AUTODESK UNIVERSITY

MP20600

Implementing Cost-Effective 3D Printing in a Professional Design Environment

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Learning Objectives

- Learn how 3D printing can be used in a design environment
- Discover the cost/benefit of different printer technology
- Discover what print materials are available for printing
- Learn how to identify real-world examples of successful implementation of 3D printing in a design/engineering environment

Description

The introduction of cost-effective, high-quality 3D printers is giving designers and engineers the ability to print prototypes right in their offices when they need them. The implementation of 3D printing into a design environment is becoming a reality for more and more design professionals. This course will explore the process behind developing an in-house 3D printing capability and what the cost/benefits are of doing so. Additionally, with the 3D printer landscape in constant flux, what are the benefits and drawbacks of the different technologies for model production? What materials are out? We will look at choosing a printer that fits your budget and needs, and, once you settle on a printer, what it takes to maintain it. This course will look at real-world examples and enable an interactive discussion of how you can use 3D printing in your office.

Your AU Expert

Steven Schain is the postproduction supervisor for all CADLearning products from 4D Technologies, specializing in the development of Media & Entertainment CADLearning products for Autodesk, Inc., software, including 3ds Max software and Maya software. In 1998, Autodesk recognized Steven as one of only 16 Autodesk Training specialists worldwide. He has since contributed to Autodesk's certified courseware for 9 releases of 3ds Max software, was a co-developer of Autodesk's ACI Program and 3ds Max software's fundamental standards, and is currently an Autodesk Certified Instructor. As a premier Autodesk trainer, he has continued teaching end users, companies, and many others, including The Walt Disney Company, Guess, and the United States Army. As a 6-year veteran of Autodesk University, Schain has taught classes ranging from creating particle fountains in 3ds Max software, to classes on 3D printing and entrepreneurship.

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Introduction

When 3D printers were first developed in the 1980s, designers were one of the first groups to recognize the amazing potential of this new technology. 3D printing allows designers to be nimbler, more fluid, and take more risks with fewer consequences. With 3D printing, designers can start testing their models in real-world situations within a few hours of drawing them in a CAD program.

In an industry where success can be measured in microns, rapid prototyping is an invaluable tool. Yet, with all of its impressive capabilities, not all design firms are equally positioned to benefit from the power of 3D printing.

During this session, we will explore how various design organizations are taking advantage of the power of 3D printing, discuss what questions you should ask yourself before implementing a 3D printing program in your organization, analyze the costs and benefits of a 3D printing program, give an overview of the types of printers and materials, and learn from some real-world examples of successful 3D printing implementation.

How are designers using 3D printing?

While there are as many unique uses for a 3D printer as there are unique design firms, learning how other design firms are using 3D printing is a good way to help formulate some ideas as to how you can put a printer to work in your organization.

Prototyping

3D PRINTED PROTOTYPE OF WEARABLE TECH BAND (IMAGE FROM STRATASYS WEBSITE)

Currently, prototyping is the most commonly cited reason for beginning a 3D printing program. When using a 3D printer to prototype, you can test an actual real-world model of your design within a few short hours of its design completion.

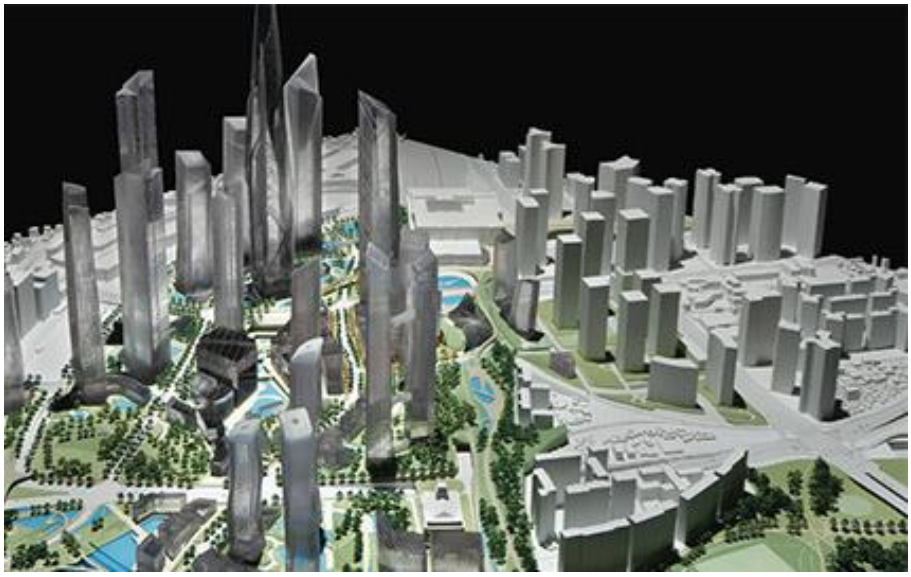
With a 3D printer, if you find that you need to make a tweak to your design, no problem. Just go back to your CAD design, make your adjustments, and print out a new model. Design. Print.

