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AUTONOMOUS VEHICLE ENGINEERING™

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Superior Interiors

How new-mobility thinking is influencing coming cabin innovations

Aptiv CTO Glen DeVos on Next-Gen AV Architectures

Is NHTSA Gun-shy About Creating AV Regulations?

Automated-driving Safety Assumes an ODD New Perspective

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Audi's Trail AI quattro concept, unveiled at the 2019 Frankfurt auto show, is emblematic of many new-mobility-influenced design and technology trends for coming production-vehicle interiors. There are few buttons or physical switches and a simplified, less-distracting execution for the driver interface. These ideas, along with unique new surface treatments, are targeted for near-term introduction. (Image: Audi)

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Audited by

Editorial

Defining and standardizing AV tech and testing

What are your greatest needs related to Standards? That question is one I typically ask during my conversations and formal interviews with mobility-industry engineers. As might be expected, those involved with AV development tend to offer a robust list of standards they'd like SAE International to pursue.

Bryan Salesky, CEO of self-driving vehicle systems supplier Argo AI, recently told me and my SAE Media colleague Bill Visnic that his development teams want "more terminology and definitions," an area in which SAE's Standards Committees are already focused. The committees' scope goes beyond vehicle nomenclatures, to include the various interrelated ecosystems.

Clearer and more detailed terminology related to AVs and their testing is in SAE Standards development.

Within this broad sphere is J3194,"Standard -Taxonomy and Classification of Micromobility." Its aim is to establish basic language for those developing, operating and regulating the booming universe of e-bikes, motorized and non-motorized scooters and other "last mile" devices – electric unicycles, anyone? - that could end up being more of a problem than a mobility solution.

Salesky, who is one of the bona-fide AV pioneers (watch for the March issue of *AVE*), also noted that the industry "needs a way to communicate to the consumer, as clearly and succinctly as possible, what they can expect from a piece of automation on their vehicle." He's not alone in this opinion. I've heard others propose that the industry offer basic performance descriptions for each feature that provides SAE Levels 1-through-4 functionality in a given vehicle. Such a roster would go beyond today's Monroney window-sticker in listing expectations for driver-assistance technology including automatic emergency braking, lane-keeping assist, etc.

An interesting idea worth further discussion. Implementing it would be far from a finger snap, I reckon. Another growing need was the creation of guidelines for the "safety test drivers" that are essential to on-road testing programs. There's good news here: Late last year, the Automated Vehicle Safety Consortium, an SAE affiliate comprised of OEMs and ride-share companies aimed at establishing a Level 4/5 testing framework, issued its first best practice related to AV test-driver qualification, selection, training and monitoring processes, along with in-vehicle operational guidance.

"There is a lot of urgency around establishing a baseline for this," AVSC Executive Director Dr. Ed Straub told me. "This step should inform those companies that maybe are new or have less experience in testing. And it can also be used as a reference by municipalities or DoTs to ask questions of companies that are doing testing on their roads."

AVSC works closely with SAE Standards committees and is now focused on introducing the ideas put forward in this best practice so it can be integrated into an open, formal industry standard.

Regulations typically can take a long time to develop, particularly for fast-moving tech such as AVs. It's incumbent upon industry, in partnership with SAE, to lead the way.

Lindsay Brooke, Editor-in-Chief

Automakers at Fault if V2X Spectrum is Lost

Sam Abuelsamid
Senior Analyst
Navigant Research
Sam@abuelsamid.com

After years of heavy lobbying from the cable and wireless industry, the U.S. Federal Communications Commission (FCC) is on the verge of reallocating most of the spectrum that had been set aside for intelligent transportation systems including vehicle-to-everything (V2X) communications. While various automakers have been vocal in their support of V2X, the industry as a whole has only itself to blame for this development.

The FCC first allocated 75 MHz of spectrum in the 5.9-GHz band for ITS (intelligent transportation systems) use 20 years ago. But precious little has been done with that spectrum since then, as other uses of wireless technology have been gobbling up the airwaves. For years, many automakers, suppliers and regulators worked to develop standards for V2X communications and large-scale pilot programs continue to operate in a number of cities including Ann Arbor, Mich., and Tampa, Fla.

Most of those efforts revolved around WiFi-based dedicated short-range communications (DSRC). The National Highway Traffic Safety Administration (NHTSA) published a proposal to mandate DSRC vehicle-to-vehicle (V2V) communications in the waning days of the Obama administration. While GM, Toyota and Honda, among others, have all expressed their support for V2X communications, there has been almost no concrete action beyond those pilot tests.

To date, the only automaker to commercially deploy V2V in the U.S. market is GM on the 2017-2019 Cadillac CTS, of which fewer than 50,000 were sold. Toyota launched DSRC on some Japan market models in 2015 but has not brought the technology to the U.S. With so little use of this spectrum, it's no wonder that other groups have been pushing the FCC to release this bandwidth.

Given FCC chairman Ajit Pai's demonstrated anti-regulatory stance on issues such as internet neutrality and prison inmate telephone-calling costs, it's no surprise that he would be inclined to undermine any potential rules around transportation safety. While NHTSA still officially supports maintaining the 5.9-GHz spectrum for ITS applications, it too has done nothing to move forward with enacting the proposed V2V mandate.

The auto industry had 20 years to do something with the 5.9 GHz spectrum it was given – but it sat on its hands.

If the automakers claiming to be so supportive of V2X had moved ahead with broader deployments over the last several years, there could potentially be millions of vehicles on the road today sharing basic safety messages and other information. However, having done almost nothing, most of that spectrum is set to be handed over to cable companies for unlicensed WiFi. Of the remaining 30 MHz of spectrum, 20 MHz of it would go to cellular-V2X, with the last 10 MHz possibly retained for DSRC or also assigned to C-V2X.

In the announcement of the proposed spectrum revisions, Pai called DSRC V2X a "promise unfulfilled" – and he is right to the extent that it has largely gone uncommercialized. However, despite the successes of pilot programs, the industry has largely failed to move forward with commercialization in the U.S. In Europe however, despite a DSRC mandate getting shelved at the last minute earlier this year, Volkswagen has moved ahead and launched the technology as standard on the 2020 Golf with plans to add it to other models as well.

The auto industry had 20 years to do something with the 5.9 GHz spectrum it was given but it sat on its hands. It now seems likely to lose it. ■

Superior Interiors

by Bill Visnic

New-mobility thinking is changing how vehicle interiors will work for everyone.

Future-vehicle interior renderings have always stoked our imaginations for what may be possible in the cabin environment. Automated vehicle (AV) developments, including high-function driver assistance features and mobility as a service (MaaS), are bringing new dimensions to those possibilities.

Ironically, while near-term prospects for privately-owned autonomous (SAE Level 4) AVs have hit the hype curve's downward slope, research and development into how passengers will interact with new-mobility technology promises interior designs and features that will likely be on the market long before most consumers experience self-driving cars.

Interior-systems suppliers, and AV technology innovators such as Waymo, insist designs and features envisioned for AV cabins are desirable for any vehicle.

According to interior-design experts, the top emerging trends include larger and more user-friendly screen-based human-machine interfaces (HMI), reconfigurable seating and individual-focused cockpit "environments". There are also safety- and health-promoting features ready to be deployed, such as biomedical monitoring. This can provide basic health metrics, but also monitor a driver's state of attention or inebriation to determine fitness to operate the vehicle at various levels of automated driver-assist functionality.

Jeff Stout, executive director, Global Innovation at Yanfeng Automotive Interiors, said the company's 2018 XiM20 show vehicle serves as an incubator for cabin innovations, and could be used for an SAE Level 5 AV.

"That (XiM20) was our best execution or vision of what we think a full Level-5 autonomous experience could be, introducing the idea of 'enclosure' versus 'exposure,'" Stout said. Think of a restaurant that offers

Faurecia

Faurecia's Cockpit of the Future signals many cabin design and technology innovations that will be in production long before highly automated vehicles become common.

Yanfeng

Yanfeng's succession of concept vehicles (this is XiM18) demonstrate leading-edge ideas such as multi-configurable seating and "smart" surfaces and trim. These are projected to enhance any interior, not just those of highly automated vehicles.

a cozy booth in a secluded room, or tables outside on the sidewalk that let you watch people go by.

A cocoon for all

The notion of individualized environments for each vehicle occupant is not new. It wasn't until MaaS became a reality – first through ride-hailing/ridesharing enterprises and now in an expanding spectrum of autonomous-shuttle demonstration projects – that the need to create distinctly segmented cabin spaces became obvious. Considerable interior design and technology development is now committed to deploying aspects of the individual-space ideal in the near-term market.

Soon-to-be-seen are MaaS-inspired personalization innovations such as interior supplier Faurecia's "audio bubble." These seats are designed with audio drivers embedded in the back and bottom cushions, coupled with sound-shaping software to direct audio content only to that seat's occupant.

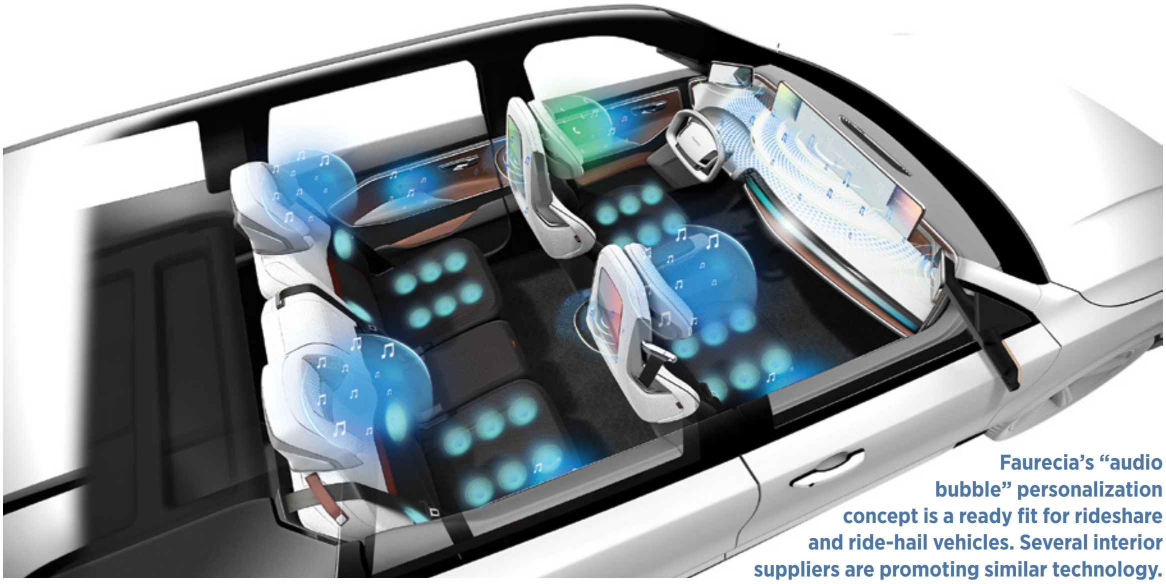
Like other cabin-systems suppliers, Faurecia is evolving into a true technology integrator, said Todd Fletemier, VP of Midwest Technology Platform. Development of the audio bubble will likely be aided by Faurecia's early-2019 acquisition of Japan-based audio specialist Clarion, creating the new Faurecia Clarion Electronics (FCE) business unit. It's an acquisition strategy many automotive interiors suppliers are mimicking.

