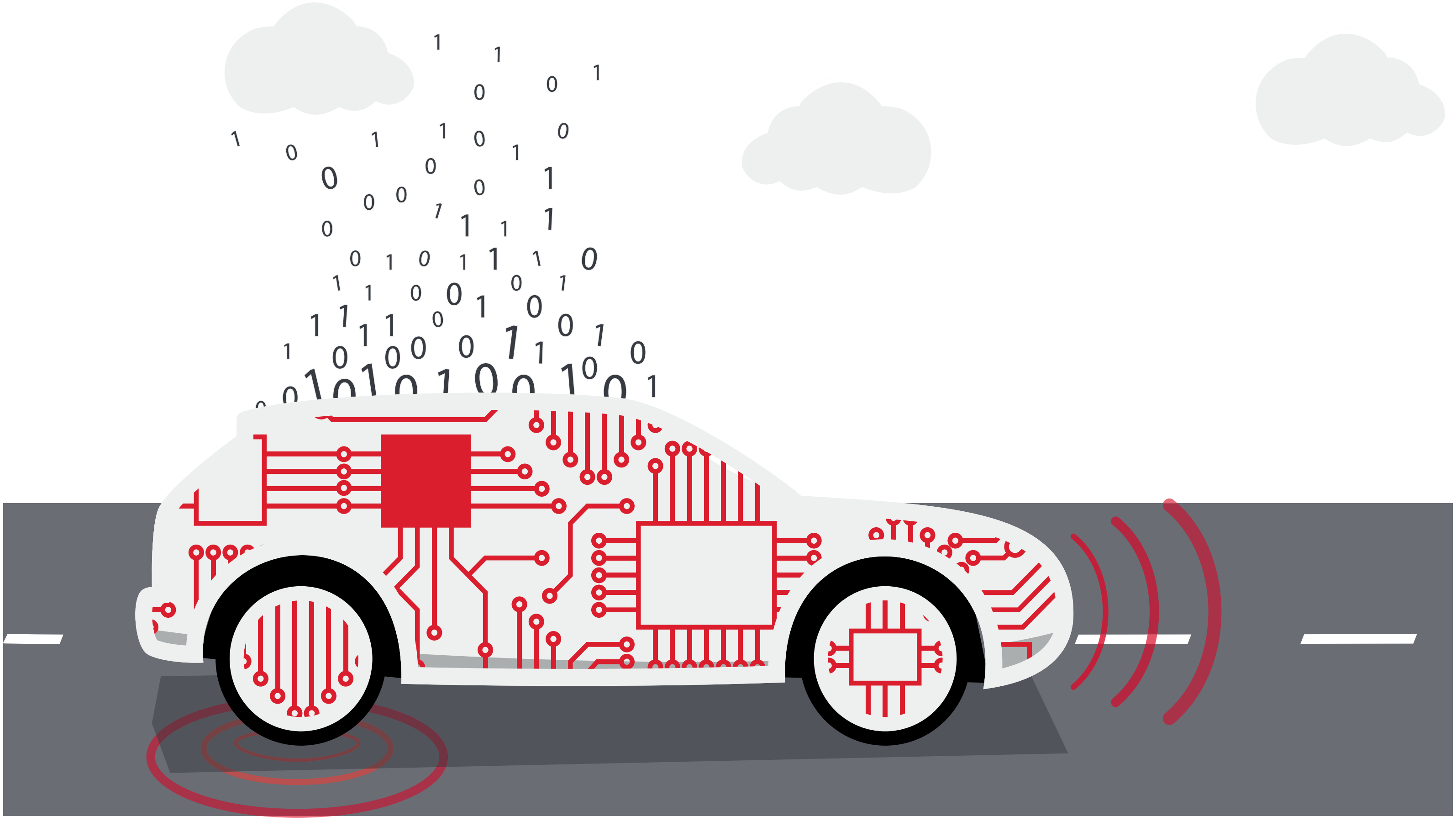
Automotive Development



Revolutionizing Automotive Development for the Digital Future

A solution for integrating innovative silicon and software design into automotive systems engineering processes

Porsche Consulting
Strategic Vision. Smart Implementation.

Introduction

Today's automotive Original Equipment Manufacturers (OEMs) are in a race to satisfy consumer demand for an expansive and rapidly evolving array of digitally reliant vehicle capabilities, functionalities, and features. The dependence of these offerings on automotive electronic architectures has drastically altered the relationship between development organizations and vehicle software and silicon. As technical teams attempt to develop capabilities to navigate this paradigm shift, they face additional pressure from legal requirements, new competitors, and profitability constraints.

The solution presented in this paper integrates the Synopsys Triple Shift Left approach with Porsche Consulting Systems Engineering principles. Triple Shift Left describes the bottom-up approach to development of electronic architectures leveraging smarter, safer System-on-Chip (SoC) IP solutions, parallel software and hardware development, and comprehensive software testing. Systems Engineering principles focus on early phase strategic planning and alignment, requirements engineering and release management, and considerations for longer product lifecycles. Utilizing Systems Engineering principles to guide Triple Shift Left implementation ensures successful integration of new techniques and tools into existing organizations and processes. The following analysis outlines how the industry's current challenges necessitate such a novel solution.

Situation

Introduction to Vehicle Electronic Architectures

The invention of the world's first self-propelled wagons, ancestors of today's cars, represented the pinnacle of 19th century mechanical engineering expertise. These vehicles could accelerate, brake, and turn in response to simple and relatively effortless commands from the operator via a steering wheel and pedals mechanically linked to the engine, axles, and brakes. As cars became more and more widespread over the following decades, automotive OEMs refined these mechanical components. In this way, although vehicle speeds, sizes, and shapes changed, the relationship between operator and vehicle remained rooted in the direct, analog connections of gears and belts.

The direct mechanical interaction of driver and vehicle began to evolve with the introduction of the very first automotive Electronic Control Units (ECUs) in the 1970s, over 100 years after the invention of the automobile[1]. The first ECUs, focused primarily on managing engine operations, were widely implemented by automotive manufacturers as a result of regulatory actions such as the Clean Air Act (originally introduced in 1963 in the United States) to regulate emissions and fuel economy. To many drivers, this technological leap from purely mechanical to electronically managed vehicle commands made little or no difference to the user experience. The command from the driver and the functionality of the vehicle remained the same: "I push on the gas pedal and the vehicle accelerates." For OEMs, however, the introduction of electronic controls marked the beginning of a massive shift in vehicle functional capabilities and Product Development Processes (PDP).

Automotive Electronic Architectures Today

From their humble beginnings, ECUs quickly proliferated throughout the automotive industry to increase the comfort, efficiency, safety, and performance of new vehicles. Offering automatic windows, anti-lock braking, infotainment systems, and other vehicle features required an increasingly complex electronic architecture of hardware and software. The clear delineation and relative independence of any given ECU's functionality and hardware plus software requirements fostered a supply chain in which automotive manufacturers could select discrete components from Tier 1 suppliers to enable specific functionalities in their products. In fact, the explosion of ECUs may be partially attributed to the relative "plug and play" ease offered to automotive development teams. This trend has continued to the point that today's luxury vehicles, boasting a wide breadth and depth of features as advanced as lane keep assist and internet connectivity, may have a network of well over one hundred ECUs (figure 1) hidden under their sheet metal[2].

As features and functionalities evolve in complexity, so do electronic architecture requirements. Self-parking functionalities, for example, require an electronic system capable of processing many types of sensor data gauging not only the host vehicle's speed, position, and orientation, but also that of other vehicles and infrastructure. Massive amounts of input data must be collected, fed into complex Artificial Intelligence (AI) algorithms, then output as a combination of indications to the driver and commands to the host vehicle's braking and acceleration controllers. To complicate matters further, the safety-critical nature of functionalities such as automatic emergency braking dramatically increases the safety, security, and performance requirements of corresponding electronic architectures.

