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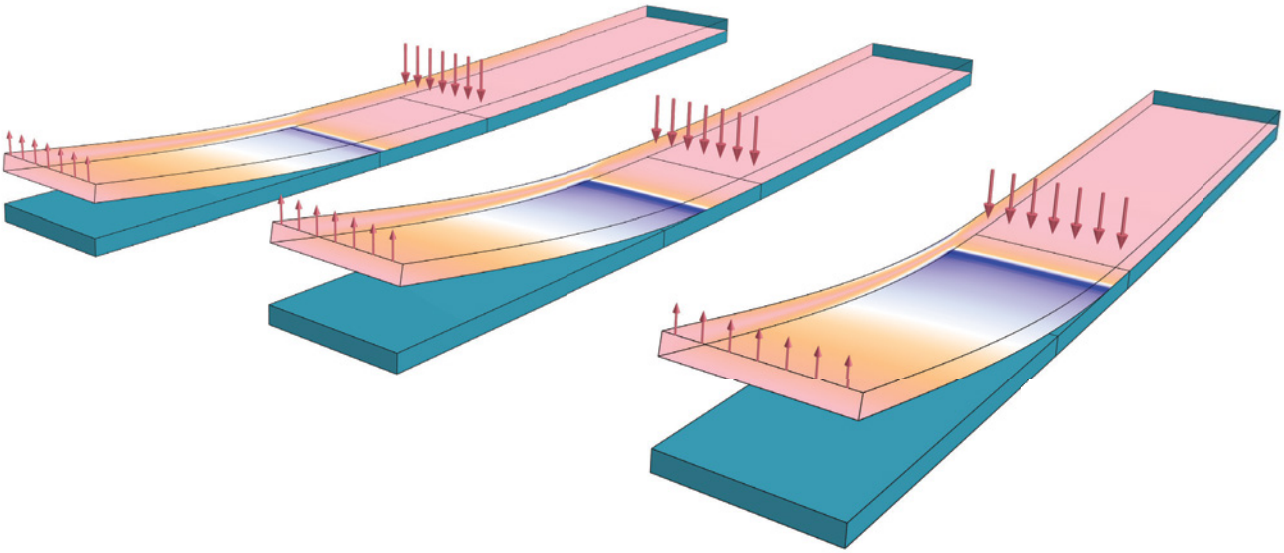

Visualization of von Mises stress distribution and applied loads in a mixed-mode delamination of a composite material.

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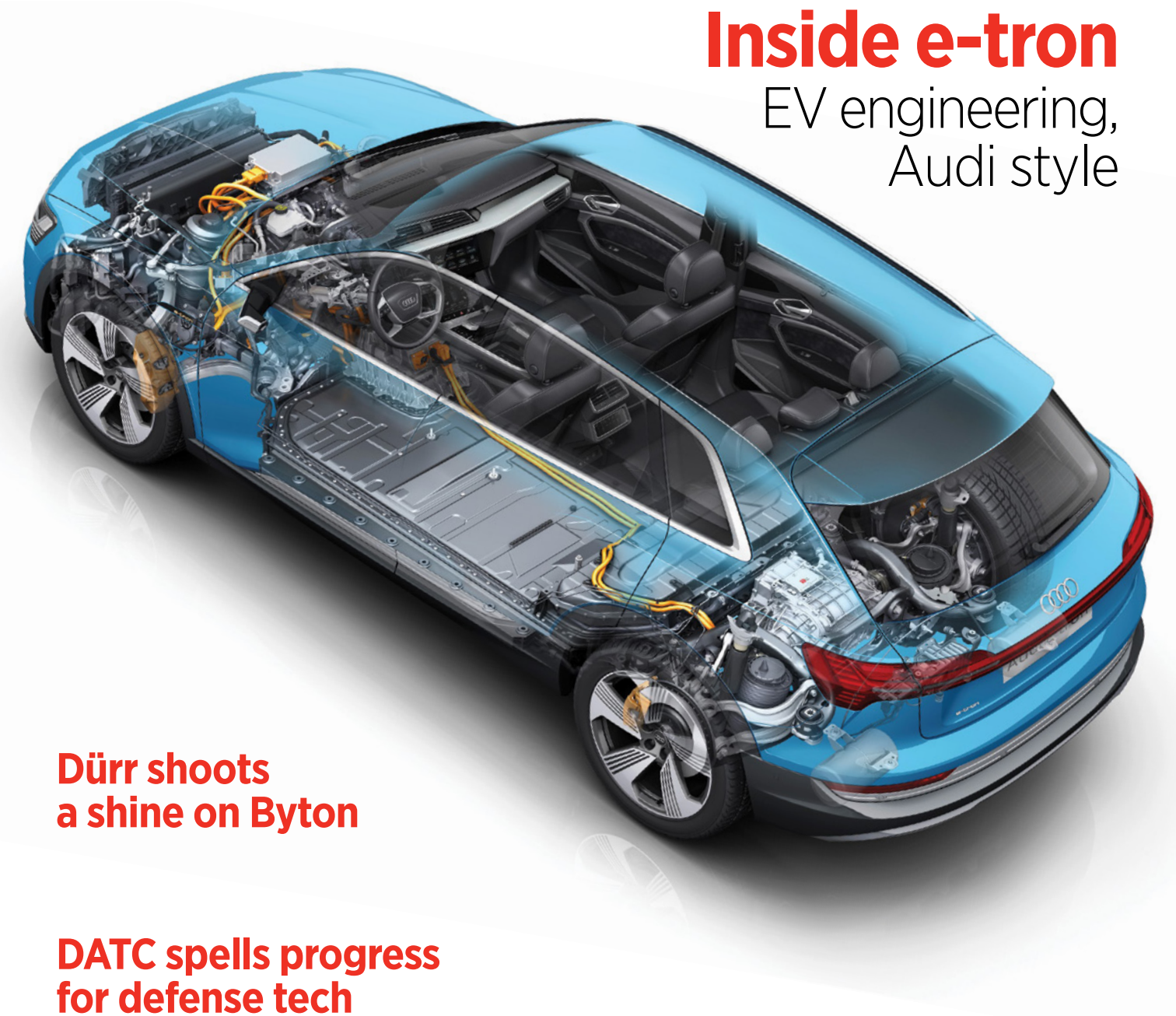

Inside e-tron

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FEATURES

ON THE COVER

VW's Audi group is the first German OEM to launch a battery-electric vehicle for the premium segment, and the second European (after the Jaguar I-Pace). The e-tron is a C/D-segment, 5-seat crossover underpinned by a unique-for-this-model platform. It features a 95-kW·h battery pack of 'sandwich-type' construction and a heat pump for thermal management. SAE Media contributor Sebastian Blanco was among the first reporters to drive the new EV and speak with its engineers; see page 24. (Audi cutaway)

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REGULARS

Automotive Engineering®, February 2019, Volume 6, Number 2. *Automotive Engineering* (ISSN 2331-7639) is published in January, February, March, April, May, June, September, October, and with combined issues July/August and November/December by Tech Briefs Media Group, an SAE International Company ®, 261 Fifth Avenue, Suite 1901, New York, NY 10016 and printed in Mechanicsburg, PA.

Annual print subscription for SAE members: first subscription, $15 included in dues; additional single copies, $30 each North America, $35 each overseas. Prices for nonmember subscriptions are $115 North America, $175 overseas. Periodicals postage paid at New York, and additional mailing offices. POSTMASTER: Please send address changes to *Automotive Engineering*, P. O. Box 47857, Plymouth, MN 55447. SAE International is not responsible for the accuracy of information in the editorial, articles, and advertising sections of this publication. Readers should independently evaluate the accuracy of any statement in the editorial, articles, and advertising sections of this publication that are important to him/her and rely on his/her independent evaluation. For permission to reproduce or use content in other media, contact copyright@sae.org. To purchase reprints, contact advertising@sae.org. Claims for missing issues of the magazine must be submitted within a six-month time frame of the claimed issue's publication date. The *Automotive Engineering* title is registered in the U.S. Patent and Trademark Office. Full issues and feature articles are included in the SAE Digital Library. For additional information, free demos are available at www.saedigitallibrary.org.
(ISSN 2331-7639 print)
(ISSN 2331-7647 digital)

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EDITORIAL

Sergio had it right

"No man is an island," wrote English poet John Donne nearly 400 years ago, and his sage words could be considered foundational for the mobility industry of the 21st century.

As we see almost weekly in the news, survival in this business is increasingly dependent on alliances—between OEMs, Tier 1s, and the deep and sometimes disruptive tech strata. Global automakers are under relentless pressure to manage the costs of developing electric and self-driving vehicles, as well as innovate new technology to meet tougher emissions standards for millions of combustion-engine vehicles they will sell beyond the next decade. Slowdowns in the world's largest auto markets—China and the U.S.—have exacerbated the pressure to cut costs.

No organization, no matter how large, established, and profitable, can afford to be an island.

The recently confirmed cooperation between **Ford** Motor Co. and **Volkswagen** AG, initially aimed at commercial-vehicle synergies, is the latest manifestation of the cost squeeze that's growing in the marketplace. In recent weeks, Ford announced it would cut thousands of jobs, discontinue building money-losing vehicles, and consider closing plants as part of a turnaround effort for its unprofitable European business. This followed Ford's declaration that it will spend at least $4 billion on autonomous vehicles by 2023—products which (along with EVs) currently do not earn a penny of profit. They may not do so for years.

VW, at the same time, announced another €3 billion of cost cuts as part of its effort to boost profit margins and fund its shift to EVs and automated driving. It was followed by the Detroit show announcement that VW would invest $800 million to build an EV manufacturing plant at its underutilized Chattanooga complex.

It's yet another team-up between giants, driven by the need to fund an uncertain future while wrestling with the crushing financials of an equally uncertain present. Readers with an historical view will note that such match-ups don't have a great track record. Most are unbalanced and many end in ugly divorces.

The Ford-VW alliance is driven by the need to fund an uncertain future while wrestling with the crushing financials of an equally uncertain present.

Ford and VW, of course, previously had **Autolatina**, their shared vehicle development and assembly operation in South America. It was dissolved in 1995, three years before the misguided **DaimlerChrysler** "merger of equals" and prior to the late Sergio Marchionne assuming command of **FCA**.

Sergio argued for years that the global auto industry needs to consolidate on technology in order to afford the regulatory mandates on the horizon.

"I think [OEM capital expenditures] ... are well in excess of what I consider a mature industry to be able to afford," he told reporters in early 2015. He correctly believed the industry's relatively low stock valuations reflect investor perceptions that car companies waste capital producing bespoke versions of commoditized technologies. That was before the level of capex required to develop electric and autonomous vehicles in volume had really hit home.

Sergio was right. And if he were still with us, he'd be riffing even louder on John Donne's original tome. Islands are functionally obsolete.

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AUTONOMY

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SHARING

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ELECTRIFICATION

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From enhancing vehicle performance for some of the world's top manufacturers to leading the way with innovative solutions for the future, Lubrizol is redefining the design process for their OEM partners. ■

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SAE STANDARDS NEWS

New year, new committees and standards

As 2019 gets under way, **SAE**'s Global Ground Vehicle Standards staff and committee members are engaged on multiple fronts to establish new task forces and committees focused on new standards activities. The fast-emerging automated/connected vehicle sector, including "micromobility" devices, are of particular focus. Highlights of some of the recent projects include:

New ORAD task force

The new SAE On-Road Automated Driving (ORAD) Infrastructure Task Force met for the first time in mid-January at the SAE International Washington (D.C.) office to begin development of standards linking automated driving and transportation infrastructure, including related infrastructure modifications, according to Tim Weisenberger, SAE Ground Vehicle Project Specialist.

The group was scheduled to meet again via WebEx in late January as this issue of *Automotive Engineering* went to press. Weisenberger said the plan was for development work to potentially begin in March.

The ORAD Task Force is seeking additional members, both infrastructure experts and developers. If interested in participating, please contact Weisenberger (tim.weisenberger@sae.org) directly.

Tackling Micromobility

As urban dwellers have witnessed in the past year, electric scooters of various sizes and capabilities appear to be everywhere. They have drawn criticism for unsafe operation in traffic and for cluttering sidewalks when not in use. These "personal mobility devices" do have the potential to expand short-range transport for a great number of people when operated responsibly, however. Some of these devices are privately owned, but a growing number may be owned by shared- or rental-fleet operators.

In general, many of these "micromobility" technologies fall outside established definitions, standards and regulations (including the U.S. FMVSS), explained Annie Chang, Project Manager, Emerging Mobility for SAE's Global Ground Vehicle Standards. For this reason, the Micromobility Devices Committee was recently established. Its initial focus will be low-speed devices, with a peak device-propelled velocity of 30 mph (48 km/h).

According to Chang, the Micromobility Devices Committee is concerned with the eventual use and operational characteristics of these scooters, and how they may be safely incorporated into the transportation infrastructure.

The committee will develop and maintain SAE Standards, Recommended Practices, and Information Reports within the "micromobility" classification. Its first task will be to develop a taxonomy of the scooters and their technologies. Currently, there is no consistent terminology or definitions used in literature and practice. This task will also help refine the scope of the committee and highlight future work.

Jennifer Shuttleworth
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SAE's Global Ground Vehicle Standards staff and committee members are engaged on multiple fronts to establish new task forces and committees for 2019.

Truck and bus safety

The Truck and Bus Control and Communications Network Committee recently published SAE J1939-76 J1939, "Functional Safety Communications Protocol" and SAE J3162, "Heavy Duty OBD IUMPR Data Collection Tool Process."

During development of SAE J1939-76, there was also a Cooperative Research Project (CRP) that included participants from 21 different companies, noted Jana Light, Global Ground Vehicle Standards Specialist.

SAE J1939-76 provides the technical requirements for implementing the SAE J1939 Functional Safety Communication Protocol in a manner suitable for meeting industry applicable functional safety standards. SAE J3162 describes the collection of IUMPR data required by the heavy-duty On-Board Diagnostic regulation 13 CCR 1971.1 (I) (2.3.3), using SAE J1939-defined messages incorporated in a suite of software functions.

The Truck and Bus Control and Communications Network Committee and the SAE J1939 Task Forces will hold their next meetings on February 18-21, 2019, in San Diego, Calif., at the Westgate Hotel.

Meeting details are available at www.sae.org/works/committeeHome.do?comtID=TETES7#.

In other Global Ground Vehicle Standards committee news, the following new chairs have been announced:

- Road Vehicle Aerodynamics Forum: Mesbah Uddin, Ph.D, Director, NC Motorsports and Automotive Research Center and Professor, Mechanical Engineering and Engineering Science, The University of North Carolina at Charlotte
- Dynamical Modeling and Simulation Committee: Denise M. Rizzo, Ph.D., Research Mechanical Engineer, U.S. Army RDECOM TARDEC ■

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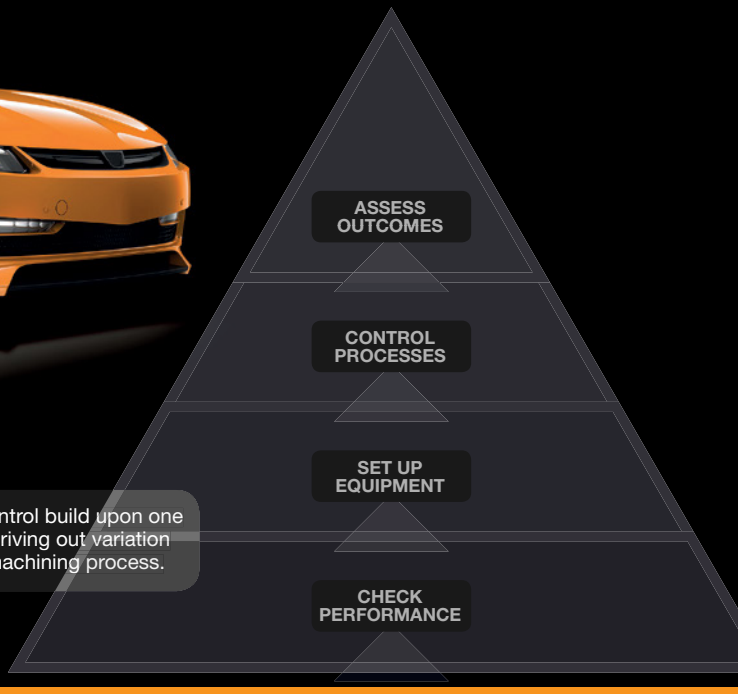

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SUPPLIER EYE

The urgency to adapt intensifies for suppliers

Since 2010 this industry has enjoyed an historic rise in both volume and profitability. All participants benefited from an expanding market—more overall volume, vehicle content, technology (driven both by regulations and consumer desire)—as well as a relatively stable global trading field.

