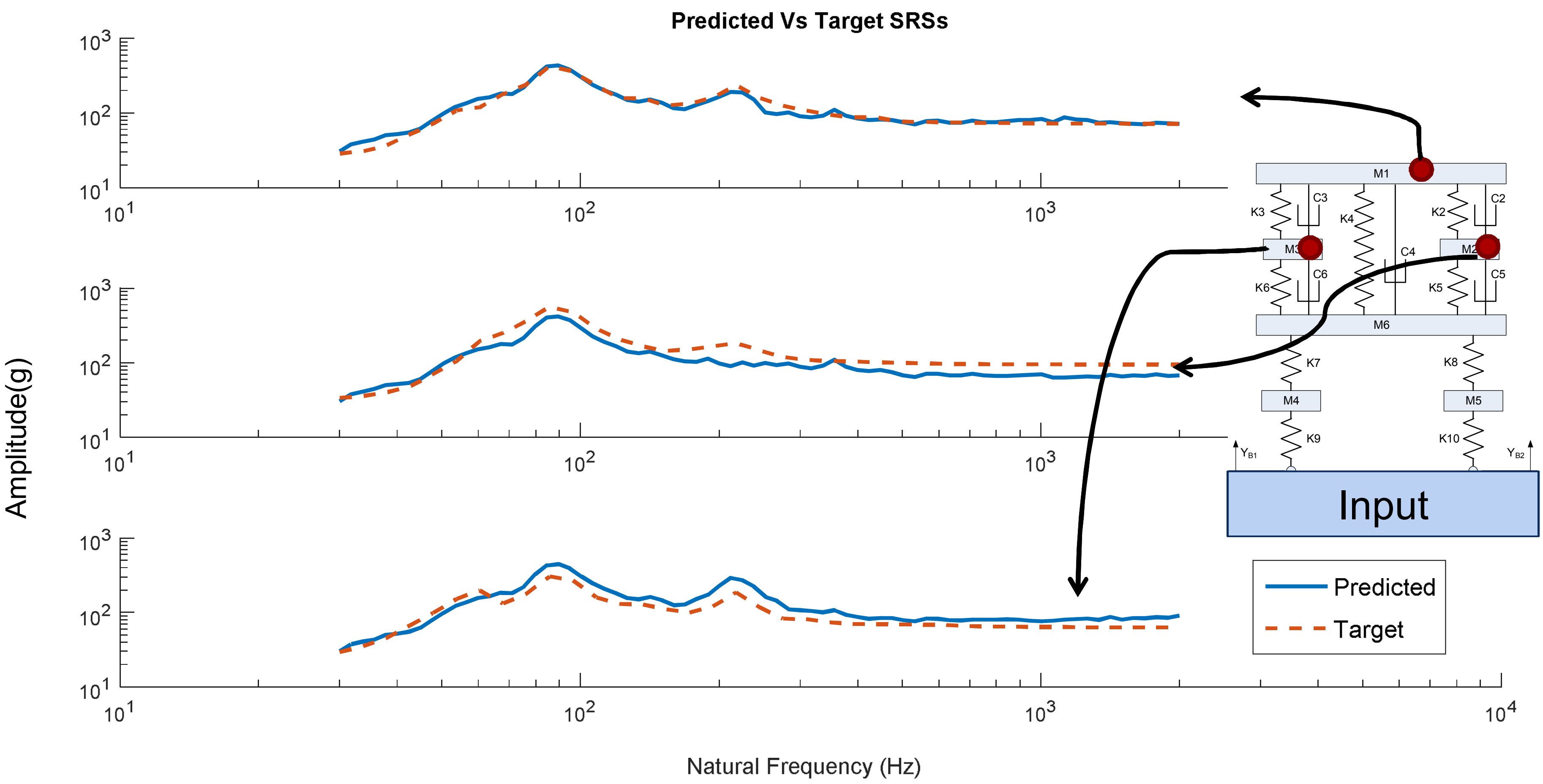
How does the computed input match the experimental input?



