DIGITAL INDUSTRIES SOFTWARE

Achieving automotive performance and reliability with end-to-end generative E/E design

Executive summary

The rise of end-to-end generative design in the automotive sector is transforming electrical and electronic (E/E) development by enabling the design process within a 3D context. Siemens' solutions play a pivotal role in this evolution, leveraging generative design to enhance every stage – from concept creation to system integration – and offering engineers a more holistic view of complex E/E architectures. By integrating design, simulation and validation into a single workflow, Siemens' tools improve efficiency, accelerate decision-making and optimize performance.

This white paper explores the capabilities of generative automotive E/E design, how 3D contextualization is driving advancements in electrical system development and paving the way for smarter, more agile vehicle designs.

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Trends shaping the automotive industry

The automotive industry is experiencing a time of great transformation, with rapid growth in complexity largely due to innovations in vehicle autonomy, electrification and data connectivity. These innovations are in part driven by E/E systems, including electrical networks and embedded software.

Historically, vehicle architectures relied on multiple electronic control units (ECUs), each serving a specific function; however, as more ECUs are added, space limitations become a significant challenge (figure 1). This complexity is prompting OEMs to rethink their design strategies to accommodate these changes effectively.

One of the key trends among OEMs is to consolidate multiple ECUs into fewer, more high-performance computation nodes. This shift addresses space constraints within the vehicle, allowing for more streamlined designs while supporting the advanced computational needs of modern vehicles. At the same time, it improves efficiency, decreases the vehicle's weight and enhances system performance.

The shift toward ECU consolidation paved the way for centralized or zonal architectures, which help to optimize space and support emerging needs for faster processing and more efficient signal transmission across the vehicle.

Additionally, with vehicles becoming increasingly connected through technologies such as wireless networks, there is a great emphasis on cybersecurity. New architectures include gateways, firewalls and separation strategies to protect in-vehicle and off-vehicle networks.

To design today's vehicles, it's critical to address the growing demands for connectivity, security and architectural complexity. Let's examine how Siemens Capital software and the Siemens Xcelerator portfolio answer the call.

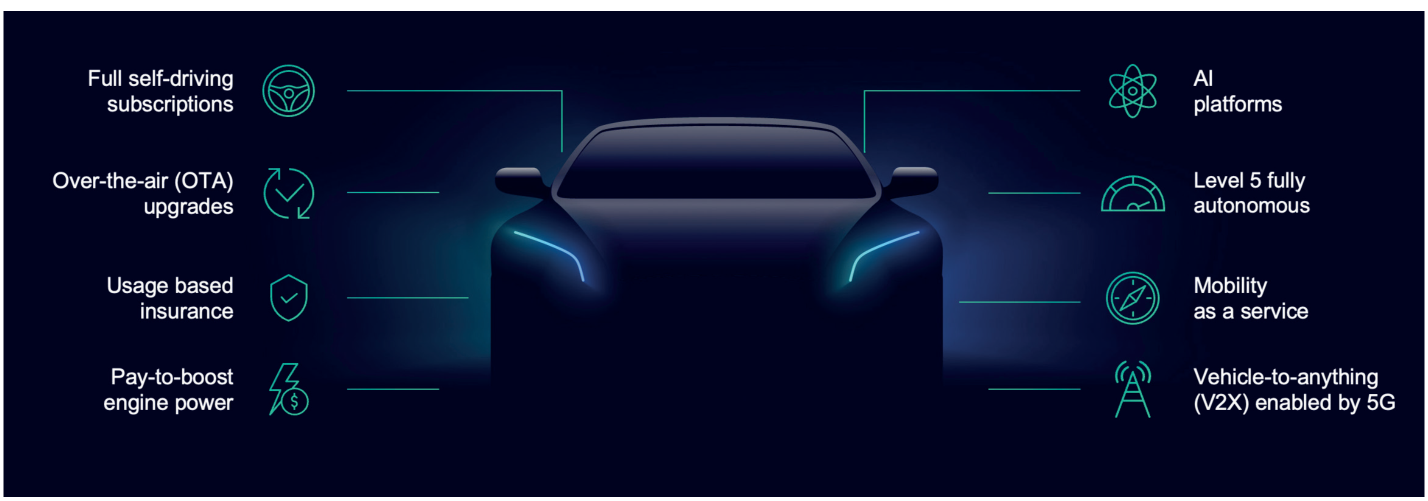

Figure 1. An explosion of complexity and changes in the structure of the physical wire harness and electrical system has led to a dominance of electronics and software in the modern vehicle.

