Ansys

Engineering What's Ahead:

ADAS & Autonomous Vehicles

e-book

Winning the Race to Autonomy

The Critical Role of Engineering Simulation

TABLE OF CONTENTS

Autonomy Opens the Door to Ubiquitous Mobility.

Each year more than a million people die on the road.[1] Accidents cost $600 billion in harm from loss of life and injury, and another $277 billion in economic costs each year.[2]

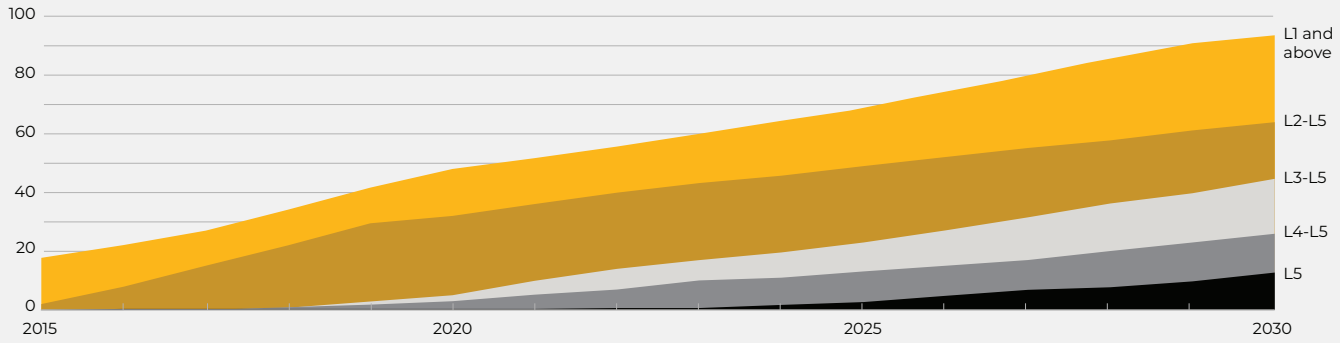
The primary source of all this pain is human error—the cause of 94% of all traffic accidents in the U.S.[3] Autonomous vehicles promise a solution.

People the world over stand on the cusp of a new era in assisted and highly autonomous mobility and the pace of adoption is accelerating.

Companies—established and new—are racing to capture the autonomous vehicle market opportunity and they know that their future success depends on the critical technology decisions they make today. Engineering teams are the key to unlocking this enormous potential.

This e-book details the technical challenges they face, identifies simulation as a common best practice adopted by autonomy leaders to tackle these challenges, highlights the resulting benefits, and details the critical simulation capabilities required to realize them.

Global penetration of connected cars[4]



From basic connectedness to complex experiences:

The five levels of vehicle connectivity

L1
General hardware connectivity: the driver is able to track basic vehicle usage and monitor technical status

L2
Individual connectivity: the driver uses her personal profile to access digital services via external digital ecosystems and platforms

L3
Preference-based personalization: all occupants enjoy personalized controls, their own infotainment content, and targeted contextual advertising

L4
Multisensorial live interaction: all occupants interact live with the vehicle and receive proactive recommendations on services and functions

L5
Virtual chauffeur: cognitive AI fulfills all occupants' explicit and unstated needs, predicting and performing complex, unprogrammed tasks

[1] "https://www.cdc.gov/injury/features/global-road-safety/index.html
[2] "The Economic and Societal Impact Of Motor Vehicle Crashes, 2010." National Highway Traffic Safety Administration, May 2015 (revised). https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013
[3] "Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey." National Highway Traffic Safety Administration, February 2015. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115
[4] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-trends-transforming-mobilitys-future

As Acceptance Rises, So Does Demand.

The rapid rise and impact of autonomous vehicles only promises to continue to accelerate globally. As proof, a snapshot of recent studies revealed:

What Consumers Want[1]

80%

of consumers globally would ride in an autonomous car in their lifetime

76%

would feel comfortable riding in an autonomous plane, train, car, or boat

72%

think autonomous cars are better drivers than humans, or will be, in 10 years

Some Projected Outcomes

94%

reduction in traffic over a 10-year span (350,000 lives saved), according to the U.S. Department of Transportation[2]

2.7m

metric tons of CO_2 emissions eliminated per year in Los Angeles [3]

$1.6b

savings in annual transportation costs in Berlin by restricting private cars and promoting autonomous vehicles and public transportation[3]

[1] Data collected through a consumer survey. Ansys enlisted Atomik Research and its team of MRS-certified researchers to conduct the online survey in March 2020. The sample included 16,037 adults 18-and-over, from the U.K., U.S., DACH (Austria, Germany and Switzerland), France, Sweden, Japan, China and India. See more survey results at https://www.ansys.com/autonomous-survey

[2] https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf, https://www.zdnet.com/article/how-autonomous-vehicles-could-save-over-350k-lives-in-the-us-and-millions-worldwide/

[3] https://www.bcg.com/publications/2020/how-autonomous-vehicles-can-benefit-urban-mobility

Autonomy is Ready to Expand. Engineers Must Lead the Way.

The opportunity before autonomy innovators is unlimited, but critical market demands must be overcome by those who want to win the race to market.

