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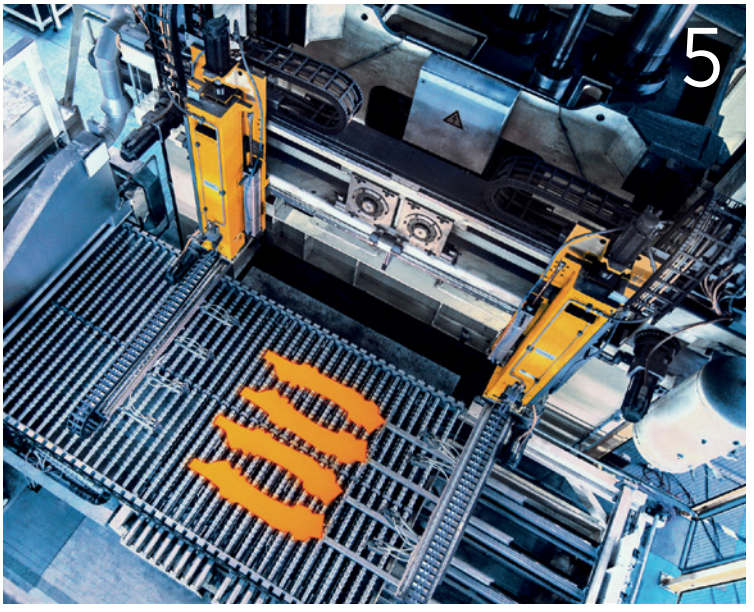
ON THE COVER

A new selectable feature called Smart Power Control (SPC) engine mode comes standard on Doosan's new DX210W-5 wheeled excavator. SPC consists of two systems—Variable Speed Control and Pump Torque Control—that work together to improve machine efficiency while maintaining productivity and reducing fuel consumption.



REGULARS

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WHAT'S ONLINE

FROM OTHER INDUSTRIES

AUTOMOTIVE

Fuel cell futures no longer a dream

The knock on fusion power is that "It is the energy source of the future, and it always will be." It has seemed like the same criticism could be levied against fuel cell vehicles, as their seemingly magical ability to turn stored hydrogen and atmospheric oxygen into motive power for personal transportation—with only water as a by-product emission—has remained tantalizingly out of reach for decades.

But as manufacturers begin to dribble out hand-built, lease-only, limited-market fuel cell cars to meet California's zero-emission requirements, the technical obstacles to fuel cells have been overcome. What remains is some challenging crossing of 't's and dotting of 'i's, because exorbitant costs and challenges like freezing temperatures have been left in fuel cells' rearview mirror.

Read the full article at http://articles.sae.org/14444/.

AEROSPACE

Uncovering safer solutions for aircraft corrosion prevention

Working with aircraft maintainers at the Ogden Air Logistics Complex, researchers from the **Air Force Research Laboratory**'s Environmental Technology (EnviroTech) Program and Coating Technology Integration Office have identified and tested a variety of non-chromium sealers to anodize aluminum aircraft landing gear components to reduce and prevent corrosion.

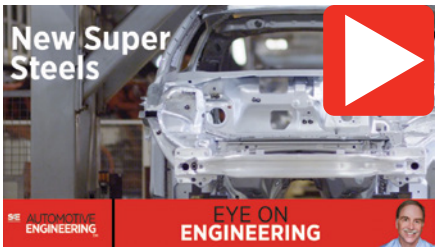
Non-chromium coatings and materials are increasingly important to the USAF because of the harmful nature of chromate-based products. Chromium is listed on the U.S. **EPA**'s list of industrial toxic chemicals due to its toxicity to humans if inhaled or otherwise ingested. In 2009, a U.S. **DoD** directive restricted the use of chromium-based compounds on military vehicles and weapon systems.

Read the full article at http://articles.sae.org/14460/.

VIDEO

SAE Eye on Engineering: New super steels

The quest to make new vehicles lighter involves much more than just using aluminum and plastics. In this episode of SAE Eye on Engineering, Senior Editor Lindsay Brooke looks at "ultra-high-strength" steels, the new materials that are lighter and vastly stronger than automotive steels of the past. SAE Eye on Engineering can be viewed at https://youtu.be/H3GVoNKralQ. It also airs in audio-only form Monday mornings on WJR 760 AM Detroit's Paul W. Smith Show. Access archived episodes at www.sae.org/magazines/podcasts.



Most-viewed articles

The following are the top 5 most-viewed commercial vehicle-related articles of the month as of mid-November. Additional articles across all transportation sectors can be read at http://articles.sae.org/.

1 **Fuel-saving KERS for big-rig trucks**
http://articles.sae.org/14349/

2 **Clean-sheet design for Proterra's all-electric city bus**
http://articles.sae.org/14386/

3 **GHG Phase 2 regs, autonomous vehicles present challenges, opportunities**
http://articles.sae.org/14328/

4 **Software's growth shines spotlight on eliminating defects**
http://articles.sae.org/14402/

5 **Oshkosh's $30B Humvee replacement makes soldier protection a top priority**
http://articles.sae.org/14350/

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EDITORIAL

Making the connection

During a speech in New York City in mid-September, U.S. Secretary of Transportation Anthony Foxx said that over the past year he had "been visiting research labs, technology companies, and manufacturers to deliver a simple message: The **U.S. Department of Transportation** wants to roll out the red carpet, not the red tape, for new technology in transportation."

He went on to say that "If an emerging technology can improve safety and how we move, we want to see it on the market as quickly as possible. And we are especially bullish about the use of connected and autonomous vehicle technology."

Of course, he was mainly talking on-highway vehicles, and he could become especially sheepish upon learning actually how long "connected and autonomous vehicle technology" has been a vital part of off-highway vehicles for industries such as agriculture, mining, and even construction.

While light-duty on-highway vehicles have become increasingly connected mainly to address safety and entertainment issues, off-highway and other commercial vehicles were at the connected party first, but with the primary purpose of addressing safety and productivity issues.

Safety is obviously the common thread, because in all aspects and forms of the transportation industry, whether moving people or product or both, safety is paramount. That's the "life" component of the "life and livelihood" existence for most owners/operators in the off-highway/commercial sphere. Productivity is the livelihood. Both are areas often in the crosshairs of engineering innovations.

When talking vehicles and equipment, productivity itself is effectively indistinguishable from reliability. One timely example of engineers enabling increased productivity in the industry could be gleaned from potential future uses of 3D printing, or additive manufacturing. For the Rip Van Winkles amongst you, 3D printing is a process that involves (unlike conventional manufacturing techniques that essentially entail subtractive manufacturing) the creation of 3D objects from CAD data through the application of successive layers of material.

The technology is not all that new and it is already used extensively in a variety of industries, though what has changed is the broadened scope of its use in inverse proportion to its costs. Thus, unlike just about any child star you could name, it has made a graceful transition to maturity and has evolved from esoteric prototyping of single components to nearly mass production of complex systems.

And the technology's potential, when aligned with connected vehicles, will not just stop at the factory or laboratory door. Using an example recently discussed at Agritechnica's "Future Farming" forum in November, consider a farmer in a tractor working a field (or a construction worker working on a remote worksite, or other possible scenarios). The equipment could potentially be equipped with any variety of intelligent sensors to collect all machine data, identify the data with a time stamp, and align the data with target values.

These data could comprise of readings for temperature, specific resistance, vibrations, output, consumption, etc., and would be compiled in a status report that could be sent to the manufacturer at regular intervals. Any deviation between target and actual data may reflect a potential problem and machine failure. This transparent connection could mean that equipment at risk of breaking down in the middle of a job that could involve downtime of one or two days at least could be prevented.

To replace any identified component, the manufacturer can save 3D printable data of fast-turnaround parts to an external database, which could be accessed by all dealers and authorized workshops or job-site trailers. Technicians would be able to produce the relevant component within a few hours using a certified 3D printer, avoiding any downtime and replacing the part before the machine actually fails.

Such levels of connectivity would dissolve any sticky red-tape disrupters, and allow a virtual red carpet to be rolled out to celebrate new technologies. The big change and hope for the future is that it will no longer be possible to tell where the red carpet actually begins, or ends.

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MANUFACTURING

Hot-stamping process from Schuler employs flexible 'pressure controlled hardening'

With its PCH (pressure controlled hardening) technology, Schuler has succeeded in halving cooling times for parts. (All images: Schuler)

In the press hardening method, parts are heated to 930°C (1706°F) and then simultaneously cooled and hardened in the subsequent forming process, which gives the parts their extremely high rigidity. At its Waghäusel, Germany site, **Schuler** recently presented its new PCHflex technology, which has been under development for about two years and is a further development of the company's "pressure controlled hardening" process.

The new process allows flexible and economical production of hot stamped parts with high output performance and consistently high quality, according to Schuler Managing Director Dr. Martin Habert. It also allows maximum process reliability and availability. "More performance pays off," he said. "In this way, costs and energy consumption per part are reduced."

PCHflex uses what Schuler claims are the fastest hydraulic presses with Dynamic Force Control and RingValve technology. With four parts per stroke (4-out mode), up to four million parts per year can be produced on one line.

By controlling pressure during hardening, the necessary press force can be distributed evenly over the part. The flexible bed cushion ensures—within the part and distributed over several parts—a uniformly high contact pressure, resulting in faster cooling, according to Jens Aspacher, Sales Manager Hot Forming at Schuler. "This ensures a reliable and optimized metallurgical transformation process," he stated. The cooling time is claimed to be half that of conventional methods, while productivity and part quality are increased.

"The material properties are the same [as with other hot-stamping processes], but the martensitic transformation becomes more reliable within the part, which leads to higher content of martensite and higher part quality," Aspacher added.

What makes the PCHflex technology unique, according to Aspacher, is that automotive manufacturers and suppliers are more independent of die and material fluctuations for process reasons; different manufacturing tolerances and sheet thicknesses can be compensated for more easily. "This reduces scrap as well as downtime and idle losses that would otherwise occur due to the reworking of dies, for instance," he shared.

An additional benefit of the new PCHflex technology is that existing conventional press hardening dies can be used on these lines, he noted. And conversely, dies designed for PCHflex technology can be used on conventional lines.

A U.S. car manufacturer has placed an order with Schuler for four production lines to manufacture lightweight parts using PCHflex technology. Options have been agreed upon for four

The new PCHflex technology also has the benefit that conventional press hardening dies can be used on these lines.

"Commercial-vehicle manufacturers are also affected by the need to reduce CO_2 emissions, which is why they, too, have to make use of lightweight parts with extremely high rigidity. And hot stamping is the most economical way to produce lightweight parts," said Schuler's Jens Aspacher.

further lines. The supplier expects PCHflex to be in operation by the beginning of 2017.

"As a systems supplier, Schuler will not only be providing hydraulic presses and automation equipment, but also the roller hearth ovens and dies," explained Habert. "Our employees will also be helping launch production in the first few months."

Is the pressure-controlled process suitable for applications on on- and off-highway heavy-duty vehicles? "Absolutely," said Aspacher. "Commercial-vehicle manufacturers are also affected by the need to reduce CO_2 emissions, which is why they, too, have to make use of lightweight parts with extremely high rigidity. And hot stamping is the most economical way to produce lightweight parts."

Paired parts such as left and right of the rocker, A-, B- and C-pillars, or the roof frame are typical applications for the process. "Now, there are more and more roof bows or connector plates under the back seat, for example. More or less all structural parts which do not need to absorb energy in crash situations [are possible]," Aspacher said. "Outer skin parts are not possible because of the rough surface."

The press-hardening equipment supplier expects demand for such technology to grow in the coming years due to requirements for passenger protection and emissions reduction. In response, the company is planning to open a new Hot Stamping TechCenter at the Group's main site in Göppingen, Germany, in early 2016. The technical center will serve both as a demonstration center as well as a location for training and research on press hardening.

Ryan Gehm

SOFTWARE

Software's growth shines spotlight on eliminating defects

Software's becoming a greater factor in vehicle development, prompting a heightened focus on reducing the number of defects in code. Early planning, discipline, and continuous attention to detail are a few of the techniques that can help design teams eliminate defects.

Unlike hardware and mechanical faults, software defects are often quite visible. Another difference is that programs are often judged by what they don't do as well as by how well they work, according to panelists at the **SAE** 2015 Commercial Vehicle Engineering Congress.

"Any implementation that doesn't meet customer needs has defects," said Mike Repko of **PACCAR** Technical Center. Repko spoke during the "Getting to Zero Software Defects" executive panel.

The potential for defects is soaring along with the volume of software on advanced vehicles. Programs now provide many of the new features and functions on vehicles, marking a dramatic change from just a few years ago.

"Twenty years ago, two of us wrote all the software for a combine," said Ashley Greer of **Deere** & Co. "Today we have 60 people, and that doesn't include people in other facilities. We're seeing a shift as software becomes the first thing developed. In the past, it was close to the last."

That drive to push software issues earlier in the development process takes many forms. Model-based design is becoming far more common, as are simulations and validation.

"We need to focus on upfront validation so people aren't writing code that isn't what's needed. We also need to simulate as much as possible early on in the process," said Timothy Burns of **Gulfstream** Aerospace. He noted that while Gulfstream makes planes, its challenges are quite similar to those of commercial vehicle developers.

Verification is another critical step. Tests can be run throughout the development process, but that doesn't always ensure a low defect count. Tests done in silos may not foretell faults that show up when all systems are integrated.

"Typically, testing approaches are vertically integrated, engines, hydraulics, etc.," Burns said. "Ultimately, it all comes together in the flight deck, and the pilot looks at it as a horizontal system, not a bunch of vertical systems."

There are a number of programming strategies created to maximize the efficiency of software development. Agile software development, which is particularly suited to the cross-functional demands of off-highway markets, is one part of a comprehensive programming strategy.

"Agile software development processes highlight a lot of

Writing software for Deere combines now requires more than 60 programmers.

problems, but it doesn't fix them," Greer said. "Managers have to make continuous improvement to make sure things get fixed and fewer problems arise in the future."

These issues are almost certain to become more complex as the volume of software rises. Managers must be able to respond to the inevitable changes that occur during designs. Software changes in one area may impact other systems, but never enough time to check each system every time something's altered.

"As software complexity grows, we need to better manage change," Burns said. "From a scheduling perspective, you can't examine every system every time you change one thing. It's a big challenge to manage change."

However, panelists agreed that it's often difficult to scrupulously apply long-term strategies when day-to-day demands get in the way. Greer compared the goal of implementing best practices and building quality software to losing weight. People say they want to lose weight, but they don't want to stop eating ice cream.

"We want quality software, but we don't want to take the steps to get it," he said. "Best practices for writing software are well known, why isn't the industry following them?"

A strict programming environment is only part of the equation. Writing useful, reliable code requires an overall approach that includes technology and a realistic analysis of personnel.

"You need disciplined people who understand the technology and their role in development," Repko said. "People think the processes are about things like standards, but the real key is to look at the people involved and the technologies that are involved, then customize everything around your goals, setting things up so the team can excel at building software that the customer wants."

Panelists also spent a fair amount of time talking about those customer wants. Interactions with customers help companies determine what features and functions are needed. But costs always come into play.

"When you do focus groups, you also need to look at costs. People may want something, but they won't pay for it," Greer said. "Once products get into the field, we're seeing faster feedback with social media."

Terry Costlow

TESTING

Rugged data-acquisition systems speed tests of off-highway equipment

Just as engineers of consumer vehicles are being asked to shorten development cycles and improve performance, reliability, and safety, so are developers of off-highway vehicles, such as construction equipment and agricultural machinery. From a practical point of view, this means running more tests and acquiring and analyzing more data in a shorter time than ever before. Good measurement data is, after all, important for optimizing designs.

