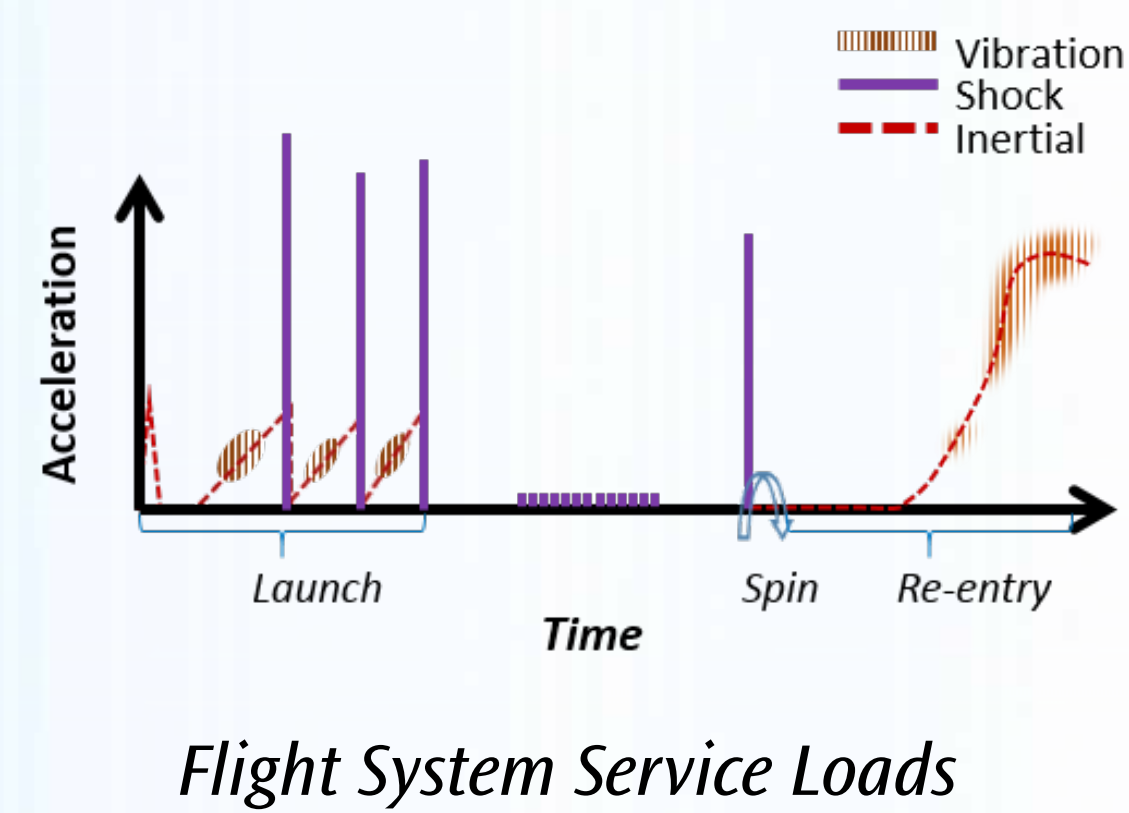
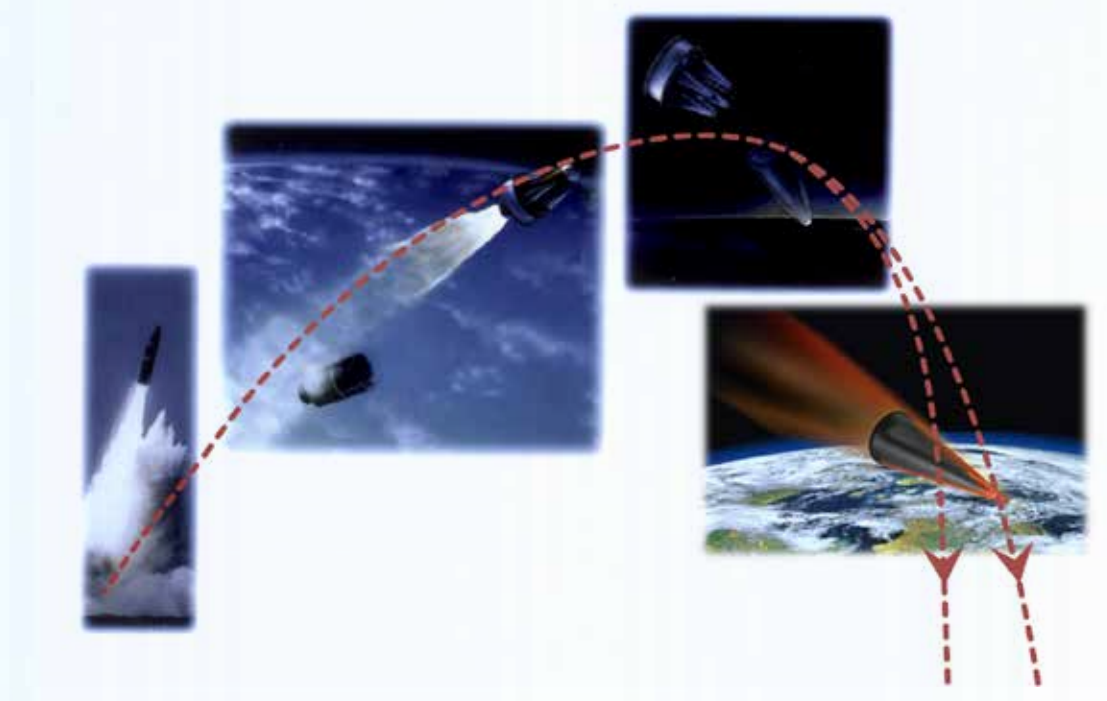


