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EDITORIAL

The future is not far-off

Approaching the end of another year, the tendency to evaluate the recent past and then contemplate what lies ahead is inevitable. Of course, OEMs and suppliers continuously evaluate their technology choices, as they navigate market and regulatory forces that impact which pathways will be most successful and profitable. As we approach the crystal ball drop that rings in each new year, it's also fun to gaze into the crystal ball to see what the future holds. This issue, which has an overarching theme of Future Look, offers insights into many technologies and trends that will shape 2017 and beyond.

A new **Frost & Sullivan** report analyzes "transformational trends" that are shaping the commercial trucking industry, such as digital transformation and autonomous technology, which is expected be a key product differentiator for OEMs in the next 10-15 years. The industry has moved well beyond basic telematics, the consulting firm notes, to integrate advanced traffic modeling, weather prediction, and social media analytics. By 2025, OEMs are expected to introduce Level 3 (Conditional Automation) autonomous trucks.

"Autonomous and connectivity technologies, Big Data analytics, and advanced powertrains are the future of trucking," said Frost & Sullivan intelligent mobility research analyst Silpa Paul. "This evolution is inevitable as a truck driver shortage in North America…strengthens the case for autonomous trucks."

Though referencing commercial trucks specifically, this Frost & Sullivan analysis could very easily apply to any number of off-highway sectors. For example, weather prediction will play a significant factor in the future of precision farming and machine automation, according to **CNH Industrial**. In the future, the company's concept tractors (read more on page 12) will be able to use Big Data such as real-time weather satellite information to automatically make best use of ideal conditions.

Mirroring Frost & Sullivan's analysis, Martin Weissburg, president of **Volvo CE**, laid out three main technology areas that the company is devoting significant R&D resources to further develop: automation, connectivity, and alternative drivelines and fuels. Volvo CE demonstrated innovations in each of these areas (see page 14) at its recent Xploration Forum event.

"In the future, you could potentially have one operator for three or four machines," said Jenny Elfsberg, director of emerging technologies at Volvo CE. "Looking ahead, I imagine that autonomous machines will be smaller and more robust [with] no need for a cab or suspension."

Big Data will not only influence vehicles, but also the manufacturing plants that produce them. "We're on the cusp of the next industrial revolution, driven by Big Data. I think that's very clear," said Nigel Francis, VP of advanced engineering & electrification systems at **American Axle & Manufacturing**. But making sense of that data once collected and applying it in a proactive way is a big challenge. (Read more on page 20.)

Phase 2 greenhouse gas (GHG) standards for commercial trucks (see pages 6 and 32) are considered a "technology-advancing" phase that will require emerging technologies not yet in widespread use, according to the U.S. **EPA** and **NHTSA**. One technology area, in particular, will benefit from these standards, believes Lukas Walter of AVL: "CO_2 reduction is the future driver for alternative fuels," he said.

Trailers are included within the new GHG mandate for the first time, and startup **Hyliion** believes it has a solution that can satisfy the requirement on its own. Its add-on intelligent electric drive axle system (see page 10) was recently awarded the grand prize in the 2016 Create the Future design contest.

"From a timing standpoint, it couldn't be better," said CEO Thomas Healy.

All of these technologies will find further advancement in 2017, whether in production vehicles or prototypes running hard hours over-the-road and on-the-dirt. The future is being created—and demonstrated—now.

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WHAT'S NEW

John Deere emphasizes drivetrain electrification for mining, construction

John Deere has invested in the integration of its engines, drivetrain components and power electronics into complete electric powertrain solutions for mobile off-highway machines that the company believes will be of benefit to mining equipment manufacturers.

John Deere Power Systems and **John Deere Electronic Solutions** featured several electric drivetrain products at MINExpo International in Las Vegas, designed for the rugged demands of mining and construction applications.

One of these highlights was the John Deere Electronic Solutions (JDES) family of inverters, which is based on a modular concept and includes power stage, bus capacitor and optional brake chopper with a common control module.

Read the full article at **http://articles.sae.org/15112/**.

WHAT'S NEW

UPS launches hydraulic-hybrid propulsion into Chicago service

United Parcel Service (UPS) has begun converting 50 of its gasoline-engine delivery trucks in the Chicago-metro area to hydraulic-hybrid propulsion. The first converted vehicles recently entered service equipped with **Lightning Hybrids**' hydraulic-hybrid system featuring an energy recovery system (ERS).

A hydraulic-hybrid vehicle blends two propulsion systems to provide benefits including improved fuel economy and emissions reductions. According to UPS, the standard-gasoline-fueled ICEs are combined with Lightning Hybrids' ERS, a system designed for medium- and heavy-duty vehicles with a front-engine/rear-drive layout, therefore suitable for this subset of the UPS fleet.

The hybrid systems are converting the 50 **Freightliner** MT-55s into cleaner and more fuel-efficient units, claims Lightning Hybrids. According to the company, the hybrid systems provide additional torque and reduce internal engine stress, which subsequently allows UPS to use less-expensive gasoline engines rather than diesels, substantially reducing NOx emissions in the process.

Read the full article at **http://articles.sae.org/15051/**.

WHAT'S NEW

Deutz and Liebherr form diesel-engine strategic alliance

Engine manufacturer **Deutz** AG and **Liebherr Machines Bulle** S.A., developer and producer of diesel and gas engines, recently agreed on the key aspects of a strategic alliance for worldwide distribution of diesel engines. With this arrangement, Liebherr intends to grant Deutz worldwide sales and service rights for its 200 to 700 kW (268 to 938 hp) diesel engines for a variety of applications, according to a release from Deutz.

The engines are being developed for the EU Stage V, U.S. Tier 4, China IV, and EU Stage IIIA emissions standards, meeting future statutory requirements for exhaust emissions. The engines, manufactured by Liebherr, will be available to Deutz for series delivery from 2019.

A fit with its product portfolio, Deutz says it plans to sell the diesel engines under its own brand to its customers, including through its network of dealers. As part of the agreement, Deutz will receive exclusive rights for the production of a Liebherr 9-L engine in China. An expansion of the use of Deutz engines in Liebherr's machines up to 150 kW (201 hp) also is planned.

Read the full article at **http://articles.sae.org/15102/**.

POWERTRAIN

Enhanced Cat 3500 engine boosts power 20%, trims fuel usage by 10%

The 3500E, the latest iteration of **Caterpillar**'s venerable 3500 engine family, provides up to 20% greater power density, 10% greater fuel efficiency, enhanced durability and longer life before overhauls. The upgraded engine maintains existing form factors, so rebuilds and replacements can be utilized with minimal infrastructure changes.

The 3500E outputs 188 kW (252 hp) per cylinder, more than double the 75 kW (101 hp)/cylinder output of the first 3500, which went into production in 1981. Overall, the engine offers up to 4040 hp (3015 kW). Engine displacement ranges from 34 L for the eight-cylinder model to 78 L for the 16-cylinder version.

While improved performance was the primary goal for developers, maintaining backwards compatibility was also a key parameter. The 3500 has been in production for 35 years, with more than 190,000 engines in the field. Those engines are operating primarily in mining, rail, electric power, oil & gas and marine applications, as well as in Cat machines.

Joe Markun, Cat's General Manager of Large Engine Manufacturing, highlighted the engine's legacy by noting that one of the first 3500Es is being shipped to a company that bought a very early 3500 engine.

Cat's 3500E engine adds power and trims fuel consumption while retaining existing form factors.

Redesigned but backwards compatible

The revamped engine series achieves its power increases from the enhanced cast-iron engine block and cylinder heads. A redesign for the block and crankshaft increases durability.

"We redesigned the crankshaft, though it remains backward compatible with existing engines," said Ronald Smith, Engineering Manager for the 3500 platform. "We added material to the cylinder head and block in some places. We also altered the processes, but we didn't change the steel. We also increased the pressure in the cylinder."

Cat has remanufactured more than 13,000 model 3500 engines at the Lafayette, IN, facility where the engine is manufactured. Rebuilds in Indiana and a second engine manufacturing plant in China augment rebuilds done by dealers and others. The factory has several ongoing programs designed to ensure quality while meeting demanding specifications. Though the 3500E is huge, it's manufactured with extreme precision.

"The crankshaft tolerances go down to five microns," Smith said. "Every fourth crankshaft is validated to maintain those tolerances. The whole factory is temperature controlled so all our measurements are precise."

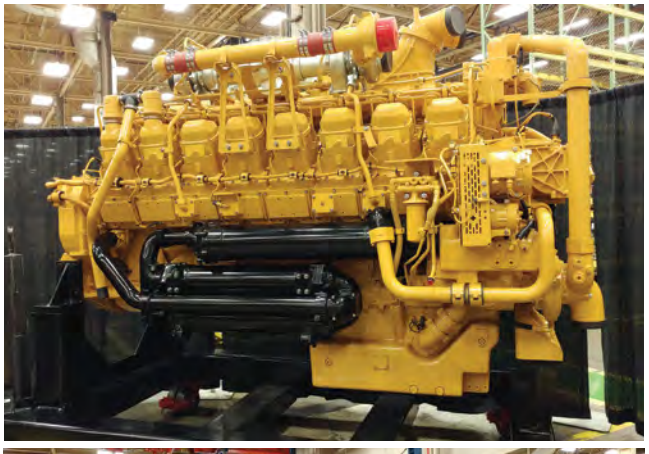
The engine has two fuel system options: mechanical electronic unit injector or common rail. Various fuels can be used. Gas, diesel, biofuels and any mixture of these options can be burned efficiently, letting users in different markets pick the best solutions for their operating environment, gaining fuel efficiency improvements of up to 10%.

Aftertreatment options are also available. The 3500E uses either a selective catalytic reduction (SCR) or an exhaust gas recirculation (EGR) aftertreatment system to meet U.S. **EPA** Tier 4 Final and EU Stage IIIB emissions standards.

"Some engines will use SCR, using urea," Smith said. "In applications like fracking, they don't want another fluid, getting it to a remote site is difficult. EGR is an alternative to urea. The cost of ownership is also different."

Those are just a few of the available options for the engine line, which is designed for customization so variants can be produced in small volumes for specific markets. In many applications, orders are for only one or two engines. Even versions built for data centers, a higher volume application where five to 10 similar units will be produced at one time, will have differences such as right- or left-hand servicing.

"We make as many as 900 variations," Smith said. "We build everything to order, 44% of our engines are unique."



Improved performance was the primary goal for developers, but maintaining backwards compatibility was also a key parameter. These 3500Es are ready to ship from Caterpillar's plant in Lafayette, IN. (Terry Costlow photos)

Telematics for predictive diagnostics

The 3500E is also getting upgraded electronics. Cat's A5 engine control module provides enhanced I/O capabilities along with a faster processor and more memory. One of its key roles is to drive the injectors.

The additional processing capabilities also help provide more diagnostics and predictive diagnostics, or prognostics. Monitoring engines so maintenance can be performed before breakdowns occur is becoming simpler. Technicians can more easily monitor usage from remote sites so they can determine the optimal time for servicing.

