WHITE PAPER

Simulation-Driven Product Development™: Will Form Finally Follow Function?

JUNE 2009

SPACECLAIM CORPORATION

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For up-front simulation to be successful and pervasive, engineers need 3D tools that are accessible, powerful, and easy to deploy. New 3D tools powered by direct solid modeling make it practical for all engineers to work in 3D and to create highly-optimized preliminary models.

"All of us had been trained by Kelly Johnson and believed fanatically in his insistence that an airplane that looked beautiful would fly the same way." Ben Rich, *Skunk Works*

EXECUTIVE SUMMARY

The traditional engineering process saw an engineer creating a design, testing it, and iterating prototypes until the design performed as desired. Although this workflow predates CAD and CAE technology, many manufacturers' design processes continue to follow it. The first wave of simulation technology reduced the need to test physical prototypes, but now the role of simulation has evolved beyond just validating CAD models. Finally, the laws of physics are starting to drive product design.

How can an organization efficiently implement simulationdriven product development? The key to developing a cutting-edge design process is to ensure that large changes occur *early* in the design process. Engineers must strive to find optimal concepts as quickly as possible, balancing complex tradeoffs before detailed CAD work commences. With the traditional iterative model, engineers are confined in their design, thereby missing breakthroughs that a more novel approach could produce. Without testing performance prior to detailed design in CAD, significant changes arise late in the design process when they can be disruptive and expensive to implement.

Until recently, simulation would lag detailed design because 3D models did not exist until designers finished the CAD models required for simulation. To break this chicken-or-egg dependency, engineers are now introducing an inexpensive, preliminary design phase that vets concept models using simulation before detailed design and design-for-manufacture begin. This preliminary design process has been proven in niche, high-budget industries where manufacturers can invest in specialized CAD personnel who are dedicated to serving the needs of conceptual engineers. However, most manufacturers cannot justify the costs and time constraints of adding CAD staff to support the conceptual design process.

For up-front simulation to be successful, engineers need 3D tools that are accessible, powerful, and easy to deploy. Most manufacturers find traditional, detail-oriented CAD systems too expensive and complex to be sensibly deployed to all engineers. However, new 3D tools powered by direct solid modeling finally make it practical for all engineers to work in 3D. Unlike history-based systems that constrain design edits, emerging direct modeling tools foster creativity and substantive engineering early in the design process. Direct modeling helps engineers evaluate the best approaches *before* detailed design commences.

IMPLEMENTATION

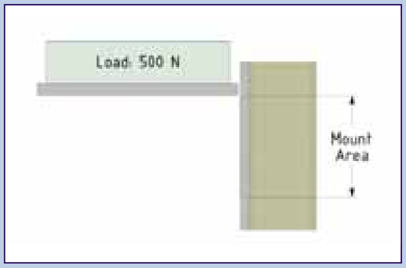
The simulationdriven design process can be grouped into three phases: specification, conceptualization, and detailing. Although individual stakeholders' exact roles vary across industry and organization, each phase typically requires distinct skills and tools.

SPECIFYING METRICS AND TOOLS

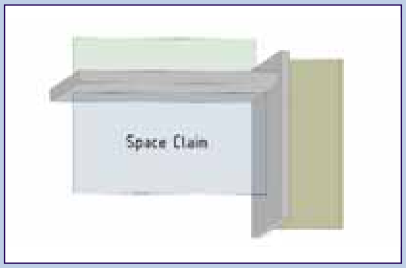
During the specification phase, lead engineers work with marketing, management, sales, and customers to define performance criteria. For many projects, these performance criteria become part of a contract with the customer or are critical to meet market demands. A simulationdriven process uses these metrics to identify the cost of the product early in the cycle, even before proposals become finalized and contracts are signed, allowing manufacturers to understand the profitability of their products and deliver them on time. Up-front simulation mitigates budget overruns and expedites time-to-market.

THE STEPS TO A SIMULATION-DRIVEN PROCESS

The goal of simulation-driven design is to converge on optimal solutions as rapidly as possible. By exploring diverse concepts early in the process, engineers can quickly understand the design approach that will best meet performance objectives and use that concept to specify detailed design.



1. For example, consider the design for a heavy-duty shelf bracket. The first step is to identify key performance requirements and goals that will act as the ultimate measurements of the suitability of a design concept and to sketch out the hard constraints. What are the key mounting points and interfaces? What fixed geometry from industrial designers, suppliers, or other engineering teams must the design accommodate?



