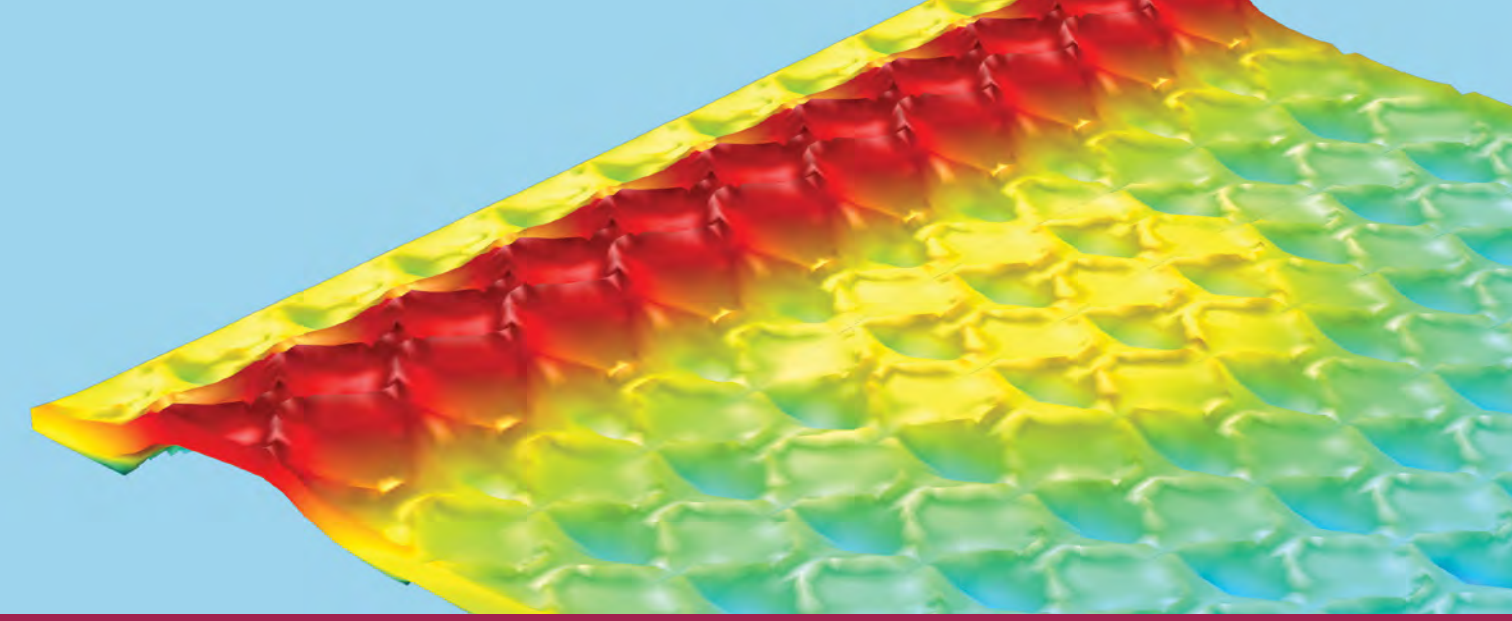

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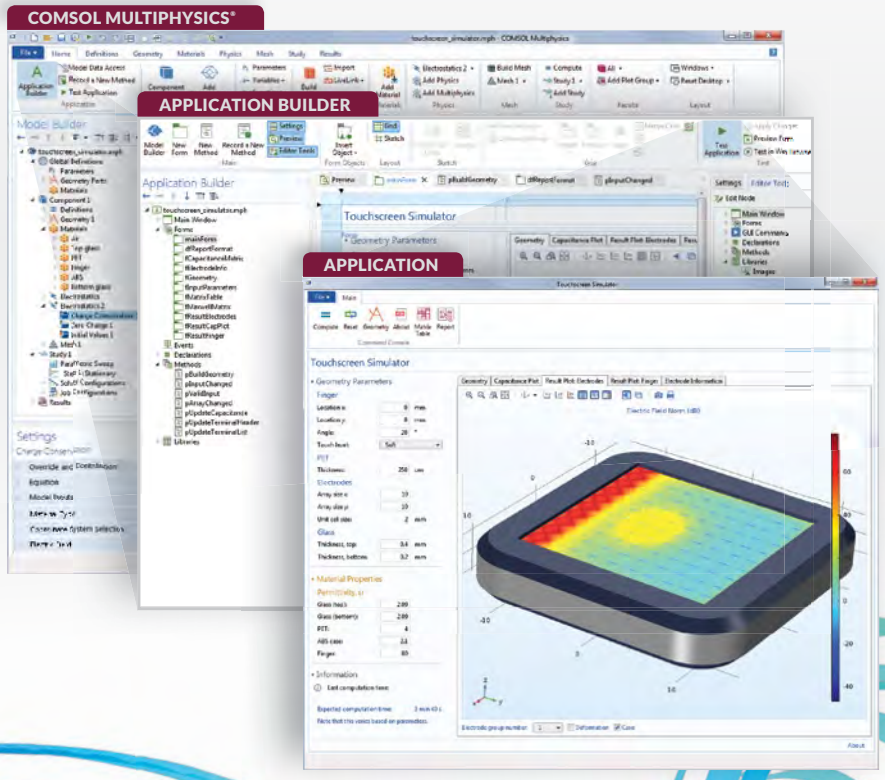

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September 2016 autoengineering.sae.org

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FEATURES

ON THE COVER

Federal regulators are in the process of assessing whether it's technically feasible for the auto industry to comply with the aggressive 2025 greenhouse-gas and CAFE fuel-economy regulations established by the Obama Administration in 2012. Against this backdrop, fossil fuels are at record low prices and consumers are flocking to larger vehicles, complicating the task of attaining the 2025 objectives.

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REGULARS

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EDITORIAL

Bad gas?

It's often the case with proverbs that many are of uncertain derivation. That's true of one of my go-to favorites: "May you live in interesting times."

The irony with this one isn't so much its origin as that it's typically misconstrued to be a positive wish to someone. Just the opposite: it's generally believed to be a translation of a barbed Chinese curse hoping you experience a life of fleeting tranquility.

I can't think of a phrase more apropos to an industry with so many diligent minds devising so much promising technology, yet the advances never seem enough to stay more than one step ahead of the sheriff. As multi-talented engineer Steven Sherman's cover story so adroitly explains, the automakers' shaky *ménage à trois* with customers and the U.S. Clean Air Act is a dance of confounding—and increasingly expensive—complexity.

The trigger for Sherman's no-stones-unturned explanation of the greenhouse-gas conundrum is the **U.S. Environmental Protection Agency**'s Mid-Term Evaluation (MTE) of technical feasibility to achieve the 2022-25 federal emissions (or fuel-economy, take your pick) standards adopted by the Obama administration in 2012. The final findings of the MTE still are almost two years away, but speculating on the outcome has been open sport for months—particularly in light of two fiercely contradictory market trends: a prolonged period of low-priced gasoline and diesel fuel and the concurrent consumer shift to larger vehicles that cheap fuel has wrought.

It's the most unfortunate of situations, but one we've seen before: Regulators want one thing, market forces seem to insist otherwise. The EPA even seemed to telegraph a potential for relaxation of the ultimate 54.5-mpg fleet goal when its assessment report in July indicated the current direction of consumer demand might warrant a reduction. CAFE opponents regarded the report as a mini-victory and a potential herald of further retreat when the final MTE is issued, but industry leaders we've queried are insistent nothing of the sort should be expected. Meanwhile, there's a presidential election well ahead of the final ruling, so these early "optics" may meaningfully shape the next administration's position on this economic- and environment-impacting situation.

For the auto industry itself, the lines are drawing for the 2018 MTE due date amidst the expected higher costs of the advanced technology needed to meet the next required step-up in vehicle fuel efficiency—the average price of a new vehicle so far this year is about $34,000, according to Kelly Blue Book. And a few wild cards have yet to be fully played, including the regulation's "footprint" formula that could begin to bear more significance in future-vehicle development.

The government's not waiting around for everybody to do the right thing. Starting in August, the **National Highway Traffic Safety Admin**. nearly tripled the fine for CAFE non-compliance from $5.50 for each tenth of a mile per gallon for every vehicle missing the calculated fleet requirement to $14 for every tenth-of-an-mpg miss. In 2011, **Jaguar** Land Rover paid NHTSA a $14 million-plus CAFE fine, **Mercedes-Benz** more than $16 million.

With engineers anxious for direction and consumers doubling down on size and comfort, the most agitating takeaway from the GHG struggle might be this: At the moment, not a single conventionally-powered vehicle can meet the 2025 emissions standard. And what should we speculate about where this thing's going when in July, **Ford** F-Series outsold the company's fuel-sipping C-Max by a ratio of 35:1?

Bill Visnic, Editorial Director

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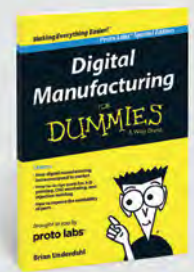

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READER FEEDBACK

Vehicle Lightweighting and "military-grade" Aluminum

I read with interest your article in the August issue and remembered the first time I saw the **Ford** ad [F-150 ad on "military grade" aluminum]. I almost fell out of my chair laughing. The Ford ad people really went over the top on this one.

The key to being "military grade" is that the material must meet certain specifications pertaining to metallurgy and mechanical properties and each product shipped must be accompanied by "certs" proving that the material meets these specifications. Also, the specification number must be printed on the material itself. Example: 6061-T6 aluminum must meet the requirements of QQ-A-250/11. Without the material marking and cert, it is regarded as commercial grade. In theory, they (Ford) should be able to provide some proof of material pedigree.

Go into your local Ford dealer and ask the salesman to define "military grade." If he or she gives you some vague reference, press him or her for further details of the material alloy and spec requirements. It would be interesting to see what kind of answer you get.

Also, the fatigue properties of aluminum are not as good as steel. If you need proof take a look at all the aluminum-skinned aircraft, both commercial and military, that have reached or exceeded their useful lives, all parked in neat rows in Arizona's Davis-Monthan Air Force base storage area.

Aluminum is a great alloy when used in a proper application. A pick-up truck is not that application.

Chuck Rearick
Rearick & Associates
Arlington, TX

Much of Mr. Rearick's career has been spent in the aerospace industry. Currently he's involved with racecar construction.

Engineering challenges are not new

I just finished reading the June 2016 *Automotive Engineering* article, "Possibilities and manufacturing challenges." The authors make it seem as though their study and report are breaking new ground. The engineering, manufacturing considerations, weight, formability, costs, etc., are not new. It is basic engineering-101.

The engineering design and tradeoffs of different materials, mixing and matching of materials in the same body design, manufacturing considerations/processes, terminology and acronyms used, etc., are old hat.

Douglas Evans
SAE Member #: 1245404004

Best issue of AE ever

I have been an SAE member for 60 years and I wanted to congratulate you on your June issue. It was the BEST issue I have ever read! Nearly every article was of interest to me. And the descriptions of new cars, new software, new standards and techniques were just excellent and understandable.

I am retired but during my career I gave four SAE papers at national meetings in Detroit, Houston, etc. The Society is in good hands!

Bill Preston
via email

Correction: Corning 'Gorilla Glass'

Our August cover story on Vehicle Lightweighting contained an error about **Corning**'s 'Gorilla Glass.' The product is actually a glass, not a polycarbonate laminate as was incorrectly stated. The thin, durable material is currently used in the screens of 4.5 billion mobile devices. The automotive-grade variant is produced using a twist on the ion-exchange process used in alumina silica glass manufacturing. Ford's new GT supercar uses Gorilla Glass as part of a 3-layer laminate in the vehicle's windshield, backlite and as an acoustic separator in the rear bulkhead.

Ford engineers claim the Corning material delivers more than five times the strength, pound for pound, of conventional automotive glass while offering a mass savings of more than 12 lb (5.4 kg). For more on the Ford GT application see http://articles.sae.org/14540/.

Lindsay Brooke

Messe München

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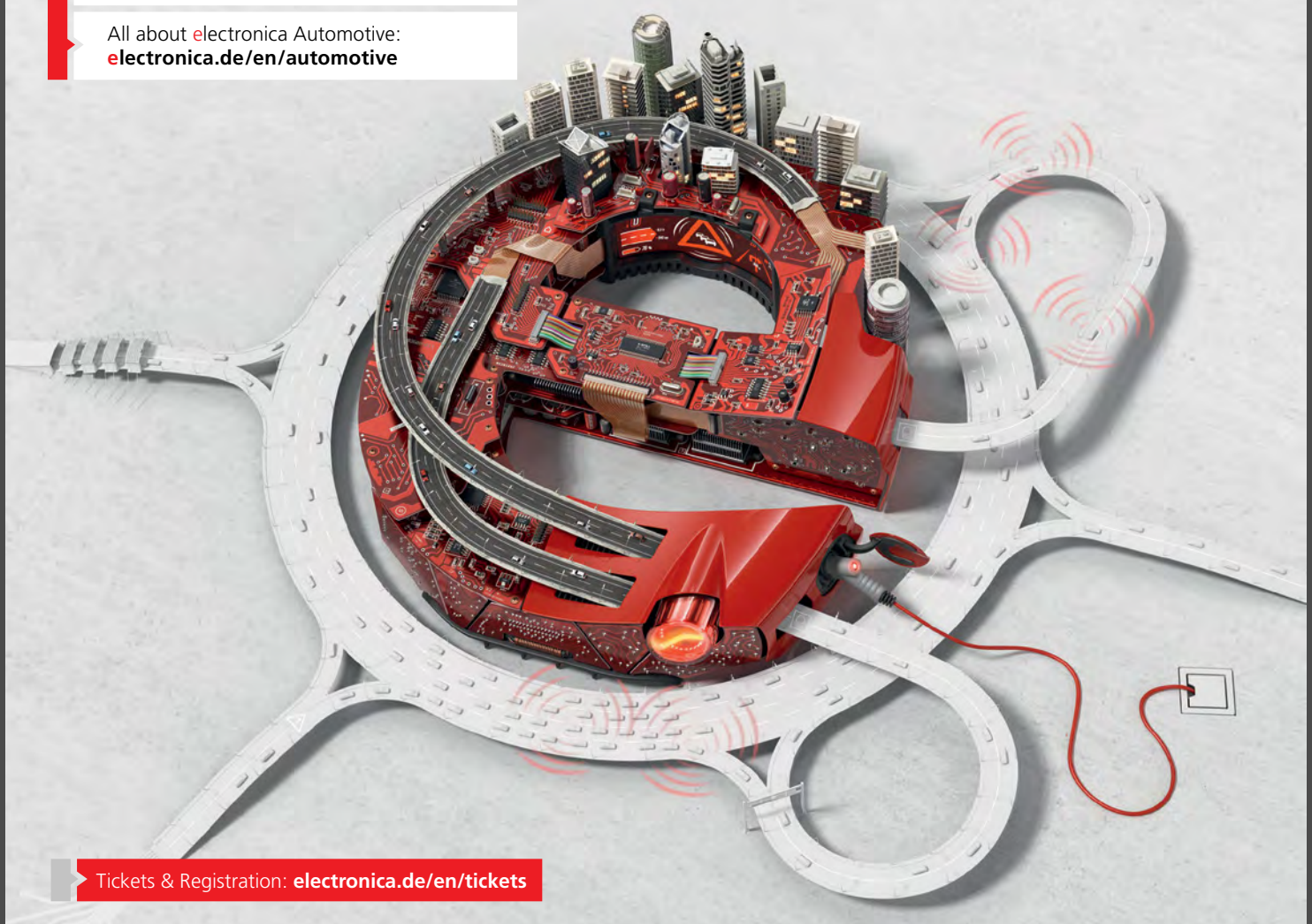

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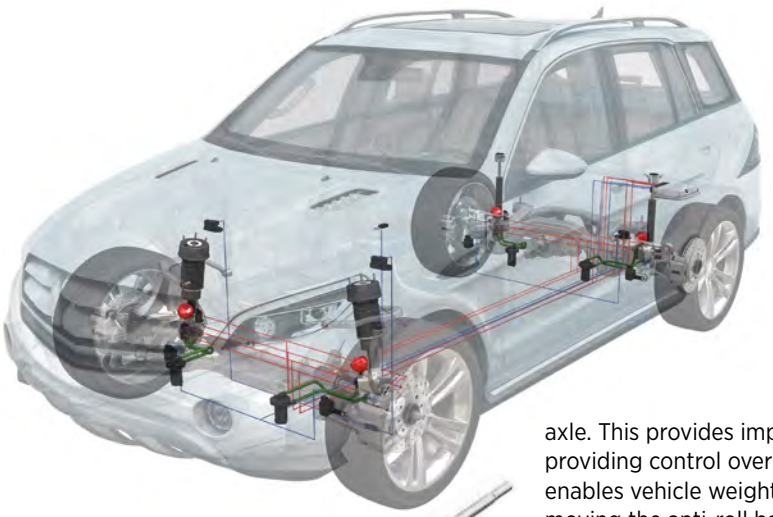
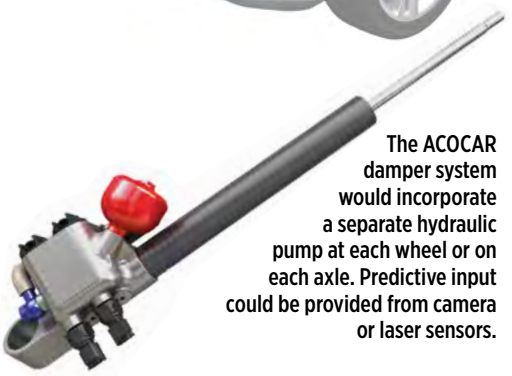
CHASSIS

Tenneco's predictive active ride control may doom the anti-roll bar by 2021



Monroe's ACOCAR system under development would provide independently acting dampers at each wheel able to deal far more effectively with speed bumps and potholes.



