Siemens PLM Software

# Generative design for autonomous vehicle electrical systems


## Executive summary

The complexity inherent in autonomous vehicle design will push the tools and methodologies used by automotive engineers to their limits. This is especially true in the electrical and electronic systems domains as they come to dominate the operation of a vehicle's safety-critical systems and convenience features. To compete, autonomous car manufacturers will need a new design methodology that enables young engineers to design accurate and optimized systems, which can only be done by capturing the experience and knowledge of veteran engineers. They will need generative design.



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# Moving towards level 5 autonomy

Autonomous vehicles will require an extensive system of advanced sensors, on-board computers, high-speed and high-bandwidth data networks, and wiring to connect it all. This complex network of cameras, radar, LIDAR sensors and electronic control units (ECUs) will be responsible for detecting and interpreting dynamic environmental conditions to inform real-time driving decisions. This means gathering, processing, and distributing gigabits of data every second to enable the algorithms and ECUs to respond to a rapidly changing driving environment.

The complexity and criticality of the electrical and electronic systems required for autonomous driving will dramatically increase the challenge of vehicle design and engineering. This is due to the extensive testing and validation required to ensure the safety of these systems. Most estimates predict that autonomous vehicles will require billions of miles-worth of testing to ensure their safety. Manufacturers will need to incorporate the lessons learned through simulated and real-world testing into their autonomous vehicle designs to remain competitive.

The technological ramp to fully autonomous vehicles presents significant challenges for the engineers tasked with their design. Advanced sensor technology, high-speed and high-bandwidth data networks, and cut-tingedge artificial intelligence are all crucial to the functional and commercial success of autonomous vehicles. The real challenge, however, begins when these advanced technologies are integrated into a single system that must perceive, communicate, and decide on a course of action (figure 1).

A car with level two autonomy, for example, may feature active cruise control, a lane departure warning system, lane keep assist, and parking assistance. In total, this car requires about seventeen sensors to enable its driver assistance systems. These sensors consist of ultrasonic, long-range radar, short-range radar, and surround cameras to monitor the vehicles environment. Furthermore, the computations performed by this car's automated systems are relatively primitive. The lane keep assist system, for instance, is only tasked with monitoring the vehicle's position relative to the lines of the road. Should the driver begin to stray, the system will notify the driver or take corrective action, but ultimate responsibility for control of the vehicle lies with the driver.

