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ENGINEERING

Volvo's Sensor Sweet

A Luminar lidar in the new EX90 enhances automated driving and safety

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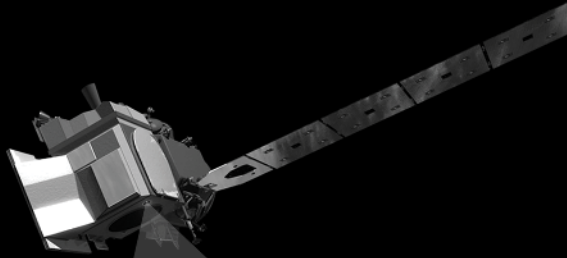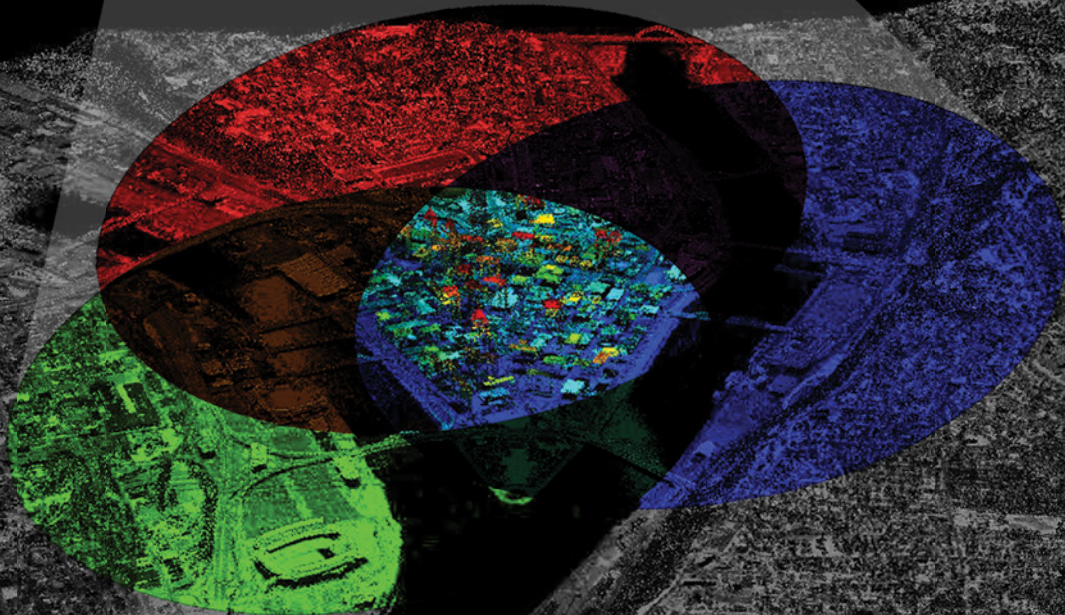**Cabin Material and Sensor Trends**

AV & ADAS Future Outlook

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Contents

Volvo's 2024 EX90 electric vehicle comes to market with Luminar's advanced Iris lidar. It uses pulsed, time of flight (ToF) target illumination for an exceptionally fast measurement rate, an immediate understanding of reflectance and no speed-dependent range error. Iris and other sensors equip the EX90 to one day be ready for SAE Level 4 driving automation, the company said. (Volvo Cars)

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Editorial

As Argo taps out, the AV industry resets

I can't get the Rolling Stones' lamenting yet confident lyrics to "Time Is on My Side," out of my head when thinking about once-promising Argo AI folding in November (the announcement came just after this magazine's previous issue went to press). In the end, time wasn't on Argo's side.

Some say that Argo is the high-profile canary in the coal mine that proves SAE Level 4 driving, at least for personal vehicles, is a fool's pursuit. Others claim Argo's demise merely demonstrates that AV-industry consolidation was, and remains, inevitable.

I spoke with Edward Straub, director of SAE International's Office of Automation who maintains that from the start, there's been "misalignment" between the expectations for automated driving and the realities of what's possible and probable. "Driving is a social endeavor. It's not just about solving an engineering problem," he said. Factor in the hype that came with the need to raise immense amounts of capital (some $75 billion has been invested in AV development, reported Bloomberg) and you get a recipe bound to include a lot of failure.

Despite what investors and the public were told, "The use case was never going to be: Get in, press a button, take me anywhere," Straub asserted. "There were always going to be constraints."

Expect the industry's level-set to be all over the map. As you'll read in our piece on page 16, analysts don't see any magic bullets. A robust business case might be many years away.

The attention and the investment already are shifting to commercial-vehicle business models. GM's Cruise and Alphabet's Waymo have ratcheted-up their "still in the game" profiles. Cruise revealed plans to expand its (truly) driverless taxi service to Austin and Phoenix by the end of 2022 and CEO Kyle Vogt vowed the company would surpass $1 billion in revenue by 2025. Not to be forgotten is Motional, the AV-development joint-venture between Hyundai and Aptiv: Uber and Lyft said they intend to bring Hyundai-based robotaxis to a number of cities in 2023.

One factor seems clear: the automakers are out. Ford CEO Jim Farley said it plainly: let others shoulder the burden of developing automation. This is how it's played out for decades in the OEM-supplier relationship: Automakers increasingly become technology integrators, final-assemblers and marketers of the end product.

If Level 4 automation is to succeed, it will be in the same crucible as most other automotive technologies. Value must overcome added cost. Automation's value case has yet to be proven. But that's not to say it won't.

SAE's Straub said the industry needs to focus on a clear description of "operating domains and use cases." It also needs an element of standardization to commonize types of automated vehicles, he noted. A level of abstraction the entire industry can rally around, to say, "Look, these are the criteria that need to be met to get out there [in the market]."

Time is on nobody's side in the AV world. Argo couldn't outpace its cash burn. Others will meet similar fate. A refocus to commercial applications and operating domains seems to be the logical move.

Bill Visnic, Editorial Director

After months of planning, we've updated this magazine's title to ADAS & Autonomous Vehicle Engineering *to better reflect the industry's evolving development directions. — BV*

2022 a mixed bag for the AV sector

The second half of 2022 turned out to be a mixed bag for the automated-driving sector. The capital that was flowing so freely from the mid-2010s onward has largely dried up and the long-expected consolidation in the sector seems to have begun. One of the leaders in the segment surprised the industry when it announced that it was shutting down. Others have reduced their operations.

For the last decade, investors around the world have willingly thrown mountains of cash at AV startups that produce no revenue and show little prospect of near-term profits. Those investors suddenly have turned off the taps. As a result, dozens of companies, including Aurora Innovation, TuSimple and Luminar, all of which went public prematurely in 2020 and 2021, have seen their valuations collapse by 80-90% or more in the past year.

Meanwhile, others like Mobileye and Argo AI waited longer and missed the window of opportunity to cash in, as the overall stock market declined and interest rates increased. Both companies had plans to go public in 2022 but only Mobileye did — and at a fraction of the originally expected valuation. When Intel announced plans for a Mobileye public offering in December 2021, it was targeting a valuation of $50 billion to help raise funds for new chip foundries. By the time of the IPO in October 2022, the valuation was about $16 billion, barely more than Intel paid for Mobileye in 2017.

Unlike virtually all companies in the automated-driving sector, Mobileye was at least profitable thanks to its driver-assistance business, where it is still the dominant player in vision systems. Argo AI, which was 80% owned by Ford and Volkswagen, didn't make it that far. The Pittsburgh-based startup was just beginning to pilot public robotaxi services in Miami, Florida and Austin, Texas. It needed to raise significant capital to scale its operations as it approached commercialization.

Ford had already decided that a profitable robotaxi and delivery business was too far down the road amid the need to invest $50 billion in vehicle electrification in the near term. Volkswagen decided that China, where Argo had no presence, was a better opportunity and formed a joint venture there with Horizon Robotics.

