

The Special Synergy of 3D Printing and Assistive Technology

By Ken Hackbarth, Volksswitch.org

Assistive technology (AT) devices have always been expensive, functionally conservative, and aesthetically bland. This is the unavoidable result of the selection of traditional mass production manufacturing methods by companies trying to serve a market that is small in size and incredibly diverse in its needs. The hallmarks of mass production are: huge set-up costs and small per-item costs. Any changes in design require significant investment, up front, that must be cost justified. The market for assistive technology, on the other hand, is small and it has no “sweet-spot” – every individual with a disability is an amalgam of unique needs and desires. AT users are required to accommodate their device rather than the other way around. 3D printing promises to turn this story on its head. 3D printing has little, or no setup cost and each item produced can be entirely unique. Best of all, high-quality 3D printers are very affordable, and the material used to make functional products is almost free. 3D printing can put highly customized and personalized assistive devices in the hands of individuals at almost no cost. A device that has been highly customized and personalized is much less likely to be abandoned than a device that requires the user to adapt to its form, appearance and behavior.

“3D Printing” ↔ “Rapid Prototyping” ↔ “Additive Manufacturing”

The term 3D Printing is often used interchangeably with the terms Rapid Prototyping and Additive Manufacturing. While these terms have very much in common, they are not really equivalent. Though 3D printing can be used to quickly fabricate prototype devices or parts, it’s just as capable of producing final products for use. In fact, some products with very complex geometries can only be produced with 3D printing.

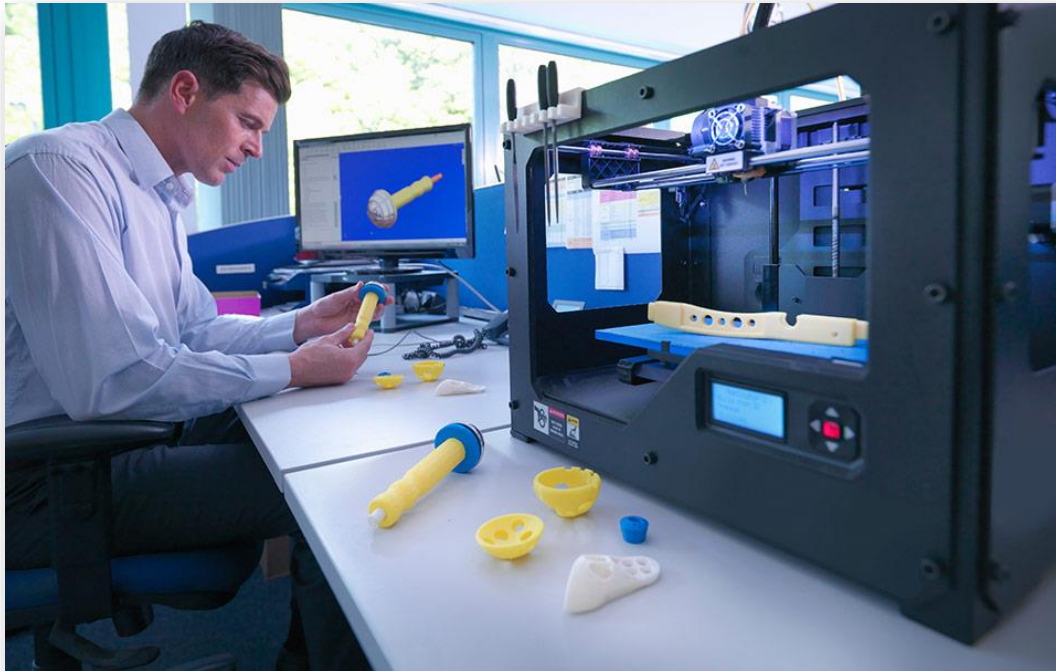
Additive Manufacturing

3D printing is most closely aligned with the concept of additive manufacturing - the process of joining materials to make objects, usually layer upon layer. While all 3D printing techniques create 3 dimensional objects by constructing them one layer at a time, there are many examples of products that are constructed by adding raw materials together and don’t involve 3D printing at all. A simple example is knitting. Whether by hand or by machine, the raw material, in this case yarn, is woven together row by row to create a final product.