90 %*

of all **innovations** are based on **software** and **electronics**, 50 % on **system level**

We have to become experts in systems engineering

100+*

ECUs are **developed** and **mounted per vehicle**

We need to strengthen system thinking

70 %*

of **vehicle systems** are currently **only vertically networked** and **integrated**

We need to use the potential of fully networked systems

* EENewsEurope, Siemens PLM

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Figure 1. Key figures for automotive electronics engineering and innovation

Warning Sign: Critical Error Curves

For automotive engineering teams, this increasingly complicated architecture of software and electronics hardware presents a major challenge. The classical automotive PDP, refined over decades of developing, testing, and integrating discrete mechanical hardware components, has not been optimized for the daunting and vital task of electronics hardware and software system development. Although many OEMs recognize the increasing importance and differentiation potential of electronics-enabled functionalities, the traditional tiered ECU supply chain has kept automotive manufacturers relatively insulated from electronics hardware and software development processes. Now car manufacturers wishing to adapt realize that tool and technology updates require significant investments, but are unable to promise a clear return when implemented in traditional processes. Furthermore, OEMs must decide if and how to develop internal competencies such as detailed electronics requirements specification[3]. Meanwhile, exponentially growing Lines of Code (LoC) require additional layers of verification, certification, and regulatory compliance testing. In addition to these individual issues, the integration of hardware and software components and their interdependence creates a "big bang" effect of critical functionality issues with interoperability.

Defect detection vs. cost-to-repair for embedded systems

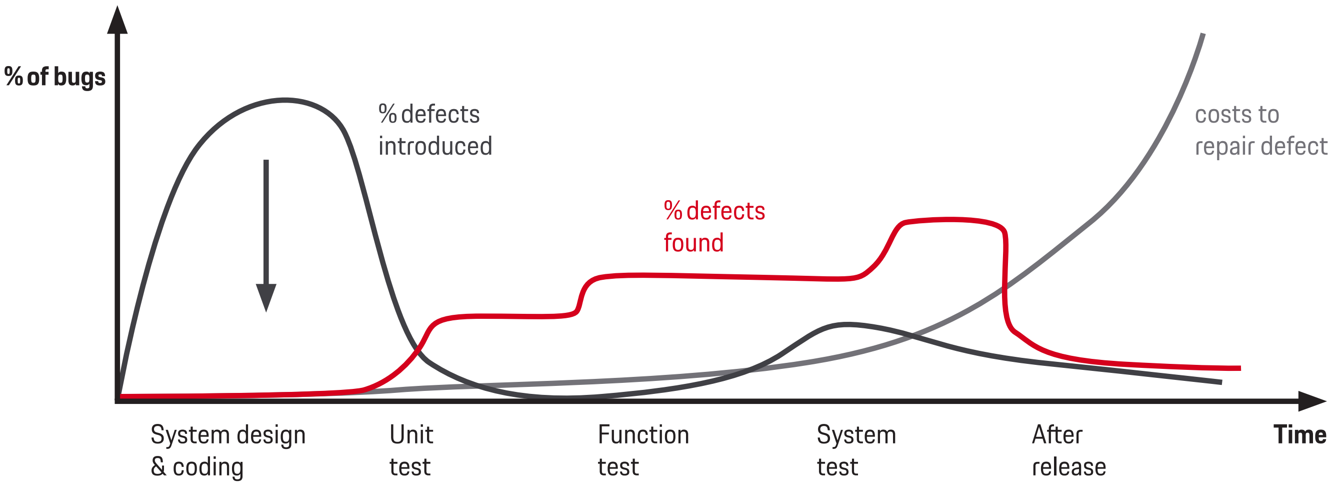

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Figure 2. The relationship between defect introduction, discovery, and cost to repair

These challenges result in an increasingly back-loaded critical error curve in feature and vehicle development (figure 2), as evidenced by the prevalence of "firefighting task forces" deployed to correct errors that the framework of existing PDPs cannot address. When these task forces cannot remedy critical errors in time, Start of Production (SOP) targets may be missed, which poses an enormous cost for OEMs and suppliers eager to recoup development investments through sales of finished product. Despite the industry's awareness of these issues and attempts to remedy them, progress has not kept pace with the rush to satisfy market demand for new functionalities and capabilities.

Future Trends for the Automotive Industry

OEMs across the globe have advertised their ongoing efforts to evolve from vehicle manufacturers and distributors to holistic mobility service providers. A growing portfolio of Autonomous, Connected, Electrified, and Shared (ACES) vehicles and business models serves as the foundation for this transition (figure 3). To demonstrate progress, OEM auto show exhibits brim with concept vehicles from electric super cars to fully autonomous sleeper pods. Within many automotive development organizations, however, designing and developing competitive products that can keep up with customer expectations, market disruptions, and financial headwinds will only exacerbate the critical error curve issues already prevalent today.

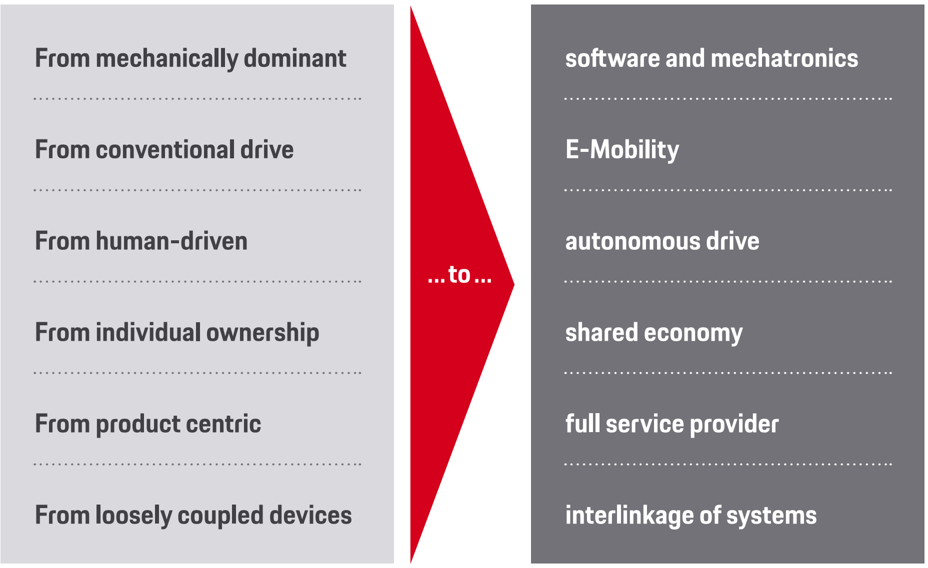

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Figure 3. Mega trends in the automotive industry as related to product development

Products with fixed functionalities and the inability to interface with the digital world no longer satisfy consumers. Instead, full connectivity and the ability to launch new features via Over the Air (OTA) updates have evolved from a differentiator to a requirement, which contrasts with the traditional automotive model of launching a vehicle with a single "face lift" over the course of its 7-year lifecycle[4]. To complicate matters, automobiles remain in service far longer than products such as smartphones, all while enduring much harsher temperature, weather, and wear-and-tear conditions.

As OEMs transition from a pure vehicle manufacturing and distribution business model, they face stiff competition from new entrants and titans of tangential industries. Technology giants such as Baidu, Apple, and Google are not only investing heavily in long-term strategic automotive projects such as Waymo, but have already made their services a key feature in many vehicles through Apple Carplay and similar offerings. Maven, Uber, and Lyft continue to disrupt private vehicle ownership. Tesla, born in Silicon Valley, has demonstrated a desire and ability to integrate electronic hardware and software development into internal operations. In short, OEMs must adapt to an industry with vastly increased competitive pressure.

