

Toyota's Mirai fuel-cell vehicle

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Z06 concept performance parts at SEMA

General Motors displayed several performance enhancements for its new Corvette Z06 at the recent SEMA Show in Las Vegas; carbon ceramic brakes and a carbon-fiber torque tube among them. http://youtu.be/r_jAbcDk498



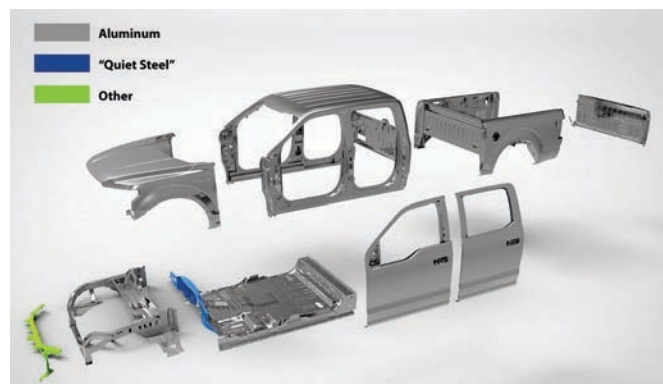
Big-data issues come to fore

Connected vehicles bring many benefits, helping both drivers and traffic managers. However, it can be difficult for traffic managers to analyze and use the enormous amounts of data collected when every vehicle constantly transmits speed, direction, and other data points. That's prompting many groups to see how big-data schemes can be adapted for the transportation industry. <http://articles.sae.org/13587>



Aluminum-repair challenge grows with F-150 in the mix

Aluminum panels in automotive applications are nothing new, but to date have been a low-volume phenomenon. With its all-aluminum body, the high-volume 2015 Ford F-150 pickup truck raises the issue of body repair to a whole new level. <http://articles.sae.org/13693>



Chinese suppliers shift focus

Chinese vehicle makers are altering their market strategies to cope with slower growth and increased competition. Many are focusing on services, often partnering with others to make this transition more swiftly. <http://articles.sae.org/13662>



Magna 4WD tech saves fuel

Magna's Actimax features fully active, electromechanical clutch actuation controlled by an integrated electronic control unit to provide variable torque between the front and rear axles. Current production applications include the **Hyundai** Genesis and **BMW** 3-, 5-, 7-Series. A two-speed version is used in the **Jeep** Grand Cherokee and **Chevrolet** Silverado. <http://articles.sae.org/13615>



Engine lube 101

"Engine oil may not be quite as exciting as some other parts of the car, but for something that is so basic, there is a pretty amazing lack of knowledge out there," observed Eric Johnson, a veteran **General Motors** fluids and lubricants engineer. <http://articles.sae.org/13555>



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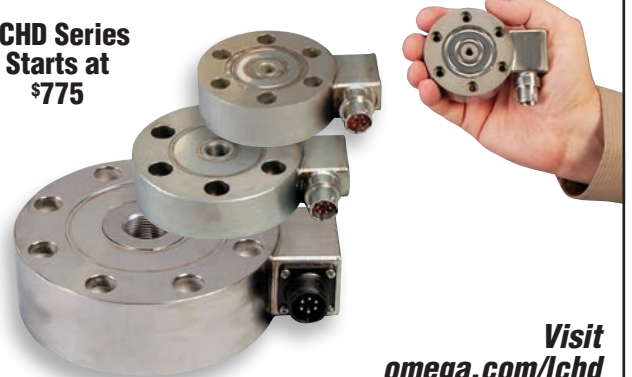


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Webcasts

The following mini webcasts are available for on-demand viewing at www.sae.org/webcasts. These free programs are presented by technology experts and offer viewers a chance to send in questions via an “Ask a Question” box.

Adhesive Bonding for Aluminum

Lightweight Structures: This 20-min webcast focuses on customized solutions for bonding aluminum body structures and closures on vehicles currently in production. Participants will have the chance to gain insight into the challenges of bonding aluminum substrates, learn how different types of adhesive technologies are used in aluminum bonding, and hear about repair technologies for aluminum vehicles. They'll also see how structural adhesives have contributed to an estimated 2.65 billion gal (10.0 billion L) of gasoline savings by providing weight savings of 70 to 100 kg (154 to 220 lb) per vehicle. Sponsor: **Dow**

Lightweighting: How Adhesive Tapes Contribute to Weight Reduction in

Automotive Production Processes: This 10-min webcast looks at how adhesive tapes can contribute to weight reduction without jeopardizing quality and performance when they replace traditional components or work in tandem with them. Participants will see specific examples of how adhesive tapes are used throughout the automotive production process, learn about the benefits of using adhesive tape within specific applications, and discover the potential weight savings per vehicle. Sponsor: **tesa tape inc.**

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Fuel-cell week

Mid-November's 2014 L.A. Auto Show media preview kickoff saw another round of new production and concept car introductions that included probably the biggest concentration ever of fuel-cell vehicle debuts. There were reveals by **Honda, Audi, Volkswagen,** and **Toyota**—all with ranges finally beyond the crucial 300-mi (480-km) mark.

Honda, which was expected to reveal its FCX Clarity replacement at the L.A. show, instead chose Japan to debut a concept and announce a 2016 production version. Honda says that the FCV Concept showcases what its new fuel-cell vehicle will look like and will provide significant gains in real-world performance, cost reduction, efficiency, packaging, and appeal.

The Volkswagen Group showed two fuel-cell vehicles at the L.A. show. The Audi A7 Sportback h-tron Quattro plug-in fuel-cell hybrid concept has electric all-wheel drive, a 170-kW fuel cell, and a supplementary 8.8-kW·h battery recharged by brake recuperation or plug power. VW's 100-kW front-wheel-drive Golf SportWagen HyMotion research vehicle, like the Audi, has a lithium-ion battery to supplement its fuel cell.

In this issue (page 41), we highlight what is arguably the most significant fuel-cell vehicle launch of the week—the 114-kW Toyota Mirai. Although initial production



goals are modest at 700 units, the car will be introduced in Japan before year's end, in Europe early next year, in California by summer 2015, and in the northeastern U.S. in 2016.

A current lack of hydrogen fueling stations means that many of these vehicle developments are being met with skepticism for future market success. However, the infrastructure is developing in some regions.

Skeptical experts remain. "Though there has been some news on the fuel-cell electric vehicle front, it still remains significantly down the road before hydrogen fueling stations are accessible enough for that to be anything more than a niche solution," said **IHS Automotive** Senior Analyst Stephanie Brinley, who attended the L.A. show.

The OEMs will also need to convince a skeptical public. Subsidized leases are making the expensive vehicles somewhat affordable for early adopters. **Hyundai**, which started selling its Tucson fuel-cell vehicle to California consumers in the summer, is helping in this effort. It published a 14-page booklet called "Hyundai Answers Your Fuel Cell Questions." Check it out at <http://www.hyundailikesunday.com/>.

A combination of adequate infrastructure, affordable pricing, and education will be needed to jump-start the nascent market.

POWERTRAIN

Flat-plane crankshaft spins 'Voodoo' into Ford's new Shelby V8



 This is the view of the 2015 Shelby GT350 that Ford engineers predict most Camaro Z-28 and Porsche 911 GT3 owners will see when the new high-performance Mustang hits the streets and track days early next year. Click to hear what the new 5.2-L flat-plane-crank V8 sounds like on the track. Ford will release engine visuals at a later date.

So you think the Corvette Stingray and **Jaguar** F-Type play the wildest V8 soundtracks through their active-exhaust systems? Or you say nothing beats a **Ferrari** 458 for pure aural delight? Well, you haven't heard **Ford's** 2015 Shelby GT350 Mustang on rising throttle. From tip-in to WOT the new Shelby, powered by a unique naturally aspirated 5.2-L DOHC V8 that was coded "Voodoo" during development, plays a

downright diabolical tune from its four exhaust outlets.

"When we would start up the first prototypes in the engineering garage, everybody's heads turned: 'What the heck is that?'" recalled Raj Nair, Ford's Group Vice President of Global Product Development, in an interview with *Automotive Engineering* prior to the 2014 LA Auto Show. "When we'd transit the cars between facilities in



Global PD boss Raj Nair had faith that the Powertrain and GT350 teams would solve the NVH issues related to the prototype V8. “We all wanted this motor,” he said.

Dearborn you’d hear their echo out on Oakwood Boulevard. Anybody at our proving ground who heard these cars knew there was something very different under the hood.”

There will be customers who will buy the latest Shelby Mustang for its 20% stiffer body structure (compared with the Mustang GT), its racetrack-focused chassis tuning, enormous **Brembo** brakes, responsive **MagneRide** damping, **Recaro** seats, and many other vehicle attributes. Others, however, will want the car for its howling exhaust note alone. The sound is created by the engine’s special flat-plane crankshaft and its related breathing and ignition characteristics.

So named because its four connecting-rod journals are spaced 180° apart, the shaft

appears “flat” in a single plane when viewed head-on. The arrangement generally does away with the large counterweights used in the typical 90° “cross plane” layout, which helps reduce crankshaft mass and enables the engine to rev more freely. The new Ford spins to a heady 8000 rpm before fuel cut-off, according to Nair, and has another 250 rpm of safe headroom. This from mildly oversquare 94 x 92.7-mm (3.7 x 3.65-in) bore and stroke dimensions.

Long the province of European high-performance V8s from Ferrari, **Lotus**, **Cosworth** (the legendary DFV **Formula One** unit) and others, flat-plane cranks were also used in the first **Cadillac** V8 in 1914. The configuration gives an alternating right-left-right-left firing order across the cylinder banks, allowing more efficient gas flow and

Ford will use its patented plasma-transferred wire arc (PTWA) cylinder bore coating technology (shown here on a cutaway of the 5.4-L Shelby V8) on the new 5.2-L engine. (Lindsay Brooke)



exhaust-gas scavenging along with improved throttle response and exotic exhaust acoustics.

Compression ratio of the port-injected, Coyote-based 5.2-L is 12:1 and max cylinder pressure is 97 bar (1407 psi), an engineer said. Final **SAE** power and torque ratings are not yet finalized, but the V8 will deliver at least 500 hp (373 kW) and more than 400 lb-ft (542 N·m), according to Jamal Hameedi, Chief Engineer, Ford Global Performance Vehicles.

Flat-plane-crank engines have limitations. First, the lack of counterweight balancing typically limits cylinder displacement to about 4.5-4.6-L due to greater second-order vibration. Ford has solved that in the 5.2-L application with a new crankshaft-mounted damper system and extraordinary

attention to NVH abatement during the design and prototype phases. According to Nair, the engine program (which was concurrent with GT350 vehicle development) nearly wasn't approved for production.

"This [vibration] was our biggest engineering challenge even after we had the first prototype," Nair noted. "Things were breaking, and the technical guys were worried. Whether or not we continued down the flat-plane-crank path for GT350 came down to a critical prototype drive we had scheduled. After that drive, we all went into a meeting room for the debriefing. And we unanimously concluded that we simply had to have this motor! We were determined to solve the issues."

What followed was, in Nair's words, "a lot

of stiffening of the cylinder block, exhaust system, and various brackets” achieved through intense FEA analysis, plus “a lot of tuning.” Nair said the result yielded unique torsional-damping technology among other patent-pending actions aimed at taming the beast.

The 5.2-L is naturally aspirated by design; boosting was not part of the plan. “We really wanted to stay with naturally aspirated technologies for instantaneous throttle response” along with a feeling of minimal flywheel effect, Nair explained. He’s familiar with both qualities as a longtime motorcyclist who rides a **Yamaha** R1 sport bike on the street and at track days.