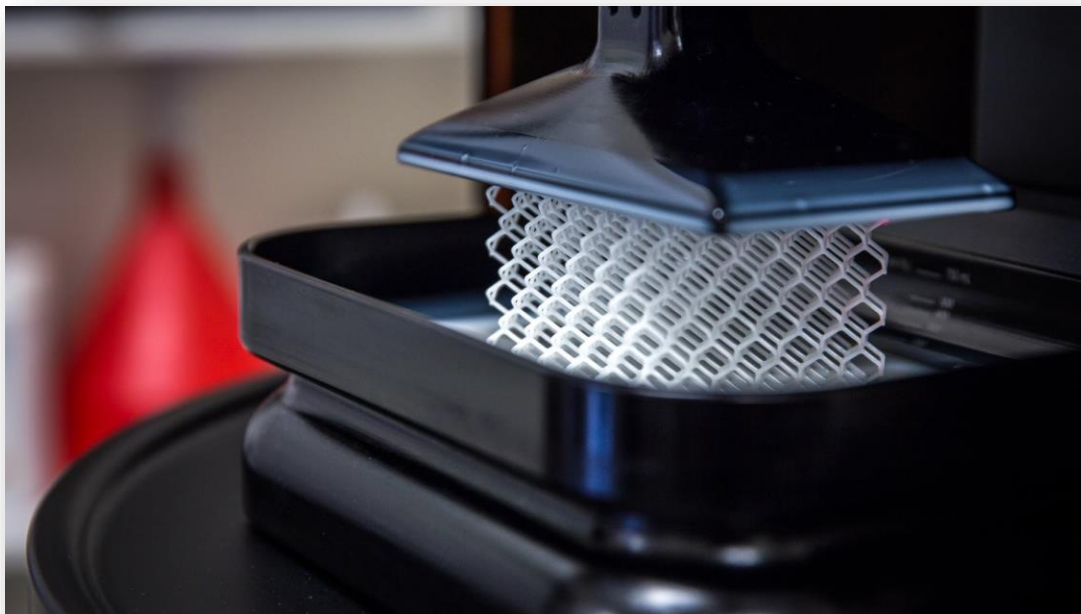


Typical 3D printing uses plastic polymers and resins to slowly build up a three-dimensional object one layer at a time.

A Fused Deposition Modeling (FDM) printer like the one below melts a thermoplastic filament and extrudes it in a specific pattern and then immediately cools it to form a solid object.



A Stereolithography (SLA) printer like the one below, uses a laser and UV light to cure and harden a liquid, photosensitive resin in a specific pattern.



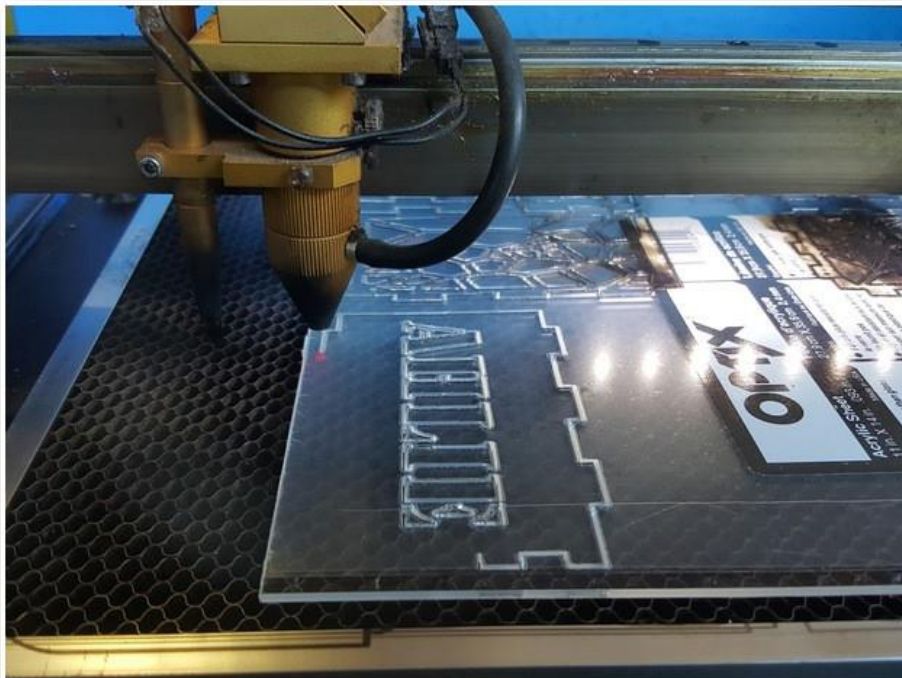
Subtractive Manufacturing

Until recently, product manufacturing has relied largely on subtractive methods - a process by which 3D objects are constructed by successively cutting material away from a solid block. Even methods that appear, at first glance, to be additive – like injection molding – still rely heavily on subtractive methods (for example, the production of the mold itself). Subtractive methods unavoidably produce large amounts of waste that often cannot be fed back into the manufacturing process.

Subtractive manufacturing examples can be as simple as cutting paper dolls from a sheet of paper:



Or they can involve using a laser cutter to cut shapes from a sheet of acrylic:



