YOUR GUIDE TO THE 4 AREAS WHERE 3D PRINTING IS UNSTOPPABLE

18 real life cases from the whole 3D printing industry

TABLE OF CONTENTS

SUMMARY

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INTRODUCTION

The challenge for many product developers, engineers, R&D managers and CEOs is knowing which manufacturing methods they're gonna pick when developing a product. If additive manufacturing, also known as 3D printing, is an obvious choice in the first steps of product development (proof of concept and prototyping), it might not be that clear when it should be used for production.

That's why there is a good chance that those of you who have considered using additive manufacturing may need more information before deciding that it is right for your project.
The goal of this ebook is to go beyond the obvious strength of 3D printing when it comes to prototyping and offer an overview of the four areas where 3D printing is unstoppable.

Through 18 different cases taken from the whole 3D Printing industry, you'll meet companies which intentionally selected 3D printing to manufacture their part or product because it was the most efficient way to meet higher standards. It is often hard to determine what actually needs to be manufactured using this technology and what can be manufactured by other means.

Those examples have been organized in four categories:

- -Complex geometries
- -Integrated assemblies
- -Mass customization
- -Engineering redesign

By the end of this ebook you will understand more about the unique strengths of 3D printing over traditional manufacturing and you will know when a product is right for additive manufacturing over traditional manufacturing methods.

COMPLEX GEOMETRIES

The first area of 3D printing that we are going to explore is complex geometries. What are they? We are using the term complex geometries to define shapes that are very complex, with intricate designs and that would for sure cause trouble when manufactured.

Complex forms are often used as an example to explain why 3D printing is a good solution for manufacturing. The reason is that complexity doesn't necessarily mean more difficulty for the actual 3D printing process in the machine. Additive manufacturing is a sure solution for designs that have intricately detailed complex angles which require precise measurements and execution. 3D printing completes the task at a lower cost than traditional manufacturing, and in some cases it may be the only way to create the desired object. Being able to accurately generate the model for your 3D print to suit your needs will likely be the most time consuming factor in your project.

CREATING EFFICIENT STRUCTURES INSPIRED BY NATURE

Nature has always been an inspiration for lots of engineers. 3D printing allows them to easily develop shapes that mimic some of the most incredible behaviours of organic materials.
To illustrate this, the Biometric Grill developed by Audioquest for its Nighthawk headphones is the perfect fit. This example utilizes the strengths of 3D printing to create an object that cannot be produced any other way. Skylar Grey, Designer and Director of Ear-Speaker production at AudioQuest, says that the biometric grill is inspired by the structure of butterfly wings which contain a lattice structure that diffuses light, and the purpose of the inspired lattice design in the grill pictured to the right is to diffuse sound. The function of the 3D printed part is to cancel out the sounds that can distort the quality of the music. If you would like to learn more about this design you can **read our previous ebook** that goes into detail about this company and their design. We are proud to say that Sculpteo assisted in the production of this Biometric Grill for AudioQuest; the lattice work contains 3 separate and intricate grids that can only be manufactured using 3D printing. Utilizing **SLS technology** and our Batch Control feature NightHawk is now providing their headphones to customers through authorized dealers.

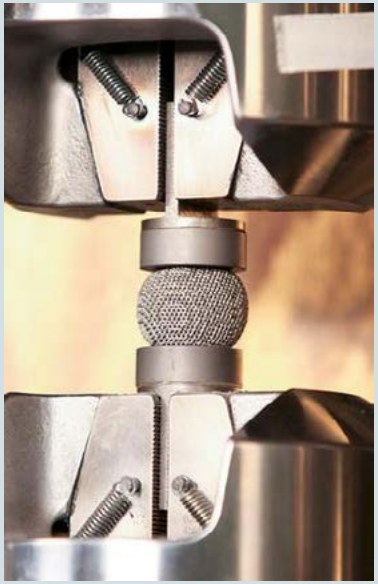
Biometric Grill for Nighthawk Headphones by AudioQuest [1]

COMPLEX GEOMETRIES

ACCURACY OF ADDITIVE MANUFACTURING IN COMPLEX GEOMETRIES

In terms of complex designs the concern is usually this: "My design is intricate and I want the design integrity to be respected. How accurate is additive manufacturing?"