Other challenges with flat-plane-crank engines include their tendency to deliver underwhelming torque. Nair admitted that the GT350 “doesn’t have that electric-motor feel off idle that the GT500 has” but the latter also uses a blown 5.8-L rated at 631 lb-ft/855 N·m. Increasing cylinder displacement (via larger bore) to 5.2-L, which is 700-cc larger than Ferrari’s V8 used in the 458, helped overcome some of the torque deficit. Nair also noted that optimizing the intake and exhaust systems for power, efficiency, and meeting cold-start emissions was tricky.

“Even the unequal-length headers we selected, to some extent, help with catalyst light-off,” he said.

According to Hameedi, the 5.2-L V8 has a linerless aluminum cylinder block that features bores finished using PTWA (plasma-transferred wire arc), an advanced coating technology co-developed by Ford and **Flame-Spray Industries** that debuted on the 2011 GT500 5.4-L V8. For PTWA details see <http://articles.sae.org/7624>.

Supplier sources involved with the 5.2-L V8 program said Ford broadcast an initial volume plan for production of 5000 units.

Lindsay Brooke

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ENERGY

A123 Systems refuses to be left out in the cold with its 12-V Li-ion batteries

Saying a lithium-ion battery would perform better than a lead-acid if not for very cold weather is about the same as saying your favorite sports team would have won the game had it just played better.

That is not the analogy **A123 Systems** is drawing for its 12-V Li-ion technology. The sports analogy is the author's. A123's message is more direct: Li-ion technology at anything but extremely low temperatures is a better battery solution than the lead-acid type for mass savings and all-around functionality.

"Because lithium-ion batteries can be more deeply discharged, they allow the engine to be turned off and on more frequently in stop/start systems," said Jeff Kessen, a degreed mechanical engineer who serves as A123's Director of Automotive Marketing. "But [brake energy] regeneration is where the value proposition gets quite a bit stronger."

Li-ion battery chemistry doesn't degrade to the extent lead-acid does when accepting charge, and so the former is a better solution for the coupling of stop/start with brake re-gen, Kessen told *Automotive Engineering*. A123 labels such dual capability "microhybrid."

Earlier, in a session on low-voltage



A123 Systems' Li-ion starter battery product offering with nominal capacity of 78 A-h.

electrification at a **Smarter Shows** event in Novi, MI, Kessen spoke of three particular A123 Li-ion applications (see top chart on page 15). One is a simple alternative to the lead-acid starter battery. This application, which he said offers a fuel-economy improvement of 5 to 10%, is the one he focused on most. He touched on a dual system for hybrid-vehicle applications using a 48-V Li-ion battery for hybridization tasks and a 12-V lead-acid type for engine cranking (fuel-economy benefit of about 15%); and a dual system for microhybrid applications using one 12-V Li-ion battery for hybridization and one 12-V lead-acid battery for engine cranking (fuel-economy

benefit of about 5 to 10%).

His main point: “There’s still a lot of untapped potential at the 12-V level” in terms of delivering a fuel-economy benefit.” The payoff for such systems may not be great, but neither is the investment required. And so “spending less to implement a fuel economy gain from a 12-V system makes sense” as part of an OEM’s larger technology strategy to keep pace with ever-stiffening fuel-economy regulations.

The European Union’s ban on lead in vehicle electronics may be extended to batteries, which currently are exempted, according to Kessen, who noted that the most recent exemption expires in 2015. There has been enough progress in Li-ion viability in the past five years that “I think there is some possibility that a [lead] phase-out might be regulated in some way,” he said.

There’s no legislating away frigid weather from Fargo, and so from Kessen’s point of view “cold-crank” performance is Li-ion’s “biggest frontier to be bridged”—that “and, of course, cost.” Given the same capacity, an Li-ion battery is about three times more expensive than lead-acid, but about half the weight, he said. “Auto manufacturers are scratching and clawing for a single pound or half a pound. So to get 20 lb in one design change is fairly significant.”

In comparison to other Li-ion strategies



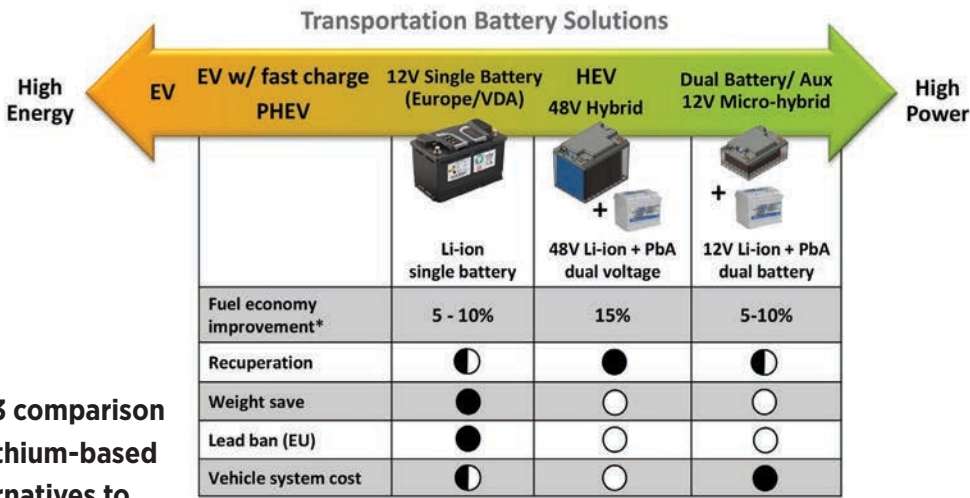
In low-voltage vehicle electrification, brake energy regeneration is where “the value proposition gets quite a bit stronger” for lithium-ion technology, said A123 Systems Director of Automotive Marketing Jeff Kessen in a presentation at The Battery Show.

involving higher voltages and dual battery systems, the big advantage for an OEM in switching to a single 12-V Li-ion battery is that they can do it “without tearing up the vehicle electrical architecture” while also enjoying the mass, life, brake regen, and additional functionality that come from a battery technology offering higher capacity, said Kessen.

For single 12-V battery applications, A123 has had an Li-ion product on the market for three years, and continues to improve cold-



Power / Energy for Low Voltage Solutions



A123 comparison of lithium-based alternatives to lead-acid.

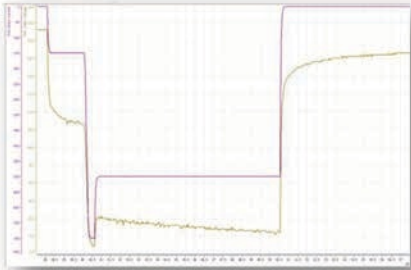
*compared to conventional vehicle
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Cold Crank Performance Improvements

Nanophosphate® Example



VDA-specified Tests	EN test	LV124 test
	800A, -18°C, 10s (7.5V min)	550A, -25°C, 10s (7.0V min)
Gen 2 starter battery, 80Ah	7.23V	6.68V
Gen 3 starter battery, 60Ah	7.60V	7.53V



A123 reports solid progress in cold-crank performance.

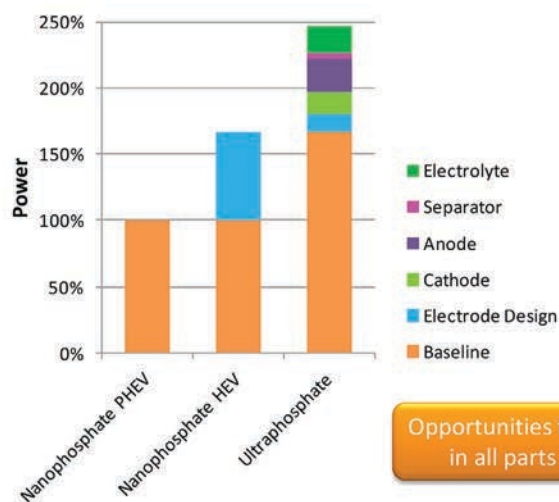
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crank performance (see chart above). Kessen said the company has expended great effort over the past 12 to 18 months in its third-generation product. Available soon in

samples, it will equal or better lead-acid AGM (absorbent glass mat) in the EN -18°C cold-crank test—and at a capacity of only 60 a-h (vs. 80 a-h for its second-generation product).



UltraPhosphate Power Improvements



Opportunities for power enhancement still exist in all parts of A123's current power cells

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For its lithium-iron-phosphate technology, A123 has made great improvement in mechanical design (electrode) and is now focusing on improvement in chemistry for its UltraPhosphate technology.

“Certainly it’s still true that lead-acid holds up better as the temperature goes down even further, but we’ve come quite a long ways in this dimension,” he said.

A123 has expanded capabilities beyond its indigenous lithium-iron-phosphate (LFP) technology via acquisitions to nickel-manganese-cobalt and lithium-titanate. “That’s not to say LFP has run out of steam in terms of stop/start—quite to the contrary,” said Kessen.

Pointing to a chart (shown on this page), he noted that A123 was able to significantly improve the power performance of the company’s base Nanophosphate PHEV technology by 79% via changes in the mechanical design of the cell (meaning revisions to the electrode), with no changes

to cell chemistry. The result was what A123 calls Nanophosphate HEV, a technology that is employed by **BMW**, among others, Kessen said.

While continuing to pursue improvement in mechanical design, A123 for its UltraPhosphate technology has been focusing on chemistry changes. “This is a substantial accomplishment, which is still in the laboratory, he said. And, unlike at some other companies, “particularly start-ups,” A123’s gains do not come at the expense of a fall-off in some other performance parameter.

Patrick Ponticel

AFTERMARKET

GM announces LT1 crate engine availability at 2014 SEMA Show



The LT1 crate engine is featured in the 400-page 2015 Chevrolet Performance catalog.

The basic architecture of **General Motors'** small block V8 has remained the same since 1955, but now a new crate engine with modern-day advanced technologies is available on the aftermarket.

"We are ready to go. We have the engines in our warehouse," said Jim Campbell, U.S. Vice President of Performance Vehicles & Motorsports for General Motors.

The **Chevrolet** designed, engineered, and tested LT1 crate engine package was a 2014 SEMA headliner at the Nov. 4-7 show in Las Vegas. This crate engine's production

counterpart is the 6.2-L V8 that powers the seventh-generation 2015 Corvette Stingray.

"We've added technologies to improve power and efficiency, but that basic small-block V8 architecture has been a constant since the beginning," Campbell said, referencing the LT1 crate engine's direct fuel injection and variable valve timing.

Rated at 460 hp (343 kW) at 6000 rpm and 465 lb·ft (630 N·m) of peak torque at 4600 rpm, **Chevrolet Performance's** LT1 crate engine is available with a wet sump for an \$11,000 suggested price or a dry sump

oiling system for \$11,250. All-new transmission installation kits mean the LT1's eight-bolt crankshaft flange can be mated to GM's 4L60-series four-speed automatic or T-56 Super Magnum six-speed manual. Electronic controller/harness kits are available for \$2250.

"We're doing the programming on the engine controller. And when you combine the engine with an automatic transmission, we also do the programming on the controller for the transmission. You don't need a third-party for the programming," Campbell said, "It's just connect and cruise."

Chevrolet Performance also offers a \$725

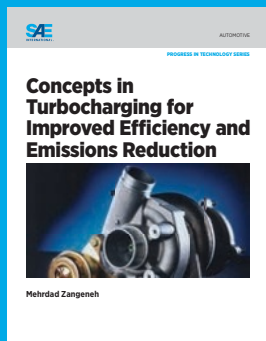
front-end accessory drive kit that includes the alternator, air-conditioning compressor, brackets, idler pulley, and serpentine belt.

Chevrolet's SEMA exhibit featured the new LT1 crate engine as the power source for a vintage 1971 Chevrolet Corvette that was redesigned with input from **NASCAR** champion driver Jimmie Johnson. The updated classic Corvette has adjustable coil-over springs to replace the original car's front and rear suspension components, a custom hood vent, restyled front fender vents, and 18-in wheels in place of the 1971 sports car's 15-in rally wheels.