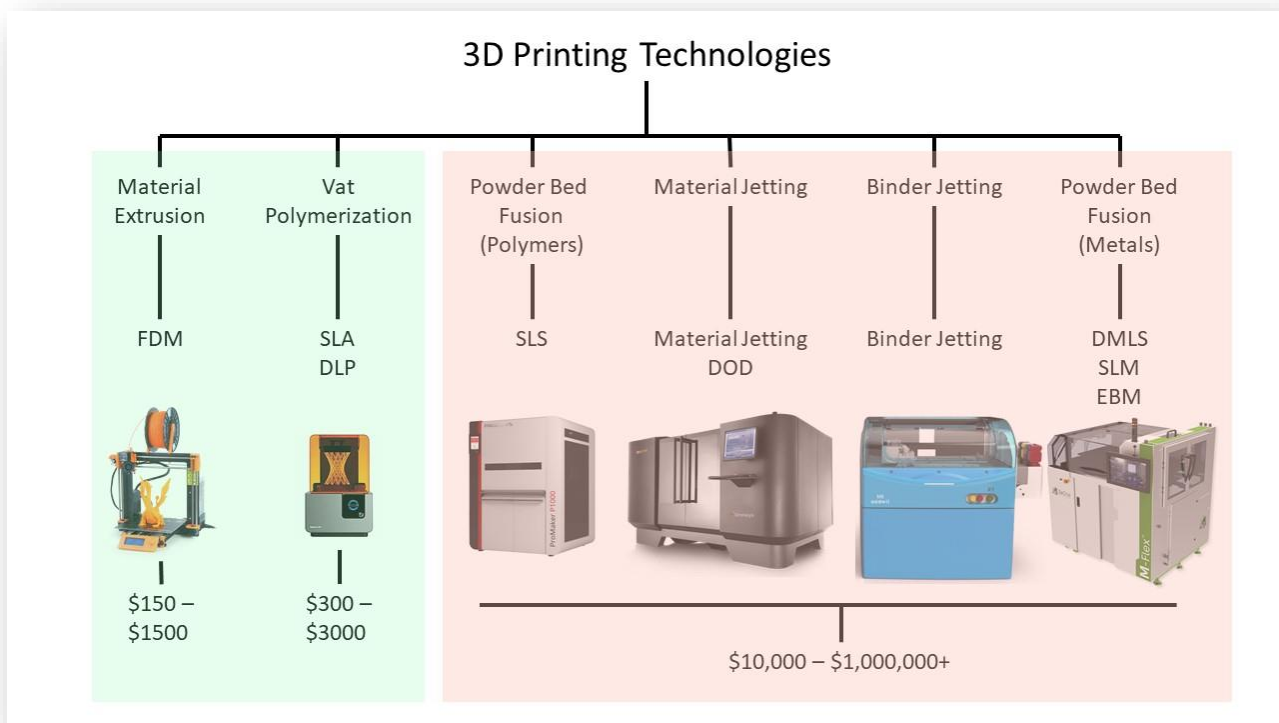
Or using a Computer Numerical Control (CNC) mill to cut a machine part from a block of aluminum:



The efficiency of subtractive methods is closely related to the amount of waste material produced.

3D Printing Technologies

While all 3D Printers produce their final product one layer at a time, the materials they use and the technologies they employ vary widely. The current set of 3D printers fall into two simple categories – consumer grade and commercial grade (indicated below by background color). Consumer grade printers can be purchased for less than a few thousand dollars – and commonly for less than five hundred dollars. Commercial grade printers can easily cost in the tens of thousands or hundreds of thousand of dollars. [Some content in this section has been taken from 3DHubs.com.]



Consumer Grade Technologies (\$150 - \$3000)

Fused Deposition Modeling (FDM) -

FDM (sometime also referred to as Fused Filament Fabrication or FFF) is the most widely used 3D printing technology. FDM builds parts using strings of solid thermoplastic material, which comes in filament form. The filament is pushed through a heated nozzle (extruder) where it is melted. The printer continuously moves the nozzle around, laying down melted material at precise locations following a pre-determined path. When the material cools it solidifies, building the part layer-by-layer.

FDM filaments can typically be purchased for less than \$25 for a one-kilogram roll. FDM produces very little waste. FDM is the most appropriate technology for the production of DIY AT.

Stereolithography (SLA)

SLA uses a build platform submerged into a translucent tank filled with liquid photopolymer resin. Once the build platform is submerged, a single point laser located inside the machine maps a cross-sectional area (layer) of a design through the bottom of the tank solidifying the material. After the layer has been mapped and solidified by the laser, the platform lifts and lets a new layer of resin flow beneath the part. This process is repeated layer by layer to produce a solid part. Parts are typically post-cured by UV light to improve their mechanical properties.

Direct Light Processing (DLP)

DLP follows a near identical method of producing parts when compared to SLA. The main difference is that DLP uses a digital light projector screen to flash a single image of each layer all at once. Because the projector is a digital screen, the image of each layer is composed of square pixels, resulting in a layer formed from small rectangular bricks called voxels. DLP can achieve faster print times compared to SLA for some parts, as each entire layer is exposed all at once, rather than tracing the cross-sectional area with a laser.

SLA and DLP resins require special handling because they are toxic in liquid form. Both techniques often result in wasted resin which can cost \$80 or more per liter.

Commercial Grade Technologies (\$10,000 - \$1,000,000+)

Selective Laser Sintering (SLS)

SLS produces solid plastic parts using a laser to sinter thin layers of powdered material one layer at a time. Sintering refers to taking a powdered material and turning it into a solid mass by heating it almost to melting and without liquification. The process begins by spreading an initial layer of powder over the build platform. The cross-section of the part is scanned and sintered by the laser, solidifying it. The build platform then drops down one-layer thickness and a new layer of powder is applied.

SLM & DMLS

Both Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS) produce parts via a similar method to SLS. The main difference is that SLM and DMLS are used in the production of metal parts. SLM achieves a full melt of the powder, while DMLS heats the powder to near melting temperatures until they chemically fuse together.

Electron Beam Melting (EBM)

EBM uses a high energy beam rather than a laser to induce fusion between the particles of a metal powder. A focused electron beam scans across a thin layer of powder causing localized melting and solidification over a specific cross-sectional area

Material Jetting

Material Jetting dispenses a photopolymer from hundreds of tiny nozzles in a printhead to build a part layer-by-layer. As the droplets are deposited to the build platform they are cured and solidified using UV light.

Drop-On-Demand (DOD)

DOD material jetting printers have 2 print jets: one to deposit the build materials (typically a wax-like liquid) and another for dissolvable support material.

