The Little Blue Book of 3D Printing

blueprint™

The first thing 3D printing should make for your business? Sense.

The business world is now witnessing and embracing the emergence of 3D printing as an essential tool for business innovation. Today, 3D printing, otherwise known as “additive manufacturing,” is increasing efficiency and growing profits in almost every sector of the economy. But 3D printing is evolving quickly, across a wide range of technologies.

Behind the myriad of ways in which 3D printing can bring value to a business, we found there are some fundamental principles that show up time and time again. Rather than keep this discovery secret, we have researched, condensed and codified these patterns and principles into simple and intuitive framework which forms the basis of our consulting approach.

We’re excited to share that insight with you.

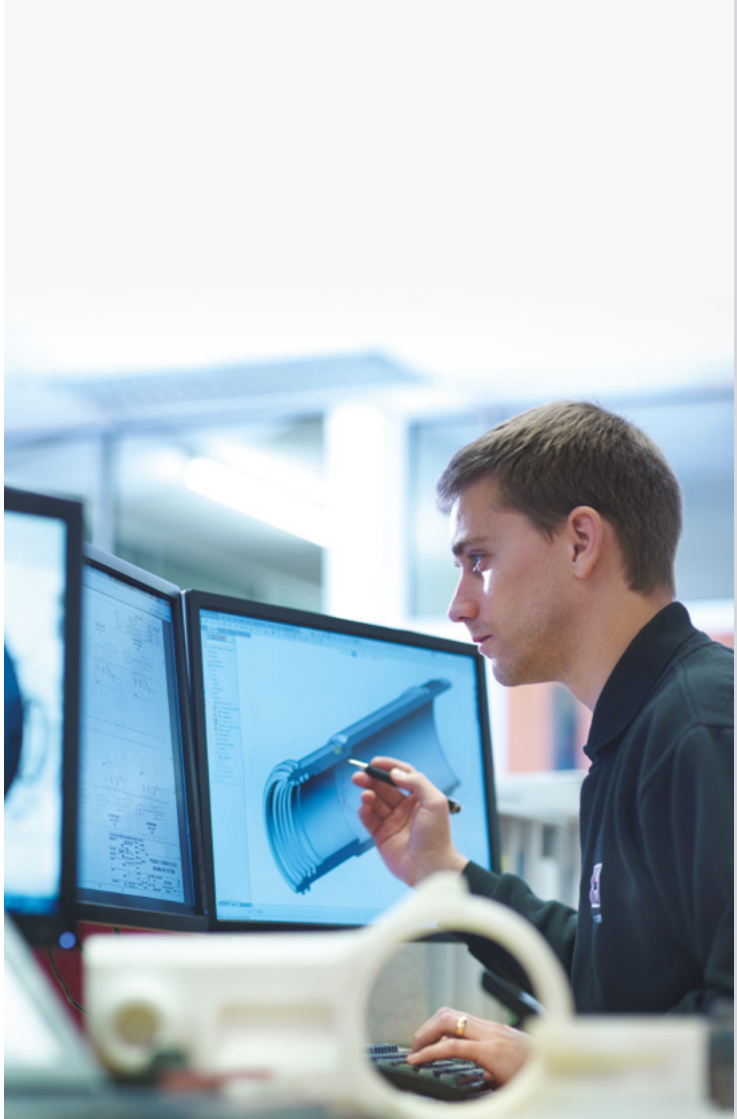
We're blueprint.
We are the world's leading 3D printing consultants with 15 years' experience in every aspect of 3D printing and how it can drive business benefit. We have earned a reputation for adding strategic value to companies across virtually every industry, large and small alike.

You know your business. But we know everything additive. From how it can disrupt global supply chains and enable brand new product designs, to how it reduces costs and drives new levels of operational efficiency.

Whatever the industry and whatever the need, our tried and tested approach allows our clients to identify, adopt and deploy this revolutionary technology, seamlessly and successfully.

blueprint™

Stratasys Minds. Independently Minded.



stratasys

Stratasys is the world's leading 3D printing company, revolutionizing the way things are made, every day. We empower global businesses to reimagine and improve the way they design and make things. We've spent over 30 years engineering first, setting standards and listening to what our customers really want.

From hardware and materials to software, we provide end-to-end support, designed to ensure you get what's right for your business. Whatever your business challenge, we'll save you time, money and resources by finding the best possible solution, delivered to the highest possible standard.

Make it with Stratasys.

06

drivers of business value

The 3D printing world is noisy. Every day there's a new technology breakthrough or industry first. It can make figuring out how 3D printing adds value to your business very confusing.

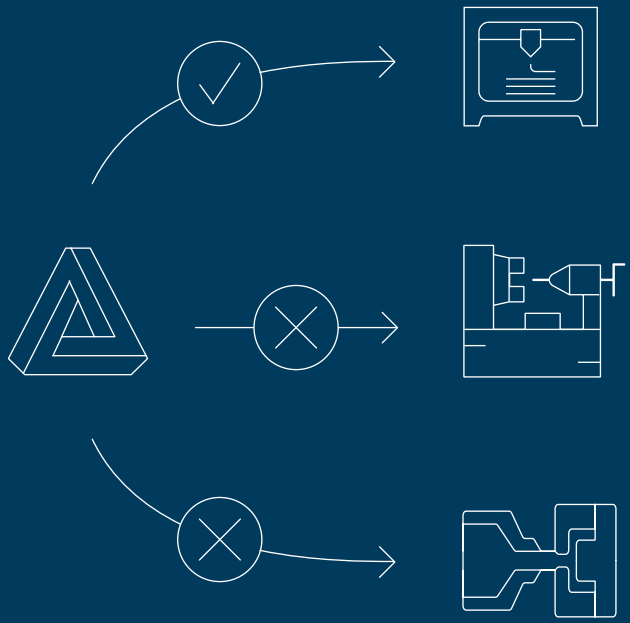
But behind the noise is a simple set of principles for how 3D printing can drive fundamental business value.

01 Freedom of design
02 Embedded functionality
03 Streamlined supply chains
04 Hyper personalization
05 Low volume manufacturing
06 Lifecycle sustainability

01

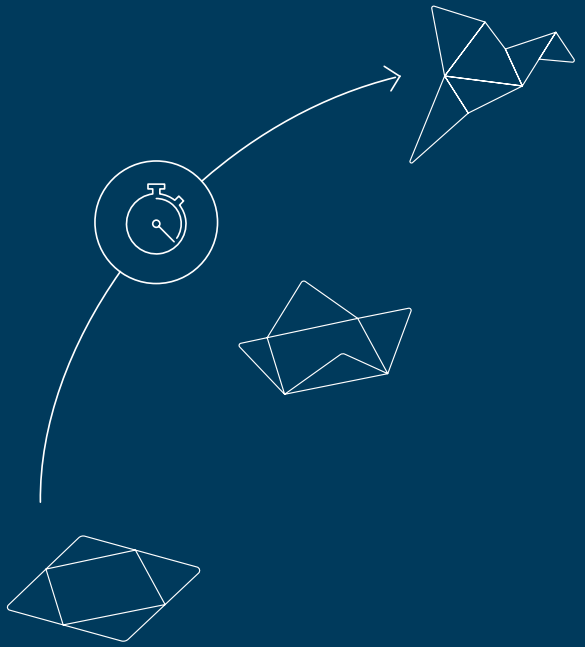
Freedom of design

Unlike subtractive, formative and fabricative processes, 3D printing does not have to abide by the traditional rules of “design for manufacturing”. This flexibility opens up new opportunities for the design and production of geometries that were previously difficult or costly, if not impossible.



Impossible design, made possible. Embrace the potential of 3D printing without the limitations of traditional manufacturing.

Add additive. Increase potential. 3D printing allows you to embed functionality, creating superior products with less risk of failure, even parts that can change shape and behavior over time.



