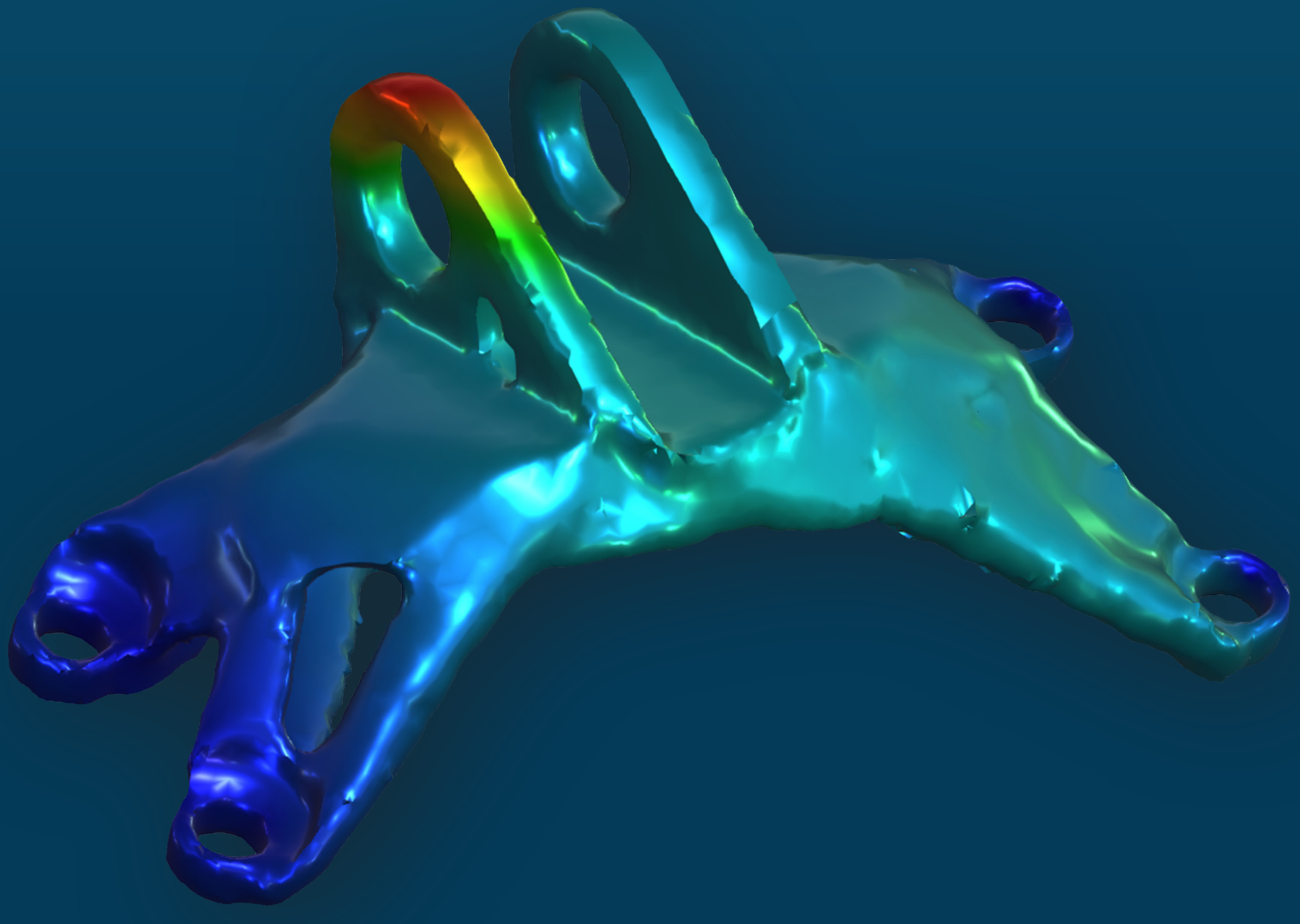
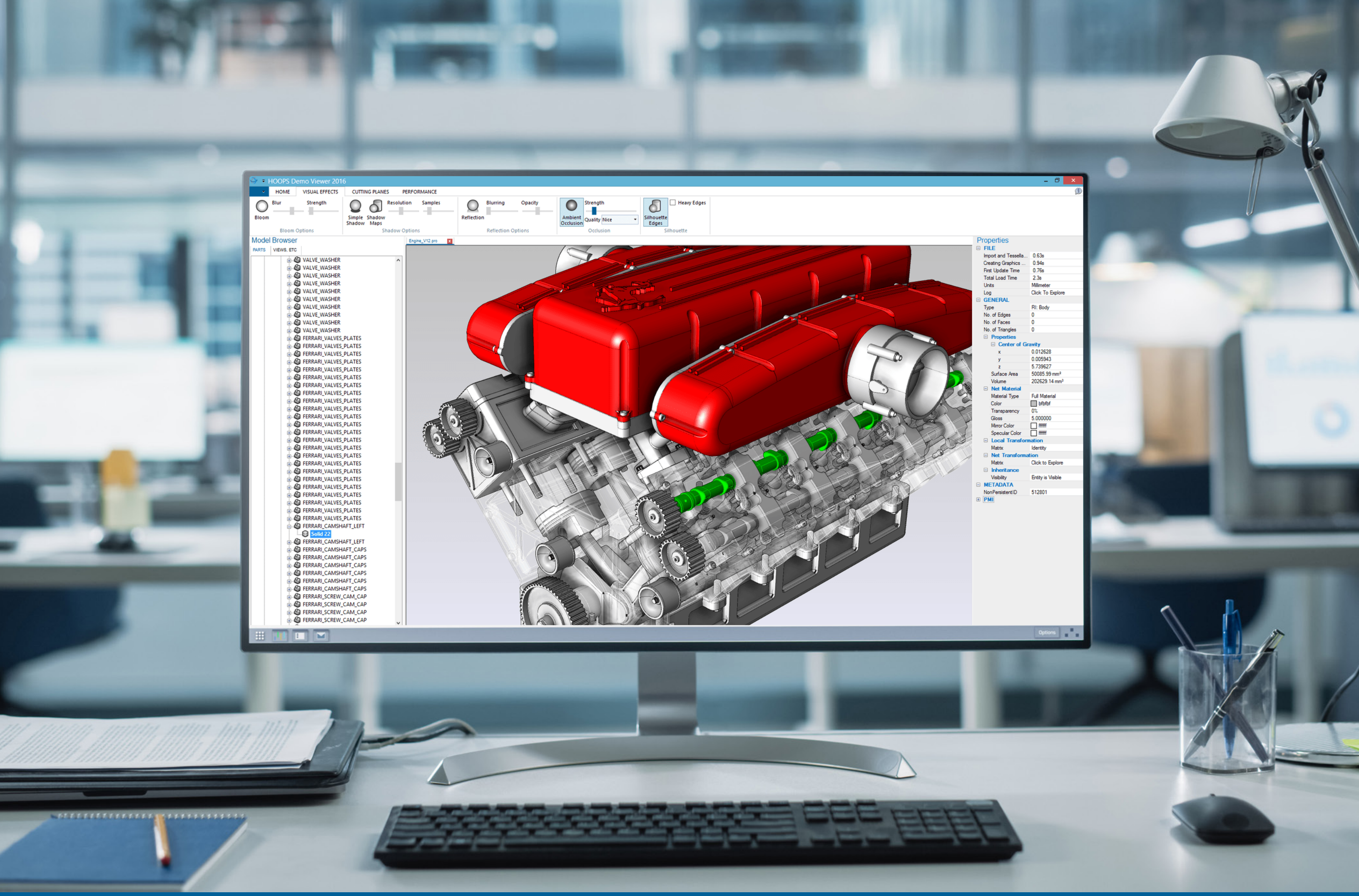
TECHSOFT3D

