3D Printing Report

Executive Summary

3D (three-dimensional) printing is becoming a centerpiece of the new manufacturing revolution, which is impacting every industry from the smallest manufacturers to the world's largest heavy industrial companies. Traditionally parts have been made by either cutting them out of stock materials, extruding them through dies, forging as a hot metal or inserting them into molds to form the desired shapes. With 3D printing, inkjet nozzles eject fluid material in a computer controlled layering process to build up the desired part.

The technology is advancing rapidly and, as a consequence, new opportunities for companies in the traditional supply chains are opening up. The materials used vary across a wide range of polymers, ceramics, composites, biologics and metals. They are often formed into wire, which is wound into reels that are fed into the printers.

Introduction

3D printing, also known as additive manufacturing (AM), refers to processes used to create a three-dimensional object in which layers of material are formed under computer control to create an object. Objects can be of almost any shape or geometry and are produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file. STL is one of the most common file types that 3D printers can read. Thus, unlike material removed from a stock in the conventional machining process, 3D printing or AM builds a three-dimensional object from computer-aided design (CAD) model or AMF file by successively adding material layer by layer.

The term "3D printing" originally referred to a process that deposits a binder material onto a powder bed with inkjet printer heads layer by layer. More recently, the term is being used in popular vernacular to encompass a wider variety of additive manufacturing techniques. United States and global technical standards use the official term additive manufacturing for this broader sense. ISO/ASTM52900-15 defines seven categories of AM processes within its meaning: binder jetting, directed energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination and vat photo polymerization.

By the early 2010s, the terms 3D printing and additive manufacturing evolved senses in which they were alternate umbrella terms for AM technologies, one being used in popular vernacular by consumer-maker communities and the media, and the other used more formally by industrial AM end-use part producers, AM machine manufacturers, and global technical standards organizations. Until recently, the term 3D printing has been associated with machines low-end in price or in capability. Both terms reflect that the technologies share the theme of sequential-layer material addition or joining throughout a 3D work envelope under automated control.

Future Importance

It is becoming more evident each day that 3D printing or AM is a significant underlying technology, which along with robotics and artificial intelligence (AI) is radically reshaping the manufacturing industry. It recalls the seismic events caused by the introduction of the steam engine in the 19th century, which started the first industrial revolution, and the semiconductor in the mid 20th century that transformed electronics. In each case, it started as an under-appreciated discovery, which was not exploited until it had advanced enough that it overtook and eventually made obsolete the previous technology. When you consider the size and reach of manufacturing as the world economy has grown to accommodate over 7 billion people, the potential for a cheaper, more environmentally safe, faster and more precise production method is truly exciting. Just as chemistry was an enormous advancement in the development of industrial production, so too can AM be expected to permeate the next phase of industrialization.

At its heart, AM is about processing material in a new and more precise way using computer technology to make products just as chemical technology has done for several generations. The companies now involved in the supply of chemicals for industry sit in a unique place to identify and exploit the opportunities for this new materials business.

Additive manufacturing, starting with today's infancy period, requires manufacturing firms to be flexible, ever-improving users of all available technologies to remain competitive. Advocates of additive manufacturing also predict that this arc of technological development will counter globalization, as end users will do much of their own manufacturing rather than engage in trade to buy products from other people and corporations. The real integration of the newer additive technologies into commercial production, however, is more a matter of complementing traditional subtractive methods rather than displacing them entirely.

The futurologist Jeremy Rifkin claimed that 3D printing signals the beginning of a third industrial revolution, succeeding the production line assembly that dominated manufacturing starting in the late 19th century. While the First Industrial Revolution introduced machines to replace hand labor, mass production -- using those machines to produce large quantities of standardized products — created an era that came to be known as the Second Industrial Revolution.
Today, more than one hundred years since Ford made his industry-defining statement, 3D printing is making its way forward in the mainstream and is allowing anyone to create customized products on demand at affordable prices. No longer do products need to be the same; we can now tailor products to meet our individual needs at little or no extra cost.

