stratasys DIRECT MANUFACTURING

Become a 3D printing expert: Material and process selection

Guide to rapid prototyping

Today, the pace of innovation in the manufacturing industry is faster than ever before, but at the same time engineers are under increased pressure to get concepts to market quickly. Development teams must make fast and accurate decisions during the conceptual stage of design. These decisions can inform numerous cost factors, such as manufacturing methods and material selection, making fast conceptual and functional prototyping essential to the development stage of the product lifecycle.

Rapid prototyping with 3D printing gives designers the ability to fail fast, produce multiple design iterations quickly and change a product design overnight to meet deadlines. But with a plethora of 3D printing technologies and materials to choose from, variation from one machine to the next, and unique process specifications, it may feel safer to take the traveled road than to pave the way for new technology and innovation—especially when your reputation is on the line.

The future of your industry involves 3D printing, so if you don't get up to speed, you risk being at a disadvantage. Luckily, we have a roadmap to help you navigate adoption quickly.

Start with your design—you know it better than anyone and are the expert in your product and industry. Then turn to the 3D printing experts. Stratasys Direct Manufacturing knows 3D printing technologies and materials better than anyone else. Making your prototype its best requires more than a great machine. It takes tried and true practices and deep industry knowledge and expertise to make a complicated process straightforward and successful.

How to choose the right material and process for your application

GPS technology concept model built with PolyJet 3D printing technology.

3D printing is ideal for two types of prototyping: concept modeling and functional prototyping.

After you've decided whether to buy a 3D printer or work with a 3D printing service provider, the second step in your journey is choosing the right process and materials for your application. Many engineers will make the mistake of starting with design for manufacturability.

This makes sense when you're prototyping with traditional manufacturing technologies, such as CNC machining or injection molding, but each 3D printing technology has very different design requirements, benefits and limitations, so it's important to have an idea of the process and materials you plan to use before designing. This will save you time and money on your design in the long-run.

Concept modeling

A concept model is a physical model used to communicate with collaborators, investors, stakeholders and/or clients. We often recommend choosing precise and high-detail 3D printing processes, such as PolyJet or Stereolithography (SL) for concept modeling to gain buy-in, secure funding, gather feedback or to sell to prospective customers. Moreover, detailed, 3D printed concept models are often built for marketing purposes, such as photo shoots, tradeshows and sales displays.

Fit and form concept models require precise, high-detail 3D printing processes, like PolyJet and SL, to ensure accurate measurements.

3D printing benefits

3D printing is especially beneficial for creating concept models because of the design freedom and the ability to print in multiple colors and textures to simulate the final product. Other advantages include speed for when deadlines are tight and high-resolution capabilities for form and fit prototypes.

Key considerations

When speed and aesthetics are critical, it's important to consider processes that 1) build parts fast and 2) print in high resolution and thin layers to minimize layer lines and therefore post-processing time.

“

Working with Stratasys Direct Manufacturing gave me access to multiple technologies to ensure we got the fit and function of the prototypes right.”

Jim deBeers
Athelete and Entrepreneur

The final HydraKlick® Solo 8TM water bottles.

3D printed concept model helps new water bottle design cross the finish line

As any runner can attest, staying hydrated is a crucial part of maintaining endurance. However, when running long distances outdoors, holding a water bottle or trying to find a drinking fountain can be challenging.

No one knows this better than Jim deBeers. A long-time runner both in competitive and non-competitive settings, deBeers wanted to create a better way to stay hydrated without derailing his workouts. With a background in project engineering, Jim began to tinker with the idea of a water bottle for runners that could attach to their bodies. With that in mind, the HydraKlick® Solo 8TM was born.

deBeers needed to validate his idea through prototyping but didn’t have the equipment or knowledge of additive manufacturing to build the parts himself. Instead, he turned to Stratasys Direct Manufacturing to build the parts. With his initial CAD files in hand, they produced concept models of the bottle and cage using 3D printing. The benefits of 3D printing were two-fold: the concept models were built faster and more affordably when compared with traditional methods like CNC machining.

Another advantage of 3D printing for the Solo 8 TM was the ability to make design changes on the fly. If testing revealed a design or material needed to be tweaked, deBeers simply had to submit an updated CAD file, and a new part could be produced immediately.

“There was some trial and error in the product’s development, with multiple rounds of design iterations,” deBeers said. “But with 3D printing, we knew that any changes could be made easily without setting our project back.”

Automotive functional prototype made with Fused Deposition Modeling (FDM) 3D printing technology.

