Automotive World

Software-Defined Vehicle MAGAZINE

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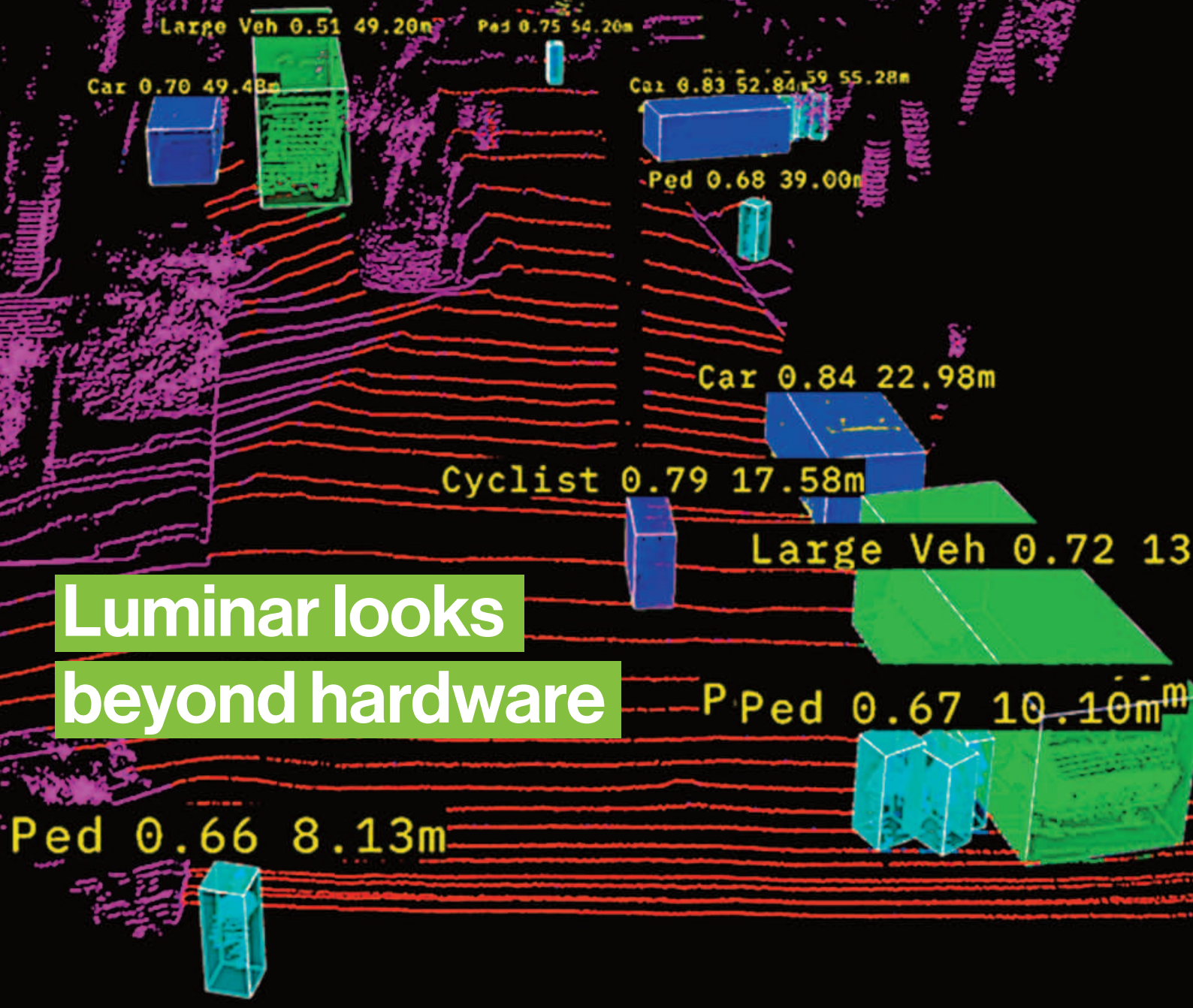
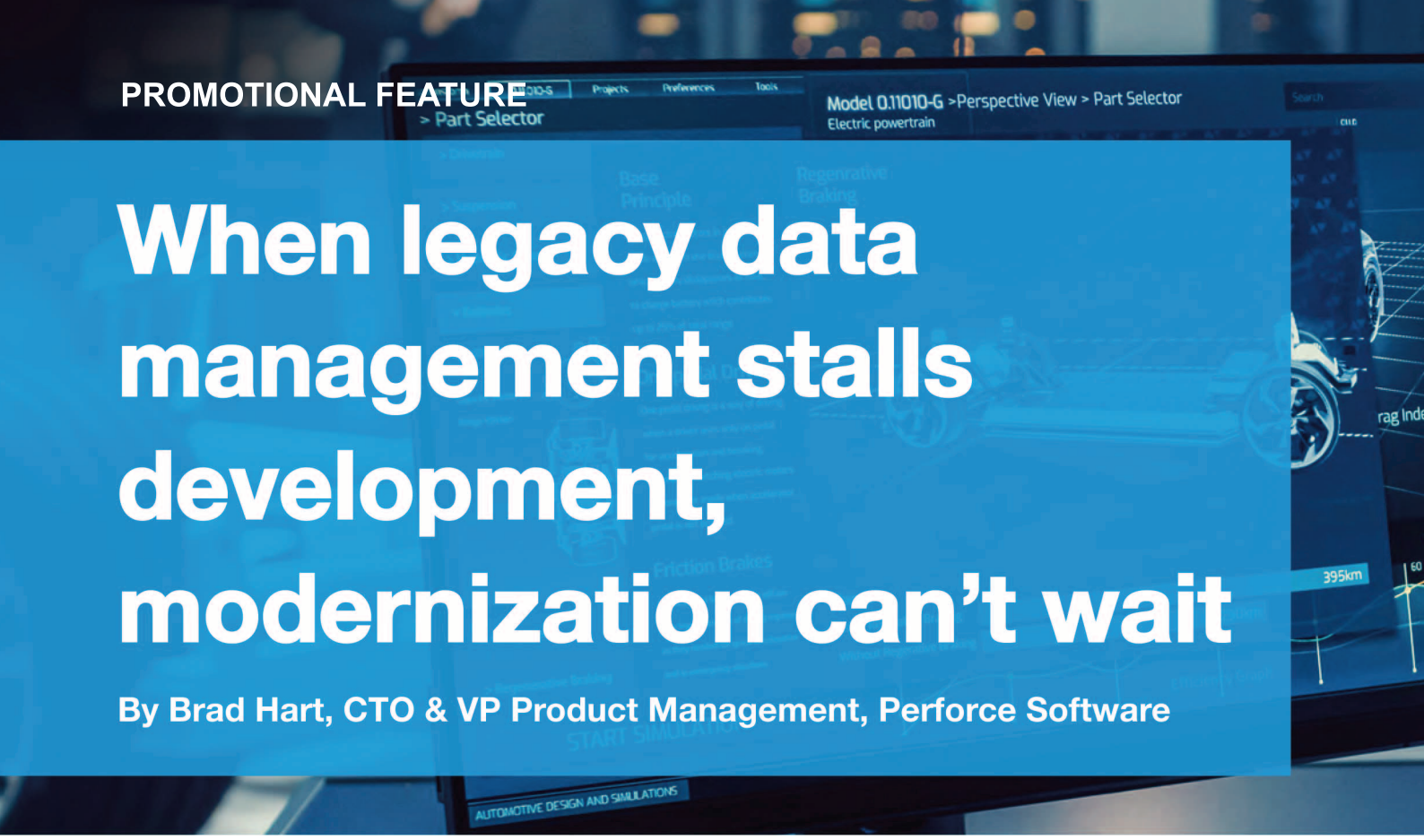


Luminar looks beyond hardware

Continental's cross-domain HPC slashes development cycles | **SoundHound's** Chat AI reshapes UX | **Elektrobit** talks open-source OS | SDVs pave the way for the AI-defined automaker | The AI-defined automaker | Automated ADAS testing advances autonomy |



When legacy data management stalls development, modernization can't wait

By Brad Hart, CTO & VP Product Management, Perforce Software

OEMs and suppliers are racing to crack the code on efficient battery management systems, improved performance through SDV technology, better predictive maintenance for fleet vehicles, more intuitive HUDs, smarter environmental monitoring, and more. With the speed at which innovations are hitting the market, execs have a real fear of being outpaced and left behind.

At the foundation of this race, for many companies, is aging data management (DM) infrastructure that cannot handle the pace, scale, and complexity of today's development.

Lags, conflicts, and crashes are just the beginning

For automotive technology developers, their DM is the lifeblood of a project, the source of truth for code, files, IP, and digital assets. With teams, file sizes, and projects growing larger every year, legacy DMs are buckling under the weight of modern development.

For some dev teams, the first signs of an outdated or insufficient DM might look like frequent file conflicts, lags, crashes, and burdensome administration. But the issues run deeper: their cumbersome branching systems can't support parallel development, they lack fine-grained security, and in many cases, they are no longer supported. At best, they slow down development, and at worst, they put your data security and competitive advantage at risk.

Scalable data management is more critical than ever

As one of the most foundational tools in the tech stack, a DM system needs to scale to support large, global teams and massive file sizes across multiple, complex projects. It needs built-in, enterprise-grade security to ensure the protection of invaluable IP and data. And it must be efficient and high-performant, streamlining collaboration between hundreds or thousands of users while minimizing operational costs.

Innovation starts with a foundation of scalable, secure data management – whether you are driving advancements in e-mobility, autonomy, and OTA updates, or implementing technology like real-time 3D engines to build digital twins for prototyping, predictive maintenance, and performance optimization.

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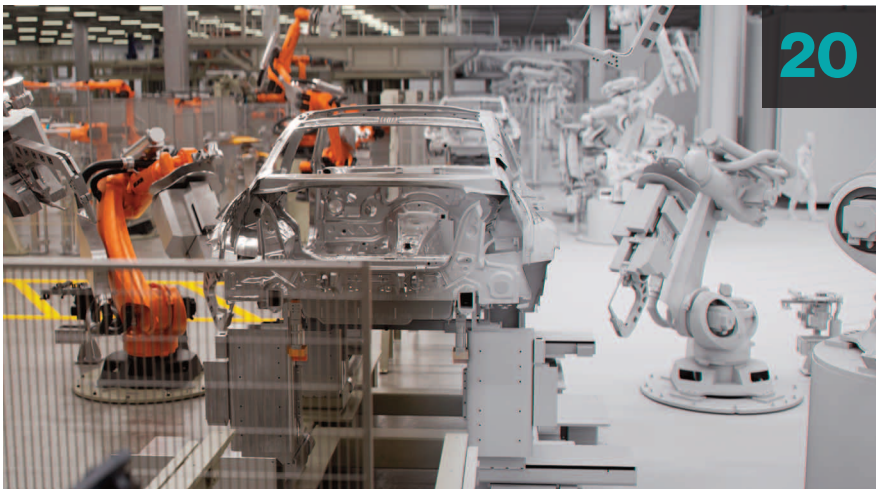
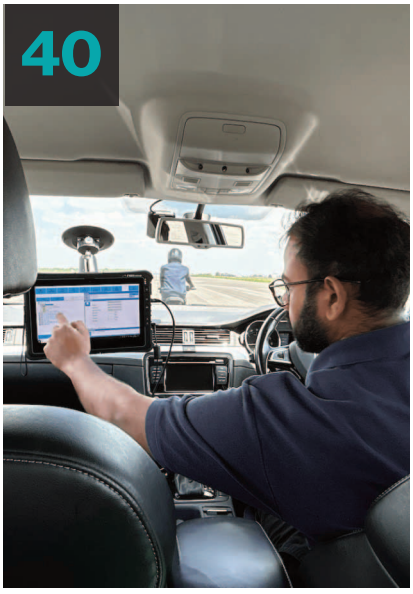


