SYSTEMS LIFECYCLE MANAGEMENT

DEVELOPING SYSTEMS ON TIME AND BUDGET THROUGH INTEGRATED MBSE AND PLM

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Table of Contents

Executive Summary

Product development and manufacturing organizations are facing competing pressures as they look to design and create new products. They are working on shorter timelines with reduced resources. They are also being asked to satisfy increasingly complex requirements for smarter features, which is leading them to incorporate more software and electronics in products, regardless of their specific industry.

Systems engineering approaches, including model-based systems engineering (MBSE), have helped organizations better manage more complex product development. Yet, when manufacturers are unable to connect multiple, disparate MBSE models across engineering domains—and to overarching product lifecycle management (PLM) solutions—they are likely to struggle as they try to integrate systems, resulting in significant delays or cost overruns.

Engineering organizations that integrate MBSE with PLM are in a much better position to manage the design and development of smarter, more complex products. Systems lifecycle management (SysLM), the integrated combination of MBSE models and PLM, provides a collaborative lynchpin for design trade-offs, democratizes design and simulation traceability, and automates digital verification and validation. This report discusses the following:

- **How complexity is driving systems engineering adoption:** With the addition of more complex features across multiple design domains, product design and development organizations are looking to systems engineering approaches, including MBSE, to help them keep track of multidisciplinary requirements across the design phase.
- **MBSE across engineering domains:** While MBSE provides engineering organizations with virtual representations of designs, most models are domain-specific and difficult to synchronize. The proliferation of divergent MBSE models can make it hard for the engineering organization to integrate vital data to optimize product design and pass integration tests. SysLM and interoperable MBSE solutions address this challenge.
- **MBSE for downstream architecture collaboration:** Organizations develop MBSE models in specialized tools. Many other stakeholders in the development process do not have access to these solutions, which hinders downstream architecture collaboration and negotiation once the models are passed to the detailed design team. SysLM democratizes access to systems architectures for stakeholders throughout development.
- **MBSE and detailed design traceability:** Similarly, the lack of democratization of MBSE models can lead to significant disconnects between those models and detailed design models. This increases the likelihood that the product design will experience failure during test and prototype phases. SysLM connects these previously disconnected definitions.
- **MBSE and simulation traceability:** The lack of traceability between MBSE models and simulation models also means that engineering organizations are not getting as much value as they could from simulation—and are missing potential issues that could require costly rework once discovered. SysLM tightly connects MBSE models to simulations, closing the loop on validation and verification.

Companies that invest in SysLM solutions able to create a single digital thread that integrates MBSE models and PLM platforms can optimize the design and development process. Each of these areas of MBSE and PLM integration can be adopted separately. However, when implemented alongside one another, organizations realize strong synergistic improvements. Then they can design high-quality products while still meeting strict deadlines and staying within budget.

COMPLEXITY IS DRIVING SYSTEMS ENGINEERING ADOPTION

Complexity Is Driving Systems Engineering Adoption

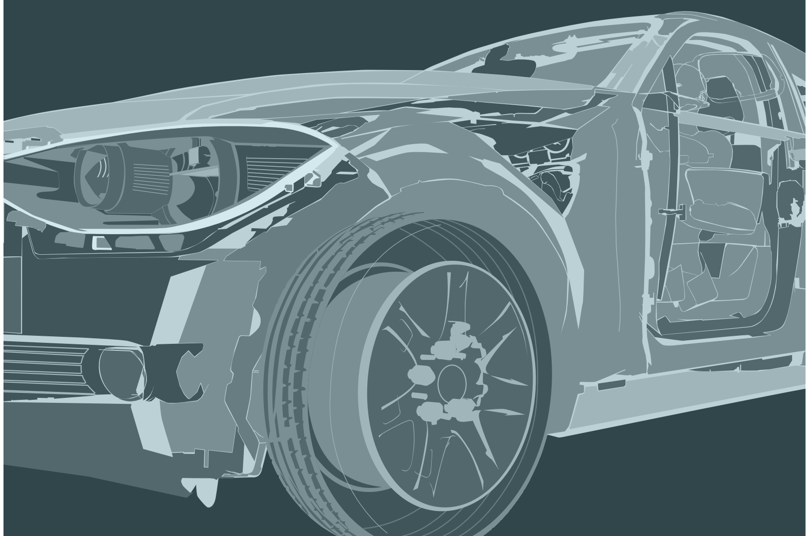
It's often said that simplicity is the ultimate sophistication. Yet, today's consumers expect more than simplicity from the products they purchase and use. As a result, product design engineers must satisfy ever more complex requirements—even for simple consumer products. In doing so, they can support the development of smarter, more adaptable, and more connected features.

Where a unique product may have once only needed an innovative mechanical design, more complex options must integrate mechanical, electrical and electronics (E/E) systems, and software design to satisfy both consumer and organizational requirements. That's why many organizations are now integrating systems engineering into their design and development practices. This engineering approach allows product designers the ability to design, integrate, and manage complex systems across the product lifecycle. This approach also allows product designers to explore and validate complicated combinations as part of a modular platform. As part of these practices, more progressive organizations also leverage MBSE, where engineers create unique models to facilitate and manage information and data exchange across domains.

This section of the report will discuss the following:

- **Rising complexity in modern products:** To meet demands for smarter, more connected products, product design engineers must be able to integrate items and systems across a variety of different design domains.
- **Managing complexity with systems engineering:** In order to manage this increased complexity, many organizations have adopted a systems engineering approach to guide the design and integration of software, E/E systems, and mechanical components that make up a product.
- **Moving beyond spreadsheets and documents:** While systems engineering provides a framework for managing requirements across different design domains, the need to manually update multiple documents and spreadsheets makes it hard to keep up with changes—and easily integrate system components.
- **Implementing MBSE:** Engineers can make up for some of the inherent challenges of keeping up with changes and updates in traditional systems engineering approaches by using MBSE to create virtual models of designs.

Systems engineering is an engineering design and management approach with practices to design, integrate, and manage complex systems across design domains over a system's lifecycle.



RISING COMPLEXITY IN EVERY INDUSTRY

Historically, design engineers, regardless of industry, have been able to satisfy requirements of various features and functions in a single design domain. For example, the brake system in an automobile was primarily mechanical. The avionics system in an aircraft was made up of mostly electronics systems. There might be an occasional interaction between domains, like between an E/E system and actuated hardware—but they were rare. While those interactions had to be managed carefully, the engineers working in their respective domains only had to integrate their design work at the end of the design process, and the product would usually function properly. Because most product designs were fairly simple in nature, this approach was more than adequate for decades.

Today, however, software and electronics have become vital features of almost every system. Waiting until the end of design to integrate these components is no longer an option. Engineers from all domains—mechanical, electrical, and software—must work closely together to integrate their design work to ensure that all requirements are met and the resulting system is fully functional. If they waited until the end of the development cycle to start this integration, they would likely hit significant roadblocks that would require more time, resources, and rework to address. In fact, such late-stage integration has been known to consume up to three-quarters of the allotted product design schedule. That's time that could be better spent iterating, refining, and optimizing product designs.

This issue is not only a challenge in the automotive and aerospace industries. Rising product complexity is prevalent in every industry that relies on software and E/E to deliver smarter, more adaptable features. Given this evolving expansion of complexity in modern products, design and development organizations require a strategic and progressive approach to manage all design data across the product lifecycle—one that facilitates communication and the sharing of all design information across different design domains. The traditional approach of trying to integrate all components on the back end just won't work anymore. It will only derail ongoing development programs, leading to significant development delays and, ultimately, undermining an organization's profitability.

Figure 1
Designs for different aspects of systems are developed independently in specific engineering domains. Such disconnected practices cause integration problems at the end of development, resulting in many failures in prototyping and testing.

MANAGING COMPLEXITY WITH SYSTEMS ENGINEERING

In order to manage surging product complexity, many organizations are turning to systems engineering to help them track design information. Systems engineering is an interdisciplinary approach to facilitating the design, integration, and management of complex systems over the product lifecycle. It allows engineers to allocate requirements to functions, functions to different aspects of a logical architecture, and then that logical architecture to a physical architecture—and do so in a way that creates traceability from one end of design to the other.

The systems engineering approach allows engineers to consider different design trade-offs and examine various what-if scenarios to understand how those changes affect everything from the product requirements to the ultimate physical architecture of the system. This approach becomes the framework from which all design and development stakeholders can understand the nuances of a particular design.

