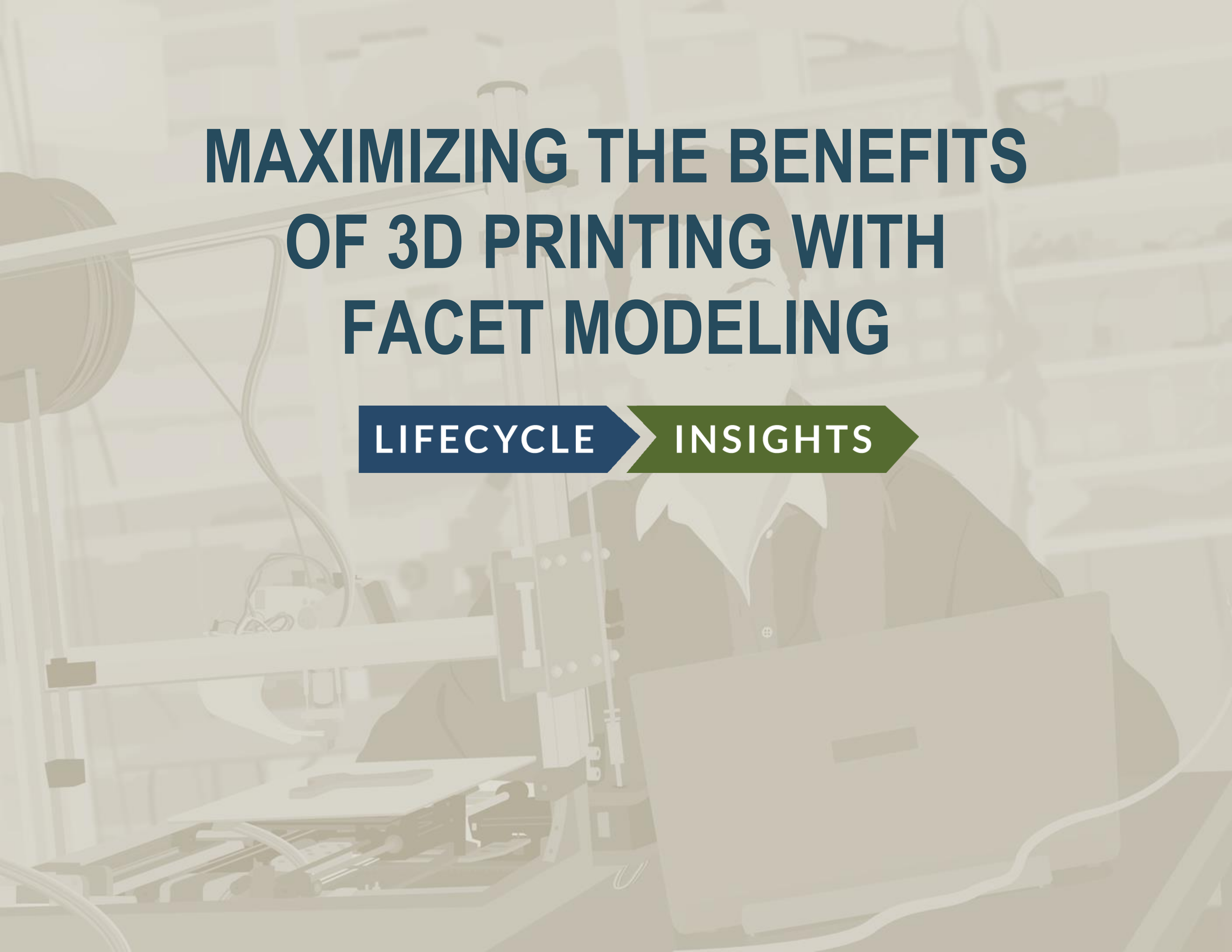


MAXIMIZING THE BENEFITS OF 3D PRINTING WITH FACET MODELING

LIFECYCLE INSIGHTS

THE PENDULUM OF DESIGN CYCLES IS SWINGING BACK…

Over the course of the last decade, the pendulum of design cycles has swung hard in the direction of virtual tools. Given the circumstances, that trend was justified. Digital prototyping offered a means to quickly check the form, fit and function of designs. It provides demonstrable advantages over building physical prototypes, which were costly in terms of both time and money. Furthermore, virtually checking performance of designs affords faster iterations earlier in the development process. Design cycles are accelerated.