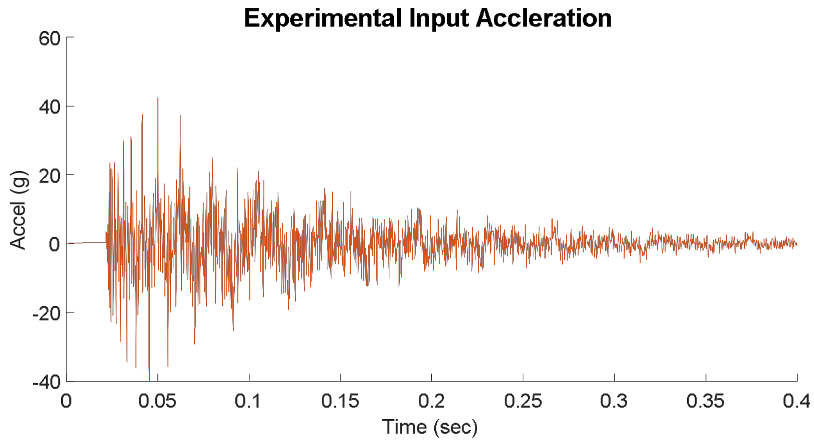
Test Case 1: Field Response for Single Input Coupled System

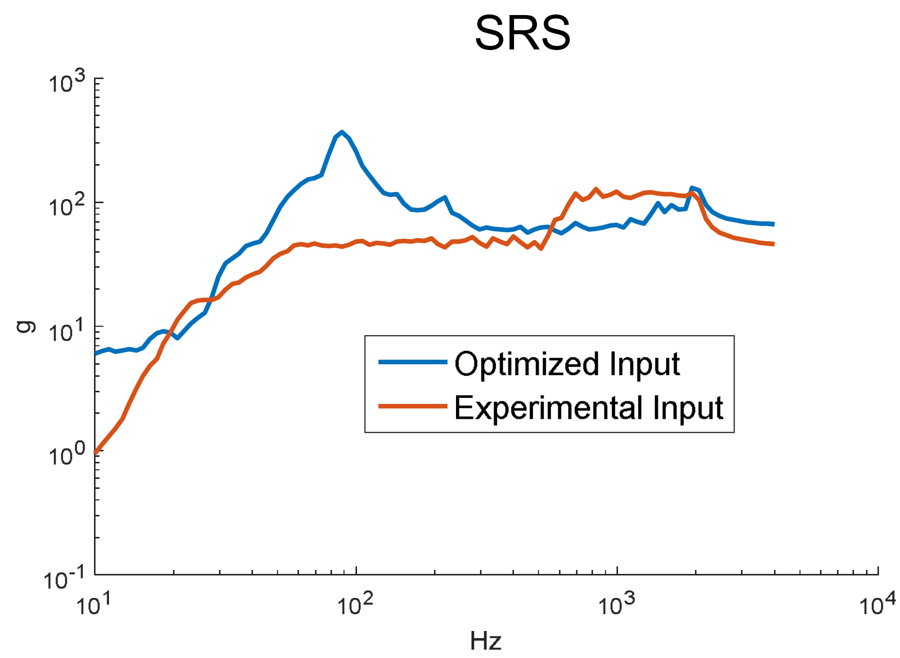


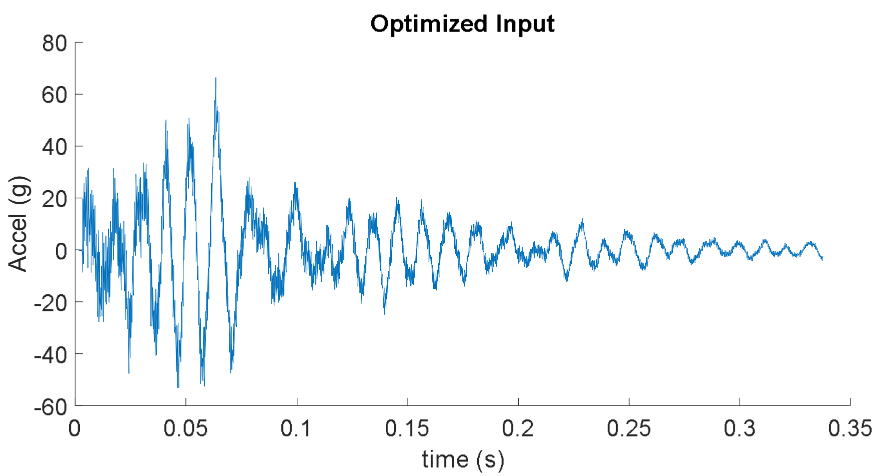
Test Case 1: Predicted vs Target SRS