"We're putting telematic modules on the engine," Smith said. "Users can interrogate any sensor, getting readings and doing things like comparisons of the sensor compared to 30 days ago. Product Link uses cellular or satellite connections to operate anywhere."

Cat isn't limiting its focus on reducing energy consumption to the hours that the engine is operating in the field. When engines are being validated at the factory, they're used to generate up to 6.5 kW of electrical energy. That's roughly half the consumption of the 1.3 million square foot Lafayette facility, Markun noted.

Terry Costlow

REGULATIONS

Phase 2 GHG rules driver for advanced technology, alternative fuels

Regarding climate change, "we really are in a race against time," said Christopher Grundler, Director of the Office of Transportation and Air Quality for the U.S. EPA.

NACFE's David Schaller noted that organizations like SAE International should be quick to develop the needed standards and practices to support the industry in its efforts.

Opening day of the **SAE** 2016 Commercial Vehicle Engineering Congress featured a well-attended symposium on "Meeting the Challenges of Phase 2 GHG: Implications and Effects." A keynote presentation by Christopher Grundler, Director of the Office of Transportation and Air Quality for the **U.S. EPA**, kicked off the event, during which he stressed the importance of implementing emissions regulations like the recently issued final Phase 2 greenhouse gas standards affecting model year 2021-2027 medium- and heavy-duty on-highway vehicles.

"We need to accelerate what we're doing because we really are in a race against time," he said regarding global climate change. "We are heading now into uncharted territory," with average CO_2 levels in the atmosphere exceeding 400 parts per million for the first time ever.

The U.S. EPA and National Highway Traffic Safety Administration (**NHTSA**) expect the new rules to save more than 1 billion metric tons of CO_2 emissions and 2 billion barrels of oil, while also saving vehicle owners $170 billion in fuel costs, over the life of the program.

For Class 7 and 8 combination tractors—one of four regulatory categories—the fully phased-in standards will achieve up to 25% lower CO_2 emissions and fuel consumption compared to the Phase 1 standards. Trailers used with heavy-duty combination tractors, a new category for Phase 2, are expected to achieve an up-to-9% reduction compared to an average model year 2017 trailer once the standards are fully phased in.

The agencies refer to Phase 2 as a "technology-advancing" phase that will require emerging technologies not yet in widespread use. Grundler is quick to note, however, that the standard is "technology neutral."

"Our job is more than just setting standards and having some numbers," Grundler said. "If the people that use these trucks don't buy them in numbers that matter, we've failed."

Following the keynote, four SAE-member industry experts provided their respective viewpoints on the topic. Timothy Blubaugh of the **Truck Manufacturers Association** echoed what several other speakers stated at COMVEC—that there needs to be one nationwide standard that allows manufacturers to build a single fleet of vehicles and engines for the U.S. market.

"California must adopt [Phase 2] as is to keep a 50-state program," he said. "We've heard noise that [**CARB**] thinks there should be aerodynamics on certain vocational vehicles where it's not required in the U.S. rules [for example]. So we're a little concerned, but it's a critical element of ensuring that we have [consistency]."

Dave Schaller of the **North American Council for Freight Efficiency** (NACFE) works with fleets to help them understand the technologies that improve fuel efficiency, and those that aren't as effective in certain applications.

"How do fleets gain the confidence to go out and spend the money. There are so many opportunities for them," Schaller said. Around 70 adoptable technologies for the Class 8 line-haul and regional-haul industry are evaluated on the NACFE website, he noted.

Five major barriers to adoption are uncertain payback time, questionable reliability, lack of access to capital, a dearth of

"CO_2 reduction is the future driver for alternative fuels," said AVL's Lukas Walter.

credible information, and lack of technology availability.

Illustrating the struggles fleets face, Schaller and his NACFE colleague Michael Roeth write in SAE technical paper 2016-01-8014, "There are areas that can be hard to monetize. Lightweighting benefits are easy for weight-sensitive fleet operations, but to all other fleets, the value of running lighter is much more difficult to factor into the payback calculation." This is one of many examples they detail in the paper.

Schaller and Roeth also note that support organizations such as SAE International and the **Technology & Maintenance Council** should be quick to develop the needed standards and practices to support the industry in its efforts to develop and quickly implement fuel-saving technologies.

On-road statistical databases that reflect real-world use are going to grow and have greater impact as better data is gathered and more is known about factors such as loads and the weather, according to Nigel Clark of **West Virginia University**. Clark conducts research within the WVU Center for Alternative Fuels, Engines and Emissions.

"On-road statistical databases are going to drive design and certification changes," he said. "We've got to know more about different vocations and loads within a class. Right now, a lot of this information is held by fleets."

Clark highlighted a number of "tools in the toolbox" to help improve fuel efficiency, pointing out those that pose some challenges such as waste heat recovery.

"When you come to use that waste heat, the technology can be quite expensive," he said. "You can use it in various ways, but it isn't economical and it also adds weight to the vehicle. So that's an example of one that requires quite a lot of examination."

Lukas Walter of **AVL** believes the industry "can definitely achieve" upcoming legislation like Phase 2 with already-demonstrated technologies that just need further development and optimization. The commercial vehicle sector should examine other industries for component-sharing opportunities to improve the business case of technologies such as battery systems, he said.

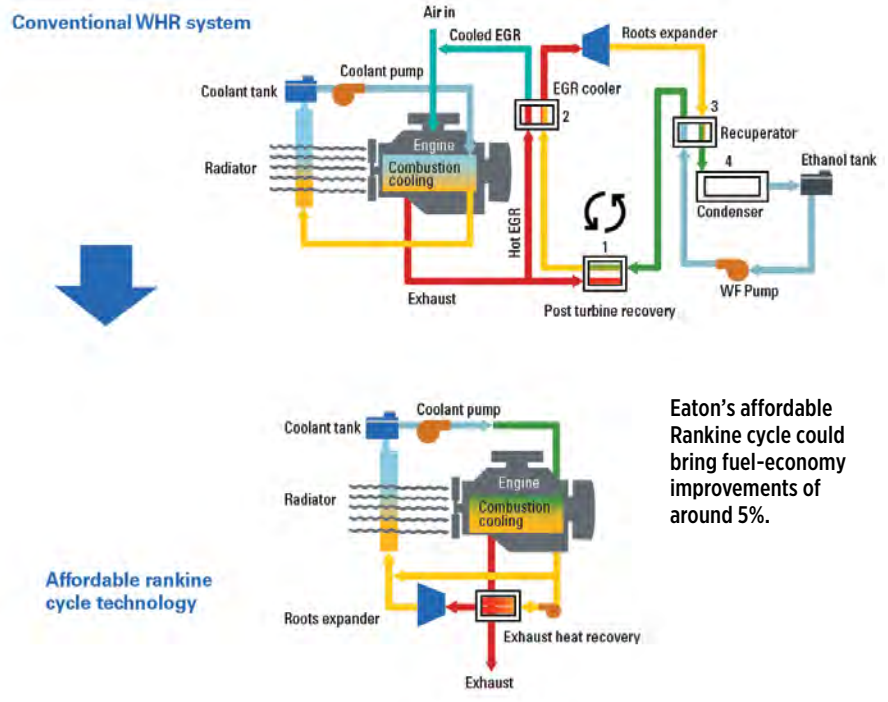
Is there a single technology that can reduce CO_2 by more than 20%? Walter posed this question and offered alternative fuels as a possible solution. Natural gas direct injection, for example, could achieve more than 20% reduction at the same torque level as a diesel engine, according to AVL testing.

"CO_2 reduction is the future driver for alternative fuels," he said.

Ryan Gehm

POWERTRAIN

Eaton demonstrates waste heat recovery, variable valve actuation for HD diesels



Eaton's affordable Rankine cycle could bring fuel-economy improvements of around 5%.

Eaton demonstrated a range of waste heat recovery (WHR) technologies for heavy-duty diesel engines at the IAA Commercial Vehicles show in Hanover, Germany, as well as variable valve timing systems, highlighting their potential to reduce fuel consumption and help reduce emissions.

Both indirect and direct WHR systems were on display. The organic Rankine cycle (ORC) design recovers waste heat indirectly using a heat exchanger with the exhaust system. Alternatively, Eaton's "electrified" system recovers energy directly using an exhaust-driven Roots compressor in conjunction with a motor/generator.

ORC WHR systems can yield fuel-economy improvements of around 5%, but system cost is high, involving a small external combustion piston engine. Eaton looked at what fluids were already carried on board the vehicle to avoid adding another for the ORC WHR system. The first fluid the company considered was ethylene glycol, already used in engine coolant systems.

As Larry Bennett, director of advanced engineering, Eaton Vehicle Group, observes, the fluid would already be hot from use as an engine coolant, but would it have the potential to add more exhaust heat to it and extract more energy? "Now we can create most of the ORC system with existing componentry," said Bennett. "We now have a **U.S. Department of Energy** (DOE) grant. We're working with **Paccar**, **Shell Oil** and **Mississippi State University**, which is where all the actual testing will take place.

"Shell is working on a fluid that has the capability to do this for us. The idea is to see if we can achieve enough waste heat and form this face transition, then utilize it and see if it's going to work."

One of Eaton's research scientists suggested that diesel exhaust fluid (DEF)/AdBlue urea solution for exhaust aftertreatment of oxides of nitrogen (NOx) would be an ideal ORC fluid.

"The idea is exactly the same—you perform the Rankine cycle by boiling the DEF fluid," explained Bennett. "One of the interesting byproducts is that after you heat it up, ammonia gas comes off and when you cool it down, it doesn't want to readily return to the liquid state. We can store that ammonia gas."

Once the engine has cooled down and is restarted, NOx output and treatment is an issue. "If you start it back up, you're producing a ton of NOx because you don't have ammonia gas to be able to treat it," said Bennett. "You need the temperature in the exhaust system to get up to 250°C in order to take the liquid ammonia you're injecting to get it to vaporize so that you can treat the NOx."

The ammonia stored from the evaporated DEF should be enough to treat NOx for the first 15 minutes as the engine comes up to operating temperature. "It's all research, all modeling simulation, but it appears feasible," he said.

The direct WHR system involves fitting a Roots compressor system right next to the exhaust manifold and using the exhaust gas flow to drive the compressor rotors. Short-term testing shows that the energy can be recaptured.

"The initial concept is to have a motor/generator hooked up to it, then basically take the energy and put it in a

A compression engine brake in diesel engines is possible by introducing variable valve actuation.

battery," said Bennett. This is not the most efficient way to recapture energy, but it offers another possibility. Eaton's research scientists believe that this system could be used as a pump when there is a need for high rates of exhaust gas recirculation (EGR). The system could potentially deliver high rates of EGR independent of engine speed.

Eaton had previously developed an electronically assisted variable speed supercharger for use with gasoline engines. "In this application, we can now vary, independent of engine speed, the amount of boost that the engine can get," Bennett explained. "On a diesel, that has a lot of advantages in the form of downsizing and instant torque. The big thing would be to manage airflow and exhaust flow independent of engine speed." That capability would be highly attractive to engine manufacturers.

