3YOURMIND

SOLID EDGE

Maximizing your 3D Printing Workflow

Integration of Solid Edge & 3YOURMIND

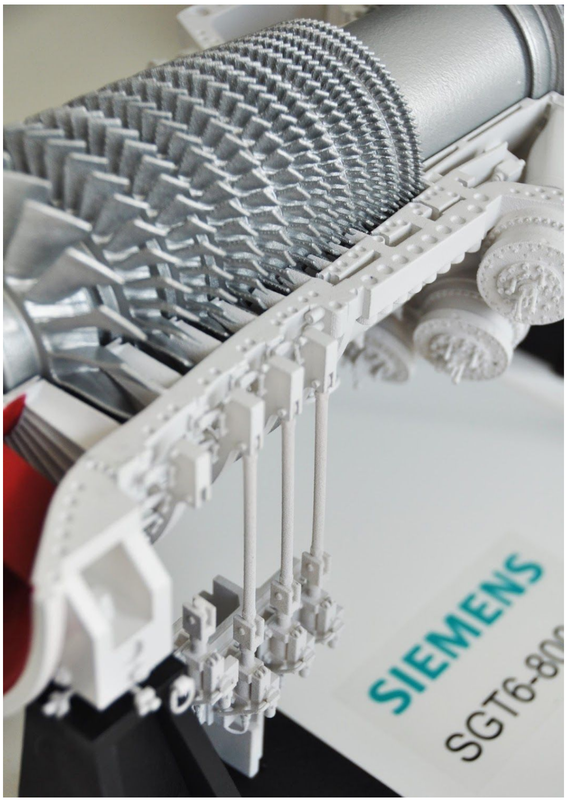
The Solid Edge-3YOURMIND print service portal provides an end-to-end additive manufacturing solution (AM) for product development.

This guide provides information about preparing printable models, including general-purpose advice, design constraints, opportunities provided by 3D printing, and guidelines to help you determine when to produce AM components in-house or use a 3D printing service.

This version is specific to the beta version of Solid Edge ST10.

What is 3D printing?

3D printing is a shared name for several technologies that transform the digital data (three-dimensional designs) into physical objects. The process works by depositing building material layer by layer to the point where the entire digital body is reconstructed.



Several printing technologies are available for producing 3D prints using various materials:

- **Material deposition** – Fused deposition modeling (FDM)
- **Melting –** Selective laser melting (SLM)
- **Sintering** – Selective laser sintering (SLS), Direct metal laser sintering (DMLS)
- **Gluing –** Colorjet printing (CJP)
- **Polymerization** – Stereolithography (SLA)

All processes are described in technical terms as additive fabrication or additive manufacturing techniques. The name 3D printing is derived from the similarities to traditional 2D printing techniques, where the thin layer of medium (typically ink) is deposited. The only difference is that a third dimension is achieved by printing the medium multiple times, layer by layer.

One of the key advantages of 3D printing versus traditional manufacturing is that objects can use almost any geometry without incurring additional production requirements or cost. The only geometry limitations are technological limitations within the material deposition process.

Usually, to meet the practical technical requirements for a part, various post-processing techniques are applied, including polishing, drilling, milling, heat treatment, infiltration or coloring.