This more progressive approach not only helps organizations develop an enhanced product design, but it also gives them the opportunity to refine requirements and budgets across various engineering teams early on and throughout the development process. The end result is increased flexibility throughout the process, even with more complex systems and products. But just as importantly, the systems engineering approach allows organizations to identify integration issues early and resolve them collaboratively before prototyping and testing. Ultimately, it enables them to hit their design release milestone and launch or deliver the product on time.

MOVING BEYOND SPREADSHEETS AND DOCUMENTS

To build a functional system, engineers must allocate requirements, functions, logical abstractions, and physical structures to one another. To do so, systems engineers have traditionally leveraged general-purpose applications to create diagrams, spreadsheets, and documents that will ultimately make up a corresponding systems model. While this has been the go-to approach for design teams for decades, it does not work as well for more complex products.

To start, the use of such traditional tools requires significant manual effort by the engineering and design team. In order to support experimentation and iteration—essential steps

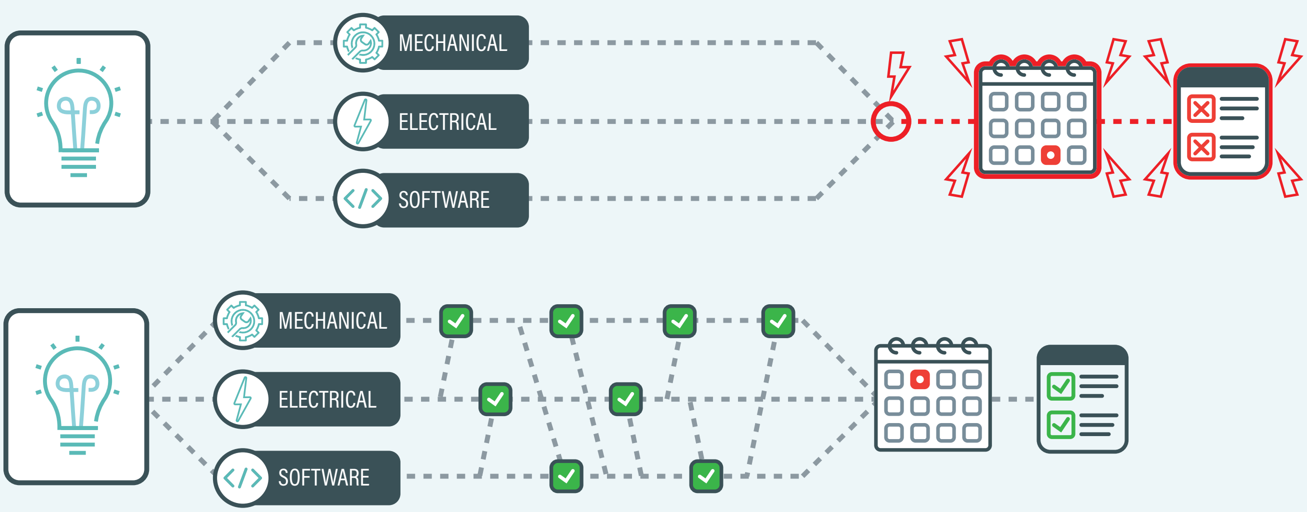


Figure 2
Systems engineering practices foster collaboration throughout the development process, uncovering and resolving integration challenges earlier, when there is more flexibility in design.

of the design process—engineers must manage ongoing changes across multiple documents and spreadsheets themselves. The assessment of any changes to the system as a whole requires the same manual burden, necessitating that engineers search for the information they need across multiple documents. Within a round or two of iteration, this approach becomes unsustainable. Engineers struggle to keep up with the onslaught of documentation, resulting in data gaps. Consequently, engineers across different design domains lack the critical information they need to support informed decision-making, which leads to less-than-optimal design choices.

The reliance on multiple spreadsheets and documents can also result in the proliferation of design errors. When the different systems models are not connected and, as such, do not easily share information, it's far too easy for errors to be inadvertently passed downstream. Even something as simple as missing a small update to the system early on in the design process can result in big problems that surface during the test and prototype phases. And since traditional approaches also require that individual engineers manually calculate different functions of the system, the potential for mistakes that can result in time delays and rework only grows.

USING MODEL-BASED SYSTEMS ENGINEERING

To deal with the challenges of traditional systems engineering, many organizations now take an MBSE approach to product design and development. This methodology leverages digital models of systems, allowing engineers to create optimized product architectures. MBSE also offers organizations the ability to assess their product designs earlier in the production cycle while supporting changes across the system with little to no disruption.

MBSE allows engineers to get rid of the old spreadsheets and documents as they design a product. Instead, they work with a digital model, which can associate requirements, functions, logical architectures, and physical architectures across the design and development process. Organizations can use the model to easily and effectively make and communicate changes to the product design, which reduces the documentation burden on the engineering team. This approach has the added benefit of preventing the errors that too often occur when integration occurs late in the design phase.

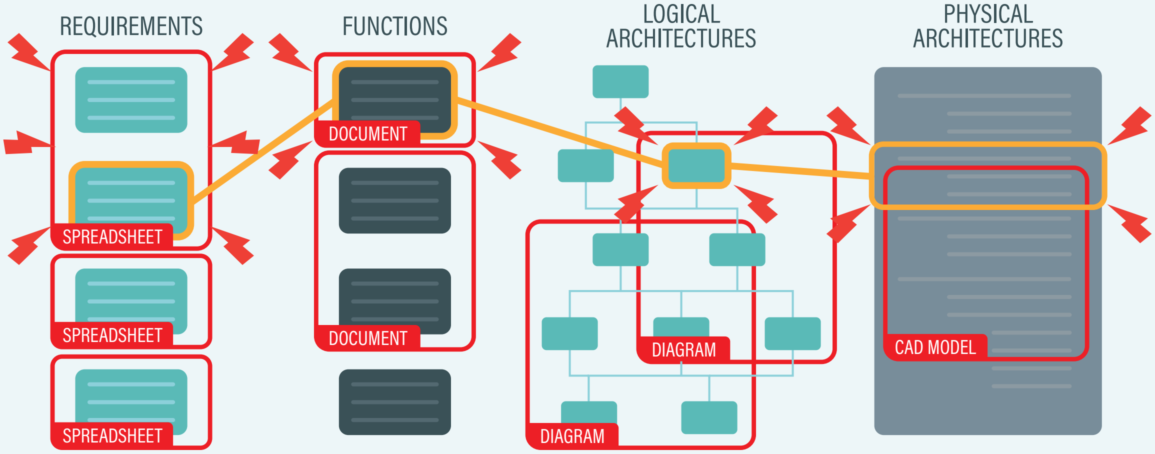


Figure 3

Using spreadsheets and documents for systems engineering is inherently flawed because it requires the manual propagation of changes. The process of coordinating such updates across many files often breaks down when developing complex products with millions of software lines of code or hundreds of electronic endpoints.

As modern products become increasingly more complex, MBSE models can help the engineering organization keep track of different design domains. The models allow for the activation and allocation of different functions, start-up cycle support, shutdown sequences, and much, much more. The models can also support the design of user interfaces and define how different subsystems interact to support the greater system's overall functionality.

By working from a single data model, engineers and product developers can more easily mitigate common challenges that arise from traditional approaches, including:

- **Product architecture planning and trade-off management:** Using MBSE, engineers from individual disciplines can connect their model to a simulation before detailed design or development. This supports easier and more effective iteration, so engineers can build out and assess a range of different product architectures while ensuring the satisfaction of all requirements. Engineering teams can use the model to predict the performance of systems, understand their behaviors, and conduct early analysis of design alternatives. As a result, they'll be much more likely to pass a high-quality architecture to detailed design, decreasing prototyping and testing rounds as well as their associated time and costs.
- **Assessing and communicating work-in-process system changes:** In the traditional design approach, downstream errors often result when two or more design domain teams need to adjust the product architecture simultaneously. An MBSE model, however, can be used to illustrate a proposed change—and communicate said change—so all design and development stakeholders can understand the potential impact. By allowing this kind of mock-up, engineering teams can better understand the costs and benefits of any change to the product design and make more informed decisions as they move forward in the development process.