However, over the past few years, the pendulum of design cycles has started to swing back the other way because of new technological advantages. 3D Printing, the idea of laying down layers of material to build up physical components, has become considerably faster, less expensive, and more accessible. It is being hailed as a major innovative breakthrough. Quite literally, a part can be built in minutes or hours.

While 3D Printing has applications in many industries, it is particularly advantageous to engineering and product development. It can be used to compliment virtual prototyping tools, or perhaps even replace them as a low-tech alternative. But 3D printing has serious ramifications for Concept Design, Detailed Design, and Prototyping and Testing.

Many engineering organizations are adopting 3D Printing. However, there are issues that should be considered. This new technology requires models composed of Mesh Geometry, which approximates precise geometry with facets, as input. Unfortunately, traditional Parametric and Direct Modeling capabilities cannot manipulate such geometry. Instead, Facet Modeling functionality is required.

Most traditional CAD applications only offer Parametric and Direct Modeling, forcing organizations to translate models back and forth with a second modeling tool that provides Facet Modeling. This compromise often requires significant effort to fix geometry that is broken during translation. Fortunately, a new set of CAD programs offer a combination of Parametric, Direct, and Facet Modeling in a single application, a fact that eliminates most of the aforementioned problems.

The purpose of this eBook is to provide insight on these topics and others. Here, you will find further details on 3D Printing and its application in development. You will also find information on the use of two CAD applications instead of a single one. Together, this information will aid you in integrating 3D Printing into your development process.

Virtual tools have provided significant benefits to engineering organizations over the years. Now, 3D Printing compliments those virtual abilities with fast, easy, low-cost physical prototyping.

3D PRINTING IN THE DEVELOPMENT PROCESS

The hype around 3D Printing is considerable, and rightly so. It offers tremendous potential in the development cycle. But before discussing the details of the technologies that can be used to prepare models for printing, it is important to understand how it can be used in the process. This section defines 3D printing, explains technical issues that need to be considered when leveraging it, and explores how it is used in the Concept Design, Detailed Design, and Prototyping stages.

3D PRINTING: WHAT IS IT?

3D Printing is a hardware technology that uses additive manufacturing methods to build physical components. Individual layers of material are laid down successively, one on top of another, culminating in a complete part. A variety of materials, including plastics and metals, can be used in 3D Printing.

Printing materials in 3D opens up a whole new means of design because it frees engineers up from the constraints of traditional machining operations. That means engineers can, for example, design hollow or latticed components which would be impossible to produce using milling or turning machining methods. Furthermore, new methods are being developed that merge additive and traditional subtractive approaches. Ongoing research is looking at varying material properties spatially, providing an opportunity for engineers to design materials, not just products.

Another advantageous aspect of 3D Printing is how quick and accessible it is. 3D Printers can be placed in the middle of an engineering office, just like a paper printer. Furthermore, the time it takes to print a part number in hours, offering a quick path to prototyping.

Note that additive manufacturing methods have been available for some time. However, constraints around their safe use, traditionally high costs and limitations in the materials kept the technology from going mainstream in design. Advances over the past few years have overcome many of these challenges.

TECHNICAL CONSIDERATIONS

From a modeling perspective, engineers must be able to transform their 3D models into outputs accepted by 3D Printing hardware, typically an STL file. These model formats and others used for 3D Printing consist of Facet Models.

Facet Models have planar faces that approximate the precise geometry created with Parametric and Direct Modeling approaches, which are widely used in the design process. The result is Mesh Geometry that cannot be manipulated, modified, or edited using Parametric or Direct Modeling capabilities. Instead, special techniques known as Facet Modeling enable changes to this geometry.

Transitioning the precisely modeled geometry created in the design process into the Mesh Geometry that 3D Printing requires is a necessary step to access this exciting new technology. Additionally, engineers must sometimes modify the Mesh Geometry produced by 3D scanning before producing it using 3D Printing. This might be done to move, add, or even remove holes, slots, and other geometry.

3D PRINTING IN CONCEPT DESIGN

In concept design, engineers develop a range of ideas that could potentially fulfill the form, fit, and function requirements at hand. Initially, they seek designs that feasibly meet those requirements. Then, depending on the role that design plays in the larger product or system, the engineer explores more alternatives or moves on to another design.