History

Early additive manufacturing equipment and materials were developed in the 1980s

In 1981, Hideo Kodama of Nagoya Municipal Industrial Research Institute invented two additive methods for fabricating three-dimensional plastic models with photo-hardening thermoset polymer, where the area is controlled by a mask pattern or a scanning fiber transmitter.

On July 16, 1984 three Frenchmen filed a patent for the stereo lithography process. The application was abandoned by the French General Electric Company (now Alcatel-Ahlstrom) and CILAS (The Laser Consortium). The claimed reason was "for lack of business perspective”.

Three weeks later in 1984, Chuck Hull of 3D Systems Corporation filed his own patent for a stereo lithography fabrication system, in which layers are added by curing photopolymers with UV light. Hull defined the process as a "system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed," Hull's contribution was the STL (stereo lithography) file format and the digital slicing and infill strategies common to many processes today.

The technology used by most 3D printers to date, especially hobbyist and consumer-oriented models, is a special application of plastic extrusion, developed in 1988 by S. Scott Crump and commercialized by his company Stratasys, which marketed its first machine in 1992.
The term 3D printing originally referred to a powder bed process employing standard and custom inkjet print heads, developed at MIT in 1993 and commercialized by Soligen Technologies, Extrude Hone Corporation, and Z Corporation.

AM processes for metal sintering or melting usually went by their own individual names in the 1980s and 1990s. At the time, all metalworking was done by processes that we now call non-additive but the automated techniques that added metal, which would later be called additive manufacturing, were beginning to challenge that assumption. By the mid-1990s, new techniques for material deposition were developed at Stanford and Carnegie Mellon universities including microcasting and sprayed materials. Sacrificial and support materials had also become more common, enabling new object geometries.

As the various additive processes matured, it became clear that soon metal removal would no longer be the only metalworking process done through a tool or head moving through a 3D work envelope transforming a mass of raw material into a desired shape layer by layer. The 2010s were the first decade in which metal end use parts such as engine brackets and large nuts would be grown (either before or instead of machining) rather than being machined from bar stock or plate. It is still the case that casting, fabrication, stamping, and machining are more prevalent than AM in metalworking, but AM is now beginning to make significant inroads, and it is clear to engineers that much more is to come.

3D/AM Techniques

A large number of additive processes are available. The main differences between processes are in the way layers are deposited to create parts and in the materials that are used. Each method has its own advantages and drawbacks, which is why some companies offer a choice of powder and polymer for the material used to build the object. Others sometimes use standard, off-the-shelf products as the build material to produce a durable prototype.

The main considerations in choosing a machine are generally speed, cost of the 3D printer, of the printed prototype, choice and cost of the materials, and color capabilities. Printers that work directly with metals are generally expensive. However less expensive printers can be used to make a mold, which is then used to make metal parts.

Some methods melt or soften the material to produce the layers. In Fused filament fabrication, also known as Fused Deposition Modeling (FDM), the model or part is produced by extruding small beads or streams of material, which harden immediately to form layers. A filament of thermoplastic, metal wire, or other material is fed into an extrusion nozzle head, which heats the material and turns the flow on and off. FDM is somewhat restricted in the variation of shapes that may be fabricated. Another technique fuses parts of the layer and then moves upward in the working area, adding another layer of granules and repeating the process until the piece has built up. This process uses the unfused media to support overhangs and thin walls in the part being produced, which reduces the need for temporary auxiliary supports for the piece.

Laser sintering techniques include selective laser sintering, with both metals and polymers, and direct metal laser sintering. Selective laser melting does not use sintering for the fusion of powder granules but will completely melt the powder using a high-energy laser to create fully dense materials in a layer-wise method that has mechanical properties similar to those of conventional manufactured metals. Electron beam melting is a similar type of additive manufacturing technology for metal parts (e.g. titanium alloys). EBM manufactures parts by melting metal powder layer by layer with an electron beam in a high vacuum. Another method consists of an inkjet 3D printing system, which creates the model one layer at a time by spreading a layer of powder (plaster, or resins) and printing a binder in the cross-section of the part using an inkjet-like process. With laminated object manufacturing, thin layers are cut to shape and joined together.