Generative Design in Engineering:

The Facts, Falsehoods, and Future of This Innovative Design Process





Engineers are facing a time of rapid change, with innovation in both what they create and the design process happening faster than ever. Generative design is one way engineers are revolutionizing how they innovate across a huge range of industries.

In this eBook, we will help you understand the generative design process and what it is capable of, how it differs from traditional design processes, and how Tech Soft 3D is supporting it. Just as crucially, we are going to discuss common misconceptions about generative design, the role artificial intelligence plays in its processes, and how engineers fit into its workflows.

Generative Design Market Statistics

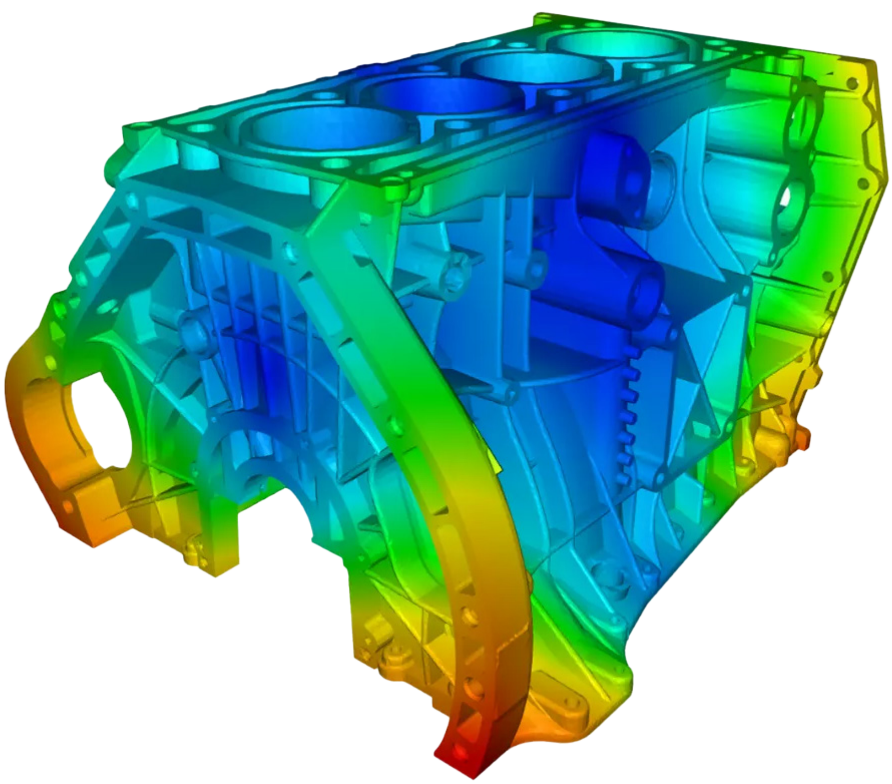
Mordor Intelligence (not to be confused with the location of Mount Doom) estimates the size of the generative design market to be USD 3.81 billion in 2024. This is anticipated to increase to USD 7.80 billion by 2029, representing a CAGR of 15.41% over that 5-year period.

The current largest markets are found in North America, with the Asia/Pacific region representing the fastest growth. The report highlights machine learning as a big player in helping support rapid growth, along with increased demands for efficiency and cost savings. Mordor Intelligence cites some of the big names in the market as Dassault, Ansys, Altair, Autodesk, and Hexagon (all of whom are partners of Tech Soft 3D).

A report from Stratis Research draws similar conclusions, estimating a market value of USD 7 billion in 2030 and a CAGR of 16% from 2022-2030.

These reports highlight several key aspects we discuss in this eBook: generative design is young, better suited to components rather than assemblies, and that AI can and will likely play a role in this process.

When examining market statistics, the overlap in media coverage of generative design and generative AI stands out. As we will discuss, these are not the same thing, nor are they directly interconnected.