Test Case 1: Experimental Input vs Optimized Input





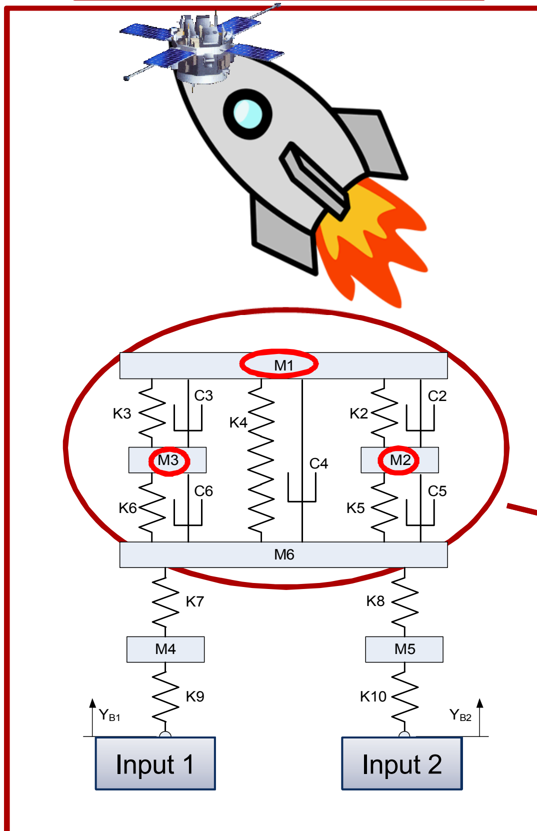


- Significant differences in experimental and optimized input
- Further investigation needed
- Not trying to match inputs
- Significant difference in complexity of each input