Furthermore, pressure on traditional OEM business models drives a need for innovation, while constraining investment funds[5]. Stable sales volumes, increasing material costs due to emissions and safety legislation, and an increasing amount of competition for lucrative after sales business are just a few examples of the factors pressuring OEM financial results.

This tumultuous industry climate forces development executives to contend with the need to justify ever-mounting innovation costs without a clear consensus on how best to prioritize and leverage these investments.

Complication

Complicating Factors for Automotive OEMs

Although transitioning into a mobility provider serves as a clear lighthouse for many in the industry, OEMs are discovering that navigating such a change is complicated by the interactions of their legacy business and the industry's new direction. Evolving electronic architectures, outdated Processes, Methods, and Tools (PMT), increasingly stringent regulatory/legal requirements, organizational inertia, and financial uncertainty all hinder OEM innovation initiatives.

Within automotive electronics, development teams are increasingly employing Centralized Domain Controllers (CDCs), which consolidate functionalities of related systems in domains such as powertrain, Advanced Driver Assistance Systems (ADAS), infotainment, and connectivity. Although this eliminates the need for many of the discrete ECUs found in vehicles today, the implementation of CDCs does not guarantee simplicity. CDCs must offer significantly more computing power and may define the vehicle's overall functionality offering, and in turn, its value to the customer. Furthermore, these systems represent a singular potential point of failure for many functionalities. Therefore, designing or selecting CDCs from suppliers necessitates a much deeper understanding of the limitations and capabilities of each system, as well as its interactions with software stacked on top[6].

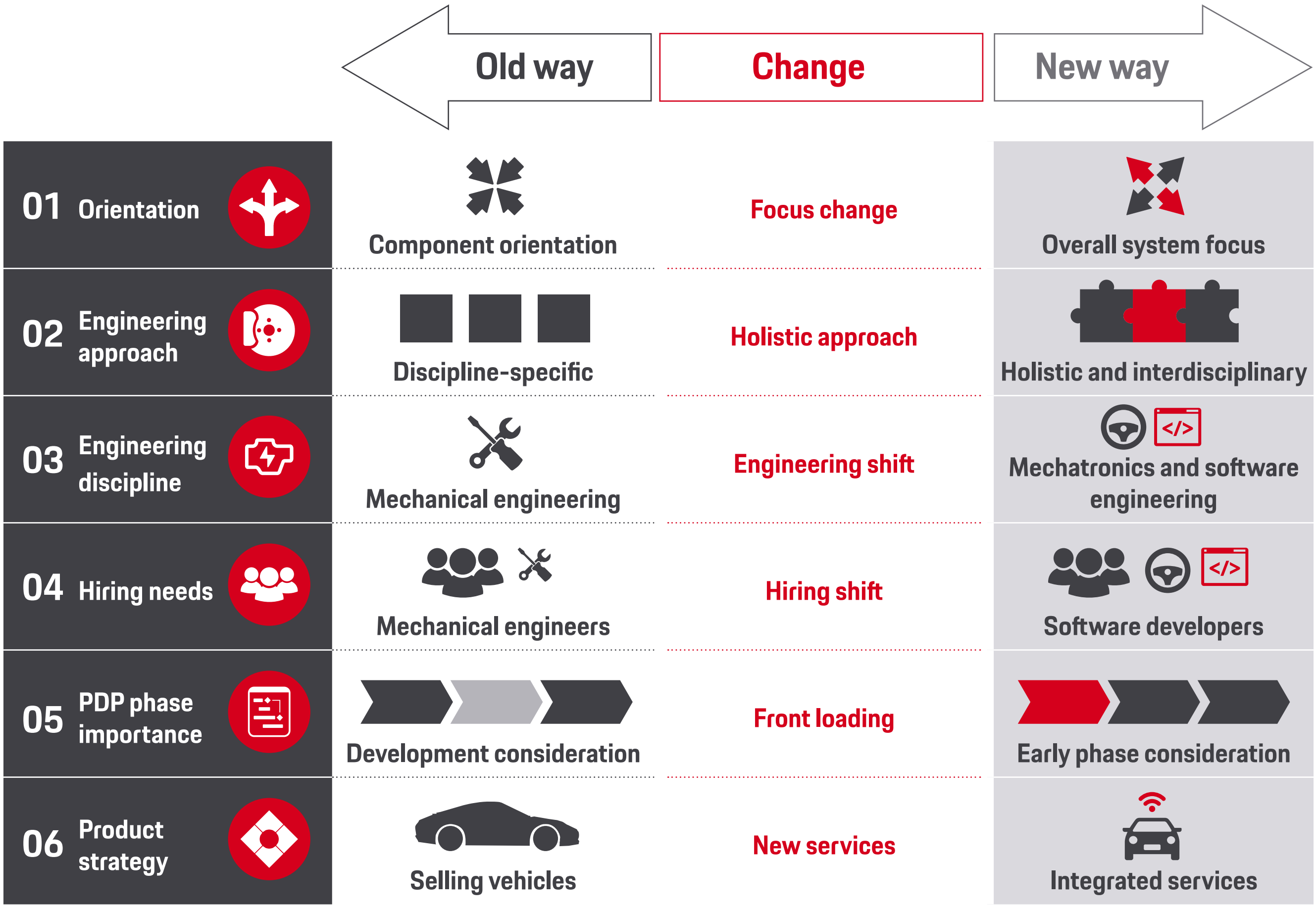
OEMs currently have expertise incorporating implications of crash and safety legal requirements into mechanical hardware (chassis, powertrain, etc.). As electronic architectures become more advanced, complex and safety critical, however, inexperienced automotive development teams encounter new requirements focusing on software integrity, functional safety, and security vulnerabilities (such as UN ECE Cyber Security Recommendations, SAE J3061, ISO/SAE 21434, and ISO 26262)[7].

Developers must also anticipate solutions addressing risks and challenges beyond the scope of legal requirements. The life or death stakes of functionalities such as ADAS, for example, necessitate an approach that ensures a failure rate asymptotically approaching zero. These challenges are exacerbated by the significant increase in technological and system complexity. In order to manage safety aspects and ensure the development of highly complex systems, OEMs need high-performing process landscapes and proper systems definitions framed by strictly defined sign-off gates. Development teams therefore face the difficult decision of how best to manage the tradeoffs between innovation investment and risk, especially in less familiar, yet increasingly vital, fields of expertise such as AI applications, cyber security, machine learning, and safety critical systems.

In short, new products and functionalities require updated PMT portfolios, the effective implementation of which necessitates organizational alignment at all levels. From vehicle platforms to electronic architectures to functionality portfolios, coordination is key to realizing investment benefits. Organizations must pair development strategies with corresponding organizational strategies, including a clearly defined roadmap of expertise development and acquisition.

Overcoming any and all of the above hurdles requires significant financial investment, yet organizations may be hesitant to approve such costs without clear business cases, often delaying necessary investment decisions[8]. A dramatic shift in perspective may be necessary to address challenges such as cost optimization through shared component strategies. Although well proven in mechanical applications, this approach may saddle new vehicles with technical debt, including software vulnerabilities, when applied to electronics applications. If OEMs and their suppliers wish to keep pace with changes in the industry, they must be willing to allow evolution of their internal financial calculations and decision-making processes[9].

In summary, OEMs face more than just a challenging market and an unclear path towards the future. They must also proactively manage the strategy and intricacies of their own transformations in order to ensure a future-proof organization without losing the vital core competencies that have enabled their success thus far (figure 4).



