# HOW **BD PRINTING** WILL INPACT SOCIETY

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### IMPORTANT EVENTS IN THE DEVELOPMENT OF **3D PRINTING TECHNOLOGY**

#### 1983

Engineer Charles Hull invents the first 3D printing method, called stereolithography (SLA). He later founds the company 3D Systems.

#### 2005

Adrian Bowyer, a British engineer, mathematician, and professor, begins the RepRap project to make low-cost 3D printers by 3D printing.

### 1987

3D Systems releases its first commercial 3D printer, the SLA-1.

### 1999

Scientists 3D print a bladder using a patient's cells. A 3D printed scaffold is used to support the organs.

#### 2008

A prosthetic leg is created using 3D printer technology.

### 1980

1990

### 1995

### 2000

2008

#### 1986

Carl Deckard of the University of Texas develops selective laser sintering (SLS) 3D printing technology.

#### 1991

Stratasys makes the first fused deposition modeling (FDM) machine. The 3D printing machine uses an extruder to deposit layers of plastic on a print bed.

#### 2000

Z Corp makes the first multicolor 3D printer.

#### 2017 2014 Apis Cor, a startup company The Portal 3D printer by a company that 3D prints buildings. called Made In Space prints the first constructs its first house near 3D printed part in space aboard the Moscow, Russia, The one floor, International Space Station. 400-square-foot (122 sq m) house is built in just 24 hours. 2009 2015 MakerBot Industries is founded A complete jet engine by Bre Pettis, Zach Smith, and is 3D printed by Adam Mayer in New York City. researchers at Monash The company soon develops the University in Australia. first 3D printers for consumers. 2009 2014 2017 2011 2015 2013 2011 Defense Distributed The first 3D printed 2017 produces the first car prototype, called US aerospace 3D printed gun. Urbee, is printed by manufacturer

### 2012

Kor Ecologic.

LaverWise of Holland makes the first 3D printed jaw. It is implanted in a patient who lost part of her jaw to a bone infection.

Rocket Lab successfully test launches its 3D printed Electron rocket from New Zealand. The Electron's engine took only 24 hours to print.

# How Does 3D Printing Work?

Before 3D printing can begin, a person must use modeling software to make a three-dimensional design on a computer. Additional software slices the design into super-thin layers. The instructions for the sliced design are then sent to a 3D printer. Instead of ink or toner, 3D printers use raw materials such as plastic or metal. The material is heated in the 3D printer until it is **molten**. Most 3D printers are fitted with nozzles or jets that deposit the molten material in a thin layer on a building platform. This layer forms one slice of the three-dimensional computer design. Once on the platform, the molten layer cools and hardens. The printer continues to add more layers of material, following the design created on the computer. It builds the object one slice at a time until the object is complete.

### THE BEGINNING OF CAD AND 3D PRINTING

3D printing, also known as additive manufacturing or direct digital manufacturing, is not a new technology. In fact, manufacturers have been using 3D printing to produce parts for automobiles, airplanes, and other machines for about three decades. Corporations frequently use 3D printing to make **prototype** models for testing products before those products are manufactured in mass quantities.

3D printing technology would not be possible without computer-aided design (CAD). CAD is the use of computers and software to make two-dimensional and three-dimensional models. Before CAD, designs were created using manual drafting. Drafting designs by hand was a time-consuming process. Engineers drew out detailed designs on paper. Correcting mistakes and making changes added time and cost to a project. In contrast, using CAD is faster and more flexible. Working on a computer means CAD designs are easy

to modify if project materials or client preferences change. Also, CAD plans can be stored, altered, and used for different projects. Because they are computerized, CAD designs are quickly shared with others.

Without CAD, 3D printers would be worthless. As computer scientist and futurist Christopher Barnatt explains, "We would indeed not be at the start of a

### WORDS IN CONTEXT

**molten** Liquefied by heat.

#### prototype

An initial model of something which is used to develop something such as a machine or part.

3D Printing Revolution were it not at least in part for the efforts of those who have coded the computer aided design (CAD) applications required to construct 3D models, as well as the control and post-processing software required to communicate digital designs with 3D printers."<sup>7</sup>

In 1963, computer scientist Ivan Sutherland created a CAD program called Sketchpad. Sketchpad allowed users to draw designs on a computer screen with a light pen. Computer users could manipulate designs and then store them on the computer's memory. With CAD programs such as Sketchpad, engineers crafted 2D technical designs. By the late 1960s, CAD systems had evolved so users could create computerized 3D models. Today's popular CAD software includes programs such as Blender, SketchUp,



Before something can be 3D printed, it must be designed on a computer using a CAD program. Some designs created with CAD programs are shared online.

SolidWorks, and AutoCAD. The programs are used by both hobbyists and professionals.

