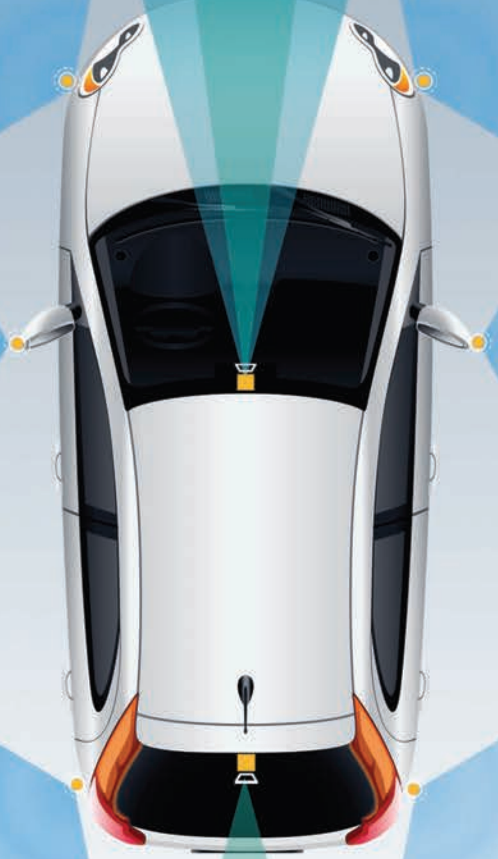
Navigating Toward Full Autonomy



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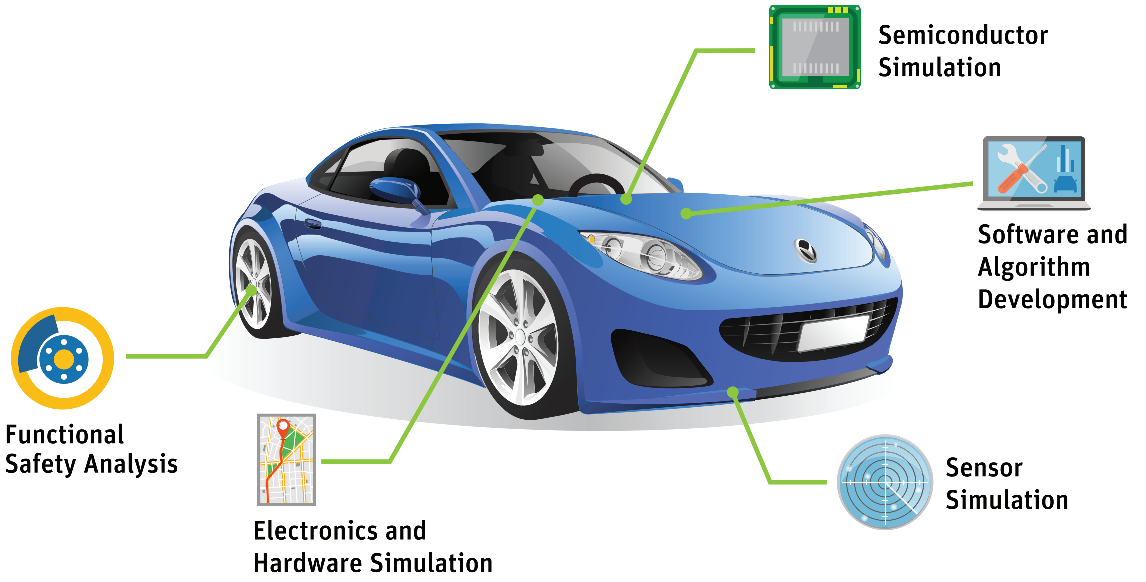
For many years, cars and aircraft have featured some degree of assisted or partial autonomous functionality that we have trusted, whether an autopilot or an advanced driver assistance system (ADAS) such as blind spot detection. Today, time to market is of the essence, and the race is on to achieve full autonomy. This represents a step change in both engineering complexity and applicable safety criteria. Since conducting road-testing over the billions of miles required to demonstrate safety is time- and cost-prohibitive, companies have turned to simulation as the only way to successfully complete an autonomous vehicle program.