The direct WHR system has shown through simulation a 22% improvement in fuel economy while reducing NOx, Eaton claims.

Variable valve actuation has not been widely used so far with diesel engines, but there are a number of potential advantages. The first is a compression engine brake. Early intake valve closing and late intake valve closing could reduce combustion temperatures and NOx, or improve efficiency.

"You could have early exhaust valve closing for a transient to give faster boost in a turbocharger," said Majo Cecur, engineering manager, advanced valvetrain, Eaton Vehicle Group.

A Roots-type compressor combined with an electric motor/generator could offer a range of waste heat recovery functions.

"You could de-activate cylinders in light load conditions so that you could have better fuel efficiency."

Eaton is investigating valve operation designs that would enable a range of such functions.

John Kendall

ELECTRIFICATION

Hyliion develops add-on hybrid system for semi-trailers that reduces fuel consumption by 30%

Hyliion has developed an add-on hybrid system for tractor-trailers that will reduce fuel consumption by about 30% with a return on investment of less than one year, according to Thomas Healy, CEO and founder of the Pittsburgh, PA-based startup.

"What makes our system unique is that we solely focus on the trailer," Healy said to *Off-Highway Engineering*. "We replace the existing rear axle assembly under the trailer with an electric propulsion system. So now what happens is when the vehicle is slowing down or going downhill, we're able to capture all that wasted energy and store it in the battery pack on the trailer."

When the truck accelerates or starts an uphill stretch, the system drives the rear tires on the trailer. "So the diesel engine in the truck doesn't have to work as hard, there's not as much load it needs to pull," he said.

The intelligent electric drive axle system was recently awarded the grand prize in the 2016 "Create the Future" Design Contest produced by **Tech Briefs Media Group**, beating out more than 1100 product ideas from 71 countries. The contest was co-sponsored by **COMSOL** and **Mouser Electronics**, with **Analog Devices** and **Intel** serving as supporting sponsors.

(Additional category winners in Aerospace & Defense, Automotive, Electronics and more can be viewed at www.createthefuturecontest.com.)

Most conventional hybrid strategies integrate an electric motor into the drivetrain of the truck. "Since we don't integrate right into the drivetrain, you can keep all that existing equipment and not make any modifications to it. We're getting the benefits of a hybrid system but with an add-on solution," Healy said.

Essentially, Hyliion is turning a passive axle into a drive axle. "It's like taking one of the axles off the truck and putting it on the trailer," he explained. "So now we have a drive axle that we can apply positive and negative torque, with an electric motor connected to the axle." The electric motor is connected to a control system with a lithium-based battery pack.

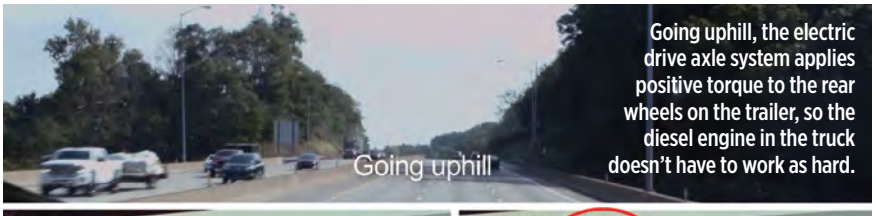
The company leverages existing components to help bring the product to market faster. For example, the axle is a production component that's already been tested and has the weight rating certifications needed to travel over the road.

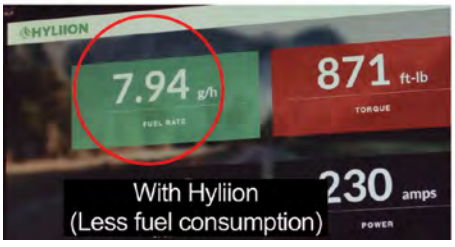
The system can be installed on nearly every trailer type in less than one hour, the company claims, without changing trailer height or length.

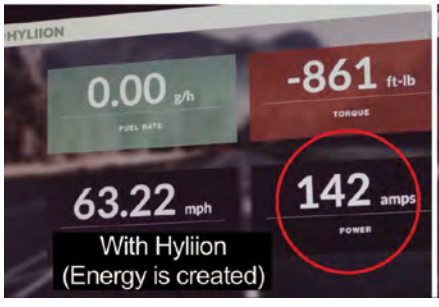
The electric drive axle system is categorized as an auxiliary power unit (APU), capable of powering auxiliaries overnight such as electronics and air-conditioning. Even though the system adds about 500 lb (227 kg) to a tractor-trailer, "the government in most states allows you to carry anywhere from 400-450 extra pounds of payload if you're running an APU. So it's really not netting much of a loss of cargo that you can carry," Healy said.

The electric drive axle doesn't have any data communication with the truck. The system's sensors are able to determine when to apply power and when to capture energy. It does have cellular communication and satellite, so the vehicle can be tracked.

"From a fleet standpoint, you can look at how fast your trailers are moving and where they're located, and we can do things like tell you how much







Hyliion's electric-drive system hybridizes the trailer portion of the tractor-trailer combination and uses regenerative braking to capture power, possibly saving the trucking industry billions in fuel costs.

load is in the trailer," Healy said.

Information is available to the driver via a mobile dashboard application. The driver also has the ability to turn the system on and off.

Final Phase 2 greenhouse gas standards, affecting model year 2021-2027 medium- and heavy-duty on-highway vehicles, mandate for the first time that fuel-saving technology be employed on the trailer in addition to the truck. (See pages 6 and 32 for more on Phase 2 regulations.)

"Our single product is able to propel you above those mandated requirements," said Healy. "We see it being a perfect solution for this new Phase 2 mandate that's coming out. From a timing standpoint, it couldn't be better."

Hyliion currently has six trucks running with its system for internal testing and validation. "The next phase is we've got over 30 fleets that have signed into our pilot program that we're going to start delivering units to before the end of this year," he said.

In-house production of the electric drive axle system is expected to begin Q1 2017, and the company is lining up outsourced production for higher volumes in Q2 2017.

"Our next big milestone is really setting up the production," Healy shared. "There is a lot of demand in the industry for a product like this...How can we manage all the production and supply chain so that we can grow at a very fast pace and get our partners alongside us to grow at the same rate? Our mindset is scaling up production as fast as possible to as high a volume as possible."

Ryan Gehm

AUTONOMOUS

Agriculture, construction, mining—even marine—are advancing autonomous technology to improve the productivity and safety of vehicles on the job.

by Ryan Gehm

In the future, CNH's concept tractors will use "Big Data" such as real-time weather satellite information to automatically make best use of ideal conditions. The New Holland T8 NHDrive autonomous concept with the 2085 air disc drill is pictured.

When engineers and executives discuss macro technology trends, regardless of the specific off-highway sector, increased automation of vehicles is inevitably among them. Though experts recognize that achieving full automation in production equipment will take some time, operator-assistance technologies such as automatic braking are becoming more widely available today.

And companies aren't shy about revealing autonomous prototypes that promise what's on the horizon. For example, **Komatsu** unveiled its Innovative Autonomous Haulage Vehicle featuring a cab-less structure at MINExpo in September. Unlike its 930E and 830E autonomous models, Komatsu claims it developed this vehicle exclusively for unmanned operation to maximize the advantages.

By distributing equal load to the four wheels when the vehicle is loaded and unloaded, and adopting four-wheel drive, retarder and steering, Komatsu is aiming for high-performance shuttling of the new haulage vehicle in both forward and reverse travel directions, eliminating the need for K-turns at loading and unloading sites.

Komatsu plans a market introduction for the new autonomous vehicle "in the near future."

CNH Industrial and **Volvo Construction Equipment** are two other companies with big plans for automation. Their latest autonomous vehicle demonstrators and development programs are detailed here.

CNH advances driverless tech for tractors

Precision farming and machine automation already play a significant role in agriculture. CNH Industrial's Innovation Group is focusing on key times of the year when farm work still requires long days in the field, particularly when harvesting a crop or planting the next one.

Working with Utah-based technology provider **Autonomous Solutions** Inc. (ASI), the Innovation Group developed concept autonomous technology to meet this challenge and demonstrated it via tractor concepts based on the existing **Case IH** Magnum and **New Holland** T8 high-horsepower conventional tractors.

"There have a been a number of groups and product platforms that have been involved with automation of some of the tractor onboard systems, and those are all enablers that allowed us to put together a very successful autonomous concept vehicle program," John Posselius, CNH Industrial Head of Agricultural Innovation Technology, told *Off-Highway Engineering*. "Things as simple as having ISOBUS Class 3 capabilities on our tractor allows us to communicate by wire to all of the important functions on the tractor such as the hydraulics, the hydraulic remote, the three-point hitch, PTO, steering, transmission and engine control."

The concept tractors are configured as two distinct versions: the cab-less Case IH Magnum and the New Holland T8 NHDrive concept that maintains its cab for operating flexibility. Both use a conventional engine, transmission, chassis and implement couplings.

A fully interactive interface has been developed to control the tractors. Three operating screens include a path-plotting screen that shows the tractor's progress, one that shows live camera feeds with up to four views (two front, two rear), and a screen that enables monitoring and modification of key machine and implement parameters such as engine speed and implement settings.

plows ahead

The Case IH Magnum autonomous concept tractor, shown with the Early Riser 2150 planter, looks futuristic with its cab-less design, carbon-fiber front fenders and signature LED status running lights.

Once path plotting has finished, the user can choose a job from a pre-programmed menu by selecting the vehicle, choosing the field and then setting the tractor out on its task. The sequence takes about 30 seconds.

The two tractors have a complete sensing and perception package in common, which includes radar, Lidar and video cameras to ensure obstacles in the tractor's path or that of the implement are detected and avoided. If an object is detected in the tractor's path, visual and audio warnings appear on the control interface—either tablet interface or desktop—which offers a choice of how the tractor should respond: by waiting for human intervention, driving around the obstacle using either a manually or automatically plotted path, or driving onwards if the object is not a danger.

"The fencing and perception is a real challenge," said Posselius. "We've built in some nice systems in our concept vehicles and they do what we need right now. But one of the real challenges to truly move forward is our sensing and perception has to get much smarter."

When operating parameters become critical, as in the case of low fuel or seed levels, the same notifying system is employed. Any critical machine alarms or loss of critical machine control functions cause the autonomous vehicle to stop automatically, or a stop button on the control interface can be activated manually.

Machine tasks can be modified in real time, such as if a storm is approaching. In the future, these concept tractors will be able to use "Big Data" such as real-time weather satellite information to automatically make best use of ideal conditions, independent of human input, regardless of the time of day, the company claims. For example, the tractor would stop automatically should it become apparent weather would cause a problem, then recommence work when conditions have sufficiently improved; or they could be sent to another field altogether where conditions are better.