Test. Tweak. This process can be completed over and over again until your prototype is just what you are looking for.

Another benefit of prototyping with a 3D printer is that it is quick and easy to create multiple iterations of your design. This way, you can test several designs in the field to discover which iteration performs the best in a real-world situation.

With 3D printing, you are able to fail faster. The sooner you know that a design won't work, the sooner you can begin troubleshooting, allowing you to arrive at your final product sooner.

Creating Models



3D PRINTED ARCHITECTURAL MODELS (IMAGE FROM STRATASYS WEBSITE)

3D printed models are a great way to translate your vision to your clients or co-workers, ensuring that every team member is on the same page during each stage in the design cycle. From architects to furniture makers, designers of all sorts can benefit from a faster, cheaper, more efficient model-making method.

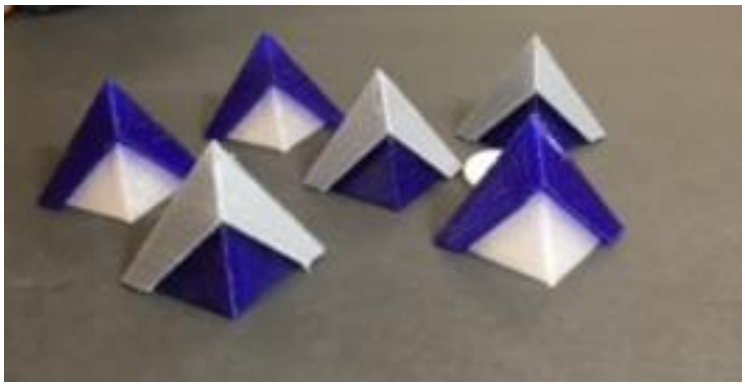
Small Scale Manufacturing

METAL PARTS 3D PRINTED FOR EUROPEAN SPACE AGENCY (IMAGE FROM ENGADGET)

In many cases, manufacturers find that using a 3D printer for a small run of parts is more cost-effective than traditional manufacturing methods.

Even for organizations that don't do any in-house manufacturing, there are plenty of places that you can find cost savings in small runs of parts. Items like clips and brackets, for example, can often be created in-house, leading to some pretty impressive savings.

Marketing



KEYCHAIN LOGO PRINTED FOR A BUSINESS EXPO (IMAGE FROM SPECTRA3D TECHNOLOGIES)

A desktop printer is a simple and effective way to create custom marketing materials and giveaways. From keychains with your logo to custom business card cases, there are many, many ways that you can keep your customers engaged with your company through 3D printed materials.

Printing will become your answer

3D PRINTED SOLUTION TO TOO MANY K-CUPS (IMAGE BY SPECTRA3D TECHNOLOGIES)

Once you have a 3D printer, you will find yourself saying, “Let’s just 3D print it!” You will probably be saying this a lot. You will also find that the printer becomes your go-to solution for fixing any little annoyances around the office.

Ready to get started? Questions to ask yourself first

What is your budget?

Before you even begin to look at printers, you must have an idea as to how much you would like to spend. When it comes to 3D printers, you can pay as little or as much as you would like. For a simple desktop printer, there are some great options in the $3,000-$5,000 range. If you are willing to compromise on build volume or are up to the challenge of building your own printer from scratch, there are even a few options in the $300 to $1,000 range. Of course, moving up the scale, there are a number of industrial printers in the hundreds-of-thousands to million-dollar range.

As you might imagine, with such a wide range of price points, the capabilities of the printers vary dramatically. As a starting point, consider how much you would like to budget for a printer, and then determine whether or not there is a machine that will accomplish your organizational goals within your budgetary constraints.

Do you have the necessary infrastructure in place?

When it comes to incorporating 3D printing into your work environment, there are several factors that you need to think about:

Space

One of the first things you should consider before shopping for a printer is whether or not you have the space. While modern desktop printers are relatively compact, they still require some

room. As you move up into larger industrial machines, the space requirements can grow considerably.