Kami Buchholz



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By Mehrdad Zangeneh

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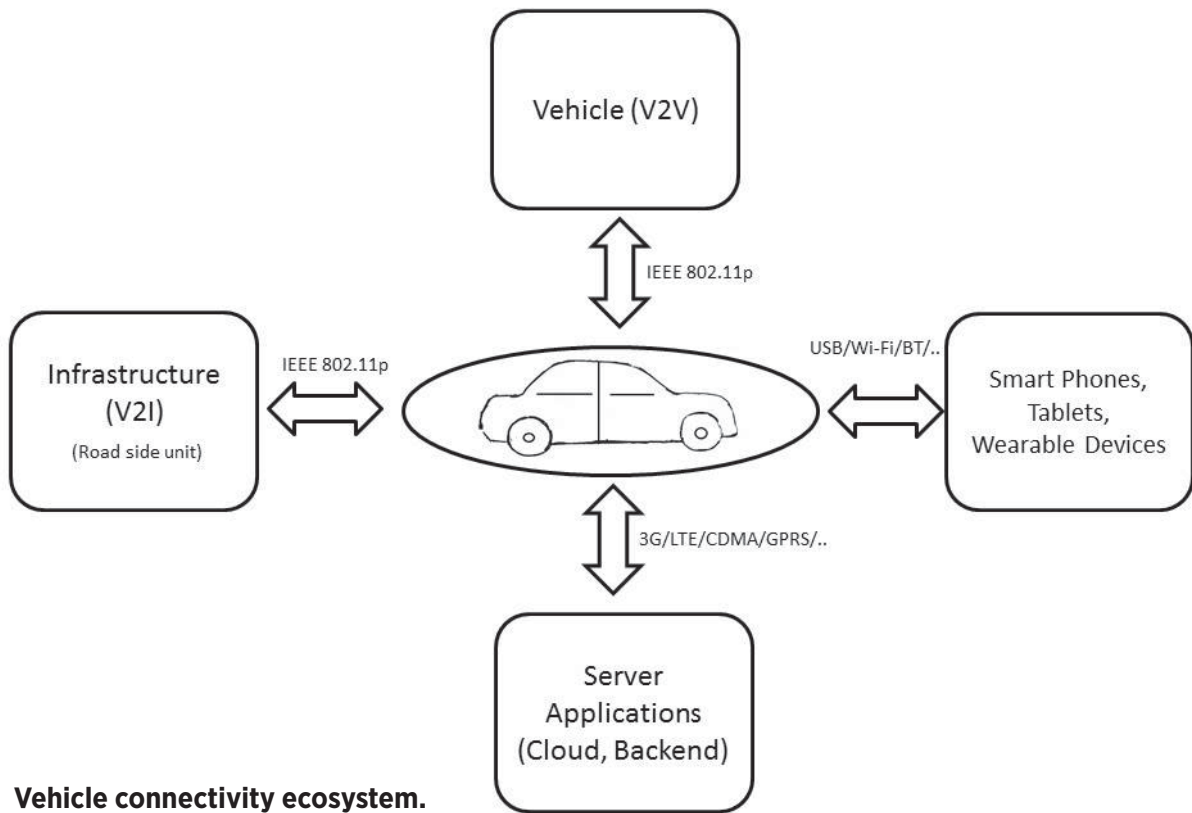
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ELECTRONICS

Integrated automotive gateway can enable connected cars



Connected-car technology has become a key differentiator for car makers and their Tier 1 suppliers. One of the biggest challenges connected cars pose is the integration of information and consumer electronics into the car and ensuring connectivity among them. Connected-car applications such as telematics, driver assistance, and infotainment require seamless connectivity to and from the vehicle.

Modern cars are built with embedded computers called ECUs (electronic control

units) that are further connected to sensors for data acquisition. The in-vehicle network is further divided into sub-networks such as CAN (controller area network), MOST (media-oriented safety transport), and FlexRay. The choice of the bus network depends on the communication requirements of the connected ECUs and the baseline vehicle platform out of which a new vehicle line is derived.

Moreover the vehicles of today are able to exchange data with external sources via Bluetooth, Wi-Fi, 3G (third-generation), and

LTE (long-term evolution) networks. The advent of V2V (vehicle-to-vehicle) and V2I (vehicle-to-infrastructure) communication has increased this trend.

In addition to communication inside the vehicle, a robust vehicle communication gateway is important to establish seamless connectivity to conditions outside the vehicle. While the communication network inside the vehicle is stable, V2I and V2V communication to the outside is undergoing rapid change.

Vehicle gateway challenges

With advancements in telematics, connectivity challenges in vehicles have also changed drastically. The vehicle gateway of the future should be designed to address the following challenges:

- Support multiple networks and provide secure wireless connectivity for/between vehicles and infrastructure
- Provide secure, intelligent switching between different networks
- Sense, select, and switch to best available network automatically based on user-defined policies
- Create a mobile hotspot for wired and wireless devices in and around the vehicle
- Support various IP devices in the vehicle
- Support upgradeability for current and future networks
- Provide secure and reliable communication for all connected devices.

Vehicle internal networks are now more

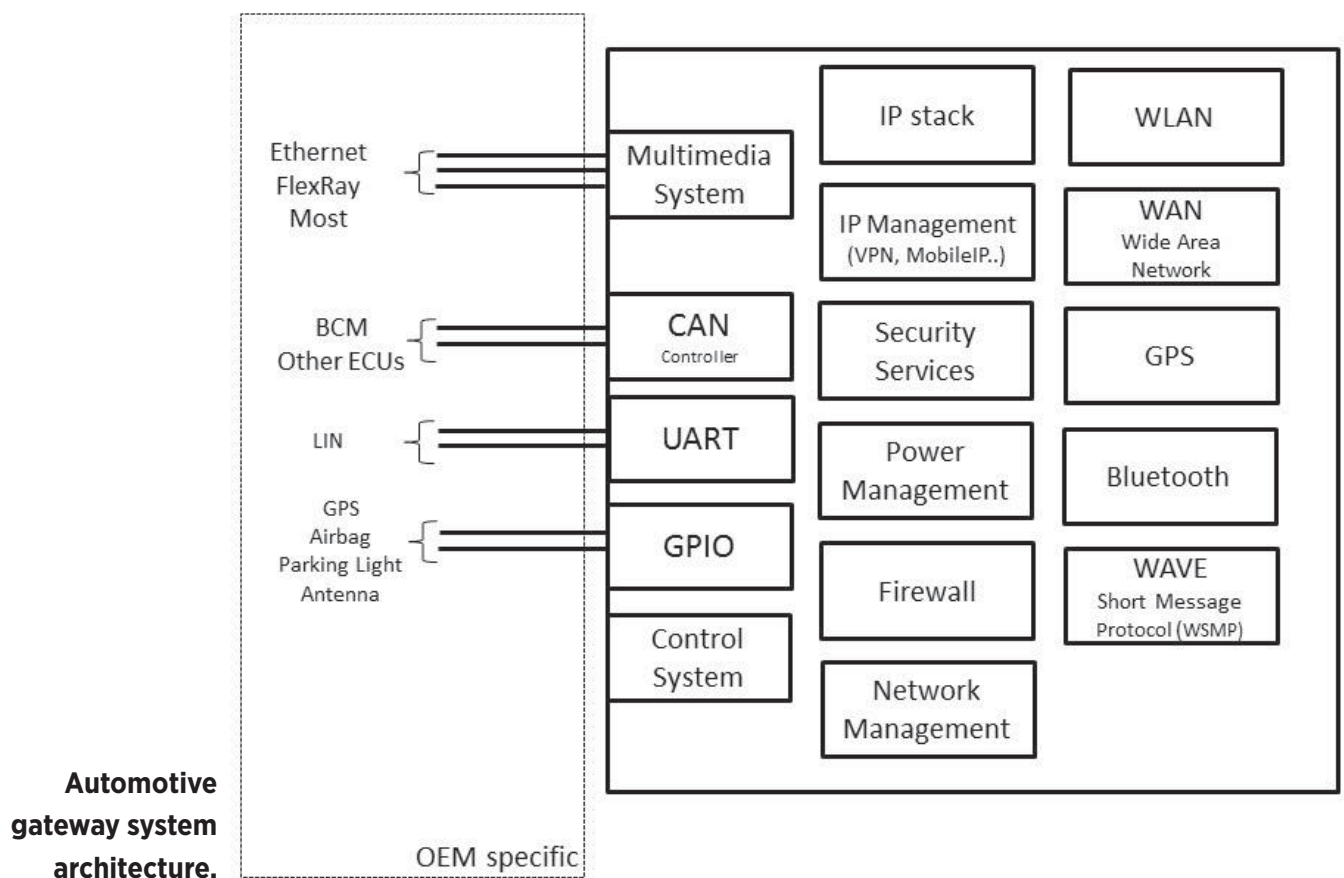
connected to external devices, thereby exposing the internal network to the outside world. The evolution of V2V and V2I communication has increased data exchange with external resources via Wi-Fi, 3G, and LTE networks.

Vehicles are no longer closed networks; they are potential targets for remote attacks. In-vehicle networks are safety-critical, and any access to an in-vehicle network may have serious safety implications. Therefore, both internal and external communication networks must be secured.

With the increased complexity of telematics services and applications, the big challenge is not about providing a platform with extensive features, but creating a future-ready vehicle gateway that has the flexibility to adapt and accommodate rapid changes and the ability to support new functionality that holds the key.

Integrated automotive gateway blueprint

The automotive gateway should provide a secure communication for data exchange, both onboard as well as off board. The gateway proposed by **Tech Mahindra** is directly involved in supporting various mobility and safety applications that run either inside the vehicle or those hosted on a mobile or off-board platform using remote servers. The company is focusing its



development on the concept of an Automotive Gateway Architecture blueprint and its realization.

The gateway supports various short-range communication systems for connecting to personal devices such as mobile phones, tablets via Bluetooth, Wi-Fi, and UART (universal asynchronous receiver/transmitter). To connect to the cloud via the Internet, the gateway supports long-range communication systems such as GPRS (general packet radio service), CDMA (code division multiple access), LTE, UMTS (Universal Mobile Telecommunications System), and GSM

(Global System for Mobile). IEEE 802.11p is supported for V2V communication and communicating with road-side units. The gateway architecture has to be designed for supporting connectivity with known and unknown entities.

Known entities could be trusted entities such as firmware over-the-air (FOTA) servers, telematics services over back-end servers, or service/plant diagnostics over Wi-Fi, while unknown entities refer to untrusted ones such as third-party applications, open cloud connections from in-vehicle devices, and smart devices brought into the vehicle connectivity network.

The software architecture is designed with a plug-and-play approach to ensure support to new connectivity changes without altering the core software.

The system architecture under consideration directly relates to connectivity mechanisms. The physical layer is 802.11p instead of 802.11 b/g/n. The vehicle gateway carries two stacks, namely:

1. IPv6 (Internet Protocol version 6) based TCP/UDP (Transmission Control Protocol/User Datagram Protocol) for supporting non-safety applications like e-toll, traveler info, construction management, commercial vehicle operations, etc.
2. WSMP (Wave Short Message Protocol) stack for safety applications such as curve speed warning, V2V-sensor data exchange, left-turn assistant, etc.

IPv6-based TCP/UDP will enable a secure and seamless connection from gateways to portal/Internet. WSMP allows applications to directly access/control physical layer characteristics without access points for ad-hoc communications.

The gateway must support multiple PHY (physical layer) requirements (connect to smart services inside the vehicle and 3G networks for telematics) to enable a range of infotainment and telematics applications.