"Clarion has that expertise in center stacks and some of the ADAS [advanced driver-assistance systems]," Fletemier noted. He said the company is working with partners as an integrator for what it calls the Cockpit of the Future (CoF), elements of which it intended to reveal at CES 2020 in a current-generation Ford F-150.

Fletemier said the choice of the F-150 was intended to demonstrate the near-term viability of many of the CoF innovations. "That's a great vehicle for us to be able to showcase because we're [already] a major supplier of the product," he said. "It allows us to take those technologies and to showcase them as one, as in what's possible inside of that interior."

Seating and electrical specialist Lear's riff on personalized audio spaces is called SoundZone. The company expects upcoming ridesharing models fitted with its Intu intelligent seats to offer the feature, which it promotes as "the ultimate in customization and privacy.

A similar concept applies to heating and cooling. Personalized thermal management lets every occupant enjoy a seat that enables an individual climate zone. These systems will be particularly useful in electric vehicles, where maintaining climate control for the



Faurecia's "audio bubble" personalization concept is a ready fit for rideshare and ride-hail vehicles. Several interior suppliers are promoting similar technology.

Faurecia

As designers and HMI experts begin to eradicate physical switches and buttons, expect to see interior surfaces embedded with pressure-sensing controls and features, many of which become visible only when required.

Yanfeng

entire cabin is less efficient.

As AVs will allow passengers to partake in cabin activities that may take them out of conventional seating positions, the "cocoon" concept also is a safety vision.

Faurecia has joined with ZF to develop its Advanced Versatile Structure, a seat with "smart kinematics" that recline, lift, adjust and swivel the seat to a variety of positions. The mechanism can quickly return the seat to the driving position, and airbags and seatbelts are integrated into the seat structure to maintain optimum effectiveness regardless of seating position.

Faurecia and other cabin-technology innovators also are interested in the potential for in-vehicle biometric capabilities. Omar Ben Abdelaziz, the company's project partner for the CoF, said a selection of biometric sensors can monitor biological signals such as heart and breathing rates, skin conductivity and even blood pressure and heart rate variability.

He added that Faurecia is collaborating with a customer to integrate smart-watch-like photoplethysmography (PPG) sensors to help monitor a driver's condition.

At the 2019 Tokyo Motor Show, Mitsubishi Electric's Emirai S concept car showcased a biometric monitoring system paired with a near-infrared camera to measure occupants' heart rate, with another sensor measuring skin temperature. The company said the system can analyze occupant conditions from sudden sickness to fatigue and drowsiness.

Faurecia has begun a study it calls "digital wellness," working with Toronto's MaRS Discovery District.

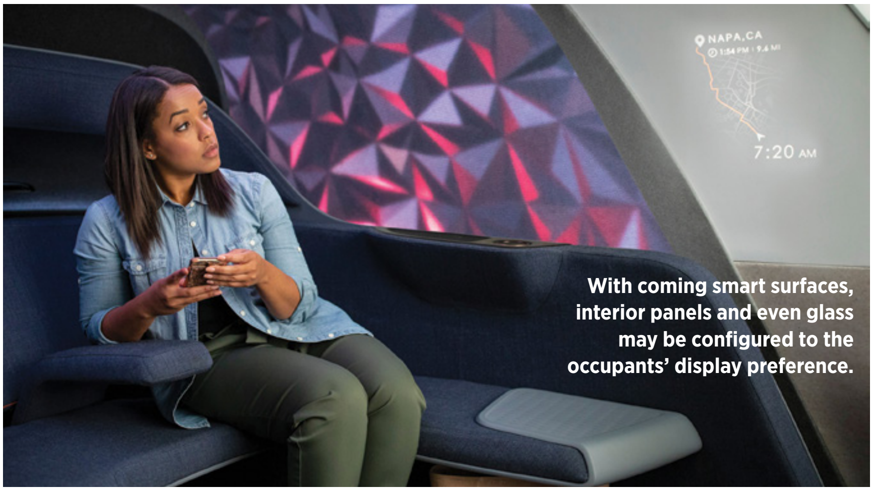
"Shortly after CES we will launch an innovation challenge in Toronto with that [MaRS] ecosystem around a concept that we're calling biometric safety," Fletemier said. "If we were to take this data or take this information that we can gather, how can we enhance the safety of the vehicles on an overall basis?"

Bye-bye buttons

As touchscreens get larger and the HMI debate rages on, initiatives are underway to integrate controls into cabin trim and panels, ushering in a new era of holistically designed smart surfaces.

"The future is heavily dependent on the fusion of electronic and trim componentry," Yanfeng's Stout said. He noted that technology integration and aesthetics will converge in multi-function cabin surfaces.

Examining the cabin illustrations accompanying this story, there is barely a button in sight. That's no accident. Nearly every automotive interior designer is on a mission to ban the button. Like it or not, at least some of this will be accomplished with touchscreens – albeit more effectively placed. Faurecia's Fletemier said his company is working intently on dash-top "pillar to pillar" displays that he claims will help alleviate driver distraction.



Yanfeng

With coming smart surfaces, interior panels and even glass may be configured to the occupants' display preference.

Waymo

Waymo notes it's vital that automated ride-hail vehicles offer cabin displays that keep occupants – who by definition aren't involved in the driving task – continually aware of the vehicle's actions.

Suppliers are developing force-sensing technology to embed controls in cabin surfaces and trim, or beneath glass screens. Many are managed by software and artificial intelligence, appearing only when necessary. These features will be available long before L4/5 autonomy.

"A very fluid design language, where the displays are integrated in the overall presentation of the door and instrument panel and floor console," is how Stout describes it, all in "one smooth, seamless organic surface."

The SAE L5 cabin use case doesn't need to be defined today, Stout added, but, "we need the tools and the toolbox product-wise to be able to execute that when the time comes. To accommodate even Level 3 with all of the higher level ADAS functions, having that be a very intuitive HMI. That's really the heart of where the development activity is taking place today."

Uniform experience goal

For Waymo, which recently provided its 100,000th ride in an AV, building trust in MaaS means giving consumers cabin-individualization options while also ensuring a uniform experience.

"We build trust with our riders through consistency," asserted Ryan Powell, Waymo's head of UX research and design, in a mid-2019 blog post. "Our passengers interact with Waymo across many different points throughout their journey, from our app to our in-car passenger screens, or even during a conversation with one of our rider support agents."

Delivering ride-to-ride consistency is also important. Waymo riders want to know that every time they step into a Waymo vehicle, they're getting the same experienced driver. "And from a design perspective, they're also viewing the same type of information on our screens, being greeted by familiar sounds and have the same choices for how to control and customize their ride," Powell said.

But familiarity is going to have its limits.

"In three years," predicts Yanfeng's Stout, "it wouldn't surprise me if there's an automaker who has a vehicle on the market that has no buttons. There won't be a mechanical button in the entire interior." ■

Democratize AV Technology!

by Lindsay Brooke

Aptiv's new generation of open-sourced architectures based on a few central processors aims to speed AV adoption. CTO Glen DeVos explains.

The software-intensive, electrified and increasingly automated vehicle will define the 2020s. Its rise is driving both the industry-wide re-thinking of electrical architectures and the growth of engineering employment behind it. At the forefront of this trend is Aptiv, the technology Tier 1 spun off from Delphi in 2017. It now has more than 19,000 engineers among its 160,000 staff, comprising one of the highest engineer-to-employee ratios among large suppliers.

"We've been adding about 1,500 engineers per year, primarily in software and systems engineering, at our 15 major technical centers," said CTO Glen DeVos. These resources, he noted, will help Aptiv accelerate its customers' development of new vehicle platforms with greater active-safety capability, including automated-driving functionality.

Glen DeVos is leading Aptiv into new vehicle architecture technology.

Aptiv

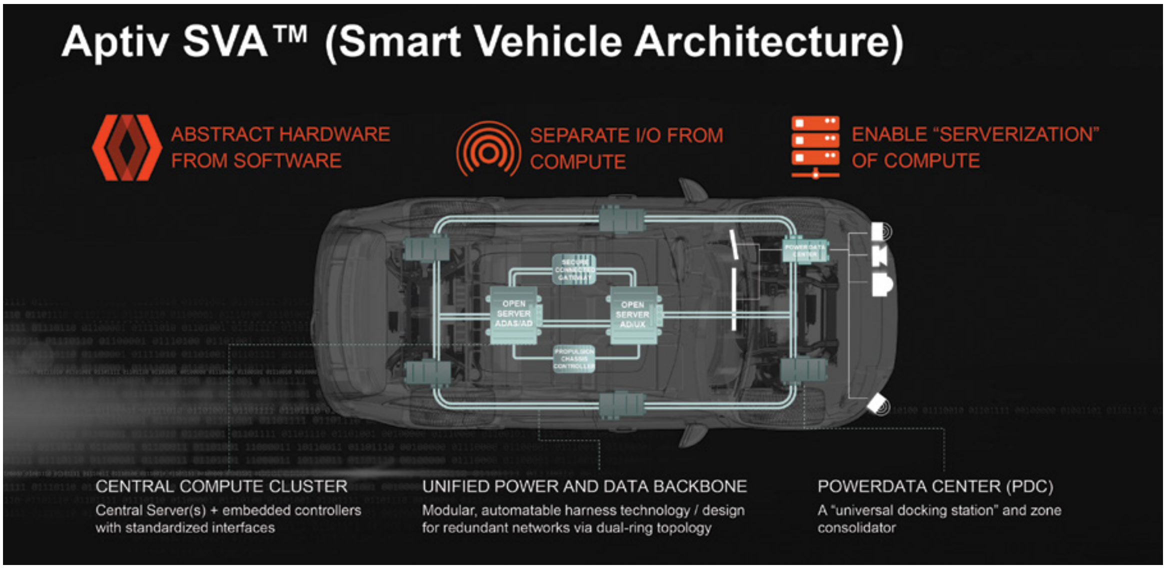
The OEMs want full upgradeability of software (FOTA; firmware over the air and SOTA, software over the air) capabilities, DeVos explained. He noted they'll also want centralization of compute—moving from today's multiple ECUs to a few domain controllers—and zonal control, all with reduced complexity and cost.