In addition to the necessary space for the printers themselves, you also require storage space for filament, extra print heads, and any accessories, such as scanners, that you might also opt to purchase. If you are interested in a printer with dissolvable filament, you will need to make sure that you also have space for the support removal system.

Electrical Requirements

Every printer has different electrical requirements. Before purchasing a specific printer, it is important to make sure that you are able to install any dedicated outlets that you may require.

Water

If the printer you have chosen is a dual head with disposable filament, you will need easy access to water to fill the tank and rinse off your parts.

Ventilation

Ventilation needs can vary quite significantly from one type of printer to the next. If you choose a type of printer that requires chemicals to finish the parts, you have to have a space that is very well ventilated.

What exactly would you do with a printer right now?

Before you make the final decision to purchase a printer, you want to make sure that you have a solid plan as to how you are going to use the printer. All too often, companies rush into purchasing a printer because they think that it is cool or they want to keep up with the next big thing. This is not a reason to purchase a printer. While I can absolutely guarantee that you will find a whole slew of uses for your printer that you don't currently anticipate, you want to come out of the gate with a plan for putting your printer into immediate action. Figure out where your pain points lie and make sure that you have a clear understanding of both the power and the limitations of 3D printing technology. Start off with a solid plan, and your printer will begin to pay dividends from the start.

How often do you anticipate using the printer?

This question will help you decide which type of printer is the best for your organization. If you view a printer as something that will come in handy every once in a while, you may opt for a less expensive model to shorten your ROI timeframe. Keep in mind, however, that less expensive printers often require more time and effort to achieve the print quality that you desire.

If, on the other hand, you are looking for a workhorse of a printer that you can run around the clock relatively unassisted, you are venturing into higher-end printer territory. With higher-end printers, however, better tolerances and greater reliability can also go a long way toward speeding up the timeframe for your ROI.

Do you have the proper staff in place?

If you don't know how to use a 3D printer, it has no better benefit to your organization than as an expensive coffee table.

I am going to assume that you have the design part of the 3D printing equation under control. But, just because you know how to create the design in Fusion 360, or Inventor, or whatever other 3D modeling program you prefer to work with, it doesn't mean that you know how to print your design properly.

The first thing that you are going to have to learn is your specific printer's optimal settings. Unfortunately, this often is a matter of trial and error, as the manufacturer's settings are rarely just what you are looking for.

Another thing that can greatly affect your print quality is the printing software. Anybody who expects to have a good quality print must be very familiar with their splicer, their mesh tools, and their printer desktop.

If your staff isn't prepared to take on the challenges of a 3D printer, you will have to consider whether you need to bring in additional staff or purchase training for your current staff.

The Costs and Benefits of 3D Printing

Quick Cost Analysis

Introducing a 3D printer to your organization is not necessarily an inexpensive undertaking, but, in many cases, it can result in significant savings in a relatively short amount of time. Before you can start enjoying the benefits of a 3D printer, however, you have to have a good understanding of the costs associated with it.

Printer

The first and most obvious cost is that of the printer itself. As we have already discussed, printers can range from a few hundred dollars to several thousands. If you want to really minimize your downtime, it is always recommended that you factor in the cost of an extended warranty along with the cost of the printer.

Materials

Like printers, the cost of materials can vary significantly. When it comes to materials, printers fall into two camps: those that require that you purchase proprietary materials and those that allow you to choose open source materials. In general, you will get better, more consistent results with proprietary materials, but proprietary materials can be significantly more expensive than open source materials. There is also a range of prices when it comes to types of materials.

Accessories

Accessories are all of those little things that can make the 3D printing experience better. If you are duplicating a large number of items, a 3D scanner is a good starting place for your designs. If you choose a dual head FDM or FFF printer, a dissolve tank helps you take advantage of dissolvable materials. Another way to decrease downtime is to order a couple extra extruders, if applicable. Small items like build plate tape or glue can also go a long way toward providing you with better prints.

Overhead

When planning for your final 3D printing budget, you don't want to forget to factor in the overhead. In the long run, these are the more "invisible" costs, which end up being the most expensive part about owning a printer. Overhead costs include any infrastructure changes that

you have to make to your facilities, the cost of utilities, and the cost of maintenance. Depending on your staffing needs, you may also factor in labor costs or contracting hours.