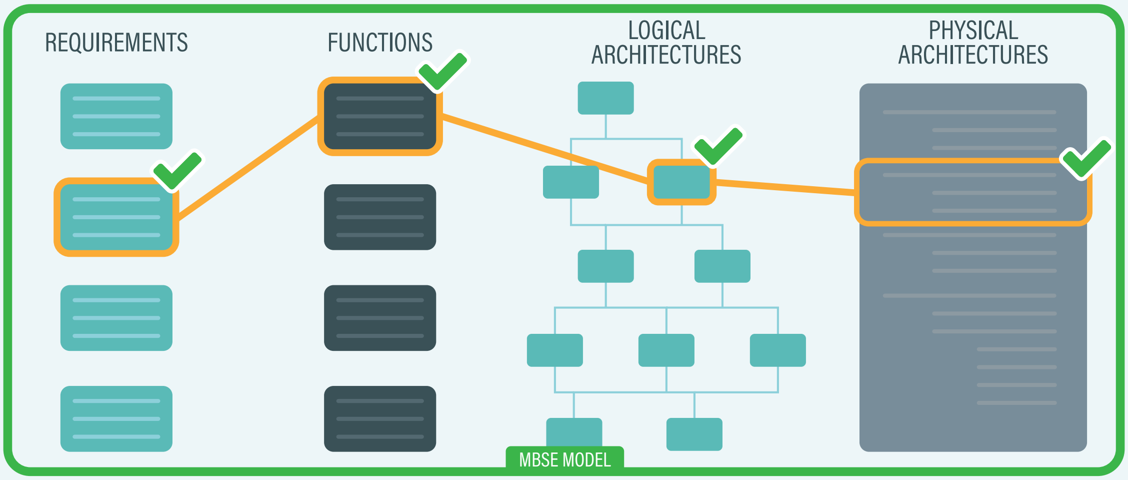


Figure 4
An MBSE model that contains and supports all aspects of systems engineering facilitates exploratory iterations, propagating changes automatically and intelligently.

MBSE ACROSS ENGINEERING DOMAINS

MBSE Across Engineering Domains

Historically, the MBSE approach has been specialized for each individual engineering discipline, with each domain developing its own model. So, MBSE in software development creates one model. MBSE takes another form in E/E systems. Additional design domains create their own disparate models. Having multiple models, often created in specialized domain-specific solutions, results in similar problems to those seen when engineers rely on spreadsheets and documents. The individual models can easily diverge, causing chaos when it comes time to move to detailed design.

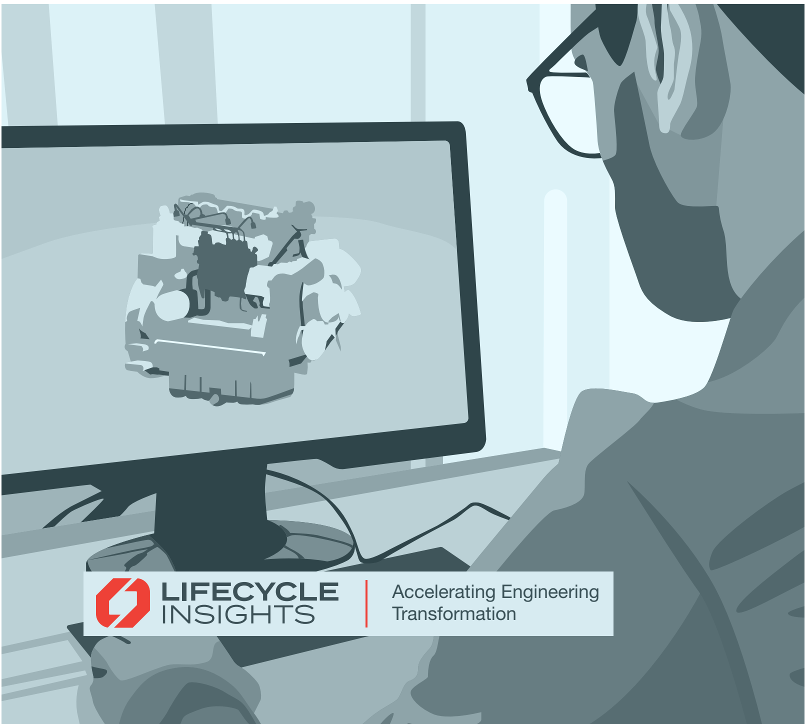
This section of the report explores:

- **The proliferation of divergent MBSE models:** Different engineering domains are responsible for different aspects of a product, so organizations often deal with multiple models.
- **Challenges with synchronization:** Different domain models are typically created in various tools, which can make it difficult to synchronize all models when it comes time to move product data to detailed design.
- **The importance of democratizing MBSE models:** When engineers across different domains are able to access data from the various MBSE models, they are in a better position to avoid errors and delays. Incorporating PLM into this effort significantly amplifies the benefits seen from MBSE synchronization across disciplines. Stakeholders across the systems lifecycle can collaborate in a frictionless manner. SysLM provides a way to exchange changes and synchronize these models from different domains.

THE PROLIFERATION OF DIVERGENT MBSE MODELS

Given that each engineering domain has its own specialized MBSE model, integrating important design data for downstream teams is a challenge. If there is a need to make changes to a system, that information does not quickly nor easily propagate across the different models. In fact, the more changes required, the larger the gap between models across different engineering domains. This means that, even if an organization is leveraging high-level MBSE solutions across different disciplines, it still runs the risk of lost data as well as later integration failures.

It is also important to note that each of these individual system models contains its own unique requirements, which have



If there is a need to make changes to a system, that information does not quickly nor easily propagate across the different MBSE models.

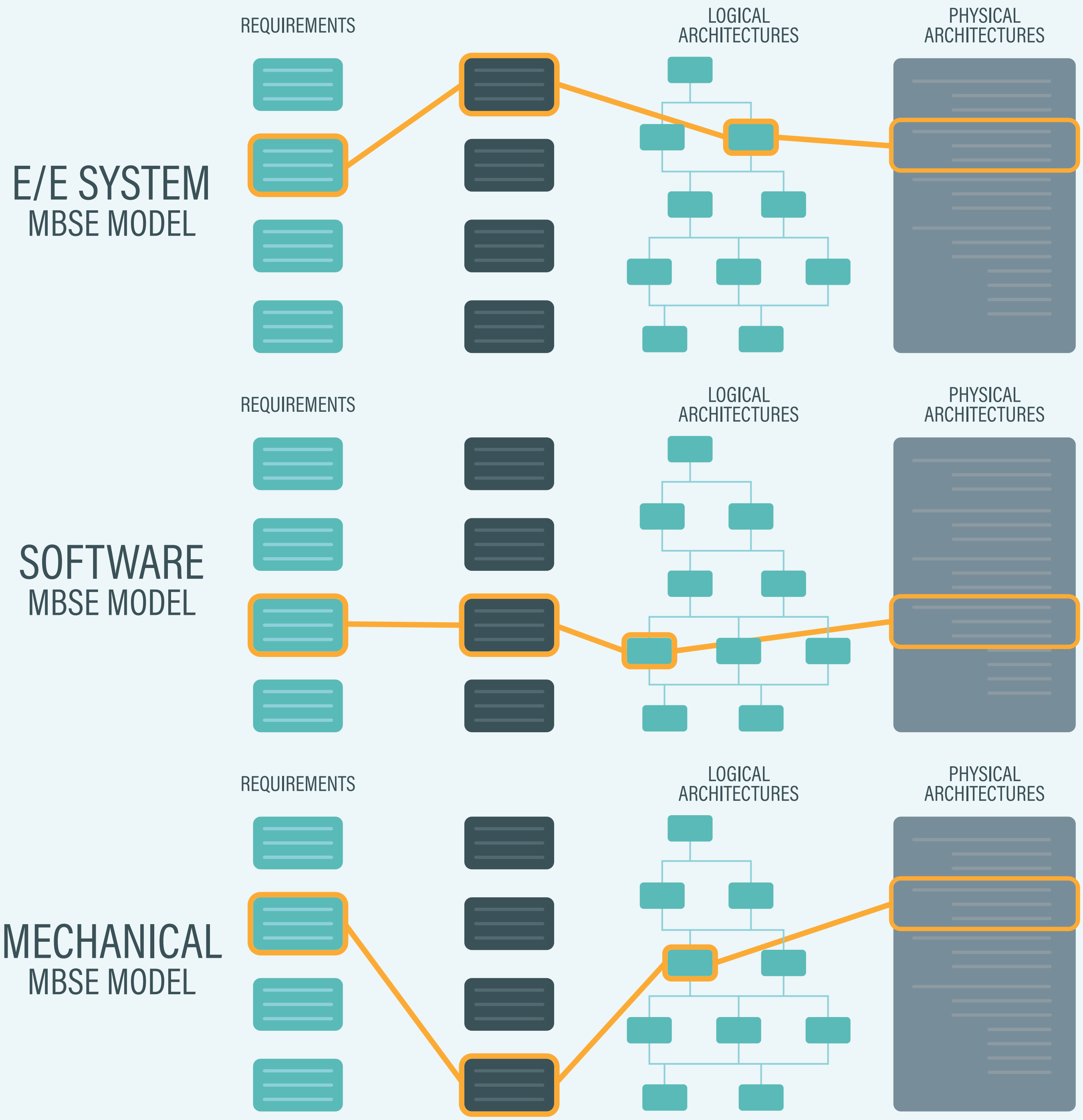


Figure 5
MBSE models built in different domains can diverge from one another. Propagating change between these models has traditionally been difficult, leading to incorrect or out-of-date information.

