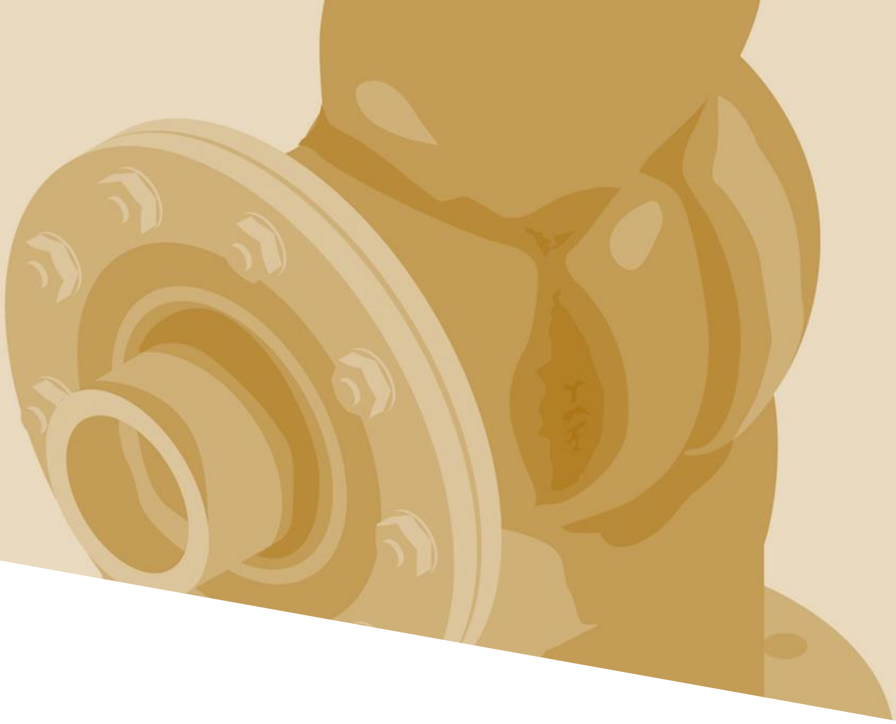
THE FOUR BENEFITS OF SIMULATION-DRIVEN DESIGN

LIFECYCLE INSIGHTS



EXECUTIVE OVERVIEW

Designing products has never been easy and, frankly, it never will. While this reality is due to an array of factors, one is more fundamental to engineering: manipulating designs to achieve performance goals. Engineers tweak variables to keep the maximum stress of components under defined thresholds. They manipulate fluid chamber geometry to eliminate energy-wasting eddies. They compare forced-convection and natural-convection approaches to see which dissipates heat more efficiently, keeping temperatures below given limits. Design challenges are infinitely varied.

In recent years, the challenge of manipulating designs to achieve performance goals and produce innovative products has become more daunting. Engineers must work with increasingly complicated requirements. Constraints are more aggressive. Design goals are more stringent, sometimes even competing with one another. Schedules are tighter. Development budgets are flat or shrinking. Nevertheless, some approaches offer hope. Simulation-driven design is one of them. The idea is to employ simulation early, often, and throughout the design cycle to make better-informed decisions, explore more alternatives, and verify performance.

Of course, simulation-driven design is not new. Engineering organizations have considered this initiative for years, even decades. Some have implemented such practices while others receded from the effort. Adoption is low overall. Today, this initiative is genuinely feasible, far more than in the past. Fresh technological advancements address the prior barriers and challenges, opening new possibilities for companies to differentiate the development of products. The time to capitalize on this opportunity is now, though — many see simulation-driven design as a means to make a difference. Organizations looking to reduce costs, accelerate schedules, and develop more innovative products must act.

This report presents the business benefits of taking a simulation-driven design approach, enabled by engineers, across the design cycle.

- The first section outlines people, process, and technology changes that businesses must facilitate when they adopt a simulation-driven design initiative. It highlights the fundamentals of this strategy, discusses the benefits of near-real-time design analysis, examines the CAD and CAE expertise required, and summarizes vital simulation-enabling capabilities.
- The second section identifies four core sources of value for simulation-driven design: increased productivity and efficiency gains from identifying first-feasible designs, increasing innovation thanks to advanced design exploration, making better decisions earlier by conducting early simulations, and avoiding costly late-stage errors.
- The third and final section makes recommendations to organizations that want to adopt a simulation-driven design approach.

Designing products has never been more challenging. Simulation-driven design in engineers' toolboxes will help get the job done. The time to capitalize on this opportunity is now, though.

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PEOPLE, PROCESS, AND TECHNOLOGY

Simulation-driven design allows organizations to decrease costs, expedite development, and generate more breakthrough products. In order to capitalize on this opportunity, organizations must deploy such an initiative in the right way, including tactical changes. This section outlines people-, process-, and technology-associated changes to implement simulation-driven design successfully.

DEFINING SIMULATION-DRIVEN DESIGN

The core concept of simulation-driven design is that analysis leads design decisions. Very early in the design process, this translates to comparing the performance of different design concepts and ideas. In the middle of it, it means using analysis to refine designs and size them. Toward the end, it means checking to make sure that requirements are satisfied.

