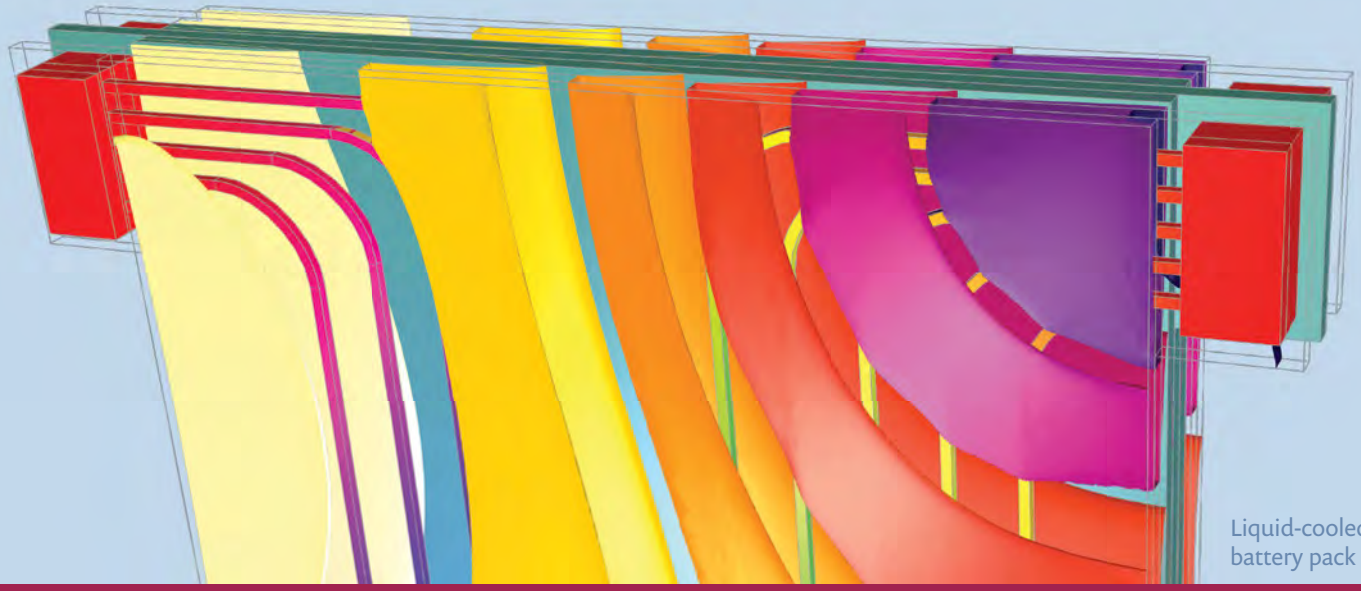


Liquid-cooled battery pack

MULTIPHYSICS FOR EVERYONE

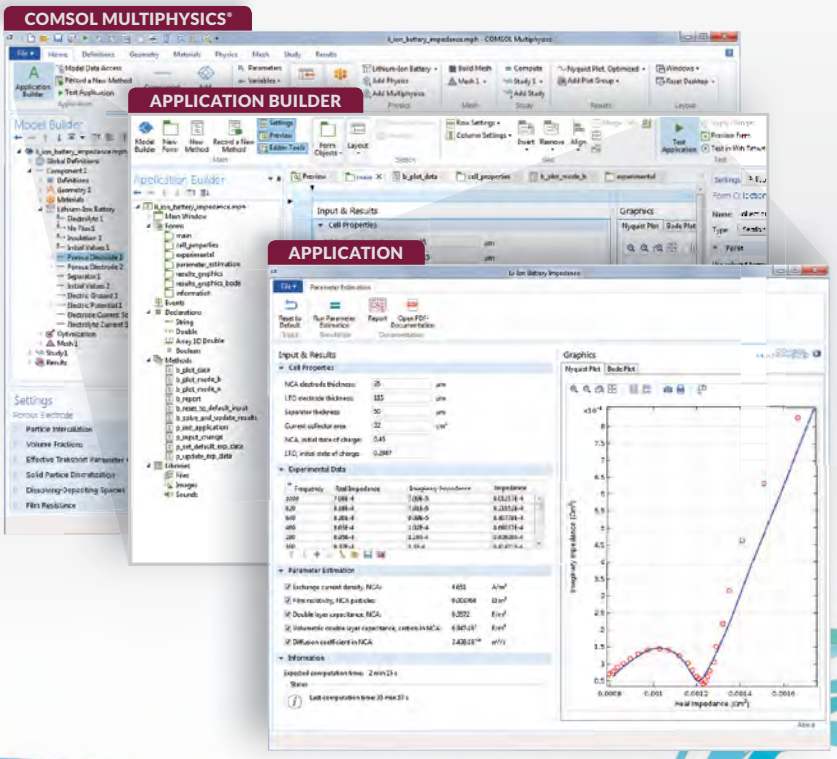
The evolution of computational tools for numerical simulation of physics-based systems has reached a major milestone.

Custom applications are now being developed by simulation specialists using the Application Builder in COMSOL Multiphysics®.

With a local installation of COMSOL Server™, applications can be deployed within an entire organization and accessed worldwide.

Make your organization truly benefit from the power of analysis.

comsol.com/application-builder

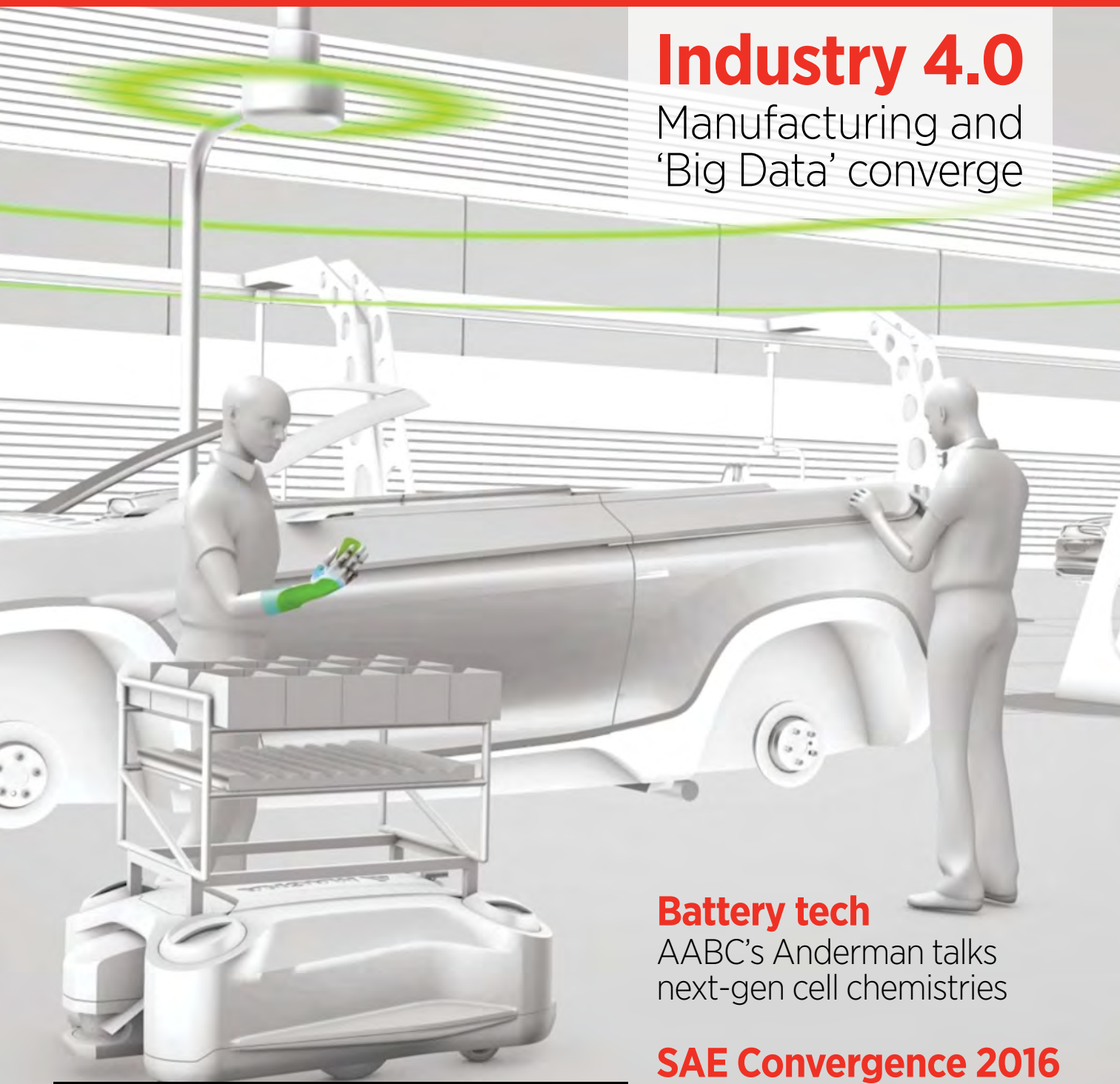


Li-ion battery

COMSOL

SAE INTERNATIONAL®

AUTOMOTIVE ENGINEERING®



Industry 4.0
Manufacturing and 'Big Data' converge

Battery tech
AABC's Anderman talks next-gen cell chemistries

SAE Convergence 2016
Vehicle autonomy unfolds

November 2016 autoengineering.sae.org

When you're connected by HARMAN, your car is your most powerful device.

From your home to the office and everywhere between, Harman connects you to everything that matters.

DISCOVER THE POSSIBILITIES AT CAR.HARMAN.COM

CONNECTED BY HARMAN™

The Heartbeat of Powertrains, Big and Small.

The combustion engine is the heart of the powertrain. At Federal-Mogul Powertrain, we pride ourselves in creating highly-engineered solutions for the toughest applications – to improve fuel economy, reduce emissions and enhance durability. Our innovative technologies enable optimized friction, supporting engine downsizing, higher compression ratios and improved performance. Our products are manufactured at single-digit tolerances and engineered to withstand the toughest conditions in today's highly loaded engines. Whether it is pistons; rings; cylinder liners; sealings, hot and cold gaskets; bearings; ignition; engine valves and valvetrain; or systems protection components we are the heartbeat of combustion engines – big and small.

Find out how Federal-Mogul Powertrain's technologies are built to keep your engine's heartbeat running at peak performance. Visit www.federalmogul.com for details.

FEDERAL-MOGUL POWERTRAIN

The Preferred Powertrain Solutions Provider

www.federalmogul.com

CONTENTS

FEATURES

16 SAE Convergence 2016 EVENTS
Talk of the healthy aspects of disruption mingles with SAE's renowned technical emphasis to foster the auto industry's continuing evolution toward electrification and autonomy.

20 The Battery Man Speaks
POWERTRAINS | PROPULSION
The speed of progress in automotive lithium batteries has impressed AABC's Dr. Menahem Anderman. So has silicon-graphite anode technology development from Tesla and Panasonic.

22 Industry 4.0: The smart factory arrives MANUFACTURING
The plants that produce automotive systems and vehicles are increasingly employing intelligent systems, Big Data and advanced analytics to improve quality, safety and efficiency.

ON THE COVER

Get ready for the Industrial Internet of Things (IIoT): vast amounts of newly-productive data, connectivity and Cobots promise a new era of quality, productivity and the end of "dirty" plant jobs. Cover image of its "digital factory" courtesy of Magna.

Follow us on social media

@SAEAutoMag @saeaei SAE Magazines

REGULARS

4 Editorial: Promise of 48 volts is no shock

6 Technology Report
6 Nissan unveils variable-compression-ratio ICE for 2018 Infiniti production model | POWERTRAINS | PROPULSION
10 Optimizing engine oil warm-up strategies for 'real-world' driving | POWERTRAINS | PROPULSION
12 In search of higher-energy-content batteries | ELECTRONICS
14 Making Multiphysics fast and convenient | SOFTWARE | SIMULATION

26 Global Vehicles
26 I.D. Concept heralds VW's electric Bolt fighter for 2020
28 Aero-slick Land Rover Discovery sheds 1058 lb, gains features
30 Honda's all-new 2017 CR-V: Larger, lighter, turbocharged
32 Ram Rebel TRX concept has 2017 Ford Raptor in its sights

34 Product Briefs
Spotlight: Product Lifecycle Management

38 What's Online

39 Companies Mentioned, Ad Index

40 Q&A
Bob Lutz on what makes a great engineer

Automotive Engineering®, November 2016, Volume 3, Number 9. *Automotive Engineering* (ISSN 2331-7639) is published in February, March, April, May, June, August, September, October, and November by Tech Briefs Media Group, an SAE International®, 261 Fifth Avenue, Suite 1901, New York, NY 10016 and printed in Mechanicsburg, PA.

Annual print subscription for SAE members: first subscription, $20 included in dues; additional single copies, $30 each North America, $35 each overseas. Prices for nonmember subscriptions are $115 North America, $175 overseas. Periodicals postage paid at New York, and additional mailing offices. POSTMASTER: Please send address changes to *Automotive Engineering*, P. O. Box 47857, Plymouth, MN 55447. SAE International is not responsible for the accuracy of information in the editorial, articles, and advertising sections of this publication. Readers should independently evaluate the accuracy of any statement in the editorial, articles, and advertising sections of this publication that are important to him/her and rely on his/her independent evaluation. For permission to reproduce or use content in other media, contact copyright@sae.org. To purchase reprints, contact advertising@sae.org. Claims for missing issues of the magazine must be submitted within a six-month time frame of the claimed issue's publication date. The *Automotive Engineering* title is registered in the U.S. Patent and Trademark Office. Full issues and feature articles are included in the SAE Digital Library. For additional information, free demos are available at www.saedigitallibrary.org.
(ISSN 2331-7639 print)
(ISSN 2331-7647 digital)

Audited by BPA WORLDWIDE SIGNET RESEARCH, INC.

SAE INTERNATIONAL®

EDITORIAL

Promise of 48 volts is no shock

It seems like everywhere *Automotive Engineering*'s editors lately have been, or whatever discussion of advanced technology is happening, 48-volt technology suddenly is spoken of almost as a given. The 48-volt revolution has gained so much momentum in such a short time that we feel like the proverbial car stalled on the railroad tracks. "Whaddya mean you didn't see that locomotive coming?"

The past year has seen 48-volt technology hammer to the forefront with the looming fury of a drafting NASCAR racer slingshotting into the lead. It all seemed still so theoretical just a short time ago—but suddenly 48-volt innovations are showing up, on production vehicles, at a pace that only hints at the technology's pending impact.

Photo courtesy of Audi

This is, after all, the foundation enabler for the true "electrification" of vehicles that has for so long been projected; 48-volt architectures are the leapfrog advance that not only will transform and enhance just about every major subsystem of conventional vehicles, but, if you listen to most of the experts, will serve as the seminal bridge technology to evolve today's combustion-based vehicle fleet to the all-electric future.

We've been told 48-volt will be a transformative thing, but we've been told that about plenty of other automotive revolutions, right? In this case, though, it's hard to doubt 48-volt is the real deal.

What won't 48-volt touch? It's front-and-center for combustion-engine power and efficiency advances delivered by electrically-accelerated turbochargers—**Audi**'s SQ7 crossover earlier this year inaugurated the first for a production vehicle—not to mention vast improvement of engine start-stop systems and on-demand operation of most ancillaries, including HVAC. And soon will come "deeper" engine transformation such as electromechanically actuated valves.