The strong performances have started to buffet headwinds. Average EBITDA profitability for mid-market Tier 1 and 2 suppliers crested at more than 12% in 2016, but has been slipping by a point per year, according to analysis by Bank of America. There are lessons from the recent past which can direct decisions for the future.

First, the speed of decisions taken recently will impact how the industry implements future strategy and structural change. OEMs are dissolving (or fallowing) operations more quickly than before. Rather than wait to be forced into actions with little room to maneuver, the industry is being proactive in addressing capacity, technology (ADAS/autonomy) and structural imbalances.

GM has signaled the closure of several North American assembly facilities. Key suppliers such as **Delphi** and **Autoliv** have split themselves into Old Co. and New Co. operations aligned with specific technology markets. And OEMs are making product-recall and warranty actions more swiftly. In an industry that still can require four years to launch a vehicle from clean sheet to Job 1, the gravity and rapidity of these decisions underscore the urgency to adapt.

Structural and transitory shifts are altering the playing field. While many of us are lamenting the decline of the sedan's dominance, customers have spoken. According to IHS Markit light vehicle production forecasts, the Detroit 3 will build more than 1.4 million fewer vehicles from 2015 to 2020, with almost 80% of the volume being an CUV/SUV or pickup—a rise of almost 13 share points from 2015. Adapting to this consumer-driven shift is more than transitory. The number of new CUV/SUVs launched by 2020 will dwarf that of sedans by more than 3:1—double the pace of 2015.

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The North American market's influence on technology paths and scale economies will continue to decline.

As propulsion-system development shifts toward electrification, the trend is sending shock waves through the supply base while also creating opportunities. The spate of new engine and transmission families launched since 2017 will continue to deploy through the 2020 time period. Engines including the 'Dragon' from **Ford**, the CSS family from GM and the A-Series from **Toyota** underscore a trend toward 3- and 4-cylinder units rated at more than 300 hp (224 kW) in some guises. These will evolve and be refined, along with increasingly electrified 8-, 9- and 10-speed transmissions over the next decade.

As this trend plays out, legions of "powertrain" engineers who began their careers in the mechanical era are shifting to development of the new e-propulsion systems. More apparent than ever, both China and Europe are forecast to widen their already significant production lead over North America through 2030. The importance of China to the global auto industry's health is now clear. Slower vehicle sales there, driven in part by the spillover of U.S. trade tensions and economic considerations, have impacted vehicle sales volumes and profitability for many OEMs active in China. Add to this the tightening of vehicle emission standards in both China and the EU against the backdrop of the U.S. potentially relaxing its emission standards through 2025, and the widening gulf between the global regions becomes critical.

The North American market's influence on technology paths and scale economies will continue to decline. It is forecast to account for just 15% of global light vehicle production volume by 2030, according to IHS Markit.

Speed, gravity and geographic influence will drive OEMs and suppliers to alter their playbooks for success—and alter our expectations. History cannot be guaranteed to repeat itself. ■

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Electrification

Global sales of new electric vehicles (EVs) – either pure electric vehicles (BEVs), range-extended electric vehicles (REEV) or plug-in hybrid vehicles (PHEVs) – passed 1 million units. Under the current growth trajectory, EV producers could almost quadruple that achievement by 2020, moving 4.5 million units – or around 5% of the overall global light-vehicle market.

Global automakers will reportedly launch approximately 340 BEV and PHEV models in the next three years, significantly reducing supply as a barrier to further market uptake. That original equipment manufacturers, or OEMs, are paying increased attention mainly reflects tougher emissions targets, especially in China and Europe. What's more, announcements that several countries, as well as cities around the world, intend to set end dates for the sale of diesel- and gasoline-powered vehicles are also driving change. Norway, for example, wants BEVs to account for 100% of its new-car sales by 2025, and California, France and the United Kingdom have declared they will end sales of internal combustion engines (ICEs) by 2040.

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THE NAVIGATOR

Needed: a step beyond STEM

For more than a decade, education advocates have made the case for a greater effort in teaching kids about science, technology, engineering and math. As an engineer, I'm all for STEM. More of our population needs to understand these topics. However, as I get older and continue to observe the impact of technology on humanity and society, I'm more convinced than ever that we need an A for Art included in that bundle.

Science is all about building a fundamental understanding of how the world around us works. Math is the language used to express that understanding. Engineering is about applying that knowledge to solve real problems, and technology is the result of all those other efforts. The key word in all four of these areas is "how."

All too rarely in these disciplines do we ask the equally (if not more) important questions of why or who? Why are we choosing to address certain problems and not others? Who will be helped, and who will be hurt...or helped?

Much of STEM focuses on articulating the quantitative. But all too often we leave out the qualitative. The result is that we frequently end up doing things or creating products because we can. What we often leave out is the discussion of what people will do with these tools that we develop.

More study of the Arts and Humanities is crucially important as technology becomes ever more sophisticated. The absence of understanding how people will use the tools at their disposal—and in some cases abuse them—often leads to products that society may well be better off without.

Take the case of automated driving.

As humans, there is no question that we do in fact make the mistakes that lead to most traffic crashes and fatalities. However, when you consider that Americans now drive more than 3.2 trillion miles per year and yet we only have a reportable crash about every half-million miles (about once every 30 years for the average driver), we're actually pretty good at it. We manage to negotiate our way through all kinds of weather and traffic conditions on a daily basis, mostly without incident.

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It's not enough for engineers to focus on the technical details of making AV driving systems function. We must also have empathy for the humans that these machines will serve.

The modern development of automated driving was launched in 2003 by **DARPA** in hopes of taking soldiers out of the way of deadly roadside bombs in war zones. But it soon became clear that the technology had important civilian uses for reducing traffic deaths and enabling mobility for those who can't drive. Over the last five years, there has been a veritable land rush of startups hoping to make a fast buck on the technology by disrupting traditional transportation and automotive industries.

While it's certainly important to find a pathway to revenues in order to have a sustainable business, it's not sufficient to simply focus on grabbing the same affluent urban dwellers who already use ride-hailing services. We need to design mobility that addresses the needs of *all* of society. That means creating safe, affordable systems that enable lower-income residents to get to jobs. It means systems that the elderly and disabled can access with minimal or no human assistance.

But such systems also need to account for the ways that other people will interact with them. Engineers can't assume optimal human behavior. People will continue to jaywalk in the path of AVs; cyclists and scooterists will cross vehicle paths without signaling. Predicting "normal" human behavior is proving to be one of the biggest challenges for AV developers.

Then there are those who simply feel threatened by automation and take out their frustrations with vandalism and violence as some Arizona residents have done with **Waymo** test vehicles.

It's not sufficient to focus on the technical details of making an automated driving system function. These machines are meant to serve human beings, making lives safer, more convenient and less stressful. Engineers must also have empathy for the humans that these machines will serve. A broader spectrum of education that encompasses humanities topics is an essential part of that. ■

2019 Audi e-tron quattro

As this month's cover story makes clear, the 2019 **Audi** e-tron is not an electric screamer. It doesn't redefine ludicrous 0-60-mph acceleration times every time you step on the accelerator. In fact, if you're used to a high-performance **Tesla** Model X, the e-tron feels decidedly neutered.

The overall e-tron package combines Audi's elegant and attractive exterior (that intentionally fits the brand's current design language), slightly tweaked for the electric powertrain, with an incredibly quiet cabin, even while cruising at 75 mph.

If you've been in an Audi Q6 or Q7 lately, then almost everything about the e-tron's interior will feel familiar. The Virtual Cockpit, along with two large HMI (human-machine interface) touchscreens contribute to a bit of a "tech overload" feeling.

But once you have the settings the way you like them, using the infotainment system is easy.

The quattro e-tron felt completely at home both on the long stretches of highway we drove during the global media launch in Abu Dhabi, as well as a few off-road desert paths Audi suggested we tackle during the car's global media introduction.

Power from this electric car was never an issue, and the cleverly placed front parking assist camera, below the bumper, is especially useful when driving over rocks (or, more likely, parking-space dividers). The camera also is a useful technology partner for when you need a higher-fidelity view of what's coming up ahead.

Sebastian Blanco

2019 Chevrolet Silverado 2.7L

Engineering a turbocharged four-cylinder engine for full-size pickup truck duty was a bold move by **General Motors**, but I expect we'll eventually see similar bandwidth stretching by **Ford** and **FCA**. This is a great combination, standard on LT and RST trims.

The new 2.7-L punches way beyond its weight class: **SAE**-rated 310 hp (231 kW) and 348 lb·ft (471 N·m). It replaces the old 4.3-L 90° V6 that's been relegated to base work-truck service. The 2.7, with cylinder deactivation, variable valve lift, a twin-scroll turbo and stop-start, outdoes Ford's base 3.3-L V6 and even Ram's new 48-V-augmented 3.6-L V6 hybrid in power and torque. However, its rated fuel economy (18-20 mpg city, 21-23 mpg highway, and 19-21 mpg combined) is no better than those V6 trucks.

The four-banger is designed and calibrated to be a truck engine, which means it delivers a deep well of torque whenever your right foot calls. It's perfectly mated with GM's 8-speed automatic; shifts under load are nearly imperceptible, and there's not a hint of shift-busyness in this application. In fact, other than exhaust note, you might think there's a V8 under the hood. During steady-state cruising at 70 mph with an empty bed, the Silverado's tach needle stands right on 1,750 rpm. On grades, the truck just hunkers down and lugs. And with less mass up front, it feels more nimble.

While it's unlikely that **Chevy**'s turbo four will enjoy the same rapid uptake as **Ford**'s Ecoboost 2.7-L V6 in the F-150, the 2.7-L is right at home in the Silverado.

Lindsay Brooke

2019 BMW X4 30i and M40i

The focus of **BMW**'s designers and engineers was toward creating a next-gen X4 that looks and drives more like a coupe than an SUV. Did they succeed?

Even with its base suspension settings, the X4 will continue to hang tight long after you're convinced you are going to fly off the road. Both the standard and optional adaptive M suspensions feature firmer springs, dampers, and anti-roll bars than in equivalent X3s. The 30i's brakes provide excellent modulation, feel, and short stops. But the M Sport brakes are incredible in their ability to vaporize speed. The steering still does not feel as linear as I would like, but the overall ride/handling/steering balance is as advertised. Dynamically, the X4 doesn't drive like an SUV.

Except for a slight lag at WOT from a stop, the X4's 2.0-L turbo motor responds more like a powerful six. Likewise, the M40i's 6-cylinder performs like a V8. Both engines come with standard all-wheel drive and a **ZF** 8-speed automatic with shift paddles at the ready.

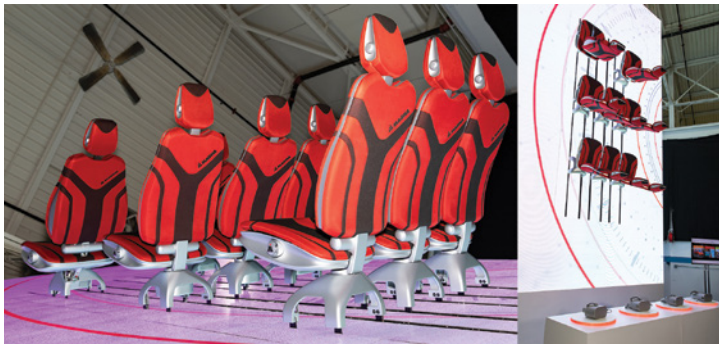
The X4 provides exceptional comfort and well sited gauges and controls. And low noise levels: The NVH guys were really on their game. Seats are comfortable and supportive and those at the rear feature rake adjustment. One of the M40i's I drove was equipped with BMW's gesture-control system, which can adjust controls such as audio volume and zooming the nav map in and out. It needs more development.

High-quality materials, and excellent fit and finish are found throughout the interior. And the central control screen can be programmed without the need for a degree in AI.

John Dinkel

AUTOMATED DRIVING

Magna unveils configurable seating concept at CES 2019



Magna provided a glimpse into its vision for the future of configurable cabin spaces with a life-size transforming seating demo at its booth during January's Consumer Electronics Show (CES). Driven by consumer research, the seating-system concept is designed to provide flexible and collaborative configurations aimed at an autonomous vehicle (AV) future.

"Magna's seating innovation is driven by the belief that while the vehicle occupant experience will be very different with the introduction of mobility and autonomy, the functional basics will remain the same: passengers want convenience, flexibility and comfort," Mike Bisson, president of Magna Seating, told *Automotive Engineering* ahead of CES. "This approach has essentially helped us create seats that adjust to the consumer, instead of having the consumer adjust to seats."

Magna has long been an innovator in the seating space, with examples including **Chrysler**'s Stow-N-Go system and the 30-way adjustable seats in current Lincoln products. According to Magna, current engineering trends continue to focus on consumer hotpoints such as third-row access and car-seat headflop. But Bisson noted that the industry is about to witness enormous changes, with features including health and wellness monitoring, new entertainment platforms and collision models requiring new thinking on safety restraints and airbags.

Beyond ever-present cost and weight constraints, Dino Nardicchio, Magna's global VP of advanced technology engineering for seating, said specific engineering challenges related to a new vision for vehicle cabins will involve power-consumption and a "fundamental shift" in load-floor design. Many future applications will need to accommodate both an under-floor battery pack and seat-configuration hardware. Sill heights will be affected, which influences the seating-critical "box height" (the distance between passenger H-point and the bottom of the seating track).

According to the Magna team, along with increased structural stiffness and tolerances required for floor-length seating tracks, there will also be NVH challenges as weight placement and resonant frequencies shift from seats changing position in the cabin, and regulatory hurdles including validating side-facing seats for safety certifications.

Concept as calling card

Magna's new platform concept is based upon in-market consumer research conducted in China, Europe and the U.S. targeted at understanding consumer perceptions of seating, and observing consumer seat interaction on a day-to-day basis. The goal was a focus on optimizing user experience and the results will help Magna and OEMs reshape vehicle-cabin architectures.

The seating concept focuses on three configurations and their related technologies. In Cargo mode, cabin-length seat rails permit seat travel extending under the instrument panel for maximum cargo volume. Flexible seating hardware provides various volume options, and a related mobile app could preconfigure the cabin loading mode (min, max, left or right side, etc.). A Road Trip configuration provides "campfire" seating with 4-way headrest sleep support, haptic seat massage for optimal blood flow and personal sound zones. An autonomous Ride Sharing mode arranges collaborative, conference-style seating as well as object detection to help ensure personal items are not left behind.

Magna expects the first products exhibiting the fore-aft modes to be on the market by 2022. It is hoping its 2019 CES display serves notice in the industry that they are ready to tackle OEM challenges in this space. To showcase some of the concept's sample seating arrangements, see SAE.org for several Magna-provided videos that illustrate the cabin concept's flexibility.

Paul Seredynski

MAGNA

CHASSIS

ZF's current innovations build for EV, AV future

As the product-development landscape for light-vehicle electrification and automated-driving technologies begins to become less cluttered, it's apparent that established automotive Tier 1 mega-suppliers are intent on merging their established competencies with whatever new product lines are required in the electrified, automated future. Whenever it comes.

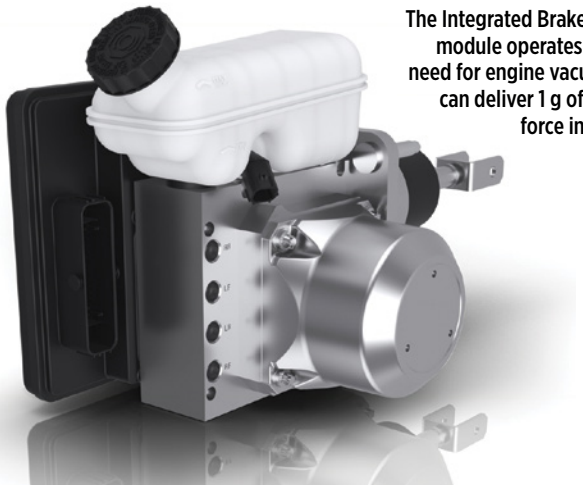
This strategy was recently on display by **ZF** at a technology background event in the U.S.. Long regarded for its transmission, driveline and chassis expertise, ZF showed journalists (and customers) the potential not just of prototypes of proposed systems, but also how the company intends to (or already does) merge current-generation components to create higher-level functionality—and value.

