SIMULIA

Connect Simulation with Modeling and Model-Based-Systems Engineering

Connected Engineering
Illustrated by an Electric Drive Development Cycle

DASSAULT SYSTEMES

Connected Engineering is defined as a way to connect Modeling and Simulation, Model-Based Systems Engineering, and Collaboration throughout a company's ecosystem.

THE NEW ERA OF TRANSPORTATION

The transportation and mobility industry is entering a new era that is efficient, affordable, clean, and green. The rise of electric vehicles is accompanied by the emergence of new technologies, like electric powertrains, which need to be integrated in existing technologies and processes. Therefore, companies must manage increased product and process complexity while maximizing efficiency and shortening development cycle times to stay competitive.

This reconceptualization forces engineers to deal with new and often conflicting requirements. It requires seamless collaboration across multiple teams—from conceptualization through detailed engineering, certification, and manufacturing. In addition, these activities take place within a dynamic environment: technologies change and new market demands emerge, all requiring adaptation and response from a global network of teams and remote workers.

New platform-based software solutions can help to map dependencies and interrelations, finding the fastest and most effective ways to work and coordinate efforts across multiple teams, domains, and disciplines. This eBook will explore the Connected Engineering approach delivered within the **3D**EXPERIENCE® platform, where Model-Based Systems Engineering (MBSE) is tightly connected to Modelling and Simulation on one unified platform. It enables organizations to improve collaboration, foster innovation, and achieve efficient product development to secure a stronger competitive position. We demonstrate these in the context of an electric drive development cycle.

THE CHANGING PRODUCT DEVELOPMENT ENVIRONMENT

The nature of vehicles is fundamentally changing. The reconceptualization of vehicles from a mechanical, internal combustion model to a "smart" electric, connected model introduces a multitude of innovative new technologies. In addition, the vehicle architecture is changing toward a modular "skateboard," or mega-platform. These platforms should be scalable, adaptable, and upgradable to accommodate multiple vehicle types and future technologies.

The need to integrate new and existing systems within a new architecture adds another layer of complexity to the development process. New approaches are needed to enable a high level of collaboration and provide optimal information transparency to all process participants. Current-state practices and tools employed in many companies are inadequate to effectively meet these challenges. Factors like siloed teams, disconnected tools, inaccessible information and documentation, uncoordinated processes, and the inability for individuals and teams to communicate and interact effectively force an undue burden on teams who, if able to work within an appropriate environment, would be capable of far greater productivity.

What, then, would a modern, high-performing vehicle development environment look like? It would necessarily provide ready access to authoritative data, enabling all teams to work from a continually updated single source of truth. It would also allow companies to coordinate processes, providing end-to-end connectivity for all team members, regardless of location. This would enable simplified, direct collaboration between team members through all stages of the development process.

ADDRESSING THE COMPLEXITY CHALLENGE WITH MODEL-BASED SYSTEMS ENGINEERING (MBSE)

Mechatronic systems that combine mechanical, electronic, and software elements, such as electric drive systems, require a complete system model to simulate the behavior at the earliest stages, ensuring that changes made at the beginning of development are reflected throughout the process. Model-Based Systems Engineering (MBSE) strives to improve integration of all engineering disciplines while delivering strategic performance insights from a holistic perspective.

MBSE is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later lifecycle phases.[1]

MBSE achieves this by permitting information to pass freely across sub-models and between stakeholders to achieve desired outcomes. The complexities of the development process become more manageable as requirements from different disciplines can be identified, cross-referenced, and conflicts resolved within a unified framework. Users gain the ability to test more variants, reveal errors earlier in the process, and shorten development cycles. The risk of interoperability failures and of costly, time-intensive rework is reduced; the ability to optimize systems' efficiency is increased; and all project elements are addressed within this unified environment, providing a holistic view of all associated activities and attributes.