With extremely limited revenue, prospects for a 2022 IPO were extremely poor and Argo instead hunted for new private investors. Bloomberg reported that a potential deal for Amazon to invest in Argo collapsed when Ford and VW couldn't reach an agreement on governance of the company with Amazon involved. Rather than go forward, the decision instead was made to shutter Argo.

While other AV companies such as Nuro are cutting staff to save money, the news isn't all bad. Cruise launched driverless robotaxi services in San Francisco in June 2022 and by December was running more than 100 driverless vehicles concurrently. The GM-backed company announced plans to add driverless public service in Austin and Phoenix, Arizona, by the end of 2022 and add operations in more cities in 2023.

Waymo also is conducting driverless tests in San Francisco and announced plans to do the same in Los Angeles. Motional is cutting some staff, but announced its intent to add robotaxi services in Los Angeles as part of a multi-city driverless service launch in 2023.

Going forward, we'll likely see a smaller but hopefully more stable AV sector as it slowly gains traction through the remainder of the decade. ■

> **Going forward we'll likely see a smaller but hopefully more stable AV sector.**

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Volvo's New
Sensor Sweet

by Lawrence Ulrich

A Luminar Iris lidar in the 2024 EX90 is engineered to enhance both automated driving and safety.

Consumer skepticism over autonomous vehicles is running rampant, thanks largely to Tesla's broken-record promises to make "Full Self Driving" a reality – along with high-profile accidents, fatalities and a federal investigation of its Autopilot system. Tesla and other automakers also continue a public spat over the best technical or social solutions. And with everyone from General Motors to Mercedes-Benz struggling to leap beyond SAE-defined Level 2 driver-assistance, Volvo has apparently had enough.

With safety as its brand-defining hallmark, the Swedish OEM threw down a gauntlet at the Stockholm unveiling of its electric EX90 SUV: In Volvo's contrarian

From any angle, the lidar blister above the Volvo EX90's windshield is barely visible.

Volvo

view, there is no need to pursue hands-free Level 2 systems such as GM's Super Cruise, which still expect drivers to watch the road and retake control at a moment's notice. To Volvo, driving will be either supervised or unsupervised. The space in between is a potentially unsafe limbo, at least for now.

To that end, Volvo executives said their flagship EX90 will go on sale in 2024 with all the hardware required for fully unsupervised (SAE Level 4) driving. The system's linchpin is the first rooftop-mounted lidar unit on an international-market passenger vehicle, developed by the Florida-based Luminar. Known as Iris, the full-stack system is considered semi-solid-state, its scanning mode using larger "macro" scanning mirrors rather than MEMS' micro mirrors. Iris's light source is a 1550-nm fiber laser, the longer wavelength (vs. more typical 905-nm shorter-wavelength lasers) being harmless to the human eye. The lidar's receiver uses indium gallium arsenide (InGaAs) microchip technology rather than silicon. Claimed resolution is greater than 300 points per square degree.

The Iris uses pulsed, time of flight (ToF) target illumination that Luminar engineers claim delivers an exceptionally fast measurement rate, an immediate understanding of reflectance, and no speed-dependent range error. Iris scans a vehicle's surroundings in real time, firing millions of laser pulses to create a virtual 3D map, with no need for GPS or a cellular connection. The lidar itself has a 120° field of view (FoV) and a 26° dynamic vertical FoV. It's part of a 30-sensor array – including 16 ultrasonic sensors, five

Exploded view of the EX90's Luminar Iris lidar and its InGaAs receiver chip (above) – designed for optimum sensitivity and dynamic range when paired with the company's receiver ASIC

Luminar (vertical label)

Luminar claims it has steadily reduced OEMs' cost (at volume) for the Iris system to the $500-to-$1,000 range. A significant cost reduction came from a mixed-signal ASIC (application-specific integrated circuit) developed in-house that delivers higher performance than complex ADC (analog-to-digital converter) chips, according to the company.

radars and eight cameras – to deliver 360-degree views around the electric SUV.

A camera in the EX90's interior handles driver monitoring. It uses artificial intelligence (AI) that can detect not only driver inattention, but also driver intoxication or medical impairment. The camera works in conjunction with a cabin-focused onboard radar capable of detecting the breathing of occupants, from a strapped-in infant to a slumbering pet, to ensure nobody is accidentally left behind.

Lidar's detection benefits

Elon Musk has been lidar's most-famous skeptic, branding it as a "crutch" and a "fool's errand." But Musk now stands nearly alone among automakers and automated-driving tech experts who see a profusion of redundant onboard sensors as a good thing.

The cameras Tesla relies on almost exclusively can struggle in darkness, poor weather or blinding light, especially when trying to make sense of broad surfaces, noted Matthew Weed, Ph.D, an optical scientist, engineer and product director at Luminar. Imagine staring at a featureless wall, where only the edges stand out, he offered.

In contrast, the Luminar Iris can detect and classify objects to a maximum range of 600 meters (1969 ft.), even at night. It can spot a pedestrian or animal darting across the road at up to 250 m (820 ft.). It can "see" an errant tire in the road, or other small objects, at up to 120 m (394 ft.). And where the acuity of laser-based vision systems typically degrades

through snow or rain, the Iris technology does so very gradually, Weed told SAE Media.

"You might lose some light energy when lidar hits snowflakes, but you still get enough back to get a useful, fundamentally 3D image," he explained. If radar sensors struggle to definitively acquire an object ahead, or bird poop fouls a camera lens, lidar remains a trusty backstop.

"Even if you then lose the lidar, you've still stored the last few frames of environmental info," Weed noted. "You still know the few hundred meters in front of you and can make reasonable assumptions of where and where not to operate."

To a software integrator, lidar "lets you take steps of responsibility that other automakers haven't yet road-mapped," he asserted.

Integration solutions

Ödgärd Andersson, CEO of the Volvo-owned autonomous software company Zenseact, said the redundancy engineered into the EX90's perception system will help future Volvos solve tricky "edge cases" and make real-time decisions without such glitches as phantom braking.

"You have to have enough confident data to be able to act on it," she said. "We can now see in scenarios that are very difficult for humans, including nighttime when there are statistically far more accidents."

Based on its voluminous, half-century-old database of real-world accidents, Volvo confidently asserts that the lidar-based sensor suite – in tandem with new core computing and software – will reduce

> *We see the lidar as a symbol of 21st century automotive safety, like our three-point seatbelt was in the 20th century.*

The 1550-nm Luminar Iris as integrated into the 2024 Volvo EX90 can detect and classify objects to a maximum range of 600 meters.

Volvo

serious-injury accidents by up to 20% and eliminate one in 10 accidents overall.

Until recently, the public face of lidar was the large, "spinning chicken bucket" electromechanical rooftop systems on robotaxis from startups such as Google's Waymo. While these older systems, with their stacked arrays, still are widely employed in vehicles used for mapping and testing, advances from Luminar and others in creating simpler, lower-cost systems (the Iris's 2-axis scanner spins only the laser rather than spinning the whole lidar device) are defying predictions that lidar would remain too expensive, bulky or complicated for production vehicles.

That doesn't mean the EX90 integration was a breeze, noted T. Jon Mayer, who heads up Volvo's California design center. When Volvo first saw the Luminar Iris lidar, "We thought, 'Where are we going to hide this thing'?" Mayer says of a unit measuring nearly 18 inches (457 mm) tall and wide.

Mayer's design team and Volvo engineers considered squeezing the lidar into the EX90's grille, but quickly dismissed that idea. "All you'd see is the car in front of you, but we wanted to see 250 meters, day or night," Mayer asserted, applying the analogy of animals whose eyes are universally up high: "You don't see an animal walking with its eyes at its knees, whether it's a lizard or a giraffe."

So, the lidar is elegantly integrated into the EX90's front roofline, where it resembles a small hood scoop shielded by a transparent cover. The teardrop-shaped

unit is sculpted to allow airflow to pass over and reattach to the roof, creating as little turbulence as possible in this wind-cheating electric SUV. Water nozzles at the end of the EX90's windshield wipers cleverly clean the lidar protective screen as they sweep near the roof. Two other nozzles clean side-facing fish-eye cameras embedded in exterior mirrors to greatly expand views through intersections.

