

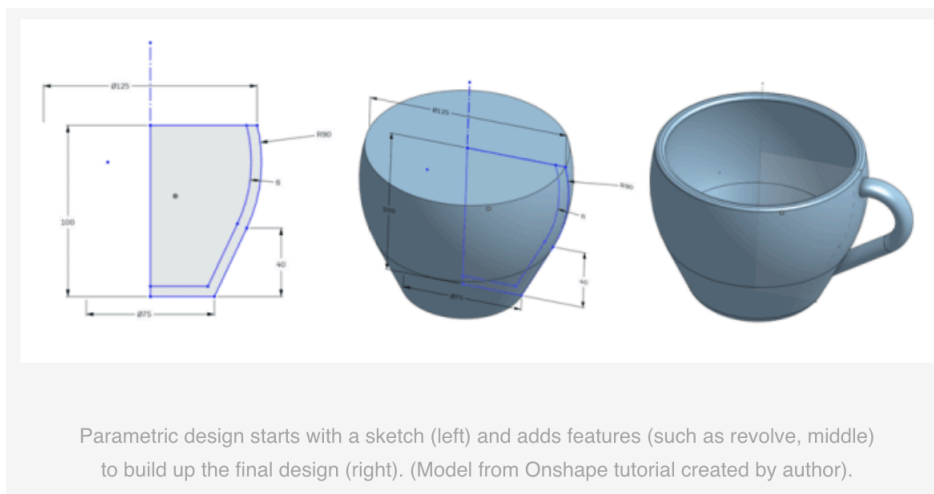
Guide to Parametric Modeling: The Efficacy of 3D Printing for a Parametric Design

Parametric modeling utilizes CAD to create functional model iterations for products as diverse as orthotics, office furniture, and skyscrapers. AI generated parametric models produce a variety of workable design alternatives based on set parameters entered into the CAD software settings. The following guide to parametric modeling provides a clear understanding of its functionality and benefits to the design process.

Pairing the efficacy of generative design systems—such as 3d printing hardware—with parametric modeling, facilitates rapid prototyping of functioning designs. Engineers, scientists, and hobbyists may then choose the most appealing prototype to download for replication. Parametric design is the next evolutionary step in design, by quickly and efficiently combining artistry with functionality.

Fundamentals of Parametric Modeling

Consider an ideal modeling system. The user simply inputs parameters into a system, such as model dimensions, patterns, wall thickness, hole depths, etc. The inputted parameters steer the 3D CAD, which quickly returns workable complex geometries that meet the provided input constraints.



The user then sits back looking through the designs until they discover an optimal model. Often the user searches for original looks, or some desirable feature to the model. One way or another, the user never needs to draw a line, make an angle, or write a single note. The user can modify areas of the model, and the rest of the design compensates for the adjustment based on the inputted parameters. There is never a need to redraw the model.

Parametric models are mathematical models mostly based off of historical inputs. Every design builds off of previous models to continue the evolution of the designs. **Parametric modeling** swiftly and accurately creates designs for all sorts of products, parts, or structures. This makes it appealing to manufacturers. Combined with 3D printing hardware that quickly produces physical prototypes, **parametric modeling** makes for an efficient design process.

Using Parametric Modeling in the Development Process

One of the best applications of **parametric modeling** takes place in the development process. Often, users simply look to get started on a project and so require ideas. The user jumps into a **CAD system** with parametric modeling built-in, inputs basic parameters of a simple design, and sees what the system comes up with.

Once the system outputs designs, the next developmental stage begins. Introducing a **direct modeling software** into the process means the user can manipulate the designs further to add more artistry and aesthetics to the design.

Ideal Projects for Parametric Modeling

Parametric models display statistics about a data population. Even something as simple as a normal distribution can utilize parametric modeling. These common statistical models accurately determine trends within **data** populations containing enough **data** points. Other common statistical **parametric** functional examples:

- Weibull distributions: a product lifetime distribution used in reliability engineering
- Poisson distributions: a probability distribution to determine the likely number of occurrences over a period of time
- Linear regressions: used to determine the value of an unknown variable based off of a known variable

The distributions listed above play a role in the design of even the most basic products. In other words, any product necessitating original design iterations, benefits from **parametric modelling**.

