Capgemini engineering

ASSISTED DRIVING

The engineering behind the new automotive business model

INTRODUCTION

Driving automation takes many forms: warning functions, active safety functions, and conditional driving automation through to fully autonomous vehicles. A third of new cars already have some form of assisted driving.

SAE International (formerly the Society of Automotive Engineers) classify ADAS (Advanced Driver Assistance Systems) in six levels, relating to both the feature capability and what the driver needs to do. These levels represent the progression that automotive companies are working through.

Level 0 means no automated vehicle control. Level 1 and 2 functions – such as Adaptative Cruise Control or Lane Keeping Assist – assist the driver but require continuous "Eyes On" and "Mind On". A new category, L2+, was introduced in 2018 which combines sensors and precision map data to support lane keeping and changing in more complex scenarios such as poor road markings and roundabouts.

Level 3 will let the vehicle make some decisions such as changing lanes but drivers must be ready to step in. Level 4 involves autonomous driving under limited conditions such as a robo-taxi in a specified area designed to accommodate it. Level 5 is fully autonomous.

Progressing through these classifications involves mastering the interaction between the driver, the vehicle and the operational domain of the ADAS feature.

These systems will be hard to develop, but once cracked they will become key differentiators for customers. Once developed, they represent high-margin/low-overhead offers which can be sold or leased virtually. Tesla already has a significant revenue stream from selling assisted driving add-ons post-sale.

But getting there presents technical, organizational and regulatory challenges.

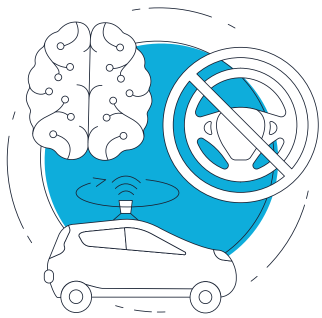
The technologies required to develop Assisted Driving (AD)/ADAS will require ecosystem transformation. Automotive companies are used to building high-value scalable services, but a key element of ADAS is software and OEMs are having to build whole new roadmaps and organizational structures to develop software-driven AD systems. This creates new roles for cloud, semiconductor, and software providers, upending well-understood supply chains. It creates needs for new engineering and IT partnerships to ensure the cost of investment in new areas vs value generated is kept under control.

The pace of innovation is also changing. The technological capabilities of ADAS systems advance rapidly, meaning – thanks to the possibility of over-the-air updates — innovation cycles happen during the life of the car. Companies like Tesla increase after sales revenues by proposing upgrades to AD systems.

An additional driver of change is regulation. For example, the Global Safety Regulation (GSR2) will require all registered cars from July 2024 to include features such as Pedestrian and Cyclist collision warnings, Emergency Lane Keeping Assist and others. These will contribute to the development of ADAS.

AD brings a new paradigm to automotive companies, adding complex layers of software and new technologies into highly engineered systems. Getting this right means adding new business lines, technologies, supply chains, capabilities, and skills – integrating data and digital technologies into the physical world of automotive engineering. This is a fine balance.

This paper will take a top-level view of what a successful end-to-end ADAS development capability looks like, and outline the major challenges that need to be overcome to get there – covering ecosystem, data, software, and safety – to create a desirable customer experience and so generate new revenues.



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56
MPH
20.0
MENU
SYNC
AUTO
A/C
PASSENGER AIRBAG
autonomous
4x4
P
R
N
D/S
MODE
OFF ROAD

1. ACCELERATING ENGINEERING & DEVELOPMENT OF ADAS FUNCTIONS

Today, basic AD features such as collision prevention, parking assistance, lane assist, maintaining a safe distance, or emergency braking are mandatory, and considered 'must haves' by many. Soon, Level 3 and beyond will delight customers with scenario-specific automation. These AD products will eventually become interconnected tools at the disposal of increasingly 'intelligent' driving systems.

Delivering these functions relies on a new set of physical technologies being deployed onto vehicles to allow them to monitor their surroundings, including cameras, lidar and radars, ultrasonics, and GPS. These will form the car's 'eyes and ears' as it moves up through the autonomy levels. These need to be of sufficient quality to allow data acquisition to feed into the AD software (see next sections). Driver monitoring systems will also become widely deployed massively in the next years to learn about driver attention in the face of new AD systems.

