

3D Engineering: How 3D Direct Modeling Empowers Conceptual Engineering and Enables Simulation-Driven Product Development

W H I T E P A P E R

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Executive Summary

Engineers have long envisioned 3D as a medium for capturing and exploring engineering concepts, performing what-if analysis, collaborating in teams, and communicating and “selling” their ideas to colleagues and customers. Missing has been consensus on what’s needed to make a 3D engineering tool accessible and appealing to all stakeholders in the product development process — from systems architects, engineers, analysts, industrial designers and detail designers, to program managers and corporate executives.

That consensus may now be taking shape around the emerging technology of 3D direct modeling. We studied a half-dozen early adopters of software from SpaceClaim Corporation across a spectrum of industries — avionics systems, custom architectural metals, defense vehicles, medical devices, automotive components, and industrial design. We sought to understand why they adopted this technology, what sets it apart from previous software they’ve used, and how it’s benefiting them in their individual professional roles as well as their organizations. This report documents our findings.

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Engineers are “divorced from the actual design process by the MCAD system.”

**Mechanical Design Specialist
Avionics Manufacturer**

What’s Been Missing for Engineering?

Why are there 10 to 15 million engineers in the world, yet only one million 3D CAD seats are in commercial use today? At one company we studied, the avionics division of a leading aircraft engine maker, a mechanical design specialist in charge of new tools and processes sums up the reason why. Of his company’s engineers, he says, the majority don’t use 3D CAD software. Instead, they “have to explain their wishes to a designer, who then interprets what he is hearing and implements it in the MCAD system. And depending on time and your relationship with the designer, you refine that, or you just accept it as good enough.” The result? Engineers are “divorced from the actual design process by the MCAD system.”

Why Many Engineers Don’t Use CAD

“Production MCAD software,” this mechanical design specialist continues, “is not really a suitable tool for engineers. You need to be using it full-time to be proficient.” 3D CAD systems deliver high value in detail design and documentation. But despite great advances over the past quarter-century, they remain too difficult for most engineers to master fluently enough to use in their day-to-day conceptual engineering work. The parametric constraint technology that gives these tools their power at the same time also inhibits their utility for on-the-fly concept investigation and what-if analysis.

The long learning curve of conventional CAD software is a particular hurdle for small companies. “You can train anyone to use any CAD program,” notes the owner of a small custom architectural metals firm, “if you are working for a large company that has plenty of money for training, and can let them sit there for months being unproductive. But when you’re a small company like mine, you need a product with which users can hit the ground running.”

CAE/analysis tools can likewise be difficult to use for creating models, even if they have some degree of modeling or sketching capability built in.

The results? Manufacturing industry’s embrace of CAD has unquestionably brought new efficiencies in design documentation and in generating manufacturing data and other downstream derivatives. However, at the same time, the growing centrality and authority of the CAD model has led to unproductive distortions in engineering processes. Product development used to make many engineering decisions early, working closely with analysts and discipline leads. However, the entrenchment of CAD technology pushed much of this early-stage engineering activity downstream into later and later phases of a project, as critical engineering decisions became increasingly dependent on having detailed CAD geometry from which to work. The penalty is that major errors are often not discovered until late in a program, when the cost of fixing them is greatest. Or, more often, the best ideas simply fail to find their way into the product.

What do engineers really need?

What capabilities are engineers and their organizations looking for beyond what their current CAD and CAE technologies afford them?

EASY-TO-USE 3D SOFTWARE Engineers have long had an array of digital tools with which to work. Many use 2D sketching or presentation tools to capture and communicate engineering concepts to customers, colleagues, and management. So-called 1D simulation tools are used to design and analyze one or another key functional criterion of a given product long before 3D geometry is available for finite-element analysis or other kinds of detailed analysis. What’s been missing is a 3D tool that every engineer can use: the value that engineers report from being able to work easily and fluently in 3D is difficult to overstate.

