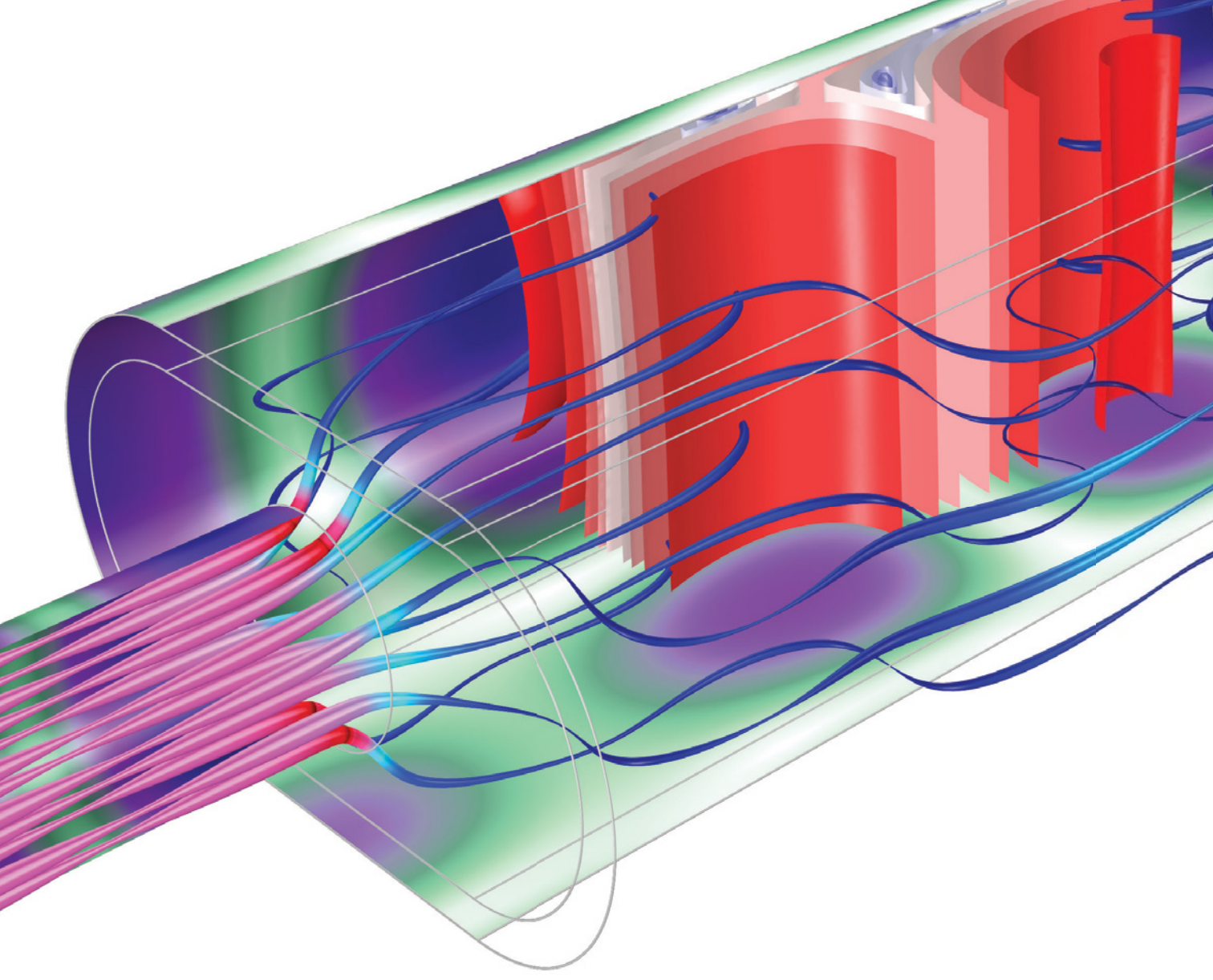

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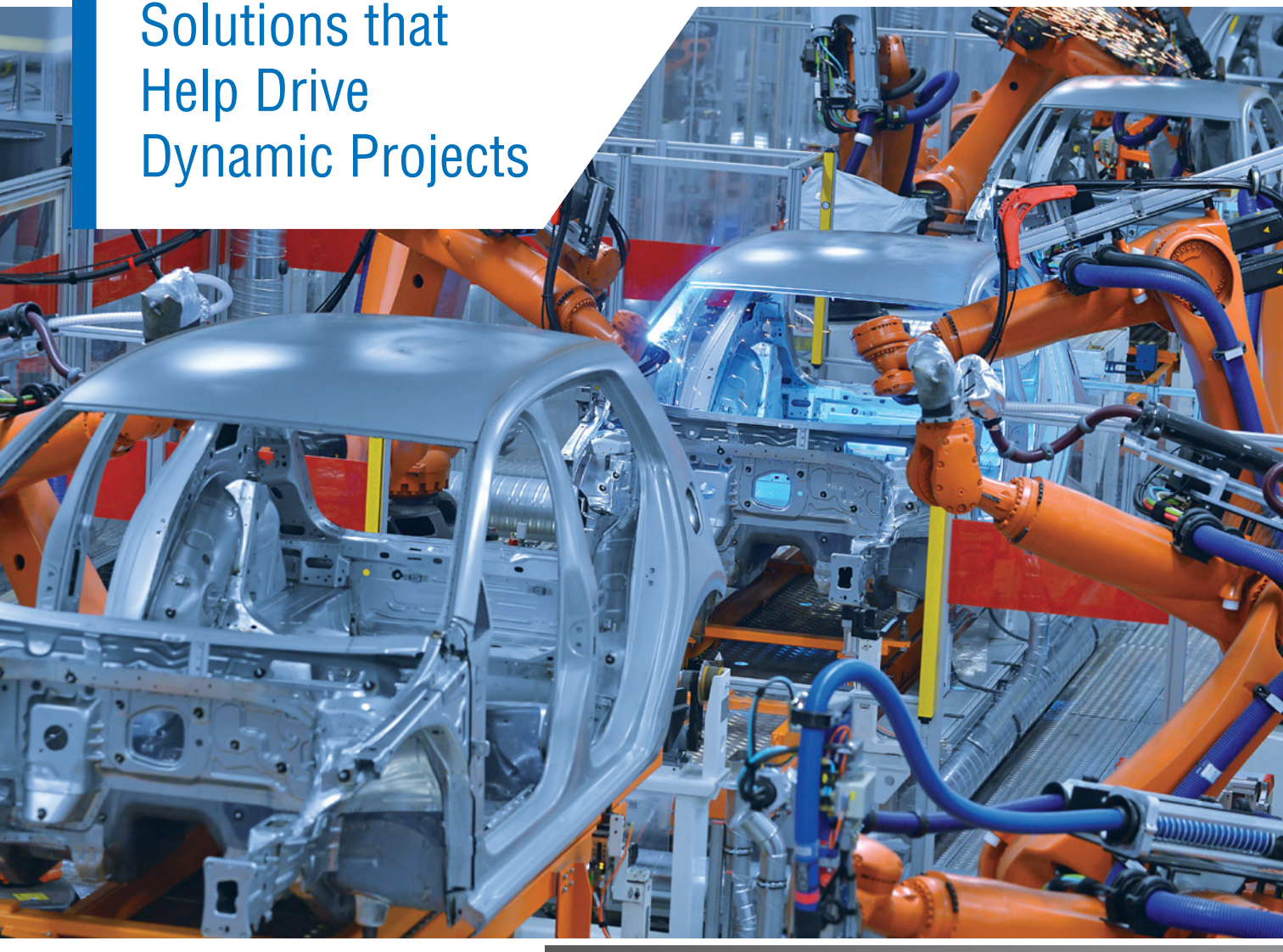

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ON THE COVER

The 2017 Clarity Fuel Cell is the culmination of 20-plus years of Honda's development of fuel-cell technology. With a driving range up to 366 miles, an expanding network of strategically-located refueling stations and driving characteristics and refinement levels that certainly match—and in some measures exceed—those of conventionally-powered vehicles, the Clarity Fuel Cell demands almost no consumer compromises. Now the trick is to see whether the fuel-cell formula can work outside of "alternative-friendly" California.

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EDITORIAL

The new engineering shortage

One of the best aspects of my job is the regular contacts I have with engineers at all levels. Since the start of 2017 I've spoken with nearly two dozen of you as part of my reporting and research for various articles in *Automotive Engineering*. And no matter the topic, I'll often add a few questions about the engineering profession.

Everybody brings up pain points. The most acute among them is the shortage of engineering talent in the industry's growth-technology areas. The challenge of finding and attracting electrical/electronics, chemical engineers and technicians to work on hybrid and electric-vehicle development, batteries, and related technologies has been a popular response to my prompts during the past five years.

The battle for talent in Artificial Intelligence and related disciplines has become an "arms war" within the mobility industry.

Not enough "Chem-Es" in the mobility sector, the CTOs of battery-cell suppliers complain. Coaxing winter-averse Californian E/Es to move to Michigan remains a lament of Detroit-area global suppliers.

Conversely, it's no easy feat to lure Midwestern engineers to relocate to the high-cost West Coast without a big bump in pay, the Sil Valley-based tech guys say. What, sell the lake place, dump the snow sled and get used to a smaller house?

The latest call is for new competencies needed for vehicle autonomy and connected-car development. Artificial intelligence, neural networks and deep learning were the stuff of the National Labs and *Terminator* film scripts until **Google**, **Tesla** and others uncorked the self-driving-car genie. Overnight the prospect of thousands of lives saved annually through **SAE** Level 4 and 5-capable vehicles was realized.

Where to find AI experts? Last month's $15.3 billion **Mobileye** deal not only helps position chipmaker **Intel** for a dominant role in the autonomous space. It also underscores the role that tech acquisitions and alliances play in shifting brainpower and talent up the supply ladder.

Bill Ford's company has itself seen such high-profile defections. The man whose great-grandfather disrupted the automotive status-quo nearly 110 years ago sees fast-moving mobility tech and the scarcity of advanced-technology engineers in battlefield terms.

"It's an arms race," Ford told a media gathering at this year's SXSW (South by Southwest) techfest. "If you have smart people, you have a chance to win. And if you don't, you won't." His message to engineers: "We can give you interesting assignments all around the world," and a more stable and perhaps equitable corporate culture than is available at the less-mature tech firms.

Recently I was a guest on veteran journalist Doron Levin's "In the Driver's Seat" radio show on **SiriusXM** channel 121. My host and I talked about Mobileye, the shortfall of advanced-software talent and why Israel has become a place to find those scarce engineers. The day the show aired I received a LinkedIn note from a listener.

"I heard you today on "In the Driver's Seat," a Philadelphia-based professional wrote. "My 11th grader wants to study mechanical engineering in college [with] an automotive career goal. Would love to speak with you briefly, RE: School. Get your input."

MEs are the backbone of everything related to mobility, I replied, so that's a great first step. Be prepared and willing to continue learning as the industry and its products change—and to dump the snow sled or put some warm togs in your closet.

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Moving EV wireless charging toward a global standard

The next big enabler for electric vehicles is wireless charging, a technology planned to be commercialized by 2020 by some automakers and infrastructure suppliers alike. "Wireless power transfer is just starting now in consumer electronics in the low wattage range (such as the iWatch and upcoming iPhone 8) and in just a few years is set to penetrate the vehicle market in the kW range. The most important task at hand is to create a worldwide standard," explained Jesse Schneider, Chairman of the **SAE** J2954 Task Force on Wireless Charging and Alignment.

It is projected a significant percentage of next generation EVs will be sold with a wireless charging option. SAE J2954—which specifies the minimum performance and safety limits and seamless interoperability of wireless power transfer (WPT)—is the key standard to the success of both EVs and autonomous vehicle fleets.

"The only way—under all weather conditions—to charge an autonomous vehicle automatically is with wireless charging. So in that way, SAE J2954 is an enabler for autonomous vehicles as it assists with vehicle alignment, parking and automated charging—even when there is snow on the ground," Schneider said.

In the upcoming SAE J2954 Recommended Practice, due out this year, a method for magnetic triangulation is used to assist in vehicle parking and alignment to be used as a basis for each WPT ground infrastructure assembly.

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SAE J2954 uniquely encompasses both the vehicle and infrastructure sides as a 'system.'

The SAE J2954 Task Force began work in 2010 (http://standards.sae.org/wip/j2954/), Schneider told *Automotive Engineering*. The comprehensive team has over 150 technical experts from more than 13 automakers (such as **Audi**, **Ford**, **GM**, **Honda**, **Nissan**, **Toyota**, etc.), five heavy-duty OEMs (including **Gillig**, **Scania**, **Volvo**, etc.), Tier 1s (such as **Delphi** and **Lear**) and technology companies (such as **Qualcomm** and **Witricity**). Also involved are the **U.S. Dept. of Energy (and their national labs)**, **Japan Automobile Research Institute** (JARI), the **American Association of Medical Instrumentation** (AAMI) and various universities.

The difference between this activity and other standardization efforts is that SAE J2954 "encompasses both the vehicle and infrastructure sides as a 'system,' which is unique," Schneider noted. "**ISO** specifies the vehicle only, and **IEC** addresses the infrastructure side. Therefore, SAE J2954 is simultaneously the key for commercialization for both the vehicle and the wireless charging infrastructure related to performance and safety."

The SAE J2954 forum also has become the global nexus for key decisions for the operation and specifications for WPT for the industry and governments. For example, the operational frequency for light-duty vehicle WPT has been determined at SAE J2954 to be 85 kHz, which is currently being petitioned nationally at the **U.S. Federal Communications Commission** (FCC) and internationally at the **International Telecommunication Union** (ITU).

Regarding performance, Schneider told *AE* that under aligned conditions, "SAE J2954 specifies a minimum level of 85% efficiency, although the testing we have done with **INL** has demonstrated that the technology can achieve 93%. When you consider the best case conductive charging is 95%; wireless charging looks even more attractive." SAE is working closely with other standardization and government organizations related to safety limits for electromagnetic field (EMF) levels.

For example, the SAE J2954 Task Force has worked with the AAMI and the **U.S. Food and Drug Admin.** on validating limits for EMF using operating wireless chargers and functioning medical devices. These groups are helping SAE J2954 verify the EMF limits are within safe limits for humans even when they are wearing devices such as pacemakers. He also explained that there are tests to confirm that a wireless charging system does not overheat when specific test objects are placed between the transmitter and receiver.

SAE J2954 also establishes a baseline for interoperability by specifying a test station for both the ground assembly (primary coil assembly or infrastructure side) and vehicle assembly (secondary coil assembly). In addition, the document describes a minimum specification for both coil sets, including circuit diagrams, etc. This allows a supplier or automaker "to design their vehicle/ground assemblies to the specifications provided in SAE J2954 and/or use the test station to validate interoperability and compatibility for an alternative design," Schneider explained.

Setting a standard is usually a slow evolutionary process. However, SAE J2954 is on the fast track in less than two years to support the impending commercialization. In 2016, the SAE J2954 Technical Information Report (TIR) was published. It is essentially a guideline for WPT up to 7.7. kW—validated in two laboratories with the U.S. DoE at its Idaho National Laboratory and **TDK** North American Laboratory. In 2017, J2954 will finish the second phase—publication of the Recommended Practice, which will provide a technical specification for both WPT up to 11 kW and vehicle-to-infrastructure alignment.

From 2017-2018, eight OEMs and six suppliers will participate in the real vehicle and infrastructure validation testing for the draft SAE J2954 Standard, according to Schneider. In 2018, the final SAE J2954 Standard will be published, anticipating the commercial roll-out of the WPT technology two years later.

Stayed tuned. ■

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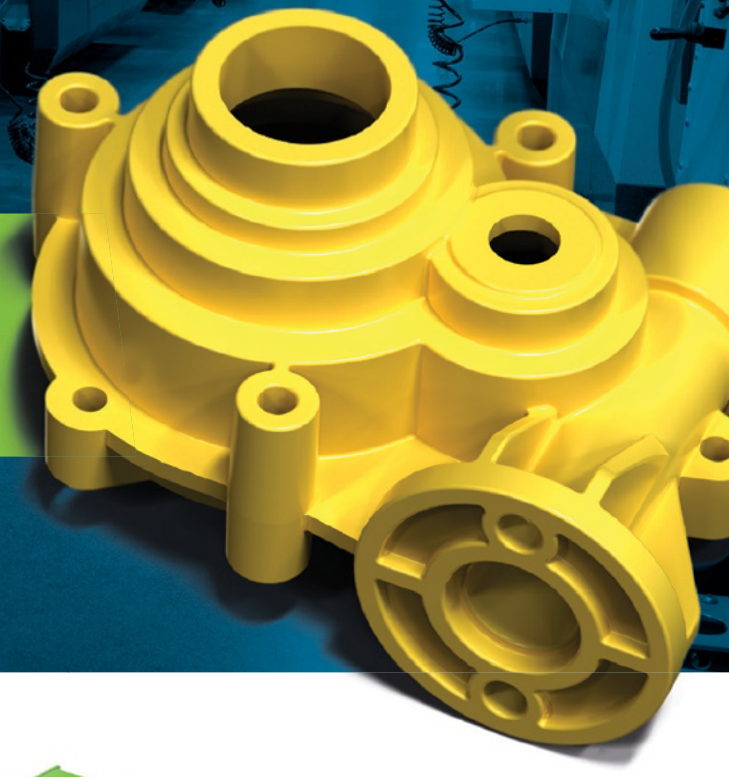

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SUPPLIER EYE

The new Supplier Invasion

Significant changes are underway within the North American light vehicle supply infrastructure. Beyond the slow though steady shift of value and resources from 'hard parts' towards the softer side (electronics/mechatronics) of system supply, as well as the pressures impacting smaller, more regional suppliers there are other critical changes underway. Chief among these are the geographic and system expansion of the supply base into new directions.

An influx of China and India-based suppliers have been quietly setting up shop in North America—mainly in Mexico and the U.S. Their respective routes to these shores are not identical, though there are common traits. System technologies requiring high levels of capital, especially "patient" capital, are destinations for transplanted suppliers. These companies are thus far predominantly involved in glass, painted exterior components, castings and stampings.

Beyond 'greenfield' operations, capital from abroad has been utilized to purchase ailing suppliers requiring an infusion of funding and scale when combined with volumes back in Asia. We've seen examples in safety systems and chassis control where new funding allows for capacity expansion and an overall technology improvement across their enterprise.