Generative design principles and capabilities

Siemens Capital software is a comprehensive E/E systems development solution within the Siemens Xcelerator, the integrated portfolio of software, services and application development platforms designed to help companies become digital enterprises. Capital directly supports systems, electrical networks, and software – technologies that are core to today's complex products.

Within the Capital solution, generative design accelerates development and generates outputs that feed the next design level, ensuring an unbroken digital thread throughout the engineering process. It takes a set of inputs and generates deterministic outputs that are inherently correct by construction.

The Capital solution uses existing design data – logical circuits, topology, layouts, libraries, parts, symbols and design rules – correctly the first time, leveraging automation and built-in constraints to minimize repetitive work. For example, Capital transforms functional models into architectures that drive downstream phases, including logical systems, communication networks, software designs and even plant and factory modeling for generating work instructions (figure 2).

Functional models aren't the only inputs to vehicle architecture. To generate the best possible outputs and give designers more accurate data for evaluation and optimization, Capital leverages carryover from existing architectures, manages complexity with product plans, and links requirements for traceability. Additionally, users can model the platform topology, incorporating mechanical computer aided design (MCAD) data to align with the physical platform. This entire process is driven by reusable, configurable rules that govern automation while ensuring compliance with manufacturing, company and certification requirements. Configurable metrics measure design compliance, offering insights into the impact of changes or alternative implementations.

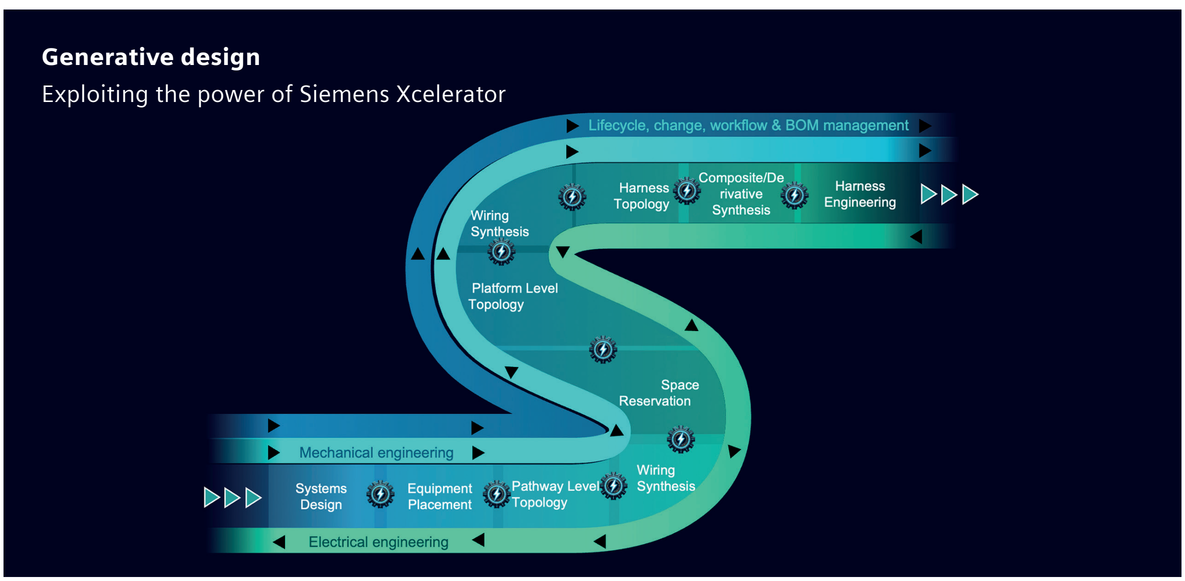

Figure 2. Within Capital, use generative design to accelerate the design process and deliver accurate outputs that feed subsequent design stages, ensuring the digital thread remains intact throughout the engineering workflow.