The architectural design of built assets makes **parametric modeling** ideal. But for more complex mechanical designs, intuitive 3D modeling integrated with mechanical computer-aided design (MCAD) **software** becomes necessary. Material density formulas or reference surfaces set MCAD apart for the more complex geometries in certain software systems.

Top Reasons Manufacturers Use Parametric Modeling

Manufacturers like parametric modeling especially with the inclusion of 3D CAD. The unique models produced by parametric designs create complications for [subtractive manufacturing—a traditional manufacturing technique where blocks of material are machined down into shape.](#) However, the additive manufacturing of 3D printers permits for a wide range of physical design variables by parametric modeling.

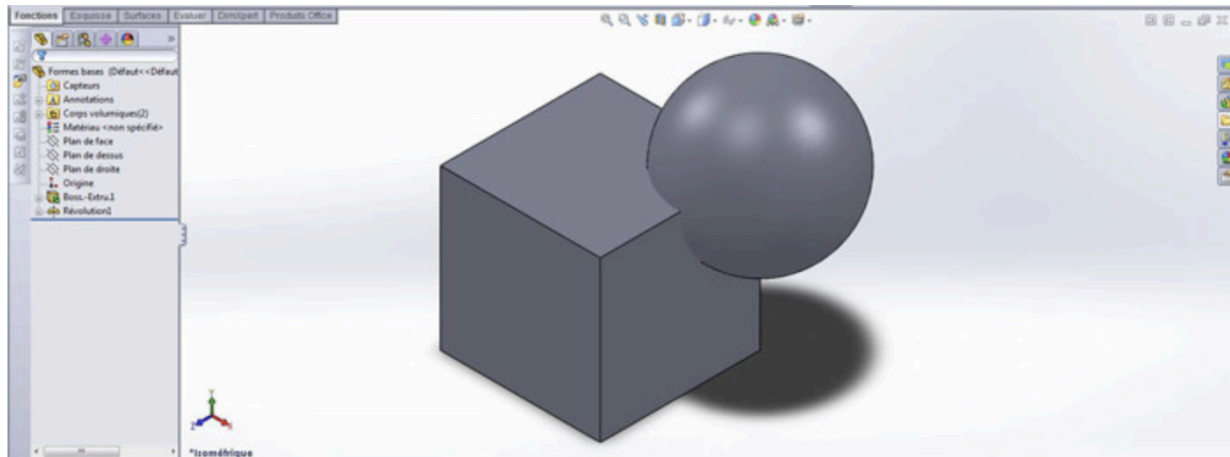
Needless to say, the speed at which parametric models can output functional designs appeals to manufacturers. Overtime, parametric models save a great deal of money due to the automation.

Manufactures also save on labor costs by utilizing parametric modeling since adjustments never skew design intent that would otherwise require a full redraw.

