

On Demand Investment Casting Solutions

Direct access to 3D printed casting patterns
and methodologies from 3D Systems



Getting started with investment casting through On Demand Manufacturing

3D printing and additive manufacturing technologies, materials, software, and services have begun to fundamentally transform our approaches to design and engineering, from product development to end-use parts. 3D printing offers an opportunity for companies to rethink old approaches using modern manufacturing technologies. With the myriad of options available to teams, deciding which technology and processes to adopt can be a daunting task for any organization.

New material developments have allowed organizations to move from 3D printed prototypes directly into low-volume production, producing both plastic and metal parts. Concept models can now be ready in a matter of hours, rather than weeks or months. Speed-to-market has been vastly improved

with design cycles that are faster and more efficient than ever before. With the help of full-lifecycle outsourced service bureaus like 3D Systems On Demand Manufacturing, organizations can tap into the virtually unlimited potential of these technologies from anywhere in the world.

Knowing when to leverage new technologies, services, materials, and partners will be the key to success for many organizations looking to modernize their manufacturing processes. This white paper is designed to introduce individuals and organizations to the power of investment casting as a process to produce many types of mechanical parts, engine parts, gears, dental work, jewelry, turbine blades, and other objects requiring complex and exact geometries.

Investment casting as a 3D printing solution

Investment casting has been successful in creating parts for thousands of years. While the process has significant advantages, the traditionally high cost and time involved in the creation of tooling have limited the casting industry. 3D printing may prove to be the way to revive this manufacturing approach, allowing high-quality parts to be produced more quickly and cheaply than ever before.

Over the past decade, professional and industrial-grade 3D printing technologies and materials have made significant advancements in both quality and reliability. An industry that was once limited to a few core materials now has access to hundreds of both plastic and metal material options. Many of these materials provide the same properties as their conventional injection molded counterparts, making 3D printing a welcome option for creating realistic prototypes as well as quick-turn and low-volume production parts. 3D Systems has been at the forefront of developing materials specifically designed for use in creating cast patterns and molds. Our On Demand Manufacturing group provides a significant opportunity for designers and engineers to gain access to these tools and fundamentally change the way they think about the foundry industry.

While most organizations have begun to bring 3D printers to their manufacturing floors, deciding whether to bring technologies in-house or use an outsourced service can be a significant business decision. Because of 3D Systems' unique ability to offer a full ecosystem of solutions, technologies, software, and support, we are able to provide engineers with access to virtually every option available, without the expense of large capital investments. This allows design teams to test out new technologies and approaches with little risk.

For teams looking to use investment casting and cast patterns in their design and production processes, 3D Systems On Demand Manufacturing offers an exclusive opportunity to have direct access to a network of tools and technologies as well as decades of experience in applying this to part and production manufacturing.

