THE 2021 SHIFT-LEFT STRATEGY FOR ELECTRONICS BENCHMARK REPORT

HOW PROGRESSIVE COMPANIES OVERCOME INCREASED COMPLEXITY IN MULTI-BOARD SYSTEMS

LIFECYCLE INSIGHTS

EXECUTIVE OVERVIEW

Market demand is rising dramatically for smart, connected products with software-enabled features. The result is a striking proliferation of electronics in everyday products. Such features also require more sophisticated electronics, resulting in increasingly complicated multi-board systems. These requirements introduce more risk to product development processes that now also have to run on shorter schedules.

Product development leaders are looking for solutions to these challenges. Some have found success in a shift-left strategy. This involves implementing new methods to: ensure system integration; boost design reuse; and employ digital prototyping during the verification, validation, and design phases of development. New processes aren't all that's required, however. This shift also requires careful change management.

To better understand how organizations are faring as they shift left, Lifecycle Insights conducted a survey-based research study, the 2021 Shift-Left Strategy for Electronics Systems Study. Survey respondents were subdivided into groups based on their adoption of progressive development methods. The results highlight that the most progressive organizations spend between $328,000 and $1,300,000 less in development funds than their least progressive counterparts.

This report discusses:

- the reasons manufacturing organizations are shifting left, including increased complexity in electronics board systems, design processes, and organizations;

- how Lifecycle Insights' 2021 Shift-Left Strategy for Electronics Systems Study benchmarked survey respondents to understand what sets the most progressive organizations apart from their peers; and
- how a shift-left strategy helps manage the costs and time involved with systems integration, design reuse, and digital prototyping tasks.

The manufacturing industry is currently undergoing a period of striking transformation. Organizations are looking for better ways to manage shorter schedules, smaller budgets, and more complex product requirements. This study reveals that taking a shift-left strategy offers companies distinct benefits that help mitigate these challenges.

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DRIVERS OF CHANGE

To understand the value of a shift-left strategy, it is important to first understand what is driving companies to consider this approach. These drivers provide critical insights into the challenges companies are facing—and the kind of return on investment (ROI) they hope to see from their improvements. The results of the 2021 Shift-Left Strategy for Electronics Systems Study provide several notable insights about companies' most pressing concerns.

INCREASING ELECTRONICS COMPLEXITY

To understand why so many executives were considering investments in product development improvements, Lifecycle Insights asked survey respondents about requirement changes in electronics systems. The shift toward smart, connected products is not only about including more electronics in various products. It's also about satisfying a larger number of competing, and often conflicting, requirements.

Survey respondents resoundingly agreed that the requirements for multi-board systems are becoming more complicated. More than two-thirds of survey respondents reported that requirements governing form factors or packaging are pushing engineers to design electronics into smaller, more confined spaces. At the same time, 74% of respondents stated that engineers must equip products with electronics that run at higher speeds to power smart, connected features.

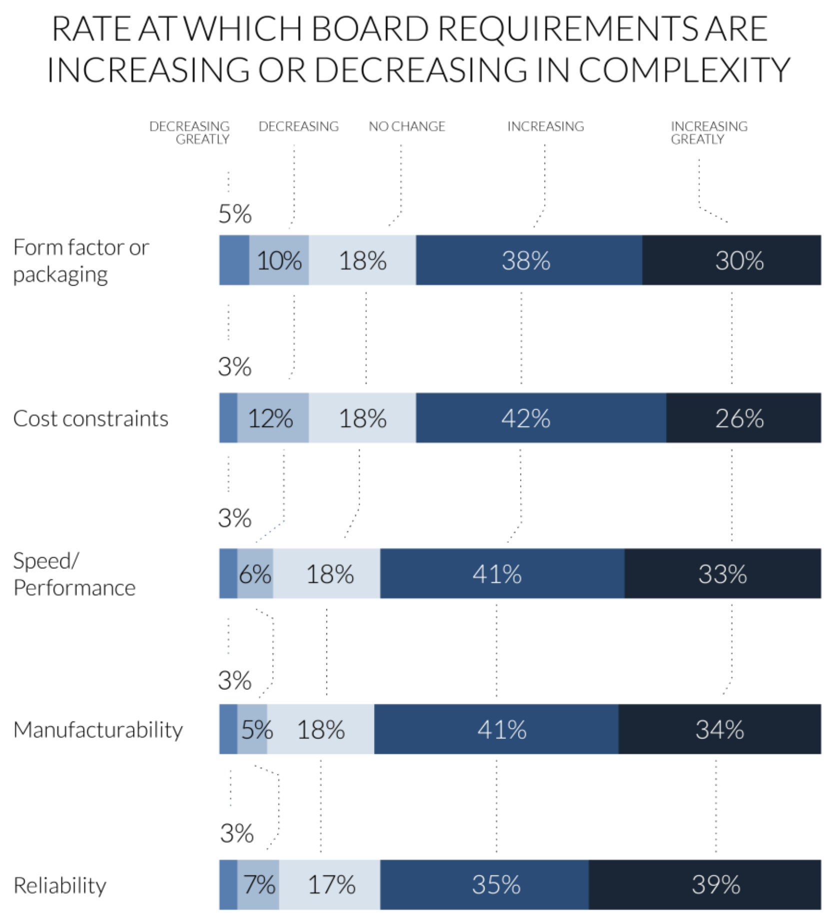


Figure 1: Study respondents cited significant increases in complexity across form, cost, speed, manufacturability, and reliability requirements.

Companies are not getting any breaks when it comes to business demands, either. Respondents noted that difficulties in satisfying cost and manufacturability constraints are increasing or increasing greatly. And finally, organizations are also struggling to support reliability. Seventy-four percent of respondents stated these requirements have become more challenging as demands for more durable products increase.

INCREASING BOARD SYSTEMS COMPLEXITY

The challenges resulting from increased complex and competing requirements manifest in very distinct ways. When asked about their board systems, a surprisingly high number of respondents reported their work was the most complex in the industry.