“Production MCAD software is not really a suitable tool for engineers. You need to be using it full-time to be proficient.”

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A 3D MODELING TOOL DESIGNED FOR ENGINEERS A key need voiced by engineers whom we interviewed is the ability to work directly in a 3D environment, rather than having to communicate concepts to a designer who then captures them in a CAD system. Indeed, some have made this a mission. The mechanical design specialist at the avionics manufacturer said, “My little crusade within our company is to have it accepted and provisioned for, that engineers have their own specific requirements [for a 3D modeling tool], and these are not the same as traditional production documentation. They come much closer to doing conceptual work; exploring variations in design; and fixing problems well into a design. Where perhaps the full-time designer has worked up a detailed design to some extent, then due to circumstances beyond our control, something changes. A component is switched, or the customer’s requirement changes, and you have to come up with a quick fix to keep the design valid.”

A 3D WORKSPACE FOR REAL-TIME TEAM ENGINEERING A 3D collaboration environment for real-time group problem-solving is a need expressed by many engineers interviewed. Some have tried to use conventional CAD as a collaboration workspace, but did not get far. For example, a lead physical architect at a defense vehicle manufacturer attempted to use Pro/ENGINEER this way, “but Pro/ENGINEER did not let us pull in multi-CAD data,” he reports. “We had to wait for it to get converted through batch translation software. And then, in Pro/ENGINEER you have constraints, [which make it] not conducive to doing things super-fast.”

BETTER COMMUNICATION THROUGH 3D Engineers “always have to sell their solutions to their peers,” the mechanical design specialist at the avionics manufacturer points out, “as well as to others involved in a project, including project managers and everyone around them. Sometimes that can be quite a difficult task.” He sums up one aspect of engineering as “a constant battle to communicate your ideas to your real customers – all the stakeholders in whatever it is you’re working on.” Again, conventional CAD software can be used this way, but it can be laborious even for trained users, to say nothing of the resulting product views being confusing and difficult to comprehend for non-users.

Bringing 3D to Conceptual Engineering

Conceptual engineering is the phase of product development focused on identifying, developing, and analyzing options and alternatives from the early stages of feasibility. Although this is where the greatest value can be, or fail to be, engineered into a new product, conceptual engineering has been long served mostly by basic tools: manual hardcopy methods, 2D sketching software, presentation packages, spreadsheets, and simple database programs.

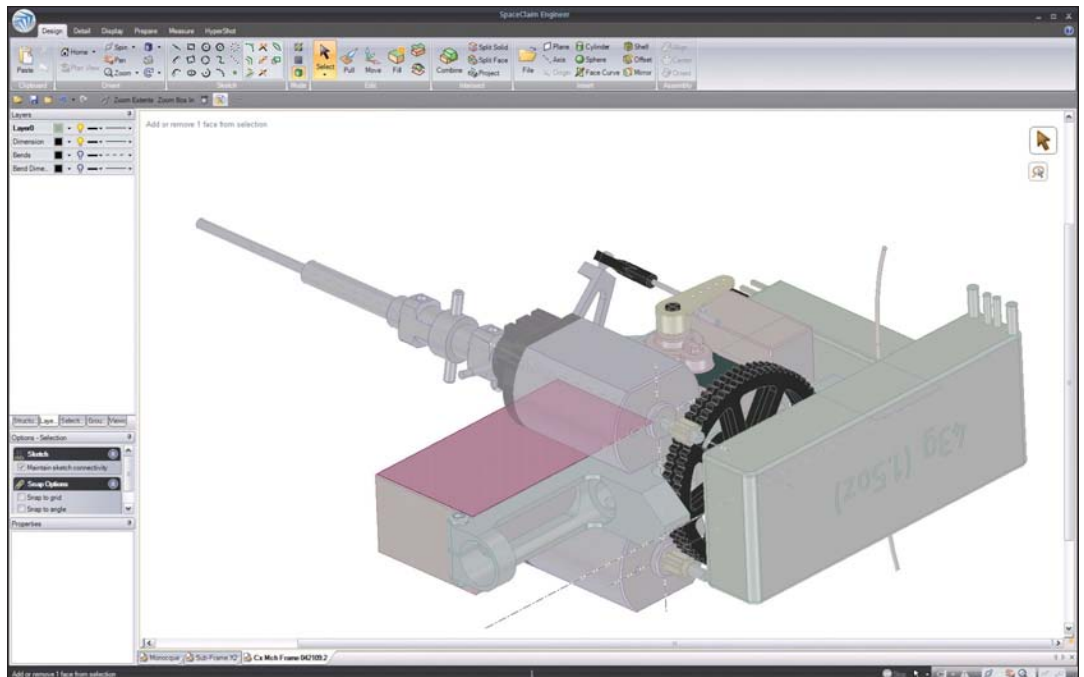
What needs of the individual, workgroup, or organization were going unmet at the companies we studied? Why did they choose SpaceClaim to fill those needs? Has it paid off?

