INTRODUCTION TO MODSIM

ITS IMPLEMENTATION JOURNEY

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Introduction

Across all industries, the digital revolution is accelerating. There exists an enormous challenge for engineering departments to address ever more complicated tasks associated with the escalating complexity of products being demanded by consumers. The end-to-end development and manufacturing processes require proficiency in formalized processes that start with well-defined and managed stakeholder requirements to field delivery and maintenance throughout the entire product or process lifecycle.

The overwhelming intrusion of the pandemic produced tremendous challenges that threatened to unhinge traditional engineering development and manufacturing methods. The existing and escalating complexities accelerated the need to meet these new challenges. (Figure 1)

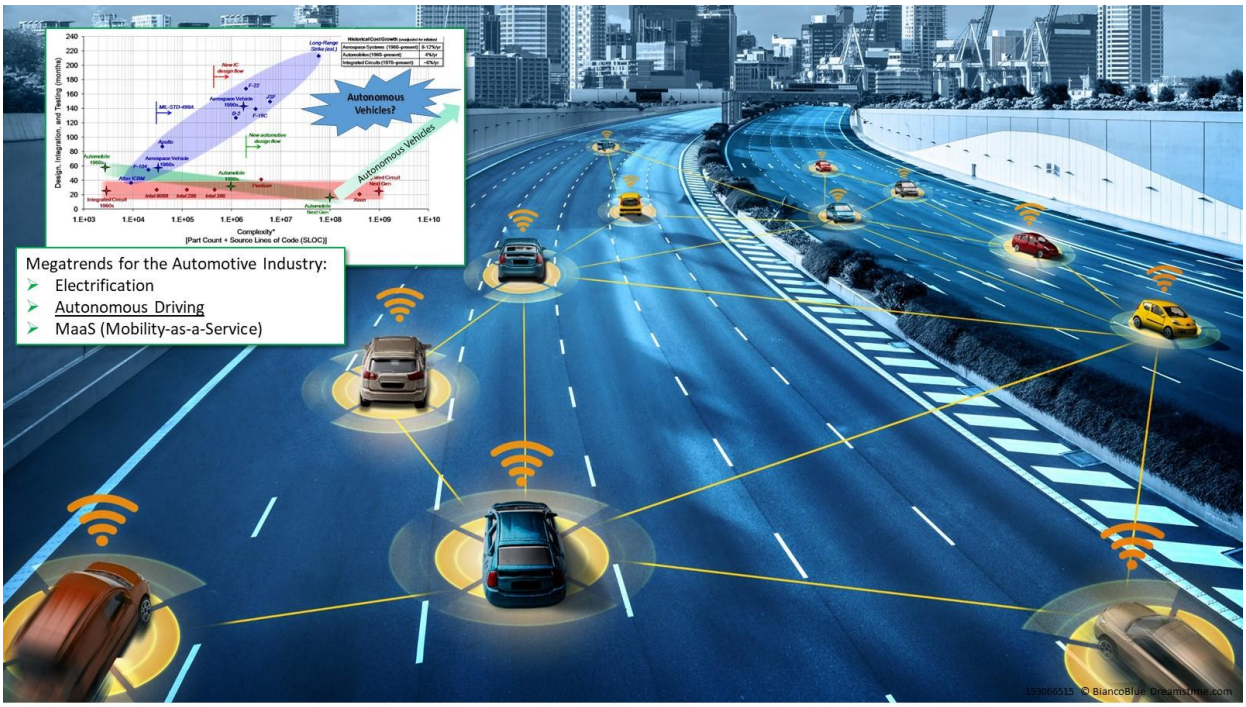

Figure 1: Complexity is increasing drastically

Companies need to reexamine their business models and methods of communication and collaboration to continue their operation. (Figure 2)

