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OCTOBER 2016

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STATE of the INDUSTRY:

Moving into 2017 and beyond, the Industrial Revolution 4.0 and the Internet of Things are bringing new opportunities for efficiency, while electrification and hybridization continue to be among the future technologies of focus for manufacturers.

The Digital Revolution

20 The Internet of Things

24 The Industrial Revolution 4.0

36 Technologies of the Future

46 Challenges on the Horizon

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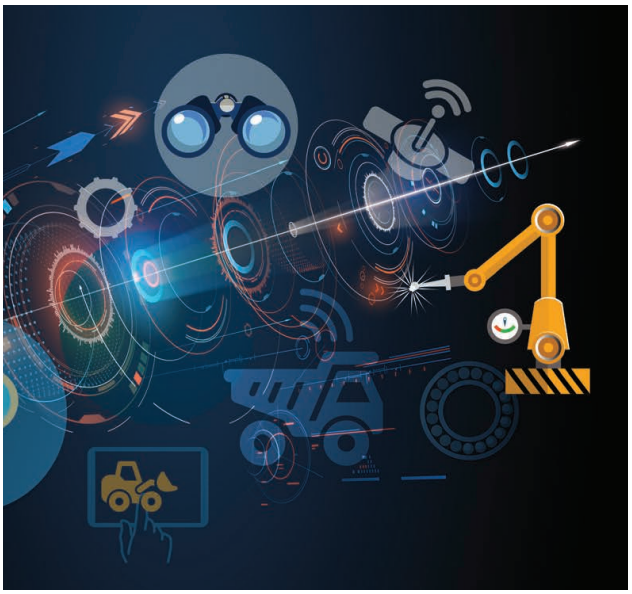
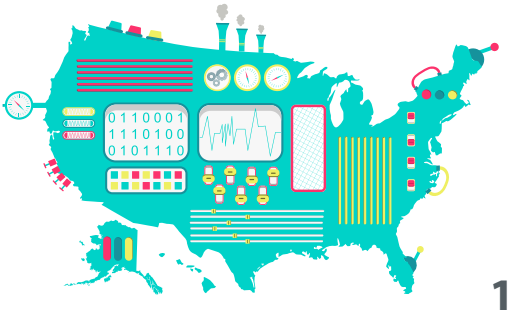


ON THE COVER

State of the Industry

The Industrial Revolution 4.0 and the Internet of Things are bringing new opportunities for efficiency, while electrification and hybridization continue to be a focus for manufacturers.



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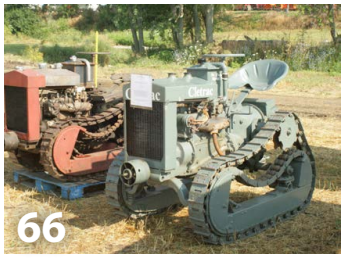

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Data and digital technologies are improving efficiency for manufacturers and their customers.
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More sensors and electronics, as well as hybrid and full-vehicle electrication will be a continued focus.
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State of the Industry Q&As for each company
Head online to read extended responses, and full Q&As from individual company executives.
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The Digital Future is NOW

The State of the Industry issue always takes a hard look at the current situation of our equipment markets and economy while also looking ahead at what is yet to come. This year it was not difficult to see how prevalent the digital age has become and been incorporated into the long-term plan of our OEM and component suppliers.

The topics of coverage include several major digital technology movements, including the Industrial Internet of Things (starting on page 20), the Industrial Revolution 4.0 (starting on page 24) and the Technologies of the Future (starting on page 36).

Even though many companies are cutting costs through downsizing, product reduction, industry exiting and factory consolidation, there is still a positive view of the long-term investment in mining as a market of opportunity. As I sat through corporate presentations at MINExpo 2016, I heard nothing but talk of investments in the digital space, in spite of (or perhaps because of) the down market.

This is the perfect cross section of technological demand, market acceptance, and performance delivery coinciding with an industry in desperate need of further optimization that can't be found by simply updating a fleet with new machines. These machines must do more than ever before in terms of productivity and profitability, and it can't always be realized in an optimized powertrain; that comes from the type of understanding and efficiency gains that can be obtained through digital technology integration and data analysis.

You will notice that we have reconfigured the format of our State of the Industry to compile our participants' responses by topic instead of by company. We want to make sure that the information we are providing is able to easily demonstrate any macrotrends or significant differences of opinion dependent on a company's position in the marketplace. Each company's complete interview can still be found online if you want to read about a specific company's perspective.

We look forward to any feedback about this new organization of the same great information provided by industry leaders and experts.

Be sure to head online to www.oemoffhighway.com/minexpo to see all of the new products, vehicles and technologies from MINExpo 2016!

editor@oemoffhighway.com
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IN THE NEXT ISSUE

NOV/DEC ISSUE

- Military Vehicle Trends
- Powertrain Optimization
- Market Performance
- Object Detection
- Engine Cooling Systems

+ Innovators' Top 10 New Products of 2016

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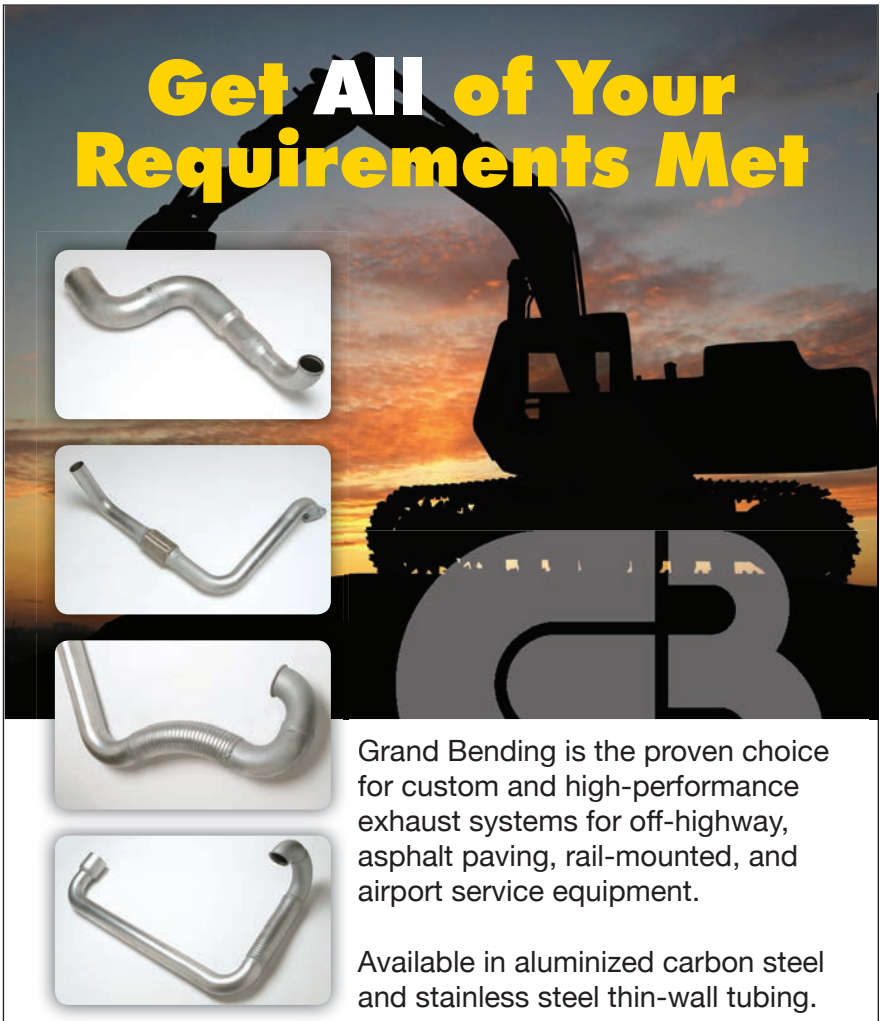

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LOOK TO THE U.S. for Construction Opportunities

The Construction Machinery industry's weakness has become expected or accepted. Companies should look to the U.S. Construction Machinery market for growth opportunities as headwinds from low commodity prices diminish into 2017. The U.S. Mining Machinery Production should see signs of recovery taking hold later this year, as commodity prices have begun rising mildly.

Europe's Construction and Mining indices, however, show continued negative internal trends which suggest further declines are likely this year. Conversely, Agricultural Machinery Production's recovery is being hindered by commodity prices in the U.S., but is persisting in Europe which may continue into the next quarter.

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QUESTIONS?

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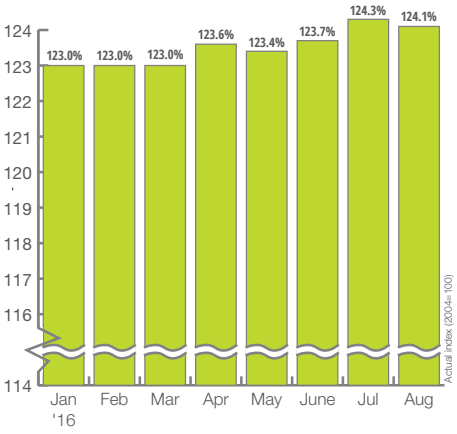
U.S. Leading Indicator:

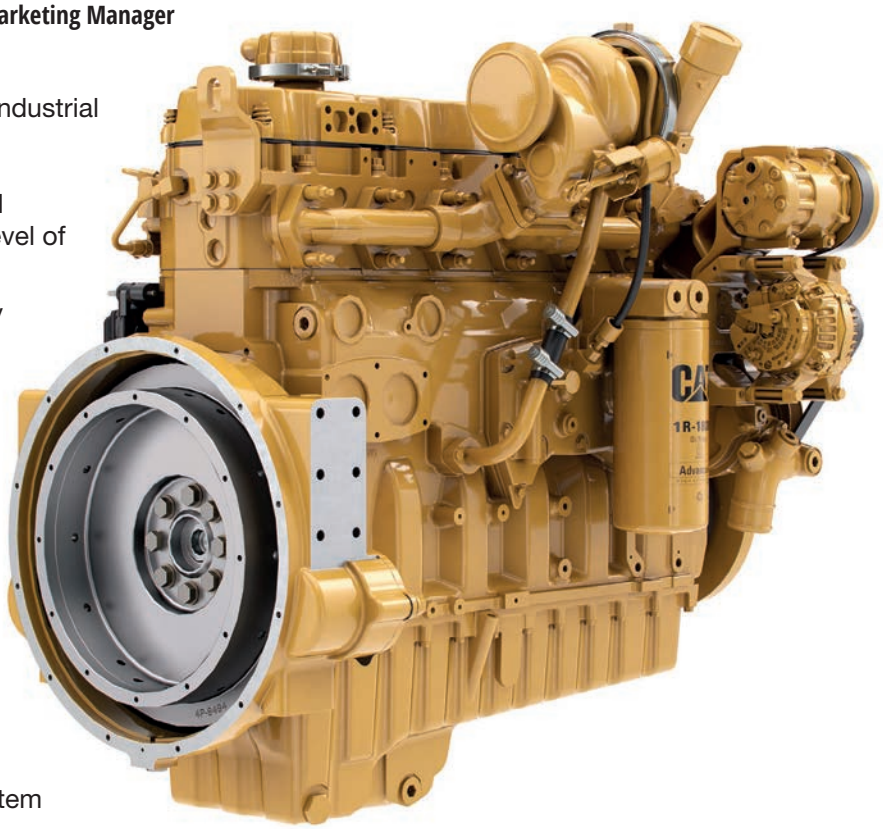
- The U.S. Leading Indicator ticked down in August.
- However, the Indicator is still above the low data set earlier this year, suggesting expansion in the overall U.S. economy in late 2016.



Editor's Note: Please note that this chart has been modified on the Y-axis to show the trend more easily.

Caterpillar 9.3 Liter Industrial Engine Delivers Increased Power Density

By Victoria Reeves, Caterpillar Industrial Product Marketing Manager



Caterpillar has built on the success of our industrial engine range with the launch of a new 9.3 liter product. To make our customers more successful, the engine's flexible design and proven technologies deliver an unrivalled level of performance.

Designed for use in heavy duty off-highway machines, the Cat® C9.3B industrial engine delivers 335-455 bhp and 2081Nm torque. It will meet EU Stage V, U.S. EPA Tier 4 Final and below emissions standards.

Customer Value

Built on a proven core, the C9.3B delivers 18 percent more power and torque, and has a simplified and 30 percent smaller aftertreatment compared to the previous Stage/Tier engine. A 6 cylinder turbocharged engine, the C9.3B's system mass has been reduced by 95 kG while a simplified air system allows for smaller radiator packaging.

Ease of installation has been supported through engine-mounted aftertreatment (EMAT), while uptime is maximized due to the compact and lightweight diesel oxidation catalyst, diesel particulate filter, and high efficiency selective catalytic reduction aftertreatment system. Multiple configurations of aftertreatment are available to support packaging flexibility.

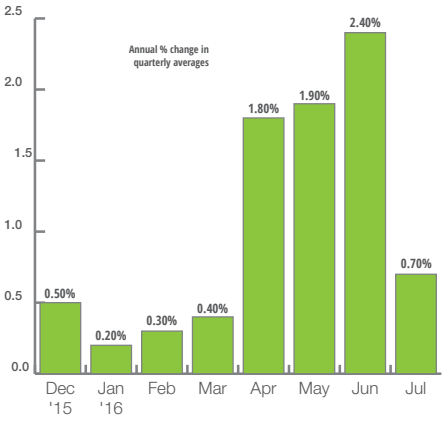
Also available as an industrial power unit, the C9.3B is a durable solution that delivers the performance our customers expect from their machines. Its flexible design reduces both installation cost and time, while ensuring quick and easy servicing and a lifetime of low cost for the end user. The C9.3B and all Cat industrial engines are designed with the customer in mind; we meet emission standards while delivering increased power density, fuel efficiency, and reduced complexity to add real value for our customers.

Our common platforms ensure maximum uptime and enable our customers to meet worldwide emissions standards from one machine platform. As a result, we have the strongest, most complete product range available for customers and manufacturers looking for a robust, fuel efficient industrial engine solution. Plus they are serviced by the most extensive dealer network in the world and backed with comprehensive warranty, financing, and extended service plans.

For more information visit CatIndustrialPower.com

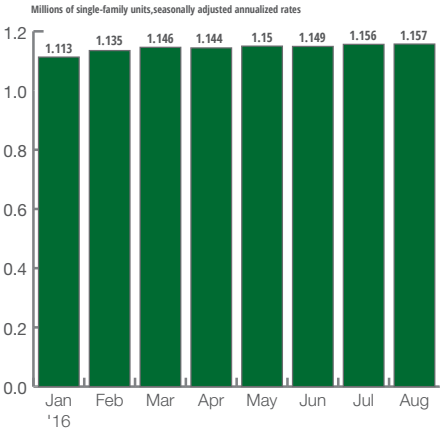
U.S. Total Industrial Production:

- Production in the three months through August was down 0.7% from the same quarter last year.
- Low oil and metal commodity prices are hindering investment in the industrial economy.



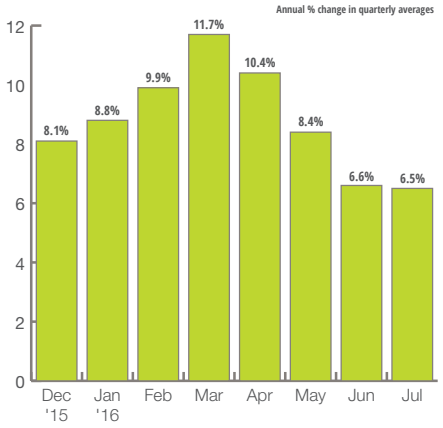
Housing Starts:

- Annual Starts held steady at 1.2 million in the 12 months through August, up 7.5% from the previous year.
- Rising wages and a tightening labor market are driving growth in the housing market.



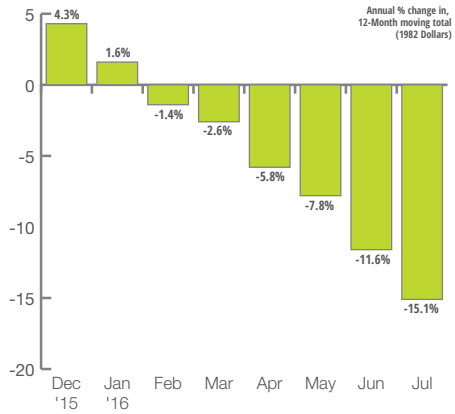
Private Nonresidential New Construction:

- The Construction quarterly growth rate slowed to 6.5% in July.
- Construction will avoid recession in this business cycle despite current deceleration.