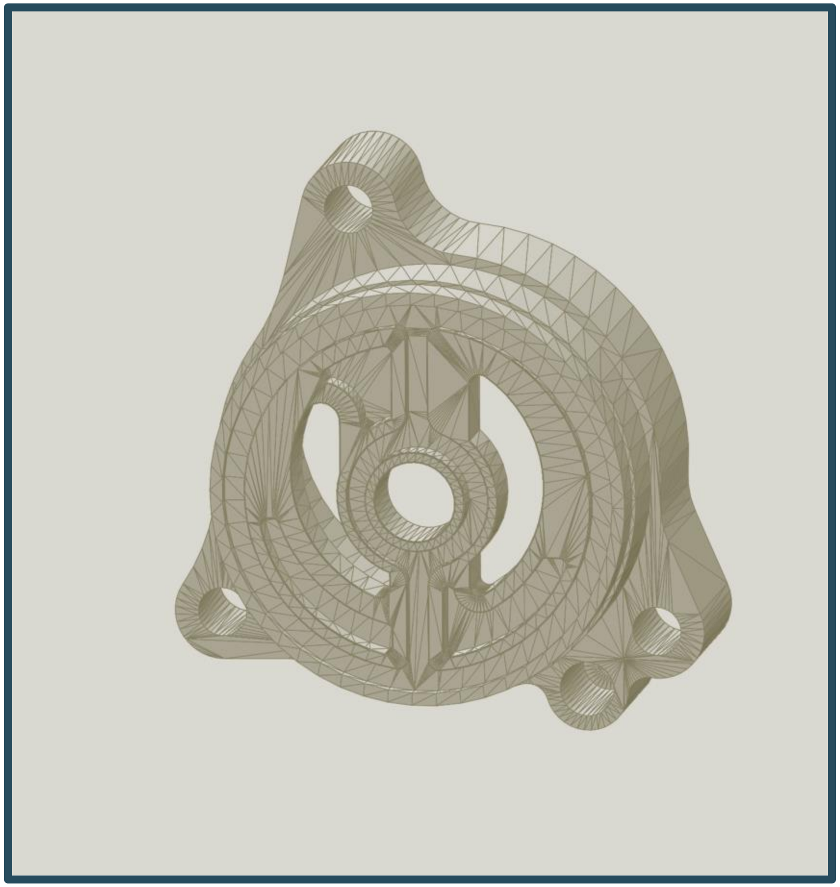
The application of 3D Printing to Concept Design is an exciting opportunity. It provides engineers and other product development roles a means to interact physically with designs that, to that point, had been exclusively virtual. While engineers may have good spatial visualization capabilities, other important roles in Concept Design may not. Simply printing the part and allowing those roles to interact with it physically can be more effective than showing it to them on a screen.

From a design perspective, there are valuable applications as well. Printing several prospective concepts allows engineers to compare them in a physical design study. Printing the results of a structural simulation, completely with fringe plot colors, lets them more accurately visualize results. Furthermore, printing off scaled down models of an entire system, color coded for easy interpretation, can act as a central collaboration resource. It can even be updated over time with newly printed parts for accuracy.

The digital geometric representations of these designs varies widely. Some use top down design techniques to cordon off volumes and spaces for specific components. Others flesh out these ideas with 2D or 3D sketches developed from curves, lines, surfaces, and other simple geometry. However, at this stage, these representations are not usually fully detailed 3D models. Those are created during detailed design.

The use of Facet Modeling in Concept Design is a critical enabler of 3D Printing. Once concept geometry is exported to a format that is friendly to 3D Printing, engineers may need to add, remove or change those designs. In other cases, they may need to refine the quality of the Mesh Geometry. Facet Modeling provides these capabilities.

In all, there are many useful applications of using 3D Printing to produce physical components for engineering and other roles in the development process.



3D PRINTING IN DETAILED DESIGN

At this point in development, engineers take a vetted design concept and fully detail it for design release, verifying that it fulfills form, fit, and function requirements along the way. This requires them to explore options for different aspects of the design in an effort to improve performance. This is especially true of engineers who seek the right balance between competing requirements such as weight and structural carrying load, cost, and natural frequencies.

Many years ago, verifying the form, fit and function of a Detailed Design relied heavily on prototypes and mockups that were expensive and time-consuming to develop. More recently, engineering organizations have made widespread use of Virtual Prototypes to achieve many of the same validation goals. However, with the broader advent of 3D Printing, engineering organizations have the opportunity and choice to utilize both Virtual Prototyping and fast, low cost 3D Printing.