Functional prototyping

Functional prototypes allow you to test, prove and perfect your part design before going into final production. We often recommend more robust 3D printing processes and materials for functional prototypes. High-performance prototypes built with Fused Deposition Modeling (FDM), Laser Sintering (LS) or Direct Metal Laser Melting (DMLM) can withstand the thermal, chemical and mechanical stress of rigorous testing, adding a new level of data to product development.

3D printing benefits

Functional prototyping is one of the most common uses for 3D printing because of the significant advantages in comparison to traditional rapid prototyping methods. 3D printing offers a wide variety of tough, engineering-grade thermoplastics and metals to choose from for demanding testing scenarios and mechanical stress. Combine that with speed and design freedom, and functional prototyping with 3D printing is a no-brainer.

Key considerations

Functional prototypes are often subjected to harsh testing environments to define strength, endurance and environmental requirements for the final part. Therefore, it’s important to consider certifications and other requirements that will determine the process and material you choose, such as biocompatibility, sterilization, heat smoke toxicity rating, fire retardancy or chemical resistance.

“Every minute in the NASA wind tunnel is vital to the assessment and feasibility of the study. We knew we’d have to make tweaks and move fast to prepare the prototypes.”

Roedolph Opperman,
Spacecraft Systems Engineer at Aurora

NASA N+3 wind tunnel model.

3D printing a functional wind tunnel testing model

Aurora Flight Sciences Corporation collaborated with the Massachusetts Institute of Technology (MIT) and Pratt & Whitney to evaluate the potential of a subsonic fixed-wing transport aircraft for a NASA Aeronautics Research Mission Directorate concept study called N+3.

A major part of the project was the assessment of aerodynamics, propulsion, operations and structure to ensure the full spectrum of design improvements. Aurora and MIT produced a 1/11th-scale wind tunnel model, with a 14-foot wingspan and three different tail configurations for testing. With a limited amount of wind tunnel time at NASA, Aurora anticipated needing a manufacturing solution that would greatly reduce its cycle times.

With recent advancements in 3D printing accuracy and material durability, Aurora decided to use Fused Deposition Modeling (FDM) to 3D print the prototypes. Producing the thermoplastic components with FDM allowed the team design flexibility while meeting high aerospace standards and process requirements.

Stratasys Direct Manufacturing produced three main thermoplastic components of each model using FDM technology: a set of engine nacelle fairings that surrounded the fan and motor assembly, conical plugs of various sizes that affect the engine outlet flow diameter and an aerodynamic bifurcation for routing the engine power cables to the fuselage. The two ABS-M30i™ engine nacelles house the aluminum engine models and the eight interchangeable plugs, each with a slightly different design depending on the configuration. Testing multiple engine plug configurations helped the team determine the best position for efficient airflow on the actual passenger jet.

With the largest FDM capacity in the world, Stratasys Direct Manufacturing was able to deliver high-quality parts ahead of schedule. Aurora went through multiple design iterations over a span of roughly two years.

3D printing technologies **overview**

You don't need to be an expert in every 3D printing technology, but it helps to have basic knowledge of the various processes on the market and their pros and cons to choose the best method for your rapid prototyping project.

There are four primary types of 3D printing that have made significant impacts on the engineering and manufacturing industries: Vat Photopolymerization, Material Jetting, Material Extrusion and Powder Bed Fusion. Each method has different technologies and materials associated with it and produces different results.

Vat photo-polymerization

Vat photopolymerization is a 3D printing process in which liquid photopolymer resin in a vat is selectively cured and solidified in thin layers. The notable technologies on the market today are Stereolithography (aka SL or SLA®) and Digital Light Processing (DLP).