The ACOCAR damper system would incorporate a separate hydraulic pump at each wheel or on each axle. Predictive input could be provided from camera or laser sensors.

Are the anti-roll bar's days numbered? The answer is probably "yes" — at least for premium-model cars and light trucks, as advanced active ride control systems that use the vehicle's sensor array become more widely adopted.

Tenneco, through its Monroe subsidiary, is currently developing a fully active suspension system with significant advances over incumbent semi-active systems.

Current production suspension systems typically rely on electronic actuation of the damper valves to improve damping response. In the case of the **Monroe** CVSA2 system, the dampers are equipped with two electronically activated valves to control both the rebound and compression strokes of the dampers. The aim is to improve ride and handling particularly for luxury models, SUVs and sports cars.

A further development of the system, called CVSA2/Kinetic, can already eliminate the need for anti-roll bars by providing a hydraulic connection between the CVSA2 dampers on each axle. This provides improved ride comfort by providing control over vehicle roll. This system enables vehicle weight to be reduced by removing the anti-roll bars, but the level of ride control is still limited by the reliance on wheel movement to generate the damping forces.

Tenneco's latest ride-control system, ACOCAR, eliminates the need for anti-roll bars. There are two variants of the system under evaluation, as *Automotive Engineering* was shown during a recent demonstration in Europe. One has no interconnection between suspension dampers on the same axle. In this case, each damper is equipped with an integrated electrically powered pump, which continuously circulates oil through the shock absorber, with damping valves that can be controlled independently to control vehicle body movement.

The other ACOCAR system uses a single pump for each axle, providing pressure to each damper as required. The result is a suspension that can react very rapidly to changes in surface quality. Our demonstration vehicle was a **Range Rover** equipped with ACOCAR. Part of the demo included driving with two wheels on smooth tarmac and the other two on a broken surface. Despite the significantly different surfaces the vehicle showed little deterioration in ride quality.

Cornering at speed also demonstrated the system's ability to contain roll. Roll angles were limited to a few degrees by the calibration, but the controlled wheel movements ensured tire/road contact to improve vehicle handling.

A production version of the ACOCAR system is expected in the 2021-22 timeframe, according to Esteban Mendez, Tenneco Senior

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Research Engineer.

"The ACOCAR system has a much bigger impact on the total vehicle than the CVSA2 system," Mendez said. "The ACOCAR system requires much more from the OEM from an integration point of view. It requires a power source for the hydraulic pumps and it also requires full integration with the vehicle's ECU and everything around it."

The basic ACOCAR system is still a reactive set-up, able to respond much more quickly to changes in surface and to control roll angles. Further improvements could be offered if the system incorporated other sensors. For example, a camera scanning the road surface ahead of the vehicle would enable the system to anticipate factors affecting ride quality and prepare the damping system for them. Signals from such a camera system could be combined with existing cameras responsible for road sign recognition as well as scanning road markings and traffic lights.

If road scanning is added to the primary ride control, "you would be really able to pre-set the suspension at events like a speed bump, or pothole to minimize the body motion even further, compared with what we are doing today," commented Gunther Bismans, Monroe's Technical Team Leader for Vehicle Dynamics.

"Even in the case of potholes, if you know that they are coming, you can keep the wheel up and prevent it from falling into the pothole to minimize the resulting impact," he explained, adding "I would expect a big improvement from such a system."

Other sensors, such as radar and laser based systems are also under evaluation. Camera-based systems would obviously not work effectively in low light conditions.

Tenneco engineers would not proscribe the sensor technology it is using, but would leave that choice to OEMs to decide which system they would prefer to offer. Testing with a range of sensors is being carried out to ensure that the system would work effectively regardless of the sensor system chosen.

John Kendall

CHASSIS

More details emerge of Citroën's new "hydraulic cushion" suspension

Citroën is using a Cactus as a test vehicle for its "Advanced Comfort" development program.

First details are emerging of **Citroën**'s new vehicle refinement package including an innovative suspension system, the existence of which was revealed by *Automotive Engineering* late last year; see http://articles.sae.org/14498/.

At that time, Citroën CEO Linda Jackson said of the still secret program: "The technology we are developing will deliver what I call the 'Citroën ride.'" Since then the Advanced Comfort Program has moved toward production. It uses secondary dampers that Citroën quaintly refers to as "hydraulic cushions" to complement the regular shock absorber and springs of each suspension unit.

The dampers work progressively, one for rebound, a second for compression, positioned at the upper and lower extremes of each a unit instead of conventional bump stops. They should deliver better control throughout much of the suspension's travel.

The new suspension is designed to be cost effective and applicable across Citroën's model range. When it becomes available, possibly early 2017, it will mean au revoir to the relatively complex and expensive oléopneumatique systems that started with the ground-breaking 1955 DS and that are still used on some current versions of the C5.

Striving to reduce system cost

Citroën chassis engineers are refining the system on a Cactus test vehicle together with other complementary technologies to provide an integrated, holistic approach to smoother, quieter travel. More than 30 patents have been applied for, which means Citroën engineers are being a shade diffident about its design and development of the new system.

But what they are saying is that in instances of what it terms "slight compression and rebound," springs and shock absorbers work together to control vertical movement without need of the "cushions." But in "more significant" compression and rebound situations, springs and shock absorbers then work together with the "cushions" at suspension travel extremes gradually slowing movement, absorbing and dissipating energy, whereas typically, regular bump stops absorb energy suddenly and then partly return it.

Jackson said that if manufacturing costs can be met the new suspension's use will be extended across Citroën's car range, even to the little C1. This would mean the end of oléopneumatique. But it is not a standalone technology to smooth Citroën's future. Said Jackson: "Comfort is not just about suspension; it also encompasses seats, storage and the way you drive."

Going big on adhesive bonding

So when the suspension has completed its subtle damping, the bodyshell then enters the picture. Body stiffness figures have risen rapidly and hugely for

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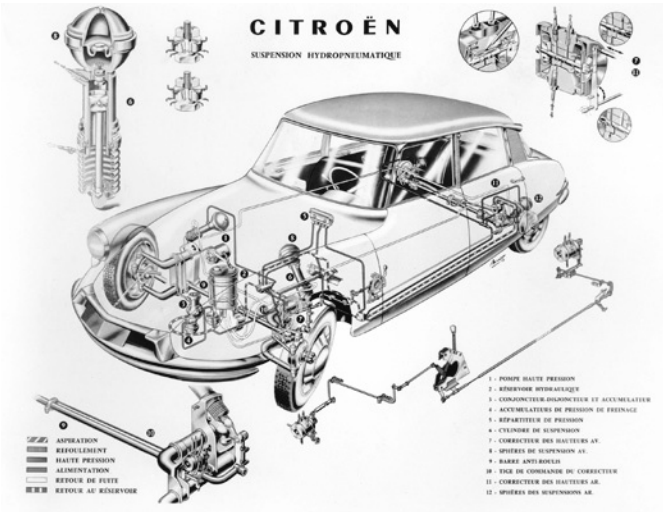


All pipes and spheres; what the plumbing looked like in the 1950s Citroën DS, one of the era's most advanced production cars.

almost all cars in recent years and Citroën believes that its use of structural bonding will take this further.

It is developing an "industrial process" specific to the company to bond structural parts using a discontinuous line of adhesive with an electrical weld point used only if the line is interrupted.

It is known that secondary dampers which Citroën engineers call "hydraulic cushions" complement the regular shock absorber and springs of each suspension unit. The dampers work progressively, one for rebound, a second for compression, positioned at the upper and lower extremes of each a unit instead of conventional bump stops.

Citroën refers to "significantly greater overall body rigidity" being achieved – typically some 20%, a huge improvement over what is already in production and that should achieve a very considerable reduction of vibration. There will also be cost and weight benefits, with the reduction in electrical welds required.

Seating is another complementary area to improve comfort. Comfortable seats have long been a Citroën forte but now memory foam, a la mattresses, are set to play a role, shaping to an individual passenger's body contours. Materials used include polyurethane foam and viscoelastic or textured foam.

The company has improved acoustic comfort and reduced vibration in recent models, including the latest C4 Picasso, which uses the PSA (**Peugeot Citroën**) Group's EMP2 platform, via damping of the front subframe and use of a dual-material acoustic shim for the rear suspension.

All of these development programs are incorporated in the test program Cactus. Depending on development program advances, including further patent applications, Citroën may release more information on its advanced comfort program at the 2016 Paris Motor Show, and some elements of the technologies will appear sooner rather than later.

Stuart Birch

AUTONOMOUS TECHNOLOGY

JLR prepares to leave the road — autonomously

JaguarLandRover engineers are confident that when a driver of one of their future all-terrain autonomous vehicles wants to leave the pavement, technology will continue to provide guidance along gravel lanes or mountain trails, automatically checking ahead for anything from changing surfaces to overhead branches and threatening boulders.

And just as future V2V (vehicle to vehicle) communications capability will become available for autonomous on-road driving, it will also be available for off-road, constantly transmitting and updating warning information about obstacles and potential dangers to any following vehicles.

All this is part of a significant R&D program focused on off-road connected convoys. "In the future we will offer autonomous driving over any surface or terrain," said JLR Product Strategy Director, James Towle.

Over the next four years, JLR will conduct real-world testing of Connected and autonomous technology using a fleet of 100 vehicles. Currently, it is running at least 10 main research projects in this area.

But that doesn't mean the driver can take a nap while the vehicle claws its way through the jungle. There is a distinct difference between autonomous and driverless system capability, explained Towle. So R&D is concentrating on giving the driver focused technology support: "We aren't looking at simply replacing the driver," he said

JLR is also determined to retain the established character of its products while imbuing a different type of emerging trust in the vehicle and its driver-support technologies.

Sensor building blocks

For its autonomous program, JLR is collaborating with **Bosch** in integrating next-generation sensor technology and processing power. "For example, we are adding more megapixels to stereo cameras," said Bosch Customer Chief

All-terrain autonomous driving including vehicle convoying is a major part of JLR's R&D program.

Part of JLR's autonomous all-terrain driving research is Terrain Based Speed Adaptation.

Engineer, Sven Lanwer. "This will increase in the future to provide more precise information; bandwidths are going up to give greater capabilities."

Lanwer works closely with Chris Holmes, JLR's Senior Manager Research, who said advances in sensor technology allied to software are providing significant new solutions. Ultrasonic sensors developed from those used as parking aids, are part of JLR's predictive off-road autonomous R&D to anticipate surface changes.

While information quality needs to improve, increased quantity needs to be controlled. Is there a danger of giving the driver too much information by not filtering it sufficiently?

"It is a difficult question to answer," stated Holmes. "What we are showing you [at JLR's 300- acre Gaydon, U.K., proving ground] are some baseline building blocks that we are putting in place. It is the art of the possible. Technologies are evolving at a rapid rate based on sensor improvement and, coming together with software advances, are giving high level capabilities. So we are looking at many ways of how to advise the driver."

This could include increased use of head-up displays and certainly of voice-command systems, the engineers told *Automotive Engineering*. It is no use in potentially dangerous or stressful situations putting up information on a screen while the driver's eyes are focused where they should be—outside the cabin. Could tonal gradations of voice alert be considered to soothe and provide confidence without adding to tension? Possibly.

Certainly the driver must have confidence and belief in what the car is telling them, just as he or she has confidence today in brakes and steering operating safely.

Said Towle: "An intelligent car is never distracted because it is connected—it can even be aware of situations developing over the horizon. The aim of our autonomous all-terrain driving research is to make the self-driving car viable in the widest range of real life, on and off-road driving environments and weather conditions."

He added that over time the driver would indeed learn to "trust" the vehicle.

JLR is confident that this is going to happen. Peter Virk, JLR's Director of Connected Technologies, added: "In less than three years I predict that every new car sold in the world will be 'connected'." But he also stressed that giving the right information at the right time to the driver was essential.

DSRC is key to convoying

While the company is making use of off-the-shelf and established technologies like ultrasonics, radar, stereo cameras, LiDAR and radio systems, these are being improved although it is more a matter of evolution than revolution.

Key autonomous or semi-autonomous programs demonstrated by JLR to the author included Terrain Based Speed Adaptation, which adapts speed automatically to changing surface conditions and also improves comfort via suspension settings. A stereo camera scans the route ahead with features mapped against different target speeds, making decisions about appropriate speeds for conditions.

Surface ID is a fundamental element of autonomous driving on any terrain. Artificial intelligence can assess surroundings and make what JLR describes as "appropriate decisions," ultrasonic sensors scanning 5 m (15 ft) ahead of the vehicle. Surfaces including sand, gravel and snow are scanned-in to create a database, which is cross-referenced with real time ultrasonic returns, allowing the vehicle to pre-emptively optimize relevant settings.

The Connected Convoy System using wireless Dedicated Short Range Communications (DSRC) uses information including vehicle location, wheel-slip, changes to suspension height and wheel articulation. The DSRC works with current production technologies such as All-Terrain Progress Control and Terrain Response settings.

Although seemingly useful for

JLR Connect research into V2V data sharing could lead to a major safety advance for off-road driving in challenging conditions.

military applications (a **Land Rover** bailiwick), a JLR spokesperson said the R&D Connected Convoy system is focused only on civilian applications.

Overhead Clearance Assist, another new system, is aimed at both on- and off-road applications. It can cope with overhanging branches off road or warn the driver that roof-carried objects such as bicycles could cause a problem when entering a low-overhead parking structure. To operate the camera-based system, the driver simply adds the height of anything carried on the roof to the known height of the vehicle and would then be alerted by the system to any likelihood of entrance to a low height area.

On-road technologies under development include a "Safe Pullaway" system to prevent a vehicle colliding with one in front, typically at roundabouts or intersections when driver mental workload is high. A forward-facing stereo camera keeps watch on the area immediately ahead of the vehicle. If the driver tries to accelerate from standstill and an object ahead is detected, the car will not move and a visual warning is shown.

Of particular interest in JLR's on-road technology demonstrations was Co-operative Adaptive Cruise Control (C-ACC) using vehicle-to-infrastructure (V2I) and V2V communications to enhance existing radar ACC systems.

DSRC wireless is used to facilitate reaction within "a few milliseconds" to messages from the vehicle in front. The following vehicles would brake at precisely the same moment and rate as a lead car. This could facilitate autonomous platooning, with a gap time between vehicles of as little as 0.4 s. At present, depending on market, ISO standard for ACC is about 0.8 s.

