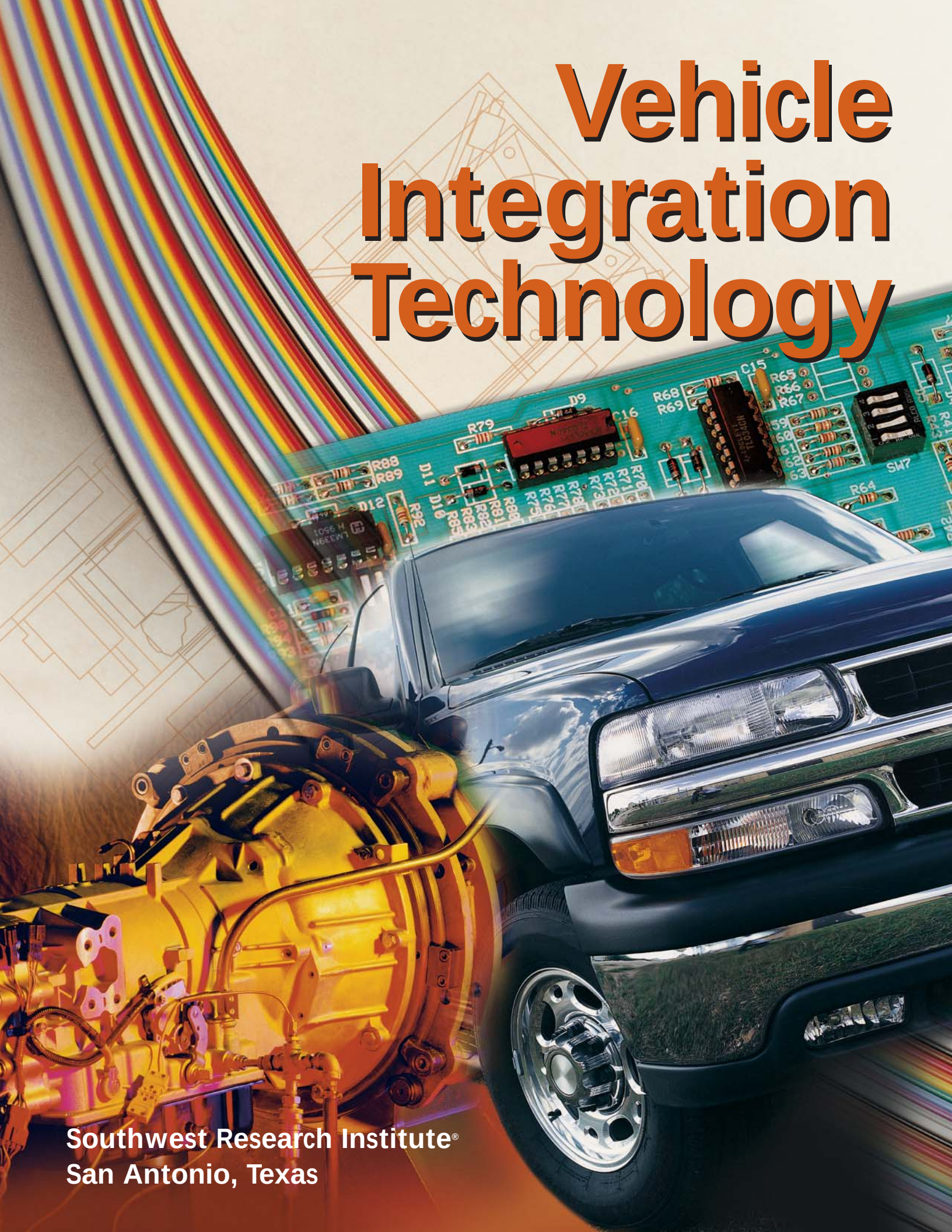
Vehicle Integration Technology



Southwest Research Institute®
San Antonio, Texas

Southwest Research Institute®

Founded in 1947 as an independent, nonprofit research and development organization, Southwest Research Institute provides a significant research, engineering, and testing resource for industry, businesses, and government. The Institute uses a multidisciplinary, integrated approach to solving complex problems in science and applied technology.