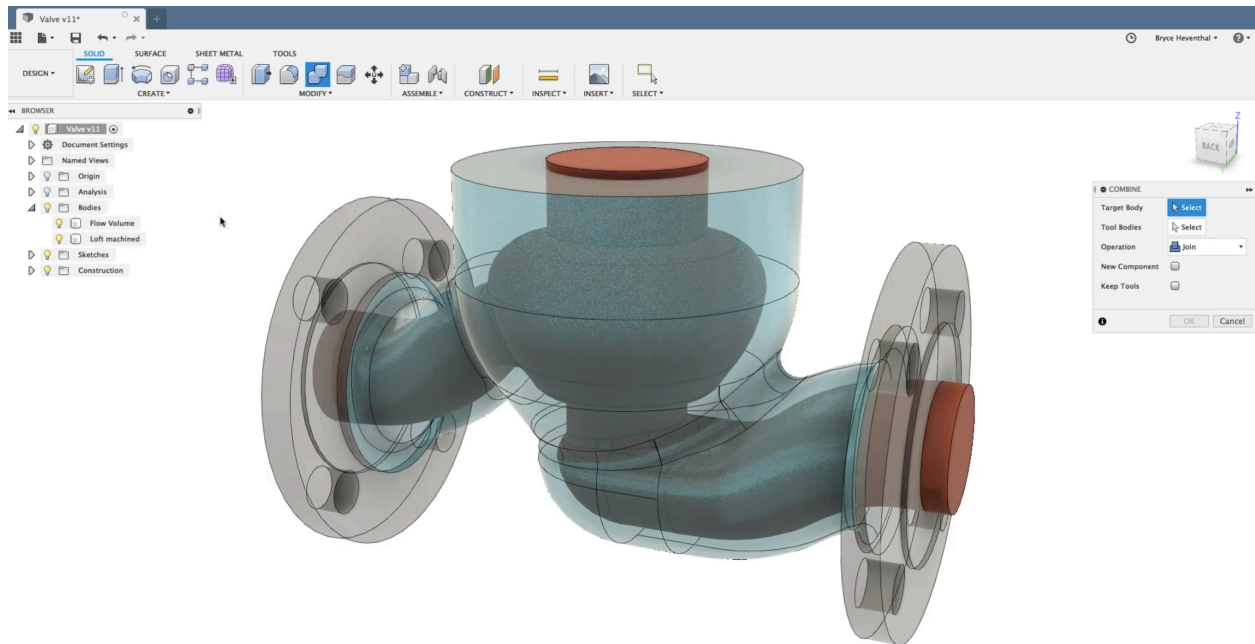
Parametric Modeling Software

Most parametric paradigms are available on every mainstream CAD software. These software applications also function on most common operating systems.

SolidWorks

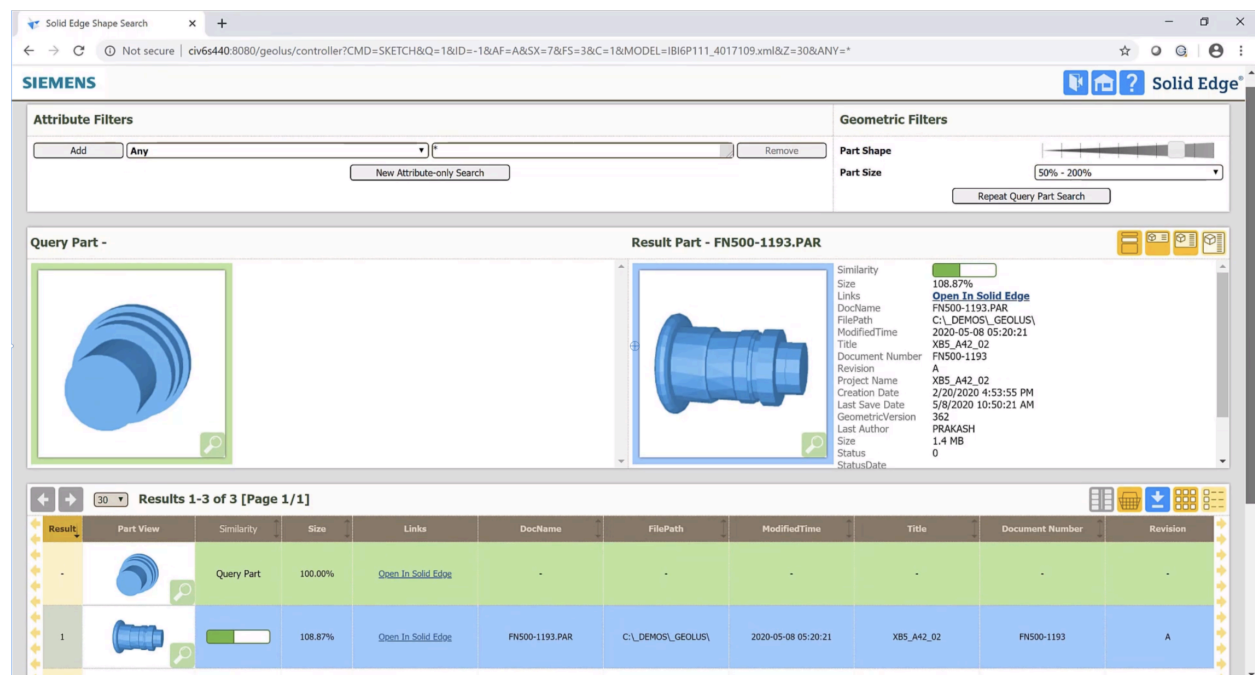


The SolidWorks modeling CAD software is a user-friendly application allowing users to design all sorts of projects. It provides three interconnected files: the part, the assembly, the drawing. When any of the files are altered, the other files automatically compensate for the alterations. Final model designs are downloadable in many file formats.



The Fusion 360 **software** is a subscription-based fully comprehensive CAD application with many included features like parametric modeling. The parameters available include: extrude, revolve, sweep, and more. Like all parametric models, the system responds to any adjustment to a **feature** with an automatic update across the entire design.

