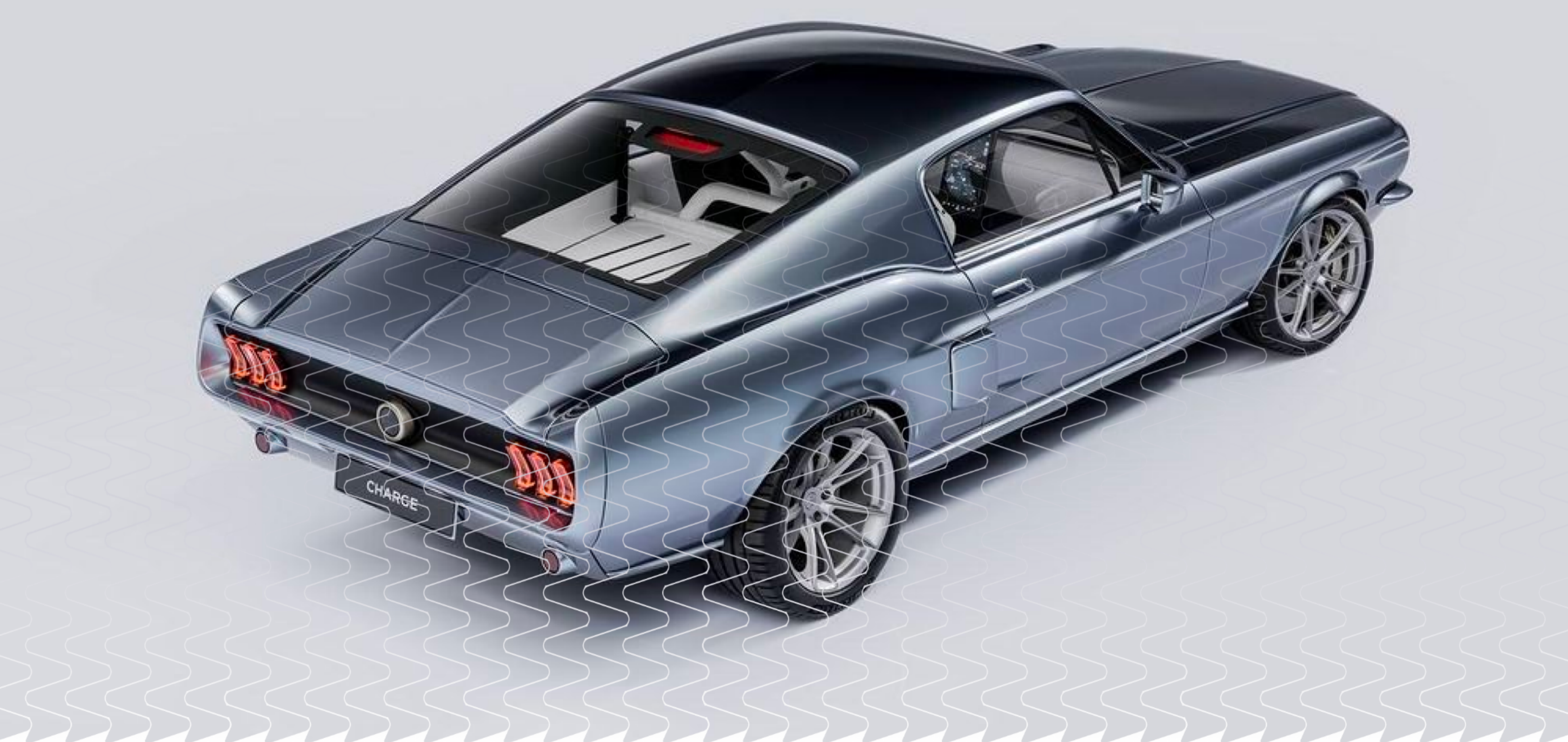

2x faster vehicle software development proven by digital twin operating model

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Content

Executive Summary

The automotive industry is currently facing significant challenges. Customers increasingly demand new features in sold vehicles without requiring hardware upgrades, while manufacturers face pressures like accelerated time-to-market and shrinking budgets for new vehicle models. All of this is complicated by the increasing complexity of automotive software.

Market research[1], including a significant study involving 5,000 participants from the US, China, and Europe, highlights that 73% of consumers prioritize digital features when purchasing new cars. Traditional original equipment manufacturers (OEMs) are struggling[2] to keep pace, dealing with the integration of over 100 electronic control units from various suppliers. This not only slows down engineering processes but also limits the speed and flexibility of deploying new features.

In this context, the Software-Defined Vehicle (SDV) approach has gained global recognition as a significant step towards addressing the automotive industry's challenges[3]. However, it's important to note that the concept of SDVs is interpreted in various ways, sometimes quite limitedly, across the industry. While SDVs represent substantial progress in integrating digital features and capabilities into vehicles, they alone are not a complete solution to the numerous challenges faced. Here, the concept of a digital twin emerges as a critical factor. The digital twin approach, focusing on both the product/system and the operational process, offers a more holistic solution and addresses the complex needs of the modern automotive sector.

A practical illustration of this approach is seen in the collaboration between SODA and VSOptima. SODA, known for their tools for creation, validation, and certification of SDVs, teamed up with VSOptima, specialists in digital twin process tools. Together, they compared the traditional process of engineering a new automotive model with one utilizing SODA V innovative toolkit. This comparison demonstrated a remarkable 2x increase in the speed of engineering new automotive models using SODA's methods.

These results are supported by real-world implementation at Charge Cars and reviewed by automotive industry experts. The synergy between SDVs and digital twin technology, as evidenced by SODA.Auto (SODA) and VSOptima's collaboration, presents a compelling case for enhancing traditional automotive engineering processes. It's a shift that promises to address the current challenges in the industry effectively, clearing the way for more agile, customer-responsive, and efficient vehicle engineering.

Automotive Context and Challenges

Today's automotive landscape is defined by digital innovation and consumer preferences for advanced technology. The demand for vehicles equipped with features like Advanced driver-assistance systems (ADAS), artificial intelligence (AI), and integrated digital ecosystems is rising[1]. Consumers now expect vehicles to be not just transport, but also living spaces on wheels, connected devices capable of receiving real-time software updates over-the-air, eliminating the need to physically visit service centers. This transition to Software-Defined Vehicles has been championed by Tesla[4] who has first integrated these technologies into their operations, providing enhanced user experiences and staying at the forefront of automotive innovation.