Investment casting in the 21st century

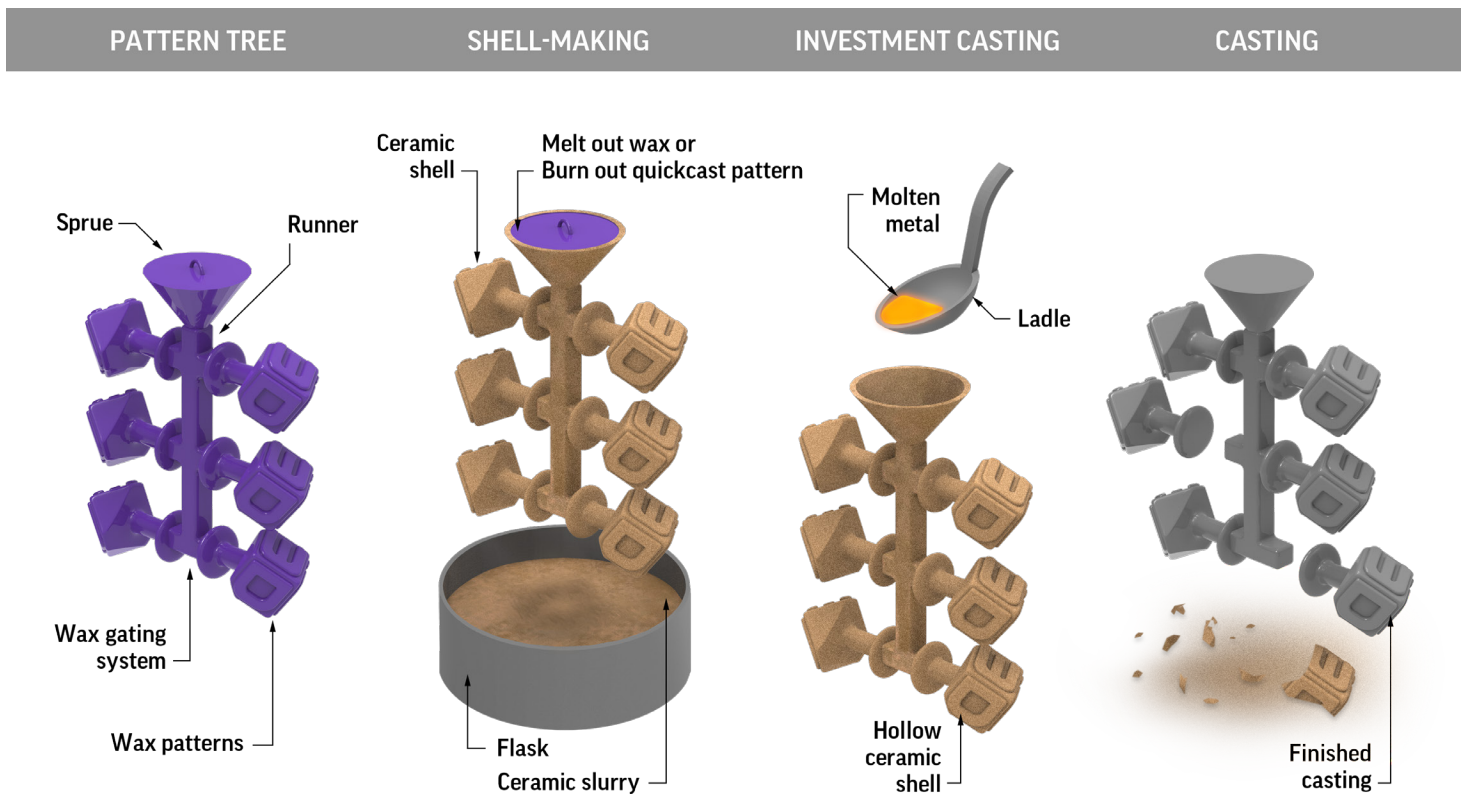
Investment casting is an important manufacturing process with a history that is thousands of years old. Lost-wax and shell-investment casting, the process of shaping molten metal into objects using wax patterns and ceramic molds, is still used today. The process is commonly used for objects requiring complex and exact geometries.

Investment casting is often used when extreme smoothness and accuracy are required, production quantities are low, and design complexity is high.

The process starts with a pattern — also known as a master, or master pattern. Traditionally this pattern is made of wax and produced with injection molding, but 3D printing revolutionizes this time-consuming step. Once the pattern has been created, whether traditionally or with 3D printing, the process is the same. The pattern is dipped in an ultra-fine ceramic slurry and then coated with one or several layers of a coarser sand/ceramic, depending on

design specifics. If the original pattern was wax, it is then melted and drained; if the original pattern was printed, it is burned out. With the right 3D printing material, this burnout leaves very little ash, which is an important prerequisite for certain applications. At this point the pattern is ready for metal casting.

Investment casting is precise, but it is also time-consuming and expensive. For example, the traditional method of using a wax injection tool to create an axial turbine blisk mold requires at least five weeks and can cost upwards of \$20,000 from start to finish. Compared to traditional methods, the time and cost investments for 3D printed investment casting patterns are much lower, and 3D printing can also produce patterns of greater complexity. A typical 3D Systems customer can create a 3D printed investment pattern overnight; in the morning it is ready for the foundry at a cost of under \$2,000.



The lost-wax or shell-investment casting process

Specific benefits of 3D printed casting patterns

3D printed casting patterns have enabled the evolution of significantly more timely and cost-efficient production of casted parts. In direct comparisons between 3D printed casting patterns and traditional methods, customers have saved anywhere from \$20,000 to \$200,000 per part, and removed weeks and months from the process. Additional benefits of 3D printed casting patterns include:

Producing patterns with greater design complexity

- Removed from the limitations and restrictions of traditional wax pattern production processes, 3D printed casting patterns can deliver higher design complexity.

