

# Generative Design: The Latest Tool in the Engineer's Toolbox



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# INTRODUCTION

Any engineer would like to do their best work in less time – but how? Generative design provides a compelling answer to that question. By intelligently automating basic shape design, generative design accelerates the design process and frees the engineer to perform more advanced design functions.

## SO, WHAT YOU CAN DO WITH GENERATIVE DESIGN?

- Save time: Establish your constraints and requirements – including materials and manufacturing processes – and generative design will automatically create solutions from which to choose.
- Maximize lightweighting: Generative design helps to remove excess material without sacrificing performance against other criteria.
- Innovate: Need new ideas, quickly? Generative design can create solutions you might never had considered.

## IN THIS EBOOK, WE'LL ALSO ADDRESS THESE COMMON MISCONCEPTIONS OF GENERATIVE DESIGN:

- “3D printing is required for generatively designed parts.” The truth is that generative design can conceive conventionally manufactured parts.
- “Generative design is only for specialists.” Rather, it can be used by product designers at any skill or experience level.
- “There is no difference between generative design and topology optimization.” In fact, they are different technologies, but topology optimization is used in generative design.

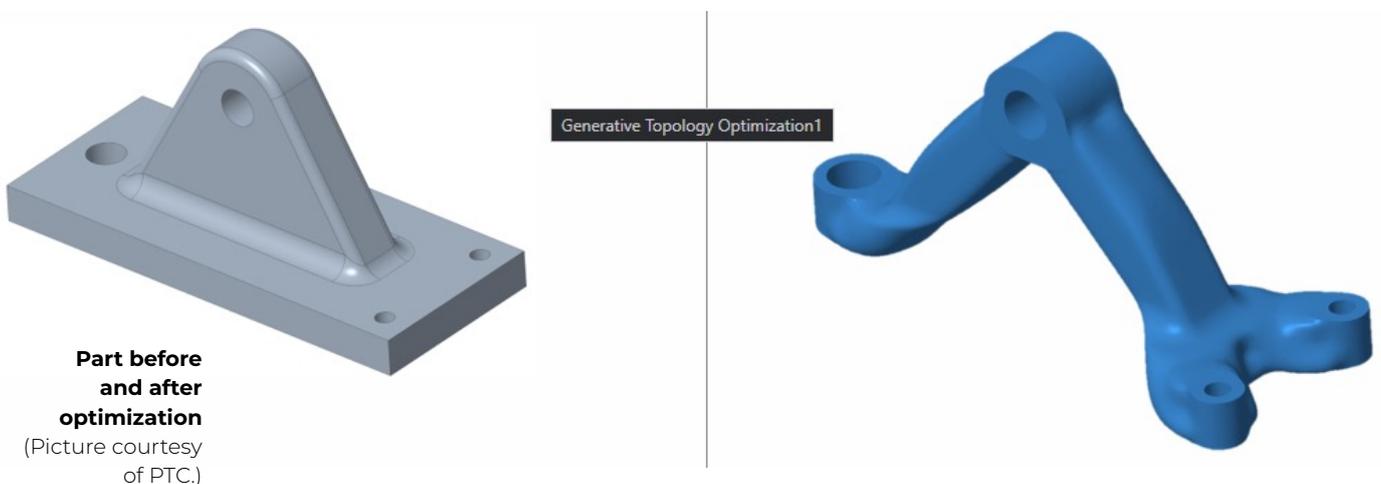
# HOW GENERATIVE DESIGN WORKS

A rough yet simple definition of generative design is fully automated CAD, turbocharged by machine learning. Give a generative design program a goal, and it will generate a design, test it against all user-defined parameters, identify areas of improvement, and use that learning to generate another, better design. This cycle repeats at silicon chip-powered speed until an optimized design is achieved.

Generative design and topology optimization are often thought to be one and the same. In fact, topology optimization is a key technology underpinning generative design.

Generative design automatically generates designs that meet specifications. It starts with a designer defining the volume the part will occupy, the interfaces to the rest of the assembly, and the loads the part will encounter. The designer also defines conditions and parameters of the design, such as the material the item will be made of, the manufacturing process used to make it, and goals such as least weight. The generative design application produces multiple shapes, all meeting the stated requirements.

**Topology optimization** finds the one ideal shape for a specific loading or restraint case by numerous iterations. The shape is broken down into a mesh of elements. It is analyzed with the finite element model for stress from the given loads. The shape is reduced where there is no stress. The new shape is meshed with finer elements, then analyzed for stress, and the process is repeated. By removing material where there is no load, topology optimization results in a part with the minimum required amount of material along load paths, making it particularly valuable to any engineer in charge of lightweighting. But only one optimized shape results.



