# Modeling Simulation and Software (MS2)


# LABORATORY TESTING OF TRACKED VEHICLE SUSPENSIONS

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# OUTLINE

- Motivation
- Testing Approach
- Results
- Future Use Cases
- Questions

# MOTIVATION



- Reduction of operating and support (O&S) costs
- These costs include not only the parts but also the labor and down time
  - Certain parts incur far more down time and labor than the cost of the part itself
  - A bearing in the suspension is critical to the function of the system, and it is relatively cheap to buy a replacement, but requires an exceptional amount of work to get to.
- Potential solutions, don't get to the underlying issue of the design
  - Preventative and predictive maintenance will minimize the issues
  - Improving the design (form, fit, and function) will stop the issues
- Secondary goal to improving system reliability is weight reduction, as they tend to go hand-in-hand

# MOTIVATION: Background



- Laboratories have generally lacked in the ability to apply the relevant loads to cause failures
  - Therefore, the issues of tracked reliability haven't been worked on at a component level, with high fidelity
- The research and development of this new lab capability aimed to fill this gap
  - First of its kind test system
  - Produces vertical motion and speeds relevant to the vehicles
  - Simultaneously can apply cornering forces necessary to excite failure modes
- Both baseline parts and prototype parts have been tested
  - Baselines are current production parts, same as what shows up in the field
  - Prototypes are geometrically optimized, direct fit parts

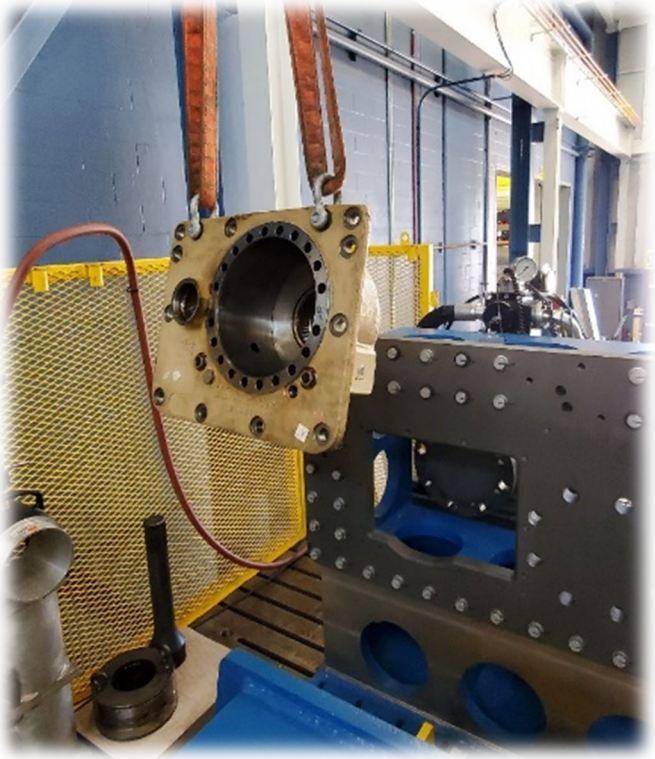
# MOTIVATION: Failure Modes & Parts of Interest



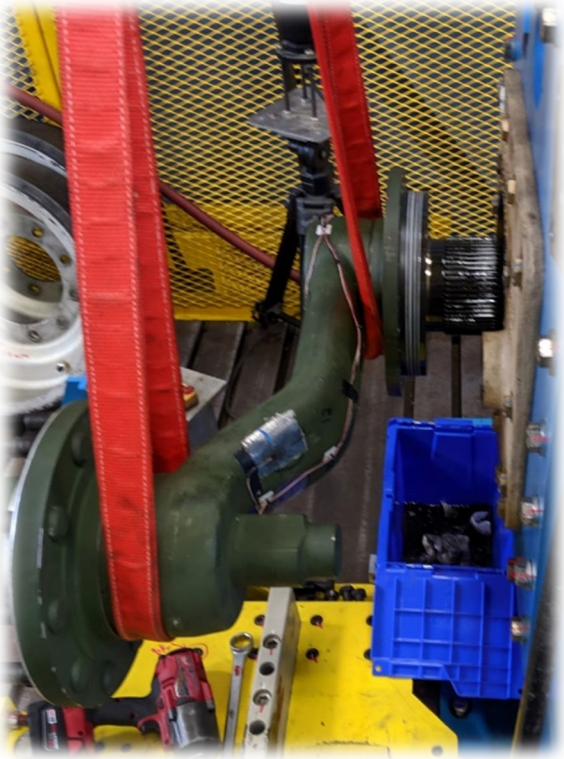
- Many components involved
  - Multiple interaction types between parts
  - Road arms, bearings, seals, dampers, and springs that comprise of various metals, plastics, and rubber materials
- These interactions fail due to highly complex phenomena
  - Can't be predicted by **purely** analytical Modeling and Simulation (M&S) approaches
  - Physical experimentation in conjunction with M&S required
- Example in current Abrams Road Arm
  - Sharp, small radius immediately adjacent to a heavy press fit
  - Complex stress state
  - Complex weld geometry immediately adjacent to the splined joints
- Physical testing is normally performed at the proving grounds
  - Vehicles are operated over varying terrains, from pavement to cross country
  - Loads and motions accurate to field physics
  - High costs; several years, millions of $
- Prototype testing at proving grounds is difficult
  - Variations with vehicle evaluations
  - Lumped testing option
    - High preference from the PMs to prove out in the lab before full vehicle
- Experimental testing
  - Issues with contaminating the environment