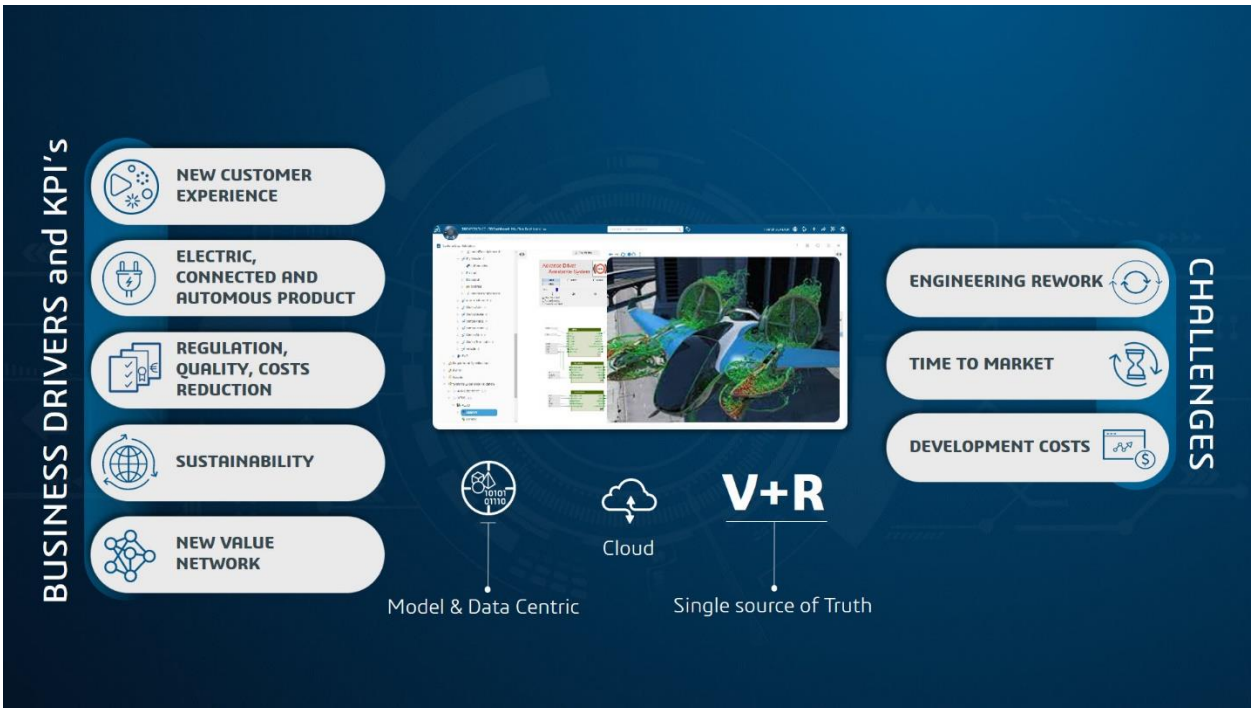

Figure 2: Business Drivers and KPI

(Courtesy of Dassault Systèmes)

Consumer demands are driving smart, connected, and autonomous technologies. These technologies may include many different engineering disciplines (electrical, electronic, controls, thermal, hydraulics, etc.), working to provide the optimal customer experience. To deliver these products to market quickly, efficiently, and safely, the product development and manufacturing cycles must be tuned to explore multiple simulation cycles. These cycles focus on the stakeholder needs and wants and are then decomposed into system requirements that must be met to ensure stakeholder final acceptance. Derived requirements fall into many distinct categories (regulatory, functional, performance, etc.) that have associated test cases to ensure their validity, and approval. Process assumptions made through the decades must now be questioned for viability. Non-value-added tasks need to be eliminated. Engineering groups are being tasked to examine legacy processes and make fundamental changes in their efficiencies. These examinations will start in the concept stage of the development process.

The MODSIM Approach - Unification of Modeling and Simulation

Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE) evolved separately over decades. Because of legacy processes, design and simulation continue to be employed sequentially as discrete tasks. Isn't it time to fully leverage simulation throughout the full design cycle? Companies must remove inefficient handoffs between designers and simulation experts that occur too late in the development cycle. Typically, specialized simulation tools do not support integrated design and simulation processes.

Dassault Systèmes has introduced a new concept called, "MODSIM" implemented on the 3DEXPERIENCE innovation platform. By separating the terms, "MOD" referring to the development and execution of the engineering model, while "SIM" describes the simulation of the developed model. The inclusion of these two terms can refer to a component, subsystem, full product system, or system of systems. Most importantly, it goes well beyond the integration of two disciplines and involves an end-to-end approach where the characteristic behavior of the entity under design and analysis can be identified virtually, in a

cloud environment. Additionally, MODSIM brings the engineering groups together forming a foundational pillar to ensure effective collaboration. As a result of native CAD-CAE associativity, the CAD and CAE worlds form a single source of truth resulting in more opportunities for development 'discoveries' toward better designs, more efficient process execution and an environment that provides an opportunity for sustainable innovation (Figure 3).