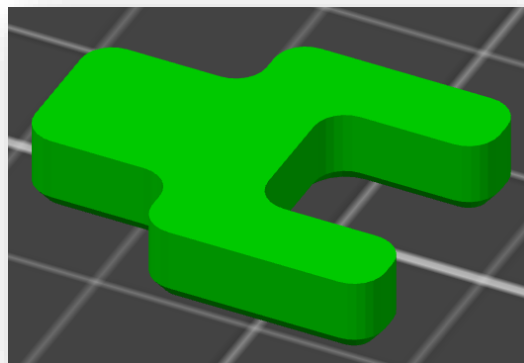
Binder Jetting

Binder Jetting deposits a binding adhesive agent onto thin layers of powder material. The powder materials are either ceramic-based (for example glass or gypsum) or metal (for example stainless steel). The print head moves over the build platform depositing binder droplets. When a layer is complete, the powder bed moves down, and a new layer of powder is spread onto the build area. The process repeats until all parts are complete.

3D Printing Materials

3D Printed objects can be produced in an ever-increasing variety of materials from simple thermoplastics to silver, gold, and even titanium. In Table 1, all but the last two example materials (PLA and TPU) require commercial grade printers and were manufactured by Shapeways (shapeways.com). The descriptions of the materials for the Shapeways printed objects come directly from Shapeways.

The following small, simple (25 mm x 20 mm x 5 mm) object was printed in each material:



Though small and simple, the cost of manufacture varied significantly. It can be produced in PLA plastic at a cost of 2¢ but the same object produced in aluminum costs well over \$26. Clearly, plastic has very different physical properties than aluminum but, for Do-It-Yourself (DIY) projects, you will often find that plastic is more than sufficient. In particular, many assistive technology devices, printed in plastic, will fully meet the needs of their users.

Two materials (green background in the table) are particularly suited to DIY production of AT – polylactic acid (PLA) and thermoplastic polyurethane (TPU). Both can be printed on FDM printers. PLA prints very easily and produces strong, light objects. TPU requires only slightly more skill to print and produces flexible, almost indestructible devices.