While the benefits of digitalization are evident, traditional OEMs face significant difficulties in adapting to this new era:

1. **Transition to Proactive Vehicle Interaction**
   The industry is shifting from passive command-based interactions to vehicles that proactively engage with human beings, necessitating a reimagined vehicle design philosophy centered around user experience and interactive features[5].
2. **Integration Challenges**
   There is the challenge of integrating multiple electronic control units from various suppliers, turning the vehicle into a complex puzzle of over 100 different components, each with its own specifications and communication protocols[2].
3. **Continuous Value Addition Post-Sale**
   Automakers are tasked with the ongoing goal of adding value to vehicles after sale, meeting consumer expectations for continuous feature enhancements without hardware upgrades[6].
4. **Global Competitive Pressure**
   The emergence of numerous competitors, especially from China, and the ongoing economic crisis, compel automakers to innovate and develop new vehicle models within tight financial frameworks[7].

As the automotive industry navigates its current challenges, it's insightful to look at how other sectors have addressed similar complexities. The space industry, for example, has faced challenges similar to those in the automotive world, such as the need for intricate system integration and rapid innovation under strict safety requirements. The solution that proved transformative for them was digital twin technology. Originally conceptualized for space missions by NASA, this technology has since revolutionized various industries. In aerospace, digital twins have been instrumental in simulating and monitoring spacecraft, enhancing safety and efficiency. Similarly, in the manufacturing and healthcare sectors, digital twins have enabled process optimizations, predictive maintenance, and patient-specific treatments. These cross-industry successes underscore the potential of digital twins as an essential tool for the automotive sector as a catalyst of software defined vehicles. According to Gartner[8], the digital twin technology can substantially benefit product testing, enabling engineers to simulate real-world performance of designs without the need for physical prototypes.

Today we can witness first use-cases of that technology application. For example, BMW has partnered[9] with NVIDIA to use the Omniverse platform for factory planning and R&D, effectively simulating changes and modifications to product designs and processes, thereby saving time and costs. Similarly, Ford is utilizing digital twin technology[10] for developing predictive headlights and improving manufacturing efficiencies, notably in its Powertrain Manufacturing Engineering department with tools like the Ford Interactive Simulation Tool and Ford Assembly Simulation Tool. These applications exemplify the rapidly growing adoption of digital twin technology in the automotive sector, signaling a trend that is expected to gain even greater credibility as more manufacturers recognize its potential to revolutionize design, manufacturing, and operational processes.

To overcome those challenges, traditional OEMs must transform their approach to vehicle design, engineering, validation, testing and manufacturing. Adopting technologies like digital twins offers a strategic advantage. By simulating vehicle systems and processes, digital twins enable these manufacturers to tackle software complexity, streamline integration processes, and enhance development efficiency. This adoption drives greater operational efficiency and allows traditional OEMs to be more responsive to market trends and consumer expectations, which is a critical step in rethinking their role in the rapidly changing automotive landscape.

Enhancing Automotive Development Lifecycle Through Digital Twins

By leveraging virtual models of vehicle systems, companies can significantly enhance their design, development, validation, and maintenance processes. We'll delve into five key enablers that illustrate how digital twins are revolutionizing automotive development.

1. Modeling is a way to create a virtual representation of a real-world system. The use of a digital twin makes it possible to widely use this approach in vehicle development. You can simulate this virtual representation under a wide range of conditions to see how it behaves. It allows to minimize the number of physical prototypes.
2. Given the stringent delivery timelines for features, the capacity to test the concept at the design stage in a test environment that closely resembles the final form is crucial. The validation tool capable of working with vehicle digital twins allows the creation of a hybrid testing environment consisting of parts of MIL, SIL, HIL or even AD/ADAS simulation tools in a very fast, automated way.
3. Digital twins facilitate early integration, allowing architects and developers to regularly merge their changes into a shared mainline of the evolving digital twin. Each integration is verified through automated builds and tests, swiftly identifying integration errors. Given the digital nature of these twins, automating testing and deployment tasks within a continuous delivery process becomes significantly more feasible.
4. The digital twin provides a complete data representation of the vehicle, enabling its use at every stage of the vehicle development process, including design, development, configuration, validation, and verification. Furthermore, the digital twin serves as a vital specification tool during the vehicle maintenance phase for monitoring and diagnostic purposes.
5. Undoubtedly, OTA updates offer a faster and more convenient method to deliver new features and improvements to customers, eliminating the need for dealership visits. However, ensuring seamless installation without service interruption presents significant challenges. The use of digital twins enables the easy and automated way to validate various scenarios of the remote software upgrade process.

In summary, the integration of digital twins in automotive development offers a multitude of advantages. These include efficient modeling and simulation, accelerated testing and validation, enhanced integration and automated testing, comprehensive data utilization throughout the vehicle lifecycle, and streamlined remote updates. However, it's crucial to recognize that these benefits are contingent upon the presence of the sophisticated next-generation toolchain. This toolchain must be adept at handling the complexities and nuances of vehicle digital twins.

Without a toolchain that is specifically designed to interact with and leverage digital twins, companies risk missing out on the full spectrum of advantages offered by this technology. A robust toolchain enables seamless integration of digital twins into various stages of the development process, from design to maintenance. It ensures that the digital twin's potential is fully realized, leading to more innovative, efficient, and effective automotive development.

In this context, the SODA company emerges as a pivotal player. Offering a unique toolchain specifically designed to harness the power of vehicle digital twins, SODA provides the next-generation toolchain for automotive companies to seamlessly integrate these digital twins into their development processes. SODA toolchain stands out for its ability to manage the complexities of digital twins, ensuring that automotive companies can maximize the potential of this technology. From facilitating smoother design, development and validation phases to optimizing maintenance and remote update processes, SODA's solutions are integral to transforming the theoretical benefits of digital twins into tangible, real-world results.

Use-case/Example Impact of the New Operating Model from SODA

SODA offers an AI-powered technology and toolchain that enables automakers to create, validate and certify software-defined vehicles. For established automotive companies, transitioning to a new toolchain is an overwhelming task and requires significant motivation. Because of this, it's crucial to assess whether adopting SODA's approach and tools for engineering a new vehicle model gives tangible benefits. This leads to a key inquiry: Do the tools provided by SODA positively influence the speed, efficiency, and cost of development in the vehicle engineering process?