Autonomous vehicles are proliferating, and not just in the automotive market. Companies like Amazon are investing heavily in drone delivery capabilities, while military organizations have utilized drone technology in combat situations for years. Manufacturers are using mobile autonomous robots in their production facilities, while transportation companies are developing tractor trailers that can run 24 hours a day, moving goods across thousands of miles quickly and cost-effectively. There is little doubt that autonomous vehicles are in our near future as consumers. However, getting there presents significant technology challenges for us as engineering professionals.



Critical technologies for autonomous vehicles

There are good reasons to be excited about this trend. Autonomous vehicles and drone delivery promise to practically eliminate the element of human error, which caused 94 percent of the record-high 37,461 highway accidents that occurred in 2016.[1][2] As the degree of autonomy increases, the probability of human error declines significantly. Fully autonomous vehicles, supported by artificial intelligence and neural network algorithms, will enjoy a continuous 360-degree view of their surroundings — and those algorithms will never take a break to text their friends.

If we can replace flawed human behavior with fail-safe autonomous control — while consolidating our transportation investments — it only makes sense to pursue full autonomy for cars, drones and other machines. However, before this can happen within the bounds of engineering certainty, a number of technology challenges must still be solved.

It has been estimated that demonstrating the safety of an autonomous vehicle could take over 8 billion miles of physical road testing.[3] In the race to achieve full autonomy, this is simply not practical. At the current rate of progress, road testing would take centuries to complete.

Engineering simulation is the answer, as it enables autonomous vehicles to be tested and verified in a risk-free, low-cost, time-efficient virtual environment. A recent safety report from Waymo — formerly the Google self-driving car project — described how its engineers are simulating the performance of a fleet of 25,000 virtual self-driving cars across more than 8 million road miles every day.[4]

Fast-Tracking Autonomous Vehicles, Drones and Robots Via Engineering Simulation
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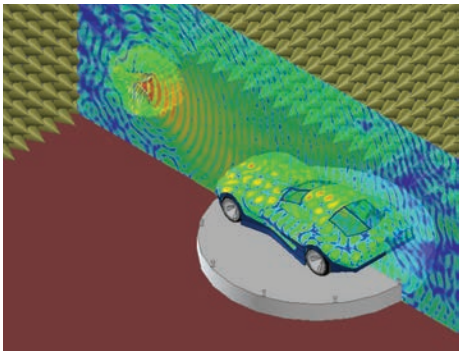
Demonstrating Safety Through Closed-Loop Simulation
At the highest level, these simulations must be able to capture the behavior of the vehicle in its environment. This can be characterized as a closed-loop simulation of the vehicle as it "sees," "thinks" and "acts," guided by artificial intelligence. The simulation includes virtual cities and roads, the sensors that function as the eyes and ears of the vehicle, the control software and algorithms that make critical decisions, and the vehicle dynamics, which are based on the instructions received from the software and algorithms. This simulation represents a continuous, closed-loop process through time, as the vehicle senses, executes and maneuvers through its journey.



Of course, these closed-loop simulations can only be considered reliable if they contain accurate representations of all the relevant components of the vehicle and its surroundings. There are five critical engineering capabilities that support an accurate virtual road-testing exercise:

- **Sensor design** based on the real-world conditions they must perform in
- **Semiconductor optimization** that balances high performance with risks such as electronics density and thermal build-up
- **Reliable electronics** designed to withstand actual operating environments
- **Safety-critical embedded software development** that integrates with machine learning and artificial intelligence components
- **Functional safety analysis** that minimizes the risks associated with component- or system-level failure

Each of these critical engineering applications is discussed as follows.

Reliable Sensors for Real-World Perception
Sensors are the eyes and ears of any autonomous vehicle, and thus are some of its most critical components. They are also among the most complex, tasked with gathering and processing large volumes of environmental data in real time and communicating this data to a perception algorithm. Common sensor types for autonomous vehicles include radar, lidar, cameras and ultrasound.