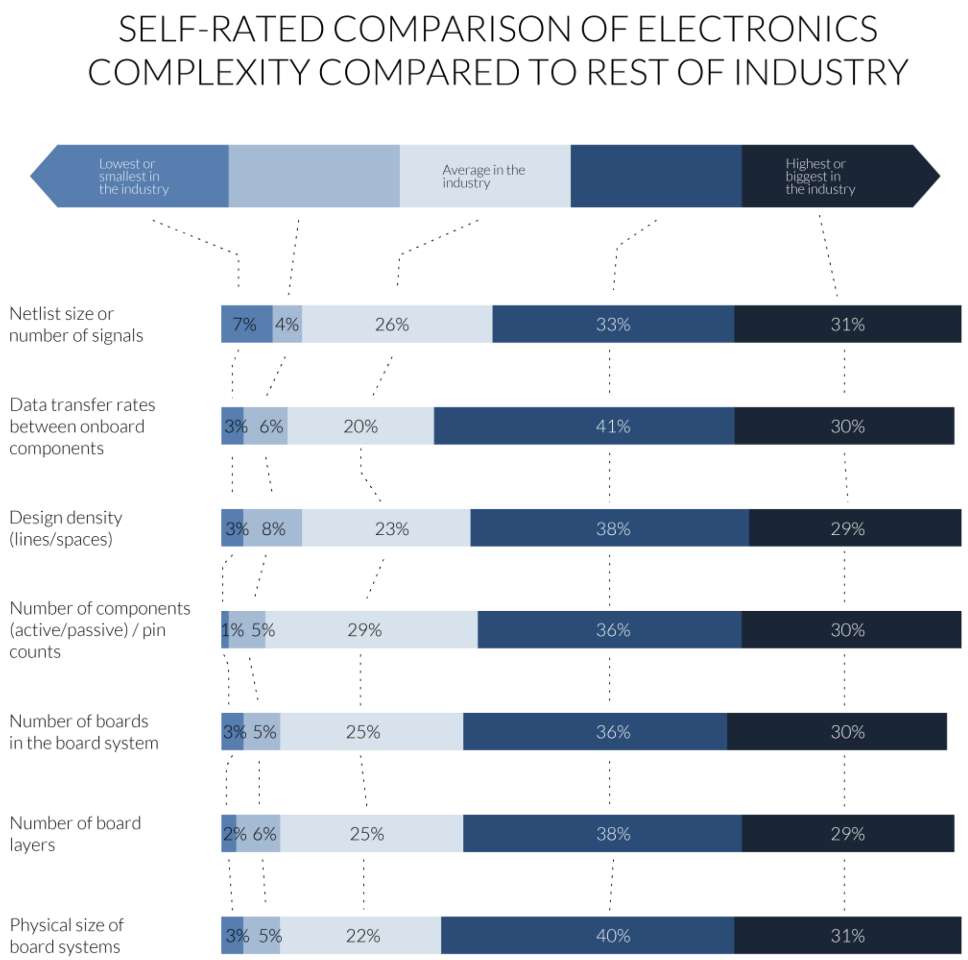


Figure 2: Study participants often rated their own electronics work as some of the most complicated in the industry.

Approximately 30% of all respondents stated their company was dealing with the greatest complexity in the:

- netlist size or number of signals,

- data transfer rates between onboard components,
- design density,
- number of components and pin counts,
- number of boards in the board system,
- number of board layers, and
- physical size of board systems.

The challenges of meeting all these new requirements have left engineers with the impression that their work is more complicated than everyone else's. Yet, they do not see that the rest of the industry has to manage more complexity right along with them. A system that was rated complex a mere five years ago is now likely considered simple.

The takeaway here is clear: More difficult and competing requirements on modern board systems are driving a tangible rise in the complexity of common electronics. Given the importance of electronics to smart, connected products, this trend is more than likely to continue well into the future.

INCREASING DESIGN PROCESS COMPLEXITY

Rising complexity affects all areas of product development, even the execution of processes. And that is exactly what the 2021 Shift-Left Strategy for Electronics Systems Study found.

Survey respondents reported increased complexity in system architecture development; logical and functional design; physical implementation, verification, and validation; and even in project or program management. These difficulties are a direct consequence of increased complexity in electronics systems that require more upfront planning and verification of performance and behaviors, among other things. Organizations that do not effectively manage complexity are more likely to experience negative outcomes, such as more change orders and respins, higher costs, and unnecessary delays.

RELATIVE CHANGE OF COMPLEXITY IN ELECTRONICS DESIGN PROCESSES

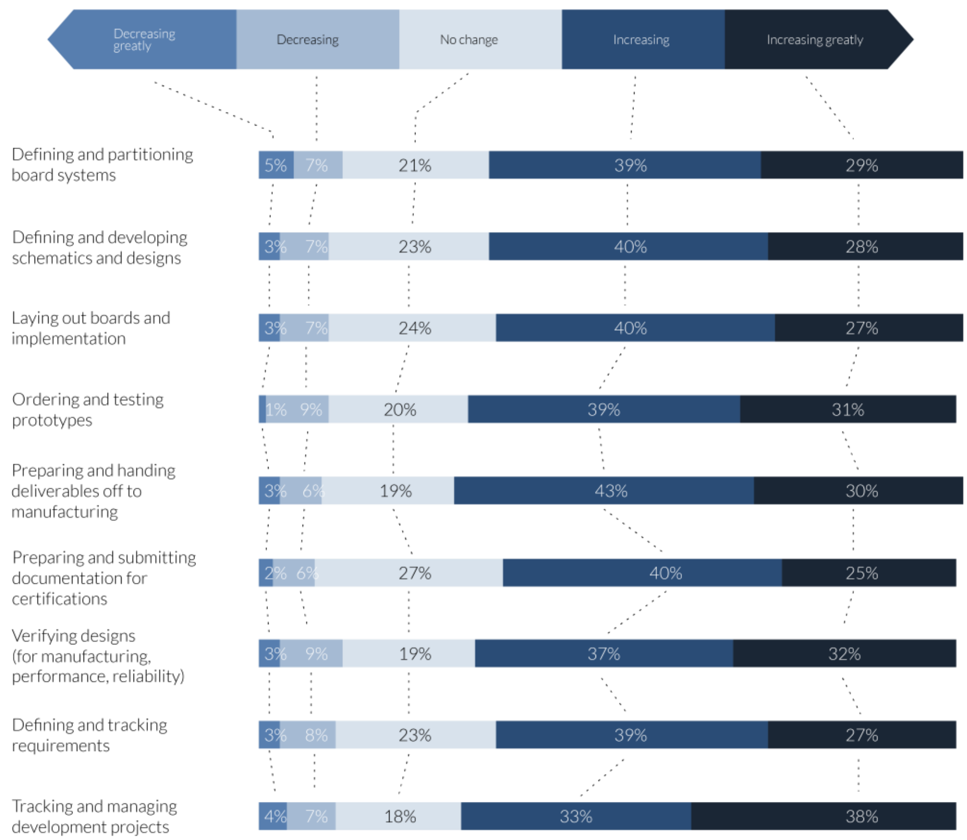


Figure 3: Study participants cited complexity that is increasing or increasing greatly in many steps of the electronics design process.

INCREASING ORGANIZATIONAL COMPLEXITY

The trend towards smart, connected products has transformed more than just electronics systems development. Manufacturers also have to deal with significant organizational changes that influence product development.