MBSE delivers the following key benefits:

- **Promotes the reuse of complex subsystem models, reducing duplication of work**
- **Provides traceability, impact analysis, cost analysis, and product change visibility**
- **Enables effective collaboration between different technological silos**
- **Enables heightened insight at all stages of the development process, helping to eliminate errors and accelerate innovation**

[1] Source: Definition used by: System Modeling and Simulation Working Group (SMSWG), joint INCOSE and NAFEMS initiative

ADVANCING PRODUCT DEVELOPMENT WITH MODELING AND SIMULATION (MODSIM)

Historically, Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE) emerged as distinct technologies. While each delivered significant product development benefits, they have remained largely discrete tasks, undertaken sequentially. The need to translate design data for simulation increases the cycle time required and introduces opportunity for errors. On the other hand, efficiency is sacrificed as data gained through simulation must then be reincorporated in a subsequent design iteration to drive design refinements.

MODSIM, the integration of modeling with advanced simulation within a unified environment, magnifies the benefits of each while accelerating and streamlining the development process. By embedding simulation within the design process, engineers are empowered to utilize simulation at the earliest stages of design development, checking design performance and executing refinements concurrently. This way, they minimize the risk of costly redesigns. The need for data translation between the design and analysis stages is eliminated, and CAE models immediately adapt to design changes. This facilitates collaboration and parallel development from multiple teams, all of whom are working from accurate, continuously updated data; changes made in any one area are propagated throughout the model in real time.

The economic benefits of MODSIM become readily apparent, as companies can:

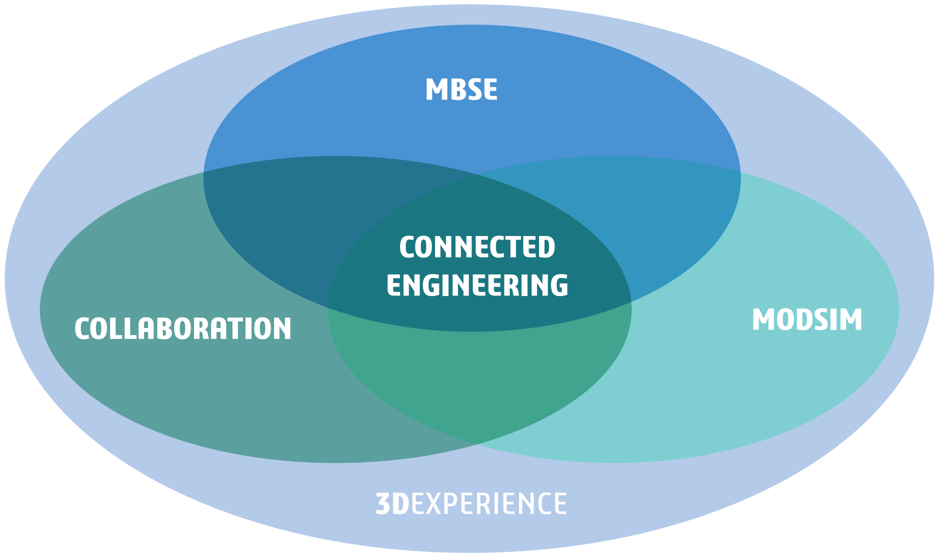
- **Reuse models, saving both time and cost**
- **Accurately predict product behavior in early concept or prototype phases**
- **Reuse accrued knowledge to eliminate non-value adding tasks and support a steep technological learning curve**
- **Reuse physical testing data to improve models and enhance simulation results**
- **Evaluate alternative concepts quickly, assessing the strengths and weaknesses in each and combining high-performing aspects of different concepts into new designs**

At the same time, MODSIM delivers benefits to an organization's teams and individual members:

- **Integrated modeling and simulation accelerates innovation by providing a holistic view of project data**
- **Efficiency improvements free up time for team members to pursue additional technical advancements**
- **Real-time collaboration enables team members to harness each others' knowledge and expertise in order to realize solutions more rapidly and reduce rework**

CONNECTED ENGINEERING (CE) AND ITS KEY ADVANTAGES FOR THE PRODUCT DEVELOPMENT PROCESS

A true Connected Engineering (CE) environment is much more than merely the introduction of new tools or the optimization of processes. It is a shift of the entire development environment which fundamentally transforms—and optimizes—the way work is done and the results that are achieved. Connected Engineering is the creation of an ecosystem that encompasses and integrates all disciplines, information, tools, and processes. This is the concept of Connected Engineering practiced within the **3D**EXPERIENCE® environment.