02

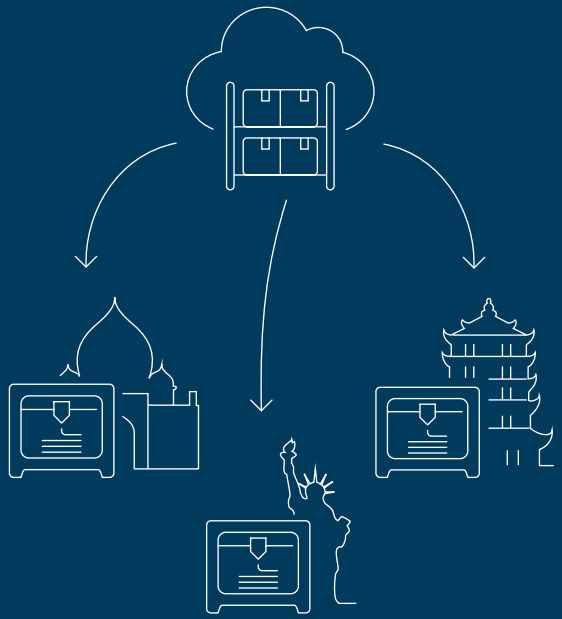
Embedded functionality

The digital, layer-wise approach of 3D printing allows for the creation of parts and products that possess more advanced properties and functionality with reduced potential for failure than traditionally manufactured or assembled products.

03

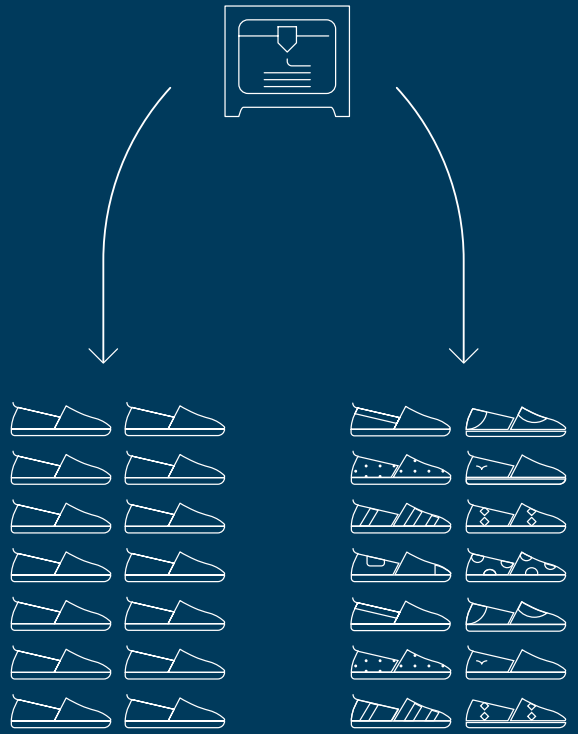
Streamlined supply chains

As a digitally-driven manufacturing process, 3D printing can produce parts on-demand, allowing for the radical re-think and reconfiguration of how companies structure their internal processes, distribution channels and supply chain.



Produce on-demand, anywhere in the world. Digitalized storage lets you rethink your supply chains without missing a deadline.

Personalize without the premium. Economies of scale don't affect 3D printing, so you can create unique products without the high premiums.



04

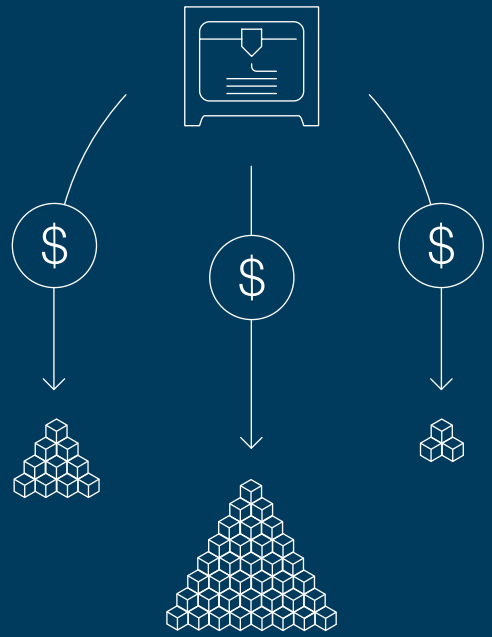
Hyper personalization

As a manufacturing process, 3D printing does not suffer from the effects of "economies of scale," meaning personalization of products can transition away from the realms of high-cost, niche and premium to become a fundamental differentiator for all products, markets and industries.

05

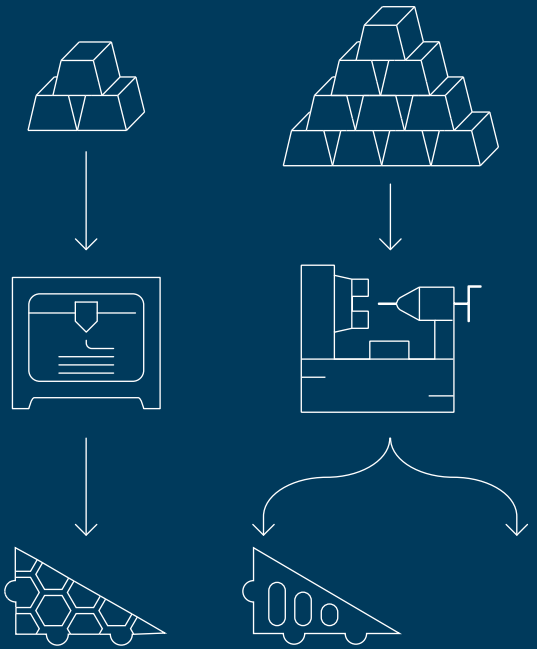
Low volume manufacturing

3D printing produces parts directly from digital data without the need for tooling, meaning there is little to no capital cost difference between 3D printing a batch of one, one hundred or one thousand parts.



One? Or one thousand? With no need for tooling, 3D printing allows you to print how ever many you like, with little to no fixed costs.

Use less. Achieve more. Additive creates better, more durable parts resulting in less waste and more sustainability.



06

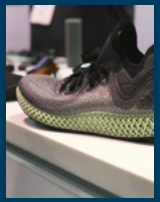
Lifecycle sustainability

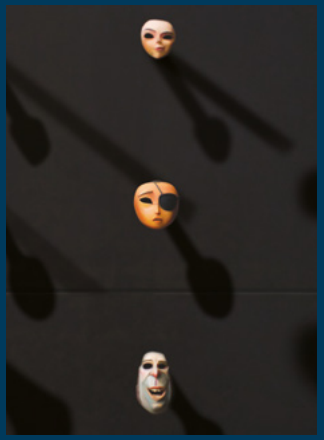
From minimizing production waste by producing more geometrically optimized parts to prolonging the useful life of products by eliminating the risk of obsolesence, 3D printing can reduce negative environmental impact while simultaneously growing the bottom line.

The 50 tactics

The 6 drivers help you frame how 3D printing can drive value at a fundamental level, but how do you start to apply these principles at a more tactical level?

To help you start applying the benefits of 3D printing to your business, we have created the 50 tactics; 50 industry-proven examples of how the 6 drivers are being applied to create tangible business value.