From a resourcing perspective, such efforts are powered by engineers independently gaining insight through analyses. They gain insight during design, empowering better decisions. Expert analysts are qualified, but they often have deep queues of verification and validation work that leave them little time to take on new responsibilities in the design cycle.

CHANGES TO PRACTICES AND PROCESSES

Changes to practices and processes are crucial to enabling initiatives. Updated practices define the how, when, and what of an individual stakeholder's actions. New processes define how multiple stakeholders work together.

In the context of simulation-driven design, processes do not change. The major stages of the design cycle still include concept design, detailed design, verification and validation, and prototyping and testing. Therefore, executives avoid process-related disruptions when adopting simulation-driven design. However, engineers use several new practices, and there are implications for expert analysts. Modified or new practices include the following:

- When organizations employ simulation-driven design early, engineers conduct fast, simple, directional analyses to facilitate informed, quick, impactful decisions. Such simulations allow engineers to compare two designs to identify which performs better against specified criteria. Design A might be stiffer, resisting a load. Design B might be lower cost and avoid excitation. Engineers, armed with this knowledge, make better decisions.
- Simulation-driven design in the middle of the design process gives more directional guidance to engineers. It allows them to size designs to, say, determine the thickness of a rib or the depth of a pocket. This helps engineers make better decisions as they refine designs.
- Directional analyses offer more guidance than a best guess or quick spreadsheet calculation. The accuracy of these simulations is not, and does not need to be, at the same level of fidelity as analyses conducted by expert analysts during verification and validation.
- Late in the design cycle but before verification and validation, engineers use analyses to get progressively closer to requirement targets. Engineers refine designs as they progress in the design cycle, shifting designs closer and closer to requirement objectives. Simulations at this stage of the design cycle are not simple and directional but rather more accurate and absolute.
- Analyses in simulation-driven design do not eliminate the need for expert simulation or physical testing and prototyping, which are essential and distinctly separate tools.
- Analyses conducted by engineers during the design cycle increase the likelihood that designs will pass the expert simulations of

verification and validation at a higher rate. Expert analysts can automate these compliance-style simulations.

- Expert analysts focus their efforts and expertise on the more complex but beneficial full-scale, highly complex analyses. The company realizes more value from expert analysts' skills and knowledge. Directional analyses followed by expert simulations accelerate the entire design process.

In summary, the adoption of simulation-driven design requires little to no process change. There are, however, numerous changes to engineering practices with some implications for expert analysts.

CHANGES TO SKILLS AND KNOWLEDGE

As with any new initiative, simulation-driven design requires specific skills and knowledge. Engineers must build their knowledge in three areas:

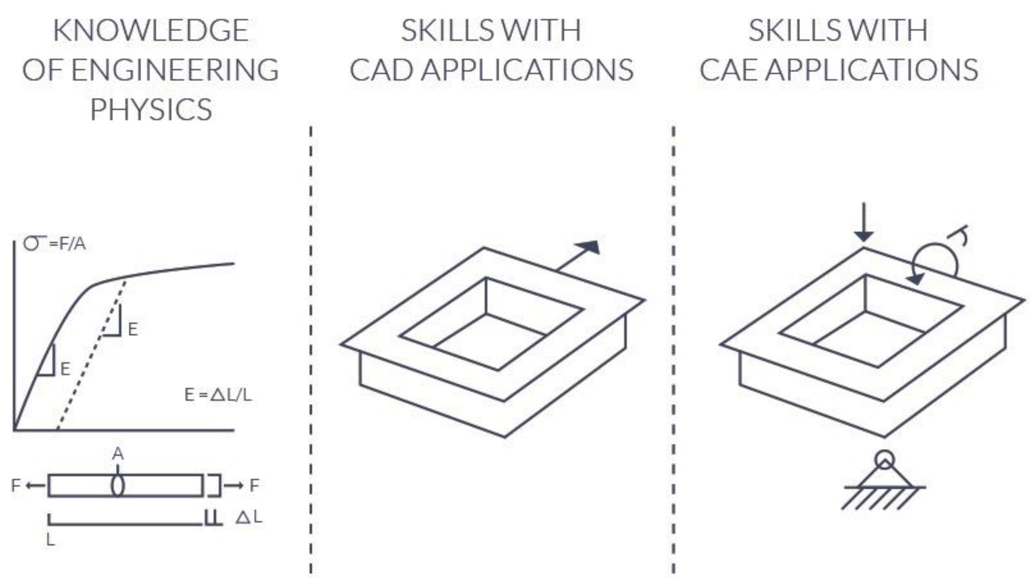


Figure 1: Engineers need skills and knowledge in three separate areas to succeed in a simulation-driven design initiative.

1. **Understanding engineering physics.** When engineers run a simulation, they receive analysis results. Accurately interpreting these results is critical. Engineers must be able to comprehend analysis outcomes and what they mean for their design. To do so, they need an understanding of many different aspects of engineering physics—statics, dynamics, and thermodynamics, to name a few. Without this background knowledge, engineers lack the context to understand the

consequences of results. They could make the wrong decision because they do not know the difference between, for example, shear and von Mises stresses.