SAFETY

Autonomous vehicles would have to be driven hundreds of millions if not billions of miles, to demonstrate their safety across the myriad scenarios that can be encountered on a journey.[1]

COMPLEXITY

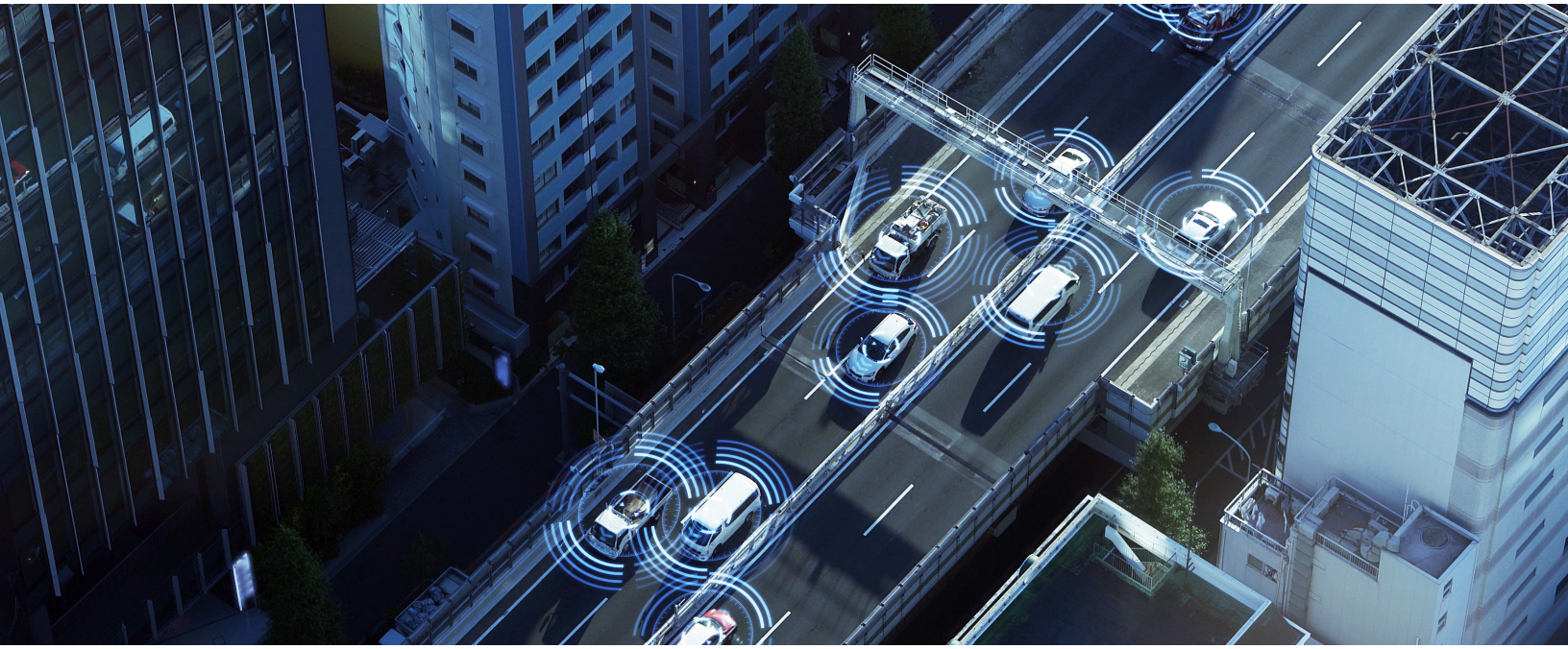
A modern car has nearly 100 million lines of software code in it. To become fully autonomous some estimates suggest this will increase 10x to 1 billion lines of code. What's more, many elements of this software are safety critical, meaning any errors could result in damage, injury or even worse.[2]

COST

While estimates of the cost of integrating advanced driver-assistance systems (ADAS) and autonomous vehicle technology vary from the tens of thousands to hundreds of thousands of dollars, the incremental costs of sensors and validation of the software system need to be brought down drastically before autonomous vehicles can be commercialized.[3]

TIME TO MARKET

Over 45% of vehicles sold by 2030 are projected to be highly automated.[4] This places intense time pressure on vehicle makers to develop ADAS and automated driving technology within the next decade. For traditional automotive companies, it is a race for market share. For new mobility companies, time-to-market is a make-or-break factor.



[1] https://www.rand.org/pubs/research_reports/RR1478.html
[2] https://spectrum.ieee.org/transportation/self-driving/accelerating-autonomous-vehicle-technology
[3] https://qz.com/924212/what-it-really-costs-to-turn-a-car-into-a-self-driving-vehicle/
[4] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-trends-transforming-mobilitys-future

Critical Engineering Challenges Explained.

Meeting these market needs presents critical engineering challenges.