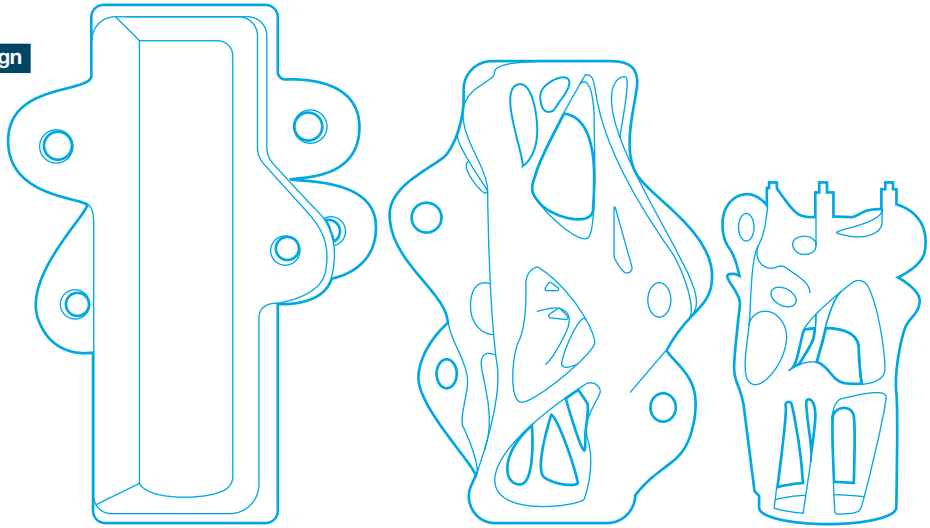




01/

Freedom of design

Structural cable nodes
Arup – Engineering & Design



01/01

Lightweight structures

You can now manufacture highly-complex designs with an optimal weight-to-strength ratio that can only be realized using an additive approach, using advanced simulation and CAD software.

Arup constructed a large outdoor street light structure, which could not have withstood its own weight if the 1,600 steel cable nodes were not optimized to reduce their weight by 75%.

01/02

Assembly consolidation and part count reduction

3D printing allows you to consolidate assemblies into fewer parts and eliminate the complexities of design-for-manufacturing. This reduces both engineering and assembly costs while improving reliability and performance.

Rocket engine
Relativity Space – Aerospace Manufacturer

The Aeon 1 rocket engine simplifies a design that would have required 2,700 individual parts from multiple suppliers into a few core pieces made in-house in a matter of days. This allows Relativity Space to continue its mission to slash the cost of getting payloads into orbit.

01/03

Dislocation of cost vs complexity

The more complex a design is, the more expensive it becomes to manufacture. 3D printing eliminates assemblies and the need for high-cost, multi-stage production methods, reducing the cost of highly complex parts.

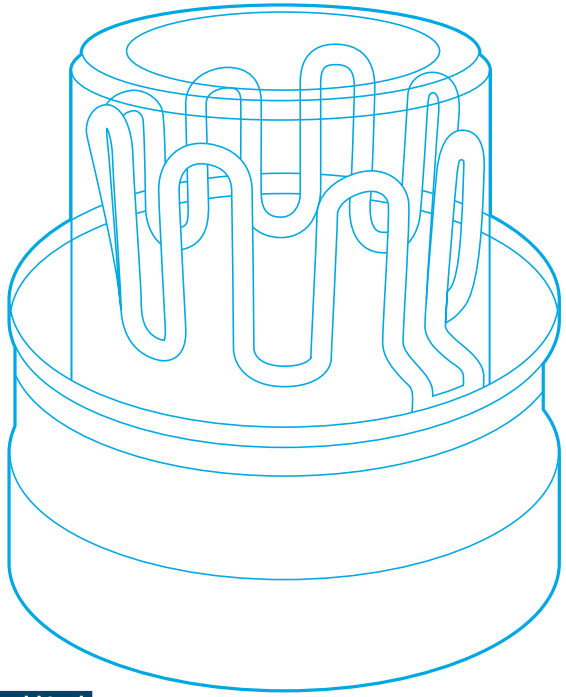
Pre-surgical heart model
SickKids – Paediatric and Teaching Hospital

Pre-surgical models help surgeons plan operations, but the historic cost of these complex models has meant they are only used in high-risk scenarios. 3D printing makes these complex models far more cost-effective and accessible to surgeons.

01/04

Non-linear holes, channels and features

The limitations of subtractive and formative processes greatly restrict the ability to design internal channels within a part. By using an additive approach, you can design vastly more complex internal geometries and features that can greatly increase the functionality of your design.



Injection mold tool
Texer – Toolmaker

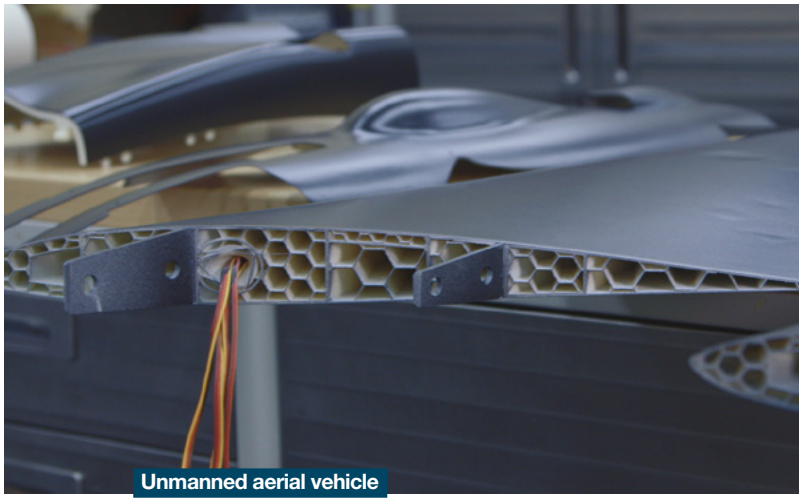
The Performal System from Texer combines simulation and CAD software with 3D printing to build tool inserts containing complex, non-linear cooling channels that would be impossible to create with traditional manufacturing, leading to better performance in plastic injection and die casting.

01/05

Entrapped volumes and internal features

Certain 3D printing processes are capable of creating internal voids or entrapped features with no need for escape holes. This ability to create fully enclosed structures opens up new possibilities in structural design, tamper-proof features and improved reliability.

To design a UAV that could reach 150mph, Aurora used 3D printing to create an entirely enclosed yet hollow aircraft structure which was structurally capable to support the jet engine but far less dense and more lightweight than what could be achieved by conventional manufacturing methods.



Unmanned aerial vehicle
Aurora Flight Sciences – Aviation Research Division

01/06

Biomimetic structures

There is no better designer than nature. Because 3D printing does not face the geometric limitations of traditional manufacturing methods, you can now faithfully replicate the designs found in nature that have been optimized over millennia of trial and error.

Acetabular cup
LimaCorporate – Medical Device Manufacturer

The “Trabecular Titanium” cup is a 3D printed hip implant with a complex, hexagonal cell structure on its external face. This structure mimics the morphology of bone and results in the patient’s bone bonding more effectively and prolonging the life of the implant from 10 years to 20 or more.

01/07

Variable porosity surfaces and volumes

3D printing can create geometries with variable and highly-tunable porosity at both a macro and micro scale. This allows you to implement cooling systems, filters, reactors and catalysts that would be impossible with traditional manufacturing.

Kengoro humanoid robot
JSK Lab – Robotics Developer

Rather than use conventional cooling systems such as sinks, fans or radiators that take up space and add weight, the humanoid robot Kengoro cools its motors by "sweating" water from its 3D printed aluminium skeletal frame that has high-tuned porous properties.

01/08

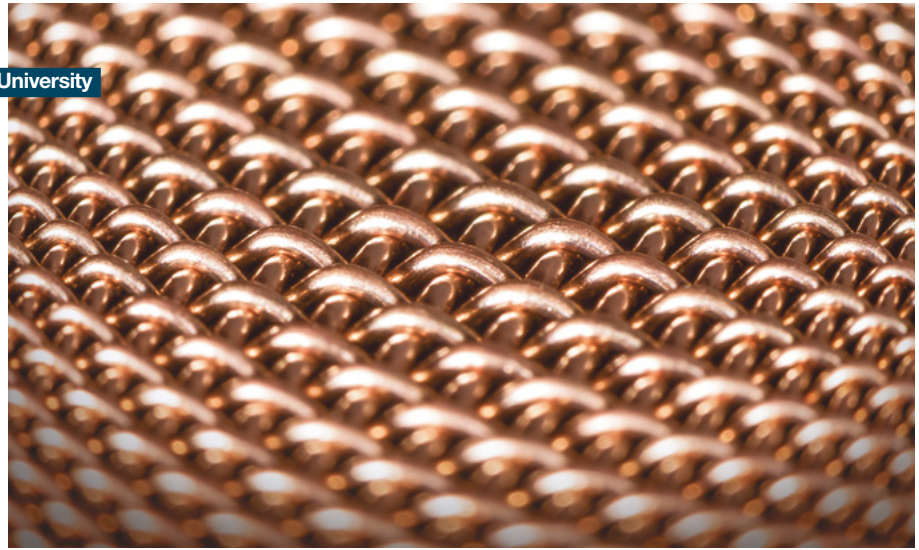
New styles and aesthetics

With so few limitations on what is now possible, 3D printing allows designers to unleash their creative thinking and imagine truly unique aesthetic styles, visual identities and compelling sensoral experiences that would be impossible using conventional fabrication methods.