This understandable and common concern was recently evaluated by DARPA's DMACE Sphere Challenge. It put both complex design and accuracy to the test.

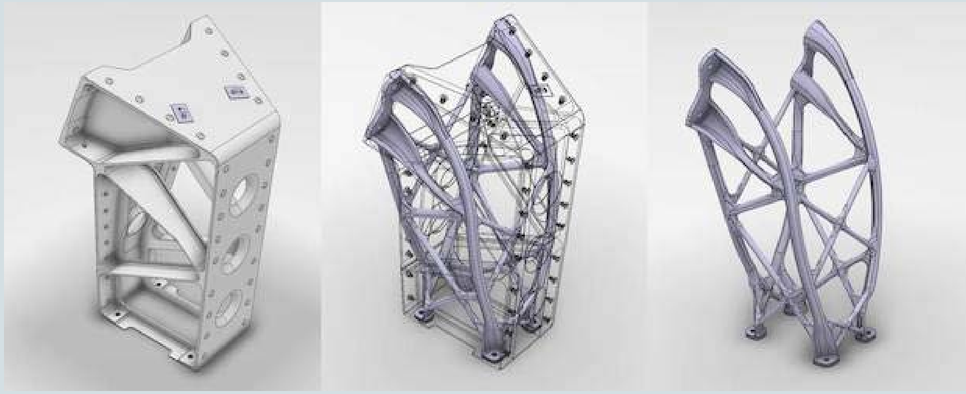


Destructive test of titanium mesh sphere in lab at ORNL [2]

In this challenge, 180 3D printed titanium spheres were subjected to destructive testing to determine the parameters of the mechanical properties. You can see in the picture to the left each sphere was placed in a machine at the ORNL lab and crushed. This challenge was critical to demonstrating that components with complex geometry fabricated via additive manufacturing can be computationally modeled, and their performance predicted. The mixture of strong yet lightweight materials like titanium and the computational models allowed in additive manufacturing have caused industries such as aeronautics and space exploration to utilize this form of manufacturing.

AERONAUTICS PUTS COMPLEX GEOMETRIES TO USE

In terms of the aerospace industry, 3D printing has become an essential solution for prototyping, tooling and parts manufacturing. Engineers have relied on additive manufacturing for a while now.

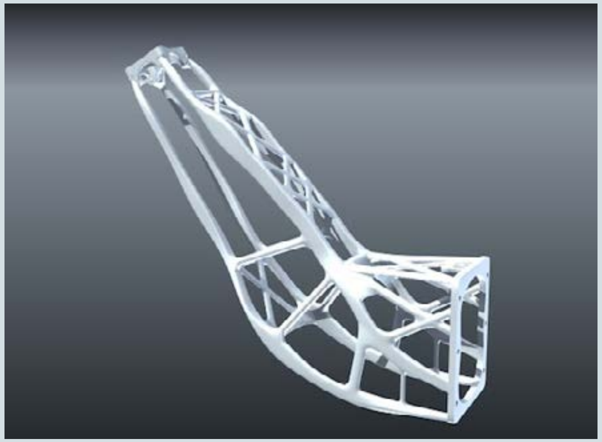


Evolution of existing multi-part bracket by Airbus Defence and Space Ltd [3]

In this sector of additive manufacturing, weight directly translates to dollars, and as we discussed finding the right material, with just the right balance of strength and weighlessness is essential to the bottom line. In most cases adding an extra milligram would increase the cost noticably for a satellite or shuttle launch.

COMPLEX GEOMETRIES

This is why companies like Airbus and Altair are making use of additive manufacturing technology and topology optimization methodology to fabricate lighter and stiffer components for use on satellites. The components shown above and below were manufactured in aluminum with laser melting, and they are both used as support structures for antennas on satellites.
These components utilize trussed structures reminiscent of organic, natural features. These features are a result of the optimization process locating material during which, load simulation stress concentrations are predicted to occur.



