

Active Suppression of Drilling System Vibrations For Deep Drilling

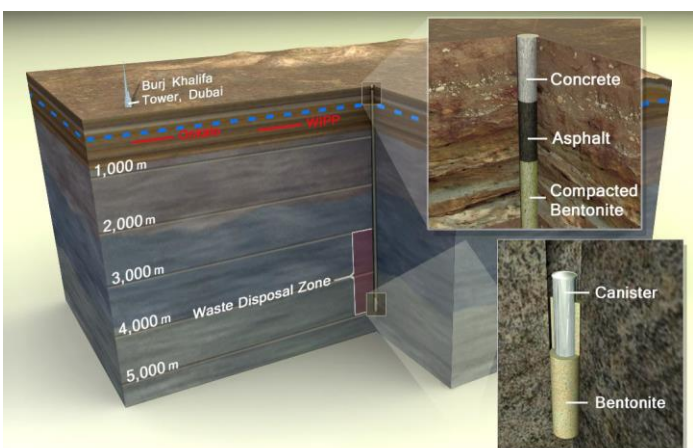
LDRD Project # 165620

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Background & Problem Statement

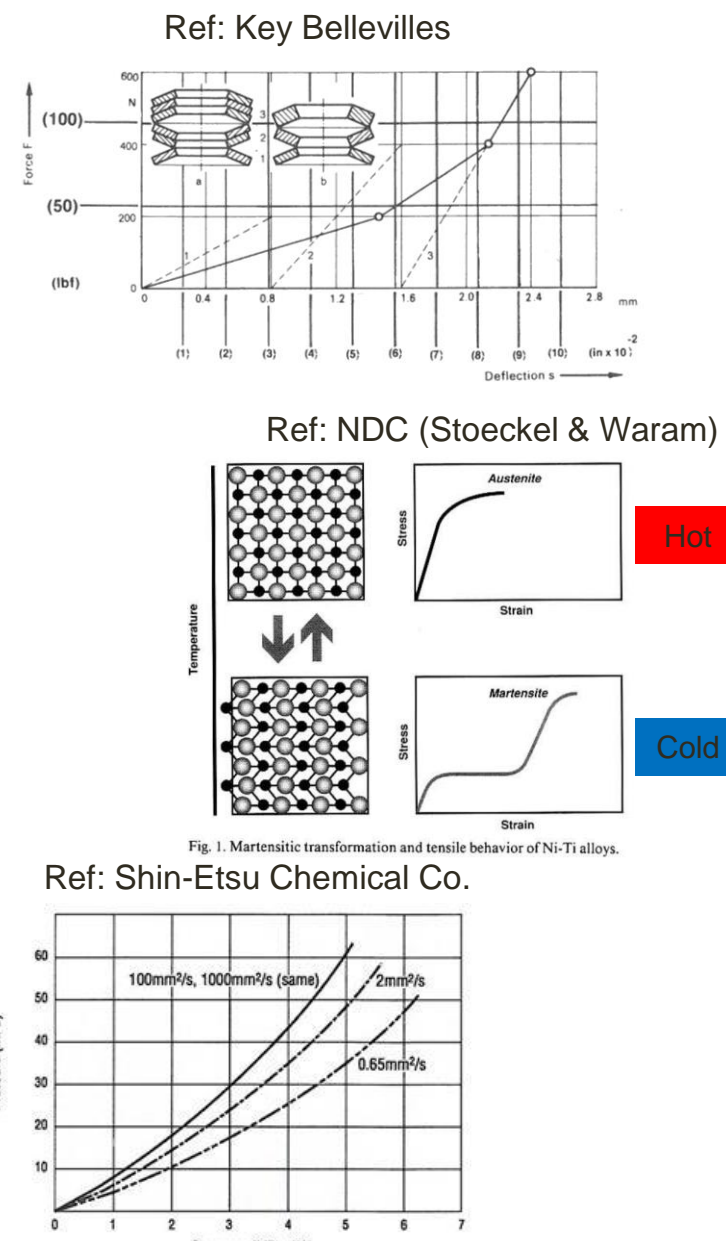
- A high-reliability drilling system is needed for construction of a deep borehole disposal system to depths of 5 km in continental crystalline basement rock
- A reference design has been developed that demonstrates viability of the engineered system (SAND2011-6749, Arnold et al)
- Vibrations of the drill string are of vital concern in deep holes as they increase the technical risks and final costs of well construction
 - trouble (non-productive time)
 - damaged components
 - reduced ROP (rate of penetration)
 - decreased bit and tool life



