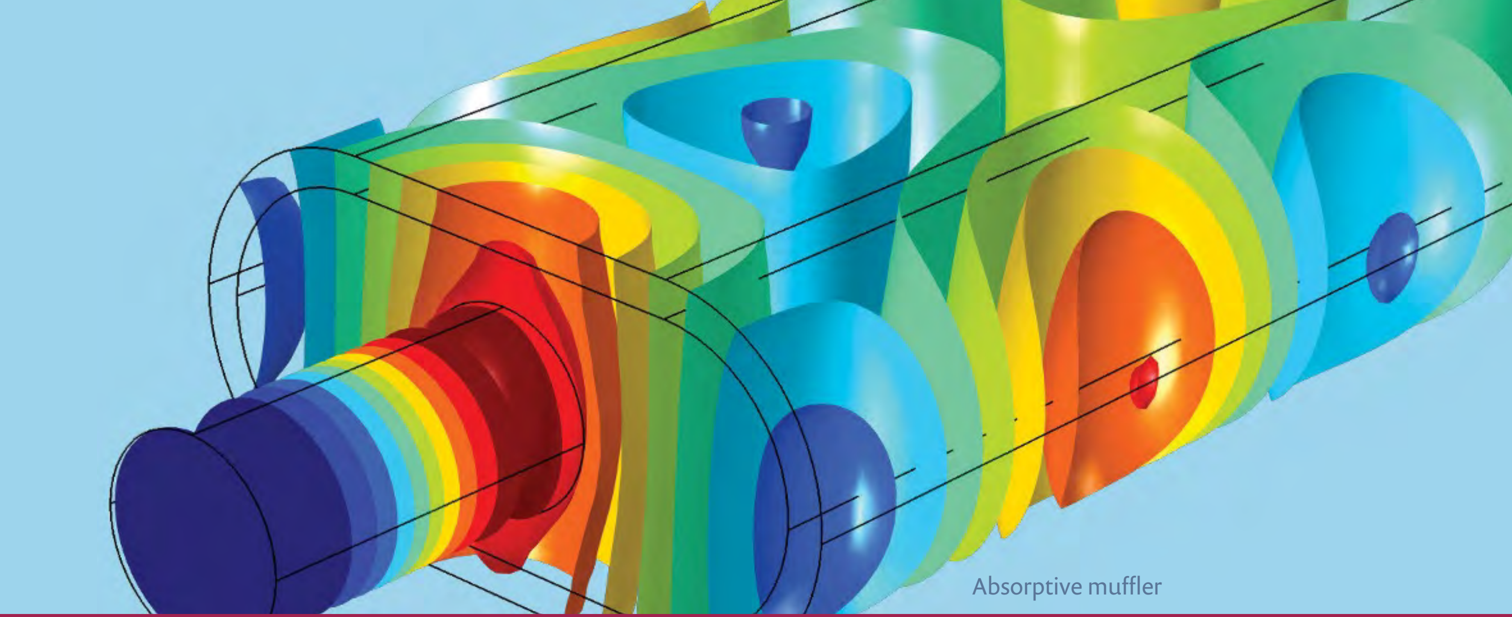

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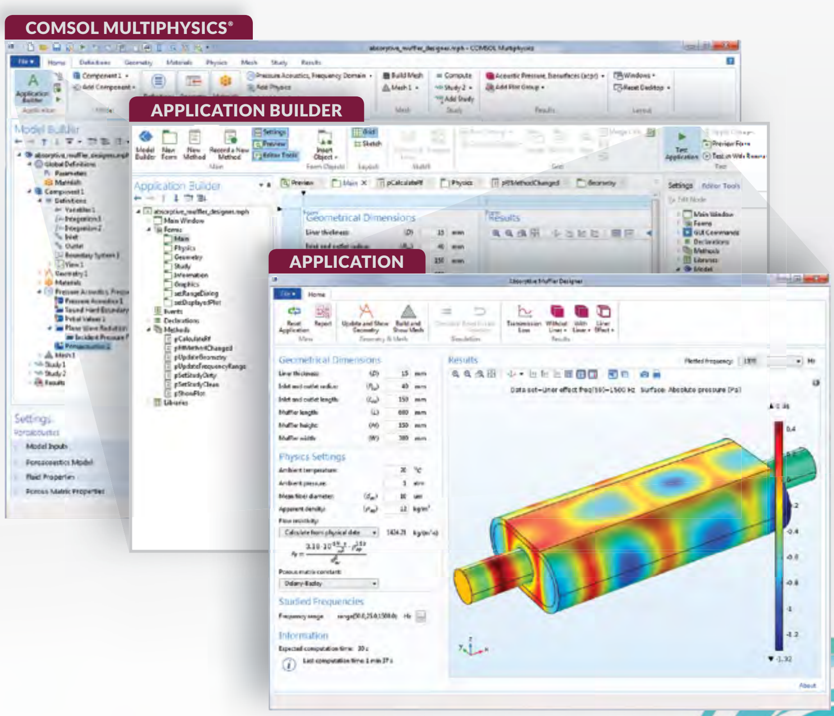

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Mazda's unique course

Chairman Kanai on Skyactiv, vehicle autonomy —and the rotary

Seita Kanai with the Mazda CX-9

Delphi's engineering boss looks to the future

MEMS for next-gen HUDs

Tire development's new paradigm

October 2016 autoengineering.sae.org


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ON THE COVER

Mazda Chairman Seita Kanai poses with the all-new CX-7 crossover, the latest example of how Mazda's true-to-itself product-development philosophy continues to produce some of the industry's most engaging and critically-acclaimed vehicles.

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SIGNET RESEARCH INC

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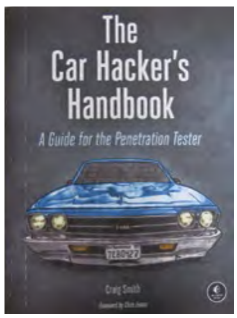
EDITORIAL

A how-to for car hackers

The new vehicle you've just spent 40 months engineering, testing and validating, that's soon to be in customer hands, is now a big, fat target. The hackers want in.

How robust was your threat modeling during development? Where among the vehicle's many potential entry points—the high-risk "attack surfaces" including Bluetooth, Wi-Fi, USB, the OBDII port, tire pressure monitoring system, infotainment, CAN bus, sensors and even an electric car's charging connections—could malicious external data sneak past your built-in defenses to wreak havoc?



You may have overlooked a potential vulnerability, somewhere within the dozens of microprocessors, the 100 million or more lines of code and two miles of wiring that constitute a typical vehicle's electrical architecture. The hackers might be sharper than your EEA design team—they could even be former colleagues. Their aims may range from the inquisitive to the downright sinister—vehicle theft, remote shut down, taking over control or installing ransomware.

As **Delphi** engineering VP Mary Gustanski has noted, it's not so much a question of "if" your increasingly complex electrical architecture gets hacked. It's more about how quickly you can identify and "box" the intrusion when it happens.

The automotive cyber wars are just getting started. Regardless of what side of the battle you're on, there are valuable insights into the other guy's strategies and tactics in *The Car Hacker's Handbook* (No Starch Press, 304 pages, $49.95) published last spring. Author Craig Smith, a bright and articulate engineer, has worked at auto companies and runs a research firm, **Theia Labs**, specializing in security auditing and hardware/software prototyping. He is also founder of the **Hive13** hackerspace and **OpenGarages.org** online community of vehicle-security probers and "penetrators." He's even spoken at SAE International professional events.

Smith's subject expertise is apparent in this first-ever dive deep into the multi-layered computer networks of today's vehicles—and what makes them (and the V2X infrastructure) vulnerable to attack and manipulation.

"A primary reason for writing the book was actually to help make the next generation of vehicles more secure," Smith told me by phone soon after his book was announced. "As vehicles get more connected and complex we need more car hackers so we all can know more about the security risks," he asserted. That's useful for the electrical architecture design teams that are one audience for the book.

I'm not an EE but I've successfully unraveled some frustrating electrical mysteries in my own vehicles over the years. Smith's writing is nicely balanced for guiding both the hacking novice and expert. His editors made sure the neatly organized and well-illustrated format presents plenty of relevant examples in good "how to" detail.

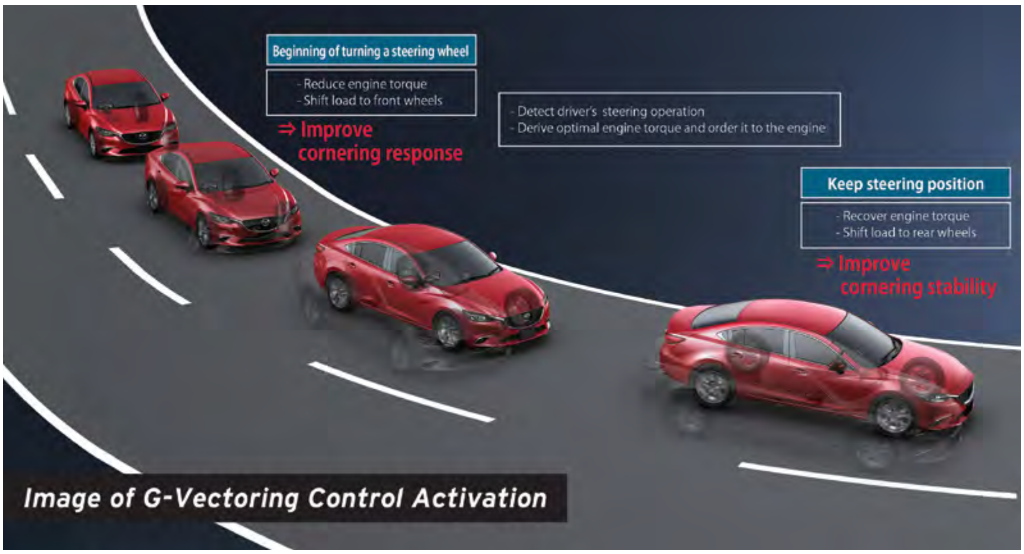
Topics include how to write Metasploit payloads to attack the infotainment system and take control of a vehicle's engine, steering, brakes, temperature control, door locks and more; reverse engineer the CAN bus and hack the ECU; feed exploits to a vehicle through V2V communication systems, and override factory settings to improve engine performance.

No matter where you stand on the vehicle cybersecurity issue—and perhaps like me you need to learn more about this subject—*The Car Hacker's Handbook* (www.nostarch.com; 1-800-420-7240) is an excellent guide and reference. Let's hope Smith's publisher keeps it updated.

Lindsay Brooke, Editor-in-Chief

CHASSIS

Mazda's 2017 G-Vectoring Control brings dynamic refinement



Co-developed with Hitachi Automotive and the Kanagawa Institute of Technology, Mazda's GVC monitors the speed of steering-wheel inputs then signals the engine to reduce torque to a minute degree. The resulting deceleration, nearly imperceptible to the driver, delicately loads the front axle and thus tightens up compliance in the car's steering and front suspension.

Spend time with **Mazda**'s talented vehicle-dynamics engineers as they fine-tune a new model before production release and you may hear the Japanese term *jinba ittai*—the concept of driver and car (more literally, horse and rider) as one. And that concept was very much at play during development of the automaker's latest technology for improving steering response, smoothness and precision.

It's called G-Vectoring Control (GVC), a name that is a bit of a misnomer. It is not a torque-vectoring system aimed at dramatically improving race-circuit lap times. Rather, the purpose of the system is to endow the vehicle with refined and natural smoothness in normal day-to-day driving environments.

To hear Daisuke Umetsu, Mazda's 35-year-old development leader explain it, "Longitudinal acceleration is modulated in response to lateral jerk for harmonious *g* transition. The GVC control applies minute, almost imperceptible longitude deceleration, less than 0.05 *g*—far less than normal engine braking—sensing two input sources: steering input angle and vehicle velocity." He says the resulting system, standard on the 2017 Mazda3 (Axela in Japan) and Mazda6 (Atenza) and expected to spread to other models, is designed to provide "peace of mind."

Controller integrated with PCM

A simpler explanation is that GVC, co-developed with **Hitachi Automotive** and **Kanagawa Institute of Technology**, closely monitors the speed of steering-wheel inputs then signals the engine to reduce torque to a minute degree. The resulting deceleration, hardly perceptible to the driver and without drama, delicately loads the front axle and thus tightens up compliance in the car's steering and front suspension.

Umetsu likens the function to that of the top expert drivers, citing the example of the legendary Yoshimi Katayama, who drove various Mazda works racing cars at Le Mans and elsewhere. Turning into a bend or curve, Katayama would have smoothly increased vertical force up front, through steady-state, to accelerating with vertical force shifting rearward.

Developed over a nearly eight-year period, GVC performs the expert-like function seamlessly and smoothly while using the engine as "the actuator, with no additional hardware required," Umetsu explained to *Automotive*

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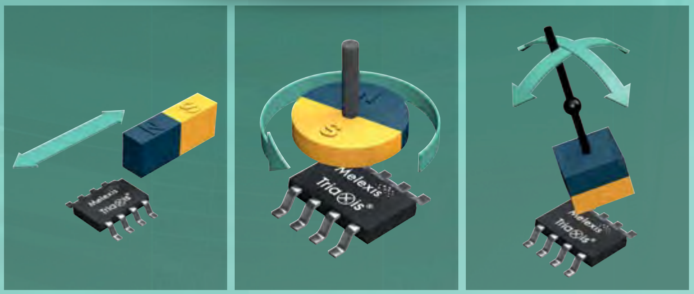

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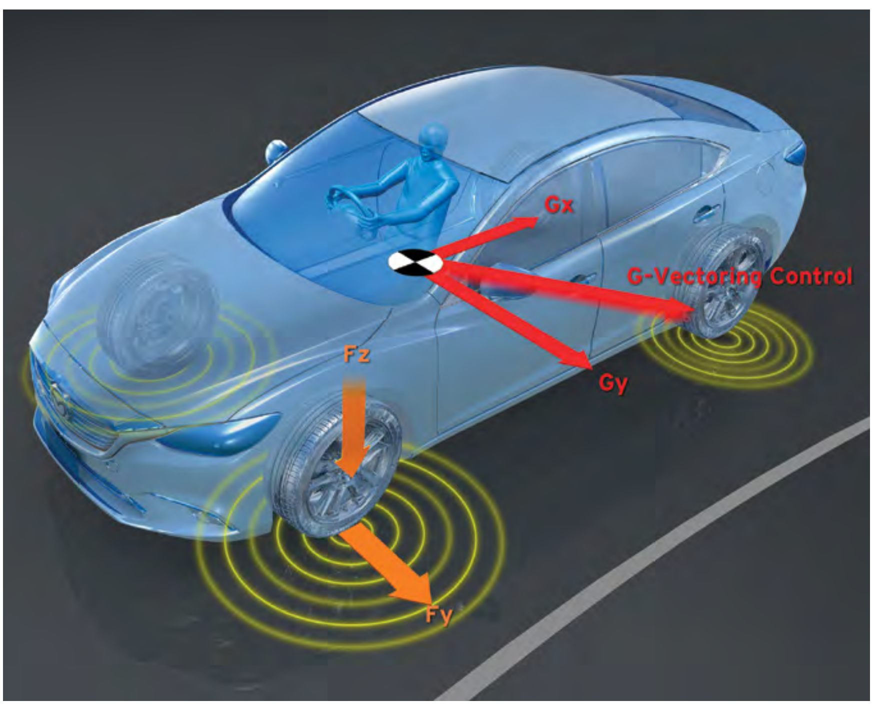
Daisuke Umetsu, the 35-year-old development leader of Mazda's G-Vectoring Control system. (Jack Yamaguchi photo)



The GVC control applies almost imperceptible longitude deceleration, less than 0.05 *g*—far less than normal engine braking—sensing two input sources: steering input angle and vehicle velocity.