Sampled by the author on a track, the effect was both worrying (initially) and reassuring (subsequently) as the system was activated. Following very close behind another vehicle improves radar ACC effectiveness but does concentrate the driver's mind, with a need to overcome the reflex action of braking hard as the red lights of the vehicle ahead illuminate.

Quite what the law would make of this has not been defined. But like most aspects of autonomous driving, it will be legal and driver/vehicle occupant acceptance of such apparently esoteric systems that will determine their introduction—even though their efficacy may have been proven beyond reasonable doubt.

Stuart Birch

AUTONOMOUS TECHNOLOGY

Delphi launches driverless pilot program in Singapore, aims for SAE Level 4 operation by 2019

Delphi Automotive on August 1 announced an extensive autonomous-vehicle pilot program in Singapore, aimed at demonstrating cloud-based fully automated mobility on demand (AMoD) capability "at the [**SAE**] Level 4 performance level" by late 2019, said Glen DeVos, Vice President of Delphi's Business Services Unit based in Mountain View, CA.

Operational capability is expected by 2022. Delphi is partnering with the Singapore government's Land Transport Authority (LTA) on the multi-phase project. The initial phase, to be conducted through 2019, will involve a fleet of six modified production vehicles operating at low speed on fixed routes in the island nation's "one north" area, a business park that is currently serving as a test bed for autonomous-vehicle development, DeVos explained in a recent media briefing.

Engineers acting as "safety drivers" will accompany select commuters during the first pilot phase. The program's second phase "will use a true purpose-built, autonomous mobility-on-demand vehicle," DeVos said—essentially driverless taxi-pods that can be summoned by customers. When completed the program "will show we have the complete 'ecosystem' and durability, including data analytics and reaction by the end consumer," he said.

Delphi will announce an additional pilot in North America later this year and will also replicate the program in Europe. The second-phase bespoke vehicle will require automated door operation to easily accomodate passengers with physical disabilities, DeVos explained.

Delphi President and CEO Kevin Clark said in a statement that the AMoD project will demonstrate his company's prowess in automated software, multi-modal sensor technology

The project's initial phase through 2019 will involve a six-car fleet of modified production vehicles operating at low speed on fixed routes in Singapore's business park autonomous-vehicle test bed. (Sid Quah photo)

Audi "has a good success using modified Audi SQ5 vehicles" in its autonomous road testing to date said Greg DeVos, but details on the Singapore phase-1 test fleet were not yet released when this article was published.

and systems integration while showcasing Singapore's leadership in connected-vehicle and autonomous infrastructure. Since 2014 the **Singapore Autonomous Vehicle Initiative** (SAVI) has increased autonomous-vehicle research and testbedding with various industry partners.

CTO Jeff Owens noted that the Singapore program will leverage technologies used in the first-ever coast-to-coast U.S. autonomous drive conducted by Delphi in 2015. That project used an **Audi** SQ5 platform and was a significant step in creating what Owens called "an end-to-end solution" for new mobility markets. The trans-U.S. drive "caught Singapore's attention," noted DeVos.

The Singapore LTA is studying ways to assist commuters in their daily round trip from home to mass-transit station to workplace. Offering on-demand automated vehicles on a 24/7 basis for what planners call "the first mile" and "last mile" of the typical commute would, they believe, increase use of mass transit systems and reduce overall traffic congestion and vehicle emissions in the process.

"It's not easy to get to mass transit in Singapore so people take taxies, increasing congestion in the process," DeVos asserted. He added that Delphi intends the service to include goods and services in addition to people.

Delphi is conducting its own mapping for the three highly controlled routes included in the Singapore project. The company is still finalizing its "five or six" supplier-partners, including that for the cloud platform. The team could include **Mobileye**, said DeVos. The effort "could possibly lead to a production-intent mapping service," he said.

Mapping the 7 to 8 km (4.3 to 4.9 mi) of each of the three routes to a 30-cm (12-in) level of accuracy consumed 4 to 6 weeks of time, including data compilation.

Delphi had not yet revealed OEM and models of the initial test-fleet vehicles at the time this article was published.

"With AMoD, the cost of the trip goes down significantly," DeVos said. "We expect this project will prove our [autonomous] technology is robust and that consumers will use it."

Lindsay Brooke

MATERIALS

Honda's new e-motor slashes expensive rare-earth content

Honda Motor Co. and **Daido Steel Ltd.** recently scored a strategic win when they announced the first production application of a new magnet material for electrified vehicle motors.

The material—hot deformed neodymium—is being used first in a new permanent-magnet traction motor powering Honda's 2017 Freed Sport Hybrid compact minivan. Significantly, the material is not a "heavy" rare-earth metal, one that requires "doping" with dysprosium or terium rare earths to achieve high heat-resistance characteristics. Yet it has the high magnetic and thermal performance necessary for use in EV and hybrid vehicle e-motors, according to the companies.

A rotor used in Honda's new e-motor for the 2017 Freed hybrid containing the new magnet material co-developed with Daido Steel.

The new magnet material, co-developed with Daido Steel, brings Honda one step closer to effectively reducing content of "heavy" rare earths in its e-motors going forward. Cost and reliable supply are the reason: Chinese mines currently supply more than 93% of the world's rare earth elements including neodymium and dysprosium that are essential to scores of magnetic products (though 65% of the world's reserves lie elsewhere).

In 2010, China briefly embargoed exports of rare earths to Japan after a maritime incident involving one of its fishing boats allegedly operating in Japanese waters. Increased tensions with China over disputed oceanic boundaries, the metals embargo and opportunity to reduce material cost likely prompted Honda powertrain planners to develop less risky alternatives to replace the heavy rare-earths, according to experts.

The **U.S. Dept. of Energy**'s REACT (Rare Earth Alternatives in Critical Technologies) program also aims to find low-cost and reliable alternatives for rare earths.

Although classified as a rare earth, neodymium (Nd) is a fairly common element, no rarer than cobalt, copper and nickel. When compounded with iron and boron (Nd2Fe14B) it inherently offers much greater magnetic strength than other permanent magnets, allowing use of smaller, lighter magnets in a wide range of commercial applications.

Daido Electronics, a subsidiary of Daido Steel, has been mass-producing neodymium magnets using hot deformation. The process differs from sintering which is typically used in magnet production. Hot deformation enables nanometer-scale crystal grains to be precisely aligned. The resulting crystal grain structure is approximately 10 times finer than that of a sintered magnet.

This makes it possible to produce magnets with greater heat resistance properties without the need for doping with the expensive "heavy" rare earths. To accommodate the new magnet Honda designed a new traction motor with a revised rotor shape designed to optimize the flow of the magnetic flux.

A market for the newly-developed hot deformed neodymium magnet opens the door for Daido Steel into the global electrified vehicle supply chain, which for traction-motor magnets has been dominated by sintered Nd magnets. Daido Electronics built a new production line at its Nakatsugawa City plant, and sources its magnetic powder from **Magnequench International** in Toronto, Canada.

Interestingly, the Nd2Fe14B magnet alloy was developed in 1982 by **General Motors** and **Sumitomo Specialty Metals** in response to the high cost of samarium-cobalt (SmCo) magnets.

Lindsay Brooke

PROPULSION | FUELS

GM, Honda execs agree: Higher octane gas needed to optimize ICE efficiency

Raising the octane level of pump gasoline in the U.S. is integral to optimizing advanced combustion engines now in development, said **GM** and **Honda** executives at the 2016 **CAR** Management Briefing Seminars in Traverse City, MI. Their comments prompted positive but non-committal comments from Chris Grundler, Director of the Office of Transportation and Air Quality for the **U.S. EPA**.

During a panel discussion on future powertrains, Dan Nicholson, VP of Global Propulsion Systems at GM, and Robert Bienenfeld, Assistant VP of Environment and Energy Strategy at American Honda, agreed that the industry must push for a higher fuel-octane "floor" in the U.S.

"Higher octane fuels are the cheapest CO_2 reduction on a well-to-wheels analysis," Nicholson told panel moderator Brett Smith of CAR. "Fuels and engines must be designed as a total system. It makes absolutely no sense to have fuel out of the mix" of engine-technology discussions, he asserted.

Nicholson added that higher-octane, purpose-designed fuels "can be delivered very cost effectively." A **U.S. Dept. of Energy** analysis proved the benefit of higher octane levels in improving combustion efficiency and reducing engine-out CO_2, he said.

Honda's Bienenfeld pointed out the benefits of higher fuel octane levels on advanced turbocharged engines operating under high-load conditions and in large-vehicle applications. He noted that boosted gasoline engines, hybrids and fuel-cell vehicles are on the future-development path at Honda. Nicholson touted the trend toward higher Otto-cycle compression ratios and said his engineering teams are looking at Miller cycle combustion, in conjunction with turbocharging, "earning its way into the portfolio."

Nicholson also said he's bullish on diesels in the U.S., "which is one of the few

Robert Bienenfeld of Honda (left) and GM's Dan Nicholson are on the same page regarding the engine-efficiency benefits of higher octane fuel. (Lindsay Brooke photos)

growth markets" for compression-ignition engines, he stated.

Regarding 48-volt hybrids, Honda considers them to be cost effective "if the [current] standards stop at 2025," Bienenfeld said.

EPA's Grundler, speaking at MBS later in the day, noted that his agency is participating in the U.S. Dept. of Energy's Optima project studying future fuels and has a working group focused on gasoline octane. "Fuel changes are not part of the TAR [Technology Assessment Report, part of the Mid-term Review of the current CAFE regulations]," he said, while suggesting that higher octane levels be considered for after 2025 "as long as increasing octane levels do not increase greenhouse-gas emissions."

The Optima project aims at developing co-optimized fuels with a range of new engines for light-, medium-, and heavy vehicle use. Announced at the **SAE** High-Efficiency Engines Symposium by Dr. Wagner, Director of the Fuels, Engines, and Emissions Research Center at **Oak Ridge National Laboratory**, Optima is targeting a 30% reduction in petroleum consumption, per vehicle, compared with a projected 2030 base case that uses today's fuels. The initiative is a collaboration with producers of gasoline and ethanol and the auto industry.

If Optima achieves its goal, it could reduce petroleum consumption by 4.5 billion barrels and save consumers up to $50 billion, according to the DoE.

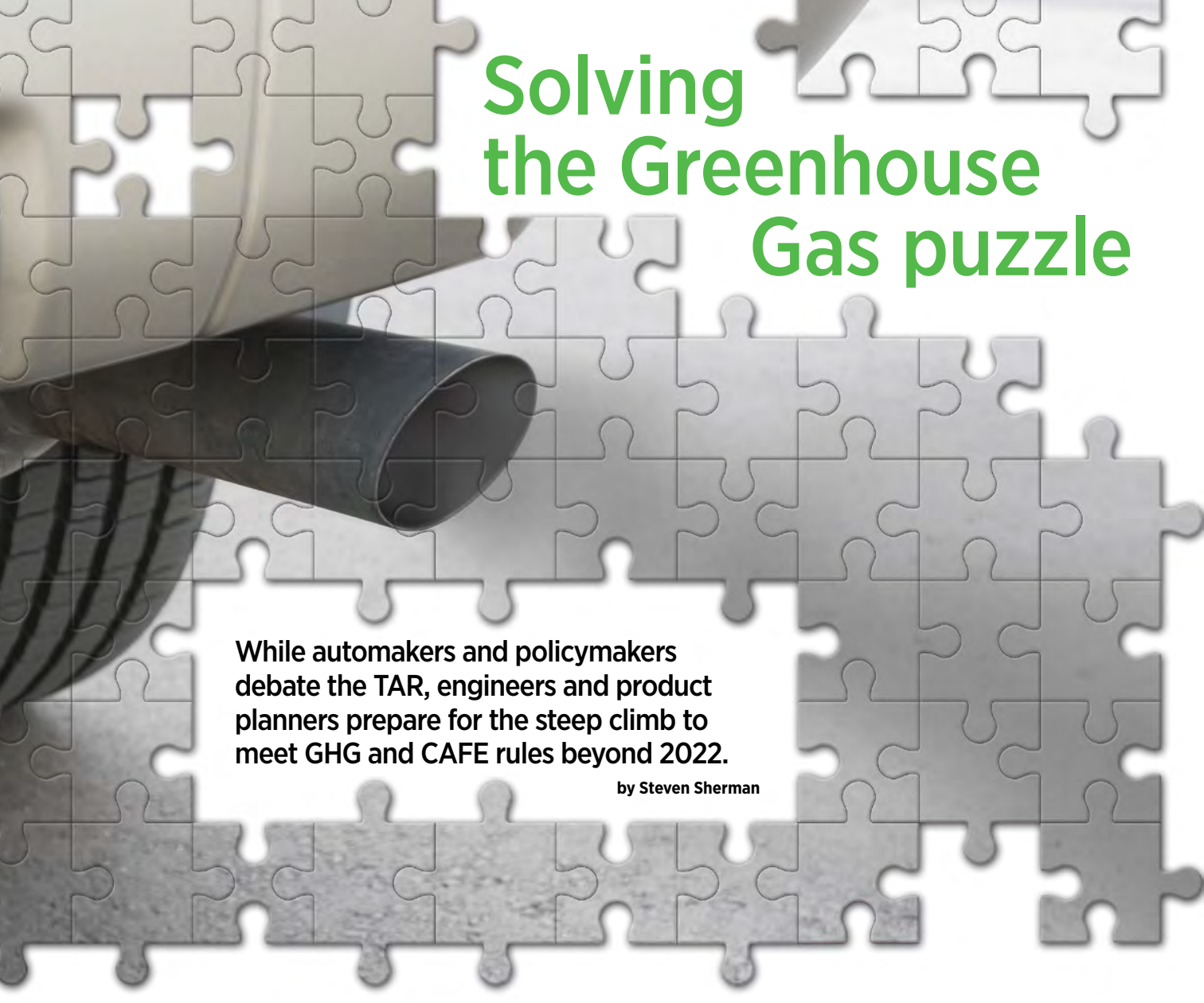
Raising the U.S. octane "floor" will be essential for new combustion strategies currently in development for the 2020s including advanced Miller cycle and those combining lean-burn and stoichiometric operation aimed at achieving peak efficiency levels of 50% and above. ORNL's Dr. Wagner told the SAE audience that some multi-cylinder dyno engines have pushed beyond 55%.

Mazda's Skyactiv program is progressing through G1, G2, and G3 development stages toward a marriage of Otto and Diesel cycle characteristics. Engineers' target for the G3 is 18:1 compression ratio at lambda 2.5—a 40% improvement in thermal efficiency by setting the ideal pressure and temperature for homogeneous charge compression ignition (HCCI).

In Europe, the 102-RON (research octane number) "super premium" gasoline that's widely available helps deliver a 10% increase in fuel efficiency for engines running compression ratios above 11.5:1, compared with engines running 9.0 to 9.5:1 using the 95-RON fuel that's marketed as the mid-grade gas in Europe.

Lindsay Brooke

Solving the Greenhouse Gas puzzle



While automakers and policymakers debate the TAR, engineers and product planners prepare for the steep climb to meet GHG and CAFE rules beyond 2022.

by Steven Sherman

When the **U.S. EPA** published its Technical Assessment Report (TAR) draft in July on how well the auto industry is meeting federal fuel economy mandates, as a prelude to the Mid-Term Evaluation of the 2022-2025 national program for Corporate Average Fuel Economy, voices from all sides chimed in.