Table 1: Examples of 3D Printing Materials

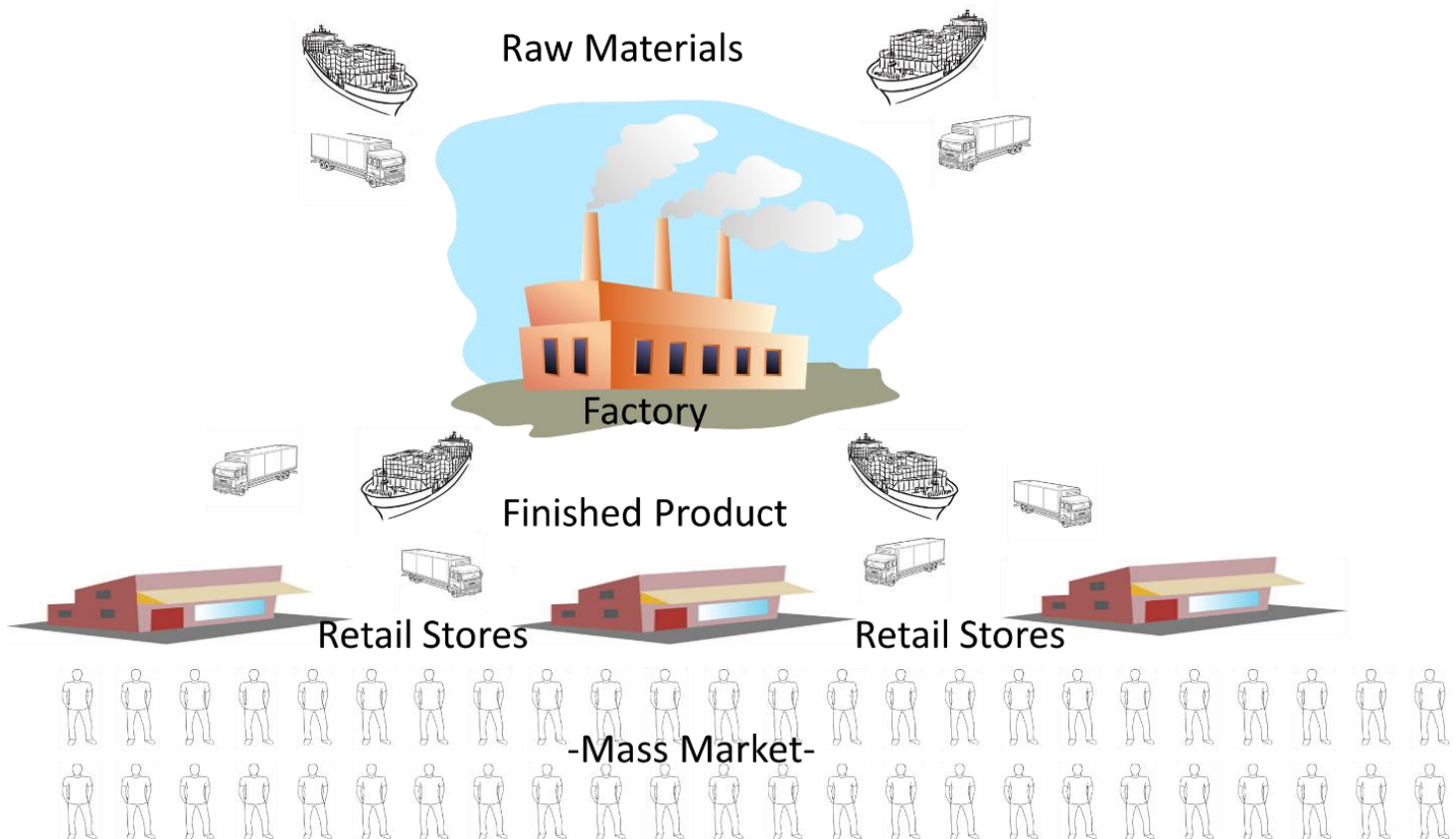
Sample Print	Material	Cost	Technology	Characteristics/Uses
Aluminum	Aluminum is a light and strong material recommended for functional parts requiring high strength, stiffness, low weight and high accuracy. It's printed using a process called Selective Laser Melting. Aluminum (alloy AlSi10Mg, 10% Silicon 0.5% Mg) also has great corrosion resistance, making it an ideal material for outdoor applications, and high electrical and thermal conductivity. It can also be machined, milled and tapped.	\$26.62	Selective Laser Melting	<ul style="list-style-type: none"> • Strong and lightweight • Rough surface • Scale model accessories • Skin-Friendly • Good Electrical Conductivity • Heatproof to 570C/1058F
Bronzed Steel	Steel is an affordable and strong metal that is well-suited for consumer products both small and large with an industrial look and feel. It's printed using a binder jetting process and is later infused with bronze, creating a material that is 60% steel and 40% bronze and can range in color from a silver gray to reddish bronze. It is strong enough for metal parts like bottle openers and dice but is not recommended for industrial load bearing applications.	\$13.88	Binder Jetting	<ul style="list-style-type: none"> • Robust and durable • Visible print lines • Supports complex geometry • Not Food-safe • Heatproof to 831C/1521F
Professional Plastic	Professional Plastic is HP's nylon plastic with excellent mechanical properties and a smooth, finished and semi-glossy surface, making it an ideal choice for a wide range of applications from industrial parts to high quality finished goods. It's strength, durability and stiffness make it great for functional parts, such RC car parts and mounts. However, it's also popular for jewelry, home decor, eyewear and games. Professional Plastic is printed using HP's new Multi-Jet Fusion Technology and supports very complex geometries and thin features.	\$7.50	Multi-Jet Fusion	<ul style="list-style-type: none"> • Superior strength • Improved properties in the z-axis • Supports complex geometry • Skin-Friendly • Heatproof to 175C/350F • Watertight • Good Chemical Resistance
Fine Detail Plastic	Fine Detail Plastic is an acrylic material capable of extremely high detail and is a popular choice for hobbyists creating scale models, miniature sets, and other decorative products. Although the surface can be uneven in color due to the nature of the printing process, most people opt to paint their models. Due to the smooth surface, occasionally, models are used to make mold masters. This material is not recommended for functional parts due to its brittleness.	\$6.31	Material Jetting	<ul style="list-style-type: none"> • High detail • Paintable surface • Can be brittle • Heatproof to 80C/176F • Watertight • Not Food-safe • Poor UV Resistance
Sandstone	Full Color Sandstone offers multi-color printing, making it the best material for figurines, architecture, medical models and other applications that require many colors. Although it's a great material for decorative models, it is not well suited for handling due to its low strength and brittle nature.	\$4.28	Binder Jetting	<ul style="list-style-type: none"> • Coarse surface • Hard and brittle (must be handled with care)

Versatile Plastic	Versatile Plastic is a durable nylon plastic that can be used for a wide range of applications, both for prototyping and for end products. Printed using Selective Laser Sintering (SLS), when thin, it's flexible enough for hinges and springs and when thick, it's strong enough for structural components. Try the Premium finish for a higher quality look and feel.	\$2.70	Selective Laser Sintering	<ul style="list-style-type: none"> • Strong and durable • Supports complex geometry • Dishwasher Safe • Heatproof to 163C/325F • Skin-Friendly • Good Chemical Resistance
Thermoplastic Polyurethane	Thermoplastic polyurethane (TPU) belongs to a class of polyurethane plastics having many important properties such as ability to perform at low temperature, rubber-like elasticity, transparency, and resistance to grease, oil, and abrasion. It is unique due to its extremely flexible nature. Think of flexible TPU has a hybrid material between hard plastic and soft silicone.	\$0.09	Fused Deposition Modeling	<ul style="list-style-type: none"> • Commonly used in caster wheels, sporting goods, power tools, medical devices, footwear, drive belts • Used in the outer cases of mobile devices such as tablets and phones
Polylactic Acid	PLA is manufactured from renewable sources and is compostable, addressing problems in solid waste disposal and lessening our dependence on petroleum-based raw materials. It is currently the second most produced and consumed bioplastic in the world in terms of volume.	\$0.02	Fused Deposition Modeling	<ul style="list-style-type: none"> • Most popular of all 3D printing filaments due to its ease of use and reliability • Strong but can be brittle • Heat and UV sensitive so not recommended for outdoor uses

Mass Production vs. Mass Customization

Traditional (Centralized) Manufacturing – “Mass Production”