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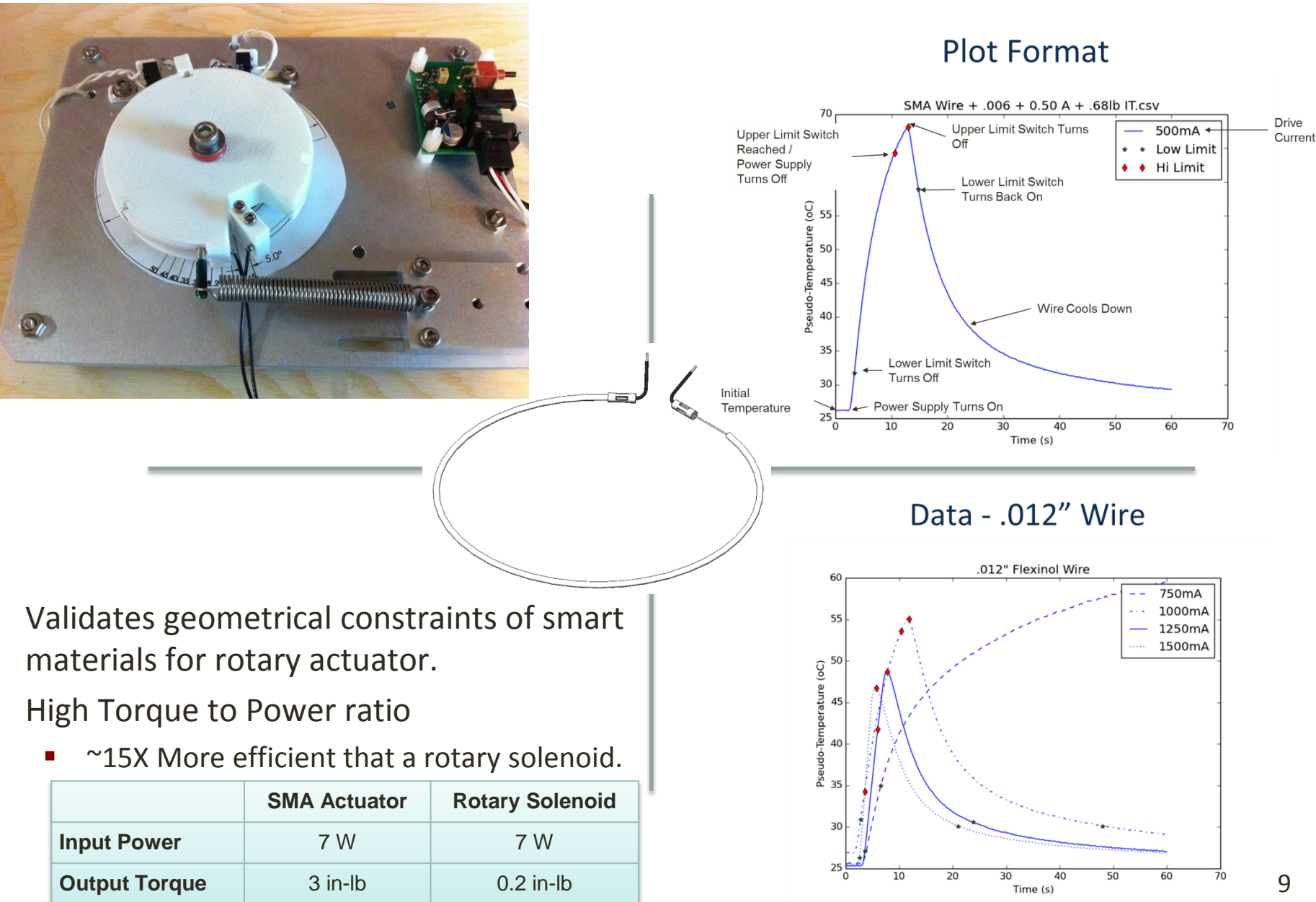
Controllable Element Technologies

- Variable Rate Springs
 - Solid State Belleville stack
 - Modular activation approach with drillstring form and function
 - Stacks can be selectively engineered for preferred response
 - Shape Memory Alloys (SMA)
 - Sandia internal and external industry contacts established
 - Viability for drilling application addressed
 - Liquid Springs
 - Contracted with Taylor Devices
 - Design study for application suitability completed
- Downselect for VRS Concept
 - Belleville Spring Stack
 - Shape Memory Alloy (SMA) Actuators
 - Downhole Sensors, DAQ & Controller



