WHITE PAPER

Disruption Is Here in Automotive and Ground Transportation: Are You Ready?

The automotive and ground transportation industry is being disrupted with the rise of shared, connected, self-driving, electrified vehicles. For those who can innovate fast, it is a once-in-a-century opportunity to leapfrog the competition and win the race to dominate the new mobility industry. Simulation is the key enabler. Are you ready for innovation through simulation?

Engineering simulation is a proven tool for accelerating technology development and has been used in the automotive industry for decades. As the industry is being disrupted, it needs to disrupt the way it uses simulation. These tools are ready and available for developing new technologies, such as lidars, radars, traction motors and lithium-ion batteries, and are expanding into use-cases such as self-driving car closed loop simulators. Leveraging these capabilities will be the key to winning the race.

/ Disruptive Trends: Threats or Opportunities?

Bob Lutz, the iconic former vice chairman and head of product development at General Motors, recently wrote in an Automotive News editorial: “It saddens me to say it, but we are approaching the end of the automotive era.” [*Automotive News*, Redesigning the Industry, November 2017]

Indeed, the automotive and ground transportation industry that has thrived for the past 120 years is on the cusp of a major disruption of such magnitude that, as Lutz says, we may be witnessing the end of this industry as we know it. Disruptions such as autonomous vehicles and ride-sharing are likely to turn the automotive industry into a mobility industry. In a world of self-driving cars, we might no longer own vehicles privately, but simply hail a “robo-taxi” to get from point-A to point-B. “Travel will be in standardized modules,” as Lutz puts it, rather than in privately owned cars. That will be a totally different industry than the automotive and ground transportation industry that we are familiar with today.

Dr. Lawrence D. Burns, another visionary and former vice president of R&D at General Motors, explains the disruptions as a fundamental change in the “Automobile DNA” (Figure 1). Ever since the beginning of the automotive industry nearly 120 year ago, the automobile has had a combustion engine that consumed petroleum-based fuels and turned the wheels with mechanical drives and mechanical or hydraulic controls. Vehicle electrification is changing all these aspects, as newer vehicles increasingly have electronic controls, electric motors and electric drives that run on electricity generated from diverse sources, ranging from petroleum and coal to wind and solar.

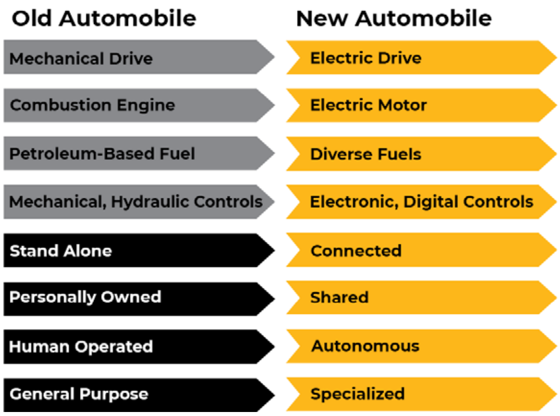

Figure 1. A fundamental change is happening in the “Automobile DNA.” (Credits: Dr. Lawrence D. Burns, et al. llc, lawrencedburns.org)

Bloomberg projects that by 2040 nearly a third of the entire fleet of vehicles worldwide will be fully electric (Figure 2). Likewise, analysts predict that by 2035 about 25%, and by 2040 over 90%, of new vehicles produced will be fully autonomous (Figure 3). Also, by then about 60% of the vehicles worldwide will be fleet units, with the remaining 40% being privately owned[1].

With such major changes, the automotive industry will undergo an unprecedented structural change. Today the industry is a B2C industry in which car companies sell their products directly to end consumers. However, the car companies will take a B2B role in the upcoming mobility industry, in which they will supply vehicles to robo-taxi fleet operators, who will in turn assume the B2C role.

This disruption is not only happening in the car and light vehicle market, but pervasively across the trucking, off-highway and industrial vehicle segments, with the development of electric, self-driving trucks and tractors.

Hundreds of startup companies funded with tens of billions of dollars are rapidly bringing disruptive innovations into the ground transportation industry. Traditional players likewise are focusing on disruptive innovations. This upheaval can be an existential threat — or a major opportunity, if one takes the right initiative and acts quickly.