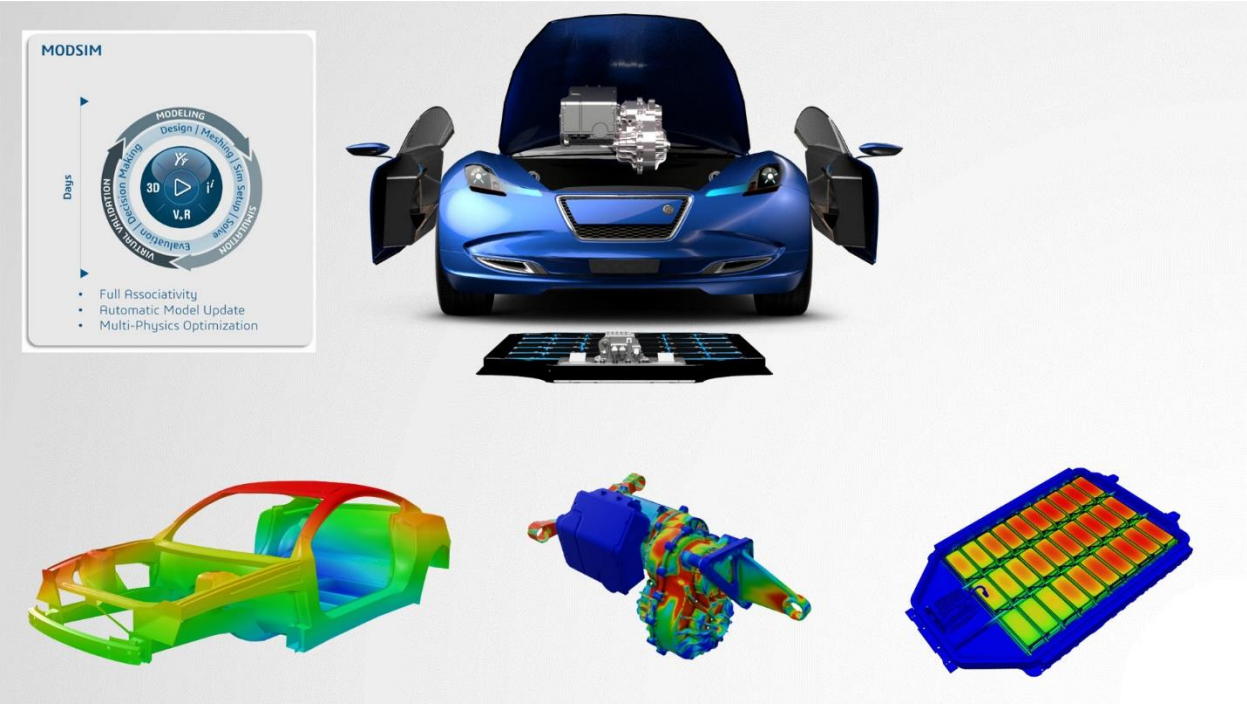

Figure 3: MODSIM – A Foundational Pillar on the 3DEXPERIENCE Platform for 'Discoveries' and Sustainable Innovation

(Courtesy of Dassault Systèmes)

Democratization of Simulation

Democratization Definition

> A solution delivery approach which enables individuals who are not simulation specialists to execute simulations and obtain valid results within specified ranges of parameters in a managed, traceable environment, built by a simulation engineer who is responsible for the results obtained.[1]

With the ever-increasing consumer demands for new products and features comes an escalating demand for organizational change accompanied by the need to establish new innovative processes. Typically, the expertise for understanding and executing extraordinarily complex simulation tools reside with a relatively small number of disparate engineering groups across the enterprise.

Simulation democratization increases the power of advanced thinking and decision making across the engineering community by providing the CAE analyst with capabilities to create highly specialized templates and processes to the design engineers (see Figure 4).

[1] NAFEMS - Glossary Terms D-I

Figure 4: Democratization of Simulation

The extended design community benefits by providing a more holistic view of the component and system requirements. This results in an increased understanding of the design engineer's mission. Errors are identified early in development process and more design iterations are performed stimulating design innovation.

The component and system CAE simulation teams also derive great benefit by having a complete component and/or system model developed to ensure consistent and highly accurate results. Additionally, the time and resource savings resulting from transitioning repetitive analysis tasks to the design community allows for greater experimentation within the CAE community and promotes innovation on a highly technical level enhancing engineering performance.

The design/analysis loop is closed promoting increased collaboration across the engineering enterprise.

MODSIM's Contribution to Model-Based Engineering

Model-Based Engineering (MBE) is a is a software and systems development approach emphasizing the application of virtual modeling principles and best practices throughout the product development lifecycle.

Integrating disparate domains which are typically silos of excellence is paramount in the MBE journey. MODSIM's inherent unification of 3D modeling and simulation analysis provides a solid foundation for the adoption of Model-Based Engineering best practices.

The inherent benefits of design and simulation unification is readily identified by Figure 5 showing these disciplines at the core of a Product Lifecycle Management (PLM) implementation providing much needed simulation data management capabilities as well as close integration and linkages to manufacturing and related disciplines. Unification on a broad platform is paramount to establishing a consistent and progressive Model-Based Engineering strategy and execution.

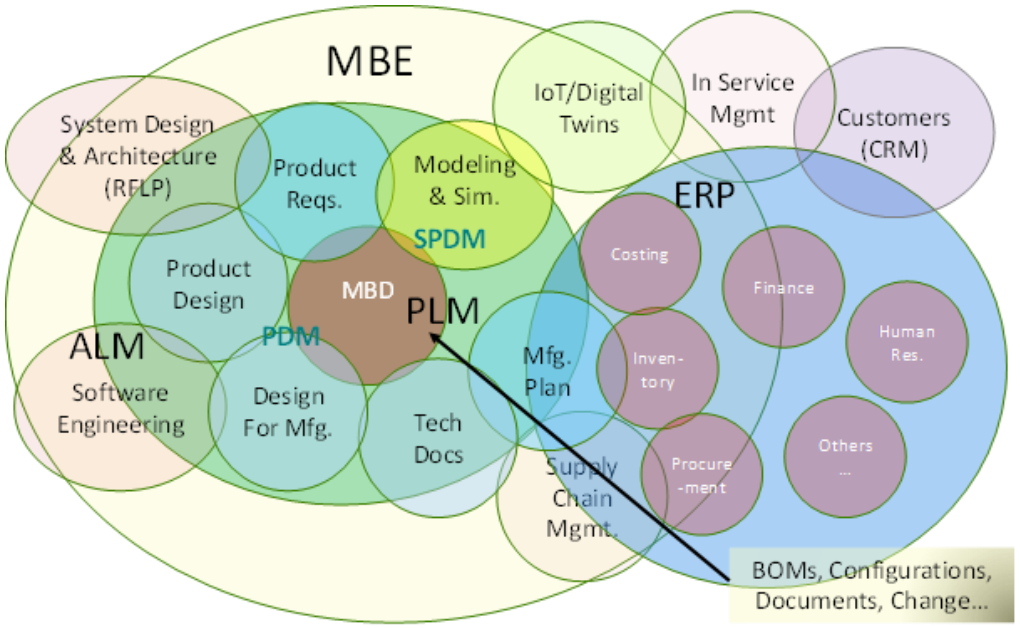

Figure 5: Building Blocks of Model-Based Engineering

(Courtesy of CIMdata)

When positioning MODSIM within the commonly used engineering "V" model, the simulation efforts shift to the left-hand side of the "V". This shift is a direct result of unifying the design and analysis efforts permitting more up-front simulation (Figure 6).