Light shade
Nervous System – Design Studio

The team at Nervous System decided to put their expertise in biology, architecture and simulation into 3D printing fashion accessories and lighting designs that are generatively designed, based on patterns found in nature, from algae growth to coral formation.

Radio wave focusing lens
Massachusetts Institute of Technology – University



01/09

Metamaterial structures

A metamaterial is a construct of one or more materials that exhibits new and useful characteristics, such as how it reacts to forces or interacts with light and radiation. Many metamaterials are only achievable through a combination of innate material properties and 3D printed geometry.

By 3D printing a polymer coated with a thin layer of copper, researchers at MIT have created a metamaterial that can focus radio waves to a precise point. This function is impossible to achieve with any known natural material.

01/10

Manipulation of difficult-to-work and next-gen materials

The layer-wise approach of 3D printing is often the best way and sometimes the only way to create parts from next-generation materials and composites, including super-alloys and advanced polymer chemistries.

By having the ability to 3D print tungsten, a notoriously brittle and difficult-to-work material, GE could stop hand glueing 200 brittle plates and instead print an entire collimator in one piece, reducing scrap and failure from plates breaking during assembly.

Tungsten collimator
GE Healthcare – Medical Device Manufacturer

02/

Embedded functionality

02 /11

Embedded components

Voids can be deliberately designed into parts to house electronics, sensors or mechanical components. These components can be inserted during part manufacture, allowing for better part integrity and lower post-processing costs.

Companies such as Voxel8 use a 3D printer to print the body of its drones. At key stages during the print, the printer is paused and electrical components such as wires, circuit boards, batteries and motors are inserted. Afterward, printing is resumed and these components become fully enclosed.

Drone
Voxel8 – 3D Printed Electronics R&D Company

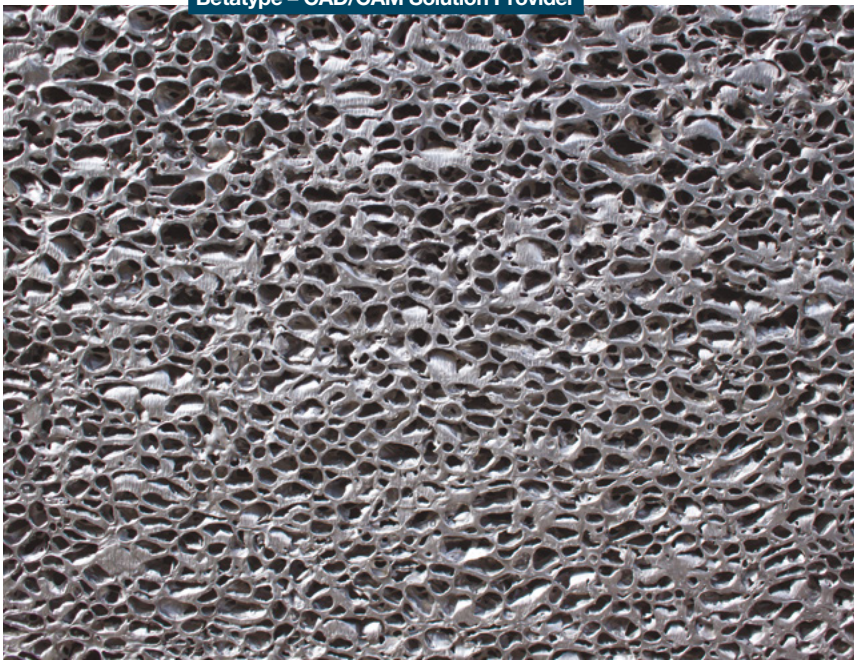
02 /12

Anisotropic properties

Many additive materials exhibit anisotropic material properties due to the way in which the materials are deposited. This is useful for auxetic structures or producing light weight, highly stressed designs, just how engineers take advantage of fiber composites.

3D printing can produce metal foams by printing fine lattices. These micro-structured materials can be designed to exhibit useful anisotropic properties such as having different stiffnesses or thermal conductivities in their various planes.

Directional thermal conductor
Betatype – CAD/CAM Solution Provider



02 /13

Eluting parts and materials

3D printing can process a variety of materials including ones which may contain volatile organic compounds, subliming polymers, dissolving substances and cells. These can be formed into complex components or implants to provide additional functionality.

Drug eluting implants
Louisiana Tech University – University

Researchers at LTU used 3D printing to create low-cost, patient-specific implants with embedded antibacterial and chemotherapeutic compounds. The 3D printed plastic is absorbed by the body while simultaneously delivering the therapeutic compound.

02 /14

Shock absorption

3D printing can economically produce accurate and complex lattice structures. You can use this ability to design lattices that offer different levels of stiffness within a material or even fail plastically in compression like the crumple zone of a car.

Running trainers
Adidas – Sports Apparel Company

Adidas has taken advantage of the ability to produce complex lattices to manufacture their range of Futurecraft shoes. Different types of lattices are used to address the different cushioning needs of the foot. This type of midsole has superior breathability and is easy to clean.

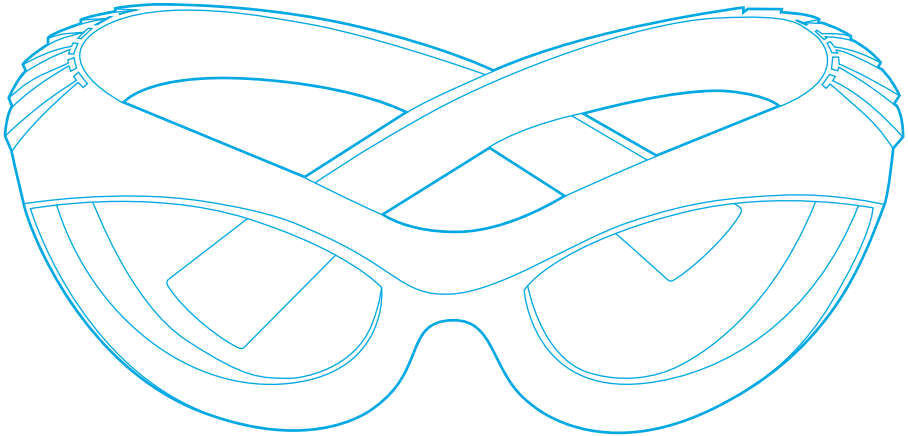
02 /15

Variable stiffness

Many production methods and materials constrain designs to a uniform material stiffness. Using 3D printing, you can produce products that have complex structures that vary the effective stiffness of a single material in a continuous part.

PQ Eyewear used 3D printing to create these designer sunglasses, which have an innovative single piece hinge-less frame.