Accessible 3D concept modeling environment

Most distinctive about 3D Direct Modeling, users told us, is that it’s truly a tool for engineers and not just “designers” (CAD operators). SpaceClaim, we heard repeatedly, removes the “designer” from standing between the engineer and the engineer’s work. As the mechanical design specialist at the avionics manufacturer sums it up, “It puts design back into the hands of engineers.”

SpaceClaim “puts design back into the hands of engineers.”

**Mechanical Design Specialist
Avionics Manufacturer**



Created in SpaceClaim: Miniature actuator assembly for avionics system

RAPID CONCEPT GENERATION IN 3D The freedom to rapidly generate and modify product concepts is a key need of engineers. One SpaceClaim user we studied works for a major manufacturer of defense vehicles. His job, as lead physical architect of a vehicle modernization program with 10 platform variants, is to ensure that all components involved — each subsystem and design variant — are integrated correctly, with no physical clashes in the virtual environment before fabrication and assembly of the vehicles begin. “One of the things we use SpaceClaim for,” he said, “is to rapidly generate concepts. To come up with several packaging concepts for our engine compartment, we import Pro/ENGINEER and NX models of engines, exhaust, air intakes, cooling modules, and fuel systems into SpaceClaim, then move components around inside the package envelope. SpaceClaim is a starting point to spark conversation.”

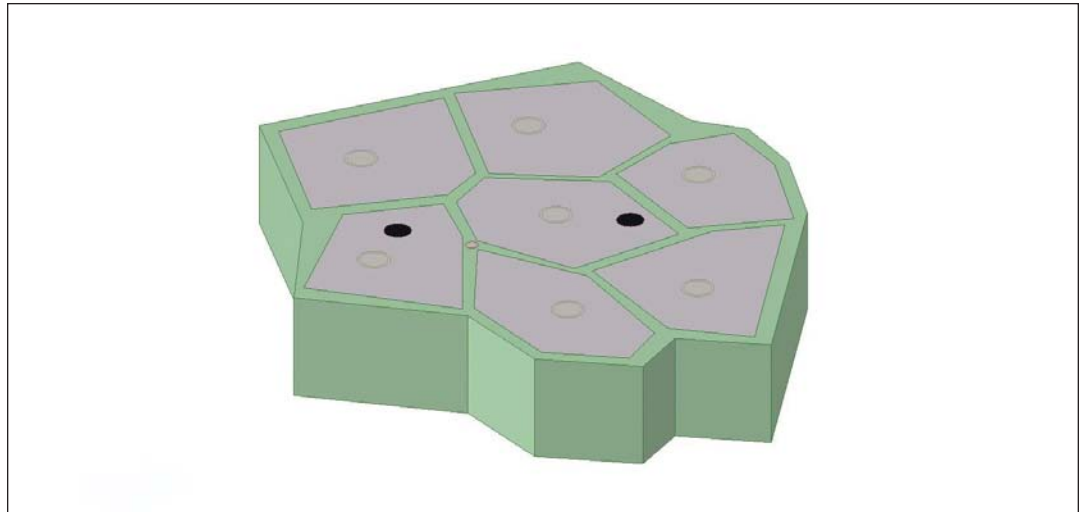
A BETTER BRAINSTORMING TOOL Another company we studied is a medical device manufacturer that uses SpaceClaim to model cancer electrotherapy devices and the body tissue into which they will be inserted. “People will use SpaceClaim more and more in activities where we sit together and do brainstorming,” envisions the principal design engineer driving the software’s adoption at his firm. The reason – “it’s quick and easy to make changes.”