To ensure V2X, telematics, and infotainment functions, the gateway solution must support and implement the IEEE 802.21 specification for “handover

between heterogeneous networks” to ensure seamless handover between network switches and controls when the vehicle is on move.

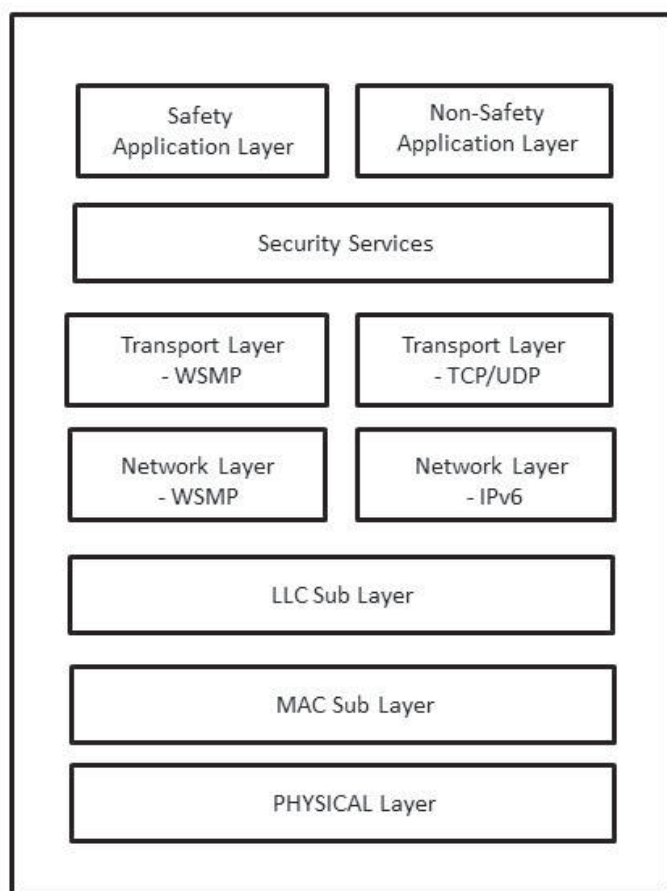
A true future-ready automotive gateway should be able to send IPv6 packets over 802.11p and 3G networks with a seamless vertical handover. Seamless handover happens when the vehicle is moving through different WLAN (wireless local area network) and 3G networks, constantly switching between heterogeneous networks for always best connected services.

Security model of the gateway

Initially, in-vehicle networks were designed to operate in a closed environment where security was not a major concern.

Considering that the gateway must support V2X communication and a number of external interfaces to in-vehicle networks, threat levels are perceptibly higher with consequent increases in safety and security requirements.

The security mechanism in the gateway must be designed to contain attacks by rooting the security mechanism on hardware with crypto algorithms. This ensures that sensitive information such as cryptographic keys is not vulnerable to software attacks. The hardware security module protects the key store, acting as crypto hardware and supporting well-defined software interfaces. Hardware-



Automotive gateway system stack.

based security is proposed to handle ad-hoc message exchange load in varying high-speed road traffic conditions.

The security module must be designed for use in combination with vehicle manufacturers' security policies. Additionally, the gateway security mechanisms must be clearly intended for generic connectivity to vehicular networks as operational environments change dynamically.

Enabling future convergence

Data encryption and the security of the telematics backend have been primary concerns in automotive telematics. The automotive gateway will act as a convergence point for the cooperative networks of the future, which will support a variety of safety critical and mobility applications that either run inside the vehicle networks or are hosted on smart devices or on remote servers. In next-generation telematics, in which vehicles will connect ad-hoc to random entities and route data through unknown networks along the way, all-round vehicle security will be of paramount significance.

The automotive gateway is expected to play a significant role in vehicle security in addition to its traditional data gateway functionality. While the future of connectivity infrastructure is speculative, we know the broad outlines of what might transpire. The automotive gateway has been envisioned based on these broad outlines. The adoption of the gateway approach will, ultimately, ride on the ease of providing seamless connectivity over the vehicle's mobility envelope, safely and securely.

This article was written for *Automotive Engineering* by Karthik P. Rao, Consultant, and Balakrishnan Muthukrishnan, Principal Consultant, for the Connected Cars Practice at Integrated Engineering Solutions, Tech Mahindra.

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2015 HOT TECHNOLOGIES

Our annual year-end review of new and significant technology applications for the upcoming model year's vehicles.

by the Editors of *Automotive Engineering*

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For OEMs and suppliers, the level of technology development and deployment has never been higher, judging by the new systems, components, and materials that have recently entered production for MY2015. Industry engineers are focusing hard in areas that save vehicle mass for improved fuel efficiency, reduce emissions, and boost occupant safety and convenience. See the hot new stuff your competitors have been working on for the upcoming model year in the following pages.

Mercedes Active Curve Tilting



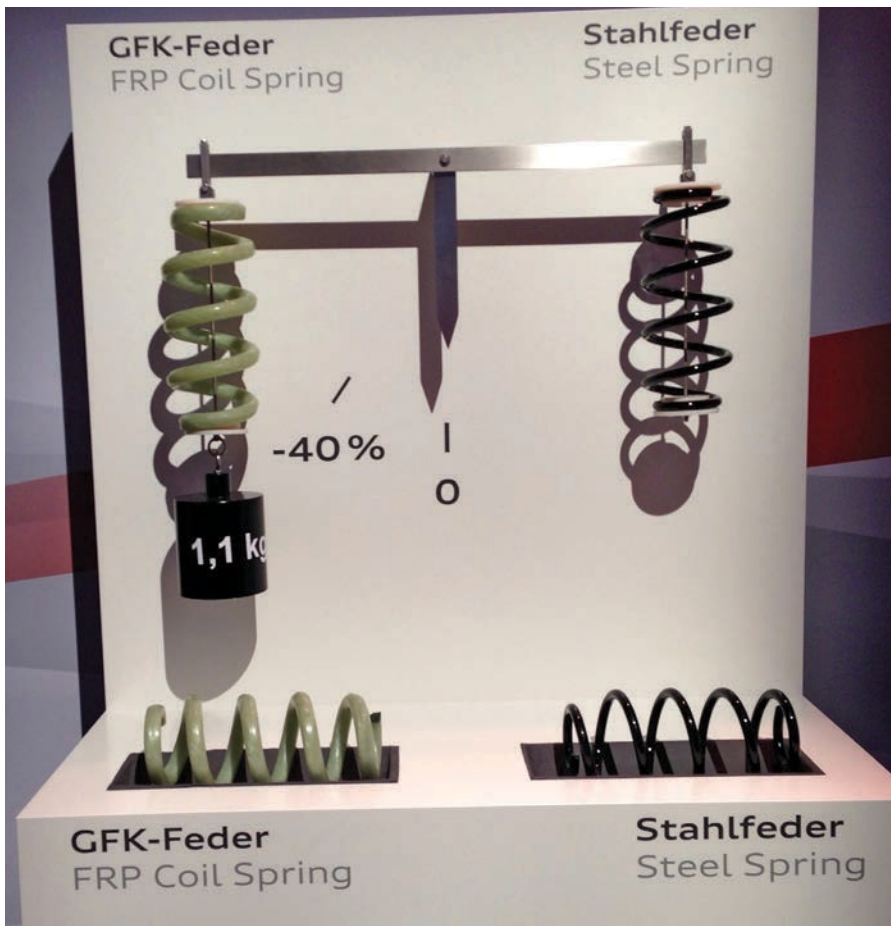
Mercedes has been working on new chassis-dynamics and suspension-articulation solutions for years and in 2015 brings its Active Curve Tilting system to the production S-Class Coupe.

Making its production debut in the 2015 **Mercedes-Benz** S-Class Coupe is the Active Curve Tilting Function (ACTF), arguably the automotive equivalent of high-speed “kneedown” motorcyclist cornering techniques. Its tilt action is orchestrated by the car’s Magic Body Control (MBC) system,

which monitors the road 15 m (49 ft) ahead via a stereo camera (see <http://articles.sae.org/12330/>) and uses a transversal acceleration sensor to produce the required lean via adjusting the pressure within hydraulic struts that are part of the suspension system. The “lean” effect varies according to the

radius of the curve and speed of the car (between 30 and 180 km/h; 20 and 110 mph), up to a maximum 2.5°. ACTF is switchable within three drive modes available via the car’s Active Body Control. Read more at <http://articles.sae.org/12884/>.

Composite coil springs for Audi A6 Avant



Co-developed with Sogefi, the composite-plastic coil springs in Audi's A6 are of slightly larger diameter than conventional steel coils. The spring material is made of long glass fibers twisted together and impregnated with epoxy resin. Audi claims a major mass savings.

The industry's been talking about composite-plastic coil springs for years; now **VW Group** is beginning to deploy them in production. **Audi's** latest version of its A6 Avant, the 2.0-L TDI ultra, is using glass-fiber-reinforced polymer (GFRP) springs to succeed conventional steel components, reducing weight by about 40%. Developed in collabo-

ration with **Sogefi**, the coil springs are of slightly larger diameter than conventional steel. There are also fewer coils. The springs comprise long glass fibers twisted together and impregnated with epoxy resin. Additional fibers are wrapped around the resultant core at alternating angles of $\pm 45^\circ$ to the longitudinal axis. Audi claims that a typical steel

spring weighs 2.7 kg (6.0 lb), compared to the 1.6 kg (3.5 lb) of the composite alternative. About half of the total 4.4 kg (9.7 lb) saved for the A6 ultra is unsprung weight. VW-Audi plans to increase its usage of composite springs in the future. Read more at <http://articles.sae.org/13642/>.

Ford's airbag-in-the-glovebox

Integrating a passenger-side knee airbag system inside the glovebox door won **Ford** engineers and their supplier partners both the Grand Award and Safety Award at the 2014 **Society of Plastics Engineers (SPE)** Automotive Innovation Awards. Called an “active glovebox,” the system is supplied by **Faurecia** and debuts on the 2015 Mustang. It replaces a traditional textile airbag with an injection-molded plastic bladder, integrated into the glovebox door. The system is 30% smaller and provides a weight savings of 65% versus a traditional glovebox and airbag pairing, with \$5 to \$10 saved per car, Ford claims. A 75% smaller inflator enabled movement of the Mustang's instrument panel closer to the windshield, creating more space in the cabin. Upon impact, the bladder is inflated, extending the outer glovebox door panel toward the front