# Assembly / Disassembly of Parts





Installing Housing

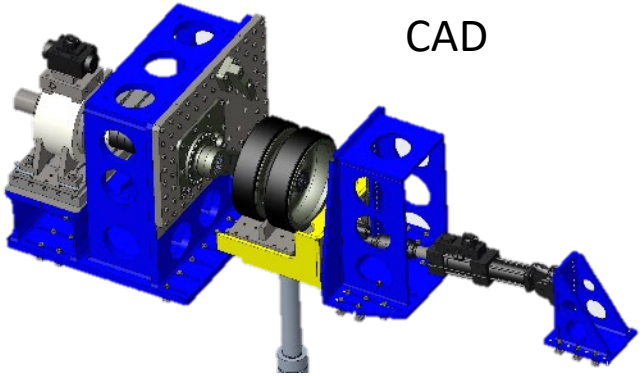


Installing Trailing Arm

Big Oily Mess

# TESTING APPROACH





CAD

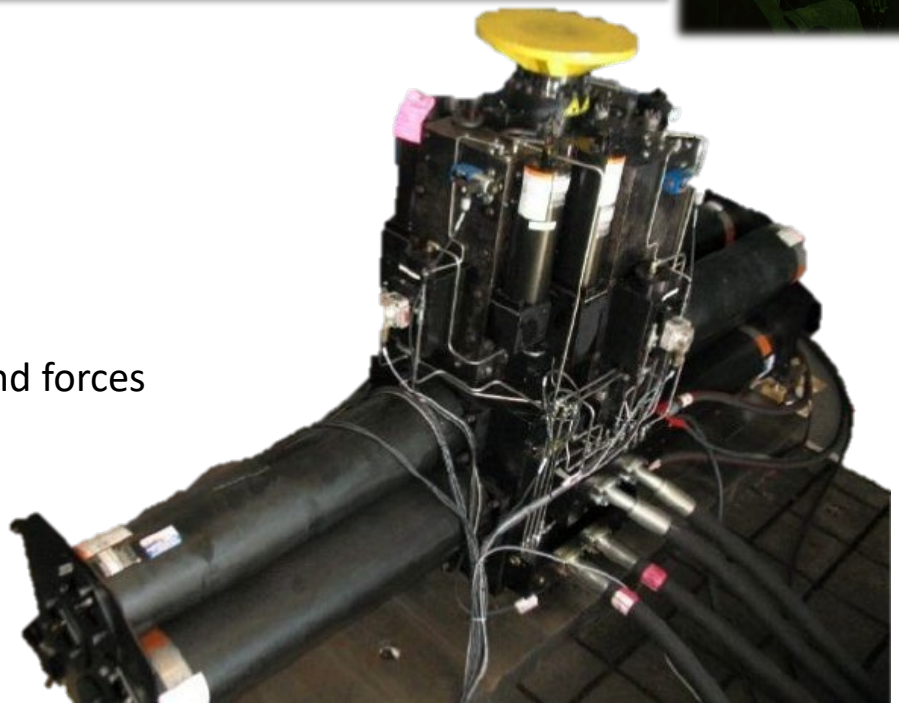
Assembled in Lab

- Need to establish a baseline for comparison
  - Produce known failure modes
  - Develop procedures to improve turnaround on test items
  - Complete multiple test runs in a short amount of time, for statistical confidence of the results
- Testing in this way isn't as common as it should be in the military test world
  - Rather than just verifying that a requirement is met, it's exploratory and iterative
  - The benefit is finding failure modes, that might not be seen until put in the field, sooner and designing solutions from the start

