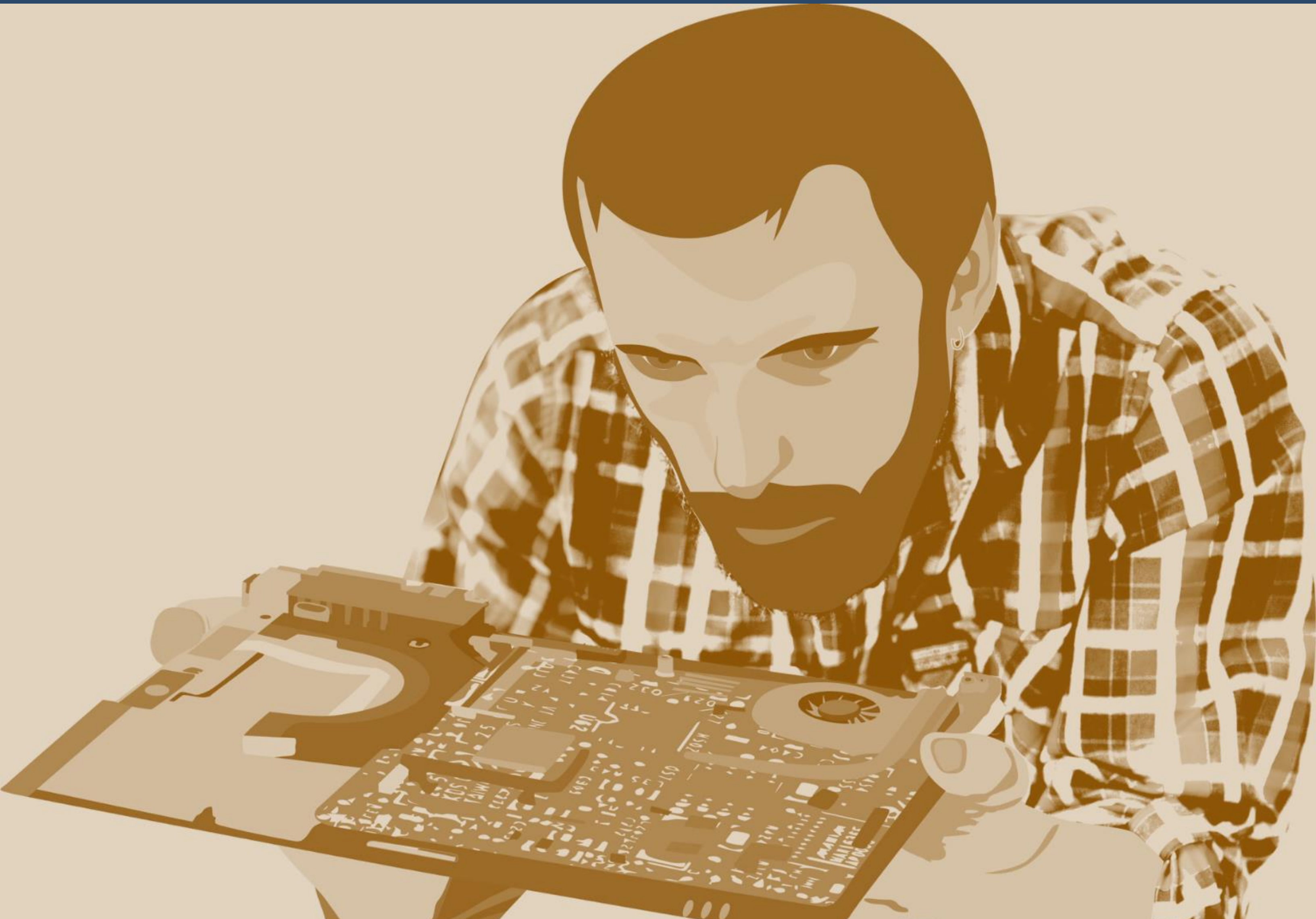
COMPRESS BOARD SYSTEMS DESIGN WITH ELECTRICAL-MECHANICAL COLLABORATION

LIFECYCLE INSIGHTS



EXECUTIVE OVERVIEW: CHANGING PRODUCTS, CHANGING PROCESSES

Today's products are undergoing a fundamental change. They are increasingly connected, logging data into the cloud and communicating with other products. They are increasingly smart, reading their own operation and environment in order to react intelligently. Such changes are arising due to a sea change in the product composition, with an ever-growing number of sensors, antennas, embedded systems, and electrical systems.

This report compares approaches for electrical and mechanical engineers to collaborate more closely in an effort to compress the design of board systems.

Despite increasing product complexity, engineering leadership seeks to further shorten development schedules, including those of board systems in embedded systems. One way to compress the development of board systems is to enable earlier and more continuous collaboration between electrical and mechanical engineers. Such a change would resolve design issues earlier in the development cycle, allowing compression of the overall cycle. However, the established approach is too error-prone to accomplish this goal. Instead, engineering leadership must look to broader, more novel, approaches.

