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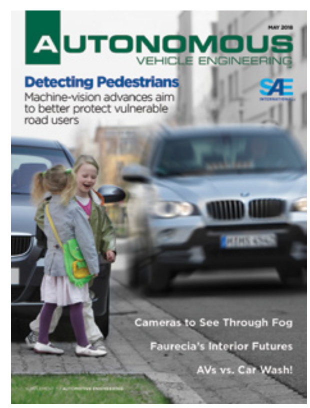
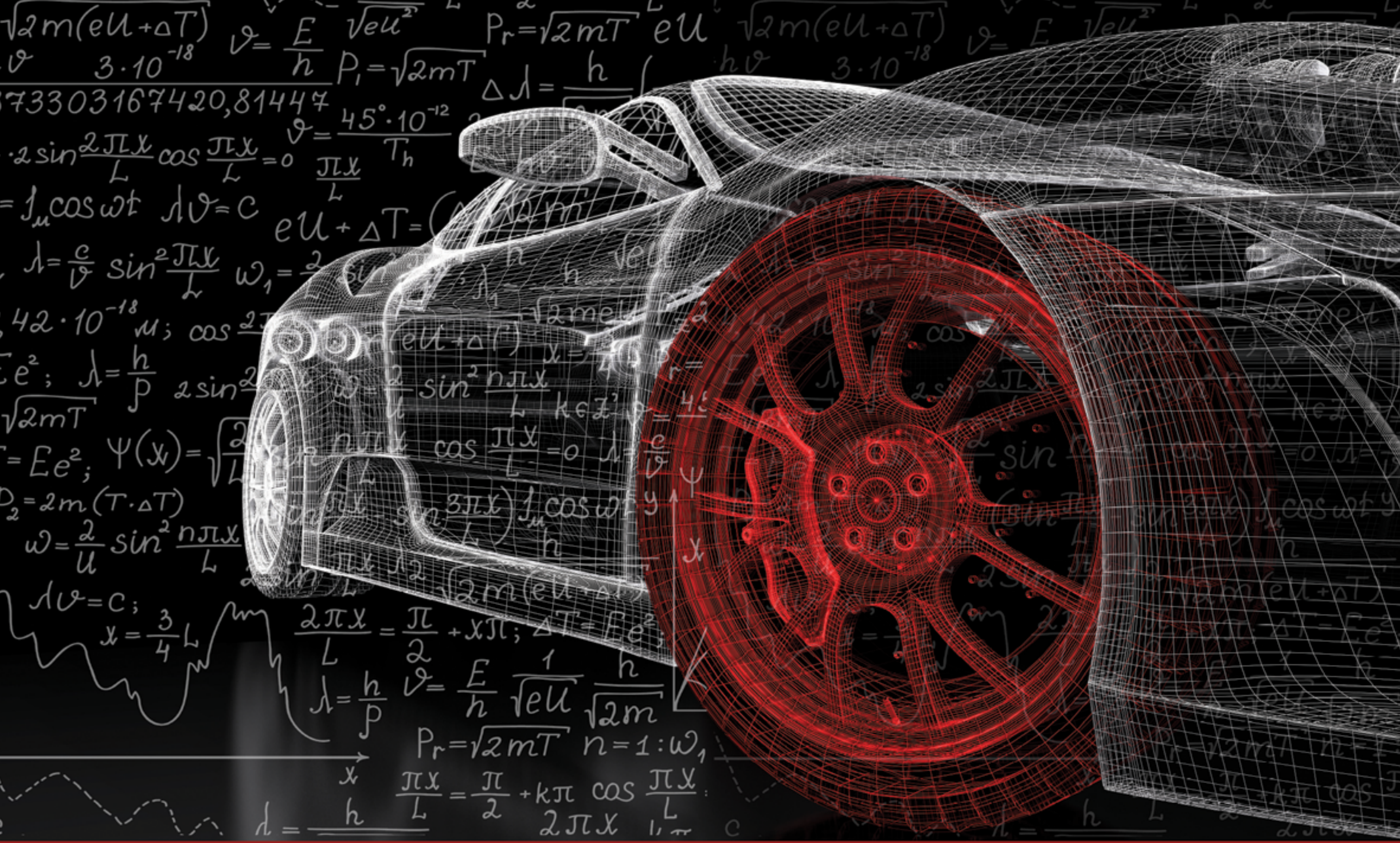


On the Cover

Ensuring that pedestrians, cyclists and motorcyclists—known as Vulnerable Road Users—are accurately detected, identified, and kept out of harm’s way from larger road vehicles is an ongoing challenge for AV engineers. Our cover feature begins on page 6. (image: BMW)



Editorial

Tragedy to Transform AV Testing?

Tempe, Arizona was as likely a place as any for the "autonomous age" to irrevocably veer from what many argued was an overly-optimistic course. Like a star major-league pitcher leveraging an umpire's generous strike zone, automated-driving development seemingly was getting all the breaks before an Uber test car, operating in SAE Level 4 autonomous mode, struck and killed a pedestrian in the desert night.

Elaine Herzberg lost her life. In the aftermath, public-road autonomous testing lost the carte blanche some suggested was just another example of the technology "industry" leveraging our inability to understand technology—and public officials' zeal to appear forward-thinking and business-friendly.

Immediately after the March 18 incident, Uber suspended public-road testing. Not long after, so did Toyota. Lina Karam, director of the Image, Video and Usability Laboratory at Arizona State University, told *The State Press* that the accident was evidence more testing in controlled environments was in order.

Beyond the obvious impact on the formerly free-wheeling attitude most states adopted regarding public-road testing of autonomous vehicles (AVs) of all stripe, the accident that killed Ms. Herzberg raised the inevitable question of blame.

In an incisive analysis on page 10, engineer-attorney Jennifer Dukarski, an expert on the legal implications of disruptive technology, examines the Tempe accident and other recent automated-driving mishaps to demonstrate how, as automated-driving miles pile up, legal "blame" is almost certain to shift to a product-liability framework. That transformation will have enormous implications for the developers of automated-driving systems and their integrators and operators, whether they be automakers, ride-share enterprises or auto-industry suppliers.

But what about the future of AV testing? If it transpires that public-road evaluation will be drastically regulated or curtailed (even if it's not forever), the need for development "miles" isn't going away. It seems inevitable that demand will expand for testing time at proving grounds-type facilities. But good heavens, proving-grounds time is expensive. And complicated to arrange.

More important, what can't be replicated in controlled environments are the incalculable—and therefore immensely valuable—variables that present themselves in "no-cost" everyday driving.

That's why on-road testing must continue. But after what's believed to be the first fatal collision between an AV and a pedestrian, we can expect to hear more about whether increased use of artificial intelligence and machine learning can generate the situational understanding that we've relied on public-road testing to deliver.

One developer recently suggested to me that AV on-road testing doesn't have to be so much about vehicles *operating* autonomously as it does about collecting, collating and learning from what those vehicles "see" while traveling—and the subsequent reactions to those observations then can be simulated. In other words, allowing vehicles to "pretend" to be autonomous might be almost as good as the real—and for now, maybe too-dangerous—thing.

Simulation as savior? It's certainly not a new idea. But the seemingly preventable loss of a life should deepen our motivation to expand less-risky methods to enable the end game we're seeking.

Bill Visnic, Editorial Director

Detecting **Pedestrians**

by Terry Costlow

Safety of vulnerable road users is driving new technologies as pedestrian deaths rise worldwide.

Automakers and legislators are focusing on pedestrians, aiming to reduce injuries that are rising as more people worldwide migrate to cities. Camera systems have surpassed passive technologies to become the key technology for protecting people on foot who venture into harm's way with cars and trucks on the roadway.

The death rates are already soaring for pedestrians, cyclists and motorcyclists—an aggregate group called Vulnerable Road Users (VRU). The World Health Organization said that nearly half the 1.25 million people killed in traffic accidents in 2016 (the most recent data available) are VRUs. In the U.S., VRU deaths reached the highest levels in more than a decade. NHTSA said that in 2016, pedestrian deaths increased by 9% to 5,987. By comparison, motorcyclist fatalities increased by 5.1% to 5,286 and bicyclist deaths rose 1.3%, reaching 840.


BMW

Small pedestrians such as children are more difficult for human drivers and advanced vehicle sensor systems to see and identify.

The auto industry is racing to help reduce this trend, leveraging the rapid advances in advanced safety systems. Legislators are also ramping up their efforts.

"We're focused intensely on VRUs—pedestrians, cyclists and motorcyclists," said Kay Stepper, Vice President of Driver Assistance and Automated Driving for Chassis Systems Control at Bosch North America. "European regulations call out VRUs, and in the U.S. they're looking at back-over avoidance legislation."

Government interests are going beyond forcing automakers to react. Many cities are beginning to monitor pedestrian movement as part of their "smart cities" programs. Understanding patterns that cause accidents can help urban planners make changes to enhance safety.

"Downtown Las Vegas is an innovation district; we have lidar systems at intersections to detect whether anyone is in the intersection," said Joanna Wadsworth, Program Manager for the City of Las Vegas. "We'll work with Cisco on dashboarding to make that data available. That data's also helpful to us as planners; it's important to know how many people are crossing where."

The need to look very closely

Automotive engineers and technologists are moving away from passive safety systems that lift the vehicle's hood on impact and deploy exterior airbags that

ZF

Cameras with greater acuity and processing power are vital for fast and accurate pedestrian identification.

cushion pedestrians. Those systems posed many design challenges but offered minimal benefits.

"Market interest has shifted to avoidance and mitigation instead," said Aaron Jefferson, Director, Product Planning, ZF Global Electronics. "It was difficult to package [exterior] airbags and there was the question of what happened to the pedestrian after the collision."

The change comes as cameras and radar are becoming commonplace, helping stop vehicles before accidents occur. Tweaking systems to spot VRUs in addition to cars leverages existing technology, reducing costs and space requirements.

Camera systems are evolving rapidly as developers increasingly use them to spot people who may be in danger of being hit. It's harder to see and identify comparatively small VRUs than cars, so higher resolution is important. Humans move more freely than cars; newer systems are also looking to the side to see people who may drift in front of the vehicle. Those two approaches can be at odds with each other.

"It's always an engineering compromise, looking at range or field of view," Stepper said. "When it comes to VRUs, there's great advantage to increasing resolution. There's talk of a minimum camera resolution of one megapixel, and there's already a lot of effort to go to two megapixels, four megapixels and beyond."

Developers are also finding ways to spot people when cars are turning. Right-hand turns are often dangerous, particularly in busy cities. People may walk in front of the car while the driver is watching traffic coming from the left.

"Today, typical forward-looking cameras have a field of view of around 50 degrees, focusing on vehicles and pedestrians who step out in front of the car," noted Andy Whydell, Vice President, Systems Planning and Strategy at ZF. "Next-generation systems increase that to around 100 degrees, which lets them see pedestrians when cars are turning around corners. As vehicles pull around for a right-hand turn, cameras detect pedestrians and slow the vehicle down."