I'm fascinated by the possibilities for incorporating 48-volt-energized machines in any number of locations in the driveline. We'll soon be reporting on the surge of electrified-axle "modules" that enable quick and easy all-wheel-drive and torque-vectoring capabilities, with the bonus of recovering deceleration and braking energy. You'll already find e-axles on more than a handful of current European models—not all of them expensive luxury choices, either—and you can bet they'll be transforming the vehicles Americans prefer as fuel-economy regulations dictate increasingly sophisticated solutions.

And 48-volt's promise is more important than just "mainstreaming" a once-advanced and expensive technology, although reports from Europe that **Volkswagen** plans to offer a 48-volt system to mild-hybridize the next-generation Golf means the technology's going about as mainstream as it gets.

No, electrification of once exclusively mechanical components also brings digital control—the software revolution.

I'll let Audi finish this point: in announcing work on a promising new electromechanical rotary-damper system to replace conventional hydraulic dampers, the company pointedly said that electrically-actuated dampers not only allow "entirely new possibilities for adjusting the suspension," but that once electric actuation comes into play, response characteristics of a component (or system) become definable almost exclusively with software.

Software control is the "other" revolution 48-volt technology enables. And that's why 48-volt is coming like that freight train.

Bill Visnic, Editorial Director

EDITORIAL

Bill Visnic
Editorial Director
Bill.Visnic@sae.org

Lindsay Brooke
Editor-in-Chief
Lindsay.Brooke@sae.org

Ryan Gehm
Associate Editor
Ryan.Gehm@sae.org

Jennifer Shuttleworth
Associate Editor
Jennifer.Shuttleworth@sae.org

Lisa Arrigo
Custom Electronic Products Editor
Lisa.Arrigo@sae.org

Contributors

Kami Buchholz
Detroit Editor

Stuart Birch
European Editor

Jack Yamaguchi
Asia Editor

Steven Ashley, Dan Carney, Terry Costlow, Richard Gardner, John Kendall, Bruce Morey, Linda Trego, Paul Weissler

DESIGN

Lois Erlacher
Creative Director

Ray Carlson
Associate Art Director

SALES & MARKETING

Joe Pramberger
Publisher
joe@techbriefs.com

Debbie Rothwell
Marketing Director
drothwell@techbriefs.com

Martha Tress
Recruitment Sales Manager
+1.724.772.7155
Martha.Tress@sae.org

REGIONAL SALES

North America

New England/Eastern Canada:
ME, VT, NH, MA, RI, QC
Ed Marecki
+1.401.351.0274
emarecki@techbriefs.com

CT:
Stan Greenfield
+1.203.938.2418
greenco@optonline.net

Mid-Atlantic/Southeast/TX:
MD, DC, VA, WV, KY, TN, NC, SC, GA, FL, AL, MS, LA, AR, OK, TX
Ray Tompkins
+1.281.313.1004
rayt@techbriefs.com

NY, NJ, OH:
Ryan Beckman
+1.973.409.4687
rbeckman@techbriefs.com

PA/DE:
Desiree Stygar
+1.908.300.2539
dstygar@techbriefs.com

Midwest/Great Lakes:
IN, MI, WI, IA, IL, MN
Chris Kennedy
+1.847.498.4520, x3008
ckennedy@techbriefs.com

Midwest/Central Canada:
KS, KY, MO, NE, ND, SD, ON, MB
Bob Casey
+1.847.223.5225
bobc@techbriefs.com

Rocky Mountain States/NM:
CO, ID, MT, UT, WY, NM
Tim Powers
+1.973.409.4762
tpowers@techbriefs.com

Southern CA, AZ, NV:
Tom Boris
+1.949.715.7779
tomboris@techbriefs.com

Northern CA, WA, OR, Western Canada:
Craig Pitcher
+1.408.778.0300
cpitcher@techbriefs.com

International

Europe – Central & Eastern:
Sven Anacker
Britta Steinberg
+49.202.27169.11
sa@intermediapartners.de
steinberg@intermediapartners.de

Europe – Western:
Chris Shaw
+44.1270.522130
chris.shaw@chrisshawmedia.co.uk

China:
Alan Ao
+86.21.6140.8920
alan.ao@sae.org

Japan:
Shigenori Nagatomo
+81.3.3661.6138
Nagatomo-pbi@gol.com

South Korea:
Eun-Tae Kim
+82-2-564-3971/2
ksae1@ksae.org

Integrated Media Consultants

Angelo Danza
+1.973.874.0271
adanza@techbriefs.com

Patrick Harvey
+1.973.409.4686
pharvey@techbriefs.com

Todd Holtz
+1.973.545.2566
tholtz@techbriefs.com

Rick Rosenberg
+1.973.545.2565
rrosenberg@techbriefs.com

Scott Williams
+1.973.545.2464
swilliams@techbriefs.com

SUBSCRIPTIONS

+1.800.869.6882
AEI@kmpsgroup.com

Proven performance
in the most demanding applications

From high-performance structural adhesives to stronger, faster composite resin systems, Huntsman understands the demands for faster processing and reduced production cycles. With over 60 years' experience developing adhesive and composite resin technologies, Huntsman scientists work with designers and engineers every day to help solve increasingly complex design issues.

Give us your challenge and see what we can do.

For more information, visit:
www.huntsman.com/auto

HUNTSMAN

Enriching lives through innovation

POWERTRAINS | PROPULSION

Nissan unveils variable-compression-ratio ICE for 2018 Infiniti production model

Nissan broke new ground for gasoline engines at the 2016 Paris Motor Show when it unveiled the first production-intent variable-compression-ratio gasoline engine. The VC-Turbo, a 2.0-L inline four cylinder designed in house, features a novel cranktrain and control system that enables the effective compression ratio to be varied between 8.0:1 and 14:1, depending on load.

Making its debut under the automaker's **Infiniti** brand, the VC-Turbo (VC-T) has been designed to replace the company's 3.5-L V6, with a target output of 268 hp (200 kW) and 288 lb·ft (390 N·m). Using two fuel-injection systems, Infiniti has set a target for fuel consumption reduction of 27% compared with the V6. The engine is being readied for series production in early 2018. The initial vehicle application is the new QX50 crossover.

Visit this link to see Nissan's U.S. patent application: http://pdfaiw.uspto.gov/.aiw?PageNum=0&docid=20130327302

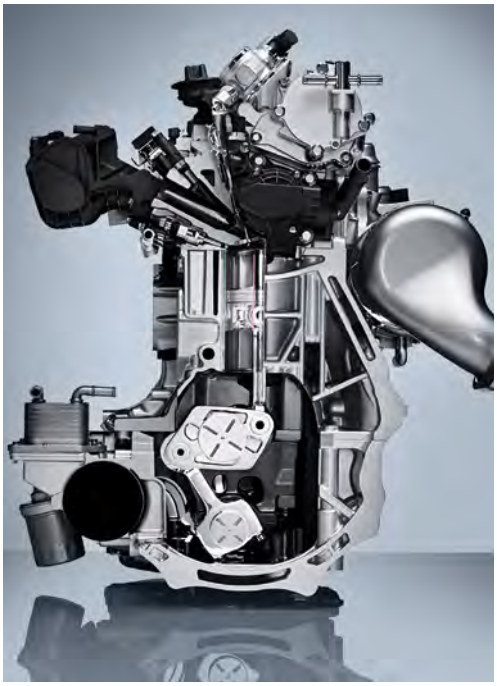
'Harmonic Drive' system

Typically, VCR engines alter the compression ratio by raising or lowering the height of the piston at top dead center, but the Infiniti engine achieves this in a unique fashion. Nissan engineers have adopted a multi-link system with an electric motor actuator, with what they describe as "Harmonic Drive reduction gear."

The electric motor drives the reduction gear, which moves an angled actuator arm. The arm in turn rotates a control shaft with four aligned eccentric cams, one for each cylinder. An intermediate link with bearings at each end connects the eccentric cam at the bottom end to the multi-link at the top end. The center of the multi-link runs in a bearing around the crankshaft journal.

A second bearing on the multilink, positioned 180° degrees from that connecting the intermediate link effectively serves as the piston connecting rod big-end bearing. This arrangement produces a 17° offset of the conrod from the crankshaft journal center point.

The Harmonic Drive is controlled by a dedicated ECU which gathers data from engine sensors to determine the compression ratio required for given driving (load) conditions. Since a low compression ratio is desirable when power is required and a high compression ratio when efficiency is preferable, the piston height at TDC can be continuously varied as required by rotating the Harmonic Drive, which will determine the position of the multilink and hence the height of the piston in the cylinder bore.



The 200-kW Nissan VC-Turbo engine is designed to replace the company's 3.5-L V6, first in Infiniti's QX50, while reducing weight by 25 kg and targeting fuel consumption reductions of 27% vs. the V6.

See this Nissan video of the VC-T's operation: https://www.youtube.com/watch?v=3rngZNJBIU

Outperforms the 3.5-L V6

As with other VCR engines, complexity, mass and cost are greater than in a conventional 4-cylinder gasoline engine. "Instead of one conrod (for each cylinder), we have three," noted Alain Raposo, Global Vice-President Powertrain and EV Engineering for the Renault-Nissan Alliance at the engine's debut.

Raposo admitted that while the VC-T is more expensive to build than a conventional 4-cylinder turbocharged gasoline engine, it is also "cheaper, lighter and performance is also better" than the 3.5-L V6 it is designed to replace.

LIGHT WHERE YOU NEED IT.

Lightweighting solutions to optimize system performance.

Shiloh's multi-material portfolio of lightweighting products serving **body, chassis and powertrain** enables:

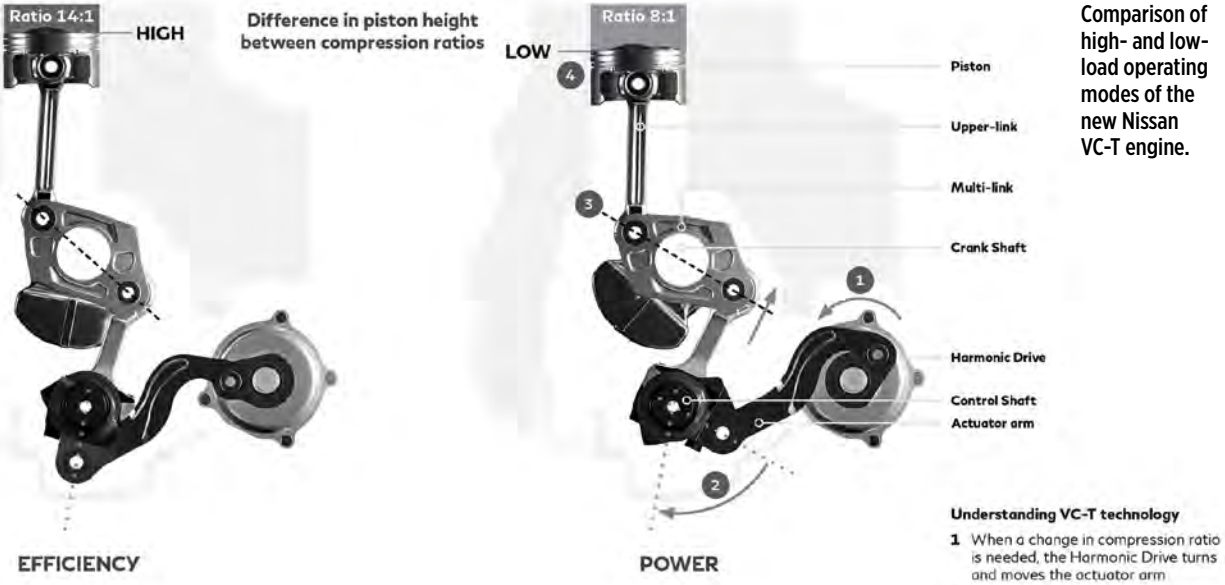
- Weight reduction without compromising performance or safety
- Reduced NVH without adding weight
- Optimized materials to improve assembly and productivity
- Lower emissions and improved fuel economy

SHILOH®

Lightweighting without compromise.™

shiloh.com

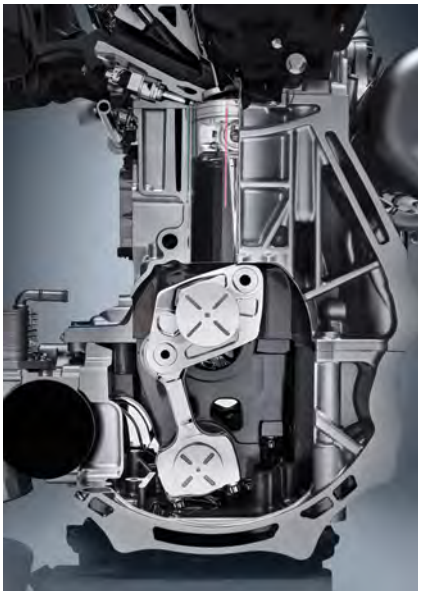
Safe. Silent. Strong. Sustainable. **Aluminum. Magnesium. Steel.**



Comparison of high- and low-load operating modes of the new Nissan VC-T engine.

The VC-T engine is around 25 kg (55 lb) lighter than the V6, according to Infiniti. The linerless cylinder block and head are aluminum and the multi-link cranktrain components are high-carbon steel alloy.

The motion described by the piston conrod big end is not circular as in a conventional engine's big-end bearing, it is more elliptical, with the conrod not passing through the vertical axis between the big and small end bearings. During the power stroke, the conrod remains more or less vertical: this reduces the side force on the piston and helps to reduce vibration.



Piston height is altered by rotating the lower shaft, which changes the position of the multi-link connected to the piston conrod.

Raposo claims the engine produces 33% less vibration than generated by a conventional gasoline I4 and no balance shaft is required. There is more pressure on some bearings, he admits, but the pressure is similar to the pressures acting on diesel engine bearings, he explained.

Reduced side force on the reciprocating components in the cylinder during operation results in lower friction between ring and bore, Raposo claims. Nissan's development team specified plasma-jet-coated bores that are hardened and honed to produce a low friction surface. The company claims a 44% reduction in cylinder friction as a result and no cylinder liners are required.

Two fuel injection systems

The development team addressed the fueling needs generated by the range of compression ratios by fitting both multi-point injection (MPI) for low compression and direct injection (GDI) for high-compression operation. Since GDI engines inherently generate higher particulate emissions, the continual phasing between GDI and MPI helps to contain particulates, Raposo noted. Both sets of injectors are brought into use under high load and high-rpm conditions.

Both the inlet and exhaust camshafts are fitted with variable valve timing—electronically controlled on the inlet side and hydraulically actuated on the exhaust side.

Forced induction is provided by a single-scroll turbocharger equipped with an electronic wastegate actuator. The variable-compression system results in a variable displacement between 1.97-L and 1.997-L.

The VC-T engine development process was highly iterative. Engineers tested more than 100 prototype engines, covering the equivalent of more than 3 million km (nearly 1.9 m miles) of road testing and 30,000 h on test beds.

The new engine currently is in final development and on-road testing.