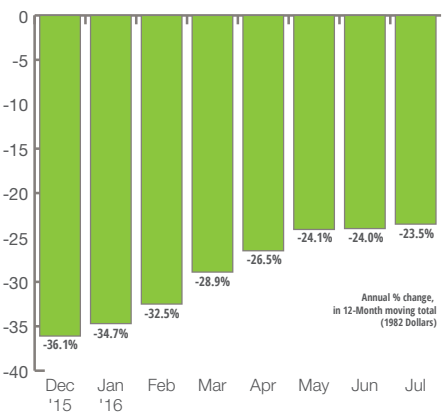
Construction Machinery, New Orders:

- New Orders in the 12 months through July were down 15.1% from the previous year.
- Low metal commodity prices are weighing on the surface mining component of New Orders.



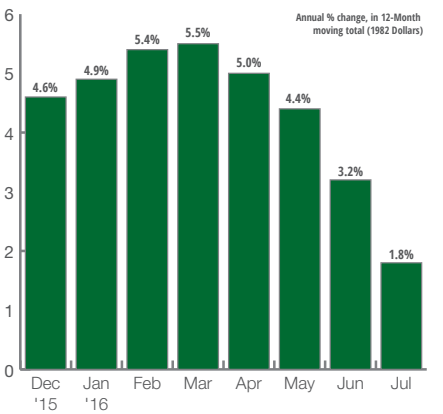
Farm Machinery & Equipment Shipments:

- The U.S. Farm Machinery & Equipment Supplies fell 23.5% in the 12 months through July, but contraction is generally easing.
- Negative internal trends suggest this industry may revert back to a recession phase in 2016.



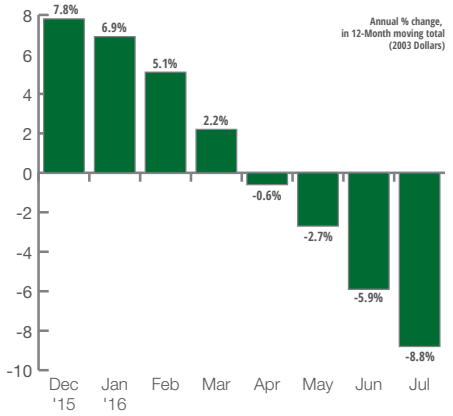
Total Public New Construction:

- U.S. Total Public New Construction in the 12 months through July was up 1.8% from the previous year.
- Construction will transition to a recessionary phase in late 2016, but decline in this segment will be relatively brief and mild.



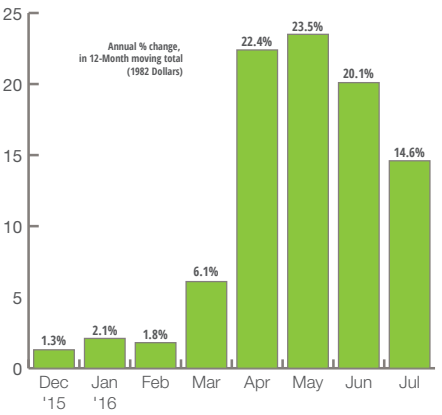
Heavy-Duty Truck Shipments:

- U.S. Heavy-Duty Truck Shipments in July were down 8.8% on a year-over-year basis.
- Expect upward momentum on the Shipments annual growth rate in 2017 as business-to-business activity picks up.



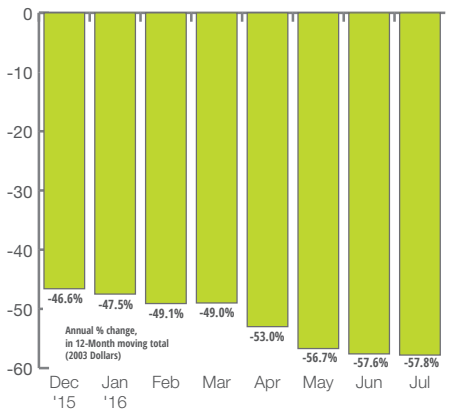
Defense Industry, New Orders:

- U.S. Defense Capital Goods New Orders in the 12 months through July were up 14.6% year-over-year.
- Expect New Orders to generally expand through 2018.



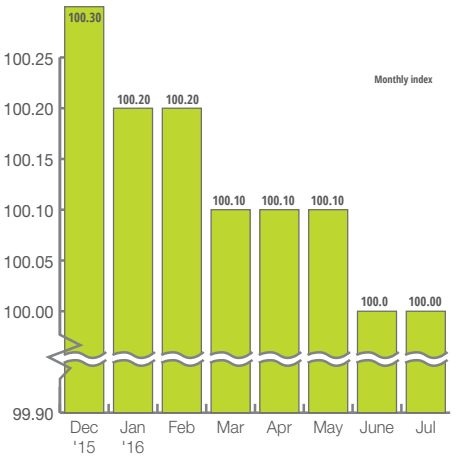
Mining, Oil & Gas Field Machinery New Orders:

- New Orders fell 57.8% in the 12 months through July.
- Expect upward momentum in this segment in 2017 as rising oil prices stimulate investment.



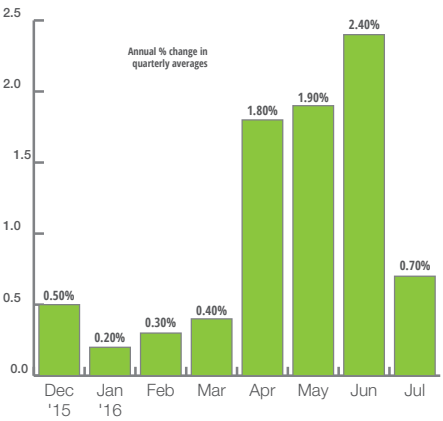
Euro Area Leading Indicator:

- The Europe Leading Indicator ticked down in July.
- Mild decline in the indicator over the past year suggests the European economy could face headwinds through 2017.



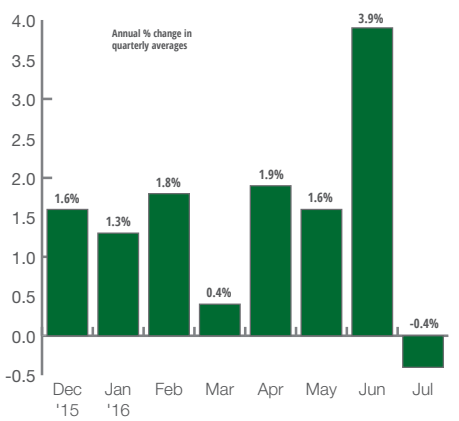
Industrial Production, United Kingdom:

- The U.K. Industrial Production quarterly growth rate slowed to 0.7% in July.
- Headwinds from the uncertainty surrounding the Brexit referendum this summer are beginning to show in the data.



Industrial Production, Germany:

- Germany Industrial Production in the three months ending in June fell 0.4% from the year-ago level.
- Expansion in the auto industry is no longer able to buoy the German industrial economy as a whole.



Editor's Note: Please note that this chart has been modified on the Y-axis to show the trend more easily.

Perkins® Syncro engines help OEMs access new markets

By Oliver Lythgoe, Perkins Product Concept Marketing Manager

Perkins has launched a new family of 4 cylinder, 2.8 and 3.6 liter diesel engines delivering 60-134 hp to meet multiple global emissions standards including U.S EPA Tier 4 Final and EU Stage V.

Engineered to integrate into more than 80 different Original Equipment Manufacturers' (OEMs) machine models, the new 2.8 and 3.6 liter engines deliver the performance, value and reliability our customers expect to help them access new markets and support their business growth.

Perkins® Syncro: Power, torque and fast response ideal for the rental industry

High power and torque and fast response are key enablers for engine downsizing, and can help OEMs deliver machines that are easy to operate. As many machines in this power band enter the rental sector, the 2.8 and 3.6 liter engines are both compact and reliable.

With up to an 8 percent improvement in fuel economy during machine use, the 3.6 liter engine offers powers up to 134 hp with up to 500 Nm of torque. The 2.8 liter turbo aftercooled engine variant delivers a maximum of 74 hp with torque of up to 325 Nm.

The Perkins® Syncro range benefits from a common rail fuel system, electronic control, advanced air systems and aftertreatment configurations. A 90 percent commonality in the customer interfaces between the 2.8 and 3.6 liter engines gives OEMs the freedom to determine machine platform strategies that suit their businesses and markets.

Recent advances in fuel systems, control systems, predictive engineering and aftertreatment ensures our new 2.8 and 3.6 liter engines are the right solution for a variety of off-highway machines like wheeled loaders, tractors, telehandlers and excavators.

The engine's modular design ensures the 2.8 and 3.6 liter models ease of integration into existing – and future – generations of machine.

www.perkins.com

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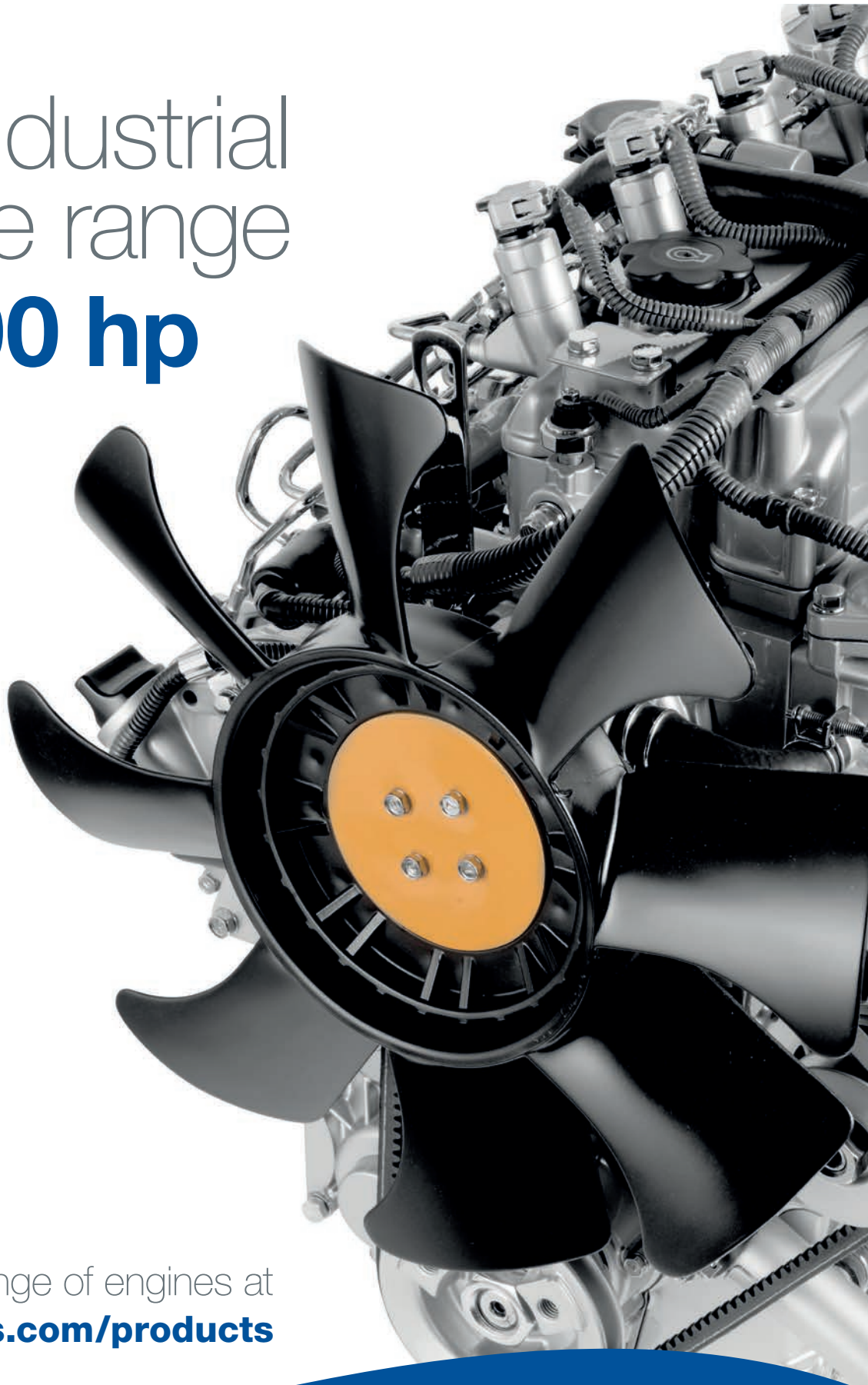
New industrial engine range

11-800 hp



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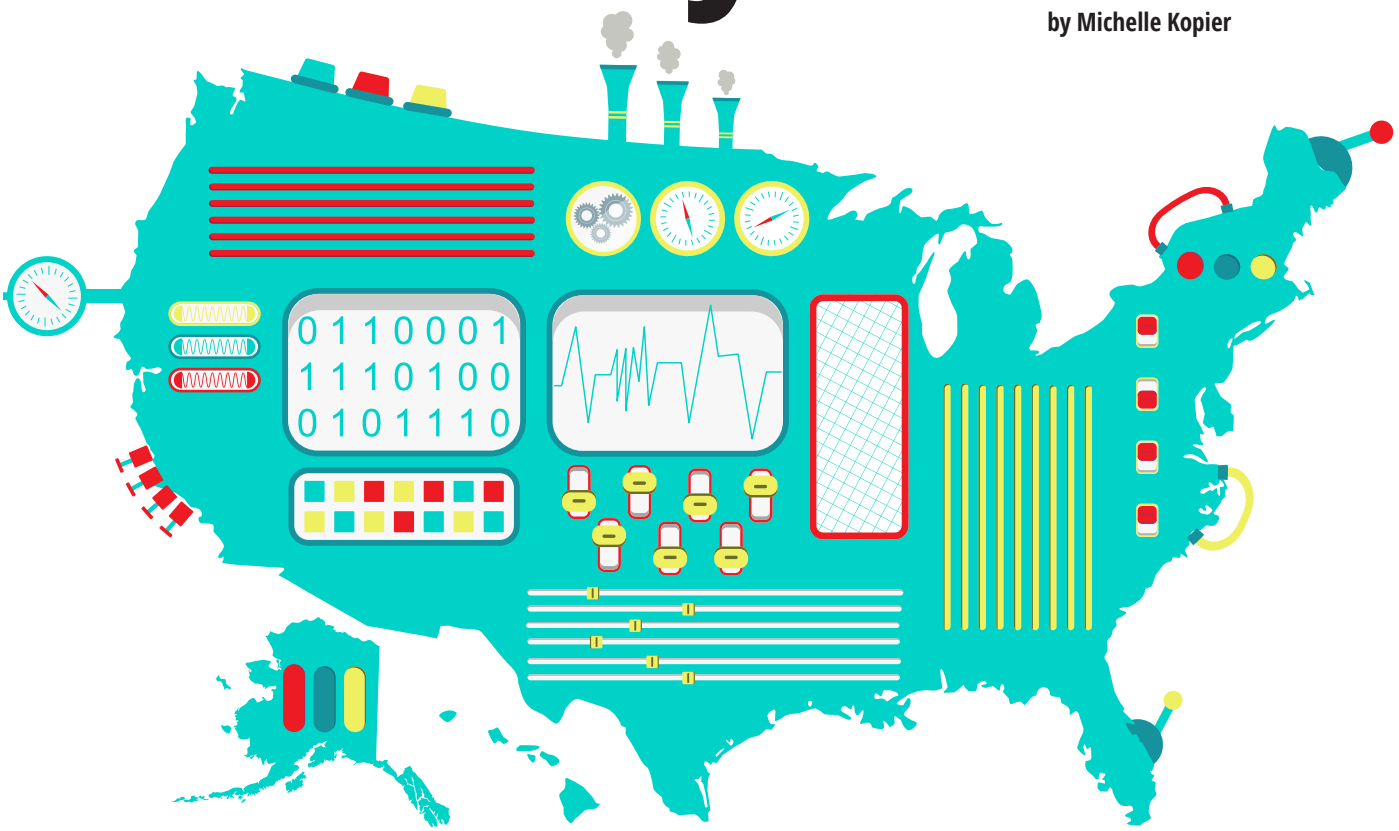
Your Pre-Election Study Guide

by Michelle Kopier



AEM has put together countless resources for its members to utilize to help them do their homework on the candidates and their stances on the policies and platforms that matter most for equipment manufacturers.

One of the most difficult things about a highly publicized and scrutinized political climate is sifting through the slew of misinformation or skewed facts to serve a candidate's position. As a service to its OEM members, the Association of Equipment Manufacturers (AEM) has made a strong effort to supply clear and unbiased information about the relationship between political positions and their implications for the manufacturing industry.