Consider the following types of vehicles:

- A tractor plowing the dusty expanses of a Kansas wheat field, powering through the mud in blistering heat.
- A crane at a skyscraper building site, conveying tons of materials up several hundred meters high.
- A ship carrying needed supplies to offshore oil rigs that must get through no matter how bad the weather.
- A truck transporting material carrying tons of recently-mined ore.

Each of these scenarios share some common measurement requirements. The data-acquisition system used to test these vehicles must be rugged enough to withstand field testing, provide accurate and repeatable measurements, and be able to transmit data over the Web.

In addition, however, each scenario has its own unique requirements. That being the case, the flexibility to adapt to different measurement tasks is a very desirable feature for data-acquisition systems used to test off-highway vehicles.

The SomatXR data-acquisition system from HBM combines robust protection from humidity, water, dust, shock, and vibration with an extended temperature range (-40° to +80°C) for measuring voltage, current, temperature, and more under the most extreme conditions.

Rugged design

To optimize prototype testing time, it is important for the measurement system to be able to withstand all kinds of harsh conditions. Rugged data-acquisition systems are needed for testing in harsh environments to reduce test times and keep the cost of repairs as low as possible.

Testing off-highway vehicles presents many challenges. Perhaps the most challenging is the operating temperature range. Some vehicles must operate at temperatures as low as -30°C, if, for example, they will be used in northern climates during the winter, while others may have to operate at temperatures up to +80°C, if they are to be used in the desert during the summer.

For performing winter tests, such as cold-cranking tests, and summer tests, such as cooling tests, a data-acquisition system is needed that can operate at very low temperatures and very high temperatures. A data-acquisition test with an extended operating temperature range doesn't need any special packaging to operate under these extreme temperature conditions.

Shock and vibration is also a consideration for testing vehicles that operate off-highway. To help ensure that a data-acquisition system will operate reliably in an environment with harsh vibration and sudden impacts, look for equipment that has been tested using test procedures found in MIL-STD-202G, "Test Method Standard: Electronic and Electrical Component Parts." This standard specifies environmental tests used to test military electronic gear, including shock and vibration testing. Look for a MIL-STD-202G vibration rating of 10 *g* and a shock rating of 75 *g*.

Dusty and wet conditions are common when testing agricultural and mining vehicles. To ensure that test equipment will operate in conditions that are dusty or wet, look for equipment that has an

IP65/67 rating. IP ratings, or ingress protection ratings, specify how well the enclosures protect against dust and water. IP65 enclosures are dust-proof and protect against water jets. IP67 enclosures are dust-proof and immersible in water up to a depth of 1 m.

IP ratings were developed by the IEC (International Electrotechnical Commission) and are mostly used in Europe, but there are NEMA equivalents. An IP65 rating corresponds to a NEMA 4 or 4X rating. An IP67 rating corresponds to a NEMA 6 or 6P rating.

Protect against unforeseen events

When operating under such extreme conditions, it's hard to anticipate all of the problems that may occur. Nothing is more aggravating than losing measurement data because of unforeseen events, such as a power failure or the data-acquisition program crashing. This is especially true for long-term tests, when the user is not always on site to monitor error-free recording of measurement data.

For situations like this, a measurement system that records data as it goes, and can pick up where it left off, is indispensable. Should there be a power outage, or some type of vehicle failure that interrupts a test, a user would at least have all the data recorded up to the interruption. The system should also automatically resume logging data after the interruption without any need for user interaction.

Another way to protect against unplanned interruptions is to check to see that the system purchased uses a stable operating system. Using a Linux operating system has in the past provided the most stability for applications such as these.

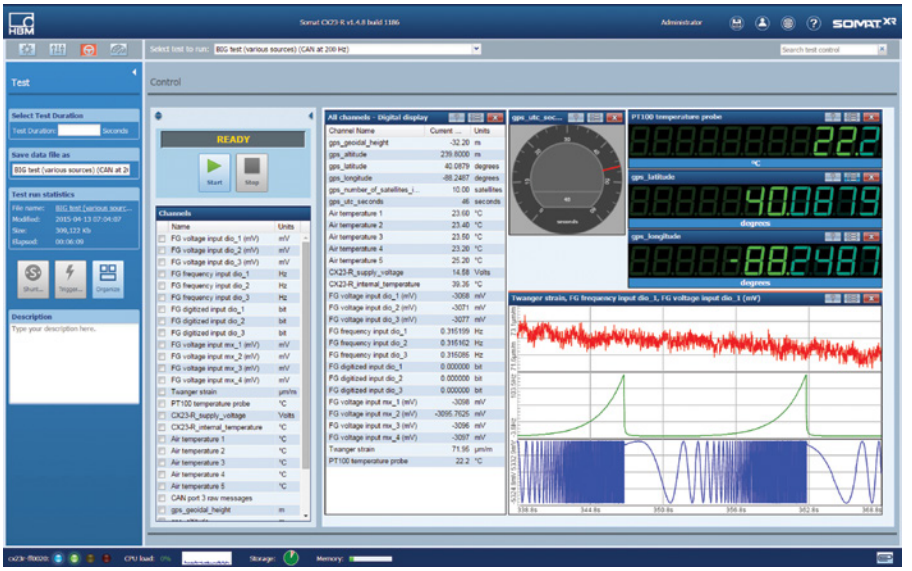
The ability to access a measurement system via the Web is very convenient when testing in harsh environments and when performing long-term tests. If a measurement system has a Web interface, it is possible to monitor the test remotely without having to monitor it on-site.

Typically a Web interface provides direct access to the measurement data–anywhere, from any Web-capable device. With the right software, it is possible to visualize test results in real time too. In addition, a Web interface can allow multiple clients to access the system and focus on the test data that is important for them.

Modular architectures for flexibility

Because off-highway vehicles come in so many different shapes and sizes, and the measurement requirements are so diverse, data-acquisition systems need to be very flexible. Systems with a distributed modular architecture make it possible to structure the system according to these varying requirements, thereby reducing overhead.

For example, when testing a very large system, such as a construction crane, the



The SomatXR data recorder's Web interface simplifies monitoring the progress of a test from anywhere using either standard Ethernet technology or wireless access, with no software download or installation required.

The SomatXR can survive the harshest test conditions due to its robust design.

system should allow the positioning of a data-acquisition module close to where the measurements need to be made. Positioning the module close to the measurement point will minimize the effect of long sensor leads and common-mode noise, which are the leading causes of measurement errors.

Another feature that can improve the flexibility of a data-acquisition system is universal inputs. Modules with universal inputs allow users to connect different types of sensors to a data-acquisition module and record different types of parameters with a single module. This reduces the number of modules needed for a particular test.

Finally, consider how the intelligence of the software built in to the data-acquisition system can reduce the time needed for data analysis after the test. One feature to look for is intelligent processing of channel data. It is, for example, very convenient to perform real-time calculations on acquired data and then record the calculated values as an independent channel or trigger measurements using the calculated data.

Testing off-highway vehicles is definitely challenging. Modern data-acquisition systems help make it easy, offering reliable and robust measurement capability that can be used in all kinds of adverse conditions, and ultimately makes the engineer's job easier.

This article was written for *Off-Highway Engineering* by Finn Lange, Product Manager Test & Measurement, HBM.

ELECTRONICS

The benefits and advantages of digital signal processing

In the quest for increased performance, flexibility, configurability, communications, and remote monitoring and control, the power electronics industry is increasingly moving from analog to digital power converters, particularly when high-density power output is required.

Many mission-critical operations in aerospace and defense, as well as some industrial applications, require high output power in the multi-kilowatt range. Given the mission-critical nature of these applications and the extremely rugged conditions in which they must operate, these power converters must also withstand stringent vibration, shock, EMI, humidity, and other environmental settings without breaking down.

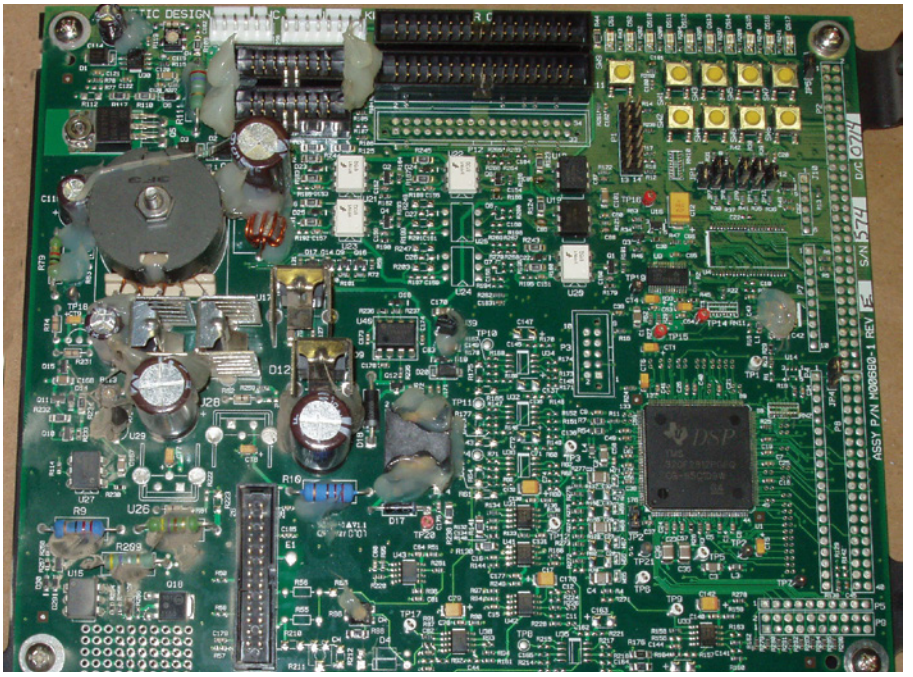
Meeting all of these requirements often requires a custom solution from a power converter designer proficient in digital signal processing (DSP) techniques as well as military and aerospace specifications and high-reliability (hi-rel) standards.

"You generally don't just go to a catalog and pick out something that's going to provide you with 50,000 watts of power. Almost everything is custom made in that arena," said Kamran Kazem, Vice President and Chief Technology Officer at **Magnetic Design Labs** (MDL), which designs and manufactures analog and digital switching and linear power supplies, dc-ac inverters, and dc-dc converters.

According to Kazem, digital power devices are capable of operating over a very wide operating range, require few external components, are easy to communicate with, and introduce a degree of flexibility in control not previously available with analog techniques.

"The main reason to go with digital over analog is that almost anything can be customized fairly easily with just a little bit of code," says Kazem. "Whereas with an analog type of converter, once it is designed it is rather difficult to change or get any additional information from it and there is no real-time communications."

Digital signal processing (DSP) is also far more precise than analog. Settings do not drift with time and temperature changes since they are controlled only by



Pure sine wave inverters are suitable when operating sensitive electronic devices, including communications equipment, that require high-quality waveform with little harmonic distortion.

the DSP clock and the software, not cap or resistor values that change over temperature and time.

"Perhaps the most important feature of a digital converter is its flexibility," said Kazem. Digital power converters offer an array of programmable parameters including output voltage settings, output current, current limit trip point, power sequencing routines, voltage margining, and multiple thresholds for warning and fault conditions for overcurrent, overtemperature, and under- and overvoltage. Fault conditions and power usage can also be stored in nonvolatile flash memory for later recall.

Designers can program any of these parameters at any point during the product's life cycle. These, and other function or feature changes, often simply require updating the flash memory, and can even be updated remotely over the Internet. With analog, similar parameter or function changes require part (hardware) changes and often also require a new PC board.

Real-time communications for monitoring and diagnostics is another major benefit. Digital power conversion devices can be tied into existing networked systems as well as communication processors and the information used to monitor and control the output.

Despite these and other advantages of DSP technology, for most engineers the major downside of digital power conversion is the learning curve that the technology demands.

"It takes a very high skill level and advanced education to successfully design for digital control of analog signals using a DSP processor," said Kazem.

Kazem adds that despite excellent programming and debug tools from the DSP chip vendors, these tools can be very difficult for the inexperienced designer.

"Designers that are used to working in the analog domain can get into a sophisticated DSP application and find that it takes too long or becomes too difficult to complete the work," said Kazem.

Hi-reliability applications

In addition to DSP, many mission-critical electronics used in military and aerospace applications must be designed to satisfy stringent ruggedization and hi-rel requirements.

Hi-rel is defined as the probability of

failure-free performance under stated conditions, usually over a specified interval of time. These electronic systems, down to component-level technology, must be able to operate for many years without failure, often without the opportunity for repair, and operate in temperatures that can range from -55 to +85°C.

Bob Seidenberg, former Senor Quality Assurance Manager with **BAE Systems**, describes the importance of high-reliability, ruggedized digital inverters that were installed in the M1068, a command communications variant of the **U.S. Army**'s M113 family of armored personnel carriers (APCs). BAE Systems designs and manufactures electronic systems and subsystems for commercial and military applications.

The original M113 APC revolutionized mobile military operations when first fielded in Vietnam. To date, an estimated 80,000 M113s, including a long list of variants, have been produced and used by over 50 countries worldwide, making it one of the most widely used armored fighting vehicles of all time.

During this time, the M113 has been continuously updated over the years to meet the ever-increasing demands of the modern battlefield. Since then the M113 family of vehicles are being upgraded, reconfigured, and introduced as entirely new systems, including the M1068.

The M1068 variant is used as a tactical operations center capable of long range communications and includes 4.2-kW auxiliary power unit (APU) mounted on the right front of the vehicle to provide 24-V power.

As part of this project, BAE Systems required two hi-rel, ruggedized 2500-W pure sine wave inverters per vehicle to convert 24-V dc power generated by vehicle-mounted APU into usable multi-kilowatt levels of ac for powering communications devices, lighting, computers, and other electronic devices.

Although more expensive, pure sine wave inverters provide cleaner, utility grade power than quasi sine wave models. Pure sine wave inverters are ideal when operating sensitive electronic devices, including communications equipment, that require high quality waveform with little harmonic distortion.

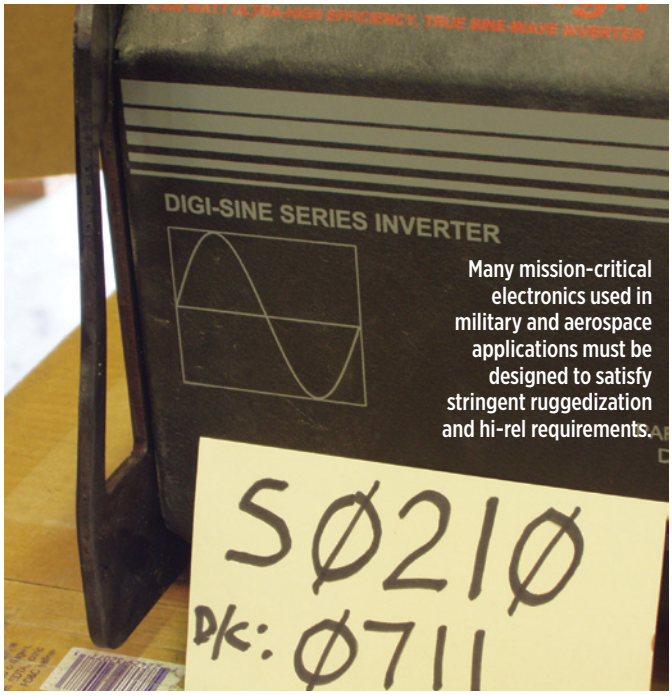
In addition, pure sine wave models have a high surge capacity which means they are able to exceed their rated wattage for a limited time. This enables vehicle motors to start easily, which can draw many times their rated wattage during startup.