OEMs which are establishing new operations away from the U.S. Midwest and thus trying to reduce logistics costs may find the new Asian suppliers who are incremental to the NA supply base more willing to set up shop in new locales. The various motivations include filling a void within a supply sector with too few players (per the opinion of the OEMs) or being offered business by an OEM seeking to 'expand' their supply base—allowing for more sourcing options.

The lure is understandable. Geographic diversification to North America for these new players gives them exposure to new technologies which can benefit capabilities back home.

Michael Robinet
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The traditional supplier tiers are under attack by new players as vehicle systems change.

Another subset of new suppliers to North America are from Europe, Korea and Japan. Many of them did not establish operations over the past couple of decades in parallel with their main OEM customers. Increasing volume and a shift towards incremental capacity in Mexico has brought a tranche of new players, some of whom are aligned with **Mazda**, **Kia** and even **Volvo**. While many of them are Tier 2s following their larger Tier 1 customers to North America, the increased volumes and the chance to diversify their customer base is important.

Possibly the most visible of new suppliers are those start-ups from Silicon Valley and Israel, the wellsprings of new players in advanced technology. The small, non-traditional, tech-intensive companies are bringing innovative ACES-related content to the vehicle. ACES—the **IHS Markit** acronym for Autonomous, Connected, Electrified and Shared—is truly preoccupying our industry as it races towards 2020. Tier 1s and OEMs alike are acquiring or building joint ventures with these players at a staggering rate and with commensurate capital outlay.

The net result is new technologies and collaborations for the mobility industry. Nonetheless, these suppliers would be wise to ensure they understand scale, as well as the timelines, tooling and testing protocols and the extreme level of integration with other light-vehicle systems, before they dive in.

Additionally, the traditional "tiers" are under attack as vehicle systems change, causing the method by which these are supplied to change as well.

Any supplier who envisions that their current competitors, upstream customers and suppliers will be the same a decade from now is in for a rude awakening. Only those with the outlook, analysis and foresight to view the road ahead will be able to react. ■

Supplier Infrastructure Shifts in North America

Chinese-controlled Suppliers
- Seeking improved scale economies
- Customer and market diversification
- New talent pools driving innovation
- Willing to focus on high capital requirement sectors
- Ability to transfer knowledge and capability

SilV and New ACES Entrants
- Driven by constant shift in resources and value towards 'softer' components (electronics/software)
- Alternative work structures with faster cadence
- Access to innovations from the larger non-auto electronics industry

Indian-controlled Suppliers
- Geographic and market diversification
- Customers seeking innovation from lower-cost focused suppliers
- Possibility of utilizing existing upstream suppliers based in a lower cost jurisdiction (Southeast Asia)
- Exposure to new technologies can improve capability

Incremental Sub-Tiers from EU, Japan, Korea
- Increased capability in North America by non-Detroit 3 OEMs is propelling increased 'domestic' supply
- Logistics, domestic value add, currency exposure and inventory reduction all support this shift

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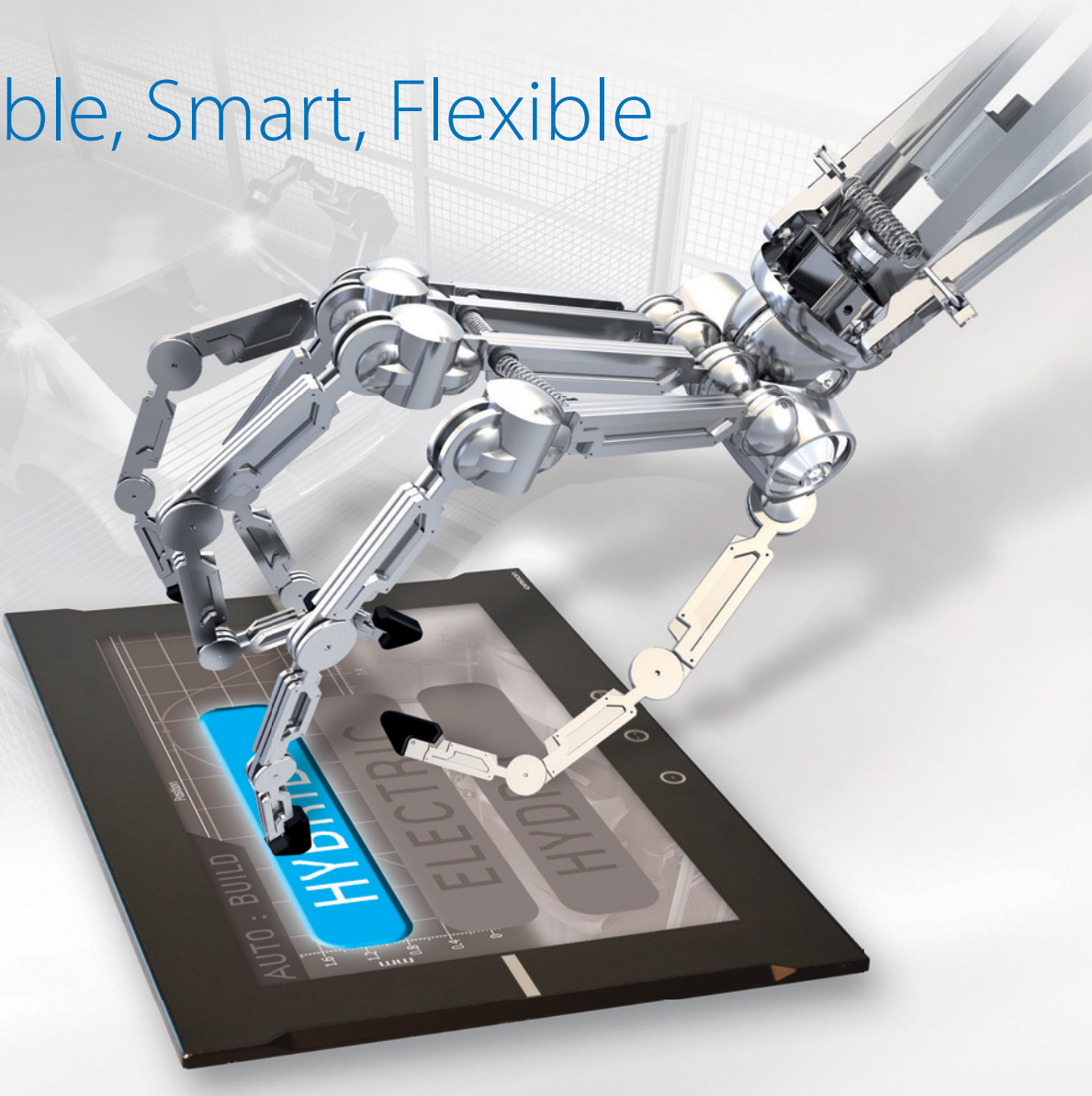

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Proliferating electrification and performance

Ford's Vice President of Powertrain Engineering Bob Fascetti oversees one of the industry's most diverse propulsion-technology portfolios. He shared some thoughts with *AE* ahead of his April 6 WCX Leadership Panel, "How, What and IF You Will Drive in the Next Decade." The panel also includes propulsion-engineering chiefs of **FCA** (Bob Lee), **Lucid Motors** (David Moseley), **General Motors** (Dan Nicholson) and global industry analyst Marc Winterhoff of **Roland Berger**.

Ford is setting an SAE record this year in publishing more than 200 SAE Technical Papers. How did you inspire the team to achieve this milestone while simultaneously raising the quality of the papers?
We really challenged our engineers this year, to make this a part of doing business. The SAE papers we're publishing really tell the story of how Ford is both a consumer-based company and a technology-based company. WCX is going to be a big part of that. Publishing the tech papers also allows our engineers to come to WCX and participate in the dialogue.

If you take our company's technology focus—such as electrification, connected-car, vehicle autonomy, powertrain—and you combine that with a real priority to get out there and tell our story, it equals an opportunity that's rich with value for the engineering community at WCX.

Is the EPA's recent decision to re-open the Mid-Term Review of 2022-2025 fuel economy standards a good thing, in your view?
At Ford we're simply committed to improving our products' fuel economy. We have to do that across the globe, regardless whether they relax standards here. That's one reason we're adding 13 new electrified vehicles to our lineup by 2020. We think that's important. So from my standpoint we just need to continue to provide value and get out the technology that improves economy and performance.

Do you have concerns for vehicle affordability? Nobody walks into a new-car showroom and says, "Give me the one with the cooled EGR system and the gasoline-engine particulate filter"—technologies that add cost but aren't saleable features.
And those things you noted are good for the environment. We remain committed to year-over-year improvements, which ensure that we compete favorably in the industry across the globe, not just in the U.S., and we're committed to leading on those fronts.

How do the ride-sharing, connected-car and autonomous trends impact future powertrain strategies?
You'll see an evolution of what we have to do in these areas. We're currently a leader in full-hybrid technology and you'll see a proliferation of those, followed by plug-in hybrids. Then after those, you'll see the same with electric vehicles. The good thing about plug-ins and full hybrids is they require an internal-combustion engine to make them work. The technology 'revolution' in powertrain allows us to transition progressively to fully electric.

What does the next decade promise for Ford Performance, the 'sub brand' that brings so much enthusiasm to Ford Motor Co.?
Performance vehicles are a good piece of our business. They represent the 'art of the possible' to our customers. We need to continue to provide vehicles that those customers want and value, with increased performance year-over-year. I think that will continue. And we have to harmonize that value with the regulatory front in making our emissions performance better and better.

What can you report on Ford's latest Ecoboost play, the new 1.5-L turbocharged 3-cylinder with cylinder deactivation unveiled at the Geneva show?
It's going to be a great engine for us. A real benefit of it being three cylinders is it bodes well to sitting either 'north-south' [longitudinally] or 'east-west' [transversely] in the vehicle. And I think the displacement is just right for a number of markets.

Offering both naturally-aspirated and boosted versions will give customers the fuel economy and performance they want and value. And the cylinder deactivation is giving us a measured improvement in fuel economy.

Lindsay Brooke

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SAFETY

Euro NCAP to adopt autonomous vehicle ratings

How crash results used to be and how they are now: Above, a current Honda Jazz; below, a 1997 Rover 100 undergoing comparative Euro NCAP tests. What will SAE Level 4 and 5 vehicles look like after they complete the new NCAP testing?

The Euro New Car Assessment Program (NCAP) safety-test rating will establish a separate category for autonomous vehicles, but there is not likely to be one for cars that are claimed to protect all occupants from serious injury or death. And while there is currently little sign of a harmonized engineering and cost saving global test system, there may be an opportunity in the future, reckons Matthew Avery, Director of Insurance Research at **Thatcham Research**, which carries out Euro NCAP tests in the U.K.

According to Michiel van Ratingen, the Euro NCAP General Secretary, there has been a "slow down" in new safety systems' progress. According to Avery, this isn't due to lack of ideas.

"We continue to see significant progress," he told *Automotive Engineering*. Development of passive safety systems (seatbelts, belt tensioners and airbags) has plateaued; industry penetration of these innovations has resulted in a 63% reduction in killed and serious injured (KSI) over the past 20 years. Meanwhile, there has been a dramatic acceleration in 'active' safety technology, which works hand-in-hand with the passive safety net.

"Ultimately, prevention is better than cure," Avery said. "When it comes to investment and cost benefit, there's much more that can be done to prevent the crash entirely than there is to improve how a car behaves during a crash."

Harmonizing Euro and U.S. standards

Recently the latest generation Ford Mustang scored only a 2-star result in Euro NCAP tests, leading some safety experts to amplify the call for global test harmonization. They argue that the present individual regional standards make for engineering complexity, increased costs and an element of confusion.

"Unnecessary engineering complexity could be looked at in a different way, as an opportunity for increased engineering robustness," Avery observed. "Having different tests in Europe and the U.S. delivers a more robust end product because we have to be able to accommodate different crash types.

He said the U.S. does not test differently as a result of idiosyncratic driver behavior; rather, it designs for a very common crash situation.

"What we do is not unique to Europe per se, but it is also in response to one of the most common types of injurious crash. If you put the two together, you have a more robust system," he noted. Does that mean it's more costly for OEMs? Yes. But it also means that the engineering is more robust for the consumer.

Presently there is little or no global harmonization of the NCAP standard; the tests reflect individual markets and prominence of specific types of vehicles. So for Europe to have to engineer for large pickup trucks—or for the U.S. to engineer for A-segment city cars—wouldn't

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SAE WCX17

Ford sets tech-paper record as SAE boosts quality standard

SAE International and its industry partners are continually improving the quality and topicality of technical papers published annually. And as the paper review process has become more rigorous, the industry has responded with an increased number of manuscripts submitted over the last five years. That has helped SAE deliver maximum value to its members and WCX attendees.

OEMs are helping to raise technical paper quality overall by learning from each other. The 'Written Only' paper category was established to give authors the opportunity to submit a manuscript at any time. With this, SAE did not need to be reliant on event 'call for papers' (CFPs) for manuscripts. And rather than simply rejecting a paper, organizers can now suggest that authors withdraw their paper, continue to work on it, then submit it to the Written Only portal for publication consideration. This has raised the bar on paper quality and has boosted quantity as well.

For 2017 **Ford Motor Co.**'s well-planned-and-supported process for employees to submit manuscripts has set a new benchmark. Ford engineers will have over 200 technical papers published for 2017—a record number from a single OEM, according to SAE staff.

Over 2,000 technical papers were submitted for review and consideration by SAE International for publication at WCX17. Typically 60% of those submitted are approved for publication.

Lindsay Brooke

[continued from page 12] be right for either market, Avery asserted. He noted that in 2008 such a scenario actually was played play out in Euro NCAP testing when a series of U.S.-style pickup trucks performed poorly as a group.

In the future, however, there is an opportunity for harmonization and that is already in process to some degree. "The Autonomous Emergency Braking (AEB) testing we developed at Thatcham Research, for example, is now part of Euro NCAP's overall testing regime and has also become an essential part of the U.S. testing system," he explained. The process exists for pedestrian, car-to-car, city and inter-urban AEB, along with a new Global Vehicle Target test also co-developed by Thatcham engineers.

"Harmonization ideally needs to come at the embryonic ideas stage," Avery stated.

Separate 'star' rating for autonomous vehicles

Will there be a separate "star" rating system for autonomous vehicles—and are there likely to be new safety technologies for autonomous vehicles that would allow them to achieve maximum star rating?

Thatcham's Matthew Avery says avoiding death and serious injury completely, won't be a standard which comes into Euro NCAP testing.

"We are likely to see a separate rating beyond the 5-star system, to help drivers understand how well the autonomous system of any given vehicle performs in relation to others," Avery noted. At present, autonomy is about braking and steering assistance, for example Emergency Lane Keeping (ELK), a subsystem of the wider testing program. He believes that because 93% of accidents are a result of human error, it is possible to eradicate the human error element completely through the integration of ADAS sensors and algorithms.

Steering intervention is a safety technology that Avery believes is likely to help vehicles achieve maximum safety ratings. "ELK will be a feature of testing for 2018 and by the early to mid-2020s we will be looking at Autonomous Emergency Steering (AES)," he noted.

These systems are required for true vehicle autonomy and they introduce a whole host of new opportunities to avoid the crash. There are occasions where the two operating in tandem are better, Avery said, and others when they operate individually to avoid an accident.

While Volvo is aiming for occupants of its post-2020 models not to suffer death or serious injuries, what about the entire industry achieving such a standard? Would this goal likely become a Euro NCAP requirement for a maximum star rating?

"Avoiding death or serious injury completely will not be a standard which comes into Euro NCAP testing," Avery asserted. "Other vehicle manufacturers however will be keeping a keen eye on **Volvo** and how successful it has been, especially where a marketing advantage can be gained."

However, Euro NCAP won't look at that because it would require a huge, well orchestrated analysis of pan-European crashes. "It also fails to account for "Acts of God" which are beyond the means of any safety technology, passive or active," he said.

Stuart Birch

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POWERTRAINS | PROPULSION

The upside of engine downsizing: senior auto executives give their views

Mercedes-Benz's Dr. Thomas Weber always talks of 'rightsizing' rather than downsizing—and emphasizes the importance of powertrain electrification.

To downsize or not to downsize? That's the engine-development question facing all OEMs. In an initial move to be seen to be more environmentally responsible, for many, downsizing seemed to be a thoroughly sensible answer. Engineers were delighted to demonstrate their ideas for extracting maximum energy from minimum cubic capacity—and marketing executives were equally delighted with the advent of a new angle for product promotion.

But as with most elements of automotive engineering, engine downsizing has proven to be not quite that simple. "Rightsizing" is the alternate term to emerge to describe rather more pragmatic solutions to reducing a vehicle's carbon footprint. Not as emotive or positive-sounding as downsizing, "rightsizing" nevertheless has found approval among several OEMs and Tier 1 suppliers.

Arguably, "rightsizing" simply means doing it as it's always been done. For an OEM, the whole point of engine design is to match it to the entire vehicle and sell the result in large numbers at an equally large profit, while meeting fuel-consumption and emissions legislation, not to mention buyers' expectations.

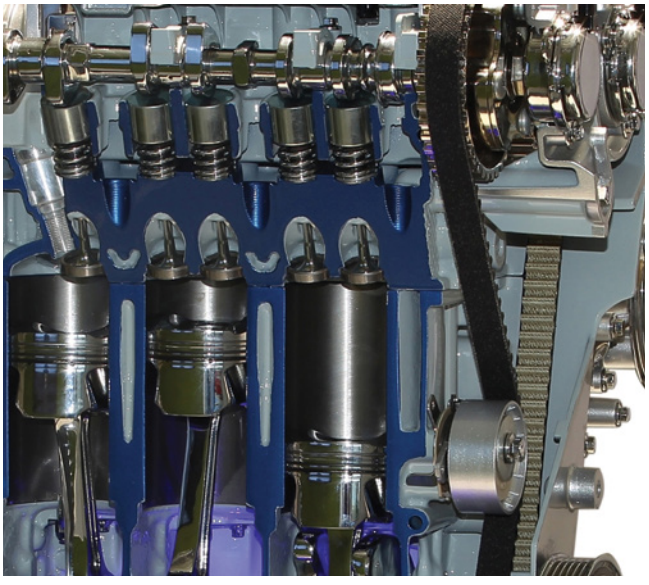
Mercedes-Benz recently revealed new 3.0-L 6-cylinder engines and even a new V8 (http://articles.sae.org/15093/), albeit with capacity reduced by a relatively modest 0.7-L compared to the previous generation. It regards these engines as rightsized for present and anticipated future legislation, environmental responsibility and efficiency requirements, while giving customers what they expect a Mercedes to provide.