The tablet interface also can be mounted in another machine whose operator can supervise its activities. As an example, from the seat of a combine or tractor, the operator can monitor the progress and eventually modify the performance of an autonomous tractor/planter combination working in the same or neighboring field. This allows autonomous tractors to "seamlessly integrate" into an existing farm machinery fleet, with minimal operational changes.

According to CNH, the autonomous technologies have been designed so that, in the future, they could be further developed to enable their application across the full range of equipment in a farmer's fleet. This could encompass the full range of tractors, harvesting equipment and support vehicles, such as sprayers.

Being a diverse company with operations in three segments—Commercial Vehicle, Agricultural and Construction Machinery—transfer of technology from one application to another is not only possible but an actuality. CNH's construction business is in the early stages of applying autonomous technology to some of its smaller equipment.

"What we develop in one sphere we can very easily adapt and apply in the others," a spokeswoman told *OHE*. "You've got truck platooning [by **Iveco**] and all the technology behind that, which we can sort of cherry-pick what we can from the experience there and then apply it to the Ag sphere and Construction business. We're not operating in silos."

With the autonomous tractors, the company is already working with some customers in the U.S. to set up an initial pilot program over a

AUTONOMOUS *plows ahead*

Komatsu's Innovative Autonomous Haulage Vehicle, shown at MINExpo 2016 in Las Vegas, demonstrates a trend toward cab-less structures as vehicles become fully automated.

small group of farms with diverse operating conditions and environments. The program, which is expected to start next year, will help to determine how these products work in the real world and where some of the snags might be when operating in different conditions.

"So far, work has been strictly under the engineering organizations, specifically the Innovation Group, but we are broadening that," said Posselius. "As we work with our customers, what we're trying to see is how they would use something like this if it was a production piece of equipment. What specific needs do they have that we may not have foreseen yet? A lot of that work will not be done by our other organizations that deal closer with our customers."

Volvo CE demos prototype autonomous machines

Automation is one of three main technology areas—along with connectivity and alternative drivelines and fuels—that Volvo Construction Equipment is devoting significant R&D resources to further develop. At its recent Xploration Forum in Eskilstuna, Sweden, the

Self-driving by land—and by sea

Sea Machines Robotics is developing autonomous technologies that it believes will revolutionize the marine sector, enabling smarter, safer and more efficient operations via self-aware and self-driving boats and ships.

"The transition of one of the world's oldest forms of transportation to autonomous operation is inevitable and necessary," said Michael Johnson, founder of the Boston-based startup. "Sea Machines provides systems that give real and immediate value to vessel operators by increasing safety and efficiency. And our technology will facilitate entirely new oceanic applications, enabling better use of the seas to accommodate a growing world."

Founded in 2013, Sea Machines develops advanced control systems for boats and ships and specialized unmanned surface vessels. The technology can be deployed as an autonomous "overwatch" system on manned vessels. A Remote Command System, called RC-NXT, provides PLC-based wireless control of a vessel and is suitable for day-vessel operations such as work boats, tugs, and launches operating within 1000 m (3280 ft) of the pilot. With the RC-NXT upgrade kit, full manual controls of the vessel are retained and rapid transition between remote and traditional operations is possible.

An Autonomous Navigation System, called DP-NXT, uses vessel-based sensors—inertial navigation system/GPS, 4G radar, AIS (automatic identification system), EO/IR camera, sonar—and proprietary algorithms to enable watercraft to self-motor from point-to-point while avoiding active and passive obstacles or collaborate in tandem with another vessel.

DP-NXT is currently offered for vessels up to 24 m (80 ft) in length but can be configured for larger craft operations. The system can be integrated to various propulsion and steering configurations including electric, gas/diesel, diesel-electric, inboard, outboard, sterndrive, and water jet and can be augmented by maneuvering thrusters.

Sea Machines is currently testing its technology on commercial vessels in Boston Harbor where remote piloting of an unmanned vessel,

Sea Machines' DP-NXT autonomous control system, shown integrated with an OEM hull, allows vessels to be operated in Line of Sight, Over the Horizon, Collaborative, and Direct Belt Pack Control modes.

unmanned oil spill response, and autonomous waypoint navigation have already been demonstrated. Upcoming demonstrations include collaborative multi-vessel operations and automated obstacle avoidance.

The company believes the marine domain is even better suited for autonomous systems than aerospace, automotive and off-highway sectors. Why? Fewer barriers to entry, a high risk operating environment, and an accommodating regulatory space make marine ripe for a transition to highly automated operation.

With more than 20 million vessels plying the world's waters including 15 million recreational boats and 100,000 cargo ships, Sea Machines foresees autonomy disrupting this largely manual sector and developing into a $60 billion space.

This vision includes eliminating everyday boating accidents and shipwrecks via self-aware, self-driving navigation; increasing commercial marine productivity by automating vessel tasks; furthering safety of personnel by using unmanned vessels to perform work in hazardous environments like oil spills, marine firefighting, or other high risk operations; and enabling new remote oceanic industries such as deep sea fish farming and clean energy production.

Ryan Gehm

company demonstrated for select media including *OHE* several advanced prototypes highlighting these technologies. Among them were a prototype autonomous wheel loader and articulated hauler working together: The wheel loader filled the articulated hauler, before dumping its load and repeating the cycle.

"The technologies that are exploding in autonomous cars, we are able to leverage in our industries—infrastructure solutions, construction equipment, highway trucks, buses," said Martin Weissburg, member of the Volvo Group executive board and president of Volvo CE. "And you can easily argue that autonomous vehicles are easier to launch first in an infrastructure setting like a quarry or a mine or even roadworks, because they're contained."

Volvo CE conducted a one-hour comparison between the autonomous wheel loader and one run by a skilled operator, and found that the autonomous prototype could reach productivity levels at the equivalent of 70% when loading and unloading. Jenny Elfsberg, director of emerging technologies, notes that this finding is not just theoretical—the machine has done "real work" for a Volvo CE customer at an asphalt plant in Sweden.

"The demonstration machines were programmed to work together and carry out a specific set of actions on a pre-defined route," Elfsberg explained. "The machines can perform the same task over and over again, along a fixed route, for a relatively long period of time. But it's still early days for this technology; we are working on developing solutions that have the required safety and performance levels that the market will accept."

Significant work still needs carried out before such machines can carry out more complex tasks and ultimately reach production, she said: "There are no plans for industrialization at this stage. Currently these prototype machines don't communicate with each other and machine-to-machine communication technology—where machines 'talk' to one another and to a central control point—is crucial when it comes to avoiding collisions and facilitating an efficient flow of equipment."

The demonstrator machines are standard Volvo products—a L120 wheel loader and an A25F articulated hauler—which have been upgraded with autonomous technology. Add-on equipment includes high-performance computers compared to the standard ECUs, roof-mounted GNSS on the hauler, which provides about 1-cm (0.4-in) accuracy in positioning, and a Lidar system and radar on the loader. Algorithms can recalculate a vehicle's route in real time for obstacle avoidance.

Once a solution is finalized, the technology could be applied to other products in Volvo CE's range, Elfsberg said.

"In the future, you could potentially have one operator for three or four machines, increasing productivity and further decreasing costs," she said. "Looking ahead, I imagine that autonomous machines will be smaller and more robust. There will be no need for a cab or suspension, much like the HX1 concept which Volvo CE unveiled as part of its electric site research project."

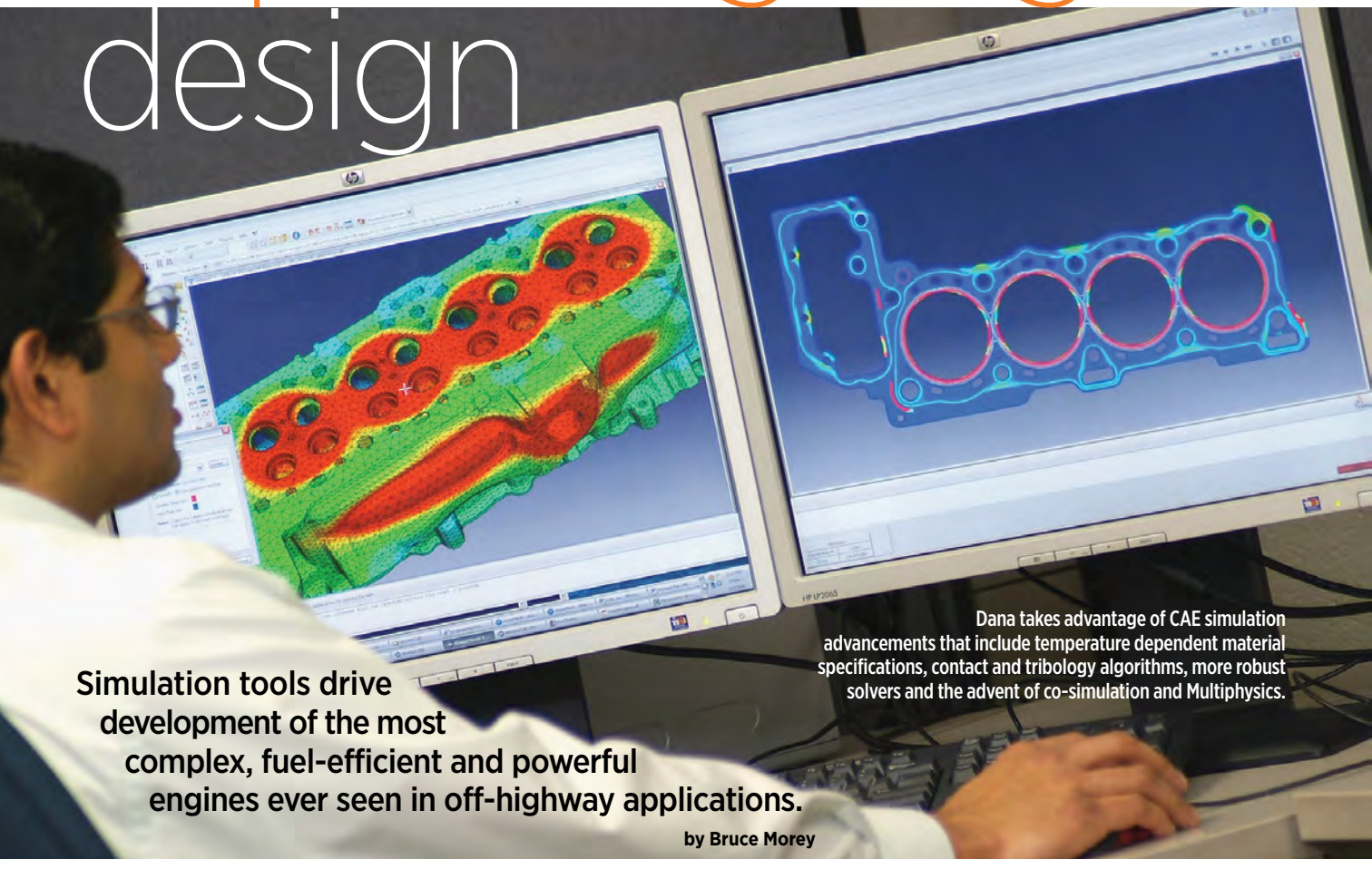
The demonstrator machines are standard Volvo products—a L120 wheel loader and an A25F articulated hauler—which have been upgraded with autonomous technology. Add-on equipment includes high-performance computers, roof-mounted GNSS, a Lidar system and radar.