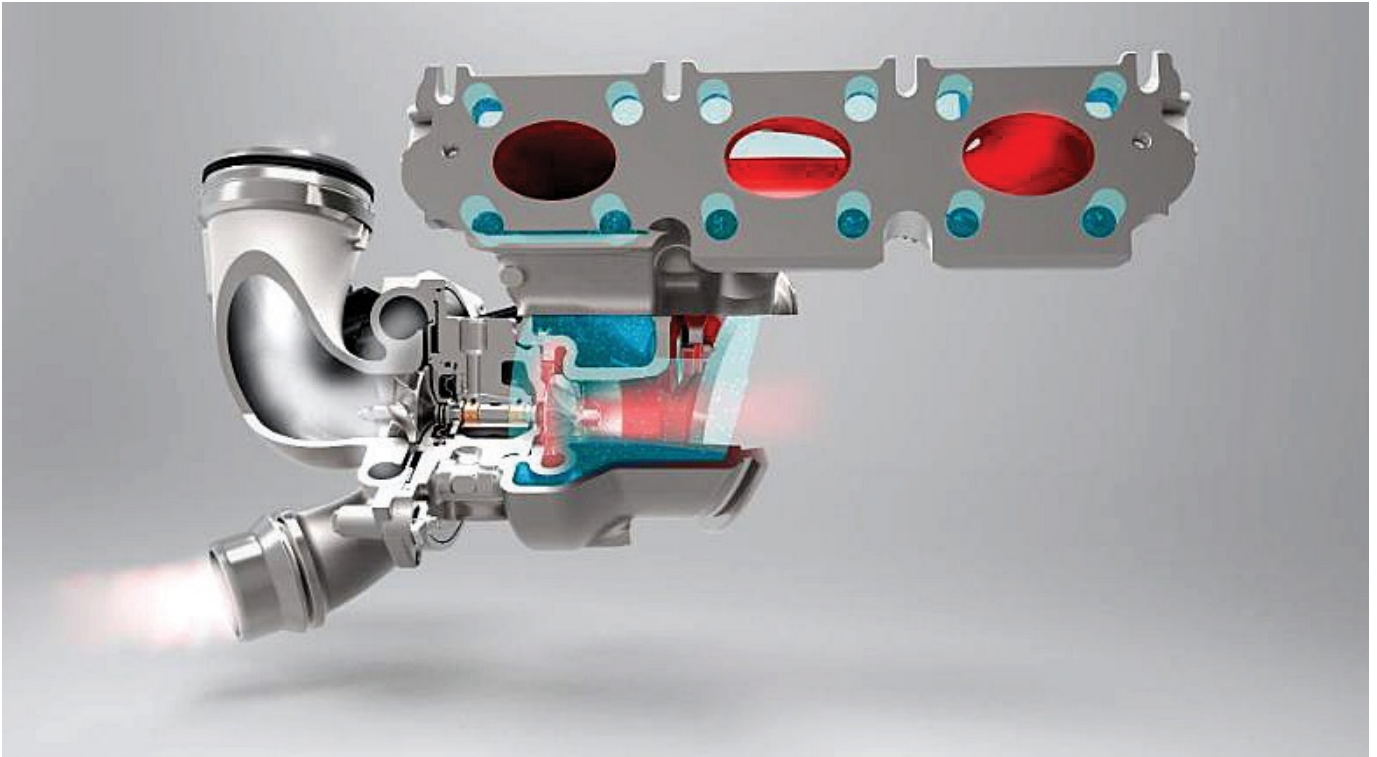


Ford's award-winning glovebox-door airbag system on the 2015 Mustang is 30% smaller and provides a weight savings of 65% versus a traditional glovebox and airbag pairing, with \$5 to \$10 saved per car and significant package efficiencies.

passenger's legs to provide cushioning. The bladder is attached via hot plate welding. Ford also developed a hydrostatic burst tester to validate the strength of the seal. The unit is made with 20% talc-filled polypropyl-

ene from **Advanced Composites** Inc. Ford has been granted 15 patents for this technology, with more pending. Read more at <http://articles.sae.org/13677/>.

Hot turbos #1—Conti's first production Al turbo housing



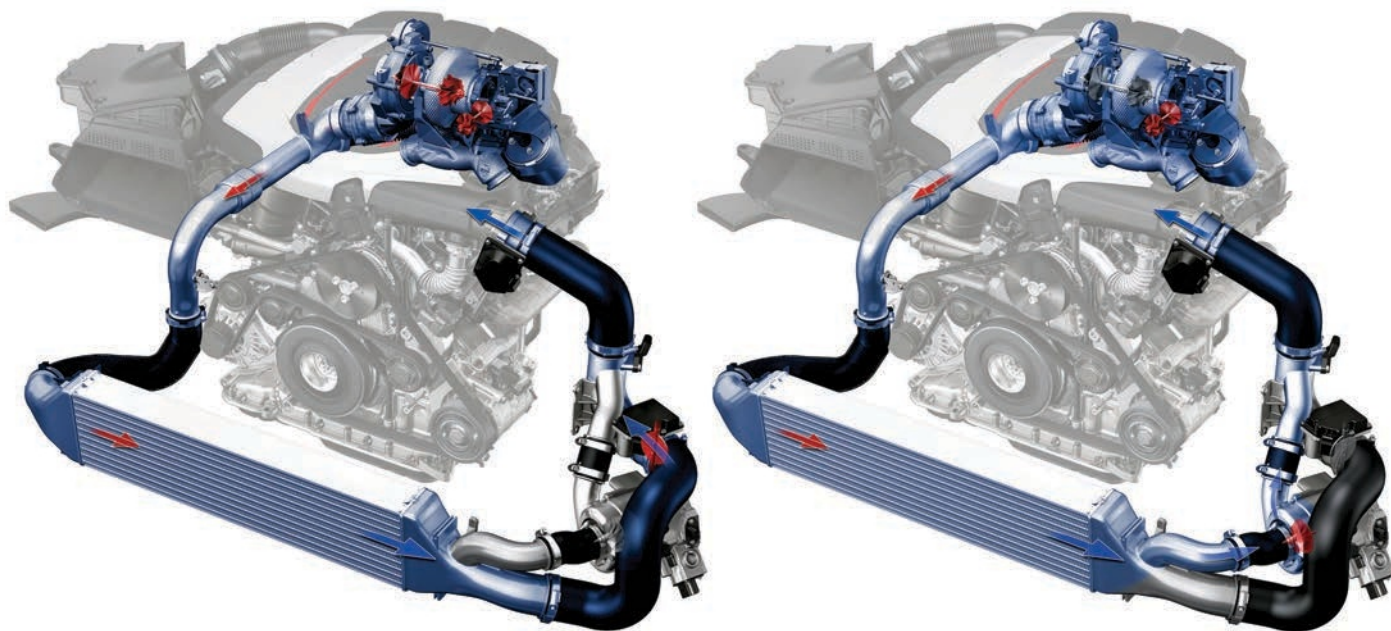
Continental's Al turbocharger housing debuts on BMW's new 3-cylinder gasoline engine powering the new Mini three-door. The double-walled housing offers a nearly 30% weight saving (2.65 lb/1.20 kg) and lower cost compared with a typical heat-resistant cast steel unit.

Continental will supply the first turbocharger with an aluminum turbine housing to enter automotive series production on the **BMW** 1.5-L three-cylinder gasoline engine used in the **Mini** three-door. The Al housing

is double-walled and water-cooled, and offers a nearly 30% weight savings—2.65 lb (1.20 kg)—and lower cost compared with a typical heat-resistant cast steel unit. Conti's design is claimed to reduce thermal

load on the catalytic converter, increasing its durability. Fast catalyst light-off is ensured by an electric actuator at the turbo wastegate. Read more at <http://articles.sae.org/13463/>.

Hot turbos #2—first e-turbo on new Audi diesel



The biturbo V6 diesel powering the new Audi Q7 will pioneer electric turbocharger systems in production vehicles. The Valeo turbo and e-boosting system is an alternative to two-stage turbocharging, with estimated fuel consumption improvements up to 15% when combined with regenerative braking.

A new high-performance version of **Volkswagen Group's** new-generation 3.0-L V6 diesel is expected to be the first production engine equipped with an electric turbocharger system when it is introduced on the 2015 Audi Q7. Developed with **Valeo**, the e-boosting system is an alternative to two-stage turbocharging,

with estimated fuel consumption improvements up to 15% when combined with regenerative braking. While the system requires 48-V power to spin up the turbo, boost is available instantaneously and the increased mass-airflow the e-turbo produces at low loads can help reduce PM (particulate matter) emissions. The new

V6 diesel also will feature a NOx storage catalytic converter that is combined with a diesel particulate filter and SCR (selective catalytic reduction) injection in a single assembly—claimed to be a first. Read more at <http://articles.sae.org/13223/> and <http://articles.sae.org/13421/>.

GM/Cosworth performance data recorder



Part of the unique Valet Mode system in the 2015 Corvette Z06, the Cosworth Performance Data Recorder records video, audio, and vehicle data using the Sport Mode overlay, which includes details on speed, engine rpm, gear position, and *g*-force among other capabilities.

Chevrolet's performance data recorder (PDR) that debuts in the 2015 Corvette Stingray as part of a new Valet package is claimed to be the first integrated application of this technology in a production car. Co-developed with **Cosworth** and aimed at track-day use, the PDR is able to capture high-definition video of the

road ahead using a camera embedded into the windshield header trim. It also captures audio using a dedicated cabin microphone. A key element is a telemetry recorder that uses a dedicated GPS receiver operating at 5 Hz—five times faster, says Chevy, than the car's in-dash navigation system. The recorder is hard-wired into

the Stingray's CAN bus to access vehicle information such as speed and braking force. Information is stored on a removable SD card of whatever capacity the driver chooses. The video of the drive, overlaid with telemetry data, can be viewed on the in-dash touchscreen when the car is parked, or on a computer later.

BMW outshines Audi to claim laser-headlamp first



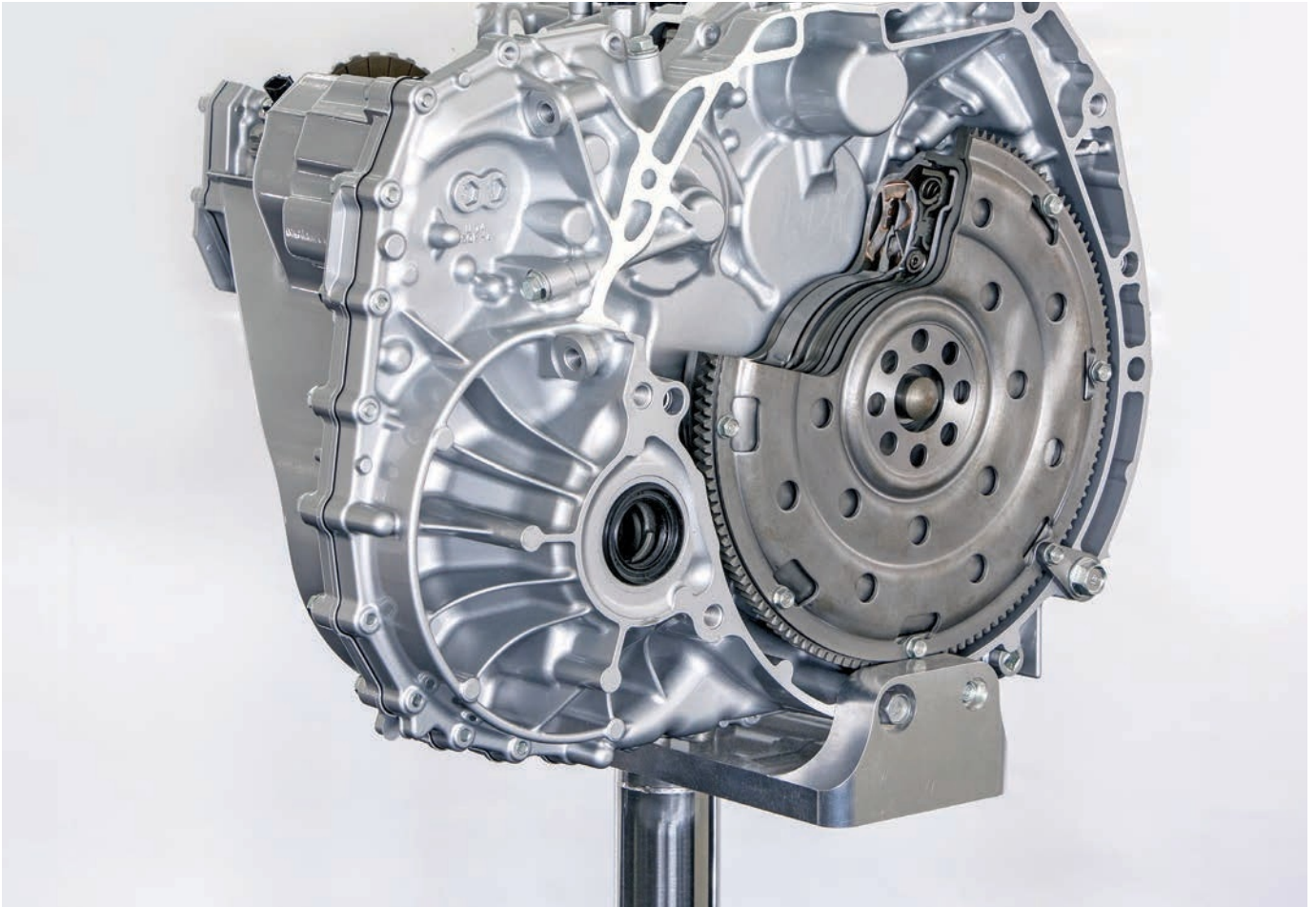
BMW's i8 beat Audi to the claim of first production car with laser headlamps, which are supplied by ZKW and offer double the distance-illumination of LEDs with 30% greater energy efficiency. They're not yet legal in the U.S.