	Old way	Change	New way
01 Orientation	Component orientation	Focus change	Overall system focus
02 Engineering approach	Discipline-specific	Holistic approach	Holistic and interdisciplinary
03 Engineering discipline	Mechanical engineering	Engineering shift	Mechatronics and software engineering
04 Hiring needs	Mechanical engineers	Hiring shift	Software developers
05 PDP phase importance	Development consideration	Front loading	Early phase consideration
06 Product strategy	Selling vehicles	New services	Integrated services

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Figure 4. Necessary evolutions within automotive development organizations

Summarizing the Overall Need

Overcoming the development challenges facing automotive OEMs requires an evolution not only of distinct capabilities and departments, but also of the entirety of the company. Although industry players recognize the need for change, defining a sustainable path forward remains a seemingly insurmountable challenge. Furthermore, established OEMs often find themselves under shareholder pressure to prioritize short-term financial results, which exacerbates a reluctance to invest in bleeding-edge technologies with unproven business cases. The time investment necessary to enact these vital changes only reinforces the industry's need to act quickly. Complacency will result in falling behind competitive pressure. Realizing immediate value from change management efforts throughout the company is therefore vital, but only achievable through a strategically aligned vision of the company's future.

Drawing on decades of electronic architecture and automotive engineering experience, Synopsys and Porsche Consulting have jointly devised a holistic solution to overcome these exact issues facing OEMs and their supply chains. Below is an outline of this approach to update decision-making processes, increase productivity, and dramatically increase development process flexibility.

Solution

Establishing state of the art electronic architecture development competencies necessitates anchoring new product development tools and technologies in an aligned and holistic approach to processes, organizations, and strategy. Many OEMs are now discovering, however, that managing this change is extremely difficult without a clear implementation framework. The solution roadmap presented in this paper guarantees sustainable gains in engineering quality, speed, and efficiency by combining Porsche Consulting's top-down Systems Engineering approach with the Synopsys' bottom-up "Triple Shift Left" methodology.

This concept is an evolution of the classical "V-model" first developed by Boehm (1979), which illustrates the systems development lifecycle and its major milestones. The left side of the V-model focuses on requirements engineering, while the right side focuses on component integration and validation. Porsche Consulting and Synopsys have evolved the V-model into a proven framework for managing today's demand for individual services, complex functions, and the systems that they compose.

This joint solution consists of four major components (figure 5). Each of these, described in detail below, are vital components to a holistic approach for future-proofing OEM development efforts.

Systems Engineering enabled by Triple Shift Left

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Figure 5. Overview of the integrated automotive Systems Engineering enabled by Triple Shift Left

01 Strategic Planning for Technical Development

The first solution element focuses on strategic alignment in the early stages of the development process, a specialty of Porsche Consulting. Even before conceptualizing initial models and building first prototypes, it is essential to develop a cohesive high-level strategic plan, delineated into three phases (figure 6).

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Figure 6. Technical development strategic planning framework

CORPORATE SITUATION

A proper strategic plan begins with the analysis of the current company's situation to develop and align a clear view of existing capabilities and weaknesses. For example, OEMs possess deep expertise in mechanical engineering, refined through many years of experience. Suppliers, on the other hand, have historically handled software development responsibilities. A truly comprehensive understanding of the corporate situation requires a deep-dive analysis of cross-functional indicators such as financial structures and organizational configurations. Depth, breadth, and quality of input data is paramount to the robustness of this corporate situation analysis.

TECHNOLOGICAL STRATEGY

The second component of strategic planning is technological strategy definition. This vital undertaking grants insight into which technologies the company prioritizes, and has developed competitive advantages in, relative to the industry. For example, powertrain electrification or autonomous vehicle technology development represent technological pillars used to benchmark OEMs or other industry players. Having a clearly prioritized technology investment roadmap is vital to bringing concepts into series production. Accordingly, required budget and resources must have guaranteed and predictable availability. Otherwise, effort invested in the planning process may result in projects that never reach full implementation, which represents a common, but highly inefficient, allocation of resources. In order to develop and maintain a clear technological strategy, high-performance innovation management organizations are required. These teams are responsible for anticipating and prioritizing technological developments, then recommending corresponding investments. Establishing these mechanisms enables timely decision making for efficient project prioritization or rejection.

PROJECT REALIZATION

The third component prioritizes projects offering the best return on investment and effort. Although many development organizations may voice preference for developing products that include “breaking-the-boundary” technologies, it is imperative that these products first align with the company's strategy and competitive advantages. Properly mapping these approved technology projects drives optimal utilization of the company's existing capabilities and resources.

These three components, when properly integrated into an organization's existing processes, comprise a crucial foundation enabling the evolution of OEM technical development efforts. In the context of automotive electronics engineering, for example, these efforts highlight which technologies and tools the OEM needs to develop high-performing, safe, and secure SoCs. Proper implementation necessitates not only involvement of the entire organization (rather than isolated strategy teams), but also continuous processes (rather than distinct, time-constrained strategy projects). Although strategic planning for technical development does not ensure an OEM's technical processes are future-proof by itself, it enables further actions that push an organization into a new era of Systems Engineering.

02 Requirements Engineering and Release Management

The second key solution enabler has been adapted from two essential aspects of Porsche Consulting's approach to developing complex products and services (figure 7) – requirements engineering and release management. Properly addressing these topics ensures technical development teams are well equipped to answer questions such as "How do I know what customers value? How do I quantify and prioritize value-generating features? How do I determine a product as fit for release? Does the final product offer the functionality the customer desires?" Automotive engineers face these questions every day, but evolving competency requirements (from mechanical to digital) and shifting customer demand (from hardware to functionalities) have made the consistent and timely delivery of confident conclusions extremely difficult.

