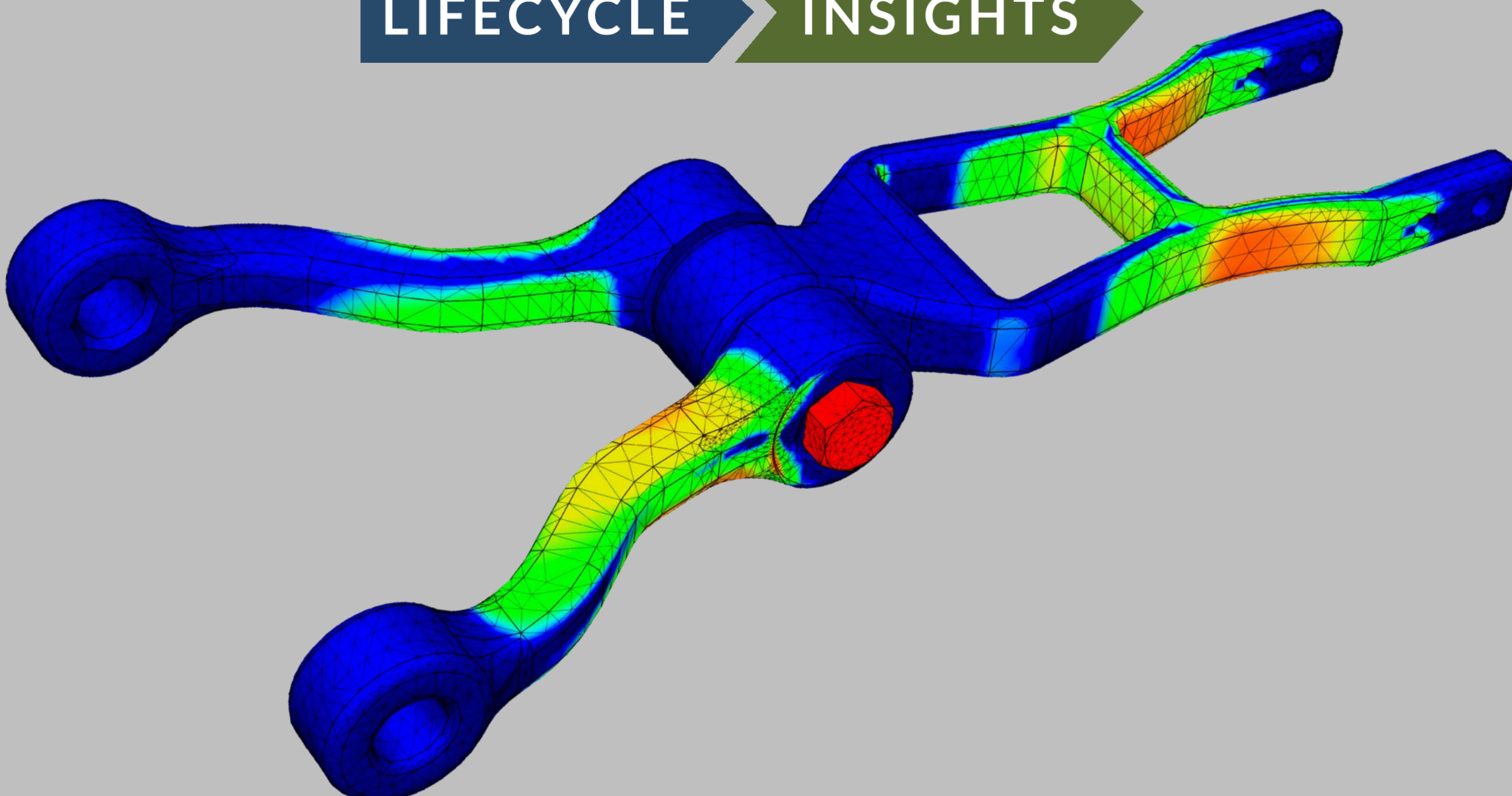
SIMULATION LED DESIGN EXPLORATION

POWERED BY SIMULATION PLATFORMS

LIFECYCLE INSIGHTS



INTRODUCTION

When it comes to the *functional* aspects of engineering, there are clear advantages to conducting simulations during design. During the conceptual stages, running such analyses lets engineers know if their target requirements are feasible and perform trade studies on different ideas. In detailed stages, conducting such activities lets engineers interactively size the geometry of their designs and avoid costly errors that could turn into catastrophes downstream. In all, running simulations during design allows engineers to make more informed decisions that translate into better designs, fewer change orders, lower product costs, fewer failed prototypes, and innumerable other advantages.

However, it has not been easy to realize the benefits of simulation in design. Tactical execution matters. It requires skills and knowledge in four crucial areas: engineering physics, analysis methodologies, Computer Aided Design (CAD) software and Computer Aided Engineering (CAE) software. To date, the burden of enabling such an effort has fallen to a single role: the engineer. Yet with all of the responsibilities they bear, modern engineers have little time to gain and retain skills and knowledge in all of these areas. More importantly, they rarely have the time to execute such activities even if they do have the necessary knowledge and skills. So far, technology hasn't helped address these challenges, as they so often have merely simplified analysis tools and integrated them into Computer Aided Design (CAD) applications.

However, a new technological solution is emerging that mitigates these challenges in unique ways. The first capability allows analysis experts to define the traits of the analysis that requires simulation expertise. The second capability allows engineers to apply that expertise to their designs in a guided manner. This approach drastically reduces both the depth of understanding needed of the analysis methodology and the skill required to use the simulation software. As a result, engineers can focus on their background in engineering physics and some knowledge of creating and iterating on design geometry in CAD software. This lets them explore designs and understand their performance during concept and detailed design phases.

The purpose of this eBook is to delve deeper into this topic. Here, you will find more information on the value of conducting analysis during concept and detailed design. You'll find out more about the four crucial skill and knowledge areas that enable such efforts and how various roles can fulfill them. Finally, you'll get specifics about the new solution that is breathing life into Simulation Led Design Exploration.