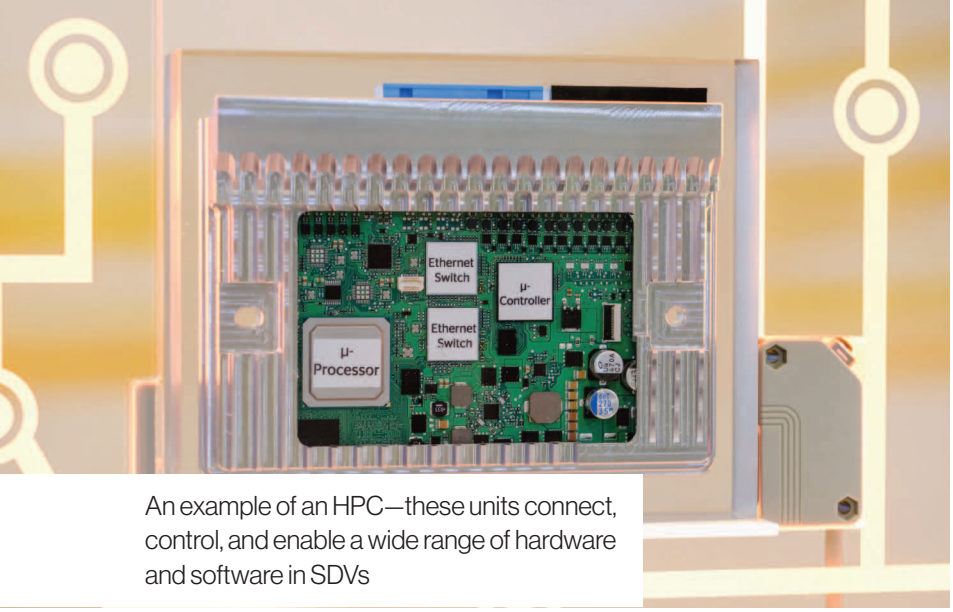


Continental makes SDVs close to personal computers on wheels

Continental's work on high-performance computer functionality and virtual testing could accelerate the development cycle for SDVs. By Will Girling

High-performance computers (HPCs) are a central component enabling the rise of software-defined vehicles (SDVs). This hardware provides the processing and computing power necessary for automakers to realise innovative, software-driven features. Combined with over-the-air updates, HPCs can enable automotive to iterate vehicle functionality continuously in an equivalent manner to the tech industry.

Today, automotive engineers continue to chase higher system performance while also seeking reductions in overall cost and power consumption. Enhanced HPC functionality could come increasingly under the spotlight as an important area for optimisation. As such, multi-national Tier 1 supplier Continental has been exploring not just how hardware and software can be enhanced to unlock new functions but also how to bring SDVs to the market faster.



An example of an HPC—these units connect, control, and enable a wide range of hardware and software in SDVs

Fragmentation to consolidation

Martin Schleicher, Head of Software Strategy at Continental, explains to *Automotive World* that the use of HPCs in vehicles has historically been fragmented. The first generations were kept separate from each other and targeted specific domains, such as cockpit and advanced driver assistance systems (ADAS). In May 2024, Continental became the first company to buck this trend by implementing a cross-domain HPC in a real vehicle.

The shift from domain to server-zone architectures enables vehicle electronics to be grouped into sections with their own ECUs and specific functions. For Continental, the critical enabling component was the Snapdragon Ride Flex System-on-Chip, which supports multi-modal workloads on a single hardware device.

"Cross-domain HPCs mean we can run ADAS functions on a cockpit computer, for example, even though their functionalities are usually separate," says Schleicher. This includes complex features like automatic parking using ultrasonic sensors and surround view cameras. In addition to broadening system capabilities by consolidating several functions across the same HPC, Continental can deliver software updates and new functions.

Unlocking new business models

Although cross-domain HPCs hold exciting potential, Schleicher emphasises that their practical implementation is currently far from simple. Certain functions could require substantial graphics power or accompanying machine learning capabilities on the device to run properly. Discovering how disparate domains running on the same HPC interact will be an important learning experience. "That's one of the reasons we're doing this: to understand how far we can take domain consolidation," he says.

Schleicher anticipates that consolidating systems will not only reduce vehicle weight and potentially shrink overall vehicle size over time but also unlock new business models. The ultimate outcome would effectively be general-purpose computers on wheels with sufficient compute power to add a wide variety of software-driven features over the lifetime of a vehicle—a distinct monetisation opportunity that only SDVs can unlock.

"By retaining the same hardware but upgrading the functionality with software, automakers can keep their cars attractive and differentiate their brand," he says. "The flexibility of a cross-domain HPC will also allow them to move functions that don't fit in one ECU to another, meaning OEMs can determine how and where their compute power is distributed." Since everything in an electric SDV will be drawing from the same power source—

> **Continental wants to demonstrate both what's possible in terms of hardware and what we can offer automotive engineers as standalone software**

the battery—customisable efficiency will also help maximise range, another important consumer consideration.

Building enthusiasm for SDVs

By 2030, McKinsey & Co forecasts that global automotive software and electronics will be worth US$462bn—up from around US$2.5bn in 2019. In the wake of the CrowdStrike system outage, automotive players will be more aware than ever that bugs and software errors can lead to disastrous results on a global scale. With the consultancy also estimating that 90% of vehicles sold by 2030 will have connectivity features, some of which will be critical safety functions, this is something the industry cannot afford to risk. The challenge with automotive becoming truly software-defined is that development must balance speed with safety: test cycles must be as short as possible to be competitive without creating undue risk because of unvalidated work.

Through the Continental Automotive Edge Framework (CAEdge), a cloud-based development environment, Schleicher states that automotive engineers could examine, develop, and maintain system software on a virtual HPC: "We can accelerate the time-to-market for new functions by allowing engineers to test new software in a virtual environment before it goes into production." Continental estimates that CAEdge can generate five million virtual kilometres and 100PB of test data in just one week. By facilitating parallel hardware and software development, the company claims that product development cycles can be significantly condensed. "A cockpit HPC, for example, might have taken 24 to 36 months to validate. We can bring that down to 18 months," states Schleicher.

The road to SDVs will be challenging: automakers must balance functionality, upgradability, and compatibility while also considering how a system fits holistically within the dimensions and specifications of a vehicle. Demand for these time and cost saving tools already exists, according to Schleicher, although the industry might need to wait up to three years for a fully commercially viable cross-domain HPC. "At this point, Continental wants to demonstrate both what's possible in terms of hardware and what we can offer automotive engineers as standalone software functions." He hopes this technical "showcase" will continue to build enthusiasm for the possibilities of SDV technology in the coming years.

SoundHound: OEMs embrace AI-powered software-centric UX

AI-powered digital assistants are emerging at the heart of the software-defined vehicle. By Megan Lampinen

AI-powered features promise to reshape the in-vehicle experience, and the rise of the software-defined vehicle (SDV) is making it easier than ever for automakers to incorporate them. The industry is increasingly moving towards vehicles that use software not only to manage their operations but also add functionality and enable new features. Generative AI (GenAI) is one of the hottest commodities on this front, particularly around voice interaction with the vehicle's digital assistant. The promise on offer is one of smart, natural interactions with an AI assistant that not only hears but listens, understands, and responds.

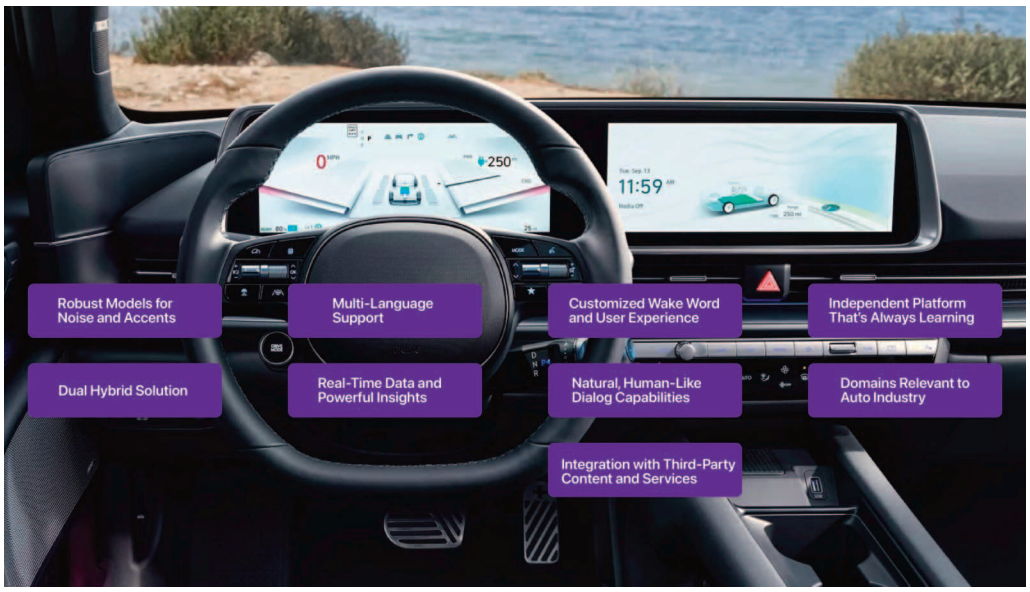
SoundHound Chat AI for Automotive uses a proprietary approach to avoid misleading and unpredictable responses

Spotlight on SoundHound

California-based SoundHound's Chat AI for Automotive was one of the first products to offer an in-vehicle voice assistant with GenAI capabilities. "Chat AI integrates with third-party generative AI models, like ChatGPT, enabling seamless conversations and quick, accurate responses–without any of those 'I'm sorry I didn't get that' moments," says Chief Operating Officer Michael Zagorsek. "You can now speak naturally to the vehicle assistant and get immediate responses from GenAI that work seamlessly alongside other real-time SoundHound domains."

For example, a user may start by asking what the weather is like in Edinburgh. They can follow up with a query on the quickest route into the city, followed by a request for some picturesque stopping points along the way. If something feels 'off' with the car's mechanical operations at any point, they can ask the assistant about it, such as 'Why do my brakes feel sticky?'

"Our proprietary technology stands out because it can manage the voice assistant's responses across different domains to consistently deliver accurate responses–whether for vehicle controls, real-time weather and travel updates, or complex GenAI responses," emphasises Zagorsek. To select an appropriate response quickly, the system draws on proprietary SoundHound AI software engineering technology called CaiLAN (Conversational AI Language) and the in-house machine learning technology CaiNet (Conversational AI Network). CaiLAN builds knowledge domains like weather, restaurants, traffic, and local search, while CaiNET uses machine learning to better understand queries and provide the right responses. CaiNET can connect to SoundHound AI's internal models as well as external models like ChatGPT. CaiLAN controls and arbitrates the results to provide the best response to the user.



The range of potential use cases is vast. As well as trip planning, recommendations for food, and fuel and parking suggestions, it could also help with vehicle maintenance: Chat AI has a Vehicle Intelligence feature that allows the user to access information directly from the car's manual just by speaking. In-car education and entertainment are another potential area for growth, as AI can create a dynamic in-car experience for interactive games and learning activities. For example, an AI voice assistant could provide occupants with a guided tour of what they are seeing out the window based on topics of interest.