Test Case 2: Decoupled Lab Test

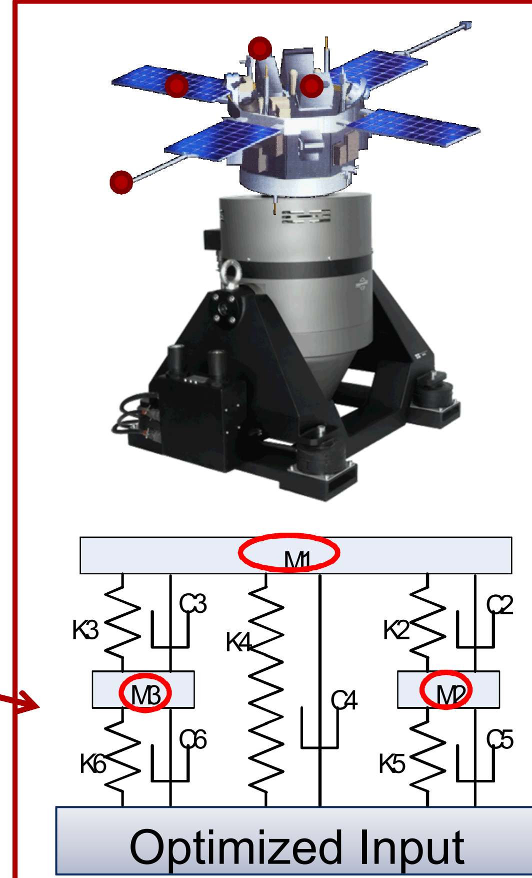
Target SRSs

Field Test

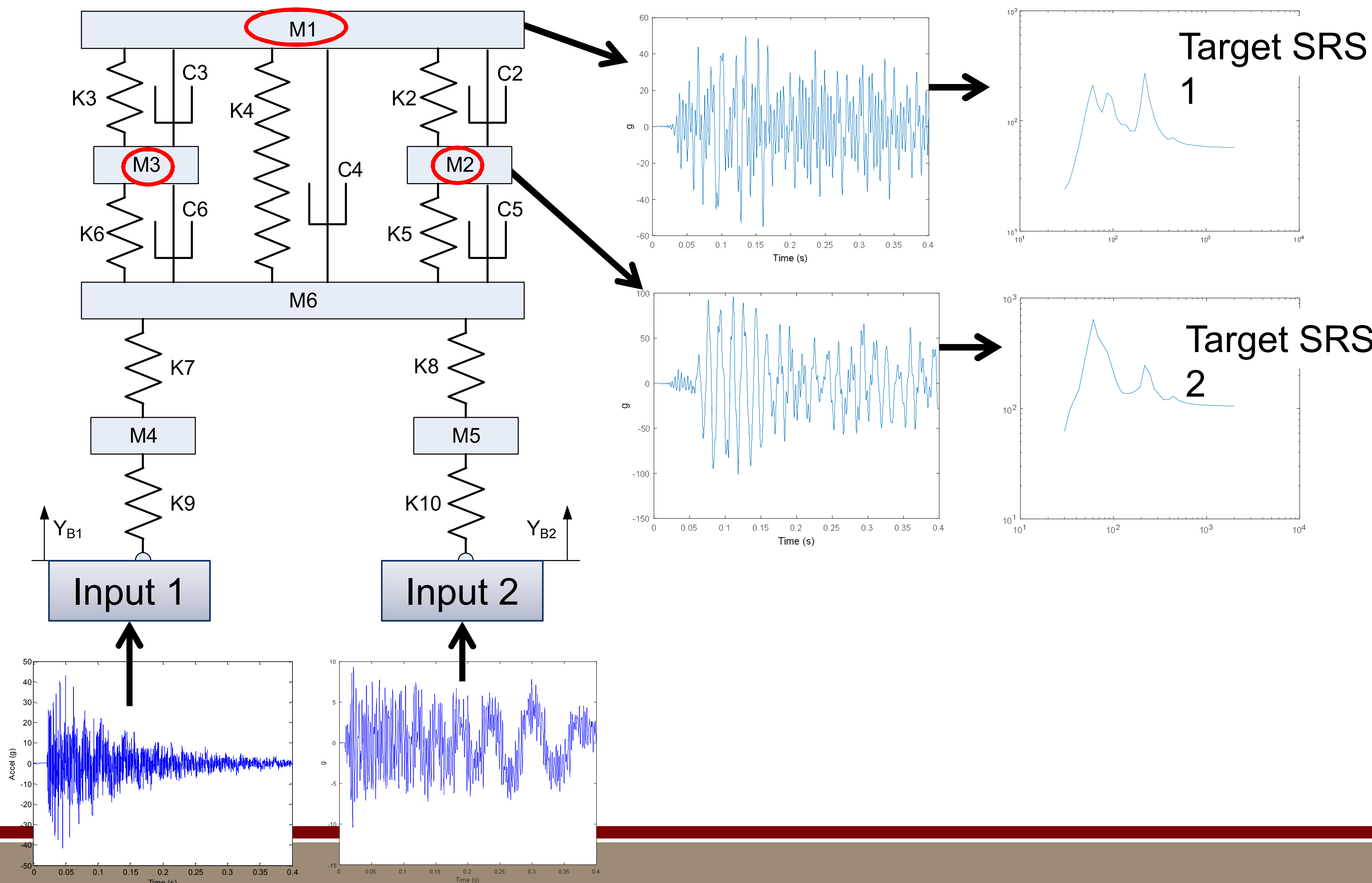


In reality the target SRSs are developed from field data that has different boundary conditions and different inputs