Using analysis to drive design decisions has long been a vision full of potential. With new technologies, engineers and manufacturers gain the powerful benefits of running simulations in design.

THE THEORETICAL VALUE OF SIMULATION DRIVEN DESIGN

The concept of driving design decisions with simulations was developed some two decades ago, but the core ideas behind it have not changed significantly since that time. This section reviews the key notions central to the concept.

CONSTRAINTS INCREASE DURING DEVELOPMENT

Fundamentally, as a design progresses through development, it becomes increasingly constrained. In this context, by conducting simulations to reveal and fix design flaws *early* in development, designers can avoid catastrophic downstream costs. To clarify this concept, this section dives into the details.

To start, recognize that design progresses through distinct stages with specific tasks in development. During concept design, an engineer can explore many different ideas that present solutions to the initial set of requirements. For example, they might consider making a bracket from sheet metal or from casting and machining operations. Then, during detailed design, the engineer refines that idea into a specific form, focusing on its precise shape and size. For instance, after deciding to go with casting and machining operations, the engineer calculates wall thickness and rib placement. Next, during prototyping, they build the design so it can be verified and validated. In other words, the engineer needs to make sure the bracket doesn't crack under operating conditions. At release, that design is handed over to procurement and manufacturing for production. At this time, the manufacturer may even make commitments to their customer with respect to design details.

As a design progresses from one stage to the next, it becomes more constrained because of dependencies. In our example, during detailed design an engineering peer might develop a linkage that mates up with that bracket. In prototyping, a procurement agent might order long lead time raw materials, such as casting tooling for that design. At the same time, a manufacturing engineer might start prepping the production environment for it by developing the machining toolpaths for that specific bracket. If our engineer decided to make a dramatic change at this time, such as switching to a sheet metal component, it could have a costly cascading impact on many downstream activities, both from a budgetary and schedule perspective.

