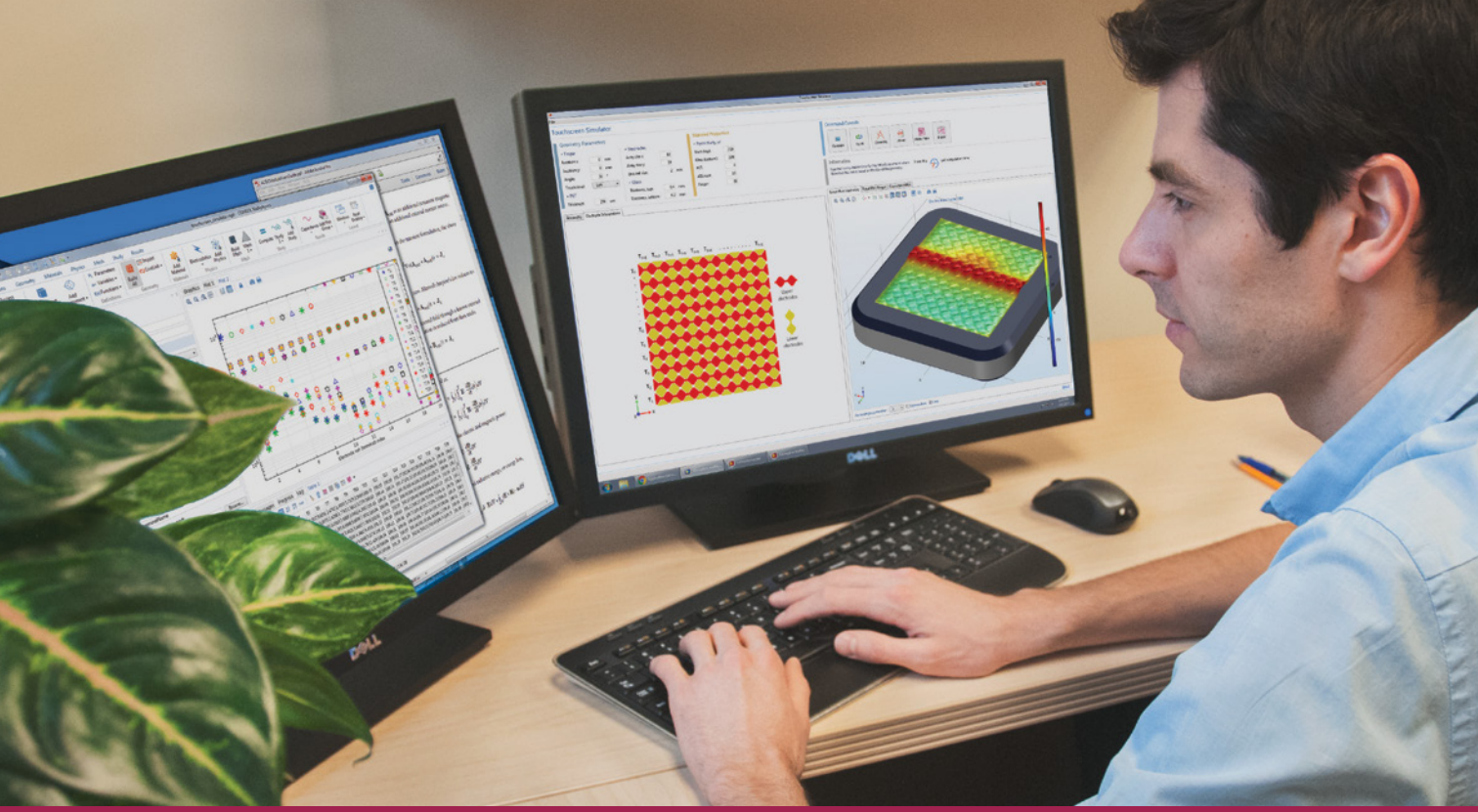

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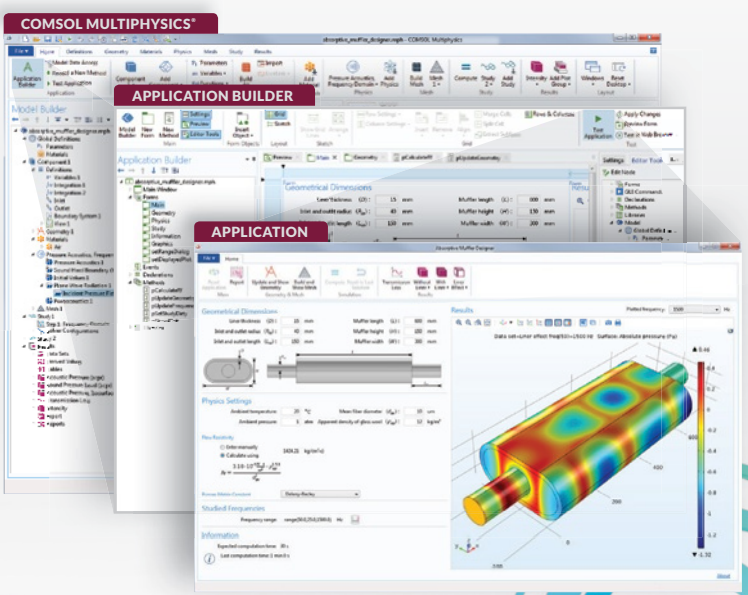

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ON THE COVER

There's no denying tech-company start-ups have profoundly influenced the auto industry's move into vehicle electrification, connectivity, and autonomous driving. But "traditional" OEMs and Tier 1s are defying the disruptors and, in many cases, driving greater innovation. In our April cover feature, four top engineering execs from GM, LG Chem Power, Delphi Automotive, and AVL discuss their technology opportunities and business growth amid the start-ups.

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WHAT'S ONLINE

NEW YORK AUTO SHOW 2016 COVERAGE

Mazda reveals retractable-hardtop MX-5 RF

Moving quickly to expand the appeal of the all-new, fourth-generation MX-5 Miata roadster introduced last year, **Mazda** revealed prior to March's 2016 New York auto show a folding hardtop version of the car called MX-5 RF, for "retractable fastback."

Mazda invokes the "fastback" descriptor because, unlike the prior-generation MX-5's power retractable hardtop (PHRT) that folded the entire roof assembly in a storage area behind the seats, the 2017 MX-5 RF effectively is more of a "targa" design: only the roof's center section and the rear glass are removed, leaving buttresses on either side. When the roof-retraction process begins (no exact figure yet from Mazda regarding how long it takes), the one-piece side-buttress section briefly unlatches to release the retractable roof section—but then somewhat disappointingly reattaches instead of disappearing.

Read more at http://articles.sae.org/14695/. Other New York reveals, including the 2017 **Toyota** Prius Prime and the **Lincoln** Navigator Concept, are covered at http://autoengineering.sae.org/.

VIDEO

SAE Eye on Engineering: Regulating self-driving cars

Before self-driving cars without steering wheels and gas pedals can be sold in the U.S., automakers and states will have to clear some major regulatory hurdles. In this episode of SAE Eye on Engineering, Editor-in-Chief Lindsay Brooke looks at some of the issues facing the driverless revolution. The video can be viewed at https://youtu.be/FfLg6GCPpb0. SAE Eye on Engineering airs in audio-only form Monday mornings on WJR 760 AM Detroit's Paul W. Smith Show. Access archived episodes at www.sae.org/magazines/podcasts.

MEDIA PARTNERSHIP

Automotive experts to judge lightweighting contest

The group of automotive industry professionals serving as judges for the fourth annual 2016 **Altair** Enlighten Award includes *Automotive Engineering* Associate Editor Ryan Gehm. This year's panel will judge entrants in two categories: full vehicles and modules such as components, systems, and enabling technologies. The winners will be announced during the CAR Management Briefing Seminars in Traverse City, MI, on August 1, 2016. The award is held in collaboration with the **Center for Automotive Research** (CAR) and media partner **SAE International**.

The judging panel is joined this year by James Brancheau, a Member of Altair's Board of Directors and former Chief Technical Officer. The complete list of judges for 2016 can be found at www.altairenlighten.com/award.

"Lightweighting is one of a few strategic technologies that every auto manufacturer is striving for to improve performance and reduce fuel consumption. I expect to see the challenges of mixed materials to be demonstrated in this years' entries and look forward to the challenge of judging this years' nominations," said Dr. Jay Baron, CAR President and CEO.

"I believe the Enlighten Award is important to the automotive industry because it highlights and rewards one of the most significant challenges the industry faces: Creating efficient, cost-effective, lightweight structures is critical to reducing CO_2," said returning judge Chris Theodore, President of **Theodore & Associates** automotive industry consulting.

Applications for the 2016 Altair Enlighten Award must be received on or before May 20, 2016. Manufacturers and suppliers can access additional information about the nomination process at www.altairenlighten.com/award.

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EDITORIAL

C'mon Jeep, walk the walk

I stopped counting the marketing presentations I've attended that included a slide with the alleged Henry Ford quote regarding the folly of soliciting customer opinion: "If I had asked people what they wanted, they would have said faster horses."

Those words (which likely didn't really come from Henry) are perpetually employed as justification for "risk."

So, quick—what's the most recent production vehicle you can name that was a risk? I think there hasn't been one since the Great Recession began—with the possible exception of the aluminum-bodied **Ford** F-Series.

Jeep Comanche concept.

Risk-aversion thoughts red-lined to this page when we got a look at some of the spectacular concepts **Fiat Chrysler Automobiles' Jeep** brand trotted out for its annual Easter Jeep Safari in Moab, UT. Most who attended the media reveal of Jeep's seven concept vehicles believed the brand truly outdid itself for the Easter Safari's 50th anniversary. The vehicle that impressed most and seemed so ripe for production was the Comanche concept (p. 38), a small pickup based on FCA's global unibody structure used for the successful Jeep Renegade.

Sticking with the concept's soft top would be a low-volume death sentence, of course. But with a hardtop and a few other concessions to production necessities, the single-cab Comanche appears to be the "compact" truck many industry watchers believe is the missing link that closes the loop on the American consumers' current lust for all things pickup. The Comanche could sell, and in real volume.

Then the Henry Ford moment: While Jeep brand boss Mike Manley gave the boilerplate "we'll see" reply about the Comanche's production potential, some Jeep sources were conceding, in effect, "Management would never let us make it without four doors." That's code for "make it more profitable and less risky."

Four-door pickups are the family car of this generation. They have driven the Detroit 3's titanic post-recession profitability, and I understand why nobody wants to mess with that. But why put the brakes on expanding and exploiting the pickup segment in the same fashion as, say, crossover vehicles? **Honda** HR-Vs generate less margin and make less profit than Pilots, but that hasn't stopped Honda, or other automakers, from expanding downward to take advantage of the public's infatuation with crossovers.

For those who argue there is no profit in a small pickup, ask **General Motors** about "moving down": GM has a sales hit with its new midsize pickups all the experts said wouldn't be good business. GM salespeople tell me the **Chevy** Colorado and **GMC** Canyon sell themselves to customers who plainly say the full-size pickup footprint has become too gargantuan, their prices too inflated.

At a time when the expanding roster of B-segment "urban" crossovers are the hot ticket, a small urban pickup with two doors effectively addresses the same "need"—and the crazy-popular Jeep badge should seal the deal.

Or forget the marketing arguments. What happened to the product flexibility, investment efficiency, and speed-to-market global platforms are supposed to impart? It's time for FCA to make good on that big talk and green-light a genuine entry-level pickup.

Rather than ponder Henry Ford's mythical advice about consumer opinion, I'd look at the Comanche in light of a more-pertinent (and verified) Henry quote: "The competitor to be feared is one who never bothers about you at all—but goes on making his own business better all the time."

Bill Visnic, Editorial Director

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Automatic braking pact for 2022 will alter systems development

ZF TRW is among the Tier 1s who have done extensive work on AEB systems.

Vehicle OEMs have pledged to make automatic emergency braking (AEB) a standard feature by 2022, a move that is likely to alter electronic architectures and increase collaboration between module suppliers.

Twenty automakers recently teamed up with the **U.S. National Highway Traffic Safety Admin.** and the **Insurance Institute for Highway Safety** to set voluntary programs to move emergency braking from a luxury option to mainstream vehicles over the next few years.

For that to happen, many vehicle platforms will leverage hardware and software that's already being proven on roadways. However, these systems will all have to be tweaked to provide efficient performance on hundreds of different vehicle models.

"The main effort will be to validate and test systems on new platforms, which is not an insignificant job," said Dean McConnell, Project Management Leader at **Continental Automotive Systems**. "The other question mark is what the actual functional requirements are, the speed range, stopping distance and other functions that will be important differentiators."

IIHS estimates that as many as 20% of the 5 million vehicle crashes that occur annually in the U.S. could be prevented by the technology. The advantages of AEB were recently demonstrated to *Automotive Engineering*'s Editor-in-Chief during a winter-test session at **ZF TRW**'s proving ground near Arvidsjaur, Sweden.

Having driven AEB-equipped prototypes from various suppliers in previous dry-surface tests, this was the editor's first experience with AEB on a low-mμ-surface frozen lake. He came away convinced of the technology's high value in avoiding crashes as well as reducing the severity of crashes that may not be avoidable, by prepping the restraint systems before impact (see https://www.youtube.com/watch?v=8RxifQ_UDoA&feature=youtu.be).

Taxing engineering capacity

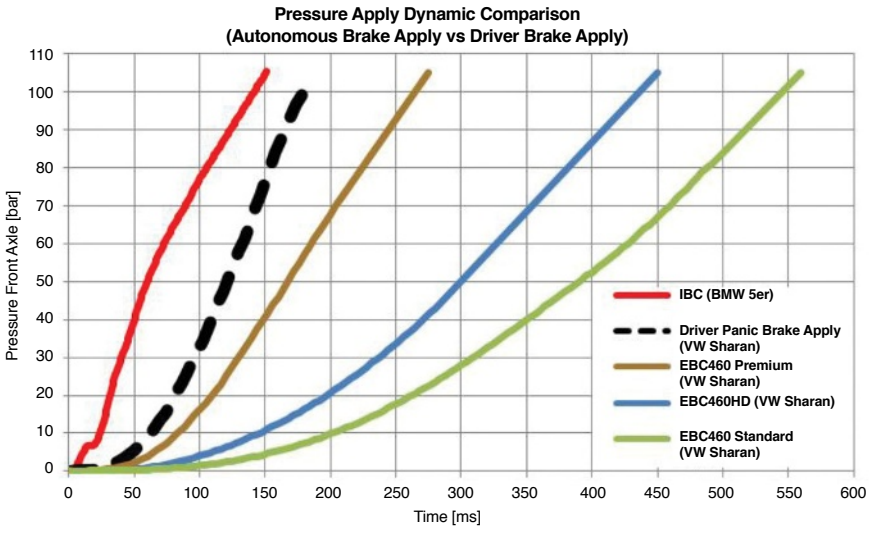
For the industry, the engineering task to implement AEB will encompass a number of different modules. Sensors will have to guarantee they're seeing something that's a potential threat. When a collision is imminent, several systems will have to work harmoniously to slow the vehicle without destabilizing it.

"There's generally a combination of sensors like cameras and radar, along with controllers, software and algorithms," said Frank Sgambati, Director of Innovation, Chassis Systems Control, at **Robert Bosch**. "They all have to work with vehicle braking systems and electronic stability control, all operating in concert."

Outfitting all these vehicles with AEB in just six years will require a lot of design and development effort. Modules will often come from multiple suppliers, which is likely to foster closer working agreements between suppliers as well as OEMs.