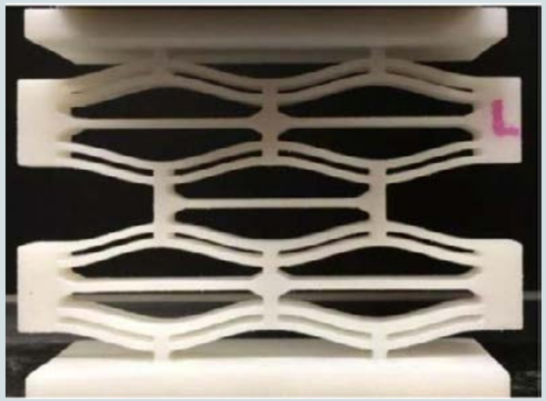
3D bracket by Altair in collaboration with RUAG Space [4]

Generally 3D prints are not made 100% solid, the reason being that it can be a huge waste of material, as well as, a waste of money and time. So if they are not hollow and they are not 100% solid, you might wonder...what's inside? Most 3D designers will choose a lattice styled honeycomb pattern that will ensure the print is strong and won't take a lifetime to print.

In terms of complex geometries we're starting to see an influx in utilizing the honeycomb pattern for more than just in fill, for example, recently control over the topology of these structures has allowed researchers to demonstrate the true advantage of introducing a controlled cellular geometry to parts with load bearing applications.

DESIGNS THAT ABSORB IMPACT

The "negatvie stiffness honeycomb structure" pictured below was developed as part of a project investigating energy absorbing structures. When exposed to quasi-static loads, it was found that recoverable energy absorption is possible without sacrificing the high energy-absorbing capacity of regular honeycombs.
This means that when the SLS negative stiffness honeycomb structures were compressed to a point of densification, they recover their original shape and dimensions when the load was removed. These structures could find applications in impact-protection devices such as helmets or car bumpers and reusable packaging. As you can see there is significantly more utility to these honeycomb shapes in 3D printing. Using nylon 11 with Selective Laser Sintering, researchers at UT Austin have printed honeycomb structures that can be designed for a specific mechanical response. The structure to the right absorbs considerably more impact energy than a solid structure of the same weight due to the truss design.



Negative Stiffness honeycomb for recoverable shock isolation by a research team at the Univ. of Texas [6]

COMPLEX GEOMETRIES

This is a Lightweight Metal Cellular Structure and it was manufactured using Binder Jetting technology. If you aren't familiar with the process of binder jetting it is when an automated roller is used to spread a layer of powder onto the build platform, the platform is lowered and adhesive is applied, then another layer of powder is applied with the automated roller again. The process is repeated until you have your object. This is valuable in applications requiring lightweight strength and impact absorption, which presumably includes vehicle armor.

Lightweight Metal Cellular Structure by the DREAMS Lab at Virginia Tech. [5]

The object shown here was created by using binder jetting technology to print the negative of this shape in casting sand. The casting sand model is then used to cast the complex geometry from aluminum in a typical foundry process.

MASS CUSTOMIZATION

One of the most prolific examples of the benefits of additive manufacturing is the development of consumer products using mass customization. Not limited by tooling requirements, companies can now cheaply produce thousands of customized parts for customers on a daily basis. By developing a process that integrates customer data into a physical part, consumers now have access to affordable custom fit products.

One of the longest running applications of custom product development via 3D printing is in the dental industry. Since 1998, Invisalign has been using Stereolithography (SLA) 3D printing technology in their manufacturing process of their teeth-aligning trays. In this process, an impression of the teeth is taken, which is then scanned and digitized. Algorithms generate the molds for the aligner trays in the treatment plan, which are then 3D printed. These 3D printed molds are then used to thermoform the aligner trays, which are processed and sent to the customer. Using this technology, this company is capable of manufacturing 40,000 parts a day.

