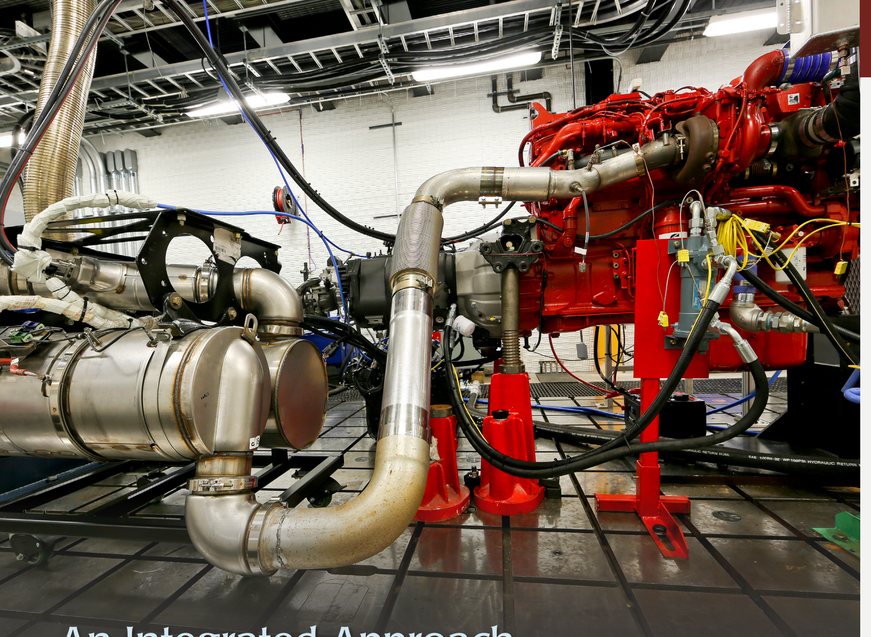


An Integrated Approach

to Advanced Transportation Technologies

Using Advanced Technologies to Research Transportation

Rising transportation fuel costs and clean air regulations have increased the focus on vehicle fuel efficiency and emissions control, highlighting a need for more aggressive research into advanced powertrain technologies. Developing technologies that meet the requirements of integrating these novel designs can be taxing on limited budgets and engineering resources.

ORNL's Vehicle Systems Integration (VSI) Laboratory was created to accelerate the pace of powertrain development by performing prototype research and characterization of advanced systems and hardware components. In doing so, the VSI Lab contributes to the larger mission — established by ORNL's Center for Transportation Analysis (CTA) — of supplying the foundational data needed to define future vehicle architectures. The VSI Lab is capable of accommodating a range of platforms from advanced light-duty vehicles to hybridized Class 8 powertrains with the goals of improving overall system efficiency and reducing emissions. Coupling this data-rich asset with CTA's complementary capabilities in analysis, modeling, simulation, and visualization represents a powerful resource for users.

Bridging Core Competencies at ORNL

The VSI Lab is co-located with two transportation-centric research centers at ORNL, enhancing its comprehensive responsiveness to virtually any request or project requirement in vehicle systems integration. The Fuels, Engines and Emissions Research Center (FEERC) at ORNL offers advanced combustion cycle and analytical chemistry expertise and unique emissions measurement capabilities, as well as extensive expertise in high efficiency combustion, alternative fuels, and advanced lubricants. For in-depth power electronics and electric machine component analysis and evaluation, the VSI Lab can access complementary capabilities in the Power Electronics and Electric Machinery Research Center (PEEMRC). PEEMRC offers a broad spectrum of state-of-the-art measurement equipment along with a rapid prototyping mechanical fabrication shop. Characterization of high power traction drive systems is critical to understanding overall vehicle system efficiency.