The autonomous battery-electric HX1 load carrier prototype was demonstrated by Volvo CE as one component of its electric worksite project, which can possibly result in 95% fewer carbon emissions and a 25% reduction in total cost of ownership.

Volvo CE has been working on autonomous-machine research for more than a decade, resulting in the development of what the company terms "mid-term innovations." Semi-automated or automated functions will support more immediate developments years before realizing full autonomy. For example, Volvo Co-Pilot, launched earlier in 2016, offers a range of intelligent machine services to help operators, including Load Assist, Dig Assist, Compact Assist and Pave Assist.

"We are starting to see systems that are less dependent on operator skills, ones that support operators with guidance or control primary functions," said Elfsberg. "In the future, we will see increased machine autonomy and the operator will act more in a supervisory capacity...Of course, some tasks are so complicated that you really need to feel what you're doing; in those cases, we will still need operators controlling the machines from inside the cab." ■

Expediting engine design



Dana takes advantage of CAE simulation advancements that include temperature dependent material specifications, contact and tribology algorithms, more robust solvers and the advent of co-simulation and Multiphysics.

Simulation tools drive development of the most complex, fuel-efficient and powerful engines ever seen in off-highway applications.

by Bruce Morey

Creating or updating a new engine today is more complicated than ever. Most heavy-duty and off-highway engine makers are expanding their product lines, responding to an increasingly diverse global marketplace. A good example is **Perkins**.

"[Our] priority is in expanding our engine range, not only with new models for U.S. **EPA** Tier 4 Final, but also by offering OEMs a full range of global platforms," said Oliver Lythgoe, Perkins product marketing manager. "Whether they are based in the Americas, Europe or Asia, OEMs are increasingly wanting to participate in global markets, and that means having platforms that can be cost-effectively adapted to the different global emissions standards without excessive R&D expenditure."

The front end of the development process has changed considerably, Lythgoe explained to *Off-Highway Engineering*. Apart from the considerable advancements in CAE, he noted that they are also able to consider, through CAD collaboration with customers, how engines will be installed in machine designs in the early phases of engine design. Other experts have noted the importance of this system integration.

"System integration has been going through a transformation in recent years with the introduction of electrified powertrains, including hybrid solutions," said Michael Franke, director, light-duty and diesel commercial engines for **FEV North America**.

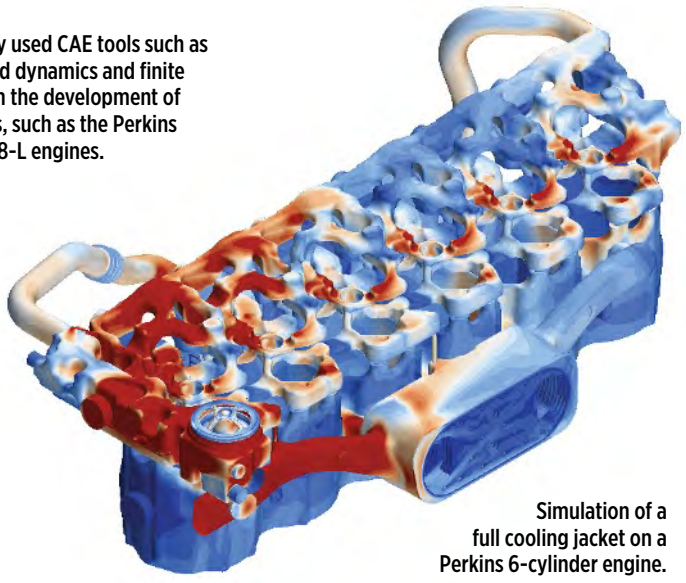
Franke believes development processes are not fixed. They continuously change with the introduction of new technologies and new engineering tools. New technologies used to meet Tier 4 final regulations include electronic fuel injection, electronic boost control, exhaust gas recirculation (EGR) and exhaust aftertreatment. Add to this their associated control functions and new development methods are required, he said. This implies mandatory implementation of systematic systems-engineering approaches, and especially model-based design methodologies.

Another theme expressed by most experts interviewed for this story is the adoption of simulation-led design—using simulation tools to create the design rather than validate an already existing one.

"CAE tools are well suited to be used to lead the design process, providing accurate and efficient design direction," explained Brian Campbell, chief engineer, design engineering, FEV North America. Why? "[Because the] capabilities of CAE tools and hardware platforms continue to evolve, allowing for faster solutions to more complicated CAE problems," he said.

This speed is enabling simulation-led design techniques such as structural optimization, the process of choosing a "best" design that meets specified constraints using CAE. "With today's focuses on increasing

Perkins extensively used CAE tools such as computational fluid dynamics and finite element analysis in the development of its latest platforms, such as the Perkins Syncro 3.6- and 2.8-L engines.



Simulation of a full cooling jacket on a Perkins 6-cylinder engine.

engine power and reducing weight, design optimization tools can provide significant insight toward meeting these often-conflicting objectives," he said.

CAE-designed components and details

While simulation design and enhanced systems engineering are useful for those looking at engines and powertrains, CAE is proving its worth in designing components as well. One example is **Dana**, a supplier of cylinder head gaskets, exhaust gaskets, secondary gaskets, and turbo gaskets as well as various heat shields and other smaller—but vital—components. The push for better fuel economy and cleaner emissions is translating into higher peak operating pressures as well as weight reduction, Rohit Ramkumar, manager of CAE for the Power Technologies Group, Dana, explained to *OHE*.

Ramkumar agrees that product development processes across the board are moving toward simulation-led design, even for the components that Dana provides.

"You also hear about the 'virtual' or 'digital twin' as well," he said, where companies evolve the specifics of a design from the concept stage into manufacturing and beyond. "There is definitely more push for suppliers like us to come up with design options up front. Simulation is not a 'feel good factor' anymore, but a reality of the product development process and ensuring the engine will meet the requirements of stringent operating conditions."

As Ramkumar described it, adoption of simulation-led design is clearly enabled by improvements in both algorithms and the advancing power of inexpensive computing. Co-simulations combine multiple disciplines, such as finite element structural code with a computational fluid dynamic (CFD) code. This captures temperature induced stress, for example.

"These have helped us in general improve our processes including better correlation with test," he said. He also cites optimization tools as more powerful than ever, providing useful insight when developing designs using CAE tools.

CAE tools advance

Gamma Technologies, maker of the well-known GT POWER modeling tool for engines and its GT SUITE for powertrain and vehicle-level simulations, has seen the growing complexity in engines over time.

"In anticipation of these trends, GT-SUITE has been created specifically as an integrated vehicle system tool capable of responding to these demands," explained Dr. Thomas Morel, president and founder of the company. "Integration of the whole vehicle system enables evaluations of subsystem alternatives, even individual component alternatives and their effect on fuel economy, emissions and NVH."

The tool also combines modeling methods, using so-called 0D and 1D system models integrated with 3D models. The company notes that this makes GT-SUITE a particularly useful tool for model-based systems engineering, or MBSE, which enables the progressive development of an engine or powertrain from an initial concept to the final product. It does this by first using 0D and 1D system modeling tools then switching to high-fidelity 3D models that examine system performance, efficiency, dynamics, structural stresses and temperatures and other parameters.

Morel emphasized that GT-SUITE models the whole vehicle. "From fuel combustion to the wheels, including the effects of fluids, hydraulics, all mechanical systems, thermal analysis, chemistry, tribology, friction, hardware-in-the-loop and controls," he said.

Another key point that Morel emphasized—and was echoed by many other tool suppliers—is the growing need to interface and incorporate simulation tools from other suppliers. For example, the company offers an engine combustion tool from **Convergent Science** and a CAD-to-model tool as well as a virtual analysis tool for complete vehicles, including GT-SUITE and the predictive 3D chassis models, from Adams, the dynamics tool from **MSC Software**.

Toward that end, the company recently released its own unique

Expediting engine design

technology for co-simulation employing xLink. To simulate a system, it accepts any tool that matches the Functional Mockup Interface (FMI) standard, Simulink, or executables compiled as a Dynamic-Link Library (DLL). It can also implement a user-defined code through the xLink interface.

(For further information on Functional Mockup Interface, see "CAE's next leap forward" at http://articles.sae.org/14859/.)

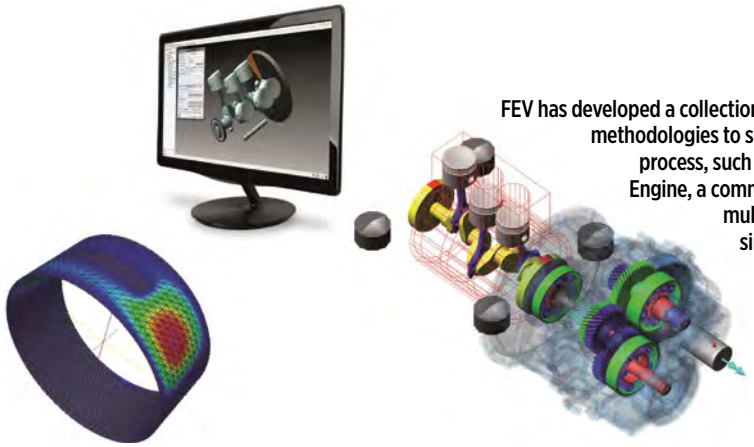
"Access to the right computing power will not be a limiting factor." That is the view of Vivian Page, engineering systems team leader, **Cat Industrial Engines**. "The challenge will be in how we manage and process the vast amounts of data and information that are generated by these simulation tools to understand the complex multi-physics environment within a diesel engine."

Closing the loop with the real world

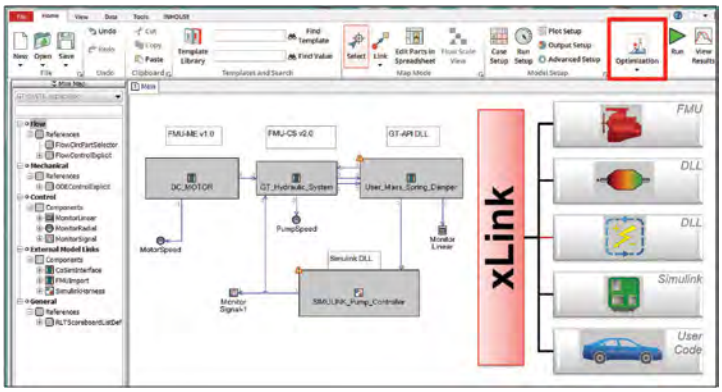
Siemens PLM Software is responding to comments like Page's, looking at a grander view of engineering. "There is a movement across all industries, including off-highway, that is looking to incorporate a new set of technologies," explained Ravi Shankar, director of marketing, simulation and test solutions, Siemens PLM Software. These include use of advanced lightweight materials, additive manufacturing, mass customization and wide deployment of inexpensive sensors.