Invisible braces made with SLA technology by Invisalign [7]

HOW DO YOU TURN A GOOD INTO A SERVICE?

Offering a product unique to your customer and fitted especially for them elevates your product into a service. Mass customization is the solution for this task, and it saves time, money and in most cases material. Here are a few examples of products being elevated from a good into a service thanks to 3D printing.

SOLS is working to get custom fit orthotics to customers. Using 3D scanning technology, SOLS 3D scans the customers foot in several weight-bearing and non-weight bearing scenarios to collect the data necessary and generate a customized 3D model. The models are then printed using **Selective Laser Sintering technology** and delivered to the customer in as little as 6 days.

Customized Othopedic shoe soles by Sols [8]

MASS CUSTOMIZATION

HEARING AIDS

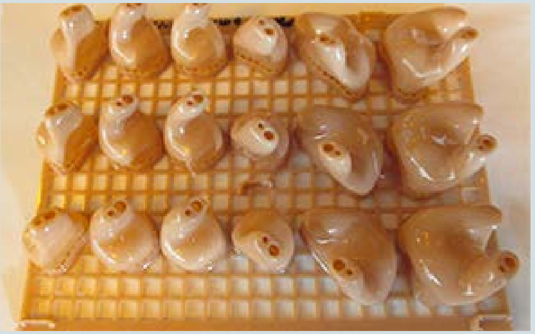
Similar to the way in which an impression of the teeth are taken for the Invisalign process, a silicon impression of the ear canal is taken, which is 3D scanned and digitized. **CAD software** is then used to generate the model to print. GN ReSound uses mask projection **SLA technology** to manufacture custom hearing aid shells in which the electronic components of the hearing aid are housed. Used in this process are the EnvisionTEC line of Digital Shell Printers, with the high resolution necessary for the complex geometry of the ear as well as having throughput high enough to manufacture 30 shells in 90 minutes.

CUSTOM EAR BUDS

Custom-fit Earphones is an industry that is newer to the game, but there is a start-up company that is revolutionizing accessibility of custom products for the average consumer. Utilizing **Fused Deposition Modeling** of ABS plastic, Normal is fabricating custom-fit 3D printed earphones. With only a 2D image taken by the customer on their own smartphone in the Normal App, this company is capable of fabricating a custom-fit pair of earphones in as little as 48 hours. Normal earphones retail at $200.

INNOVATIVE ADVERTIZING CAMPAIGNS

Škoda Auto in France launched a special campaign with the help of Sculpteo earlier this year. This campaign was for customers who have taken a Škoda car for a test-drive, for a limited time Škoda allowed their customers to customize and 3D print their own miniature Fabia! It is the first time a brand has used 3D printing for a campaign of this type. For more information about this campaign or to watch a video about the process **click here**.



Customized hearing aids by EnvisionTec [9]

Custom-fit earbuds by Normal [15]

Personalized Skoda Fabias by Sculpteo [10]

INTEGRATED ASSEMBLY

An area of additive manufacturing showing a lot of promise is integrated assemblies; imagine reducing the print time of your objects simply by integrating an assembly plan into your 3D model before printing, this will reduce the items you need to print and save you time in the print process. Let's look at a few more examples of Integrated Assembly.

PRINTING WITH INTEGRATED ASSEMBLIES CAN REDUCE YOUR PRINT TIME

With appropriate tolerances, parts with functional hinges and joints, chain-link style textiles, and other types of moving components can be fabricated in a single print without the need for post-print assembly. Tied in closely with engineering redesign, this manufacturing advantage can also reduce the number of necessary components for any application, which reduces the overall time and cost of product manufacture.

In the **2014 Virginia Tech Additive Manufacturing Grand Challenge**, students were tasked with designing an RC 3D printed air and/or ground vehicle to complete a set of obstacles. The goal of the challenge was to demonstrate the utility of on-demand manufacturing in remote locations from raw 3D printing material and a stock set of electronics. One group of students looked towards origami for inspiration in design.