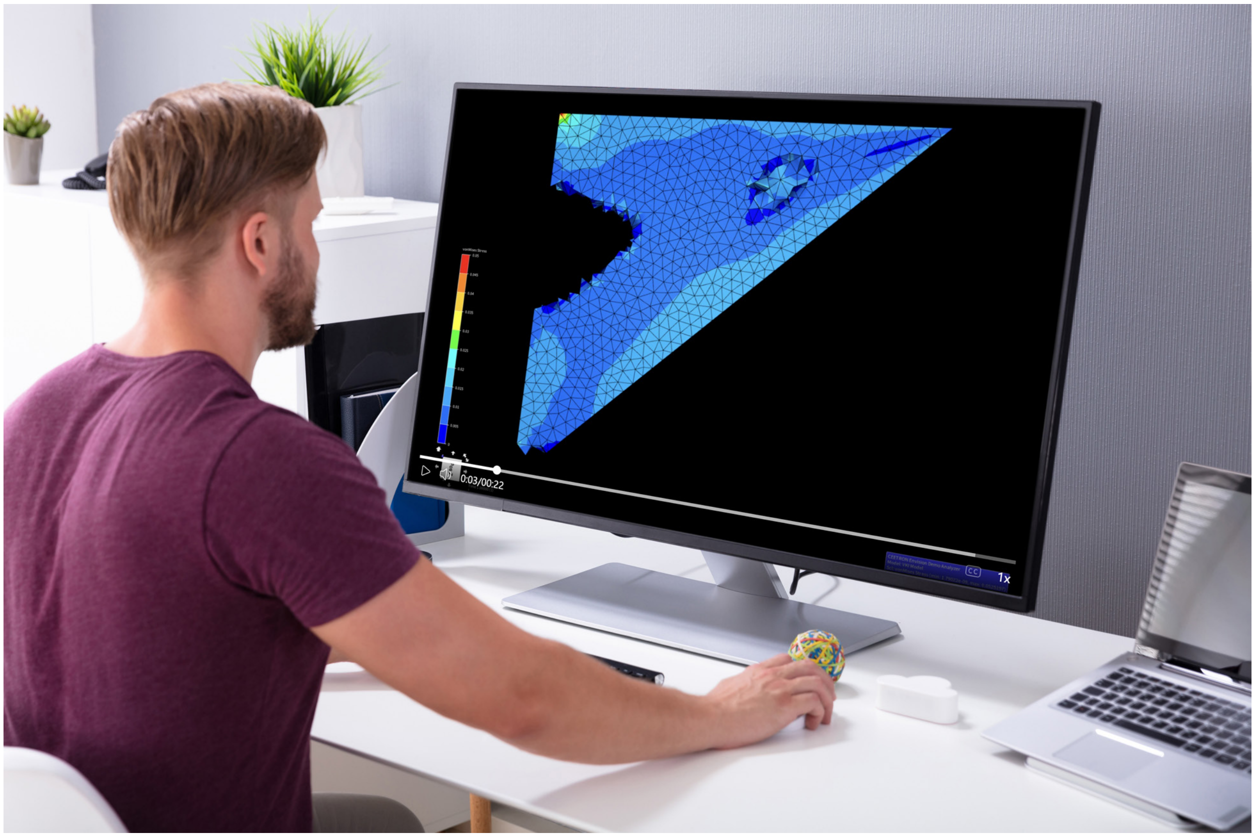
Defining Generative Design

In simple terms, generative design involves outlining a series of clearly defined criteria, or constraints, and using software tools to create outputs based on these parameters. This type of design process is iterative, with both the output and criteria being refined until the end product is satisfactory.

✔ Generative Design IS	✖ Generative Design is NOT
An iterative process, defined by its establishment of clear constraints before the creation of a near-finalized design	A form of generative artificial intelligence, or any other type of AI
Distinct from the traditional engineering design process	A replacement for the traditional design process
Useful for efficient design and optimization of components and parts	Not capable of independently creating large assemblies and complex designs
A powerful way to help engineers create and test thousands of potential designs	A replacement for engineers or a simplification of their duties
Beginning to leverage AI tools, with tons of potential for their use in the future	Dominated by generative or other forms of AI

Generative design is used across a wide array of industries, from engineering, aerospace, and architecture to the design of consumer products and urban planning. Crucially, the term generative design does not refer to one set of technologies or single process, but a broad design process defined by its iterative nature, constraints, and deviation from more traditional design methods.

In this eBook, we focus on generative design in engineering, with emphasis on what the process involves and is capable of.



Generative Design vs. Artificial Intelligence

Artificial intelligence is arguably the hottest trend for discussion across nearly every tech space. While the capabilities of AI are exploding, the rapid pace of change in the market naturally causes confusion as to what is and is not AI.

There are many different types of AI. The current explosion in conversation on the topic is fueled in part because of developments in **generative AI**. This type of AI, as the name suggests, can be used to create text, images, and other data based on prompts. It uses large AI models, to learn from vast amounts of data and then produce new content that's statistically likely to be relevant to the prompt. The terminology and "creative" nature of the technologies have led to some confusion as to the relationship between generative design and AI.

To be clear, generative design is not a type of AI-based technology. While there are places in the generative design workflow where AI tools can be used, the process itself is not inherently AI-based, nor is AI widely used in engineering applications of generative design.

Generative Design vs. Traditional Design Processes

Here we will highlight the common features of traditional engineering design process and contrast that to how generative design stands apart.