The vision: zero

Perhaps the most dramatic demonstration comes from ZF's Vision Zero concept vehicle, a rolling showcase of in-development technologies combined with in-production components to express the "what if" goal of the Vision Zero: complete elimination of accidents and vehicle-borne emissions.

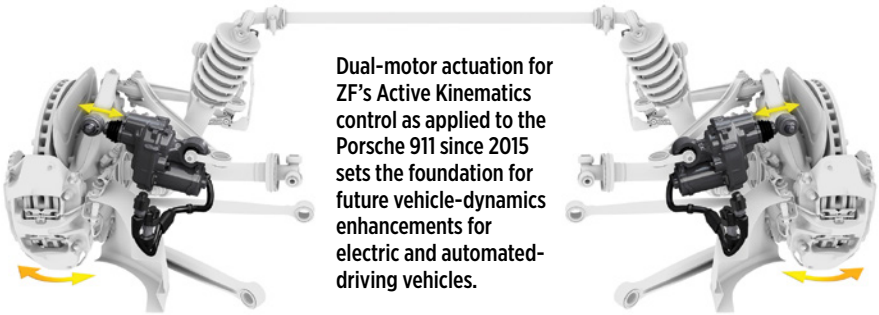
The Vision Zero concept rolls on ZF's production modular semi-trailing-arm rear suspension that also integrates an electric-drive axle and rear-steering capability. It makes for a decidedly complete rear axle that could theoretically be "added" to virtually any light-vehicle design, ZF's engineers expounded.

But the concept car also demonstrates ideas for next-generation vehicles that may be equipped with so-called "mid-level" automated-driving functionalities. There's an intriguing Driver Distraction Assist system that monitors the driver's state of attention, but ZF is going further with a new Interior Observation System (IOS) that uses a sophisticated 3D camera to augment information from other sensors to not only determine if the driver is attentive and prepared to take back



ZF

The Integrated Brake Control module operates without need for engine vacuum and can deliver 1 g of braking force in 150 ms.



Dual-motor actuation for ZF's Active Kinematics control as applied to the Porsche 911 since 2015 sets the foundation for future vehicle-dynamics enhancements for electric and automated-driving vehicles.

Vision Zero concept vehicle demonstrates technologies intended to eventually reduce accidents and emissions to zero.

control of the vehicle if it is in an automated-driving mode, but also can ascertain the position and size of other occupants—information that can be leveraged for a variety of other safety and convenience features.

Due to be production-ready by late 2021, IOS' "visual data from the interior of the vehicle can be highly valuable from many standpoints," said Norbert Kagerer, senior VP engineering for ZF's occupant safety systems business. "The development of our 3D interior observation system leads to enhanced safety, convenience and helps support the evolution toward automated vehicles."

At the event's test track, ZF also offered another near-term driver-aid that dovetails with automated-driving features: Wrong-way Inhibit employs known road-mapping data to prevent the driver (or autonomous system) from entering a street or highway on which traffic is traveling head-on to the vehicle. On a small spur of the track that engineers had designated as having opposing-direction traffic, the test vehicle automatically came to a halt and refused further progress in that direction.

Steered by today

Equally exciting, though, are the expanding possibilities for rear-wheel steering as used by Vision Zero, but already in production today for the **Porsche** 911, **Cadillac** CT6 and other current-production vehicles. Active Kinematics Control (AKC) as ZF calls it, was fitted to a wild-child demonstrator vehicle that enabled, with the twirl of a dial, any proportion of front and rear steering. The vehicle could virtually "crab" sideways, for example, into a tight parking spot, while high levels of rear-steer also impart incredible agility in completing a slalom course.

And what the AKC system does for the maneuverability of a fullsize pickup is an eye-opening window into what now can be done much less expensively and with more whole-vehicle integration than the early, unsuccessful rear-steer systems for pickups.

Same for the Integated Brake Control (IBC) launched for the 2019 **Chevrolet** Silverado pickup truck. The IBC modularizes "all major braking functions in a single control unit" that, crucially, is totally non-reliant on engine vacuum. It's motor-driven actuator is "capable of brake pressure builds that translate into an up to one G of vehicle deceleration in less than 150 milliseconds for significantly reduced stopping distances," ZF said. That kind of power and quick response will be critical to achieve future regulatory performance standards for automated braking systems. Those recently adopted by Euro **NCAP** simulate pedestrians and bicyclists in short reaction-time scenarios—protocols many expect U.S. regulators to emulate.

Bill Visnic

PROPULSION

Ricardo reveals details of latest e-motor and eDCT

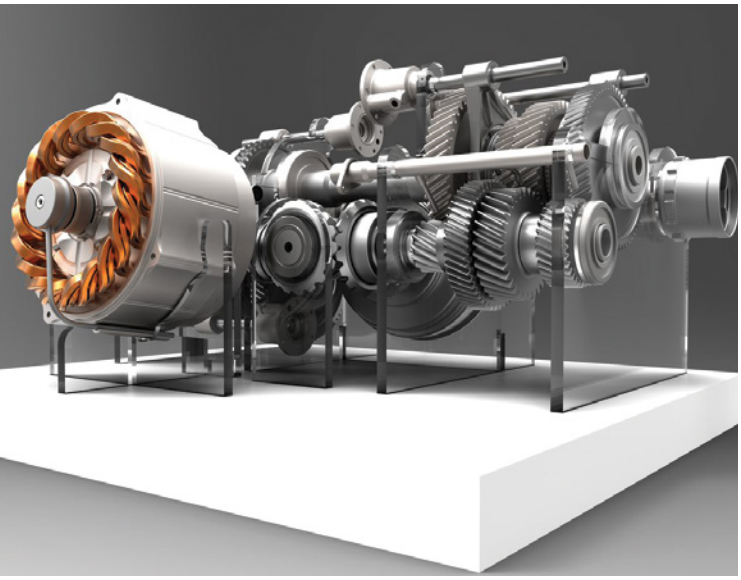
United-Kingdom engineering specialist **Ricardo** recently revealed extensive development details of its latest automotive 48-V 25-kW e-motor and associated inverter, which it claims can deliver up to a 50% increase in power density compared with current production electric machines. The project is of potential significance to automotive OEMs moving towards high-volume electric-vehicle (EV) production models requiring enhanced motor power density without cost and complexity drawbacks.

Emphasis during the new e-motor's development was placed on thermal management—chiefly, gaining efficiency via reduction of thermal resistance, particularly concerning the inverter's metal oxide semiconductor field-effect transistor (MOSFET). Ricardo revealed its solution is based on the use of direct oil cooling of the heat sink, using the same automatic transmission fluid used to cool the e-motor itself.

The project was the subject of a paper read by Ricardo's Dr. Lawrence Alger, Technical Business Manager, at the recent CTI (Car Training Institute) Berlin Symposium. Ricardo's electric powertrain sees the compact silicon inverter driving a frameless 6-phase, 8-pole interior permanent-magnet motor with ATF (automatic transmission fluid) cooling and "novel" windings. Both oil- and water-cooled inverter variants were explored, but from the outset, a salient development aim was cooling of motor, inverter and the associated dual-clutch transmission (DCT) from the same oil supply, reducing thermal resistance of the inverter via jet cooling.

Neville Jackson, Ricardo's Chief Technology and Innovation Officer, told *Automotive Engineering*: "48-V mild hybrid solutions are very likely to be the key enabler to meet medium-term fleet average CO_2 targets as cost-effectively as possible. Whilst the first generation of 48-V systems are largely standalone components added to existing powertrains,

BOTH IMAGES: ZF



Ricardo's new e-motor and DCT, detailed at the 2018 CTI Berlin Symposium.

cost and weight reduction will increasingly demand more integrated solutions.

He added that the company's 25-kW motor, inverter and dual-clutch transmission "are focused on the requirement for even more cost-effective integrated designs. They offer not only cost-efficiency but can deliver improvements in vehicle drivability through the additional instantaneous torque delivered to the vehicle during pull-away and transient maneuvers."

25kW "sensible" for mild hybrid

At the Berlin event, Alger stated that the conclusions drawn from extensive test results and simulation data showed a 25-kW peak rating to be a "sensible" upper limit for a 48-V mild hybrid and that a motor close to that rating could be fitted into a current eDCT (electronic dual-clutch transmission) and thermally controlled via existing oil cooling, demonstrating that a "relatively small" oil-cooled inverter could be created for the application.

An added plus was that the inverter demonstrated the feasibility of cooling electrically live surfaces under powerboard components with an electrically insulating fluid in an automotive application. "Conventional PCB construction methods are used to reduce manufacturing costs, utilizing mass produced off-the-shelf devices," said Alger, "whilst still breaking down thermal barriers using impingement cooling."

Ricardo also showed its new transverse eDCT concept at the Berlin Symposium. Based on the company's experience in supercar transmission design, it is described as being some 37% shorter than its target/reference products, aiding better weight distribution and reduced vehicle polar moment of inertia.

Stuart Birch

ELECTRIFICATION

China's NIO making EV battery swapping work

A vehicle prepares for installation of a charged battery. For now, an attendant places the vehicle in the station; in the future, NIO expects the process to be fully automated.

Emergent electric-vehicle automaker **NIO** believes battery swapping makes sense for EVs and the company's customers almost universally agree. In front of 10,000 guests at the 2018 NIO Day in mid-December, company founder and CEO William Li announced that 9,726 units of the company's first vehicle, the ES8 SVU, had been delivered. And more than 95% of those buyers chose to *lease* the battery, which is only possible with battery packs designed to be swapped out for recharging.

Swappable, leased batteries mean NIO can offer its EVs at a much lower up-front cost than other OEMs selling electric vehicles. NIO customers who opt to lease the battery reduce the cost of their EV by 100,000 RMB ($14,476 US). These ES8 buyers then pay a subscription fee, either 980 RMB ($142) per month or 10,800 RMB ($1,570) annually, to access NIO's battery swap stations and other "Power Express" services, like a public charging network and the use of NIO's Power Mobile charging trucks. A similarly priced subscription service will be available for buyers of the upcoming ES6 SUV EV.

The footprint for NIO's battery-swap station is about the size of three parking spaces (45 square meters), including space to hold five battery packs in reserve. NIO also has plans for a five-space station that can hold more batteries in higher-demand locations. While the stations are designed to be fully automated in the future, for the first two years a NIO

Inside the battery-swapping station, a vehicle battery module is ready for placement.

CLOCKWISE FROM TOP LEFT: RICARDO; NIO; NIO

employee will be on site to maneuver cars in and out of the station. The actual battery swap takes three to five minutes, on average, with the entire process including maneuvering requiring around 10 minutes.

All NIO batteries use cells from **Contemporary Amperex Technology** (CATL). The only NIO pack currently available is a 70-kW·h lithium-ion unit that uses NCM523 ternary cathode material and has an energy density of 135 watt-hours per kilogram. A larger, 84-kW·h capacity pack with NCM811 ternary cathode material will be released alongside the ES6 later in 2019. More technical details about this pack will be revealed at a later time.

Both battery packs are the same size and have the same heat-management port, which allows the swap stations to put either pack into a ES6 or ES8 as long as the vehicle's software parameters have been updated to account for the different cells. Today, some of NIO's stations are used 20-30 times a day, others just once or twice, according to Feng Shen, NIO's VP and chairman of quality management. He said that NIO is collecting usage data to determine which stations may need to be expanded or upgraded.

"It's easy to say, difficult to do," Shen said. "How you make sure that all the different vehicles handle all the different batteries is a very, very challenging technical target. But we are ahead of the world in this area." NIO has over 300 patents covering the tech in its swap stations. These patents cover precise positioning of the vehicle in the station, rapid removal of the pack, compact integration, and more.

Charging a full pack takes about one hour, and the 300-kW stations cool the batteries as they charge. NIO also monitors charging status and sends detailed information to its cloud while the company's battery management system monitors the pack for faults in real time. NIO also has over-the-air update capabilities that can upgrade the software of the battery management units and cell supervising circuits and switch boxes.

NIO has installed 18 swap stations at 14 service areas along a 1,420-mile (2,285-km) route along the north-south G4 Expressway in eastern China. It also has stations installed around its joint production facility with **JAC** in Hefei and in Beijing, Shanghai, Chengdu, and other cities. NIO has had discussions with other vehicle OEMs about having other EVs use the NIO battery swap stations, but no deals had been finalized as of early January 2019.

Sebastian Blanco

Detroit auto show 2019: Next-gen Ford Explorer goes rear-drive

The sixth-generation Ford Explorer rides on the company's new CD6 architecture, one of five new flexible platforms to take Ford into the future.

The 2020 Explorer features turbocharged 2.3L and 3L V6 engine choices—and yes, they're mounted longitudinally.

New Explorer's cabin highlighted by minimal clutter, upright central touchscreen.

The 6th-generation **Ford** Explorer looks to retain its all-time best-selling-SUV in America status by adding driver assist and other technologies, while dropping its former front-drive/all-wheel-drive (AWD) platform in favor of Ford's new "corporate" CD6 rear-wheel-drive/AWD architecture first revealed for the 2020 **Lincoln** Aviator.

The 2020 Ford Explorer and its Lincoln Aviator sibling are the first midsize SUVs arriving in the marketplace after the automaker's 2018 downshift from nine global platforms to five flexible vehicle architectures. "This is a pretty significant change for us," Hau Thai Tang, Ford Motor Company's executive VP of product development and purchasing told reporters at the 2020 Explorer's January 9 global debut at Detroit's Ford Field.

The 2020 Explorer reflects the learnings of a product development team that has been with the vehicle over multiple cycles, Thai Tang explained, noting: "They have a really good, intuitive understanding of our utility vehicle customers and what's made the Explorer so successful. We're just building on that."

The new RWD architecture is paired with an available 4-wheel-drive system that provides a front-axle disconnect. Its body structure employs a mix of materials, including aluminum alloys and ultra-high-strength steels. Base curb weight is 4345 lb (1970 kg). When properly equipped, the 2020 SUV provides a 5600-lb (2540-kg) towing capacity, 600 lb (272) more than its predecessor.

New-for-Explorer technology includes Ford's 10-speed automatic transmission (replacing a 6-speed), an available 10.1-inch/256-mm touch screen that's mounted vertically on the center stack and an available Terrain Management System with up to seven selectable drive modes, including deep snow and sand, sport, and tow/haul.

The vehicle's standard Co-Pilot360 is a package of driver assist technologies including rearview camera with built-in lens washer, hill start assist, and pre-collision assist with automatic emergency braking and pedestrian detection. The available Ford Co-Pilot Assist adds driver assist technologies such as adaptive cruise control with stop-and-go, and a "smart" lane-centering feature.

"It's smart enough that if there's a large vehicle in the lane next to you, it will bias the vehicle toward the other side of the lane – exactly what a human driver would do," Thai-Tang explained.

Base, XLT and Limited Explorer models will be powered by a 2.3-L turbocharged I4 that produces an estimated 300 hp/310 lb·ft (224 kW/420 N·m), while the Explorer Platinum will be powered by a twin-turbo 3.0-L V6 that delivers an estimated 365 hp/380 lb·ft (272 kW/515 N·m).

The 119.1-in (3025 mm) wheelbase SUV will be produced at Ford's Chicago assembly plant and will also be offered in high-performance and hybrid-electric versions. Vehicles are slated to begin arriving at dealerships in summer 2019.

Kami Buchholz

ALL IMAGES: FORD

Detroit auto show 2019: Cadillac finally gets its 3-row crossover

Cadillac's 2020 XT6 is powered by a 3.6L V6 in either front-drive or all-wheel-drive configurations.

Cadillac has added another SUV to its lineup with the global debut of the all-new, three-row XT6 at the 2019 Detroit auto show. The XT6 joins the two-row XT4 and XT5 in Caddy's lineup and is a unibody alterative to Cadillac's other three-row SUV, the truck-based Escalade. The 6- or 7-passenger XT6 will be available in two trims—Premium Luxury and Sport—with each offering distinct interior and exterior styling. The XT6 provides a host of available safety technology and should compete directly with Lincoln's new 2020 Aviator three-row SUV.

