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## Torque-transfer Transition

How Amsted is delivering driveline efficiencies for the EV future and the ICE present

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**July 1, 2022**



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Amsted Automotive's  
Jeff Prout, Jeremy Holt,  
and Carl Beiser

**ALSO:**  
Honda's stuck on adhesives  
High-voltage F-150 Lightning  
Solutions for EV cabin heat

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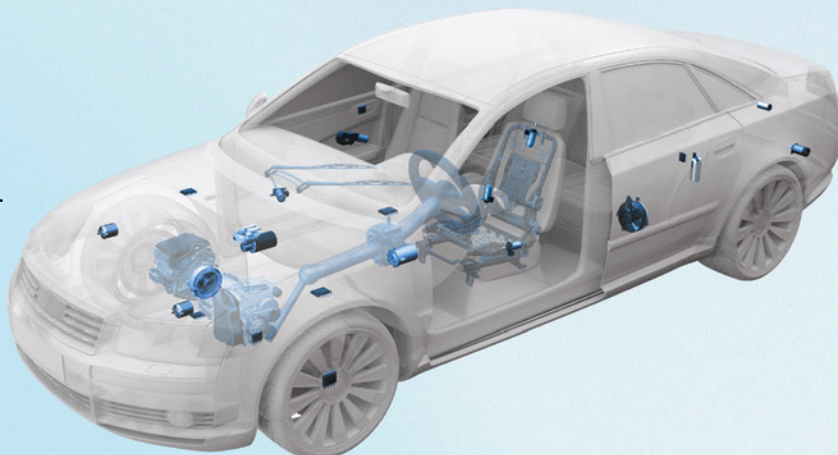
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# EDITORIAL

## EV, give me heat!

Cabin heating and cooling, and its negative impact on vehicle efficiency and range, are among the challenges still to be resolved in battery-electric vehicles (EVs). For drivers and passengers, interior comfort — being warm when it's cold and cool when it's hot outside — simply is expected of any vehicle, regardless of its tailpipe-emissions profile. Pushing the HVAC button in an EV, though, elicits second thoughts such as, "If I turn on the heat, will I have enough range to get home?"

Air-conditioning use in hot ambient temperatures typically causes a modest loss of EV driving range. But it's the 30-40% range reduction in cold weather when the cabin heater is deployed that continues to challenge EVs' ability to supplant ICE-powered vehicles, according to veteran SAE Media contributor Paul Weissler, an HVAC tech expert who sits on SAE's standards committee. That kind of hit to an electric delivery van rated at 125-150-miles' (201- 241-km) range, for example, would leave it with only 75-90 miles (120-144-km) of operation before charging is needed. The problem is exacerbated as the mercury falls.

Fleet owners would find such a serious range drop to be a non-starter as they consider when and whether to go electric. Most passenger-vehicle owners won't accept the tradeoffs in cabin comfort that accompany doing away with the "heat engine." The 14.8-gal. (56-L) gas tank in the new hybrid pickup sitting in my driveway holds the equivalent of 500 kWh of energy — roughly five times more onboard energy than can be stored by the extended-range battery in Ford's Mustang Mach-E. In the often-overlooked cabin-heat/range metric, the most humble hybrids put even the most expensive EVs on the proverbial trailer.

As happened over the course of automotive air-conditioner development, EV cabin heating technology will improve dramatically and steadily. Early A/C

compressors were so inefficient, with that their use dragged down a vehicle's fuel efficiency by as much as 20%. EV cabin heating can and must follow a similar path toward higher efficiency. Heat pumps are one potential solution.

Proven in residential and commercial buildings, heat pumps harvest waste heat energy, transferring it from cold space and releasing it to a warmer one. They act like a refrigerator in reverse. A formidable mix of HVAC systems suppliers including Bosch, Brose, Denso, Hanon Systems, Mahle, Mitsubishi Electric, Panasonic, Sanden, Valeo, and Zhengzhou Guchen have made automotive heat-pump R&D a priority. Unique among OEMs, Tesla spun its heavily scrutinized 'octovalve' heat pump from SpaceX technology. By my count, more than a dozen 2022-23 EVs are equipped with heat pumps. As SAE

Media has reported, GM is engineering heat-pump technology into all its Ultium-platform EVs; <https://www.sae.org/news/2022/04/gm-heat-pump-system-boosts-ev-range-reduces-charge-times>.

But as SAE readers know, there's rarely a free lunch in any design engineering or product-development solution. Heat pump performance is limited by slower refrigerant flow rates in low temperatures, sometimes forcing the switch to less-efficient resistance or PTC (positive temperature coefficient) heaters. Alternatives are being investigated. As our feature by Mr. Weissler on page 19 details, Toyota and its HVAC partner Denso have developed a system incorporating liquid-gas separator technology that enables heat pump operation down to -10°C (14°F). It's now in production on the 2023 Toyota BZ4X.

I expect a flurry of new HVAC approaches to enter production in the next few years, as engineering innovation and customer demand force solutions to one of vehicle electrification's greatest compromises.

**Lindsay Brooke**, Editor-in-Chief

**Expect a flurry of new HVAC approaches to enter production in the next few years.**

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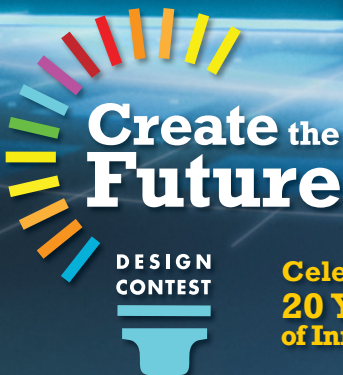
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## Inflation ignites another supplier squeeze

**F**or more than 100 years, OEMs and suppliers have partnered to build components, engineer and integrate systems, offer services such as logistics, software, and marketing support, and even manufacture complete vehicles. Some of these relationships have lasted decades —transcending corporate buyouts and mergers, new leadership and shifting technology requirements. Others have been, well, short-lived. In the end, OEMs can't build today's vehicles without a vibrant and stable supply base. And suppliers have a finite number of OEM customers. It is an ongoing dance, refined over time.

During the past couple of decades, while U.S. inflation roughly averaged 2%, suppliers were integrating economics into the bulk of their production costs over the life of the program cycle when quoting business. A cycle is approximately five years for vehicles and a couple years longer for powertrains. Additionally, many suppliers have enjoyed the reduced risk of material resale programs (the OEM or Tier 1 buys the material) or they are able to adjust pricing on a quarterly cost index structure — popular with plastics-resin buys. Whatever the structure, suppliers still assume numerous risks over the program cycle — everything from unpredictable volume swings, logistics turmoil, labor issues and infrastructure costs.

Until recently, such risks were viewed as 'controllable.' But recent gyrations in manufacturing economics are testing even the strongest of these relationships.

As I write this in early May, U.S. inflation is the highest since 1981, and the industry is reeling. From January 2021 to March 2022, the S&P Global U.S. Materials Price Index rose 92%. Cold-rolled steel skyrocketed by 56% and WTI (West Texas Crude) petroleum jumped 108% over the same period. While some readers will note that commodities are inherently volatile, labor costs



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**The chief concern is the ability of smaller Tier 2s without deep pockets to weather sustained inflationary pressures.**

also have escalated. Wage rates rarely ratchet downward, especially in an economy with sub-4% unemployment.

Rising wages and fuel costs also lead to rising logistics costs. In recent columns, I've articulated how suppliers have been impacted by the inflation driven by ILL — Inputs, Labor and Logistics. Russia's war with Ukraine and its subsequent impact on global supply chains for several key automotive inputs have only extended this problem.

Suppliers are caught in the middle. Raw-material suppliers follow the hills and valleys of market dynamics with variable pricing driven by supply and demand. OEMs can adjust real pricing through modifications in vehicle MSRPs, incentives and adjusting content. But they need to proceed carefully. Though inventory currently is low in historical terms, competition will again heat up as inventories start to rise — we can't stay at 25 days' supply forever.

With all or a portion of supply contracts being fixed over a cycle, component suppliers are sandwiched in an increasingly difficult situation.

After close to three years of erratic production volumes and inefficiencies driven by COVID, the chip supply crisis and a host of other factors — suppliers are seeking a stable environment. Secular shifts such as the impact of vehicle electrification ensure that more challenges are looming.

Many Tier 1s and larger Tier 2s have strong balance sheets and are diversified across several automotive sectors, or even have non-auto exposure. The chief concern is the ability of the smaller Tier 2s without deep pockets to weather sustained inflationary pressures.

In the end, the industry must ensure a viable supply base. The ability for suppliers to innovate and invest in new technologies, take advantage of new production structures and react to emerging opportunities is critical for all industry participants. ■

## EXPERT Insight

### Keysight Technologies offers efficiency and scalability with latest EV battery-test systems

*As electric vehicles (EVs) become more and more popular, EV batteries become more and more important. Testing these batteries to assure reliability and extended life is a critical step for all EVs. For this Expert Insight interview, SAE's Automotive Engineering spoke with Keysight Technologies' Jim Duffy, Business Development Manager for electric vehicle powertrain test solutions and Steve Mango, automotive market industry manager, about the rapidly-evolving demands of EV battery testing and how Keysight's strategy for test systems optimizes scalability and investment cost.*

**Automotive Engineering:** Steve, can you explain how Keysight's history and its acquisition of Scienlab fit into shaping the company's current strategy for battery-test solutions customized for each customer?

**Steve Mango:** Keysight has a long, rich and proud legacy dating back to 1938 when Bill Hewlett and Dave Packard started a little test business in a small garage in Palo Alto, California. That company grew to be Hewlett Packard, or HP. Fast-forward from the 1930s to the 1990s, when HP spun off the test-and-measurement area in 1999 to create Agilent Technologies. We continued to work under the Agilent umbrella until 2014, when it was decided to split into two companies. Keysight Technologies continues to focus on electronic test and measurement.

Part of our EV and battery test business included the acquisition of Scienlab in 2017. Scienlab is in Bochum, Germany and is focused on high-power, grid and machine emulation, EV charging interoperability and battery cell, module and pack testing.

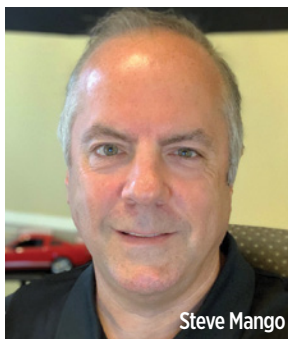
So Keysight can provide a comprehensive portfolio of current turnkey test solutions relating to the entire EV ecosystem, which we break into the following areas: the first is grid power — everything from the power on the grid up to and including the EV supply equipment or charging station. The second piece is battery power, whether that be in R&D, manufacturing or even final testing. And the last piece is EV power, ensuring the EV battery supplies efficient power to the road where it counts.

**Automotive Engineering:** What are Keysight's different approaches for addressing the needs of battery testing for R&D, manufacturing and cell, module and pack applications?

**Jim Duffy:** Keysight has comprehensive test solutions when it comes to battery test, and it doesn't matter where you are; you could be experimenting with chemistry and R&D before you actually form a cell, to now that you have a cell, testing at that level, the module level and the pack level. We also, have a very good lithium-ion self-discharge measurement capability. Lithium-ion cells and batteries have a very long shelf life. So, how do you measure that accurately and do it very quickly? We have an instrument that can do that within an hour and test 32 channels simultaneously with the one instrument. If you have multiple instruments, of course, then you can test a lot of cells at the same time.



Jim Duffy



Steve Mango

**Automotive Engineering:** What are the most prominent challenges for engineering groups currently doing battery testing?

**Jim Duffy:** There are issues with operating costs as power levels continue to go up. We're going through these charge-and-discharge cycles even at cell formation until a cell is formed; we're going through charge-and-discharge cycles all the way up through and including pack-level testing. So keeping down the costs of that energy is important, because on the discharge cycle, normally you'd waste that energy in heat — not only are you wasting electricity, but you're also dealing with getting rid of a substantial amount of heat, which, for example, can tax HVAC systems in your facility.