Autonomy System Definition

Critical engineering challenges:

- *Hazards caused by malfunctioning behavior*
- *Various safety analysis methods (HARA, FTA, FMEA, HAZOP, etc.)*
- *"Compliance with ISO 26262 (Functional Safety), ISO/IEC 15408 (SOTIF) and ISO/SAE 21434 (Cybersecrity)*
- *Hazards related to nominal system performance (occurrence in the absence of failures)*
- *Cyberattacks*

Autonomy Hardware Development

Critical engineering challenges:

- *Sensor (radar, camera, lidar, ultrasonic) design, packaging and placement*
- *Optimization of emitter and receiver design, including optomechanical interactions*
- *Meet regulations*
- *Complexity and breadth of interactive human-machine interaction (HMI) components*
- *Understand and efficiently assess how hardware and software specifications impact user experience*
- *Robustness in the face of increased complexity*
- *Real-time simulation to evaluate perception-algorithm-execution*

Autonomy System Validation

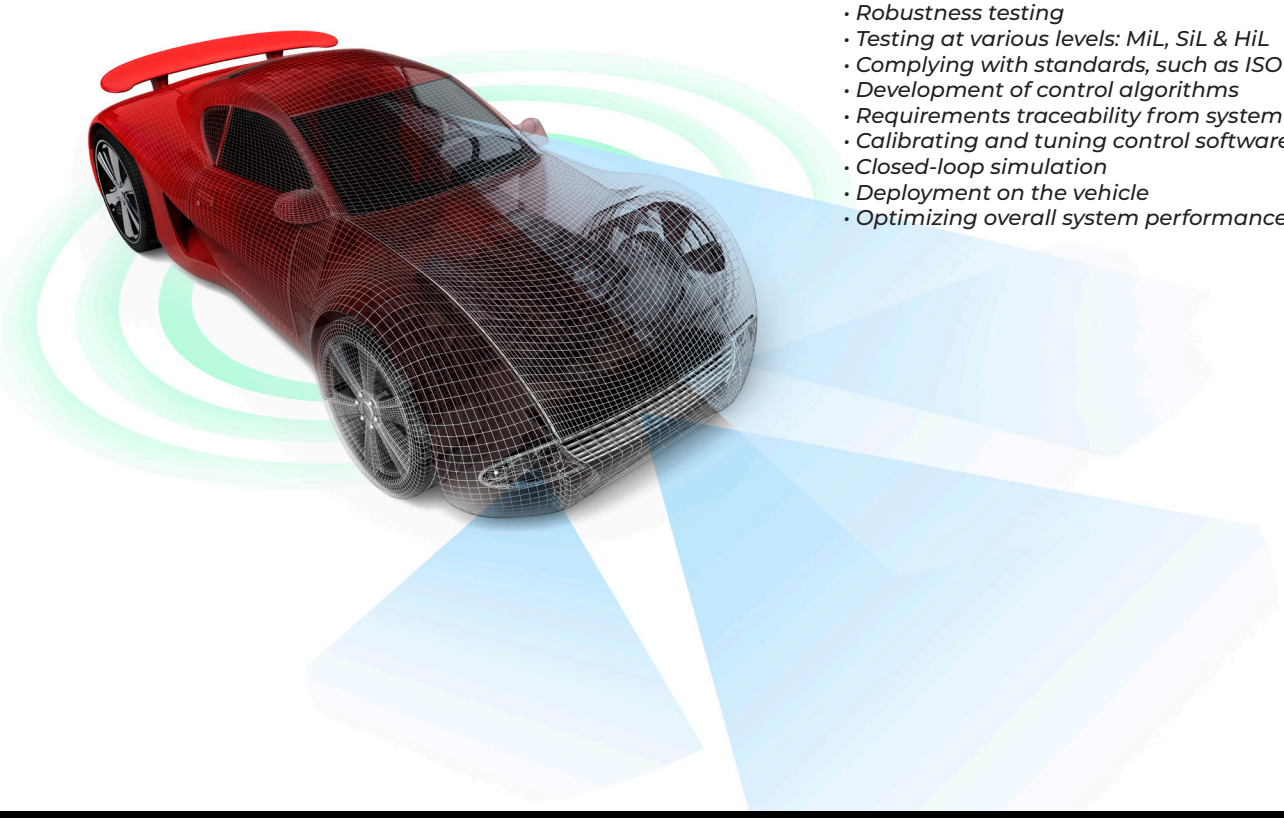
Critical engineering challenges:

- *Scenario definition, selection, creation, and edge cases*
- *Safety system assessment on edge cases*
- *Test plan*
- *Traceability*
- *Creating and auto-generating realistic world models*
- *Limited sensor capabilities when using traditional gaming engine models*
- *Compatibility and integration with high-fidelity sensor models*
- *Traffic models*
- *Driver behavior variation*
- *Real world variability: Weather conditions, lighting conditions, infrastructure, types of road users*
- *Run real-time asynchronous or externally synchronized simulation*
- *Sensor and vehicle models on real-time targets*
- *Multi-camera stream*
- *Synchro screen/camera*

Autonomy Software Development

Critical engineering challenges:

- *Drive–find–fix barrier*
- *Scalable testing & labeling*
- *Finding & defining edge cases*
- *Perception algorithm development*
- *Robustness testing*
- *Testing at various levels: MiL, SiL & HiL*
- *Complying with standards, such as ISO 26262 ASIL D*
- *Development of control algorithms*
- *Requirements traceability from system to software levels*
- *Calibrating and tuning control software*
- *Closed-loop simulation*
- *Deployment on the vehicle*
- *Optimizing overall system performance*



Simulation is *the* Autonomy Solution.