Automation and integration in design processes

A key aspect of the design flow is automation, which combines simple system connectivity with physical harness topology, synthesizing thousands of wires and splices to implement the electrical distribution system. The process begins with space allocation and reservation studies, enabled by 3D data points, and progresses to system design, incorporating devices and signals in the vehicle context. Wiring synthesis then produces accurate, optimized wiring automatically. Automation also optimizes configuration complexity, supporting all possible combination orders and ensuring production-ready wiring architecture.

With this integrated approach, wiring definitions can flow seamlessly through the Capital Systems Integrator tool, enabling fast and effective change management across domains.

Challenges in domain collaboration

There are many challenges to overcome when attempting to integrate the electrical and mechanical domains, including:

- **Cross-discipline integration:** Traditional separation between electrical and mechanical engineering creates complex data incompatibilities, requiring seamless electronic computer aided design (ECAD) and MCAD integration to maintain an unbroken digital thread.
- **Data alignment challenges:** Multiple touch points and independently developed processes make aligning data difficult, as coordination often occurs on different schedules.
- **Managing design complexity:** The increasing complexity of modern vehicles demands robust change management to handle numerous trade-offs and maintain a synchronized feedback loop.

From these challenges, we can identify the key capabilities needed for automotive tools to effectively overcome them.

"Collaboration across domains is crucial. Leveraging capabilities that enable faster, easier collaboration is key to accelerating innovation."

Chad Jackson
Lifecycle Insights

How Siemens Capital and the Siemens Xcelerator Portfolio address today's automotive design challenges

As mentioned, Siemens Xcelerator is a comprehensive and integrated portfolio of software and services for electronic and mechanical design, system simulation, manufacturing, operations and lifecycle analytics. Let's dive into how they work together to support generative E/E design in a 3D context.

Continuous integration and cross-collaboration
The Siemens Xcelerator portfolio is a solution for creating a comprehensive digital twin that manages data across multiple engineering domains. It is highly customizable, allowing companies to develop a modern, personalized ecosystem that serves all engineering teams. Recognizing that most projects don't start from scratch, Siemens Xcelerator integrates into existing OEM and software ecosystems, providing the flexibility needed to connect tools and workflows. Capital, a key part of the Siemens Xcelerator portfolio, collaborates with other MCAD and product lifecycle management (PLM) tools to deliver the requested capabilities.

Visualizing 3D assembly for accurate fabrication
The integration of Capital and MCAD enables seamless data exchange at various stages, helping users understand the interdependencies between electrical and mechanical domains. For example, factors like connector and battery blocking angles – essential for achieving proper installation – are defined within MCAD but must also be represented on harness drawings for accurate fabrication.

Managing change with the digital twin
Change management plays a critical role by supporting concurrent design processes and retaining mapping data, ensuring updates are synchronized across all design stages. The integration provides enhanced visibility through the digital twin, which allows for the verification of electrical interconnects before building a physical prototype to minimize errors, control design costs and ensure quality targets are met.

Capital and NX in action

The integration between Capital and NX, the Siemens Xcelerator software for design and manufacturing, enables a workflow for electrical and mechanical design. Figure 3 shows the items we will cover in this section.

The process begins by synchronizing devices and nets across platforms: device and net data from Capital Wiring Designer are displayed alongside the corresponding NX model, and the Component Navigator is automatically populated with the data. The designer can then place devices automatically or manually based on the configuration of the PLM tool, such as Siemens Teamcenter, integrating Capital, NX, and Teamcenter libraries (figure 4).