Successful vehicle integration merges thousands of individual components into a smoothly functioning vehicle. Problems with efficiency, performance, weight, vibration, packaging, and noise are solved using advanced engineering techniques and creative problem-solving approaches. With more than 50 years of experience in providing innovative solutions to complex problems for the automotive industry, Southwest Research Institute (SwRI®) has extensive expertise in a wide range of vehicle-related technologies, including:

- Component modeling
- Efficiency projections
- Energy and power consumption
- Vehicle performance simulation
- Control logic development
- Component packaging
- Structural evaluation
- Weight distribution and handling
- Wiring and hose routing
- Packaging

As a multidisciplinary research and development organization, the Institute is uniquely qualified to aid automotive manufacturers and their suppliers in producing world-class vehicles. SwRI's Engine and Vehicle Research Division has achieved certification to ISO 9001, ensuring compliance with stringent quality control procedures in design, development, and research.

Engine and Vehicle Simulation

A vehicle consists of many different types of components. Integrating this diverse group involves tradeoffs of performance, efficiency, cost, reliability, weight, and packaging. Modeling and simulating components and subsystems of the vehicle allow engineers to optimize the overall system. SwRI engineers have developed a comprehensive vehicle simulation program that evaluates a wide variety of vehicles and their components, including:

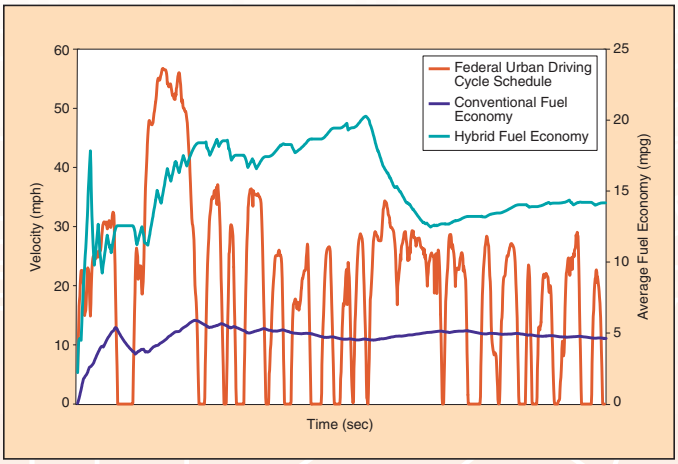
- Engines
- Transmissions
- Powertrain controllers
- Axles
- Electric motors
- Motor controllers
- Batteries
- Suspension systems
- Brakes
- Chassis
- Hydraulic systems
- Auxiliary systems

SwRI-developed simulation programs evaluate numerous vehicle parameters, such as:

- Powertrain systems
  - Conventional
  - Parallel hybrid
  - Series hybrid
  - Fuel cell and reformer
- Weight
- Aerodynamic configuration
- Rolling resistance
- Vehicle type
  - Passenger
  - Military
  - Commercial

SwRI has developed a system for transferring simulation results to the laboratory for hardware-in-the-loop tests and evaluations. This proven system includes:

- Real-time simulation code porting and execution
- Rapid prototyping hardware development
- Vehicle and powertrain component simulation via advanced dynamometer control

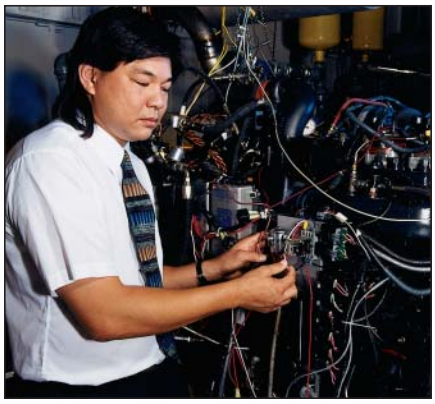


SwRI conducts numerous vehicle simulations such as this fuel consumption analysis that predicts and compares conventional with hybrid vehicles operated over different driving cycles.

An SwRI-developed vehicle controller operates this vehicle as a "flex-fuel" system, using advanced model-based algorithms to control the engine and transmission based on different fuel types.