Advanced Powertrain Development

from a Vehicle Perspective

Full Heavy-Duty Powertrain Integration R&D Facility

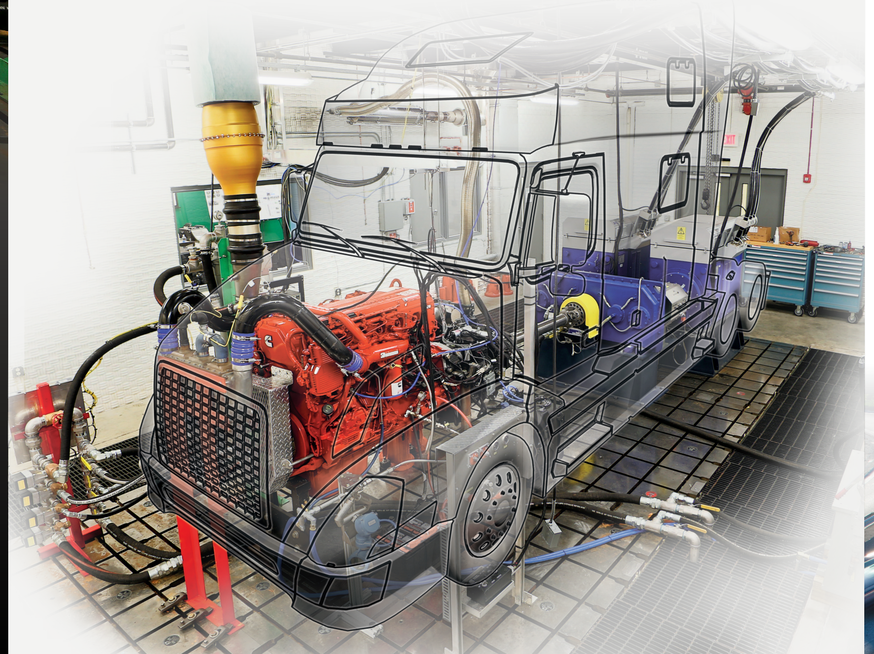
- Capability for light-duty through heavy-duty vehicle powertrain systems
- Scalability from component level (engine, electric motor, and energy storage) to powertrain integration research
- Versatility of vehicle types such as conventional, traditional hybrid, and grid-connected

Advanced Energy Storage System Emulation

- Bi-directional, high power transfer capabilities with scalable energy capacity
- Industry standard modeling framework to simulate wide variety of battery chemistries and architectures, kinetic energy recovery systems, ultra capacitors, as well as battery management systems

Virtual Vehicle Level Test and Simulation

- Rapid deployment of vehicle models for use in real-time hardware-in-the-loop (HIL) platform to simulate a variety of weight classes, vocations, and architectures
- Emulation of transient drive cycles – such as standard, user-defined, or custom-developed – using extensive field-collected data retained in ORNL's exclusive MTDC and HTDC databases
- Hardware configurations analyzed through simulation of real-world conditions



VSI Test Cell Capabilities

VSI Powertrain Test Cell

- Powertrain "X"-in-the-loop environment capable of testing light-duty to full heavy-duty Class 8 powertrain at a vehicle level
- Heavy-duty focus to evaluate engines, transmissions, and integrated powertrains, as well as inherent full light-duty powertrain capability

Specifications:

- Twin AVL 500 kW AC transient dynamometers, each capable of up to 3,750 N·m of torque
- Acceleration/deceleration rates of up to 3,500 rpm/sec
- Up to 20,000 N·m of torque when dynamometers are linked through summing gearbox for powertrain applications

VSI Component Test Cell

- Component "X"-in-the-loop environment capable of testing engines, electric machines, and energy storage systems at a vehicle level
- Light-duty focus with medium-duty powertrain component capability

Specifications:

- An AVL 250 kW, low-inertia dynamometer capable of up to 650 N·m of torque
- 12,000 rpm high-speed capability
- Double-ended to accommodate two independent experiments simultaneously

Shared Features:

- An AVL 400 kW (up to 800 V and 600 A) energy storage emulator with stand-alone flexibility to simulate and evaluate different energy storage systems
- A dSPACE HIL real-time platform for vehicle and subsystem emulation
- Dual transient emissions measurement system for criteria emissions and particulate matter

