HMIs extend beyond cab
Role of connectivity continues to grow for operators

Simplifying the design of complex electronics
AUTOSAR enables shift in software development

Lightweighting engineering challenges
Rethinking equipment design and manufacture

Truck & Bus Engineering: Waste heat recovery

Q&A with PACCAR’s Phil Stephenson

October 2015
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Handling communications from outside the vehicle is a logical extension of human-machine interface capabilities, highlighting the central role that user interfaces play in making vehicles more useful and productive. HMIs play an important role throughout the vehicle’s life cycle and are the central communication hub in many off-highway vehicles today, and will be more so in the future.
Getting smarter

There is a reason why diversification is considered a desired characteristic in many business strategies. Just ask any company currently focused solely on mining or agricultural equipment. Or even less than soley.

**Caterpillar** and **Deere** are two companies with interests in mining and agriculture, respectively, that are currently hurting financially due to the major slowdown (if not outright stoppage) in equipment sales in those two particular off-highway industries. While mining equipment may not be what the layperson associates right away with Caterpillar, agriculture is certainly what comes to mind first when considering Deere, and for good reason. Reuters reported in August that “farm and turf equipment sales account for more than two-thirds of [Deere’s] total revenue, [which] fell 24% to $5.41 billion in the third quarter [that] ended July 31.”

That said, it is not hard to project that other agricultural companies suffering through reduced new equipment sales and thus reduced revenue this year could only wish that their revenues would have **dropped** to $5.41 billion, as opposed to, say, **dropped from**. Deere is fortunate enough to have other interests such as in construction and forestry (which would have been even more fortunate if those two areas weren’t also down about 5% for the year), but most important, they have plenty of interests in engines and other systems.

The bottom line: if customers aren’t replacing their older equipment with new equipment, it then becomes even more necessary to offer the proper systems and subsystems that could bring older equipment closer into the realm of productivity of newer equipment, in essence allowing an old tractor to learn new tricks.

Making equipment smarter is nothing new, especially in the agriculture industry. Ever increasing electronics content in equipment has enabled enormous increases in functionality and productivity, as well as increased opportunities for automation. In this month’s feature, “HMs extend beyond the cab” on page 14, it is made clear that smart and connected have become interchangeable.

The feature’s author, Terry Costlow, observes how off-highway and commercial vehicle developers are using communication technologies to make vehicles safer and more productive, and then he takes the point one step further via a quote by Manuela Papadopol, Marketing Director, **Elektrobit**. “Automotive HMs focus on infotainment, in off-highway and commercial vehicles, safety and operations are more important. HMs with connectivity are now a key differentiator.”

It used to be that off-highway equipment was only as smart and productive as its operator; that is, the operator was the differentiator. But now, off-highway engineers have changed the user experience such that “The ability to fix bugs or add new functions by simply reloading memory in an ECU brings big benefits. Making it easier to update firmware in the field is a critical factor as software becomes more of a product differentiator,” writes Costlow.

The irony, of course, is that it would seem the easier it becomes to upgrade functionalities and thus technical capabilities remotely in the field, the less necessary it would be to buy new big-metal products to plow, construct, or mine with. That is, of course, it was not for a variety of other technologies that continue to propel the off-highway industry forward via efficiency advances that will prove the ultimate differentiators between competitors. The good news is that often differentiators aren’t grown from scratch, but via splices from other industries. One example of that in this issue is the feature “Lightweighting to improve off-highway emissions” on page 21. Another example would be the article on page 6 that mentions how **MTU** engineers have leveraged some of the knowledge that their **RRPS** aerospace colleagues have learned along the way, and vice versa. Ultimately knowledge comes from one another, the sharing of experience and the sharing of engineering.
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FPT plans engines for complex market

Expected in 2019, the impending European Stage V emissions regulations for off-highway engines will remain top of the agenda for FPT. EU regulators will limit both particle number, or PN, as well as tighten the existing particle mass limits. Stage V also reduces NOx, HC, and CO limits.

While these are stringent, it is also true that the EU market governed by Stage V is only a small part of the global market, according to Federico Gaiazzi, Vice President of Marketing & Product Management for FPT Industrial. Sharing his views with *Off-Highway Engineering*, Gaiazzi noted that these EU regulations may well affect how regulators approach their own national needs in other parts of the world. Gaiazzi believes it is likely that emissions regulations and fuel quality restrictions imposed in other countries will tighten in response to the EU actions.

This means FPT will need to upgrade global engines to use similar advanced technologies needed for the EU market. “While working toward the anticipated emissions standards, FPT is looking at solutions that will continue to increase engine efficiency and reduce total cost of ownership, which is why we will not be deviating from our long-term high-efficiency selective catalytic reduction [Hi-eSCR] only strategy,” he said. This technology, according to Gaiazzi, frees FPT’s engines from using exhaust gas recirculation (EGR) in medium- and heavy-duty applications, simplifying the engines and reducing costs.

He predicts that the next generation of FPT’s Hi-eSCR aftertreatment solution will incorporate a diesel particulate filter (DPF) integrated on the SCR. Part of the SCR catalyst will be replaced by the DPF in this solution to avoid impacting the aftertreatment layout. This is a technology that is reportedly efficient in meeting both particle mass and PN emissions. In general, these combined SCR and DPFs reduce packaging and make it easier to manage the temperature needed for the SCR (See “The complicated future of off-highway engines,” *OHE*, August 2015).

“The Hi-eSCR system was originally developed at FPT’s R&D Center in Arbon, Switzerland, and was the first maintenance-free aftertreatment system, achieving NOx reductions of more than 95%,” he said. Observations from others in the industry note that newer SCR technologies could achieve 97%-98% efficiencies in reducing NOx, a key enabler in eliminating EGR.

When asked what were the most important advanced technologies for achieving better fuel efficiency and total cost of operation, his answer reflected a broad perspective. “No one technological area will create a breakthrough in improving fuel consumption or performance in engine development,” he said. The key is increasing an engine’s brake thermal efficiency. “It is a challenge with no quick-fix technological breakthroughs on the horizon; instead, progress will be the sum of improvements to several aspects of the engine.”

These include the optimization of combustion and air handling, reduction of power losses, the introduction of smart auxiliaries, and waste heat recovery in the exhaust line, as well as energy management controls in the engine, its related systems, and all elements of the vehicle that influence its fluid usage.

Bruce Morey
Virtual Test Drives for Everyone
Test driver assistance functions on your own PC

The challenge: Test scenarios not available
Validating ECU functions in realistic test scenarios during the early stages of development is becoming a more common practice. Simple unit tests do not provide enough coverage anymore, especially for safety-critical driver assistance functions which, by nature, are networked with many other systems. In cases like this, function developers must test the functions’ interaction with other control algorithms closed-loop with complex environment models.

The idea: Virtual test drives
The pragmatic approach takes the environment simulation models that already exist for ECU testing and reuses them on the developer PC. dSPACE VEOS® is the bridge between these two worlds. It lets function developers perform virtual tests of functions whenever they want to so that they can easily test many different environment scenarios. This holds the number of real test drives at an affordable level. It also makes reproducing virtual test drives much easier, which is useful for checking a corrected function. VEOS also includes established error analysis methods such as debugging and code coverage, which are not possible in real test drives. If function developers do not have access to the environment models, they can use the dSPACE models that cover many ADAS areas.

The advantages: VEOS for virtual test drives
- Use your own PC for closed-loop tests of ADAS functions
- Reuse plant and environment models
- Use models and automated tests seamlessly throughout all development phases
- Support of Simulink®, TargetLink®, legacy C code, AUTOSAR, and FMI

One example: Developing complex intersection assistant functions
Performing automated tests of intersection assistance functions on a hardware-in-the-loop simulator involves constructing many test scenarios that describe the exact traffic situations (the course of the road, how many traffic participants there are there, what the roadside looks like, etc.) to test all the participating ECUs in detail. With VEOS, function developers can take the relevant function algorithms that were developed in Simulink or AUTOSAR and simulate them in interaction with these environment models. VEOS provides them the same features for visualization, simulation control, and automated tests as a HIL simulator.