"There are a lot of issues that matter to equipment manufacturers and their employees this season," says Dennis Slater, President of AEM. "We've focused on four key issues—infrastructure, trade, agriculture, and taxes and regulations. Our focus this election season has been to raise awareness of the importance of these issues and how they affect our industry for all manufacturing voters."

Most of the activities involved in this space have been administered through the AEM grassroots effort, I Make America (www.imakeamerica.com). The association's approach to the political topic has been emphasized on education, not any particular party alignment, so its members and their employees can feel well-informed on important

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manufacturing issues effecting their job and economy.

"We felt that AEM's best role during this election year was to serve as a resource for our members and their employees, and to raise broader public awareness of our industry's views on the issues that really matter. Our goal has been to raise the salience of manufacturing issues for as many voters as possible, so that they are taking those issues into account when deciding for whom they will vote—whoever that candidate might be," says Slater.

Infrastructure

There can be no denying the significance of a sound transportation infrastructure, not only for the ease of the shipment of goods and resources, but also for economic growth and development. While there are countries around the world still in need of development, the U.S. is in need of repair to its degraded roads and bridges.

The Highway Trust Fund (HTF)—dedicated to improvements, maintenance and repairs of the country's roads and bridges—was recently extended by five years through 2020, which marked the first long-term extension in several years and provided much needed industry confidence in the highway construction industry. Unfortunately, the fund's primary revenue source is the federal gas tax which hasn't kept pace with inflation.

Below, and in future sections, are excerpts from information gathered by AEM which can be found in full on its website www.imakeamerica.com:

Trump has pledged to rebuild America's infrastructure and spend far more money on infrastructure than the United States has in recent years. Trump has not detailed how he would finance a dramatic expansion in infrastructure spending, but has indicated that he may redirect funding for military engagements overseas or foreign aid to domestic infrastructure spending.

Clinton proposes a five-year, $275 billion infrastructure plan, $250 billion of which would be spent directly on projects. She proposes using the remaining $25 billion to capitalize a national infrastructure bank. Clinton says this bank could use its seed money to support as much as an additional $225 billion in direct loans, loan guarantees, and other forms of credit enhancement, which she says would result in a total of $500 billion in total, federally-supported infrastructure investment.

WHY INVEST IN INFRASTRUCTURE?

288,000

estimated jobs are generated annually for every $1 billion spend on highway construction nationwide.

BY 2020

without infrastructure repair an estimated $20 billion reduction in total exports of goods.

SOURCE: AEM

Trade

AEM and its members strongly favor trade agreements because they represent the obstacles OEMs face in regards to exportation of agricultural and construction machinery. Because AEM and I Make America felt as though the campaign season was distorting the true relationship between trade and the strength of U.S. manufacturing, the association created a video *(learn more, 12263246)* to clarify the benefits of trade deals for manufacturers.

There are several trade opportunities being discussed in this election. The Trade Promotion Authority (TPA)—aggressively supported by AEM—was passed by Congress in June and expires in 2018, at which point it will be subject to renewal by Congress. The TPA, or "fast track authority" as it is commonly referred to, allows the administration to negotiate comprehensive trade deals with foreign governments, and to then send the agreement to Congress for an "up-or-down" vote, in exchange for the administration taking congressional priorities into account before finalizing an agreement.

AEM is urging lawmakers to use this window of opportunity provided by TPA to complete comprehensive trade agreements with Asian-Pacific and European trading partners.

Trump has made adamant opposition to free trade agreements such as the Trans-Pacific Partnership (TPP) and is an opponent of already-established trade agreements like NAFTA.

Clinton opposed the TPP in its current form, however she indicated that she could support TPP if its provisions were fixed to her satisfaction, particularly on issues related to currency manipulation, and labor and environmental standards.

Specifically related to the Export-Import Bank, a U.S. national export credit agency, AEM is waging a significant lobbying effort to reauthorize and reinstate it as soon as possible.

Trump opposed reauthorization of the Export-Import Bank during the Republican primary campaign, calling it "unnecessary."

Clinton was a vocal proponent for reauthorizing the Export-Import Bank, calling it a "no-brainer."

Taxes and Regulations

Changes and modifications to tax legislation should aim to improve U.S. economic growth and competitiveness while hopefully simplifying the tax system. When it comes to taxes related to the manufacturer members of AEM, there are several provisions that are particularly important including the corporate tax rate, bonus depreciation and Section 179 expensing, the estate tax, ag

equipment depreciation, the R&D tax credit and specific provisions of the international tax code.

AEM and I Make America have stated that the federal estate tax should be fully and permanently repealed because of its harmful economic impact, particularly for small businesses.

As both candidates have very differing perspectives on what is a complex and multi-faceted topic, head online to www.imakeamerica.com to get a full account of their positions.

"[W]e're grateful to Congress for passing its first long-term highway bill in years, supporting the Export-Import Bank and for granting fast-track trade authority that clears the path for breaking down trade barriers that hurt manufacturers' ability to export their products. Congress also did well to permanently extend Section 179 expensing, the Research & Development tax credit, and further support bonus depreciation rules that benefit manufacturers and their customers," says Slater.

"The past 8 years haven't been without setbacks. While Congress passed a highway bill, it still hasn't developed a long-term, sustainable approach toward our infrastructure. The Trans-Pacific Partnership (TPP) is also stalled on Capitol Hill and deserves a fair vote," Slater continues. "Overzealous regulations like the Waters of the United States (WOTUS) rule and other unchecked regulations have been a definite negative for manufacturers that we hope the next administration and next Congress will address."

As Election Day draws nearer, it is important for manufacturers to stay aware of each candidate's position on the critical issues that impact the manufacturing industry and how manufacturers go to business. The industry is global, so while the efforts of I Make America and AEM are dedicated to awareness for its members in the U.S., it is important to remember that to participate as a global economy, one must play in the

international market and recognize its foreign implications and effects.

Be sure to continue to check back with I Make America online for additional information (such as an AEM exclusive interview with Mike Schmidt, a senior economic adviser to the Clinton campaign) and continuously updated news and resources for this important election.

PowerView Brings Man, Machine Together

By Osas Imade, Murphy Product Manager for Enovation Controls

Simple, intuitive, configurable displays enhance applications by providing vital information to the user while remaining cost effective and reliable. The human-machine interface device is rapidly becoming one of the most important pieces of equipment in industrial applications. Various factors such as increased electronic integration and new emission requirements have created a multilayered labyrinth making an HMI device essential to keeping users up to date.

Murphy by Enovation Controls' PowerView® 300 Series includes the PV350 and PV380 displays and offers that same ruggedness with its host of features that include: a 3.8-inch sunlight readable LED backlight QVGA monochrome display; wide viewing angle; IP-67 sealing; extensive testing for vibration and shock; operating temperatures of -40°C to 85°C (-40°F to 185°F) while also passing stringent EMC/EMI directives. Mounting the display is done via a 3.5-inch hole cut out, and the small footprint provides quick integration into existing or new designs.

Equipped with a 168 MHz processor, 2MB of flash memory and a real-time clock, the PowerView 300 Series, featuring multi-language support, boots into software in less than three seconds while allowing enough storage for multiple engine configurations and event logging with timestamp. Both displays have CAN 2.0B with support for SAE J1939/ Freeform protocols, a resistive input, a digital 500mA switched low-side output and power and ground on a Deutsch DT Series 6-pin connection.

In addition to the above I/O, the PV 380 adds three analog inputs capable of 0-5V/4-20mA measurements; three resistive inputs for four in total; a digital output; RS-485; and a frequency input on a Deutsch DT Series 12-pin connector. While the PV350 which boasts ECE-R10 certification, includes an isolated NMEA 2000 CAN Port on a 5-socket M12 receptacle.

Built for use as a stand-alone unit or as part of a distributed system, the PowerView 300 Series is an out-of-the-box solution for multiple applications. Its standard software includes an intuitive user interface that provides an easily configurable solution. Operators can quickly set up an electronic or mechanical engine type and configure the engine according to their application directly from the display. Quick changes can be made and parameters updated with the push buttons.

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The Industrial Internet of Things

Machine connectivity through the use of telematics systems and mobile apps which allow operators to remotely control and monitor their equipment are just some of the ways manufacturers are putting the Internet of Things (IoT) to use within the heavy equipment industry. This enables them to provide solutions to increase customers' productivity, as well as monitor their own products to improve service and design of future iterations.

With the Industrial Internet of Things (IIoT), companies are employing IoT technologies to improve their own productivity and efficiency from both a design and manufacturing perspective.

Companies note that getting customers to understand the benefits of IoT technologies and how best to utilize them are among the biggest challenges associated with expanding their adoption into various industries. In addition, the lack of broadband internet for more remotely located customers poses a challenge.

However, with an unlimited amount of possibilities available through the use of IoT technologies, manufacturers see it as a key area in which to continue expanding their development efforts.

How is your company approaching the IIoT and implementing it into the company's day-to-day operations?

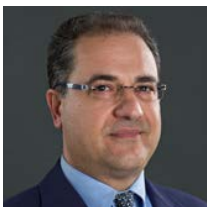
Peggy Gulick, Director Business Process Improvement (Jackson Operations), AGCO Corp.

From a manufacturing standpoint, AGCO is leading the way in use of IoT in our factories. We were recently recognized with a 2016 Manufacturing Leadership Award in the Internet of Things category for our use of Google Glass on the production floor.

At the Jackson Operations in Jackson, MN, they focus on the collaboration between humans, machines and products. The use of smart watches, ring scanners, tablets, Google Glass and smart andons allows the plant to focus on quality, safety, productivity, and in the end, happy customers.

Dan Ricklefs, Vice President of Global Marketing for Danfoss Power Solutions

By any name, we see this field as a tremendous opportunity for our company, the industry and ultimately the end users of the equipment in which our products are used. **The possibilities to provide additional value increase exponentially as we move from a focus on products to subsystems, vehicle systems and even fleet or jobsite ecosystems.** Operationally, this evolution is really just starting. We have worked with system and application data in control systems for many years. Adding data storage, connectivity and cloud features to the equation are some of the enabling technologies we have been working on in our portfolio. There's much more to do.



Ivan Di Federico, Topcon Positioning Group Chief Strategy Officer and Chairman of Topcon Agriculture

It is part and parcel to everything we do. Topcon embraces the philosophy of the IIoT by integrating it into virtually every phase of the solutions we provide to the marketplace. Whether it is construction, survey, or agriculture products — interconnected smart technology is both central to how we engineer our solutions and their functionality in the hands of our customers.

Arjun Mirdha, President & CEO of JCB North America

Our LiveLink Technology is built standard into most JCB machines at this point. JCB has a LiveLink center that tracks all machines subscribed to the service and monitors their use. Customers can monitor their fleet as well and download reports on their cellular phones or computers. The LiveLink data center shares data with our field-based service teams to assign work and locate machines in need of preventive maintenance or repair. It helps us be more efficient in servicing our customers.

What opportunities are you seeing and challenges are you facing in regards to the IIoT?

Matt Rushing, Vice President, Global ATS Product Line, AGCO Corp.

The IoF (Internet of Farming) is a great way to understand what telematics in agriculture can do to improve a farm operation, and we're doing it today. Smart, connected machines capture detailed information about every field operation, from field prep to harvest, and send the data to the farm's back office software, agronomist or other trusted service providers where analysis is performed and insights are derived.

So, as these new technologies demonstrate their effectiveness in both big and small operations, we expect to see more and more farms adopt them. We're already seeing a proliferation of manufacturers and technology providers. It's not always clear for farmers what technologies they need, or how best to harness the power of their data. This can lead to confusion and concern in terms of how their data is handled and who can see it. An opportunity now is to promote transparency within the precision agriculture industry.

In the years to come we also expect some of the providers to consolidate and merge, simplifying the landscape.

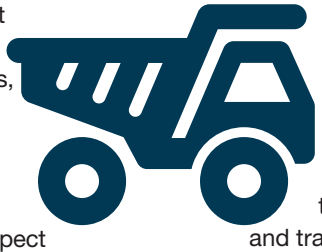
Ricklefs: Some of the more obvious use cases, such as remote machine connectivity for diagnostics, are fairly easy to recognize and implement. There are some challenges even here as vehicle subsystems may be controlled in different architectures. Data formats don't always match, and bus networks don't always communicate. Connectivity technologies can also be relatively expensive or unreliable in more remote areas where we find many of our applications. Even more fundamental is that the business model of a connected machine may not always be obvious. Can the extra cost generate enough benefit for the supplier, the OEM, the user? It's an equation that doesn't always have an obvious answer. But moving beyond that to a world where we can connect and analyze data from many systems,

applications and vehicle types to find ways to optimize performance, the challenges multiply quickly. For example, how much data do we really need to move to the cloud to be able to model performance? Is there proper security in our architecture? Fortunately, we are not the only industry looking for answers to these types of questions.

Di Federico: The opportunities are seemingly limitless. **The power of IIoT provides comprehensive planning, process control, workflow monitoring and extensive reporting that will bring our customers the full advantages of connectivity.** The challenges, as with most innovation, have mostly to do with adoption. Once the customers have an opportunity to see first-hand how the solutions we provide make them more efficient, the concept of IIoT makes perfect sense.

Is general IoT playing a role in your company's product designs? If so, how? And if not, do you anticipate it will at some point in the future?

Rushing: Absolutely – AGCO's Fuse strategy...helps drive AGCO's product development across our platforms (tractors, harvesting and crop care equipment) and heavily influences investment in engineering and IT. We expect this investment and focus on farm optimization to continue to grow.



Ricklefs: We are continuing to develop our PLUS+1 control system platform, which offers telematics solutions that connect to vehicle systems in the field. **We have also focused on providing flexible, cloud-based solutions that are easy to implement. This enables our OEM customers to focus on the use cases that add the most value to their particular situation** without having to invest in the expertise or infrastructure required to make IoT work. We are able to provide easy access to almost any data that exists in the control system. Within hydraulic systems we continue to look for useful and robust data sources, including sensors that can add value in this environment.

Di Federico: We absolutely design our solutions with IoT top of mind. Our latest software systems such as MAGNET 4.0 provide real-time connected support for hardware, as well as integration with our Sitelink3D service for instant data transfer and connectivity into active project sites. The web-based access allows them to manage jobs from anywhere. When practically any new product is designed, integration with these solutions is standard and expected procedure for Topcon.

Mirdha: Yes in short, all machines are now designed with sensors that allow us to capture and transmit data so that we can better serve our customers and help them run a more efficient business. Technology integration is always considered during the development of new products.

What potential benefits are available by implementing IoT technologies within your products?

Rushing: With our telemetry product, AgCommand, enabling Fuse Connected Services, growers can realize a wide range of benefits that all boil down to time and cost savings, and increased yield. These are derived through optimizing machine health and performance, improved machine resale value, input cost reduction, streamlined logistics, reduced waste, reduced downtime and maximized uptime. On AGCO's side, being able to **understand with more accuracy how the machines are being used in the field, and understanding where machine challenges are occurring helps us to build better machines.**

Di Federico: Our smart and connected solutions enable comprehensive monitoring of conditions, operations and environment through sensors and data, which means monitoring knows no boundaries. Assets can be monitored from everywhere.... It enables real-time control of assets that can be customized based on needs and priorities. We call it "descriptive, predictive and prescriptive" analytics. The result for customers is higher productivity, less downtime and waste, and ultimately more profitability and with less stress.

