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Siemens PLM Software

Integrating complex hardware and software processes for autonomous vehicle development

Executive summary

The race to autonomous vehicles is transforming the automotive industry. The IHS Markit technology analysis firm forecasts that total global sales of self-driving cars will reach 33 million annually in 2040, up from nearly 600,000 units in 2025.[1]

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Contents

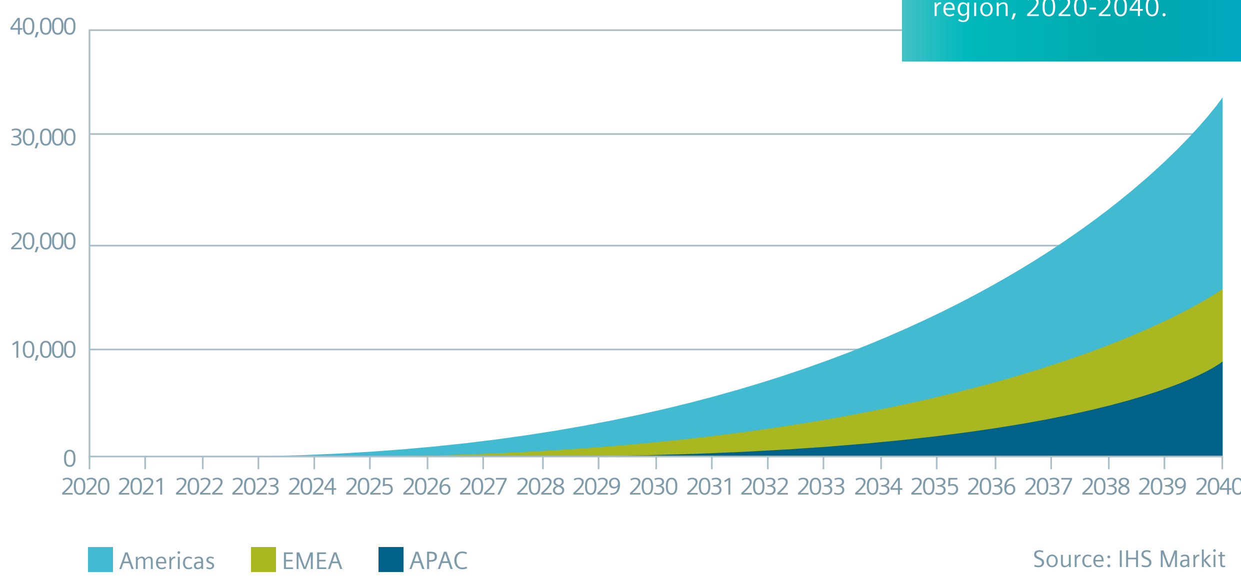
Introduction

Autonomous vehicles will have disruptive impacts on our relationships with cars. The *Wall Street Journal* reported in 2017 that ride-sharing and self-driving vehicles is upending the entire model of car ownership.[2] The *New York Times* reports that autonomous vehicles will shift passenger expectations, and that the automobile will become "a living room on wheels," a space of smart mobility that connects people with information.[3] A 2017 article in *IEEE Computer* projects that by 2040, all vehicles will be completely driverless, and that it may even be illegal for humans to drive on public roads.[4]

The idea and intent of autonomous vehicle is not new: in fact GM featured a film at the 1956 Motorama festival[5] depicting what could be in store with driverless cars by the far-flung future year 1976. However, recent developments in several technologies are quickly converging to make autonomous vehicles a reality. These include artificial intelligence, electrification, sensors, big data, connectivity and cloud computing. All of these technologies share a common component – software. Software makes each of these technologies transformative and exciting, and integrating them into autonomous vehicles introduces formidable complexity. Managing that complexity requires tight management of systems of systems. As companies move into hundreds of millions of lines of code, they will not survive without exceptional organization, and must become well-orchestrated digital enterprises.