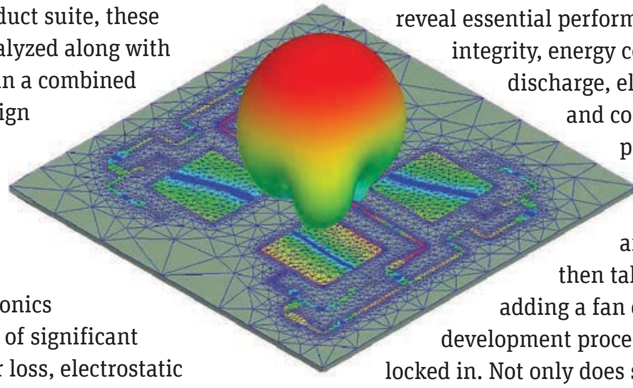
Testing and verifying the performance of the sensors represents a significant engineering challenge. For example, radar sensors are typically mounted behind the front fascia of an automobile. While perfectly controlled physical testing environments, such as anechoic chambers, can help engineers design these systems, the reality is that their radiation patterns will be skewed in real-world applications by the material properties and geometric configuration of a car's front fascia. To operate predictably and reliably on the road, radar systems must be designed to operate behind the front fascia of dozens of different types of vehicles, each with its own unique geometry and material properties. Physical building and testing is simply not practical due to the time and costs involved in each design iteration.

ANSYS offers a full suite of radar and antenna simulation solutions designed to replicate real-world performance with a high degree of fidelity. By leveraging ANSYS software, electrical engineers can predict sensor performance accurately — whether the sensor system is studied independently, mounted on a vehicle, placed into a static environment or studied throughout a fast-moving closed-loop simulation.

ANSYS also offers solutions for other sensor technologies, such as ultrasound, which is primarily used for parking assistance.

Optimizing Semiconductor Performance

ANSYS also enables the simulation of the semiconductor components that underlie radar systems and support signal processing. By leveraging the ANSYS semiconductor product suite, these semiconductors can be analyzed along with the surrounding circuitry in a combined chip–package–system design environment.



Semiconductors support much of the functionality of autonomous vehicles, yet the sheer number of electronics required can be the source of significant performance issues. Power loss, electrostatic discharge, electromagnetic interference, and thermal and structural stresses can all negatively impact product reliability and integrity. For example, a 25 C temperature increase typically leads to a 3-times to 5-times degradation in the expected lifetime of electronic devices.

ANSYS offers a number of specialized solutions, including ANSYS RedHawk 3DIC and PowerArtist, that can optimize the design of integrated circuits. These solutions help engineers manage electronics density and make intelligent trade-offs among product size, thermal build-up and overall product performance. The product development team can launch vehicles with the confidence that semiconductors will perform as expected in real-world operating environments.

Electronics Reliability: Building Hardware to Last

Advanced electronics hardware is one of the most critical components of any autonomous vehicle, supporting such key capabilities as communication, image and data capture, system control, artificial intelligence, and mobility. This hardware must be robust enough to withstand electrical, thermal, vibrational and mechanical stresses.

Instead of subjecting hardware prototypes to physical tests, engineers can apply a range of ANSYS tools — including Icepak, SIwave and Mechanical — to analyze packages, boards, enclosures and systems in a virtual design space. Simulations via ANSYS can reveal essential performance aspects such as power integrity, energy consumption, electrostatic discharge, electromagnetic interference and compatibility, thermal performance, and structural robustness.

Based on their analysis, engineers can then take corrective actions — e.g., adding a fan or a heat sink — early in the development process, before final costs are locked in. Not only does simulation via ANSYS speed up the hardware design cycle and cut costs, but it also helps engineers avoid real-world performance problems associated with power dissipation, thermal overload and structural deformations, among other potential defects.

Safety-Critical Embedded Software Development

While invisible, computer software and its associated algorithms underlie the safe, reliable performance of every autonomous vehicle. For the vehicle to gather data and make intelligent decisions, every numerically based function — from signal processing routines to object recognition functions — must perform flawlessly. This means that the underlying software code must also be flawless.