To address this, all of our systems are regenerative. When we're on the discharge cycle, we're converting that energy from DC back to clean, three-phase AC that we can loop back to the charging side — and we're 95% efficient in doing that. You only have to deal with the dissipation of 5% of the energy and heat. That's a lot of cost savings on your electric bill and keeping operating costs at a minimum. And as

these power levels continue to go up, safety also is very important and we have comprehensive safety solutions that, stand-alone, are very comprehensive — but also, we can integrate very well with the customer's existing safety systems.

**Automotive Engineering:** It seems that pack level testing in particular is becoming increasingly important. So, why is your new SL1700A pack-level battery test system important in this specific area of testing and to whom are you targeting it?

**Jim Duffy:** The new 1700 Series is based on silicon carbide [SiC] technology. That reduces the footprint — that's very important. It's operating in over 95% efficiency on the regeneration side. Also, the capital investment is kept at a reasonable level; as your requirements expand and as you grow. For example, you could initially buy a tester that's rated at 90 kW. As your needs increase, you can move up to 120, 180 all the way up to 270 kW testing capability, and the real estate has not changed. That's what we've built into the platform, a lot of flexibility and scalability. You don't have to be concerned about the need for more real estate. ■



Watch the full interview with Jim & Steve.



## SAFETY

### Toyota reinvesting in collaborative safety research



Over the last decade Toyota's CSRC has collaborated with a host of research partners, including the National Advanced Driving Simulator at the University of Iowa.

To adapt to a swiftly changing mobility ecosystem, **Toyota** announced in late April a new five-year, \$30-million investment in its Ann Arbor, Michigan-based **Collaborative Safety Research Center (CSRC)**. Created in 2011, the CSRC focuses on foundational safety research, and the \$85 million apportioned over its first ten years funded research including the factors that lead to distracted driving and developing tools and testing procedures related to advanced driver-assistance systems (ADAS).

Since its inception, CSRC has completed 85 research projects with more than 30 different institutions, the output of which Toyota shares globally in the name of shared safety. "The foundation of CSRC is built on collaborations to tap outstanding safety researchers and institutions throughout the country," said Danil Prokhorov, director of Toyota's CSRC and Future Research Department (FRD). "We'll also continue to publish our CSRC research discoveries for others, to help foster societal benefit."

The nine new projects will engage the expertise of: **University of Massachusetts - Amherst; Children's Hospital of Philadelphia; University of Michigan Transportation Research Institute; Massachusetts Institute of Technology; University of Iowa; Virginia Tech; and Indiana University - Purdue University Indianapolis.**

The newly funded research will involve a wide spectrum of safety issues, including:

- driver training
- vulnerable road user (VRU) interactions
- SAE Level-2 "non-driving" activities
- post over-the-air (OTA) feature-update education
- intersection evasive-action trends
- predicting bicycle and e-scooter behavior
- considerations in human anatomical variation when assessing post-crash injuries

"We are aligning with the next emerging trends," explained Jason Hallman, senior manager for the CSRC. "Talking about safety systems integrations, we're really asking what future crashes will remain and what new opportunities will be presented as we have an evolution and a convergence of active and passive safety systems. We're also asking what new tools are needed as automation becomes a bigger component of driving today. Particularly, as we think about future automated vehicles and technology, what tools do we need to evaluate passive safety."

#### Mental models

To help characterize the types of diverse research funded and supported by the CSRC,

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Toyota presented some of the findings completed in its last five-year funding program, including a fascinating study on driver “mental models.” Kicked off in 2017, the multi-year project studied the interaction between vehicle safety systems and the mental images users of the technology generate in response to the technology.

“In this research, the concept of mental model was very broadly applied to include not only drivers’ understanding of how the driver-assistance technology works, but how drivers interact with and relate to the systems,” noted psychology Ph.D. James Jenness, senior researcher in Westat’s Transportation Research Group. “This included knowledge of driver-assistance functional capabilities and limitations, understanding of the underlying technology, subjective feelings about the technology, trust in the systems and the drivers’ metacognition about their own under-

standing – how confident are they that they know everything they need to know about how the systems work?”

Jenness noted some of the goals of the research included forming queries about how driver mental models form, how they change over time as drivers get more exposure to the technology, and how drivers’ mental models differ. “We conducted focus groups to learn how drivers typically think and talk about their driver-assistance systems,” Jenness said.

He added that design personas based on cognitive learning and personality variables may be useful for understanding drivers’ mental models of vehicle technology. This approach, he noted, could be beneficial for supporting consumer education and user-interface (UI) design. “By better understanding drivers’ mental models,” he said, “designers can create systems that are more intuitive or easily learnable.”

Paul Seredynski

#### CYBERSECURITY

### SAE and NREL partner to strengthen EV-charging cybersecurity

Members of the electric vehicle industry gathered at the **National Renewable Energy Laboratory (NREL)** in early April to evaluate enhanced cybersecurity for the connections between EVs and charging infrastructure. As more EVs enter the market and connect to the electrical grid, potentially exposing cyber vulnerabilities, vehicle security is drawing increased interest. The collaborative event supports a two-year project led by SAE International to strengthen EV cybersecurity through wide industry engagement on pre-competitive research and technology prototyping in the EV charging space.

The event, held at NREL’s Golden, Colorado Energy Systems Integration

## YURA in EV Era

We are moving the frontier of electric vehicle Technology.

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Rivian engineers Sarah Hipel and Gabriel Lopez plug in an R1T during tests at NREL.

Facility, was organized to evaluate the application of public key infrastructure (PKI) — a method for encrypting information exchange and certifying the trusted authenticity of devices — to help protect the connection between vehicles and charging stations. Although PKI had been adopted for many industries, this kind of authentication between different companies' electric vehicles and charging stations is not commonplace nor has it matured in the EV charging ecosystem.

NREL has previously studied the vulnerabilities associated with EV interconnections and has evaluated strategies to mitigate those vulnerabilities. The event went a step further into showing how PKI could improve security of communications required to enable charge sessions to take place. Successfully securing these communications would help protect against financial fraud and defend drivers, vehicles, manufacturers, and charge network operators from other cyber intrusions.

Participants including **Ford Motor Co.**, **Rivian**, **Shell Global Solutions** and **ChargePoint** brought EVs and charging infrastructure to this initial test event. The teams used a PKI system designed

by **Eonti** and implemented with Digicert to focus on establishing primary system functionality for the PKI-strengthened charging connection. Once basic functions have been demonstrated, the participants and NREL can begin planning for future efforts that will guide the team to implement a defensible system for protecting charging infrastructure in the field.

"NREL has assembled unique power systems, cyber facilities and insights to assist these teams to assess the cybersecurity of electrified transportation systems under real operating conditions and this project is a great opportunity to marry industry expertise and government evaluation resources," said Tony Markel, project lead at NREL.

The product teams completed dozens of tests, using valid and invalid PKI implementations to ensure systems are robust enough to correctly capture and identify accurate and faulty behaviors. In follow-on tests, researchers intend to expand the number of companies involved and the test cases performed to widen the impact of testing on the EV charging sector. The test cases will include adversarial drills against EV connections in the spirit of a hack-fest to

confirm the full cyber strength of a PKI implementation strategy.

The interest in PKI for EV charging follows an industry assessment that found opportunities for improvement in current standards pertaining to EV cybersecurity. SAE is organizing the international EV charging sector, as well as public and research entities, to collaboratively increase overall security in this critical connection between the mobility and energy industries. The project is intended to deliver an operational PKI method agnostic to the charging platform that is available to industry worldwide.

SAE International is seeking to expand the network of participating entities to join this critical project. Future activities include proving the scalability of PKI for EV charging, ensuring its compatibility across products, and sharing results to influence standards. Learn more about NREL's cybersecurity for grid-vehicle integration research and other sustainable transportation and mobility initiatives: <https://www.nrel.gov/transportation/electric-vehicle-grid-cybersecurity.html>.

**Tim Weisenberger, SAE Program Manager of Emerging Technologies**

## NVH

## Expanding the 'bubble' of cabin acoustics

Noise cancellation has been a viable technology for many years, used on board turboprop aircraft to counter engine noise and familiar to consumers when applied to headphones to reduce background noise, among other applications. Like many technologies, advances in computer processing speeds and computer chip design, as well as loudspeaker and microphone design has enabled more effective noise cancellation systems to be developed.

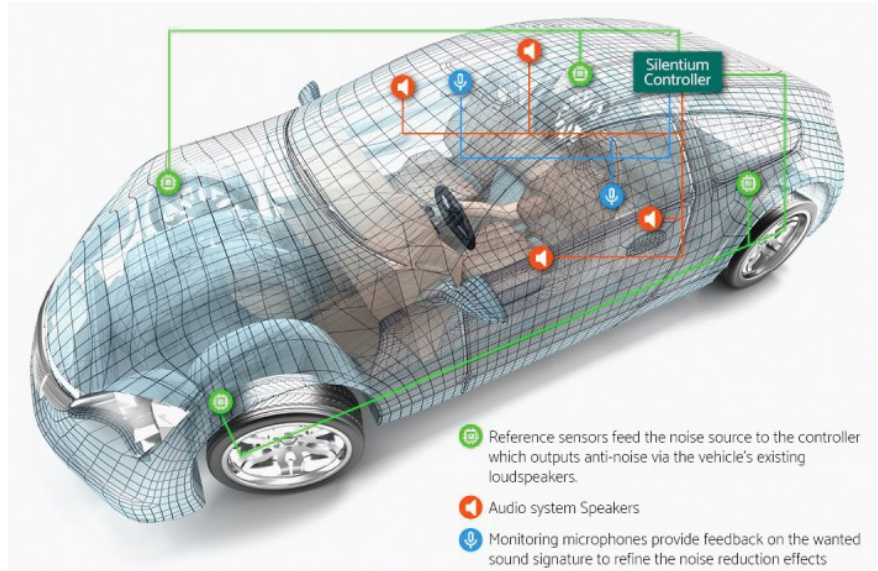
Israel-based **Silentium** has been active in this field for many years with automotive customers including Jaguar Land Rover and others. "The objectives of applying our active road noise technology solutions to any car is to make the cabin quieter," explains Anthony Manias, head of automotive at Silentium, "You give more of a premium feel, particularly under some use conditions where, in the case of road noise, due to the contact between the tire and the road, this would produce unwanted noises inside the cabin."

## The ANC solution

The traditional route to contain noise has been to use passive sound deadening techniques including sound absorbing materials. Silentium's solution, called Active Noise Cancellation (ANC), "enables more freedom for design and sometimes cost saving," Manias said. The ANC technology uses the vehicle's audio system to control, significantly reduce, and eliminate unwanted noises in the cabin.

With input from the vehicle OEM, Silentium's technique is to measure actual noise at the ear of the vehicle occupants under different use conditions, at different speeds, on different roads and surfaces, with windows up and windows down and with different levels of occupancy in the car. Company engineers use a vast amount of data and proprietary tools to analyze and predict ANC performance under those conditions.

Silentium can then propose a range of solutions to the customer. This might



Silentium wireframe showing ANC sensor positioning.

involve using the loudspeakers already fitted to the vehicle, or it could involve incorporating more loudspeakers if the customer wants higher performance, or alternatively improving some loudspeakers if the objective is higher performance up and down the audible frequency range.

The company also carries out a noise marking exercise, which Manias describes as "characterizing each vehicle with an acoustic signature, a transfer path for the noises, particularly airborne noises coming into the cabin. Engineers analyze and measure the vehicle to find out the optimum number of sensors required within the cost criteria. They then position and orient the sensors to detect the unwanted noise and therefore create the anti-noise signals, "ideally to coincide at the ear drums at the same time as the noise and therefore cancel it."

Although all vehicles are different, they are similar in some respects when it comes to noise. "Really, what you find out is that tire rumble, cavity noise permeates the cabin in the region of between 100 and 300 hertz, typically, about 120 to 150 hertz," he explained.