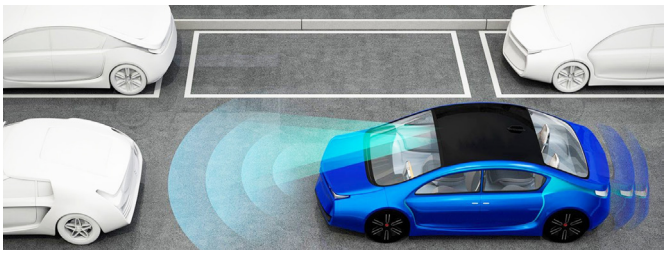
Simulation enables

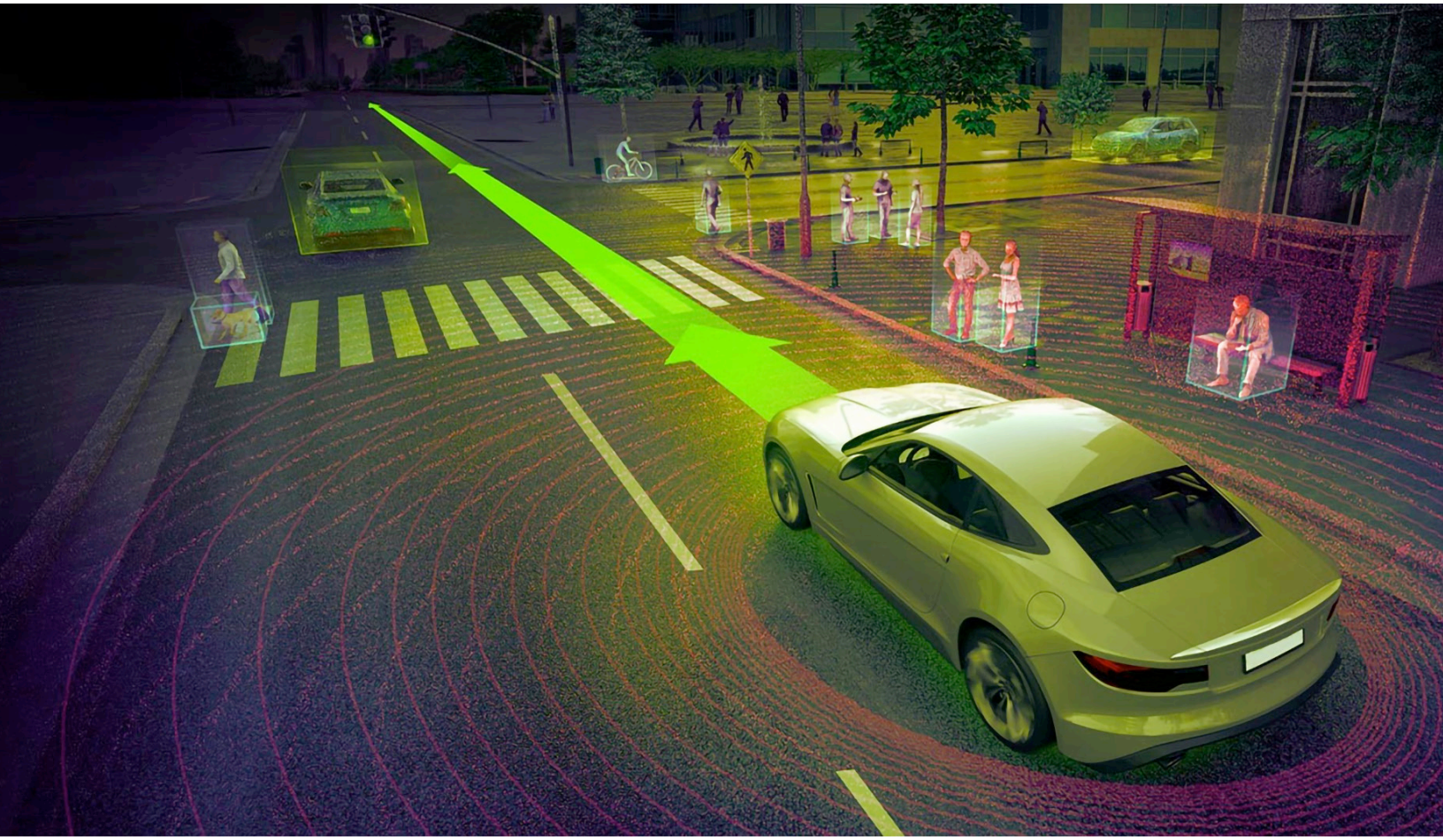
1,000 times more

scenarios to be examined, collecting enormous amounts of high-value data more quickly and economically than ever.

A leading automated driving system maker states that it has driven prototype autonomous vehicles over 5 million miles, but through simulation has extrapolated results to the equivalent of driving over 5 billion. [1]

Leaders in the autonomy revolution know they can win the race through simulation.





[1] https://storage.googleapis.com/sdc-prod/v1/safety-report/Safety%20Report%202018.pdf

Going Behind the Statistics.

The real story of how simulation drives autonomous vehicle innovation can be found behind the statistics. These case studies highlight the impact of simulation in real-world autonomous vehicle breakthrough situations.