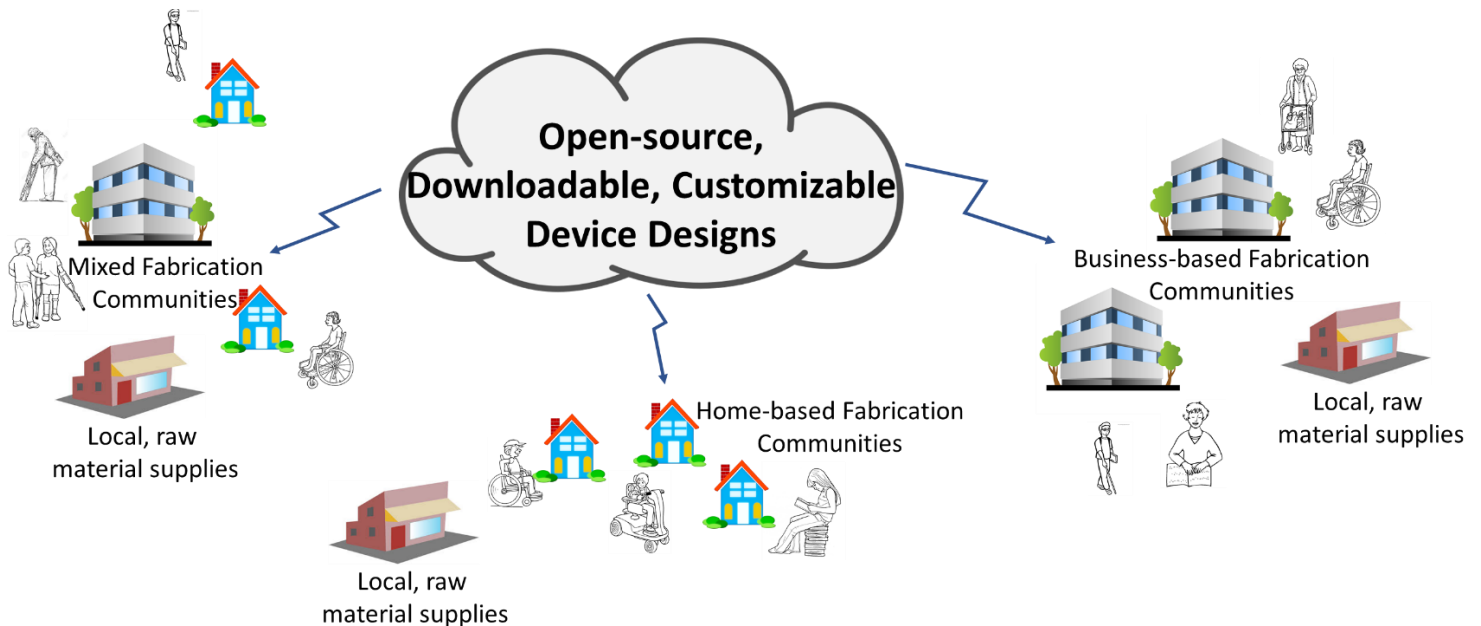
Almost every product we’ve encountered in our lifetimes has been produced by the traditional manufacturing process of mass production. Competitive pressures have driven these commercial enterprises to centralize their production – often in low wage regions of the globe. Mass production requires the existence of a mass market of indistinguishable customers.



- Proprietary product designs – designs must be protected because they target a mass market and allow anyone with access to the designs and similar processes to easily compete in the same market
- Complex / Expensive machinery – mass production requires high precision manufactured parts and therefore complex, high precision processes and machines that require large capital investments and complex operation
- Reliance on subtractive methods – additive methods cannot yet provide the precision required of mass production processes
- Significant waste produced – the waste must then be transported elsewhere and disposed of
- High fixed costs / low per-item costs – significant up-front costs are invested to create processes that can be reliably repeated with high precision and low cost
- Significant planning & logistics – the system has many moving parts that must be scheduled and managed carefully to control costs
- Transportation-heavy – because the manufacturing and assembly process is most efficient if centralized, raw materials, parts for assembly, waste, and final products must be transported to and away from the centralized manufacturing site
- Mass market for standardized product – mass production is only feasible if there is a mass market of indistinguishable customers to purchase the product

3D Printing (Local Manufacturing) – “Mass Customization”

3D printers are general-purpose machines that are inexpensive, high quality and simple enough for a therapist or mildly technical consumer to use. Raw materials are simple, inexpensive, and locally available or can be purchased from online retail sites like Amazon.com or Alibaba.com. Device designs are often posted online and can be freely downloaded. The result is to put simple, high quality manufacturing within easy reach of therapists or individuals with disabilities or their caregivers. Easy, inexpensive access to manufacturing and closeness to the final user facilitate the direct involvement of the user in the design, customization and testing of their devices. 3D printers support local manufacturing which supports mass customization.