RELATIVE CHANGE IN ORGANIZATIONAL COMPLEXITY IN ELECTRONICS DEVELOPMENT

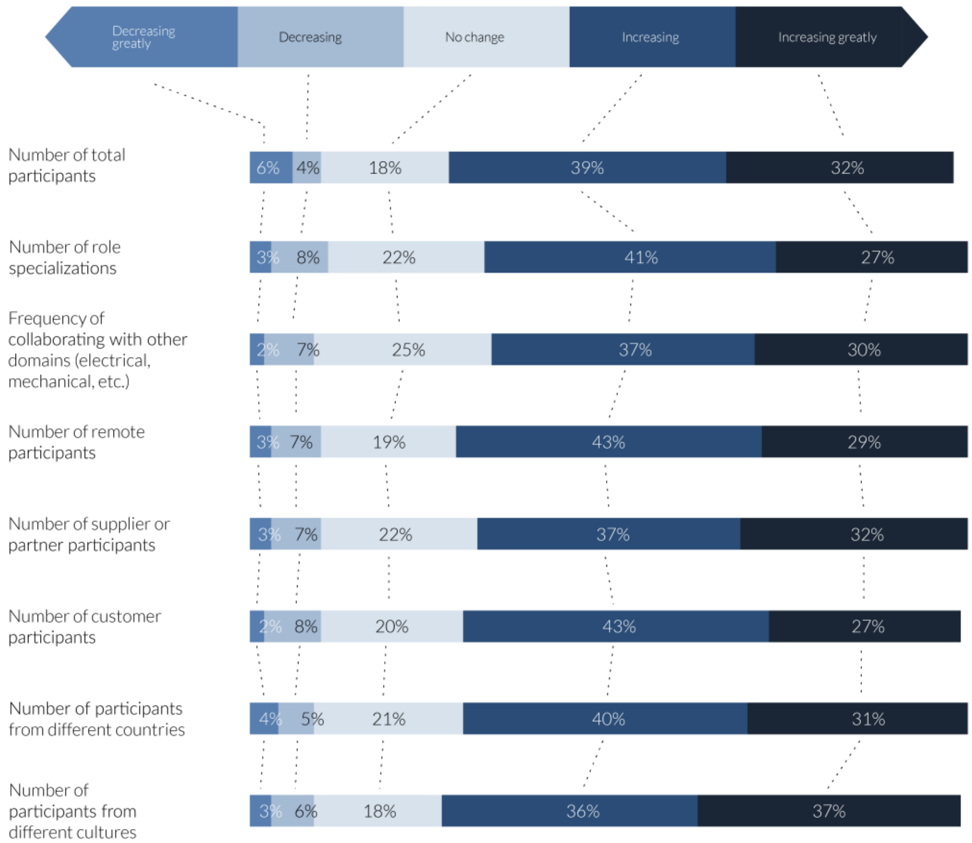


Figure 4: Study respondents stated that the organizational complexity of the electronics development process is accelerating with more participants across many phases.

Findings from the survey show many organizational factors are driving change. Respondents noted increasing complexity connected with the:

- number of total participants,
- number of role specializations,
- frequency of collaboration with other domains,
- number of remote participants,
- number of supplier or partner participants,
- number of customer participants,

- number of participants from different countries, and
- the number of participants from different cultures.

Manufacturing organizations must manage more people, both inside and outside of the company. Consequently, they have to support more frequent collaboration and communication. Furthermore, the survey results also reveal that more organizations have shifted to allow remote participation by key stakeholders across the board. Participants in nearly every functional department and across the supply chain—some of whom reside in distant regions—must find ways to work together to facilitate the development process. This change, which began several years ago but has accelerated over the past two years, represents a “new normal” that companies need to manage.

DRIVER TAKEAWAYS

There’s no doubt about it: Developing electronics systems has become more complicated. The electronics themselves are more complex, thanks to a more challenging, not to mention competing, range of requirements. The design process is also more difficult, and now participants are scattered across remote locations, making collaboration trickier. These are the drivers inspiring executives to pursue improvements.

BENCHMARKING METHODOLOGY

While some organizations may be struggling in response to these challenges, others are performing well. Lifecycle Insights explored this disparity by separating the respondents into groups and comparing them on key measures. This benchmarking analysis revealed important insights about the differences in practices that influence the groups' overall performance. This section describes how the study divided respondents into three distinct groups—least progressive, moderately progressive, and most progressive—and highlights the performance of each group.

FOCUSING ON THE MOST COMPLEX BOARD SYSTEMS

The study investigated how the adoption of progressive practices correlated with business performance. It is important to note, however, that the impact of progressive practices depends on the complexity of the board systems being developed. Advanced approaches have a limited return for the simplest board systems.

Therefore, the study sought to isolate the impact of progressive practices on the most complex board systems. Lifecycle Insights awarded points to respondents based on the following factors:

- netlist size or number of signals,

- data transfer rates between onboard components,
- design density (lines/spaces),
- number of components (active/passive) and pin counts,
- number of boards in the board system,
- number of board layers, and
- physical size of board systems.

These points were then summed into a board systems complexity index. Based on that index score, respondents were evenly split into four separate groups: low, moderate, high, and highest complexity. The low board complexity group was excluded from the analysis to better compare the ways organizations working on more complex electronics adopt progressive practices.

SEPARATING RESPONDENTS INTO GROUPS

Lifecycle Insights rated the remaining respondents based on the number of practices and capabilities they leveraged to deal with increased complexity. Respondents chose from:

- Seven practices or capabilities used to develop multi-board system architectures, reuse cross-board circuitry, and verify electronics systems at the system level.
- Five practices or capabilities used to develop and run simulations and then validate single and multiple electronics schematics.
- Four practices or capabilities for laying out boards and developing physical implementations of electronics systems, integrated circuit packages, and more.
- Six practices or capabilities used to check, simulate, verify, and validate manufacturability, enclosure or packing fit, and other key performance requirements.

Based on this analysis, respondents were split into three final groups: the lowest 40% were categorized as the least progressive, the middle 35% were considered moderately progressive, and the top 25% were named the most progressive organizations.

TOTALING SPEND ON RESPINS AND SYSTEM PROTOTYPES

Respins and prototypes are costly endeavors for manufacturers. Whether a particular product requires a single board or a multi-board system, engineers rely on prototypes to validate performance and requirements satisfaction. This is even more important given rising complexity. Prototyping is a crucial development stage in which all the design elements come together.

Yet, while prototypes are essential to the success of a product, companies must consider their financial implications. Each prototype represents a sunk cost in terms of its components, manufacturing, and testing. It also takes significant time to build out each prototype. So it is important to minimize the number of respins and prototypes for both single and multi-board systems.