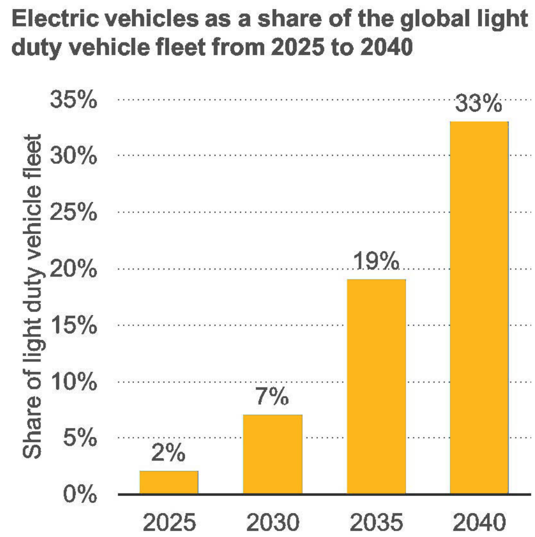

Figure 2: Fully electrified vehicles are projected to make up nearly a third of the entire global vehicle fleet by 2040. (Source: Bloomberg via Statista.com)

/ Taking Initiative: Barriers to Capturing Disruptive Opportunities

To capture disruptive opportunities, innovators must focus on overcoming three key challenges: unprecedented technology, safety and speed of innovation.

Unprecedented Technology

Disruptive developments such as self-driving cars and electric vehicles depend on technologies that are unfamiliar to the traditional automotive and ground transportation industry. For instance, self-driving cars rely on environment scanning sensors such as lidars and radars, and use machine learning and neural networks in their control systems. Likewise, the automotive industry has only recently started developing key electric vehicle components such as traction motors and advanced lithium-ion batteries. Developing such unprecedented technologies is one of the significant barriers that technologists in the automotive industry now face, since developing unprecedented technologies requires an undue amount of design exploration and large investment with high risk.

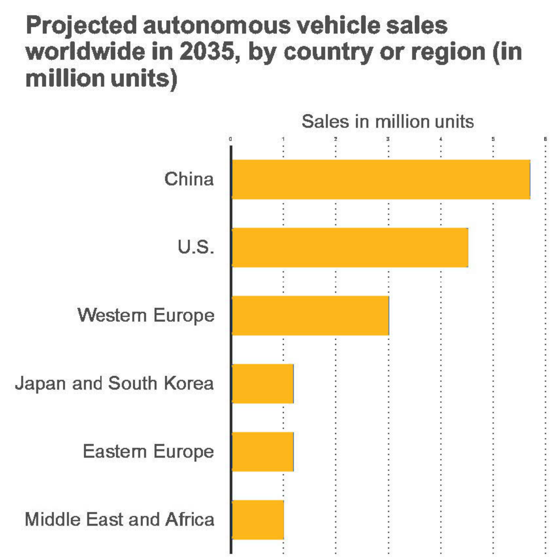

Figure 3. About a fourth of all vehicles sold globally each year are projected to be autonomous. (Source: IHS via Statista.com)

Safety

Automobiles are inherently dangerous, causing 1.3 million traffic fatalities globally each year, and untold millions of injuries. Self-driving cars must be at least as safe as human-driven vehicles before they can be introduced into the market. From a technological perspective, this is a task much easier said than done. Additionally, from a business perspective, the safety of self-driving car technology poses a new challenge. Whereas today a human driver is liable for accidents caused by driver error, in the case of self-driving cars such accidents are the car-maker's liability.

An autonomous vehicle needs to safely navigate through every possible challenging situation that could arise in practicality — from children darting unnoticed into the path of a speeding vehicle, to low visibility in heavy snow fall, to a broken-down vehicle stalled in a highway lane.

Analysts project that billions of miles of road tests will be needed to ensure the safety of an autonomous vehicle's design and software[2]. This impractical task will take hundreds of years to complete.

