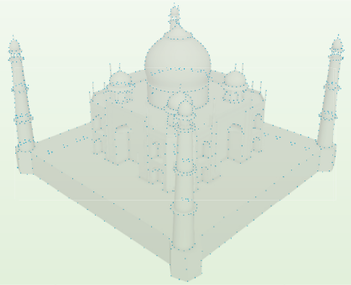
How Printers Create in 3D

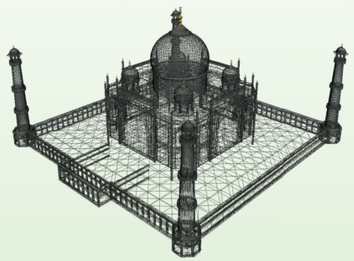
OLD JOKE: A man tells a sculptor of horses, "Your work is so lifelike. How do you do it?" "Simple," the sculptor replies, "I start with a big rock and chip away anything that doesn't look like a horse."

For centuries that's the way we've made most our stuff—from toys to turbines. We started with a piece of metal, stone, or wood and milled, ground, or carved it to become whatever it was we needed. These methods are all **subtractive processes**. Now that is changing with the increased use of **additive manufacturing**—or more commonly, **3D-printing**.

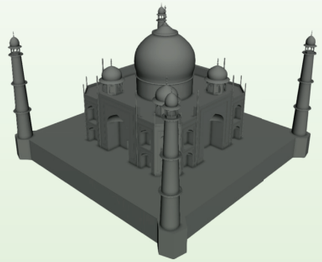
There are many varieties of 3D-printing, but they all are additive. Some material—a liquid, a powder, bits of plastic or metal—are added together until they take on the size and shape of whatever a 3D printer is creating. The result is a real object you can hold in your hand—or use to replace a scarce part, display as sculpture, wear as jewelry, or replace a bone. .



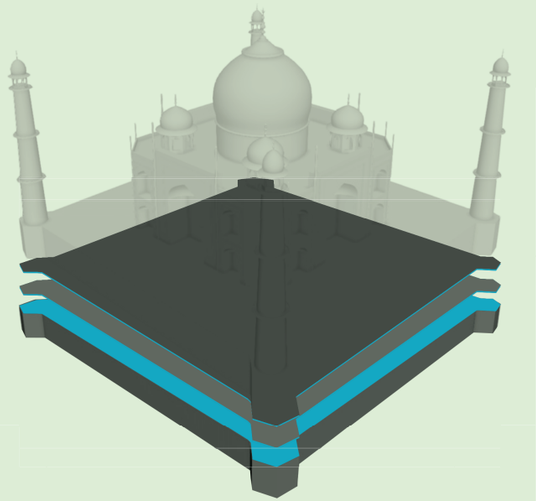
1. All 3D printers have in common that their work starts with a **computer-aided design (CAD)** that describes in mathematical terms the size and shape of an object. It begins with points in a three-dimensional space along the X (width), Y (height), and Z (depth) axes. Located at the intersection of three or more surfaces, the points define the object.



2. CAD adds lines between certain points to create a **wireframe** vision of what the object will look like if it consisted only of corners and intersections. Although the object may appear to have some curved surfaces, they are actually constructed from myriad flat triangles, the simplest and most versatile shape for constructing three-dimensional objects. The smaller the triangles, the more realistic the design appears.

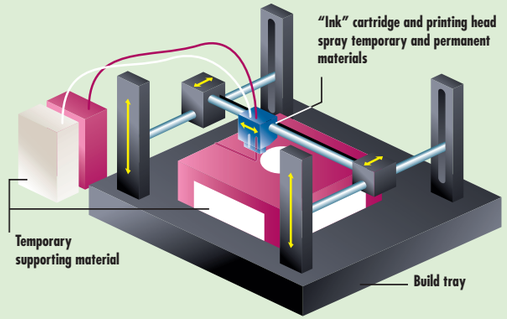


3. The computer can, in effect, paint those surfaces, finally making the object recognizable by humans. We see only the "painted" sides of the object facing us. Other planes are hidden behind those opaque surfaces, although the software lets you tilt, turn, and flip the image so that you can view it from all angles.