Prof. Dr. Thomas Weber, retiring head of **Daimler** Group Research and Mercedes-Benz Cars development, always talks of "rightsizing" rather than downsizing: "Instead of trimming the number of cylinders from the outset, thereby foregoing refinement and output, there are much more intelligent solutions. Our M176 V8 engine uses cylinder shut off; at part-load up to 3600 rpm it is an especially efficient 4-cylinder. Then, imperceptibly for the vehicle's occupants, cylinders 2, 3, 5 and 8 cut in."

Mercedes also is heavily committed to powertrain electrification via 48V technology to enhance efficiency.

At **Delphi**, Vice President Engineering (Powertrain), Martin Verschoor, believes progress in downsizing won't slow—but it will change: "So far we have seen very successful downsized engines that are enabled by pressure charging and variable valve control. The benefits on a gasoline engine of keeping the load high and the throttles open are so significant that I can't see this trend abating, but I can see diverging technical strategies, with different solutions for different types of vehicles."

While there is a variety of clever solutions proposed by the pressure-charging specialists, he believes that electrification of the powertrain will provide an attractive answer for all but the lowest-cost vehicles: "Testing shows that Delphi's new 48V electrical system for mild hybrids delivers 50% to 70% of the CO_2 and fuel economy benefit of a full hybrid for just 30% of the cost. But the advantages run deeper than that: with a 48V electrical machine, you have enough instant traction energy to fill the low-rpm torque gaps of a highly-downsized engine. We see 48V as an enabler for continuing downsizing for the majority of passenger cars, removing the need for some of the additional complexity that could slow progress in this field."



Downsize a "three," even? Deactivating one cylinder in Ford's 1.0-L inline 3-cylinder, effectively turning it into a 670-cc twin under certain load conditions, will improve fuel consumption and lower emissions.

'Clever controls'

New control strategies that take advantage of very powerful yet affordable computing are a vital part of 48V systems, he explains. What he terms "clever control" is being used to release further downsizing opportunities through areas like variable valve control and cylinder deactivation techniques that can also be used to enhance Miller-cycle operation, too.

An additional consideration is NOx, which can be more of an issue with aggressively downsized engines. Says Verschoor: "This could lead to some engine designers deciding to increase capacity. "However, for the majority, the benefits of downsizing are so well-established, I can't see the overall trend changing significantly."

But there are limits to downsizing, stresses **Federal Mogul** Powertrain Chief Technology Officer, Gian Maria Olivetti, who recently stated: "We have reached the end of extreme downsizing. It is difficult to imagine a certain level of power with fewer than three cylinders. Also, (Europe's) Real Driving Cycle (RDE) is not helpful for further downsizing because extreme downsized engines—both gasoline and diesel—run at really high loads, so their emissions and fuel economy are compromised."

Advances outside the engine

Oil companies also have views on downsizing/rightsizing. **Castrol**, a subsidiary of global oil company **BP**, recently launched its advanced NEXCEL oil-change system. Nexcel's Chief Engineer, Oliver Taylor, said the company is confident of a strong future for ICEs. "The increased loading present in the WLTC (Worldwide harmonized Light Vehicles Test Cycle) and RDE cycles in Europe means that manufacturers will review what the 'right' size approach is for modern engines;

"We have reached the end of extreme downsizing," said Federal Mogul Powertrain Chief Technology Officer, Gian Maria Olivetti.

some will be downsized, some may be bigger. The trend now is rightsizing.

"Engine development is driven by the need to reduce emissions. Increasing the effective engine load level through downsizing reduces the relative magnitude of friction present and, for a spark-ignition engine, reduces the pumping work at part-load. We expect to see increasing levels of sophistication as mild-hybrid control systems mitigate the transient loads on the ICE, enabling tighter control of NOx and PM (particulate matter)."

The UK company **Torotrak** has developed a CVT-controlled variable supercharger system called V-Charge (*Automotive Engineering*, March 2017, p.13) to make engines downsized to only a liter return performance similar to a 1.5-L, with fuel consumption of that engine significantly reduced.

"For some time, we have raised concerns about the sole use of turbochargers for the increasing levels of boost being employed on downsized engines, both gasoline and diesel," said Torotrak Group's Chief Technology Officer, Doug Cross. "Turbocharging creates higher combustion temperatures and pressures that increase the formation of NOx and introduces additional thermal mass into the exhaust stream, which makes it harder to maintain catalyst temperature when running at part-throttle. It is also least effective at matching intake charge delivery against demand when operating at low engine speeds and torque levels that reflect the driving style of owners seeking maximum economy."

Cross is confident that variable supercharging—instead of turbocharging—in the lower engine speed range (but retaining a larger turbo for higher engine speeds) offers significant advantages, improving control of intake charge delivery while maintaining adequate exhaust temperatures. "Combined with aftertreatment using selective catalytic reduction (SCR), this approach enables effective downsizing while meeting lower NOx and particulate targets."

Stuart Birch

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New Lexus LC brings new platform, hybrid system

Riding on a 113-in/2870-mm wheelbase, the new Lexus LC benefits from extensive underbody CFD analysis and development.

For Chief Engineer Koji Sato, the greatest engineering achievement on the 2018 **Lexus** LC is the coupe's sharp and refined driving dynamics.

To help achieve that crisp performance, engineers focused on finding the ideal inertia specifications, including a low center of gravity that's close to the driver's H-point. They designed the LC's body structure with the highest torsional stiffness of any Lexus and they developed a new suspension design.

"We had to be creative with the suspension architecture so the suspension tower height would be kept low while still being able to house large 21-in wheels," Sato explained. "We also focused on the design and suspension pick up points to not only lower the height but also to enhance the rigidity.

"So we applied a multi-link suspension," he said. "It took six months to find the best geometry of the suspension arms." Veteran **Toyota** engineer Sato and Lexus product experts spoke with *Automotive Engineering* during a February media preview of the all-new LC 500 and the hybrid LC 500h on the Big Island of Hawai'i.

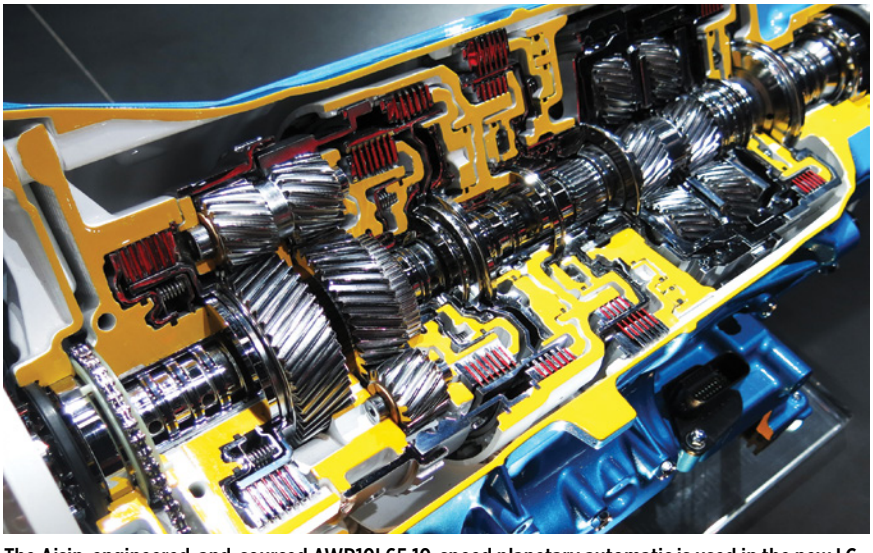
Lightweight materials mix

Both versions of the visually captivating LC coupe debut Toyota's GA-L (Global Architecture-Luxury) front engine/rear drive platform for high-performance/luxury models, for global markets. The car's design is exceedingly close to the LF-LC concept shown at the 2012 Detroit auto show. But what's unseen is equally intriguing. The coupe's underbody went through extensive CFD simulation and wind tunnel testing for downforce and diffuser design evaluations.

"We needed to create suitable airflow in correlation to the air pressure being produced from the upper body towards the rear of the vehicle," Sato explained. "The underbody is obviously covered to have optimum airflow. We also have created an air duct in the front part of the rear wheel to reduce turbulent air flowing through the door side panels as well as the wheel housing."

The 113-in (2870-mm) wheelbase LC rides on run-flat tires supplied by **Bridgestone**, **Dunlop** and **Michelin**. Eliminating the need for a spare tire provided trunk space for the auxiliary battery and weight savings. LC's 4280-lb/1935-kg curb weight (4435-lb/2012-kg for hybrid version) derives from a mix of lightweight materials.

Front fenders, hood, and side door panels are aluminum. The die-cast aluminum front suspension towers were joined to steel via self-piercing rivets, a Lexus first. Carbon fiber reinforced plastic (CFRP) is used in the inner door panels and trunk lid. And a CFRP roof is available with the performance package, which also adds an active rear spoiler. The platform extensively uses ultra-high-tensile steel.



The Aisin-engineered-and-sourced AWR10L65 10-speed planetary automatic is used in the new LC coupes. (Lindsay Brooke photo)

Aisin 10-speed, new Hybrid system

The normally aspired Toyota 5.0-L gasoline V8 delivers a rated 471 hp (351 kW) at 7100 rpm and 398 lb·ft (539 N·m) at 4800 rpm. This engine is based off that used in the Lexus RC F sports coupe and the GS F sedan. "The intake/exhaust valve design and layout as well

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as the exhaust pipe configuration is newly developed for the LC," noted Sato, and the ECU is remapped. A sound generator fine-tunes the V8's intake noise that is piped to the cabin.

The V8 mates to **Aisin**'s new Direct Shift 10-speed planetary automatic with a full range lock-up control torque converter. "By having 10 gear sets to work with, it allowed for a quiet and comfortable drive at higher cruising speed, while still being able to enjoy a wide range of gearshifts through acceleration and deceleration," Sato explained.

The transmission's AI-SHIFT control, a Lexus first application, selects the optimum gear based on vehicle speed, accelerator use and via an estimation of the driver's preferences/intentions. LC is the first in its segment with a 10-speed automatic, with 8- and 9-speed units predominating.

LC 500h debuts Lexus' first Multi Stage Hybrid System. Unlike a conventional full hybrid powertrain in which engine output is amplified by an electric motor's reduction gear, the multi-stage system amplifies the electric motor via the automatic transmission.

The multi-stage shift device changes the output in four stages: first/second/third simulated gears to match the first mechanical gear; fourth/fifth/sixth virtual gears to match the second mechanical gear; seventh/eighth/ninth simulated gears to match the third mechanical gear; and an overdrive virtual gear ratio to match the fourth mechanical gear.

LC can be outfitted in 20-in cast aluminum wheels, or the optional 20-in and 21-in forged aluminum alloy wheels.

According to Bill Kwong, a Lexus College technical expert, "The multi-stage aspect is akin to a transfer case or an automatic differential." The LC hybrid driver can opt for manual gear selection using the steering-wheel-mounted magnesium alloy paddle shifters that provide a Lexus hybrid-first 'manual-hold' feature.

LC 500h uses a 3.5-L gasoline V6, similar to the current RX 450h crossover vehicle. It's rated at 295 hp (219 kW) at 6600 rpm and 256 lb·ft (347 N·m) at 4900 rpm. The "dual injection" system uses both direct and port injectors, with variable valve timing with intelligence wide (VVT-iW) on the intake and VVT-i on the exhaust.

"The previous hybrid system could only go into Atkinson cycle," Kwong said. "But now with both Atkinson cycle and auto-cycle, it's possible to have wide, broad cam-phasing." This new hybrid system essentially responds to driver inputs without a lag between rpm and vehicle speed.

There are two permanent-magnet synchronous motors on the LC hybrid. The primary generator (Motor Generator 1/MG1) handles engine start and controls engine speed. Motor Generator 2 (MG2) drives the rear wheels and handles regenerative braking. Positioned between the rear seats and the luggage compartment are 84 lithium-ion cells producing 310.8 V. This Li-ion battery pack, a first for a Lexus vehicle, is 20% smaller than the NiMh pack in the Lexus LS.

The LC 500 and 500h will be sold globally with U.S. sales beginning in spring 2017.

"We're forecasting that the sales split will be 90% for the LC 500 and 10% for the LC 500h," said Brian Bolain, Lexus' General Manager Product & Consumer Marketing. MSRP for LC 500 is $92,000 and $96,510 for the LC 500h.

Kami Buchholz

LC Chief Engineer Koji Sato was involved in the process of developing a new seat design that underwent 50 test cycles.

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805-hp Mercedes-AMG GT Concept hybrid heralds production model

The 600-kW (805-hp) hybrid 4-door **Mercedes-AMG** GT unveiled at the 2017 Geneva motor show may be a concept now, but its production line is being readied.

The GT Concept, as it is currently designated, incorporates an operating strategy cascaded down from the Mercedes **Petronas** AMG Formula 1 car's powerpack. It links to road cars via AMG HPP (High Performance Production).

A 5-door fastback sports sedan, the GT Concept is powered by a 4.0-L bi-turbo gasoline V8 and what AMG Chairman Tobias Moers describes as "a high performance" electric motor. The GT Concept and Hypercar will have modular, compact, upwardly scalable, energy-dense lightweight batteries, the whole system "intelligently networked," he noted. This provides a total system output of up to 600 kW, delivering a claimed sub-3-s 0-100 km/h (0-62-mph) dash time.

Distinctive rear of the Mercedes-AMG GT Concept includes a diffuser and very prominent exhaust tailpipe.

"The energy storage unit is more powerful than conventional hybrid batteries," Moers said. When necessary, the battery charge is topped up by the V8 and via brake-energy recuperation.

The car signals the future at AMG,

Is the Mercedes-AMG GT Concept a sedan, coupe or sports car? No details yet regarding a Cd figure, but it looks very promising, particularly as cameras supplant regular rearview mirrors.

said Moers. "We are giving a preview of our third completely autonomously developed sports car. Like the AMG Hypercar, which we are presenting at the [2017] international motor show in Frankfurt, it illustrates how we are defining performance of the future at AMG." The limited production run Hypercar promises to be the first street-legal car with a F1 engine.

Mercedes-AMG plans what it calls "segment specific" hybrids. All its hybrids will be designated EQ Power+.

The GT Concept gets fully variable 4MATIC+ all-wheel drive, the electric motor driving the rear wheels. Torque vectoring is applied to all wheels.

By no means for the first time on a concept, the GT Concept abandons door mounted rear-view mirrors in favor of (as AMG refers to them) "aerodynamically favorable" miniature cameras, which it dubs "mirror cams." Mounted low down on the front fender, they look potentially vulnerable to both accidental damage and road dirt, but doubtless AMG engineers have solutions for both possibilities.

The concept is clearly a close relation of the 2-seat Mercedes-AMG GT but has its own identity. Its radiator grille with prominent bars is similar to that of the 1950s Panamericana 300 SL. Active grill shutters and side vents improve aerodynamic and thermal efficiencies.

The car has a carbon fiber rear diffuser (the material is used for other body elements, including the roof), and a centrally positioned exhaust tailpipe reminiscent of the Mercedes-AMG GT R. Carbon ceramic brakes are fitted.

The car's greenhouse is said to be "crouched and dynamic"; side windows are frameless. The vehicle is being alternately descrbed as a "4-door sports car" (previously used by **Nissan** for its Maxima) and as a "sports coupe," but more details of the Concept GT are expected to emerge on the run-up to production.

Stuart Birch

Renault claims Chevy Bolt-beating range for new Zoe EV

LG Chem's new Z.E.40 battery delivers a claimed 41 kW·h. The pack has 192 cells and 12 modules.

When switching on a pure electric car, the first thing any sensible driver will do is check the remaining estimated battery range. The figure displayed is often likely to create varying degrees of anxiety and/or trigger some mental arithmetic. But **Renault**'s message is all about confidence as it launches the latest hatchback 4-seat, 5-door Zoe R90 supermini EV.

Featuring a new **LG Chem** lithium-ion battery that delivers significantly greater energy density than used previously, the new R90 electric is expected to deliver just over 400 km (249 mi) on the NEDC (New European Driving Cycle), with an 'honest figure' of 300 km (186 mi) and a "worst case winter" range (with lights,

Renault's Zoe EV is an ultra compact 5-door 4/5-seat family car, with a claimed practical range of some 300 km.

heater and wipers on full blast) of 200 km (124 mi).

If those claims by Renault are validated, the new Zoe will offer the longest range outside of **Tesla** and will beat the current non-luxury EV champ, the 2017 **Chevrolet** Bolt EV. The Bolt carries an EPA rating of 238 mi (383 km) and Bolt owners in southern California have squeezed over 300 mi (483 km) range on a single charge.

LG Chem's new Z.E.40 battery delivers a claimed 41 kW·h. Assembled at Renault's Flins, France facility, the Z.E. 40 pack has 192 cells and 12 modules. The increase in output to 41 kW·h—claimed as the highest energy density EV battery currently in production—was achieved through revised chemistry and adding "active materials," state company engineers.

Renault has applied for 95 patents on the Zoe traction motor, which is rated at 220 N·m and 68 kW. The car is claimed to accelerate to 100 km/h (62 mph) in 13.5 s and can reach a top speed of 135 km/h (84 mph). Curb weight is 1468 kg (3236 lb). On the road, the car's power feels adequate, as judged by the author in a test drive, but it does not have the snappy tip-in that some EVs provide.

The Zoe is fitted with a heat pump as standard, which uses about three times less energy than a regular HVAC system for an equivalent level of heating, claims Renault. The car has an Eco mode said to enhance range by around 10%.

Renault derives its road EV technology from the company's involvement in e-motorsport. The e-dams team, highly successful in the **FIA** Formula E Championship, is managed by four times F1 World Champion Alain Prost and e-dams founder, Jean-Paul Driot.

The test program for the Zoe includes experiencing -20°C in Sweden to check battery performance. The car was also driven through 40 cm (16 in) of water at 10 km/h (6.2 mph), totally immersing the battery.