Organizations that adopt more progressive practices are better positioned to reduce the number of respins and prototypes per project. That's why, before calculating gains realized by the most progressive organizations, it is important to total an organization's monetary spend on the two. To further refine the groups, Lifecycle Insights averaged the cost of a respin and electronics system prototype by each complexity group. The calculations extended to the total spend per project. Those averages are listed below.

PER-PROJECT MONETARY SPEND ON BOARD RESPINS AND MULTI-BOARD PROTOTYPES

BOARD COMPLEXITY	Average cost of a single board respin	Total spend on respins per project	Average cost of a multi-board system	Total spend on board system prototypes per project
Low	$11,954	$74,116	$22,297	$120,404
Moderate	$19,469	$120,708	$25,842	$139,546
High	$20,254	$125,576	$24,414	$131,834
Extreme	$21,113	$130,898	$27,326	$147,562

Figure 5: The cost of single-board respins and multi-board prototypes varies significantly by complexity, representing an opportunity to save development budget.

It should be mentioned that these calculations are based on an assumption of 6.2 respins or prototypes per project, an average drawn from over 1,650 respondents across six distinct Lifecycle Insights research studies administered over the past three years. Lifecycle Insights also used that data to forecast the total monetary spend on respins and prototypes based on the number of projects organizations take on each year.

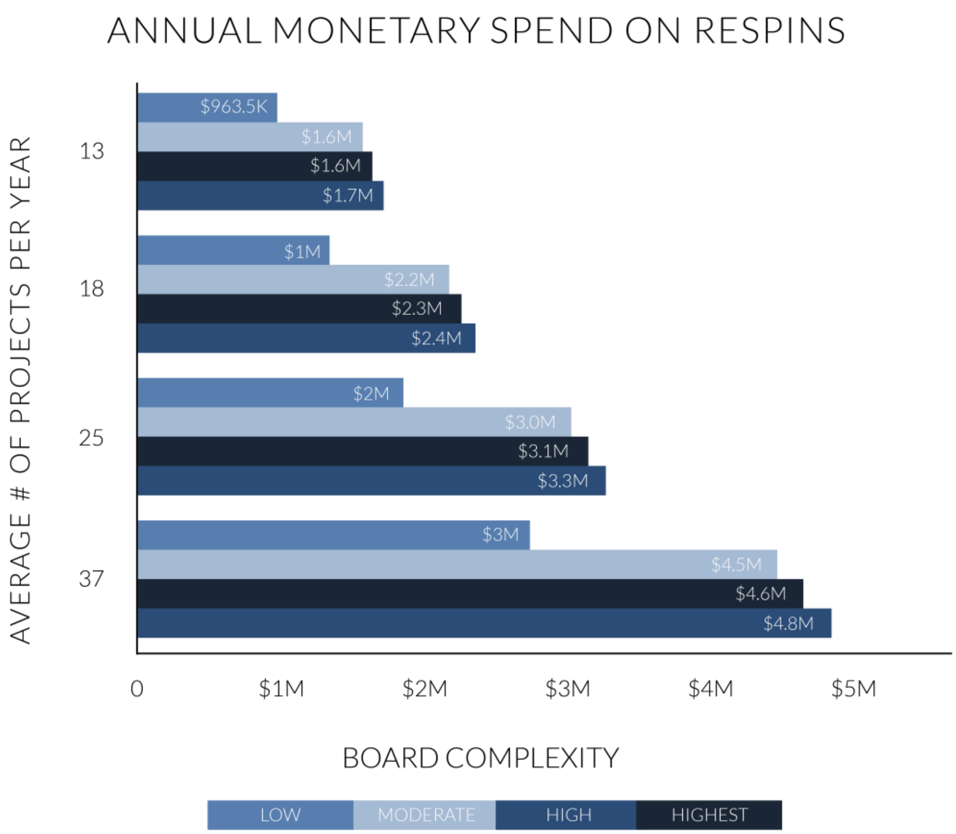


Figure 6: The annual monetary spend on board respins varies by complexity and number of development projects.

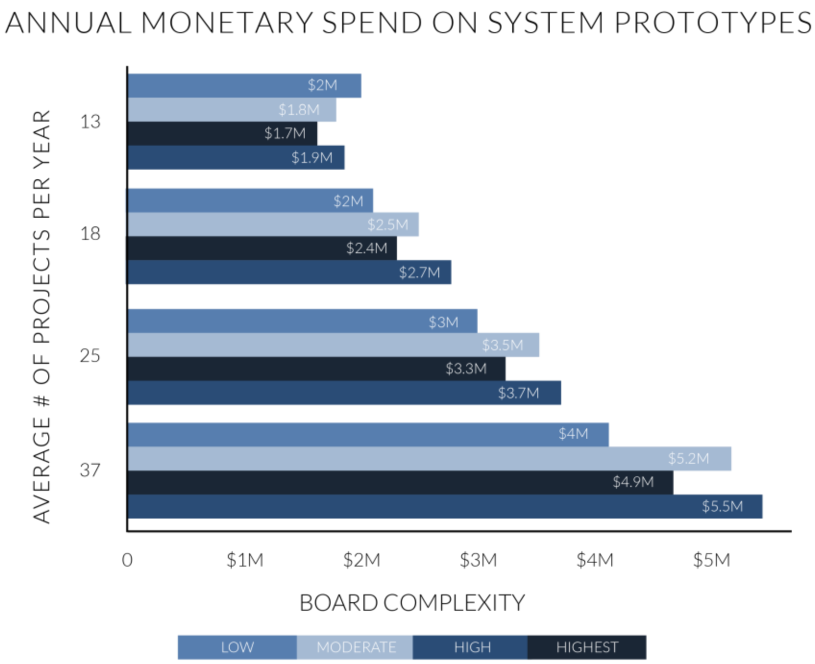


Figure 7: The annual monetary spend on multi-board system prototypes also varies by complexity and number of development projects.