Designer sunglasses
PQ Eyewear – Fashion Brand

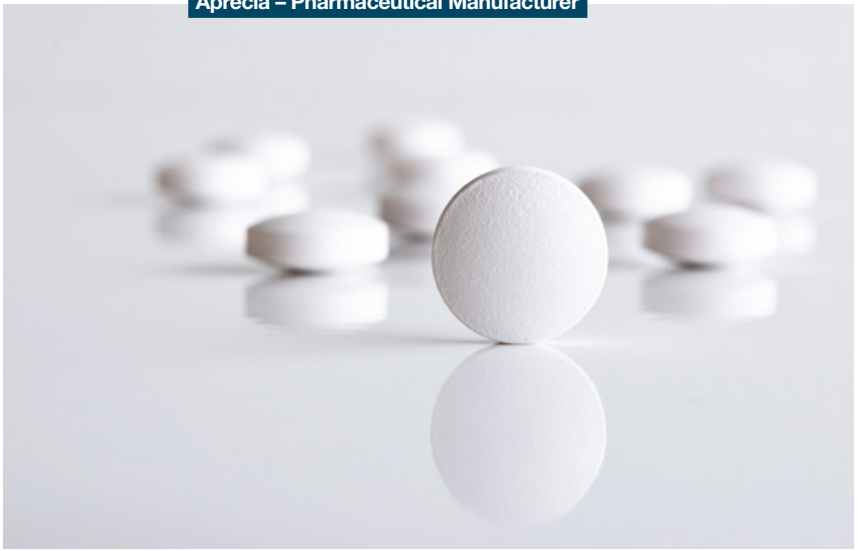


02 /16

Predictable degeneration and absorption

Having fine control over micro-structure enables designers to create porosity or microfluidic channels that control how liquids flow into parts. Capillary action can be used to produce complex effects with a single material through clever design.

Spritam seizure medication
Aprecia – Pharmaceutical Manufacturer

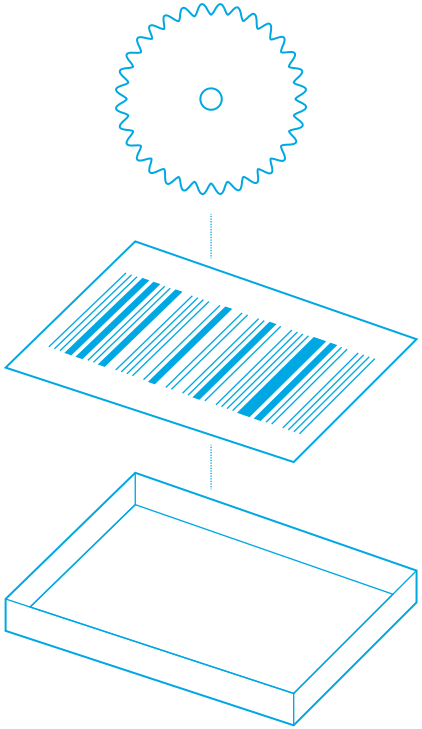


Aprecia was the first manufacturer to receive FDA approval on a 3D printed medicine. Their anti-seizure pill is printed with a porous open cell lattice structure that rapidly wicks up water causing it to almost instantly disperse and dissolve once inserted into the mouth.

02 /17

Embedded traceability and sensing

Using 3D printing, you can embed traceability directly into parts. By changing materials or tooling paths within a print, you can embed serial numbers, barcodes or “product fingerprints,” enabling immutable traceability from the moment of part creation.



Gears
HP – Information Technology Company

Some machines are able to print in multiple inks and deposit subtle speckle patterns or UV-reactive inks onto a part. This enables you to produce parts with hidden barcodes to aid traceability or prevent counterfeits.

02 /18

Programmable shape-change properties

The ability to manufacture using multiple materials in complex geometries enables 3D printing to produce pre-programmed structures that can change their shape in response to external stimuli such as heat, light or moisture. This can be done using chemical or biological drivers.

Adaptive sweat control vest
Massachusetts Institute of Technology – University

A team of MIT researchers produced a breathable workout suit. Parallel lines of E. Coli embedded in small flaps swell up in response to the moisture generated by exercise, increasing the ventilation on the back of the suit by curling the flaps open.

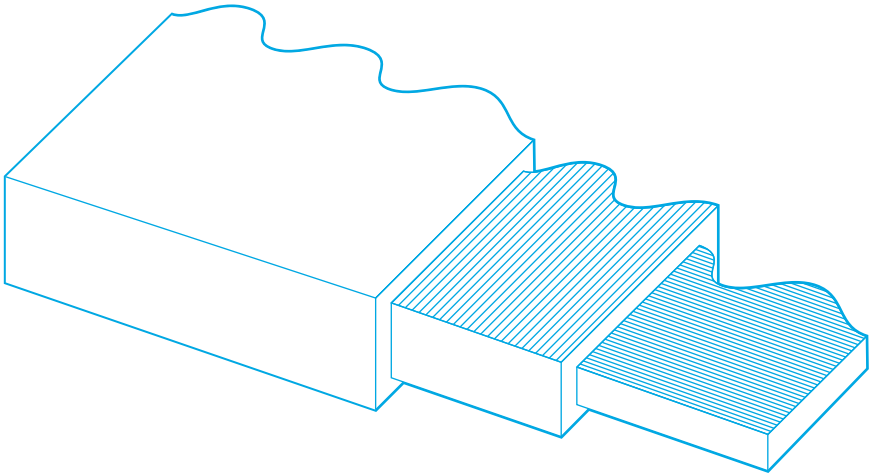
Drive belt
HP – Information Technology Company

Color can be 3-dimensional, within the part or on its surface to produce visible indications of wear or damage. Simple visual inspection can be used to determine if a part must be replaced or has been tampered with.

02 /19

Embedded part-wear indication

3D printing allows precise changes in color and geometry to be embedded within parts. By altering color or geometry, you can embed part-wear indication that is easily identifiable and maintains the uniformity of the material.



02 /20

Hydrophobic and hydrophilic properties

Some materials become hydrophobic or hydrophilic based on their surface morphology or geometry alone. Using 3D printing to deposit these materials in complex geometries, you can create products containing both hydrophobic and hydrophilic properties.

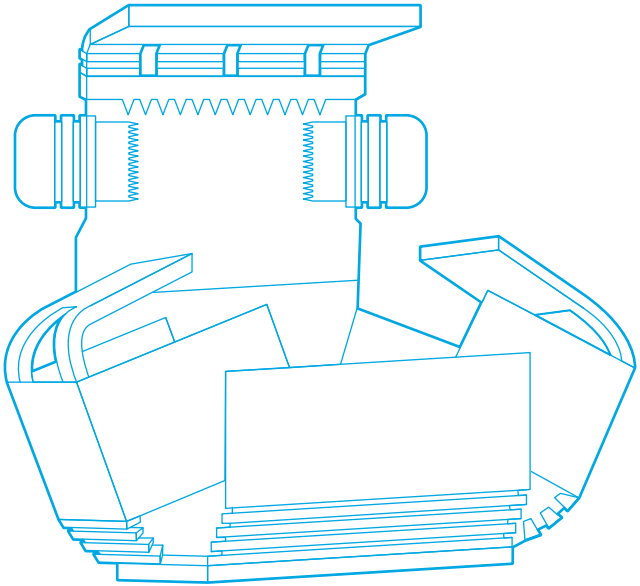
Inspired by structures found in nature, the University of Southern California used "immersed surface accumulation" 3D printing to produce super hydrophobic and olephilic (oil-absorbing) structures for use in cleaning up oil spills.

Microdroplet manipulator
University of Southern California – University

02 /21

Integrated mechanisms and actuators

By combining a layer-wise production method with pick-and-place components, designers can produce parts with integral mechanisms and actuators. When combined with flexible materials these can be sealed into moving parts.



Self-folding container
Georgia Institute of Technology – University

Shape memory materials can be programmed to remember one shape and change into another following a stimulus. By combining flexible and shape memory materials, the Georgia Institute of Technology was able to print this self-folding container which closes shut when heated.

03/

Streamlined supply chains

03/22

Reduced transportation time and costs

By locating manufacturing closer to the point of use, 3D printing can eliminate the need to transport finished parts or products across the globe, ensuring parts are available at the point of need quicker and potentially cheaper.