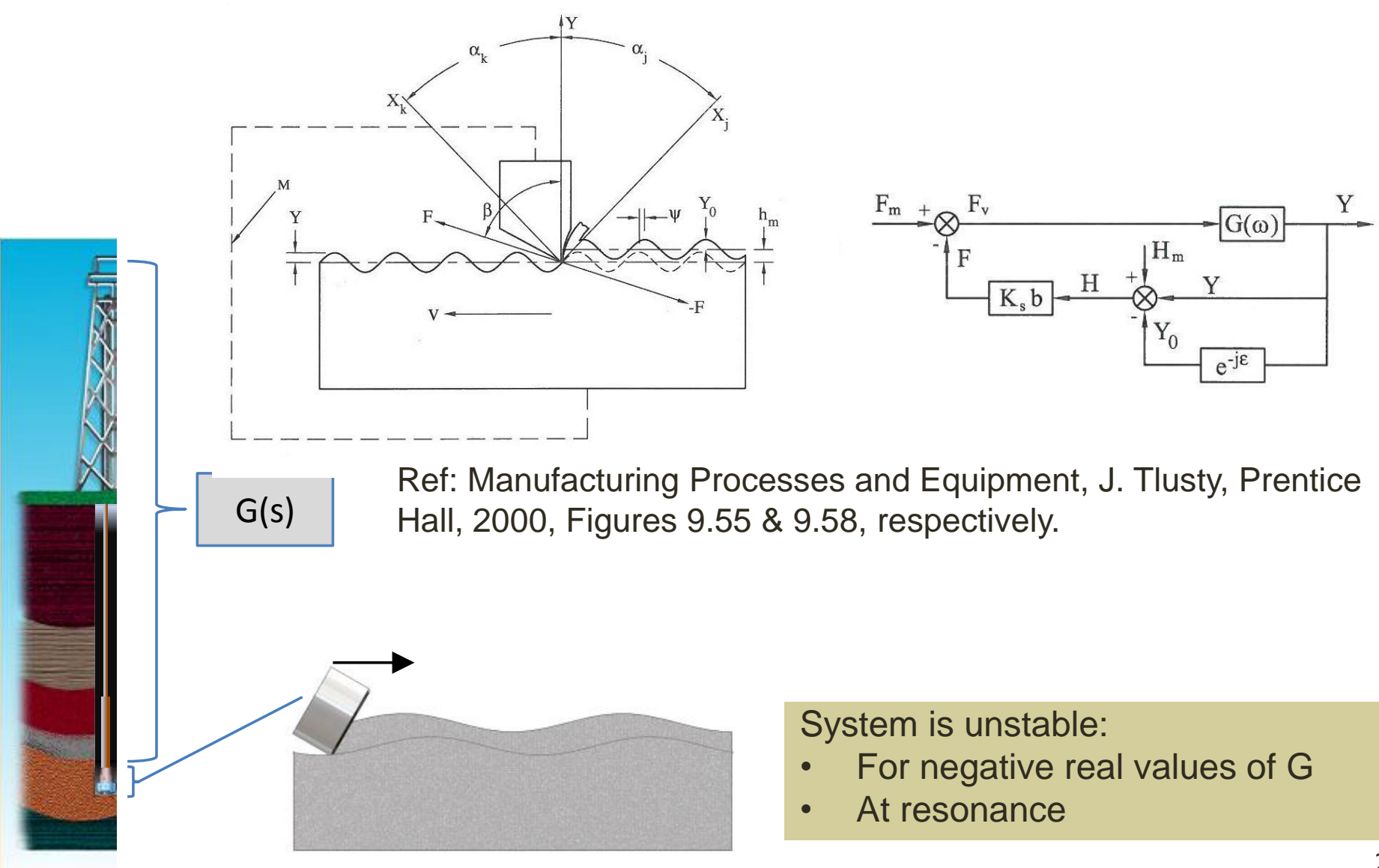
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Shape Memory Alloy (SMA) Test Bed



