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Faurecia engineers a bold jump into the fuel-cell future

Cooling that Satisfies the World's Most Demanding Customers.







Scalable sim for ADAS, AV development

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Interview: Toyota's '22 Tundra chief

Making VW batteries in the U.S.

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November/December 2021

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# CONTENTS

# FEATURES

### 23 High on hydrogen COVER STORY

Through its Symbio joint venture with Michelin, Faurecia expands far beyond its interior-systems base into the fuel-cell future.

# **19** Simulating a faster route to ADAS and AV validation SIMULATION

With its new cloud-based Simphera platform, dSpace responds to demand from global automated-vehicle development teams to help manage their expanding, complex workload.

# 27 Innovating the methanol fuel cell

### ADVANCED PROPULSION

Using methanol as the source fuel provides an alternative to a gaseous-hydrogen distribution and storage infrastructure, among other potential benefits.

### **29** Engineering the 2022 Toyota Tundra

### PRODUCT DEVELOPMENT

Chief Engineer Mike Sweers talks structure, materials and a different approach to hybrid power.

### ON THE COVER

Best known as a top seating and interior systems Tier 1, Faurecia has invested heavily in hydrogen fuel cell technology to become a supplier of pressure tanks, related hardware and, with its Symbio JV with Michelin, fuel-cell stacks. Our cover photo shows a Faurecia engineer, in the company's Bavans Global R&D Center of Hydrogen, placing sensors on 700-bar storage tanks. These sensors provide data about the state of the tank during the tests. (Faurecia)



# REGULARS

4 Editorial: Ford C2 is model for EV scale

### **5** Supplier Eye

Suppliers battle a new set of ILLs

### 8 Technology Report

- 8 No-batteries-included Corvette Z06: More sting for the 2023 Stingray | **PROPULSION**
- 11 Bosch debuts new CV-specific electric motor and inverter | **ELECTRIFICATION**
- 12 Innovative 'Afreecar' wins SAE 2021 Create the Future Design award | AWARD-WINNING CONCEPT
- 14 3D graphene boosts new batteries beyond lithium-ion | ELECTRIFICATION

### 15 Road Ready

- 15 Hercules readies Alpha electric pickup prototypes
- 16 VW adds traction in budding EV market with AWD for ID.4

### **31** Product Briefs

Spotlight: ADAS Sensors, Electronics & Semiconductors

### 34 Q&A

Conversation with the two engineers largely responsible for readying and running Volkswagen's new U.S. battery-pack plant.

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### Ford C2 is model for EV scale, lower costs

The biggest

'gotta-have' for

electrification is

significantly lower

vehicle costs.

Has the auto industry ever seen a more dynamic and outright crazy time than today's second coming of the electric vehicle? Few of us who visited Rivian Automotive's L.A. auto show display a few years ago would have imagined startup Rivian generating such a blockbuster IPO in 2021. Twelve years in the making, with a mere 200-odd units built to date (most sold to employees), Rivian made history by eclipsing the market valuation of Ford and Nio and briefly topping General Motors — in its first trading day.

Crazy indeed — but Rivian's inaugural product is cleverly engineered and compelling. Recently I drove a production-spec R1T on a 50-mile loop around Ann Arbor, Michigan. My route, with a development engi-

neer riding shotgun, included an interstate highway, rural 2-lane roads and in-town driving. It showcased the R1T's multiple drive modes, sophisticated suspension and intuitive human-machine interface. Overall, the Rivian pickup is state-of-the-art. But to my thinking, it's still not yet a practical choice to satisfy most pickup owners' duty cycles - that thinking being informed by data showing that more than 90% of Tesla owners have at least one other vehicle on which to rely. And these happen to be ICengine powered. Even the products of Wall St. darlings, many customers seem to believe, have limitations.

Lucid Motors' Air is another recent EV entrée that's receiving rave reviews — an "electron-fueled magic carpet ride" is how one colleague described the electric luxury sedan. The Air's wow factor is enhanced by the fact that many of Lucid's key technologies, including the electric drive module and infotainment system, are in-house developments, with higher costs. Like the Rivian R1T, the Lucid's base price is more than \$74,000, putting these two electric interlopers into rich-customer

4 November/December 2021

territory. Of a similar stripe is GM's Hummer EV, brought to market in a remarkable high-speed, aggressive development program. The beastly Hummer, with its \$108,000 base sticker is, sadly, another play to rich folks.

While the Hummer EV leverages GM's new electric truck platform and Ultium propulsion system (shared by upcoming Silverado/Sierra EVs and their electric SUV counterparts to eventually build production scale), Rivian, Lucid and many other EV startups lack similar bandwidth. Broad and deep product

> pipelines that are engineered for platform, subsystems and component commonization, at high volume, are essential for lower cost. And the biggest "gotta have" for electrification right now is sig-

nificantly lower vehicle costs.

OEMs seeking inspiration on how to leverage their upcoming EV architectures should consult Ford's C2 playbook. The global C2 platform currently underpins Escape, Escape Hybrid, Bronco Sport and the conventional and hybrid variants of the new Maverick compact pickup. While it doesn't encompass battery-electrics, C2 is a case study in getting the base platform right — particularly costly-to-reconfigure hard points which carry over into subsequent models. The C2 architecture has proven its ability to successfully support a growing range of models, bodystyles and powertrains and to help drive down cost.

Every new EV program needs the cost/features/quality balance that Ford achieved with the Maverick hybrid, resulting in the truck's revelatory \$19,995 base price. Most of all, the EV customer needs it. GM's recent claim to have an upcoming EV priced less than \$30,000, likely on a new compact platform, and Volkswagen's efforts with its modular MEQ, give hope that others are pursuing similar strategy.

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# **SUPPLIER EYE**

### Suppliers battle a new set of ILLs

uch has been written about the challenges facing the automotive industry's impending shift to an electrified future. Along with the growth of advanced automated driving systems (ADAS) content, one might assume that supplier plates are full. Unfortunately, the industry is grappling with the critical near-term issues of supply-chain outages, labor shortages and the unprecedented economics for virtually every raw material input. This constant cost-and-supply firefight weighs heavily on the suppliers at every tier.

Rising costs are not new. Within the planning process, smart companies account for economics within three key variable-cost drivers: Inputs, Labor and Logistics (ILL). To this point, suppliers would look to the past for economics as well as integrating expected known structural changes into future contracts; this would offer a level of protection from cost increases. Recently, however, the economics facing suppliers are not normal, anticipated, nor easily accommodated in this capital-intensive industry.

While many will point to the COVID pandemic as the sole driver of unprecedented economics and the variable costs within, the situation has exasperated many and revealed the soft underbelly of ongoing industry issues. Labor/skills availability and the fragility of both global logistics and raw-material supply chains are all exposed. Adding to the mayhem are man-made issues such as U.S. Section 232 steel/aluminum tariffs artificially inflating costs, or the chip-supply issue spurring ecosystem inefficiencies.

What has impacted suppliers can best be characterized as successive "black swan" events – outside the normal course of business. Shortages of skilled and semi-skilled U.S. labor has driven extraordinary wage hikes ranging from 10-20% over the past two years. Such levels were never anticipated. Government COVID subsidies, competing options for auto labor, early retirements and the exodus of some workers choosing other occupations are factors reducing



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The result of this... will impact the ability for suppliers to reinvest in their business and develop new technologies. the available pool. A core tenet of economics theory states that wages don't ratchet backwards — only automation or structural shifts can reduce labor costs.

The new 'stay-at-home' economy has helped upset the precarious balance of container ships, containers, ports, warehousing and truck/rail capacity. Countless cargo ships waiting to unload and supply chain inefficiencies are raising costs. While one would hope this is transitory, several shippers have signed longer-term contracts at accelerated price levels.

The industry has faced rising raw-material costs in the past. This time, however, the situation is different. Steel, aluminum, magnesium, resin, oil and other key commodities are impacted by the aforementioned labor and logistics issues — all driving prices higher. While the experience is especially acute in North America versus other regions, global input prices are impacted for all. According to recent IHS Markit forecasts, prices are expected to settle at new, higher plateaus, at a level of economics not anticipated by suppliers.

Grouped together, these cost impacts are not transitory. Accelerating labor economics, shipping customers signing long-term contracts to guarantee capacity and surging material input costs are placing significant pressure on suppliers. Unless a supplier is on a commodity resale program (i.e., their customer purchases key inputs on their behalf), or can adjust input costs according to an industry index, fixed contracts mean there are few levers for suppliers to gain price relief.

The result of this unparalleled cost squeeze will impact the ability for suppliers to reinvest in their business and develop new technologies. It will impair their capability to withstand future extraneous events. At this industry juncture, with the enormous investment pressures of electrification and ADAS/AV integration, a strong and resilient supply base — not one facing an unprecedented cost crunch — is critical. ■

# Ask the Expert

ames Singer graduated from Utah State University with a BS and MS in electrical engineering and began his career working in the server industry as a hardware design engineer and as a technologist for the last 29 years employed by Compaq, RLX Technologies, HP/HPE and Everspin. For the past three years, James has worked as a technologist in Dell Technologies' CTIO office, focusing on Intelligent Connected Vehicles (ICV) and Edge-use cases.