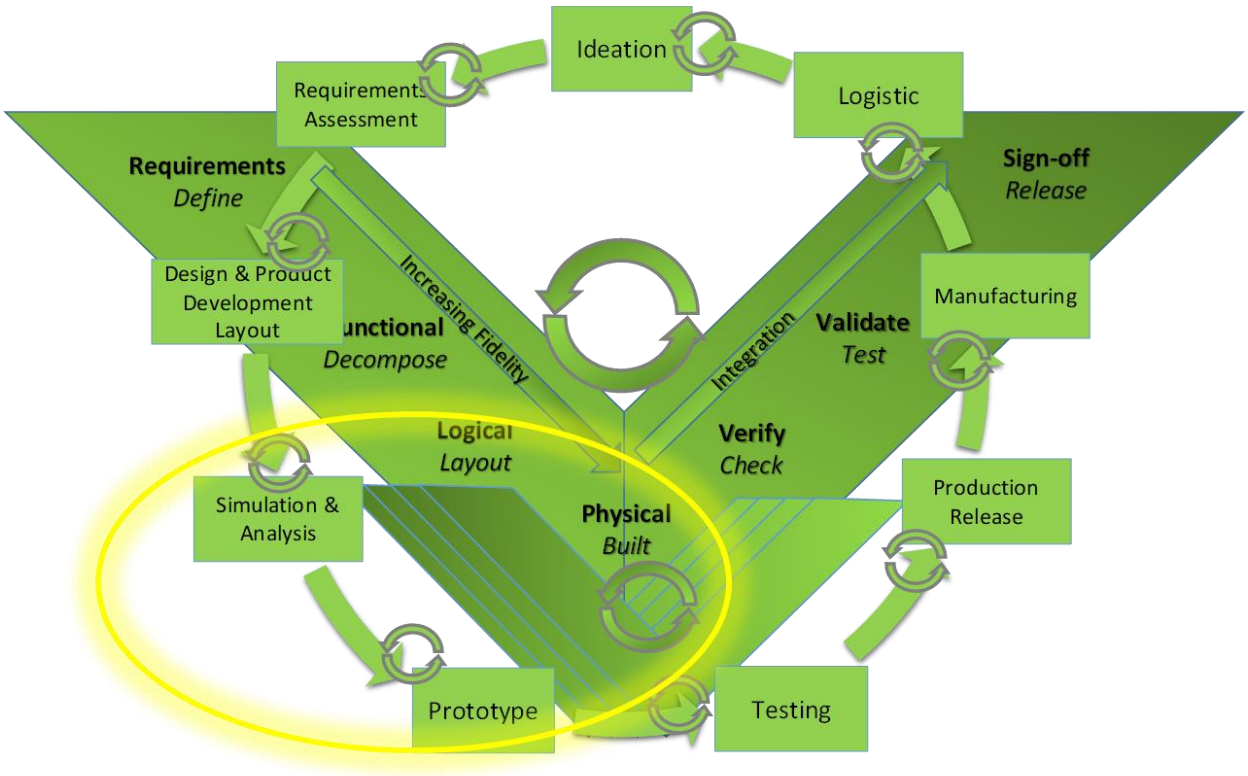

Figure 6: Positioning of MODSIM on the engineering "V" Model

Engineering in a reactive state is no longer sustainable. To address the ever-increasing product complexity, reduce escalating design costs, shorten time to market and improve or maintain quality products, a new approach to component and system optimization and early verification must be adopted. This will significantly reduce the time, money and risk associated with product and process deficiencies discovered once prototypes are created.

The reliance on physical test to identify problems is rapidly becoming excessively expensive and time consuming. Engineering groups function as 'silos' with limited communication, and more important, limited collaboration among them. The "loose" exchange of information, which may include data, geometry, simulation results, emails, texts, notes, lunch discussions etc. has become detrimental to the organized process flow for product design, delivery, and maintenance. By automating the model to simulation iterations, a broader design experience that involves trade-off studies and design of experiments involving engineering multi-disciplines can also contribute to left-shifting the simulation. (Figure 7)