Through acquisitions and investment, Siemens PLM is looking to help companies incorporate these new technologies in a new way. It has created a comprehensive portfolio of simulation and data management tools in its newly announced Simcenter portfolio, combining advanced simulation and the potential to access real-world data through the Industrial Internet of Things (IIoT).

Siemens PLM integrates a host of technologies within its Simcenter portfolio, mirroring the trends in the field.



FEV has developed a collection of CAE tools and methodologies to support the design process, such as the FEV Virtual Engine, a commercially available multi-body dynamics simulation package based on the well-known MSC/Adams solver.



Increasingly, companies like Gamma Technologies are creating links so that Multiphysics and co-simulations can access other codes through a variety of gateways.

"Data can be fed back to engineering teams to provide more useful predictive results and react with more updates to the customers," explained Shankar. "We think of that as opening a new front with [Big Data] analytics combined with physics-based simulations that we are now calling Predictive Engineering Analytics."

This means constraints for optimization runs can be further honed from actual data on, say, bulldozers or agricultural equipment. Actual operator preferences can be accounted for, and actual operating cycles can be used for setting engine parameters for best fuel economy in engines. This sort of talk leads naturally to discussions of "digital twin," a simulated version of a real engine used to monitor and predict its behavior—at its heart the Predictive Engineering Analytics that Shankar describes. This is especially relevant to off-highway engine development, with the focus on operating economics and the equipment's high duty cycles.

"With our acquisition of **LMS** and now **CD-adapco**, we have a comprehensive portfolio of simulation, test and data management solutions—as well as established consultancies—we think we are unique in our ability to combine that with IIoT," said Shankar.

However, the future of CAE in engine development is not limited to Big Data and analytics. Much new development is going into microscale simulation, especially in combustion, as well as co-simulation and Multiphysics. "For example, modeling the engine and its coolant flow requires multiple disciplines, and as engines get more efficient, modeling these types of physics will get ever more important," he said.

That said, physical testing remains important. "One thing that has not changed is that we still have a strong commitment to field validation for all our products," stressed Perkins' Lythgoe. "Expectations of OEMs and machine users are high, so we spend thousands of hours testing our engines, including in extreme temperatures and conditions."

The virtual can only go so far. ■

INDUSTRY 4.0: The smart factory arrives

The plants that produce vehicles and their high-tech systems are increasingly employing intelligent systems, Big Data and advanced analytics to improve quality, safety and efficiency.

by Ryan Gehm

Human-centered Industry 4.0 is utilized in the production of TraXon transmissions for commercial vehicles in ZF's Friedrichshafen plant. The assembly process is supported step-by-step by software via an integrated user interface.

A new "data-driven" manufacturing facility that **Faurecia** opened in Columbus, IN, in October 2016 embodies perfectly the premise and promise of the Industrial Internet of Things (IIoT): a smart environment that gathers vast amounts of information, seamlessly intermingles automated robotic vehicles with humans and ultimately ushers in the end of "dirty jobs." The 400,000-ft^2 (37,160-m^2), $64 million state-of-the-art plant will employ 450 people and produce a new, advanced emissions-control product for the commercial vehicle industry.

One of those employees will be a full-time, on-site mathematician whose sole purpose is to help mine the terabytes of data being generated daily at the factory, cull insights and forecast issues before they occur. This job illustrates the shifting nature of the manufacturing landscape, according to Dave DeGraaf, president of Faurecia Emissions Control Technologies North America—to one that is clean, technologically advanced and proactive, and aimed at attracting employees with different and advanced skillsets.

"This facility represents our entry into Industry 4.0, a revolutionary concept incorporating connectivity, automation, data processing and hardware to advance the manufacturing industry," said Mike Galarno, plant manager of Columbus South. The new plant employs, among other technologies, self-learning autonomous intelligent vehicles (AIVs) to transport components to the assembly line.

Automotive supplier **Magna** develops advanced driver assistance systems (ADAS) for vehicles, and many of these same technologies can be applied in factories, according to Ian Simmons, vice president of business development, corporate engineering and R&D at Magna International.

"Radar, multiple sensors, sensor fusion in vehicles, some of these you'll find in intelligent guided vehicles within the manufacturing space," he said. "And even how to interface with people with different sensors and biometrics."

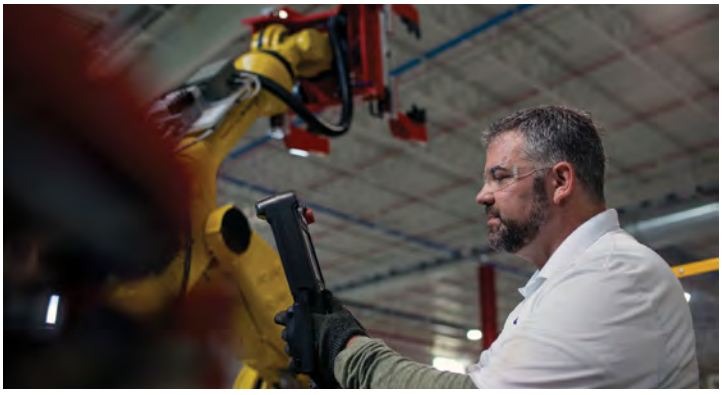
Cloud communication is another shared experience between cars and factories: "It's already a challenge for the automotive industry in terms of product," Simmons said. "If manufacturing is going to start using the Cloud to send huge amounts of data for analytics, it's going to be a concern. Is there capacity to handle this traffic?"

Trends come and go, but the shift to an advanced manufacturing environment is no mere trend, according to Stu Johnson, director of product marketing, **Plex Systems**.

"The difference here is this level of connectedness," he said. "Sensors communicating data about machines to the Cloud, the analytics, connecting people [who] are the orchestrators through mobility and wearables, and ideally connecting the entire supply chain. The Cloud's really the only scalable model for this kind of data. This indeed is the next industrial revolution."

Big Data, predictive analytics

There's a popular saying, "You can't improve what you don't measure." By collecting data and connecting plants to the Cloud, companies theoretically have more avenues to improve their manufacturing operations in areas like preventive maintenance, logistics, inventory operations and material handling.



Senior process engineer Tim Esham analyzes robot activity at Faurecia's new $64 million Columbus South digital manufacturing plant in Indiana.

The key is turning Big Data into "smart data" to support decision-making and offer new insights, according to Magna's Simmons. "The more data you have, the more you can measure, the more you can improve the quality of your parts and processes—and you've got end-to-end transparency of the process."

The problem, he added, is that 80% of all data today is currently unstructured and therefore unusable.

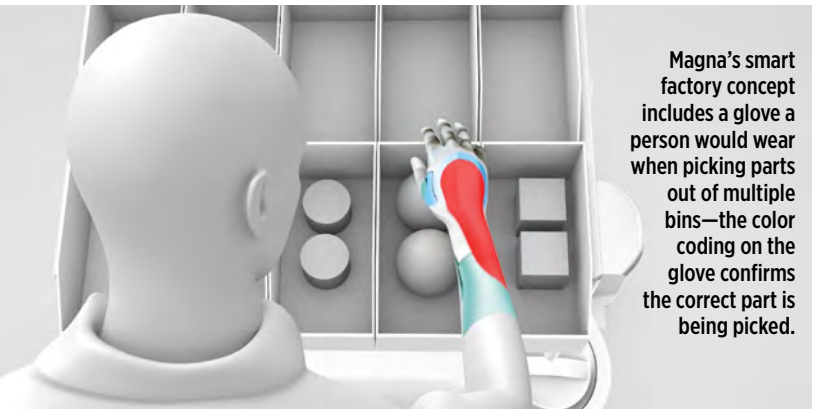
"Big data: this is probably where the real revolution will come," Simmons said. "With a lot of legacy equipment out there, it becomes difficult to get and really understand the data necessary for decision-making." Sensors are key to making this a reality, as technology accelerates and costs drop.

"There's the potential to add sensors to legacy equipment to start to get the data you need," he noted.

On the flipside, collecting all of this data creates a huge Big Data and analytics problem, according to Plex Systems' Johnson. Cloud computing is the solution.

Self-learning autonomous intelligent vehicles, or "cobots," transport components to the assembly line at Faurecia's new plant.

INDUSTRY 4.0: The smart factory arrives



Magna's smart factory concept includes a glove a person would wear when picking parts out of multiple bins—the color coding on the glove confirms the correct part is being picked.

GE's Brilliant Factory demonstrates how the "digital thread" can provide end-to-end connectivity for operational acceleration.

"Taking these huge streams of data up into the Cloud, using analytic platforms to look for predictive analytics like machine tool wear or machine vibration, and delivering it back to the machine to make better decisions about production quality—in more and more cases, autonomous decisions. Something as simple as stopping a machine or stopping a line if an SPC (statistical process control) chart is trending out of tolerance. This is the state of play," Johnson said.

Not only gathering data, but applying it in a proactive way—that's the goal for many manufacturing companies, including **American Axle & Manufacturing** (AAM). "We have a lot of data [but] we're using it in a reactive way," said Nigel Francis, vice president of advanced engineering & electrification systems at AAM.

He said his company is moving toward actively applying predictive analytics. "It's more than experimental but it's not scale at this stage," Francis noted. "The goal is to basically have adaptive machining driven by Big Data, so you have reliability, repeatability and good quality as a matter of fact."

Experts agree that companies need to run their own value analysis to determine, first, if they even have enough data to be meaningfully measured and, second, can turn that data into value by improving process, throughput, and efficiency.

"It's not going to be a panacea for every problem that exists within a manufacturing organization," said Simmons.

Cybersecurity jitters

While careful analysis and some caution are recommended, **GE Digital**'s head of manufacturing industries Paul Boris wants to make manufacturers "a little more nervous" than they might already be, stressing the need to move "fast, small, light" for the digital factory.

"We've got to get comfortable with the fact that the lean use of technology drives the continuous improvement cycle in operations," he told a recent conference of automotive professionals. OEMs need to be willing "to deploy something quickly, consume it, drive the process, get some value, and then 'pivot'—maybe we discard some things we built, maybe we add on to some of those things, but we've got to move [forward]."

Boris likened it to the consumer-goods manufacturing space, in which the **Apple** iPhone 7, for example, becomes available—and highly desired—even though there's absolutely nothing wrong with the iPhone 6.

GE practices what it preaches. Its FastWorks program takes a software-development approach to developing new products, with quick deliverables and fast learning. The program was the answer to a poignant question: "How do we do a project that's large enough to have a tangible impact on process, but small enough so that if it's an utter disaster we can bury it in the backyard and we all get to keep our jobs?" Boris said, to audience laughter.

Another issue making manufacturers more than a little nervous is cybersecurity. As connectivity and autonomous advance, in factories as in vehicles, this issue becomes paramount, experts agree.