not traditionally been reconciled across the rest of the models when teams are using different solutions. This can result in duplicated requirements or divergent results that are not easily resolved. It can also contribute to integration issues that only manifest themselves during the prototyping and testing phase.

Finally, it is imperative that organizations recognize that this decentralized approach, with multiple MBSE models, can result in traceability issues. Understanding the connections between requirements and an end item is imperative to creating a feasible final product. This thread is easy to maintain when there is only a single MBSE model. When you have many of them representing different aspects of the system, however, it becomes more and more difficult to trace changes as they occur. These challenges are exacerbated by the scale and complexity of modern systems and products, which may include thousands of requirements, tens of thousands of components, and thousands of decisions. The end result is divergence in allocations—and even greater risk of integration and test failures.

SYNCHRONIZING MBSE MODELS

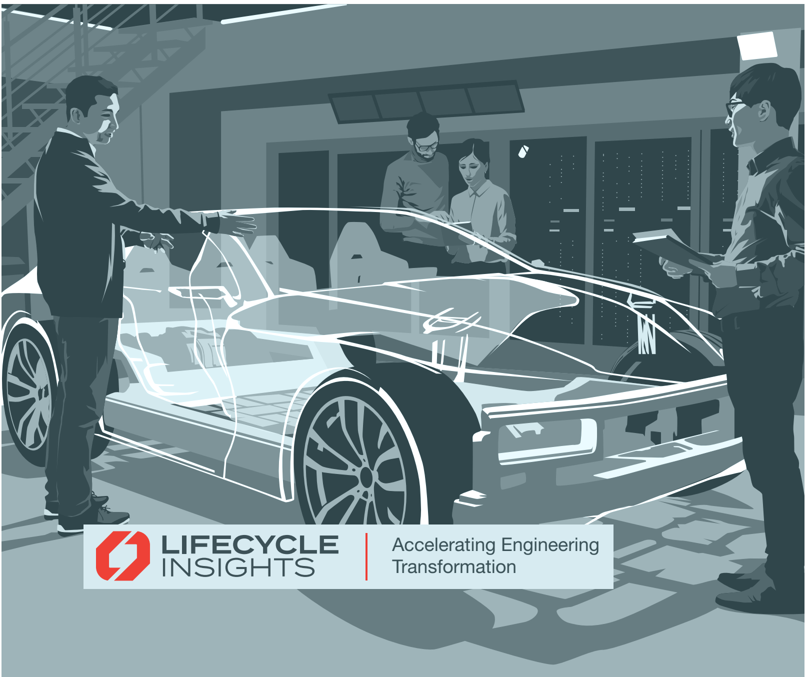
Teams across different engineering functions develop architectures that will ultimately be passed to detailed design engineers. Unfortunately, these models traditionally have not been integrated or even synchronized. This increases the likelihood that important design information is lost before it gets to the detailed design phase.

To avoid this, resolve integration issues, and perhaps even get to an optimized design, organizations must have the ability to synchronize the different systems models, likely created in domain-specific MBSE solutions. Much like sharing a CAD model between different applications, it's imperative that engineers, regardless of domain expertise, leverage interoperable applications so they can exchange models between teams. This ensures that any design changes are propagated across all MBSE models and that detailed design engineers have all the data needed to do their job.

Integrating MBSE models results in easier convergence and reconciliation across the product lifecycle. Furthermore, it allows all design stakeholders to get on the same page across models, domains, and updates. This kind of integrated approach can establish an accurate and accessible set of parameters for a product, preserving traceability across its lifecycle.

CONVERGING MBSE MODELS WITH PLM

Design and development stakeholders benefit when they have access to a living model architecture for their product, which permits and propagates changes as needed across design and development. Such a model can come to fruition when MBSE models are further integrated with PLM solutions, forming SysLM. This integration supports collaboration across design teams, allowing them to understand the effects of any updates across the entire design. The engineering organization, as a whole, can use SysLM to more easily and accurately inform technical budgets, interface needs, product requirements, product functions and features, and so much more.



Design and development stakeholders benefit when they have access to a living model architecture for their product, which permits and propagates changes as needed across design and development.

Because all design and development stakeholders are working from a single digital source of truth in SysLM, they can easily collaborate and negotiate changes throughout the entirety of the product lifecycle. Engineering teams, regardless of domain expertise, can work together to resolve any issues, validate integration, and ensure all product requirements are met. This reduces the likelihood that the engineering organization will hit unexpected roadblocks once they reach the prototyping and testing phase of development—and their associated costs or schedule overruns.