> *It (autonomous driving) has the potential to offer mobility to those who would not otherwise have it, such as older people and those with special needs. In order to accomplish this safely, it is estimated that some 14.2 billion kilometers (8.8 billion miles) of testing, including simulation, are required.*
>
> **Akio Toyoda**
> President of Toyota Motor Corporation, speaking at Paris Auto Show, Sept 29, 2016. (www.forbes.com)

Speed of Innovation

Time is the most crucial element in a disruption race. Companies that can develop unprecedented new vehicle technologies, make them safe and get them to market the fastest will capture a disproportionate share of tomorrow's mobility market. Companies must innovate faster than ever to survive and thrive in the ongoing automotive disruption. It is imperative to deploy methods that expedite innovation.

/ Innovation through Simulation

Engineering simulation is a proven tool for accelerating technology development. The automotive industry has been using simulation for decades and must expand the deployment of simulation into the product development processes of these disruptive technologies. With simulation, virtual tests can be conducted in a computer on virtual prototypes. Thousands of virtual tests can be completed within the time and budget available for a single physical test, thus greatly accelerating technology development.

Simulation provides three broad benefits:

a. Faster time-to-market: Simulation is conducted in a virtual environment and is significantly faster than physical prototyping and testing, expediting a new product's time-to-market.

b. Reduced cost: Being virtual, simulation is far less expensive than physical prototyping and testing, and can cut costs by an order of magnitude.

c. Enhanced product quality: Simulation provides deep insights into the underlying physics involved in the construction and operation of a product, helping solve quality issues upfront.

With simulation, the vast amount of design exploration necessary for developing unprecedented technologies, such as lithium-ion batteries and lidars, can be accomplished speedily and without undue expense. Furthermore, simulation is the only practical way to test autonomous vehicles over the billions of miles of test driving that are needed to make them safe.

Simulation Delivers Tangible Business Benefits

The Aberdeen group surveyed hundreds of companies regarding their use of engineering simulation in their product development processes. Aberdeen classified companies into those that systematically use simulation in their product development processes and those who don't. They found that companies that use simulation are 21% better at meeting their product launch targets, 22% better at meeting cost targets and 17% better at meeting quality targets than companies that do not use simulation (Figure 4).

Simulation is most beneficial when deployed pervasively throughout the product development process, including ideation, design, manufacturing and product operation — and even within the operating product (Figure 5).

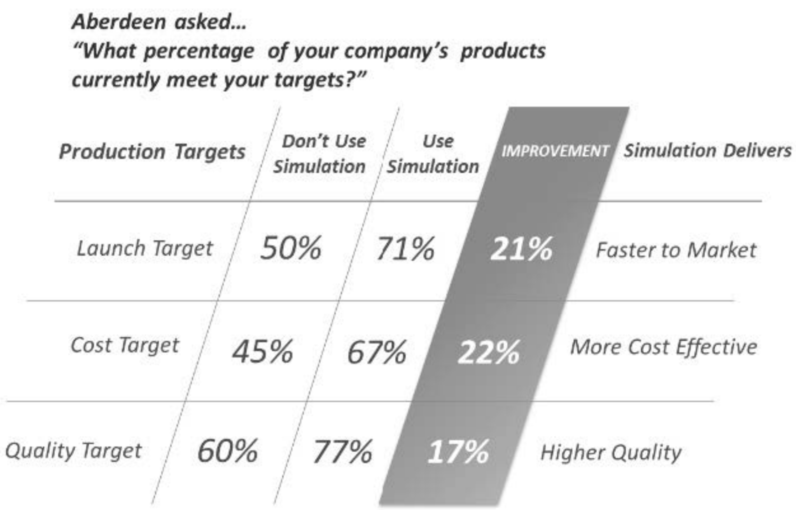

Figure 4. An Aberdeen Group survey found that companies that systematically use simulation show substantial gains in meeting product launch dates and cost and quality targets.

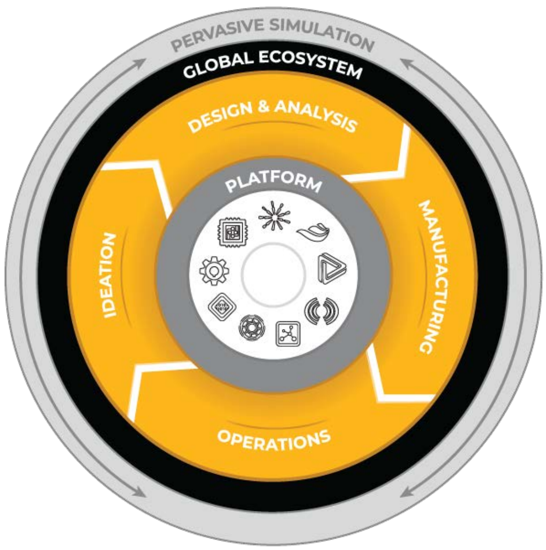

Figure 5. Simulation is most beneficial when used pervasively throughout the product development process.