John Kendall

REFUSE TO LET DESIGN FALL FLAT

Proto Labs is the world's fastest manufacturer of prototypes and low-volume parts. To help illustrate the design challenges encountered with injection molding, we created the Design Cube. See thin and thick sections, good and bad bosses, knit lines, sink and other elements that impact the moldability of parts.

proto labs®

Real Parts. Really Fast.®

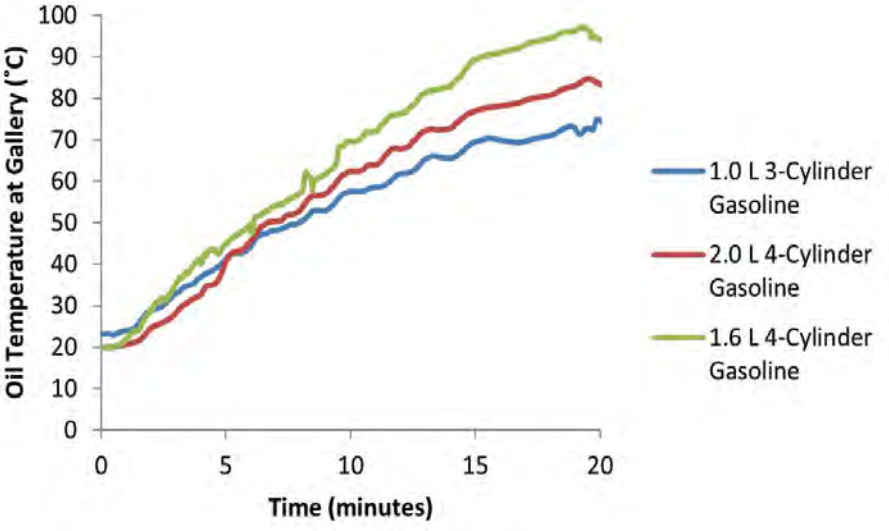
3D PRINTING | CNC MACHINING | INJECTION MOLDING

FREE DESIGN CUBE

Get your free Design Cube at **go.protolabs.com/SAE6A.**

POWERTRAINS | PROPULSION

Optimizing engine oil warm-up strategies for 'real-world' driving



The importance of warm-up time: BP Castrol Nexcel chart showing test results from simulated WLTP cycles using three European engines.

Optimizing engines for the new era of 'real-world' driving cycles will require new lubrication strategies—fast warm-up being a particular area of focus. A recent U.K. government survey showed that the average car journey time has fallen to only 22 minutes and average distance to 12 km (7.5 m), most of it in urban areas. And such extreme duty cycles are increasingly typical in other global regions. They emphasize rapid warm-up for reducing emissions and fuel consumption, faster cabin heating and reduced maintenance.

But the contribution to warm-up time due to heating the oil within the engine is often under-estimated, experts note.

"The specific thermal capacity of oil surprises many people because it's substantially higher than for the metals used for the high-mass engine components," said Oliver Taylor, a chief engineer at **BP Castrol**. "Saving three liters (approximately 2.6 kg/5.7 lb) of oil is equivalent to shedding 6.4 kg (14 lb) from an aluminum block, or nearly 12 kg (26.5 lb) from an iron block. With that perspective, it becomes very clear how reducing the lubricant volume helps an engine to warm up more quickly."

Less oil in the sump

High levels of internal friction during cold-start conditions are the dominant reason for increased fuel consumption and emissions during warm-up, which can comprise a significant proportion of the average journey. Taylor explained that in Europe's new World Harmonized Light Vehicle Test Procedure (WLTP), up to 20% of the fuel energy is lost into warming the metal parts, coolant and oil of a typical current-generation engine.

That engine's oil volume throughout that time has to be sufficient to cater for the extremes required by a number of factors. In addition to that actually required for steady-state lubrication (i.e., the oil gallery requirement), the sump must contain sufficient lubricant to accommodate operation at a typical inclination of up to 30° from vertical, to allow de-aeration when the engine is working at maximum speeds for prolonged periods and to achieve increasingly long oil-change intervals.

Another challenge comes from the increasingly complex lubricant additives required by today's significantly downsized boosted engines. Additives "push up the viscosity, imposing a limit on viscosity reduction, however thin the base oil," said Taylor. He told *Automotive Engineering* that electronic control of sump-oil volume can remove the need to always heat the full capacity required to accommodate the outer limits of these requirements.

BP Castrol testing shows that on a 2.0-L, highly-boosted, direct-injection gasoline engine, more than two liters of oil can be removed from the engine lubrication circuit—effectively reducing the parasitic drag, or windage, that results from sump oil splashing on the crankshaft during operation. The reduction can significantly improve emissions and fuel consumption during most journeys.

Containing the oil within what Taylor terms an "intelligent cell"—remote from the engine—also permits new approaches to the management of vital additives included within the oil formulation. One such approach is BP Castrol's self-contained, electronically managed sealed-cell system called Nexcel; it is installed via a docking system (http://articles.sae.org/14426/) and can be changed within 90 s, according to Taylor, who led its development.

Governing the oil-additive content

The concept of a sealed-cell, easily changed engine oil module is increasingly viable within the complex issue of thermal management during warm-up, Taylor argues. He and colleagues presented results of an investigation into the effect of oil warm-up on CO_2 emissions in a 2016 **SAE** Technical Paper (http://papers.sae.org/2016-01-0892/).

Nexcel has the capability to operate in a dry-sump architecture, but it can also be applied to a wet-sump installation, he explained. The system maintains sufficient oil in the engine's oil pan to ensure adequate coverage of the oil pick-up, but retains the surplus within the cell. This "substantially reduces the thermal capacity of the oil circulating in the engine," he said.

Contemporary engine oils contain up

www.dspace.com

dSPACE Test Benches – Highly Dynamic with Maximum Flexibility

Whether you're developing electric steering systems, brake systems, or electronic control units with integrated sensors – dSPACE provides tailor-made test benches for each use case. Put your systems to the test under extreme conditions, with forces and torques from measurement data or real-time vehicle dynamics simulations. Benefit from our know-how that covers everything: design, planning, installation, and support. All from a single source. Our scalable systems range from small rotary test benches for office use, to large test benches for complete steering systems.

Maximum flexibility and turn-key solutions – from dSPACE.

Embedded Success dSPACE

Self-contained Nexcel oil module being installed in an Aston Martin. The sealed-cell concept is also being investigated for medium- and heavy-duty trucks and equipment in addition to light-duty passenger vehicles.

to 15% additives by weight, enabling them to remain effective for the extended oil-change intervals required by OEMs. But the additives' high viscosity contradicts the use of low-viscosity base stock to reduce engine friction. Taylor explained that the Nexcel unit "can be arranged to govern the additive system, allowing the engine to be supplied with oil containing 'tailored' additive content.

"That makes advanced oils a very attractive, low-cost route to reducing friction," he said.

So far, BP Castrol is keeping secret details of the technique, but Taylor indicated that it is related to a new technology the company is developing based on "unique new chemistries" to actively control lubricant quality over the oil drain interval. "These techniques together will allow a precise and stable composition of the lubricant throughout the change interval," claimed Taylor. He believes this is one of the major factors that will enable a significant further step toward highly optimized, vehicle-specific oils.

"Because the closed nature of the Nexcel system ensures the engine always receives the oil specified by engine designers, they can extend the envelope of possibilities in areas like bearing loads and temperatures while retaining robust durability margins," Taylor said. "Add the ability to manage oil quality through the change interval and you have a very powerful new tool for enabling new generations of downsized, highly-efficient engines."

Oil-recycling benefit

The complexity and care needed to efficiently collect and manage the various oil grades drained from vehicles means that the vast majority of used oil becomes contaminated by other grades, or even by completely different fluids. This makes it impractical to re-refine, leading to a high proportion of recovered lubricants being used as fuel for burners that are "often of poor efficiency and questionable" environmental performance, noted BP Castrol Sustainability Director John Ward-Zinski.

"The benefit of controlling the feedstock for re-refining will be very significant," he explained, noting that just one-half liter of lubricant can be produced from 42 L of crude oil. BP's research suggests 34 L of lubricant can be extracted from 42 L of recycled oil — "but only if you eliminate cross-contamination during the recycling process," Ward-Zinski said.

The sealed-cell system enables this "because it keeps individual oil types protected within their cells up to the point of re-refining."

Stuart Birch

ELECTRONICS

In search of higher-energy-content batteries

As suppliers, automakers, and others join forces to develop high-performance battery components aimed at increasing the range of electric vehicles, current advanced batteries are edging closer to the end of their electrified vehicle lifespan.

"We've been very fortunate with almost 500,000 vehicles on the road that we haven't gotten a lot of those advanced batteries back yet. But there will be batteries coming out of service. And as technologists, as automakers, and as suppliers, we have an obligation to think through how we might use them, recognizing that the new ones cost half of what the old ones did," said Denise Gray, CEO of **LG Chem Power**, Inc.

Even with substantially decreased capacity these lifespan-limited powertrain batteries still have energy, so a secondary life is possible. "You just can't put them in a landfill," Gray asserted, stressing industry collaboration is the best path to battery re-use.

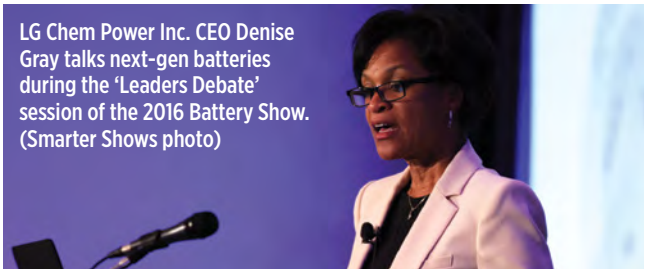
Gray and other executives talked on assorted battery topics during a 'Leaders Debate' plenary session during the 2016 Battery Show North America in Novi, MI.

The experts forecast that in the next decade, electrified vehicle batteries could be using solid ion conductors that would enable the creation of batteries with more than 30% higher energy content than today's packs.

IONICS technology progress

Solid conductors with high ionic conductivity and other desired attributes would be a major innovation breakthrough, likely replacing today's conventional liquid electrolytes. The IONICS (Integration and Optimization of Novel Ion Conducting Solids) initiative aims to help bring solid-ion conductors and other innovations to commercialization.

Dr. Paul Albertus, Program Director for the **U.S. Department of Energy**'s Advanced Research Projects Agency-Energy (ARPA-E), said the agency recently awarded $37 million for 16 new IONICS projects, whose targeted goals



LG Chem Power Inc. CEO Denise Gray talks next-gen batteries during the 'Leaders Debate' session of the 2016 Battery Show. (Smarter Shows photo)

also include a pathway to produce battery packs at less than $125 per kW·h, considerably less than current costs.

Focus areas for these academic, small business, and national lab IONICS projects include developing lithium conductors that can enable the cycling of lithium metal without short circuits or battery degradation; replacing today's graphite anode with a lithium metal anode and developing a solid separator not made from polycrystalline ceramics.

"We want to develop a solid separator with an amorous glass structure that has a thickness of less than 20 microns," said Albertus, admitting that will be difficult to achieve for an inorganic material and at a targeted price of $10 per square meter. "One vision of how this could work is to leverage some of the glass processing technologies that are used to make thin flexible displays," he said.

Li-S batteries by 2020?

Lithium sulfur and lithium metal have crucial roles in the IONICS initiative.

"In the lithium metal portion of the program, the goal is to develop higher-energy-density lithium batteries that would reduce mass, volume and cost, leading to longer range electric vehicles. So we're working to get lithium metal out-of-the-lab and onto a clear commercialization pathway with a core cell technology that would be relevant for automakers," Albertus told *Automotive Engineering*.

According to Dr. Ramesh Bhardwaj, Director of the X-Battery Group of **Google** parent **Alphabet**, today's battery materials are cost-heavy. "Li-S or lithium metal batteries with the potential of 350 to 400 W·h/kg are needed to reduce the cost of electric vehicles," said Bhardwaj. He noted that mass production of Li-S batteries is possible in the next three to five years.

"Sulfur is the cheapest material and it's also a raw material that comes from the oil industry. So if you can use sulfur to make batteries, then we can reduce the cost. However, the biggest challenge is it doesn't cycle very well," Bhardwaj said.

Gray of LG Chem pointed out that in recent years there has been a steady progression with battery systems overcoming assorted technical challenges.

"Take a look at where the technology has been and where it's going. It's not just because of the work that we're doing within our company," she said. "It really is working collectively with our OEM partners and with universities and governments in the U.S. and around the world to keep pushing the technology forward."

Kami Buchholz

SOFTWARE | SIMULATION

Making Multiphysics fast and convenient

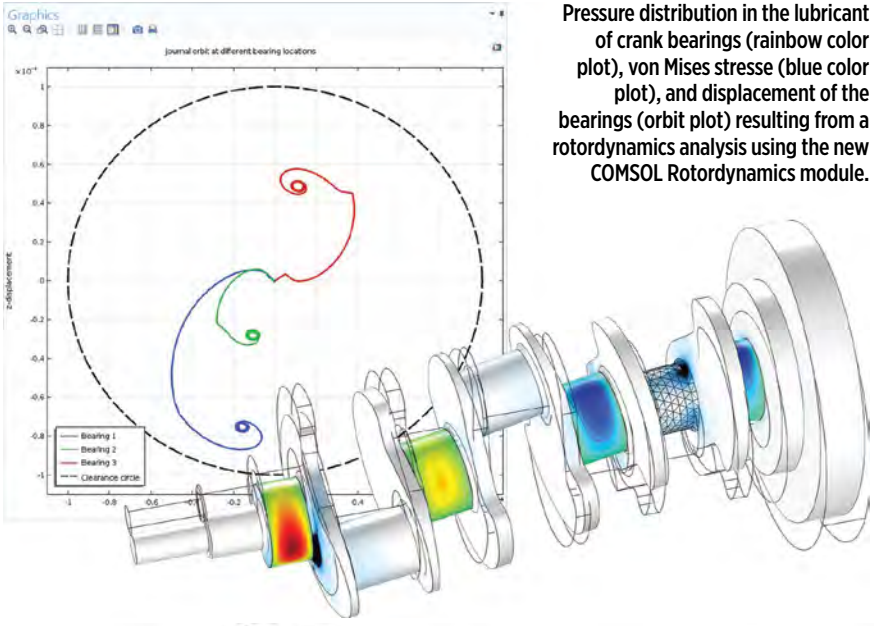
Mimicking real life interactions in complex products like automobiles or aircraft often requires a Multiphysics approach. It requires combining, for example, simulations of combustion, heat transfer, fluid flow and stress analysis to truly understand whether an engine is going to perform reliably in real-world conditions.

As computer memory grows and software developers learn how to create efficient codes, practical Multiphysics is expanding. However, challenges remain beyond the technical—the sheer intellectual complexity in creating simulations and scenarios that span such a range of knowledge. Increasing technical capabilities now highlight some human limitations: creating a valid Multiphysics model often is confined to a small group of highly specialized, highly educated 'power' users.

Sweden-based CAE simulation tools specialist **COMSOL** is tackling this human complexity problem in two ways: with specialized modules and dedicated "apps" deployed in Windows or even on a smartphone. Both approaches are aimed at making software easier to use for a broader group of engineers. This is especially important for mobility-industry engineers and managers, explained Dr. Valerio Marra, COMSOL's Marketing Director.

"Putting together an R&D team is quite an endeavor—to find them, to train them in your industry and for them to find the right tools," Dr. Marra told *Automotive Engineering*. "If you want to keep up with progress in innovation in the industry, you have to free up their time." He emphasized that the answer is not always to hire more engineers. These additional engineers would need training on the core COMSOL Multiphysics product as well as deep understanding of the underlying physics.

"What managers should know is there is a technology now that engineers can use to package the complexity of their knowledge into an 'app,' so that other engineers can go on with their design work," he said.