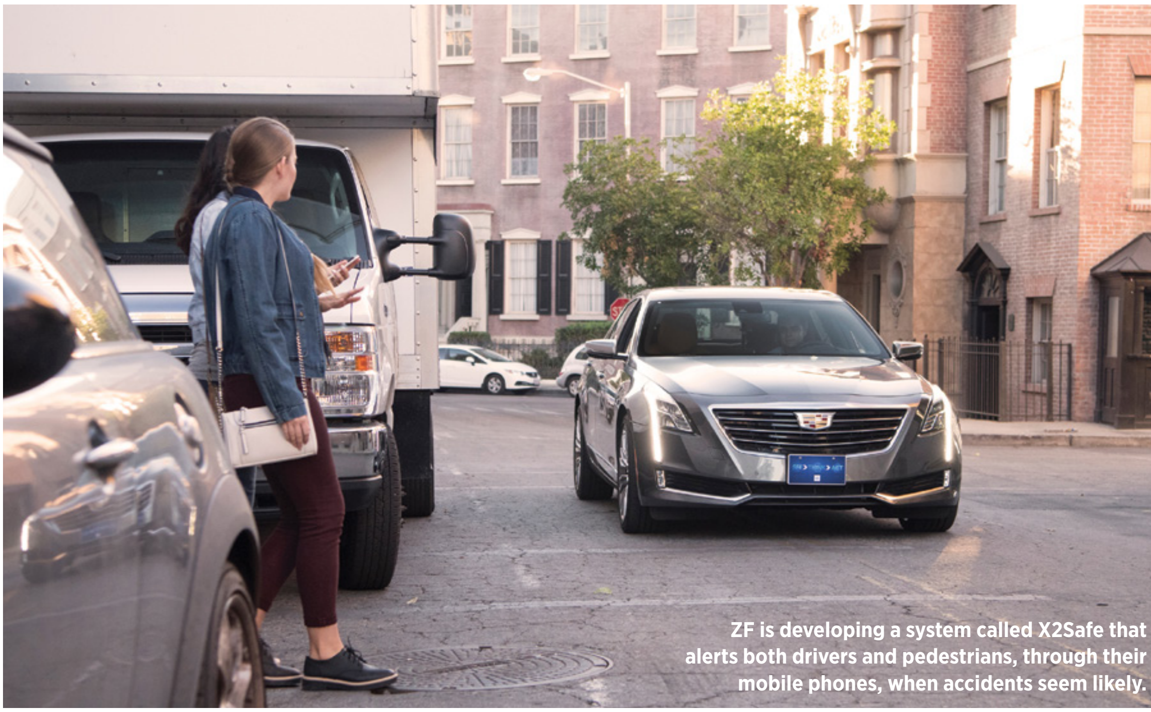
VRUs are far more unpredictable than vehicles, in terms of their next move, because they have more degrees of freedom. Crowds also pose significant challenges—one person can move in a different direction, breaking away from the others to enter harm's way.

"In urban environments, it's not just one pedestrian or cyclists; they're often in groups," Stepper said. "The trick is to be able to resolve groups of humans down to an individual human being. Another problem is that it's not as obvious to predict the movement of pedestrians, they can move in 360 degrees. The trick here is to use predictions based on recent data sets. We are using artificial intelligence to support us on this research."

Looking forward

As safety and autonomous systems evolve, more technologies will be used to protect VRUs. Artificial intelligence (AI) can help systems discern a human from a pole or perform other complex recognition tasks.

Camera systems with higher resolution are evolving rapidly.



ZF is developing a system called X2Safe that alerts both drivers and pedestrians, through their mobile phones, when accidents seem likely.

ZF

Making these decisions in all light conditions can be a problem for current-generation camera systems.

"The technology of image recognition is being improved with AI," said Takayuki Nagai, Director of Advanced Driver Assistant Systems for Denso International America. "Additionally, each sensor's performance is improving every day. For example, we now produce a vision sensor that can recognize pedestrians at night."

Denso

Camera suppliers are developing products that can spot pedestrians in low light, such as this one from Denso.

Recognizing VRUs quickly and accurately is no simple task. It is difficult to avoid false positives, for example. Avoiding unexpected stops will be important in crowded urban areas since quick stops may result in rear-end collisions. That's prompting researchers to look at ways to use multiple sensors to ensure that potential safety threats are indeed real. Radar may augment cameras.

"We have proven that it's possible implementations can use solely radar to detect pedestrians and still meet NCAP requirements," Stepper said.

Developers are also exploring ways to alert pedestrians when they're entering a dangerous area. Cell phones may become part of an alert scheme designed to protect people.

"We have an R&D program for a cloud-based warning system," ZF's Jefferson said. "It allows bidirectional messages to be sent to pedestrians who are about to step into the path of a vehicle. The system will send a message to both the pedestrian and the vehicle." ■

When Autonomy Underperforms: the Evolving Liability Model

As autonomy-related accidents expand, expect legal liability to shift to products rather than people.

by Jennifer Dukarski

When humans drive a vehicle, safety liability issues are well-established and depend largely on whether a state has adopted no-fault liability or whether a product was at the root of the issue. When human drivers are at fault, either no-fault liability or traditional negligence liability usually controls.

But what happens when the vehicle is the "driver?"

The answer: product liability

As fatalities and injuries related to automated driving arise, plaintiffs' lawyers likely will switch from traditional negligence suits to product-liability suits, with the following options:

Negligence-based product liability: The plaintiff must establish that a manufacturer breached its duty to use reasonable or ordinary care under the circumstances in the planning and/or designing of the product so that the product was reasonably safe for its intended purpose.

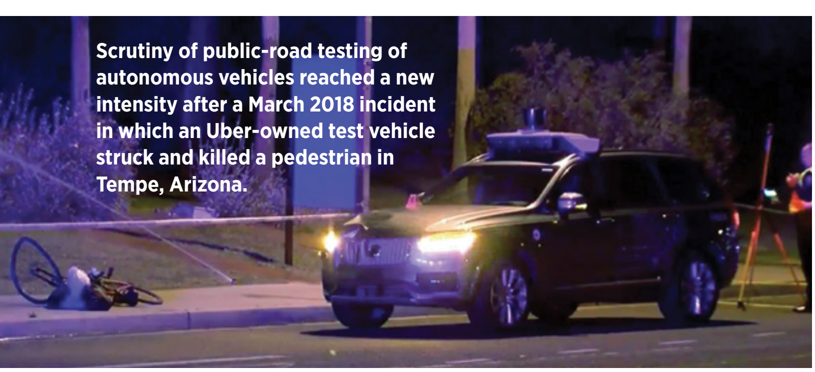
Design defect: The plaintiff must prove that the manufacturer's process or decisions did not properly weigh alternatives and evaluate tradeoffs to develop a reasonably safe product.

Implied warranty: The plaintiff must prove injury caused by a defect in the product—attributable to manufacture—that made it not reasonably fit for its intended, anticipated or reasonably foreseeable uses.

Manufacturing defect: A faulty manufacturing process delivers a product that does not meet the specification or standards as dictated for that component or vehicle.

Duty to warn: Manufacturers that know or ought to know of a danger inherent in a product, or in the use for which the product is intended, have a duty to give adequate warnings about that product.

So, when the vehicle is the driver, how does the analysis change?



Scrutiny of public-road testing of autonomous vehicles reached a new intensity after a March 2018 incident in which an Uber-owned test vehicle struck and killed a pedestrian in Tempe, Arizona.

ABC15 via YouTube

Here come the plaintiff's attorneys

May 2016 Tesla Model S Fatality

This fatal accident occurred while the vehicle's driver engaged Tesla's "Autopilot" driver-assist functions. Root-cause analysis showed that the Autopilot sensor failed to distinguish a white tractor-trailer crossing a

Rogers' Laminates: Paving the way for tomorrow's Autonomous Vehicles

Autonomous "self-driving" vehicles are heading our way guided by a variety of sensors, such as short and long range radar, LIDAR, ultrasound and camera. Vehicles will be connected by vehicle-to-everything (V2X) technology. The electronic systems in autonomous vehicles will have high-performance RF antennas. Both radar and RF communication antennas will depend on performance possible with circuit materials from Rogers Corporation.

High-performance circuit laminates, such as RO3000® and RO4000® series materials, are already well established for radar antennas in automotive collision-avoidance radar systems at 24 and 77 GHz. To further enable autonomous driving, higher performance GPS/GNSS and V2X antennas will be needed, which can benefit from the cost-effective high performance of Kappa™ 438 and RO4000 series materials. These antennas and circuits will count on the consistent quality and high performance of circuit materials from Rogers.

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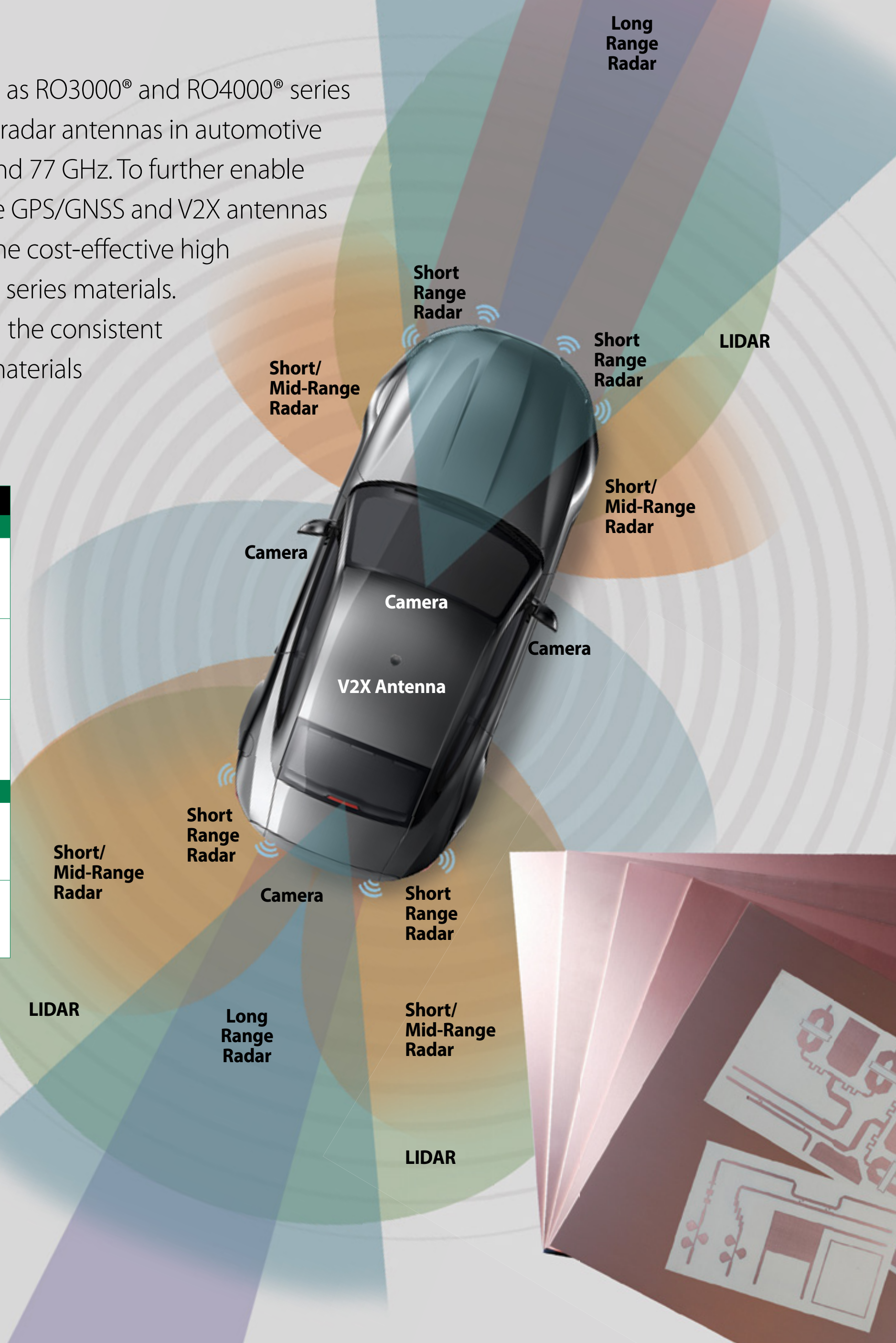
ANTENNA	
RO4000 Series Circuit Materials	Low loss, FR-4 processable and UL 94 V-0 rated materials
Kappa™ 438 Laminates	Higher performance alternative to FR-4



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USA - AZ, tel. +1 480-961-1382 • EUROPE - BELGIUM, tel. +32 9 235 3611 • **www.rogerscorp.com/acs** divided highway against the backdrop of a bright sky. The Tesla vehicle struck the tractor-trailer as it crossed an intersection that was not managed by a traffic signal.