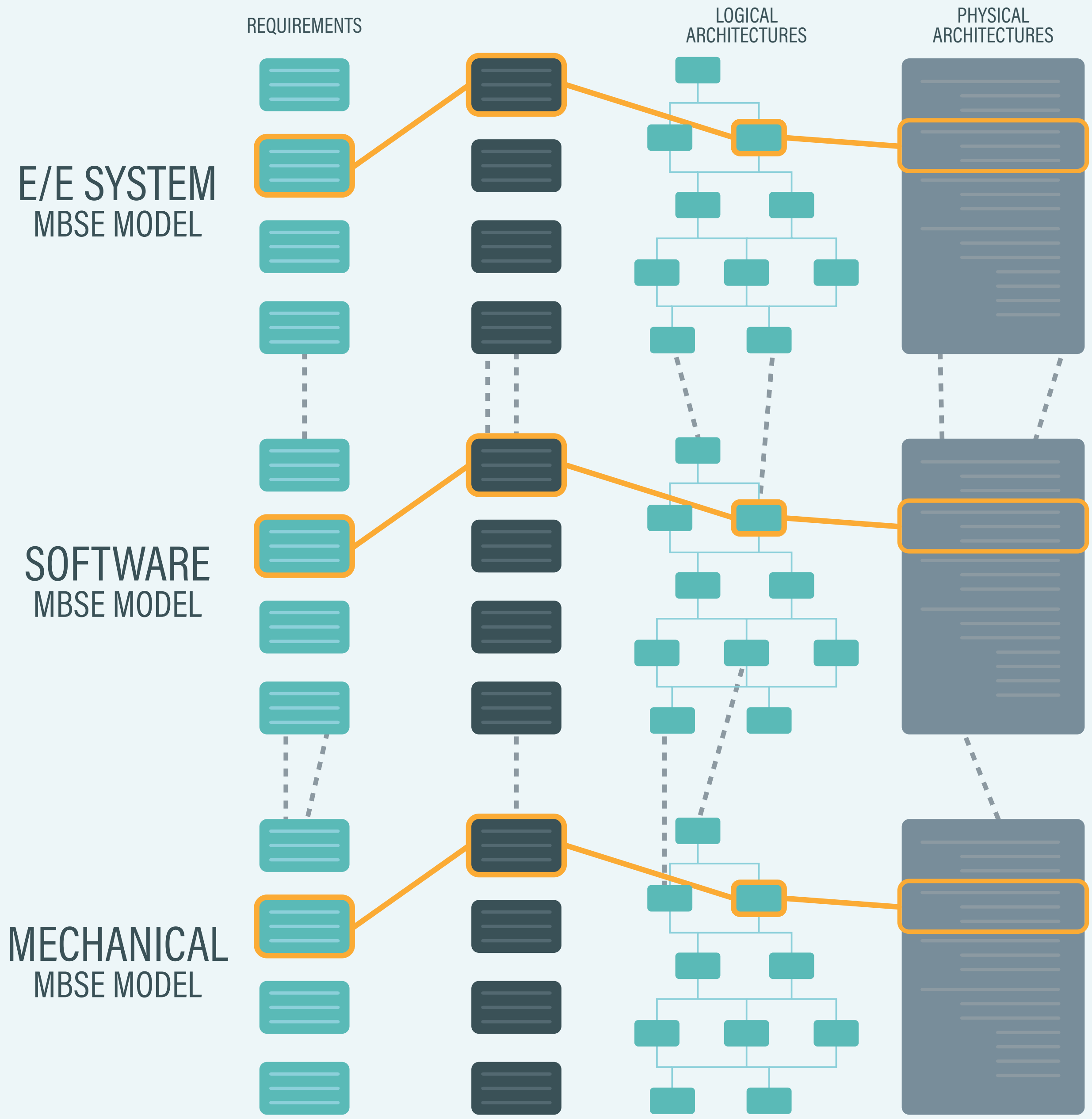


Figure 6
Interoperability between MBSE solutions allows for the propagation and reconciliation of change between models in different domains, ensuring that stakeholders are working from the same set of information.

MBSE FOR DOWNSTREAM ARCHITECTURE COLLABORATION

MBSE for Downstream Architecture Collaboration

Ideally, product stakeholders would use MBSE models as the lynchpin for collaboration between systems engineers who contribute to early design models and those working downstream on detailed design efforts. Unfortunately, MBSE models have traditionally required specialized training and solutions for access and collaboration, resulting in inaccessibility for product development stakeholders. When organizations integrate MBSE models with PLM solutions, resulting in SysLM, they can better ensure that all stakeholders are working with the most up-to-date design information. Engineers need access to the details of the MBSE model without having to use the highly specialized tools used to build such models. Such access allows engineers in any domain to identify issues prior to detailed design work, minimizing or eliminating the need for rework and redesign once the product design gets to the prototyping and testing phase.

This section will highlight:

- **The challenges inherent to collaborating across multiple MBSE architectures:** When engineers are unable to access critical design data from different models, integrating all components becomes a significant challenge.
- **Democratizing data across MBSE models with SysLM:** When engineering organizations can integrate multiple MBSE models with PLM platforms, they can more easily get to the data they need—and ensure that all engineers, regardless of domain, are working from the same single source of truth. Additionally, democratizing MBSE with PLM works synergistically with synchronizing MBSE definitions across domains.

CHALLENGES IN COLLABORATING AROUND MBSE

Once the detailed design teams start implementing the architecture, product development stakeholders inevitably encounter unexpected limitations or constraints that require change or even negotiations with other design domain teams. Imagine a situation where one system will be over existing weight requirements. To remedy the situation, detailed design engineers must be able to negotiate with design teams back upstream, as well with other stakeholder groups, to determine how to lower the weight of the particular system in question. They must also be able to work with other design teams to see whether they have any flexibility to lower their weight constraints. It may require considerable back-and-

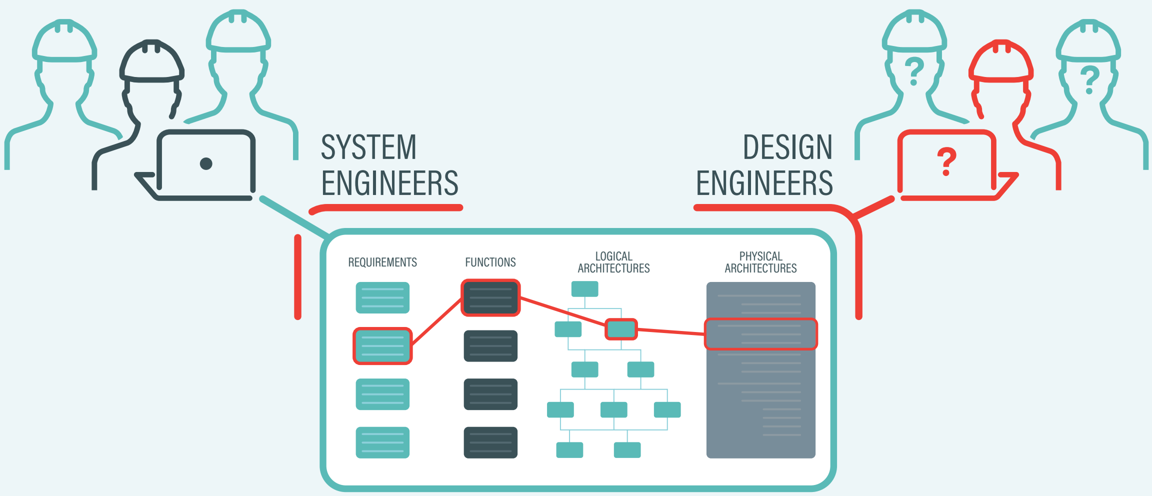


Figure 7
System engineers use specialty tools to build MBSE models. Design engineers often do not have access to such tools nor applicable training. As a result, the rich information in MBSE models is not exposed to the broader set of development stakeholders.

forth to come to a feasible solution that satisfies the product requirements.

Stakeholders should be able to leverage the MBSE model to support these kinds of design negotiations. Unfortunately, far too often, the very details they need to consider and collaborate upon are only available in highly specialized tools or solutions that cannot be easily accessed or used by all design teams. The necessary models do not support the kind of collaboration required to get to the right design solution.

This is a problem that requires correcting. When organizations cannot iterate and refine their initial designs, they are far more likely to encounter roadblocks downstream in the product development process—particularly in the prototyping and testing phases. The MBSE model must be democratized so that all stakeholders can access it.

DEMOCRATIZING MBSE MODELS WITH PLM

When organizations integrate their PLM with MBSE models, however, engineers both upstream and downstream can view and access the model. SysLM allows them to better negotiate, collaborate, and move toward an optimized design. Universal access to a living model architecture can help the entire design team more accurately determine technical budgets, interfaces, requirements, functions, and more.

This kind of integrated, democratized model also allows for tighter collaboration by different domain teams throughout the entirety of the product lifecycle. Organizations can work together at any point in the design and development process to resolve potential failures and validate integration. SysLM provides a powerful digital thread that connects every aspect of design, ensuring that design teams, regardless of their particular domain, are working from the same data—and can make more informed decisions as they guide the development process further downstream.

Note that there is strong synergy between the democratization of MBSE models through PLM and the synchronization of MBSE models across design domains. When these two capabilities are implemented together, stakeholders across the lifecycle and across design domains have access to a single, synchronized architecture spanning the entire system. This source of truth acts as the center point for collaboration for all.

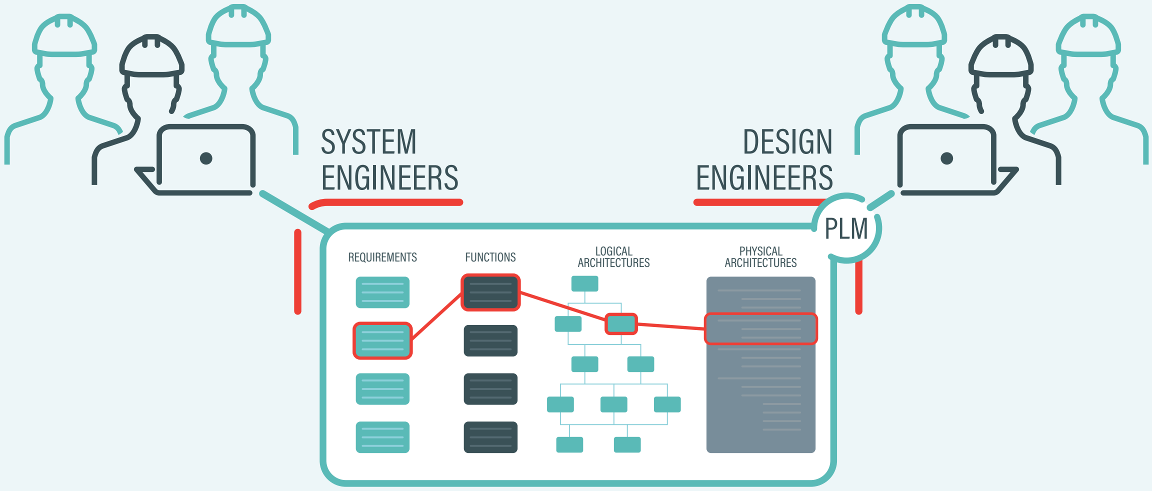


Figure 8
Integrating MBSE models with PLM solutions democratizes access to systems definitions for development stakeholders, transforming such models into a collaboration medium to make design tradeoffs.