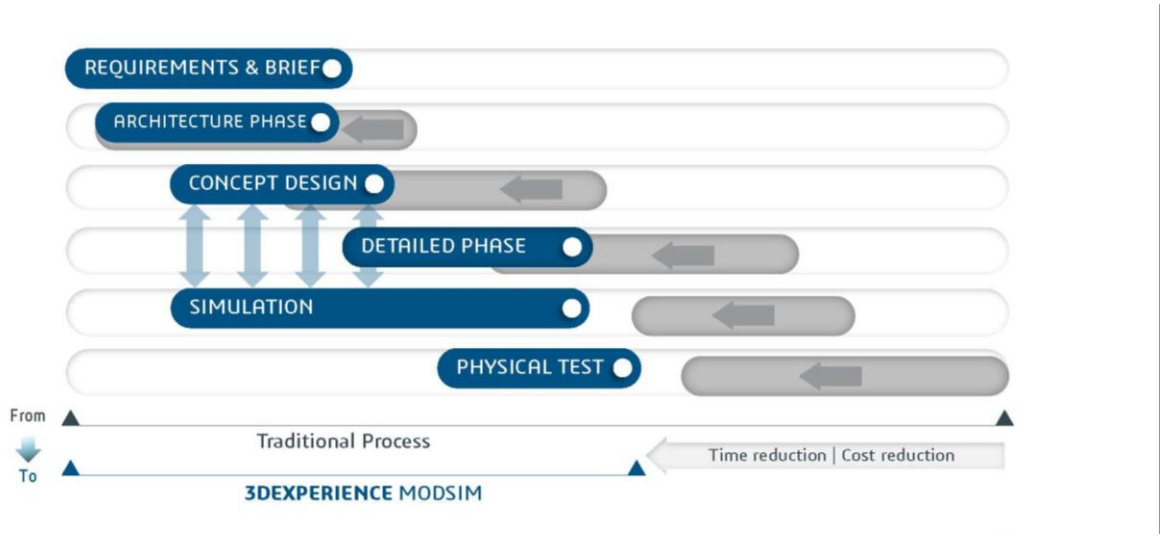

Figure 7: Simulation Democratization – Left Shifting of Project Execution
(Courtesy of Dassault Systèmes)

As was shown utilizing the engineering "V" model in Figure 6, democratization shifts the introduction of simulation to the left side of the "V" model where the criticality of authoring good requirements originates (Figure 7). Everyone has heard the phrase "garbage-in, garbage-out". One of the greatest challenges in implementing an MBE practice is the ability to author, manage and link well-written requirements that can be readily decomposed with test cases. System requirements form the basis of system integration and verification activities. They function as a reference for validation and stakeholder acceptance. Requirements provide a strong link between various technical disciplines throughout the project. They provide the impact of change for a given condition or set of conditions. Requirements ensure compliance with strict regulatory requirements in aerospace, automotive and energy. Government agencies dictate the compliance to critical product and process operations and dependencies before the OEM can bring their products to market. Most requirements include (but are not limited to):

- functional,
- performance,
- usability,
- interface,
- cost,

- schedule,
- operational,
- environmental,
- and others.

Requirements[2]

Requirements form the backbone for every engineering project. Refer to the top far left (Figure 7) where the requirements are developed and verified that we can influence the design and design trade-offs reducing the overall development cycle by introducing a greater amount of simulation. Many diverse types of requirements exist, but it is up to the end user to develop the most efficient structure to adhere to best systems engineering practices while ensuring simplicity for their engineering community.

The “Requirements Manager” organizes and decomposes the stakeholder’s needs in collaboration with the other engineering disciplines. The benefits related to following Model-Based Engineering (MBE) best practices and with the 3DEXPERIENCE platform brings together all associated multi-disciplinary groups around a single set of data, which come from all design activities including the concept, the requirement, or even the verifications and eventual validation. (Figure 8)

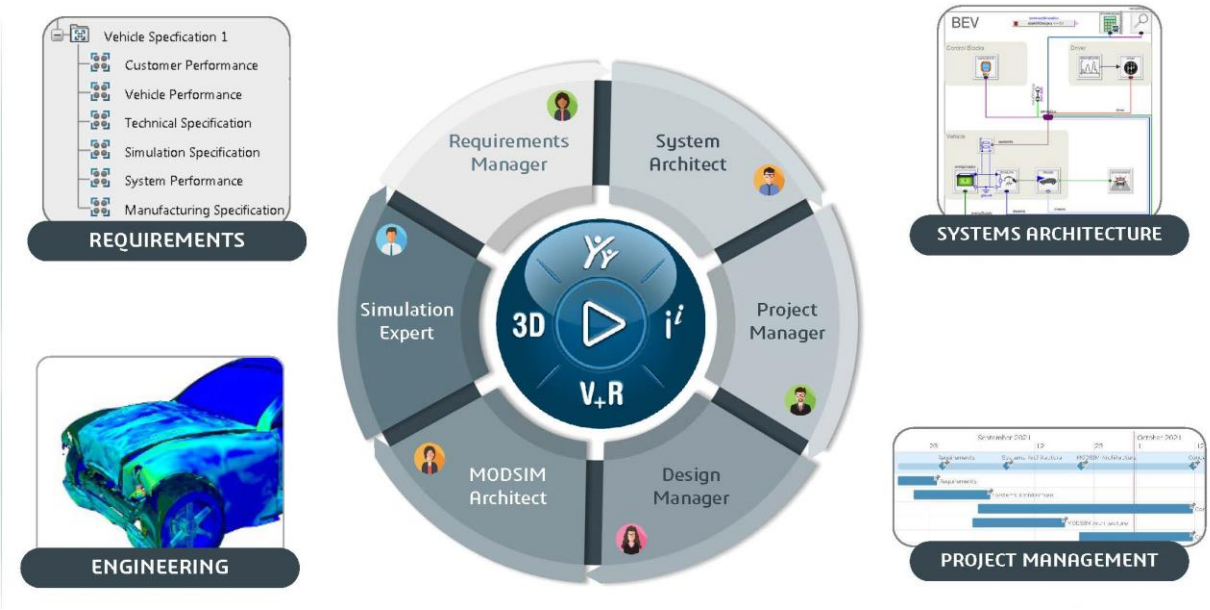

Figure 8: The Integrating Role of the Requirements Manager

(Courtesy of Dassault Systèmes)

Requirements can be checked for viability, achievability, and cost effectiveness earlier and errors can be identified, reduced, and potentially eliminated in some cases. Identifying product issues early on provides a competitive edge to companies that have started and are proceeding on their digital transformation journey.