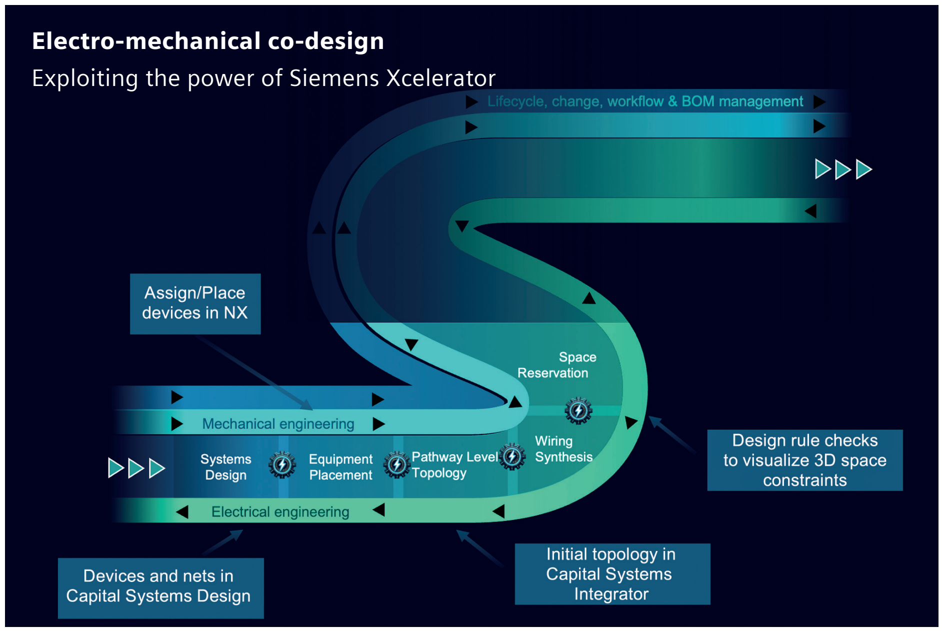

Figure 3.

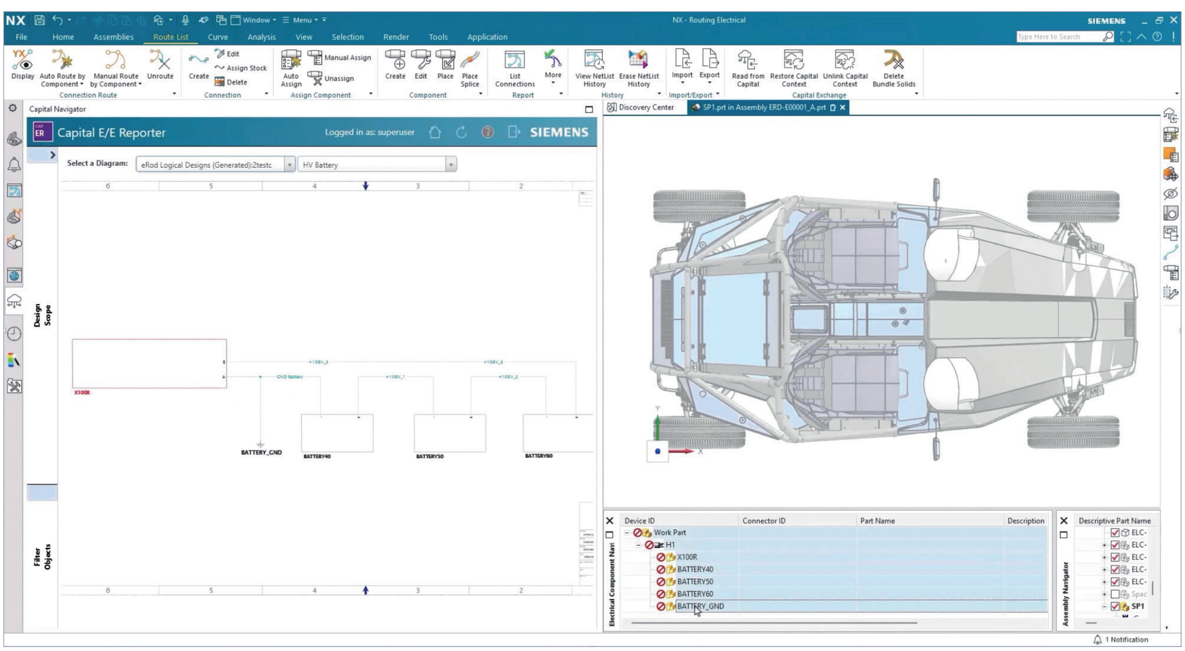

Figure 4. Space reservation flow: with devices and nets in Capital Wiring Designer on the left, and 3D model in NX the on the right, you can populate the component navigator below.

Once devices are in place, the designer can create pathways for signals to ensure all devices interconnect using cross-highlighting between Capital and NX to verify connectivity. Next, they can define space reservation diameters, representing the maximum bundle diameters allowed by 3D constraints. This information is critical for maintaining accurate space allocation throughout the design.