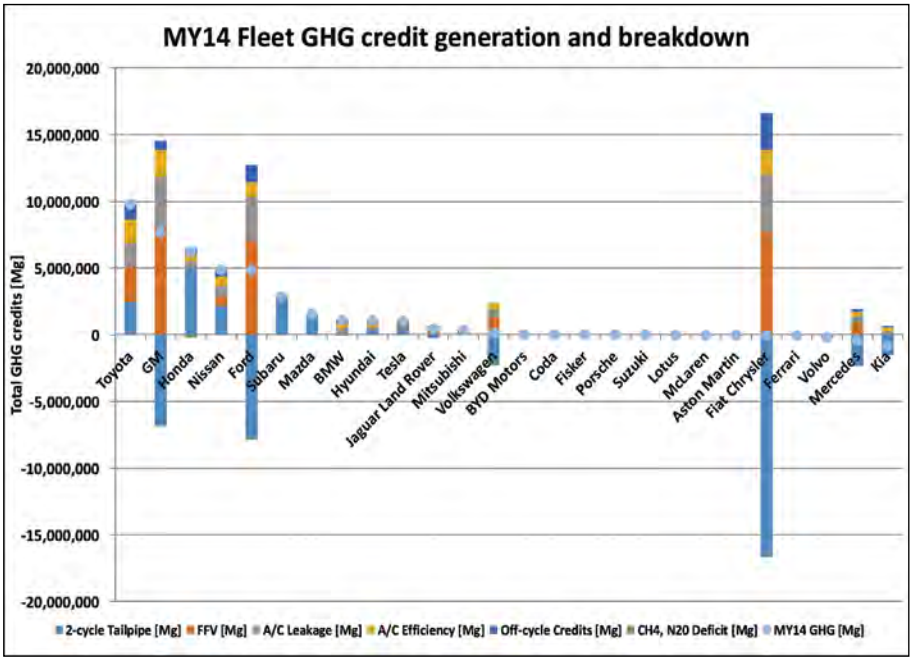
Seeing the TAR draft, some media misinterpreted it as the government backing off from its 54.5-mpg target. That certainly is not the case. Recent presentations and statements from EPA and **California Air Resources Board** (CARB) leaders indicate the agencies are already thinking beyond 2025. California even has some legislation to reduce greenhouse gas (GHG) emissions to 80% below 1990 levels by 2050. Outright calls for retreat from the present course have been rare thus far, despite low retail fuel prices not expected when the current program was established in 2012.

Few industry leaders are betting that the 2025 standards will be relaxed in the Mid-Term Evaluation of progress made to date. Due to be announced no later than April 2018, the MTE determines the technical feasibility of reaching the 2025 GHG targets. (CAFE and GHG are subtly different; see sidebar.) Overall, OEMs broadly appear committed to stay the course—a logical path given their multi-billion investments in technologies aimed at improving fuel efficiency and reducing CO_2 emissions, not only in the U.S. but also in global markets.

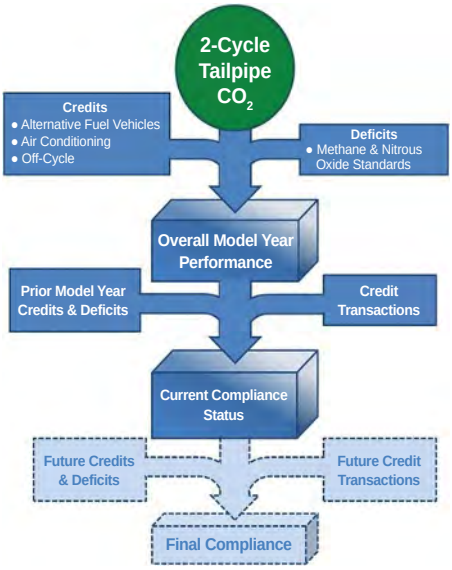
They also face dramatically increased fines for noncompliance, arguably making GHG reduction slightly more important than CAFE, given that it is enforced under the Clean Air Act. Violation means fines up to $37,500 per vehicle and loss of sales certificate. Penalties for CAFE were recently increased to $140 for every mpg under the standard, per vehicle (up from $55).

U.S. politics could impact the current regulations. There's no way to discern whether the next U.S. administration will be in full accord with the last seven years of GHG-reduction efforts.

While OEMs continue wringing higher efficiency from internal-combustion engines (ICEs) and conventional drivetrains, it's clear that more electrified vehicles will be required. Those companies already ahead of the curve are well aware that the challenges ahead present excellent opportunities to stand out in the market.



The source of credits and credits generated from OEMs in MY14 show Toyota in the lead, generating almost 10,000,000 Mg of excess credits. Other major OEMs follow behind. Note that VW and FCA have a net closer to zero because of their 2-cycle deficit made up through the various flexibilities.



Off-cycle credits for technologies are not fully accounted for during typical 2-cycle testing. (EPA)

Footprints and flexibilities

Considering that CAFE plateaued for nearly three decades, the Obama administration's much quicker "doubling of fuel economy standards to 54.5 mpg" sounds like a lofty, if not admirable, goal. U.S. fuel economy testing is sometimes criticized for being outdated, with some procedures used since 1975. But the process fundamentally does work, especially with the built-in 'flexibilities' that serve as incentives to adopt a variety of technologies noted below. These make the 54.5-mpg target less aspirational than it appears.

The core of these standards is a vehicle's "footprint"—the wheelbase-times-track width equation that sets a vehicle's fuel economy and CO_2 targets. The concept is to avoid penalizing inherently less-efficient vehicles that provide more capability and to control the impact of the standards on full-line OEMs. The car and light-truck footprints are each set on curves, with smaller vehicles having more stringent targets than larger ones.

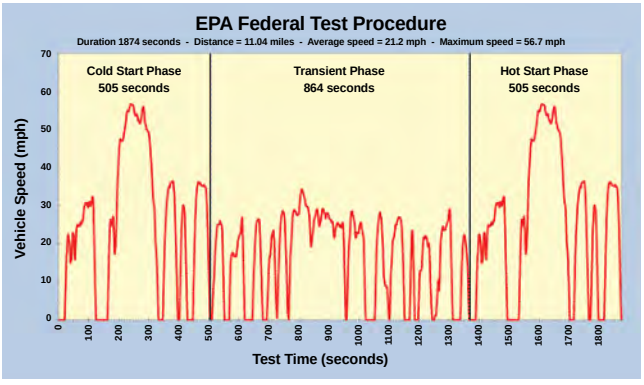
Some critics claim the footprint-based metric has been encouraging OEMs to build larger vehicles. In 2015 the average new vehicle's footprint was 49.9 ft^2—a new record according to the EPA, and an increase of 2% (about 1 ft^2) since the agency began tracking the metric in 2008. EPA acknowledges that the footprint "creep" reflects consumer demand for trucks and SUVs. Of course, all automakers largely will use conventional strategies—more efficient powertrains, lighter curb weights, more aerodynamically efficient exterior shapes and lower frictional losses—to comply with the tighter standards.

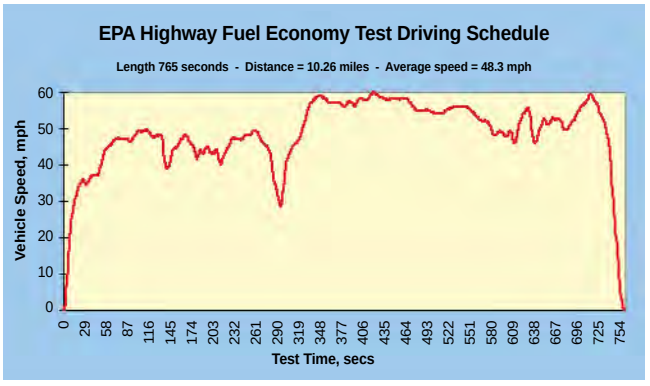
As of 2016 only electrified vehicles are 2025-compliant. And the toughest climb is yet to come.

To verify compliance with the new GHG/mpg standards, the existing Federal Test Procedure (FTP or "city") and Highway Fuel Economy Test Driving Schedule (HWFET or "highway") test cycles carry over. This regimen is known as 2-cycle testing. Beyond the "traditional" 2-cycle standards and vehicle improvements, OEMs have a number of fuel-efficiency flexibilities at their disposal. These include:

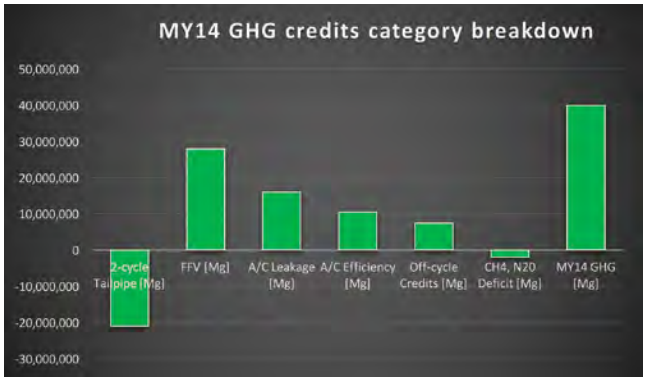
- Electrics, plug-in hybrids, fuel cell electrics and CNG vehicles earn special "sales multiplier" factors to boost their impact, even at lower volumes.
- Consumption of grid electricity is not charged against electrics in the program's early years (hence a BEV's "zero-emissions" declaration).
- Flex-fuel vehicles (FFVs) earn petroleum-reduction (CAFE) and GHG credits; this flexibility is only for CAFE beginning MY16, however.
- Advanced pickup trucks employing some type of hybridization.
- A/C leakage credits—earned through the use of low global warming potential (GWP) refrigerants and reducing system leakage.
- A/C efficiency credits—improving system efficiency through a number of advanced air-conditioning technologies.

Solving the GHG puzzle





Beyond the "traditional" 2-cycle standards and vehicle improvements, there are a number of fuel-efficiency flexibilities OEMs have at their disposal.



Looking at the breakdown of GHG credits across the fleet the largest contributor is FFV flexibility, which is set to expire in MY16. The two A/C flexibilities and off-cycle credits also play a significant role, bringing a strong incentive to improve A/C systems and adopt technologies that have a high benefit in real world use.

• So-called "off-cycle credits" for technologies that are not fully accounted for during typical 2-cycle testing (this flexibility deserves its own discussion—see below).

Other GHG tailpipe constituents such as methane and oxides of nitrogen (NOx) result in deficits in the new compliance methodology. Compared to CO_2 their impact is small, typically less than 1%.

OEMs are allowed to carry a negative GHG balance for up to three years. They may purchase credits at market-determined prices from overachievers—a group of OEMs currently led by companies such as **Tesla** and **Toyota**. Compliance is determined by the equation shown here that encompasses production volume, individual vehicle or technology credits, and an EPA-defined expected vehicle lifetime miles (VLM).

$$GHG\ credits\ [megagram] = Vehicle\ or\ Technology\ Credit\ \left[\frac{g}{mile}\right] x\ Production\ x\ VLM\ \div 1M$$

Vehicle or Technology Credit [gCO_2/mile]: the credit value for a specific vehicle compared to its footprint-based standard or a technology credit generated through use of a flexibility (advanced air conditioning, off-cycle credit, etc.)

Production: the total number of passenger cars or light trucks produced with corresponding 2-cycle value or technology credit.

VLM: vehicle lifetime miles is EPA-defined for passenger cars at 195,264 mi (314,247 km) and light trucks at 225,865 mi (363,495 km).

Example (2-cycle tailpipe):

Vehicle X (classified as a light truck) has a 2-cycle tailpipe emission value of 330 g/mile

Its compliance target (based on footprint) is 340 g/mile

200,000 vehicle Xs are produced annually

$$\left([340-330]\frac{g}{mile}\ x\ 200{,}000\ trucks\ x\ 225{,}865\ \frac{miles}{truck}\right) \div 1M$$
$$= +451{,}730\ Mg\ GHG$$

Example (off-cycle credit flexibility):

Engine idle stop-start is applied on vehicle Y, a passenger car

Technology has an off-cycle menu credit value of 2.5 g/mile

100,000 vehicle Ys are produced annually

$$\left(2.5\frac{g}{mile}\ x\ 100{,}000\ cars\ x\ 195{,}264\frac{miles}{car}\right) \div 1M$$
$$= +48{,}816\ Mg\ GHG$$

When accounting across an OEM's entire fleet is complete, a positive GHG credit value [Mg] indicates compliance. Any negative balance lasting three years results in a Clean Air Act violation with the penalties noted above.

2014 model year standings

Data transparency is, according to the EPA, important to program compliance. The adjacent plot indicates the source of credits and credits generated from OEMs in MY14 (previous model-year balances are not included).

MY14 standings, not including previous-year balances, show Toyota was in the lead, generating almost 10,000,000 Mg of excess credits. Other major OEMs (**GM**, **Honda**, **Nissan**,

Ford) follow behind. Companies like **Volkswagen** and **FCA** have a net closer to zero because their 2-cycle deficit is offset through various flexibilities.

One important aspect to note, however, is the breakdown of where these credits come from. Looking at the breakdown across the fleet, the auto industry as a whole is not keeping pace with the core metric of the regulation—2-cycle tailpipe. The largest contributor is the FFV flexibility, which is set to expire (for GHG at least) in MY16.

The two A/C flexibilities and off-cycle credits also play a significant role. This brings a strong incentive to improve A/C systems and adopt technologies that have a high benefit in real-world use.

Off-cycle credits and credit transactions

This flexibility is a notable change from tradition because the associated environmental benefits of many technologies don't always show up in 2-cycle testing. There are three opportunities to generate off-cycle credits:

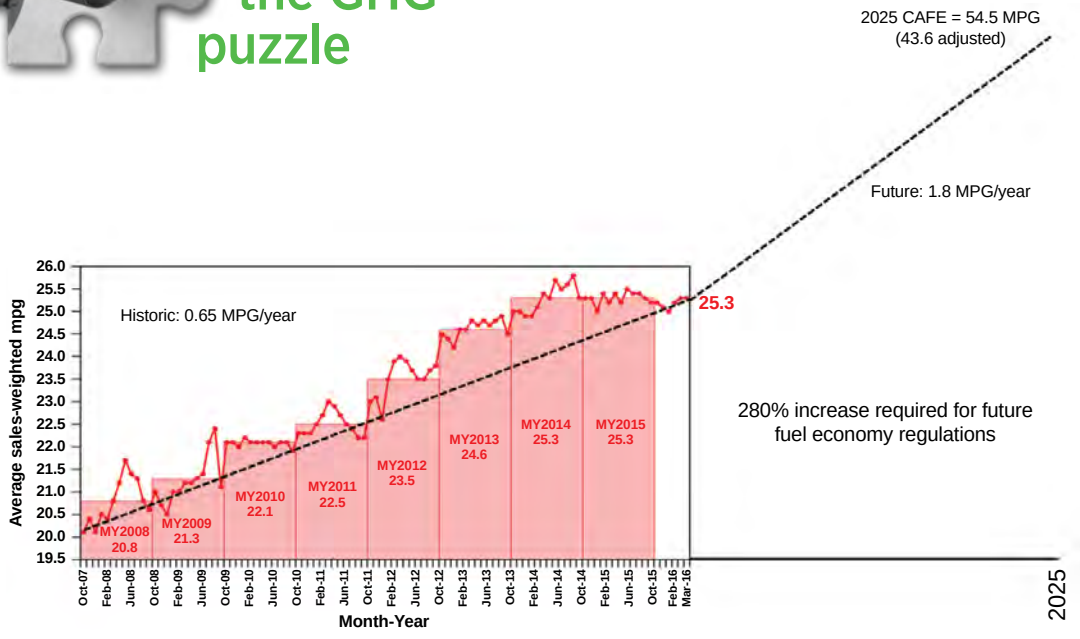
- From an EPA-authorized menu with defined or scalable credit values
- By using the EPA's 5-cycle testing, which includes aggressive driving (US06), hot-temperature and A/C use (SC03) and cold-temperature (cold FTP) test cycles in addition to FTP and HWFET tests.
- By petitioning the EPA for non-menu credits with a test plan and measured data. Thus far, **Mercedes-Benz**, GM, Ford, and FCA have used this "public process" option.

Another noteworthy flexibility is the buying and selling of GHG credits according to market-driven prices. The EPA publishes the buyers and sellers without divulging prices paid. Only OEMs may buy, sell, or hold credits. Unsold credits expire after five model years. Third parties may be used to facilitate sales.

Thus far, Honda, Nissan and Toyota have sold their surplus credits to help offset costs associated with developing and implementing advanced technologies. Tesla also is making hay from its envious 0g/mile status—as an early-adoption incentive, emissions from grid electricity are not yet counted against plug-in vehicles.

Lower-volume makers such as **Ferrari** and Mercedes-Benz that sell high-margin vehicles appreciate the opportunity to purchase credits so that despite substandard overall fuel efficiency, they can maintain their reputation for delivering luxury and high performance. The high number of credits FCA has purchased in a relatively short term probably is not a sustainable long-term strategy.