DeVos called this broad trend "a blank-sheet approach to move away from traditional architectures" to more advanced, open-sourced ones. "We formed our Smart Vehicle Architecture group a little over two and a half years ago when we saw a trend developing: The massive content occurring in SAE Levels 1, 2 and 3 vehicles that is creating pain points for our OEM customers," he said.

More features equals more data and not just for Level 4. "It's across the board," he said. "We realized that to pack everything they wanted and that we were thinking about into an L4 vehicle, there was no way to do it economically without fundamental architecture change."

Based on its booked orders, Aptiv expects deployment to begin in 2022 in premium vehicles, ramping up steadily from 2025. And while the company has multiple programs developing SAE Level 4

We want to make the compute agnostic and independent from all those sensors and actuation.



Aptiv

Central Compute Cluster is the heart of Aptiv SVA.

automated-driving functionality with customers aimed at commercial geo-fenced operations, such performance is not anticipated to be ready in consumer-level vehicles until the 2030 timeframe.

"We've always talked about automated driving being on the continuum of active safety," said DeVos, who was part of Delphi's pioneering work on Jaguar's first Active Cruise Control launched in 1998. "Going from Level 2 to 3 and ultimately to Level 4 and 5 is all on the continuum. We want to take the technologies we're developing for Levels 4/5 and apply it to Levels 2/3 as the next generation of advanced capabilities and features. It's important to think how we can bring both ends of the spectrum together."

Focus on SAE Level 2/3

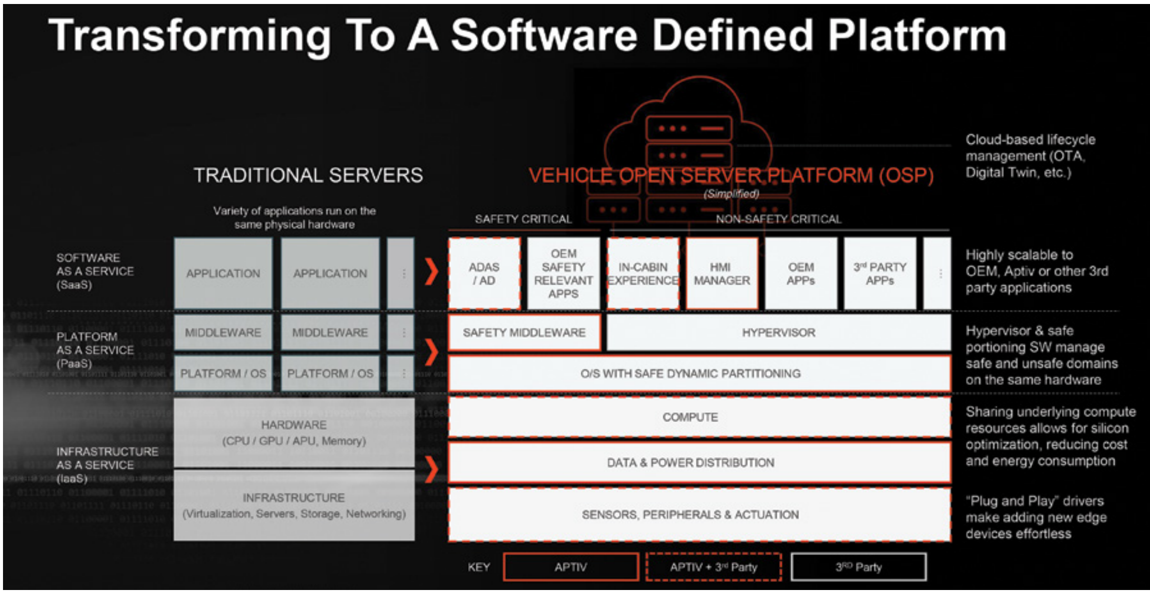
SAE Level 2 to Level 3 is currently Aptiv's main focus for automated-driving systems development. "We know Level 0 and Level 1 systems, with the progression of Euro and U.S. NCAP [impact safety] requirements, is going to be the baseline by 2025," DeVos says. "You won't have cars that are significantly de-contented from Level 2. That's where the market is moving. It's our 'sweet spot.'"

An ADAS domain controller provides the fusing and perception modelling, the "brains" that DeVos compares to having a file server on board. In the new architectures, consolidating from the dozens of discrete ECUs on today's vehicles to up to five powerful central compute controllers, will drive a change to smaller "decontented" cameras and radars with less integrated processing capacity and thus lower cost. The controllers would be responsible for active safety, the user experience (UX), propulsion and chassis systems.

"We're seeing costs getting 'democratized' for those [up to SAE Level 2] systems," DeVos noted. "But as you go from Level 2 to Level 3, however, there's an inflection point. This is driven by everything that supports the driver being out of the loop. In our view, Level 3 is advanced driver assistance where the car is basically in control. It's able to make decisions with the driver disengaged."

That brings the need for fail-operational and safe-stop capability, and the need for redundancies. "Power systems, controls, everything that avoids a single-point failure," DeVos explained. "With a Level 2 system, the driver is that redundancy. With Level 3, it drives a lot of additional components in today's architectures." That includes driver sensing and some level of mapping, the latter typically provided by lidars which remain expensive.

Then there's the reality of what DeVos describes as "just more sensors." While for SAE Level 2 the vehicle may have forward-looking cameras with



Aptiv

Aptiv is increasingly serving as a middleware integrator in the transformation from traditional to software-defined architectures.

360-deg. radar—a cost-effective approach—going to a Level 3 system may include an array of 360-deg. camera, 360-deg. radar and a lidar sensor.

"360 vision systems add a lot more complexity and drive a lot more processing," DeVos noted. "The compute requirements go up dramatically. The domain controller would have a lot more capability than your previous Level 2-plus controller, and you need a secondary controller in case that fails. Adding those pieces together the cost adds up."

Driving down the cost curve on ADAS technologies will take some time and will be a function of volume and systems cost optimization, DeVos said. Then ultimately it will be a function of vehicle architecture, because today's Level 3 systems basically are an overlay on the Level 2 architectures. The redundancy is an add. "But with the next-gen 2025 architectures, there are things we can do to bring the cost and complexity down. That will be helpful in terms of market adoption," he noted.

A key aspect of Aptiv's new approach to system architecting is what engineers call 'Safe Dynamic Partitioning'. A traditional operating system (OS) would never mix Infotainment (typically a Linux- or Android-based platform) with anything that has functional safety aspects such as ADAS. Each has its separate ECU. And both are typically underutilized.

"The industry norm is not to use any more than 80% of a box at peak load," DeVos said. "But when I add all that up and look at the total loading, I'm grossly underutilizing the silicon that's in the vehicle. And I'm paying for each box, over and over again." He explained that Safe Dynamic Partitioning allows design engineers to take a general compute platform and install whatever they want—infotainment or functional safety, each partitioned and managed safely.

"I don't need two boxes; I can consolidate them. Without the ability to have this mixed criticality, you end up with a lot of redundant boxes," DeVos said. "For example, you can use the infotainment compute as a backup [such as if a failure were to occur] and put my Level 3 ADAS controls on it. If I architect the product right, I can get redundancy and fail-operational capability without duplication."

The advent of purpose-built EV architectures entering volume production this decade can help reduce cost and the speed to market of Level 3. Properly architected, they will not require add-in duplication to get redundancy. Instead, it can be accomplished through more effective sharing among controllers. "We'll have capability for moving processes from a failed controller to another, as opposed to just duplication, which is where we are today," he said.

An agnostic approach

Aptiv's 'SVA' approach is based on lessons learned from mobile computing (smart phones) and other industries where software is embedded and inseparably connected to the hardware in purpose-built machines, each one separate from the other and from one generation to the next. The lessons include:

The industry's move to purpose-engineered EV platforms such as Ford's 2021 Mustang Mach-e (shown) works in favor of the trend to the new AV architectures.

Ford

- Abstracting software from hardware means decoupling software development from the underlying ECU or component development. DeVos admits that today it is a massively complex task in getting everything to work properly. Proof of that came in 2014, the first year that warranty costs for software at the OEMs became greater than those for hardware. The situation will only worsen as today's distributed architectures proliferate, according to DeVos.

- Separating I/O from computing—with all the sensors, actuators and data that's flowing around the vehicle, with hard connections back to each of the compute platforms, changing those sensors and actuators at new-model time requires changing everything—re-architecting the compute and sensor interfaces.

And that's not how servers operate, DeVos said. They abstract compute from the I/O. "All the I/O comes in standard format to that server so it's managed very carefully," he said. "And that's the third important point: enabling the 'serverization' of the platform." This involves aggregating compute into several modules that support all the features of the vehicle and doing it more effectively.

"Essentially, what we want to do is make the compute agnostic and independent from all those sensors and actuation," DeVos explained. "For us it's not reinventing the wheel; it's applying this separation to the automotive space." ■

Wired for Autonomy

by Dan Scott and Ulrike Hoff

Wiring harnesses are already heavy, complex and costly, so what happens when AV equipment is added? Two experts weigh in.

Engineers and product planners are already grappling with the complexity of autonomous vehicles (AVs), with the prospect of complexity increasing. Every second, AVs manage advanced-sensor fusion via high-bandwidth networks, while onboard computers run AI algorithms to process gigabits of data. Connecting it all is the wiring harness, which has become increasingly heavy, more expensive and more difficult to package within the vehicle.