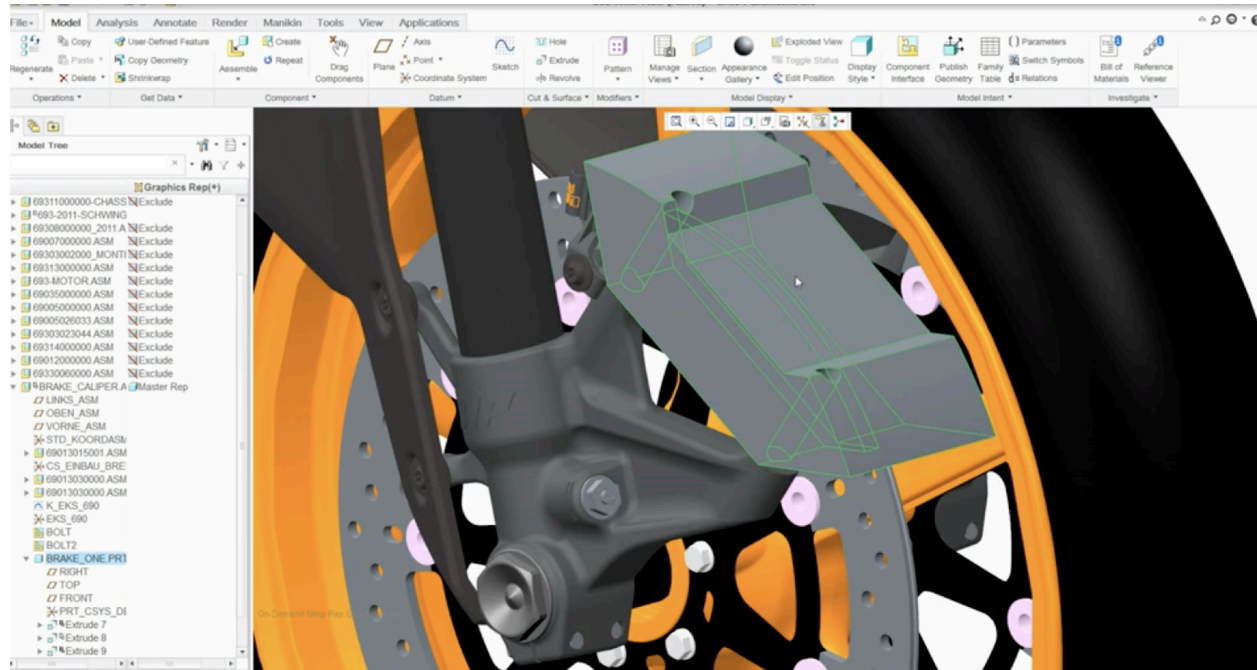
Solid Edge 2021



With the Teamcenter application, Solid Edge 2021 is a versatile 3D CAD program. Solid Edge 2021 integrates with their cloud-based server to ensure any update changes throughout the