Benefits

Monetary benefits from a 3D printer can vary quite considerably from one design firm to another. If you are currently ordering a significant number of prints from an outside vendor, the cost benefit to your organization is almost certainly going to be significant. If you intend to use the printer for small trinkets or promotional materials, however, the economic benefits may not be quite as substantial.

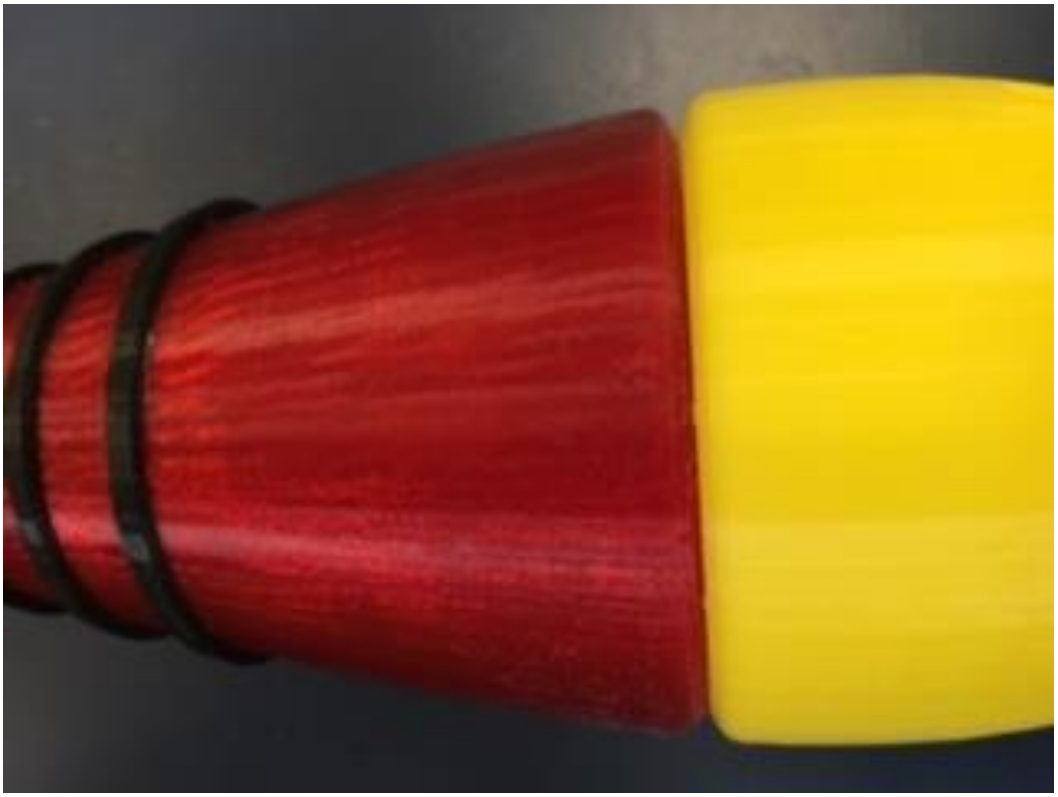
In any case, it is important to understand your expected Return on Investment (ROI). Typically, the ROI formula looks something like this:

$$ROI = \frac{(\text{Investment Gain} - \text{Investment Cost})}{(\text{Investment Cost})} \times 100$$

Types of Printers

FDM/FFF

When it comes to desktop printers, Fused Deposition Modeling (FDM) and Fused Filament Fabrication (FFF) are the most popular types of printers. With both of these printer types, the filament is run through an extruder, softened to the appropriate temperature, and then laid down layer by layer until the print is created. With current FDM and FFF technology, the finished print will have visible layers. If this is not desired, however, the layers can be softened with a number of different finishing techniques.



EXAMPLE OF THE LAYERS THAT YOU WILL SEE WHEN USING AN FDM OR FFF PRINTER (IMAGE FROM SPECTRA3D TECHNOLOGIES)

As the part is printed, the printer will add supports. With single head machines, these supports are simply made from the same material as your part. After the part is complete, the supports must be broken off or removed manually. With dual head machines, you can opt to use dissolvable filament in one of the heads and print your supports with this material. With dissolvable supports, you simply submerge your parts in a dissolve tank, and within a few hours the support material will have disintegrated.