## A STRESS ANALYST IN YOUR POCKET

The ability to detect load paths may seem intuitive, but engineers hone that skill through decades of experience in stress analysis. Load paths are invisible, revealing themselves only in FEA simulation or in the forensic analysis of failed parts.

Generative design is like having a seasoned product engineer and an expert stress analyst do your work for you, but at the speed of a computer. Since it relies on the solution of finite element analyses (FEA) and automatically adds material where stresses are too high, designers can be assured their parts will work in the intended environment.

## WHEN INEXPERIENCE IS A FUNDAMENTAL ADVANTAGE

Ample experience in product design can be good news and bad news at the same time. The good news is that an experienced design engineer can draw on their past work to produce designs faster. The bad news is they are likely to draw only upon the memory of designs that worked. For instance, if a metal bracket that supports a motor has been safe and steady for years, why not use it again exactly as is in the next design? This can result in continued acceptance of less-than-optimal shapes.

An experienced designer may consider CAD shapes optimal – assuming straight, round, flat, and symmetric are always optimal. Generative design makes no such assumptions; rather, it subjects each shape to a rigorous analysis to identify an optimal shape.

The shape optimization of generative design results in shapes that have material where it's needed and nowhere else.

# MANUFACTURING IN THE REAL WORLD

Unlike a human designer, whose ideation is likely to be informed by familiar, common shapes, generative design starts and continues without any preconceived notions of what shape will work, nor any bias toward geometric shapes or symmetry. Thus, generative design can produce parts of almost alien appearance. However, if a generatively designed shape is unfeasible in some way – say, its usability or manufacturability using available means – engineers can rework the shape to their specifications.

That said, the need to rework generatively designed shapes for manufacturability is largely a thing of the past. Additive manufacturing methods, including 3D printing, are no longer prerequisite. Recent generations of generative design programs can be set to produce shapes that can be machined, cast, or molded.

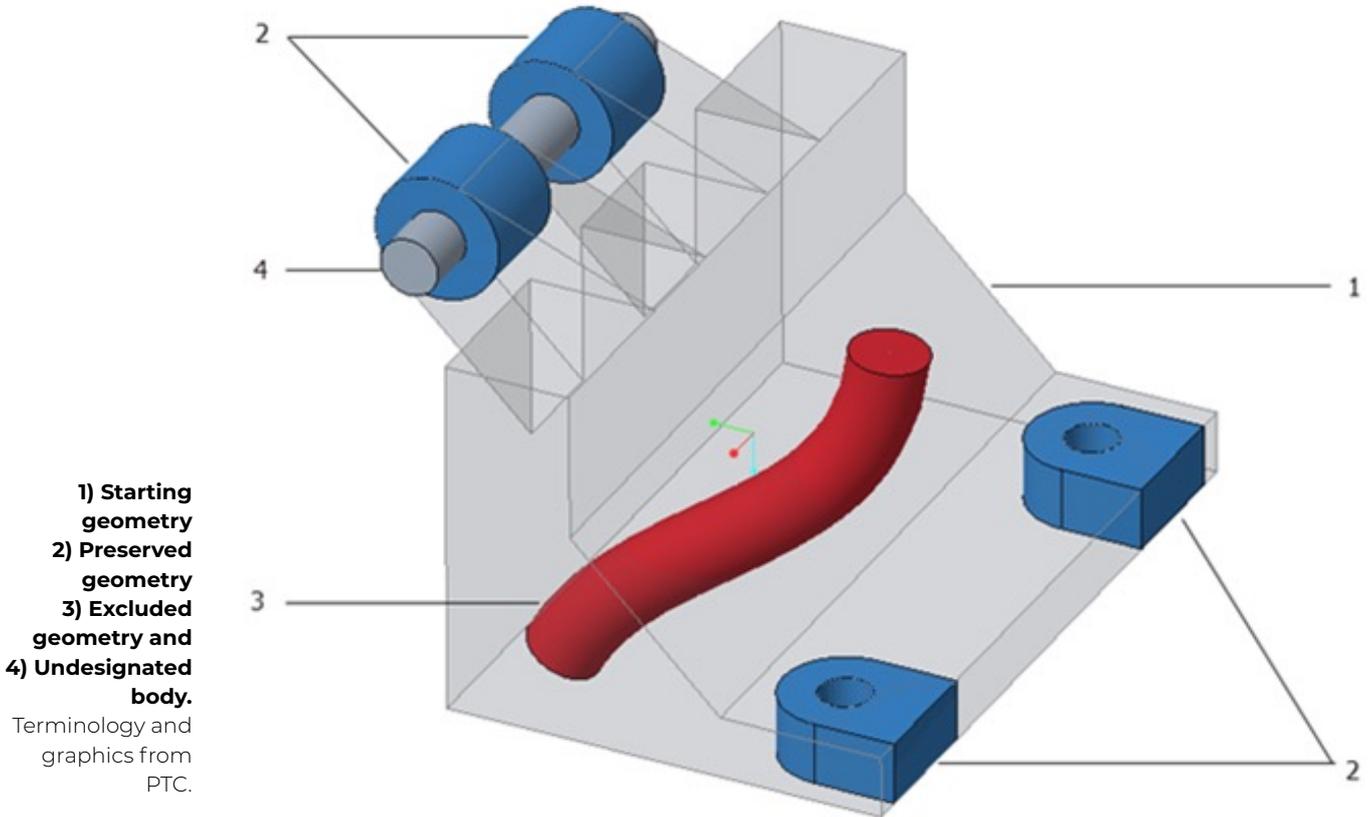
The latest generation of generative design programs have addressed manufacturability. Previous generations of topology optimizers resulted in a faceted shape that would be difficult to machine and impossible to cast or mold. But the latest generation of generative design programs take the extra effort to convert their faceted models into B-rep geometry, i.e., a solid model, that can be easily shaped further with Boolean operations (add, subtract union). They are also usable down the line because CAM programs can import solid models.