"We see the lidar as a symbol of 21st century automotive safety, like our three-point seatbelt was in the 20th century," Mayer said. That relative bird's-eye view brings a more-subtle advantage, Weed noted: A higher angle-of-incidence makes it much easier to measure and make sense of the roadway.

"The lower to the ground you are, the less far you can detect the road and lane markers. Mounted on a tall truck, we can see for days," he said.

Sweden's Volvo, owned by Geely Holdings of China, will integrate the roof-mounted sensor on other models built on its SPA2 platform, including the South Carolina-built Polestar 3 from Volvo's new EV division. Luminar's tech already is going into a Chinese model from SAIC and should see light of day on both upcoming Mercedes-Benz models and Nissans built on a new EV platform.

Weed confirmed Luminar has steadily cut automakers' cost for the Iris system to about the $500-to-$1,000 range. A significant cost reduction came from a mixed-signal ASIC (application-specific integrated circuit) developed in-house that delivers higher

Ödgärd Andersson, CEO of the Volvo-owned autonomous software company Zenseact.

Volvo

performance than complex ADC (analog-to-digital converter) chips, he noted.

'Diamonds of data'

Powerful Nvidia-based core computing is another key to the EX90's performance. Andersson said it will use machine learning and collect data to help Volvo understand and refine operating behavior. The "diamonds of data" that Volvos collect will go into driving simulations to improve performance in tricky real-world scenarios, with Tesla-like improvements delivered via over-the-air (OTA) updates.

While GM, BMW, Mercedes-Benz and others have been rolling out hands-free systems featuring increasing sophistication, Volvo argues those systems have no proven safety benefit. Those Level 2 and 3 driver-assistance systems may even detract from safety, by lulling drivers into inattention or a false sense of security. Where GM touts its Super Cruise as strictly a convenience feature for now – avoiding any real claims for accident or injury reduction – Volvo insists it will never roll out semi-autonomous or autonomous functions until it has hard data showing accident reductions or other safety benefits.

"We fundamentally believe autonomous driving can and will be a safety gain," asserted Lotta Jakobsson, senior technician for injury prevention.

The EX90's hardware and software still will support Advanced Driver Assistance Systems (ADAS) that dovetail with commonly understood Level 2 functions such as automated emergency braking, pedestrian/cyclist detection and adaptive cruise controls. The new sensors will improve the reliability and performance of Volvo's assisted-driving Pilot Assist system, including new steering support during lane changes.

Henrik Green, Volvo's head of advanced technology and sustainability, underlined that his company will take its usual conservative approach to rolling out unsupervised driving via OTA software updates, likely beginning with limited use on geofenced highways. Green acknowledged Volvo has been slower than some rivals in bringing semi-autonomous functions to market. But the company must stay true to its values, he asserted.

"Safety comes before being fast," Green said. ■

Inner **Visions**

by Bill Visnic

Automated-driving and ADAS functionalities continue to influence some of the latest cabin safety and materials trends.

Evolving market realities have OEMs and automated-driving system developers adjusting once-aggressive timelines for deploying high-level driving automation. But new materials and safety technology for vehicle interiors continue to be influenced by advancing AV and ADAS functionalities. Regardless of how much driving automation is at play, vehicle cabins are evolving because of the possibilities – and challenges – automation and ADAS present.

An array of launching or soon-to-arrive safety features, driver-information technology and materials innovations don't need AV applications as a reason for being, however. Drew Winter, Informa Tech Automotive's principal analyst – *Cockpit of the Future*, said that some of the feature and safety requirements of electric-vehicle and younger-demographic

Continental's Cockpit Vision 2025 concept.

customers align with the technology directions for AVs and ADAS. New sustainable upholstery choices are a feature many current EV and young buyers desire, for example. Those same types of materials may also better address the durability and serviceability needs of automated shuttles and robotaxis.

Visions for the direction of new-generation vehicle cabins have changed in the past five years, Winter asserted in a new research report, *The Cockpit of the Future: Now to After 2030*. "Possibilities for L4 and L5 autonomy in personal cars have dimmed steadily," Winter said in the report. Many advanced safety and materials technologies and features conceived for fully-automated and assisted driving nonetheless are coming to even relatively conventional vehicles, he added. And discussions with many suppliers related to these features reinforce that reality.

"A few of the [advanced cabin] technologies we think are critical are the evolution of the next-generation seatbelt and a true push to try to solve the alcohol-driving problem," said Len Cech, executive director, Safety Innovation, at Joyson Safety Systems. Technology already under development for AV-related purposes will in many senses prove directly applicable to these and other use cases.

Driver monitoring moves ahead

Expanding availability of "hands-off" ADAS such as GM's Super Cruise and Ford's Blue Cruise is increasing the focus on driver-monitoring technology to assure drivers don't abuse their newfound freedom by excessively averting attention from the road. Current driver-monitoring systems (DMS) typically are camera-based with software to help assess attention levels. But
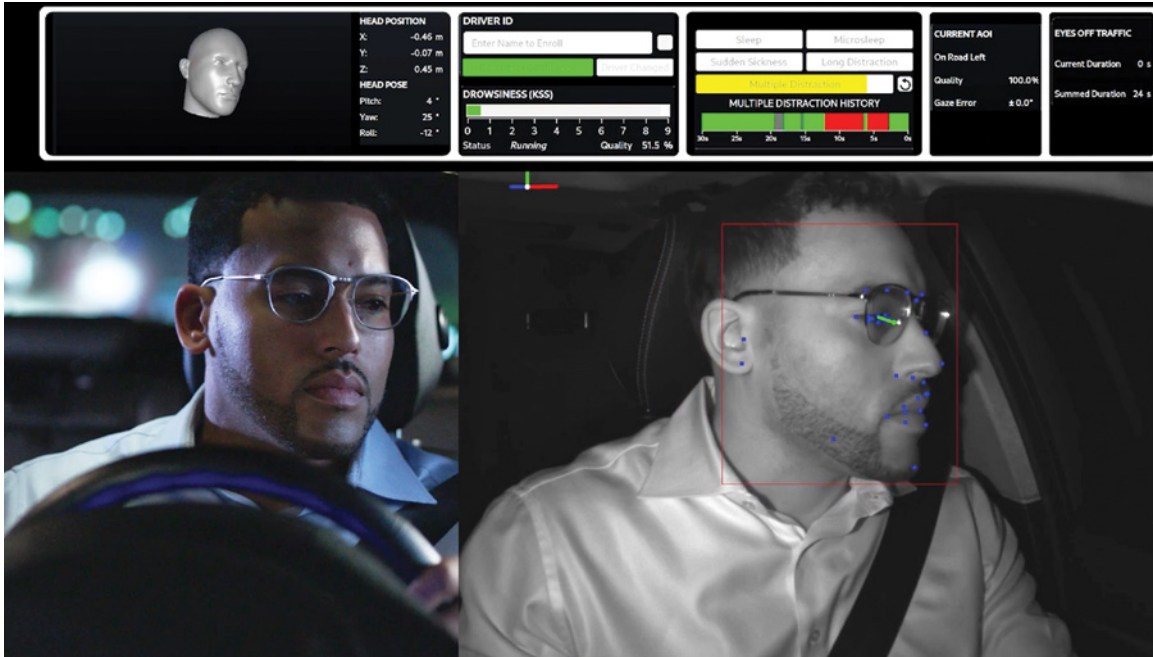
Gentex driver-monitoring system.
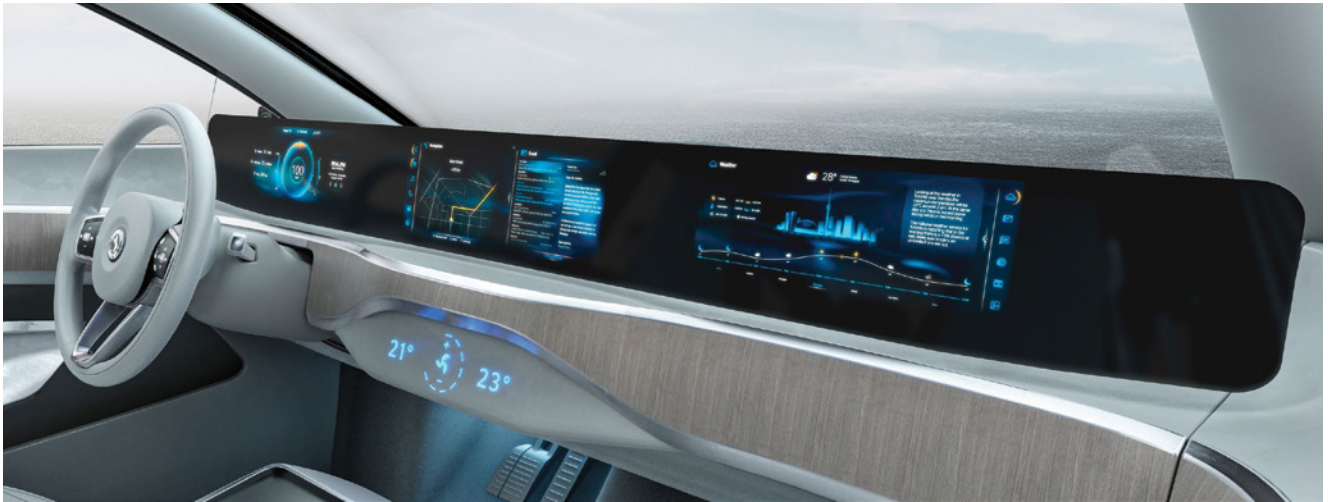
Continental's cabin-spanning display incorporates distraction-reducing technology, and a smart-surface material that engages a display only when required.

