BERYLLS STRATEGY ADVISORS

# MODEL BASED SYSTEMS ENGINEERING IN TRUCK R&D

September 2023

# AGENDA

# INTRODUCTION

**The trucking industry is currently grappling with significant pressure induced by an ongoing transformation predicated on three fundamental changes to its long-standing operations.**

**Electrification:** A primary catalyst for change in the industry is the mounting concern over environmental impacts, particularly greenhouse gas emissions. The transition from diesel-powered to battery and fuel-cell electric vehicles necessitates a new breed of software-based powertrain and energy management systems.

**Connectivity:** The advent of digital logistics ecosystems has given rise to increased complexity and a rapid transformation of business models, customer requirements, and system interfaces. Trucks are becoming edge devices within a highly interconnected and interdependent 'internet of transport', powered by cutting-edge software.

**Autonomous driving:** Self-driving trucks have the potential to create a transportation system with unprecedented productivity, efficiency, and safety. At the same time, they require a new dimension of high-performance compute. Despite current disillusionment with autonomous trucking, the pressing shortage of drivers may necessitate the adoption of this technology.

Truck manufacturers, component and system suppliers as well as engineering service providers must keep pace with these advancements to remain relevant in the market and defend their positions against new players. They face the challenge of rapidly integrating new technologies into their products while meeting customer expectations and staying within budget. They must deliver fast and cost-efficient solutions in a highly complex innovation environment.

These trends underscore the urgent need for a swift transition to software-defined vehicles. The increasing complexity of E/E architectures and vehicle functionality make this fundamental shift inevitable. Resource scarcity, notably in software development, presents a growing challenge for the broader automotive industry, and specifically for truck manufacturers.

Traditional development processes, once the mainstay of the trucking industry, are ill-equipped to handle such a dynamic environment. Much time and effort is consumed in aligning various stakeholders to deliver holistic solutions, often leading to costly and time-consuming misunderstandings, and consequently, quality issues in product development.

To effectively navigate these challenges, the truck industry must adopt strategies such as agile development methodologies, leveraging digital technologies for simulation and virtual prototyping, and enhance collaboration with external partners. Model Based Systems Engineering (MBSE) is a systematic approach that supports OEMs, suppliers, and engineering service providers in enforcing shorter development cycles, more efficient use of resources and higher quality results.

# TRUCK INDUSTRY UNDER PRESSURE TO INNOVATE

**Transport and logistics** hold a significant position in the global economy of the 21st century. Facilitating the movement of goods around the world, this industry serves as the backbone of both industrial production and private consumption. The rapid expansion of eCommerce in recent years underscores the need for fast and reliable land transport. In fact, in Europe, trucks constituted nearly 80% of the modal split in 2021.

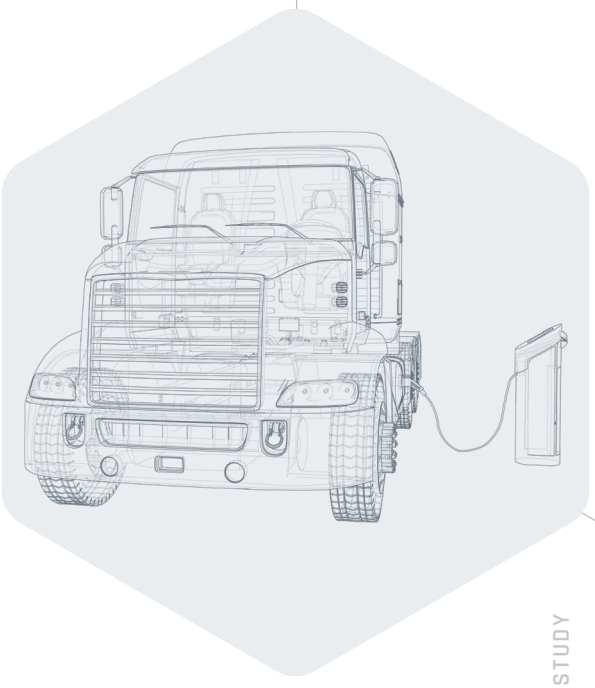
According to data from VDA and IHS approximately 3.4 million medium- and heavy-duty trucks were manufactured worldwide in 2021. The rate of production for new models is predicted to accelerate in the coming years, with a rising number of vehicles anticipated to incorporate electric power, either through battery-electric or fuel cell electric powertrains. New players like Designwerk, Volta Trucks or Nikola Motor put the incumbents under massive pressure to innovate at fast pace.