- Freely-shared product designs – the designs are often created by volunteers and posted at websites like Thingiverse.com or MyMiniFactory.com. The designs are usually licenced under the Creative Commons making them free to use and distribute for non-commercial purposes.
- Greater focus on and involvement of the end user and therapists – placing manufacturing close to the customer makes it possible for end users to be directly involved in the specification and customization of the devices they will use.
- Electronic delivery of designs – designs exist as files that can be downloaded from the cloud.
- Simple/ Inexpensive machinery – quality 3D printers are finally available to the maker community at reasonable prices; and social media – especially Facebook and YouTube – have made assembly, use, and troubleshooting things that you no longer must undertake on your own.
- Leverages additive methods – 3D printing creates three dimensional objects by repeatedly laying down thin layers of thermoplastic or a resin-based photopolymer. Objects can have complex geometry and be printed in one piece – without assembly.
- Minimal waste produced – 3D printing is an additive manufacturing method and FDM, in particular, produces objects that are almost entirely a 1 to 1 transformation of raw materials into final product. The waste associated with a final print is normally negligible. Most waste is produced during the design and test phase.
- No fixed costs / medium per-item costs – 3D printers are general-purpose machines which means they use simple processes that can produce products of almost any geometry without specialized jigs, molds, or forms. Each

item produced can be completely different from the product produced previously or the one that will be produced next.

- Small, highly specific market for a customized and personalized product – Because each item produced by a 3D printer can be different from the last without any re-tooling, there's little or no cost associated with altering a design to accommodate the specific needs and desires of the individual who will use the product. Because the cost of materials is almost free, 3D printing creates a frictionless process of iterating through design, implementation and test.

NASA ISS Wrench



While not an example of assistive technology, it's a wonderful example of 3D printing as local manufacturing. When International Space Station Commander Barry Wilmore needed a wrench, NASA knew just what to do. They "e-mailed" him one. This is the first time an object has been designed on Earth and then transmitted to space for manufacture on the space station's 3D printer. The design is available for free at:
www.nasa.gov/mission_pages/station/research/news/3Dratchet_wrench

3D Printing and AT

The synergy between mass customization methods like 3D printing and the creation of AT for individuals with disabilities is so strong that it's important to take a close look at the pros and cons of doing so.

Pros –

- General purpose machines and inexpensive materials – the “mass customization” model of 3D printing is only possible because the printers are inexpensive, general-purpose machines. The low operating costs, in terms of filament and power used, facilitate the iteration of a design or implementation until it's “just right” for the final user.
- Time from concept to prototype/product can be very short – printing can begin just a few minutes after a design has been translated into the machine language of the printer and most prints complete in a few hours.
- Open-Source designs freely available - ready-made designs are often available on line and just waiting to be downloaded – meaning that the design phase of manufacturing can be minimal. For individuals interested in

designing their own AT, free and powerful computer-aided design tools are available to download or use directly online.

- Local fabrication facilitates consumer involvement – 3D printers are simple enough to use and of high enough quality that therapists, individuals with disabilities and their caregivers can be directly involved in the design and customization of the final device.
- Rapid iteration facilitates customization – 3D printing filament is inexpensive and power consumption is very small so if a design doesn't exactly meet the needs or desires of the end user, it is simple and quick to modify the design and reprint a new version of the device.

Cons –

- Materials may have limited strength and temp./UV stability – FDM prints are anisomorphic meaning that their strength depends on the direction in which stress is applied. The weakest points of any print will be between printed layers. This shortcoming can be mitigated by considering how the device or part will be stressed and then using that information when orienting the model for printing. Because FDM printing involves thermoplastics the 3D printed object will have difficulty retaining its shape or strength under high temperatures and plastics in general are negatively affected by UV radiation making them a questionable choice for applications that require long periods of exposure to the sun.
- Open-Source designs and devices are unlikely to have undergone testing to validate their safety and effectiveness – Open-Source designs are usually created by technical people who are not professionals in the domain of AT. They also rarely undergo any testing beyond the use by a targeted individual and little thought is given to safety issues. You shouldn't make any assumptions about how well a device will work for you. Fortunately, if it doesn't work out, printing the device didn't cost all that much. You should monitor the use of the device closely until you're confident that it can be used safely. In general, you should avoid 3D printed devices that will be stressed significantly or will be required for stability by the user. Examples of devices that have been proposed for 3D printing, but I believe should be avoided, are portable wheelchair ramps and crutch tips.
- Liability for injury is unclear – Open-Source/Creative Commons licensing place responsibility for injury on the user of a design. Even popular efforts like EnablingTheFuture.org and e-NABLE.org are unsure of the liability they might incur if a user of one of their devices is injured through use of their prosthetic hands. It's even less clear what the responsibility of the person producing the 3D print might be. Many therapists avoid DIY devices simply because liability issues haven't been settled and the limitations of Good Samaritan laws haven't been tested in court.

Characteristics of an AT device that make it a good candidate for DIY 3D Printing –

3D printing technology will steadily improve over time because additive methods are so promising, but, for now, some types of AT are a better fit for 3D printing than others.

- It presents rich opportunities for customization – individuals with disabilities don't fit the "mass market" model specifically because their abilities and needs vary so much. 3D printing tools have the inherent capability to easily modify the size of an object prior to printing and color choices of filaments are almost unlimited; but the best AT device candidate will be a model that is highly customizable through built-in parameters whose values can be set by the user prior to printing.