The challenges will continue to grow, and companies will need new competencies in technology growth areas that are driven by sensors, electronics and software. A 2017 report by McKinsey&Company indicates that hardware innovations will deliver the required computational power, but that software will remain a critical bottleneck.[6] In 2016, Toyota president and CEO Akio Toyoda stated that 8.8 billion miles of testing will be needed before its autonomous vehicles reach customers.[7] The Roland Berger consultancy predicts that design validation is expected to be a major – if not the largest – cost component in the overall development of automated systems.[8]

Autonomous vehicle sales by region, 2020-2040.



Source: IHS Markit

From disruption to opportunity

Automotive executives are mindful of the challenges of autonomous vehicle development, and seek to transform them into business opportunities. As consumers demand product differentiation, automotive companies will exploit differentiation to gain a competitive advantage and increase sales. They will innovate unique features, as well as improved safety, reliability, quality and performance, along with aftermarket insights and delivery options. Meeting market and consumer demands in a rapidly shifting environment is going to be a very delicate dance for many of these companies. Gaining critical mass with customer trust and confidence in autonomous vehicles is challenging. Compatibility and standards play such an important factor when integrating supplier components, particularly software, upon which the majority of innovation will come. Connectivity with safety, including cybersecurity, will be paramount. When so much function relies on external systems, manufacturers will find it difficult to assure the protection of their vehicles. Vehicle certification against regulations that have yet to be drafted will be difficult, especially as product liability now rests 100 percent with the manufacturer. This is uncharted territory for many companies. But the potential benefits are enormous, and companies who enter the market sooner will reap those gains. Companies need to move quickly – go fast, go very fast.

"To survive disruption and thrive in the digital era, incumbents need to become digital enterprises, rethinking every element of their business."

2016 World Economic Forum

The automotive aftermarket is undergoing a revolutionary transformation, and automotive companies must manage disruptive changes in products and services, as well as their monetization. Regulatory changes will demand that automotive companies respond more quickly in finding and fixing problems and in executing recalls. As most of the new and modified features are being driven by innovative software components, extreme collaboration, re-use and traceability across all development activities has become a necessity.