The winning design from the team "Lobstrosity" was a quadcopter featuring fully integrated hinges into the design of the vehicle's four arms. By incorporating the hinges into the folding unibody arms, the entire build height of the print was limited to only 9 mm. Restricting the build height limited the print time of the entire quadcopter to only 3 hours and 22 minutes on an Stratasyst PolyJet printer. The four flat structures folded around a central hub and snap securely closed to serve as the arms of the quadcopter. The design won 1st place in the competition, as well as earning accolades for "best use of additive manufacturing" and "best performance."

Lobstrocity's winning Quadcopter by Stratasys [11]

INTEGRATED ASSEMBLY

THE FASIONABLE SIDE OF INTEGRATED ASSEMBLIES

Although it's very common to think of electronic devices or elements such as hinges or joints when considering integrated assemblies, it may come to a surprise to you that the fashion and textile industry is really making waves with 3D printing and it is all thanks to integrated assemblies. Architecture students at Virginia Tech successfully manufactured 3D printed flexible textile structures with both FDM and SLS technologies.

Designed to have both flexibility and rigidity, these textiles can easily be manipulated into a fixed shape due to interference between the links. Thanks to the unique design freedoms of powder bed fusion 3D printing (SLS), these textiles were printed as a single part and demonstrated full articulation immediately upon print completion. Ideas inspired by these flexible 3D printed fabrics have potential to impact the medical, textile and fashion industries.

Combining function with manufacturing awareness in terms of 3D space available in the build volume of a printer is a serious consideration when it comes to economizing your 3D print runs.

Flexible Textile structure, a research by Negar Kalantar and Alireza Borhani in collaboration with the DREAMS Lab at Virginia Tech [13]

Flashlight holder Designed by Phil Lampert, printed by Sculpteo [14]

SAVE SPACE ON YOUR PRINT BED WITH INTEGRATED ASSEMBLIES

The bounding box, or the volume of space that the part populates within the printer, translates to money (and time, as seen by the quadcopter above). In material deposition printers like **FDM** and **Polyjet**, space can also mean increasing support material usage, which in turn increases cost. By designing with a print process in mind, you can reduce your bounding box by integrating hinges or linkages, which will unfold or open when removed from the printer.

The wall mounted flashlight design pictured below [14] won the "**Redecorate Your Room**" contest by Sculpteo, and it printed in a folded orientation to conserve space, and unfolded to perform it's function. The same theory could be applied to the textiles mentioned above, where a garment may be printed as a tight ball that unfolds into a dress or shirt.

ENGINEERING REDESIGN

With regard to Engineering Redesign, 3D printing allots the designer the freedom of recreating a product without regard for the restrictions of assembly, part standardization, or traditionally restricted geometries.

By removing the need for tool generation, the designer is granted the freedom to design a part perfectly optimized for an application. An interesting application of this design freedom is the use of a design approach called topology optimization. This optimization process uses mathematical algorithms to optimize material usage within a given design space based on prescribed boundary conditions and applied loads. This approach typically produces very organic structures that resemble bone or plant growth, shapes that are prohibitively expensive or impossible to manufacture by any other means.

ECO-FRIENDLY REDESIGNS

An iconic example of engineering redesign for additive manufacturing is the eco-design study conducted by EOS and the Airbus Group Innovations on the Airbus A320 nacelle hinge bracket. The study was focused on reducing the CO_2 emissions over the whole lifecycle of the hinges. Thanks to design optimization and the manufacturing freedom enabled by **Direct Metal Laser Sintering** of titanium, nearly a 40% CO_2 savings was realized. Most significantly, using DMLS to manufacture the redesigned hinges reduced the weight per plane by 10 kilograms.