Following the accident, the National Highway Traffic Safety Admin. (NHTSA) initiated a Preliminary Evaluation (PE 16-007) to determine whether the system acted according to its design parameters and expectation—or if the system experienced a defect. On January 19, 2017, NHTSA closed the file, finding that a "safety-related defect trend has not been identified at this time and further examination of this issue does not appear to be warranted."

December 7, 2017 Cruise Automation Chevrolet Bolt

In this incident, a motorcyclist claimed the Bolt initiated a lane change then abruptly returned to its previous lane, now occupied by the motorcyclist. In contrast, GM's report to the California DMV stated the Bolt returned to its lane when a nearby vehicle decelerated, leaving an insufficient gap to make the originally-intended lane change. As it returned to the initial lane, the motorcyclist "wobbled and fell over" when attempting to perform a lane split (riding between two lanes, which is legal in California).

On January 22, 2018, the motorcyclist filed a personal-injury lawsuit against GM alleging traditional negligence and suggesting that GM owes other drivers on the road a duty of care "in having its Self-Driving Vehicle operate in a manner in which it obeys the traffic laws and regulations." The plaintiff contends GM "breached that duty in that its Self-Driving Vehicle drove in such a negligent manner that it veered into an adjacent lane of traffic without regard for a passing motorist, striking Mr. Nilsson and knocking him to the ground."

March 18, 2018 Uber / Volvo XC90 Fatality

In March, an Uber-owned Volvo XC90 involved in testing struck and killed a woman in Tempe, Arizona. The vehicle was in fully-autonomous mode when it struck the woman as she walked her bike across the street. As of late April, the root cause had yet to be established, but reporting suggested that Uber "disabled the standard collision-avoidance technology in the Volvo SUV." Commentators questioned whether a sensor may have contributed to the failed detection or whether algorithms are implicated. The matter was settled less than a week after the woman's family retained an attorney.

March 23, 2018 Tesla Model X Fatality

Also in March, a Tesla Model X in Autopilot mode was involved in a fatal crash and vehicle fire. Tesla, now removed from the NTSB investigation, placed the blame with the driver and a road divider. The driver's family retained an attorney.

Design decisions that bolster product safety

One of the largest emerging risks is the potential exposure from a design defect. Future litigants will likely scrutinize the test protocols, algorithms and engineering decisions used in the development of systems that make substantial safety decisions for users. Key to mitigating potential claims is adherence to a design and test plan that addresses these alternatives and tradeoffs—while incorporating legislative, executive and judicial constraints found in rules, regulations, laws and case law.

One way to assess these alternatives is for AV developers to perform more robust assessment of potential risks and failure modes. To incorporate the principles of product liability into a robust DFMEA, these points should be considered:

- What alternative designs could achieve the same function?
- Assess how differences in conditions (weather, night, gender, age, etc.) might impact the use of the product.
- Review potentially relevant standards.
- Reflect on newsworthy cases that provide lessons learned, particularly if issues resulted in legal challenges.

In sum, these concepts should be cascaded into a robust test plan to validate the system with a competent model—one that tests the product for all demographic and environmental variables. ■

A self-described "recovering engineer" with 15 years of experience in automotive design and quality, Jennifer Dukarski is a Shareholder at Butzel Long, where she focuses her legal practice at the intersection of technology and communications, with an emphasis on emerging and disruptive issues that include cybersecurity and privacy, infotainment, vehicle safety and connected and autonomous vehicles.

Seeing Through **Fog**

by Art Stout

Fog, rain and snow are big challenges for optical sensors, particularly active systems. Engineers need to understand the impact of fog conditions on cameras and thermal sensors used in AVs.

As the mobility industry advances with ADAS and autonomous vehicle (AV) operation, the safety challenges of applications involving nighttime warning systems, pedestrian detection and driver situational awareness will surely warrant redundant systems. Thermal sensors will continue to be an important component of the sensor suite that makes safe autonomy a reality.

WikiCommons

A 2006 example of the notorious and deadly Tule fog in Bakersfield, Calif.

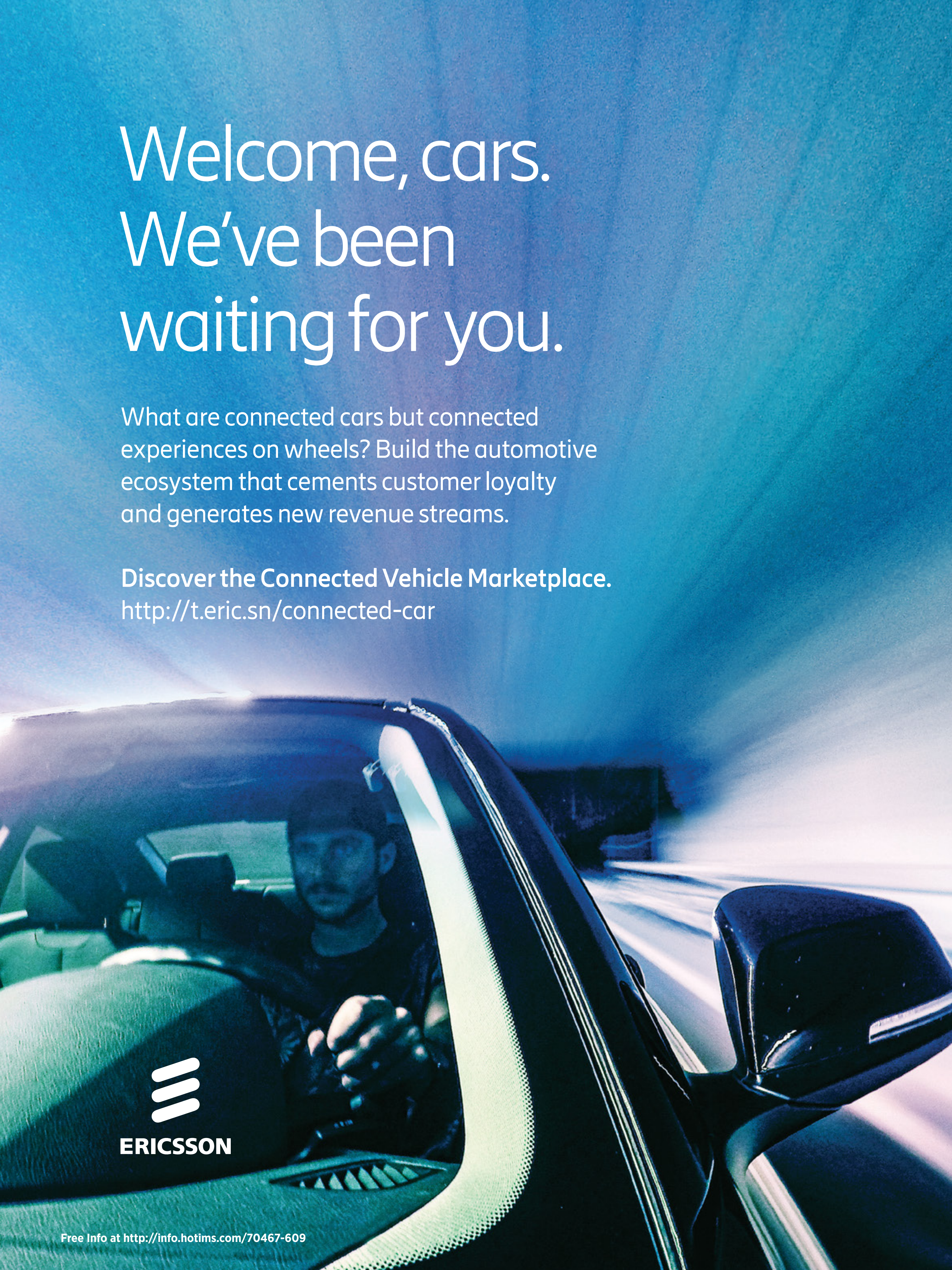
Although the value of thermal sensors is widely acknowledged for nighttime driving, a key issue that has limited their full-scale adoption has been cost. It is important to note that infrared imaging sensors are semiconductors, so the same economics of scale apply to infrared sensors as apply to other silicon-chip products. The costs for high resolution thermal sensors are projected to decline to well under $250 with their large scale adoption in ADAS systems.

As the price enables developers to include thermal sensors, it is important to identify why they are needed and where they complement the ADAS sensor suite to make roads safer.

Delivering high-quality data and images to the 'brains' of autonomous vehicles in low light and under poor driving conditions is a major challenge for ADAS developers. Fog, rain and snow are big challenges for optical sensors, particularly active systems. Engineers need to understand the interaction of light energy across the visible and infrared spectrum with water vapor—specifically, the impact of fog conditions on optical systems such as visible cameras and thermal sensors.

Modeling with MODTRAN

Fog is a visible aggregate of minute water droplets suspended in the atmosphere at or near the surface of the earth. When air is almost saturated with water vapor, the relative humidity is close to 100% and fog can form in the presence of a sufficient number of condensation nuclei, which can be smoke or dust particles.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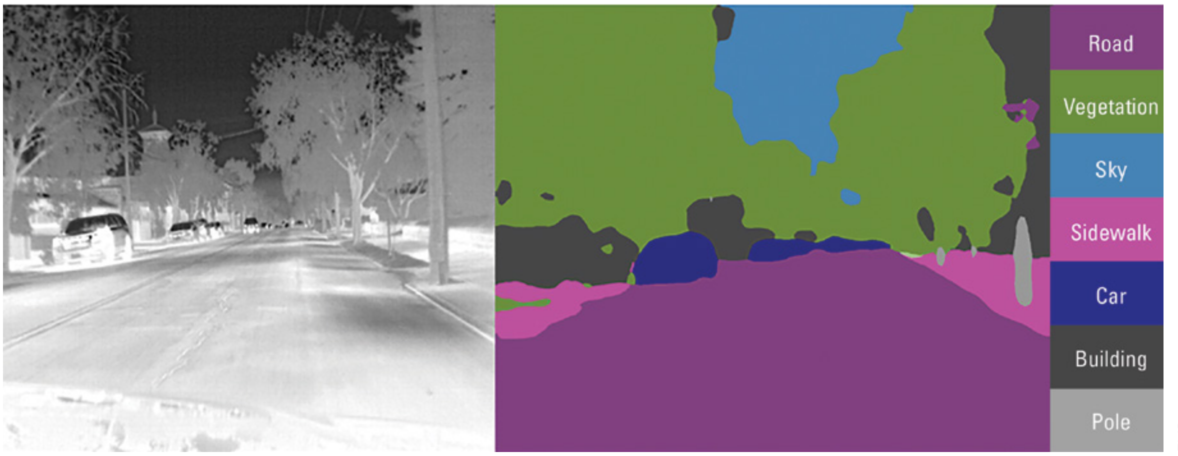


Semantic segmentation classifier using thermal sensor.

Oncoming headlight effect on visible and thermal camera comparison in nighttime foggy driving conditions.

There are different types of fog. Advection fog is formed through the mixing of two air masses with different temperatures and/or humidity. Radiative fog is formed in a process of radiative cooling of the air at temperatures close to the dew point. Some fogbanks are denser than others because the water droplets have grown bigger through accretion. The question whether scattering is less in the IR waveband compared to the visible range depends on the size distribution of the droplets.