"The main challenge to meeting this goal is engineering capacity — the amount of work needed to add AEB technology to several hundred vehicle models," noted Aaron Jefferson, Director, Product Planning for ZF TRW Global

ZF TRW Automatic Emergency Braking with Integrated Brake Control (IBC)



ZF TRW has AEB systems with Integrated Brake Control (IBC) in the late-prototype stage. Advantages include regenerative functionality, no need for engine vacuum (a CO_2 benefit), smaller packaging and component and weight reduction.

Electronics. "This further enhances the need for multiple suppliers to work together efficiently."

More powerful controllers needed?

Shifting from option to standard function may also alter electronic architectures. Distributed computing is currently quite common, with microprocessors deployed in both sensors and controllers. When all cars have more generic types of emergency braking system, the need to use modules that can be added as options can disappear, opening the door for integration.

"The need to design for options is part of why the strategy has gone towards separate controllers for different functions," McConnell said. "The redundancy of separate modules may go away once it's a standard feature. Some redundancy will still be required because it's a safety function."

That could alter requirements for semiconductors. Advanced driver assistance programs now rely on intelligent sensors that make some decisions before data is transferred to control modules. AEB could reduce the usage of this type of distributed computing, putting more focus on more powerful controllers.

"ADAS today is decentralized; the sensors all have brains," said John Buszek, Segment Marketing Manager for ADAS Solution at **Renesas Electronics America**. "OEMs may decide to remove some of those brains and centralize intelligence, which will probably mean using more-powerful controllers."

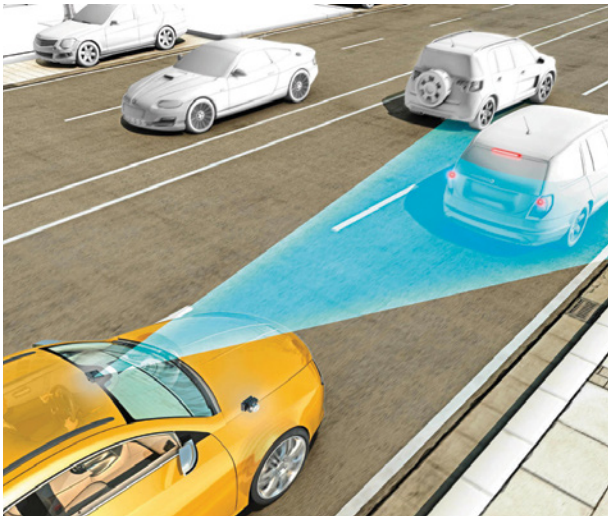
Boosting computing power and memory size might not be the only change for chipmakers. Over the past several years, semiconductor makers have been providing more software. The standardization of AEB is likely to broaden the role of AUTOSAR, a standard that helps OEMs employ modules from multiple suppliers.

"The big thing for many OEMs will be time to market," Buszek explained. "One way to move faster is to use standards — they provide a common base so work can proceed quickly. AUTOSAR already has momentum, I think there will be more of a push behind it, so silicon vendors will probably be asked to create that software."

Though the AEB agreement may impact a number of aspects of vehicle and subsystems engineering development, most observers feel that it won't cause the type of scrambling seen in some efforts to meet tighter fuel economy regulations mandated by the U.S. The voluntary pact relies on existing technology to improve safety.

"AEB will greatly help reduce the number of accidents," Jefferson said. "The AEB agreement is based upon the foundation that these systems are in the market today, performing well and providing safety benefits, but on a relatively small scale."

Terry Costlow



Calibrating emergency braking systems for all vehicle makes and models "is not an insignificant job," according to Continental's McConnell.

CHASSIS | MATERIALS

Cadillac XT5's new platform cuts weight—at less cost

It now practically goes without saying that a newly introduced vehicle will tout a weight savings compared with not just the predecessor model, but also with competitor vehicles that may (or may not) have been developed at an earlier point in the industry's pell-mell lightweighting initiative.

So few were surprised when **GM** engineers announced during the recent media introduction for the 2017 **Cadillac** XT5 that their all-new midsize crossover is a ringing 292 lb (132 kg) lighter than the SRX it replaces. No, the revelation came when they noted that XT5's new global C1 platform essentially eschews any "mixed-materials" strategy increasingly employed across the industry to achieve mass reduction on a vehicle architecture-level scale.

This seems to be a distinct materials-philosophy shift for GM's luxury unit.

The 2017 XT5 departs from Cadillac's recent predilection for mixed-metal construction, but still is nearly 300 lb lighter than the SRX it replaces.

Compared with the aggressive lightweighting efforts for the brand's two newest cars, the 2017 CT6 full-size sedan and the midsized CTS, there is virtually no aluminum or other lightweight metal or composite found in the C1 structure—or anywhere on the XT5 body. Instead, GM engineers first approached this new modular crossover platform with the notion of "driving out waste" by carefully analyzing and then optimizing how the C1's various steel alloys were used—and joined—said Paul Spadafora, the CT5's Chief Engineer.

Spadafora told *Automotive Engineering* that the C1 structure employs a range of high-strength steels and that by intricately modeling how each contributes to the overall chassis assembly, then paying particular attention to optimizing the joints not only between those steels but throughout the structure, "every ounce was looked at" and eliminated if not required.

"As different high-strength steels come together," he said, "the joints have room for optimization."

Despite gaining 2 in (51 mm) in wheelbase, an inch (25 mm) in track, and serving up 3.2 in (81 mm) more rear-seat legroom compared to the outgoing SRX, the new XT5 has nominally smaller exterior dimensions. Meanwhile, the vehicle is at minimum one full test weight class below SRX, revealed Larry Mihalko, the XT5 Vehicle Performance Manager. And, it's two classes below SRX in some trim levels.

Perhaps even more a signal of the difference a couple of years makes in today's weight-scrutinizing product-development cycles, the XT5 is a staggering 650 lb (295 kg) lighter than the like-sized **Mercedes-Benz** GLE-Class crossover and 100 lb (45 kg) lighter than **Audi**'s Q5, which itself is 7 in (178 mm) shorter than the new Cadillac.

"We did it with steel," asserted Mihalko. "We were able to do it without [extensive reliance on] expensive materials." The strategy is an unmistakable departure from Cadillac's CT6 flagship, where GM's new Omega platform is a combination of

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aluminum and high-strength steels and the body-in-white also is a complex multi-metal mix. In all, 64% of the 2016 CT6 is said to be aluminum. The CT6, reported *Automotive Engineering* in April 2015, is "arguably the industry's most aggressive combination of lightweight materials, forming technologies and new joining methods in a non-exotic sedan."

Prior to the CT6's launch, Cadillac took a similar path with the all-new 2014 CTS midsize sedan, where a weight-prioritizing development program cut poundage 7% compared with the previous CTS and made the car some 200 lb (95 kg) lighter than an equivalent BMW 5-Series.

Despite the CTS's acknowledged dynamic excellence, however, its hardline lightweighting translated to a cost that put the CTS at a disadvantage in the hyper-competitive midsize luxury sedan market. Johann DeNysschen, GM Executive Vice President and President of Cadillac, flatly admitted to journalists at the XT5 launch that the aluminum-intensive CTS "costs a lot of money to make."

Whether the experience from its newly lightened sedans had any influence on the C1 platform's "steel only" development direction is difficult for outsiders to know. But what's certain is that the C1 achieved a high degree of mass reduction with a 10% upgrade in torsional stiffness (and hit its first-order beaming-mode targets, said Mihalko) without resorting to high-cost light materials.

However, the platform is not the only source of the crossover's significant weight loss. Also contributing were the design of the vehicle's all-new 5-link rear suspension, which accounted for 70 lb (32 kg) of the XT5's total reduction. Advances to the dissipative materials used for acoustic attenuation chopped another 30 lb (14 kg).

But for the C1 architecture, which will underpin a spate of different-sized future Cadillac and other GM-brand crossovers including the upcoming **GMC** Acadia, design optimization was, in effect, more important than the materials themselves.

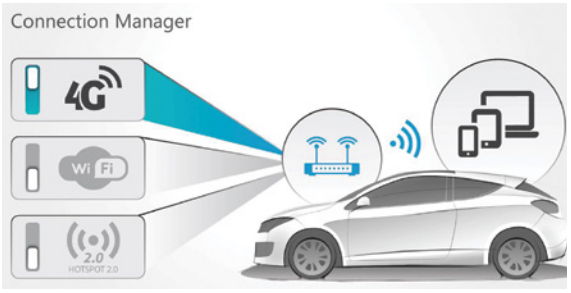
"It all goes back to analytical tools," Mihalko claimed. "They just keep getting better."

Bill Visnic

ELECTRICS | ELECTRONICS | AVIONICS

Autos gain spotlight as telecoms gear up for 5G

The telecommunications industry has begun firming up plans to upgrade from 4G to 5G cellular networks, citing the automotive industry as an important beneficiary. Tier 1s are beginning to incorporate this fifth-generation wireless technology into their plans to enhance safety as they push toward autonomous driving.



Visteon's connectivity architecture will expand further as 5G cellular systems emerge.

Deploying 5G into the market by around 2020 was a focus at the recent Mobile World Congress, with connected vehicles playing a large role in show's telecom-industry announcements. **LG Electronics** and **Intel** teamed up to bring 5G technologies to the vehicle. **Ericsson** and **Geely Auto** partnered around connected-car services, saying they will gradually introduce 5G-based autonomous-driving functionality.

Interest in the 5G upgrade is global. The European Commission and the 5G Public-Private Partnership, a consortium formed in 2013, highlighted ways that 5G could improve vehicle safety. The eventual transition to 5G will alter the role of connectivity.

"In the past, faster cellular technologies were perceived as the harbingers for increased infotainment," said Rob Gee, Telematics Systems Engineering Manager at **Continental Automotive**. "With the rising installation rates of ADAS (Advanced Driver Assistance Systems), we anticipate the next generations of cellular to be increasingly used to improve highly automated driving systems and to improve vehicular safety."

Can V2V and 5G coexist?

Upgrading to 5G cellular technology is appealing because it will significantly increase bandwidth while slashing latency. The latter is a critical factor for safety, since quick responses are mandatory. Suppliers are gearing up to ensure that automakers can adapt quickly once 5G materializes.

"Visteon is investing in in-car technology, known as a wireless gateway, which will enable automakers to quickly transition to 5G without having to tear up the vehicle architecture," said Martin Green, Telematics and Connected Car Technology Manager at **Visteon.** "We are already incorporating some of the intermediate technologies between 4G and 5G, specifically LTE-Vehicle."

Market watchers note that once telecom suppliers finish trials, they are able to incorporate new technologies fairly quickly. The transition from 4G to 5G could be shorter than the shift from 3G to today's 4G connections.

"Companies can enhance 4G to 5G comparatively easily," said Ramnath Eswaravadivoo, **Frost & Sullivan**'s Mobility Senior Research Analyst. "The costs won't be nearly as high as they were going to 4G. A couple more towers can make it work."

He noted, however, that in the U.S., adding towers won't be nearly as easy as in small countries like South Korea, which he said may be a leader in the 5G rollout. If the U.S. launch begins around 2020, it may coincide with the advent of vehicle-to-vehicle/infrastructure (V2X) communications. The industry has developed V2X standards using dedicated short-range communications (DSRC) as an enabler for automated and autonomous driving.

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said Hans Roth, Director of Business Development at **Harman**. Harman recently teamed up with **NXP** Semiconductors to develop V2X technologies.

That raises questions about how V2V and 5G will co-exist and compete. Many believe there's a spot for both. V2X studies have been going on for years, so it's viewed as the more mature option.

"5G can definitely do some of the things that V2X can do, but current V2X systems have been in the field for years," said Maurice Geraets, Senior Director Business Development Automotive at NXP. "5G is still looking at doing its first tests next year."

The competition aspect of the V2X-5G matchup may occur on the infrastructure side. Vehicle-to-infrastructure links such as roadside stations may require investment by cash-strapped traffic-management agencies, so those functions may drift to 5G, leveraging the investment of cellular providers.

"Cellular solutions such as LTE-V, which is on a roadmap to 5G, can partially reduce the infrastructure cost, especially in cars," Green said. "However, like V2X, the business-case issue of installing service on a roadside in the middle of nowhere remains. A purely car-based V2V solution, whether it is 5G or DSRC, can only be effective when there is sufficient population density."

He noted that this can only be driven by "a mandated approach around international standards to ensure inter-operability."

Safety and security issues

Regulatory mandates for V2X systems are expected, and many observers feel they're necessary to get companies to spend money creating systems that only work if other vehicles have compatible links. Spending on 5G will occur as providers ramp up consumer products that may work with automotive systems.

"Less-complex systems, such as 5G-enabled home door locks or home lighting-control modules, could be developed quickly and independently from the automotive realm and could greatly expand the number of features that are wirelessly compatible with 5G-equipped vehicles," Gee said. "This would allow such fast-moving consumer technologies to be available for automotive use, allowing OEMs to select the most appropriate products to interface with their vehicles."

More complex projects, such as an incident tracking and reporting system, would still take time due to complexity and its safety-related nature, Gee explained.

The focus on safety also highlights the need for security, which has become a critical issue as connectivity opens doors for hackers. When cars take action based on these communications, already high security concerns are ratcheted up.

"With V2X, there will be even higher needs for secure communications," Roth said. "All the information goes to vehicle electronics so the system can make the right decisions for action. If your car receives a message that causes it to brake, you must be sure that message is authentic."

Terry Costlow

POWERTRAINS | PROPULSION

Ferrari's CTO details patented torque-vectoring AWD with rear-wheel steer

Based on the FF, Ferrari's new GTC4 Lusso is a 4-seat two-door.

At first, reading the words "**Ferrari**" and "all-wheel drive" (AWD) seem as compatible as "oil" and "water," but with the company's original FF entering its fifth year of production, the Maranello engineers decided it was time for its unique AWD system to get an update by incorporating a new, patented torque-vectoring capability and rear-wheel steering.

The first Ferrari to feature this integrated capability is the new GTC4 Lusso, a nameplate that conjures both the GTC and Lusso classics, with the '4' denoting not the number of driven wheels but the seating capacity.

"In general we wanted to improve the torque vectoring, with more flexibility to put the right amount of torque to the correct wheel," explained Ferrari Chief Technology Officer Michael Leiters during the new Lusso's debut at the 2016 Geneva Salon. "Therefore, we had to do two things: firstly, to estimate and control more precisely the slip of any wheel and, secondly, to improve the flexibility of the system to distribute the torque,"

He added: "We are now able to put up to 20% more torque to the front axle with a maximum of 1400 N·m (1032 lb·ft) to either wheel and up to 90% of torque to the outer wheel during cornering."

To view an animation of the new Ferrari driveline: https://www.youtube.com/watch?v=JVsZ2A3mXgs.

Rapid response time

Leiters told *Automotive Engineering* at Geneva that his team's idea for the new driveline was "to increase driveability in low-grip situations, which is why we decided to have AWD available through to fourth gear of the main transmission: We wanted to improve that system, especially in low-grip, wet and snow conditions."

To achieve that, Ferrari developed a new software algorithm to estimate wheel slip. Known as 'Slip Control Version 4'

it employs a different suite of sensors, including speed sensors for the wheels and acceleration sensors, to more accurately calculate the precise manner in which the wheels slip, while improving reaction time over the outgoing technology by between "10 to 20%," according to Leiters.

Although **ZF** provides the GTC4 Lusso's mechanical hardware, the software and algorithm development has all been done in-house at Ferrari and is subjected to its own patents.