“To literally pull on [a model] and be able to quickly make these shapes — it’s pretty remarkable.”

**Principal Design Engineer
Medical Device Manufacturer**

“Doing things super-fast — that’s the main advantage of SpaceClaim.”

**Lead Physical Architect
Defense Vehicle Manufacturer**



Created in SpaceClaim: 3D model of liver anatomy with electrode insertion points

CAD, of course, plays a valuable role at this company, but a different one for a different constituency. This engineer convinced his company to buy multiple SpaceClaim licenses because he “wanted to fill in all the blanks” in the company’s work process automation. “This way, I can include all the people who want to be part of the brainstorming, but who aren’t going to learn SolidWorks,” he explains. “There are a lot more of these people than the handful of experts in solid modeling.”

EASE-OF-USE The key is accessibility of the tool — specifically its usability. “To literally pull on [a model] and be able to quickly make these shapes — it’s pretty remarkable,” says the principal design engineer at the medical device manufacturer. “SpaceClaim does intuitively what a person wants to do. The user interface is very easy, almost to the point that you ask, ‘Why doesn’t anyone else do it this way?’”

Engineers Integrate Concepts and Resolve Conflicts before Detail Design

FACILITATING COMMUNICATION A key part of this is facilitating communication within and among engineering teams: rapidly, in formal, planned design-review meetings, as well as ad hoc discussions. “We will put together various concepts, then we will have a meeting with a lot of subsystem engineers involved,” added the principal design engineer at the medical device manufacturer. “We throw these concepts out there and say, ‘Tell me what you think of this approach? Is there a better one?’ We use SpaceClaim as a communication tool to keep the project moving forward. Often, even outside that main meeting, we may have a quick group meeting at a subsystem engineer’s desk where two or three people will concept up an idea on the spot. [With SpaceClaim] we can get the ideas and concepts down quickly.”

ACCELERATING ENGINEERING PROCESSES Accelerating engineering processes is a key benefit of 3D Direct Modeling. “Doing things super-fast — that’s the main advantage of SpaceClaim,” the lead physical architect at the defense vehicle manufacturer declares. “I’ve been using Pro/ENGINEER for 14 years, and me saying that this is a significant improvement in efficiency over Pro/ENGINEER is a pretty big statement.”

SpaceClaim “rapidly allows us to ‘concept up’ ideas and convey them to the greater team.”

**Lead Physical Architect
Defense Vehicle Manufacturer**

ENABLING REAL-TIME ENGINEERING A related value of 3D Direct Modeling is the way it enables real-time engineering decision-making. “The most important benefit I see,” says the lead physical architect at the defense vehicle manufacturer, “is it rapidly enables us to ‘concept up’ ideas and convey them to the greater team.”

At last, teams can achieve synchronous rather than asynchronous engineering. Who uses SpaceClaim at the defense vehicle manufacturer? “Me,” says the lead physical architect. And, “we have systems engineers. We have subsystem engineers. We have the designers themselves, that is, the CAD people. My people are not labeled ‘designers’. My people do the systems-level engineering; designers are the CAD jockeys. Systems integrators are responsible for integrating real components on real vehicles. We also have human factors engineers. We have logistics folks who work with manufacturing engineers. My people drive the SpaceClaim system in conversation with all of them.”