To address this critical inquiry, SODA partnered with VSOptima, a leading platform in the field of process digital twins. VSOptima's digital twin platform leverages a combination of advanced technologies: simulation, analytics, and machine learning. This collaboration is aimed at meticulously analyzing and quantifying the operational impacts of SODA innovative platforms.

VSOptima's role is instrumental in providing a comprehensive assessment of various process changes. By applying their sophisticated digital twin technology, they enable SODA to simulate different operational scenarios, thus quantifying the impact of such scenarios.

Process Digital Twins

A digital twin of a process is a virtual model that accurately mirrors a physical process, enabling the analysis, monitoring, and optimization of processes, providing insights that were previously unattainable. For example, such digital twins can simulate an entire production line, enabling operators to test changes and predict outcomes without interrupting actual production. The power of digital twins lies in their ability to collect vast amounts of data from the physical world, process it, and use it to predict future states through simulation, ultimately leading to more informed decision-making and innovation.

Specifically, the VSOptima process digital twin leverages a stochastic agent-based queue-server simulation framework. This advanced framework empowers operational leaders to construct a digital twin using synthetic data that delineates the process network, details the behaviors of various activities, and characterizes the actions of agents involved in these activities. An advantage of this approach is its capacity to initiate the construction of a digital twin, even in scenarios where data availability is incomplete.

Process Digital Twin Value

The integration of process digital twins platform, such as the VSOptima, within an organizational operating model yields a plethora of tangible benefits. Firstly, processes digital twins enable a profound level of processes transparency. By replicating every facet of the process in a digital environment, organizations gain a comprehensive view of the current performance of their operations, illuminating areas that were previously opaque or misunderstood. This heightened visibility is crucial for identifying inefficiencies, bottlenecks, and potential areas for optimization.

Moreover, process digital twins facilitate proactive problem-solving. Through the predictive analytics capabilities of these models, organizations can foresee potential issues before they manifest in the physical world. This foresight allows for preemptive action, thereby minimizing disruptions and maintaining operational continuity. In the fast-paced automotive industry, where time-to-market and responsiveness to customer needs are paramount, this capability provides a significant competitive advantage.

Another critical benefit is the enhancement of collaboration across departments. Process digital twins create a unified, accessible model of operations that can be utilized by various teams. This shared resource fosters a more collaborative environment, encouraging cross-functional teams to work together in identifying and implementing process improvements. It ensures that changes made in one area of the process are understood and accounted for across the entire value stream, leading to more cohesive and effective operations.

Lastly, these digital twins support continuous improvement. With the ability to simulate and test process changes in a risk-free virtual environment, organizations can experiment with various scenarios to identify the most effective strategies. This iterative approach to process refinement aligns perfectly with agile methodologies, enabling organizations to adapt swiftly to market changes and technological advancements while consistently striving for operational excellence. The adoption of a process digital twin, therefore, becomes not just a technological upgrade, but a catalyst for cultural and procedural transformation within the organization.

Process AS IS

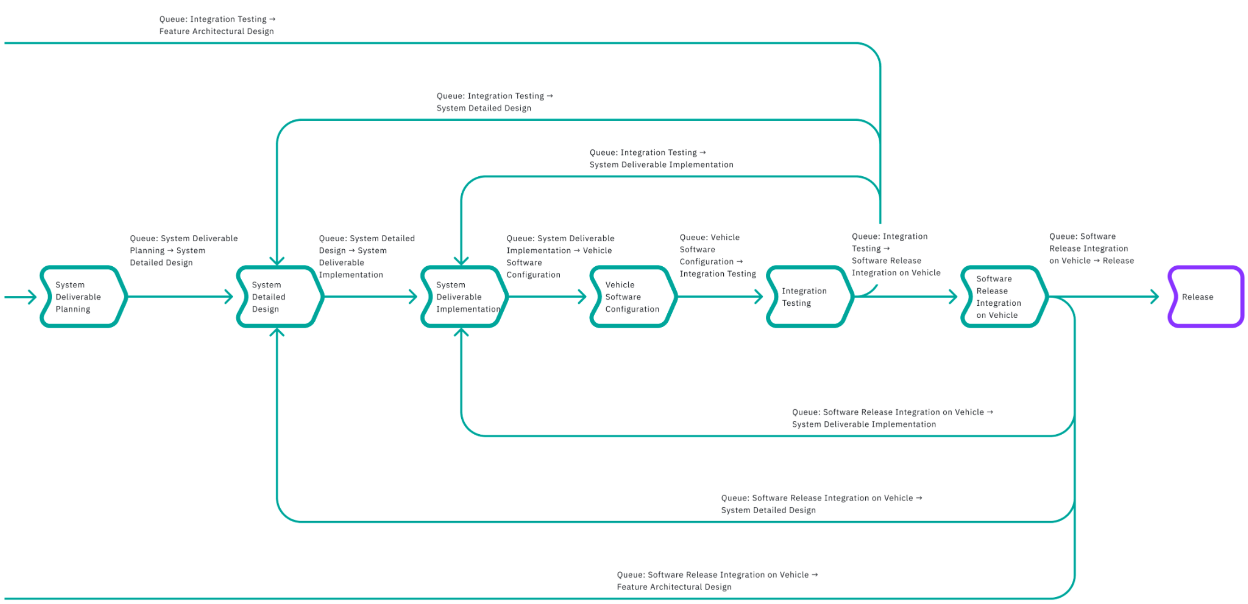
As a baseline process model, we took a rather optimistic and swift automotive SDLC model. Such a model has a number of specialized teams that orchestrate the workflow to deliver a software feature for vehicle systems.Each team contributes its unique operational capabilities and incurs a particular hourly cost rate. For the sake of simplicity, it's assumed that each team consists of 7 members, with the overall team expenses amounting to approximately $600 per hour (each ~$85). The organizational topology encompasses the Solution Architecture Team, 5 System Teams, Vehicle Integration Team, Cybersecurity Team, Functional Safety Team, Integration QA Team, and Vehicle Configuration Team.

The operational sequence unfolds by first capturing the essence of customer needs, setting the stage for a systematic journey through the product development lifecycle, which is divided into two primary stages, each with its distinct cycles.