The next generation of commercial vehicles will be governed by highly complex software and needs a high degree of connectivity, both in-vehicle and externally. These vehicles are required to receive over-the-air software updates throughout their life cycle, and autonomous driving systems will need to connect to real-time data on road conditions and hazards.

By adapting their R&D organizations and processes to address the complexity of future truck functionalities, OEMs can better align their personnel, processes, and technologies to meet the challenges posed by connected and software-defined vehicles.



# NAVIGATING COMPLEXITIES: IMPACT ON TIME, COST, AND QUALITY IN TRUCK R&D



**Historically,** the research and development (R&D) departments of truck Original Equipment Manufacturers (OEMs) have prioritized individual components within specific domains such as powertrain, chassis, or infotainment systems. However, the increasing complexity of modern truck functionalities, which often span multiple domains, has posed challenges for these traditional R&D structures.

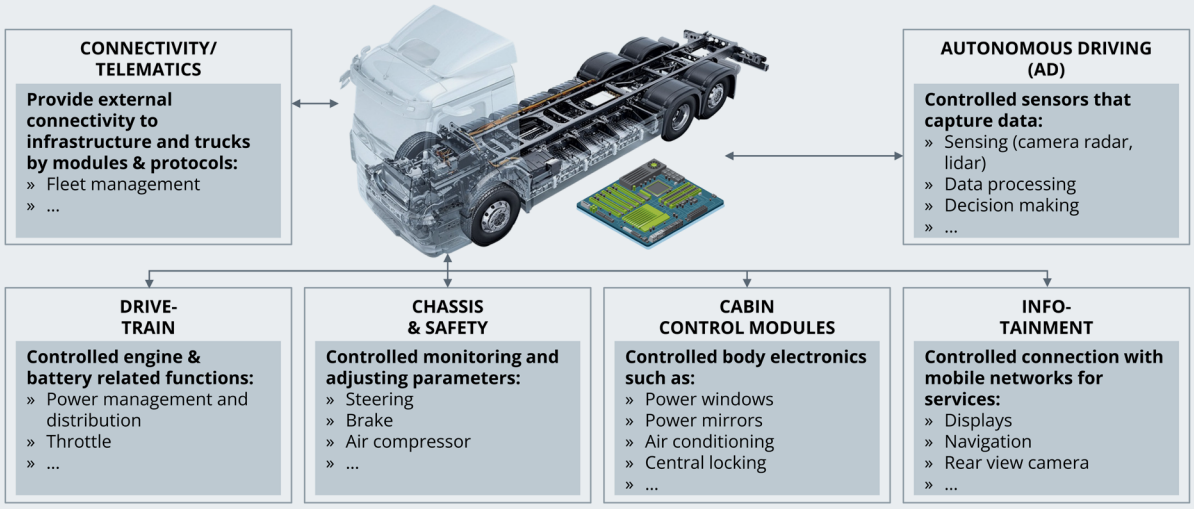
Significant effort and time have been expended by OEMs in an attempt to align personnel and processes across these domains, with the objective of integrating elements of software systems post-production. With their current approach, truck manufacturers face time wastage, increasing costs and quality issues, particularly regarding software development.

In the following, the essential changes in the E/E architecture of trucks will be discussed. Current architectures are characterized by multiple Electronic Control Units (ECUs) and the crucial role of embedded software in controlling various systems and processing sensor data.

Modern trucks often incorporate 120 or more ECUs to regulate hundreds of functions, in part through intercommunication. ECUs are designed to process data from sensors located throughout the vehicle and to make decisions based on that data. ECUs use embedded software to control the operation of these systems and to process data from various sensors. Embedded software is developed from scratch to run exclusively on that hardware in that precise configuration. Complex control algorithms deployed with the embedded software ensure the proper timing of functions, needed inputs and outputs, and data security. The following illustration shows essential truck functions that are controlled and provided by ECUs.

FIGURE 1

## VEHICLE FUNCTIONS CONTROLLED OR PROVIDED BY ECUS




Source: Berylls Strategy Advisors

Advanced driver-assistance systems (ADAS), connectivity, and the push towards e-mobility boost the value contribution of software in modern trucks. This shift is mirrored in the overall innovation and development process, which now requires a greater effort to integrate novel functions with existing hardware and software and successfully introduce them into the market. More and more stakeholders, organizations, roles, and cultures must be synchronized within a dynamic flow that can be aligned according to customer needs.