Read full Q&As online

Matt Rushing, Vice President, Global ATS Product Line, AGCO Corp. and Peggy Gulick, Director Business Process Improvement (Jackson Operations), AGCO Corp.– *Search:* 12260553

Dan Ricklefs, Vice President of Global Marketing for Danfoss Power Solutions - *Search:* 12260557

Ivan Di Federico, Topcon Positioning Group Chief Strategy Officer and Chairman of Topcon Agriculture - *Search:* 12260574

Arjun Mirdha, President & CEO of JCB North America – *Search:* 12260568

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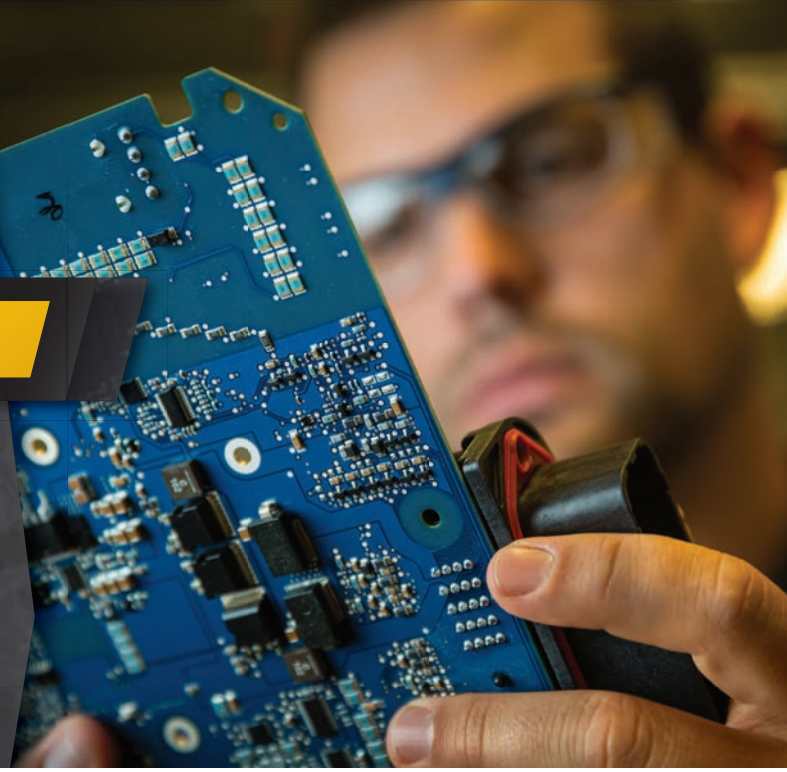

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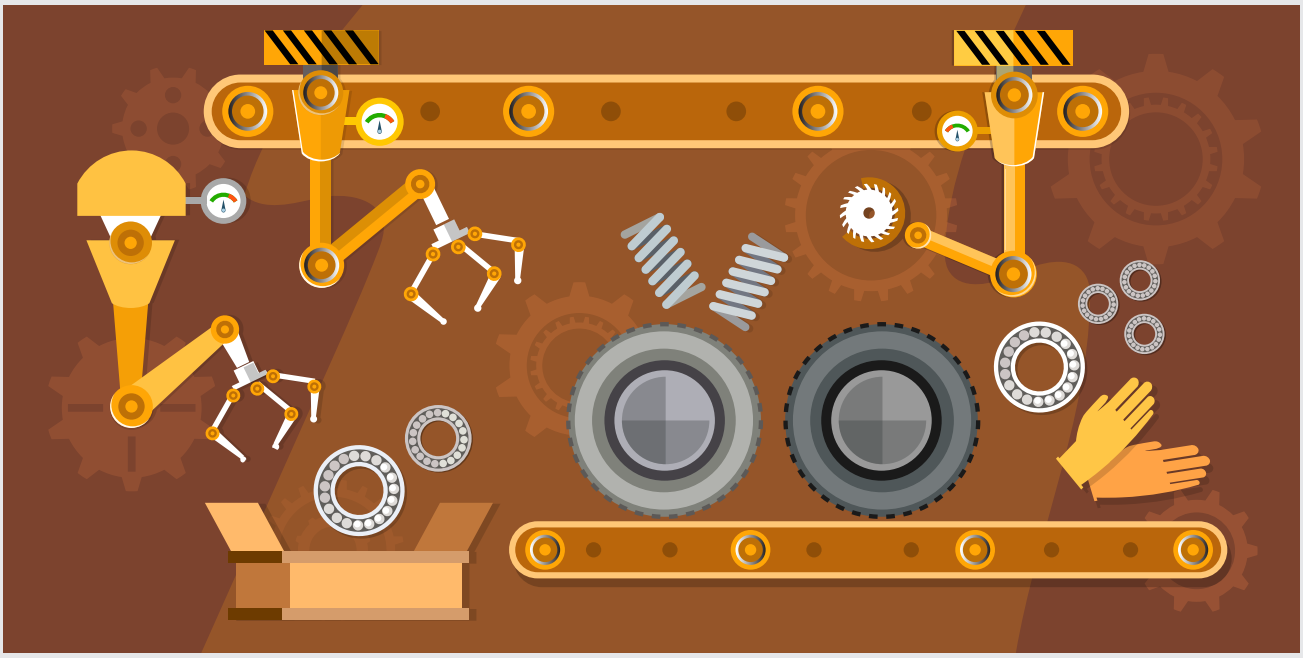
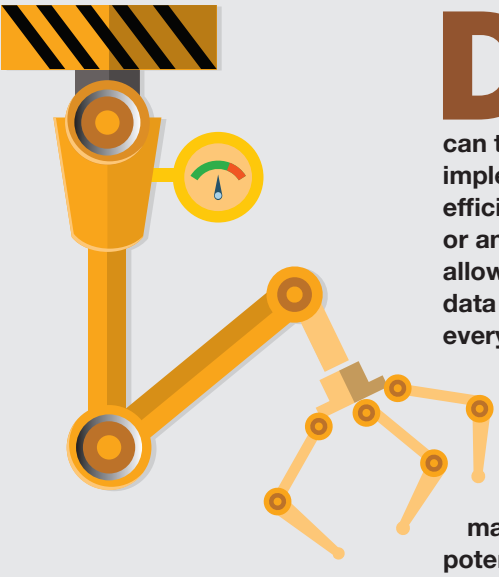


The Industrial Revolution 4.0:

Data, Connectivity and Automation



Data and digital technologies are the key elements of the Industrial Revolution 4.0 (IR4.0), also known as Industry 4.0. It can take the form of a manufacturer implementing technologies to improve efficiency in their production facilities or an OEM offering products which allow customers to collect and analyze data from the machines they operate every day.

The buzzword "Big Data" is a large part of the IR4.0. Big Data enables manufacturers and their customers to collect a wealth of information about their machines—how they're operating, potential service issues, etc. While some say the more data the better, others note the vast amount of data that is available to be collected and analyzed can be overwhelming for both manufacturers and their customers. Determining what is the most important information to collect, and how to use it, will continue to be an evolutionary process as the IR4.0 progresses.

As with any new technology or way of doing things, early adopters of the IR4.0-associated technologies will see the most benefit. Implementing these technologies is not an overnight job, but rather takes time to develop and determine how best to utilize them; so the sooner a company implements or develops the technologies for their customers, the better positioned it and its customers will be to see the benefits possible.

What does "Industrial Revolution 4.0" mean to your company?

Matt Rushing, Vice President, Global ATS Product Line, AGCO Corp.
Agriculture 4.0 is the industry answering the question of how information technology and data science can evolve farming practices for greater and greater efficiency, sustainability and productivity. AGCO is very focused on being a leader of Agriculture 4.0, which will mean smart and connected machinery systems and always looking for new ways to improve the farm operation. We continuously pursue R&D projects in these areas and bring the smartest machines to market with each production cycle.

Several of AGCO's R&D projects in recent years demonstrate some ways in which autonomy and robotics can help farmers address productivity and efficiency challenges and opportunities, specifically our Fendt GuideConnect, Valtra ANTS and, more recently, AGCO's Fendt MARS project. The MARS concept is focused on eliminating not only the cost and inefficiencies of an operator, but also the cost of the tractor and the planter tool bar as well, which can eliminate cost, increase labor efficiency, reduce soil compaction and allow for much more accurate placement of inputs. Within the next few years, AGCO will be introducing a generous number of new technologies and services (that also includes autonomous solutions) that as a package, will provide broad cost reductions and yield improvements for the farmer that go well beyond simply removing the operator.

Caterpillar Inc. representative: The story of our digital vision is one of silicon and steel; it's about leveraging digital and data, alongside our world-class machines and engines, to improve the productivity of our customers worldwide. The digital vision will be a foundational element of each strategic business within Caterpillar as we amp up our technology offerings while continuing to make great products and provide the best aftermarket support. We are not changing our core business, but we are expanding what we're know for.

Arjun Mirdha, President & CEO of JCB North America
This phase of the industrial revolution centers around digital technology. **When compared to earlier industrial revolutions it is markedly different on speed alone, with everything happening at an accelerated pace. The challenge for all manufacturers is determining how and what technologies to incorporate into their business systems, processes and products to gain a competitive advantage.**

Nathan Sheaff, founder and CEO of Sciemetric Instruments
Our team works with manufacturers to help them increase yield, improve quality and optimize their processes. We do this by adding advanced technology, sensing and analytics to the plant. That means we've been doing pieces of what's now called "IR4.0" long before we even knew what to call it, by measuring, recording, analyzing and digitizing the data generated by all the processes on a line.

In some industries, such as off-highway, this was often a tough sell, because production volumes weren't high enough to force the need for greater automation, which in turn, drives a willingness to adopt new technology. For the longest time, factories in many industries were underfunded with the philosophy of "let's make it as cheaply as possible," but this has changed. **Manufacturers have come to appreciate the value of squeezing all they can out of their technology and their data to make better parts because this can save them a fortune.** Plant managers are finally getting the latitude to innovate, to invest. This validates what we've been saying for years and helps us refine the message we take to the market.

Luke Zerby, New Holland North America PLM Marketing Manager
New Holland has always strived to be a leader in the ag equipment industry and as such, we focus on the evolution of ag equipment and on increasing in capabilities that we offer to customers. The "Industrial Revolution 4.0" is part of the overall evolution in manufacturing and equipment. We are very excited about the capability that we now have to offer our customers.

What role do any of the following branches of IR4.0 play within your company and/or its product designs?

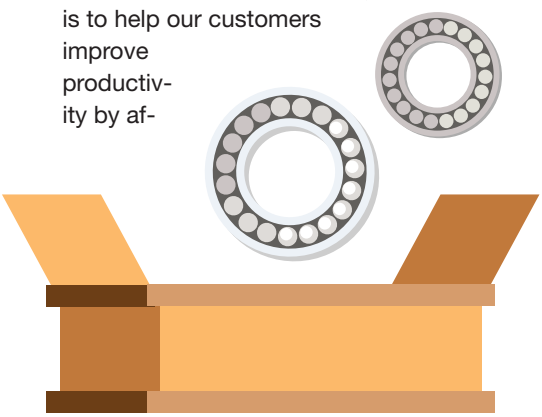
- ***Big Data (Smart Data) – acquisition, management, extrapolation and presentation***
- ***GPS, Telematics and Connectivity***
- ***Automated Systems and Vehicles***
- ***Are there other branches or areas of focus?***

Eric Hansotia, Senior Vice President, Global Harvesting, Crop Care, Advanced Technology Solutions and Dealer Technical Support, AGCO Corp.
Big data in agriculture is best understood as the opportunity to unlock potential, both in the machine

and in the field. It's not enough to simply create and capture the data, **harnessing the power of the data is the name of the game. GPS, telemetry, automation and precise application technologies are the tools that work in concert to unlock this potential in the field.** Smart machines equipped with these technologies collect the data and make it accessible to growers and ag service providers. Data visualization tools enable analysis and deliver actionable insights, which can then be utilized to more accurately control the factors impacting crop germination, growth and yield.

We must keep in mind that while Big Data is a massive quantity of information growers can gather and use to make better decisions, you also need the right machines to actually engage the ground, with the aid of the other technologies, to really see the benefits of the data.

A key guiding principle for AGCO, driving how we approach Big Data and these technologies, is our Fuse strategy, which is an open approach to precision agriculture. And by open, we mean facilitating connections between AGCO equipment and our customers' preferred agricultural service providers, regardless of OEM. Other OEMS in the industry have taken a less inclusive approach, requiring growers who use their machines to then also use the OEM's proprietary farm management software. By contrast, AGCO offers connections to a constantly growing list of farm management software and tools. AGCO's ultimate goal is to help our customers improve productivity by affording them the flexibility to manage their operations the way they see fit. This means the grower isn't locked into a single solution – they can use the tools that best suit their needs.



Caterpillar Inc. representative: Caterpillar has been focused on leadership in technology for decades, but now is the time to accelerate the transformation of sophisticated applications and analytics into solutions. We are leveraging leading edge applications of advanced analytics and disruptive technology to accelerate Caterpillar's transformation to merge the physical with the digital.

Mirdha: *Big Data (Smart Data)* – Data allows us to quite simply be smarter and more efficient in how we build the JCB brand. The more data we have on our current customers and how they are using our equipment, understanding the buying wants, needs and habits of prospective customers, the more strategic we can be in our approach. Today all of our marketing is triggered by data whether its product, service, parts or finance related.

GPS, Telematics and Connectivity – **We can now see how long customers are running machines, when and if preventive maintenance is being performed and receive error codes and alerts when there's an impending problem so that we can be proactive in helping our customers better maintain their equipment.** All this data allows us to better support our customers whether on the phone or in person onsite. It helps us resolve issues much quicker than we could have years ago, ensuring the customer's machine delivers maximum uptime.

Sheaff: *Big Data (Smart Data)* – I've been in so many factories where data is siloed, where you can't correlate or organize it to understand causal effect. **Data by itself is useless – it's a means to an end. In this context, that end is to make better parts or eliminate a warranty recall. If your data is trapped in silos, or unorganized and lost in that deep, dark data lake, it's not doing you any good.** In reality, we've been working in the big data space for 20 years or more with real-time, multi-terabyte databases. When we talk about big data, it's about how to organize and structure it so you can squeeze value out of it fast. We're acquiring the data from many machines, sensors and processes on the floor, and managing it by putting it into an organized data model. Google showed us how you can unlock value from data quickly if you organize it so that it's accessible and easy to correlate and visualize.

Automated Systems and Vehicles – We don't look at this in terms of fleets and vehicles out on the worksite, but in terms of tooling and processes and machines in the factory. What we try to do is gather all the pertinent data from all the automated processes so you have a digital flight recorder that allows you to retrace your steps and analyze for continuous improvement.

Are there other branches or areas of focus? – It's long been common in manufacturing to look at statistical averages, to look at hundreds or thousands of parts in a pool, rather than at single parts. But this approach doesn't help you track down that one in a thousand that could lead to a warranty claim or a mass recall. What we do is provide manufacturers with a digital fingerprint for every part made—the means to track the attributes of a part right down to the individual serial number. It takes this kind of big data analysis and scientific process to understand and catch failures early, find root causes and prevent costlier problems down the road.

Zerby: *Big Data (Smart Data)* – From the product design standpoint, we are focusing on how we can help

All work and no play as Piher's 'through shaft' sensor effectively wraps around any shaft

Piher's 'through shaft' sensor delivers position data directly from source. One slimline, 9mm package contains two discrete non-contacting components – a full circle magnet and a separate electronics module. Easy to integrate with no mechanical interfaces, this through-shaft sensor provides at least 50 million rotational cycles exactly as installed from day one.

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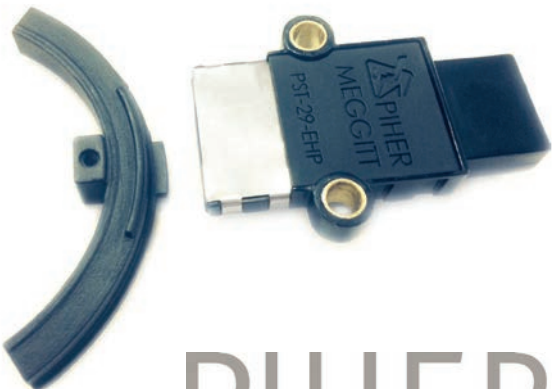

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our customers take advantage of the large volumes of data collected in the field. Our producers now have more data to help guide them in making management decisions then they have ever had in the past, but, there is also the possibility of too much data. What New Holland is focusing on is how we can help our customers manage and extrapolate that data. This can happen through the precision farming system, in the equipment locally, or the data can be shared with the customer's desktop computer or sent through our PLM Connect Telematics to be shared with a third party that the customer is working with. All data transfer happens over secure systems. New Holland is very clear that while we want to help our customer better manage and use their data, they retain complete ownership of the data.

GPS, Telematics and Connectivity – GPS, and Telematics, have become a deciding factor in a large portion of our product offering. In many products, Integrated Guidance that uses GPS, is a standard feature. We are also now offering Telematics as a factory fit option in several product lines. The customers need to be connected and all of the benefits that they can achieve because of this, is why we are focusing on continuing to improve our connectivity capability to ensure we are providing our customers with the best tools to help them achieve success.

Automated Systems and Vehicles – New Holland unveiled the NH^{DRIVE} Concept Autonomous Tractor at the Farm Progress Show in Boone, IA, this year *(learn more, 12251734)*. This was a very exciting event for New Holland. The NH^{DRIVE} highlights not only what can be done in the future with a fully autonomous vehicle, but illustrates many features we have today in our equipment— IntelliSteer, Headland Management, ISOBUS implements with prescription and variable rate application. The step from our current vehicle to a fully autonomous vehicle is not such a large step.

We have also focused on increasing the automation in many other pieces of equipment to help remove human error while improving efficiencies. These automatic features, like section control on a planter, can pay for themselves in one or two seasons, and continue to be a savings to improve the customer's bottom line.

Is there a particular route or focus the company is taking amidst the IR4.0 set of opportunities?