We found that when team problem-solving becomes possible in real time, it shortcuts the long iteration loops that resulted when engineers had to feed the results of design review meetings into the CAD department, and then wait for the changes to come back. And now, the CAD group can be more productive without unscheduled edits, interruptions, or big last-minute changes.

Demonstrate New Design Concepts to Prospects and Colleagues

3D Direct Modeling is also a powerful medium for communicating and selling engineering concepts to customers and prospects. For example, the mechanical design specialist at the avionics manufacturer is responsible for the tools and processes that his organization uses in mechanical design, specifically for electronics packaging design. “I work with sales teams in selling our ideas,” he reports. “I see SpaceClaim as an ideal tool for concept work and design architecture formulation... At the front end of projects, we evaluate a requirement received and come up with ideas as to how to satisfy that requirement. I start using SpaceClaim at that point, to help generate our sales proposal response.”

The value of accessible 3D in helping to “sell” engineering concepts to stakeholders inside the company is equally great. “A tool such as SpaceClaim is very, very useful in quickly making ideas tangible,” he explains.

Users point out the much greater power, impact, and information content of a 3D model than the presentation or illustration tools often used to present engineering concepts to corporate management. “If I give a design to the boss’ boss, and they want to know about the product,” explains the principal design engineer at the medical device manufacturer, “before SpaceClaim, I would have given them a presentation. Now I can give them the model in SpaceClaim, and they can manipulate it as well.”

Users who are not used to working or communicating in 3D emphasize how empowering it is. “It’s a feeling of power, to be able to connect my ideas with something that I can show people,” the mechanical design specialist at the avionics manufacturer reports. “Engineering is a constant battle to communicate your ideas to your real customers – all the internal and external stakeholders in the project.”

"It's a feeling of power, to be able to connect my ideas with something that I can show people."

**Mechanical Design Specialist
Avionics Manufacturer**

"SpaceClaim is easy to learn and use, and it's powerful."

**Lead Physical Architect
Defense Vehicle Manufacturer**

Detail Design Is More Efficient Because Concept Models Specify Consistent Design Intent

At the same time that 3D Direct Modeling is empowering engineers, we found that it's also freeing CAD designers from interruptions, digressions, and regressions in both their own work processes and the overall progress of a design. "We have marketing directors, we have design engineers, we have preclinical scientists, the veterinarians who might have an idea and go draw something," the principal design engineer at the medical device manufacturer explains. "Or, they might want to change a product." With SpaceClaim, he can say to them, "Here, let me give you the model, and you go into SpaceClaim and change it." For all these people involved in developing product, having a hands-on tool they can use helps them, the organization, and the CAD department. He says that with SpaceClaim, "instead of all these people clamoring to one [CAD] designer to make these changes, they can make them themselves."

How Does 3D Direct Modeling Make All This Possible?

GREATER 3D ACCESSIBILITY How does SpaceClaim make the power of 3D accessible to non-full-time users? We found both technological enablers and business enablers.

The key technological enabler of accessibility is 3D Direct Modeling's ease-of-use, ease-of-learning, and ease-of-retention. What a design analysis manager at a supplier of automotive drive train components likes most is that "SpaceClaim is easy to learn and use, and it's powerful." Similarly, something the lead physical architect at the defense vehicle manufacturer likes a lot is that "it's very simple to use – not a big learning curve." What the owner of the custom architectural metals firm likes best is the "instant pickup by new users." Indeed, many experience SpaceClaim as being as easy to learn as everyday productivity applications. "I equate it to an Office application," says a design analysis manager at an automotive supplier, "like getting started using PowerPoint or Word or Excel. It's powerful software, but not hard to get up and running."

Key business enablers of accessibility are price point, availability of free trial downloads, and the ease with which internal advocates can deliver compelling value proofs to decision-makers in their organizations, without heavy investment or effort.