A **3D**EXPERIENCE® Connected Engineering environment encompasses all of the diverse activities and multidisciplinary systems necessary for effective product development—Model-Based System Engineering, Modeling and Simulation (MODSIM), and comprehensive communication and collaboration capabilities—and breaks down traditional barriers between them. By "connecting the dots" between locations, teams, disciplines, processes, technologies, and data sets, all necessary work can be done within one unified ecosystem.

The Connected Engineering approach establishes an environment of digital continuity. It eliminates the need for data conversions and model importing/exporting, and creates uniform access to current data. Changes are automatically reflected throughout the environment, eliminating rework and reconversions: Modifications made "upstream" in the development process are immediately reflected "downstream." CE connects the dots between requirements, design, and simulation, enabling the physical behavior of subsystems and the final product to be virtually—and continually—evaluated and optimized across multiple domains, enabling ongoing revision and improvement.

Working within a Connected Engineering (CE) environment, companies and teams realize a broad range of powerful benefits:

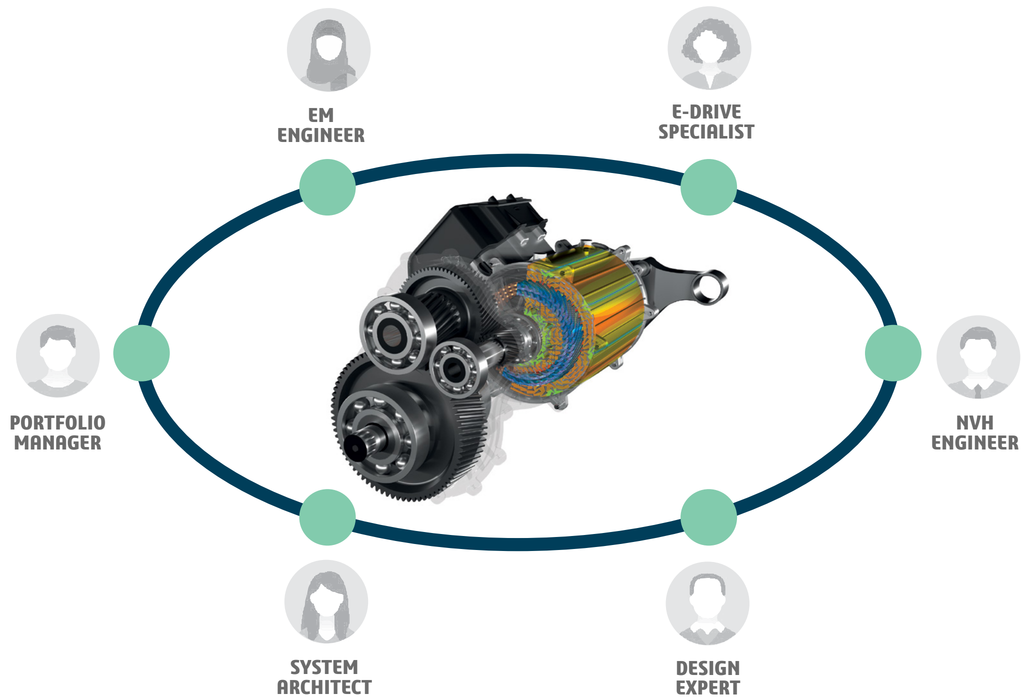
- **Teams work within a unified, holistic environment with full digital continuity**
- **The CE environment facilitates complexity management**
- **Better management of changing requirements—changed data or requirements are automatically reflected throughout the ecosystem**
- **Changes made at any point are immediately reflected throughout the development stream**

CONNECTED ENGINEERING AND THE ELECTRIC DRIVE DEVELOPMENT CYCLE

Electromobility, with its continuous technological advancements and ongoing flow of new stakeholder requirements, requires engineering processes to be managed and mapped with a high level of interaction and traceability. In particular, electric vehicles with a skateboard architecture and its modular features require a perfect fit of all systems and sub-systems, e.g. the electric drive.

The electric drive development cycle is fundamentally unique, and multiphysical in nature. Engineers need to address intertwining, often conflicting characteristics such as thermal, mechanical, electromagnetic performance, durability, noise and vibration, and lubrication requirements. Optimal multi-domain objectives need to be defined.