The 2020 XT6 will be powered by GM's 3.6L V6 (310 hp/231 kW). Active fuel management permits V4 operation in lower-load scenarios. All models will feature a 9-speed automatic and four selectable drive modes, with AWD available on the Premium Luxury model and standard on the XT6 Sport. The Sport model will also feature a "twin-clutch" AWD setup with active yaw control, a quicker steering ratio and active dampers. The Sport model will be available with 21-in (533-mm) wheels, a first for a Cadillac SUV.

"The new Cadillac XT6 models provide two expressions of the signature Cadillac experience, allowing more personalized appearance and driving character," said John Plonka, chief engineer. "Premium Luxury models provide an elevated level of refinement, while Sport models offer a performance-oriented feel."

Standard safety tech on the new 2020 XT6 includes a Safety Alert seat, forward collision alert with automatic emergency braking and pedestrian detection, lane-keep assist and rear cross-traffic alert. Optional tech includes rear pedestrian alert, reverse automatic braking, hitch guidance, surround-view camera/recorder, head-up display and night vision. Though adaptive cruise control is available on the new XT6, **GM**'s lauded Super Cruise driver assist system is not expected to make an appearance until MY2021.

The XT6 will be available with a host of convenience and entertainment tech, including Cadillac's first **Bose** "Performance Series" sound system with 14 speakers, heated/ventilated front seats, heated second-row seats and steering wheel, hands-free tailgate, in-vehicle air ionizer, Wi-Fi hotspot, **Apple** CarPlay/**Android** Auto, wireless charging and Teen Driver controls.

Pricing info is expected closer to production start, which begins this spring. Models are expected in dealerships by summer 2019. Along with the Cadillac XT5, the XT6 will be assembled at GM's manufacturing complex in Spring Hill, Tennessee.

Paul Seredynski

GM

Ford returns to midsize-pickup game with 2019 Ranger

The roads east of San Diego twist and rise through the mesa hills towards the Laguna Mountains, providing an ideal drive for any sports car. But **Ford** boldly chose these winding paths for the first drive impressions of its new midsize pick-up with a familiar name, the 2019 Ranger. Gone is the previous compact model that languished for years while its full-sized brethren enjoyed the lion's share of Ford's product-development resources: the new-age Ranger re-enters the North American market as a midsize pickup ready to take on its competitors with claimed class-leading capabilities, fuel economy and performance.

The previous-generation Ranger rolled out of Ford's Twin Cities Minn. Assembly plant in 2011; outside of North America, the Ranger nameplate expanded into a wholly different midsize truck. Based on the global T6 platform, it competes with vehicles like the **Volkswagen** Amarok and **Toyota** Hilux. But with an 80% growth explosion in the U.S. midsize-pickup market since 2014, Ford could no longer ignore its home customers asking for a smaller option to the F-150.

Unique powertrain for truck

The 2019 Ranger was revealed more than a year ago at the 2018 North American International Auto Show (NAIAS). The company said the sole powertrain option would be the turbocharged 2.3-L 4-cyl. paired with Ford's 10R (10-speed) automatic transmission. This came as a surprise to many due the variety of 4-cylinder, 6-cylinder and diesel engine options available for other midsize trucks.

However, having that single engine option allowed Ford engineers to focus on efficiency improvements to provide claimed class-leading gasoline fuel economy of 26 mpg highway/21 mpg city and 23 mpg combined in 2-wheel drive configurations. For four-wheel drive Rangers, economy drops slightly to 24 mpg highway, 20 mpg city and 22 mpg combined. The only midsize truck that bests those numbers is **GM**'s **Chevy**

Colorado/**GMC** Canyon with a 2.8-L 4-cyl. turbodiesel, an extra-cost engine upgrade.

The 2.3-L boosted engine is widespread in the Ford model range. For the 2019 Ranger, however, it's seen a number of changes to make it more suitable for truck application, while also improving fuel economy and emissions. The fuel pump has been upgraded to a 250-bar (3626-psi) unit to handle higher-pressure direct injection. New pistons have been incorporated to increase the compression ratio from 9.5:1 to 10.1:1. The exhaust gas recirculation (EGR) system is now liquid cooled and a dual-scroll turbocharger with an electronic wastage supplants the vacuum-acutated wastegate.

The water pump has been moved to the front of the engine block for better cooling and easier access. A variable-displacement oil pump also is integrated—as well as the engine's twin balance shafts—into the block. A new lightweight, forged-steel crankshaft features grooved bearings on the main journals but not the rod journals.

While there were several changes made to the engine for the Ranger, the 10-speed automatic is essentially the same 10R80 unit used in the Mustang and F-150. First gear provides a ratio of 4.696:1 and tenth gear is set at an overdrive of 0.636:1. The rear-axle final drive is 3.73:1. The only difference between the transmission in the Ranger and the F-150 is the mounting-bolt profile on the bell housing, as the 2.3-L engine has a unique mounting pattern.

Meanwhile, the 2.3-L calibration is unique in the Ranger, here producing 270 hp at 5500 rpm and 310 lb·ft (420 N·m) at 3000 rpm. While these numbers are down when compared to the Mustang, the ratings are for 87-RON fuel rather than the 93-octane rating for the pony car. Ford representatives did confirm that the Ranger power numbers would be higher on 93-RON, but the company did not want to require premium fuel for truck owners.

The 2019 Ford Ranger is produced in two cab configurations: 2-plus-2-door SuperCab and 4-door SuperCrew.

Chassis is heavily revised

Although the 2019 Ranger may look like the international truck that has been available since the domestic Ranger ended production, there have been significant updates made to the chassis for this new version. Ford engineers would not provide exact numbers for the extent of new chassis components, but they did confirm that the 2019 Ranger is not merely the non-North America T6 with a Mustang engine.

For one, they said, the frame mounts for the engine and transmission had to be updated, since this powertrain has never been an option on the truck. And the rear bed support structure saw significant upgrades to handle the increased payload and towing capacities that North American buyers demand; those updates led to a claimed best-in-class payload of 1860 lb (844 kg) and towing capacity of 7500 lb (3402 kg). While the diesel Colorado and Canyon are tow-rated to 7700 lb (3493 kg), these capacities are available for all configurations of the Ranger.

Other small updates were made as well. The front steering knuckles are forged aluminum rather than cast iron; this reduces the unsprung weight on the front tires for more responsive handling, engineers claim. The rear suspension is a Hotchkiss-type live axle with outboard shock absorbers to handle the increased capacities of the North American truck. Various other frame components were upgraded to high-strength steel.

However, many items did not change from the international truck. The wheelbase of 126.8 in (3221 mm), length of 210.8 in (5354 mm) and height around 71 in (1803 mm) are consistent with those of the T6 Ranger. While the North American truck will be built at the (Wayne) Michigan Assembly Plant, there remain multiple plants around the world that will build the international versions. Keeping consistent the dimensions and hard mounts on the frame allows for obvious production-cost reductions and minimal assembly line variations and changes.

For the U.S. market, there are two cab configurations: a 2-door-plus-2 SuperCab with a 6-ft (1829-mm) bed and a 4-door SuperCrew with a 5-ft (1524-mm) bed.

Matthew Borst

Ranger cabin displays mostly conventional styling, mixed with new driver-assist features.

BOTH IMAGES: FORD

2019 Toyota RAV4: Doubling down on a best-seller

The 2019 RAV4 is lighter, larger and has markedly upgraded driveline technology.

TOYOTA

To say the RAV4 is a crucial product for **Toyota** might be underselling it. In the U.S., the 5-seat, 5-door FWD/AWD mid-size SUV has become Toyota's best-selling vehicle, the nation's best-selling non-pickup truck and the best-selling vehicle in its class. The market's SUV sway is also apparent in RAV4, as its annual sales volume has doubled in the last five years, cresting 400,000 in 2017.

According to Yoshikazu Saeki, Rav4's chief engineer, his team spent the last four years working to ensure each version of the all-new 2019 RAV4 felt more confident and responded more naturally to driver input. "It sounds simple," Saeki said, "but getting the intent of the driver to match the action of the vehicle is difficult to implement."

New TNGA underpinnings

The 2019 RAV4 is based on Toyota's proliferating TNGA platform, sharing the same K-variant that underpins Camry and Avalon; the RAV4 previously shared a foundation with the Corolla. That change in platform was significant, Saeki noted, as they were no longer constrained by the limits of the Corolla architecture.

"If you try to engineer items at the limits of performance, there's not too many things you can do," Saeki, who has managed RAV4 since 2003, explained. "But if you use a Camry platform, you don't have to push anything, you don't have to stress anything. There's all kinds of different possibilities that become apparent, and now we can try these

things that we couldn't do before."

Compared to the previous-gen RAV4, overall length/width/height are within 0.4 in, but shorter front and rear overhangs and a longer wheelbase (+1.20 to 105.9 in) provides more second-row legroom and a 2.5-in longer luggage compartment. Ground clearance is up 2.3 in, and both the front (+1.2 in) and rear tracks (+1.9 in) are wider. The 2019 RAV4's unibody structure sees stiffness increase 57% compared to the previous model, allowing a more compliant tune for the front-strut and rear multi-link suspension.

Even with additional standard content, curb weights have dropped roughly 100 lb (45 kg) for gasoline versions and 170 lb (77 kg) for hybrid trims, with only 220 lb (100 kg) separating base AWD gasoline and hybrid models.

RAV4 standard equipment includes the second generation of Toyota's Safety Sense active-safety technology.

All-4-cylinder powertrains; Hybrid/CVT refinements

Both the gasoline and hybrid 2019 Toyota RAV4 feature DOHC 2.5-L 4-cyl. engines with direct/port injection and variable valve timing that is electrically adjusted on the intake side. In non-hybrid models, the 4-cyl. sports a 13.0:1 compression ratio, is paired with a conventional 8-speed automatic transmission and produces 203 hp (149 kW) at 6600 rpm and 184 lb·ft (249 N·m) at 5000 rpm.

For the RAV4 Hybrid, an Atkinson cycle 2.5-L with a 14.0:1 compression ratio is coupled to a CVT and is rated at 176 hp (131 kW) and 163 lb·ft (220 N·m). Total hybrid system power is rated at 219 hp (163 kW).

Hybrid-model updates include a transaxle that mounts the two, higher-rpm front electric motors coaxially (rather than in-line), reducing friction and packaging size. The reduction gear is now a parallel shaft (vs. planetary), and a new multi-function gear integrates the power-split planetary ring gear, parking gear, and counter-drive gear. Combined with better integrated and lighter power electronics installed directly above the transaxle, Toyota claims transmission losses are reduced 25% compared to the previous model.

Other efficiency improvements include a variable cooling system using an electric water pump and thermostat, and a fully variable oil pump. The new 244.8-V Ni-MH battery pack is more efficient than in the previous RAV4 Hybrid, engineers said. It is now small enough to be installed under the rear seats, creating equal cargo space for gas and hybrid models.

To reduce CVT "wail," the system optimizes electric-motor assist and engine rpm so engine speed is synchronized with vehicle speed. A differential preload function yields better standing-start performance and straight-line stability.

The 2019 RAV4 now is based on Toyota's widespread TNGA architecture.

Three AWD systems

Hybrid RAV4 models are AWD-only (an on-demand setup), and gasoline versions of the 2019 RAV4 offer two AWD variants. The on-demand AWD option for LE and XLE RAV4 gasoline trims can send up to 50% of available torque to the rear wheels when necessary. Standard on AWD-equipped Limited and Adventure gasoline trims is an all-new dynamic torque-vectoring setup, a first for the compact SUV class.

The torque-vectoring setup on the RAV4 sends up to 50% of available engine torque rearward via a ratchet-type dog clutch that can stop the rear driveshaft's rotation when AWD is not needed. Torque is dynamically apportioned to either rear wheel via two multi-plate clutches. The complementary Active Cornering Assist can brake an inside front wheel and overdrive an outside rear wheel to sharpen cornering response. A Multi-Terrain Select feature offers modes to maximize traction depending on surface type, with an entertaining gauge-cluster display (below) to view torque allocation.

The 2019 Toyota RAV4 will be assembled in Japan, China and Canada, with U.S. models sourced from Canada and Japan.

Paul Seredynski

BOTH IMAGES: TOYOTA

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INSIDE E-TRON

The e-tron is designed to appeal to "normal" car buyers, not "electromobility freaks."

Insights into the German approach to developing a premium-class EV.

by Sebastian Blanco

Audi has made its ambitious electromobility goals clear, saying it will offer 10 all-electric and 10 plug-in hybrid models by 2025, accounting for at least one-third of its sales. To help achieve this, the company carefully designed the all-new 2019 Audi e-tron luxury SUV to not alienate its core audience. As engineer Anno Mertens, Audi's product manager for electrification put it: "In the end, it's an Audi, it's not an electric car."

Audi's target for the e-tron (yes, the name is all lower case) is the same SUV buyer who might also have shopped for a Q7, Mertens said (the e-tron's wheelbase sits between the Q5 and Q7 in Audi's SUV lineup). To that end, early in the development process, Audi surveyed its customer base to learn just what kind of EV they would use. The questions included how many business trips they take and whether they live in detached homes or in multi-family dwellings.

"The things the customer looks for, they are basically the same no matter if it's a combustion-engine car or a battery-electric car," Mertens said. "In the end, we needed to design the e-tron so that it would appeal to normal car buyers, not to electromobility freaks." Selling mainly to EV zealots "would be too narrow a segment," Mertens said. "If you look at our product plan right now, selling 30% electric cars in 2025, there are not enough electric-car freaks."

Range and fast-charging targets

The e-tron's program parameters were defined more than four years ago. The engineering team focused on making the EV-specific systems (i.e., the battery and the brakes) transparent to Audi customers who are familiar with combustion-engine models.

Even before digital simulation work began, Audi engineers established a target range of more than 500 km (310 miles) on the then-current NEDC (NEFZ) European cycle to minimize range anxiety issues. The result is a 95-kW·h, 400-V lithium-ion pack that weighs around 700 kg (1,543 lb) and will offer a range of more than 248 miles (400 km) using the WLTP cycle (which would have been more than 500 km on the old test). EPA numbers for U.S. models are not due until closer to the e-tron's on-sale date, but they will be lower than the WLTP figures.

The battery pack is made up of 36 modules. The base layer houses 31 modules, with five on a "second floor" that fits under the rear seats. Each module contains 12 pouch-type 60-A·h cells housed in an aluminum-coated polymer outer skin. Audi has said it can use "technically equivalent prismatic cells" in this pack, but battery-development engineer Andreas Deindl would not say how many prismatic cells would fit into each module.

Another battery target was to enable 150-kW DC fast charging—a first for a series-production vehicle. The e-tron pack accepts both AC and DC charging, with AC limited to 22 kW and DC fast charging accepting up to 150 kW. This requires some enhanced infrastructure, like a CCS connector on a cooled cable. Mertens said all of the DC fast-charge stations currently

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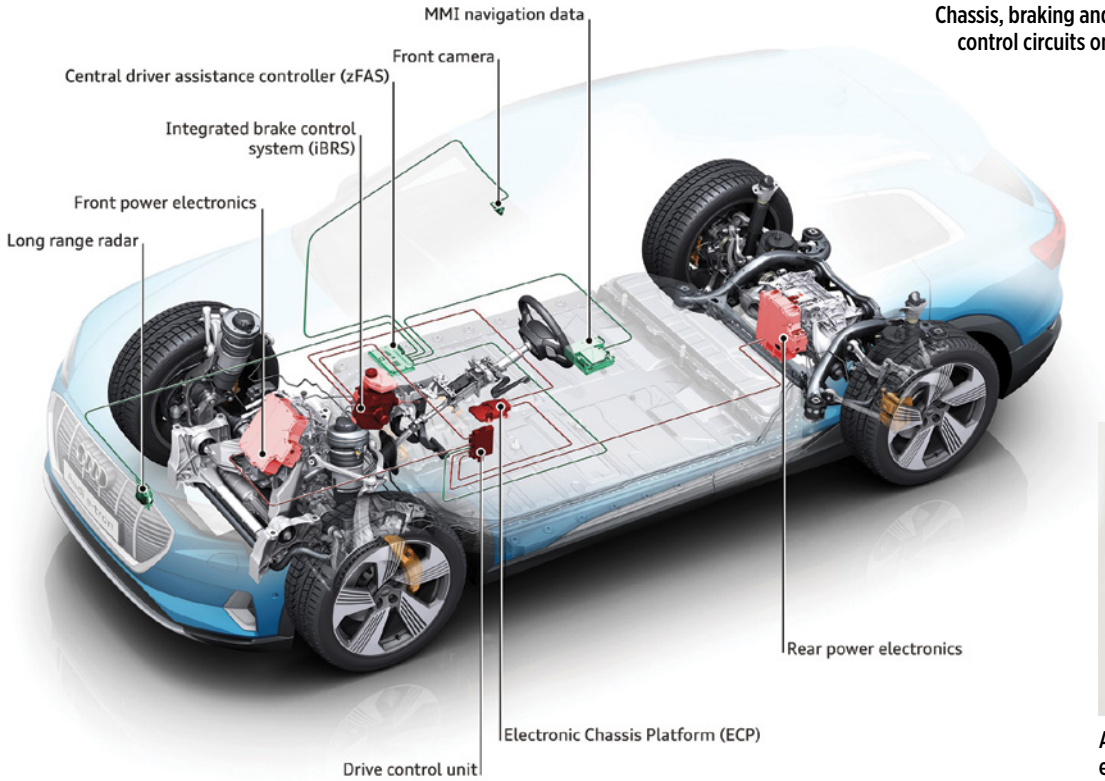


Chassis, braking and propulsion control circuits on the e-tron.