2. Next, create a "space claim" or "envelope" for the design. Which rough shapes will work? At this phase, 3D design work commences. Use the surrounding geometry and interfaces to create a rough shape for the design, or, for relatively unconstrained concepts, start drawing directly in 3D.

Metrics enable engineers to measure the performance of their designs, becoming the virtual instrumentation that defines success and provides guidance for design improvement. With defined metrics, engineers understand from the beginning the questions they will need to answer throughout the entire process. Engineers can identify the specific CAE resources, such as structural, dynamic, electrical CFD, and multi-physics analysis tools, which must be available to the design team. As the design progresses, engineers become highly confident in their decisions and can tenaciously optimize against those metrics.

CONCEPTUAL DESIGN

The objective of the preliminary design phase is to remove as much uncertainty as possible about the final design and deliver preliminary models that will work once fully realized in CAD and manufactured. In addition to the rough shape of the components, this phase should also identify the materials and the manufacturing processes required, resulting in a reliable estimate of cost, mass properties, and lead time.

In the past, much of the preliminary process would occur on paper, on whiteboards, and in 2D drawing programs. Preliminary simulation would be done by hand or in tools such as Excel or MATLAB. The design and analysis activities were typically decoupled; critical values would be copied back and forth, resulting in a difficult-to-trace and error-prone process. Modern multi-physics, multidiscipline, and abstract modeling technologies help engineers exceed simple first-order analyses and produce more accurate results.

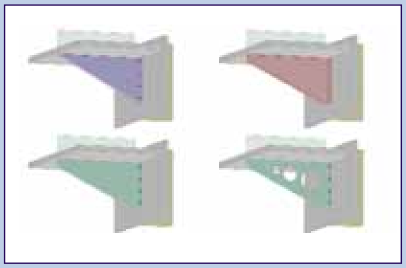
The emerging availability of direct solid modeling tools enables engineers to immediately draw thoughts in 3D and test the concept via simulation. The simplicity of direct modeling fosters design exploration, unlike traditional CAD systems that require users to lock down one possible version of design intent. With direct modeling, engineers can perform what-if studies to understand the different metrics' sensitivity to key design parameters and identify the parameters that force trade-offs between those metrics. Once understood, those key parameters become design intent to be embedded in the detailed design models.

Direct modeling also accelerates conceptual design by leveraging existing designs when building concept models. Reality dictates that many new designs rely heavily on their predecessors, but traditional CAD systems do not facilitate broad changes to existing models. New design data often comes from suppliers using different CAD systems, and direct modeling makes it easy to incorporate and edit solid models, regardless of origin.

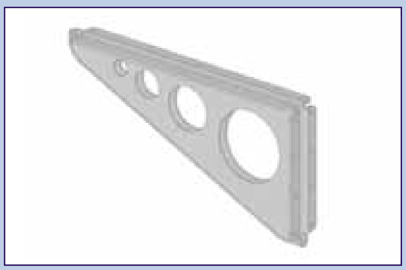
DETAILING IN CAD

In addition to producing the most efficient solutions, a formal preliminary design process creates measurable value for the extended team. Related engineering groups gain early visibility to the proposed design and can comment and integrate their data, fostering robust decision making. Disparate engineering groups can collaborate before going to production CAD, when models are expensive and time consuming to change. Most importantly, the CAD team can commence detailing using a rough model with well-documented parameters and design intent to create a proper, feature-based detailed design. Solid models are the best possible specification for detailed design in CAD, greatly accelerating the detailed design process. When manufacturing is outsourced, the accurate concept models enable their suppliers and manufacturing facilities to perform more of the CAD work, creating easily measurable cost savings, improved cycle times, and a more agile business.

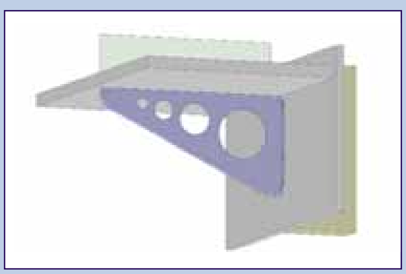
THE STEPS TO A SIMULATION-DRIVEN PROCESS *continued*



3. With context specified, the preliminary design begins. Explore different options while accommodating manufacturing constraints. During this phase, there is no need to model any more detail than necessary to evaluate the design. In this example, FEA only requires half of the design due to symmetry, and the thin-walled concepts were adequately represented as a simple surface.



4. Now that the design specifications are known, feature-based CAD users can create a detailed model with proper parameterization and design intent.



5. Finally, validate the detailed design to ensure that features introduced for manufacture do not degrade performance. In this example, model preparation software split the CAD file in half and extracted a midsurface to simplify the model for simulation.