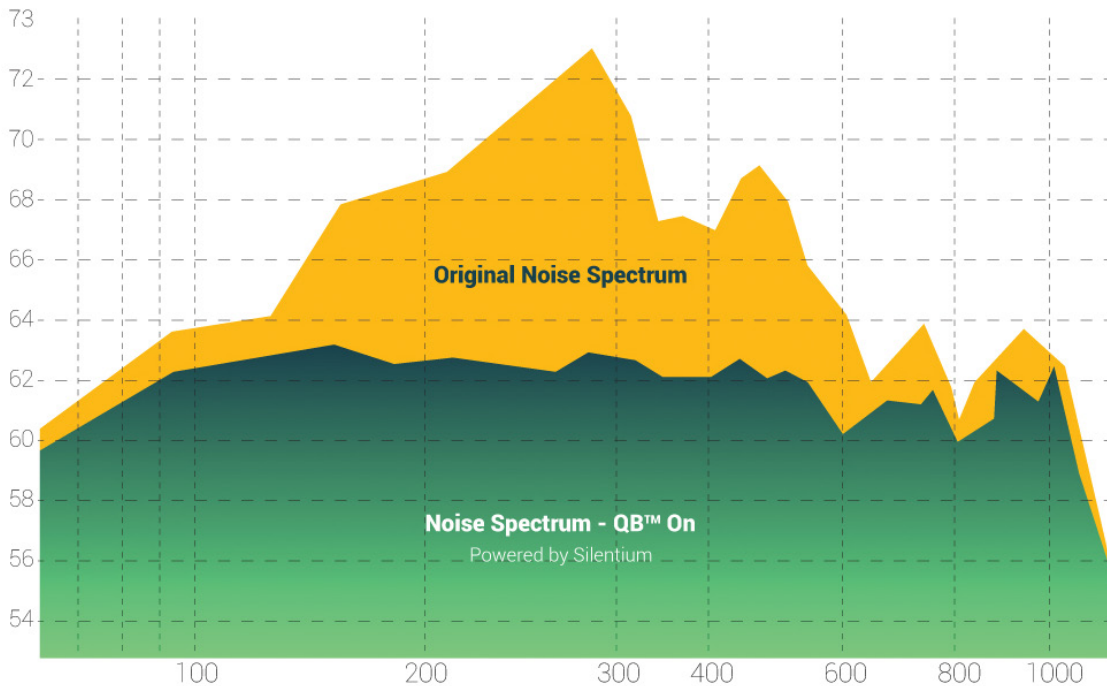


Anthony Manias said the Personal Sound Bubble is the future for in-cabin acoustic design.

## Personal 'quiet bubbles'

Silentium has been using headrest speakers in its quest to improve ANC performance. According to Manias, these provide "surety to cancel higher frequencies" where the wavelengths are very small. Because of this, positioning of the anti-noise signal is critical and the node that cancels the noise signal needs to be very accurate. Having proximity speakers near the





Advanced active noise cancellation techniques significantly alter and tailor in-vehicle sound profiles.



**Occupant-monitoring cameras offer new opportunities for creating new vehicle cabin environments, said Silentium's Tzvika Fridman.**

occupants' ear drums helps to reach the higher frequencies.

Silentium has been working on ANC systems for electric vehicles, which generate lower noise levels than those powered by ICEs. But when the noise is mitigated, "the user can experience the other noises that were masked by the internal combustion engine more and more," explained Silentium CTO Tzvika Fridman. The old noises that were always there

now become more dominant, including wind noise and HVAC noise.

"There is a new challenge, a high frequency whining noise that is introduced in electric vehicles, a tonal component that adds noise to the cabin but it's above 1,000 hertz, sometimes above 1,500 hertz," Fridman said, adding that Silentium's active acoustic software package can mitigate this. Developing technologies such as driver- and occupant-monitoring cameras in vehicles will bring further advantages, Fridman noted.

"You can use the cameras to locate the head, or the ears and once you have the pre-knowledge of where they're located, you can make the frequency range much wider," he said. With this technology, fewer loudspeakers may be needed to achieve the same performance once it is possible to precisely locate the position of occupants' ears in the cabin. That wider frequency range should make it easier to control both the low frequency noises and deal with the EV-related high frequency sounds, he said.

Being able to provide more effective ANC control also opens up a further possibility. Manias refers to this as personal sound: "Not only do you have a "quiet

bubble", a personal quiet bubble, but you cut out unwanted noise for the occupant. Typically, you want to cut out that noise for all occupants", he explained.

Vehicle occupants now have the opportunity, especially with headrest or proximity speakers, to also have their individual sound. "You can be listening next to me, I'm driving the car, you can be listening to your radio, or favorite song and I could be listening to mine. You won't hear mine and I won't hear yours," he asserted. "We can both hear the passengers behind, or the ambulance on the outside, or other noise, so the system can basically tailor to your personal sounds."

This is a technology that Silentium is at an advanced stage of developing. The company refers to it as a Personal Sound Bubble. Manias noted that it is the future for in-cabin sound design. "Personalized individual sound zones for each occupant including autonomous vehicles and hopefully later in mass transportation, where you can have not just a quiet bubble; you can also have a noisy bubble with the noises that you want, without disturbing your adjacent passengers," he said.

**John Kendall**

## 2022 Ford F-150 Lightning redefines the pickup paradigm

Just before the media test drives of the 2022 F-150 Lightning, the battery-electric variant of Ford's market-dominating light-duty pickup truck, the Lightning's specs were updated to reflect modest last-minute enhancements in horsepower and payload capacity. The freshly-extracted extra horsepower and payload are useful, but hardly necessary: the F-150 Lightning would've been plenty spectacular regardless. If the F-150 Lightning is the standard we can expect from "electrifying" what we're already familiar with, nobody will need to be dragged, kicking and screaming, into the EV future.

Ford planners and engineers took the bull by the horns when it was decided the EV variant of a pickup that's sold some 40 million copies had to fulfill the same product brief — that is, offer essentially the same work-ready capabilities as every F-Series that's come before. Not only does the F-150 Lightning accomplish that, adding either the 98-kWh (standard range), **SK Innovation**-made lithium-ion battery or the 131-kWh extended-range battery offers all manner of new capabilities linked to having so much electricity onboard.

### Battery-defined capabilities

The choice of battery packs is important in two chief ways and effectively defines the F-150 Lightning for users. The standard range battery powers a maximum driving range of 230 miles



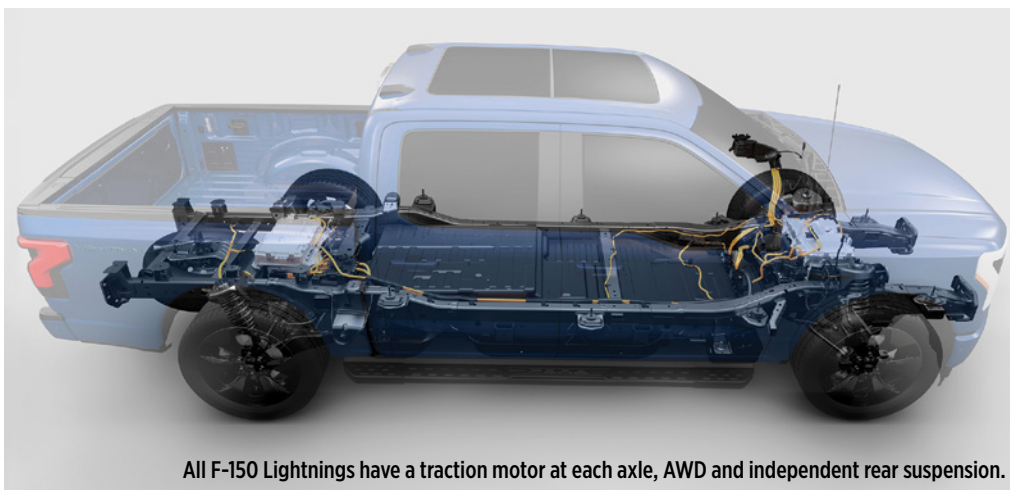
The 2022 Ford F-150 Lightning offers a choice of two battery-pack sizes for differing driving range and horsepower ratings.

(370 km) and means the twin traction motors — one at each axle for full-time all-wheel-drive (AWD) — deliver a combined 452 hp and 775 lb-ft (1051 Nm). The extended-range battery's 131 kWh hikes maximum range to 320 miles (515 km) and allows 580 hp to be extracted from the twin drive motors; torque output for either battery pack is the same. The battery pack is situated between the rails of the Lightning-specific high-strength steel frame and is protected by a steel skid plate in the event the Lightning's 8.4 inches (213 mm) of ground clearance isn't sufficient (con-

ventional F-150 4X4: 9.4 inches). Ford engineers said just eight easily accessible mounting points allow the entire battery pack to be removed.

The standard-range battery, then, appears adequate for those users who, like many light-truck owners, don't have rigorous hauling or towing demands — or, in the case of the fleet operations targeted by the base-model Pro trim, might have specifically defined duty cycles and routes that reliably return to a central charging location. Not to say the standard-range battery precludes genuine work duty: its maximum tow rating is a

chunky 7700 lb (3493 kg) and the extended-range battery enables towing up to 10,000 lb (4536 kg). Either battery pack facilitates a max payload rating of 2235 lb (1014 kg) — the late-arriving increase mentioned earlier over the 2000-lb (907-kg) payload capacity Ford originally listed. Engineers at the media drive program in May said 75% of current F-150 customers tow, but fully 80% of that number do not tow more than 10,000 lb.



All F-150 Lightnings have a traction motor at each axle, AWD and independent rear suspension.





Tow ratings run to 10,000 lb. for an appropriately equipped F-150 Lightning.

Towing and hauling capability are the “real-truck” metrics, however, and Ford gamely set up journalists with plenty of options to test the Lightning in order to dispel what some engineers called “myths” about towing’s derogatory effect on driving range. With trailers ranging up to 9500 lb (4309 kg), the Lightning yanked them as easily as you’d pull a toddler across the snow on a plastic toboggan. And without any driveline “windup” or fuss, no blaring exhaust (a downside for the ‘coal-rolling’ crowd, I suppose), just the crisp and smart step-off of 775 lb-ft applied instantly and silently.

The Texas hill-country test roads were rolling but fairly low-speed. The handy functionality of the Lightning’s Intelligent Range feature (program your trailer’s weight and other environmental effects are calculated), generated a forecast, backed up by on-the-fly mile-per-kWh figures that indicated the extended battery pack’s 320-mile range might be cut in half by a heavy trailer. The impact is “very similar to what you get on the F-150 gas,” said Jim Caruso, vehicle engineering supervisor.

High-speed highway towing probably would consume more. But unless you’ve got an IC pickup with large or even twin fuel tanks, more than 160 miles before refueling can be a stretch — although the refueling time is a fraction of the 41 minutes required to take the extended battery from 15% to 80% capacity at a DC fast-charger, according to Ford. A 15% to 100% recharge with a 48-amp Level 2 setup at the high end of what consumers are likely to have installed at



The 2022 F-150 Lightning cabin is similar to that of its IC-engine counterparts; the striking portrait-format center touchscreen is for all trims except the base Pro.

home is a 13-hour commitment, although if one is of the means to plump for the 80-amp Charge Station Pro, that Level 2 recharge is cut to eight hours.

It’s doubtful those maxing out the payload or towing light-ish trailers would find a too-painful effect on driving range — but those who plan on routine towing of heavier loads had best figure on the extended-range battery. With either battery, the 2022 F-150 Lightning isn’t the ultimate work-focused configuration (the payload and tow ratings place the Lightning about in the middle of the conventional F-150’s capability range) but it’s more than able to serve most consumer (and even commercial-oriented) light-pickup duty cycles. For the rest, electric in its current state of development simply isn’t the answer.

## New-age dynamics

We spent the better part of a day road-driving the F-150 Lightning Pro fitted with the extended-range battery, the Tow Technology and Max Trailer Tow packages and a few other options that took it from a base price of \$39,974 to \$56,109 (which included the \$1,695 destination charge), a configuration that appealed as a heap of electric truck for the money. The Ford-developed, 3-phase AC induction motors replicate the imperceptible AWD traction expected of a family crossover, while the standard electronically locking rear differential and the truck’s also-standard off-road drive setting equip the Lightning to scramble up challenging loose-rock hill climbs and traverse slimy-mud water crossings.