An AI voice ecosystem

Hallucinations have been one of the drawbacks with early applications of AI-powered systems, but a growing number of players are now claiming to have successfully tackled that problem. SoundHound is among them, attributing the elimination of such misleading and unpredictable responses to "a proprietary approach." While still early days, momentum for its system is growing.

In February 2024, Chat AI entered full production with Stellantis' DS Automobiles, rolling out across 18 countries in 13 languages. Stellantis later added it to the Peugeot, Opel, and Vauxhall brands. Zagorsek suggests the recent product wins are "testament to the success of the technology and its popularity with drivers". For certain previously released Stellantis models, SoundHound Chat AI with integrated ChatGPT will be available on-demand and can be delivered over-the-air (OTA) with no need to visit a dealer.

At the time of writing, SoundHound' is currently running pilots with other unnamed OEMs in Europe and anticipates a growing market in the US market as well. In 2023, it commissioned a survey that found 50% of regular drivers in the US are likely or very likely to use an in-car voice assistant with Gen AI

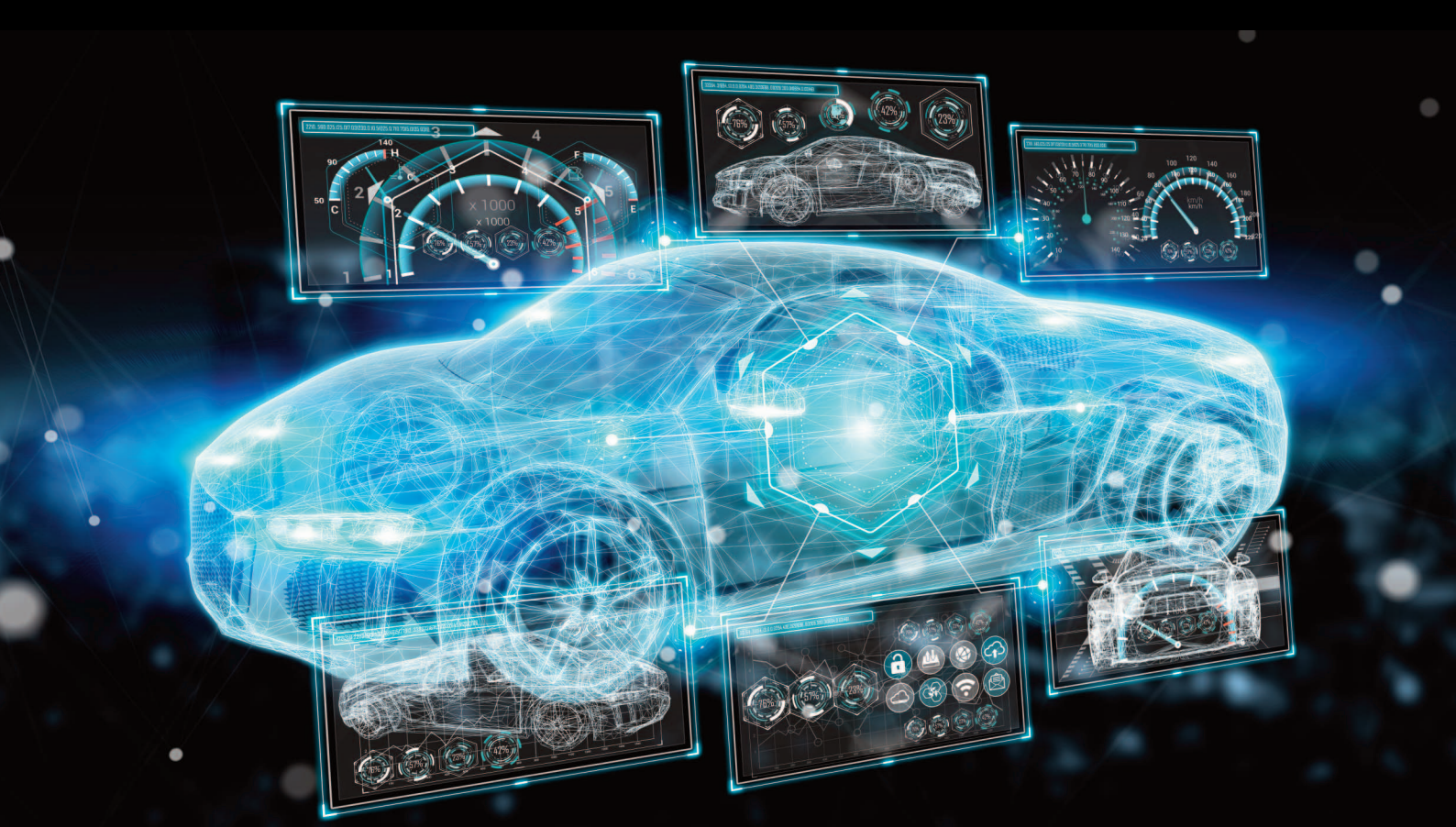
ChatGPT launched in 2023 on all DS Automobiles models with the DS Iris System

capabilities. “We can fairly assume that figure has risen by now due to the increased popularity of AI among consumers,” Zagorsek tells *Automotive World*.

As interest grows, so too will the competition. In Q1 2024, Cerence’s Chat Pro arrived on the first Volkswagen Group models in Europe and North America, offering very similar capabilities and targeted at identical use cases. Deployments across such big-name volume players as Stellantis and Volkswagen Group point to the mass market potential of AI voice technology, which is only at the start of its journey. “The automotive industry is undergoing rapid change and beginning to embrace software-centric experiences fuelled by AI,” notes Zagorsek. “We anticipate that many OEMs will look to harness the power of voice AI in their vehicles. The market potential for our offering is as big as the automotive industry itself.”

Or even bigger. SoundHound also provides voice AI solutions to restaurants and can be found in more than 10,000 such locations, as well as other customer-facing businesses. In the past 12 months, it made two significant acquisitions in the restaurant space with the purchase of SYNC3 in December 2023 and Allset in June 2024.

“Our vision is to build the voice commerce ecosystem of the future, whereby drivers and passengers will be able to use our in-vehicle voice assistant to complete all kinds of transactions,” says Zagorsek. This could include food ordering or appointment scheduling, among other things, and would be entirely hands-free and directly from the vehicle, television, or connected device. “This creates a meaningful, hands free and convenient new experience for consumers, and in turn adds more value for OEM partners,” he adds.



SDV success requires a harmonised approach

Accenture's SDV-oriented LearnVantage Academy aims to transform existing strategies for automotive software development. By Stewart Burnett

Industry efforts to realise software-defined vehicles (SDVs) have proven far from smooth. Various automakers have reported their struggles to establish a proper strategy—a lack of cohesion and many disparate teams working on separate aspects of the vehicle are recurring themes. Even partial software integration has faced significant bottlenecks. "We have 150 different companies that develop software [for us]," remarked Ford Chief Executive Jim Farley on an episode of the *Fully Charged* podcast. "They're written in over 100 different languages that don't talk to one another, and we can't even understand it all." This decentralised and multitudinous approach to design has hamstrung the speed at which core software is created and updated.

In response, some automakers have made relatively drastic moves to shore up their developmental resources, sometimes to chaotic effect. For example, Volkswagen announced in July 2024 that it would invest up to US$4bn in pure electric vehicle (EV) brand Rivian as part of a new joint venture to create "next generation SDV platforms." Volkswagen Chief Executive Oliver Blume noted it would help lower the cost of its software strategy, reducing its reliance on wholly-owned software firm Cariad, which struggled with overrun budgets and two-year delays. Amid threats of factory closures and mass redundancies, however, the investment has been received poorly by staff. Works council Chair Daniela Cavallo characterised the failures of Cariad as the result of "egoism" between Volkswagen's competing brands. "Can we be sure this [joint venture] won't be the next billion-euro grave?" she asked.

Juergen Reers, Senior Managing Director, Global Automotive and Mobility Lead at Accenture

Since the automotive industry is still getting to grips with software development, realising the potential of SDVs may not be an easy task. Therefore, digital transformation consultancy Accenture is working to help automakers overcome this teething stage by introducing an 'academy' intended to provide the structural backbone for SDV development. This academy places talent transformation at the core of its vision of SDV realisation and eventual adoption, guided by a "digital native" mindset.

Supporting all parties

Accenture emphasises the importance of clear process and smooth communication to the success of SDVs. "It's not only what to do differently, but how to do things differently," explains Juergen Reers, Senior Managing Director, Global Automotive and Mobility Lead at Accenture. "This is what allows you to bring new features at speed and scale in a manner that's very different to the delays you see today in software programmes." Such struggles are the reason there is a

timely and widespread need for a learning platform specifically geared towards SDVs.

Accenture's LearnVantage academy for SDVs was established to help its automotive clients' workforces meet the needs of intensive software development. It aims to educate technical teams, C-suites, and board members on how to succeed within this new framework. It will offer technology learning programmes; specialised, predesigned technology academies; ecosystem learning certification services; managed services for a client's own learning capabilities; and nanodegree programmes, certified online programmes designed to provide users with hands-on experience and industry-relevant skills in specialised fields. All courses will be highly personalized with artificial intelligence (AI) to meet the specific needs of teams and individual users.

In March 2024, the company committed to investing US$1bn over three years into the academy, including the acquisition of digital learning platform Udacity. The platform uses AI to continuously adapt learning systems to meet the unique needs of both individual teams and team members, ensuring that every stakeholder has exactly what they need to thrive in a newly SDV-oriented environment. "This is a huge transformation for the industry. Education is an important component, and it begins with developing talent," remarks Reers.

A practitioner's approach

One of the most important aspects of this "talent transformation" will be the promotion of a pro-digital mindset. "Digital nativism is the 'big ask' in the automotive industry today across all functions, and the absence of this mindset is one of the key impediments to most automakers' transformation," explains Raghavendra Kulkarni, Managing Director for SDVs at Accenture. As he explains, it is "foundational" for automakers to have talent that exemplifies this mindset both in decision-making positions and throughout core teams to mitigate the need for expensive acquisitions and continuous talent hunts. These teams must work harmoniously towards

> **"It's not really about teaching particular knowledge sets; it's about delivering a practitioner's approach to SDV development**

> **We have 150 different companies that develop software [for us]. They're written in over 100 different languages that don't talk to one another, and we can't even understand it all.**

shared goals with open communication in place and minimal space permitted for divergences in approach.

Automakers, Kulkarni continues, cannot become software companies in spirit alone: it is a shift that must touch upon every aspect of a company's practice, including who it employs, the structure of its workflows, and how its employees approach every design challenge. "It's not really about teaching particular knowledge sets; it's about delivering a practitioner's approach to SDV development via this academy."

The relevance of Accenture's learning platform extends beyond the realisation of SDVs for their own sake. For Reers, it will reflect his vision for a more sustainable, carbon-friendly future mobility sector. "It's about offering the freedom to move both goods and people, not only without carbon emissions but also safely and affordably in the absence of congestion and irrespective of whether they have a driver's licence," he states, largely in reference to autonomous driving. "But more broadly, digitisation, software platforms, and digital services offer huge opportunities to accelerate this transformation."