Hinge Bracket by EOS in collaboration with the Airbus Group [17]

REDESIGN FOR AERONAUTICS

An example from the Aerospace industry is the redesigned duct assembly pictured below on the left. The original design contained five custom components, 15 fasteners, adhesives and several assembly steps prior to heading into service. By redesigning this part for SLS manufacture, the total weight was reduced, the total part number was reduced from 20 to 1, and the strength was increased. Furthermore, with no need for assembly, labor costs were reduced as well. Another convincing example from the

Flying Eye Hospital Duct by Stratasys Direct Manufacturing (www.stratasysdirect.com) [18]

Aerospace industry is yet another redesigned duct assembly pictured above on the right. A company called Orbis has developedairborne facilities called Flying Eye Hospitals with the aim to aid communities around the world and eliminate unnecessary blindness. To achieve this lofty goal, Orbis converted a MD 10-30 aircraft into a hospital and training facility. Stratasys and Structural Integrity Engineering (SIE) worked together to design a air duct required to conform to complex curvatures as well as meet FAA airflow requirements.

ENGINEERING REDESIGN

Thanks to FDM and the engineering plastic ULTEM 9085, the SIE team was able to design an air duct that met FAA regulations, as well as reduce part count and assembly time by incorporating mounting features into the component. By circumnavigating the traditional fiberglass approach, the company was able to have a product in their hand in a few days at a fraction of the cost, rather than several weeks required by the mold machining and lay-up process for fiberglass manufacture

Conformal Duct by Stratasys Direct Manufacturing (www.stratasysdirect.com) [16]

RESURRECTING OBSOLETE PARTS: MAKING THEM BETTER AND STRONGER

3D printing makes it easy to replicate old parts that have been discontuned by the manufacturer but redesign also allows for innovation and creativity to make the product better than the original.
Sculpteo was commissioned to replicate this component in a CAD software, so that it could be 3D printed in polyamide with SLS technology, thus producing an exact copy of it for the client.
Sculpteo deals with these kind of tasks on a daily basis because it is one of the most common and appropriate applications for 3D printing: spare parts manufacturing.
The original component that their client provided belonged to a 30 year old ice cream machine whose production was discontinued by the manufacturer. The component needed to be replaced due to wear and tear, and because the customer couldn't rely on the original manufacturer they turned to 3D printing.
The part was "reverse engineered" by the Sculpteo team and 3D printed, thus saving a lot of money compared to the cost of buying a new machine.

The client agreed that redesigning the part and optimizing it for additive manufacturing is the best option because it not only reduced its price, but also make it more efficient.
This room for improvement is due to the fact that the original part's shape derives, apart from its function, from the manufacturing need of being extracted from a mold; this last can be ignored since we are now using 3d printing to produce it.
Thanks to the "layer by layer" manufacturing process involved in 3d printing Sculpteo was able to give life to high complex shapes, with cavities and undercuts, otherwise impossible to produce with any other technology.
The goal then was to define a new shape that would have allowed the piece to perform the same function, with same performances and durability, while considerably reducing the amount of material needed.

Talking with the client in order to understand how the part works inside the machine and interacts with other components was essential to the redesign; after doing so Sculpteo was able to apply loads, constraints and objectives to the digital model, relating them to the new polyamide material that was used.

ENGINEERING REDESIGN

This process is called “stress analysis” and it has a visual output that allows the Sculpteo to understand how forces work across the part while performing the specific function. Because of this analysis they were able to design a new, more efficient, shape that was avoiding unnecessary material. There are several software or plugins on the market able to perform this task, like Inspire by Solidthinking or project Arro by Autodesk. Lastly Sculpteo decided to reduce the weight of the part even more by applying a “lightweight” algorithm to the resulted model, transforming it in an even more intricate but still very resistant structure.

Spare part redesigned by Sculpteo

CONCLUSION

As the technology grows and matures, each day reveals exciting innovation in additive manufacturing. Researchers and professionals are revealing truly innovative products with the support of additive manufacturing, and companies ranging from major aerospace manufacturers to start-up consumer earphone brands are finding value in incorporating 3D printing into their business model.

We hope that these 18 examples of the 4 areas where 3D printing is unstoppable has given you a better idea of what can be done with additive manufacturing you can find more ebooks like this one here. If you have similar projects yourself, you can reach out to Sculpteo and let us help you add value to your business by supporting your process with the design and manufacturing advantages of 3D printing.

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