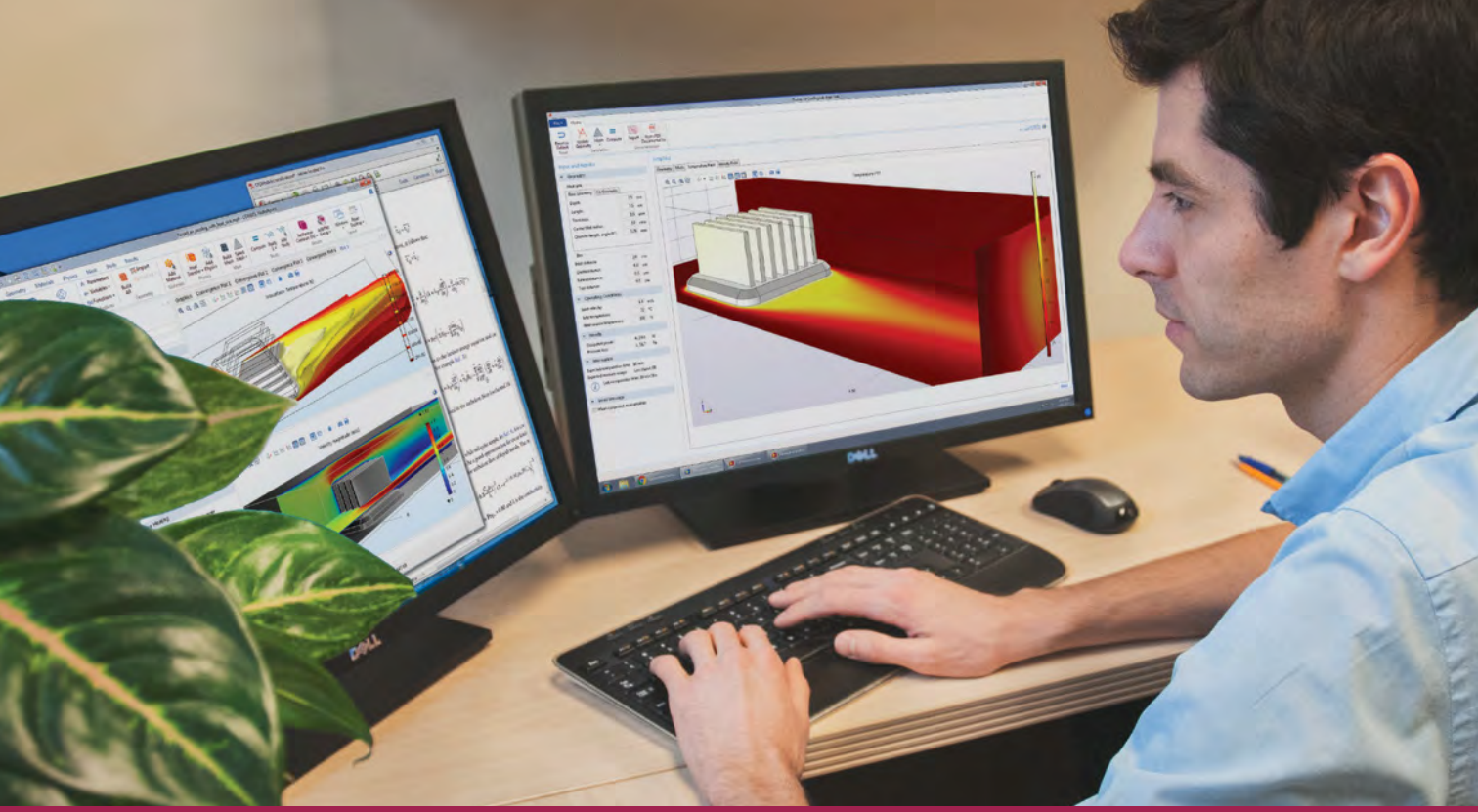

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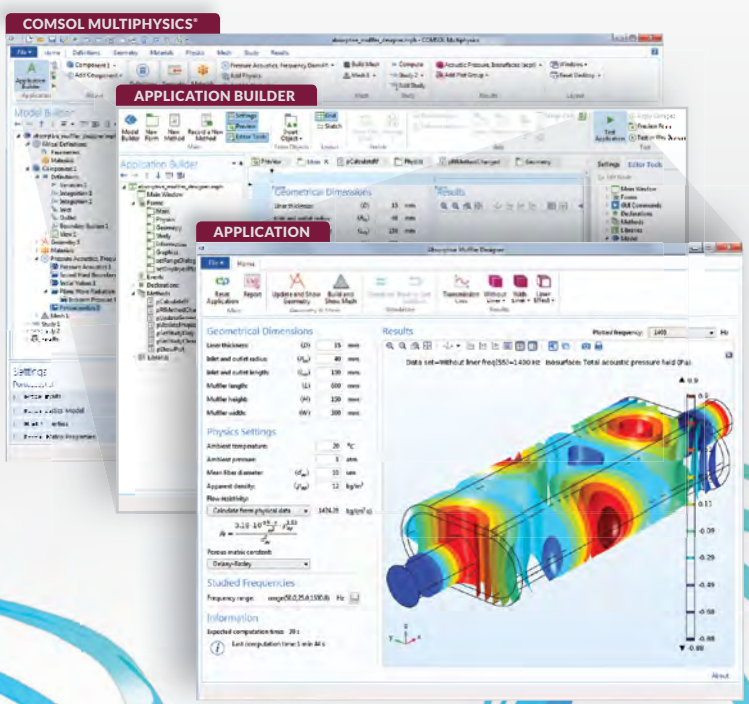

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FEATURES

ON THE COVER

Automakers and suppliers have found mass-reduction a religion. But with much of the low-hanging fruit of the lightweighting tree already picked, experts discuss the advanced materials and processes needed to take mass-reduction to the next—and surely tougher—phase.

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EDITORIAL

‘Military-grade’ aluminum

When Teddy Roosevelt led his Rough Riders in their famous charge up San Juan Hill during the Spanish-American War, he was carrying a piece of leading-edge military technology: an aluminum canteen. Since that epic day 118 years ago, aluminum alloys have helped lighten all manner of land-combat equipment, including howitzers, 5-ton trucks, Humvees and even assault bridges.

And the stuff is tough. Armor-tough. In fact, 5000-series (or 5xxx) aluminum alloys widely used in the auto industry are also used extensively in the world’s army vehicles. The stronger heat-treatable 7xxx alloys—not yet in volume automotive use because they’re difficult to form—provide superior ballistic protection in specialized aluminum armor

USS Belknap post-fire under tow.

compared with rolled homogenous-steel armor. Both 5xxx and 7xxx alloys protect the crews of U.S. Bradley Fighting Vehicles. Military duty cycles also demand supreme corrosion- and shock-resistance. Aluminum delivers.

So it was no stretch in 2015 for **Ford** Truck marketers to create the tagline “military-grade” for the 5xxx and heat-treated 6xxx series aluminum bodies of the new-generation F-150. They knew they had to convince skeptics that light-metal bodies would equal or even outperform steel in overall strength, dent resistance and crash protection.

Aligning the new pickup with the “bulletproof” image of combat tanks in the public’s mind would be a clever play. Never mind the TV ad from **Chevrolet** that appeared soon after the F-150’s launch. It showed a nuclear submarine—steel hull, of course—surfacing through thick Arctic ice with a Silverado in the foreground.

A downright sobering naval image came to mind when I first heard the Ford guys trumpeting “military-grade aluminum.” My thoughts were of the USS *Belknap*, a U.S. Navy cruiser that collided with the aircraft carrier USS *John F. Kennedy* off the coast of Sicily in 1975. A fire broke out on *Belknap* that melted the ship’s aluminum superstructure right down to the main deck. Seven sailors on *Belknap* were killed and one died on the carrier. Newspaper photos of the burned out and gutted cruiser, its charred steel hull under tow to the U.S., remain etched in my memory.

Although aluminum does not burn, it starts to lose its structural integrity at 500°F (260°C) and severely deforms—in effect, melts—at 1500°F (815°C). By comparison, steel doesn’t begin to soften until it reaches 1800 to 2000°F (982 to 1093°C). The *Belknap* investigation taught the Navy a lot about aluminum’s survivability. But it wasn’t until 1987 that the **Naval Sea Systems Command**, in charge of vessel design and engineering, announced it was reverting to steel superstructures for new shipbuilding programs.

The reason: Aluminum superstructures were cracking in 263 ships, half the U.S. fleet at the time. Repairing the stress-induced cracks cost billions, averaging $445,000 per ship, said the **Alcoa** marketing manager who had to face the media. Navy admirals also admitted that the aluminum sections required far more routine maintenance than those of steel ships.

While the cracking debacle didn’t cause the Navy to halt aluminum use in all ship construction, it did prompt a re-think of future architectures and materials. The subsequent 62-ship Arleigh Burke-class destroyers are built of steel.

But none of them come in a Crew Cab 4x4 King Ranch model.

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SIMULATION

Jaguar, Exa say simulation to eliminate prototypes by 2020

Exa aerodynamic simulation applied to the Jaguar XE.

Finding the right ratio of "emphasis" (aka "compromise") between design and engineering priorities has long been part of the enduring magic behind the conception and creation of vehicles.

Today's increasingly advanced CAD and CAE software solutions have arguably eased this tension and reduced the longstanding conflict to more of a mere tussle, but now it's going a step further: **Jaguar Land Rover** (JLR) and its close partner, simulation-software expert **Exa** Corp., say design software has become so sophisticated that by 2020 they can eliminate the need to build physical prototypes of a new vehicle under development.

At later stages of development, there always will be the need for driveable prototypes, of course. But the two companies said Exa's integrated visualization tools—and Jaguar's decade-plus of focused experience in applying them—create a technology platform for state-of-the-art, simulation-driven development that they project can eventually eradicate prototypes.

Jean-Paul Roux, Paris-based President of European Operations for Exa, explains: "Carmakers that utilize visualization modules integrated within CAE software, such as Exa PowerFLOW, are beginning to reap the benefits of immersive, photorealistic rendered representations of every stage of the design process."

Long gone are the days of "stock" presentation software for communicating intricate and continually changing design phases as carmakers "step into the future," he asserted.

He emphasized, for example, that gaining a clearer understanding of which design feature impacts which area of aerodynamic performance on a vehicle plays an integral part in creating a more open discourse between the design studio and engineers: "This allows both parties to undertake the creative process with one another's priorities and objectives in mind, actually resulting in bolder and more expressive design concepts with greater aerodynamic capabilities."

Roux added that large-scale, latent- or minute-flow dynamics now can be detected to what he terms "the utmost degree of accuracy" with these sophisticated visualization tools—and such intricate views are not available in the wind tunnel: "This provides design and engineering teams with a level of insight into their conceptual alterations, in real-time, which revolutionizes what components look like and how they are created."

JLR used Exa's system for the XE, which particularly helped to achieve excellent aerodynamics (a best Cd figure of 0.26) without requiring excessive styling compromises. In what may amaze many rivals, JLR did not use a single physical aerodynamic prototype during development of the XE — all aerodynamic optimization was done exclusively through Exa PowerFLOW simulation, Ales Alajbegovic, Exa's Vice President of Ground Transportation Applications, told *Automotive Engineering*.

Mark Stanton, JLR's Director of Special Vehicle Operations (SVO) and formerly its Director of Vehicle Engineering, said, "We use Exa for all of our current-production vehicles to work on development of the aerodynamic properties of those vehicles. Another example is the F-Pace (crossover). Here we use Exa to

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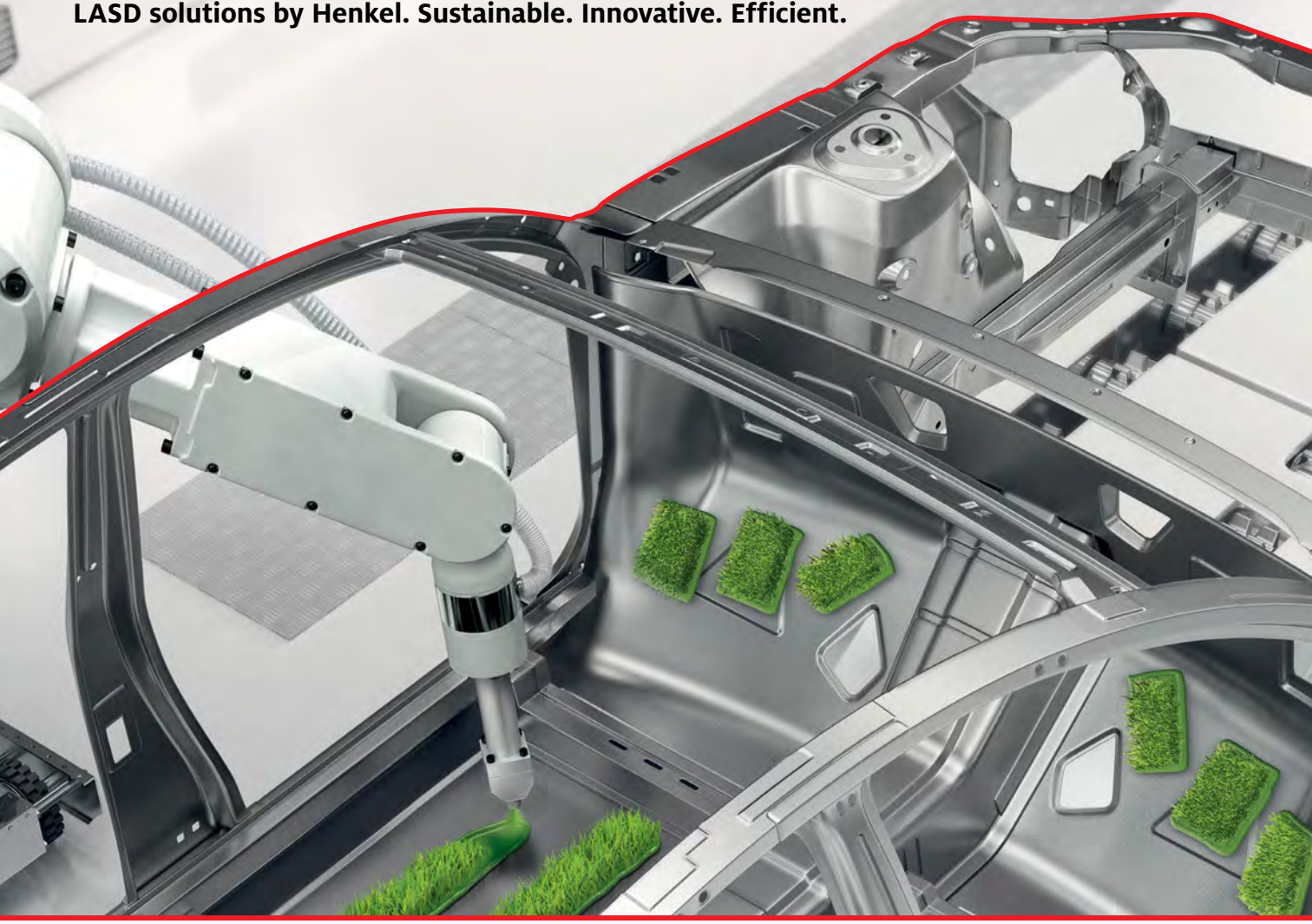

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No actual road-burning here, but a simulated version of Jaguar's XE sedan with Exa's visualization software at work.

achieve perfect lift balance—you have seventy 'counts' of lift on the front and rear, which really contributes to the sporty driving experience of the vehicle.

