

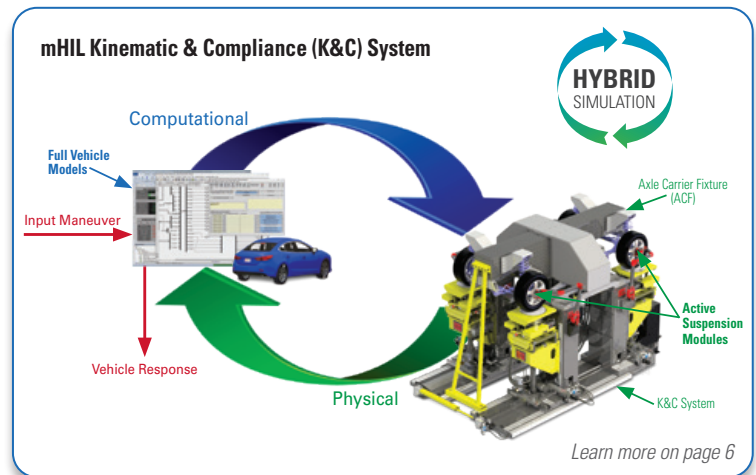
## MTS GROUND VEHICLE SOLUTIONS



### Sustainable Vehicle Engineering

Booth 2000

Automotive OEMs and suppliers worldwide rely on MTS for the testing technologies, expertise, and support needed to accelerate next generation vehicle development while meeting energy efficiency and decarbonization targets. Visit Booth 2000 and explore how MTS solutions can help you achieve more sustainable vehicle engineering and thrive in a competitive global market.



### Innovation Showcase



**Reduce Energy Usage by +35% Using Hybrid HPU Technology**

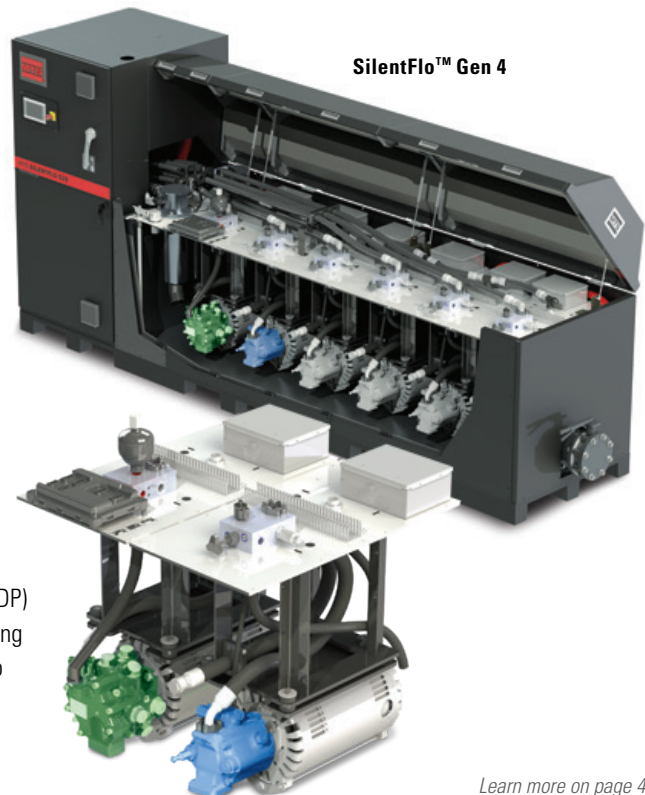
**James Hennen**  
Senior Business Development Manager

**Date:** Tuesday, October 22

**Time:** 1:10 p.m.

**Stage:** Expo Floor

Learn about innovative hybrid approach to hydraulic power generation that employs highly efficient radial flow Digital Displacement Pump (DDP) modules (green) to modulate flow during typical demand, while engaging conventional axial flow swash plate pump modules (blue) as needed to achieve maximum energy efficiency during peak use.



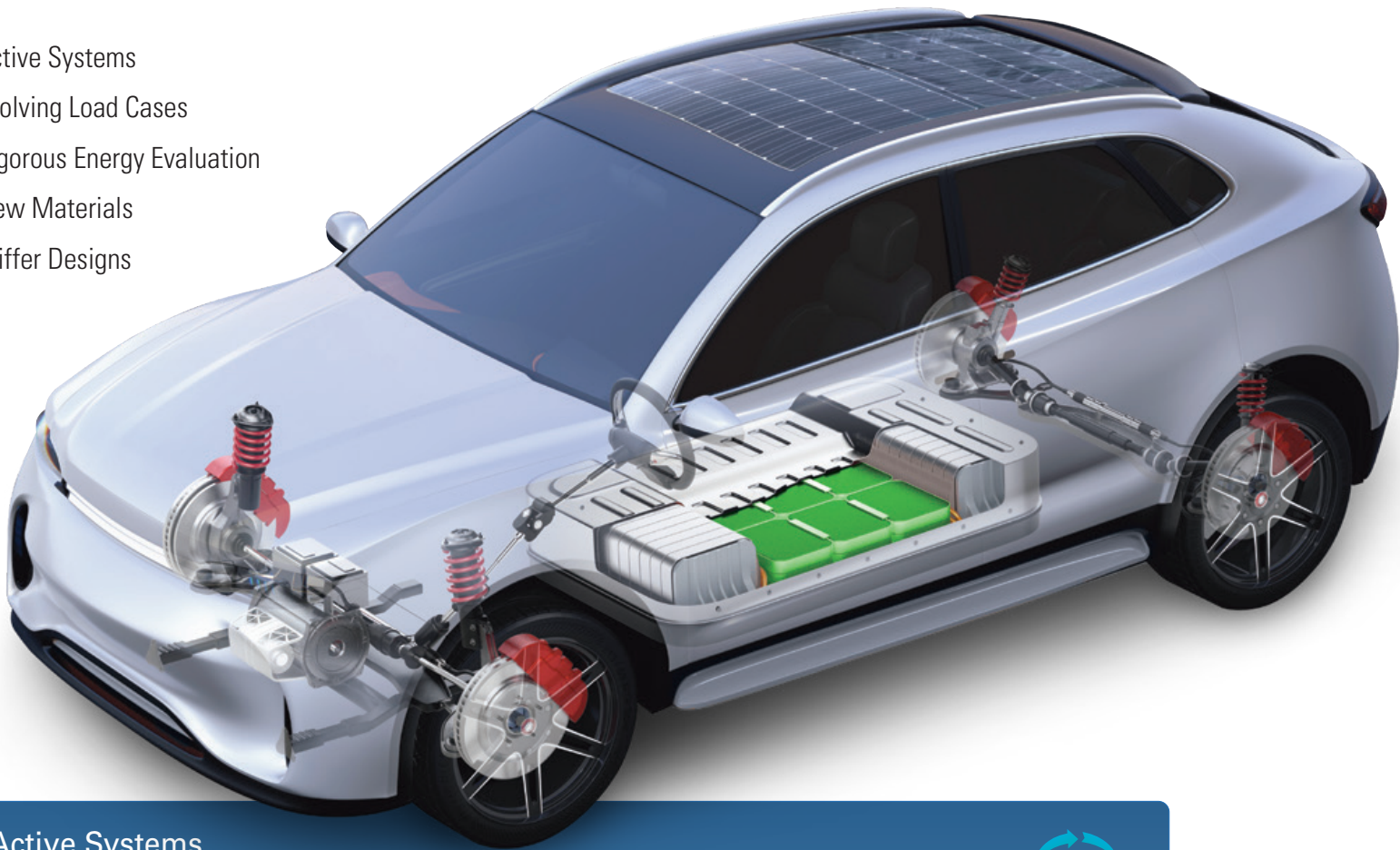
Learn more on page 4



Electric & Autonomous Vehicle Testing Solutions

With a proven portfolio of laboratory-based testing solutions for materials, components, subsystems, and full vehicles, MTS is uniquely positioned to help vehicle OEMs and component suppliers confront the myriad challenges posed by electric and autonomous vehicle development, including:

- » Active Systems
- » Evolving Load Cases
- » Rigorous Energy Evaluation
- » New Materials
- » Stiffer Designs



**Evolving Load Cases**  
*Changing component duty cycles*

Motor Mount Test      Lower Control Arm Test      Knuckle Test      K&C Test System

**Rigorous Energy Evaluation**  
*Aggressive consumption and loss targets*

Flat-Trac® Dynamometer      Turnkey EV Battery Test System      MTS Landmark® Test System