To help eliminate human error, ANSYS offers its proven SCADE family of solutions for software development and verification. By numerically modeling and controlling all code-generation activities, SCADE solutions equip software engineers to meet industry safety standards and deliver high levels of performance. To support autonomous

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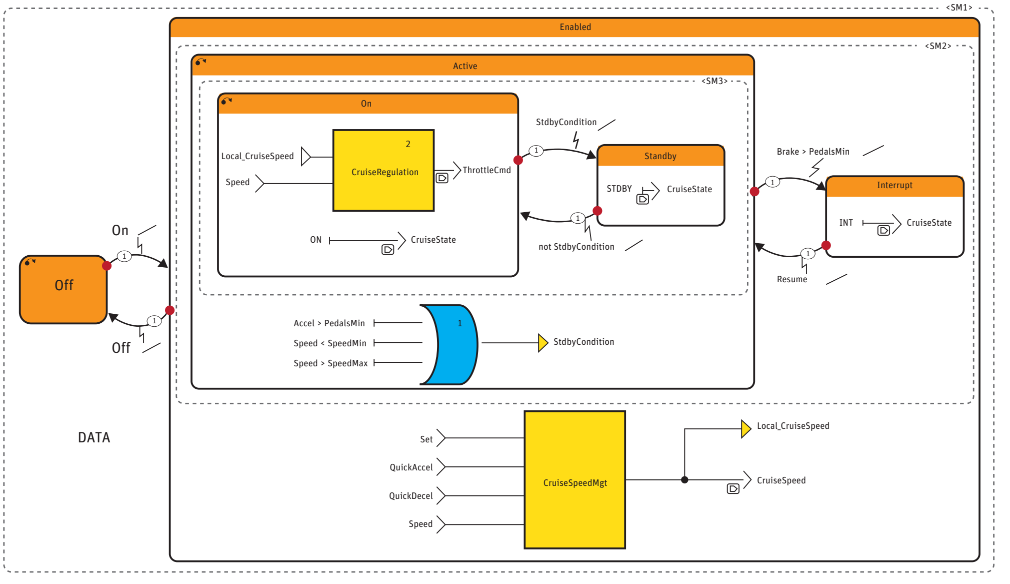

product development, SCADE solutions are designed for easy integration with third-party neural network and machine learning software.

In addition to improving the reliability of software code, ANSYS SCADE delivers significant improvements in development time and costs, as compared to manually based code-generation methods. Some customers report that software development time has been reduced by a factor of three by using ANSYS SCADE, as compared to a process without automatic code generation and verification.

Functional Safety: An Automated Approach

No matter how rigorous the upfront engineering process, any electronic system can fail in the field. Unfortunately, this holds true for autonomous vehicles, where system-level failures can be catastrophic. Engineers need to build in a high degree of functional safety, which ensures that the overall system can respond appropriately should one component fail.

Because autonomous vehicles are composed of a multitude of mechanical parts, electronics, hardware and software, the process of functional safety analysis can be enormously complicated. Manual verification processes can be not only tedious and expensive, but are inherently prone to human error.

To address this problem, ANSYS offers the medini analyze solution family, which automates functional safety analysis and seamlessly integrates this critical activity into overall product development. Instead of working with assumptions about how the vehicle will perform in the event of a functional failure, engineers can evaluate potential failure modes using a fact-based method. They can then design a system-level response that mitigates the effects of that failure mode and protects human safety.

Winning the Race

Today the question is not “Will we see fully autonomous vehicles transform multiple industries in the near future?” but “Who will be first?”

As companies race to solve the remaining engineering challenges and launch innovative, yet practical, autonomous vehicles, simulation is a competitive imperative. ANSYS is building the industry’s only comprehensive solution for simulating the performance of autonomous vehicles over the billions of miles they must be driven, flown or maneuvered.

Whether you are developing an entire vehicle or a component, simulation is relevant to your engineering challenges. ANSYS offers a single, configurable platform for validating vehicle performance against safety requirements. Its open nature integrates autonomous vehicle design into an ecosystem that includes, but is not limited to, high-fidelity physics studies, diverse sensor models, vehicle dynamics, world scenarios, embedded software code development, connectivity optimization, data analytics and functional safety analysis. Simulation software from ANSYS can be configured to a given development environment, hardware-in-the-loop requirements and the vehicle’s unique architecture.

Whatever challenge you are facing related to vehicle autonomy, we hope that you will find inspiration in this issue of *ANSYS Advantage*, as we profile some of the ground-breaking simulation work being accomplished by customers worldwide who are currently focused on winning this exciting race.

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