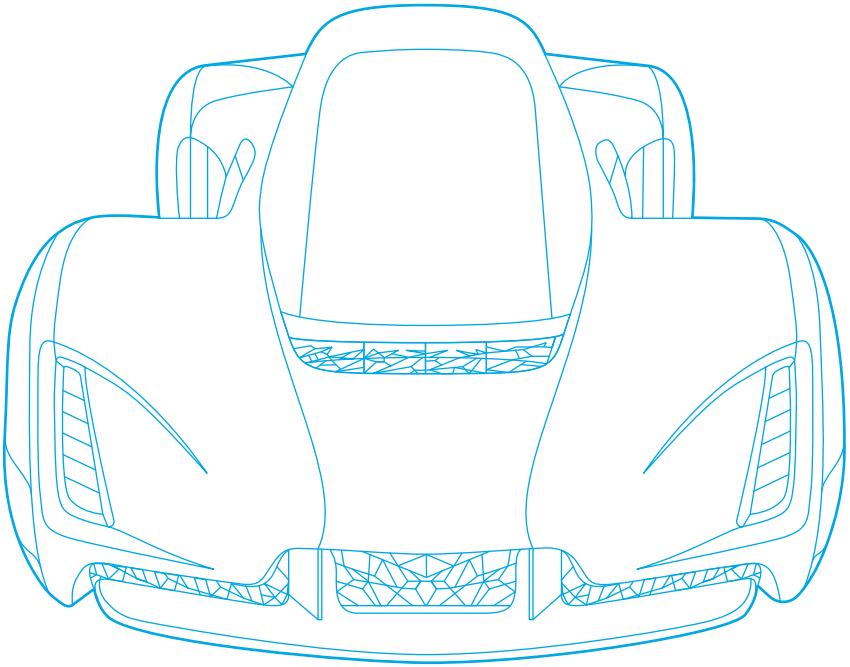
Mobile additive manufacturing unit
FieldMade – Technology Development Company

FieldMade has designed a series of modular, self-contained additive manufacturing facilities that can be deployed in the field, at the point of need, making it easier for companies to decentralize their manufacturing and get parts quickly where and when needed.

03/23

Reduced import and export costs

By decentralizing manufacturing or locating it closer to the point of use, you can avoid many of the costs of moving parts and products through economic and political borders.



Blade supercar
Divergent 3D – Automotive Manufacturer

Divergent 3D upended the standard approach to car manufacturing by developing "mini factories": self-contained and highly-flexible manufacturing platforms that could produce vehicles locally using 3D printing. These mini-factories reduce Divergent's reliance on global supply chains.

03/24

Supplier consolidation

As an on-demand production technology, 3D printing can greatly compress the length of supply chains. This can enable you to shorten supplier lead times or offer a wider range of services to your customers.

On-site spares & tool production
Jabil – Electronics Manufacturer

Jabil, one of the world's largest manufacturing service providers, wanted to cut costs and lead times for their tooling. Their solution was to move the production of their tooling in-house using 3D printing, reducing the time it took to get a tool from months to hours.

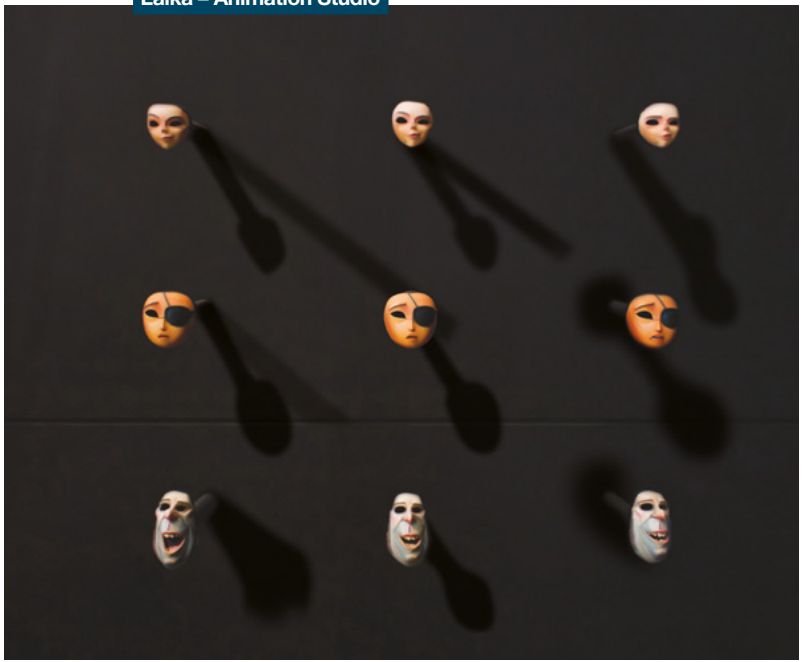
03/25

Process displacement and supply chain compression

3D printing can produce highly complex parts in a single production process using only digital data. This can allow improved repeatability, decreased cost and increased throughput in both hand-finished, highly customized and complex, multi-stage processes.

In stop motion animation, each facial expression is an individually hand-crafted element. With the ability to 3D print in full color, Laika digitized this process allowing them to create millions of facial expressions which would have been impossible in the time available using traditional craft methods.

Stop motion facial expressions
Laika – Animation Studio



03/26

Availability of legacy parts

Sourcing and storing legacy parts is costly. By digitizing your parts catalog, you can provide unlimited legacy support and sidestep the conventional costs of producing and storing spare parts by printing them on-demand when needed.

Classic car spare parts
Porsche – Automotive Manufacturer

Porsche is implementing a “digital inventory” management system to better support customers of their highly sought-after and iconic range of classic cars. Porsche provides select spare parts by 3D printing them on-demand.

03/27

Stock mitigation and digital inventory

3D printing allows you to free up the working capital that is sitting in inventory. Converting some traditional inventory to “digital inventory,” which can be printed on-demand, can reduce the amount of capital tied up in slow-moving parts.

To service hundreds of trains a month, the rail service center at Dortmund had to keep a large variety of inventory parts. Siemens’ transition of slow-moving inventory to digitized, 3D-printable parts means lower carrying costs and opportunities to improve existing designs.

Digital rail maintenance center
Siemens Mobility – Transportation Manufacturer

03/28

Manufacture to order or need

3D printing allows for entirely demand-driven production, producing parts only when an order is placed. This removes the need for traditional up-front investment and helps to democratize access to manufacturing enabling new entrants to break into previously cost-prohibitive markets.

3D printing marketplace
Shapeways – Manufacturing Service Provider

By providing easy access to 3D printing via their web portal, Shapeways allows individuals to upload and sell their product designs and receive payment for a sale before ever having to commit money to manufacturing, meaning there is never a risk of being stuck with unsold stock.

03/29

Manufacture lineside or at point of use

Many manufacturing methods require parts to be produced in volume or in locations far away from the point of use. Using 3D printing, you can produce parts on-demand, in lower volumes and in less space, which means you can manufacture closer to the point of use.

Refabricator
Tethers Unlimited Inc. – Aerospace Company

Rather than produce parts on Earth and launch them to the International Space Station, Tethers Unlimited developed a 3D printer that allows astronauts to manufacture parts on the station by recycling waste from packaging into feedstock for the printer.

03/30

Production automation and flexibility

By integrating 3D printing as a production platform, you can increase process automation while increasing production flexibility. 3D printing can switch to producing different products at the click of a button without the need for tool changes, downtime or line reconfiguration.

Patient-specific surgical guides
Northwell Health – Healthcare Provider

Northwell already used 3D printing to create patient-specific models but wanted to upscale this capability to all of its 23 hospitals. So they invested in a more automated 3D printing platform that could produce a much higher number of patient-specific models with the same level of manual labor.