Curb weights for EVs are a current flashpoint and Ford was cagey about the Lightning's poundage, electing not to provide a listing in the truck's specifications. Various sources said on-site that weights range from about 6200-7000 lb (2812-3175 kg). Pickup weights vary widely, so we'll just say roughly 1000 lb (454 kg) heavier than an equivalent IC-powered F-150. The weight and its low positioning — not to mention the Lightning's independent rear suspension — help impart a confident effect on cornering, while, fortuitously, the gutting of the engine up front, said engineers, leaves the truck with a nearly 50/50 front/rear weight distribution. The F-150 Lightning rolls sweetly and crushingly silently down the road and accelerates hard enough to scandalize just about any common IC vehicle. So-called “one-pedal” driving is a delight; using it, owners might not need brakes for years (Ford in fact projects scheduled-maintenance costs some 40% lower than a conventional F-150 over five years or 75,000 miles). The only dynamic foible we could discern was the damping seems overworked to control rebound when humps, bumps and dips were encountered at highway speeds.

### Familiarity mixed with new features

Mercifully, the F-150 Lightning lineup is pared-back by pickup standards. There are just four trim levels: Pro, XLT, Lariat and Platinum. And compare Lightning's “single-spec” — a drivetrain setup of a battery pack, two motors and AWD available in a crew-cab body — with the five engine variants, separate transmission, 2WD/4WD, seven trim levels and three cab-configuration matrix currently available for the IC-propelled F-150 lineup and one can see why electrification can liberate (force?) product-complexity benefits.

There's a certain features reset provided by the Lightning's nifty new functions, such as Pro Power Onboard (9.6 kW of mobile power for anything you want to plug in, including 240V power hogs), the 14.1 cu-ft “frunk” storage (“the hardest thing we did, insisted Darren Palmer, VP, electric-vehicle programs) and myriad software enablers,



There's 14.1 cubic feet of capacity in the Lightning's frunk lockable storage area.



Ford-designed and -manufactured traction motor for the 2022 F-150 Lightning.

but maybe the triumph of the Lightning is that there's nothing “EV recherche” — most of the Lightning's body and interior are straight off the IC pickup's line. There's still the big ‘ol T-handle shifter, after all. Only F-Series watchers or EV enthusiasts won't have a hard time identifying the Lightning isn't one of its fossil-fuel counterparts.

For Ford and its perennially best-selling F-Series, departing from what's familiar probably wasn't ever an option. And for now, it doesn't need to be — the 2022 F-150 Lightning's “real-truck” credentials are plenty sufficient,

while the clever and convincing integration of electric propulsion and all its feature-facilitating trimmings make it a thoroughly convincing EV in its own right. The F-150's gargantuan size won't be for everyone — particularly ardent EV enthusiasts — and gilded versions on the press preview topped \$95,000. But given the sparkling reception the F-150 Lightning already is enjoying, Ford need merely transfer its winning engineering to more-manageable and less-costly footprints and there's probably no looking back.

**Bill Visnic**



## GM's Hummer EV is like nothing else



The Hummer EV will debut with the Edition 1 model. Other trim levels and an SUV variant will also be available later in production.

The revival of the **Hummer** brand has produced a vehicle that is concurrently of its time and a throwback to conspicuous consumption from the decade that spawned its predecessor. Like the original, there's no mistaking the **GMC** Hummer EV on the road for anything else. Thanks to its wide stance and distinct grille, even today's overfed full-size pickups shrink in the presence of GM's self-marketed "Supertruck."

The 2022 Hummer EV is a convergence of astonishing numbers: a 9,046-lb. (4101-kg.) curb weight, 1,000 hp, 11,500 lb-ft of torque (combined, at the wheels), and 18 feet (5.5 meters) long. Had the fictional scientists who visited the Jurassic Park laid eyes on the new Hummer, they may have similarly questioned if GM's engineers were so preoccupied with whether they could, they didn't stop to think if they should. However, more than 65,000 reservations to date have validated the company's decision to revive brand many once perceived as a dinosaur.

The rated driving range of the Hummer EV, 329 miles (529 km), also is impressive, particularly considering how much heft GM's three-motor e4WD drive system must motivate. And motivate it does: watching a Hummer launch from a standing start to 60 mph (97 km/h) in roughly three seconds while

wearing 35-inch (889 mm) Goodyear Wrangler all terrain tires is like watching Usain Bolt set the 100-meter world record in Wellingtons. If the EV future was intended to be one of modesty, the engineers on the Hummer program missed that memo.

### The Ultium Solution

The Hummer's evolution as an EV began with GM's BT1 platform and Ultium drive system, which will underpin future

EV products from the company. GM states that the Ultium batteries are unique in the industry because of their large-format, pouch-style cells, which can be stacked vertically or horizontally inside the battery pack. The cells were the result of a joint venture with **LG Chem**, and will be produced at a facility in Lordstown, Ohio.

The pack in the Edition 1 Hummer consists of two layers of vertical cell modules, which will be used to produce a combined 24-module pack. The pack is mounted in the center and lowest point of the vehicle platform. This not only keeps the center of gravity as low as possible, but as GM points out, enables very short front and rear overhang (34.7-inches or 881 mm front, 46.5-inches/1181 mm rear). The Ultium cells are comprised of a mixture of nickel, cobalt, manganese and aluminum, though GM claims that these cells use 70% less cobalt than their previous generation batteries.

The Hummer EV will be capable of 350-kW DC fast-charging, thanks to its unique ability to switch its battery pack from its native 400-volts to 800-volts when fast charging. This is enabled by the pack's disconnect unit, which GM states can switch the battery from parallel to



The two rear motors independently power each wheel through a 10.5:1 fixed gear ratio and can vary torque output to each wheel.

series operation, thereby resulting in 100 miles (161 km) of additional range during a ten-minute charge.

### Freedom in Watts

The ballyhooed Watts to Freedom mode is the Hummer EV's launch-control function. When the driver selects this feature, the propulsion system's energy is optimized for pure acceleration. The vehicle's ride height is also lowered via the air suspension by two inches (50 mm). GM states that the Hummer can hit sixty in around three seconds in this mode. Only an initial chirp from the all-terrain tires indicates that the equivalent of a 40-ft (12 m) shipping container is hurtling through time and space.

While the acceleration is a neat party trick, it's off road where the Hummer really earns its stripes. Literally in fact, as the truck's 86.7-inch (2201 mm) overall body width not counting the mirrors meant many trucks returned from off-road excursions with some non-factory pinstripes. It's a shame that the tested Hummer EV Edition 1's MSRP of \$112,595 USD may discourage some owners from ever venturing off the beaten path, because these trucks are more than worthy of the Hummer name.

The adaptive air ride may be the Hummer's most underrated feature, thanks to its ability to raise the vehicle to a water-fording depth of 28-inches (711 mm) in terrain mode. A late avail-



Hummer EV's cabin is a mix of tech and tough.

ability extract mode will be capable of raising the Hummer EV an additional four inches (101 mm). Another feature that may go unappreciated is the one-pedal drive mode. The Hummer is the first GMC vehicle to offer this feature, which is both equally useful in rush hour traffic and in the woods. Terrain Mode also integrates the brake system with one-pedal driving, which is an invaluable feature when stopped on a sharp offroad incline or decline.

Our off-road excursion through the Arizona desert included several obstacles and various forms of terrain, including sharp climbs and descents, rocky and sandy trails, and tight turns with obstructed views. The Hummer EV tackled all of

these without itself or its occupants breaking a sweat, even with the roof panels removed. The four-wheel steering system makes the Hummer far nimbler in tight quarters than anything this size has a right to be; the system can either turn the turn the rear wheels opposite of the fronts, or in the same direction depending on vehicle speed and drive mode. The Hummer's touted CrabWalk feature can turn the rear wheels at the same angle as the front wheels at a rate of up to 10 degrees at low speeds.

The Hummer's drive system is also responsible for its off-road capabilities. The single-motor front drive-unit's electronic lockable differential can deliver up to 100% of the motor torque to one wheel. The two rear motors independently power each wheel through a fixed gear ratio (10.5:1) with the capability to vary torque output to each wheel. Additionally, motor output to all four wheels can be fully synchronized to replicate a rear locking differential.

Bringing back this once iconic brand from extinction was no small feat for GM and its engineering team. The entire development cycle from getting the greenlight to the first preproduction models rolling out of the factory took just 18 months. The Hummer EV is a technological moonshot in every metric. And though some may wonder why this vehicle exists, there is no denying its capabilities as a showcase of what's possible for EVs.

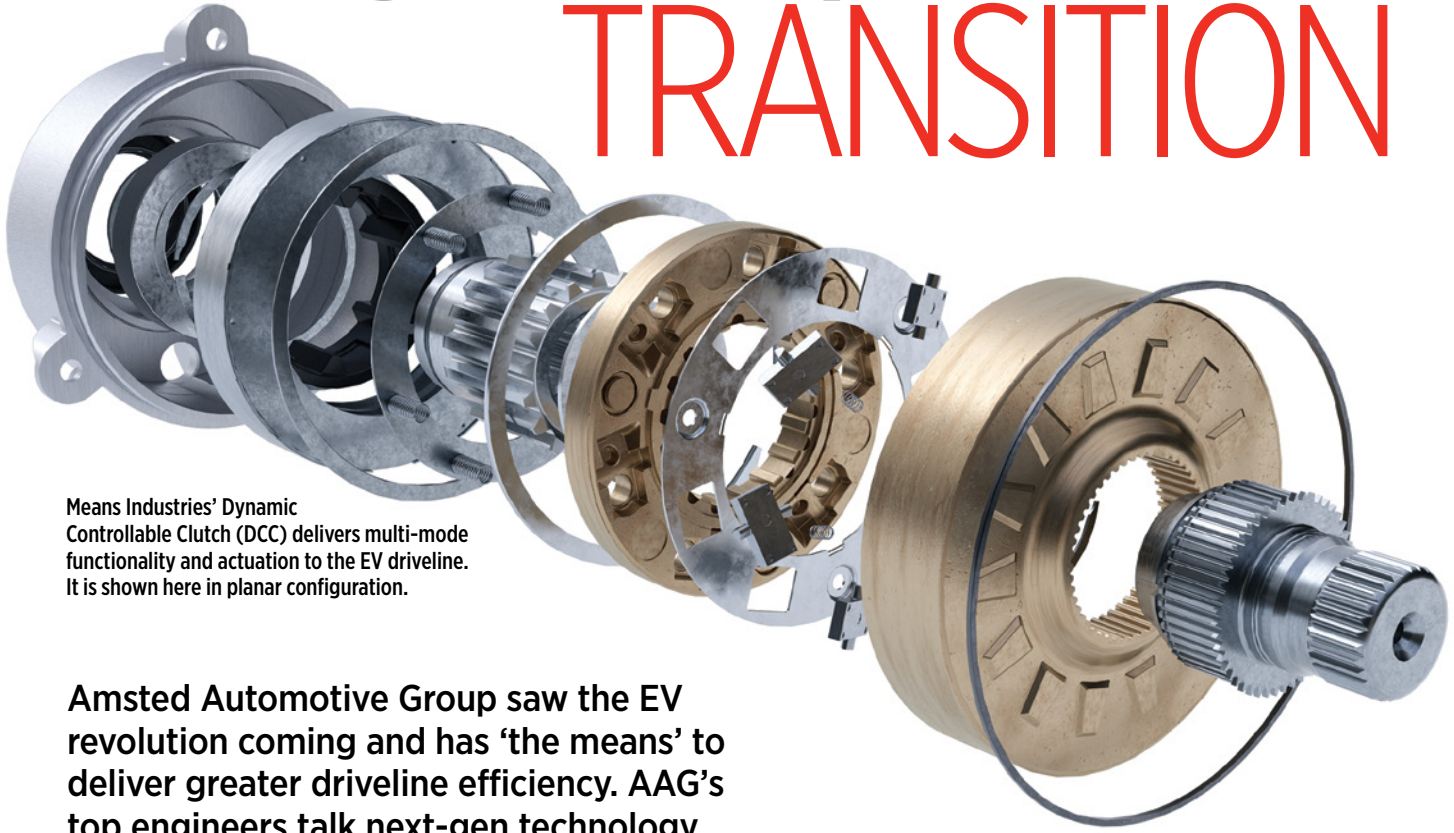
**Matt Wolfe**



Ultium battery configuration helped deliver short front and rear overhangs.