Stuart Birch

CLARITY OF PURPOSE

With the 2017 Clarity Fuel Cell, Honda gets serious about fuel-cell power and a hydrogen infrastructure.

by Bill Visnic

A packaging marvel: Honda said the Clarity Fuel Cell is the world's first fuel-cell-powered sedan to package the powertrain—including the fuel-cell "stack"—entirely under the hood (image: Honda).

We expected some pop and sizzle–at least something vaguely adventurous—to mark the occasion of refueling **Honda**'s all-new 2017 Clarity Fuel Cell sedan with compressed hydrogen pumped in at a heady 10,153 psi (700 bar).

Instead, standing under the stylish translucent sunshade protecting this hydrogen refueling station—one of 26 such public facilities currently operating in Southern California—the experience is exactly how Honda and hydrogen-fuel interests want it to be: nearly indistinguishable from the upscale gas station a stone's throw away.

Even the time to fully fill the Clarity Fuel Cell is about the same, maybe five or six minutes to fully replenish the fuel-cell car's two-tank capacity of 141 liters (37.3 gal). A few minutes and you're on your way in this large and comfortable sedan for another maximum of 366 miles (589 km). We cruise the California freeways and breeze through snaky backroads in utter silence and with an unassailable refinement that, if we shut our eyes, convinces us the Clarity Fuel Cell could be an all-electric Accord that Honda's had in production for years. The EPA-estimates this all happens at a combined fuel-economy rating of 68 mpg (3.5 L/100 km).

So what's *not* to like about these fuel-cell cars, anyway?

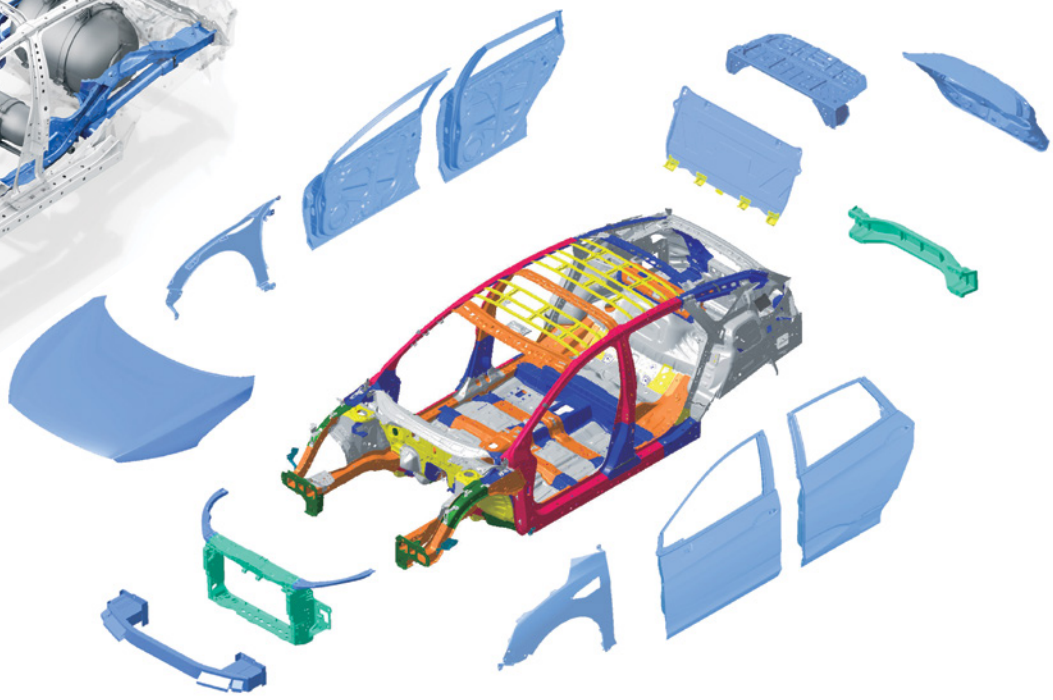
Technical challenges resolved

Kiyoshi Shimizu, chief engineer and development leader for the 2017 Clarity Fuel Cell, has led Honda's FCV Powertrain Development Dept. since 1997. He seems almost the personification of why the new Clarity Fuel Cell need make no excuses as a fully viable "everyday" vehicle. The company's dogged decades of R&D have progressed fuel-cell technology from 1998's "one-and-a-half-passenger" minivan he almost sheepishly describes as a "chemical plant on wheels" to today's Clarity that packages the entire powertrain—fuel-cell stack, drive unit and all associated power and control electronics—neatly under the hood. The entire propulsion system requires less physical space than Honda's 3.5L V-6.

Several innovations combined to reduce drivetrain size for the 2017 Clarity Fuel Cell, chiefly in the fuel-cell stack and the AC synchronous propulsion motor (image: Honda).

Honda claims that tidy packaging is a world-first, and considering arch-rival Toyota's Mirai is the only other production FCV sedan on the road, we won't dispute it: Mirai locates the fuel-cell stack under the passenger-compartment floor, much like the Clarity Fuel Cell's predecessor, the FCX Clarity, launched in 1998. The only other series-production FCV offered for sale to the public is **Hyundai**'s Tucson Fuel Cell, although Hyundai recently revealed a concept crossover model using fourth-generation fuel-cell technology that the company promises will impart a 2018 production crossover with 800 km (497 mi) of driving range.

An all-new platform designed for Honda's three-model family of electrified Clarity variants incorporates a cabin-space-maximizing "straight frame" configuration that aids packaging and is claimed to impart better crashworthiness. For the Clarity Fuel Cell, the platform also was specially designed to accomodate the car's twin hydrogen storage tanks (image: Honda).



The 2017 Clarity Fuel Cell mixes a variety of materials to cut weight in the suspension, structure and body; the red and orange sections are claimed to be the world's first use of high-formability high-tensile steel for automotive components. The green parts are hybrid plastic materials; the glass-fiber reinforced plastic (GFRP) rear bumper beam is said to be a first-ever use of the material in this high-impact area (image: Honda).

As the Clarity Fuel Cell's almost miraculous packaging demonstrates, the eight years between fuel-cell generations have delivered demonstrable progress in almost every sense.

The powertrain's packaging advance—including a 34% cut in motor height—comes from several development areas, chief being a 30% reduction in the number of cells in the stack. The new cells themselves are 20% thinner. And thanks to the new stack design, the unit now can be situated horizontally rather than vertically.

Despite the decrease in the number of cells, each now has 1.5 times more electrical output, for a total of 103 kW, or a power density of 3.1 kW for each of the stack's 33L of volume. More voltage from the stack means more power available to the traction motor.

Drivetrain: more power, less noise

But while engineers aimed to improve system power and efficiency, they were similarly bent on cutting noise, both from the "intake" portion of the fuel cell and the drive unit itself.

First, oxygen supply is critical to allow the more power-dense fuel-cell stack to do its job; a considerable advance—both technically and in terms of NVH—comes from the adoption of a new, electrically-driven two-stage air compressor to shove air into the stack. Not only does this ICE-type turbocharger produce less sound, and of a higher frequency that can be muffled by a simpler silencer than the former Roots-style compressor—but it pushes 1.7 times the air volume. The compressor body is about 40% smaller, too.

The quiet and more-powerful electric turbocharger is an energy-hungry devil, though: chief engineer Shimizu told *Automotive Engineering* it typically might draw between 1-2 kW of power. But the heightened energy density of the new fuel-cell stack allowed for the draw attributable to the electric turbo, a joint development between Honda and "a supplier" Shimizu smilingly would not name.

Also new to the Clarity Fuel Cell's powertrain is a "fuel-cell voltage control unit," a 4-inch-thick booster (and the uppermost component one sees when lifting the hood) that steps up power from the cell stack to a maximum of 500 volts via a silicon-carbide power semiconductor material. The design vastly improves switching frequency while allowing a much-smaller heat sink than would a more-conventional silicon-only power semiconductor.

The upgraded 500V input—the most power the previous FCX Clarity fuel-cell stack could deliver was 330V—to the AC synchronous electric motor means its power output is hiked by 30% to 174 hp, while torque climbs to a robust 221 lb·ft (300 N·m) compared to the previous 189 lb·ft (256 N·m). Maximum motor rpm also is increased slightly from 12,500 rpm to 13,000 rpm and top speed climbs 4 mph to 103 mph (166 km/h).

The motor itself enjoyed incisive development tweaks to cut noise. The rotor now is sliced into four sections instead of two, which Honda said reduces torque fluctuation, while the stator is optimized to reduce vibration and the motor housing has additional structural ribs. Honda calculates that motor noise transmitted to the cabin at 0.2 *g* of acceleration is reduced by 25%.

The quieted motor and the new electric turbocharger team to all but nullify an NVH bugaboo that has lingered for most FCVs: loud compressor noise and motor whine. *Automotive Engineering*'s hard

CLARITY OF PURPOSE

Wide collaborations aim to advance the fuel-cell future

Fuel cell technology has come a long way since 2003, when President George W. Bush in his State of the Union address issued a call-to-action for U.S. engineers and scientists to develop fuel-cell vehicles, "so that the first car driven by a child born today could be powered by hydrogen and pollution free."

Bush's policy speech triggered significant R&D spending by automakers, suppliers and the federal government in hydrogen storage systems, H_2 transportation solutions and fuel-cell stack development. At the time, **Daimler** AG and **General Motors** were already in the vanguard of stack R&D and vehicle demonstrations, GM having built a leadership position in fuel-cell-related intellectual property since its pioneering 1960s work related to the U.S. space program.

Meanwhile, Honda, **Toyota** and **Hyundai** joined the incumbents, driven by California's zero-emission vehicle mandate. Key specialist suppliers increased their efforts to find lower-cost alternatives to precious-metal content in the stack and investigated reduced-NVH solutions for the stacks' noisy air-delivery systems. Stack performance, durability and reliability leaped forward impressively in the next decade.

Finding lower-cost alternatives to spiral-wound composite, cylindrical pressure tanks for on-board H_2 storage remains an ongoing R&D focus, according to Charlie Freese, Executive Director of GM's global fuel cell business (with its 2017 Clarity Fuel Cell, Honda aims at this development bogey with a world's first aluminum-lined cylinder). Besides its collaboration with Honda to develop and manufacture automotive fuel cells (http://articles.sae.org/15234/) GM also is working with the U.S. Army on a fuel cell demonstrator (http://articles.sae.org/14473/) while emergent truck maker Nikola Motor is building a Class-8 semi-tractor.

One of about 26 hydrogen fueling pumps currently in operation in southern California. Automakers and public and private entities have collaborated to create a viable hydrogen refueling network in California and plan to expand to a national footprint (image: Bill Visnic)

Mobility-industry engineers and planners realize that despite the EPA's recent decision to re-open the Mid-Term Review of 2025 CAFE standards, California won't budge on its ZEV standards. They reckon the industry will need alternatives to battery EVs if ZEVs are to make up roughly 15% of all California auto sales by 2025; the current share is stalled at 3%.

Sales of the Clarity Fuel Cell, the Toyota Mirai and FCVs from Hyundai and potentially GM will deliver emission credits under the **California Air Resources Board**'s complex credit scheme. One sale of an FCV is worth nine credits, compared to four credits currently given for each battery-electric Tesla Model S sold and three credits for each Nissan Leaf. The credits are worth thousands of dollars each, "offsets" that enable full-line OEMs to sell their combustion-engined vehicles in high volume in North America's largest vehicle market.

"They're hedging their bets and that's [California] the reason," observed Egil Juliussen, Ph.D, Director of Research at **IHS Markit**. "The fuel cell has made very good advancements lately, but the investments and overall momentum in the industry for improving lithium battery technology are so large, it will be very difficult for fuel cells to catch up with that."

Nonetheless, Dr. Juliussen noted that FCV fueling times equivalent to those of liquid-fueled vehicles is a major selling point compared with battery EVs. "Fuel-cell vehicles will have some market share over time," he asserted.

Fueling infrastructure continues to be the main hurdle for FCVs, many experts conclude. California currently has 26 operating public H_2 fueling stations with 40 more scheduled to come online by the end of 2018, according to Honda. The current target is 100 stations online in the state by 2020; all will be funded by tax revenues.

Despite the infrastructure's slow growth compared with EV charging, other industry players have recently entered the FCV arena. **Nissan** and **Magna** are investigating using hydrogen fuel cells rather than ICEs as hybrid range extenders. Nissan will soon introduce such a propulsion system, in partnership with fuel-cell maker Symbio, into the European taxi market. The Nissan e-NV200 electric van will offer three-minute refueling time for 3.8 kg of H_2 at 700 bar (10,152 psi).

Magna Steyr also has developed a fuel cell range-extender concept, based on a **Mercedes-Benz** Viano minivan. Its downsized fuel-cell stack supplied by Proton Motor is rated at 30 kW, compared to 103 kW for the Clarity Fuel Cell. One potential customer for such a production vehicle could be urban delivery companies that don't want to devote excess time to recharging EV batteries. With electric front-axle drive, the Magna van's claimed range is 350 km (217 mi), about 70 km (43 mi) of which can be on battery power alone.

Lindsay Brooke and Bill Visnic

standing-start acceleration could wring little more than a high-pitched whine in the cabin, nearly inaudible even with the entertainment system turned off. The same was true for floored-throttle roll-on acceleration at freeway speeds. This powertrain is all but noiseless.

New underpinnings, mass-optimization innovations

The 2017 Clarity Fuel Cell's cutting-edge driveline propels an all-new platform that Honda doesn't seem to be calling anything in particular, but said its fundamental "straight frames" structure was designed to maximize cabin space, cut weight and deliver optimized driving dynamics for a fuel-cell vehicle (and the pending battery-electric and hybrid-electric Clarity-family variants). Designed specifically to handle the weight of the aluminum-lined carbon-fiber/fiberglass storage tank (said to be a world-first), the new platform's center of gravity is some 4 in (10 cm) lower than an Accord Hybrid.

The four-wheel independent suspension flourishes a few clever lightweighting techniques: the front strut

A pleasing ultrasuede material made from recycled polyester covers much of the dashboard and door-panel areas, while Honda's new-generation gear-selector layout is packaged in a unique center-console surround (image: Honda).

Dimensionally similar to Honda's Accord midsize sedan and competitor Toyota's fuel-cell-powered Mirai, the Clarity Fuel Cell feels spacious inside and has reasonably brisk acceleration that belies its 4134-lb curb weight (image: Honda).

setup uses forged-aluminum lower arms that are 30% lighter than a common pressed-steel arm and hollowing the knuckle saves 10%. At the rear, the multilink arrangement's arms all are aluminum (worth a 40% cut compared with steel) and the tie rods come from what Honda said is the world's first high-strength aluminum forging, allowing the rods to be 20% lighter than a conventional aluminum forging.

Another world-first for the Clarity Fuel Cell: a hollow die-cast aluminum front subframe eliminates the welding of multiple pieces and saves 20% in weight; the technique, borrowed from motorcycle-frame development, creates a seamless and exceptionally rigid structure.

Want some more claimed world-firsts? Look to the Clarity Fuel Cell's body, where Honda has the first glass-fiber reinforced plastic (GFRP) rear bumper beam. Meanwhile, there's a "hybrid" plastic bulkhead at the front that replaces steel and 40% of the vehicle's platform is comprised of super-high-tensile steel; the company said the car marks the world's first (again) use of high-formability 980 MPa-class steel for automotive application. Along with aluminum body panels and other lightweight advanced materials, the Clarity Fuel Cell's structure is claimed to be stronger than that of a conventional midsize sedan—yet 15% lighter.

In terms of size and weight, the Clarity Fuel Cell has a 108.3-in (2750-mm) wheelbase (Honda's Accord: 109.3) and is 192.7 in (4895 mm) in overall length, nearly the same as the Accord and also quite dimensionally similar to Toyota's Mirai, although the Clarity seats five and the Mirai is a 4-seater. The Honda fuel-cell sedan's interior volume is listed at 102 cubic feet and the most spacious Accord variant offers 103.2 cubic feet of passenger volume. The Clarity Fuel Cell weighs 4134 lb (1875 kg), while a typical automatic-transmission Accord is about 700 lb (318 kg) lighter.

In terms of size and utility, then, the 2017 Clarity Fuel Cell gives up nothing (okay, maybe some sheer trunk usability) to a conventional midsize sedan. But the green-oriented in California have further incentive: Honda's opening "deal" for this FCV is compelling: a $369/month lease for 36 months with $2500 down. But factor in a California HOV-lane sticker, the state's instant $5000 rebate and Honda's debit card for $15,000 worth of fuel over the lease term and the monthly out-of-pocket outlay is almost laughably skimpy. Many California dealers have waiting lists for the car that for now is being built in Tochigi, Japan, but is moving to a mass-production plant somewhere (the U.S., perhaps?) early next year, said a Honda source.

Ah, that fuel, that infrastructure

You'll find plenty of contradictory opinion about the environmental friendliness of hydrogen fuel. Critics say its production and subsequent compression is energy-intensive and balloons hydrogen's carbon profile (one prominent study concluded, however, the well-to-wheels CO_2 emissions of hydrogen produced from natural gas for an FCV is approximately half that of gasoline). Chief engineer Shimizu told us the well-to-wheels energy efficiency of hydrogen derived from natural gas is better than a gasoline-fueled hybrid-electric vehicle—and reminds that an FCV has zero tailpipe emissions.

The carbon-dioxide argument will continue, but few can argue the almost complete lack of a national refueling network makes FCVs, for now, strictly a California "compliance" play (see sidebar, opposite). Stephen Ellis, Honda's sage veteran of alternative-fuel implementation, said fast refueling times, the Clarity Fuel Cell's plump driving range and the expanding "hydrogen highway" of conveniently-located refueling stations now make FCVs utterly practical in California. He then said to expect imminent news (likely at New York's auto show in April) regarding an initiative to extend refueling strategies to the northeastern U.S., where many states have adopted California's emissions standards.

After a full day's sampling of the refinement and brisk performance of the 2017 Clarity Fuel Cell, few could question the car's potential for mainstream acceptance. And Honda and other FCV proponents are correct in pointing out fuel-cell advantages over battery-electric vehicles. If and when hydrogen fuel becomes more widely available, the marvelously-developed Clarity Fuel Cell is proof the fuel-cell approach could give batteries a run for the money. ■

A challenge in developing closure systems is to create a bond between two different metals without encouraging corrosion to occur and rust to take over.