Vehicle Component Design and Modification

Institute engineers design, develop, and modify a wide range of automotive components. SwRI subsystem specialists use available technologies and advanced developments to integrate these components into the vehicle. Components include:



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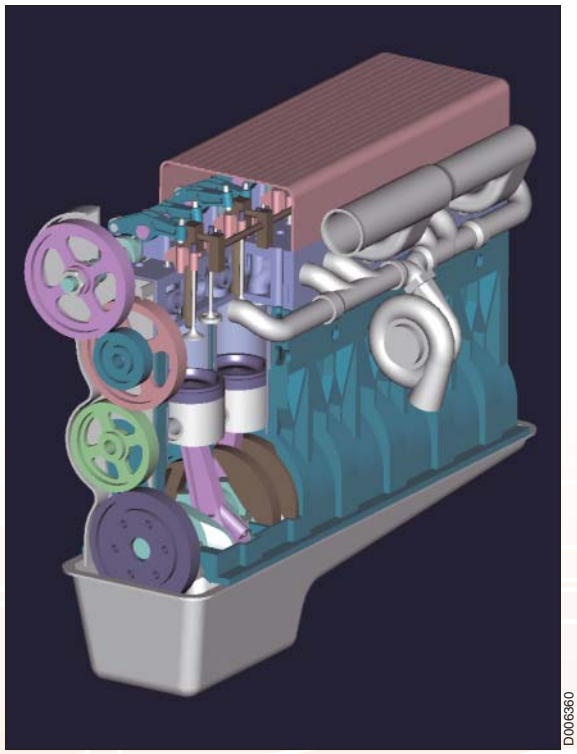
Institute staff members routinely modify gasoline, diesel, and natural gas engines from 50 to 1,000 horsepower.



D006360

SwRI engineers model complete engines to improve performance, emissions, and durability characteristics.

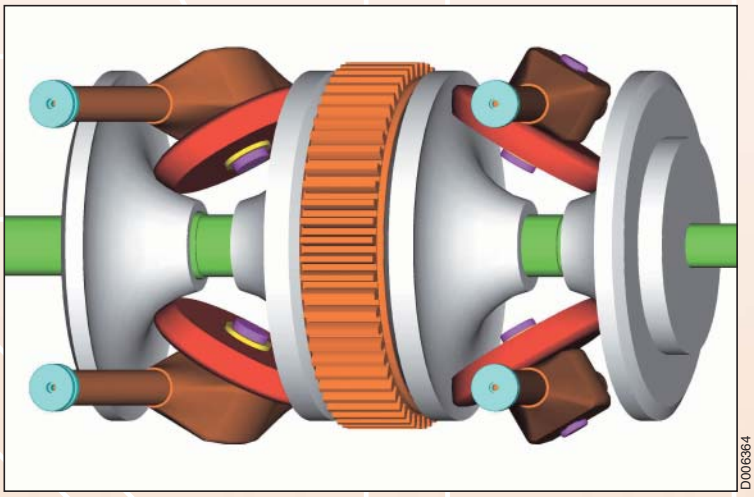
Engines

Complete vehicle design and vehicle modification typically involve new and different engines. SwRI has extensive experience with all types of two- and four-stroke engines, including:

- Gasoline
- Diesel
- Homogeneous charge compression ignition
- Natural gas
- Sterling
- Wankel

Transmissions and Gearboxes

Since 1947, the Institute has helped improve conventional transmissions and develop innovative automatic, manual, and continuously variable transmissions for the automotive, agricultural, and construction industries, as well as the military. With this comprehensive experience, SwRI engineers modify vehicle drivetrains to operate in a wider portion of the vehicle torque-speed operating regime.



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This SwRI-designed dual-cavity, half-toroidal transmission achieves continuously variable ratios across a large ratio range.