Anno Mertens, head of electrification.

No automotive pack currently in production offers fast-charging capability like e-tron's.

being installed by **Electrify America** and **Ionity** have cooled cables. Without this feature, the limit is unlikely to climb over 140 kW.

In the desert heat of the e-tron's December 2018 media launch in the United Arab Emirates, a temporary EVTEC station setup did not have a cooled cable and was able to offer only a maximum 137 kW. Based on the in-car display, this energy flow would be enough to put more than 350 miles (217 km) of range into the pack per hour.

No automotive pack currently in production offers such fast-charging capability, even those that are liquid cooled like the e-tron's. DC fast charging will fill a pack to around 80% state of charge, then slow the charge rate for the remaining capacity to avoid cell damage. The e-tron does this automatically, but the dash screen still gives a charging rate in distance/hour, another sign of tailoring the experience for Audi owners accustomed to ICE nomenclature.

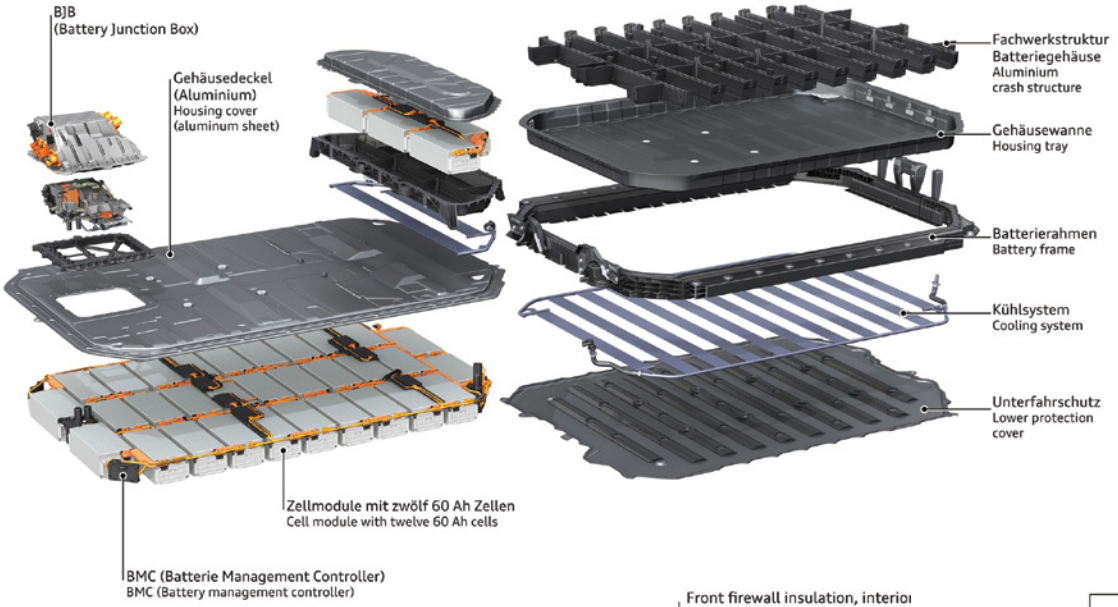
Boxes-in-a-box

The e-tron's battery pack is a "boxes-in-a-box" design with a dedicated aluminum impact-protection structure. The battery package is bolted to the body structure at 35 points, which increases torsional rigidity by a claimed 27%. Audi engineers said the car's overall torsional rigidity is 45% higher than that of its conventional SUVs.

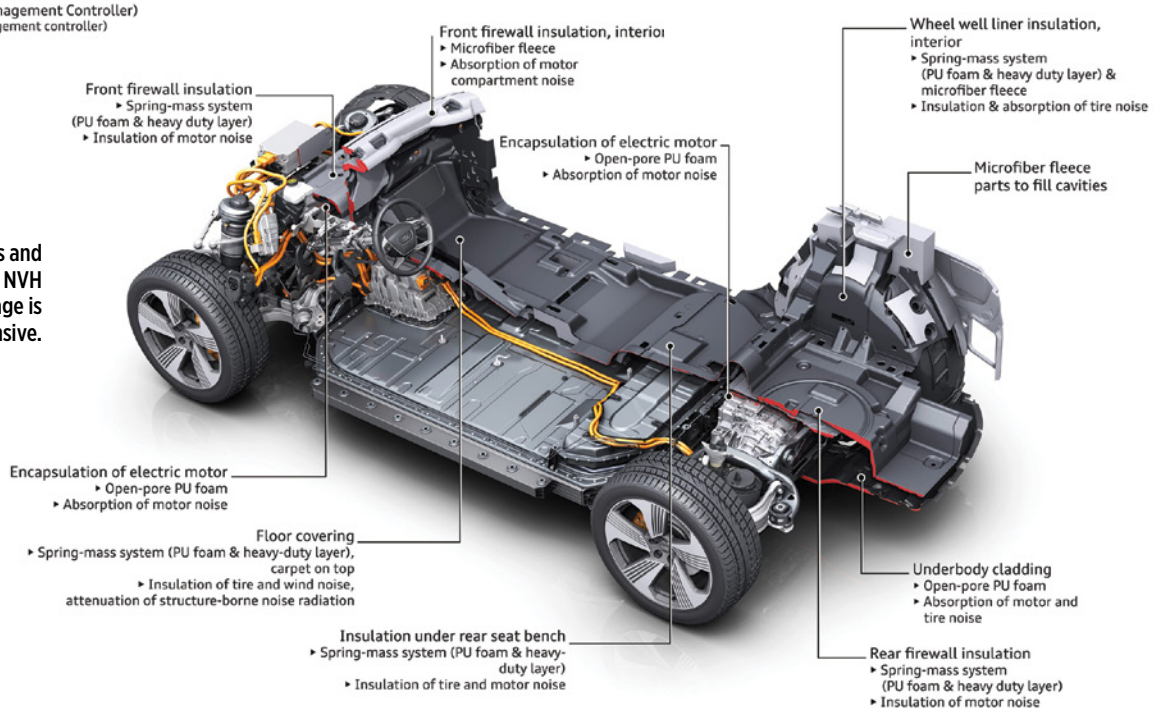
The battery's thermal-management system is designed to keep the pack at a peak temperature of 35°C while also lowering the risk of fire in a crash. The system uses 5.8 gallons (22 L) of coolant flowing through 131.2 ft (40 meters) of pipe just outside the battery modules. The coolant channels are fastened to the modules using a thermally conductive adhesive.

The thermal-management system also cools the power electronics, the charger and the electric motors—including the rotors. According to Audi engineers, waste heat from the electric motors (up to 3 kW of actual power losses) can be used by the e-tron's thermal-management system to heat or cool the cabin. This energy recycling can increase driving range by up to 10%, they noted.

INSIDE E-TRON



Construction of e-tron's 95-kW·h battery pack which weighs 1,500 lb. Each of the 36 modules contains 12 pouch-type LG Chem lithium cells. The advanced thermal-management system uses a heat pump and is designed to maintain 25° to 35°C in all operating conditions.



e-tron's chassis and propulsion system NVH abatement package is extensive.

Regenerative braking with ICE feel

Stepping on the brake pedal in the e-tron feels like braking on most any recent conventional SUV. Deceleration is controlled by a new electro-hydraulically integrated brake control system that Audi claims is 30% lighter than a conventional brake system, weighing less than 13.2 lb (6 kg). Deceleration up to 0.3 *g* is handled by the electric motors in regenerative braking mode, and three levels of regenerative braking are adjusted by +/- paddles on the steering wheel.

Level Zero lets you "sail" on the highway in **Volkswagen Group**'s terminology, with no regenerative-braking activation. Level 1 applies minimal deceleration when you step off the accelerator pedal, and Level 2 applies more regen, but not enough for one-pedal driving. The software calibration results in smooth motor ramp-out and no harsh feedback in the pedal.

In developing the e-tron, Audi has engineered-out traditional EV quirks in order to broaden the vehicle's appeal. You can't drive an ICE-powered car with one pedal, and you can't drive the e-tron that way, either. Even the labeling for the paddles on the steering wheel is meant to make Audi drivers feel right at home. The left paddle, which downshifts the transmission in Audi ICE models, activates a higher regen level in the EV, despite the "minus" symbol.

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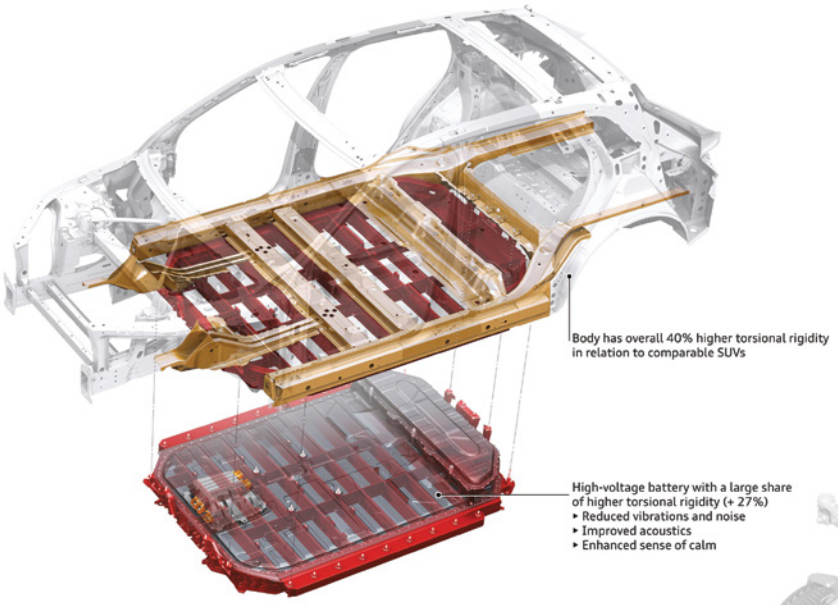
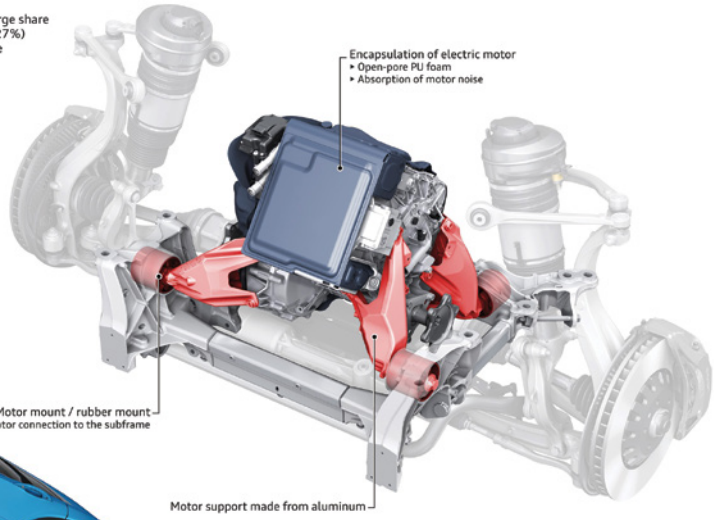
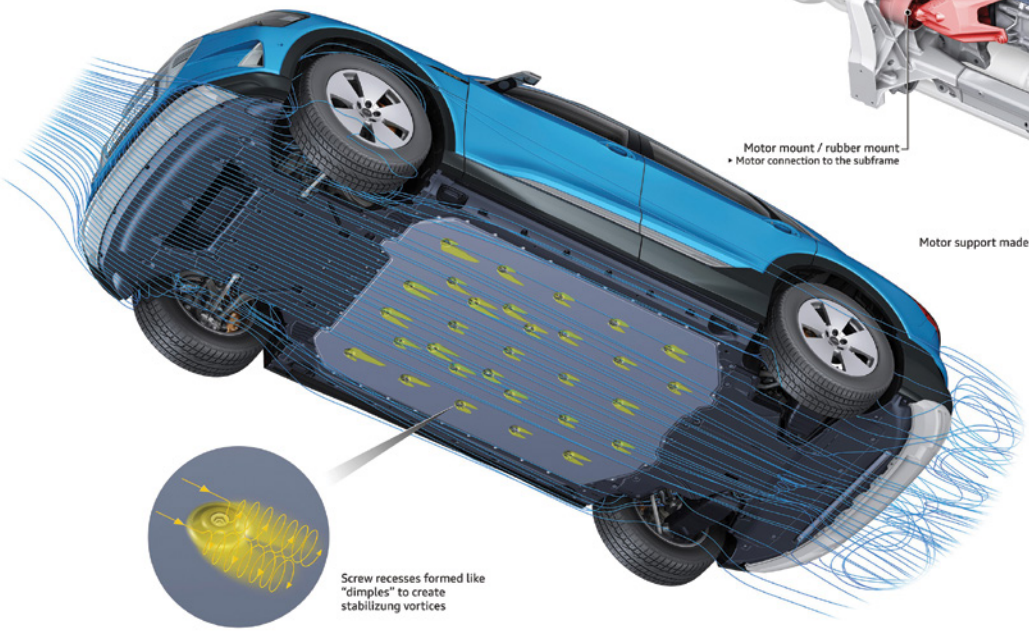


Body structure and battery pack integration on the e-tron. Note the pack's ladder-type aluminum structure. The lateral members are filled with glycol and joined to the cells using a special structural adhesive with excellent heat-transfer properties.



Details of e-tron's front axle/drive module acoustic package.



Underbody aerodynamic treatment includes specially designed fastener heads for airflow control.

