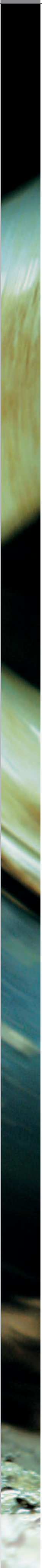
Active suspension control design for off-road applications

Surviving Tough Terrain



In commercial and military vehicles, the improved mobility provided by advanced active suspensions – especially in rugged terrains – becomes a matter of survivability, effective crew performance, safety and reliability. Active suspensions can boost the speed and comfort of off-road vehicles. Prototypes can be used to demonstrate the efficiency of active systems on wheeled and tracked vehicles.

Development Processes for Active Suspensions

The University of Texas Center for Electromechanics (CEM) has been conducting research and development on active suspension technology for over 20 years, and has established a model-based design and validation approach to develop hardware prototypes quickly and economically. The researchers use the proven approach of modeling and simulation with low-level laboratory testing (figure 1) and high-level hardware verification in the field. A model-based design approach requires the use of multiple domain-specific expert tools that can be integrated and used for overall development. Mechanical component model design and controller design are two different paradigms that are closely interconnected. The vehicle platforms, actuators and mechanical components are developed with the 3-D Multibody Simulation with LMS virtual.lab, formerly known as the Dynamic Analysis and Design System (DADS) package from LMS International. The controller models are developed in MATLAB®/Simulink® from Mathworks. The controller simulation is computed concurrently with the DADS Kinematic simulation for offline development and verification of the controller algorithms (figure 2).

Real-Time Simulation, In-Vehicle Testing and Development

After satisfactory performance of the offline, PC-based simulation in research programs that progress to vehicle demonstrations, the EMS controller (EMS = electromechanical suspension system) with its actuator and sensor interface is directly transferred to a dSPACE real-time system. The code generated with the MathWorks Real-Time Workshop in combination with dSPACE Real-time Interface (RTI) is directly targeted to a modular dSPACE system consisting of a processor board and I/O boards. This process facilitates a straightforward transition from simulation, to prototype demonstration, to production hardware.

Role of dSPACE Platform in the Development Process

The development of controller models for real-time application evolves, along with I/O models, to include sensor and actuator interfaces, interrupts from external signals, as well as communication buses such as CAN. An easy, one-button code generation and deployment process makes the iterative development task much easier and faster. It is further aided by a strong user interface and data capturing with dSPACE's ControlDesk tool. ControlDesk is also utilized for code and parameter downloading, terrain stimulus function generator control, and both manual and automated suspension controller parameter tuning tasks. The use of multiple UI layouts allows the operator to quickly get to graphical parameter controls specific to

> "Without a doubt, much of the success of these programs may be attributed to the seamless interaction of the various dSPACE software and hardware components."

Damon Weeks, Center for Electromechanics, University of Texas at Austin

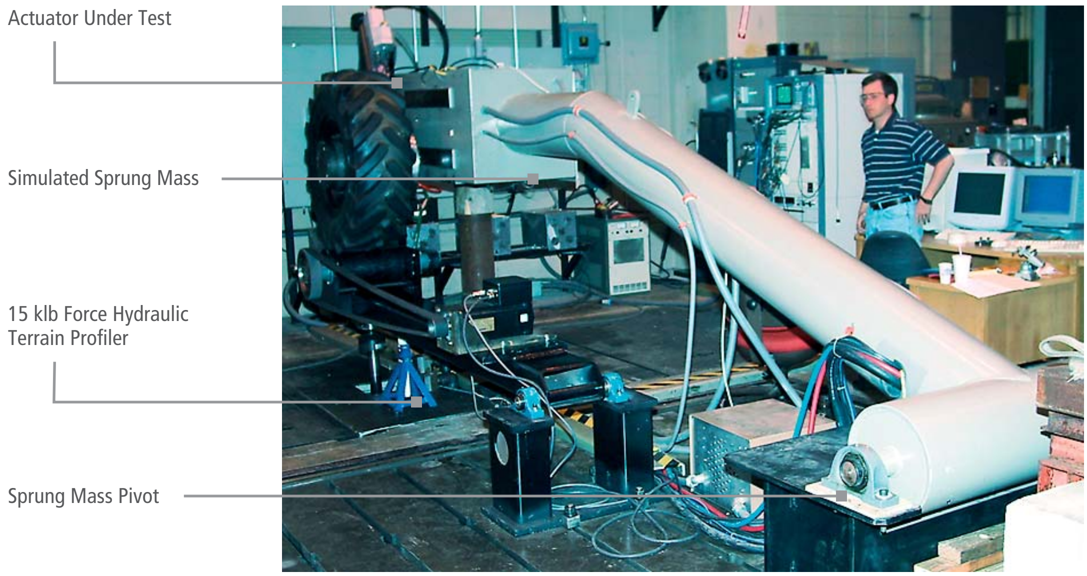


Figure 1: CEM laboratory dynamic test rig used to validate dynamic actuator performance for both mobile (vehicular) and stationary applications. The test rig is suitable for testing at full scale and allows dynamic and static testing. The vertical degree of freedom for sprung mass is approximated by a long pivot arm rotating about the pivot point. The hydraulic ram provides up to 20 inches of simulated vertical motion.

each of the previously mentioned task areas (figure 3).