Seidenberg explained that the 2500-W inverters also had to meet some shock and vibration requirements that could only be met by hi-rel inverters.

"The shock requirement for the inverters installed on the M1068 was close to 30 *g*, in three directions (vertical, horizontal, and transverse) and the vibration spectrum was also very demanding, but MDL was able to meet those requirements with an innovative pure sine wave inverter design that was basically non-destructive," said Seidenberg.

According to MDL's Kazem, despite the 30 *g* requirement for the M1068, the military specified that the inverters had to withstand 100 *g*. This was well beyond the amount of shock the vehicle would ever realistically experience, based on military tests conducted in the roughest terrain that maxed out at 15 *g*. Still, MDL was able to deliver 2500-W, pure sine inverters that met the requirement as verified by an independent testing lab.

"The military has a number of requirements that we had to follow," said Seidenberg. "So, naturally, our supplier had to pay a lot of attention to those requirements and ensure that they were met in a way that was correct for the application."



Many mission-critical electronics used in military and aerospace applications must be designed to satisfy stringent ruggedization and hi-rel requirements.

Kazem believes that high-reliability electronic systems and components are no longer the exclusive domain of aerospace and defense. Today, medical, transportation, communications, infrastructure, and industrial all have applications where the price of failure is high.

"These power converters might not have to withstand the same extreme conditions as the military, but vibration, shock, humidity, and other inherent environmental problems are still factors, so the need for hi-rel and rugged power converters certainly applies to those markets as well."

DSP modules

DSP is also a key element in a new generation of modular, stackable inverter options designed to provide a range of 1 to 20 kW of dc-ac power via a single, customizable unit.

This type of system, available from custom power converter designers like MDL, consists of rack-mounted inverter modules that can be stacked in a parallel configuration, enabling the user to add as many inverters as needed to meet the power requirements.

Each unit connects to a communications controller that is responsible for synchronization, load sharing, and any external communications. The individual inverters are hot swappable, enabling the addition or replacement of modules on the fly.

"This type of modular design provides project managers with a system that fits their power requirements without having to develop a new unit just for their specific project," said Kazem. "This eliminates the need for many application-specific designs, and could also enable faster delivery of the power converter at a much more economical cost."

Jean L. Broge

SIMULATION

Evaluating new forestry machines in a fraction of the time

Traditional forwarder on a steep slope.

Simulation of a forwarder with pendulum arm suspension going over an obstacle.

Adams model and the physical test model of a traditional forwarder.

The predominant forest harvesting method used in northern Europe is cut-to-length logging (CTL). CTL is based on a two-machine solution—a harvester is used for felling, delimbing, and bucking trees, and a forwarder carries the logs from the harvesting area to a roadside loading area where they can be picked up by a truck. These are both off-highway machines with a frame-mounted crane that operate in areas not accessible by conventional wheeled vehicles at low speed.

To stay competitive, the Swedish logging industry needs to increase productivity by 2-3% per year. Increasing the speed with which forwarders can move logs is one area where logging companies are hoping to achieve productivity improvements.

"A key limitation in the ability of forwarding machines to drive in the terrain is the vibrations that the driver is exposed to," said Abbos Ismoilov, Ph.D. student at **KTH Royal Institute of Technology**. "In addition, forestry machines are heavy and the risk for rutting and soil compaction is high. Improving the productivity of forest machines will require new suspension systems that offer improved operator comfort and are gentler to the soil than current designs."

A fully suspended forwarder prototype

Skogforsk (the Forestry Research Institute of Sweden) is the central research body for the Swedish forestry sector, and is financed jointly by the government and the members of the Institute who include most of the major manufacturers of forestry equipment. Skogforsk has funded a KTH research initiative intended to help improve the suspension of forestry machines with the goal of achieving significant productivity improvements. But improving the design of forestry machines using conventional methods is very expensive and time consuming. It can easily cost millions of dollars to build a prototype and test it in remote logging regions. KTH's mission is to streamline the design process by validating the capability to simulate the operation of forestry machines under real-world operating conditions.

Most current forwarders on the market have articulated steering and are equipped with bogie suspension systems. Bogies serve as a mechanism for averaging and smoothing the path of the center of gravity of the vehicle when it encounters obstacles in the terrain, but with bogie suspensions the only damping is provided by the tires. Thus, severe limitations exist on the speed with which bogie machines can be driven without generating excessive vibrations in the cabin and causing soil damage.

One alternative that is being considered is a pendulum suspended system in which each wheel is independently mounted on a link arm that is mounted on a revolute joint on the main frame. Usually a hydraulic cylinder is mounted between the arm and the frame to provide vibration damping and potentially also a leveling function.

A fully suspended six-wheel prototype was recently manufactured and assembled. This pendulum arm-suspended forwarder prototype will serve as a demonstrator of suspended logging machine technology and a research tool for active control and automation. A pendulum suspension enables all wheels to adapt individually to the terrain, making it easier to

Real forwarder undergoing bump test on proving ground.

Adams model simulating the same bump test.

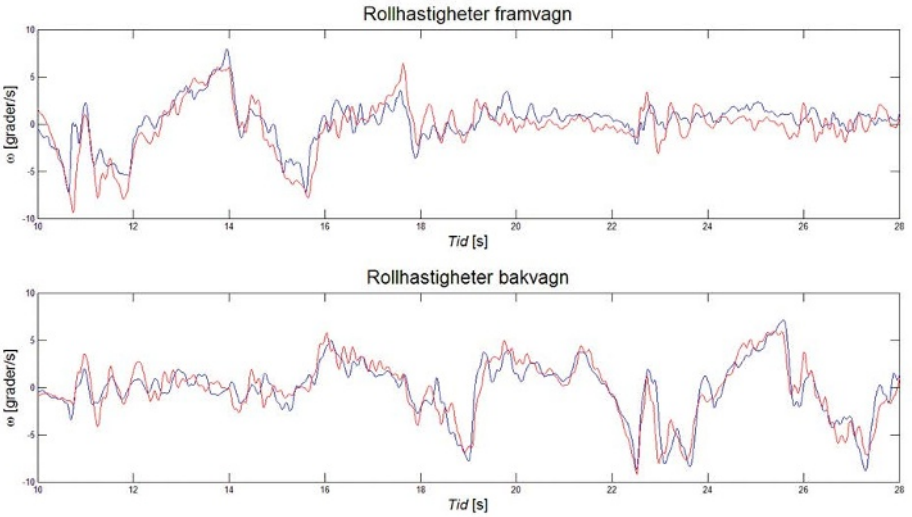
pass over large obstacles with good ride comfort. In addition, a pendulum suspension can be upgraded to an active system.

KTH researchers were asked to simulate the new forwarder and validate the ability of the simulation to accurately predict its performance under realistic operating conditions.

Simulating suspension configurations

KTH researchers used **MSC Software**'s Adams to model three different suspension concept configurations. The first is a standard **Komatsu** bogie forwarder with the wheels mounted on four bogies. The second configuration is a six-wheel machine with rear bogies and pendulum suspension for the two front wheels. The front and rear frames are connected with a roll joint and an articulation joint so they cannot move vertically relative to each other. A variant of the second configuration has an additional linkage between the middle joint and front frame to enable the front frame and cabin to move vertically relative to the rear frame. The third configuration is a six-wheel vehicle with all wheels individually mounted on separate pendulum arms.

The CAD model with the dimension and mass parameters of a popular industry forwarder was imported into Adams. Three variants of the model were developed and simulated on a representation of the standard Skogforsk hard ground test track. FTire was used to model the tires based on regular tire properties such as diameter and inflation pressure. Adams calculated the wheel forces, joint forces, displacements, velocities, and accelerations on the test track. The time history responses were imported to **MathWorks**' Matlab and transformed to the frequency domain for further analysis.



Comparison between roll rate predicted by simulation (red) and measured during testing (blue) for front wagon (top chart) and rear wagon (bottom chart) of forwarder.

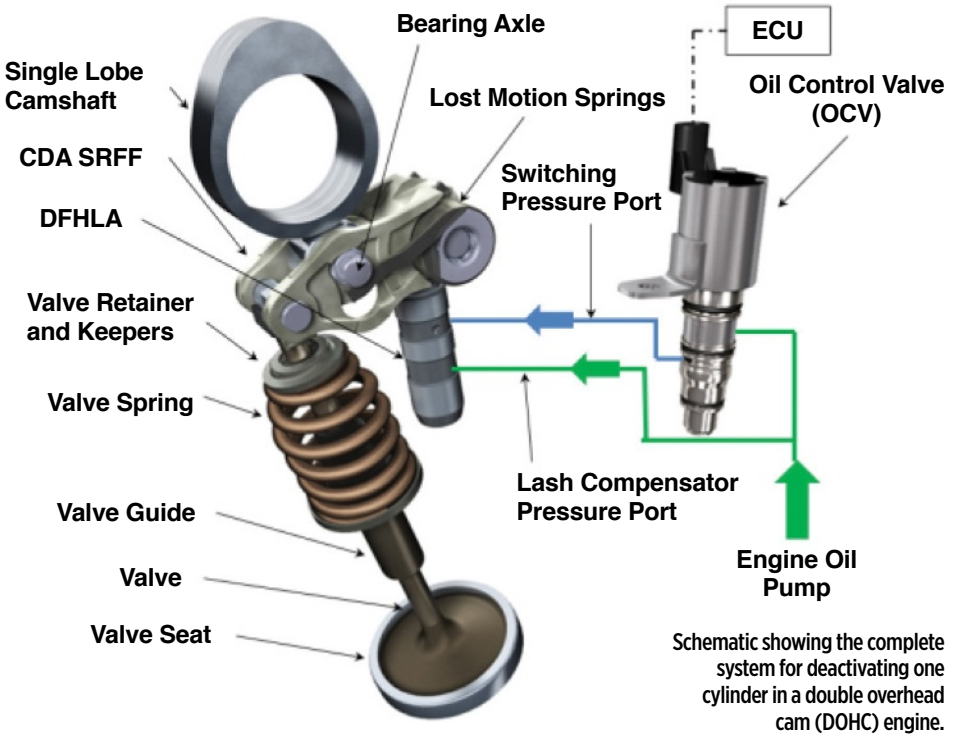
The performance of each concept was analyzed and its performance in terms of operator comfort and impact on the soil were estimated relative to the performance of the traditional forwarder. The relative values were defined in such a way that higher values indicate higher performance. The vehicle with the pendulum suspension performed substantially better than all of the other configurations. The simulation results for the traditional forwarder and pendulum suspended forwarder were compared to the existing prototypes, and both provided a very good match.

"Now that we have validated the ability of Adams to accurately simulate the performance of forwarders, we will be able to evaluate new design alternatives and optimize the performance of concept configurations in a fraction of the time required by the build and test method," Ismoilov said. "The ability to evaluate more designs in less time will make it possible to optimize the suspension and other components of the vehicle to provide higher productivity without causing discomfort to the operator or damage to the soil."

Yijun Fan, Product Marketing Manager for Adams and Easy5 at MSC Software Corp., wrote this article for *Off-Highway Engineering*. This case study is based on an interview with Abbos Ismoilov, KTH Royal Institute of Technology, Sweden.

IMPROVING HEAVY-DUTY ENGINE COMPONENT EFFICIENCIES

Cylinder deactivation can improve fuel economy by using a reduced number of cylinders that operate at higher loads and thermal efficiency, while other cylinders are turned off, when the engine operates at partial load conditions. A switching roller finger follower is one of the technologies that help make it work.



Schematic showing the complete system for deactivating one cylinder in a double overhead cam (DOHC) engine.

Cylinder deactivation (CDA) is an effective method to fine-tune engine displacement for maximum output and improve fuel economy by adjusting the number of active cylinders in combustion engines.

A switching roller finger follower (SRFF) is an economic solution for CDA that minimizes changes and preserves the overall width, height, or length of dual overhead cam (DOHC) engines. The SRFF is a mechanically actuated device that is hydraulically controlled using engine oil. A CDA SRFF provides the flexibility of either transferring or suppressing the camshaft movement to the valves influencing the engine performance and fuel economy by reducing the pumping losses.

The fuel economy benefits of CDA technology are estimated to be between 2-14%, depending on engine displacement and the number of cylinders that are deactivated. Typical fuel economy gains are 3-6% for six- and eight-cylinder engines. The improvements in fuel economy are possible by reducing the pumping losses when the engine operates in partial load conditions.

Researchers from **Eaton** recently studied the performance and durability of a CDA SRFF system that meets the reliability requirements for gasoline automotive engines. Of most importance, this technology—which provides a means for aftertreatment temperature management and fuel economy benefits—is scalable and can be applied to light-, medium-, and heavy-duty applications for gasoline, diesel, and natural gas engines.

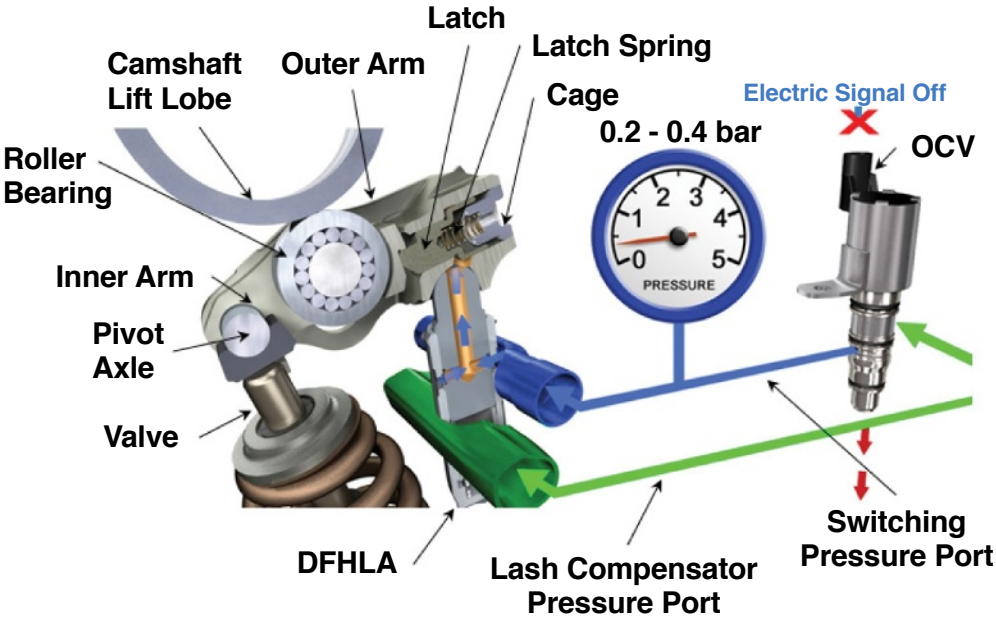
Extensive tests were conducted to demonstrate the dynamic stability at high engine speeds and the system capacity of switching between high and low engine displacement within one camshaft revolution. The system durability was demonstrated with high and low engine speeds, various oil temperatures, mode switching, and abuse tests, meeting the end of life criteria in wear and function.

CDA system description

Several CDA systems exist today, each customized for a specific valvetrain architecture. The CDA design during the Eaton research project was configured for DOHC engines, in which a SRFF was used along with a single lobe camshaft for each of the deactivated valves.

The system included two single lobe camshafts, four CDA SRFFs (two SRFFs for intake and two for exhaust valves), four dual-feed hydraulic lash adjusters (DFHLAs), one oil control valve (OCV), and four sets of the valve subsystem that include valve retainers, keepers, valve springs, valve guides, valves, and seats.