While ADAS functions are currently found in only one out of five trucks, their penetration rate is expected to increase rapidly in the coming years. Vehicle safety remains a key criterion for truck customers, driving the demand for ADAS features that enhance safety and improve the driving experience.

For OEMs aiming to achieve autonomous driving capabilities, substantial investments in ADAS will be crucial. ADAS provides a fundamental groundwork for the development of advanced perception, decision-making, and motion control systems, all vital components of autonomous driving. The amount of data handled by autonomous driving systems will trigger a quantum leap in high-performance compute as well as E/E architecture.

# SHIFTING PARADIGMS: FROM DECENTRALIZED TO CENTRALIZED ARCHITECTURES

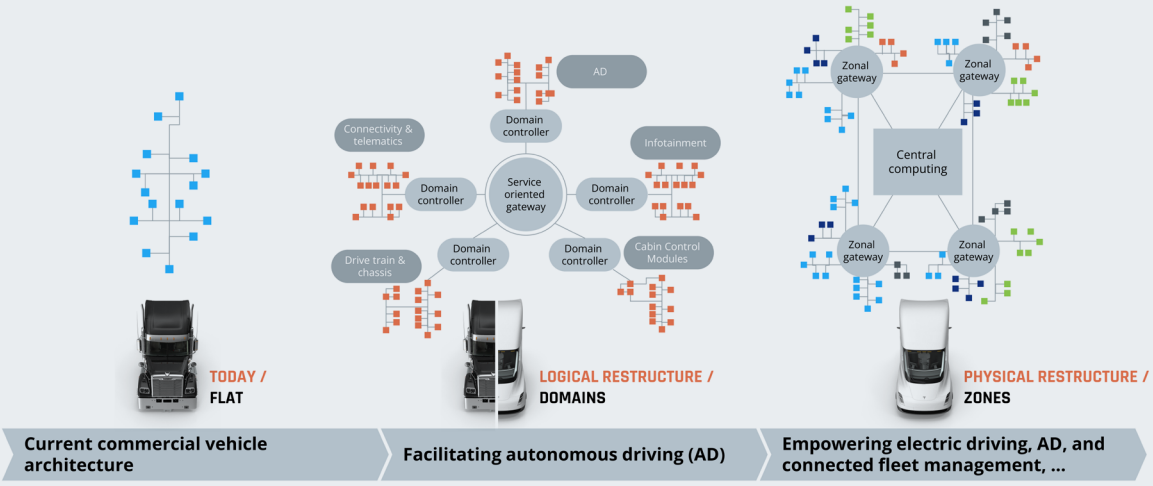
**To cope** with the growing complexity and communication needs, automotive systems are moving towards more centralized E/E architectures. These architectures involve decoupling software and Electronic Control Unit (ECU) hardware, allowing for more flexible and dynamic communication. Decoupling allows enhanced scalability, easier software updates, and better adaptation to changing requirements throughout the vehicle life cycle.

**We observe the following trends:**

Significant R&D spending growth: Vehicle manufacturers are expected to boost their spending on E/E technologies by 64 percent over the next decade. This substantial increase reflects the industry's recognition of the pivotal role played by E/E systems in modern vehicles.

FIGURE 2

## TRANSFORMATION OF THE VEHICLE ARCHITECTURE




Source: S&P Global Mobility, Expert Interviews, Berylls Strategy Advisors



Emphasis on software: Within the E/E domain, software will account for a significant share of the increased spending. According to Berylls research, software is projected to reach 56.2bn Euro automotive R&D spending by the end of the decade, indicating its critical role in enabling advanced functionalities and driving innovation in vehicles.

The next evolutionary step from the current E/E architecture is zonal. This architectural model enhances efficiency while simultaneously facilitating the integration of new technologies and functions. This approach is based on more efficient management of E/E systems and enables easier software updates and customizations. The segmentation into zones facilitates the organization, communication, and control of diverse components, modules, and subsystems.

The following schematic overview illustrates that hardware abstraction based on the virtualization of functions leads to increased scalability and adaptability in developing commercial vehicle systems. Function virtualization will further accelerate innovation cycles. We expect that vehicles' overall functionality and performance will improve as a result.

The advancement of software defined vehicles requires all-new R&D processes that enable significantly shorter development cycles. Therefore, truck manufacturers must urgently bring their competencies and cultures up to date to build sustainable competitive advantages.