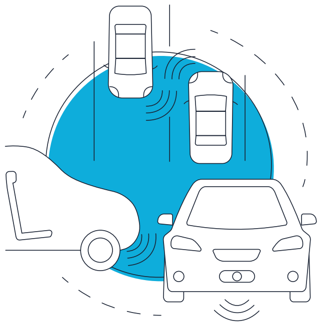
The other physical side of AD is a vehicle control system which can take instructions from the AD software (run left/right, etc). Behind the decision layer, actuators perform actions on the physical driving components (steering, powertrain, braking, etc). These components must also be equipped with sensors which feedback into the AD model – to validate that the instructions are being followed and monitor for any unexpected results that deviate from the AD instructions (which may necessitate a human intervention or safety backup). As you develop more advanced automated driving systems, you will be able to upgrade the software over-the-air.

The data that drives innovation

Data is the fuel of the development process, especially as the level of automation increases. To understand and model different systems that respond to different driving scenarios, road conditions, and corner cases, companies will need vast amounts of data collected from high-grade sensors on fleets of test vehicles, as well as third-party sources such as maps and weather. Worldwide data must be collected to master the diversity of local driving context, and provide safe and adapted services. This data represents the inputs for AI-based algorithms that will ultimately make real-world driving decisions, and for verification and validation.

All of this amounts to a huge volume of data that needs to be stored and managed – we expect daily data collection for R&D to be in the petabytes range. Many companies are investigating the new notion of what we call the "Augmented Hybrid Database", which involves engineering companies capturing physical and virtual data on their vehicles, which are then augmented by advanced tools for data management and virtualization provided by tech vendors.

All of this presents many new challenges related to the transport and the storage of a huge amount of data, as well as the management of that data, which must be of a quality and consistency to train AI algorithms, and to validate ADAS systems.



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Overcoming AI & software complexity

Sitting behind the physical systems will be complex AI algorithms, wrapped in complex software, that take input from the sensors, make decisions, and provide instructions to the actuators. It's the digital equivalent of a driver seeing an obstacle, deciding the best course of action, and then applying steering or braking to respond. Whilst the human brain does this quite naturally, training AIs to do it represents complexity unprecedented in most industries, let alone in traditional engineering sectors like automotive. Even simple AD systems contain thousands of lines of code – more than military aircraft automation systems. Levels 4 and 5 will need millions.

But developing such AI requires a large amount of good-quality data. Collection from test vehicles has been discussed above. That needs to feed into digital twins of the vehicle and simulations of environments. And data needs to be representative of the real-world driving environment which means a rigorous fine tuning of the virtual models and scenarios to be able to generate realistic behaviors.

This needs significant computing power shared between on premise computing centers and cloud computing. This optimized hybrid architecture will need to consider many criteria for computing distribution such as cost, project planning, data transportation constraints and so on.

In this context, Cloud providers will be needed to provide the digital space in which to innovate, but they may not have the engineering domain skills to serve OEMs. Meanwhile, internal engineers and Tier 1s may have the skills but not the digital know-how. To bridge this gap, development teams will need to reinvent themselves with hybrid profiles: a combination of engineering and IT.

Systems engineering

The many software and hardware platforms within the car need to be connected up seamlessly, to ensure inputs produce the right outputs. Ultimately, we are mapping the whole digital vehicle system onto the physical vehicle, so that it can recognize complex real-world scenarios and make the appropriate physical response by applying steering, braking, or accelerating in the right proportions. This represents thousands of subsystems that must all work together. System engineering is needed to manage this development complexity.

Designing such a complex digital and physical system-of-systems needs a new approach to engineering. This will mean embracing a new set of digital design tools that allow these engineering systems to be mapped, tested, and modelled in silico.

Tech vendors provide many of the answers through new digital systems engineering platforms. But the real challenge will be choosing the right ones, and integrating these into OEMs diverse legacy systems, where there are already many overlapping tools. Digital transformation inevitably comes with collateral damage in terms of delays whilst people get used to new systems. But these tools are critical to this new world of physical and digital engineering.