The initial topology – still in its early stage – is imported into the Capital Integrator plane. Capital applies different types of flattening based on specific requirements, creating bundles and holes. It associates devices with their respective logical designs and generates wiring content automatically. This process includes the placement of devices, grounds and wires (figure 5).

During wiring synthesis, the solution generates required wires, splices and IOS configurations automatically. It verifies that bundles adhere to the space limits set in MCAD. If bundles exceed those limits, a design rule check provides feedback, prompting adjustments to wire routing or device placement. In the case that space reservation is updated, data is sent back to Capital, where it undergoes another design check to ensure all bundles comply with constraints.

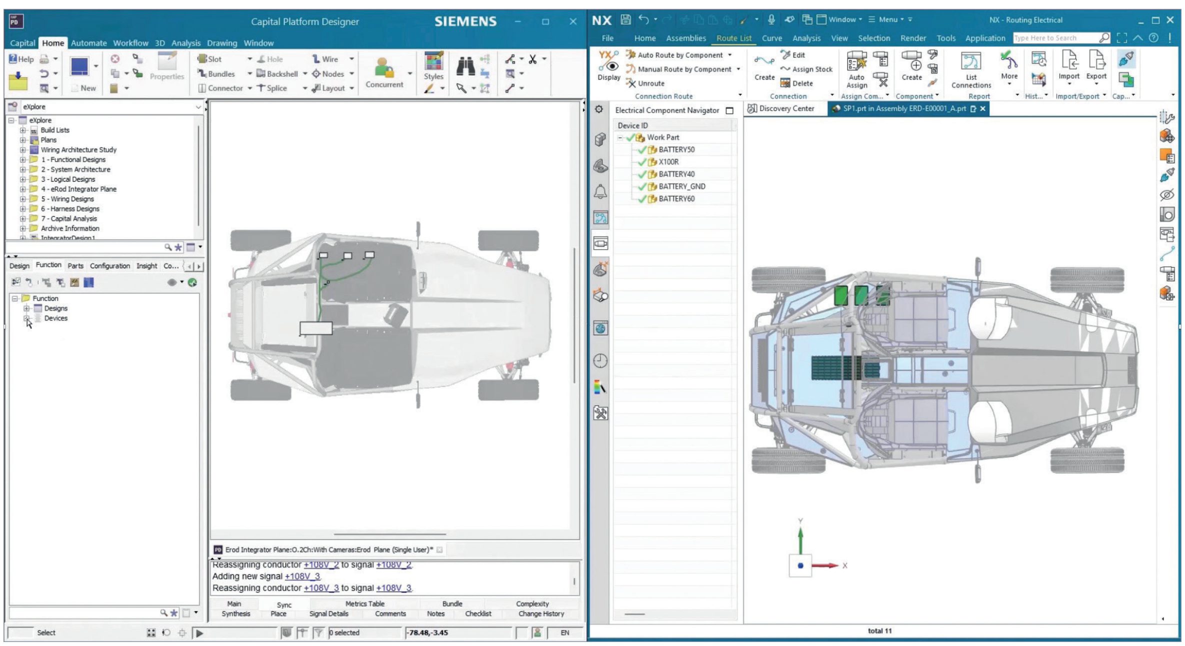

Figure 5. Initial topology: Associate required logical designs and generate the wiring content. Once wiring designs are assigned, you can automatically place all the devices including grounds.

The next steps (figure 6) involves adding inlines and breaking pathways, and separating harnesses to create a platform-level topology. MCAD engineers facilitate this process with data from the Capital design. Using the platform-level topology, they can create the next phase topology design with slots and bundles, and leverage automatic wiring synthesis to add connectors, create splices and route the wires. Wiring synthesis defines the individual harness levels, considers the impact of optional devices, and calculates the maximum complexity for each harness configuration.