3D UNCONSTRAINED BY PARAMETRIC MODELING For users familiar with parametric solid modelers, "the first thing you notice [about SpaceClaim] is the benefit of having been freed from the constraints of parametrics," reports the mechanical design specialist at the avionics manufacturer. This freedom "changes the way you go about doing things: it means you can model differently, and things you wouldn't do with a parametric modeler, you automatically do with SpaceClaim. With a parametric modeler, for example, you would leave all the fillets off until the very last, because if you try and make a significant change to the model, they will govern whether you can make that change; and they can be very laborious to remove. The opposite is true of SpaceClaim. It's that freedom to model ideas on-the-fly, without any constraint. You can focus on your design, not your design technique."

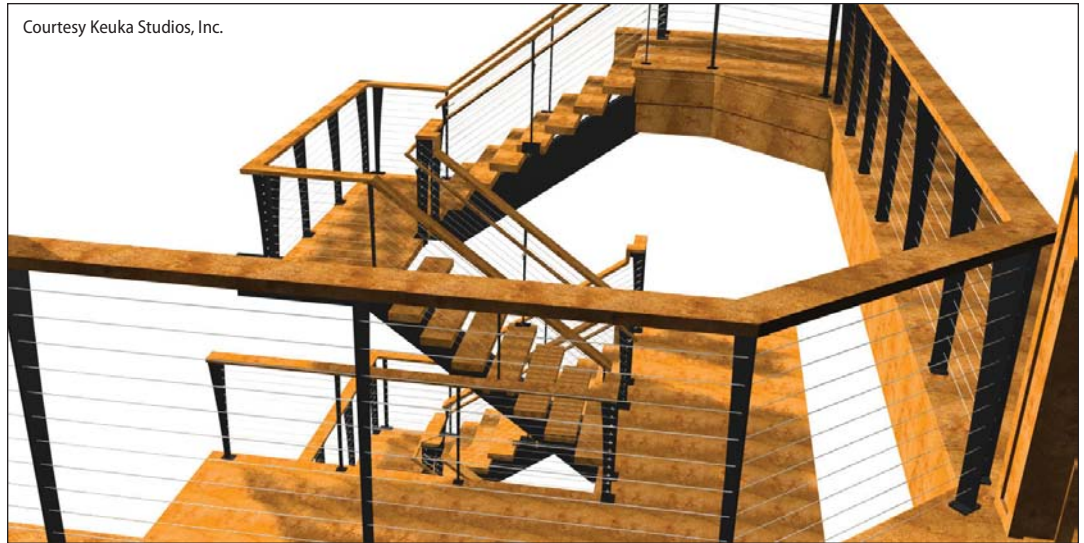
IMPROVED PRODUCTIVITY THROUGH SHORT LEARNING CURVE Unprecedented 3D accessibility also helps alleviate one of the worst resource constraints afflicting engineering organizations: the human-resource constraint. "This weekend is probably the first weekend in many years where I actually took a day off," the owner of the custom architectural metals firm told us, "because I finally found that I had a 3D modeling system that enabled me to train someone who could take some of the load off me." Ease-of-learning and use lets new hires come up to speed rapidly, without long, unproductive training cycles, and with no penalty for failing to learn the model-constraint discipline that's key to succeeding with parametric modelers.

"You can focus on your design, not your design technique."

**Mechanical Design Specialist
Avionics Manufacturer**

"Exchange of CAD models between different companies and contractors, without any loss of data, is one of the biggest advantages."

**Industrial Designer
ID Firm**



Created in SpaceClaim: Custom mono stringer stair railing

3D MODEL SHARING AND EXCHANGE Being able to work with models from almost any source is another important convenience reported by many users. Indeed, users say that SpaceClaim's model exchange capabilities are superior to many alternate approaches — both faster and more accurate. When he decided to bring SpaceClaim into his organization, an industrial designer at a German ID firm convinced decision-makers by highlighting the software's model sharing capabilities. "The first [benefit] is file compatibility," he said. "Exchange of CAD models between different companies and contractors without any loss of data is one of the biggest advantages — and to actually be able to use our customers' CAD data without rebuilding it manually."