things are poised to get a lot more sophisticated, said several cabin-tech suppliers.

Brian Brackenbury, director, product line management at Gentex Corp., a key supplier of cabin technology widely known for its electrochromic rearview mirrors and Homelink connectivity system, said the company currently supplies 2D driver-monitoring via a camera housed in the rearview mirror. But the next evolution, he said, is 3D vision merging camera

imaging with a near-infrared dot projector "that will allow us to do 3D facial ID."

The 3D vision enables a more-sophisticated understanding of the driver's (and potentially other occupants') attention and actions. The technical competency largely comes via Gentex's acquisition of Israel-based Guardian Optical in 2021.

There is a range of features 3D functionality will bring to cabins, said Joyson engineers, some of

As a concept at CES 2020, BMW's ZeroG Lounger foresaw flexible seating arrangements that robotaxis, AVs and assisted-driving potentially enable, while also demonstrating the possibilities for properly restraining occupants who are seated unconventionally.
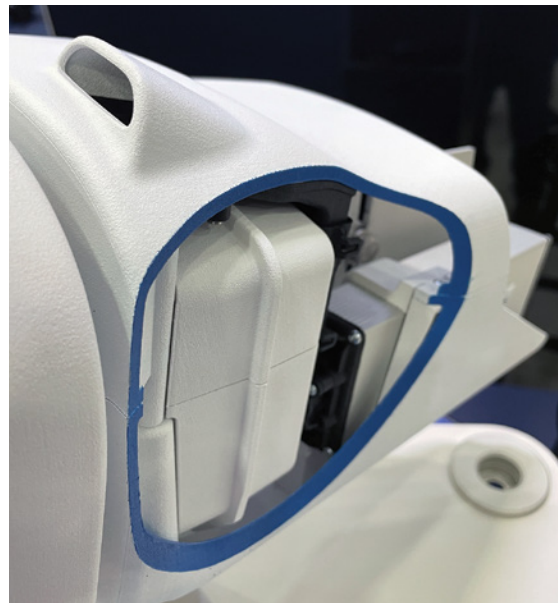
Steering-column mock-up showing Asahi Kasei's concept for integrating a breath-sensing driver-impairment monitor; intake is the nacelle atop the column.

which are particularly targeted at automated vehicles. These include proximity to deployable restraints or surfaces, smoking vapor detection, occupant posture and seatbelt positioning.

For enhanced driver/occupant monitoring, "You need high fidelity," agreed Joyson's Cech. "We think 3D provides that." Joyson also is working on a DMS/occupant-monitoring system leveraging infrared capabilities – "Kind of radar and vision tied together," he said. However, "there's still a fair amount of work to do before it reaches production," probably sometime around 2027, added Jason Lisseman, Joyson's VP, Integrated Safety Solutions GPL.

Gentex also is developing an iris-recognition system, said CTO Neil Boehm. "That technology isn't quite ready for the automotive space," he said, adding that cameras backed by increasing degrees of artificial intelligence and neural networks currently are the company's favored approach. Although there are differing regulations in various world markets, Boehm said his company is prepping for driver monitoring to essentially be required globally in all new vehicles approximately by the 2026 model year.

Meanwhile, Volvo thinks current driver monitoring has room for improvement – via better understanding of a driver's cognitive state. For the DMS of its new EX90 crossover EV (see page 4), the company employed naturalistic driving research to create algorithms that

"understand" the driver's attention level. The system's real goal: to be less intrusive and more forgiving before it questions the driver's attentiveness.

But there's another task DMS will be asked to tackle: pending rulemaking from the NHTSA to require a system to detect driver impairment, whether alcohol- or drug-related. The federal infrastructure bill of 2021 directed the NHTSA to develop a final rule by 2024 that requires all new passenger vehicles to be fitted with a system to detect driver impairment. Automakers then would have two or three years to begin installing the system as standard equipment. But there currently is no consensus on which type of technology can or should be used. Most development is directed at breath detection or a spectroscopic (touch-based) approach, but vision-based methods also may be viable.

"Vision (impairment detection) is one interesting way," claimed Gentex's Brackenbury. But he said there is considerable work remaining on determining accuracy and repeatability standards, regardless of the chosen technology. Meanwhile, breath-detection is "flawed," said Lisseman. "Our view is that you can do that through touch. We feel that spectroscopy is evolving and it's becoming quite feasible." He said MEMS-based systems hold promise for the touch-based approach for the requirement that he thinks will "take hold" in perhaps 2026-27.

Supplier Asahi Kasei, which specializes in filtration

> *As long as AVs have to share the road with non-autonomous vehicles, there will be seatbelts.*

Joyson

Joyson envisions motorized seatbelt retractors as central to ensuring occupants are properly restrained in unconventional seating arrangements.

Joyson

Head and torso protection from Joyson's BARS belt-integrated airbag.

media and electronics among other automotive technologies, in early 2021 displayed both breath- and touch-based impairment-detection systems. Michael Franchy, director of North American Mobility at Asahi Kasei America, told SAE Media that the company was collaborating with the Virginia-based Driver Alcohol Detection System for Safety (DADSS) research program. Volvo, on its 2024 EX90, is among the first OEMs to deploy cabin sensors to monitor potential driver intoxication.

Best seats in the house

Flexible and adaptable seating arrangements are another cabin innovation set to gain momentum, said Informa Tech's Winter. At first, new seating arrangements and designs "probably will be for commercial-type applications," he noted, such as shuttles (driven or driverless) and robotaxis.

The challenge, Joyson engineers explained, is to ensure the same or better levels of occupant safety than regulated today. The company is developing a spectrum of solutions for what it also sees as an inevitable trend. These include its Belt Attached Restrain Supplement (BARS), a seatbelt-mounted, head and torso cocooning airbag designed specifically for "new interior concepts" with non-traditional seating possibilities. The BARS

airbag, working in conjunction with the company's new digital motorized seatbelt (DMS), is intended to protect occupants not only in an unconventionally placed seat, but also if in a deeply reclined posture, the engineers noted.

This BARS airbag and DMS seatbelt ideally would be adaptively deployed according to what a cabin-monitoring system indicated about all occupants' positioning. Joyson's Len Cech stressed that this safety hardware, however, requires crash-testing regulations that address freedom-of-position seating.