BMW: A Simulation Tool Chain for Validation of Autonomous Vehicles

Autonomous vehicles could boost the global economy by $7 trillion, significantly reducing traffic accidents and saving more than 600,000 lives annually. Before that, however, autonomous vehicles must first survive rigorous testing in complex driving environments, traversing billions of miles of multiple road conditions and weather scenarios. BMW Group is leveraging Ansys' broad pervasive engineering simulation solutions and experience to speed up the development of a safety-focused solution for the validation of autonomous driving systems. Simulation greatly reduces the need for physical testing and will help bring safe automated vehicles to the highways in a fraction of the time.

FLIR: Thermal Cameras for Safer Cars

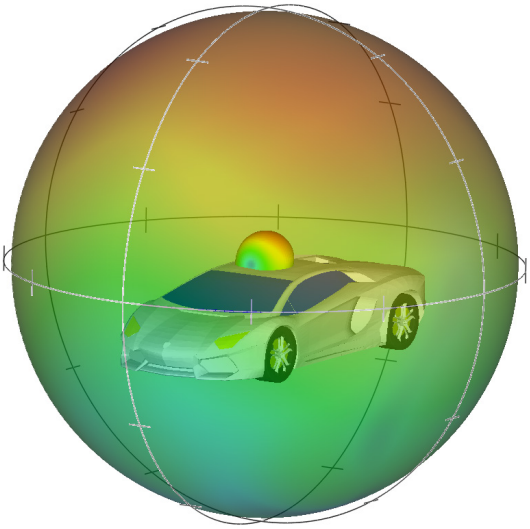
With safety of paramount concern, the addition of thermal cameras can improve how autonomous vehicles detect objects and pedestrians in adverse weather and lighting conditions, as well as improve performance in everyday daylight scenarios. FLIR has conducted preliminary tests to demonstrate how thermal cameras improve automatic emergency braking, especially in low-light and dark conditions. FLIR is taking steps to improve upon this work by fusing visible, thermal, and radar sensors to achieve superior braking performance. In collaboration with Ansys, thermal sensors are being developed in the virtual thermal world to enable rapid, physically accurate simulation validation of edge cases.

Ansys Comprehensive ADAS and Autonomous Vehicle Simulation Solution

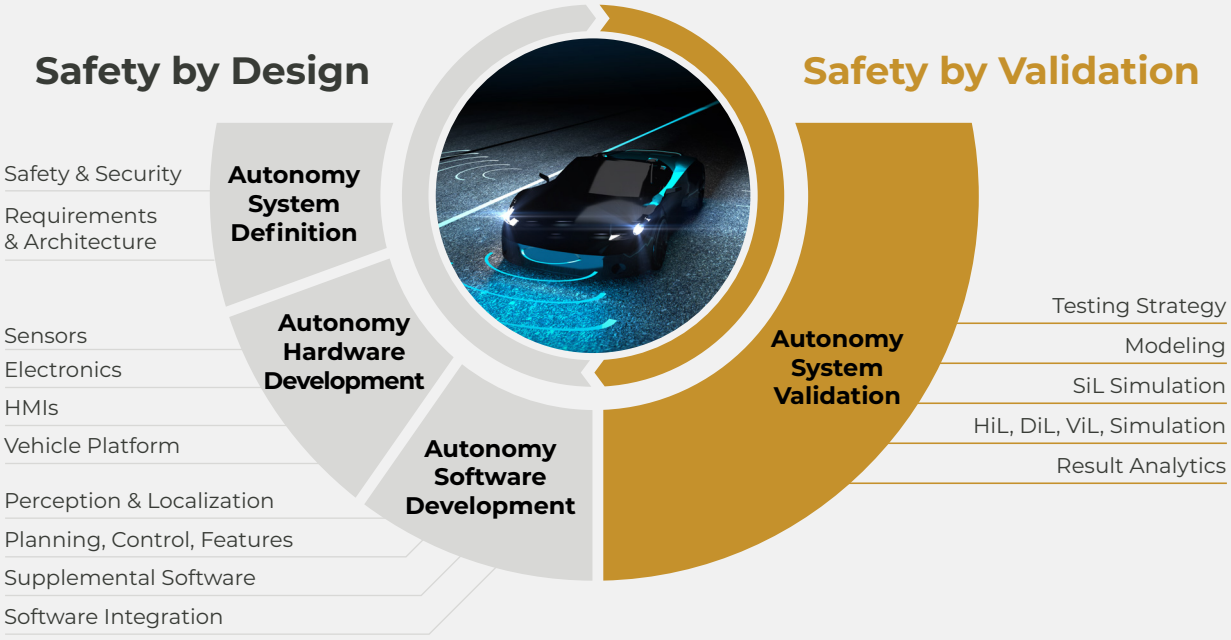
Ansys Autonomy provides a high-fidelity multiphysics simulation solution from the component to the system, including:

- *Automatic generation of safety certified embedded software and functional safety analysis.*
- *An open environment for optimization, simulation data and process management, workflow customization, access to cloud, and high-performance capacity.*
- *Support of third-party integration for deployment across the enterprise.*

All backed by the world's leading center of simulation expertise, providing customer enablement through technical support, services and training.