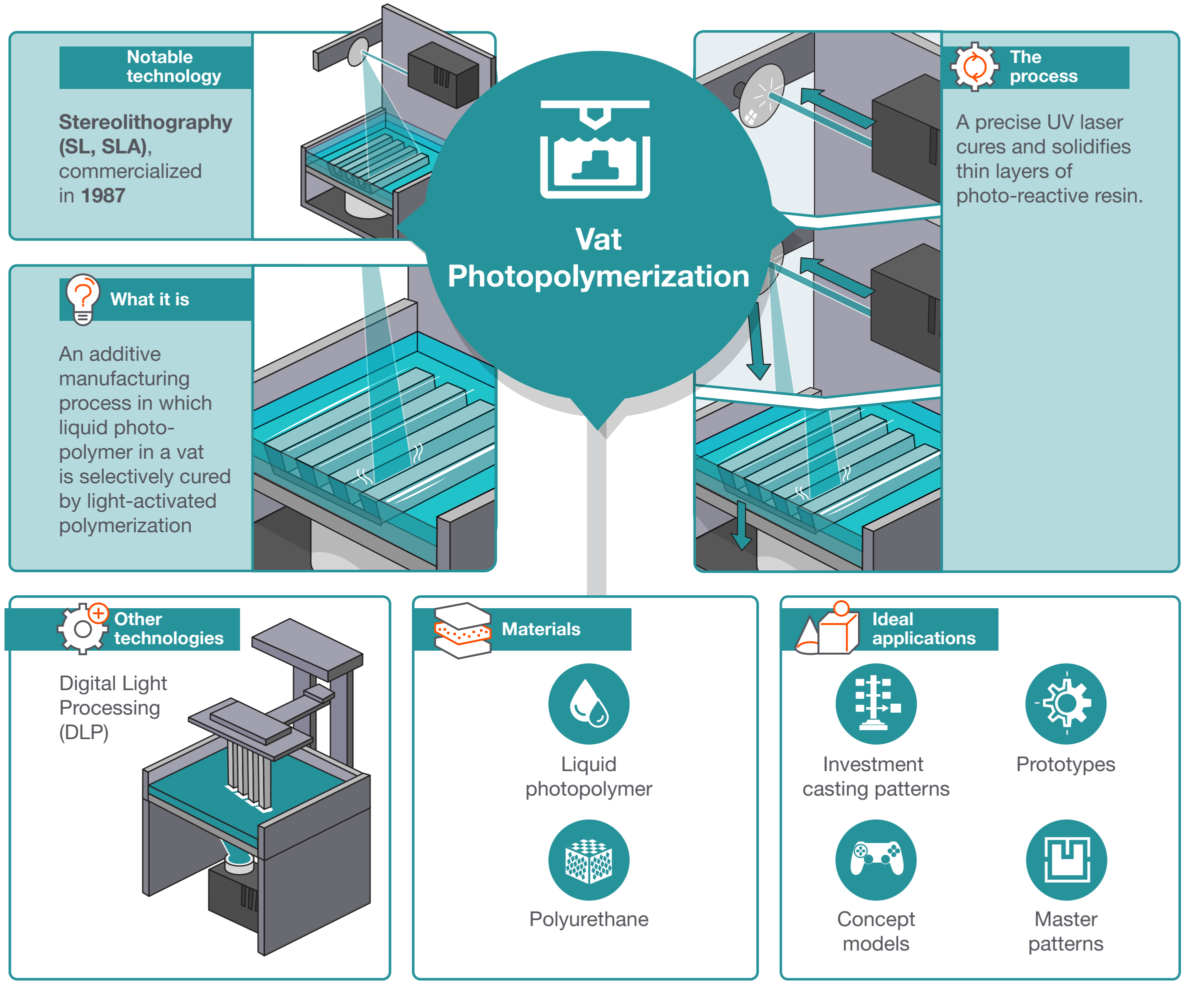
Vat photopolymerization processes are ideal for non-structural concept models and form and fit prototypes because of their speed and ability to print in thin layers for smooth surfaces. They can also build models with a hollow or lattice-structured interior for extremely lightweight prototypes.

Benefits

- Smooth surface finish right off of the machine
- High accuracy and detail
- Ability to build lattice-structured interiors for lightweight prototypes