Engineering during a technical presentation and ride-and-drive event earlier this year. He noted that the GVC controller is integrated within the powertrain control module (PCM), occupying a scant 3-kB in Mazda's 3-MB passenger car PCM.

Mazda dispatched a development team to Europe with the GVC-equipped Mazda6 prototype to obtain subjective responses and evaluations on public roads including high-speed motorways in the hands of 20 drivers of different nationalities and varying driving skills. Reactions were most positive, noted Umetsu.

Unique development team

The cross-functional GVC team of about 40 members is an interesting and unique joint R&D entity of OEM, supplier and academic engineers. There is no middle-management supervision, but the organization has the full support of Mazda Chairman Seita Kanai, R&D head Kiyoshi Fujiwara and his predecessor, Hirotaka Kanazawa.

Umetsu, an-art-major-turned-neuroscience-graduate of the **University of Tsukuba**, joined Mazda in 2006. He is a senior specialist in the vehicle development department, responsible for chassis dynamics. Like the team's other members he does not specialize in GVC; his primary job function is a vehicle development engineer-driver. Umetsu has been involved in the development of such vehicles as the CX-5, the new MX-5 roadster and its near-twin Fiat 124 Spider, spending a year with the latter in Italy.

The initial proposal came from Hitachi, employing brakes for vehicle dynamics control with higher deceleration intervention. This ordinary approach was quickly abandoned. Umetsu's first encounter with the GVC concept was on the Tsukuba race circuit where he met Prof. Yamakado, at the time a Hitachi researcher specializing in engine control and fuel injection and a fellow track-day enthusiast. Their meeting, and conversations with others at J-SAE events, spawned ideas that led to G-Vectoring Control.

Umetsu also attributes quantum leaps in powertrain control and chassis technologies. Included were learnings from development of the Mazda Demio (Mazda2) battery-electric vehicle that the company offered to selected lease customers. That car's brake- or electrically-actuated deceleration was in the order of 0.1 to 0.3 *g*, versus the production GVC system's 0.05 *g*. But a key enabler is the Skyactiv engine family, both gasoline and diesel, that incorporates extremely high control precision and responsiveness.

Technical details of the G-Vectoring Control can be found in JSAE technical papers 20165248, 49, 50 (in Japanese).

Jack Yamaguchi

AUTONOMOUS TECHNOLOGY

Volvo, Uber share the ride to safety with autonomy

Volvo and Uber will use the Sino-Swedish OEM's Scalable Product Architecture (SPA) for a base vehicle in the development program.

The news that **Volvo Cars**, renowned for its safety focus, and ride-sharing company **Uber**, are working together to develop next generation autonomous driving (AD) cars eventually reaching full **SAE** Level-5 standard (no steering wheel or controls), may bring comfort to those who are scared, skeptical or just scorn the advent of being driven by such radical robotics.

But this latest development sees a further step to AD being taken in parallel with Volvo's avowed intent that no one traveling in its new models from 2020 onwards will be killed or seriously injured. That bold statement was first uttered in 2007, presaging the introduction or development of a plethora of safety features that the automaker believes will enable it to achieve its target.

Volvo is also confident that AD will take out the human factor as the major cause of auto accidents. It promises to project driving safety into a once unbelievable new dimension.

Backing Volvo's confidence is a massive database of accident analyses stretching back to 1970. It concerns 42,000 accidents, from minor to fatal, involving 72,000 vehicle occupants. This information forms a matrix to assess its aims for the 2020 target, says Anders Eugensson, Director Governmental Affairs at Volvo Car Group.

As the 2020s unfold, by then more than 60 years after Volvo engineer Nils Bohlin innovated the 3-point seat belt, not only is AD likely to become commonplace "sometime in the future," but restraints and airbags may no longer be needed, believes Eugensson.

SAE Level 5 "a big step"

"We are working now on SAE Level-4 of autonomous driving technology," he told *Automotive Engineering*. Reaching Level-5 will be a big step and one which will take a lot of investment, he explained, but will bring huge benefits to society in general, not just via traffic management but also in regard to health-care economics as safety levels soar.

Concept model off Volvo's Compact Modular Architecture is designated 40.1.

The Volvo-Uber link will see both companies using the same base vehicle type for the next stage of their own autonomous strategies in what is expected to be a long-term industrial partnership.

The new base vehicle will be created off Volvo's modular Scalable Product Architecture (SPA) used by the current XC90, S90 and V90 models. The SPA's scalability will allow required safety, redundancy and other features central to AD operation.

Uber Chief Executive, Travis Kalanick, states: "Over one million people die in car accidents every year. These are tragedies that self-driving technology can help solve but we can't do this alone." Hence the link-up with Volvo that will enable both companies to meet anticipated schedules for full AD introduction internationally.

That schedule will vary depending on differing legislation in individual countries, a fact that adds to the investment needed just to demonstrate the potential capability of fully autonomous systems. The cost includes running large fleets of autonomous-capable test vehicles in major European cities, which Volvo is now undertaking.

Underlining Kalanick's words, Eugensson states that 90-95% of accidents are due to human error. So does that mean that fully autonomous vehicles will see accidents reducing by a similar figure?

"Almost. The car can make every decision and will not get tired or distracted," he said. "But there would still be an interaction with some 'normal' road users." This means pedestrians and cyclists, and there remain some specific challenges regarding other vehicles (conventional and AD), particularly at intersections, with such dangers as other cars running a red light.

While he admits that the accident rate may not go down by 95%, in a year or two Volvo's systems will have more intelligence to deal with this, he believes. "Also, if an autonomous car enters an area where there are a lot of pedestrians we have to be very cautious and drive very slowly."

Volvo IntelliSafe auto pilot interface is part of its autonomous programs.

First step coming 2017

Most of the technology that will be used for autonomous driving will be an extrapolation of systems already used on Volvo cars. These include radar, stereo cameras, ultrasonics, satellite navigation—and anything and everything that allows the car to be aware of what surrounds, it or approaching, from any direction—even above, such as a low bridge or entry into a parking lot.

Eugensson is so confident of the efficacy of future Volvo technology that he adds: "Maybe the future car will be a mobile living room, too. It could be used as a way of socializing with other occupants because if we produce cars so there are no crashes you, as the 'driver' would be able to turn around and maybe even have a meal on the move! In fact, there would not be a driver as such."

No one would need to be in what now would be the driving seat; the vehicle would be totally autonomous, he projected, offering a 30-years-from-now forecast.

It is a seemingly remarkable statement from a senior executive of an established OEM but it underlines the level of technology advances that are now within reach.

Although Volvo would retain its safety USP, all other autonomous vehicles would also need to conform to very high legislated standards, which would in theory, create a level safety technology playing field. Therefore Volvo has to modify its USP. It is already doing that, planning to lift its quality and image into the premium class, combining safety with high levels of comfort and capability.

"But it is not just about putting technology into a car; we have to assure our customers that we have done everything absolutely thoroughly," says Eugensson.

Complementing Volvo's large car SPA is its Compact Modular Architecture (CMA) for smaller cars that must also meet Volvo's safety criteria for 2020 and its AD plans. Helena Bergström Pilo, Vice President of Vehicle Line 40 (smaller series cars), says: "SPA and CMA are related but are of different sizes. The first car using the CMA will appear at the end of 2017. We are not releasing details yet but we have shown two concepts, the 40.1 and 40.2 which show the architecture's capability."

The CMA can take a range of powertrains including pure electric, which broadens the design and engineering challenges of meeting Volvo's ultimate safety aim, while keeping mass and cost down, comfort and quality up, in a fiercely competitive segment.

But the common challenge across all model ranges is AD, noted Pilo: "It is to expand that technology and to the level where it can really be called fully autonomous in all traffic situations. That is the challenge that faces Volvo — and the automotive industry in general."

Stuart Birch

POWERTRAINS | PROPULSION

Inside Porsche's new V8 and V6 powertrains

Porsche broke a "golden rule" of automotive engineering when it began development of the second generation Panamera: Never develop a new car, a new powertrain and a new factory simultaneously. So confessed Dr. Manfred Harrer, Vice President of Chassis Development.

But despite the transgression, the resulting technologies lift the latest Panamera into a new dimension of sedan capabilities, as previously reported (http://articles.sae.org/14896/). We now have full details of its powertrain, plus experience of how the most powerful, twin-scroll gasoline V8 performs on track.

Panamera owners who favor track-day activities will discover, as the author did, that 0-100 km/h acceleration comes in 3.4 s with the optional SportPlus via Launch Control. And they'll find that pulling 1.5 *g* in tight corners, as we did on the Lausitzring EuroSpeedway near Dresden, is no problem. Owners also should rest assured that the new Panamera has been extensively tested on the Nürburgring-Nordschleife circuit, achieving a lap time of 7 min 38 s, 14 s quicker than the previous generation Panamera.

Porsche's new high torque, bi-turbo 404-kW gasoline V8 goes into the Panamera before it sees duty in other VW Group applications. Note twin turbochargers located in the V of the cylinder block. The engine features cylinder deactivation and a new type of cylinder bore coating.

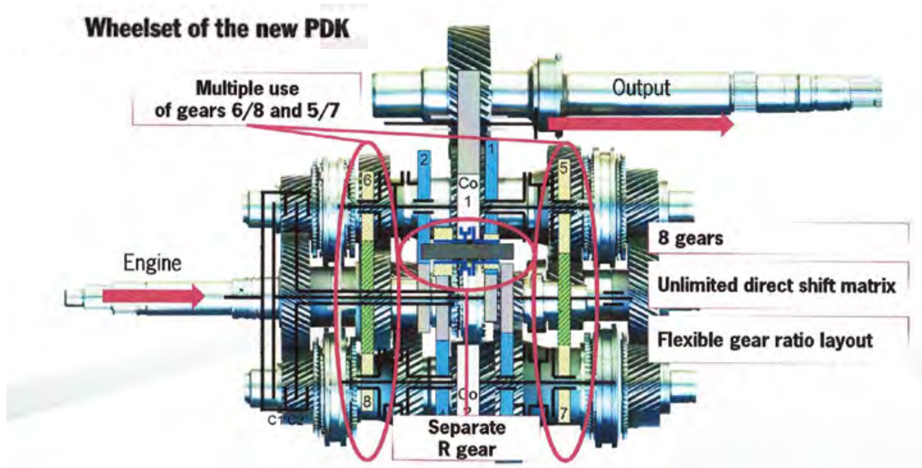
More hp/L, another gear for PDK

There are two new V8 and V6 gasoline units and a new **Audi**-sourced V8 diesel. An 8-speed PDK twin-clutch designed and developed by Porsche and built by **ZF**, replaces a 7-speed. In order to leverage scale within the **VW Group**, the new gas engines are expected to see future use in Audis, **Bentleys**, and potentially even a **Lamborghini**.

Criteria for the new engine lineup, as listed by Dr. Thomas Günther, Director of Powertrain, will not surprise **SAE** readers. The list includes lower fuel consumption and emissions; reduced weight; more efficient packaging; enhanced performance and that essential for all Porsches—the "right" aural signature. Modularity, to facilitate the flexibility demanded for hybrid variants, was also essential.

The Panamera's "halo" power unit is a new 4.0-L DOHC V8 with two twin-scroll turbochargers delivering a torque plateau rather than a curve: 770 N·m (568 lb·ft) from 1960 to 4500 rpm. Zero to 200 km/h (124 mph) takes a best 12.7 s. Fuel consumption for this version shows a 1.1-L/100-km improvement to a best 9.3 L/100 km and 212 g/km CO_2 emissions. Claimed specific power is 137.5 hp/L versus 108.3 hp/L for the outgoing 4.8-L V8.

The longitudinally-mounted engine's aluminum cylinder block is made using what Porsche engineers describe as "a special sand cast process." The block weighs 39.1 kg (86 lb), a 6.7 kg (14.7 lb) reduction of mass versus the 4.8-L.



Wheelset detail of the new PDK gearbox for the Porsche Panamera.

A new development of iron coating on the cylinder linings is used. Engineers describe it as being very highly wear resistant and durable. Wear is reduced by about a tenth at the motion reversal point of the piston rings, which have a chrome nitride coating. This should help with the high load changes generated by hybrid versions. An atmospheric plasma spray method is used to give a coating layer of 150 microns.

Mass reduction actions are evident throughout the block and include a crankshaft drive weight that weighs 1.4 kg (3 lb) less and uses an intermediate shaft to drive the water pump and timing drive. The switchable water pump has a toothed gear drive inside the engine which improves power unit packaging. Best weight reduction for the new V8 engines is 9.5 kg for the gasoline unit.


Convincing on track, the new 4.0-L 404-kW engined, 306 km/h-capable Porsche Panamera Turbo demonstrated 1.5-*g* capability with the author behind the wheel.

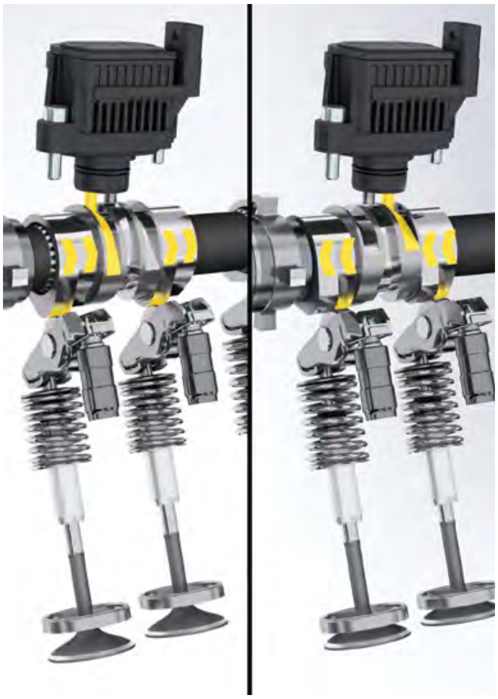
Packaging was also aided by a central turbo configuration, said Günther. The twin-scroll turbochargers, with counter-rotating turbines, have a maximum charge pressure of 0.3 bar (4.3 psi). Compact, isolated exhaust manifolds are fitted. Process air for the chargers is configured as a dual-branch system. It passes through intercoolers on each side of the engine, through one throttle valve on each side and into the left and right cylinder banks.

Fuel injectors are placed centrally in the combustion chamber. Fuel pressure is 250 bar (3626 psi) compared to the old engine's 140-bar (2030-psi) injection system. The injectors have seven nozzles and each cylinder bank gets a high pressure pump.

Low friction lubricants are used throughout the engine. Oil consumption is said to have been reduced by up to 50%.

Broad-bandwidth cylinder deactivation

For high-*g* driving enthusiasts the new Panamera's oil circulation gets a lot of attention. Oil passages are partitioned into the oil supply for the engine and



The VarioCam Plus system controls cylinder deactivation in Porsche's new V8.

for the cylinder head. A fully variable vane oil pump is fitted with a valve controlling map-specific figures. An electronic switching valve located centrally in the V of the block controls piston spray nozzles. Churning losses are reduced and oil circulation volume controlled.

The Turbo has cylinder deactivation capability, a system increasingly used within VW Group. In 4-cylinder phases, fuel economy can be improved by up to 30%. Deactivation and reactivation of the cylinder is via Porsche's VarioCam Plus, using a 2-stage sliding cam system. Under suitable load conditions, cylinder deactivation is available from 950 rpm to 3500 rpm with a 250-N·m (184 lb·ft) torque limit.

It is 30 years since Porsche introduced a twin-clutch transmission (PDK) into its race cars and into production models in 2008. The new PDK allows the car to achieve top speed in 6th, with the added two ratios providing overdrive. There is an 11.17 ratio spread against 10.2 spread with the previous 7-speed. The gearbox remains compact—in fact its "internals" are 142-mm (5.6-in) shorter than the 7-speed. It brings a claimed 1.4% fuel economy gain.