Informa Tech's Winter said flexible seating is one of three or four AV-inspired cabin features that's definitely on the horizon. But none of it will happen without the appropriate safety enablers. "Cars are always going to have seatbelts," he insisted. "As long as AVs have to share the road with non-autonomous vehicles, there will be seatbelts."

Screening for safety

For those who believe display screens have taken over our lives, there's bad news: expect more of them. Measurement soon may come by the square foot. And expanding assisted-driving capabilities will offer more likelihood for all occupants to be engaged with in-cabin displays.

Most In-Demand Features for Smart Materials

(Bar chart showing percentages)
- Electrical conductivity
- Softness
- Dead front (Hidden until backlit)
- Integrating biometric monitoring features
- Color/pattern variation
- Anti-microbial surface treatment
- Surface cleanability
- Heated/cooled surfaces
- Ambient lighting through material
- Capacitive controls (hidden touch-...

0% 10% 20% 30% 40% 50%
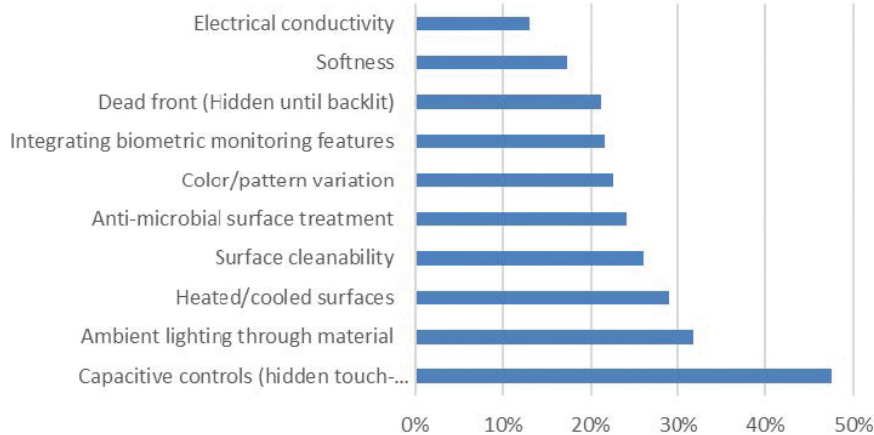
Research by Informa Tech/Ward's Intelligence indicates most-desired attributes for "smart" cabin materials.

Ward's Intelligence

For the increasing number of buyers eschewing leather, Volvo's new EX90 electric SUV offers sustainably produced wool-blend seat upholstery, as well as Nordico, its own textile made from a blend of recycled materials.

Volvo

Informa Tech research shows screens per vehicle proliferating through at least 2028. But with the goal of mitigating distraction, displays are becoming smarter. Continental's Switchable Privacy Display and ShyTech technology show the way: Although both unashamedly boast A-pillar to A-pillar coverage, they use technology that in many instances activates the display only when required. The Switchable Privacy Display uses a variation of the concept, angling potentially distracting images or content such that it only can be viewed by the front-seat passenger.

Consumers overwhelmingly indicate they want more – and larger – screens, but the newest technology almost paradoxically aims to tone it all down. "The idea that you can turn off some of this distraction is a big deal" for the future of in-cabin displays, said Winter.

Motivating materials

The industry is well underway with efforts to improve the recyclability of cabin materials, particularly seat fabric and foam, which account for the bulk of a vehicle's non-recyclable content. Automakers and suppliers have heard the customer voice regarding more sustainable materials for inside the vehicle.

Winter said Volvo is proving to be one of the most assertive automakers in introducing sustainable materials, with Rivian and BMW also breaking new ground. BMW's all-new iX EV uses sustainably-grown wood and "a high proportion of recycled plastics in the surfaces of the door panels, seats, center console and floor coverings, plus floor mats made from recycled nylon waste material," the company claims. Volvo's new EX90, mentioned above, also boasts a variety of sustainable cabin materials. Continental recently introduced its Benova Eco Protect, a robust but premium soft-touch material with a low VOC profile and a low carbon footprint – that also happens to be 20% lighter than comparable conventional materials.

Winter said that some of the knowledge gained from applying new alternative and sustainable materials will transfer to commercially operating AVs such as roboshuttles and rideshare vehicles, where durability and ease of cleaning are paramount concerns. "First it was just a COVID response," he said, "but people are just more germ-conscious now." ■

The Olfactory Factor
in AV Interiors

Aryballe Technology's unique sensors-on-a-chip solution aims to end the subjectivity of the human nose while neutralizing vehicle cabin odors.

by Lindsay Brooke

Whether they're riding in an autonomous shuttle, a transit bus, a train or a rental car, passengers often face cabin air full of "mal odors" – bad smells – including cigarette and vape smoke, pungent food, blatant lack of personal hygiene and worse. Where the off-gassing of plastics and leather in new vehicles had been a minor issue in the past, the olfactory (science of smells) experience is increasingly a key differentiator in rider satisfaction as new mobility solutions emerge.

Ensuring a neutral-smelling passenger space is a growing focus of fleet owners and managers, particularly as autonomy becomes established in the commercial-transportation sector. Looking to a future of driverless shuttles, OEMs in the field (i.e., Cruise Automation, Waymo, Navya, Transdev, EasyMile and a host of players in China) are investigating olfaction-based sensing and notification technologies for integration into their AVs.

"Fleet owners want their vehicles to be truly autonomous in terms of the comfort of the experience," noted Terri Jordan, executive VP of global business development at Aryballe Technologies, a Grenoble, France-based digital olfaction company founded in 2018. Aryballe's sensor technology uses

Cruise Automation

The smell of public-transportation vehicle interiors, such as the Cruise Origin roboshuttle cabin shown here, is a key factor in customer satisfaction.

> ## "We can build a 'library of smells' for customers."
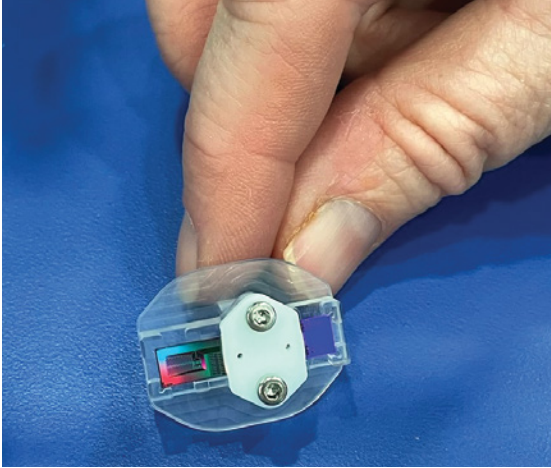
A prototype of Aryballe's olfaction sensor, shown at the 2022 SAE WCX.

Lindsay Brooke

biochemical sensors, optics and machine learning to detect odor and turn it into data. "We're taking the human being out of the cabin cleaning decision," added Jordan, who holds a Ph.D in polymer physics and also serves as president of the company's U.S. enterprise, based in Albany, NY.

Humans can sense an average of 1 trillion odors, Jordan said, but in most cases our noses cannot distinguish between them. Jordan explained that unlike color and sound, smell does not inhabit a clear spectrum, so comparing various odors is highly subjective. Aryballe's sensor tech was originally developed for the "flavor and fragrances" industries (i.e., food/beverage and personal care/cosmetics). It evaluates the characteristics of individual scent molecules and compares them against a database of known smells using a combination of biochemistry, advanced optics and machine learning.

Its first commercial product, the NeOse Pro, is a handheld sensing tool aimed at field use. Launched at CES 2018, NeOse Pro (get it?) surprised Jordan and her team by attracting the interest of automotive OEMs and suppliers. "Their positive reaction meant that we had a new and potentially huge market," she said.