MODTRAN is used to model the atmosphere under a variety of atmospheric conditions. Developed by the U.S. Air Force, it can predict atmospheric properties including path radiances, path transmission, sky radiances and surface reaching solar and lunar irradiances for a wide range of wavelengths and spectral resolutions. MODTRAN offers six climate models for different geographical latitudes and seasons.

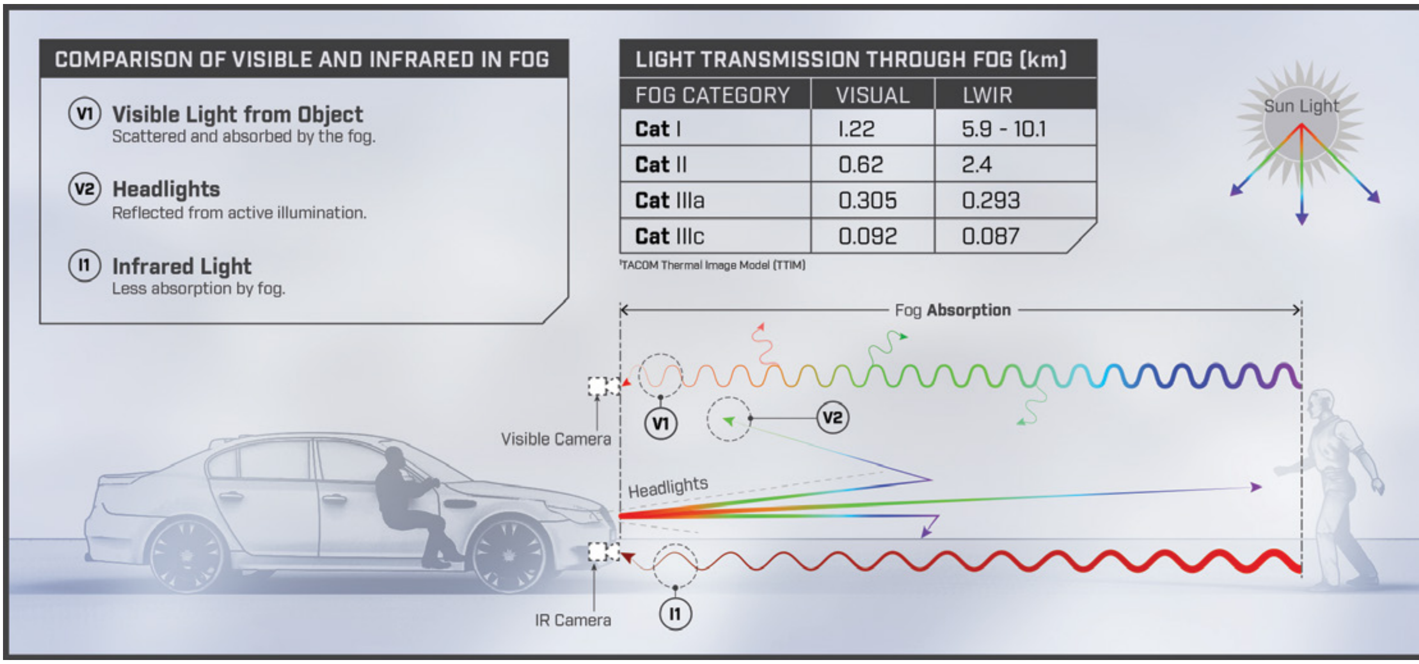
The model also defines six different aerosol types which can appear in each of the climates. Each of the climate models can be combined with the different aerosols. The distance an optical sensor can see will also depend on the climate and the type of aerosol which is present in this specific climate.

The spectral transmission of the atmosphere for varying ranges enables a simple qualitative comparison of the visible (0.4 to 0.75 microns) and thermal (8 to 12 microns) transmission in different atmospheric conditions and fog type. The International Civil Aviation Organization (ICAO) classifies fog in four categories:

- **Category I**: In fog in mid-latitude summer and rural aerosols, the visible spectral waveband demonstrates significantly lower transmission than in thermal IR wavelengths.
- **Category II**: Radiative fog is used in this category and the model predicts that transmission in the thermal band is superior to the visible band.
- **Category IIIa and Category IIIc**: The model states that transmission in the visible and thermal wavelengths are essentially equivalent.

The model compares the detection range in kilometers through fog with the naked eye and an LWIR camera, given a temperature difference of 10°C between the target and the background and a detection threshold of 0.15 K. The graphic on p. 17 includes the qualitative results of the model.

The model and data provide transmission performance, which is driven by several factors. The reason for degradation of visibility in a foggy atmosphere is the absorption, reflection and scattering of illumination by water aerosols. All drivers have experienced driving in heavy fog and poor visibility when using headlights. The light photons from headlights immediately begins to scatter and reflect.



FOG CATEGORY	VISUAL	LWIR
Cat I	1.22	5.9 - 10.1
Cat II	0.62	2.4
Cat IIIa	0.305	0.293
Cat IIIc	0.092	0.087

FLIR

Pathlength losses for visual and thermal energy in fog.

The limited light, if any at night, coming from the driving scene is absorbed and scattered, so the main visible photons the visible camera collects are of the fog itself.

While thermal light photons exhibit the same basic characteristics as visible light, the thermal energy is emitted by the surroundings so the path the thermal light energy takes between an object and the camera takes only one pass. There are loses due to scatter and reflection, but in most fog conditions the transmission is higher in the thermal bands than in the visible spectrum, so the losses are much lower.

Thermal imaging, Machine learning

The addition of thermal sensors to the ADAS sensor suite will clearly increase safety on the road. Thermal sensors see in darkness and challenging lighting conditions such as fog. As the photos on p. 16 illustrate, a vision-based autonomous system will simply become blind in a frequently experienced driving condition. They can detect and classify objects in a cluttered environment. The next challenge is to integrate thermal sensors into the fused detection and classification algorithms.

An additional promising area for thermal sensors, beyond seeing at night and through poor visibility situations, is semantic segmentation or dense labeling, a deep learning technique that describes the process of associating each pixel of an image with a class label (structure, person, road marker, animal, road or car). Initial results demonstrated by FLIR Systems, which has delivered more than 500,000 longwave infrared (LWIR) thermal cameras to date, indicate that thermal images can produce accurate classifications of most of the object classes of interest.

The ability to classify complex automotive driving scenes quickly and accurately using thermal imagery is a key part of increasing safety of ADAS and future autonomous vehicles. While open-source visible light training data sets exist, publicly-available thermal image training data sets do not, making the initial evaluation of thermal imaging more challenging. An annotated training data set from FLIR will create the opportunity for developers to more quickly test and integrate thermal sensors into their ADAS sensor suites.

Thermal cameras are and will become even more affordable with additional manufacturing scale. They deliver high resolution data and fill significant sensor gaps that exist in current ADAS approaches, especially in challenging lighting conditions. ■

Art Stout is Director of Business Development, Office of the CTO, FLIR Systems OEM Division.

Rethinking Architectures: From Chips to the Cloud

by Terry Costlow

New concepts and strategies for controls architectures are emerging as AV boundaries expand and options skyrocket.

Creating a powerful, robust electronic controls architecture is among the most important tasks faced by those chosen to create autonomous-vehicle systems. Risk-averse developers who are devising scalable, efficient hardware and software strategies need to make tradeoffs between clean sheet designs and leveraging proven systems.

Airbiquity

Vehicle computing and the electrical architecture that underpins it are no longer limited by the body of the car – cloud computing can help.

That's only the start of the process. Adding parallel image processors to the conventional microcontroller base requires rethinking the mix of distributed and centralized computing power. Numerous suppliers will provide boxes and programs, driving a shift to open platforms. Even factors that were once trivial, like semiconductors' power consumption, have become important.

"When you're going to [SAE] Level 4 or higher, it can be safer, more secure and more robust if you start with a new architecture," said Stephan Tarnutzer, Vice President, Electronics, Smart Vehicles, at FEV North America. "You can also account for higher power consumption. When you're adding GPUs with 15-20W consumption alone, power is important. All the sensors also need power. It can be simpler to start from scratch."

Although a new architecture always provides more freedom, engineers focused on reliability, safety and cost typically want to reuse proven technologies. In these early days of autonomy, some are using the PC's virtual capabilities to learn how sensor systems work together to identify objects; PCs aren't practical for production, but they help engineers create architectures that determine the right levels of distributed and centralized intelligence.

"Building an autonomous architecture would be much easier by leveraging any existing system/subsystems," noted John Buszek, Director of Autonomous

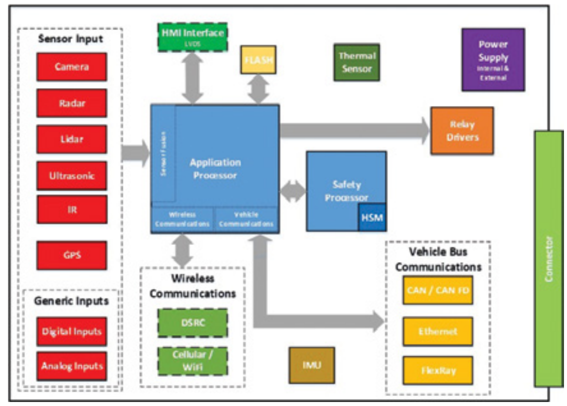
Driving Systems at Renesas Electronics. “Although, current PC servers utilized today in the autonomous space are stopgap solutions, consuming greater than 2 kW power and incurring a much higher cost than an embedded platform.

“To fully realize an autonomous driving capability, at minimum, the perception processing has to migrate to an embedded platform, fully decomposed for distributed processing,” he asserted.

Once companies establish the functional architecture for their vehicle, they move on to their technical architecture. OEMs are dealing with a number of system and software suppliers, typically building a number of partnerships to address the many facets of autonomy. That’s putting a greater emphasis on open platforms that allow carmakers to mix and match hardware and software, which will both be developed independently.

“That technical architectural approach looks at how things are connected and interface into the car,” explained Karl-Heinz Glander, Chief Engineer for ZF’s Automated Driving Team. “When hardware and software are abstracted from each other, software can be implemented by OEMs much more easily.”

When vehicles are making life or death decisions, there’s no room for failures. If electronics fail, they



FEV

Controllers in some FEV designs, such as shown in this Level 3+ high-level control module block diagram, are monitored by a supervisory/safety processor that watches for problems.

The computational workload for autonomy is daunting— and curtailing power consumption is becoming more important.

Renesas is testing various new architectures on vehicles, often using PCs to speed development.

Renesas

will typically downgrade to some sort of safe mode, often telling drivers that they must take control instead of relying on vehicle systems. Some designs include modules that watch over the sensors and CPUs.

"Many architectures are focusing on supervisory-type control, with controllers that serve no other task than to see if everything works," Tarnutzer said. "If not, the main controller will drop down to Level 4 or Level 2 for safe operation. Supervisory controllers are not that powerful."

Some OEMs are taking a different tack, providing redundant controllers capable of taking over if one of the domain controllers fails. This approach provides more safety but it's more costly, because the redundant module must be as powerful as the controller it's backing up.

Up in the sky

When system planners sketch their computing architectures, they're no longer limited to the vehicle. Cloud computing can handle aspects that don't require real-time responses, such as using high-definition mapping to help steer the car.

"Companies have to decide what processing they want to do on the vehicle and what processing they want to do in the cloud," observed Scott Frank at Airbiquity.

In the vehicle, that connectivity function will probably be integrated into gateways that collect data from safety systems and other controllers. These modules will typically have the capability to oversee many of the functions using input from a range of subsystems.