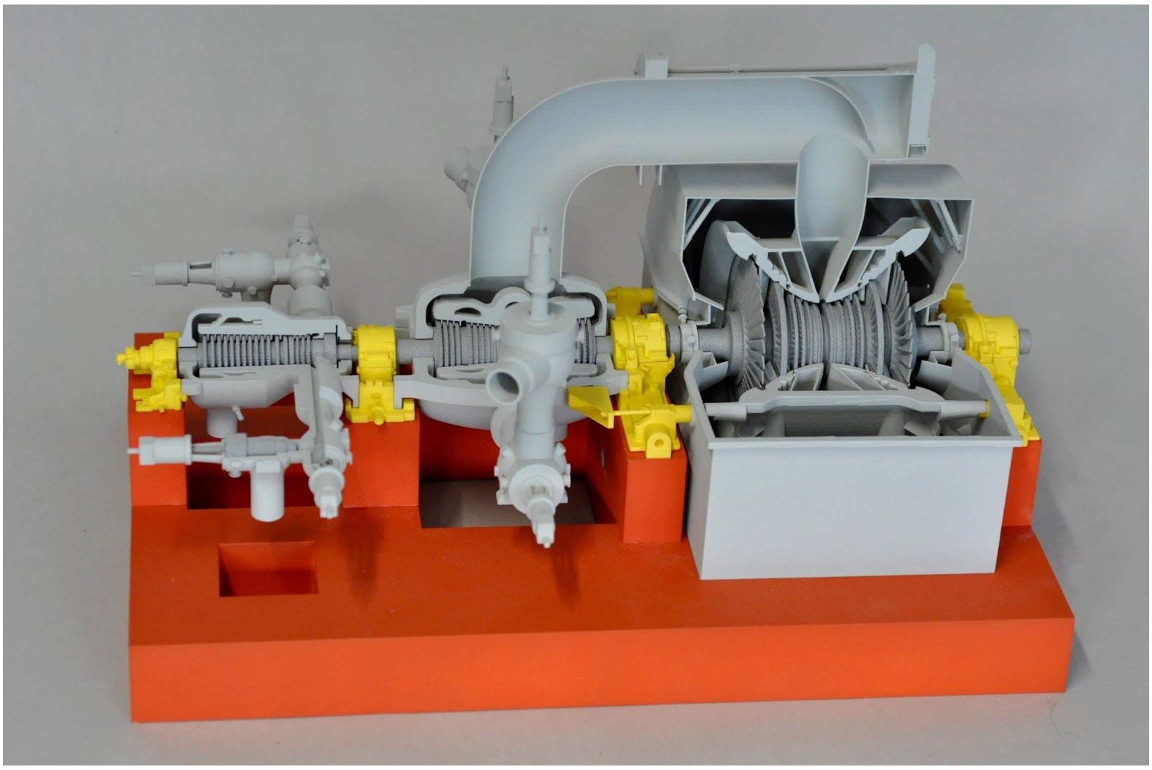
Why Use 3D Printing?

Small Series Production (up to few hundred pieces)

The production price per piece for 3D printed objects is generally constant. The price of 100 pieces is the result of linear multiplication of price per piece. In industrial scale production, typically initially high costs of setting up a production line are compensated by low cost of production per piece. It also allows for rapid retooling (uploading a new file) and no cost individualization.

Rapid Prototyping

Digital models can be generated quickly and a compact 3D printer can be placed nearby to allow for physical models during the design phase.