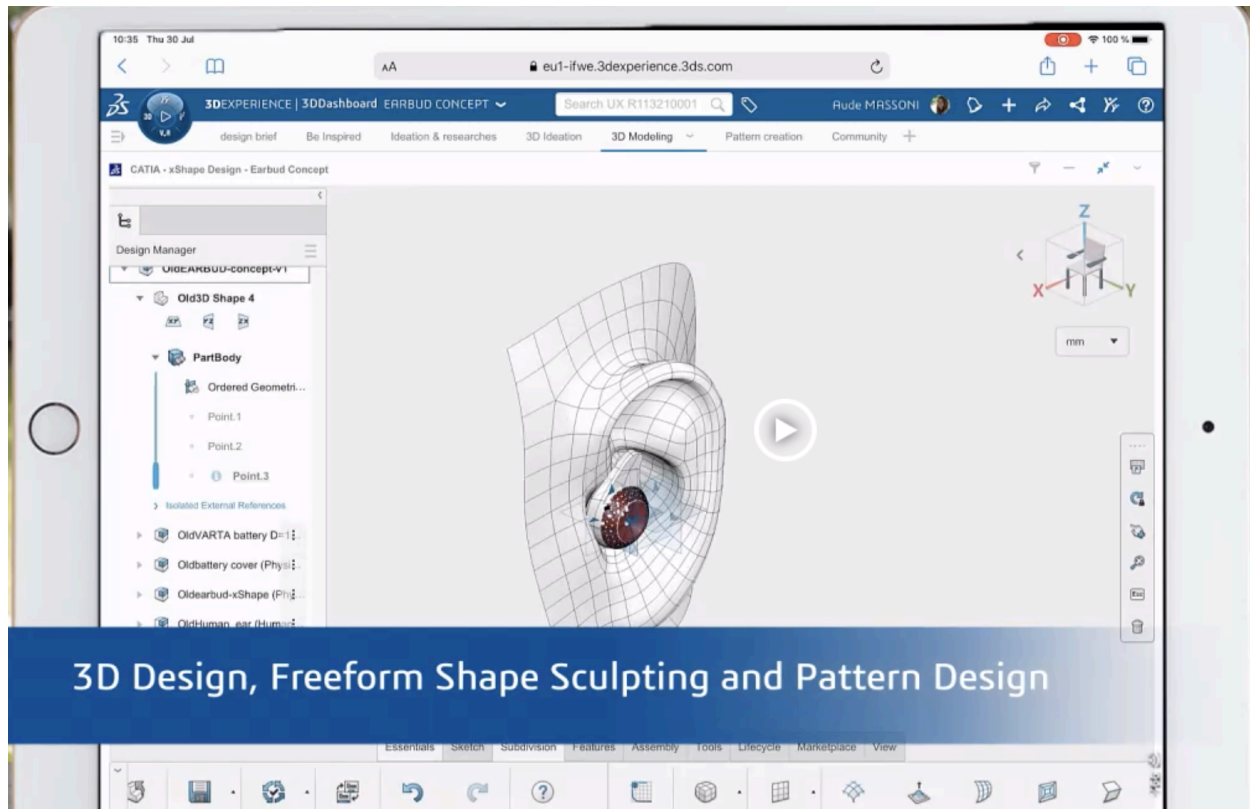
simulated model. Mechanical engineers find the tool particularly advantageous with 2D layouts of industrial control panels and reverse engineering applications.

Creo Parametric



The **Creo parametric software** includes a **direct modeling** program and all the applications typical to CAD **software**. It also includes sub-divisional **modeling** capabilities and simulation for testing individual parts in real-world conditions.

CATIA



Whether the user is a system's architect, construction professional, or an engineer, CATIA's far reaching capabilities set it apart. Its costs reflect its capabilities, sleek look, and range of applications too. The all-inclusive CATIA 3D CAD makes it ideal for designing entire systems.

Comparison Table for Available **Parametric Modeling Software**

Software	Feature	Best for
SolidWorks	<ul style="list-style-type: none"> • Topology optimization • Parametric modeling • 3D environment • Direct Modeling 	<ul style="list-style-type: none"> • Mechanical parts • Experienced CAD software users • Solid designs
Fusion 360	<ul style="list-style-type: none"> • Topology optimization • Parametric modeling • 3D environment • Direct Modeling 	<ul style="list-style-type: none"> • User friendly • Cloud based • Affordability • Beginners
Solid Edge 2021	<ul style="list-style-type: none"> • Topology optimization • Parametric modeling • 3D environment • Mobile applications • Cloud based • Synchronous technology 	<ul style="list-style-type: none"> • Electrical engineers • Good for large and complex assemblies • User friendly
Creo Parametric	<ul style="list-style-type: none"> • Topology optimization • Parametric modeling • 3D environment 	<ul style="list-style-type: none"> • Good for industrial designs • Top-down designs • Resurfacing

	<ul style="list-style-type: none"> • Synchronous technology 	
CATIA	<ul style="list-style-type: none"> • Mobile applications • Expensive • 3D Environment • Parametric modeling • Topology optimization • Synchronous technology 	<ul style="list-style-type: none"> • Full system designs • Experienced CAD software users • Aviation • Marine • Automotive

Best Qualities in Parametric Modeling Software

There are a few qualities anyone shopping around should look for. While some of these features do not directly correlate to a parametric model, they are necessary for testing, aesthetics, and manufacturing.

- Downloadable files for 3D printing
- Inclusion of a direct modeling program
- Virtual simulation
- 3D simulation

Parametric Modeling and 3D Printing

The uncommon geometries of a parametric modeling design make traditional manufacturing practices incompatible. The additive manufacturing capabilities of 3D printer hardware allow for a variety of creative geometric designs.