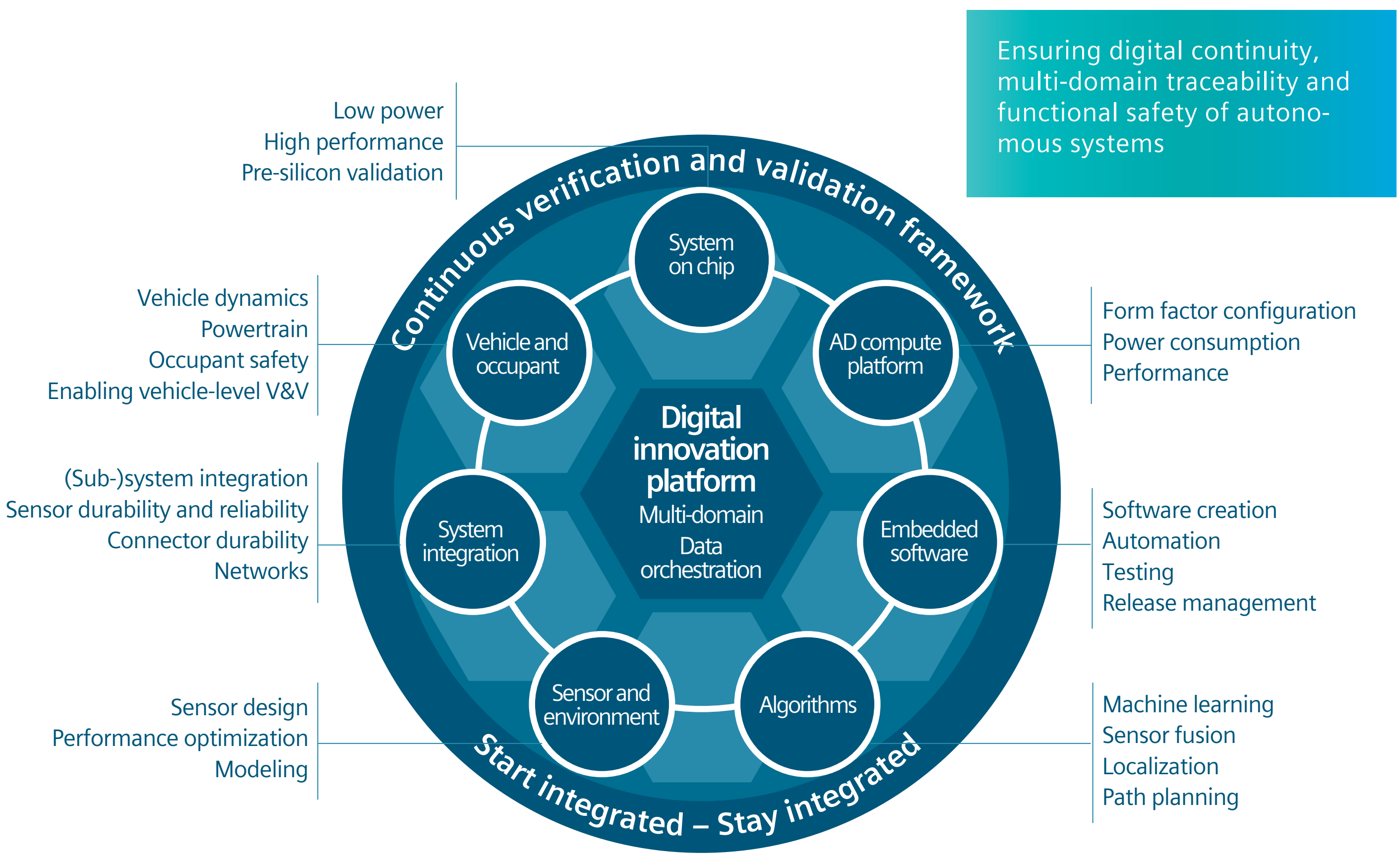
The complexity of the product development process for autonomous vehicles will also demand unprecedented levels of operational excellence and efficiency to produce more products, more quickly with more people. Most OEMs and suppliers involved with getting autonomous vehicles on the road are now transitioning their innovation model to include traditional IT in vehicle development, and some are even giving IT the lead for the overall innovation, integrating autonomous vehicles with smart mobility services and vehicle-to-everything (V2X) connectivity. Companies that can manage more across the supply chain will be rewarded with new opportunity. The explosion of software content in autonomous vehicles will challenge OEMs, suppliers and aftermarket players alike.

Building the digital enterprise

At the heart of a company's evolution to a digital enterprise is a strategic commitment to digital transformation. This commitment spans the entire automotive company's value chain – including suppliers. The key requirement in enabling this transformation is an integrated portfolio of industrial software and automation. With it, companies can create digital twins – digital replicas of products, processes and systems – that can be used throughout the product lifecycle; through ideation, realization and utilization.

The digital twin of the product is first created when a new product is defined and designed, and enables the simulation and validation of products, including mechanics, multiphysics, electronics and software management. The digital twin of production enables planning, simulation and optimization of production with programmable logic controller (PLC) code generation and virtual commissioning. The digital twin of performance is constantly fed with real-world data from the product and its production facilities, which leads to new insights and generates a fully closed decision-making loop that enables optimization of the product and production.

Moving from silos of automation and sequential processes to agile, parallel processes through digitalization yields a significant productivity bonus. A Siemens study estimates that the potential productivity bonus from global digitalization is from 6.3 to 9.8 percent of total annual revenue by 2025.



The Siemens Digital Innovation Platform delivers comprehensive solutions for autonomous vehicle development, including:

- Low-power, high performance system-on-chip development with pre-silicon validation
- Autonomous driving compute platform emulation with form factor configuration for sensor fusion, and low power-consumption
- Embedded software development, automation, testing and release management
- Control algorithms for machine learning, sensor fusion and path planning
- Sensor development for automotive environment and performance optimizations
- Integration of complex electrical subsystems considering sensor durability and reliability
- Optimization of electrical/electronics (EE) vehicle architectures for distributed software and network communication
- Validation and verification of autonomous systems at vehicle and occupant level with virtual environments synthesizing millions of real-world scenarios with digital twins to ensure regressive and rare safety-critical test coverages