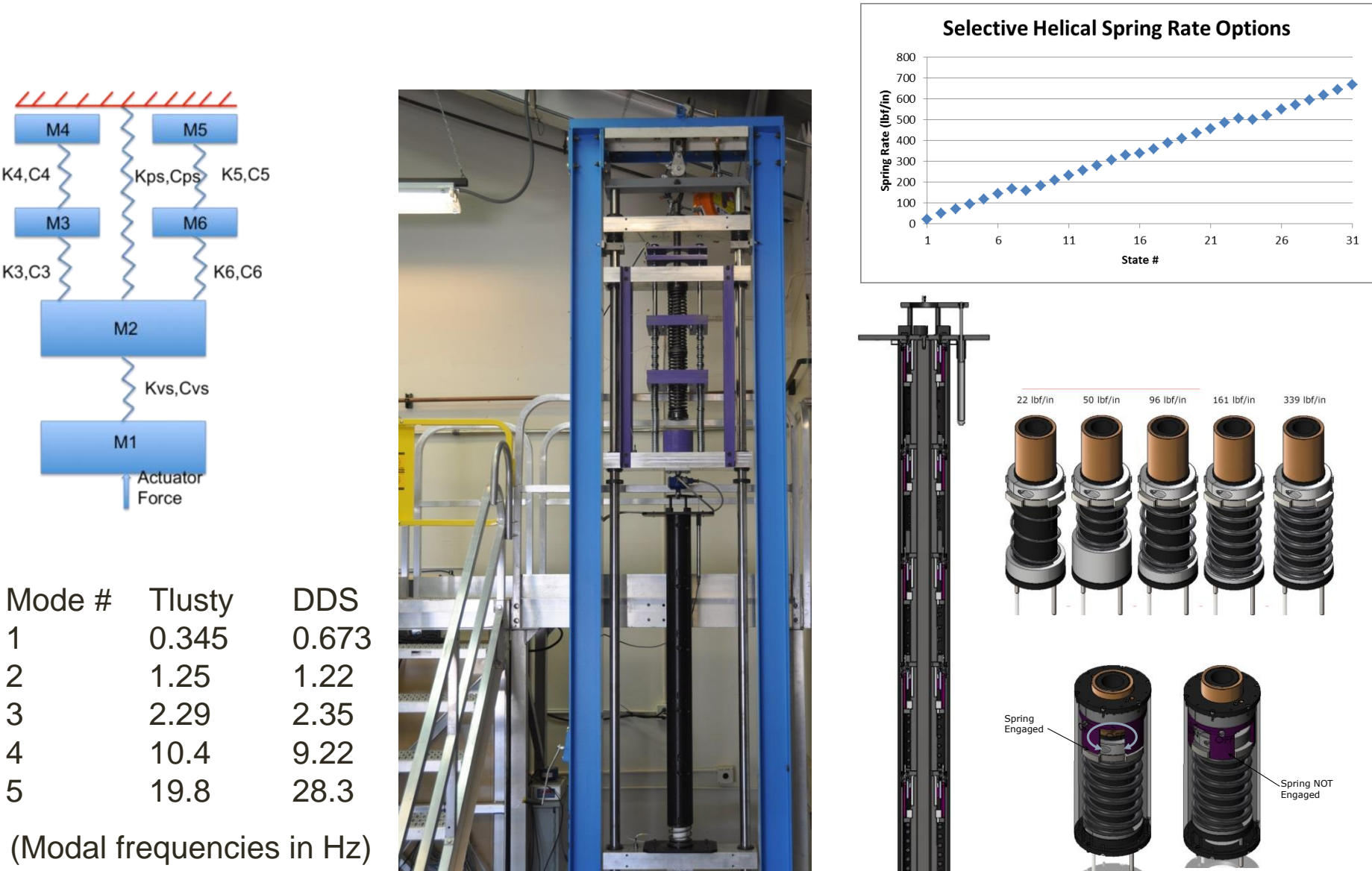
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Drillstring Vibration Problem



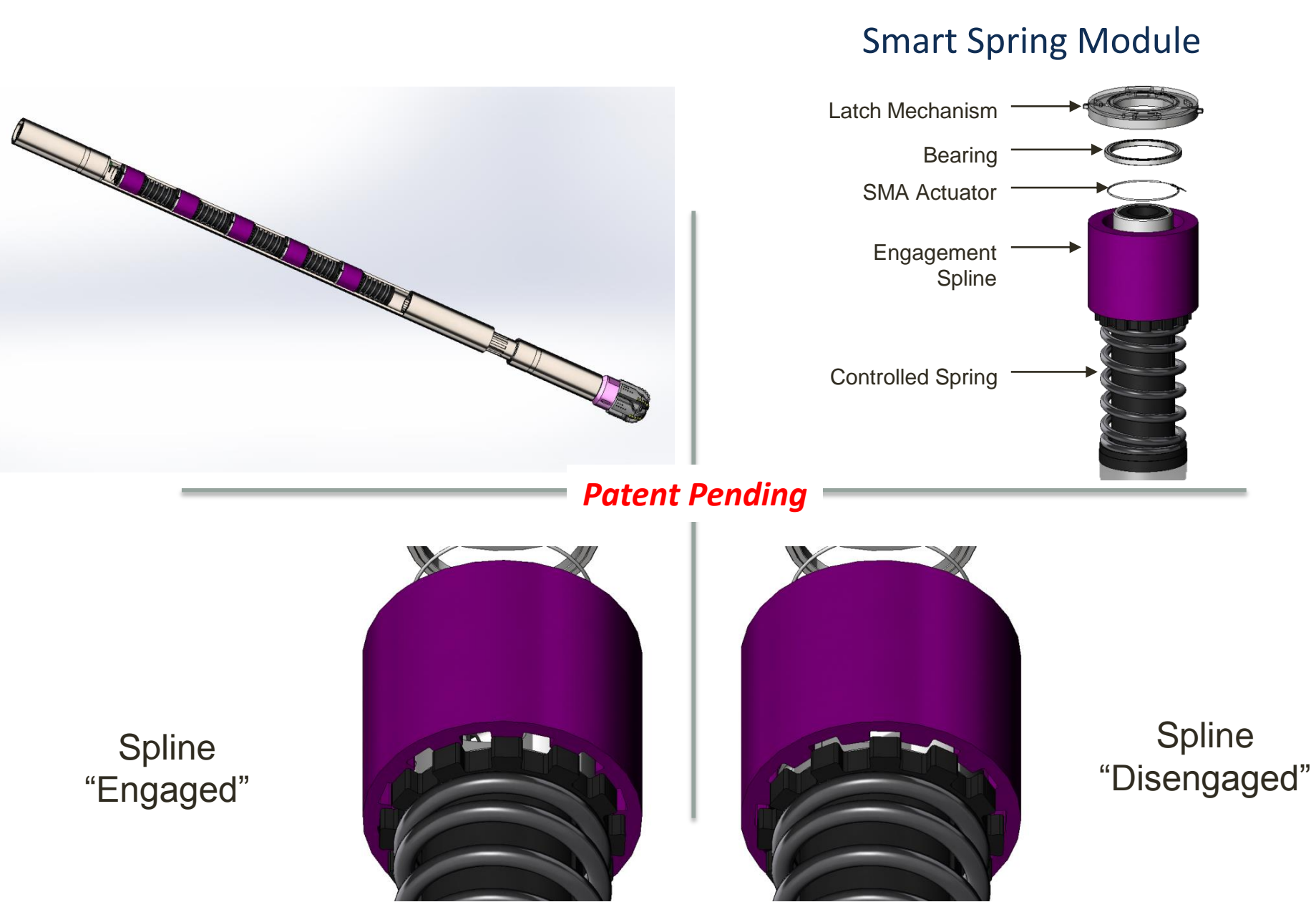
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Hardware Developments and Demonstrations