Early on, the engineer has a lot of flexibility to explore different design ideas. Late in development, that same engineer has little freedom to make design changes because it would cause detrimental effects on many other roles. The conclusion is that as a design moves through development, it becomes increasingly constrained.

ASSESSING FUNCTIONAL PERFORMANCE

Every design decision is based on a number of inputs. Engineers must consider cost, ease of procurement, manufacturability, serviceability and much more. However, one crucial consideration is whether the design fulfills its *functional requirements*. Will it break after introduction to its operating environment? Will it move, rotate, provide torque, or deliver force as expected? When it comes to *engineering* a product, these are some of the prime responsibilities of any design engineer.

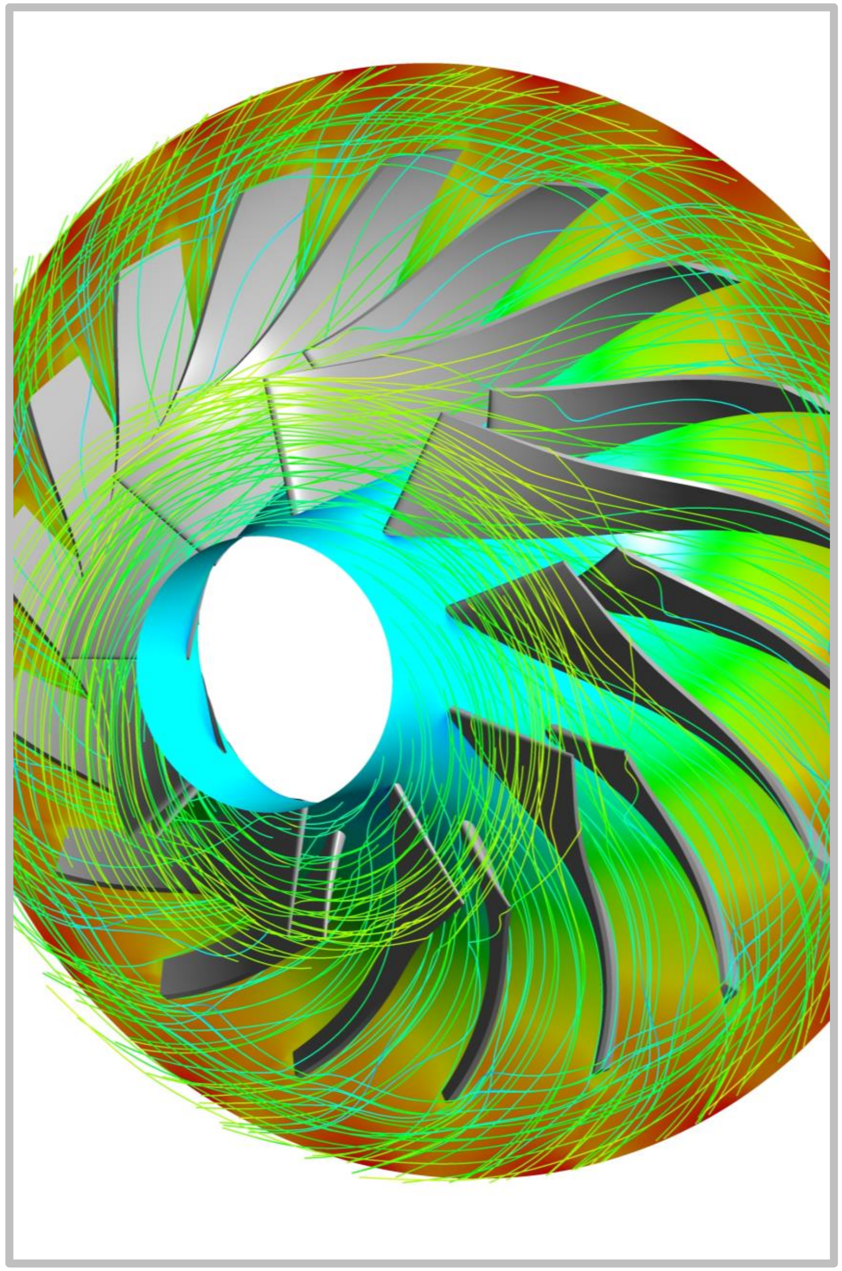
As a result, engineers must somehow assess how their design will perform. This starts at the beginning with concept design when they consider different alternatives. It continues through the last steps of detailed design, as they consider even the smallest of modifications.