Simulation Technology Pervasively Addresses Disruptive Automotive Technologies

Simulation technologies are ready and available to accelerate product development in all the major disruptive trends in the automotive and ground transportation industry.

Autonomous Vehicles
Simulation solves three major challenges in developing autonomous vehicles (Figure 6).

1. Closed-Loop Simulation
   The primary challenge in developing autonomous vehicles is to validate that they will drive safely in millions of possible situations. In a closed-loop simulation, a virtual representation of the autonomous vehicle, complete with high-fidelity virtual sensors and actuators, is placed in a virtual environment and driven by the same software that controls the real-world.

2. Open-Loop Simulation
   The second major challenge in designing autonomous vehicles is to develop advanced environment sensors such as radars, lidars and cameras, along with the electronics and semiconductors needed to process information collected by the sensors. Designing and developing these components requires high-fidelity, physics-based simulations conducted in an open-loop environment. Such simulations ensure that the performance of the sensor and its interaction with the environment is captured in the most accurate way possible; that in the real world these sensors will perform as expected; and that they will be able to survive the harsh operational environment to which they will be exposed.

3. Software Development and Functional Safety
   The third major challenge in developing autonomous vehicles is the complexity of the automated driving control software. The embedded software responsible for perception, localization, motion planning and motion execution is the brain of the autonomous vehicle. To ensure bug-free operation, a model-based software development approach integrated with methodical functional safety analysis is needed. Such an approach provides clear traceability between the outputs of the algorithms and the functional safety requirements of the system; compliance with accepted best practices for high integrity safety-critical software such as those defined by ISO 26262 standards; and safety analyses and certified code generation.

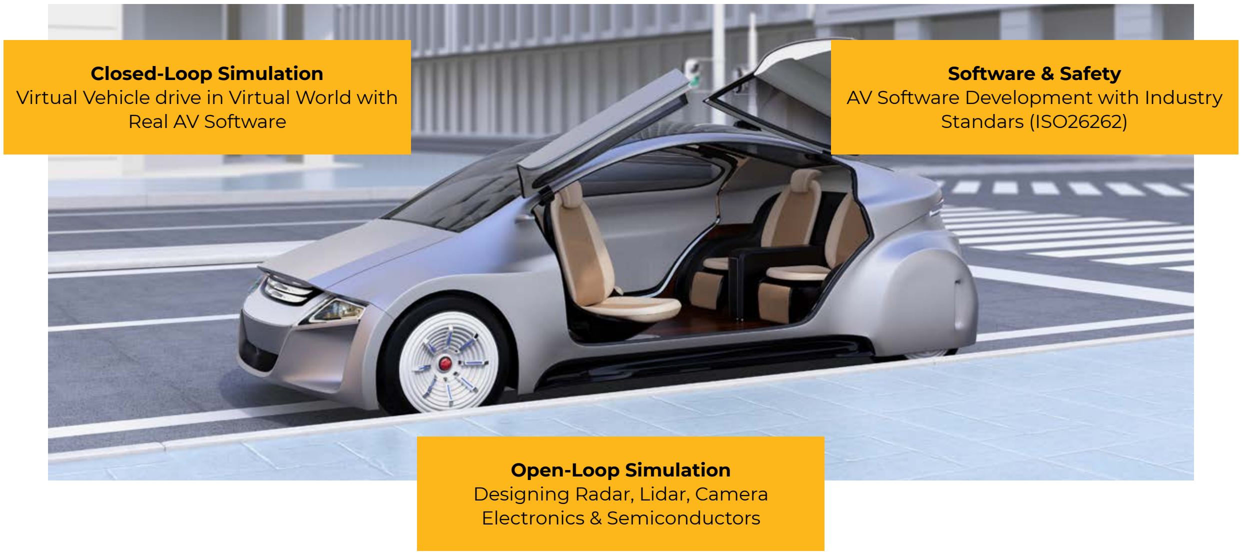

Figure 6. Simulation addresses three of the most important challenges in the development of autonomous vehicles: simulating miles-driven; developing sensors and components; and developing automated driving software.