**Active Systems**  
*ADAS, Tire, Braking, Damper, Steering, Suspension, etc.*

Driver Input      Computational      Vehicle Response      Physical

Tire      Damper      Steer      Axle      Suspension

HYBRID SIMULATION

**New Materials**  
*Changing body structures and dynamics*

Model 329i Spindle-coupled Road Simulator      MTS Materials Test Systems

**Stiffer Designs**  
*Higher frequency duty cycles, NVH, Ride Comfort*

Model 353.20 MAST      Model 853 Damper NVH Test System      Model 831.50 Elastomer Test System



Introducing SilentFlo™ Gen 4 Technology

ATE Technology Forum



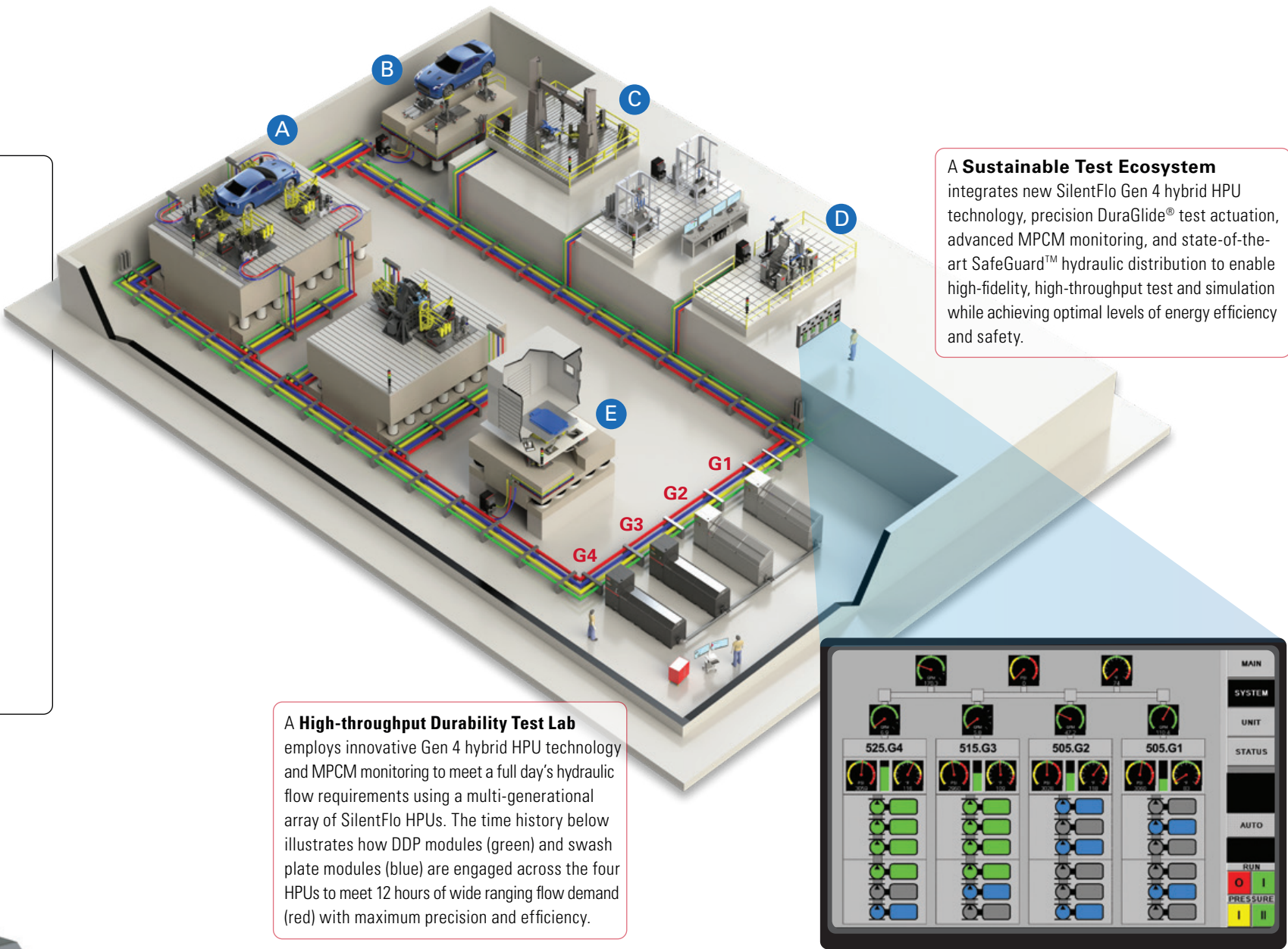
**Presenter:** James Hennen  
Senior Business Development Manager  
**Date:** Tuesday, October 22  
**Time:** 1:10 p.m.  
**Stage:** Expo Floor

Reduce Energy Usage by +35% Using Hybrid HPU Technology

The need to maximize energy efficiency and comply with regional and global decarbonization mandates poses daunting challenges for test laboratory managers.

In response, MTS has engineered a new, hybrid approach to hydraulic power generation that employs state-of-the-art digital displacement (radial flow) technology to modulate flow during typical demand, while engaging conventional swash plate (axial flow) technology to achieve maximum efficiency during peak use.

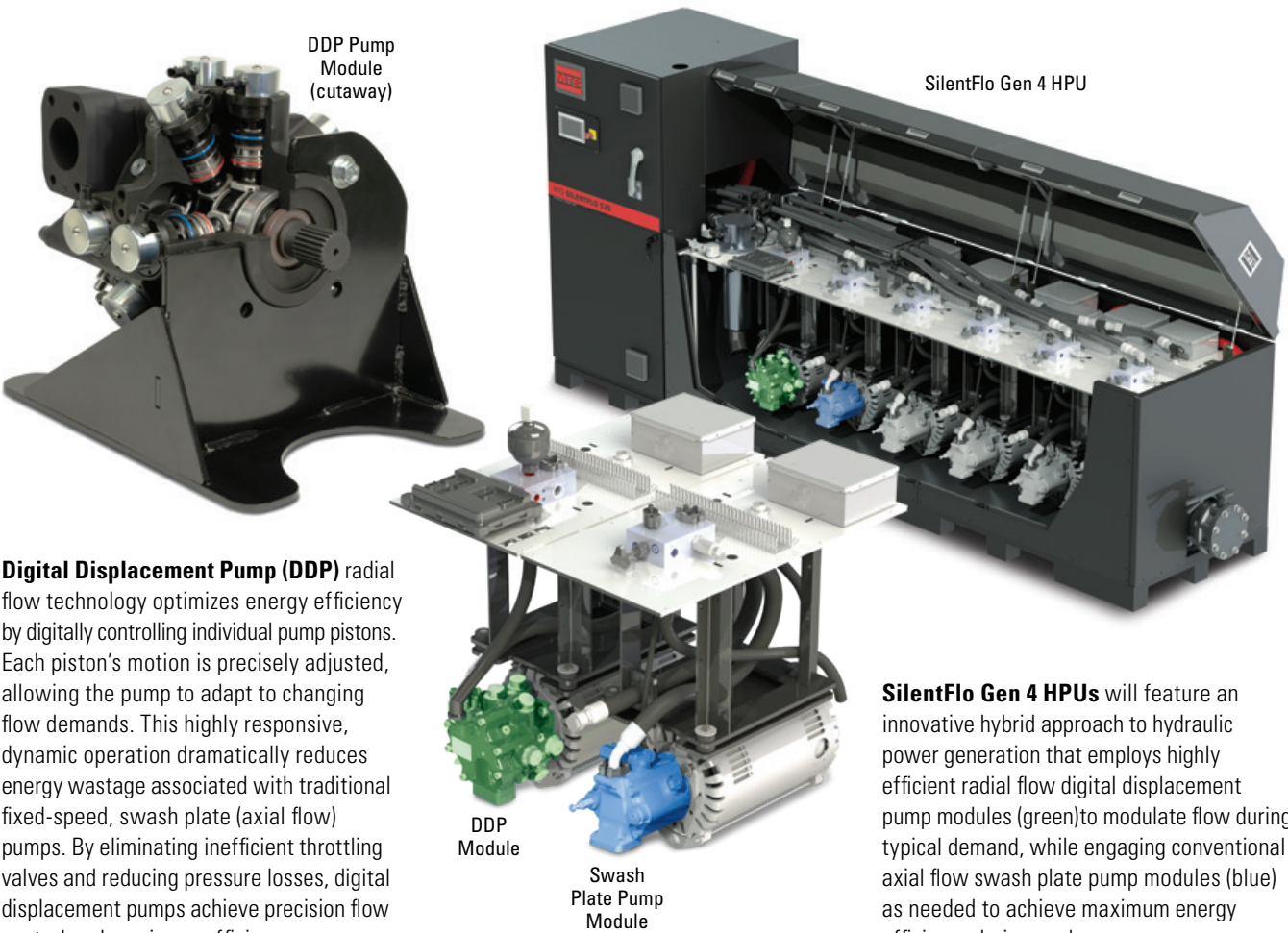
James’ presentation examines the benefits of this new hybrid power generation technology, presents data that demonstrates its effectiveness, and explores the numerous ways it will be integrated throughout existing test laboratory infrastructure to dramatically reduce energy usage.