Limitations

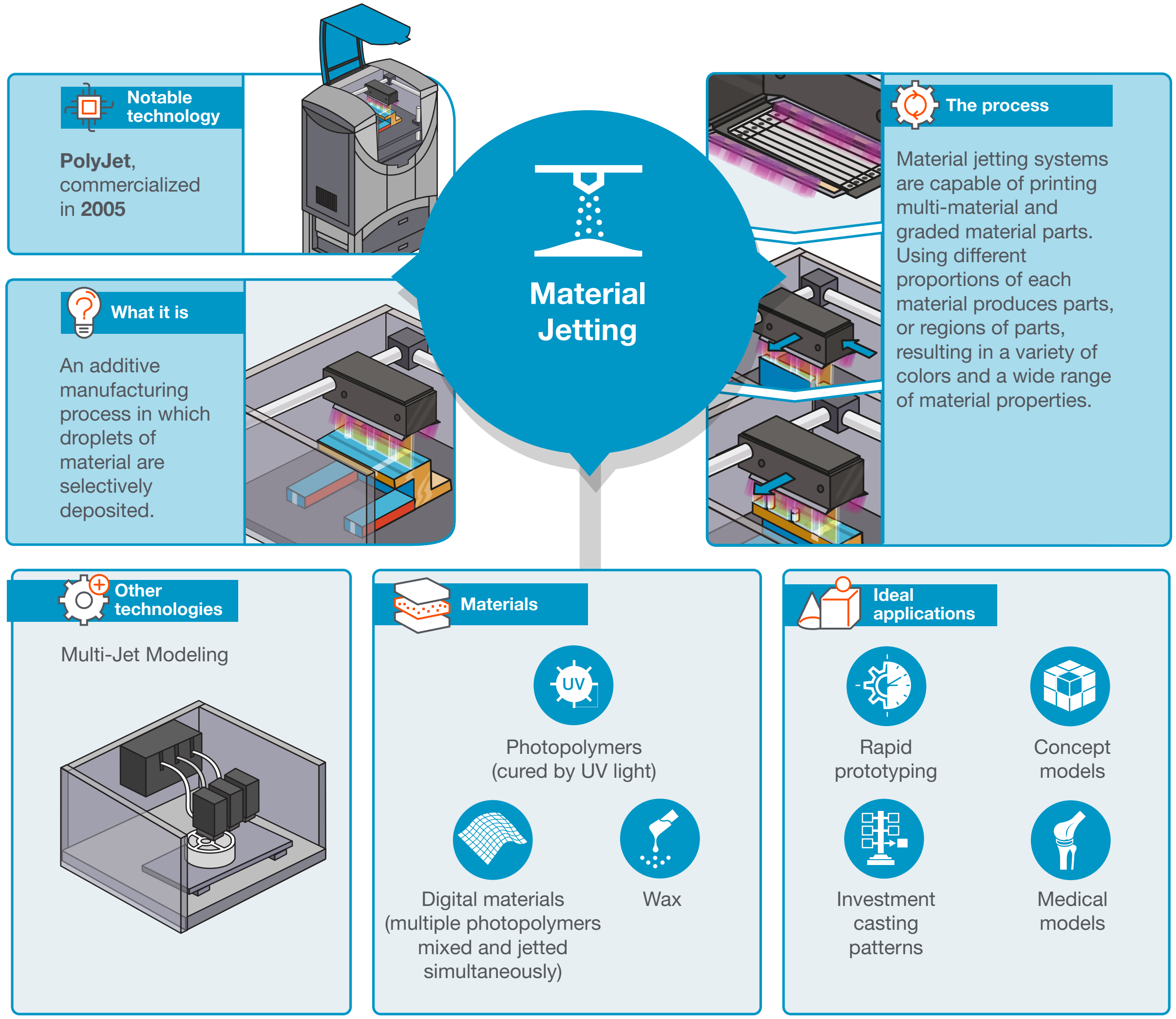
- Lower impact strength and durability
- Degradation with exposure to UV light



Material **jetting**

Like vat photopolymerization, material jetting technologies use light-activated photopolymer resins to build parts. The print head deposits droplets of the liquid photopolymer onto a build platform, which is cured with a UV light layer by layer. PolyJet and Multi Jet Modeling (MJM) are popular technologies in the material jetting family.

Material jetting systems are capable of printing multiple materials at once, opening design possibilities for multiple colors and stiffnesses throughout one part without assembly. Multi-material and multi-color capabilities come in handy when creating realistic concept models to replicate the aesthetic and feel of the end product. In addition, PolyJet is one of the fastest 3D printing technologies on the market and offers more than 360,000 CMYK color options, including transparent materials to simulate glass or other see-through features.



Benefits

- Smooth surface finish right off of the machine
- High accuracy and detail
- Full-color
- Ability to build flexible and rigid components within one part
- Speed