The initial stage is dedicated to laying the groundwork—it's where the pivotal activities of requirements analysis and system design take place. To simplify the model, we put aside activities related to the requirements analysis since there will not be any changes in that part of the process. The cycle time for system design is about 20 days. The team responsible for that stage is the Solution Architecture Team. This stage starts with Solution Architecture Planning, in which the team engages with each item for a quarter to a half of a working day, a span that allows for agile yet thorough planning. As the plot progresses to the Feature Requirements Analysis, the narrative requires a deeper commitment—each item is afforded a full 1 to 2 working days. This duration is indicative of the careful consideration required to analyze the nuances of feature requirements. Entering the phase of Feature Architectural Design, the story unfolds over a more extended period, dedicating 5 to 10 working days to each item. This significant allocation of time reflects the complexity and creativity inherent in architectural design. The System Team Review and Interface Design marks the next stage, with each item meriting 1.25 to 2.25 working days. This time is spent ensuring that the system's interface is both user-friendly and technically sound, balancing meticulous review with innovative design.

In examining the automotive design process, a critical question emerges: to what extent is it necessary to design every feature from scratch? A closer inspection reveals that numerous basic functionalities — such as common logic for vehicle state machines, network management, exterior lights control and drivetrain operation — are common across various vehicle models. This observation raises the possibility of reusing or configuring certain software code elements across different car models. Such a strategy could significantly streamline the design process, leveraging existing technology to enhance efficiency and reduce time-to-market.

However, this approach encounters a complex challenge in the form of aligning system infrastructure design with software design. Traditionally, these two critical components are handled by separate teams, often utilizing distinct tools and methodologies. This separation can lead to a range of issues, from communication breakdowns to inconsistencies in the final product and integration issues. Addressing this challenge necessitates a strategic shift towards a more integrated and collaborative environment. The question then becomes: How can organizations foster a cohesive design ecosystem where system infrastructure and software design are conducted in tandem? Breaking down these silos requires not only a technological solution but also processes changes, cultural and organizational changes.



Following this initial phase, the process transitions into the **second stage**, where the focus shifts to bringing the plans to fruition. Here, the activities are centered around the actual coding of the system and the rigorous testing that follows. This stage is where the theoretical designs are transformed into tangible, working software, meticulously scrutinized for quality and performance before it can be deemed ready for deployment. Its cycle time in the baseline is 60 days. The System Deliverable Planning is the prelude to the cycle, where the System Team engages with each deliverable for a precise duration ranging from a quarter to half a working day, setting a brisk yet efficient tempo for the initial phase. As we advance to the System Detailed Design, the plot expands significantly, with the team dedicating a substantial 5 to 10 working days to each element. This interval reflects the depth of focus required for the intricate details that define the system's architecture. The narrative reaches a critical juncture with the System Deliverable Implementation. Here, the commitment deepens further, with each deliverable absorbing 10 to 20 working days of the team's effort. It's a testament to the intensive labor involved in bringing the system to life, ensuring each deliverable's functionality aligns with the meticulous design. In the Vehicle Software Configuration phase, the Vehicle Configuration Team takes the helm, allocating 2 to 5 working days to process completed items. This phase is pivotal in ensuring the software is optimally configured for the vehicle. Integration Testing follows a chapter where the Integration QA Team's dedication mirrors the previous implementation phase, with an extensive 10 to 20 working days invested in a batch of 5 changes. This rigorous testing is crucial to ensure the system's resilience and reliability upon deployment. Lastly, the Software Release Integration on the Vehicle marks the final stage in this comprehensive journey. The Vehicle Integration Team commits an equal measure of 10 to 20 working days for all tested features.

Looking into the system implementation phase, which is the most expensive, we can see the feedback loops from quality from two milestones of quality assurance integration testing and testing on the vehicle test stand. Such a feedback loop represents unplanned work that eats the capacity of the system team from the planned work. The integration testing takes significant time to deploy all components and run integration testing itself. Automation is the obvious solution for this case, however, for automotive software, it will require an abstraction layer of the hardware to make sure the components work individually and are fully integrated.

Delving into the system implementation phase, widely recognized as the most resource-intensive stage of the development cycle, we observe critical feedback loops emanating from two quality assurance milestones: integration testing and testing on the vehicle test stand. These feedback loops, often resulting in unplanned work, significantly consume the capacity of system teams, diverting their attention from scheduled tasks. The integration testing phase, in particular, demands substantial time and effort to deploy all components and execute the tests. Moreover, the efforts and time required to execute the test integration cycle determine the duration of the entire implementation cycle.

To address these challenges, an automation approach for the environment configuration, deployment automation, and test automation is essential. The key objective is to reduce the time and effort required for release testing. The shorter it is, the more frequently the test can be executed, and the cycle time can be shorter.

Environment configuration should involve setting up a virtual environment that accurately simulates the hardware layer, allowing software components to be tested without false positives due to misconfiguration. The same is relevant for the deployment automation, focusing on streamlining the process of deploying software components for testing.

Incorporating test automation into the delivery process is a critical milestone as well. Test automation involves developing and using specialized software to control the execution of tests and compare the actual outcomes with predicted outcomes. Ideally, automated and integration tests are developed simultaneously with a feature and are part of the definition of done. This process not only accelerates the testing phase but also enhances its accuracy and repeatability.

Performance Evaluation Approach

Our evaluation of the model's performance encompassed two distinct experiments. The first involved dispatching 100 feature requests within the first quarter, and monitoring how many were processed by year-end. The second experiment aimed to determine speed and cost, controlling the minimum number of items necessary for comprehensive model processing.

In assessing the base model, we focused on four critical performance metrics. The productivity metric was defined by the number of departed items, indicating the total items successfully processed. We analyzed speed in two dimensions: processing time, as the cumulative average time for each process step, and lead time, measuring the average duration from the initiation to the completion of the process. Lastly, the cost metric was calculated based on the average effort cost for all delivered items.

The evaluation of the base model in the first experiment:

Productivity Departed Items	Speed Process Time (day rounded)	Speed Lead Time (day rounded)	Cost Cost Per Item
38	27d	74d	$52,808

The Process Time, the duration of diligent labor where work is actively undertaken, tallied up to nearly 25 days—a testament to the time invested in hands-on, value-adding activities.

The Lead Time, the chronicle from inception to completion, stretched to approximately 75 days, encompassing both the bustling periods of activity and the silent spells of inactivity. This duration encapsulates the entire journey of an item through the system.