The purpose of this report is to provide more details on this issue and to introduce one such novel approach. It contains five discrete chapters, as follows:

The first chapter, *Driver of Change: Software-Hardware Validation*, looks at the pressures driving engineering leadership to compress the design cycle of board systems.

The second chapter, *Upgrade Opportunity: Electrical-Mechanical Collaboration*, details three opportunities to compress the design of board systems, each focusing on collaborative activities between electrical and mechanical engineers.

The third chapter, *The Established Approach: Manual and Sequential*, details the capabilities and implications of a traditional technology that enables the established approach for collaboration between electrical and mechanical engineers.

The fourth chapter, *The Novel Approach: Automated and Concurrent*, describes the capabilities and implications of a progressive technology that enables earlier and more frequent collaboration between electrical and mechanical engineers.

The fifth chapter, *Summary and Recommendations*, recaps the highlights of this report and offers guidance on next steps for those pursuing the compression of their board systems design process.

Many have resigned themselves to the limited opportunities for improvement in the established approach to designing board systems. Nevertheless, greater gains are possible a novel approach, empowered by progressive technology enablers, is adopted. Such a change represents a genuine means to compress the board system development cycle.

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DRIVER OF CHANGE: SOFTWARE-HARDWARE VALIDATION

The pressures driving engineering leadership to further compress the development of board systems are not simple. In fact, there are a myriad of conflicting evolving constraints that make it difficult to realize any schedule or productivity gains in development. These drivers of change, and their interactions, are detailed in this chapter.

This chapter examines the pressures driving engineering leadership to compress the design cycle of board systems.

THE MANY INNOVATION OPPORTUNITIES IN EMBEDDED SOFTWARE

For years, the primary source of product innovation was the design and development of new mechanical or electrical hardware. Although companies still invest in new hardware-based ways of fulfilling requirements, software has become the new source of significant breakthroughs.

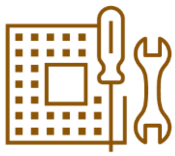
Some companies, even manufacturers and suppliers with a longstanding heritage in mechanical or electrical design, have made significant commitments to pursuing software innovation opportunities. Some have hired so many coders that they now outnumber hardware engineers by two, three, or four times.

VALIDATING THAT SOFTWARE RUNS ON TARGET ELECTRONIC HARDWARE

One fundamental challenge to developing any type of software is the need to ensure it runs as intended on its target electronic hardware. For embedded systems, this means that new-to-the-world code must be run on new-to-the-world board systems that runs new-to-the-world custom processors. All three of these items must work together seamlessly and without error. That, by itself, is a significant challenge.

The established method of software development relies on frequent tests where code is compiled and run on a *daily basis*. The value of such frequent testing is its ability to isolate software errors to code written on a specific day. That, in turn, allows software engineers to focus on fixing issues in a specific set of code.

This tried-and-true method is enormously effective, but is difficult to apply to embedded systems. The target electronic hardware often takes weeks, months, or even years to design and develop. Without the availability of such board systems, even just prototypes, software engineers cannot test their code using this methodology. Engineering leadership cannot afford such a significant delay while electrical engineers to finish their board systems and deliver prototype hardware.



Ensuring that new embedded software runs on target electronic hardware is no easy task. Testing code against a prototype board system is a critical step in the development of any smart, connected product.

MODEL-BASED SOFTWARE DEVELOPMENT: A PARTIAL SOLUTION

The fundamental problem, the significant delay in software-hardware validation, gave rise to a new approach: Model-Based Software Development (MBSD). In this methodology, software engineers progressively use digital models for their tests instead of waiting for prototype board systems. This approach includes:

- Model-in-the-Loop (MiL): In this process, the software engineer connects their software model to a 1D simulation that emulates the behavior of the physical product.
- Software-in-the-Loop (SiL): Here, the compiled software, written from the software model, is connected to the 1D simulation to verify behavior.

Model-Based Software Development (MBSD) allows software engineers to test their code against digital 1D simulation models of the physical product.

While the MBSD approach allows the software engineers to make progress in their development efforts, it does not eliminate the need for board systems prototypes. The extended development schedules for board systems might still be longer than the MiL and SiL phases. It buys electrical engineers some time, but they must nevertheless compress their development schedules.

THE EXPLODING COMPLEXITY OF MODERN BOARD SYSTEMS

The need to compress the development of board systems is very real, but recent technological trends in electronics are making it *harder*, not *easier*, to shorten design cycles. Smart, connected products demand more power and higher data transfer rates. The form factors of board systems are small and continue to shrink. On top of this, engineers are continuously driven to integrate the latest protocols and devices into their designs.

From a physical design perspective, engineers are simply running out of room. The space allocated to embedded systems is getting smaller as their numbers increase, leading to the rise of rigid-flex multi-board systems within control units. With increased power comes increased heat generation, leading to considerable thermal dissipation challenges.

The challenge of balancing all these design requirements directly counters efforts to compress the design cycle.

The complexity of modern board systems are growing exponentially. This acts as a counterbalance to the pressures driving engineering leaders to compress development.