Combined Multi-Axis Vibration & Acoustic Environment Testing

Garrett Nelson, Kevin Cross, and Norman Hunter

Motivation



Multi-axis vibration, acoustic excitation, and combined environments testing can simulate more realistic NW environmental conditions

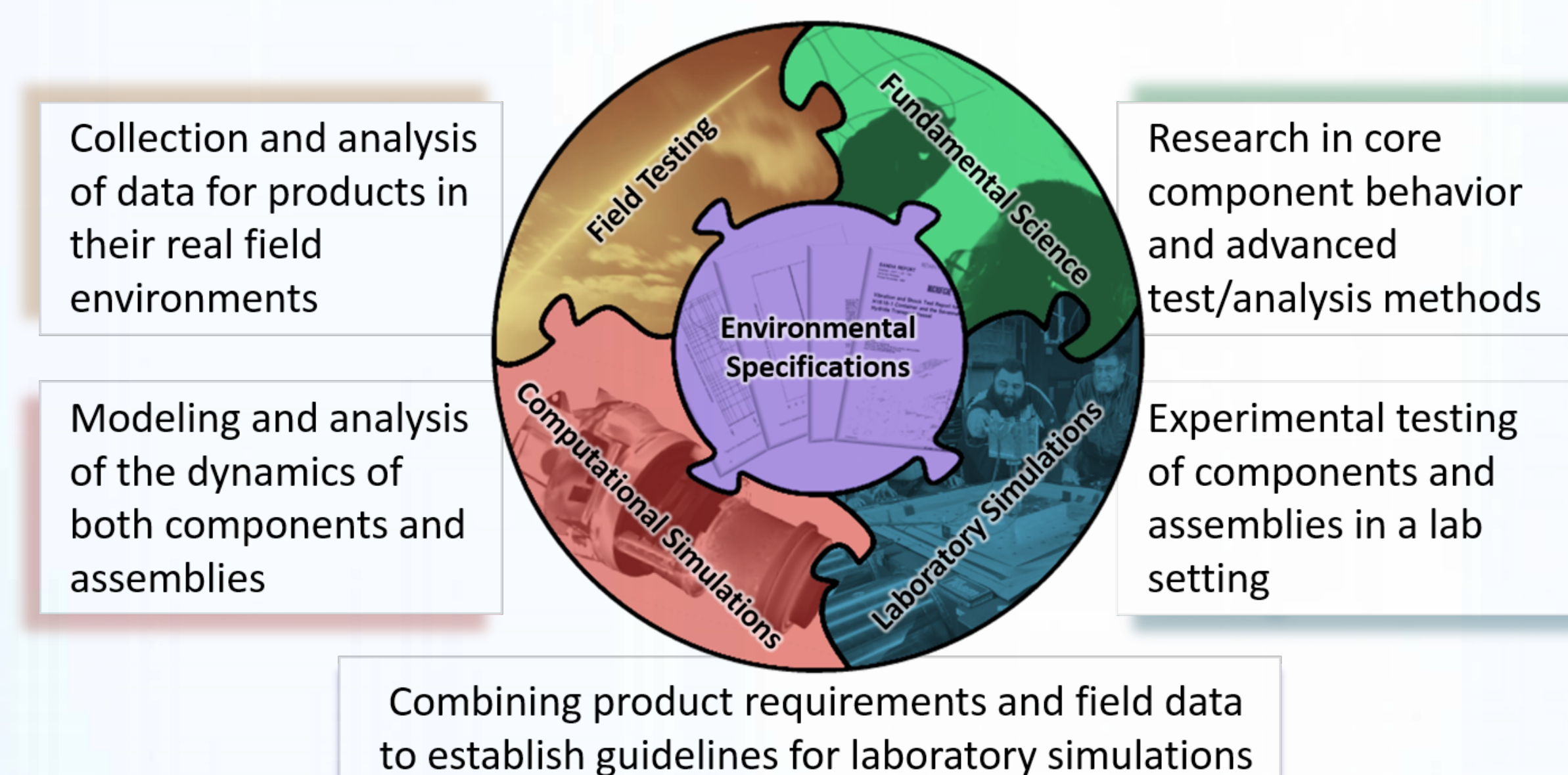
Traditional sequential single axis vibration testing can be time consuming and may not excite components and assemblies with accurate service loads

- Single axis tests can result in different stress states, failure modes, and rates of damage accumulation