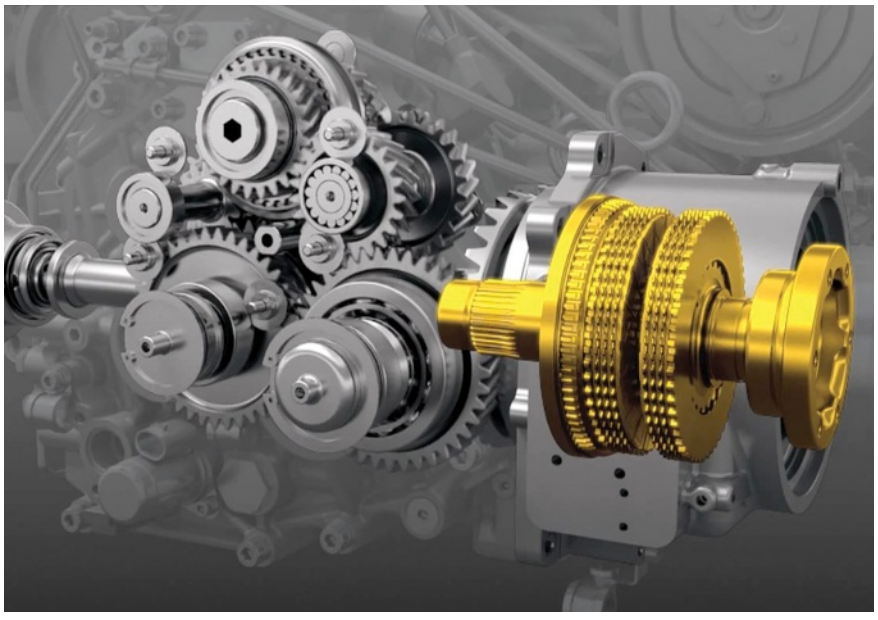
The second major update was increasing the amount of torque available to the front wheels by optimizing the AWD system's thermal management. "Previously that was one of our limits, but the cooling system and heat exchanger is more efficient than the previous one," claimed Leiters.

From its original concept, Ferrari's AWD was intended to be much more than a stand-alone system.

Ferrari CTO Michael Leiters, third from left, with FCA Group CEO Sergio Marchionne and colleagues at the 2016 Geneva Salon.

With the GTC4 Lusso, the car is "very precise and predictable, so you feel how the car is at the back. It's much easier [to control] than the previous FF when we tested it on ice," Leiters noted.

Although the system alters the rear-wheel angle by no more than 3°, Leiters maintained that the speed of reaction is



Detail of the ZF-Ferrari AWD power takeoff mechanism mounted directly to the front of the V12 crankshaft.

most important. Beyond saying that it's "very, very fast" he wouldn't divulge reaction time. He added that the keys to the system's enhanced effect on stability are the new algorithms that predict both the car's behavior and the driver's inputs.

Comparing the rear-wheel steering to that introduced on the F12tdf (where it remains in parallel production), Leiters explained that the GTC4 Lusso system has two modes.

"On the FF we do both parallel and counter-steering depending on the situation: on a dry road and you want to drive through a dynamic curve, we always [rear steer] in parallel [with the front wheels], because if you go in counter-steer the car feels as if it's slipping away. That gives a strange feeling, not emotional driving," he said. Meanwhile, "if you go on ice and you have to correct the slip angle of the car, you have to do both."

From the nose of the V12

While Leiters admitted that Ferrari will develop rear-wheel steering "for further applications and cars," he made it clear that agile cars like the 458 will remain resolutely focused as driver's cars without any dynamic enhancements.

The AWD drive unit takes its power directly from the nose of the 680-hp (507-kW) V12 engine's crankshaft, so there is no transfer case or forward-leading propshaft. The engine is mounted far enough back in the vehicle structure that the whole front-drive system can be fixed to its nose. The rear wheels drive through a 7-speed dual-clutch sequential transaxle similar to that used in Ferrari's rear-drive California model.

Within the front drive-unit casing are a 2-speed gearbox and a pair of electronically controlled multi-plate oil-bath clutches. When the car's ECU determines that drive to the front is required, it progressively closes the clutches. The two clutches are independently controlled; one drives the left front wheel, the other the right. Thus there is no need for a front differential and torque vectoring is provided.

The front gearbox's two ratios are similar to second and fourth gears in the primary rear-axle gearbox. Any discrepancy in the drive ratio between front and rear wheels is taken care of by the slippage of the clutch packs.

Ian Adcock

TESTING | POWERTRAIN

Accelerated ash load testing of particulate filters on an automated test rig

The detrimental effects of ash on diesel particulate filter (DPF) and now gasoline particulate filter (GPF) performance is of significant concern because the resulting permanent backpressure penalty compromises both fuel economy and soot storage capacity, leading to more frequent regeneration intervals with further fuel economy impact.

The ash is thought to be derived primarily from oil additives but also from fuel, engine wear, and other sources. As these filters accumulate more miles on customer vehicles, the long-term effects are becoming of more concern to vehicle and filter manufacturers.

However, the time taken to accumulate a representative amount of ash—over, say, 100,000 km (62,100 mi)—is significant. **Cambustion**'s DPG, an automated particle filter testing system, can be used to load DPFs/GPFs with ash over a matter of hours, the company claims.

Initial tests at Cambustion involved mixing oil additive "packs" to the fuel tank of a DPG and burning the resulting fuel/additive mix in the DPG's burner. Note that the production of ash can be obtained at the same time as soot yield and regeneration events.

The Cambustion DPG is a self-contained system for testing the performance of diesel and gasoline particulate filters at real engine conditions.

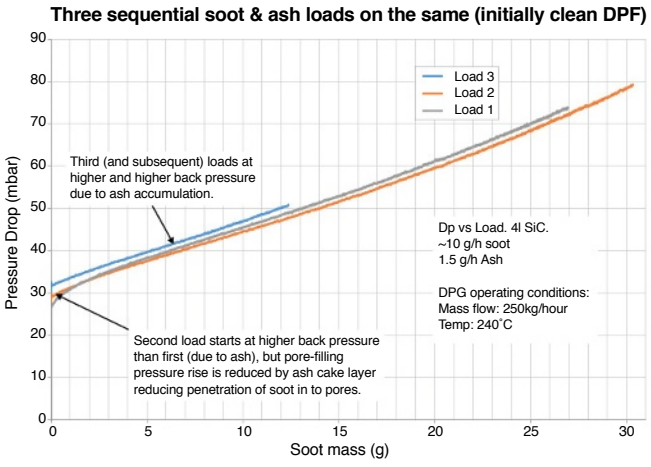


Figure 1. Three sequential soot & ash loads on the same (initially clean) DPF.

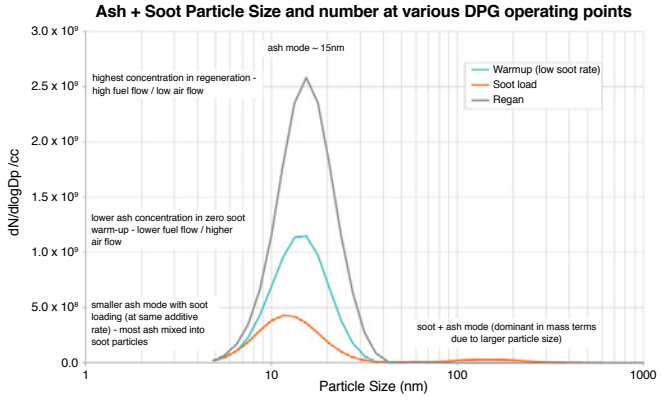


Figure 2. Ash + soot particle size and number at various DPG operating points.

While the DPG itself is not new, this is a new application of the test system for studying the effects of ash build-up in DPFs and GPFs. The DPG can handle DPFs up to heavy duty, so it's suitable for on- and off-highway commercial applications in addition to automotive.

Backpressure results from multiple loads (from clean)

Tests using a 4-L SiC (silicon carbide) DPF have been conducted where a yield of 1.5 g/hour of ash was achieved along with 10 g/hour of soot. The results for three loads—interspersed with regenerations performed on the DPG—on a clean (without soot or ash) DPF are shown in Figure 1.

Load 1 shows the classic pore-filling curve within the first gram of loading. The backpressure then continues linearly until the part is regenerated—then Load 2 begins.

The second load begins at a higher backpressure because a layer of ash has been deposited during Load 1 as a "cake" layer. Note also that the pore-filling and pore bridging phase is

absent from Load 2 because ash is preventing as much soot entry into the pores. Also, the gradient of the linear pressure increase thereafter is slightly less than for Load 1. This is because the reduced soot within the pores (displaced by the ash) is unable to dominate the Dp (pressure drop) during the cake layer build-up.

The third (and all subsequent) loads begin at a higher and higher initial backpressure indicating permanent ash backpressure penalty.

The deposition position and quantity have yet to be assessed for the DPG, but the backpressure characteristics and filtration efficiency changes (not shown here) appear to be similar to engine tests performed by a variety of customers.

Further tests are planned using alternative loading temperatures, flow rates, doping rates, and soot rates.

Assessment of ash

Some measurements have been taken with a DMS500 particle sizing instrument to identify the ash and soot particles that are being produced by the additive-in-fuel technique, the results of which are shown in Figure 2.

A clear, small ash size mode was identified centered at about 15 nm (compared with the DPG soot mode at approximately 100 nm). The amount of ash being generated is basically linked to the fuel flow into the burner and the additive dosing rate. The maximum ash yield is therefore occurring during regeneration where the burner is operating in a hot (but non-sooting) mode with high fuel input.

It is interesting to note that the soot load mode and the warm-up mode actually consume very similar fuel rates but where soot is being produced, it is clear that the ash particles are being bound-up onto the surface of the soot particles.

Note that this technique contaminates the entire fuel system with the additive, which can be problematic if the DPG is required for other conventional work. Both the fuel system and the surfaces upstream of the test part need to be cleaned of ash deposit before accurate soot-only tests can resume.

Information about these test results will be available at the company's **SAE** 2016 World Congress exhibit (Booth 906), and Cambustion engineers will be able to explain in detail how the instrument works and its applications.

Bruce Campbell and Kingsley Reavell, directors at Cambustion Ltd., wrote this article for *Automotive Engineering*.

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Defying the disruptors and DRIVING

Four top engineering executives discuss how their "traditional" companies are finding new technology opportunities and business growth amid the start-ups—and are even doing some disrupting themselves.

by Lindsay Brooke

Need proof of the auto industry's crazy pace of change? Look no further than the daily news, where reports of each emergent player—and their impact on what remains of the status quo—seem less and less startling. Consider a vacuum cleaner company that has its eye on more than cleaning carpets.

Dyson, whose efficient high-suction machines created a new technology paradigm, has applied for government funding in its native U.K. and is looking to hire up to 500 engineers, ostensibly to develop electric vehicles. **Dyson**, which purchased Michigan solid-state battery start-up **Sakti3** for $90 million, said it plans to invest nearly $1.5B in battery technology through 2020.

Who would scoff at the prospects of a Dyson EV, given the growing influence of emergent technology players in the automotive sector? OEMs and Tier 1s increasingly need them to help deliver in-vehicle connectivity quickly, at lower investment, and to accelerate autonomous car development. Last year M&A activity by automotive suppliers reached nearly $50 billion, more than three times that of 2014, according to **PriceWaterhouseCoopers**.

Before **GM** bought Silicon Valley sensor developer **Cruise Automation** in early 2016, there were several other significant actions. **Toyota** hired the entire staff of **Jaybridge Robotics**, an MIT spinoff in autonomous vehicles, to join its **Toyota Research Institute** aimed at artificial intelligence, among other technologies. **Continental AG** bought a 3-D laser-sensor (LiDAR) business from **Advanced Scientific Concepts**. Last year, **Delphi Automotive** acquired a stake in **Quanergy**, a competitor to Advanced Scientific that is developing a low-cost LiDAR, and it purchased **Ottomatika**, an autonomous-driving software company that was incubated at **Carnegie Mellon University**.

Meanwhile, collaborations among competitors are becoming vital to share technology and development

> I see two 'buckets' of autonomous vehicles emerging: those intended for personal use, in the ownership model, and those designed for fleet use. Probably 0 to 100 km/h acceleration isn't an important experience in the latter!
>
> **— Dan Nicholson, GM Global Propulsion Systems**

INNOVATION

costs and slash time to market. And engineering services providers are taking on greater responsibilities in everything from software development to combustion system design to multiple-vehicle calibrations.

Clearly, many businesses that may have been in danger of being disrupted are now themselves driving disruption. For insight into how "traditional" OEMs and suppliers are navigating it all, Automotive Engineering spoke with four high-level engineers during the course of our field reporting: Dan Nicholson, Vice President of GM Global Propulsion Systems; Jeff Owens; Chief Technology Officer of Delphi Automotive; Denise Gray, CEO of **LG Chem Power Inc.**, and Dr. Uwe Grebe, Executive VP, Global Business Development, Passenger Cars and Powertrain Systems at engineering services provider **AVL**. Highlights of their observations follow.

DAN NICHOLSON: Rethinking propulsion

"In the whole discussion of Connected Car, a lot of other areas come to mind before engines, transmissions, and drivelines. We're in the 'fourth or fifth row,' so to speak, but we're not unimportant. Connected Car impacts design of the hard components very indirectly. But as part of a vehicle's overall controls strategy, we've got to be compatible with GM's global electrical architectures. So we're directly impacted in the controls space.

"What will this mean to customers? Connected-car technologies give us greater diagnostic and prognostic capability, in which OBD is a huge area of development. We're working on expanding prognostics to be able to predict problems before they get to a critical level—where prevention may actually be possible, versus waiting for something to cross a threshold and then service it. It will allow us to do more 'customized' 60-point vehicle inspections during normal service visits. We're looking at taking the engine oil-life example and OBD and expanding it to other areas where we can provide predictive information related to powertrain service to the customer using connected car.

"Having the capability to use the vehicle's electronic sensors to optimize efficiency of the propulsion system and the vehicle overall presents some opportunities with 'mild' electrification. But in the U.S. market one has to be careful; there are some OBD-II design issues in considering those types of technologies. For example, if you use a camera as a sensor input to decide when to do stop-start or when not to do it, it has OBD-II implications. Because now you've made it, according to CARB definitions, part of the CO2 compliance system because it affects tailpipe emissions and fuel economy.

There's an advantage to developing battery technology when you know your company is also working on propulsion components and power control that will go into the same customer vehicle.

— Denise Gray, LG Chem Power

"In terms of automated vehicles and autonomy, I see that falling into two 'buckets.' One is autonomous cars intended for personal use, in the ownership model. It's a normal car, a Camaro or **Cadillac** CTS for example, with the enhancement of being able to drive autonomously—

Defying the disruptors and **DRIVING INNOVATION**

> Take the driver out of the seat and you've got to have 100% positional integrity, all the time. The car's performance has to be far greater than today's if you're going to hand over control to the computer.
>
> **—Jeff Owens, Delphi Automotive**

[an **SAE**] Level 0 car with Level 0 performance expectations. The other 'bucket' is cars designed not for personal ownership but as part of a fleet. The kind of vehicles that companies providing transportation services as a business are probably interested in buying. It's hard to know today whether those cars would be fully electric.

"I expect companies like **Lyft** and **Uber** to be early adopters of these technologies because of the duty cycles they have, particularly in cities. It could be a selling point, because the customer buying transportation services has a much different expectation of vehicle performance. Probably zero-to-100 km/h acceleration isn't an important experience! But those services exist today with conventional propulsion technologies, so it's not necessary.

"In both cases, we'll be constantly rethinking propulsion-system requirements—this is a fast-changing and evolving space. A lot of the things that are enablers, such as battery energy density, we're making good progress on. You can never predict when breakthroughs are going to happen, but it's not just one breakthrough—it's incremental breakthroughs that sometimes have a multiplicative effect."

DENISE GRAY: Lithium battery 'second phase'

"When you talk about automotive batteries as they relate to vehicle electrification going forward, there are three main pillars: performance, manufacturing, and the ability to support the industry. The industry has entered a 'second phase' following the shake-out among battery suppliers and the shake-out in battery and systems designs. The first phase, if you will, was to get product out into the industry and to understand if it's meeting the customer requirements. And so much learning has occurred in that area during the last eight years.