When engineers have access to 3D tools, they can be more involved as the detailed designs emerge, adding value to the detailed design process. They can subsequently subject the detailed models to the same metrics and tests as the concept models and perform a final optimization on the manufacturing model. Direct modeling technology can play an integral role here too: Leading direct modelers provide de-featuring tools to prepare detailed models for FEA and CFD by removing small features, creating midsurfaces, and extracting relevant volumes. Often, engineers with expertise in CAE find these tools to be an invaluable utility to move CAD data to CAE without distracting the CAD team.

THE RIGHT TOOL FOR THE JOB

3D direct solid modeling offers engineers and other casual 3D users the ability to work and interact with CAD data. By replacing CAD concepts such as constraints and modeling intent with simple tools to create and edit 3D solids, direct modeling achieves unprecedented simplicity and low cost-of-ownership. Feature-based CAD systems, however, are most appropriate for detailed design and design for manufacture.

FEATURE-BASED CAD	DIRECT MODELERS
Model based on a recipe of features	Model is a simple solid
Editing requires changes to the recipe and regeneration	Interactive tools edit the design
Welldesigned models can be extremely versatile, but unplanned edits can require major rework	Small, unplanned edits are usually trivial, while extreme edits are straightforward
No ability to effectively edit imported data	Imported data is as easy to edit as native data
Requires dedicated, disciplined users	Little training required
High total cost-of-ownership	Low total cost-of-ownership
Appropriate for detailed design and knowledge-based engineering	Appropriate for concept design, analysis, and model reuse

CULTURAL CHALLENGES

Implementing simulationdriven design using preliminary models introduces a process where engineers use new design tools. Many engineers have assessed traditional CAD systems as inappropriate for concept modeling or have found that 3D tools don't work the way they had assumed. Modern direct modeling tools designed for conceptual design can change engineers' opinions about 3D. Engineers are starting to realize that not only does concept modeling improve time-to-market and profitability, it can also be fun and liberating.

A common concern is that sharing coarse but accurate concept models subjects designs to premature criticism. Simulationdriven design fosters a high degree of collaboration and data sharing between engineers from diverse disciplines. The philosophy for preliminary design should be to release ideas *early and often*. Welldefined metrics and documented results remove ambiguity and casual opinions. By opening up ideas to early testing and feedback, engineers create better designs and become more widely recognized for it.

ABOUT THE AUTHOR

Blake Courter is a co-founder of SpaceClaim Corporation. His role at SpaceClaim includes helping customers to leverage SpaceClaim's solutions to use solid modeling in new and innovative ways and to make 3D more accessible to all engineers and designers. Blake started his career at PTC, where he held a range of product management and business development positions. He received a Bachelor's degree in Mechanical Engineering from Princeton University in 1996.

ABOUT SPACECLAIM

SpaceClaim provides the world's fastest and most innovative 3D direct modeling solutions. Led by a world-class team of executives and developers with deep experience in bringing new 3D and design software to market, SpaceClaim has created a quantum leap in engineering productivity, delivering accessible 3D solid modeling to conceptual engineers, CAE analysts, and the extended product development team.

CAD administrators and IT managers have long understood that a multi-CAD environment creates interoperability challenges that can fragment product definition and cause long-term implementation hassles. However, direct modeling for preliminary design is not a replacement for CAD; it is a replacement for scraps of paper, 2D tools, and other untraceable documents that are typically handed off to the CAD team.

Direct modeling tools require less training and IT support than full-featured CAD systems and therefore realize a much lower total cost-of-ownership than CAD. Given that they function as personal productivity tools for engineers to sketch in 3D, sophisticated data management tools are not normally required to support the preliminary design phase.

Many organizations have already overcome these hurdles and can quickly point to their return on investment and improved competitive position by measuring the lower development costs and faster time-to-market that a simulationdriven process delivers.

CONCLUSION

Businesses are quickly realizing the impact when preliminary 3D models and up-front simulation drive detailed design in CAD. They are bringing competitive products to market more quickly, and with more ease and greater efficiency than before. They're revolutionizing and improving the way they do business, internally and externally.

With 3D direct modeling finally available for the extended product development team, engineers and analysts increase their ability to innovate and reduce cycle times. New direct modeling products for concept modeling and simulation also provide them with the power to sketch in 3D and interact with CAD models with ease and flexibility.

Businesses are building on the success that 3D direct modeling brings to the design-through-manufacture process. It simply comes down to streamlined efficiencies, a greater contributing engineering team, better products, and increased profitability.

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