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In late July, a €40 million, 9000-m² (96,875-ft²) test facility in Friedrichshafen, MTU’s lead site and main R&D location, officially went into service. The new five-story test facility “was already at the planning stage before Rolls-Royce became sole owner of [MTU] and before we began intensive cooperation with other R&D units at Rolls-Royce, [Construction] began in spring 2013, and Rolls-Royce obviously supported this investment,” according to a company spokesman. “Since then, our operations have become fully integrated into the R&D activities of Rolls-Royce, and we both benefit from that collaboration.”

Rolls-Royce has two main business divisions, Aerospace and Land & Sea, the latter of which comprises Marine, Nuclear, and Power Systems. MTU, MTU Onsite Energy, Bergen Engines, and L’Orange are all part of Rolls-Royce Power Systems (RRPS). Of the 15,500 engineers that Rolls-Royce employs globally, about 1600 work in the Power Systems segment.

MTU has R&D test stands that are similarly equipped in its Aiken, SC, plant, and RRPS has over 100 test stands in service all over the world used for R&D, series production, and repairs and engine overhauls.

“This facility supplements existing capacities with new measuring and analysis technologies,” Werner Hussal, Head of Test Stand Planning, RRPS, told Off-Highway Engineering. “Our test stands are manned by experienced engineers, researchers, and technicians. For the new facility, certain staff have received targeted training to familiarize them with the new technologies and teach them to make the most of the potential that the systems offer.”

The company stresses that it intends to use the new facility not only to test further developments on existing engines, but to break into new territories, with one such new territory being R&D into a gas engine for mobile applications.

Gas engines used continuously in stationary applications such as in MTU Onsite Energy’s combined heat and power modules are a proven technology. RRPS is now looking to develop a gas engine for use in ships, said the spokesman. This is a major challenge because the gas engine must not only be ecologically sound but offer as many of the advantages as possible as conventional diesel engines.

In this first phase of the facility, three stands for testing 2500-kW (3350-hp) engines were set up. Construction is currently under way for a gas supply network for the gas engine research that is to go into service in mid-2016. Additional test stands can also be installed as future programs are identified.

For now though, the focus on meeting emissions standards is clear, and MTU believes that future emissions standards are going to be another tough technological challenge that will force it to think in terms of bigger systems, and systems integration. “For example, the way the engine interacts with the exhaust aftertreatment can be extremely complex,” said the spokesman. “Exhaust gas aftertreatment is one of five key technologies on which we focus very closely. We develop our own exhaust aftertreatment systems so that they can be perfectly tuned to our engines and their applications. We work closely with leading catalyzer and component manufacturers so that we can provide
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our customers a complete systems package from one source that has been qualified in-house. Developing exhaust aftertreatment systems that optimally meet the needs of customers is one of the main missions of the new test facility.”

Even in this day and age of ever-increasing sophisticated simulation and virtual design tools, brick-and-mortar test facilities are as important as ever. “Equipment for the analytical configuration and simulation of the thermodynamic processes that take place in an engine are essential tools for effective R&D, especially when it comes to large diesel engines. However, these are mathematical tools that can be used to back up high-level real-life testing, but not replace it,” said Hussal.

“By simulating components and processes, we can limit the number of time-consuming and expensive test runs we carry out and clearly demarcate test scopes in advance. But the intricacies of a highly complex process, such as, for example, the interaction between the engine and a specific exhaust aftertreatment system, can only be reproduced using simulation to a limited extent. A real-life test run helps us to verify and perfect the results of our simulations. Simulation and real-life testing go hand-in-hand.”

To highlight correlations from anything between two and eight parameters, and all the associated interactions, MTU uses DOE (design-of-experiment) methods in connection with model-based optimization. That way, the company minimizes test run expenditure and maximizes information gain.

“During the test runs, we only vary those performance and emissions-relevant parameters that were revealed as significant in simulations. This can be done automatically at the test stand,” said Hussal. “The results we then receive are mathematical models that describe engine behavior (e.g., emissions, consumption, etc.) as a function of the various input values. So in the engine test, a large number of parameter variations can be implemented very efficiently within a short space of time. In the model-based optimization that follows, we calibrate the engine optimally to achieve the desired levels of emissions and consumption according to specific ambient conditions.”

A special feature of the new testing facility is what MTU refers to as a “gallery” that has been built above each test stand booth. “The gallery is a special platform above the engine that can carry its exhaust aftertreatment systems, such as SCR for reducing nitrates. These systems are often very bulky, and we did not have enough space for them on our existing test stands,” said Hussal. “We now have enough space to set up close-to-reality testing and measurement scenarios using high-tech measurement paths and calming sections.”

He added that another feature of the new building is a set-up hall outside the actual test stand area. It is there that engineers will build the test configurations on mobile platforms, keeping the time needed for preparations at the test stand itself to a minimum and improving operational efficiency.

Rolls-Royce does not split out its R&D spending by division, but the majority of that money is currently invested in Aerospace, mainly because the investment cycles are longer and more costly than they are in (non-nuclear) Land & Sea operations. That said, the spokesman estimated that in 2014 its R&D spend for gas turbines was ~£1 billion, and for reciprocating engines (MTU and Bergen Engines) ~£150 million.

Wherever the R&D investment money goes, Rolls-Royce has in place internal systems and processes that allow its engineers to share ideas and look for innovative solutions to common problems. Engineers in one part of the business are able to pose challenges that other areas of the business can comment on and suggest solutions for. For example, knowledge of material science from its aerospace division has enabled it to develop new seals for marine, while automated manufacturing technology developed for marine propeller surface finishing is now being applied to aerospace fan blades.

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Physics-based robot simulation leverages stochastic optimization and game theory

For obvious reasons, conditions on lunar and planetary surfaces can understandably be hard to duplicate physically, even in the best case when they are “well understood,” if only from a distance. This makes digital simulations an essential tool during mission planning and development. Simulation can be used to study the effects of changes in terrain, lighting, reflectance, and other environmental factors on mission success.

In a typical space mission, though, many conditions are poorly understood. There may, for example, be limited understanding of soil—or regolith—properties before contact on a lunar mission. Addressing this requires special conceptual and mathematical tools. Parameters must be randomized to capture potential outcomes, and results must be optimized to discover the corner cases and unexpected outcomes that could impact a mission. Energid Technologies Corp. has been funded by NASA to develop a new robot simulation that accommodates uncertainty and discovers exceptional behaviors during mission planning, technology that will someday no doubt have more terrestrial applications. Energid Technologies specializes in the control, simulation, and sensing of complex systems for the aerospace, agriculture, transportation, defense, and medical industries.

Actin provides powerful tools for camera, lidar, radar, and other sensors on all types of robots, from oil exploration to collaborative manufacturing, according to James English, CTO at Energid. The project with NASA will enable high-fidelity extensions for space environments and focus primarily on NASA’s KREX platform.

“Our approach is to apply concepts from game theory and stochastic optimization to deeply simulate NASA’s robotic missions,” said Ryan Penning, Project Manager on the program. “The result will be a breakthrough ability to reason about uncertain environments...
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Actin will be tailored to the space environment by modeling lunar regolith with highly parallelized particle models implemented on GPUs, which allow execution of high-fidelity simulation in real time on common computer hardware. Actin will also be tailored to support the appearance of lunar and planetary surfaces.

and understand the extremes of what a robot can do.” Energid’s Actin software supports randomizing simulations of all types of robotic systems. It has physics-based models for articulated dynamics, contact dynamics, sensor simulation, and communications. In this effort, Actin, and its stochastic simulation capability, will be extended to specialize this capability for new NASA space applications.

Some of Actin’s characteristics that make it particularly suited for such applications include automated reaction to dynamic workspaces, including collision avoidance; finely scripted velocity profiles of manipulated objects; and complex dexterous manipulation. Actin is built on what Energid says are “industry-leading” proprietary optimization codes that enable the robots to run some of the most challenging tasks in robotics today, all within a drag-and-drop interface.