- Uniaxial shakers often exhibit uncontrolled, coherent off-axis energy which tends to be ignored although the effects may be significant

Combined test environments provide richer data to improve model fidelity that enables more accurate predictions of dynamic behavior for both current and future NW design alterations

Collaboration

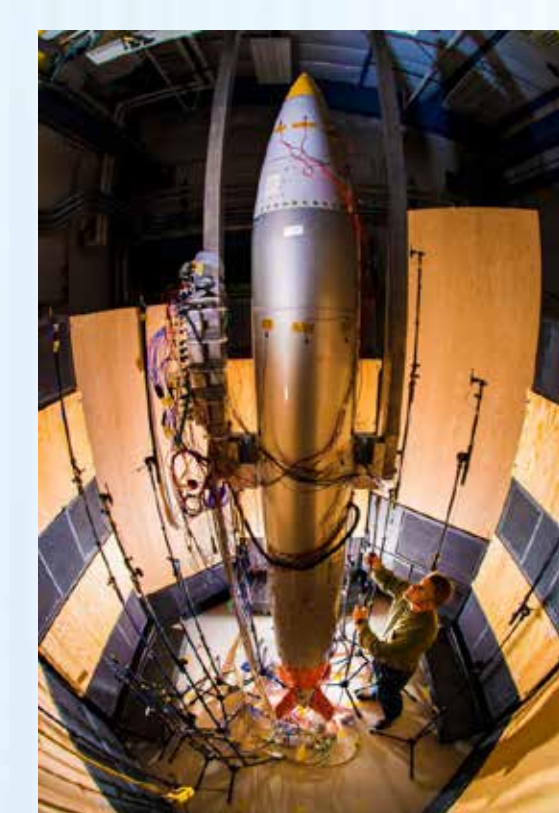
Requires a high level of collaboration between many core Sandia technical areas in both research and development