Solving the GHG puzzle



The U.S. vehicle market as a whole is not on pace for compliance. A nearly three-fold improvement in fuel economy and GHG reduction will be necessary. (Sivak and Schoettle, UMTRI)

Automakers Play the GHG Credit Market

	OEM	2010	2011	2012	2013	2014	Total
Credits Disbursed	Honda	-3,609,383	-	-	-	-	-3,609,383
	Nissan	-200,000	-1,000,000	-250,000	-	-	-1,450,000
	Tesla	-35,580	-14,192	-177,941	-1,048,689	-1,019,602	-2,296,004
	Toyota	-2,507,000	-	-	-	-	-2,507,000
Credits Acquired	Ferrari	265,000	-	-	-	-	265,000
	Fiat Chrysler	5,651,383	500,000	-	1,048,689	1,019,602	8,219,674
	Mercedes	435,580	514,192	427,941	-	-	1,377,713

Honda, Nissan and Toyota have sold their surplus credits to offset costs associated with developing advanced technologies. Tesla, as the only EV-exclusive OEM, also has leveraged the GHG credits system. It has helped sustain exotic makers such as Ferrari whose high-performance cars have less than sterling fuel efficiency.

GHG and CAFE: Different objectives, similar outcomes

Greenhouse gas (GHG) is perhaps the lesser-understood side of U.S. energy/climate policy. While CAFE has a goal of reducing petroleum consumption and is administered by **NHTSA**, GHG is primarily CO_2 reduction and is administered by the EPA. The two regulations are closely related but subtly different. They are mostly harmonized, but not completely. One example among the few differences is the A/C leakage flexibility—this is GHG only and not in CAFE.

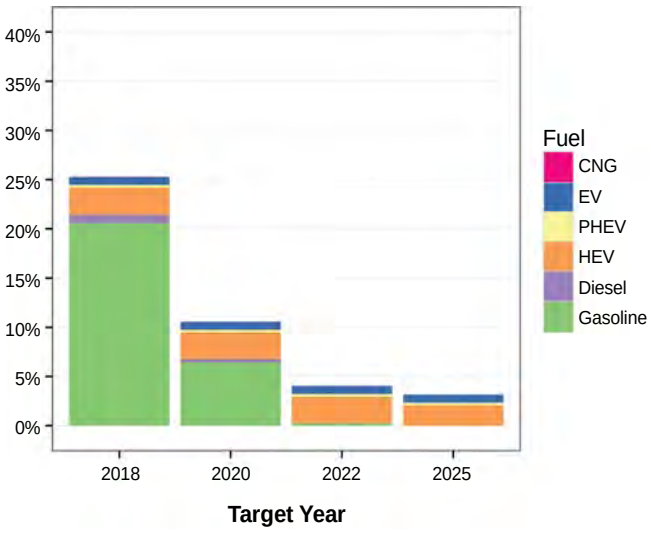
Concern over GHGs really kicked off the modern era of U.S. energy and climate policy in April 2007, when the Supreme Court, in *Massachusetts v. the EPA* ruled that GHG emissions, including CO_2, threatened human health and were therefore subject to Clean Air Act regulation. Two years later, the Obama administration issued a presidential directive to "harmonize" national fuel economy and CO_2 standards. The resulting 54.5 mpg directive, equivalent to 163 g/mi of CO_2 by 2025 effectively reshaped the auto industry.

Anyone familiar with basic chemistry understands that various exhaust emissions result from combusting hydrocarbon fuels; 99% of the objectionable content is CO_2. In 2010 rulemaking, the EPA and **U.S. Dept. of Transportation** assumed that nearly all of the carbon in fuel is converted to CO_2 and that burning a gallon of gasoline yields 8887 grams of CO_2. That figure was used to (mostly) harmonize GHG limits and CAFE regulations for 2012-2025.

The projected societal and environmental benefits of the 2025 fuel-economy targets include: a 6-billion metric ton reduction of GHG emissions from 2012-2025 model-year vehicles, fuel costs cut by $1.7-trillion, a 2-million-barrel daily reduction in oil consumption by 2025 and significantly improved energy security and sustainability. (The originally stated goal of CAFE in the 1970s was to enhance energy security through petroleum reduction.)

Of course, the costs related to achieving these benefits are equally outsized.

-S.S.



Powertrain/fuel types that currently can meet the 2025 fuel economy regulations. (EPA)

The 2025 GHG challenge

Meeting the 2025 163 gCO_2/mi standard with internal-combustion engines and traditional vehicle architecture is a formidable yet admirable challenge. In truth, the U.S. market as a whole is not on pace for compliance. A nearly three-fold improvement in fuel economy and GHG reduction will be necessary.

Tellingly, of the 3% of the 2015MY fleet that meets the 2025 standards, all employ hybridization or full electrification. Not a single 2015 conventional gasoline or diesel vehicle is yet 2025 compliant. While there are still efficiency gains to come from the 130-year-old ICE, automakers must weigh their benefits in the context of greater investment and compromises (i.e., additional mass, complexity and packaging challenges).

So, while we wait for the Mid-Term Evaluation decision, R&D and product-development teams continue to focus on technology and vehicle solutions aimed at 2022-2025 compliance—the "steepest" and increasingly costliest part of the climb toward 54.5 mpg. And in roughly three months, a new administration takes up residence in Washington, D.C. How will it approach the GHG challenge—with or without a sustained market jump in fuel prices?

Regardless of these and other factors, industry engineers will deliver whatever it takes to meet the needs of customers and of the increasingly stringent regulations. ■

Steven Sherman is a Fuel Economy Development Engineer at the Hyundai America Technical Center, Inc. (HATCI) based in Ann Arbor, MI. A three-time University of Michigan graduate, he is passionate about solving the terawatt problem of global energy consumption. The analysis and commentary in this article are his own.

Revving up thermal characterization in the component lab

Airbags after eyeblink-fast deployment in Honda Pilot crossover (courtesy American Honda)

The latest generation of high-speed infrared cameras can capture airbag deployments and other fast-moving actions quickly and accurately.

by Chris Bainter

The dangers of faulty car airbags recently have become all too clear. The product-liability issues associated with airbags and the largest, most-costly automotive recall in history make it essential to characterize them thermally at high speeds and with high levels of sensitivity and accuracy.

When designing an airbag system, researchers must be able to study, during the deployment, the thermal results of the complex interactions between the various components such as crash sensor(s), the electronic controller unit, propellant, inflator/ignitor and bag design.

Thermal characterization of fast-moving components using traditional methods such as mounting contact-temperature sensors—thermocouples, thermistors, or RTDs—is often impossible. Non-contact techniques such as spot pyrometers and infrared (IR) cameras with thermal detectors typically aren't fast enough to stop motion in order to characterize temperature with sufficient accuracy and sensitivity.

Fortunately, the latest generation of high-speed infrared (IR) cameras with quantum detectors can translate infrared radiation into data faster than earlier generations, which were equipped with uncooled microbolometer (thermal) detectors. But before investing in new characterization equipment, it's critical to understand the strengths and weaknesses of various aspects of camera design.

High-speed thermal images of airbag deployments, captured with a **FLIR** SC6800-series MWIR science-grade IR camera, demonstrate the ability to capture airbag images quickly and accurately. This capability is essential to understanding and documenting deployment interactions (see the video at: www.flir.com/HighSpeedIR).

Cooled quantum detectors are key

Traditional IR cameras were designed to react to incident radiant energy: infrared radiation heats the pixels and creates a change in resistance that is used to calculate temperature. Although they offer high durability and portability at a relatively low price, standard IR cameras have limitations for high-speed R&D applications.

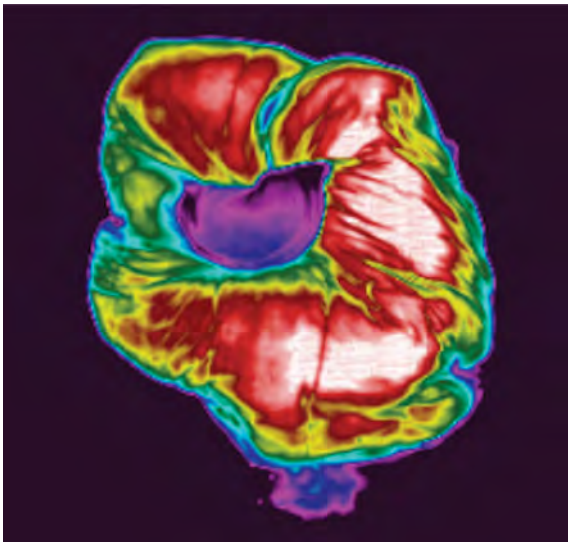
According to Markus Tarin, CEO of **MoviTherm** (a company that uses quantum-detector IR cameras to measure temperatures on fast-moving objects), a traditional uncooled microbolometer camera has a fixed integration time of 8–12 ms.

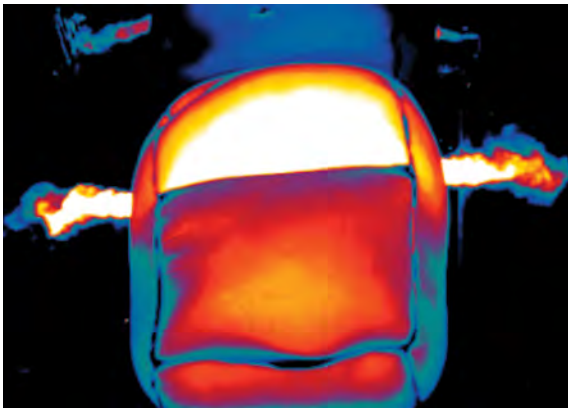
"This means that the object image is smeared over multiple frames," he explained. "High-speed quantum cameras have adjustable integration times, allowing the camera to freeze the frame and perform accurate temperature measurement of fast-occurring events. By being able to capture details by a factor of 100 times better, quantum detectors allow our technicians to see the impossible."

Although more expensive than uncooled microbolometer thermal cameras, high-speed IR cameras with cooled quantum detectors are capable of capturing high-resolution images at 1000 frames per second (fps). These quantum detectors typically are made of indium antimonide (InSb), indium gallium arsenide (InGaAs), or Strained Layer Superlattices (SLS) and are photovoltaic. This means the detector's crystalline structure absorbs photons that elevate its electrons to a higher energy state, which changes the conductivity of the material.

These cameras essentially are counting photons, which allows for upgraded sensitivity and the ability to detect temperature differences of less than 18 milliKelvins, or .018°C.

In addition to improved sensitivity, quantum detectors also react quickly to temperature changes, with a time constant on the microsecond timescale. This combination of short exposure times and high frame rates makes quantum detectors ideal for stopping motion on





High-speed thermal images of airbag deployments, captured with a FLIR SC6800 series MWIR science-grade IR camera. The ability to capture airbag images quickly and accurately is essential to studying the complex interactions between the crash sensor(s), electronic controller unit, propellant, inflator/ignitor and bag design, among other factors.

high-speed targets for accurate temperature measurement, as well as proper characterization of how thermal temperatures rise over time on fast-heating targets.

Dr. Robert Madding, President of **RPM Energy Assoc**., noted that quantum detectors work by photons of the proper energy impinging onto the detector. "They add their energy to electrons in the semiconductor, elevating them above the detector energy bandgap into the conduction band," he said. "This can be measured as a change in detector voltage or current, depending on detector design. This can occur very fast."

For high-speed automotive applications, look for infrared cameras that offer high frame rates at high resolution. FLIR's X6900sc high-speed MWIR camera, for example, captures full 640 x 512 images at 1000 fps.

For high-speed automotive applications, look for infrared cameras that offer high frame rates at high resolution. FLIR's X6900sc high-speed MWIR camera, shown here, captures full 640 x 512 images at 1000 fps.

0.03°C sensitivity

Factors other than frame rates affect an IR camera's suitability for characterizing rapid temperature changes on fast-moving components:

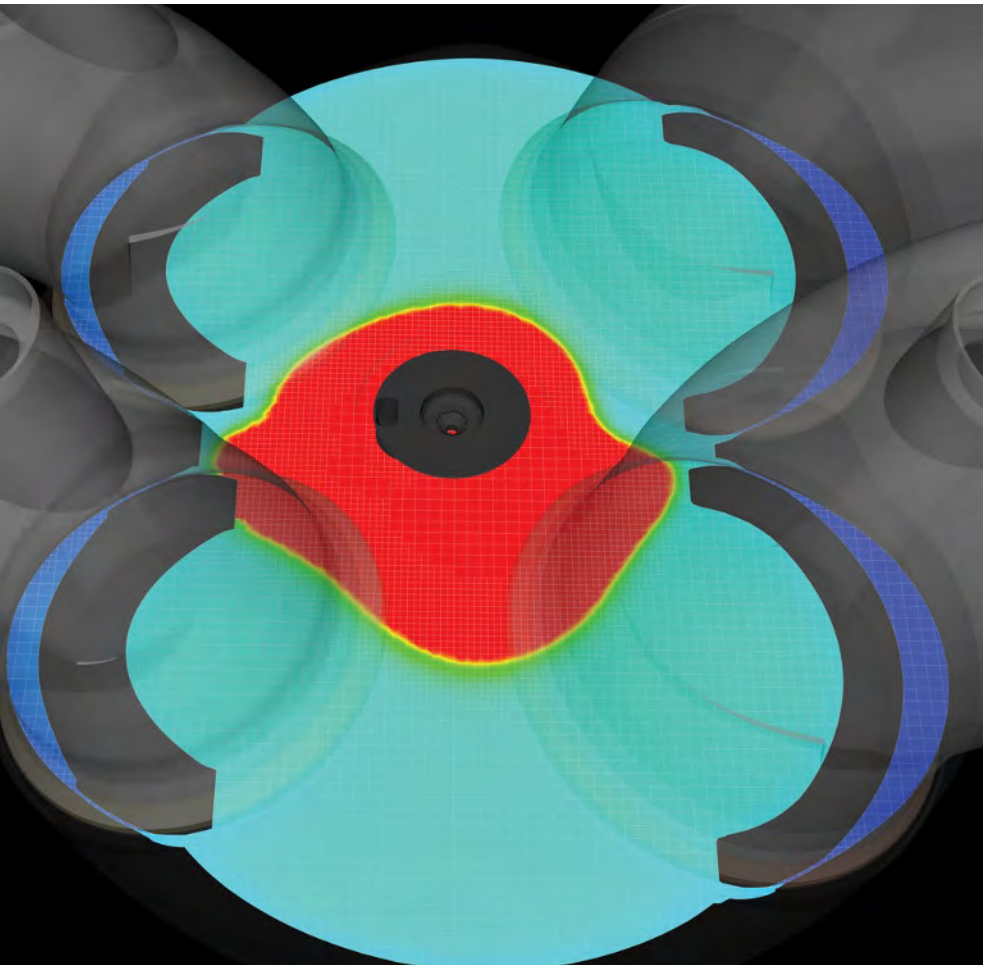
- Integration time (how long the camera collects data for each frame).
- The temperature of the target can have an impact on integration time (snap shot speed) of the camera. Hotter targets emit more radiant infrared energy, thus more photons; colder targets emit fewer photons. Look for cameras with enough sensitivity to measure colder targets at fast frame rates.
- The number of A/D converters or channels available. High-speed IR cameras typically have 16 or more channels; low-performance cameras typically have just four.
- High-speed pixel processing. Check for processing speeds (pixel clock rates) of 200 megapixels/sec or higher.
- Use of a next-generation Read Out Integrating Circuit (ROIC). Earlier ROICs were non-linear at low well fills, which caused the camera's Non-Uniformity Correction to break down, resulting in poor imagery and questionable temperature-measurement accuracy at high speeds on colder targets. Newer ROIC designs are linear-to-low well fill.
- The ability to synchronize and trigger to external events, such as an airbag deployment. A separate triggering system better allows for synchronizing recordings by strictly controlling the integration start time and the frame rate.
- Sensitivity to subtle temperature changes simplifies detecting small hot spots. Cooled IR cameras can detect changes as small as 0.02°C; uncooled cameras have a sensitivity of around 0.03°C. Although that difference may sound insignificant, it represents more than a 30% improvement in sensitivity.