Actin will be tailored to the space environment by modeling lunar regolith with highly parallelized particle models implemented on graphical processing units (GPUs). GPUs allow execution of high-fidelity simulation in real time on common computer hardware. Actin will also be tailored to support the appearance of lunar and planetary surfaces. This will allow high-fidelity simulation of cameras and other sensors.

“Actin already provides powerful tools for camera, lidar, radar, and other sensors on all types of robots, from oil exploration to collaborative manufacturing,” said James English, CTO at Energid. “This project will enable high-fidelity extensions for space environments.” English told Off-Highway Engineering that this work in particular will focus primarily on NASA’s KREX platform.

The technology will be further commercialized by applying it to configure robotic systems and workcells on Earth. There is a pressing need for easier robotic programming to lower costs and empower people and businesses untrained in robotics but familiar with application domains where robots can contribute.

“Much of the cost of applying robots lies in configuring environments and workcells,” said Neil Tardella, CEO at Energid. “The prediction and simulation technology developed under this project will lower the cost of fielding robots and expand their application.”

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Human-machine interfaces (HMIs) are evolving in multiple paths—they’re becoming a more important product differentiator while also expanding their control functions outside the vehicle. As connectivity moves deeper into the mainstream, HMIs are being redesigned to make it easier for operators to utilize the broad range of features and functions that come with telematics.

Fleet operators who have utilized connectivity to gain information for some time seek improved techniques for making some of this data available to operators, while those new to telematics want a wealth of basic functions. Tool providers note that off-highway and commercial vehicle developers are using communication technologies to make vehicles safer and more productive.

“Autoromatic HMIs focus on infotainment; in off-highway and commercial vehicles, safety and operations are more important,” said Manuela Papadopol, Marketing Director, Elektrobit, which makes HMI design tools. “HMIs with connectivity are now a key differentiator. Many of the instrument clusters are very graphical.”

Handling communications from outside the vehicle is a logical extension of HMI capabilities. It highlights the central role that user interfaces play in making vehicles more useful and productive. HMIs play an important role throughout the vehicle’s life cycle.

“The HMI is already the central communication hub in many off-highway vehicles today,” said Christiana Seethaler, Product Development Director at TTTech Computertechnik. “Alternatively, it is also useful as a development and debugging interface during application development.”

The tight link between HMIs and communication modules is following a common arc: once developers and users get comfortable with a few features, they start adding more functionality.
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Connectivity’s swift journey from a high-end offering to a mainstream option is now evolving to include a range of communications interfaces. It’s no longer uncommon for vehicles to have more than one outside link.

“Wireless connectivity options like Wi-Fi and mobile telecommunication options like GSM are becoming more prevalent in HMI devices as enablers for telematics solutions like remote assistance/maintenance and fleet management,” Seethaler said.

While this data often flows from vehicles to operation centers, bidirectional links often let operators access the Internet or their management system. That makes it easy for them to get detailed information to enable educated decisions.

“Operators are no longer limited to radio weather reports,” said Stephan Tarnutzer, Vice President, Electronics, FEV North America. “Someone on a tractor can run an app when it’s raining to get information to help them decide whether to stop or continue planting seeds or spraying.”

The role of connectivity will continue to expand as developers find more ways to utilize remote links. The continued growth of electronic controls and software means that more data can be accessed by letting communications modules transmit data gathered from a range of CAN buses.

“We expect to see increased use of software to feed data to telematics systems in off-highway equipment,” said Kirk Lola, Business Development Manager, Parker Hannifin Electronic Controls Division. “Telematics allows for the owner to track machine usage and productivity, but also allows the service manager to view faults and performance to help reduce machine downtime.”

Taking control

Currently, remote technicians can look at data from the vehicle, but they can’t control the ECUs. That’s expected to change. Specialists in operation centers may be able to control some functions. That capability may be extended to personnel carrying tablets or even smartphones.

“Depending on the robustness of the telematics solution, they might even have the option to make adjustments to the machine remotely or run automated functions such as remote upgrades or geo-fencing,” said Kevin Faulds, Product Marketing Manager of Software Solution Services, Danfoss Power Solutions. “Bluetooth technology allows operators to connect a phone or tablet and get status reports or make adjustments to the system without actually needing to be near the machine.”
Manual controls hold onto their popularity

Multiple flat panel displays are showing up in more and more cabs, with many of them featuring touch input technology. While touch is seeing significant growth, conventional knobs, buttons, and joysticks are evolving to remain relevant control technologies.

Versatility has become an important factor for the input devices used in cabs. Screens and controls alike must be capable of performing different tasks when vehicles are operating in different modes, such as transforming from infotainment to repair manual.

“Many drivers know how to fix things, so the systems need to give them information that will help them make repairs,” said Manuela Papadopol, Marketing Director, Elektrobit. “Multi-function keys let operators control lights or radios at one time and drill down for more information when they need to fix something.”

Touch input devices are inherently versatile, making them a popular technology for providing operators with versatility while not quite displacing many longstanding control technologies.

“Touchscreens are increasingly being used in off-highway equipment for operator input and menu manipulation,” said Kirk Lola, Business Development Manager, Parker Hannifin Electronic Controls Division. “However, we see operators still prefer mechanical HMI devices such as joysticks and levers for the control of the essential machine functions like boom control and ground drives. The use of capacitive touchscreens isn’t effective in cases where the operator needs to wear gloves.”

Often, knobs can be used to let operators scroll through menu items on an LCD. These screens are often located out of the operator’s reach. Knobs can be placed close to other manual controls, making it simple for people to shift from one control to another.

“Because operators are not always able to interact directly with a screen, twist knobs allow them to make changes remotely,” said Kevin Faulds, Product Marketing Manager of Software Solution Services, Danfoss Power Solutions. “Additionally, knobs allow for convenient page-scrolling, function-switching, or fine-tuned adjustments.”

Joysticks are also letting operators do more tasks without removing their hands from one controller. As these manual devices evolve, comfort is becoming more important. Preventing issues like carpal tunnel syndrome is an increasingly important factor in design.

“Joysticks have seen significant changes in the wide variety of handle designs that are available,” Lola said. “This has allowed joystick providers to offer a handle design that fits the ergonomic requirements of the operator as well as the operational requirements of the application. In addition, more degrees of freedom of the joystick handle are being offered in a single joystick as well as mode selection in software that allows the same joystick to change operating modes when selected by the operator.”

More commercial technologies like displays and touchscreens are expected to make their way into cabs. Most vehicle operators are quite familiar with tablets and smartphones, so it will be easy to convert screen control and manipulation techniques from consumer to off-highway environments.

“The biggest operator interface advances are ideas borrowed from the mobile devices industry,” said Nick Keel, Group Manager for Automotive Applications, National Instruments. “Navigable menus, software hierarchy, and intuitiveness have all become significantly more important as the product complexity has grown. Software can now offer significantly more functionality without making the user experience more difficult, because customers now have a predefined expectation about how their software should behave.”

Links between connected HMIs and CAN buses aren’t the only new connections showing up in man-machine interfaces. Commercial technologies like USB and Ethernet are expected to move into the off-highway world.

“As the number of ECUs connected to the HMI increases, the required number of CAN interfaces also grows,” Seethaler said. “In addition, USB and Ethernet interfaces become more and more important. USB is typically used for software updates (not only to update the software of the HMI, but also to use the HMI as gateway for updating the ECUs connected to the HMI device). Ethernet can be used as high bandwidth interface to ECUs like our HY-TTC 580 HMI, which features an Ethernet interface, or to connect Ethernet cameras.”

Making it easier to update firmware in the field is a critical factor as software becomes more of a product differentiator. The ability to fix bugs or add new functions by simply re-flashing memory in an ECU brings big benefits, so design teams are exploring many ways to simplify updating.