Premium-segment cars and full-size trucks can contain 40 different harnesses comprised of 700 connectors and more than 3,000 wires. Stretched in a continuous line, these wires would span 2.5 mi (4 km) and weigh approximately 132 lb. (60 kg). In addition, there can be more than 70 specialty cables that include coax, high-speed data and USB runs.

This does not encompass the added AV sensors and processing content that will further expand harness size, mass, complexity and cost. The implications of escalating electronic content are a significant issue for AVs built on electric-vehicle (EV) platforms. Engineers can undertake several strategies at the architectural- and harness-level to resolve this dilemma.

Mentor

As OEMs integrate automated-driving systems and other new-technology content into their vehicles, wiring harnesses have the potential to become ever larger, more complex and expensive and heavier.

Mentor

AVs rely on a dense network of powerful sensors and computers to detect and react to highly dynamic driving scenarios.

Architectural optimizations

Automakers are investigating new electronic/electrical (E/E) architectures that will simplify the harness design to minimize cost and weight. Such designs can reduce the wiring needed to support vehicle functionality and offer an opportunity to reduce mass while making automated production easier, driving down cost. And OEMs have begun consolidating electronic components, such as ECUs and sensor modules, moving from highly distributed to increasingly centralized architectures. The architectural consolidation is driving reduced bills-of-material (BoM), which directly impacts harness complexity.

ECU consolidation has become a popular strategy as automakers integrate more powerful integrated circuits (IC) and microprocessors into their vehicles. The increased computational capabilities of these chips enables a single box to manage tasks that used to require multiple units. As a result, vehicle architectures are converging with powerful domain controller units using sensor fusion and artificial intelligence algorithms to pre-process sensor data before sending it to a centralized processing unit.

However, there is a balance to be struck with consolidation. An architecture that features only one or two control units managing all vehicle functions will require an immense amount of wiring to connect with all the components that are necessarily distributed around the vehicle. OEMs will need to perform dozens of analyses to determine the optimal balance between distribution and centralization for harness functionality.

OEMs and Tier 1s also are developing technologies that directly reduce harness weight through smaller wires and new materials. Ultra-thin-diameter wiring (0.13 mm^2) is a notable example. Unfortunately, the industry still is struggling to develop sufficient terminal substitutions for all currently existing terminals that can crimp to such a small diameter. The available products on the market currently do not support a large-scale migration to ultra-small diameter wiring.

The same applies to aluminum wiring. For small-diameter wiring, pure aluminum is too brittle and thus not a feasible option. Terminal suppliers are developing optimal aluminum alloys for the specifications of their terminals. This has led to a multitude of different alloys on the market that, in most cases, are incompatible with other suppliers' terminals. To use these wires, a vehicle would have to use one supplier's connectors across the full vehicle, which is not realistic.

Finding alternatives to specialty cables will further reduce weight/cost and bundle diameters of harnesses. The number of data-intense sensors and displays will only increase in the future, making it crucial to develop solutions to transmit video and other data-rich signals via standardized wiring. Alternatively, finding ways to multiplex signals onto a single shared specialty cable while multiple devices tap in will have the same effect: reducing weight/cost/bundle diameters.

Leveraging digitalization

In concert with architectural and harness optimizations, adopting E/E software solutions to support development flow will be crucial. Software solutions need to enable rapid tradeoff studies to optimize module locations and identify any module that can be combined to save

> *Adopting an E/E engineering software solution that supports the entire E/E and harness development flow will be crucial.*

Mentor

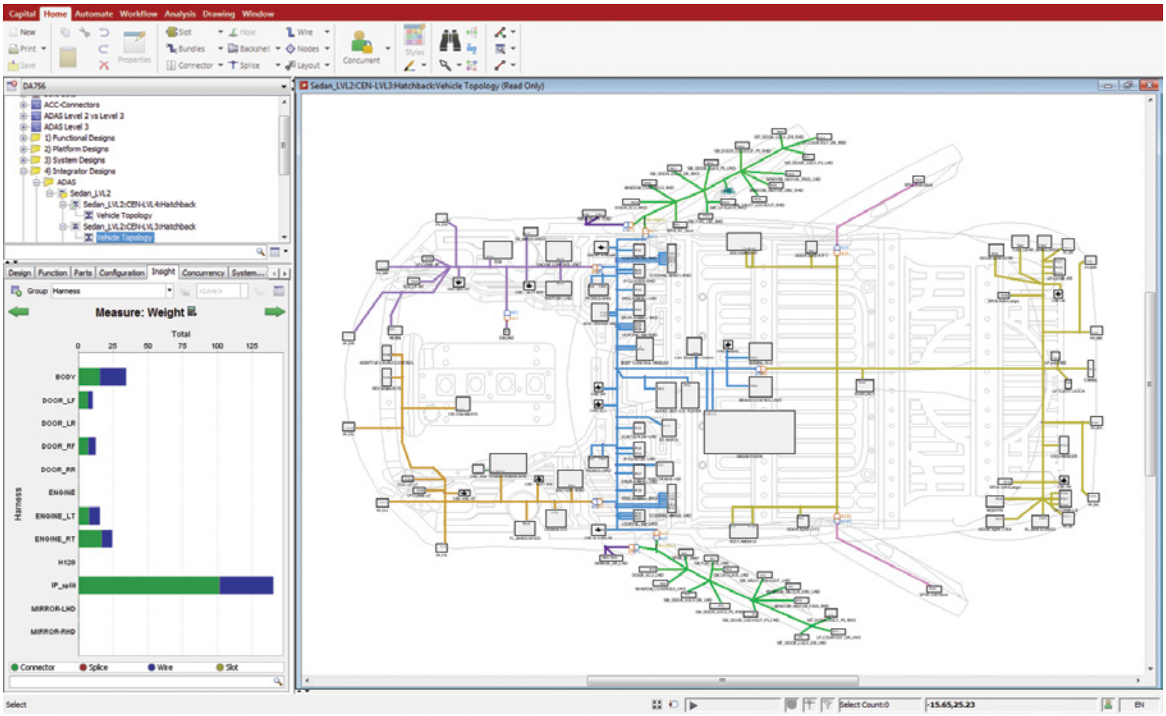
Automated data transfer reduces errors in the harness design by streamlining the interaction between domains.

weight/cost/complexity. With the ability to compare and analyze layouts for their impact, engineers will be able to choose the optimal system architecture.

Additionally, the most advanced E/E engineering solutions support data continuity throughout harness development, integrate with other engineering software and automate design tasks. An example is Mentor's Capital software suite that enables the engineering of electrical systems for large platforms such as vehicles. Such capabilities will help OEMs to design harnesses for even the most sophisticated vehicles.

Data continuity ensures that engineers at all stages of E/E architecture and harness development have access to accurate and up-to-date information. This replaces manual data exchange with a robust digital twin of the vehicle architecture and wiring harnesses. As a result, engineers can collaborate more effectively through automated data exchanges that remove errors from manual data exchange and reentry. Likewise, integrations with software from other domains, such as mechanical design tools and product lifecycle management solutions, facilitate collaboration and automated data exchanges across engineering domains.

Automation capabilities help engineers further optimize vehicle architectures and wiring harnesses. Wiring synthesis combines system connectivity information, such as device and signal types, with the physical harness constraints to generate optimized wiring and splices within the context of the vehicle. Today's wiring synthesis tools support complex wiring types, multiple



Mentor

The Capital software suite enables tradeoff studies with cost, weight and bundle-size metrics to optimize a harness design.

shielding materials, various network protocols and can even automatically create ground points.

Finally, ongoing architectural optimizations and system-level changes can have wide-ranging effects on the E/E system and wiring harness. In addition, changes can be initiated throughout the engineering and manufacturing processes, driving constant redesign efforts. It is extremely important to develop a structured and disciplined approach to change management early on in the project.

Advanced E/E engineering software can provide an elegant solution. Integrated device databases can be enhanced with change-control mechanisms to determine ownership over design data and the direction in which certain changes should flow.

With these enhancements, this database will immediately provide automated and structured change-management procedures.

New challenges, new solutions

The move to electrification and AV driving places additional burdens on the wiring harness. As OEMs pursue these trends, they must consider the number and sophistication of technology features they integrate into vehicles, as they have a direct effect on wiring harness weight/diameter/cost.

Modern harness design and engineering tools provide a solution to problems wrought by automotive innovation. By leveraging engineering solutions with high levels of automation, advanced metrics and analytical capabilities, engineers can overcome these challenges. Such solutions enable tradeoff studies to optimize harness materials, component placement and routing for minimal harness weight/cost/diameter.

Design automation then can generate optimal wiring based on device and signal location, and the physical constraints of the vehicle. As the development of the E/E architecture and wiring harness progresses, comprehensive change-management facilities and a robust digital twin ensure that the various engineering domains remain in step with all needed information.

Vehicle automation, electrification and connectivity are coming closer to mainstream reality. These technologies will progressively shift the emphasis in automotive enginering from mechanical systems to E/E architecture.

The resulting capabilities provided by an advanced E/E engineering software solution will be critical to delivering a robust, reliable and cost-effective vehicle platform. ■

Engineer Dan Scott is Integrated Electrical Systems market director at Mentor, A Siemens Business. Ulrike Hoff is an independent automotive wiring consultant.

Autonomy's 'Pirouetting' Future

by Stuart Birch

Protean Electric's novel 360-degree steering and in-wheel drive systems add new potential for urban mobility.

Designing and engineering a 360-degree steering capability for a production electric autonomous road vehicle's four wheels is no mean achievement. But Protean Electric also combines this pirouetting capability with an in-wheel electric motor, "innovative" suspension and pneumatic ride height control into an all-in-one package. Its adroit wheel-at-each-corner module, called Protean360+, is designed initially for next-generation urban mobility pods. But it could also be applied to a wide variety of other autonomous vehicles.

Development of the 360-degree capability began in early 2018. It is the latest element to be added to the company's ProteanDrive in-wheel system, on which work started more than a 10 years ago to specifically meet emerging needs for radical new urban vehicle technology combined with autonomous transport visions. These include autonomous passenger cars, light-duty commercial vehicles and other future mobility solutions.