As a result, we can see that the idle time, the interlude when the gears of production grind to a halt, is amassed to a considerable 50 days. This gap is a potential improvement opportunity.

At the simulation's close, out of 100 items that arrived in the process in a year, we still see 62 items in progress on their voyage through the process. Therefore the throughput, the tempo at which items were processed, maintained a modest rhythm of approximately 0.1 items per day, a cadence beckoning for acceleration.

In the ledger of production, Variable Costs accrued to about $52,808.

The Evaluation of the Base Model in the Second Experiment:

In that experiment, we observed variations in processing speeds attributable to differing workflow paths among the items. Specifically, 35 items traversed the full spectrum of process variations, in contrast to an earlier experiment where 62 items were still in the midst of processing. Of these, only 38 reached completion, representing a limited range of the potential workflows. This distinction in experimental conditions accounted for the observed differences in speed metrics.

Speed Process Time (day rounded)	Speed Lead Time (day rounded)	Cost Cost Per Item
36d	66d	$74,165

Examples of Solutions with SODA.Create:

SODA.Create stands at the forefront of automotive software development, revolutionizing the way vehicle models and features are designed and implemented. This advanced tool is a pivotal element within the pipeline of vehicle digital twins, it ushers in a new era of precision, efficiency, and innovation in automotive design. Here are some distinctive features of

SODA.Create compared to traditional model-based design tools commonly used in companies developing vehicles.

Scalable and Agile Development Environment

SODA.Create seamlessly integrates Feature Driven Development approach for development processes and Model-Based Systems Engineering for vehicle design, two methodologies at the heart of modern automotive development. This unique fusion empowers teams to tackle complex design challenges with agility and foresight.

By fostering a collaborative environment that brings together architects and engineers across various automotive domains, SODA.Create enhances the understanding and execution of feature scopes, enabling rapid and precise design decisions. This unity, combined with the tool's feature management capabilities, allows for swift information exchange and precise decision-making, thus streamlining the entire design process.

Adapting effortlessly to the ebbs and flows of project and organizational scales, SODA.Create redefines scalability. Its approach to breaking down complex feature sets into manageable iterations ensures that as your project expands, management efforts and resources align proportionally, avoiding the pitfalls of exponential increases often seen in traditional methods. This flexibility is key in responding rapidly to evolving customer needs, significantly cutting down delivery timelines.

With its full adoption of MBSE, SODA.Create facilitates the creation of logical, hardware-independent models, significantly reducing design time and integration costs. The tool's adeptness at harmonizing system interfaces of electric/electronic systems from early design stages significantly slashes integration costs and complexities.

Advanced Automation and Integration

SODA.Create introduces automated algorithms for hardware layer optimization of developing vehicle models ensuring cost-efficiency and resilience in vehicle design. The tool excels in finding the optimal number of processing nodes and creating robust network topologies according to selected vehicle architecture (zonal or domain architecture). It automatically generates electric circuit diagrams and software allocation, ensuring optimal hardware resource utilization and communication efficiency.

The tool creates a complete digital twin of the modeled vehicle, ensuring a consistent and comprehensive development cycle. This single source of truth approach guarantees that every phase of the process, from design to verification, aligns perfectly, reducing management overhead and enhancing automation opportunities.

One of these opportunities is a continuous integration system under the hood that streamlines the development cycle, enabling concurrent workflows and efficient progression through various validation stages. This feature ensures that each software change is seamlessly integrated, tested, and verified, fostering a rapid and reliable development process. Thanks to the use of a digital twin of the vehicle, the system enables the complete avoidance of manual software configuration during assembly, as all data required for such an automatic operation are represented in the digital twin.

SODA.Create Operating Model Performance Impact

The SODA.Create solution transforms the operating model, cutting down the duration of integration testing by 20%, automating the vehicle software configuration shortening it from days to hours, and decreasing the backward flow from integration testing to the Feature Architectural Design stage by half.

When we run our two experiments, we can see the impact on the key performance characteristics

	Productivity Departed Items	Speed Lead Time	Cost Cost Per Item
Base line	38	66d	$74,165
SODA.Create	54	59d	$69,307
IMPACT	**37% more features**	**14% faster**	**7% cheaper**

Examples of Solutions with SODA.Validate (Testing Phase):

SODA.Validate stands as a transformative solution in the automotive software validation landscape. This sophisticated test management system is designed to seamlessly integrate with a software-defined rig, allowing users to configure a test environment tailored to the specific vehicle model. Embedded within the digital twin framework, SODA.Validate is set to revolutionize the way automotive validation is approached.

Intuitive Interface with Contextual AI Assistant

Focusing on the aspect of a low barrier to entry, SODA.Validate not only offers a user-friendly and intuitive interface but also takes a leap forward by integrating AI-based features to streamline the test scenario creation process. This integration is particularly crucial in making the tool accessible to architects and engineers across various disciplines, ensuring that the complexity of the tool does not hinder its usability.

This advanced feature leverages AI to understand the specification of test environment and requirements of the test, thereby guiding users through the scenario creation process with suggestions and automated inputs.The Copilot feature is designed to minimize the need for extensive training or in-depth reading of product documentation. By providing real-time assistance, it dramatically reduces the learning curve for new users, enabling them to start creating effective test scenarios quickly.

AI integration in SODA.Validate also plays a pivotal role in early error detection and correction. The system can analyze test scenarios as they are being created, identifying potential errors or inefficiencies and suggesting optimizations. This proactive approach to error management is crucial in the early validation stages, where correcting errors is less costly than in later stages of the validation process.

The AI capabilities of SODA.Validate are designed to learn and adapt over time. As users interact with the tool, the AI system becomes more attuned to their specific testing patterns and requirements, continually refining its assistance to provide more accurate and relevant support.

Simulation-Based Testing and Hybrid Testing Environment

One of the most compelling benefits of the SODA.Validate product is its Hybrid Testing Environment, coupled with its state-of-the-art Simulation-Based Testing capability for ADAS/AD Development. This dual approach represents a significant leap in automotive software validation, addressing crucial needs in the industry.

The hybrid testing environment provided by SODA.Validate is a game-changer for early-stage concept testing. It allows engineers to validate software in an environment that closely mirrors the final product without the need for all physical hardware components to be present. The tool allows to compose a hybrid testing environment that consists of Model-in-the-Loop, Software-in-the-Loop, Hardware-in-the-Loop parts or even AD/ADAS simulation facilities.