### How many miles would autonomous vehicles have to drive to demonstrate they are safer than a human driver?

Each year automobile crashes result in about one fatality per 100 million miles driven. A study conducted by the Rand Corporation estimates that to properly train an autonomous vehicle to perform equivalent to a human driver requires 8.8 Billion miles, and 11 Billion miles to perform 20% better than a human driver. With a fleet of 100 autonomous vehicles being test-driven 24-hours-a-day, 365 days a year at an average speed of 25 mph, that would take more than 400 years. Increasing the safety and reliability of an autonomous vehicle requires billions of simulated miles and hundreds of thousands of captured and dec-

orated simulated scenarios to supplement the millions of miles driven by a real-world fleet. All this can be accomplished in an infrastructure optimized for Machine Learning Operations, Software-in-the-Loop (SiL) development and testing and Hardware-in-the-Loop (HiL) validation in an on-premises or multi-cloud environment. Also of utmost importance is the software-application ecosystem. Aligning and partnering with the best software application expertise in the automotive industry (bit.ly/3ChMrIO) will be the optimal path to success.

# True or false: Managing a small environment is the same as managing a large scale-out environment.

False. Managing up to 10 servers and a few GB's of storage is very different than managing thousands or even tens of thousands of servers and hundreds of PBs of storage. Consider the analogy of owning one cow versus a herd of cattle. At scale, the primary focus is herd management, not the care and feeding of individual animals. Optimizing at small scale and preparing for large-scale operation requires us to first understand the fundamental challenges of a growing environment. The amount of storage and compute grows exponentially as customers move from SAE L2 to L5 autonomy. This requires looking ahead to the future and investing in platforms that can easily scale with increasing data requirements.



What value does the Edge offer to companies in the automotive space? Industry analysts predict that more than 50% of new IT infrastructure will be deployed at the edge by 2023. And the number of new operational processes deployed on edge infrastructure will grow from less than 20% today to more than 90% by 2024 (bit.ly/3cdBvef). The Edge represents both a dramatic opportunity and a potential stumbling block due to the physical limitations that are often found locally, as well as the imposed constraints of latency and data gravity that make it difficult to transport data to clouds. Dell Technologies is in a unique position to provide a complete Edge solution for the auto-motive industry, with experience managing, operating, and securing heterog-

enous systems deployed at a massive scale that are remotely and widely distributed. In fact, 69% of Fortune 100 companies already use Dell Technologies for their edge computing solutions.

# Why is Dell Technologies important to the automotive industry?

Dell Technologies has years of experience building server and storage systems and managing data at scale – some 80% of the leading automotive suppliers use Dell PowerScale storage (bit.ly/3l08GHd). Dell is also making significant Edge investments to enable the automotive industry to capture, process and manage massive amounts of data. using end-to-end infrastructure solutions spanning HPC, compute, storage, acceleration, and networking capabilities. Automotive customers choose to work with us because of our years of experience with large Enterprise and Edge environments, expertise in data management and our robust portfolio of partnerships. Dell Technologies has a clear vision of the entire automotive pipeline from the Edge to Core to Cloud.

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### PROPULSION No-batteries-included Corvette Z06: More sting for the 2023 Stingray



Topping the eighth-generation (C8) 2020-22 **Chevrolet** Corvette is no mean feat. Customers still pay premiums and patiently wait in line to own one. Yet the new Z06 edition, due next summer as a 2023 model, suggests that the Corvette design and engineering team is just hitting its stride. The Z06 is an ambitious blend of Corvette heritage, state-of-the-art technology – including a new 670-hp DOHC V8 – and lessons learned in racing. This latest member of the C8 family, soon to include two hybrids, is a championship-winning racer tamed just enough for street driving.

Sixty years ago, Corvette patron saint Zora Arkus-Duntov attached the first letter of his name to a sub-rosa component set engineered for racing. Only 199 customers selected the ZO6 option (\$1,818), making a 1963 Corvette so equipped worth millions today. In 2001, the badge was reprised for the hottest model in the lineup, and ZO6s have thrived through three subsequent generations.

### 'Flat-plane' 5.5-L DOHC V8

Sharing only its 90-degree V-angle, 4.40-in (111.8-mm) bore-center spacing and a few fasteners with the immortal ohv small-block, GM's new "flat-plane" LT6 V8 is a totally fresh design. A horizontally split block secures each main bearing with four bolts. The block and heads are cast aluminum reinforced with cast-iron cylinder liners and valve-seat inserts. A drysump lubrication system provides six stages of scavenging and an 8-quart oil capacity. The star of the LT6 show is a crankshaft with all four throws lying in a single plane (versus the standard approach of four throws spaced at 90-degree intervals). Flat-plane cranks provide 180° of spacing between the exhaust pulses of adjoining cylinders to augment power at the expense of NVH. This approach is standard racing practice, and the reason why exotic Italian sports cars shriek at their red lines rather than emit an American V8 engine's motorboat rumble.

The LT6 V8's steel crankshaft, titanium connecting rods and aluminum pistons are all forgings. The four chain-driven overhead camshafts are equipped with phasers to facilitate variable valve timing. Finger followers lie between each cam lobe and its adjoining valve stem. A pair of coil springs closes each valve and lash is set with shims which require no attention throughout the life of the engine. Intake valves are titanium to minimize mass and exhaust valves are sodium-filled for heat resistance.

Combustion chambers yielding a 12.5:1 compression ratio and the engine's intake ports are all fully machined. A molded-plastic intake plenum with valve-connected runners and an electronically controlled throttle body feeds each bank of cylinders. Unlike the C8's LT2 overhead-valve V8, the LT6 does not deactivate cylinders to reduce fuel consumption.

Using a 4.104-in (104.25-mm) bore inhibited coolant flow between the cylinders. The solution – drilling passages through the block's deck – does provide some lateral flow to cool the very

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GM's all-new LT6 is the first DOHC, 32-valve V8 in a production Corvette since the problematic 1990 LT5 that was developed jointly by Chevrolet and Lotus and assembled by Mercury Marine.

top of each cylinder, according to a GM Propulsion engineer familiar with the LT6 who spoke privately with SAE Media. The LT6's 3.150-in (80-mm) stroke, originally selected to duck under the international racing displacement limit, yields a net displacement of 5.5L (333 cu in.).

Ready to rip, LT6 delivers a remarkable 670 net (per SAE Standard J1349) horsepower at 8400 rpm. The redline is 8600 rpm, while the torgue curve peaks with 460 lb-ft (623 Nm) at 6300 rpm. The super-short stroke minimizes the crank's rotating inertia, expediting the rush to the redline. Though executive chief engineer Tadge Juechter insists the Z06 is not a "numbers" car - its official GM-listed top speed is actually slightly slower than that of the conventional Stingray - he does tout a 2.6-second 0-60 mph time.

### New Z07 chassis for trackaholics

A superlative chassis is an essential ally in this performance pursuit. While the C8 aluminum spaceframe, control-arm suspensions and magnetic-adjustable dampers are essentially carryover, every variable has been optimized to collaborate with the more aggressive engine and fresh tire and brake specifications. Supplementing the base Z06 hardware, there's a new Z07 option aimed at hard-core track use.

The Z07 package includes 20x10-in. front wheels wrapped with 275/30ZR-20 tires and 21x13-in. rear wheels fitted with 345/25ZR-21 rubber. Base tires are Michelin Pilot Sport four season run-flat designs while the Z07 package includes stickier Sport Cup summer radials. Skid pad tests revealed that these tires yield 1.22g of lateral grip, according to Chevrolet.

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#### AUTOMOTIVE ENGINEERING

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The 2023 Corvette ZO6 features a uniquely trimmed cabin.



The **Brembo**-supplied foundation brake system is upgraded with 6-piston (versus four) front brake calipers, larger 14.6-in. front rotors and 15.0-in. rear rotors. Included with ZO7 and available standalone are exotic and highly fade-averse carbon-ceramic brake rotors that are 15.7-in diameter in front and 15.3-in. rear. The ZO6's options list also offers carbon-fiber wheels that shave over 10 lb. (4.5 kg) of unsprung weight at each corner.

### **Exterior and interior uniqueness**

To house the ZO6's meatier rolling stock and to cool its more powerful engine, unique fenders and fascias were essential. The new nose cover provides a fifth centrally located radiator while at the rear, exhaust outlets have been pulled inboard from the corners. Side-scoop openings are significantly larger to enhance cooling airflow and overall width is 3.6-in. (9.1-cm) greater to shroud the rear tires.

Extensive wind tunnel and racetrack development yielded major aerodynamic gains, engineers noted. The front splitter is notably larger and the rear spoiler accepts an add-on vertical tab (called a wickerbill) that adds 365 lb. (166 kg) of downforce at high speed. The ultimate choice is an optional package including a larger front splitter, front-corner dive planes, rear under-car strakes and a huge, adjustable carbon-fiber wing. Those aids raise the net downforce to a remarkable 734 lb. (333 kg) at the Z06's factory-claimed 186 mph (299 km/h) top speed.

In keeping with an anticipated base price of \$85,000, the Z06 will come lined with finer materials and offered with new trim choices. There will be seven interior colors coordinated with the dozen available exterior hues and seven different wheel packages. Three seat choices will be available plus two carbon-fiber packages; both the steering wheel and the shift paddles can be wrapped with that racy-looking material.

Juechter's team invested six years of painstaking effort to make sure that the ZO6 succeeds as a supercar without peer. With the exotic brands expeditiously vacating this turf in favor of hybrid and BEV technology, this seems the perfect opportunity for the Stingray to advance its cause.

Don Sherman

### ELECTRIFICATION Bosch debuts new CV-specific electric motor and inverter

A new **Bosch** electric motor paired with an advanced power inverter bring an integrated propulsion solution to the commercial vehicle (CV) market. "Electrification is the future, and we think there's going to be a wide variety of e-powertrains for the medium-duty segment in the very short term," said Dr. Shyam Jade with Bosch in North America.