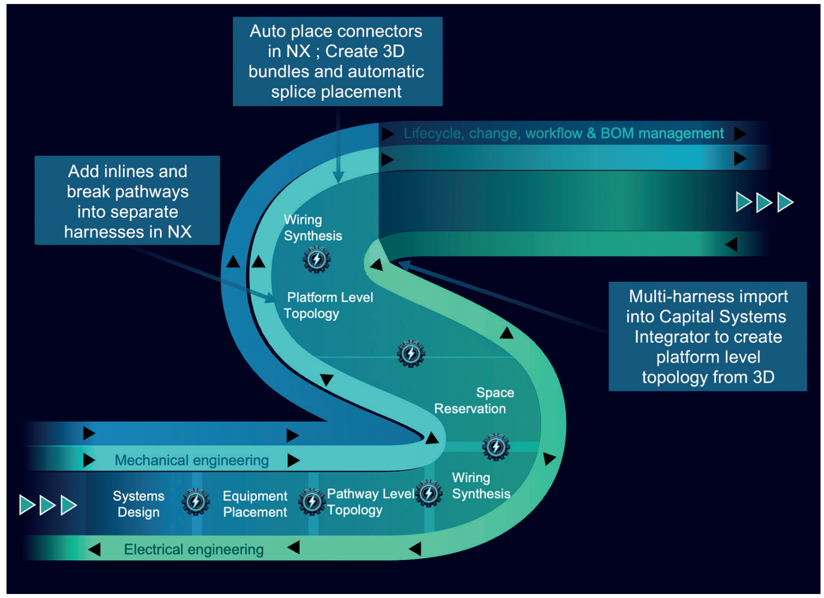

Figure 6.

The design then transitions to the harness assembly phase, importing the harness layout into the integrator, which enables configurable naming, inline creation and connector slot assignments. Multiple harnesses – body, door, and IP – are integrated simultaneously, with options for flattening and other customization settings. Once all harnesses are processed, they are placed in the topology (figure 7), and the 3D

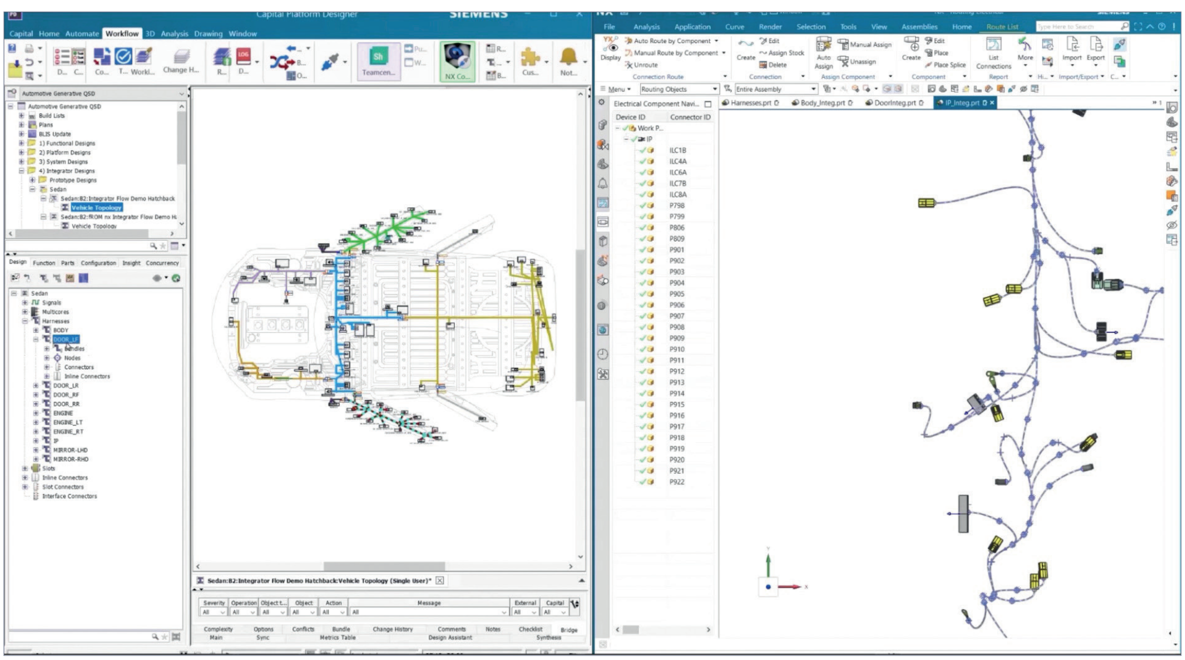

Figure 7.

bundles and wiring synthesis are created automatically.