### THE FIRST 3D PRINTER

In 1983, American engineer Charles "Chuck" Hull invented the first 3D printer. Hull experimented with an ultraviolet laser beam and a tank of liquid photopolymer. Photopolymers are light-sensitive plastics. They harden when exposed to light, such as the light from a laser beam. Hull's machine projected a laser beam from above, down onto a vat of photopolymer. The first 3D object Hull made was a small cup. The laser beam traced out a single layer of liquid photopolymer into the shape of the cup. The thin layer solidified. The solid layer was then covered by another layer of liquid photopolymer. The laser then traced out the shape of the cup again, creating a second solid layer. Hull repeated the process, building layer upon layer until the whole cup was printed. The process, known as stereolithography (SLA), is the most commonly used 3D printing technology that involves photopolymers. In 1986, Hull founded 3D Systems Corporation, now a leader in 3D printing. The company began selling its first commercial 3D printer, the SLA-1, in 1987. This 3D printer was used to construct detailed prototypes for industrial parts.

### SUBTRACTIVE MANUFACTURING

Traditional mass manufacturing techniques are subtractive. They start with raw materials, such as metals, that must move through a series of steps. The raw materials may be milled, **machined**, and drilled. Some require folding and polishing.

During each step, some of the raw material is subtracted from the product until a finished product is formed. Traditional manufacturing also uses molds or dies to cut and shape materials. Molten metal or plastic is poured or injected into

### WORDS IN CONTEXT

### machining

To make with a machine or to operate on with a machine.

molds to produce the desired object. After it is formed in the mold, the object must be trimmed and polished before it is ready for use. These traditional methods of making objects have been common for centuries, since the Industrial Revolution. Subtractive manufacturing platform, depositing the next layer on top of the first. The process is repeated until the entire 3D object has been formed. Sometimes plastic supports are needed to prevent parts of the object from bending before the printing is done. Once the object is formed, the supports can be removed.

Some FDM 3D printers can be modified to extrude other materials, such as concrete, chocolate, or Laywood, a composite wood material. FDM produces many items, including airplane parts, helmets, pens, and cases for electronics. Lipson describes the versatility of FDM: "Any raw material that can be squeezed through a nozzle can be 3D printed. Frosting, cheese, and cookie dough are popular raw material. . . . Another emerging printing material is 'living ink' [a blend of living cells] that medical researchers use for bioprinting research."<sup>11</sup>

### **POWDER BED FUSION**

The ASTM's second category is powder bed fusion. Powder bed fusion encompasses a number of techniques that use a laser or electron beam to melt powdered raw materials. Common materials

### WORDS IN CONTEXT

### sinter

To make a powdered material form a solid mass by heating it.

include powdered metals, plastics, glass, and ceramics. A directed, high-energy beam **sinters** or fuses the particles, forming a solid. Selective laser sintering (SLS) was the first commercialized powder bed fusion method. SLS

was invented in 1986. It was the brainchild of Carl Deckard, then a student at the University of Texas at Austin, and his professor Joseph Beaman. In a 2015 interview, Beaman described their goal: "To make the first one of something takes you six months, so why does it have to be all that slow? Essentially what we wanted to do was go right

# CONTOUR CRAFTING

Behrokh Khoshnevis is an engineering professor at the University of Southern California and also the director of the Center for Rapid Automated Fabrication Technologies (CRAFT). He is credited with developing the 3D printing technology known as contour crafting. This 3D printing technology uses extrusion to construct full-size buildings using concrete. The specialized 3D printers are robotic and have a reach between 24 feet (7.3 m) and 40 feet (12.2 m). The printer moves over the construction site on a track system. The nozzle follows a computerized outline of the building's design. As it moves, it deposits a five-inch (13 cm) layer of concrete. About an hour is needed to allow the concrete to harden before another layer can be poured. An adhesive in the building mixture binds the particles of concrete together. According to Khoshnevis, the technology can build a single home or several houses, each with a different design, in a single run. Doka Group, an Austrian concrete formwork company, has invested in Khoshnevis' Contour Crafting Corporation. A spokesperson for Doka, Maria Tagwerker-Sturm, says Doka is especially drawn to the 3D printing method because of its speed and safety. "People can move into a new house only two to five days after the beginning of construction. This technology saves cost, time . . . and adds a lot of occupational safety as it is an automated process." Other applications for contour crafting technology include constructing homes for disaster relief and low-income housing. One exciting concept currently under exploration is using contour construction to build homes on the moon and Mars.

Quoted in Michael Petch, "Contour Crafting Begins Manufacture of 3D Printer for Construction," *3D Printing Industry*, June 2017. www.3dprintingindustry.com.

from a computer to the object by hitting 'hard copy.'" He added, "Selective Laser Sintering is . . . a way of making very complex objects very fast . . . now I could make things I had never made before."<sup>12</sup>

During SLS, a leveling roller spreads a thin layer of powdered plastic, ceramic, or glass across the printer's powder bed, a platform that holds the powdered material. Next, the beam of energy traces

### **Source Notes**

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