Standards vs. subjectivity

In a 2021 SAE Technical Paper (*Use of Digital Olfaction to Standardize Cabin Odor Testing in Automotive Interiors,* 2021-01-0297), Aryballe scientists and engineers note that subjectivity in olfactory testing for automotive validation processes is typically a sticking point for OEMs and suppliers. For vehicle interiors, in addition to laboratory testing, human panels of "trained noses" are used to judge the smell of different components and the completed vehicle. Jordan noted that the industry lacks standardization in this area: each OEM has its own testing specifications, rating scales and methodologies.

There also are various global specs issued by SAE, ISO and VDA. The resulting overall situation regarding olfactory standards can result in more variation in lab testing, protracted development times and higher cost. "It's definitely a factor that's hindering more rapid adoption of autonomous commercial vehicles," Jordan observed.

To help solve this logjam, Aryballe in 2019 launched the DOAC – the Digital Olfaction Automotive Consortium. DOAC members include Hyundai, Denso and Asahi Kasei, along with IFF, a stalwart in the flavors and fragrances industries. The consortium's mission is to address industry trends related to AVs and new mobility services. Together, Aryballe and the consortium's founding members will establish standards for measuring and categorizing odor in the auto industry and inform olfaction product development and services.

In addition to setting standards, the DOAC is collaborating to create an accessible reference database for odors. It's also helping to evaluate prototype sensors, proof-of-concept initiatives and new versions of analytic software from Aryballe Technologies.

Aryballe also is involved with SAE's J3263 task force that is focused on VOCs, specifically using digital olfaction methods to measure odor from materials, parts and assemblies used in automotive cabins. The task force includes plastics suppliers SABIC and Asahi Kasei as well as seat fabric suppliers.

A bio-sensing breakthrough

Aryballe's bio-sensing technology was innovated at CEA, the French government research lab. The biosensors are peptides – short strings of amino acids, considered the "building blocks" of proteins. The human nose has roughly 400 different olfactory receptors that sense those peptides that have an affinity or reactiveness to the gases – the smells – that flow over them. Those fluidics bring

the smells into our nose; the brain, in turn, interprets the pattern from these inputs and determines that the smell is strawberries, or a day-old tuna sandwich, for example.

"We graft the peptides onto a slicken surface using a chemical process. With this, the sensor we've created recognizes a pattern based on interferometry, which is much more cost-effective and scalable than the previous SPR [surface plasmon resonance) reflective technology we were using in early development," Jordan explained. "So, it's not doing chemical analysis; it's doing pattern recognition and turning the pattern into the equivalent of a picture. We then store that picture as a 'fingerprint' in a digital library for recall."

Aryballe uses proprietary machine learning to "teach" the device as more and more odors are encountered and captured. Jordan said the Aryballe sensors are powerful and accurate. They're able to distinguish between different brands of cola, between cigarette smoke and marijuana smoke, or cigar smoke and smoldering seat fabric, for example, as well as the level of intensity of the smoke smell.

Aryballe is building the ontology, a portal, through which the vehicle cabin odor data collected by the sensor can be uploaded to the cloud, for almost real-time

Lindsay Brooke

Aryballe aims to "take the human being out of the vehicle-interior cleaning decision," noted EVP Terri Jordan.

access by fleet operators. Jordan said vehicle OEMs will create their own parameters for odor detection.

"We can build a 'library of smells' for them, or maybe they use a more generic cloud-based library." Once Aryballe and customers have validated the onboard sensor to automotive spec, "we want to be inside vehicles in three years," she said. ■

AV Life After **Argo AI**

by Lindsay Brooke

Every new industry sector goes through a consolidation process where the strongest survive, and so it is with automated and autonomous driving technologies.

The recent shuttering of Argo AI, one of the autonomous-vehicle industry's leading tech companies, by Ford and Volkswagen might come as a surprise to commuters in San Francisco and in Phoenix, Arizona. Those who regularly use the robotaxi services of GM-backed Cruise Automation and Alphabet's Waymo see these and other AVs under development during their daily travels. On public roads. Every day.

Indeed, Argo AI's demise (which insiders said was mainly due to friction among Ford and VW) and difficulties at other startups including AV pioneer Aurora, have highlighted the engineering challenges of safely achieving SAE Level 4 driving automation, while reinforcing AV critics. But as Guidehouse Insights' leading e-Mobility analyst Sam Abuelsamid notes in his Navigator column on page 3, the AV sector's leaders appear to be moving out ahead of the pack. Cruise has expanded its robotaxi service into Austin, Texas, with operations in more cities planned in 2023. The company's CEO Kyle Vogt claims Cruise will reach $1B in revenue by 2025. GM CEO Mary Barra is a believer.

Waymo is moving shuttle operations into Los Angeles after getting approval to operate without a safety driver in San Francisco. The company is co-developing a purpose-designed electric robotaxi with Geely-owned Zeekr. And Hyundai robotaxis are joining the
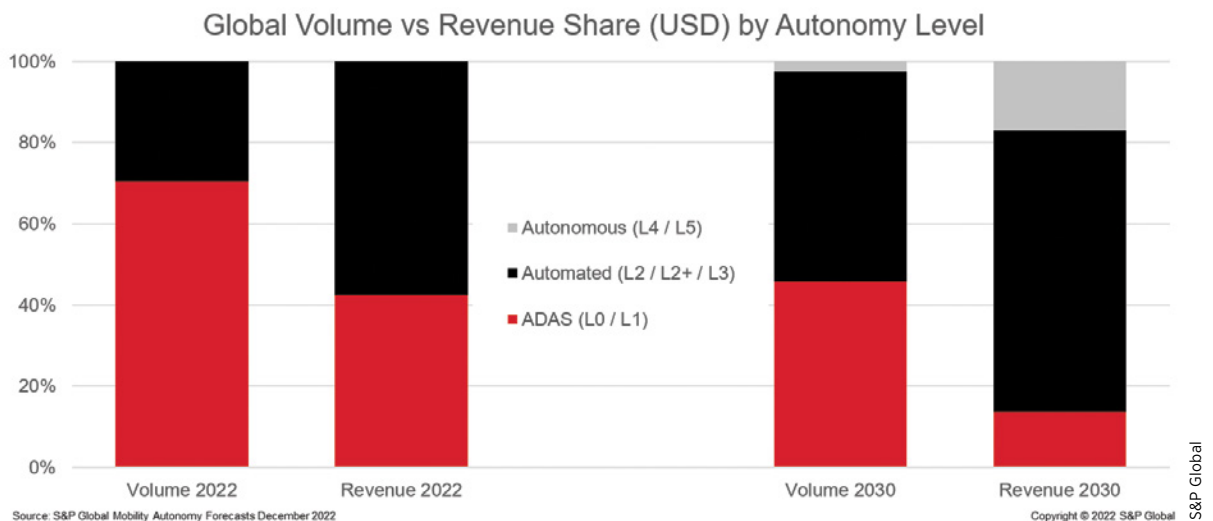
S&P Global's December 2022 AV market forecast data comparing the five levels of SAE driving automation.

ride-hailing fleets of Lyft and Uber, in partnership with AV tech startup Motional, starting in 2023.

Functionality advances

Meanwhile, ADAS technology continues to expand beyond the formal SAE Level 2 category. The enhanced (and unofficial) "Level 2-Plus" — the term was coined by supplier giant ZF — is the industry's hottest automated driving playing field, engineers tell SAE Media. While SAE Level 3 remains controversial, Honda recently said it is developing technology to enable its L3 system to function at any speed below legal limits on highways by the second half of the 2020s.

Honda in March 2021 became the first OEM to sell a vehicle with L3 capabilities, but only in its Japan home market. Likewise Audi, which did not homologate its L3 system, is forging ahead with enhanced ADAS.

The shift of AV development focus into commercial vehicles, and the parallel rise of super-enhanced ADAS, has "the market for radar, camera, lidar, and computing accelerating very fast," reported Pierrick Bouley, senior analyst at Yole Intelligence. In September 2022, he placed the market's compounded annual growth rate (CAGR) at 13.2%. "We see this market growing from $15.4 billion in 2022 to $28.6 billion in 2027," Bouley noted. A recent report by *Fortune Business Insights* pegged the global lidar market value to reach $6.71B by 2026, compared with $1.32B in 2018. Through the 2019-2026 forecast period, Fortune expects automotive lidar's CAGR to reach 22.7%.