Safety by Design and Safety by Validation



Making It Real: ZF Group

Applying Ansys Autonomy:
Autonomy System Definition Solution

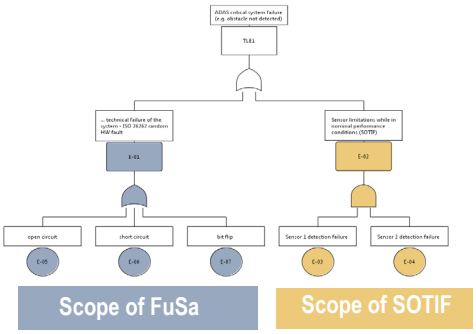
Critical engineering challenges:

- *Safety & Security*
- *Requirements & Architecture*

Since 2014, ZF has been a pioneer in applying Ansys medini analyze to its functional safety engineering practices, delivering significant benefits in terms of consistency and completeness of work products. Beginning in 2017, a ZF ADAS project team began collaboration with Ansys to customize medini analyze to meet the challenging task of cybersecurity threat analysis — including threat analysis and risk assessment, and attack tree — anticipating the eventual release of Ansys medini analyze for Cybersecurity, a standalone product. Ansys medini analyze has also helped many ZF project teams to deliver work products required by functional safety standards for the worldwide automotive industry, such as ISO 26262.

"Ansys medini analyze has streamlined and accelerated functional safety analysis for hardware, software and systems — delivering possible efficiencies including an up to 50% reduction in the time devoted to these tasks," said Kamil Svancara, Cyber Security Manager, ZF Friedrichshafen AG.

Autonomy System Definition Solution



Solution Capabilities

Functional Safety Analysis (FuSa)
- Integrated and model-based safety analysis
- Compliance with ISO 26262 and other applicable safety standards

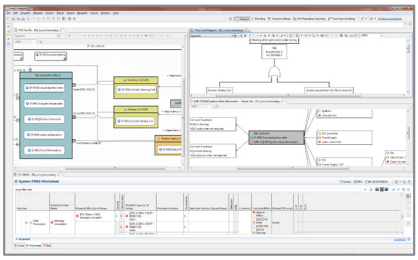
Safety of the Intended Functionality (SOTIF):
- Systematic causal analysis of SOTIF hazards
- Compliance with ISO 21448 and other applicable safety standards

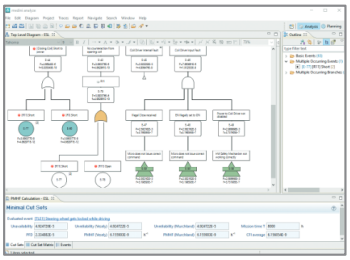
Cybersecurity
- Identifies cyber vulnerabilities across the entire electronics architecture
- Integrates architectural and functional design models with cybersecurity analysis methods

Key Outputs & Benefits

Technical Outputs
- Safety-critical E/E and software-controlled systems in compliance with ISO 26262
- Compliance with ISO 21448 standard achievable with reduced development time
- Streamlined and accelerated cybersecurity assessments
- Compliance with customer needs and upcoming industry standards

Technical Benefits
- Decrease in functional safety analysis time by 30-50%, accelerating time to market
- Complete end-to-end traceability
- Reduction of physical test driving necessary to validate safety
- Reduced risk of damaging cyberattacks





Making It Real: Autoliv, Inc.

Applying Ansys Autonomy:
Autonomy Hardware Development Solution

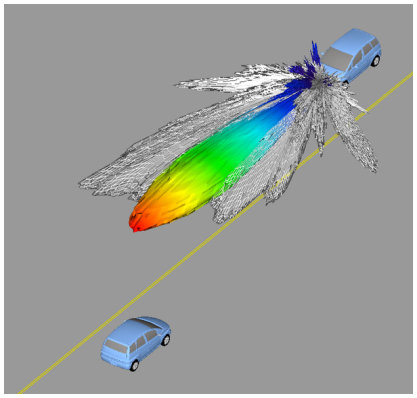
Critical engineering challenges:

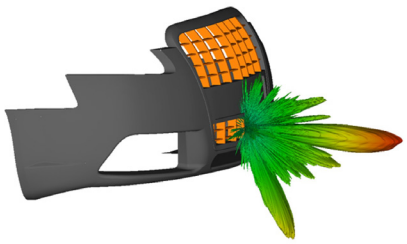
- *Sensors*
- *Electronics*
- *HMIs*
- *Vehicle Platform*

Radar systems looking outward at the autonomous vehicle's environment play a critical safety role. The packaging design of these radar systems is carried out early in the vehicle development process, before a prototype vehicle is available for performance testing. Design errors could lead to a repeat of the packaging process, causing delays in vehicle launch and costing roughly $1 million.

Autoliv, the worldwide leader in automotive safety systems, avoids these costs by using Ansys simulation to predict how the fascia and other nearby components affect radiation patterns so they can validate the design long before the prototype phase. Engineers select the radar system to be used on the vehicle and position it within the bracket of the simulation model as an initial design according to Autoliv packaging guidelines. They then assign measured electrical properties of the fascia, paint and bracket to their respective objects within the model, using Ansys simulation tools.