Experimental Equipment

Multi-Axis Vibration Systems

- Simulate six degree of freedom rigid body vibration through the control of twelve independent shakers
- Applies multi-axis dynamic loads through the base of a test article, e.g., Vibrations propagating from superstructure during flight event



Large Scale
Reverberation Chamber
Acoustic System

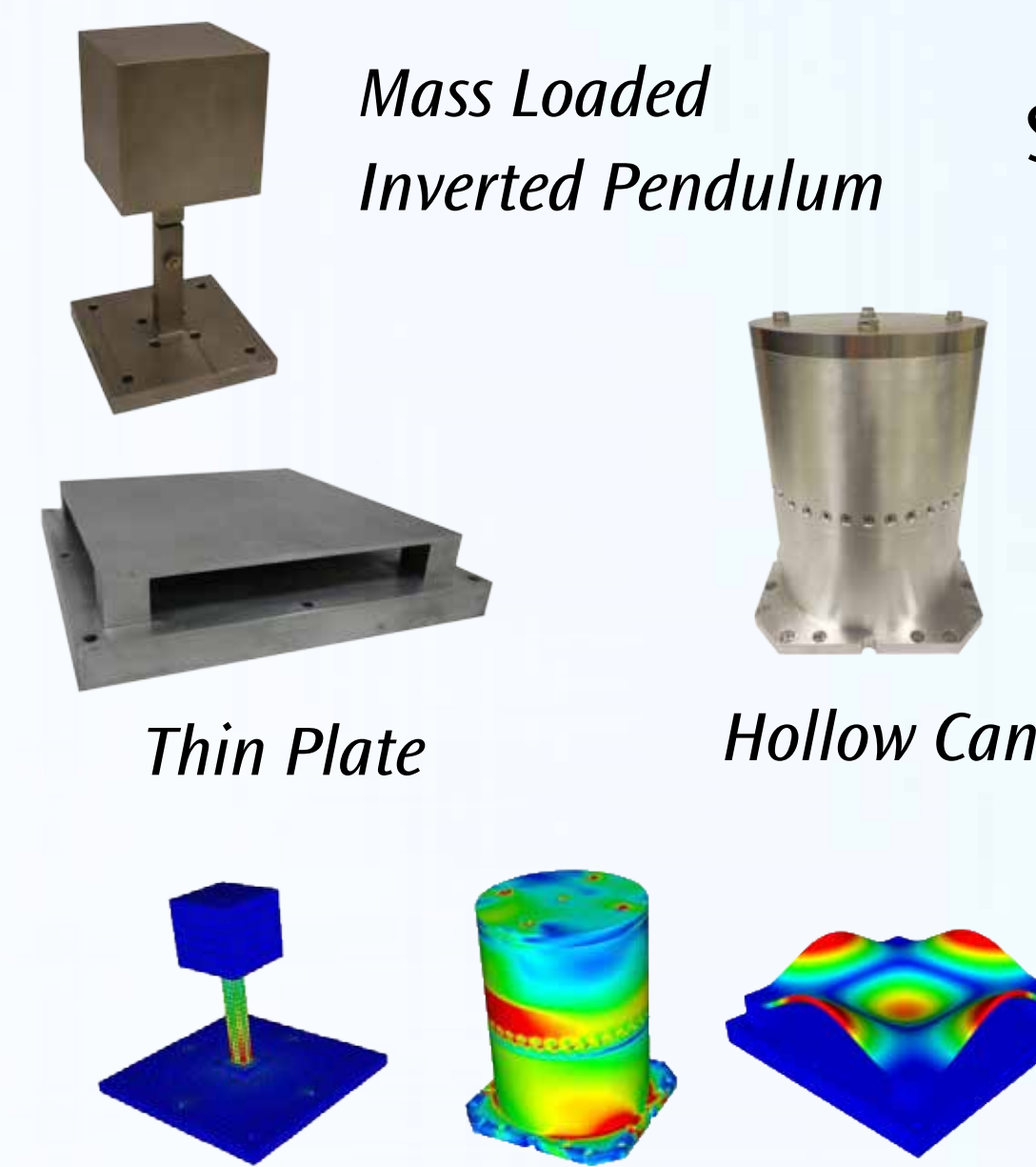


Small Scale
Direct Field
Acoustic System

Acoustic Test Systems

- Simulate broadband vibrations induced by external acoustic or aerodynamic pressures with speaker array in reverberant or quasi-anechoic chamber
- Applies distributed pressure load across outer surface of a test article, e.g., Aeroacoustic load encountered during atmospheric re-entry