Protean Electric particularly anticipated the need for moving people and goods in urban areas where parking and maneuvering regular vehicles could be increasingly challenging. Application of the deft Protean360+ allows for curbside precision in very tight spaces. Once parked, the module's pneumatic ride control system allows a vehicle to "kneel", lowering

Protean Electric's 360-degree steering system fitted to an autonomous shuttle - one of a variety of potential applications.

Protean Electric

its entry point to curb height.

Interviewed by *AVE*, Dr. Chris Hilton, the company's chief technology officer, said his team is "not aware of any other systems with the same capabilities, including unlimited steering and ride height control. Part of its attraction is that it allows creation of a very flexible, totally flat-floor vehicle platform that can be adapted for various uses including commuting and delivery of goods and services, so the range of vehicles supported will be very varied."

Operation cost efficiencies

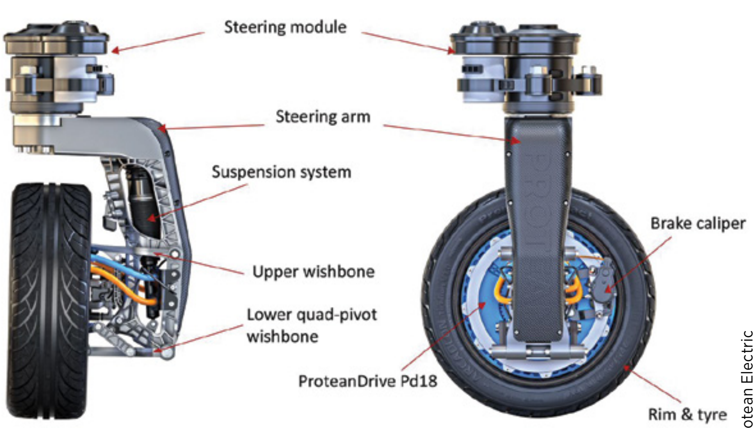
Cost of such radical solutions is invariably a question raised by OEMs. Although he was unable at present to give an indication of unit cost, Hilton said Protean Electric is convinced that its adoption in target vehicles, relative to traditional solutions, would result in economic advantages for operators and vehicle manufacturers via increased safety, greater maneuverability, superior efficiency and enhanced robustness, together with reduced cost of ownership and a higher earning potential from the interior space gain.

"Operational cost efficiencies can be realized, too," he said. Electronics are integrated into the electric motor enabling real-time monitoring of wear on bearings and suspension, thus improving predictive maintenance.

Packaging proved the most challenging development. The 360-degree steering had to be compact and able to fully rotate without consuming excessive vehicle space. "Novel solutions were required, for which we have patent applications," Hilton explained. "First, for the steer-by-wire unit that supports unlimited rotation without stressing the cables and pipes that supply the Protean 360+ module; and second, to a multi-link suspension system with an additional lower-wishbone pivot. This quad-pivot system keeps the suspension system within the required packaging envelope while allowing the desired suspension kinematic."

For the in-wheel module, Protean's novel steering and suspension solutions are critical.

Protean Electric



Protean Electric

The Protean360+ "wheel at each corner" module.

The steering system includes a rotating interface above the module's main arm. The top of the interface is fixed to the vehicle and a lower interface is fixed to the arm of of the module.

The system allows a vehicle to spin through 360 degrees within its own footprint. As the arm module rotates, the full component set rotates with it. The steer-by-wire unit is positioned above the interface enabling axis points at the bottom of the wheel. The module also incorporates a pneumatic ride height system that shares its reservoir and compressor with other systems in the vehicle. It provides independent control at each corner of a vehicle.

Prototype trials

Examples of the 360+ will start prototype vehicle trials this year, stated Hilton. Development work is being carried out at Protean Electric's R&D center in the U.K. in partnership with Arcadlon, a specialist engineering company in Graz, Austria.

"Arcadlon has expertise in the rapid implementation of advanced concepts," said Hilton. For the in-wheel motor system, Protean has been collaborating with several universities and "high-quality technology partners" for more than a decade.

The ProteanDrive Pd18 in-wheel motor system is used for the 360+. Designed for integration into an 18-in wheel, it develops peak outputs of 1,250 Nm (922 lb-ft) and 80 kW (107 hp). The permanent magnet synchronous motor is integrated with the inverter and dedicated liquid cooling circuit, all packaged within the wheel rim.

Positive or negative torque can be applied "within milliseconds," aiding performance of ESC, ABS and traction control systems.

The design also supports shorter stopping distances – typically 7% less – according to an independent study (Satoshi Murata "Innovation by in-wheel motor drive unit," *International Journal of Vehicle Mechanics and Mobility*, Vol. 50, issue 6, 2012).

The rotor of the electric motor connects to the hub, delivering torque directly to the wheel, reducing losses in power transfer. Hilton explained that the Protean360+ module including drive motor is scalable to suit a range of vehicle requirements.

Initial applications may be what he terms "constrained environments" such as campuses. Customer on-the-road use is expected "within five years."

Adds KY Chan, CEO of Protean Electric: "Transport-as-a-service urban mobility is gaining momentum, and with it the need for a new class of urban transport vehicles. The Protean360+ corner module was born from our team's innovative thinking about how to meet the requirements of these next generation urban vehicles." ■

Restructuring for Autonomy

by Terry Costlow

At the dSPACE World Conference, engineers gained new insights into digital development, virtual design and testing.

The rapid cadence of new automotive technologies continues to drive massive change. Automakers are revamping corporate structures while simultaneously altering vehicle architectures, as engineers strive to meet the demands of autonomy, connectivity, electrification and advanced safety.

The transformations driven by the escalating impact of electronics were a central focus for automotive executives who addressed the recent dSPACE World Conference, held in Munich. The impact is reaching into the upper layers of corporate staffs. At BMW, for example, new training is endowing every manager with a deeper understanding of electronic technologies and digital design tools.

"All managers have to go through a course in electronics and software," said Alejandro Vukotich, senior VP, fully automated driving, at BMW AG. "They even need to take a test after each module to ensure that people actually learn what's in the coursework."

Even engineers are being retrained. Specialists in mechanical systems are getting updates in the latest digital technologies, which include simulation and validation, along with fundamentals of digital technologies. OEMs that have added thousands of electronics engineers and programmers in recent decades now are making sure that other specialists understand how digital devices interact with vehicle mechanics.

"One challenge has been with our mechanical-engineering team – they have been training themselves not to be afraid of electronics and software," Andy Griffiths, chief engineer, software and system integration and test, Jaguar Land Rover, told SAE's *Autonomous Vehicle Engineering*. "Every engineering manager is being trained in key elements of software, test and validation."

Several speakers at the event noted that the rapidly expanding role of digital design tools is prompting similar restructurings in design, development and test processes. Streamlining processes and ensuring that tests can be repeated and reused are among driving

dSPACE

The inaugural dSPACE World Conference explored how engineers can best use digital tools to meet new requirements for simulation, validation and homologation of automated and electric vehicles.

Terry Costlow

Jaguar Land Rover's Andy Griffiths (left) and Alex Heslop (right) described the automaker's training and technical changes as digital vehicle development expands.

factors for some OEMs and software-generated virtual tests now dominate many strategies.

Toward a 'golden point'

"A year-and-a-half ago, we started a consolidation with vehicle architectures for test; everything needs to fit in this architecture," said Dr. Peter Oel, head of E/E integration, simulation and test at Volkswagen AG. "If we don't change our processes, we won't be successful. This is disruptive in the way we use testing and integration techniques. We won't buy standard test benches any more. We want to get modular systems and to be able to use best-in-class tools for each job."

He added that cloud technology is a critical element of this new test strategy. Using the cloud makes it possible to run tests using massive parallelization so that voluminous full-vehicle tests can be run in comparatively short timeframes.

Strategies for enhancing design and validation take many forms. The same technologies that make designs more complex can be used to help engineers better meet users' needs. For example, JLR is leveraging connectivity and firmware over-the-air (FOTA) updates to help engineers speed new features and functions into production, then tweak them after they've seen how drivers interact and use the technology.

"Rather than trying to develop fully a complex product where we're guessing the user requirements, we try to define a minimum product target, then learn from it and add features with FOTA," said Alex Heslop, director – electrical engineering at Jaguar Land Rover.

dSPACE Buys AI Startup, Adds Staff

The deluge of data used by vehicles and the need to accurately predict how myriad automotive systems interact makes predictive design analysis a critical tool for vehicle development. At its first worldwide user conference, dSPACE described how the company has transformed to address new demands.

Martin Goetzeler, dSpace's CEO, detailed the company's expansion to a full-service provider during the past two years. "We've become an end-to-end simulation and validation provider," Goetzeler said. "We've extended our hardware-in-the-loop capabilities to include software simulation, software-in-the-loop and cloud simulation as a service."

Over the past two years, manpower has increased by more than 30%, passing 1,800 and new corporate R&D and test facilities opened. In June, dSpace acquired three-year-old startup Understand.ai to address the burgeoning role of artificial intelligence.

This broad restructuring sets the stage for years of double-digit growth, Goetzeler predicted. While the changes in the past two years have been significant, the restructuring at dSPACE and many other automotive companies is far from finished.

"We're in the middle of a transformation driven by e-mobility and autonomy," Goetzeler said. "We need to continue altering our company and work with new partners."

dSPACE CEO Martin Goetzeler said the company has broadened its portfolio to meet burgeoning demand for design and simulation tools.

dSPACE

The volume of data from inside and outside the vehicle continues to soar and the interactions between modules that create and use this information also are multiplying. That puts more emphasis on ensuring that all parties involved in development and testing are working closely towards common goals.