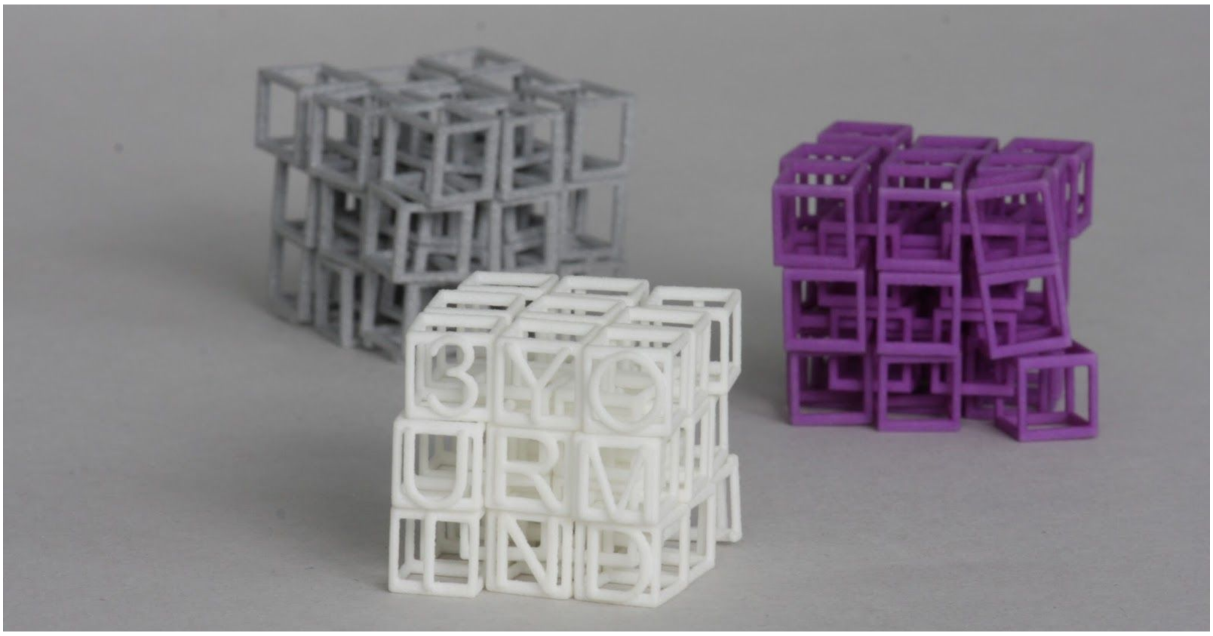
Customization and Individualization

Software solutions are making it very easy to generate custom objects. For example, models generated in Solid Edge can be easily modified and sent to be printed without leaving the software platform.

Complex Geometries

3D printing allows for the production of an entirely new class of objects, because designs are not limited by the geometries of traditional manufacturing methods. Because the model is created layer by layer, where one layer is the horizontal (XY plane) section of geometry, you can create complex structures inside the printed object. You can even print interlocking objects within one printing session.

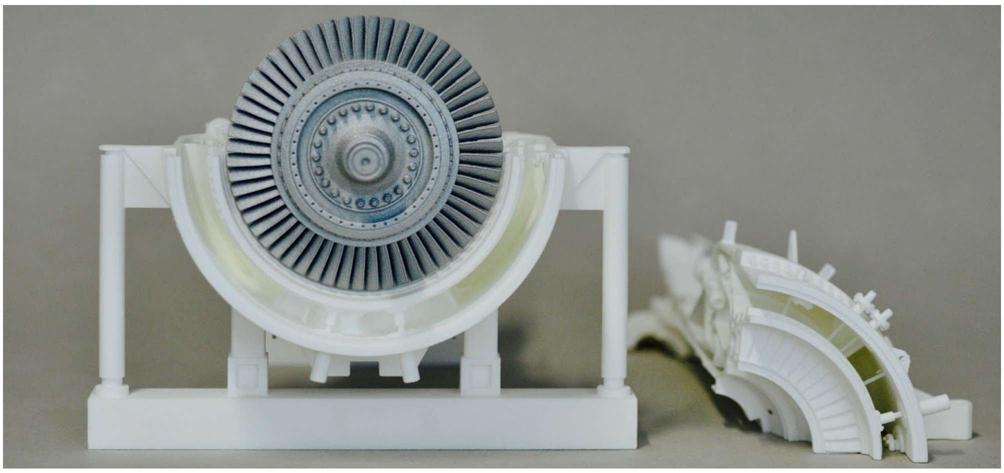
Price is not dependent on the design, only on the utilized material. Typical design applications include inner spatial grids, interlocking geometries, multi-surface voids, among others.



Small Scale Objects

3D printing is appropriate for small scale objects (measured in mm^3). Building volumes of 3D printers are measured in mm^3. The technology is quite precise, with typical accuracy in the Z direction (layer thickness) of 100 µm and in the XY direction of 50 to 100 µm.

Some machines can print layers as thin as ~15 µm. Production times of small objects are relatively small, ranging from minutes to a few hours.



Cost-effective Intermediate Products

More and more, 3D printing is being used to produce intermediate products in a larger production workflow. There are a variety of different materials (ranging from wax to metals) that allow the printed object to become an automatically generated component rather than being made by hand. This saves cost and manpower. A good example is wax casting where a wax master model is printed and used to produce gypsum molds. Another example is an object that needs to be completed using a second post-production method, such as a ceramic form that needs to be hardened in a kiln.

Why (sometimes) Choose Traditional Production Methods?

Industrial Scale Production

The 3d printing technology is not affected by a decline in product prices due to the economies of scale. Production costs are linearly dependent on the number of produced pieces, so above a few hundred pieces, it is almost always more cost effective to use traditional production methods.

In addition, 3D printing is still a slow process. Production of objects by thin layers takes time. Typically, printing objects bigger than 100x100x100 mm can take hours or even days.

Large Objects

Objects that measure in the tens of cm or in meters are bad choices for most additive manufacturing processes. As noted previously, 3D printing is a slow process, with production times ranging from hours to days. In addition, due to technical limitations, typical building volume of current 3D printers oscillates at around 200x200x200 mm. Although it is possible to fabricate bigger objects by connecting smaller pieces, additional physical effects, such as warping or springing may occur in the building material.