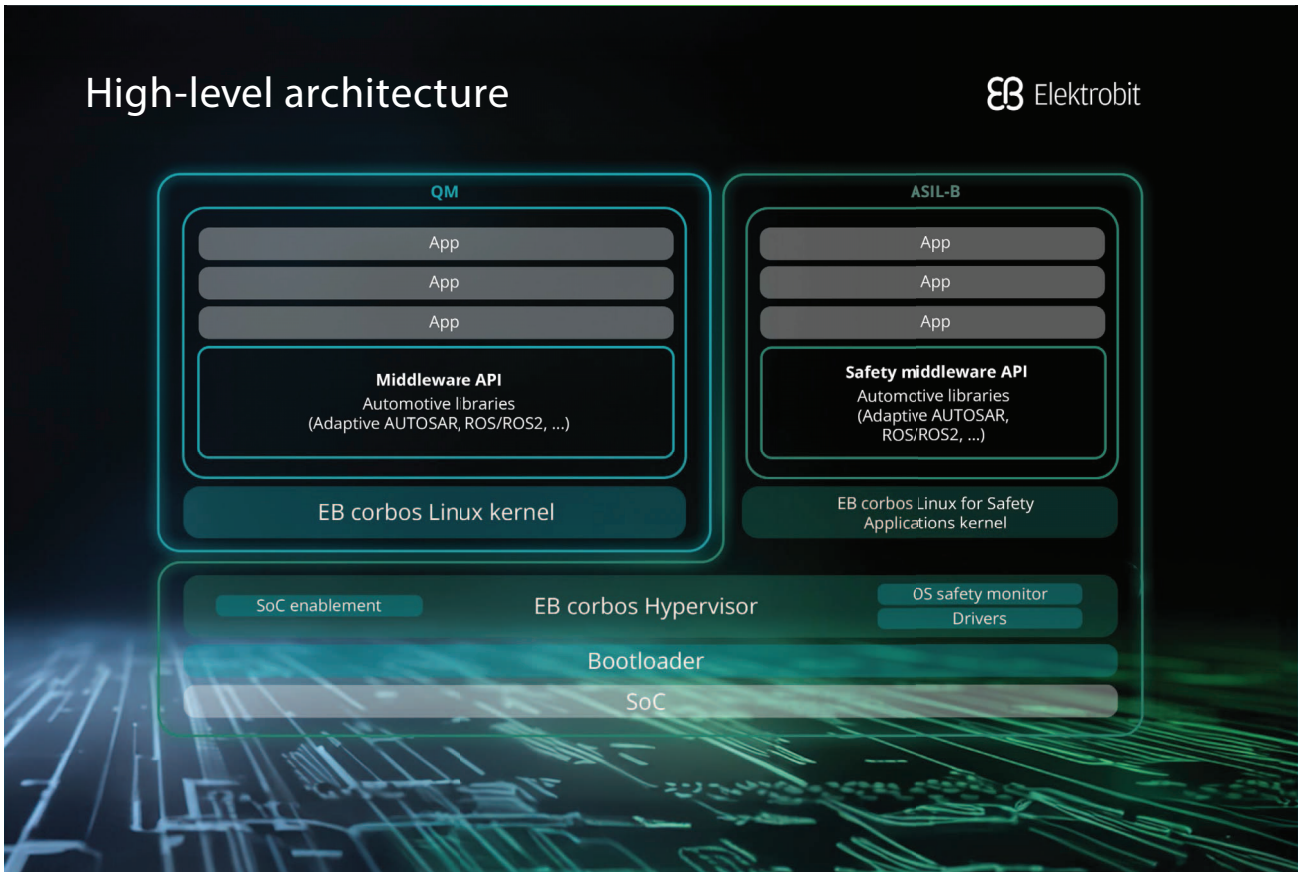
Accenture wants to situate itself as a "transformation partner" for automakers on this journey. Ultimately, what differentiates the LearnVantage Academy from more standardised educational programmes is that it helps break down the walls between different aspects of software development. "It is all about integrating the digital strategies of customer experience, product digitisation and enterprise-wide digital solutions," concludes Kulkarni. "Stitching all of these things together into a unified vision is what the industry needs to move forward with SDVs."

An open-source OS changes the value proposition of vehicles

Elektrobit's open-source OS facilitator, EB corbos Linux for safety applications, could help usher in a new era of residual value opportunities for SDVs. By Will Girling

Software-defined vehicles (SDVs) are increasingly expected to include a range of advanced safety, driver assistance, self-driving, and infotainment features. Importantly for electric vehicles, all of these functions will need to work harmoniously while consuming as little power as possible. More than ever, automakers need the skills and knowledge to act like tech companies.

Operating system (OS) innovation will become an essential for creating the vehicles of the future. The global automotive OS market was valued at US$11.83bn in 2023, according to Grand View Research, rising to around US$30bn by 2030. To date, this growing demand has been fulfilled through a multitude of closed-source proprietary solutions specifically tailored for the automotive industry. This may not continue for much longer.



"When you factor in safety and compliance rules for automotive-specific OS, both the entry barrier and cost for developers is really high, and turnaround times for new updates are long," states Moritz Neukirchner, Strategic Product Manager, SDV, at automotive software company Elektrobit. If automakers want to eventually iterate their cars at a comparable speed to smartphones, they will need to change their approach.

Bridging the gap

Neukirchner tells *Automotive World* that SDVs are motivating a consolidation in the automotive OS market. The need for constant software innovation that also meets safety and compliance regulations means as many developers as possible must be empowered to take part. "This requires an open-source OS, and perhaps the most established is Linux, the developer's OS of choice."

However, Linux's huge global community does not strictly adhere to automotive development processes and generates around 500 kernal updates–a programme that prevent conflicts between different computer processes–each year. "That makes it impossible to qualify its safety for use in vehicles," states Neukirchner. It took Elektrobit around seven years to resolve these issues. Finally, in April 2024, the company announced EB corbos Linux for Safety Applications–the first open-source OS that meets automotive safety compliance standards.

The solution has been positively assessed according to ISO 26262 ASIL B and IEC 61508 SIL 2 standards. "We run an off-the-shelf Linux but make it usable in an automotive context," he

explains. A hypervisor enables multiple virtual machines to operate on a single piece of hardware, so although the OS can now be used in high-performance computer domains relating to features like driver-assistance or autonomous driving, it is supervised to prevent interference with safety-related functions. “This means we can participate in the development community without infringing on industry requirements.” In effect, EB corbos helps bridge the gap between automotive and tech. But what does this mean for SDV development?

Updateability becomes value

For Neukirchner, the promise of SDVs is an inversion of how vehicles are typically valued. “When you drove a car away from the dealership, that was the best it was ever going to be; everything went downhill from there.” By opening up programming interfaces and development environments, he believes SDVs can enable innovation that wouldn’t have been conceivable in the hardware manufacturer’s original business plan. According to this idea, vehicles could actually become more valuable over time. “It will be equivalent to the leap from regular cell phones to smartphones and the App Store.”

The sensor hardware increasingly incorporated in vehicles for a range of connected and autonomous functions offer a rich seam of untapped potential. For example, while some automakers might initially want to include biometric sensors for secure payments inside the vehicle, the open-source OS developer community might expand their functionality to include speed restriction for younger drivers. LiDAR and parking sensors could also be used for highly accurate weather and road condition monitoring programmes. “Without changing any of the hardware, companies can add value purely through software,” says Neukirchner.

In much the same way that removing the ability to update smartphone software would ruin the market, he believes new SDV ecosystems will become inextricable from the future of automotive. “Cars might remain

> **Proprietary OS solutions [. . .] cannot compete with the speed, efficacy, and affordability of open-source OS**

mobility devices, but updateability will become the value proposition." Elektrobit is positioning itself to be the facilitator of this industry inflection point through streamlined software development with Linux.

Creating a developer community

The importance of pursuing an open-source OS approach, Neukirchner continues, is that creating a de facto standard for vehicle software will necessarily be a joint effort; no automaker can achieve the portability required by itself. "Harmonising some aspects of software across every automaker and creating a less fragmented market will be a big future trend." This is not to say that individual brands will lose the opportunity for differentiation: ADAS functionality, for example, could vary according to each OEM's investment. However, he states that establishing an open language and framework for development will accelerate updates.

Elektrobit estimates that EB corbos can shorten product development cycles by up to 50% and subsequently save significant R&D costs. Looking ahead, Neukirchner envisages the solution joining a tapestry of open-source automotive hard/software initiatives– such as Connected Vehicle Systems Alliance (COVESA) and Eclipse SDV– that prioritise collaborative, community-based solutions. However, the industry will need to address the current dearth of auto-specific IT qualifications and skills holding back this movement's full potential.

The wider importance of expanding the software development and testing ecosystem is already clear. In early 2024, Porsche was forced to discontinue the Macan in Europe, as UN Regulation No. 155 (R155) cyber security compliance would have been prohibitively expensive. Proprietary OS solutions, states Neukirchner, cannot compete with the speed, efficacy, and affordability of open-source OS. By bringing together developer communities and automotive standards, he concludes that EB corbos could help prevent future product recalls on the basis of cyber security and safety. The ultimate result will be SDV systems that are more durable, remain market-viable for longer, and subsequently create a fresh business paradigm for the automotive industry based on new residual value.

Software-defined vehicle advances to AI-defined automaker

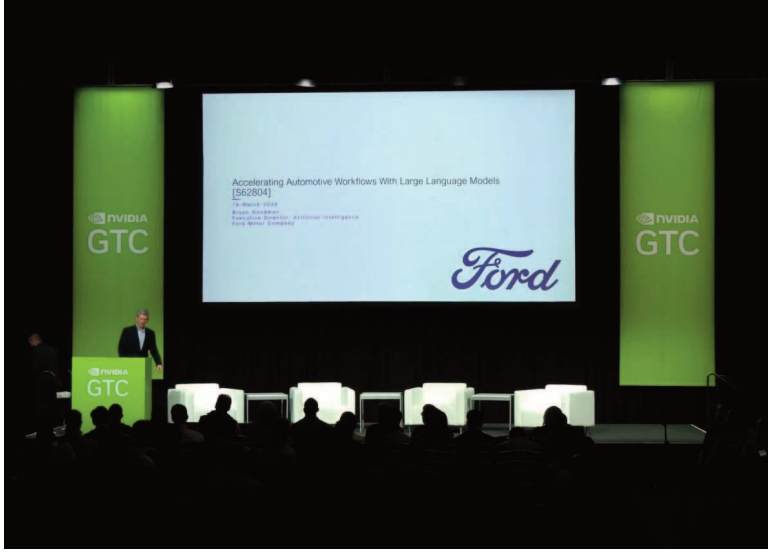
Empowered by advancements in digital twins, automakers are deploying AI-powered solutions to boost efficiency and innovation. By Pedro Moreno

Three decades ago, the introduction of electronics into vehicles marked a significant shift in the automotive industry, requiring new skills and working methods. The arrival of active safety functions, automated driving features, and digital cockpits accelerated this trend. The advent of over-the-air (OTA) updates ushered in a new era, allowing vehicles to evolve after market release, integrating new functions and services customers would pay for. This is the era of the software-defined vehicle, where software activities are primarily limited to functions within the vehicle.

The landscape further evolved with OpenAI's release of ChatGPT in 2023. This development made industries realise the potential of generative AI and the impact that new applications and services would have on their businesses. Capgemini estimates that 16% of large automotive OEMs can increase operating profits by deploying AI at scale.

AI will not only improve functions within the vehicle but will also enhance efficiencies across the automotive production workflow. That includes anything from designers using AI-generated images to imagine new vehicles, to design and engineering teams using generative AI application programming interfaces to connect their tools to build digital twins of their facilities, to marketing and retail sales departments adopting generative AI tools to brainstorm and develop marketing copy and advertising campaigns.