"This allowed the big battery companies who are 'in it to win it' to increase our collaborations with the OEM customers and to learn with them, to make the product better. That learning is continuous regarding the core battery cell technology, battery systems technology, the battery-and-vehicle systems integration, and customer use.

"Battery design and manufacturing now has us into the second-generation of lithium-ion technology for automotive and you see that many of the companies who were emerging five to eight years ago are no longer here today. In that timeframe we've seen a pretty amazing reduction in battery price due, in large part I'd say, to the design optimization at the OEMs and from the battery Tier 1s.

"And in this 'second phase' of vehicle electrification, there's an even greater focus on full systems development. My company is not just a battery cell supplier going forward, but part of holistic propulsion-system development, all the way to the vehicle integration level. As you know, LG Electronics is providing major

component and subsystems to the Chevrolet Bolt EV. LG Electronics coupled with LG Chem and LG Innotek [the latter develops core material and component technologies including EV components, advanced photonics and solar cells] is a 'three-legged stool' that has enabled us to increase our responsiveness to meet GM's needs to supply full powertrain.

"So there's an advantage to developing battery technology when you know your own company is also working on propulsion components and power control that could go into the same customer vehicle. I've always said that the battery cell chemistry and cell design, and the management of that cell, are closely coupled. If you understand the chemistry, you understand how to control it—and better understand the full system."

JEFF OWENS: LiDAR under $1000 per vehicle

"LiDAR is going to be one of the active-safety building blocks on the path to a fully automated vehicle. We learned a lot in our coast-to-coast drive in early 2015, with 20 sensors including 6 LiDARs fitted to the car. We found out what radar did well, what [camera] vision did well, what LiDAR did and V2V as well. Looking at optimizing a system, we recognized we could maybe make radar a little less expensive because we know we're going to have vision there—or maybe make them both less expensive because we know we'll have LiDAR.

"We got a good feel for the tradeoffs. And one conclusion we came to was we have to have LiDAR in our portfolio for SAE Level 3 and 4 automated driving. I don't think it's going to become particularly important for Levels 1 and 2. Part of that is the price point and the value received for it, but LiDAR's value to a fully automated excursion is tremendous. So we looked at doing it ourselves, and at people who are already pretty far down that road. We found Quanergy and felt they had the best roadmap, the best line-of-sight, to get to a cost-effective solution. Now 'cost effective' here is in the eye of the beholder because the comparison is to the $70,000, 64-beam **Velodyne**. That one's not only expensive but hard to style on the vehicle!

"Many in the industry are concluding that you need a LiDAR sensor on each of the four corners of the vehicle, with a 120° sweep. The idea is to generate a point-cloud of information around the vehicle. LiDAR is one of the best technologies available because it's the fastest—it works at the speed of light. It gives you instant data at a distance, and you establish a point cloud around the vehicle. That means if you're not going to do it on top [top mount on the

Defying the disruptors and **DRIVING INNOVATION**

> This is a new era that is about 'requirement engineering' and managing the result of the engineering to where the OEM is confident of the excellence of the final product.
>
> **—Dr. Uwe Grebe, AVL**

vehicle] you put one on each corner then coordinate the data extraction and analysis.

"In the case of radar you generate a beam or beams of energy, then you steer the beams electronically by phase shifting. Quanergy has exactly the same concept. You take maybe 8 beams—you don't need 64—and make the LiDAR electronically scanned by phase shifting of the optical beams. Of course, first it has to be proven that it has the technology attributes we're looking for, and second that it'll go down the cost curve.

"We think Quanergy has a great line-of-sight to something that'll be around a $200 sensor, in volume. That sounds like a lot because you'll have four on a vehicle. So $800 per vehicle, but it's compared with a $5000-$10,000 unit today. We think getting cost under $1000 per vehicle will be the 'trip point' where the OEs would say, 'Okay, that's a value proposition I can afford because of all the benefits you can get from LiDAR.'

"We think LiDAR will give the vehicle planner and platform team a lot of flexibility regarding their choices for the sensor package. The more you want the car to be automated, or take the driver out of the seat, the more you've got to ensure the vehicle is very sure of its surroundings. Radar is good at this; radar-plus-vision is better; radar-plus-vision-plus-V2V is better yet—and all of that plus LiDAR is best yet. You also need it for high-def map matching.

"Take the driver out of the seat and you've got to have 100% positional integrity, all the time. The car's performance has to be far greater than today's if you're going to hand over control to the computer.

"There's opportunity for greater sensor fusion as we incorporate LiDARs, as we did with the Delphi Raycam on the **Volvo** XC90—it's the best example of radar and vision fusion in the business. Because of the corner coverage with the LiDAR, you probably won't combine it with a vision system. But there is a possibility of fusing LiDAR and radar. There's also the opportunity to replace the vehicle's ultrasonic sensors. As radar technology comes down in cost, could we put a radar-LiDAR sensor at each corner and share the processing? I'm sure there's an opportunity there—but its time will come."

UWE GREBE: Engineering 'from the virtual to the road'

"The need to develop electrified vehicles, connected-car technologies and automated and autonomous driving systems—on top of the ongoing pressures of faster development cycles and reduced cost—have created a new business model in this industry. And that model is where the OEM takes much more ownership of delivering a great vehicle, but doesn't necessarily do the engineering of certain parts and systems. And the Tier 1s have more responsibility to deliver increasingly sophisticated, tailored systems.

"This is a new era that is about 'requirement engineering' and managing the result of the engineering to where the OEM is confident of the excellence of

the final product.

"There is additional complexity that comes with the controls, data processing, and power requirements of the new electrified and electronic systems, of course. As an engineering services provider, we at AVL are in a position of helping to integrate these things with the OEM. We do a lot of benchmarking and it goes way beyond the classical definition, where I tell you, for example, what the part weighs and how it was cost-engineered. Instead, our benchmarking goes deep into vehicle attributes: what is the set of competitors, what is the objective performance, what the customer perceives as tip-in performance, brake-pedal, whatever.

"This helps the OEM define the market requirements for the Tier 1 and engineering service provider for development. So the OEM can say, 'I follow your release recommendation. I would have done it in the same way if I'd had my own people doing it.'

"This is a new scenario for AVL and other engineering service companies. But there is also a growing demand for developing far-reaching ideas or implementing a new technology. And it's still an important part of AVL's business, by the way, particularly in the powertrain arena, which is a core strength. The innovative stuff, providing a deep, deep understanding of combustion systems, for example, and helping OEMs through their technology roadblocks.

"If you look at where the OEMs are investing in engineering resources, it's on the software and algorithm side to support the safety systems, infotainment and connected-car areas. It's not so much in traditional mechanical engineering, but there is increasing demand for more efficient and reduced-emissions engines and their drivetrains.

"To support work in these areas, we have new developments in what we call 'from the virtual to the road.' Our methodology is called the Integrated Open Development Platform. Think of the office environment with the math tools then going to Software in the Loop, then hardware in the loop, then to a powertrain dyno, then to a chassis dyno and on to the road.

"What is important here is consistency of test cases and models. You can front-load into the math environment, but you need to be sure that whatever the model is for this powertrain or vehicle, it must have fidelity and needs to be representative. You have to ensure the vehicle performs in the same way, and your math model has to do the same thing. So these are the test cases you put through from the real-vehicle environment to the math environment.

"It's called 'Integrated and Open' because every customer is free to choose. Our customers like this approach, even though we like for them to use our tools! It's always difficult to accurately look into the crystal ball. I see continued growth for AVL and for our part of the business. I hope for many more partnerships in the industry.

"Automotive is a highly competitive environment and that's a good thing, it keeps you running fast. But in this triangle of OEM, Tier 1 and engineering services provider, partnerships are crucial going forward and we need to maintain partnership continuity." ■

Preparing for a 48-volt REVIVAL

Four times the voltage means four times the power—and far less cost than "full" hybrid systems. 48/12-V is poised to take on the WLTP.

by Dan Carney

While most 48-V systems employ belt alternator-starter systems located at the engine's P1 (front accessory drive) position, Bosch also is examining one that integrates into the transmission to permit limited electric-only operation for tasks such as automatic parking.

More than a decade after the widely anticipated 42-volt electrical revolution died—the victim of increasingly efficient 12-volt components, wiring strategies, and digital controls—demand for greater on-board electrical capacity is again driving plans for higher-voltage systems. This time 48-V (or more accurately, dual-voltage 48-V/12-V) hybrid systems soon to enter the market will deliver performance and functionality at a fraction of the cost of high-voltage systems.

A key to the emergence of 48-V hybrids is the move by European Union regulators to replace the current NEDC test protocol with the new Worldwide Harmonized Light Vehicles Test Procedure in 2017. The WLTP cycle was devised to more accurately reflect real-world driving and vehicles' expanding electronic feature content. Engineers say WLTP compliance is more challenging than the NEDC; the benefits of 12-V stop-start systems are diminished by nearly half, for example.

As a result, meeting the WLTP will require new powertrain technologies that can deliver greater electrical power than is available from current engine downsizing and down-speeding strategies. Combining integrated starter-generator "mild hybrid" systems with the rapid transient response of electrically-enhanced e-superchargers, the experts explain, can optimize energy recuperation, reduce vehicle NOx and CO_2 emissions and even improve the fun-to-drive quotient.

Mild-hybrid technology is hot again because "We're out of power. Four times the voltage means four times the power," observed Mary Gustanski, **Delphi Automotive** Vice President of Engineering. She noted that mild hybrids present a better value than "strong" hybrids: "You get 70 percent of benefit of a full hybrid at 30 percent of the cost of a higher-voltage hybrid."

Not surprisingly, momentum toward 48-V-equipped vehicles is rising. Last December, **IHS Inc.** revised upward its 2025 forecast to reflect 10 m global sales in 2025—exceeding sales of conventional strong hybrid by one million units that year. Activity is particularly intense among German OEMs, according to suppliers, as those companies want to use, first in Europe, 48-V technology to replace today's 12-V start-stop components.

Audi recently announced a 48-V system in its new SQ7 sport SUV, to power electrified boosting and an active roll control chassis system (p. 34); both are power-hungry subsystems. **Delphi** is going into production with an unnamed OEM next year, according to Gustanski. Similarly, **Robert Bosch** has customers for its mild-hybrid module preparing to launch in the next two to three years, reports Jason Schwanke, Senior Engineer for Gasoline Systems. **Continental** soon will have a 48-V system in production (see http://articles.sae.org/13186/), and **Valeo** also has a 48-V package with engine e-boosting under development.

Recovering energy during braking contributes to a fuel savings of as much as 15% using a 48-V mild-hybrid system, according to Bosch.

General Motors has deployed three types of mild hybrid systems in production cars and trucks since 2004, using batteries from **Hitachi Automotive** and Continental. While its Gen-1 36/42-V belt alternator-starter (BAS) systems fell victim to unfavorable economics, said Larry Nitz, GM Executive Director of Electrification Powertrain Engineering, GM offers its latest-generation mild-hybrid system, eAssist, in the 2016 **Buick** LaCrosse and Regal. Company engineers continue to develop the technology, which GM will deploy next in its full-size pickups.

Cost and safety threshold

The 48-V systems operate near the 60-V upper threshold of mortal electrocution threat, providing the most power possible without the need for costly shielding or specialized wiring connectors that cost ten times more than lower-voltage components. "A 12-volt connector is about $2, but a high-voltage connector is about $20," Gustanski noted.

"At 48 volts, you are leveraging the components we've been using for 60 or 70 years," said Schwanke.

A lithium-ion battery is the preferred energy-storage medium for 48-V mild hybrids, because "their charge acceptance is well above what you can do with lead-acid batteries," noted Daniel Kok, Manager for Advanced Electrification at **Ford**. That enables the mild hybrid to recover more energy under braking (see http://articles.sae.org/13908/).

The previous obstacle to 48-V acceptance was its weak added-value proposition. GM's eAssist equipment package cost consumers more than $2000. But the increasingly stringent regulatory environment has skewed those calculations in favor of mildly hybridized internal-combustion powertrains. According to Schwanke, Bosch can offer its 48-V mild hybrid systems to OEMs for less than $1000.

Also, the first wave of 42-V mania envisioned complete conversion of vehicles to the higher voltage, while to reduce costs, the current design calls for parallel 48/12-V systems. The object for engineers to is apply the higher voltage to systems that can benefit most from the higher available current, while retaining the majority of the 12-V system. Engineers expect the inexpensive, reliable (and heavy) lead-acid battery will remain to handle hotel loads.

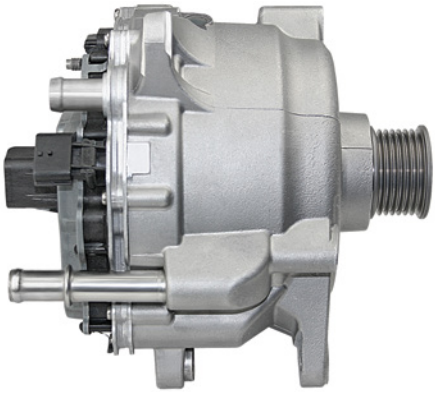
Improved driveability

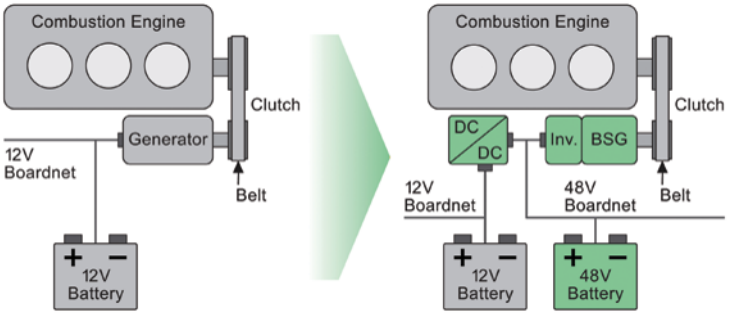
Some of the primary benefit of 48-V mild hybridization comes from its ability to stop and start the IC engine even more frequently than 12-V stop-start systems, including shutting off the engine while the vehicle is in motion or seamlessly restarting it on the fly if the driver slows but doesn't come to a complete stop, then tips into the accelerator.

Preparing for a 48-volt **REVIVAL**

Delphi's Mary Gustanski says consumers will appreciate the acceleration assistance 48-V mild hybrids can provide for increasingly downsized IC engines.

Latest-generation Continental 48-V liquid-cooled starter-generator motor with integrated power inverter.





Continental graphic shows basic layout differences of 48V and 12V systems.

Additionally, drivers annoyed by the intrusive behavior of many of today's lesser 12-V stop-start systems will be less inclined to switch off the systems, boosting their real-world efficiency. "Consumers are saying 'thanks but no thanks' on the stop-start," said Gustanski. "[The systems' performance] is a disgrace."

Moreover, a stronger electric machine can provide some degree of torque assistance to the IC engine when the driver asks for maximum acceleration.

Experts note that using the 10- to 12-kW (13-16 hp) available from a 48-V belt alternator-starter system to power an e-supercharger not only entirely eliminates the lag of exhaust-driven turbochargers, it allows the booster to provide extra performance the instant the IC engine restarts.

The forced induction helps offset the downsized-displacement trend. "They went so small with the IC engine to save on fuel economy and emissions they just don't have enough power," explained Gustanski.

In addition to the functional improvements to the drivetrain, the benefit of running the high-load accessories at higher voltage enables use of lighter, smaller-gauge wiring, which contributes to vehicle mass reduction.