03/31

Consumer driven supply chains

Thanks to the ability of 3D printing to produce batches of unique parts on-demand, you can transform a linear supply chain model into "consumer-driven" approach where your operations can respond quicker and are closer to your customers.

The peer-to-peer economy started with digital sharing and moved into e-commerce. Now 3D Hubs is enabling peer-to-peer manufacturing by offering a digital platform for 3D printer owners and those needing 3D printing services to connect. Consumers manufacturing for consumers.

3D printer network
3D Hubs – Manufacturing Service Provider

04/

Hyper personalization

Orthotic insole
Podfo – Orthotic Manufacturer

04/32

Ergonomic personalization

One size may fit all, but does it fit you? With 3D printing, your products can be exactly tailored to fit the precise ergonomic profile of your customer.

Podfo is embracing digital technologies and 3D printing to create the next generation of personalized orthoses by capturing not only the shape of the patient's foot, but how it changes shape during walking. Using this information and 3D printing, Porfo creates a truly ergonomic orthotic.

04/33

Aesthetic personalization

Personalization is increasingly becoming the expectation.
3D printing allows you to differentiate yourself through low volume batches of unique products that offer greater levels of personalization.

Car trim & dash components
BMW Mini – Automotive Manufacturer

People buy a Mini because it's iconic, and BMW knew this, so they made a digital configurator so customers could personalize parts of the vehicle which would be 3D printed and installed, letting customers put their individual stamp on this iconic piece of British design heritage.

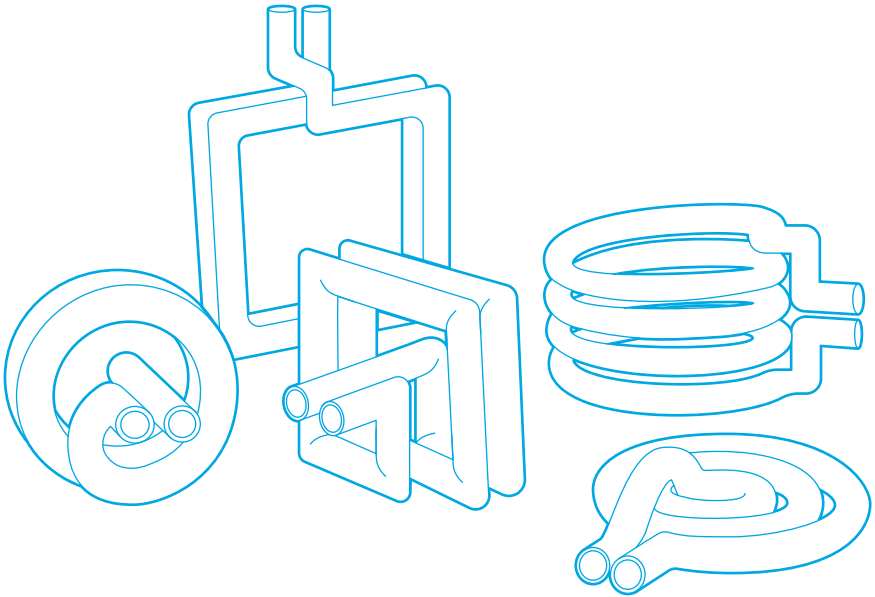
04/34

Functional customization

Customization driven by 3D printing allows you to better configure products to meet precise functional requirements or to achieve optimal performance, meaning you can move away from standardization and toward specialization of parts to best-fit the demand or need.

Protiq allows customers of their 3D printed copper inductor coils to precisely define parameters such as pipe diameter, overall size and number of rotations so that the product provides the optimal level of performance for the user's application.

Copper inductor
Protiq – Design and Manufacturing Service Provider



04/35

Product servitization

Consumers are increasingly interested in replacing periodic purchases with services that provide customized, on-demand products. 3D printing can help you tap into this market and offer personalized, on-time or optimized products as a service or subscription.

Vitamin supplements
Multiply Labs – Pharmaceutical Manufacturer

Most supplements are one size fits all and often aren't taken regularly. Multiply Labs addresses both of these issues by offering a subscription-based service of 3D printed vitamin pills that contain a custom dose of vitamins and minerals based on your personal lifestyle.

Thingmaker app
Mattel – Toy Manufacturer

04/36

Co-design experiences

With fewer design constraints to consider and an entirely digital path to manufacturing, customers and end-users can get much more involved in the design process of their products without the need for specialized knowledge or costly CAD software.

Mattel decided not to sell 3D printed toys, but to sell 3D printers as toys. The ThingMaker prints modular characters that are designed though a simple-to-use but highly expandable free app for tablets, allowing children to engage in both design and making as part of the fun.

04/37

New point of sale experiences

From the boutique shop to the largest department store, retailers fight to stand out from the crowd. By taking manufacturing out of the factory and putting 3D printing directly in the store, not only can you reduce lead times but you can add a sense of creation to your in-store experience.

In-ear headphones
Nrml – Consumer Audio Brand

How do you win over audiophiles? Nrml's approach was to streamline the process to get custom-fitted headphones by allowing customers to use their phone to photograph their ears and then have their measurements converted into perfect-fit headphones 3D printed in the store.

04/38

Mitigate OPEX for personalization

As a digitally driven process that can be highly automated, 3D printing can drastically mitigate the costs associated with providing a personalization option to your products by reducing the need for both labor and tooling.

Digital Forming developed an online software platform that provides a front-facing configurator and full back-end order fulfilment which can be licensed to brands who want to allow for customization of their products with the minimum investment in CAPEX and OPEX.

Parametric product configurator
Digital Forming – Software Platform Provider

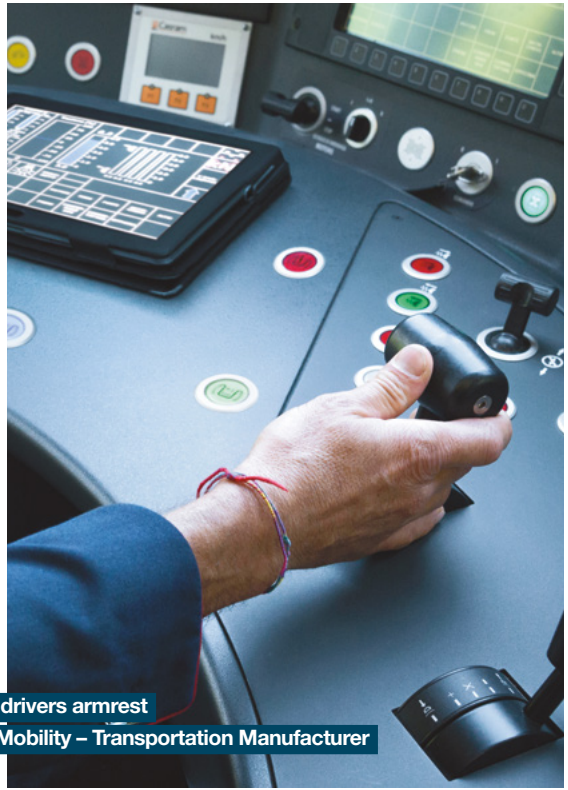
05/

Low volume manufacturing

05/39

Mitigate CAPEX in tooling

Tooling is a large component of manufacturing CAPEX. This is fine for large production volumes, but it makes small batches cost prohibitive. 3D printing is able to minimize tooling costs and eliminate the fear of high costs from last minute design changes.



Streetcar drivers armrest
Siemens Mobility – Transportation Manufacturer

Several tram drivers requested that their armrest configuration be changed to add extra buttons for turn signals to the side of the armrest. 3D printing was able economically deliver on this request without additional tooling, despite relatively low volumes.

05/40

Mitigate economies of scale factor

Traditional manufacturing has high fixed costs of tooling, machines and production line setup, which is often only economical for large production runs. 3D printing's lack of tooling and highly digital workflow enable economic production for batch sizes of one.