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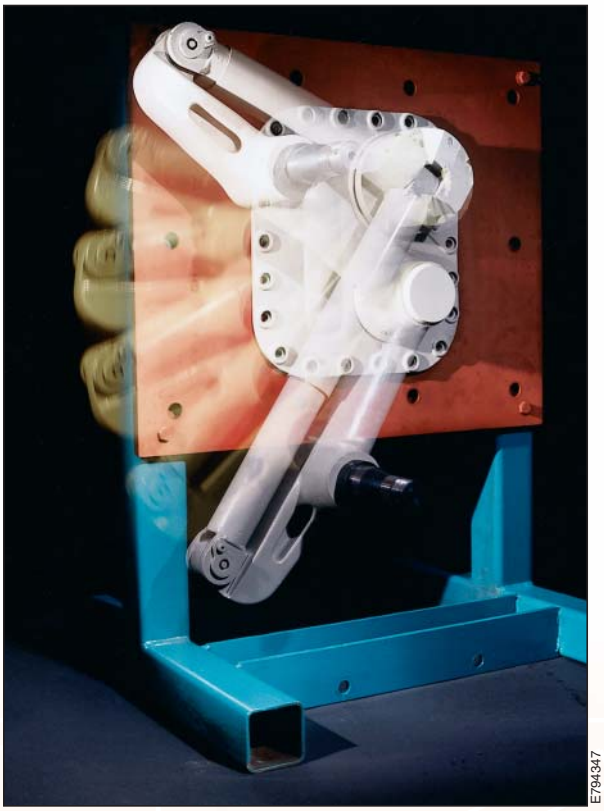
The Institute provides rapid prototyping of all transmission components, including gears, shafts, clutch drums, and housings.



E794347

In working with an amphibious track vehicle, Institute engineers designed and produced a prototype suspension system that retracts during high-speed, water-borne operation and uses a compressible fluid as the spring element for a smooth ride on land.

In obtaining the highest efficiency from a transmission, engineers:

- Evaluate fluid flow
- Select appropriate clutch pack axial clearances
- Use low-drag friction material groove designs
- Design optimal clutch drum evacuation hole profiles
- Reduce windage and churning
- Optimize gear tooth profile

Suspension System

Many vehicle integration projects require the relocation of powertrain components, which affects vehicle weight distribution and alters suspension characteristics. SwRI has developed a vehicle suspension software program that:

- Models springs and damping components
- Determines vehicle response with road configuration, load, and turning maneuvers

D005963

SwRI developed an active large-vehicle suspension system that recovered 75 percent of the actuation energy through regeneration while reducing suspension stiffness and body pitch and roll by half.

E130234

Using innovative rotor material with improved insulating properties, SwRI engineers dramatically increase the kinetic energy loading of the braking system, which permits the vehicle to transport heavier loads.

Braking System

During the design life of a commercial or off-highway vehicle, the vehicle's size and power output are routinely increased. To accommodate these additional requirements, engineers must also increase braking capacity. Using an Institute-developed software program, engineers determine appropriate braking system modifications, including:

- Brake material type and size
- Actuation chamber, cylinder, and line dimensions
- Supplemental braking system requirements
- Hybrid vehicle regenerative braking capabilities

E77810

Institute engineers eliminated unacceptable brake fade associated with this vehicle through modification of friction material type and size, brake chamber size, and fluid valving.