Producing patterns significantly faster

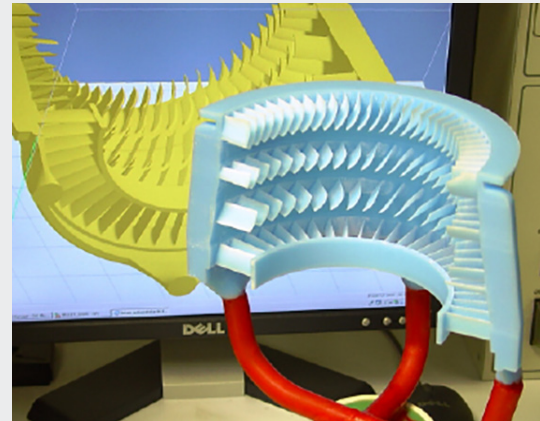
- Customers have cut weeks and months from the time taken to produce casting patterns and reduced time to casting by 90% or more.

Saving significant costs of production

- Customers have saved hundreds of thousands of dollars with 3D printed casting patterns in direct comparisons to traditional methods.
- Rapid production of casting patterns also helps quickly identify design flaws, reducing costly design changes and reworks that can lead to massive time and cost overruns.

Increasing product quality and finish

- The perfect surface resolution of stereolithography (SLA) casting patterns delivers an unprecedented level of quality to the final casted parts, reducing lengthy machining and post-processing requirements.



TURBINE TECHNOLOGIES IMPROVES TURBINE BLADE PRODUCT ITERATION WITH 3D PRINTED WAX PATTERNS

Challenge:

Expert R&D team needs to reduce costs yet increase quality of 3D printed blade casting patterns for critical product development.

Solution:

3D printed wax parts from the ProJet MJP 3D printers

Results:

- Created 3D printed wax casting patterns for one-tenth of the cost of traditional processes (\$20,000 compared to \$2,000)
- Produced casting patterns overnight, compared to weeks waiting for traditionally created patterns

	CONVENTIONAL PROCESS	TECH CAST PROCESS
Total time to finish casting	10-12 weeks	4 weeks
Labor cost (at \$60/hr)	Base	Base - \$81
Purchases	\$40,000	\$3,150

Customer benchmark shows that 3D printed investment casting can provide an impeller in roughly one-third of the time and at one-tenth of the cost compared to conventional processes.



**AEROSPACE PARTS SUPPLIER, VAUPELL,
DELIVERS CASTED PARTS MORE QUICKLY
AND COST-EFFECTIVELY THAN EVER
BEFORE WITH 3D PRINTED SLA
CASTING PATTERNS**

Challenge:

With the market becoming yet more competitive and cost-conscious, how can Vaupell work to compete successfully for its aerospace clients?

Solution:

3D Systems ProX® 800 SLA 3D printer and Accura® CastPro Free materials

Results:

- Cut delivery time for complex casting patterns from several months to a few days
- Cut costs of casting patterns from \$200,000-300,000 to \$6,000-15,000
- Enabled very iterative process without high costs

The 3D Systems end-to-end approach to investment casting

3D Systems offers two key 3D printing technologies for creating investment casting patterns: stereolithography (SLA) and Multijet Printing (MJP). Yet while 3D printing technology is a major contributor to the drastic cost and time reductions possible with investment casting, there is more to the solution than a 3D printer alone. 3D Systems' end-to-end manufacturing solutions help to streamline this time- and labor-intensive task with the software, hardware, and printing materials required to transform the investment casting methodology into a 21st century process.

3D Systems also offers On Demand Manufacturing services, bringing the benefits of investment casting to those who are new to the concept or need to occasionally farm out extra work.

Stereolithography and the QuickCast® build methodology

Stereolithography (SLA), the original 3D printing technology invented in 1983 by 3D Systems' co-founder and chief technology officer, Chuck Hull, is widely considered the gold standard for accuracy in 3D printing.

The QuickCast build style is an SLA print methodology developed by 3D Systems to answer a pressing need for the investment casting industry. The speed advantages and the high accuracy and quality of 3D Systems' SLA technology have made QuickCast one of the most popular and effective methods for 3D printed casting patterns in North America, as well as the preferred method for medical, aerospace, and defense casting applications.