For final adjustments (figure 8), the engineer can place splices and connectors manually or automatically. The design allows for ongoing synchronization between electrical and mechanical teams, easily bringing any changes back into Capital. As the harness topology is developed, Capital generates composite and derivative breakdowns automatically based on option expressions, which can be visualized in both Capital and NX.

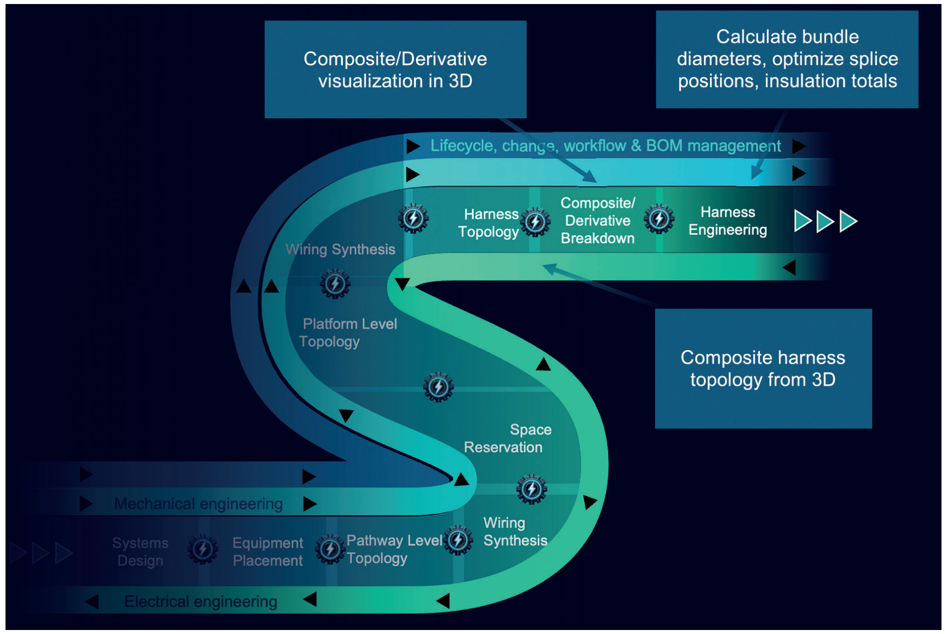

Figure 8.

The embedded navigator mode in NX enables direct access to Capital data, supporting real-time data exchange and visualization of both composite and derivative harnesses. This mode makes it easy to view complex designs, eliminating rework and simplifying the process of refining the topology to ensure compliance with engineering requirements.

Engineers can also exchange data using file-based imports or integrated PLM tools such as Teamcenter. They can import and visualize complete harness information, including connectors, wires and derivatives, as well. This flexible approach ensures a fully integrated design process that supports seamless collaboration across electrical and mechanical engineering domains.

Integrated electrical-mechanical design: Key capabilities

By integrating Capital with MCAD, Siemens delivers on all essential capabilities of integrated electrical-mechanical design:

- Engineers can work independently with shared data
- Designers have easy and direct access to all data
- Seamless cross-domain PLM interaction
- Smooth intelligent change management
- Support for sustainable best practices

Conclusion

The automotive industry is rapidly evolving, driven by advancements in vehicle autonomy, electrification and connectivity. Siemens delivers essential capabilities for integrated electrical-mechanical design, including shared data access, seamless cross-domain PLM interaction, intelligent change management, and support for sustainable best practices. By integrating design, simulation, and validation into a cohesive workflow, Siemens enhances efficiency, accelerates decision-making, and optimizes performance across electrical and electronic systems.

Siemens Capital and NX address the challenges of modern automotive design by providing comprehensive tools for continuous integration, cross-domain collaboration and intelligent change management. These solutions empower engineers to develop smarter, more agile vehicle designs that meet the growing demands for connectivity, security, and architectural complexity.

As the automotive sector continues to innovate, Siemens' solutions will play a crucial role in shaping the future of vehicle development, ensuring performance, reliability and sustainability in an increasingly complex landscape. Learn more about Capital at siemens.com/capital.

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