2. Skills with CAD applications to make modifications to geometry. Engineers use computer-aided design (CAD) software to create geometric models of assemblies and components. They build models using specific methods, such as parametric modeling or direct modeling, that capture design intent. In simulation-driven design, engineers change models based on analysis results. Therefore, engineers need to understand the implications of any geometry modifications to the model.
3. Skills with CAE applications to apply loads and boundary conditions. Computer-aided engineering (CAE) software simulates a product's performance in its intended operating environment. Such analyses require setup, including the application of loads, boundary conditions, and materials. Each of these criteria—and others—directly affects the accuracy and applicability of the results in subtle ways. Engineers must understand how these nuances affect simulation outcomes.
4. Knowledge of analysis methods: the depreciated skill. In the past, knowledge of analysis methods was critical to simulation-driven design. Nuances of simulation algorithms directly affected the accuracy of results. A finite element mesh that was too coarse might miss a peak stress, undermining the impact of the entire simulation. Simulation users needed this knowledge. Fast forward to today, and things have changed. New analysis solution algorithms now automate and track the convergence of simulation results. For example, a structural application will progressively increase the density of a finite element mesh, tracking the peak stress until it reaches a stable measurement. For a wide variety of engineering physics, such automation and tracking capabilities are an integral part of analysis solutions. As a result, engineers do not need to understand the fundamentals of many simulation methods. These technologies relieve engineers of this burden while delivering accurate results.

KEY TECHNOLOGICAL ENABLERS

It is imperative to find the right technological tools for simulation-driven design initiatives. Consequently, upon applying simulation to the design process, businesses should source a solution with the following capabilities:

Automated, Intelligent Setup

Automation is always useful in accelerating a simulation process. To power simulation-driven design, it is invaluable. Once the minimum required inputs are defined, solutions with these capabilities automatically begin

- solving the analysis, employing the right kind of solver;
- refining the model parameters to converge on an accurate answer;
- and presenting the results, preferably in a real-time, progressively revealed manner.

This set of capabilities is advanced, yet it is key to engineers' use of simulation during design. It aids engineers in the process and provides a shortcut to the most immediate results. Analysis solutions with automated, intelligent setup to enable simulation-driven design initiatives should be strongly considered.

Near-Real-Time Results Changes

Making changes and exploring alternatives are fundamental aspects of designing products. When the costs of investigating options are high, either in terms of time or budget, engineers fall back on experience, manual calculations, and conservative decision-making. They often dismiss a universe of design options because they lack insight into how such alternatives would perform.

The best analysis solutions for simulation-driven design recognize the reality that exploration is key. They facilitate it. They deliver functionality that reruns analyses as engineers change geometry, variables, materials, and many other design inputs. The simulations run in the background, updating and presenting the new results to engineers. As design changes are made, the results of the simulation update seconds later.

The near-real-time nature of this capability is incredibly important. It shows engineers how their changes impact the design by allowing them to interact with the design in a live environment. When the cost of exploring options and alternatives is so cheap, engineers are encouraged to more fully understand the design space, leading to more innovative designs. They get insight fast. They make better decisions. Analysis solutions with real-time results changes to enable simulation-driven design initiatives should be strongly considered.

Controlled Accuracy

The application of simulation-driven design calls for increased accuracy as a design progresses through the design cycle. Early on, simulations can be fast, simple, and directional. Late in the process, they must be accurate and absolute.

Ideally, the simulation solution that powers a simulation-driven design initiative allows engineers to control the accuracy of the analysis results. In this way, they can specify the level of accuracy that matches the task at hand without switching to a different solution.

Multi-CAD Support

Designs often come from various sources, including suppliers, partners, and customers. These stakeholders invariably use different CAD solutions to develop designs. Engineers not only integrate models from external applications into their designs but also conduct analyses on them. Consequently, engineers must be able to run simulations in a CAD-agnostic way.

Modern analysis solutions allow engineers to open such models natively, without the hassle of cleaning up translated geometry. This capability allows engineers to incorporate foreign models into simulations quickly and easily. Analysis solutions with multi-CAD support to enable simulation-driven design initiatives should be strongly considered.

Direct and Parametric Modeling

As noted in “Real-Time Results Changes,” design is fundamentally about change. Engineers design products by exploring new ideas and concepts until a feasible design emerges or until they find a better, potentially optimal, design. To do that, engineers need modeling capabilities that power super-fast changes as well as capture deep design intent. This need for modification is true of native models and foreign ones coming from other CAD solutions.

The modern answer for these needs lies in direct modeling and parametric modeling. Direct modeling allows engineers to grab geometry and then push, pull, or drag it into the desired shape. Parametric modeling allows engineers to progressively build up geometry using features, dimensions, parameters, equations, and relationships. Analysis solutions with both direct and parametric modeling capabilities to enable simulation-driven design initiatives should be strongly considered.