SAE Media asked Jeremy Carlson, the Los Angeles-based associate director at industry analysts S&P Global who specializes in AV and ADAS technologies, for his view as Level 2-Plus and L3 systems development rushes ahead and AVs move to a commercial-vehicle play.

"The shift is not necessarily at the expense of autonomous Levels 4 and 5," he said. "Early on, the messaging from automakers indicated a fear of missing out on light-duty AVs — an "are the tech companies going to eat our lunch?' kind of mentality. They wanted to explore Level 4, but it's a pretty big upending of the business model to get into this mobility-as-a-service, fleet-centric model." The industry's concerns about such a profound

Waymo's latest roboshuttle will see expanded operations in 2023, the company promises.

change weren't based only on the cost and development time of the technology, but also the relationship with the customer.

"All of that has context in bringing in automated driving at Levels 2, L2-Plus and L3. It represents an advancement of functionality. It's also quite accessible to a lot of customers in terms of cost, and accessible to the automaker and suppliers in terms of investment and fewer redundancies required."

The further up the SAE Levels scale OEMs take their systems, the greater the technology and cost challenge. Carlson noted that many of the L2-Plus capabilities essentially are convenience features: "Customers are mostly happy to pay for them because they deliver tangible benefits."

While some sensor and hardware content, such as forward-looking cameras, radars, and some blind-spot radars, are approaching heavy penetration rates, suppliers continue to realize rising profits as the value per sensor increases, Carlson said.

And regarding the AV "stack," the growth of autonomy domain controllers is ongoing in Level 2 and L2-Plus, as engineers integrate ever-expanding sensor arrays. The domain-control architectures enable features such as vehicle path planning.

"They're making this area more vertically integrated. There is significant innovation in all these areas," he asserted. ■

Robotic ADAS Testing
Bridges the Sim Gap

by Chris Clonts

ASI's Swarming technology allows collision-avoidance and other tests at high speeds on vehicles that human drivers find hard to match.

A Utah company has developed a system to allow fully robotic testing of ADAS on production vehicles as one solution to the dangers of testing such systems with human drivers at high speeds and in real traffic.

At the 2022 Automotive Testing Expo in Novi, Mich., ASI Automotive Product Manager Jed Judd talked about the system, called Swarming, and its control software Mobius. He said the company's development is a response to OEMs finding that simulation testing alone isn't enough for advanced ADAS. He also said that even professional human drivers have difficulty executing different test scenarios accurately due to what he called "a significant pucker factor" at high speeds.
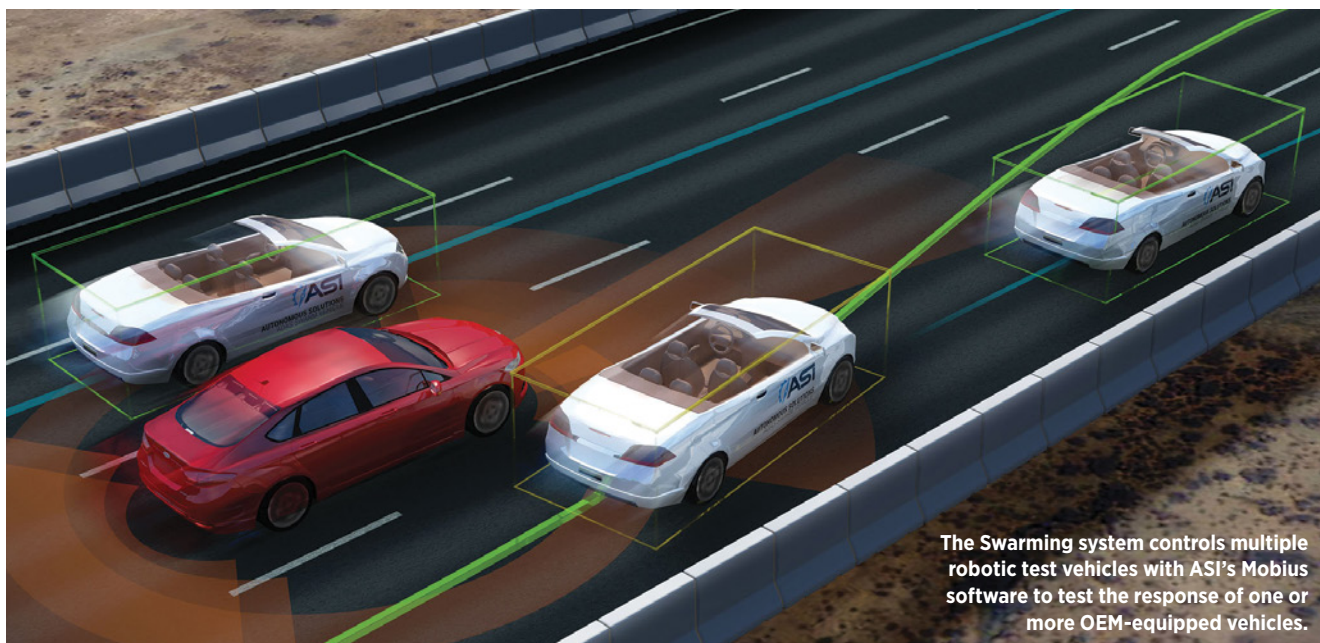
The Swarming system controls multiple robotic test vehicles with ASI's Mobius software to test the response of one or more OEM-equipped vehicles.

ASI
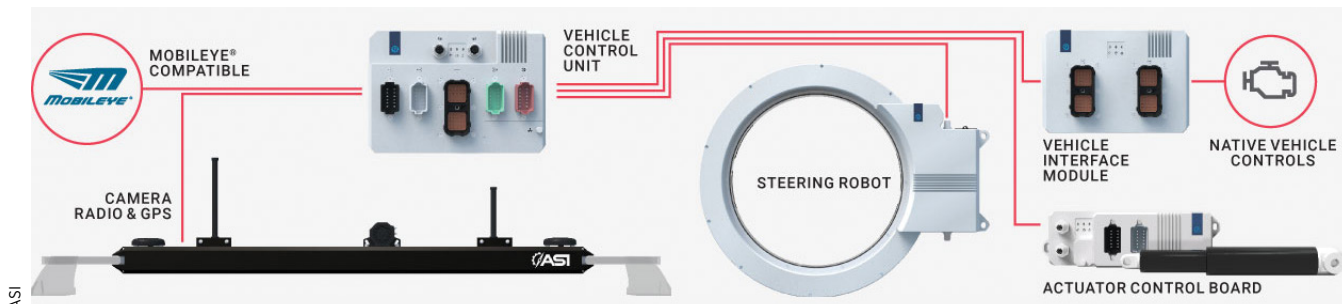
Test vehicles are controlled by a number of onboard components that constantly communicate with the Mobius software.

Judd said that the Swarming technology allows multiple fully robotic scenario-inducing vehicles to simultaneously test multiple ADAS components in highly repeatable fashion on test surfaces like those at OEM proving facilities. Those robot-driven vehicles — and the OEM models being tested — are monitored by the Mobius software. So, for instance, in a scenario where two OEM vehicles are in separate lanes, ASI-robot-controlled vehicles could simultaneously test responses to being "cut off" by a vehicle while also overtaking another vehicle.

In most tests, Mobius controls the test vehicle until it is up to speed and in the correct position. The software then hands over control to the ADAS-equipped vehicle being tested. Those scenarios can be directly imported from simulations, enabling near-real-world testing of the simulation results.

Why is this robotic approach an important option? The robotic systems are capable of far more accurately and repeatedly matching the positioning of simulations than are human-driven vehicles, especially at high speeds. For instance, in a simple test to determine an adaptive cruise control's response to an aggressive cut-in, the cut-in distance between vehicles decreases as speeds increase. It's just another scenario for the robot driver — but a human driver might involuntarily attempt to make the maneuver safer.