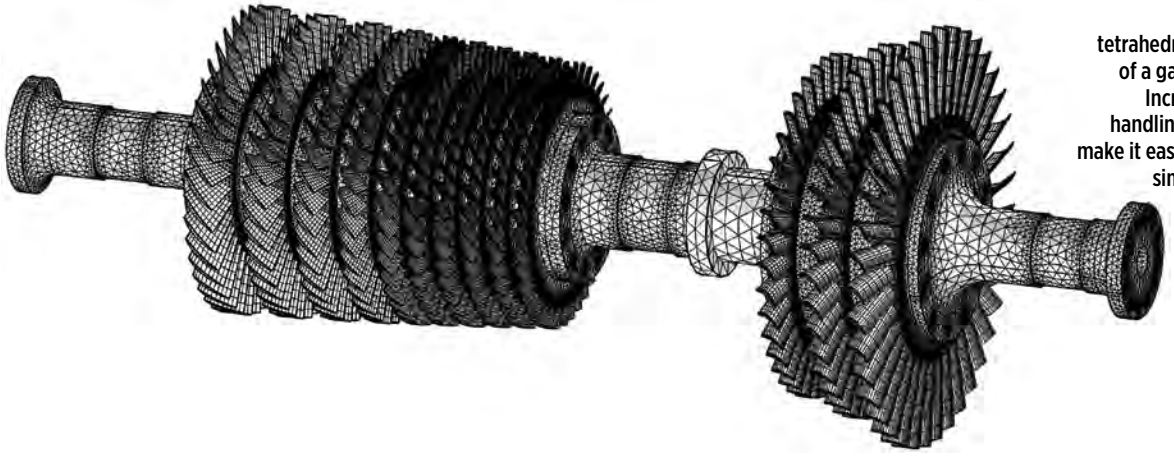


Pressure distribution in the lubricant of crank bearings (rainbow color plot), von Mises stresse (blue color plot), and displacement of the bearings (orbit plot) resulting from a rotordynamics analysis using the new COMSOL Rotordynamics module.

Building apps and interfaces

COMSOL is not the only CAE company offering such tools for packaging and hiding complexity. Offering it as a specialty in Multiphysics should come as a welcome addition for those attempting to solve higher-fidelity problems where multidisciplinary interactions are key.

A COMSOL app is a multiphysics model wrapped in a custom user interface. The user interface is built through a graphical, interactive tool called the Application Builder. Apps can be



A combination of a tetrahedral and swept mesh of a gas turbine is shown. Increasing speed up in handling large models will make it easier for Multiphysics simulation, according to the company.

deployed as a client in Windows, or even through a web browser, by connecting to a local installation of COMSOL Server software. They can also appear on a smartphone.

"Building an app is especially useful when there are repetitive operations that need to be done, perhaps even on a routine basis. When accessing complex software becomes a problem, accessing the app that hides much of that complexity becomes a valuable asset," explained Marra.

The company claims that custom applications can be created for anyone from technicians, support staff, designers, to customer service representatives, "empowering them to make on-the-fly design iterations and report generation," he said.

Specialty modules

In a variation on packaging complexity, the latest update of the COMSOL suite includes the new Rotordynamics Module. It helps engineers in analyzing vibrations due to gyroscopic effects in rotating machinery, evaluating critical speed, whirl, and bearings. It is targeted for users who design or evaluate turbochargers, turbines, pumps and electrical machinery in the automotive, aerospace, energy and marine sectors among others.

The company notes that additional tools for modeling geared rotors are available when the Rotordynamics Module is combined with the Multibody Dynamics Module. Postprocessing capabilities include creating Campbell diagrams, modal orbits, harmonic orbits, waterfall plots and whirl plots. The new module is in addition to 28 other modules for specialty applications, including electrical, structural & acoustics, fluid & heat, and chemical applications. The core COMSOL Multiphysics software is required to run any of these add-on products.

A related improvement to the latest release of COMSOL is speedier processing of larger models and meshes. The company emphasizes models with several thousand domains and boundaries, with functionality speedups including a 10-times speed improvement in selections of domains and boundaries, virtual operations for mesh preparation, swept meshing and OpenGL rendering and a 5-times improvement in CAD imports.

One of the past issues with simulating Multiphysics has been the size of the resulting numerical model, but increasingly fast and inexpensive computing is giving numerical specialists the opportunity to fine-tune codes to ingest and compute ever larger models.

For related information, see "Simulation apps for virtual prototyping" (http://articles.sae.org/14960/).

Bruce Morey

SAE Convergence 2016

Talk of the healthy aspects of disruption mingles with SAE's renowned technical emphasis to foster the auto industry's continuing evolution toward electrification and autonomy.

By Terry Costlow and Bill Visnic

The auto industry is at the moment ravenous for discussion and guidance regarding the ongoing integration of electronics into vehicle development—but particularly regarding the almost daily deluge of news and speculation about vehicle automation. **SAE**'s 2016 Convergence conference supplied a diverse forum for those conversations while providing a new format that grouped each of the conference's three days into a distinct subject-matter theme.

From an insightful, consumer-focus keynote address from **Ford**'s Raj Nair, Executive Vice President, Product Development and Chief Technical Officer, to technical sessions that explored everything from trends in human-machine interface to supply-chain transformation, Convergence once again was the rallying point for technical and strategic discussion at a high level.

Automakers, suppliers firm that autonomous driving not decades away

For those who believe it unlikely autonomously-piloted vehicles will be on the road in numbers in the foreseeable future, senior technology executives from automakers and major suppliers have this response: autonomous vehicles are "going to be here very shortly."

That's the conclusion of Jeff Owens, Chief Technology Officer for automotive mega-supplier **Delphi**, a position supported almost universally by his fellow panelists on the opening day of the Convergence conference near Detroit. Ken Washington, Vice-President, Research and Advanced Engineering at Ford, agreed with Owens.

"The evidence is all around us," Washington asserted. "I am very optimistic that [Ford's] target of 2021 (for launching a fully-autonomous vehicle as defined by the SAE's J3016 standard) is going to be achievable."

General Motors has accelerated its autonomous-technology development and partnerships with autonomous-related tech companies, said Jon Lauckner, GM Vice President, CTO and head of **GM Ventures**. He noted that GM has autonomous-vehicle testing underway on public roads in San Francisco, CA and Scottsdale, AZ.

"I can assure you our plan is not to test for the next 30 years," Lauckner quipped in response to naysayers' position that it will be a generation or more before autonomous vehicles are a fixture on U.S. roads.

Phillip Eyler, Executive Vice President, Connected Car at **Harman International**, generally agreed that autonomous vehicles are coming sooner than later, but the position of Harman—a supplier of in-car infotainment systems, driver-interface hardware and software and other cabin electronics—is that the date of introduction may be one thing, but wide adoption of

Strong teams drive strong results.

"Our team is behind every order, providing quality and reliable products when you need them."

Erin Trentel – Senior Sales Representative

Chris Easter – Technical Service Regional Manager

ENDLESS RECYCLING

A solid relationship with your supplier is vital to the success of your business. Our experienced team of inside and outside sales representatives along with our highly trained and knowledgeable technical and engineering experts work together to support your entire manufacturing process. From the planning stages through order fulfilment, delivery and support after the sale, Gerdau steel is the strength behind your brand.

GERDAU

www.gerdau.com/northamerica

autonomy will come on a more-protracted timeframe.

"I believe there will be a long transition to a high population of autonomous cars," Eyler said.

One of the automotive and tech industries' chief talking points currently centers around which SAE level of autonomy is going to be most appropriate for initial—and eventual widespread—deployment.

High-level driving automation "needs to be approached top-down instead of bottom-up," said Ford's Washington. In the interim, he added, Ford is tripling its investment in Level 2 driver-assist technology. "Ford is skipping Level 3 at the moment," he said. "The economics don't make sense to us."

Harman's Eyler agreed. "Level 4 is a totally different set of technologies and investments," he stated. However there will be a Level 3 transition at some OEMs, Eyler believes.

The cost of developing technology capable of accommodating SAE Level 3 automation is beginning to appear unproductive on several fronts. First is the direct cost of the divergent Level 3 and Level 4 technologies. Economics of such development "are going to make Level 3 almost a moot point," contended Delphi's Owens. "You're going to go right by Level 3."

Touchscreens, speech, HUD the likely future of in-car interface

Touchscreens are far from perfect and the state of speech-recognition remains marginal, but those are the two driver-interface technologies consumers overwhelmingly prefer—and probably are likely to prefer in the near future, according to the results of a recent **IHS Automotive** survey presented at the SAE 2016 Convergence conference near Detroit.

Brian Rhodes, analyst for HMI and usability at IHS Automotive, said consumers' responses regarding their preferences for the "input" portion of the in-vehicle user experience (UX) is particularly intriguing because most consumers' experience with touchscreens has been with spotty-responding resistive technology—and "speech (recognition) generally today is bad. Consumers don't like it."

Innovators panel at SAE 2016 Convergence included senior-level technology executives from Delphi, FiatChrysler, Ford, GM and Harman. (Lindsay Brooke photo).

IHS Automotive analyst Brian Rhodes on user experience for in-car tasks: "For every single function, the consumer wants to use a touch screen."

"It's fascinating," Rhodes noted of the findings from the survey's 4000 respondents, saying that despite the fact that both technologies "haven't worked too well," consumers still want them.

The main reason, Rhodes suggests, is because drivers and passengers are seeking less complexity from the UX environment—and touchscreens and speech recognition appear to be the choice methods for clearing the clutter.

Expect curved display screens to soon make an appearance in automotive interiors. This proposal from Continental Corp. features two 12.3-in AMOLED haptic touch screens—one horizontal and one vertically oriented. (Source: Continental)

On the "output" side of the UX—methods for relaying information to the cabin occupants—head-up displays (HUD) appear ready to take off, Rhodes said, but consumers are expected to continue to prefer center-stack and instrument-panel screens to receive the bulk of their information.

Rhodes said that in 2016, about 35 million touch screens will be produced for automotive use. But only about one-quarter will use capacitive-touch technology, which has better response speed and reliability and allows additional functions such as pinch and zoom. But IHS data indicate that by 2022, that ratio will be flipped, with 80% of touchscreens using capacitive technology and only 20% resistive.

"For every single function, the consumer wants to use the touch screen," he concluded. Speech input is the distinct second preference, he said. Interestingly, one current highly promoted input technology—gesture recognition—scored dead last in the consumer survey.

"It's probably too early to be surveying about gesture," Rhodes explained, adding that his company nonetheless is projecting a 34.5% compounded annual growth rate (CAGR) for gesture-recognition technology between 2015 and 2022, the high figure based largely on low initial penetration. He also said that gesture recognition is expected to largely remain the province of the luxury market.

As consumers move more effortlessly between vehicle, home, and office, the automotive supply chain must focus on implementing rapidly changing consumer technologies, as exemplified by the smartphone industry.

Bridging the automotive/consumer electronics product cycle gap

Vehicle owners increasingly expect to move seamlessly between homes, offices, and vehicles. That trend is forcing the entire automotive supply chain to focus on techniques for implementing rapidly changing consumer technologies.

Techniques for leveraging smartphones and wearables were among the topics explored during the "Leveraging Consumer Electronics" session at SAE 2016 Convergence. Gregg Johnson of **Connected Strategy Advisors** opened the discussion by quantifying the disparity, noting that vehicle lifetimes are 11.4 years, while those of smartphones average 21 months. Vehicle development cycles typically take two smartphone generations.

Louis Brugman of **Pioneer Automotive Technologies** detailed the potential for disaster. A few years ago, Pioneer developed a technique that linked **Apple** iPhones to the vehicle display. This early mirroring scheme relied on Apple's cable, so the technology was basically rendered useless when Apple changed cables. Panelists said that using industry standards is necessary to avoid similar problems going forward.

"It's a big challenge for us as developers to make standards work," said Steven DiLodovico of Ford. "OEMs all need to come up with standards technology strategies that are seamless. Having open architectures so people from diverse backgrounds can develop software is very important."

Consumer products are transforming many facets of the industry. Display technologies created for home and office continue to revamp vehicle design. Virtual-reality headsets may help dealers sell more personalized vehicles while reducing their standing inventory.

"The influence of consumer displays is huge," said GM's Partha Goswami. "They continue to transform interiors, and in the near future they can replace side-view mirrors. Virtual reality is just starting to transform dealerships. Dealers won't have to carry as much inventory when people can see what they want and order features they want." ■

The Battery Man SPEAKS

The speed of progress in automotive lithium batteries has impressed AABC's Dr. Menahem Anderman. So has silicon-graphite anode technology development from Tesla and Panasonic.

by Lindsay Brooke

"The CO_2 regulations are pushing everybody—but how much are the auto companies willing to allocate capital, with a risk of no or little return [on EVs]?" asked Dr. Anderman. (Lindsay Brooke photo)

The future of vehicle electrification is all about the battery. The industry's steady progress in reducing lithium-ion battery cost while increasing energy density, durability and reliability has surprised one of its leading experts, who is quick to admit a miscalculation he made six years ago.

"Battery costs are coming down faster than I predicted—and faster than the major Japanese cell producers who have been my clients for many years predicted," said Dr. Menahem Anderman, independent battery-industry consultant, founder of the well-known Advanced Automotive Battery Conference (AABC) series and frequent speaker at **SAE**'s Hybrid & Electric Vehicle Symposia.

In 2010, Dr. Anderman completed a milestone study on battery cost in which he interviewed top cell and material suppliers and vehicle OEMs. "They believed then that it would take 10 years to reduce costs to $300/kW•h. Well, that's already happened," he asserted in an interview with *Automotive Engineering*.

Significant work is still ahead, he cautioned, in order to reach the $150-$100/kW•h threshold that will finally put EVs on a cost par with IC engine vehicles, "tipping the scales" to widespread electric mobility. And while energy density is improving, "maintaining safety is really the biggest barrier to improved performance," Dr. Anderman explained.

Plug-in hybrids, he observed, were almost anathema to **VW-Audi**, **BMW** and **Mercedes** engineers six years ago, because they carried the high cost of two powertrains and a large battery—and diesel was still their preferred propulsion source. Now the German OEMs are introducing PHEVs across their platforms because they deliver range.

"And unlike EVs, they know they can sell PHEVs if they price them the same or slightly more than a regular car and can add-in performance features," Dr. Anderman said.

A year ago, he forecast that PHEV volume would be bigger than EV, based on input from most OEMs. This year his projection is about the same for the two propulsion modes. Are PHEVs a more practical choice for customers because they offer better functionality than even a 200-mile-range EV?

"The CO_2 regulations are pushing everybody—but how much are the auto companies willing to allocate capital, with a risk of no or little return?" he asked. "The companies look at how much regulatory credit they get for a vehicle that costs them $3000 more than their regular vehicles. With EVs this still is not clear."

EVs might have to be cheaper than a conventional car to sell in volume, beyond the early adopters, he opined. If, for example, **Tesla** ends up having to sell its Model 3 below cost, "how long can they sustain that? They might be planning to sell a lot of EV credits," he offered, "but that's a risky proposition and not sustainable over time."

There is no comparison between the mobile-devices market and that of electrified vehicles, because "the iPhone is driven by customer demand," Dr. Anderman said.