The QuickCast build style consists of a hollow stereolithography pattern with internal hexagonal supports that add strength to the pattern. This structure also facilitates the collapse of the pattern during thermal expansion, which helps to prevent the shell from cracking.

The internal design of a QuickCast pattern minimizes the amount of material used, creating an almost ash-free burnout that reduces manual steps and can deliver a higher quality cast. The QuickCast method improves upon other 3D printing-based methods for creating investment casting patterns, offering advantages such as lower moisture absorption, smooth surfaces, high dimensional stability, and the ability to produce large pattern sizes to bypass or limit the need for assemblies.

With QuickCast patterns, castings can be created at a fraction of the time and cost of traditional tooling to produce wax patterns. This allows designs to be evaluated in days instead of weeks or months. The use of QuickCast patterns can also provide the user with invaluable gating and shrinking information prior to hard tooling.

3D Systems offers a selection of high-quality SLA printers, engineered to deliver true-to-CAD parts to meet a wide range of applications. These printers create exact plastic and composite material parts without the restrictions of CNC or injection molding. With the accuracy, surface quality, size, and detail achievable with 3D Systems' SLA technology, producing low- to medium-run parts is faster and per-unit part costs are lower.

Developed specifically for its SLA print engines, 3D Systems' portfolio of Accura® materials delivers a variety of material features and properties for high-quality performance, including polypropylene-like, tough/durable, clear, castable, and resistant to high temperature, as well as composite and specialty materials to meet application and product requirements.

Accura® CastPro™ material

3D Systems' Accura CastPro is an accurate, expendable pattern material ideal for QuickCast investment casting. It is good for both metal-parts prototyping and low-to-medium production runs without tooling. It can be used to create titanium, aluminum, magnesium, and zinc castings, as well as ferrous castings.

“Customers often create 2 or 3 casting patterns with different gating options in order to fully test which works best. This enables higher quality of the final castings without the costs and time normally involved with running prototypes using traditional investment casting patterns.”

- Jeff Smith, On Demand Manufacturing, 3D Systems

Accura® CastPro™ Free for aerospace castings

Accura CastPro Free delivers antimony-free casting patterns for the clean burnout necessary for aerospace applications. It is a durable, transparent, general-purpose SLA resin well-suited for metal casting. It is highly accurate, allowing for stable, superior quality investment casting patterns free of heavy metals for excellent casting results.

Key Benefits:

- Higher quality master patterns for investment casting parts
- Less part finishing time with ease of post-curing
- Accurate and tough parts that retain their dimensions and impact resistance over time without switching the material vat for different applications

Other casting materials

3D Systems offers a selection of materials for the investment casting process, varying in durability, resolution, moisture resistance, and purity, among other properties. Specialized materials for casting include clear plastic, wax-plastic hybrids, styrene-based for expendability, and more.

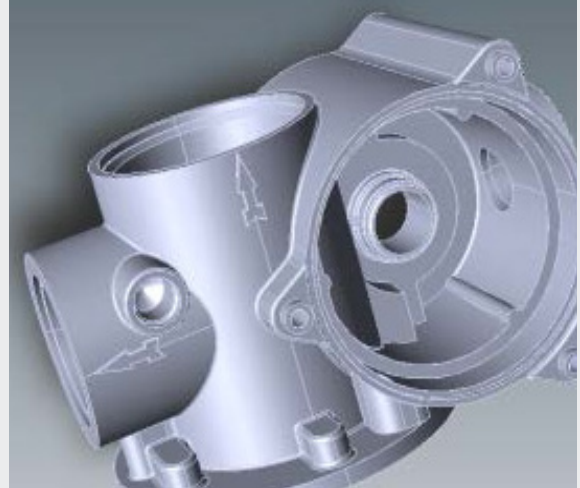
Wax Multijet Printing for investment casting

Wax Multijet Printing (MJP) from 3D Systems uses an inkjet process to deposit RealWax™ materials layer by layer to offer very high-resolution builds. Depending on the model and the material in use, layer thickness can be as thin as 16 microns (0.000591 inches). Advancements in materials science have improved the durability of wax parts printed in MJP, making the patterns more robust and reliable throughout the casting process.

In the case of investment casting, MJP wax materials deliver very fine detail for patterns quickly, with excellent outcomes for very small parts in jewelry and dental applications as well as smaller industrial parts.