THE COMPETING CONSTRAINTS OF BOARD SYSTEMS DEVELOPMENT

Overall, the design and development of board systems is facing competing drivers and constraints.

- The number of sensors, antennas, electrical systems, and embedded systems in smart, connected products is growing quickly. The innovation opportunity in software has led to a significant increase in software engineers in traditional mechanically oriented companies.
- The extended development timeframe for prototype board systems delays software engineers' ability to test on target electronic hardware.
- Model-Based Software Development (MBSD) allows software engineers to test their code against digital models instead of board systems prototypes.
- While MBSD buys electrical engineers time, the schedule to develop board systems is being significantly compressed.

Today's engineering leadership is being handed a difficult mandate: shorten the development cycles of board systems, despite the challenges.

Engineering leaders need to find ways to compress the development of board systems. Yet the increasing complexity of these board systems makes achieving that goal difficult.

UPGRADE OPPORTUNITY: ELECTRICAL-MECHANICAL COLLABORATION

To find ways of compressing the development cycle for board systems, engineering leadership can pursue a number of different strategies. One such initiative is to improve collaboration and coordination between electrical and mechanical engineers around the design of circuit boards within enclosures.

There are three collaborative activities between these engineers that can be improved. The following sections detail the tasks and objectives involved with those activities. They offer a baseline for comparing established and novel approaches, as defined in the following two chapters.

This chapter details three opportunities to compress the design of board systems, each focusing on collaborative activities between electrical and mechanical engineers.

PLANNING AND VERIFYING BOARD FIT AND FORM IN THE ENCLOSURE

A foundational point of collaboration between electrical and mechanical engineers is planning and then verifying that the board system will fit within the enclosure.

The process begins when the mechanical engineer creates an outline as well as any connectors interfaces for the circuit board in a Mechanical Computer Aided Design (MCAD) application. This is often defined and constrained by the space claim allocated to that embedded system within the larger product. Depending on the space available, engineers may need to use a rigid-flex approach, a multi-board approach, or some combination of the two.

Once the outline of the board is defined, electrical engineers open it in their Electrical Computer Aided

Design (ECAD) application, where they can get to work. Based on a board schematic, which captures the logical design, they start placing components according to their constraints. In more complex designs, they may need to partition boards further to address the needs of the logical design.

With components placed upon the board, the electrical engineers share their design with the mechanical engineers, who use the information to populate a 3D assembly model of the board in the MCAD application. Each component spatially placed in an automated way to match the electrical engineer's ECAD layout. This 3D assembly model is then used to virtually check for clearances and interferences to ensure the board will, in fact, fit into the enclosure.

The first and perhaps most important collaboration activity between electrical and mechanical engineers is ensuring that the board will fit into the enclosure. This is becoming more difficult with the increasing complexity of modern board systems.

Few designs are satisfactory after the initial pass in this process. An interference may require that some electronic components be moved around on the board. Engineers may need to change the outline of the board to accommodate logical requirements. This process often requires multiple passes back and forth between the mechanical engineer and their MCAD application and the electrical engineer and their ECAD application.

PREDICTING, ADJUSTING, AND VALIDATING THERMAL PERFORMANCE

A second point of collaboration between electrical engineers and mechanical engineers designing board systems is conducting analyses to predict, adjust and validate the thermal performance of the board system.

One of the most crucial issues in development is the need to properly cool electronics. Modern electronics use a great deal of power in a very small space, and this generates a tremendous amount of heat. If left unchecked, the temperatures of pins and components skyrocket, and this could fry the board. To ensure proper heat dissipation, electrical and mechanical engineers must find ways to evacuate heat from the enclosure housing the circuit board.

Setting up and running fluid and thermal analyses of electronics cooling requires a 3D assembly model. Creating such a model relies on the process as described in the section *Planning and Verifying Board Fit and Form within the Enclosure*. Designers share the layout information within the ECAD application with the MCAD application, where it populates the 3D assembly model.

Once that model is available, the mechanical engineer or expert analyst then applies boundary conditions and thermal loads representative of the cooling strategy for that board system. This may include natural convection, forced convection, water cooling, and more. Engineers can then run a simulation and use its results to make informed design decisions.

Note that if the design changes, such analyses will need to be run again to predict, adjust, and validate thermal performance again. Furthermore, it becomes critically important to track which layout populated which 3D assembly model that was simplified and abstracted into a simulation model. Otherwise, it becomes difficult to know which simulation results apply to which design.

Modern electronics generate high levels of heat in small spaces. Electrical and mechanical engineers must work together to predict and then validate that temperatures in the enclosure and on the boards stay below specific thresholds.

PREDICTING, ADJUSTING, AND VALIDATING STRUCTURAL PERFORMANCE

A third point of collaboration between electrical engineers and mechanical engineers is conducting analyses to predict, adjust and validate the structural performance of the board system.

Cooling is not the only potential problem that needs resolution during the design phase. Board systems, when exposed to vibration loads, experience enough structural excitation that the pins connecting electrical components to the circuit board can fail. Systems exposed to such loads over long periods of time can fail due to fatigue.