There is therefore a need for a clear strategic direction and a joined-up approach to selecting and deploying the tools of systems engineering and digital continuity, to reduce the risk that many overlapping tools will stifle the ability to innovate collaboratively. This requires a rigorous process, investment, configuration management, and traceability.

While this is critical for all manufacturers, the path here is easier for newcomers as they are not dependent on legacy systems and can build their approach around the needs of digital products.

Software engineering architecture

The output of AD development is pieces of software that will be integrated into vehicles. These must be reliable, robust, and easy to upgrade – with safety at the forefront.

Developing such software will require setting up a new "Service Oriented Architecture" for software engineering – within the new digital systems engineering setup described above. This is a software architecture that allows lots of different components (or services) – such as computer vision, actuator controls, or security protocols – to be accessed and reused by many different business applications. So rather than building each new software product from scratch, users can access proven components - either off-the-shelf, or those developed for earlier or alternative versions – and use them as a basis for the new product.

A service-orientated architecture is a strategic cross-domain area for OEMs, which will enable teams to collaborate and innovate more rapidly, and release and deploy updates more quickly. But it needs to be carefully setup to ensure adequate compute power for advanced software engineering, suitable modularity to enable teams to innovate, and adequate safeguards to ensure safety in an environment of rapid innovation. And of course, in all of this, choices need to be made around the architecture design to ensure the cost is proportionate to value.

Key considerations

- Take a whole system approach to developing an AD function, starting with objectives and building the solution.
- Understand long-term vehicle needs and specify required technological capabilities at the design stage.
- Define what is expected from the system upfront and feed this into software design.
- Map the sensors, actuators and compute you will need to deliver your AD plans. Install the ones you need to deliver immediate value, whilst leaving open the possibility to easily retrofit new or upgraded versions in future.
- Map potential suppliers of new technologies and establish new supplier ecosystems.
- Work with suppliers to acquire and integrate leading-edge technologies, such as perception algorithms.
- Build and test AI models and simulations using data collected from sensors.
- Ensure software is performant – the algorithm needs to answer the input from cameras with over 99% accuracy. Be prepared to check every line of code.
- Develop supply chain and cost models, considering a full range of purchase and pay-per-use options, to de-risk complexity around acquiring new technologies.
- Evolve traditional automotive engineering principles and tools to integrate fast-evolving digital components in software architecture.


Autonomous Mode
Speed: 46 km/h
Arrival: 13:25
Time to Dest: 0:14
RADIO
MEDIA
TRIP
RESET

2. CREATING TRUST OUT OF COMPLEXITY

Capgemini Engineering has run more than 4M KM for ADAS data collection in over 60+ countries.

Even with good engineering, people will take time to trust AD. The idea of a car making decisions will feel alien. Even if systems are safer than humans, people overestimate their own ability and are not good at making rational judgements about data. Rare incidents are likely to get outsized media attention.

OEMs need to build trust. This means rigorous testing and validation before assisted and autonomous systems are put in the hands of users. Beyond meeting industry regulations, OEMs need to show they have met their own high safety standards, both to provide data-baked assurance to users, and to avoid the possibility of incidents that will undermine trust. The more users see AD working well, the more willing they will be to accept (and pay for) the next step as it arrives.

Validating AD systems

Testing is familiar to automotive. Mechanical testing of brakes, crumple zones, corrosion etc – which follow well-understood rules of physics and chemistry – are all well-established processes.

Testing AD is different. The AI behind the system has 'learned' a complex range of overlapping scenarios. As it learns, it creates hugely complex rules for itself. It is very hard for a human to dig into this model, analyse it line by line, and understand whether it will behave in the right way. So the vehicle needs to be put into a wide range of scenarios and its performance monitored to ensure it consistently drives according to high standards of safety. Such standards are starting to be established formally but considerable internal work is still needed to develop adequate Verification and Validation (V&V) and vehicle homologation. The route to trusted and safe autonomous mobility remains challenging.

It is crucial for automakers to prove full traceability of requirements through test cases in all relevant scenarios, which must be derived into hardware and software.

In an ideal world, we'd test the vehicle in wide-ranging real-life scenarios and make changes where it underperformed. And some testing will indeed need this – in fact Capgemini Engineering has run more than 4M KM for ADAS data collection in over 60+ countries.