The fast output by 3D printers also allows for fast prototyping and testing for real world applications. Prior to the invention of 3D printers, the dynamic potential of parametric modeling fell short. Sorting through multiple functioning design iterations and quickly creating a prototype for real world testing, only happens with the pairing of the two innovations.

With the flexibility of additive manufacturing and the variety of 3D printing material available for heat resistance, durability, water absorption, etc., projects continue forward uninterrupted.

Advantages of Combining 3D Printing with Parametric Modeling

Scientists and engineers find the ability for fast prototyping a great advantage to 3D printing. The entire design process only picks up speed with the inclusion of algorithms like parametric models and topology optimization. With AI, the necessity for actual human involvement in the design process lessens even more, reducing labor costs over the long-term especially.

Prototyping

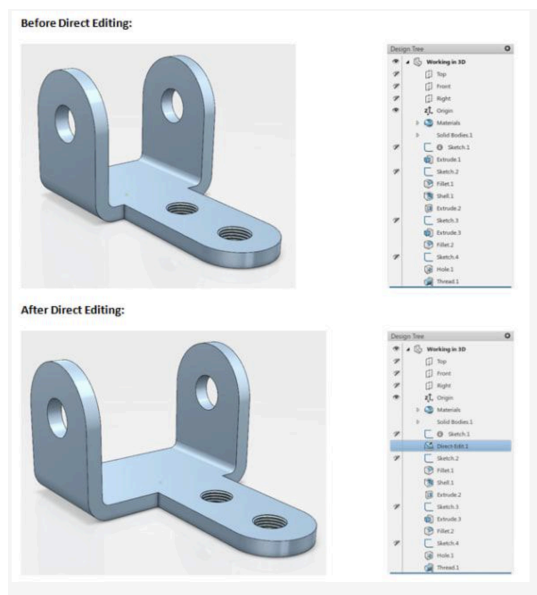
For engineers, rapid prototyping remains essential despite real-world simulation 3D CAD software. Shareholders often still require physical representations of a design to satisfy the need

for proof of concept. Regardless, testing products, parts, and molds in real life applications remains the most accurate means of testing.

Differences Between Parametric Modeling and Direct Modeling

People often confuse parametric modeling with direct modeling. While overlap exists in the functionality of both design models, they share little in common. Parametric models require a history tree of inputs that set design intent. Direct modeling allows users to add artistry and aesthetics to any feature of a design.

Direct Modeling



The simple example of the above images shows that one bracket is wider than the other. The push and pull capabilities of direct modeling sets it apart from parametric modeling. The user simply clicks and drags a 3D design feature to manipulate its geometries. Direct modeling fails to account for necessary modifications to the rest of the design or system as a result of the change.

A parametric model sets itself apart with synchronous changes occurring simultaneously across the system as a result of even the smallest parameter modifications. The distinction between the two models makes them very dissimilar.

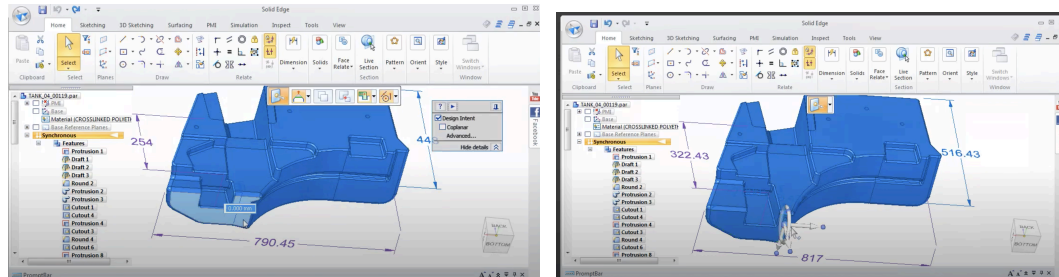
The Disadvantage to Parametric Modeling

Parametric modeling inspection uncovers its inability to add topographic or cultural context to designs. As an example, historically, local communities identified with unique architecture and its artistic nuances. The structures often facilitated the life styles of the local people as well.

AI generated CAD **models** utilizing parametric **modeling**, come from a more practical mindset. Speed and accuracy trump all other aspects of the design. In other words, the buildings generically fit anywhere in the world.