MJP wax is ideal for a wide range of parts and patterns requiring fine feature detail. These systems are economical to own and operate, and use a separate meltable or dissolvable support material for quick post-processing. The process of removing support material is virtually hands-free; even the most delicate features and complex internal structures can be thoroughly cleaned without damage.

MJP wax printers are suitable for many direct investment casting applications where digital workflows already exist. Their ease of use and office compatibility make them a time-saving and cost-effective alternative to traditional lost wax casting processes. MJP wax printers can create virtually any geometry for one-off or scalable volume throughput.



ELSTER AEROTEH DELIVERS CASTED GAS REGULATION ASSEMBLIES IN A MATTER OF DAYS

Challenge:

Romanian team needs to cut months from its gas regulation assembly casting process by producing casted parts locally.

Solution:

3D printed wax parts from the ProJet MJP 3D printers

Results:

- Fulfilled production of casted parts in 12 days rather than months



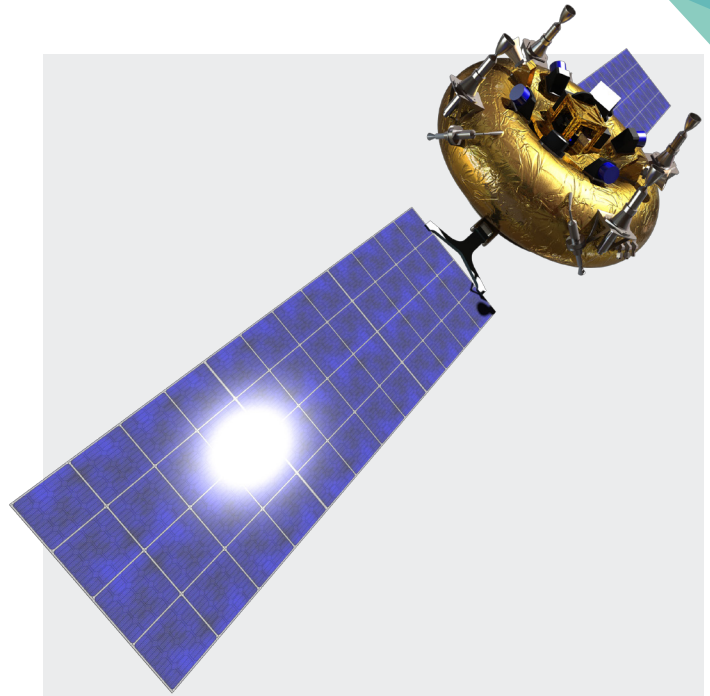
On Demand Manufacturing services for investment casting

3D Systems' On Demand Manufacturing offers a broad range of processes and technologies globally without requiring customers to invest in their own systems and materials. It is an ideal way to start using 3D printing for investment casting, or to extend existing capabilities in both additive and traditional manufacturing.

The online quoting process is instant, and requires only that users upload a 3D CAD file and indicate their project specifications. Using this information, 3D printing and manufacturing experts in strategically located facilities around the world respond with lead times and custom quotes.

3D Systems' On Demand Manufacturing is certified to meet ISO quality management system standards as well as ITAR and AS9100C specifications.

A wide range of 3D printers suitable for investment casting is available through this service, allowing customers to order parts from the smallest to the largest possible. 3D Systems' team of dedicated project managers reviews each individual order for manufacturability and can assist in producing the pattern only or the entire casting process, identifying opportunities to reduce development costs along the way as applicable.



PLANETARY RESOURCES DELIVERS LIGHTER, BETTER SATELLITE COMPONENTS WITH 3D PRINTED SLA CASTING PATTERNS OF CONSOLIDATED ASSEMBLIES

Challenge:

Deliver a satellite system with a total weight of 24-33 pounds, far smaller and lighter than any satellite before.

Solution:

Consolidating assemblies into a single, combined design and 3D printing SLA casting patterns deliver the weight reductions needed. Embedded parts and features enable the small sizes required.