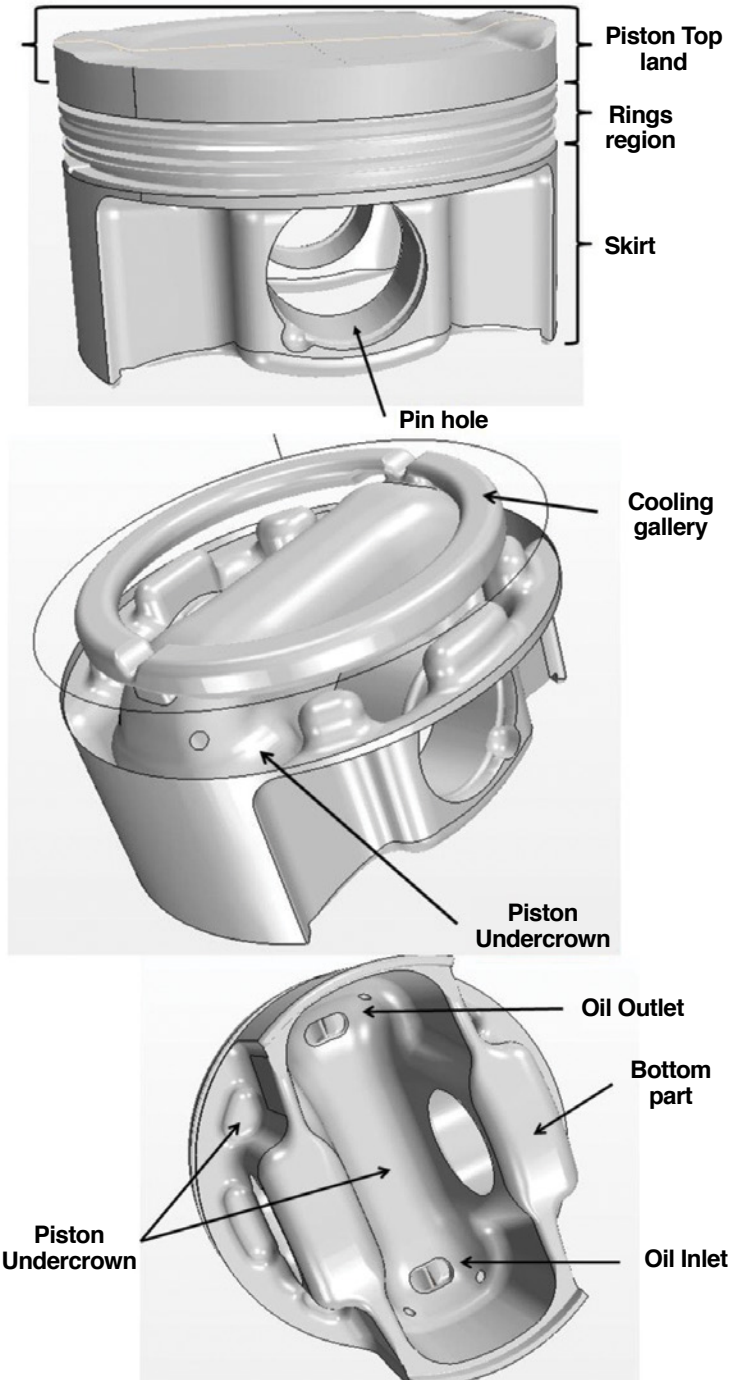
"Aircraft went to higher voltage years ago for the same reason: lightweighting and more cold-weather reliability," remarked Mike O'Brien, Vice President of Product Planning at **Hyundai Motor America**.

The additional power enables all manner of appealing ancillary features and systems for Hyundai's Genesis luxury models, O'Brien explained. "It is good for anything that requires a high-torque motor, like ABS pumps, stability-control systems with high-load actuators and adjustable stabilizer bars," he said. "When you think about customer needs and where 48 volts can be most leveraged, our large luxury products are the best fit for it now," he concluded.

What Ford likes about 48-V is that it is an "overlay technology," said Kok. That means that the company can install such systems relatively easily in all kinds of vehicles, diesel- or gasoline-powered, with automatic or manual transmission, because of the system's similarity to a conventional starter system. But it doesn't mean there is no work involved in the conversion. Calibration is tricky and space must be found for the 48-V battery. "What may package in a Fusion may not package in a Fiesta," he cautioned.

But while dedicated hybrid models may nor may not achieve high-volume sales, the popularity of mainstream conventional models - which serve as the base for the predicted boom in 48-V hybrid systems - is certain to continue. ■

ADDITIVE MANUFACTURING enhances GTDI pistons



Piston regions for conjugated HT-FEA 3D-CFD modeling.

Selective Laser Melting may help manufacture future gasoline-engine pistons with enhanced heat-transfer properties and reduced weight.

by Miguel Angel Reyes Belmonte, Sam Akehurst, Colin D. Copeland, Drummond Hislop, George Hopkins, Adrian Schmieder, Scott Bredda

The trend toward downsized gasoline turbocharged direct-injected (GTDI) engines has raised peak combustion chamber pressures to 160 bar (2321 psi) and temperatures above 2000°C—nearly the limit of traditional materials and design. More than ever, effective thermal management is vital for durability and combustion stability. Techniques such as adding oil-squirt jets to spray lubrication oil under the piston crown, while simple and effective, are often not sufficient for increasingly high-power-density engines.

In order to better understand the heat transfer and mechanical stress effects inside a downsized GTDI engine, the authors conducted a conjugate heat transfer and finite-element analysis. The intent was to study the piston design possibilities afforded by the use of the Selective Laser Melting (SLM) additive manufacturing process and its impact on further increasing engine efficiency, combustion stability and phasing. Potential benefits using SLM also exist in reducing piston mass and friction.

Model set-up

For the study, an aluminum piston in 2618A T6 alloy was used. An internal cooling gallery was added near the top land and first ring groove to improve piston thermal management and analyze the benefits on engine overall performance. A flat-top piston crown was selected over more complex geometries that may be possible with the SLM process, in order to target high temperature regions near the piston bowl.

The piston model was divided into the components

shown in the main illustration. Due to the complexity of defining a full 3D-CFD conjugate heat transfer simulation including the combustion chamber flow field, it was decided to impose heat transfer coefficients obtained from previous research at the different piston elements. A temperature level of 1,000°C and 120 bar (1740 psi) were chosen as combustion gas conditions at the piston crown. A normal force of 70 kN (7.8 t) was considered at the piston pin bore for later FEA analysis. Finally, a mesh with a base size of 3 mm (.19 in) was selected for the HT modeling; see Figure 2.

In order to analyze the influence of introducing a cooling gallery near the top land, a heat transfer analysis was repeated for the same piston model with and without the cooling gallery. Heat-transfer study results were analyzed in terms of temperature and heat flux ratios at each of the piston regions. To simplify the analysis, the same color scale was used for both cases.

As can be observed, temperature differences between both models are evident, showing the higher temperature at piston top land and rings for the non-cooled case, as was expected. The lower temperature observed at those regions for the cooled piston is beneficial to prevent abnormal combustion events such as knocking or pre-ignition.

Average temperature results are summarized in Table 1, the main differences observed on temperature distribution across the piston can be explained due to the fact that literature survey data for the cooled piston have been obtained from diesel piston suppliers. This is because cooled pistons for gasoline engines have not been widely used and there was not enough detailed information on that topic.

As shown in the table, modeled temperature agrees with the results found in previous works, biggest differences have been observed predicting oil temperature at the outlet of the cooling gallery. Modeled results show lower temperature at the oil outlet—a consequence of simplifying the complex phenomena of heat transfer to the oil due to the shaking effect. The temperature reduction found near the top land will help to optimize position of piston rings; this possibility and its benefits are studied in the next section.

Shown in Table 2, the heat transfer ratio found for the original (non-cooled) piston matches with the data observed on the literature survey. Regarding the heat transfer ratio calculated for the cooled piston, it was observed that the cooling gallery was not removing enough heat compared with previous works. The same fact was already detected from the lower oil outlet temperature obtained from the temperature analysis presented on Table 1. This difference can be explained due to the simplification assuming a constant value for the oil heat transfer coefficient, instead of doing a more complex analysis.

Figure 2: Piston mesh for HT modeling (cooling gallery in blue).

	COOLED PISTON		NON-COOLED PISTON	
Piston Region	**Model**	**Literature**	**Model**	**Literature**
Top land	267	290-330	300	300-320
Rings	233	240-280	269	230-300
Skirt	187	180-230	212	179-200
Undercrown	212	170-250	243	180
Cooling gallery	249	250-300	-	-
Pin hole	209	200-250	238	-
Bottom part	177	170-190	198	-
Oil Out	107	115-130	-	-

Table 1: Piston temperature distribution. Comparison between CFD modeling and literature survey data (temperature in °C)

	NON-COOLED PISTON		COOLED PISTON	
Piston Region	**Model (%)**	**Liter. (%)**	**Model (%)**	**Liter. (%)**
Top land	100	100	100	100
Rings + Skirt	55	56-64	39	30-33
Undercrown + Bottom	42	36-44	31	16-22
Cooling gallery	0	-	27	48-51
Pin hole	3	-	2	-

Table 2: Heat transfer ratio comparison (in %) between CFD modeling and literature survey data.

enhances GTDI pistons

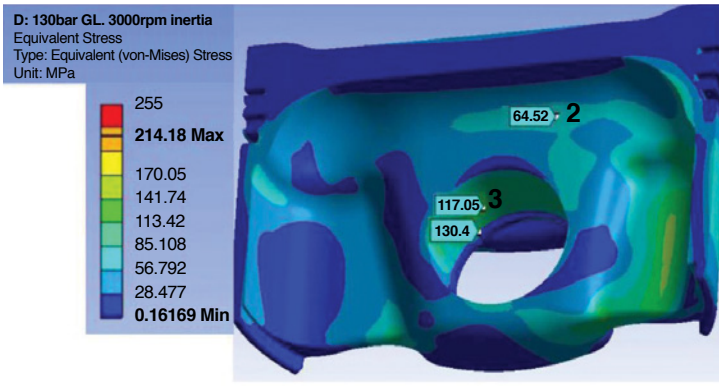


Figure 3: Stress distribution for piston design that includes a cooling circuit.

FEA stress analysis

Following conjugate heat-transfer CFD modelling, further piston modelling work was completed by undertaking FEA (Finite Element Analysis) by means of **ANSYS** R14.5 software. In order to do so, two load conditions were considered. Figure 3 shows the stress distribution map for the piston including a cooling gallery. Three regions have been chosen to study in detail von-Misses equivalent stress; these regions correspond to the piston crown, piston undercrown and piston bore.

In addition, safety factors (SF) have been calculated at each region using fatigue material data. This data is available at 200, 250, 300 and 325°C, and in the case where the temperature falls between two data sets, the fatigue limit at the higher temperature is used in order to give conservative values of SF. It was found that the weakest piston region of the three is the pin bore. Meanwhile the lower temperature due to increased cooling in the region of the new oil gallery increases the safety factor above 2.

As it was observed from piston heat-transfer analysis, temperature near the top land was reduced by around 50°C for the piston that included a cooling gallery. That temperature reduction would allow moving the top ring groove up closer to the crown, which would reduce piston crevice volume.

It has been widely studied that the piston crevice region, where the flame cannot penetrate, is the largest contributor (up to 80%) to engine-out hydrocarbon (HC) emissions. Meanwhile, an 86% decrease in piston top-land volume can decrease HC emissions by 20 to 40%. The authors analyzed different scenarios of modifying top ring groove position and focused on two iterations: moving the groove up by 1 mm and by 2 mm, as is depicted in Figure 4.

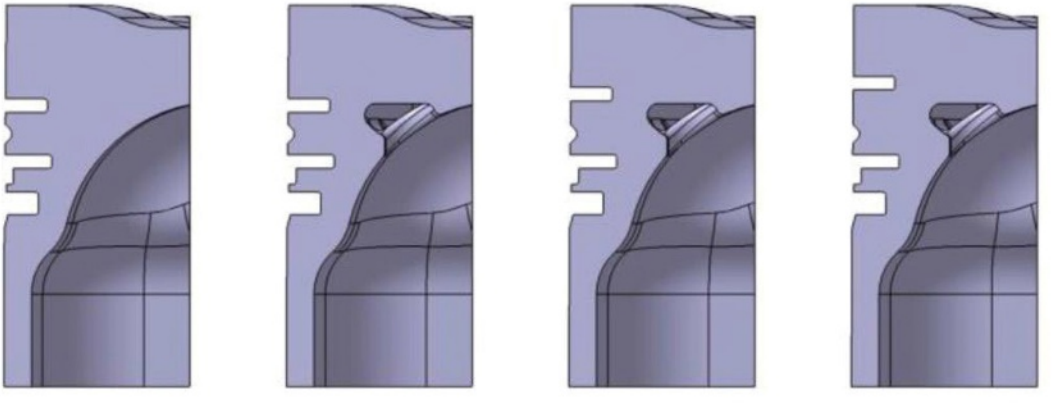
FEA was performed to determine mechanical stresses distribution on piston design due to the ring movement; see figure 5. The ring groove fatigue strength is improved, as this region is approximately 50°C cooler than at the standard piston. Also, as the groove is moved up, the wall section increases where it is not directly adjacent to the cooling gallery, thus improving the stress condition further.

Taking into account the standard piston analyzed in this paper had a top-land height of 8.25 mm (.32 in), moving first ring groove up 2 mm (.07 in, a 25% reduction in top land height) will lead to an HC emissions reduction of approximately 10%.

SLM and piston lightweighting

Utilizing the SLM manufacturing technique could potentially enable lighter-weight pistons. The process is capable of creating complex internal geometries that include tailored internal voids. Less aluminum is used, and structural integrity of the piston maintained by including lattice structures above the pin bore.

Figure 6 shows the kinds of lattice structures that could be introduced internally using SLM. Heat transfer and FEA analysis were repeated for the piston model that included an internal region meant to be



UB100 Piston Std groove position

GE ULBO 0153 Std groove position

GE ULBO 0153 groove moved 1mm

GE ULBO 0153 groove moved 2mm

Figure 4: Top ring groove-position modification.

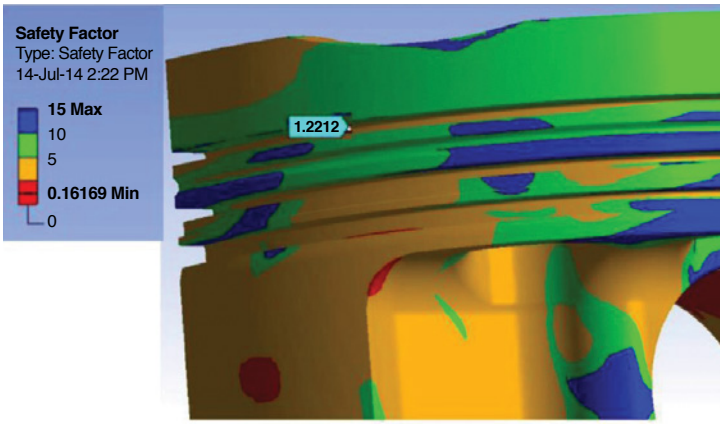


Figure 5: FEA for piston after moving up first ring.

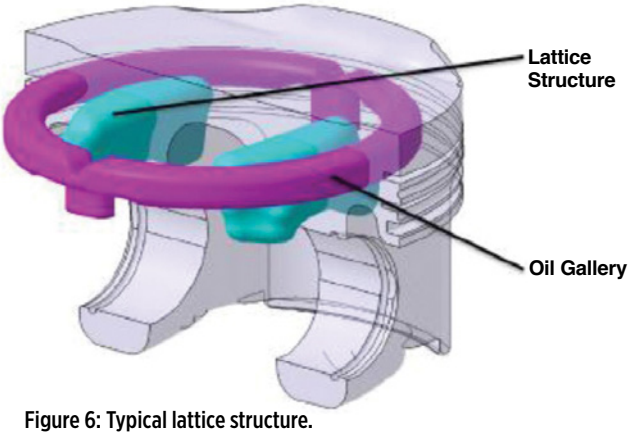


Figure 6: Typical lattice structure.

representative of the lattice structure. In order to perform this analysis, two approaches were adopted: First the lattice structure is considered as simply a void and secondly the same void is treated as possessing half of the material density.