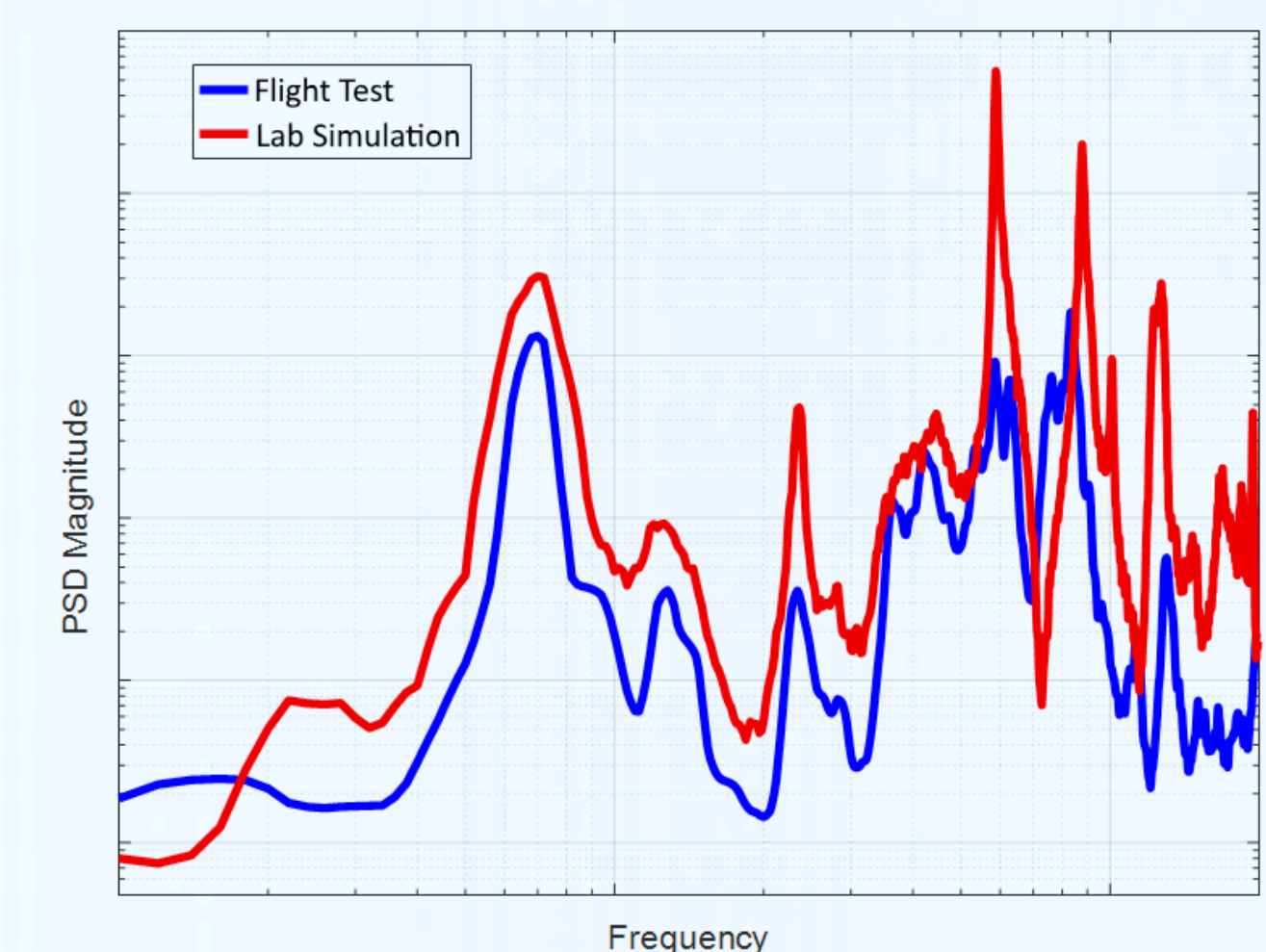
Experimental Results



Finite Element Analysis of Simple Test Articles

Move from simple structures to flight hardware

- Simulate flight data on multi-axis shaker system with input specifications derived with cross-axis interactions



Flight Test Laboratory Simulation Result



Combined Multi-Axis Vibration & Direct Field Acoustic Test System

Combine environments for complex loading

- Add uncorrelated acoustic input to a multi-axis vibration test
- Extended control methods to accommodate multi-domain test configurations