Most automakers are evaluating 100 to 150 use cases for AI deployment, making it hard to imagine a single function that will not be improved with generative AI. This transformation leads to a new era, the "AI-defined automaker."



At GTC 2024, Ford presented a deep dive into accelerating automotive workflows with Large Language Models

Knowledge chatbots enhancing customer service

Ford, which receives around 15,000 customer calls a day, uses generative AI throughout the call centre workflow. First, a speech-to-text system automatically manages the data associated with the customer request while removing any personal identification information, which is mandatory in many countries. This intelligent data management enables the creation of a second AI service, a chatbot used by supervisors and engineers to query the database on questions such as the number of call centre calls or even how many were related to a specific issue. Additionally, AI assists the call centre operator by suggesting the best answers to customer queries, thereby improving call centre speed, efficiency, and customer satisfaction.

Another example is the use of knowledge chatbots at repair shops and dealerships. For example, if a vehicle's air conditioning is broken, the technician can simply ask for the best way to repair it on the specific car model, and the chatbot will provide step-by-step instructions and visual examples.

Automated vehicles (AV) 2.0

AV 1.0, the traditional way of developing automated driving functions, is based on a modular architecture of perception, prediction, and actuation. Perception is primarily based on Convolutional Neural Network (CNN) classification AI, and it was a common belief that by solving perception, meaning having perfect classification of objects in a driving environment, the autonomous driving problem, even for high levels of automation, would be solved. However, after more than a decade of efforts, it became clear that the long tail of use cases is endless, and more than perfect perception, a right interpretation of the scene is required for the vehicle to manage previously unseen scenarios.

Transformer engines, which are the foundation of generative AI, are not trained exclusively on automotive data but on general data, enabling them to abstract and correctly understand driving scenes that have never been encountered before, making the right decisions. This is the core of AV 2.0, where an end-to-end architecture, with sensors' raw data

Debrecen is the BMW Group's first facility to be planned and validated completely virtually thanks to a partnership with Nvidia

as input and vehicle actuation (acceleration and direction) as output, replaces the traditional AV 1.0 modular architecture. In addition to performance benefits, this approach optimises the computational resources allocation, as there is only one function being calculated, rather than several modules competing for available resources. It also facilitates the transfer of a vehicle to different cities and countries, a difficult problem for rule-based AV 1.0 systems.

Startups like Wayve, a developer of embodied AI for assisted and automated driving, and Waabi, an AI company building the next generation of self-driving technology, are making tremendous progress in this field, demonstrating impressive results.

The superpower of digital twins

Digital twins are physically accurate virtual replicas of assets, processes, or environments that exist in the physical world. In industry, digital twins can be used throughout the product lifecycle, from design and manufacturing to maintenance and operations, to sales and marketing.

Digital twins enable physically accurate visualisation and precise testing of different product versions and scenarios. They allow for superpowers: travel in space to virtual factories or inside vehicle prototypes to help teams optimise designs, and travel through time to understand past errors and avoid future ones by working on alternative futures. Instead of teams relying on in-person meetings and static planning documents for project alignment, digital twins streamline communication and ensure that critical design decisions are informed by the most current data. Digital twins allow project stakeholders to visualise designs in context during design. Teams can identify errors and incorporate feedback early in the review process.

Recent advancements in digital twins include the adoption of OpenUSD (Universal Scene Description), an extensible framework and ecosystem for describing, composing, simulating, and collaboratively navigating and constructing 3D scenes. HTML is the standard language for the 2D web, while USD can be seen as the powerful, extensible, and open language for the

3D web, enabling communication between the many different tools and siloed departments in the product life cycle. The latest developments in physically-based rendering and accelerated scalable computing enable the creation of large-scale, physics-based digital twins that are truly representative of the real world.

In early 2022, BMW introduced the iFACTORY for virtual planning in digital twins. All of the BMW Group's vehicle and engine plants were 3D-scanned, as well as more than seven million square meters of indoor and 15 million square meters of outdoor production space. BMW has a vast workforce of factory planners, including those working at facilities like the future Debrecen plant, who play a critical role in the planning and operations of the company's factories worldwide. Their jobs are highly complex, and even the slightest miscalculations or mistakes can result in massive real-world costs.

This is why physically accurate virtual planning is highly desirable, as it allows planners to experiment and make changes at practically no cost. Planners can pre-optimise production processes using virtual environments before committing to massive construction projects and capital expenditures. This approach significantly reduces costs and production downtime caused by change orders and flow re-optimisations on existing facilities.

The combination of digital twins and generative AI further enhances the benefits of each. Generative AI can assist in generating assets, providing teams and customers the ability to interact with assets and knowledge bases in natural language, navigating the digital-twin environment, and creating visually and physically accurate digital worlds for product development and training, such as teaching autonomous vehicles to drive or robots to walk. The digital twin becomes a digital gym or training ground in which the product's software functions can be developed. Digital twins are also used for synthetic data generation, creating the data required to train the AI algorithms that will be used by the product being developed.

The AI-defined automaker is here today

The automotive industry is undergoing a profound transformation, not only introducing software-defined vehicles, but also entering the era of the AI-defined automaker. Generative AI is revolutionizing every aspect of the business, including design, engineering, customer service and autonomous driving. Empowered by advancements in digital twins, automakers are rapidly deploying AI-powered solutions to boost efficiency, innovation, and customer experience. As the industry embraces this AI-driven future, every function can be enhanced and optimised by the power of generative AI. This evolution promises to unlock new levels of efficiency, innovation, and customer-centricity, positioning the automotive industry for continued success in the years to come.

About the author: Pedro Moreno Lahore is Senior Account Executive, Automotive, at Nvidia

May Mobility: AVs must prioritise safety and accessibility

To win over an increasingly distrusting public, AV technology must recast itself as a pillar of local communities and not a threat. By Stewart Burnett

Winning over an uncertain public is one of the biggest challenges facing the realisation of autonomous vehicles (AVs). In the last few years, a wave of high-profile accidents has caused public excitement for driver assistance and self-driving technology to turn into discomfort.

One notorious incident involved a Tesla Model S using a beta version of the automaker's Full Self-Driving feature: the car came to an abrupt halt while crossing the San Francisco Bay Bridge, resulting in an eight-car pile up. Nine people were injured, and traffic was held up for more than an hour. SAE Level 4 developers are faring no better. In November 2023, General Motors' Cruise had its licence to operate on Californian roads revoked following an incident in San Francisco the month prior.

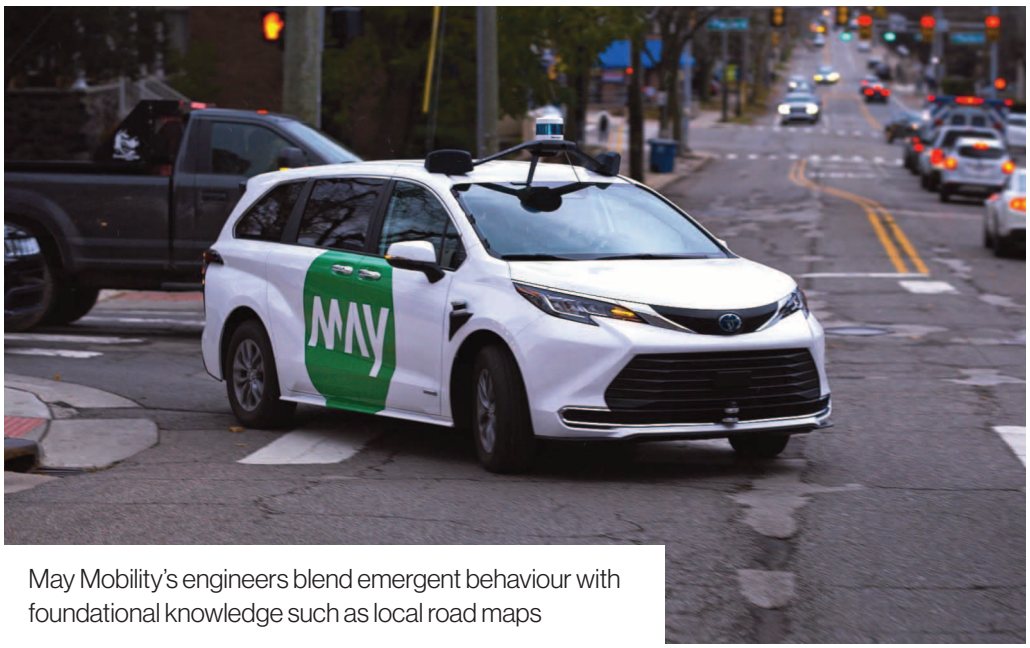
Consumer sentiment towards automation technology is nearing rock bottom in the US. 93% of respondents in a January 2024 Forbes Advisor poll indicated they had concerns about some aspect of self-driving cars, with safety and technology malfunctions the most widespread. 61% indicated they would not trust an AV to transport a loved one. These concerns are backed by National Highway Traffic Safety Administration data: 9.1 crashes occur per million driverless miles, compared to only 4.2 in human-operated vehicles.

Growing distrust means that companies operating in the autonomous driving space must make significant efforts to demonstrate the safety and reliability of their technology. For Michigan-based AV firm May Mobility, this means two things. First, developing self-driving software should not be bound to a rigid and therefore potentially dangerous rules-based system. An entirely rules-based system not coded for every possible scenario will inevitably lead to unsafe behaviour. Second, self-driving technology must be deployed in situations where everyday members of the public—not a self-selecting audience of robotaxi users—can actually experience it.

Safety is everything

Unlike many firms in the autonomous driving space, May Mobility has kept a low profile. This is partly due to a lack of controversy: in the nearly seven years that May Mobility has been in operation, there have been minimal reported crashes, injuries, or traffic jams. Despite this, the company has continued to raise significant amounts of money while others have seen their funding dry up. In November 2023, it announced a US$105m Series D investment round led by Japanese telecommunications company NTT.

The secret to this success is May's prioritisation and strong track record of vehicle safety. "We develop AVs, but we're particularly focused on validating this amazing technology that just works and is safe to use," remarks Sarah Gryniewicz, Strategic Commercial Development Lead at May Mobility. Her dream for autonomous driving is simple: it must not stand out to the vehicle occupants. Rather, they should almost forget they are experiencing an AV. "It should be boring because it is driving completely safely—in fact, boring is a really fantastic goal to work towards.



May Mobility's engineers blend emergent behaviour with foundational knowledge such as local road maps

Creating a "boring" autonomous driving experience means driving in an entirely predictable and human-like manner, enabled by May Mobility's patented self-driving software algorithm, Multi-Policy Decision Making (MPDM) technology. Instead of an AV adhering to a rigid and rules-based system, which can lead to serious issues when encountering a situation for which it has not been prepared, MPDM is developed to allow for emergent behaviour and enables the car to navigate through almost any situation.

MPDM works by continuously running thousands of simulations on vehicle hardware in real-time to anticipate any possible change or development in the driving situation. Using this information, the vehicle is able to decide for itself what action is the safest. "What makes our software special is that it's learning even while it's on the road," adds Karsten Kutterer, Senior Communications Manager at May Mobility. "When you have a team of engineers, they can only imagine so many rules to put into the code."