A **High-throughput Durability Test Lab** employs innovative Gen 4 hybrid HPU technology and MPCM monitoring to meet a full day’s hydraulic flow requirements using a multi-generational array of SilentFlo HPUs. The time history below illustrates how DDP modules (green) and swash plate modules (blue) are engaged across the four HPUs to meet 12 hours of wide ranging flow demand (red) with maximum precision and efficiency.

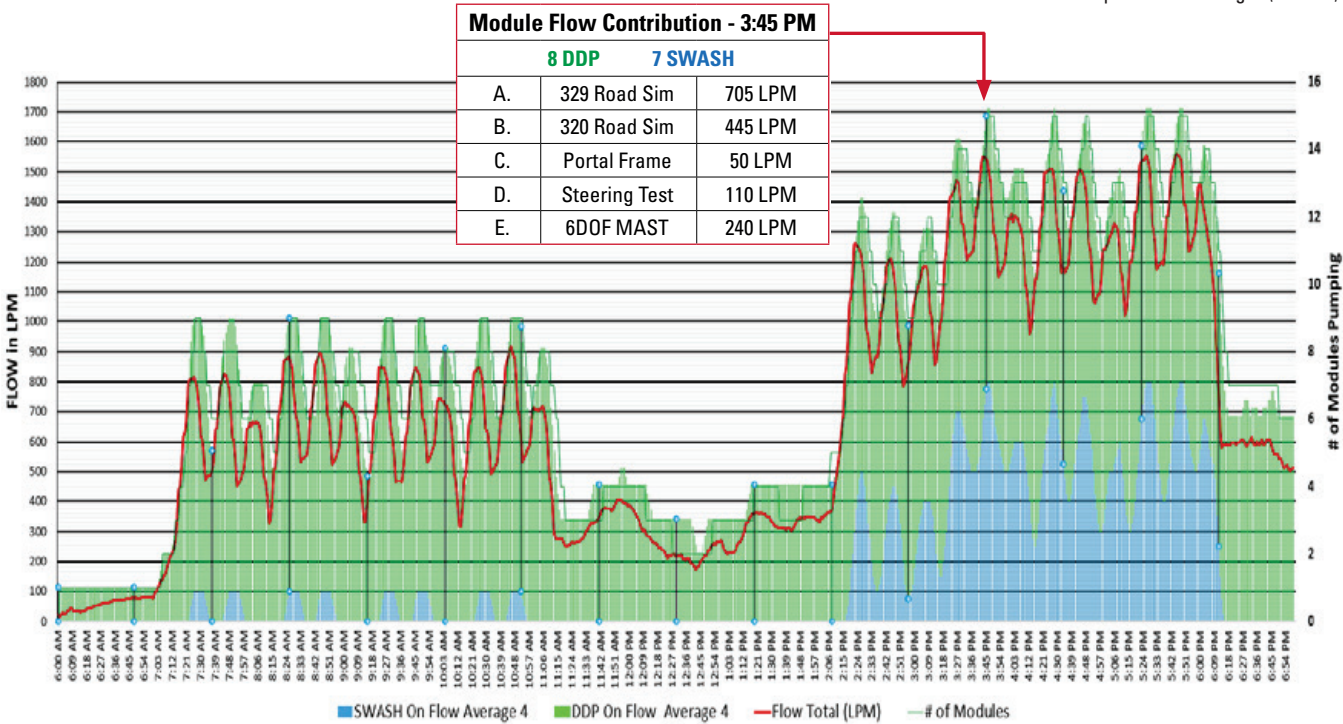


Multi-Pump Control Manager (MPCM)

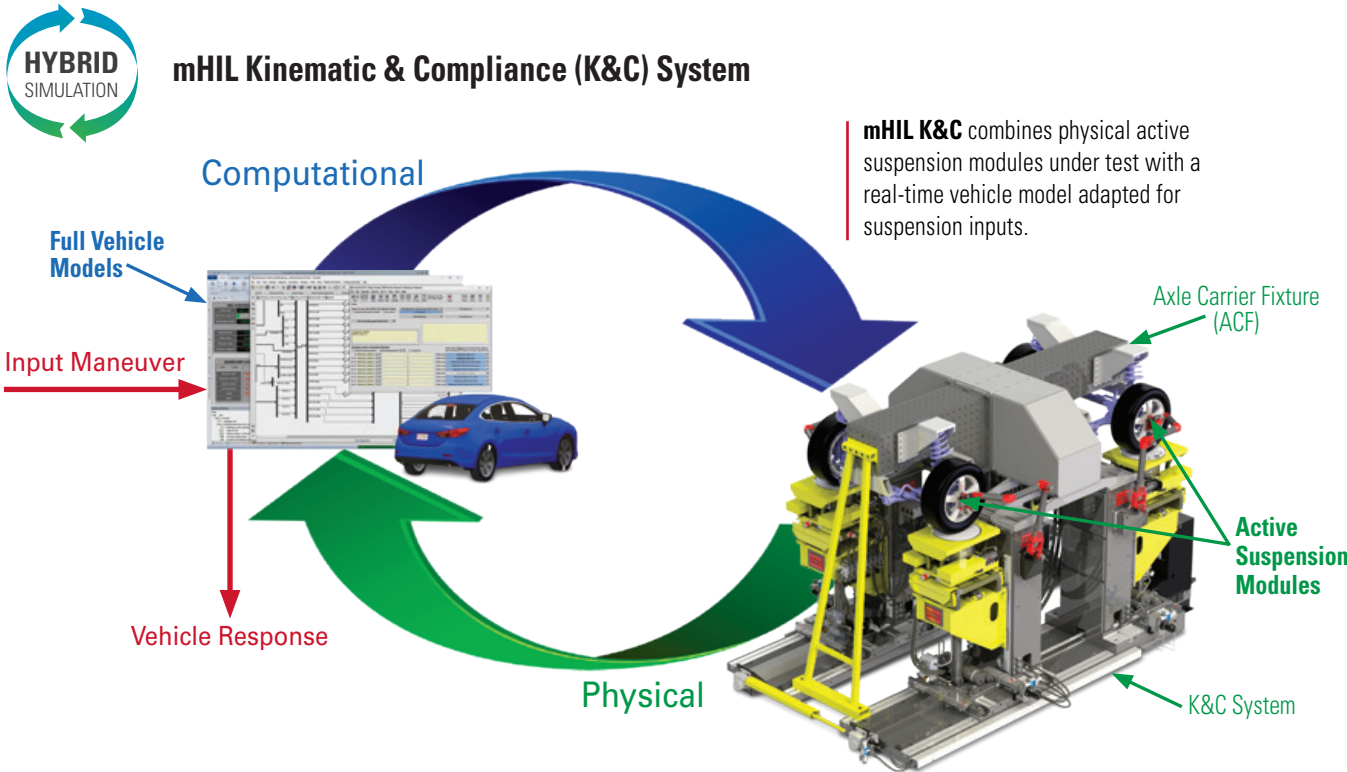


**Digital Displacement Pump (DDP)** radial flow technology optimizes energy efficiency by digitally controlling individual pump pistons. Each piston’s motion is precisely adjusted, allowing the pump to adapt to changing flow demands. This highly responsive, dynamic operation dramatically reduces energy wastage associated with traditional fixed-speed, swash plate (axial flow) pumps. By eliminating inefficient throttling valves and reducing pressure losses, digital displacement pumps achieve precision flow control and maximum efficiency.

**SilentFlo Gen 4 HPUs** will feature an innovative hybrid approach to hydraulic power generation that employs highly efficient radial flow digital displacement pump modules (green) to modulate flow during typical demand, while engaging conventional axial flow swash plate pump modules (blue) as needed to achieve maximum energy efficiency during peak use.







Using K&C Hybrid Simulation to Accelerate Active Chassis Development

Meaningful evaluation of interconnected active systems used in next-generation ICE, electric, and autonomous vehicles must extend from early-stage modeling through proving ground validation, which presents numerous simulation challenges for OEMs.

MTS has proven that hybrid simulation can be used to establish vehicle-level simulation environments where developers can evaluate, integrate, test drive, and certify active systems well in advance of full-vehicle prototypes.