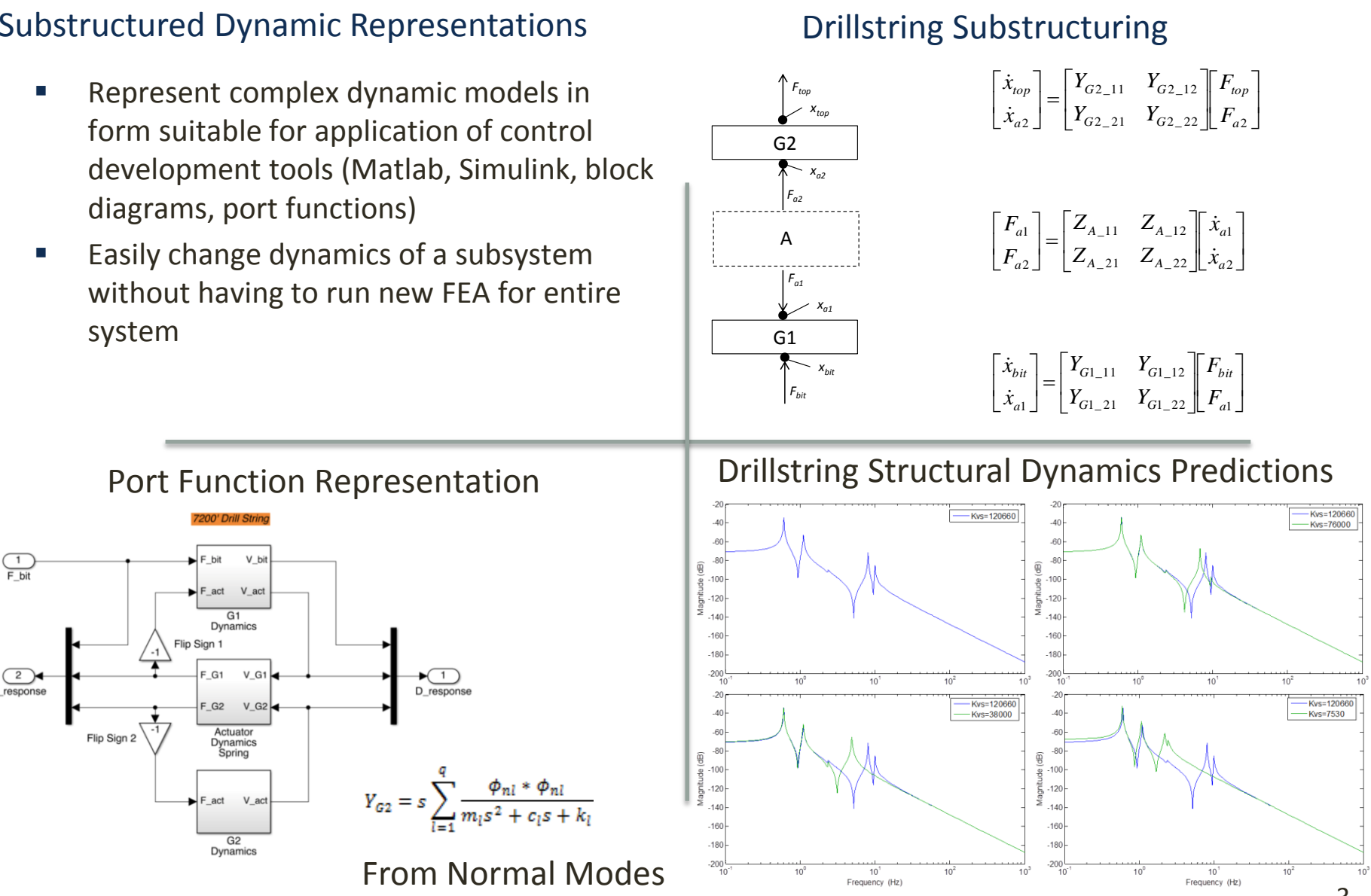
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Prototype Tool Concept with Smart Material Actuator