Cost-sensitive Components

Because economies of scale don't apply yet to 3D printing, it remains an expensive and skill-demanding process, especially when using more advanced technologies such as DMLS and SLM. Initial machine costs are very high, materials are expensive, technology is still not widely used or understood, and materials must be carefully prepared. In addition, there is usually a need for finishing or postproduction, such as polishing, coloration, and clearing.

The 3YOURMIND print service portal lowers the barrier to entry by moving the cost of ownership and operation from upfront costs to a rental basis using industrial 3D print services. Unless the part is high-value, however, in general it should not be produced using additive manufacturing.

The future of 3D printing

3D printing technology is a rapidly developing field with new possibilities becoming available every couple months. There are five main fields of development are vital for the future of this technology

3D printing hardware development

3D printing is a relatively young technology. Like any technology in the initial phase of development is subject to dynamic development. The technological development of new printers is primarily focused on accelerating the printing process time and enlarging the working area machines. Both components increase the integration of 3D printing into standard production workflows.

The important concentration for hardware development is increasing the reliability of 3D printers and increased use of automation and unattended machine operation. These aspects help bring the production cost lower in order to make additional products cost-competitive for additive manufacturing versus traditional production methods.

New materials

One of the most important part of 3D printing development are the 3D printing materials. The technical specifications of materials as well as their print-friendliness can mean the difference between large-scale adoption and niche use cases. Companies are focused both on continuous expansion of the material database available in 3D printing, searching for materials with the multiple properties (such as Stratasys Digital Materials) and increasing the reliability of materials after the additive manufacturing process.

New applications

The development of 3D printing is also connected with the search of new areas of application. The most important areas are medicine and pharmacy. Bio 3D printing is one of the most dynamically developing branch of this technology. Another trend is the expansion of 3D printing capabilities to produce complex mechanical designs in a single process, such as printing of electronic systems and sensors.

3D printing software development

3D printing is inextricably linked with the development of powerful and integrated 3D modelling software. In the 3D modelling software development there is a continual simplification of the modelling process by increasing the software usability, the integration of tools managing user errors occurred during the modelling process as well as the progressive integration of 3D printing management tools and outsourcing service providers. Another direction is the automation of the 3D models creation by the development of generative design tools and 3D geometry optimisation algorithms.

Development of 3D modelling software leads inevitably to the need of creation of a new information medium for 3D printing technology. 3MF file format is potentially new universal file format for 3D printing. The format can store larger amounts of information describing the 3D model than currently used STL format. By storing additional information at the point of design, companies are setting the stage for more complex 3D printing integrated into full industrial production workflows.

Change of distribution and production systems

The production process associated with 3D printing are also in the midst of change as companies add the technology into various stages of their industrial processes. There are many indications that the future of this technology is the outsourcing of 3D printing services to external specialized 3D printing providers - specifically setup to optimize the 3D production cycles. This allows the transition to a manufacture model based on the dynamic production on demand, without the need for a permanent storage facilities and production infrastructure.

Review of 3D Printing Technologies

Note: The names of technologies and 3D print materials often vary, depending on the supplier.

FFF (Fused Filament Fabrication)

FDM (Fused Deposition Modeling)

The technology works by depositing a melted material (usually a thermoplastic) using a heated nozzle. The process begins by translating the 3D data into machine commands understood by 3D printer. The model is oriented on the machine building platform and is sliced into horizontal (X-Y plane) layers of a selected thickness. The edges of each horizontal slice correspond to the movement of the heated 3D printer nozzle.

After the translation process is completed, production begins. The object is built by depositing small amounts of melted material along the horizontal plane. When each layer is complete, the machine rises the appropriate distance in the Z direction and begins the next layer. Building material is supplied to the heated nozzle using a feeding mechanism which unwinds it from a coil. The building material stabilizes directly after extrusion by cooling.

This technology is widely used because of its flexibility and the low initial investment cost for equipment and materials. For Fused Filament Fabrication (FFF) and Fused Deposition Modeling (FDM), a major constraint is the limitation of printing geometry due to overhanging areas and unsupported structures. To produce those zones, the printer creates additional support structures that are removed after the production process is complete.