“OEMs are going more to Android and Linux-based systems that provide them with the ability to deliver upgrades,” said FEV’s Tarnutzer. “It’s not mainstream, but it’s being more widely supplied.”

Terry Costlow
Standards step forward in design of off-highway electronics

Functional safety standards are starting to impact many development projects, while the auto industry’s AUTOSAR standard is being deployed to help enable software reuse and simplify designs.

by Terry Costlow

Even memory chips in the control modules for Dana’s transmissions are selected with safety standards in mind.

Functional safety has become a watchword in many fields as regulators and product developers attempt to ensure that failures will be minimal, and that safety isn’t impaired when things do fail. ISO 26262 was developed for the automotive industry, and other standards like IEC 61508 are required in some fields.

On another front, the AUTomotive Open System ARchitecture (AUTOSAR) is slowly gaining acceptance. It shifts software development to a function-based system design, which helps companies manage the growing complexity of electronics by creating standard interfaces between hardware and software components.

Safety first

Some regulations already require compliance with functional safety standards, and more legislation is set to follow suit. That’s prompted many companies to make these concepts part of their design methodologies. Implementing risk assessment and other functional safety ideas is no small task.

“We have a whole department dedicated to checking safety standards,” said Steven Dumoulin, Team Leader for Controls at Dana Holding Corp. “It’s a huge job that has an impact from the highest to the lowest levels. Even memory, flash and RAM, has to have memory checks.”

Complying with the standard requires some changes to the design process, forcing developers to consider potential safety issues and remediate them. Additional hardware and code are needed to provide redundancy and diagnostics. Many companies say the extra elements will become the norm.

“ECUs are becoming more complex and costly as additional processors are required to monitor or work in conjunction with the existing application processor,” said Paul Brenner, Marketing Manager, Electronic Controls & Software and Mobile Piston Portfolio, Eaton.

“The European Machinery Directive 2006/42/EC requires compliance for machines sold within the EU. The
Secure the vehicle

The security breaches that plague commercial and consumer applications are quickly moving into the connected vehicle world. In response to highly publicized breaches, off-highway makers are joining the cyber security movement begun by automakers.

The volumes of off-highway vehicles with connectivity are small compared to consumer products and automotive, and the potential for financial gain is far less than if hackers focus on commercial networks. But as more vehicles become connected, some hackers will eventually focus on this field.

Simple hacking may not be the biggest concern. Equipment makers must also consider the potential that extortionists will find a vulnerability and ask for a payout to prevent them from exploiting the breach. These threats are forcing design teams to start implementing protective strategies.

“In the past, most communications were customized, so security hasn’t become a big issue yet,” said Dave Rogers, Ricardo’s Commercial Director for Engines. “With generic tools that plug in and things like Bluetooth, cybersecurity is becoming more important. We are taking a look at encryption and validation techniques, ensuring that a device that asks for acceleration or deceleration is authorized to make that request.”

Strategies for safeguarding vehicle electronics must include nearly every facet of the electronic architecture. Security should be considered from concept phases through end of product lifetimes. It’s no simple task to implement safeguards that are as effective when a vehicle’s 10 years old as when the first model rolls off the production line. Every node on the vehicle network must be protected.

“Security touches everything, AUTOSAR, functional safety, and all other aspects of design,” said Tom Tasky, Manager of Controls and Functional Safety, FEV. “You have to assess the vulnerability of every entry point, CAN, Ethernet, Wi-Fi, Bluetooth, cellular. Every module has to have protection.”

Protective techniques must also account for intentional or unintentional problems caused by operators or maintenance technicians.
Simplifying software

Off-highway equipment developers are tracking another automotive trend, adopting the AUTOSAR standard. Now roughly a decade old, it provides a common structure for basic system functions and functional interfaces, letting teams focus on higher level applications instead of interfaces.

“AUTOSAR provides a convenient way to compartmentalize pieces of software,” said Tom Tasky, Manager of Controls and Functional Safety, FEV. “Using a standardized interface lets you reduce size and ensure that software is portable. Our software platform is built on the foundations of AUTOSAR. We can adapt if customers are not using fully compatible versions.”

Implementing a new software architecture isn’t an easy task, so AUTOSAR won’t be showing up for a while. Though many companies are employing limited aspects of the standard, they still expect to gain meaningful benefits.

“Almost all of our early development work for ECU in the 2019-2020 timeframe have some level of AUTOSAR requirements,” said IAV’s McConnell. “Legacy technology is a challenge, but using this software architecture as part of a development enables you to have better control over the system life cycle. AUTOSAR lets software reuse happen.”

Not so fast

While standards bring many benefits, vehicle manufacturers are often slow to adopt them. It’s often time consuming and expensive to devise a transitional strategy.

“In the off-highway industry, only the very big OEMs are investigating the use of AUTOSAR,” said Marc Weissengruber, Product Marketing Manager, TTControl. “For small and mid-size OEMs, the effort and cost is currently too high compared to the benefit.”

Others note that the need to maintain proven software prevents many companies from adopting the standard. However, some ideas used in AUTOSAR are being used in conjunction with legacy programs.

“Everyone has something they’re already using, so unless they’re going to a fully new software platform, it’s difficult to use AUTOSAR,” Ricardo’s Rogers said.

“There’s piecemeal usage, people take part of it and create software abstraction layers. They create a big map for variables, it acts like a big library that lets one module play with another.”

Tier 1s who must implement the standard for large OEMs are implementing it throughout their new designs. Many companies are using their own versions rather than spending time to develop fully compliant technologies, feeling that the concepts bring significant benefits.

“Reuse is the reason we started exploring AUTOSAR,” said Dana’s Dumoulin. “We didn’t want to rewrite software over and over. We now have proven software that’s reusable across platforms. Its structured approach also improves maintainability, when a change is requested, we can easily see whether it can be done and what the impact will be.”

The structured approach required by the standard also helps companies comply with safety regulations that are rapidly altering the industry. These standards must be considered from the outset of a project, so they are often complementary.

“Using an AUTOSAR framework helps us comply with functional safety standards like ISO 26262,” FEV’s Tasky said. “Functional safety has a huge impact on hardware and software development, customers need to understand their safety requirements early in the concept phase.”
In many segments of the ground-vehicle industry, lightweighting is a hot topic, and yet the off-highway segment lags behind in terms of more eco-friendly vehicle design. However, legislative pressures are inspiring change.

Automobiles are thought to be responsible for around 12% of total EU emissions of CO₂, the main greenhouse gas. In response, EU legislation has set mandatory emissions reduction targets for new cars—by 2021, the fleet average of CO₂ to be achieved by all new cars is just 95 g/km, a reduction of 40% when compared with the 2007 fleet average; an engineering challenge not new to the off-highway industry.

Lightweighting is one answer to the emissions problem and the automotive industry has been quick—and able—to respond, with multiple new products and solutions. Ford has recently announced its collaboration with DowAksa and the U.S. Department of Energy to “develop manufacturing innovations in automotive-grade carbon fiber for use in future products,” and the Mercedes GLC is constructed from “a high percentage of lightweight parts, with high-strength steel and aluminum used extensively in the chassis and suspension.”

Modern steels, despite receiving less press than other solutions, remain a popular option for weight reduction. General Motors’ Chevy Malibu, for instance, demonstrates 300 lb (136 kg) of weight savings, more than a third of which comes from the redesigned body structure, which utilizes thinner, high-strength steel components in some areas.

Lightweighting engineering challenges

While lightweighting has long been a popular option for reducing emissions in the automotive sector, it continues to be less so in the design of off-highway vehicles, and there are many reasons for this. One is that the duty cycles of off-highway vehicles tend to be unpredictable because the applications the owner uses them for are so wide ranging.

One example is telescopic handlers, which are designed for pick and place operations but can be used for many diverse applications from shoveling material to driving in posts. Even if OEMs were able to design for every possible application, the resulting product would be unfeasibly expensive to produce. However, there is a balance to strike.