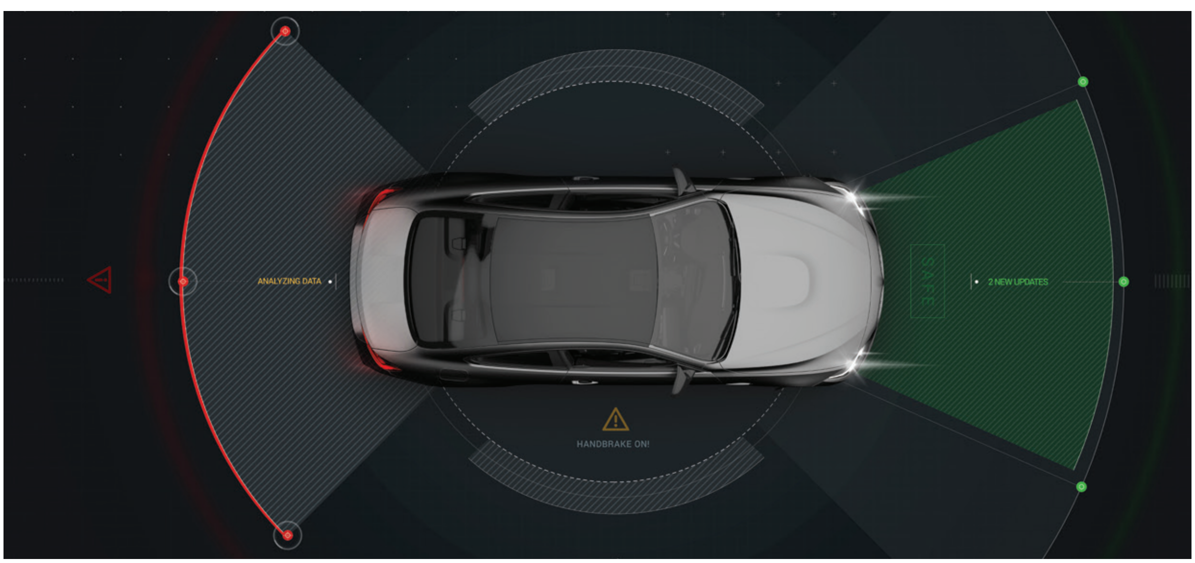


Figure 1: Autonomous vehicle platforms must connect an array of advanced sensors and computers through high-speed data networks to perceive, assess, and act on environmental stimuli.


Figure 2: A fully autonomous vehicle will require many types of sensors to accurately perceive dynamic driving environments.

A level five autonomous vehicle will have complete responsibility for control over the driving task, requiring no human input. As a result, a level five car is projected to have more than thirty additional sensors of a much wider variety to cover the immense number of tasks an autonomous vehicle will need to perform (figure 2). On top of the ultrasonic, surround camera, and long- and short-range radar sensors of a level two car, level five will require long range and stereo cameras, LiDAR, and dead reckoning sensors. The increase in sensors will increase the amount of wiring needed in the harness and the necessary computational resources to handle the gigabits of data being produced by the sensors.

During design, engineers will need to perform architecture and tradeoff analyses to investigate architectural proposals, such as a centralized vs. domain vs. distributed architecture. For an autonomous vehicle platform, these analyses will need to account for hundreds of components and millions of signals while optimizing function locations, network latency, error rates and more.

Despite these challenges, autonomous drive is a burgeoning market. At least 144 companies have announced autonomous vehicle programs, and annual spending on semiconductors for ADAS applications is projected to grow year over year (figure 3). Some of these are major automotive manufacturers seeking to stay ahead of the coming industry disruption, but most are startups or companies from other industries seeking to enter a traditionally impenetrable market. These companies lack industry-specific experience and the engineering resources to brute force their way through the complexities of autonomous vehicle design. Even the major automotive OEMs will face problems that their legacy design flows are ill-equipped to handle.

This will be true especially as companies move their autonomous vehicle projects from research, development, and one-off prototyping into full-scale production. Autonomous systems will need to be optimized for cost, weight, and power consumption while adhering to the most stringent safety requirements the automotive industry has ever faced. To compete, these companies will need a new design methodology that enables young engineers to design accurate and optimized systems, which can only be done by capturing the experience and knowledge of veteran engineers. They will need generative design.

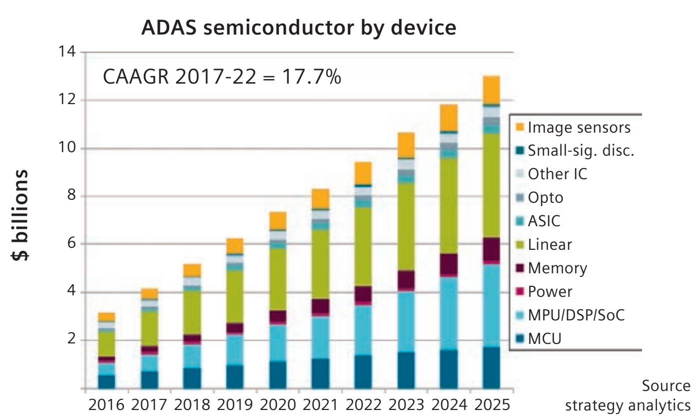


Figure 3: Annual spending on semiconductor devices for ADAS applications is expected to grow year over year.