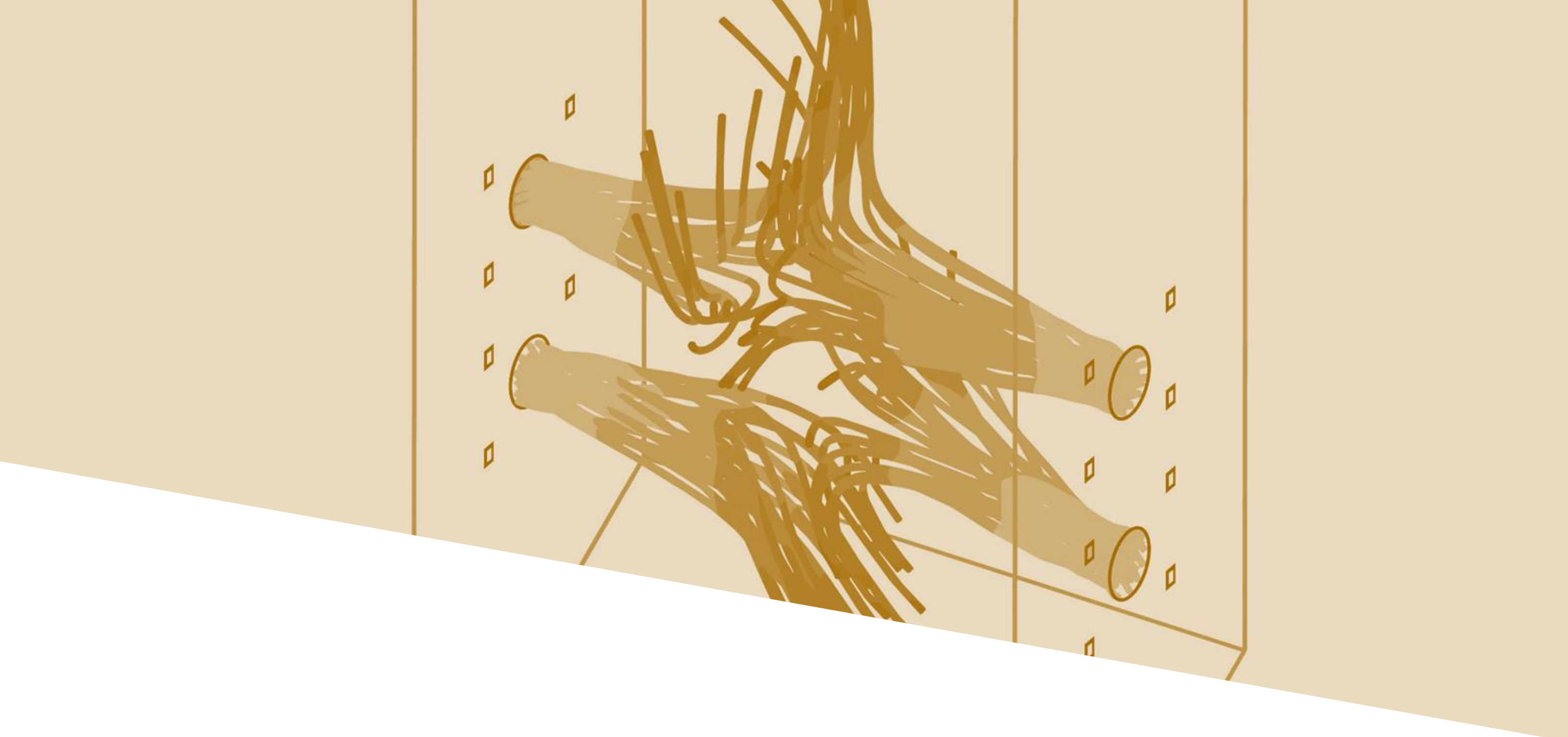
Design Exploration and Optimization

For some designs, engineers don’t want to find only the first feasible design—they want to find a significantly better design. This demand might be applicable, for example, to a critical heavy structural component where taking weight out counts or to a heat sink where maximizing heat dissipation through convection is vital.

While manual exploration is an option, there are better capabilities. Some analysis solutions offer design exploration as well as design optimization functionality.

- With design exploration, engineers define which variables or parameters to vary and which measures to track. The solution varies the variables or parameters, reporting back to engineers on how the measures changed. This functionality provides deeper knowledge of how each variable affects the measured outcome. Armed with such insight, engineers make better-informed decisions.
- With design optimization, engineers define which variables or parameters to vary, which goals to minimize or maximize, and the limits of other measures. The solution explores changes, calculates the sensitivity of the goals and constraints to design changes, and then makes educated guesses about how to improve the design. These optimizations can yield far better designs.

Both capabilities can significantly impact engineers' effectiveness. Analysis solutions with design exploration and optimization capabilities to enable simulation-driven design initiatives should be strongly considered.



SOURCES OF VALUE

From developing market-disruptive breakthroughs to dramatically cutting prototyping and testing expenses, simulation-driven design delivers real value in a variety of ways. Organizations can adapt it to the nuances of the business, industry, or specific product. This section breaks down the benefits of this initiative into four areas.

FINDING FIRST-FEASIBLE DESIGNS FASTER

Not every design needs to be optimal. In today's hectic, time-compressed schedules, engineers don't have the time to optimize every single design. Instead, they must develop feasible designs as soon as possible. How engineers get to feasible designs is critically important because it so intimately affects how long it takes.