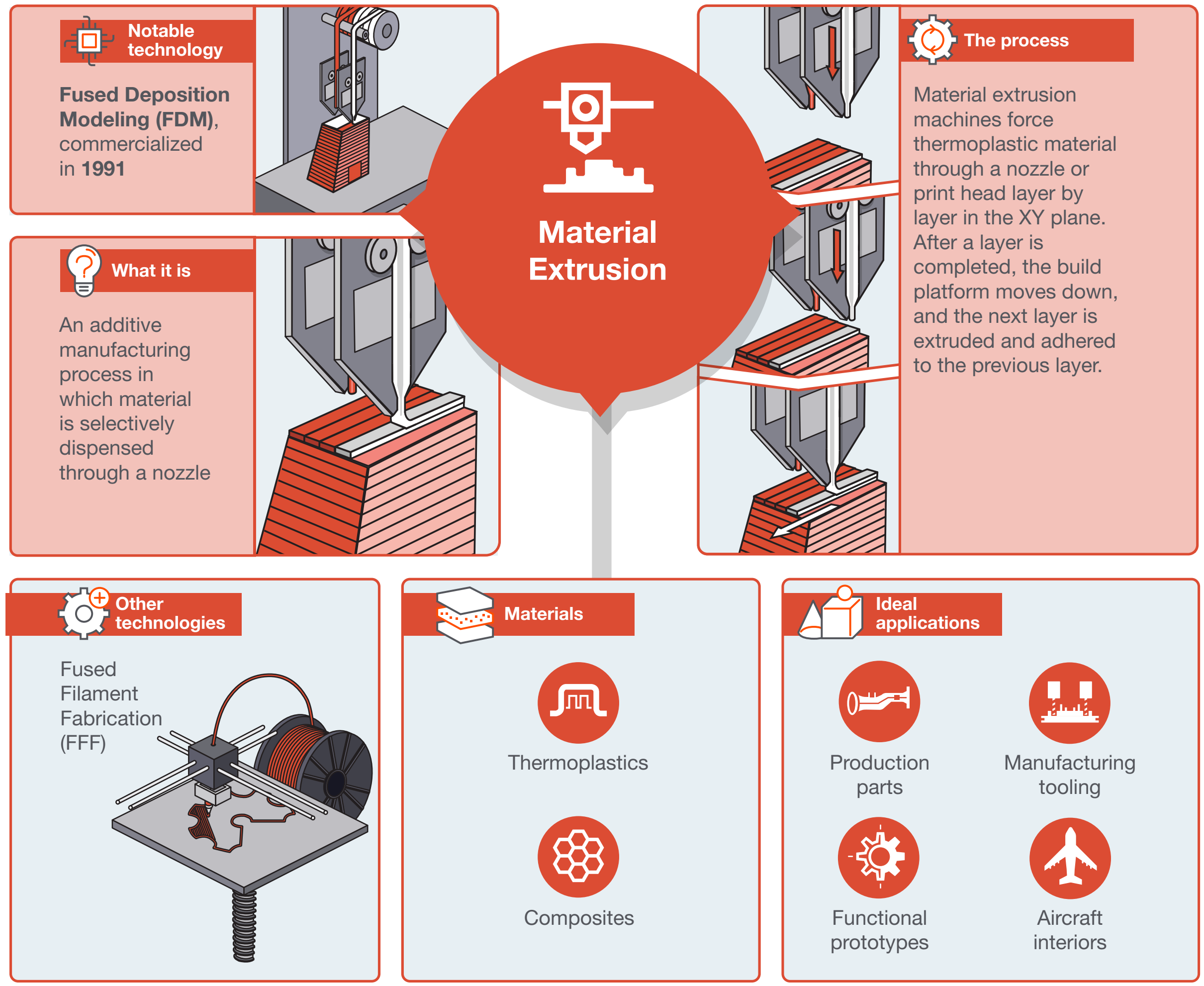
Limitations

- Lower impact strength and durability
- Degradation with exposure to UV light

Material extrusion

Material extrusion machines heat and extrude thermoplastic material through a nozzle or print head layer by layer in the XY plane. After each layer is complete, the build platform moves down to the next layer until the part is complete. The main technology that uses the material extrusion process is Fused Deposition Modeling (FDM), followed by Fused Filament Fabrication (FFF).

While you often hear of engineers using FDM for complex production parts in aerospace, it is also an ideal technology for robust functional prototyping. FDM parts are fit for demanding testing environments because the engineering-grade thermoplastics are mechanically, chemically and thermally strong.



Benefits

- High impact strength
- High durability
- Heat, smoke and toxicity rated materials
- Chemical-resistant materials