By including thermal imaging during the design and testing phases of airbag innovation, R&D teams can more readily identify weak points and improve overall safety. But the type of camera and its features can have an impact on imaging success.

Choosing a cooled thermal camera with the highest available speed, sensitivity and integration times allows researchers to track temperature shifts accurately over the airbag ignition period. These cameras will also provide crisply detailed stop-motion frames, so researchers can closely examine each stage of inflation and identify the exact moment a problem begins. ■

Author Chris Bainter is Americas Business Development Director - Science Segment, at FLIR Systems, Inc. The Wilsonville, OR-based company's name comes from the acronym for forward-looking infrared imaging systems. FLIR was founded in 1978 with airborne IR systems.

C3 CONSORTIUM aims for soot solution



A newly formed group of companies led by CFD specialists Convergent Science targets exhaust particulate reduction in the combustion chamber.

by Ian Adcock

Reducing SI and DI engine-out particulates in the combustion chamber requires close collaboration among fuels experts, engine designers and simulation specialists.

Predicting more accurately what happens in the complex chemical reactions between air and fuel when they are compressed and ignited in an IC engine's combustion chamber—and solving the challenge of exhaust particulates—may have taken a step forward with the creation of the **Computational Chemistry Consortium (C3)**, driven by the auto industry's need to meet increasingly stringent global emissions regulations.

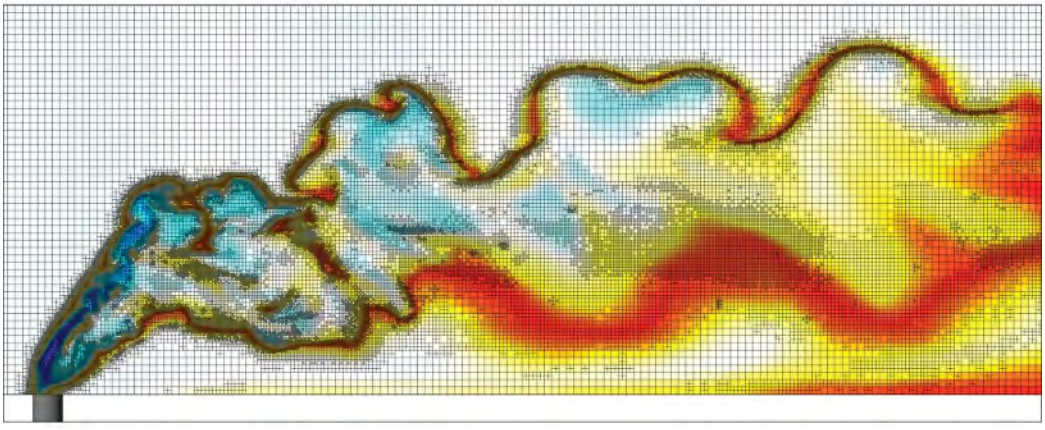
"Several of our existing clients asked if we could develop an open format fuel consortium that wasn't tied to any particular software and would allow them to run it in conjunction with their own programs, a bit like an open source format," explained Eric Pomraning, Ph.D., Vice President of **Convergent Science, Inc.**, a maker of computational fluid dynamics (CFD) analysis toolsets based in Madison, WI. Its Converge numerical tool is used for combustion chamber simulations.

Customer demand led Dr. Pomraning's company to organize and co-sponsor an event, the 2016 Combustion Summit, which included technical presentations by research experts from **FEV**, **Aachen University**, **IFPN Energies Nouvelle**, **Volvo Cars**, Brandenburg University of Technology (**BTU Cottbus**), **Renault**, **PSA Peugeot Citroën** and the **NUI Galway**. *Automotive Engineering* attended the two-day conference in Nice, France, and spoke with a number of presenters and attendees.

Although there have been previous attempts to model combustion these tend to have tied users to specific software sets. Among the advantages of running an open platform, claimed Kelly Senecal, Convergent Science's Vice President and co-founder, are no restrictions on what tools you can use it in, he noted, which benefits the user community at large.

Convergent Science is encouraging fuel companies such as **Saudi Aramco**, as well as OEMs and consultancies, to partner in the new consortium while allaying any fears that competitive advantages in either fuel formulations or engine designs will potentially leak to rivals.

"We'll build up base mechanisms and if they [oil companies] feel they have an additive or something that really improves the combustion, knock resistance, emissions, they can add that to the mechanism on their own away from the rest of the consortium," explained Dr. Pomraning, who was a research associate at the **University of Wisconsin-Madison Engine Research Center** prior to co-founding Convergent Science.



Speakers at the inaugural combustion-science conference noted the lack of adequate CFD software and meshing capability capable of accurately predicting the amount of soot an ICE will emit. "It's very important for us to check that we have a system which prevents generation of too-small particles [so] we comply with the European requirements for particulate size and numbers," explained Fréderic Ravet of Renault.

He said the combustion-research community is looking for "a good mechanism to predict emissions and soot because the chemistry is so complex." The same rings true for the OEMs, consultancies or Tier Ones: "Anything proprietary like piston bowl design, for example, won't be part of this [consortium]," added Senecal.

Meeting the soot challenge

Exhaust particulates, or soot, are a significant technical challenge for the industry as well as an ongoing public health issue. Although some of the latest simulation models are capable of predicting particulate size and distribution, Senecal warned that "You have to get the chemistry right before you even worry about that, as that's what kicks off the soot formation—that will be a big part of C3 understanding the chemistry to start the prediction of soot."

"Maybe we have to develop some new CFD models for this," offered Clément Dumand, Manager-Modeling of Energetic and Combustion Systems, Advanced Engineering and Research at PSA. He said the industry needs "more detailed combustion simulation for HC [hydrocarbons], soot and knock" and suggested that perhaps "large eddy simulation (LES) might be the answer."

Convergent Science co-founder Kelly Senecal noted that while some simulation models are capable of predicting particulate size and distribution, the new consortium will focus on understanding the chemistry of soot formation first.

Dumand was quickly joined by other speakers bemoaning the lack of adequate CFD software and meshing capability capable of accurately predicting the amount of soot a gasoline or diesel ICE will emit. "It's very important for us to check that we have a system which prevents generation of too-small particles [so] we comply with the European requirements for particulate size and numbers," explained Fréderic Ravet, a combustion systems expert at Renault.

Added Mattias Ljungqvist, a combustion simulations engineer at Volvo Cars: "Soot modelling is an issue. Even if NOx is supposed to be easier to handle we don't always get the benefits that we see in simulations."

"Soot is like the house of cards that's built on everything else," observed Senecal. "You have to get the flow reasonably right, the turbulence, combustion, spray and part of why soot is so challenging is because it's at the end of everything. Compared to other things it's also at very small levels so being able to predict a value at that kind of detail is very difficult."

And the physics of soot are not fully understood, the experts agreed. "We have a general idea of how it works, but we haven't got it entirely figured out," Senecal noted. "The other thing is we model soot as another gaseous species, so there's an issue right now in that we don't model the right phase. We're starting to work on that with some other collaborations modelling those particles, the solid particles mix and the load numbers, but it's not easy."

In the complex chemistry that's involved in building up soot, the formation of polyaromatic hydrocarbons (PAH) is critical—and getting that chemistry right is a challenge, according to the experts. Scientist Dr. Fabian Mauss of BTU Cottbus is working on mechanisms that involve numerous species involving lots of reactions that are expensive to solve. Experts at the Combustion Summit noted that their teams are investigating what short cuts are possible and what assumptions can be made to get solutions.

Senecal said some of his company's latest models are capable of predicting particle size and distribution. Getting the chemistry "right" first is vital because it's what "kicks off" the soot formation. That's a major goal of the C3 project. The consortium is actively seeking partners for the project, which Senecal predicts will last for at least three years with a renewal option. Interested organizations can contact company leadership through the website: https://convergecfd.com/. ■

INSIDE THE autonomous vehicle

With less focus on driver needs, comfort, safety, and occupant productivity will become key.

Mercedes-Benz envisions a railcar-like potential for autonomous road travel, with occupants' seats swiveled to face one another. Some studies suggest this setup could lead to nausea, however.

As self-driving technology eventually becomes reliable and safe, the role of the human driver will change dramatically. Instead of acting as a full-time operator, the driver will become a part-time operator and part-time passenger—ultimately transitioning to a full-time passenger who simply occupies the vehicle while it is in motion.

Current automotive design trends are taking cues from today's evolving driver/passenger experience. For example, recent growth of ride-hailing services, like **Uber** and **Lyft**, ride-sharing and peer-to-peer renting is transforming the car ownership/operator dynamic, including how interior amenities and features are designed.

These trends are accelerating a shift in the driver's role from vehicle operator to occupant, raising the question: What does the inside of the car look like when drivers aren't spending their time steering, accelerating, and braking?

Some estimates indicate that eliminating those operations will give the average driver about 50 minutes per day of "free time" to simply ride inside the vehicle as a passenger.

But how will that extra time be used? Clues can be seen in the off-highway industry, where driverless GPS-guided tractors and combine harvesters are becoming more widely used. Inside the cab, operators are tweaking the quantities of fertilizer and water being applied to crops, or analyzing other application factors.

The long-haul truck industry also offers a model of how interiors are changing. With operators on the road four to five days at a time, their truck cabs are becoming a high-tech home away from home—complete with appliances, sleeping quarters, and complete digital entertainment and information systems designed to be stowed away during operation and easily accessed when needed.

It's easy to imagine that operators of self-driving cars will want innovations that support passenger activities such as listening to or watching digital media, working on laptops or tablets, or talking on the phone or wirelessly through the cabin itself. The orientation of the passenger vehicle interior will change—from two or three rows fixed and forward-facing, to flexible seating and cabin features that can face forward, face inward, and change based on each trip's purpose, duration, and passenger comfort preferences.

The transformation of the driver's role in an autonomous environment will present a number of design challenges in three areas of automotive interior design:

• **The quantity and quality of "touch points" will increase.** Touch points are those components and areas of access that the user interacts with—such as a glove box handle, an LED display, or a center console.

If the driver can cut their time at the wheel in half, then those minutes will be spent doing something else. That could triple the number of application points inside the vehicle, which will require extensive re-engineering of the physical appearance and elements of each additional touch point.

From a design standpoint, fewer obtrusive electrical and mechanical controls will be needed, because they won't need to protrude from the interior to be accessed while driving. Instead, design focus will shift to streamlining the interior space with more elegant styling. Rather than considering if a latch point must be

There's still a steering wheel and a semblance of pedal controls in Toyota's FCV Plus concept, which merges aspects of autonomous driving with fuel-cell propulsion.

Inset: Without a bulky gasoline engine and related driveline, the hydrogen-fueled FCV Plus can sculpt its cabin around the occupants for maximum aerodynamic effect.

visible or concealed, the designer will aim for a clean appearance and smooth operation. Designing in a standardized mechanism, such as a hidden latching solution, for instance, allows the same mechanism to be used throughout the vehicle, but exterior styling can be easily changed by modifying the touch point. This allows consistent operation while satisfying design requirements, with a look that matches the cabin's interior styling.

• **Personal space inside the cabin will be designed for greater flexibility.** It's easy to imagine the cabin interior evolving into its own unique environment—reminiscent of the approach to airline first-class travel "pods" available on long-duration flights—with its own lighting and digital landscape to enhance the passenger experience. Front seats will not just be designed for 100% recline, but also to rotate to create a limousine-like conversation area or a collaborative workspace. Cabin entertainment systems will also change to accommodate the autonomous environment.

The increasing use of portable devices is influencing many automakers to replace traditional embedded entertainment systems like seatback display screens with removable tablets or mechanisms that can be used with existing personal tablets. Display mounting solutions, such as swing-out positioning arms with integrated constant torque, allow the passenger to position the screen according to height and lighting preferences and have it stay in place while the car is in motion. These display arms can be integrated directly into vehicle surfaces to improve the viewing experience and maximize end user operation and can also be folded in when not in use, allowing designers to optimize space in the cabin.

• **Safety and component "strength" will be evaluated differently.** Crash testing is already critical to the interior design process, but even with autonomous vehicles, there are still going to be accidents. Autonomous car interiors will still have to meet Federal Motor Vehicle Safety Standard (FMVSS) requirements, which will evolve to meet the unique challenges of self-driving vehicles.

In response, standards for mechanisms and materials—the inertial loading, shear strength, and tensile strength requirements—will need careful consideration. Additionally, the location of safety devices will need to be rethought. For example, airbags are now deployed from the glove box panel to keep driver and passenger from crushing their knees during accidental deceleration. The industry responded by developing strong, two-point latching mechanisms to keep the glove box door closed during impact.

In an autonomous environment with more passenger space and application points, designers will need to apply the same level of technology to other access panels to prevent the risk of false latching and keep passengers safe during operation.

Automotive designers can stay ahead of autonomous design trends by prioritizing component decisions early in the design concept stage. Substantial re-engineering will be required to investigate new materials and design elements, which will in turn, extend design time. Additionally, more testing will be required to validate compliance with safety regulations.

Designers can meet the challenges of designing user spaces in self-driving cars by working with suppliers today to ensure the success of autonomous vehicles tomorrow. ■

Author Steve Potter is General Manager, Transportation, at Southco Inc.

Racing toward autonomous future, Cadillac and Mercedes-Benz reveal sultry, drive-it-yourself concept cars

In the autonomous-vehicle future, will the ultimate luxury become driving for yourself?

That appears to be the suggestion from **General Motors**' Cadillac premium-car unit and Germany's **Mercedes-Benz**—both unveiled lusciously-proportioned concept cars at August's Monterey Car Week, where executives for both companies took pains to say the vehicles would be best enjoyed if, well, you actually *drove* them.

The **Cadillac** Escala (Spanish for "scale") concept and the Mercedes-Benz Maybach 6 (named for its 6-m/19.6-ft overall length) mostly are intended to demonstrate the future direction both brands might pursue in interior design, not to mention grand proportion: the Escala, at 210.5 in (5437 mm) overall and with more than 10 ft (3 m) between its front and rear axles, nearly matches the Maybach 6's Industrial Revolution length.

Although Mercedes-Benz indicated the Maybach 6 has autonomous-driving functionality, "This is a car you want to drive yourself," *Bloomberg* quoted Gorden Wagener, Daimler AG chief of design, as saying. Wagener didn't stop there; in an apparent rejoinder to the industry's well-documented embrace of autonomous technology, he added:

Cadillac Escala: rear-drive, based on GM Omega large-car platform, has grand proportions and showcases Cadillac's next thematic styling direction.

Mercedes-Benz Maybach, named for its (nearly) 6-meter length, has gullwing doors, 738-hp electric power.

Cadillac said Escala interior uses high-tech to engage front occupants, ultra-luxury for those in the rear.

Four-door liftback sedan body style and smallish-displacement V8 power both could be a look at Cadillac's near future.

"Driving has been a pleasure for 130 years and will stay that way for another 130 years."

Meanwhile, Cadillac's media information for the Escala, while waxing effusively about the car's luxuriously crafted interior with "intensely focused modern technology" and advanced connectivity, conspicuously avoided any mention of autonomous-driving capabilities. And like Mercedes, Cadillac overtly focused on the potential joy of manually driving a car like the Escala, its press release saying the concept is "designed to be both a driver's car and an indulgent flagship sedan." Andrew Smith, executive director of Cadillac Global Design, added: "My brief to the designers was to create a car you desperately want to drive, and also one in which you want to be driven."

Johan de Nysschen, President of Global Cadillac, chimed in, telling *Bloomberg*: "You'll desperately want to drive yourself" in such a car.

V8 or battery?

The Escala is an Audi A7-esque 4-door sedan with a rear-sloping roofline leading to a liftgate rather than a traditional trunklid. "Escala is a concept with two clear objectives," said de Nysschen. First, it is a statement of intent for the next iteration of the Cadillac design language, and also technical concepts in development for future Cadillac models. And second, Escala builds Cadillac's aspirational character, "signaling the brand's return to the pinnacle of premium."