Farmers need products that meet all of their needs—a Swiss Army knife approach. The key is developing a vehicle that is as capable as efficient design and engineering allows and demonstrating to buyers this range of abilities. In comparison, automotive designers can work to very specific requirements. Drivers understand the limitations of their vehicles and work within them.

Another reason is the unpredictable nature of the loads themselves, due to the range of operations a single machine may be used for in its lifetime. Without predictable loads it is difficult to use simulation to accurately predict stress levels and hence to ensure that the equipment would be able to stand up to all conceivable tasks. The same is true for the unpredictability of the conditions these vehicles work in.

Due to the large variety of applications of off-highway vehicles, in the past there was very little legislative requirement for the performance of this equipment, with the exception of safety regulations in roll-over and falling-object protection systems (ROPS and FOPS). In comparison, automotive design is extensively legislated—for example, crash performance—which leads to an understanding and expectation of the loads on a vehicle structure. This is a
Lightweighting to improve off-highway emissions

A key focus for the industry is reducing strain on the operator and offering automotive-comparable performance on all terrains. A recent example of this work is the new JCB Fastrac 4000, the chassis stiffness of which was optimized to reduce vibration.

As weight is reduced in the structures of off-highway vehicles, designers can look to a more automotive manufacturing process, utilizing pressing and folding to reduce the amount of welding.

The right materials

NVH (noise, vibration, and harshness) optimization is another example of an area of study that is carrying over from one discipline to the other. A key focus for the industry is designing vehicles that feel more like a car to drive, both reducing strain on the operator and offering comparable performance on all terrains, whether that’s on road between fields or off-road across them.

A recent example of this work is the new JCB Fastrac 4000 where one of the design challenges was to design a vehicle that is more comfortable for the driver. With this in mind, the chassis had to be optimized to reduce vibration, and the operator cab was completely re-worked to allow for a significant increase in glazed area to give better visibility. For this purpose, optimizing the stiffness of the chassis structure was an important focus area.

The challenge with improving driver comfort and vehicle durability is to increase the chassis stiffness without adding weight to the vehicle, which would compromise meeting emissions targets. To meet these multiple and often conflicting objectives, clever design is required to improve the vehicle without adding weight. Reducing parasitic mass is a common area of study for off-highway designers.
While weight is needed in certain parts of the vehicle, either for stability or to react to digging loads, there are also areas where gains can be made. An example of this is the arm of an excavator, which can be considered as parasitic mass as its prime function is to support the loads from the bucket.

Another area is in the design of ROPS. While strength in these parts is essential for safety, most of the time it is dead weight. OEMs in the off-highway industry are working to better understand the impact of parasitic weight and how reducing 10 kg (22 lb) from the boom, for instance, would improve fuel efficiency.

One key factor steel suppliers have been quick to recognize is that using the right material in the right place is an important way of optimizing vehicle design. While lighter, more modern materials such as carbon fiber and aluminum have their part to play, particularly when trying to reduce weight, for the foreseeable future steel will still account for 80% of the structure of off-highway machinery such as backhoe loaders.

In some cases, the steel will need to be highly abrasion-resistant steel for applications such as construction, aggregates, and quarrying. For example, steels with 400 and 450 Brinell hardness that can work at temperatures down to -40°C (-40°F) would be suitable for tough mining and quarrying conditions. Such steels could be used in thinner sections to replace conventional steels, in dump trucks and dustcarts for instance, providing an effective way of reducing weight. Also, in many applications a steel can be chosen with a low carbon-equivalent value, making it easily weldable and allowing high-strength components to be produced without changing standard weld procedures.

Manufacturing knowledge

Reducing weight in the structure is just a starting point, however, and opens up a whole host of opportunities for improving processes throughout the manufacturing cycle. As weight is reduced in the
From marine to off-road, from stationary power generation to rail traction - all applications of the large engine industry are under high pressure to reduce costs and emissions. Engines with a much higher degree of complexity, completely new engine concepts and the optimisation of the entire system are required by implication. The popular AVL Large Engines Conference is focusing on these new industry challenges. OEMs, operators and suppliers are meeting in Graz, to discuss potential solutions in order to meet the trade-off of facing complex and challenging individual development topics and - at the same time - facing the need of a holistic system optimisation.

Do not miss the conference and register now: www.avl.com/-/7th-avl-large-engines-techdays

Learnings from one industry often influence development in another, and in that sense the automotive, aerospace, and off-highway industries have all benefited or been inspired in some way, big or small, from the other. With the pressure now on for off-highway OEMs to meet strict Tier 5 emissions standards, the focus on lightweighting these traditionally heavy weight vehicles will come to the fore.

This article was written for Off-Highway Engineering by Derick Smart, Customer Engineering Manager, Tata Steel.
Four things that helped create over 20 million ISUZU Diesel Engines Worldwide

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PRODUCT BRIEFS

SPOTLIGHT: TESTING EQUIPMENT

**Strain measurement**

Instron offers the AVE 2 second-generation advanced video extensometer, using patented measurement technology in an accurate noncontacting strain measurement device that conforms to rigorous testing standards. The fully integrated device adapts to the normal fluctuations of environmental conditions and can be adapted to any testing machine that uses a ±10 V analog input. Designed to reduce errors from thermal and lighting variations common in most labs, the AVE 2 uses a real-time 490-Hz data rate while achieving 1 µm accuracy. The versatility allows for testing under multiple environmental conditions and can be used for advanced strain measurement with digital image correlation. The AVE 2 measures both modulus and strain-to-failure of most materials including plastics, metals, composites, textiles, films, and bio-materials.

**Automated data collection**

DTS’ TSR data logger line includes a ±20 g sensor range. With built-in X-Y-Z accelerometers that eliminate the need for sensor hook-up, an internal battery, and simple software, the TSR makes it easy to start collecting data. The device can capture up to 2000 transient shock events or run as a continuous data recorder for seconds to days. Data writes directly to 1 GB flash memory and is downloaded via USB. Several bandwidth options and sensor ranges, from ±20 to 6000 g full scale, are available. The rugged TSR is suited for high-impact applications such as sled testing, blast measurement, and drop testing. An advanced motion detection mode saves battery life and makes the TSR also suitable for unattended monitoring of high value equipment.

**Current sense resistor**

KOA Speer Electronics introduced the new SLN3 molded current sense resistor, featuring a 3-W power rating in 4528 size. The SLN3 is a molded resin resistor that provides excellent dimensional accuracy, mountability, and shock resistance. Due to its metal plate terminal electrode, it also offers enhanced terminal strength, heat and shock resistance, and solderability. KOA Speer’s SLN3 resistor has low TCR (temperature coefficient of resistance) available down to ±75 ppm with resistance tolerance as low as 0.5% and an operating temperature range of -55 to +180°C (-67 to +356°F). It will be offered in resistance values of 5 mΩ up to 110 mΩ. The AEC-Q200 qualified resistor is a surface-mount type with flameproof UL94V0 molded case. Used primarily for current detection, SLN3 current sense resistors are suitable for transportation, industrial, and consumer electronics markets in applications such as dc-to-dc conversion, automotive modules, motor control and power supplies. Lead time for the SLN3 is 12 weeks; samples are available upon request.

**Voltage drop simulator**

EM Test now offers the VDS 200Q Series, a four-quadrant voltage drop simulator that can source and sink current using a programmed voltage in both positive and negative polarities. The amplifier generates dips and drops, short interruptions, and voltage variations to simulate a wide range of phenomena occurring on a vehicle wiring harness. With unlimited operation from -15 V to +60 V, this dc voltage source simulates a wide number of battery supply waveforms for international quality standards. The VDS 200Q Series are fast bipolar amplifiers that operate across all four quadrants that sink as well as source current. This allows the new simulators to drive capacitive loads and absorb energy feedback from the DUT up to the nominal current. A source impedance of less than 10 mΩ and a high bandwidth of 150 kHz (full signal) enables these new sources to support low voltage drop, class-leading inrush current, and extremely fast recovery. The QuickStart feature allows parameters to be adjusted during test to evaluate the DUT’s susceptibility level. Test routines are programmed using the intuitive front panel with menus and function keys.
Advanced simulation aids aerodynamics

- Waste heat recovery proof-of-concept
- Semi-solid casting aluminum components
- Samsung’s ‘see-through’ truck
The FPT Industrial range of engines currently achieves a brake thermal efficiency (BTE) of approximately 46%, which is higher than comparable engines on the market today. However, through a series of detailed updates and continuous innovation, the aim is to improve this well beyond 50% by 2020.