Electrification

All electrified components and systems of a vehicle are highly multiphysical in nature, involving tightly interconnected fluid, thermal, structural, acoustic, electromagnetic and electrochemical aspects (Figure 7).
High-fidelity multiphysics simulation accelerates development of all these components and their system integration. For example, simulation addresses the following key design aspects of electric powertrain components:

1. Traction Motors, Electric Machines
   Simulation is used to maximize motor efficiency by calculating copper losses and lamination core losses over a wide range of operating conditions. Simulation also helps improve motor reliability by validating severe vibrations, hard-duty cycles and rough road conditions. Simulation is also used to evaluate various design alternatives, such as solid or stranded winding design and magnet positions, and for predicting torque ripples (Figure 8).

2. Batteries
   Simulation accelerates battery development at all levels — the chemistry of the electrode, the cell, the module, the pack, the battery management system and powertrain integration. Detailed electrochemistry simulation helps optimize electrode design and improve battery life. Coupled fluid-thermal-electrical simulations at the cell level predict charging–discharging characteristics, heating–cooling and thermal safety. Conjugate heat transfer simulations help develop cooling strategies at the module and pack levels, while structural simulations help improve battery durability and mechanical abuse resistance. Reduced order models (ROMs) and equivalent circuit models (ECMs) are used for system-level characterization of the thermal–electrical behavior of the battery, which helps optimize the battery as a part of the overall powertrain. ISO 26262-certified embedded software development methods help create robust battery management system (BMS) software.

3. System Integration
   Putting two or more individually optimized components together does not make an optimized system. This is particularly evident in electrified systems such as the electric powertrain, where it is crucially important to design and optimize the motor as part of a larger system comprising the power electronics, controller and other components. A multidomain system simulation software program is essential for designing such high-performance systems that include electrical, thermal, electromechanical and electromagnetic components. It must tie all these different physical analyses together to optimize the whole electric powertrain as one coherent system.

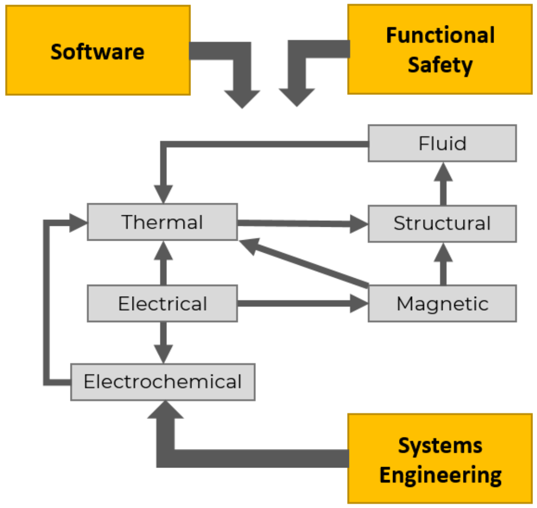

Figure 7. Electrified systems involve tightly interconnected fluid, thermal, structural, acoustic, electromagnetic and electrochemical aspects, in addition to software, safety and system engineering needs.