New 8-speed PDK and V8 diesel

We asked Michael Funk, PDK Project Manager, about the decision to plump for an 8-speeder not a nine. He replied, "It's right

for us"—keeping in sync with the Panamera's combination of performance and comfort.

Sourced from ZF, the PDK is package-protected for hybridization. It uses racecar-derived spray lubrication via a demand-based variable vane oil pump, claimed as a "first" for a road car. The gearbox uses a new oil, developed to reduce friction losses; full details were not yet released when this article was written.

Net weight reduction for the complete powertrain of the Panamera Turbo is 2.5 kg (5.5 lb), the 8-speed gearbox adding 7 kg (15.4 lb) compared to the 7-speed.

The newly developed 4.0-L V8 diesel is sourced from Audi but it has been tuned and adapted by Porsche. It replaces the previous Panamera's 6-cylinder diesel and delivers 850 N·m (627 lb·ft) from 1000-3250 rpm—another broad plateau rather than a curve. It has a claimed output of 310 kW (415 hp). Similar to the gas V8, the diesel also has a central dual turbocharger configuration but these are sequential. The peak torque at 1000 rpm is achieved with only one turbo engaged. Both turbos have variable turbine geometry.

Sequential turbocharging is facilitated via variable valve timing of intake and exhaust valves. Axially sliding cam pieces on the camshaft are used to change switching positions, explained Dr. Günther. Electromagnetic actuators slide the cam pieces.

The diesel's common rail system operates at 2500 bar (36.259 psi).

Best 0-100 km/h time with optional Sport Chrono Plus is 4.1 s; the 200 km/h dash takes 16.8 s. As an option, the car has a larger fuel tank of 90 L (23.9 gal) to provide 1475 km (916 mi) range potential.

V8 births a V6

The 2.9-L V6 makes the third Panamera power source and was designed in house by Porsche without VW involvement, engineers claim. It produces 324 kW (434 hp) at 5650 rpm and is rated at a claimed 550 N·m (406 lb·ft) from 1750-5500 rpm. Claimed performance figures include a best (with Sport Chrono package) 0-100-km/h time of 4.2 s.

The new V6 also has its two turbochargers tucked between the cylinder banks. The engine weighs 14 kg (31 lb) less than the previous car's V6. Although similar in design to the V8 gasoline unit, the V6 has variable valve timing in both part- and high-load operation.

Stuart Birch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Seita Kanai has instilled the gospel of superior vehicle dynamics throughout Mazda.

Steering Mazda's UNIQUE COURSE

A chassis engineer at heart, Chairman Kanai challenges his engineers to think differently and embrace the Skyactiv technology that has made Mazda a benchmark.

by Jack Yamaguchi

In 1999 **Mazda** Motor Corp.'s current Chairman, Seita Kanai, had just taken over as program manager for the first-generation Atenza/Mazda6. The new car was a top priority and its success was deemed vital to the Hiroshima-based automaker's survival—this was Mazda's first new product in 18 months. Considered an "engineer's engineer" within a company that prides itself on technical creativity, Kanai was under significant pressure from both Mazda management and from **Ford** Motor Co., which owned a controlling stake, to deliver an exceptional car.

"It was then Kanai-san's dream—and he strongly believed—that Mazda would someday produce a car that would 'beat up' the German premium sedans," recalled Masahiro Moro, the CEO of Mazda North American Operations and good friend of Kanai, who at the time was the young head of product marketing. But in his first benchmarking drive of the incumbent Mazda sedan on the German autobahn, Kanai was shocked.

"Our car's speed was less than 180 kph and was shaking a lot," Moro noted, "while **Mercedes** and **BMW**s were passing him by. Because of this experience, Kanai was determined to build Mazdas that would lead the industry in vehicle dynamics and efficiency."

While the Ford product-development system at the time was focused on delivering middle-of-the-road driving characteristics, Kanai—a long-time fan of the Hiroshima Carp baseball team—preferred to deliver "the high inside fastball—the really surprising stuff," Moro said.

"I could hardly qualify myself as a 'car guy' in my youth," Kanai told *Automotive Engineering*. But he was energetic and a natural problem-solver. Not long after he joined Mazda's chassis design department in 1974, fresh out of university, he developed a passion for the mechanics and physics of vehicle dynamics. Kanai played a role in several chassis innovations, including the TTL (twin-trapezoidal link) rear suspension of the 1980 front-drive 323 and the 1982 626—two cars that greatly contributed to Mazda's rebound and growth.

He then gained further acclaim for his team's patented "E-link" rear suspension of the 929 large sedan, a clever reactive multi-link type endowing the car with a combination of agility and stability.

Finding unique value

Nearly two decades later, the chassis engineer and Carp fan is at the helm of Mazda, perhaps best known for its purist MX-5 sports car and a brand built on being agile, flexible and delivering a high fun-to-drive quotient across the product segments in which it plays. His influence is apparent. Superior steering, handling and agility enabled by stiffer, lighter-weight structures and components has indeed made Mazda a clear alternative to the Germans on multiple fronts, including its latest line of CX-3, China-exclusive CX-4, CX-5 and CX-9 sport-utilities. Such engineering attributes including advanced powertrains are part of Mazda's holistic vehicle-efficiency strategy known as

Stiff, lightweight vehicle structures and responsive, efficient powertrains are hallmarks of the Mazda3 sedan and MX-5 roadster—two different architectures that exemplify the Skyactiv philosophy.

Skyactiv-D diesel is a surprise hit in the Japan market but was deemed not viable for the U.S. due to aftertreatment costs and despite a major road-racing program to help market it.

Skyactiv, which Kanai helped spearhead.

Industry analysts traditionally have viewed Mazda as lacking scale and financial muscle but driven by a strong "overdog" spirit that enables it to innovate and power forward against much larger rivals. U.S. boss Moro agrees: "We always 'punch above our weight class!'" he quipped. This was particularly true in 2008 when Ford control ended and Mazda was again left alone with a paltry R&D budget.

As one of Japan's most export-dependent automakers, Mazda is especially sensitive to exchange rate swings. Unfavorable exchange rates typically hit Mazda hard and a more expensive yen reduces the profit the company can book on the vehicles sold overseas. About 63% of its global output comes from Japan and 80% of that is exported. The Japanese yen's appreciation took ¥34 billion off the company's operating profit in second quarter 2016.

Mazda's strategy is to grow unit sales volume and profit by: investing more in and expanding deployment of its Skyactiv platform and powertrain technologies; introducing more crossovers; and establishing a broader overseas production footprint.

"When we copied the strategy of the big players and fought under their rules and on their battleground, we lost," Moro noted. "When we competed only on price and discount, we disappointed people. So Kanai-san challenged us to change our mindset—to find Mazda's unique value: Vehicle development technology, vehicle dynamics and fun-to-drive. Engineering excellence and vehicle efficiency are the focus."

Hybrids and hydrogen

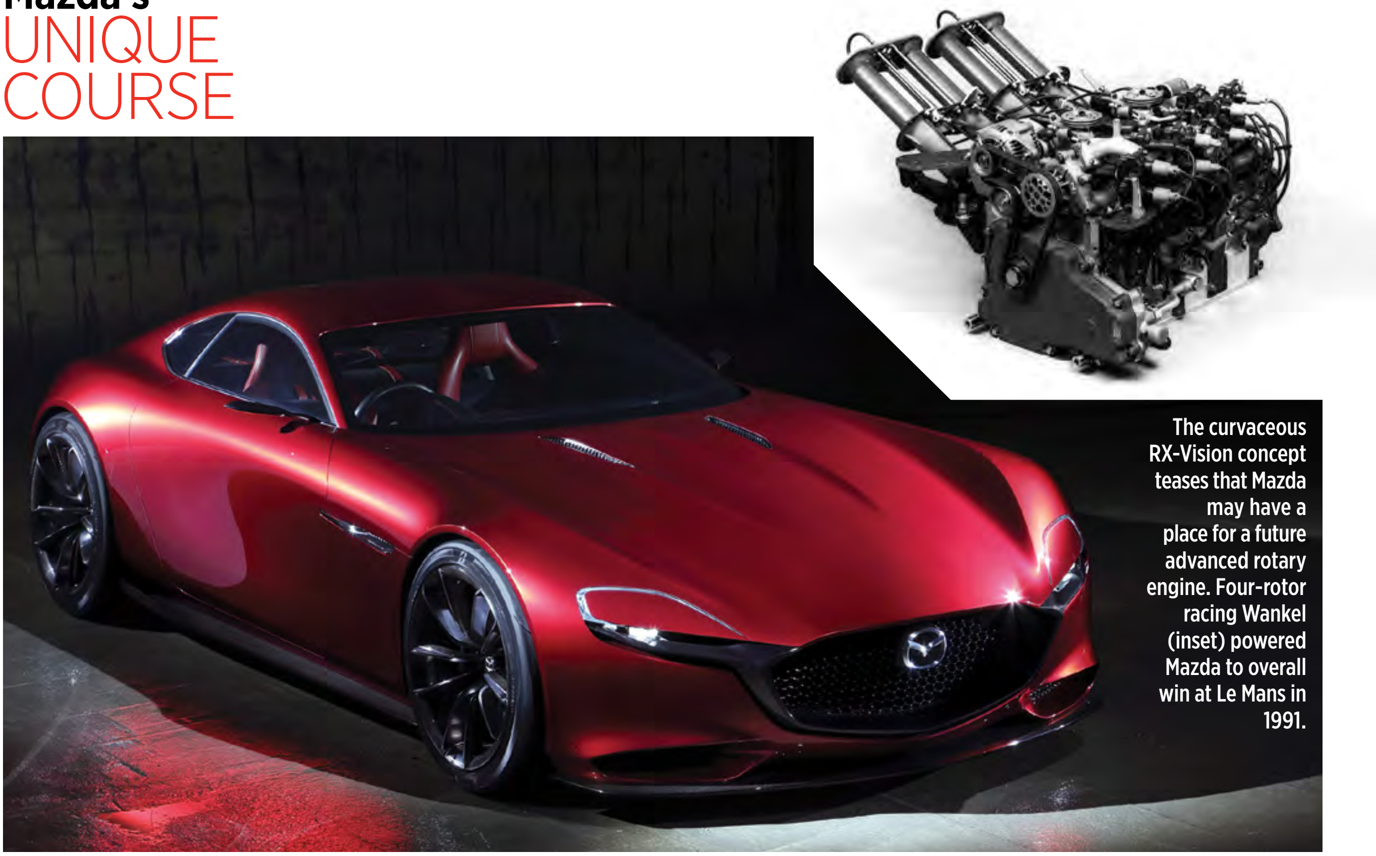
Mazda has yet to make a major commitment to vehicle electrification, with only a few Japan-only hybrids and battery-electric vehicles in the field thus far. A Mazda twist on hybrid technology is the "E-Loop" regenerative brake system, now in production, that stores electric energy in a capacitor and supplies it to power vehicle accessories. Talk of a diesel-hybrid surfaced within the diesel program and leveraged a works-supported endurance racing effort to promote the (stillborn) Skyactiv-D models in the U.S. This was quietly swapped for the Skyactiv-G (gasoline) power unit.

Mazda powertrain engineers realized that the cost of full urea-based aftertreatment for light-duty diesel was too burdensome—for North America.

But in Japan, the Skyactiv-D is outselling the G, an extraordinary phenomenon in a market where diesels have not been popular. The CX-3 in the home market is exclusively diesel. At this time, Mazda is the only Japanese OEM that offers diesel cars—albeit with vastly different emissions-control suites than in the U.S.

But Kanai realizes that Mazda may need to incorporate electrification to meet at least some U.S. regulations. Mazda is among a group

Steering Mazda's UNIQUE COURSE



The curvaceous RX-Vision concept teases that Mazda may have a place for a future advanced rotary engine. Four-rotor racing Wankel (inset) powered Mazda to overall win at Le Mans in 1991.

of OEMs that must comply with California's zero-emission vehicle mandate beginning in 2018. Along with other smaller carmakers it successfully lobbied to change the regulations so that plug-in hybrids can count toward the sales totals. While Mazda continues its hydrogen-fuel R&D, supplying a fleet of H_2-fueled rotary RX-8s to be evaluated in Scandinavia, Kanai is pragmatic. He considers fuel cell vehicles a variation of the EV.

Hybrids are mostly and primarily ICE-propelled, Kanai reasons, so Mazda should concentrate its resources on ICE optimization that would enable reducing the degree of electrification that involves cost, mass and complication. However, the company has joined with Toyota in a "long term" technology-sharing deal that is expected to provide Mazda with components and know-how for future Mazda HEVs and PHEVs.

While Mazda may have fallen behind in the hybrid race, it is widely acknowledged as a benchmark in further optimizing internal-combustion engines. The Skyactiv program is well along in marrying Otto and Diesel cycle characteristics as development progresses through G1, G2, and G3 stages.

At the 2015 **SAE** High-Efficiency Engine Symposium, Mazda ICE Technical Center Research Manager Hiroyki Yamashita noted that "Our target with the G3 is 18:1 compression ratio at lambda 2.5—and up to a 40% improvement in thermal efficiency by setting the ideal pressure and temperature for HCCI combustion." He said the G3 program focuses on heat transfer from the combustion chamber and employs a special sprayed-on thermal insulation coating on the piston crown and chamber walls.

Mazda also is in the vanguard of reducing internal friction across its ICEs, noted Marc Sens, **IAV Automotive**'s Head of Department Thermodynamics/Boost Systems. "We've tested their [G1] Skyactiv engines and their claim

Changing Mazda's engineering culture

Mazda North America CEO Masahiro Moro.

After Kanai was promoted during the **Ford**-management period, he became a kind of 'guru' for **Mazda**'s entire product-development group, said Masahiro Moro.

"He showed the light at the end of the tunnel—the way out, so to speak, for Mazda," Moro recalled. "His significant contribution, development of the Skyactiv technology, was a very big thing because Kanai challenged everybody to make Mazda the industry benchmark in vehicle dynamics and efficiency. And in order to do that we had to break through conventional thinking."

To do this required starting from scratch. "Kanai-san knew we had to be bold or we would not make the quantum leap," Moro explained. "This was very adventurous and it shows the spirit and strong DNA that is Mazda. Everything he said, the engineers listened and were very motivated. He changed the culture of our entire R&D organization from being conservative and afraid to fail, into one that constantly challenges to make things better.

"It was a big swing for us in terms of mindset when Kanai-san became our leader," Moro recalled.

Lindsay Brooke

New-for-2016 CX-9, shown here during winter testing, achieved a 300-lb mass reduction vs. its predecessor, and combines fun-to-drive dynamics with a high-quality premium cabin.

of 30% friction reduction over the previous generation is real—very impressive," he told *Automotive Engineering*.

Learnings from Ford

The period under Ford's 34% majority stake included many joint engineering programs and is seen as a "difficult time" by some in Mazda management. But Kanai said he "learned hugely from Ford's logical and painstakingly exacting marketing and product planning, and analytical methods, versus what we at Mazda had been doing."

The product planners in Hiroshima had been used to putting passion at the top of their proposals. "Surely we calculated target cost but invariably preceded by ideals, relegating such 'earthly' issues as sales volume, retail prices, marketing and sundry expenditures to their respective executives and specialists," Kanai noted.

Today he lavishes praise on "the young lions Dearborn dispatched to Mazda" including current Ford CEO Mark Fields (then president) and the successive Senior Managing Directors for R&D, Martin Leach, Phil Martens and Joe Bakaj. In late 1999, Fields gathered all managers in the company's auditorium and delivered an impassioned speech that Kanai remembers as a call to battle: "Firmly establish and strengthen the Mazda brand, or else!"