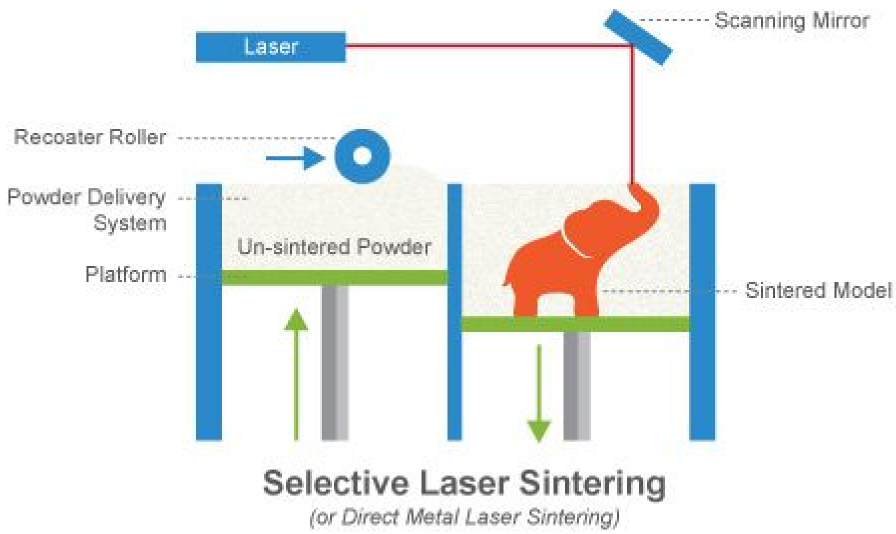
Materials:

PLA, ABS, PC, PA, CopperFill, BrassFill, BronzeFill, WoodFill, Flexible (TPE, TPU), special filaments (transparent, fluorescent, conductive).

SLS (Selective Laser Sintering)

This technology uses a laser to sinter powdered printing material into the final form. The heat and precision of the laser sinter the adjacent particles of material to create the final solid structure.

The general idea of the production process is similar to the FDM technology. Digital objects are recreated layer by layer. The primary difference is materials are fused on location, rather than using pre-melted material. The position of the laser light is determined by the 3D data. After a layer is sintered, the printing bed level drops slightly and a fresh layer of powder is applied to fill the bed. The process iterates until the object is finished. This technology does not use support structures because the printed object is continuously bounded by powder. After production, the object is taken to a sealed container and the extra powder is removed using compressed air.



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Materials:

PA, PAGF, TPU, ALUMIDE, Steel Alloys (though an additional sintering post-production process is needed), PACF, Carbon.

SLM (Selective Laser Melting):

The SLM technology is very similar to the SLS technology. The primary difference is that the heat and precision of the laser fully melt the particles of material, and the cooling will fuse back together to create the final solid structure. Metal powder is consistently spread onto a building plane surface. Particles are melted together with the application of laser light directly to the powder surface. A high power laser builds each layer of the sliced item until the object is finished. Because shrinkage of the building material is high in this process, SLM uses support structures to reinforce overhanging parts of the model and to keep the object connected to the building plate.

Materials:

Aluminum, Titanium, Stainless Steel, Cobalt Chrome

Note: SLS and SLM technologies are especially suitable for small, complex geometries with complicated inner structures, such as voids, networks, and special grids.

DMLS (Direct Metal Laser Sintering)

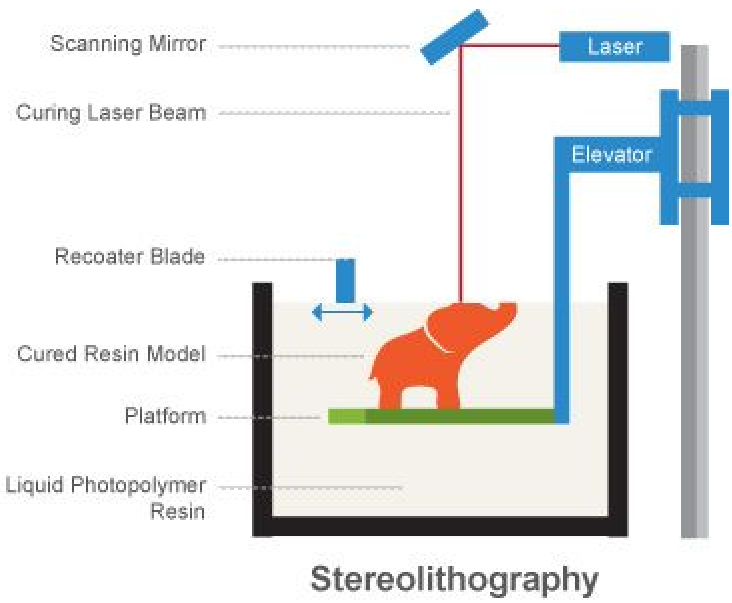
In principle, this is an SLM technology specifically for metals. The core difference is that DMLS sinters particles of metal powder, which produces parts that have a higher porosity than those produced by standard SLM. SLM directly melts the particles, which creates a solid object of mono-material. DMLS is usually used for alloys, while SLM can be used for single-component metals such as aluminum. DMLS does not require support structures, because the printed object is continuously bounded by metal powder.