MBSE AND DETAILED DESIGN TRACEABILITY

MBSE and Detailed Design Traceability

The other advantage of SysLM is increased traceability. As discussed above, the resulting living model architecture acts as a centerpiece for collaboration and negotiation across design teams, making it easier for stakeholders to make the necessary changes to forward models to detailed design. But this kind of democratized model also allows design teams to directly connect aspects of their MBSE models to design artifacts such as 3D CAD models, logic diagrams, software models, and more, so everyone can understand how design work is implemented. Furthermore, SysLM provides insight into where, why, when, and how changes occurred—and how they may impact the rest of the system. By providing this kind of enhanced traceability, downstream engineers can understand both the design and intent of any alterations to the model as they do their own work. That way, when programs reach the prototyping and testing phase, there will be fewer errors or failures that must be addressed—and a decreased risk of increased costs or schedule overruns.

This section of the report highlights:

- **Common disconnects between MBSE and detailed design models:** Far too often, MBSE models are disconnected from detailed design models and documentation, making it difficult to keep track of and integrate necessary changes and updates.
- **Overcoming MBSE and detailed design disconnects through integration:** When MBSE models are connected with PLM platforms, engineers can leverage tools and guidance for more efficient roll-outs. The synergy gained through SysLM is powerfully extended with this design traceability. SysLM allows any development stakeholder to identify, collaborate around, and resolve issues before they bloom into significant problems.

DISCONNECTS BETWEEN MBSE AND DETAILED DESIGN MODELS

MBSE models are, far too often, completely disconnected from the logical and physical representations of detailed designs—namely, the representations created by mechanical computer-aided design (CAD), electronic design automation (EDA), and software platforms. Today, there are few options to connect MBSE models to detailed design models, such as 3D design models, printed circuit board (PCB) logic diagrams or layouts, electrical system diagrams, or software libraries. Simply

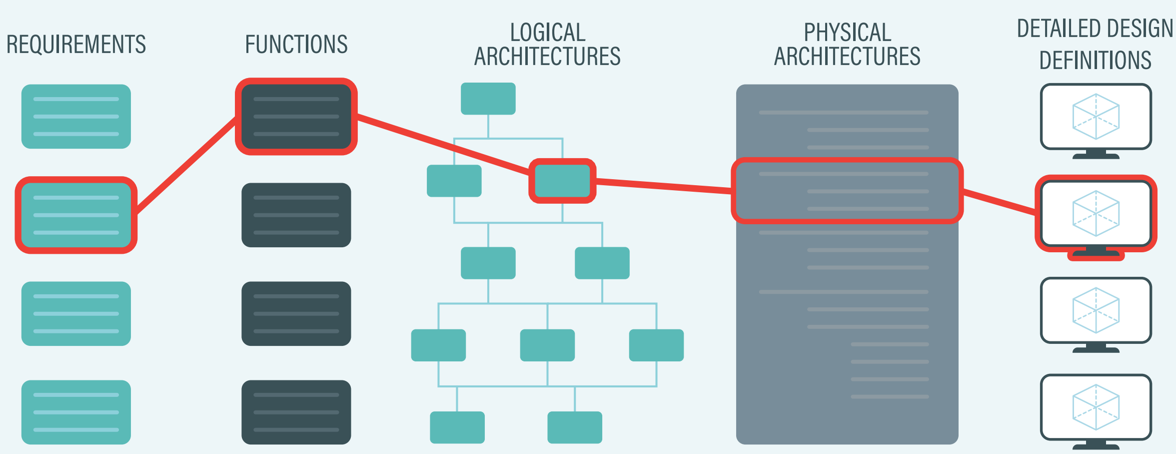


Figure 9
Connecting physical items in MBSE models to their corresponding detailed design models, such as 3D models, board layouts, or software code, creates a closed loop from requirements all the way through to design implementation.

stated, there is no traceability across these vital, interconnected systems. If a change is needed in one aspect of the design, there is little visibility or insight into how that change may impact other systems.

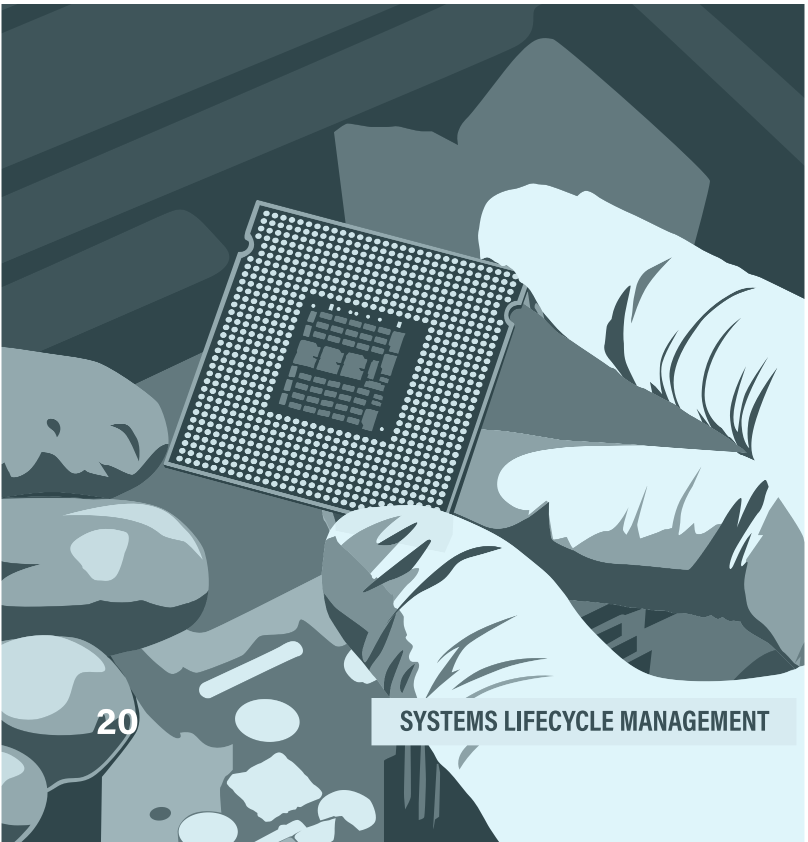
Even once design teams get to the detailed design phase of product development, changes can and do still occur. Such changes can shift how a requirement is fulfilled, sometimes requiring one or more domain-specific teams to get involved in order to determine how to best solve the problem. Since design teams spend the majority of their time complying with product requirements, these changes can lead to significant costs and time delays when design engineers only have access to MBSE models. By connecting MBSE models and detailed design models, organizations have an opportunity to optimize the whole system in one place for long-term cost-saving measures.

CONNECTING MBSE AND DETAILED DESIGN THROUGH PLM

Integrating MBSE with PLM allows organizations to easily verify allocations from requirements and functions and ensure they line up with physical items. Representations in the systems model directly connect to the 3D model, logical diagram of a multi-board system, or component of an E/E system. SysLM's completeness and continuity ensure that each and every requirement has been met—and implemented in a matter that is consistent with the overarching systems model.

SysLM can also help manage the deployment process, operational functions, and retirement of older systems when leveraged in a production environment. It can provide guidelines, checklists, and tools for more efficient roll-out, which can help organizations avoid major downtime while supporting long-term success for the business. Organizations can rest easy knowing they can fulfill proper systems integration. Furthermore, a well-established deployment process will enable more effective operations and maintenance through expanded monitoring, performance optimization, and incident management capabilities. This creates a productive and progressive working environment where old systems can be retired once they've outlived their usefulness, and organizations can smoothly transition to the next generation of tools and systems.

The synergy between the first two aspects of SysLM, synchronizing MBSE definitions across domains and using MBSE models as a centerpiece of collaboration, extends into this aspect of SysLM. The source of truth for architecture is extended to detailed design definitions, leaving no ambiguity regarding how a function is implemented as a design. That powers an organization's ability to identify and resolve issues early in the development process.