LIGHTWEIGHTING hinges on the details

Multi-material design approaches require careful integration of all adjacent constituents.

by Chris Needes and Hans-Jürgen Jäger

In the ongoing design and engineering crusade that is vehicle lightweighting, grams count. In some cases, tenths of a gram count. Regardless of how fuel price has moderated in the U.S. in recent years, the importance of global platforms and global markets means the drive to create more mass-efficient vehicle structures, subassemblies and components continues unabated.

Automakers are scrutinizing even the smallest parts in order to shed unnecessary weight on their final design.

The Multi-Material Lightweight Vehicle (MMLV), a concept collaboration by **Ford** and **Magna** under a project funded by the **U.S. Department of Energy**'s Vehicle Technologies Office, achieved nearly 25% overall vehicle weight savings, while increasing its fuel efficiency by 15% to 20%. These outstanding results were achieved by combining the aluminum-intensive structure with a variety of reinforced composites including carbon fiber and selective use of light metals such as magnesium and titanium. Other vehicle mass-optimization studies show similar opportunity.

Galvanic corrosion threat

Integrating MMLV principals into production vehicle programs at every level, including within major subsystems such as electrified propulsion systems, presents various challenges, noted Chris Needes and Hans-Jürgen Jäger, global market managers in the automotive chassis/powertrain and exterior areas, respectively, at **Saint-Gobain**.

"Multiple materials used within a small confine of space within systems such as a steering column, door hinge or motor stator, for example, can lead to an accelerated rate of corrosion and therefore risk damaging more expensive parts of the car over a shorter period of time—eliminating the benefits of weight saving in the short term," Needes explained.

Jäger uses the example of a closure-panel hinge. "There is the possibility that steel and aluminum will be interacting in a tight space. This could be due to the hinge straps (aluminum) playing the role of a cathode, the bearing and pin (often steel or steel elements) the anode, and together with an electrolyte you've created a battery—a perfect environment for accelerating corrosion."

The challenge, therefore, is to create a bind between two different metals without encouraging corrosion to occur and rust to take over. Needes noted that Saint-Gobain has invested heavily in R&D for multi-material applications in vehicle components and built considerable expertise in how they react with one another.

"In certain critical areas, such as: steering columns, door hinges and electric motor stator mounts, the use of innovative small, but important, parts can make a big difference to the overall mechanism performance."

Grams saved add up

Needes explained that in order to remove weight from the vehicle for the goal of reducing its emission and fuel-consumption footprint, his team first had to identify what he calls potential "sacrificial elements" where dissimilar materials can be used in place of heavier metals.

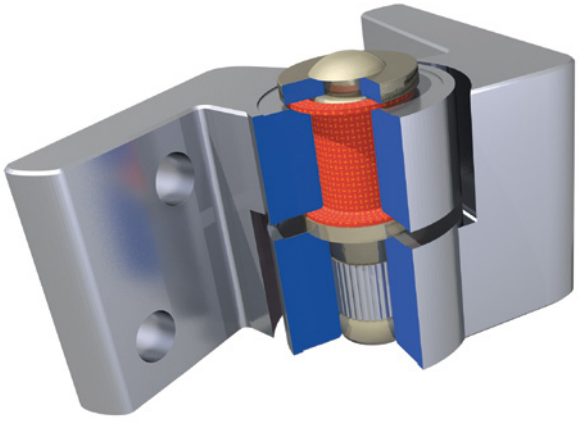
"The collapsible steering column, for instance, poses an ideal candidate for light weighting," he said, as it consists of interlocking shafts where steel can be replaced with aluminum. Specifically for this application, Saint-Gobain designed high-quality carbon steel-and-alloy-based tolerance rings. These radially-sprung component fasteners enable optimal joining between mating steering column shafts, thus enabling the use of dissimilar materials.

The tolerance rings' design also dismisses a further manufacture and customer concern during the light weighting of vehicles–noise.

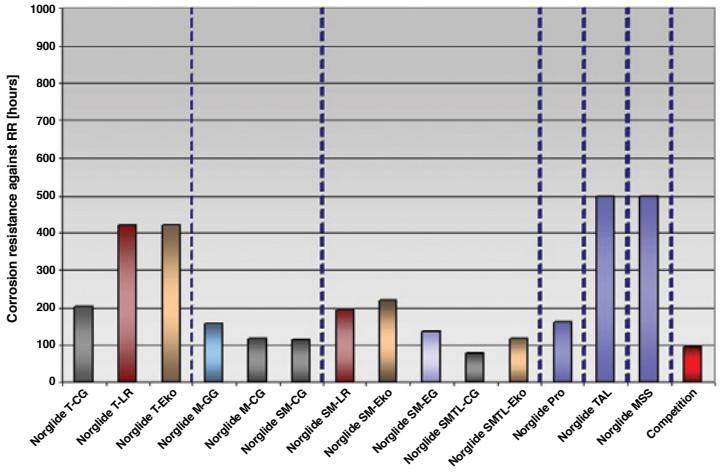
"By using specially developed tolerance rings we can ensure a perfect fit between steering shafts, which leads to reduced vibration, ensuring a noise-free environment inside the car," Needes asserted.

Tolerance rings are often used to replace heat-to-press methods and adhesives, for example, in electric motor stator mounts as a way to save weight by allowing the stator casing to be made of lighter aluminum. According to the Saint-Gobain experts, tolerance rings streamline assembly by simply being inserted around the stator and press fitted into housings.

Needes noted that a contemporary passenger vehicle can contain up to 25 electric motors. A few grams'



Composite hinge bearings with PTFE liners (Norglide shown) enable the use of lighter materials such as aluminum in the door, decklid, hood and other exterior hinges, resulting in up to a 40% lighter overall mechanism weight.



In ISO-certified tests, the new composite bearings have proven to offer the highest corrosion protection while simultaneously providing high load capabilities for a long life. Results show that Norglide bearings stand up to salt and moisture conditions well beyond their normal applications and more than other bearing types on the marketplace, the company claims. After 1,000 hours in salt spray tests, where galvanized steel or aluminium hinges housed the component, the bearings displayed no red rust at all, according to company engineers.

saved on each individual motor, multiplied by 25, adds up to significant aggregate mass savings.

PTFE's benefits in hinge design

The tolerance rings also compensate for differential expansion, greatly reducing the chance of assembly failure when dissimilar materials like steel and aluminum are used.

Where manufacturers can save on weight, they will—including in the doors, decklids, hoods and in particular, the hinges used for those closures. The number of closures on a typical passenger vehicle means the opportunity for weight saving can be substantial.

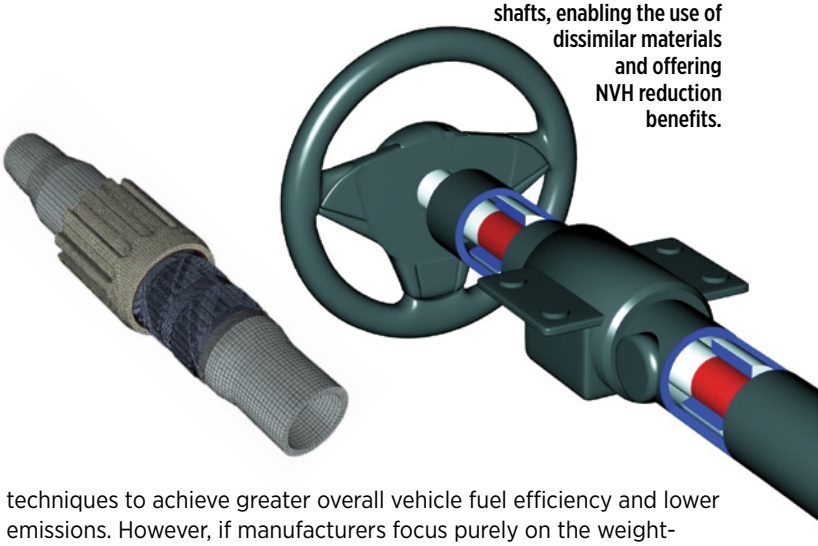
"In the car hinge application, automotive manufacturers and suppliers can now achieve up to a 40% weight saving of the total component compared to using purely steel parts, for example," observed Jäger.

He explained that the bearings in these components sit between the hinge pin and housing to ensure smooth movement when the door is opened and closed. As opposed to the conventional bearing, a composite bearing's Polytetrafluoroethylene (PTFE) liner (as used in Saint-Gobain's Norglide bearings) also compensates for any misalignment between the straps and the pin within the car hinge, ensuring smooth movement, he claimed.

Composite bearings in this application extend the lifetime of the hinge, preventing paint from chipping and eliminating red rust. In addition, when the vehicle is in use, the PTFE liner within the composite bearing compensates for tolerance variations, such as thermal expansion, ensuring the perfect fit between the hinge pin and the housing. The PTFE properties in the layer greatly reduce the risk of the door squeaking when opened or closed throughout the car's life cycle.

The multi-material vehicle is clearly a step forward in terms of optimizing material properties and joining techniques to achieve greater overall vehicle fuel efficiency and lower emissions. However, if manufacturers focus purely on the weight-reduction issue they run the risk of facing problems further down the line, such as the aforementioned corrosion and rust.

Collapsible steering columns are ideal candidates for lightweighting because their steel shafts can be replaced with aluminum. Saint-Gobain tolerance rings enable optimal joining between mating steering column shafts, enabling the use of dissimilar materials and offering NVH reduction benefits.



By collaborating with supplier partners and gaining an understanding of the bigger picture (including the most intricate details), OEMs can make the best use of their investment in multi-material vehicle lightweighting activities. ■

Chris Needes is Global Market Manager, Automotive Chassis, Norglide bearings and Rencol tolerance rings, Saint-Gobain and Hans-Jürgen Jäger is Global Market Manager, Automotive Exterior for the aforementioned product lines, Saint-Gobain.

Haptic feedback for gesture-control HMI

BMW has gesture control in production on its 7 and 5 Series cars. At CES17 the company unveiled a concept called HoloActive Touch (shown) which combines gesture control, head-up display and direct touchscreen operation. (BMW photo)

Mid-air gesture controls rely on sophisticated sensing to aid the human-machine interface and help keep drivers' eyes on the road.

by David Owen

Gesture control is becoming more commonplace in many of the devices we use in our daily lives, from games consoles, swiping and pinching on mobile phones, to point-of-sale devices such as ticketing systems in train stations. The automotive segment is already adopting gesture control for infotainment systems as well as serving as a human-machine interface (HMI) for subsystems such as the sunroof, climate control and audio.

BMW's latest 7 Series and 5 Series offer an HMI system that can detect four different gestures: setting the car's navigation, browsing apps and starting the audio, answering phone calls and controlling the on-board computer. **Volkswagen** last year announced gesture controls on its Golf and pledges to spread the technology across its model ranges. Other major OEMs have the technology in their product pipelines.

Early reviews of gesture controls from the road-test media have been a mixed bag. While the reviewers have been impressed with the technology, they've not been thoroughly pleased with the functionality. In the 7 Series, for example, the driver can change the audio volume via a hand-circle motion, answer or dismiss a phone call using a left and right swiping motion, and use a two-fingers-down swipe to affect a user-configurable setting.

For designers and engineers developing and integrating new HMI, one of the challenges is providing the driver with the ability to manipulate gesture-controlled equipment while driving, without taking his or her eyes off the road. The logical solution is in using virtual controls combined with mid-air haptic feedback. Future systems from **Ultrahaptics** could offer designs that are infinitely more flexible.

The missing link

How can gesture-controlled interfaces integrate with the automobile infotainment/comfort control system in both safe and simple ways which the driver can trust? Current forms of touchless gesture control fall short of the requirements for effective human-machine communication: Feedback.

Voice-controlled systems can be difficult to operate; often exact phases require memorization and long menu chains must be navigated to obtain the desired effect. Voice can have such a variation from one user to another that the recognition software can make mistakes when 'listening;' the result can be a very frustrated driver that defaults back to traditional controls.

Touch is a modern form of control and works to a point. The disadvantage is that drivers can lose sight of the road for precious seconds while manipulating the infotainment or comfort system controls. Again, it is often difficult to navigate multiple nested menus and options while driving safely.

Tried and true physical controls are becoming increasingly sophisticated with multi-function switches, navigation knobs and selection buttons. There is a lot of wiring and hardware for designers and engineers to consider here, not to mention packaging/real estate and placement.

Gesture control has become a simple and familiar approach to system control and is used quite well in many industries. Mid-air gesture control, most commonplace in gaming systems and virtual reality, is well suited for the automotive environment. While driving, the driver can maintain vigilance while manipulating vehicle amenities; one would seldom need to glance away from the road. The failure of mid-air gesture control lies in feedback to the user. The driver may never know where the controls are or whether the control was confirmed and executed. But that is about to change thanks to new developments.

Leap Motion Sensing is the key

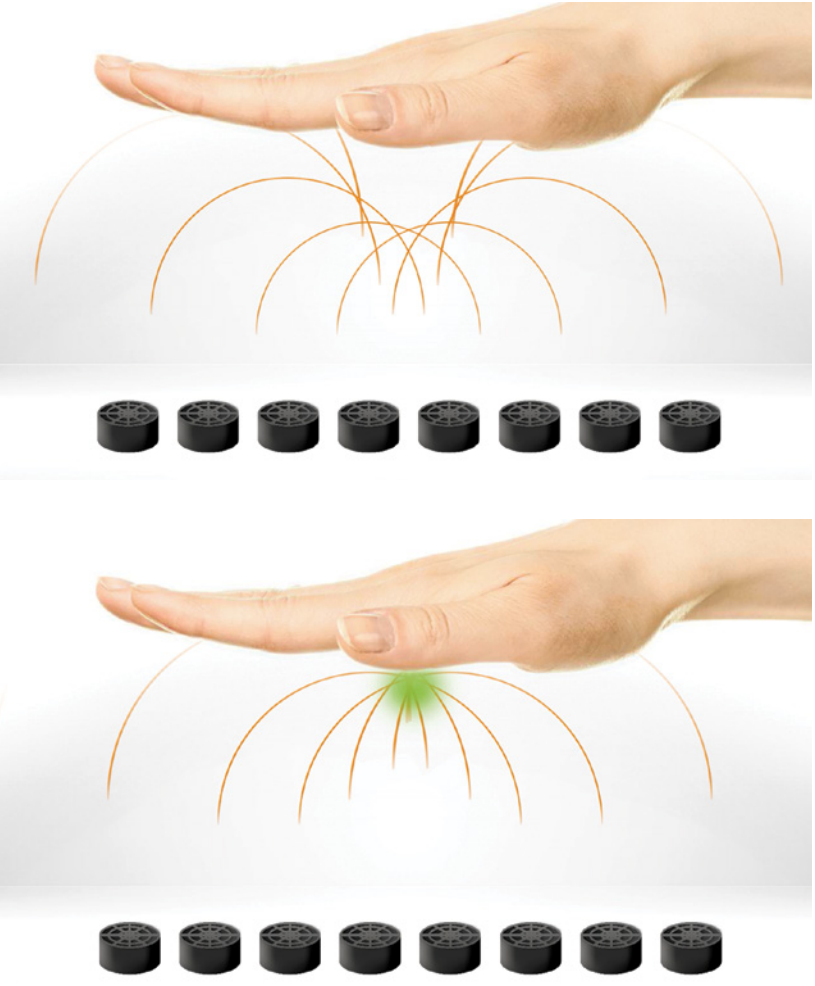
Ultrahaptics' mid-air haptic technology is currently unique in the industry. The haptic system allows a user to feel and manipulate virtual objects in mid-air as if they were touching real physical controls.

Currently, the system's motion tracking ability is mainly based on the Leap Motion sensor, which tracks your hand in free space. The tactile interface is generated by an array of ultrasonic transducers, similar to those used in the reverse-warning systems in most modern cars.

Having haptic feedback and touchless gesture control at a variety of vehicle HMI points enables the driver to keep eyes on the road.

The transducers generate ultrasonic waves at 40 kHz that cause constructive interference where the waves meet. These interference points can be manipulated to create invisible turbulence points that you can feel. The secret is, to control the touch sensation, sophisticated computer algorithms are implemented to manage this distortion by modulating the ultrasound beams.

Haptic feedback for gesture-control HMI



Ultrahaptics technology uses ultrasound transducers to create focal points which generate haptic feedback on the skin.

Using a 16 x 16 array, haptic sensations can be produced up to 1 m (3.2 ft) away, with a focal point accuracy of 8.6-mm (.33-in) diameter—within a finger's width.

The result of this modulation is that the user feels pressure where the beams focus on the hand. For example, a close-focused beam could simulate the sensation of a curved knob or button and a rapid modulation pattern would feel much like rubbing over a corrugated surface.

'Touchless infotainment/HMI'

In the case of automotive infotainment systems, progression toward gesture-based controls seems to be the natural industry evolution. Most consumers are already familiar with the control method. Mid-air gestures are well suited for the automotive environment. What might such gesture control look like?

One implementation might be to create an interaction zone somewhere central to the dashboard (in a traditional placement). If the driver passes their hand through an acoustic barrier, they could actively feel where the boundaries of the interaction zone are. They would then know they can make appropriate gestures to control the infotainment system.

Another method might look for the driver's hand. Imagine that the driver places their hand within an interaction zone, then using the systems cameras and image processing ability, a virtual control could be locked to the hand. While activating the ultrasonic transducers with a predefined gesture a virtual button or knob could be continually available to the driver, even if their hand moves around within the interaction zone.

With these new design concepts, HMI related to drive control of the HVAC, power windows, sunroof, seat adjustments, and other systems, could be easily integrated into the infotainment center creating a new kind of all-inclusive control nexus within the cockpit.

Development of integrated, stylish and easy to use infotainment and comfort control systems are now only limited by the designer's imagination. Displays could be set up in a conventional way, with a primary central screen that contains all the visual feedback the driver needs. This would effectively leave controls as familiar to drivers as they have been for years.

Alternatively, automotive interior designers could explore new approaches to in-car infotainment. With new curved screen technologies, display information could integrate into the dash almost anywhere, in almost any shape. The ultrasonic sensor array could be placed appropriately to allow for effective mid-air feedback, creating an innovative, modern interior design.