But doing everything in the real world is cost prohibitive. Road testing costs about €3-€10 per kilometer. That's a

AD and sustainability

A challenge sometimes noted of AD is that it needs a lot of data storage and computing power, and a new generation of hardware. Those create energy and materials needs. In the short term this puts AD at odds with sustainability goals. However the bigger picture is much more positive for the green agenda, for two reasons:

1. AD will inherently reduce emissions by making driving much more energy efficient, for planning efficient routes, adopting efficient driving styles and using the powertrain in optimal ways.

2. Autonomous mobility will eventually offer low cost shared transport that will reduce the need for private vehicles.

lot of road-testing time and money even to test every emergency braking scenario. It will be a lot more to test fully autonomous vehicles.

So, the challenge for V&V is optimising the process and managing cost. Mostly this means moving as much as possible into simulation.

AI should be applied to data collected from sensors on vehicles in the wild, to generate digital twins of real-world driving scenarios, then aspects of different twins should be combined to replicate the unpredictability of the natural world. The vehicle can then be 'driven' in these scenarios, using so called 'Software in the loop' and 'Hardware in the loop' testing, whereby first the software model and then the real components are run in a simulated environment, and performance monitored.

Where this works perfectly and consistently, we can say with confidence that there is little or no need for real world testing. Where there are 'corner cases' – scenarios when a system is unstable or on the limit of safety / functionality – we will need to move to open road testing to learn more and validate.

This may get easier. Once connected cars with all the right sensors are on the road, they can also be used to validate beta versions of new AV functions. These can run in passive mode, making decisions that are not executed, and comparing them to the human driver response. Once the testing is complete, it can be activated over the air.

All V&V will be iterative: testing, improving, and re-testing until we are sure it all works. If braking is too sharp on one scenario, it goes back to Autonomous Driving engineers to adjust, then we run the scenario again, moving towards our safety verification criteria. We can even build AIs to analyze responses and figure out where we need to do extra testing.

Key considerations

- When specifying the system, generate a validation plan that covers all things you expect it to deal with in real life – which will vary by vehicle and country – and see it through to test execution and reporting.
- Harness the full range of scenario models available to put AD systems through their paces.
- Leverage cloud hyperscalers to ensure adequate storage and data infrastructure to run simulation programmes and manage validation data.
- Build a detailed understanding internally on new and evolving regulations. (GSR2 is not specifically relevant to testing as it relates to feature requirements, not validation targets). Carry out a gap analysis between your current approach and requirements, integrate documented rules into V&V processes, and appoint people responsible for ensuring compliance.
- Communicate rigorous testing processes clearly to customers (e.g., kilometers driven without an incident) to build trust.

Building such AD teams will need whole new skillsets – the same skills all industries are fiercely competing for.

3. CREATING A CULTURE FIT FOR DIGITAL INNOVATION

To build and maintain these intelligent systems for the long term, the automotive industry needs to embrace new ways of working, cultures, and skills, and to do so in a way that does not undermine its existing engineering capability.

All of this also requires a whole new raft of technologies to be specified, bought, and integrated, which will mean new supply chain ecosystems set up and mastered. The traditional automotive approach of working with Tier One suppliers will need to move to a more complex ecosystem to ensure these new technologies are accessible.

Building such AD teams will need whole new skillsets – the same skills all industries are fiercely competing for. Manufacturers will need to identify the skills they need and begin training programs of their engineers.

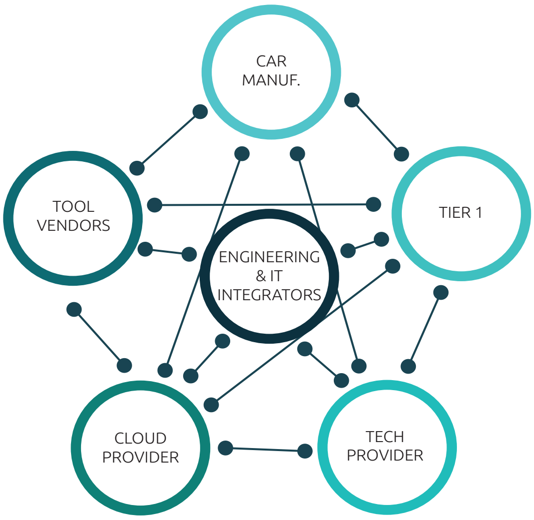
This means recruitment, training, and partnerships. Automotive manufacturers need to ramp-up the acquisition of new skills in areas such as software, AI, and DevOps. This will inevitably involve harnessing the vast talent around the world including remote, onsite, offsite, near-shore and offshore capabilities – a style of working that may be new to organizations used to physical factories. This in turn means setting up cloud-based platforms for building AD systems, which foster collaboration and ensure traceability in the development cycle.