Such intensive simulation may give the impression that May Mobility's self-driving software is particularly demanding and can only run on the most advanced hardware, but Gryniewicz dismisses this idea. "MPDM is designed to home in on scalability–it's extremely energy and data-efficient." She explains that the particular method of decision-making uses less compute power than relying on a large base of existing data. This isn't to say the system entirely disregards the benefits of foundational knowledge: before a vehicle is brought into operation in a town or municipality, it is equipped with and trained on a map of the local area.

Bringing AVs into the mainstream

"We think AVs powered by our software can make a difference everywhere, not just in major cities and robotaxis," explains Gryniewicz. "There's a ton of people out there for whom there is a mobility gap, so having something that's scalable

> **We want to enact change within the community that makes up our customers and partners**

makes it more useful across all of these applications." She states that May Mobility's technology is designed to be platform agnostic, able to be tuned and adapted across a variety of different vehicle types, ranging from passenger cars to buses.

Gryniewicz emphasises that the company's system enables a degree of affordability that other solutions may not be able to reach. Crucially, May Mobility achieved this without sacrificing other pivotal redundancy features, such as backup power and sensor communication systems and a fallback vehicle safety system.

In combination, these factors are intended to make May Mobility's autonomous driving software, alongside the actual vehicles it produces, the ideal solution for its target audience: transit agencies, municipalities and businesses. "We're very bullish about these segments. There are transit companies all over the US that need to fill gaps and help people get around. I think there are really good use cases for autonomy in that," she explains. "These cities and private companies have budgets, and we all know they are facing driver shortages. They need sustainable economics, and you can use AVs to fulfil that need."

The company's strategy is to start at a small scale within a given area and then expand as trust grows. This will be achieved not only by demonstrating to locals that the technology is safe to use but also by prioritising accessibility and expanding mobility access in areas that were previously lacking. "We want to enact change within the community that makes up our customers and partners," says Gryniewicz. Accessibility–such as for those in wheelchairs–is also a key AV design priority.

This approach forms not only May Mobility's strategy for commercial success but also what it believes is the best way to sway consumer sentiment towards the AVs. Rather than presenting it as a threat to human jobs–a common critique of robotaxi firms–the technology is instead cast as a tool for safely connecting communities and individuals with limited mobility options. "AVs need to serve all people, and we design them for that purpose. That's something we're proud of, but it's also something that's especially important to our markets," concludes Gryniewicz.

Luminar: software is the key differentiator in sensor tech

While the automotive industry debates what sensor hardware is optimal for autonomous features, software could be the key differentiator. By Will Girling

Demand for connected vehicles, advanced driver assistance systems (ADAS), and autonomous driving (AD) are all prominent factors driving automotive software development today. The global market's value is expected to reach US$117bn by 2032—up 241% from 2023, according to Precedence Research.

However, unlike in the tech industry, automotive players must carefully balance the desire for a fast time-to-market with the safety considerations of deploying new ADAS/AD features on the road. "The software needs to pull together radar, cameras, LiDAR, compute platforms, and other hardware," says Aaron Jefferson, Vice President of Product at Luminar Technologies. "The big challenge is engineering software that works first time out of the box."

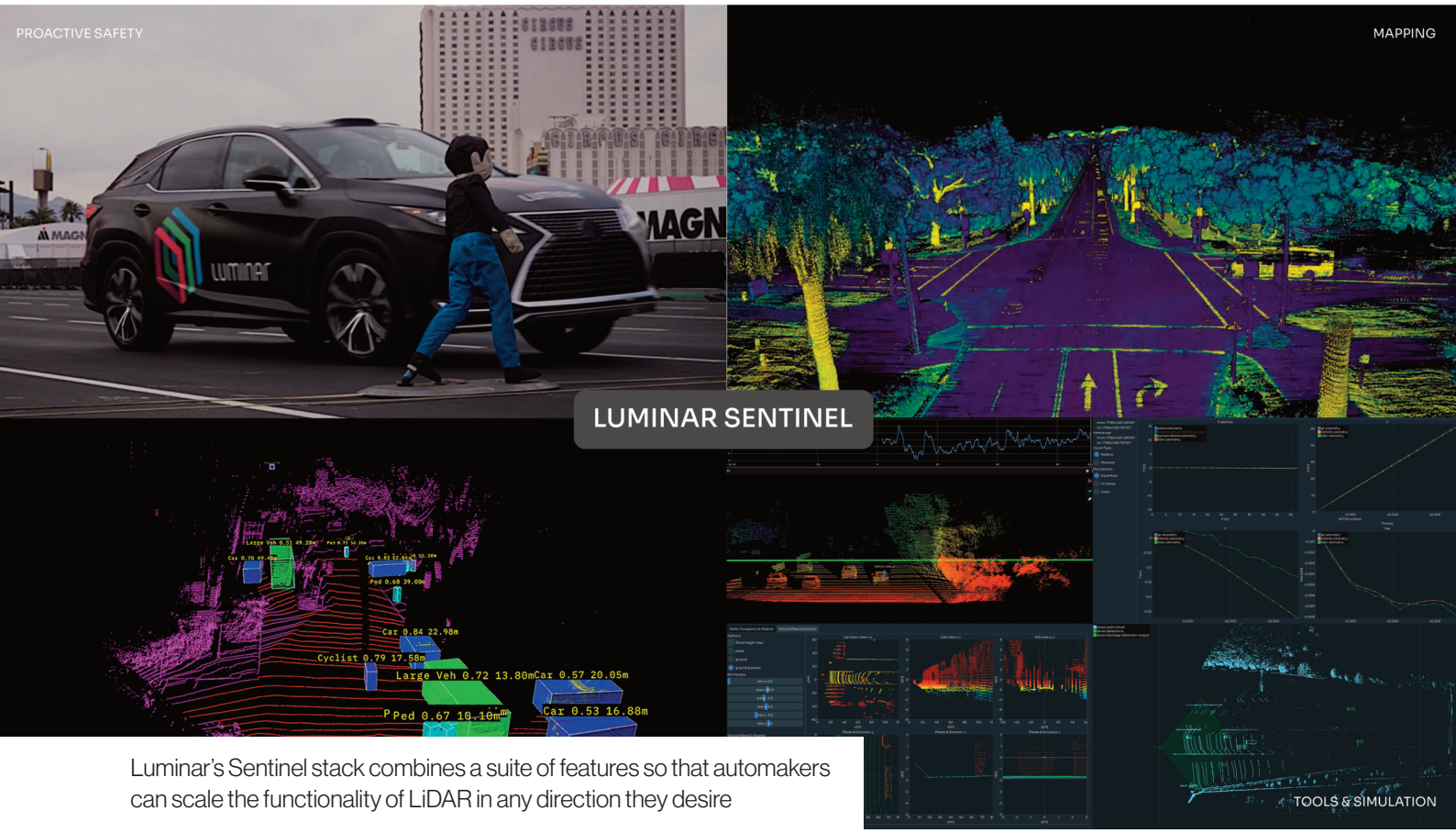
More frequent industry discourse around software-defined vehicles (SDVs), he tells *Automotive World*, can give the false impression that this challenge is now easily surmountable. "In fact, it still takes a lot of design, development, and testing to make sure software won't glitch once it's in use." As such, Luminar has been developing a new stack—Sentinel—to help provide automakers with the toolkit necessary for safely realising next-gen vehicle functionality.

Assessing true value

Although it's a Tier 1 more commonly associated with LiDAR and machine perception technology, Luminar is pushing past a strict focus on hardware. "The value of LiDAR is ultimately what you do with the data it generates," comments Jefferson. "OEMs often cycle alternately through wanting to create ADAS/AD software in-house and partnering with a third party. The truth is very few have invested in software tied to high-quality LiDAR data." It was by identifying this gap in the market that Luminar arrived at the idea for Sentinel.

Development started based on perception software used for the company's LiDAR sensors: a point cloud—collection of data points arranged in 3D space—which facilitates the identification of sidewalks, lane boundaries, pedestrians, vehicles, etc. "From there, it was a case of deciding how to package it in a stack and match it to the KPIs customers might want to track, such as accuracy of object detection in low levels of lighting." This took some time: an initial Sentinel prototype with limited capabilities emerged in 2021. A commercially viable version was launched in July 2024.

The final product consists of a compute platform based on an Nvidia Orin processor, a LiDAR sensor with core software and point cloud output, a perception stack, and 3D mapping and localisation features. This suite is then integrated with an existing system. Sentinel's capabilities are diverse—or "à la carte" in Jefferson's words—as each automaker's initial architecture and project goals will invariably differ from another's. "Luminar wants to provide a ready-made kit so that OEMs can develop the safety and functionality of their software without having to invest a billion dollars in their own," he states.



Luminar's Sentinel stack combines a suite of features so that automakers can scale the functionality of LiDAR in any direction they desire

Broadening tech horizons

In April 2024, insurance firm Swis Re published an audit of Luminar's LiDAR combined with a pre-release version of the Sentinel stack. In total, 800 individual tests–including car-to-car and car-to-motorbike incidents and vulnerable road user scenarios–were conducted on a vehicle with SAE Level 2 ADAS functions. Swis Re found that a vehicle equipped with Luminar's technology was 25% less likely to be involved in a collision than an equivalent vehicle without it, and overall collision severity was reduced by up to 40%.

While this research is promising, Jefferson notes that Sentinel cannot be used simply as a plug-and-play shortcut for bringing the next generation of ADAS/AD solutions into production immediately. Rather, it is complementary software for helping more mature players assess and improve LiDAR-based features already under development. Although it is still too early for the company to report on individual customer use cases, these are currently ongoing.

Much in the same way that Luminar partnered closely with Volvo Cars to integrate LiDAR sensors seamlessly into the roofline of its EX90, Jefferson believes an ongoing industry dialogue can help marry ADAS/AD software with brands' wider goals. "Based on our back and forth with an automaker in the Asia-Pacific region, it's already become clear that new software solutions can help manufacturers realise the unexplored potential of their existing hardware." It is by capitalising on these broadened horizons, he adds, that future SDV innovation could be realised.

> **We're going to see [LiDAR's] democratisation across all vehicle segments as software helps deliver the sensor's true value**

Democratising LiDAR

Although the industry has not yet reached consensus on what sensor hardware or fusion will enable mass market Level 4+ autonomy, many consider LiDAR's functionality valuable for building consumer trust during a difficult time in the market. High-profile incidents involving AD systems have decelerated interest among stakeholders, but a software-driven re-examination could help development regain momentum. From an engineering perspective, Jefferson states, "we haven't even scratched the surface of what LiDAR can deliver."

In April 2024, the US National Highway Traffic Safety Administration stated that automatic emergency braking (AEB) must become standard—rather than a luxury—in all cars and light trucks by 2029. Jefferson anticipates that LiDAR technology expanded and improved through software will play an important role in fulfilling this requirement, setting the foundation for Level 2 ADAS functionality and beyond. "The challenge is that this will represent a paradigm shift from the camera and radar fusion with which many OEMs are comfortable." However, he believes the rigours of a rapidly changing industry make previous solutions inadequate.

One of the most attractive prospects of SDVs is that they can unlock previously inaccessible monetisation opportunities. For the first time in the automotive industry's history, vehicles could become more valuable with time, not less, as new features can be added quickly through software. For ADAS/AD, automakers will need a system that provides foundational safety for the mass market while also containing the scalability for advanced AD features. Software stacks based on LiDAR, concludes Jefferson, can help fulfil this need. "LiDAR is fundamentally a safety technology, not just a facilitator of autonomy; it works equally well for both. We're going to see its democratisation across all vehicle segments as software helps deliver the sensor's true value."