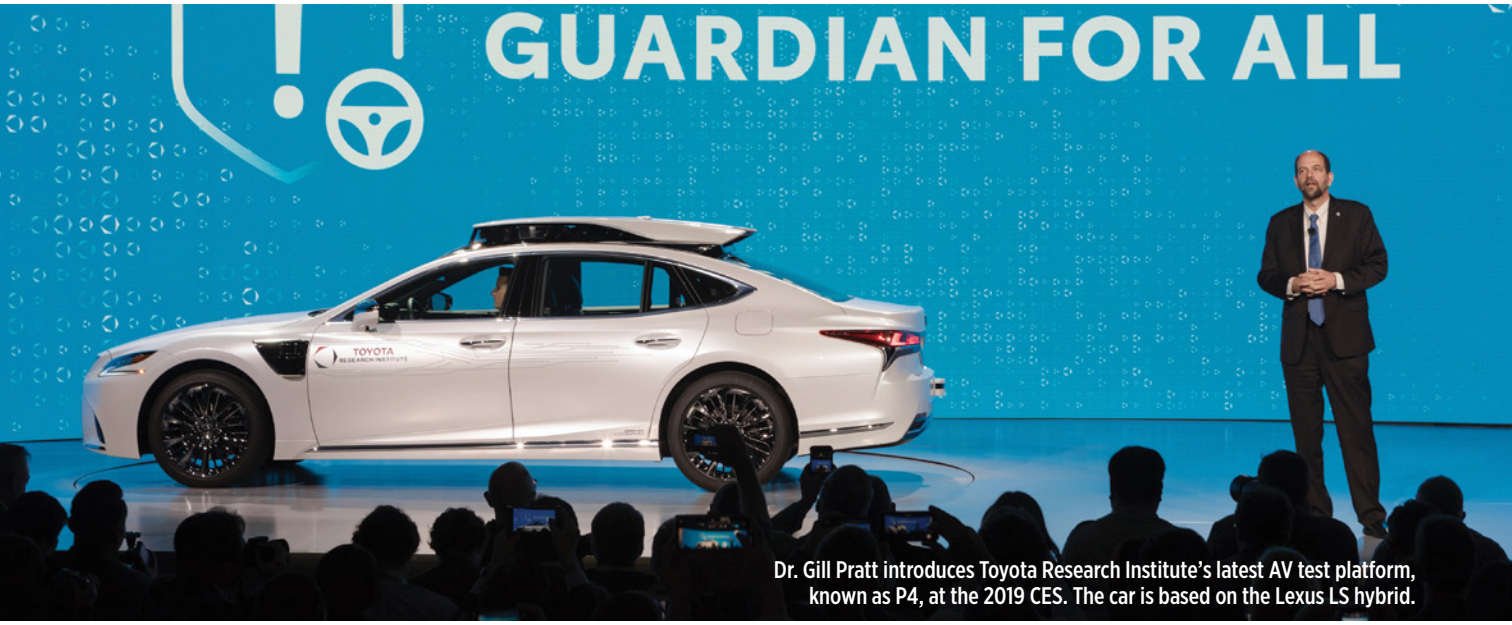
A new, temporary E-platform

The e-tron rides on its own platform, which attracted a fair share of new hires to help develop it. About half the platform team were fresh faces, according to chassis development engineer Victor Underberg. "In the early phase, it's really important that the new guys work closely with the veterans," Underberg explained, "because they have the huge know-how." The air suspension, for example, is similar to that found on other Audi models. "In a car like this, you need a really high knowledge of how to apply the suspension system," he said. "So guys who worked on the Audi Q7 or Q8 also worked on the e-tron."

Despite the work devoted to the dedicated platform, it will basically be a one-off (not counting the e-tron Sportback spin-off) as the VW Group has a new platform called PPE under development. The PPE platform will incorporate lessons from both the e-tron and the J1 platform that underpins the upcoming E-Tron GT and the **Porsche** Taycan. VW uses the MEB platform for its smaller EVs, including the I.D. variants.

As it deploys e-tron, Audi will need to educate owners on fast-charging and the car launches in Europe with side-view cameras in lieu of mirrors, another technology that will require customer familiarization. But on most other fronts, Audi has managed to engineer an EV that offers the benefits of an electric powertrain without making its first EV look or drive like something foreign to its customer base. With its closest competitors likely the **Tesla** Model X and the new **Jaguar** I-Pace, the e-tron is designed to help make EVs mainstream. It appears set to help accomplish that goal. ■

CES 2019: Blueprint for



Dr. Gill Pratt introduces Toyota Research Institute's latest AV test platform, known as P4, at the 2019 CES. The car is based on the Lexus LS hybrid.

TRI

Mobility technology of every stripe was showcased at this year's techfest in Vegas.

by Lindsay Brooke, Terry Costlow, Paul Eisenstein and Bill Visnic

The mammoth annual trade event formerly known as the Consumer Electronics Show has escalated into an automotive techfest, with OEMs and suppliers of every size and from every industry segment using the week-long event to showcase their advanced technologies. It's a mind-boggling, often unwieldy and grueling grind in Las Vegas for reporters, but CES is undeniably a must-attend event both for media and for all organizations working in autonomous and connected mobility.

Talk about diversity: At what other trade show would you see demonstrations and displays by **John Deere**, **PACCAR** (which showed the latest iteration of its hydrogen-fueled **Kenworth** tractor powered by two **Toyota** fuel cells), **Bell Helicopter** (displaying its vertical-takeoff, electric-fan-propelled Air Taxi), along with expansive booths from **Honda**, **Daimler**, **Hyundai**, **Ford**, **Aptiv**, **Delphi**, **Continental**, **ZF** and others?

And proving that CES may be the prototype for future auto shows, **FCA** came to Vegas with a display of new trucks and Jeeps—and without any AV/connected news or message. Remarked one veteran tech-geek reporter to *Automotive Engineering*, "Did you see that orange **Jeep** pickup with the dirt bikes in the bed? So cool!"

Toyota advances Guardian concept

Toyota Research Institute (TRI) again used CES as a news platform, with CEO Dr. Gill Pratt and VP of Automated Driving Dr. Ryan Eustice laying out TRI's next steps.

"We have a moral obligation to apply automated vehicle technology to save as many lives as possible, as soon as possible," said Dr. Pratt, during a media roundtable. To that end, Dr. Pratt and TRI, which is Toyota's think tank for AV technology development, made two significant announcements at CES: the introduction of a new "Platform 4.0" (P4) research and development car, and that Toyota will offer its Guardian driver-assist system to other OEMs. TRI will soon begin testing Guardian and its SAE Level 4-5 Chauffeur system, on the new R&D car. Dr. Pratt indicated Guardian will enter production "in the early 2020s."

Toyota will offer the system as standard equipment on the e-Palette platforms that it introduced at CES 2018. At the North American International Auto Show that followed CES, Dr. Pratt told *AE* that Toyota has received inquiries from OEMs regarding the Guardian offer. He said the company has not yet decided whether it will license both its hardware and software, or only the software. The technology includes artificial intelligence. He said it aims to "amplify, rather than replace, human ability" in driving a vehicle.

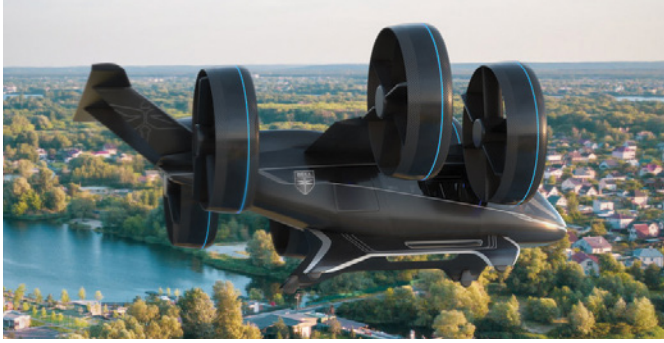
Guardian, whose performance Dr. Pratt describes as "blended envelope control" that combines the sensing of both the car and the human driver, could have prevented the crash of a TRI 2.0 development vehicle last year on Interstate 80 in California (it was struck by another vehicle), he believes. TRI showed video, both in-car and externally shot, during the CES media conference.

The P4 development platform, currently under construction at Toyota's York Township, Michigan, facility, is based on a Lexus LS hybrid. Visually, the car does a better job in integrating its sensors into the body; its rooftop sensor array is part of a streamlined module.

future auto shows?

The P4's first role will be testing the Guardian and Chauffer software packages. Compared with TRI's previous P3 R&D cars, the P4 adds two cameras for side view and new LiDARs fitted front and rear with greater fidelity and dynamic range. The car's imaging-sensor suite is optimized to improve the vehicle's field of view (FOV), in particular at close range. The P4's LiDAR array employs eight heads to scan 360° around the vehicle.

The car has greater processing power compared with its predecessor. The car's 288-volt nickel metal-hydride battery pack that is used solely for propulsion and regenerative braking in the production LS500h, now powers the P4's computing system. It also features a second set of driving controls for system redundancy, as well as for developing future by-wire control strategies.



Digital artist's rendition of Bell Helicopter's air taxi that debuted at CES. Powered by electric fans, the vertical-takeoff aircraft is designed to "solve transportation challenges in the vertical dimension," Bell president Mitch Snyder told the CES audience. Bell is leading development, with partners Safran (hybrid propulsion), EPS (batteries) Thales (flight controls and related computing), Moog (actuators) and Garmin (avionics integration).

BELL HELICOPTER

ZF debuts enhanced CPUs, adjusts autonomous focus

Electrified and autonomous-vehicle (AV) technologies have seen heavy investments from automotive suppliers, but sales haven't yet begun to support the expenditures. That's a major challenge for top-tier suppliers like ZF that need to stay at the forefront of technology, yet still remain profitable. This challenge is among many discussed by the supplier during the 2019 CES conference in Las Vegas.

On the technology front, ZF unveiled new controllers and other technologies to advance AV processing and sensing. The company is among several jump-starting the AV market with vehicles developed within an ecosystem of partners. ZF is focusing on AVs that operate in

CES 2019: Blueprint for future auto shows?

e.GO Mover: Staying at the forefront of advanced technology must be balanced against profits, according to ZF's CEO.

Byton M-Byte concept crossover's signature cabin feature is difficult to ignore: a sprawling 48-in LCD screen traversing nearly the entire width of the dash top.

geofenced areas in the near term, an application that many believe will grow more quickly than AVs with unlimited operating envelopes.

This shift in focus doesn't slow down spending in emerging areas. As part of its ongoing plan to diversify from mechanical parts to digital technologies, ZF plans to invest more than 12 billion euros in automated driving and electrification over the next five years. Connecting all its products to the Internet of Things by 2025 is another aspect of its transition.

While autonomy and electrification are major investment areas, revenues from advanced technologies like its ProAI processors for AVs aren't likely to significantly contribute to the bottom line for some years. "With the changes in the mobility industry, we need to finance our projects without impacting earnings," said CEO Wolf-Henning Scheider. "We need to do it with speed to keep up with industry demands. Sales of ProAI are currently very small, they're mostly going to test applications."

Scheider predicted that SAE Level 4 vehicles will start appearing in restricted areas in the next two to three years. Building familiarity with those driverless vehicles will pave the way for broader acceptance of vehicles that operate in open environments. "We have to get people on board, to get their confidence in geofenced areas," Scheider said. "After that, it will be a bit like flying, most people have flown on planes that use autopilot and they are no longer concerned."

ZF aims to facilitate the acceptance of robotaxis and ride-hailing vehicles with its electric automated shuttle, the e.GO Mover. **Transdev**, which manages transit for over 11 million passengers per day, is adding the e.GO Mover to its vehicle fleet. Scheider said he expects sales volumes for the e.GO Mover to reach five-figures by 2020-2021, but it's mainly a proof of concept for its ecosystem collaboration, and not targeted at making ZF a vehicle supplier.

ZF also announced upgraded technical offerings at CES. The latest version of its ProAI line, RoboThink, can run at up to 600 teraflops per second (TFLOPS), with a base speed of 150 TFLOPS without the addition of optional computing modules (a marked improvement over the first-gen, 1-TFLOP ProAI board introduced in 2017). The high throughput of RoboThink lets it fuse and analyze input from a range of sensors, and also facilitate the use of artificial intelligence, which many say will be a necessary component of fully autonomous vehicles.

"Only in the last three or four years have we gotten the computing power needed for AI," Scheider said. "It's important to note that ProAI is scalable, so customers can choose the level of computing power they need."

Auto, tech industries launch PAVE coalition

Acknowledging the need for enhanced public and policymaker understanding about automated-vehicle (AV) technology, a new coalition of 26 industry, academic and non-profit institutions announced the Partners for Automated Vehicle Education (PAVE) initiative at CES 2019.

In a press release announcing the group's formation, PAVE said it "will seek to bring realistic, factual information to policymakers and the public so consumers and decision-makers understand the technology, its current state and its future potential—including the benefits in safety, mobility and sustainability."

PAVE intends to sponsor workshops in partnership with **SAE** to provide consumers with opportunities for hands-on experience with developing AV technologies.

PAVE's initial membership list: **AAA**; **American Public Transportation Association**; **Audi of America**; **Autonomous Intelligent Driving**; **Aurora**; **Consumer Technology Association**; **Cruise**; **Daimler**; **General Motors**; **INRIX**; **Intel**; **Miami-Dade County**; **Mobileye**; **Munich Reinsurance America**, Inc.; **National Council on Aging**; **National Federation of the Blind**; **National Safety Council**; **Nvidia**; SAE International; **Securing America's Future Energy**; Toyota; **U.S. Chamber of Commerce**; **Volkswagen**; **Voyage**; **Waymo** and **Zoox**.

FROM LEFT: TERRY COSTLOW; PAUL EISENSTEIN

Byton M-Byte SUV concept presages the Chinese vehicle manufacturer's first electric vehicle for production.

BYTON

The coalition's website is www.pavecampaign.org and it also can be found on most major social-media platforms.

Byton details EV, autonomy vision

The 48-in (1219-mm) LCD screen atop the **Byton** M-Byte concept car's instrument panel is not only the auto industry's largest in-vehicle display. It also signals what could be a radical shift in the classic automotive business model.

The Chinese-owned automaker gave a close-up look at the M-byte SUV and its second model, the K-byte sedan, during a news conference at CES 2019. In keeping with the digital theme of CES, Byton focused on the user interface that will become one of the critical parts of both its new products and its business strategy. The M-byte SUV will be the first to market. The company expects to launch production of the M-byte at a new plant in Nanjing, China, late this year, sales starting in that country by the fourth quarter; U.S. and European sales are expected to begin by the third quarter of 2020. The K-byte will launch in 2021, with a third model to follow two years later.

Byton's approach reflects a variety of changes sweeping through the world of transportation. "Our business model will not just be about selling cars, but using the car as a platform," CEO Carsten Breitfeld said in an impromptu interview following its CES news conference. "In the future, we will make more money selling digital content and shared mobility."

That starts with the new screen which is as wide as seven **Apple** iPads, as well as a screen mounted in the center console and another floating above the steering wheel. The M-byte also will utilize gesture and voice controls; the electric SUV integrates **Amazon**'s Alexa personal voice assistant.

As vehicles add degrees of advanced driver-assistance systems (ADAS) and automated-driving capability, experts anticipate occupants will need to be entertained. The M-byte's large front screen, along with dual displays for rear occupants—all linked to the cloud by 5G wireless connectivity—will be used to provide a variety of services. That includes pay-per-view video, as well as the opportunity to play games and even shop using Amazon Alexa. ■

One of two prototypes of aluminum armored-vehicle hulls, fabricated by CTC using its unique friction-stir welding capability.

CTC

DATC spells progress for defense prototyping

A public-private partnership between the U.S. Army's TARDEC and SAE International is making it easier for suppliers to engage the government on military ground-vehicle technology projects.

By Lindsay Brooke

A slogging bureaucracy, miles of "red tape" and a sea of acronyms are just some of the hurdles that keep many suppliers from working with the U.S. defense industry on ground-vehicle projects. For years the government, led by the U.S. Army Tank-Automotive Research, Development and Engineering Center (TARDEC), sought to develop a streamlined procurement process. Their aim was to speed the adoption of private-sector innovations, particularly for prototype development, while expanding access for smaller, non-traditional military suppliers.

A breakthrough came in 2016, when TARDEC partnered with SAE International's Industry Technologies Consortia affiliate to form the non-profit Defense Automotive Technologies Consortium; DATC currently has 190 members—70% of which are non-traditionals. The consortium serves as a gateway between the government and the auto industry for OTA Prototype projects (OTAs, or Other Transaction Agreements, run for seven years, during which up to $700 million in projects can be awarded).

The partnership is open to both traditional and non-traditional defense contractors; non-profits, and academic and research organizations. According to DATC executive director Dave Porreca, members benefit from reduced red tape and enhanced visibility. He said the technology focus is on cybersecurity; vehicle occupant protection; lightweighting; autonomous and connected vehicles and related systems; advanced energy storage; propulsion technologies and active suspension technologies.

For a member roster, see http://datc.saeitc.org/membership/.

In DATC's first year, six members collaborated on a successful proposal for the Next Generation Combat Vehicle (NGCV) prototype program, worth $237 million. *Automotive Engineering* wanted to learn more about how the consortium is working and contacted two suppliers—one a well-known automotive Tier 1, the other a defense-focused engineering firm—to find out.