Jade, a senior engineer of control system development for electrified vehicle system engineering, recently spoke with SAE Media. "This new e-motor is an enabler, whether it's for a full electric, a hybrid or a fuel-cell commercial vehicle," Jade said. The motor's debut coincides with the company's 40% investment increase, year-over-year, in e-mobility.

The 230 motor gets its name from its stator diameter – 230 mm (9.05-in.). "The e-motor is slightly bigger than what you see in a typical passenger electric vehicle. But it's significantly smaller than a typical gasoline or diesel engine," Jade said, noting the e-motor's compact size and other attributes will appeal to the CV market.

Battery-electric CVs are a rarity in 2021, with less than 1% of the medium-duty and heavy-duty vehicles (Classes 4-8) claiming the designation, according to Kenny Vieth, presi-

BOSCH



dent and senior analyst for **ACT Research**, a firm that provides data, industry analysis, and forecasting services for CV and transportation markets. By 2026, battery-electric adoption is expected to reach 11%. "But there are material differences in adoption between medium-duty Classes 4-7 and





Bosch's Shyam Jade stands next to the new 230 electric motor for commercial vehicles.

heavy-duty Class 8. In the former, we anticipate sales rising to around 20 percent in 2026 with Class 8 at just 4 percent adoption," Vieth predicted. In the Bosch 230, oil cooling and water cooling have specific roles. The rotor and stator are internally oil cooled and the active parts are installed in a water-cooling jacket. "Oil cooling really helps with the heat transfer," Jade said.

Scalability makes the 230 e-motor appropriate for a range of CV applications. "We can size it for light-duty commercial vehicles, medium-duty trucks, all the way up to Class 8 semitrucks. The 230 e-motor stays the same, but we would make modifications to scale it," Jade said. "For really large vehicles, it might take two of the units."

Bosch's 230 can provide up to 230 kW (300 hp) of continuous power, an important asset in medium-duty vehicles that are on the road for a long period of time, Jade said. Efficiency is a hallmark of the 230 motor with an 800-volt rating. "We get up to 97 percent efficiency with this system in terms of converting the electrons into rotational energy," Jade said. That efficiency is significantly higher than a typical gasoline or diesel engine's 30-40% brake-thermal efficiency (BTE).

The 230 motor can be paired with Bosch's advanced inverter with silicon carbide (SiC). SiC helps reduce heat losses, enables higher switching frequencies and improves the power density versus a traditional inverter with silicon. "Our inverter with SiC helps drive inverter efficiencies above 99 percent and the overall system efficiencies above 97 percent," Jade said. The SiC inverter is a Bosch-first for the CV market.

Kami Buchholz

### AWARD-WINNING CONCEPT

### Innovative 'Afreecar' wins SAE 2021 Create the Future Design award

His middle name doesn't begin with "I," but innovation is what made Dr. Chris Borroni-Bird's reputation as one of the most creative minds in the auto industry. Best known for a string of remarkable advanced concept vehicles he led at **Chrysler** and General Motors in the 1990s and 2000s, including the now-ubiquitous EV 'skateboard' platform, Borroni-Bird has a new mission. He's focused on bringing electric power and mobility to the roughly 1 billion people worldwide (primarily in sub-Saharan Africa and rural India) who are without electricity.

And his solution, called Afreecar, has impressed an independent panel of technically qualified judges to win – along with development partner Rich Saad – SAE's 2021 Create the Future Design Award, in the Automotive/ Transportation category.

"Winning the Create the Future Award was fantastic news – I was over the moon!" he told SAE Media. "It was like a breath of fresh air, because I've been evangelizing Afreecar for several years now (see *Automotive Engineering*, January 2018: https:// www.sae.org/publications/magazines/ content/18autp01/). For the idea to be recognized for the power that it has is extremely gratifying. People are finally getting it!"





Dr. Chris Borroni-Bird's creativity has influenced many advanced mobility concepts.

The Create the Future Design Contest was launched in 2002 by SAE Media's Tech Briefs group to help stimulate and reward engineering innovation. The contest covers eight categories.

Borroni-Bird, who has spent considerable time in Africa observing and learning potential use cases, describes Afreecar as "a low-cost, briefcase-sized e-kit." It includes a small lithium-ion battery module. electric motor and electronics and can be fitted with a solar panel. Afreecar is designed to be produced locally and easily attached to various non-motorized vehicles, including tricycles, hand carts, wheelbarrows and wagons. The e-kit also serves as an power source to drive (via a powertakeoff) water pumps, corn grinders and to deliver electricity for cellphones, ventilators, dialysis machines and other agricultural, healthcare and communication devices (https://vimeo. com/433832992).

Borroni-Bird recently entered an advisory partnership with **EVage** (https:// www.evage.in/), an Indian EV startup focused on small, simple and low-cost commercial vehicles for the India market. He said the relationship could extend to a manufacturing arrangement, "although I can't say yet whether Afreecar will use a licensing model," he noted. "I've always thought that this would be made in rural Africa or India. A kit is easier to make and assemble than a complete vehicle. It would be great to share the EVage supply base for electric components and so forth.

"EVage were excited before the partnership, but the Create the Future Award reinforces it," Borroni-Bird asserted. "It's a third-party validation." He added a shout-out to companies working on EVs that are open to collaboration.

"I'd like to partner with an OEM that may be interested in re-using end-oflife motors, batteries and electronics and applying them to the low-cost Afreecar kit. Some companies are already looking at what to do with endof-life EV batteries and are looking for a good second-use market. There is plenty of life left in those components for this application."

#### **Lindsay Brooke**



### ELECTRIFICATION

### 3D graphene boosts new batteries beyond lithium-ion



Lyten is developing Li-S battery technology for use in various applications, including automotive, aerospace, defense, commercial vehicle and off-highway markets.

Lyten, a Silicon Valley materials company, aims to displace the incumbent lithium-ion (Li-ion) cell chemistry from mainstream electrified vehicle (EV) applications using lithium-sulfur (Li-S) technology. "Our current generation materials perform at an almost 2.5X rate over conventional Li-ion batteries," Dan Cook, Lyten's president and CEO, told SAE Media.

The technology enabler is the San Jose, California-based company's invention of three-dimensional (3D) graphene versus traditional two-dimensional (2D) graphene, in which an allotrope of carbon consisting of a single layer of atoms is arranged in a flat, 2D honeycomb lattice nanostructure.

"What we've done is create a carbon scaffold to cage the sulfur within 'bars," Cook explained. "We have a proprietary way of putting the sulfur in between the bars so that the sulfur will stay in place." The bars are small enough to hold the sulfur, yet wide enough for the Li-ion to enter and exit the scaffold structure. Sulfur containment also means that the chemical element doesn't escape into the electrolyte, which would destroy the battery.

Lyten's trademarked 3D Graphene is a first-generation battery technology

that Cook describes as "a leap-frog technology" to today's Li-ion chemistry. The firm has many patents relating to the processes, tools, and material needed to produce a Li-S battery. "By thirdparty judgment, we have the largest 3D graphene intellectual property portfolio in the world," Cook claimed.

The Li-S battery cells can be manufactured in multiple formats: cylindrical, pouch, or prismatic. Lyten intends to produce the batteries in the U.S. using a domestic supply chain. Unlike a Li-ion battery in which the positive electrode is typically a metal oxide via a layered oxide (such as lithium cobalt oxide), or a polyanion (such as lithium iron phosphate), or a spinel (such as lithium manganese oxide), Li-S is metal-oxide-free.

"The safety factor is compelling because we don't have metal oxides," Cook noted. "Therefore, we don't have oxygen to react with lithium metal during thermal runaway, which can happen when batteries overcharge." Part of the process for producing the Li-S battery relies on methane gas. Carbon is captured from the stream of methane and a solid, nucleated material is created for use in the battery, Cook said.

In-house lab testing has shown that the Lyten's Li-S batteries' operating



Lyten's Dan Cook said the company has Li-S batteries in development that from a gravimetric energy density standpoint are outperforming the theoretical limit of solid-state Li-ion batteries.

range is from -30° C to 60° C. "We've demonstrated operation in this temperature range with no warming or cooling of the battery, and no loss in performance," said Gregory Deveson, Lyten's president of automotive. Fast charging time is less than 20 minutes for an 80% charge. Current battery cycle life is at 1000, he said, but the target is 1800 cycles – which translates to more than one million miles of driving.

Lyten executives are in discussion with five global automakers, primarily U.S. and European-based. At press time, there were no signed contracts. "When we get to production for an electric vehicle application, it won't be with our first-generation battery technology," Cook said. Targeted start of production for Lyten's Li-S batteries is 2025-2026. Kami Buchholz



### Hercules readies Alpha electric pickup prototypes

Hercules Electric Vehicles aims to start production of its Alpha full-size pickup truck in January 2023, but the Alpha won't be the Detroit-based startup's first product application. "A recreational boat gets our first deployment with the same powertrain technology, the same parts and the same software controls as the Alpha," company founder and CEO James Breyer told SAE Media.

Modular design enables the electric propulsion system to be used across mobility sectors, noted Breyer, who launched Hercules in December 2018. Initial Alpha prototypes will test a commercially available single radial-flux e-motor rated at 160 kW (214 hp) and operating through a 10:1 gear ratio. Using the off-the-shelf motor offers "production quality at the prototype stage," Breyer asserted. The truck is expected to have a towing capacity of 12,000 lb. (5443 kg).