THE FLAW IN THE DESIGN: WHEN IS IT FOUND?

Now, what if there is a functional flaw in the design discussed above. Once that flaw is found, the design will have to change. The crucial question here is simple: when is the flaw found?

If the design flaw is discovered during concept design, the engineer has plenty of flexibility. If necessary, he can switch to an entirely new idea. However, if it is discovered during detailed design, any change he considers must take into account the work of others and the monetary investment to date. Finally, if it is found during prototyping, the impact will likely be dramatic, and the available alternatives to fix the flaw will be highly constrained.

There lies one of the most attractive benefits of running simulations early in design. With its relatively high accuracy, it can reveal such flaws during the concept design or early detailed design stages, so engineers can address the issue before the design becomes too constrained.



DESIGN EXPLORATION, FINDING BETTER OPTIONS

Finding design flaws is a primary duty of engineers. However, they also have another key responsibility: *finding better designs*. Based on schedule constraints, engineers can go beyond the first feasible design option to find alternatives that more successfully fulfill requirements.

To find better designs, engineers modify, tweak, and iterate the geometric representations of their concepts and ideas. However, to understand how those designs match up against their requirements, they must assess them. This is true for cost, weight, and any other number of measures that vary dramatically from industry to industry and application to application. One common measure is some aspect of functional performance. Once a number of feasible options are generated, the engineer can contrast and compare those alternatives in a trade study.

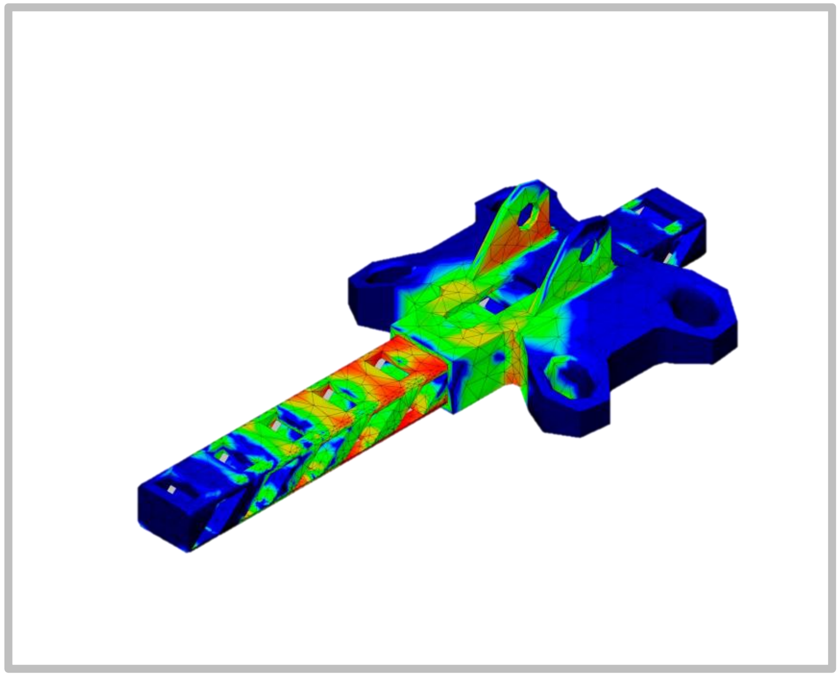
In such scenarios, it is crucial to get accurate, timely assessments of functional performance. It lets engineers generate a larger number of alternatives and gives them greater confidence in those alternatives. Simulations conducted during concept design and detailed design empower engineers.