In the traditional approach, engineers develop a design and run a quick performance check with hand or spreadsheet calculations. Sometimes these checks are accurate. Sometimes they aren't. Engineers don't truly understand if their designs meet performance requirements until the analysis phase or prototyping and testing. Too often, the designs fail. Engineers modify the design, perform hand or spreadsheet calculations again, and initiate more simulations or tests. This cycle repeats until they find feasible designs. This approach is inefficient and slow. It wastes the time of engineers, expert analysts, and testing engineers.

Using the simulation-driven design approach, engineers independently gain deep, actionable insights into the performance of designs. They don't need to involve expert analysts or testing engineers. With such insight, engineers make better decisions to guide modifications into a feasible zone of performance. With feasible designs, engineers hand their work off to expert analysts, where it passes simulation verification, and then to test engineers, where it passes prototype tests. Overall, engineers uncover a feasible design far more quickly without taking up the time of expert analysts or testing engineers.

Figure 2 compares these two approaches. Finding first-feasible designs more quickly is the first source of value of simulation-driven design.

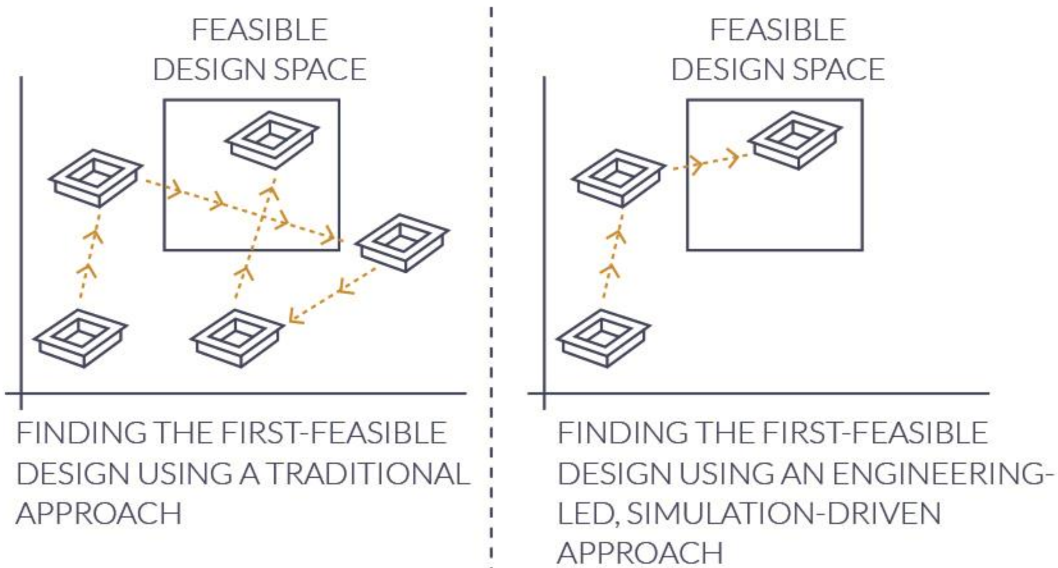


Figure 2: Simulation-driven design allows engineers to chart a faster, more direct path to finding feasible designs.

BOOSTING INNOVATION THROUGH MORE EXPLORATION

While engineers often need to find a first-feasible design quickly, investing time and effort pays off for some designs. Some designs have more of an impact on the final product than others. A component may make up a significant proportion of the product's weight. An assembly method may comprise a large portion of the product cost. Gaining insight into the trade-offs between requirements and constraints is crucial in these cases. Engineers need to take the time and effort to explore the design space fully.

The traditional approach is for engineers to wait to work with time-constrained expert analysts to run simulations on a limited set of designs. Based on the results, the engineers and expert analysts guess at ways to improve the design or whole new design spaces to explore. The challenge with this approach is the deep queue of work for expert analysts. Such collaboration becomes a stunted back-and-forth affair. There are often long breaks due to switching between projects.

Using the simulation-driven design approach, engineers explore more design concepts, ideas, and alternatives for two reasons. First, the analysis solutions are incredibly fast, giving near-instant feedback on performance. Second, engineers can explore more designs on their own, eliminating exchanges with expert analysts and test engineers. Engineers rapidly modify their designs, get simulation results, and move on in remarkably short timeframes. They gain deeper understanding of the trade-off between design variables and performance. This greater insight is the payoff of independent digital experimentation.

Figure 3 compares these two approaches. Uncovering more innovative designs through more exploration is the second source of value of simulation-driven design.