At the 2013 Consumer Electronics Show, **Audi** and **BMW** began a public battle over which would be first to market with laser headlamps on a production vehicle. Last spring, it looked like Audi would prevail, when it unveiled a special-edition R8 LMX featuring laser headlamps. But about a month later, in June, BMW actually delivered the first eight i8

models equipped with laser headlamps (supplied by **ZKW**) to customers in Germany. The technology—which promises double the distance-illumination of LEDs with 30% greater energy efficiency and more compact packaging—remains illegal in the U.S. due to a 1968 regulation that requires all vehicle headlights to be capable of switching

from high-beam to low-beam—a function that is actually eliminated by the self-adjusting laser lights. Both OEMs' headlamps use a laser spot light, each comprising four high-power laser diodes, for speeds above 60 km/h (37 mph), supplemented with an LED high beam.

Honda's new eight-speed DCT uses torque converter



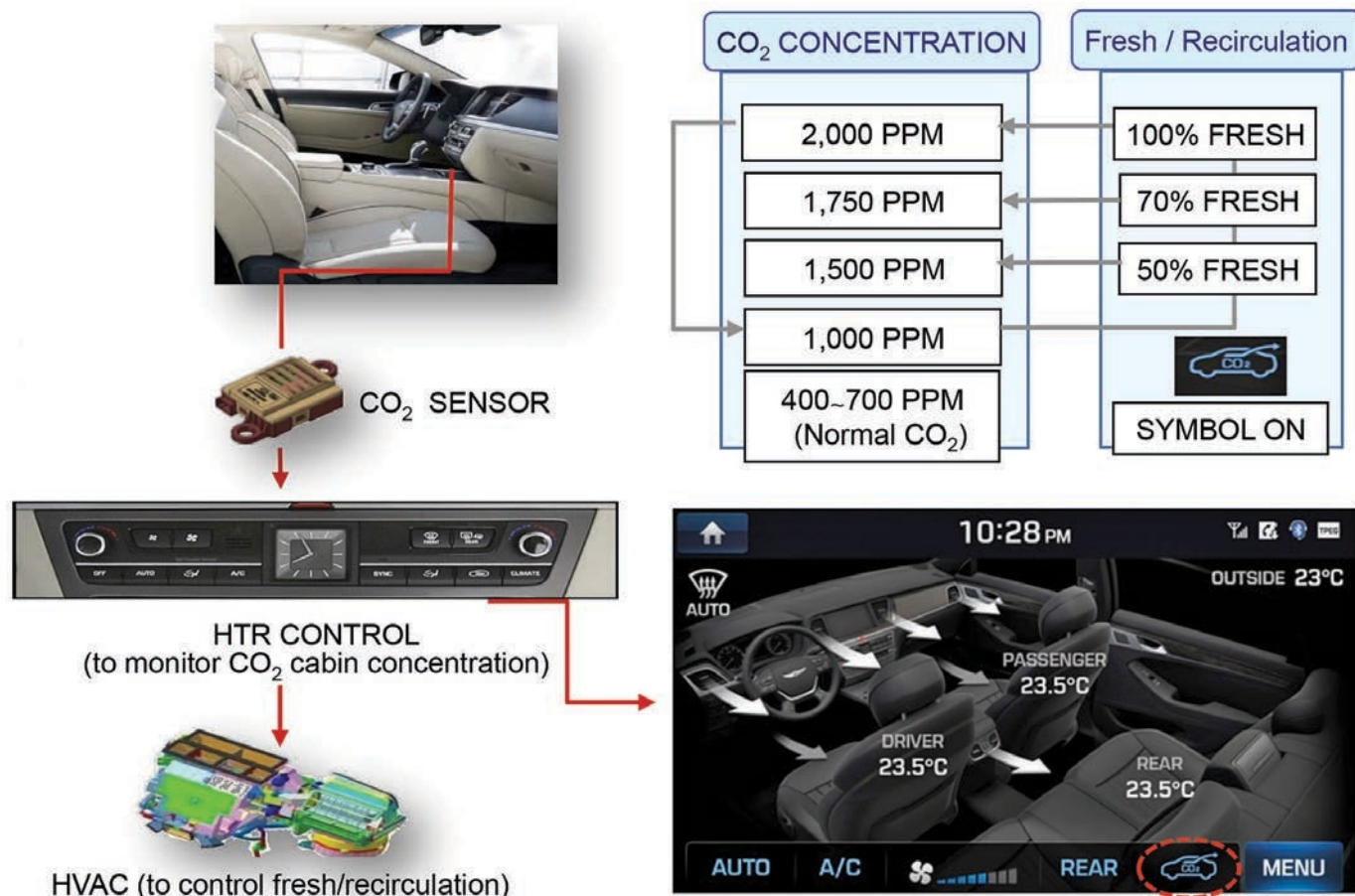
Cardington Yutaka was Honda's development partner on the new torque-converter that transforms the new Acura 8-speed DCT.

Replacing the TSX and TL models, the 2015 **Acura** TLX pairs its 2.4-L I4 with a **Honda**-developed eight-speed dual clutch transmission (DCT), which features the novel twist of a torque converter in place of a

clutch. Honda claims it's the first production DCT so equipped, and notes internal NVH benefits and greater torque multiplication for stronger off-the-line acceleration. The 2.4-L TLX accelerates to 60 mph (97 km/h)

1.5 s faster than the TSX did, which engineers attribute in large part to the use of the torque converter, supplied by **Cardington Yutaka Technologies**. Read more at <http://articles.sae.org/13432/>.

Hyundai controls cabin CO₂



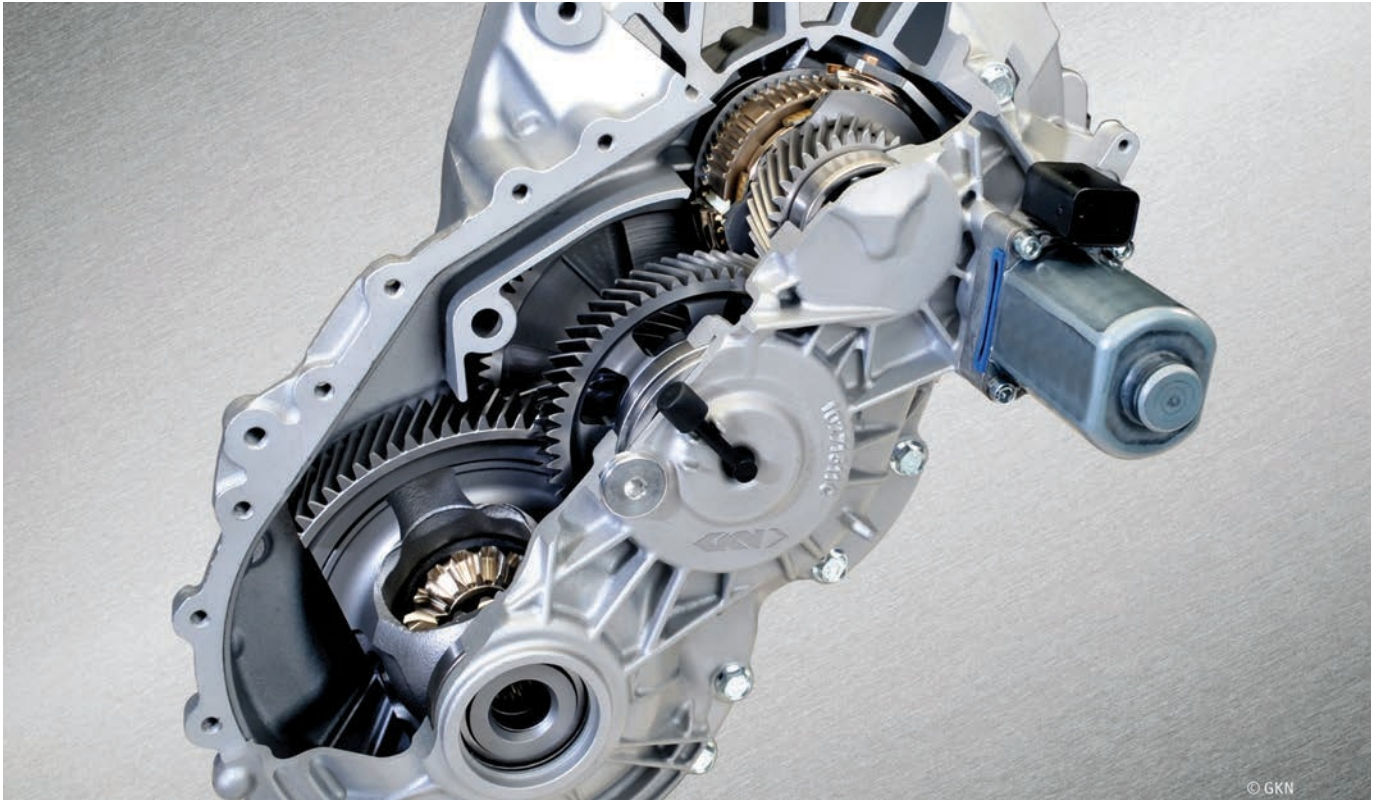
When cabin CO₂ levels reach a specific ppm threshold in the 2015 Hyundai Genesis, an in-cabin sensor control system begins fresh-air circulation to ward off driver drowsiness.

Among the many premium interior features in the 2015 Hyundai Genesis is an in-cabin CO₂ sensor control system, located under the glovebox, which defends against occupant drowsiness. When CO₂ levels reach more than 2000 ppm—the

threshold for when occupants start to get drowsy, according to Hyundai engineers—the new ventilation system circulates freshly ventilated ambient air. The system, claimed to be a first for production vehicles, monitors the intake of fresh or re-

circulated air using a dedicated CO₂ sensor supplied by **Halla Visteon Climate Control Corp.** System development began in 2010. Read more at <http://articles.sae.org/13694/>.

GKN's two-speed eAxle



GKN's 2-speed eAxle makes its first production appearance in BMW's all-wheel-drive i8, providing torque to the front wheels.

For electrified vehicles, providing an additional gear ratio beyond the typical one-speed improves acceleration and pure electric range.

GKN's two-speed eAxle, which powers the front wheels of **BMW's** i8 hybrid supercar, also enables the motor and all its associated systems to be downsized, reducing mass and further increasing efficiency. The AWD

i8 is an "axle-split" hybrid powertrain in which the combustion engine powers a 6-speed automatic to drive the rear wheels. The eAxle technology responds intelligently to deliver all-wheel drive, pure electric range, or parallel hybrid mode. To achieve high torque density in a package that weighs just 27 kg (60 lb) and measures less than 325 x 562 x 313 mm

(12.8 x 22.1 x 12.3 in), the shift mechanism sits on the input shaft instead of the intermediate shaft in the middle of the transmission. Even with the input shaft spinning at up to 11,400 rpm, GKN's software control of the eMotor and the synchro-actuation achieves a smooth gearshift in all conditions. Read more at <http://articles.sae.org/13691/>.