# TESTING APPROACH: Actuators



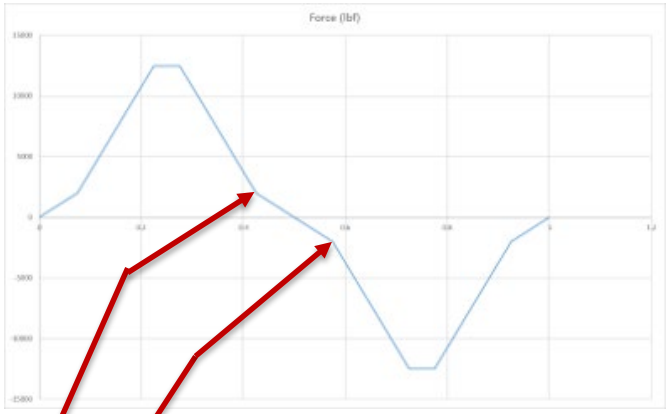
- GVSC's Durability Test Lab
  - Suspension Test Analysis Rig (STAR)
  - Vertical actuator
  - Lateral Actuator
  - Reconfigurable table top
  - Reaction fixture
  - Slip Table
  - Torsional Actuator
- Vertical actuator was custom built to simulate ground forces and motions experienced by heavy tracked vehicles
  - $1 million bought for tracked vehicle testing FCS
  - 18.5 inches of dynamic displacement
  - 400 GPM valves (three simultaneously available)
  - 80 gallons of hydraulic accumulation
  - Max static force: 72,000 lbf
  - Peak velocity of 11 m/s
- The main fixture simulates the mounting of the vehicle hull
  - Can be reconfigured via an adapter plate to accept multiple other vehicle types
  - Capable of replicating the torsional setups, but also external spring/damper parts, via the same adapter plate
  - Specific to the Abrams testing, the bolts and cut outs are matched to the Abrams suspension housing, and bump stop location

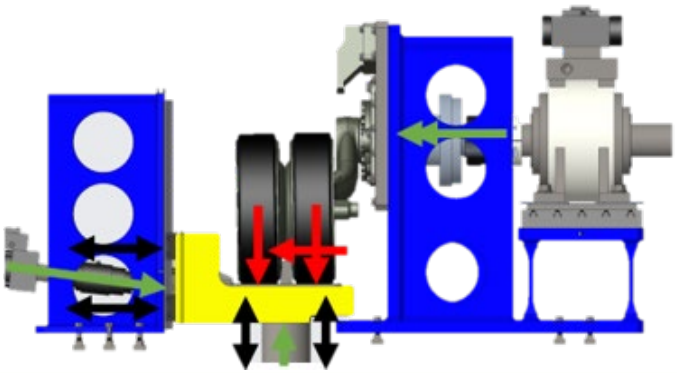


# TESTING APPROACH: Testing Setup



- Torsion bar torque simulation
  - Rotary mounted on a flexure for actuator longevity
- Cornering forces
  - Non-standard control schemes required
- Tuning of the system
  - PID, Accumulation, and Valve tuning
  - All minimized wear and tear on the system while allowing for faster operation
- Fixture design
  - Moving force centers
  - Remove axial loading into actuators
  - Support moments on actuators to improve life
  - All this also improves the actual loading of the test item