The camshaft for the CDA SRFF is very similar to camshafts used on traditional DOHC engines. The difference is that the camshaft ramps on the CDA system are longer than the ramps on the traditional systems in which typical



Cross section of the switching mechanism of the CDA SRFF in the default position when no electric signal is transferred to the oil control valve (valve in lift mode and latch engaged).

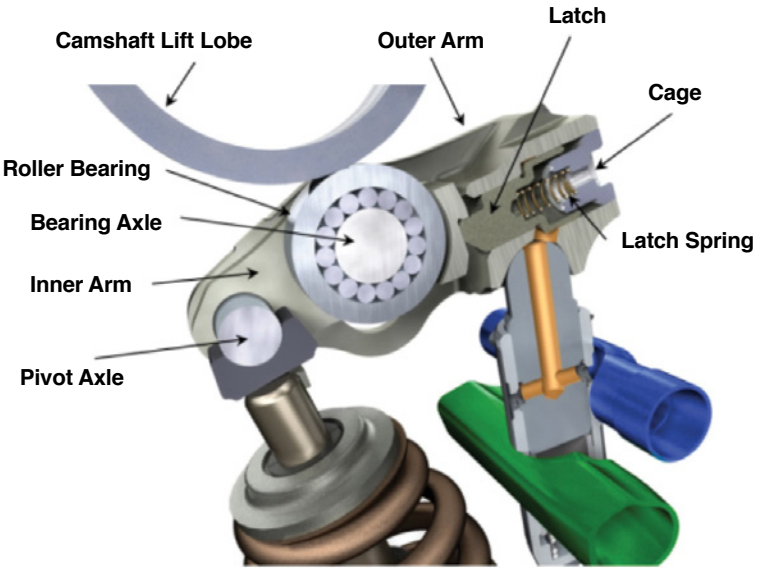
valve components are used. The CDA SRFF includes an additional internal lash due to the switching mechanism that is not present on a traditional RFF that does not have a switching function. The camshaft ramps used on the CDA SRFF described here are longer to absorb a larger lash prior to the valve lift event. The CDA system does not require changes for any component of the valve subsystem.

The DFHLA is a specifically designed hydraulic lash adjuster (HLA) for SRFF systems that retains the functionality of lash compensation with the added function of providing a hydraulic conduit between the OCV and the SRFF. Engine oil is plumbed to the lash compensation port of the DFHLA. The DFHLA upper port is connected to the OCV through the switching pressure port. The OCV is an electronically controlled on/off valve that receives input from the engine control unit (ECU).

In the SRFF system, an inner arm resides inside an outer arm, and the two arms are connected at one end with a pivot axle, which is a permanent cylindrical joint. The latching mechanism is located opposite to the pivot axle of the SRFF and acts as the second connection for the inner arm. This connection can be turned on or off by moving the latch.

The latching mechanism consists of a latch, a latch spring that forces the latch to engage the inner arm, and a cage that is permanently connected with the outer arm. A roller bearing is connected to the inner arm via a bearing axle. A pair of lost-motion springs are connected to the outer arm at one end and the bearing axle on the other end, providing a permanent contact between the roller bearing and the camshaft.

The CDA system provides two operating modes. Standard lift mode is available at any engine speed and operating temperature. The oil pressure in the switching port is regulated to 0.2-0.4 bar, gage pressure, resulting in the latch being extended, engaging the inner arm

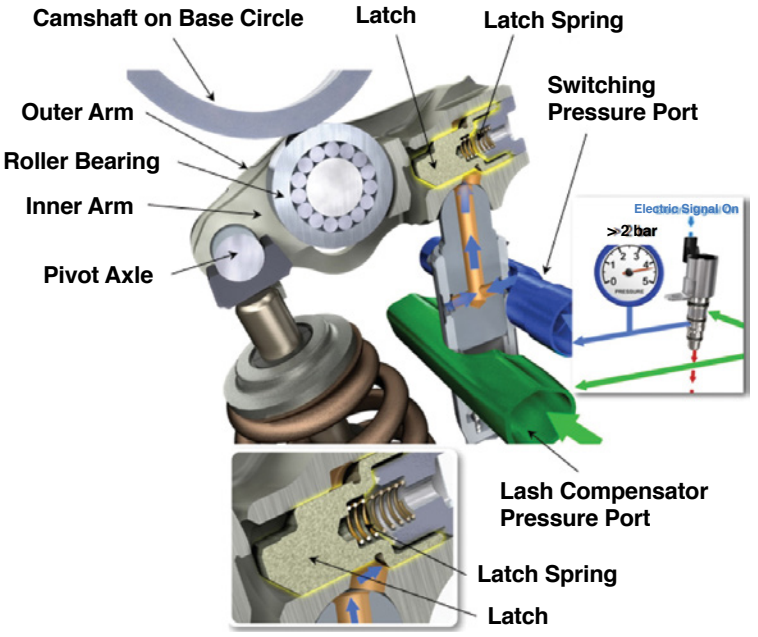


Cross section of a switching roller finger follower (SRFF).

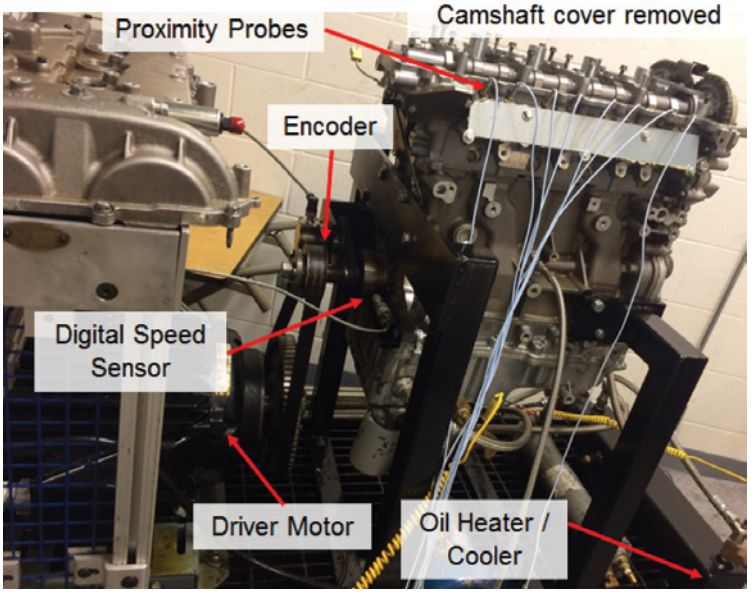
when no electrical signal is sent to the OCV. The CDA (or no-lift) mode is available at speeds up to 3500 rpm and oil temperatures above 20°C. An electrical signal from the ECU triggers the OCV to open the switching pressure port to engine oil pressure that is above 2.0 bar, gage pressure at that moment. The increase in pressure moves the latch, disengaging the inner arm from the outer arm.

The engine switches to CDA mode in an operating range driven by the time available to switch between modes in one camshaft revolution. The factors accounted for in calculating the switching time available are the valve event duration, phasing between the intake and exhaust events, oil viscosity, oil pressure, and engine speed. Details about time available to switch within one camshaft revolution on VVA systems that use an SRFF are detailed in SAE International technical paper doi:10.4271/2012-01-1639.

IMPROVING HEAVY-DUTY ENGINE COMPONENT EFFICIENCIES



The CDA, or no-lift mode, is illustrated here (valve in CDA mode and latch disengaged).



The durability and performance tests were conducted on two motored engine fixtures: a V-6 and an inline four-cylinder. The V-6 fixture was used for performance verification and extreme limit testing. The four-cylinder engine (shown with camshaft cover removed) was used for subsystem testing and accelerated aging.

Engine oil pressure is plumbed to the lash compensation port of the DFHLA and to the OCV. No electric signal is sent to the OCV. The OCV regulates the oil pressure in the switching pressure port to 0.2-0.4 bar with the purpose of keeping the switching port free of air for fast latch movement when mode switching is required. This pressure is below the required pressure to overcome the latch spring force and move the latch. The latch is engaged with the inner arm. The camshaft rotational motion is transferred to the valve through the inner arm that is connected with the outer arm. The valve motion follows the camshaft profile.

During the no-lift mode, an electric signal from the ECU energizes the solenoid inside the OCV, opening the switching pressure port to the engine oil pressure. A minimum of 2.0 bar oil pressure is needed to overcome the latch spring. The increase in pressure moves the latch to the retracted position, disengaging the inner arm. The inner arm and the outer arm remain connected at the pivot axle.

The absence of the secondary connection between the two components results in the camshaft rotational motion being transferred to the inner arm, which pivots around the axle and no camshaft motion is transferred to the valve, resulting in the valve remaining seated.

Engine life testing

Quality Function Deployment (QFD) methodology was used to understand the connection between the engine performance and durability requirements to SRFF targets for design, performance, durability, and reliability.

The CDA SRFF was divided into four primary subsystems: fatigue, wear-out, switching mechanism, and lost-motion. Each of the four subsystems was investigated to determine the appropriate life targets equivalent to 200,000 mi.

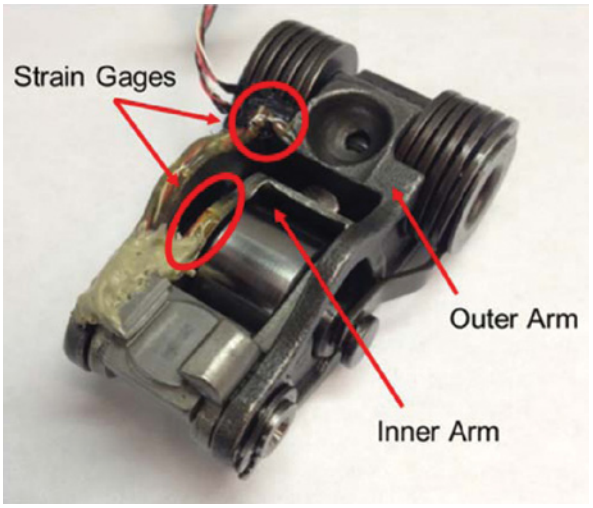
The 200,000 mi target was converted into a number of events that each subsystem would encounter over its lifetime. The number of valve events equivalent to 200,000 mi engine life is more than 300 million. This number was calculated based on a series of duty cycle scenarios.

Valvetrain component wear was accelerated by increasing the engine speed to reduce the test time. A proprietary high-speed durability test cycle was utilized to establish valvetrain wear that is equivalent to 330 million valve events while only requiring a fraction of the test time.

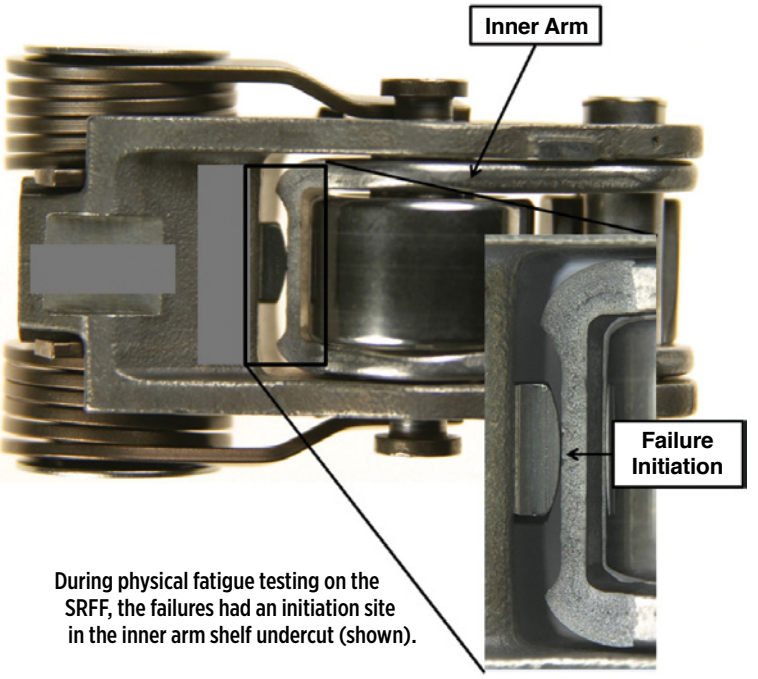
An aggressive target of 15 switching events (lift to deactivation and back to lift again) per mile was established to ensure a robust design. The resulting target was 3 million switching events for the life of the engine. The lost-motion system life target was defined by a high-end user, which provided a conservative target.

The resultant life target was approximately 160 million lost-motion cycles. The SRFF must withstand several abuse events such as critical shifts (unintentional switches from lift mode to deactivation partway through a lift event) and high-speed excursions at speeds above the designed operating range over the course of 200,000 mi.

A target of 5000 critical shifts was set during the development of the CDA SRFF, a conservative approach considering the low frequency of critical shift occurrences. Excursions of five consecutive 10 second bursts were considered as the target for the over-speed test when in lift mode. The system was additionally tested to twice the rated lost-motion speed for a total of 10 million cycles to protect the engine in case of an SRFF being in CDA mode unintentionally for an extended time.



The SRFF was instrumented with strain gauges for dynamics performance testing. The strain gauges were applied to the areas of uniform stress for accuracy in the load measurement.



During physical fatigue testing on the SRFF, the failures had an initiation site in the inner arm shelf undercut (shown).

Valvetrain lash is a key end-of-life measureable for tests performed on the CDA SRFF. The camshaft profile is made for a max lash, which includes the SRFF lash as produced and the lash increase from wear. The acceptable SRFF lash target is set for a maximum increase of 20 micron over the course of 200,000 mi. The camshaft opening and closing ramps are designed for a set maximum lash value that must be absorbed prior to the lift event.

Lash was monitored at discrete inspection intervals throughout all tests to qualify the success of an ongoing test. Lash data acquired at each inspection interval are used to understand the trend of lash increase for the system, determine when the system stabilizes, and predict end of test lash increase.

The four subsystems of the SRFF were tested extensively to demonstrate reliability and durability to the life target of 200,000 mi. Demonstration of the SRFF reliability and durability was achieved by testing the subsystems of the SRFF beyond their respective single life targets.

Test results summary

The CDA SRFF was subjected to a series of tests encompassed by the four pillars of SRFF durability demonstration. First, the system performance was validated by successfully completing all tests in the performance verification pillar. Next, the subsystems of the SRFF were proven to function beyond the 200,000-mi life target. The SRFF proved to be robust to the abuse of extreme limit testing by successfully passing all tests without losing function. Finally, the SRFF showed it was capable of surviving five system durability lives, the equivalent of 1,000,000 mi of wear and tear.

The testing achievements were attained by testing greater than 500 SRFFs for a total cumulative test time of greater than 40,000 hours (320,000 component test hours).

The performance verification pillar is meant to ensure that the design of the SRFF meets certain design criteria to ensure consistent and acceptable performance in all engine operating conditions. The CDA SRFF demonstrated a fatigue suspension load more than twice the maximum dynamic load measured during valvetrain dynamics. Closing velocities of the SRFF maintained greater than a 40% margin to their limit for both intake and exhaust positions. Finally, the lost motion spring design was verified by demonstrating a minimum of a 10% margin to the pump-up condition in the worst-case condition with minimum specification lost motion springs.

The subsystem testing pillar was designed to ensure that the major subsystems of the SRFF function appropriately and will endure for the full duration of expected life. The switching mechanism managed to achieve a milestone of 15 million switching events compared to a life target of three million. After completing five lives on test, the SRFF maintained a 21% margin from the limit of lash wear. The lost-motion system proved it is robust to the extreme ends of the fatigue spectrum, achieving 200 million lost-motion cycles, which is 1.2 times greater than the expected worst case end-user.