"The big challenge is addressing the holistic complexity of the car's functions; there are a lot of concerns inward and outward, and they're highly dynamic," said Dr. Chen Ma, Product Owner, Volkswagen AG. "You need everyone to work towards one goal. That's not easy, because everyone normally works towards their own goals. This is now a highly interdisciplinary domain – companies need to find a level of working together that is a golden point." ■

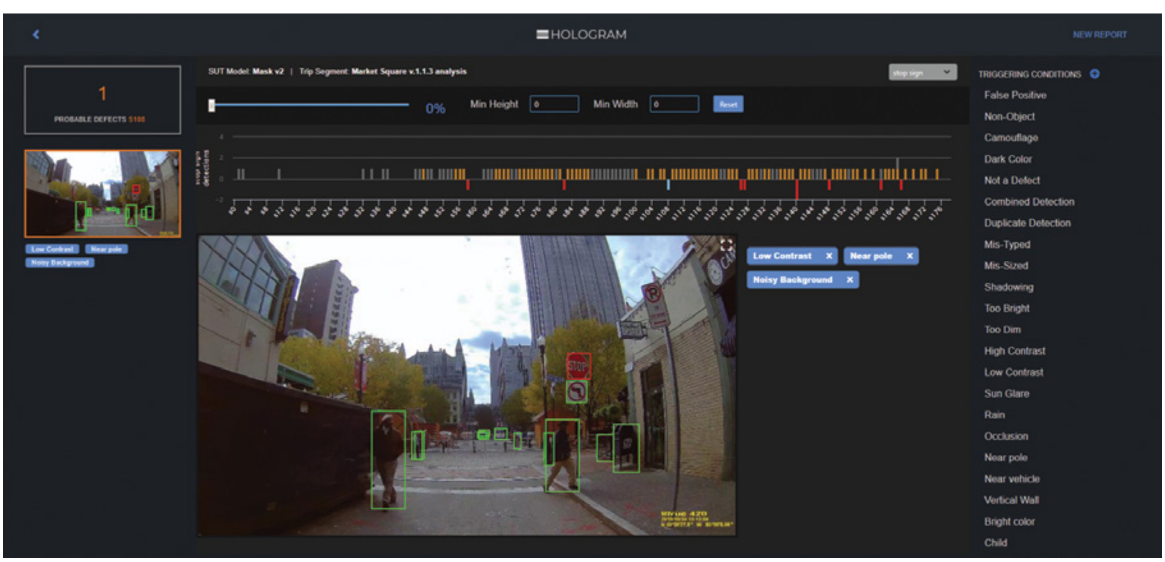
The Key to **AV Safety** is ODD

by Bradley Berman

Truly safe automated driving depends on defining the exhaustive list of overlapping conditions, use cases, restrictions and scenarios an AV might encounter.

In a perfect world, an automated vehicle (AV) would be all-knowing. Its sensors, communication systems and computing power could predict every road hazard and avoid all risks. But until a wholly omniscient self-driving vehicle is a reality, there will be one burning question for AV developers and regulators – and the public: How safe is safe enough?

Despite about $100 billion of investment in AVs to this point, nobody has an adequate answer. Safety standards and metrics have not yet been established. The world's leading roboticists are scratching their heads. Regulators are largely perplexed. Until there's an answer to this almost abstract question, the great promise of AVs to reduce accidents and save lives, free up our time and democratize mobility will remain beyond our grasp.



Edge Case Research

Hologram, a simulation tool created by Edge Case Research, identifies Operational Design Domain (ODD) risks that are difficult to find with other types of testing.

"The leading players reached a point where we're going through validation and testing. And we realized that the safety question is in our critical path," said Karl Iagnemma, president of autonomous mobility at Tier-1 tech supplier Aptiv, in an interview at the TechCrunch Mobility 2019 conference. "It's the biggest unanswered question in the industry today," he asserted.

Aptiv launched the world's first commercial AV ride-hailing service in 2018. That pilot project, using Lyft vehicles, is based in Las Vegas. Aptiv also deployed AVs on the streets of Singapore, Boston and Pittsburgh.

While easy answers to the AV safety question are elusive, the path forward could come down to the industry's widely and often-debated three-letter acronym: ODD, or Operational Design Domain. The term defines all conceivable overlapping conditions, use cases, restrictions and scenarios that an AV might encounter – even the most esoteric edge cases.

The last 2%

Dr. Phil Koopman, associate professor of electrical and computer engineers at Carnegie Mellon University, is a decade or two ahead of the pack in realizing the critical importance of ODD.

Koopman said that since 1995, he's known about the importance of establishing the scenarios in which AVs can and cannot remain safe. That's when a team of Carnegie Mellon roboticists traveled coast-to-coast in a Pontiac minivan decked out with a video camera, personal computer and a GPS receiver. "We had our hands off the wheel for 98 percent of the trip," he told SAE's *Autonomous Vehicle Engineering* via phone last fall while attending a safety conference in Finland. "And for the last 20 years, we've been working on the last two percent."

Common ODD factors include time of day, weather, terrain and road features. But the list gets very long, very fast.

In January 2019, Koopman, a co-founder of Edge Case Research, co-authored a white paper, "How many Operational Design Domains, Objects, and Events" (co-author was Frank Fratrik, lead engineer at Edge Case Research.) The paper essentially is four pages worth of bullet points of factors related to ODD object detection, faults and maneuvers.

The paper's laundry list of ODD oddities – impactful factors that an AV might encounter – includes glare, social norms, outdated mapping detail, tollbooths,

Aptiv has deployed AVs to the streets of Las Vegas, Boston, Pittsburgh and Singapore. The same system needs to handle very different scenarios based on location and manifest other factors.

Aptiv

water-filled potholes, overhanging vegetation, downed power lines, icing, uncooperative people, falling objects, delivery robots and common human rule-breaking.

Koopman cautions against overly simplistic approaches to ODD.

"If you take a city block and say that's my ODD, it doesn't tell you what you need to know," he said. "It just limits the possibilities even if you've driven along that street for three months." Koopman added that even a simple street has way more variability than most people appreciate.

"If you never drove on that street on October 31, I will guarantee you things change on that day, at least in the United States." He said that humans can immediately recognize things – construction workers wearing yellow high-visibility uniforms, for instance – that are sometimes missed by even the best AV systems.

Start at the Beginning

Xantha Bruso, manager of autonomous-vehicle policy at AAA Northern California, Nevada & Utah, fully recognizes the complexity of establishing ODD-based AV safety standards. But seeing the public-safety imperative, she's undaunted. "The bar is really low. There are currently no performance-based standards," she said. "You have to start somewhere."

In a conference room at AAA Northern California's innovation lab in Berkeley, Calif., Bruso rattled off the key questions. "What conditions can the AV operate in? What happens when something changes in the environment that prohibits it from operating safely? How can it sense that it's getting close to the edge of the ODD? What happens then? How does an AV company make its safety case? How does all this mesh with how regulators are defining safety?"

These questions and others informed AAA Northern California's work to develop AV safety metrics sorely lacking in the industry. For the project, the organization partnered with Securing America's Future Energy (SAFE) and RAND Corporation. "When we gave it a careful look, we realized that we were putting the cart before the horse," Bruso said. "First, we need the foundational definitions for where it's safe to operate. What are those conditions?"

So the project team turned its attention to developing an ODD for GoMentum Station, the Bay Area's 2,100-acre AV testing facility owned by AAA Northern California. "We're starting there," said Bruso. "We're using GoMentum Station as a proxy for an industry-wide test environment. We can make those conditions defined and repeatable." Bruso's plan is to publish and promote its ODD with the hope of having other test tracks use its definitions – or at the least, the same conceptual framework. The long-term vision is to establish a testing protocol for apples-to-apples comparisons of AV systems throughout the world.

Bruso explained that those comparisons currently are not possible. "A Cruise vehicle testing in San Francisco has a more-complicated ODD than a Waymo in Phoenix," she said. "You need a baseline of conditions to evaluate these vehicles on an equal footing."

AAA plans to publish and promote an ODD for its GoMentum AV test facility that is envisioned to serve as a proxy for an industry-wide ODD.

GoMentum

One ODD at a time

Flexibility will be crucial. Industry players follow a wide array of business cases, from long-haul trucking on highways to low-speed deliveries in the suburbs. The ODDs also need to be agnostic to technology, ignoring which sensors a company uses to achieve safety-performance benchmarks. The quest for equal footing becomes still more challenging given the diverse set of stakeholders all trying to establish standards.

"Our next step is to call out to the whole industry," said Bruso. "How can we come together?"

Koopman believes the mile-long list of ODD factors must be put to a higher, broader purpose. "Safety is always about engineering rigor," he said. Sometimes that means making sure that "perfect is not the enemy of the good," as the 18th-century Italian aphorism states.

For Aptiv and other leading AV companies, it's a balancing act. There's a strong impulse to get self-driving vehicles on the road, earning revenue and delivering on the promise for greater safety. "What that means in practice is that we are going to deploy our technology initially in easier driving environments," said Aptiv's Iagnemma. "And over time, we will deploy in increasingly complex locations."

Koopman said that the UL 4600 standard, still in development, explicitly allows AV makers not to be perfect. "You need good empirical test data to say that you're not presenting an undue risk," he said. "But you can't stop conditions from changing." In other words, you'll never develop an ODD that takes every scenario, use case and road condition into consideration; AVs need to know what they don't know – and then respond with a fix as fast as possible after an incident. ■

This article was sponsored by AAA Northern California, Utah & Nevada.

Who's Making the Rules in the **Fast-moving AV Age**?

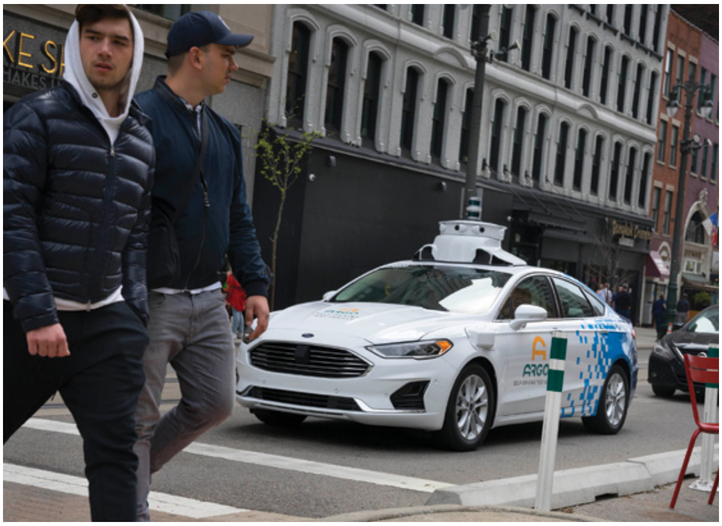
by Jennifer Dukarski

The auto industry's impact on NHTSA's regulatory cadence is apparent – and it's challenging theories of rulemaking.

Even to casual observers, it's clear that the regulatory landscape for autonomous vehicles (AVs) is a void filled with uncertainty. Outside of requirements that mandate technologies often considered "enemies" of autonomy, very little work has been completed related to AVs. To fill the regulatory vacuum, NHTSA has issued several often-discussed "guidance" documents.