"We've also used it [Exa simulation software] to help improve the aerodynamic drag," Stanton continued. "We have apertures in the front bumper which we use to turn the airflow around the front corner to really improve the aerodynamic efficiency of the vehicle.

"All of this," he said, "was done in the virtual world before we ever had any physical properties. We really only validated with a physical (prototype) right at the end of the process, as we have all of the confidence in these virtual tools."

Aligning design with engineering

Paul Stewart, Exa's Design and Visualization Director at the company's Burlington, Massachusetts, headquarters, added that when working on different timescales—perhaps with conflicting objectives—it had not been uncommon for designers and engineers to find themselves out of sync when working on the same project, particularly when day-to-day contact may be limited.

"What some carmakers have now discovered, however, is that simulation-driven design can help repair this disconnect thanks to integrated visualization tools provided in CAE software such as Exa PowerFLOW."

Stewart said that for both designers and engineers, simulation software provides an "intricate" real-time understanding of design alterations: "This doesn't mean that designers are now having to concede ground on more daring projects—quite the opposite, as this holistic approach to design encourages multidisciplinary collaboration right from the start of the development process, resulting in expressive yet feasible designs."

Jean-Paul Roux, President of Exa's European Operations.

Mark Stanton, Jaguar Land Rover Director of Special Vehicle Operations (SVO).

Beyond aerodynamics to full-vehicle validation

Jaguar is confident about its 2020 timeframe for eliminating prototype builds largely because its decade of collaboration with Exa has generated an "evolution" of prototype reduction, starting with the elimination of earliest prototype phases, said the Exa spokesperson.

Stanton confirmed the company is aiming to achieve full-vehicle verification exclusively through digital simulation by 2020, going straight from virtual into the final physical production vehicle: "The use of Exa software now is really key in what we do at Jaguar Land Rover. We used over 36 million hours of CPU time in 2014 on Exa and that's the equivalent of about 7000 physical wind tunnel tests, so that's pretty immense!"

He added: "We are trying to 'left shift' (from physical) our engineering, and virtual engineering is absolutely a key part of that shift. It enables us, far earlier, to validate that we have met all requirements for the program and ensure that we have the quality baked in right up front."

Meanwhile, Exa's Alajbegovic asserted that full-vehicle verification by simulation likely will generate immense cost and time reductions in the product-development process.

"The most significant cost savings when an automaker commits to virtual design comes from avoiding late changes and fixes," he said. "Late-discovery and fixes that prompt a one- or two-month delay of the market launch can cost an automaker hundreds of millions of dollars. Problems requiring tooling changes also cost several million dollars. (Improved) ability to design vehicles on cost and time will be enabled using virtual design."

Apart from process savings, reducing or eliminating prototypes also will have a significant bottom-line impact, Alajbegovic added. "Considering just the prototype vehicle costs (not including testing costs), static clay models may cost between $500,000 to $1 million per unit and traditional automakers may build two or three models for early testing," he said. "Drivable prototypes may cost between $500,000 - $1 million per unit (depending on the carryover versus prototype-parts content), with automakers building between 100-200 driving prototypes for physical tests."

Roux opened the company's Paris office in 2002, further expanding the company's client list. Together with JLR, that lineup now includes **BMW**, **Delphi**, **Denso**, **Fiat Chrysler**, **Ford**, **Honda**, **Hyundai**, **Nissan**, **Peugeot**, **Renault**, **Toyota**, **VW** and major commercial vehicle and off-highway companies.

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POWERTRAINS

OEMs expand testing of FEV variable-compression ratio engine

Dean Tomazic, FEV North America CTO, with a mock-up demonstration engine featuring the company's 2-stage VCR technology. (Lindsay Brooke photo)

Centerpiece of FEV's 2-stage VCR system is its cleverly engineered eccentric connecting rod, shown here in the company's demo mock-up. (Lindsay Brooke photo)

Road testing of a new variable-compression ratio (VCR) combustion system in Europe has been "very successful to date" as OEMs validate the **FEV**-developed technology, reports Dean Tomazic, Executive Vice President and CTO of FEV North America.

"We're working with several customers and there are more to follow. We've been conducting test-fleet operations for many months," with 50 engines in use, Tomazic told *Automotive Engineering*.

He described FEV's 2-step VCR, which offers a 3-5% increase in fuel efficiency, as "a relatively big 'hammer' to employ for CO_2 reduction. It can significantly extend the operating window, allowing you to operate at higher power levels without incurring (engine) knock."

With the expanding European test program, the VCR technology is "gaining momentum" toward productionization, with FEV in discussions with potential Tier 1s, Tomazic noted. The modular technology can be adopted as a clean-sheet or retrofit for diesel, gasoline, flex-fuel engines in any cylinder configuration.

FEV has been in the vanguard of VCR design, development and testing since the 1990s. In 2009 the company published an **SAE** technical paper (http://papers.sae.org/2009-01-1457/) describing the 2-stage VCR system now under test by OEMs. The mechanical centerpiece is a clever adjustable-length connecting rod featuring a rotating eccentric eye within the rod's "little end."

"It's a simple, passive system, requiring just a bit of hydraulics and a 2-way valve to lock the system into positions 'A' and 'B,'" Tomazic explained. The con rod's unique design incorporates two small hydraulic pistons, each within a dedicated chamber; the hydraulics in the two small cylinders serve only as a locking function to stabilize the mechanism in the 'A' position.

"We basically drain one chamber and make the other one accessible to low-pressure oil that comes through the crankshaft and the con rod into that chamber," Tomazic said. The chamber fills up and the oil flows back through a check valve. The primary (large) piston is moved up and down relative to the rod exclusively by the mass and inertial forces.

Transitioning from compression ratio 'A' to 'B' is achieved within 0.2 to 0.6 s. According to Tomazic, a typical ratio change in a gasoline engine would be from 11:1 to 15:1. The piston's maximum vertical lift threshold of 1.5 to 2 mm (.06 to .07 in) is adjusted in real time according to load and available fuel quality, via inputs from knock and fuel-octane sensors.

FEV engineers have evolved the VCR using one of the company's proprietary analysis toolsets known as CMD (Charge Motion Design), based on optimized CFD. Compared with fixed-ratio and full-variable compression-ratio designs, the 2-stage VCR enables higher potential fuel economy in spark-ignited ICEs, particularly as average peak firing pressures (up to 170 bar/2466 psi) increase.

Some powertrain engineers have commented that even with the presumed cost benefit of mass production, FEV's sophisticated con rod would be many times more expensive per unit than a current-production conventional steel rod. Tomazic argues that the greater complexity is part of the industry's investment in advanced ICE technologies to meet the next phase of CO_2 regulations.

"It's getting more expensive to reduce emissions and improve fuel economy," he noted. "OEs are weighing variable-compression-ratio engines versus electrification. They're finding 2-step VCR is very cost competitive, whereas five years ago it wasn't—because there was lower-hanging, lower-cost fruit available to meet their targets."

Lindsay Brooke

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POWERTRAINS

Growth of FCVs and EVs tied to infrastructure

More hydrogen fueling stations in California and additional electric vehicle charging stations across the U.S. could reduce the range anxiety consumers have about driving these-advanced technology vehicles, Bill Elrick, Executive Director of the California Fuel Cell Partnership told an xEV Infrastructure session audience at the 2016 Advanced Automotive Battery Conference in Detroit.

"You can't sell a car if there isn't infrastructure to support it," Elrick flatly stated.

At the end of 2015, California had only two retail stations selling hydrogen fuel. "We didn't have enough infrastructure out there to let the early automaker deployments prosper," Elrick admitted.

Now, California has 20 hydrogen retail stations, the most of any state in the U.S., and "By the end of 2016, we expect more than 30 stations. That will put California in a prime place for the other fuel-cell vehicles (FVCs) that are coming to market," Elrick said.

Fuel-cell passenger vehicles in the California market include the **Toyota** Mirai and the **Hyundai** Tucson Fuel Cell. The **Honda** Clarity Fuel Cell arrives late this year; Clarity will be the industry's first vehicle to use the same platform underpinnings for fuel-cell, battery-electric and plug-in hybrid variants. Electric and plug-in hybrid versions of the Clarity are slated for U.S. launch in 2017.

With the present network of hydrogen retail stations in California, it's possible to drive an FCV from Los Angeles to San Francisco. "And it will take the same amount of time as it does in a gasoline car because of the 3- to 5-minute fill time with hydrogen," said Elrick.

The Hyundai Tucson Fuel Cell vehicle creates its own electricity on-board from hydrogen. Assembled in Ulsan, South Korea, at the same plant that produces the conventional Tucson, the Tucson Fuel Cell vehicle has a driving range of up to 265 miles.

AC Transit's 3rd-generation hydrogen fuel-cell electric bus has been in service since September 2010 in California. (CaFCP photo)

California's mid-range goal is 100 retail hydrogen stations. "On the one hand, 100 stations seems rather small compared to the 13,000 gas stations in the state. However, 100 well-placed stations throughout California will put the majority of the state's citizens within six minutes of a hydrogen station," he concluded.

Beyond light-duty passenger vehicles, four transit agencies in California operate fuel-cell buses.

"Fuel-cell buses are just on the verge of full commercialization. The costs are getting down to $1 million or less and we think the next round of government co-funding will be a push for mass purchases, bringing the costs down even more," said Elrick.

The first appearance of fuel-cell medium- and heavy-duty vehicles is likely later this year. "It's just in the early demonstration stage, so we're about where we were with light-duty vehicles about a decade ago," said Elrick.

California's supply of hydrogen is coming from reforming gas and other industrial processes. "But we need to look at new hydrogen production—and what we should really be focusing on is renewable sources," said Elrick.

EV charging: more still needed

Meanwhile, the charging infrastructure for electrified vehicles remains a work in progress, according to Mark Duvall, Director of Energy Utilization for the Electric Power Research Institute, a non-profit organization headquartered in California.

"I think we've solved a lot of the infrastructure problems with plug-in vehicles, but there are still some gaps," said Duvall, noting a need for more workplace and public charging stations.

AC charging and DC fast-charging are on different trajectories.

"I find it very unlikely that passenger vehicles of any size—even when you start electrifying large SUVs and pickup trucks—would need more than what we have available through the AC standard, which is (a maximum of) 19.2 kilowatts," Duvall said in an interview with *Automotive Engineering*.

With municipalities, utility companies and others enabling different infrastructure pieces, Duvall said that it doesn't matter who does the work or who owns it. "It's about getting the work done. I think for drivers, it has to look like one system and I think we have quite a bit of work yet. I see that as a key challenge," Duvall said.

Kami Buchholz

INTERIORS

Bolt EV seat design cuts weight, delights taller passengers

GM-designed, Magna-supplied front seats in new Bolt EV are lightweight, save space and help mitigate occupant crash protection according to the car's Chief Engineer Josh Tavel. (Lindsay Brooke photo)

Stepping into the back seat of **Chevrolet**'s 2017 Bolt EV, one attribute of the car is immediately evident: the designers and engineers didn't neglect the outsized physical dimensions of tall passengers.

In fact, even those whose height and inseam length are well beyond the 90th percentile—that would include the author—will appreciate the Bolt EV's surprisingly easy ingress and egress. That's because the car's front seats were designed with the back-seaters in mind, as well as being designed to reduce mass.

Bolt EV's front seats were designed in house by **GM**. They're known internally as UTSB—Ultra Thin Seatback. The seats are designed and engineered in combination with the similarly well-considered rear-seat system (both supplied by **Magna Seating**) to improve the interior spaciousness of a vehicle that feels larger inside than its compact exterior form would indicate. The front seats are engineered with a light steel seat frame over which a flexible plastic shell is fitted. The shell is lined with 0.4-0.6-in-thick (10-15 mm) foam.

Swing your torso and legs into the rear seat area, as *Automotive Engineering* did during a pre-production test drive last winter, and the Bolt's rear knee room feels extra

Magna's FutureForm concept seat boast a 20% mass saving versus comparable production seats, the company claims.

special for a B-segment vehicle. The rear seat back still has a metal structure and includes a sculpted back panel to provide increased rear-seat leg room. Behind the fold-flat 60/40 rear seat, the Bolt offers 16.9 ft^3 of cargo space—more than the current B-segment leader in this metric, the 2016 **Honda** Fit.

The front seats' backside fascias are molded with a concave surface geometry in their center so that taller backseat passengers are not always required to ask the driver and front-seat passenger to slide their seats forward. Pam Fletcher, GM's Executive Chief Engineer for Electrified Vehicles, explained that the Bolt EV "was designed with ride-sharing as a potential consideration." Think GM's investment in **Lyft**.

According to the Bolt's Chief Engineer, Josh Tavel, the UTSB front seats also are lighter overall than comparable GM seats as used for the Chevy Sonic, for example, but he was not yet prepared to reveal the exact mass delta. The front seats also incorporate the side airbag modules as a design element.

Magna Seating is responsible for the Bolt seats' foam and trim design. The company also handles complete assembly of the seats at its Detroit plant, which also produces seats for the Chevrolet Volt, the Bolt EV's plug-in hybrid cousin.

Magna has itself been a pioneer in developing lightweight, thin-profile seat designs. It first exhibited a thin-section lightweight (less than 22 lb/9.9 kg) vehicle seat in 2000, on GM's 80-mpg Precept hybrid concept car. The company's latest FutureForm concept is claimed to offer a 20% mass reduction versus comparable production seats, along with a nearly 2-in (50 mm) improvement in rear-seat passenger leg room, the company claims.

Lindsay Brooke

DESIGN | INTERIORS

Rolls-Royce reveals a Vision of its future

"When it doesn't exist, design it," was Sir Henry Royce's maxim aired some 100 years ago. Now it is being followed to the letter with the revealing in London of the **Rolls-Royce** Vision Next 100, an extraordinary concept that is a huge departure from anything that Sir Henry could possibly have envisaged.