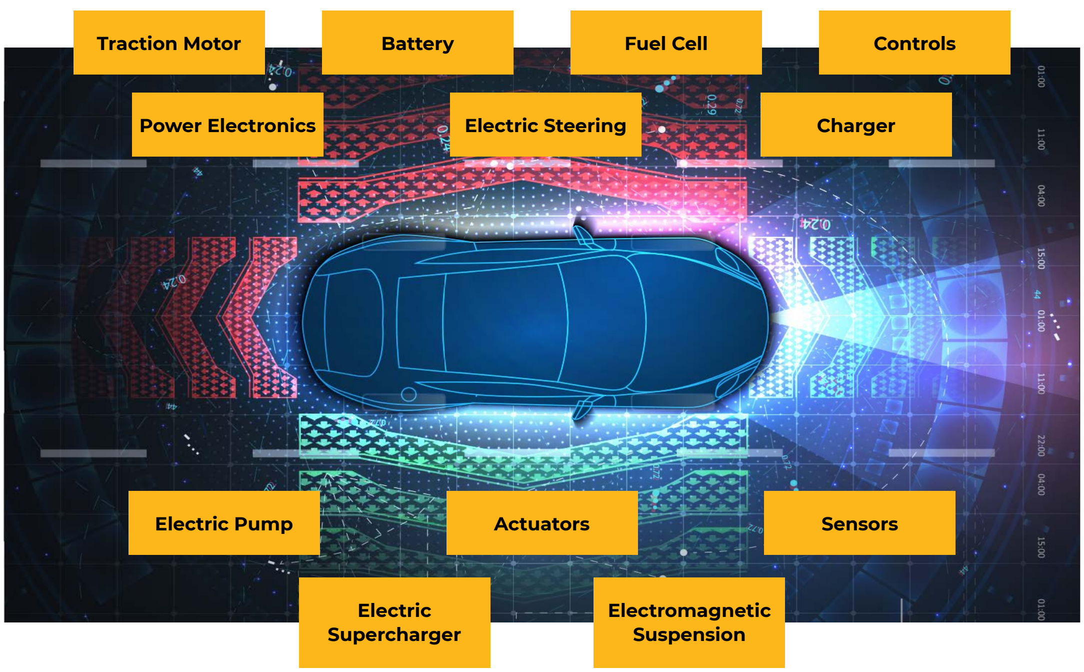

Figure 8. High-fidelity multiphysics simulation accelerates development of all electrified vehicle systems.

Smart Connected Products

An automated, integrated toolkit (Figure 10) for designing a robust embedded system architecture — and ensuring its functional safety — delivers numerous advantages, including:

- Increased consistency because all involved engineering teams would be working with the same toolkit, processes and workflows — leading to predictable, repeatable design methods and results.
- Improved quality and accuracy of system architecture design as an intelligent, automated toolkit would eliminate the possibility of human error.
- Faster time-to-market as time-consuming, labor-intensive modeling and verification activities would be automated and accelerated.
- Lower financial resource demands because the engineering staff would be working more productively and engineers would be free to work on higher value, more strategic tasks.
- Enhanced traceability resulting from the fact that, from requirement definition to verification, every activity would be captured and tracked in the toolkit.

Further, such integrated, methodical approaches expedite compliance with standards such as ISO 26262, particularly with the help of certified automatic code generators.

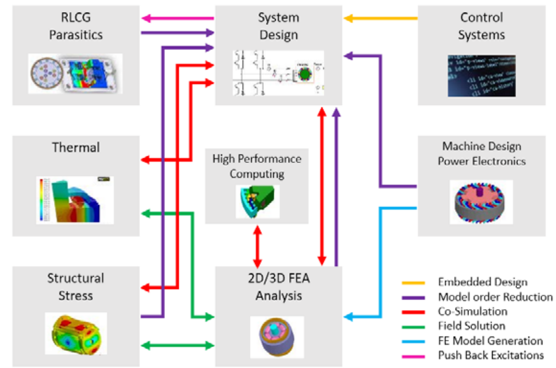

Figure 9. High-fidelity, multiphysics, multidomain simulation helps optimize traction motors at component and system levels.

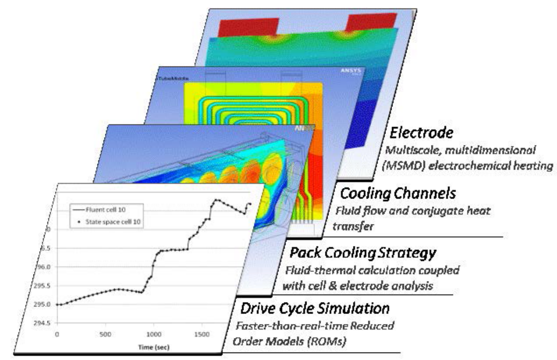

Figure 10. Multidomain simulation of a battery helps develop thermal management strategies at all levels inside a battery, and to test them under various driving cycles.