Other methods cure liquid materials using different sophisticated technologies, such as stereolithography. Photopolymerization is primarily used in stereolithography to produce a solid part from a liquid. Inkjet printer systems like the Objet PolyJet system spray photopolymer materials onto a build tray in ultra-thin layers (between 16 and 30 μm) until the part is completed. Each photopolymer layer is cured with UV light after it is jetted, producing fully cured models that can be handled and used immediately, without post-curing. Ultra-small features can be made with the 3D micro-fabrication technique used in multiphoton photopolymerisation. Due to the nonlinear nature of photo excitation, the gel is cured to a solid only in the places where the laser was focused while the remaining gel is then washed away. Feature sizes of under 100 nm are easily produced, as well as complex structures with moving and interlocked parts. Yet another approach uses a synthetic resin that is solidified using LEDs In Mask-image-projection-based stereolithography, a 3D digital model is sliced by a set of horizontal planes. Each slice is converted into a two-dimensional mask image. The mask image is then projected onto a photocurable liquid resin surface and light is projected onto the resin to cure it in the shape of the layer. Continuous liquid interface production begins with a pool of liquid photopolymer resin. Part of the pool bottom is transparent to ultraviolet light (the "window"), which causes the resin to solidify. The object rises slowly enough to allow resin to flow under and maintain contact with the bottom of the object. In powder-fed directed-energy deposition, a high-power laser is used to melt metal powder supplied to the focus of the laser beam. The powder fed directed energy process is similar to Selective Laser Sintering, but the metal powder is applied only where material is being added to the part at that moment.

Applications

As of October 2012, additive manufacturing systems were on the market that ranged from $2,000 to $500,000 in price and were employed in industries including aerospace, architecture, automotive, defense, and medical replacements, among many others. For example, General Electric uses the high-end model to build parts for turbines. Many of these systems are used for rapid prototyping, before mass production methods are employed. Higher education has proven to be a major buyer of desktop and professional 3D printers, which industry experts generally view as a positive indicator. Libraries around the world have also become locations to house smaller 3D printers for educational and community access. Several projects and companies are making efforts to develop affordable 3D printers for home desktop use. Much of this work has been driven by and targeted at DIY/Maker /enthusiast/early adopter communities, with additional ties to the academic and hacker communities.

The earliest application of additive manufacturing was on the toolroom end of the manufacturing spectrum. For example, rapid prototyping was one of the earliest additive variants, and its mission was to reduce the lead time and cost of developing prototypes of new parts and devices, which was earlier only done with subtractive toolroom methods such as CNC milling, turning, and precision grinding. In the 2010s, additive manufacturing entered production to a much greater extent.

Additive manufacturing of food is being developed by squeezing out food, layer by layer, into three-dimensional objects. A large variety of foods are appropriate candidates, such as chocolate and candy, and flat foods such as crackers, pasta and pizza.

3D printing has entered the world of clothing, with fashion designers experimenting with 3D-printed bikinis, shoes, and dresses. In commercial production Nike is using 3D printing to prototype and manufacture the 2012 Vapor Laser Talon football shoe for players of American football, and New Balance is 3D manufacturing custom-fit shoes for athletes. 3D printing has come to the point where companies are printing consumer grade eyewear with on-demand custom fit and styling (although they cannot print the lenses). On-demand customization of glasses is possible with rapid prototyping.

In cars, trucks, and aircraft, AM is beginning to transform both (1) unibody and fuselage design and production and (2) power train design and production. For example:

- In early 2014, Swedish supercar manufacturer Koenigsegg announced the One:1, a supercar that utilizes many components that were 3D printed. Urbee is the name of the first car in the world car mounted using the technology 3D printing (its bodywork and car windows were "printed").
- In 2014, Local Motors debuted Strati, a functioning vehicle that was entirely 3D printed using ABS plastic and carbon fiber, except the power train. In May 2015 Airbus announced that its new Airbus A350 XWB included over 1000 components manufactured by 3D printing.
- In 2015, a Royal Air Force Eurofighter Typhoon fighter jet flew with printed parts. The United States Air Force has begun to work with 3D printers, and the Israeli Air Force has also purchased a 3D printer to print spare parts.
- In 2017, GE Aviation revealed that it had used design for additive manufacturing to create a helicopter engine with 16 parts instead of 900, with great potential impact on reducing the complexity of supply chains.