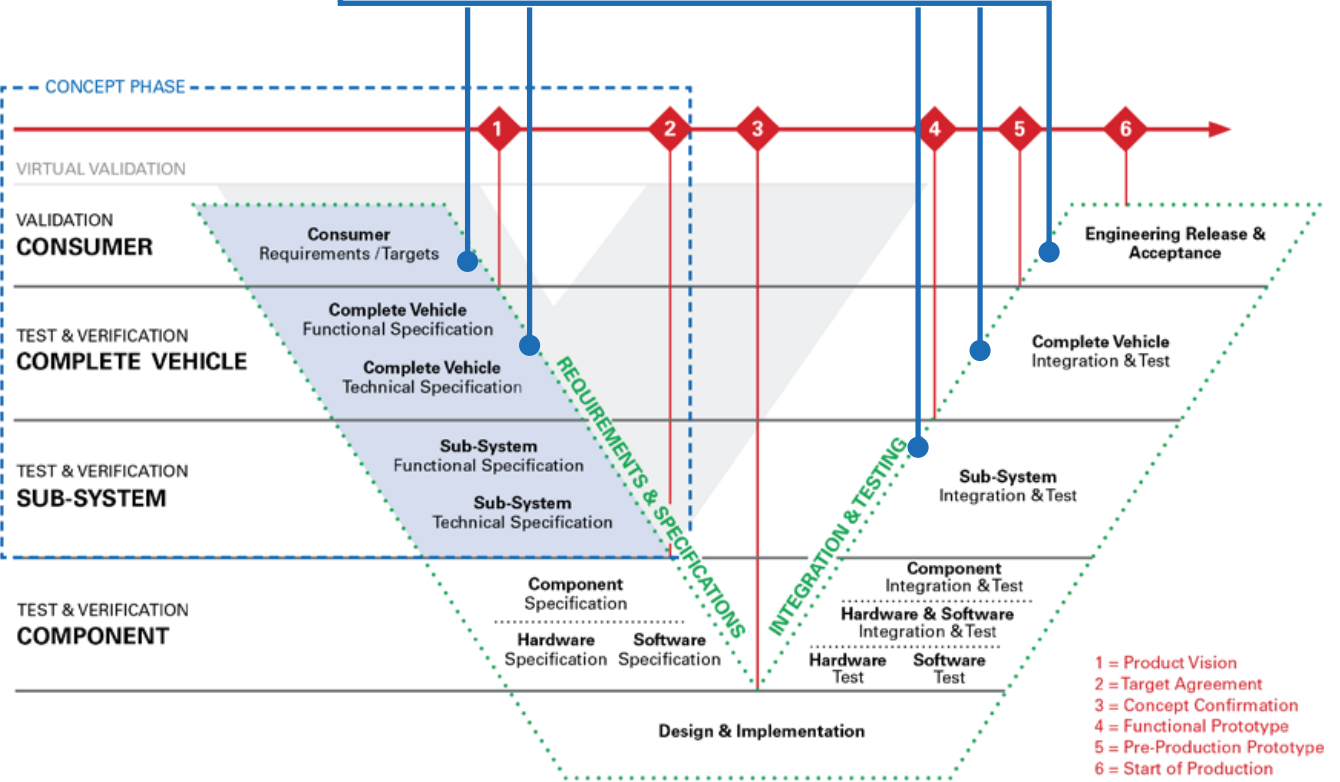
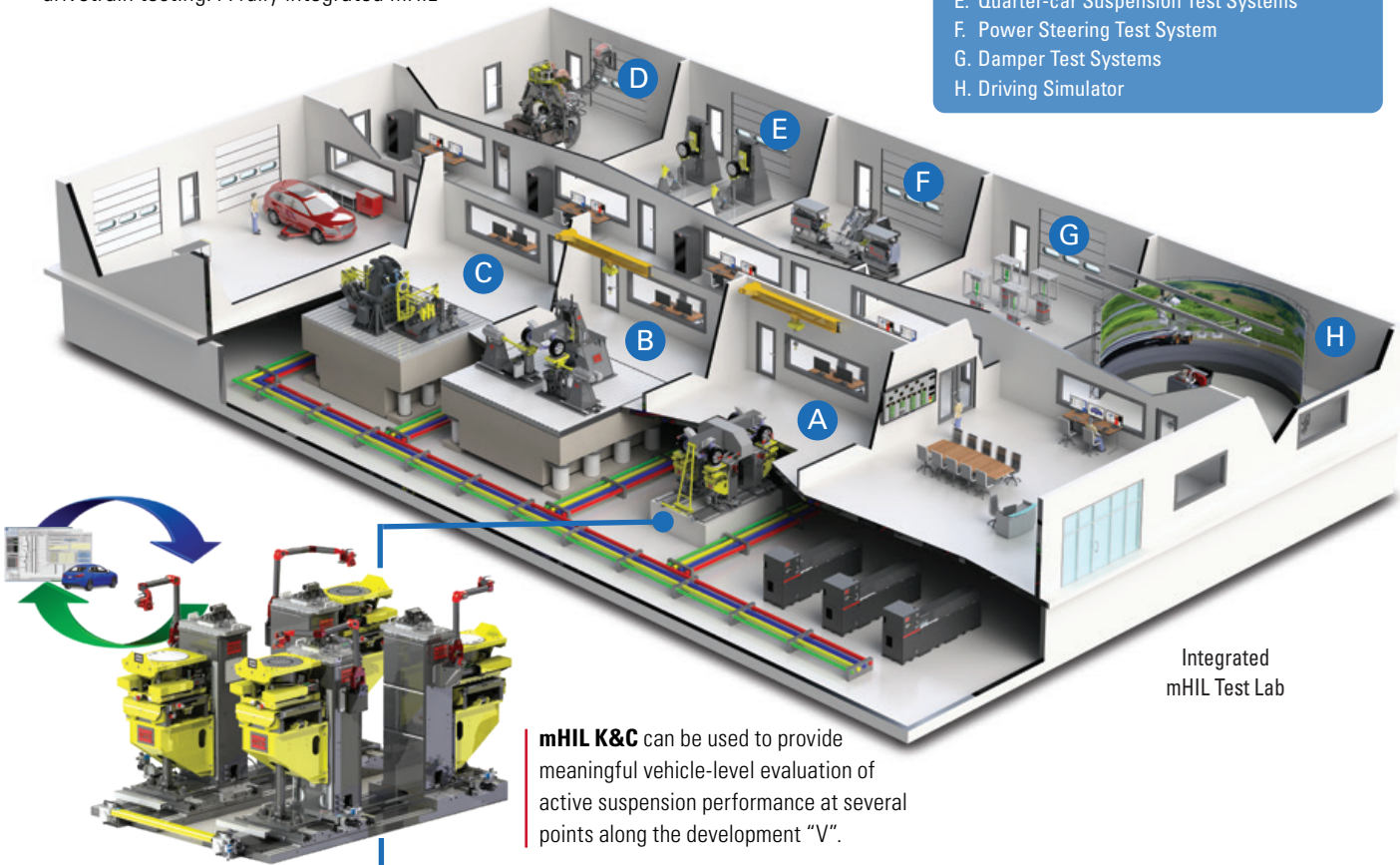
mHIL K&C is a hybrid simulation approach that integrates vehicle models and active suspension modules under test to enable meaningful vehicle-level evaluation of suspension performance throughout the development cycle to realize faster, more efficient active chassis development.

mHIL Solutions

MTS has pursued mHIL solutions to complement a broad array of physical test systems, including those purpose-engineered for damper, tire, steering system, suspension, axle, and drivetrain testing. A fully integrated mHIL

lab with a driving simulator functions as a collaborative tuning environment to enable faster, more efficient active chassis development.

- A. K&C System with Axle Carrier Fixture
- B. Ride Comfort Roadway with Axle Carrier Fixture
- C. 6DOF Road Simulator – Axle
- D. Tire Force & Moment Measurement System
- E. Quarter-car Suspension Test Systems
- F. Power Steering Test System
- G. Damper Test Systems
- H. Driving Simulator



mHIL



mHIL Damper

**Mechanical Hardware In-the-Loop (mHIL)** is a proven hybrid simulation technique that integrates a computational vehicle model with a physical sub-system under test in a closed control loop to establish a real-time, vehicle-level simulation environment. This environment can be employed across all phases of vehicle development to simulate real-world driving or proving ground events in the test lab, allowing test engineers to integrate, test drive, and certify active system performance well in advance of functional, full vehicle prototypes. These simulations provide the mechanical test feedback needed to optimize vehicle models, accelerate subjective and objective evaluation, reduce the need for rework and prototypes, and streamline proving ground validation.