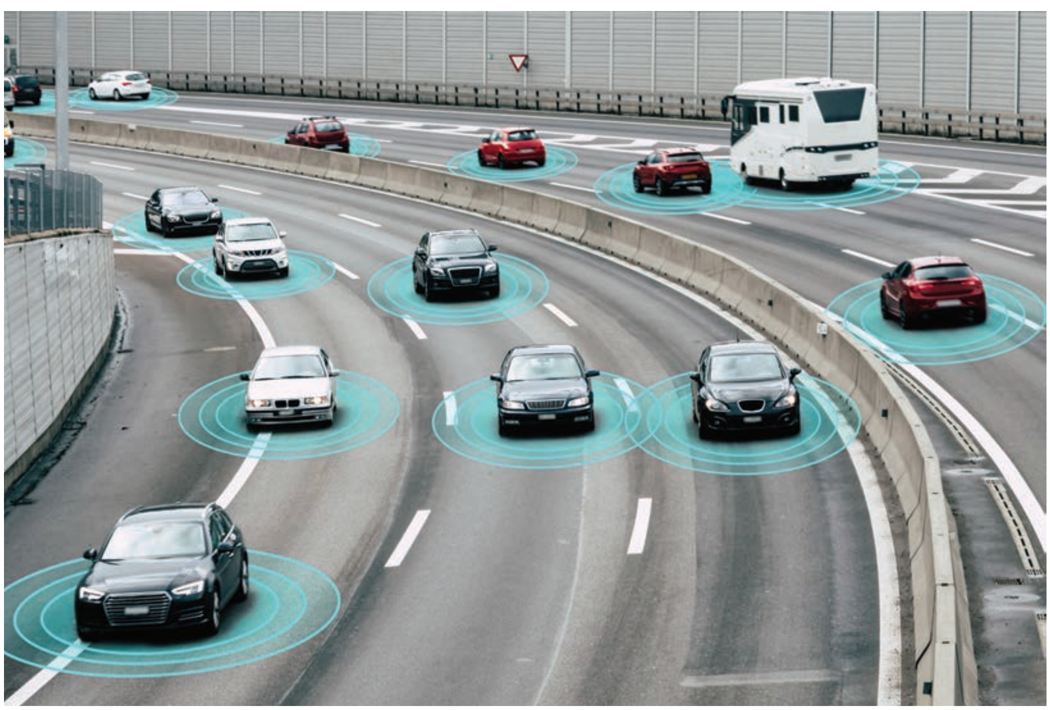
A complete ecosystem for autonomous systems development

Siemens solutions deliver a multiple-domain, integrated systems engineering ecosystem for developing self-driving vehicles. The key to challenges posed by autonomous vehicle development is to have an engineering environment which inherently integrates hardware (including mechanical and electrical/electronics) and software development processes.

The Siemens Digital Innovation platform provides a toolset and ecosystem that is integrated where it needs to be and independent where necessary. This platform provides the necessary openness to capture the needs of autonomous vehicles along with the engineering constraints to build and collaborate on a common vehicle architecture for hardware and software engineering teams.