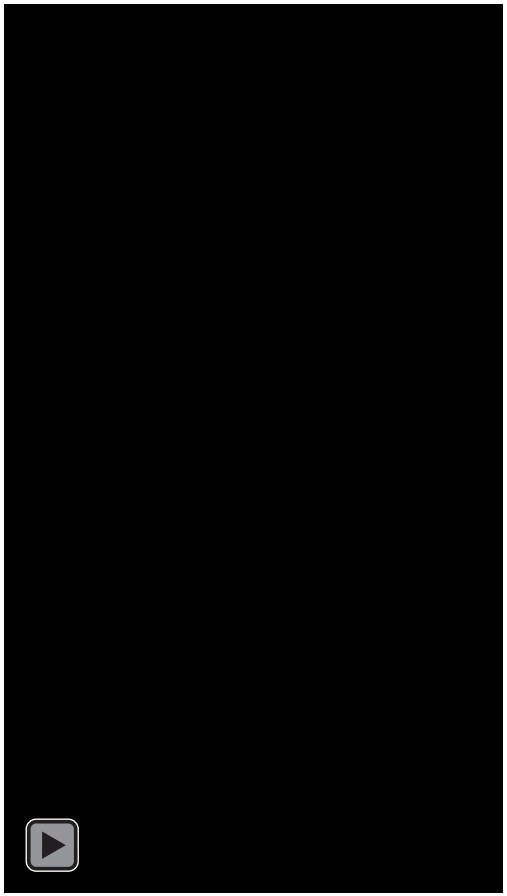
- Results so far
  - Testing continues on more prototypes
  - Prototypes were optimized based on the early results from the baseline parts
- Exploratory loading
  - Stepped loading of baseline arms
- Lateral loading
  - Lateral loads were found to be the important factor for failing an arm
  - Vertical loads will fail the torsion bar before the arm fails
  - Forces and displacements of the vertical and torsional actuator set to mimic real world

Lateral Testing

# RESULTS: Weld Cracking and Seal Leaks



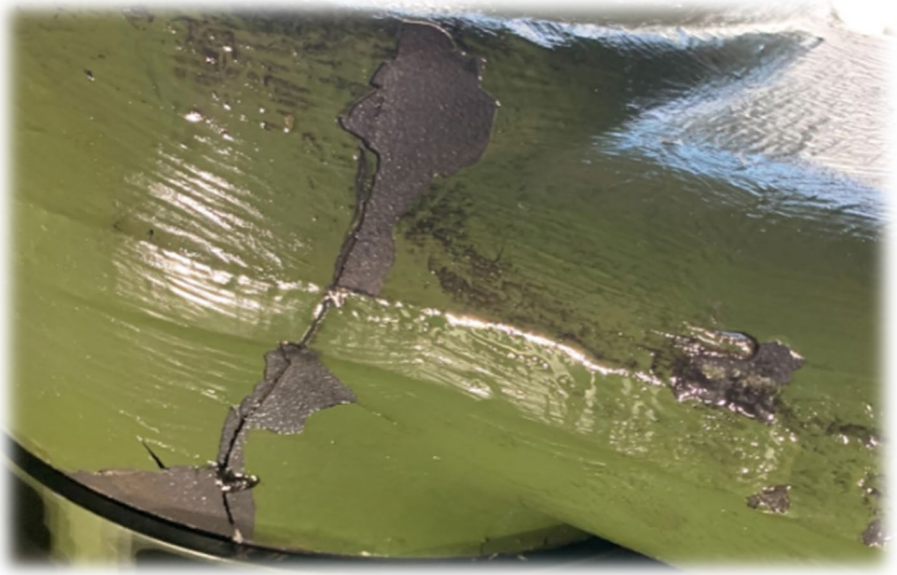
- Weld cracking
  - Same failure of the arm as occurs in the field
  - Consistent with fully reversed turning on pavement
  - Major contributor to O&S costs
- Unexpected findings
  - The number of cycles to crack the welds on the baseline arms are inconsistent
  - Large variation in weld quality, including undercutting and other defects
  - Also found that the amount of torque is incredibly important in cracking the weld, point out the vehicle weight being a huge factor in component life
- Prototype parts
  - Doesn't have a weld
  - Still caused leaking in the same area
  - Facilitated a change in the design to correct the issue



# RESULTS: Spline Bursting



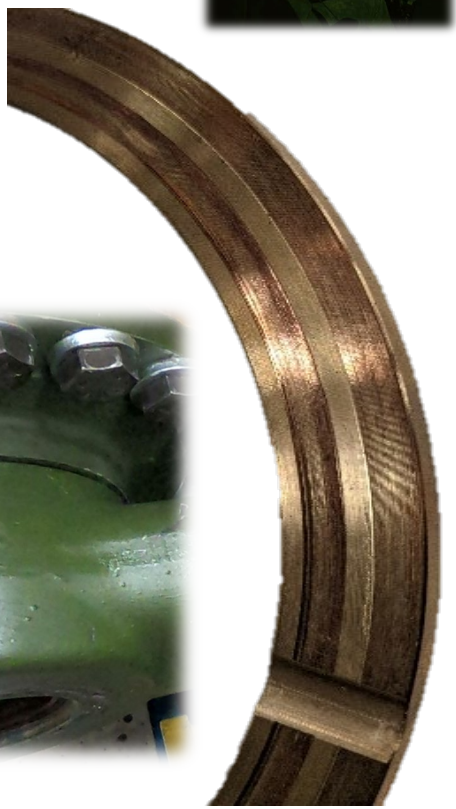
- Weld cracking; First failure mode replicated
  - Usually means the end of testing
  - What comes next?
- Higher load levels continued
- Baseline vs Prototype arms