The now familiar "Zoom-Zoom" strategy and brand identity that followed was in perfect synch with Kanai's own development concept that focused on vehicle agility and dynamic precision. "I am hugely grateful and owe to the Zoom-Zoom movement. The whole company and our suppliers responded to the dynamic cause represented by the strategy," he said.

Autonomy and rotary future?

Having revealed the full Skyactiv technologies in September 2011, Mazda's powertrain engineers continue to push the combustion frontiers (and help rationalize gasoline and diesel engine production). Kanai is particularly proud of the latest offering, the CX-9, calling the mass-efficient SUV "the best premium vehicle we have ever produced." Its Skyactiv turbocharged 2.5-L inline four replaces the previous-generation CX-9's Ford Cyclone-based 3.7-L V6 with a much smaller, lighter and more powerful package.

Mazda has been researching autonomous vehicle operation for many years, like other major OEMs. "Self-driving is not in our planning scope," Kanai asserted. "People—maybe excepting professional transport drivers—derive pleasure when they could drive to their satisfaction, taking corners, bends, up and down hill, etc. Our neuroscientists conform that driving invigorates brain functions. We are not taking that pleasure away by driverless operation," he said while noting that Mazda is incorporating the latest driver-assist technologies.

An inevitable question regards the future, if any, of the rotary engine at Mazda. Does the recent RX-Vision concept herald a production car? Rumors and speculation are rampant in Hiroshima. Kanai recognizes the biggest challenge still ahead is the rotary's inherent shortcoming, fuel consumption. His engine teams are working on the issue and may have some promising measures for a solution.

"It [a rotary] would have to be [in] a sports car that could match if not exceed the best of the world," said Kanai. Mazda has already hinted the number "16," signifying single chamber volume of 800 cm^3.

Mazda also has demonstrated a range-extender EV based on the Demio/Mazda2 hatchback. It's a single-rotor engine with 330-cm^3 chamber capacity mounted with its eccentric shaft (crankshaft equivalent) vertically driving a generator. The whole system fit neatly under the luggage compartment. Chairman Kanai said the rotary could fill the bill for such applications.

Stay tuned. ■

DELPHI'S multi-domain mindset

From tackling the cyber threat to putting 48-volt hybrids with Dynamic Skip-Fire on the road, Engineering VP Mary Gustanski is harnessing a technology powerhouse.

by Lindsay Brooke

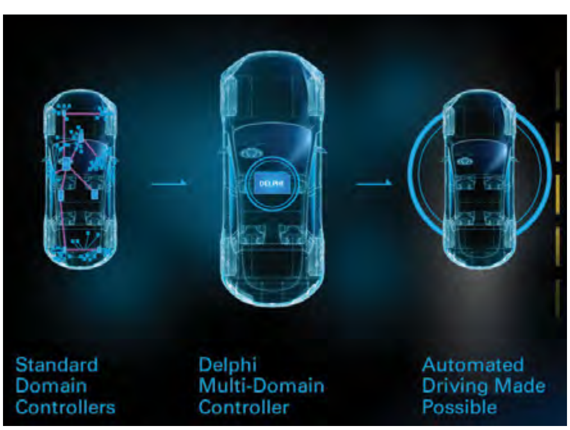
Delphi VP Mary Gustanski oversees an increasingly diverse technology portfolio. (Lindsay Brooke photo)

Mary Gustanski lives in a James Bond movie. It hasn't yet been released but she's certain it will be at some future date. In her film-nightmare, the evil-genius villain on the remote island has hacked into the 'cloud' to wreak havoc on the world's vehicles and their drivers. Chaos is rampant on the highways, streets and in every parking garage and car wash.

"That's actually how we look at the security threat as we develop advanced vehicle technologies," said Gustanski, the Vice President of Engineering & Program Management at **Delphi Automotive Systems**. "The one thing we know for sure is, someone is going to get in. We start out with that premise."

Gustanski acknowledges that despite intense analysis and discussion of this hottest of industry topics, there is no single solution yet to the cybersecurity challenge. And every vehicle OEM "is in a different place" in terms of their approach. Delphi's approach, she says, is different.

"We're going to protect the easy things—the phone, Bluetooth, cellular—but we also want to know when someone's hacked in," she noted in a wide-ranging and lively interview with *Automotive Engineering* at Delphi's Troy, MI, offices. "That requires robust intrusion detection on your communication, so that you're monitoring the intruder. Then we want you, the OEM, to be able to put the intruder into a 'box' before it touches your safety-critical elements."



Delphi is a leader in introducing multi-domain controller technology into production.

Rise of the MDC

Development of such cyber-detection technology and related countermeasures, in addition to advanced propulsion systems, connected car and autonomous-driving programs, are transforming megasupplier Delphi into an organization that is resembling, to a degree, a tech company—one that last year conducted the first successful coast-to-coast driverless-car transit of the U.S.

While discussing the cyber threat, Gustanski noted that some OEMs are moving toward networked multi-domain controllers (MDC)—essentially a single 'brain' that has authority over various subsystems. **Audi**, for example is using Delphi's recently introduced MDC, based on **Nvidia** multi-core processor technology, to oversee the entire automated-driving sensor array in its electric eTron Quattro.

"There are segments of the vehicle—safety-critical is one and Powertrain is another—that are kept under separate control for a reason, including redundancy," she asserted. "Above all else, the vehicle must be safe to operate 100% of the time." And regarding the debate over government access to vehicle data and its potential role in anti-cyber defense, Gustanski believes "the consumer will eventually warm up to it."

When the question of what assets differentiate Delphi from its competitors such as **Bosch** and **Continental** arises, Gustanski points to a longstanding staple in the technology portfolio: Electrical architecture (EEA) supply, right down to the wiring harness and connectors. It's not-so-simple stuff anymore, and still a pillar of Delphi's revenue. She noted that there are, on average, 1½ miles (2.4 km) of wiring in the harness of a typical vehicle. "But when you realize it's 1½ miles of copper and 280 connectors, it gets heavy," she said.

Next year Delphi is launching a novel thin-walled harness technology featuring aluminum wire in some sections. In a typical vehicle application the new-tech harness will be longer overall but it enables the copper sections to be down-gauged. The end result will be a 50% mass savings over an all-copper harness, Gustanski explained.

Still, the explosion of vehicle electronics hardware is overdriving system complexity and creating a challenge not only of power and signal, but of data speed. And that means the move beyond incumbent CAN-based technology, in many cases, to Ethernet.

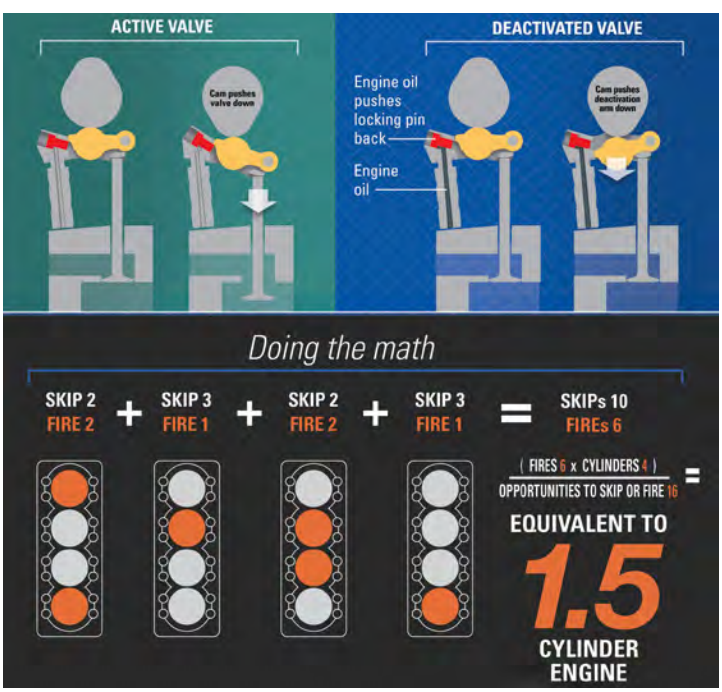
"We're going from 65 megabits-per-second today to 1.5 gigabits/second—and an advanced project we kicked off this year is going for 6 gigabits/second," she reported. How fast is 65 megabits/second? Gustanski's engineers calculated it to be 65,000 pieces of data in the blink of an eye.

Next step: 48-V plus DSF

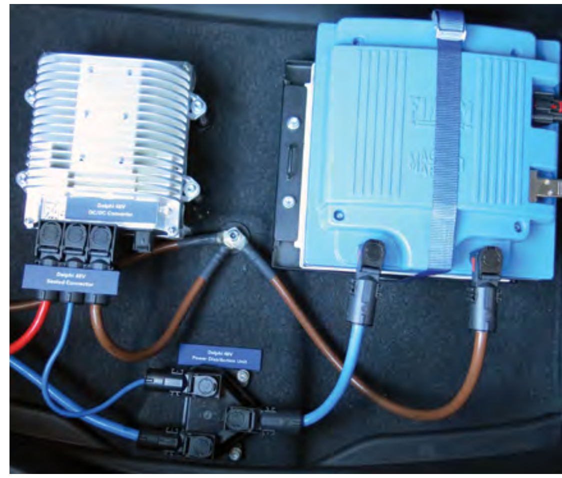
In addition to connected-vehicle and automated-driving systems, faster data speed also plays a role in the ongoing development of two key Delphi programs: 48-V hybrids and Dynamic Skip-Fire (DSF) which will soon be together in the same propulsion system for OEM demonstrations.

The DSF, being productionized by Delphi, was invented by San Diego-based **Tula Technologies** in which Delphi holds an investment stake. Based on digital-signal processing, it is the industry's first individual-cylinder deactivation system. DSF has demonstrated 10-15% fuel efficiency gains versus engines without cylinder deactivation. Delphi has had V8 engines equipped with DSF under vehicle test and recently added I4-powered vehicles, Gustanski said.

With global OEMs increasingly interested in 48-V technology—next month's *Automotive Engineering* will cover this in detail—Delphi's two converted European model **Honda** Civic diesels are getting a workout in customer demonstrations, Gustanski reported. The Phase-2 demo vehicles being completed by Delphi will also feature



Delphi is productionizing the novel Dynamic Skip-Fire cylinder-deactivation technology invented by Tula Technologies, in which it owns a stake along with GM Ventures and others.



48-V power electronics (right) and DC-DC converter with Delphi sealed connectors and power distribution unit (center) in the company's European Honda Civic diesel demonstrator. (Lindsay Brooke photo)

DSF gasoline engines. She expects the demo cars to be ready by early 2017.

"It's an internally-funded program," she said. "We've modeled it and typically our modeling of fuel efficiency is conservative when compared to real world. I can say that we've demonstrated 15% gains for the 48-V and 10% or better for DSF, separately."

EEs going software

The "revolution in engineering" Gustanski sees propelling new emissions, safety and automated-driving developments with greater demand for software expertise is reshaping the technical workforce.

"We have 20,000 engineers working at Delphi today," she noted. "About 5,500 of those are in software and the associated competencies including systems engineering. That's about 1 in 4 working in software. A few years ago we were about 1 in 5. Tomorrow it's going to be 1 in 3."

Delphi is still hiring mechanical and electrical engineers—in fact, it is actually hiring more MEs and EEs and training them to be software engineers, she said, for two reasons.

One is there aren't enough software engineers coming out of universities to fill the pipeline—"and the ones who are typically want to work in IT," she revealed. Second, Delphi prefers computer-engineering majors over computer science, "because when you grow to be a systems engineer you have to have some understanding of how a vehicle works. You need some engineering mindset," Gustanski believes. "So we'd just as well take an EE and teach them to be a software or system engineer. We have an internal development track for that." ■

The evolving tire-development paradigm

Advanced tire-simulation modeling allows tire development to keep pace with accelerated vehicle-development cycles.

by Dean Tener and Michael Stackpole

Nothing will fully replicate real-world tire-testing with human drivers, as shown here at Smithers Rapra's winter test facility in northern Michigan. But new tire modeling tools offer numerous development advantages. (All images and data plots courtesy Smithers Rapra)

Engineers working in today's vehicle-development environment are faced with a unique challenge in relation to prototype vehicles: the cost of constructing prototypes and assemblies limits their accessibility—and contemporary development cycles often outpace the opportunity to build physical prototypes. And when a prototype vehicle or assembly is produced, it quickly may no longer be representative of the most current vision.

While the most-thorough method for evaluating tire suitability for a given vehicle obviously is to drive it with the specific tires installed, the increasing limitations of access to driveable prototypes can be an obstacle. But there have been significant advances in virtual tools that can assist with the process of developing an optimized tire and vehicle system.

Contemporary computational resources now are readily available and hardware and software capabilities are exceptionally powerful. These tools can be utilized to create simulation models to predict the performance of one iteration of a vehicle's design with a specific tire—and also expedite multi-variate and multi-physics optimization processes.

The subsystems and components which represent the vehicle model must reflect an actual or viable part, of course, and there lies the potential conflict: the pneumatic tire is a complicated, non-linear component and modeling its complex properties requires careful attention to detail. Simply ordering "a tire model" will generally not produce final results as accurate as those that can be obtained through a cooperative process.

In the past, the tire-development process typically entailed the creation of a specification document, program kickoff, several rounds of experimental physical builds and an eventual winnowing of that data to a suitable tire specification produced by one or two vendors.

The process requires access to prototype vehicles at different stages of development, submission tires and expert evaluation by a driver. The process does identify suitable tires for the vehicle but is somewhat limited in scope. And, not the least, it can require a timeline of several years.

Computational simulation

Nothing will completely replace the expert human evaluator. The goal of every vehicle program is to create a vehicle that delivers a satisfying and safe driving experience for the customer; the expert evaluator is the best option to rate a given tire design against that target.

But there are several advantages to augmenting the classic approach with computational methods. Simulation permits investigation of components which cannot be physically installed onto a prototype vehicle. Designed experiment methods can incorporate hundreds or thousands of computational variations that show how vehicle responses change with respect to component properties.

Moreover, virtual models can be constructed rapidly and inexpensively, especially when compared to the cost of testing with hand-made prototype vehicles. The computer modeler has the significant advantage of knowing exactly what is in the model, whereas the details of components in a physical prototype may be uncertain or even unknown.

A computational tire model is required for any type of full-vehicle simulation modeling. These mathematical representations of tire data serve as the numeric interface between the virtual vehicle and virtual proving ground. Because tires are the foundation of vehicle handling and performance, vehicle models require the data produced by tire

The evolving tire-development paradigm

models to reliably predict how the vehicle will handle under different driving situations.

The ensuing computer simulation offers many benefits to the design process, such as eliminating the need for high-cost testing methods, providing a rapid objective evaluation of vehicle performance and safely investigating design alternatives.

Generating tire models

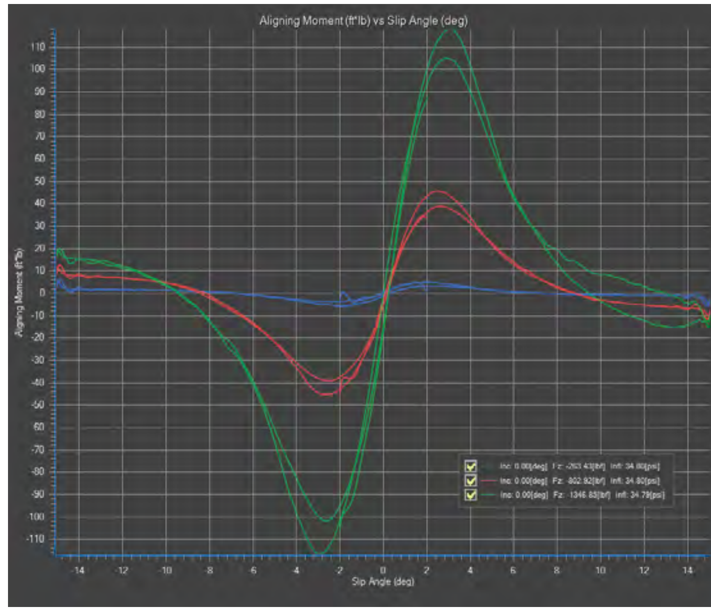
The tire-modeling process starts with data. A variety of tire measurements may be required, including force and moment, spring rates, impact response and geometry. Traditionally, tire models have been generated with little or no knowledge of how the tire was tested or its end use. Typically, data in these cases was collected by a test organization using a series of standard procedures.