Alongside various technologies, waste heat recovered from exhaust by means of an Organic Rankine Cycle (ORC) will play a significant role to reach this ambitious target. Simulations suggest that by tapping multiple heat sources, up to 5% improvement in engine efficiency is possible. A simplified system harvesting heat from only EGR and exhaust gas will allow up to a 2.5% increase of BTE.

As a proof-of-concept, AVL and FPT Industrial launched a joint project with the aim to develop a cost-effective mechanical waste heat recovery (WHR) system for an Iveco Stralis Euro VI truck.

Project targets were to demonstrate: the performance of the WHR technology, an ROI (end-user price) of ≤2 years, a vehicle fuel-consumption reduction of ≥3%, and an integrated system into the engine/vehicle, packaged on the Stralis.

At the beginning of the project, a thorough assessment of the most appropriate fluids, architecture, and available sub-component technologies was carried out.

Technology assessment

The study was initiated with thermodynamic ORC calculations for ethanol, water, and R245fa in view of the operating fluid selection. The boundary conditions for the cycle calculation were chosen based on realistic conditions for a real-world cycle of a long-haul truck in Europe.

The temperature of the hot reservoir (exhaust gas) was set to 348°C and the cold reservoir (cooling water) was set to 70°C in the calculation. Results of the ORC cycle calculations reveal that ethanol has the highest power output compared to water and R245fa, but also the highest condenser cooling power needed. Water has a considerably lower power output, but with a slightly higher ORC efficiency. The major advantage of water is the low condensing cooling power requirement.

Based on the temperature levels available in the long-haul truck application, ethanol is considered as the best choice due to the highest power output enabling the highest overall efficiency of the complete combustion engine and WHR system.

For system architecture, investigations showed advantages for a parallel compared to an in-series exhaust and EGR heat exchanger setup, enabling highest waste heat into the system with lowest complexity for the given
Simulations were started with ORC simulations using ethanol, first without detailed component input from the suppliers. The target of these simulations was a parameter identification study where the influence of each individual parameter was analyzed. This information was useful for the later supplier discussions leading to the choice of the best available components for our specific concept. All simulations were performed with temperature and pressure dependent properties of ethanol for each calculation step.

The parameter identification showed that of the 14 WHR parameters chosen, the heat source enthalpy (temperature and mass flow) and the expander isentropic efficiency have the highest influence on the WHR power output. Additionally, the parameter identification showed only linear dependence between the WHR power output and the 14 parameters indicating less challenges with regard to complete system control and optimization.

Simulation activities

After the initial supplier discussions, the steady-state simulations were extended with detailed component characterization input from the suppliers. A comparison was made between steady-state simulation and testbed measurement at A25, A50, and A93. Two approaches were used for the simulations: Prediction—only measured engine exhaust data taken for WHR simulation input, all other input data from supplier maps (expander, heat exchanger); and Recalculation—measured engine exhaust data and measured expander intake pressure taken for WHR simulation input, all other input data from supplier maps (expander, heat exchanger).

Good correlations between measurement and simulations were shown for temperature and pressure. For expander power and WHR B-Efficiency, the recalculation and measurement were slightly lower especially at operating point A93. The main reason for the differences are the slightly lower expander efficiency for the measurements compared to the supplier maps at this specific load point.

For proper prediction of fuel economy under real-life driving conditions all interdependencies and interactions between vehicle subsystems had to be taken into consideration—i.e., all transient energy fluxes (mechanical, thermal, hydraulic, electrical) have to be simulated.

Therefore, a complete vehicle system model consisting of engine model, powertrain model, and simplified control logic for the auxiliaries was built within a vehicle modeling environment. A thermal model of the engine structure, cooling system, and lubrication system was created in Mentor Graphics’ Flowmaster to appropriately simulate the
The compact “WHR box” is placed directly after the exhaust aftertreatment system. The vehicle model was validated with wind tunnel measurements per test facilities. Good agreement of both cooling system and transient response of components provided by the hardware supplier was achieved, with deviations mainly caused by small differences in the control strategy of cooling auxiliaries and necessary simplifications introduced in engine thermodynamic and exhaust aftertreatment modeling.

The validated model is used for fuel economy simulation on real-life cycle, as plant model for the development and optimization of WHR control software functionalities, and for hardware sensitivity investigation. Non-trivial dependencies such as interaction between WHR power generation and parasitic loss of auxiliaries can be evaluated and an optimal trade-off is determined. The simulation results contribute to the definition of requirements for each of the WHR components.

The current status of the transient simulation results predict slightly less than 3% fuel-consumption reduction for the Stralis Euro VI truck during the real-world driving reference cycle utilizing waste heat from both the EGR and exhaust evaporator. However, the transient simulation also shows a potential of increasing the fuel-consumption reduction to around 3.5% by applying further realistic cost-effective measures such as efficiency improvement of the ethanol pump and expander, vehicle cooling system and fan control strategy improvements, a separate 60°C cooling system for the WHR condenser, as well as enabling under-pressure conditions. Performing the calculation with a typical U.S. real world transient cycle results in up to 5% fuel-consumption reduction due to the higher load profile in the U.S. compared to Europe.
Stationary measurements at 1200 rpm with exhaust as the only heat source.

Testing activities

Three major test series were planned in the overall project: stationary testbed testing (detailed here), transient testbed testing, and vehicle testing on road.

For the stationary test bed setup, an FPT Cursor 11 Euro VI engine (including exhaust aftertreatment system), WHR components, and required measurement equipment were all integrated to an Iveco Stralis vehicle frame and put on a testbed pallet system. Using this approach, very similar component packaging can be achieved compared to the demo truck, leading to similar system behavior of e.g. thermal inertia, heat losses, or pressure drops.

The positive effect of the WHR system on fuel consumption is evaluated by means of the engine torque measured on the engine dyno and precise fuel-consumption measurement. Optionally, the expander torque is also measured using a strain gauge-based system.

The stationary testbed testing was split into the following work packages: engine start-up and initial WHR system operation; WHR control system application; parameter variation and mapping; component characterization; mechanical development and safety; and fuel-economy measurements and influence on overall performance and emissions.

The testing activities were performed in close interaction with simulation, thereby enabling the optimum operation of the WHR system with the given boundary conditions.

Stationary measurements at 1200 rpm (A-speed) with exhaust as the only heat source confirmed the simulated fuel-consumption reduction of more than 5 g/kW·h.

The fuel-consumption reductions with the WHR system were achieved without any significant changes to the emission or performance of the combustion engine. This is due to the closed-loop air path control together with the fact that the increased backpressure of the exhaust evaporator (<30 mbar) is well within the range of the backpressure differences experienced during the loading of the diesel particulate filter (DPF).

Wind tunnel validation, performed at Mahle test facilities.

ROI target range.

ROI and outlook

With the prototype system, the ROI target of ≤2 years can be met considering only direct material cost. Until start of mass production of the WHR system, however, further cost-reduction effort is required to allow for sufficient cost margin. This depends very much on the final economics of scales for WHR components.

First results from bench testing indicate a final fuel-economy gain of 3.5% for the Stralis Euro VI truck during the real-world driving reference cycle utilizing waste heat from both the EGR and exhaust evaporator.

At the time of this paper’s publication, transient testbed tests will be performed at AVL continued by vehicle tests under real-life driving conditions at CNH Industrial by end of 2015.