The US Navy is planning to place 3D printers on board its ships so they can make parts at sea, thereby reducing inventory and weight on board. Merchant ships and fishing vessels will follow suit. Remote military bases on land and in the air can also take advantage of this capability.

In the space and missile defense market, a team of Lockheed Martin engineers successfully tested a six-inch rocket with 3D printed propellant grain. They are also building spacecraft fuel tanks and other large parts with AM.

AM's impact on firearms involves two dimensions: new manufacturing methods for established companies, and new possibilities for the making of do-it-yourself firearms. In 2012, the US-based group Defense Distributed disclosed plans to design a working plastic 3D printed firearm "that could be downloaded and reproduced by anybody with a 3D printer." After Defense Distributed released their plans, questions were raised regarding the effects that 3D printing and widespread consumer-level CNC machining may have on gun control effectiveness.

Surgical uses of 3D printing-centric therapies have a history beginning in the mid-1990s with anatomical modeling for bony reconstructive surgery planning. Patient-matched implants were a natural extension of this work, leading to truly personalized implants that fit one unique individual. Virtual planning of surgery and guidance using 3D printed, personalized instruments have been applied to many areas of surgery including total joint replacement and craniomaxillofacial reconstruction with great success. One example of this is the bioresorbable tracheal splint to treat newborns with tracheobronchomalacia developed at the University of Michigan. The use of additive manufacturing for serialized production of orthopedic implants (metals) is also increasing due to the ability to efficiently create porous surface structures that facilitate osseointegration.

The hearing aid and dental industries are expected to be the biggest area of future development using the custom 3D printing technology. In March 2014, surgeons in Swansea used 3D printed parts to rebuild the face of a motorcyclist who had been seriously injured in a road accident. As of 2012, 3D bio-printing technology has been studied by biotechnology firms and academia for possible use in tissue engineering applications in which organs and body parts are built using inkjet techniques. In this process, layers of living cells are deposited onto a gel medium or sugar matrix and slowly built up to form three-dimensional structures including vascular systems. Recently, a heart-on-chip has been created which matches properties of cells. The pharmaceutical industry is in the early stages of 3D printing applications.

The construction industry is also engaged with AM. A University of Southern California professor has developed a 3D printer that has potential to revolutionize construction. Professor Behrokh Khoshnevis invented technology called Contour Crafting; a massive printer that he says has the capability of building a 2,500-square foot custom home in 20 hours. The 3D printer lays concrete and interlocking steel bars to frame the structure and can build a multi-story home equipped with plumbing, electrical work and tile flooring.
Once the printer has laid the bones of the project, human handiwork is still required for work such as installing windows, cabinets and more.

Architects around the globe are racing to build the world's first 3D printed houses — a breakthrough with profound implications for housing affordability and customization. In China, a company named Winsun this year said it built 10 3D printed houses in just one day. The reported cost for each: just $5,000. In Amsterdam, a team of architects has started construction of the 3D Print Canal House, using bio-based, renewable materials. The site is both construction site and public museum; Hedwig Heinsman, co-founder of DUS architects. The team behind the project says that in addition to being eco-friendly, "The main goal, I think, is really to deliver custom-made architecture."
3D printers build structures layer by layer. A three-year U.S. Army program has resulted in 3D printed barracks, also known as a B-Hut. The program, called "Automated Construction of Expeditionary Structures," or ACES, used 3D printing to create semi-permanent structures from concrete made with locally available materials. The revolution in 3D printed housing is well underway.

As of 2012, domestic 3D printing was mainly practiced by hobbyists and enthusiasts. However, little was used for practical household applications, for example, ornamental objects. Some practical examples include a working clock and gears printed for home woodworking machines among other purposes. Web sites associated with home 3D printing tended to include backscratchers, coat hooks, doorknobs, etc.