This electric drive development process necessarily requires the committed, cooperative involvement of a multitude of discrete teams, disciplines, and specialties. These include:



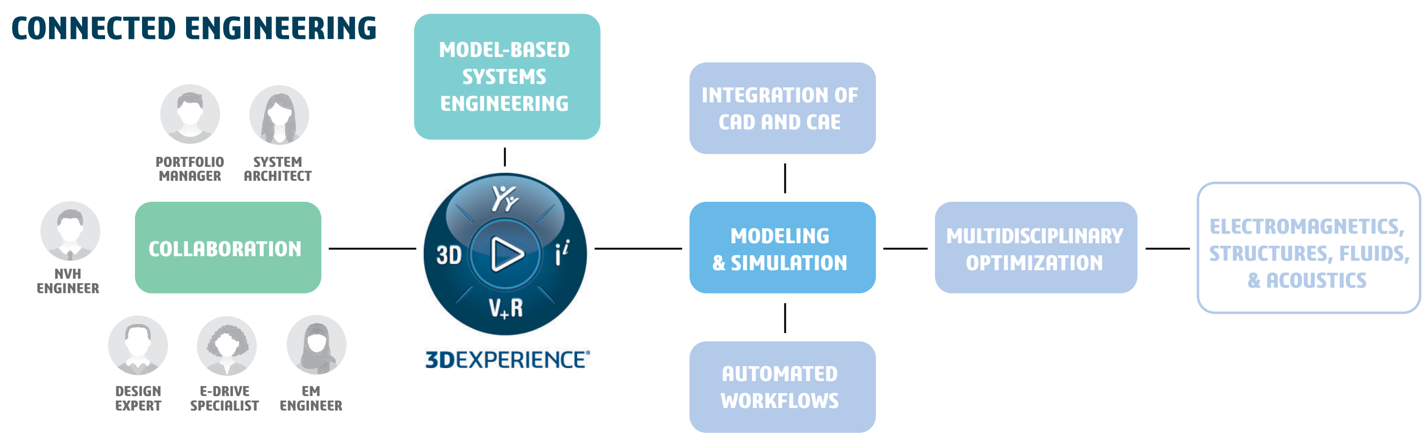
Together, they address the project's requirements, system architecture, design, and validation. They begin by recognizing that since the elements of the electric powertrain depend on each other, they can't be developed individually.

Developing a best-in-class electric drive system compels teams to thoroughly analyze a huge number of design options, and to understand the effect of each parameter on varied—and often conflicting—KPIs. To define the best, most balanced design alternative considering all requirements and goals, it is necessary to map each project stakeholder's goals, connect them, and define objectives for each party. Some of the areas of focus include:

- **MULTIDISCIPLINARY OPTIMIZATION, balancing the competing needs for electromagnetics, structures, fluids, and acoustics disciplines**

After initial optimization, some requirements still need to be verified by more detailed analyses:

- **STRENGTH, STIFFNESS AND DURABILITY, ensuring structural integrity and reliability of all parts**
- **ELECTROMAGNETIC PERFORMANCE, verifying power, torque, and efficiency requirements as well as limiting the impact of fault conditions (e.g. on permanent magnet demagnetization; creating loads for thermal and mechanical analyses)**
- **THERMAL MANAGEMENT, including assessing complex fluid dynamics and heat transfer issues in oil cooling systems, and sustaining high-power densities with thermal reliability**
- **NOISE AND VIBRATION MITIGATION to ensure passengers' acoustic comfort as well as safeguarding the functionality and reliability of the system**
- **LUBRICATION for longer service life by ensuring that oil levels provide both sufficient surface coverage and minimum induced drag torque**



By working within a Connected Engineering environment, all experts involved are able to work with the same data set, in real time, to ensure that all components are designed to function properly within—and as—a system. If requirements change during the development process, the verification of the system can be quickly redone by utilizing automated workflows. They enable an easy parameter or design update without requiring manual rework to update simulation models and meshes.

The efficiency and speed gains possible within the Connected Engineering environment permit the rapid execution and analysis of multiple design iterations before final prototype validation.