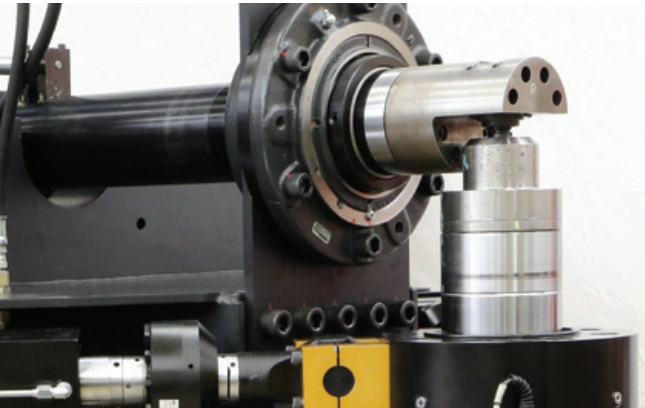
# Durability Solutions

## Proven, Reliable Lab-based Assessment Solutions

MTS sets the standard for providing highly accurate and repeatable correlation between the proving ground and the lab with a broad array of proven durability testing solutions. Comprising a variety of robust, multi-degree-of-freedom test rigs and industry-renowned RPC® Connect software, the MTS portfolio includes all the tools you'll need to accurately evaluate the durability of components, subsystems and full-vehicles, ranging from motorcycles to passenger cars to heavy trucks and agricultural equipment.

The MTS durability portfolio features:

- » Model 329i Spindle-Coupled Road Simulators that provide up to six degrees of measurement and control at each of the vehicle spindles to deliver the most efficient, accurate and repeatable reproduction of even the most challenging proving ground road surfaces, maneuvers and events.
- » Model 320 Tire-Coupled Road Simulators for both early stage testing and full vehicle assessment
- » Versatile multiaxial simulation table (MAST™) systems for general component and subsystem testing
- » Numerous subsystem-specific testing solutions
- » A variety of elastomer, damper, bushing and materials test solutions
- » Leading-edge hybrid simulation solutions



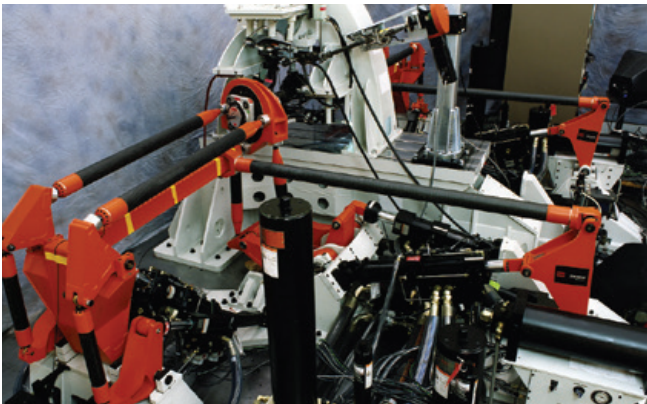
Ball Joint Test System



Damper Test Systems



Multiaxial Simulation Table (MAST) Systems



Axle Test Systems



8 Tire-coupled Road Simulators



Spindle-coupled Road Simulators

## Expanding MAST Capabilities

### High Frequencies - Models 353.20, 353.50 & 354.20

Address emerging electric vehicle battery testing needs and comply with various international standards.

- » Test up to 200 Hz when performing Power Spectral Density (PSD) tests and Time History (TH) replication
- » Apply force and motion in full six-degrees-of-freedom
- » Streamlined integration with third-party environmental chambers, battery cyclers - or battery management systems - and specimen monitoring systems
- » Functional safety per ISO 13849-1:2015 (Safety of machinery – Safety related parts of control systems)

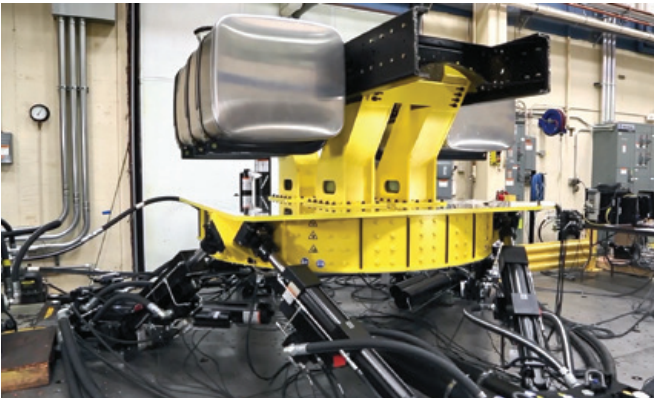


Model 353.20

### High Payloads - Models 353.50 & 354.20

Test larger, heavier electric vehicle, commercial truck and agricultural vehicle components, assemblies, and subsystems.

- » Test specimens up to 3000 kg (353.50) and 2000 kg (354.20)
- » Choose from a variety of standard and custom table sizes/ configurations (largest: 2.5 x 2.5-meter square)



Model 354.20

### Large Geometry Specimens - Model 354 LG

Conduct vibration tests on large battery packs used in next-generation commercial and off-highway electric vehicles.

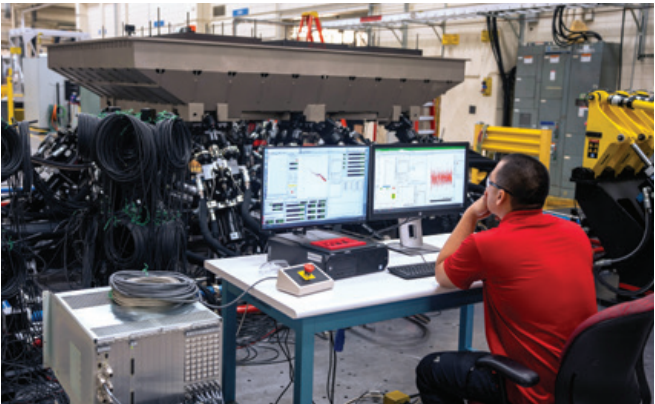
- » Accommodate large lithium-ion battery packs on a 2.5 x 3.5 meter table
- » 6DOF 12-actuator (dodecapod) configuration
- » Test specimens up to 2000 kg at 200 Hz
- » Meet ISO 12405, UN R100, UN R136, and UN 38.3 requirements
- » Compatible with third-party environmental chambers, battery management systems, and specimen monitoring systems



### Advanced Compensation Tools - FlexTest Software (793)

Achieve the highest levels of MAST system controllability and fidelity to accelerate RPC drive file convergence.

- » Degree of Freedom Control establishes a coordinate space where actuators work in 6DOF concert
- » Three-Variable Control enables simultaneous control of displacement, velocity, and acceleration variables
- » Amplitude Phase Control (APC) compensates for errors between command and feedback sine waves
- » Adaptive Harmonic Cancellation (AHC) removes distortion and generates clean sinusoidal inputs in conjunction with APC

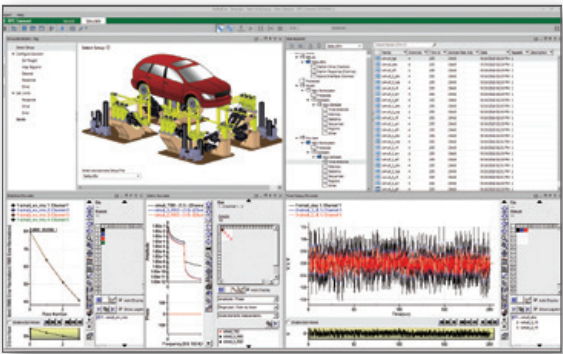




State-of-the-art 6DOF Road Simulation

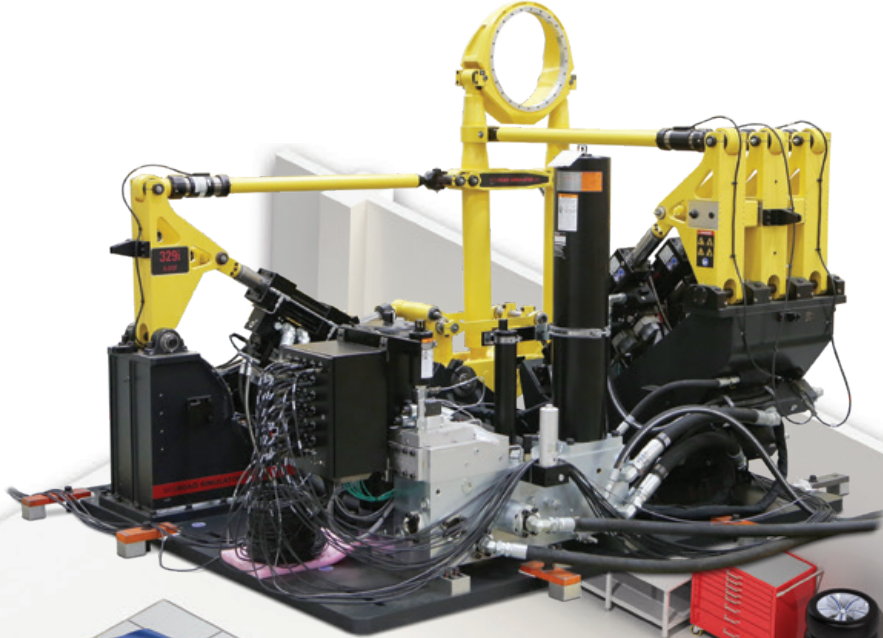
The new Model 329i Spindle-couple Road Simulator integrates the latest in MTS hydromechanical, controls, and software innovation to achieve new levels of durability test fidelity and productivity.