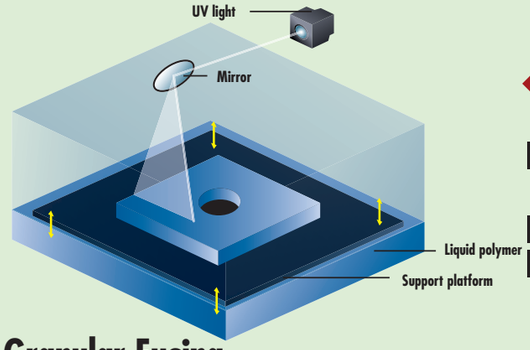
4. For 3D printing, CAD software transforms the design into virtual horizontal cross-sections typically 0.15mm to 0.5mm thin. The design is saved as an **STL formatted file** that a variety of 3D printers read. Free STL files are widely available on the Internet. Some printing enthusiasts use the Kinect game device to scan objects and gather the data a 3D printer would use to re-create the objects. In any case, that's where printing methods diverge.

Inkjet 3D Printing



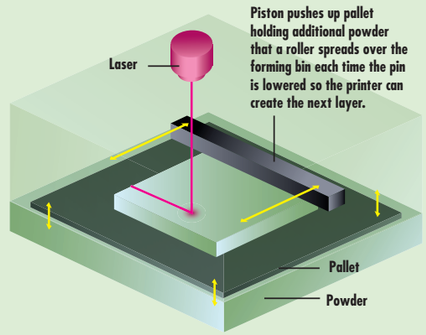
1. **Inkjet 3D printing** should be familiar to anyone with an inkjet. The principle is the same, except that instead of liquid ink, the 3D printing cartridge contains a powder, such as plaster or resin, that is sprayed through a system of jets that pass over the construction area.
2. An ultraviolet light causes newly sprayed material to immediately harden and bond with the underlying layer. The printer may add wax or a polymer to the layers to strengthen them.
3. By using colored powders in a **multi-tank cartridge**, it's possible to make a full-color object. Multi-cartridges also can deposit a material that serves as a temporary support. Chemicals dissolve it from the finished object to create voids.

Stereolithography

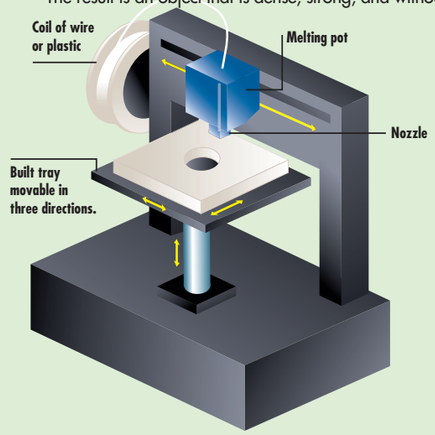


1. In a dark room, a **stereolithographic** printer positions a platform in a vat of liquid polymer so that the platform is just below the surface (typically 0.2mm).
2. A **digital light processor** focuses a sharp-edged pattern of bright light on the liquid above the platform. The light pattern matches the shape of the first layer of the object being printed.
3. The light causes the polymer to harden in the shape of the light's pattern.
4. The printer moves the platform down the distance of one layer, and the light again hardens another layer of polymer, which binds to the first layer. The process repeats itself until the liquid can be drained from the vat, leaving the solid model.

Granular Fusing



1. Working with materials as varied as candy and titanium, **granular fusing** uses a beam of heat to **sinter**, or fuse, thin layers from a powdered form of the material being shaped. As with stereolithography, a platform lowers with each new layer to leave free the space needed for the next layer.
2. **Selective sintering** uses a laser to bind the powder, typically ceramic or plastic, without melting it. The laser sinters the powder, heating it only enough to cause the atoms in each granule to break free and intermingle with atoms from adjacent granules.
3. **Electron beam melting** works with metal powder in a vacuum. The electron beam melts the powder layer by layer, one layer into the previous one. The result is an object that is dense, strong, and without voids.



Molten Polymer Deposition

1. The printer feeds plastic, ceramic, or filament from a coil to an extrusion nozzle, which heats the filament to about 500°F. to melt it.
2. A computer controls **stepper or servo motors** that can move the nozzle horizontally and vertically with extreme precision. The computer also tells the nozzle when to turn on and off the flow of molten material.
3. The extruded material hardens immediately after leaving the nozzle, forming one of the object's layers as the printer moves the nozzle in the pattern needed to create that layer. The size of the excretion can vary from that delicate enough for jewelry to thick enough to fabricate furniture. When one layer is done, the printer deposits new material on the previous layer to create another section.