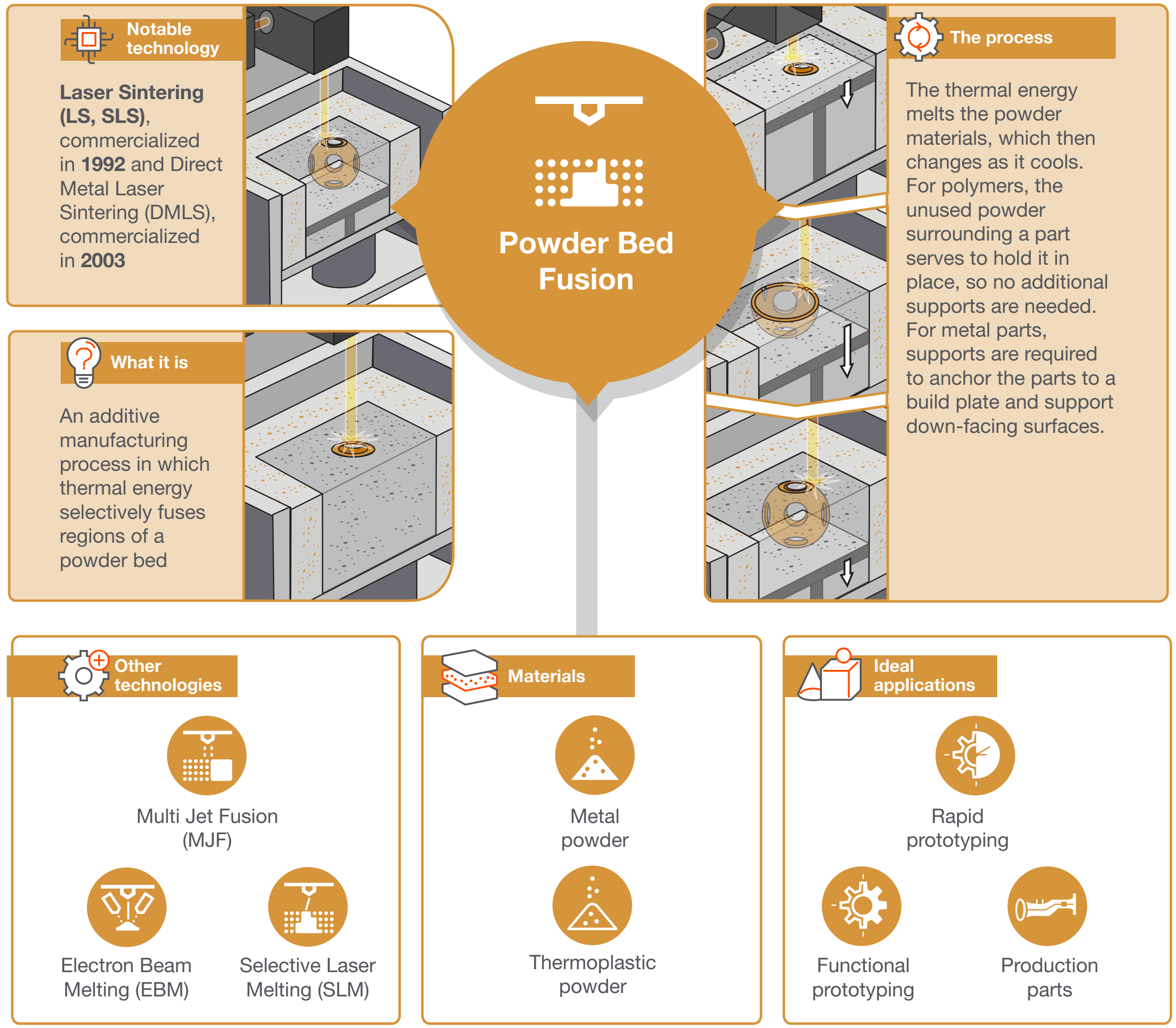
Limitations

- Visible layer lines
- Weaker in one direction than the other or anisotropic

Powder bed **fusion**

Powder bed fusion processes selectively fuse powdered polymer, metals or alloys using thermal energy. Polymer powder bed fusion technologies have a bed of powder that supports the model as it's being built. Metal powder bed fusion technologies deposit powder onto a build platform and require support structures for overhang features and holes that need to be CNC machined off in post-processing. The notable powder bed fusion technologies are Laser Sintering (LS, also known as SLS® for Selective Laser Sintering), Direct Metal Laser Melting (DMLM) and Multi Jet Fusion (MJF).

Since powder bed fusion processes use engineering-grade thermoplastics and metals, they create tough, complex parts for the entire product development lifecycle, including functional prototyping.



Benefits

- High impact strength
- High durability
- No support materials (plastic)
- Isotropic
- Ability to build complex metal parts

Limitations

- Requires advanced material handling procedures
- Longer lead times due to post-processing and cooling times
- Expensive (metals)
- Small build volume (metals)

Top considerations for choosing a technology

Manifold prototype 3D printed with Laser Sintering technology.

The “one-size-fits-all” approach doesn’t apply to 3D printing. The various technologies and materials can be difficult to navigate, especially if you’re new to 3D printing.

1. What does the prototype need to accomplish?

The technology and material(s) you use should depend on your performance needs. Your prototype may need to serve just an aesthetic purpose—simply needing to look and feel like an end-use product. In this case, PolyJet, with its speed and ability to print in multiple colors and textures may be the best technology. SL, capable of building light-weight pieces with a smoother finish, could also be an ideal technology.

If you’re building a functional prototype that needs to resist impact and/or high temperatures, FDM or LS is the best choice. These technologies are capable of producing strong and durable parts and can print in a host of high-performance thermoplastics. If the prototype’s design includes a complicated undercut for airflow or a durable living hinge, we would recommend thermoplastics with LS.