"It's become very public in terms of cybersecurity impact on vehicles," said Simmons. "But imagine if you've got a manufacturing plant with millions of dollars of capital equipment being automated and suddenly you're hacked, possibly causing safety issues, perhaps crashing the equipment. So we have to apply the standards and concerns over cybersecurity to the 'factory of the future' as you do in automobiles."

Toyota has a large team dedicated to cybersecurity issues from a vehicle perspective, and that mindset is migrating to security on the plant floor, according to Trever White, divisional information officer, manufacturing & engineering business systems, information systems, Toyota Motor North America (TMNA).

"We have a group that's focused just on security and with this IoT program [in factories], we have a dedicated member from our security team that's working with us," said White. "We've created new network and security architecture that's focused on IoT, because there's a lot of opportunity on the plant floor now for exposing data that we haven't had before."

Enter the "cobot"

As manufacturing facilities become more connected and highly automated, integration of the worker with production is critical—perhaps even more so than with less-advanced systems. Because no matter how intelligent

Cat explores drones inside factories

At a recent year-end press briefing, **Caterpillar** not only detailed new iron but also some of its "digital" activities, such as augmented reality in the cab and drones at the worksite. Caterpillar has been working with **Redbird** the past year to provide drone data analytics for customers at construction and excavation sites, and now Caterpillar is exploring the use of drones inside of its own facilities.

"There's a lot of different groups around Caterpillar that are interested in using drone technology," said Todd Crawford, senior engineer at Caterpillar Innovation & Digital. "We help them to get up and running, train those using it, and monitor [activities]."

Drone technology is being examined for indoor use in a variety of different applications and locations, according to Caterpillar. Site security and monitoring is one possibility. To improve workforce safety, drones could be used to inspect manufacturing equipment and operations in otherwise hard-to-access places.

One Caterpillar project, in its early stages, is employing drones to perform inventory audits for distribution centers. In this application, drones would be able to audit all locations (rather than random selection by employees) in a fraction of the time it currently takes.

No further details could be provided, but Caterpillar promised more news in this area in the future.

Ryan Gehm

High-resolution images from drones can offer a different perspective on manufacturing operations, as demonstrated on screen in a Caterpillar facility. A DJI Inspire drone is on the tabletop. (Ryan Gehm photo)

the factory floor becomes, humans will always be involved in the process, experts say.

"You're never going to replace your human associates on the line," said Magna's Simmons. Robots will supplement what the workforce is doing and become more "user-friendly" toward manufacturing staff, he said.

Collaborating robots, or "cobots," that support the workforce are integral in Faurecia's new Columbus South plant. "People have been an important part of the equation," said DeGraaf. "Ultimately, these advanced technologies, like the AIVs and cobots, will enable employees to work more efficiently, experience less physical stress and improve work-life balance."

The interface between human and robotics is key. "We need to have agile, flexible, gentle and intelligent means of manufacturing things. If you look into the future, the possibility—or rather the probability—of an intelligent machine needing to work in the same workspace as a human being is very, very high," said AAM's Francis. "That brings about a completely different thought process. We're already thinking about this and hope to be working on it within our own facility very soon."

Research is being conducted that allows robots to sense humans and avoid them to prevent injuries.

Augmented reality—whether wearable, visual, or hearing sensor system—can be used to improve quality and inform decision-making. **Volvo**, for example, has been testing **Microsoft** HoloLens technology—essentially a self-contained, holographic computer—on the manufacturing floor to support training, problem solving, etc.

"But challenges remain," said Simmons, "namely, cost, socialization of workers with the HMI [human-machine interface] and training."

GE is exploring "smart" lighting that facilitates communication in the factory. "Those LEDs can talk on a unique frequency of light that can register them on a device, so when an operator is standing with an iPad, I can tell you within 10 cm where that operator is standing," Boris said. "**Clearpath** AGVs can actually listen on a signal and go around and collect data from all of the material units on the floor."

Don't interrupt me

This is a sampling of the possibilities. But the question looms: How do you implement new technology without interrupting production?

"We have a sub-minute takt time and all of our plants are running 100% plus capacity right now, so getting new technologies implemented in a factory is a very challenging thing to do," said Toyota's White. TMNA typically focuses on new plants or a new line to introduce the latest technology.

"From an existing [plant] perspective, we try to do a lot of trial activities and parallel implementations, where we allow the team members to work in the traditional process and also use new technologies—the iPhone/iPad applications, for example—until they feel comfortable," he explained.

Toyota began its Advanced IT for Manufacturing program about three years ago to help modernize its traditional approach to manufacturing. "We saw an explosion of digital opportunities on the plant floor, so we started to lean in," White said.

ZF also tries to implement the latest technology when building new lines and plants. "But more interesting is the potential to bring in new technology in a brownfield environment," said Dr. Jürgen Sturm, CIO at ZF Friedrichshafen AG. "This is easily possible at low cost. This includes bringing in sensing technologies, [and] we also started early to have Raspberry Pi technology, things like this." ■

Tech-heavy Iveco Z Truck concept spawns 29 patents

The Iveco Z Truck concept immediately stood out on the IAA Commercial Vehicles show floor with its futuristic—and aerodynamic—shape. (Ryan Gehm photo)

Designed in collaboration by **CNH Industrial**'s Design Center and Innovation department, the **Iveco** Z Truck concept that debuted at the IAA Commercial Vehicles show is the company's take on what future trucks may look like. This vision includes alternative energy—a new-generation LNG (liquefied natural gas) engine running on bio-methane derived from refined biogas—automated driving, enhanced aerodynamics, improved safety and the creation of a new living space in the cab.

The long-haul concept truck breaks away from every constraint, the company claims, to be a zero-impact vehicle for a totally sustainable transport system.

"With Iveco Z Truck and its 29 patents, we are defining where our efforts could lead us in the future: a vehicle with a human dimension, designed to accommodate comfortably and safely the work and leisure activities of the driver, adapting each time to his needs," said Pierre Lahutte, Iveco Brand President. "We are defining a future of long-haul freight transport that is totally sustainable—a vehicle that has zero impact on its environment, with zero emissions and zero accidents."

The LNG powertrain has rated power of 460 hp (343 kW), torque at 2000 N·m (1475 lb·ft), and a transmission with 16 gears automated with powershift in the upper gears. The Z Truck reportedly uses up to 33% less fuel. Two tanks with a capacity of 1200 L (317 gal) result in a range of 2220 km (1380 mi)—60% greater compared to the current Stralis NP natural-gas model, according to Iveco.

The HMI is designed to adapt the way it provides information to the driver, including on the truck's "smart" windshield. Views from a multi-camera system are displayed on a wide screen at the top of the windshield.

The truck adopts a new concept tank developed with **SAG**. It is made of aluminum insulated with a new Multi Layer Insulation, a reflective foil that protects from heat radiation. The technology allows for a squared shape, making it possible to optimize the use of space and accommodate two tanks with a single recharge.

An onboard Rankine-cycle waste heat recovery system exploits exhaust gas as a heat source to recover energy.

Petronas Lubricants International supported development of the Z Truck. LNG used in conjunction with Petronas Urania low-viscosity engine oils contributes to Iveco's zero-emissions target.

Alternative energy plays a key part in Iveco's plan for sustainable transport. A new-generation LNG engine in the long-haul concept runs on bio-methane derived from refined biogas. (Ryan Gehm photo)

Zero accidents are the vision for this concept truck through the deployment of active and preventive safety technologies up to full automated driving technologies, according to Lahutte. Iveco sees a future in which these new technologies and autonomous driving will change the role of the driver, who they say will become an "onboard logistics operator."

Lahutte also shared that zero stress and zero waste of time is the goal of the driver-centered design where the cab is freed from traditional constraints and can be totally reconfigured according to the various activities of the day (driving, automated driving, office working, resting). The seat, steering wheel system, pedals and controls console form a self-contained unit that is suspended independently from the cab.

The seat and retractable steering wheel combine two systems that move together in a double arch rotation: while the steering wheel moves forward, the seat moves back to provide a comfortable position for the driver. Parts of the side wall, the pavilion and the floor are integrated to form a self-supporting box-sliding structure, adding 50 cm (20 in) of interior length.

A sliding door opens and moves away with a rototranslating movement, enabling a retractable platform and 5-step stairs to slide out parallel to the vehicle. This provides full ergonomic access to the cab similar to home stairs.

The HMI (human-machine interface) is designed to adapt the way it provides information to the driver. The information on the truck's functions is projected on the "smart" windshield as it becomes necessary and changes according to what the driver needs at the time. Views from a multi-camera system are displayed on a wide screen at the top of the windshield, giving the driver full visibility around the vehicle in every driving phase.

Connectivity extends to the futuristic tires supplied by Michelin, which exhibit very low rolling resistance and feature RFID embedded tags that can track each tire throughout its life cycle. (Ryan Gehm photo)

Integration of the trailer and extreme geometry changes on the tractor result in a drag reduction of up to 30%. Platooning configuration provides potential for further improvements.

"We are facing a revolution triggered by the concern for the environment, the economy, and safety on and around vehicles," said Lahutte. "With our focus on our values of sustainability, TCO (total cost of ownership), technology and business partnership with our customers, at Iveco we have been working to constantly reduce the impact of our vehicles with alternative fuels such as bio-LNG, and putting the driver and the customer at the center of our technological and design development."

Connected technology extends to the futuristic tires supplied by **Michelin**. The Michelin X Line Energy tires are the first range to be awarded the AAA grading in rolling resistance, which saves long-haul convoys up to 1 L of fuel per 100 km. The tires feature RFID embedded tags that can track each tire throughout its life cycle, providing real-time information such as type, size, model name, wear, performance or temperature. Used with Tire Pressure Monitoring System sensors on the rims, they can also provide pressure data. Any or all of this data can be displayed in the cab as necessary to alert the driver.

Anticipated improvement in aerodynamics results from the integration of the trailer and the extreme geometry changes on the tractor. As a result, drag is reduced by up to 30%, according to Iveco, with potential for further improvement in platooning configuration.

Greg Muha and Ryan Gehm

PRODUCT BRIEFS

SPOTLIGHT: SENSORS & ACTUATORS

Inductive sensor technology

Baumer's (Southington, CT) inductive sensor technology measures a distance on a target with high speed and high precision, enabling equipment condition assessment. Thereby maintenance, output quality and cost of operation of the equipment is being optimized. A specially developed Baumer inductive sensor is a key enabling technology for one of the latest **John Deere** product innovations for which the company was selected as a recipient of a John Deere supplier innovation award for 2015. The innovative sensor solution was made possible by close collaboration between the OEM and Baumer, Frauenfeld. The demanding requirements of the application ruled out the usage of standard sensors. Baumer's capability to analyze the application and the requirements during the collaboration resulted in specifically optimized inductive sensors. These sensors allow for fast and high resolution distance determination even during operation. For more information, visit **www.baumer.com**.