"We'll probably see four or five domain controllers all coming together in a gateway," Tarnutzer said. "Within the gateway, there will be a connectivity module for going to the cloud for things like data and over-the-air updates (OTAs)."

Designers typically obsess over factors like sensor resolution, processing requirements and power budgets, but they can't ignore considerations like memory requirements. Flash memory sizes on microcontrollers have soared in recent years: Renesas' RH850, for example, packs up to 16 Mbytes, but some designers think there's need for more.

"Current CPUs have plenty of flash—from a pure execution standpoint, they have enough memory," Tarnutzer said. "But I still see the need for external memory on the circuit board. It's for data storage like high definition maps and some storage for OTA updates."

Parallel Paths

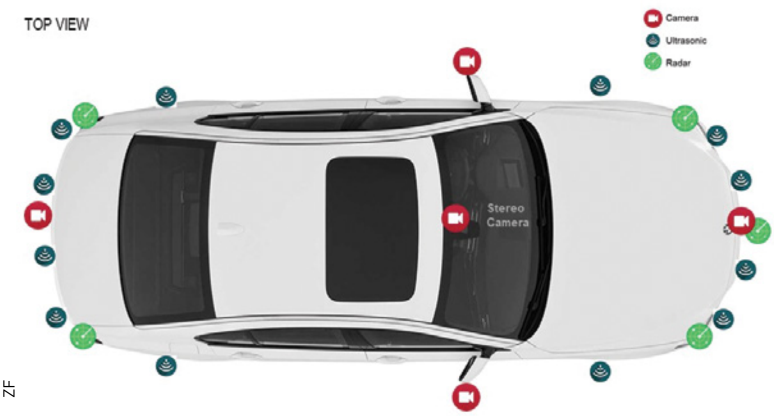
After decades of dominance, conventional CPUs are going to be complemented by parallel processors. Graphic processing units (GPUs) popularized by Nvidia will be needed to handle image processing and artificial intelligence. Field-programmable gate arrays (FPGAs) provide an alternative path. Both alternatives have their tradeoffs.

"In general, GPUs and FPGAs will be chosen based on preference," Tarnutzer said. "Some companies will jump on the Nvidia bandwagon, others will say GPUs suck too much power and cost too much, while FPGAs consume less power and can offer better cost. The question is whether FPGAs can be as efficient and powerful as GPUs."

The selected technologies will be part of a computing hierarchy that includes a range of computing techniques. The computational workload for autonomy is daunting. At the same time, factors like power consumption are becoming more important as electronic content rises and electrified powertrains address range anxiety.

"For the most part, GPUs, CPUs and programmable devices like hardware accelerators or dedicated intellectual property within a 'system on chip' complement each other in various tasks," Renesas' Buszek said. "Each has its own advantages and disadvantages depending on the application/algorithm intended to be executed. For example, the major bottleneck, especially if artificial intelligence and deep learning is needed, is camera data processing. The programmable devices tend to show way better performance per watt than a GPU or CPU."

Image processors will have to combine input from cameras, radar and lidar to create a single picture of vehicle surroundings. Sensor fusion is no simple task; data comes in at varying speeds and one sensor may see something that another misses. In just a few milliseconds, the controllers must determine what's actually there and decide whether it's a threat. That takes a lot of computing cycles.



ZF

Expansion of a typical vehicle's sensor array is helping to drive new control architecture concepts.

"All the sensors come from different backgrounds in history, so they all have different cycle times," said Kay Stepper, Vice President for Driver Assistance and Automated Driving at Bosch North America. "You need to look at processing power and network speed when you're doing fusion. The challenge is that the controller needs to make decisions based on a number of complete data sets that come in each second." ■

Cabin **Fever**

by Terry Costlow

As humans do less actual driving, autonomous vehicle interiors will transform radically to provide more creature comforts.

The transition to autonomous driving will transform many aspect of vehicles, not the least being interiors. Cabins will evolve significantly to give drivers and passengers more freedom and varied entertainment options.

Partnerships, ecosystems and holistic designs are among the buzz words associated with driverless cars, which are so complex that many companies are needed to supply all the necessary hardware and software. That's giving providers a more influential role in the look and feel of a vehicle's cockpit.

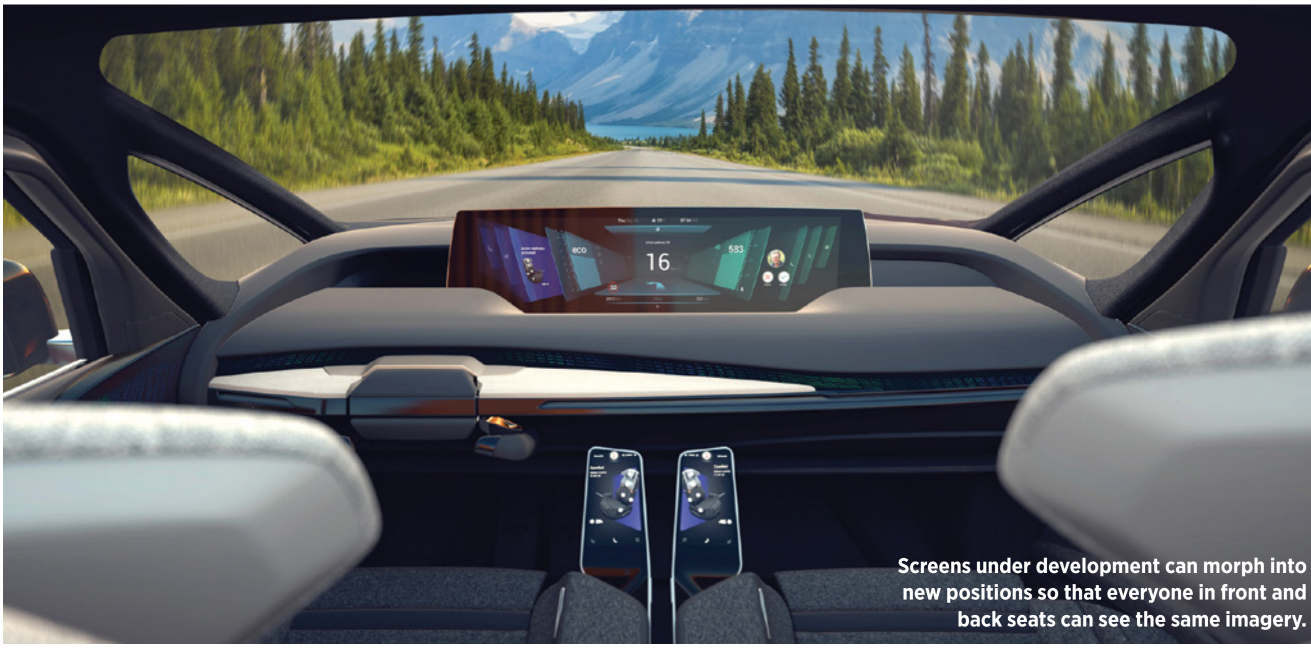
"Suppliers are in a stronger position to influence the industry—the normal master-slave relationship is inverted," said Andreas Wlasak, Vice President of Design at Faurecia Interiors. "There's less of a hierarchy where they're the customer and we're the supplier. Now everyone starts at zero, whether we're working with a new startup carmaker or one that's 100 years old."

In an exclusive interview with *Autonomous Vehicle Engineering*, Wlasak detailed many of the factors that will change as the industry makes its way to fully autonomous driving. The interim period, when drivers will

Retracting the steering can enhance the feeling of roominess in the cabin, as shown on Faurecia's Renault Cockpit of the Future.

Faurecia

Vehicles can't look like space ships; they can't be all screens. People still want wood, rich leather…It's not just a digital world. **— Andreas Wlasak**


Faurecia

Screens under development can morph into new positions so that everyone in front and back seats can see the same imagery.

interact with electronic controllers of SAE Level 3 and 4 vehicles, will be challenging. But when vehicle systems make all the decisions, things change dramatically.

"At Level 5, interior design almost becomes easier again, you can do anything and everything," said Wlasak, a leader on Faurecia's Cockpit of the Future team. "You don't need a steering wheel, all the cost and space it used to take can be given over to comfort and design.

"For the last 100 years, we've been trying to avoid driver distraction. Now we're trying to create it," Wlasak continued. "Displays are very important, but vehicles can't look like space ships; they can't be all screens. People still want wood, rich leather, maybe fabrics. It's not just a digital world."

Interim steps

Until full Level 5 autonomy emerges, interiors will need to entertain drivers who have much more freedom, but must remain engaged in driving in case roadway scenarios require human intervention. Wlasak views this transitional period as a time for automakers to try new things and see how consumers interact with interiors that aren't designed according to conventional constraints. Retracting steering wheels to give drivers more room during long drives are possible when automated systems take control.

"Big things happen at Level 3 and 4; you can physically transform the interface," Wlasak said. "You can put the occupants in a more relaxed position, like pivoting the seats. You do need to return people to a safe position, so there's still a need for redundancy at Level 3 and 4. You need belts and safety systems, because accidents will still occur."

Swiveling the seats even a few degrees makes a huge change in the perception of roominess, so it's an attractive concept. However, turning the seats requires a lot more than changing the seat mounting. Ergonomic factors related to buttons, switches and ventilation all shift when people move.

Safety factors also change. It is no simple task to protect passengers when seat positions change often, but it will remain important until accidents no longer occur. This is one area where teaming up with partners can help provide solutions like quickly returning the seat to a safe spot.

"A seat frame we developed in a partnership with ZF has airbag pyrotechnics built into the frame; it will work when the seat is swiveled," Wlasak said. "That's

HMIs will evolve rapidly as demands on drivers decline

Human-machine interfaces have evolved rapidly since their emergence in autos in the 1990s. HMIs are expected to expand to provide more creature comforts and increase the types of control techniques, as vehicles move towards autonomous driving.

Modeling, simulation and virtual reality will be key tools used to determine how human drivers can do more when the vehicle's driving itself while still being ready to take over if needed. Design tools and software from suppliers like Elektrobit will play a major role in creating safe, comfortable and entertaining cabins.

Elektrobit

HMIs will give drivers more information on larger screens.

Matthias Hampel, Head of HMI Technology and Innovation at Elektrobit, recently detailed what the Continental Automotive subsidiary is seeing from its customers.

"Just as smartphones have become the extension of our hands, we believe cars are going to be the third place for users outside their homes and workplaces," Hampel told *Autonomous Vehicle Engineering*. "Cloud technologies, IoT, connectivity and big data also have a big impact on the HMI. Multimodal HMIs will continue to play a big role and will be enhanced with the inclusion of augmented reality technology, biometrics with emotion and sentiment detection and situation awareness.

"The end result is a combination of voice, touch, GUI and augmented reality," he said.

A decade from now, two technologies that have minimal usage today will be as common as swiping a touch screen, Hampel predicted. One is digital assistants like Amazon's Alexa and Google's Assistant, which have already seen some automotive introductions. The other is gesturing, borrowed from the gaming industry.

"A voice assistant in the car could easily be combined with gesture so the driver could ask the assistant a question such as 'Is that a restaurant?' while gesturing or pointing to the right/left," Hampel said. "The combination of respective HMIs' gesture and voice inputs would result in an answer. The assistant recognizes the question while the user interface recognizes the gesture."

Augmented reality (AR) will also emerge, giving drivers more information. Multiple displays will also become the norm. These screens can be configured for various users, and it will eventually be possible to move information or entertainment from one to the other. As all these technologies move from limited luxury models towards the mainstream, artificial intelligence will help personalize vehicle operations.

"The next step is a combination of all these modalities with machine learning," Hampel said. "This means an in-car voice assistant that learns about users, their preferences, the way they interact with the car, their usage of the different user interfaces in the car."