3D printing, and open source 3D printers in particular, are the latest technology making inroads into the classroom. Some authors have claimed that 3D printers offer an unprecedented "revolution" in STEM education. The evidence for such claims comes from both the low cost ability for rapid prototyping in the classroom by students, but also the fabrication of low-cost high-quality scientific equipment from open hardware designs forming open-source labs. Future applications for 3D printing might include creating open-source scientific equipment.

In the last several years 3D printing has been intensively used by in the cultural heritage field for preservation, restoration and dissemination purposes. Many Europeans and North American Museums have purchased 3D printers and actively recreate missing pieces of their relics. The Metropolitan Museum of Art and the British Museum have started using their 3D printers to create museum souvenirs that are available in the museum shops. Other museums, like the National Museum of Military History and Varna Historical Museum, have gone further and sell through the online platform Threeding (see p.19) digital models of their artifacts, created using Artec 3D scanners, in 3D printing friendly file format, which everyone can 3D print at home.

3D printed soft actuators is a growing application of 3D printing technology, which has found its place in the 3D printing applications. These soft actuators are being developed to deal with soft structures and organs especially in biomedical sectors and where the interaction between human and robot is inevitable. The majority of the existing soft actuators are fabricated by conventional methods that require manual fabrication of devices, post processing/assembly, and lengthy iterations until maturity in the fabrication is achieved. To avoid the tedious and time-consuming aspects of the current fabrication processes, researchers are exploring an appropriate manufacturing approach for effective fabrication of soft actuators. Thus, 3D printed soft actuators are introduced to revolutionize the design and fabrication of soft actuators with custom geometrical, functional, and control properties in a faster and inexpensive approach. They also enable incorporation of all actuator components into a single structure eliminating the need to use external joints, adhesives, and fasteners.

Market

The 3D printing market globally was $13.2 billion in 2016 according to IDC, but it is estimated to be worth $32.78 billion by 2023 at a CAGR (compound annual growth rate) of 25.76% between 2017 and 2023, according to one market research report. The growth is attributed to the factors such as the ease of development of customized products, ability to reduce overall manufacturing costs, and government investments in the 3D printing projects for the development and deployment of the technology. There are several other forecasts by various parties that show lesser numbers, but most have proved to underestimate actual progress to date. PwC estimates 67% of manufacturers are already using 3D printing. Siemens predicts that 3D printing will become 50% cheaper and up to 400% faster in the next five years.

Segments

The global market for 3D printing is segmented based on component, application, and geography.

By Component

- Technology
  - Stereolithography
  - Selective laser sintering
  - Electron beam melting
  - Fused deposition modeling (FDM)
  - Laminated object manufacturing
  - Others
- Material
  - Polymers
  - Metals & Alloys
  - Ceramics
  - Others
- Services

By Application

- Consumer products
- Aerospace
- Industrial
- Automotive
- Healthcare
- Defense
- Education & research
- Others

By Geography

- North America
- Europe
- Asia Pacific
- LAMEA

Asia-Pacific region is expected to be the fastest growing market for 3D printing. This growth in 3D printing market is likely to take place due to the growing applications of additive manufacturing in healthcare, automobile and consumer industry. Rather than using conventional production techniques, additive printing is used for manufacturing automobile, consumer and healthcare products, such as mobile phones, toys, prosthetic implants, medical devices, engine parts, and others.

North America held the largest share of the market in 2016, followed by Europe and Asia Pacific for 3D printing market. The growth of the market in North America was driven by strong demand from aerospace and defense, healthcare, education, and consumer products industries. Additionally, the strong government support and presence of key manufacturers are further expected to add to the growth of the market in this region. The US held the largest share of the North American 3D printing market, but Asia-Pacific region is expected to be the fastest growing market for 3D printing.