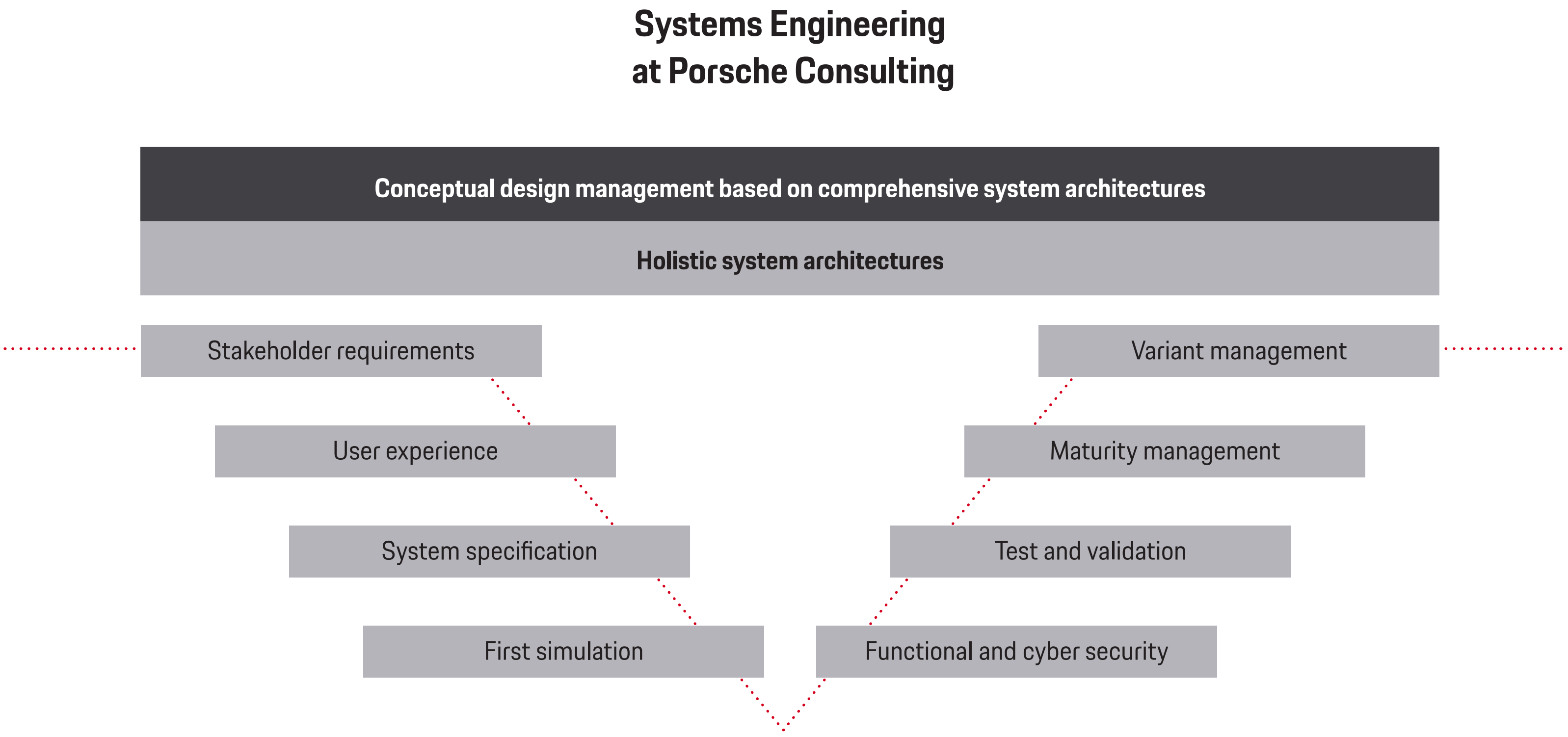

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Figure 7. Overview of Porsche Consulting Systems Engineering approach

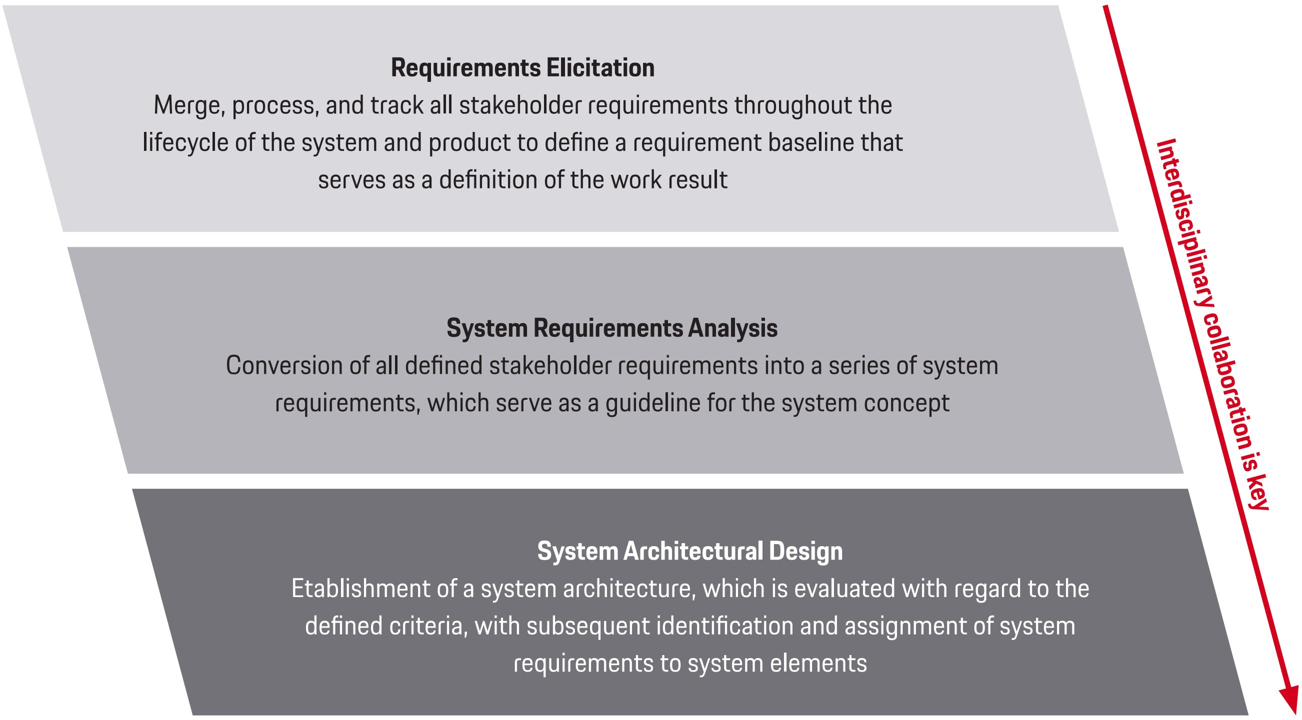
The Porsche Consulting Systems Engineering approach grants OEMs perspective regarding how to establish best practice processes, methods, tools and organizational structures for Requirements Engineering and Release Management. This approach examines two defining aspects of Requirements Engineering and Release Management – holistic system thinking and traceability.

HOLISTIC SYSTEM THINKING

Today's product development processes are predominantly oriented around individual system components and their refinement over product generations, fostering a tiered supply chain. Successful development of innovative products, however, requires a more holistic approach that prioritizes end-to-end linkage of customer requirements with products and services. This paradigm shift results in OEMs that sell cars plus the back-end functions, infrastructure components, and everything else connected to the vehicle. As an example, autonomous driving requires "V2X" (vehicle to infrastructure, other cars, internet, etc.) connectivity. This phenomenon naturally leads to more holistic ecosystem thinking as customers increasingly derive values from functions, rather than just the vehicle hardware. Keeping pace necessitates a shift in OEMs' mindsets – from developing components within cars to systems within ecosystems.

VERTICAL AND HORIZONTAL TRACEABILITY

A structured view of the relationships between systems, functionalities, and components enables vital transparency throughout the various stages of the development process. The benefit of and need for this traceability applies not only to functions and systems but also to requirements. Employing appropriate techniques such as systematic documentation and cross-functional cooperation ensures development teams will achieve the levels of granularity and cohesiveness necessary to enable vertical traceability. Vertical traceability refers to the ability to trace requirements through the various levels of ecosystem and component development (figure 8). In turn, this allows technical organizations to ensure that functions and services deliver desired customer value.



Requirements Elicitation
Merge, process, and track all stakeholder requirements throughout the lifecycle of the system and product to define a requirement baseline that serves as a definition of the work result

System Requirements Analysis
Conversion of all defined stakeholder requirements into a series of system requirements, which serve as a guideline for the system concept

System Architectural Design
Etablishment of a system architecture, which is evaluated with regard to the defined criteria, with subsequent identification and assignment of system requirements to system elements

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Figure 8. Progression of systems requirement definition and design

As illustrated by the right side of the V-model, structured requirements and releases exhibit co-dependencies. Further connecting the left and right sides of the V model enables systematic release management, referred to as "horizontal traceability". As an illustrative example: if component/function x fulfills requirement y, component/function x is released. This logic entails a paradigm shift from traditional development logic; components and functions release only with fulfilled customer requirements, not when the component or function is working in isolation. This logic is transferrable to all system levels and supports legal requirement and industry standard conformity.

BOTTOM-UP ELECTRONIC ARCHITECTURE DEVELOPMENT

Through strategic planning for technical development and requirements engineering for release management, OEMs can establish a robust top-down view of required system functionalities. For automotive development organizations, the benefits of these approaches in mechanical engineering efforts are quickly realized by leveraging existing internal expertise. In the realm of electronics engineering, however, many OEMs need the support of additional technical expertise. Partners such as Porsche Consulting and Synopsys, offering experience, proven techniques, and specialized technologies, represent the ideal partners for OEMs seeking to overcome the challenges of adapting their development processes for an electronics-centric world.