On first approximation, it was considered an overly aggressive assumption to introduce two voids on the studied region. Under that assumption, piston weight was reduced 12%. For these studies the same two cases as explained before were analyzed. In order to perform a conjugated heat transfer analysis of revised piston design, the same heat transfer coefficients in the previous section were used.

Equivalent von-Misses stress was analyzed in detail at the same three numbered piston regions that were presented before. The assumption was that two voids inserted on the piston model have little effect on the crown peak stress or fatigue safety factor. However, it was detrimental at the undercrown and pin bore. Including a cooling effect from the oil gallery is unlikely to improve this, as this would only increase the fatigue life adjacent to the crown and ring grooves.

For this simulation, the void was modeled as a separate bonded piece assuming a 50% material density (aluminum) to the rest of the piston. However, the cooling gallery would mean the crown, undercrown and ring grooves would run significantly cooler. Thus they would have a higher fatigue limit than was taken into account for this analysis. Under this assumption, piston mass was reduced by 9% and the same loaded case setup and boundary conditions presented previously were repeated.

Stress is reduced at region 2 and 3 under the assumption of considering the lattice structured region as same material than the rest of the piston, but assuming half of its density. Peak stress at the top of the piston remains more or less unaltered whatever assumption was employed. Meanwhile, the peak stresses at the pin bore are within the safety material limit.

Next steps and conclusions

In order to complete the lightweighting analysis on the piston work it is planned to repeat the heat transfer and FEA stress analysis with the same piston model but introducing a real lattice structure. That structure will be built by means of SLM manufacturing process and will be placed at the region where a void had been considered for this paper.

The influence of introducing a cooling gallery placed near the top land was studied and temperature reductions between 30°C and 50°C were observed. The temperature reduction observed after introducing a cooling gallery makes the piston less sensitive to knocking. The top land temperature reduction also could help to increase engine compression ratio and/or reduce piston height, which would result in friction reduction. In addition, the observed temperature reduction will allow a more optimal first ring grove position thereby reducing the crevice volume.

The study suggests the potential for reducing piston mass by introducing lattice structures that are able to be built by utilizing SLM. As a first approach, it was assumed the lattice structure as a void and it was found that stress near the pin bore and void region rose significantly. As a second approach, it was assumed that lattice structure region could be represented by means of same material but using half of its density.

Under that assumption, peak mechanical stress and material fatigue limit are found near the piston bore region. However, the authors expect piston bore stress will be far from the material limit once realistic lattice structure properties replace the void assumption. ■

This feature is based on SAE Technical Paper 2015-01-0505 authored by: Miguel Angel Reyes Belmonte, Sam Akehurst and Colin D. Copeland (Univ. of Bath), Drummond Hislop, George Hopkins and Adrian Schmieder (HiETA Technologies Ltd.) and Scott Bredda (GE Precision) titled, "Improving heat transfer and reducing mass in a gasoline-engine piston using additive manufacturing."

Audi claims first production electric boosting on 2017 SQ7

Audi's SQ7 V8 bi-turbo TDI with electric compressor.

Audi is renowned for winning races and it announced another first at its Annual General Meeting (AGM) at Ingolstadt, Germany, last week: The first application of an electric-powered compressor on a series production car.

The EPC (Electrically Powered Compressor), with its compact electric motor, is to be used on the first diesel "S" version of Audi's flagship SUV, the 7-seat Q7, complementing a pair of sequential turbochargers to boost output to 320 kW (429 hp) and peak torque to 900 N·m (664 lb·ft).

The 2017 SQ7 also gets electromechanical active body roll stabilization (EAWS) and a 48-V electrical subsystem. And the Audi Valvelift System (AVS) is used on a **VW Group** diesel engine for the first time.

Turbo lag "is history" according to Audi executives—at least in this model. But expect the technology to be cascaded through the brand's ever-widening range. At the AGM, Audi Chairman Dr. Rupert Stadler announced the company will invest more than €3 billion in 2016 for future-mobility technologies, while pushing forward "with the electrification and digitization of our products."

EPC eliminates turbo lag

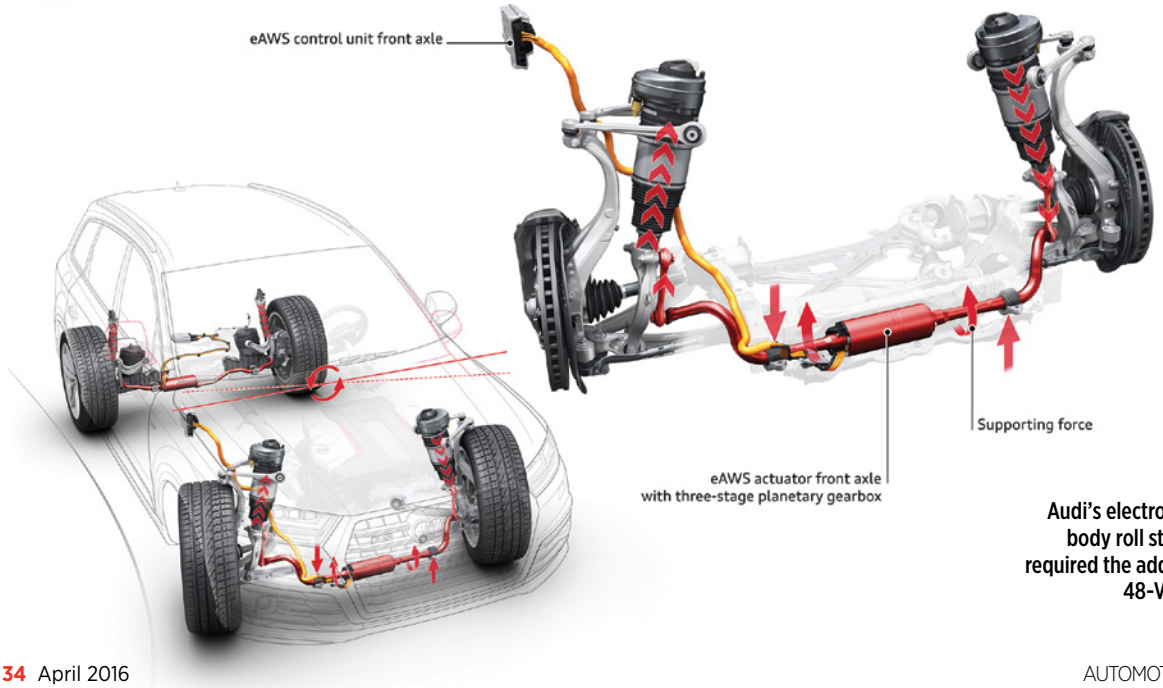
The new EPC technology in the SQ7 "is a world first in the competitive environment," claimed Dr. Stefan Knirsch, Member of the Audi Board of Management for Technical Development. The Audi SQ7's engine is described by the company as a redesigned V8 BiTDI. Dr. Knirsch claimed that the electrically powered compressor "dispenses with any sign of turbo lag from step-off acceleration."

The EPC is placed in the air path downstream of the intercooler, close to the engine and can deliver boost in less than 250 ms. Its compressor wheel spins up to 70,000 rpm.

Claimed performance figures for the SQ7 include 0-100 km/h in 4.8 s. Top speed is limited to 250 km/h (155 mph), and its NEDC fuel consumption is 7.4 L/100 km combined, with CO_2 emissions of 194 g/km. Audi describes this as the fuel consumption level of a 6-cylinder diesel.

The two exhaust-gas turbochargers are activated selectively, controlled by the sequential charging system. Exhaust gas flows through one turbocharger at low and intermediate load, the other at higher load. The EPC is particularly beneficial at lower engine speeds, so markedly improving off-the-line performance.

Another first for an Audi diesel is the use of the company's AVS variable valve timing. The inlet and exhaust camshafts each have two cam contours per valve, explains the company. On the inlet side, one cam contour supports starting off in conjunction with the EPC, while the other optimizes cylinder



Audi's electromechanical active body roll stabilization system required the additional power of a 48-V electrical system.

The new technology-dense 2017 Audi SQ7.

filling and so power at high engine speeds. The AVS system on the exhaust side enables activation of the second exhaust-gas turbocharger.

The exhaust streams from the two exhaust valves are hermetically separated, with each driving one of the two turbochargers. In the lower engine speed range, one valve per cylinder remains closed, so that the full exhaust stream flows to the active turbocharger.

When load and engine speed increase, the AVS opens the second exhaust valves. This directs flow to and activates the second exhaust-gas turbocharger. The engine achieves its maximum output in this biturbo mode. The switching by the AVS is said to enable fast and precise activation of the second exhaust-gas turbine.

48-V powers active roll stabilization

Power for the EPC (maximum 7 kW) comes from the car's 48-V electrical subsystem. This also is used to power the electromechanical active roll stabilization (EAWS).

The SQ7's optional EAWS uses a compact electric motor with a 3-stage planetary gearbox separating the two halves of the stabilizer. On an uneven road surface, they are actively decoupled from one another for improved ride comfort. During faster driving, the tubes are interconnected and twisted against each other to "significantly" reduce body roll, claims Audi.

Together with the transmission, the electric motors produce anything up to 1200 N·m (885 lb·ft). The vehicle's front and rear stabilizers can be adjusted independently of each other. Use of a 48-V system provides more power, enabling the system to work faster and to be activated even at low speeds. The electromechanical active roll stabilization is maintenance-free.

A 48V lithium-ion battery mounted beneath the luggage compartment has a nominal energy content of 470 W·h and peak output of up to 13 kW. A dc/dc converter connects the 48- and 12-V systems.

A MOSFET (Metal Oxide Semiconductor Field Effect Transistor) generator reduces electric losses and increases efficiency, with an efficiency of over 80% at an output of up to 3 kW. MOFSETs replace the diodes used previously. The 48-V storage unit supports the 12-V electrical system when required to reduce load on the 12-V lead battery.

The car drives through an 8-speed automatic transmission.

Electromechanical power steering, the Audi drive select driving dynamics system, and adaptive air suspension with S-specific tuning are standard. Carbon fiber-ceramic disc brakes will also become available later this year following the SQ7's launch (dependent on market). Wheels are 20-in with 285/45 tires, with options up to 22-in.

All-wheel steering also is an option and the car's Quattro (AWD) system can be fitted with a sport differential.

Stuart Birch

Mercedes' 2017 E-Class takes a leap towards autonomy

Michael Kelz, Chief Engineer for the new **Mercedes-Benz** E-Class, does not underestimate its present and future potential: "This car is a big step in the direction of autonomous driving. With our Drive Pilot, we have the possibility of processing really high rates of data, a very impressive system that can be used in many situations, including reaction to speed limits, the car decelerating or accelerating automatically."

Kelz compares the knowledge requirements of autonomous driving systems with his kids' need to gain and retain experience. Like them, the E-Class has great intelligence but it has to acquire knowledge. "The car has the necessary technology on board," he noted, but to drive fully autonomously it needs more precise street map data—and more knowledge of what is happening around it.

The MY2017 E-Class already is about 80% ready for autonomous driving on an autobahn, according to Kelz. He said the Drive Pilot can follow vehicles ahead at speeds up to 210 km/h (130 mph), and at up to 130 km/h (81 mph) will find its own way, "even in the absence of clearly visible lane markings."

Also, to make a lane change, the driver needs only to operate the indicator stalk for a couple of seconds and Active Lane-Change Assistant supports steering provided the adjoining lane is clear. And Active Brake Assist with cross-traffic function now has extended speed thresholds and when necessary also brakes on approach to the tail end of a traffic jam.

Evasive Steering Assist is another new system that adds torque to help a snap maneuver and its recovery, such as in pedestrian avoidance. Other advanced technology elements are being added, including heating for the front-mounted radar for Distance Pilot Distronic.

A challenge for Mercedes, as with many OEMs, is to keep ahead of ultra-high profile software companies entering the auto sector that could change

The new E-Class on the Estoril race circuit near Lisbon. Three steel suspension systems are offered plus multi-chamber Air Body Control.

the dynamic of the industry's comprehensive software and hardware business structure.

But the 10th generation E-Class's driver assistance systems and their associated present and potential new technologies, represent just one (albeit very significant) aspect of the car's capabilities. These span remote parking (via a smartphone app for very tight parking situations); new multi-chamber air suspension; aerodynamics honed to achieve 0.23 Cd; and a "world first" hand-motion swiping of steering wheel touch control buttons.

All-new OM654 diesel

Internally designated W213, the new E-Class is nearly 2 in (51 mm) longer overall than its predecessor and rides on a 2.6-in (66-mm) longer wheelbase. Base powerplant for the European market is a new 4-cylinder 1950-cm^3 diesel capable of 5300 rpm and rated at 400 N·m and 143 kW (192 hp) in its launch form. Other powertrains include the E350e plug-in hybrid with 2.0-L gasoline engine and total system output of 210 kW (282 hp); its 550 N·m proved quite convincing to the author on a short test-drive.

Despite some doubters, Mercedes maintains its continuing confidence in diesel technology. Dr. Thomas Weber, R&D head of **Daimler Group** research, said: "In our opinion, the diesel engine is indispensable in trucks and cars if we want to further reduce the CO_2 emissions from traffic. The new diesels are designed to meet all future global emissions standards."

The new 2.0-L diesel, designated OM654, was four years in development. It replaces the 2143-cm^3 OM651 engine produced since 2008. Dr. Weber noted that the new diesel will

Compact and efficient: OM654 is the first example of a planned family of Mercedes-Benz 2.0-L aluminum diesels.

E-Class Chief Engineer Michael Felz said the new E-Class's bodyshell uses a combination of materials with the accent on aluminum and high-strength steel.

play a significant role in Mercedes' future powertrain programs. It is a modular design sharing a 500-cm^3 cylinder, and capable of longitudinal and transverse applications in front-, rear- and all-wheel-drive drivelines. Later, there will be what Mercedes engineers describe as "a series of innovations on the basic engine."

The OM654 is Mercedes' first production diesel featuring all-aluminum construction, but it has steel pistons with stepped combustion bowls, riding in Nanoslide-coated cylinders (see http://articles.sae.org/10507/). The common rail injection is 4th generation. Particularly significant is the positioning of all exhaust treatment directly on the engine. The power unit is also 17% lighter than the its predecessor in the E-Class. Its use in other models requires all-new electronic architecture.

Mercedes has focused on reducing noise and vibration compared to the old OM651. Despite output raised from 125 kW to 143 kW (from 167 to 192 hp), fuel consumption and CO_2 emissions are both reduced by some 13% for the E-Class, engineers told *Automotive Engineering*.

The 90-mm (3.54-in) cylinder spacing is 4 mm (0.16 in) more compact than that of the OM651. It's also 46 kg (101 lb) lighter, in fully dressed form, than its predecessor. The mass reduction was achieved via the new engine's reduced displacement, as well as the aluminum crankcase (designed to withstand peak pressure of 205 bar/2973 psi), the Nanoslide cylinder coating, single instead of two-stage turbocharging and plastic engine mounts.

With all relevant emissions reduction components installed directly on the engine, plus insulation and improved catalyst coatings, the new OM654 does not require temperature management during cold starts nor at low load, according to the engineers.

Multiway EGR (exhaust gas recirculation) combines both cooled high pressure and low pressure flows.

Piston bowls and safety systems

Further details of the engine design include twin Lanchester balancer shafts mounted on each side of the crankshaft rather than below it, to save height. Mercedes has been a leader in the adoption of steel pistons in passenger-vehicle diesels.