It would mean that the assistant performs manual tasks that the driver would normally perform, such as updating the driver's calendar with the latest information or connecting them to a conference call. "It can also learn the users' interactions outside the car, like smart devices and smart homes," he asserted.

- T.C.

Faurecia

A Faurecia seat designed in conjunction with ZF embeds pyrotechnics in the frame, making it easier to return passengers to safe positions.

not possible without integrated pyrotechnics. By the time the car senses an accident is coming, it's too late for normal motors to drive the seat back to a safe position. With pyrotechnics, you're almost shooting the passenger seat to a safe position."

Once people are comfortable and safe, the focus shifts to entertainment. Faurecia is working more closely with suppliers of radio head units and screens. Displays are a central focus. A Faurecia concept called 'morphing' moves screens as driving modes change.

"Instrument panels need to be designed for two situations, autonomous and manual driving," Wlasak explained. "Screen positions are in their normal position for manual driving, but the passenger screen can move right or left, up or down. For autonomous driving, the instrument panel can be moved to the center to expand the display. Passengers in the rear seat could see it then."

Over the next few years, cabin accoutrements are going to transform rapidly. The vast number of options for seats, electronics and visual/tactile materials make interiors a major differentiator for vehicles. OEMs will gain or lose market share based on how they position the look and feel of different makes and models.

"Interiors are becoming a playground for expression," Wlasak said. "Probably the most important thing every carmaker has to decide is where to position itself in the whole user-experience spectrum. Morphing may have a 'wow' effect, but it might mean there's less to spend on lighting. Some brands may have a lot of switches. Others may decide on all touch-entry. " ■

Threat Vector: Car Washes!

By Kami Buchholz

For vehicles with automated-driving sensors, the "cleansing" experience can go too far.

What can happen inside a car wash to a vehicle equipped with advanced driver-assistance systems (ADAS)? Try havoc and damage, according to a recent 36-page report released by the leading car-wash trade association.

Nearly 40% of the surveyed 245 U.S. car wash owners reported instances of a vehicle's forward-collision avoidance system applying the brakes during the automated car cleaning process. About 16% of those surveyed noted incidents of bumper-embedded sensors being damaged by the wash's cleaning brushes and bristles.

The survey, conducted by Schwartz Advisors for the International Car Wash Association, underscores the fact that probably not many vehicle owners read their manual to find out what needs to be done in preparation for an automated car wash.

"We have a simple idea, and that is to route all car wash-sensitive functions to a common switch inside the vehicle and reduce the instruction in the owner's manual to one line: push this button," said Derek Kaufman, Schwartz Advisors' Managing Partner, during his presentation at SAE International's WCX 2018 conference. The one-button solution would deactivate and reactivate systems that could be damaged—or confused—during a car wash.

In a future with autonomous vehicles, the solution could be vehicle-to-infrastructure (V2I) communication: "We believe the ultimate solution is telematics," said Kaufman. ■

Tomwsulcer/Wiki Commons

Spinning brushes, swinging soap nozzles, narrow tracks and other dangers to AVs lurk within the typical automated car wash, notes a recent survey by the ICWA.

Nvidia's 'Kitchen Sink' for AV Testing

by Sebastian Blanco

A new cloud-based simulation system aims to deliver millions of road test miles – virtually.

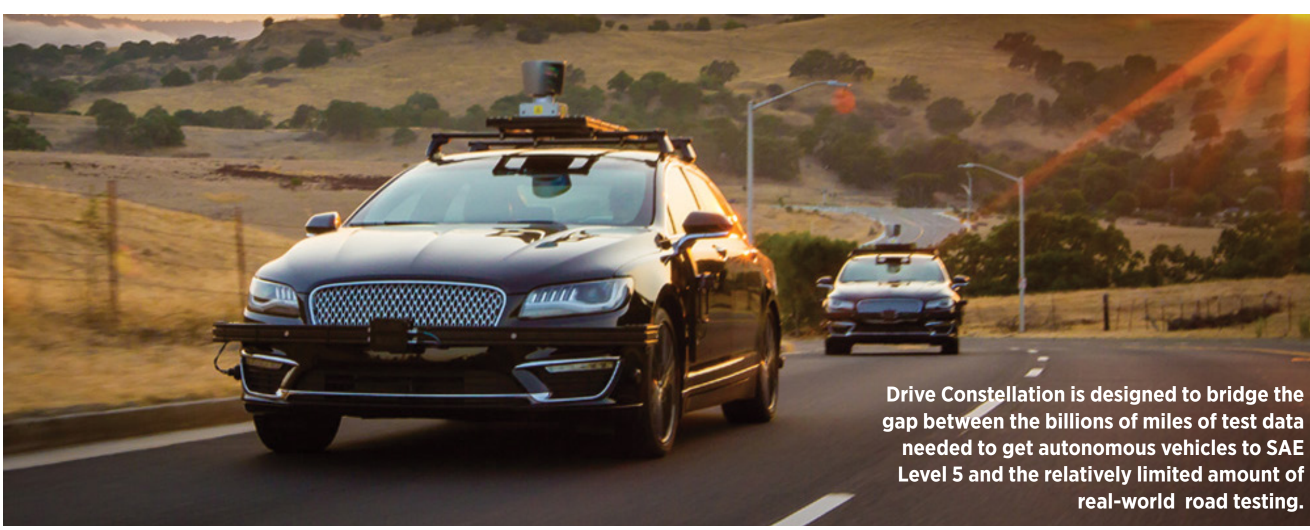
Nvidia CEO Jensen Huang laid out the problem during his keynote address at the company's 2018 GTC conference in San Jose in late March. Autonomous driving technology is "probably the hardest computing problem that the world has ever encountered," he said.

Huang then announced a new cloud-based system for autonomous-vehicle testing that uses two servers to create a complex virtual environment and then virtually "drives" autonomous vehicles through it. Called Drive Constellation, the system is meant to bridge the gap between the billions of miles of test data needed to get autonomous vehicles to SAE Level 5 capabilities and the limited amount of time these cars can spend testing in the real world.

Drive Constellation blends a simulation of a self-driving vehicle's sensors (cameras, LIDAR, and radar) that comes from Nvidia's Drive Sim software in one server, with a self-driving car fitted with the company's Drive Pegasus high-performance AI computer to process the data. The result is a virtual autonomous vehicle that can cover the ground real cars can't.

"We call this Drive Constellation," Huang said. "Pegasus in the Sky. A constellation of them. With just 10,000 constellations, we can cover three billion miles a year."

That sort of testing is what will give OEMs and



Drive Constellation is designed to bridge the gap between the billions of miles of test data needed to get autonomous vehicles to SAE Level 5 and the relatively limited amount of real-world road testing.

Nvidia

regulators the confidence in self-driving vehicles, said Tim Wong, an Nvidia technical marketing specialist.

"All the regulatory guys—and even the car companies—are scratching their heads and asking, 'How do I know I've done enough testing for Level 5 vehicle to put it on the road and let it go?' But if it's passed a hundred million tests and we've thrown everything and the kitchen sink at it, I'd feel a little bit better," he said.

Wong's virtual 'kitchen sink' allows for reproducible tests, which is a challenge for on-road testing.

"Engineers hate when they have to get the algorithm right, but every time they test it, it's going to be different," Wong asserted. "It's never going to converge. Having 'sim' gives you a way to do reproducible test conditions and then test all these different scenarios. The regulatory people are enamored with this."

Drive Constellation also will allow Nvidia to do 'hyperspeed' testing, which means more miles tested in less time, the company claims.

"That's 60,000 miles in one hour, or every road in the U.S. in three days," Wong noted. "We can do that in rain, do that in the summertime, do that in the fog. Then I start to have a better feeling about how good this autonomous car is going to drive."

It's not just the engineers who feel better. "The whole hyperspeed thing is a big deal because regulatory agencies, who are very conservative, want to certify a billion miles tested," Wong said. "Well, good luck with that physically. We'll see in you 10 years. Drive Constellation gives them a tool to actually realize something safe."

CEO Huang said that Nvidia's on-vehicle autonomous drive devices will be both ISO 26262 and ASIL-D certified. The company's automotive partners will have access to Pegasus in mid-2018. Early-access partners will be able to get Drive Constellation in 3Q18. ■

SOI 'Sauce' for Next-gen Microelectronics

Fully depleted silicon-on-insulator semiconductor is a mouth full, but FD-SOIs are vital for meeting the performance specs of automated vehicles and the IoT.

by Bich-Yen Nguyen and Philippe Flatresse

Automotive applications and the Internet of Things (IoT) will be the next big drivers for semiconductor growth through 2025. Vehicles are increasingly relying on greater intelligence, simultaneous connectivity and sophisticated, reliable electronics. Today many vehicles have on-board systems that monitor conditions, alert the driver and even automate some functions (SAE Levels 2 and 3) to enhance driving safety, avoid human error and protect pedestrians.

In the future, these features will be extended to create fully autonomous SAE Level 5 vehicles. To cost-efficiently mass produce these vehicles, the adoption of secure, reliable, high-performance and low-power microelectronics is essential.

Designing and managing automotive electronic systems to execute advanced functions in mobility mode will depend heavily on complex semiconductor circuits and advanced components such as a variety of sensors, microprocessors, microcontrollers and mixed-signal analog/radio-frequency (RF) ICs. These microelectronic components must operate on low power and have superior reliability in harsh environments while

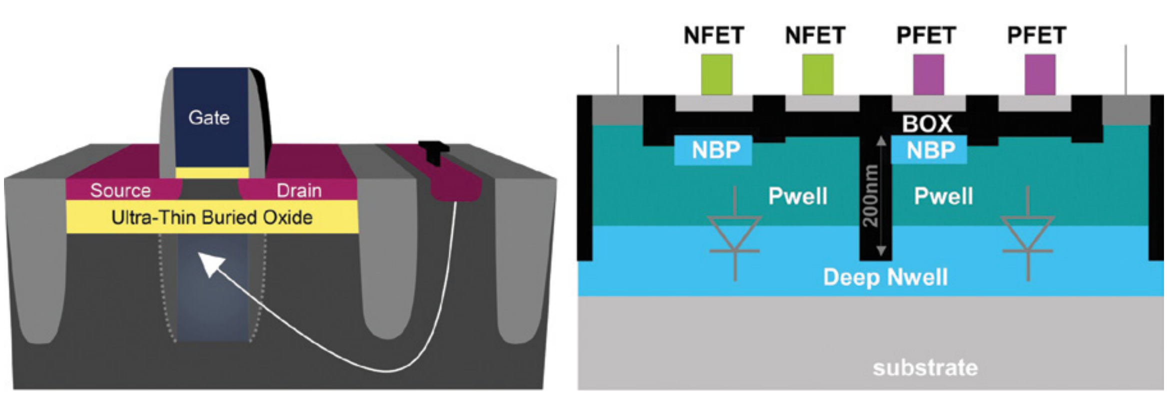


Fig. 2A
Fig. 2B

Soitec

FD-SOI device structures (Fig. 2A) enable body biasing (Fig. 2B) by using dual shallow trench isolation (STI) with dielectric insulation or two different wells without area penalty.

BMW

Advanced sensors and intelligent ICs are required from driver-assisted (SAE Level 2) to fully autonomous (SAE Level 5) vehicles.

delivering high performance; fast data-transfer rates; simultaneous, multi-point connectivity; and the cost effectiveness to be implemented in all vehicles.

FD-SOI with body biasing

Fully depleted silicon-on-insulator (FD-SOI) semiconductor technology enables scalable, planar semiconductors with key advantages over ICs made with bulk-silicon technology. Body- or back-bias is one of the benefits of chips manufactured on FD-SOI substrates. It serves as an adjustable dial that allows the chips to run faster when required or to be more energy efficient when performance is not as critical.