PPG: advanced tire tech

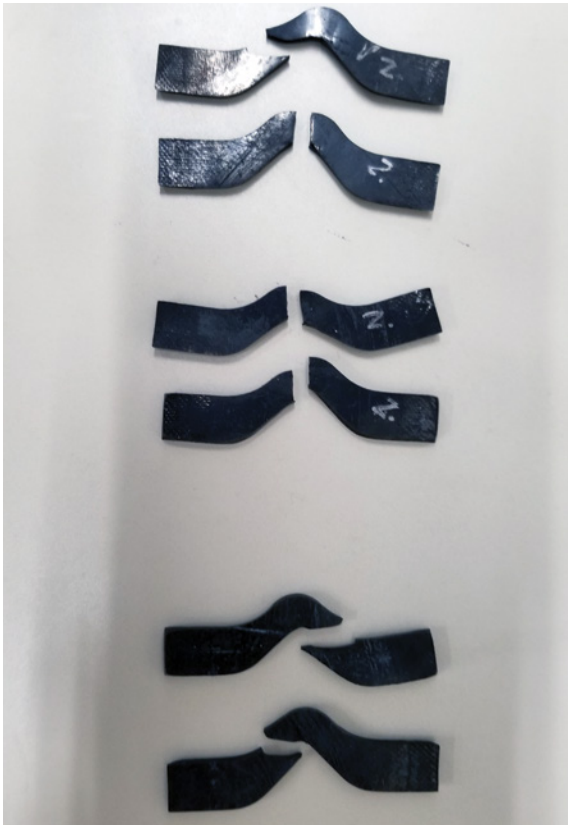
Well-known among mobility OEMs, **PPG's** products are also found in both air and ground military vehicles and weapon systems. As a DATC member, the company is working on advanced silica filler technology for military-vehicle tires, aimed at increasing fuel efficiency.

"We've had commercial success with these materials in the form of Agilon performance silica and are working with the Dept. of Energy to transition the technology to truck and bus radial (TBR) tires," noted Lucas Dos Santos Freire, PPG senior research engineer, Silica Products R&D and principal investigator for PPG's Advanced Silica Filler Technology for Fuel Efficient Military Tire Development Prototype project.

"Compared to synthetic rubber-based passenger-vehicle tires, TBR tires are predominantly based in natural rubber," Dos Santos Freire explained, "which poses additional technical challenges to incorporate the silica. The primary goal of our work is to enhance fuel-efficiency, but it must not be done at the expense of other critical metrics such as traction, wear resistance, braking, handling, and chip/chunk resistance."

He said that while DoD ground vehicle tires are also primarily natural rubber, military requirements and applications differ from those of commercial

Agilon® performance silica tire (above) developed by PPG to improve ground-vehicle fuel efficiency. The image below shows the results of a tire-shred test.



BOTH IMAGES: PPG

trucks and buses. There is a greater need for on-/off-road capabilities, hot and cold weather environment performance and overall mileage and lifetime requirements differ. The military tires require unique material design considerations and testing.

Working with TARDEC within DATC, PPG's collaborative focus has been on "enhancing survivability and reducing [the Army's fuel] logistics burdens," explained Sarah Topper, PPG proposal manager at the company's Coatings Innovation Center in Allison Park, Pennsylvania. Membership in DATC "greatly facilitates our ability to respond to TARDEC needs and create, contract, and manage collaborative research projects," she stated. And as a non-traditional defense contractor, PPG also gains access to potential automotive projects.

The project agreements PPG has with DATC have been collaboratively developed "to ensure the project's technical scope was clearly defined and mutually agreed-upon by both PPG and DoD stakeholders." During project execution, DATC directs monthly and quarterly progress updates to ensure the project remains on-scope and to minimize timeline slippage. They also serve as an interface to minimize bureaucracy associated with project-funding management, Topper noted.

The tire-silicas project is nearing its one-year mark. Phase 1 established a baseline tread model formulation for military tires with input from TARDEC and tire makers. The PPG team used this formulation to evaluate baseline prototype silicas. Their work identified a prototype formula with 10% improved rolling resistance for continued development.

Researchers targeted surface treatment and manufacturing process changes in the development of a second set of prototype silicas. Their goal is to improve dispersion of the silica and optimize mixing in the rubber formulation. The project will conclude with comprehensive on-vehicle performance testing of prototype tires, Dos Santos Freire told *AE*.

CTC: friction-stir welding

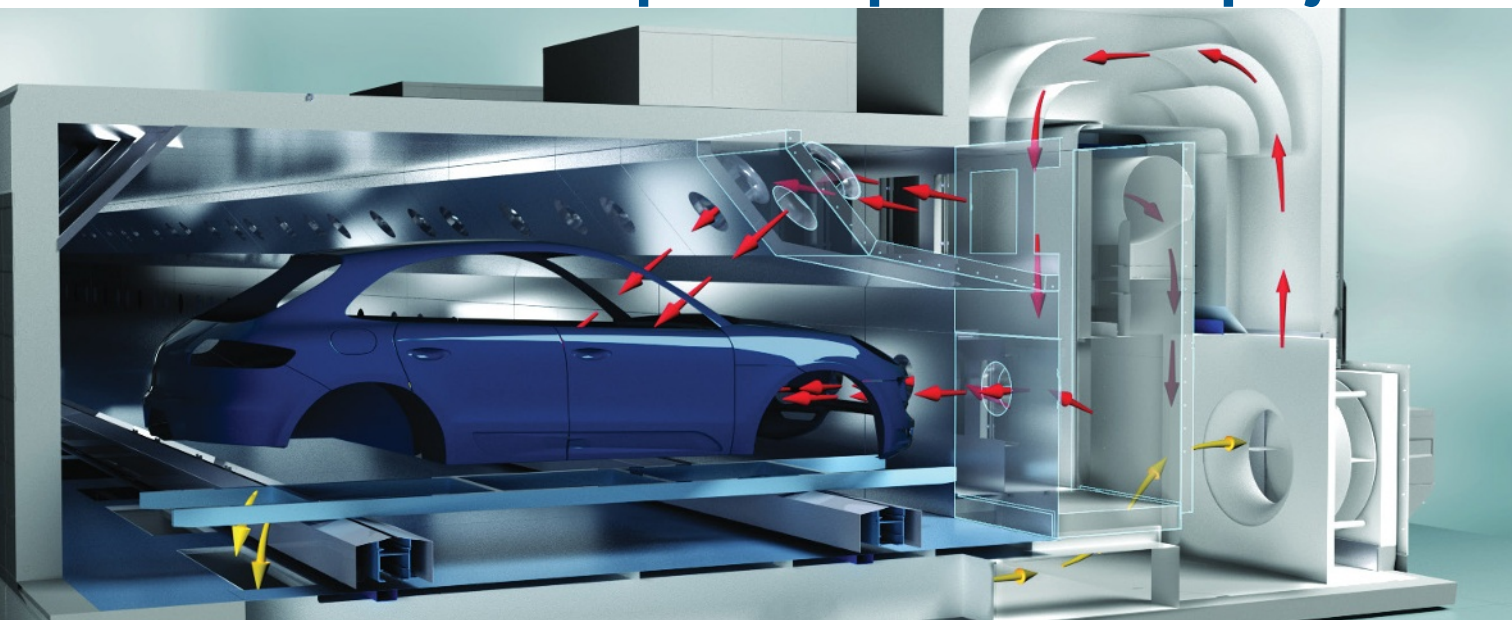
Concurrent Technologies Corp. (**CTC**) is a non-profit R&D firm whose roots are in advanced metalworking technologies. Based in Johnstown, Pennsylvania, CTC has expanded over the years to include expertise in advanced IT, readiness and training, and energy and environmental technologies. The company has extensive experience in friction-stir welding of thick aluminum plate—a construction which interests the Army for future combat and tactical vehicles.

"We have unique capabilities in fabricating lightweight vehicles with both high strength and survivability," said PJ McMullen, manager of advanced technologies. One of those is a machine that's capable of friction-stir-welding an entire vehicle hull. "The machine offers 26 feet of horizontal stir-head travel and can move 13 feet vertically," he said. "It can weld high-strength 2000-series aluminum plate, up to 3¼-inches thick, in a single pass." Recent underbody blast tests conducted by the government of two CTC-manufactured prototype hulls showed no hull breach—and increased occupant survivability.

Regarding the DATC process, "We have more flexibility and the process is faster," said Michele Stosick, CTC's senior proposal lead. She said that under the old firm-fixed-price system before DATC, "it would sometimes take a year or 18 months before we'd receive a reply. By comparison, the consortia's turn-around timeframe is sometimes six months.

"That really benefits our bottom line, knowing when we submit our white papers and proposals we'll be notified about whether we get the work this calendar year or fiscal year versus a year or two down the road. The consortia really helps us with planning and the bottom line," she said. ■

Dürr builds advanced paint shop for EV startup Byton



Dürr's EcoInCure paint-shop oven employs a novel "inside-out" heating process with more-uniform temperatures ideal for mixed-material structures.

Electric-vehicle hopeful Byton's advanced-manufacturing plan includes a suite of innovative new paint-process technologies from Dürr.

By Bill Visnic

China-based automotive startup **Byton**, fresh from beguiling attendees of the recent Los Angeles auto show and the subsequent CES at the start of 2019, confirmed it intends to begin manufacturing its M-byte battery-electric SUV at its assembly plant in Nanjing late this year, followed by a sedan. Standing behind its pledge to break new ground in many aspects of automotive development and manufacturing, Byton commissioned German automotive manufacturing specialist **Dürr** to outfit the Nanjing site with a state-of-the-art paint shop.

The payoff is big: Dürr said its full "ECO+" layout reduces the physical footprint of the paint shop area by 20% while delivering throughput and cost reductions.

Byton—the brand name of China's Future Mobility Corporation (**FMC**)—intends to initialize the Nanjing plant with a 150,000-vehicle annual output, which equates to roughly 30 vehicles per hour. Dürr's new paint shop can handle the doubling of plant capacity Byton envisions.

Ideal for EVs

The central new feature of Dürr's advanced paint shop for Byton is the EcoInCure oven, which Dürr said "is ideal for electric vehicles" because it provides more uniform drying of the painted vehicle body.

The EcoInCure system cleverly heats the body from the inside out, using a pair of high-velocity nozzles directing drying airflow through the windshield opening and another two nozzles forcing air through the engine compartment area. Dürr said the new oven concept is ideal for electric vehicles that typically seek to optimize overall vehicle weight with mixed-material structures, as EcoInCure "goes hand-in-hand with modified body concepts that use new materials or combine materials in new ways.

"Conventional ovens reach their limits when steel, aluminum and composite materials are used together," the company said in a release. But a Dürr source told *Automotive Engineering* that the new EcoInCure oven's unprecedented uniformity for heating and cooling means the maximum temperature differential "is reduced by approximately 50%. This leads to a reduction in heat-up and cooling time or to a reduction of 'tension' for vehicles with mixed-material body structure."

The EcoInCure oven design is largely what contributes to the claimed 20% reduction in the total area required for the paint shop—mainly because the oven transports bodies transversely, halving its required length, Dürr said, and also shortening the external conveyors. Also contributing is a central high-bay "warehouse" that saves the space typically needed for multiple intermediate buffers, bringing improved efficiency to material flow control. All this makes the paint-shop building smaller; a physically smaller building is mostly what creates a cost-saving compared to conventional layouts.

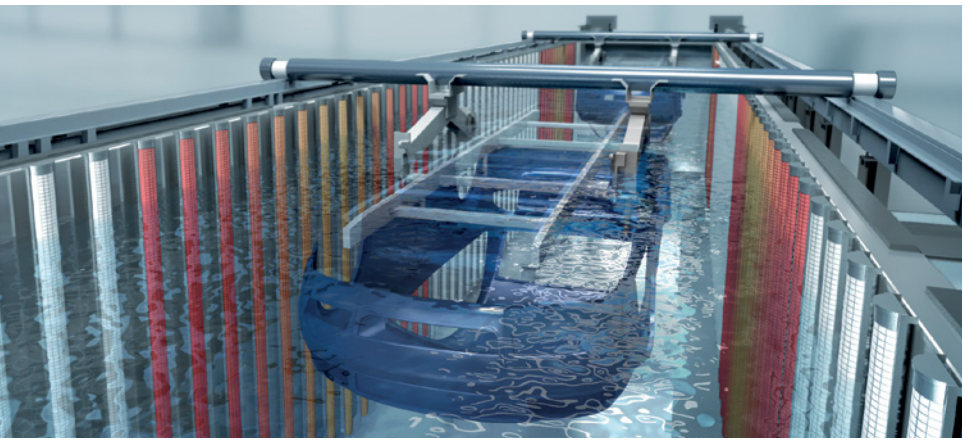
Meanwhile, shorter throughput times and higher-quality paint finish also come from the EcoInCure design.

"The reduced footprint of our ECO+ layout is the result of the use of our high-bay storage concept in combination with our EcoInCure ovens; this leads consequently to a reduced throughput time because it shortens the lengths of the external conveyor connections and reduces the number of elevators," the Dürr representative said.

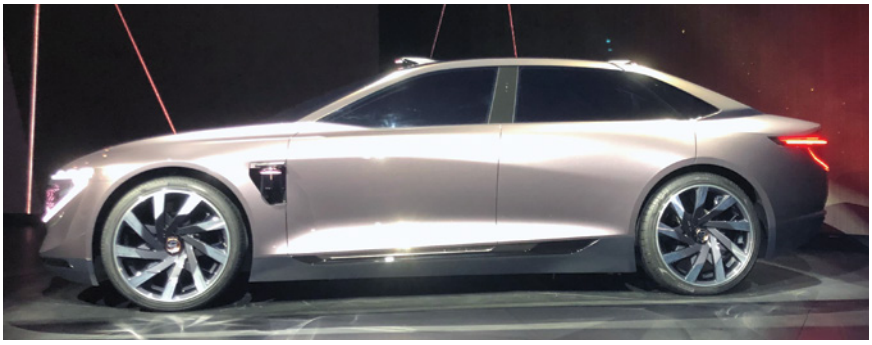
And because of the heat-uniformity of the inside-out heating process, paint quality is enhanced because of reduced thermal stresses.

Compared with conventional ovens, there is "a sig-

DÜRR



EcoDC MACS electrostatic vehicle-body dip: Voltage in the electrostatic dip tank travels with the vehicle body.



At CES 2019, Byton said the battery-electric M-Byte sedan will be the second product to come from the company's assembly plant in China, following an SUV debut in late 2019.

nificant improvement in top-coat quality and process performance, because heating from the inside out reduces the risk of pinholing," the company said in a release. "In addition, minimized flow velocities along the freshly-painted surfaces ensure a completely undisrupted top-coat appearance."

Until now, Dürr said, high-bay storage and the EcoInCure oven design "have been used in several other projects, but not in combination." The company has implemented high-bay storages in the latest **BMW** paint shops (BMW-Mexico, BBA-Tiexi, BBA-Dadong) and for several other customers, while EcoInCure ovens have been installed at the manufacturing facility of startup **VinFast** in Vietnam and for **Skoda** in the Czech Republic.

Better dipping and coating

Dürr's scope of delivery for Byton's Nanjing paint shop also includes the company's RoDip rotational dip process for pretreatment and electrocoating, which at the Byton paint shop already is installed to accommodate a 60-units-per-hour line speed. And Dürr also handles the robotic and application technology for the sealing and painting processes.

For the Byton paint shop, Dürr also delivers an energy-efficient and failsafe electrocoating stage called EcoDC MACS. The technology employs modular anode control to create a voltage profile in the tank that moves with the vehicle body. Dürr also has installed its semi-automatic EcoDryX dry separation system, which separates the overspray in the paint booths for primer and top coat and requires no water or chemicals. ■

FROM TOP: DÜRR; PAUL EISENSTEIN

SPOTLIGHT: ON-BOARD PROCESSORS

Brushless dc motor controls

The PML Series from **American Control Electronics** (South Beloit, Ill.) is a family of versatile, configurable controls for brushless dc motors. PML drives can control motors that range from 90 to 280-V dc, up to 5 A/1.5 hp, using either 115 V ac or 230 V ac line sources. On-board trim pots allow operators to quickly set maximum and minimum speeds, acceleration and deceleration rates, motoring and regening current limits, as well as the proportional and integral feedback gains. An on-board microprocessor allows for custom programming the PML Series for tasks as simple as changing the purpose of a jumper or trim pot, or as complex as programming an entire application-specific routine. The PML also seamlessly integrates PLC-like functionality into operations, allowing users to eliminate the need for a separate PLC altogether or enhance a system that currently doesn't have one.