However, recruitment alone will not solve the problem. There is currently a 1.4 million shortfall of software developers worldwide, and stiff competition for talent with high paying tech giants. To deliver quality AD systems, OEMs will need to upskill their existing workforce from traditional engineering areas to new digital disciplines.

Reskilling is now essential in domains like V&V, system engineering, software development or electrical and electronic. Reskilling also has the added benefit of bringing deep industry experience of automotive engineering onto AD teams, to complement the new digital and data skills being recruited from other industries.

AD development and validation teams will likely bring together lots of diverse skills from different, geographically diverse teams, many of them non-traditional automotive skills. They will need to be flexible, and react quickly to changes throughout the product development life cycle.

Companies must find a good balance between corporate processes and an agile mindset. They will need to adopt agile methodologies, transforming the classical rigid system-engineering based development process into a more agile data-driven development and validation process.



Key considerations

- Develop plans to identify required skillsets aligned to need
- Cast your net wide in global recruitment to find the right skills
- Set up technology systems, flexible working practices, and cultural integration programmes that are practical and attractive for a global talent pool
- Develop upskilling programs to transition exiting engineers to AD teams
- Embrace agile working practices

CONCLUSION

Assisted driving is a big opportunity. Getting this right will make driving safer and more reliable. It will create big opportunities for carmakers to sell high-value digital products, whilst capturing valuable data.

Most OEMs are already on this journey to digitalization, building software-driven business units, and forming relationships with technology partners and cloud hyperscalers.

But many want to move faster, having seen opportunities for first mover advantage, but also intense competition from their peers. They need to innovate rapidly, whilst also optimizing costs, and being rigorous when it comes to safety – a challenging combination to navigate.

As they progress, they will need to manage an ever-growing ecosystem of partners who can help them access skills, technologies, and testing. Many of these potential partners are already there and ready to support, with new technologies and thinking emerging all the time that could present an advantage. For all the recent progress, we are still just at the beginning of this journey and there is all to play for.

How Capgemini Engineering can help

Capgemini partners with automotive innovators across the globe to help them win the ADAS race. We provide solutions including function and software development, system architecture development, partnerships with hyperscalers to manage large-scale data collection and analysis, a fully automated V&V platform (simulations and real-world), and a wide range of training to upskill engineers in digital capabilities.