It is a purely visionary concept from today's Rolls-Royce design and engineering teams indicating their views of what could become super-luxury mobility reality over the next 100 years. This ultra-time projection, created using extensive 3D printing, brings exterior aesthetics the like of which Rolls-Royce has never before dared to present. Fully autonomous technology obviates the need for a steering wheel, a driver's seat, and all instruments except an analog clock—itself a reminder to passengers that "time not lost is the highest form of luxury."

What potential customers will make of this project, code named 103EX, will probably be a dichotomy. Some will applaud the 5.9-m-long (19.3 ft), battery-electric Next 100's image and promise, and others might dismiss it—to borrow the phrase of British writer and poet John Betjeman—as showing "ghastly good taste."

Details of the far distant technology involved are necessarily nebulous. But Rolls-Royce expects the vehicle to be based on an advanced, hand-built, lightweight platform equipped with two high performance traction motors positioned front and rear producing some 500 kW (670 hp) combined, driving all four of the car's 28-in-high (711-mm) wheels. Everything from wheelbase to body design and the car's various specifications and equipment, could be tailored specifically to suit the needs of the individual customer.

Progress in composite materials and technologies is

If you fell asleep in 2016 and woke up 100 years hence to see this vehicle, you'd recognize it as a Rolls-Royce. The Vision Next 100 concept carries forward the marque's design language including the Spirit of Ecstasy mascot and iconic radiator grille.

No steering wheel, no instruments except a clock, no driving seat, just a sofa for two in the Rolls-Royce Vision Next 100.

expected to provide the production capability to provide such levels of customization.

Rolls-Royce sees these vehicles as "unique masterpieces curated as a 'fingerprint' of their owner"—a description that could only come out of this brand. The interior becomes a "personal retreat." For trim, the designers have chosen a carpet of hand-twisted silk with "extraordinarily soft silk" for the upholstery.

Passenger entry and egress sees roof and coach doors opening. Occupants would stand to step from the vehicle onto a light-projected red carpet effect. Their bespoke luggage would be housed in a compartment between front wheel and side door.

A virtual intelligence capability would control the vehicle, embodied in a digital representation of the Rolls-Royce Spirit of Ecstasy mascot. This would appear on a full-width transparent OLED display. Called Eleanor after the human model that posed for the original mascot, the more time spent with a passenger the more "she" learns of their preferences in terms of favored routes, restaurants etc.

A real mascot of hand-cut lead crystal with interior illumination (yes, really) would adorn the car's traditional Palladian-style radiator grille. Of course, all this must not be taken too literally. But there is some indication of future thinking. And it is good to see technology imbued with a fun factor.

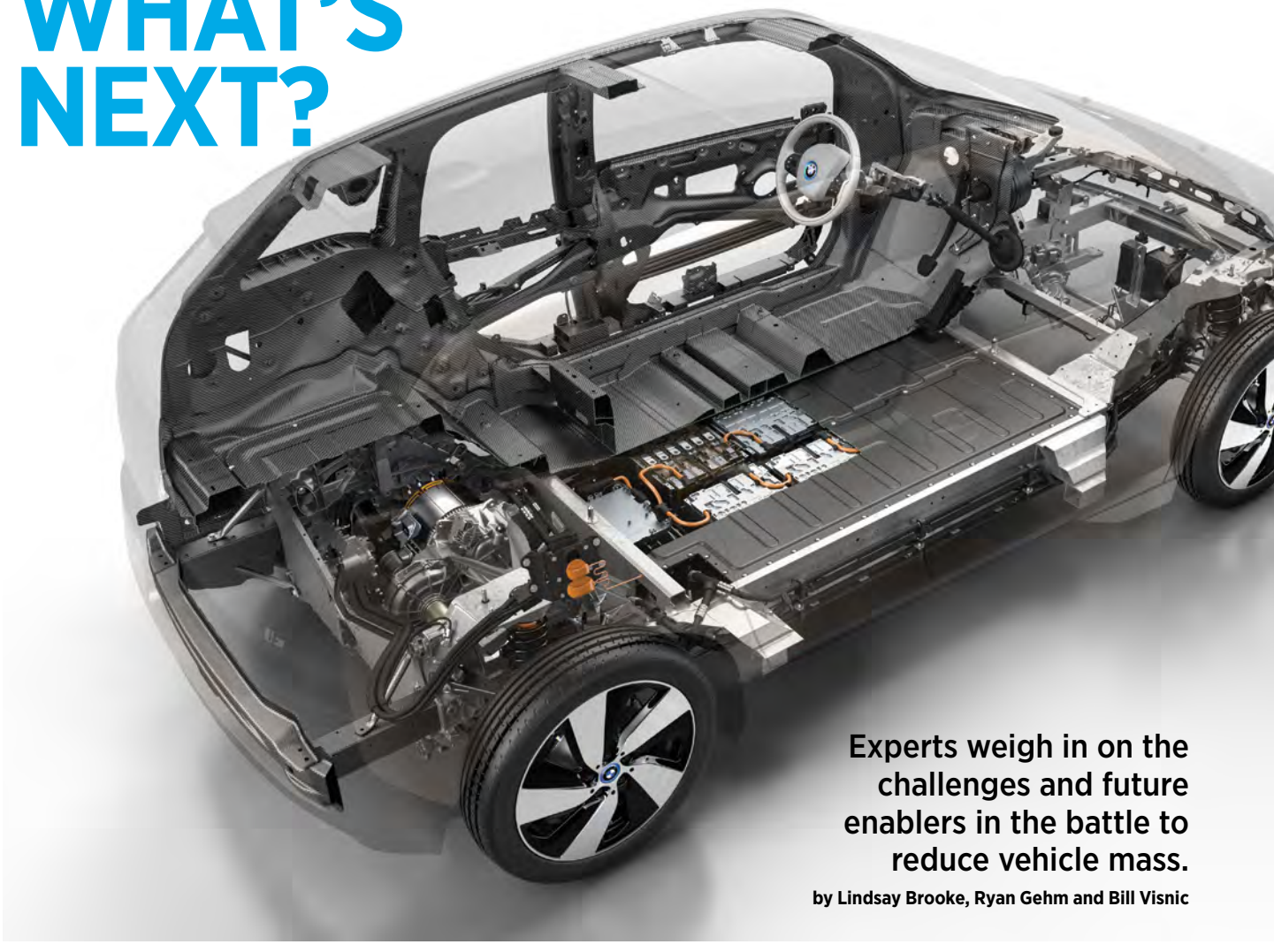
The company states: "The customer's taste will shape exactly how his or her Rolls-Royce will look and how it will be configured." So a production derivative of the Vision100 might itself prove entertaining.

As Adrian van Hooydonk, Head of Group Design at Rolls-Royce's parent company **BMW** sums up the Next 100 concept: "It is an enlightening vision of the fascinating possibilities of Rolls-Royce Motor Cars in the future."

Would Sir Henry now regret his words uttered long ago, or applaud the freedom of design that may be in prospect if Vision becomes reality? Good or ghastly? Only the next 100 years will tell.

Stuart Birch

Lightweighting: WHAT'S NEXT?



Experts weigh in on the challenges and future enablers in the battle to reduce vehicle mass.

by Lindsay Brooke, Ryan Gehm and Bill Visnic

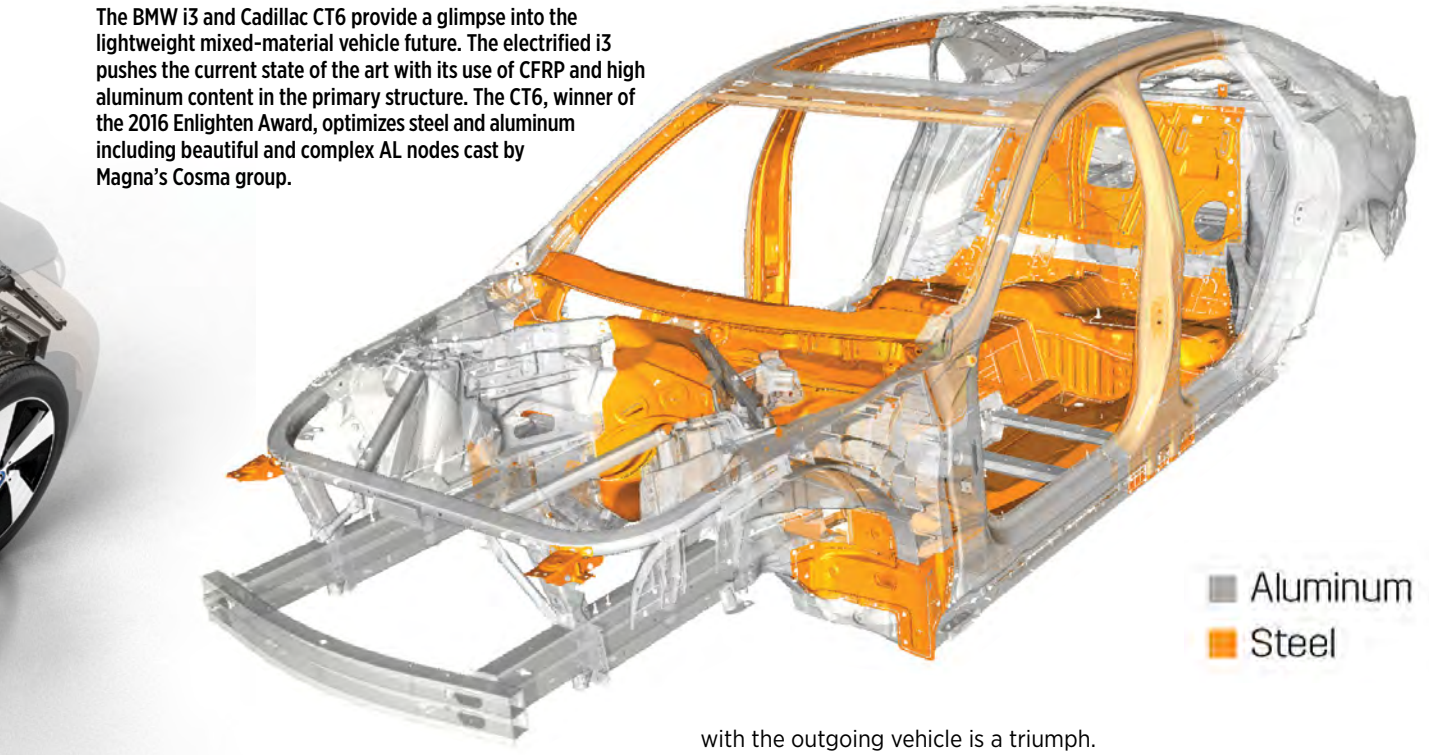
Are there any automakers who haven't yet put at least one new model through the weight-reduction wringer? Vehicle mass efficiency has joined the vanguard of product development where every gram lost is heralded. And it's no passing fad—escalating global fuel economy and safety regulations ensure that lightweighting, as a product-development tenet, is here to stay.

The list of 2016 vehicles that are lighter than their predecessors continues to grow. It includes such notables as the **Nissan** Altima, which dropped 80 lb (36 kg). **Acura**'s TLX is lighter by 55 lb (25 kg). The **Chevrolet** Malibu, part of GM's mass reduction crusade, shed a whopping 300 lb (136 kg) versus the previous car. Experts say a 100-kg (220-lb) reduction in vehicle weight typically brings a 3%-5% reduction in CO_2 emissions, depending on vehicle size and powertrain solutions.

Mazda's new CX-9, a 3-seat unibody SUV, is a shining example of lightweighting driven by holistic design and analysis. Aiming for the quietest cabin in its class, the CX-9 team engineered a thicker-gauge floor pan, added 53 lb (24 kg) of NVH mastics and blankets, more robust door seals and acoustic-laminated glass. But while the pounds were piling on to create the quietest Mazda ever, the powertrain team squeezed 132 lb (60 kg) from the new engine, 56 lb (25 kg) from the all-wheel-drive system and about 100 lb (45 kg) more in other areas. These reductions more than offset the NVH countermeasures, leaving the new CX-9 about 250 lb (113 kg) leaner than the 2015 car.

"The industry has become more aggressive in its lightweighting actions and its rate of introducing the technology is accelerating," observed Jay Baron, Ph.D, President and CEO of the **Center for Automotive Research** (CAR). "The data we've been collecting shows it's gone from an average of about 3% per year to 5% per year, depending on how you want to measure it."

Dr. Baron and other experts note that the supply base has become fully engaged. "The industry's doors are open wider than ever before—if you're a supplier and have a lightweight technology solution, the car companies want to hear about it," Dr. Baron noted.



The BMW i3 and Cadillac CT6 provide a glimpse into the lightweight mixed-material vehicle future. The electrified i3 pushes the current state of the art with its use of CFRP and high aluminum content in the primary structure. The CT6, winner of the 2016 Enlighten Award, optimizes steel and aluminum including beautiful and complex AL nodes cast by Magna's Cosma group.

Vehicle lightweighting "is arguably no less of an important consideration as powertrain selection nowadays," asserted Andrew Fulbrook, **IHS Automotive** Director of Global Powertrain Forecasting. Both technology domains have the ability to provide efficiency gain while maintaining or improving performance and drivability, he said, with lightweighting also offering potential reductions in road load.

Overcoming 'mass creep'

In a recent survey published by CAR on future vehicle-lightweighting trends, industry decision-makers indicated that mixed-materials solutions will predominate over aluminum-intensive programs going forward—a practical strategy driven by cost and by manufacturing considerations such as part formability, dissimilar-material joining and paint-shop capability, commented Dr. Baron.

The CAR respondents echo the views of nearly 20 experts interviewed for this article. Both groups highlighted the nagging challenge facing every lightweighting initiative: How to overcome what Chevy Malibu Chief Engineer Jesse Ortega calls "mass creep"—the weight of added safety, emissions and feature content that can offset the weight saved during base vehicle development. For many vehicle program managers, simply attaining curb-weight parity with the outgoing vehicle is a triumph.

The CAR survey asked, "Between now and 2025 do you feel you need to add weight to the car? And what's forcing you to add it?" Respondents replied that they expect a 5% overall mass gain, split 50-50 (about 2.5% each) between added mass for performance and for safety.

"You can't sell cars that are almost as good as last year's," Dr. Baron explained. "Customers want the better performance that comes from increased body stiffness, for example, which may come at a price of structural reinforcements and mass. Same with lower NVH—it's a big issue because light materials tend to transmit vibrations more."