To set up and run structural, excitation, and fatigue analyses of electronics requires a 3D assembly model. The procedure in this scenario mirrors that associated with *Predicting, Adjusting, and Validating Thermal Performance*. The layout populates the 3D assembly model.

However, where the structural process diverges is in the need to apply simplifications and abstractions. These modifications to the geometry of the board enable faster analyses that are still be functionally accurate. Engineers can run the simulation and use its results can to make informed design decisions.

As with electronics cooling simulations, future modifications to the board system will require new iterations of those simulations. Additionally, tracking the relationships from layout to simulation result is also important.

Some smart, connected products are exposed to repeated vibrating loads. That can excite the natural frequencies of components on the board system or expose pins to fatigue loading. This is another aspect of electrical performance that must be predicted and then validated.

THE ESTABLISHED APPROACH: MANUAL AND SEQUENTIAL

A number of pressures are driving engineering leadership to compress the development cycles, despite the increasing complexity of board systems. To achieve that goal, they must make changes to design processes, including the collaboration between electrical and mechanical engineers. To understand the gains that such changes could deliver, it is critical to identify the opportunities for improvement in today's established approach. This chapter details that established approach and the underlying technology enabler that powers it.

This chapter describes the capabilities and implications of a traditional technology that enables the established approach for collaboration between electrical and mechanical engineers.

THE TRADITIONAL TECHNOLOGY ENABLER: FILE-BASED EXPORTS AND IMPORTS

The established approach to collaboration between electrical and mechanical engineers relies on a traditional technology enabler, the file-based export and import of design information between the ECAD and MCAD application.

The process starts when the mechanical engineer exports the board outline as 2½D geometry file from the MCAD application. The electrical engineer then imports that file into the ECAD application. There, the outline is used as the basis for the board system layout, where components are placed and traces are routed.

The process continues when the electrical engineer exports the board layout, which includes the board outline and the placement of electronic components on the board, from the ECAD application as a file. The

The established approach to electrical-mechanical collaboration is based on traditional technology enabler: the file-based export and import of files between ECAD and MCAD applications.

mechanical engineer imports it into the MCAD application, which interprets the information and automatically places electrical components within the 3D assembly model.

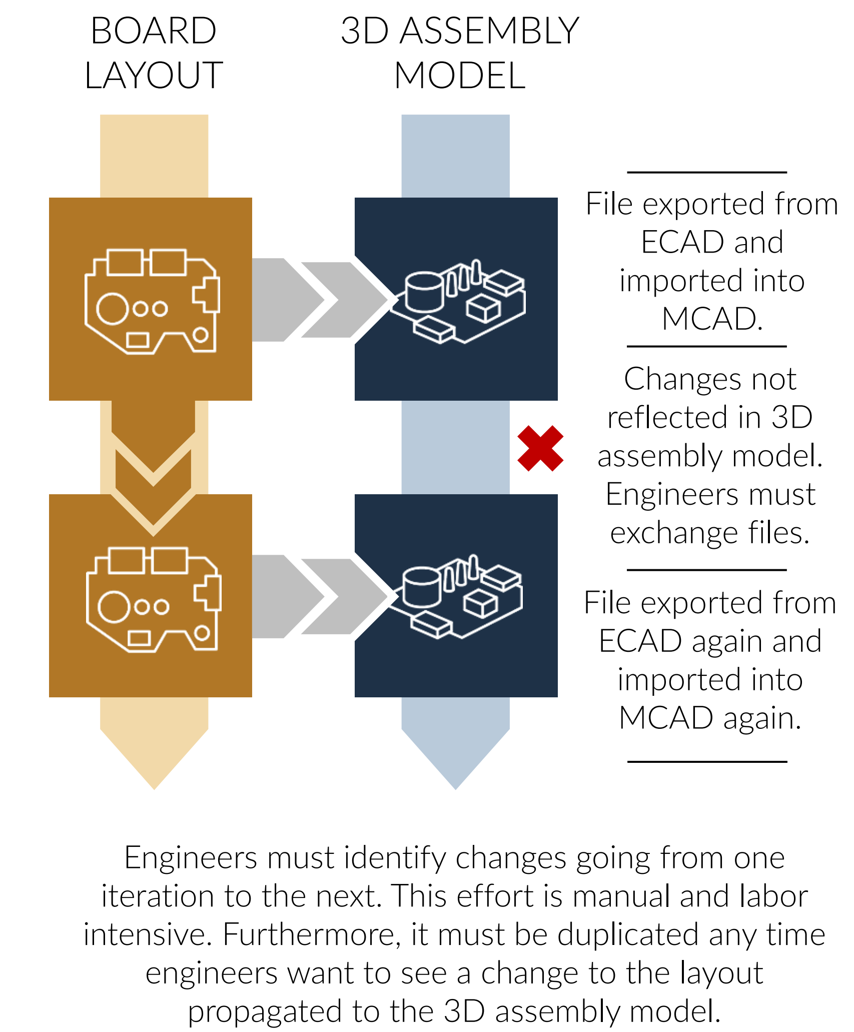


Figure 1: Illustration of traditional technology enablers, file-based exports and imports, used to share design changes between electrical engineers using an ECAD application and mechanical engineers using an MCAD application for board system design.