Power-electronics calibrations enable the motor to produce 196 kW (262 hp) for production applications. A dual-motor configuration is expected to produce about 550 hp (410 kW) and a four-motor arrangement will deliver "over 1000 hp with full torque vectoring," Breyer promised. He noted that Hercules engineers investigated in-wheel motors but



The Hercules Alpha full-size electric pickup truck, shown in pre-production form, will feature a standard solar tonneau cover, a 6-ft. cargo bed and deliver up to 1000 hp and 800 lb-ft.

were "not comfortable" to commit to the technology.

At launch, the prismatic-type Li-ion batteries will be housed in two identical battery cases, each case packaged between the crossmembers of the body-onframe Alpha's chassis, one in front, one in the rear. "That's part of the modularity – design it once, design it right, then reuse it to provide an economy of scale in an economy-of-scope business," Breyer said.

### Solid-state batteries coming?

A change to solid-state Li-ion batteries is possible as early as Alpha's second



production year. Hercules has an agreement with startup **Prieto Battery**, **Inc.** that covers two years of commercial exclusivity for electric pickup trucks and large SUVs. Prieto, based in Fort Collins, Colorado, has 28 issued patents covering materials, process and the architecture of its advanced "three-dimensional" solid-state Li-ion batteries. Compared to a typical

Li-ion battery's two-dimensional structure with three layers of materials (anode, separator, cathode), Prieto's solid-state battery is different, according to CEO Mike Rosenberg. The 3D architecture enables high power, fast charging, high energy density, better safety and extreme operating temperatures, the company claims. Prieto has demonstrated an operating range of -30° to 120° C (-22° to 248°F) in laboratory testing.

### **Prototypes, production plans**

The first batch of 20 Alpha prototypes, scheduled for completion in late 2021, will undergo vehicle dynamics, cold/hot weather and other tests. The next batch of 20 prototypes will be used for durability and manufacturability evaluations. The prototype builds will use a yet-to-be revealed global OEM's chassis and cab; that same automaker will serve as Hercules' contract manufacturer. Pininfarina has been retained for exterior and interior design work on the production Alpha.

At production launch, Alpha is expected to have a 350-mile (563-km) driving range with the four-motor configuration. "We did about 2,500 hours of modeling to make sure that we can hit the driving range target going up a hill, down a hill, and at different masses," said Breyer. Alpha's peak production volume will be 15,000 units annually. "Serial production occurs once you exceed that number and since we're buying excess manufacturing capacity, we need to stay around that number," he explained. Starting MSRP for Alpha will be around \$100,000, Brever said. Kami Buchholz

# ROAD READY

### VW adds traction in budding EV market with AWD for ID.4



Volkswagen is adding all-wheel-drive (AWD) to its all-electric C-class SUV, the ID.4. This should make VW's swiftselling submission in the world's most popular vehicle segment even more compelling, particularly when combined with free charging promotions and applicable state and federal tax credits no longer available to other EV makers. These factors place VW's projected ownership costs below gasoline-powered competitors such as Toyota's RAV4 and Honda's CR-V - with the ID.4 feeling a size-larger from an interior-space viewpoint. It also trumps the ownership-cost structures of the ID.4's nearest competitors, the Ford Mustang Mach-E and Tesla Model Y.

VW showed off the new AWD ID.4 on the snaking roads surrounding Chattanooga, Tennessee, where the ID.4 will begin localized production in 2022 at the German automaker's sprawling and expanding production facility. The ID.4 is presently manufactured in China and Germany (the current source of U.S-bound vehicles), where production first began at VW's Zwickau facility in August 2020. The ID.4 is Volkswagen's first all-electric SUV, the brand's first global EV, and is built on VW's MEB (modular electric drive matrix) EV architecture.

### AWD, second motor, more power

The ID.4 launched with rear-wheeldrive (RWD), so creating an AWD version meant adding a second motor to the front axle. At the rear is a singlespeed AC permanent-magnet synchronous motor located above the axle and in front of the wheel centerline, producing 201 hp (150 kW) and 229 lb-ft (310 Nm). VW claims more than 90% efficiency for the rear motor, partially due to hairpin windings of the square copper wires used in the stator coils, permitting tighter packaging to increase power and cooling efficiency.

When traction requirements demand, the ID.4 AWD can engage its single-speed front asynchronous electric motor within a few hundredths of a second. The second motor produces 107 hp (80 kW) and 119 lb-ft (161 Nm), with total system output SAE-rated at 295 hp (220 kW) and 339 lb-ft (460 Nm). VW claims a spritely 5.4-second 0-60 mph (0-97 km/h) time, which felt easily authentic, and traction management is prescient enough to eliminate nearly any wheelspin, even when launching on loose surfaces. The AWD version also nets a Traction Mode that locks the driveline into all-wheel propulsion at speeds less than 12 mph (20 km/h), a potential boon for steep driveways in colder climates.

### Same battery, reduced range

The AWD ID.4 uses the same 82 kWh (gross)/77 kWh (net), 1,087 lb (493 kg) lithium-ion battery pack as the RWD version, netting slightly lower EPA range ratings: 249 vs. 260 miles (400 vs. 418 km). The modest range hit likely speaks more to the AWD model's 223 lb (101 kg) curb-weight gain than driveline losses, as the savvy traction management system only engages the front



Initial U.S. ID.4 production will arrive from Germany, in two heavily contented trims.



driveline as needed. The battery is comprised of 288 pouch cells in 12 modules, with a fifth of its total weight comprising the pack's scalable aluminum construction, its interior a framework of extruded and pressure-cast profiles.

The ID.4's onboard charger is a Level 2 unit with an 11-kW maximum rate, and it's also equipped with a DC fast-charging capability at a maximum rate of 125 kW; VW claims the ID.4 can go from a 5% state of charge to 80% in about 38 minutes with 125-kW charging. The ID.4's battery pack uses a liquid-cooled floor plate to help keep the battery in the ideal temperature range of around 77°F (25°C) to benefit power output, DC charging and battery service life. The ID.4's high-voltage-system warranty provides that the battery will still have at least 70% of its original capacity after eight years/100,000 miles.

### Big on the inside

The steel unibody ID.4 AWD is 4.6 in. (117 mm) shorter than Volkswagen's Tiguan, at 180.5 in. (4,585 mm), with a 0.9-in. (23-mm) shorter wheelbase (108.9 in./2,762 mm). Despite the smaller footprint, the 99.9 ft2 passenger volume is very similar to the Tiguan (101.1 ft2), as is cargo volume behind the second row (30.3 ft2 vs. 33.0 for the 2-row Tiguan) and with the seats folded (64.2 vs. 65.7 ft2). Where the ID.4 AWD trumps an AWD Tiguan is curb weight at 4,782 lb (2,169 kg), vs. 3,847 lb (1,745 kg). The ID.4 AWD model's towing capability is in a useful range, rated at 2,700 lb (1,224 kg) for a braked trailer, 1,650 lb (748 kg) for an unbraked conveyance.

"In terms of dimensions, we're within a few inches of length and width from CR-V and RAV4, the segment leaders. So exterior wise, very similar," explained Jeffrey Lear, product manager of electric vehicles for Volkswagen of America. "But on the interior with our MEB platform, it's packaged really nicely. Batteries in the floor. Obviously, no combustion engine. Wheels are pushed out. And the longer wheelbase means more cabin and trunk space."

With the high-voltage battery located between the axles, VW claims the AWD

ID.4's weight distribution is very close to 50:50 while keeping the center of gravity low. The front suspension is a strut-type with lower control arms, coil springs and an anti-roll bar. A first for Volkswagen, the ID.4's steering rack is

located in front of the wheels' centerline, which it claims maximizes cornering stability. The rear features a compact multi-link suspension with coil springs and an anti-roll bar. Compared to the RWD version, ride height of the



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# ROAD READY



The AWD version of VW's ID.4 will provide a braked-trailer tow rating up to 2,700 lb (1,224 kg).



Both the RWD and AWD versions of the ID.4 share the same 82 kWh (gross)/77 kWh (net), 1,087 lb (493 kg) lithium-ion battery pack.

ID.4 AWD has increased 0.6 in. (15 mm), and it uses firmer springs/dampers and thicker anti-roll bars.

### Loaded trims, Level 2 ADAS

With ID.4 models initially sourced from Germany, like its RWD stablemate, the AWD version will be offered in only two trims. The ID.4 AWD uses a front radar, front camera, two rear radars and eight ultrasound sensors to provide a full complement of safety and assist features. These include forward collision warning, emergency braking with pedestrian detection, blind spot monitoring, rear traffic alert, adaptive cruise control (ACC) with stop and go, lane keep assist and an Emergency Assist feature that can bring the vehicle to a controlled stop in its lane should the driver become unresponsive, such as in a medical emergency.

The ID.4 AWD also sports an SAE Level 2 partially automated hands-on driving function called Travel Assist. The system can be enabled at speeds up to 95 mph (153 km/h) and uses the ACC and lane keep assist features to steer, accelerate and brake the vehicle in response to traffic, while centering the vehicle within lane markings. The capacitive steering wheel is used to confirm continued driver engagement, and the system performed well even on more winding secondary roads.

Paul Seredynski

# SIMULATING A FASTER ROUTE **INVLATION FEATURE to ADAS and AV validation**



## The Simphera sim offers a cloud-agnostic implementation for public/private clouds on IT infrastructures and open interfaces (REST API) for integration into existing workflows (CI/CD pipelines).

# With its new cloud-based Simphera platform, dSpace responds to demand from global automated-vehicle development teams to help manage their expanding, complex workload.