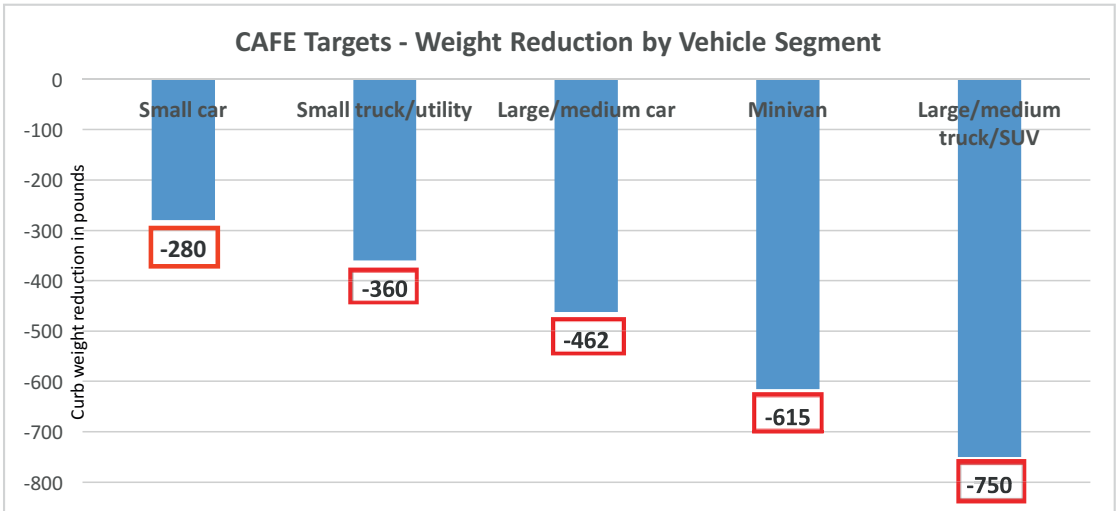
His advice: "If you're planning for a vehicle to be 10% lighter, you've got to reduce mass by 15%."

Product planners tell *Automotive Engineering* they're concerned about the capital cost of premium materials—new higher-strength steel and aluminum alloys, carbon-fiber-reinforced plastics (CFRP) and magnesium—and how rising cost will impact vehicle retail price. Veteran industry analyst Mike Robinet, Managing Director at IHS Automotive, talks of an impending "cost cliff" driven by a combination of lightweighting, vehicle electrification, increased demand for advanced driver-assistance systems (ADAS) and connectivity content. And faster product cadences will likely affect cost amortization.

Recent vehicle programs reflect the cost-prudent approach that is expected going forward. **GM** chose a metals mix for the 2017 Chevrolet Bolt EV. According to Chief Engineer Josh Tavel, the car's underbody consists of 95% high-strength steel or advanced high-strength steel (see Steel's Scorecard sidebar, p. 24), including some new alloys making their auto-industry debut. Bolt's upper body is 80% HSS.

"The team saved about 50 pounds by using aluminum for the closures," Tavel reports. Another 200-mi (321-km)-range EV with a

Lightweighting: WHAT'S NEXT?



To reduce the 2025 curb weight by 12% or 460 lb (1014 kg) compared to 2008, the required weight reduction by vehicle segment is shown above.

Source: Ducker Analysis

Whether or not the mid-term review of U.S. CAFE regulations ends up moderating the 54.5-mpg fuel efficiency target as could be inferred by the July 2016 Technology Assessment Report draft, OEMs continue to work aggressively toward meeting vehicle lightweighting bogies for each market segment.

heavy battery pack, **Tesla**'s "affordable" 2017 Model 3, reportedly also uses mixed-materials construction—the company's first non-aluminum-intensive vehicle.

Lightweighting the pickup

Experts believe steel and aluminum will continue to dominate vehicle structures and chassis systems beyond the 2025 timeframe. Stronger and more formable alloys aimed at making lighter components and subassemblies are in the pipeline. Meanwhile structural composites, engineering plastics, and specialty light metals including magnesium will find greater opportunity.

A conversation with Paul Belanger, Director of R&D, Body in White at **Gestamp North America**, revealed the impact of new alloys and forming technologies. "We worked with Honda R&D on the new [2016] Civic, employing hot-formed ultra-high-strength steel (UHSS) for the rear rails. The material properties enabled Honda to reduce complexity of the car's rear structure, improve its kinematics and achieve a 20% weight saving vs. the previous Civic.

He said Gestamp is currently involved with development of a super-strong 2-gigapascal UHSS grade "which will allow even further down-gauging." Industry newcomer **NanoSteel** and partner **AK Steel** are prototyping a new automotive UHSS grade designed to simplify production, enabling the stamping and forming of parts at room temperature, reported CEO Dave Paratore.

The aluminum industry is firing back with new high-strength 7000-series alloys designed to challenge steel's hegemony in impact-critical areas such as B pillars. "We're out to make inroads in those exact areas with higher-strength grades now in development," said Duane Bendzinski, Global Director of Technology, Automotive, at **Novelis**.

Bendzinski notes that the OEMs' urgency to reduce vehicle mass is pushing suppliers to shorten their own development processes. "We're validating new products and getting them into customer evaluation faster for incorporation into new vehicle designs in the upcoming 3-to-6-year window," he said.

The heavy steel ladder frames underpinning most pickup trucks are even a target market for aluminum as future CO_2-driven regulations get tougher. "We think it's more of a design question than a materials one," Bendzinski asserted. "In the not-too-distant future there will be opportunities to take weight out of those heavy ladder frames. It's a primary area for the extrusion folks and it's an opportunity to use roll-formed (aluminum) sheet in large quantities."

Composites' opportunities

BMW's pioneering use of CFRP for the "black bodies" of its electrified i3 and i8 models signaled a serious commitment to bring lightweight composites, long proven in aircraft and racecar structures, into the automotive mainstream, albeit at comparatively low volumes. Carbon fiber's main attraction is its strength-to-weight ratio and the potential for net vehicle weight reductions up to 60% via mass de-compounding, according to ORNL.

CAR's Dr. Baron believes the structural composites industry "has a whole world of opportunity waiting for it in automotive—but it's going to have to learn to work together in the steel industry model," he said. "Lack of a robust supply chain will continue to hold them back." He cautioned that the sector's reliance on unique solutions

Ricardo-led program opens doors to future lightweighting approaches

The capital-intensiveness of automobile manufacturing is an inherent hurdle to innovation, including new ideas for vehicle weight reduction. Tooling costs for the closures of a 4-door passenger car can total $25 million, according to Piyush Bubna, an analyst at **Ricardo Strategic Consulting**. The company led a recent program that found new solutions to reduce capital cost in manufacturing door systems at lower volumes using 3D printing.

The program, a collaboration with the **United Technology Research Center** (UTRC), also found new opportunities for lightweighting and use of new materials through analysis and optimization of in-production designs. It also drove publication of two 2016 **SAE** technical papers related to the findings.

"The project was a response to an ARPA-E Funding Opportunity Announcement," Bubna explained during an interview with *Automotive Engineering* at Ricardo's Van Buren Twp., MI, office. The goal was to identify and mitigate investment barriers in auto manufacturing in order "to break down barriers to entry"—in effect opening the door, Bubna said, for new companies, emerging technologies and innovative production techniques with a focus on annual production volumes of less than 30,000 units.

"We wanted to quantify at what 'breaking point' does cost really climb as you decrease in volume," he noted. "We also wanted to find out the production cost impact of lightweighting."

As the program lead, Ricardo dug deep to identify incumbent practice, cost and barriers. The team then coordinated with a group of industry experts who provided guidance and feedback. UTRC handled the technical review and economic assessment of alternative manufacturing processes.

BMW's i3, in the vanguard of mixed-materials engineering (carbon fiber and aluminum) strategy, provided program target metrics in the area of floor structure and front-door construction, in comparison with a baseline **Toyota** Corolla. The i3's assembly plant had a 50,000-unit production plan when the Ricardo program began.

A cost analysis of the i3 door identified use of plastic and aluminum parts that resulted in 36% mass reduction, with potential to offer attractive implied cost of light-weighting of $0.95/lb saved, Bubna noted, versus the Corolla's steel door. The related SAE technical paper, "Impact of lightweight design on manufacturing cost – a review of BMW i3 and Toyota Corolla body components," is no. 2016-01-1339.

A comprehensive tear-down analysis and benchmarking of the i3 also was conducted separately by **Munro and Assoc.** during 2014 (see http://leandesign.com/bmw/).

Ricardo's door system analysis also found that 3D printing of production dies used for door outers offers significant potential to reduce capital expense, with opportunities for mass reduction through part design. "Our analysis shows a 20% cost savings in manufacturing the door-skin dies using the wire-arc additive technique," Bubna reported, with the same technique also offering up to 70% cost reduction in making an injection-molding die set for a door trim. He added that selective laser melting is another cost-effective 3D printing technique that provides higher dimensional accuracy.

For details see SAE technical paper 2016-01-0329: "*Barriers to entry in automotive production and opportunities with emerging additive manufacturing techniques.*"

Lindsay Brooke

The BMW i3's door system construction offers significant cost/mass reduction opportunities at lower production volumes, according to ARPA-e program analysis conducted by Ricardo and UTRC.

delivered company by company is an impediment.

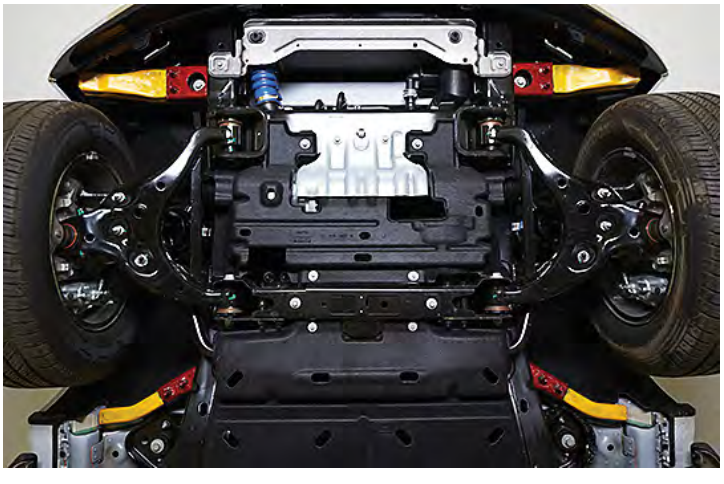
"If I'm an OEM looking for a new materials solution, I want to be able to buy it from four companies—not just from one," Dr. Baron observed. Steel's commodity-focused product model enables standardized specifications and testing and in some cases, a more rapid entrée into production. There is no analog to DP700 [a dual-phase steel] in the composites world, he opined.

New technology relationships are spreading among the auto industry, government agencies and academia. **Ford Motor Co**. and **DowAksa** recently formed a joint development agreement to create new families of more cost-effective thermoset and thermoplastic CFRP components and take them to the proof-of-concept level. The new JDA is part of the **U.S. Dept. of Energy**-sponsored Institute for Advanced Composites Manufacturing Innovation (IACMI) which aims to commercialize CFRP-related processes.

Another composite, polycarbonate, has long been expected to replace conventional automotive glazing with less mass and other benefits. Ford claims **Corning**'s new 'Gorilla Glass' (a thin polycarbonate laminate widely used in mobile devices) used first on the 2017 GT supercar is 30% lighter than conventional glass and is stronger, more durable and optically clearer. Is polycarbonate glazing a light-weight candidate for volume vehicle programs after 2020? Perhaps.

Coatings technologies that offer collateral lightweighting benefits as well as friction reduction and NVH attenuation are receiving greater attention by suppliers. A proven example is the liquid acrylic sound-deadening coating (LASD) produced by **Henkel** that's replacing

"Mass creep" affects nearly every new vehicle program, as marketing and sales cannot resist piling on features that add weight. The nature of pickup trucks makes them a common victim. Chevrolet and GMC dealers install these optional factory-engineered tubular steel, powder-coated step assemblies, one per side, on Colorado and Canyon models. (Lindsay Brooke photo)



Lightweight vehicle design sometimes gets sideswiped by new test procedures and regulation. Ford's development of the 2015 aluminum F-150 was underway when the Insurance Institute of Highway Safety introduced its new small-offset front crash test. The new test forced Ford engineers to retrofit four tubular steel "Rigid Barrier Countermeasures" (painted yellow/red in this photo) on certain F-Series cab configurations. (IIHS photo)

relatively heavy bitumen acoustic mats in critical areas. Henkel claims mass reductions up to 30% for its incumbent low-density LASD which weighs 0.9 to 1.1 g/cm^3.

New processes drive future actions

Robust processes to enable lightweight solutions in high-volume automotive manufacturing are at least as important as the materials, most experts agree. "The development of creative, low-cost methods to assemble and join multi-material solutions on existing assembly lines is an imperative," said Dick Schultz, a former **Alcoa** executive and long-time materials analyst at **Ducker Worldwide**.

A process "enabler" with huge future potential is the ability to weld steel with aluminum. GM and Honda are both using new multi-patented innovations in this area, which engineers believe are vital for greater mixed-material construction. GM's spot-welding process is currently underway for the rear seatback frame of the **Cadillac** CT6 and is expected to be expanded to the CT6 hood assembly—then to higher-volume applications.

Honda has used Friction Stir Welding since 2012 to join steel to aluminum in vehicle subframe production. This was followed by another welding method for joining aluminum outer skins with steel door subframes, first implemented in series production on the 2014 Acura RLX. Using a hem-like double seam filled with adhesive enables the two metal surfaces to be welded with minimal thermal deformation. Honda engineers claim the new welding process helps to reduce door-panel weight by approximately 17% compared to standard steel doors.

Weld bonding pairs spot welding with structural adhesives to increase stiffness and improve crashworthiness, while reducing the number of spot welds. It's a key to future mixed-material vehicle construction. Adhesive suppliers **Aderis Technologies**, **Ashland**, **Atlas Copco**, **Dow Automotive Systems**, Henkel, **PPG** and **3M** are in the thick of developing new adhesive-joining solutions. Dow engineer and marketing director Peter Cate noted that parts consolidation through design offers significant weight reduction using CFRP components bonded within "hybrid-material" subassemblies.

Despite the billion-dollar investment by **BMW** and its material partner **SGL Group** to develop CFRP for series production (see http://articles.sae.org/8548/), new innovations are still needed to mitigate the cost of the material's process-intensive fabrication. CFRP composites currently cost about three times more to produce than the $5/pound the auto industry seeks. **Oak Ridge National Laboratory** and Knoxville, TN-based **RMX Technologies** recently launched co-development of a

Congratulations **Cadillac** and **ContiTech**, Winners of the 2016 Altair Enlighten Awards

Winner: Full Vehicle

2016 Cadillac CT6

Cadillac took the prize in the full vehicle category for the CT6. The vehicle's 'Omega' architecture was developed utilizing innovative computer aided engineering (CAE) methods to create an efficient, lightweight, high-performance, mixed-material vehicle structure. The vehicle is 157 lbs (71.5 kg) lighter than an equivalent size traditional body frame integral (BFI) construction.