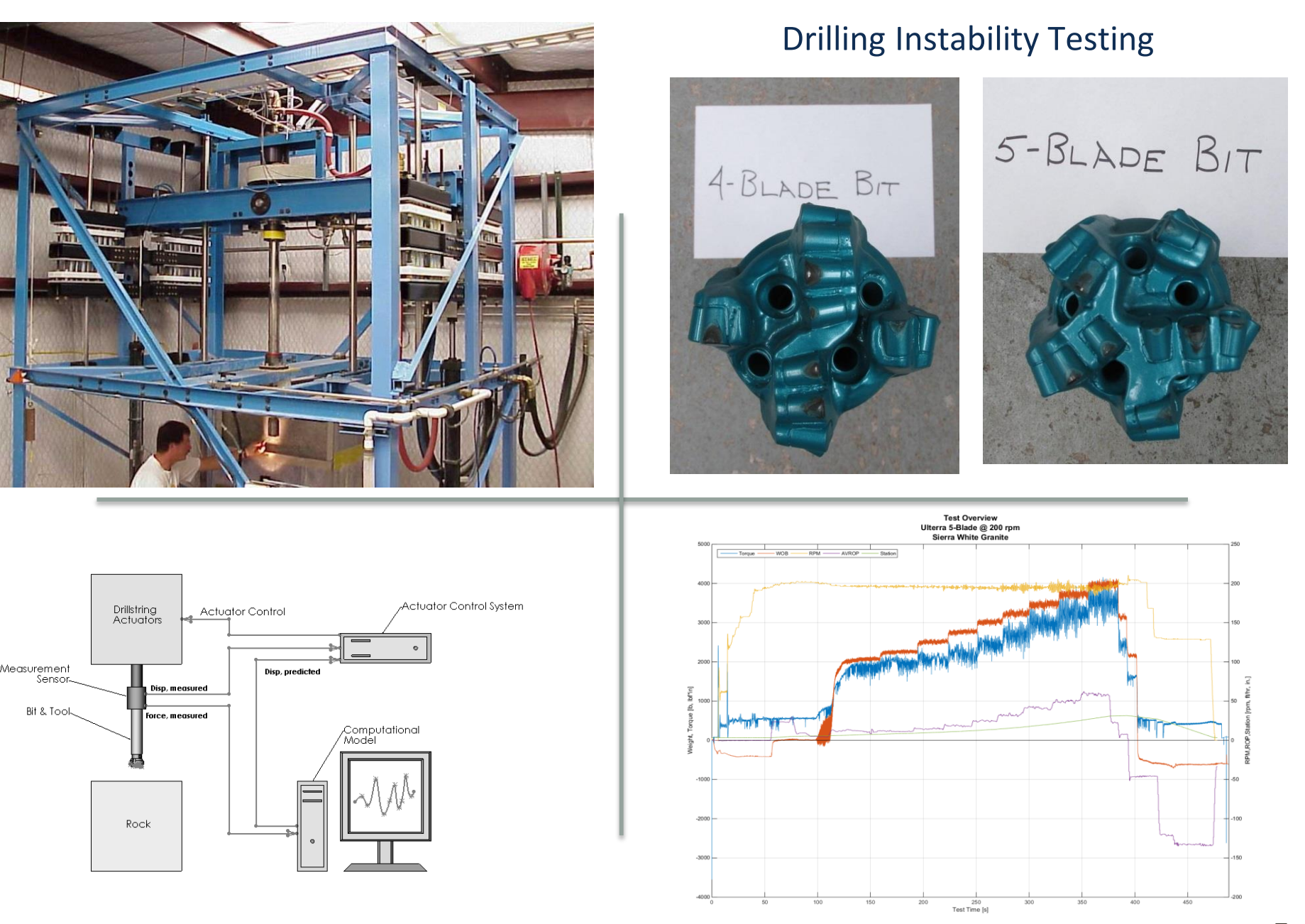
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Drillstring Modeling



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Laboratory Drilling Simulations