EXAMPLE OF A PRINTED PART WITH DISSOLVABLE SUPPORTS (IMAGE FROM SPECTRA3D TECHNOLOGIES)

Materials

While many FDM and FFF printers are only able to print in either PLA or ABS plastic, depending on whether or not they have a heated bed, this is rapidly beginning to change. Today, you can find a wide variety of open source materials for these printers, including nylon, polycarbonate, and even wood polymer. Because each of these materials print differently than the others, it does require a good deal of trial and error in order to print effectively with different materials.

Since so many customers have expressed a desire for more materials, printers with proprietary materials are also starting to expand their options. MakerBot, for example, is rolling out materials that they call PLA Plus. Using PLA as the base, PLA Plus will incorporate bronze, limestone, iron, and maple wood.

Pros

- One of the biggest benefits of FDM and FFF printers is that they are compact and easy to use. Compared to other types of printers, they keep distractions in the workplace to a minimum.
- FDM and FFF prints are relatively easy to clean and finish, especially with dual head printers that can print with dissolvable filament.
- With the recent advancements in available materials, most FDM and FFF printers are capable of printing in more materials than other types of printers.

Cons

- Compared to SLS and SLA, FDM and FFF printers are relatively slow.
- Depending on what you are doing with the part, the visible layers can also be a problem. In some cases, parts will require some type of finishing in order to function as you want.
- This can also mean that parts are not as strong as those that were printed on other types of machines.

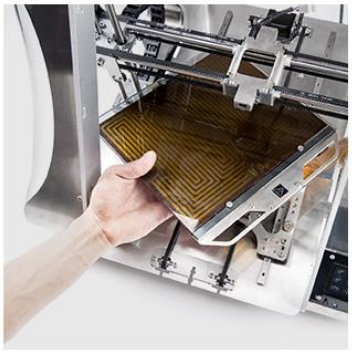
Popular FDM and FFF Printers

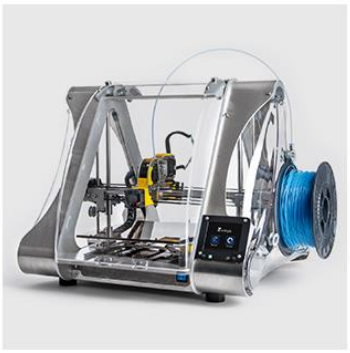
These printers make excellent entry level printers due to the use of a standard filament and limited material handling issues.

The MakerBot Replicator+ (6th Generation)

Starting at $2,499, the MakerBot Replicator+ (6th Generation) is a great entry-level option. Changes to the printer and software have resulted in a dependable machine that creates consistent, detailed parts.

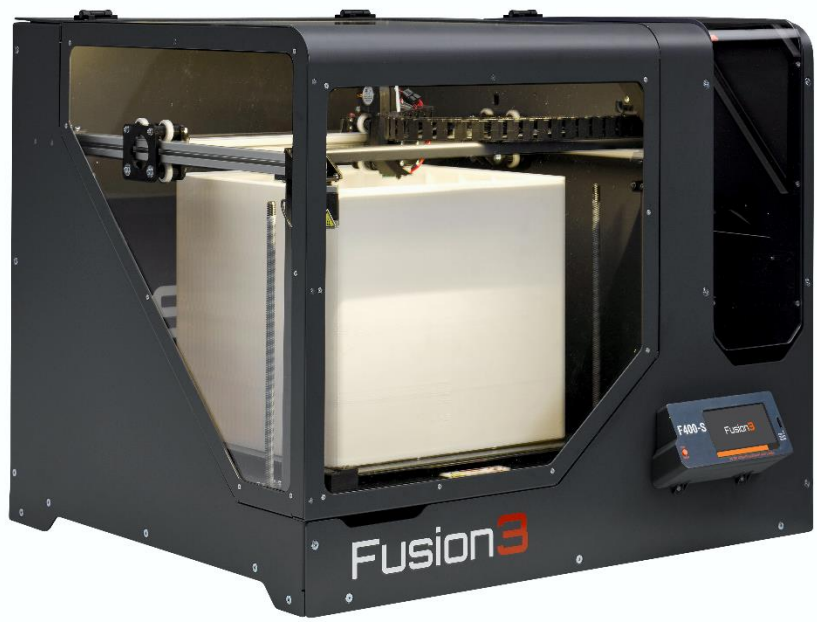
The ZMorph 2.0 SX





Starting at $2,699 for the basic set, the ZMorph 2.0 SX represents a new wave of 3D multi tool digital fabrication platforms. Not only can the 2.0 SX be used as a high quality 3D printer; but it is also can be equipped with one of several useful tool heads. While there are single and dual extrusion heads for 3D printing, there are also tool heads available for laser cutting and engraving, CNC routing, and extruding thick paste, like chocolate or cookie dough.