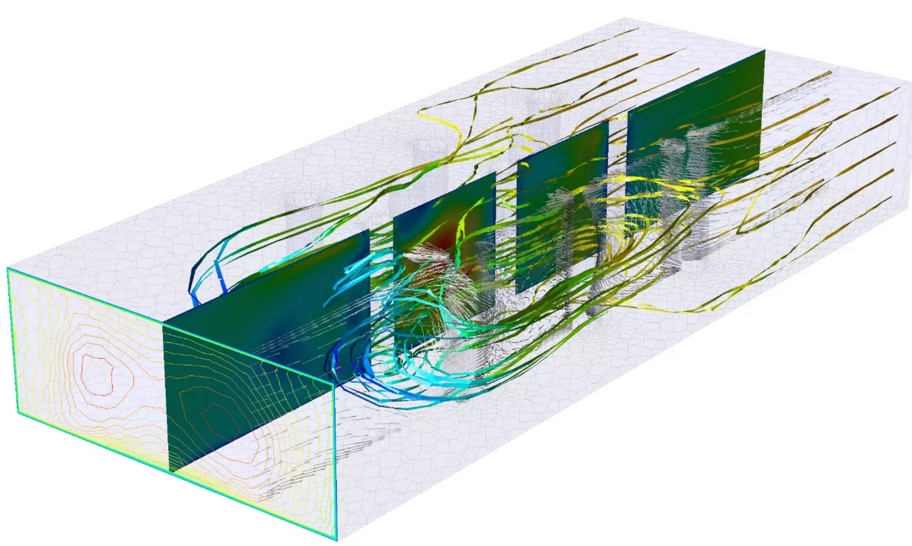
Traditional Engineering in Modern Settings

In a traditional engineering design process, Computer-Aided Design (CAD) software is used to design a model manually. Many times, the design is run through simulations to test the response to loads, temperature, pressure, manufacturing feasibility, and other constraints. For example, a simulation may seek to answer the question, “Is this bracket going to fail if a certain amount of force is exerted in this direction?” From here, engineers may adjust the design based on the simulation results and prior experience.

Notably, there is a disconnect between common CAD design processes and common manufacturing techniques. CAD software is usually additive. You start with a base plane, sketch features, extrude, cut, and round profiles into the shape you need. The most common forms of Computer Aid Manufacturing (CAM) are usually subtractive, starting with a block and then creating holes, slots, and other features, teaching a CNC machine or other manufacturing tool how to create your product.

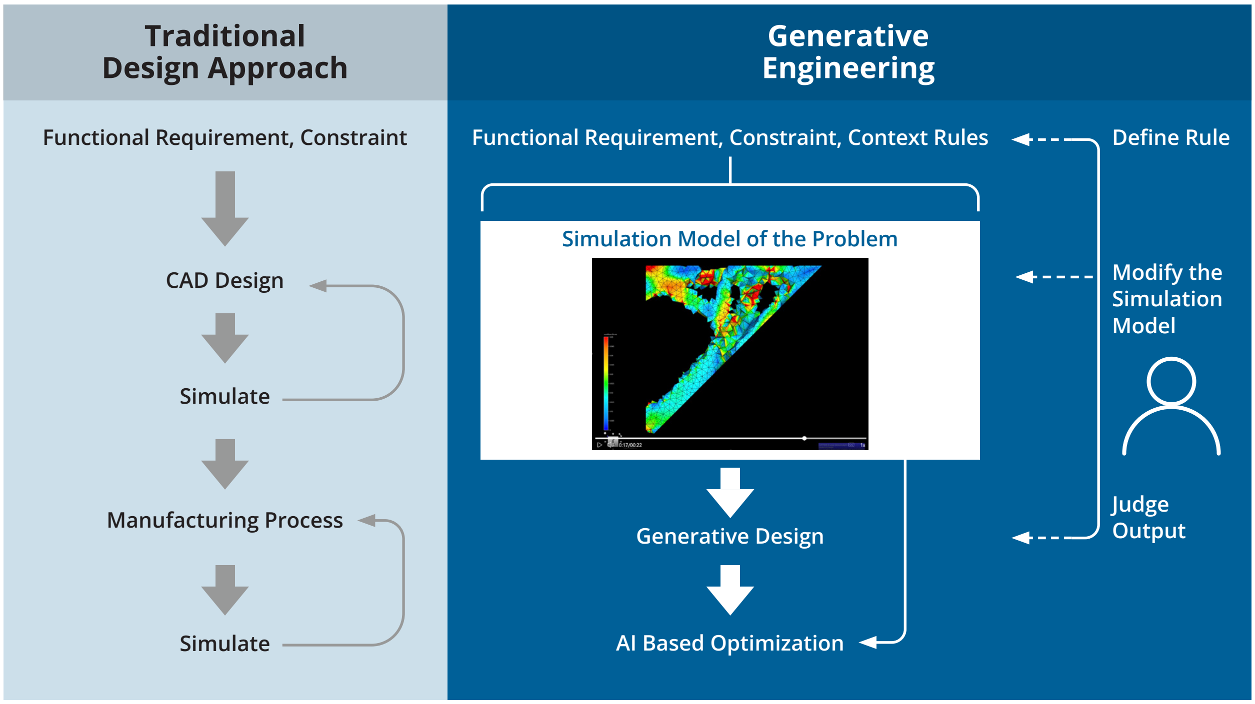
This discrepancy shows how traditional design techniques often fail to take manufacturing processes into account. Designs must be refined after the fact to make them either possible or more efficient to create in the real world.

The need for manual redesigns in every iteration is time-consuming and expensive. Limited budgets and deadlines can leave engineers forced to settle for suboptimal designs.



How the Generative Design Process Works

Generative design fundamentally changes the design process. Traditionally, a CAD model put through simulation is intended to be close to the final product, with the results ideally used to make minor changes to the design instead of completely transforming it.



Generative design sees engineers spend far more time and energy outlining constraints **before** the creation of a design. The design is created using algorithms that are informed by these criteria and is then tested through simulation tools and optimized. The different stages of this process are repeated until the engineers are satisfied with the results.