THE ESTABLISHED APPROACH TO PHYSICAL DESIGN

While this file-based export and import of information allows an exchange of designs between electrical and mechanical engineers, it has its drawbacks. This established approach is simple during the first exchange of design information between the two applications. However, as soon as one side makes a change, the two representations fall out of synch. To rectify this requires another export and import procedure.

The problem is that this approach is *manual*. Either the electrical or mechanical engineer must recognize that changes have been made and should be communicated to their counterpart. Placing such a notification and explicit effort to export the changes responsibility on engineers in the middle of design introduces the possibility of unintentionally not sharing such changes.

The effort and risk involved in the established approach drives unintended behaviors in the development process of board systems. Engineers, who often are working against tight schedules, contain the effort-intensive exchange of information to specific milestones in development. These milestones frequently occur after the work-in-process phases of development, when designs are already relatively complete.

While this less frequent exchange means less churn for both electrical and mechanical engineers during design, it translates into problems downstream. Less frequent checks for form and fit increases the likelihood that physical prototype boards won't fit into their enclosures, introducing extra rounds of prototyping that incurs more costs and schedule delays. This established approach unintentionally undermines engineering leadership's efforts to compress the development cycle.

File-based exports and imports require manual efforts to share changes between engineers and demand significant effort to closely inspect modifications. This results in delayed and infrequent collaboration in design.

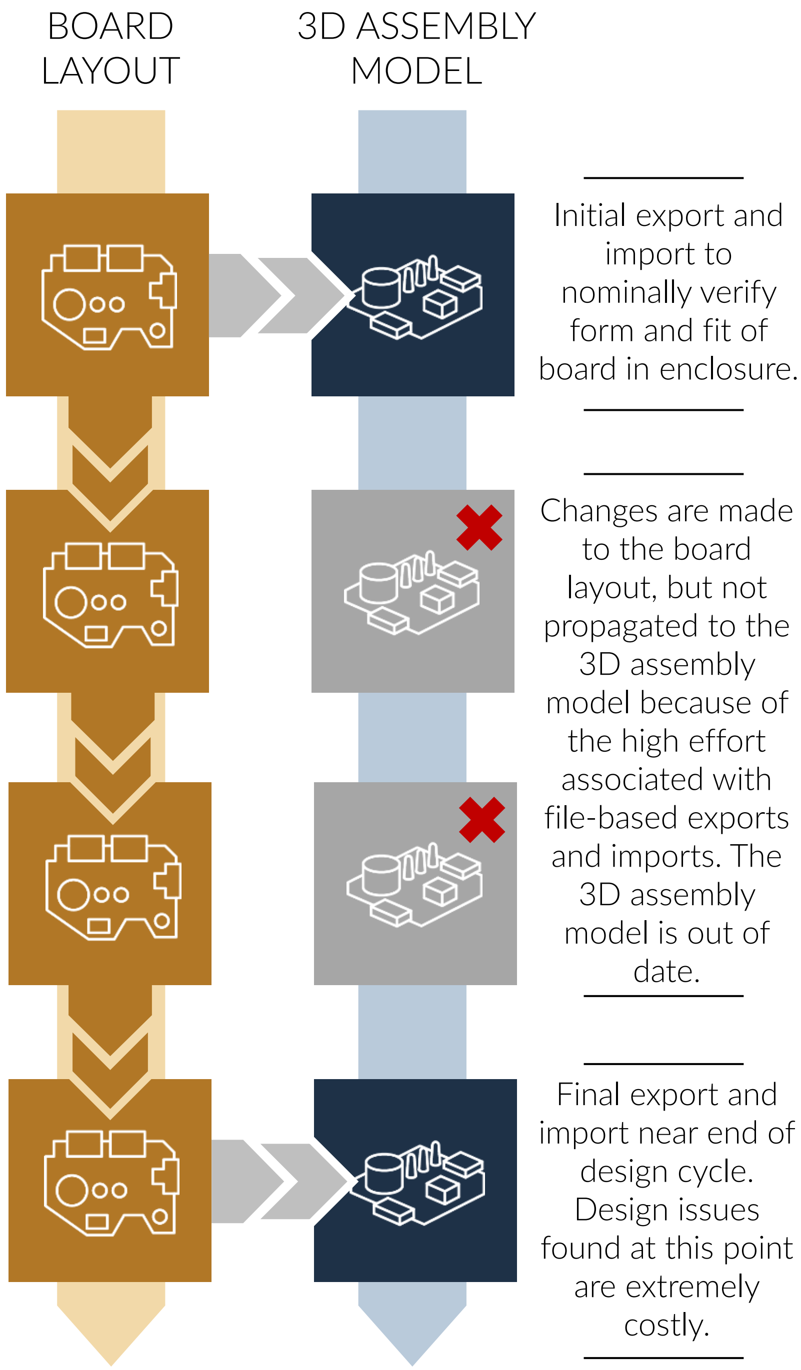


Figure 2: Illustration of the delayed exchange of design changes between electrical engineers and mechanical engineers on board system design due to the established approach.