### by Paul Seredynski

Iready a well-known provider of hardwarein-the-loop (HIL) and software-in-the-loop (SIL) systems, **dSpace** has launched a new scalable, cloud-based simulation platform called Simphera, designed to speed development of automated and autonomous vehicles by managing computation-intensive validation of their driving functions. Its web interface and cloud architecture are geared towards global development teams, and the sim features reusable models and scenarios to permit continuous testing on SIL and HIL platforms.

The Paderborn, Germany-based dSpace is responding to growing demand within the advanced automated-driving systems (ADAS) and autonomous-vehicle (AV) development communities to help manage the number of tests that require large and scalable computing infrastructures. The new sim platform also serves the increase in virtual tests frontloaded into earlier phases of ADAS and AV development.

"Simphera will make life easier in all phases of development and validation — from the initial idea of an algorithm to the release test of an ECU," said Tino Schulze, executive VP of automated driving & software solutions at dSpace. "By providing this integrated solution, we not only accelerate development, but also make it more efficient, thereby increasing our customers' return on investment." Simphera's capability also has been enhanced with the recent integration of the BTC ScenarioPlatform (*see sidebar*).

### Prepare, simulate, validate

The Simphera simulation platform is based around three key modules. The first, Prepare, provides the tools needed to generate and modify artifacts required for development or validation tasks, including sophisticated (or dedicated) sensor-, road- and traffic-simulation models. The Simulate component brings the plant model together with the controller in specific scenarios within interactive simulations and lets users check algorithm behavior via visualization and measurement functions. The third component, Validate, helps users perform scenario-based testing on a large scale.

The initial Simphera release is focused on providing validation solutions for autonomous-driving functions, scenario-based testing and SIL testing. According to dSpace, its reusable models permit a more seamless transition to automated HIL tests, and the traceability in troubleshooting reduces cost while speeding development homologation.

"Everybody knows dSpace from hardware, because we are one of the pioneers in HIL," explained Michael Peperhowe, lead product manager at dSpace for simulation models and scenarios, automated

### SIMULATING A FASTER ROUTE to ADAS and AV validation

"Our customers already have some infrastructure they would like to reuse, or at least partly reuse. Therefore, it is important that Simphera is not just a 'black-box,' but an open framework."



The Simphera AV simulation platform can automatically create, execute and evaluate simulations in the cloud, and can identify system-under-test (SuT) performance insufficiencies, critical situations and edge cases.

driving & software solutions. "But now it also gets more and more into the SIL environment."

"Usually, our customers already have some infrastructure they would like to reuse, or at least partly reuse," Peperhowe continued. "Therefore, it is important that Simphera is not just a 'black-box,' but an open framework. It brings everything out of the box. This is what many customers also like."

### Meeting AV development demand

According to Peperhowe, a new platform like Simphera was needed to help development engineers meet the demands of increasing test complexity. "Especially at these SAE [automated-driving] levels, we have different levels of complexity and driving functions, from active safety until autonomous driving," Peperhowe noted. "AV development is one of the most complex tasks. Multiple smart systems have to work together with the utmost reliability. For the development and validation of such systems, the newest technology is needed."

"To bring such systems into homologation, on the roads, it will not work with [physical] prototypes only. You need simulation. You need to drive millions of miles per night," he continued. "This was the motivation to develop something new that meets these requirements for different driving functions. Create thousands of tests with just a few clicks and scalability in the cloud. You do not have to wait step-by-step until the results are ready. You can have a large number of simulation runs in parallel, which saves real time."

Moving to the cloud lets customers choose how much of the computing assets they wish to dedicate to the simulations — often crucial in terms of meeting homologation milestones. "For sure, we need a flexible platform for doing [these] really huge amounts of tests. That means you need something to run in the cloud," Peperhowe said, pointing out that by its nature, the cloud also enables global collaboration.

### Automating edge cases

Simphera's simplified interface is designed to let engineers quickly generate variations on standard testing

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### SIMULATING A FASTER ROUTE to ADAS and AV validation



Prepare
Simulate
Validate

Image: Service Servi

# The Simphera sim provides a guided workflow to simplify development and validation tasks

regimens such as NCAP (New Car Assessment Program), or craft edge-case scenarios to validate less-common parameters. "This is quite important. Let's say the customers want to do homologation to get an approval of their controller for cars on the street. This will not work without qualified simulation models and tools behind that," Peperhowe explained. "To generate scenarios from scratch, we have interactive editors available," he added.

"Physics-based sensors are needed — camera, radar, lidar and so on — so you have different levels of test depth that you could take into account," he qualified. "The full AV stack, just the sensor perception or the pure ADAS algorithm. Even if everybody's talking about ADAS, often it's forgotten to take the powertrain into account. If we are combining e-mobility, [energy] recuperation, fuelcell technology, etc., it has big benefits if you have models for all of these. That means you can use it for single-component test or for full integration tests."

Its experience in hardware testing likely provides dSpace an advantage in simulation software development. "We know what needs to be tested because of our long history, especially from the HIL side. Now, in addition, everybody wants to bring it into a virtual environment, front-loading to an earlier development stage," Peperhowe

# The power to create graphical traffic scenarios

Hot on the heels of the Simphera launch came an important addition to the platform's capabilities: a highly automated solution for creating graphical traffic scenarios, generating tests and evaluating tests based on coverage. The solution, called ScenarioPlatform, comes from BTC Embedded Systems, a maker of automotive software test and verification tools and a long-time partner of dSpace. ScenarioPlatform can be integrated seamlessly into Simphera, the companies announced in summer 2021.

The traffic scenarios are created intuitively using BTC's ScenarioComposer. The tool's high level of abstraction makes it possible to express thousands of test cases with just one abstract scenario, the companies claim. The automated test generation functionality uses advanced technology such as model checking and artificial intelligence (AI). And its intelligent weakness detection allows test cases to be generated efficiently based on statistical methods and meaningful coverage metrics. Compared with random or "brute force" test generation approaches, this strategy considerably reduces the amount of test data, while delivering clear metrics. This makes it possible to determine when the test activities have been completed even with regard to future homologation criteria, according to the companies. The simulations are evaluated automatically by another BTC tool, RuleObserver, to ensure compliance with traffic rules or safety objectives.

Lindsay Brooke

claimed, emphasizing the flexibility of the cloud platform. "It's completely scalable by the user. You can start it on Friday before going home and come back Monday. Or, if you are in a hurry — 'I want to have results within half an hour,' — just scale it up. The limit is not on the dSpace tooling side, it's on the infrastructure from the cloud side. [Engineers] do not have to spend their brain about how to handle the tooling, they can concentrate on their work."

**COVER STORY** 

# High on hydrogen

Clean Mobility group GM Jose-Vicente March with pressure tanks at Faurecia's Farmington Hills, Michigan, tech center.

Through its Symbio joint venture with Michelin, Faurecia expands far beyond its interior-systems base into the fuel-cell future.

by Lindsay Brooke

ith only a single proton and electron, hydrogen is the lightest element in the Periodic Table, but it is having a heavy impact on **Faurecia**. The French Tier-1 supplier, whose automotive seating and interiors businesses accounted for nearly 69% of sales in 2020, is staking a significant slice of its future growth in hydrogen fuel-cell systems. It's a bold and admittedly disruptive strategy that Jose-Vicente March, Faurecia's general manager, Zero Emissions in the Clean Mobility group, is confident will establish his company as a technology and market leader.

"Yes, it's been disruptive — but it's applied disruption! Our initiative on hydrogen and fuel cells is a key mission for us," March explained in an interview with SAE Media. "It's part of Faurecia's commitment to be  $CO_2$  neutral by 2050. One of our four business groups, Clean Mobility [its exhaust-aftertreatment products accounted for 26% of sales in 2020], was already addressing the market transitions from IC engines to zero-emissions engines. So, it was logical for them to lead our hydrogen effort. From both the business and environmental points of view, we will be part of the powertrain revolution."

Faurecia could have expanded into battery-electric technologies, but more than four years ago company leadership bet big on hydrogen. "We believe the real solution for zero emissions commercial vehicles — trucks, buses, fleet vehicles — as well as some passenger vehicles and light trucks such as pickups and SUVs, is fuel-cell power," March said. "The commercial-vehicle market especially is based on total cost of ownership (TCO). Fuel cells offer faster fueling, much lower mass than a battery pack and, we think, better range and payload."

While a fueling infrastructure is being built out and there is growing demand for stationary storage, "distribution is a clear challenge for hydrogen in the U.S." noted March, a Spanish engineer who began his career at **Grupo Antolin**.

Industry forecasts and investors are equally high on hydrogen. An August 2021 report by **Market Research Future** projected the global hydrogen fuel-cell market to be worth U.S. \$46.89 billion by 2028, registering a CAGR of 68.52% during the 2021-2028 forecast period. The market was valued at U.S. \$1.17 billion in 2020. A growing list of vehicle OEMs, including **BMW**, **GM**, **Honda**, **Hyunda**i, **Mazda**, **Mercedes-Benz**, **Nikola**, **PACCAR**, **Renault**, **Tata** and **Toyota** have active development programs. Faurecia itself projects demand for 2.5 million hydrogen-powered vehicles by 2030, including 500,000 commercial trucks.