The extreme limit test was designed to push the SRFF past intended functionality and ensure it was robust to conditions caused by failures of other systems within the engine. The SRFF demonstrated it could survive greater than 10,000 critical shifts, or two times the life target. The SRFF successfully passed all other abuse tests to which it was subjected.

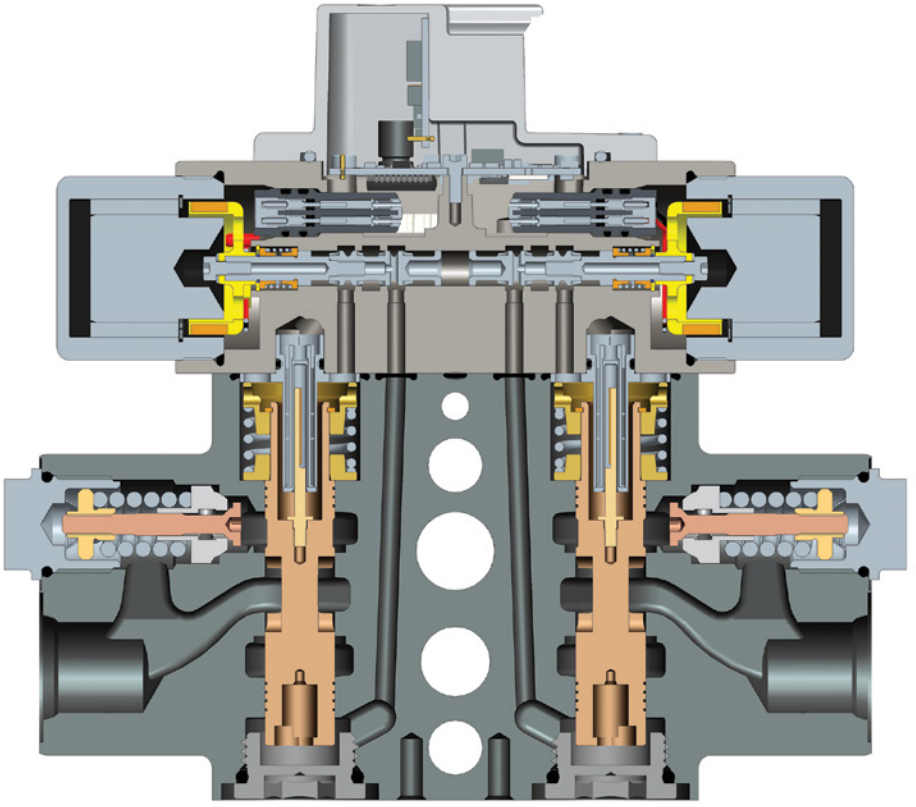
Finally, the accelerated system aging pillar was meant to simulate a full 200,000-mi duty cycle on the valvetrain by maintaining an elevated engine speed and exercising all of the major SRFF subsystems. The CDA SRFF maintained a 51% margin to the maximum allowable lash increase after completing five lives of the system durability test, equivalent to 1,000,000 mi of wear and tear. ■

This article is based on SAE International technical paper doi:10.4271/2015-01-2816, by Andrei Radulescu, Leighton Roberts, and Eric Yankovic, Eaton.

PUMPING UP hydraulic capabilities

Electrohydraulic advances keep coming as distributed electronics flex their muscle.

by Terry Costlow



Eaton is fine-tuning its valves and using smarter electronics to control them more precisely.

Hydraulic technologies are evolving rapidly as clever engineers figure out how to alter spools and valves. These mechanical changes pale in comparison to the advances that transpire as design teams leverage rising computing power and falling prices for electronics.

Electrohydraulic systems are employing more sensors and utilizing controls that are networked to a growing number of components. That's making it possible for design teams to continue to improve performance while adding more sophisticated features and functions. These trends show no signs of slowing down.

"Our hydraulic division has focused on digitizing our portfolio and embedding computational horsepower on many of our individual products," said Paul Brenner, Senior Systems Engineer, **Eaton**. "Now we are taking the strategy to the next step, networking complementing product groups and subsystems with the goal of reducing commissioning time and enabling advanced functionality. We term this next step as Intelligent Machine Control."

Valves, spools, sensors, and smarts

Valves are changing dramatically as engineers come up with new fluid flow techniques, add sensors, and enhance electronic controls. Spool design helped **Case IH** improve the efficiency of hydraulics on some of its newer tractors.

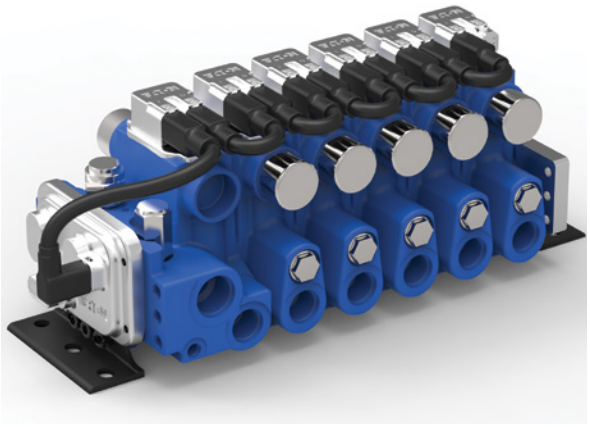
"We altered our spool to get better tolerances and adjusted its shape to provide improved flow," said Mitch Kaiser, a Marketing Manager at Case IH.

Some design teams are moving to dual-spool configurations, which help engineers overcome some of the compromises inherent when there's a fixed relationship between inlet and outlet metering.

"Through the use of twin-spool architecture, onboard sensors, and electronics, our CMA design senses load conditions, flow demand, and available flow and implements proprietary control strategies to optimize performance and reduce parasitic loses at the machine level," Brenner said. "The customer can now focus on specifying the force and velocity requirements of the machines actuators."

Advances in various sensing technologies has made it viable to employ more sensors in valves. That lets engineers more closely monitor positioning and other parameters.

"We are seeing sensors in applications that did not have them before," said Kirk Lola, Business Development Manager at **Parker Hannifin** Electronic Controls Division. "In particular, Hall-effect sensors give spool position feedback for better system performance in systems using hydraulic spool valves. In addition to valve feedback,



Networking lets Eaton's hydraulic valves work cooperatively with the vehicle's engine.

Parker has added position sensors to our piston pumps for swash plate position feedback for improved hydraulic system performance."

Ready for Mensa

The expansion of sensor technologies is being surpassed by the growth of computing power throughout the hydraulic field. Powerful electronic control units (ECUs) are being placed on more devices, pushing the intelligence level of vehicles skyward. Networks link these elements to add features and improve efficiency.

"Hydraulic ECUs are evolving as the interconnectivity of the system grows," Lola said. "By placing the electronics on the hydraulics, the ECU is dedicated to the performance of that device. This allows it to work smarter and more efficiently. Hydraulic ECUs need to not only control electrohydraulics very well, they also must be able to communicate with the rest of the control system and in many cases, the engine controller."

These controllers are all linked by CAN bus, either using the **SAE** J1939 or CANopen. ISO bus is available as a higher level protocol. These links make it fairly straightforward to set systems up and link them together for maximum efficiency.

"These protocols provide solutions for the needs of embedded architectures, like start-up, boot load, parameter storage, data exchange, and error handling," Brenner said. "The availability of advanced controllers now enables modular electronics and control architectures. Each subsystem function is operated by its own embedded controller; networking to the vehicle system is simple with no, or minimal, change to the other controllers in the system."

Significant benefits come when all the elements work together. When the engine and the hydraulic systems communicate, they can work in harmony to conserve fuel without sacrificing performance. That's true in **Caterpillar**'s 336F excavator, a hydraulic hybrid that

Hydraulic hybrids step into the limelight

Hydraulic technology is joining in the fight to reduce fuel consumption and emissions. Hybrid vehicles that use hydraulics are becoming increasingly common, bringing solid benefits without adding the cost and complexity of battery packs for electric hybrids.

Hydraulic systems are beginning to make a significant impact, prompting increased development. **Parker Hannifin** continues to deploy and improve its RunWise Hydraulic Hybrid Drive Transmission, while **Lightning Hybrids** is producing hydraulic hybrid drive systems for shuttle buses, delivery vehicles, and work trucks.

Automakers may follow the lead of off-highway and commercial vehicle suppliers. **PSA Peugeot Citroën** and **Bosch** developed a hydraulic hybrid car expected to get over 80 mpg when it comes out next year.

Earlier this year, **Caterpillar** unveiled its 336F XE Tier 4 Final hydraulic hybrid, which trims fuel consumption by up to 25%. This technology leverages existing elements, so it's easier to implement than an electric hybrid power architecture.

"We chose a hydraulic hybrid solution because our excavators already have a hydraulic architecture," said Randy Peterson, Chief Engineer, Hydraulics, at Caterpillar Advanced Components & Systems Division. "Utilizing a hydraulic hybrid architecture with electronic controls allows minimal impact and cost to the machine, making it affordable for our customers. Also, the power density (size) advantage for hydraulics over electrics is still in the neighborhood of 10 to 1 or more, making packaging electrics a challenge."

Government researchers are also pushing hydraulics. At the recent **SAE** Commercial Vehicle Engineering Congress, Kevin Newman, Control System Engineer for the **Environmental Protection Agency**, detailed the hydraulic hybrid technology used in a **UPS** delivery truck. More than 50 patents were issued to its developers, who designed a pair of 22-gal carbon-fiber hydraulic accumulators to store energy and significantly reduce fuel consumption without sacrificing power.

"The hydraulic system delivered more than 200 kW, more than enough to match the engine's 130 kW," Newman said. "In real-world package deliveries, it provided a 52% mpg increase."

While the hybrids bring significant fuel savings, performance can't be sacrificed. Design teams make sure that the hybrid's electronic controls are closely intertwined with the engine and human-machine interface so operators can quickly forget that they're running a hybrid.

"The machines have an electrohydraulic control valve and an electrohydraulic pump that communicate with the engine controls to manage the electrohydraulic hybrid system," Peterson said. "These systems work together to provide electronic handoffs of load to allow the operator to do what he or she does best."

Terry Costlow

Cat is using hydraulics to help its hybrid excavator meet Tier 4 requirements.

PUMPING UP hydraulic capabilities

Case IH altered the spool to improve hydraulics in its Steiger line.

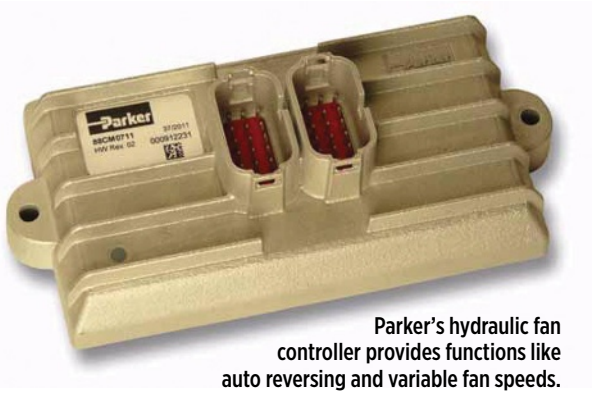
The Electronic Standardized Programmable pump is a critical element for the hydraulic hybrid system on Cat's 336 excavator line.

uses a proprietary pump tightly linked to the engine.

"The key piece of our hybrid system is the electrohydraulic pump, the Electronic Standardized Programmable pump," said Randy Peterson, Chief Engineer, Hydraulics, Caterpillar Advanced Components & Systems Division. "By controlling it electronically and communicating to the electronic engine, the system is very responsive. This allows us to lower the engine speed to save fuel. In the past, dropping engine speed usually caused excessive lugging and poor response to load. That isn't the case with our system."

Most observers expect to see more distributed architectures as it becomes more cost effective to mount ECUs on or in pumps and other components. That highlights the rising contribution that electronics and software have in off-highway and other commercial vehicles.

"We see a continuing trend toward more distributed systems, as more hydraulic components have some intelligence on board," Lola said. "More powerful ECUs dedicated to a particular hydraulic component allow for faster and better control of the hydraulic components. By spreading out the ECUs across the whole machine, the overall machine intelligence goes up."



Parker's hydraulic fan controller provides functions like auto reversing and variable fan speeds.

Broader horizons

The increased intelligence of electrohydraulic systems is making it viable for the technology to expand its role. Hydraulic fans are one of the functions that are increasingly converting to hydraulic power.

"We are more deeply integrating hydraulic cooling fans into the engine, exhaust aftertreatment, cooling, and hydraulic systems to make the overall machine more efficient," Peterson said. "By doing this, we can keep the fan speed as low as possible to minimize parasitic losses and reduce noise while attending to the cooling needs of the machine."

Fluid power is efficient and it leverages some of the systems already found on vehicles. Intelligent systems bring many benefits for engineers tasked with reducing fuel consumption while offering more capabilities.

"One of the largest advantages for hydraulics is that it offers higher power density than many other forms of actuation," Lola said. "The electronics and software allow intelligent functions like auto reversing and adjusting, fan speeds to match engine loading, and smart operation to more accurately maintain a target coolant or oil temperature. Having a separate hydraulic control system for the cooling system allows the cooling system to run independent of engine speed vs. traditional direct fan drives that ran the fan proportional to the engine speed." ■

Tracking the trends in commercial vehicle communications

Commercial vehicle manufacturers are using more blade-and-receptacle connectors designed for high-vibration, under-the-hood powertrain applications while still maintaining a small packaging size.

Industry insiders at Molex offer what they think the future may hold for heavy-duty components in 24/7 communications systems.

Seasoned operators of commercial vehicles will say they can sense how their vehicles are performing based on the sounds and vibrations the vehicles produce. Today, the latest commercial vehicles can do that on their own via sophisticated communications systems that monitor performance, position the vehicle, schedule needed maintenance, communicate with accessory equipment, and even help drive the vehicle, among other functions.

These communications systems require myriad electronic components. In this article, **Molex** examines some of the communications component trends it anticipates for commercial vehicles in 2016, including challenges to implementing 24/7 communications, interaction with other communications systems, and changes in standards.

There are a host of vehicles that require complex interconnect systems, such as agricultural vehicles that precisely monitor sprayer output; commercial buses with Wi-Fi networks, plug-and-play entertainment systems for passengers, and multiple security and driver-assist camera systems; and emergency vehicles that process critical data from patient monitoring equipment. For purposes here, Molex focuses on two critical heavy-duty applications: agricultural and construction/mining vehicles.

Commercial vehicle communications scenarios

Agricultural vehicles with 24/7 communications systems offer important competitive advantages. For example, communications modules in tractors and implements ensure that croplands are precisely planted and harvested with greater efficiency. These modules can regulate distribution of fertilizer and seed, which improves cultivation and crop yields.

Also, if there is a problem with a tractor, combine, or implement, the dealer or the operator can be automatically alerted via wireless communication, depending on the severity of the issue. Since machine uptime is vital, this application can improve farming productivity.

Communications systems are obviously a key part of autonomous agricultural vehicles, which free farmers to perform other tasks. Some of these systems coordinate multiple autonomous vehicles, such as when a tractor grain hauler receives grain from a combine that is harvesting a field of crops.

For construction and mining vehicles, 24/7 communications systems have an added importance. Unlike, agricultural vehicles, which are used heavily for certain periods and then housed, many construction and mining vehicles operate nearly 24/7 for indefinite periods, making maintenance diagnostics and communications systems that much more critical.