This unique feature was demonstrated for ultra-low-power microcontrollers in Japan and manufactured by Renesas. This versatility means that FD-SOI can be used to create on-board automotive systems capable of higher performance, greater energy efficiency and superior reliability.

FD-SOI's back-bias enables threshold voltage (Vt) tuning for better performance/power trade-off and variability control. The principle of body biasing is well known in bulk silicon technologies, but as transistor sizes are scaled smaller than the 40-nm node, body biasing becomes much less efficient, especially for the three-dimensional device architecture known as FinFET. With planar FD-SOI technology, the presence of a buried-oxide (BOx) layer within the semiconductor wafer and back-gate isolation enables high efficiency and extension of the back-bias voltage range up to -2V/+2V without degrading the drive current (Ion) and off-state current (Ioff) universal relationship and their distribution.

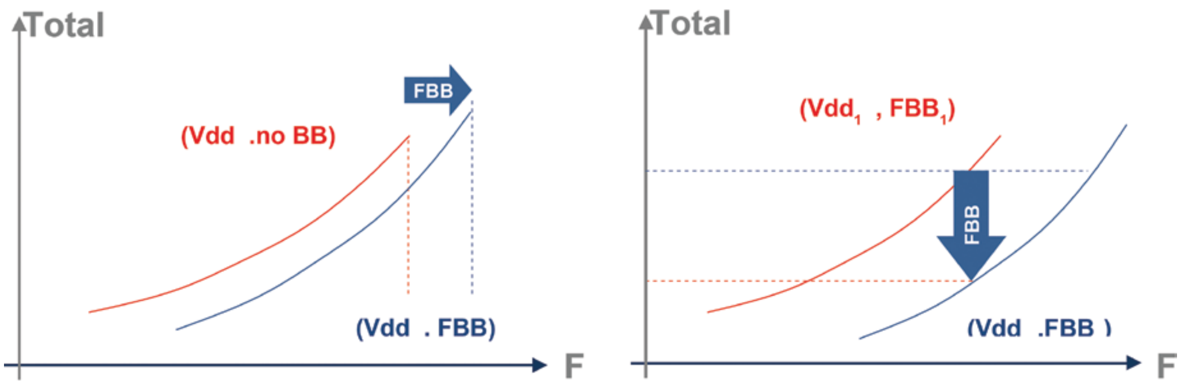
Thanks to this extended range, body bias can improve circuit performance up to 200% or reduce leakage power by one decade. This is a major differentiator for FD-SOI compared with planar bulk and FinFET technologies. It provides an additional way to reach optimal energy efficiency.

As semiconductor feature sizes are reduced, thermal management becomes an issue. Planar FD-SOI devices with thin BOx layers demonstrate much lower thermal resistance than FinFET. The larger self-heating effect in FinFETs results in lower reliability, prolonged gate delays, increased power leakage and higher overall chip development costs.

Reliability benefits

Adaptive voltage scaling (AVS) is the most common low-power technique used in CMOS technologies to compensate for variability, reduce power consumption or boost performance by modulating the voltage supply. Another technique unique to FD-SOI, called adaptive body biasing (ABB), can be applied by simply modulating the back-gate voltage in a static or dynamic way during application runtime. The combination of both techniques provides outstanding results such as 36% speed gain or 50% power savings on high-performance applications compared to all other CMOS technologies.

Additionally, FD-SOI is more than 25 times more resilient to soft error rates (SER) than bulk silicon.



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The impact of forward body bias on performance boosts or power savings.

At the circuit design level, this means that FD-SOI requires less error correction and redundancy, making the design much simpler and less power consuming.

Body biasing also offers tremendous help in variability control. In advanced semiconductor technologies below the 45-nm node, variability has become a key concern due to increasing process complexity.

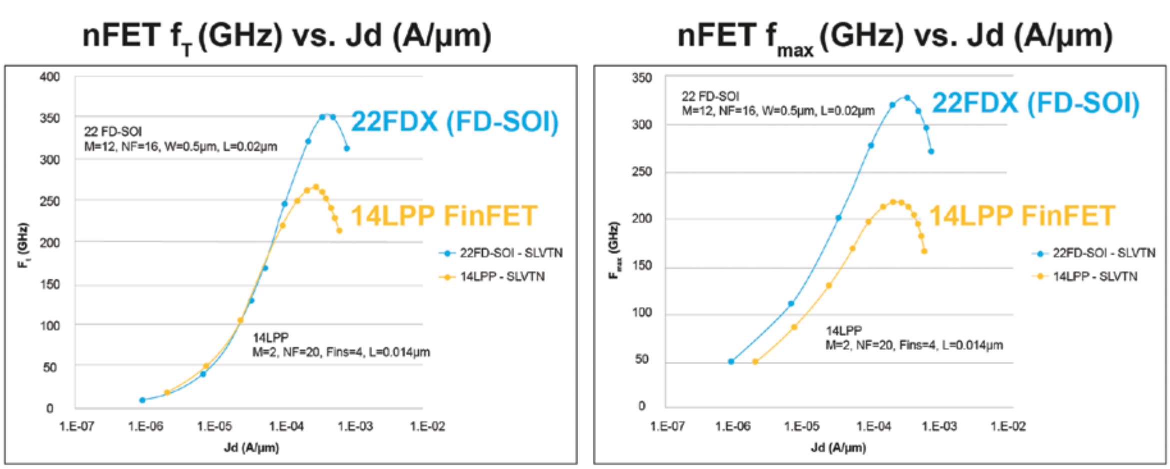
For leakage-driven ADAS and infotainment products, STMicroelectronics and NXP Semiconductors developed an innovative built-in body-bias methodology to fulfill customer requirements. It incorporates body biasing in all design stages, from synthesis to engineering. This strategy enables significant improvements including a 30% reduction in static power as well as 4X frequency and 2X leakage spread reductions.

The body-biasing-based process compensation technique also allows chip designers to take full control of the minimum voltage (Vmin) by reducing it several tenths of a millivolt and making it independent of the process corner. This results in significant dynamic power reduction and reliability improvement by scaling Vdd. As shown in the graph on p.31, with the process, temperature and aging compensation capability, FD-SOI guarantees a high level of robustness at <1 ppm to meet automotive safety requirements.

5G connectivity for smart cars

In addition to ADAS, enabling technologies to realize the Level 5 vehicle include high-data-rate communications for vehicle-to-everything (V2X) and in-car data transfer. Fifth-generation (5G) connectivity presents three main benefits: faster speed, lower latency and increased bandwidth.

FD-SOI technologies provide not only high performance, but also the lowest power consumption solutions for any RF or mmWave transceivers. This is due to having low gate resistance and parasitic capacitance that is at least 30% lower than other bulk CMOS approaches. The 65-22-nm FD-SOI-based technologies are already qualified for high-volume manufacturing by Renesas,



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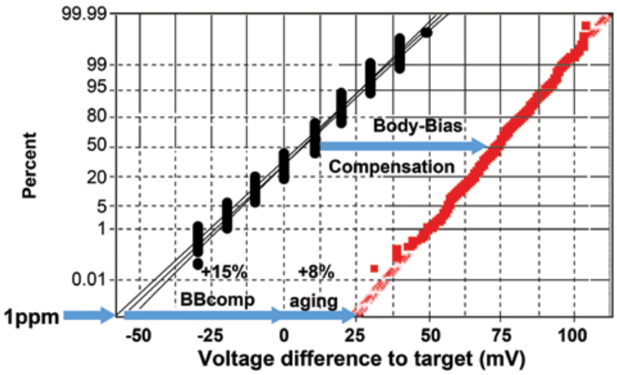
Comparing Ft and Fmax for 22-nm FD-SOI and 14-nm bulk FinFET.



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Adaptive body biasing has been used to tighten Vdmin distribution and enable Vdd scaling to reduce dynamic power.

STMicroelectronics, Samsung and GlobalFoundries. A 22nm FD-SOI can provide nearly twice the performance (F_t and F_{max}) of a 14-nm FinFET at lower cost per square millimeter of real estate due to the intrinsic properties of the planar, thin undoped body and the total isolated device structure with a gate-first approach.

More importantly, using body-bias RF transceivers can retain high Ft and Fmax at lower operation voltage for reducing dynamic power consumption.

FD-SOI is well suited for automotive applications with its low active and static power, better performance/power trade-off, cost effectiveness, high-performance analog/RF co-integration and—most importantly—better reliability, lower self-heating and lower leakage at the high temperatures faced in automotive electronics operations. A wide range of companies including NXP Semiconductor, Mobileye and Renesas have shown FD-SOI to be a viable ultra-low-power IC candidate for IoT, ADAS and autonomous automotive applications.

FD-SOI's full body-bias capability offers outstanding performance, power, reliability and cost advantages while leveraging mature planar design and manufacturing processes to accelerate time to market. FD-SOI-based devices are available today and will continue improving in performance, density and integration levels to provide cost-effective solutions for global automotive markets. ■

Bich-Yen Nguyen is a Senior Fellow at Soitec supporting the technology development of new device fields and applications. She holds over 140 worldwide patents and has authored more than 150 technical papers on IC process, integration and device technologies.

Philippe Flatresse, Ph.D, Soitec's Business Development Manager, is a pioneer of SOI technology and demonstrated its key advantages for low power/high performance digital applications. A microelectronics engineer, he has authored or co-authored more than 70 technical papers in advanced CMOS technologies.

Miracle Wires

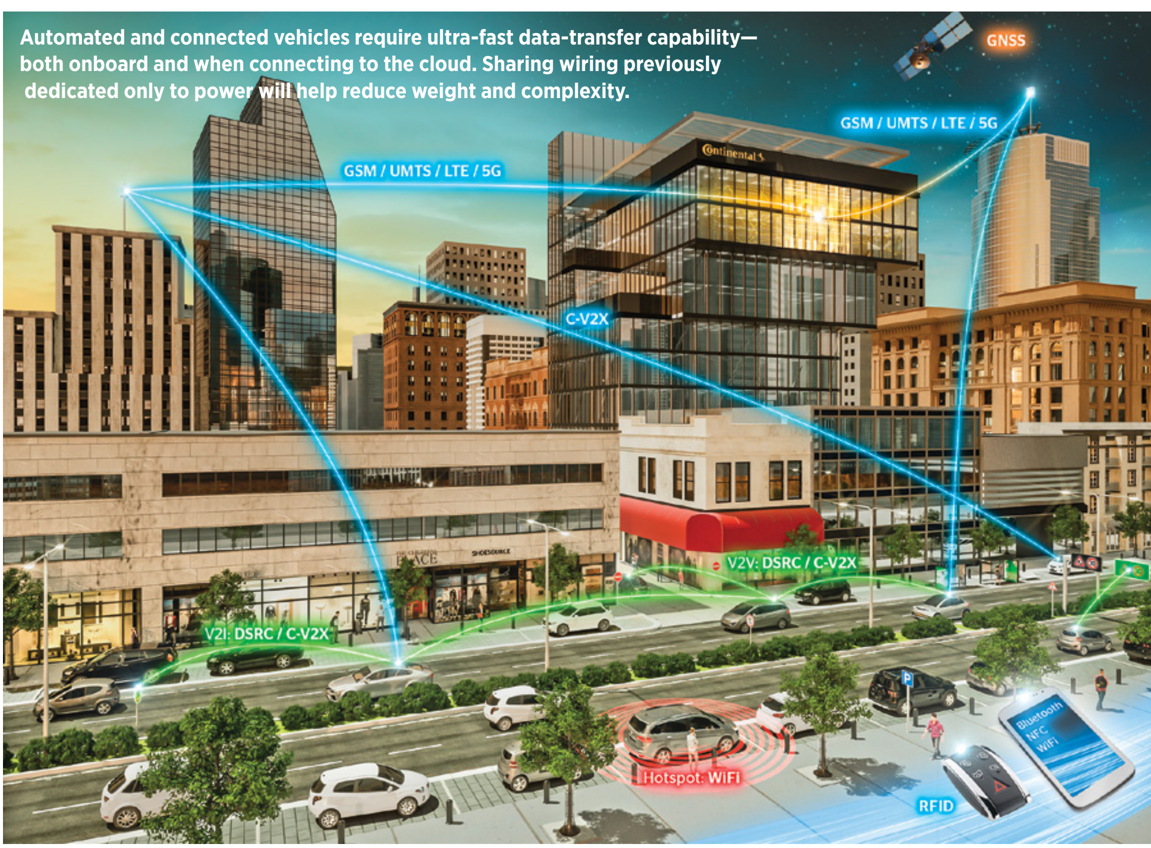
by Eric DiBiaso and Guadalupe Chalas

Data-intensive automated vehicles will benefit from new technology that delivers Gigabit data and power through the same wires.