The authors thank all of their partners and suppliers in the project (Amovis, Mahle-Behr, Norgren, Magna).
Advanced simulation aids heavy-truck aerodynamics

There is more pressure than ever on heavy-truck engineers to find and create significant improvements in fuel economy and reduce tailpipe greenhouse gas (GHG) emissions. This is being driven primarily by two factors. First, customers are looking for ways to improve their business model by reducing fuel consumption. Diesel fuel prices in the past few years have been volatile, ranging from $2.931/gal (Sept. 6, 2010) up to $4.159 (Feb. 25, 2013) and back down to $2.561 (Aug. 24, 2015), according to U.S. Retail Diesel Price data from ycharts (http://ycharts.com/indicators/us_diesel_price), showing the need to be prepared for possible upswings in fuel costs of 50% or more. Additionally, regulations are driving fuel-economy improvements and GHG reduction to unprecedented levels.

To compound the challenge of these customer and regulatory pressures, the low-hanging fruit for these gains is already long gone. Aerodynamic enhancements have historically offered the biggest opportunity, but finding significant improvements today requires a shift in testing and development to be efficient and successful, and new advancements in CFD may be the key. The aerodynamic challenge with heavy trucks is that they’re pulling a brick-like shape that has a flat wall at the end. The closing of the airflow at the end of that brick creates a wake, and inside that area is extremely low pressure that pulls on the surface, creating about 40% of the pressure drag of the entire tractor and trailer. Pressure drag is about 90% of total drag on a truck and trailer combination, thus, a key target for refinement.

Exa Corp. has been working with several truck and component manufacturers in the heavy-truck industry, and has shown how its CFD software, PowerFLOW, can evaluate and quantify small changes without expensive and time-consuming prototype builds or wind tunnel testing. PowerFLOW also offers an Optimization Solution, which uses algorithms to test hundreds and even thousands of variations, literally overnight, between a baseline design and end parameters set by the engineering team. Designs can be morphed quickly using CFD, and unlike physical testing where the design has to be modified for the consecutive tests, users can easily and accurately return to the baseline. Additionally, wind tunnels cannot accurately address how the moving road surface and spinning tires affects airflow; this is critical now as many opportunities for aero improvements—skirts, under-vehicle panels, and wheel covers—are parts of the tractor and trailer that are close to the pavement.

Exa recently worked with Laydon Composites on a trailer skirt solution that explored which design would provide optimum results. The result of extensive simulation was a 9.3% improvement in fuel economy, and achieving U.S. EPA SmartWay Elite status without a boat tail.

“Anyone can put a fairing under the trailer and get a 2-5% improvement,” said Doug Hatfield, Managing Director, Heavy Vehicles, Americas, at Exa. “We developed one with extensive simulation and achieved a 9.3% improvement in fuel economy.”

Even with improvements in fuel economy through the optimized design of a trailer fairing, Exa believes there are more opportunities. Simulation provides insight into the airflow so engineers have more control to influence it. For example, through simulation and analysis, better integration of the airflow under the truck and trailer combination can be achieved to maximize the fuel-economy gain. Already popular in Europe, there is more talk in the U.S. about matching truck and trailer systems for better aerodynamics, but it would require fleet homologation to make it more realistic for the U.S. business model.
There are also aerodynamic opportunities with active grille shutters, which are becoming common in passenger vehicles. Active grille shutters allow more airflow for cooling, but can close (forcing airflow around the engine compartment instead of through it) when not needed. Exa has found that closing off the grille to airflow results in about a 1% improvement in fuel economy overall with current design of tractors, and that there’s potentially a 3-5% gain on the table if the tractor design is optimized to make use of active grille shutters. This would require a paradigm shift in tractor design and manufacturing. Vehicle manufacturers may be more willing to embrace these shutters as pressure for improvement from customers and regulations increase.

Even without active shutters, with simulation software it is possible to explore the front-end design to reduce the frontal area but still provide what’s needed for cooling. There are opportunities with trucks designed for specific routes to optimize the front-end design to balance airflow for cooling and reduced frontal area for cooling. For example, today all trucks are designed for worst-case heat scenarios: pulling full CGVWR (combined gross vehicle weight rating) at a grade at ambient temperatures above 100°F (38°C). But if the customer will never operate the vehicle in those extreme conditions, then it will never need that much cooling capacity, and the front-end design could be swayed to favor aerodynamics.

It also will be interesting to watch as technology for self-driving trucks evolves. Truck platooning, for example, presents an interesting mix of opportunity for fuel-economy improvement and unique cooling challenges. The rear trucks in a draft will have better fuel economy, but it will have increased cooling needs. Exa has
High-integrity, low-cost aluminum components produced by semi-solid casting

Semi-solid casting is a near-net shape casting process that is capable of producing extremely high-quality castings. It differs from all other casting processes as it does not use fully liquid metal to produce the castings, instead using a feed material that is preferably about 50% solid and 50% liquid. The high solid fraction of the feed material results in a slurry that acts like a highly viscous liquid, and while a semi-solid slug is rigid enough to maintain a cylindrical shape, it is still soft enough to be cut by a spatula.

Semi-solid casting is a modified die casting process that uses a high-pressure die casting machine to inject this viscous semi-solid slurry into a hardened, reusable steel die. Semi-solid casting maintains many of the advantages of conventional die casting such as the production of complex, near-net shape components with thin walls.

Cole Quinnell on behalf of Exa Corp. wrote this article for Off-Highway Engineering.
cosmetic surfaces, and close dimensional tolerances. However, while conventional die castings often suffer from high levels of residual porosity (up to 1% porosity, or more) that limits their usage in structural applications, the high viscous feed material used with semi-solid casting provides controlled filling of the die cavity that essentially eliminates residual porosity and other defects. Semi-solid castings, therefore, can have exceptionally high component integrity, which provides excellent mechanical properties and allows them to be used in structural, pressure-tight, and welded applications.

SEED process

Numerous methods have been proposed for the production of semi-solid castings, but many of these processes treat the liquid metal in a turbulent manner that can introduce detrimental oxides and entrapped gasses during the production of the castings. To produce high-quality components capable of meeting the quality requirements for safety-critical and pressure-tight applications, it is crucial that such defects be avoided, and so a semi-solid casting process must be used that treats the metal gently. The SEED (Swirled Enthalpy Equilibrium Device) process was designed to prevent the formation of defects that can be pervasive in other casting processes.

In the first step of the SEED process, a tilted crucible is gently filled with fully liquid aluminum. In the second step, the crucible is gently swirled to uniformly distribute the solid particles. Within a minute or so, the alloy has cooled to the appropriate solid fraction, and the crucible is transferred to a high-pressure die casting machine, where the slug is ejected from the crucible into the shot sleeve. Finally, the slug is injected into the die using a controlled injection process.

Once the die cavity is filled, the plunger continues to apply high pressure throughout the solidification process, so that solidification shrinkage can be completely eliminated. A commercial SEED system contains several crucible systems, to match the high production rate achievable with the semi-solid casting machine.

Performance and applications

Semi-solid casting utilizes many of the same alloys as conventional casting processes, including A356 (Al-7%Si-0.35%Mg) and 357
Examples of semi-solid castings used in structural and pressure-tight applications: a) automotive suspension control arms, b) various mounts, c) fuel rails and master brake cylinders.

(Al-7%Si-0.55%Mg). Typical mechanical properties of components semi-solid cast from these alloys are listed in Table 1. Of special interest are the extremely high elongation values achievable with semi-solid casting, which is due to the low levels of defects such as porosity and oxide inclusions.

Semi-solid castings also exhibit extremely good fatigue properties, primarily as a consequence of their low defect (porosity and oxide) content. Data measured by Cummins comparing the fatigue behavior of semi-solid cast 319S-T6 against both wrought and cast alloys reveals that not only is fatigue strength of the semi-solid cast 319S significantly better than other casting alloys, it is comparable to components produced by forging. A turbocharger impeller is a good example of a complex geometry part used in a fatigue application.