In a new and more-integrated approach centered around the needs of the modeler or tire analyst, the choice of measurements and test conditions will depend on the ways the tire model will be used and the conditions under which the tire will operate. More-advanced tire models then are developed and certified for fit within the design parameters of intended use. In this approach, direct feedback on model performance is key to adjusting test procedures and improving future testing.

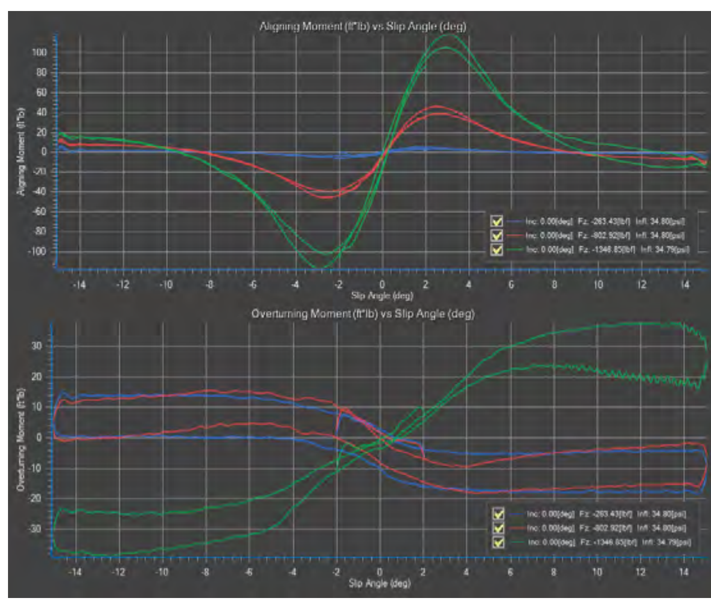
Identifying the right tire model involves a detailed understanding of how the model will be used. Commercial tire models are available and typically adequate for most general applications. Custom tire models are required only with specialized simulations or targeted analysis. Tire models can be broken into three classes: performance-based, component-level and finite-element models.

Performance-based models generally are employed to evaluate vehicle handling characteristics such as load, slip angle, speed and driving/braking torque. They rely on force and moment testing—without physical construction being characterized—and use either tables, splines or equation-based models. The Pacejka or, "magic formulas" model is one of the most widely used models in this class because of its accuracy, ease in programming and speed. The Pacejka equations were developed to fit the data gathered from experimental tests with real tires—and predict behavior with great precision.

Component-level tire models test the structure and physical properties of the tire, with a rigid or flexible ring and are most commonly used for vehicle ride and durability analysis. While complex in design, component-level tire models are the most appropriate tool for this analysis. A strong example is the FTire, flexible-ring tire model, a full 3D in-plane and out-of-plane tire simulation designed to test vehicle comfort and performance in relation to road irregularities. Other popular component models include MF-Swift 6.0 and 6.1 and CD-Tire.



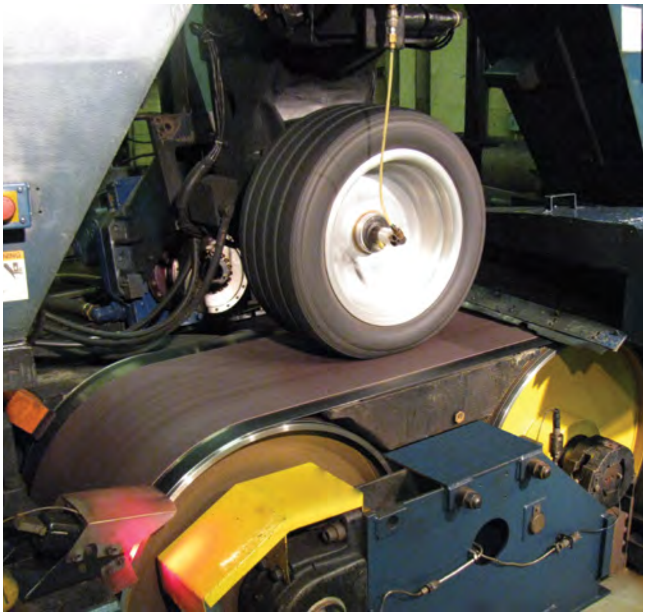
Sample data trace from a tire-model simulation.



Sophisticated tire-simulation models can provide for hundreds or even thousands of variations without ever being fitted to a test vehicle.

Finite-element models require a detailed knowledge of the tire's component materials and internal structure. These models are most useful for tire manufacturers, since specific details of elastomer behavior and geometry can be difficult or expensive for an outsider to acquire.

Once a tire model is selected and produced, the customer should have access to the raw data collected for testing, along with a report illustrating the model's performance.



Testing of a tire's physical properties on a test rig.

Testing and data-fitting

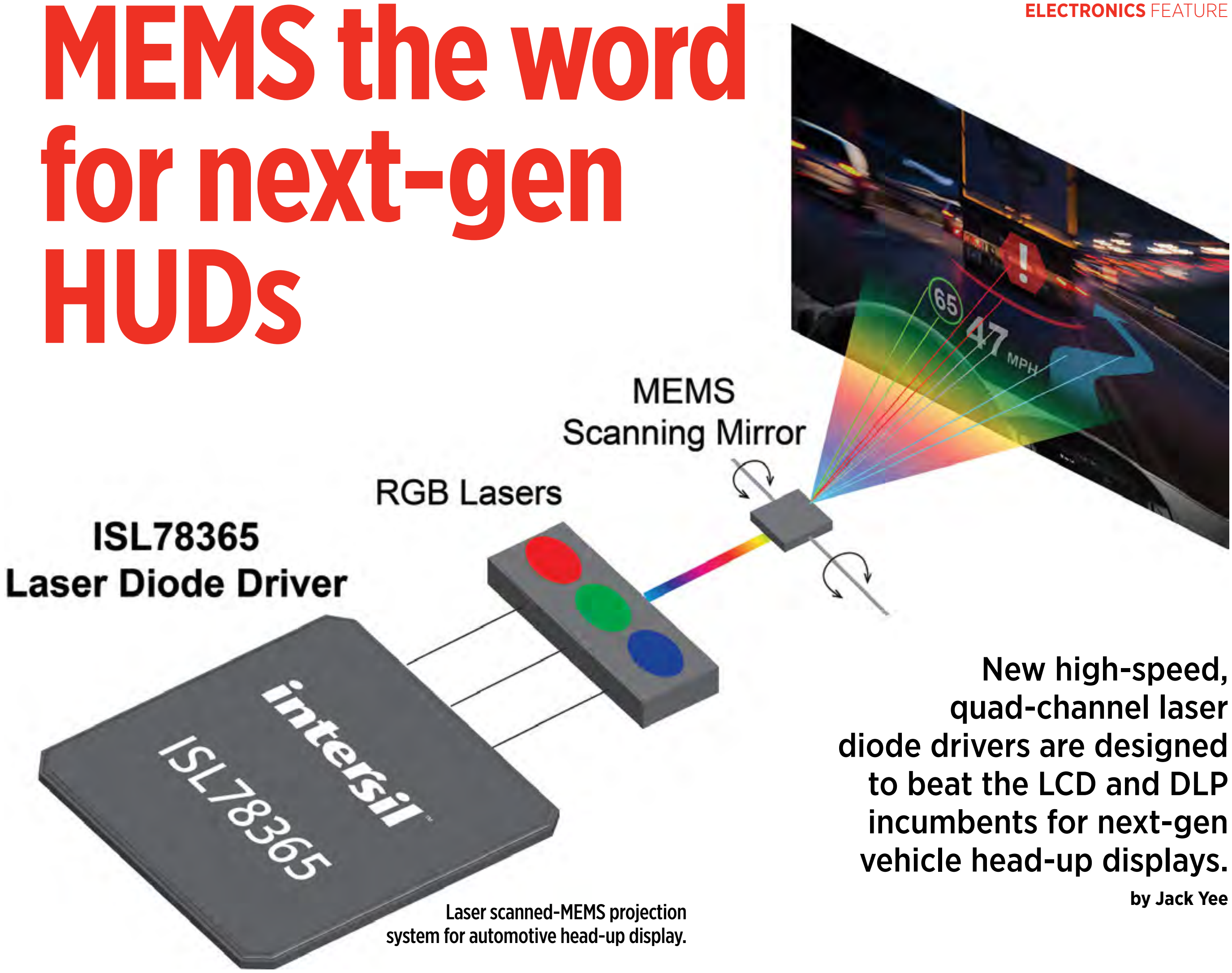
For automakers, finding the right partner to assist in making the best vehicle-design decisions is crucial. Tire and modeling experts who work with manufacturers at every stage of the supply chain, from initial ingredient evaluation to end use, offer a unique advantage in choosing the right tests and "fitting" the data. It can be beneficial to work with a partner with the expertise and capability to combine modeling, subjective handling and traditional laboratory tire testing.

Instead of relying on generic procedures, robust tire models are designed to meet the needs of the vehicle OEM and require a detailed understanding of the tire's properties, design and intended use. By choosing a partner that offers a customer-centered approach to tire modeling, manufacturers can count on advanced, tailored testing and modeling techniques and a commitment to improving the future of tire and vehicle safety.

As the industry continues to evolve toward the use of more virtual testing and development, the need will grow for more precise modeling techniques. The tire is the foundation of the vehicle's interaction with the road and continued work on higher-fidelity tire models will go a long way toward meeting the industry's future needs. ■

Dean Tener is Technical Manager at Smithers Rapra Ravenna (OH) Laboratory, Smithers Rapra's main tire testing center in North America. He has held positions at General Motors, Honda R&D Americas and Bridgestone/Firestone. Michael Stackpole is the founder and President at Stackpole Engineering, a technical services provider specializing in tire testing, data-fitting and advanced tire model development. He has more than 30 years' experience in tire and vehicle simulation, testing and modeling that includes positions at Goodyear and Firestone.

MEMS the word for next-gen HUDs



Laser scanned-MEMS projection system for automotive head-up display.

New high-speed, quad-channel laser diode drivers are designed to beat the LCD and DLP incumbents for next-gen vehicle head-up displays.

by Jack Yee

Nearly 30 years after the first automotive head-up display (HUD) for production cars was offered by **GM** on the 1988 **Oldsmobile** Cutlass Supreme and **Pontiac** Grand Prix—and 55 years after the first airborne HUD appeared on the British Navy's **Blackburn** Buccaneer strike fighter—HUDs are steadily gaining popularity in the industry. They're available as standard or optional equipment on a growing list of mainly luxury car models and being incorporated into an expanded suite of advanced driver assistance systems (ADAS) to help keep drivers focused on the road ahead rather than looking down at their dashboard instruments.

Distracted driver studies have shown that taking your eyes off the road for more than two seconds doubles the risk of a crash. The automobile HUD places driving speed, warning signals, and indicator arrows on the driver's windshield directly in their line of sight. One of the newest HUDs uses laser diode drivers to pulse high-intensity red, green and blue (RGB) lasers that project high-definition (HD) video onto the windshield.

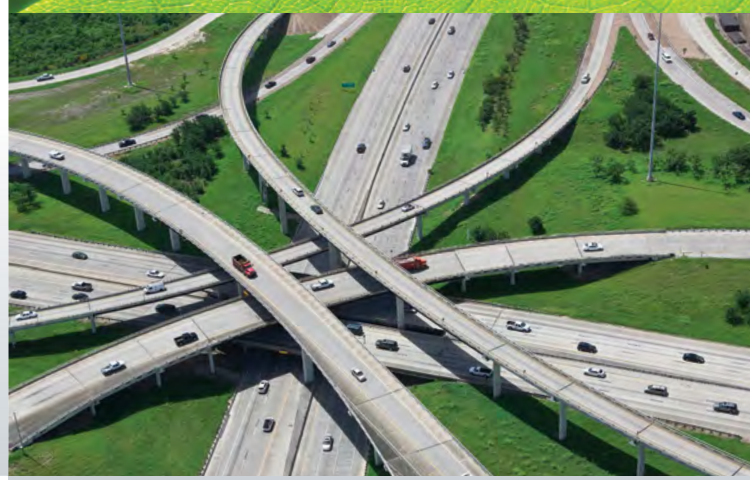
These augmented-reality HUDs paint a transparent arrow directly onto the street in front of the car, making color turning signals and navigation directions easy to follow. They also highlight other objects, like pedestrians or vehicles that might present a hazard, and brings them to the driver's attention. Two incumbent technologies—liquid-crystal display (LCD) and digital light-processing (DLP) HUDs—face new competition in the form of laser-scanned MEMS projection systems. Enabling this next-generation solution are high-speed, quad-channel laser diode drivers.

More efficient, higher resolution

The LCD panel is the most commonly used technology in automotive HUD systems. It employs a transmissive display technology and LED backlights that illuminate the entire image when light passes through it. The illuminated image is magnified, reflected off a fold mirror and focused onto the windshield in front of the driver's field of view.

The LCD HUD's dark pixels are created by blocking the backlight, which makes the LCD less transmissive for those pixels. However, not all light can be completely blocked, especially in low ambient light settings. The result is a projected image overlaid onto the windshield that looks like a transparent postcard sized rectangle. Automotive OEMs see this as a major safety drawback because the illuminated rectangle is a distraction to the driver.

DLP is similar to LCDs but offers better resolution. DLP has thousands of micromirrors arranged in a two-dimension (2D) array. Each mirror in the 2D array



MEMS the word for next-gen HUDs

Example of an LCD-type HUD as viewed from the driver's seat.

serves as a pixel, and each mirror is modulated to reflect the incident light to create the desired pixel intensity. A 100% bright pixel will have zero modulation, while a dark pixel will have the mirror set to reflect the light out of the imaging path.

To give a uniform image result, the incident light source is collected and focused onto the 2D array, with equal intensity on each pixel. The reflected image is then magnified, refocused and projected to a folding mirror, and then onto the windshield, a process similar to the LCD HUD implementation.

DLP is a rectangular panel that requires a flat horizontal surface to project information. Windshields are relatively flat in the vertical direction, but not in the horizontal. Therefore, for DLP to place information onto the windshield, designers must use aspherical optics to accommodate the windshield's curves, which increases the size of the HUD system.

Compared to DLP systems, a laser scanned-MEMS projection system takes advantage of the scanning mirror's deformed image, enabling the use of lower cost optics to reduce the system's opto-mechanical cost.

The main components of a laser scanned-MEMS system are the laser diode driver, laser diodes, some small beam shaping/alignment optics, and the oscillating MEMS mirror and its control electronics. The RGB color laser diodes are pulsed synchronously as the mirror is scanned across the display field. The image is then drawn pixel-by-pixel across the display field, which is overlaid onto the windshield.

In a laser scanned-MEMS projector, each pixel is pulsed very rapidly to create the full HD resolution. And, because the laser beam is always in focus, the image can be projected into the windshield without requiring refocusing optics. This greatly reduces the overall optical system complexity and size, and it eliminates costly optical components and assembly.

Laser scanned-MEMS projection systems offer better electrical efficiency than LCD or DLP frame-based projection systems. Unlike a front projector where the entire display is filled with a presentation, the automotive HUD's navigation and instrument information does not fill the entire HUD field display area. The HUD only presents time-sensitive information on the windshield for a short duration of time. The augmented reality information is comprised of an image that can have over 70% of the display pixels turned off.