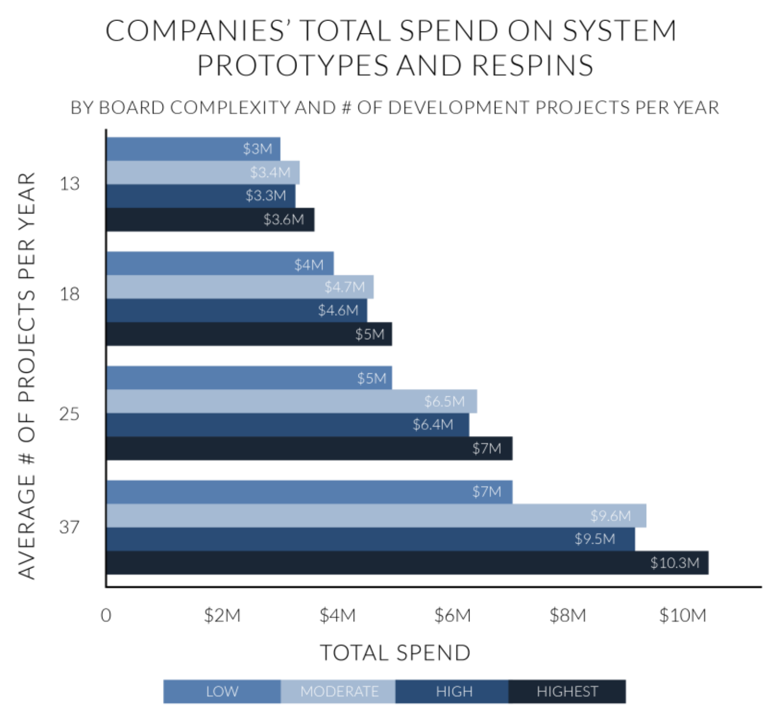


Figure 8: The annual, combined monetary spend on board respins and multi-board prototypes varies by complexity. This represents a significant investment in development projects.

Note that the average number of projects executed per year was calculated to be 23.2 across three years' worth of Lifecycle Insights studies. Based on those figures, the total spend on respins and prototypes ranges from $3,000,000 to $10,300,000.

COMPARING PERFORMANCE ACROSS GROUPS

The number of respins and prototypes executed per project is a metric that can illuminate the value of progressive approaches. Analysis of these measures showed that the most progressive organizations executed 5.5 respins and prototypes per project. The least progressive, comparatively, executed approximately 6.2 respins and prototypes per project. The most progressive enjoy a significant financial advantage due to their lower estimated total spend on respins and electronics prototypes.

By categorizing respondents into these key groups, it is apparent that the most progressive organizations experience tangible cost savings over the least progressive organizations.

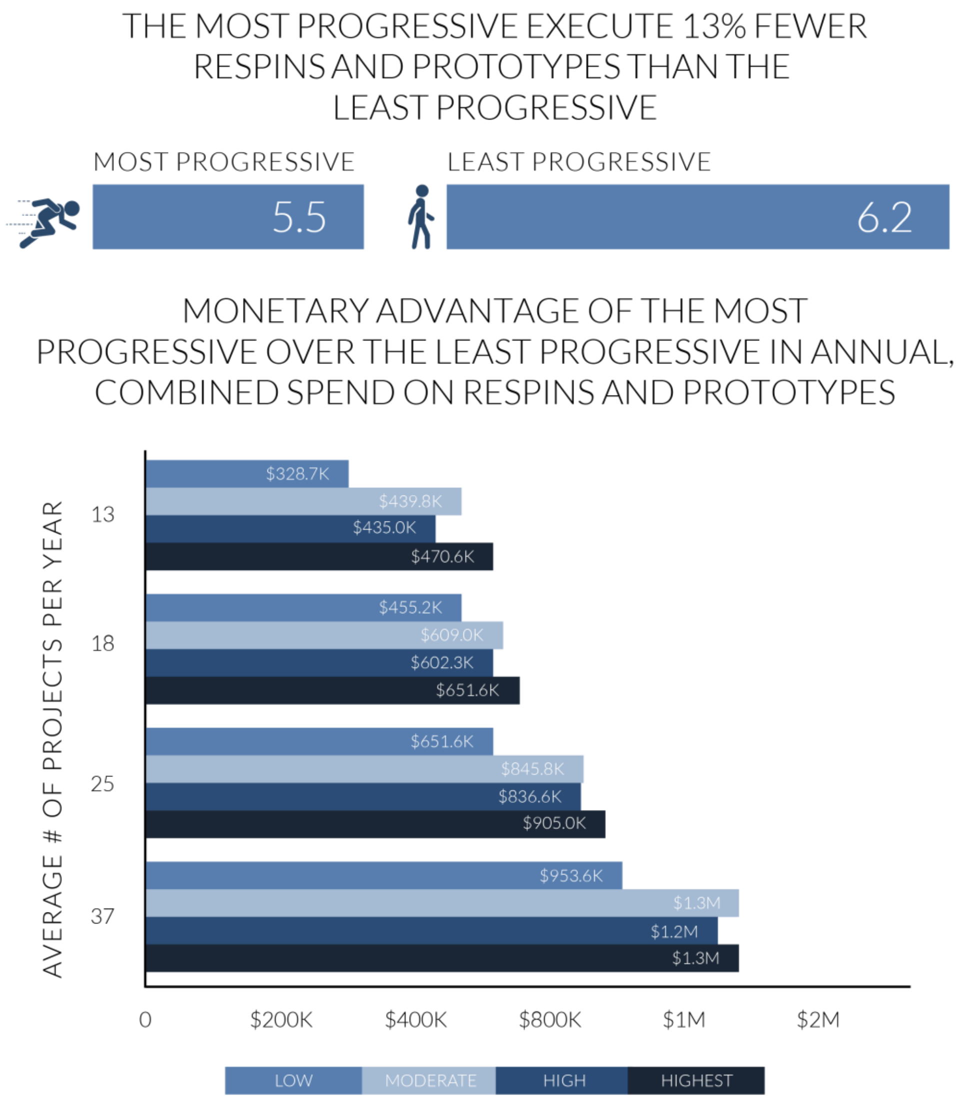
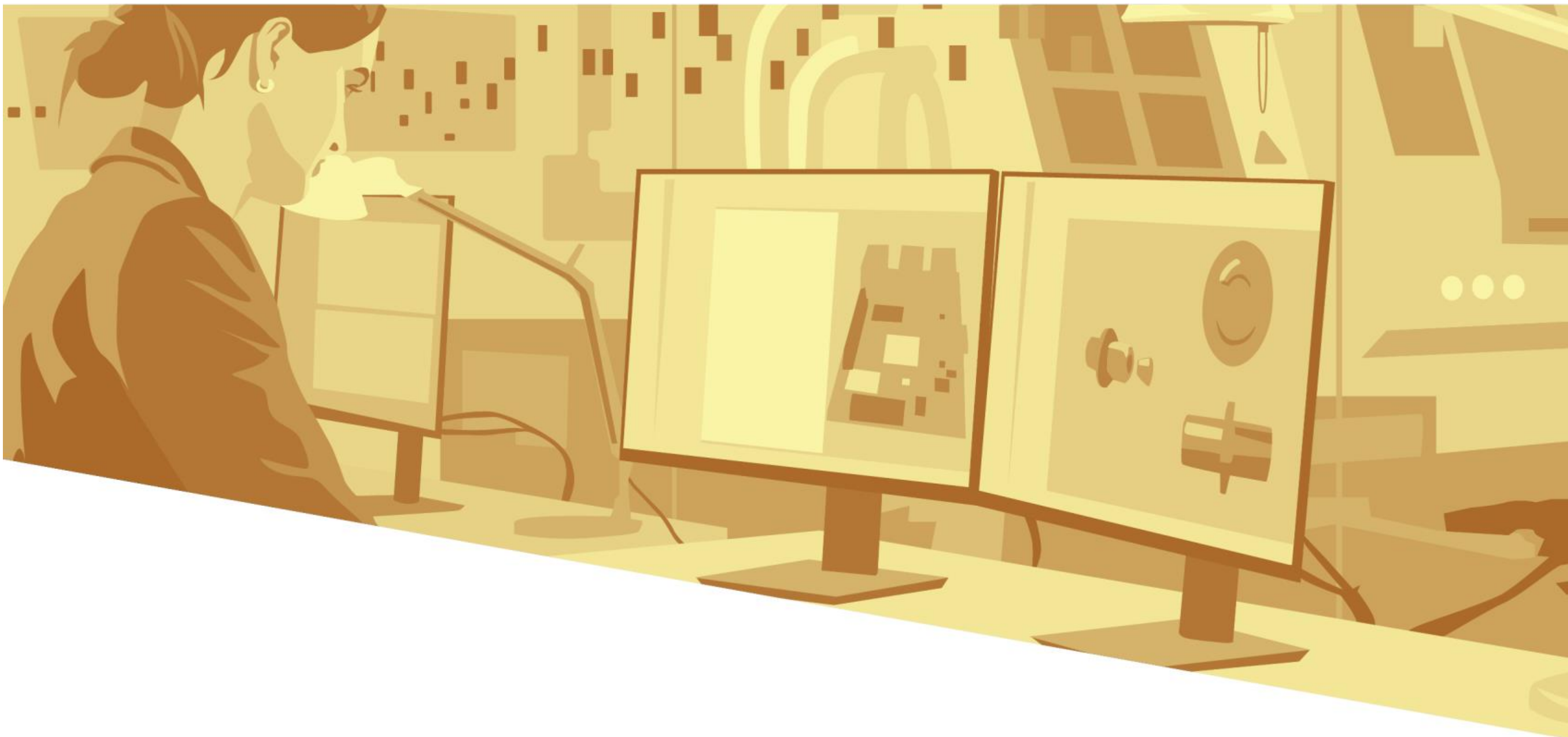