The three broad stages of the generative design process are:

1. Defining the constraints
2. Exploring the shape
3. Simulation and optimization

Defining the Constraints

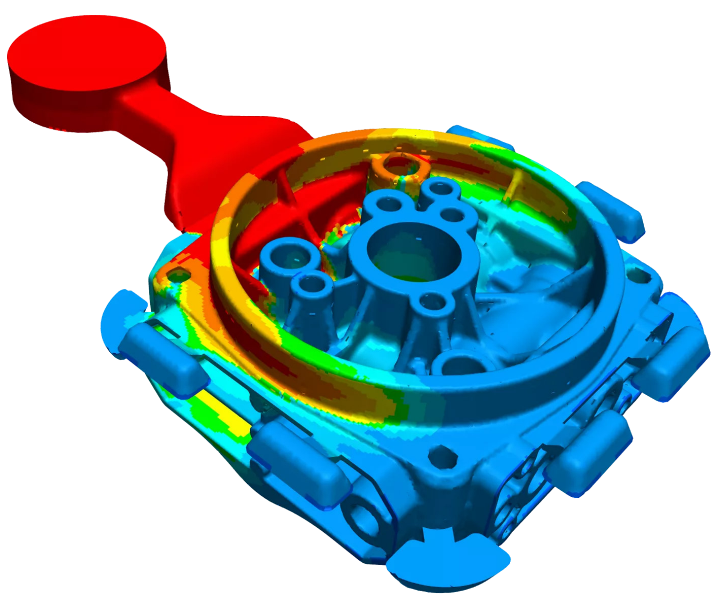
Engineers start by creating or adjusting the functional requirements and constraints; a huge amount of effort goes into this process. This stage also relies on establishing a clear definition of the goals of the design, the data that will be used to inform the algorithms, and the best algorithms to use.

Constraints can include physical and functional needs like thermal dynamics, structural requirements, and then materials, costs, availability of resources, etc. These requirements inform the generative design algorithm **before** the creation of a 3D model, instead of traditional simulation **after** a model is created.

To use an example of designing a bike seat, a generative design process would create logic graphs that describe the necessary constraints. This could include the anticipated weight of the rider, the materials the seat is to be made from, an instruction to minimize the amount of material where possible, etc. The more complex the part and the loads it will be subjected to, the more complex the process of creating these rules is.

Engineers can also define the method of manufacturing that will be used in the creation of the real component – for example, a part made by an XY plane CNC machine would not be able to call for material to be removed on the Z axis. The expert may factor this into the constraints, so a slot is not cut along that plane. For another example, a designer creating a product by injection molding could create a constraint calling for even cooling of the product to reduce cracking.

This process of **clearly defined rules that inform the design** process is a cornerstone of generative design. With these constraints established, the expert is ready to begin leveraging the chosen algorithm to create a design.

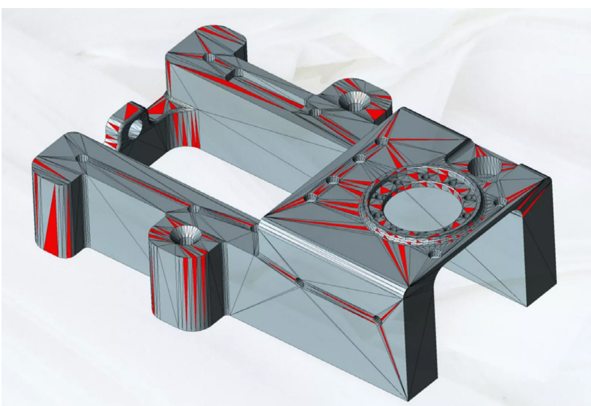


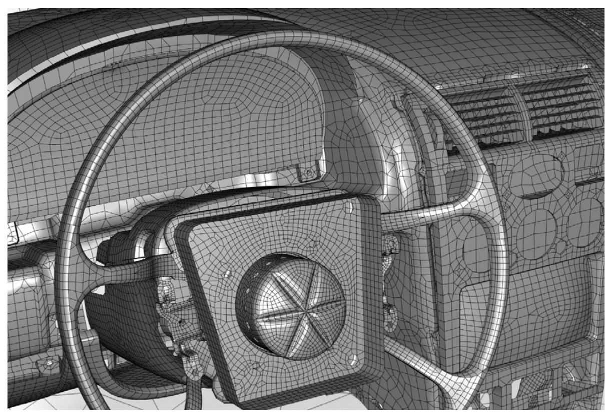
Exploring the Shape

The next phase of the process is where a design of the object is created, using algorithms informed by the constraints established in the last step. The two common technologies used for this stage of generative design algorithms are based on **topology optimization** and **parametric modeling**. Many other techniques to explore the shape exist, but the CAD industry can ultimately only utilize ones that produce manufacturable shapes.

Most generative design technology on the market today utilizes **topology optimization**. Not dissimilar to how traditional manual CAD design often begins with a shape and sees material taken away, the process starts with a cube (or other shape) and material is removed from there.

A **parametric modeler** would take a different approach. This process starts with an initial parametric design. The design might include a hole with a radius of 5 cm. Exploring the shape would involve the algorithm exploring different sizes for that hole.