These include the *Federal Automated Vehicles Policy* (AV 1.0), *Automated Driving Systems: A Vision for Safety* (AV 2.0) and *Preparing for the Future of Transportation* (AV 3.0). Crucially, these are guidelines and are not legally binding. They provide little in terms of concrete, technical details outside of AV 3.0's strong support for industry standards. If you were to ask yourself what's holding up the creation of actual legislation, consider these three issues:

- Talent. In its September 2016 policy directive (AV 1.0), the U.S. Department of Transportation noted that it needed to build a staff of in-house experts who are cutting-edge in science, mathematics and engineering. Unsurprisingly, attention was paid to "greater flexibility on pay" and recruiting and retention practices. Plain and simple, NHTSA needs a larger, more technically proficient headcount.
- The speed of automated-technology development. Any regulatory agency must remain nimble enough to understand the scope of the technology and how to create the appropriate framework for operation. This includes conducting research to develop and validate new performance metrics; establishing minimum or maximum thresholds for those metrics; developing



Argo AI

A crucial aspect of regulating automated vehicles is how they should be expected to interact with their environment.

A particularly vexing regulatory problem comes in defining and setting performance standards for widely disparate types of advanced driver-assistance systems (ADAS), such as Cadillac's Super Cruise.

test procedures and test equipment, and conducting notice-and-comment rulemakings to incorporate those metrics, procedures and tests into new FMVSS.

- The time required for rulemaking. The DoT noted in its October 2018 *Preparing for the Future of Transportation* (AV 3.0) that the "pace of innovation in automated vehicle technologies is incompatible with lengthy rulemaking proceedings and highly prescriptive and feature-specific or design-specific safety standards."

We did it to ourselves

It's hard to deny that a lack of financial resources, the speed of technology, the time to create regulations and a hyper-partisan Washington are contributing factors to a lack of progress in substantive rulemaking. But a walk through history shows that there may be undercurrents – deeply influenced by manufacturers' needs and wants – which created a less-than-receptive regulatory environment.

NHTSA earns its stripes: In 1966, Congress passed the National Traffic and Motor Vehicle Safety Act, legislation that gave NHTSA broad jurisdiction over all elements of design in motor vehicles. Principally, the Act empowered the new regulatory agency with three charges: compel the industry to pursue innovation in automotive technology; make rules to ensure citizens are safe in their vehicles; oversee the recall of defective vehicles. As part of the Act, NHTSA was given the power to issue Federal Motor Vehicle Safety Standards (FMVSS) targeted to reduce motor vehicle collisions and fatalities.

Manufacturers slow NHTSA's progress: With its newfound authority, NHTSA rolled out regulations and accompanying test protocols. But not all of these were welcome news to the industry, leaving manufacturers running to the courthouse to challenge the scope and breadth of NHTSA's power. One of the first legal challenges to the newly empowered agency came in 1972 to FMVSS 208, the standard addressing occupant crash protection. In Chrysler Corp. v. Department of Transportation, several OEMs and the Automobile Importers of America challenged the implementation of several provisions of the standard.

In 1978, the Supreme Court declined to hear an appeal of the decision of the Ninth Circuit in Paccar, Inc. v. NHTSA which addressed FMVSS 121, the standard addressing air brake systems. NHTSA created a substantial road-testing procedure which was challenged for its practicability and objectivity. The court determined that the "amorphous due care standard" was neither practicable nor objective.

Overall, NHTSA lost six out of ten court cases in the first fifteen years of its existence.

In their 1990 book, *The Struggle for Auto Safety*, Jerry Marshaw and David Harfst suggested that these cases, and the Chrysler case in particular, gave the public a sense that the industry was being forced to endure "costly interventions of a technically incompetent bureaucracy." Further, it made businesses and the public believe that standards created a large burden on the industry. With a pro-business, pro-manufacturing perspective, rulemaking hit an

> The more effective use of NHTSA's existing regulatory tools will help to expedite the safe introduction and regulation of new HAVs [*highly automated vehicles – ed.*]. However, because today's governing statutes and regulations were developed when HAVs were only a remote notion, those tools may not be sufficient to ensure that HAVs are introduced safely, and to realize the full safety promise of new technologies. The speed with which HAVs are advancing, combined with the complexity and novelty of these innovations, threatens to outpace the Agency's conventional regulatory processes and capabilities.
>
> ***Federal Automated Vehicles Policy*, September 2016**

Uber

An Uber experimental vehicle. Federal regulation of AV testing on public roads is regarded by many as a critical regulatory void that currently is unaddressed.

almost insurmountable hurdle.

NHTSA shifts to enforcement power: While the courts found NHTSA's regulations lacking in "reasonableness," "practicability," and "objectivity," they did support the power of enforcement of recalls for safety defects. In contrast to the string of losses, NHTSA won two major decisions against General Motors in 1975 and 1977 dealing with wheel failures and steering linkages. In their critical assessment, Marshaw and Harfst called this "a reorientation of auto safety regulation, from science and planning to crime and punishment."

Rulemaking runs out of gas: Between 1974 and 1986, experts and even NHTSA itself acknowledge that very little rulemaking occurred and that no significantly new safety rules emerged. In the years following, little progress arose from NHTSA itself, with Marshaw and Harfst dubbing this period (1987-2002), the "Ice Age of Rulemaking." What became clear was that NHTSA rulemaking was more responsive to the demands of Congress and the executive branch.

Seeking to continue the support for the automotive industry and its manufacturers, the executive branch worked to remove regulatory barriers. Within the first sixteen months of the Reagan administration, NHTSA rescinded rules and ended rulemaking in twenty-one different situations. In contrast, most of

Waymo

Testing how two markedly different automated vehicles will share the road. But so far, AV testing metrics and practices are not standardized.

the major rulemaking developments in this era arose from direct Congressional action, including ISTEA, TREAD and SAFETEA-LU.

What's past is prologue

The pace of AV development continues unabated, and the regulators at NHTSA have not consented to be left behind. AV 3.0 may not have foreshadowed concrete rulemaking, but NHTSA is undertaking efforts to review the existing FMVSS for compatibility with AV technology. This is a slow process, but it shows a commitment to understand which of the FMVSS standards must adapt.

It seems ironic that an industry so desperate to constrain the early rulemaking power of NHTSA now is calling for new regulations in an even more complex technological area. History shows years of industry and regulators moving in separate circles, challenging each other at every opportunity. But it's now time to procced in a more collaborative approach, playing our role in creating the voluntary technical standards that NHTSA highlighted in Appendix C of AV 3.0.

We should continue to show support and seek to positively influence legislation that will enable and encourage NHTSA to create feasible standards. We should partner, as an industry, with NHTSA to support the drafting of FMVSS that will not require fifteen years of court challenges and setbacks. Here, learning from the past is a necessary path to the greatest automotive innovations of the future. ■

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.

Next-gen Sensors Advancing Commercial-Vehicle ADAS, Autonomy

ZF's director of ADAS & Autonomy says the supplier will be very well positioned in 2020 for the SAE Level 2 market, which he views as "a real sweet spot" for commercial vehicles.

by Ryan Gehm

Together with its many partners, ZF supplies camera and radar technology and advanced components for both the passenger car and truck markets, the latter being especially suited for the move to more complex driver-assistance systems, according to Dan Williams, director of ADAS & Autonomy. "The business case in commercial vehicle for reduction in driver hours of service, fuel cost reduction and safety have strong economic incentives to adopt ADAS/automated driving technology," he said. "Additionally, the regulations placed on the industry will require our customers to utilize certain solutions."

Dan Williams, director of ADAS & Autonomy at ZF.

ZF

ZF is working on both highly automated "revolutionary" systems and on "evolutionary" driver-assistance systems that are increasingly complex, he noted, citing the supplier's OnTraX lane keep assist that will launch in 2020 with its first major OEM customer. Williams spoke with SAE's *Truck & Off-Highway Engineering* the recent NACV Show in Atlanta. He's scheduled to participate in a Commercial Vehicle Safety technical session at the SAE Government/Industry Meeting, January 22-24, in Washington, DC.

Which industry will lead with the integration of automation systems?

One very reasonable prospect might be passenger car, which has a lot of scale and a lot of money to invest in R&D that's definitely required for these very expensive systems to develop. But passenger car has their own problems—they've got very diverse and sometimes very complicated duty cycles, or we'd say operational design domains…The opposite extreme is off-highway, like with automated mining trucks and other [machines] in remote areas. All of these off-highway examples are very low volume, very particular to a given site—they require a lot of engineering without much volume. We would say that commercial vehicles are kind of the Goldilocks scenario for automation, where things are just right. There's more concentrated commercial-vehicle activity in fewer specific use cases that are more simply automated. Two-thirds of our vehicles spend more than 95% of their time going straight down the highway at the speed limit, maintaining the lane. I don't want to undersell that—that's still a very difficult thing

Commercial vehicles are kind of the Goldilocks scenario for automation, where things are just right.

ZF and Ibeo

ZF has partnered with Ibeo and ams to develop solid-state lidar sensors that provide complete 3D imaging of the vehicle's environment and a precise perception of complex traffic situations.

to automate, but it's far easier to automate than some of the very strange urban-environment scenarios that passenger cars can get themselves into.

What can we expect from ZF in the next year or two?
In 2020, we'll be launching our next generation of sensors that will support increasingly complex ADAS functions. By that I mean these new camera and radar sensors will have a longer range, they'll have a wider field of view, and they'll have higher resolution. All these things taken together will allow them to do any number of things, probably most significantly is to allow us to do a better job of detecting pedestrians and other stationary and semi-stationary objects. Apart from that we're working with NVIDIA and Ibeo on components that power even higher levels of technology and full automation. [In May 2019, ZF announced a partnership with ams and Ibeo Automotive Systems to develop solid-state lidar sensor technology.]

Can you elaborate on these next-gen sensors?
The next-generation radar is going to be operated at a higher frequency, at 77 GHz [vs. the current 24-GHz sensor], and that will do a better job of detecting slow-moving, sort of stationary objects—it's not really the 'soft tissue' as much as the 'slow moving' that causes problems. And the camera, it has kind of a dual mode of operation, where it's got a narrower field of view that extends longer for on-highway operation at high speed, and then the camera and the radar have a wider field of view that they can go into at slower speeds. The trade-off is shorter range, but at slower speeds you really don't care. And then a new sensor we'll be adding in this next generation is a short-range radar that can be placed on the side of the vehicle to detect bicyclists and pedestrians. That in concert with these forward-looking sensors gives us a more complete view not only in front of the vehicle but all the way around the side.