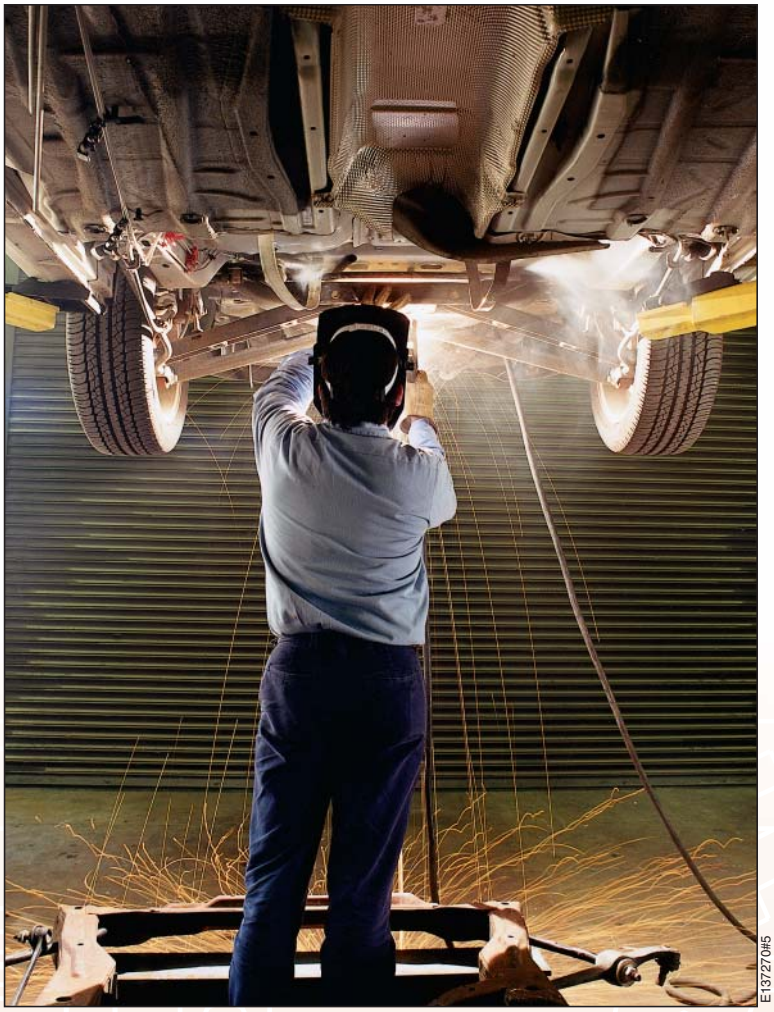
Cooling System

Hybrid vehicles require dramatic upgrading to accommodate the additional cooling requirements of electric motors, electronic drives, batteries, and pumps. To provide adequate cooling for hybrid vehicles, SwRI engineers:

- Determine cooling requirements
- Design heat exchangers
- Develop efficient component heat transfer paths
- Incorporate compact electric pumps
- Design heating circuits to maintain preset temperatures

E13727#5

SwRI staff members, with extensive experience in automotive and vehicle heat flow, modify automotive cooling systems to accommodate higher powertrain capacity.



E13727C#5

Institute engineers evaluate and modify automotive frames to improve riding and handling. Here, an SwRI technician increases the structural integrity of a frame on a test vehicle.

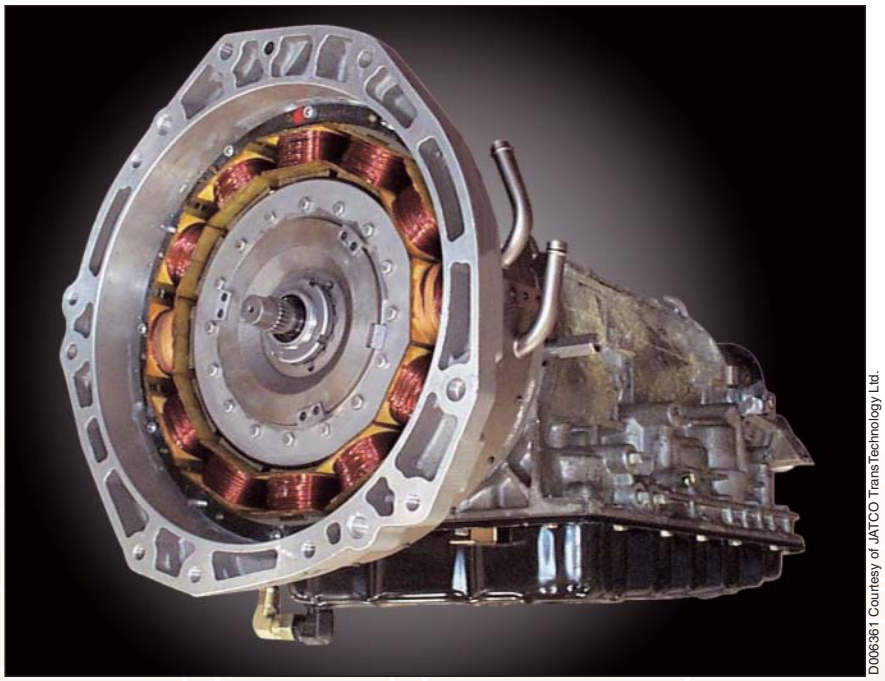
Frames

Higher powertrain capacity results in increased weight and torque-producing drivetrain components, frequently requiring frame modification. Using sophisticated finite element analyses, Institute engineers evaluate numerous vehicle frame characteristics, including:

- Strength and stiffness
- Deflection
- Ride and handling
- Mount isolation

Hybrid Vehicle Design and Development

Automotive manufacturers strive to provide vehicles with dramatically improved fuel economy and reduced emission capabilities. Hybrid vehicles offer the best opportunity to meet these requirements. SwRI offers unique capabilities for electric and hybrid vehicle research and development. The Institute has on staff specialists in modeling, energy-recovery and storage systems, combustion, materials, manufacturing, emission control, and systems integration.