Synchronous Technology

When a designer includes **direct modeling** into the **design process**, elements of artistry and aesthetic return to the **model**. The ability to shape and mold designs with **direct modeling**, along with the functional objective of parametric modeling, result in **synchronous technology**.



The above example demonstrates synchronous technology. When the **direct modeling** component pulls the bottom of the design down, the parametric **model** takes into account the **parameter** adjustment across all aspects of the design.

Non Parametric Models

The purposeful constraints of a parametric model ensure that any design iteration remains compliant and the predictions remain explainable. Imagine a system with no constraints though. The model pulls data from any source allowing for myriad design iterations.

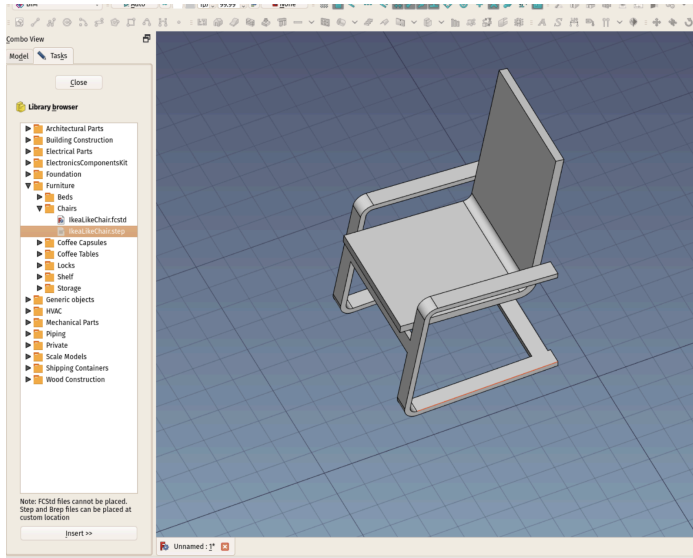
A non parametric model fits large numbers of functional forms allowing for a great deal of flexibility, power, and potentially high performing models. However, the infinite amount of data points makes training very challenging, and the predictions difficult to explain.

The Ways Different Industries Use Parametric Modeling

One of the important contributions to manufacturing parametric modeling provides includes its indiscriminate nature. The dynamics of the innovative modeling system means it can design products as small as nanotechnology, as large as buildings, and as simple as retail items.

Furniture

The furniture industry sets a great example for unique every day uses of **parametric modeling**. Boundary representation, as an example, defines surface dimensions based on spatial boundaries. In other words, a couch adjusts to fit the specific inputted dimensions of a room. That way both furniture designers and customers can find just the right piece for a home or office.



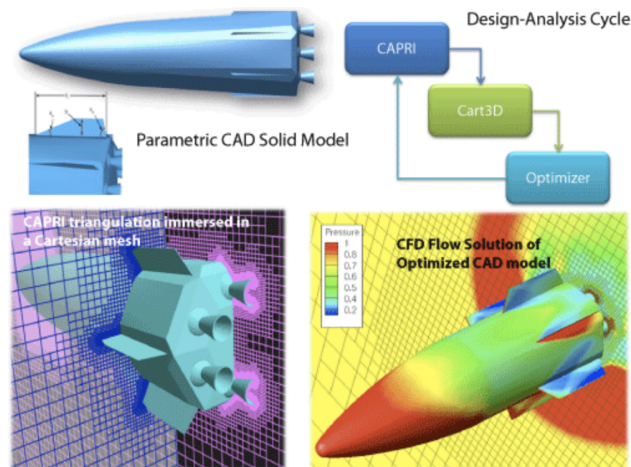
Shoppers can actually see the furniture in their home virtually before making any final decisions. Parametric modeling flows downstream to the consumer. With cloud-based **parametric design**, information updates on designs are shared instantly for everyone involved in the supply chain. The manufacturing process continues undisturbed.

Sports



Competition, choreographed shows—and most recently—exceptional [architecture](#), captures viewers' attention at the Olympic Games. The stadiums, in particular, use parametric modeling for the unique organic look of the structures.