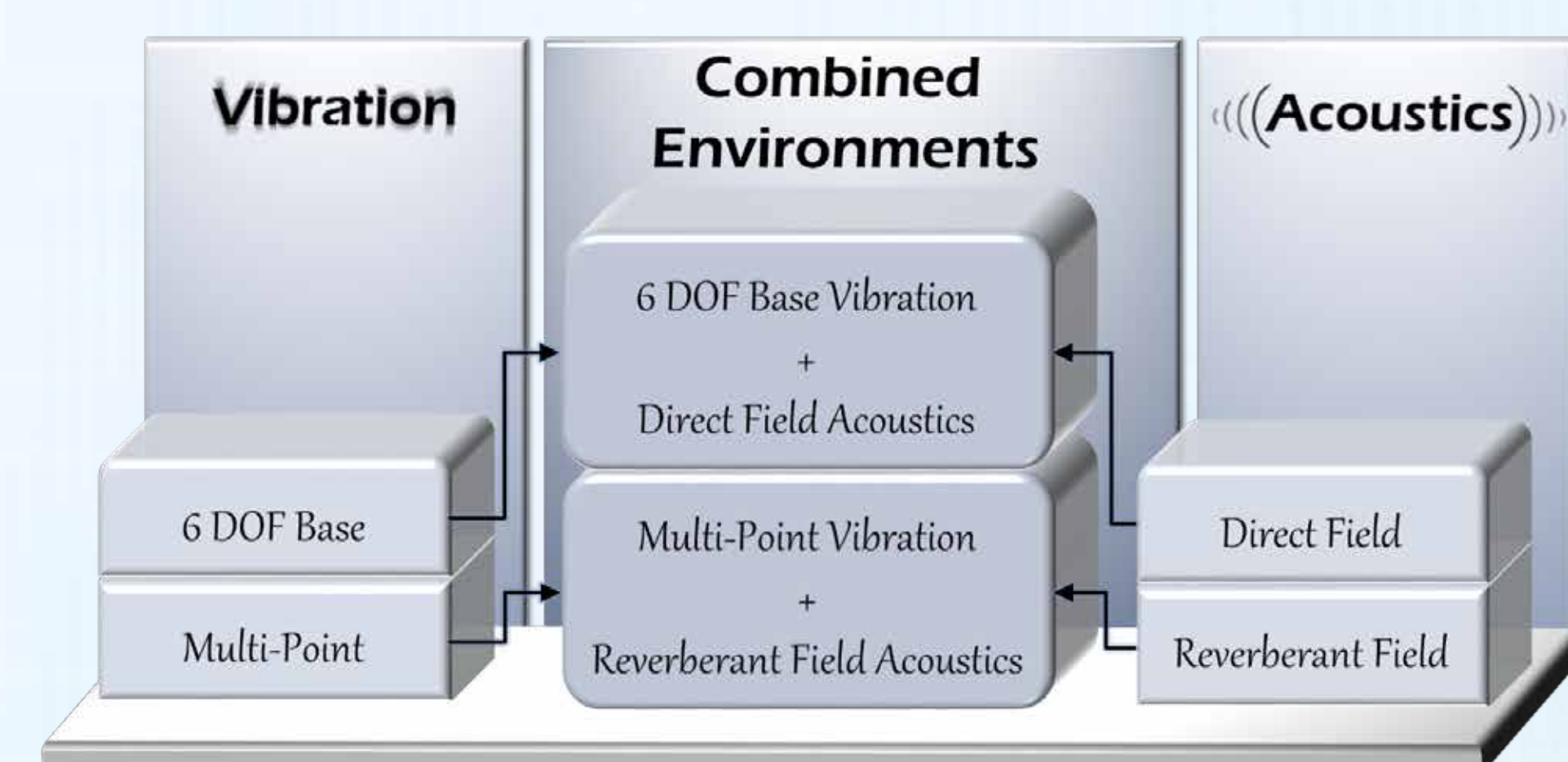
Future Work

Programmatic Advancements

- Develop standard procedures for multi-axis testing and specification derivation and conduct further case studies on flight hardware

Technical Advancements

- Implement vibration control at response locations, and investigate methods for “straight-lining” multi-axis specifications
- Improve direct field acoustic test methods
- Combine multi-point vibration with diffuse field acoustics
- Derive combined input specifications which properly identify input sources



Conclusions

- Combined environments testing simulates more realistic environmental conditions, leads to advancements with existing modeling and testing techniques, and provides tools which enable better designs in the future
- New test methods and research in combined environments lead to improved understanding and progress of Sandia's core test capabilities

Publications

- [1] L. Jacobs, M. Ross, G. Tipton, K. Cross, N. Hunter, J. Harvie, and G. Nelson, "Experimental execution of 6DOF tests derived from field tests," in Proc. 35th Int. Modal Anal. Conf., Garden Grove, CA, Jan. 2017.