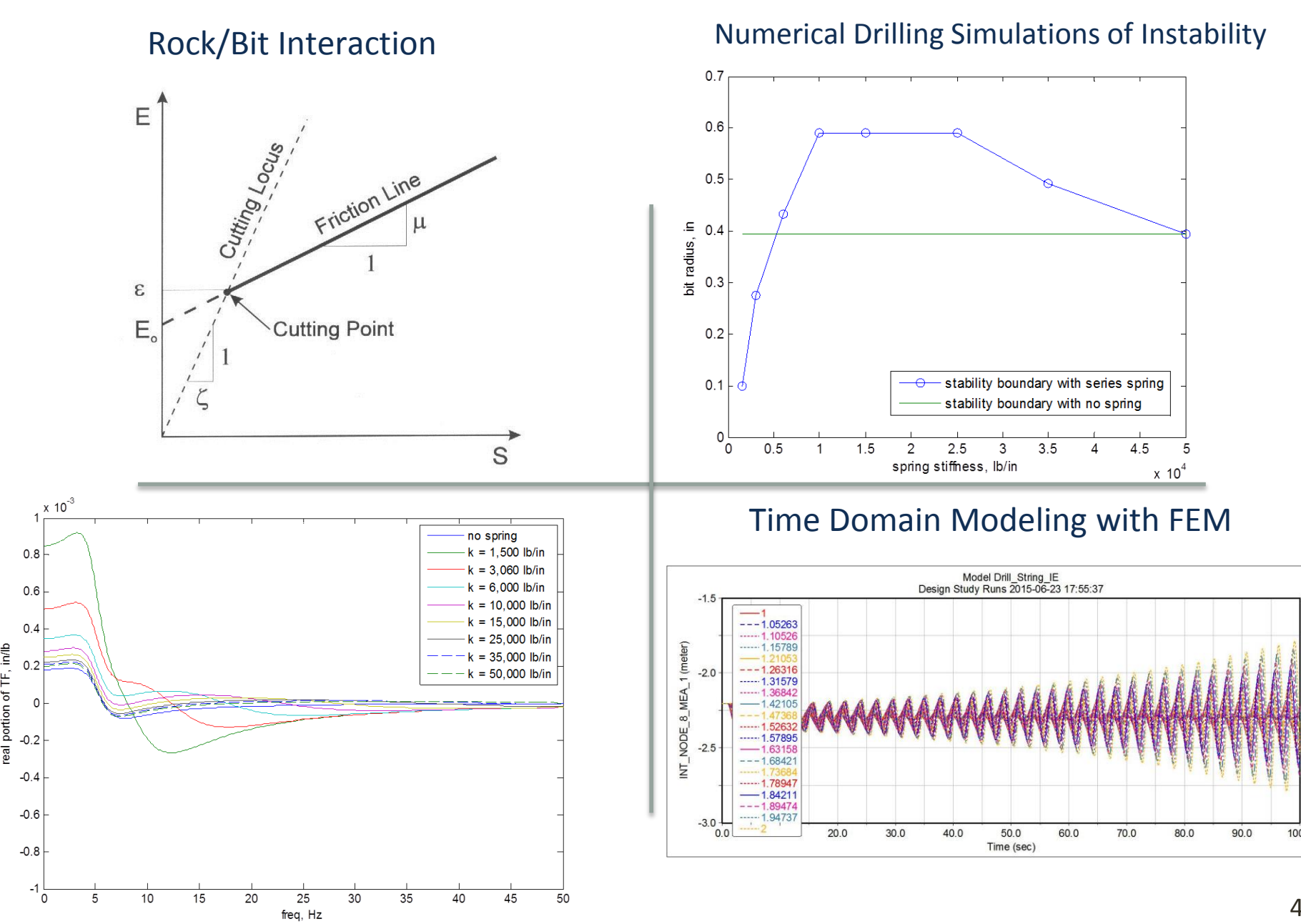
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Publications and Intellectual Property

- Publications**
 - SAND Report – Active Suppression of Drilling System Vibrations for Deep Drilling
 - DYNAMIC SUBSTRUCTURING OF DRILLSTRING COMPUTATIONAL MODELS FOR EXPLORATION OF ACTUATOR ALTERNATIVES, David Raymond, Mikhail Mesh & Steve Buerger, Third International Colloquium on Nonlinear Dynamics and Control of Deep Drilling Systems, University of Minnesota, Minneapolis, May 29-30, 2014.
- Intellectual Property**
 - Technical Advances Filed:
 - 12849 Active Cancellation of Drill String Vibrations Using Inertial Exciters
 - 12869 Solid State Spring Using Shape Memory Alloys (SMA)
 - 12870 Variable Rate Mechanical Spring for Suppression of Drilling Vibrations
 - 12871 Variable Rate Liquid Spring for Suppression of Drilling Vibrations
 - Patent Application Filed and Pending:
 - U.S. Patent Application No. 62219481, entitled "DRILLING SYSTEM VIBRATION SUPPRESSION SYSTEMS AND METHODS," filed September 16, 2015.