### Ambitious growth targets

To create and accelerate a new business in an almost alien technology space required what March calls "a piece-by-

# **High on hydrogen**



The whimisically-named Citroen e-Jumpy Hydrogen commercial van is Stellantis' first fuel-cell-electric production vehicle. It is powered by a Symbio 45-kW fuel-cell stack and a 10.5-kW battery that acts as a 50-km reserve if fuel from the Faurecia-supplied trio of 700-bar pressure tanks is depleted. The two energy sources combine to power the drivetrain: the hydrogen fuel cell ensures the vehicle's range; the battery handles load transitions such as when strong acceleration and tackling long gradients are required. Regenerative braking helps replenish the transversely-mounted battery, which is automatically charged using electricity generated by the fuel cell to ensure a sufficient charge level. The battery can also be charged using a cable at EV charging stations. The van offers a practical range of over 400 km based on WLTP testing, according to Stellantis. The base vehicle is produced at Stellantis' SevelNord plant and is then transported to Stellantis' hydrogen fuel cell R&D center in Russelsheim, Germany, for conversion to the hydrogen-fueled model. RamPromaster and Opel versions also are planned.

piece approach:" establishing key partnerships, acquisitions and sharply focused hiring. While Faurecia had done some hydrogen R&D with the French government, the real entrée came in 2019 — a €140 million joint venture with tiremaking giant **Michelin**. The JV, called **Symbio**, is devoted to making hydrogen fuel-cell kits and related hardware and services. Faurecia then acquired **CLD**, a Chinabased specialist in carbon-fiber hydrogen storage tanks. The deal brought a contract with **SAIC Motor** to provide tanks for a large fleet of commercial vehicles. In fall 2021 it announced a partnership with **Air Liquide** to develop liquified hydrogen technology. it also launched two new hydrogen-systems development centers in France and South Korea. A U.S. technical center is planned.

"Symbio is developing the fuel-cell stacks and Faurecia is focusing more on the development and manufacturing of gaseous storage systems," March explained. "Together we're able to provide 75 percent of the value-add of the powertrain. So, we can really tailor our product to the customer's requirements, from full systems to flexible solutions." He added that Faurecia also supplies power electronics for fuel-cell electric propulsion systems. With this set of capabilities, Symbio aims to capture 25% market share and achieve a turnover of around  $\leq 1.5$  billion by 2030. The joint venture will eventually have three industrial sites supplying the Europe, Asia and U.S. mobility markets.

Faurecia currently has hydrogen-related development activities with nine OEMs. Three of them — Hyundai, **Stellantis** and **Renault** — have hydrogen fuel-cell vehicles fitted with Faurecia storage tanks and related hardware entering production in 2021. The Hyundai build is 1,600 commercial trucks; Stellantis is producing a fuel-cell version of its **Citroen** Jumpy light cargo van, which will carry a **Ram** ProMaster badge for the U.S. market. The 'e-Jumpy' uses Faurecia storage tanks and a Symbio fuel-cell stack.

### **Technology challenges**

Pressure tanks for compressed-hydrogen storage are highly engineered vessels. Their primary form factor is a cylinder, but in specialized cases

### **COVER STORY**



Fuel cell module engineering for light-duty vehicles incorporates the cell stack and centrifugal-type air pump, on display at Faurecia's 2021 IAA Munich booth.

the tanks also can be toroidal in shape. The cylinders are robustly constructed of reinforced, spiral-wound carbon fiber to ensure safe storage of the gas at the high pressures typically used in fuel-cell vehicles.

Tanks must be certified to the rigorous ISO/TS 15869 standard, requiring a battery of tests including burst (typically more than 2X the working pressure), fatigue (several thousand cycles of charging/emptying), fire (exposing the tank to open fire), leak/permeation (measuring the volume of gas escaping within a period of time) and ballistics, where live ammunition is fired at the tank. Faurecia has invested heavily in in-house testing capabilities, March said.

Tank technology continues to progress, albeit incrementally, explained Charles Shappell, engineering director at Faurecia's Zero Emissions group in Farmington Hills, Michigan. "We are focusing on 350-bar (5,000-psi) and 700-bar (10,000-psi) pressures because that's where the tank technology is today for automotive use — and it's where we think the pressures will be going forward," Shappell said. "We have Type III tank capabilities through our acquisition of CLD, but we're really focusing on Type IV tanks."

Type III tanks feature a carbon-fiberresin outer shell encapsulating a steel or aluminum vessel inside. The CF exterior shell is engineered to take loads placed on the tank. Type IV tanks are better suited for mobility applications. They're constructed entirely of carbon fiber, with a polyamide- or polyethylene-plastic liner. The tank's port is a metallic boss integrated into the structure.

The hydrogen molecule's tiny size means it's a natural escape artist. Gas retention is an ongoing challenge in tank and systems design, said Shappell, who spent a decade as Faurecia's innovation director. "The tank liner is where the technical challenge begins. The boss between the liner and tank is critical, too," he explained. Liner materials R&D is a focus of Shappell's team and



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# **High on hydrogen**

# "We have a level of flexibility in this market that competitors can't match."



Clean Mobility group North America engineering boss Charles Shappell.

progress in this area has helped lower system leakage levels (both through tanks and related valves and fittings) in recent years.

Type IV tanks offer lighter weight and very high strength. They're also far more expensive than the fabricated steel, aluminum and blow-molded plastic fuel tanks that are familiar to vehicle engineers.

"Cost, along with safety and recyclability, is an area that we're working to improve," March said. "In the end we're going make it or break it if we're competitive with this technology. Hydrogen storage in a vehicle is approximately half the cost of the fuel-cell propulsion system, so we need to make this technology affordable for all OEMs." He cited production volume and the scale effect as keys to reducing storage-tank cost. Current volumes are very low. "For hydrogen-powered city buses, it's about 60 vehicles per year, and the OEMs are starting with small fleets for their proof-of-concept validations," March noted. "And there's the challenge of how to scale up when vehicle production volumes increase."

Faurecia's Generation-1 hydrogen tank range currently includes small (D200), medium (D300-500) and large (D600) models, available in 350- and 500bar specifications. Gen-2 tank development is nearly completed, according to March. He said Gen-3 tanks will offer "significantly lower cost." To that end, engineers also are focused on increasing the company's efficiencies in the use and manufacture of carbon fiber.



Faurecia illustration showing hydrogen-tank fitments in a Class-8 semi-tractor.

The company has researched aerospace-industry processes as well as BMW's holistic enterprise, with materials partner SGL, established for carbon-fiber production for the 2013 BMW i3.

"We're looking at how to optimize carbon-fiber winding and how to improve curing times, which are really still slow for higher-volume automotive applications," Shappell said. Engineers also are investigating how to improve tensile strength of "tow," the yarn used to weave carbon-fiber fabrics. A 24K tow, the industry's highest tensile strength, is composed of 24,000 individual carbon filaments.

March describes the rising investment and near-flood of competitors in the hydrogen fuel cell space as good news for Faurecia. "People are seeing the market for hydrogen development and that can only help us to be more competitive and challenge ourselves." With the increasing number of players, both suppliers and OEMs, Faurecia's competitive advantage comes from its auto-industry experience, global presence, and the expanding capabilities of the Symbio joint venture.

"We can deliver full system integration — the customer gives us the requirements and we build the powertrain for them," March said. "We also have customers who are interested in just the hydrogen storage system. And there are customers who are only requesting hydrogen tanks. We have a level of flexibility in this market that competitors can't match."

# Innovating the methano FUEL CEL

Industrializing the manufacturing process is key to getting fuel cells into scale production. Shown is methanol FC stack assembly at Blue World Technologies.

# Using methanol as the source fuel provides an alternative to a gaseous-hydrogen distribution and storage infrastructure, among other potential benefits.

by John Kendall

hile there are technological hurdles still to overcome, the hydrogen fuel cell remains an attractive source of electricity generation, particularly for the heavyduty transport sector currently dominated by diesel power. **Daimler** and the **Volvo Group** entered a joint venture to produce fuel cells systems last year. **Toyota** and **PACCAR** are collaborating. **General Motors** and **Stellantis** each are launching production fuel-cellpowered delivery vans and many other OEMs are involved in programs to develop the technology further for commercial transport applications.

Refueling with pressurized gaseous hydrogen is one of the issues that would need to be resolved, requiring a distribution and storage infrastructure that might need building from the ground up. One possible alternative would be to use methanol ( $CH_3OH$ ) as the source fuel. Using a reformer, liquid methanol could be split into a hydrogen-rich gas that would feed the fuel cell.

The reforming process would release greenhouse gas (GHG) emissions, but if the methanol is produced from renewable sources – renewable electricity with atmospheric carbon dioxide, or carbon dioxide from biomass, or landfill sites for instance – the well-towheel cycle should be carbon-neutral. Methanol is already produced, stored and transported in industrial quantities and its handling requirements are widely understood, advocates note. As a liquid, it could be readily distributed through the current diesel and gasoline road-fuel infrastructure, assuming a gradual transition away from fossil fuels. This would solve one of the big problems facing fueling with hydrogen gas. It could also address the infrastructure challenges, requiring no significant additional infrastructure, with just the modifications required for handling methanol at current gasoline and diesel refueling and storage sites.

This is loosely the strategy being pursued by the Danish company **Blue World Technologies**. The company's senior management has been involved in fuel cell research for more than 20 years.

### **Newfound efficiency gains**

Commercial, military and aerospace fuel cells have been around for many decades and have been explored in various ways, Blue World Technologies co-founder and CEO Anders Korsgaard told SAE Media. "We also worked with conventional hydrogen fuel cells for the first five years of our professional career, back in the late '90s and early 2000s. But we decided to focus our attention on e-fuels, and basically liquid e-fuels that would all solve the market barriers associated with a gaseous fuel," he said.