# Making the torque-transfer TRANSITION



Means Industries' Dynamic Controllable Clutch (DCC) delivers multi-mode functionality and actuation to the EV driveline. It is shown here in planar configuration.

**Amsted Automotive Group saw the EV revolution coming and has 'the means' to deliver greater driveline efficiency. AAG's top engineers talk next-gen technology.**

by Lindsay Brooke

**A** reckoning has arrived at suppliers whose product portfolios, engineering resources and R&D activities are not aligned with the EV horizon. The challenge of pivoting their focus to electrification, while sustaining the incumbent business, has been particularly vexing for many Tier 2s and Tier 3s rooted in "legacy" powertrain supply, as S&P Global analyst Michael Robinet has noted in his Supplier Eye column in this publication.

But for **Means Industries**, whose clutch-technology IP is inside most automatic transmissions made worldwide, balancing today's business with tomorrow's propulsion opportunities has been part of the company's strategic roadmap for years.

"The OEMs have shifted their spend from ICE into EVs, which are inevitable," said Jeremy Holt, the veteran engineering executive and president of Means Industries' parent company, **Amsted Automotive Group (AAG)**. "But if the shift takes longer than is forecasted, we have a business plan that's agnostic to that. We can survive with a rapid transition to EVs, and we can also do well in an extended-ICE scenario."

Founded in early 2021, employee-owned AAG consolidates the synergies of Means (mechatronic clutches, driveline disconnects, e-motor housings), powder-metal pioneer **Burgess-Norton**, and **SWM Manufacturing**, a leader in advanced cold-forming and precision machining processes. The company's 16 engineering and manufacturing facilities in North America, Asia and Europe are engaged in EV programs with both legacy and start-up OEMs looking to expand their new vehicles' torque-transfer capabilities and overall efficiency.

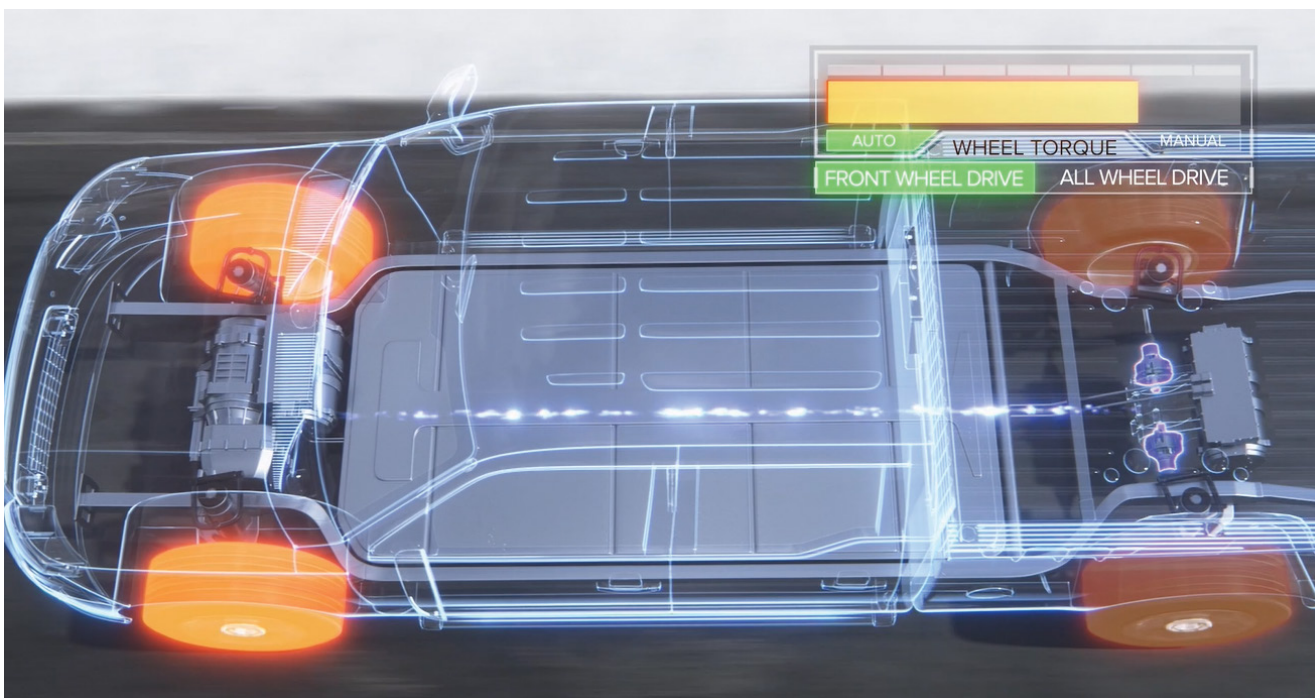
A solid book of business in "the surviving engines and transmissions" chunk of the industry, as Holt calls it, is expected to sustain revenues

and ongoing product development for at least the next decade until EVs reach mainstream volume.

## Needing a 25,000-rpm clutch

For the past six years, Means Industries has aimed its evolving R&D program to "address the unvoiced needs of EV propulsion — the greater efficiencies that the OEMs have not yet realized," Holt explained. The Saginaw, Michigan-based company leverages the proprietary materials and metal-forming expertise of the sister AAG units, along with Means' expanding muscle in mechatronic engineering, control software and electromagnetic actuation.

Anticipating the steep curve in research and testing required for electric drivelines meant the company had to replace and reconfigure laboratory equipment "for going from ICE engine speeds to electric-motor speeds," observed Carl Beiser, director of advanced engineering. "We've been listening to the customer about their needs for things like a 25,000-rpm clutch. We're putting those learnings into our advanced R&D portfolio work so we can generate unique IP that can then be applied." AAG's investments in virtual design and simulation toolsets is paying off in "exponential progress" in actuation development, Beiser said. NVH analysis is another vital focus. And the company is even doing its own coil winding, he added.



Growing sophistication of EV propulsion systems and demand for increased vehicle efficiency are driving product development and manufacturing synergies across AAG's business units.

While the first generation of EVs are relatively basic in terms of propulsion and gearing, Holt's team noted the second and third generations will require significantly greater transmission and driveline sophistication in the quest for higher overall efficiency.

"The transition into EV transmission and driveline architectures is a natural evolution for us," said Jeff Prout, AAG's VP of product technology. He noted that next-gen EV drivelines will feature more multiple-motor layouts, multi-axis torque delivery, disconnect axles and "unique combinations in the differential" and even multi-speed gearing. All require the "smart" torque-transfer approaches now being prototyped by Means and in some cases evaluated by its customers. Quicker driveline response times and more precise control are a must, he asserted, to reduce internal parasitics and deliver the refined actuation that OEMs and EV buyers demand.

**Rivian Automotive** is among the new-wave EV makers that have engineered AAG technology into its production vehicles, SAE Media has learned from publicly available sources. The novel RIT is equipped with an electromechanical axle system with disconnect functionality, enabled by Means Industries' Dynamic Controllable Clutch (DCC) and Burgess-Norton powder metal processes. The patented DCC is a keystone technology that enables the rapid (<20 ms) and smooth decoupling/recoupling of the electric pickup's

drive axles and rear drive module, via electromagnetic actuation and engagement. Devoid of hydraulics, the compact mechanism contributes a range increase for RIT of more than 10%, according to engineers.

Beiser argues that traditional dog clutches and friction-type clutches can be a compromised solution for electric propulsion systems, notably in efficiency, size and cost. He cited Means' consistent innovation in 1-way mechanical diode (MD) clutch development, progressing to the CMD (controllable mechanical diode) and recently to the DCC (CMDs are capable of transmitting torque in reverse and first gear using a set of locking elements, thus eliminating the need for the low/reverse clutch pack). CMD benefits in an automatic transmission include reduced spin losses, smaller size and mass and potentially lower systems cost.

The multi-mode DCC brings faster actuation and disengagement. "We first presented publicly on EV technologies in 2018, and at the time the DCC was more of a shifting element than a disconnect," Beiser noted. "But when you figure out how to control it, it's agnostic to the systems that it can be used in. It can be a shifting element and it can be a disconnect. It's multi-mode functionality depending on how you actuate it." Ongoing development includes the potential for greater torque density, new control strategies, "and functionality that a dog clutch doesn't offer; functionality that the customer hasn't really thought about yet. It's that 'unvoiced need,'" he offered.

Increasingly sophisticated clutch actuation is core to the IP that AAG is generating. Holt stressed the importance of building a strong team in mechatronic engineers and directing R&D investment to that space. "We have some future technologies that we've been experimenting with that are heading for customer evaluation," he said.



“Increasingly sophisticated clutch actuation is core to the IP that AAG is generating.”



Cell manufacturing at Means Industries' Saginaw facility.



The Dynamic Controllable Clutch's design makes for compactness. Mechatronic engineering is key for Means' family of clutches and disconnect products.

## Mechatronics muscle

The EV trend and the rise of the mechatronics and software disciplines is affecting changes in Amsted's hiring of engineers, according to Prout. “For context, ten years ago we were a group of mechanical engineers, and we did some FEA. When we added our first electrical engineer, he spent most of his time out in the test lab keeping the test equipment running! It wasn't until about five years ago that we started looking for mechatronic and electrical engineers. Now we have a team of them, and I'd say one-third to half of our R&D projects are being driven by the mechatronics team.”

Beiser surmised that nearly 100% of AAG's advanced R&D activities with customers are related to electrification. Asia seems to be more focused on hybrids in the last 18 months. And what of advanced R&D in the legacy-powertrain arena? “If there is a new automatic transmission platform being developed, we're not aware of it,” he stated.

A robust co-op program for engineering students is keeping Mean Industries in the hunt for new talent, within today's super-competitive market. “The young engineers coming out of university are more versed in electrical and mechanical today,” Prout said, “and the importance of electrical engineering now is at an all-time high. If you're studying electrical engineering or software, your opportunities will grow immensely” as the industry moves into electrification at the component, tiered supplier and vehicle levels, he advised.

As the industry begins to usher in the next generation of EVs, Holt's teams are already seeing differences in collaborating with their incum-

bent-OEM customers versus those at the EV startups who tend to have leaner organizations and internal capabilities.

“We recently launched a new disconnect with a startup,” Prout reported. “They leaned very heavily on us, where typically when we go into an OEM they will have already sketched in some sort of mechanical or friction-based clutching device. Not only did the start-up come in with a blank sheet of paper — ‘this is the box, we need something here’ — but they also gave us half the amount of time to do it! That was quite challenging. But I'd say we had a lot more design and engineering freedom working with the startup.”

From all of AAG's customers, however, the three words they hear most often in EV program meetings related to systems performance are fast, smooth and quiet. “Fast is relative to the OEM in question, but smooth — that's a table stake!” Beiser exclaimed. “So, the challenge becomes, increasing the disconnect speed without sacrificing smoothness. And that opens the door for control software.”

“You can smooth things out with friction clutches, but you can't have friction clutches in an efficient EV drivetrain,” Holt concluded. “It's the perfect place for highly efficient, multi-mode clutches that have the ability to lock, to do regen and disconnect, and don't create waste energy in the shifting process, all within one controllable device.” Unvoiced needs to be met. ■

# Electric radiant heat for EV cabin comfort



Toyota's 2023 BZ4X EV uses the new radiant heat system co-developed with Denso.

## New HVAC tech helps Toyota tackle the EV heat-vs.-range conundrum.

by Paul Weissler

Vehicle OEMs have been steadily increasing the range of their electric vehicles (EV) and plug-in hybrids (PHEV), but the ranges they claim publicly are in ideal thermal conditions. Now comes the hard part: Deliver those same ratings in real-world weather, in the kind of thermal extremes that challenge the performance of lithium-ion battery packs.