THE HUMAN ADVANTAGE

The **3D**EXPERIENCE® platform is the technically advanced environment needed for optimal development of electric drive systems. For all of its capabilities and technological sophistication, however, much of the value it delivers is human rather than technical in nature. Universally accessible, continually updated, responsive data and automated processes provide value to the people responsible for driving development and innovation. Through CAD/CAE associativity, process automation in the modeling and simulation workflow, and support for Multiphysics Optimization, the Connected Engineering environment delivers the following benefits for the electric drive development:

- **Capability for optimal communication and collaboration across teams and people, i.e. System Architects, Domain Experts, Portfolio Managers, Design Experts, and others.**
- **Confidence in the absolute currency and integrity of project data, including synchronized models for all disciplines: thermal, mechanical, electromagnetic performance, durability, noise and vibration, and lubrication.**
- **Reduction in time-consuming, repetitive, non-value-adding tasks is achieved, for example, by CAD-CAE integration and use of parametric models which dramatically reduce simulation model preparation time and enable the easy reuse of those models.**
- **Ability to rapidly iterate designs, modify them, and optimize them. Integrated multiphysics design optimization of electric machine design, as well as automated complex workflows like noise and vibration analyses, are examples of this.**
- **Ease of working within a unified environment where all solutions work seamlessly together.**

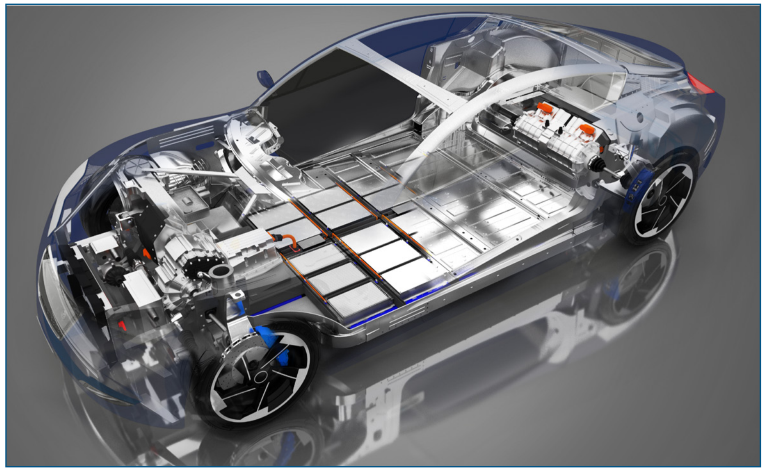
Beyond the development teams, the availability of accurate, current project data delivers considerable value to managers, executives, and the project at large. Senior management can make more informed strategic decisions with confidence as a result of absolute data visibility. Marketing departments, partner firms, vendors, and other stakeholders such as suppliers can similarly benefit from the increased predictability and reliability of development timelines, progress metrics, and change notifications which may dictate their actions or require their response. The entire business benefits from a dramatically shortened product development timeline; the reduced risk of errors, which can result in product defects or recalls; heightened efficiency; and contained costs—not least from the reduced need for costly physical prototyping.

As the pace of electric vehicle development accelerates, the **3D**EXPERIENCE® Connected Engineering environment is ready to keep pace with it—and empower electric drive developers to deliver on the promise of their innovations and technologies.

CONCLUSION

The field of Electromobility is highly dynamic and subject to constant transformation. Companies need to react quickly, rapidly generating innovations while simultaneously managing the associated cost and risk factors. Developing and integrating new technologies requires effective collaboration between multiple stakeholders and alignment of the flow of information.

New, holistic approaches are required in order to integrate all disciplines, information, tools, and processes. One such approach, provided by the **3D**EXPERIENCE® platform. is Connected Engineering—defined as a way to connect Modeling and Simulation, Model-Based Systems Engineering, and Collaboration throughout a company's ecosystem. Connected Engineering enables companies to manage complexity, gain flexibility, and increase efficiency throughout the development process, thereby securing a powerful competitive advantage in the age of Electromobility.



Join our SIMULIA Community and become part of a global user network focused on advancing the use of SIMULIA simulation solutions in Science and Engineering.

CONNECTED ENGINEERING ILLUSTRATED BY AN ELECTRIC DRIVE DEVELOPMENT CYCLE **Watch the demo in our community!**

For more information explore our **Electric Vehicles pages.**

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