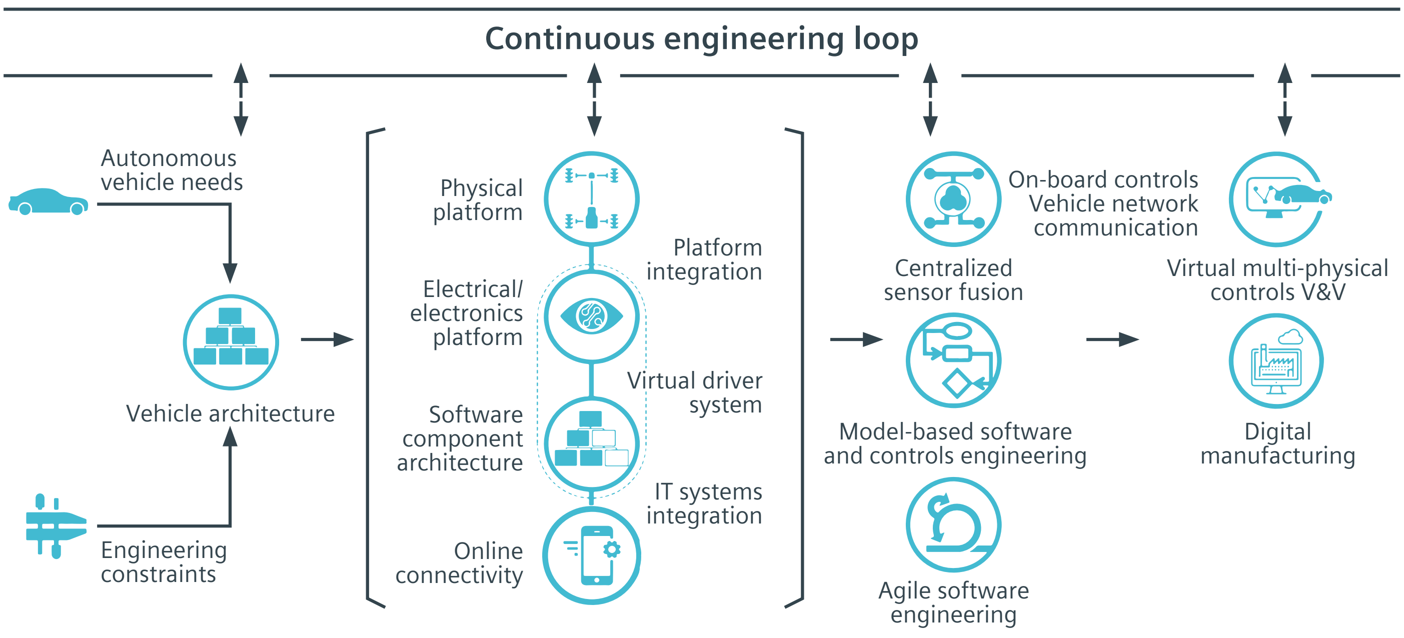
Such a platform enables the teams to build the necessary physical platform and integrate it with electrical/ electronic (EE) platform and software component architecture to facilitate the considerations and trade-off studies to build a robust, safe, secure and reliable virtual driver system for autonomous vehicle.

While IT systems develop web services for customer business models such as multi-modal mobility, fleet management and diagnostics, autonomous package deliveries, and other capabilities to be integrated with vehicle systems, the vehicle architecture with appropriate engineering views allows vehicle teams to collaborate and integrate software application development with vehicle systems. This integration allows hardware and software teams to collaborate and develop key elements of autonomous driving with intelligent



on-board systems, effective and secure network communication, and centralized sensor-fusion leveraging a model-based engineering approach to not only build a smart digital thread but also to facilitate robust supplier communication and agile software development. This flow incorporates a continuous engineering loop to integrate virtual verification and validation of systems at various milestones, and enables abstractions of hardware and software development. This continuous engineering loop is required to enable identification of issues and defects early in the development process and facilitate flawless vehicle assembly and manufacturing.

An integrated digital innovation platform provides a proven solution for engineers working in various domains to collaborate when they need to, and ensures traceability where needed. As electrical engineers do not typically work with software engineering tools (and vice-versa), the digital innovation platform allows engineers to comfortably work in their domains of expertise while the platform ensures integration and orchestration of the overall design across all activities and domains.



Aligning product development and software development

The typical ecosystem of product development tools is inadequate to address the needs of autonomous vehicle development. Most companies rely on silos of domain-specific tools, including

- Mechanical computer-aided design, engineering and manufacturing (MCAD/CAM/CAE)
- Electrical and electronic design (EDA)
- Application lifecycle management (ALM), with or without a variety of task-specific software development tools
- Product lifecycle management (PLM)

The lack of cohesion and integration across these tools leaves multiple domains disconnected and unaligned, impeding the speed, flexibility, quality and efficiency of the development process. This tool isolation results in massive costs due to late rework, vehicle integration and ultimately warranty issues.

As software becomes the key source of innovation and the primary bottleneck – especially with a giant leap from ADAS to autonomous vehicle development – the integration of the required software development across the optimized electrical hardware architecture for sensor fusion and complex controls and algorithms is absolutely essential. As software increasingly delivers product function, the importance of systems and model-based engineering methodologies continues to grow, and manufacturers must shift from loosely orchestrated mechanical design, electronics, and software development to a more tightly executed systems-centric approach. Companies that do not make the switch will struggle competitively.