Interestingly, 3D Printing offers a means of checking many product characteristics that a Virtual Prototype does not. In some industries, the quality of a product must be judged by its weight and balance in someone's hand. Aesthetics and feel are likewise difficult to assess virtually. Some products require a specific texture or feel to differentiate themselves. These types of physical examinations are very difficult to achieve without 3D printing.

In other functional areas, 3D Printing is a more accessible means of validation than Virtual Prototyping. Make no mistake; a product can be virtually tested in almost every way imaginable. You can leverage simulation to check if it will break under certain loads, if it is susceptible to excitation, or if it overheats. But those analyses require simulation applications, software knowledge, and domain expertise to complete successfully. Checking those measures on a 3D Printing component requires far less technological knowledge. For some engineering organizations, 3D Printing is actually a better fit.

The digital geometric representation of the design at this phase is a fully detailed 3D model. These models are frequently built using Parametric and Direct Modeling capabilities that result in smoothly rounded geometry. A key capability in detailed design is transforming such models into Mesh Geometry that can be sent to a 3D Printer. However, other functionality is needed as well. Engineers need the ability to modify such Facet Models to add, remove, or modify geometry that represent design changes or improvements for print-ability.

Overall, 3D Printing is exceptionally applicable to Detailed Design. It offers a nice complement to Virtual Prototyping and delivers value on its own. Using Facet Modeling to manipulate Mesh Geometry gives engineers an important set of capabilities that enable 3D Printing in Detailed Design.

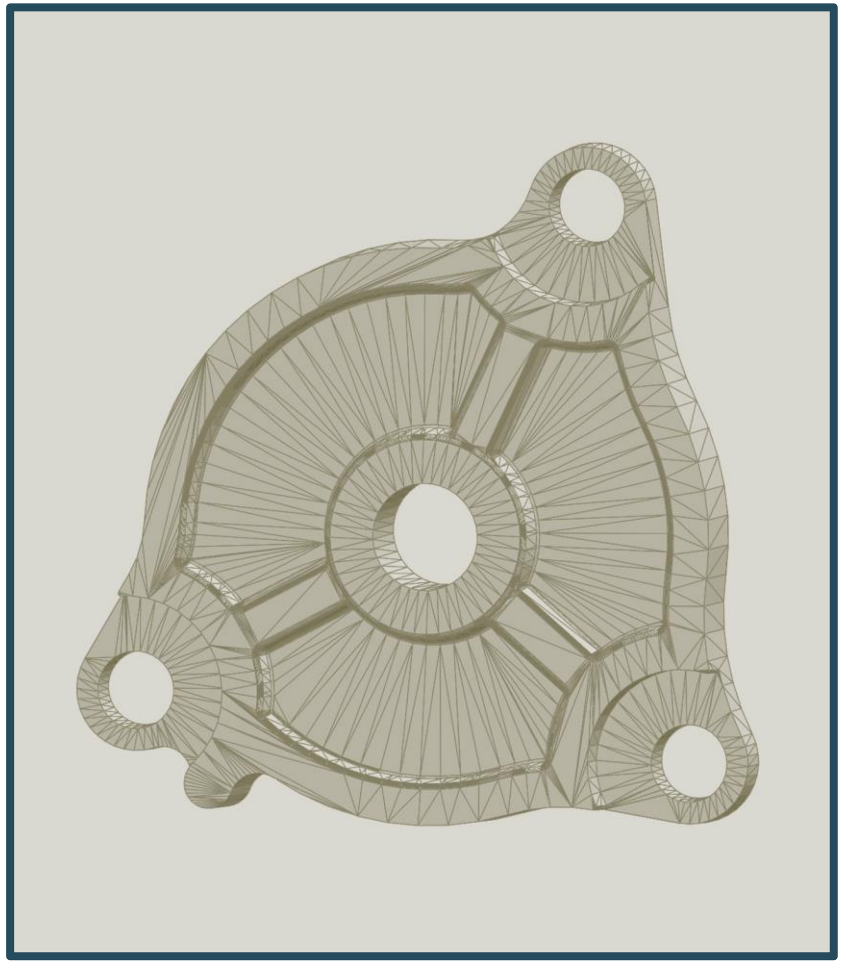
3D PRINTING IN PROTOTYPING AND TESTING

When a design gets to Prototyping and Testing, it is physically built and tested. The objective is to verify that the design does, in fact, fulfill all of the allocated requirements. Additionally, a released design might reenter this phase if it fails. Prototyping and Testing can be used to identify the root cause of the failure before developing a modification.