Figure 9: The most progressive experience a tangible and quantifiable advantage over the least progressive in annual monetary spend on respins and prototypes.



ENABLERS

Findings from Lifecycle Insights' 2021 Shift-Left Strategy for Electronics Systems Study suggest the transition to smart, connected products introduces dramatic increases in complexity into board systems, the development process, and even the design organizations themselves. The study's benchmark analysis reveals distinct differences in how much companies spend to develop board systems. The most progressive organizations are seeing significant savings compared to those in the least progressive group.

What might account for such differences? These kinds of performance gains are the direct result of tactical practices. This section discusses the types of practices each respondent group uses to design and develop electronic systems and how the most progressive practices enable greater success. The findings demonstrate that targeted investments to support system integration, design reuse, and digital prototyping all pay off.

SYSTEMS INTEGRATION

One of the most critical aspects of developing an electronics system is identifying the right architecture and subsystem design. Executing this stage of development correctly requires having the right level of detail. Engineers need to explore alternative approaches, collaborate with the right stakeholders, verify the performance of the architecture, and even perform trade studies to ensure they have the right design. Findings from the 2021 Shift-Left Strategy for Electronics Systems Study show significant differences in the respondent groups' practices concerning systems integration.

USE OF ELECTRONICS SYSTEMS-SPECIFIC PRACTICES BY RESPONDENT GROUP

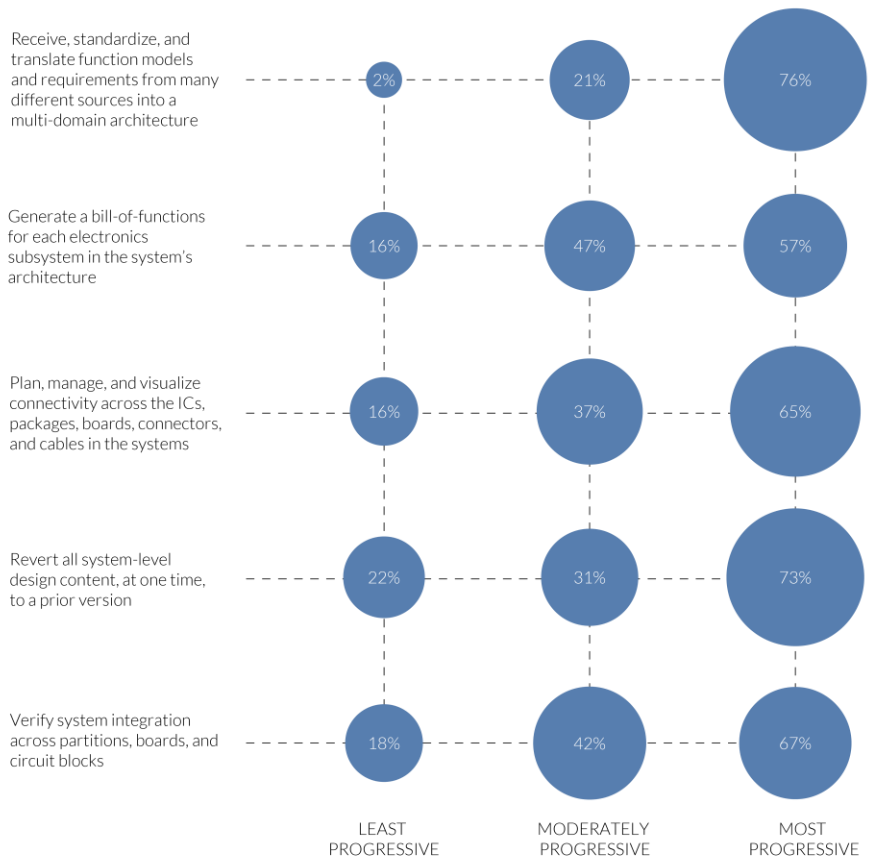


Figure 10: The most progressive employ five system-focused practices, enabling them to select the right architecture, validate performance, perform and visualize checks, and digitally verify integration.

Each of the following practices supports a shift-left strategy, which, in turn, translates into fewer system-level prototypes. It is easy to see how the use of such practices helps the most progressive organizations save money and time on respins and prototypes.