03 Triple Shift Left Approach

Technology companies in Silicon Valley have developed various approaches enabling a "shift left" of electronic architecture development. The term "shift left" originates from within the software industry, referring to identifying bugs early in the design process rather than during post-release testing. IBM found that fixing a software bug during the design phase is 100 times less expensive than fixing it after release[10]. When physical semiconductors and other electronics hardware components are involved, the cost of bug fixes increases even more. Over the past thirty years, Synopsys has guided system-on-chip (SoC) designers tackling exactly these issues through a solution dubbed "Triple Shift Left", which enables not only early error reduction, but also parallel electronics hardware and software development.

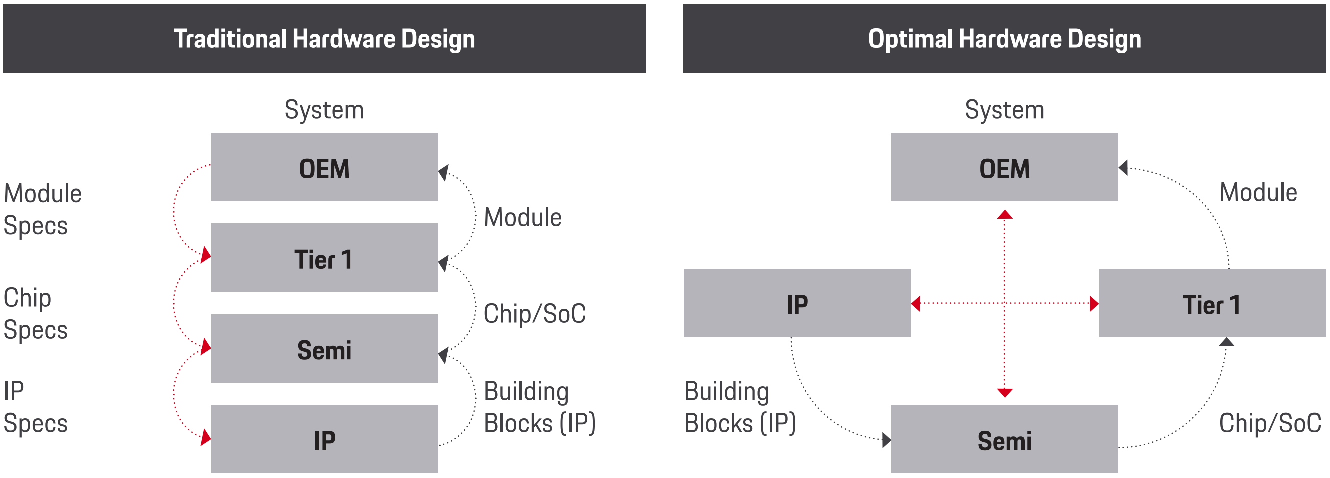
This approach transforms serial development processes into parallel ones, enabling not only earlier (and cheaper) flaw identification, but also deeper insight into the vital intricacies of early design phases. The Synopsys solution consists of three main levers: smart and safer automotive SoC design, parallel software and hardware development, and comprehensive automotive software testing. These capabilities allow ground-up incorporation of safety, security, and reliability into SoCs, identification of software issues up to 18 months earlier, and integration of security and quality into software development.

SHIFT LEFT I – SMARTER, SAFER AUTOMOTIVE SOC DESIGN

As vehicle functionalities become more and more advanced, so does the underlying electronic hardware. In the traditional automotive electronic hardware supply chain, OEMs define system requirements to Tier 1 suppliers, who pass chip specifications to semiconductor manufacturers, who pass intellectual property (IP) "building block" specifications to IP developers[11]. Deliverables advance up the supply chain and integrate with each other, all the way up to the OEM system level (figure 9). In this way, each link in the chain does not need technical expertise beyond their domain. While this model has functioned well for mechanical applications and relatively simple electronic hardware applications, it exhibits several disadvantages.

As the various parties in the supply chain generally communicate requirements through a Request for Quote (RFQ) or Request for Proposal (RFP), specifications may be misinterpreted. Additionally, a certain amount of information gets "lost in translation" as it passes through the supply chain. Lastly, and perhaps most importantly, this model limits OEM quality assurance efforts and visibility into what the various players in the supply chain may be capable of, currently or in the future.

Automotive Electronic Architecture Supply Chain



- Specifications are communicated down supply chain with increasing levels of granularity
- Entities do not have technical expertise to skip a link in the supply chain

- Partnerships facilitate direct communication to ensure minimal "loss in translation"
- Greater technical expertise allows more transparency

The traditional automotive electronics hardware supply chain does not grant OEM sufficient insight or confidence into the components which comprise their electronic systems

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Figure 9. Evolution of the automotive electronics system supply chain

Leveraging silicon expertise allows OEMs to translate desired functionalities into detailed specifications to build the best electronics hardware (optimized for safety, security, and reliability) from the ground up. OEMs and other supply chain players can save years of effort by front-loading SoC designs with safe, secure, reliable, and reusable automotive-grade IP specialized for automotive applications such as ADAS, infotainment, or powertrain management.

These building blocks, when combined into function-dedicated SoCs (rather than the traditional “pick and choose” separate ECUs model), reduce overall system costs, power draw, space consumption, and security risks. Furthermore, utilizing IP with ISO 26262-compliant logic guarantees various levels of ASIL (A, B, C, and D) compliance throughout an OEM’s electronics supply chain. Selecting the right IP is also vital to fulfilling stringent AEC-Q100 reliability standards and support the latest protocols required in new applications such as embedded vision, sensor fusion, and cloud connectivity user interfaces.