Winner: Module

ContiTech Polyamide Cross Member

ContiTech won the supplier focused module category for its front cross member of the rear suspension on the 2016 Mercedes S-Class Coupe. This is the first time a rear suspension cross member has been designed and produced in polyamide for production. The conversion to polyamide from the original aluminum resulted in a 30% reduction in mass.

The Altair Enlighten Award

The Altair Enlighten Award, presented in partnership with the Center for Automotive Research (CAR) and SAE International, highlights achievements in lightweight design across the automotive industry. Learn more about the 2016 winners and nominees, and see how you can get involved in the 2017 awards at **altairenlighten.com/award.**

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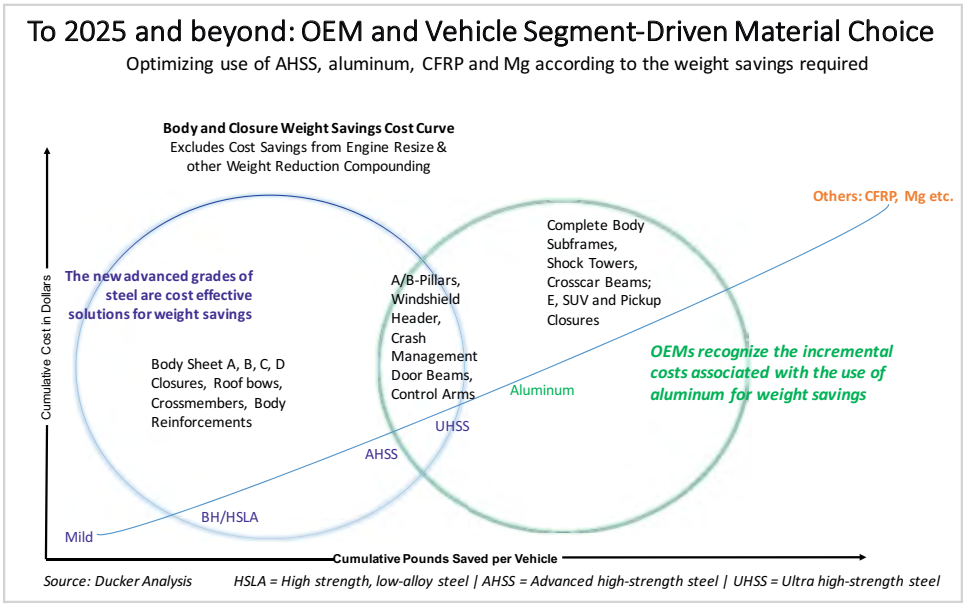
Lightweighting: WHAT'S NEXT?



The future automotive materials portfolio will offer greater choices of new lightweight metals and engineered composites tailored to specific vehicle applications.

cold-plasma-based processing technology that has the potential to significantly cut the time and energy required to make affordable CFRP fiber.

The ORNL/RMX technology aims to improve the oxidation stage of carbon-fiber's conversion process. The oxidation process offers a 20% cost reduction versus current commercial methods—but more cost needs to come out. The team is working with German acrylic textile maker **Dralon** on a high-strength fiber that is projected to deliver another 20% cost reduction.

Such progress is good news to Dale Brosius, chief commercialization officer at the **Institute for Advanced Composites Manufacturing Innovation**, an industry-government partnership. In a recent interview with this magazine, he said IACMI's goal is to drive a

Cadillac CT6, ContiTech polyamide crossbeam are 2016 Enlighten Award standouts

The auto industry's annual award program devoted exclusively to vehicle mass-reduction innovations recently named the Cadillac CT6 and **ContiTech**'s polyamide crossbeam as winners of its 2016 Full-Vehicle and Module categories, respectively.

Now in its fourth year, the Enlighten Awards are sponsored and organized by **Altair Engineering** in collaboration with the Center for Automotive Research. The awards cover multiple categories and are open to OEMs, systems/parts suppliers and materials suppliers from all auto industry segments. The winners were announced during the 2016 Management Briefing Seminars at Traverse City, MI.

The CT6 prevailed over seven Full-Vehicle finalists because of its outstanding strategic approach to weight reduction, the panel of eight judges concluded. The all-new CT6's acclaimed on-road dynamics and vault-quiet interior are achieved in part by extensive simulation work to create a multi-material variant of GM's global Omega II vehicle architecture. The Omega structure is aluminum-intensive, but for the CT6 it uses 13 different materials customized for each area of the car.

In total, about 64% of the CT6 body structure is aluminum, including all exterior panels. Various grades of steel are employed in key structural areas. GM engineers said the base CT6 is 90 kg (198 lbs) lighter than a predominantly steel counterpart (http://articles.sae.org/14020), "and it's lighter than an aluminum design would be as well," Travis Hester, Executive Chief Engineer, told *Automotive Engineering*. Base curb weight is less than 3700 lb (1678 kg), about equal to that of the (mid-size) Cadillac CTS, which is 8 in (203 mm) shorter overall.

Software simulations used in developing the CT6 body-in-white are credited for optimizing the full-size car's weight. The lower cabin structure, for example, uses steel close-out panels. The simulation analyses showed that steel alone would be

Winner of the 2016 Enlighten Awards' Module Category is ContiTech's composite transmission crossmember as used by Mercedes. It is molded in BASF Ultramid polyamide. Not long ago this structural member would have been steel.

25%-50% reduction in CFRP costs within 10 years, while reducing by up to 75% the energy required to produce the material. Brosius conceded that cost and energy-intensive manufacturing are CFRP's chief drawbacks. "We (the CFRP industry) can't be doing things at aerospace rates—we've got to get to automotive rates," he asserted.

Magnesium (Mg) alloy is 30% less dense than aluminum, but its applications tend to be aimed at large components such as cross-car beams and recently the liftgates of the **Lincoln** MKT and **Chrysler** Pacifica. GM is among many OEMs looking for Mg cost-reduction solutions. It has been operating a new vertical squeeze-casting (VCS) machine at its China Advanced Technical Center that is designed to more affordably produce magnesium castings.

Designed by teams in Shanghai and Detroit, GM's VSC machine uses high squeeze pressure to improve casting integrity by eliminating oxide inclusions. GM engineers believe the new process will allow magnesium castings to displace certain forged components, reducing a part's overall cost. The machine is sited to leverage the material's availability—China accounts for about 80% of the global magnesium output.

Shultz, the Ducker Worldwide veteran, acknowledged magnesium's potential but underscored its current shortcomings. He said the $2.50/lb of weight saved with Mg die castings and supply uncertainties "are considered a deal-breaker for most OEMs." However, for OEMs to attain the final 20% of the 500-odd pounds the average vehicle needs to shed to meet 2025 regulations will require "a 3-5% penetration from

lighter than aluminum without requiring the NVH abatement measures necessary for an aluminum-intensive design to meet GM's cabin-noise requirements.

GM's mixed-material strategy also enabled Hester's development team to achieve a 20% reduction in body-structure bill of materials—the CT6 has 412 parts total—versus a normal steel body, he said.

Winner of the 2016 Enlighten Awards' Module category, beating out 13 other finalists, is ContiTech's polyamide transmission crossbeam featured on the latest **Mercedes-Benz** S-Class as well as other Mercedes models fitted with all-wheel drive. Incorporating **BASF**'s Ultramid fiberglass-reinforced polyamide, the composite crossbeam is claimed to be about 25% lighter compared with an aluminum diecast counterpart.

"The new rear-axle transmission crossbeam is a milestone in the use of polyamides in the chassis and has the potential to set a new trend in the automotive industry," said Kai Fruhaf, head of the ContiTech vibration-control business unit. "Polyamide is increasingly replacing metal. And we're right there in the forefront of helping manufacturers gradually replace metal with high-performance plastics."

Company engineers claim that polyamide, unlike aluminum, can be formed at lower temperatures and offers various recycling options. Fruhaf's team has been using BASF Ultramid since 2006 for bearings and also uses the material in other automotive applications that include millions of torque-reaction mounts. Interestingly, the Cadillac CT6 also uses a polyamide material for its suspension strut mounts.

Bill Visnic

Lightweighting: WHAT'S NEXT?

Steel's expanding scorecard—on the path to 3rd-gen AHSS

Still the workhorse automotive material for vehicle structure and body panels in particular, steel technology continues to evolve in response to competition from lighter materials. New alloys and material grades deliver greater strength with less material, effectively narrowing the mass delta versus aluminum, magnesium and composites. Broadly termed advanced high-strength steel (AHSS) is the fastest-growing lightweighting material, its rate of usage (in pounds per vehicle) exceeding independent forecasts by 10% or more since 2013, according to analyst firm Ducker Worldwide.

That growth has fostered an expanding roster of steel grades—more than 200, according to the **American Iron and Steel Institute**—with an equally expansive matrix of vehicle applications. The new grades are matched to specific material qualities largely defined by unique microstructures:

Conventional steel grades still account for much of the "appearance" portion of a light vehicle—fenders, doors, roof panels. Based on a mostly ferritic microstructure, their chief advantages are superior formability, ready acceptance of Class-A paint finish and comparatively low cost.

High-strength steels offer moderately greater strength in the 400-800 megapascal range (MPa, a stress measure in force per unit area) with good formability. The HSS grades are widely used in chassis and suspension components. A variation, high-strength low-alloy steels (HSLA), have strength enhanced by micro-alloying elements.

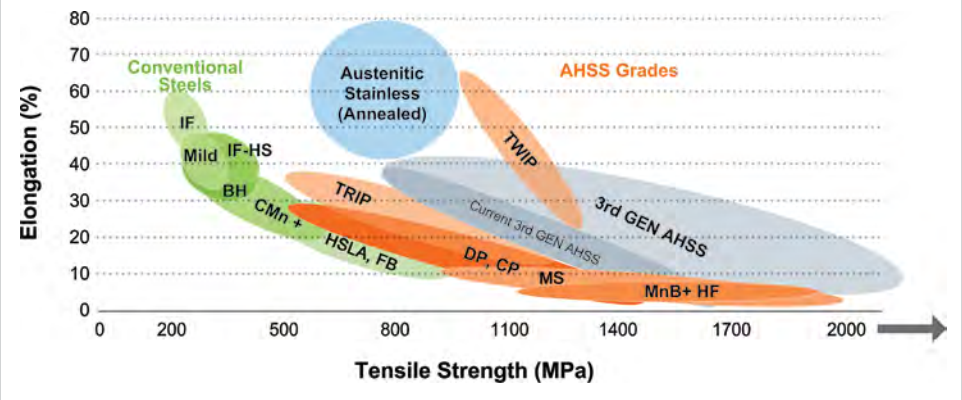
Advanced high-strength steel grades begin at around 500 MPa. AHSS was created for load-bearing, energy-absorbing, and crash-mitigation structures including sill and roof-pillar reinforcements. Their strength-to-weight performance offers potential to downgauge and reduce component cross-section, making this steel family difficult to replicate with other materials. Where HSS has mostly a single-phase ferritic composition, the microstructure of AHSS boasts extra phases such as martensite and austenite that help produce specifically tailored, unique mechanical properties. These come at a higher purchase cost than the lower grades, however, and AHSS demands a rigid cooling regimen.

Dual-phase steels have strength in the 500-1200 MPa range and are excellent for energy-absorption duties. The DP steels achieve their enhanced properties from a martensitic phase introduced into the microstructure, while the ferritic phase allows them to still exhibit good formability.

Ultra-high strength steels (UHSS) ratchet up tensile strength to the 800 MPa-to-1.9 gigapascal (1900 MPa) spectrum. They include hot-formed "boron" steel often cited by automakers and widely used to beef up B-pillars and bumper beams. With a yield strength of 1000 MPa and an ultimate tensile strength of 1500 MPa, boron UHSS is nearly three times stronger than regular HSS. Derived largely from special milling and processing techniques, UHSS's exceptional properties are offset by formability challenges in some cases.

In the pipeline are so-called 3rd-Generation AHSS, under development by the steel industry and automotive OEMs under the auspices of a **U.S. Dept. of Energy** program. The goal is to create high-strength steel formulations that retain a high degree of formability, making them suitable to employ in most incumbent steel-stamping operations. The twin targets for the third-generation AHSS: a 1200-MPa grade with 30% ductility and an "exceptional strength" grade at 1500 MPa with somewhat less ductility.

Bill Visnic



Steel strength and ductility by family graph shows this material's ever-broadening portfolio. Abbreviations reveal the complex metallurgies of BH (bake hardenable), TRIP (transformation induced plasticity), TWIP (twinning-induced placticity), IF (iInterstitial-free) and FB (ferritic-bainitic).

a combination of magnesium and carbon-fiber reinforced epoxy and SMC composites."

If the OEMs do not do this, "it will be because they are not willing to spend the necessary money on the new plant and equipment to make it happen—not because the materials needed to save a significant amount of weight are unavailable, unproven or too expensive," Schultz said.

The foundry industry has also heeded the lightweighting call. In Europe, 24 steel and forging-industry companies have formed the **Lightweight Forging Initiative** to demonstrate the potential of forged parts to enable lightweight designs versus competing production processes and materials. Phase I studies conducted in 2013-14 determined that advanced steels and forging technologies could reduce light-vehicle mass by up to 42 kg (93 lb), mainly applied to powertrain and chassis components.

Grede, a U.S.-based producer of cast-iron automotive components, is using its experience with thin-wall lost-foam casting as a member of LIFT, a public-private partnership operated by the **American Lightweight Materials Manufacturing Innovation Institute** (ALMMII) that is developing and deploying advanced lightweight solutions. According to Jay Solomond, Vice President, Engineering & Technology, Grede "has completed optimizing the design and chemistry which has resulted in 40% weight reduction and 50% thickness reduction." Trials on differential-

As CO_2 regulations become more stringent, every vehicle component becomes a potential candidate for future lightweighting measures. Ford has prototyped forged AL connecting rods, an example of which is shown at right next to a production steel rod. (Lindsay Brooke photo)

case parts created as part of LIFT have begun.

Solomond told *Automotive Engineering* that through the LIFT process Grede has been using existing production lines and advanced molding techniques. "This means we can make improvements entirely with existing capital and it doesn't require any new equipment," he noted.