2. In what environment does the prototype need to function?

Functional prototypes often need to function in higher temperatures or humid environments. Some 3D printing technologies and materials are quickly ruled out by these parameters. Photopolymers with PolyJet or SL will degrade in appearance and performance as they’re exposed to ultraviolet light. Moisture can also adversely affect some photopolymers and cause a part to warp, curl or lose dimensional accuracy. If your part is exposed to outdoor elements, FDM ASA would be a good choice.

Prototypes that need to function in a medical or food environment often require biocompatibility, meaning they’re safe to come into contact with the human body. In these instances, metals like Titanium Ti64 with DMLM or thermoplastics like ABS-M30i or ULTEM™ 1010 resin used in FDM are the most applicable.

PolyJet full-color concept model.

3. How long does the prototype need to last?

The number of use cycles a prototype will go through can eliminate technology and material options, as well. For example, a functional prototype for aerospace or automotive may go through weeks of testing and withstand a significant amount of stress, while a fit test prototype may only need to function once. Engineering-grade thermoplastics from FDM or LS can withstand significant amounts of stress and pressure, making them ideal technologies for functional prototypes. Photopolymer materials, on the other hand, are more effective for short-term, low-stress applications, such as marketing display models.

4. How does the prototype need to look?

Prototypes built with PolyJet and SL are smoother, have higher resolution right off the machine and are more easily hand-finished to the desired cosmetic state. PolyJet also prints in multiple colors and textures. Thermoplastic parts from LS and FDM machines are harder to finish cosmetically, and require more labor and skill to achieve a smooth surface, leading to higher costs and increased lead time. DMLM metals and alloys take even more time, effort and expertise to become polished prototypes.

5. What is your budget, timeline and quality requirements?

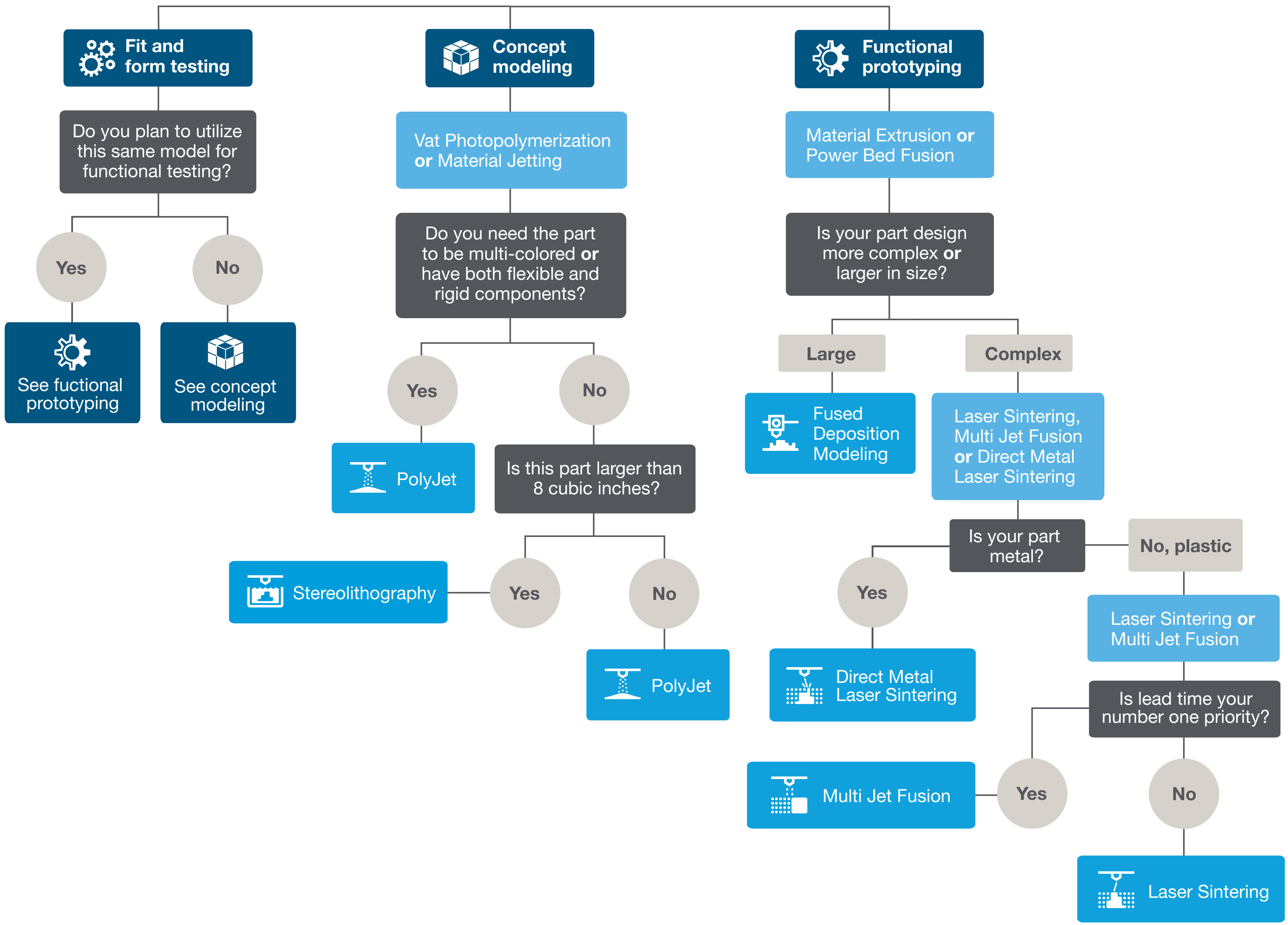
With a limited budget, your decision may depend on price. Similarly, with a tight deadline, time may be the deciding factor. Time and quality can often contradict one another—if you need a quick turnaround, it may be at the expense of a certain level of quality. However, there are ways 3D printing experts can reduce lead time and cost without sacrificing quality.