DeepRoute.ai CEO: SDVs and AGI herald 'the era of robots'

DeepRoute.AI's CEO believes software-defined vehicles are the key to artificial general intelligence in the physical world. By Megan Lampinen

Artificial intelligence (AI) is shaping the development and functionality of software-defined vehicles (SDVs). The promise is great but the journey has only just begun. Many industry players are working towards the vision of driverless cars that can navigate 24/7 in any and all conditions. For Chinese self-driving company DeepRoute.ai, the AI capabilities needed to realise that paradigm open up tremendous potential in applications far beyond the roadways.

The starting point

Led predominately by China, connected and intelligent interactions in vehicle cockpits are rapidly becoming the norm. Most Chinese consumers purchasing even a mid-range car expect it to offer a host of smart driving functions. "Today, cars are controlled from screens and preferably by voice interaction," says Maxwell Zhou, Chief Executive of DeepRoute.ai. "Automakers are starting to integrate ChatGPT to improve the in-car digital assistants and make interactions even smarter." Volkswagen Group and Stellantis are two big-name players leading the integration of these early generative AI (GenAI) systems across their vast line-ups.

GenAI is also facilitating real-time decision-making in automated driving systems, which are gradually taking on more of the driving tasks, particularly in urban areas. "This is a top priority in new car purchases," Zhou points out. Data from the China Passenger Car Association shows that in 2023, more than 55.3% of new energy vehicles came with integrated SAE Level 2 and L2+ functionality.

But as the industry moves towards greater levels of automation, another form of AI is gaining traction: artificial general intelligence (AGI). While GenAI refers to algorithms that generate new content—videos, code, images, etc.—AGI acts more like a human in terms of common sense, understanding and learning. It can then apply that 'general' knowledge to all sorts of tasks. "The most important difference with AGI is the generalisations," Zhou tells *Automotive World*.

Today's self-driving systems are highly tailored and trained for specific use cases and regions, usually relying on a high-definition (HD) map that needs constant updating. But with AGI, an autonomous vehicle (AV) that can drive in London can also drive in San Francisco or Beijing with its generalised learnings applied from one city to another. "Waymo can only drive in a few places like Phoenix or San Francisco," says Zhou. "If it goes somewhere else, it won't work. The power of the new AI technologies is totally different and gives us the potential to drive everywhere."

It also means there's no need for an HD map, which has been one of the unique selling points of DeepRoute.ai's self-driving system. "You would need to hire thousands of people just to maintain these maps, and you would need to cover everywhere—Europe, the Americas, China. It's simply not going to be possible. AGI is the way to Level 5 autonomous driving, as well as to robots," Zhou proclaims.

Cerence's Chat Pro leverages a multitude of sources, including ChatGPT

Data is the key

Zhou, who has led autonomous driving projects at Baidu, Texas Instruments, and DJI, suggests cars are the starting point for a wider evolution within all of robotics. Specifically, they represent the first kind of robots that will exist in the tens of millions of units. Hedges and Company estimates that there are about 1.5 billion vehicles on the world's roads today. Over time these vehicles will inevitably be retired and replaced by highly automated or fully autonomous vehicles. These vehicles will produce enormous amounts of data about the physical world, which can be harnessed to further train and iterate on the AI algorithms. "You need to collect more data and train your models," he says. "There's a lot of work to be done, but data is the key."

The learnings can feed into a foundation model that could be easily transferred to other robots' scenarios. And in the opinion of many industry players, cars are indeed becoming robots. In his 2024 GTC keynote, Nvidia Chief Executive Jensen Huang asserted, "Everything that moves will be robotic–there is no question about that. And one of the largest industries will be automotive."

As Zhou explains, "The foundation AI model that we train is based on the data we collect from cars. It could benefit all robots. In the past,

> **The power of the new AI technologies is totally different and gives us the potential to drive everywhere**

robots were built for a single purpose, and that purpose would need to be defined. But we're moving towards this new approach in which there is no need to input a specific definition for the robot task. If these models work for autonomous driving, they should work for other robots."

The starting point

One of the most important aspects of training these AI models is the need to understand the physical world. "There needs to be common sense," says Zhou. "The AI needs to understand distance, humans, how vehicles work–for instance, that they don't drive on top of a fence. We believe the common sense in these neural networks will eventually be transferable for other tasks, and the best place to start is with autonomous cars."

In 2021, DeepRoute.ai launched a production-ready autonomous driving solution that does not rely on HD maps. That same year it also launched a robotaxi service, concentrated in the central business districts of Shenzhen. It is currently working with a Chinese automaker on mass production of smart driving cars and at least three mass market car models are expected to debut later in 2024. As these and other similar systems appear in vehicles, they can feed into the foundation model, which can be migrated to other forms of robotics thanks to the move towards what Zhou calls 'AI 2.0'. As he emphasises: "We really see the power of the new AI; it's not like traditional AI. Up until last year we were trying to enter the data and train the models, but we realised we simply couldn't solve the problem that way. Using this new architecture, we solved it. This new technology should be able to migrate for all robots. The era of robots is coming."

And the timeline? Zhou suggests that within the next five years the world could see "a lot of general robots" across various applications. As for the "era of robots", that could be another ten years, but he emphasises that "it will definitely happen."

SDVs will be enabled by "deep integration" of generative AI

Generative AI could shorten software development cycles while also creating distinct, hyper-personalised customer experiences. By Stewart Burnett

Software-defined vehicles (SDVs) promise to transform the mobility landscape but realising them is no easy task. Even the launch of vehicles with partial software integration has proven rocky. For example, Volvo Cars stalled the launch of its EX90 SUV by almost a year due to problems with software development. The vehicle will finally ship in Q4 2024, albeit with fewer features than initially expected. For Volkswagen, software development has proven highly expensive. In addition to the US$13.3bn it has poured into wholly-owned software firm Cariad—only to be racked with numerous delays to vehicle launches—it has also invested US$5bn into Rivian to develop an SDV platform.

Clearly, automakers need all the help they can get, and there are many companies looking to pitch in solutions. Technology services firm Tata Elxsi—part of the wider Tata Group—believes the deep integration of generative AI tools will be crucial for any automaker looking to be competitive within the emerging SDV space. Many automakers have already experimented with generative AI in areas such as vehicle architecture prototyping. However, Tata Elxsi wants to see the technology implemented not only throughout software design at the coding and

> **Any application that is required to interact with the vehicle absolutely needs to be handled offline**

validation levels but also in a range of customer-facing applications.

Establishing the foundations

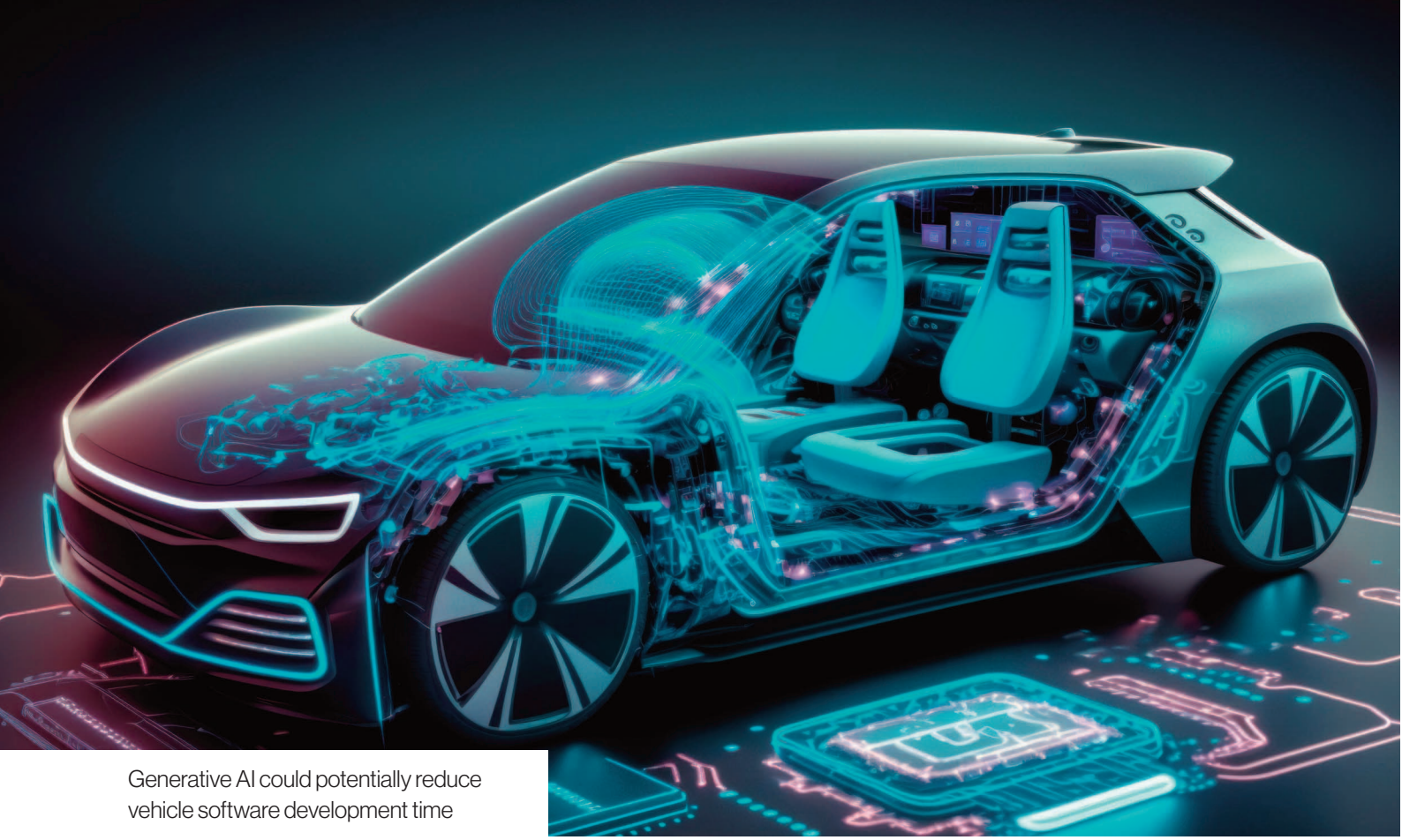
"At Tata Elxsi, we are putting in a lot of effort to help our workforce and automotive clients get ready for generative AI and SDVs," Biswajit Biswas, Chief Data Scientist at Tata Elxsi, tells Automotive World. Regardless of application, the journey towards generative AI integration begins with laying out extensive groundwork: "This is an important transformational tool, but it also requires quite a lot of different pieces to work effectively."

The first step is to bring in large language models (LLMs) alongside other types of AI–typically under lease from major tech companies–to conduct the fundamental task of generation. LLMs, for instance, can generate everything from written content to programming code. However, all of these require a significant amount of computing power to function. As such, Biswas recommends also implementing "Vehicle Foundation Models" (VFMs), which are specifically targeted for SDV vehicles. VFMs are core building blocks for SDV co-pilots that can aid in every process of the design lifecycle.

It is crucial to supply the LLM with an "enormous" amount of training data so that it can generate contextually relevant and useful results. This may require some work beforehand to convert data into compatible file types. Some data–such as real-world vehicle use, including the owner's sensitive personal information–will require the careful navigation of regulations, especially if transported across borders.