But, best of all, generative design programs can be set to create parts for manufacture by casting, molding, or CNC milling – without post-processing. For instance, PTC's Creo, with a GTD and GDX extension, can create parts that can be manufactured by a CNC machine with a Linear Extrude setting: either a Bidirectional Extrude for 2-axis milling or a Unidirectional Extrude for 3-axis milling.

A parting line constraint helps create a part that will be forged or cast. Designers can specify the pull direction that separates the parts of the mold as well as a draft angle.

## HOW DO YOU START WITH GENERATIVE DESIGN?

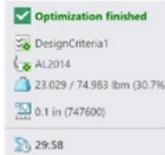
A generative design begins with a starting shape – the volume that totally contains the part. As the part “grows,” it will be limited to the starting shape. The starting shape can be a newly created volume or the surface and volume of an existing part. Within the starting shape, other volumes can be designated as unaffected (either “preserved” or “excluded”).



## IMPROVING LEGACY PARTS

Generative design is equally applicable to improving existing parts as it is to creating new ones.

Product-development timelines often limit engineers to incorporating existing parts, even if they’re suspected of being suboptimal – perhaps because they were designed pre-CAD or before the advent of certain manufacturing techniques. Generative design presents new opportunities to optimize parts within the necessary timeframe. Parts improvements that would take hours for an engineer to accomplish could be done in minutes using generative design. For instance, the relatively complicated part pictured below took less than a minute to generate using a local workstation. It’s not a common result, but it is possible.



Supports for a reflector form from a generative design, spreading the load from the top (small red areas) to the bottom of a part.

(Picture courtesy of Andreas Vlahinos.)

## INDUSTRY APPLICATIONS

Generative design is used most by the aerospace and automotive industries, so it stands to reason that generative design excels at weight reduction, which is crucial when getting an object off the ground or down the road.



Jacobs used generative design by Creo to lightweight their space backpack, the xPLSS (Exploration Portable Life Support System).

(Picture courtesy of PTC.)

# WHEN SHOULD YOU USE GENERATIVE DESIGN?

Whether the goal is to develop an optimal new part or to optimize an existing part, generative design is best applied at the conceptual stage of the development process.

Consider this simple example: the only requirements for the object are that it seats a person on a flat surface and has three points of support on the floor. Is a three-legged stool the best solution? The only solution? Generative design might give surprising answers in the many shapes it creates that satisfy the design specifications. One or more of them could be lighter, stronger, less expensive to produce and more environmentally sustainable than a three-legged stool of the same material. Refinements will likely need to be made, but a design project that launches with multiple, viable options is surely better than a design project that launches with none.

Using generative design is like having a head start in the design process. But it can do more than just cut time off the clock. Generative design doesn't follow convention or favor the familiar, making it more likely to produce groundbreaking designs that humans might never have conceived. It doesn't replace designers and engineers; it empowers them to do their best work in less time, and liberates them to focus on endeavors that generate greater rewards for their employers and themselves.



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