Autonomy Hardware Development Solution





Solution Capabilities

Radar
- Modeling of the driving environment
- Closed loop simulation
- Physics-based simulation for in-depth analysis and edge-case detection
- Interconnected simulation tools using open standards

Camera
- Multiphysics optimization (optical, thermal, structural) at component level
- Rapid camera placement studies using high-fidelity lens transfer functions
- Vision performance analysis in different environments with full camera pipeline

Lidar
- Design and optimization of a phased array of grating antennas
- Multiphysics optimization hardware (optical, thermal, structural)
- Extensive optical material properties library (including IR)
- Optical simulation within 3D CAD environment for rapid lidar placement studies
- Full physics-based lidar model for edge case simulation

Ultrasonic Sensors
- Ansys Multiphysics—coupled piezo-electro-mechanical-acoustics
- Vibroacoustics (sensor only and installed performance)
- Lighting systems
- Advanced Ansys optiSLang optimization to meet robustness requirement of complex systems
- Multiphysics workflow to ensure integrity in all physics domains
- Verification of entire ADAS lighting system in real time
- Automatic generation of large amounts of code to meet engineering and safety requirements using Ansys SCADE model-based code generator

Key Outputs & Benefits

Technical Outputs
- For radar: System behavior analysis in various driving environments, analysis of sensor returns on different abstraction levels, decreased amount of necessary physical testing, scalability and interchangeability of data between different simulation tools
- For Camera: physically accurate images
- For Lidar: physically accurate point clouds
- For Ultrasonic Sensor: impedance, amplitude, peak voltage vs. frequency, near field pressure field, acoustics signal strength and free space directivity, change in directivity due to installed conditions
- ISO 26262 compliant controllers
- Robust, smart headlamp that meets structural, optical, thermal requirements
- Closed-loop simulator for complete ADAS system, with MiL, SiL and HiL capability

Technical Benefits
- Fill autonomous vehicle sensor gaps
- Perform virtual testing of camera perception to speed up development
- Perform virtual testing of augmented reality (AR) head-up display (HUD)

Making It Real: SkyAngels

Applying Ansys Autonomy:
Autonomy Software Development Solution

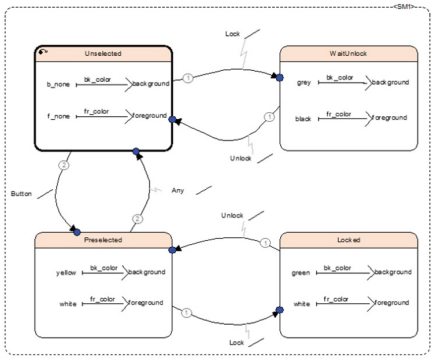
Critical engineering challenges:

- *Perception & Localization*
- *Planning, Control, Features*
- *Supplemental Software*
- *Software Integration*

Unmanned aerial systems and vehicles, both for civil and military applications, rely on avionics adaptive and learning agents to address novel situations in complex air space environments and accomplish their missions. SkyAngels uses cognitive architecture to transpose human or animal cognitive capabilities in pursuit of general artificial intelligence.

Ansys simulation assists SkyAngels in developing computational intelligence to autonomous aerial vehicles, aimed at navigating in non-segregated airspace in a predetermined certification path. This represents software engineering challenges related to adaptability and learning requirements specification and verification, algorithms convergence, deterministic behavior, absence of emergent comportments, and resistance to cyberattacks. Ansys simulation tools serve as a certified source code generator, avionic systems model, and safety and cybersecurity analysis.

Autonomy Software Development Solution



Solution Capabilities

Perception Software
- Cloud-based robustness testing
- Review weaknesses to identify root causes: triggering conditions
- Generate a report to list weaknesses and triggering conditions

Planning and Control Software
- Model-based software development
- Develop, validate, and auto generate code for control and HMI
- Ensures software will meet industry standards (i.e., ISO 26262 ASIL D)

Software Integration
- Closed-loop simulator solution
- APIs and middleware
- Automatic code generation

Key Outputs & Benefits

Technical Outputs
- Identify failures of perception software: false negatives, weak detections
- SOTIF triggering conditions
- Auto generated ISO 26262 ASIL D certified code
- Coverage analysis
- Traceability metrics
- Target compatible code
- Real-time operating system (RTOS) integration

Technical Benefits
- Make perception software more robust
- Expedite software generation process
- Adhere to industry standards such as ISO 26262

Making It Real: SKODA Auto

Applying Ansys Autonomy:
Autonomy System Validation Solution

Critical engineering challenges:

- *Real-Time Data*
- *Physics-Based Camera HiL Testing*
- *Sensors*
- *Scalable Testing*

Skoda, a car brand of the Volkswagen Group, validates the robustness of advanced driver-assistance systems (ADAS) functions in series production cars through a physics-based camera hardware-in-the-loop (HiL) simulation from Ansys. Simulation tools allow the generation of raw data injected in real time to the camera, allowing for a wide spectrum of testing in varying conditions. The high-fidelity simulation provides the infrastructure for scalable testing and automated reporting. In one example, a virtual night drive on a country track demonstrates how high-beam assist functionality is tested and validated.