ENABLING IT ALL WITH SIMULATION LED DESIGN

Whether an engineer needs to find design flaws early in development or assess design alternatives more accurately, simulation plays a key role in concept design and detailed design. It gives engineers performance insight so they can make better-informed decisions. It lets them find a feasible option quickly or explore more design options to find the very best alternative. Such efforts can result in designs that better fulfill requirements, more products being released on schedule, lower product costs, reduced change orders and non-conformances, less scrap, and failed prototypes.

The key enabler in this vision is the simulation technology that lets engineers conduct analyses. These analyses are more accurate than other performance prediction approaches, such as hand calculations, spreadsheets, or even standards, because it is based on an accurate geometric representation of the design and it leverages proven analytical methods.

Overall, Simulation Led Design offers great promise. However, how easily can it be achieved?



THE CHALLENGES TO EXECUTING SIMULATION LED DESIGN

The idea of running simulations during design to make more informed decisions holds significant merit. However, there are challenges to doing it successfully. This section reviews each of those challenges and explains how they can be overcome.

FOUR ENABLING SETS OF SKILLS AND KNOWLEDGE

Conducting analyses during design is a highly technical process. As such, an organization must possess four distinct skill sets or knowledge bases: an engineering science background, an understanding of analysis methodology, familiarity with CAD software, and a knowledge of simulation software. Each of these is discussed in depth in the following sections.

- **Background in Engineering Science:** Almost anyone can recognize when a design functionally fails. However, it takes a background in engineering science to understand the precursors that predict such failure. Students who attain an engineering degree almost universally take classes in structural statics, dynamics, thermodynamics, and fluids. There they learn the key technical measures of performance, such as von Mises stress, deflection, velocity, acceleration, heat transfer rates, and temperature, as well as the equations that govern them. With such a background, engineers can assess and predict a design's performance long before they create anything physical, allowing them to make informed decisions. This area of knowledge is crucial to any simulation led design effort.
- **Understanding of Analysis Methods:** All simulation technologies utilize an analysis methodology that can be used in hand-written calculations. Some methods were developed long ago, while some emerged more recently. The one common trait these methods possess is that each has advantages as well as flaws. For example, when using the Finite Element Method (FEM), placing a load on the same element vertex as a constraint will result in an infinite stress. Knowing about these quirks is crucial when interpreting analysis results. Furthermore, some methods are better suited for certain kinds of physics. For example, the Finite Element Method (FEM) and Finite Difference Methods (FDM) can provide very different results based on how calculation models are set up. Understanding such fundamental characteristics about these methods lets individuals interpret the results correctly.

- **Familiarity with CAD Software:** One of the prime objectives of a simulation led design effort is to explore and assess more designs. The main tool used to create and change the geometric representations of these designs is CAD software, which leverages a variety of modeling approaches, including parametric feature-based modeling, direct modeling, and even facet modeling. The simulation software uses the resulting design geometry to run analyses. In addition to modeling the design accurately, there are instances where it may not be necessary to analyze all of the design's fine details. As such, the geometry can be simplified or even abstracted, and the analysis can still predict the performance of the design. For all of these cases and more, CAD software skills are crucial to simulation led design.
- **Knowledge of Simulation Software:** While calculations of extremely simple designs could be performed by hand, analyzing real-world designs requires mathematics far too complicated for manual calculations. Simulation software automates much of the work to set up and run the analysis, as well as to review the results. Nevertheless, many options require expertise to run these analyses successfully. A number of procedures and approaches can be used to set up the model, and a variety of simulation methods and numerous solvers can be employed. All of these fine details can affect the accuracy of the analysis results considerably. Thus, simulation software skills are yet another critical requirement for simulation led design.

FULFILLING THE FOUR ENABLING SETS

As discussed above, four sets of skills and knowledge are needed to pursue a simulation led design effort successfully. To make such an initiative actionable, the organization must determine the best way for their staff to fulfill those four sets. The following discusses the roles most likely to have those capabilities.