Simulation and Optimization

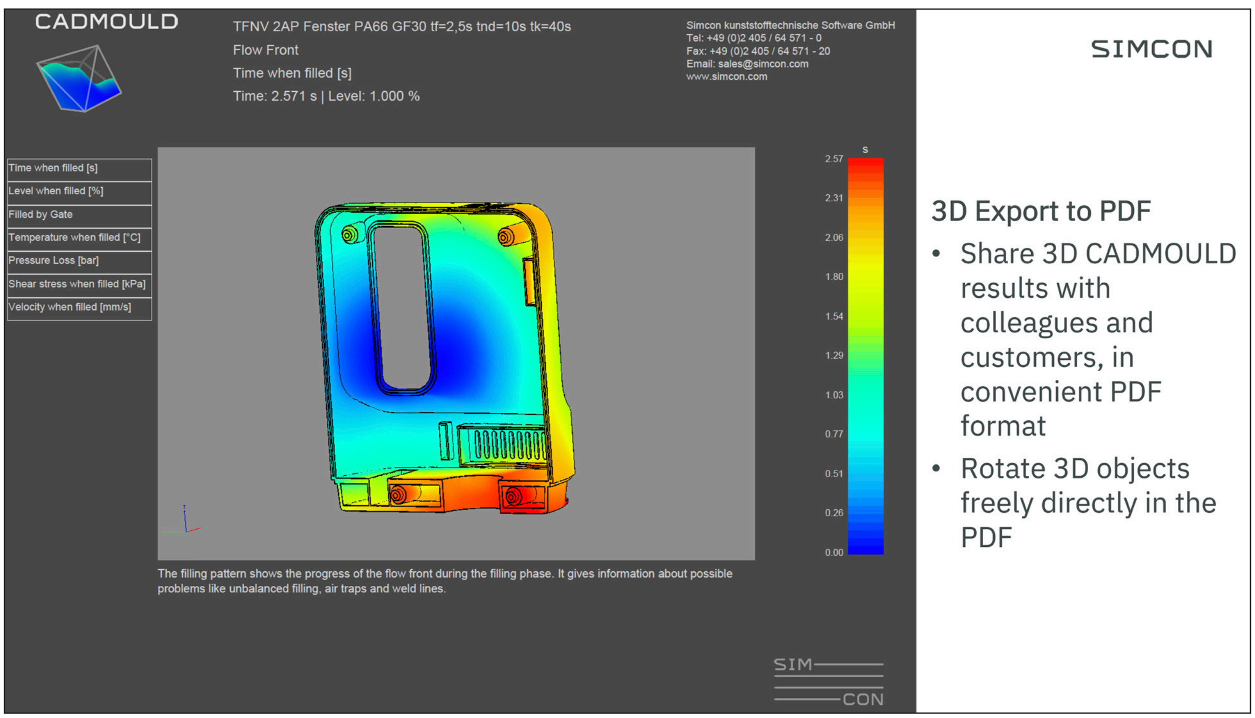
Engineers use a variety of simulation tools to evaluate the product of the algorithms in the previous steps. This will vary significantly depending on what you are creating. For our example of an injection-molded component, you may simulate the hot material entering the mold and how it would cool over time.

Now, the engineer uses optimization tools and the parameters they've outlined to iterate on different shapes. Engineers try to get the part as close to their ideal as possible and then repeat the previous steps to refine as needed. The underlying algorithm and constraints can be changed, with the engineer modifying the process to get close to the desired result.

Simulation plays a role throughout the generative design process. With the key constraints outlined and tweaked repeatedly, the algorithm simulates many designs and presents some that may fit the acceptance criteria. The algorithm itself is also adjusted. Just like in a traditional workflow, the results are used to iterate and improve the final result.

SIMCON

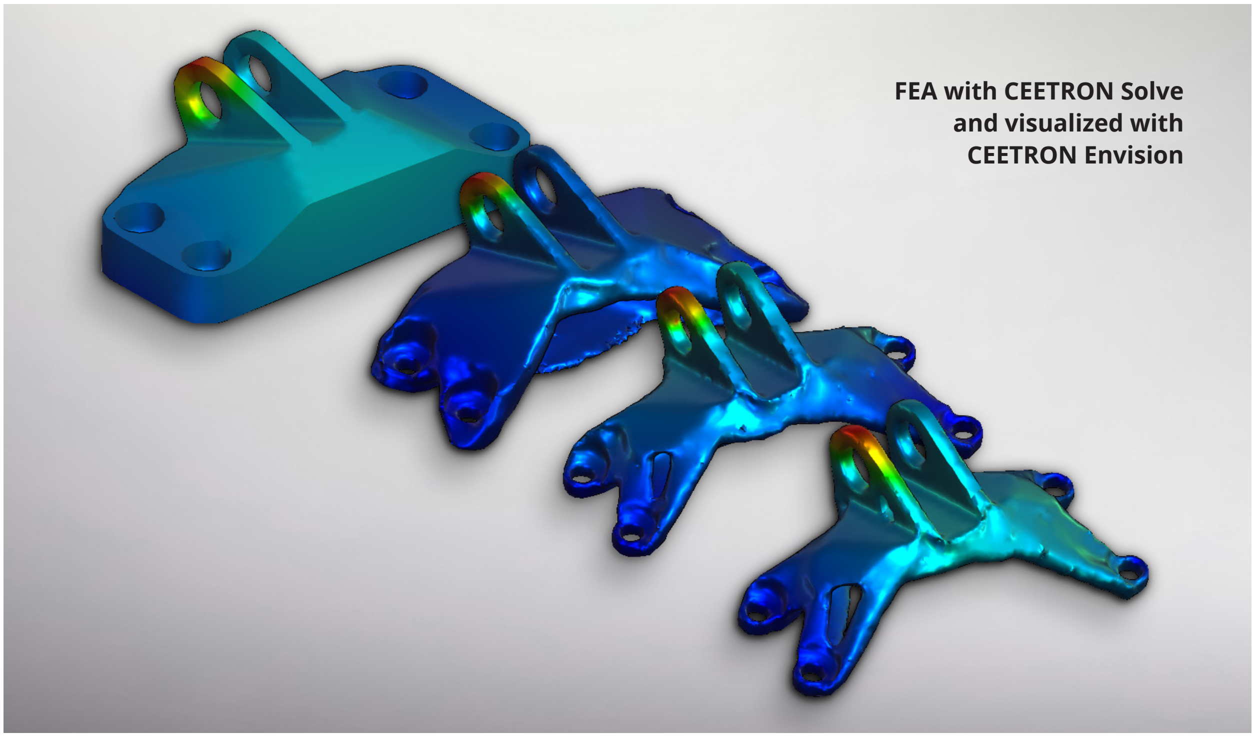
[Read about](#) an example of how Tech Soft 3D SDKs help power SIMCON's injection molding tools.



The final output will often still require work. This can involve recreating the object in CAD software, utilizing a mesh smoothing tool, or processes to take the generated design from concept to manufacturable reality.