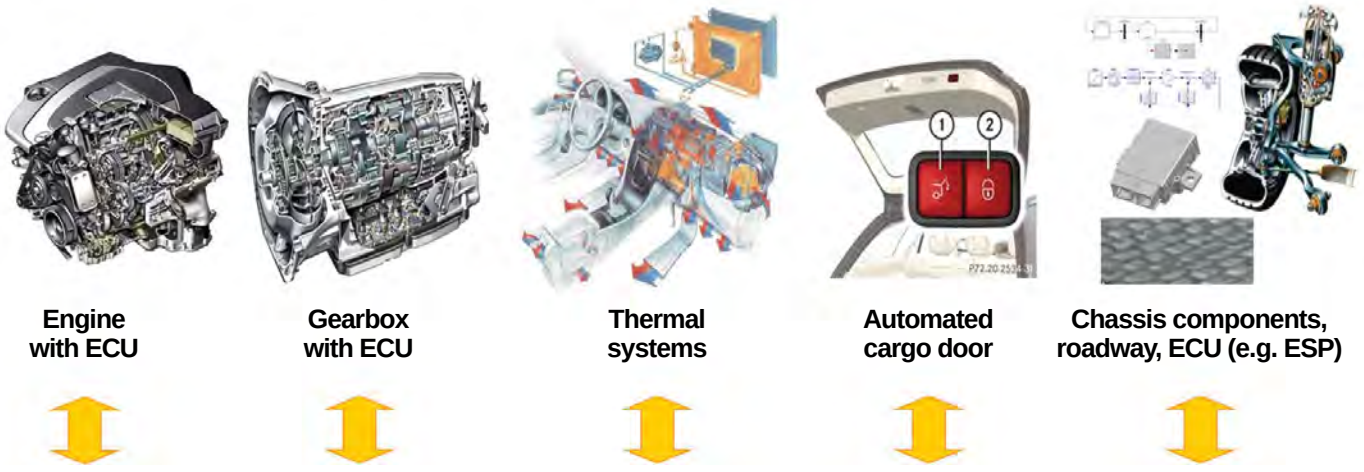
How extensive will lightweighting be? Forged aluminum connecting rods investigated by Ford and Honda would offer a 30% weight saving on reciprocating and rotating mass per engine versus today's cast iron or steel rods. Long-term durability remains an issue in automotive use, engineers say.

With all the possibilities offered by lightweighting technologies, what will the construction of post-2025 passenger vehicles consist of? Experts we spoke with pointed to today's BMW i3 and i8, Cadillac CT6, Ford F-Series, Tesla Model S and even the Chevrolet Corvette as directional inspirations for the cars and trucks to come. Opinions were divided on how widespread aluminum-intensive vehicles will be in the 2025-30 timeframe. Most predicted that cost will continue to make mixed-material solutions—incorporating a greater percentage of composites—the reigning choice. Whatever the details, "lightweighting" appears certain to remain a product-development mantra. ■

CAE's next leap forward

With 3D simulations skyrocketing, engineers are looking forward to highly optimized toolsets to keep pace with complexity.

by Bruce Morey



The Functional Mock-up Interface (or FMI) defines a standardized interface to be used in computer simulations for complex systems, particularly those involved in automotive development (Modelisar).

The enormous complexity of today's vehicles is well-recognized. Not only are automakers turning to simulation as a cost-effective means to enhance physical test, it is becoming a fundamental tool in the design process. This is true in sometimes surprising ways, as computers get faster and engineers get smarter.

"In just the last three years, an important trend for us is the increasing use of 3D simulations," said Curtis Collie, Principal Technical Specialist for **Gamma Technologies**, in an interview with *Automotive Engineering*. This is significant for a company that established itself in 0D and 1D engine simulations with its GT POWER software. Now, with its expansion into GT SUITE and software that simulates and optimizes entire vehicles, expect the mantra of simply "simulating more" to continue in targeted ways.

Collie sees the future as "increasing levels of optimization to match increasing levels of complexity." He noted that from simple models, engineers "can now simulate more components connected through more interfaces with complex interactions. Optimizing those complex interactions are what is needed and what the industry will continue to grow towards."

Are you part of an EMDO?

Just as importantly, the organizations that design them are also growing in complexity. Companies need a varied engineering staff to meet a complex welter of worldwide regulations while satisfying ever more specialized customer niches. This has led to automakers employing thousands of expert engineers, often in a network of engineering centers worldwide.

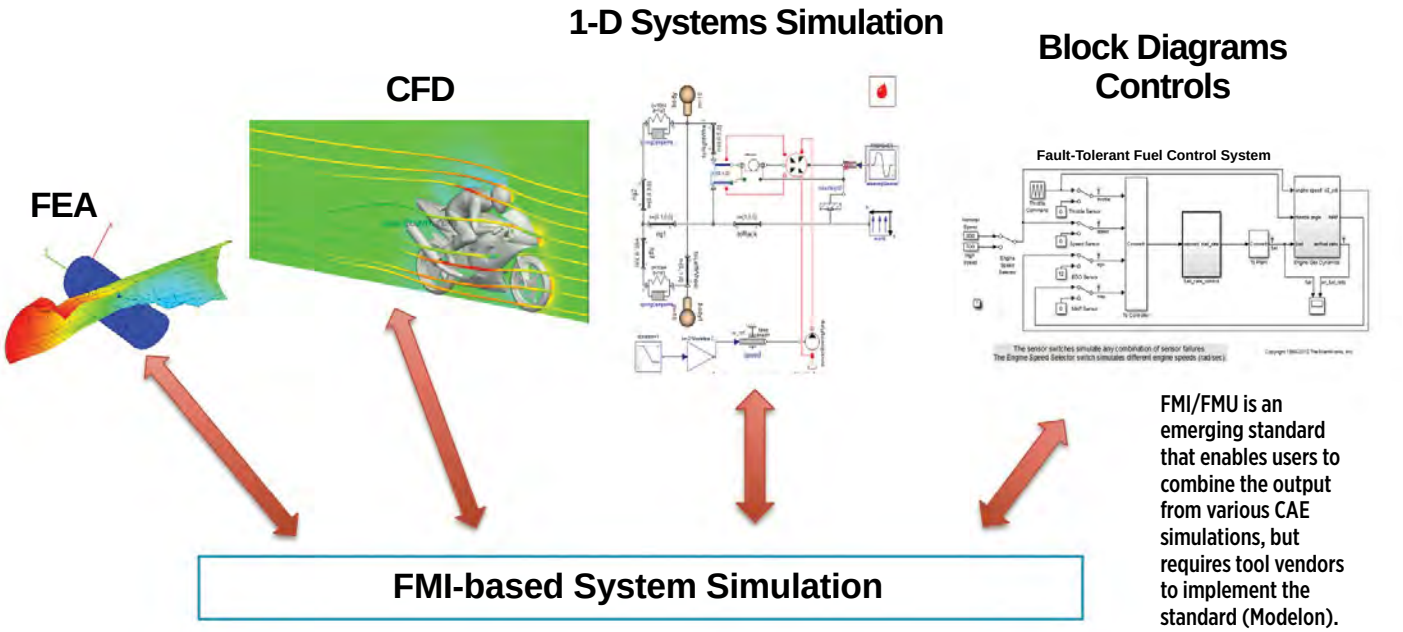
That is certainly true for **Ford**, according to Yan Fun, Manager and Technical Leader, Product Development and Strategy Analytics. She offered several intriguing points in a presentation earlier this year at a symposium sponsored by **NAFEMS**, the International Association for the Engineering Modelling, Analysis and Simulation Community.

In her talk, Fun described how Ford is developing an Enterprise Multi-disciplinary Design Optimization, or EMDO, system.

"One of our objectives was to understand how we can help Ford utilize our tens of thousands of engineers worldwide," she explained. Most engineers are experts in their field, from brake design to vehicle NVH, so integrating that knowledge to produce an optimized vehicle is an ever greater challenge.

Equally important is the need to build a system that helps train new engineers and capture the knowledge of experienced ones. Developing a system to combine that knowledge is just as important, Fun said, as vehicles require a balance of attributes to perform well.

There are emerging tools that provide opportunity to meet these goals. Mobile computing such as smartphones connected by the internet is a key enabler in Ford's EMDO. High performance computing, or HPC, combined with advanced databasing, and 24/7 web-based services enable a flexible, worldwide optimization process.



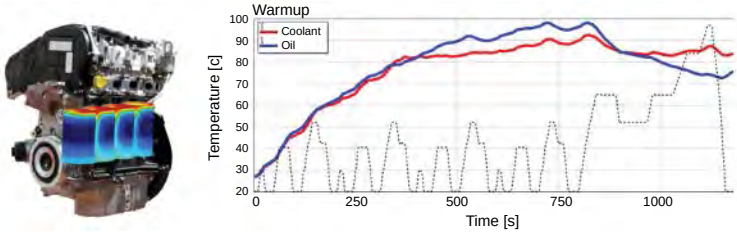
FMI/FMU is an emerging standard that enables users to combine the output from various CAE simulations, but requires tool vendors to implement the standard (Modelon).

Another key enabler is using advanced commercially available multi-disciplinary optimization tools, in their case ModeFrontier and SOMO from **Esteco**. ModeFrontier, as a desktop solution, is used by individual engineers and small groups to streamline an engineering process. SOMO, on the other hand, is a web-based platform for integrating multidisciplinary design projects across multiple departments and geographically distributed organizations such as Ford.

While presenting the results of a pilot study that used a prototype of this system to balance NVH and Safety attributes, Fun also pointed out the emergence of a new type of engineer: the MDO expert. This is an engineer who combines individual attribute models created by specific experts into a multi-disciplinary optimization run. The emergence of such a discipline makes sense, since there are a wide variety of MDO algorithms to choose from. These include algorithms that are gradient based, deterministic, or heuristic, so choosing the right one might require expert knowledge.

Connections and standards - FMI

Simulation tools also vary greatly based on their underlying principles. A CAE model for NVH is quite different from one used to analyze drivetrain performance or vehicle aerodynamics. A system or vehicle optimization method must both be able to accept such models and combine their individual results. While MDO tools can be customized to support model exchange, an important emerging standard is the



3D visualization of powertrain cooling from Gamma Technologies' GT Suite simulation software (Gamma Technologies).

Functional Mock-up Interface, or FMI.

"The reason FMI is such a hot topic in the industry right now is that it addresses critical needs for users to exchange, integrate, and deploy models in a tool neutral way," said Ed Ladzinski, manager for **Modelon**. "Once the output from a modeling tool is put into the form of a Functional Mock-up Unit (FMU), it typically frees the simulation model from requiring further access to the authoring tool."

Also, output as FMUs from a range of modeling formalisms, including 3D finite element stress analysis, a controls model created in Simulink, and computational fluid dynamics, can all be combined into a system model providing more realistic simulation of the actual real world performance.

As an emerging standard, it requires the CAE and systems modeling companies to produce a standard output that allows for collaboration and interoperability. The good news is that there is a growing list of these vendors that see the advantages – and the market demand.

"As FMI continues to mature in the next few years, expect to see even larger and more integrated full vehicle simulations and optimizations across a range of disciplines, modeling formalisms, and tools," Ladzinski noted. ■

2016 SAE CONVERGENCE brings new program for tech collaboration

Meet the disruptors, network with peers, and learn about the latest tech solutions that are rapidly changing the auto industry.

by Lindsay Brooke

Connected vehicles. Autonomous driving. Radical new electrical architectures. Open-source solutions. And a new wave of software-centric players rapidly transforming the mobility industry. What do these trends mean for engineers and technologists whose careers depend on staying ahead of the pace?

SAE's 2016 Convergence is a valuable place to get answers. This year's conference, themed "Personal Mobility: Creating a Smart and Autonomous Journey," is September 19-21 at the Suburban Collection Showplace in Novi, MI. The more than 2000 attendees expected at Convergence will meet the disruptors, network with peers and learn about the latest technology and software solutions that are transforming the automotive business.

"We are migrating from a focus on building reliable cars and trucks to creating comprehensive mobility experiences enabled by technology," noted Jim Buczkowski, the 2016 Convergence General Chair and Henry Ford Technical Fellow and Director, Electrical and Electronics Systems, **Ford Motor Co**.

This "evolution in mobility engineering," he said, requires input from a broad community of partners beyond the traditional auto companies—with Convergence continuing as a major venue for promoting such collaborations.

CTOs talk innovation

Launched 42 years ago to bring together the automotive electrical/electronics and mechanical engineering communities, the pioneering Convergence event also has evolved. Ever-popular sessions on systems engineering, embedded and off-board software and new electronics technologies continue to anchor the 2016 event, while expert panels also bring new insights into innovation, data and analytics, user experience (UX), vehicle autonomy and connectivity and mobility services.

Embrace disruption—don't fear it!

While trends in vehicle connectivity, autonomy and even electrification have shaken up the automotive establishment, new technology disruptors are on the way. How will they impact engineering, product development, your company's business model—and your career?

Tuesday's panel of experts at 2016 SAE Convergence will share their insights on how human behavior, "cloud" technology, changing business models and the mobility infrastructure will continue to rattle the status quo and bring new opportunities. It's a must-attend two-part show:

Disruption from the West is the morning session keynoted by Saeed Amidi, CEO and founder of **Plug and Play**, with experts from **Stanford University**, **Autotech Ventures** and **Ellis & Assoc**.

Disruption from the East in the afternoon brings **Local Motors**' David Woessner, joined by experts from **Movimento**, **Allianz**, **P3 North America**, and **Hitachi**.

L.B.

"There's a lot of excitement around the 2016 program," said Jim Sherman, SAE International's Technical Conference Developer who has the Convergence lead. "First there's the Novi facility which has a totally different vibe about it than [Detroit's] Cobo Hall and is located in the center of tech development within the supply chain," he noted.

Sherman is enthusiastic about the new Convergence format, arranged into themes for each of the event's three days. Leadership Day, the first-day program for Monday, Sept. 21, kicks off with the highly-anticipated Innovator's panel.

"We have the Chief Technology Officers of **FCA**, Ford, and **GM**, plus those of **Delphi** and **Harman International**. These literally are the guys making decisions on what's next in terms of technology," he said. Following the Innovators is an expert panel focusing on the electronics and tech Supply Chain.

"The supply chain has transformed itself over the last two decades and is currently transforming itself again," Sherman observed. "So as a new topic we're bringing in thought leaders from the investment world to talk about where they believe the electronics and tech supply chain is going next."

He added that SAE Convergence serves as a 'gateway' for technology companies that are established, looking to grow and enter the whole automotive ecosystem. "We provide that linkage," he said.

The Monday program concludes with the lead electrical engineers from Toyota and other OEMs discussing state-of-the-art technologies and common challenges.

"We do the E/E panel at each event and it's always a big hit and audience draw," Sherman said. "We've scheduled it at the end of Day 1 so that we can capture some of the thoughts of the earlier panels and have the lead E/E's provide a somewhat shorter-term view of what the Innovators and Supply Chain experts are looking at."