Measurements with the Flight Recorder

ControlDesk's flight recorder capabilities were used in the development of an adaptive EMS controller. CEM incorporated neural network system identification to update its model parameters. dSPACE engineers worked together with CEM on the nonvolatile storage of the learned model parameters so that they could be written to the flight recorder at shutdown and then read at startup.

Vehicle Demonstrations

CEM has successfully demonstrated EMS technology in multiple vehicle platforms that include manned military wheeled and tracked vehicles (HMMWV High Mobility Multipurpose Wheeled Vehicles, LMTV Light Medium Tactical Vehicles und FCS-Tracked Manned Ground Vehicles). In addition, EMS technology has been deployed on an advanced technology transit bus and an off-road emergency vehicle (figure 4). Off-road performance was measured by a metric called average absorbed power, the mechanical power per kilogram that the vehicle occupants and equipment are subjected to.

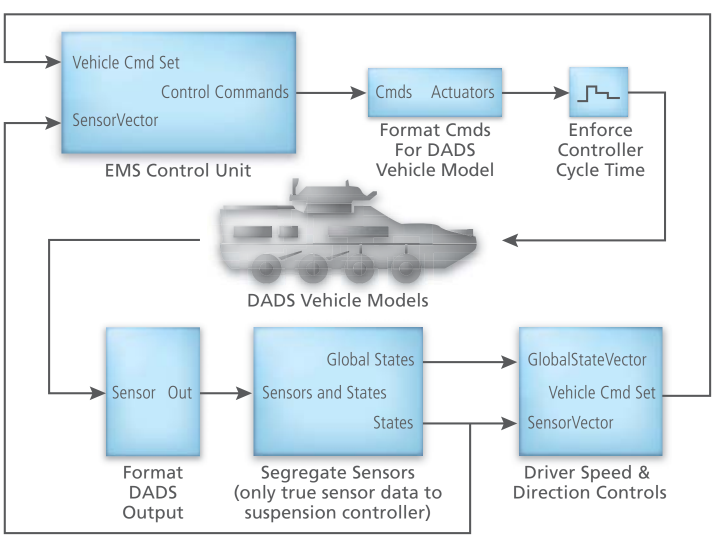


Figure 2: CEM's simulation environment links the Simulink control system and the multibody DADS vehicle model in a co-simulation. Shown here is the top level of the resulting Simulink model.

Figure 3: A typical ControlDesk layout used to develop the active suspension.

> "A common remark from the test team during EMS evaluations was how amazing it was that we could incorporate their suggestions into software changes in just a few minutes."

Damon Weeks, Center for Electromechanics, University of Texas at Austin

Greater Speed and Comfort, Lower Costs

The generally recognized ride limiting absorbed power for a vehicle while negotiating off-road terrain is 6 watt on average. For the military and off-road civilian vehicle demonstrations tested to date, the EMS suspension roughly doubles the 6-watt ride limiting speeds on all but the most severe terrains (with amplitudes so severe that they impinged with vehicle bumpers, skid plates, and/or drive sprockets at higher speeds).
In HMMWV human factors testing performed by the National Automotive Test Center (NATC), US Marine soldiers performed a variety of tasks while negotiating off-road trails. EMS demonstrably improved the ability to complete common tasks such as map orientation, radioing in coordinates, and targeting.
Although initially conceived to improve vehicle ride quality, EMS has demonstrated a 30 % improved off-road fuel economy in coast-down tests, enhanced safety and handling performance through improved understeer characteristics and active vehicle height control, and 50% lower vehicle lifetime operational costs. ■

Damon Weeks,
University of Texas at Austin

Conclusion

Over the past two decades, the Center for Electromechanics (CEM) at the University of Texas has completed more than a dozen EMS demonstrations, of which more than half were prototype demonstrations on military vehicles. CEM used a model-based design approach that coupled expert tools LMS DADS, MATLAB/Simulink and dSPACE Real-Time Interface with dSPACE rapid prototyping systems to develop EMS control systems, design EMS actuator and power system hardware, and predict system performance. Testing performed at various independent test facilities indicates that EMS may double cross-country ride limiting speeds, provide a 30 % improvement in off-road fuel economy, and improve crew function and vehicle handling.

Figure 4: Areas where the EMS suspension demonstration is used.

Damon Weeks
Damon Weeks is a research engineer responsible for electromechanical design at the Center of Electromechanics at the University of Texas in Austin, USA.