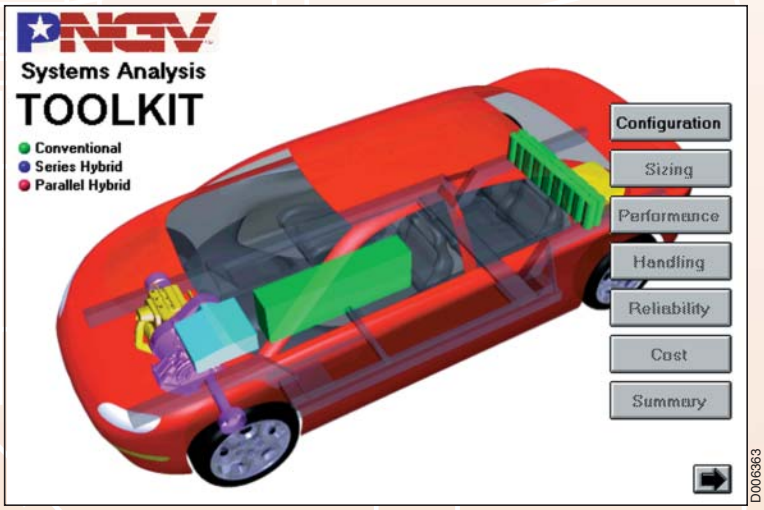
D006361 Courtesy of JATCO TransTechnology Ltd.

Institute engineers designed, prototyped, and developed this hybrid integral transmission to use in a passenger car.

Hybrid Electric Vehicles

In designing and fabricating a hybrid electric vehicle, Institute engineers perform a variety of tasks, including:

- Vehicle and component simulation
- Control algorithm development
- Mode-to-mode transition optimization
- Electric component sizing
- Energy storage determination
- Powerplant and component integration
- Battery evaluation
- Regenerative braking optimization



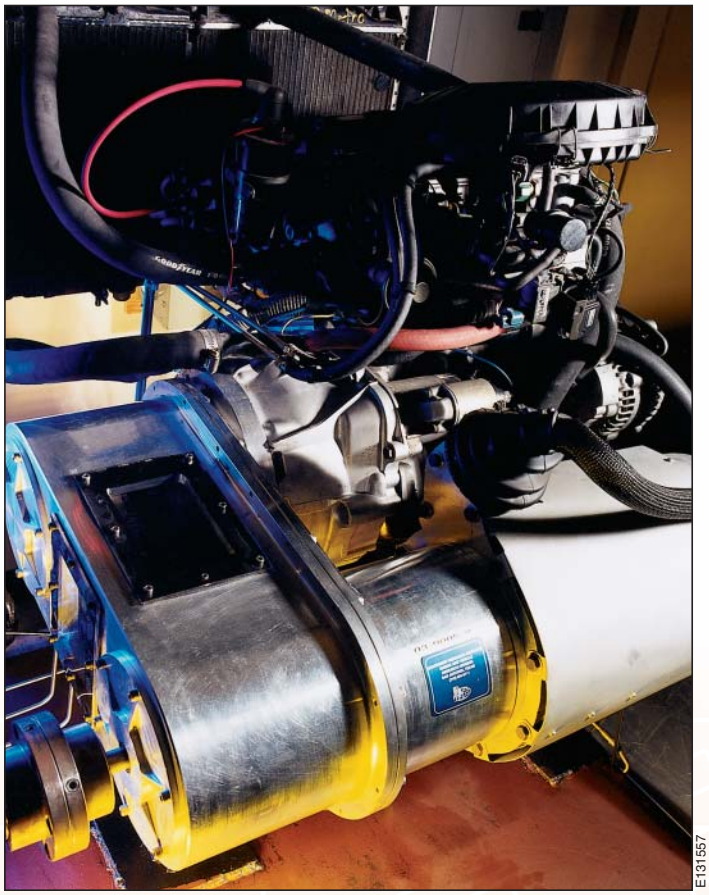
D006363

SwRI developed the Advanced Powertrain Assessment Comparison and Evaluation (APACE) model to allow the Partnership for New Generation Vehicles (PNGV) to optimize components, configurations, and power control strategies for conventional and hybrid vehicles. After entering vehicle information into the model, engineers run the simulation, assessing desired vehicle parameters under varying conditions.