Multibeam headlight of the E-Class uses 84 individually controlled LEDs. All functions of low and high beam modes can be depicted digitally without mechanical actuators, and a purely electronically implemented active light function is incorporated.

Engineers noted that thermodynamic efficiency is improved due to the lower heat conductivity of steel, allowing higher component temperatures for better combustion. The lower expansion rate of steel at normal engine operating temperatures also provides increased clearance between the "very compact, lightweight" pistons and the crankcase, thus reducing friction by up to 50%.

Last year, Mercedes and piston supplier **KS Kolbenschmidt** won materials-industry awards for use of forged steel pistons in the all-aluminum V6 diesel of the E350 BlueTEC. Those "slugs" are forged using a patented technique which produces a sealed coolant passage. The resultant thinner wall between the coolant passage and the hot zone of the piston is the key to efficient cooling (http://articles.sae.org/7009/). Mercedes also uses steel pistons in other 4-cylinder engines.

Mercedes claims a "world first" for the stepped combustion-bowl design incorporated in the OM654 pistons. Engineers said this geometry brings a "positive effect" to the combustion process (higher burning rate), the thermal loading of critical areas of the pistons and reducing the ingress of soot into the engine oil.

Driving the new E-Class at the car's European media launch in and around Lisbon, Portugal, the author found the 2.0-L diesel to be generally quiet and smooth and, considering it was propelling a 1680-kg (3700-lb) car, relatively vigorous. Complemented by its 9-speed transmission, 0 to 100 km/h acceleration takes 7.3 s. Vmax is 240 km/h (149 mph). But short of encapsulating the cabin, low-speed/high-load situations will inevitably transmit some diesel noise. The car is extremely quiet when cruising.

Interesting new safety systems include an air chamber in the front seats to push an occupant away from the area of a side impact, and Pre-Safe Sound, which involves the stapedius reflex of the human inner ear.

If the risk of a collision is detected, the car's sound system emits a short interference signal to action the reflex. This prepares the ears of the E-Class's occupants for the sound of the accident (often rather loud!) and is said by Mercedes to help reduce stress. It should be noted that the author did not real-time test the car's safety aspects.

Stuart Birch

Jeep will test pickup concepts at Moab 50th

The Crew Chief 715 is one of seven 2016 Jeep concept vehicles that will see off-road activity in Moab.

The Dana 60 rear axle and Fox remote-reservoir shocks on the Jeep Crew Chief concept. This may be the most "garage creeper-friendly" vehicle yet. (Lindsay Brooke)

Military vehicle strength, functionality, and styling underscore two Jeep-based concept trucks that took on the challenging off-road trails of Moab, Utah, during the recent annual **Jeep** Safari.

"It's a very, very important event this year because it's the 50th anniversary of the Easter Jeep Safari, and it's coinciding with the 75th anniversary of Jeep," asserted Mike Manley, Head of Jeep Brand for **FCA Global**.

The feedback provided by the thousands of Jeep enthusiasts attending the Moab Jeepfest is highly valued by FCA and its **Mopar** aftermarket brand.

The Renegade-based Comanche and the Wrangler Unlimited-based Crew Chief 715 trucks are among this year's seven Jeep concept vehicles modified with Mopar and Jeep Performance Parts. They were unveiled to media recently at FCA's Auburn Hills, MI, technical center.

Pietro Gorlier, Head of Parts and Service (Mopar) FCA Global, told *Automotive Engineering* that Jeep is a perfect match for accessory parts. "When you build a Jeep—whether it's a big one or a small one—you always can add capability and additional features," he said. "Jeep is a brand that is king for customization."

Crew Chief is M715 inspired

Crew Chief is a "big one," its design inspired by the U.S. military's **Kaiser Jeep** M715 of the 1960s, according to Mark Allen, Head of Jeep Design. It is underpinned by a Wrangler Unlimited chassis stretched by 33.2 in (843 mm) to 148 in (3789 mm) overall.

The four-door concept's tactical green-exterior color scheme offsets a customized steel mesh grille, and the texture pattern of the forward-leaning grill (itself inspired by the classic Gladiator-series Jeep trucks) is also showcased on the sides of the cargo bed and front fenders.

"We unbolted the Wrangler piece and put this nose on the front. The production nose and this custom nose are actually interchangeable," said Allen. "We came up with the unique grille pattern, then folded it in a way that recalls the production Jeep's slotted grille."

The Mopar steel front bumper does double-duty. "We use it in the front and in the rear so we could have a winch in the back of the vehicle as well," Allen explained. Other aftermarket parts on the Crew Chief include **Dana** 60 front and rear axles with air-locking differentials, and a 4-in (102-mm) Mopar lift kit with Jeep Performance Parts/Fox 2.0 remote reservoir shocks.

Crew Chief's 40-in-tall non-directional tires (STA 9.00 x 20's) are mounted on 20-in beadlock wheels. "It's an old-school military tire, and these skinny, tall tires help convey the attitude of this tough truck," Allen said. "The control arms and springs are heavier than the production Jeep to handle the Crew Chief's tire/wheel package."

The open-air/fabric soft-top, full roll cage Crew Chief with military-styled tailgate accessing a 5-ft-long (1.5-m) cargo box featuring wood flooring. The vehicle is powered by a 3.6-L Pentastar V6 and 5-speed automatic.

Comanche reborn in Renegade-based diesel pickup

In its Comanche concept, Jeep reprises the nameplate of its last production compact pickup sold by **AMC** from 1984-96. The latest Comanche transforms the Renegade into a mid-sized soft-top pickup with a 5-ft bed.

Said Allen, "It has a full roll cage, and we built a frame where there wasn't one. The box is composite with a steel

Jeep Comanche concept based on the Renegade. Might this indicate FCA's intentions for a future compact Jeep pickup to accompany the Wrangler-based pickup that's confirmed?

Cargo area of the Jeep Comanche concept features a structural-composite bed with steel floor. (Lindsay Brooke)

floor underneath."

Comanche's cargo bed carries a spare 32-in **BF Goodrich** All Terrain T/A tire, unlike the spare tire-less Crew Chief. "There was just nowhere to put it. The tire is just so big," said Allen, noting the Comanche stretched Renegade's 101.2-in (2570-mm) wheelbase an additional 16.4 in (416 mm). The truck rides on 16-in painted steel wheels.

A 9000-lb (4082-kg) Warn rock crawler winch was fitted into Comanche's re-crafted front bumper. The vehicle sports a modified Wrangler Rubicon steel rear bumper. Off-road capability is also enhanced via a 2-in (51 mm) Mopar lift kit.

The open-air/soft-top Comanche comes 25 years after the last convertible pickup, the **Dodge** Dakota Sport, of which less than 3600 units were produced in 1989-91. Comanche is powered by a **Fiat** Multijet II (JTD) turbodiesel that's available in the European-market Renegade. The 2.0-L unit is mated to FCA's **ZF**-designed 9-speed automatic with Jeep Active Drive Lock, which includes low range and a locking rear differential.

"We're pretty excited to try this diesel-powered Comanche off-road," said Allen. "We've made the suspension articulate a little more than the stock suspension system. By adding a lift kit and taking the sway bars off that allowed for a lot more flexible suspension."

A Jeep pickup based on the Wrangler is under development, but is likely 18 to 36 months from production, according to Manley. When asked by *Automotive Engineering* if a Renegade-based production pickup is possible, Manley said, "I would never rule anything out. We'll see what people think of this [Comanche] concept when it gets to Moab."

Other 2016 Jeep concepts getting a work-out at the Easter Jeep Safari are the extreme-offroader Trailcat (powered by a Hemi Hellcat V8) and the more moderate Trailstorm; both are Wrangler based. There's also the CJ-5 inspired Short Cut, based on a significantly shortened Wrangler chassis, the mildly modified Renegade Commander, and an upgraded and customized **Willys** FC150 cabover that is certain to draw smiles from the Jeep faithful at Moab.

Kami Buchholz

2017 Hyundai Ioniq offers three electrified powertrains

Hyundai's 2017 Ioniq will be available with hybrid, plug-in hybrid, and battery electric power options.

Hybrid and plug-in hybrid electric motor is fitted between engine and transmission. (John Kendall)

Hyundai unveiled the 2017 Ioniq at the Geneva Show, a car only available with an electrified powertrain—actually three of them. There will be three variants of the car, offering a conventional parallel hybrid, plug-in hybrid, and battery electric drive.

Hybrid and plug-in versions use the new Hyundai/**Kia** Kappa 1.6-L direct injection gasoline engine announced in October 2015. The long-stroke engine uses Atkinson Cycle principals and cooled exhaust gas recirculation (EGR) to achieve a claimed 40% brake thermal efficiency. According to company engineers, the engine's EGR rate exceeds 20%, with a 98% cooling efficiency for the EGR cooler and a 56.9-ms response time for the EGR valve. These three features are said to provide a claimed 3% gain in fuel economy.

Hyundai claims that fuel savings are boosted by setting separate thermostat cooling temperatures for the block and cylinder head, set at 105°C and 88°C, respectively.

Other details of the Kappa engine include six-hole laser-drilled GDI injectors and a 200-bar fuel system pressure. The engine is rated at 77.2 kW (104 hp) with peak torque of 147 N·m (108 lb·ft).

Three electrified powertrains

In the hybrid and plug-in hybrid variants, the engine is coupled with a 6-speed dual clutch automated transmission and the slim electric motor/generator is conventionally sandwiched between the engine and clutch. The motor is rated at 32 kW (43 hp) and produces peak torque of 170 N·m (125 lb·ft).

Electric power is supplied by a lithium-ion polymer battery of 1.56 kW·h capacity. Hyundai claims the Ioniq can achieve a maximum velocity of 185 km/h (115 mph). No official emissions and fuel consumption figures are currently available, but Hyundai claims target CO_2 emissions of 79 g/km or lower.

The same basic architecture is used for the plug-in hybrid, but both battery and electric motor are uprated. Hyundai claims battery capacity of 8.9 kW·h, using lithium-ion polymer chemistry again. The electric motor is rated at 45 kW (60 hp) and Hyundai claims range greater than 50 km (31 mi); CO_2 emissions are said to be as low as 32 g/km.

The Ioniq EV also relies on a lithium-ion polymer battery pack, rated at 28 kW·h. The battery can be charged from a regular domestic power point or fast charger. Hyundai claims that using a 100-kW fast charger, the battery can be charged to 80% capacity in 24 min. The motor is rated at 88 kW (118 hp) and drives the front wheels through a single-speed reduction gearbox.

The motor in all three Ioniq variants is of the permanent-magnet synchronous type, with the thickness of the electrical sheet steel core components reduced by up to 10%, claims Hyundai. Rectangular-section copper wire is also used to improve efficiency.

In all three models, the battery is located under the rear passenger seat. Battery electric variants carry more batteries under the spare wheel well. Up to 750 L of cargo space is said to be available in hybrid models and up to 650 L in plug-in and battery electric models.

Aero and mass reduction measures

Hyundai states a 0.24 Cd drag coefficient for the Ioniq. To achieve this, the development team used a variety of techniques including front wheel air curtains, rear spoiler and diffuser, molded rocker panels, a cover beneath the car, and closed wheel designs.

All Ioniq models are fitted with low rolling resistance Michelin tires on 15-, 16- or 17-in rims. Hybrid models with 17-in wheels are fitted with silica tires, which can combine good grip characteristics with low rolling resistance.

Weight reduction measures include the use of aluminum in the hood and tailgate, reducing weight by 12.3 kg (27 lb) compared with using steel. Other weight-saving measures include the roller cover over the cargo space claimed to be around 25% lighter than similar covers in other Hyundai models.

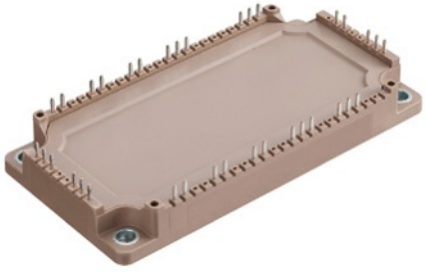
Aluminum is used extensively in the suspension components, reducing weight by around 10 kg (22 lb). Each front lower arm weighs a claimed 2.3 kg (5 lb) less with a 3.57-kg (8-lb) weight saving for each rear lower arm. The chassis is made from a claimed 53% of high-strength steel to improve rigidity and limit weight.

Two different rear suspension arrangements are used. Battery electric models use a torsion beam rear axle to provide greater space for the battery pack. Hybrid and plug-in models are fitted with a multi-link independent design.

John Kendall

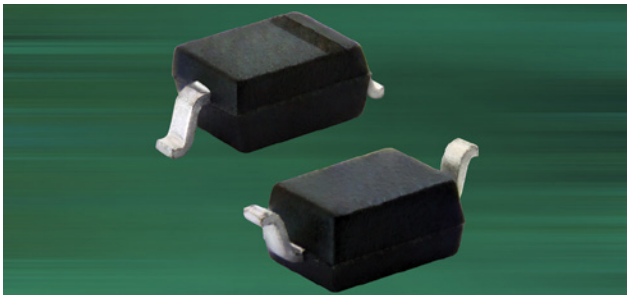
SPOTLIGHT: SEMICONDUCTORS

IGBT module



Fuji Electric has introduced its 7th generation IGBT (insulated-gate bipolar transistor) modules featuring advanced chip and package technologies for industrial applications, uninterruptible power supplies, and power conditioning systems. The latest addition to its semiconductor product portfolio offers an increased current rating for reduced package sizes, improved power cycling capability for enhanced reliability, and is capable of continuous operating temperature of 175°C (347°F) for increased output current. Additional product features include a performance improvement in the trade-off relationship between Von and Eoff (characteristics) as a result of the thinner drift layer and fine pattern of the trench pitch. The structure and materials of the module have been improved to increase its stability and durability under high-temperature operation, thereby improving the stability and reliability of the equipment on which the module is installed. The series will be available in phases: 1200V IGBT modules are currently available for shipment, and will be followed by the 650V and 1700V modules. For more information, visit **www.americas.fujielectric.com**.

Bidirectional ESD protection diodes



Vishay Intertechnology, Inc. has released two new bidirectional single-line ESD protection diodes in the compact SOD-323 package. Measuring 1.95 x 1.5 mm (0.077 x 0.06 in) with a low 0.95-mm (0.037-in) profile, the space-saving Vishay Semiconductors VLIN1626-02G and VLIN2626-02G offer low capacitance and leakage current for the protection of automotive data lines against transient voltage signals. For LIN bus applications, the diodes provide transient protection for one data line as per IEC 61000 4 2 at ± 30 kV (air and contact discharge). The AEC-Q101-qualified devices feature low load capacitance of 15.5 pF typical and 18 pF maximum, low maximum leakage current of <0.05 µA, and working voltages of -16 V / +26.5 V or ± 26 V. The protection diodes are lead-free and RoHS-compliant. Samples and production quantities of the new VLIN1626-02G and VLIN2626-02G are available. For more information, visit **http://www.vishay.com/**.

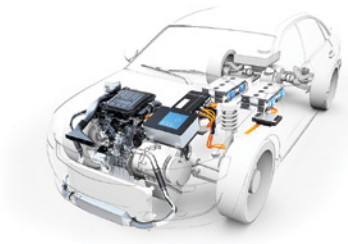
Miniature relief valve

The **Lee** Company's miniature, poppet-style pressure-relief valve provides a faster opening rate and more stable flow than typical ball-style relief valves. Measuring 5.5 mm (0.2 in) in diameter and 19 mm (0.75 in) long, the valve weighs 1.7 g (0.06 oz). The valve uses Lee's field-proven insert principle that provides secure retention and eliminates the need for threads, O-rings, or in-house designs. To install, simply insert the relief valve into a drilled hole and drive the expansion pin flush to seal and lock the valve in place. Designed for reliable operation, the relief valve features all stainless steel construction and 100% performance testing to ensure consistent, long-term performance. The valve's compact size, enhanced performance, and ease of installation make it suitable for high-volume applications in automotive, off-highway, and other industrial hydraulic systems. For more information, visit Booth 522 at the **SAE** 2016 World Congress or **http://www.leeimh.com/**.