Although air conditioning use in hot summer weather typically causes a modest loss of EV range, it's the 30-40% drop of range in cold winter weather when the cabin heater is deployed that continues to challenge EVs' ability to fully replace ICE-powered vehicles.

To date, most efforts to improve EV heating performance have focused on electric seat heaters, some electric steering wheel heaters and for the most part, heat pumps built into the HVAC refrigeration system. But the heat pump performance is limited by the fact that refrigerant flow slows with low winter temperatures, so heat pumps must switch to less-efficient resistance or PTC (positive temperature coefficient) heaters when ambient temperatures drop below 0°C (32°F). The **Toyota** Prius Prime PHEV's A/C refrigeration system incorporates a liquid-gas separator and injection of refrigerant gas, a development adapted

from static-mount commercial heat pumps. This technology enables heat pump operation down to -10°C (14°F).

### First use on bZ4X

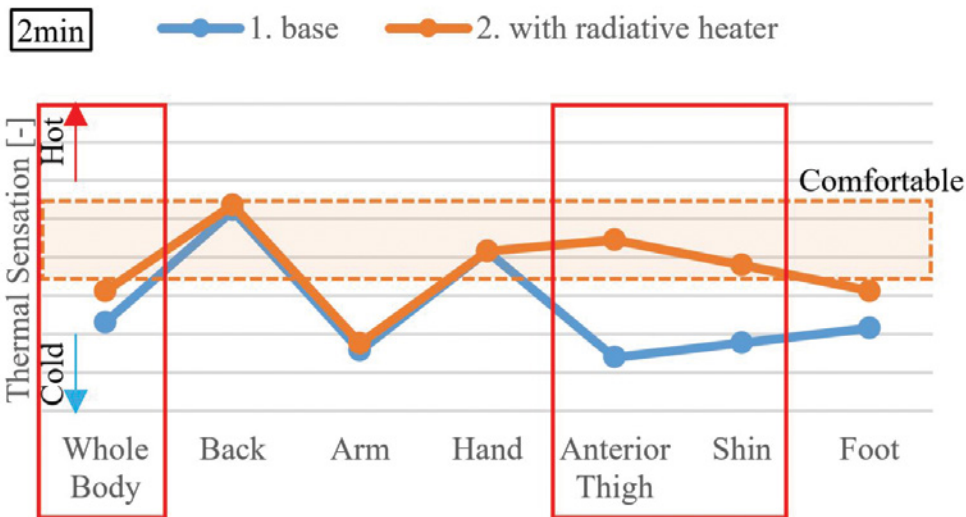
In a presentation at the 2022 SAE WCX, Toyota detailed its test installation of an electric radiant heater in a Prius Prime, describing the system as a method for providing supplementary cabin heat quickly and with greater efficiency than other methods. This effort may indicate the Prime, which also has seat and steering wheel heaters, is being used as a testbed for solving the EV cabin heat-vs.-range conundrum. The Toyota testing showed use of the radiant heater resulted in a 5.3% reduction in fuel consumption, and much improved driver comfort within two minutes of cabin entry.

Radiant heating employs one of the three forms of heat transfer. When turned on, a radiant heater emits invisible infrared waves a relatively short distance in a narrow band. The infrared wave band quickly contacts objects in its path and warms them. Aimed at a driver in the Prius Prime's cabin, the system warms some of the front part of the driver's body, working in conjunction with a seat heater that covers the back of the body from the shoulders down to the knees. A steering-wheel heater warms the hands and the floor outlet from the HVAC eventually adds warmth to the driver's knees down to the feet and provides some heat for the rest of the body.

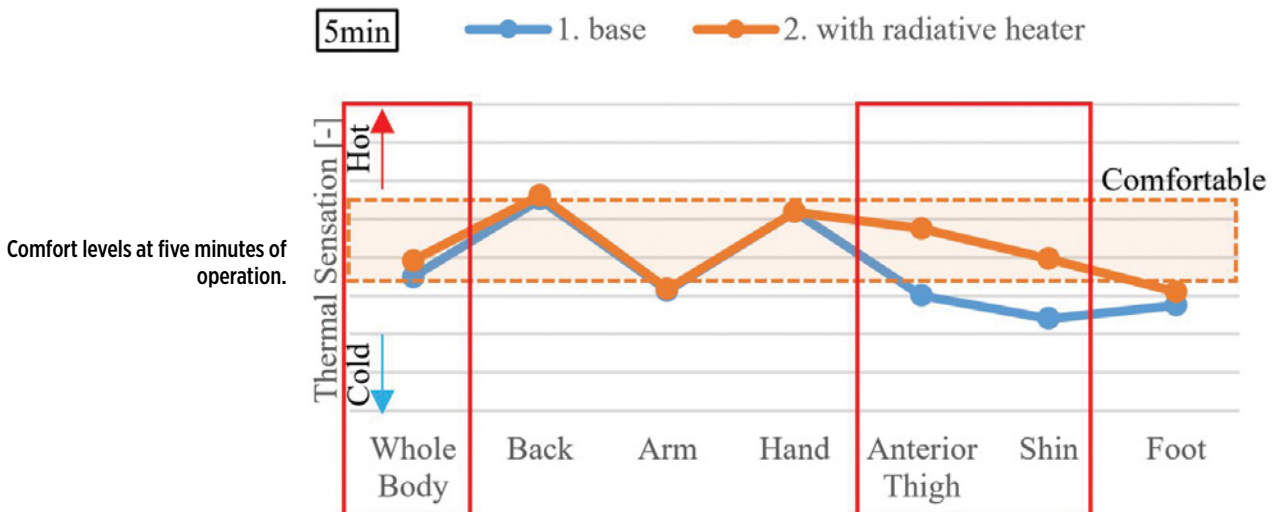
Seat and steering-wheel heaters represent another type of heat



# Electric radiant heat for EV cabin comfort



Comfort levels at two minutes after entry and vehicle operation. Toyota engineering refers to the radiant heater as “radiative heater” in these comfort level graphs.



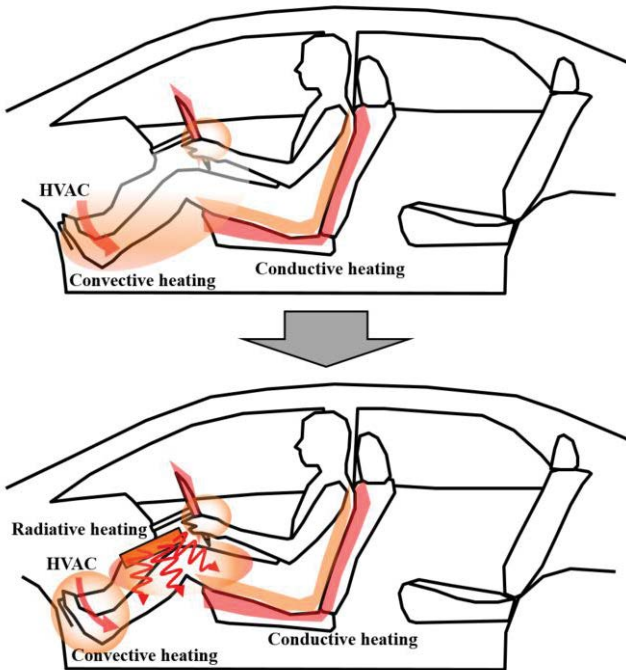
transfer — conductive heating, which is direct contact with a warm surface. The HVAC produces the third type of heat transfer: convective. This is via the movement of liquids, such as coolant from the engine or the liquid cooling system of an EV battery pack and vehicle drive system, to a heater core. In a conventional ICE-powered vehicle, HVAC often is designed to warm the entire cabin, a gradual process that slows the heating effect, with the time to achieve cabin warmth extended. In the Prime test vehicle, HVAC is required to provide only some warmth for the feet and lower legs up to the knees. It still takes time to reach operating temperature, however, and Toyota relies on the other (electric) heaters to fill the early time gaps.

Because the Prime has a combustion engine, there also is some heat from its cooling system. But it needs to generate more heat, at a faster rate, particularly during EV-only operation. To fill this time gap, Toyota proved the value of the electric radiant heater, which is mounted in the dashboard below the steering wheel. EVs would, at this point, operate a conventional electric heater, typically a PTC or resistance type, but Toyota’s radiant heater provides instant warmth and is more efficient

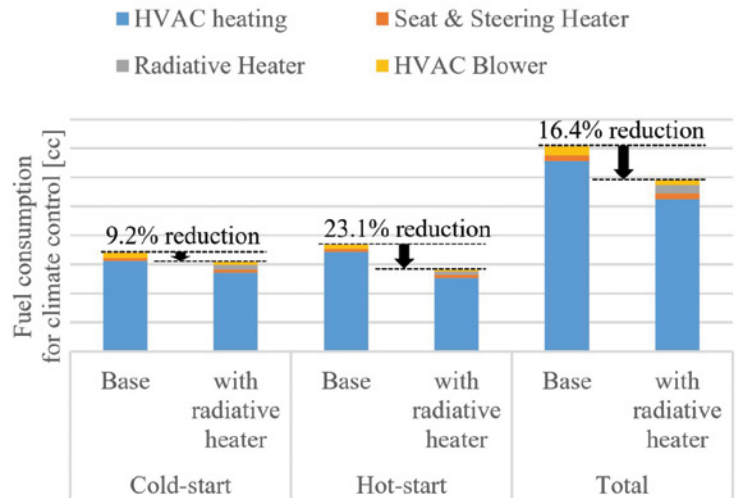
because it covers only a small zone. It will be used on Toyota’s first BEV, the 2023 bZ4X, and might also be installed under the glovebox to assist passenger-side heating, according to engineering sources.

## Feet still need heat

Research proved the benefits of the radiant-heat design on the Prime, where a Denso-developed thermostatically controlled 150-watt heater was installed on the driver’s side. A cold-weather test then was performed by a test driver trained in comfort-level sensing, in a test chamber per the EPA Cold FTP driving schedule. The HVAC was set in Auto/ 22°C (72°F) and the chamber temperature was maintained at 6.7°C (19.9°F). This was compared with HVAC set to the same temperature with reduced HVAC airflow volume and radiant heater activation to heat just the anterior

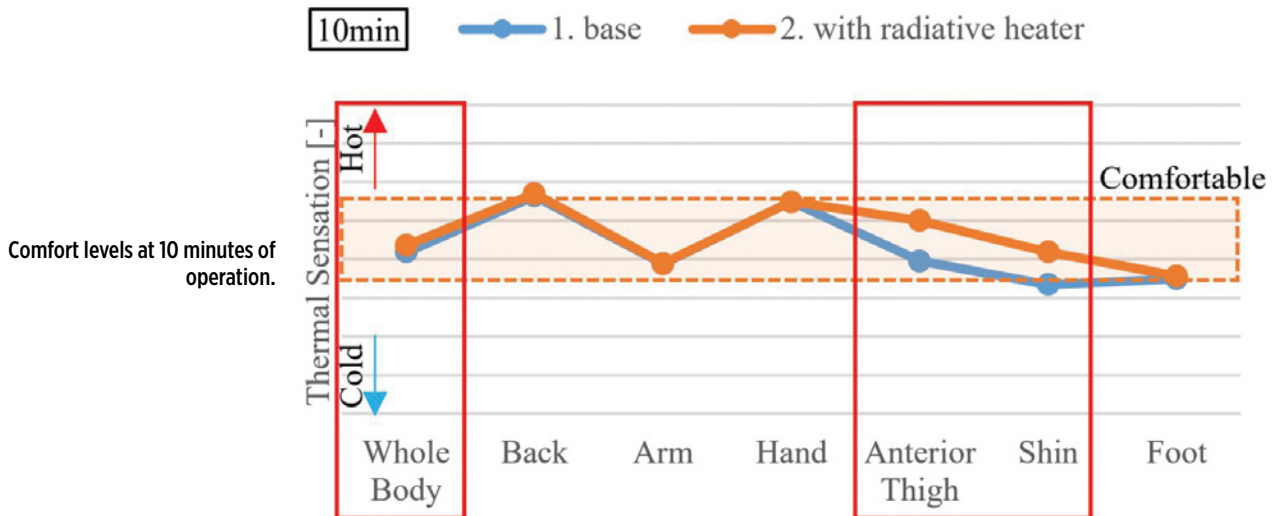


How different types of heating were used to warm the driver in the Prime cabin.