Audi TT virtual cockpit



Audi's "virtual cockpit" in the 2015 TT replaces analog instruments with a fully digital and highly flexible display array, supplied as a system by Bosch. Nvidia's Tegra chip 30 provides the processing power.

Aimed at reducing driver workload and distraction, the "virtual cockpit" on Audi's 2015 TT replaces analog instruments with a fully digital and highly flexible display array, supplied as a system by **Bosch**. In front of the driver is a 12.3-in (diagonal; 312-mm) thin-film transistor (TFT) screen with 1440 x 540-pixel resolution.

Development partner **Nvidia's** Tegra chip 30 drives the virtual cockpit's capability; Audi is claiming to be the first vehicle OEM to use a fast graphics processor, with a clock frequency of more than 1 GHz. Within the display is an electronic tachometer delivering engine-rev info at 60 frames/s. Drivers can switch between two user

interfaces via "view" control, positioned on the steering wheel, itself a multi-function device. If the driver wishes, almost the whole screen can be taken up by the navigation display which changes color according to base menu selection. Read more at <http://articles.sae.org/13091/>.

Toyota's Atkinson-cycle assault

To achieve its goal of increasing gasoline-engine brake thermal efficiency to beyond 40%, **Toyota** is deploying a range of new Atkinson-cycle (high-expansion ratio) engines, including its first applications in non-hybrid vehicles. For MY2015, the Atkinson-cycle assault includes a 1.3-L four; two 2.0-L fours (both naturally aspirated and turbocharged), and a 5.0-L V8 that powers the new **Lexus** RC-F performance coupe. Others are planned through 2017. Some of the engines, notably the turbo 2.0-L and the V8, start and run Otto-cycle at high load and high rpm, then shift to Atkinson cycle at low loads for greater fuel efficiency. The company is aiming for light-vehicle fuel efficiency improvements of up to 15%. Wide-bandwidth intake phasers on the VVT-iW con-



Exhaust-manifold geometry and construction, along with expanded VVT authority, help optimize the inherent efficiencies of Toyota's 1.3-L Atkinson cycle engine used in European models.

tinuously variable valvetrains enable the shift between the two operating cycles. The single, twin-scroll turbocharger was developed in-

house and uses a dedicated air-to-liquid intercooler. See **SAE** Technical Paper 2014-01-1192 and <http://articles.sae.org/13525/>.

Ford/Takata adaptive steering

Housed completely within the steering wheel, **Ford's** new adaptive steering system launches in the Edge and S-Max. The system changes the steering ratio according to vehicle speed and steering-wheel angle, improving steering performance across the spectrum but particularly in low-to-medium-speed maneuvers. Similar in concept to systems available from **Audi**, **BMW**, and **Lexus**, Ford's is the most package efficient and, we reckon, cost-effective. Co-developed with **Takata**, the system is compatible with both EPS and hydraulically assisted systems. It is comprised of a dc motor, a low-friction worm/helical gearset (48:1 reduction ratio), a pair of needle-roller bearings, and an electronic control circuit. The hardware set weighs 2 lb (0.9 kg), and requires a new, more compact airbag module. The e-motor serves as a



Debuting in the 2015 Edge and S-Max, Ford's new adaptive steering system changes steering ratio according to vehicle speed and steering-wheel angle. Co-developed with Takata, the system is comprised of a dc motor, a low-friction worm/helical gearset (48:1 reduction ratio), a pair of needle-roller bearings, and an electronic control circuit. The hardware set weighs 2 lb (0.9 kg).

±35% steering assist, adding to or reducing the driver's steering inputs according to vehicle speed and steering-wheel position. In the Focus mule *Automotive Engineering* tested last summer, full

lock-to-lock turns were reduced from 2.5 turns to two turns—the vehicle reacted to steering inputs faster and more precisely in all situations.

Kia's CFRP sunroof frame first



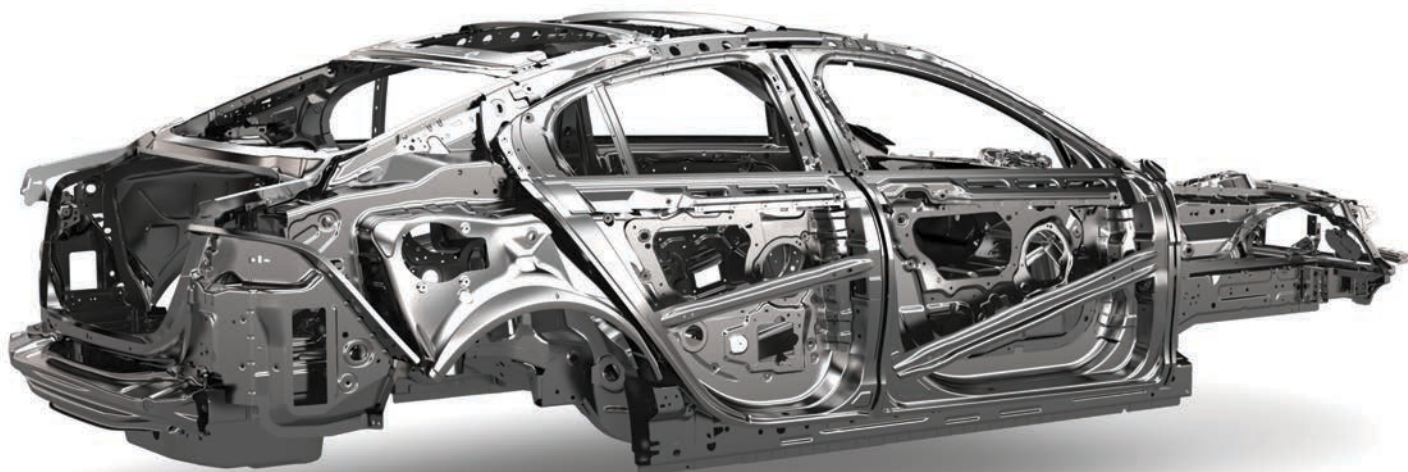
The sunroof frame in Kia's 2015 Sorento is the industry's first use of CFRP in this application. It is supplied as a four-part module by Inalfa Roof Systems and weighs 6.7 kg (15 lb), a 50% mass reduction.

The panoramic sunroof frame of Kia's 2015 Sorento claims industry-first carbon-fiber-reinforced thermoplastic (CFRP) construction. CFRP enabled the frame, supplied as a module by **Inalfa Roof Systems**, to be made in four parts (includ-

ing two steel inserts), compared with 33 parts in a typical steel frame that also requires welding and painting. It weighs 6.7 kg (15 lb), a 50% mass reduction. The resin compounding process used to manufacture the frame uses a patented twist-

pultrusion mechanism that results in a longer-length fiber per pellet. **GS Caltex**, the compounder, uses pellet production technology under license from **Kobe Steel**. Read more at <http://articles.sae.org/13677/>.

Jag XE's recycled-aluminum body structure



The aluminum body structure of Jaguar's 2015 XE is the first of its kind to use RC 5754 Al alloy made predominantly from recycled material.

The aluminum-intensive XE sports sedan is claimed by **Jaguar** to be the first production car to use RC 5754 aluminum alloy made predominantly from recycled material. Future **Land Rover** models will also use it. The

first use of RC 5754 helps Jaguar toward achieving a target of 75% use of recyclable material by 2020. (The XE also uses 40 kg [90 lb] of recyclable plastics.) Jag's new 3-Series fighter enters production early next

year as the company's stiffest (20% torsionally better than the XF), lightest (from 1474 kg [3250 lb]), and most aerodynamic (0.26 Cd) sedan ever. Read more at <http://articles.sae.org/13509/>. ■

Can Toyota's Mirai be the next Prius?



Toyota thinks that its new Mirai fuel-cell car can open up new horizons like its Prius hybrid did.

A decade and a half ago, low gasoline prices and rebounding car sales did nothing to stop **Toyota** from introducing its fuel-saving Prius hybrid-electric vehicle. During those years the Prius, whose name means “to go before,” pioneered an entirely new green-car category while it burnished the company’s environmental credentials. Hybrid-electric propulsion has now gone fully mainstream, with total U.S. sales of hybrids topping 3 million in late 2013.

Today, with fuel prices sagging and auto sales rising, the Japanese carmaker is again attempting to open up a whole new green-car segment with its first hydrogen fuel-cell production vehicle, the Mirai. Whether the Mirai, which means “future” in Japanese, presages Prius-like success is hotly debated.

‘Like any other car’

“The Mirai is like any other car,” Takeshi Uchiyamada, Toyota’s Chairman of the Board and “father of the Prius,” told the press who had assembled Nov. 16 in Newport Beach, CA, at a lead-in event for the Los Angeles Auto Show. “It has a 300-mile range, fills up in 5 minutes, and accelerates from 0 to 60 mph in about 9 seconds,” he said. “The big difference is that this car uses no gasoline and emits only water vapor from the tailpipe.”

In the U.S., the four-door Mirai sedan will have a sticker price of \$57,500. But with about \$13,000 in federal and California state incentives and subsidies, that figure drops to \$45,500. Toyota expects the majority of customers to lease the car for \$499 per month



Success for fuel-cell vehicles depends on building many new hydrogen fueling stations. (Toyota)

for 36 months, however.

The initial production goals for the Mirai will be 700 units, according to the company. The car will be introduced into the Japanese market before year's end and will go on sale in Europe early next year. California dealerships will get the new car by summer 2015, and those in five northeastern U.S. states will receive the first shipments in 2016.

The Mirai, which is the production version of the FCV Concept that was unveiled at last year's Tokyo Motor Show, is built around a 114-kW fuel-cell stack that converts compressed hydrogen gas into electricity. That electricity is stored in a nickel-metal-hydride battery pack that powers electric motors, which drive the front wheels.

The car's proton-exchange-membrane fuel-cell stack, which is encased in a protective carbon-fiber composite housing, has a power density of 3.1 kW/L. Unlike many previous units, it requires no humidifier to keep the polymer membranes damp to promote proton transport. Instead, the system circulates the water that the stack itself produces. The compressor and blower whirs and whines that have accompanied most earlier fuel-cell systems have been mostly eliminated to help keep the passenger cabin quiet.

The Mirai contains a pair of 10,000-psi hydrogen storage tanks, one under the rear seats and another just behind them. The tanks, which have 62.4-L (16.5-gal) and 60-L (15.9-gal) capacities, respectively, feature



Most of the fuel-cell system components are placed low in the frame to improve the Mirai's handling.

outer protective shells composed of filament-wound fiber/resin composites that are lined with impermeable membranes.

Why hydrogen?

“Why hydrogen?” Uchiyamada asked the crowd rhetorically. The rate of cost reduction for fuel-cell systems is falling faster than that of electrochemical batteries, he answered, noting that “a 300-mile battery would be much larger and heavier than a fuel-cell stack and fuel tank. Our fuel-cell system is really just a better battery.”

Uchiyamada added that the fuel-cell tanks contain enough hydrogen to power an average American home for a week in emergencies, should buyers choose to add an optional power take-off port.

At 1850 kg (4100 lb), the car is still 100 to

150 kg (220 to 330 lb) lighter than a Camry hybrid, said Satoshi Ogiso, Managing Officer at Toyota and lead on the product planning group for the Mirai. Engineers placed all the fuel-cell system components low in the frame to create a low center of gravity for good handling performance. The underbody of the car is completely covered to cut road noise and aerodynamic drag because the fuel cell's heat output is less than that of a traditional car engine.