# Generative design and engineering

Generative design takes system definitions and requirements as input and generates architectural proposals for the logic, software, hardware, and networks of the electrical and electronic systems using rules-based automation (figure 4). These rules capture the knowledge and experience of the veteran engineers to guide younger engineers throughout the design. Capturing this IP helps companies to develop both vehicle architectures and new generations of engineers as they learn and implement existing company knowledge.

A generative design flow begins with functional models. A functional model represents the functionality of the electrical system to be implemented, without specifying how it should be implemented. It accounts for aspects such as communication networks, power sources, and components. These models may be captured in a variety of formats such as spreadsheets, SysML files, and MS Visio diagrams.

Design teams then normalize these various functional models into a unified format within their electrical systems design environment, such as Capital. Once normalized, the engineers can generate potential architectures for the E/E system logic, networks, hardware, and software. Valuable company IP is integrated automatically into these proposals through the design rules that govern proposal generation. At this stage, the electrical engineers can rapidly generate, assess, and compare multiple architectural proposals, optimizing the design from the initial solutions presented.

From the selected architectural proposal, the engineers can extract discreet logical systems to generate platform- level network designs and the electrical distribution system (EDS). With this in place, the team can synthesize wire harness designs for each subsystem, generate manufacturing aids and bills-of-process costs, publish electrical service data, and generate VIN-specific service documentation.

**Generative design – Workflow**

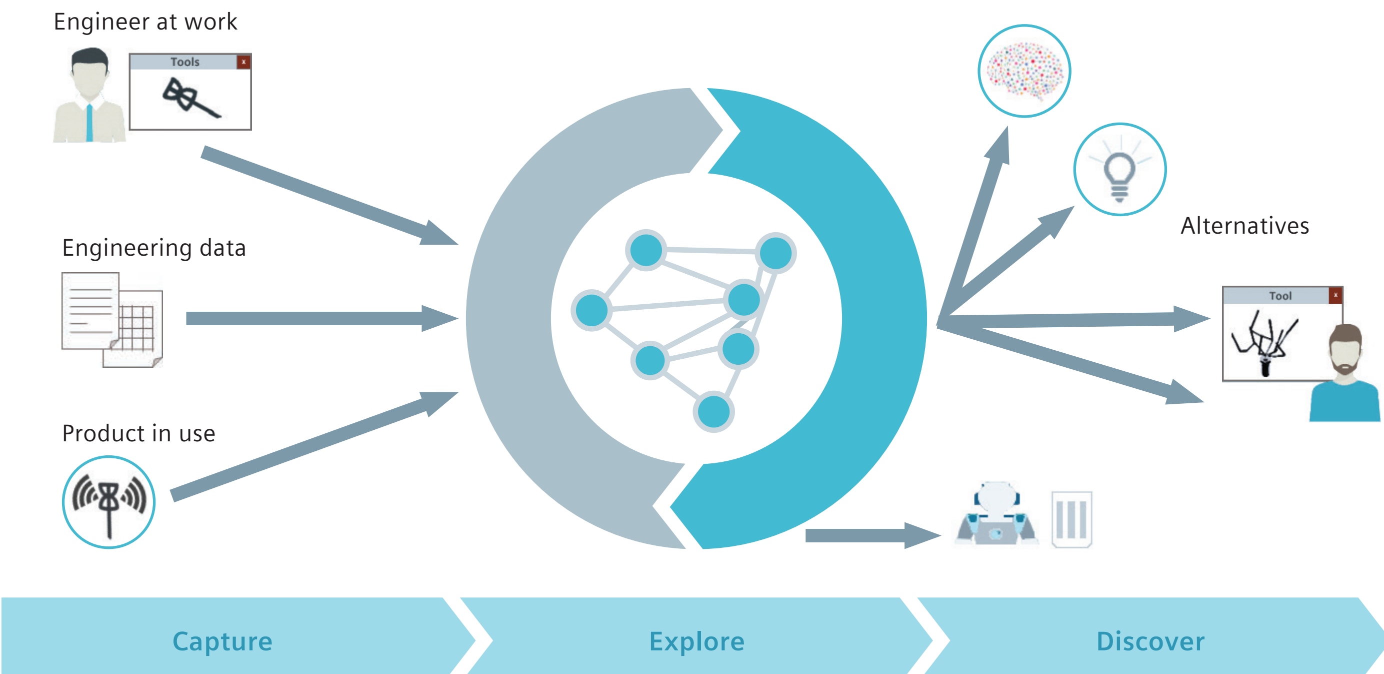


Figure 4: Generative design uses rules-based automation to generate proposals for the logic, software, hardware, and networks of the E/E system.