NASA

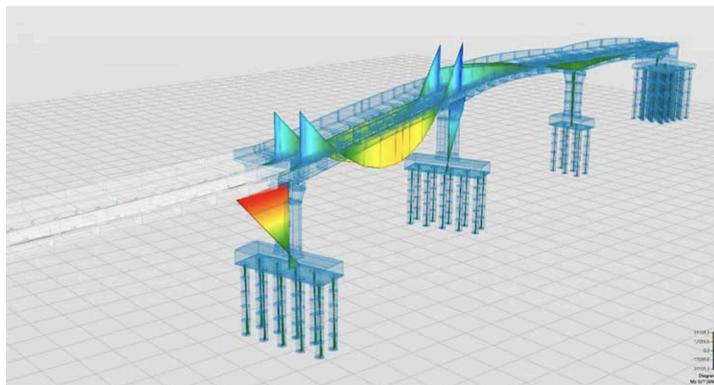


NASA uses **parametric modeling** in many ways. From communication systems and satellite development, to fluid systems for propellant and spacecraft designs, parametric modeling plays an important role in aerospace designs. Algorithmic models provide fast solutions, and NASA even uses a parametric-based repository for [just-in-time problem solving](#).

Astronauts need fast, practical solutions. The vacuum of space gives them little choice. The combination of parametric modeling and **3D printing** technology, means that engineers can find design solutions fast and physically produce models for immediate use.

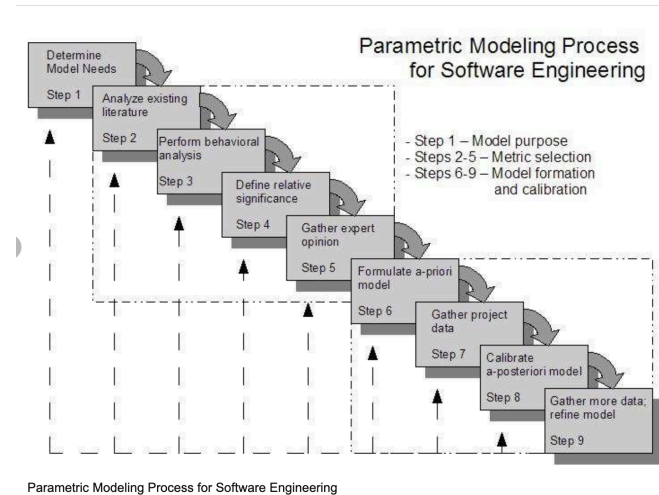
The US.Military

The military designs bridges and other structures regularly. They focus mainly on functional design intent. [Parametric CAD modeling](#) helps the Army Corps of Engineers construct schools, cost feasibility studies, and more.



The military takes particular advantage of building information modeling (BIM). BIM modeling utilizes its data for parametric modeling of a built asset such as bridges, tunnels, and highways. BIM permits the military to create practical, functional designs for quick implementation.

Parametric Modeling Tips



Before diving into some sophisticated 3D CAD **software**, users should consider researching it first. 3D printers are not common household items yet. Bear in mind that engineers, scientists, and professional architects use parametric modeling in their careers.

Start Slow

Consider a beginner CAD **software** like Fusion 360 to start. Offers pop up regularly for free trials or student discounts. Learn the basics of how the **software** functions before spending a lot of money. While **software** and 3D printers are easier than ever to use, users still need to get comfortable with manipulating settings before they can produce anything worthwhile.

Maintain Perspective

Complex **parametric** designs are often unnecessary. Start with basic designs and build from there. Consider the **design intent** regularly. Like designing anything else, taking a step back occasionally to gain perspective, makes a lot of difference in the long run. If ultimately the **model** looks nice, but fails to function properly, then the model failed to meet design intent requirements.

Outline the Necessary Parameters Before Beginning

Parametric modeling requires parameters inputted into the system for it to function. What are the parameters? By knowing what **input** parameters are required for the design, users can gain a true fundamental understanding of parametric modeling.

Parametric Modeling and the Future of Design

The speed, efficiency, and lower costs associated with generative designs—aided by algorithmic **models** like topology optimization and parametric modeling—make it very appealing to manufacturers. Many industries depend on technology for quick solutions.

In all reality, the speed at which innovations are developed will continue to control the business of design. Together with **3D printing**, parametric **modeling** could bring the most sophisticated designs into every household eventually.

As synchronous technology develops, even the artistry and cultural aspect of structural design so desired by the intellectual community, could integrate into the future of design.

Create beautiful designs in CAD **software**, and then easily upload the file into the Formlabs **software**, [PreForm](#).