The Fusion F400



Starting at $4,499, the Fusion F400 is available in Standard or High Flow Rate options. This printer is fast, consistent, and, because it allows open source materials, enables you to print in nylon, polycarbonate, ABS, PLA, and many more materials. The Fusion F400 also boasts one of the largest build volumes in its class.

Stratasys uPrint SE Plus

Coming in at around $27,000 with materials and accessories, if you want to move into the industrial printer market, the uPrint SE Plus is a great option. This printer is a true workhorse, consistently churning out high-quality parts with very little oversight. With dual heads and a dissolve tank, you can opt to print in two colors of ABS or use dissolvable filament.

SLA Printers

SLA, or Stereolithography, printers were the first printers to be developed. Invented by Charles Hull, who went on to found 3D Systems, SLA printers work by curing a photo-reactive liquid resin with a laser. Inside of the build chamber, which is filled with the liquid resin, you will find an elevator build plate. The plate lowers by the size of a layer as the laser traces that layer onto the build plate. The elevator continues to descend layer by layer until the entire part has been traced by the laser.

Once the part has been fully printed on an SLA machine, it requires some additional finishing in order to function as a useable part. First, an SLA part goes into a chemical bath to remove any remaining resin. The part is then cured in an ultraviolet resin. Like FDM and FFF printers, SLA

printers will create a support system to maintain the structure of the part. The supports will then have to be manually removed before you can use the part.

"SLA produced part" by Wizard191 - Own work. Licensed under CC BY-SA 3.0 via Commons - https://commons.wikimedia.org/wiki/File:SLA_produced_part.JPG#/media/File:SLA_produced_part.JPG

Materials

Photo-reactive resins for SLA printers are typically available in a variety of soft and hard plastics, as well as reinforced composites.

Pros

- SLA printers create beautiful parts. With layer thicknesses as small as 25 microns or less, you can achieve a great deal of accuracy with an SLA printer.
- SLA parts are very durable. SLA printers are often used to create working parts in everything from jets to automobiles.

Cons

- SLA printers require you to work with some rather unpleasant materials. These printers are not recommended when working in small spaces or areas with little ventilation.
- Because of the nature of the material properties, parts are limited in light functional testing.
- Material options are rather limited.

Popular SLA Printers

XYZ Printing's Nobel 1.0

With a price point of just $1,499, this printer is a great way to get started in SLA printing. The Nobel 1.0 features a closed printing area to prevent printer byproducts from leaving the chamber. An autorefiller also ensures that the printer maintains the proper amount of necessary material to complete your parts. The printer is able to print in 25, 50, or 100 microns.

Ilios Beam

Ilios is a company that is focused on creating high-quality SLA 3D printers that create very high-resolution parts. The Ilios Beam, starting at about $2,600 is an affordable entry level printer. With a massive SLA build volume of 6.6 x 10.8 x 7.2, it can deliver print layer quality down to 6 microns.

Formlabs Form 2

With a build volume of 5.7 x 5.7 x 6.7, this $3,499 printer is at the top of its class. Formlabs has created a new peel mechanism and a heated resin tank for this printer, resulting in more accurate, highly-detailed prints. The automated resin system allows you to print larger prints with less mess. And, with print layer resolutions down to 25 microns, the print quality is excellent for jewelers.

SLS Printers

Selective Laser Sintering (SLS) printers work very similarly to SLA printers. The primary difference is that the base material is in powder form, rather than liquid form.

SLS printers are one of the more advanced 3D printing technologies. And today, they are in a state of rapid progression. As it stands right now, SLS printers are typically used for prototyping and low-run production of parts.