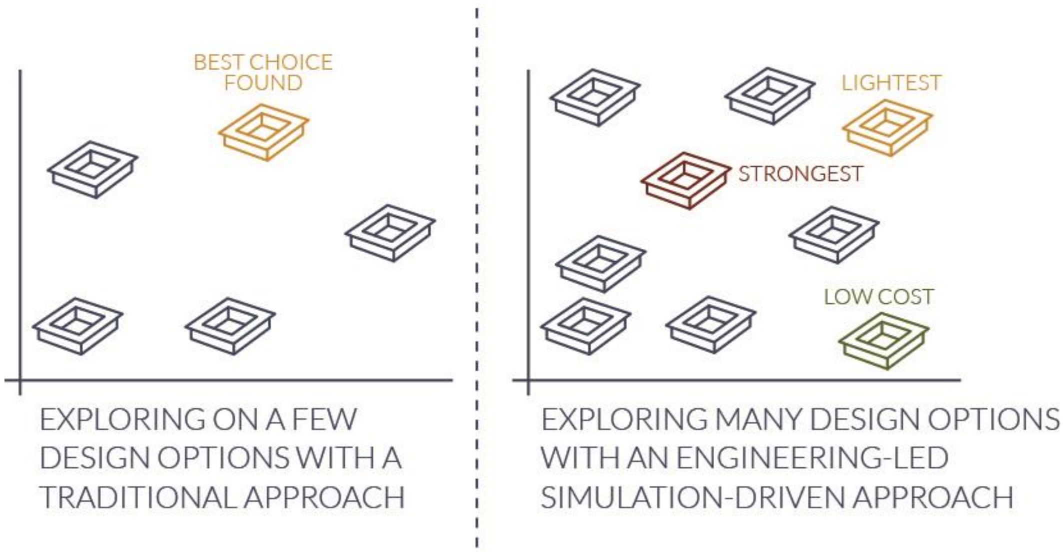


Figure 3: Simulation-driven design delivers more insight into the trade-offs between design variables and requirements, allowing engineers to choose more innovation options for designs.

MAKING BETTER DECISIONS EARLIER

When it comes to making design decisions, timing matters. Early in the cycle, engineers have flexibility in making choices because surrounding components and assembles are not yet locked in. Late in the cycle, however, engineers' choices are highly constrained. Too big of a modification causes a cascade of changes across the entire product. Companies can't afford that kind of disruption late in development. Instead, engineers must find compromises and half-measures to make things work. Given this reality, it is important for engineers to make well-informed decisions *early* in the design cycle instead of *late*.

Using the traditional approach, engineers gain marginal insight from their hand or spreadsheet calculations. They gain accurate insight into performance only when expert analysts conduct simulations or when they test prototypes. Both occur late in the development process. By that point, the range of options for modifications is narrow. Furthermore, a lack of insight early means engineers miss entirely new branches of potential design choices that are more feasible overall.

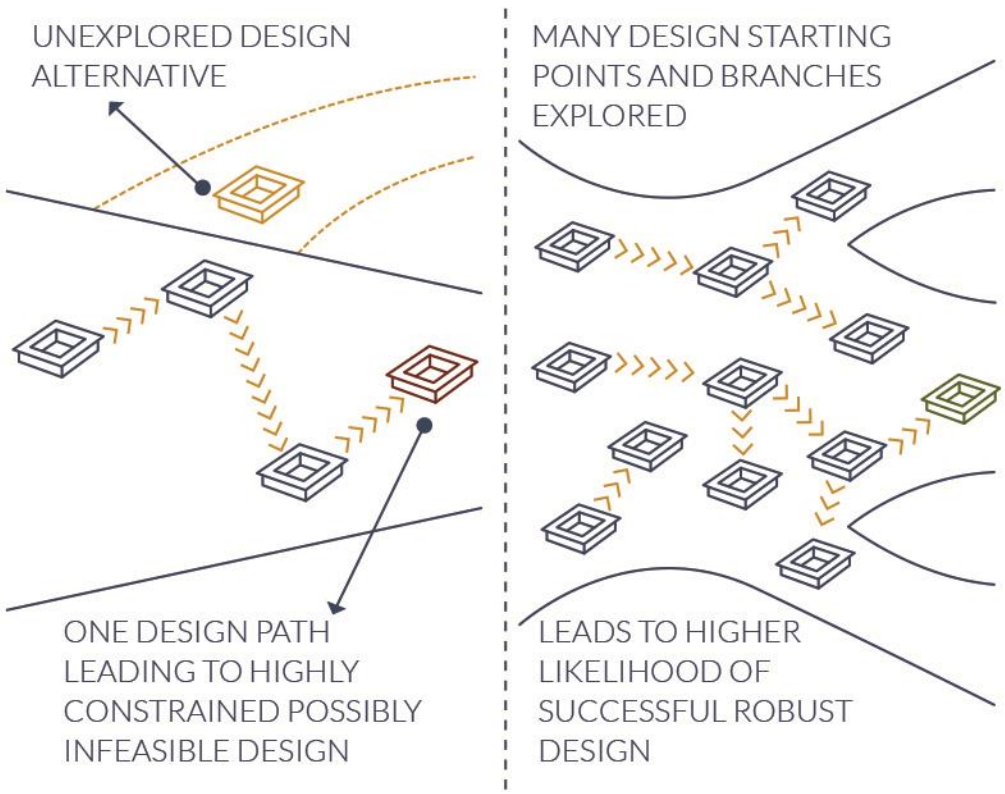


Figure 4: Simulation-driven design gives more insight to engineers, allowing them to make better decisions early.

Using the simulation-driven design approach, engineers gain accurate insight early in the design cycle, independently from expert analysts and test engineers. They can thoroughly explore design options or find the first feasible design fast. They uncover robust design options that represent better choices or expose poor choices that would fail later in the development cycle.