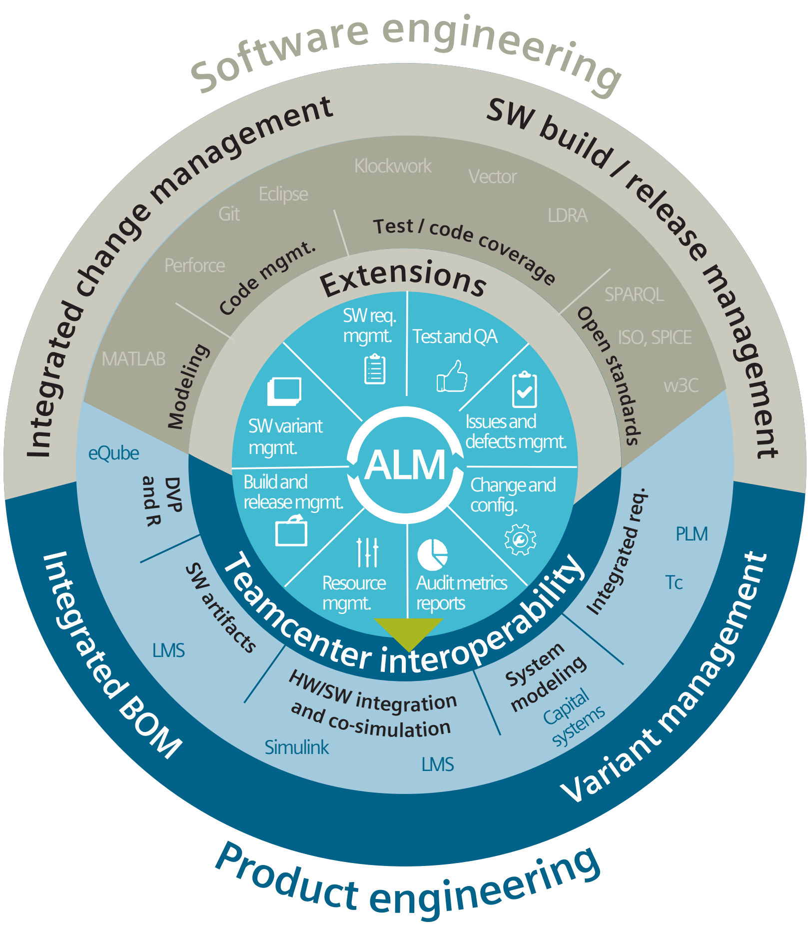
Unified ALM

In contrast to the uncoupled technologies of heterogeneous software development tools – separate systems for requirements, quality assurance, integrated development environment, configuration and release management – unified ALM encompasses the full range of processes on one integrated platform that manages requirements, quality and test, change, tasks and software builds. Unified systems like Polarion ALM include features like traceability, agile templates and methodologies, and access and version management that make it easy to move flexibly through software development cycles, with tools to manage fluid, rapidly changing development while maintaining visibility with project oversight, audits and metrics.

Unified ALM integrates all software development workflows and processes.

Managing product and software lifecycles with ALM and PLM

The methods for managing a product's lifecycle with PLM and the lifecycle of a software application with ALM share some similarities. Both PLM and ALM systems are built around an integrated process and set of core disciplines, but there are important differences. Typical PLM systems are not ideally suited to the complexity and file management in software development processes, especially with iterative development cycles, changing requirements, traceability and relationships of items, and other idiosyncrasies. Conversely, ALM toolsets are not well suited to manage other domains of product development. The solution is integration and interoperability of PLM and ALM solutions. Developers of autonomous vehicles will use both ALM and PLM in an integrated process that enables all disciplines and design processes to share and link hardware and software requirements, and to collaborate more closely by establishing cross-domain relationships. Such an approach is supported by Siemens' Teamcenter PLM software and Polarion ALM.