Generative Design Example

In the example below, a jet engine bracket is run through an FEA simulation. An open-source optimizer was used to reduce its weight by 40% and still meet its design constraints. This involved repeatedly removing material and restimulating. The model is constrained by a load point and 4 fixed mounting points, which are set as non-optimizable. The rest of the piece is optimized, aiming to achieve a 40% reduction in weight.



The final image is the result of 57 iterations and is something unlikely to be created through traditional design processes. The designs would then need to be either manually remade in CAD software and machined or be 3D printed as is.

Why Use Generative Design?

The generative design process is significantly different from traditional design processes and offers a variety of benefits to engineers.

Traditional design requires different designs to be created and tested. Human input is required throughout the process. Arriving at the optimal solution relies on refining the model, guided by simulation, testing, and experience. Each iteration takes time and money, and teams can often manage only a handful of iterations in the time/budget available.

Generative design allows teams to potentially iterate **thousands** of times, testing each under a larger variety of conditions and constraints. As you can see in the example above, the results can be unlike something you would see a human designer create. This allows engineers to test far more ideas than humanly possible, thus arriving at more optimal designs that may be missed in more traditional workflows. Generative design, as a result of this efficiency, can save organizations significant time and money when used well.

The Role of Engineers in Generative Design and It's Limitations

Engineers remain integral to every phase of the generative design process, playing a role just as crucial as in traditional workflows.

The creation of requirements, constraints, and contextual rules for the simulation model is one of the most complex parts of the new design process. Engineers must carefully boil down the problem into its core elements and constraints, an extremely difficult task.

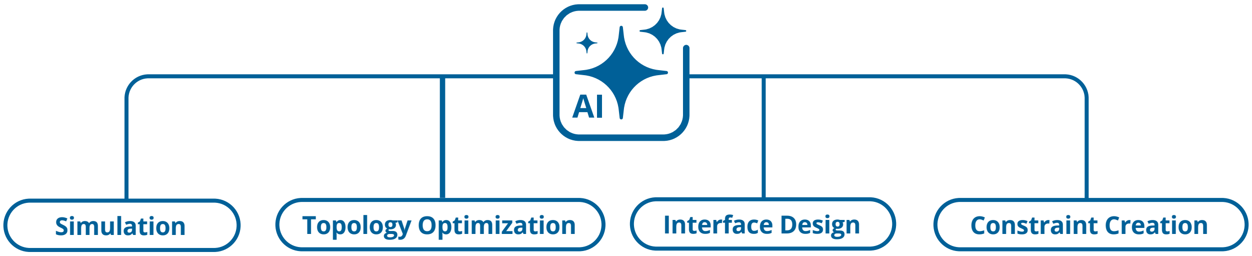
Engineers in the generative design process use their experience to outline and implement constraints, select and refine algorithms, run and improve simulations, and verify results.

Engineers are critical to modifying, or coaching, the simulation model and judging the output. After the model creates a design and evaluates it through its process, engineers must examine the results and determine what needs changing.

Despite its utility, the generative design process is extremely limited in its ability to create more complicated parts. While our simulation and constraint-building technology is powerful, these tools are not perfect representations.

For larger and more complex parts and assemblies, multiphysics simulations and testing yield far from fully accurate results. As a result, engineers must use generative design carefully, on individual parts or small assemblies, before using their own experience and other tools. The more detailed a component or the loads it will be subjected to, the more challenging the role of the engineer.

To summarize, generative design is a powerful tool that is fantastic at rapid design iteration of specific components with limited complexity. It does not replace traditional design processes, nor is it likely to.



The Role of AI in Generative Design

Despite generative design not being inherently artificial intelligence based, AI tools are just beginning to be used in the process. AI technologies are evolving faster than almost anything else. Moore's Law has famously described the astonishing trend of the number of transistors on a microchip doubles every two years, and with it, computing power. In contrast, AI software performance is doubling every 6 months in some cases. So, is AI rapidly coming in and conquering the entire generative design process?

The short answer is no, not yet, and it's unlikely this will happen in the near future. While many industries grapple with the very real fear of AI-powered technology taking their jobs, for engineers, the effect is likely to be more transformative to their process rather than replace them.

While these tools are in their infancy, there are some exciting areas where AI can be useful that we must keep an eye on.

During simulation, AI tools could be useful for evaluating a wide range of results faster than a human could alone. Generative AI models could be used in place of topology optimization or other algorithms to create designs for testing. Natural language processes, powered by AI, could allow for an easier, more intuitive interface with the entire design process, allowing engineers to simply describe changes they would like to see. AI tools could help engineers come up with constraints and program them into simulators or help them adjust their algorithms.

AI is, of course, having a significant impact on engineering, design, and simulation. To learn more about this, check out our blog post/podcast episode on this topic below.

How AI is Impacting Engineering, Design, and Simulation

How Does Tech Soft 3D Support Generative Design?

Generative design is changing the way engineers work across a wide range of industries. This introduces new challenges and opportunities for developers. Our SDKs provide unique ways to address pain points, drive innovation, and get the most out of generative design and other creative processes. No matter what engineering software you are creating, Tech Soft 3D toolkits can offer you a competitive advantage while saving you time and money in the development process.

We can support your CAD data import needs with HOOPS Exchange for direct access to over 30 different CAD file formats, while CEETRON Access delivers API access to just as many CAE file formats, including simulation results and preprocessed meshes. These toolkits allow you to access rich 3D within your application and provide easy creation of learning sets to train an AI model or, as a prompt, a starting point for a generative algorithm.

Generative algorithms need tools to both define and solve simulation models. CEETRON Solve is a set of developer tools that jumpstart algorithm development and implementation with a diverse set of linear algebra and matrix tools and interactive linear and eigen solvers.

Another way Tech Soft 3D is supporting the evolution of computer aided design and manufacturing is through our powerful visualization toolkits.

Generative design algorithms can output many varying designs that need to be reviewed by an actual person. A reliable and powerful graphics framework for visualizing and navigating this information is crucial. Our toolkits empower developers to create intelligent, interactive 3D interfaces within their applications.