- **Receive, standardize, and translate functional models and requirements from many different sources into a multi-domain architecture.** Given the complexity of today's multi-board systems, more suppliers, partners, and customers are participating in the systems definition phase of design. All stakeholders will need to contribute their own work to the definition, and that information may come in different formats with varying levels of complexity. Organizations that have this capability can quickly merge work from different stakeholders into a single architecture. The design team can also easily incorporate changes to the definition as they occur.

- **Generate a bill of functions for each electronics subsystem in the system architecture.** The systems development process translates requirements into functions, allocating those functions to the logical or physical architecture of subsystems. Given the sheer volume of requirements and functions for today's products, this becomes a highly complex task, especially considering the work-in-process phases of design. Automating this translational task eliminates human error while quickly and easily producing the necessary deliverable.
- **Plan, manage, and visualize connectivity across the integrated circuits (ICs), packages, boards, connectors, and cables in the system.** Today's multi-board systems must carry signals across and through many interfaces. Developing and exploring alternative architectures happens at a record pace. It often seems impossible to plan, manage, and track connectivity as iterations occur. This capability automates such tasks, allowing engineers to visualize connectivity even in the middle of the work-in-process phase of development.
- **Revert all systems-level design content, at one time, to a prior version. Any design process is reliant on exploration.** When the design team is exploring different architectures, engineers need the ability to easily step back to a prior configuration of the system. This capability supports that process without requiring the engineer to manually track changes, enabling them to focus on what's most important: Finding the best possible design.
- **Verify systems integration across partitions, boards, and circuit blocks.** The trend of breaking electronics down into smaller subsystems is unlikely to slow down anytime soon. Integration within the system is key, but it can be challenging to track how interfaces change and how integration persists when changes are made. This capability automates the verification of integration within the system and permits engineers to explore changes and conduct checks when necessary.

Developing the right system architecture is essential for producing today's complex electronics systems. The most progressive organizations employ these capabilities at dramatically higher rates than the other cohorts. As a result, they require fewer respins and system-level prototypes during the development process, saving significant time and costs.

DESIGN REUSE

As the amount of complexity continues to grow in electronics systems, design reuse is not only attractive but valuable. Engineers can take the known, good designs for complete subsystems, boards, packages, or circuitry, and use them to help accelerate the development of a new system.

Design reuse, however, can come with pitfalls. Any reused components must still be verified within the context of the new system—and these components can lack the full context of their initial use. Just like system integration capabilities, design reuse practices varied dramatically across the different respondent groups.

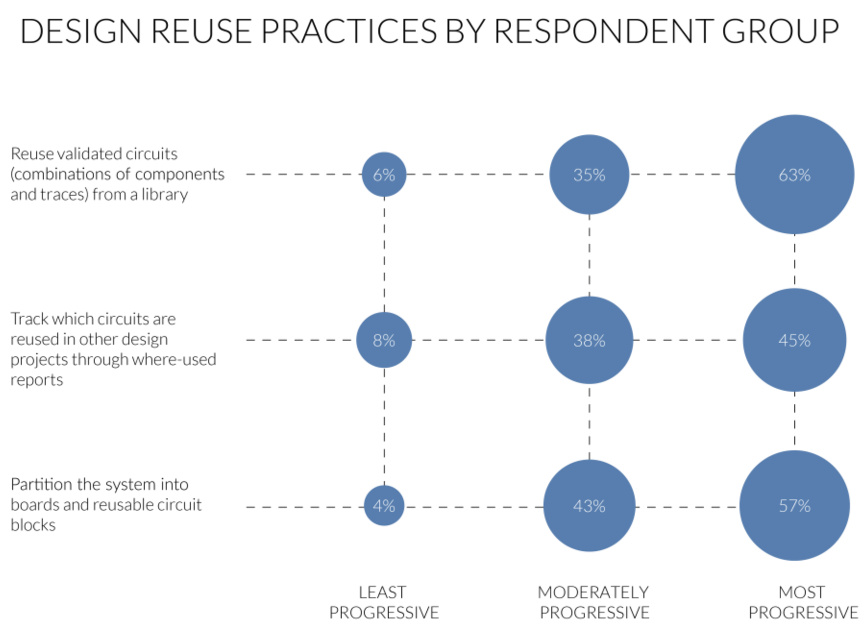


Figure 11: The most progressive employ three design reuse practices that allow them to accelerate the design process with validated circuitry, understand where else that circuitry is reused, and partition systems into reusable blocks.

Each of the following design reuse practices supports a shift-left strategy. Once again, the use of these practices translates into fewer respins and system-level prototypes.

- **Reuse validated circuitry (combinations of components and traces) from a library.** Isolating the set of components and traces that equate to a specific function, especially if they span multiple boards, has not always been possible. The inability to find and use that set of components and traces has stymied design reuse in electronics. But new technological capabilities now make this possible. The focus isn't on simply reusing a component or even the whole board, however. The focus is on the reuse of a functional set of circuitry, even if it spans multiple boards. This can help accelerate the development process, especially in the face of rising complexity.
- **Track which circuits are reused in other design projects through where-used reports.** Understanding where and how boards, components, and subsystems have been used in previous designs can also be challenging. This information constrains how they might be modified to suit a particular purpose in a new design. Having the capability to quickly and easily understand how a component is used in other designs provides that crucial context. Informed engineers can then make better decisions about holistic reuse or simply using that component as a starting point for an entirely new design.
- **Partition the system into boards and reusable circuit blocks.** The ability to cut up existing systems into items that can be reused is a major enabler. Traditionally, this has been done either at the board, subsystem, or component level. Partitioning capabilities, however, allow engineers to identify functional circuits, composed of components and traces, so they can feed and enable the reuse of such circuitry in other designs.

Manufacturing organizations need to manage increasing complexity in new products, but their schedules are shrinking. Design reuse helps them do more in less time. It is clear that the most progressive organizations are leveraging these capabilities at a far higher rate and seeing significant advantages as a result.

DIGITAL PROTOTYPING

Another critical aspect of developing modern electronics systems is the ability to verify and validate them. It is how organizations ensure that all requirements are fulfilled, and the system performs as expected. Protracted physical prototyping and testing at the systems level, as demonstrated by this study's findings, is a major stumbling block in development. The most progressive organizations have adopted digital prototyping practices that reduce the number of physical respins and prototypes during development.