Similarly, thanks to the software's "very easy access to data from almost any source," the mechanical design specialist at the avionics manufacturer reports, "I can pick up CATIA files, NX files, and go on the web and download STEP files from suppliers; and I can mix and match all that in SpaceClaim, without any worries or inhibitions or limits."

More Ideas in the Innovation Pool

The net benefit is that more people can participate in the engineering process. "Innovation is such an over-used term," the principal design engineer at the medical device manufacturer comments, "but we always want to innovate and brainstorm, and we want to include everyone in that process. If you include everyone, you get more ideas that work."

Enabling Simulation-Driven Product Development

At the same time that SpaceClaim is helping conceptual engineers work more effectively in the front end of product development, it's also helping CAE analysts contribute earlier in the process and be more effective and efficient throughout a project.

"SpaceClaim is that bridge that lets us go in and tweak that [CAD] geometry as needed."

**Design Analysis Manager
Automotive Supplier**

"Geometry rarely comes out of the CAD group in the form needed for CAE."

**Design Analysis Manager
Automotive Supplier**

Tactical Return for Analysts: Accelerating CAE Model Preparation

A perennial barrier to doing all this has been the technological gaps between product geometry on one hand and simulation models on the other. The result is that penalties in time and, sometimes, accuracy exacted by the need to prepare geometric and functional models for input to analysis, as well as difficulties in communicating analysis results back to the design group.

FAST, EASY GEOMETRY EDITING TO PREPARE MODELS FOR CAE/ANALYSIS The design analysis manager at the supplier of automotive drive train components describes barriers in the workflow used to turn CAD geometry into models for input to CAE analysis. "We get the CAD model from our CAD department, and try to bring it into ANSYS and mesh it," he explains. But geometry rarely comes out of the CAD group in the form needed for CAE. "More often than not, it does not mesh because of geometry nuances and the requirements needed to automatically mesh it in ANSYS."

The conventional remedy was for the analyst to "go back to the CAD group and wait on them to try and figure out what's wrong, and fix it so it will mesh." But this delay imposes an unacceptable penalty on the program schedule. Writing a work order to have this done "could take a couple of days or more." To speed things up, typically the analyst would "personally ask a designer to work on it so they could move forward." That favor can cut the delay down to two hours or less. But still, "it's a big interruption in workflow" for the designer, as well as the analyst.

What has 3D Direct Modeling done for this manager and his analysts? "SpaceClaim is that bridge that lets us go in and tweak that [CAD] geometry as needed," he reports. "SpaceClaim has given us a way to take matters into our own hands."

FREEING ANALYSTS FROM DEPENDENCE ON THE CAD GROUP The principal design engineer at the medical device manufacturer recounts how he first recognized the potential of accessible 3D to improve the fidelity, efficiency, and cost-effectiveness of his organization's existing investments in multiphysics analysis technology. "I'm not a designer; I don't spend hours each day working with SolidWorks or AutoCAD. I work with drawing packages to produce images. In my case, that needs to be a 3D image: I can take that, and then do finite element analysis with COMSOL. I just need a shape, a solid body, then I pour it into COMSOL, then align those [analysis] solutions with the results I get from animal testing."

APPLYING CAE RESULTS TO REFINE DESIGNS After an initial analysis has been run, the next challenge is to modify geometry to improve the design, based on what the analysis revealed — another step in product development that CAD-CAE gaps traditionally hindered. "Once we have an analysis done in ANSYS," says the design analysis manager at the automotive supplier, "should we want to make design changes, we have the ability with SpaceClaim to do so — move ribs or fillets. We can do all that, then, re-analyze the model ourselves."