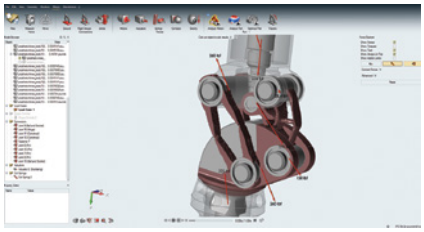
For more information, visit http://info.hotims.com/73002-400

Rugged box PC

The BL72E fanless, maintenance-free box computer from **MEN Mikro Elektronik** (Nuremberg, Germany) is suited for embedded applications in transportation. It is based on **AMD**'s Ryzen V1000 APU family that features a Radeon Vega next-generation 3D graphics engine. With up to four high-performance processor cores and AMD virtualization support, and up to 32 GB soldered-down DDR4 SDRAM, the BL72E offers powerful computing for handling data-intensive work loads. To provide Internet connection for passengers or locating the vehicle, many wireless options are available. This includes a GNSS positioning interface, two PCI Express Mini Card slots and two M.2 slots for implementing mobile service standards up to 4G LTE or WLAN IEEE 802.11, and derivates. A total of eight externally accessible micro-SIM card slots are available as well. If needed, the box can also be delivered with a second I/O board offering additional LTE modems, storage and I/O.

For more information, visit http://info.hotims.com/73002-401

Simulation-driven design platform



The **Altair** (Troy, Mich.) Inspire simulation-driven design platform and the Altair 365 cloud collaboration platform combine early concept development, virtual validation, manufacturability, and cloud collaboration. Altair Inspire enables manufacturers to leverage simulation to drive the entire design process, accelerating the pace of innovation and reducing time-to-market. This new platform brings together simulation solutions for generative design, engineering analysis, and manufacturability under a single, intuitive-user environment, appealing to designers and engineers with little or no simulation experience. Together with the release of Altair Inspire, the company also debuts its Altair 365 engineering collaboration platform on **Microsoft** Azure. Altair 365 allows customers the flexibility to access Altair Inspire and the entire solidThinking suite in the cloud.

For more information, visit http://info.hotims.com/73002-402

SPOTLIGHT: POWER ELECTRONICS

Plug-and-play thermo module

The compact, completely preassembled and precharged standardized refrigerant system from **Pierburg** GmbH (Neckarsulm, Germany) eases driveline electrification and addresses both traditional commercial vehicle manufacturers and industry start-ups with lean development facilities. As a complete package, the plug-and-play thermo module can be integrated into both new and existing vehicle platforms while also being suitable for customer-specific applications, thus supporting each individual vehicle configuration. As a proactive thermal management unit for the entire vehicle the thermo module performs such essential functions as precise temperature control for the battery and power electronics (cooling/heating) through a connected coolant circuit of water and glycol. The module also takes care of interior air-conditioning and temperature control for the electric driveline components, including the electric motor.

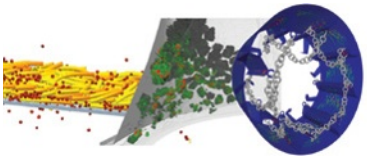
For more information, visit http://info.hotims.com/73002-403

Hybrid connector system

Molex's (Lisle, Ill.) stAK50h Unsealed Connection System is designed to deliver both signal and Ethernet connectivity in automotive body electronics, safety and driver assist, comfort and infotainment devices and modules. The USCAR-2-compliant stAK50h Connection System expedites validation time for Tier 1 automotive manufacturers making design changes and launching new vehicle models. The stackable header design eliminates costly custom tooling, engineering and validation time typically required in multi-bay automotive device and module configurations. Incorporating through-hole style unsealed headers and hybrid connectors, the single- to multi-bay stAK50h Connector System meets industry-standard footprints based on 0.50-mm, 1.20-mm and 2.80-mm terminal sizes widely used in automotive applications. The hybrid system is available with 12- to 56-circuit receptacles and can be used in applications ranging from low-current signal (5.0 A) to high-power applications (30.0 A).

For more information, visit http://info.hotims.com/73002-404

Multi-GPU solver engine



EDEM 2019 from **EDEM** (Edinburgh, UK) is the latest update of the multi-GPU solver engine. Using multiple GPU processors increases the maximum size of simulation that can be run on GPU as well as increases performance. Users can run large simulations faster but it also opens more possibilities to run much larger simulations, which would not be possible on CPU only. Performance gains from adding a second GPU range between 30-90% depending on the distribution and size of the simulation. The multi-GPU solver is fully double-precision to guarantee accuracy and has been developed on OpenCL thus providing flexibility for users to use either **AMD** or **NVIDIA** cards.

For more information, visit http://info.hotims.com/73002-405

READER FEEDBACK

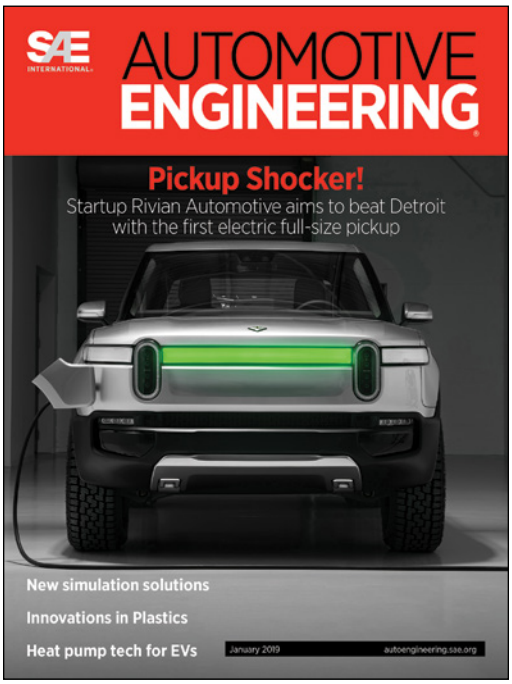
Kudos to Rivian and its R1T

Your article on the Rivian R1T shows that a small but focused team of engineers can show the big boys how to shake up a market segment. But is the American full-size pickup truck segment ready for an EV? Maybe not yet, but I agree with you that it should have been Ford, GM, or FCA that tickled our imaginations first. Kudos to Rivian and thank you SAE for these interesting details.

Kirk Prattenberger
Columbus, Ohio

Regarding the Rivian R1T electric truck: Once again, driving ranges are speculated. In this instance, their largest battery-pack is rated for a maximum 400 miles. Furthermore, the R1T has a 11,023-pound tow rating. How does that translate into real world driving? I would like to see a R1T tow a 10,000-pound trailer at highway cruising speeds. And not just in a flat Plains state like Nebraska, but rather over a route that includes mountain grades. Then publish how far they went on a single charge.

Isaac Martin
Sherman Oaks, California



Yamaha's wild Ackermann ride

I was particularly impressed with one detail in the Yamaha Niken article [Nov./Dec.]. Some fifty-odd years ago I was a grad trainee working for a truly fine chassis engineer. One of the things he explained to me was that what we call 'Ackermann steering' was invented by a German named Lankensperger; the Ackermann name came from the guy who filed the patent. That was the first and last time I heard or saw the Lankensperger name until I read the Niken article. It was really great to see the proper attribution for such a basic and important invention.

Irv Usner
Beverly Hills, Michigan

Electrify the U.S. Postal Fleet!

If BEVs make any sense, it appears to be [in the USPS fleet application; Nov./Dec. 2018 issue]. Stop and go, return to base, limited range, quieter (if not driven at higher speeds), no NOx locally. What needs to be carefully looked at, however, are the emissions produced both in manufacturing of batteries as well as during driving from electric power generation.

Most people think with a growing portion of renewable generation in the mix, CO_2 goes away. They're mistaken, because all that matters is the MARGINAL power generation, not the mix figure.

One needs to ask what power plant will participate in generating the charging power. This does not follow the mix number. Explanation: Normally, all renewables should be running at full tilt BEFORE charging a car. Because then we get the maximum ecological benefit. Countries like Germany even have made that into law.

Now, if added power is required on the grid for charging or anything else, renewables have nothing to add. The mix does not scale.

So what kind of power plant will jump in? That depends on availability of power reserve, contracts and power control. If nuclear plants can jump in, fine, no CO_2. But if fossil plants jump in, a lot of CO_2. Natural gas burned in modern gas-and-vapor plants still gives a little benefit over ICEs. Hard coal not necessarily, and lignite is even worse.

I drive a small 2-seater BEV in my city. Fun to drive, but horrible CO_2, as we in Germany will have mostly lignite power as marginal power for a long time to come.

Lastly, battery manufacturing is CO_2-heavy. A renowned German engineering provider recently calculated that a compact car BEV needs about 50,000 miles to drive before breaking even with its gasoline brother. To a large degree, that's because of battery production.

You may say this isn't too bad, but they based all calculations on the EU27 power mix which is wrong, as explained above.

Break-even may never be reached when our marginal power generation is taken into account.

Dr.-Ing. Herbert Hanselmann
dSPACE GmbH
Paderborn, Germany

READERS: Let us know what you think about *Automotive Engineering* magazine. Email the Editor at Lindsay.Brooke@sae.org. We appreciate your comments and reserve the right to edit for brevity.

COMPANIES MENTIONED

AD INDEX

Q&A

Electrifying 'the ultimate driving machine'

Which premium vehicle OEM currently offers the broadest range of plug-in vehicles? That would be **BMW**, with 12 production hybrids and battery EVs including new-for-2019 PHEV variants of the 3-Series sedan and X5. With many more in the pipeline and the company's fifth-generation electric drive system in development for 2020, *Automotive Engineering* Editor Lindsay Brooke sat down recently with Stefan Jurascheck, BMW VP Development for Electric Powertrains, to discuss details of "the ultimate electrified driving machine." Jurascheck, an electrical engineer, is a 32-year BMW veteran.

BMW's next-gen electric drive architecture is due to launch in 2020. What can you tell us?
Development is in-house; we've done this since we started the i3 and i8 programs. We learned a lot from these pioneering electric cars. When we started development on them and also on our PHEVs, it was very difficult to find suppliers who could fill our wide range of technical requirements—including electric motor scalability, the need for front- and rear-axle drivetrains, and so on. You can cover the one-off development costs if you make a modular 'kit' out of it. To do that you must decide on the set of exterior dimensions, internal ratios, and power electronics. That's very important. Because if the OEM doesn't have full control over the power electronics, you're forced into greater complexity in terms of hardware and software, including updates.

We have only one power electronics package. Its highly integrated box fits a range of our powertrains from 100 kW up to 350 kW. The box might be a little bit larger than optimum size, but we can use it on every vehicle and electric axle. We used a very flexible, build-to-print approach; we know the precise price points. Our development of this box is driving our expertise in our electric motors and also for our engine development.

What components constitute the hardware e-module?
The electric motor, transmission and power electronics are engineered into a single integrated e-drive unit. It's very compact. The DC/DC charger will also be integrated. The unit is designed to be scalable, enabling it to fit many vehicle applications and power requirements. It will allow us to incorporate new battery types flexibly, according to vehicle requirements. Also, our new electric machines will be free of rare-earth metals.

And, this new series-production electric drivetrain is developed by the same people in my department who are responsible for the Formula E BMW electric racing drivetrain we launched in 2018. They are pushing the envelope to see what can be achieved in 3-5 years in this area. The racing system uses a silicon-carbide inverter, but the two systems are running with the exact same software! This year we had a test campaign, trying to identify issues under extreme loads and conditions on the racetrack. Combining the racing and series software developments has increased the speed of our series-production development.


Stefan Jurascheck

"In the next five years we'll have significant applications of 48-V in our cars."

What's the production plan?
We'll do production of the electric powertrain in-house as well, in scales up to 500,000 units per year. It will give us a lot of experience in this field. Our flexible production can build motors from 100 kW to 350 kW, all on one line.

How about 48-volt hybrids?
In the next five years we'll have significant applications of 48-V in our cars. We're doing 48-volt model by model but we need the right 'stepping in' point to introduce it—for instance, when we update an engine or a gearbox, we'll also try to do an update of the voltage system.

When do you expect the cost per kilowatt-hour of EVs to finally intersect the cost of, say, that of a typical 3-Series powertrain?
It depends on what you expect for vehicle range. If you expect a 250-300-km range, then we are not far away—maybe 2024-25. But we have demand for longer ranges and higher capacity batteries, beyond 100 kW·h. Cell price is definitely driving EV cost because of the raw material. ■

UPCOMING WEBINARS

AUTOMATED AND CONNECTED COMMERCIAL VEHICLES: NEXT STEPS FOR "HANDS-OFF OPERATION"

February 7, 2019 at Noon

Demonstrations of increasingly connected and automated heavy vehicles on public highways and bustling worksites are becoming more commonplace, as the commercial vehicle industry continues to pursue improved fuel efficiency and operator productivity, while enhancing safety.

This one-hour Technical Webinar from the editors of SAE International explores how we get from advanced driver-assistance systems and wireless connectivity, which enable platooning formations and remote-control operation, to Level 4/5 autonomous vehicles.

Speakers:

Jace Allen
Business Development Manager of Simulation, Test, and Electrical/Electronics Data Management, dSPACE Inc.

Chris Woodard
Business Development Manager of Autonomous Machines, Danfoss Power Solutions

Joerg Luetzner
Head of Commercial Vehicles, Systems & Technology Department, Continental

Sponsored by: THOMAS For Industry., dSPACE, kontron S&T Group, BOKER'S, INC., aras, FLIR

Hosted by: SAE INTERNATIONAL

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NEXT GENERATION DESIGN FOR AUTOMOTIVE AND TRANSPORTATION INDUSTRIES

Available On Demand Until September 24, 2019

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Speaker:

Dave Lauzun
Vice President, Automotive and Transportation Strategy, Siemens PLM Software

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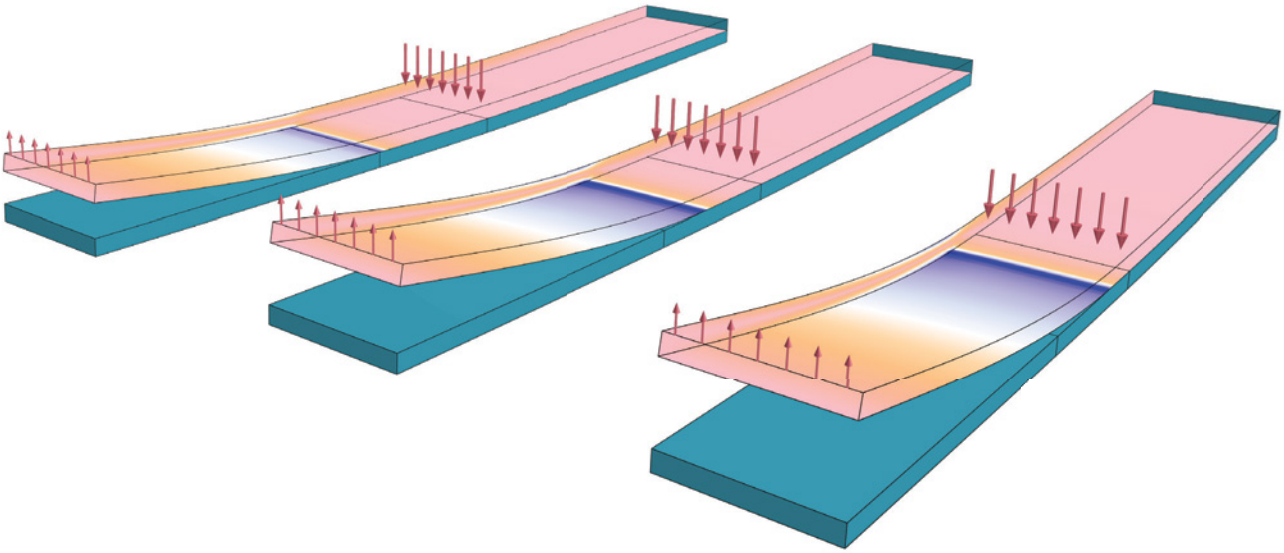

Visualization of von Mises stress distribution and applied loads in a mixed-mode delamination of a composite material.

Adhesion and decohesion modeling is useful for analyzing manufacturing processes that involve the joining of parts and for studying the maximum load-bearing capacity of structures. The right contact modeling tools deliver fast and accurate results, empowering you to develop more efficient and reliable manufacturing processes.

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