The factors driving this market are reduction of errors, high degree of accuracy, efficient use of raw materials, ability to build customized products, simultaneous use of multiple materials for printing, efficient use of production time and financials, and competency over traditional techniques among others. On the contrary, high production cost to individual users, expensive 3D printing software, lack of channel partner assistance, and scarcity of skilled labors are some of the restraints for the global 3D printing industry.

Automotive industry was the largest revenue-generating segment in the Asia-Pacific market in 2014 with the highest revenue. Consumer products industry would be the largest revenue-generating segment by 2020. Major factors contributing for this growth are the increasing demand of automobile and consumer products in Asia-Pacific market. This surge in demand for these products has developed due to the change in consumer lifestyle and increase in the spending capacity. The defense industry is expected to grow with higher CAGR from 2015 to 2020.

Consumer products industry has been the highest revenue-generating segment and is expected to remain the highest generating segment during the forecast period. The market for the desktop segment is expected to grow at a higher CAGR between 2017 and 2023. Product innovation, customization, reduction in the cost of desktop 3D printers, and the introduction of new materials are the major drivers for the growth of the market. Desktop 3D printers are now being used by both hobbyists and professionals to develop functional parts, especially for consumer products, owing to the availability of advanced 3D printing technologies at an affordable cost.

Plastic and metal segments occupied the largest and second-largest shares, respectively, of the global 3D printing material market. However, the market for other materials is expected to grow at the highest CAGR during the forecast period, driven by the increasing demand for biomaterials used in the healthcare vertical and certain specialized materials (such as laywood, wax, paper) in emerging applications. 3D printing has started penetrating into new verticals, such as electronics, biomedical, pharmaceuticals, and construction. Hence, with the growing demand, the rate of consumption of the mentioned printing materials is expected to grow at a significant rate in the next five years.

The aerospace and defense vertical segments held the largest share of the global 3D printing market in 2016. In the aerospace industry, 3D printing is mainly used to manufacture critical parts of airplanes or for low-scale production associated with the components demanding high performance and quality. The aerospace industry offers tremendous opportunity for 3D printing technologies and holds a promising potential for the market in the coming future. However, the markets for the emerging verticals, namely, food and culinary, printed electronics, education, and energy are expected to grow at the significant CAGR during the nearest future. The U.S. Postal Service (USPS) estimates turning postal processing centers into 3D printing hubs could generate an incremental $646M in commercial package revenue.

Market Players

To give an approximation of the number of companies in the market, a year old survey included 51 industrial system manufacturers, 98 service providers, 15 third-party material producers, and many manufacturers of low-cost desktop 3D printers.

Major companies in the global 3D printing market:
Stratasys Ltd. (US)
3D Systems Corporation (US)
EOS GmbH (Germany)
Materialise NV (Belgium)
SLM Solutions Group AG (Germany)
Arcam AB (Sweden)
Concept Laser GmbH (Germany)
The ExOne Company (US)
Voxeljet AG (Germany)
Proto Labs, Inc. (US)
Optomec Inc. (US)
ARC Group Worldwide, Inc. (US)
GROUPE GORGÉ (France)
EnvisionTEC GmbH (Germany)
Mcor Technologies Ltd. (Ireland)
Beijing Tiertime Technology Co. Ltd. (China)
Renishaw plc (UK)
XYZprinting (Taiwan)
Ultimaker BV (Netherlands)
Koninklijke DSM N.V. (Netherlands)
Höganäs AB (Sweden)
taulman3D, LLC (US)
Nano Dimension (Israel)
Carbon Inc. (US)
Markforged, Inc. (US)
Cookson Precious Metals Ltd. (UK).
HP Inc. (US)
Autodesk, Inc. (US)
Organavo Holdings, Inc. (US)
Ponoko Limited (NZ, US)
Voxeljet AG (Germany)