A designer could also go as far as exploring new technologies. Head-up display options may be viable, or perhaps laser display projectors within the windshield. All are plausible options due to mid-air gesture control and feedback. The result is virtually endless design possibilities.

Smart Design

The technology that Ultrahaptics has introduced may well transform the way in which vehicle drivers control the technology at their disposal. New users bringing their experience with gestures from other tech gadgets will help minimize learning curves and make systems more intuitive to use. Line-of-site would be less used, leaving the driver's eyes trained on the road rather than on various in-car distractions. And under the 'skin,' control systems can be made less complex regarding physical wiring, mechanical mechanisms, and the bill of material. ■

David Owen is VP Business Development at Ultrahaptics. A graduate engineer, he has held senior management roles with Philips, GEC Plessey and Ferranti.

Just another day in the Texas boonies with Jeep engineers and the new 2017 Compass Trailhawk.

The C-segment Compass's exterior form is inspired by the Jeep Grand Cherokee (image: Ron Sessions).

Road-efficient mud machine

Jeep's all-new 2017 Compass gets its go-anywhere guts from GKN's AWD system.

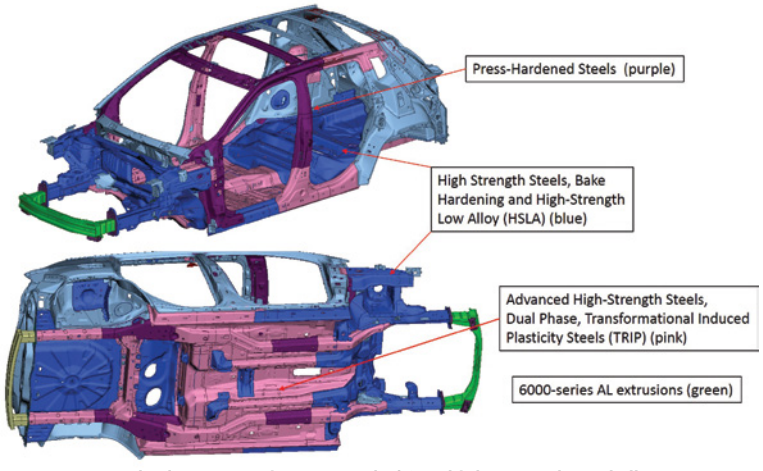
by Lindsay Brooke

Replacing the decade-old **Jeep** Compass is the new-for-2017 Compass, **FCA**'s (and Jeep's) first truly global vehicle program. Styled to resemble a slightly scaled-down Grand Cherokee, the new C-segment SUV is being produced in four plants (Mexico, China, India and Brazil) and offered in 17 powertrain combinations that include diesels and 6-speed manual gearboxes. The U.S. gets the manual 'box but not the diesel.

The new Compass is based on a stretched version of FCA's so-called "small-wide 4×4" vehicle architecture that also underpins the smaller Jeep Renegade. That platform is designed primarily as front-wheel-drive and accommodates nicely the axle-disconnect all-wheel-drive system supplied by **GKN** (see sidebar). As a "4.4-meter" car designed to fit European and other global parking spaces, the Jeep's overall length is 173 in (4394 mm), riding on a 103.8 in (2636 mm) wheelbase.

Power for U.S. models is the 2.4-L Multiair four also used in Renegade that's SAE rated at 180 hp (134 kW) and 175 lb·ft (237 N·m). Front-drive variants offer either the 6-speed manual transmission or optional 6-speed automatic transaxle that's sourced from **Hyundai**; 4×4 models get the **ZF**-designed 9-speed automatic.

There are four trim levels: Sport, Latitude, Limited, and the off-road-focused Trailhawk. *Automotive Engineering* spent a day on Texas Hill Country roads in a 4x4 Latitude, the volume model. While FCA's calibrators did a fine job making the Compass's new stop-start system unobtrusive in operation, the 9-speed is calibrated to hold its higher ratios rather than kick down and force the engine out of its fuel-consumption 'happy zone.' This creates disappointing throttle tip-in. Otherwise Compass's strut-type suspension with self-adjusting dampers gives it a nice taut feel on the road, with **Continental**-supplied electronic stability control. The chassis' dynamic experience is hampered only by slightly vague steering feel. Off-road, the Trailhawk—with 8.5 in (216 mm) of ground clearance—is a rock-crawlin' mud machine, bringing more capability here (for the roughly 10% of customers who want it) than most or all of its competitors.



Compass's body structure is composed of 65% high-strength steel alloys. The hood inner and outer are aluminum to meet global Ped Pro (pedestrian protection) impact regs. (images: FCA)

Efficient structure

The interior provides plenty of leg- and headroom for the 6-ft-3-in-tall author and overall the cabin has 27.2 ft^3 of utility with the seats deployed and 59.8 ft^3 with them folded down. A cabin highlight is FCA's latest UConnect infotainment module with larger 8.1-in screen.

One of Jeep's main selling points for this vehicle is its fuel economy: 22 city/30 mpg highway for 9-speed 4x4 models. According to veteran FCA engineer and vehicle line exec Art Anderson, credit for those numbers goes to a combination of features, including the 'smart' AWD system that delivers refined road manners with 20:1-ratio rock-crawling capability; newly-adopted (dual battery) stop-start system that's not offered on Renegade and a mass-efficient body structure composed of 65% high-strength steel alloys (illustration at left).

The hood panels are aluminum for weight savings as well as an enabler to meet European pedestrian protection regulations.

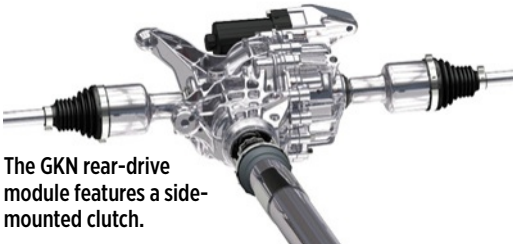
Building a single global team

Asked about the program's biggest challenge, Anderson responded: "It's truly global! Setting up the business practices and the 'rules' to manage development, the

Road-efficient mud machine

functional objectives, the money and the 10 million customer-equivalent development miles while preparing to launch in four plants on three continents (with diesel engine supply from a fourth, Europe) was what sets Compass apart from any previous program," he noted. It is remarkable to consider that no **Fiat** program in that marque's more than 100-year history, and no Jeep in that brand's 75 years, even came close to the world-ranging scope of the 2017 Compass.

GKN's axle-disconnect AWD completely decouples the rear axle for greater on-road fuel economy.



The GKN rear-drive module features a side-mounted clutch.

Many time zones separated the regional engineering teams. "We had a lot of 6-a.m. meetings and a lot of 6- to 10-p.m. meetings," Anderson explained. "We used Telepresence, which is a video phone call; we've had up to 7 offices from all around the globe connected on a single video discussion. And email remains reliable and effective for asking questions and getting answers across time zones."

While the Renegade program was "industrialized" across multiple regions, Compass was run as a single global team with industrializations in the four regions. Simply managing the logistics of shipping components and systems was daunting at first until FCA experts invented some new processes including "IRF", interregional flow, to move and keep track of material. "We've learned a lot about maintaining flow and keeping the supply chain running," Anderson said.

Change Control was another learning. The global team would meet on 'live' calls to discuss whether to agree to make a bill-of-material change or not. Typically these involved a specific feature request by a region; China's take rate on sunroofs is 90%, for example. "We did a good job in blending guidelines, rules and flexibility," Anderson said, echoing his praise of the entire global engineering team and FCA's suppliers in pulling it all off without a hitch. Speaking of hitches, Compass's towing capacity is rated at 2000 lb (907 kg).

GKN reprises its axle-disconnect AWD on Compass

"The system is very efficient and gives us a lot of capability," said Art Anderson about the new Jeep Compass's AWD setup supplied by GKN. It's an axle-disconnect system with a single-side friction clutch, fully disconnecting, on the rear-drive module (RDM). A single-speed power takeoff (PTU) is on the back end of the front axle, which is the vehicle's primary axle. The system disconnects at the rear differential and it also disconnects the propshaft via dog clutch at the PTU.

When the system engages it closes the clutch in the rear, spins the propshaft, and the dog clutch at the PTU engages. The four-mode 4x4 system (Auto, Snow, Mud, Sand) then is fully connected, all within hundreds of milliseconds.

To find out more about GKN's development, *Automotive Engineering* spoke with Ray Kuczera, GKN Senior Vice President Program Management and Strategy, and Jim Kulka, Global Chief Engineer, after our return from the Compass media launch in Feburary.

Was this system developed specifically for FCA?
Kulka: It was developed initially for the Jeep Renegade and is also used on the **Fiat** 500X. The full system was developed on that program and carried forward into the Compass. We tried to keep as much componentry common between Renegade and Compass. The Compass is a little wider and heavier and longer, so we had to make some minor adjustments to fit.

What was GKN's greatest challenge for this program?
Kuczera: That the Compass program is truly global. It's launching in four different regions, so we couldn't manufacture all that in one plant—we had to do it in three different locations. The PTU and RDM components are manufactured in Europe, North America and China. This is one of the great accomplishments of our collaboration with FCA: this is the first global program I'm aware of that's launched at virtually the same time in four regions. They're launching now in Mexico, Brazil, China and India will launch in a few months.

FCA picked the right partner because we have the right combination of technology and global footprint. We serve them in every market they're in.

Does GKN also supply propshafts to Compass?
Kulka: Basically this is the first AWD system for which we supply the entire component set from the transmission to the wheels; every component in the driveline along with the software and calibration. We did the PTU, the RDM, propshaft, all the side shafts. It's a first for GKN, but I believe it's the first for anybody. No one has had those components in production going to customers.
Kuczera: FCA made a great decision in not 'parting out' this system, and selecting a single supplier. What we're most proud of is we do the software and controls specifically for each vehicle—the 'brains' as well as the 'bones.' And FCA expects each vehicle to drive differently; the 500X has to drive like a Fiat and the Jeeps must have Jeep capability. Not only did we have to launch the hardware in a short timeframe [for Renegade, 500X and Compass] but we also had to do two different tunings to be aligned with each brand 'experience,' then do the tunings for each Compass trim level.

Did this program have mass-reduction bogies?
Kulka: Supplying every component in this AWD system allowed us to internally look at options of putting together a really streamlined package. We were able to remove the companion flanges on the PTU and RDM; we 'owned' every interface for every component. This allowed us to reduce mass for the whole system, instead of having to interface with different suppliers.

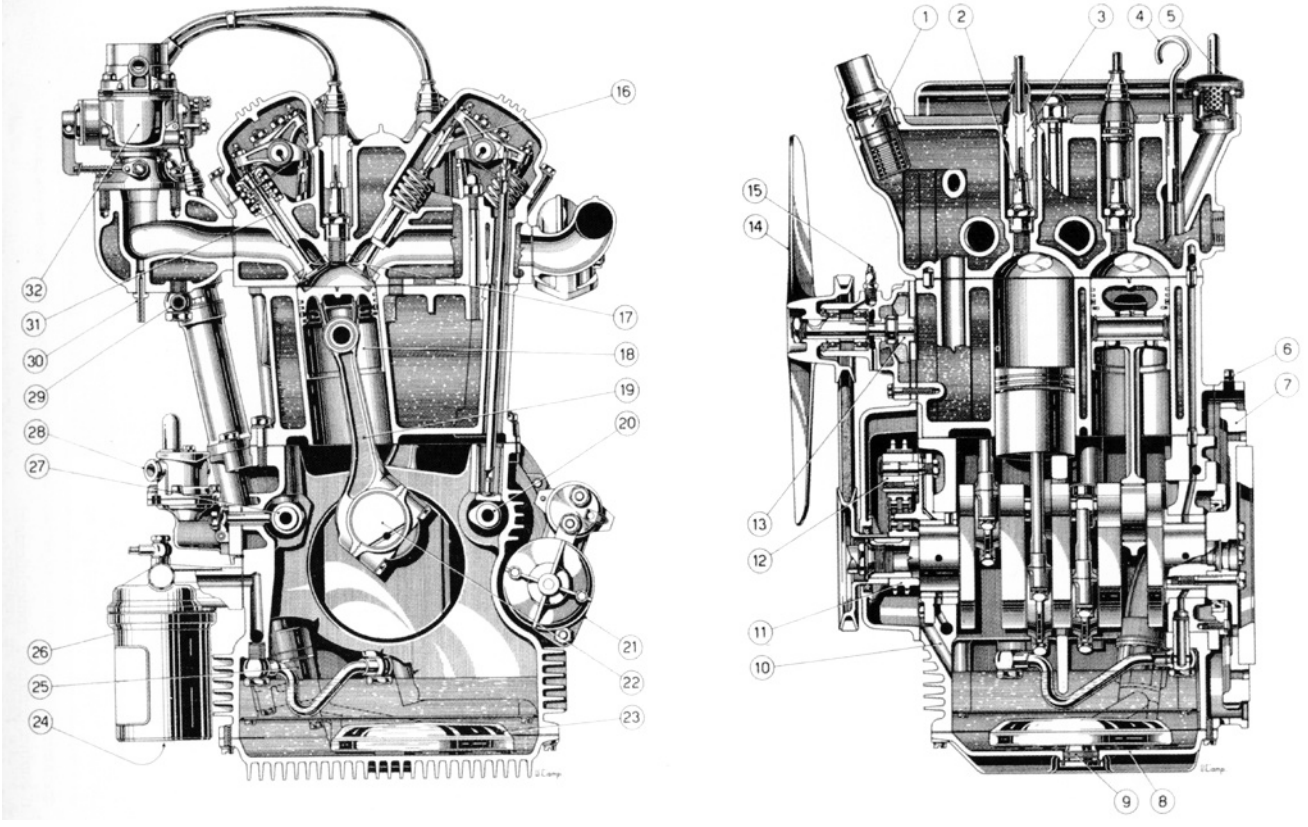
We were able to take out backlash and make every component as small and light as possible. It's a benchmark for a small SUV. ■

WCX17 WORLD CONGRESS EXPERIENCE

Past as prelude to the

SAE's Mobility History Committee brings a trove of knowledge—and cool technology.

by Lindsay Brooke



Lancia pioneered the compact, narrow-angle V4 engine from the 1920s through 1970s. Shown is an early 1950s 1.0-L Appia V4 with 10° cylinder bank. At WCX17, Italian-car expert Geoffrey Goldberg talks "Lancia: 60 Years of New Ideas & Unique Vee-Engines." (Ludvigsen Archive)

Engineers who have done patent searches know there's truth in the old saying: Few things are truly new under the sun.

First hybrid-electric car? 1899. First autonomous car tests? 1920s. First car with a cast-aluminum body structure? 1946. First aircraft to employ titanium in its initial design phase? 1952. First head-up display in aircraft? 1958. First drivable fuel-cell vehicle? 1966. First composite-plastic truck cab? 1967. The list of such pioneering developments is long indeed and rarely fails to surprise.

Presenting "the past as present, as prelude to the future" is the vision of **SAE**'s Mobility History Committee (MHC), one of the most experienced, enlightened and downright fun groups within SAE International. Among MHC members you'll find a trove of knowledge, culled from deep industry experience: veteran chief engineers, program managers, inventors and even internationally renowned authors (see sidebar).

Sure, the MHC bunch knows vintage and classic cars, trucks, aircraft, engines, drivelines and anything with wings, wheels, or tracks. Visit the MHC displays at WCX and other SAE events and activities and you'll see technological milestones. The committee, which meets monthly, has unique access to cool stuff. Ask them about how product development was done in years past and you'll likely pick up useful insights for solving tomorrow's challenges.

At WCX17, visitors cannot miss the MHC Display Area showcasing several historic cars specific to this year's MHC Technical Session subjects, explained committee chair Martin Rowell. "We've got fascinating

FUTURE

At WCX17, Jason Torchinsky talks steam power in his "Cars before Cars" presentation. On display in the MHC area will be the pinnacle of steam-car technology: a Stanley Model 740 (shown).

talks on tap at WCX, all on Thursday, April 6, at two Cobo Hall locations before and after lunch." They include:

10.00am-12.00pm, at the new "Learning Lab" on the Main Floor: Internationally-renowned MHC Member Karl Ludvigsen presents the subject of his new book, Reid Railton—Man of Speed. Italian-car expert Geoffrey Goldberg talks "Lancia: 60 Years of New Ideas & Unique Vee-Engines."

1.30-4.00pm, in Room NR331A, Marion Pottinger presents the "History of Characterizing Tire Forces & Moments Applied to a Vehicle;" Jason Torchinsky talks steam power in "Cars before Cars—A Survey of Automobiles before 1885." Chairman and CEO of **Link Engineering**, Roy Link, will discuss "The Evolution of the Brake Dynomometer." And, eminent engineer John Holmes will highlight "A Century of Environmental Technologies for Light Duty Vehicles."

In addition to WCX17, the MHC works with SAE's Commercial Vehicle and Aerospace sectors to organize similar historic-themed sessions at their big events. MHC this year also will display at the **Chrysler** Employees Motorsport Assn. festival in Auburn Hills, MI (June 10) and the **Concours d'Elegance of America** in Plymouth, MI (July 28-30). An evolving cooperation with the Historical Vehicle Association is ongoing, Rowell said. At all events, MHC promotes SAE's Education Programs including "A World in Motion" (AWIM).

New members are always welcome; visit the MHC Booth at WCX17 for details. ■

WCX17 WORLD CONGRESS EXPERIENCE

Past as prelude to the *FUTURE*

SAE INTERNATIONAL Mobility History Committee

A rare Railton will be displayed by the MHC during WCX17. Inspired by Reid Railton, this English sports car was built on an RHD Hudson chassis. With a modified Hudson straight-8 and lightweight body it was impressively quick.

57-year SAE member Ludvigsen brings world-renowned Mobility History to WCX17

Karl Ludvigsen is one of SAE's most famous and longest-serving members. The Michigan native and MHC stalwart is best known for his work over 50 years as an award-winning automotive journalist (including Editor of *Car and Driver*), author and historian with over 40 books to his credit. His *Porsche: Excellence Was Expected* is considered the benchmark of automotive marque histories. After attending **MIT** and the **Pratt Institute**, Ludvigsen was a **GM** designer in the mid-1950s, invented the practical Halon-gas fire suppression system for racing vehicles and served as a **Ford** Europe VP in the 1980s, among many other achievements.