Noise and vibration-resistant rotary latch

Southco, Inc. (Concordville, PA) has launched the stainless steel R4-10 rotary latch with integrated bumper that can be combined with the company's line of mechanical and electronic actuators and cables for a complete rotary latching system. Available in single- and two-stage options, the R4-10 features an integrated rubber bumper that eliminates noise and vibration caused by normal operation. The R4-10 with integrated bumper features a design that traps the striker between a rubber bumper and rotor. Without extra clearance or room to move, any noise potential that could be caused by metal-on-metal movement or vibration is eliminated. According to the company, these latches are specifically designed for applications, like off-highway, where operation of larger, more powerful equipment has the potential to create unwanted noise or vibration. The stainless steel version offers corrosion resistance for consistent performance in harsh environments. For more information, visit **www.southco.com**.

Pre-heater system

The **Eberspaecher** (Ontario, Canada) Hydronic S3 Economy 5-kW (6.7-hp) engine pre-heater offers compact dimensions and flexible installation options for retrofitting in a large number of day cabs, sleepers, off-highway and construction equipment, marine, bus, municipal and work truck vehicles. According to company claims, the all-in-one solution with comprehensive peripheral devices offers installation partners many practical advantages. With the new EasyScan diagnostic and service tool, workshop staff can analyze the operating condition of the pre-heater easily and quickly. The **CARB**-approved Hydronic S3 has CAN bus interfaces and offers stepless heating power control. The coolant heater works efficiently with all popular types of fuel. Due to its robust construction—with an encapsulated fan motor and the separation of cold and hot components—it is designed for longevity. For more information, visit **www.eberspaecher-na.com**.

SIDACtor protection thyristors

The new series of SIDACtor protection thyristors in DO-214AB (surface-mount) packages from **Littelfuse**, Inc. (Chicago, IL) are designed to protect low-data-rate interfaces and outdoor data interfaces in general industrial applications. The Pxxx0S3NLRP Series offers robust surge protection performance at up to 2.5 kA, while maintaining much lower switching threshold (VS) and on-state voltage (VT) than traditional protection solutions like Gas Discharge Tube (GDT) technology. The series also offers crowbarring power fault protection that, according to company claims, is superior to typical clamping devices. Applications include protection for general industrial outdoor data interfaces, such as short loop interfaces (<10 m) located at base station sites, and low-data-rate interfaces such as RS-232 or RS-423. For more information, visit **www.littelfuse.com**.

Heavy-duty LVIT inductive linear position sensors

Alliance Sensors Group (Moorestown, NJ) has expanded its sensor product offering with the addition of the LR-27 LVIT (linear variable-inductance transducer) Series Inductive Linear Position Sensors. Operating from a variety of DC voltages, this line of devices is designed for factory automation and a variety of heavy-duty industrial or commercial applications. The LR-27 sensors feature a compact yet robust design and according to company claims, superior performance and excellent stroke-to-length ratio. Features include contactless operation that prevents wearout from dither or cycling; four ranges from 50 to 200 mm (2 to 8 in); 27-mm (1.05-in) dia anodized aluminum housing sealed to IP-67; and a radial cable exit version that comes with swivel rod eye ends. For more information, visit **www.alliancesensors.com**.

Rapid overmolding process

Proto Labs Inc. (Maple Plain, MN) has expanded its rapid injection molding offerings with the launch of its new overmolding process. The company claims this new capability can produce 25 to 10,000+ custom overmolded parts in 15 days or less. Proto Labs' overmolding process uses engineering-grade thermoplastics and liquid silicone rubber materials to create prototypes and end-use production parts. The company says it is focused on accelerating product development, and the introduction of rapid overmolding offers designers and developers a tool to make high-quality prototype or low-volume production parts as quickly as possible. Overmolded parts go through a multi-step process, which results in common products like tool handles, medical devices and more. For more information, visit **www.protolabs.com**.

Biodiesel hoses

GH100 and GH101 hoses from **Eaton** (Eden Prairie, MN) are suited for high-percentage biodiesel blend and high-temperature oil applications. Engineered for maximum performance in systems with a variety of fuel types, the hoses feature a unique polymer that more effectively resists degradation. The GH100 and GH101 are designed to perform in high-temperature mobile applications, including trucks, buses, agriculture and construction equipment and eco-friendly power vehicles. Compatible with high-percentage biodiesel fuels and new synthetic oils, the GH100 and GH101 support a longer hose life while also ensuring safety requirements and quality standards are met. They are qualified for -40 to +150°C (-40 to +302°F) with B2, B5 and B20, -40 to +125°C (-40 to +275°F) with B100. For more information, visit **www.eaton.com**.

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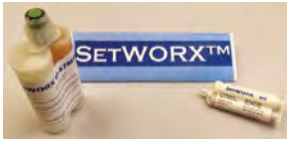
PRODUCT BRIEFS

Non-hazardous specialty polymers



EpoxySet Inc. (Lincoln, RI) has released SetWORX specialty polymers, a line of high-performance materials. According to the company, SetWORX was developed to be non-hazardous for shipping, therefore reducing costs. Most SetWORX materials contain no BPA, tin or phthalates—for example, the SetWORX USEAL U47MP and SetWORX 60. The USEAL U47MP is a durable, abrasion-resistant urethane adhesive and sealant for environmental protection yielding strong bonds to most substrates. The SetWORX 60 is a toughened epoxy exhibiting high bond and peel strength to metals, ceramics and many hard-to-bond plastics such as PVC, Lexan and Ultem, even at higher temperatures. It also features enhanced electrical insulating and dielectric properties, claims the company. For more information, visit **www.epoxysetinc.com**.

Fan selection application

The OPTIMISER 10 Fan Specification App, from supplier of high-performance axial-flow fans **Multi-Wing America** (Burton, OH), is a resource for original-equipment engineers to specify the most-efficient, tailor-made Multi-Wing fan for their application. The app is suitable for specifying fans in several applications, including engine cooling in off-highway equipment and power generators. It features an intuitive user interface, advanced natural-frequency sound calculations and visual display of total efficiency on the fan performance curves. OPTIMISER 10 also offers blade-profile previews with available diameter ranges, materials and rotations. For more information, visit **www.multi-wing.net**.

Arc suppressors

NOsparc arc suppressors from **Arc Suppression Technologies** (Bloomington, MN) are designed for both AC and DC power applications. The AC products are currently produced to operate between 100-V AC and 480-V AC while DC products operate from 12-V DC through 250-V DC. The company claims the devices suppress 99.9% of the electrical arcing in relays, which increases their operational life and saves the cost of up to nine replacement relays, as well as protects the associated motors from failing. This off-the-shelf technology is easy to install, says the company. Widely used in applications including railway operations and precision manufacturing, the **Oshkosh** Striker aircraft rescue and fire fighting vehicle recently became the first commercial vehicle to use NOsparc arc suppressors. For more information, visit **www.arcsuppressiontechnologies.com**.

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December 13: Off-Highway Engineering
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December 15: Automotive Engineering
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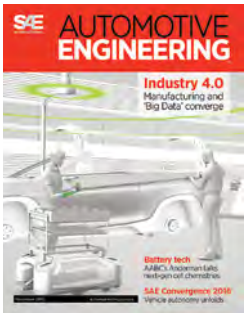

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COMPANIES MENTIONED

AD INDEX

Q&A

"U.S. truck manufacturers will be in the driver's seat in the future and will be leading the world in clean and efficient trucks," said Christopher Grundler at the SAE 2016 COMVEC event.

EPA's Grundler talks Phase 2 regs

As the Director of the Office of Transportation and Air Quality (OTAQ) for the **U.S. EPA**, Christopher Grundler and his staff of nearly 400 employees strive to protect public health and the environment by reducing air pollution from vehicles, engines, and the fuels used to operate them. Grundler gave a keynote speech at the **SAE** 2016 Commercial Vehicle Engineering Congress (COMVEC) as part of a symposium discussing Phase 2 greenhouse gas standards impacting heavy trucks and trailers (see page 6 in this issue to read more). He's scheduled to be a featured speaker on the opening day of the SAE 2017 Government/Industry Meeting (www.sae.org/events/gim/) taking place January 25-27 in Washington D.C. This excerpt is from the audience Q&A session following his COMVEC presentation.

Do you feel the Phase 2 rule is future-proof such that technologies not yet developed will be recognized?
We're not in the habit of establishing standards that aren't feasible, so we do need to have a technology forecast. That's based on the technical record that we've built, but very often that's wrong because you guys [a roomful of engineers] invent something else. We see this on the car side, we see this off-road, we see this on-highway. So when you read the twenty-five hundred pages [of the rule] and you see all the tables with these very precise testaments of effectiveness and cost, that's just us fulfilling our obligation to demonstrate that there can be a feasible pathway—and we do show more than one [pathway]. But in reality what's going to happen is firms are going to decide what's best for their customers, what's best based on their technology position. And these standards are performance-based, so they establish a performance level but they do not prescribe the way that that needs to be achieved. So it opens up the door for all kinds of alternative approaches and we can provide different testing procedures [if] something gets invented or you have something now that isn't recognized by the current test procedures.

How did the industry make itself heard during the rule-making process?
Loud and clear. A school of thought is that most of the progress in human history is the result of technology progress. That's what's really at the forefront of our mind. I think we went several extra miles to go out and discover new approaches, new technologies, new perspectives. Not only through our testing but we took advantage of test programs that other organizations did on their own. We sought as much information and data as we could...Thank you for all those who accepted our invitation, were patient answering all of our questions, and hosting us at your development centers. It really made a difference.

Is there a realistic path to global harmonization of emissions regulations?
In principle, that sounds really good, especially when you're dealing with global products...The truth is, different countries place different values on public health. We're always a little bit glib about this—we're always eager and willing to participate in the harmonization process so long as everyone harmonizes with us. (Audience laughter.) But seriously, there has been progress in the heavy-duty world on test procedure development, so I think at a minimum the idea that all these markets ought to test the same way seems pretty basic. But again, I hate to be a skeptic here—it turns out there are good test procedures and there're not-so-good test procedures, and there's no way that we're going to compromise American [public health] to come up with a lowest-common-denominator test procedure.

Are you willing to comment on an ultra-low NOx standard?
Yes, I am. We got a lot of comments...as part of this [Phase 2] rule-making process. We disappointed some of those stakeholders, but we were very clear from the beginning that this rule was about greenhouse gases. We didn't feel that we had enough information to act on NOx. There is no question that there are parts of the country that need further NOx reduction to achieve clean-air goals. We have numerous petitions in front of us right now asking us to act on NOx in a new national heavy-duty emissions standard. So we're considering that right now. The way we're going to go about this...we're going to be asking for your perspectives, individual firms, our friends at the **Engine Manufacturers Association**, we'll talk to environmental groups, [etc.] before we make any decisions. If we decide to pursue a new NOx standard, I can promise you one thing—it will be a comprehensive effort. Before we intervene in the economy with federal regulations, we want to make sure it will produce a [positive] result in the real world.

Ryan Gehm

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