Cadillac, though definitively billing the Escala as a concept car, wouldn't shut the door on a possible production variant: "Escala is a concept car, but one based upon the unrelenting rise of our product substance," said de Nysschen. "Depending on the development of market segment for large luxury sedans, Escala is a potential addition to our existing product plan."

Moreover, the Escala showcases some significant pending production-vehicle components, chiefly what Cadillac said is a new, twin-turbocharged 4.2-L V8 that is "a prototype of a new system in development for future Cadillac models.

Four drive motors deliver AWD propulsion for Maybach 6; Mercedes-Benz claims a 200-mi driving range and potential for 5-minute DC recharge good for 62 mi.

Maybach 6 interior: autonomous capability, but "This is a car you want to drive yourself."

The V8 engine, with a smaller-than-typical displacement, incorporates GM's Active Fuel Management cylinder-deactivation system to impart fuel-saving 4-cyl. operation. The Escala runs on the rear-drive-oriented Omega vehicle architecture and multi-materials body structure introduced for the Cadillac CT6 large car.

The Maybach 6 concept is a pure coupe design—it has just two doors and gullwing at that. The company explained the car's intriguing retro-tech styling by saying: "The classic aesthetic proportions of the show car—an extremely long hood, low roof line and rearward positioning of the greenhouse—recall the aero coupes of days gone by. But this is not retro design - this is a reinterpretation of classic, aesthetic principles."

Perhaps the most polarizing aspect of the Maybach 6 design is the raised central spine running down the car's roof and rear deck, bifurcating the rear of the car, including the back glass, in a fashion vaguely reminiscent of the "split-window" 1963 **Chevrolet** Corvette.

There is no throwback insinuation in the Maybach 6's driveline: the car is a pure-electric vehicle with a claimed total of 738 hp (550 kW) delivered by its four permanent-magnet electric motors, one for each wheel to impart all-wheel-drive. The batteries are carried low under the floor and have a capacity of 80 kW·h. The company said the car can hit 62 mph (100 km/h) in less than four seconds and could have a driving range up to 200 mi (322 km).

A high-capacity DC quick-change function could deliver 62 mi (100 km) of driving range with just a five-minute charging session, Mercedes said. The car's onboard charging system includes a wireless-charging capability.

Bill Visnic

2017 FiatChrysler: more Dodge muscle, fewer Fiat models

At a mid-summer media program to reveal its 2017 model lineup, nobody from **FiatChrysler Automobiles** said anything about some fizzy rumors speculating the company might have engineered a power boost for the already outlandish 707-hp generated by its supercharged 6.4-L "Hellcat" V8. There's no new power for the thunderous V8, but FCA's 2017 lineup does include some Hellcat-inspired niche models, continued expansion of the popular Jeep range and a consolidation of the Fiat small-car line as U.S. buyers continue to veer toward crossovers and pickups.

The **Dodge** brand, FCA's musclecar specialist, has two special throwback models for 2017: the Charger Daytona and Challenger T/A, both harking to the golden-era originals with special graphics, chassis upgrades and, of course, bawdy V8s—while also paying homage to the modern-classic Hellcat models by borrowing some of their "functional performance styling."

The Challenger T/A and Charger Daytona offer either the whopping 6.4-L ("392" for the nostalgic) or the 5.7-L version FCA's Hemi V8; it's 485 hp (362 kW) claimed for the 392 and as much as 375 hp (280 kW) for the 5.7-L. The big-engine version of the Challenger T/A brings functional hood ducts and special air-grabbing headlights, electronically controlled active exhaust and chassis tweaks that include unique front-suspension tuning and **Brembo** 6-piston front brakes.

The 2017 Charger Daytona will sit atop the performance ladder of 5.7-L Chargers with revised intake and exhaust, a cold-air intake, the active-exhaust system and special transmission calibration. The 6.4-L Daytona churns out 475 lb·ft (644 N·m) to accompany its 485-hp **SAE** rating. Both cars also offer unique High-Impact Paint (HIP) body colors.

For the powerhouse **Jeep** brand, 2017 brings a variety of detail upgrades and model tweaks, perhaps most notable being the extension of the popular Trailhawk trim to the Grand Cherokee

2017 Dodge Challenger T/A offers throwback colors and cues, up to 485 hp from a 6.4-L V8.

The outrageous rear spoiler of the original Charger Daytona didn't translate to Dodge's 2017 tribute, but the rear-fender stripe does.

The 5.7-L Hemi V8 is standard for the 2017 Dodge Challenger T/A and Charger Daytona; develops up to 375 hp with new electronic active exhaust.

line. The Grand Cherokee wears the off-road-gnarly Trailhawk appearance well and planners have wisely situated it a couple spaces down from the Grand Cherokee's top trim level. The pre-production model *Automotive Engineering* briefly drove was motivated by the company's thrusty-but-refined 3-L turbodiesel V6; the diesel's 420 lb·ft (569 N·m) seemed an ideal companion for the Trailhawk trim.

Meanwhile, the **Fiat** line continues to struggle for relevance in a U.S. market enamored with large models and awash in cheap fuel. Consequently, the 500 2-door and 500L (4-door) lineups have been consolidated from five trim levels to three—and prices have been reduced.

The starting price of the base 500, the Pop, is $14,995, for example, a cut that makes the car more than $1,000 less than the 500's base price when it was launched in 2011. The top-of-the-line, performance-focused 500 Abarth now has a base price of $19,995—more than $2500 less than in 2016—a tempting bargain for the throaty 160-hp performance of its 1.4-L turbocharged 4-cylinder and the Abarth's slot-car chassis responses.

Bill Visnic

All-new 2017 Porsche Panamera moves to VW modular platform

Porsche's new-for-2017 Panamera is still a large, heavy car but looks more svelte than its first-generation predecessor. The diesel version is claimed to be the world's fastest production diesel car.

Creating any new **Porsche** is one of the most challenging design and engineering tasks in the auto industry. Whether sports car, sedan or SUV it has to embody the essence of the iconic 911 but also meet the practical and aesthetic expectations of buyers who believe they know exactly what they want.

In the view of some critics, the 2009 Panamera sports sedan—or 4-door Gran Turismo as Porsche describes it—did not wholly meet those criteria, although with more than 150,000 built it was hardly a failure.

Now comes the second-generation Panamera based on **Volkswagen Group**'s MSB (*Modularen Standardbaukasten*) modular platform that will underpin various VW Group premium vehicles including a sport wagon version of the Panamera. The vehicle is claimed by Porsche engineers to have been developed using know-how acquired from the 918 Spyder and 911 Turbo programs.

Said design boss Michael Mauer, who also heads VW Group design: "Its strengths have been reinforced, its weaknesses eradicated, and above all its character preserved."

Use of the word "weakness" in connection with products is very unusual for any OEM let alone Porsche. But the Panamera has certainly been improved throughout. Its road presence is sharpened (there is an "arrow-shaped" hood), becoming more balanced front and rear. The overall exterior form, with its "faster" coupe-like roofline and new LED matrix headlamps, is now far more convincingly linked to the 911 than was the original.

Explained Porsche Chairman Oliver Blume: "In the new model, you see a completely redeveloped automobile." The raft of new technologies includes optional 48-V electric anti-roll control; rear axle steering similar to that used on the GT3 and 3-chamber air suspension; and Night Vision Assistant, an infra-red-based imaging system that shows pedestrians and animals in the display cluster. The latest adaptive cruise control uses navigation data to allow the vehicle to adjust speed in relation to terrain as well as to vehicles ahead.

There are more lightweight structural solutions to mitigate "mass creep" and new engines—V6 and V8 gasoline engines and high performance V8 diesel. The **ZF**-sourced 8-speed PDK twin-clutch transmission also has been redesigned. All-wheel drive is fitted as standard at launch but 2wd is expected to become available.

Porsche chairman Dr. Oliver Blume (left) and design boss Michael Mauer with the new Panamera.

Larger car, new HMI interfaces

Compared to the first generation Panamera, the new version rides on a wheelbase lengthened by 30 mm (1.9 in) and widened by 6 mm (.24 in). The new car's overall length is 2950 mm (116 in), a 34-mm (1.33-in) stretch. Although 5 mm (.19 in) taller, the sloping roofline is 20 mm (.78 in) lower over the rear passenger area.

The original 2009 car—described by magazine testers as "long, large and low"—was a pioneer in what is now called "mixed material" lightweight body construction. It featured a combination of seven steel alloys, cast and sheet aluminum, cast magnesium and various composites. Nonetheless, curb weight of the base 2wd model was 1800 kg (3969 lb). The 2017 model makes further use of aluminum alloys (bodysides, hood, liftback, roof and wheel arches) but still weighs 1994 kg (4398 lb) in base form which includes AWD.

Interior ergonomics are improved with interactive displays and a reduction in mechanical switchgear and enhanced and future-proofed connect capabilities. Porsche aficionados will be relieved to know that an analog tachometer remains the dominant driver-information source—it is still placed centrally in the instrument cluster, where it has been since the original 356. It is flanked by two 7-in displays offering speed, fuel state and other information.

The new Porsche Panamera has a best power:weight ratio of 3.6 kg/hp for the V8 gasoline. Its new V8 diesel engine delivers maximum torque of 850 N·m from just 1000 rpm.

The center of the console is occupied by a 12.3-in main touchscreen using the "next generation" Porsche Communication Management. The system embraces online navigation, smartphone integration via **Apple** Car Play, and a new "natural language" voice control. Louvers on a central air vent are electrically adjusted by touch sensitive sliders.

The InnoDrive adaptive cruise control "looks" 3 km (1.9 mi) ahead of the car and, using the navigation data and signals from radar and video sensors, computes optimal acceleration and deceleration rates, gear choice and coasting phases. Road bends, inclines and speed limits are all part of the applied intelligence.

Pumped up powertrains

Claimed by Porsche engineers to be the world's fastest production diesel vehicle, the Panamera is able to reach 285 km/h (177 mph) maximum velocity and accelerate from zero to 100 km/h in 3.6 s. Rated output of the 4.0-L V8, fitted with sequential turbochargers and 2500 bar (36,259 psi) fuel injection, is 310 kW (415 hp) and 850 N·m (627 lb·ft)—the peak

Engine line-up for the Porsche Panamera spans bi-turbo V8 and V6 gasoline, and V8 diesel.

Driving position of Porsche's new Panamera. Button and switch counts have been reduced.

torque available from 1000 rpm to 3250 rpm. Optimum fuel consumption according to engineers is 6.8 L/100 km NEDC.

The direct-injected gasoline engines have their turbos nestled between the cylinder banks to aid packaging and facilitate lower mounting for improved center of gravity. The 4.0-L V8 is fitted with VW's adaptive cylinder control (cylinder deactivation). In the Panamera Turbo version the V8 is rated at 405 kW (543 hp) at 5750 rpm. Peak torque (770 N·m/568 lb·ft) is available from 1960 rpm to 4500 rpm. Claimed top speed is 306 km/h (190 mph).

The V6 that powers the Panamera 4S displaces 2.9 L and is rated at 324 kW (434 hp). With a claimed top speed of 289 km/h (179 mph), the V6 model is hardly a sluggard. More powerful engine variants are expected.

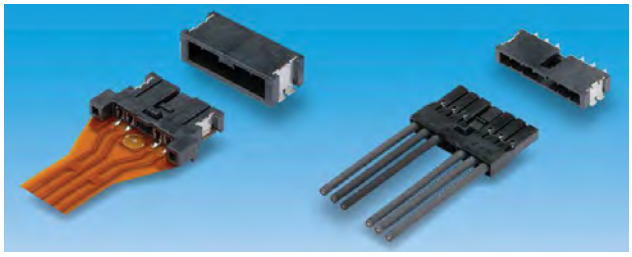
On the Turbo model, the rear spoiler divides as it deploys, thus increasing airfoil area and effect. The lower rear body has a diffuser with integrated exhaust tailpipes.

Also new is the car's manufacturing—it's now done entirely at Porsche's Leipzig plant. The 500 M euro investment includes an all-new body shop, Blume noted. Previously the Panamera white bodies were built and painted at VW's Hanover complex then transferred to Leipzig for final assembly.

Stuart Birch

SPOTLIGHT: ELECTRICAL COMPONENTS

In-vehicle LED lamp module-to-board connectors

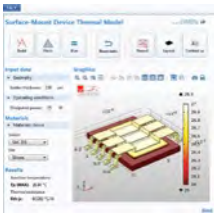


Developed for connecting in-vehicle LED lamp modules to control boards, **Panasonic** Corp.'s (Osaka, Japan) connectors improve designing in-vehicle LED lighting. The "board-to-FPC connector" is the first of its kind in the industry, claims the company, that is suitable for cable connection to daytime running lights. The connector has a metal terminal connection structure that eliminates the need for FPC contacts, a claimed first for the industry, realizing direct connection between the LED-chip-mounted FPC and the control power board. The new "board-to-wire connector," described as the lowest-profile connector in the industry suitable for LED headlamp modules, has an in-house-developed terminal shape that gives the connector a height of 3.4 mm (0.13 in). The low-profile connector exerts a minimal effect on the lighting angle of the LED, enabling smaller and low-profile LED lamp modules to be easily manufactured. For more information, visit **www.panasonic.com/global**.

Molded current sense resistors

The new SLN5 molded current sense resistor line from **KOA Speer Electronics** (Bradford, PA) features a 7-watt power rating in 4527 size. Used primarily for current detection, the SLN5 resistor is suitable for transportation, industrial, telecommunications and consumer electronics markets in applications such as personal computing devices, dc to dc conversion, automotive modules, motor control and power supplies. The AEC-Q200 qualified SLN5 is a molded resin resistor that provides dimension accuracy, mountability and shock resistance. It also offers a terminal port temperature of 70°C (158°F). Due to its metal plate terminal electrode, the series also features terminal strength, heat shock resistance and solderability. The SLN5 resistor has low temperature coefficient of resistance available down to ±75 ppm with resistance tolerance as low as 0.5% and resistance values of 5 to 200 mΩ. The SLN5 also has an operating temperature of -65 to +180°C (-85 to +356°F). For more information, visit **www.koaspeer.com/**.

Simulation apps for virtual prototyping



Engineers at **BE CAE & Test** (Catania, Italy), a **COMSOL**- (Burlington, MA) certified consultant, have taken the simulation process beyond the typical approach of "run a test/deliver a report." Using the COMSOL Multiphysics software and the Application Builder, they have created a series of easy-to-use custom applications that perform virtual prototyping of their customers' surface-mount device designs. According to BE CAE & Test, the apps (pictured) hide the complexity of the underlying detailed model, yet still provide access to the powerful functionality of the simulation. BE CAE & Test is creating custom applications to give device designers interactive tools to access, analyze and share the vast amount of information available from the mathematical models they created without needing app users to be simulation specialists themselves. For more information, visit **www.comsol.com** or **www.be-caetest.it/**.

Molded seals

Minnesota Rubber and Plastics (Minneapolis, MN) features a large inventory of standard size molded Quad Brand family of products including Quad O-Rings, Quad-Rings and Quad Rubber Balls for sealing in a range of industry applications. The sealing products are offered in select sizes in small to large quantities for 48-hour lead time global delivery. Available in 12 different materials with outside diameter sizes from 0.070 in (±0.003) to 0.139 in (±0.004), the Quad O-Ring seals serve as a general-purpose seal for use as static, reciprocal and oscillating seals in low-speed and low-pressure applications. According to the company, Quad-Ring Lobed seals have twice the sealing surface to withstand distortion and extrusion while providing longer life compared to O-Ring seals. In addition, they reduce friction and eliminate leakage with strategically placed parting lines. Designed for pneumatic, hydraulic and water applications, Quad Rubber Balls are molded of 70 Shore A nitrile compound specially formulated for precision grinding the ball surface. For more information, visit **www.mnrubber.com/**.

Polymer range for electronics

Solvay Engineering Plastics (Brussels, Belgium) has developed a new Technyl range for the demanding environment of automotive electronic applications. With both unfilled, glass-fiber-reinforced and heat-stabilized engineering plastics, the Technyl grades will have a specified and controlled halogen content tailored to fit sensitive electrical and electronic automotive applications, such as sensors, relays, bobbins, chargers and control units. In all these cases, says the company, customized Technyl grades for electronic applications are demonstrating first-rate retention of properties, including high chemical and hydrolysis resistance, even after long-term exposure to elevated temperatures, while at the same time enduring demanding mechanical loads. Pictured is the Technyl PA6.6 range in application in **Continental**'s Tire Pressure Monitoring System sensor. For more information, visit **www.technyl.com**.