**WITH SOFTWARE DEFINED COMMERCIAL VEHICLES AND E/E-ARCHITECTURE, IT HAS BECOME INDISPENSABLE TO USE MBSE.**

Product Owner – Tier 1 Radar Supplier

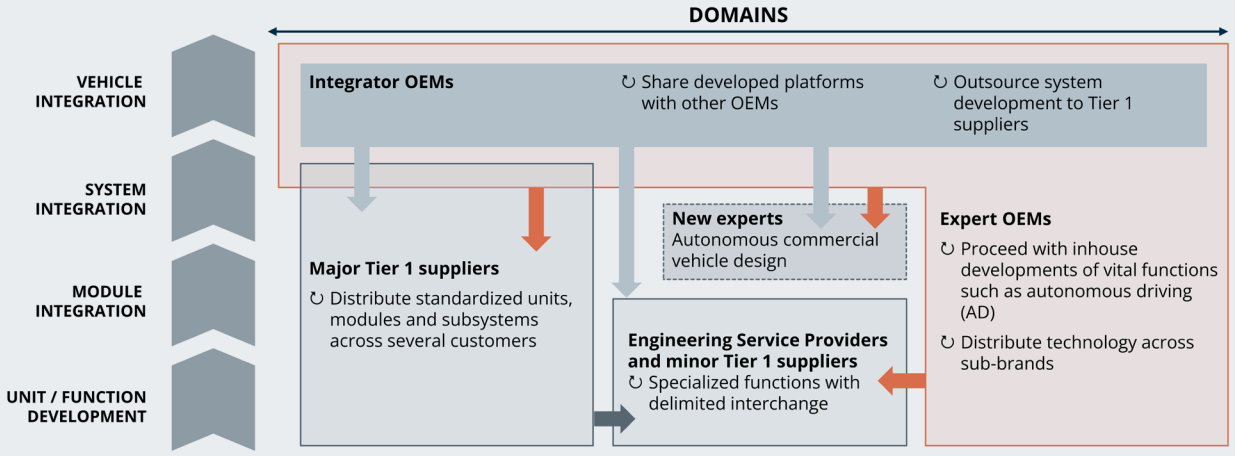
# FASTER AND EVER MORE INTEGRATIVE DEVELOPMENT CYCLES

**Some manufacturers** follow the aspiration to independently develop their own software solutions, thereby mitigating dependency on third-party suppliers. Historically, such attempts have rarely been successful. The failure of most initiatives can be ascribed to a lack of expertise, inadequate resources, fluctuating requirements, or scalability concerns.

Due to the accelerated innovation cycles, there is an increased demand for specialized know-how and outsourcing of entire subsystems. Increasing outsourcing of the development process drives the complexity of value creation and can lead to quality issues or even failure.

FIGURE 3

## EXEMPLARY VALUE CREATION IN SOFTWARE ENGINEERING & E/E SYSTEMS




Source: Expert Interviews, Research, Berylls Strategy Advisors

Truck OEMs, therefore, need to follow an integrative approach on R&D value creation as illustrated above. They have massive pressure on time to market both from regulatory requirements and competition by new players. For example, the competitive landscape for buses has changed significantly in Europe with the emergence of battery electric vehicle concepts. Chinese brands like Golden Dragon and Yutong now hold significant market shares.

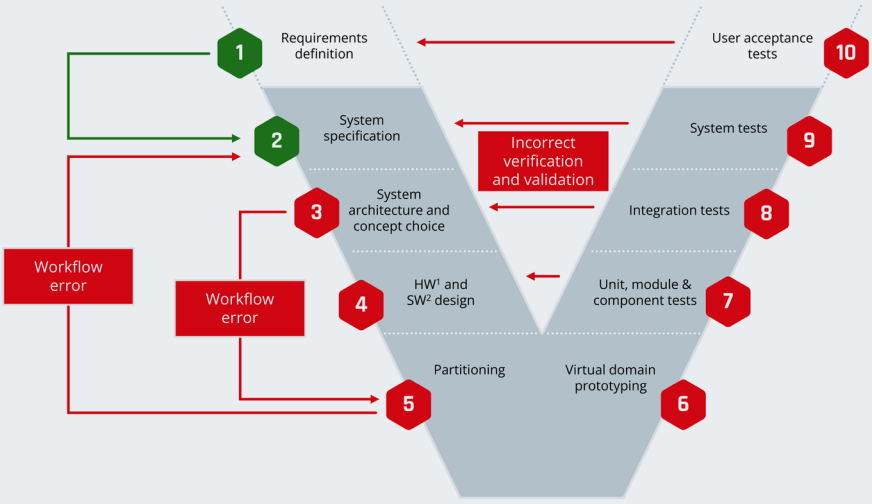
This triggers the need for faster development processes. The acceleration is a burden for R&D departments and leads to higher costs as resources must be reallocated to speed up. Faster and more integrative development cycles also require a state-of-the-art tool chain. An approach that offers significant benefits in that respect is the so-called Model Based Systems Engineering (MBSE).