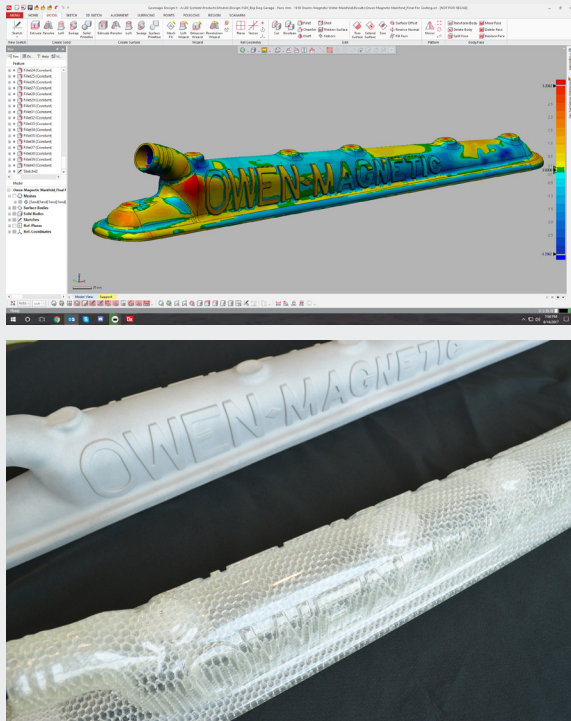
Results:

- Significantly reduced part count and met the required weight restrictions.

Investment casting technologies

3D Systems offers two core technologies, QuickCast® and ProJet®, to meet the needs of the investment casting industry. QuickCast is favored for high-accuracy medical, aerospace, and defense applications, while ProJet is preferred by the jewelry, medical, and aerospace industries. QuickCast uses hollow build styles and offers large pattern size and smooth surfaces. QuickCast patterns can provide invaluable shrink and gating information prior to hard tooling, as well as accelerated timelines compared to tooling to create wax patterns.

Our ProJet wax patterns deliver high-detail, high-resolution builds with quick lead times and lower initial development costs. They can be created without tooling, which accelerates the casting process. Although no special finishing is required, 3D Systems has the capabilities to produce the finishes required by the aerospace and medical industries.



RAPID CREATION OF CASTED ENGINE PARTS WITH OWEN MAGNETIC

Challenge:

Quickly recreate old parts to deliver foundry castings.

Solution:

Scan the old parts and recreate the data in Geomagic Design X software to print the SLA pattern for foundry casting. 3D printed casting patterns delivered by On Demand Manufacturing services.

Results:

- Accurate recreation of part
- Quick SLA pattern turnaround
- Completed part in 4 weeks

The final result

Using 3D Systems' end-to-end manufacturing solutions for investment casting can revolutionize manufacturing processes. 3D printing enables casting patterns to be created much faster than with traditional methods, at significantly reduced costs. The ability to print, test and adapt casting patterns quickly also makes 3D printing the only repeatable and cost-effective option for casting patterns that may need to undergo change. The materials available are precise, and the printing process is true-to-CAD. Furthermore, 3D printing allows companies to create digital inventories of casting pattern models to print or modify on demand. 3D printing technology delivers logistical benefits with high-strength, lightweight molds that are easier to handle and transport than their conventional tooling counterparts.

Visit 3dsystems.com/odm to get a free online quote for your tooling project, or contact us at quickparts.quote@3dsystems.com or 770-901-3200.