Simulation based testing should be an integral part of ADAS/AD vehicle development. Only this can put relief on the infeasible amount of real-world testing that would be required by a traditional verification concept. The only way to comply with the SOTIF standard is to have a reliable and scalable way to automatically create unknown/unsafe scenarios and be able to quantify the criticality of such scenarios. The presence of such tools allows you to be sure of the completeness of the test coverage. The scenario-based assessment approach tests the AD/ADAS vehicle in the complex, unpredictable situations that can occur in real-world driving. These scenarios include edge cases that may not have been anticipated when a requirement-based approach is used.

Vehicle Digital Twin and New Automation Capabilities

Of course, SODA.Validate provides all the necessary capabilities for building an automated test solution. Such a pipeline can be created in just a few clicks, especially when using other SODA tools within the company's toolchain. It enables developers to regularly integrate their changes into a shared mainline (e.g., a master branch in a version control system). Each integration is verified through automated builds and tests in the hybrid test environment, allowing for quick detection of integration errors. This automation, extending from build to deployment, not only speeds up the development cycle but also significantly improves the overall quality of the software. This is a feature that is often less emphasized in traditional testing environments.

Leveraging the power of digital twins, SODA.Validate utilizes this comprehensive digital representation to enhance the vehicle validation stage. The tool efficiently compares digital twins under test, identifying opportunities for reusing test scenarios and data, thereby streamlining the test design process for new vehicle configurations. Additionally, SODA.Validate utilizes the digital twin to create detailed monitoring profiles for the testing vehicle models. These profiles play a crucial role during the validation process, especially in conducting root cause analysis when errors are detected.

SODA.Validate Operating Model Performance Impact

The SODA.Validate solution updates the operating model, streamlining the integration testing step by 70% and shortening it from 10 to 20 days to 3 days to 7 days.

Making such changes, we can see the following impact on the key performance characteristics

	Productivity Departed Items	Speed Lead Time	Cost Cost Per Item
Base line	38	66d	$74,165
SODA.Validate	95	47d	$65,910
IMPACT	**150% more features**	**40% faster**	**12% cheaper**

Examples of solutions with SODA Feature Library:

The SODA Feature Library is a comprehensive collection of over 200 design elements, crucial for vehicle functionality, known as "Features." These Features are integral in defining the use-cases for vehicles, taking into account safety, security, and regulatory constraints. They offer detailed insights into requirement decomposition and allocation across various vehicle systems, along with specifying communication protocols and APIs for system interaction.

Each Feature in the library details the system application's blueprint at the software level, showcasing interconnected atomic software components. These components are designed for versatility and can be distributed across different vehicle Electronic Control Units. This modular approach enhances adaptability and allows for significant component reuse in various projects.

The Feature Library streamlines vehicle software design and development through several key methods. It creates standard design templates, promoting consistency and minimizing redundant effort across projects. Rapid prototyping is enabled through predefined elements, accelerating development cycles. The library’s modular design facilitates component reuse, enhancing software reliability and efficiency. Collaboration is more efficient due to shared standardized templates, fostering a collaborative environment and simplifying the onboarding process for new team members. The library's configurable nature makes adapting to changing project requirements easy, crucial in the dynamic field of vehicle software development. Additionally, it embeds best practices and compliance guidelines into the design templates, ensuring adherence to industry standards and regulations. This comprehensive approach not only accelerates development cycles but also ensures that the resulting software is safe, secure, and compliant, thus significantly speeding up the vehicle software development process while maintaining high-quality standards.

SODA Feature Library Operating Model Performance Impact

The Feature library updates the operating model by adding a fast lane for features that require configuration instead of implementation, which cuts off the implementation cycle completely and affects the lead time substantially.
Making such changes, we can see the following impact

	Productivity Departed Items	Speed Lead Time	Cost Cost Per Item
Base line	38	66d	$74,165
Feature library	47	55d	$68,264
IMPACT	**24% more features**	**20% faster**	**8% cheaper**

SODA V Suit Implementation (Create + Validate + Feature Library)

Combining all these operating model changes, we can witness a synergetic effect on the speed, productivity, and cost per feature.

	Productivity Departed Items	Speed Lead Time	Cost Cost Per Item
Base line	38	66d	$74,165
SODA V Suite	96	46d	$38,095
IMPACT	**153% more features**	**43% faster**	**49% cheaper**

In our study, we undertook two critical experiments centered on the development of software features within an automotive context. In the first experiment, we initiated the delivery of 100 software features at the beginning of the first quarter, aiming to track their completion rate by year-end. Under the conventional framework, we achieved completion of 38 features by the end of the year. However, a significant enhancement was observed with the implementation of the SODA V methodology, which led to the completion of 96 features within the same period. This remarkable improvement indicates a 150% increase in the development speed, equating to the SODA V approach being 2.5 times faster w.r.t. vehicle software end-to-end features delivery speed, features per year, than the traditional method. Consequently, we confidently claim that SODA V approach results in a twofold faster delivery of vehicle end-to-end software features, a conservative estimate that accounts for the potential modeling inaccuracies.

The Road to Successful Implementation

When You Need SODA.Validate and Soda.Sim AD/ADAS Capabilities

For efficient integration testing in Software Defined Vehicle development, SODA.Validate is key. It accelerates and improves test scenario creation with its user-friendly, AI-enhanced, and advanced testing capabilities, supporting integration with vehicle digital twins. This tool is vital for developing reliable, high-quality vehicles, enhancing the validation process for more effective vehicle development.

The integration of AI based Copilot in SODA.Validate streamlines the test scenario creation process. This AI feature understands the specifications of the test environment, the test language syntax and the initial requirements under test, guiding users through test scenario creation by automated test steps suggestion. Also, the Copilot ability to learn and adapt to users' testing patterns further refines the test design process. As the Copilot becomes more attuned to specific user needs and patterns, it offers increasingly accurate and relevant support, making the test design process more efficient over time.

Another distinguishing feature of SODA.Validate is its simulation-based testing capability, which is a critical component of AD/ADAS vehicle development. This approach significantly alleviates the need for extensive real-world testing that traditional verification methods typically require.