Where do these next-gen sensors position you on the SAE levels of automation?
They're evolutionary, really. I think we're going to be very well positioned in 2020 for the L2 market, and we see that as a real sweet spot; we think that's going to be around for a while. Drivers are going to be driving these vehicles for some time, and if we can use some of this technology to improve their

ZF's OnTraX assist offers further capabilities with the addition of short-range radar, including lane change and city drive assist.

ZF

productivity, to increase the safety, that's going to have value for quite a while.

What's the timeline for Level 4 autonomy?
That's a tough question. Anything that I'd say would be further out than what you hear from Silicon Valley. [Laughter] There's a lot of work to get this going in Arizona, New Mexico, Texas, and there's going to be even more to get it beyond that into more challenging duty cycles, in snowstorms and rough weather up north. But it'll happen, there's no doubt it's going to happen. It's just a matt;r of when.

What are the challenges to get to L4?
A lot of it is just having the ASIL-qualified sensors, and that brings in redundancy. You can pile a bunch of sensors together that have a lower ASIL [Automotive Safety Integrity Level] to get to what you need for safety-critical functions. But that adds expense and that's not really an elegant solution. The sensors that really satisfy the functional safety requirements, basically it's lidar, and the old joke is, it's two years out and it's been that way for the last five. There needs to be some breakthroughs in highly reliable sensing technology to be able to do that.

What's the role of powertrain in ADAS and autonomy?
Powertrain will be increasingly integrated into more complex ADAS functions on the way to autonomy. An easy thing to describe is platooning. Everybody suspects that as we shorten the following distances with platooning we can increase the fuel savings. When you shorten the following distances, you need to more tightly control the powertrain. You need knowledge of grade information and stuff like that and feed that into the powertrain. It's a fairly difficult problem to be able to smoothly start and stop these heavily loaded vehicles on a grade, that challenges powertrain control—to have them in an automated way to back up and very gently kiss the loading dock. That requires a lot of control.

What's ZF's position on cameras replacing exterior mirrors on trucks?
We'd like to do it, for sure. We are working with our passenger car people that are involved in the regulatory affairs with this action. We think it'd be a good step for the industry to be able to replace the mirrors with rearward-looking cameras. It's maybe a little bit easier to do in Europe right now based on the regulation. We've got a demo going on with a platooning project over there that actually does exactly this. We've got what we call 'wings' that come out of the vehicle at the top of the cab, and that's where we put the V2V [vehicle-to-vehicle] communication between the platooning vehicles and we've also got rearward-looking cameras in there. It's obviously something where we've got to see regulatory change over here before that can happen. ■

Silicon Valley Summit Identifies Safety Strategies for Self-driving Cars

AV industry leaders pinpointed several effective tactics, such as limiting vehicle speeds and empowering safety operators to ground vehicles.

by Bradley Berman

Until recently, leading autonomous vehicle (AV) technologists posited that ultra-safe, go-anywhere robotaxis would soon be on the road. But questions about those timelines—and the safety of testing AVs on public roads—emerged in 2018 after a series of high-profile accidents. Consumers have since been caught in the middle between promises of eliminating highway fatalities and reports about deadly crashes.

The World Safety Summit on Autonomous Technology was organized by Velodyne Lidar to help clear up the confusion. The second annual event, which took place in Santa Clara, Calif., on Oct. 2, gathered some of the AV industry's sharpest thinkers. While attendees did not walk away from the day's speeches and panel sessions with a well-defined roadmap, the summit yielded several common-sense guidelines for increasing self-driving safety.

All AVs have domain limitations

If there's only one insight derived from the 2019 World Safety Summit, it's that no self-driving car can safely perform all driving functions "under all conditions." Those three words in the SAE J3016 standard are critical to defining a Level-5 vehicle in SAE's hierarchy of autonomy. But the times have changed since the standard was issued in 2016. Presenters at the summit acknowledged that Level 5 is aspirational, and not a relevant goal.

"I don't even think about Level 5," said Larry Burns, the former VP of Research and Development for General Motors. "It's not even on my radar screen." Burns, who is also the author of the book *Autonomy*, gave one of the event's three keynote speeches.

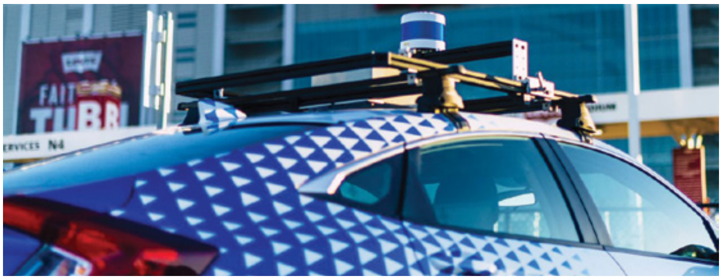
SAE's system of levels was designed only as an initial conceptual framework. But the conversation has since shifted to defining a vehicle's operational design domain (ODD; see page 21), the many scenarios and conditions that limit their operations.

Companies like Zoox, which are creating AVs without steering wheels or foot pedals, also acknowledged that Level-5 operation is beyond scope. "Zoox is a Level-5 vehicle that is optimized and designed to be able to perform in almost any environment, but it will be a Level-4 service," said Bert Kaufman, head of corporate and regulatory affairs at Zoox. "It will be constrained to ODDs."

The geographical region is a common ODD. For example, most AV companies will entirely avoid certain zones, especially rural areas. Jean and Eddie Rowe, who traveled to the summit from their home in

Velodyne Lidar

At the World Safety Summit, Aurora's Chris Urmson said that building a culture of safety is paramount.



Velodyne Lidar

Velodyne Lidar and other vendors demonstrated their technology in the Levi's Stadium parking lot.

A Zoox developmental AV in Las Vegas; at the World Safety Summit on Autonomous Technology, a company executive said Zoox intends to create SAE Level 5 vehicles, but relegate them to Level 4 mobility service.

Zoox

Pennsylvania—to participate in the panel, "The Voice of the AV Rider." The couple, who recently traveled to Detroit to take their first ride in a self-driving car, were impressed.

The Rowes, as aging baby boomers, believe they could greatly benefit from the mobility provided by AVs. However, they question if a self-driving service will reach their region during their lifetime. "Where we live, there are roads that don't have any lines," said Jean.

Regardless of geographical constraints, setting speed limits will also be helpful, according to Marta Hall, president and chief business development officer at Velodyne Lidar. "I hear our engineers talk about the complexity of the problem with full autonomy," she said. "I've also heard them say that traveling at 35 miles per hour is one-thousand times less complicated than 65 miles per hour."

Hall said that AV fleet customers using Velodyne Lidar want their sensors to have a range of 200 to 300 meters (656 to 984 ft). But that long-range perception should be combined with limiting vehicle speed to about 40 miles per hour. "That's the key," she said. "Slow it down so the car can react in time and get everything correct."

Simulation vs. public roads testing

AV companies proudly report the number of miles—sometimes in the millions—that test vehicles travel on public roads. More miles, it has been assumed, means giving AV algorithms more opportunities to learn about roadway behavior. At the same, logging a lot of miles allows engineers to better understand challenging conditions that force autonomous systems to disengage.

However, panelists at the summit questioned the value of prematurely placing self-driving cars on public roads, only to study how they fail. "Disengagement reports really don't mean anything," said Danny Shapiro, senior director of automotive at Nvidia. "When you're testing in the real world, the safety driver takes over and never gives the system a chance to determine what it would actually do to prevent that accident." Shapiro instead advocated that companies use extensive simulation to study dangerous scenarios with numerous random factors such as time of day and weather.

Colm Boran, senior manager of AV system engineering and safety at Ford, agreed. "There's a lot of work to be done in a simulation environment" to ensure that the AV's software is "vetted and tested in lots of scenarios first." Boran said that simulation should be followed by similarly rigorous testing on closed test tracks.

"After we've become satisfied with that, then we put them on public roads," he said.

Empowering safety drivers

Chris Urmson, co-founder and chief executive of Aurora, shared some of his company's safety strategies—starting with the critical role played by vehicle safety operators behind the wheel. In the event's opening keynote speech, Urmson said that Aurora's operators are employees rather than contactors.

"We want them to have an ownership stake in the outcome of what we build," he said. Furthermore, Aurora's safety operators are aggressively screened and then put through a six-week training process.

"Safety is not one of the things that you bolt on at the end of a process," he said. "It's something that you have to be thinking about throughout the process."

For Aurora, that means giving all employees the power to ground vehicles. "When they see something that's not quite right, let's bring everything back, shut it down, and understand how we can do better."

SAE International recently updated J3018, which provides AV testing guidelines. The new rules stipulate the required skills needed for testing prototypes at various stages of development, how long a test driver can work without a break, and how to ensure that the safety driver maintains attention. ■

UPCOMING FROM THE EDITORS

January: Autonomous Vehicle Engineering
Print Magazine
- AV Interior Tech & Materials
- Radar, LiDAR, Cameras
- Software & Processors
- Testing & Simulation

January/February: Automotive Engineering
Print Magazine
- Special coverage: CES '20
- Technologies for SAE Level 3 Automated Driving
- Propulsion: ICE, Hybrids, EVs
- Product Spotlight: Power Electronics & On-board Processors

January 13: Automotive Engineering Technology eNewsletter

January 23: Autonomous Vehicle Engineering Technology eNewsletter

February: Truck & Off-Highway Engineering
Print Magazine
- Special coverage: Engines & Subsystems: Internal-Combustion Engine Advances & CONEXPO-CON/AGG Preview
- Hydraulics/Electric Actuation: Fluid Power & Motion Control & Vehicle Testing
- Cybersecurity
- Product Spotlight: CONEXPO Preview, Imaging/Cameras & Simulation/Analysis Software

February 5: Automotive Engineering Technology eNewsletter

February 10 : Truck & Off-Highway Engineering Technology eNewsletter

February 12: Autonomous Vehicle Engineering Technology eNewsletter

February 19: Vehicle Engineering Technology eNewsletter

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