THE ESTABLISHED APPROACH TO THERMAL AND STRCTRAL SIMULATIONS

In addition to passing design information between electrical and mechanical engineers, file-based export and import allows the creation and update of a 3D assembly model engineers can use for simulation and analysis. However, the drawbacks of the established approach when applied to exchanging design modifications become more significant when applied to developing and updating a simulation model for thermal or structural analyses.

The technical flaw lies in the additional derived modifications necessary to create a simulation model. Engineers or expert analysts take the 3D assembly model of the board system and make additional simplifications and abstractions to the geometry. That, by itself, is not an issue. Problems arise when the electrical or mechanical engineer makes changes to the layout and must propagate the modifications to the 3D assembly model. This is effort intensive and subject to potential human error. Then the engineer or expert analyst must update their simulation model to match. In a best-case scenario, this requires significant rework. In a worse-case scenario, it requires the recreation of the simulation model.

These issues drive unintended behaviors, much like those seen in exchanging design updates between electrical and mechanical engineers. Engineers or expert analysts who conduct simulations delay their efforts until the designs are complete. While this saves them a significant amount of time, it deprives the organization of one of the core benefits of early simulation: improved design decisions. Engineers make better decisions because early simulation lets them they see how their ideas and concepts affect performance. Better decision making enabled by simulation results in fewer rounds of prototyping and respins. By delaying simulations until designs are complete, the opportunity to make better

Mechanically oriented simulations, including ones that assess thermal and structural performance, require an accurate and up-to-date 3D assembly model. For the established approach, this effort depends on directly on the file-based export and import technology enabler.

decisions has passed and engineers must instead rely on multiple rounds of prototyping.

THE OUTCOME OF THE ESTABLISHED APPROACH

- The established approach of facilitating interaction between electrical and mechanical engineers relies on file-based exports and imports.
- The significant manual effort involved in this approach drives electrical and mechanical engineers to delay their exchange of design changes. It also postpones structural and thermal simulations until late in the design cycle.
- This behavior undermines engineering leadership's efforts to compress the development cycle of board systems.

THE NOVEL APPROACH: AUTOMATED AND CONCURRENT

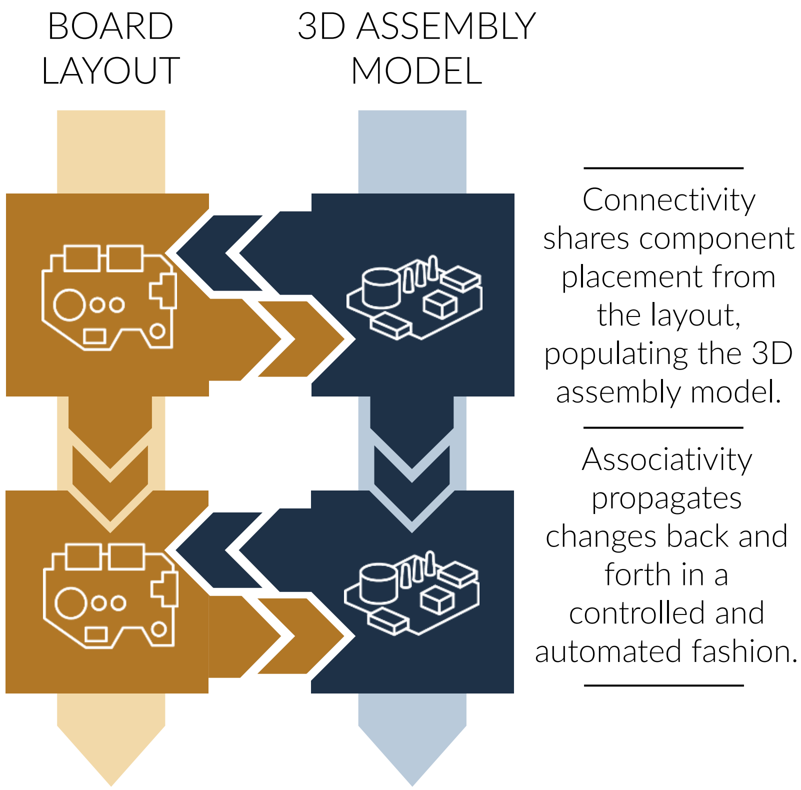
Due to its limitations, the established approach leaves engineering leadership little chance to compress the development cycle of board systems. However, new technology enablers can improve collaboration between electrical and mechanical engineers. This chapter details a novel approach, empowered by progressive technology enablers, and the process changes it makes possible.

This chapter describes the capabilities and implications of a progressive technology that enables earlier and more frequent collaboration between electrical and mechanical engineers.