The red boxes in the accompanying images show typical HUD display areas where the projection system must be able to present the navigation information. Note the amount of pixels turned on relative to the amount turned off in each example. Depending on the information, that ratio (on:off pixels) can range anywhere from 1:3 to 1:6.

For example, in the DLP frame-based display technology, regardless of how many pixels are turned on, the light source must fill the entire pixel array. As shown, the light for "dark" or "pixels not turned on" in the red box display area is generated and then discarded either by reflecting it away from the area of view or by blocking it. This is energy consumed that counts against the HUD's system efficiency.

Even worse is that this lost energy contributes to additional heat generated by absorption of the redirected light and the cost of the electrical energy to create the light in the first place. These two factors ultimately increase the frame-based thermal cooling requirement and electrical energy needs.

Photo on the left shows a typical HUD output. On the right is an example of typical HUD information.

MEMS the word for next-gen HUDs

A laser scanned-MEMS HUD only consumes electrical power when there are relevant pixels to be projected. With the typical navigation and instrumentation information shown here, most of the electrical energy is consumed when there is a need to put a pixel onto the display. This dramatically reduces the electrical requirement, resulting in a lower thermal profile and less thermal dissipation. And since the laser scanned-MEMS HUD integrates the driver electronics, its projection footprint is smaller than frame-based HUD systems.

Less pixels more brightness

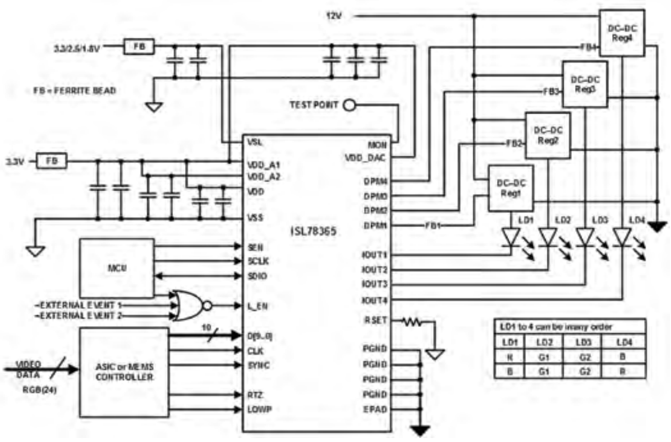
Next generation HUD systems can employ the ISL78365 four-channel laser diode driver made by **Intersil** Corp. to deliver augmented reality video information to the automobile windshield. The laser driver includes an interface that integrates with the MEMS ASIC to create a compact laser scanning projection system, as shown.

The ISL78365 provides four high-speed 750 mA programmable current sinks, which regulate the current and optical output of up to four laser diodes. It provides 1.5 ns rise-and-fall times, resulting in high frame rate HD color video, as illustrated in the accompanying image. The laser driver offers independent color, threshold, and scale settings for each current sink, and its flexible high-speed parallel video interface supports full-HD projection and pixel rates up to 150 MHz or 1900 pixels per line. It includes multiplexing of pixel data to simplify the opto-mechanical to electronic layout requirement.

Dynamic power management for each laser diode supply and three power saving modes further reduce total system power consumption during blanking time. The laser driver's programmable return-to-zero pulsing functionality de-speckles the displayed image, and a programmable over-temperature protection enables customized thermal performance.

The laser scanned-MEMS projection system is better suited for automotive augmented reality HUDs than alternative DLP or LCD frame-based display systems. While a laser HUD scanned image only needs 25% to 30% of its pixels turned on, the DLP and LCD HUDs require 100% of their image pixels driven to generate the same amount of brightness.

DLP and LCD systems waste light and power required to display the black pixels. This results in a slight bright spot where the black pixels area should be.



ISL78365 quad-channel laser driver pulses four high-intensity laser diodes. (Intersil schematic)

Laser head-up display presents full-HD video information in driver's line of sight.

During daytime sunlight, this envelope might not be an issue, but at night, it is much more apparent.

From a driver safety perspective, it becomes another distraction—and tips the scale in favor of OEMs using a laser scanned-MEMS projection system for their next-generation vehicle head-up displays. ■

Jack Yee is a senior applications manager for automotive head-up display (HUD) products at Intersil Corp. He has held engineering and engineering management positions over his more than 15-year semiconductor career. Before joining Intersil, Yee was a technical marketing manager at C-Cube Microsystems, and senior director system architect at Aurora Systems, Inc. He holds a BSEE from San Jose State University.

Citroën to unveil CXperience concept at 2016 Paris show

Citroën's CXperience concept has a 3-m wheelbase and is only 1.37-m tall. The vehicle is set to debut at the 2016 Paris Motor Show.

Exterior rearview cameras take the place of conventional side mirrors on the Citroën CXperience concept. Can this technology for production vehicles be far behind?

Having shrugged off the inhibiting effects of conventional design that took it into the category of the mundane for many years, **PSA Citroën**'s latest demonstration of its original technological and aesthetic design capabilities for its **Citroën** brand is the CXperience concept, timed for unveiling at the 2016 Paris Auto Show.

A gasoline plug-in hybrid with a maximum combined power output of around 220 kW (295 hp), it has progressive hydraulic "cushion" suspension (http://articles.sae.org/14867/) and a long (4.85-m / 15.7-ft) and low (1.37-m /4.5-ft-high) body. The concept sits on 22-in wheels and features aft-hinged rear doors. The overall exterior form has a bit of the radically different 1955 DS about it, including a single-spoke steering wheel.

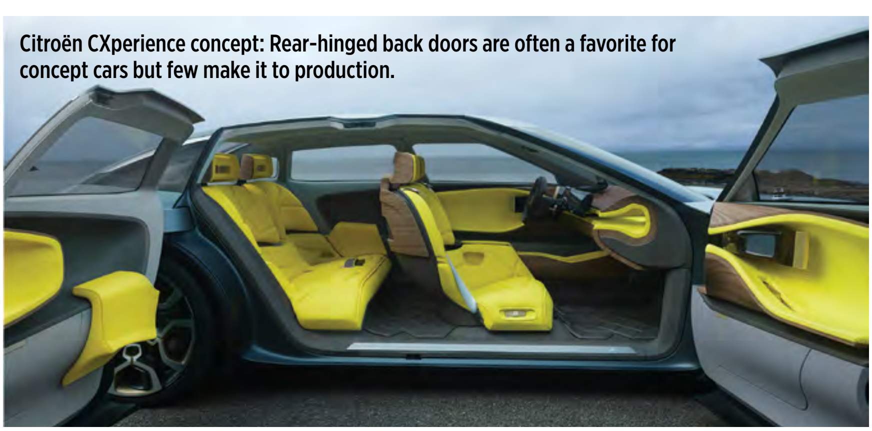
CXperience marks a new offensive in brand strategy, according to Citroën CEO Linda Jackson. Interviewed by the author late last year, Jackson indicated that the company would re-establish its focus on comfort and individual design.

Said she of the new concept: "It challenges convention. It also fits in perfectly with the ambitions of the Citroën Advanced Comfort Program and illustrates our 'be different, feel good' promise in this segment."

That segment is described as an executive hatchback. The concept has highly distinctive frontal treatment that includes V-shaped LED daylight running lights (DRL) comprising narrow strips above three LED directional headlights. Active air intakes integrated into the car's bumpers improve both aerodynamic and thermal efficiency.

The rear window is concave with what Citroën describes as a "moving fin" aerodynamic aid. Laser fiber optic rear lights are fitted. And the backward-opening closures are described as "autoclave doors." The car has twin sunroofs.

Exterior mirrors are replaced by rearview cameras; images are sent to small screens positioned along the inner door panels, which also carry speakers and air vents.



Citroën CXperience concept: Rear-hinged back doors are often a favorite for concept cars but few make it to production.

The car's dashboard comprises a 19-in rectangular touch-screen that can be configured in one, two or three sections. It is central to an interior that makes unusual use of fabrics, including textured leather floor covering bordered by chrome-finish sills. Shape-memory foam is used for the seats.

Occupant information sees emphasis placed on a very wide range of connected services. Those sitting in the back seats have a mobile tablet giving access to seat adjustment and air conditioning, plus media sharing via a new app: Share with U.

A head-up display (HUD) is fitted. Placed behind the interior rear view mirror is a wide angle HD camera capturing the view ahead. Images can be stored or shared on social networks.

The CXperience can be used in ZEV mode with a range of up to 60 km (37 m), its lithium-ion battery re-chargeable in a claimed 4.5 h with a standard domestic charging system, but "less than" 2.5 h using a solution based on a specific hybrid vehicle charger. The battery is tucked away under the car's floor and drives the rear axle.

An 8-speed electrically-actuated automatic gearbox is positioned between the gasoline engine and the electric motor which can deliver up to 80 kW (107 hp).

Stuart Birch

With 2017 Fusion Sport, Ford pushes further toward Audi

The 2017 Fusion Sport marks several "firsts" for Ford and the midsize-sedan segment.

All Fusion models get a quite mild exterior refreshening for 2017; one visual giveaway for the Fusion Sport is quad exhaust tips.

Nobody's ever had much trouble liking the slinky look and agreeable driving dynamics of **Ford**'s Fusion midsize sedan since the second-generation model was launched for the 2013 model year. But three years into its lifespan, a refresh is due—and in addition to a not-so-you'd-notice front-styling revision and some unexpectedly high-quality interior upgrades, the 2017 Fusion lineup adds a convincingly-executed Sport model to slant this family car distinctly to the sport-sedan part of the spectrum.

Todd Soderquist, global chief program engineer for the Fusion and Mondeo, told *Automotive Engineering* that because Ford's new-ish twin-turbocharged 2.7-L V6 was developed concurrently with the second-generation Fusion, the midsize sedan was designed from the start to accept the Ecoboost V6, even though the car was launched with a 4-cylinder-only engine lineup. Thus the heart of the new Fusion Sport, the 2.7-liter—here generating an **SAE**-certified 325 hp (242 kW) and a chesty 380 lb·ft (515 N·m)—was three years ago ready for this duty.

At last, a V6 for the Fusion

The Ecoboost V6 represents a blustery 80-hp (107 kW) and 105 lb·ft (142 N·m) boost over the Fusion's next most-powerful engine, the turbocharged 2.0-L 4-cylinder. The power upgrade is significant, but curiously in this era of engine downsizing, part of the Fusion Sport's reason for being is old-school cylinder count: Ford reckoned the Fusion was losing out to at least two of its chief competitors, the **Toyota** Camry and **Honda** Accord, which still (almost inexplicably, we think) offer V6 power.

There's another, bigger-picture reason it's a good time for the Fusion lineup to get a shot in the arm: midsize family sedans, the time-honored cornerstone of the passenger-vehicle market, are fast losing ground to crossover vehicles. In August this year, sales of midsize sedans hit a five-year low, according to trade journal *Automotive News.*

This 2.7-L is somewhat special in the already tech-rich feature set of all Ecoboost engines in that it features Ford's first use of a compacted-graphite iron (CGI) cylinder block for a gasoline engine (see http://articles.sae.org/13388/ for more detail). Manufactured in Lima, OH, the engine's CGI construction blends the durability attributes of grey iron with weight-savings similar to (or potentially better than) aluminum. Already used for the F-150 pickup and the Edge Sport crossover, for the Fusion Sport the V6's torque peak is slightly higher even than the F-150 pickup's rating. There also are several SAE technical papers relating to the Ecoboost 2.7-L; one starting place is here.

The addition of the grunty V6 unquestionably adds a new dimension to the Fusion, delivering brash acceleration from a standstill, even if the collaboration between the V6 and an uprated version of Ford's 6-speed automatic transmission doesn't seem entirely copacetic. *Car and Driver*'s experienced speculation indicates the the Fusion Sport will cut about a 5.3-s 0-to-60 mph run, a figure that requires no excuses in sport-sedan company. Thanks to a "sport" button centered in the new rotary-dial shifter, the engine-transmission interface can be made more urgent and the engine's aural output is enhanced to a

The Fusion Sport comes standard with a twin-turbocharged 2.7-L V6 that generates 325 hp and 380 lb·ft.

slightly too loud and almost uncomfortably artificial howl.

Pin the throttle in a tight backroad bend and the V6 has the Fusion Sport bolting with authority—just when you're sure that blistering torque will send a front wheel fluttering, the standard all-wheel drive swallows the excess and channels it where it won't be wasted. This combo alone makes the Fusion Sport well worth its $34,350 starting price, in the author's view, even if with all this thrust hardware it seems the car should be able to do better than its mediocre 21-mpg combined fuel-economy rating. In this metric, the Fusion Sport's plumpish 3982-lb (1806-kg) curb weight—450 lb-plus (204-kg) more than a front-drive, 4-cylinder Fusion—surely is no advantage.

First adaptive damping for family sedan

What may be as impressive as the Fusion Sport's propulsion-per-dollar ratio is its continuously controlled damping (CCD) suspension—the adaptive dampers the company uses in several Lincoln models, the system's first-ever standard-equipment appearance in a U.S.-market Ford-branded vehicle.

The CCD dampers, made by **Tokico** but algorithmed by Ford specifically for the Fusion Sport, receive input from a dozen high-resolution sensors and are said to react in 30-50 ms to adjust damping rates. The Fusion Sport is the first car in its class to offer electronically-controlled adaptive damping and it's an upgrade we predict competitors—particularly those with sporting pretensions—are likely to adopt: CCD's impact on the Fusion Sport is stupendous.

The system slurps up the most distressing road-surfaces with disdain; hard-driving on twisting and poorly maintained backroads, the kind of challenge that can leave even sport-oriented vehicles wallowing for grip and suspension fluidity, is handled brilliantly by CCD. We can't think of many Germany sport sedans that have better body control or could feel any more pinned to the road than the Fusion Sport. It's a highwater mark for the Fusion's already solid CD4 platform.

The secondary joy of CCD is that the system doesn't seem to require selecting the car's "sport" driving mode—sharper steering, throttle and transmission response and overall stiffer damping calibration—to get most of the benefits. We found

2017 Fusion models are treated to a host of interior revisions and additional electronic features; Sport gets specific seats and instrument-cluster configurations.

Signature new feature of the 2017 Fusion interior remake is rotary-dial gear selector; sport mode has easily accessed central pushbutton.

the base tuning's automatic responses adequate to handle fairly aggressive cornering while still delivering superb comfort. Ride quality, in fact, seems little compromised even when sport mode is selected.

The Fusion Sport's chassis upgrades also run to stiffer rollbar and spring rates. There are special 19-in alloy wheels and the front brake rotors are larger (by some unspecified amount) than the 11.8-in front discs of the standard Fusion. The increase or its related calibration isn't enough, as probably the Fusion Sport's only chassis shortcoming is limp braking.

Better vision for better interior

Like CCD, you can't help but notice the Fusion Sport's signature interior feature, a change from a center-console shift lever to a rotary dial. It's also on the center console but offset to the driver. The dial does palpably open the center-console area, and the standard shift paddles handle the transmission-control functionality lost with the shift lever.

Less apparent than the new shifter is an upgrade of certain interior trim pieces—including a surprisingly rich, soft-touch upper covering the bulk of the upper dash—and slimmed A-pillars that noticeably improve sightlines. And the new "Miko" microsuede (think Alcantara by a different name) mixes with leather for the seats to lend a sporty and premium appearance, as well as some degree of grip during spirited driving. All 2017 Fusions benefit from the rotary shifter, improved interior trim and slimmer A-pillars.

Several available electronic-feature upgrades for all 2017 Fusions include adaptive cruise control with collision-avoidance braking and genuine stop-n-go functionality in traffic, lane-departure warning and lane-keeping assist, as well as automatic parking capability that adds auto-parking for standard parking spots in addition to parallel parking.