Strategic Return for the Organization: Enabling Up-front CAE

Across the manufacturing industry there are initiatives to use digital simulation and analysis — computer-aided engineering, or CAE — in the earliest stages of a new project, and then pervasively throughout product development. In some industries, such as automotive, the focus is on transforming CAE's use from a late-stage, go/no-go decision tool to one used early in a program to give guidance, then throughout the program to aid refinement and optimization and to minimize physical prototype fabrication and testing. In others, such as aerospace and defense, simulation is already used early and pervasively. Here, the focus is on enabling even faster and more revealing investigation of early product configurations and design alternatives; an often heard phrase is "bring fidelity forward."

“If we didn’t have that tool, we’d be losing days, potentially” in program schedules.

**Design Analysis Manager
Automotive Supplier**

ANALYSIS KEEPS PACE WITH THE DESIGN PROCESS In helping bridge longstanding gaps between CAD and CAE, users told us, 3D Direct Modeling alleviates what may be the single greatest challenge for simulation/analysis groups in moving analysis upstream in the design process: namely, keeping up with the pace and cadence of the design groups. How does this happen? By liberating analysts from dependence on the CAD group for:

- Ready initial geometry for input to analysis
- Altering geometry based on analysis results, to perform re-analysis
- Communicating changes indicated by analysis back to the design groups

What is the net benefit to the automotive supplier that adopted SpaceClaim? “If we didn’t have that tool, we’d be losing days, potentially” in program schedules, the analysis manager reports — or else programs would simply move on, without the insight that analysis could have provided.

EASY CREATION OF ANALYSIS MODELS BEFORE CAD GEOMETRY EXISTS Another longstanding barrier to achieving up-front CAE has been the absence of an easy way for analysts to create detailed 3D analysis models from scratch, early in a project when CAD geometry is not yet available. In some cases, this is what’s needed to make up-front analysis possible at all; in other cases, it can help advance the goal of “bringing fidelity forward.”

The more detailed and realistic the 3D model, the higher-fidelity the analysis results. For example, the designer of cancer electrotherapy devices explains how 3D Direct Modeling helps him carry out higher-fidelity analysis than before. “The more detailed my 3D image for input to COMSOL, the more accurate my analysis. I can take a cross section of a tumor that was removed from a patient in treatment; using SpaceClaim, I trace it, then extrude it in 3D. And now, my predictions with COMSOL become even more accurate.” He adds, “To be able to do that in an hour is just remarkable.”

REDUCE COST AND SCHEDULE BY MINIMIZING PHYSICAL TESTING For the medical device company that adopted SpaceClaim, the freedom that it brings to do more and more detailed analyses “will reduce the number of animals [required for in vivo testing of new designs] and the cost of animal testing,” the principal design engineer at the company reports. “By using simulation [to model surgical instruments’ effect on tissue], I require less animal testing and less time — all those things that [are important] in a company like mine.”

The result of all this is greatly increased ability for engineering organizations to achieve early-phase, up-front analysis before CAD geometry has been developed, then continue being nimble and responsive in simulating throughout a project or program.

Empowering Conceptual Engineering; Achieving Simulation-Driven Product Development

In conclusion, users reported that 3D Direct Modeling offers new levels of empowerment to conceptual engineering, where the most fundamental decisions determining a product’s performance, cost, and success are made. By empowering engineers to quickly create concepts and communicate design intent to the product development team, SpaceClaim is fostering creativity and reducing time-to-market.

"The more detailed my 3D image for input...the more accurate my analysis."

Principal Design Engineer
Medical Device Manufacturer

At the same time, SpaceClaim is bridging work-process gaps that long impeded users' and organizations' move toward simulation-driven product development. For individual analysts, the opportunity is to become more visible, productive, and relevant — to become known as a professional whom program managers seek to help their projects succeed. And for discipline leads and CAE department heads, as well as companies as a whole, the potential is to change the value that CAE delivers to the organization — to transform analysis from a late-stage, go/no-go tool, to a trusted advisor informing and guiding the engineering process from the earliest phases of product development — yielding lower costs, shorter schedules, and better, more innovative products.

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