6-track techfest for engineers

Engineers Day on Tuesday, Sept. 20, will feature deep-dive technical presentations from industry experts. The six parallel subject tracks include: Architecting to Enable and Scale; Open Source as an Enabler; People/Technical Workforce Transformation; Designing for an Experience; Technology Disruptors; and Leveraging Consumer Electronics.

"The point of Day 2 is take what we learned in Day 1 from a vision standpoint and look at how the tools and actual engineering piece fits in," explained Sherman. The six subject tracks are different enough between them to provide valuable takeaways for all Convergence attendees.

For the last Tuesday session, Leveraging Consumer Electronics, the SAE team has enlisted experts from far outside the automotive realm. One of them is from **Waze**, the world's largest community-based traffic and navigation app that allows drivers to share real-time traffic and road info.

SAE Convergence "stands apart in its consistent ability to expose participants to leading-edge technology and software ideas that influence our business," said Ford's Jim Buczkowski.

"Hearing from Waze will be interesting because they've just been gobbled up by **Google** while still acting independently," Sherman commented. "It's just one example of the 'outsider' companies that will be transforming what we know as the automotive industry rather quickly."

The final day of Convergence 2016, Wednesday Sept. 21, is industry Partner Day. The program features technical seminars and training sessions presented by SAE's partner associations and organizations who are engaged with or have a stake in the automotive electronics industry.

Included will be professional development classes with topics including mobile compliance and connected vehicle and a hands-on workshop conducted by **dSpace**.

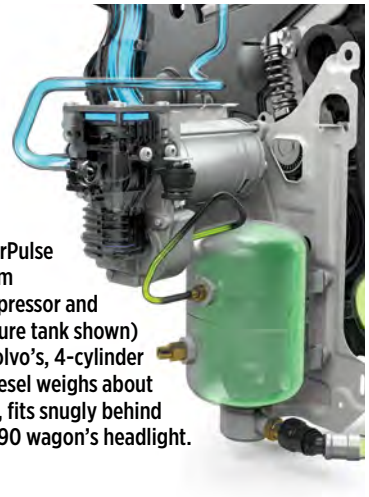
The day will also bring a status update from the **U.S. Dept. of Transportation** on its ITS [intelligent transportation systems] program plus SAE Standards Committee meetings.

Convergence has always included a focus on the 'nuts and bolts' of automotive electronics and that component continues in the 2016 program, Sherman noted.

"But we're also into the externals—the integration of the vehicle into its environment and other factors that will drive future vehicle designs," he said.

For more 2016 Convergence information and to register, visit www.sae.org/convergence. ■

Volvo bets on new PowerPulse, not 48V, to attack turbodiesel 'lag'



PowerPulse system (compressor and pressure tank shown) for Volvo's, 4-cylinder D5 diesel weighs about 10 kg, fits snugly behind the V90 wagon's headlight.

Volvo is using a blast of compressed air to boost torque delivery and exorcise turbo "lag" of its new D5 diesel engine. It's a comparatively simple technology solution that works quite effectively, as company engineers recently demonstrated to *Automotive Engineering* on a lengthy and often demanding test drive of the D5-powered V90 station wagon in southern Spain.

Volvo has dubbed the novel, heavily-patented diesel air-delivery system "PowerPulse." It serves as a cost-effective alternative to using a 48-V hybrid system with electrically-driven turbocharger or supercharger to rapidly accelerate turbines at low engine revs.

Volvo powertrain engineers spent more than three years developing PowerPulse, on the same critical path as the D5 engine. The 2.0-L 4-cylinder direct injected diesel delivers a claimed 173 kW (232 hp) and 480 N·m (354 lb·ft). A lower-powered D4 version producing 140 kW (188 hp) and 400 N·m (295 lb·ft) without PowerPulse also is available.

A simple, compact system

On the road PowerPulse literally blows into action, helping the V90 wagon accelerate from standing start to 100 km/h (62 mph) in 7.2 s which, bearing in mind the car's power output and 1817-kg (4006-lb) curb weight, is brisk but not exceptional. The car's automatic transmission is an 8-speed **Aisin**. No manual gearbox is offered.

Powertrain Program Manager Fredrik Ulmhage said the PowerPulse system was conceived entirely in-house. "No one else has it," he asserted. "We have a 4-cylinder diesel strategy (as we have for our gasoline engines) and decided we needed to deal with any turbo lag, getting the turbo running before exhaust pressure built.

"So basically, we push compressed air into the exhaust manifold as the driver pushes the accelerator pedal and within milliseconds the turbo spools up," Ulmhage explained.

This can happen twice consecutively, with virtually no pause between applications. If a third rapidly-required consecutive step-off is needed (regarded as an extremely rare likelihood), it would take a couple of seconds for the system to re-charge to provide a further pulse. A small compressor squeezes air into a 2.0 L tank at a pressure of 12 bar (174 psi), with a magnetic valve controlling the action phase of the system.

Volvo's D5 engine is configured with two **BorgWarner** turbo machines, respectively sized 38 mm and 53 mm and operating sequentially. Engineers claim the turbo reaches its peak 150,000 rpm from idle in 0.3 s. "When we matched the system against competitors' 6-cylinder diesel engines from stationary, our new 4-cylinder was ahead of them for up to 50 to 60 meters," noted Ulmhage. He confirmed that Volvo's XC90 SUV will also be offered with PowerPulse. And the setup is likely to be fitted to other upcoming models.

The PowerPulse system adds about 10 kg (22 lb) to the base diesel engine. It fits into a convenient underhood space behind a headlamp housing. Volvo engineers are investigating lightweight materials that could be used to reduce mass of the pressure tank.

Volvo has a series of high-priority technology programs with the emphasis on hybrid efficiency and is aiming to take gasoline powertrains much closer to diesel fuel consumption potential.

A 3-cylinder gasoline engine is in the pipeline with a rated output expected to exceed 130 kW (174 hp). It will be used to power smaller Volvo models, bringing not only "performance efficiency" but also reduced unit cost compared to diesels, the cost of which rises as more engine controls and aftertreatment are incorporated to meet emission regulations.

The V90 is joined by the new gasoline-engine S90 T6 sedan (http://articles.sae.org/14568/), paired as part of Volvo's determined bid compete with **Mercedes-Benz** and **Audi**. Both vehicles are underpinned by the company's Scalable Product Architecture (http://articles.sae.org/12739/), as is the XC90.

Stuart Birch

SEAT to spearhead VW's new platform and 48V technology

"**SEAT** has been through hell, in a way," asserted Luca de Meo, who became chairman of the Spanish automaker, part of **Volkswagen Group**, late last year. But after it survived a lengthy recession a recovery is underway, he insisted, in which the company will launch a flurry of new products and spearhead use of new vehicle architecture and technologies through 2020.

In a recent interview with *Automotive Engineering* in his Martorell office, near Barcelona, de Meo—an executive never at a loss for words—hit back against doubters who say SEAT is a lost cause. The company will be the first VW brand to use the Group's new MQB A0 platform that will underpin the next generation Ibiza. SEAT also majors on distinctive design, connectivity, sportiness, and a degree of "emotion," with 48V hybrid powertrain applications also in the pipeline to support and broaden its systems' repertoire, he reported.

De Meo admitted, however, that SEAT needs to establish a distinct identity, one that can be communicated effectively in a word or short phrase to the public and the business community.

Emerging from VW's shadow

"In the next 18 months, we will benefit from the biggest product offensive that SEAT has ever had," de Meo asserted.

With the advent of the Ateca SUV and a planned crossover wholly developed and manufactured in Spain, SEAT's market coverage will rise from 55% to 75%, de Meo claimed, saying he sees SEAT emerging for the first time from the shadow of other VW brands to look for its own way of doing things. Last year the company spent €586 M on investments and R&D. It has 1000 engineers and specialists who develop suspension, dynamics, and electronic systems, although powertrains are Wolfsburg's responsibility.

These will continue to include diesels. SEAT was not seriously affected by VW's "dieselgate" emissions scandal, and de Meo remains confident of the technology's future. "Until you get another technology to meet our customer benefits and requirements, it [diesel] will stay solid," he opined. "People like their diesels for fuel consumption, low CO_2 emissions, and torque. There are no longer turbo lag or noise negatives. I believe in it."

De Meo said he wants to see SEAT eventually taking leadership in some aspects of Group technology, although he gave no detail. "There is something in being a smaller cog in the huge VW Group; we can move a little quicker, and for sure the attitude to achieve is present here," he explained. "The Ibiza has always been the backbone of SEAT and now we have the chance to introduce the MQB A0."

Diesels over EVs

This new A0 platform will be used for several Group models including the Audi A1, Q3 and Polo. The new A1 will be built by SEAT at Martorell. The factory produced 477,000 SEATs and Audi Q3s last year, the total up 60% over six years.

SEAT Chairman Luca de Meo with the new Ateca SUV. The company, he said, "has been through hell" but is now preparing for a product and technology-led recovery.

SEAT's technology priorities for the next five to 10 years particularly embrace decisions on the connected car, electrification, and autonomous driving. For the two latter, SEAT can access the "technology supermarket" of the VW Group, although SEAT customers generally do not have the purchasing power for costly electric vehicles.

A Leon EV would not find many customers, said de Meo: "I need to concentrate on a technology that brings real CO_2 reduction but that our customers can afford. Hybrid is certainly in the SEAT scope but at present that is not likely to be a high volume solution. So even though downsized engines including a 3-cylinder gasoline will be used in products, diesel remains significant.

Stuart Birch

PRODUCT BRIEFS

SPOTLIGHT: METALS

Atmosphere control system for annealing

Linde LLC's Hydroflex atmosphere control system (ACS) is a solution for clean and bright oxide-free annealing of steel, stainless steel, copper, bronze or brass with high reliability and repeatability and is suitable for applications including automotive, aerospace and military components, construction and industrial equipment and electrical systems. According to the company, the system can use one or more carrier gases—nitrogen (N2) or argon—to maintain the furnace pressure while a controlled ratio of hydrogen (H2) helps prevent oxidation. With this technology, many annealing tasks can be completed with non-flammable gas mixtures containing less than 5% H2, which contributes to fire safety while optimizing the use of H2 in the process. Features and benefits of Hydroflex ACS include precisely controlled atmosphere, improved heat transfer, uniform heat distribution, faster cooling rate, automatic safety purging with N2 and storage of process data history. For more information, visit **www.lindeus.com**.

Hemming of thin gauge AHSS achieves weight savings

The **Auto/Steel Partnership**, a consortium of North American automotive companies and the **Steel Market Development Institute**'s Automotive Applications Council, announced its Hemming of Thin Gauge Advanced High-Strength Steel (AHSS) project achieved a 30% weight savings using thinner gauge AHSS for automotive closure panels. Conducted in an effort to assist automakers in meeting stringent fuel economy requirements, the project demonstrated thin gauge AHSS can be successfully hemmed into automotive closure assemblies; computer-aided engineering tools can be developed accurately, predicting results of hemming operations involving thin gauge AHSS; and post-hemming baking operations do not adversely affect hemmed thin gauge AHSS assemblies. "We took hemming to new limits and proved it with results. Thinner gage AHSS, real-world closure shapes, extremely tight breakline radii, and weight reduction in outer closures make this a winning project," said Giovanni Costa, project lead for the A/SP Hemming of Thin Gauge AHSS team and corporate hemming specialist at **FCA US** LLC. For more information, visit **www.a-sp.org**.

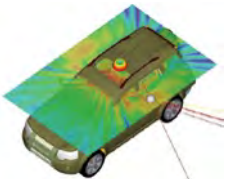
Custom, high-performance mufflers

Modular Exhaust, a division of **GLSV**, features custom sizing for three different shapes of mufflers—circular, elongated, and rectangular—as well as custom-shaped non-modular mufflers, which are available upon request. The company offers customized design for both a desired flow and a desired noise level performance. Designing to a specific noise specification and backpressure are all made possible through advanced exhaust modeling tools. Modular Exhaust works with a wide range of materials including carbon steel, stainless steel, titanium, and Inconel and also offers a range of heat treatments including reflective ceramic coating and integral wrap. Benefits and features include maximum engine performance and high efficiency, corrosion resistance and thermal protection, and streamlined design and manufacturing process. For more information, visit **www.modularexhaust.com/introducing-modular-exhaust/**.

Absolute encoder series

Baumer's absolute HeavyDuty encoder series HMG 10 and PMG 10 offer a resilient housing, optimally spaced fixed/floating bearings on both sides, and generously sized hybrid ball bearings. These features provide long service life and reliability, according to Baumer. The robust magnetic precision sensing supplies a signal quality that is nearly identical to that of optical sensing principles, but withstanding dust, dirt and condensation. Even at high temperatures up to 100°C (212°F) and in adverse environments, the shock- and vibration-resistant sensing technology ensures high-precision signals for maximum processing accuracy and control quality in the application. The HeavyDuty encoders are particularly suitable for steel and rolling mills, cranes and lifting systems, and material handling and conveyer systems. For more information, visit **www.baumer.com/HMG10**.

Simulation software for antenna, RF systems



The latest release of **ANSYS**' Savant and EMIT software gives engineers the power to design and predict the performance of installed antenna and radio frequency (RF) environments quickly and more accurately for a range of products—from wearable and mobile devices to autonomous vehicles. Savant and EMIT work in conjunction with ANSYS HFSS software, enabling users to optimize a complete workflow to simulate the entire electromagnetic environment, including antenna synthesis and design, installed antenna performance and RF system analysis. According to ANSYS, the new releases feature significant advances in solver technology, design flow automation and high-performance computing for applications that include wireless system planning, platform co-site interference, coexistence and defense for electronics devices. For more information, visit **www.ansys.com**.

High-performance polyamide

Based on Stanyl polyamide (PA) 46, **Royal DSM**'s new high performance Stanyl HGR1 reduces frictional torque in automobile engine timing systems. The new material will provide OEMs with a cost-effective tool for reducing fuel consumption, claims Royal DSM. The company has continued to work on developments to improve the properties of Stanyl PA 46 for use in chain tensioners. According to the company, extensive tests have proven that chain tensioners in Stanyl HGR1 produce lower frictional torque than any other material at relatively low engine speeds ranging from idle to 1800 rpm. HGR1 also performed well at vehicle cruise speeds. Stanyl HGR1 PA 46-based material made its market debut on the latest version of the Pentastar V6 engine, built by **Fiat Chrysler America** and fitted to numerous vehicles. For more information, visit **www.dsm.com**.