But having just one simulation environment does not solve the problem of compliance with the SOTIF standard. There is also a need for a way to automatically create unknown/unsafe scenarios and the ability to quantify the criticality of such scenarios. The presence of this feature in SODA.Validate allows you to be sure of the completeness of the test coverage. The scenario-based assessment approach tests the AD/ADAS vehicle in the complex, unpredictable situations that can occur in real-world driving. These scenarios include edge cases that may not have been anticipated when a requirement-based approach is used.

Furthermore, SODA.Validate provides the hybrid testing environment for accelerated validation of vehicle functionality. This hybrid testing environment, which includes MIL, SIL, HIL, and

AD/ADAS simulation facilities, enables testing concepts at the design stage without waiting for all electric/electronic components to be available.

When Do You Need SODA.Create and Feature Library

When developing a transportation vehicle, especially in situations where a rapid, feature-driven engineering approach is required, SODA.Create becomes an essential platform. It's particularly useful when your project demands efficient management with a focus on delivering valuable features, and when there's a need for flexibility in integrating future hardware innovations.

SODA.Create is ideal for projects that require streamlining the software development process for new features or emerging hardware components. This scenario often arises in competitive markets where staying ahead with innovative functionalities is crucial. The tool's alignment with Model-Based Systems Engineering (MBSE) makes it particularly valuable in the early stages of vehicle design, where developing functionalities at a logical level, independent of specific hardware, is critical.

The tool is also necessary for automatic code generation and assembly of composite models for each Electronic Control Unit (ECU) minimizes manual coding errors and enhances the overall integration of software components. The continuous integration feature further ensures that all software changes are seamlessly incorporated and validated in a simulation environment.

The internal optimization algorithms for determining the optimal number of ECUs, coupled with smart algorithms for network topology creation, ensure your vehicle's systems are not only robust but also cost-effective. The automated creation of electrical circuit diagrams and software allocation matrices further adds to the tool's efficiency.

Perhaps one of the most compelling features of SODA.Create is its ability to unify all design parameters – from requirements to hardware topologies – in a single tool. This unification ensures that every aspect of your vehicle model is thoroughly evaluated for completeness and consistency, vital for maintaining the integrity of the design. With SODA.Create, you get a complete digital twin of your vehicle model, a crucial asset in the digital age. This digital twin, encompassing every detail in a domain-specific language, ensures that all phases of your vehicle development are based on a consistent and comprehensive model.

The tool offers predefined hardware topologies and a vast library of implemented software features and modules, enabling you to design vehicles that are not only cutting-edge but also grounded in proven, efficient architectures.

When Do You Need Processes Digital Twin

In the realm of software development, particularly when embarking on the creation or enhancement of a digital product with numerous components, the process digital twin proves to be a vital tool. It's especially beneficial in scenarios where there's a need to understand and optimize the value stream and enable continuous improvement within the development processes.

It allows teams to experiment with different structural decisions, understand the capacities of their talent pool, and set benchmarks for quality, all within a controlled, virtual environment. By using synthetic data to simulate various scenarios, it enables informed decision-making before fully establishing or altering the process.

For those in established SDLCs who are facing the challenge of accelerating release cycles or striving to enhance quality assurance practices, a process digital twin becomes crucial. It provides a detailed and real-time representation of current processes, revealing inefficiencies and bottlenecks. This insight is key to exploring and evaluating different improvement scenarios, assessing their potential impact on the value stream. The process digital twin enables not just one-time changes, but fosters a culture of continuous improvement by allowing ongoing monitoring and fine-tuning of processes. Post-implementation, it ensures that any modifications lead to the desired improvements and helps in adjusting strategies as necessary. Thus, it plays a pivotal role in maintaining and enhancing efficiency and effectiveness in complex and dynamic software development environments, ensuring that every change adds value to the overall process, and promote value stream management.

Example: ’67 by Charge Cars & SODA

'67 by Charge Cars is a perfect example of how rapid, dynamic, and challenging the design and development of software features for the small-series electric vehicle manufacturer can be, targeting a luxury customer experience along with the performance and capabilities of a sports car.

Control software engineers at SODA, in collaboration with system and integration engineers at Charge Cars, successfully navigated the project’s technical evolution through the prototyping stage, rapidly delivering a functionally rich product to meet the dynamic roadmap of ever-changing stakeholders’ requirements while supporting numerous events.

However, to achieve the project's ultimate goal — delivering a production-ready car with a full feature set including both manual and automated wipers, body controls, advanced vehicle dynamics, energy-efficient climate control, and a smart AI-powered Human-Machine Interface (HMI); while keeping it perfectly safe, secure, and without any compromises on end-to-end quality – even experienced engineering teams utilizing modern model-based systems engineering and software development techniques are not enough.

Bringing the vehicle project to maturity levels where it can pass certification (complying with regulatory requirements), meet all functional safety and cybersecurity standards, and be prepared for production and post-production stages required two essential elements: a robust requirements management process supported by a well-defined system and an automated Hardware-in-the-Loop (HIL) validation toolchain, seamlessly integrated with the requirements management system.

Fully covering the first point while maintaining compact engineering teams that communicate directly without needing additional architecture and requirements management teams, the Feature Driven Development “Lite” process was initiated. Charge system engineers are responsible for gathering requirements, combining various sources (vehicle level use-cases, customer, safety, cybersecurity goals, and regulatory requirements). In collaboration with the SODA control software team, they design the vehicle's high-level architecture. This specifies how systems affected by a feature integrate and satisfy requirements to support the feature. System requirements are then aligned with a set of features, defining the scope for the system deliverable, which is developed for a specific software bundle release.

There are a few more steps in this process, but ultimately, the requirements management system, with traceability between all levels of requirements, acts as the backbone of the development lifecycle, ensuring that customer expectations are carefully captured and translated into detailed specifications for the set of vehicle features, down to the specification and implementation of each atomic application software component. This, in turn, fosters clear communication between the customer and the different engineering teams, laying the groundwork for a streamlined development process.

Integrated with the SODA.Validate HIL testing toolchain, recently adopted in '67 by Charge Cars control systems quality assurance process, these requirements not only serve as the blueprint for software development but also become the basis for automated testing scenarios, creating a comprehensive and traceable link between requirements, software code, and validation tests. This traceability ensures that the developed software, control systems and vehicle features align with specified requirements and facilitates swift identification and resolution of any deviations. The incorporation of automated HIL validation tools further accelerates the development cycle by enabling rapid and repeatable testing, reducing the time traditionally spent on manual testing processes. This automation, in turn, paves the way for a highly efficient and reliable test regression, ensuring that any modifications or enhancements to the software are promptly validated against established requirements. Even at the early stage of SODA.Validate implementation in the delivery process for this project, on average there is more than seventy percent less time spent cumulatively for all stages of release quality assurance, reducing at the same time amount of defects found at each level of testing (system level, feature level, vehicle level).