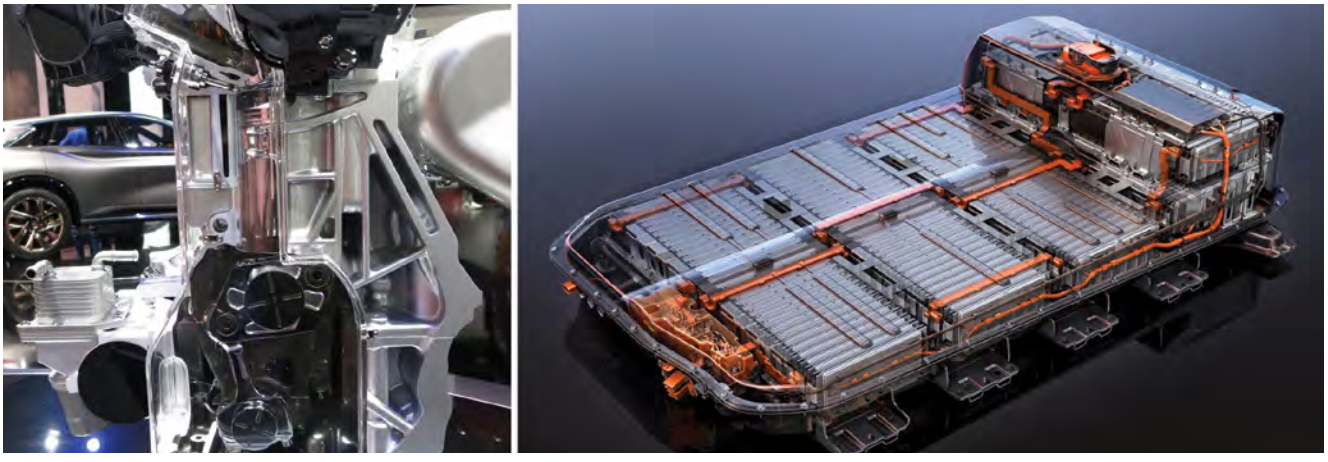
Improving the lithium-ion 'system'

Anderman's not surprised at the difficulty and failure that various rising-profile battery startups faced to develop lithium ion. He tells their engineers and financial backers that the real test is not technology—it's manufacturing.

"I don't care about how your latest anode looks or what is the color of your cathode. Survival in the automotive battery business means getting to high volume, high speed, with a low defect rate and low cost. That's where **Panasonic** and the Japanese in general are very strong," Dr. Anderman noted. "When people tell me they have achieved 10% better energy density in the lab, that isn't even a factor. What's important are battery life, safety and the ability to produce cost-competitively in high volume."

Is there a "battery breakthrough" coming, as lithium-ion chemistry was in 1991, and nickel-metal hydride was before that?

"Lithium ion put us on a faster improvement curve than we had with NiMH. The great thing about lithium ion is,



The emerging vehicle propulsion battle pits advanced IC engines with added-cost technologies such as variable-compression ratio (Nissan's 2017 VC-T shown at left) and increased exhaust aftertreatment versus sophisticated liquid-cooled high-voltage battery packs such as that of the 2017 Chevrolet Bolt, the cost of which is expected to drop due to greater production volume. (VC-T cutaway photo by Lindsay Brooke).

BEV BATTERY COSTS ($/kW·h)		
	NAS	ICCT Est.
2010	450	450
2015	375	355
2020	300	225
2025	275	175
2030	250	125
2035	225	120
2040	200	115
2045	180	110
2050	160	110

NAS: National Academy of Sciences

Projected battery cost comparisons presented by the ICCT's John German at the 2016 AABC.

Can a battery 'gigafactory' such as that being built by Tesla-Panasonic near Reno, NV (rendering shown) dramatically reduce battery cost? "You have to separate total production volume from localized production from one plant," Dr. Anderman explained. "Total production volume for automotive currently is 10-15 gW•h. The industry is going to 75 to 100 gW•h—that will reduce cost. Will having 50 parallel lines of 18650 or 2700-series cells in Reno make a significant impact versus 5 to 7 separate locations as are being constructed in China? Probably not very big."

it's a system—an umbrella of technology. You can replace the cathode, the anode, the electrolyte, change the shape of the cell and it's still lithium ion," he explained.

"I'm a pragmatic person and when I look at all the barriers, versus what you get if you solve them, solid electrolytes for automotive batteries don't have all that much promise. Because you're talking less than 50% improvement if everything goes well, and you have a lot of challenges like manufacturability and safety."

Nor does Dr. Anderman currently see much hope in lithium-sulfur batteries for automotive, due to volume issues and cycle life. He called lithium-air batteries that often garner media attention "a vision that is more complicated than a fuel cell if you look at the technology. Lithium air operates under conditions that you try to avoid with lithium ion."

Same with lithium-metal: "It's got all the issues that if you have them with lithium-ion you've lost the game."

Promising auto battery R&D

Silicon and silicon-compound developments, as Tesla has admitted to working on in a new cell with partner Panasonic, interest Dr. Anderman.

Adding a percentage of silicon to the standard graphite used in lithium-ion battery anodes has the potential to increase the battery's capacity to store energy and thus help lower the cost per kW•h. Research efforts using silicon to date often have resulted in battery "swelling" and failure, however.

Tesla and Panasonic engineers have been adding 5% to 10% silicon to the anodes of production battery packs, the silicon-graphite anode emerging as a "hot rodding" feature of the electric-car era. For proof of its value, look no further than the $10,000 option price that Tesla is charging for its new-for-2017 P100D pack that delivers a claimed 100 kW•h per charge—an increase from the incumbent 90 kW•h P90D battery available in Model S and Model X.

It really is all about the battery, as Dr. Anderman's analysis of the industry continues to show. ■

Industry 4.0: The smart factory arrives

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

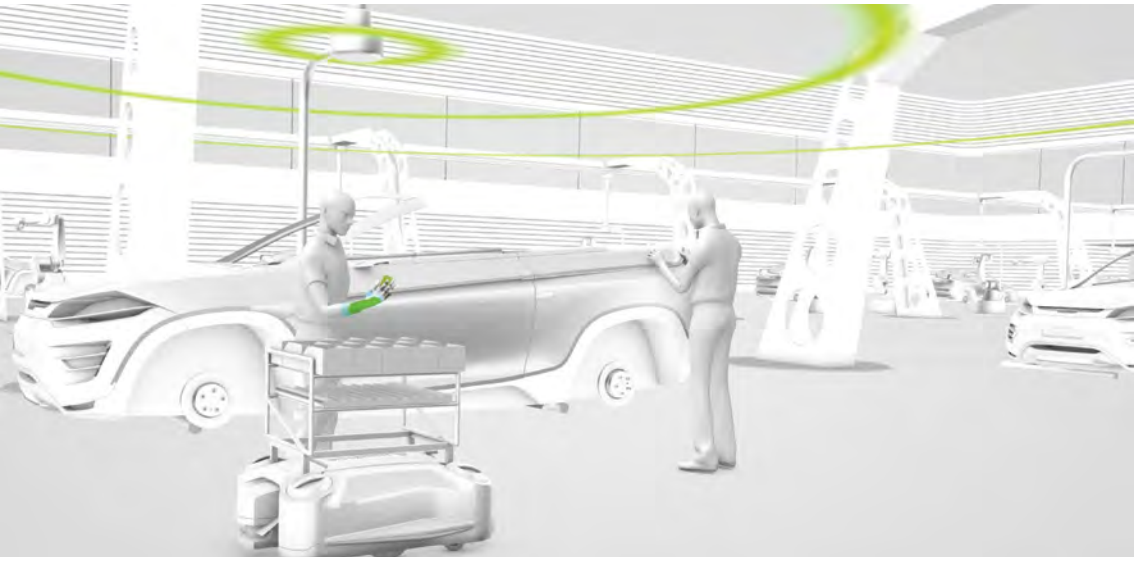
by Ryan Gehm

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

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

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

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



Turning Big Data into "smart data" to support decision-making and offer new insights is a priority for Magna's digital factory.

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

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

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

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

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

Big Data, predictive analytics

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

A material handling robot allows components to move safely and easily at Faurecia's new digital manufacturing plant in Columbus, IN.

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

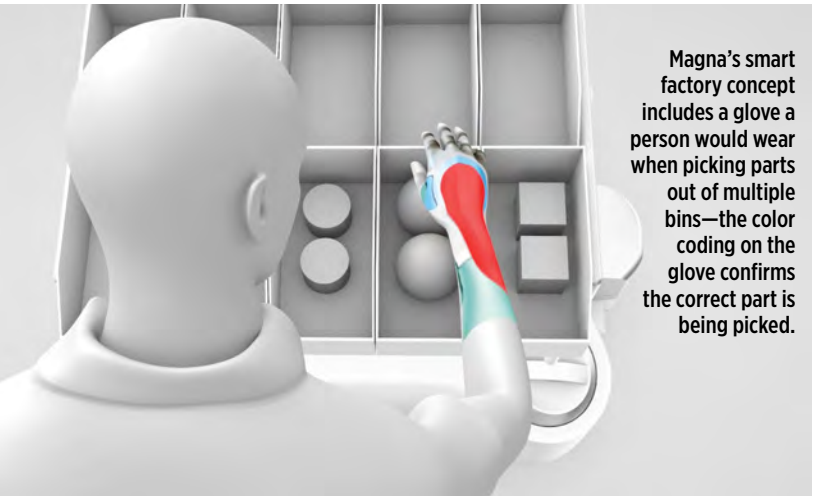
The problem, he added, is that 80% of all data today is currently unstructured and therefore unusable.

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

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

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

Industry 4.0: The smart factory arrives



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

8-speed automatic transmissions in ZF's Saarbrücken facility equipped with RFID chips are part of the location's fully networked production, process, diagnosis and test data.

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

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

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

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

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

Cybersecurity jitters

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

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

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

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

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

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

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

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

GE Digital's Paul Boris (far right) wants to make manufacturers "a little more nervous" than they might already be, stressing the need to move "fast, small, light" for the digital factory. Dr. Jürgen Sturm of ZF (far left) and Toyota's Trever White look on. (Ryan Gehm photo)

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

Enter the "cobot"

As manufacturing facilities become more connected and highly automated, integration of the worker with production is critical—perhaps even more so than with less-advanced systems. Because no matter how intelligent the factory floor becomes, humans will always be involved in the process, experts say.

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

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

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

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

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

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

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

The Toyota way

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

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

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

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

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

I.D. Concept heralds VW's electric Bolt fighter for 2020

VW CEO Diess with the I.D. Concept at its Paris Show debut. (Lindsay Brooke photo)

"Our future is in efficient and 'connected,'" said **Volkswagen** CEO Herbert Diess as he introduced his company's battery-electric product future at the 2016 Paris Motor Show.

The VW I.D. Concept, with a claimed range of up to 373 mi (600 km) on a single charge, heralds a blitz of new electrified vehicles based on the company's new MEB modular platform dedicated to battery-electric models. A production version of the I.D. is planned for 2020, Diess said, with an autonomous version following by 2025. Diess compared the new BEV to the original VW Beetle, promising "it will be a real people's car" priced about the same as today's Golf.

The four-door I.D. electric will compete directly with **GM**'s 2017 **Chevrolet** Bolt and its near identical twin, the **Opel** Ampera-e, the latter being unveiled later the same day at Paris. Opel CEO Dr. Karl-Thomas Neumann said the Ampera-e will be capable of 500 km (310 mi) range. The EV ranges claimed by both the VW and Opel are based on the NEDC driving cycle.

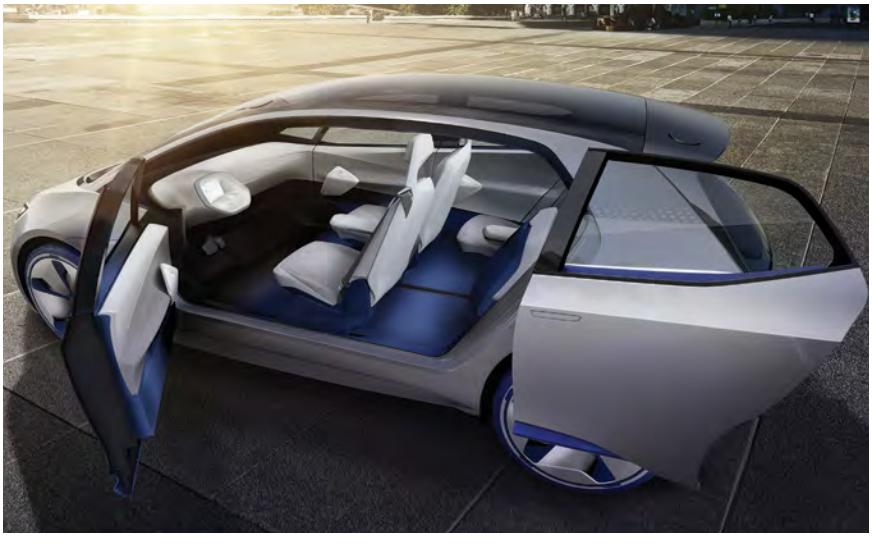
Excellent packaging

VW is configuring the MEB platform to include **SAE** Level 4 autonomous driving capability by 2025, a feature that the I.D. Concept car and its production version will include, Diess said. VW's post-Dieselgate goal is to sell 1 million electric cars per year (approximately 25% of volume) by 2025. Beginning in 2021, OEMs in Europe will be expected to cut their fleet-average CO_2 emissions from the current level of 130 g CO_2/km to 95 g/km. Zero-emission vehicles will be vital to meeting the regulation.

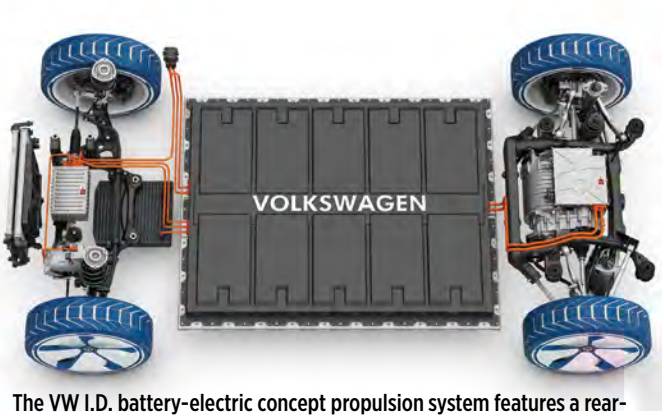
The I.D. Concept is 161.4 in (4099 mm) long, six inches (152.4 mm) shorter than a 2016 Golf. Overall width is 70.9 in (180 mm) and the car's overall height measures 60.2 in (1529 mm). The I.D. rides on a 108.3-in (2750-mm) wheelbase, about 5 in (127 mm) longer than the current Golf. I.D.'s chiseled skin and clever sliding rear doors—no official details yet on exterior panel or body-in-white materials—sit on a rear-drive platform that, combined with short front/rear overhangs, provides a claimed 32.5-ft turning circle.

VW officials at Paris did not provide details on the I.D.'s "flat" lithium-ion battery pack that is mounted in the floor pan. The exceptional 373-mi range being claimed—63 mi/101 km greater than the Chevy Bolt—indicate VW is adopting a new battery strategy for its next-gen EVs. For a look at how much improvement the 2020 car will need, consider VW's current EV, the 2017 e-Golf. Its newly upgraded 36 a·h, 34.9 kW·h battery (a 48% improvement over 2016) will deliver a claimed 200-mi (322 km) range. The company is reportedly in discussions with both **Panasonic** EV and **LG Chem** for its next-gen cells.