# MODEL BASED SYSTEMS ENGINEERING: A MUST-HAVE IN THE R&D TOOL CHAIN

**The need** for speed in the development cycle must be addressed by truck manufacturers. Here, Model Based Systems Engineering (MBSE) offers itself as a solution. MBSE can be understood as a structured and systematic approach to the development process, using models as a central tool for system design, analysis and management. Challenges in developing complex systems are overcome by providing a visual and integrated representation of the system and its requirements. In the following, the differences in processes with and without MBSE are explained.

FIGURE 4

## DEVELOPMENT PROCESS & SIMULATION WITHOUT MBSE



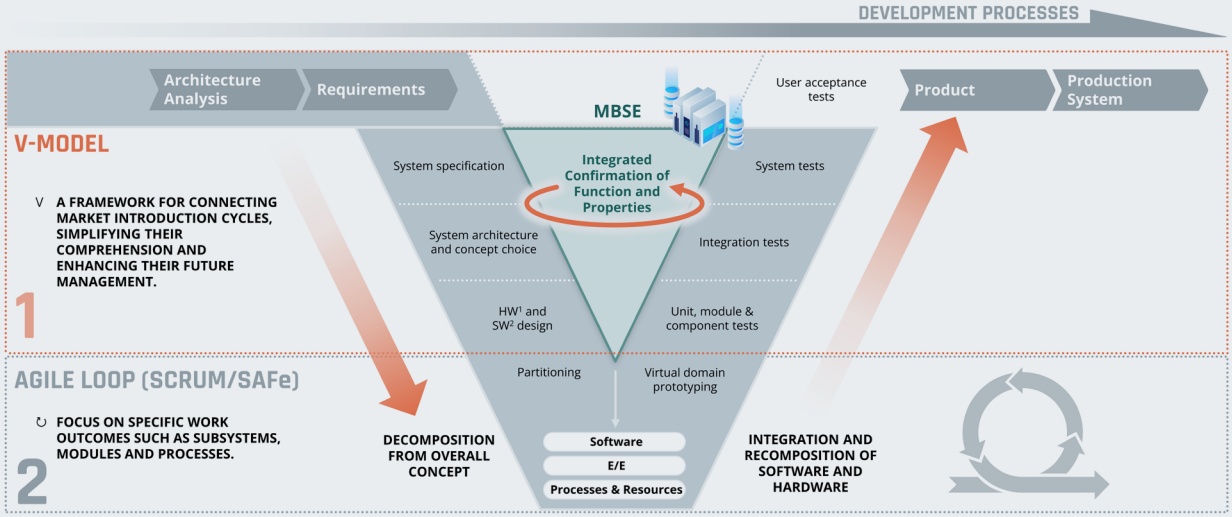

1 HW: Hardware 2 SW: Software Source: Berylls Strategy Advisors

As the illustration above shows, it is imperative to acknowledge that a component-oriented approach, in which hardware and software components are developed separately, can result in a fragmented and ineffective process. This is especially true for intricate distributed functions like advanced driver assistance systems (ADAS).

Conversely, a system-oriented approach defines the overall system architecture and the specific technology details, enabling each piece of hardware and software to optimize the overall system rather than retrofitting it. In this approach, workflows are agile, and the process flows logically from one stage to the next.

FIGURE 5

## MBSE EXCEEDS THE V MODEL AND CLOSES THE LOOP




1 HW: Hardware 2 SW: Software Source: Expert Interviews, Berylls Strategy Advisors, Fraunhofer IPK

The successful implementation of the system-oriented model across different industries, including defense and avionics, along with its use by automotive OEMs under the ASPICE & ISO 26262 framework for evaluating technology suppliers, holds promising implications for truck manufacturers. The system-oriented development approach simplifies responsibility and reduces coordination efforts required at the interfaces. This ensures effective coordination and division of subsystems and assigns all hardware and software components and functions to a system that is overseen by a system project manager with end-to-end responsibility. The main objective is to streamline the processes and increase efficiency. Naturally, MBSE requires adaptations to OEMs' organization, processes, and tools (OPT).