/ Industry Leaders Partner with Ansys

Leading automotive companies — including the top ten global OEMs, and 23 of the top 25 suppliers — use Ansys today to accelerate their product development. Ansys provides unparalleled ability to simulate real-world conditions in software, so companies can evaluate thousands of product scenarios in a safe, controlled environment and rapidly answer the "what-if" and "how can I" questions that engineers have about their products. Common reasons for choosing Ansys are:

1. Quality and reliability. Ansys solutions are recognized for accuracy that is built on a foundation of 50 years of simulation industry leadership. Ansys' long-standing presence in the A&D industry gives you confidence that they are a solution partner, not a product vendor.
2. Enterprise deployment of technology across disciplines from the desktop to the cloud. Engineering organizations typically contain tens and sometimes hundreds of computational tools with high levels of redundancy. The breadth of Ansys solutions — including multiple physics, embedded software, systems and functional safety — are integrated into a single platform. This unified approach enables organizations to deploy a common solution across the enterprise on a range of hardware configurations, thus substantially increasing engineering productivity, reducing IT and training spending, and streamlining the QA process.

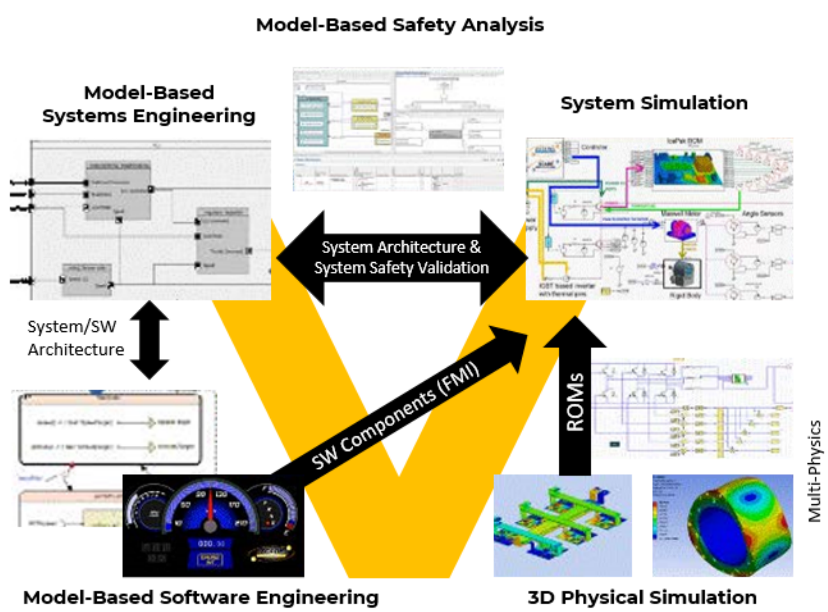

Figure 11. Product safety and compliance with standards such as ISO 26262 are achieved with a fully integrated toolkit for model-based embedded software development and functional safety analysis, combined with high-fidelity physics and system simulation.

3. Implementation risk management. Deployment of simulation technology able to model the complexities of autonomous, electric, smart, connected and shared vehicles requires not just the tools themselves but also a partnership for implementation. This includes technical support and experts in the industry, as well as a services organization capable of customizing tools and workflows so they can be seamlessly integrated into a customer's workflow. Ansys has an acknowledged best-in-class customer excellence organization.

4. Integrated ecosystem. Complex product development typically involves a broad range of solution partners. The Ansys partner ecosystem of industrial, academic, regulatory and policy experts is extensive and open to adapt to the needs of a customer's end-to-end design process.

/ Conclusion

The automotive and ground transportation industry is being rapidly disrupted and transformed into a mobility industry with self-driving, electric, connected and shared vehicles. It is a once-in-a-century opportunity to leapfrog competition and gain a dominant market position in the upcoming mobility industry. Speedily developing unprecedented new, yet safe, technologies is key to win in the mobility race. Simulation solutions are ready and available to help speed your product innovation. Are you ready?

/ Learn More

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[1] G. Muster, "Auto Outlook 2040: The Rise of Fully Autonomous Vehicles," Loup Ventures Research, (2017)
http://loupventures.com/auto-outlook-2040-the-rise-of-fully-autonomous-vehicles/
[2] Kalra N. and Paddock S., "Driving to Safety: How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?" Rand Corporation, RR-1478-RC (2016)
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ANSYS, Inc.
Southpointe
2600 Ansys Drive
Canonsburg, PA 15317
U.S.A.
724.746.3304
ansysinfo@ansys.com

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