[2] SMS_ThinkTank LLC; “Simplifying Model-Based Systems Engineering – An Implementation Journey”; June 2020

Simulation Maturity[2]

As simulation is introduced earlier in the development cycle, companies undergo a transformation that affects their systems modeling and simulation maturity. In this automotive example (Figure 9), Vehicle Lab (full vehicle tests) is beginning to be replaced with more Bench Lab (sub-system/component tests) and Virtual Lab (virtual simulations). Notice the transition from a “Reactive” engineering state to a highly prized “Cognitive”” engineering state is achieved through the greater maturity of employing a left shifting approach to use of simulation during model development .

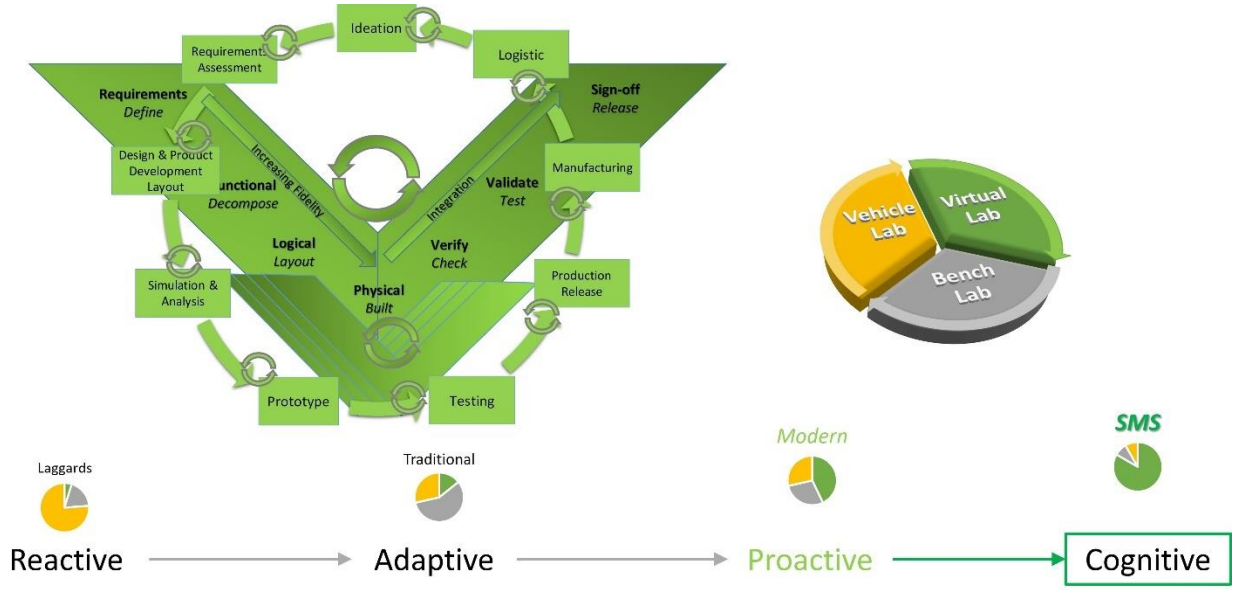

Figure 9: Systems Modeling & Simulation and Business Maturity

Trusted Data[2]

After defining requirements and ensuring an acceptable model storage strategy, trusted data is one of the greatest challenges. The accuracy of the Computer-Aided Engineering (CAE) and data multi-domain models (mechanical, electrical, controls, fluids, thermal, optics, acoustics, and others) is frequently not trusted and as a result, considerable time is wasted in reproducing simulations. This has been experienced within the same department and especially across engineering domains. Having a unified modeling strategy and a directory of commonly used system models will accelerate the development of a project and help reap the benefits of a model-based engineering implementation.

MODSIM brings the disparate engineering groups together forming a foundational pillar to ensure effective collaboration. As a result of native CAD-CAE associativity, the CAD and CAE worlds form a trusted single source of truth resulting in more opportunities for development success and better engineering.

Industry Examples[3]

These industry examples are from the 2021 3DEXPERIENCE Global MODSIM Conference. Replays are available below.[4]

Jaguar Land Rover

Jaguar Land Rover's (JLR) vision is for the close integration between modeling and simulation results to reduce the typical eight-to-twelve-week cycle to one day. With the range of vehicles JLR produced it is simply impossible to rely heavily on physical testing. Additionally, they want to be in a position where they can assess the functional attributes of any design throughout its life. Within JLR, this vision is called the "Engineering Continuum".

MODSIM as part of the overall 3DEXPERIENCE platform will help JLR to realize this vision. Well defined processes within MODSIM will allow to capture the knowledge as well as make the simulation processes repeatable in a sustainable way. In addition, this puts simulation capabilities into the hands of non-simulation experts effectively linking the design and simulation worlds in a closed-loop manner. This allows for the evaluation of huge amount of design combinations, upfront.

Airbus

Environmental sustainability is a major focus for Airbus. To accomplish this feat, Airbus created a digital design manufacturing and service (DDMS) transformation program to pioneer sustainable aviation for a better world. Another key consideration is to address the continuously accelerating digital transformation steps.