USE OF DIGITAL PROTOTYPING PRACTICES
BY RESPONDENT GROUP

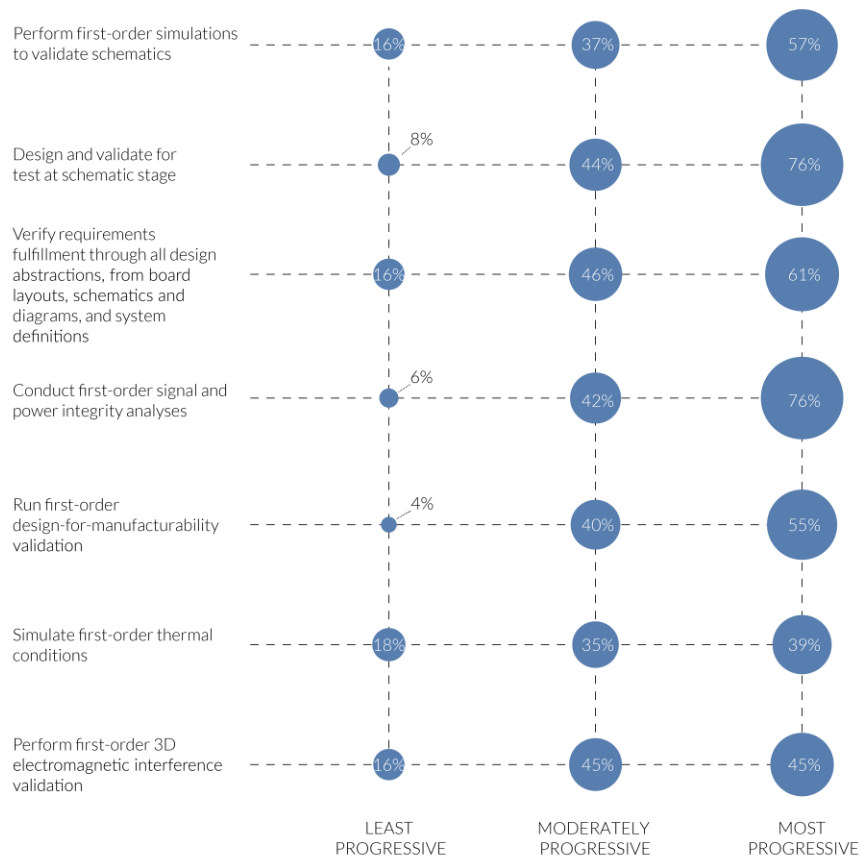


Figure 12: The most progressive leverage seven practices to digitally prototype their designs, allowing them to understand performance, behaviors, and requirements satisfaction long before building physical board or system prototypes.

Each of the following digital prototyping practices supports a shift-left strategy. Once again, the use of these practices translates into fewer respins and system-level prototypes in the most progressive organizations.

- **Design engineers perform first-order simulations to validate their schematics.** Today's electronic systems will be exposed to a variety of environments, so companies need to check their behavior and performance against a range of different engineering physics. Specialists can conduct simulations, analyses, and checks digitally, but their activities usually represent a final check before prototyping and testing. These late-stage checks often result in respins or multiple rounds of systems-level prototyping. Engineers in the most progressive companies provide verification much earlier in the process by:

- conducting first-quarter signal and power integrity analyses;
- simulating first-quarter thermal conditions;
- performing first-order three-dimensional electromagnetic interference validation; and
- running first-order design for manufacturing validation.

Running these checks earlier allows engineers to make better, more informed decisions.

- **Design and validate for test at schematic stage.** Test cases for electronics systems are expansive, covering every aspect of a broad range of operating conditions they might experience. Frequently, the first time these systems are checked against requirements is during the actual test. If engineers design and validate at the schematic stage when they are far less constrained, they can explore alternative approaches more freely and verify requirements are met far earlier.
- **Verify requirements fulfillment through all design abstractions, from board layouts, schematics, diagrams, and system definitions.** Ultimately, the electronics systems must satisfy requirements. As shown in Lifecycle Insights' 2021 Shift-Left Strategy for Electronics Systems Study, those requirements are becoming more difficult to fulfill, especially as they now frequently compete with one another. Verifying requirements late in the design process leaves little room for engineers to adjust and accommodate changes. Thus, the capability to verify requirements fulfillment through all design abstractions, from board layouts to system definitions, is incredibly powerful. This dramatically increases the likelihood that the system-level prototype will pass with fewer rounds of testing.

Once again, the most progressive organizations are leveraging digital prototyping capabilities, including a range of simulations, analyses, and tests, much earlier in the development process than their least progressive counterparts. In doing so, they are in a better position to ensure their electronics systems meet all requirements and perform as expected.

ENABLER TAKEAWAYS

The use of more progressive approaches pays off for manufacturing organizations. As demonstrated by the findings in Lifecycle Insights' 2021 Shift-Left Strategy for Electronics Systems Study, the most progressive organizations employ advanced practices in systems integration, design reuse, and digital prototyping. In doing so, they can realize dramatic cost savings compared to the least progressive group.

SUMMARY AND RECOMMENDATIONS

The complexity of today's smart, connected products is expected to continue to rise. This rapid proliferation of electronics systems in products brings a multitude of challenges to manufacturing organizations. Companies face greater demand for complex multi-board systems that must satisfy complicated and sometimes competing requirements. Organizations benefit when they adopt progressive approaches to optimize product design and development.

Lifecycle Insights fielded the 2021 Shift-Left Strategy for Electronics Systems Study to better understand how, where, and why manufacturing organizations were moving toward a shift-left strategy in product development. The study divided the respondents into three key groups, based on the complexity of the electronics in their products, their total spend on respins and prototypes, and the progressive practices they currently use.

The findings revealed:

- Engineering organizations face several distinct drivers of change, including increasing complexity in electronics systems, board systems, the design process, and their development organizations.
- The most progressive organizations, which have adopted a shift-left strategy to improve product development, are performing at a much

higher level than their least progressive peers. As a result, they enjoy significant savings in terms of fewer respins and prototypes.

- Organizations benefit from capabilities that support strong systems integration, design reuse, and digital prototyping. There were stark differences between the most and least progressive organizations when it came to employing these capabilities. This can account for the most progressive organizations' savings during the product development process.

Based on these findings, Lifecycle Insights recommends that manufacturing organizations do the following to make improvements to the product development process:

- Assess how electronics systems requirements are changing. Are they increasingly in competition with one another?
- Determine how the complexity of electronics systems is changing. Identify how electronics complexity may be impacting process and organizational complexity.
- Calculate the total spend on respins and system-level prototyping and testing. Evaluate how much the company might save if it could shave off up to 17% of those costs.
- Adopt system integration capabilities to support the exploration and development of system architectures.
- Employ design reuse capabilities to accelerate the development process.
- Leverage engineer-powered, first-order simulations, analyses, and checks to verify and validate that all requirements are satisfied and the system is performing as expected earlier in the design process.

Chad Jackson leads Lifecycle Insights' research and thought leadership programs, attends and speaks at industry events, and reviews emerging technology solutions.

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EMAIL - contact@lifecycleinsights.com

SITE - www.lifecycleinsights.com