The new Sync 3 driver-interface system is optional and incorporates **Apple** CarPlay and Android Auto integration.

Bill Visnic

Volvo S90: Niche for now, but...

It's no secret the reconstituted **Volvo**, since 2010 owned by China's **Zhejiang Geely**, is doing interesting and innovative things—one of the most intriguing, maybe, being that it's survived and in some senses thrived (particularly if fellow Swedish auto brand Saab is used as a measure) under Geely's control.

Fact is that Volvo and Geely have shut up the naysayers: in the nearly seven years Geely's been in charge, a studied and benevolent guidance (not to mention $11 billion in product-development funding announced in 2012) has delivered a Volvo that's somehow managed to evolve its brand back to a relevancy few thought it could ever recover.

Geely and Volvo well know the auto business maxim that "product is king" and after a transition period that left showrooms thin with transition product, the new-generation Volvo is emerging. First (and perfectly timed for a crossover-crazy U.S. and Europe) was the XC90 fullsize crossover (http://articles.sae.org/13390/) built on the company's new, widely-adaptable Scalable Product Architecture (SPA) platform.

Now the S90 sedan—also based on SPA—is ready and the dwindling interest in sedans in every market segment will only add pressure on Volvo's latest attempt to tackle the German luxury-brand triad to which every luxo-sedan is compared.

Part of owner Geely's massive investment in Volvo is a range of high-tech modular 4-cylinder "Drive-E" engines. This range-topping variant uses supercharging and turbocharging to mitigate turbo lag.

"Not a sport sedan"

Volvo wisely is trying to play off its reinvented brand—a niche image to which the "former" Volvo could never fully

The 2017 Volvo S90 leverages all of Volvo's most recent major vehicle-development investments: an all-new platform and engine family and its latest autonomous-driving innovations.

With roughly the exterior size of the BMW 5-Series or Cadillac CTS, the S90 cabin is spacious and comfortable, although the "depth" of some luxury details isn't up to the standards of costlier competitors.

accept—saying matter-of-factly at a recent media launch that the 2017 S90 "is not a sport sedan." With that off the table, the S90 can go about being what it is: a roomy, comfortable and safety-focused luxury car that's more about safety and minimizing environmental impact than carving backroads.

Beyond the apparently wide size flexibility that its SPA architecture imparts, the S90's Drive-E engines perhaps are its most fundamentally impactful engineering. For the U.S., the gasoline 4-cylinder 2.0-L Drive-E engine comes in two configurations: a turbocharged variant for front-drive S90 T5 models that develops 250 hp and 258 lb·ft (350 N·m). The all-wheel-drive S90 T6 is fitted with a turbocharged and supercharged version of the same 2.0-L that cranks up output to 316 hp and 395 lb·ft (536 N·m). Next year, Volvo will offer the wonderfully complex plug-in hybrid variant of this setup for the S90.

At 195.4 in, the S90 is marginally longer in overall length than the **BMW** 5-Series and **Mercedes-Benz** E-Class and is almost exactly the same length as **Cadillac**'s CTS, but the Volvo weighs at least a couple hundred pounds more than any of the three, so the energy with which the T6 engine propels the S90 is practically a dynamic revelation. This and the Drive-E engine's smoothness and isolation from the passenger compartment means any concern about cylinder count and refinement effectively is not a concern. The supercharged/turbocharged 4-cylinder is, as claimed, all but free of perceived turbocharger lag and the AWD system ensures that no uncouth torque steer reveals to the driver that there's a hard-working 4-cylinder up front.

The standard 8-speed automatic is an agreeable collaborator and helps this mighty engine to settle in enough to deliver a 34-mpg highway rating and 27 mpg combined.

Refinement and technology focus

The T6s *Automotive Engineering* drove also displayed rewarding ride quality—particularly those cars with the optional air suspension to augment the car's distinctive independent rear-axle design that employs a single transverse leaf spring to augment the hydraulic or air dampers. The front suspension for all S90 models is a double-wishbone layout that delivers the fine steering precision expected of this typically more-expensive design.

So the 2017 Volvo S90 is large enough inside to telegraph true luxury—even if, frankly, some of the interior trim and equipment don't totally seal the deal—and offers enough performance to back up the luxury claim. So Volvo thinks its competitive edge—apart from openly not trying to compete on "sporting" credentials—will be in its envelope-pushing use of autonomous technology.

The S90, Volvo claims, is the first car in the world to offer a standard-equipment semi-autonomous driving system (http://articles.sae.org/14568/)—Pilot Assist II—a "hands-on" configuration that steers and brakes on highways and at speed up to 80 mph. Volvo is careful to say it's mainly designed to reduce the fatigue of driving in stop-and-go traffic. The system is augmented with the S90's "road-edge detection," which Volvo similarly said is the world's first system to eliminate accidents caused by running off the roads.

Bill Visnic

2017 Nissan Titan gets new platform, powertrain, cab and bed features

The second-generation **Nissan** Titan launches with the model's first-ever single cab and adds a direct-injection V8 and 7-speed transmission plus significantly improved vehicle aerodynamics and NVH attenuation. And while the 2017 model does not achieve a net mass reduction versus the previous Titan, fuel efficiency has been improved 28%, engineers claim.

The new Titan also brings a cool new approach to cargo bed illumination and claims an industry first: the first full-size pickup with a 5-year/100,000 mile bumper-to-bumper warranty. There's also a V6 engine in the development pipeline.

With these features Nissan is looking to lure a greater share of the half-ton truck segment's 2.5 million U.S. consumers. "We're standing behind our truck and putting the money where our mouth is," explained Richard Miller, Nissan North America's Director of Product Planning for Truck/SUV/CUV. "We looked at all of the data and all of our testing, and we decided that this is the best way to give buyers who have never driven or owned a Nissan truck before a 'peace of mind' about the Titan's quality."

Miller concedes that a truck is the hardest vehicle to develop because of its broad duty cycle—handling everything from day-to-day commuting to serious work. "It needs to be able to haul, tow, and go off-road," he said. "And it needs to do all of this with a quiet, comfortable cab for the driver and passengers."

New platform and powertrain

Miller and other Nissan technology product experts spoke with *Automotive Engineering* during a recent media preview that spotlighted Titan and two other 2017 models: the all-new Armada full-size SUV and the mid-cycle-refreshed Pathfinder. Each of the three trucks now rides on a unique platform—the 2017 Armada no longer uses the Titan undercarriage as it moves to Nissan's global Patrol platform. (For additional Armada and Pathfinder information, see http://articles.sae.org/14567 and http://articles.sae.org/14902.)

2017 Titan under test in California. Nissan's North American truck engineering team bestowed their latest pickup with greater efficiency and more surprise-and-delight features.

The 2017 Titan adds a direct-injected V8 and two more gear ratios. There's also a new V6 in the pipeline. "Nissan has shown that we have quite a few technologies on our engines, so I think it's safe to say that we're going to have a lot of the existing innovative technologies and a few more to apply," said product planning boss Richard Miller. (Kami Buchholz photo)

The new Titan adds a single cab version for the first time, in addition to crew cab and king cab models. The single-cab half-ton truck's maximum payload is 1930 lb (875 kg). Max towing is a claimed 9730 lb (4413 kg). Starting price for the 4x2 crew cab is under $35,000.

As per the first-generation Titan, power is supplied by a 5.6-L gasoline "Endurance" V8. The new VK56VD engine is rated at a claimed 390 hp (290 kW) at 5800 rpm and 394 lb·ft (534 N·m) at 4000 rpm. Its VK56DE predecessor offered 317 hp (236 kW) at 5200 rpm and 385 lb·ft (521 N·m) at 3400 rpm.

That performance bump is achieved by the addition of direct injection, variable valve timing and lift, as well as new-design pistons, cylinder heads and intake and exhaust systems. The new DI enables 11.2:1 compression ratio, versus the previous 9.8:1.

A **JATCO** 7-speed automatic transmission replaces the previous 5-speed JATCO unit. To help boost fuel economy, the 7-speed uses a cooling line bypass valve. "When the transmission is cold, it will bypass the fluid back into the transmission to get it hot. The key point is that cold oil has a tendency not to flow as quickly or as easily as a hot fluid, so this fluid warmer makes our transmissions and torque converters run more efficiently," Miller explained.

Pairing the V8 and 7-speed represents a claimed 28% fuel economy gain for the 2017 Titan compared to the prior generation truck. Combined fuel economy climbs from 12 city/17 highway to 15 city/21 highway.

Big focus on reduced NVH

Nissan engineers cannot claim a net mass reduction for their new truck. But while Titan isn't lighter than its predecessor, engineers and stylists worked to optimize greater efficiency in other areas of the vehicle.

The 2017 Nissan Titan is offered in five trim levels, three bed lengths, and three cab variants including a new single cab version.

"With quality as a top goal, we didn't want to give up strength and durability just to get mass savings," Miller argued. "So we did everything we could in other areas to improve fuel economy," including using an aluminum hood and various aerodynamic cues that netted a 10% Cd reduction compared to the previous model.

Titan's aerodynamic attributes include an active grille shutter; an extended front overhang; spoilers integrated with the front bumper, roof, and tailgate; aero fairings for the underbody and even a cover for the tow-hook hole; bumper seals;

The 2017 half-ton Titan provides more interior stow space than its predecessor with front storage increasing 33% and rear storage increasing 28%. New second row (shown) under-seat storage includes a locking lid and an integrated foldout flat floor.

and a Titan-first cab-to-bed seal. Miller described the latter as "a rubber seal that works as an air deflector because if air comes into the bed that's like putting a sail out to stop the wind flow."

NVH revamps include replacing solid rubber cab and bed mounts with fluid-filled mounts, resulting in a 10-dB vibration improvement. "By eliminating the higher frequency vibration that typically comes through with a body-on-frame truck that [the new mounting system] means a smoother ride. There's considerably less bounce during highway driving," Miller said. Cabin noise is reduced from improved body sealing, laminated windshield and front side glass, and a three-layer dash blanket versus the prior single layer dash insulator.

Brent Hagan, Titan's Product Planning Manager, claims Titan is a segment leader in cargo utility features. "We know that the bed is what separates a truck from every other vehicle on the road and that utility can make or break a truck," he observed. New cargo attributes include under-the-bed-rail LED lighting: "You can load anything into the bed, and you won't have dark pockets or shadows being cast because when you turn the lights on at night, those 18 LEDs are akin to stadium lighting," he said.

Finally a V6 in the works

While the **Ford**, **GM**, **Ram** and **Honda** Ridgeline competition currently offer V6 power, Nissan is edging closer to its first V6 for Titan. While Miller declined to pinpoint when the gasoline six will join Titan's powertrain portfolio, he said it will be sometime in the second-generation truck's lifecycle.

Titan's future V6 is an all-new engine not used in any other Nissan application, Miller said. "We don't typically develop an engine for one product only. If we buy an engine, like the **Cummins** 5.0-L V8 diesel engine that's available on the Titan HD, then it's OK to have it for one product. But if we internally develop an engine, it's typically applied to multiple programs in North America or globally."

Kami Buchholz

SPOTLIGHT: NOISE, VIBRATION, HARSHNESS

Anti-friction coating

Dow Corning Corp. (Midland, MI) offers a new silver-metallic color for a proven Molykote brand anti-friction coating (AFC) to enhance design options for reducing friction, noise and wear on various automotive components. According to Dow, the new silver-colored Molykote D-709 anti-friction coating offers the same high-performance dry-film lubrication advantages as glossy black Molykote D-708 anti-friction coating, which is proven effective in such applications as brake pad clips, springs and pins. Each Molykote AFC is formulated with polytetrafluoroethylene (PTFE) solid lubricants, organic resin binder and carrier solvent. Properly applied to pretreated parts with various coating methods, these AFCs provide a clean, dry, slippery film as the lubricating solids fill in surface asperities and smooth roughness. Processing is cleaner with less dust and potential contamination. For more information, visit **www.dowcorning.com/auto**.

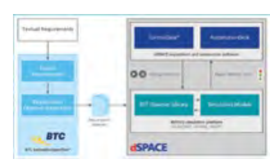
Signal analyzer software upgrade

To speed up noise and vibration data analysis for vehicle manufacturers and industrial machinery, **Brüel & Kjær** (Norcross, GA) offers RT Pro 7.3 enhanced software for its Photon signal analyzer. The RT Pro 7.3 release provides enhanced Fast Fourier Transformation, signal analysis, 1/nth octave/acoustic analysis, modal data acquisition and swept sine measurements, making it suitable for testing acoustic and vibration in applications such as rotating machinery and automated production lines. Powered via a USB 2.0 port and weighing less than 227 g (8 oz), the PHOTON+ unit operates on a notebook PC battery. It has been designed specifically to turn any PC into an instrument-quality portable analyzer that provides instant multi-channel noise and vibration results, as well as onsite data verification. With its extremely low measurement noise floor, PHOTON+ is suitable for performing low-level acoustic and vibration tests in applications such as vehicles and aircraft cabins, claims the company. For more information, visit **www.bksv.com**.

DEF tank drain solution

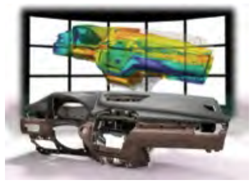
A full stainless-steel version of EZ Drain Valve from **Global Sales Group** (Redmond, WA), the manufacturer of the EZ Oil Drain Valve, is now available for diesel exhaust fluid (DEF) tank applications. Unlike a plastic valve or plug used on some DEF tanks that have the potential to break, the durable, stainless-steel DEF Drain Valve can withstand harsh external elements. Since DEF is highly corrosive, the DEF Drain Valve is designed to withstand these properties, using all stainless steel 304 components and a Viton O-ring to seal. Using a ball-valve design, the DEF Drain Valve is available in different thread sizes and a new lock nut feature allows the valve's final position to be orientated during installation. According to the company, OEMs such as **Caterpillar**, **CNH** and **John Deere** use the EZ DEF valve for their DEF tank drain solution. For more information, visit **www.ezoildrain.com**.

Real-time validation



dSPACE (Wixom, MI) and **BTC Embedded Systems** (Oldenburg, Germany) offer a solution that improves test depth for the real-time validation of safety-critical applications with extension of classical test methods, easier compliance with safety standards and optimal integration and cross-platform use. The combination of the new dSPACE Real-Time Testing (RTT) Observer Library and the tried-and-tested specification tool BTC EmbeddedSpecifier makes it easier for testers to perform simulation-based formal verification. For example, formal verification is recommended by the ISO 26262 standard for testing the functional safety of road vehicles. The new solution complements existing model-in-the-loop, software-in-the-loop and hardware-in-the-loop environments by so-called "requirement observers," which are always active and monitor the compliance with every safety requirement in real time. Any violation of the requirements is registered immediately, triggering an informative message for the user. Continuous requirements monitoring increases the achieved test depth, so more test cases can be covered for each function. For more information, visit **www.dspaceinc.com**.

Foam-fill simulation of polyurethane systems



BASF (Florham Park, NJ) offers an additional service for polyurethane (PU) systems in automotive interiors. The Ultrasim simulation tool has been expanded so that the behavior of PU systems during foaming can now be reliably predicted. According to BASF, the new service has proven especially successful with instrument panels made with the company's Elastoflex E semi-rigid system. **Yanfeng Automotive Interiors** is using the virtual process design for the instrument panels it manufactures for current models such as the **BMW** X1. Based on the CAE model for each panel and a new material description of the semi-rigid system within Ultrasim, a foam-fill simulation is created that allows the customer to spot potential problems with the design and manufacturing of the component before the mold is made. For more information, visit **www.basf.com**.