Fuel consumption reductions from HVAC operation. The overall reduction for the Prime PHEV using the new electric radiant heater was 5.3%.

**“Toyota’s radiant heater provides instant warmth, is more efficient — and will be used on Toyota’s first BEV, the 2023 bZ4X.”**



thighs and shins to the ankles instead of waiting for convective heat from HVAC. The strategy was for HVAC to heat just the feet and legs well below the knees for fast engine warm-up and use radiant heat primarily above that. The additional electricity consumed was deemed insignificant.

Within two minutes of vehicle entry and activation of all systems, the driver in the test vehicle with the radiant heater engaged was largely comfortable except for arms, head and feet, whereas most of the

driver’s body without radiant heat was still cold, except for back and head. Within five minutes, the test driver with the radiant heater engaged was almost fully comfortable, with only the hard-to-warm feet close to but below the comfort level.

With the radiant heater disengaged, it took 10 minutes for the driver to reach a barely comfortable level for almost the entire body (unsurprisingly, with the feet slightly below comfort level), whereas with the radiant heater engaged, all parts of the driver’s body were in the comfort zone after 10 minutes. At 20 minutes into the test, both systems reached fully comfortable levels. ■





# Honda sticking with **STRUCTURAL ADHESIVES**

Honda extends its use of adhesive bonding to the 2022 Acura MDX, enhancing the vehicle's dynamic performance among other benefits. Principal engineer Patrick Shafer explains.

by Paul Seredynski

The DuPont adhesive used by Honda for body assembly (shown here in non-Honda application) now is available commercially.

For the all-new 2021 Acura TLX sedan, **Honda** revealed a new design for its front shock towers ("damper housings") that leveraged dissimilar materials, self-piercing rivets (SPRs) and adhesives. Carrying that experience forward to the 2022 Acura MDX, which for the first time offers a performance Type-S trim, the MDX features a similar design for its front damper housings, each of which require more than two meters (6.6 ft) of structural adhesives.

The adhesive, developed by **DuPont** to Honda's specification and now available commercially, is the same structural compound used on the TLX [<https://www.sae.org/news/2021/08/acura-tlx-is-honda-body-build-benchmark>] and on other portions of the new SUV's body structure. Applied by robot at room temperatures, the adhesive cures during the normal e-coat heating-oven cycle. In the damper housings, the adhesive is used to bond steel components to e-coated aluminum castings.

According to Patrick Shafer, principal engineer and body design leader for the 2022 Acura MDX, growing expertise in adhesives has been key in helping meet the program's performance targets. The materials play a key role, he noted, in the relationship between body rigidity and the chassis' dynamic response, with the goal of providing a more connected feeling between the driver, the vehicle, and the road.

"Adhesive was one of the tools we used to achieve significant increases in both global body rigidity and local stiffness in the MDX,

especially when you consider our high dynamic targets for the first-ever MDX Type S," Shafer said.

"Utilizing adhesives in key areas of the vehicle structure to further improve joint efficiency enabled us to efficiently achieve our targets while managing the overall body weight. Ultimately, the driver experiences a smoother ride with less handling delay." Our interview with Shafer, edited for space, follows.

## **What learnings were carried forward from the 2021 TLX to the 2022 MDX?**

Many of the same technical team members were involved in both the TLX and the MDX developments. This consistent oversight allowed any key learnings during the TLX development to be immediately fed into the MDX's design. The majority of those items were in the details of casting features, CAE method improvements, or joining details. The most visible example of learnings being carried forward is the expansion of self-tapping bolts to structural areas on the MDX. The TLX applies M6 self-tapping bolts in non-structural locations where brackets are assembled to the castings. With the history and detailed understanding we gained during the TLX development, we



The 2022 Acura MDX Type-S (above) uses more than two meters of structural adhesives in its front damper housings.

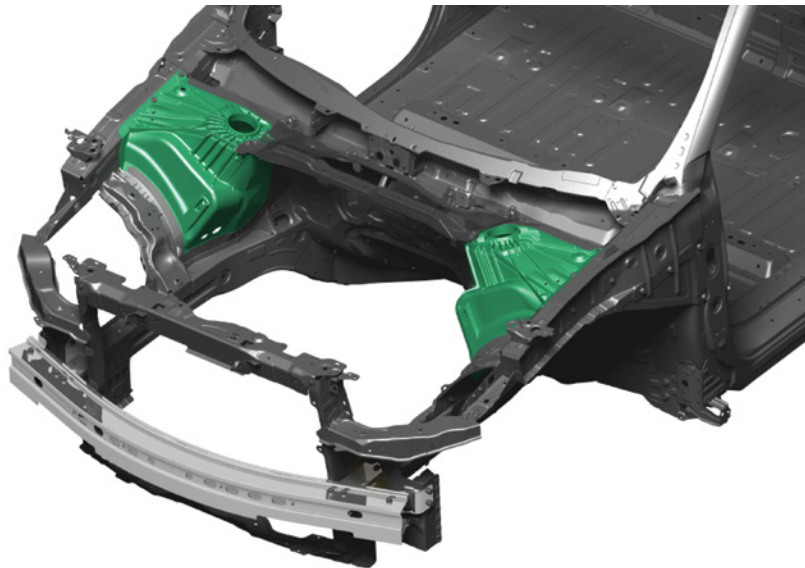
expanded the application on the MDX to encompass M8 structural bolts between the casting and the dash enclosure, further improving the packaging. The dash enclosure includes an integrated tower bar structure and lateral suspension loads are directly carried by this joint.

#### Do the TLX and MDX share the same front architecture?

The TLX and the MDX have very different front-end architectures and are produced at separate Honda plants in Ohio. While TLX and MDX are unique platforms at these facilities, their white bodies are built on the same high-volume, steel resistance spot welding lines as the other vehicles produced. For example, the TLX shares the same weld line that produces the Honda Accord among other models at the Marysville Auto Plant, and the MDX shares the same weld line that produces the Honda CR-V and Acura RDX at the East Liberty Auto Plant.

Early in the development planning phase, we made the strategic decision to consolidate both damper housing assemblies to a single new multi-material joining line at one of our nearby core Tier-1 suppliers. This multi-material joining line was concurrently developed to support both vehicles' differing architectures and to supply both Honda plants. This enabled us to deploy the cast aluminum damper housings directly into our high-volume, resistance spot welding steel weld lines without the need for additional joining equipment at the two Honda plants.

While very different in architecture and construction, the materials in use within the TLX and MDX front damper housings are the same. The casting alloy is the same, as are the steel sheet grades joined to it, and



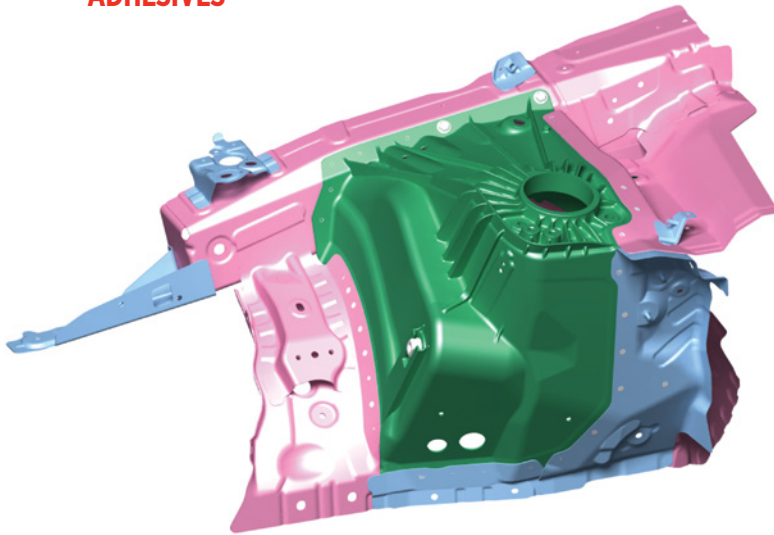
The new front-end architecture of the 2022 Acura MDX was engineered to provide a more connected feeling between the driver and the road.

the structural adhesive. Not all of the rivet lengths are shared due to differences in joint stacks between the models.

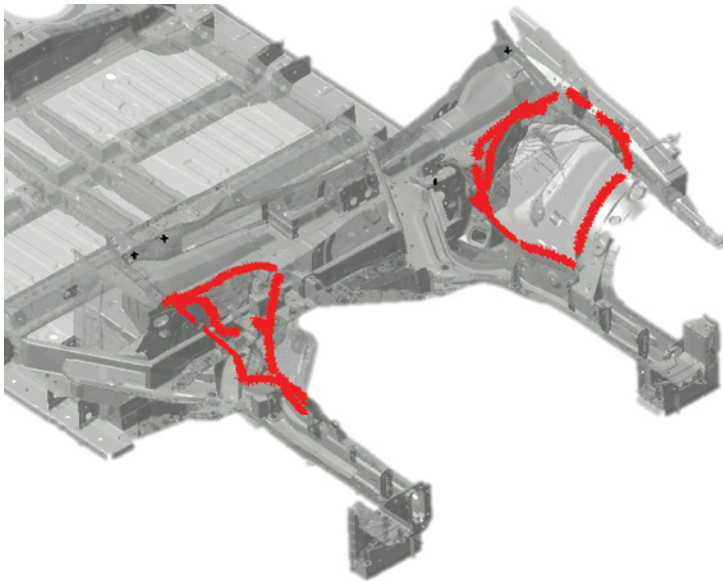
#### How does the adhesive help increase structural rigidity?

In a traditional point-joining method, such as a spot weld, SPR, or bolt, the force applied to the joint is localized around the weld or the fastener. The areas between the connections still have freedom of movement and the potential to deform separately. These micro-deflections reduce the efficiency of the joint. Adhesive bonds the two surfaces in a larger area than the fastener or weld itself, more effectively distributing the loads across the entire adhesive length and





The 2022 MDX front damper housing combines an e-coated aluminum casting and hot-dipped galvanized-steel stampings.



In the MDX front damper housings the adhesive path follows the same connection areas as the self-piercing rivets (SPRs) around the perimeter of the casting where it joins the steel structure.

utilizing the entirety of the joined surfaces more cohesively. This improves the joined area's efficiency and leads to improvement in deflection, thereby increasing body rigidity.

#### **Does the adhesive follow the same connection path of the other joining methods?**

In the case of the TLX and MDX damper housings, the adhesive follows the same connection areas as the SPRs around the perimeter of the casting where it connects to the steel structure. In both damper housing designs, we minimized the contact area to the SPR joining

locations; we do not have areas where bonding was the sole joining method.

#### **Are there benefits to using adhesive with SPRs?**

There are advantages. Aside from the joint-deflection improvements, the durability performance of the SPR joint is also improved. The adhesive distributes the forces across the adhesive area. Depending on the type, direction, and magnitude of the cyclic loading, the adhesive bonding can significantly delay the onset of localized fatigue cracking or loosening of the SPR connection.

The adhesive's primary purpose in the TLX and MDX damper housings is for body rigidity, but there is a secondary benefit for corrosion toughness. The TLX and MDX apply a multi-layer approach to galvanic corrosion protection to the dissimilar material joining areas. The primary isolation between the steel and aluminum is the e-coat applied to the casting prior to the joining operation. We also utilize dust seal on both sides of the joint edges and in high water-splash areas to the SPR heads, to prevent water intrusion into the joint. The adhesive applied within the joint also aids to isolate the materials, but it is a side benefit and not its primary purpose within the joint.