Hansotia: AGCO's path has always been toward making farmers more efficient—first with always improving machinery, next with industry-leading technologies, and now with services. We intend to stay on that path in the context of IR4.0. As a manufacturer of world-class, long-standing equipment brands we will always be focused on improving machine efficiency today's farmers need to feed the world. Over the last 5 years, we've also elevated our focus on delivering industry-leading technology tools, and now services, that will transform our customers' practices into lean, efficient and sustainable operations. AGCO's Fuse Connected Services are designed to help growers identify efficiencies and optimization opportunities while supporting their connections with other trusted service providers like crop consultants and agronomists. We believe this new level of grower support will unlock potential across their operations through streamlined logistics, data management, and waste reduction.

A key opportunity and differentiator for AGCO in this new era has been our commitment to customer data privacy. Understandably, there is a lot of sensitivity around farm data—where it goes, who can see it, and how to manage it. AGCO is unique in the industry in that we provide two different data pipes—one for machine data such as engine RPM and fuel consumption, and the other for more sensitive agronomic data. We've found that our customers highly value being able to better control what happens to their farm data in this way.

Mirdha: There's no one particular focus for JCB. We are open-minded to any evolving technology that helps us to be a better partner to our customers. New technologies are being implemented across all facets of our organization from research and development, to marketing and sales, to distribution, allowing us to deliver product faster than before with improved quality and value.

Zerby: Efficient Data management for our customers is an area that we are focusing on, giving our customers the best tools for collection,

Read the full Q&As online

Matt Rushing, Vice President, Global ATS Product Line, AGCO Corp. and Eric Hansotia, Senior Vice President, Global Harvesting, Crop Care, Advanced Technology Solutions and Dealer Technical Support, AGCO Corp. – *Search: 12260553*

Caterpillar Inc. – *Search: 12260555*

Arjun Mirdha, President & CEO of JCB North America – *Search: 12260568*

Nathan Sheaff, founder and CEO of Sciemetric Instruments – *Search: 12260571*

Luke Zerby, New Holland North America PLM Marketing Manager – *Search: 12263952*

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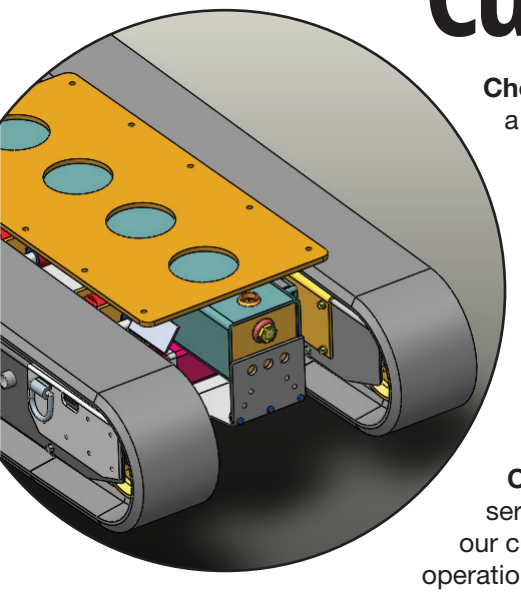

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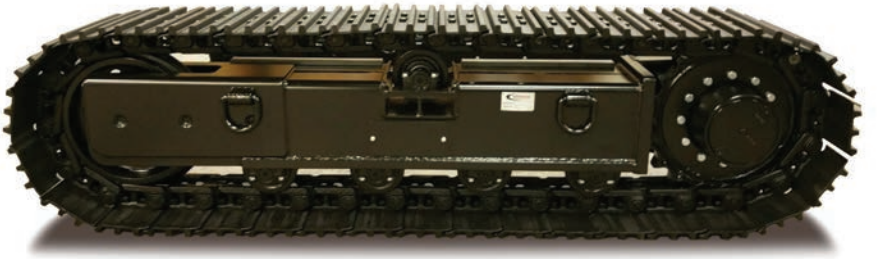

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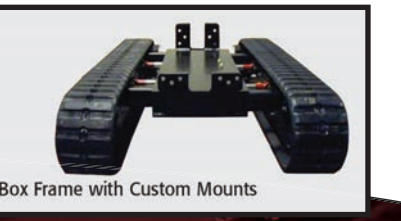
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management, and implementation in their operations.

What is the opportunity potential, and what benefits are you already seeing?

Hansotia: The opportunity and demand is for farmers to double productivity over the next 20 years. Technologies like guidance and rate and section control get us going in that direction... As connectivity, computing and data science improve, we will see consistent improvement in what our core technologies and services deliver. While every operation is different with varying crops, size of operation, equipment and climate conditions, Fuse Connected Services is showing efficiency benefits in the double digits in areas ranging from improved fuel consumption, uptime optimizations and fleet maintenance efficiencies. Our pilot programs in North and South America are proving what smart, connected machines can do.

Sheaff: It's a great pity when a latent defect that should have been caught in the plant sneaks through—like a $600,000 truck that's shipped to Indonesia brought down by an oil leak caused by a missing bit of silicon or a faulty hose clamp. But **better tools for measurement, data analysis and data visualization are already helping manufacturers dramatically improve yield and reduce warranty claims.** In the off-highway industry alone, billions of dollars can be saved by avoiding defects.... Almost all customers can fix a problem if they know what to fix, but they need help to pinpoint the root cause. This requires better access to the data, with the right dashboard and real-time reporting so they can take action now, rather than be stuck waiting till tomorrow, by which time they may have already passed a thousand more faulty parts.

Zerby: We understand the margins that the farm and ag producers work with continue to get tighter as seed, oil, fertilizer and land cost continue to increase while the prices that they receive for their crops have not kept pace. By using increased technology and minimizing their inputs while trying to maximize their outputs, many producers have been able to survive in market conditions that would have forced them out of business. New technology will allow us to keep up with the demands of the growing population.

How do you foresee the IR4.0 affecting the industry as a whole? Are there any new or improved opportunities it will enable?

Hansotia: One exciting opportunity we see on the horizon as more farms adopt more data- and insight-centric practices, and as growers reap the benefits of these new tools and agronomic methods, is that data quality itself will start to improve. **The industry's move toward data format standardization also serves to improve data quality. More data is good, but better data is great**; it will increase the value of farm equipment and tools, and deliver an even better ROI for the farmer, while also serving the broader purpose of increasing efficiency and productivity.

Caterpillar Inc. representative: This is an evolution for the industry. Caterpillar envisions a world where we continue to cultivate our understanding of customer challenges and opportunities so well that we can anticipate and deliver what customers need before they even know they need it.

Mirdha: Technological advancement will continue to lead to long-term gains in efficiency and productivity. Transportation and communication costs will likely continue to drop. Logistics and global supply chains will continue to become more manageable. Opportunity is always out there for those looking for it. As an organization, we must continue to challenge traditional methods and assumptions to better understand today's business climate and customers, keeping a sharp focus on innovation. [It's] the very principal on which JCB was founded and [a] core focus of our business that has allowed us to grow into the world's third largest manufacturer of heavy equipment.

Sheaff: The people who embrace IR4.0 and all that entails are going to be big winners. It's a fundamental change in the landscape that can't be ignored. Companies that embrace it, challenge their employees and architect this technology into their processes early will be the winners by a long shot because it will take years. Even though it seems easy, it's not as simple as just plugging in a server and collecting some data from a bunch of sensors. There's a lot of things that have to change in how some plants operate. **The early adopters will gain a great advantage as they optimize their processes and the laggards are going to have a hard time catching up.** They won't be able to compete because the other guys will already be faster, better and cheaper.

Zerby: IR4.0 as a whole has allowed us to learn more about the work we are doing on a micro level. It allows us to take knowledge and wisdom gathered over centuries of agricultural development, combine it with state-of-the-art equipment resulting in an ag industry that is able to work more in unison with nature and be able to produce the quantities needed to feed the population.

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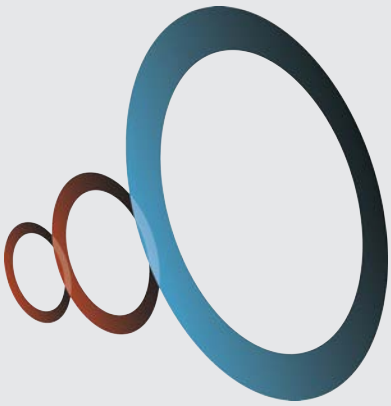
Technologies of the Future:

Hybrids, Electrification and Smart Systems



The consensus appears to remain that there is no true single alternative energy strategy for the heavy-duty market. Improving efficiency and reducing emissions is the ultimate goal, and manufacturers continue to investigate whether hybridization, full-electrification, or some other method is the means with which to achieve this.

Some say that full-vehicle electrification is the ultimate goal, but to get there hybrid technologies—such as bringing together electrical and hydraulic systems to get the efficiency and torque required by heavy-duty equipment—is a necessary stepping stone.

Cost remains the biggest hurdle to overcome. While advancements in the automotive industry are helping to alleviate this, it still remains a factor both in terms of development for OEMs and what customers are willing to pay. Energy storage is also a challenge, particularly for larger pieces of equipment.

Developing overall smarter systems through the use of sensors and other electronics, as well as integrated systems are ways many companies are meeting those efficiency and emissions-reduction goals now, and helping develop the path towards greater hybridization and full-vehicle electrification.

Have there been any recent advancements in hybrid technology which will help, or have the potential to, further increase their prevalence in the heavy-duty equipment industry?

Dr. Ravi Godbole, Global Lead, Research & Advance Engineering, AGCO Corp.

There are more component makers and designs are more compact and robust. The costs are starting to come down thanks to its prevalence in the automotive industry. The off-road industry is slowly developing consensus around voltage levels (e.g. 700V) and common standards around safety and connections.

Frederick J. Ross, CD-adapco Director, Ground Transportation

Our technology allows design engineers to optimize and build more efficient hybrid technology, on an individual component and full system level. Put simply our technology helps OEMs and suppliers to discover better hybrid designs faster by building a "digital twin" of a proposed vehicle that can be used to test its performance under real-world operating conditions, ultimately reducing both emissions and fuel consumption.

Mahendra Muli, Director of Marketing & New Business Development, dSPACE

Electrification of vehicles, both on- and off-highway, has become quite critical from both the fuel efficiency and emissions control perspectives. In general, the overall industry has gained significant experience in the integration of the two energy (gasoline or diesel and electrical) and actuation systems (internal combustion engine and electric msotors). Industry has both experimented and applied various architectures of series and parallel hybrid systems in vehicles successfully. The goal, however, remains to transition to full-electric mobility solutions and zero emissions.

Use of electric drive technology (beyond powertrain in the vehicle for new generation of autonomous vehicles, and for ADAS features like steering assist) will continue to rise. Power management, energy availability, battery sizing and recharging, electric motors, drive technology, and other technical issues will, therefore, continue to evolve.

Future semiconductor devices and the evolution of battery technology to help break barriers of energy density and high-power applications are awaiting. These innovations, when available, could unleash potentially much more innovation and applications that are conventionally powered by internal combustion engines.

Curtis Hutchins, President of Eaton's Hydraulics Group

We are seeing more and more applications where electrical and hydraulic power are being combined to satisfy the critical performance requirements stipulated by the machine builders. In the true sense of a hybrid system, two different technologies are applied to power the individual service needs of a machine platform. For example, electrical drives offer excellent control bandwidth but require high voltage to generate torque. The high voltage aspect creates safety, complexity and training concerns in mobile machinery service and operator communities, whereas a medium–to-high pressure hydraulic system is very familiar and presents fewer concerns. A blended technology solution supports a balance between superior performance, helping end users exceed productivity and fuel efficiency goals, and the technology is still familiar to the folks who have to operate and service the hybrid system.

Breakthroughs in hybrid technology have not come in the form of any single major development. Fundamentally the primary goal is to down-size or down-speed the prime mover while still maintaining overall performance to get the job done. Hybrid solutions are required to integrate seamlessly, fill the performance gap and provide additional advantages. Application and controls teams need to think creatively about how different technologies are architected together—not just from a physical perspective but also from a communications and controls perspective.

Keith C. Weiss, Senior Vice President, Industrial Sales, SKF USA Inc.

Heavy equipment manufacturers designed and released hybrid power systems to improve the fuel economy and operating performance. Hybrid technology and its application vary with the OEM. Hybrid powertrain technology achieved high success in the automotive field. However, due to high load, low speed, and periodic operation, hybrid technology cannot be directly applied in heavy-duty equipment. This brings the attention back to hybrid powertrain technology. Recent advancements have been made in the construction machinery space, specifically in the wheel loaders and the excavators, and these

solutions offer a unique strategy for energy conservation.

Federico Gaiazzi, FPT Industrial Head of Marketing

We all know that municipalities and public transport agencies - especially in booming major cities - need to count on a transport fleet [that is] more cost-efficient and, above all, sustainable for the environment. In our vision, hybrid solutions can have an even more strong spread also in [the] light commercial vehicles market and for urban distribution applications.

We believe that coupling [a] hybrid solution with a natural gas engine could bring benefits to the customer and to the environment. Concerning natural gas we can leverage on over 25 years of experience and more than 30,000 CNG engines sold. Today...we can offer engines capable to run with compressed (CNG), liquefied (LNG) or renewable form (bio-methane) [fuels].

In regards to hybrids, what technological limitations currently exist that are impeding the ability to harness the full potential of hybrid power?

Godbole: The cost of the total package translating to a clear value proposition for a customer, beyond the "wow-factor", is limiting its prevalence. The battery costs must also come down, which we expect to occur due to the automotive industry's focus in this area.

Ross: There are not any real technological limitations, except if you get a full-electric vehicle. In that case it becomes battery storage and recharge time. The main limitation of hybrid systems includes the additional costs for hardware needed for a secondary, electric system, and then to fully optimize the control systems to make sure all systems work efficiently together.

Muli: Current applications of electric drive technology – both from battery utilization and motor efficiency – seem to have reached their limit. Likewise, currently available power electronics semiconductor technology has reached its potential. Therefore, **engineers are looking at the system level to increase overall system efficiency and prevent any energy losses**. Even with these limitations, these devices and technologies have proven to provide a significantly efficient operation.

Hutchins: The limitations of any hybrid implementation are always the balance between efficiency benefits against the incremental cost of the system itself, plus the potential incremental service costs incurred over the lifetime of the machine. The duty cycle is another important factor that plays a significant part in the success of a hybrid system. Hybrid solutions are typically developed for machinery used in highly-productive applications where fuel costs represent a high percentage of the overall operating costs. If the machine is not in a dynamic state, then the primary benefits of the hybrid system will not be realized.

Russ Schneidewind, Vice President, Global Sales & Marketing, HydraForce Inc.

For the most part, the technology already exists to harness the potential of hybrid power, but the cost is probably the biggest limitation at this point. **Machine designers are forced to compromise in the design of the hybrid system to balance the cost increases for the additional products with the return on investment that should be realized within 1-1.5 years.** Hybrid systems could be optimized if fuel prices increased high enough to justify the increased expense with a return on the investment to the end user within 1 year or if the hybrid system can eliminate or reduce the complexity of the existing system by removing some products from the system and replacing it with items required for the hybrid function.

Oliver Lythgoe, Product Marketing Manager, Perkins Engines Co. Ltd.

The performance demands for off-highway equipment create a challenge for hybridization given current energy storage options – these sophisticated vehicles are required to deliver hard work over long hours in often challenging environments. While most people think of hybrids in terms of electrical energy storage (as is common for light-duty automotive vehicles), some off-road equipment utilizes hydraulic energy storage where duty cycles and equipment tasks lend themselves to this approach. **Complete machine system integration (powertrain, hydraulics, etc.) is critical when approaching hybrid design tasks.**

Weiss: Current challenges in hybrids for heavy equipment are around powertrain configurations. There is a lot of work being done by the OEMs in this area. Compared with traditional heavy equipment, an additional energy storage device is required, which increases the initial cost of the equipment.

What progress is being made in regards to developing fully optimized systems as opposed to individual components [e.g. overall powertrain optimization versus optimizing the drivetrain and engine separately]?

Godbole: AGCO has demonstrated the "e-RoGator" and "X concept"

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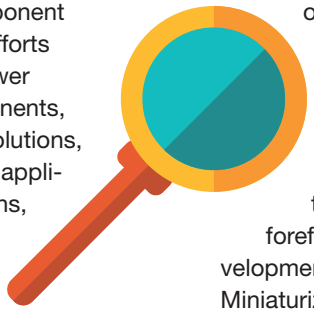
tractor with "e-rake" recently. Electrification of machines by itself has some value, such as a 10-15% fuel savings. But going beyond that, we are working on improving the total machinery system (e.g. hybrid tractor, plus implement) that brings more value in terms of additional yield and also helps reduce other input and maintenance costs. This journey is very similar to factory automation during the last 100 years (from steam and centralized mechanical power to decentralized, intelligent individual electric drives/robots).