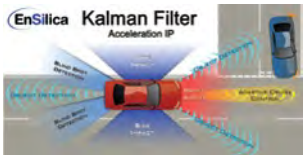
PXI radio frequency multiplexers

Pickering Interfaces expands its range of PXI 50Ω 600MHz radio frequency (RF) multiplexers with 18 different configurations including a PXI two slot 32:1 configuration. This new range of PXI RF multiplexers (series 40-760) is available in the following configurations: dual, quad and octal SP4T; single, dual and quad SP8T; single and dual SP16T; and single SP32T. All of the multiplexers have versions with automatic terminations to manage voltage standing wave ratio effects (VSWR), which could degrade the performance of a test system. Additionally, all versions of this range of PXI RF multiplexers exhibit low insertion loss and VSWR through the use of modern RF relay technology. For more information, visit **www.pickeringtest.com**.

Vin dc/dc controller

The 2.2-MHz, dual-channel synchronous buck converter from **Texas Instruments** (TI) provides a unique set of features designed to significantly reduce electromagnetic interference and high-frequency noise in high-voltage dc/dc step-down applications such as automotive infotainment and high-end cluster power-supply systems. The LM5140-Q1 controller includes dual outputs with phase interleaving and is offered in wettable flank packaging that speeds manufacturing. The device's wide 3.8- to 65-V operating range handles start-stop and load-dump conditions for 12-V/24-V lead-acid and emerging 48-V lithium-ion automotive batteries. According to TI, low 35-uA quiescent current (I(Q)) in standby (one channel operating with no load) extends battery life in "always-on" applications. For more information, visit **www.ti.com**.

IP core for ADAS situational awareness



EnSilica offers the Kalman Filter acceleration IP core for use in situational awareness radar sensors for advanced driver assistance systems (ADAS), such as electronic stability-control systems, pre-crash impact mitigation, blind-spot detection, lane-departure detection and self-parking. Kalman filtering is used in sensor-based ADAS as part of the radar tracker to smooth out position and velocity measurements obtained from the radar sensors and front-end digital signal processor (DSP) unit. According to EnSilica, the compact, low gate-count architecture of the device enables the computationally intensive matrix operations involved in Kalman filtering to be cost-effectively off-loaded from the CPU. For more information, visit **www.ensilica.com**.

Probing software package

Renishaw features an enhanced probing software package that automatically optimizes on-machine measurement cycles to minimize cycle time and maximize productivity. Inspection Plus with SupaTouch optimization uses intelligent in-cycle decision making to implement either a one- or two-touch probing strategy for each measurement routine and eliminates the need for manual optimization of on-machine positioning feedrates, measurement feedrates and strategies. It offers cycle time reduction of up to 60% on CNC machine tools compared with traditional software cycles, claims the company. Designed to ensure maximum accuracy, the software detects any measurements taken during machine acceleration or deceleration phases and compensates for errors by taking corrective action and remeasuring. For more information, visit **www.renishaw.com/mtp**.

WHAT'S ONLINE

VIDEO

SAE Eye on Engineering: Survey Wary of Driverless Cars

Americans are wary of driverless cars. In this episode of SAE *Eye on Engineering*, Editor-in-Chief Lindsay Brooke looks at a recent national survey following the death of a **Tesla** Model S driver using his car's "Autopilot" feature. This video can be viewed at **video.sae.org/12192/**. SAE *Eye on Engineering* also airs Monday mornings on WJR 760 AM Detroit's Paul W. Smith Show. Access archived episodes at www.sae.org/magazines/podcasts.

WHAT'S NEW

Mississippi State's Car of the Future features novel innovations

A rear-wheel-drive sports car's estimated triple-digit mpg and predicted 5.7-s 0 to 60 mph (0 to 97 km/h) acceleration time are the prime performance cues associated with a hybrid-electric retrofit that features multiple innovations.

Engineers at **Mississippi State University**'s Center for Advanced Vehicular Systems (CAVS) are creating fresh solutions via electrifying a 2013 **Subaru** BRZ.

"On our other product-driven projects, we don't always have the flexibility to create intellectual property for the university. With this project, we can divert resources to follow ideas that show promise," said Matthew Doude, CAVS' Program Manager - Powertrain Engineering Business Development Officer. Doude is the project leader for the Subaru BRZ conversion, dubbed The Car of the Future.

Read the full story at **articles.sae.org/14865/**.

GM shines brightest in latest OEM-supplier relations study

"The continuing challenge facing automakers is very simple: They need to understand the difference between process improvement and work relations improvement. Some OEMs don't understand this simple point. They think they're working to improve relations when in fact, they're working to improve business processes," asserted Dr. John Henke Jr., President of **Planning Perspectives Inc.** (PPI). The Birmingham, MI-based company studies OEM-supplier relations.

In PPI's 2016 North American Automotive OEM-Tier 1 Supplier Working Relations Index (WRI) Study released May 16, suppliers evaluated and ranked their working relations with **Fiat Chrysler Automobiles**, **Ford**, **GM**, **Honda**, **Nissan** and **Toyota**. The 2016 report findings were based on responses from 647 supplier personnel from 492 Tier 1 companies, representing 63% of the six OEMs' annual purchases.

Of those automakers, only GM notched significant improvement with a gain of 26 points from last year's rankings. But GM's improvement falls well short of being in the WRI's Good-Very Good range.

Read the full story at **articles.sae.org/14823/**.

WHAT'S NEW

More details on Citroën's new 'hydraulic cushion' suspension

First details are emerging of **Citroën**'s new vehicle refinement package including an innovative suspension system, the existence of which was revealed by *Automotive Engineering* late last year (articles.sae.org/14498/).

At that time, Citroën CEO Linda Jackson said of the still secret program: "The technology we are developing will deliver what I call the 'Citroën ride.'" Since then the Advanced Comfort Program has moved toward production. It uses secondary dampers that Citroën quaintly refers to as "hydraulic cushions" to complement the regular shock absorber and springs of each suspension unit.

The dampers work progressively, one for rebound, a second for compression, positioned at the upper and lower extremes of each unit instead of conventional bump stops. They should deliver better control throughout much of the suspension's travel.

Read the full story at **articles.sae.org/14867/**.

COMPANIES MENTIONED

AD INDEX

Q&A

Dr. Jay Baron: The cost of meeting the 2025 regulations "is going to be greater than everyone says it will be even with mass production."

Driving the CAR toward 54.5 mpg

Chances are good that if you're involved with automotive manufacturing strategy, you know Jay Baron. As President and CEO of the **Center for Automotive Research** (CAR) in Ann Arbor, Dr. Baron and his research teams are engaged with technology issues across a broad front, but even a brief conversation with him reveals his deep passion for plants, advanced processes and materials. Get him talking about lightweighting and he won't stop. The following exchange was taken from our July 2016 interview.

At what point does the rising cost of vehicle compliance allow the over-the-horizon lightweighting technologies to enter production?
The industry is inching forward on new technologies. In the body structure the trend is to stay primarily with steel as long as possible. Clearly the lowest-cost strategy is to add high-strength steels then slowly introduce more aluminum and composites. Aluminum hoods and decklids have been popular for some time. Our latest survey says the next frontier is moving to aluminum doors. They're coming on strong across the fleet. Going from steel to aluminum can be a fairly easy change; you can often use the same dies. It can offer a backup if there are issues. But going from steel to composite is different—no backup.

Engineers now say "every ounce counts" in reducing vehicle mass. True?
That's correct. We're trying to remove weight by the ounce because it's cheaper by the ounce. If you go for the 'home runs' that means going all-aluminum, which costs hundreds if not thousands of dollars more per vehicle. On top of that you have launch complexities and concerns about increased NVH, too. This industry introduces new technology incrementally. Even though there's new technology on the shelf, the industry can only absorb so much introduction at any one launch. We only have so many engineers and every new technology has a certain development time and level of risk associated with it. The qualification for a new material can be decades long—I've been hearing about 3rd Generation steels for 25 years!

Mitigating "mass creep" from new vehicle to vehicle is a challenge, and some of it is related to emissions and safety compliance.
One company was concerned about the new frontal-offset crash standards adding weight. You think auto companies have gamed the system around fuel economy? They've also gamed the system around meeting crash requirements. That's why they push 5-star ratings. Our team is looking at 'scoring' the crash test data of a car, over time. Because as cars have gotten heavier their crashworthiness has improved. I'm interested in seeing what we find.

What's your bet on the mid-term review? Do you expect the regulators to retreat from the original 2025 plan?
Here's what I think will happen. First, nobody looks good fighting 'green' technologies. Our industry doesn't have the best reputation on this front. They've already got a lot of R&D sunk into achieving 54.5 mpg. And you have CEOs who have said they promise to make this work. They're not going back on that promise. They may try to negotiate special credits for technologies not measured through the CAFE process, but I don't see the OEMs trying to change the regulations.

And your thoughts on the projected cost to the consumer for meeting 54.5-mpg?
The industry will meet the regulations one way or the other. We will lightweight these cars. However, I think the cost is going to be greater than everyone says it will be even with mass production. The price of raw aluminum is the price, for example—that's not going to change. The regulators estimated the cost hit per unit was roughly $1800—and that's cost, not selling price. The rule of thumb our team always uses to add overhead burden is to add 50%. So 1.5 times 1800 is $2800 added to the selling price. That's based off 2010 model year and off the regulators' estimate, which clearly is not going to be on the high side. The automakers' estimate is going to be much higher than that.

If all of a sudden the car I want to buy is $4000 to $5000 more, that's going to change what I do. And it's going to change the industry.

Lindsay Brooke

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Heidi Holden
– Product Metallurgist

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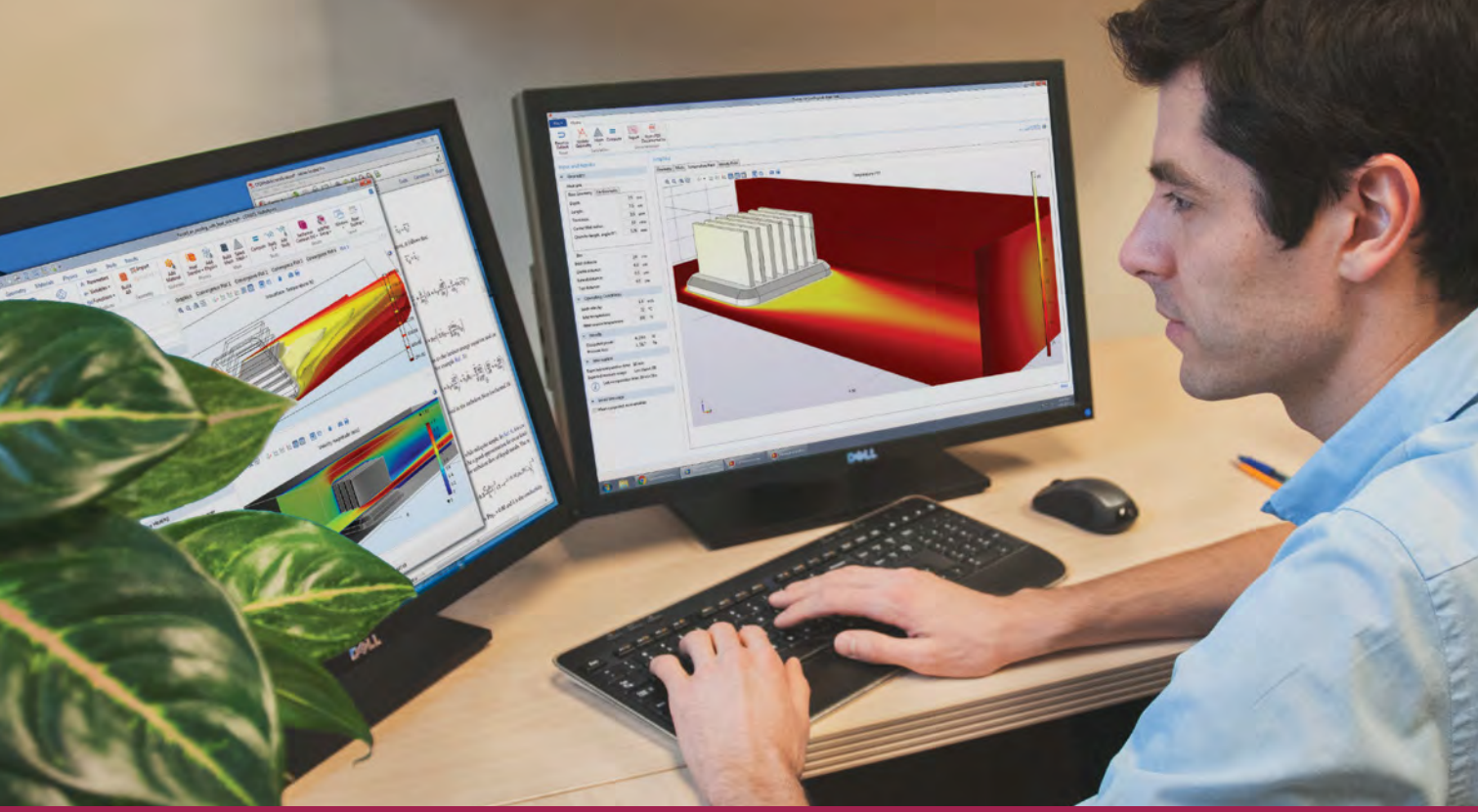

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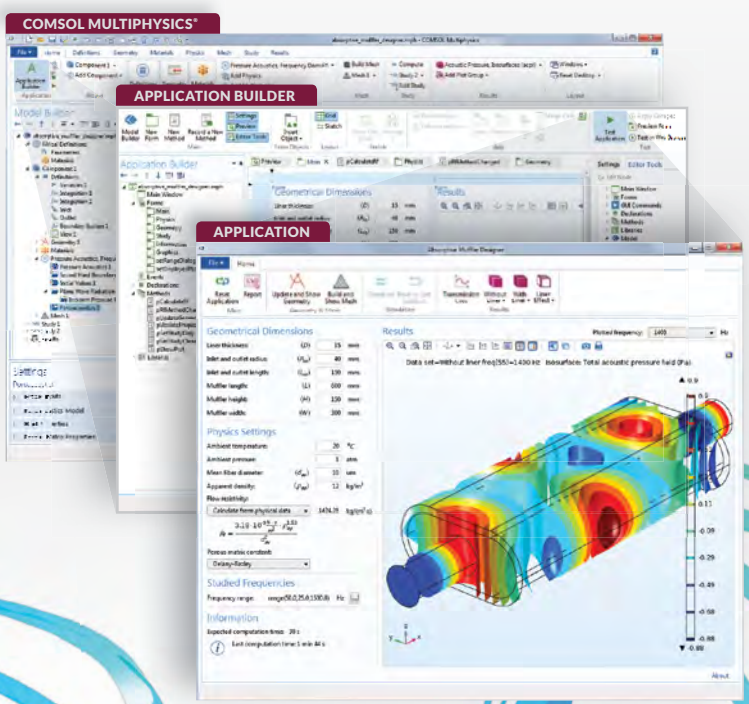

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