The success recipes of MBSE encompass several key factors that contribute to its effectiveness and positive outcomes. These recipes include:

Agile and Integrated Development Environment (IDE): MBSE enables agile development methodologies and enables iterative and flexible development processes, allowing for faster feedback, adaptation to changing requirements, and efficient use of resources. By utilizing MBSE, developers can benefit from IDE to enhance their productivity. IDE minimizes setup time, accelerates development tasks, keeps developers up-to-date on the most recent best practices and potential threats, standardizes the development process, and allows everyone to collaborate seamlessly.

System Understanding and Description: MBSE enables a comprehensive understanding and description of the system under development. By using models, various aspects of the system can be captured and represented, including requirements, behavior, structure, and interfaces. This facilitates a clear understanding of the system's purpose, functionality, and interactions.


Basis for Faster Product Development and Improved Product Performance: By creating digital twins, which are virtual representations of physical systems, MBSE allows advanced analysis, testing, and optimization of the system's behavior in a virtual environment. Additionally, MBSE-based model fidelity can help reduce the total cost of ownership. By considering wear and degradation models, MBSE can increase fleet operational efficiency, prognostics and health management (PHM), reduce downtime, and the reusability of worn parts for second-life applications.

Interdisciplinary System Architecture: MBSE promotes an interdisciplinary approach to system architecture. It involves the active participation of different engineering disciplines and stakeholders in the modeling and design process. This collaboration ensures that all relevant aspects, such as mechanical, electrical, software, and control systems, are considered and integrated effectively.

Reusability of Model Components: MBSE emphasizes the systematic modeling of the system, subsystems, assemblies, and model components. This approach enables the reusability of model components across different projects or systems. By leveraging existing models and components, development time and costs can be reduced, and consistency can be maintained.

Management of Redundancies: MBSE enables the systematic and structured modeling of the system, which helps manage redundancies. Redundancies refer to duplicated or overlapping information or functionality within the system. By identifying and managing redundancies through effective modeling practices, system complexity can be reduced, and consistency can be maintained throughout the development process.

Consistency and Completeness: MBSE supports the achievement of consistency and completeness in the system description. The use of models helps ensure that all relevant aspects of the system are captured, and dependencies between different components are properly represented.

This leads to a more coherent and comprehensive system description, minimizing the risk of errors or omissions.

Safety and Reliability: MBSE increases the safety and reliability of the system. By utilizing MBSE, it is possible to analyze functional and operational safety aspects more accurately. This is beneficial during functional hazard analyses and helps to validate fault tree analyses (FTA) and subsequent system safety analyses (SSA). The model is designed to focus on critical parts of the architecture. With MBSE, it is possible to evaluate safety-related systems or functions more efficiently and effectively.

These success recipes highlight the benefits of adopting MBSE in systems engineering and development. By embracing meaningful contributions, an open culture, and complementary business models, organizations can leverage MBSE to enhance system understanding, improve development efficiency, promote interdisciplinary collaboration, and achieve higher levels of safety and reliability.

**MBSE SIMPLIFIES SYSTEM MODELING BY ENABLING ENGINEERS TO GENERATE, SCRUTINIZE, AND AUTHENTICATE MODELS WITH VARIOUS TOOLS. THIS PROCESS DETECTS FLAWS EARLY ON AND FACILITATES EXPLORATION OF ALTERNATIVE DESIGNS.**

Systems Engineering Team Leader – Tier 1 Supplier

**USING MBSE IMPROVES COMMUNICATION AND COLLABORATION WITH STAKEHOLDERS. IT SIMPLIFIES PROJECT REQUIREMENT TRACKING AND MAINTENANCE, MAKING PROJECT MANAGEMENT EASIER AND LEADING TO SUCCESSFUL OUTCOMES.**

Chief Project Manager – Commercial Vehicle OEM

# CALL TO ACTION

**With vehicles increasingly defined and differentiated by their software, the complexity of systems consisting of hardware and software is constantly increasing. Traditional component-oriented approaches to R&D and project management may struggle to effectively address this complexity, leading to rising development costs that can impact the profitability of original equipment manufacturers (OEMs). MBSE can increase efficiency, optimize system performance, reduce development costs and improve the time to market.**