With data-transmission rates ranging from 10Mbps to 10Gbps being standardized or already in place, Ethernet technology has a promising future for automotive applications. To reduce the level of cabling, a technology known as Power over Data Line (PoDL) has been developed that enables the data and power to share the same pair of wires.

We believe this technology will see expanded consideration by automated vehicle engineering teams as they seek efficiencies in their cabling-architecture strategies. This is likely given the immense volume of data shared between a phalanx of onboard processors—as well as between the vehicle and the "cloud."

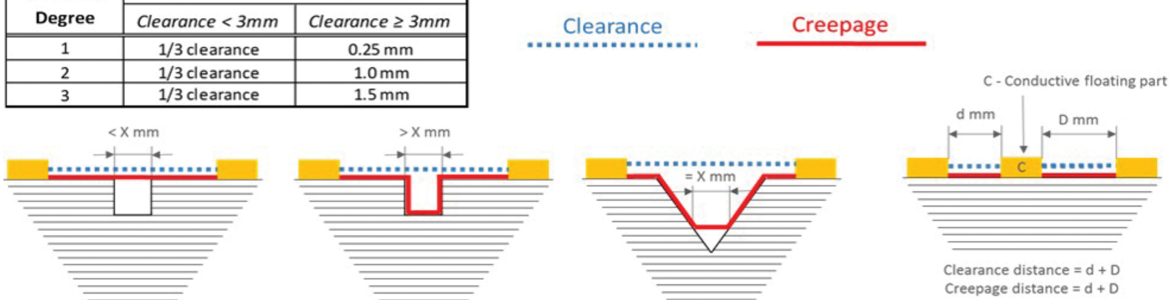
It's also likely that this dual-function "hybrid"



Automated and connected vehicles require ultra-fast data-transfer capability—both onboard and when connecting to the cloud. Sharing wiring previously dedicated only to power will help reduce weight and complexity.

Continental

Pollution Degree	Dimension X minimum value	
	Clearance < 3mm	*Clearance ≥ 3mm*
1	1/3 clearance	0.25 mm
2	1/3 clearance	1.0 mm
3	1/3 clearance	1.5 mm



Examples for calculating creepage and clearance distances.

cabling—one single unshielded twisted pair (UTP) carrying data and power—will be attractive to manage the sum total of cabling links necessary in future automated vehicles.

Finally, the potential for much stronger encryption of vehicle network data will be hard for engineers to ignore, as onboard algorithms increasingly are responsible for driver, passenger and pedestrian safety decisions.

TE Connectivity's Automotive group is studying the connector requirements needed to insure safe power transmission for these PoDL voltages and is developing a design that meets these requirements.

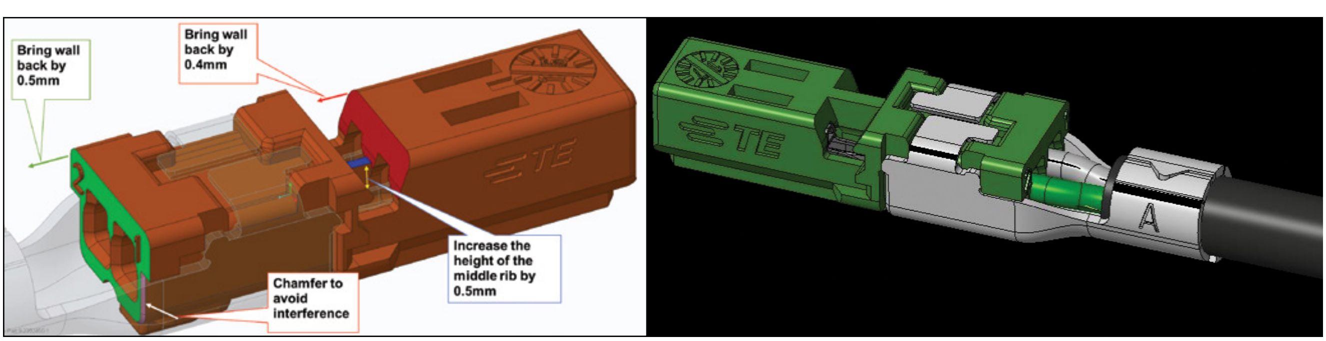
Documents such as IEC60664-1 have been used as a reference to calculate the required creepage and clearance distances for electrical connectors. In the automotive sector, many OEM requirements for high-voltage connectors are based on this document. These connectors are usually designed for high voltage and current applications where larger wire and higher pitch connectors are required. In these instances, the required creepage and clearance distances can usually be met without much difficulty.

PoDL changes the game

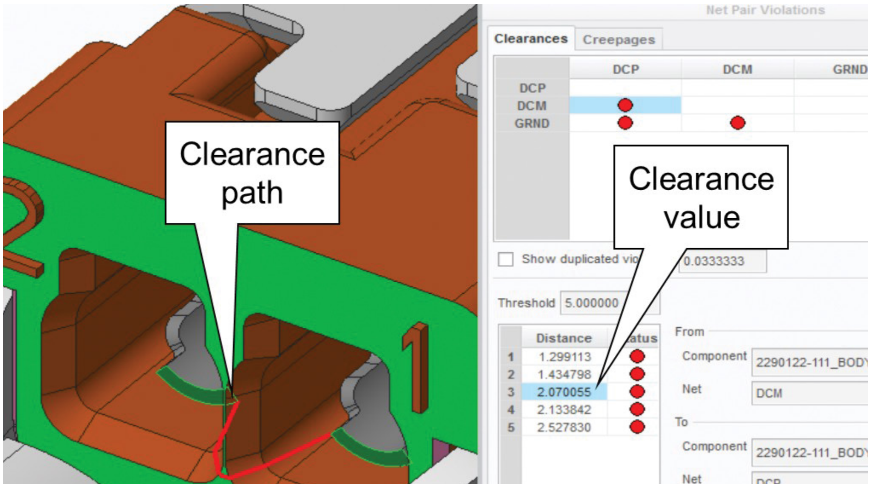
However, with PoDL technology, data and power now are being transmitted over considerably smaller-gauge wire. Smaller pitch connectors are advantageous for the signal integrity of the high-speed data, but this begins to pose design issues for meeting the required creepage and clearance distances. This is especially true in the automotive environment, where higher pollution degree ratings need to be met.

The requirements are highly dependent on the selected insulating material for use between conductors, as well as environmental conditions such as pollution degree and altitude. Clearance—the shortest measured distance in air between two conductive surfaces—of a connector should be dimensioned to withstand the expected steady-state voltages, temporary overvoltages or recurring peak voltages of the system to prevent possible arcing.

Consideration of these factors led to TE Connectivity's MATEnet connection system: a modular and scalable connector designed specifically for automotive Ethernet. It is based on the miniaturized NanoMQS standard automotive terminal and is



Recommended design changes (left) and PoDL compliant plastic housing (right).



Clearance and creepage paths.

designed to withstand the harsh automotive environment. While these connectors were designed to meet the signal integrity requirements of the data path, they were not designed for PoDL requirements.

When measuring the clearance and creepage distances on the MATEnet connector system, the PTC CREO Spark Analysis Extension (SAX) tool allowed for rapid calculations using an accurate 3D representation of the electromechanical system and a spreadsheet specifying a parameter known as "groove width," as well as the clearance and creepage target requirements. The tool output is an array of values and visual representations that allows the user to clearly identify the areas of concern and quickly proceed to the optimization phase of the process.

The groove width (x) is defined as the largest gap that the creepage can jump across. This value is dependent on pollution degree and it is only used to measure creepage; for clearance distances less than 3mm, the minimum dimension is reduced to one-third of this clearance. If the thickness of a gap, groove or protrusion between the terminals is greater than x, the creepage is measured along the contours of the groove. However, if the thickness of a gap, groove or protrusion is smaller than or equal to x, it is understood that the voltage "jumps" or shorts from one wall to another.

For the MATEnet connector, the nominal terminal pitch is 1.8mm. Provided there is no insulation between the terminals, once the thickness of the terminals is considered, the maximum clearance of the system at a nominal pitch is 1.2 for the male terminals and 0.8 for the female terminals. It was discovered that while the PCB header side (male) met the clearance requirements for pollution degree 3, the plug side (female) did not and thus had to be optimized to meet the clearance requirements.

The creepage of the system, like the clearance, was measured using the CREO SAX tool. Unlike clearance, creepage calculations required the input of the groove width x value. Since in this case the overall clearance cannot be greater than the pitch, the groove width is taken as one-third of the required clearance for each pollution degree and the analysis is performed using x values equal to 0.086mm for pollution degree 2 and 0.344mm for pollution degree 3.

While the MATEnet system met the clearance and creepage requirements for pollution degree 2, some modifications were required for the system to meet pollution degree 3 requirements at the different voltage levels. Since the output of the tool includes both values and a visual representation of both the clearance and creepage paths in the form of a red line across the zone of interest, the critical zones were easily identified.

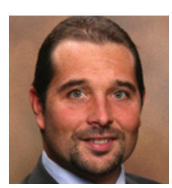
An additional step was performed to confirm the terminal's tolerance of the true position (TP) was considered. With a 0.1mm tolerance requirement, the three cases analyzed involved a nominal pitch of 1.8mm, a lower value of 1.7mm and an upper value of 1.9mm. This was done to confirm the part would meet clearance and creepage requirements regardless of TP variation given by the tolerance zone.

Optimizing the design

Once the zones were identified, the optimization process began. Lengths and thicknesses were changed to increase the clearance and creepage paths until the part met the requirements for pollution degree at the nominal pitch as well as the upper and lower values of the tolerance spectrum. The optimization was done in small increments to avoid adding too much material to the plastic housing.

When this optimization was completed, recommendations for design changes were sent to the design team, which utilized these recommendations and made the necessary changes to the plastic parts, while considering the manufacturing processes already in place as well as moldability of the housings.

The result was validated creepage and clearance requirements for automotive Ethernet PoDL-compatible connectors that will help enable a new level of automotive wiring and data-transmission flexibility. The new PoDL technology should improve the efficiency and capability of the wiring architectures for autonomous vehicles. ■



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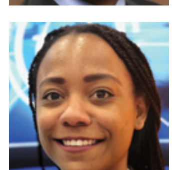

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The authors thank the following colleagues for their assistance with this article: Zachary Lyon for his support with the CREO SAX tool, Robert Wuerker for the MATEnet connector implementation support and Marjorie Myers for reviewing the paper.

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