Materials:

Stainless Steel, Maraging Steel, Cobalt Chromium, Aluminum AlSi10Mg, Titanium Ti6Al4V

SLA (Stereolithography):

Similar to SLS, this technology uses a laser as the main joining medium. The technology uses photopolymerization to build 3D models layer by layer. A UV laser traces the shape of the object on the surface of liquid photopolymer. Since the material is UV sensitive, it solidifies under the UV laser light, forming a full layer of the 3D object. The object is lowered one layer into the liquid photopolymer and the process is repeated until the model is finished. Similarly, to SLM technology, SLA uses support structures to adhere it to the baseplate and support the details.



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Materials:

Photopolymer resins, including castable, transparent, and a variety of colors and technical properties.

POLYJET

This technology uses similar principles to the SLA technology. It works like desktop ink printing, but deposits small drops of liquid photopolymers from multiple cartridges to be deposited in the 3D form and solidify under exposure to UV light. The key advantage is that you can print with multiple materials in one process to achieve composites with complex properties. This is done in the design process by mixing materials in specific concentrations and printing microstructures.

Materials:

Photopolymer resins, composite materials with properties based on photopolymer resins.

CJP (Colorjet Printing)

3DP (3D Printing)

These technologies selectively fuse 3D parts by placing aggregating liquid on the printing material. The binder nozzle travels as it does in FDM, and applies the liquid selectively to the surface of the building platform that is filled with powdered printing material. The binder element also contains dyes for color printing. After the 3D print is complete, the object is strengthened in an additional bath (infiltration) of cyanoacrylate glue or a similar liquid. CJP does not require support structures because the printed object is continuously bounded by gypsum powder.

Materials:

Gypsum, Ceramic

LOM (Laminated Object Manufacturing)

During this process, spatial objects are recreated by applying layers of flat material glued together. The material (usually paper) is glued together and the layer outline is cut with a computer-controlled knife or laser cutter.

Materials:

Paper, Plastic Sheets, Metallic Sheets

3D BIOPRINTING

This process uses manufacturing principles of 3D printing – the creation of 3D structure layer by layer using BioInks. BioInks are hydrogel biomaterials that enable the production of special structures containing living and functional cells. The goal is to create life-like organs or structures.

Materials:

Various Biomaterials and BioInks

Exotic Technologies

3D printing includes several unconventional and experimental technologies. One of the most notable is robotic 3D printing – the combination of industrial robotic arms with the 3D printing technology (usually FDM) to create large objects (measured in meters) from various materials. Additional examples include using laser cladding with the robotic arm to create bridge or grid-like metal structures. Concrete 3D printing is becoming more advanced. It is a macro-scale technology that uses the principles of FDM to deposit concrete layers and produce building-like objects.

Indirect Manufacturing Methods Using 3D Printing

Vacuum Casting

This technology uses a vacuum to draw material into a mold casting for the hardening of polymers. Typical usage of 3D printing in relation to this technology is to prepare the master model for the mold or the mold itself.

Materials:

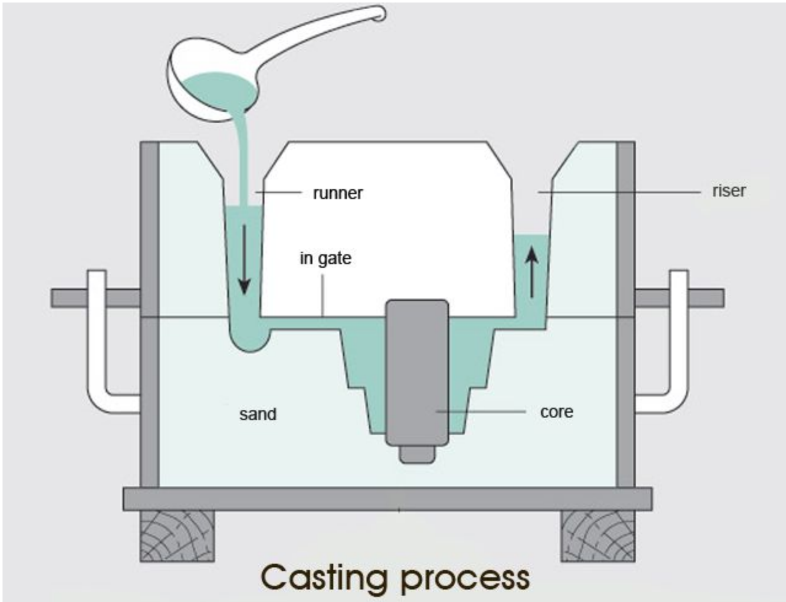
Various Polymers

Lost-wax Casting

This is a traditional technology where objects are cast from a master form made of wax. 3D printing technology is particularly suited to this purpose because it allows printing of master forms directly in wax, in almost any geometry.

Materials:

Various Metals and Alloys, Polymers



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Optimizing 3D Models for 3D Printing

Data Creation Process

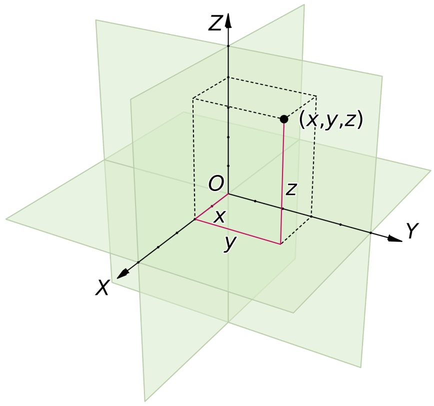
1. Modeling

3D models can be developed directly in Solid Edge using standard techniques. The primary additional criteria is to add thickness to the walls for the 3D Model (over 1mm).

2. Export to a Correct File Format

- **3D model without color/texture information**

  STL (STereoLithography) format is the industry standard file format for rapid prototyping. It is widely used for 3D printing technologies. The format creates a triangular mesh representation of 3D object and contains raw information on each triangular surface.



The triangle is defined by its vertices coordinates within a Cartesian system. The STL format generally does not save the texture information, although some variations of this file format can store the face color. This file format is widely recognized and almost every 3D modeling software has the option to export 3D model to STL format. This is the primary format used within the 3YOURMIND print service portal.

- **3D model with color "per face" information**

  If your model contains vertex/face/surface color information you can save the 3D model to STEP or IGES file format. You can also export your 3D model to one of the STL file non-standard variants that support color information.

- **3D model with color "per face" information**

  Solid Edge does not support directly the texture information export. In order to use textures for 3D printing please use some external software. Various file formats support color 3D printing. The most common types are OBJ, FBX or VRML formats, which store a polygonal mesh representation of the 3D model with additional information for the UV mapping position of each texture coordinate vertex.

3. Mesh Healing, Model Optimization for 3D printing

The final step is the preparation of the triangulated mesh of exported spatial model specifically for 3D printing. This is handled automatically by the 3YOURMIND print service portal. Almost every 3D model can benefit from additional optimization before 3D printing and to ensure a smooth production cycle. This can also be done by other software platforms that allow more specific adjustments to the process rather than a general optimization.

3D Model Best Practices for 3D Printing

1. Digital Becomes Physical

Models created in a digital environment are not limited by physical forces such as gravity or inner tensions. During 3D printing, your model becomes a physical object and is exposed to physical forces. Because of that you need to prepare your model to:

- Avoid thin walls that can break easily.
- Avoid disconnected pieces within the geometry that will become separate objects during 3D printing.
- Keep your model watertight.
- Use one continuous flow to the outer surface.

2. Printing Technology & Material Guidelines

Each 3D printing technology has its own technical restrictions and material specifications. The restrictions are generally based on the method used to build the model. The most important points to remember are:

- For FDM and SLA printing, support structures are needed to support overhanging places. Generally speaking, powder technologies do not require support structures (exception being SLM).
- When printing bigger objects, hollow your model to save material (cost) and production time.
- For SLA and powder technologies (SLS, SLM, CJP), include escape holes to take away the inner material that was not sintered.
- When creating large parts, many elements – especially planar and thin elements – may warp or shrink. This is due to the cooling process and inner tensions resulting from the cooling process.
- 3D printing has its own resolution. In general, details smaller than 0.1 mm will not be visible after the production process.
- 3D printing has its own dimension tolerance, meaning that the dimensions of

the physical object can be different from the digital one. In general, the tolerance is -/+ 2%.