**We recommend three key actions in combination with MBSE to address these challenges:**

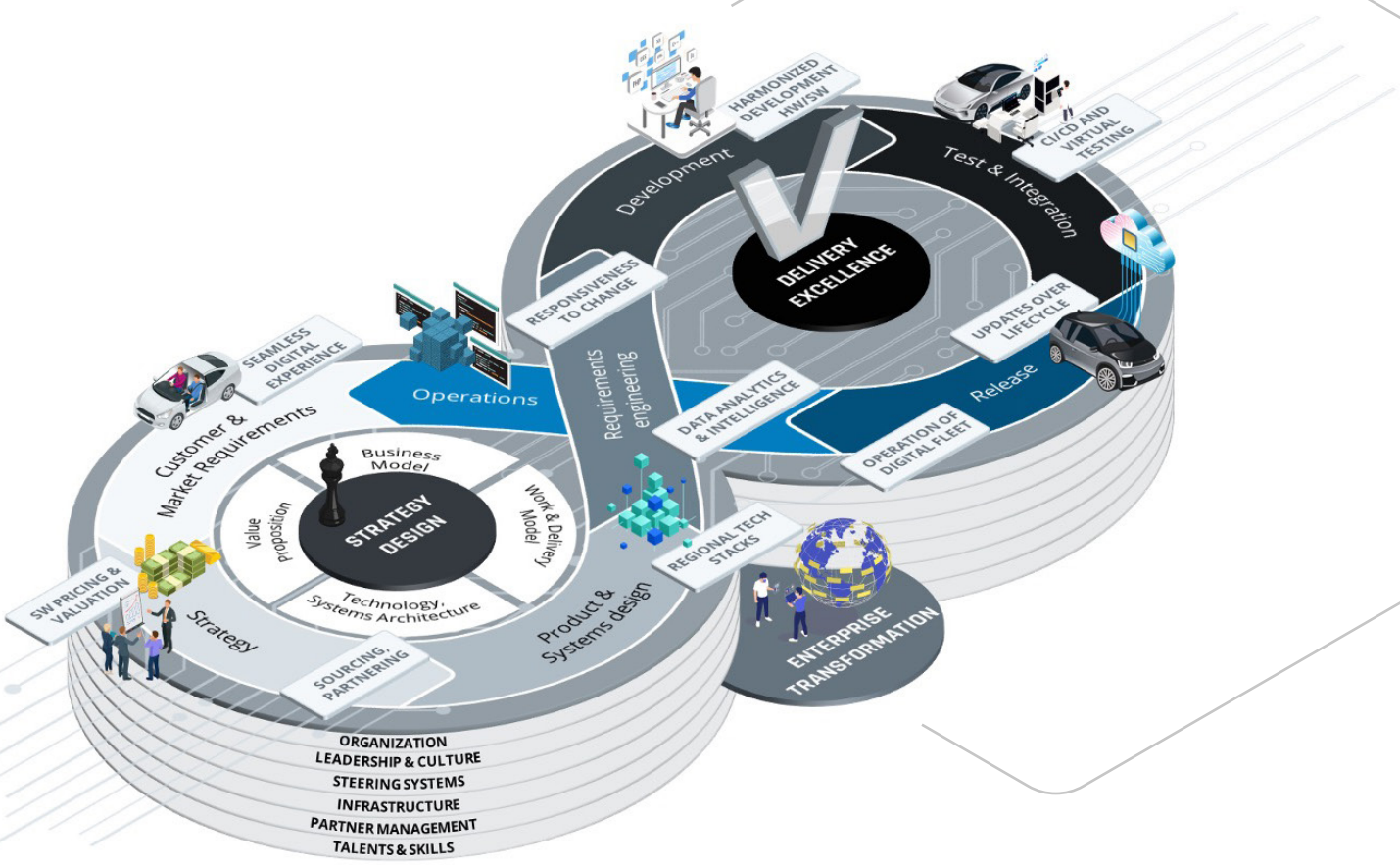
- Combining Coherent Systems: The system-oriented approach involves integrating and aligning various systems within the vehicle organization. Simultaneously, to bypass organizational overhead, a sound division of the overall system architecture in meaningful organizational sub-domains plays a crucial role in the MBSE framework. This requires establishing clear interfaces and communication channels between different system components, such as hardware and software teams. Collaboration and coordination among these teams are crucial to ensure that the systems work together seamlessly.