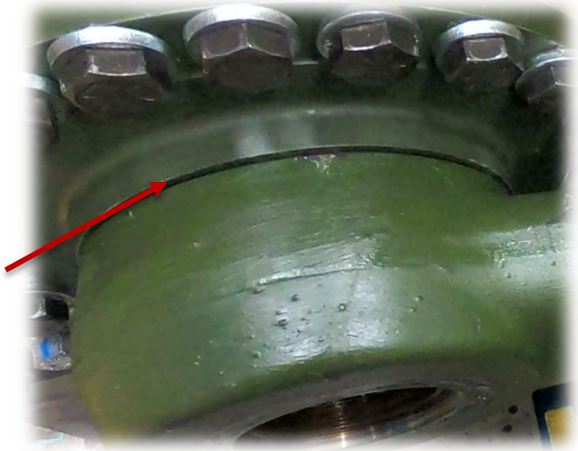


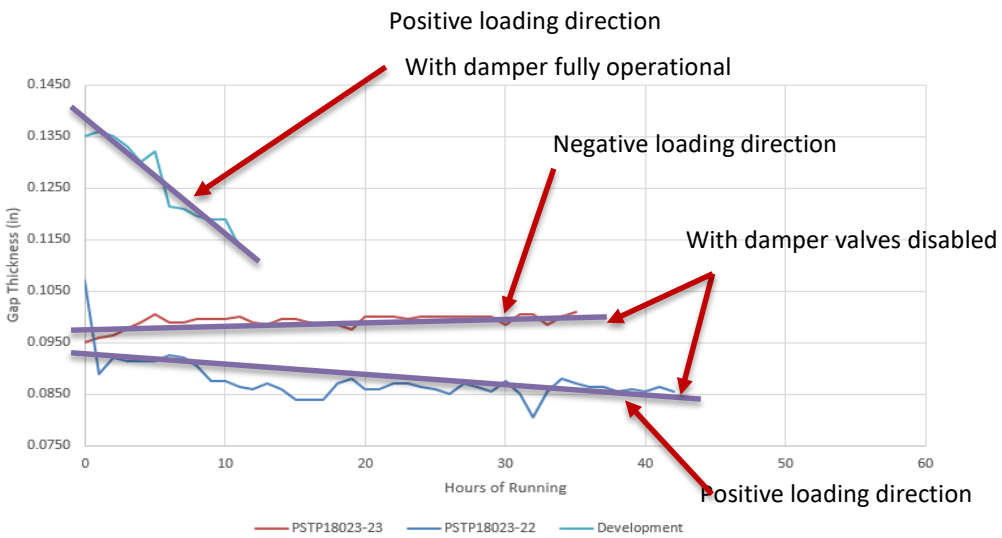
# RESULTS: Bearing Thrust Washer Wear



- Another component of interest can be targeted for redesign
- Producing wear
- Measuring the wear rate
- Found that temperature is an important factor
- Further studies planned