Muli: Developing mixed energy mode, managing battery operation, and developing an overall efficient system is challenging for engineers. Further integration of subsystems to validate the overall system behavior also remains a challenge. Developing such complex systems with prototypes is an unviable option. We, as an engineering tools provider to the mechatronics community, realize these challenges and have developed a whole suite of tools that make the challenges of developing and testing hybrid systems easier.

Recognizing the need for very high-speed simulation corresponding to the fast dynamics of electrical systems, we provide FPGA-based computing and hardware devices. Additionally, we have further expanded our scope of test solutions to include complete electrical subsystems, such as power steering systems for validation in a lab environment. These electrical system simulations can be combined with conventional powertrain simulation for hybrid system simulation.

Lythgoe: Perkins very much believe that an integrated powertrain approach delivers the best solutions for OEMs and machine owners for reliability, productivity and fuel consumption. We've been supporting our OEM customers with technologies, as well as our expertise to help push this forward, and still see plenty of opportunity for development in integration of clean diesel engines, hydraulics and electronic systems.

Weiss: SKF is not involved in making and delivering systems; we focus our efforts on a component level. SKF-focused efforts [are] in improving power density of the components, improvised sealing solutions, reduced friction, and application-specific designs, and these directly tie into powertrain optimization.



What role is electrification and smart systems playing within your company's product designs?

Hutchins: While today's hydraulic product categories are quite similar to those of the past, (pumps, motors, valves, hoses, and fittings etc.), their sophistication has evolved dramatically as electronic controls provide new capabilities at the product level and at the system level. This allows similar and dissimilar product technologies to be easily networked together.

Software has enabled sub-systems and complete systems to work together seamlessly.

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Schneidewind: Electrification and smart systems in the form of increased reliance on controllers and electronic inputs for machine control is good for our industry since our product is required to integrate the electronic inputs with the hydraulic outputs. In response to the demands for more electrohydraulic functionality, we are developing products for higher flow and higher pressure applications.

Weiss: Electrification and smart systems bring the mechanical and electrical regimes together. The impact of VFD's (Variable Frequency Drives) and direct driven motors on bearings and mechanical components is very heavily investigated at SKF. SKF's experience with railway electrical systems, electric motor testing, and predictive analytics puts us in the forefront in the design and development of compatible products. Miniaturization and application of technology are becoming more and more critical and SKF is also on the forefront for this development.

How has or will the use of prognostics and predictive technologies continue to progress within your product designs, and the industry as a whole?

Ross: Prognostic and predictive technologies are at the early stage of impacting design. The automotive companies are furthest along in this area. The use of CAD software, moving into the digital world, and creating a digital twin allows for components to be tested in a virtual environment, either simulating real-world operating conditions, or test conditions. This helps reduce turnaround time, costs, and helps build better designs, faster. This allows engineers to evaluate many design evaluations before the first prototype has been built.

Muli: The applications of autonomous systems and large demanding operations like mining leave no room for downtime and maintenance. Every minute of suspended operations can cost thousands of dollars. Thus, any opportunity to monitor the health of the system and provide prognostics and predictive guidance for maintenance is highly welcome. This leads to additional sensing and software implementation on the vehicle.

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Weiss: Machinery prognostics and predictive analytics continue to progress at a high rate. There is a lot of interest for these technologies in the marketplace. However, the definition of predictive analytics and requirements varies with each customer and there are no industry regulations for heavy equipment. **With the advent of Big Data and IoT (Internet of Things), the landscape for predictive analytics is changing rapidly.** SKF has...experience with traditional predictive analytics and machinery health services. We are focusing on miniaturizing the technology to fit and adapt to the needs of our customers.

What's next on the technology horizon? Are there emerging technologies which will affect your products or the industry as a whole? How will hybridization, electrification and smart systems continue to progress within the next year and on into the future?

Matt Rushing, Vice President Global ATS Product Line, AGCO Corp. We are looking forward to new coming developments with sensors and UAV technology, realizing we've only begun to scratch the surface of what sensors and aerial imagery can capture about machines and their efficiency, as well as more about what's going on in the field. The degree of electrification, smart sensors and autonomous machinery will only increase in coming years. Smart systems will help producers make decisions on the go and increase the overall efficiency and profitability of their operation.

Collecting the data is only half the story. The game-changer is in analyzing it and turning it into insights that you can use to make decisions that will improve productivity. Enabling connectivity and analytics through strategic partnerships is where OEMs, like AGCO, can add value while supporting growers' choices of agricultural service providers.

Ross: The first step is the merging of technology to move vehicles from the CAD environment to the "digital twin" to enable virtual vehicle design. This is moving existing tools into the mainstream of our clients. Once components are designed, using the digital twin, 3D printers can then save time on manufacturing, further reducing time to design, and build a new hybrid vehicle.

Muli: We are always working in step-lock mode with our user community to develop solutions required to innovate, research and design. We endeavor to support the engineering community for making the development process efficient and easy to reach the highest quality goals. We look forward to further breakthroughs in electronic components, battery systems, and overall systems and supporting them with our portfolio.

Schneidewind: Our customers continue to develop machines with the goal of improving energy efficiency and productivity. Smart systems that provide more information to the

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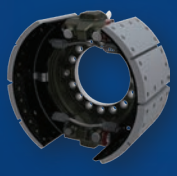

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operator and the machine itself will contribute to improved efficiency and productivity and therefore will continue to progress in the future especially as costs for these feedback devices and controllers continue to drop.

As electronic feedback devices are introduced into more electrohydraulic systems, we can actually simplify our hydraulic circuits by removing some of the "hydraulic" feedback devices and lower our cost for the system.

As a result, we want to develop new products and technologies that will take advantage of the feedback devices in the electrohydraulic system so that our devices can add more value to the smart system.

Weiss: Total cost of ownership, emission requirements, energy conservation, and fuel efficiency are driving heavy equipment manufacturers towards developing more sustainable hybrid solutions in the marketplace. It is clear that there are uncertainties around the approach and the final solution (based on equipment and the upfront costs). However, the benefits outweigh the hurdles and OEMs are increasingly bringing hybrids into the spotlight.

At SKF we are focusing on fine-tuning the products to bring better and higher value to the customers and make them more competitive. This will help in reducing the total cost of ownership to our customers.

Gaiazzi: To face future pollutants and CO_2 reduction challenges the right combination of these technologies is a key element. Furthermore, regarding powertrain hybridization, we are living a situation similar to the one [that] has been experienced with alternative fuels several years ago: the challenge is a wide diffusion of products in terms of volumes and of supporting infrastructure networks.

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Challenges on the Horizon

The challenges manufacturers in the heavy equipment industry face are as varied as the products they develop. However, designing products which meet customer needs, and doing so in a quick and efficient manner, is an area of continual improvement for OEMs and suppliers.

Increasing globalization is also a noted challenge, particularly in terms of developing and manufacturing products that meet the needs of customers in various markets. It has also brought about more consolidation of manufacturers and suppliers as companies look to enhance their product offerings, as well as better manage uncertain global market conditions.

The rising use of data and digitization has helped many companies to better grasp what their customers need, or how they are really using their products, and then make improvements that will further benefit those customers' needs. It has also helped manufacturers to better analyze their own inefficiencies and provide faster, more efficient ways of designing new products.

What new challenges have arisen that effect the way your company designs or manufactures its products? How it does business? How it goes to market? How it differentiates itself from the competition?

Oliver Lythgoe, Product Marketing Manager, Perkins Engines Co. Ltd.

Emissions standards are leading to a convergence in technology recipes between manufacturers. Important technology differences continue to exist but they are increasingly subtle; for example, precious metal "recipes" used in aftertreatment systems, or sealing designs on sensor connectors, or noise signatures in gear-train designs are not readily obvious to customers but can make an impact on product performance, reliability and durability. So product differentiation is more about how well technology has been implemented and integrated rather than which building blocks have been selected.

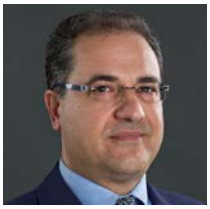
Frederick J. Ross, CD-adapco Director, Ground Transportation

The new challenge is moving from looking at 3D simulation to also include system simulations for the complete design process. Clients are looking to develop a full virtual vehicle, using digital sign-off before they start building the first prototype. For complex vehicles, this can have thousands of different tests which are normally done in a test environment that now needs to be done in a virtual environment. STAR-CCM+ provides great range of automation today which allows for these systems to be built quickly, and enables design space exploration. With multidisciplinary simulation co-simulation, our clients can use design exploration to look at trade offs in design while simulating real-world operating conditions.

Nathan Sheaff, founder and CEO of Sciemetric Instruments

We've been heavily investing in R&D and engineering for years and engaging with a host of manufacturers to understand what they need, what they want to see and how they want to see it, to do their jobs better. It often comes down to speed – collecting more data faster, analyzing that data and generating pertinent reports, faster. We're past the point where we need to experiment to give a customer what they ask for because we've already invested the time to understand their reality.

But the pressure hasn't let up. In fact, it's getting worse. "The Rise of IR4.0" just means **we're getting buried under more and more data. We've come to realize that the best way to deal with that torrent is to increase data processing and edge computing power**—have more automated computing take place on the plant floor between networked devices instead of pushing all that data through a wireless network and into a cloud. That's the future.



Ivan Di Federico, Topcon Positioning Group Chief Strategy Officer and Chairman of Topcon Agriculture

The successes of our innovations have frankly raised customer expectations in not only the aftermarket, but also OEM segment. Operators expect and rely on our technology to get their jobs done faster and more efficiently. Topcon differentiates itself in the market by maintaining an open access OEM philosophy, which allows higher integration into more OEMs and, ultimately, more control in the hands of our customers.

Justin Fluegel, Vice President - General Manger, Hengli America

Our product development process has evolved to ensure we have a customer in place as we develop new products. We also know going into the design phase that quality and price are important; however, we have to provide a performance enhancement to help differentiate our product in the market. Comparative testing generates strong results and positive feedback we receive from our customers, and deepens the long-term relationships.

Russ Schneidewind, Vice President, Global Sales & Marketing, HydraForce Inc.

The pace of new product development requires us to be able to design and test new products quickly. **Our customers demand that products we deliver at the prototype level work the first time without problems. In addition, the specifications we need to meet for new products continue to get more difficult.** As a result, we have invested significantly in our capability and capacity to conduct the performance, qualification and verification testing before the customer puts our new product on their machine. In addition, we have enlarged our applications laboratory to bring full-scale machines from customers into our facility for proprietary testing. Our customers are demanding customized solutions in order to differentiate themselves from their

competition, thus requiring us to be flexible in manufacturing these solutions at a globally competitive cost.

Federico Gaiazzi, FPT Industrial Head of Marketing

The present and future challenges FPT is addressing are linked to the pollutants (NOx and PM) and CO_2 reduction, maintaining the best performances for customers. Our response to these challenges is continuing to develop more efficient engines and focusing on alternative fuels, a sector FPT plays a leading role. This has to be matched, according to the missions, with hybridization/electrification technologies of the powertrain.

The interaction between the components within the engine and the vehicle, and the connection of these with the outside world via telematics are catalyzing factors that are coming overwhelmingly in the market and will affect future developments. At FPT we want to continue to play a key role because we want to give our customers more and more efficient solutions, respectful of the environment and capable of improving their productivity.

Stephen Roy, President, Sales Region Americas, Volvo Construction Equipment

We are in an exciting era for the industry. On the one hand there's low demand and overcapacity of supply, which in turn leads to greater competition and the competitive challenges that brings with it.

The upside is the flight to quality. Customers want the best products they can receive. Couple that with exciting new technology, which allows greater flow of information, and the result is the ability to complete jobs to higher quality using less time and fuel – and more safely. Machines are now more reliable than before and with the onset of telematics and manufacturer monitoring systems, uptime has seldom been higher.

Volvo CE has a history of innovation in its corporate DNA and this puts it in a good position to benefit in important industry changes, supported by its global distribution network.

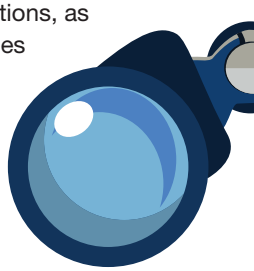
Alan Loux, Vice President of Global Marketing, JLG Industries

Keeping people safe when working at height is our number one priority at JLG. As a result, safety remains a common thread as we develop innovative new product designs, manufacturing processes, and training programs.

A number of innovative technologies are already in place to improve the safe use of the machines, including pothole protection systems, analog envelope control, automatic outrigger leveling, fall arrest, enhanced protection against involuntary operation, load-sensing systems, and optional equipment, including a reverse sensing system and rearview camera with multipurpose display that shows integrated electronic load charts, diagnostics and analyzer functions.

Bob Straka, Business Development Manager, Transportation, Southco Inc.

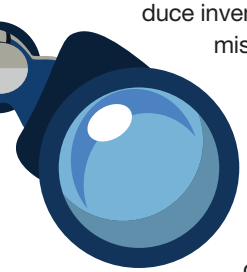
Fuel efficiency and emission requirements are driving off-highway OEMs to optimize the weight distribution, including utilization of existing lightweight components for their evolving equipment designs. In response, many are looking to the aerospace industry for inspiration, where lightweighting is the norm. At Southco, we are taking our design expertise in aerospace grade hardware, such as fasteners and quick-access solutions, as well as new technologies that offset the weight of heavy panels and doors, and using these same products to replace heavier components across larger pieces of off-highway equipment.



Changes in equipment styling are also creating a demand for new access hardware solutions that can support larger doors and panels. Engine hoods for example, are being designed together with fenders into one assembly, offering more options for styling. And, while adding the ability to lift these elements together as one piece allows OEMs to refresh equipment at a lower cost, it also results in a heavier, more expensive hood. This adds additional challenges when it comes to lifting and controlling heavy weight, and stretches the limits of current design solutions, like gas struts.

In addition to the challenges of providing solutions that meet changing OEM design requirements, another challenge that many off-highway component suppliers are facing is advancing business systems at the OEM level, resulting in greater expectations from its suppliers. **OEMs are becoming better connected globally, and thus, are considering global supply, design resources and pricing in the overall decision-making process when choosing their suppliers. With more discriminant customers and end users, manufacturers are seeking consistency across their entire supply base.**

At Southco, we focus on designing components that are tested and validated against risk, allowing OEMs to focus on their overall equipment design. Our global presence allows us to localize the production of our products, allowing OEMs to decrease cycle times and reduce product development costs in line with their business systems. Using regionally



serviced parts also helps OEMs reduce inventory without compromising service or productivity. Global access to design components has become more important than ever. By designing and manufacturing components closer to the source of demand, we enable our off-highway customers to meet their global supply needs and keep up with changing design requirements.

What new challenges do you see the industry as a whole facing, and how is your company looking to address/provide solutions with which to solve those challenges?

Fluegel: As some markets are down, our customers require new product development and projects to include a strong business case with Hengli's new products and enhancements. Consolidation of manufacturers and suppliers is developing within the fluid power industry. The extent of the impact on the industry will be felt as markets begin to grow again.

Lythgoe: The **increasingly complex pattern of global emissions standards is a major challenge for the industry**. Our OEM customers want to play in multiple markets to grow their business, but it drives a lot of manufacturing variety and research and development costs. Perkins is responding by offering global platforms so that the OEM can maximize the commonality of powertrain designs between different regions.

Ross: The biggest challenge when simulating real-world conditions is the computational effort needed to calculate long thermal transients (90-plus minutes). Typical simulations can run from days to hours, depending on the level of detail being investigated. A lot of our efforts are spent finding methods to accurately predict

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real-world events, but minimizing computer efforts.

Some methods we are working on to solve these issues are to improve scalability on large process counts. We also have licensing which enables customers to run on thousands of cores with no additional cost. There are also methods of co-simulation between fluids/solids, so we can use the time domain most efficient for the physics needed. The third area is to add advanced multiphase physics to help reduce computational costs. That includes finding efficient ways to model the impact of water particles on surfaces to form puddles on the vehicle, for example.

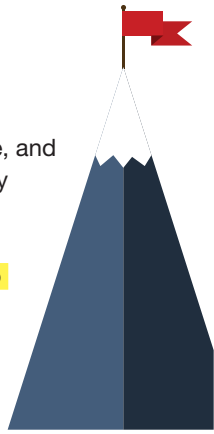
Tony Casale, Executive Vice President, Business Development, HydraForce Inc.