- **Drafters or Designers:** Of all the roles in an engineering organization, these roles interact with design tools most frequently. They are responsible for creating drawings and building 3D models, so they have deep ***familiarity with CAD software***. While this is technical work, individuals in these roles often do not have an engineering degree, so they often do not have a ***background in engineering science*** or an ***understanding of analysis methods***. Lastly, because they do not conduct analyses, they also frequently do not have ***knowledge of simulation software***.
- **Engineers:** While similar in nature, these roles are different from Drafters and Designers in a few key ways. To start, they have an engineering degree, which requires a ***background in engineering science***. That education also probably provided them some ***understanding of analysis methods*** in theory, if not in practice. Many engineers do use design tools, so there is some ***familiarity with CAD software***. However, few use analysis tools on a consistent basis, so they often have little ***knowledge of simulation software***. Above and beyond these four areas, engineers today carry many responsibilities that take them far from their designs. Lifecycle Insights Hardware Design Engineer study found that, on average, engineers have 7.3 responsibilities, nearly half of which are outside the realm of design.

- **Analysts:** In the engineering organization, these roles are primarily responsible for digitally checking the performance of designs before prototyping and testing. They have often have advanced engineering degrees, providing them a deep ***background in engineering science*** and an expert-level ***understanding of analysis methods***. Furthermore, the primary technology they utilize in their role are analysis tools, giving them excellent ***knowledge of simulation software***. The only one of the four areas where they lack skills is ***familiarity with CAD software***. By the time a design comes to them, it is nearly ready for release. Their goal is often to conduct an analysis that checks whether the design will fail or not. Although they can provide some suggestions for design changes once it fails in a simulation—or even a prototype—it is not their responsibility to provide a solution. That task falls to the engineer who originally developed the design.

TAKEAWAYS

Four distinct sets of knowledge and skills are needed to successfully pursue a simulation led design effort, including:

- Background in Engineering Science
- Understanding of Analysis Methods
- Familiarity with CAD Software
- Knowledge of Simulation Software

A review of the main roles found in engineering organizations revealed that these four sets of knowledge and skills are present. However, no single role has ***all*** four of these skills and knowledge. This is important, as the different technology solutions provided to enable such an effort are reviewed in the next section.

Table 1: Knowledge and Skills by Role in Engineering Organizations

	Designers and Drafters	***Engineers***	***Simulation Analysts***
Background in Engineering Science	◔	●	●
Understanding of Analytical Methods	◔	◑	●
Familiarity with CAD Software	●	◕	◔
Knowledge of Simulation Software	◔	◔	●

TRADITIONAL STRATEGIES FOR SIMULATION LED DESIGN

To realize benefits from a simulation led design initiative, roles with four sets of knowledge and skills must participate. However, the two different strategies commonly used to enact simulation led design have relied on only one role, either the engineer or the analyst. This section takes a closer look at that those two strategies and their inherent flaws.

TASKING ENGINEERS WITH ANALYSIS

One of the more popular approaches to facilitating simulation led design has been to provide engineers with new technologies so they can conduct analysis during design. The enabling technology includes simplified simulation capabilities embedded within CAD software systems. Many organizations have provided these tools to engineers and asked them to apply it to their design processes and procedures.

Unfortunately, there are two fundamental flaws to this strategy. First, as noted in the prior section, engineer have the necessary ***background in engineering science***, likely a theoretical ***understanding of analysis methods*** in theory and some ***familiarity with CAD software***. However, they often lack ***knowledge of simulation software***. This leaves a gap in terms of the skills and knowledge required to pursue simulation led design.

There is another issue, as well. As mentioned before, engineers already have, on average, 7.3 responsibilities, and organizations are asking those engineers to take on *yet another one*. Frankly, most engineers don't have time to dive deeply into developing a practical ***understanding of analysis tools***, even if they do have time to invest in ***knowledge of simulation software***. As a result, few engineers conduct analyses on their own today.

INVOLVING ANALYSTS EARLIER IN DESIGN

Another popular approach has been to get more analysts involved in design activities. The idea has been to enable them with expert level pre-processors, solvers, and post-processor software applications. Some organizations simply have them apply their processes and procedures earlier, during development.