I.D.'s electric propulsion system also features a 125-Kw (168-hp) traction motor and single-speed gearbox integrated in the multi-link rear axle. The rear propulsion/axle unit is mounted on an



Sliding rear side doors are a key to superb ingress/egress in the VW I.D. concept, but will they make it to production?



The VW I.D. battery-electric concept propulsion system features a rear-motor/rear-drive configuration.

isolated subframe for reduced NVH and improved driving dynamics, according to VW engineers. The I.D.'s weight distribution is 48:52 front/rear.

Claimed performance of the concept is zero to 62 mph in less than 8 s and top speed of 99 mph (160 kph). The MEB (modularen elektrifizierungsbanksten) platform is designed for a variety of electric machines and different battery capacities. The charging system will offer both SAE Combo Level 1 and 2 cable charging and wireless inductive. VW claims the system will achieve an 80% state of charge in 30 mins using 220 volts.

VW's new UX

Mounting the battery down low in the car's floor structure, a la **Tesla** Model S, enabled VW designers and engineers to create a cabin that is functionally larger that the car's exterior indicates—"a Passat-sized interior with a Golf-sized exterior," Diess noted. Thin-cross-section lightweight seats add to the "Open Space Design" airiness, and in the subsequent autonomous version the car's steering wheel is designed to telescopically retract (by pushing the VW logo in the center horn hub) into the dashboard during SAE Level 4 operation (what VW calls "I.D. Pilot" mode). Those cars will have a total of 10 LiDAR emitters located around the vehicle, Diess said.

Sideview cameras replace today's fixed external glass mirrors and a central interior e-Mirror combines data from the three external cameras on a monitor. The images are transmitted from the door mirror cameras on the left and right-hand sides of the car as well as a rearward facing camera. Doing away with the mirrors improves the vehicle's aerodynamics.

The "I.D." nameplate is derived from the abbreviation for personal identification—part of VW's aim to make driving (and being transported by) the I.D. a personalized experience. Drivers of these cars will upload, via smartphone, secured personal information and preferences to the cloud then receive a "Volkswagen ID" that includes personal information and preferences aimed at making the user experience more comfortable.

The concept car also features an augmented-reality head-up display (HUD) to aid driver navigation during SAE Level 2 to 4 operation.

Lindsay Brooke

Aero-slick Land Rover Discovery sheds 1058 lb, gains features

JaguarLandRover engineers continue to achieve significant vehicle mass reductions, this time with the new generation Land Rover Discovery. Shifting to aluminum construction for the bodyshell instead of steel and complemented by an intensive light weighting program for the whole car, has yielded a remarkable 480 kg (1058 lb) saved compared with the previous model. This exceeds even the 420 kg (925 lb) reduction of the **Range Rover** in 2012 when it was switched to an aluminum-intensive architecture.

The new Discovery, revealed at the 2016 Paris Motor Show closely echoes the Discovery Vision Concept which debuted at the 2014 New York Auto Show. For the production car, Land Rover has abandoned a steel body on a steel frame for an aluminum monocoque.

"The (weight-reduction) figure of 480 kg may sound almost incredible, but we have checked it out many times!" said Alex Heslop, Chief Program Engineer. "And the Cd for the new car is 0.33 compared to 0.40 for the previous Discovery." The combination of weight shedding and efficient aerodynamics help deliver improved performance and reduced emissions.

Single-piece bodysides

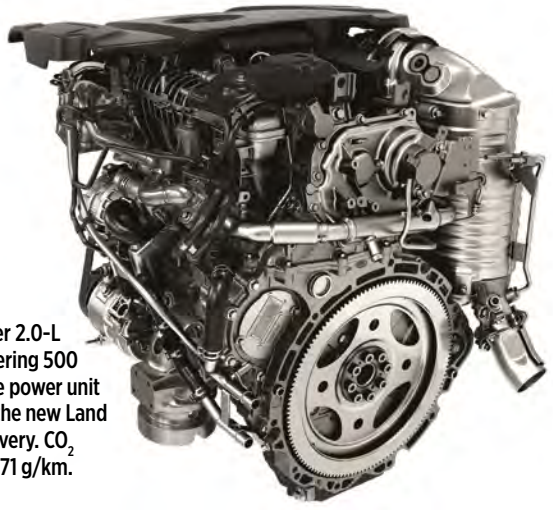
The new monocoque also allowed what he described as "a versatile, spacious seating solution (for seven 1.95-percentile adults) like no other." Seats are configurable from a smartphone as part of what Land Rover claims as a "world first" remote Intelligent Seat Fold solution—a vehicle occupant could change the seat layout while in a store buying a bulky item.

Those seats are also part of the weight-saving achievement, using lightweight high-strength steel (HSS). Extensive use of high strength aluminum alloy has been incorporated within the crash structure. The whole bodyside of the car is stamped as a single panel to reduce joint count and improve rigidity, and the underside of the Discovery is also stamped from a single aluminum blank to enhance structural integrity.

Of the total monocoque, 85% is aluminum, with 43% of that recycled. Simplified exhaust and driveline systems also save weight and magnesium is used for the instrument panel crossbeam, a now-common application for the material.

Clear visual cues link the new Discovery to other Land Rover models.

Virtual testing of the 7-seat Land Rover Discovery included sand dune impact.



Four cylinder 2.0-L diesel delivering 500 N·m is in the power unit line-up for the new Land Rover Discovery. CO_2 emissions, 171 g/km.

Across the Discovery range, best unladen weight is 2115 kg (4662 lb), the company claims. Luggage space is a maximum 2406 L (85 ft^3).

Connection capability includes 9 USB ports, four 12-V charging points and an in-car 3G WiFi hotspot for 8 devices.

Tough test regime

Heslop emphasized that the car is as good or better off-road as the previous Discovery and has a wading-depth capability of 500 mm (20 in, increased by 200 mm/8 in), which he said is close to flotation point!

Combining both tough-terrain ability and fine ride quality is a salient aspect of all Land Rover products. The new car has "optimized" steel front and rear subframes to meet stiffness and steering-response and chassis-refinement requirements.

Suspension is fully independent with wide-space double wishbones at the front; the multi-link configuration at the rear also has an integral link to deliver stiffer damping without

decaying comfort or impact absorption performance.

Air suspension is an option, lowering the car 60 mm (2.4 in) for easier loading or raising it 75 mm (3 in) for very rough terrain driving. Regular ground clearance is 283 mm (11 in, an increase of 43 mm/1.7 in), approach angle 34°, break-over angle 27.5°, departure angle 30°.

Engine line-up includes a 177-kW (237-hp) version of JLR's Ingenium 4-cylinder diesel delivering a claimed 500 N·m (369 lb·ft). It gets the Discovery to 100 km/h in 8.3 s, the engineers claim. Common rail injection pressure is 2200 bar. The range also includes a 3.0-L V6 gasoline with 250 kW (348 hp) output and 450 N·m (332 lb·ft). All engines get an 8-speed **ZF** automatic transmission. A 2-speed transfer case is standard.

New 'Nose Load Measurement'

Chassis systems are extensive and include All-Terrain Progress system (allowing the driver to set crawl speeds from 2 km/h to 30 km/h), controlling engine and braking. It also gets Terrain Response 2, automatically monitoring driving conditions that span regular driving to rock crawl via gravel, sand and mud modes.

Maximum towing capacity is 3500 kg (7716 lb) and Advanced Tow assist is available. A semi-autonomous system for reversing, the driver uses a rotary switch on the central console after configuring requirements on the car's central screen. Responsive trajectory lines help the driver, with information fed from cameras fitted to the car's door mirrors.

A claimed "industry-first" is Nose Load Measurement that facilitates a quick check on weight being applied to the towbar by a trailer to ensure it is within a 129-kg (284-lb) limit. It can be operated via the Discovery's touchscreen or a smartphone.

Interior packaging improvements

Vehicle length is 4970 mm (196 in) on a wheelbase of 2922 mm (115 in). Height is 1846 mm (72.6 in) and width including mirrors 2220 mm (87.4 in).

Packaging has been a major aspect of all Discovery iterations. The Discovery has a one-piece upward opening tailgate but there is also a powered, fold-down panel that doubles as a load restraint and also as a 285-mm-long (11.2-in) bench for event seating such as horse shows. It is designed to support a weight of 300 kg (661 lb), to cope with the Discovery's occupants consuming an exceptionally good picnic lunch.

Stuart Birch

Honda's all-new 2017 CR-V: Larger, lighter, turbocharged

Honda said the 2017 CR-V is all-new, with larger dimensions and a more-spacious interior.

The 2017 CR-V's chassis doesn't stray from the current norm: strut front suspension and a multi-link rear arrangement.

Barely a week after **Honda** announced its CR-V compact crossover posted an all-time U.S. sales record for the month of September, the company revealed an all-new, fifth-generation 2017 CR-V that is larger than the outgoing vehicle, somewhat lighter and offers a turbocharged engine for the first time. Honda said the 2017 CR-V will be in U.S. showrooms in December.

With crossover models threatening to eclipse sales of perennially best-selling sedans in many car companies' model lineups, the CR-V is increasingly important in Honda's cosmos, said John Mendel, Executive Vice President of American Honda, at a press briefing in Detroit. In September 2016, sales for the incumbent CR-V surpassed Honda's Accord and Civic passenger cars—and the CR-V's year-to-date sales of 263,493 brushed ahead of Accord and trailed by just 20,000 units the Civic, which itself is experiencing one of its strongest-ever sales years.

New platform, more space

Although Honda had yet to provide all technical details, the 2017 CR-V's Civic-based vehicle architecture is claimed to be all-new and extends wheelbase to 104.7 in (2659 mm)—a 1.6-in (41 mm) stretch over the outgoing CR-V—while the new model's overall length of 180.6 in (4587 mm) is 1.2 in (30 mm) longer.

At 73 in (1854 mm) wide, the 2017 CR-V is also 1.4 in (36 mm) wider than the current-generation model. Jeff Conrad, Senior Vice President of the Honda division of American Honda, said

The CR-V's first-ever turbocharged engine is a 1.5-L inline-4 that generates 190 hp. The prominent assembly atop the engine is a resonator to process and dampen turbocharger intake noise.

the new 2017 CR-V has 2 in (51 mm) more rear-seat legroom and will claim class-leading interior volume, including a cargo area that is 10 in (254 mm) longer than before.

Lightweighting remains an industry mantra and despite the new CR-V's increased size, Honda has somewhat reduced weight for its newest compact crossover. A base 2017 CR-V LX with front-wheel drive weighs 3358 lb (1523 kg)—roughly 51 lb (23 kg) lighter than a comparable current-generation CR-V. At the top of the lineup, an all-wheel drive Touring model, at 3512 lb (1593 kg), comes in 112 lb (51 kg) lighter than its 2016 counterpart. Honda said 14% of the new CR-V structure/body is comprised of high-strength steel.

First-ever turbocharged power

The 2017 CR-V LX—the base level of four-trim lineup—uses the carryover naturally-aspirated direct-injection 2.4-L inline-4 that delivers a claimed 184 hp (137 kW) and 180 lb·ft (244 N·m). But the CR-V EX, EX-L and Touring models are standard with a turbocharged 1.5-L unit that generates 190 hp (141 kW) and 179 lb·ft (243 N·m). The 2017 model marks the first use of a turbocharged engine for the CR-V.

The new engine, which first was fitted for the current Civic lineup, features a mono-scroll **Mitsubishi** turbocharger capped at 16.5-psi (1.1 bar) boost pressure and a large resonance chamber atop the engine that is unique to the CR-V application. The engine has a 10.3:1 compression ratio and while Conrad said Honda expects best-in-class fuel-economy ratings, the company was not yet prepared at the media preview to specify either fuel-economy or "top class" acceleration figures.

The only available transmission is a continuously-variable automatic; the LX model gets a 5.05:1 final-drive ratio, while all other models use a 5.64 final-drive. Front- or all-wheel-drive will be available for all 2017 CR-V trim levels and towing capacity for all models remains 1500 lb (680 kg).

Higher refinement, more electronic safety

Conrad said Honda decided to increase the luxury and refinement quotient for the new CR-V, making standard higher-grade trim and a variety of electronic and convenience features.

A rearview camera (required by U.S. regulations for May 2018) is standard for all models; guidelines are dynamic for all but the LX. And all but the LX come standard with the company's Honda Sensing suite of electronic safety features (forward-collision warning, lane-departure warning, collision-mitigation automatic braking).

Further increasing the safety content, all CR-Vs but the LX also are fitted with blind-spot warning, lane-keeping assist, adaptive cruise control and automatic high-beam headlight control.

The new CR-V will be built in three plants in North America: East Liberty, OH and Alliston, Ont., Canada, which build the current model, and Honda is adding CR-V production for the first time at the company's assembly plant in Greensburg, IN.

Bill Visnic

Ram Rebel TRX concept has 2017 Ford Raptor in its sights

It was a showdown between the latest full-size performance pickups at the 2016 State Fair of Texas in Dallas, where **SAE** torque and towing ratings are worshiped as devoutly as homemade barbeque. At this year's State Fair, **Ram**'s Rebel TRX 2017 concept was pitted against **Ford**'s eagerly awaited production 2017 F-150 Raptor—two trucks aimed at the most rabid fans of each brand and off-road pickup enthusiasts in general.

Under the hoods

Heart of the Ram Rebel TRX concept is a 6.2-L supercharged Hemi V8 delivering an SAE-rated 575 hp (428 kW) mated with the 8-speed 8HP70 automatic. According to **FCA North America**, the TRX concept is the most powerful half-ton truck the company has ever built.

The 6000-lb GVW (2721 kg) concept "demands an engine with specific abilities in a small package. Reaching such horsepower per-liter efficiencies requires forced induction," Bob Lee, FCA North America's propulsion system engineering chief, said. New engine and driveline calibrations were required, including in the Ram 4x4 Performance Control System, to optimize the expected duty cycle for punishing off-road driving.

The engine uses a Roots-type blower, rather than the twin-screw Lysholm-type supercharger used on the 707-hp (527-kW) "Hellcat" version of the Hemi. The inherently tall stance of the blower/intake manifold system made for a tall engine package. This in turn required alterations to the Ram 1500 engine bay and forward cab area and a modified Ram 2500-series HD hood is used for additional clearance. A custom induction system was designed to keep the ravenous blower adequately fed.

"This is the first time we've mated such an engine to this drivetrain and this vehicle architecture, so there was a lot of adaptation required," Jeff Reece, vehicle development engineer from FCA North America's SRT group and member of the Rebel concept build team, explained during the State Fair. A key upgrade is the forged-steel crankshaft with induction-hardened bearing surfaces able to withstand firing pressures of 1595 psi (110 bar). A specially tuned crank damper has been tested to 13,000 rpm.

Ford engineers took a markedly different route to performance on the 2017 Raptor, using Ford's all-new second-generation 3.5-L twin-turbo high-output V6. The EcoBoost engine is SAE-rated at 450 hp (335 kW) and 510 lb·ft (691 N·m), delivered across a wide power band.

"Raptor was designed to be a no-compromise, off-road performance machine," said Matt Tranter, Ford performance engineering supervisor. "That is why we made the switch from the cast-iron V8 to the aluminum block, high-output GTDI V6 EcoBoost engine that our team tuned to add 39 horsepower and 76 lb·ft of torque for today's Raptor."