The Mirai's powertrain is 95% cheaper to build than the fuel-cell system in the 2008 Highlander fuel-cell SUV, he said. Some of the cost savings stem from the decision to adopt much of its drive system—controls, energy management system, and batteries—from the company's hybrid models. Beyond the use of common parts, a brand-

Toyota designers aimed for a “distinctive, futuristic” look for the new Mirai.



new converter triples the system voltage, which saves space, weight, and cost. Other savings stem from minimizing the use of high-priced platinum-family catalysts in the stack, said Ogiso, who added that R&D work is continuing to develop less costly catalyst alternatives.

He explained that the Toyota fuel-cell system is fully scalable and that company planners are contemplating hydrogen-fuel vehicles ranging in size from forklifts to sports cars to trucks and buses.

Ogiso stated that the car's exterior was styled to be both “distinctive” and “futuristic,” with a feeling of flowing water. Whether Toyota's design effort was successful depends upon one's taste, but it must be said that the car has something of the look of a Cylon Centurion from “Battlestar Galactica” from the front. The huge air intake grilles are there not only to help cool the fuel-cell

system's three radiators, but also to feed the vehicle's air-management system. The rear end reminds many of the back of 1970s-vintage **BMW**s. Whatever the styling, the new Mirai has a slippery aerodynamic drag coefficient of 0.293.

Building a fueling infrastructure

Although the company president and CEO Akio Toyoda in a video touted the Mirai as “a turning point in automotive history” that would cut dependence on oil and environmental degradation, fuel-cell vehicles face an impediment that hybrids do not: a dearth of hydrogen fueling stations and the costly supply infrastructure to support them. This classic “chicken-and-egg” dilemma accounts for much of the skepticism now aimed at the technology.

Opposition to the adoption of hydrogen



The Mirai's interior design is intended to be clean and functional, with few hints of anything unexpected.

as a fuel has arisen in the U.S. because much of today's hydrogen is made by steam reforming natural gas, which undermines its positive environmental impact. **Tesla** chief Elon Musk has, for example, called fuel cells "a load of rubbish."

To help address the fundamental fueling issue, Toyota is partnering with **Air Liquide**, a global producer of hydrogen and other industrial gases, to develop new regional markets, said Chris Hostetter, Group Vice President for Strategic Planning. Part of the initial plan is to install a dozen hydrogen stations across Connecticut, Massachusetts, New Jersey, New York, and Rhode Island by 2016. Using the Street, a computer model developed at the **University of California - Irvine** that estimates the number of hydrogen stations needed to supply a fuel-cell fleet, planners have selected strategic locations to create a "hydrogen highway" be-

tween the New York and Boston metropolitan areas, said Ole Hofelmann, CEO of Air Liquide.

Hofelmann said that the hydrogen should sell for around \$10/kg—energy-wise, a kilogram of hydrogen is roughly equivalent to a gallon of gasoline. Because fuel-cell powerplants offer double the energy efficiency of conventional car engines, \$10/kg translates into an effective price of about \$5/kg, which would be more competitive with conventional fuels.

Toyota already has invested in hydrogen fueling infrastructure in California, which hopes to set up a hydrogen highway along the West Coast all the way up to British Columbia. UC Irvine's Street model, which keeps potential customers at all locations within 6 min of a station, indicates that only 65 stations can support some 10,000 fuel-cell vehicles in California. In May, Toyota an-



The Mirai's passenger compartment is reasonably roomy and comfortable.

nounced a \$7.3 million loan to **FirstElement Fuels** to support the operation and maintenance of 19 hydrogen fueling stations across the Golden State, which hopes to have 20 stations in operation by 2015 and 40 stations by 2016.

The tide is also rising for hydrogen fueling infrastructure elsewhere in the world: Germany now has 15 stations and has plans for 50 by the start of 2015 and 1000 by 2020. Japan currently has 17 stations, but hopes to have 100 by 2016. Korea plans to have 160 stations by 2020; the U.K. expects to have 15 stations by 2015 and 65 by 2020; and Denmark wants to install 15 stations by 2020.

Meanwhile, other automakers are launching hydrogen fuel-cell initiatives as well. **Hyundai** began selling a hydrogen-powered version of its Tucson SUV in certain California markets this summer. And at the L.A. Auto Show, **Honda** displayed its latest,

the FCEV Concept, which is to hit the market in 2016. The FCEV Concept builds on the company's six-year-old FCX Clarity leasing program. It has a newly designed 100-kW fuel-cell stack that, like Toyota's, features a power density of 3.1 kW/L. The fuel-cell system is one-third smaller than that in the FCX Clarity and therefore can fit entirely under the hood, Honda said. A single 10,000-psi hydrogen storage tank gives the FCEV Concept a range of 435 mi (700 km).

What perhaps distinguishes the Mirai from the others is that Toyota plans to add the car to its core product lineup rather than simply lease it to individuals. Toyota seems deadly serious about developing a hydrogen-powered "people's car," but Uchiyamada stressed that consumer education will be key to any eventual success. Whether fuel-cell vehicles are finally ready for the mass market "rests less on the car, and more on the ownership experience," he said. After all, it took a decade or so for Toyota's global sales of hybrids to reach a million units, and today the Mirai faces a similarly long journey.

(To view a **YouTube** posting of the audio and Powerpoint slides from a recent **U.S. Department of Energy** Webcast reviewing **SAE International** standards on hydrogen refueling, go to <http://energy.gov/eere/fuel-cells/webinar-introduction-sae-hydrogen-fueling-standardization>.)

Steven Ashley

2015 GT350 Mustang aimed at track-day dominance



With the new +500-hp Voodoo V8 under its muscular hood, a chassis designed for handling, and bodywork optimized for downforce and powertrain cooling, the GT350 could be an ultimate American track-day weapon.

The original **Shelby** GT350 Mustang introduced nearly 50 years ago wasn't built for comfort, or even street use. It was built to dominate the B-Production class in **Sports Car Club of America** road racing, which it did for three straight years and became a legend. With its 2015 GT350, **Ford** has captured a considerable amount of the original car's spirit but wrapped it in a more livable package—the first high-performance iteration (Ford calls them “buzz actions”) of the all-new Mustang architecture and unveiled at the 2014 L.A. Auto Show.

“Starting from the base vehicle, which is quite good, the development team's focus was even more so on track and winding-road performance,” said Raj Nair, Group Vice President, Global Product Development. “It will make a great basis for a track-day car right out of the box. Certainly the street-vs-track development ratio was more biased toward the track than the majority of cars

we do—even versus the GT500, which is pretty good on track but more of a straight-line car. The GT350 is more about handling,” Nair told *Automotive Engineering* in a pre-L.A. Show interview.

Added Ford Global Marketing Chief Jim Farley: “This car is similar in character to the **Porsche** 911 GT3”—a bold statement that car-enthusiast magazines will certainly try to prove when they comparison-test the Shelby against Europe's best and against the usual domestic suspects such as the **Chevrolet** Camaro Z-28.

According to Nair, during the sixth-generation Mustang's planning GT350 emerged as the “buzz car” the team wanted to do first. And it just so happened that Ford Powertrain had begun exploring a wild new rev-happy V8 based on the existing Coyote architecture around the same time; the two became the foundation for continuing the Shelby Mustang legacy. (See <http://articles>.

GT350's cabin equipment includes Recaro seats and both Tech Pack and Track Apps packages.



sae.org/13709/.) The “Voodoo” V8 is offered with either a **Tremec** 3160 six-speed manual or Ford’s own 6R80 six-speed planetary automatic.

Multiple mass offsets

Besides the new Voodoo V8, Ford supported the GT350 project with significant investments in structural engineering (achieving a 28% stiffer body), body tooling (all panels forward of the A-pillars are unique), lightweight materials (hood and front fenders in aluminum), and premium component hardware including a **Torsen** limited-slip differential and **Recaro** seats.

Front track has been widened by 35 mm (1.4 in), and the car sits about 2 in (50 mm) lower than the GT and rides on bespoke **Michelin** Pilot Super Sport tires constructed exclusively for the new Shelby. **BWI Group’s** MagneRide dampers control suspension action using magnetorheological fluid, a sensor set, and a subsystem ECU.

Farley’s GT-3-fighter dreams aside, the

GT350’s expected competitor will be the Z-28, at its heart a muscle machine aimed at track-day purists and devoid of many typical creature comforts. “Z-28’s a great car, but it’s got a lot of tire underneath it, and its track manners are built around that,” said Nair, himself an accomplished amateur road racer. “We’re less reliant on tire and we’re going to be a little more crisp and nimble. It’s a typical difference in approach between us and GM. I think we’ve coupled that into a better all-around vehicle rather than something that’s so track focused like the Z-28.”

According to Jamal Hameedi, Chief Engineer of Ford Global Performance Vehicles, most of the team’s lightweighting measures went into “offsetting all the mass we added in terms of power, driveline, and brakes.” The development budget even included a line for a carbon-fiber grille opening and reinforcement, a lightweight metal strut-tower cross brace, and lightweight functional rear diffuser for improved aero and grip.

While Ford did not announce curb weight (or other key specs, including power and torque ratings) during the car's L.A. show reveal, Raj Nair earlier told *Automotive Engineering* that he expected the GT350 will come in "slightly lighter than the current base Mustang GT—3618 lb (1641 kg) with a manual transmission.

The GT350's standard brakesets are by **Brembo**, which is highly respected among global OEMs who realize that the latest foundation-brake technology and a strong brand are not inexpensive. They feature new two-piece cast iron rotors mounted on aluminum hats, 395-mm (15.6-in) diameter front with six-piston calipers and 380-mm (15.0-in) rear rotors with four-pot units.

Like an "amped up" Mustang GT

The car's bodywork is designed for optimum grip on the track and aerodynamic efficiency. The front fascia includes a lower front splitter; there's a ducted belly pan to provide added downforce. The hood outlet serves as a heat extractor while also reducing lift at high speed, and the front fenders incorporate vents in their flanks to extract turbulent air in the wheelhouses and direct it smoothly along the bodysides. At the rear, there's a functional diffuser that works to boost downforce and provide cooling air to the optional differential cooling package, along with a subtle lip spoiler across the trailing edge of the decklid.



Ford's Vehicle Performance Chief Engineer Jamal Hameedi said about 30 actions were taken by the development team to enable use of the flat-plane-crank 5.2-L V8 in the 2015 GT350.

How does the GT350 feel to drive? Chassis tuning was done at **Virginia International Raceway** and the Nurburgring as well as Ford's U.S. proving grounds. Nair has had seat time, and he describes the car as having "a Mustang GT feel, amped up to the next level." He said that while steering may not be quite as nimble-feeling as that of the 2.3-L EcoBoost Mustang (lighter in front and thus better balanced), the MagneRide dampers "make it really surprising how aggressive you can be with the car without it getting upset. It handles crisply; on track you can ride the curbs a lot harder than with the prior vehicle or with the base GT," Nair said.

While price has not been announced, Ford insiders indicate the new Shelby Mustang will come in underneath the roughly \$74,000 retail figure of the 2014 Z-28. And that's significantly less than a GT-3 Porsche.

Lindsay Brooke

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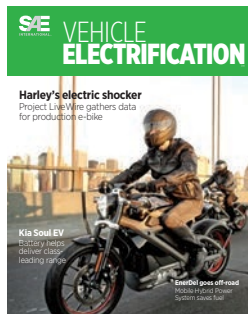
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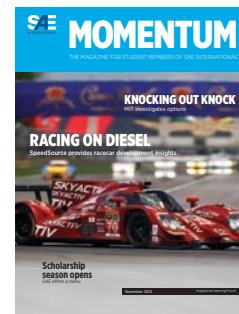
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