3. Wall Thickness

This is the most commonly overlooked aspect of physical objects. Unlike in the real world, in the digital world it is possible to create a surface without thickness. Thin elements, especially when clustered, will break, warp, or not have enough durability to support other parts of the model. Avoid creating models with elements that are less than 1mm thick.

4. File Resolution

3D printing is created from a mesh representation, which is an approximation when modeling using NURBS or solid geometry. When creating the triangulation, consider the number of triangles the file has when output. Using too many triangles will restrict the 3D printing because of technical limitations regarding resolution. Too few triangles will result in a rough (low resolution) model.

Detailed Modeling Tips

Before you start the modeling process, consider the technical limitations of the 3D print technology you choose. Based on this knowledge you can adjust your digital model accordingly.

- **Create solid bodies, not surfaces.**

  Model your object as a single watertight mesh – a mesh with one continuous flow. Every physical object requires a thickness of a minimum of 1-4 mm. Wall thickness depends on the size of the 3D printed object, material, and 3D print technology.

- **Shared edges do not translate to 3D Prints**

  Due to technical limitations, no two elements of your model can share an edge. If you want to print them as one object, they should be intersected into a single volume. If they should be separate prints, they should have complete walls and be placed directly abutting each other.

- **Unified normal**

  Each triangle face has a normal line that indicates the side of the model (inside/outside). All model normals must face in the same direction - outside of the object volume.

- **Ensure that all holes are filled**

  The mesh must not have missing triangles or walls or it will not process correctly. The mesh will be marked as inconsistent and will produce an error during the 3D print.

- **Build volume of the 3D printers**

  Each 3D printer has its own build space. The dimensions of the build space vary by machine and by technology. Keep your model bounding box within the total dimensions of the 3D printer build space.

- **1:1 scale**

  Because your model will have physical dimensions, it is best to model in a scale of 1:1 relative to the size of your final 3D print.

- **Scaling (costs and resolutions)**

  3D print cost and print time rise significantly based on the size of the printed object. Before developing the model, consider the target scale, details, and technical limitations of the 3D print.

- **Include gaps between moving or interlocking parts**

  If you want to create interlocking parts (for example, in SLS), there must be a clearance between each separate part. The amount of clearance depends on the technology. Note that interlocking parts cannot be produced in all 3D print technologies (for example, FDM).

- **Consider the strength of the components**

  Thin elements will break, warp, or not have durability to support other parts of the model. Avoid creating models with elements that have a thickness less than 1mm.

- **Overhangs**

  Depending on the materials and technology, overhangs may need to have additional thickness added to handle the weight or have extra printed support elements that are later removed.

- **Hollow the model and use escape holes**

  To make the 3D print less expensive, it is good practice to hollow out your model. For sintering processes, escape holes must remain, to allow for removal of unused material powder.

- **Warping**

  When printing large, flat parts, elements may warp. Those can be reinforced with additional material to avoid warping.

- **Surface details and engraves**

  Each 3D printing technology has a minimal detail size. Avoid small elements or thin engravings that do not account for those standards.

When Should You Buy a 3D Printer?

Buy a 3D printer when you:

- Know what 3D printing is and understand the technical limitations of the machine you want to buy.
- Know how to prepare digital data for 3D printing in your chosen technology.
- Know what can be 3D printed. You know the costs, production process, post production process, and have enough volume to justify the upfront investment in the technology.
- Have money, resources, and time. 3D printing, like all production technologies, is demanding and requires a significant initial learning curve. A 3D printer is not (yet) a marvelous machine which can produce anything out of the box.

When Should You Use Industrial 3D Print Services?

Use industrial 3D print services when you:

- Do not have a significant volume of prints to justify the upfront investment of cost and time.
- Want to 3D print in a variety of materials that will change over time.
- Want to print a single large or complex part that requires a high-end (expensive) machine.
- Do not have the knowledge or resources. Outsource 3D data preparation and printing to an industrial 3D printing service to ensure quality and expert handling of your design.