In summary, the introduction of the requirements management process and system described above, together with SODA.Validate, not only instills confidence that all necessary requirements are properly covered by the Feature Specifications and propagated down to each software module but also removes the fear of introducing further functional improvements in the project at the current (quite late) stage. The validation toolchain automatically identifies the scope of requirements at any level potentially affected by the change, and each new software release is fully covered not only with new requirements testing but also with the necessary scope of regression testing.

In terms of the framework and toolchain, the next steps for this project are to completely adopt SODA.Validate. This involves considering the use case for a Software-Defined Hardware-in-the-Loop (HIL) Rig, which serves as a substitute for missing hardware components on the Lab Car while also allowing some level of automation for Lab Car-based tests. The further step is the introduction of SODA Sim for the preliminary (and more detailed and scenarios-rich) validation of vehicle dynamics and Advanced Driver Assistance Systems (ADAS) features before testing on the track (so the expensive time on track is saved). Additionally, the project aims to introduce SODA.Create with an embedded AI co-pilot and assistants to automate and enhance the quality of requirements design and decomposition, as well as software configuration, before generating the software vehicle bundle.

Conclusion

In conclusion, the whitepaper presents a compelling case for the adoption of Software-Defined Vehicles (SDVs) and digital twin technology in the automotive industry to meet the evolving demands of consumers and the complexities of modern vehicle design and production. The collaboration between SODA and VSOptima exemplifies the practical application and benefits of these technologies, demonstrating significant improvements in the speed and efficiency of automotive engineering processes. This approach paves the way for more responsive, efficient, and customer-centric vehicle engineering in the future.

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Expert opinions

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Dmitry Galper, Expert Partner of Boston Consulting Group

“I view the adoption of digital twin technology in the automotive industry as a strategic imperative, transcending mere technological enhancement. This shift reflects transformative trends in sectors like aerospace, manufacturing, and healthcare, where digital twins have significantly bolstered efficiency, innovation, and customer engagement. Look at how these other sectors have embraced the digital twin technology, and now it's the time for automotive to do the same. In aerospace, they enable real-time aircraft monitoring and predictive maintenance, while in manufacturing and healthcare, they streamline production and contribute to personalized medical solutions and advanced diagnostics.

The adoption of digital twins in the automotive sector parallels the integration of other advanced technologies like AI, Cloud computing, and Hyperautomation across various industries. These technologies have reshaped business landscapes, driving profound changes in operations and strategy. AI has revolutionized data analysis and decision-making processes, Cloud computing has democratized access to powerful computing resources, and Hyperautomation has redefined efficiency in numerous processes. Just as these technologies have become indispensable for staying ahead in a competitive market, digital twins represent a similar level of transformative potential for the automotive industry.

This whitepaper underscores an ongoing pivotal shift in the automotive industry, necessitating a comprehensive overhaul of the operating model. Aligning the company's structure, talent, and processes is crucial to harness the full potential of digital twin technology. This should be on the agenda of any organization's top leaders, not just some IT people deep down in the hierarchy. The role of leadership, particularly the CEO and senior management, is crucial in spearheading this evolution. Far from being a mere technological add-on, digital twin technology forms a cornerstone of a broader business strategy, fostering a culture of innovation and agility. It's an essential ingredient for automotive companies aiming to maintain competitiveness and adaptability in a dynamic and rapidly advancing digital world.“

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Glenn Saint, Commercial Vehicle Industry Expert and Chairman of SMMT Commercial Vehicle Section

“With the current advancing technologies for zero emission vehicles together with Connected Autonomous vehicles and the general push for software-based features I know very well that the pressures placed upon vehicle software engineering teams is immense and growing. Time to market is all important today and the cost to market is similarly under pressure given the Global financial situation. Colleagues in the industry regularly share with me their frustration at the time taken and the complexity of work that today goes into our vehicles, today we truly manufacture a device on wheels.

I honestly believe that these tools from SODA can be a game changer for any automotive product team, drastically shortening development time and the time to validate and prove systems, ultimately speeding product to market and reducing costs”.

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Ben Jardine, CEO eVersum UK and 20 Years developing products in the Motorsport, Sports Car & Commercial Vehicle industries

“*Speed is the most important attribute for existing and new OEMs within the Automotive Industry today. Here today, gone tomorrow. Technology, though becoming more advanced adjusting to the rise of Electrification, is becoming more simpler within its form factor.*

Though form is becoming more simple, the competitive advantage between one OEM to another is no longer the amount of power or torque an engine can produce, but it's the introduction of new features, improvement of UX & how we continue to improve the product throughout the duration of its life.

SODA I believe are creating this environment, not only with model based software & access to simplified hardware....but also with end to end tool-chain/simulation environments which are essential to the speed & accuracy of engineering development.”

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Matas Simonavicius, CTO of Charge Cars

“*Working with SODA's tools and processes allowed Charge to deploy features in vehicles that before only large OEM's were able to do! The speed, quality and cost of developing vehicles with complex systems can be compared to consumer market products. No medium or Large OEM can compete with this!*”

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About Companies

SODA

SODA (Software Defined Auto) is transforming the automotive industry by doubling the speed of vehicle software engineering with its AI-powered tools and digital twin approach. SODA V Suite, including SODA.Create, SODA.Validate, SODA.Sim and Feature Library, addresses the challenges of modern vehicles and integration. SODA offers innovative, free solutions to reshape vehicle software engineering from concept to certification.

VSOptima

VSOptima is B2B SaaS operations digital twin platform, harnessingthe power of simulation, advanced analytics, and machine learning technologies, to becomes a co-pilot for operations leaders, saving time and money on operations optimization. This advanced solution decodes complex processes, exposes hidden performance patterns, pinpoints inefficiencies, and streamlines optimization. Its predictive prowess enables organizations to foresee and strategically navigate through potential disruptions, ensuring a competitive edge in operational efficiency. Furthermore, VSOptima's intelligent system stands out by empowering the operations improvement efforts by augmenting decision-making along with the whole improvement cycle.