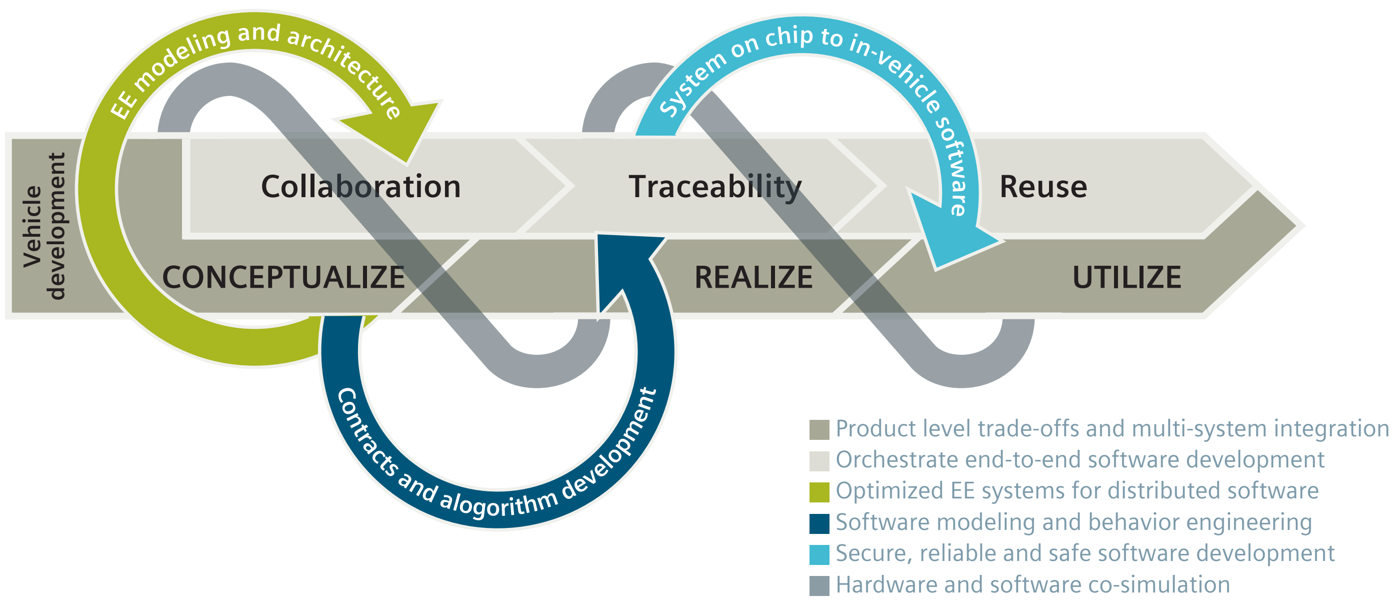


Autonomous vehicles will be developed with an integrated combination of ALM and PLM technologies, with linkages between software, electrical/electronic and mechanical engineering domains.

Summary

Software is the critical component of all of the technologies that are converging to make autonomous vehicles possible. As the primary source of functions and innovations in future vehicles, software introduces an unprecedented level of complexity that will require companies to digitally transform their enterprises.

The increased focus and content of software systems in autonomous vehicles requires an approach that integrates electrical and electronics systems engineering with software domains. These integrated solutions will enable vehicle engineering to optimize EE systems for the highly distributed nature of software controls, while allowing the software domain to leverage model-based software engineering, ensuring that system behavior and timing aspects are captured. These solutions must address system-on-chip design with pre-silicon validation, all the way up to in-vehicle software binaries on individual ECUs, with closed-loop continuous verification and validation to ensure that EE hardware and software can be continuously co-simulated.



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About Siemens PLM Software

Siemens PLM Software, a business unit of the Siemens Digital Factory Division, is a leading global provider of software solutions to drive the digital transformation of industry, creating new opportunities for manufacturers to realize innovation. With headquarters in Plano, Texas, and over 140,000 customers worldwide, Siemens PLM Software works with companies of all sizes to transform the way ideas come to life, the way products are realized, and the way products and assets in operation are used and understood. For more information on Siemens PLM Software products and services, visit www.siemens.com/plm.

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