Core Research Areas

Powertrain Systems Integration

- Focus on interfacial relationships among individual powertrain components
- Analysis of transient phenomena including thermal effects and emissions
- Evaluation of advanced component technologies in a vehicle systems context

Development of Practical Energy Management Strategies

- Understand how vehicles are bounded by powertrain limitations and performance expectations
- Holistic strategy development encompassing emissions reduction and fuel efficiency trade-offs

Evaluation Procedures and Standards Development Applicable to Individual Components and Integrated Powertrain Systems

Shaping America's mobility future

Hybrid Powertrain X-in-the-Loop Architecture

The VSI Lab features an "X"-in-the-loop platform to test a powertrain component or subsystem in a virtual vehicle environment. For instance, a hybrid drive system commissioned in the VSI Powertrain Test Cell would comprise:

Unit Under Test

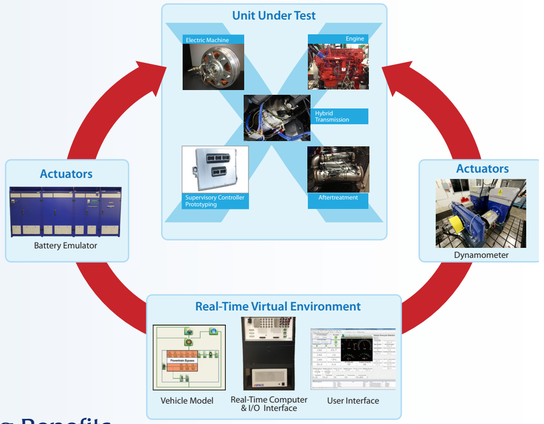
- Engine with or without corresponding emission aftertreatment
- Hybrid transmission including necessary electric machines and power electronics

Real-Time Virtual Environment

- Modeling of driveline and vehicle characteristics
- Modeling of energy storage system with representative battery management controls

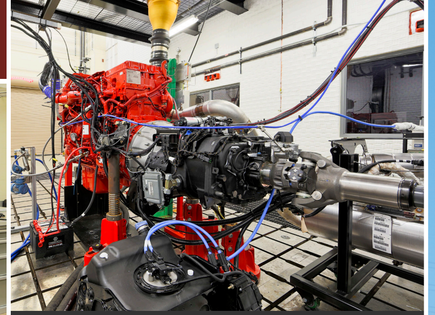
Actuators

- Energy storage system emulator
- Twin 500kW dynamometers through summing gearbox



X-in-the-Loop Testing Benefits

- Flexibility to change virtual vehicle architectures and experimental conditions
- Accuracy of real engine and aftertreatment measurements
- Repeatability of a controlled transient operating environment
- Lower costs and safer environment compared with track or on-road vehicle analysis



Significant Collaborations

- Cooperative Research and Development Agreement with Meritor, Inc. for the development and characterization of Meritor's Dual Mode Hybrid Powertrain system and its power management control algorithms for optimized fuel economy for Class 8 heavy-duty line haul vehicles
- Cooperation with government, industry, and other national laboratory partners to develop standards and procedures for conducting fuel economy and emissions evaluations of heavy-duty powertrain systems with emphasis on "power pack" evaluation methods
- Support of the DOE's Vehicle Technologies Office by providing advanced transient component benchmarking capability

Vehicle Systems Integration Laboratory

Shaping America's mobility future

For more information about Vehicle Systems Integration research, contact:

CENTER FOR TRANSPORTATION ANALYSIS
Oak Ridge National Laboratory
2370 Cherahala Blvd.
Knoxville, TN 37932
Website: http://cta.ornl.gov
(865) 946-1324

Developing vehicle technologies through integrated systems emulation to address America's demand for cleaner, more efficient powertrains.

U.S. DEPARTMENT OF ENERGY

Vehicle Systems Integration Laboratory research will directly support the DOE Office of Energy Efficiency and Renewable Energy, as well as the DOE Office of Science. The research will also support other DOE offices and programs, other government agencies, research organizations in the private sector, and private industry.

15-G00969/cae

OAK RIDGE National Laboratory