## Why generative?

The increasing electrical and electronic content of modern vehicles is already pushing current design methods to their limits, yet the complexity of automotive systems will only continue to grow in the future. Autonomous cars will contain the most complicated electrical and electronic systems yet seen in the automotive industry. More than thirty sensors, miles of wiring, and hundreds of ECUs will be required to gather, move, and process the data necessary for autonomous driving. The data networks will need to be extremely fast to support real-time perception, decision-making, and action to prevent collisions and harm to human passengers or pedestrians. Engineers developing these vehicles will also need to balance performance requirements against power consumption, physical space constraints, weight, and thermal considerations.

Generative design empowers automotive engineers to tackle the challenges of electrical and electronic systems design for autonomous vehicles. It employs rules-based automation for rapid design synthesis, enables engineers to design in the context of a full vehicle platform, and tightly integrates various design domains to ensure data continuity.

Firstly, employing automation throughout the process will help design teams manage design complexity without increasing time-to-market. Automation helps engineers focus on the most critical aspects of the design and verification of the functionality of the E/E system and reduces errors from manual data entry. This empowers engineers to focus more of their time on applying their creativity and ingenuity to creating the next generation of automotive technology breakthroughs. Automation also applies company IP to the generated proposals through design rules, increasing the accuracy and quality of the designs.

Next, designing in the full platform context helps engineers to understanding the way signals, wires, and other components are implemented across the entire vehicle platform, thereby reducing errors at interfaces or due to the intricacy of the harness. This design flow also enables teams to re-use validated data across vehicle platforms to improve quality and reduce development costs.

Finally, a tightly integrated environment enables the electrical engineers to share data with engineers and tools in other domains, such as mechanical or PCB design. The interactions between the electrical, mechanical, and software components of a vehicle are increasing. Seamless synchronization of data between these domains improves the integration of them into a single system.