As noted above, analysts have a deep ***background in engineering science***, an expert-level ***understanding of analysis methods*** and excellent ***knowledge of simulation software***. The only one of the four area where they lack skills is ***familiarity with CAD software***. This leaves a gap in their skillset.

However, the gap issue has not been the biggest barrier to success. The main problem is bandwidth. Analysts have a unique skillset and as such, they are a fairly rare commodity. If an organization re-tasks the analysts working on verification and validation and has them work on design, then there is *no one to do the final check before prototyping*. The core issue with this strategy is bandwidth.

Beyond that, the purpose of analysis in design is dramatically different than it is during verification and validation. In design, the idea is to get directional feedback to make informed design decisions. In verification and validation, the concept is to do a final go or no-go check before investing in a prototype for testing. As such, the processes and procedures must be different.

A COLLABORATIVE STRATEGY FOR SIMULATION LED DESIGN

In the past year, a different strategy for enabling simulation led design has emerged. It relies on not one, but several roles in the engineering organization. This section offers a deeper view of this approach.

USING EVERYONE'S BEST SKILLS AND KNOWLEDGE

Running a simulation led design effort requires four distinct sets of skills and knowledge. While all are required, there is no requirement that all of them be supplied by a *single role.*

Of all the roles involved in design, engineers can best leverage their ***familiarity with CAD software***. This is true not only from a skills perspective, but also from the fact that the engineer who builds the concept or detailed model of the design also knows how any relevant intelligence was built into it. They are the ones that can best manipulate it to generate the right design alternative. The engineer's ***background in engineering science*** may not equal that of the analyst, but the engineer knows the most about the operating environment of the design. That means they can be the best judge of the analysis results.

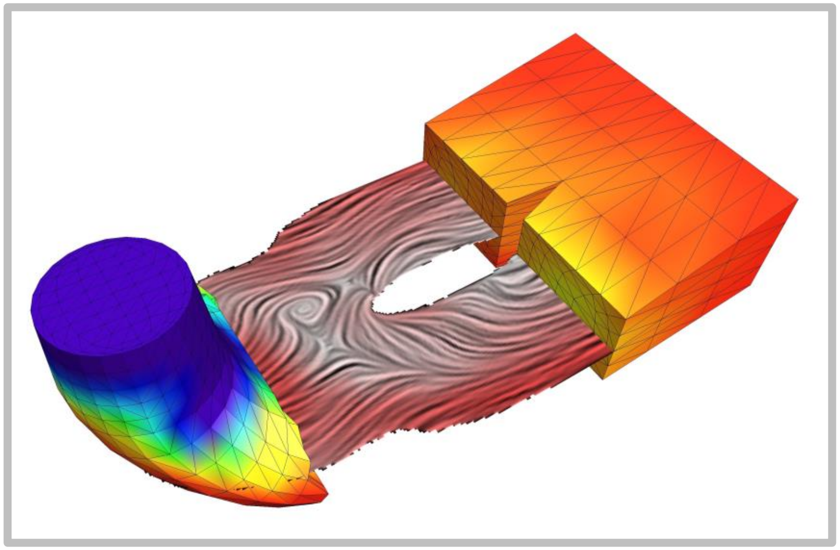
There's no doubt that analysts have the clearest ***understanding of analysis methods***. They have often spent years involved in those methodologies, both from a theoretical and practical perspective. Furthermore, analysts have the most intimate ***knowledge of simulation software***. They spend most of their day interacting with those kinds of applications. That experience makes them the best choice to set up and run analyses.

Note that, between these two roles, all four sets of knowledge and skills are present. The best roles are contributing their knowledge in the areas they know the best.

THE EMERGENT TECHNOLOGY NEEDS

Pairing these two roles together to execute a simulation led design effort is logical. However, any successful strategy must leverage technologies that address a few issues.