The technology associated with fuel cells dating back to the 1990s was the low-temperature Proton Exchange Membrane (PEM) 'stack.'

# Innovating the methanol FUEL CELL



Innovations in fuel cell technology have enabled significant performance gains compared with the low-temperature PEM-type cell stacks of the 1990s.

"The problem with that technology is that it is very sensitive to any impurity," Korsgaard noted. "Basically, what you do to overcome that is to increase the temperature from typically 70-to-80-degrees C [158° to 176° F] to 160-degrees C [320° F] and above. Anything above let's say 150-degrees C [302°F] to 160 degrees would be pretty tolerant to most impurities generated by the reformer. We are focused on that temperature window of about 160 to 170 degrees C, because this is where most of the problems disappear in supporting liquid fuels."

There also are efficiency gains generated by the thermal integration between the reformer reaction and the fuel cell, he added. "And in that way, you can say for a conventional hydrogen fuel cell, taking hydrogen in and converting it into power, when we look at the combined system with the methanol reformer and the fuel cell itself, we are looking into pretty much the same peak efficiency as working with hydrogen."

The high-temperature PEM fuel cell technology that Blue World Technologies is working on was invented in the mid-1990s. According to Korsgaard, the technology now is approaching the same power density as low-temperature PEM fuel cells. The objective is to make it more efficient than the low-temperature designs.

### **Cost parity with ICEs**

Critics of the methanol fuel cell system highlight the fact that the system does emit GHGs. Korsgaard contented that "clean methanol" is often manufactured from biogas. "In that sense, it has potential" as a "stepping stone," he said, explaining that "it's a cheaper version of getting bio-methanol than just going directly to getting carbon dioxide from air capture."

Among the "concentrated carbon dioxide sources" is biogas, which contains roughly the same amount of methane as already exists in CO<sub>2</sub>,



Liquid methanol has the potential to solve the market barriers associated with gaseous hydrogen, says Blue World Technologies' CEO Anders Korsgaard.

Korsgaard noted. "If you take the methane out and put it into the grid or whatever you use it for, you are making a lot of carbon dioxide. You can do it because it is basically just re-cycling, going back to the farmlands and so on. But alternatively, you can capture it there, because you have a very concentrated carbon dioxide source." Combining the CO<sub>2</sub> with hydrogen from electrolysis, as in conventional hydrogen production, produces methanol.

"Then you have something liquid and you don't need to pressurize it," he said. "You can distribute it exactly like you do today. One of the benefits is that you can also put it into combustion engines – just mixing it with gasoline. We don't need to roll out hundreds of gigawatts of fuel cells before you can actually enable a take-up of bio-methanol, because you can also use it in combustion engines."

Improving the cost-efficiency of the system will take time, however. Korsgaard noted that in time, the methanol fuel cell will be on a par, in cost terms, with IC engines. "We can see how solar technology and battery technology have decreased by 15, 20, or 25 percent, depending on which time you are looking at, per year," he said. "This will be at similar levels to ours – and at some point, we predict that even the capital expenditure will be comparable to IC engines."

The bottleneck in commercializing the methanol fuel cell has been the industrialization of the manufacturing process. Korsgaard said Blue World Technologies is building the largest fuel cell factory in Europe, with production scheduled to start in the latter half of 2022. "That's really our focus, it is actually to make sure that we can drive down the cost to a certain level where basically we can begin the commercial rollout," Korsgaard said. Engineering the 2022 Toyota Tundra

Chief engineer Mike Sweers talks structure, materials and a different approach to hybrid power.

by Steve Macaulay

The 2022 Toyota Tundra loses its V8 and gains a hybrid option, with NiMH battery, rear coil springs and an SMC cargo bed.

PRODUCT DEVELOPMENT FEATURE

oyota's third-generation 2022 Tundra was developed under the direction of veteran Mike Sweers, who has been the program's chief engineer since 2010. The all-new pickup is based on Toyota's F1 platform, shared with the Land Cruiser and the 2022 Lexus LX600 SUV. Sweers, who is also senior VP, Product Development Office, detailed the new Tundra's significant changes in a recent interview with SAE contributor Steve Macaulay.

Sweers noted that the new truck gets a fully boxed frame, whereas the outgoing truck's frame featured open channels. "You've heard me talk for years about open C-sections and why open 'Cs' are important," Sweers said. "My competitors have criticized me for using a 'C' because our current pickup truck has a lot of compliance." That benefits ride quality, a key focus of the Tundra development team and an attribute worth carrying into the new SUV.

"A truck shouldn't ride like a truck," he asserted. "If you jump out of an SUV or a car and get into this new Tundra you should say, 'Oh, that's nice." While Sweers admitted that the ride quality with a fully boxed frame is inherently stiffer than an open-C structure, his engineers addressed that by replacing the rear leaf spring pack with a multilink setup with dual-stage coil springs as standard.

When driving some competitors' trucks on Michigan I-94, Sweers observed their rear ends "kicking out," a result of their frames being too rigid and their suspensions configured with heavy leaf packs to accommodate loads. He acknowledged a dynamic characteristic of coil springs: With a fully loaded bed or heavy tongue load while towing, the rear end wants to come down. Toyota is offering load-leveling air suspension in the rear for those who need the extra capability.

### Tailor-welded frame rails

The Tundra's new frame differs from most boxed truck frames in using laser-tailored steel blanks, Sweers explained, for strength with optimum mass efficiency. The frame build starts with steel sheet, followed by blanking out areas that are later filled in — via a wire-fed laser welding process — with the appropriate types and gauges of steel. These "tailored" blanks are formed into Cs, then two Cs are MIG welded together to form the full box.

His team changed the roof design for 2022 and even made the CHMSL part of the aero package. Now the wind separates as it

comes off the roof and hits the tailgate spoiler. This ended an interior "chaff" problem when the power rear window is down. Toyota's aerodynamics team — Sweers described as "a riot to work with" and "super-passionate about what they're doing" — came to him and said they wanted to rent a 20-foot covered trailer so they could test it in a wind tunnel. "We ended up buying it," he said.

### **Materials mix**

Engineering Tundra's body and cargo bed called for a mixed-materials execution. Aluminum is used for the hood, front doors, and deck outer. There are steel fenders, bumper and tailgate. The bed is constructed of sheet molded compound (SMC).

"We asked ourselves how we could get mass out of the back of the truck," Sweers said. The team looked at aluminum and high-strength steel for the application. But they decided on SMC because "it doesn't dent like steel or puncture like aluminum. It doesn't corrode," he explained. And it's lighter than the alternative materials. "We've used composite on Tacoma forever," noted Sweers, who also is the engineering chief for the midsize pickup.

The downside of SMC, he admits, is that it costs a lot more than steel and aluminum. "The people in purchasing weren't particularly happy because the decision was made to use a one-piece design for the composite bed, which impacts shipping costs," Sweers said, adding, "This will sound like hooey, but our customers are expecting our stuff to last forever."

### The simple tailgate

Tailgates that have lots of articulation is a current trend in the pickup segment, and a point of controversy for Sweers. Are such tailgates answering a question that no one asked? "Do I really need Dutch doors

### *Engineering the 2022 Toyota Tundra*



on a tailgate?" he said. "What purpose does it serve? Do I have a door that swings out that I can't open if I have a trailer on the back? Do I have a tailgate that opens down and smacks the ball of a trailer hitch?"

The Tundra team conducted a survey to find out what pickup owners were doing with their trucks' tailgates. The answer: Loading ATVs, snowmobiles, dirt bikes and UTVs (utility terrain vehicles) is the priority. UTVs weigh more than the other vehicles and have a different tire-tread pattern, so

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Departing from pickup-engineering convention, the 2022 Tundra uses coil springs at the rear axle — as does chief competitor Ram, which is widely considered the best-riding of fullsize pickups.

the team focused on strengthening the rear structure around the tailgate. Their solution included engineering a steel reinforced composite structure for the bumper. There is a button on the key fob that automatically opens the Tundra's tailgate. Otherwise, it is simply a tailgate.

### A different hybrid approach

The 2022 Tundra offers a hybrid-electric powertrain, but the approach to its implementation is unique in the segment, Sweers explained. The V8 is gone and in its place are two engine choices based on two 3.5-L twin-turbocharged gaso-line V6s. The i-Force generates 389 hp and 479 lb-ft while the i-Force Max is fortified with an electric motor, located in the P2 position within the transmission bell housing. The Max's output is rated at 437 hp and 583 lb-ft. "I can sell torque," Sweers said.

He originally wanted to use a diesel, which Toyota offers in other markets — and, he admitted, "I was not a hybrid guy." But during a development drive in Montana, he met a ranch owner who had several gasoline-powered pickups. Sweers asked him why none of the trucks were diesels. "Ever try to start a diesel truck at  $-40^{\circ}F$ ?" the rancher replied.

Then there was the hybrid issue. Sweers said that the objective with Tundra is not to achieve fuel efficiency but torque. The electric motor is used to supplement the power of the IC engine as it ramps from 0 to 2,400 rpm, at which point the turbos kick in. This, he says, is particularly advantageous in applications such as towing. Interestingly, the Tundra's electric motor is being powered by a 1.87-kWh nickel-metal hydride (NiMH) battery pack that is located beneath the rear seat of the truck. Sweers explained that they decided use long-proven NiMH rather than lithium-ion batteries.