3D Printing has a wide array of applications in Prototyping and Testing. With the increasing ability to print production materials, including plastics and metals, 3D Printing can be used to create components that are suitable for this phase of development. In fact, 3D Printing offers a faster means of developing those parts than machining or other manufacturing methods. It is easier and quicker to export a print-ready model than to generate CNC toolpaths. This can enable further acceleration of product development overall.

However, making a component using 3D Printing isn't always as easy as pushing a button. In most cases, 3D models must be prepared. This might include slight modifications to the design that would not affect performance. It also might include supporting structures like lattices to support overhanging material in the component. In these cases, individuals need the ability to modify the Mesh Geometry of the 3D model for additions, removals, and changes. This is where Facet Modeling comes into play. It enables such changes instead of going through circuitous iterations between Parametric, Direct, and Facet Modeling environments. In fact, this is one of the most important benefits of having a single environment that provides all three modeling capabilities. Changes can be made in one place instead of bouncing between two or more applications.

In summary, 3D Printing has great use in Prototyping and Testing. It can be leveraged to accelerate the steps in the process. Facet Modeling is an important enabler as well, since it allows modifications to support 3D printing.



THE TWO APPLICATION SOLUTION

In Concept Design, Detailed Design, and Prototyping and Testing, 3D Printing represents a great opportunity in the development process. However, the use of multiple, unintegrated software applications, as is often done in support of 3D Printing, creates friction in the digital workflow.

TWO GEOMETRY TYPES, THREE MODELING TYPES

In general, traditional geometry modeling takes one of two forms: Parametric or Direct. Parametric Modeling can be used to create a model feature-by-feature, using parametric dimensional controls. Direct Modeling modifies existing geometry by pushing, pulling, or dragging it. Both of these modeling approaches work with 'boundary representations,' in which the geometry is represented by flat or smoothly curved surfaces.

Mesh Geometry, in contrast, contains a cloud of points representing the outer surface of a design. Some CAD applications turn this into solid geometry by creating planar triangles or trapezoids and stitching them together into a 'watertight' solid. Facet Modeling lets engineers tweak the quality of the resulting mesh and modify that geometry by adding or removing material.

As noted earlier, there are cases where engineers need to manipulate Mesh Geometry, sometimes alongside the geometry created from Parametric and Direct Modeling. In many different phases of development, engineers need the ability to add, remove, and change the geometry of the models being used for 3D Printing.

THE TWO APPLICATION SOLUTION

Traditional CAD applications used for building 3D models often use some combination of Parametric and Direct Modeling, both of which result in boundary representations. Together, this powerful combination of modeling tools can be used quickly and easily to produce physical components and to develop design concepts or detailed designs. Unfortunately, very few offer Facet Modeling alongside these conventional capabilities.

Because most CAD applications do not work with Mesh Geometry, engineers must turn to other solutions to get the job done. Some standalone specialty vendors, typically ones that offer laser scanning hardware, provide a CAD-like application that includes Facet Modeling. Theoretically, engineers can use both traditional CAD applications and these specialty CAD-like applications together. However, there are numerous drawbacks to this scenario.

LACK OF A SINGLE ENVIRONMENT

There are many cases in development where engineers need to combine Parametric, Direct, and Facet Modeling ***interchangeably***. For instance, the user might work on facet data, then build a parametric feature, and then modify something with Direct Modeling before using Facet Modeling again. If these three capabilities do not exist in a single software application, then designers and engineers simply cannot complete this kind of workflow. Instead, they need to find a means to move the design data between the traditional CAD application and the specialty CAD-like application.