- Analysts need a way to set up and run simulations for the engineer *without being involved with every single analysis.*
- Engineers need a way to change and iterate on designs to explore alternatives and initiate simulations *without being involved with the setup.*



LEVERAGING A SIMULATION PLATFORM

It is within the context of these two needs where the concept of a simulation platform applies. This type of technology platform, which has emerged in the last year, solves both of these issues. This solution has the following characteristics:

- The platform is built upon a set of capabilities that can be used to develop several software applications.
- One such software application lets analysts build simulation templates. Another software application lets engineers create design geometry and run those simulation templates.
- The analysis models and results can be opened and modified by either software application.

THE NEW COLLABORATIVE SIMULATION WORKFLOW

The resulting process of running analyses in concept and detailed design looks dramatically different. It no longer relies on a single role; instead, it leverages everyone's best skills and knowledge without overtaxing anyone. Here are the resulting steps:

1. Analysts prepare templated analyses by dialing in the right setup for that particular combination of physics, load cases, and desired outcome.
2. Engineers model their designs in a conceptual, detailed, simplified or abstracted manner, quickly and easily. They then apply the templates prepared by the analysts and run the simulation. Analysts can review such simulations as necessary.
3. The analyses are calculated, producing highly accurate results using the same intelligent solver leveraged by the analyst.
4. The engineer, analyst, or both reviews the results, making a design decision for that stage of development.

The entire process can be repeated as necessary, supporting activities in both concept and detailed design.

ADVANTAGES AND BENEFITS

This new, progressive approach, leveraging a simulation platform, delivers on many of the promises offered by a simulation led design initiative, including the following:

- Simulation analysts can continue their current responsibilities, as templated and automated technologies allow engineers to conduct their own analyses.
- Design engineers can run their own simulations without being burdened with the complexities of the analysis method or familiarity of simulation software functionality. They focus on iterating on design geometry and plugging it into templates.
- This process delivers accurate analysis results which can be used as the basis for good design decisions.
- Organizations can realize the larger benefits of simulation led design, including designs that better fulfill requirements, products that come out on schedule, lower product costs, reduced change orders and non-conformances, less scrap, and fewer failed prototypes.

SUMMARY AND CONCLUSION

Simulation in design has long held great promise in development. It lets engineers find design flaws earlier and explore more alternatives. There is little doubt that such an effort offers tangible benefits to engineering organizations.

THE CHALLENGES OF SIMULATION LED DESIGN

Pursuing a simulation led design initiative requires four distinct sets of skills and knowledge: background in engineering science, understanding of analysis methods, familiarity with CAD software and knowledge of simulation software. These four areas have good coverage in engineering organizations, but no single role has all of them.

TRADITIONAL STRATEGIES AND TECHNOLOGIES

The predominant strategy to enable simulation led design has been to provide simplified analysis capabilities embedded within CAD software to engineers. Unfortunately, engineers often lack a deep understanding of analysis methods and knowledge of simulation software. Furthermore, engineers have a wide variety of existing responsibilities. These two drawbacks undermine their ability to execute simulation led design.

An alternative strategy has been to get analysts more involved in concept and detailed design. However, they often lack familiarity with CAD software and, more importantly, they are a precious resource. Dedicating their time to design means far less verification and validation work is completed, putting engineering organizations at risk of more failures during the prototype and test phase.

A COLLABORATIVE STRATEGY AND TECHNOLOGY

A strong alternative to enabling simulation led design has been emerging over the last year, leveraging the combined knowledge and skills from engineers and analysts. In this approach, analysts set up simulation templates, embedding guidance and automation in it. Engineers geometrically explore design alternatives and run these templates against them, gaining insight in their performance. All of this is enabled by a simulation platform upon which the analyst's and engineer's software applications are built. Furthermore, the models and data generated by each are interchangeable, allowing analysts and engineers to see each other's work. This collaborative effort allows each role to contribute their best skills and knowledge.

FINAL TAKEAWAYS

Simulation led design has held great promise. Leveraging a simulation platform to enable a collaborative strategy between engineers and analysts represents a feasible and actionable approach. It is finally time to get value from simulation led design.

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