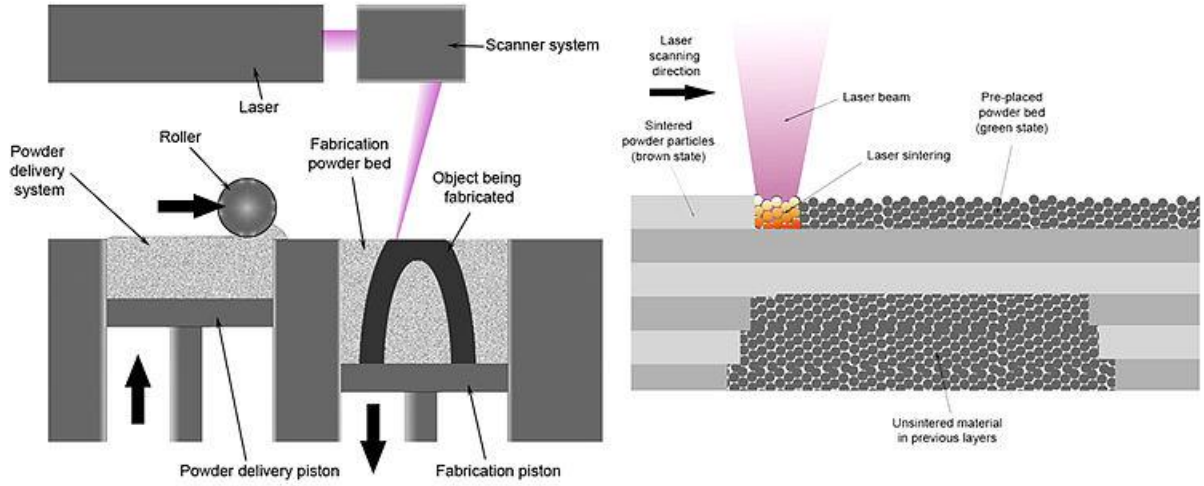


DIAGRAM OF SLS PROCESS (IMAGE BY MATERIALGEEZA FROM WIKIMEDIA COMMONS)

Types of Materials

SLS printers typically print in metal, but you can also use ceramic, plastic, and glass in some models.

Pros

- One of the biggest benefits of SLS over SLA is that you can print with a wider variety of materials.
- SLS parts tend to be less brittle than those printed on SLA printers.
- SLS printers are fast and accurate.

Cons

- Models that are created on SLS printers are typically pretty porous. This can make them difficult to finish.
- Directly out of the printer, the surface quality is poor.
- So far, SLS printers are much more expensive than other types of printers.
- Powder material can be hazardous to handle.

SLS Printers

Currently, there are no consumer/prosumer-level SLS 3D printers available on the market. That's due to several factors, the first being the amount of engineering that goes into the development of an SLS printer. The second factor—and really the most important one—is the material handling issues that come with the powered materials used in SLS printing. Besides being hazardous if inhaled, some of these materials are explosive under the right circumstances.

The Sinterit Lisa

Although there is not currently a consumer or low-end industrial level SLS printer on the market, Sinterit is trying to change that. Available for pre-order, this machine costs about $5,000.

Printer Maintenance

In order to ensure continued high-quality performance from any printer, you must keep all materials dry and protected from the elements. Practical precautions, such as maintaining a clean working area, can also go a long way toward keeping the printer functioning properly.

With all printers, you will eventually have to replace the print head. Knowing how to unclog a print head, however, can extend the life of your print head significantly.

As you are printing, make sure to keep an eye on your print. If you notice that something looks a bit off, be sure to investigate. Just by being attentive, you can stop a lot of problems in their tracks before they become much worse.

Case Studies

Mishimoto Automotive

Since opening in 2003, Mishimoto Automotive has become one of the top manufacturers of aftermarket performance cooling products in the world. Because they bring about 150 new products to market each year, it is integral to Mishimoto's bottom line that they go through the design cycle as quickly as possible.

When Mishimoto first decided to introduce 3D printing into their process, they didn't fully think out the costs and benefits of their chosen printer. As a result, Mishimoto ended up with a printer with proprietary materials that were so expensive it was cost prohibitive to do much designing on the printer.

Soon, Mishimoto opted to cut their losses and order a new printer, choosing the MakerBot Replicator Z18 3D Printer. With a larger build space, Mishimoto was able to begin printing parts in one solid piece. Plus, the print materials were much less expensive. Mishimoto's engineers were then able to take full advantage of the prototyping capabilities of 3D printing.

Today, 30% of Mishimoto's prototypes include some form of 3D printing. The company also claims that printing allows them to get their products to market six to eight weeks faster than their competitors. This results in hundreds of thousands of dollars' worth of additional sales each year.[i]

1212-Studio

From an artistic perspective, 3D printers allow designers to produce pieces that wouldn't otherwise be possible. That's why, when 1212-Studio was approached to design the lighting for U2's tour, they immediately turned to their Stratasys Dimension BST 1200es 3D Printer.