Impairment noise generator

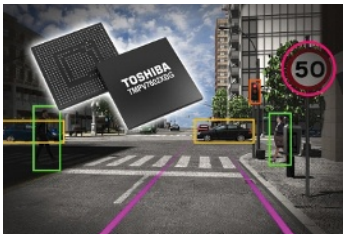
A solution from **Spirent Communications** will help reduce the development time and cost of automotive Ethernet/BroadR-Reach (BRR) systems. The AING-5000 automotive impairment noise generator reduces the cost of development by simulating noise and removing the need for electromagnetic compatibility (EMC) physical chamber testing by up to 80%. New BRR electronic control units (ECUs) require physical EMC chamber testing, and typically manufacturers are testing these ECUs up to 25 times over a three-year development cycle. This is expensive, and an EMC chamber can be difficult to schedule for testing time. The AING-5000 can perform advanced modeling of a diverse range of scenarios, such as starter motor on/off or electromechanical switch on/off settings. Also available are pre-recorded noises and user-selectable parameters such as duration, burst, spacing, and power. Users can also create customizable noise libraries, and the system can be programmed to offer automated testing. For more information, visit Booth 814 at **SAE** 2016 World Congress or **www.spirent.com/Automotive**.

Integrated open development platform



The Integrated and Open Development Platform (IODP) from **AVL** features the first integration product, Model. CONNECT. Designed around the system requirements, this platform can be applied in a range of powertrain and vehicle applications such as vehicle dynamics, energy management, real driving emissions, or advanced driver assistance systems (ADAS). It creates vehicle prototypes built with virtual and real components available at every development step. The software contains the advanced execution engine ICOS (Independent CO-Simulation) and ACORTA (Advanced Co-Simulation Methods for Real-Time Application), which solves the complex interaction between virtual and real components with advanced coupling algorithms. The package includes multiple simulation tools for various domains supported (e.g., AVL CRUISE, AMESim, MATLAB, ECS Kuli, Dymola, MSC Adams), and unique solver techniques to link models with different time domains (multi-rate) and to minimize coupling errors. It provides full support of interface standards (FMI – model exchange and co-simulation) and customized wrappers that empower the coupling of preferred tools. For more information, visit Booth 801 at **SAE** 2016 World Congress or **www.avl.com/en/web/10138/iodp**.

Image recognition processor



The TMPV7602XBG image recognition processor from **Toshiba America Electronic Components**, Inc. is suitable for monocular cameras used in advanced driver assistance systems (ADAS) and will help designers implement ADAS applications using a cost-optimized camera system with a small form factor. Featuring 13 hardware-based image recognition accelerators, the TMPV7602XBG incorporates ADAS features that will become part of the camera requirements for the European New Car Assessment Program in 2018. These include autonomous emergency braking, traffic signal recognition, lane departure warning / lane keeping assist, high-beam assistance, and forward-collision warning. In addition, the processor supports such new applications as traffic light recognition and night-time pedestrian detection. ADAS applications are processed concurrently within a typical time window of 50 ms inside the image recognition processor and with relatively low power consumption due to the purpose-built hardware accelerators and media processing units. The processor integrates new, enhanced accelerators that provide higher image recognition accuracy than previous Toshiba devices, particularly in low-light and night conditions. For more information, visit **www.toshiba.com/taec**.

Integrated electronic stability control

ZF TRW has enhanced the capabilities of its electronic stability control (ESC) system—in addition to its wide range of advanced braking functionality, the technology can act as a "black-box" integration hub, hosting software algorithms to control automated driving, safety, chassis and drivetrain functions. The firm has developed advanced six-piston premium ESC technology (EBC 460) that offers one of the most powerful microcontrollers in the automotive industry and can host considerably more software than the previous version. Launching later this year with a major European vehicle manufacturer, the ESC module will host the control algorithms for an advanced automated-driving function. In addition, it will provide the integration platform for enhanced chassis actuators including the center clutch, rear-axle steering, electric park brake and drivetrain, which will help to achieve the maximum comfort and control of all vehicle dynamics. For more information, visit **www.trwauto.com**.

Lightweight CV joint system

GKN Driveline has developed a family of lightweight constant velocity (CV) joint systems that enables rear-wheel drive platforms to save more than 4 kg. The VL3 CV joint increases torque capacity by up to 27% with no increase in packaging size. Available in four sizes, the VL3-33ISM variant has a torque capacity of 3300 N·m in a package previously capable of delivering only 2600 N·m. The system can also maintain performance while reducing package size by approximately 7%. With a plunging distance of 18 mm, the VL3 is the best choice for a rear constant velocity sideshaft for medium working angles with low axial forces and best-in-class minimum backlash. It uses a Monobloc tubular shaft and face spline connection to the wheel hub to achieve significant packaging and weight advantages as well as noise, vibration, and harshness (NVH) behavior benefits. The VL3 Monobloc joint uses a track geometry with four pairs of opposed ball tracks instead of three, which enables it to transmit more torque to wheels within the same packaging space. The VL3 joint has been selected by BMW to launch on its 7 Series. For more information, visit **www.gkndriveline.com**.

COMPANIES MENTIONED

UPCOMING FROM THE EDITORS

April 12: Automotive Engineering Technology eNewsletter

April 19: Off-Highway Engineering Technology eNewsletter

April 27: Automotive Engineering Technology eNewsletter

May: Aerospace & Defense Technology Print Magazine
- Special Issue: Unmanned Vehicle & Robotics Technology

May: Automotive Engineering Print Magazine
- Global Viewpoints 2016
- Design meets engineering
- Drivelines for greater efficiency
- Intuitive interactions (human-machine interface)
- Test Equipment product spotlight

May 2: Electronics & Connectivity Technology eNewsletter

May 4: Aerospace Engineering Technology eNewsletter

May 10: Vehicle Engineering Technology eNewsletter (all markets)

May 12: Off-Highway Engineering Technology eNewsletter

May 18: Automotive Engineering Technology eNewsletter

May 24: Heavy Duty Engineering Technology eNewsletter

June: Aerospace & Defense Technology Print Magazine
- Embedded/Rugged/SFF computing
- Lasers & optics
- Rotorcraft developments
- Digital design tools

June: Automotive Engineering Print Magazine
- Next-generation advanced combustion/aftertreatment (Webinar feature)
- Thermal management
- Sensors & cameras
- Metals show their mettle
- CAD/CAM/CAE product spotlight

June: Off-Highway Engineering Print Magazine
- Executive Viewpoints annual series
- Supplier Directory
- Annual Product Guide

AD INDEX

Q&A

Seiya Nakao: "We will expedite collaborations" in advanced mobility technologies.

Toyota's "trigger" for innovation

"**SAE** is the 'engineers' foundation," reflected Seiya Nakao. "When I was a young engineer, we learned a lot from SAE, and personally this is a good opportunity for me to return something to it." Nakao, President of the 1M-ft^2 **Toyota** Technical Center (TTC) near Saline, MI, is serving as General Chairman of the 2016 SAE World Congress. He is clearly excited about his company's leadership role in the event, and the 100 technical papers being presented by Toyota. Nakao believes this year's World Congress, and its "Powering Possibilities" theme, will serve as a "trigger" for new innovation. *Automotive Engineering* spoke with Nakao-san recently at TTC; an exerpt from our interview follows.

What is your own vision of mobility in the next 30 years?
I believe in variety. There should be a lot of options for people to choose: driving by themselves, autonomous vehicles, car sharing. But while in the next 25-30 years we will still have gasoline hybrids and PHEVs, this will be a very important transition time for fuel cell and electric vehicles. And it will be hugely exciting for new technology.

TTC is undergoing a big expansion. What role will TTC play in the new mobility era?
Our main job here consists of two 'pillars': vehicle development and cutting-edge technology and research. So while we evolve the current technologies such as hybrid, we also have to develop or invent new solutions—longer range batteries and affordable fuel cell system. And, of course, infrastructure.

Will TTC take on more of a core vehicle-development role?
In vehicle development we're now doing U.S.-exclusive product such as Avalon and Tundra. But in the coming years, in my opinion, we will take a main role in full vehicle development, such as the 'K' platform [Camry]. That kind of shift in responsibility will happen, I believe. And on the Research side, we created the new **Toyota Research Institute** (TRI), which is an artificial intelligence company (http://articles.sae.org/14546/). That technology is used to create autonomous vehicles and we believe it should definitely be led by us. And other cutting-edge technologies such as battery systems—the U.S.A. is the best place for research in these areas.

Are you confident there will be a battery "breakthrough," as the battery guys keep promising?
Should I answer that officially or personally? [laughs] Actually I hope so. But my personal impression is, I haven't seen good progress in this area. It's kind of a struggling point for Toyota. But we don't give up; we're aggressively developing these technologies.

How will Toyota's recent reorganization impact product development?
We're now producing 10 million vehicles per year. But our organizational structure was stuck where it was 30 years ago. We had many [silos] that prevented cross-functional engagement and quick decision making. That's why Akio Toyoda decided to make the change. His purpose is very clear: quick decisions! So we destroyed the old [highly centralized] organization and created what are essentially four product-based divisions.

What do the Production guys—the traditional "core" of Toyota and key to its profitability—have to say about this?
The Toyota Production System is very efficient and low cost—great system. But unfortunately Production became too strong! So we have the new idea. We will start the new system April 18, officially.

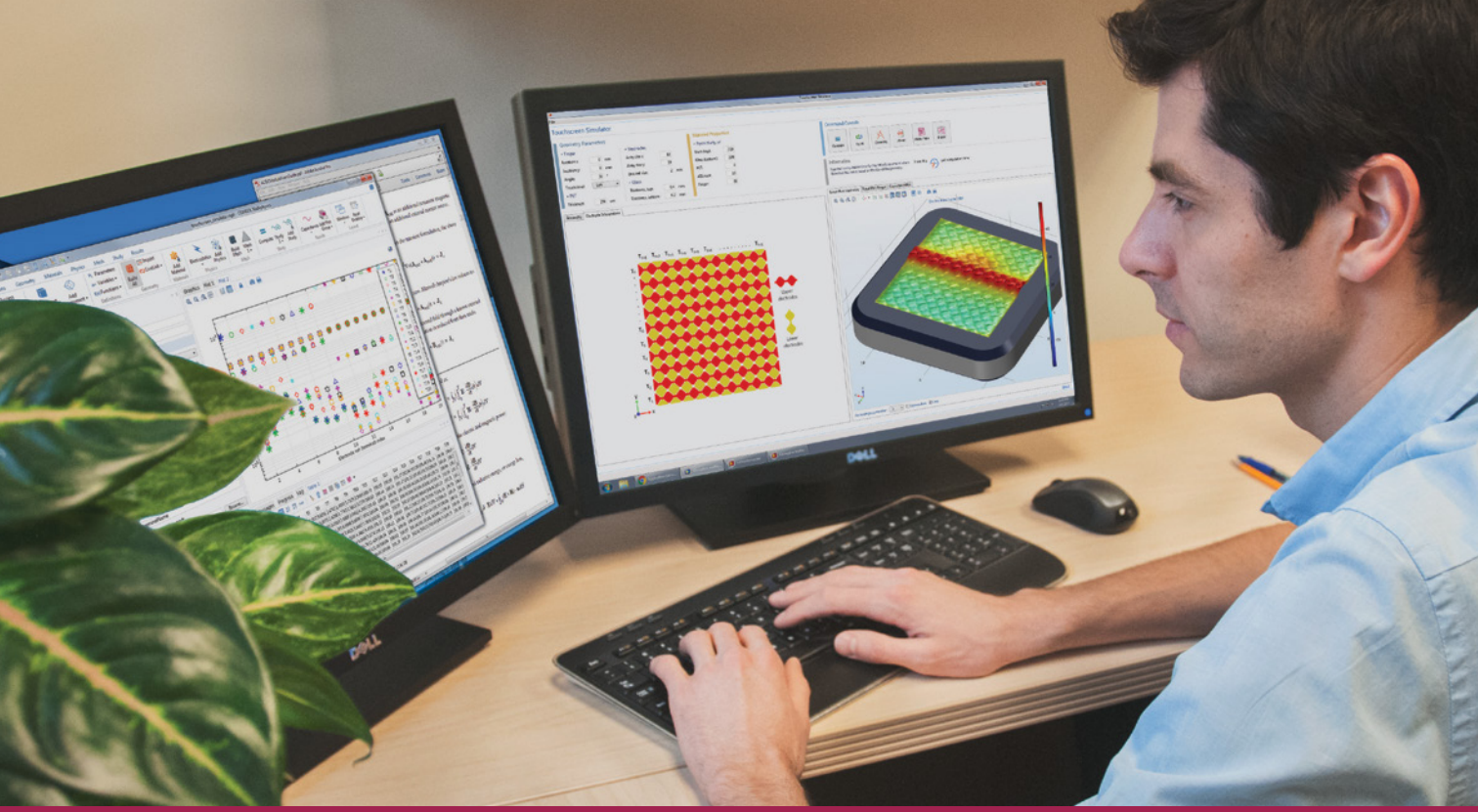
How are things going so far?
[chuckles] Not so perfect! But we will improve that through kaizen. As Akio Toyoda said, 'This is not a solution. It is an opportunity.'

Toyota in recent years has collaborated with Fuji Heavy, Mercedes, Tesla, Ford and Mazda. Are technology and product-development partnering now vital activities?
They are necessary, especially for autonomous and connected-vehicle technology developments. The speed of new developments in those areas is so fast—faster than I expected. If we tried to do it by ourselves, we couldn't catch up. That's why we are doing a lot with academia, with a lot of fine universities, and even with government. But even that's not enough. So we will expedite the collaborations.

If Google or Apple came to you wanting Toyota to build their cars, would that be an interesting proposition?
Oh, yeah! [laughs] Internally we are discussing a lot. The smart phone is kind of the de facto standard already and if we ignore it, the customer isn't satisfied. So we have to seriously think of how to collaborate with them [tech companies].

Are you worried that young professionals no longer stay with the same company for very long?
Yes. The highest turnover ratio in our systems is probably 5 to 7 years' experience.

Lindsay Brooke



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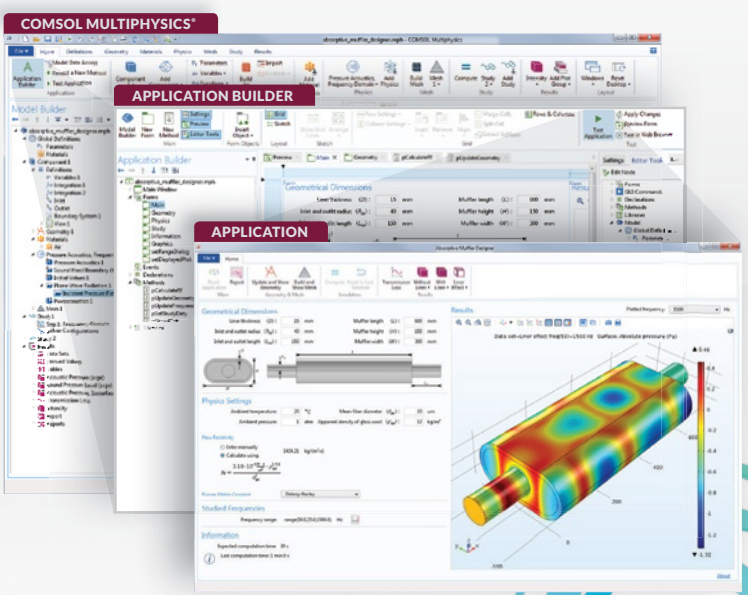

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