A look inside Ford's all-new 3.5-L twin-turbo V6 as used in the 2017 Raptor delivers 510 lb·ft to the new Ford-GM co-developed 10R70 10-speed automatic. (Lindsay Brooke photo)

Internal engineering upgrades include a new twin fuel injection set-up that employs both direct and port-injection strategies; stronger and lighter crank and valvetrain components; a redesigned twin-turbocharger system with electronic wastegate and a redesigned valve train and variable-displacement oil pump.

Among the high-output EcoBoost performance enhancements for Raptor, according to Ford, are more aggressive turbo compressors with increased boost calibrations, cast stainless steel exhaust manifolds (feeding full dual exhaust), oil-cooled pistons and more aggressive engine control calibrations.

"Looking at the torque curve of the Raptor's EcoBoost engine, you see the twin turbos spool quicker for faster time to torque—it hammers quick and keeps delivering torque for a more brawny feel than its V8 predecessor," said Al Cockerill, Raptor's powertrain development engineer.

10-speed vs. 8-speed

The new Raptor represents a milestone for Ford and for the auto industry overall—the first production application of a 10-speed planetary automatic in a light-duty vehicle. Mated to an exclusive-to-Raptor transfer case and managed by a six-mode Terrain Management System, the new 10R80 was co-developed with **General Motors Global Propulsion Systems** engineers (see July 2016 cover feature, http://magazine.sae.org/auto/).

The new 10R80—8th, 9th and 10th gears are overdriven—brings new features including a standard Auto Start-Stop function and an integrated electric fluid pump. Its 7.4 ratio spread and Ford-patented hydraulic control system better optimize the power and torque curves of the new EcoBoost engine, according to Ford.

Raptor's all-new adaptive shift

algorithms monitor more than a dozen powertrain and driver inputs in real time. Drivers have normal, sport, weather, mud/sand, rock/crawl and Baja modes at their disposal for tackling nearly any traction condition. A high-speed, one-way clutch allows for non-sequential shifting.

While it makes do with "only" eight forward ratios, the Ram Rebel TRX concept's **ZF**-designed 8HP70 has more than enough input torque capacity to handle the supercharged V8. The truck is fitted with paddle controls for manual shifting capability—and in Auto mode, more than 40 individual shift maps are available for specific driving, performance and fuel-efficiency conditions, engineers said. Sending torque to the four driving wheels is a standard Ram 1500 front driveshaft and a custom rear driveshaft.

'Bones' of the trucks

FCA and Ford engineers also chose different paths for their performance trucks' structures, the Ram Rebel TRX concept relying on a high-strength-steel-intensive cab and cargo bed, while the Ford guys employ the same 5000- and 6000-series aluminum alloys from **Alcoa** and **Novelis** as those of the standard F-150. Both trucks use fully boxed steel ladder frames.

Under the skin of the Rebel, front and rear bypass-type performance shocks deliver fast-reaction time, improved damping and improved heat dissipation for traversing harsh terrain at speeds greater than 100 mph, engineers claim. The truck's "purpose-built hourglass design," as Ram brand boss Jim Morrison describes the exterior styling, includes six inches (152 mm) additional width versus the current production Ram Rebel. This enables the concept vehicle "to house the 37s [mammoth 37-in-diameter tires] at full jounce and rebound—you can get full-wheel motion here with the extra six inches and the big fenders that are built into the truck," Morrison said.

Ford's latest Raptor sports new gas-charged 3.0-in-diameter (75 mm, up from 2.5-in) **Fox** shocks. They feature a base valve piston to allow lower internal gas pressure, for increased ride comfort on the road. The internal bypass in the front and rear shocks has nine distinct zones that progressively manage shock forces, allowing for smooth on-road trips along with hard-hitting off-road driving.

Near monster-sized wheels and tires, huge front skid plates, in-your-face styling and stump-pulling torque make the 2017 Ford Raptor (left) and Ram Rebel TRX concept off-road performance trucks the antithesis of the autonomous transportation pod.

To be or not to be?

Industry speculation is rampant regarding whether or not the Ram Rebel TRX concept will make it to production to give the Ford Raptor competition in the off-road performance truck segment.

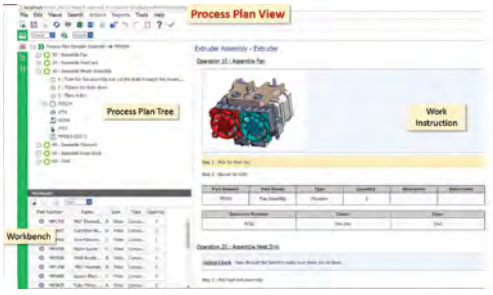
"One of the reasons we build a concept vehicle is to gauge interest, so we are looking for feedback. We made it a runner so we could learn from it," Reece told *Automotive Engineering* at the State Fair. While FCA's next steps are yet to be determined, the Rebel TRX and its rapid 77-day gestation are impressive.

Jennifer Shuttleworth

PRODUCT BRIEFS

SPOTLIGHT: PRODUCT LIFECYCLE MANAGEMENT

PLM platform for manufacturing process planning



Aras Manufacturing Process Planning (MPP) is a new product lifecycle management (PLM) platform-based application from **Aras** (Andover, MA) for managing the complex business processes that extend from product development through manufacturing. New capabilities bring together the MPP, Work Instructions and Manufacturing Bill of Materials (MBOM), making them interdependent and automatically synchronized as changes occur. According to the company, this capability enables direct Engineering Bill of Materials (EBOM) to MBOM translation, bridging the gap enterprises have and creating the process foundation necessary for Industry 4.0 and Industrial Internet initiatives. Additional benefits, according to Aras, include letting automotive product teams eliminate time-consuming manual processes and costly EBOM/MBOM conflicts, improve efficiency by synchronizing process plans, MBOMs and work instructions, and implement a digital thread with as-designed to as-planned traceability. For more information, visit **www.aras.com**.

Test and CAE simulation software application

Aqira from **HBM Prenscia** (Tucson, AZ) is a brand-new software application that leverages existing nCode products and enables streamlined processes for durability, for both test and CAE simulation. According to HBM Prenscia, Aqira addresses the demanding requirements of engineers, managers and IT in an intuitive and efficient system. Using the latest technology, Aqira delivers an integrated engineering solution for all levels of users, across physical test and virtual simulation departments globally. It provides the ability to manage processes and share analytical processes, run nCode software fully over the Web with no nCode software stored on user machines, create and use engineering apps, perform scalable, server-based analysis, benefit from cost-effective deployment and licensing, and control and track Prenscia Access license token usage. For more information, visit **www.ncode.com/aqira**.

Rapid overmolding process

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

SIDACtor protection thyristors

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

Electric-vehicle fuses

Eaton's (St. Louis, MO) new Bussmann series electric vehicle (EV) fuses are specifically designed to protect sensitive electric and hybrid automotive equipment, including high-voltage, high-capacity batteries, power-conversion equipment, contactors, cabling and other auxiliary circuits. According to Eaton, the design enhances electrical system safety and reduces potential warranty costs. With protection as low as 135% of rated current, the compact and lightweight Bussmann series EV fuses can protect a wider range of overcurrent conditions while avoiding nuisance operations associated with cycling fatigue. In addition, the fuses are engineered with a 20 kA interrupting rating to enable longer vehicle range by protecting higher capacity and more efficient batteries with higher fault currents. For more information, visit **www.eaton.com**.

Non-hazardous specialty polymers

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

High-flow transmission valve

Nachi America, Inc.'s (Greenwood, IN) automotive hydraulics division has developed a 2-way automatic transmission valve that supports the increased OE demands for large volumes of transmission fluid. New architecture features like Idle Stop technology require a higher flow of fluid to clutches. According to the company, its design is one answer to this challenge: the design can fill the accumulator in a short time to prepare the system for the next cycle. It's capable of 40 L/min (10.6 gal/min) while working with a low differential pressure application of 800 kPa (116 psi) at 80°C (176°F), while also keeping the leakage to a minimum of 1.5 cc/min. For more information, visit **www.nachiamerica.com**.

Flying probe technology and high frequency testing

The push toward miniaturization in the electronics industry has left designers little or no room for test points, and the expansion of high frequency (HF) technologies has resulted in a growing need for test equipment that has the capability to verify these types of generally very small circuits. **Seica**'s (Salem, NH) Pilot4D V8 HF offers a solution combining flying probe technology and high frequency testing. Using its very precise probing capabilities to contact even the smallest points (down to 008004 components), the system's dedicated HF instrumentation has been integrated to provide the capability to verify HF signals up to 1.6 GHz. The solution includes a number of hardware and software innovations to create the electrical conditions necessary to perform these high performance measurements, which include clock frequency, rise and fall times, setup and hold time of critical signals. For more information, visit **www.seica.com**.

Heavy-duty LVIT inductive linear position sensors

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

Gas-damped auto crash sensor

The new Endevco model 7264H from **Meggitt Sensing Systems** (Irvine, CA) is an optimally gas-damped accelerometer for automotive safety testing with target applications that include pedestrian safety, military-vehicle and sled testing. Small in size and mass, the 7264H eliminates irrelevant frequency content generated by breaking glass and metal-to-metal impact. Unlike fluid-damped sensors, it performs consistently over temperatures ranging from -18 to +66°C (0 to +150°F). According to the company, using an innovative MEMS design, the 7264H has a much wider frequency measurement range compared to conventional fluid-damped sensors. Key features include frequency response flat from dc to 3500 Hz, full scale range of 1000 g, and 0.50 to 0.85 damping ratio. For more information, visit **www.meggittsensingsystems.com**.

Interactive 3D PDF technology

Tech Soft 3D (Bend, OR) offers enhancements to its Tetra 4D Converter, a solution for converting 3D CAD to 3D PDFs, and Tetra4D Enrich, a new application that enables the creation of rich, interactive 3D PDF documents quickly and easily directly inside of **Adobe** Acrobat [Professional]. Together, Tetra4D Converter and Tetra4D Enrich support multiple workflows that allow users to package precise solid geometry and all necessary PMI into a lightweight, sharable format. The enhancements include format updates for **Dassault Systèmes** CATIA and **Autodesk** Inventor, as well as adding STEP AP242 export, a standard for 3D model-based engineering suitable for the defense and automotive industries. For more information, visit **www.techsoft3d.com** and **www.tetra4d.com**.

UPCOMING WEBINARS

SIFT-MS: THE SINGLE SOLUTION FOR RAPID VEHICLE INTERIOR AIR QUALITY (VIAQ) TESTING

Available On-Demand until November 2, 2017

Regulators and consumers demand lower levels of harmful volatile emissions in motor vehicle passenger cabins, pushing manufacturers toward more comprehensive testing. This 60-minute Webinar introduces SIFT-MS and outlines the benefits that make it the ideal tool for product emission testing applications from component screening through to complete vehicle testing on the production line.

Speakers:

Barry Prince, Ph.D.
Director of Global Sales, Syft Technologies

Vaughan Langford, Ph.D.
Director of Applications & Marketing, Syft Technologies

Lisa Arrigo
SAE International

Sponsored by: syft™ Technologies

Hosted by: SAE INTERNATIONAL

For additional details and to register visit: www.sae.org/webcasts

---

VALIDATION OF MATERIAL MODELS: STUDY OF JOINING AND ASSEMBLY SYSTEMS FOR THERMOSET AND THERMOPLASTIC COMPOSITE MATERIALS

Thursday, November 10, 2016 at 1:00 pm U.S. EST

This Webinar presents an overview of a four-year study to validate and assess the ability of physics-based material models to predict crash performance of automotive primary load-carrying carbon fiber composite structures. The Webinar focuses on the joining of the front bumper and crush-can system components and will examine: joining approach and design, adhesive selection, joining procedure, and an assessment of the joining technology.

Speakers:

Arthur Cawley
Group Leader, Dow Automotive Systems

Dr. Manish Mehta, Ph.D.
USAMP VMM Project Manager, President, M-Tech International LLC

Lisa Arrigo
SAE International

Sponsored by: DOW®

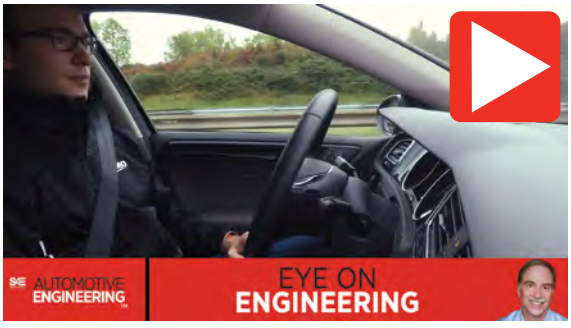
Hosted by: SAE INTERNATIONAL

For additional details and to register visit: www.sae.org/webcasts

WHAT'S ONLINE

VIDEO

SAE Eye on Engineering Quick Take: Valeo demo ride in Paris



The term "sensor fusion" describes how a car's radar, cameras and other sensors work together to keep the vehicle moving safely in any situation. In this episode of SAE Eye on Engineering, Editor-in-Chief Lindsay Brooke gets a first-hand look at **Valeo**'s self-driving prototype car. SAE Eye on Engineering can be viewed at **video.sae.org/12224**. It also airs in audio-only form Monday mornings on WJR 760 AM Detroit's Paul W. Smith Show. Access archived episodes of SAE Eye on Engineering at **sae.org/magazines/podcasts**.

WHAT'S NEW

First-of-its-kind high-volume production cell set to start producing competitive CNG tanks for auto industry

Composite machine manufacturer **Mikrosam** delivered a fully automated filament winding line for compressed natural gas (CNG) tanks to automotive supplier **Magna**'s Austria plant. According to the Macedonian company, this high-volume production cell was invented for manufacturing a cost-effective, lightweight CNG tank module. Using filament winding technology and application of composite materials produced an alternative propulsion system that would result in reduction of car weight up to 50%, as well as 40% lower fuel expenses, claims Mikrosam.

The filament-winding technology also has the potential to reduce manufacturing cost of composite pressure tanks needed for both CNG and hydrogen—for years an impediment to the introduction of high-pressure gaseous fuels for automotive use. The current price of such tanks is, of course, many times that of incumbent stamped-steel or blow-molded plastic gasoline tanks.

Read the full article at **articles.sae.org/15013/**.

WHAT'S NEW

Bosch inaugurates tech center in Pittsburgh

Increasing its presence in a region some are beginning to refer to as "Silicon Valley – East," Germany-based auto supplier **Bosch** in September opened an expanded technical center in Pittsburgh, PA, doubling the size of its longstanding technical facility at another site in the city that has become a hotbed of autonomous-vehicle and robotics development.

The 51,000 sq-ft facility, which eventually will house 170 personnel, is located in Pittsburgh's historic Strip District and is near **Carnegie Mellon University**, Bosch's research partner for more than 25 years. Also nearby is ride-hailing giant **Uber**'s Advanced Technology Center, central hub for a fleet of autonomous-driving **Ford** Fusions the company recently placed in service around the city.

At the opening ceremony for the new facility, Bosch officials said the facility will become part of an "innovation framework" between several of the company's technical business units and departments and research institutions in Pittsburgh.

Read the full article at **articles.sae.org/15007/**.