DDMS' mission is to completely rethink the way they design, operate, support, and service their products. The concept of digital twins will be paramount to the success of DDMS where they will have many more models, not only of their products, but also for their industrial systems and supporting services connected with their respective digital shadows.

MODSIM allows the enablement of a design feedback loop to validate their models by shifting simulation upfront of the engineering development process. Through the enablement of the MODSIM approach as part of the 3DEXPERIENCE platform, the concept of co-development and integration across various development teams, which may have different optimization targets, can be realized. Well defined simulation workflows to automate digital exploration within MODSIM are key to achieve optimized targets in a highly efficient manner.

Novo Nordisk

The medical industry is highly regulated and demands simulation-driven approaches to provide very high levels of quality products and stay competitive.

The development of new products spawns a new learning cycle. The primary objective for utilizing simulation-driven approaches is to significantly decrease this learning cycle. There are three components

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[3] Dassault Systèmes "3DEXPERIENCE Modeling and Simulation Conference - Inspiring Innovation through Unified Design and Simulation on a Single Business Platform" Virtual Conferences 2021, October 13

[4] For replays use the following links: 2021MODSIM-replay

to decrease the iteration cycle time. One is to make the virtual test faster; the second is transitioning more physical test to virtual test; the third is to use the virtual test as an optimization tool.

Using MODSIM, specialists developed new automated processes and the associated templates, guidelines, workflows to conduct automatic simulation tasks, and provide training and support to address the most complex tasks, thus, democratizing simulation practices. This allows the designers to explore more upfront design alternatives and produce assessments of their components and of their design changes. Additionally, the adoption of the 3DEXPERIENCE environment for their data backbone not only made the data easily accessible but also enabled collaboration across the various domains of excellence during the engineering development cycle.

This transformation resulted in having approximately ten times more simulations per month and decreased the lead times significantly – from days to hours.

Discussion on Model-Based Systems Engineering (MBSE)

During both 3DEXPERIENCE Modeling and Simulation Virtual Conferences 2021 for the European Union (EU) and the Americas, deep-dive panel discussions took place on the following topics:

- Accelerate Advanced Design Concepts for the Future of Mobility
- Drive Faster Innovation with Modeling & Simulation
- MBSE: Integration the Systems Model and Its Simulation
- Improve Your Design Concepts Through Additive Manufacturing & Light weighting

All panelists provided insights regarding the role MODSIM plays or can play in their development cycles. In this paper we will highlight the various aspects of the discussion regarding their MODSIM implementation journey. Details from the panel discussions can be found in the separately published commentary[5].

MBSE Panels

Panelists representing different industries were asked a series of questions relative to MODSIM. Specifically, for the MBSE focus panels, the topic was the importance and impact of integrating the system models and its simulation and the path forward.

Boeing, for instance, is spending a significant amount of time in the development of digital twins and digital system models and the associated workflows related to their development process on newer programs. Project architectures are constantly changing, developing, and evolving on these systems. Thus, the complexity compounds especially when there are multiple releases of a particular model type. Especially in exceptionally large programs, configuration management is shifting to a model-based world presenting a great challenge.

For ManTech, model-based collaboration allows for the better development of design rules to perform requirements checks early on in development. By applying a MODSIM approach, tasks that would typically take years or months are now taking ManTech weeks and days. This helped ManTech to distribute data across the organizations more freely and better understand the existing structures that are in place.

[5] SMS_ThinkTank Commentary: “Dassault Systèmes 3DEXPERIENCE Modeling and Simulation Conference - Inspiring Innovation through Unified Design and Simulation on a Single Business Platform” – February 2022

SAIC relies heavily on modern CAD modeling. They transitioned from document-intensive systems engineering into a discipline that will support modern emerging systems and support simulation competent modeling early in the design phase.

Engineering is becoming much more complex and cross-functional silos of excellence need to collaborate to be sustainable. Most important, the proper authoring, linkage and management of requirements is a critical issue. If organizations don't have a good handle on their requirements, especially when they are rapidly changing, they are "lost at sea".

Another challenge are uncoordinated processes referring to institutional lifecycle documents. Organizations must move away from document-based processes and whiteboards, etc. Organizations need to embrace MBSE best practices where they can use a common systems model to create discipline centric descriptive models. This common model becomes the authoritative source of data and information. It must be calibrated and developed through closed-loop processes and made accessible to everyone as required.

If organizations utilize the traditional approach where simulation is applied without having the system thinking, such environment is not sustainable and does not get the business anywhere. (See Figure 9)

The common theme among the panelists is that a move to simulation-driven design as part of a major overall digital transformation is needed in their organization. To make this transformation successful, there are some major elements that play a key role:

- Education: all parts and levels of an organization need to be able to communicate effectively with each other, understand what is involved to make it happen and how it needs to be done. Business as usual does not work anymore.
- Trusted data: data, independent of the source must be reliable, understand it's origination and be accessible.
- Repeatable simulation processes: democratization of simulation capabilities and the capture of tribal knowledge for future reuse.
- Closed-loop processes: promote more efficient collaboration within organizations and establish the appropriate framework to make the correct decisions.

To begin this transformation journey, an organization needs to understand and assess their existing engineering landscape and identify the gaps from a determination of where they need to be in 3-5 years to remain competitive.

To get started, organizations need to educate their people but not try to convince the entire cooperation of much needed change all at once. Start with passionate individuals that are willing to drive such transformation forward.