As a prelude to his WCX17 presentation, Ludvigsen (who lives in the U.K.) and Editor Lindsay Brooke shared the following e-mail conversation:

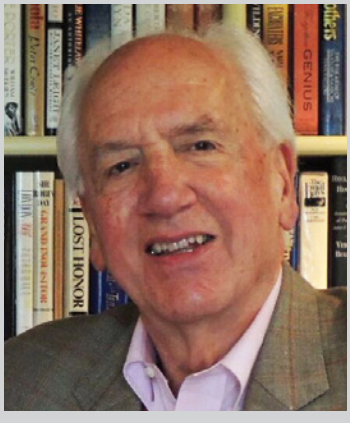
When did you become an SAE member, and what value have you derived from your membership over the years?

From an early age I was well aware of the SAE because my father, Elliot L. Ludvigsen, was a long-time member. He was vice president and general manager of transmission maker **Fuller**, which in 1958 became an **Eaton** property. He subsequently rose to the top of Eaton. So I was reading his *SAE Journal* every month, which certainly contributed to my life-long interest in automobiles. I have a certificate whose fine calligraphy says that I became an Associate Member of the SAE on January 26, 1960. Soon afterward I was promoted to full membership.

I recall giving a talk on Grand Prix car design to the SAE New York Section around that time. Over the years I organized several meetings, including one on sports-car design. That was as a member of the Vehicle Configuration Committee, which segued into the Aerodynamics Committee.

When the Wankel engine was a hot theme I was a member of the committee setting its original SAE standards. I was an outlier in the position I took, which was that all three chambers are constantly power-producing and thus all should be counted when assessing its swept volume. For obvious reasons this was not what Wankel-engine makers wanted but it is in fact the correct way to rate the engine. We ended up providing three different ways to rate the capacity!

Through the years I've kept a close eye on all SAE publications because they are grist for my mill as an author on topics like **Porsche** and the Corvette. The access provided to historical papers through the SAE's website is a blessing to an author who likes to know what went on in the olden days.

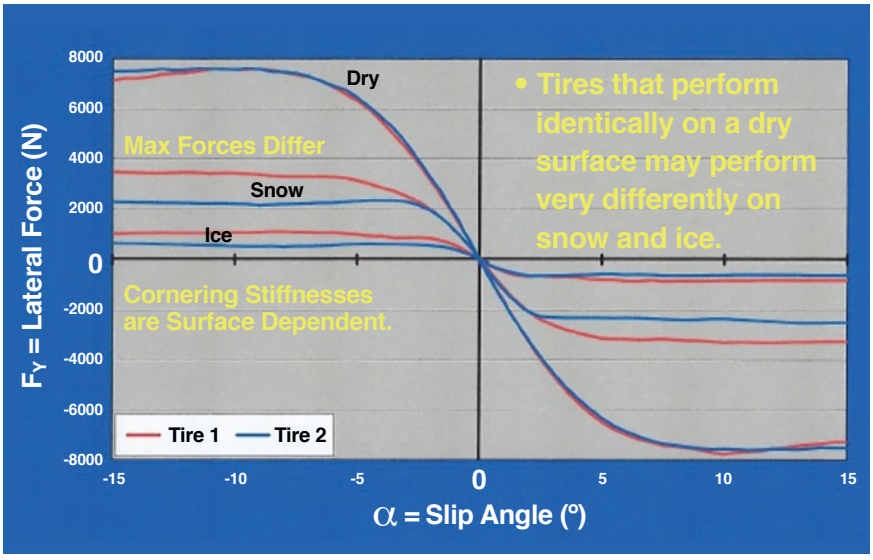


Karl Ludvigsen

You're one of the world's preeminent automotive historians. How many books have you written, and how do you decide your book topics?

Well, thanks for that. I probably would have written more books if I hadn't spent 10 years in the industry and another fifteen running a management consulting company. But these stints helped me understand better what goes on behind the scenes. I'd say the total of substantial books is around 40 plus several dozen picture books like the ones I've done for **Iconografix**.

The choice of topics swings back and forth between my notions, those of publishers and sometimes third parties. My book on V12 engines came about when I realized that the extensive files I bought from engineer Van Wyck Hewlett contained great info on early American twelves. Similarly I was inspired to



Veteran vehicle dynamics expert Marion Pottinger presents the "History of Characterizing Tire Forces & Moments Applied to a Vehicle" in room NR331A during WCX17.

write about Stirling Moss when I assessed the rare early images I had from Rudy Mailander. This started a seven-book series on [race car] drivers for **Haynes**.

Your latest title covers Railton. What intrigues you about this marque and its cars?
For me the twin-engined, four-wheel-driven car that Reid Antony Railton designed for John Cobb is one the best-engineered cars of all time. In its last outing in 1947 it averaged 394.2 mph at Bonneville with a one-way run at better than 403, a record for wheel-driven cars that stood until 1964. I wrote about Railton's career for *Automobile Quarterly* in the early 1970s, an initiative that led to contacts with his daughter and to my current book project, a biography of her dad. We expect to publish in the autumn.

Previously Railton designed from scratch the car that John Cobb used to set absolute world records up to 24 hours and the fastest-ever lap of Brooklands. His record-car designs for Malcolm Campbell were first to 250 and 300 mph. The body he shaped for Goldie Gardner's special **MG** helped it hold speed records in all classes from 350cc to two liters. The boat Railton designed for Campbell set a world record at 141 mph that stood until 1950.

Such was Reid Railton's reputation that it was a no-brainer for an entrepreneur to name a new range of cars after him. Based on **Hudson** chassis, they were esteemed as the quickest road cars of their day. Railtons were built from 1933 to WWII.

What significant technologies and vehicles that have debuted in the past decade do you feel will deserve their own history books in the future, and why?
One that I rate highly is the **McLaren** P1, introduced in 2012. This was conceived as a no-excuses hypercar whose advanced systems allowed it to perform with equal competence on a track and on the road. For this the RAC committee of which I'm a member awarded it the Dewar Trophy.

I'm prejudiced but I reckon that the 2014 **Chevrolet** Corvette Stingray—especially its Z06 version—will be a car to inspire more than a few books. At least one of them will be mine when I complete my history of Corvettes C4 through C7.

The **Tesla** Model S is an obvious pick. Albeit a loss-leader, it overturned all perceptions of what an "outsider" to the auto industry could achieve. The Tesla adventure deserves a good book, even if it fails to survive these early years.

Back in 1975 I wrote a history of **Opel**. Soon it will be the task of a good business/industry writer to pen the history of that great company up to 2017 and its sad sale to the French.

Remembering the tragedy of Chrysler Europe, I hold out little hope for Opel's future in the hands of **PSA**. I hope they prove me wrong.

-L.B.

The new Fellow from Ricardo

Prof. Neville Jackson will be recognized as an SAE Fellow at WCX17.

Interview by Stuart Birch

New SAE Fellow Prof. Neville Jackson emphasizes the importance of a "user-centric approach" to the development and consumer acceptance of the EV experience.

Recently elected an SAE Fellow, Prof. Neville Jackson is Chief Technology and Innovation Officer of **Ricardo** plc. He is also a member of the Boards of Ricardo Innovations and Ricardo Inc. During his nearly 34 years with the company Prof. Jackson has been, and continues to be, responsible for a wide range of new technologies and innovations. He also supports Ricardo's diversification strategy to meet emerging challenges related to transport, urban mobility and energy. Prof. Jackson will be recognized by SAE on April 3 at a special SAE Fellows dinner in Detroit during WCX17.

Ricardo is a century-old company of huge experience; what is its role in the unfolding connected, autonomous, electrified car era?

Throughout those 100 years, it has been focused on efficiency and optimization. Looking at the new era, I believe it is largely a continuation of that theme. Ricardo started as an engine company before expanding into transmissions, drivelines and controls. We then considered how the powertrain interacts with the vehicle—and with the environment.

Now, we look at a much bigger picture of mobility, taking a more holistic view of energy, environment, cities and connected information, which together offer another opportunity to optimize the individual elements in that mobility system. It is a continuously expanding area for us. To optimize individual components we increasingly need to look at the whole system, and how it operates, in order to deliver much improved characteristics to vehicle owners.

In research, we don't believe in plateaus; things will always change. For example, the rate that ICT (Information and Communication Technologies) has improved—and goes on improving—is phenomenal.

What specific engineering support will Ricardo engineering and expertise provide to OEMs and Tier 1 suppliers (and motor sport) as we move into and through the 2020s?

Again, it is formed around the whole systems' engineering issue, ensuring that we continue to improve the product and services we provide, always with an understanding of the requirements of the environment. What we try to do as a business, and what we try to provide in engineering support, is to give our customers something they do not have themselves: technology, capability, and maybe a broader understanding that they don't have in-house.

With motor sport the technology can be pushed much harder—and faster—than with road cars. We may bring to customers something that they may not even have thought of!

Is the auto industry sufficiently aware of the opportunities that "smart cities" and the Internet of Things may deliver?

The ICT revolution will probably have more impact on the auto industry than anything else it has faced before. Smart cities, in which Ricardo is heavily involved, and the Internet of Things are closely linked. It's all about how to make the total city infrastructure, energy resources and mobility systems, work in close harmony.

Having connected autonomous, more intelligent systems that can 'understand' how it all fits together rather than operating individually, is a major opportunity. But there are also potential disrupters, such as what might happen in terms of business and ownership models.

Real steps forward will come in the cognitive pattern recognition AI machine learning area, where we can bring together and optimize many more things than we once could: understanding both patterns and interactions, and how to operate systems as a whole to deliver the best individual performance.

The key change we have to see on electrification is not just about such things as batteries, it is the user-centric approach. To achieve the majority market, we have to make it better for us all to live with an electric type vehicle than a conventional vehicle. That means we have to look very seriously at both the charging issue and infrastructure.

But the big issue that must be resolved is this: As a consumer, am I really happy to deal with the everyday living experience of an electric vehicle? ■

SAE INTERNATIONAL

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Collaboration. Despite today's highly competitive world, it's still how problems are solved, challenges overcome, and advances are made.

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PRODUCT BRIEFS

SPOTLIGHT: WCX17 EXHIBITOR PREVIEW

Five-piece hot-stamped laser-welded door ring and B-pillar

To reduce the weight of the 2017 **Chrysler** Pacifica while meeting or exceeding crash test requirements and minimizing costs to the consumer, **ArcelorMittal** (Chicago, IL) and **ArcelorMittal Tailored Blanks** began co-engineering work with **FCA** US LLC in 2012 to identify applications that would meet all objectives. Using ArcelorMittal's patented laser ablation process, the company combined two high-strength steel grades—Usibor, a hot stamping grade that supports weight reduction in advanced shapes that require higher tensile strength, and Ductibor, an energy-absorbing grade designed specifically to complement Usibor in hot-stamping applications and offer ductility—to better manage the crash energies. Together, the partners identified the side structure of the vehicle's body-in-white, specifically the door ring and B-pillar, as the area of most opportunity for weight reduction and improved safety performance. The team came to an agreement on one central concept, what ArcelorMittal claims is the world's first five-piece hot-stamped laser-welded door ring and B-pillar. Visit Booth 3806 at SAE WCX17.

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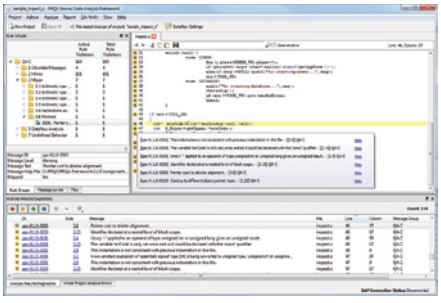
For more information, visit http://info.hotims.com/65850-400

Static application security testing tools



Programming Research Inc. (Boston, MA) features updates to its static application security testing (SATS) solutions for the C and C++ languages, QA·C and QA·C++. The company is a founding member of the MISRA (Motor Industry Software Reliability Association) C and C++ committees and is noted in the industry for its MISRA compliance capabilities, which are used by automotive OEMs and Tier 1 suppliers. With recently improved security capabilities, Programming Research has complementing MISRA compliance with CERT C, CERT C++ as well as compatibility for CWE C and CWE C++, enabling compliance/compatibility enforcement that can be applied to both new and legacy source code, increasing code reusability and decreasing time to market. Additionally, it is also involved in addressing processes and is one of the members of the RePhrase project (a funded project), which is looking to create a C++ coding standard for multi-threading and parallelism. Visit Booth 4119 at SAE WCX17.

WCX17 WORLD CONGRESS EXPERIENCE EXHIBITOR

For more information, visit http://info.hotims.com/65850-401

Camera and sensor wash system

Foreign materials like dust, mud, road salt, snow and other related debris can cause lens or sensor obstruction that will lead to degraded or non-functional system performance. Any vehicle using optical or sensor dependent systems needs a clear, unobstructed surface to function properly and ensure safe operation. The number of cameras and sensor systems present on new vehicles is ever increasing and 360 surround-view parking assist systems and advanced driver-assistance systems (ADAS) have made the integration of cameras and sensors into vehicles commonplace. **dlhBOWLES'** (Canton, OH) Camera and Sensor Wash ensures that these systems operate at peak efficiency. Key advantages of the system include oscillating spray, optimized flow rate, targeted spray area, optimized packaging and non-invasive integration. Visit Booth 2003 at SAE WCX17.

WCX17 WORLD CONGRESS EXPERIENCE EXHIBITOR

For more information, visit http://info.hotims.com/65850-402

Model-based development tool

UniPhi from **SimuQuest**, Inc. (Ann Arbor, MI) is an intelligent power tool that frees up time for innovation by automating error-prone manual tasks in the design and development of vehicle control systems and software. Users can rapidly architect the control system and logic for any type of vehicle control, whether an autonomous vehicle, an engine or a power window or seat. With a single button press, users can automatically generate a "simulatable" model of the system with test vectors, control system and plant model. According to SimuQuest, UniPhi's intelligence guarantees consistent data and architecture with real-time validation preventing interface errors. There is no more waterfall-type process: a new, completely flexible process is enabled that embraces change and innovation throughout development. Visit Booth 4500 at SAE WCX17.

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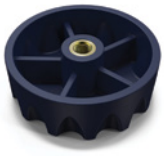
For more information, visit http://info.hotims.com/65850-404

Insert molding

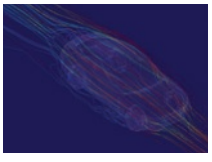


Expanding on its rapid injection molding offerings, **Proto Labs** Inc. (Maple Plain, MN) now provides insert molding service. The company claims this new capability can produce 25 to 10,000-plus insert molded parts in 15 days or less. Insert molding is the process of overmolding thermoplastic material around a preformed component (an insert) to create a finished part that incorporates multiple materials. A variety of components are manufactured with insert molding, such as electronic parts, housings, knobs, handles and dials, and are found in several industries, including automotive and consumer products. Product designers and engineers use insert molding for improving part strength while trimming part weight and reducing assembly costs, production time and labor. Visit Booth 2210 at SAE WCX17.

WCX17 WORLD CONGRESS EXPERIENCE
EXHIBITOR

For more information, visit http://info.hotims.com/65850-403

Simulation consultants



Noumenon Multiphysics (Pune, India) simulation consultants use an advanced understanding of physics and mathematics to build new simulation platforms or help customers optimally use simulation platforms. They collaborate with customers' engineering teams to set up accurate, fast simulation methodologies at the customers' organization that are tailor-made to fit well in their engineering workflows. They specialize in multiphysics simulations involving optics, electromagnetics, structural and fluid mechanics, thermodynamics and chemistry. Noumenon Multiphysics simulation consultants apply these abilities to complex problems in the automotive domain. Visit Booth 4219 at SAE WCX17.

WCX17 WORLD CONGRESS EXPERIENCE
EXHIBITOR

For more information, visit http://info.hotims.com/65850-405

Prototype motor

Oak Ridge National Laboratory (Oak Ridge, TN) researchers have developed a new motor that they claim achieved 75% higher power than a comparably sized commercial motor for electric vehicles. The prototype uses ferrite, iron-based, permanent magnets instead of the expensive imported rare-earth permanent magnets commonly used in motors today. "We are focused on increasing energy security for the nation by designing efficient high-performance motors built with materials that are both economical and abundantly available here in the United States," said Oak Ridge National Laboratory researcher Tim Burress. Visit Booth 3413 at SAE WCX17.

WCX17 WORLD CONGRESS EXPERIENCE
EXHIBITOR

For more information, visit http://info.hotims.com/65850-406

UPCOMING WEBINAR

FROM THE EDITORS OF SAE: HYBRID & EV PROPULSION

Thursday, April 27, 2017 at Noon U.S. EDT

Greater use of vehicle electrification is essential for OEMs to meet the far more stringent global CO_2 emission standards coming early in the next decade, and the technologies related to batteries, power control, and e-motors are progressing steadily. This 60-minute Webinar discusses what's over the technology horizon and what challenges engineers face as the plug-in future approaches.

Speaker:

Benjamin Koerner
Lead Application Engineer, dSPACE Inc.

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

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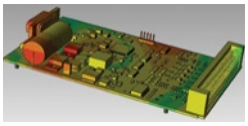
Vibration and acceleration simulation



Mentor Graphics Corp.'s (Wilsonville, OR) Xpedition vibration and acceleration simulation product for printed circuit board (PCB) systems reliability and failure prediction addresses the challenges of harsh environments for today's electronics. Xpedition Design for Reliability (DfR) augments mechanical analysis and physical testing by introducing virtual accelerated lifecycle testing much earlier in the design process. According to MG, it is the industry's first PCB-design-specific vibration and acceleration simulation solution targeting products where harsh environments can compromise product performance and reliability, including automotive, military, aerospace and industrial markets. Bridging mechanical and electronic design disciplines, MG claims Xpedition DfR provides vibration simulation significantly faster than any existing method. Visit Booth 3209 at SAE WCX17.

WCX17 WORLD CONGRESS EXPERIENCE
EXHIBITOR

For more information, visit http://info.hotims.com/65850-407

Calibration tool

Engine specialists at **Ricardo** (Van Buren Charter Township, MI) have a method to streamline calibrations: a global design of experiment (DoE) approach paired with the proprietary EfficientCal tool. The company claims this tool has demonstrated a 20-50% reduction in expensive test cell work. Built on 15 years of calibration data, Ricardo says engineers can easily understand the trade-off between events or systems that are unpredictable and have better insight to balance conflicting requirements, much earlier in the calibration process. The combination of DoE and EfficientCal tool sets enable fast and efficient calibration of today's complex engines. This step-change can bring cars to market with a robust solution—fast and cost effectively.