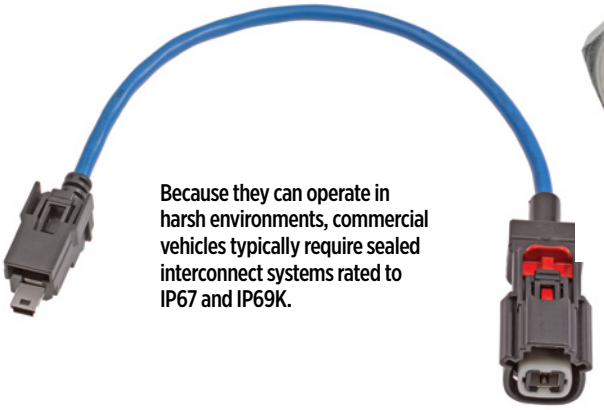
Also, multiple cameras and sensors are needed on both agricultural and construction and mining vehicles to ensure safe operation in often dangerous work environments. These communications systems typically include devices such as video cameras and displays, along with complex sensor and control systems that produce large volumes of high-speed data that assist operators with crucial tasks.

Free-flowing data

With more data flowing through commercial vehicles than ever before, communications systems require high-speed connectors and cables that can transmit 5 to 10 Gbps of data to transfer images and video. While some of these connectors handle data only, the trend is to use hybrid connectors that can handle both data and power, some of which can be specified with two or four lines of signal and power.

One major challenge with hybrid connectors is the electromagnetic interference (EMI) generated when power is transmitted through the connectors. As a result, connectors and cables in these systems must be shielded to protect them from EMI and crosstalk. Common shielding methods include individual shielding via aluminum foil for each twisted pair; foil shielding, braided shield or braiding with

Tracking the trends in commercial vehicle communications



Because they can operate in harsh environments, commercial vehicles typically require sealed interconnect systems rated to IP67 and IP69K.

More commercial vehicle manufacturers are using hybrid connectors, such as these Brad MicroChange M12 circular hybrid technology (CHT) connector and cordsets. The IP67-sealed M12 CHT connector, with a wraparound shielding, combines Cat5e Ethernet speed with power lines for use in harsh applications.

foil across all of the pairs; and individual shielding via foil between the twisted pair sets combined with an outer foil or braided shielding.

While much of this technology is not new, its application to the commercial vehicle industry is more recent. Manufacturers are now adopting various high-speed protocols that have been used by other industries for years. The difference is that communications systems for heavy-duty vehicles must be ruggedized, particularly in terms of latching and sealing.

That means communications networks in commercial vehicles must provide all the benefits of high-speed networks found in automotive vehicles as well as greater protection from increased vibration, shock, and fluid ingress. Plus, they must accomplish this while being housed in more complex and denser packages. As a result, high-speed interconnect systems have been modified to meet the challenges emerging from the commercial vehicle industry.

Networking evolution

Typical USB interconnect systems are based on passive, unlatched, plug-in connectors, but automotive USB applications must be latched. As a result, unsealed USB connector systems for automotive applications include shrouds and latches that meet USCAR standards.

Compared to automotive applications, however, heavy-duty, off-highway applications typically require sealed systems with additional protection against increased vibration, shock, and fluid ingress. For that reason, interconnect systems for commercial vehicles require fully protected perimeter seals and wire seals rated to IP67 and IP69K for use in off-highway environments.

Sometimes, an even more ruggedized product is required for use on vehicle exteriors. These metalized interconnect systems, which are sometimes available in high-speed CAT 6 versions, are typically sealed, threaded, and have metalized shells and push/pull locks. Some versions can even withstand a 300-lb (1.33-kN) pull force and are designed to withstand the driver of a vehicle standing on the cable when entering or exiting the cab.

Likewise, sealing technology that has been tested and approved in other industries can be used in electronic components for commercial vehicles. That includes different levels of sealing proficiency, from protection against dust or light sprays to protection from a stream of water from a hose to being able to be fully immersed in water.

When protecting components from vibration in commercial vehicles, it helps to have multiple contact points within the connector system. Commercial vehicle manufacturers have traditionally used vibration-resistant pin and socket connectors because they provide multiple points of contact for the socket around a cylindrical pin. Their counterparts in the automotive industry, however, have mostly transitioned to less-expensive blade-and-receptacle connectors, which also offer multiple contacts.

Commercial vehicle manufacturers are now embracing this trend. Traditionally, blade-and-receptacle connectors were not appropriate for high-vibration environments, but newer designs have been refined to the point where, based on the contact's geometry, they can withstand up to 20 *g*. For example, the MX123 sealed connection system from Molex is basically a blade-and-receptacle system. It is designed for high-vibration, under-the-hood powertrain applications while still maintaining a small packaging size.

Changing sensors and standards

Another key component trend in commercial vehicles is the growing use of sensors. The challenge will be determining how information is collected from those sensors and how it is provided to a screen or interface in a manner that doesn't overwhelm the operator.

Both the types of sensors and their sheer numbers are increasing, including sensors for lighting, air/tire pressure, current, and positioning, along with gas, brake, and hydraulic fluid levels. Sensors specific to agricultural vehicles include hopper level, application-rate, and high-rate seed sensors.

Also, the manner in which sensors and connectors are specified in communication systems is evolving. Agricultural vehicle manufacturers tend to follow ISO Bus communications standards such as ISO 11783, and construction and mining vehicle manufacturers tend to follow **SAE** standards. In addition, commercial vehicle manufacturers also use their internal proprietary specifications for higher-level communications, which make vehicles and equipment made by the same manufacturer interoperable.

However, this also means they may not effectively communicate with equipment made by other manufacturers. While these proprietary specifications and requirements are a problem for customers using vehicles from different manufacturers, it allows individual manufacturers to differentiate their products and develop a competitive edge for their vehicles.

For example, many manufacturers of connectors for commercial vehicles work with the SAE J2030 specification, which encompasses connectors between two cables or between a cable and an electrical component and focuses on the connectors external to the electrical component. The specification describes the minimum criteria needed to establish that a connector will work in a ruggedized application.

When developing a connector for commercial vehicles, Molex will typically test it to J2030 because that provides the company with a "calling card" when it wants to qualify the part with a customer, such as **Caterpillar** or **John Deere**. Customers may accept a part based on it passing J2030, then test it further to determine if it meets their own internal specifications. Some manufacturers share those internal specifications with suppliers and some do not.

Managing the 'pizza box'

One thing to keep in mind when designing a high-speed and high-power interconnect system for a commercial vehicle is that it is part of an overall vehicle architecture involving high-speed communications and high-power electrification systems. For example, in addition to standard body/chassis, safety, powertrain, and infotainment connectors, an emerging trend is toward electric drives and accessory connector systems for high-voltage power applications.

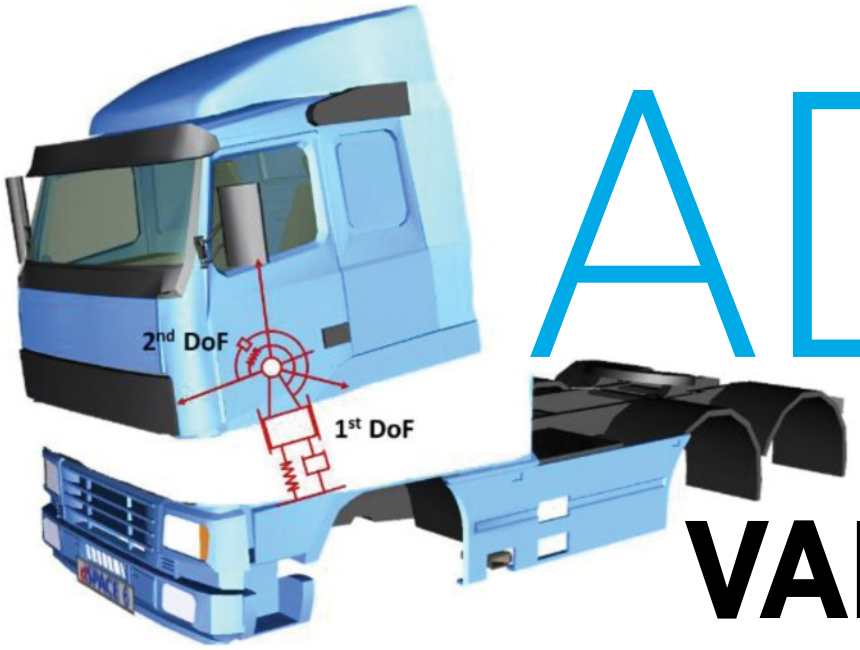
A large number of wires and connections are routed to control modules that can be the size of a pizza box. Just trying to get the mixture of straight and right-angle entry wires routed through the vehicle is an ever-increasing challenge.

As a result, smaller, lighter, and more flexible connectors that allow easier cable exits are required. For example, a 1.5-mm terminal may need to be downsized to 1.2-mm, and 18- or 20-gauge wire replaced with 22-gauge wire. Likewise, smaller insulation diameters and lighter weight aluminum wire may need to be used instead of copper wire.

Another option might be to move to single-mode glass or plastic fiber optic cable. One fiber optic line can replace multiple copper wires. Also, some manufacturers are using flat cabling because it can be mounted flat to the sides of the vehicle and does not have to be bundled like traditional wiring (a bundle of wires creates a circular cross section with a larger diameter whereas flat cable does not).

Finally, a communications network for a heavy-duty vehicle must be integrated based on system speed requirements, number of required ports, desired protocols, cable design, cable shielding levels, and connector attachments. That means connector suppliers must also be experts in systems design, preferably working as a team with the customers on initial communication systems designs. Selecting the right interconnect scheme, including overall resistance and shielding of the system, can be critical to creating 24/7 communications systems that help control heavy-duty vehicles now and in the future. ■

This article was written for *Off-Highway Engineering* by Gregory LaMirand, Global Business Development Manager; Arnold Perry Tchiegne, Industry Marketing Manager; and Dan Prescott, Director, Key Accounts and Industry Marketing, Molex, LLC.

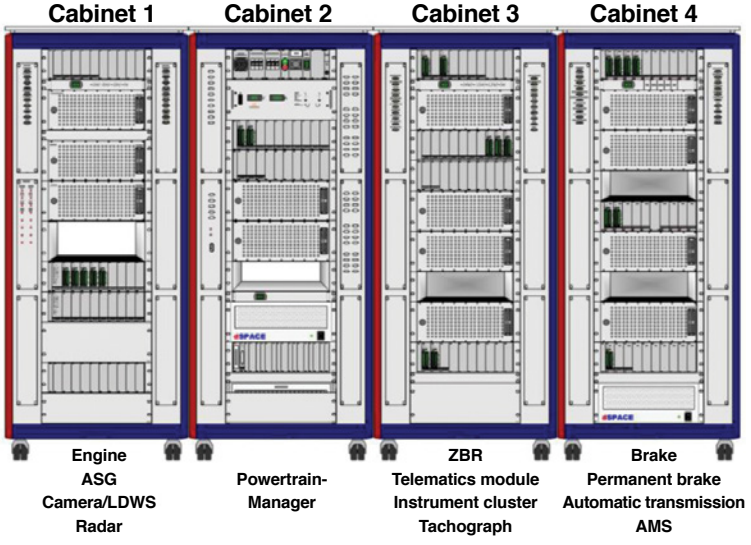


ADAS SYSTEM VALIDATION

It is crucial that different advanced driver assistance systems (ADAS) functionalities interact seamlessly with existing electronic control unit (ECU) networks.

Hardware-in-the-loop (HIL) systems have become the state-of-the-art technology for developing and testing ECUs in the automotive field. Testing of controller functionality in a virtual environment is rapidly becoming more important, especially for applications for commercial vehicles.

Due to higher numbers of axles, gear types, suspension systems, and trailer combinations, the number of possible vehicle variants is nearly unlimited. Today, over 90 ECUs are connected to network simulators at the same time and are used closed-loop with dynamic plant models. Eight years ago, only just over 20 ECUs were integrated in parallel. In addition to the validation of the many vehicle-specific variants, ever stricter laws on safety further increase the test effort.



ECU distribution of the multirack HIL simulator. Three PX20 expansion boxes from dSPACE are distributed across these four cabinets.

Some examples of concrete steps toward these goals in Europe are the mandatory installation of emergency brake assistants (EBAs) and lane keeping assistants in all new truck models from November 2013 and in all newly registered trucks from 2015. These European and international laws also specify the requirements for the lane guard system (LGS) and the EBA.

These typically radar- and video-based systems (EBA and LGS) particularly address the two main causes of accidents: driving into the rear of another vehicle and unintentionally leaving the road.

New requirements in the ADAS field increase the complexity of validating networked functions. In addition to accident-free driving, the areas of energy efficiency and digital networking also offer great innovation potential for vehicle manufacturers and suppliers. This increases the range of functionalities that the ECUs have to provide. These functionalities are now usually implemented in ECU networks and no longer assigned to dedicated ECUs.

Lab-based testing and system overview

Until recently, ADAS functionalities were significantly less interconnected and limited to particular ECUs. As these functionalities have become more interconnected and certain functions distributed across the ECU network, an end-to-end test is necessary to ensure the operational reliability of the system within the virtual vehicle. Thus, in addition to common component and integration tests on the HIL simulator that use dynamic plant models for sensors as well, integrating real sensors and actuators is especially important for ADAS applications.

On the other hand, the real human being has to be

replaced with a validation system to come to fully automated end-to-end tests. Thus, one major advantage of HIL simulation for ADAS functionalities is the possibility to test and calibrate the driver warnings of the actuators fully automatically. No real person has to be subjected to the continuous sounds and acoustic alerts of the driver assistance system.

One goal of the lab-based testing is to reach the highest possible driver acceptance for the different ADAS functionalities, like LGS, via maximum system availability and equipment quality. Error messages must be reduced without limiting the use cases.

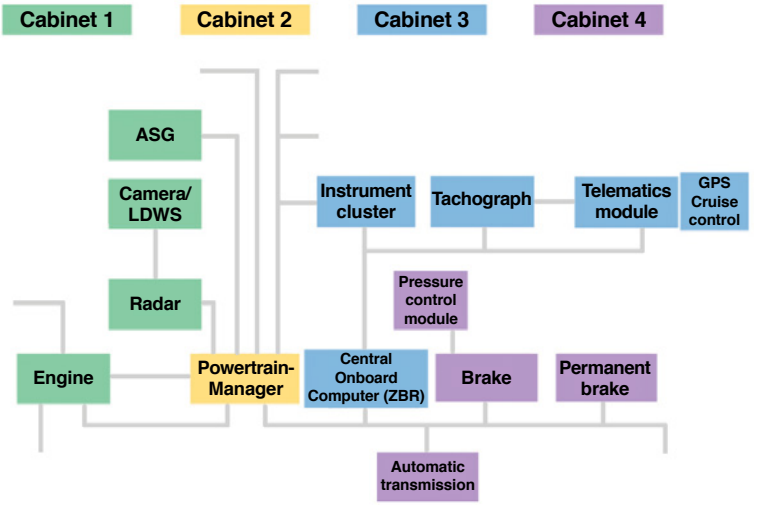
An HIL simulator was designed by **MAN** and **dSPACE** for testing the following ADAS functionalities in a virtual vehicle in the laboratory:

- LGS: A video camera behind the windscreen records the lane markings. Acoustic signals from the left or right speaker in the vehicle doors issue warnings for the driver.
- EBA: As a component of MAN BrakeMatic, the EBA aims to prevent or at least reduce rear-end collisions at the tail ends of traffic jams on highways.
- Adaptive cruise control (ACC): The ACC system automatically adjusts the driving speed and the distance to the vehicle ahead according to the specified settings.
- MAN EfficientCruise: A GPS-controlled cruise control that uses saved map material to take upward and downward gradients in the route ahead into account and to adapt the vehicle's speed strategy accordingly. Thus, the fuel consumption can be optimized.