#### **Can the adhesive can be used across dissimilar materials?**

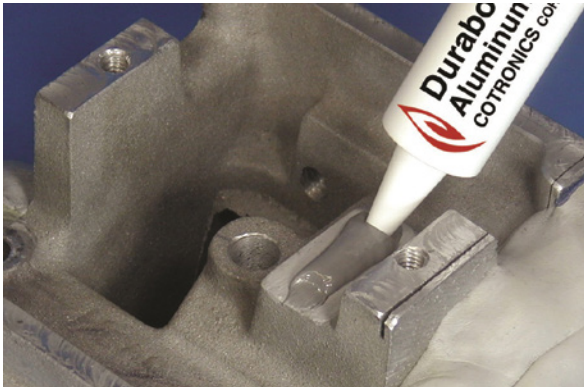
The adhesive was formulated to join both the steel and the aluminum components and their associated coatings. In the damper housing assembly, the aluminum casting is e-coated prior to the SPR joining process. In this application, the adhesive joins the previously e-coated aluminum casting to the surrounding hot-dipped galvanized-steel stampings. At the Honda plant, the completed damper assembly's steel components are resistance spot welded into the rest of the body structure on our weld line. The completed white body is e-coated, and the adhesive cures in the e-coat oven prior to body paint.

#### **Can the adhesive be used within multi-layer material stack-ups?**

There is the possibility adhesive could be applied between all layers of a three-sheet stack, depending on the vehicle's targets and the specific loading condition of the joint. In the case of the TLX damper housing, the optimized solution was achieved through application between the casting and the first sheet only. During our developments, every adhesive application is thoroughly vetted through CAE optimization to determine the adhesive locations that achieve the maximum benefit to meet the vehicle's performance targets. In this way we can ensure we are efficient in providing the maximum benefit while limiting equipment and consumable cost. ■

## SPOTLIGHT: ADHESIVES

### Aluminum putty



**Cotronics** (Brooklyn, New York) released its new Durabond 7032 stainless steel aluminum putty. The latest compound is capable of curing at room temperature to form a machinable composite. According to the company, the compound maintains high bond strength at temperatures of up to 2,000°F (1,093°C) while also offering excellent resistance to chemical corrosion and shock. Cotronics also states that Durabond 7032 is machinable and resistant to most chemicals and solvents. It can be utilized for high-temperature repairs such as rebuilding, filing holes and plugging leaks in automotive, maintenance and industrial applications. It is available in one- and two-pound kits and is ISO 9001:2015 certified.

For more information, visit <http://info.hotims.com/82333-400>

## SPOTLIGHT: FASTENERS

### Retaining clips



**Smalley** (Lake Zurich, Illinois) recently partnered with **Beneri** (Valmadrera, Italy) to produce a new series of tapered section retaining clips, or circlips. The companies state that these clips are designed for high thrust loads and heavy-duty applications, such as automotive, naval, agricultural and high-temperature machinery. Both internally and externally tapered section retaining rings are available and range in diameter from 0.25 to 3 inches (6 to 75 mm). The axially assembled rings are designed to be installed in either a housing groove or bores or shafts. The rings also function as a removable shoulder to safely secure the assembly.

For more information, visit <http://info.hotims.com/82333-401>

## Microcontrollers

### Infinion Technologies

(Munich, Germany) announced the expansion of its AURIX microcontroller family and availability of the first samples of the company's new AURIX TC4x family of 28 nm microcontrollers (MCUs) for ADAS, automotive E/E architectures and artificial intelligence (AI) applications. The new family features scalable performance enhancements from the AURIX accelerator suite. This includes the new parallel processing unit (PPU), a SIMD vector digital signal processor (DSP) that addresses the demands of various AI topologies. Additionally, new software over-the-air (OTA) features help fulfill OEM demands for fast and secure vehicle-to-cloud connection. It also supports high-speed communication interfaces like 5 Gbit Ethernet and PCI Express along with new interfaces such as CAN-XL and 10BASE T1S Ethernet.

For more information, visit <http://info.hotims.com/82333-402>



## Semiconductor module

### Hitachi Energy

(Zurich, Switzerland) announced the launch of the RoadPak semiconductor module for electric vehicles at PCIM Europe, in Nuremberg, Germany. The company states that RoadPak uses state-of-the-art silicon

carbide (SiC) technology to achieve exceptional levels of power density for faster charging, reliability over the vehicle's lifetime, and the lowest possible power losses to help enable the longest possible driving range. The component has reportedly been tested by EV manufacturers and has also been used for two seasons on the Mahindra Racing teams' Formula E car. RoadPak is available in both the 750V and 1,200V ranges and is intended for use on all types of electric vehicles including passenger cars, buses, agricultural EVs, heavy-duty trucks and high-performance racing cars.

For more information, visit <http://info.hotims.com/82333-403>





## Noise-reducing material

**SABIC** (Riyadh, Saudi Arabia) announced their LUBRILOY N2000 compound, a new internally lubricated material for prevention of buzz-squeak-rattle (BSR) noise in automotive interiors. The new LNP compound is based on an amorphous blend and offers both molded-in color capability and paintability. SABIC states that the proprietary, compatibilized olefinic alloy is free of silicone and polytetrafluoroethylene (PTFE) and that by replacing standard PC/ABS with this material, automotive OEMs and suppliers can significantly reduce friction and stick-slip behavior between molded parts to limit or prevent unwanted noise. Additionally, the new material can reportedly be used in consumer electronics applications where reduced friction or improved wear is required.



For more information, visit <http://info.hotims.com/82333-404>

## Cartridge fuses

**Littelfuse Incorporated's** (Chicago, Illinois) new 607 compact cartridge fuse series is now available. The fuses carry a rating of 500Vac/Vdc with current ratings from 40A to 63A and a 10,000A interrupting rating. The company states that the 607 Series is designed for overcurrent protection applications while also providing a robust solution for demanding high-voltage power supply circuits. The 500V fuse rating is suitable for both AC and DC inputs. Littelfuse also claims that a with new 10mm x 32mm cartridge body requires less board space than previous designs that used multiple lower-current-rated fuses in parallel, which means designers can reduce the board space they reserve for protection components when designing high-wattage equipment.



For more information, visit <http://info.hotims.com/82333-405>

## Impedance testers

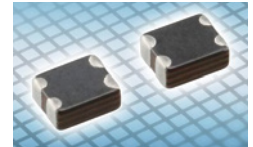
**Rohde & Schwarz** (need location) launches its new LCR meter family of high-performance general-purpose impedance testers. The LCX features a supported frequency range from 4 Hz to 10 MHz across two models. The R&S LCX100 covers a frequency range from 4 Hz to 300 kHz, the R&S LCX200 a basic frequency range from 4 Hz to 500 kHz with options to cover all frequencies up to 10 MHz. The auto-balancing bridge technology used by the LCX supports conventional impedance measurements by measuring the AC voltage and current for the device under test, including the phase shift. This is then used to calculate complex impedance at any given operational point.



For more information, visit <http://info.hotims.com/82333-406>

## Common-mode filters

**TDK** (Tokyo, Japan) developed the KCZ1210DH series common-mode filters for automotive applications. This series provides a noise control function for high-speed differential transmission signal lines for automobiles. TDK states that the product supports high-speed signals with over 10 Gbps transmission rates. Additionally, it contributes to noise control in the GHz band generated due to increased speed. TDK also states that by supporting an operating temperature range from -55 to 125 Celsius (-67 to 257 Fahrenheit) and adopting a conductive resin-based electrode mitigated cracks from thermal shock while increasing durability against mechanical stresses like substrate strains. The outer dimensions are 1.25 (L) x 1.0 (W) x 0.5 mm (H) (.049x.039x.19-inches), which saves board mounting space.



For more information, visit <http://info.hotims.com/82333-407>

## Water-based emulsifier

**Solvay** (Brussels, Belgium) has developed Reactsurf 0092, an alkylphenol ethoxylates-free and non-ionic reactive water-based emulsifier for solid epoxy resins. The intended use for this emulsifier is industrial coatings and paints or binders. Solvay claims this emulsifier can match or exceed the performance of solvent-based coatings but with an appreciably lower level of VOCs. Solvay also states that waterborne epoxy emulsions that incorporate Reactsurf 0092 are still flowable under -10°C (+14°F) at up to 5 F/T cycles. Results of salt-spray tests (ASTM B-117) on cold steel rolled plates coated with epoxy emulsion paint reportedly displayed a combination of high corrosion resistance, superior wet-adhesion and no peel-off.



For more information, visit <http://info.hotims.com/82333-408>

## Hall-effect sensor

**Allegro MicroSystems** (Manchester, New Hampshire) announced its new A33230 3D sine/cosine hall-effect position sensor. According to Allegro, the A33230 is the smallest 3D sine/cosine sensor currently available. The sensor contains two discrete analog signal paths for high-speed performance and can also be used as an angle sensing device, provided the system includes an electronic control unit (ECU) capable of performing CORDIC calculations on the two outputs. The A33230 also incorporates vertical and planar Hall-effect elements with sensing axes that are orthogonal to one another and is pre-programmed to measure angle in any plane while providing independent sine and cosine outputs.



For more information, visit <http://info.hotims.com/82333-409>

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# UPCOMING WEBINARS

## FROM VIRTUAL ECU TO REAL VEHICLE: CONTINUOUS TESTING OF FUNCTIONAL REQUIREMENTS

Wednesday, June 8, 2022 at 11:00 am U.S. EDT

Today, most of the software functions in a car can be tested efficiently using virtual ECU models and DevOps engineering methods. However, final acceptance tests with real vehicles are still mandatory, even though they are expensive and time-consuming. This 30-minute Webinar presents a flow for seamless testing of functional requirements throughout the entire development process by formalizing the functional requirements using a Requirement Modelling Language (RML).

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## GET EVEN MORE OUT OF YOUR EVs WITH THERMOPLASTICS

Thursday, June 9, 2022 at 10:00 am U.S. EDT

One of the biggest obstacles facing electric-vehicle development is finding a balance between high-performance components and safety. This 60-minute Webinar covers the latest methods to overcome additional battery cooling challenges, including a new technology to manage tab cooling on EV batteries and thermoplastics that can withstand heat shocks for use on bus bars in motor and power electronics.

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## NECESSARY COMMUNICATION PROTOCOLS TO SUPPORT HIGH-PERFORMANCE COMPUTE AUTOMOTIVE ARCHITECTURES

Wednesday, June 15, 2022 at 2:00 pm U.S. EDT

Whether it's electric vehicles, autonomous-driving applications, or connectivity to the cloud, more data in the vehicle means communication protocols play an increasingly critical role by transferring and distributing real-time and on-demand data through network communications systems. This 60-minute Webinar will discuss what should be taken into consideration to address the challenges that exist when developing new architectures.

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# UPCOMING WEBINARS

## EV BATTERY & ELECTRIFICATION TESTING – FROM THE GRID TO THE ROAD

Thursday, June 16, 2022 at 2:00 pm U.S. EDT

Electric vehicles (EVs) are driving the future of the automotive industry. Success in this fast-paced, high-voltage, high-power transition to EVs requires readily available, safe, flexible, and accurate test equipment. With the demand to bring EVs to the market faster, getting there now is no longer an option — it is a requirement. During this 60-minute Webinar, you will learn how to test your EV designs in key areas.

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## SUSTAINABLE ELECTRIFIED TRANSPORTATION AND MOBILITY

Tuesday, June 21, 2022 at 3:00 pm U.S. EDT

Transportation is the world's fastest-growing source of energy-related carbon emissions. A new generation of electric transportation will lead to an era of clean transportation and reduce dependence on fossil fuels, but to propel the development of sustainable electrified transportation, it is imperative to handle the complexity of its design with effective and efficient methods. This 60-minute Webinar discusses the importance of solving the complexities of sustainable electrified transportation design.

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## SIMPLIFY & STREAMLINE DEVELOPMENT OF ISO 26262 COMPLIANT AUTOMOTIVE SoCs

Wednesday, June 22, 2022 at 2:00 pm U.S. EDT

Standards such as ISO 26262 define strict requirements, processes, and methods that all stakeholders must abide by when designing safety-critical automotive products. One such requirement is the Development Interface Agreement (DIA), which defines the interactions, interfaces, responsibilities, dependencies, and work products exchanged between customers and suppliers for all distributed safety-related activities.

This 60-minute Webinar explains the details of distributed development based on DIA and outlines the different activities for which DIAs must be signed.

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