One:1 hypercar
Koenigsegg – Transportation Manufacturer

Koenigsegg only produces around 18 vehicles a year and tooling represents a significant cost for such low production volumes. Koenigsegg makes extensive use of 3D printing to reduce production costs.

05/41

Eliminate tooling lead times

3D printing offers a route to direct part production without the intermediary step and cost of producing tooling. Functional prototypes can be produced on-demand and production can begin immediately once design is complete.

Biolase was looking for a way to speed up their manufacturing turnaround, as their traditional tooling method took five to eight weeks. By 3D printing production parts directly, they reduced this product development cycle down to two weeks.

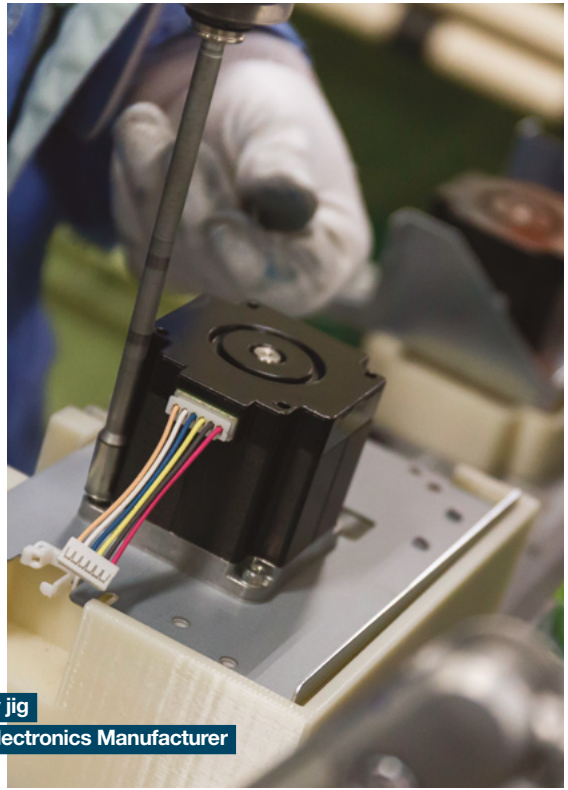
Medical devices

Biolase – Medical Device Manufacturer

05/42

Increase layout efficiency

Though lean manufacturing principles improve efficiency and lead to cost savings, they can still be expensive and slow to implement. 3D printing offers a cost-effective tool to rapidly produce custom jigs, fixtures, go-no gauges and part sorting bins.



Assembly jig
Ricoh – Electronics Manufacturer

Ricoh is using 3D printed anti-static ABS jigs to increase assembly speed and accuracy in their Japanese Production Technology Center. As well as being anti-static to protect delicate electrical components, the plastic jigs are also much lighter than their traditional counterparts.

World of Warcraft figurines
FigurePrints – Figurine Manufacturer

05/43

Service smaller market segments

Diseconomies of customization can make small market segments difficult to economically service. 3D printing is economical at low-volume, enabling highly customized products to be produced on-demand in batch sizes of one.

FigurePrints has developed software that enables gamers to take a 3D snapshot of their in-game character in any pose and clothing configuration they like. This 3D model is then printed as a full-color miniature figurine and shipped to the customer.

05/44

Increase design-change responsiveness

Many companies have mandatory design freezes due to the CAPEX and time costs of committing to tooling or production setup. 3D printing's digital and toolless workflow enables you to be more responsive to market needs and accepting of design changes.

Olli is an autonomous bus whose chassis is 3D printed in fiber-reinforced plastic. Local Motors says that their use of 3D printing enables them to make rapid design changes to the bus to suit the local requirements of their different customers rather than having a one size fits all policy.

Autonomous shuttle bus
Local Motors – Automotive Manufacturer

06/

Lifecycle sustainability

Domestic appliance spare parts
Whirlpool – Domestic Appliance Manufacturer

06/45

Mitigate obsolescence

Because 3D printing only needs a digital file, spare parts can be manufactured from a digital inventory, allowing economic support of legacy products for longer – potentially indefinitely.

Whirlpool performed a catalog analysis of more than 11,000 SKUs to tackle two key issues: obsolescence and part shortages. 7% of the SKUs were found to be technically and economically advantageous to produce by 3D printing.

06/46

Reduce material waste

In 3D printing, material is added layer by layer rather than being removed; less material is used for manufacturing the same part compared to traditional manufacturing. This means both reduced cost of material and smaller environmental impact.

Near-net forging
Arconic – Metals Engineering And Manufacturing

Using the Ampliforge process, Arconic designs and 3D prints a near-net part, then treats it using an advanced manufacturing process, such as forging. This process reduces material input and production lead times.

06/47

Reduced lifecycle impact of parts

3D printing can have a positive environmental impact, not only during the manufacturing process but also for the whole life of the part. By enabling manufacture of lightweight designs, 3D printing can reduce fuel consumption and emissions.

Airbus utilized 3D printing to produce light-weight cabin partitions that were inspired by bionic design principles. These lighter parts reduced fuel consumption and environmental impact.

Aircraft cabin partition
Airbus – Aeorospace Manufacturer

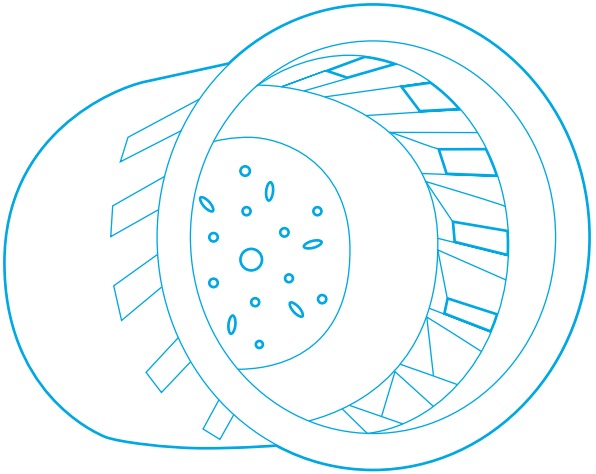
06/48

Increase product efficiency

Thanks to the geometrical freedom offered by 3D printing, fuels can be processed more efficiently. New geometries also allow the use of more sustainable and environmentally friendly fuels. Often this leads to less carbon being released for the same energy output.

This new burner is able to use gaseous and liquid fuels equally effectively. A new, optimized geometry also allows the use of liquid fuels that are classified as difficult to burn, such as fusel oils that are created from the distillation of alcohol.

Multi-fuel micro-burner
Euro-K – Engineering & Design Company



06/49

Design for repair, refurb and remanufacture

Because 3D printing works by adding material on top of a layer, it is well suited for repairing components. Parts can be fixed by adding material where needed; previously disposable parts can become economically repairable.

Gas turbine burner tip
Siemens Energy Sector – Power Generation

Siemens Industrial Turbomachinery was able to significantly reduce the time to repair their gas turbine burner tips. 3D printing also opened up opportunities for cost reductions and improved maintenance processes.

06/50

Convert waste into production materials

Because 3D printing can use recycled material more readily than traditional manufacturing, 3D printing opens up the potential for "circular economies" where waste can be reprocessed into entirely new products, such as recycling 3D printed prototypes back into feedstock for new prototypes.

EFF's idea is a unique offering with filament sourced directly from waste picker groups in developing countries. Filament with the EF mark will be produced ethically on a "fair trade" basis, enabling waste pickers to receive more income from the recyclable materials they collect.

Upcycled 3D printing filament
Ethical Filament Foundation – Non-profit

Now that you've made sense of 3D printing, how do you make it happen?

Now you have an understanding of how 3D printing can drive business value, how do you put ideas into action? Start to build a community of practice in your business and share this booklet to identify opportunities. Then form a group and pilot your first 3D printing initiative.

But if you feel you need help on your journey to 3D printing adoption, we can help you: from identifying the opportunities across your business, to generating and validating solutions, to deploying your enterprise-wide additive strategy.

Interested? Let's talk.
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