### Traceability supporting compliance and certification

All abstractions and domains natively connected and integrated into ALM and PLM

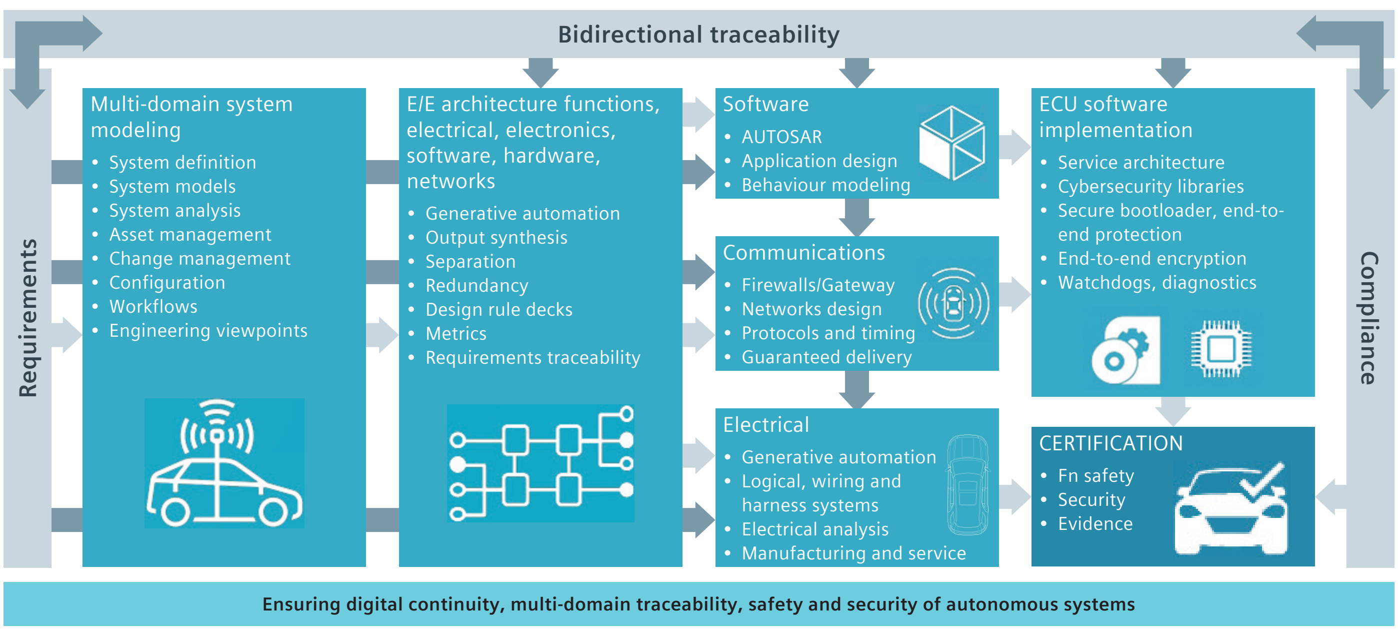


Figure 5: Generative design ensures data continuity from initial system definitions through production and after-sales for full traceability and compliance with requirements.

## Data continuity

Generative design creates a continuous thread of data from the initial system definition and requirements to full-scale production and service. The same data feeds each stage of the generative design flow so that nothing is lost between design stages or design domains. This continuous thread of data keeps all engineering team members up to date and working with the most current data while also ensuring that designs are meeting various requirements for functionality, safety, weight and so forth (figure 5).

Built-in design rules enable engineers to check designs for flaws automatically, flaws that can easily be lost in the sheer complexity of an autonomous vehicle. These design rule checks can catch unterminated wire ends, inconsistencies in graphical and physical bundle lengths, and check for current loads on wires, generated heat, and other faults. Again, generative design employs company IP through these design rule checks to catch design flaws that have caused trouble in the past or that new engineers may not think to check.

Additionally, data continuity enhances the engineer's ability to analyze the impact of design changes. Traditional design methodologies struggle to quantify the knock-on effects of design changes. Each change affects the rest of the system, and the second- and third-order effects can be very difficult to predict. Migrating an ECU to a new location or network in the architecture may affect performance elsewhere in the system. This change in behavior may cascade, invalidating any number of subsystems.

Data continuity ensures that projects have a single data source, providing a clear picture of the myriad interdomain and inter-system interactions. As changes are made to the design, they can be examined with detailed impact analysis that will inform the engineer of issues the change may cause in other domains. For instance, moving or removing an ECU could be assessed for its impact on network timing, signal integrity, or physical clearance and collision issues. As a result, changes are made knowing their full impact on the system.

## Enabling the autonomous drive winners

Generative design will be a key enabler for new and established automotive companies in their pursuit of developing fully autonomous vehicles. The ability to generate electrical system architectures automatically enables early exploration and optimization of designs while embedding company IP into the design flow. Additionally, a singular source of data promotes consistency between domains, design reuse, and enhances the analysis of change impact. Finally, tight integrations between the electrical domains and with mechanical and PLM tools streamlines the entire design flow from conception through production.

The massive complexity inherent in autonomous vehicle design will continue to push the tools and methodologies used by automotive engineers. This is especially true in the electrical and electronic systems domains as they come to dominate the operation of a vehicle's safety-critical systems and amenities. The winners in this disruptive technology will be those companies that can most effectively integrate the advanced technologies required for autonomous drive into a package that is reliable, safe, and attractive to consumers, and then get those technologies to market quickly and with a high level of quality.

## References

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