Figure 4 compares these two approaches. Making better decisions earlier in the design cycle, when there is more decision-making freedom, is the third source of value of simulation-driven design.

AVOIDING ERRORS AND DISRUPTION

All too often, design errors come back to haunt engineers. An issue early in the design cycle manifests later as a problem in development. This mistake can result in a failed prototype in testing, significant scrap on the manufacturing floor, an engineering change order, a lost customer, or all of the above. Each of these issues could come back to an engineer's desk, disrupting their day because they must drop their current project to resolve the present, more pressing issue.

Using the traditional approach, engineers use hand and spreadsheet calculations for performance checks that may or may not expose design issues. If left unchecked, the problem proceeds unnoticed to verification and validation and then to prototyping and testing. If missed, the flaw passes design release where it causes havoc in manufacturing, planning, and full production.

Using the simulation-driven design approach, engineers conduct analyses that catch design issues early in the design cycle before they cause problems for the company and significantly disrupt the engineering team. This also means that the company avoids costly, time-consuming repercussions.

Figure 5 compares these two approaches. Avoiding errors and disruption for engineers by catching design issues early is the fourth source of value of simulation-driven design.

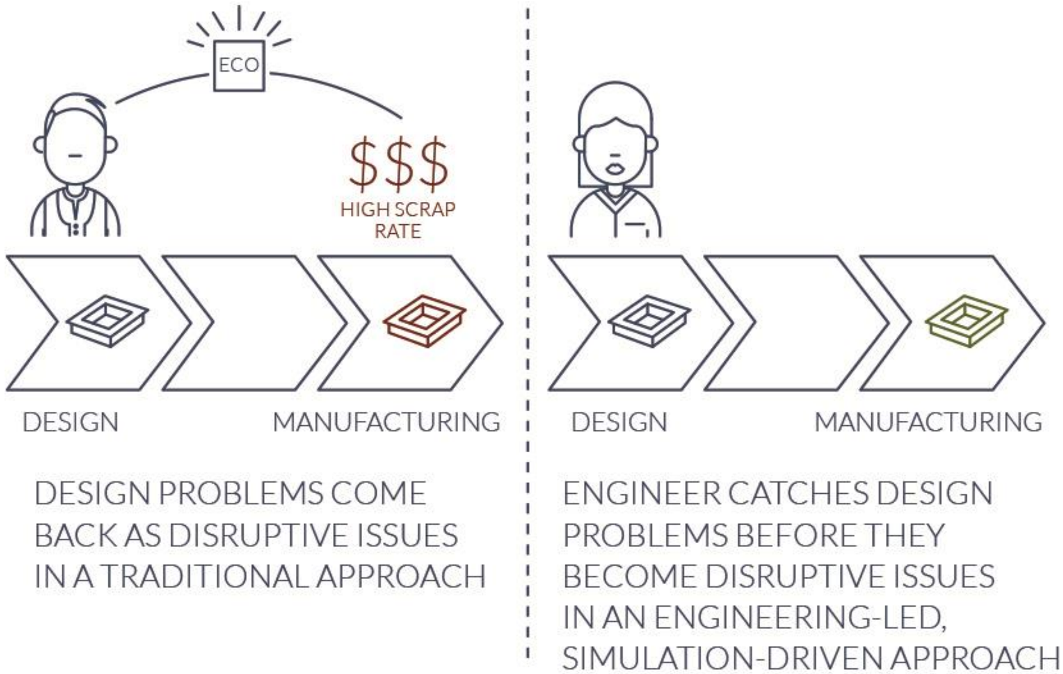
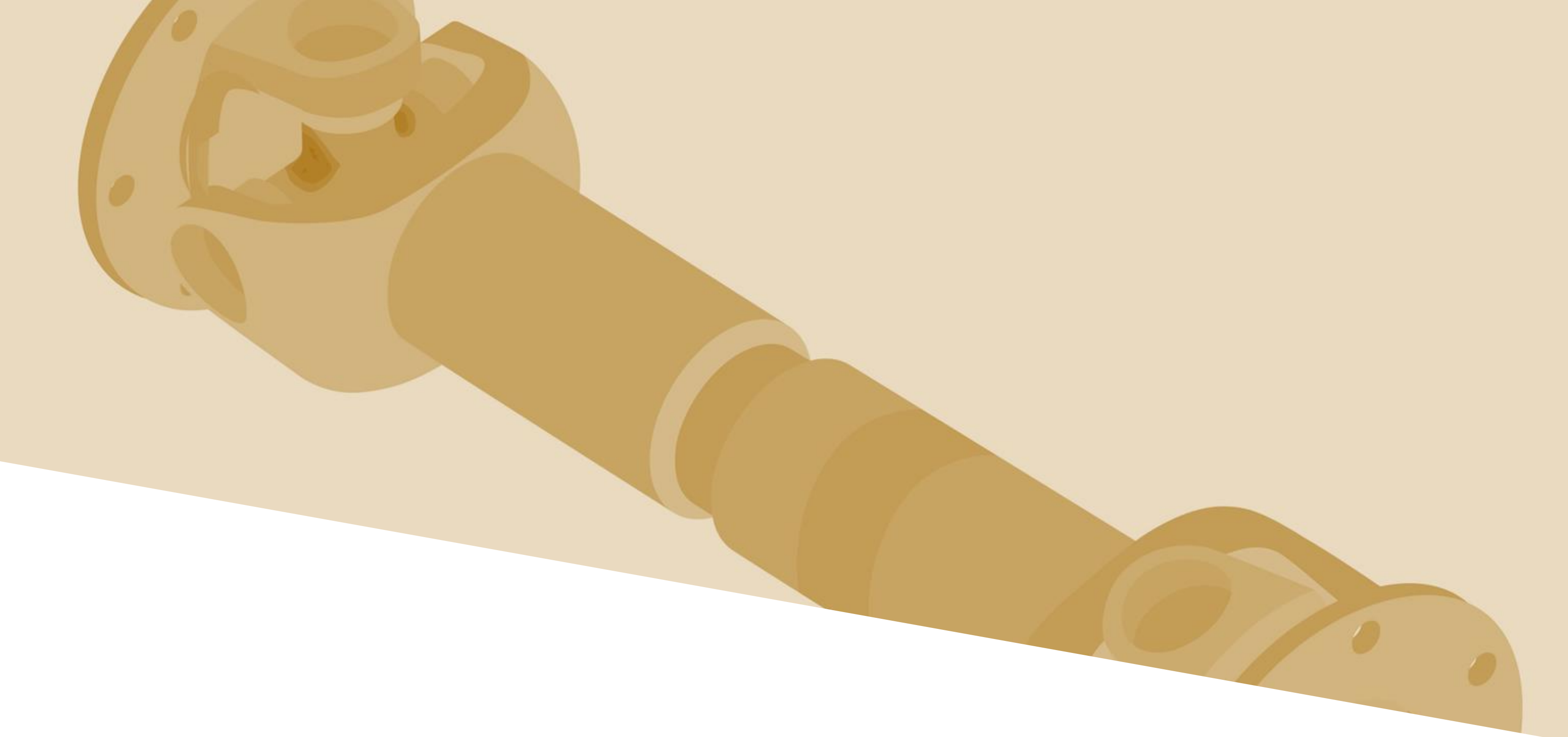