Power tester

The MicReD Power Tester 600A from **Mentor Graphics** Corp. (Wilsonville, OR) tests electric and hybrid vehicle (EV/HEV) power electronics reliability during power cycling. The device allows EV/HEV development and reliability engineers to test power electronics for mission-critical thermal reliability and lifecycle performance. Built for manufacturing as well as laboratory environments, the MicReD Power Tester 600A provides a simple reliability testing process for lifecycle estimation. It powers IGBT modules through tens of thousands of cycles, providing real-time failure-in-progress data for diagnostics, reducing test time and eliminating the need for post-mortem or destructive-failure analysis. Up to eight MicReD 600A Power Testers can be chained together to allow users to power cycle up to 128 IGBTs simultaneously in a system test. For more information, visit **www.mentor.com/powertester-600a**.

Electric vacuum pump for brake systems

HELLA's (Plymouth, MI) electrically driven vacuum pump for vehicle brake systems is designed to provide on-demand brake-system vacuum for high-efficiency gasoline engines, diesels and turbo- and super-charged engines, as well as hybrid or full electric powertrains. New fuel-saving approaches often have a direct impact on other engine functions that, for example, provide vacuum to support brake-booster systems. According to HELLA, the UP5.0 Electric Vacuum Pump solves this problem by meeting vacuum requirements for brake boosters under the most demanding applications. Fuel efficiency and fully independent vacuum generation were objectives for the development of the UP5.0. For more information, visit **www.hella.com**.

Smart force sensor

Design engineers can now rapidly evaluate and deploy new human-machine interface devices using **Maxim Integrated Products**' (San Jose, CA) MAXREFDES82# smart force sensor reference design, according to the company. Typical weigh scales provide one dimension of information, downward force, whereas MAXREFDES82# provides both downward force and center of mass, by collecting responses from four load cells using the MAX11254—a 24-bit, six-channel analog-to-digital converter (ADC). This unique configuration, enabled by the highly integrated 24-bit ADC, provides second and third dimensions of information about whatever object presses upon it. The MAXREFDES82# is a new concept, operating as both a weigh scale and 3D touch interface in rugged environments. For more information, visit **www.maximintegrated.com**.

Bearing preload series expansion

Smalley Steel Ring Co. (Lake Zurich, IL) has expanded its bearing preload (SSB) series to add diameters ranging from 9 to 13 mm. With this expansion, more than 300 SSB series springs are stocked in carbon and stainless steel with free samples available to test in various applications. According to Smalley, the SSB series' single-turn wave spring helps eliminate bearing play and minimize noise. The constant light/medium pressure they apply removes play between the ball bearings and the bearings' inner and outer races. Preloading can reduce the possibility of bearing damage due to vibration (vibratory loading) and wear due to repetitive and non-repetitive runout, claims the company. For more information, visit **www.smalley.com**.

Connected-car test solution

Anritsu Co. (Richardson, TX) introduces Cellular Module Test Application (CMTA) software for its Signaling Testers MD8475A/B, which provides test cases to simplify testing chipsets and automotive-related telematics modules used in connected-car designs and implementation. Integrating the new CMTA test package with the MD8475A/B through Anritsu's SmartStudio GUI allows automotive manufacturers and suppliers to verify operation in various carrier environments more efficiently to lower the cost of test and decrease time to market, claims Anritsu. CMTA provides a set of semi-automated test scenarios via SmartStudio for testing and debugging automotive-use cases more efficiently by replicating real-world scenarios as a replacement to conducting expensive, time-consuming drive tests. For more information, visit **www.anritsu.com**.

COMPANIES MENTIONED

AD INDEX

UPCOMING WEBINARS

SMART NVH SOLUTIONS FOR NEXT-GENERATION BRAKE DESIGN

Thursday, September 15, 2016, at 10:00 a.m. U.S. EDT

Brake noise is one of the most frequent complaints from car owners. Consumer expectations and the high cost of warranty repairs have created heightened demand for optimized brake NVH performance. This Webinar provides insight on tribology's role in brake system design and examines how selecting the appropriate lubricant can simplify design and improve performance.

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ADVANCED LIGHTWEIGHTING COMPOSITE PROCESS FOR AUTOMOTIVE MASS PRODUCTION

Tuesday, September 20, 2016, at 2:00 p.m. U.S. EDT

With growing demand for lighter, more fuel-efficient vehicles, the automotive industry has turned to materials suppliers to provide innovative materials that can deliver solutions to challenging applications. This 60-minute Webinar examines the new Direct Fluid Compression Molding Process (DFCM) and how it takes the next step toward mass-produced composite automotive parts.

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NEW POLYURETHANE POURABLE FLOORING AND SEALING TECHNOLOGY FOR COMMERCIAL VEHICLES

Wednesday, September 21, 2016, at 1:30 p.m. U.S. EDT

The wear and tear experienced by buses and other commercial vehicles requires advanced solutions to improve durability and safety. This Webinar examines the manufacturing and service requirements of commercial vehicle flooring systems and introduces an easy-to-apply flooring and sealing technology that eliminates side wall moldings and sealers as well as center aisle aluminum extrusions.

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UPCOMING WEBINARS

INTRODUCING SURFACE ANALYSIS FOR AUTOMOTIVE APPLICATIONS

Thursday, September 22, 2016, at 10:00 a.m. U.S. EDT

As materials used in the construction of automobiles become more advanced, the breadth of analytical challenges also increases. One of the most widely used techniques for surface chemical analysis is X-ray photoelectron spectroscopy (XPS). This 30-minute Webinar examines the XPS technique and explains its complementary nature to other materials science tools such as EDS and Raman spectroscopy.

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AUTOMOTIVE INDUSTRY STANDARDS AND TRENDS

Tuesday, September 27, 2016, at 1:00 p.m. U.S. EDT

The development of new vehicle lines, enhanced features, and safety improvements among automotive manufacturers has led to an increased focus on modularity, reusability, and manufacturing efficiency. This focus is driving the need for new and updated standards relating to software design, management, and testing in the automotive arena. This 30-minute Webinar examines trending standards activities and their impact on the software development life cycle and safety, security, and quality of components used in vehicles.

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FROM THE EDITORS OF SAE – ADDITIVE MANUFACTURING: FROM PROTOTYPING TO PRODUCTION PARTS

Thursday, September 29, 2016, at 12:00 p.m. U.S. EDT

Additive manufacturing is gaining steam in the automotive industry, and not just for prototyping parts. 3D printing processes are being evaluated for production components, with their promise of shorter development times, lower tooling costs, parts consolidation, and dramatic part shapes and sizes. In this 60-minute Webinar, three experts discuss these benefits as well as implementation challenges.

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Q&A

Daimler AG's Vice President–Group Research and Sustainability and Chief Environmental Officer, Anke Kleinschmit.

Sustainable transformation—the Daimler way

Interviewed recently by *Automotive Engineering* European Editor Stuart Birch, Anke Kleinschmit, Vice President–Group Research and Sustainability and Chief Environmental Officer, **Daimler AG**, addressed critical issues facing today's designers and engineers.

Is reducing vehicle mass continuing to be a matter of combining materials, particularly high-strength steel and aluminum, or is the focus now on other areas to achieve lightweighting? Does carbon fiber remain too exotic and too costly for high-volume applications in the near- to mid-future?
Our lightweight construction strategy at **Mercedes-Benz** is derived from the dictum, "The right material in the right place." Depending on its operation purpose, each material has its own strengths in terms of weight, strength, stiffness and crash performance.

When it comes to lightweighting technologies in body, chassis and drive, we pursue the clear goal to reduce the weight of all our new models in comparison to their predecessors.

Talking about carbon fiber, we do have a quite extensive experience using it as a lightweight material; we use CRP materials in Mercedes-Benz cars, especially within the area of our high-performance cars from Mercedes AMG, to improve the performance and of course save weight. Since carbon fiber is still a very cost-intensive material, the main focus is on hybrid (body) shells with an intelligent mix of all steel grades and advanced aluminum alloys in mass production.

Electric-vehicle technology is improving, but are you confident of its ability to deliver (batteries, motors) what is required both for Mercedes-Benz and the auto industry in general, in terms of cost, longevity, quality, and buyer acceptance?
We are absolutely convinced that in the long run, the electrification of the drivetrain is one major element of the "future of mobility."

We believe that different technologies will apply to different requirements—and therefore pursue a flexible strategy on our path to zero-local-emissions driving:

First: we're further maximizing the potential of high-tech combustion engines. Second, we're increasing hybridization to further reduce consumption. Third, we're working on zero-local-emissions driving with batteries and/or fuel cells.

It is natural that new technologies are more cost-intensive at the time of their introduction. But we already feel a great commitment to the electrified cars in our portfolio, from plug-in hybrids up to our B-Class ED (Electric Drive) and the upcoming new generation of the smart ED—the first time as a 2- and a 4-seater. And there is more to come. Before the end of the decade, we're bringing a large electric vehicle to lay the foundation for our future electric strategy with a range of up to 500 km (311 mi). That's why we are investing 500 million euros in a second battery factory on our battery production site in Kamenz. It is clear that battery technology increasingly allows higher ranges at decreasing costs.

Can aerodynamics continue to improve or will they, realistically, plateau at a best of around of 0.22 - 0.25Cd? Do they inhibit design (styling)—or is design inhibiting the figures?
The potential for reducing air resistance has not been exhausted, although it will slow down. As long as there are no major changes in the basic architecture of vehicles—like their length and form—there is an asymptotic limit of about 0.20 Cd with "conventional" vehicles. With a drag coefficient of 0.22 our CLA, which we introduced in 2013, is coming quite close to this.

Finding the best solution for portability, space and our overall design philosophy can be further supported with active aerodynamic measures, like our "Transformer" Concept IAA's features.

Do you regard Autonomous vehicle technology as inevitable? If so, when?
For us, it is not a question if the technology of autonomous driving will evolve, but at what pace this will happen. Autonomous driving will become reality step-by-step.

We expect that it will be possible to realize the first highly-automated driving systems in just a few years on certain types of roads, such as autobahns, and in suitable weather conditions. Fully automated driving in any situation will take much more time to achieve; legislative and technology issues both play a major role in the challenges we are facing to reach the breakthrough of autonomous driving.

Customer acceptance of autonomous driving functions is closely linked to the degree of their reliability and availability. Away from motorways, such a function has to cope with the increasing complexity of the surroundings and manage a greater number of dynamic and static objects as well as different weather and daytime conditions.

And of course, the legal questions need to be resolved. It is clear that 'political will' and above all, social acceptance, are decisive factors for the introduction of autonomous vehicles. ■

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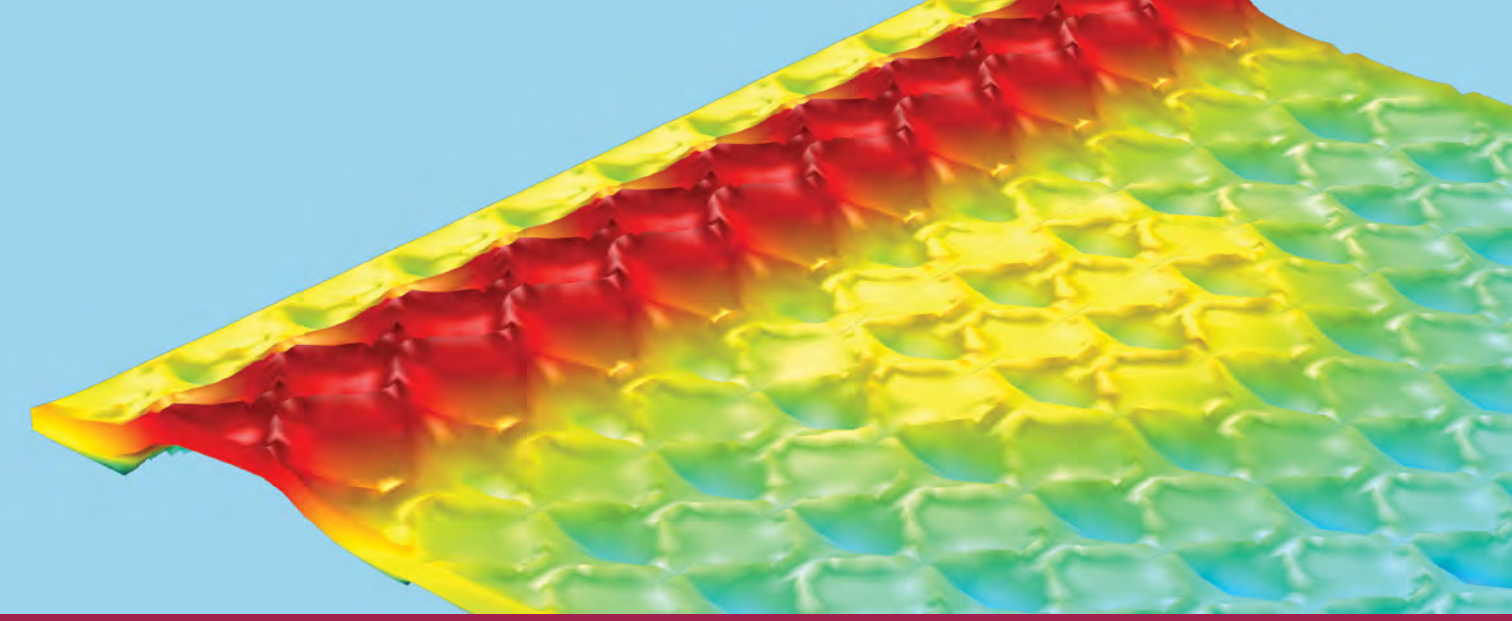

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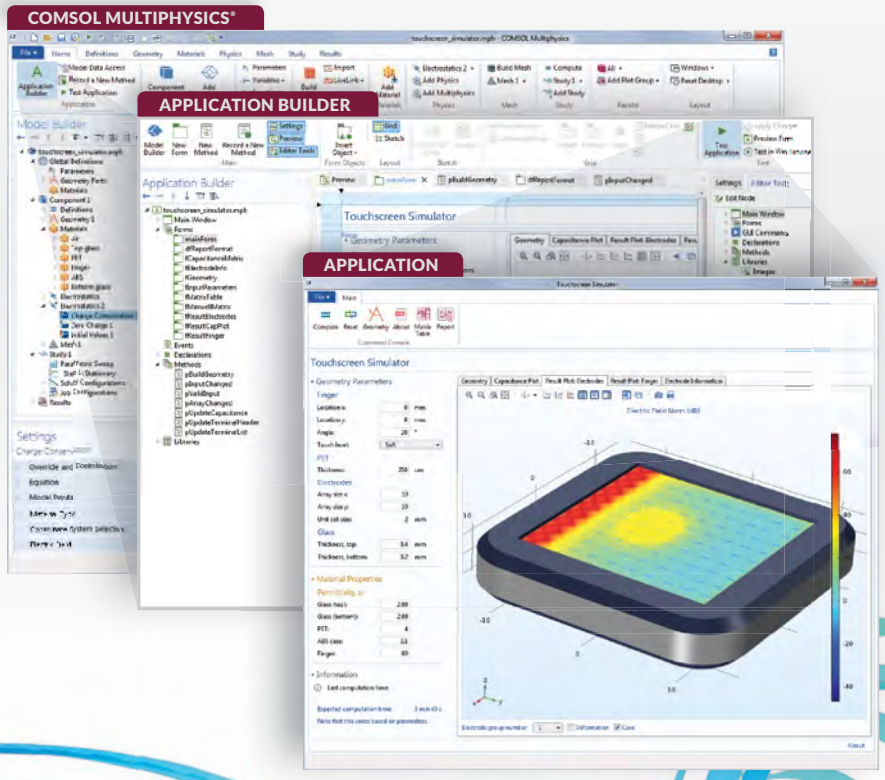

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