6. Of the factors, which is the most important?

Ultimately, you should consider all of these factors and decide which are the most important to your prototyping goals. Sometimes there are several competing requirements, but your main priorities should drive your decision.

3D printing decision tree

What is your Prototyping Use Case?



Top considerations for material selection

While 3D printing technology and material selection go hand-in-hand, there are unique considerations for material selection.

3D printing offers many of the plastics and metals found in conventional manufacturing, such as casting, CNC machining and injection molding plastics and metals. Although they often share the same names, the mechanical properties of materials for 3D printing technologies vary because of the way they are developed to react to different energy sources, such as heat, UV light, lasers, extrusion and binding agents. Therefore, it's important to examine each material's mechanical properties and match them to your prototyping requirements.

While there are hundreds of 3D printing materials to choose from, there are common categories they fall under:

Photopolymers

SL and PolyJet use photopolymer thermosets that start as liquid and then are cured with ultraviolet light. PolyJet photopolymers have properties that range from rubber-like to rigid, transparent to opaque and neutral to full-color. SL photopolymers can be soft or hard in both transparent and opaque formulations.

Thermoplastics

FDM, LS and MJF use production-grade thermoplastics that start solid or in powder form and are melted and solidified. FDM offers the widest range of thermoplastic options for 3D printing, including everything from ABS-M30™ and ASA for simple fit and function prototypes to static dissipative materials and durable polycarbonate materials, and its most robust materials, chemical and heat-resistant ULTEM™ resin and PEKK. LS and MJF mainly use various formulations of high-strength nylons and nylon composites.

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Metals

DMLM uses metals and alloys in powder form, including stainless steel, aluminum, INCONEL®, Titanium, Cobalt Chrome and Copper, that are melted with a laser. 3D printed metals deliver dense, corrosive-resistant and high-strength parts, which can be treated through heat, coating and sterilization.

Certification requirements

During the selection process, it's also important to ensure your material covers off on the requirements and meets industry certifications. Many 3D printing materials have been formulated to meet strict industry standards, including biocompatibility, sterilization, FDA certifications for skin contact, heat smoke and toxicity certifications and chemical resistance. Always thoroughly inspect specification sheets and work with your service provider to choose the right material; you can also ask for tensile bars.

Discover what material to choose based on your application and specifications with Stratasys Direct's *Material Wizard*.

Conclusion

The pace of product development isn't slowing down any time soon. It's an exciting and challenging time to be a design engineer.

Those who embrace and understand new technology and techniques will have a competitive advantage. But learning new technologies doesn't happen overnight. That's why it's our job to work with you on your ideas and champion them into real products and parts by identifying ways 3D printing can bring them to life faster and easier.

About Stratasys Direct Manufacturing

You want quality parts, fast – and for a fair price. We have that covered. But building parts demands more than acing the basics. It requires specialized know-how of the materials and technologies. With our problem-solving experts working tirelessly to match to designs and specs, Stratasys Direct Manufacturing is your partner in making that happen. When it comes to 3D printing or other custom manufacturing services, our responsive team isn't satisfied until you are.

With decades of experience and an insatiable appetite for collaboration, we know firsthand the challenges you face – and won't stop until we overcome them, together.

Supported by Stratasys' strong commitments to R&D and innovation, we regularly push processes and materials to their limits. And with ISO 9001 and AS9100 certifications, we ensure your parts meet the standards for any industry, including aerospace, automotive, medical and consumer.

Learn more about rapid prototyping with 3D printing »

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