About the author

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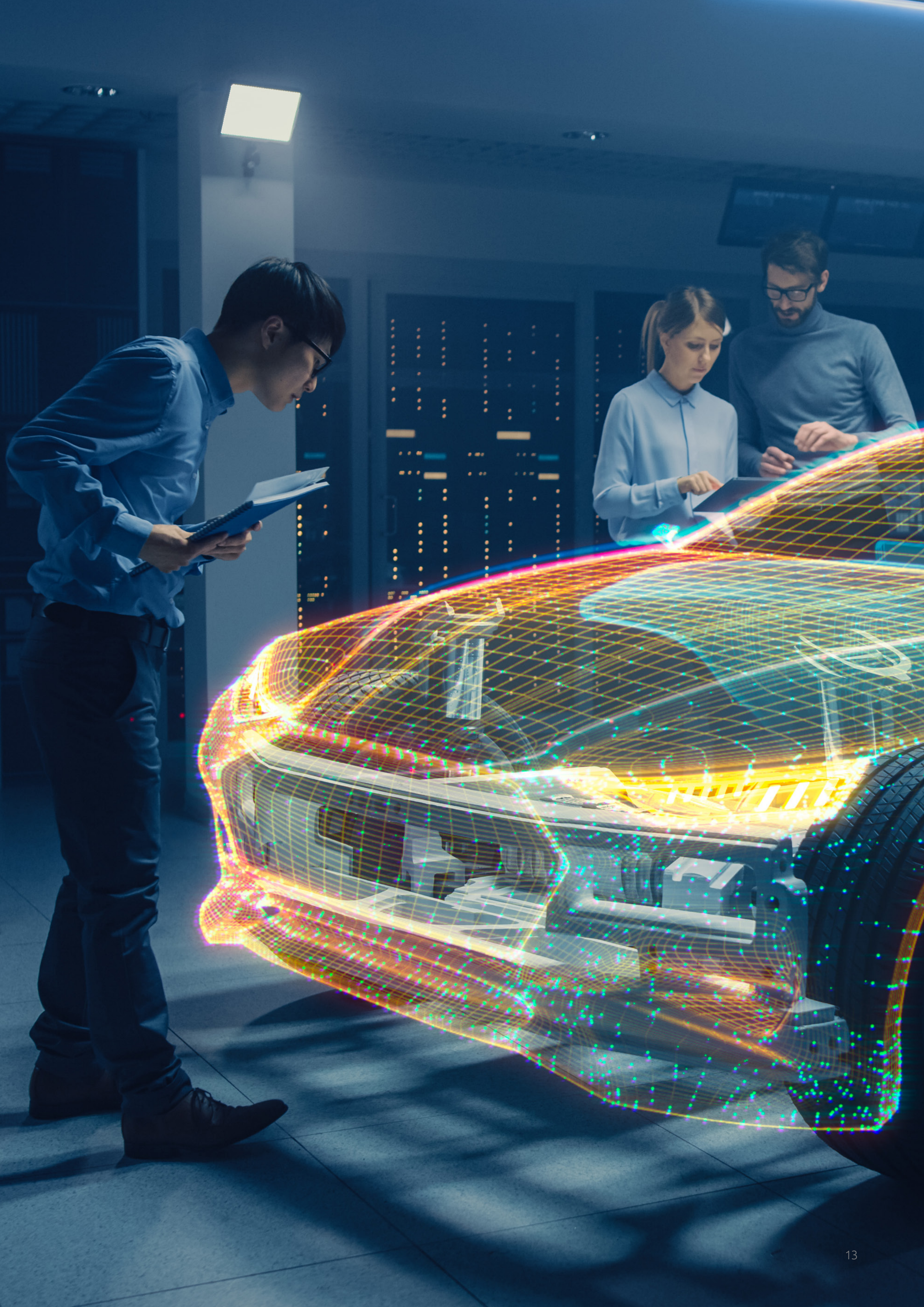
Oussama Ben Moussa is the founder of the group's ADAS academy, a training and skill development structure that addresses the needs of dedicated specialists to design ADAS and autonomous cars. He has applied for more than 10 French and European patents related to energy storage, engine performance, depollution, driver comfort, and innovative driver assistance systems.



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About Capgemini Engineering

World leader in engineering and R&D services, Capgemini Engineering combines its broad industry knowledge and cutting-edge technologies in digital and software to support the convergence of the physical and digital worlds. Coupled with the capabilities of the rest of the Group, it helps clients to accelerate their journey towards Intelligent Industry. Capgemini Engineering has more than 55,000 engineer and scientist team members in over 30 countries across sectors including Aeronautics, Space, Defense, Naval, Automotive, Rail, Infrastructure & Transportation, Energy, Utilities & Chemicals, Life Sciences, Communications, Semiconductor & Electronics, Industrial & Consumer, Software & Internet.

Capgemini Engineering is an integral part of the Capgemini Group, a global leader in partnering with companies to transform and manage their business by harnessing the power of technology. The Group is guided every day by its purpose of unleashing human energy through technology for an inclusive and sustainable future. It is a responsible and diverse organization of over 340,000 team members in more than 50 countries. With its strong 55-year heritage and deep industry expertise, Capgemini is trusted by its clients to address the entire breadth of their business needs, from strategy and design to operations, fueled by the fast evolving and innovative world of cloud, data, AI, connectivity, software, digital engineering and platforms. The Group reported in 2021 global revenues of €18 billion.

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