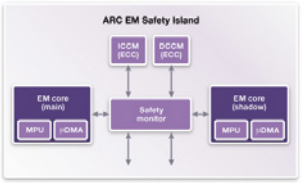
For more information, visit http://info.hotims.com/65850-408

Power transfer coupling

The TSC8300 is a new power transfer coupling from startup-company **Twin Spring Coupling** (Pearl River, NY) that is warrantied to 300 lb·ft (407 N·m) of torque. Increased flexibility with the same torque curves allows the designer/engineer to achieve increased reliability with little to no modification, according to CEO Darren Finch. The constant maintenance of the internals of a universal joint is not a factor with the company's coupling since there are no internal components—i.e., no needle bearings to maintain, no bearings to wear out. Suitable for use in automotive, mining, agriculture and industrial industries, TSC8300 applications include axle, PTO, driveshaft, steering, and conveyor belts.

For more information, visit http://info.hotims.com/65850-410

Dual-core lockstep processors



Synopsys, Inc.'s (Mountain View, CA) DesignWare ARC EM Safety Island IP dual-core lockstep processors simplify development of safety-critical applications and accelerate ISO 26262 certification of automotive system-on-chips. The new Automotive Safety Integrity Level (ASIL) D Ready certified DesignWare ARC EM4SI, EM6SI, EM5DSI and EM7DSI processors integrate a self-checking safety monitor as well as hardware safety features, such as error correcting code (ECC) and a programmable watchdog timer to help detect system failures and runtime faults. Supported by comprehensive safety documentation, the ARC EM Safety Islands are designed to meet the area and safety requirements of a range of automotive applications including advanced driver-assistance systems, radar and sensors.

For more information, visit http://info.hotims.com/65850-409

Light-curable black adhesive

DELO-DUALBOND GE4949 from **DELO** Adhesives' (Sudbury, MA) is a black adhesive that is light-curable. The black-dyed, multi-purpose, modified acrylate can be used for bonding most metals, plastics and glass. Designed for light-curing processes, the company says this adhesive is rare in that it is both black and translucent, allowing the photo initiators in the adhesive layer to decompose and start the crosslinking reaction. A small humidity-curing element is found in the adhesive that triggers curing in small shadowed areas. DELO-DUALBOND GE4949 is used to bond layers up to 500 µm in thickness. It can achieve high strength and is suitable for sealing and bonding black components on sealing wires, covering lettering, bonding clips or emblems and connecting terminals.

For more information, visit http://info.hotims.com/65850-411

Automotive push switch

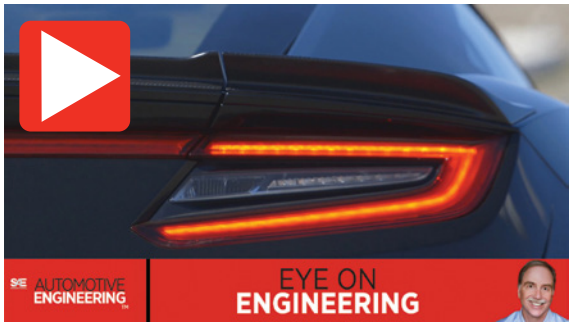
Noble U.S.A., Inc. (Rolling Meadows, IL), whose primary business includes the development and production of potentiometers, resistors, digital encoders, and custom input devices, offers its SF06 2.5-mm (0.098-in) travel push switch in surface-mount and through-hole versions. Suitable for various driver's compartment applications, the push switch is available in latching and momentary configurations. It features operating temperatures of -40 to +85°C (-40 to +185°F). Able to withstand reflow soldering, the SF06 travel push switch is available in bulk or tape and reel packaging. Samples of the product are available.

For more information, visit http://info.hotims.com/65850-412

VIDEO

SAE Eye on Engineering Quick Take: New lighting technology

Automotive lighting technology is changing rapidly—and drivers are a lot safer because of it. In this episode of SAE *Eye on Engineering*, Editor-In-Chief Lindsay Brooke looks at **Varroc**'s lighting innovations. SAE *Eye on Engineering* can be viewed at **video.sae.org/12255**. It also airs in audio-only form Monday mornings on WJR 760 AM Detroit's Paul W. Smith Show.



Access archived episodes of SAE *Eye on Engineering* at **video.sae.org**.

WHAT'S NEW

New BMW 5 Series adds PHEV, Touring, xDrive M5

The advent of every new **BMW** 5 Series reaffirms why this model 'family' is a benchmark in its segment—and why the phrase 'technology through evolution' describes BMW's overall development approach.

The seventh generation 5 Series, known internally as the G30, broke cover at the 2017 Detroit auto show, with the new Touring following at the Geneva show and an all-wheel drive M5 sedan expected at Frankfurt in September. All continue an aesthetic link to the six previous 5 Series generations.

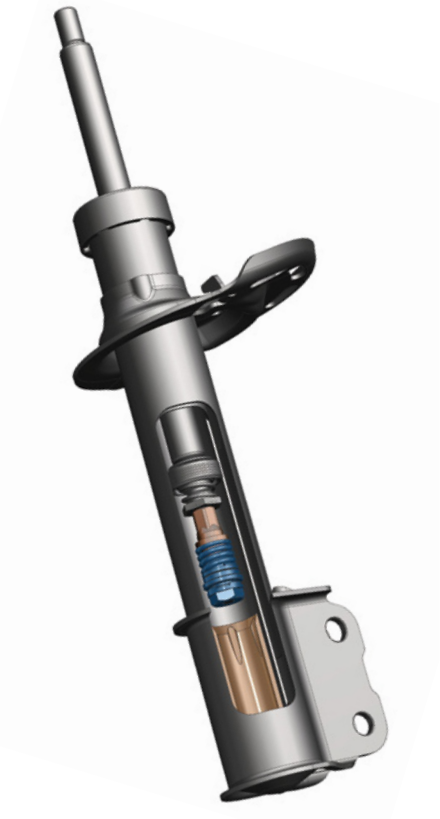
The new generation car is the subject of 3 million test miles during development. It will be available with both rear- and xDrive (all-wheel drive), with rear air suspension and active rear steering fitted as standard; M Sport suspension with a 10 mm (.39 in) reduction in ride height is optional.

BMW's focus on power, torque and mass reduction applies to all 5 Series versions. *AE* recently sampled a new 530d on a long-distance drive in southern Spain, powered by the 3.0-L inline 6-cylinder turbodiesel that is part of a newly developed modular range that includes a plug-in hybrid 530e iPerformance.

Read the full story at **articles.sae.org/15285/**.

Refining ride quality at lower cost

Achieving product differentiation without adding significant cost is on the wish list of all automakers. While targets can be reached to some degree by applying clever software changes to sophisticated systems, using purely mechanical solutions as an alternative to those systems may be difficult, particularly in that subjective area categorized as "refinement."



Ride refinement is a prime example. China-based chassis systems' supplier **BWI Group** produces the sophisticated magneto-rheological suspension control, MagneRide, used by a growing list of brands including **Audi**, **Cadillac**, **Chevrolet** (Silverado pickups and Corvettes) and **Ferrari**. But BWI also is developing what it believes will be a cost-effective system aimed at raising the ride quality of mid-class premium cars.

Read the full story at **articles.sae.org/15115/**.

READER FEEDBACK

Intel's Mobileye acquisition raises questions

Mobileye and Intel
I read your informative cover article on Amnon Shashua and Mobileye [March] two days before hearing that Intel has purchased Mobileye. It will be interesting to see how Intel treats Mobileye because Intel does not have a great track record for integrating its acquisitions. One thing is for certain: Shashua and his co-founder Ziv Aviram are now very wealthy entrepreneurs!

Love the SAE mag, keep up the great work!

Jake Miller, E/E
Brooklyn, NY

RE: Mobileye article: Interesting story and company, but I wonder if they'll continue to retain their ability to innovate under Intel's management.

Bob Zelingo
Seattle, WA

Achates powers toward production
If Achates is so great, why hasn't the company picked up the concept and sought to make and sell these engines? GM and Ford make 10-speed automatic transmissions. It seems that this is an ideal approach for engine manufacture as emission limits and mileage-per-gallon constraints are like safety regulations, making the manufacturers follow required technological paths.

Aaron Passman

Achates Power's goal is to develop the opposed-piston 2-stroke diesel as a viable and robust 21st-century power unit and sell manufacturing licenses to engine OEMs. Achates management never intended for the company to be an engine manufacturer. Their work thus far has been remarkable but Achates still has much to prove.—Ed.

The challenges of this [Achates engine] seem to be significant and it's great to see the closeness to production. By the way, about five paragraphs in: Can an engine have a CAFE number?

John Fischer
Palatine, IL

The reference to a CAFE rating was related to Achates' simulations of the engine's fuel-consumption performance as installed in a vehicle. Company engineers are confident their simulation work will correlate closely to actual in-vehicle testing later this year. —Ed.

The 'ayes' of March
Bravo on the March issue! AE is always good but March set a whole new level...what a lineup! Thanks for the great mag.

Daniel Pullum
Life Member of SME and part-time member of SAE
Decatur, IL

The case for 48-volt hybrids
Your article on 48V [January 2017] is a really compelling story. But I remember the compelling stories for 42-volt systems 15 years ago! However, with CAFE and CO_2 regs around the world 48V has a much better chance of going forward to some amount of production. Whether it becomes big remains to be seen; look how long stop-start is taking to penetrate the market. I believe the low-cost mpg gains are about done and there is less bang-for-the-buck left.

I have a new 2017 Chrysler Pacifica and I personally do not need better fuel economy on the highway. From Michigan to Florida in two days of driving, I averaged 29.6 mpg and I am not a slow driver, 75 to 85 mph depending on traffic. My 2014 Town & Country got 26 mpg on the same route. So, I now get about 3 mpg more for $3000 more for the same-trimmed vehicle. It will take a long time to make up that $3K. I saved seven gallons on that trip; times $3 per gallon equals a whopping $21. Doing the math, it will require 143 trips to Florida to break even! No way that's possible, even at $5 gas.

Here's a vote to pull the plug on escalating EPA rules beyond 2021 or earlier!

I enjoy reading the magazine. Keep up the good work.

Bob Czarnowski

Acronym overload
I apologize for not being up on the latest jargon and technology. I believe the acronym "ADAS" was used three times in the March issue before it was defined in the "New Eye/Mobileye" article. Otherwise, I enjoyed reading this issue and found the articles to be interesting and informative.

Dennis O. Taylor
SAE Member #1865678003

You're correct—we should have spelled out/defined the ADAS acronym in its first use in each article.—Ed.

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

"We're seeing on the order of 40% reduction in parasitic losses. We quantify that as about a 1% improvement in label-type fuel economy to the vehicle," noted AAM CTO Phil Guys. (Lindsay Brooke)

Engineering a Quantum leap in drive-axle efficiency

OEMs are increasing their focus on the vehicle driveline, working with Tier 1s to wring out greater efficiencies, mass and NVH reduction and cost. Making drive axles as mechanically efficient and light as possible was the impetus behind the new Quantum technology now being demonstrated by **American Axle & Manufacturing**. Quantum is a family of drive axles that AAM claims deliver a 30 to 40% mass reduction and 20% greater power density compared with incumbent axles with the same torque capacity. Phil Guys, AAM's Vice President and CTO, recently spoke with *AE* about Quantum developments.

Where did the Quantum concept come from?
From a brainstorming session with AAM's advanced engineering team. We'd just been through an internal project aimed at seeking greater efficiencies—new bearings, lighter-weight lubes, superfinished hypoid gears. A very iterative exercise, but we concluded that all of us in the Tier-1 axle space can do that. From a product-functional perspective there's not a lot of differentiation.

We had a significant dialogue about how do we truly differentiate ourselves in the market, knowing that customers want less weight, more efficiency, quiet operation, reliability and durability, at reduced cost. So our advanced team benchmarked products outside the automotive space, including aerospace, medical—anything with a torque element to it that had to transfer energy.

Six months later—this was in 2014—they came up with a proposal. And the idea that came out of it, now called Quantum, was so radical that we thought no one would want to buy it. Quantum technology is all about a totally different approach to the axle's gear-support structure. The concept encompasses beam-axle and IRS [independent rear suspension] versions for rear-drive applications and an AWD derivative.

What makes it 'radical'?
Well, it doesn't look like a traditional axle so there was a bit of skepticism from some of our customers. It is a different-looking animal, so we were right to gather a tremendous amount of validation, development, efficiency, NVH and durability data in support of the technology. We also built models to prove that it's a quiet axle when installed in a vehicle.

We built a beam axle, the top revenue generator in AAM's portfolio. It's the first application of this technology; we felt the truck market would be looking for weight and efficiency improvements as a priority. And in our prototype we saw a 30-35% weight reduction. A benchmark beam axle for a 1500-series pickup weighs 82 kg [180 lb]; the Quantum is 57 kg [125 lb]; that's a 30% mass reduction. A benchmark 2500-series axle is 144 kg [317 lb]; Quantum is 98 kg [216 lb], so we took 30-40 kilograms out of that. We haven't even tried to quantify the savings on the vehicle side that can come from the "cascade" benefits; we'll let the customers do that.

Each time we applied the technology in a different application we saw weight-reduction improvements. On the AWD version the weight savings is about 40% relative to current-market technology. And we're seeing on the order of 40% reduction in parasitic losses. We quantify that as about a 1% improvement in label-type fuel economy to the vehicle. We went through one iteration and found more opportunities to make it even better.

We did a second iteration, tweaked it a bit more and started taking that technology to customers about 14 months ago.

What's AAM's 'secret sauce' for Quantum?
I'm not ready to show the insides just yet. The center section is heat-treated 356. I can tell you that while the new ball bearings we're using for ring-and-pinion support are from aerospace applications, their cost isn't! We use tapered roller bearings for the differential. All of our efficiencies are coming out of the ring-and-pinion support. Those bearings are not double-row and are not preloaded, so we don't use shims [typically used in axles to set pinion bearing preload]. The design is radical in this regard.

Is the IP in the case design and bearing saddles?
Yes, they're totally different. But the innovation is in how we apply these bearings in an axle in the most compact, efficient manner.

Lindsay Brooke

***Automotive Engineering* will have a feature article on AAM's Quantum axle technology in the May 2017 issue.**

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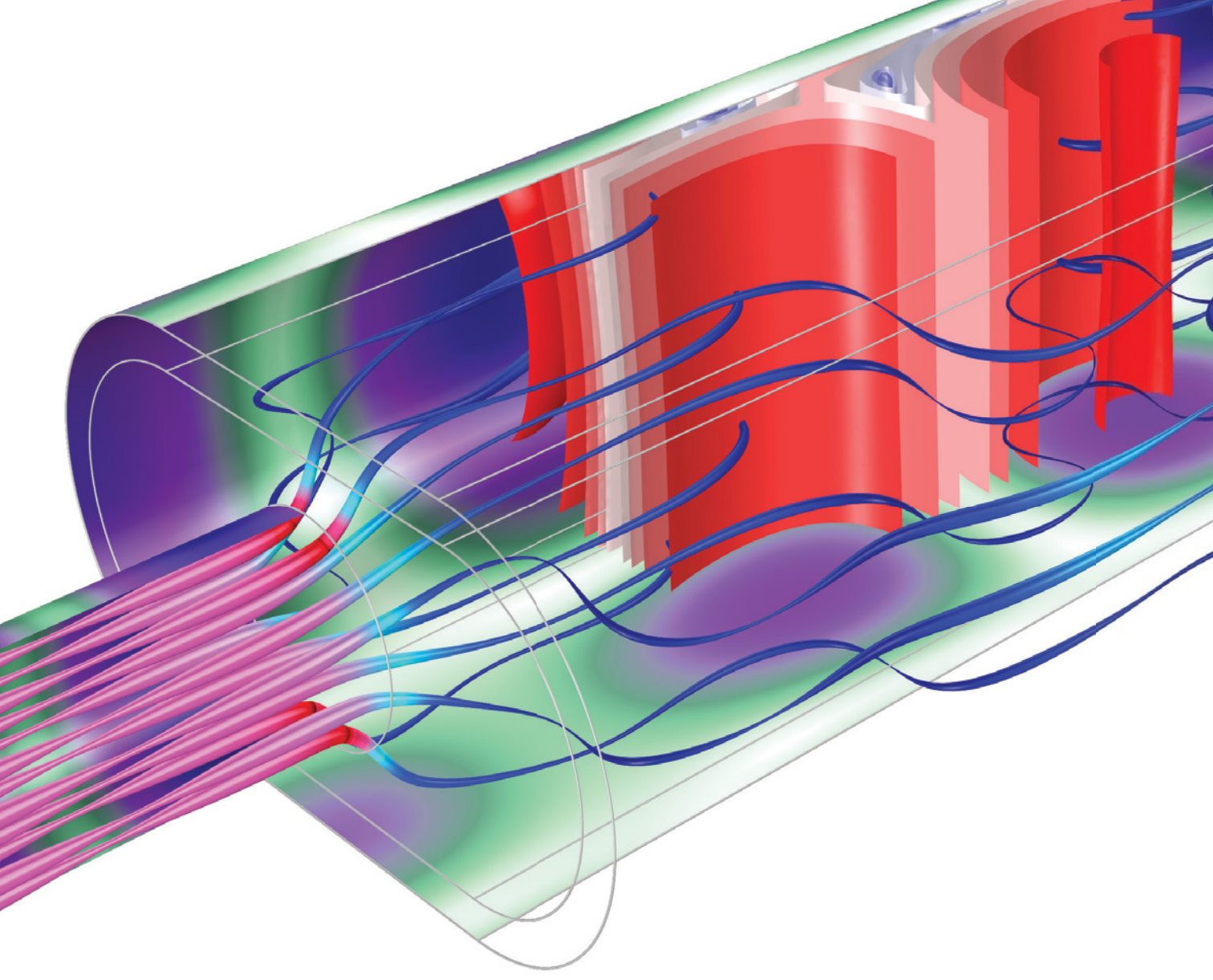

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