Integrating MBSE with PLM allows organizations to easily verify allocations from requirements and functions and ensure they line up with physical items.

MBSE AND SIMULATION TRACEABILITY

MBSE and Simulation Traceability

Simulation is a powerful tool that can validate the behavior and performance of product designs with a reduced need for physical prototypes. By creating a virtual representation of the system, engineers can test the effectiveness of different design alternatives, identify potential issues, and validate performance before investing in physical prototypes. Far too often, however, there is a disconnect between the simulations and MBSE models—which means there is a breakdown in the traceability from one to the other. This makes it harder to validate requirements satisfaction, performance, and behaviors before moving to physical prototyping. SysLM provides a means to connect aspects of MBSE models directly to simulation models, setups, and results.

This section discusses the following:

- **Common issues when MBSE models are disconnected from simulation models:** Engineers across different design domains will have difficulty gaining full value from simulation results when MBSE models, and the critical information contained within them, are disconnected.
- **The benefits of integrating MBSE and simulation:** When organizations are able to connect MBSE models with their simulation models, they can standardize and measure requirements validation, often in an automatic manner. SysLM provides a means to connect and automate digital verification all the way back to requirements defined in MBSE models. The advantage of connecting simulations to MBSE models works synergistically with prior aspects of SysLM as well.

DISCONNECTION BETWEEN MBSE AND SYSTEM SIMULATIONS

Predicting the performance of systems, especially those composed of designs from different domains, is exceedingly difficult. Some organizations have turned to systems simulations, which represent the behaviors of assemblies and subsystems as equations or formulas, to gain more insight and validate performance long before prototyping and testing. These 0D and 1D models can be assembled using individual components. Once tuned and calibrated, they can be exceedingly accurate.

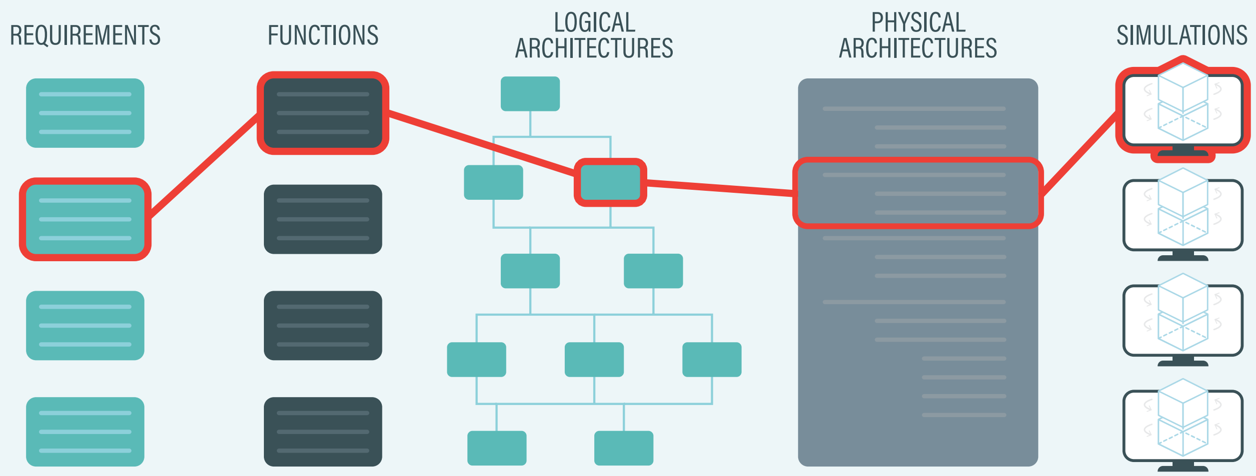


Figure 10
Connecting system simulations to MBSE models ensures the propagation of changes both ways and closes the loop on the verification and validation of systems performance.

However, the components of a system simulation do not necessarily correspond directly to the items in the physical architecture aspect of an MBSE model. Because of this lack of direct equivalence, some systems engineering teams leave the MBSE model and the systems simulation disconnected.

When engineers are working with disconnected MBSE models and systems simulations, it is much harder to validate requirements in the detailed design—or that the design even fulfills the requirements assigned to the physical item in the MBSE model. Consequently, identifying and mitigating risks associated with design and operation becomes a significant challenge. Engineers will have more difficulty anticipating potential failures, vulnerabilities, and unwanted outcomes in their designs, and they will not be able to quickly modify the design or add appropriate control measures to deal with those issues. Without adequate integration of MBSE models and PLM, engineers lose the strongest advantage of simulation: the ability to trace any potential issues back to the source.

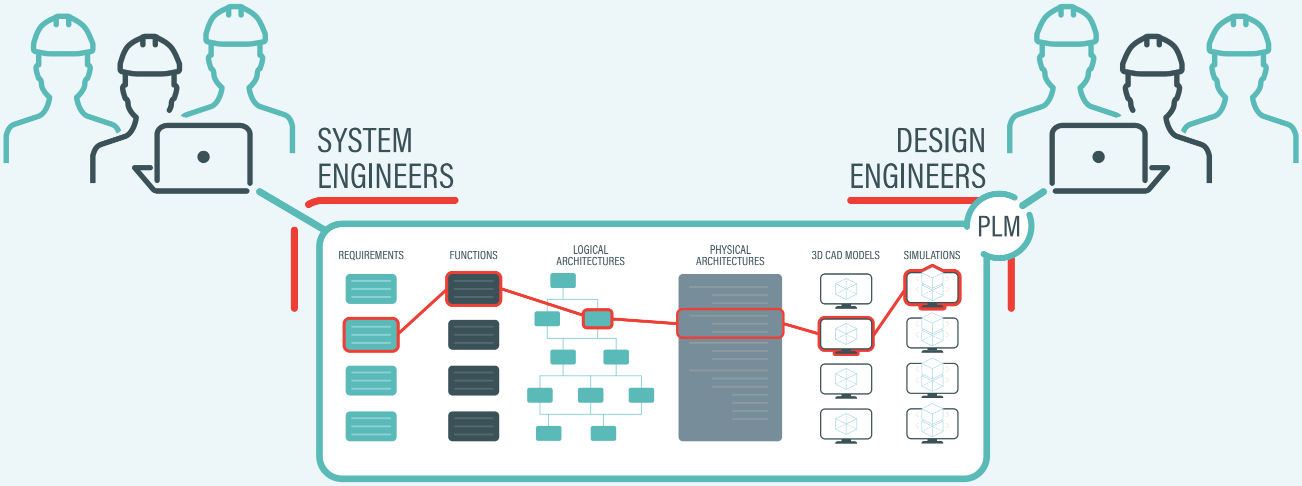
CONNECTING MBSE AND SIMULATION

To leverage traceability across the entire product lifecycle, organizations benefit by employing SysLM, which is a connection from MBSE models to systems simulations as well as to a PLM solution. Mapping the equivalent items between the MBSE model and the systems simulation connects analysis results all the way back up to the requirements, allowing for traceable verification. With such connections, organizations can easily standardize how to measure validation in terms of parameters and results, and even do so in an automated fashion.

Companies can also use SysLM capabilities to manage, access, and collaborate on the connection between simulation results and requirements across the MBSE model and the systems simulation. Where failures are predicted, systems engineers, detailed design engineers, project managers, and engineering management all have a single view of the shortcoming. Furthermore, they can collaborate on the root cause and take corrective action to solve the problem without specialized applications. Everything is accessible from anywhere. Incorporating PLM into this activity also allows stakeholders to understand the greater context of simulation results by including simulation models, loads, inputs, warning signals, set-ups, and more. This connects everything in one place, making it much easier for the product development team to digitally validate product performance.

Integrating MBSE models, systems simulations, and PLM throughout development has many benefits. But when organizations wait until later in the development phase to do so, they will likely encounter unnecessary issues that will lead to excess costs and development delays.

Figure 11
Connecting physical items to simulation models and results closes the loop from requirements definition to the verification and validation of requirements fulfillment.



Summary and Takeaways

Today's manufacturing organizations face unprecedented challenges in terms of product complexity. They successfully balance resources on ever-more truncated development timelines while creating new products that must seamlessly combine designs from many domains. To address these issues, many organizations are pursuing systems engineering practices and leveraging MBSE models. However, the transition has not necessarily been smooth. The adoption of SysLM—through the integration of MBSE models, PLM, detailed design definitions, and simulations—offers significant benefits.