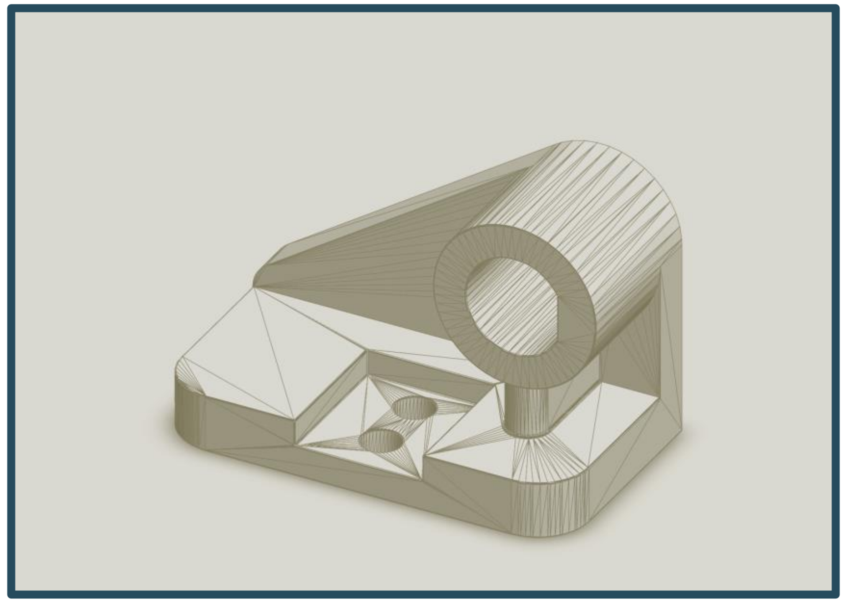
EXCHANGING DESIGN DATA

If you are familiar with the exchange of geometry between CAD applications, then you are likely familiar with the issues here. Moving a model from one software application to another often results in misaligned or missing surfaces, lines, or points. This 'breaks' the model, because it no longer represents the design, and engineers must fix these sorts of problems every time geometry moves from one type of software to another.

Moving geometry back and forth between traditional CAD applications and specialty CAD-like applications is no different. This handoff is subject to the same issues. The result is more time lost for the engineer and a likely setback for the development project.

TAKEAWAYS

It is possible for engineers to use traditional CAD applications alongside specialty CAD-like applications to enable 3D Printing Design, but not without significant friction in the digital workflow. It does not allow engineers to use Parametric, Direct, and Facet Modeling interchangeably, which constrains their design freedom. It also requires significant time to fix design data exchanged between these two software applications. While 3D Printing can provide numerous advantages in development, its applicability can be undermined by the time-consuming and painful work that becomes necessary when using two separate software applications.