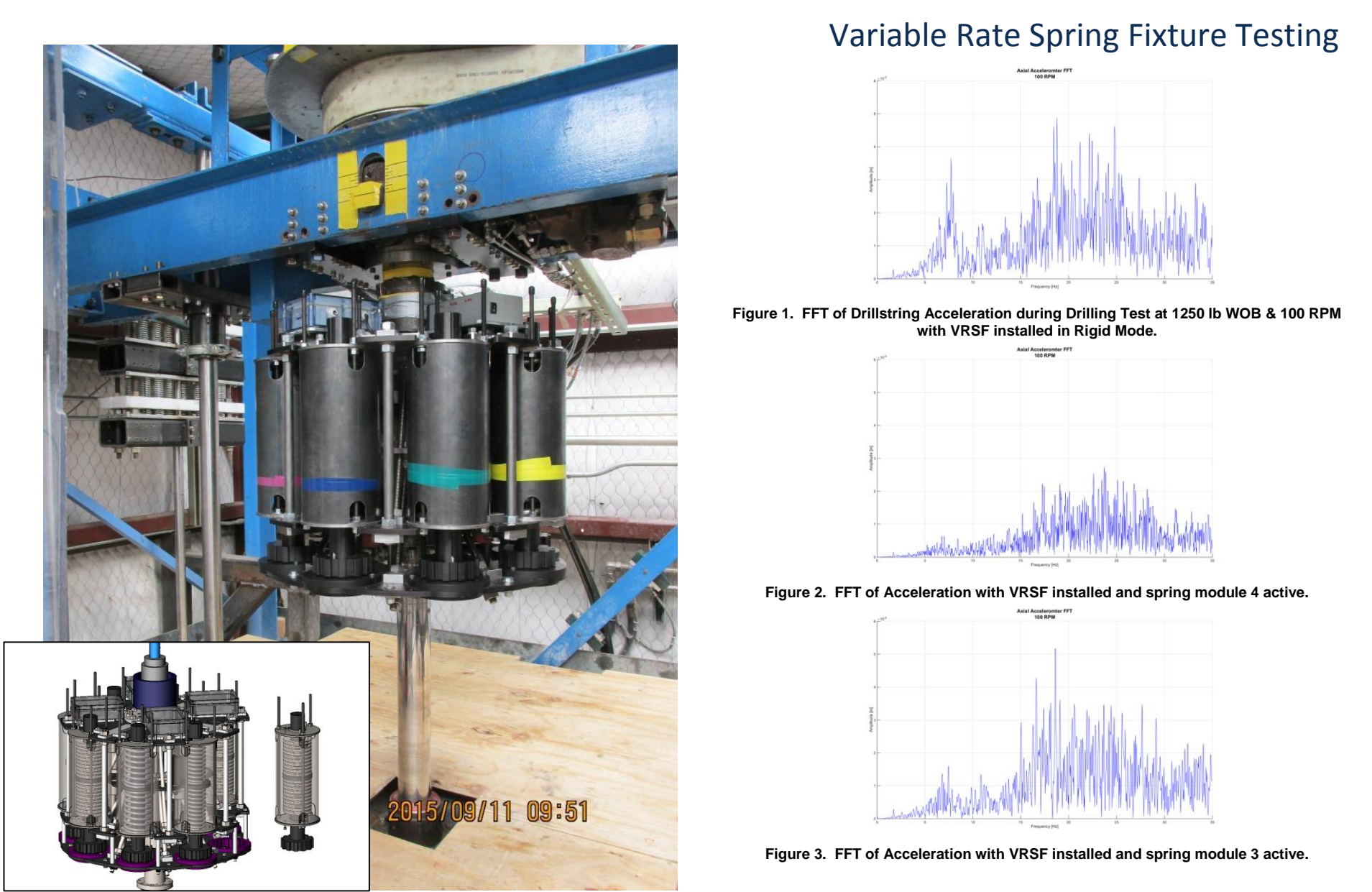
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Drilling Process Modeling & Simulations



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Drilling Applicability Simulation



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Summary

- Key R&D Accomplishments**
 - Computational model developed
 - Substructuring capability derived
 - Control evaluation achieved
 - Conceptual design for prototype tool with variable rate spring
 - Conceived use of smart materials
 - Lab drillstring validation devised
 - Drilling applicability demonstration completed
- Impact and S&E Legacy**
 - Supports initiatives for borehole disposition of NW / Applicable to broad energy drilling sector
 - Drilling vibrations a major performance limiter – work addresses this issue
 - SNL capabilities in computing, controls, engineering and testing make this effort possible – work enhances future partnerships
- Efforts to Leverage R&D**
 - DOE aware of general effort – bolsters our national leadership position in drilling research
 - Industry being informed of SNL vibration mitigation efforts
 - Work presented at International Colloquium on Deep Drilling Systems, Minneapolis, May 2014
- What's Next**
 - Identify sponsorship for continuation
 - Continue with laboratory POC testing
 - Publish
 - Engage operators and service companies
 - Identify commercial partner
 - Conduct Field Testing
 - License Intellectual Property

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