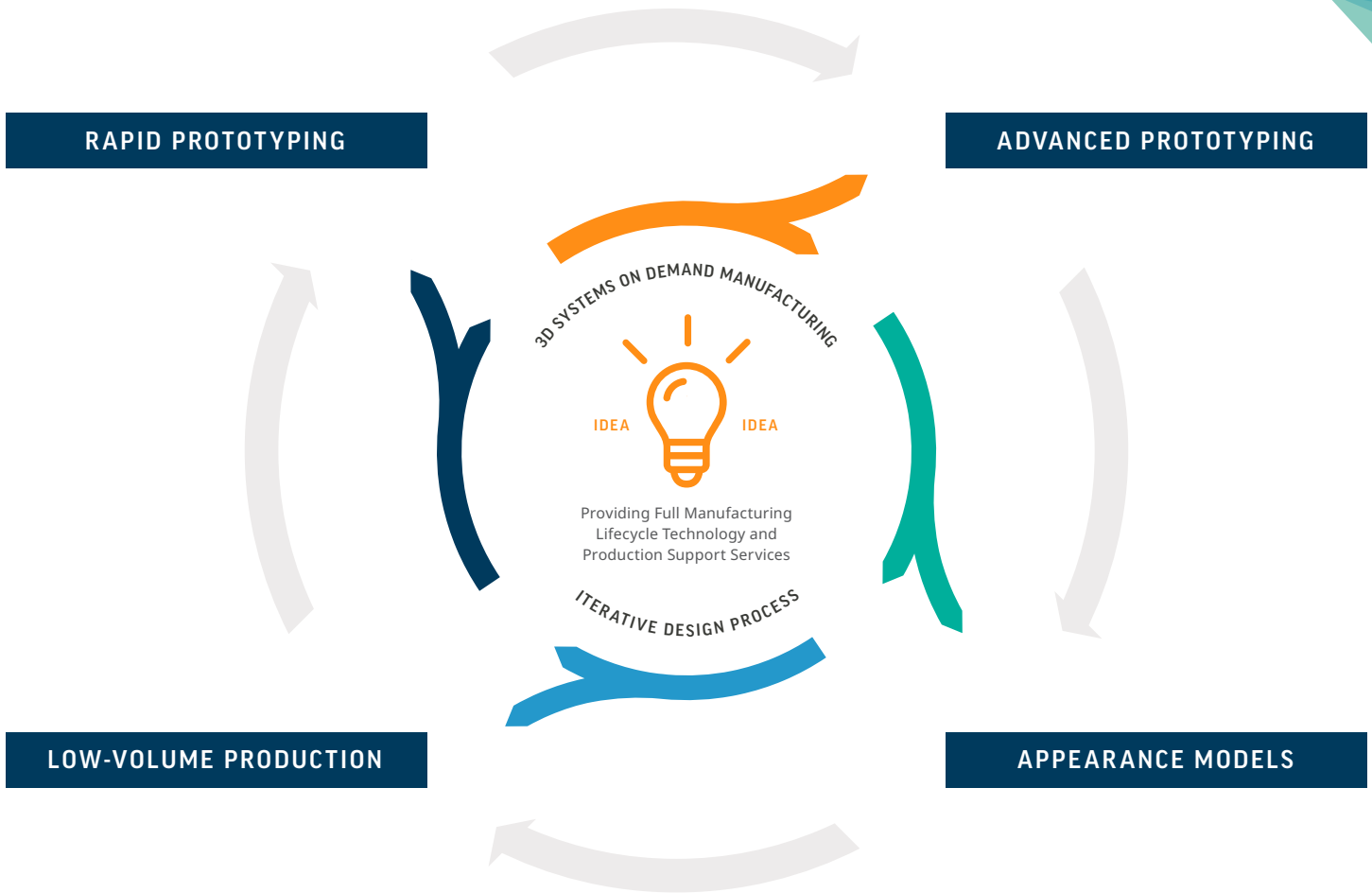
Prototype to production manufacturing lifecycle

3D Systems' On Demand Manufacturing group provides access to a full spectrum of conventional and additive manufacturing technologies that can be applied across the entire product development lifecycle, from prototyping to low-volume production. Our decades of experience and expert support have made 3D Systems a trusted industry leader.

Our services—rapid prototyping, advanced prototyping, appearance models, and low-volume production—

encompass every step of the product development process. On Demand Manufacturing allows you to seamlessly enter the production cycle at any stage, iterate within a single stage, or use multiple stages to successfully complete product development. In addition, our extensive material and technology options fit any design need.

Discover more about our modern manufacturing capabilities by visiting [3dsystems.com/odm](https://www.3dsystems.com/odm) or consulting with one of our experts.



Rapid Prototyping: Rapid prototyping is ideal for fast design iterations and part testing. Our expertise and capabilities allow for a variety of material options and ensure a consistently high level of quality while maintaining quick turnaround times.

Low-Volume Production: Low-volume production services help you reduce tooling costs and refine designs. Throughout the process, 3D Systems offers unparalleled value through our diverse range of technology and expert advice from our engineers.

Advanced Prototyping: 3D Systems' advanced prototyping helps simplify the extensive product development process. The approach can include 3D printing processes as well as traditional manufacturing methods to provide more functional prototypes. The fast turnaround allows for lower costs and reduced design risks when testing manufacturability.

Appearance Models: Our precise appearance models transform your design into working reality. We provide a comprehensive range of materials, processes, and expertise that is trusted by major manufacturers across the world.

www.3dsystems.com