Reliability or durability and driving down the number of machine infant mortality failures are the mantras of the day. This is why there has been a significant investment into our product development facilities. To meet these challenges **manufacturers have pushed more testing down to the supplier and are asking for it sooner in the product development cycle**.

Di Federico: The new paradigm is moving towards the integration of different technologies to collect data from heterogeneous sources, which is exactly where we see our business going. Similar to other sectors, our mission will be to find information patterns that will help customers to improve their workflows and business, with valuable ROI.

Loux: Changes in the regulatory environment and industry standards regularly challenge our industry to stay up-to-date on the latest industry requirements. For example, a proposed change to ANSI code A92.X will require certain work platforms to include load-sensing alarms and cutouts, which will ultimately affect safety and machine design.

We are regularly challenged to find new ways to make the workplace safer while continuing to introduce innovative products and services to the industry. Sometimes this means transferring existing technologies in other industries to our products and services—things like collision avoidance systems in automobiles and augmented reality in training simulators. It also means looking at more theoretical issues, such as the use of robotics and virtual reality to completely remove the operator from the machine, and seeing where we can apply these technologies to our products.



The industry faces two additional challenges: the strength of industry demand as both residential and nonresidential construction are forecast to grow in North America; and finding skilled workers to meet the demands of the construction industry. JLG is poised to meet all of these challenges by delivering safe...equipment that offers superior productivity and lower total cost of ownership (TCO).

Has the rate of technological advancement (such as the rapid emergence of data products) had any impact on business decisions, development, or product performance and client expectations?

Ross: The biggest impact is the increase of computational power available to our customers that can really enable digital design. The computer power becomes a lot less expensive than building a physical prototype. It then enables our client

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to look at design space exploration, and discover better designs, faster.

Fluegel: The data generated is found in conversations with customers when they discuss service intervals and look for insights into predictive maintenance program points. Our customers include this data into their service programs. Another driving force is globalization of manufacturers. It is not sufficient to be competitive in just one market. Europe, North America, and China require dedicated teams and capabilities from supply chains to include aftermarket or long-term service programs to allow an efficient support structure of globalized corporations.

Di Federico: For sure, there is significant impact. More productivity and best utilization of assets is a very attractive preposition for all our customers. Topcon is heavily committed to sustaining investments in the IIoT technology development in order to ensure continued success for our clients in running their businesses.

Casale: We have been able to take advantage of Big Data as some have termed it, in our approach to marketing. Further our company has a rich knowledge base that we have built over the years. Harnessing this knowledge until recently has been a challenge. Fortunately, bespoke search engines have been developed to help mine this data so we can accelerate product development and limit the number of problems that we may have 're-solved' without such a tool.

Roy: It's fair to say that **a revolution is happening in terms of connectivity and technology in all our lives. Customers are increasingly demanding manufacturers respond to that heightened demand** and meet this expectation. With the technological advancements, manufacturers are able to offer a host of smart solutions that help machines be more productive, more efficient, safer and better for the environment while helping to boost customers' profitability. As mentioned above, Volvo CE has innovation in its corporate DNA and will continue to innovate to benefit customers.

Loux: JLG has leveraged new technologies across the board to improve the overall satisfaction of our customers. In addition to the standardization of the SkyGuard enhanced control patent protection system, we have introduced machines that feature more fuel-efficient engines due to fully variable/on-demand engine RPMs, electronics rather than hydraulics to improve comfort

and diagnostics, self-leveling capabilities, and AC drive motor technologies that improve overall efficiencies and lower the TCO for customers.

In addition, we recently introduced our customers to a rear-sensing (detection) system. The system is optional in our newly redesigned JLG telehandlers, giving operators extra confidence when backing up their telehandlers.

JLG also offers the JLG Mobile Analyzer, a Wi-Fi-enabled diagnostics tool that gives technicians remote access to program, troubleshoot, calibrate, or customize JLG equipment performance.

We have also applied new technologies to other services, including training. When operators are well trained and fully understand how to operate a machine safely, they help protect themselves and others on the jobsite.

At JLG, we use an equipment simulator that simulates operation of various machines in a virtual environment that recreates the JLG training center and proving grounds to scale. Remotely accessible to registered students with a laptop, the simulator provides both the operator's perspective and a side view. Using the simulator decreases the learning curve when operators first enter a lift or telehandler.

Looking ahead, things like augmented reality and head-mounted displays could give the operator access to a wealth of information regarding equipment operation, safety, or hazardous conditions, as well as a quick, easy-to-reference guide for typical job functions. Ultimately, technology needs to be feasible economically, so JLG will continue to look at technologies in other industries and borrow from them, taking advantage of economies of scale.

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RENTAL Remains a Force for Equipment Makers to Consider

by Jenny Lescohier, Editor of *Rental*

Predictions for continued growth in equipment rental suggest manufacturers should heed the need for no-frills, low-cost options.

U.S. construction indicators remain stable and contractors continue to view renting as a highly cost-effective means of equipment acquisition. The industry has been growing steadily for the past several years and that trajectory shows no signs of changing direction in the foreseeable future.

While the rate of growth has slowed somewhat over the past few months, analysts assure industry observers the equipment rental market will remain in a growth mode for the next several years at least. That, plus a price-conscious customer base eager to add new models that can earn a speedy and sizable return on investment, suggests equipment manufacturers should put a renewed emphasis on designing simpler, lower-cost models when developing new products.

Growth predicted through 2020

The latest five-year forecast for the equipment rental market projects a compound annual growth rate in revenue of 4.9% to reach $57.3 billion in the United States in 2020, according to the American Rental Association's latest prediction released in August. Projections show industry revenue to increase by 4.9% in 2016 to a record $47.6 billion and to grow another 4.6% in 2017 to reach $49.8 billion.

The forecast shows steady revenue growth from 2016 through 2020 of between 4.6 and 5% each year.

What's more is the equipment rental industry continues to expand at more than double the rate of gross domestic product (GDP) growth.

Scott Hazelton, Managing Director, IHS Economics, notes the U.S. rental market's economic growth in the first half of 2016 has been tempered somewhat due to uncertain growth overseas and the increasing value of the dollar, but the future looks bright.

"This also has been exacerbated by uncertainty surrounding future policy direction from a muddled presidential campaign season," he says. "However, construction remains strong, particularly in the residential sector. While nonresidential growth is slowing, we remain on track for another year of solid gains and consumer spending also remains strong. The slight adjustment in the forecast growth reflects the weaker view for U.S. energy and manufacturing, while the still-strong growth reflects the fact that the economic and construction fundamentals remain positive."

Meanwhile, contractors have woken up—some say permanently—to the benefits of renting: a cleaner balance sheet, no maintenance or repair costs, no transportation challenges and no insurance expenses, to name just a few. Currently, 52.9% of equipment on U.S. jobsites is rented.

"There is no doubt that the secular shift to renting equipment continues in the markets those in the equipment rental industry serve," says Christine Wehrman, ARA's CEO and Executive Vice President. "Rental companies are adept at identifying customers and relocating equipment to different areas to take advantage of increased demand."

Shifting equipment from energy to construction applications

The slowdown in oil and gas drilling, resulting from the high-supply and low-demand environment, which in turn has driven down the price of oil, has impacted the utilization of both dealer rental and general rental fleets, but as Wehrman notes, those

in the industry are adapting.

According to industry sources, the reduced activity surrounding new well activity has impacted distributors, contractors and rental companies in areas with a higher concentration of energy production. The positive news in these areas is that as equipment comes off of production jobs in energy, it has been absorbed into other construction-related activities. The downside to this is there has been recent pressure on pricing for non-energy related projects, as well as downward pressure on rental rates and used equipment rates for assets related to the energy industry. The future of U.S. energy markets remains speculative, but there appears to be sufficient activity in other markets to absorb the loss of energy-related activity in the rental industry.

Glut of used equipment impacts manufacturers

Despite the economic recovery, many rental companies still have a large amount of aged equipment left over from the down years when they kept units in fleet past their typical life cycle. Those machines are now entering the already crowded secondhand market, creating challenges for equipment makers faced with slack demand from customers.

Many construction firms and other equipment users are renting or entering longer-term leases for machines to expand their fleets or replace worn out equipment in lieu of buying pricier new models, analysts say. It's interesting to note that rental businesses account for just over half of new equipment sales in the U.S., and some analysts see that climbing to 60% within 5 years.

Meanwhile, dealers are keeping smaller inventories of new machinery, hurting sales for major manufacturers such as Caterpillar, Volvo, Deere and others. Add the fact that the strong U.S. dollar is dampening demand from developing African and Asian markets that once snapped up used machines, and it's easy to see why the availability of inexpensive used equipment remains high, presenting buyers with yet another attractive alternative to buying new. The offer gets even sweeter when you consider that used machinery prices are down 10% from a year ago.

If you build it, they will come

With all of these factors at play, equipment manufacturers stand to benefit from offering a greater selection of new models that meet the various demands from divergent customer bases. We know, for example, that many rental companies are looking for a simpler, lower-cost alternative to premium machines with all the latest bells and whistles. Others, however, need to have the latest technology if their particular customer base demands it. Still others want a happy medium, and some manufacturers are working toward offering a little of everything.

The common goal for all rental buyers is to achieve the highest ROI while offering customers a simple-to-use machine with minimal Tier 4 maintenance requirements. With that in mind, many manufacturers are introducing models powered by 74 hp engines that eliminate maintenance-related activities associated with the more advanced systems found in machines rated higher than 75 hp.

Of course, performance is key, so equipment makers can't go too far in compromising the engine and associated technology. On the other hand, it is possible to eliminate a certain amount of electronics and control systems without sacrificing the machine's essential capacities. At the end of the day, rental businesses value machines that can offer their customers the performance they need but without the extras that drive up the price of the equipment.

Rental has become such a force that equipment manufacturers are already a few years deep into this trend toward designing models specifically for that market, with less emphasis on high-tech features and a greater focus on simplicity, durability and a faster return on investment. As rental continues to gain momentum among equipment users, there's an opportunity for manufacturers to offer these buyers competitively priced, stripped down models with lower-horsepower engines but comparable performance. Throw in the threat of low-priced off-shore brands inching their way into the market and it becomes an imperative for manufacturers to make a renewed commitment to including simpler, "economy" models—as well as mid-tier and premium options—in their product line if they want to win business in today's equipment market.

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A Pivot from Clean Air to EFFICIENCY

After the VW scandal shook the perception of the diesel vehicle industry, regulatory shifts in emissions and alternative fuel investments are emerging around the world.

by Allen Schaeffer, Executive Director, Diesel Technology Forum

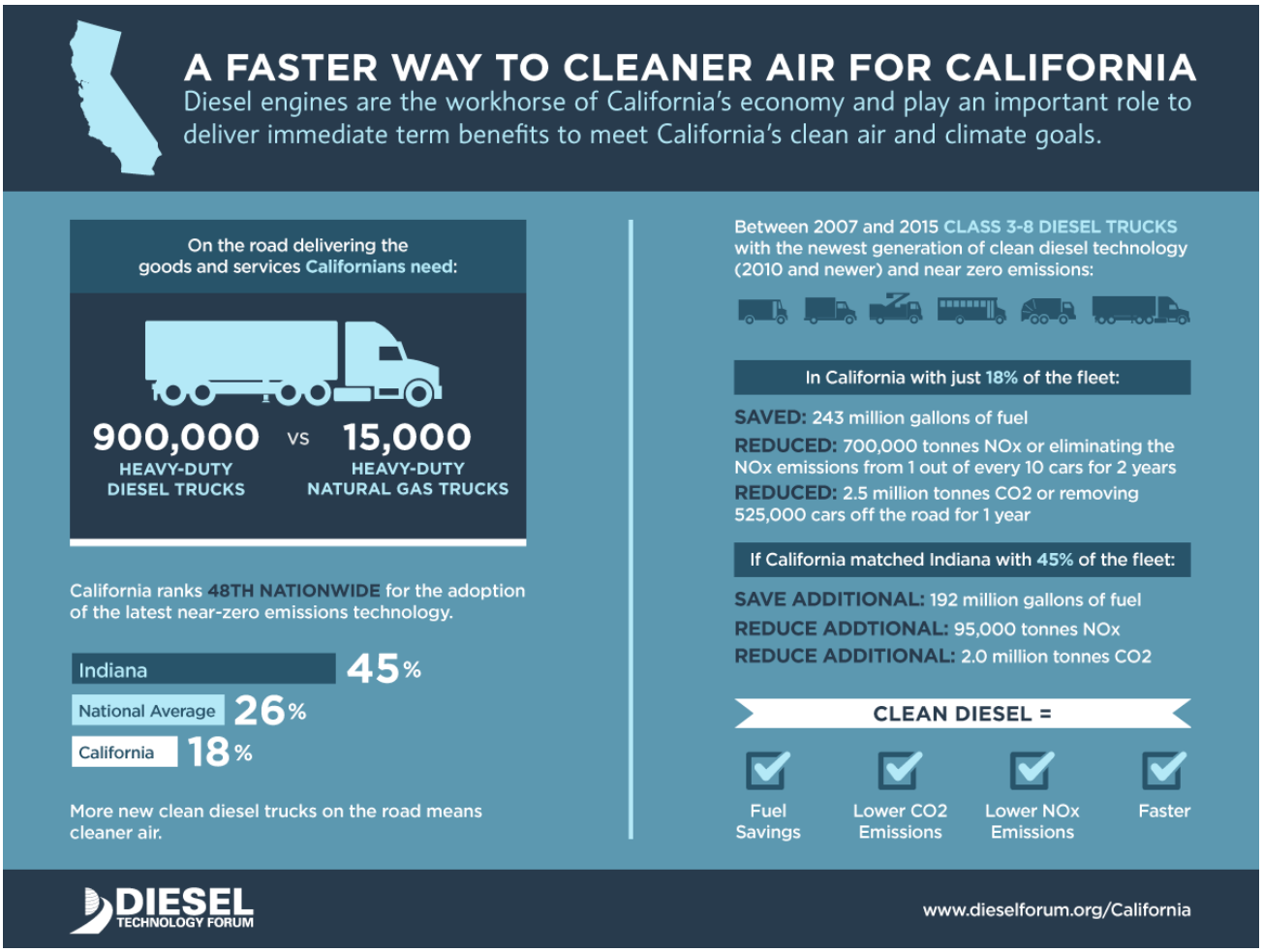
Over the last year, it's been hard to read a newspaper or have a conversation about diesel where the VW emissions scandal hasn't come up.

As a former colleague and crisis communications expert said, "you are at the beginning of the beginning." Now just a year into it, the wisdom of that statement is clearer with each passing news cycle. Defending diesel technology in the wake of this global crisis to wall off the perception spillover to the broader industry has been job No. 1 and continues unabated today.

To date, the conventional media coverage has been saturating and global, with over 12,000 international news stories on the peak day. In Europe, the VW revelations were the flashpoint triggering action on a cascade of concerns. Simmering debates about real-world driving emissions in the EU moved rapidly to real-world policymaking establishing new testing requirements for manufacturers. In Paris, London and some other European cities, policymakers adopted bans or restrictions on older diesel cars in city centers, while others reconsidered fuel tax policies that favored diesel over petrol.

Beyond the water cooler chatter, one immediate fallout is the higher attention to emissions compliance and conformance testing by regulatory agencies and industry. Time for final certifications has increased and the demands for data and supplemental information have grown; not just for passenger cars but across the board.

So, what does the VW situation mean, if anything, for diesel as a technology and for others in this business? Is there some bigger implication or fallout yet to come in the form of regulations or bias going forward?



The Diesel Technology Forum (DTF) has studied and analyzed the perception and impacts of the VW situation on the diesel industry at large, revealing many interesting findings from both online and telephone survey research of the general public and an exclusive group of policymakers.

One finding six weeks after the scandal broke is that just under half of the general public surveyed at that time were aware of the general situation. They identified it as a problem for VW, but not something they interpreted as inherent with diesel technology.

Policymakers surveyed were another story, with far higher recognition of the situation and much more nuanced views about how it influenced their perception of diesel technology in general.

It's fair to say that the broader implications of this scandal on the use, regulation and acceptance and perceptions of diesel technology will be evolving for some time. Vigilance and high visibility communications efforts are needed to ensure a clear understanding about the new generation of clean diesel technology and its role as a solution to meet future climate, energy and clean air goals.

Beyond the perception and emissions conformance issues, there is some silver lining. Beyond the $10 billion for VW vehicle buyback/lease termination and $2 billion set aside for electric vehicles and infrastructure, the Environmental Mitigation Trust (a.k.a. the NOx mitigation fund) if finalized will pump $2.7 billion into the market for buying new vehicles and equipment. Eligible equipment includes school and transit buses, commercial trucks and some off-road engines including freight switchers, workboats and ocean-going vessels, and some airport ground equipment.