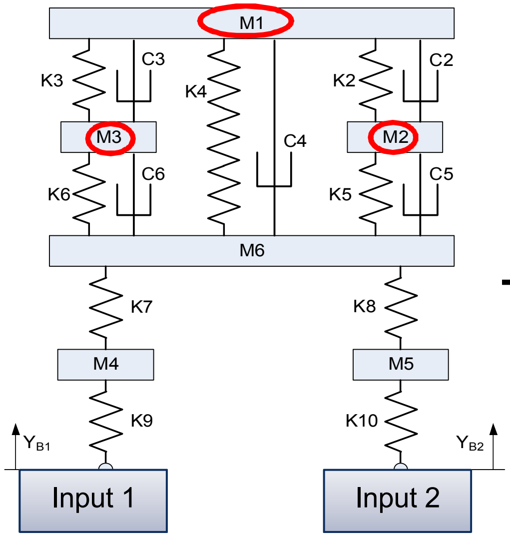
Lab Test



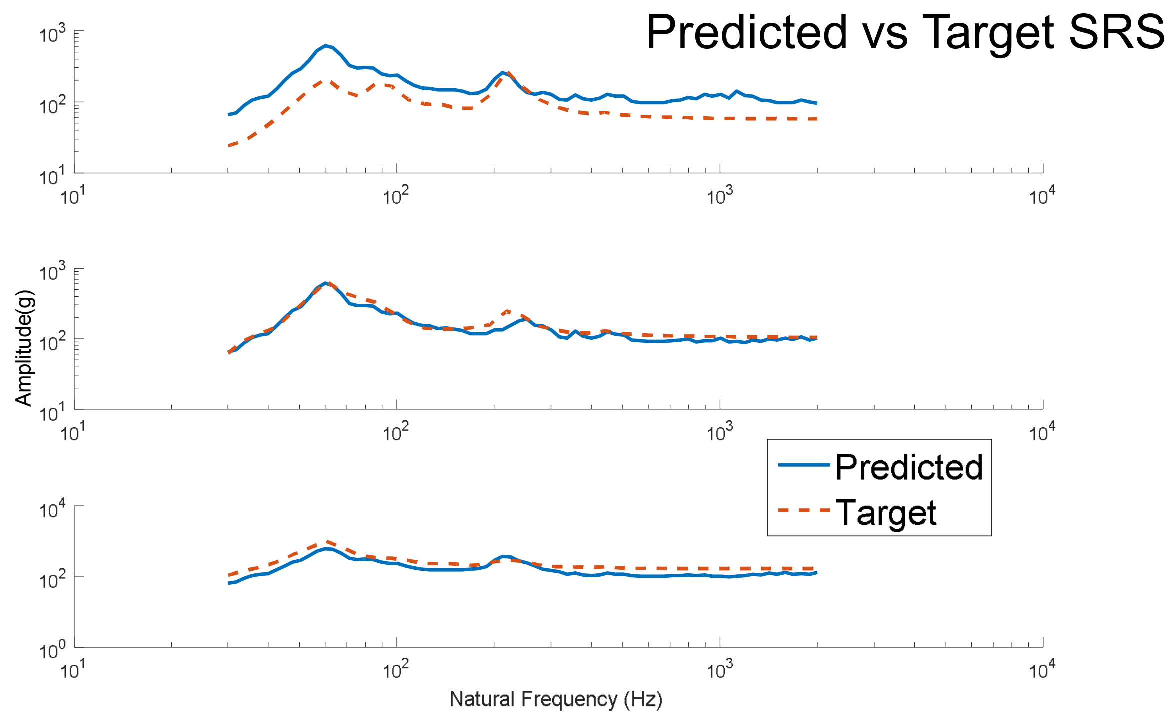
Test Case 2: Field Response for 2 Input Coupled System



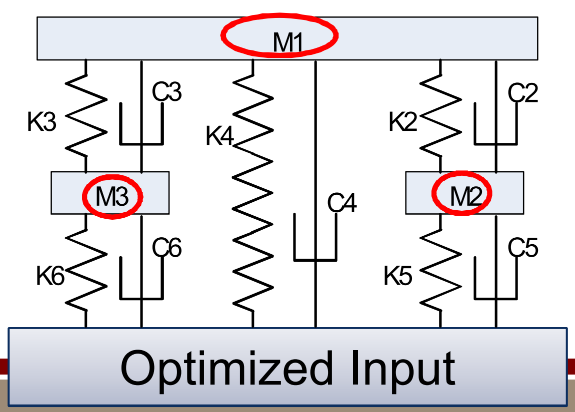
Test Case 2: Optimized Input and Predicted SRSs

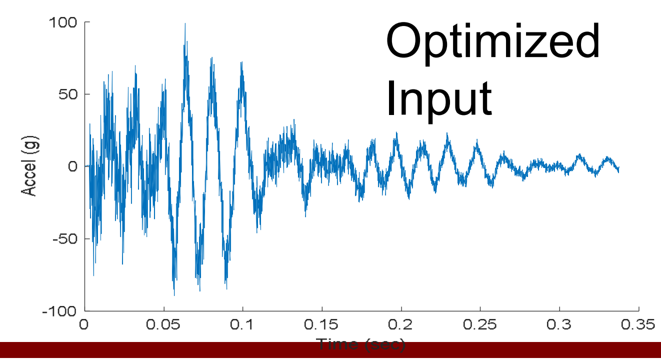


Target SRSs



Predicted SRSs





Summary & Conclusion

Find a decayed sines shaker input that will suitably match the response points of interest to their reference SRSs