Over half of today's CAD and CAM systems are powered by Siemens Parasolid, the world's leading solid modeling kernel. Tech Soft 3D is the sole reseller of Parasolid, and we have direct integrations with many of our existing toolkits, which allows for rapid application development. Solid modeling is important for BREP and parametric model creation and refinement.

HOOPS Visualize supports those building for desktop and mobile applications, while HOOPS Communicator supports developers building 3D web applications.

For those working with CAE data, CEETRON Envision offers the complete package of CAE data import, analysis, visualization, reporting, and automation.

HOOPS SDKS

HOOPS WEB PLATFORM

HOOPS Web Platform provides integrated SDKs for developing 3D web applications

HOOPS NATIVE PLATFORM

HOOPS Native Platform provides integrated SDKs for developing 3D desktop, mobile and AR/VR applications

HOOPS EXCHANGE

HOOPS Exchange is an SDK for importing 30+ CAD formats into your application

HOOPS COMMUNICATOR

HOOPS Communicator is a graphics engine for high performance web applications

HOOPS VISUALIZE

HOOPS Visualize is a graphics engine for desktop, mobile & AR/VR applications

HOOPS LUMINATE

HOOPS Luminate is a graphics toolkit for photorealistic & advanced real-time rendering

HOOPS PUBLISH

HOOPS Publish is a native SDK for generating interactive 3D PDF documents

CEETRON SDKS

CEETRON ACCESS

CEETRON Access provides universal reading and writing of CAE data through a unique programming interface

CEETRON MESH

CEETRON Mesh is a comprehensive 2D & 3D meshing component for CAE application development

CEETRON SOLVE

CEETRON Solve is a high-performance toolkit to build and solve FEM models

CEETRON ENVISION

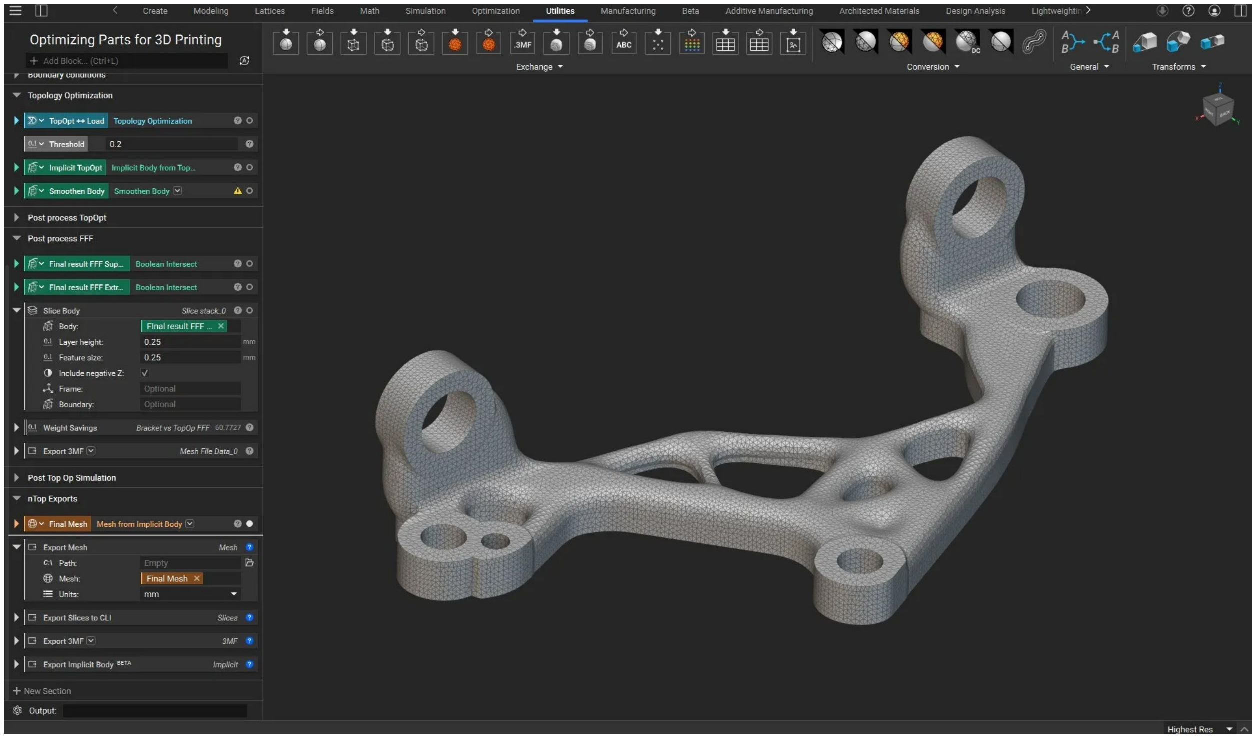
CEETRON Envision is a toolkit for CAE data import, analysis, visualization, reporting and automation

Alternatively, if your data model is based on polygons or you are building additive manufacturing (3D printing) software, we are the exclusive reseller of Machineworks Polygonica, the marketing leading polygonal and mesh modeling toolkit. As with Parasolid, we have direct integrations with many of our existing SDKs.

As mentioned, generative design is still in its formative stages. With improvements in technology, from simulation and analysis to more powerful hardware and artificial intelligence, generative design is only going to grow in its capacity to revolutionize design processes.

Tech Soft 3D is excited to support these changes and will continue to develop its capabilities in these ground-breaking technologies. Get in touch to learn more about how our products can support your application development, no matter what your workflow is

Contact Us



Spotlight: Tech Soft 3D Partners Working in Generative Design

As highlighted in our market research section, some of the biggest names working in generative design are partners of Tech Soft 3D. One of these partners is nTop. You can read about their work in generative design here. Additionally, hear directly from them what it's like to work with Tech Soft 3D through our Partner Success Story below.

Tech Soft 3D and nTop Case Studies

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