SUMMARY

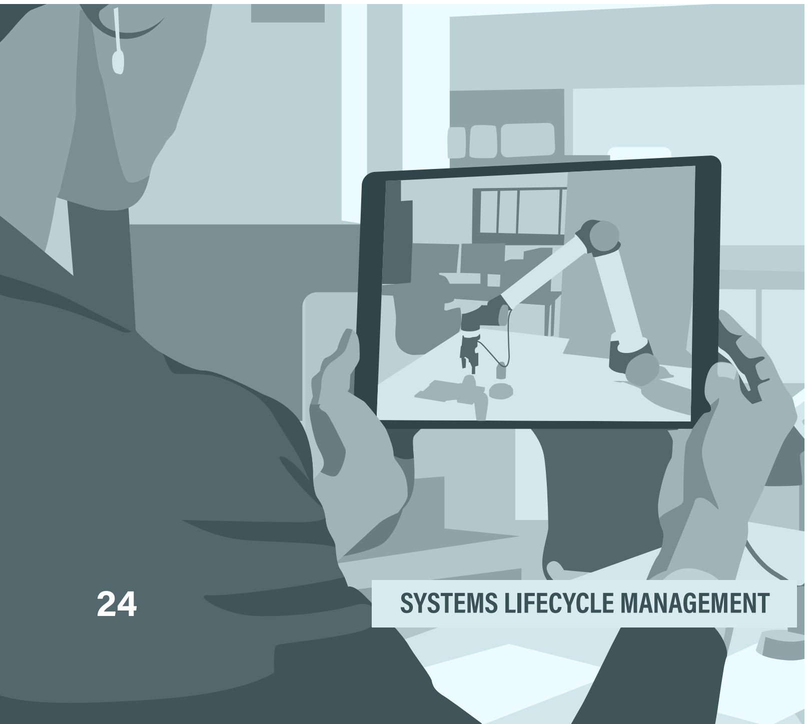
- Domain-specific design teams are using MBSE models separately, resulting in divergent representations of the system that are difficult to reconcile manually. Organizations can address this issue by using MBSE solutions with capabilities to synchronize with other models. Leveraging PLM with this synchronization, resulting in SysLM, allows these domain-specific teams to also collaborate on a common definition.

- Detailed design teams do not use nor have access to specialized MBSE solutions, giving them no ability to perform trade-offs with other teams. Integrating MBSE models into PLM, another aspect of SysLM, provides all access to these definitions and allows them to collaboratively solve problems and perform what-if scenarios.

- MBSE models are frequently not connected to the detailed design models representing items in their physical architecture, leaving no notifications or visibility into tactical design changes. Integrating PLM allows detailed design teams to connect everything, stitching together requirements all the way down to detailed design artifacts.

- MBSE models and systems simulations are frequently disconnected, leaving room for misinterpreting which analysis results correlate to which design configuration. Synchronizing MBSE models and systems simulations, which is another aspect of SysLM, allows for a clear one-to-one connection, and integrating PLM provides visibility and accessibility to all stakeholders.

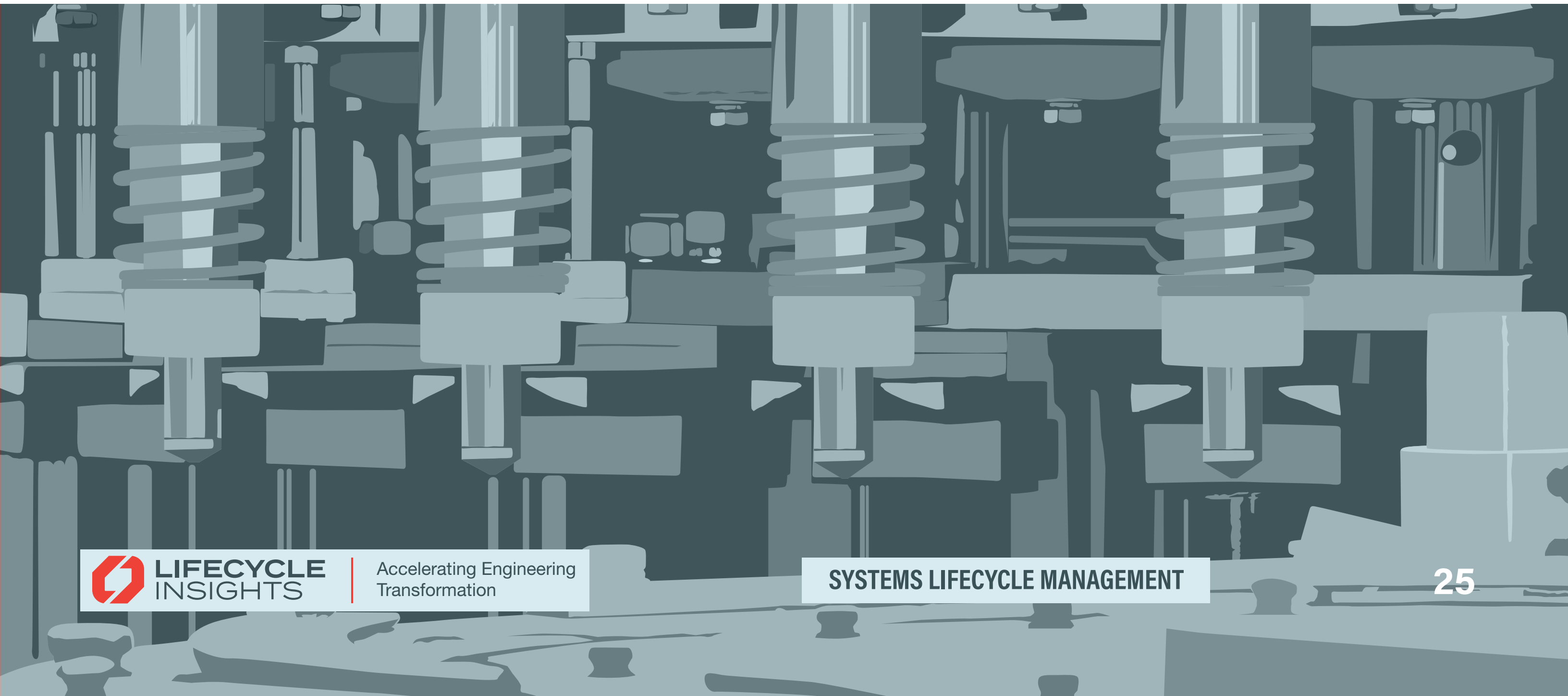
When companies integrate MBSE models, detailed design artifacts, systems simulation, and PLM, they are in a much better position to optimize limited time and resources for their product programs. SysLM promotes a more systematic, synergistic, and structured workflow to product development and management, from the very start of product planning, through simulation and requirements verification, and forward to production and manufacturing. Organizations that invest in this approach will see numerous benefits that will help them manage increasingly complex product requirements—as well as enhanced efficiency, reduced risk, lower costs, and improved quality and reliability of their products.



Without adequate integration of MBSE models and PLM, engineers lose the strongest advantage of simulation: the ability to trace any potential issues back to the source.

RECOMMENDATIONS

- As applicable, investigate the cause of any prototyping and testing failures for cross-domain systems, keeping an eye out for integration failures. Assess the difficulty of managing systems development using spreadsheets and documents to determine whether propagating change across files is a source of difficulty or error.
- If MBSE models are used in different engineering domains, assess the amount of duplication in requirements and functions. Additionally, identify the degree of divergence between those items in the models when compared to one another. Explore the impact of MBSE solutions that allow for synchronization between models used in different engineering domains.
- Determine how often detailed design teams are manually exploring trade-offs and what-if scenarios, keeping an eye out for misinterpretation and friction in the process. Leverage SysLM as a means for detailed design teams to collaborate on technical budgets early and throughout the development process.
- Identify how detailed design artifacts are connected to physical items represented in MBSE models. Use SysLM to connect these items to each other, creating traceability from one end to the other.
- If systems simulations are leveraged, determine how their components match against items in the MBSE model. Also, determine how stakeholders throughout the organization access and collaborate around systems simulation results. Explore integrations between MBSE solutions, systems simulation solutions, and PLM to pull together a complete, accessible view of digital validation to accelerate development.



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