THE PROGRESSIVE TECHNOLOGY ENABLER: INTEGRATED ASSOCIATIVITY

As with the established approach, technology acts as a key enabler for interactions between electrical and mechanical engineers. The novel approach relies on pairs of integrated MCAD and ECAD applications that *synchronize* designs. The two applications connect, allowing seamless exchange of design information about board outlines, layouts, and population of 3D assembly models. It requires no file exports or imports. Instead, the two software applications communicate with one another directly. Note that engineers must approve information sharing; it isn't executed without their consent.

This capability facilitates both the initial sharing of design information and all subsequent changes to those designs. A change log tallies each modification so that when a user selects an individual change, the corresponding geometry in the design highlights, visually identifying the modification to the engineer. This allows electrical and mechanical engineers to quickly identify and assess design changes at a granular level.



Engineers can exchange modifications back and forth, quickly and easily. This allows earlier and more continuous collaboration during the design process.

Figure 3: Illustration of progressive technology enablers, synchronization between integrated pairs of ECAD and MCAD applications, used to share design changes between electrical engineers and mechanical engineers for board system design.

The progressive technology enabler provides associativity between a board layout and the board 3D assembly model. It also provides interactive highlighting, allowing a wire selected in one application to be highlighted in the other.

THE NOVEL APPROACH TO PHYSICAL DESIGN

When it comes to exchanging information between electrical and mechanical engineers for physical design, the novel approach presents significant advantages. For instance, it removes the manual effort to export information from the ECAD application and import it into the MCAD application. Instead, each engineer can synchronize their design work with their coworkers and then assess those changes in a granular fashion.

This change in enabling technologies addresses the unintended behaviors in the established approach. Because sharing changes requires far less work and permits scrutiny of individual modifications, engineers can share changes back and forth early and throughout the design process. Ultimately, this allows electrical and mechanical engineers to interact earlier and more frequently with less effort.

Another process change enabled by integrated pairs of ECAD and MCAD applications is the real-time co-design of board systems. Interactive highlighting allows each engineer to view design information in their own application, letting them design in a familiar environment. With each engineer using their preferred application, they can interactively work through competing constraints and requirements in real-time.

The novel approach allows electrical and mechanical engineers to work together earlier, more continuously, and even in real-time. That, in turn, allows them to resolve cross disciplinary design issues far earlier in the design cycle, when there is often more decision freedom. This all aligns very closely with engineering leadership's efforts to compress the development cycle.