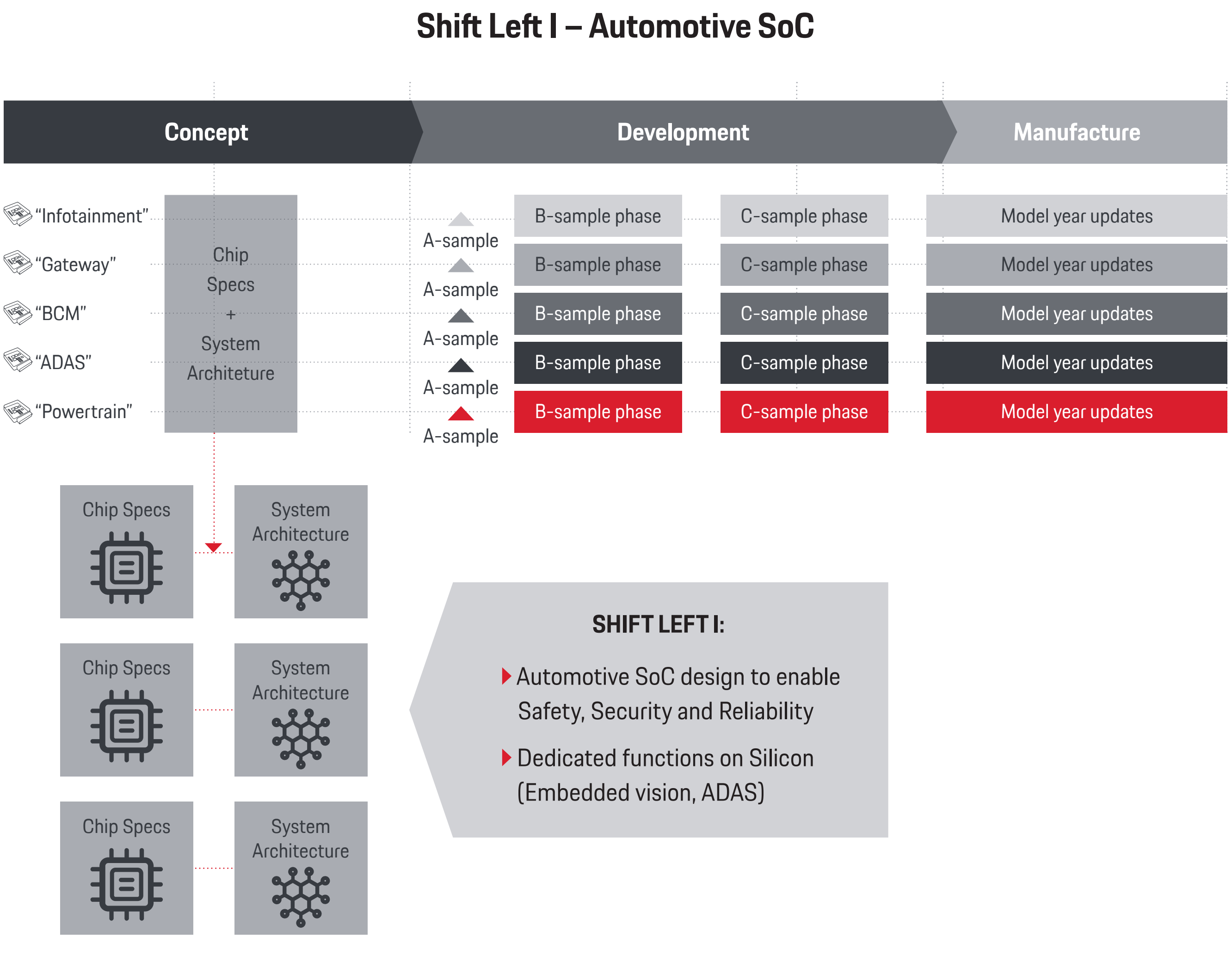

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Figure 10. Accelerating automotive SoC design [12]

SHIFT LEFT II – PARALLEL SOFTWARE AND HARDWARE DEVELOPMENT

The second component of the Triple Shift Left strategy leverages virtual prototyping to enable concurrent hardware and software design. Traditionally, automotive electronics systems development required hardware prototype delivery before software development could begin. With the advent of virtual prototyping, a digital twin of the hardware can be developed, tested, and used as a basis for software testing. As a result, software development for an ECU can be completed up to 18 months before actual silicon manufacture, rather than being constrained by hardware production timelines.

This approach not only benefits software development, but also allows implementation of agile practices in hardware development (figure 11). Users also reduce prototyping costs by identifying errors or issues in early virtual prototypes rather than physical ones. If shared throughout the supply chain, actionable virtual models replace RFQs, reducing the risk of misinterpretation while increasing quality and reducing time to production.

Virtualization decreases development costs

Co-design of hard- and software enables earlier testing and discovery of hardware defects

Scaling to Mass Production
Simulation is an Important Step To Gain Experience

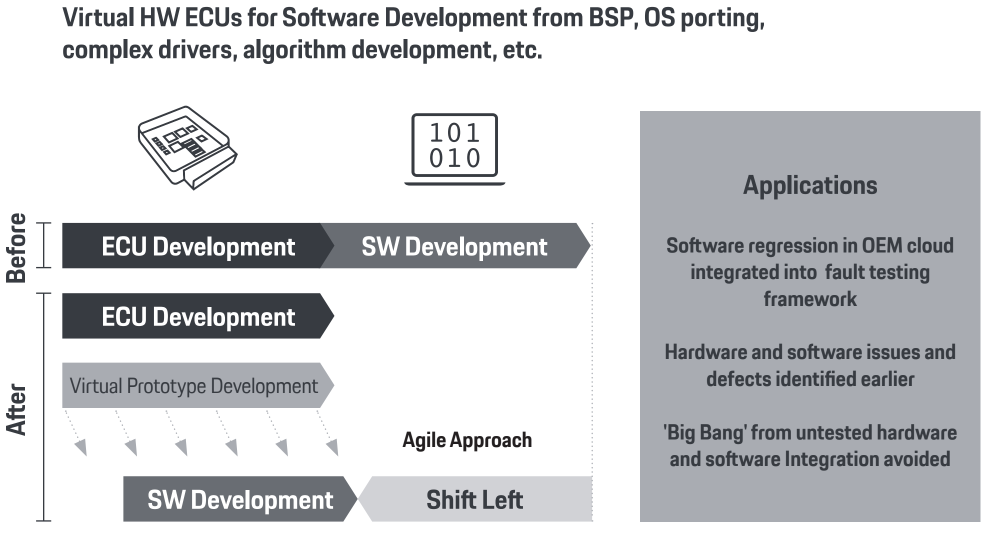

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Figure 11. Parallel development of ECU hardware and software through virtual modeling [13]

Cumulatively, these benefits allow developers to identify hardware, software, and hardware/software integration issues more quickly and with less cost, thereby shifting the critical error curve to the left, allowing for timelier and regularly paced error resolution (figure 12).

Shifting the Development Process Error Curve

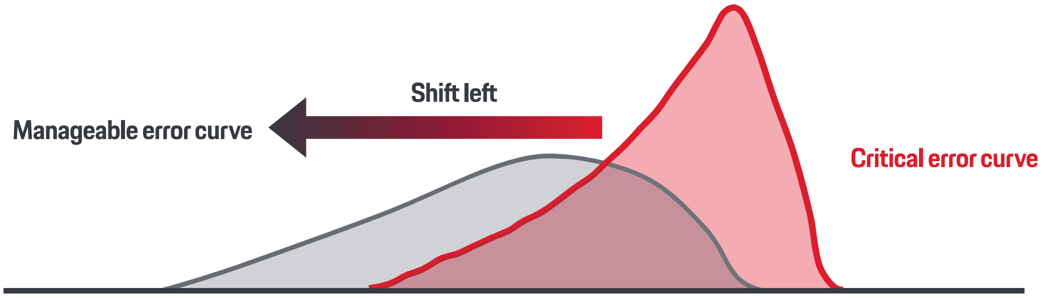

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Figure 12. Effect of ECU virtualization on the development project critical error curve [14]

SHIFT LEFT III – COMPREHENSIVE AUTOMOTIVE SOFTWARE TESTING

Oftentimes, electronics systems function as desired in their testing environments, but retain security vulnerabilities, safety flaws, or undiscovered bugs that may not become apparent until several years after a vehicle has launched series production. In such cases, an OEM's only recourse has historically been expensive recalls.

Advanced virtual testing methodologies, however, enable an unparalleled speed and depth of data for error troubleshooting and insights, while further reducing dependencies on hardware. Further leveraging virtual models of automotive electronic systems, Synopsys helps automotive OEMs and supplier create test platforms for virtual vehicle development (figure 13). This enables extensive verification through static security testing, software composition analysis, interactive security testing, and fuzz testing.

Virtual Prototype – Scaling and Cost

- Doesn't scale for variety of HW variants
- Time-consuming and costly maintenance

- Standard high-performance compute power
- Flexible and reconfigurable

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Figure 13. Scalability of virtual vs. physical prototype [15]

With virtual test platforms, scaling and derivative testing also become possible, allowing for experimentation with countless potential hardware-software configurations to reduce verification costs for low-volume derivatives. This regression forming, or automated testing, increases overall coverage and accelerates test cycles for applications, power electronics, wire harness simulations, and a variety of other specific applications. Virtual testing environments can be customized to fit each client's unique needs, including testing lifecycle measures, such as OTA updates.

04 Lifecycle Consideration

The final step in Porsche Consulting's approach to revolutionizing OEM technical organizations is the incorporation of product lifecycle considerations into development processes. In order to meet customer demand for new services and functions after purchasing an automobile, such as the latest version of a navigation, parking, or music streaming application, OEMs must ensure they integrate post-sale capabilities into their development efforts. Vehicle lifecycle development must begin with the concept phase and last until the end of the vehicle's functional life. Therefore, automotive development processes must span 12 years, expanding from the traditional 4-year development cycle to also include a vehicle's 8-year useful life.