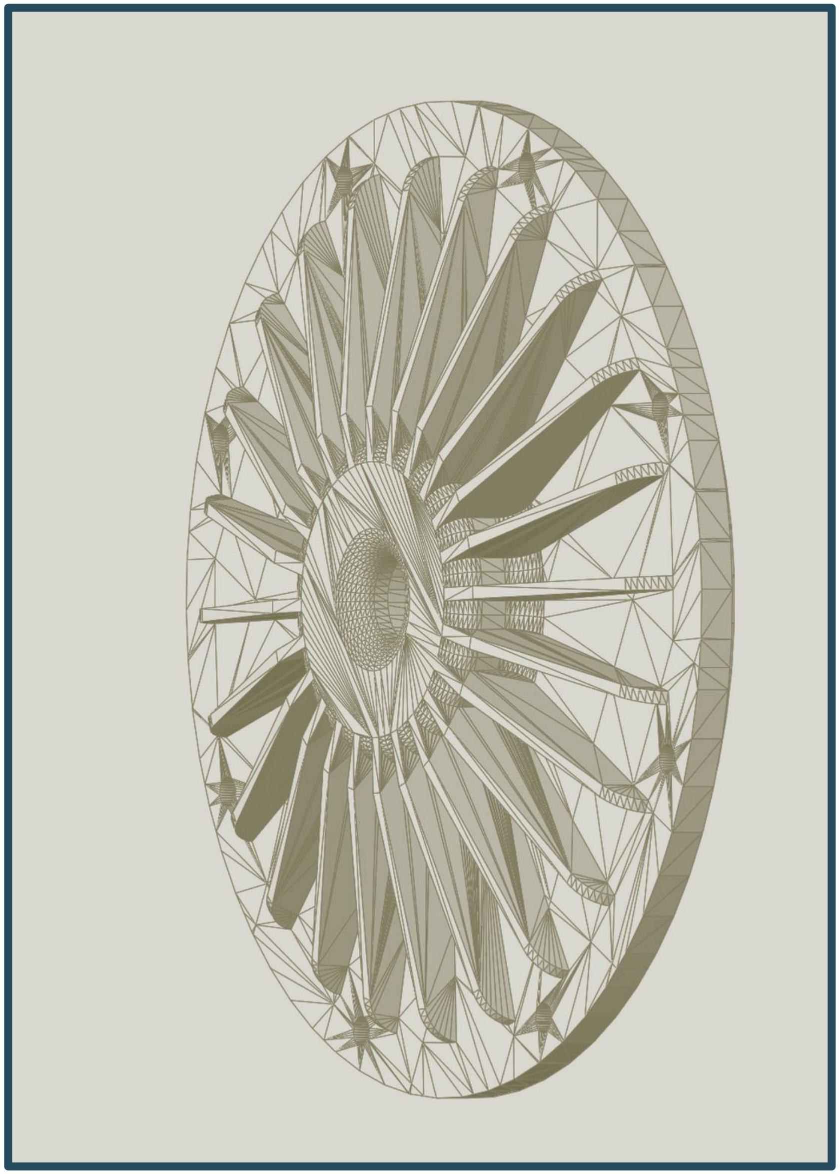
THE SINGLE APPLICATION SOLUTION

In the past year, some CAD applications have expanded their capabilities to include Parametric, Direct, and Facet Modeling. The implications for 3D Printing are important.

In many cases, a design needs to be modified or tweaked for 3D Printing. However, a model with Mesh Geometry may be the only data available. Traditionally, this model would need to be translated into a CAD application. Once there, the model could be altered using Direct or Parametric Modeling methods, modifying the design or adding support structures. This model would then be exported again into a format fit for 3D Printing. With CAD applications that include Parametric, Direct, and Facet Modeling, all of the tools necessary to change the Mesh Geometry directly are available, eliminating numerous time-consuming steps in the process.

An important point in all these scenarios is the activity that this new breed of CAD applications lets engineers avoid: *exchanging design data*. Because all of these capabilities exist in a single environment, there is no need to move 3D data, Mesh Geometry, or boundary representations between different software applications. All of the work can be done in a single environment. Engineers need not waste time fixing geometry; they can focus on design instead.

Overall, incorporating Facet Modeling alongside Parametric and Direct Modeling is a considerable boon to engineers looking to leverage 3D Printing in their development processes. It removes much of the digital friction in the workflow, allowing engineers to focus instead on design.



SUMMARY AND CONCLUSION

There is a tremendous opportunity today to adopt 3D Printing. It offers a means to quickly produce physical prototypes. It, alongside simulation tools for virtual prototyping, is an effective way to check form, fit, and function in development.

3D PRINTING IN DEVELOPMENT

3D Printing is a hardware technology that uses additive manufacturing methods to build physical component. Individual layers of material are laid down successively, one on top of another, culminating in a complete part. 3D Printing can be used on a variety of materials, including plastics and metals.

From a modeling perspective, engineers need the ability to transform their 3D models into outputs that can be accepted by 3D Printing hardware, typically an STL file. These model formats and others that are used for 3D Printing are known as Facet Models.

Throughout development, 3D Printing can be applied with significant benefits. In Concept Design and Detailed Design, it can be used to produce physical parts for comparative trade studies for traits that cannot be measured digitally, such as texture, balance, and aesthetics. In Prototyping and Testing, it can be used to generate physical components quickly, thereby accelerating the overall development process. All of these applications compliment the use of virtual methods of testing a design's form, fit, and function.

TECHNOLOGY SOLUTIONS

Traditional CAD applications used for building 3D models and other items often use some combination of Parametric and Direct Modeling, but they lack Facet Modeling. Because most CAD applications are unable to work with Mesh Geometry, engineers must turn to standalone specialty applications that feature Facet Modeling. Engineers can use these two applications together, yet cannot use these capabilities interchangeably and must deal with data translation issues.

Alternatively, some CAD applications have expanded their functionality to include Parametric, Direct, and Facet Modeling in a single environment. These solutions allow engineers to avoid the problems associated with the two-application approach.

FINAL TAKEAWAYS

3D Printing provides a fast, easy and low-cost means of producing physical parts. Nevertheless, this opportunity can be undermined by the problems that arise when working with two applications for modeling. Fortunately, CAD applications that offer Parametric, Direct, and Facet Modeling enable engineering organizations to realize the full potential of 3D Printing.

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