Materials Suppliers

1. Polymers/Plastics

Advanced RP, Inc.	Suwanee, GA
Arkema Inc.	King of Prussia, PA
Avante Technology, LLC	Cheyenne, WY
BASF SE	Ludwigshafen,
BigRep GmbH	GneisenaustrasBe
Carbon	Redwood City, CA
Chemson Group	Arnoldstein,
Cideas Inc.	Cary, IL
DSM Somos	Elgin, IL
Elix Polymers Americas LLC	Weston, FL
Essentium Materials LLC	College Station, TX
Farsoon Americas	Blue Ridge, GA
HK3D Solutions	RUGBY, UK
Plural Additive Mfg	Lake Oswego, OR
Roboze	Bari, Italy
Sabic Innovative Plastics	Wixom, MI
Solidscape Inc.	Merrimack, NH
TriMech	Glen Allen, VA
XYZprinting, Inc.	New Taipei City, Taiwan

2. Metals

Carpenter Technology Corporation	Reading, PA
Desktop Metal	Burlington, MA
Elementum 3D	Erie, CO
Farsoon Americas	Blue Ridge, GA
GE Additive Group	West Chester, OH
GKN Global	Redditch, UK
Hoganas AB	Höganäs, Sweden
LPW Technology Ltd.	Runcorn, UK
NanoSteel	Providence, RI
Praxair, Inc.	Danbury, CT
Sandvik Osprey Ltd	Neath, UK

3. Ceramics

Elementum 3D	Erie, CO

4. Composites

Arkema Inc.	King of Prussia, PA
HK3D Solutions	RUGBY, UK

3D printing marketplaces

The consumer market for 3D printers has grown tremendously over the past several years. Consumer 3D printers allow households to produce goods at home. Since most people are not CAD professionals, they have to use third party designs. 3D printing marketplaces are the largest sources of 3D printable designs and it is believed that they will dominate on the market of 3D printable objects.

3D printing marketplaces are a combination of file sharing websites, with or without a built in e-commerce capability. Designers upload suitable files for 3D printing whilst other users buy or freely download the uploaded files for printing. The marketplaces facilitate the account management, infrastructure, server resources and guarantees safe settlement of payments (e-commerce). Some of the marketplaces also offer additional services such as 3D printing on demand, location of commercial 3D print shops, associated software for model rendering and dynamic viewing of items using packages such as Sketchfab. The most widely used 3D printable file formats are STL, WRL and VML.

There are different varieties of 3D printing marketplaces. Some of them like Thingiverse are dedicated to free sharing of 3D printable files. Others, like Shapeways offer a 3D printing service for objects which have been provided for sale by designers. MyMiniFactory offers a combination of these two: their main activity being the free sharing or 3D printable files, they also offer print-on-demand and design-on-demand services. Another category are websites exemplified by Threeding and 3DPrintWise. These offer free and commercial exchange of digital 3D printable files for use on 3D printers but do not directly include 3D printing services themselves. These marketplaces do, however, offer integration to databases of 3D printers provided by third parties such as MakeXYZ and 3D Hubs. These latter two resources each contain geo-location services to several thousands of registered 3D printers. The two largest personal 3D printers manufacturers Makerbot (part of Stratasys, Ltd) and Cubify (subsidiary of 3D Systems) offer their own file repositories for sharing, respectively Thingiverse and Cubify Store. For professional 3D printing needs there are platforms, which offer a reverse-bid style auction interface, an integrated escrow payment system and many features specifically tailored for B2B transactions.

3D printing marketplace examples:
Shapeways is a New York based 3D printing marketplace and an on-demand provider of 3D printing services. Designers upload design files, and users can place orders with Shapeways to produce the 3D printed item, using industrial printers, from a variety of materials including metals, plastics, and ceramics.

Thingiverse offers free sharing of user-created digital designs for 3D printing. The website is owned by Makerbot (a subsidiary of Stratasys). Numerous technical projects use Thingiverse as a repository for shared innovation and dissemination of source materials to the public.

Treatstock is a 3D printing network in which designers and print services can meet to produce 3D printed products.

MyMiniFactory offers free sharing of 3D printable files that have been previously tested on 3D printers. The website is property of iMakr and also offers a free streaming service for 3D designers. They also provide print-on-demand and design-on-demand services.

Threeding is an Eastern European startup that offers free and paid 3D printable content. A significant portion of the 3D objects available at Threeding.com are digital copies of historical artifacts.