- Strengthening System-Oriented Roles: System-oriented roles must be identified and strengthened within the organization. System engineers, system architects and system integrators are essential for defining the overall system architecture. For example, these roles are responsible for coordinating development activities and ensuring that all components contribute to the optimization of the system. Training and supporting these roles can help increase their effectiveness.

- Interrelated and Cascading System Processes: Implementing interrelated and cascading system processes ensures that the development of subsystems and components aligns with the overall system requirements and architecture. This involves establishing a systematic approach for system releases, where the release of subsystems and components is synchronized to maintain consistency and compatibility. Such processes enable efficient integration and verification of the system.

It is crucial for commercial vehicle manufacturers to assess their capabilities, resources, and long-term needs before deciding whether to pursue with MBSE. Thorough planning, proper allocation of resources, and collaboration between MBSE experts and software developers are essential to increase the chances of success.

Berylls Strategy Advisors is undoubtedly the best choice to provide your company with outstanding support in implementing MBSE. With our exceptional knowledge of the commercial vehicle industry and a successful track record in innovation management strategy and implementation projects, we are well-equipped to meet all your needs. Berylls Strategy Advisors is prepared to adapt and grow alongside the rapidly evolving commercial vehicle innovation management landscape – **but different, as are we**.




# THINKING SOFTWARE END-TO END. MEET BERYLLS.

**We believe** that for commercial vehicle and automotive enterprises to become proficient software developers, an iterative mindset is requisite, spanning from strategy definition to delivery, and circling back to strategy revision. This is what we denote as the Berylls Software Loop.

The Berylls Software Loop consists of three major elements: **strategy design, delivery excellence** and **enterprise transformation** across the complete value chain and vehicle life cycle.

A benchmark organization for software integration is as important as capabilities to create software in-house, as is a culture that embraces software development fundamentals like DevOps, Agile and competitive collaboration.

Software development tools and organizational software operating models need to be tightly integrated into the existing product development process to ensure that costs and production start dates are met by delivering excellence.

The Berylls Software Loop leverages our full commercial vehicle and automotive expertise and commitment to a software-driven mobility future.

THE BERYLLS GROUP'S SERVICES ARE fully dedicated to the automotive industry. Our experts in Germany, China, Great Britain, South Korea, North America and Switzerland understand the industry's key challenges and are developing ways to achieve sustainable success in the automobility eco system. We use advanced digital strategies and other innovative approaches. Our professionals are networking across five specialised units to offer our clients end-to-end support, from strategy development to the implementation. We call this network our Berylls Quintet:

**Berylls Strategy Advisors** – The expertise of our top management consultants extends across the entire automobility value chain – from long-term strategic planning to operational performance improvements. Based on Berylls' automobility thought leadership, our consulting teams stand out in view of their broad experience, their profound industry knowledge, their innovative problem-solving competence and their entrepreneurial thinking.

**Berylls Digital Ventures** – Our clients' strategic concepts requires the development and operation of digital products or the implementation of new business models. The Berylls Digital Ventures team works with our clients to take up this challenge – end-to-end. At the same time, we also invest in promising start-ups and bring our own digital solutions to market, providing these ready-to-use for our clients.

**Berylls Mad Media** – The radical digitalisation of the customer interface undermines the boundaries in the automotive sales model. Our Berylls Mad Media experts develop and operate tailored solutions, including data-driven marketing, integrated service designs, and including the agile realisation of integrated process and IT architectures. We strengthen customer loyalty, market exploitation, and profitability – taking vehicles and services to market digitally.

**Berylls Equity Partners** – is a private investment company. Supported by strong anchor investors and pursuing an entrepreneurial approach, we acquire, operationally improve operationally, and furnish with a long-term strategic direction companies with value potential in the mobility industry.

**Berylls Green Mobility** – We believe that sustainability will deliver competitive advantages in the real world of the global automobility business. Whether in an advisory capacity to external clients and other Berylls entities or through our electric vehicle charging service Wall-E – the first free-to-the-user e-mobility infrastructure initiative which helps convert drivers' interest in e-mobility into a roadgoing reality – Berylls Green Mobility drives the change toward making automotive sustainable.

The automotive industry is currently facing fundamental challenges. We have made it our mission to support industry players in accomplishing an effective and future-proof change process. The unique value we bring to the table is based on digitisation, technological innovation, market insights and renowned partnerships. The Berylls Quintet is your high-performance engine to succeed on this exciting road.

The future will happen, but different.

berylls
STRATEGY ADVISORS

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