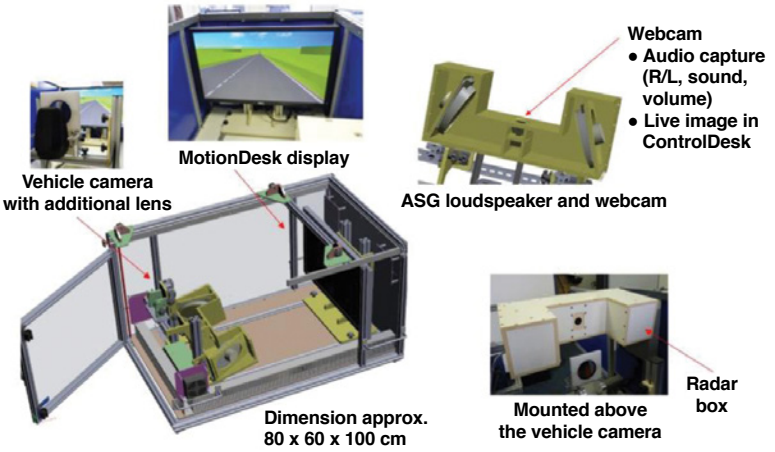
The test system simulated the complete chain of effects, starting with detecting the precarious situation up to supervising the acoustic or visual warnings in the driver's cabin. For this purpose, a real-time capable dynamic model was used with engine-related components, such as the engine itself, the exhaust system, the air path, the cooling system, and the exhaust brake; drivetrain-related components, such as the starter, the crankshaft, the clutch, and the gearbox; and components for simulating the vehicle dynamics and the environment, such as tires, brakes, the suspension and steering system, the trailer, the road, and traffic.

Due to its modular setup, the system was highly scalable and could be modified if further ECU functionalities had to be covered in later development stages. The HIL simulator contained a total of 26 CAN controllers. Twenty of them were used for establishing a "main-local" principle in which local enforcement of bus errors for individual ECUs was possible, while the remaining ECUs in the cluster or network were not affected by the manipulated bus signal.

The ECU network of the simulator was necessary to test distributed ECU functions. For example, during a brake maneuver of the antilock brake system (ABS), the electronic brake system (EBS), the engine ECU, and the transmission ECU communicate with each other. Tests of the EBA, as a further example, involve data exchange between cabinet one, which contains the connection to the camera-in-the-loop subsystem, and cabinet four, which contains the EBS.



Schematic of the CAN network of the HIL simulator distributed across the four cabinets.



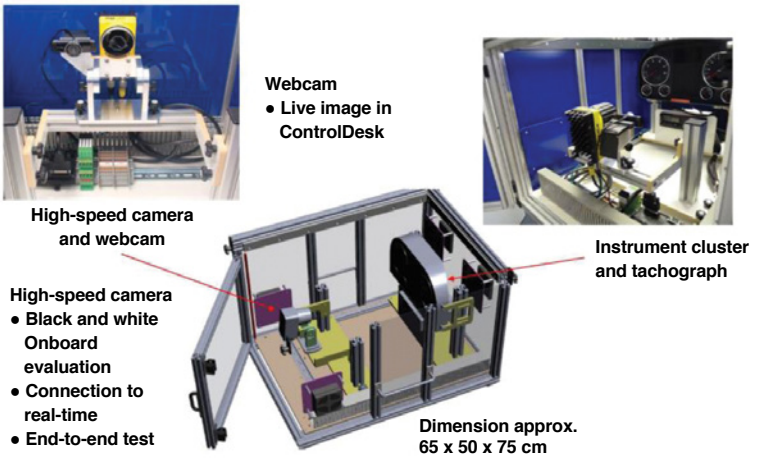
Camera box with MotionDesk display, webcam, loudspeaker setup, and radar box.

Acoustic and visual signals in the cab

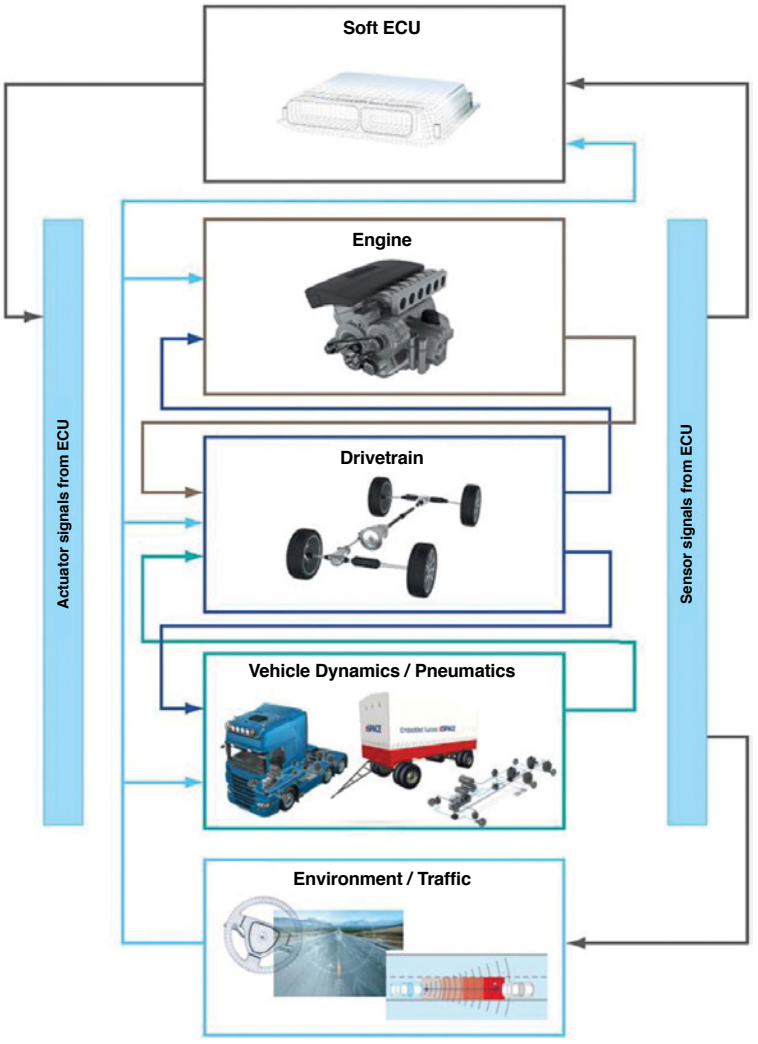
A camera box containing a set of vehicle loudspeakers, which in a real truck are integrated in the driver's cab, was embedded in a soundproof casing together with a two-channel microphone. The camera box was necessary because the HIL simulator is used for calibrating the LGS.

Because a well-calibrated driver assistance system increases acceptance by truck drivers, MAN's aim was to minimize false alerts while maintaining high system availability, especially in ambiguous traffic situations. For example, the LGS should not intervene if crossing the lane marking is inevitable at a highway exit or during an overtaking maneuver, at the beginning or at the end of curves, or during lane changing maneuvers for navigational purposes at highway junctions.

The system also had to be able to cope with various weather conditions, where lanes can be covered with snow or leaves, and faded lane markings or lane markings in different colors. The robustness of the control system was tested by utilizing a virtual driver with typical behavior patterns, as well as special vehicle model sequences for emulating standard maneuvers.



Monitoring the instrument cluster via a high-speed camera.



The ADAS HIL project used Automotive Simulation Models (ASM) from dSPACE as the basis for dynamic plant models including traffic simulation. The ASM are open Simulink models for the real-time simulation of automotive applications.

Another test field that involved the camera box was the response time of the LGS. According to the European and international laws mentioned earlier, the acoustic warning has to occur within a certain time period: No later than 1.4 s before the EBA initiates a deceleration of 4 m/s^2 or more, at least one type of haptic or acoustic warning has to be activated.

After another 0.6 seconds a second warning signal (acoustic, optic, or haptic) needs to be active. MAN wanted to exceed the minimum requirements without making the system sensitive or susceptible to errors. As a consequence the HIL needs to measure all these signals in real time with a synchronized time stamp: both the signals on the CAN bus and the occurrences of the optic and acoustic (haptic in this case is not implemented) warnings.

Microphones were used to record the acoustic output of the speakers of the LGS. The high-speed A/D boards captured the output of the microphones and passed it to a Simulink model, where it was processed via a discrete Fast Fourier transformation. Thus, it was possible to distinguish between different acoustic signals of the speakers and to track the output of the left and right vehicle loudspeaker synchronously to the real-time vehicle model and the recorded video frame.

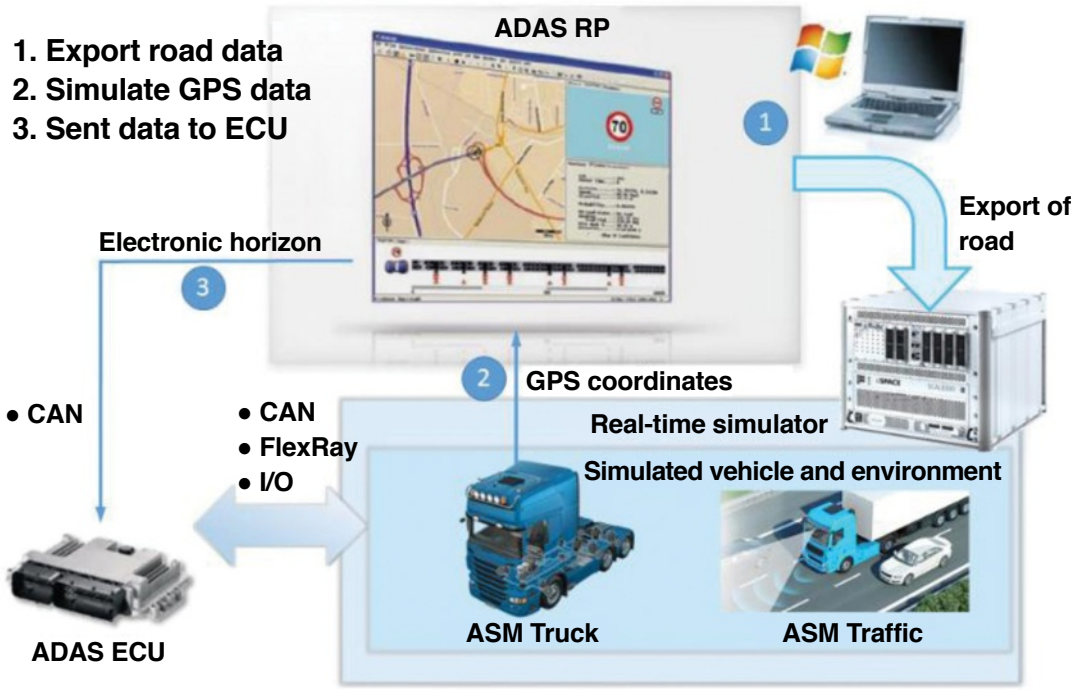
The instrument cluster was installed in a second box in the HIL simulator. A high-speed camera monitored its visual output. In addition to the states of standard truck display elements like current gear, speed indicator needle, control lamps, or fault indications, the camera also observed the states of the ADAS-relevant display elements: collision warnings of the predictive cruise control (PCC) assistant and the EBA, and warnings of the LGS. This data was sent as an Ethernet stream to the dSPACE real-time system, where the DS1006QC Ethernet Solution running on the fourth core of one processor board provided the associated Simulink interface. The state of the instrument was then mapped into specific CAN messages and transmitted on a separate measurement CAN of the simulator.

Also, a webcam within the instrument box was connected to the operating software ControlDesk as an external device and sent live images of the instrument cluster. The test system operator could therefore visually verify the data of the Ethernet data stream.

Generating data

The camera box contained the real radar sensors, encapsulated in a separate metal housing. In a real truck, these radar sensors exchange data with the radar object manager (ROM) ECU via a private CAN connection. To operate the ROM closed-loop in the HIL system, a dSPACE CAN controller was connected to this private CAN.

To generate data of virtual vehicles in front of the ego vehicle, a traffic simulation was used. Thus, the environmental data, such as movements of fellow vehicles or static and dynamic objects, was processed and mapped into the corresponding CAN messages. In this way, the ROM could be stimulated to provoke EBA actions. Both



Coupling the ADAS ECU to other ECUs creates a closed-loop environment that can be used to develop and test the different networked control strategies in the laboratory without a real prototype.

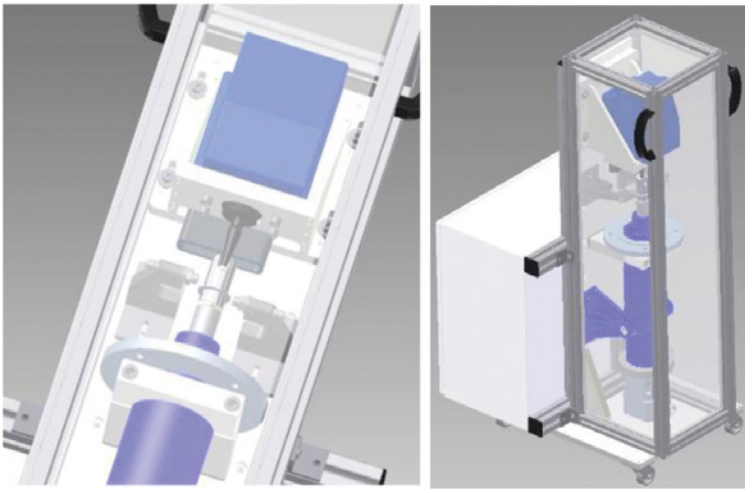
camera and radar sensors will detect such an obstacle.

Another private CAN connection between the camera and the ROM enables data transmission between the two. After data fusion within the ROM, the ROM initiates the emergency brake maneuver. If there is no valid camera input for sensor fusion, the ROM can initiate the emergency brake maneuver independently as a fallback option.

The vehicle's telematics board module (TBM) offers two interfaces for receiving GPS data: The real GPS antenna and an RS-232 development interface. The latter is used in the simulator and connected to the RS-232 port of one processor board. Appropriate road data is generated from the environment model and sent via stream, according to the **National Marine Electronics Association** (NMEA) standard, which is common practice for the data exchange of GPS devices. This NMEA stream is sent to the TBM via the RS-232 connection.

The simulator incorporates a network of ECUs that includes the EBS. As in the real vehicle this EBS ECU and the pneumatic actuator are one integrated device, the test rig has to contain a mechanical unit to stimulate the pneumatic actuator and thus the EBS ECU. The rack was developed to obtain usable test results. This rack contains a rack-and-pinion gearset and an actuator to operate the pneumatic actuator of the EBS.

Overall, the presence of ADAS functionalities in commercial vehicles will only continue to increase, and, as such, so will the effort for validating the distributed control algorithms. This research from MAN and dSPACE has shown that the integration of real sensors in closed-loop tests ultimately contributes to the test maturity of ADAS development and validation process. To make validating the high number of vehicle variants in the commercial vehicle sector more efficient, vehicle configurations can be created during run time.



The rack shown here facilitates closed-loop tests involving the virtual driver and automated tests of the simulated maneuvers, e.g. suddenly stepping on the brake pedal of a truck with trailer on an icy road. A mechanical actuator operates the vehicle brake.