COMPANIES MENTIONED

Company	Page
Adobe	36
Alcoa	33
Alliance Sensors Group	36
Alphabet	13
American Axle & Manufacturing	24
American Motors	40
Apple	19, 24
Aras	34
Audi	4
Autodesk	36
BMW	20, 40
Bosch	38
BP Castrol	10
Carnegie Mellon University	38
Chevrolet	26
Chrysler	40
Clearpath	25
COMSOL	14
Connected Strategy Advisors	19
Continental	18
Dassault Systèmes	36
Delphi	16
Eaton	35
EpoxySet	35
Faurecia	22
FCA North America	32
FiatChrysler	18
Ford Motor Company	16, 32, 38
Fox	33
GE Digital	24
General Motors	16, 26, 40
General Motors Global Propulsion Systems	32
GM Ventures	16
Google	13
Harman International	16
HBM Prenscia	34
Honda	30
IHS Automotive	18
Infiniti	6
JaguarLandRover	28
LG Chem	26
LG Chem Power	12
Littelfuse	34
Magna	23, 38
Meggitt Sensing Systems	36
Mercedes	20
Microsoft	25
Mikrosam	38
Mitsubishi	31
Nachi America	35
Nissan	6
Novelis	33
Opel	26
Panasonic	20, 26
Pioneer Automotive Technologies	19
Plex Systems	23
Proto Labs	34
Ram	32
Range Rover	28
Renault	40
SAE International	10, 16, 20, 26, 32
Seica	36
Tech Soft 3D	36
Tesla	20, 27
Toyota	24
Uber	38
U.S. Department of Energy	12
U.S. Marine Corps	40
Valeo	38
Volkswagen	4, 26
Volvo	25
VW-Audi	20
ZF	25, 29, 33

AD INDEX

Advertiser	Page	Web Link
ALPS Electric Co., Ltd.	19	www.alps.com
American Axle & Manufacturing, Inc.	35	www.aam.com/careers
Coilcraft CPS	33	coilcraft.com
COMSOL, Inc.	Cover 4	comsol.com/application-builder
dSPACE, Inc.	11	www.dspace.com
Embedded Systems Technology	15	www.essetek.com
Federal-Mogul Powertrain	1	www.federalmogul.com
Gerdau Special Steel North America	17	www.gerdau.com/northamerica
HARMAN	Cover 2	car.harman.com
Huntsman Corporation	5	www.huntsman.com/auto
KOA Speer Electronics, Inc.	30	KOASpeerAuto.com
MathWorks Inc.	3	mathworks.com/mbd
Newcomb Spring Corporation	36	NewcombSpring.com/TechCenter
Omega Engineering	13	omega.com
Proto Labs, Inc.	9	go.protolabs.com/SAE6A
SHILOH Industries	7	shiloh.com
Synopsys, Inc.	31	www.synopsys.com/autovdk
TAMAGAWA SEIKI Co., Ltd.	27	www.tamagawa-seiki.co.jp
Umicore	29	www.chemistry.umicore.com

STATEMENT OF OWNERSHIP

U.S. Postal Service Statement of Ownership (Required by 39 U.S.C. 3685) 1. Publication Title: Automotive Engineering 2. Publication Number: 0474-0100 3. Filing Date: 10/20/16 4. Issue Frequency: Monthly 5. No. of Issues Published Annually: 9 6. Annual Subscription Price: $115.00 7. Complete Mailing Address of Known Office of Publication (Street, City, County, State, and Zip+4) (Not printer): ABP International (d/b/a Tech Briefs Media Group), an SAE International Company, 261 Fifth Avenue, Suite 1901, New York, NY 10016 8. Complete Mailing Address of Headquarters or General Business Office of Publisher (Not printer): SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001 9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor. Publisher (Name and Complete Mailing Address): Joseph T. Pramberger, 261 Fifth Avenue, Suite 1901, New York, NY 10016; Editor (Name and Complete Mailing Address): Lindsay Brooke, 400 Commonwealth Drive, Warrendale, PA 15096-0001 Managing Editor: None 10. Owner (If the publication is owned by a corporation, give the name and address of the corporation immediately followed by the names and addresses of all stockholders owning or holding 1 percent or more of the total amount of stock. If not owned by a corporation, give the names and addresses of the individual owners. If owned by a partnership or other unincorporated firm, give its name and address as well as those of each individual owner. If the publication is published by a nonprofit organization, give its name and address). Full Name and Complete Mailing Address: SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001 11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages, or Other Securities. Full Name and Complete Mailing Address: None 12. For Completion of Nonprofit Organizations Authorized to Mail at Nonprofit Rates. The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes: Not applicable 13. Publication Name: Automotive Engineering 14. Issue Date for Circulation Data Below: November 2016 15. Extent and Nature of Circulation (Average No. Copies Each Issue During Preceding 12 Months/ Actual No. Copies of Single Issue Published Nearest to Filing Date): a. Total No. Copies (Net Press Run): 50,889/43,126 b. Paid and/or Requested Circulation: (1) Paid or Requested Mail Subscriptions (Include Advertisers' Proof Copies/Exchange Copies): 44,145/36,223 (2) Mailed In-County Paid Subscriptions Stated on PS Form 3541 [include paid distribution above nominal rate, advertiser's proof copies, and exchange copies] none/none (3) Paid Distribution Outside the Mail Including Sales Through Dealers and Carriers, Street Vendors, and Counter Sales, and Other Paid Distribution Outside USPS: 3,728/3,558 c. Total Paid and/or Requested Circulation (Sum of 15b(1), 15b(2), and 15b(3): 47,873/39,781 d. Free Distribution by Mail (Samples, Complimentary, and Other Free): (1) Nonrequested Copies Stated on PS Form 3541: 802/1,304 (2) Free or Nominal Rate In-County Copies Included on PS Form 3541 none/none (3) Nonrequested Copies Distributed Through the USPS by Other Classes of Mail: none/none (4) Nonrequested Copies Distributed Outside the Mail: 789/2,249 e. Total Nonrequested Distribution (Sum of 15d (1), (2), and (3)): 1,591/3,553 f. Total Distribution (Sum of 15c and 15e): 49,464/43,334 g. Copies Not Distributed: 1,425/1,096 h. TOTAL (Sum of 15f and 15g): 50,889/44,430 i. Percent Paid and/ or Requested Circulation (15c ÷ f times 100): 94.1%/89.5% 16. This Statement of Ownership will be printed in the November 2016 issue of this publication. 17. I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties): Joseph T. Pramberger, Publisher.

Q&A

Lutz: "Train yourself to realize you can't win every battle."

Bob Lutz: What makes a great engineer?

Throughout the 2016 documentary film *Live Another Day* about the fall and rise of the Detroit-3 automakers, former **GM** Vice Chairman Bob Lutz shows the insight and enthusiasm that made him one of the industry's most effective "product guys" for four decades. While Lutz, now 84, actually holds a marketing MBA, his practical knowledge of aircraft design, systems and aerodynamics learned as a **U.S. Marine Corps** fighter pilot combined with a life-long love of cars, motorcycles and aircraft made him, as he says, "a close friend of engineers and designers." He spoke recently with editor-in-chief Lindsay Brooke.

I've met many good engineers in my +30 years covering the industry. But what makes a great one?
Truly great engineers obviously have the intellect for handling the complexities of the math, combined with a thorough passion for the product. They tend to be left-and-right-brained thinkers. The president of a major engineering university once told me that General Motors would only recruit his students who had the top grade-point averages. He argued that GPA alone does not make the best engineers. He said the kids he'd hire himself are the ones who might have a 2.7 [GPA] but who are absolute fanatics about whatever project they're working on. They've got dirty fingernails from testing their theories and some even cut short their study time because they're so passionate about their projects.

I agree. Some of the best engineers I've worked with are hands-on, very outcome-focused. And non-political.

What about leadership?
The passionate engineer then must trigger that same or greater enthusiasm in the people he or she is leading. Two people come to mind whom I think were exceptionally good at that. First and foremost is Francois Castaing [Executive VP of Engineering at **Chrysler** during its 1990s heyday who achieved earlier successes at **Renault** and **American Motors**]. Castaing was fabulous—he'd been in charge of Renault's Formula 1 racing team. In racing if you don't win on Sunday you re-design on Monday, you finish re-engineering the new parts on Tuesday and Wednesday, you fabricate them on Thursday and you test on Friday. It's all short lead time, roll-up-your-sleeves and get the job done.

Francois was like that—and constantly doing things that were accepted by the system as being impossible. He loved challenges.

The other great engineer is Jim Queen [former GM Group VP Global Engineering], a superb leader and former Marine pilot who flew F4 Phantoms. I felt that Jim got a lot of things done by the power of his leadership that lesser people couldn't have accomplished. Jim wasn't as enthusiastic about driving as Francois was—at the proving ground I never got to drive first if Francois was there.

How is it that engineers who are highly effective simply being engineers often turn out to be much less so when they move into management?
Even Francois found that to be tough, because he couldn't understand senior management decisions that were counter-intuitive. But you just train yourself to realize you can't win every battle.

What's the key to engineering greatness?
The willingness to take intelligent risks—both reputational and risks with the product. If you're not willing to put your credibility on the line, I don't think you're going to achieve anything. To always 'go with the flow' is not great-engineer stuff.

How about great engineers at BMW?
When I was at **BMW** [1971-74, Executive VP Global Sales and Marketing] there were almost no engineers in senior positions. There were plenty of bureaucrats, however. That was my big surprise when I first went to BMW from GM Europe. I thought everybody was going to be enormously product focused, like me, and passionate about the cars.

When I wanted to put some nice artwork of BMW's racing history in the lobby of the top floor of BMW headquarters in Munich where the chairman and members of the management board had their offices, I was told, 'Mr. Lutz, the senior executive floor is a dignified place. Automotive subjects have no place here.' That surprised the hell out of me and it made me wonder how we made such great cars. Then I found out senior management was blissfully unaware of what was going on in the product area.

At BMW the great engineering took place at a level well below senior management. We had Alexander von Falkenhausen, the brilliant engine guy. He did our first V-12 based on two 2.5-L inline sixes, in a few weeks.

The truly great engineers like Castaing, Queen and von Falkenhausen tend to be outcome-oriented versus process-oriented. That counts a lot with me because that old 'If you get the process right, the product will be right' bullshit often doesn't work. If you have a perfect process with the wrong goals, you won't have anything worthwhile.

Lindsay Brooke

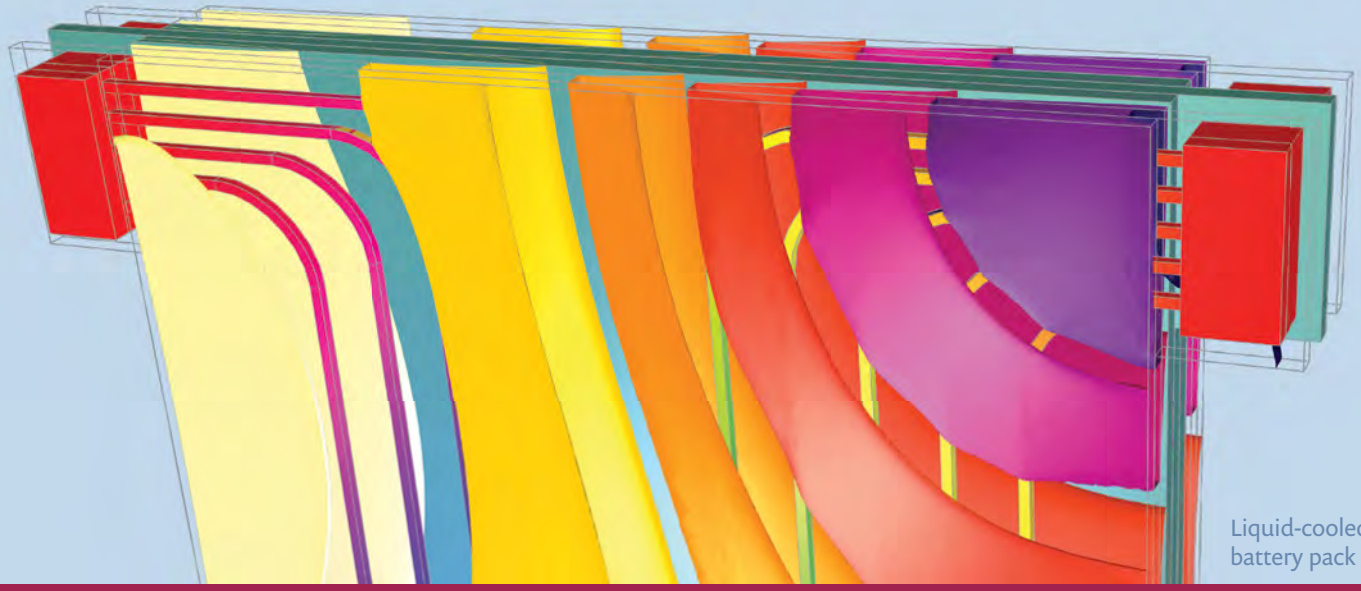
NEW

SAE CAREER COUNSELOR SERIES

Concise, effective training videos focused on your career needs:

- Time Management
- Goal Setting Strategies
- Communication Strategies
- Generations in the Workplace
- And more...

View the episodes at go.sae.org/careercounselor.html



Liquid-cooled battery pack

MULTIPHYSICS FOR EVERYONE

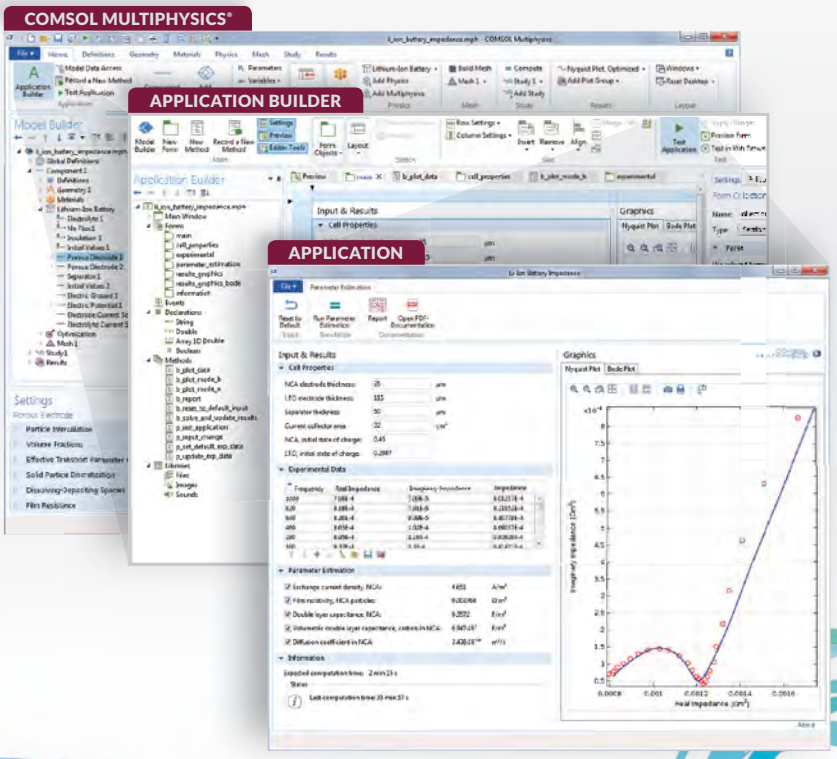
The evolution of computational tools for numerical simulation of physics-based systems has reached a major milestone.

Custom applications are now being developed by simulation specialists using the Application Builder in COMSOL Multiphysics®.

With a local installation of COMSOL Server™, applications can be deployed within an entire organization and accessed worldwide.

Make your organization truly benefit from the power of analysis.

comsol.com/application-builder



Li-ion battery

COMSOL