Hybrid Hydraulic Vehicles

Taking advantage of high specific power, hybrid hydraulic vehicles can deliver large amounts of power continuously throughout their speed-torque envelopes. Using extensive experience in designing and fabricating parallel and series hydraulic hybrid vehicles, Institute engineers:

- Package pumps, motors, accumulators, and hoses
- Accommodate high-pressure accumulators, hoses, and fittings
- Develop energy-management controllers
- Design multiple-input gearboxes



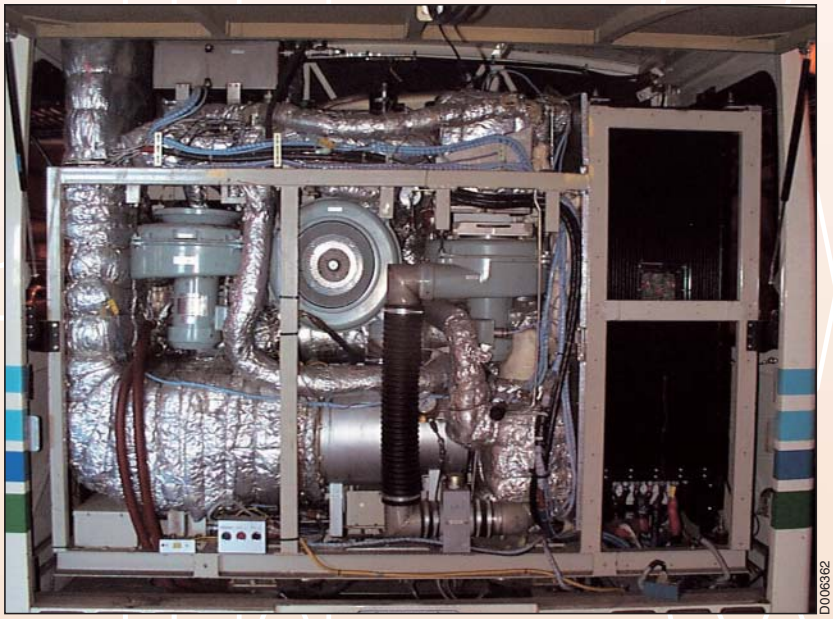
E131557

SwRI designed and developed this hybrid electric drivetrain that can operate in four different driving modes and achieve 70 miles per gallon of fuel.

Fuel Cells

Fuel cells, which harness the chemical energy of hydrogen and oxygen to generate electricity and water, have the potential of radically changing the automotive industry. Making fuel cells practical for automotive use, however, may require on-board reforming of hydrocarbon fuels. The Institute is working with government and industry on fuel cell-related projects such as:

- Performance enhancement
- Thermal management
- System integration
- Alternative hydrogen source evaluation
- Fuel cell characterization
- Materials development
- Catalytic materials



D006362

SwRI is evaluating a phosphoric acid fuel cell-powered hybrid electric bus to determine if the bus can be modified to simplify operations and to allow the bus to be operated in hot climates. Automotive engineers model the existing systems, determine which areas need modification, and integrate appropriate changes.