Panel "Accelerate Advanced Design Concepts for the Future of Mobility"

The topic for this panel was accelerating advanced design concepts for the future of mobility, and what role MODSIM can play to help this process.

Like the MBSE panel, various transformational challenges were highlighted, and key elements mentioned that will help to overcome these challenges.

Shawn Wasserman, who is a Senior Editor from Engineering.com, provided these comments:

- In a recent study by engineering.com about 46% of the respondents said they do not have access to the tools that they need to perform their simulation and design results with 33% unsure. These

two numbers are quite striking. Without leadership buy-in, one cannot really solve the cost, education, and the hardware limitation issues.

- With automotive autonomy, electrification, and connected cars making vehicles more complicated, it has not changed the fact that consumers still expect to have a yearly release.
- Tools that include generative design, simulation web design and additive manufacturing are key to addressing these current trends pressuring automotive companies. With generative design, the number of parts will also shrink. Once you are designing those parts, it makes sense that they are meshed all together reducing part count and reducing weight opening brand-new design paths.

Independent from the specific panel focus topics, all participants mentioned that big hurdles to implement MBE best practices need to be addressed regardless of industry. The biggest hurdles are the engineering silos of excellence that need to be overcome. Collaboration needs to be enabled, and the domains of modeling and simulation need tighter integrated. Only MBE best practices will help to manage the complexity the various industries are facing now and in the future. MODSIM plays a pivotal role in achieving MBE capabilities.

Education[2]

Education and research into the best MBE solutions and implementation approaches provides the fidelity upon which a company builds its engineering practices. Formulating the best systems engineering implementation approach is a critical decision for your organization and is as unique as a fingerprint. Educating and gaining the buy-in of your company's leaders is critical to developing this transformation. The "message" must be kept simple. Sharing the benefits linked to high-profile issues is an effective way to get the attention of executives. The request for executive support should include the cost of the technology and the anticipated enhancements to the organization, including its processes and workforce. Many engineering groups are unfamiliar with the "V" model or may have heard of it but do not possess any detailed knowledge. (The "V" model is a graphical representation of a systems development lifecycle). Ensure everyone has a shared understanding of the journey by developing an education roadmap with achievable levels.

Summary

Consumers demands are challenging new product development. To effectively meet these new challenges in delivering new products and features to market quickly, efficiently, and safely, the product development and manufacturing cycles must be tuned in a manner that provide the ability to explore multiple simulation cycles. Process assumptions made through the decades must now be questioned for viability.

Dassault Systèmes has introduced an innovative approach called MODSIM for the unification of modeling and simulation. The application may refer to a component, subsystem, full product system, or system of systems. Most important, not only does it go well beyond the integration of two disciplines but also involves an end-to-end approach where the characteristic behavior of the entity under design and analysis can be identified virtually, in a cloud environment. MODSIM brings the engineering groups together forming a foundational pillar to ensure effective collaboration. Typically, the expertise for understanding and executing overly complex simulation tools resides with a small number of disparate engineering groups across the enterprise. Simulation democratization increases the power of advanced thinking and decision making across the engineering community by providing the CAE analyst with capabilities to create highly specialized templates and processes to the design engineers. This enables the design community more

opportunities for development ‘discoveries’ toward better designs, more efficient process execution and an environment that provides an opportunity for sustainable innovation.

Integrating disparate domains which are typically silos of excellence is paramount in the MBE journey. MODSIM’s inherent unification of 3D modeling and simulation analysis provides a solid foundation for the adoption of Model-Based Engineering best practices providing much needed simulation data management capabilities as well as close integration and linkages to manufacturing and related disciplines.

MODSIM’s democratization shifts the introduction of simulation earlier in the development cycle where the criticality of authoring good requirements originates. System requirements form the basis of system integration and verification activities. They function as a reference for validation and stakeholder acceptance. Requirements provide a strong link between various technical disciplines throughout the project. They provide the impact of change for a given condition or set of conditions.

Additionally, as simulation is introduced earlier in the development cycle, companies undergo a transformation that affects their systems modeling and simulation maturity. Virtual labs are rapidly replacing prototype heavy vehicle labs reducing the time and resources verifying design assumptions and validating against customer requirements.

There are many customer testimonials mentioned earlier in this paper that found that MODSIM and the 3EXPERIENCE offers the optimum platform by providing digital continuity that is required for each successful initiative.

Formulating an MBE implementation is a critical decision for an organization. Educating and gaining the buy-in of your company’s leaders is critical to developing this transformation.

MODSIM provides an entry point into the MBE umbrella environment and becomes the enabler to adopt the more rigorous systems engineering environment of Model Based Systems Engineering (MBSE), which is a subdiscipline of MBE.

For more information on the topic of MBSE, refer to SMS_ThinkTank™’s White Paper “Simplifying Model-Based Systems Engineering - An Implementation Journey”.[6]

[6] White Papers | SMS_ThinkTank (smsthinktank.com)

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About SMS_ThinkTank™

SMS_ThinkTank™ LLC is the global resource and leader in system modeling and simulation, bringing the worlds of systems engineering and computer aided engineering together. SMS_ThinkTank™ is a vendor neutral firm which provides strategic systems engineering and CAE management consulting to help enterprises embrace Model-Based Systems Engineering (MBSE) to achieve sustainable innovation bringing higher quality products to market faster. SMS_ThinkTank™ helps enterprises in developing the methodologies to support these new technologies including emerging systems engineering and CAE standards.

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