Though not yet finalized at the time of publication, the initial allocation scheme has government fleets with higher allocation funding opportunities (100%) than private fleets (50%). All-electric technologies receive higher allocations than diesel and alternatives, including natural gas. For example, private fleets with 1992-2006 MY Class 8 trucks could receive 25-40% funding for new/repower with diesel or alternate fuel, or 75% for new/repower all-electric. School Bus operators (2006 and older) could receive 25-40% funding for new or alternative fuel or 75% for new/repower all-electric. Similar percentages for freight switchers, ferries, tugs and Class 4-7 local freight trucks. In each of these examples, government fleets could have

100% of the cost of the new vehicle paid by the trust.

Every state will appoint a lead agency to ensure that state's trust administration process and claim awards and verification meets the requirements of the overall settlement. Six states receive 39% of all funds with California ($381 million) leading the pack at over 14%, with Texas ($191 million), Florida ($153 million) and New York ($117 million). Thirty states get less than $30 million each.

Slow purchasing of new technology factors heavily into whether or not states, regions and even countries achieve their clean air, climate and energy goals in the expected time frames.

The federal district court overseeing the settlement is expected to issue a final order sometime in October 2016, with the general expectation that the trust would payout nearly all claims within the first 3 years after being finalized.

The process will be competitive, with many interests lining up to cash in at every state's door. Strangely, some of the eligible technologies (e.g. all-electric Class 8 trucks) included aren't even commercially available, yet the trust would pay almost all of the cost of this not-yet-existent vehicle. That and paying lesser amounts to technologies that are available today and proven to deliver reductions in NOx emissions raises questions about whether NOx mitigation is truly the main objective. Whether or not the Department of Justice and the court alter the proposed settlement based on the many comments received will be important to watch. Any way you look at it, $2.7 billion to help customers buy new engines and equipment, especially in today's slow-growth/no-growth economy, will be welcomed.

Nearer to zero emissions

Not just new GHG and CO_2 standards, but criteria emissions regulatory initiatives are also alive and well in 2016. The EU has just effectively adopted a new Stage V emissions standard for non-road mobile machinery (NRMM) engines, phased in beginning in 2019. Stage V standards include new provisions for in-service emissions monitoring as well as retrofitting of existing non-road engines. Other changes impact some marine engines. Stage V's big news is the inclusion of new particle number standard limits (1×10^{12})/kWh. It also brings in previously excluded smaller engines from 0-56 kW (0-75.1 hp) for the first time. This new number standard appears effectively to be the means to require particulate traps on all new future machines and equipment. It also upsets the harmonization between EU Stage IV and U.S. Tier 4 Final, raising speculation about the next move on particulate regulations in the U.S. About half of the heavy-duty non-road engines and equipment currently achieve Tier 4 Final emissions compliance without the use of particulate traps.

Just 6 years after the final 2010 milestone for heavy-duty on-highway standards for NOx, another chapter is beginning; one that will seek to ratchet down NOx emissions even nearer to zero than the current 0.20 g/BHP-hr standard. The EPA, with heavy influence from the California Air Resources Board (CARB), which established an "optional" low-NOx standard 2 years ago of 50-75% lower than the existing standard, now starts the process of exploring changes to the standard in the future.

A fundamental question here is whether there is a need for a lower NOx standard. New industry analysis presented at an August 2016 CARB workshop shows that the last several Air Quality Management Plans have consistently underestimated the observed rate of ozone reductions over time by a factor of two. This overstates future years' ozone levels and in turn the need for NOx reductions strategies. With standards so close to zero, the costs for achieving such a standard by any technology will be hugely expensive.

This comes on top of the ink-still-drying EPA Phase 2 requirements for efficiency and GHG, which were lauded in an editorial by *The New York Times*: "With most of President Obama's efforts to combat climate change tied up in litigation, it is heartening, if not downright astonishing, to see an industry targeted by an aggressive rule to reduce greenhouse gases welcoming that rule."

Out with the old, in with the new

Achieving the societal benefits from new emissions or efficiency standards is premised on the idea that the new technologies are acquired and put into service. Tenuous economic conditions of the last few years have slowed the acquisition of new technology across the board.

Class 8 heavy-duty truck sales in August were the weakest in that month in 5 years, and freight activity is weak and uncertain heading into 2017. Off-road and construction equipment acquisitions have been in the negative territory for some time, driven by slower housing and commercial building starts. Low

commodity prices for corn and soybeans have put the brakes on a farmer's ability to invest at a steady clip in new Tier 4 Final compliant farm equipment.

Slow purchasing of new technology factors heavily into whether or not states, regions and even countries achieve their clean air, climate and energy goals in the expected time frames.

The DTF, working with IHS Insight, has acquired and analyzed state commercial vehicle registration data to understand the level of penetration of two generations of new technology clean diesel engines (2007 model year and newer, and 2010 and newer) to then estimate clean air and fuel saving benefits.

Nationwide, acquisition of new commercial trucks (Class 3-8) is ticking upward. From 2014-2015 the percentage of trucks on the road that are 2007 and newer (i.e. with particulate filters) bumped up from 37-42%. For registrations of 2010 and newer technology, the national average is about 26% with Indiana leading all states at 46%.

A key finding is that California ranks 48th in the country with only 18% of the registered vehicles being the newest generation clean diesel. Whether the result of the business climate, regulatory environment or simply strategic business decisions, California now has one of the oldest commercial truck fleets on the road; an unlikely and unwelcome label for the state recognized as the most progressive for energy, climate and clean air policy. If more of California's trucks were of the newer generation, the benefits achieved could be far greater.

Technology for heavy-duty on- and off-road engines has come a very long way. The pivot from clean air to efficiency is underway, but it's increasingly clear that meeting the clean air challenges will drive equipment and engine design for a while.

All the while, investments in the current generation of technology are edging along. With current engine emissions standards already near zero, there is a great deal to consider, not the least of which is how slowed acquisition of today's new technology makes the legacy fleet role in achieving future clean air and climate goals more important. Getting more new technology on the road, the jobsite and in the fields is the fastest way to cleaner air and lower GHG emissions, not to mention more productivity, lower maintenance costs and greater fuel savings for customers—benefits everyone would value now, rather than 15 years from now.

CALENDAR

http://www.oemoffhighway.com/events

INTEGER EMISSIONS SUMMIT AND DEF FORUM USA
Hilton Chicago
October 25-27, 2016 | Chicago, IL
www.integer-research.com/conferences/ies-usa-2016

GLOBAL TIRE EXPO
Las Vegas Convention Center
Nov. 1-4, 2016 | Las Vegas, NV
www.tireindustry.org/global-tire-expo

EIMA INTERNATIONAL
Bologna Trade Fair Center
Nov. 9-13, 2016 | Bologna, Italy
www.eima.it/en

SAE AUGMENTED AND VIRTUAL REALITY TECHNOLOGIES SYMPOSIUM
Hilton Philadelphia City Avenue
Nov. 14-16, 2016 | Philadelphia, PA
www.sae.org/events/arvr

ELECTRIC VEHICLES: EVERYTHING IS CHANGING
Santa Clara Convention Center
Nov. 16-17, 2016 | Santa Clara, CA
www.idtechex.com/electric-vehicles-usa/show

BAUMA CHINA
Shanghai New International Expo Center
Nov. 22-25, 2016 | Shanghai, China
www.bauma-china.com/en

INTERNATIONAL LNG CONGRESS
Radisson BLU Hotel
Nov. 28-29, 2016 | Hamburg, Germany
lngcongress.com

BUSWORLD LATIN AMERICA
Plaza Mayor Medellin Convenciones Y Exposiciones
Dec. 5-7, 2016 | Medellin, Colombia
www.busworld.org

BAUMA CONEXPO INDIA
HUDA Ground
Dec. 12-15, 2016 | Gurgaon/Delhi, India
www.bcindia.com

2017

NATIONAL BIODIESEL CONFERENCE & EXPO
San Diego Convention Center
Jan. 16-19, 2017 | San Diego, CA
www.biodieselconference.org

WORLD OF CONCRETE
Las Vegas Convention Center
Jan. 16-20, 2017 | Las Vegas, NV
www.worldofconcrete.com

INTERNATIONAL ARMOURED VEHICLES
Twickenham Stadium
Jan. 23-26, 2017 | London, United Kingdom
www.internationalarmouredvehicles.com

SAE HYBRID & ELECTRIC VEHICLE TECHNOLOGIES SYMPOSIUM
Doubletree Hotel San Diego Mission Valley
Feb. 7-9, 2017 | San Diego, CA
www.sae.org/events/hybridev

NFPA ANNUAL CONFERENCE
The Ritz Carlton Kapalua
February 8-10, 2017 | Maui, HI
nfpaevents.com

AGRICULTURAL EQUIPMENT TECHNOLOGY CONFERENCE
Seelbach Hilton
Feb. 13-15, 2017 | Louisville, KY
www.asabe.org/meetings-events

SME ANNUAL CONFERENCE & EXPO
Colorado Convention Center
Feb. 19-22, 2017 | Denver, CO
www.smeannualconference.com

SIMA 2017
Paris Nord Villepinte Exhibition Center
Feb. 26-Mar. 2, 2017 | Paris, France
en.simaonline.com

COMMODITY CLASSIC, AN AG CONNECT COLLABORATION
TBD
March 2-4, 2017 | San Antonio, TX
www.commodityclassic.com

CONEXPO-CON/AGG
Las Vegas Convention Center
March 7-11, 2017 | Las Vegas, NV
www.conexpoconagg.com

OEMS ATTENDING

IFPE 2017
See us at Booth SL80131
Las Vegas Convention Center
March 7-11, 2017 | Las Vegas, NV
nfpahub.com/events/trade-shows/ifpe

GREEN TRUCK SUMMIT
Indiana Convention Center
Mar. 14-15, 2017 | Indianapolis, IN
www.ntea.com/greentrucksummit

THE WORK TRUCK SHOW
Indiana Convention Center
Mar. 15-17, 2017 | Indianapolis, IN
www.ntea.com/worktruckshow

OEM IS ATTENDING

NGV GLOBAL 2017
Ahoy Rotterdam
March 21-23, 2017 | Rotterdam, Netherlands
ngv2016.com

THE BATTERY SHOW EUROPE
Messe Sindelfingen
April 4-6, 2017 | Stuttgart, Germany
www.thebatteryshow.eu

ELECTRIC & HYBRID VEHICLE TECHNOLOGY EXPO EUROPE
Messe Sindelfingen
April 4-6, 2017 | Stuttgart, Germany
www.evtechexpo.eu

HANNOVER MESSE
Hannover Exhibition Grounds
April 24-28, 2017 | Hannover, Germany
www.hannovermesse.de/en

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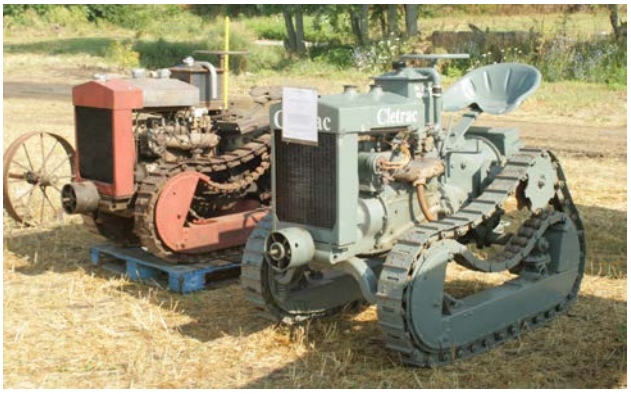
by Thomas Berry, Archivist, Historical Construction Assn.



HCEA

Narrow-gauge (left) and high-clearance (right) Cletrac Fs displayed by Historical Construction Equipment Assn. Board Chairman Larry Kotkowski at the HCEA's 2011 International Convention and Old Equipment Exposition near Penfield, IL.

The tracks on a crawler tractor are the machine's means of propulsion and travel, and as such they and all related components take a thrashing. To oversimplify, they bear the weight of the machine and absorb shocks, and they carry the tractor through all manner of abrasive and abusive materials. Moreover, the drive sprocket—a large gear on each side of the powertrain whose teeth propel the track—also bears the torque and strain of power from the engine applied to the weight and resistance tracks while being exposed to the sand, rock, grit and mud over which the tractor is passing.

In 1969, Caterpillar set about developing a revolutionary solution to the problem, a crawler tractor with an elevated drive sprocket. The first prototype was built in 1973, and in 1978 the first production tractor with this design, the massive D10, was introduced. The logic of the design was simple. Raising the sprockets several feet off of the ground got them away from the rocks, sand and so forth that could damage them, and isolated them from the shocks of passing over obstructions. It removed all machine weight from the sprockets, so they bore only the torque from the powertrain and from driving the track. The sprockets also no longer bore the strain of roller frame alignment shock loads. Combined with other design features, resistance was minimized, allowing more flywheel power to reach the ground; one of these features was a suspended bogey undercarriage system that would not have been possible with conventional sprockets.

As with so many other revolutionary ideas, one may wonder: Why didn't someone think of this earlier? It turns out that someone had. The elevated drive sprocket, while revolutionary in modern machinery, dates back—as do so many other design concepts—to the early days of construction mechanization.

Leader Engine Company of Detroit, MI, was a producer of wheel tractors. Dayton-Dick Company (later Dayton-Doud Company) of Quincy, IL, purchased Leader in 1915 and, two years later, introduced the Leader Model D 25-40 crawler tractor. This was a half-track arrangement, with a wheeled steering axle out front, and was the first use of an elevated drive sprocket. Unlike the D10, it was not large at all, weighing 6,500 lbs., and it was powered by a 6x7 Doman gas engine. A somewhat heavier full-crawler model, the GU, followed in 1921; it too had a raised drive sprocket, and was powered by a Climax gas engine. Unfortunately, only very poor images of these pioneering machines are available, and the machines themselves may be extinct.

In 1920, Cleveland Tractor Company also introduced a raised-sprocket tractor, the Model F, under its famous Cletrac brand. It was even smaller than the Dayton-Dick machines, weighing just under a ton and having a 9 hp engine. The Model F also featured another Cletrac innovation, differential steering. It was steered by a horizontal steering wheel that turned a steering differential which applied resistance to one or the other sprocket. The F was offered in standard, narrow-gauge and high-clearance models, and was discontinued in 1922. Fortunately, examples of the Model F exist today, and so these machines are well documented.

The Historical Construction Equipment Assn. (HCEA) is a 501(c)3 non-profit organization dedicated to preserving the history of the construction, dredging and surface mining equipment industries. With over 4,000 members in 25 countries, its activities include publication of a quarterly educational magazine, Equipment Echoes*; operation of National Construction Equipment Museum and archives in Bowling Green, OH; and hosting an annual working exhibition of restored construction equipment. The 2016 show is September 16-18 at the museum. Individual memberships are $35.00 within the USA and Canada, and $45.00 U.S. elsewhere. HCEA seeks to develop relationships in the equipment manufacturing industry, and offers a college scholarship for engineering and construction management students. Information is available at www.hcea.net, by calling 419-352-5616 or e-mailing info@hcea.net.*

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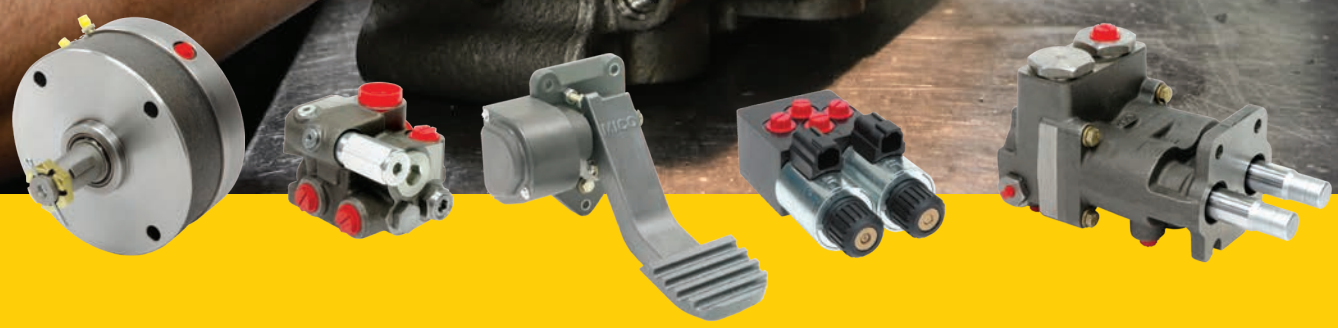

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