This, Judd said, tests entire ADAS, and not just individual components. "It's safe, repeatable testing that is a key step to the future," he said. "Any realistic testing of ADAS requires highly competent professional drivers. The robots are those professional drivers." The robots also are capable of performing multiple tests without fatigue, increasing testing efficiency and allowing concurrent testing of component durability.

A "smart stopping" feature allows Mobius to use vehicle-to-vehicle communication to halt all vehicles (including OEM test vehicles) safely in the event a test strays beyond parameters or becomes otherwise unsafe.

Jed Judd, ASI Automotive's automotive project manager.

A May 2022 study by AAA said that while driver assistance systems generally are improving in slower-speed and "obvious" scenarios, such as a vehicle stopping suddenly in front of another vehicle, that more progress must be made in more-difficult scenarios, such as a wrong-way driver or a vehicle ahead changing lanes to suddenly reveal a stationary vehicle.

"We can rapidly test these edge-case scenarios," Judd said. "At the end of the day, our solution lets you test the vehicles and not their human drivers."

ASI states that the Mobius Swarming software can control up to 20 vehicles at a time and test at speeds of 25 to 75 mph (40 to 120 km/h). The software also can coordinate multiple scenarios and switch to new ones with a single click.

The company also has its own proving grounds and currently is testing in the "[SAE] L2-plus arena with a major OEM," for ADAS production validation, Judd said, asserting that Swarming is ready to move on to testing at SAE Level 3 and higher. ◼

New Tools & Technologies

Radar test chamber

Rohde & Schwarz's (Munich, Germany) R&S ATS1500C automotive radar test chamber now offers a new temperature test option and a new feed antenna. According to the company, these additional features enable temperature-controlled measurements in a wide range, as well as parallel access to both polarizations, increasing test efficiency and flexibility. The ARC-TEMP temperature test supports a range from -40 °C to +85 °C (-40° to 185° F). The heated or cooled air is provided by an external thermal air stream system that supplies the air to the temperature bubble mounted on the positioner. The new ARC-FX90 universal-feed antenna supports 60 GHz to 90 GHz and includes an ortho-mode transducer, which reportedly enables parallel access to vertical and horizontal polarizations.

For more information, visit http://info.hotims.com/84487-400
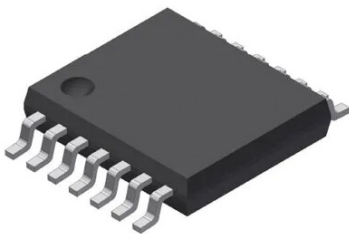
Position sensors

Allegro MicroSystems (Manchester, New Hampshire) announced its A33110 and A33115 magnetic position sensors for ADAS applications that require hig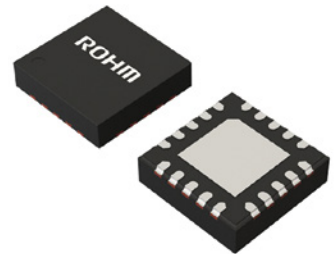h levels of accuracy and heterogeneous signal redundancy. The sensors combine the company's vertical hall technology (VHT) with tunneling magnetoresistance (TMR) in a single sensor package, the company claims. The A33110 and A33115 provide magnetic angle sensing via both the primary and secondary vertical hall transducers, each of which are processed by two independent channels, each with independent regulators and temperature sensors. The A33110 and A33115 sensors provide magnetic angle sensing via both the primary (TMR) and secondary (vertical Hall) transducers, each of which are processed by two independent channels.

For more information, visit http://info.hotims.com/84487-401

PMICs for camera modules

ROHM Semiconductor (Kyoto, Japan) announced the availability of ISO 26262 and ASIL B compliant PMICs, BD868xxMUF-C (BD868C0MUF-C, BD868D0MUF-C), for automotive camera modules. The units are equipped with an anomaly status notification mechanism, such as abnormal voltage detection and feedback via I2C. This reportedly reduces the number of components by three compared to former solutions, which results in a 25% smaller mounting area compared to conventional solutions and contributes to smaller vehicle cameras. The four power-supply systems (three DC/DC + one LDO) necessary for automotive cameras are integrated into the 3.5mm × 3.5mm (.13-inch) package, which ROHM claims is the industry's smallest size in comparable camera PMICs.

For more information, visit http://info.hotims.com/84487-402

ADAS validation

Foretellix and **aiMotive** (Budapest, Hungary and Tel Aviv, Israel) partnered to combine Foretellix's Foretify and aiMotive's aiSim platforms for verification and validation of ADAS and AV perceptions. The system supports the ASAM OpenSCENARIO 2.0 standard which uses a language and domain model for scenario-based testing required for the safe deployment of ADAS. The joint solution reportedly enables product-development teams to define abstract settings and automatically generate millions of concrete scenarios that can be executed in its GPU-based and ISO26262 ASIL-D certified simulation engine. The data from this simulation set is gathered, analyzed, and displayed on a dashboard, allowing the teams to focus on bugs, edge cases and unknowns.

For more information, visit http://info.hotims.com/84487-403

Pedestrian target

Messering (Ingolstadt, Germany) released its articulated pedestrian adult target, which replicates a 50% male adult in terms of size, shape, realistic sensor signature and leg articulation. The target complies with all specifications of the NCAP and ACEA guidelines as well as the ISO 19206-2 standard. Messering states that the target was developed to meet the exact requirements and test protocols for active safety tests such as lane-assist and AEB. The sensor signature reportedly can be reproduced for radar, lidar, camera, infrared and ultrasonic sensors simultaneously. The target is designed for collisions up to 60 km/h (37 mph) and activation of the leg motion is controlled via an IP-based interface and offers a selection of walking speeds.

For more information, visit http://info.hotims.com/84487-404

Camera PMICs

Renesas (Tokyo, Japan) unveiled its power management IC (PMIC) for next-generation automotive camera applications. The RAA271082 is a versatile ISO-26262 compliant multi-rail power IC with a primary high-voltage synchronous buck regulator, two secondary low-voltage synchronous buck regulators, and a low voltage LDO regulator. It offers four overvoltage and undervoltage (OV/UV) monitors, I2C communications, a configurable general-purpose I/O pin and a dedicated reset output/fault indicator. To meet stringent ASIL B metrics, the RAA271082 includes a second independent reference for OV/UV monitors, built-in self-test at power-up, independent OV/UV monitoring and continuous CRC error checking on internal registers and I2C communications.

For more information, visit http://info.hotims.com/84487-407

Collision-avoidance sensors

Toposens (Munich, Germany) unveiled its 3D collision-avoidance system for mobile robots. The system is intended for use with automated forklifts, AMRs and AGVs. According to the company, the system uses sound-based triangulation in combination with noise-filtering software to deliver 3D

data output for each obstacle detected within the fully adjustable warning and stop zones. Zones can be set to dynamically follow a mobile robot taking a left or right turns and adjust to the speed of the vehicle. The sensor sends the obtained data (echo reflections perceived by three microphones) in a 3D point-cloud format to the processing unit, which is equipped with 3D collision-avoidance software.

For more information, visit http://info.hotims.com/84487-405

Oscillators

SiTime Corporation (Santa Clara, California), introduced their new automotive oscillator family, based on SiTime's MEMS technology. The new differential oscillators are reportedly much more resilient and ensure reliable operation of ADAS across extreme road conditions and temperatures. The oscillators feature an operational temperature range of -40° to 125° C (-40° to 257° F). The new oscillators also reportedly feature reduced vibration sensitivity and flexible programmable features from 1 MHz to 920 MHz and 1.8 V to 3.63 V. Differential output drivers include LVPECL, LVDS, HCSL and low-power HCSL and FlexSwing, giving developers a wide range of output options for their system designs.

For more information, visit http://info.hotims.com/84487-406

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