- » Optimize road simulation accuracy
- » Maximize test system throughput, reliability, and operational efficiency
- » Integrate seamlessly with active vehicle systems and CAE models



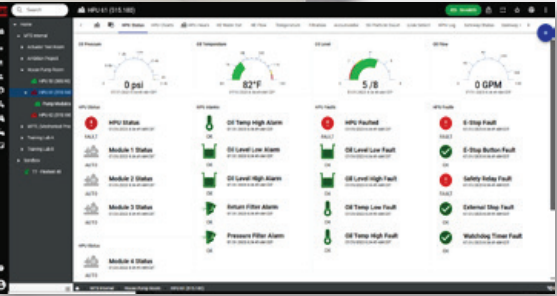
**RPC Connect Software**  
*Architected to optimize durability test efficiency and productivity:*

- » Productivity-enhancing user interface
- » High-throughput Test Stage
- » Supports advanced iteration methods and hybrid simulation

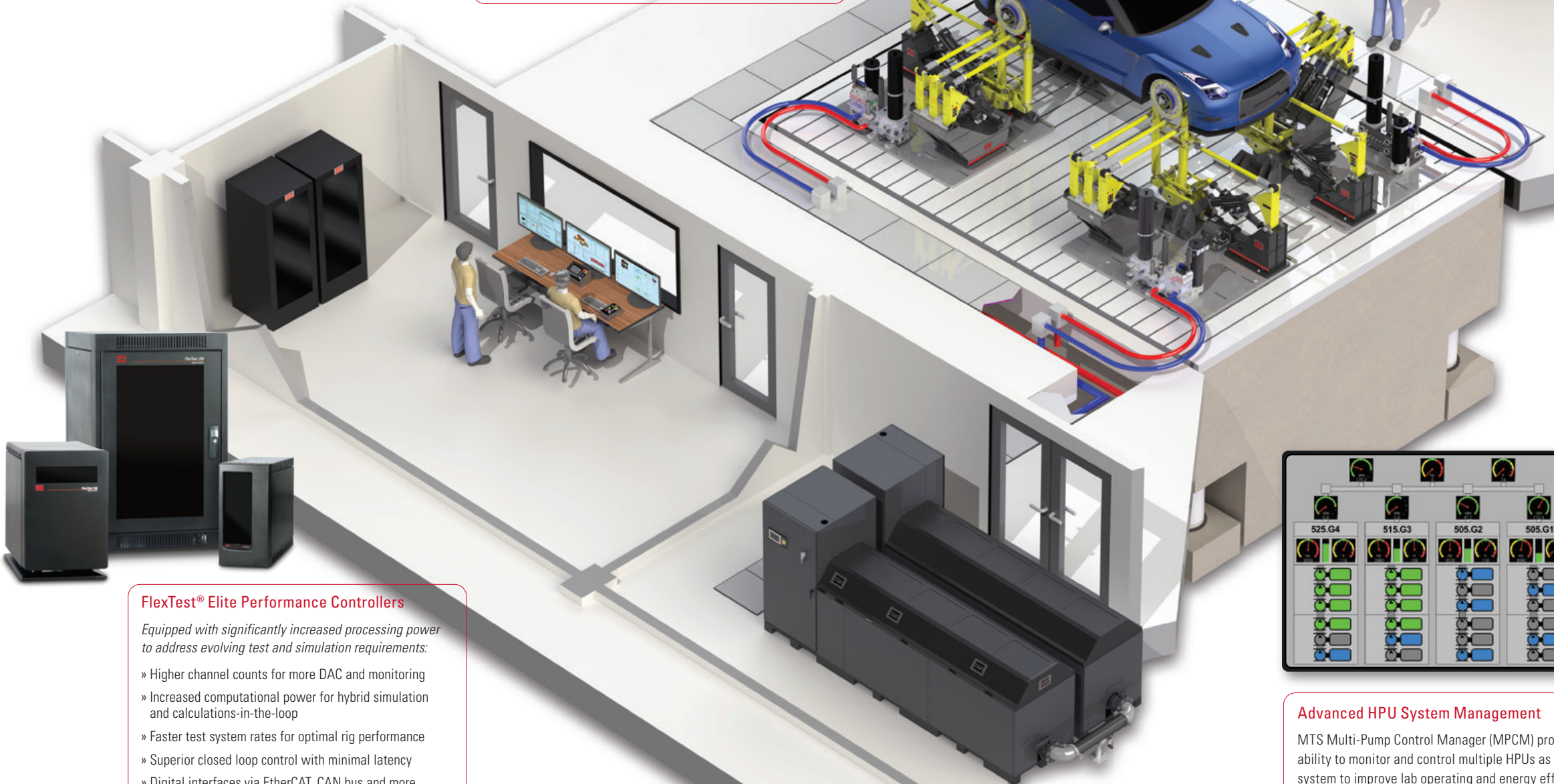


**Refined 329i Kinematic Design**  
*Engineered to maximize test accuracy, throughput, and rig longevity:*

- » Up to 80 Hz road input
- » New, robust wrist joint design
- » High-fidelity, long-lasting MTS DuraGlide linear actuators
- » Available in passenger car and light truck configurations



**Condition-Based Monitoring**  
MTS Echo® Software enables real-time, remote monitoring of test status and equipment health via web-enabled smartphone, laptop, or tablet.



**FlexTest® Elite Performance Controllers**  
*Equipped with significantly increased processing power to address evolving test and simulation requirements:*

- » Higher channel counts for more DAC and monitoring
- » Increased computational power for hybrid simulation and calculations-in-the-loop
- » Faster test system rates for optimal rig performance
- » Superior closed loop control with minimal latency
- » Digital interfaces via EtherCAT, CAN bus and more



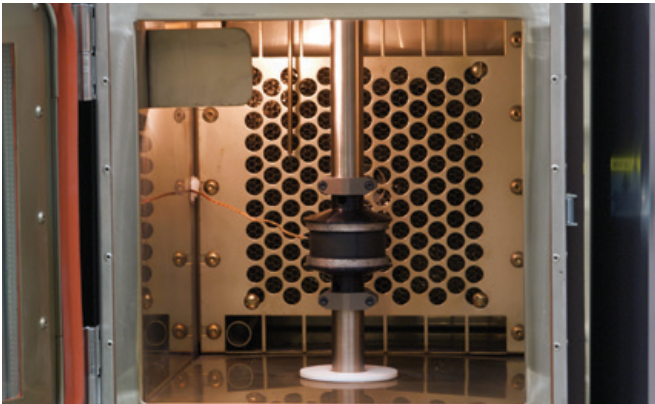
**Advanced HPU System Management**  
MTS Multi-Pump Control Manager (MPCM) provides the ability to monitor and control multiple HPUs as a single system to improve lab operating and energy efficiency and prolong equipment life.