Figure 5: Simulation-driven design allows engineers to catch errors and issues early, before they manifest as disruptions downstream.



SUMMARY AND RECOMMENDATIONS

Designing products has always been, and always will be, a challenge. One of the fundamental reasons for this is that it is necessary to manipulate designs to produce a measured, tangible performance result. Today, engineers face increasingly complicated requirements as well as shrinking budgets and schedules. In response to these issues, some engineering executives are turning to simulation-driven design: the application of engineer-led analysis early, often, and throughout the design cycle to make better-informed decisions and explore more alternatives. This report presents the business-wide benefits of taking a simulation-driven design approach.

SUMMARY

- Using a simulation-driven design approach, engineers conduct analyses to drive design decisions across the design cycle and development process.
- Simulation-driven design is not new. Overall adoption is low. Fresh technological advances address prior barriers and challenges. This initiative represents a new opportunity to differentiate. However, it is not sustainable as a differentiator — many see this effort to improve.

- Adopting a simulation-driven design initiative requires people, process, and technology changes.
- Simulation-driven design requires few process changes. However, it does require the implementation of new practices for engineers—specifically, conducting analyses. Early, these simulations are simple, fast, directional analyses. Late, they are accurate and absolute.
- To enable simulation-driven design, engineers must have knowledge and skills that include an understanding of the necessary engineering physics domains, CAD skills to make modifications to the design geometry, and CAE application skills to apply the right loads and boundary conditions.
- Simulation solutions enable simulation-driven design with the right technological capabilities, including automation in the simulation setup and design exploration and optimization stages, real-time results changes, controlled accuracy, multi-CAD support, and direct and parametric modeling.
- The first source of value of simulation-driven design comes from finding first-feasible designs more quickly, freeing engineers up for higher-value activities.
- The second source of value of simulation-driven design lies in exploring more designs, understanding the design space, and finding more innovative options.
- The third source of value of simulation-driven design is realized by making better decisions early in the development process, powered by deeper insights from simulations.
- The fourth source of value of simulation-driven design comes from exposing design flaws with simulation that would cause downstream errors and disruptions.

RECOMMENDATIONS

- Management must lead simulation-driven design initiatives, explaining how the processes and technologies they use will change because of the new initiative.
- Make sure to research a range of potential simulation solutions to get the right technological capabilities in place. Automation, real-time feedback, controlled accuracy, and CAD-agnostic solutions are core capabilities.

- Once a solution has emerged, it is time to invest in training for the engineering teams to make sure they have the relevant CAD and CAE expertise to optimize simulations and realize the best value for the business.
- When planning the rollout of a simulation-driven design initiative, make sure to take the following four benefits into account: increased productivity; increased innovation; better, earlier decisions; and error avoidance.
- To ensure realization of these benefits, put the appropriate monitoring and assessment strategies in place to quantitatively demonstrate the benefits of a simulation-driven design approach.

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