The human-machine interface is an essential part of ADAS functionalities. End-to-end testing of the entire signal chain—from ADAS sensors to actuators—has to move into the spotlight of HIL testing. In this way the compulsory time delays can be tested in a reliable and repeatable way. Specially developed monitoring systems can thereby validate the acoustic and visual feedback of control interventions and serves as a new element in the tests of networked ECUs for ADAS applications. ■

This article is based on SAE International technical paper doi:10.4271/2015-01-2840 by Michael Peperhowe and Markus Friedrich, dSPACE GmbH, and Peter Schmitz-Valckenberg, MAN Truck & Bus AG.

Doosan introduces Tier 4 Final wheeled excavator

The rubber tires on Doosan's new DX210W-5 excavator is expected to particularly appeal to operators who regularly need to drive on finished concrete or asphalt surfaces.

Doosan has expanded its wheeled excavator lineup with the Tier 4 Final DX210W-5 excavator, which replaces the -3 Tier 4 Interim model.

The rubber tires on the new -5 excavator is expected to make it a popular choice for operators who regularly drive on finished concrete or asphalt surfaces. Doosan describes its wheeled excavators are often being used in highway/street development, building, manufacturing operations, site development, and land improvement. For example, an operator can drive on the shoulder of a road to dig in an adjacent ditch or use a bucket and clamp to pick up materials and load them into a truck.

A new selectable feature called Smart Power Control (SPC) engine mode comes standard on the DX210W-5. SPC consists of two systems—Variable Speed Control (VSC) and Pump Torque Control (PTC)—that work together to improve machine efficiency while maintaining productivity and reducing fuel consumption. The engine control unit automatically manages SPC when SPC is engaged. Each of the four power modes will function with SPC engaged or disengaged; however, SPC can be active only in the Digging work mode.

The DX210W-5 is fitted with a 186-hp Doosan DL06 diesel engine and aftertreatment technologies, and does not require a diesel particulate filter or regeneration.

VSC reduces engine rpm during low workload requirements such as during the swing portion of a dig cycle. This reduces the total energy required to perform a task and improves fuel efficiency by as much as 5%. PTC works to match hydraulic pump torque and engine response to the task, preventing engine overload and excess fuel consumption, improving efficiency.

The new -5 excavator also was launched with a variety of other product enhancements. The machine is equipped with two-pump auxiliary hydraulic flow for high-flow attachments and an optional floor pedal for operators to activate the hydraulics. Its rear camera was relocated for improved rear visibility. Also relocated was the emergency stop, making it easier for operators to reach on the seat base.

The DX210W-5 is fitted with a 186-hp Doosan DL06 diesel engine and aftertreatment technologies, and does not require a diesel particulate filter or regeneration. The engine is optimized for use with a high-pressure common-rail fuel delivery system and a cooled exhaust gas recirculation system. It uses a diesel oxidation catalyst to reduce particulate matter and selective catalytic reduction (SCR) aftertreatment to reduce nitrogen oxides. Additionally, a variety of aftertreatment systems have been implemented as part of the Tier 4 compliance, such as diesel exhaust fluid, which is used with SCR technology.

Doosan excavators come with a standard three-year subscription to Doosan Telematics, which allows equipment owners and fleet managers to remotely monitor machine location, hours, fuel usage, engine idle vs. work time and error codes, as well as engine and hydraulic temperatures. Machines can be monitored via an online Doosan Telematics account.

Jean L. Broge

SPOTLIGHT: MATERIALS & MANUFACTURING

Thermal shields

Interface Performance Materials has introduced two new thermal shields in the Select-a-Shield thermal product family—THH-1010 and TFP-3065—the first innovations in a series scheduled to be released through 2016. Suitable for use in the lawn and garden, power sports, automotive, and trucking industries, both thermal shielding products feature an inorganic fiber insulating core (0.65-mm thick for TFP-3065 and 1.0-mm thick for THH-1010) and a thin embossed foil facing to create a lightweight, durable shield that is directly applied to protect sensitive elements from a high-temperature source. TFP-3065 comes with a low surface energy pressure-sensitive adhesive (PSA) backing for plastic surface applications, while THH-1010 comes with high-temperature acrylic PSA for metal and painted surfaces. Both THH-1010 and TFP-3065 are also available without a PSA backing for mechanical fastening applications. Applications include fuel tanks, plastic body panels, acoustic parts, enclosure panels, and any surface that needs to be protected from heat sources, such as engine exhaust components. Both products can be placed within 15 mm (0.6 in) of a 560°C (1040°F) heat source. Test results show the thermal shields are resistant to underhood chemicals, power washing, gravel, and harsh environments. THH-1010 and TFP-3065 are available in rolls, sheets, and finished die-cut parts.

Fiber laser system

Prima Power has introduced the Laserdyne 430 Versa 3D fiber laser system with third-generation BeamDirector, designed for the typical laser processing needs of tool rooms, model shops, and R&D centers of manufacturers. The system is suitable for laser cutting, welding, drilling, texturing, and marking of a wide range of materials. The 430 Versa provides a cost-effective path into volume production by making possible the full benefits of fiber laser processing with an "effectively priced" workstation, the company claims. The 430 Versa is equipped with an air-cooled 3000-W peak power fiber laser and the proprietary BeamDirector, which provides two axes of laser beam motion without part movement. Precision stems from the accuracy of the 430 Versa motion system and from advanced features that allow the fiber laser to perform a range of tasks—the result of integrated control of the laser, motion, and processors. Laserdyne S94P control with standard hardware and software features include Automatic Focus Control for capacitive part sensing, and as an option, the patented Optical Focus Control for sensing of non-conductive surfaces. The 430 Versa also includes a range of standard focusing lens assemblies including right angle assemblies for processing inside cylinders having diameters as small as 60 mm (2.4 in) and welding assemblies that shield the weld metal to prevent contamination and protect the focusing lens from spatter.

Two-way communication system

The **Sensear** Heavy Vehicle Communication Solution (HVCS) enables clear transmission of two-way radio communications and stereo audio for operating heavy vehicles at industrial sites. The combination of noise from different factors can bring a worker's noise exposures into the 90 dB to 95 dB range, at which most occupational health and safety sanctions require actions to reduce exposure. By using the HVCS, in most cases the exposure is dropped by 10 dB or more. Other features include the ability to charge the headsets in-vehicle if prior charging was missed; built-in redundancy, allowing the original speaker to be re-enabled via internal relay operated by a lockable key switch; and generic cabling harnesses for custom installation. The system meets heavy-vehicle standards including dust, water, and vibration requirements.

Mid-range alternator

Remy International's Delco Remy 38SI high output alternator features remote sense to reduce battery charge time and a unique stator design that improves horsepower requirements and fuel savings. According to the company, fuel cost savings and efficiency ratings improve as alternator efficiency increases 60 to 72% over a typical life cycle. A premium brushless design transfers magnetic fields between the field and rotor air-gap, eliminating the need for brushes and extending life, while equipment inspection and approval assure quality and performance for aftermarket replacements. The high-efficiency, mid-range amperage alternator offers 215 A and is suitable for school buses, line-haul commercial trucks with anti-idling equipment, emergency vehicles, refuse trucks, utility vehicles, shuttle buses, and recreational vehicles.

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PRODUCT BRIEFS

Inertial measurement unit

Tamagawa Seiki has launched a series of automotive and industrial-grade inertial measurement units (IMUs) for affordable high-performance applications. Model AU7595 features high accuracy and GPS for measuring position, direction, and attitude of vehicles or any mobile application. The AU7595 is equipped with three-axis, high-precision, piezoelectric MEMS gyros and stable accelerometer sensors for high resolution, precision, and low-noise requirements. The multi GNSS receiver is compatible with QZSS and GLONASS and includes digital interfaces (CAN or Serial IF). Software is provided and features a data logger and a traveling locus display. The Model TAG247 version of AU7595 is housed in a protective case and comes with cables. Model AU7554 is a compact—35-mm (1.4-in) square—and low-price unit with an optional GPS receiver. The AU7554 outputs triaxial angular velocity, acceleration, and angles supported by stable thermal behavior and repeatability. I/O interfaces include CAN, RS232C, and USB. The Model TAG250 version of AU7554 has various options including a protective case, GPS receiver substrate, wireless communication substrate (Bluetooth), and battery pack. Both IMUs are non-ITAR/EAR and are used in commercial products (not for military). **AdvanTech International**, Inc. is the exclusive marketing partner of Tamagawa Seiki in the U.S. and Canada.

Self-lubricating plastic bearing material

The iglide L500 plastic bearing material from **igus** is suited for continuous operation in high-speed rotation applications under low loads. The material combines high wear resistance in long-running, high-speed applications. Continuous rotational speeds of more than 16 ft/s (4.9 m/s) are possible, and the L500 material performs even under extreme environmental conditions, such as temperatures ranging from -148 to +482°F (-100 to +250°C), as well as media contact. The positive material properties of the iglide L500 enable the self-lubricating operation of electric motors, fans, and ventilators, where sintered bearings were previously used. The L500 material will also be available for the development and production of customer-specific bearing solutions.

Electric oil pump

The Model OP40i brushless dc electric oil pump from **Engineered Machined Products** Inc. (EMP) features high-performance gerotor pumping technology, including a long-life, brushless, dc sensorless motor, which is sealed and fully submersible. It delivers 4.0 gal/min (15 L/min) at 100 psi (6.9 bar). Applications include lubrication, cooling, hybrids, oil scavenge, oil change, engine parasitics, and bypass filtration. Advantages of the system include a fully integrated motor drive controller, claimed best-in-class performance (flow capacity and discharge pressure), cold start capability, low EMC/EMI signature and susceptibility, long life, IP69K rating for sealability, ease of serviceability, and customizability.

COMPANIES MENTIONED

UPCOMING FROM THE EDITORS

December 8: Off-Highway Engineering Technology eNewsletter

December 8: Aerospace Engineering Technology eNewsletter

December 15: Automotive Engineering Technology eNewsletter

December 15: Vehicle Engineering Technology eNewsletter (all markets)

January: Automotive Engineering Digital Magazine
- Consumer electronics: Infotainment & driver assistance
- Sensors product spotlight

January 5: Aerospace Engineering Technology eNewsletter

January 12: Vehicle Engineering Technology eNewsletter (all markets)

January 14: Off-Highway Engineering Technology eNewsletter

January 19: Automotive Engineering Technology eNewsletter

January 26: Heavy Duty Technology eNewsletter (on- and off-highway)

February: Aerospace & Defense Technology Print Magazine
- Surveillance/Security/Communications
- Thermal management
- HMI and the passenger experience
- Streamlining production
- RF & Microwave Technology Section

February: Automotive Engineering Print Magazine
- Cybersecurity (webinar to follow)
- New gasoline and diesel engines
- NAIAS highlights
- Vehicle electrical architectures
- Data Acquisition product spotlight

February: Off-Highway Engineering Print Magazine
- Connected vehicles (webinar to follow)
- Hybrid and electric drives
- Suspension systems
- Human-machine interface: Touch screens
- CAD/CAE Software product spotlight

AD INDEX

Q&A

"Early on in the program, we recognized that multiple pathways would be required and that we could not shut down any ideas in order to achieve the aggressive targets," said DTNA's Derek Rotz.

Lessons learned from SuperTruck

Daimler Trucks North America has referred to its $40 million, five-year SuperTruck program that concluded earlier this year as "a playground for our engineers." Overseeing this playground's development and integration activities was Derek Rotz, the Principal Investigator who was hired in 2010 when the program kicked off. "We were able to work on very high-risk, high-reward technologies, and provide functional demonstration on a line-haul program," he said. The team leveraged the knowledge and expertise of the global Daimler organization to accelerate development. For example, among other responsibilities, **Freightliner** experts in Portland, OR, took the lead on base vehicle development, aerodynamics/cooling, lightweighting, and vehicle integration; engineers at **Detroit Diesel** concentrated on base engine development, high-voltage controls, and waste heat recovery (WHR); **Mercedes-Benz** in Stuttgart, Germany, also worked on WHR as well as predictive hybrid control and powertrain electronics; while **Fuso** engineers in Japan focused on the hybrid-electric powertrain. In the end, the company "far exceeded" its expectations, achieving 115% freight efficiency improvement, 12.2 mpg, and 50.2% brake thermal efficiency. "Some of our trucks on the road already have the lessons learned from SuperTruck," Rotz shared with *Off-Highway Engineering*. For the full transcript, visit http://articles.sae.org/14446/.

What were some of the program's main challenges or trade-offs?
In some cases, there are conflicting goals that had to be resolved. For example, cooling the engine and improving aerodynamic performance are typically at odds with each other in terms of how they handle the airflow. This was one of many trade-offs that needed to take place. The answer in this case was to create the articulating grille; while at slower speeds and while climbing a grade when the engine loads increase, the grille louvres open up to provide airflow through the engine compartment and the cooling package; at higher speeds when aerodynamics is more important, the grille bars close to maximize those benefits. Also with aerodynamics and cooling, we actually have the cooling package tilted back by 20°. We have a nice, round aerodynamic hood and a very square cooling package, so we tried to find numerous ways to adjust the cooling package to make it better fit with the aerodynamic hood. We settled on keeping the cooling package as is and we just tilted it.

Another example: We have a hybrid-electric powertrain on board that we basically use for regen braking, like when you're going downhill, and essentially we're using that to intelligently manage the kinetic energy of the vehicle as it goes up and down the hill. The system worked—it's still pretty expensive, still pretty heavy, it's not commercially available—but we ended up identifying other ways of managing that kinetic energy, essentially through complicated software. We have an application called eCoast, which allows you to shift the transmission into neutral under zero engine torque conditions. The engine has this friction torque when it's not being motored so you decouple that and then you can drive more efficiently. And secondly, we introduced predictive technologies—the use of 3D digital maps and GPS to provide the vehicle with knowledge of the road ahead—hills, curves, etc. With that we're able to adjust the cruise control speed, the shifting, and essentially manage the kinetic energy that way without having used the hybrid. Essentially, we discovered that the hybrid and the predictive [technologies] were competing for the same inefficiencies, and one is sort of a vague and heavy system and the other is software. So that was another case.

Additionally, there were questions on how do we develop a safe and efficient high-voltage power distribution system, not only for the hybrid but also for the waste heat recovery systems as well. High-voltage systems are things that we had not looked at in the past.

What were some of the 'high-risk, high-reward' technologies and what's their feasibility?
By starting with a clean-sheet approach and with new ideas, we recognized that some technologies would make it into a highway tractor quicker than other technologies. In some cases, some of the systems we developed on SuperTruck are not currently feasible. Some of the technologies may not be fully mature yet; some of the technologies have a longer payback period than our customers would expect; and in other instances such as the rearview camera, regulations that mandate the use of mirrors actually impede progress. But there are a number of technologies which had immediate transfer potential to our current product line, and customers today are already experiencing those benefits. Examples include the aerodynamic packages on the current Cascadia Evolution, the integrated Detroit powertrain including technologies such as downspeeding with a 2.28 rear axle ratio, eCoast, predictive shifting, and direct drive AMTs (automatic manual transmissions).

We still continue to push forward with new and improved benefits for the vehicles: aerodynamic benefits such as drive wheel fairings, underbody covers, and the active grille—things that we're still looking at. And we also are looking to make improvements to the base engine efficiencies as well as the auxiliary systems such as the power steering, air conditioning, and air compressor systems. Currently, there are limited feasibilities with hybrid-electric technology and waste heat recovery; however, SuperTruck did give us the opportunity to explore those technologies to truly understand both the potential and the obstacles needed to introduce these challenging technologies into the product. From that we have a much better understanding.

Ryan Gehm

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