Vehicle Dynamics Solutions

MTS offers a broad selection of test & simulation solutions designed to help you gain precise measurements earlier in the development cycle, enabling more efficient optimization of component, system and full-vehicle performance. The MTS vehicle dynamics portfolio features:

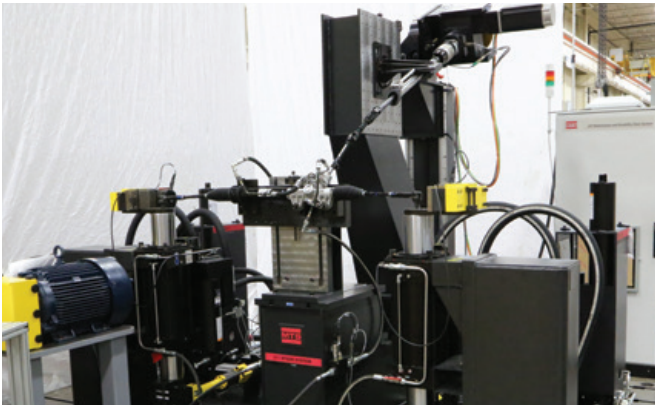
- » Flat-Trac® Roadways, which combine tire-coupled road simulation and flat-belt roadway technology to create a realistic laboratory environment for evaluating noise, vibration transmissibility, suspension performance, and fuel economy
- » MTS Kinematic & Compliance (K&C) systems for quickly and efficiently measuring key suspension parameters
- » Dynamic Kinematic & Compliance (DK&C) systems for simulating rough road inputs and transient maneuvers
- » State-of-the-art single and multi-belt wind tunnel rolling road systems for evaluating vehicle aerodynamics
- » Numerous subsystem-specific testing solutions
- » Robust and efficient tire force and moment measurement, rolling resistance measurement and tread wear simulation systems
- » A variety of elastomer, damper and materials characterization solutions
- » Leading-edge hybrid simulation solutions



Elastomer Test Systems



Tire Force & Moment Measurement Systems



Steering Test Systems



Multiaxial Simulation Table (MAST) Systems



12 Dynamic Kinematic & Compliance (K&C) Systems



Dynamic Flat-Belt Roadways

Expanding MAST Capabilities: Dual-Mode MAST System

Electric and autonomous vehicles are driving an intensified focus on occupant ride comfort, prompting increased need for human-rated, 6DOF vibration simulation capabilities. To help meet these demands, the new Model 353.20 DM (Dual Mode) MAST delivers an expanded application range that includes both durability and NVH testing, and occupants-on-the-table ride comfort evaluation.

Driven by ISO 13849-1:2015 (Safety of machinery – Safety related parts of control systems), the 353.20DM integrates advanced MTS Safety PLC technology, new hydromechanical manifolds, an array of human interfaces and test space monitoring devices to ensure safe and efficient switching between full-performance durability testing and reduced-performance ride comfort evaluation.

Available via turnkey system or 353.20 field upgrade, MTS Dual Mode MAST technology is purpose-engineered for conducting human-rated vibration simulation that complies fully with ISO 13090-1 and ISO 2631-1.



Multiaxial Simulation Table (MAST) Systems

A circular logo with 'HYBRID' in the center and 'SIMULATION' around the perimeter, with arrows indicating a cycle.

### mHIL Steer Test System

#### Accelerate ADAS Steering Development

Use proven mechanical Hardware-in-the-Loop (mHIL) technology to create a real-time, vehicle-level simulation environment for evaluating hydraulic, electric, or steer-by-wire power steering systems and ADAS steering functionality well in advance of functional, full vehicle prototypes.

mHIL Steer combines a physical power steering system under test with a real-time vehicle model adapted for steering inputs. This hybrid simulation setup can employ an MTS standard 3-5 channel multi-purpose servohydraulic steer test system, or alternatively, a custom all-electric performance variant available in 2-3 channels.

A photograph of a custom electric performance variant of the mHIL Steer test system, showing a complex assembly of actuators and control units.

A photograph of a standard servohydraulic system, featuring large hydraulic cylinders and manifolds.

- » Enhance CAE model development
- » Conduct accurate simulations earlier in vehicle development
- » Dramatically reduce proving ground dependency, validation costs and need for prototypes



Next-Generation K&C System



The latest addition to MTS' K&C portfolio is purpose-built for precise and repeatable passenger car and SUV suspension measurement.

Smaller, lighter and easier to install than its predecessors, this new Passenger Car K&C system performs the full spectrum of kinematics and compliance deflection measurement applications, including suspension and steering characterization, benchmarking and target setting, model verification, evaluating design changes, and diagnosing problems. As with all MTS K&C systems, system-level calibration methods are employed to ensure optimal measurement accuracy.

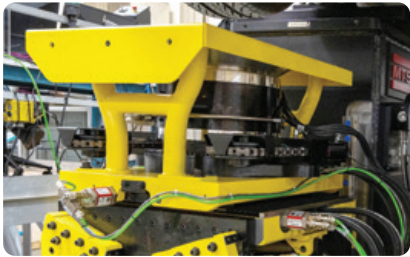
Ideal for characterizing fast-evolving electric vehicle designs, the next-generation Passenger Car K&C system features re-engineered steer input assemblies with increased torque and angle, new high-fidelity wheel motion sensors, new highly adjustable body lamping, increased track width and wheelbase adjustment, and a new operator's pendant for safe test vehicle installation.

State-of-the art MTS controls and software can be used to extend the utility of K&C systems to include dynamic operation, real-time hybrid simulation, and the integration of ancillary EtherCAT devices.



High-fidelity Wheel Motion Sensors

- Larger wheel motion range:
- » Longitudinal:  $\pm 90$  mm
  - » Lateral:  $\pm 90$  mm
  - » Vertical:  $\pm 240$  mm
  - » Camber Angle:  $\pm 10^\circ$
  - » Spin Angle:  $\pm 45^\circ$
  - » Steer Angle:  $\pm 45^\circ$



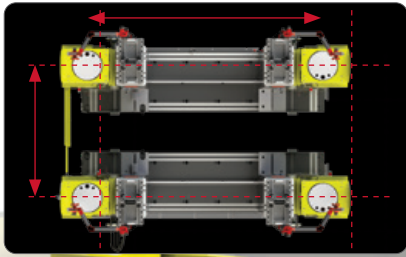
New Steer Input Assemblies

- Linear-to-rotary design delivers enhanced performance for characterizing electric vehicles:
- » Increased steer angle ( $\pm 50^\circ$ )
  - » Increased steer torque ( $\pm 1000$  Newton-meters)
  - » No backlash
  - » Better control & safe limited speed operation



Flexible Body Clamping

- » Multiple clamp offerings with varying degrees of adjustability
- » Electric vehicle clamping featured



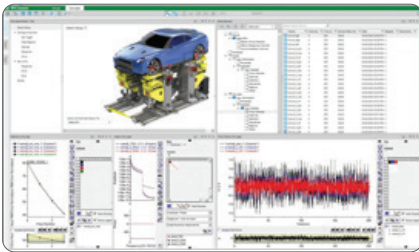
Increased Track Width & Wheelbase

- » Wheel Track: 1080 - 1830 mm (750 mm)
- » Wheel Base: 1800 - 3600 mm (1800 mm)



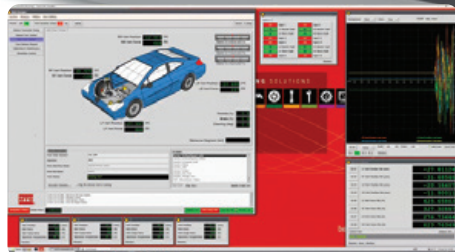
Full-featured K&C Application Software

- » K&C testing workflow
- » Multi-mode control
- » Flexible user programming
- » Analysis software



RPC® Connect Software

- » Dynamic operation
- » RPC time history playback
- » Playback and measurement to 10 Hz
- » Maneuver decomposition



mHIL Integration/User Interface

- » Mechanical Hardware-in-the-Loop (mHIL) integration and capability
- » CAN / dSPACE communications
- » EtherCAT communications
- » Control of ancillary devices



Hand-held Operator Pendant

- » Safety system status
- » Jog Mode to aid in spindle-coupled specimen installation
- » Specimen setup available with hydraulics on






System-level Calibration

- On-system calibration for maximum accuracy:
- » 6DOF calibration @ each corner (Fx, Fy, Fz, Mx, My, Mz)
  - » 4-corner system calibration
  - » Fixturing provided for quickly verifying machine accuracy between formal calibration events



# MTS Elastomer Testing Portfolio

Uniaxial







MTS Acumen System

MTS Landmark System




MTS Landmark System

Multiaxial

Model 832 System



Model 831 Biaxial System

Model 830 System

Model 831 System

Model 834 System

Model 833 System

Model 836 System

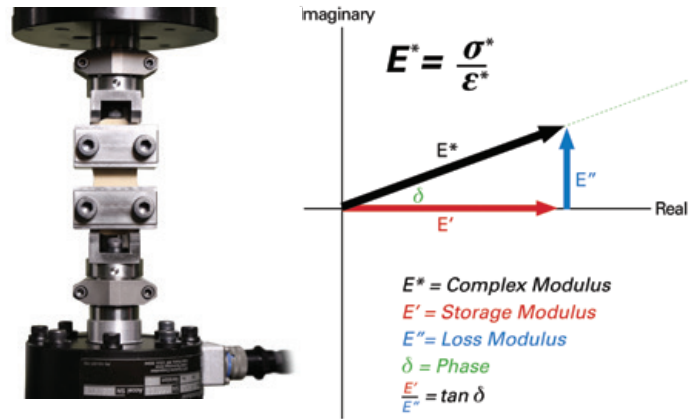
## MTS Acumen® Test Systems

Ideal for automotive elastomer characterization and materials lightweighting, MTS Acumen Electrodynamic Test Systems deliver superior precision and ease of use for dynamic and static testing. Energy-efficient electrodynamic actuation enables these flexible systems to be installed quickly with minimal impact in your facility.