In addition to customer demands, security and safety requirements considerations are vital. Although regulations such as the Working Paper 29 by UN ECE - expected to become active by September 2021 - help provide a basis for these considerations, regulatory bodies rarely move at the speed of market innovation. Accordingly, processes to evaluate vulnerabilities within a rapidly developing industry environment are necessary.

SOLUTION IMPLEMENTATION

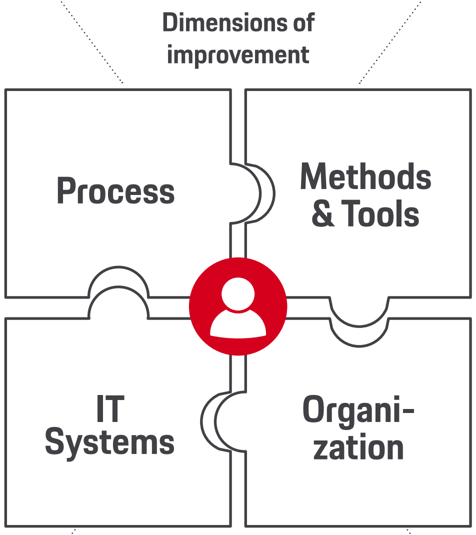
The holistic approach introduced above represents an effective solution for OEMs struggling to define paths through the many disruptive forces facing the automotive industry. The individual components must be implemented throughout OEM processes, methods, organization, IT-systems, and tools (figure 14). The unique composition and positioning of each company eliminates the possibility of a "one size fits all" solution and necessitates the involvement of partners experienced in navigating such evolutions.

01 Processes

Does the **product development** follow a **reproducible, efficient** and **system-oriented** process? Is there a **function-oriented** development breakdown?

02 Methods & Tools

Are methods available that **ensure** a **structured** requirements break-down and **systems definition**, as well as coordinated **integration** and **testing**?



03 IT-Systems

Does the IT system provide a solid **infrastructure** for applying several tools across **diverse data models** of the **product systems**?

03 Organization

Do **competencies** and **structures support system development**? How dominant are **silo structures**?

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Figure 14. Implementation areas for systems engineering principles

Summary

For years, the automotive industry has warned of the impending challenges posed by electrification, autonomous technologies, vehicle-to-everything connectivity, and the uncertain evolution of vehicle ownership. Today, these individual technological leaps, and the ultimate industry revolution they comprise, no longer represent uncomfortable uncertainties, but extremely real and daunting challenges. OEM development organizations, wrestling with the task of bringing these concepts into series production, race to remain on the forefront of innovation in areas increasingly alien to their historical expertise. Further disrupting the field of competition are titans such as Google, Apple, Baidu, and a host of other companies from all corners of the world.

Although the odds may seem stacked against traditional OEMs, recent years have shown mechanical engineering expertise remains an invaluable advantage over the sheer number of failed or unprofitable automotive manufacturing startups. For those that wish to continue their success and maintain leadership positions, however, the time to act is now. Automotive development must reinvent itself to not only bring the bleeding edge of silicon and software into automotive, but elevate electronics safety and durability to unprecedented heights (figure 15). It is not enough, therefore, for OEMs to play catch up with the tech industry. Instead, vehicle development organizations must reinvent themselves to thrive in the face of functional safety, security, and reliability challenges inherent to the marriage of mechanical and electronics engineering.

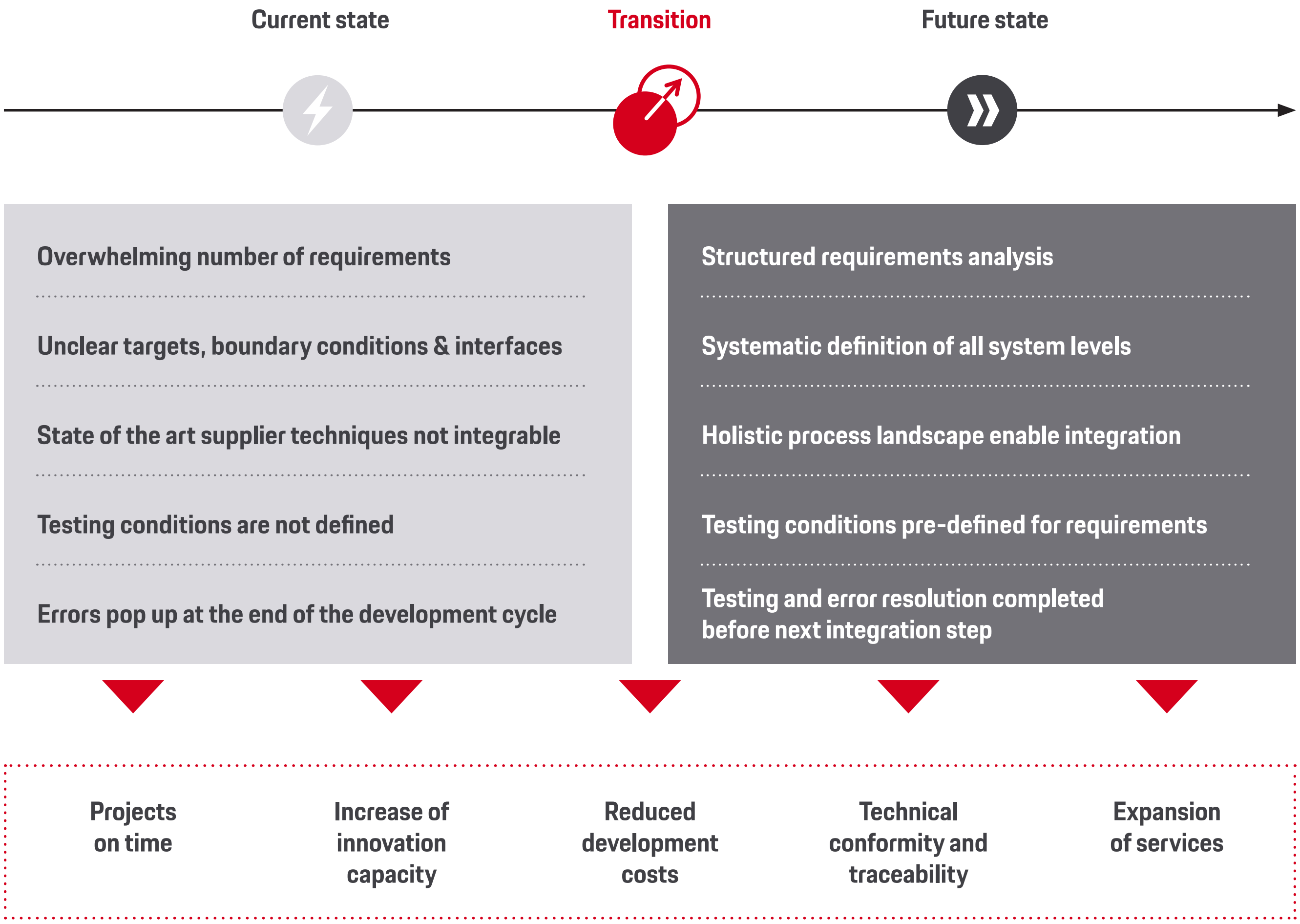

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Figure 15. Product development organization benefits of holistic solution implementation

This transformation will not happen without significant investment of effort, time, and resources. Once an OEM has made the necessary commitment, however, proper implementation guarantees a timely and significant return on investment. By approaching these changes with a top-down systems engineering approach guiding the application of bottom-up electronic architecture design, prototyping, and verification, the automotive giants can maintain the industry positioning they currently enjoy. OEMs thereby ensure their brands not only retain their positioning as vital parts of their customers' lives, but also become an increasingly vital connection to the ecosystems developed around their vehicles. The future of automotive development is not solely building vehicles, but rather enabling access to the physical and digital worlds that define life for people all over the world.

Appendix

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