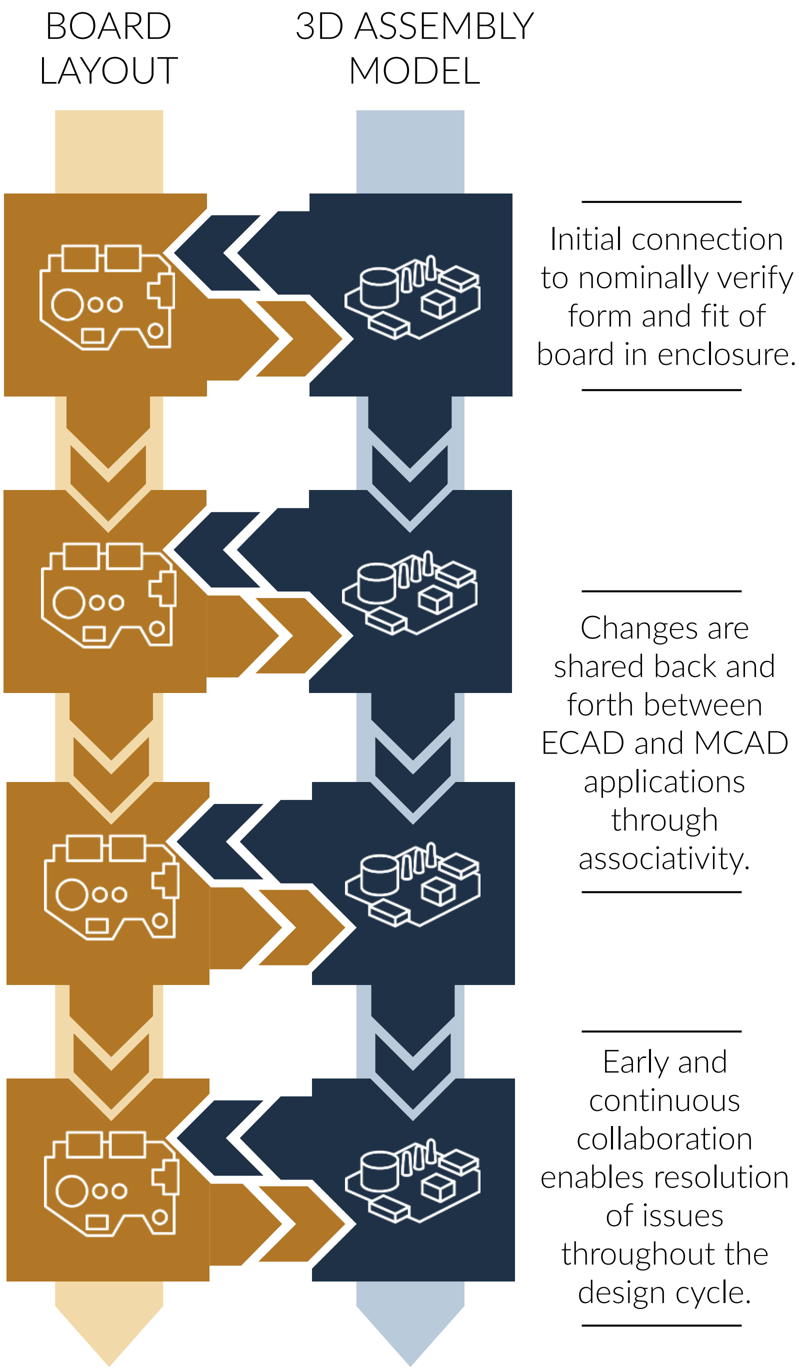


Figure 4: Illustration of the earlier and more frequent exchange of design changes between electrical engineers and mechanical engineers on board system design due to the novel approach.

THE NOVEL APPROACH TO THERMAL AND STRCTRAL SIMULATIONS

The capabilities of the novel approach also carry beneficial implications for engineers and analysts that need to conduct thermal and structural simulations early and throughout design.

The associativity of integrated pairs of MCAD and ECAD applications provides users a 3D assembly model of a board system they can keep up-to-date with the layout. When paired with analysis applications that are either associative with the MCAD application's 3D model, or directly integrated with the MCAD application, then users can propagate those changes to the simulation model.

The idea of synchronizing the simulation model with the MCAD 3D assembly model and ECAD layout of board systems enables key changes to development. It allows a simulation driven design approach where engineers can use analysis results to drive design decisions. This not only results in products that meet requirements more fully, but also allows the organization to avoid costly extra rounds of prototyping and testing. Again, this effort directly and closely aligns with engineering leadership's efforts to compress the development cycle of board systems.

The progressive technology enabler allows electrical and mechanical engineers to collaborate earlier and more continuously during development.

THE OUTCOME OF THE NOVEL APPROACH

- The novel approach of facilitating interaction between electrical and mechanical engineers relies on the associativity and interactive highlighting of integrated pairs of MCAD and ECAD applications.
- These capabilities allow electrical and mechanical engineers to share their design changes more continuously, with far less effort, and earlier in development.

- It also enables earlier thermal and structural simulations, resulting in better products and fewer prototypes.
- The novel approach aligns very closely with engineering leadership's efforts to compress the development cycle of board systems.

SUMMARY AND RECOMMENDATIONS

Today's products are undergoing a fundamental change, both in features and composition. Despite the increasing complexity of board systems, engineering leaders must find ways to further compress the development cycle.

SUMMARY

- The need to validate software against physical prototype electronic hardware is driving the compression of board system design.
- The exploding complexity of board systems acts as a counterbalance, making it more difficult to find gains in the design cycle.
- Upgrading the collaboration between electrical and mechanical engineers is an opportunity to further compress the development process, including: *planning and verifying board fit and form within the enclosure*, *predicting, adjusting and validating thermal performance* as well as *predicting, adjusting, and validating structural performance*.
- The established approach to electrical-mechanical collaboration relies on file-based exports and imports. The manual effort associated with the approach leads to the delay of collaboration between engineers.
- The novel approach to electrical-mechanical collaboration relies on associativity between integrated pairs of ECAD and MCAD applications. This automated effort leads to earlier and more frequent collaboration between engineers.

Improving how electrical and mechanical engineers collaborate is an opportunity to compress the design of board systems. The established approach, powered by file-based exports and imports, limits an organizations ability to realize that goal. The novel approach, based on associativity and interactive highlighting between integrated pairs of ECAD and MCAD applications, allows earlier and continuous collaboration.

RECOMMENDATIONS

- Review the timing of collaboration between electrical and mechanical engineers within your engineering organization. Determine if they occur early or late in the design cycle. Furthermore, identify if delays in the process are due to manual file-based exports and imports.
- Assess the impact of delayed collaboration between engineers. This usually manifests in missed milestones and deadlines as well as failed prototypes and respins during testing. Correlate the timing of collaboration between engineers with these outcomes.
- Investigate the associative and interactive highlighting capabilities of integrated pairs of ECAD and MCAD applications. Investigate whether these capabilities could enable earlier and more frequent collaboration amongst electrical and mechanical engineers.
- As appropriate, assemble a plan to adopt the novel approach to electrical-mechanical collaboration, including progressive enabling technologies in the form of integrated pairs of ECAD and MCAD applications. Include benefits such as time gains and avoiding costly issues such as respins.

The potential to compress the design of board systems is real. It is important, however, to assess how much improvement potential exists in your organization's process. Assess that potential by looking at how early and often electrical and mechanical engineers collaborate. Identify how much traditional technologies limit improvement.

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