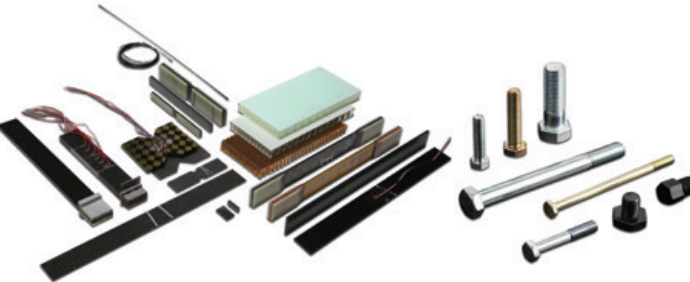
## ELASTOMER CHARACTERIZATION

Measure the static and dynamic behaviors of tire materials, suspension components, and engine and exhaust mounts.



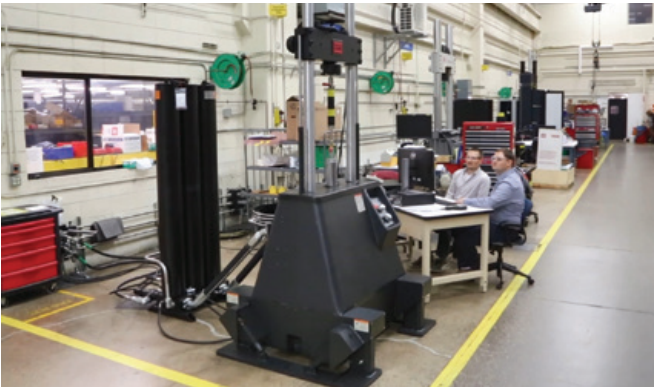
## LIGHTWEIGHTING

Determine the static and dynamic properties of plastics, composites, metals, fasteners and adhesives.



# The Evolving MTS Damper Portfolio

The MTS damper testing portfolio continues to evolve, adapting to meet more challenging test requirements and growing demands for improved test system efficiency. Once exclusively servohydraulic, this expanded portfolio now features both high-performance electric and servohydraulic systems to fulfill a complete range of test applications, spanning quality, characterization, friction force, noise and durability.







853

EMA Lo-Noise

EMA

NVH

PERFORMANCE

ELECTRIC





849

850

852

DURABILITY

SERVOHYDRAULIC

## HYBRID SIMULATION mHIL Damper Test System

### Accelerate Active & Semi-active Damper Development

Use proven mechanical Hardware-in-the-Loop (mHIL) technology to create a real-time, vehicle-level simulation environment for testing semi-active or active damper, suspension, and body control systems.

- » Enhance CAE model development
- » Conduct accurate simulations earlier in vehicle development
- » Dramatically reduce proving ground dependency, validation costs and need for prototypes



The **mHIL Damper Test System** combines a physical sub-system of components with a vehicle model adapted for damper and spring inputs.



Modular TestLine™ Component Test Solutions

Precision-engineered components for building your test solution right the first time



Photo courtesy of CTAG

TestLine Solutions comprise a versatile and reliable set of modular test components and standard hardware and software tools that enable you to create cost-effective test systems that can be reconfigured as your needs change. You supply the in-house design capability and imagination, MTS provides the premium-quality products and components to help build your test solution right the first time.

Precision-engineered to the highest quality and designed for seamless integration, the modular components and the standard hardware and software used in TestLine Solutions are the same as those integrated into the most advanced MTS custom test systems.

Modular Test Rig Concepts

Lower Control Arm Test

Motor Mount Test

Knuckle Test

Axle Torque Test

MTS TestLine Components

MOCOKIT® Portal Frames

Rod End Spacer Assemblies

Rod End Block Assemblies

Rod End Spacers

Pillow Block Bearings

Reaction Stand Weldments

Universal Struts

Bell Crank Assemblies

Lever Assemblies

MTS Standard Products

MTS DuraGlide® Linear Actuators

MTS DuraGlide® Rotary Actuators

MTS 252 Servovalves

Load Cells

MTS 293 Hydraulic Service Manifold (HSM)

MTS 295 Isolation Hydraulic Service Manifold (IISM)

SilentFlo™ Hydraulic Power Units (HPU)

MTS Application Software

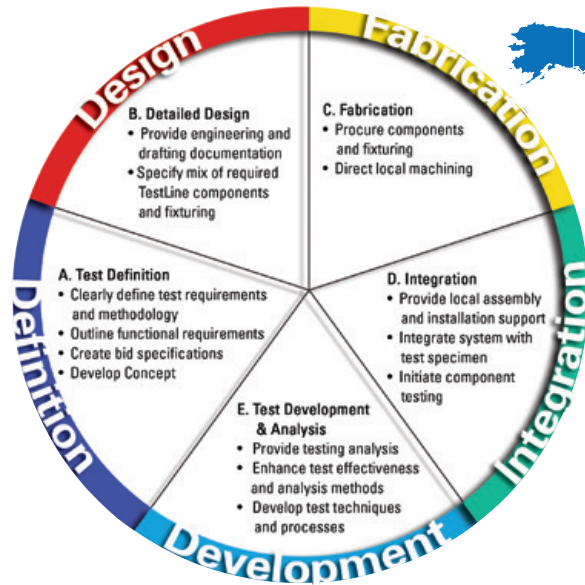
FlexTest® Controllers



## MTS TestStand Solutions

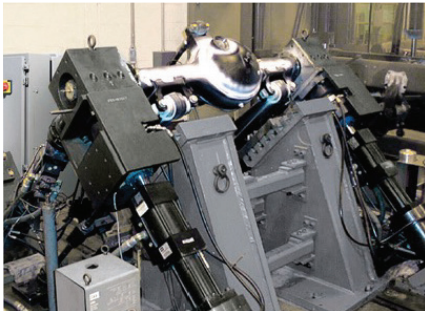
*A collaborative approach to test system design and fabrication*

The MTS TestStand approach is a collaborative effort between a test lab and MTS. Working together, lab engineers and MTS experts first define specific test objectives, and then quickly formulate a solution to achieve them within available budget and time constraints. This is accomplished by tapping decades of MTS automotive testing expertise, and leveraging the appropriate mix of MTS technology and cost-effective in-house or local manufacturing. Labs that opt for the MTS TestStand approach can expect a high-quality component test system delivered in the most cost-efficient, timely and low-risk manner possible, which can be deployed to meet today's requirements and serve as a configurable, modular platform for addressing future needs. Contact MTS today and explore how the MTS TestStand approach can help your lab adapt to evolving component testing challenges with speed, efficiency and confidence.



Available throughout North America, the MTS TestStand approach delivers high-quality test systems in the most cost-efficient, timely and low-risk manner possible.

### Custom Component TestStand Examples



#### Axle Housing TestStand - 2DOF

Designed to test and validate the durability of axle housings by introducing biaxial bending forces.



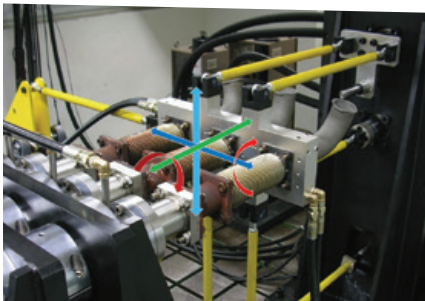
#### Agricultural Equipment TestStand - 3DOF

Designed to evaluate the durability of trailed agricultural equipment, such as furrow presses or plows, by applying vertical, roll and pitch motions.



#### Bushing Durability TestStand - 4DOF

Designed to test and validate the durability of automotive bushings by applying combinations of axial, radial, torsional and conical loads.



#### Exhaust Flex Coupling TestStand - 5DOF

Designed to test and validate the durability and performance of exhaust flexible couplings by applying lateral, longitudinal, vertical, pitch and roll motions.



#### Steering Knuckle Fatigue TestStand - 3DOF

Designed to test and validate the durability of suspension knuckles by simultaneously applying vertical, lateral and longitudinal forces.



#### Suspension Member Fatigue TestStand - 3DOF

Designed to test and validate the durability and performance of automotive suspension components by simultaneously applying vertical, lateral and longitudinal forces.



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