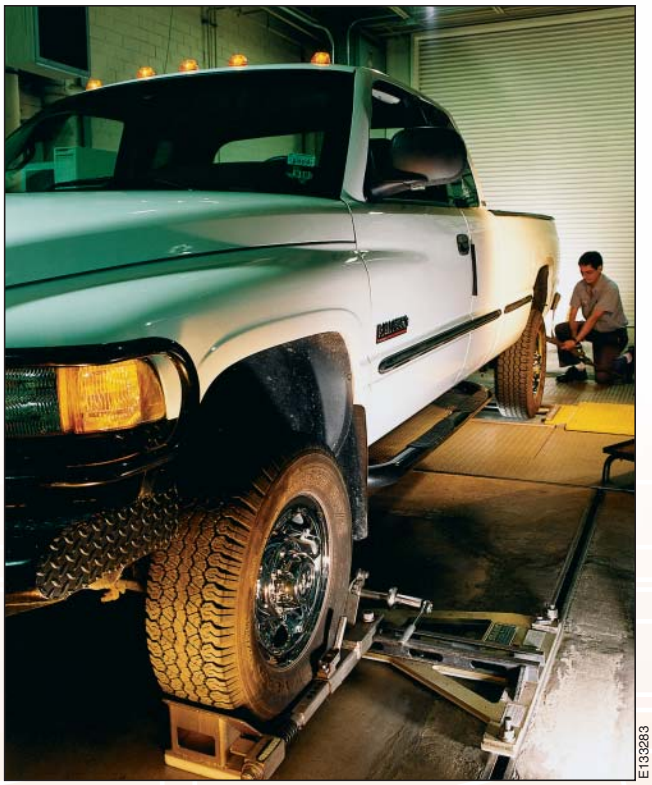
Vehicle and System Testing

After component and vehicle design and fabrication are completed, SwRI conducts a wide range of tests to ensure the vehicle meets its design requirements. These testing programs evaluate:

- Performance, efficiency, and durability
- Structures and components
- Environmental capabilities
- Electromagnetic compatibility

With its comprehensive automotive-related facilities and equipment, SwRI offers a wide range of testing capabilities, including:

- Laboratory
- Dynamometer
- Track
- Fleet



E133283

The Institute offers a variety of testing to evaluate emissions produced during different driving cycles.

The Institute performs whole-vehicle radiated immunity tests using the stirred-mode/reverberation technique, which exposes vehicular microprocessor-based systems and electronic components to a time-averaged homogeneous electromagnetic field. Such fields are produced by broadcast stations, two-way radios, cellular phones, and other radio-frequency devices.

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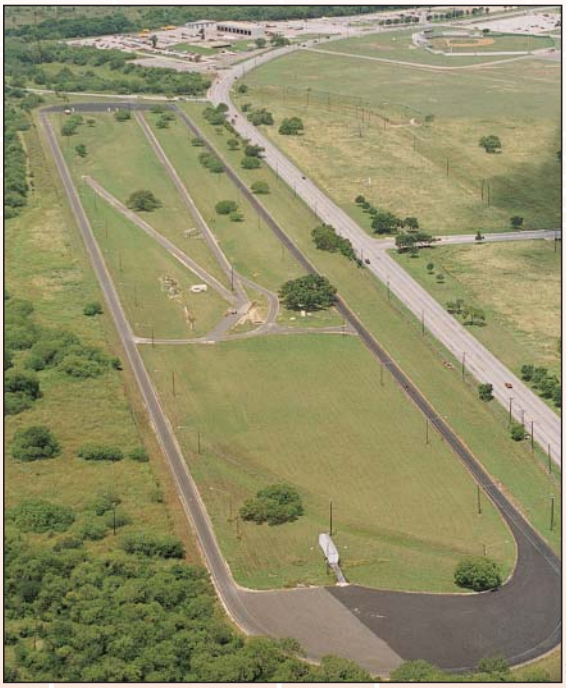
E134605

Vehicles on the mileage accumulation dynamometers are run at speeds up to 100 miles per hour. The SwRI mileage accumulation dynamometer facility provides rapid, cost-effective vehicle testing.



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A one-mile track at SwRI is frequently used to provide bumper-to-bumper driveability, endurance, and component evaluation. An eight-mile track is also available for high-speed testing.

E120024

SwRI conducts high-torque, low-speed testing of agricultural, construction, and off-road equipment to evaluate drivetrain endurance.

Southwest Research Institute is an independent, nonprofit, applied engineering and physical sciences research and development organization using multidisciplinary approaches to problem solving. The Institute occupies 1,200 acres and provides nearly two million square feet of laboratories, test facilities, workshops, and offices for more than 2,700 employees who perform contract work for industry and government clients.

We welcome your inquiries.
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