Miniature pressure sensor

Model ASUH miniature hybrid high-integrity pressure transducer from **KA Sensors** (Danbury, CT) is designed for use in rugged environments from -65 to +300°F (-54 to +149°C) and vibration levels of more than 20 *g*. Its small all-welded stainless-steel housing of 0.49 in dia x 1.31 in (33 mm) weighs 0.4 oz (11 g), excluding the cable. Offering ranges from 0-70 psi (0-4.8 bar) through more than 0-6000 psi (0-414 bar) in sealed gauge, the sensor is created specifically for on-vehicle use, including motorsports and can also be used in a wide range of development, prototype and production testing applications such as dynamometers, engine test stands and wind tunnels. For more information, visit **www.kasensors.com**.

Software platform for smart manufacturing

With FASTSUITE Edition 2, **CENIT** (Auburn Hills, MI) provides an efficient Digital Factory solution for smart manufacturing. The latest generation of CENITs' universal software platform, which is based on the mechatronic simulation of resources and components, enables systems integrators and manufacturers to emulate a real production environment. As a result, the software offers maximum performance through the digital mock-up of the true shop floor setting. FASTSUITE Edition 2 assists with factory automation tasks, from planning to ongoing operation—which includes a wide range of production technologies. According to CENIT, all the technologies and functions interact seamlessly and complement each other in a single, innovative user interface with a standardized data model. For more information, visit **www.fastsuite.com**.

PRODUCT BRIEFS

Power connector line

Able to withstand harsh environments, **Positronic**'s (Springfield, MO) new power connector family provides IP65/IP67 sealing capability. According to the company, the new Panther line of rugged electronic connectors is the first produced by the company to offer IP65/IP67 sealing capability, conformance to EN45525-2 HL3 (a globally recognized standard for smoke and toxicity requirements) and the ability to operate reliably at temperatures up to 200°C (392°F). Panther also features up to 35 amps per contact, shock and vibration performance to EIA-364-28F test condition IV and has an LCP insulator. The strong and versatile Panther family is suitable for use in rail, aerospace, battery, earthmoving and other related applications. For more information, visit **www.connectpositronic.com**.

Digital reference images for die castings

As a new option, **YXLON** (Hamburg, Germany) provides **ASTM** E2973 digital reference images for aluminum and magnesium die castings in its imaging software Image2500 and Image3500 of X-ray inspection systems, including Y.MU2000-D and MU60 AE. The reference images, which historically have only been available as an image catalog for radiographic inspections with film, can now be deployed in digital radioscopy for defect evaluation of aluminum and magnesium alloys in die castings via a second review monitor. According to YXLON, the digital ASTM reference images are an effective basis for film replacement, and users appreciate the benefits of the easy and safe image storage as well as the simple digital data exchange. For more information, visit **www.yxlon.com**.

Custom-designed and special tooling

In addition to **Heimatec**'s (Prospect Heights, IL) standard tooling line, the company offers custom-designed and special tooling service. These tools are designed to suit specific requirements for all CNC lathes, regardless of application, brand or size, with the same quality as their standard tools. Heimatec's tooling experts work directly with customers to design custom tools that solve specific application and manufacturing needs. They manufacture tools for popular machines, such as **DMG Mori Seiki**, **Haas**, **Mazak**, **Okuma** and **Samsung**. According to Heimatec, their engineers work to provide the optimum solution in cutting time, mechanical motion and productivity performance. Additionally, they offer testing onsite to validate their designs. For more information, visit **www.heimatecinc.com.**

VIDEO

SAE Eye on Engineering: Continental's Smart Access Technology

The era of needing keys and the key-fob for locking, unlocking, and starting your vehicle is steadily coming to a close. The future of these tasks belongs to the smartphone. In this episode of SAE *Eye on Engineering*, Editor-in-Chief Lindsay Brooke looks at **Continental**'s Smart Access Technology. The video can be seen at **video.sae.org/12219/**. SAE *Eye on Engineering* also airs Monday mornings on WJR 760 AM Detroit's Paul W. Smith Show. Access archived episodes at www.sae.org/magazines/podcasts.

WHAT'S NEW

Volkswagen engineer pleads guilty in U.S. diesel-emissions coverup

A veteran **Volkswagen** AG engineer pleaded guilty in federal court to a criminal charge for his involvement in the German automaker's ongoing diesel-emissions scandal, marking the first criminal charge to date in the year-long investigation into the company's efforts to circumvent diesel-engine emissions regulations in the United States and Europe.

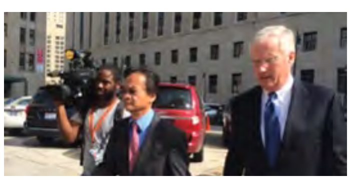


Photo courtesy of 7 Action News in Detroit/ Jonathan Carlson

According to *The Detroit News*, James Robert Liang, who was leader of diesel competence for VW from 2008 until June, appeared in early September in U.S. District Court in Detroit to enter his guilty plea to conspiracy to defraud the U.S. government, to commit wire fraud and to violate the Clean Air Act. That penalty includes five years in prison and a $250,000 fine. (www.detroitnews.com/story/business/autos/foreign/2016/09/09/vw-charges/90118226/)

Read the full story at **articles.sae.org/15004/**.

Jaguar Land Rover constructs Slovakian plant to support 'a truly global business'

Construction has started on a new **Jaguar Land Rover** (JLR) manufacturing facility in Nitra, Slovakia. According to the company, the 300,000 m^2 (3.2 million ft^2) factory—the equivalent of 164 ice-hockey rinks—will manufacture a range of all-new aluminum JLR vehicles, supporting the company's ongoing commitment to deliver high-tech lightweight cars to its customers.

"The start of construction in Slovakia represents the beginning of a new phase in our plan to create a truly global business," Dr. Ralf Speth, Jaguar Land Rover's Chief Executive Officer, said. "The factory will strengthen our international manufacturing capabilities as well as complement our existing facilities in the UK, China, India and Brazil."

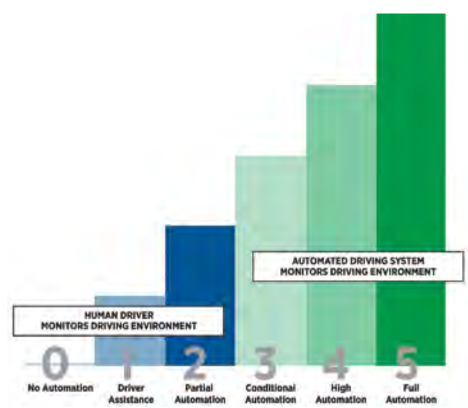
Read the full story at **articles.sae.org/15006/**.

WHAT'S NEW

U.S. DoT chooses SAE J3016 for vehicle-autonomy policy guidance

The **U.S. Dept. of Transportation**'s policy guidance released Sept. 20 on the testing and deployment of automated vehicles validates **SAE International**'s J3016 standard as the global industry reference for defining the six levels of automated/autonomous driving—a topic which had been contested until now.

The DoT guidance document, "Federal Automated Vehicles Policy," states that manufacturers are responsible "to determine their system's AV [automated vehicle] level in conformity with SAE International's published definitions. This applies to both test and production vehicles. **NHTSA** will review the manufacturers' automation level designations and advise them if the agency disagrees with the level assigned by the manufacturer.



The official guidance marks a break from the NHTSA's 2013 language which was sometimes confused as a competing or even joint standard by some in the industry and media.

Read the full story at **articles.sae.org/15021/**.

COMPANIES MENTIONED

UPCOMING FROM THE EDITORS

October 12: Off-Highway Engineering Technology eNewsletter

October 18: Automotive Engineering Technology eNewsletter

October 25: Vehicle Engineering Technology eNewsletter (all markets)

October 31: Automotive Engineering Technology eNewsletter

November: Automotive Engineering Print Magazine
- Cover Story: Here come 48-Volt Hybrids
- What's next for advanced batteries?
- Intelligent Manufacturing
- Product Lifecycle Management product spotlight

November 1: Aerospace Engineering Technology eNewsletter

November 3: Electronics & Connectivity Technology eNewsletter

November 10: Off-Highway Engineering Technology eNewsletter

November 15: Automotive Engineering Technology eNewsletter

November 22: Heavy-Duty Engineering Technology eNewsletter

November 29: Vehicle Engineering Technology eNewsletter (all markets)

December: Automotive Engineering Digital Magazine
- New Technologies in 2017-2018 Vehicles
- Engine Components product spotlight

December: Off-Highway Engineering Print Magazine
- Technology Future Look of 2017
- Drivelines and components
- Simulation: Expediting engine design
- Autonomous vehicles
- Sensors & Actuators product spotlight

December 1: Aerospace Engineering Technology eNewsletter

December 5: Automotive Engineering Technology eNewsletter

December 13: Off-Highway Engineering Technology eNewsletter

AD INDEX

"It's about moving beyond just a focus on 'how do we complete this project on time and on budget?'" notes James Morgan of the Lean Enterprise Inst.

Creating a leaner, 'greener' value stream with LPPD

James Morgan, Ph.D, is a senior advisor for lean product and process development at the **Lean Enterprise Institute**. A former global director of Body Exterior, Safety, and Stamping Engineering at **Ford**, Morgan is a two-time recipient of the Shingo Research Award and co-author with Jeffrey Liker of *The Toyota Product Development System* (Productivity Press, 2006). He has developed and taught graduate courses on both lean manufacturing and product development and shares insights from his work in this month's Q&A.

How does cross-functional planning contribute to an organization being lean and 'green'?

An important lean principle that helps improve cross-functional planning in the development process is "compatibility before completion," and it is a critical part of lean product and process development (LPPD). This is the practice of building compatibility checks into your development process to ensure that designs are compatible with all system requirements right from the start.

These requirements often include interdependent parts, manufacturing requirements, quality, serviceability, and of course, environmental impact. And these requirements must be met before moving forward in the process to production.

It's about moving beyond just a focus on "how do we complete this project on time and on budget" to "how do we align our individual processes and systems to create the best product—in fact, [best] total value stream—possible." And it's about collaboration, not siloed work. It results in minimizing the rework of late changes, reducing workload, and shortening overall lead-time. This creates less waste and optimizes your value stream—and that means less impact on the environment.

You recently toured Toyota headquarters in Japan to learn more about how the company is adapting and improving their LPPD systems. How are they applying LPPD to meet their environmental goals?

Jeff Liker and I spent about a week at **Toyota** HQ, their test facilities, engineering center and manufacturing plants. Toyota's commitment to the environment shows up throughout the organization. Waste of any kind is abhorrent to them, it is part of their DNA so to speak. Whether it's in smaller projects like reusing old Prius batteries for power storage in their facilities or massive, long-term projects like the Mirai fuel cell vehicle and working with various governments to create a "hydrogen powered society," Toyota is constantly thinking green from the start and taking a total-value-stream approach to protecting and improving the environment.

A more typical example I saw during our visit to Toyota was how they went about their effort to reduce vehicle weight to increase fuel efficiency. The interesting thing at Toyota is not just that they're making lighter vehicles but their standard process for doing it. One of the typical ways to reduce weight is to utilize thinner, high strength steels. By doing this, companies are able to not only reduce the individual part's weight, but often reduce the number of parts required. The problem with this strategy is that these materials often have to be formed in a superheated state that requires enormous gas-fired ovens that work in very large batches and require loads of time to heat the material. This process also produces an oxide residue on the parts which must be shot-blasted off after forming.

None of this was acceptable to Toyota. So design engineers, manufacturing engineers and suppliers collaborated in order to deliver both a lighter, more fuel efficient vehicle and a much better value stream. The result was not only a better product, but a remarkable joule heating process that requires only two meters of space instead of more than 30, can heat [sheet] material one blank at a time in five to 10 seconds instead of huge batches, delivers a two-thirds reduction in CO_2, and does not produce any residue and needs no extra operations.

I think this is an excellent example of what LPPD is all about: cross-functional collaboration, learning, and innovating product and process development to deliver solutions that maximize value to the customer and the environment.

Lindsay Brooke

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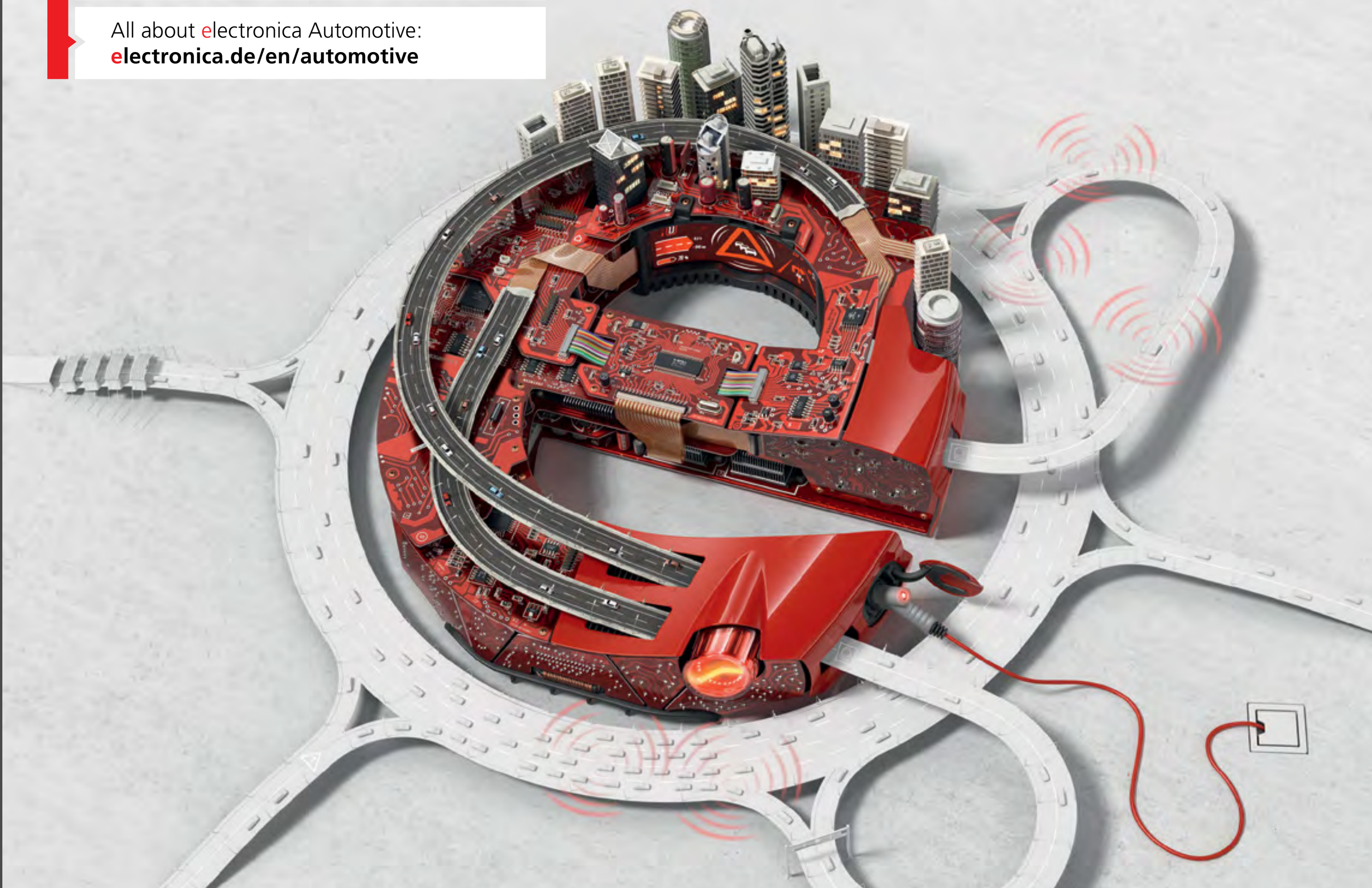

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