- [2] L. Jacobs, M. Ross, G. Tipton, G. Nelson, K. Cross, N. Hunter, and J. Harvie, "6-DOF shaker test input derivation from field test," in Proc. 35th Int. Modal Anal. Conf., Garden Grove, CA, Jan. 2017.
- [3] E. Siasounas, M. Byrner, and G. Nelson, "Predicting flight environments with a small-scale, direct-field acoustic test facility," in Proc. 35th Int. Modal Anal. Conf., Garden Grove, CA, Jan. 2017.
- [4] G. Nelson, K. Cross, and N. Hunter, "Defining the error of single and multi-axis vibration tests: A move from qualitative to quantitative metrics," in Proc. 67th Shock and Vibration Symp., New Orleans, LA, Oct. 2016.
- [5] L. Jacobs, G. Nelson, and J. Harvie, "A comparison of digital image correlation, laser Doppler vibrometry, and accelerometers for long duration vibration testing," in Proc. 34th Int. Modal Anal. Conf., Orlando, FL, Jan. 2016.
- [6] G. Nelson and L. Jacobs, "Responses of structures to single degree of freedom vs multi-degree of freedom vibration testing," in Proc. 34th Int. Modal Anal. Conf., Orlando, FL, Jan. 2016.
- [7] G. Nelson and L. Jacobs, "Comparison of multi-axis and single axis testing on plate structures," in Proc. 85th Shock and Vibration Symp., Reston, VA, Oct. 2014.