Autonomy System Validation Solution

Solution Capabilities

Testing Strategy
- Model-based safety analysis
- Integrated workflow for the development and verification of embedded software
- Identification of critical scenarios
- Robustness and reliability analysis

World Modeling
- OpenDrive compliant
- Importing map data: OpenStreetMap
- Trimming the world from libraries
- Automating 3D world model creation from HD map

Scenario Generation
- Bring ego car into a multi-agent simulated traffic model
- Create traffic models based on AI to generate any kind of traffic situation
- Create scenario via script or GUI
- Automate scenario from test plan
- Create variability of scenario
- Automate scenario creation for massive simulation test

Adverse Environmental Simulation
- Sensors: thermal cameras, occlusion models for sensor enclosures
- Environment models with: thermic sources, solar glare model, fog and rain models

Software-In-Loop (SiL) Simulation
- Open-loop software testing and model coverage
- Verification of software implementation
- Performance and system testing of safety requirements

Hardware-in-Loop (HiL) Simulation
- RTOS independent
- Vehicle and sensor models computed on real-time targets
- Continuity from design (with full virtual scenario) up to verification stages (with hybrid virtual/actual testing)
- Reproducibility of tests
- Analysis of worst-case scenarios (like night for camera or complex scenario for radar)

Driver-in-Loop (DiL)
- Ability to run and interact with your embedded software in VR
- Embedded HMI software
- Live interaction between user and virtual actuators through natural finger interaction
- Assessment of the usability and workflows of your final software in context
- Ability to gather user feedback early in the design process

Key Outputs & Benefits

Technical Outputs
- Logical driving scenario (parameterized)
- Report with malfunction occurrences and triggering conditions hypotheses
- Log: critical limits/parameter data reliability analytics temperature prediction
- Detailed and realistic environment capable of simulating environmental events like: solar glare, rain, snow, fog
- Optical and material properties included as part of scene definition to allow for interaction with physics-based sensor models
- Vehicle state information and logs for powertrain, chassis, suspension
- Auto-generated traffic agents
- Test plans
- Sensor outputs from camera, lidar and radar that can be passed through perception algorithms to understand impact on perception KPI
- KPIs
- Model-in-loop simulation with coverage analysis
- Vehicle and sensor logs
- Detections from perception-in-the-loop
- Finger motions and heatmaps
- Full cockpit use experience
- Reflection studies
- HUD optical performance and quality

Technical Benefits
- Cut down need for physical road tests by 100x to 1000x
- Make perception, planning and control software more safe and robust

Engineering Security into Autonomous Vehicles.

Every vehicle is, at its essence, a computer in motion.

The increased amount of software in vehicles, and their greater levels of internal and external connectivity, have made them vulnerable to cyberattacks. Well-publicized hacking events have demonstrated the real potential for hackers to override software systems and interfere with safe operation.

That's why cybersecurity remains a major concern as electronic systems become exponentially more complex. Ansys medini analyze for Cybersecurity is an easy-to-use modeling and analysis tool that streamlines the complex task of generating and verifying a cohesive, safe, secure, system-level architecture that is impervious to outside attacks.

This solution allows engineers to quickly identify and address vulnerabilities with key security analysis methods in a model-based environment, to:

- *Deliver analysis context establishment, asset identification, threat identification, attack trees, and threat assessment and treatment all in one integrated tool*
- *Analyze and design cybersecurity-related functions and systems according to standards like SAE J3061, HEAVENS and the upcoming ISO 21434*
- *Integrate architectural/functional design models with cybersecurity analysis methods*
- *Capture and manage cybersecurity requirements*
- *Support complete end-to-end traceability*
- *Customize work product/document generation*
- *Enable seamless collaboration between teams*

With Ansys medini analyze for Cybersecurity, engineers can deliver safe and secure products, reduce time-to-market, maximize profit margins, and comply with upcoming regulations surrounding cybersecurity.

Click here to learn more about Ansys medini analyze for cybersecurity.

Contact us to learn more about Ansys solutions for Autonomy.

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Is your startup poised to make the next ***breakthrough in autonomy?***

Arbe Robotics needed to integrate a high channel count in its radar chipset solution, a significant challenge at 80 GHz. It chose Ansys simulation software to achieve a more accurate prediction of the outcome. Ansys simulation illustrated a chip package with high channel density and 80 Gigs RF traces featuring high channel-to-channel isolation and low insertion loss.

As a result, Arbe Robotics designed an innovative and propriety (patent pending) fan-out wafer-level package (FOWLP) to achieve significant improvement in 80 GHz traces loss while maintaining the isolation required between adjacent channels. Its engineers developed package variation exceeding stripline performance with only a single redistribution layer (RDL), while having 4X channels per chip and reducing costs by 25%.

Simulation also saved hours and associated costs that would have been spent testing on the road in uncontrolled environments.

Click here to see how Ansys supports startups like Arbe Robotics.

About Ansys

If you've ever seen a rocket launch, flown on an airplane, driven a car, used a computer, touched a mobile device, crossed a bridge or put on wearable technology, chances are you've used a product where Ansys software played a critical role in its creation. Ansys is the global leader in engineering simulation. We help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and engineer products limited only by imagination.