As semi-solid castings contain extremely low levels of residual porosity, they can also be used in applications that require high levels of pressure tightness—5000 psi (345 bar) or higher. Examples of semi-solid castings used in pressure-tight applications include fuel rails and master brake cylinders.

Production costs

Conventional high-pressure die casting is generally considered the lowest-cost method for producing complex, 3D shaped aluminum components. Due to the similarity of the process equipment, it is expected that semi-solid casting should be capable of reducing cycle times and production costs.

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of similar low-cost production. This is confirmed by recently published data, which presented a detailed comparison of the manufacturing costs associated with several casting processes (Table 2). The results of this analysis confirm that semi-solid casting is only slightly more expensive than conventional die casting, but significantly lower cost compared with competing foundry processes.

As described above, semi-solid aluminum castings have been used in a range of applications and markets. Commercial components range in size from a few ounces to as large as 20 lb (9.0 kg) or more, and can be used in both automotive and non-automotive applications.

Pascal Côté of Québec-based STAS, Steve Midson of Denver-based The Midson Group, and Giovanni Pucella of STAS wrote this article for Off-Highway Engineering.
Peeking around a semi-trailer truck in an attempt to pass it on a two-lane highway or road can be an unsettling experience for drivers—edging toward the dashed center line only to swerve back behind the truck to narrowly avoid an oncoming vehicle.

To help ease drivers’ tensions in these circumstances, Samsung engineers have developed a “see-through” solution for trucks that they expect will reduce accidents and ultimately help to save lives. The Safety Truck prototype consists of a wireless camera attached to the front of the truck, which is connected to a video wall made out of four exterior monitors located on the back of the trailer. The monitors provide drivers behind the truck with a view of what is going on ahead, even at nighttime.

Such functionality makes overtaking a truck on two-lane roads a far less-strenuous activity for drivers. Another advantage that Samsung points out is that the technology could reduce the risk of accidents caused by sudden braking—for example, if an animal crosses the road just ahead of the truck, the driver following could see it and respond sooner. Of course, advanced driver assistance systems (ADAS) are coming onboard that can automatically assist drivers in such situations.

The Safety Truck was tested in Argentina—where the number of traffic accidents is among the highest in the world, the company notes—but can obviously find application on roads around the globe.

Samsung led the prototype development, providing large format display samples and conducting a test with a local B2B client; however, the prototype truck is not currently in operation. After initial testing, Samsung was able to confirm that the technology functions properly and that the concept “can definitely save the lives of many people.”

The next step for Samsung is to perform the corresponding tests to comply with existing national protocols and to obtain the necessary permits and approvals. The company says it is working with NGOs (non-governmental organizations) and governments to fulfill these requirements.

Ryan Gehm
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- **October 20**: Automotive Engineering Technology eNewsletter
- **October 27**: Vehicle Engineering Technology eNewsletter (all markets)
- **November 3**: Automotive Engineering Print Magazine
  - Aerodynamics
  - Composites
  - Testing facilities
  - PLM product spotlight
- **November 3**: Off-Highway Engineering Technology eNewsletter
- **November 10**: Aerospace Engineering Technology eNewsletter
- **November 10**: Electronics Technology eNewsletter (all markets)
- **November 17**: Mobility Engineering Print Magazine (December edition)
- **November 17**: Automotive Engineering Technology eNewsletter
- **November 24**: Heavy Duty Technology eNewsletter (on- and off-highway)
- **December 1**: Automotive Engineering Digital Magazine
  - Fuel cells
  - Engine Components product spotlight
- **December 1**: Aerospace & Defense Technology
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- **December 2**: Off-Highway Engineering Print Magazine
  - Heavy-duty powertrain components
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October 2015 39
Electrification, autonomy present challenges, opportunities

PACCAR Technical Center works closely with all of the company’s truck divisions—DAF in Europe, Peterbilt and Kenworth in North America and globally—and has two major missions, according to Dr. Phil Stephenson, General Manager of the division, and co-chairman for the SAE 2015 Commercial Vehicle Engineering Congress (ComVEC). One is to serve as the central testing and validation center for Kenworth and Peterbilt to ensure products meet customer requirements before released into production. The other major activity involves being “a big part” of PACCAR’s powertrain organization, together with DAF in Europe. Dr. Stephenson recently spoke with Off-Highway Engineering about a variety of pressing technical issues facing both on- and off-highway companies, to be discussed in greater detail at the ComVEC event from October 6-8 in Rosemont, IL. For the full transcript, visit http://articles.sae.org/14328/.

What are some mutual challenges facing both the on- and off-highway sectors?
Certainly we have different detailed requirements at the vehicle level, but a lot of the tools, a lot of the technologies that go into them can be common. The theme that we’ve defined for the ComVEC event is Quality, Technology, and Innovation: Pillars of Global Success...With so much more focus for on- and off-highway commercial vehicles on use of embedded software, more electronics, the need to diagnose problems automatically in the vehicle, we’ve chosen to have the executive panel on quality focus on software quality—how do we design systems, how do we validate them, how do we ensure that as we add complexity, we don’t create complexity for our customer. So that’s [one] area...If we look at emissions from vehicles, certainly some vehicles are running at highway speeds, and other equipment is perhaps running in a PTO mode all of its life off the road, but they both make emissions and they both need to be optimized. So at ComVEC we’ll talk about engine emissions, aftertreatment systems, whole powertrain integration—and while the applications are different, a lot of the engineering and science behind it is something that we can share and we can learn from each other.

One expert panel discussion centers on 24-V electrification for on-highway CVs. What’s at issue here?
24 V is the standard for Europe and other regions of the world. And of course in North America we have a 12-V standard. There are some advantages to 24 V; for example, lower gauge wiring is possible in some applications. There is a great deal of momentum behind 12 V in the U.S., and there’s a great deal of momentum around 24 V in other countries. And there has been some progress in developing components which are compatible with either standard, but there remain challenges to do so without either adding additional cost for systems that can operate at either voltage, or adding additional complexity to having 12- and 24-V systems. So I think it will be a great set of discussions about technical opportunities, about other ways of navigating this dual standard that we have around the world, and potentially someday getting to better commonality.

Could you discuss the trend toward self-operating vehicles, which is also a topic at ComVEC?
I see autonomous vehicles as part of a continuum that we’ve already started down. There’s sort of an underlying requirement any time you want to have autonomous vehicles that they have sensing and communication with systems so that they know where they are, what they’re doing, who else is around, are able to react to stimuli and correct what they’re doing. If you look at current on-highway vehicles, there are already some of these assistance systems which are on that continuum—for example, lane keeping assistance, adaptive cruise control, vehicle-to-infrastructure communication about the health of the vehicle. And if you look at off-highway, for a long time now there’s been farming equipment which can use GPS to steer their way and to communicate their status...So there are a lot of pieces of technology already in place; as we go further down the road and start to think about more autonomous driving of commercial vehicles, particularly on the road, we will need to bring those technologies closer together to make use of multiple sets of information types, multiple sets of ways of communicating. Think about GPS, cellular, Wi-Fi, vehicle-to-vehicle, Bluetooth, in order to implement it in a way which is safe, reliable, and brings the benefit that autonomous driving [promises], in terms of better traffic density, better speeds, better safety, better transport efficiency, and finally even to help us deal with the industry issue of shortage of qualified drivers to operate CVs.

What about cybersecurity concerns, now and moving forward?
There’ve been some articles in the press recently...about demonstration of the capability to, with some tools, get into the vehicle’s network and operate it remotely. That’s very concerning to any vehicle OEM; it’s something that we need to address. It’s an area where I think we can reach out across multiple industries, not just commercial vehicle, not just automotive, but certainly other industries like telecommunications and the military deal with these types of threats. It’s something we’ll have to take very seriously and address, in a robust way. But on the other hand, other systems rely every day on cybersecurity and have very good reliability rates...If we come together, learn from each other, apply those security algorithms and methods appropriately, it’s something that we can overcome in time and provide a product which is secure.

Ryan Gehm
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