# SPOTLIGHT: ADAS SENSORS

### **High-definition camera**



Renesas Electronics Corp. (Tokyo, Japan) and OmniVision Technologies (Santa Clara, CA) introduce an integrated reference design for a high-definition (HD) automotive camera system. The new design features Renesas' recently-introduced Automotive HD Link (AHL) technology that transmits high-definition video over low-cost cables and connectors. The AHL components in the design pair with OmniVision's OX01F10 1.3MP SoC, which the company claims "provides the industry's best imaging performance across a wide range of challenging lighting conditions, along with the most compact form factor and lowest power consumption." HD video increasingly is important in vehicle safety systems for object-recognition capability and the new RAA279971 AHL encoder and RAA279972 decoder use a modulated analog signal to transmit the video, enabling transmission rates 10 times less than required to transmit HD signals digitally.

For more information, visit http://info.hotims.com/79446-400

# Single-axis MEMS capacitive accelerometers

Silicon Designs (Kirkland, WA) said there is immediate availability of stock quantities of its industry bestselling single-



axis Model 2210 series. The company said the low-noise, low-cost MEMS capacitive accelerometer modules offer accurate and repeatable measurements across a variety of lower-frequency vibration testing applications, including those common to vibration analysis, machinery control, modal analysis, robotics, and crash event detection. Offered in standard ranges from ±2 g to ±400 g, the rugged design of the Model 2210 series incorporates a MEMS capacitive accelerometer chip together with high-drive, low-impedance buffering. When used along with a Silicon Designs recommended mounting block accessory, such as the company's own Model 2330-BLK, the series can reliably and flexibly measure vibration and acceleration on either one, two, or three orthogonal axes with equal accuracy and repeatability.

For more information, visit http://info.hotims.com/79446-401

### Electric water-pump platform

Widely known for its fluid power and power-transmission solutions, **Gates** (Denver, CO) is broadening its presence in hybrid and electric vehicle (EV) applications with the launch of its nextgeneration technology for electric water pumps (EWP) for automotive, lightcommercial and heavy-duty vehicles. The ThermalPro EWP technology is the



culmination of significant investments in electronics, software, motor design and computational fluid dynamics. The company said the ThermalPro platform incorporates design advancements that enable it to cover applications from 100W up to 3 kW and the proprietary mechanical design completely isolates the electronics assembly from potential exposure to coolant fluids. The patent-pending technology also improves motor efficiency, which is critical on fully electric platforms where electric water pumps can be significant consumers of battery life.

For more information, visit http://info.hotims.com/79446-402

### Dielectric film

The new ELCRES HTV150 dielectric film from **Sabic** (Wixom, MI) is targeted for high-temperature, highvoltage, professional-grade capacitor applications, such as traction inverters for hy-



brid, plug-in hybrid and battery electric vehicles (BEVs). This new film, featuring high-heat performance up to 150°C, surpasses the temperature and voltage capabilities of incumbent products, the company said, adding that the HTV150 film can help support the transition from conventional semiconductors based on silicon (Si) to next-generation, wideband-gap technologies based on silicon carbide (SiC), improving the efficiency of inverter modules. Based on internal testing, the film demonstrated a lifespan of 2,000 hours at 500V and 150° C and it is self-healing in the event of a breakdown caused by excessive voltage.

For more information, visit http://info.hotims.com/79446-403

# **PRODUCT** BRIFFS

### Electric motor component tester

Marposs (Bentivoglio, Italy) introduces the LT400, a laboratory windings-quality analyzer system designed to perform partial discharge (PD) measurements on electric components such as coils, motors and generators.



With the LT400, companies can perform standard high-voltage tests (AC and pulse) with PD measurements, allowing the discovery of defects not detectable with standard tests. The LT400 integrates numerous tests into one solution that is capable of providing: AC high pot test 50-60Hz with partial discharge measure; AC scanning PDIV-PDEV tests; pulse partial discharge test; pulse scanning RPDIV test; surge test with PD; insulation resistance test and DC high pot test. Compared to antenna-type solutions normally applied in this market, the LT400's partial-discharge design, based on capacitor-coupling technology, is more sophisticated and less sensitive to external noise, making it more suitable for applications in the production area.

### For more information, visit http://info.hotims.com/79446-404

### **3D HAL sensor**

**TDK Corporation** (Tokyo, Japan) expands its Micronas 3D HAL sensor portfolio with the Hall-sensors HAR 3900 and HAR 3930. The products enable stray-field compensated position detection in



automotive and industrial applications while addressing the need for ISO 26262-compliant developments. The new sensors are SEOOC and ASIL B ready, enabling ASIL D developments on system level. They feature 3D magnetic-field measurement capability and 2D stray-field robust position detection: HAR 3930 has PWM and SENT (SAE J2716 rev. 4) output, additional switch output and HAR 3900 offers measurement data available via a high-speed SPI interface. Both sensors are the dual-die SMD package versions of HAL 3900 and HAL 3930, and suit a wide range of applications, including steering-angle position detection, transmission position detection, shifter-position detection and accelerator and brake-pedal position detection.

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# **PRODUCT** BRIEFS

# SPOTLIGHT: ELECTRONICS & SEMICONDUCTORS

# Qi 1.3-certified wireless charging reference design



NXP Semiconductors (Eindhoven, Netherlands) unveils Qi 1.3, a new automotive wireless charging reference design, the first to be certified by the Wireless Power Consortium (WPC), the global standard development body for wireless

power. The reference design consists of a Qi-certified board with an NXP wireless charging MWCT family MCUs, as well as optional NFC, secure element and CAN/LIN transceiver. The solution also features a software package that includes NXP's wireless charging Qi 1.3 software library and a complete suite of customizable software solutions that help make it easier for developers to bring a Qi-certified wireless charger to market. The new Qi 1.3 standard includes new secure authentication features that verify if a smartphone or other wireless power device is Qi Certified.

For more information, visit http://info.hotims.com/79446-406

### **Gate driver IC**

### Allegro MicroSystems,

(Manchester, NH) is expanding its QuietMotion product line with the introduction of the new A89307 automo-



tive-qualified gate driver integrated circuit (IC). Designed for battery cooling fans and HVAC systems in hybrid-electric and electric vehicles (EVs), the A89307 offers ultra-low noise and vibration by using a Field Oriented Control (FOC) algorithm to drive continuous sinusoidal current to the load, helping automakers reduce noise and improve battery life. The new gate driver includes a hardware-based algorithm, which requires no external sensors or software development; the user selects parameters using a simple GUI interface and loads them into the IC's on-chip EEPROM. With only five external components, the A89307 helps designers lower material costs and its fully integrated algorithm can even eliminate the need for a separate microprocessor.

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# Readying VW's new U.S. battery-pack plant

The **Volkswagen** ID.4 is set to begin localized production in the U.S. in early 2022. The 2-row battery-electric SUV is engineered on VW's MEB platform and will share an assembly line with the MQB-based 3-row Atlas SUV, both rolling off the line at Volkswagen of America's (VOA) Chattanooga, Tennessee facility. Being an EV and using a different architecture, the ID.4 requires a battery-assembly plant and its own body shop, both of which VW is currently completing on the VOA Tennessee site.

During the recent media launch of the all-wheel-drive ID.4, **SAE** Media senior editor Paul Seredynski spoke with Jacob

Hilmes, who is helping create the space whole-cloth as the planning coordination specialist, and Tim Lovvorn, who will serve as its production manager, overseeing production, maintenance, and engineering. The duo has spent the better part of the last few years directing the facility's creation from a greenfield site.

# How long a timetable for you on the project?

Hilmes: I've been on this project three years now. It started with benchmarking the other battery plants inside Volkswagen. We went around and saw different technologies and decided what makes the most sense for Chattanooga. Long story short, we decided to go with a line builder that's internal to Volkswagen out of Braunschweig [Germany], who did the first MEB battery line. This allowed us to copy-and- paste as much as we could, get all the lessons learned because they were through a ramp-up while we were still designing.

Of course, it's not exactly copy/paste, because Braunschweig is a component plant and Chattanooga is a car-assembly plant. We have different standards, so we adapted the Braunschweig



Jacob Hilmes (right) is the VOA Chattanooga Battey Plant planning coordination specialist. Tim Lovvorn (quoted below), will serve as the facility's production manager.

# "When I first went to the plant, I thought, 'It's just a box. That's no big deal. I'm a production guy."

concepts to the car-plant standards, called VASS [Volkswagen, Audi, Seat, Skoda], and it was our main benchmark.

### Would you consider the main tasks to be logistical?

*Hilmes:* It's coordination. The planning department is making sure that Tim will be happy with it when he gets it, that we didn't put a bunch of random technology inside it. Another big thing for us, Braunschweig uses Kuka [brand] robots. At Chattanooga, we use Fanuc. Making the Braunschweig concept fit Chattanooga is where all the real work was. The battery leaves our factory and goes directly to the car body. We'll be ready for production next year.

### With such large masses involved with battery packs, these robots must be highly specialized?

**Lovvorn:** Fanuc has differentsized robots. We got the second biggest one they make. In five locations in the plant, they pick the battery up, and they have to reach far with it. We call it T-Rex. They're much larger than what we're used to seeing here at the plant.

*Hilmes:* Six-meter reach and 1,200 kilograms. I think at the time we purchased them, they were the strongest robots in the world. Now I think they've come up with another one that might do a little bit more, but they can lift a lot. Braunschweig actually used a gantry, but because we had so much heavy handling, to not have several designs of gantries, we said, "Just use one robot. One robot, one gripper."

### Sharing the production line with Atlas must present challenges?

*Lovvorn:* We've got to make sure that our part is to the right level for those guys, or we'll stop [Atlas] production. It's not just the electric car, because right now, that's a very low part of our output. I've got to make sure I don't hinder the other money train.



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