Transforming vehicle design

Once these fundamentals have been set in place, a wide variety of development tools can be implemented. "With the right tools, you can fine-tune generative AI technology to make vehicle-specific resources," remarks Biswas. These can be developed internally or outsourced from other companies. Tata Elxsi, for example, offers tools for coaching autonomous driving, as well as an SDV development and validation



Generative AI could potentially reduce vehicle software development time

framework called Avenir, which automates the process of software testing and interoperability, and according to Khan, "can accelerate the SDV journey of OEMs and tier ones".

Given the recent struggles of automakers to develop software in a timely manner, however, the most promising use of generative AI could be automatic code generation. While this could be done via a text-based prompt, Tata Elxsi believes it should be as intuitive as possible. "If we are using voice-enabled features for customer-facing applications, we can also use them to allow engineers to interact with the systems they are developing. This is far better than developing everything from scratch," states Jihas Khan, Practice Head, Virtualization, Tata Elxsi.

He adds that this approach would save a "lot of cost and effort" for automakers and Tier 1 suppliers. At the same time, it relies on pre-existing software code and so may not be a viable tool for companies just getting started on their journey towards SDV development. The more plentiful and diverse the training data, Khan emphasises, the more useful the resulting code will be. While a human engineer is generally expected to intervene in this process by reviewing the resulting generated code, this could also be automated using LLMs. "The generative AI frameworks can be utilised for review of the source code, and then we can also use LLMs to generate new codes within the given requirements."

Better customer experiences

Looking to the future, Biswas believes that generative AI could allow consumers to actively participate in the design of their SDV, from physical hardware and aesthetic features to the software capabilities it ships with.

> **These cars are going to be data centres on wheels, and that means many more monetisation options with generative AI**

"People will have the option of using an app to generate designs of their car and select all the features they want. In this case, we're also leaning towards increasing the use of digital twins." This could be of particular interest to Gen Z, a demographic he believes wants to actively shape and experience the products it uses before they are physically produced.

Beyond vehicle design, generative AI finds a range of applications within the driving experience. The most notable example is integration with the voice assistant to enable responses to nuanced or subjective queries–for example, "What is the closest restaurant that offers food I like?" However, Biswas is also a proponent of using the voice assistant for applications beyond driver comfort. By integrating the vehicle's user manual into the LLM's training data, the driver could troubleshoot in real-time. "You can check with your copilot and ask about the nature of a blinking light on the dashboard or the potential causes of a weird noise coming from the engine."

One potential issue with generative AI in customer-facing applications is the need for constant cloud connectivity. Khan notes the importance of automakers integrating 5G SIM capabilities into their vehicles at higher levels. However, even in this eventuality, there will still be connectivity dead zones. Biswas recommends that automakers try to integrate as many core generative AI features–such as the ability to relay information from the user manual–into the vehicle itself as possible. "Any application that is required to interact with the vehicle absolutely needs to be handled offline."

Ultimately, the goal for automakers is to reduce development costs while creating avenues for recurring revenue streams. Beyond voice assistants, this could mean instantly customisable infotainment user interfaces and the provision of highly tailored media content. Biswas concludes that generative AI will become invaluable for introducing new, software-driven opportunities even as the cost of physical vehicle hardware– most notably electric vehicle batteries–increases. "These cars are going to be data centres on wheels, and that means many more monetisation options with generative AI. It is one of the most promising ways to create new sales after that initial vehicle purchase."

Automated ADAS testing will take autonomy into the future

ADAS functionality is increasingly shaped by software, and automakers will need thorough testing methods to ensure their vehicles are safe. By Will Girling

"Sometimes ADAS' goal is to mitigate a collision rather than prevent one," says Andrew Pick, Director of Track Test Systems at AB Dynamics

Advanced driver assistance systems (ADAS) of various complexity are becoming increasingly common in the automotive industry, and this has made thorough scrutiny imperative. In the US, the New Car Assessment Program (NCAP)—a consumer guide that rates cars based on their safety profile—has been testing ADAS since 2009 and continues to examine how its metrics can be updated as the technology itself evolves. Other regional NCAPs, including China and Europe, are now similarly committed.

SAE Level 2 ADAS currently includes core safety functions like impending collision detection and prevention. However, some industry analysts contend that many of these partial autonomy systems currently offer limited to no real-world safety benefits. In fact, the US National Highway Traffic Safety Administration attributed 367 traffic collisions to ADAS between July 2021 and March 2022.

Meanwhile, software-defined vehicle architectures enable automakers to expand autonomy beyond core safety to more advanced functions, including lane keeping assist and adaptive cruise control. The danger is that widening the operating domain while even relatively simple functions are far from perfect risks alienating industry stakeholders, whose trust has been repeatedly shaken by bad press. To rebuild and expand that trust, reliable testing has never been more important.

Gathering ground truth data

Andrew Pick, Director of Track Test Systems at AB Dynamics, tells *Automotive World* that ADAS testing cannot be conducted on public roads because of the inherent safety risk. Nevertheless, OEMs need "ground truth data" upon which they can validate system integrity. As such, AB Dynamics manufactures test objects for proving-ground tracks based on common real-world road hazards, including pedestrians and motorcycles. However, in a rapidly evolving market, this just provides the baseline.

"The main difficulty automakers face is the sheer volume of tests, combinations, and permutations they need work through," says Pick. This applies to every single model equipped with ADAS, and each regional market will have its own specific test requirements. To manage this complexity, AB Dynamics has been developing an extensive protocol library in an attempt to simplify and automate what is otherwise a costly and time-consuming process. A June 2024 update to its Track Applications Suite added 237 tests for China NCAP, 60 for the EU General Safety Regulation, and 120 United Nations Economic Commission for Europe protocols. "In total, our database now spans more than 1,000 test cases."

Thanks to artificial intelligence and machine learning, sensors are becoming more discerning, meaning tests must be similarly sophisticated. Repeatability and realism, continues Pick, are the crucial goals. The protocol database factors in information both about the vehicle tested–for example, specific dimensions or layout geometry that could affect response–and the objects used. "If the customer can define exactly what they want, we can make it happen reliably on the proving ground. The realism comes from the test objects themselves." AB Dynamics' test objects have identical radar signatures and comparable movement to what they replicate: "That includes the motion of pedestrians' walking legs or turning heads," he explains.

The value of automated testing

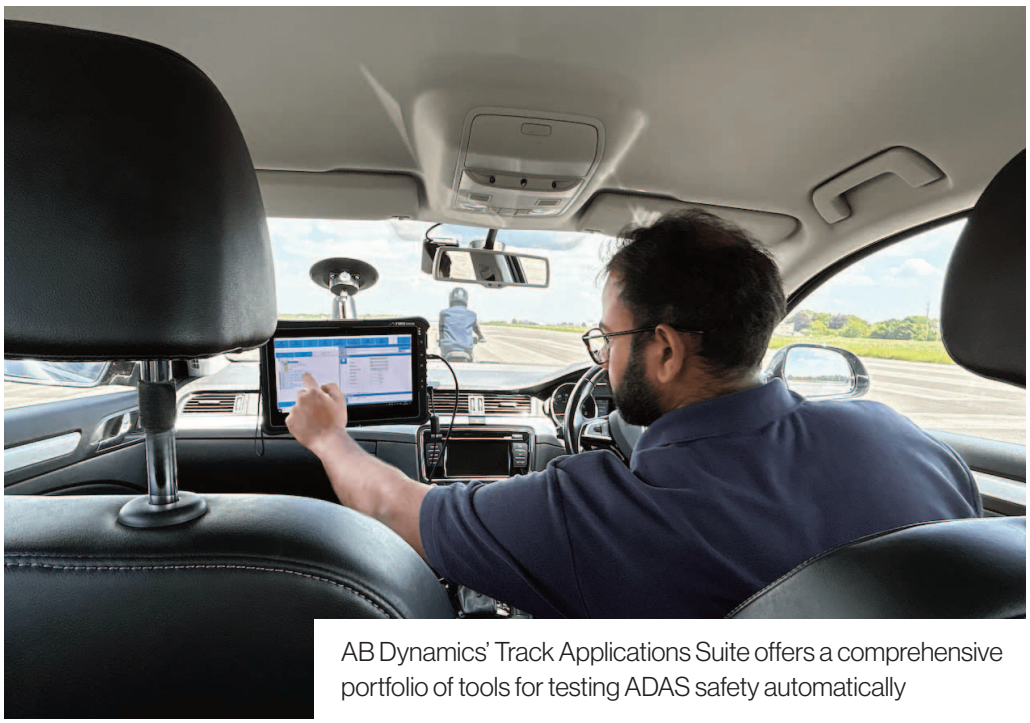
During a test, vehicles are controlled by AB Dynamics' range of driving robots–steering, pedal, and gear change automation–instead of human drivers. An automaker's selected test protocol then defines the speed and relative positioning of the vehicle and other objects during the scenario at a coordinated 'point of interest' on the track. This is where the response of the ADAS feature in question will be assessed. Aspects of the scenario can be adapted by automakers in real time according to their requirements.

"Because we're in complete control of the ecosystem, we can also manage the results by post-processing test data to compare how well ADAS performed against KPIs," says Pick Typically, this means measuring the time gap between a collision warning and the system taking action, such as applying the brakes, or recording the impact speed if a collision occurs. "Sometimes ADAS' goal is to mitigate a collision rather than prevent one," he clarifies.

AB Dynamics claims that the repeatability of automated ADAS testing using driving robots is much superior to human testing. "People just aren't capable of the same consistency: a driver could get the pathway, braking rate or speed right during a test, but getting all three perfect simultaneously is really tough," Pick states. "A single successful test run could take six or more attempts." Comparatively, robotic drivers are able to perform strings of consecutive test protocols flawlessly and in a matter of minutes.

Advancing ADAS with software

As vehicle autonomy advances beyond Level 2, the number of variables in a test scenario increase significantly. In addition to coordinating test objects and providing a library of preconfigured test protocols, AB Dynamics' Track Applications Suite includes a Scenario Generator that can import previous test data and reshape it in simulation into any conceivable scenario. Pick notes that this tool can be used to establish a virtual baseline for new ADAS functions in a safe digital environment. It also provides a data foundation for validating those simulated results in future real-world testing.



AB Dynamics' Track Applications Suite offers a comprehensive portfolio of tools for testing ADAS safety automatically

While Level 4 autonomous driving systems exist in a limited capacity, ADAS technology is far from reaching its peak in the mass market. According to MarketsandMarkets, global ADAS hardware production is expected to almost double from 334 million units per annum in 2024 to 655 million units in 2030. At the same time, mainstream automakers like Mercedes-Benz and BMW are both exhibiting Level 3 systems—Drive Pilot and Personal Pilot, respectively—and validating safety is only going to become more complicated. Pick emphasises that the testing equipment industry must be prepared to move in step with these advances.

"New ADAS functionalities are increasingly defined by software," he observes. "As acceptance for these technologies builds, the limit of their previous operating domain can be expanded." Companies like AB Dynamics will have a vital role to play in proving to regulators and consumers that this advancement does not come at the cost of safety. Pick suggests that future ADAS test scenarios could include objects in blind spots and upcoming hazards obscured by blocked sensors.

Software-defined ADAS could unlock billions of dollars in added value. However, with a limited pool of talent from which they can draw, automakers may need to build ecosystems that incorporate software developers from Big Tech. While this could enable faster R&D, these workers will need to be familiarised with the core parameters and data around which they can iterate new ADAS features. In this way, Pick concludes that the testing industry will be crucial for bridging automotive and tech. "Software developers like to be agile, and automakers want to validate vehicles as quickly as possible. We can help them both work in exactly the way they want."