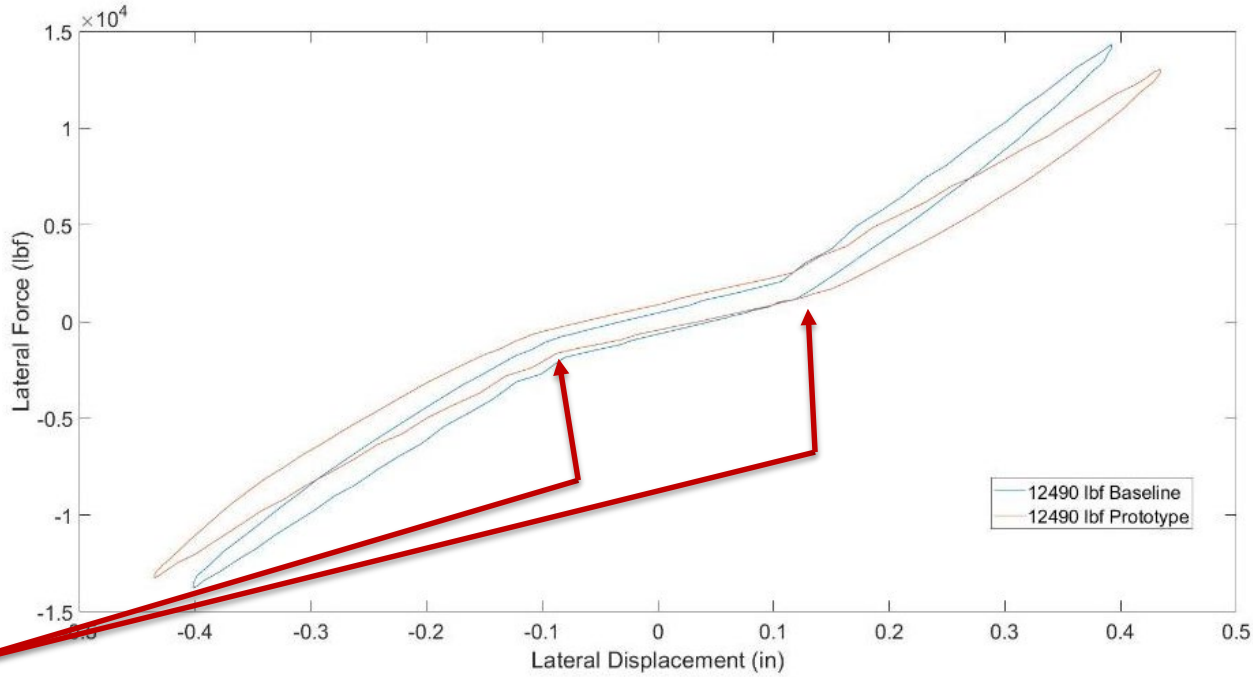


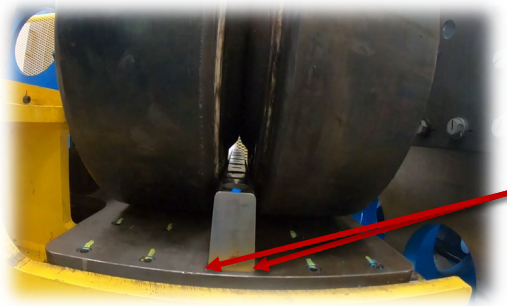





# RESULTS: Road Arm Compliance

- Stiffness measurements of the arm
- Comparison between baseline and prototype
- Baseline is stiffer as expected



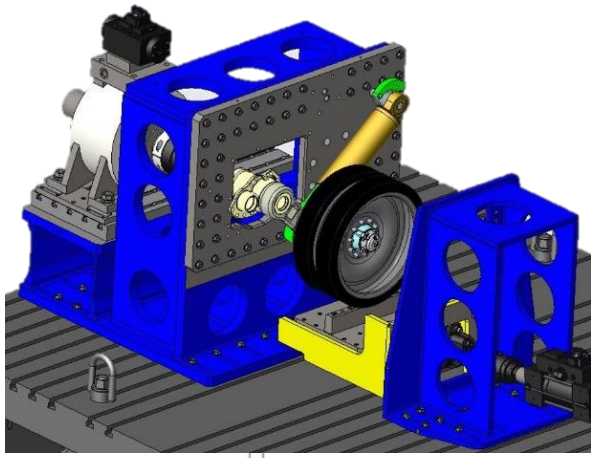



Transition zone between contact

# FUTURE USE CASES



- Other tracked platform testing
  - Abrams was the first, but not the last
- Heavy wheeled vehicle testing
  - Slight fixture modifications to allow for lateral loading of a wheeled suspension subassembly
  - Allow for component level testing, with the same
- Potential for full Kinematics and Compliance (KnC) testing of tracked suspensions
  - Additional load cells needed
  - Slight modification to the slip table
- Field load replication
  - Just requires more instrumentation of the arms themselves
  - Use an arm that's been run on test tracks and iterate to the forces seen
  - Rapid cost effective replication of proving ground forces
  - Can also be used to study components upstream of the arm



# Any questions or comments?

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