In addition to the lighting, 1212-Studio was also tasked with creating a unique microphone. This LED illuminated microphone would be suspended by a steel cable that Bono could then swing from.

During the design process, the team created several different iterations of the microphone. This allowed them to optimize pressure points and ensure that both the quality and strength were up to the studio's rigorous standards.

Once the final designs were in place, 1212-Studio actually manufactured the final products directly on their 3D printer. Tommy Voeten, the company's president, explained that the material provided them with just the strength and finish that they required. Voeten also went on to state that the manufacturing process was also much faster than it would have been with more traditional manufacturing methods: "Access to the Dimension 3D printer has been invaluable… We can flip the switch and have simple models in hours or complex models overnight."[ii]

GE First Build

As a subsidiary of General Electric, GE First Build was tasked with figuring out how the company could get products to market faster, allowing them to better capitalize on current consumer trends. At GE First Build, the focus is on prototyping, testing, and tweaking as quickly as possible.

3D printers have really helped GE speed up their product development time. With a printer, engineers and designers can be testing their models within a couple hours. This enables the designers to quickly iterate their products and make design changes. With the help of this technology, GE First Build claims that their development time has decreased dramatically. [iii]

Lockheed Martin

When Lockheed Martin was tasked with helping NASA design the James Web Telescope—AKA the largest space mission that NASA has ever launched—the engineers turned to desktop 3D printing.

Engineers at Lockheed Martin explain that, while they have used rapid prototyping for years, they had previously relied on outsourcing their parts. By bringing the printing in-house, however, they are now able to move from technical design, to CAD model, to test part much quicker.

With the help of MakerBot printers, Lockheed Martin is designing a system that will operate 1.5 million kilometers from the earth.[iv]

Boeing

Boeing has been one of the early adopters of 3D printed technology. Not only does the company use their 3D printers for prototyping, they also use the printers to create usable parts for their aircraft. In fact, by 2013, Boeing already had more than 20,000 3D printed parts installed in their aircraft.[v]

For the most part, Boeing uses 3D parts to create things like vents. Recently, however, the FAA approved the use of a 3D printed part within a jet engine itself.[vi]

Another innovative way that Boeing is using 3D printing is with the development of a whole new type of metal. More than 100 times lighter than Styrofoam, this new 3D printed microlattice can be used in aircraft to significantly reduce the weight of the plane.[vii]

Conclusion

When a design organization implements a 3D printing program correctly, it almost always pays dividends quickly. Giving your engineers and designers the chance to experiment more, try out design iterations, and find out quickly what works and, more importantly, what doesn't, makes your organization nimbler and helps to get your products to market or your models to your customers faster. But, in order to get the most benefits out of your 3D printer, you have to make sure that you have the answers to important questions like "does a 3D printer fit within my budget?" "how will my organization use a 3D printer?" and "do I already have the space and employees to start a 3D printing program, or will we have to expand the organization?" Being able to answer these questions, along with having a good understanding of how to implement a 3D program, as well as the costs and benefits of various types of printers, will help ensure that your organization benefits from the immense potential of 3D printing.

[i] From “MakerBot Success Stories: Mishimoto Automotive” (http://pages.makerbot.com/rs/444-ZTM-866/images/MakerBot%20success%20stories%20Mishimoto.pdf)

[ii] From Stratasys white paper “1212 Studio: Design Studio Creates Unique Polyps and Microphone for U2’s 360 Tour” (http://www.stratasys.com/resources/case-studies/commercial-products/1212-studio)

[iii] From MakerBot Stories (http://makerbot3d.asia/ap-stories-pro.html)

[iv] From MakerBot Stories (http://makerbot3d.asia/ap-stories-pro.html)

[v] Stat from “Hope You Trust 3D Printers – Boeing Uses Them to ‘Print’ Parts or Its Planes” by Megan Rose Dickey at Business Inside (http://www.businessinsider.com/boeing-uses-3d-printers-for-airplane-parts-2013-6)

[vi] From “The FAA Cleared the First 3D Printed Part to Fly in a Commercial Jet Engine from GE” by Tomas Kellner at GE Reports (http://www.gereports.com/post/116402870270/the-faa-cleared-the-first-3d-printed-part-to-fly/)

[vii] From “Boeing Says Its 3D Printed Microlattice is ‘World’s Lightest Metal’” by Benedict at 3Ders (http://www.3ders.org/articles/20151016-boeing-says-its-3d-printed-microlattice-is-worlds-lightest-metal.html)