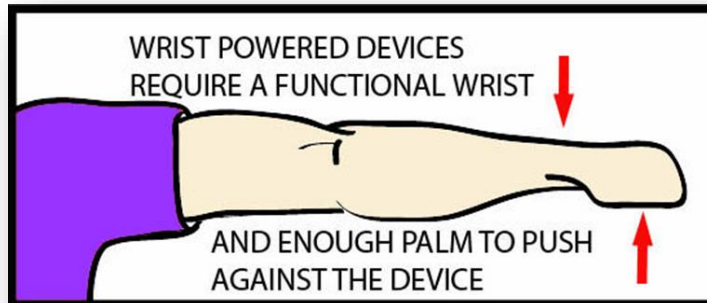
- All parts are greater than 10 mm and less than 300 mm on any dimension (i.e., part sizes should fall within the build volume of a typical consumer-grade 3D printer) – 3D printing is a slow process. Very large items will take a very large amount of time (days) to print. If they have to be printed in parts, and the parts then have to be assembled (usually by gluing them together), the aesthetics and strength of the final device may be affected or could require additional hours of post-processing. On the tiny end of the spectrum, the smaller an FDM printed part, the weaker it will be – particularly along the layer lines.
- It doesn't need to support loads greater than 50 lbs. or temperatures greater than 150 degrees Fahrenheit – without invoking fringe materials like polycarbonate filaments that require specialized 3D printer parts and greater expertise to print, 3D printing filaments and the devices they produce are not rated to support significant weight or operate outside of normal room temperatures.
- It doesn't require transparency or softness and will spend a limited amount of time directly in contact with the user's skin – most 3D printing materials produce rigid parts and FDM printed objects have a rough surface. These two characteristics can make them irritating if placed in contact with the skin for a long time. One could sand the surface of the part to make it smoother or wrap it in a softer material, but an optimal device would be one that goes directly from the printer into use, not one that requires lots of post-processing.
- It will likely require iterations to fit the individual physically, functionally, or aesthetically – a key feature of 3D printing is the ability to rapidly make changes to a design, print the modified design, and test the modifications – if necessary, to repeat the process with new modifications. A device that is a perfect fit for everyone, right from the start, will be much cheaper to produce using mass production methods.
- All non-3D-printed parts of a device are inexpensive and can be assembled with minimal skill (*by the way, soldering is not a minimal skill*) – the best DIY designs are very simple to assemble – simple skills and simple tools. Parts that snap or screw together are unlikely to become a barrier to therapists, individuals with disabilities or their caregivers. There's already significant inertia in the system without introducing more by requiring advanced skills to assemble a device.
- The device can be modeled as a collection of 2 and 3 dimensional primitives as opposed to purely organic shapes – 3D modeling tools and 3D printers are optimized for creating models and printing objects that can easily be specified as a collection of x, y, z coordinates. It is possible to form an organic object in clay and then 3D scan that object to produce a solid model but a DIY, FDM printer will struggle to print it. Large amounts of support will be required, or it will have to be carefully sliced into sub sections and then glued together. Such models provide few opportunities for modification without repeating the process from scratch.

Examples of 3D Printed AT Devices

Cyborg Beast Hand Prosthetic



Developed by Jorge Zuniga and his research group at Creighton University, the Cyborg Beast is one of e-NABLE's most popular wrist-powered designs. Among its features are textured finger tips for improved grip, Chicago screw joints, protected cable routing through the body of the palm, and integrated tensioning system in the gauntlet. The Cyborg Beast is licensed under the Creative Commons-Attribution-Non-Commercial license. *Nothing that eNABLE provides is medically certified.

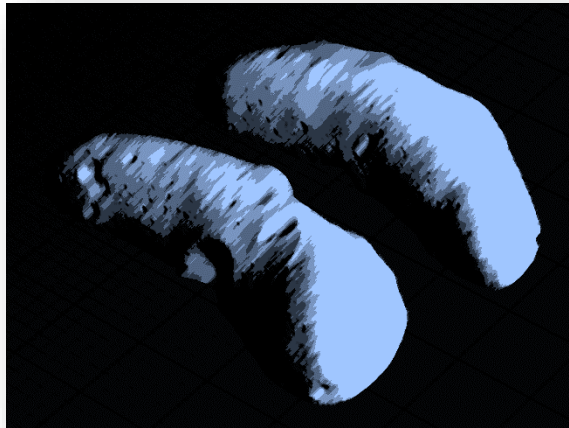


Cost to print: \$15

- 3D printed components (\$3)
- Fasteners and straps (\$12)

The design is available for free at: <http://enablingthefuture.org/upper-limb-prosthetics/cyborg-beast/>

Eros Asteroid Model

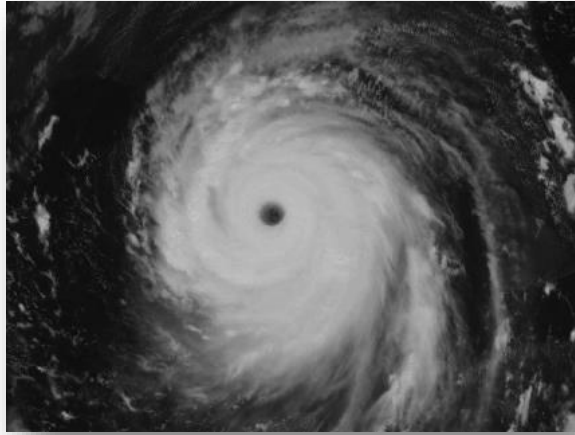


Eros has a length of approximately 34 km. Printed at its default size (5cm long) this model is at an approximate scale of 680,000 to one (1 cm = 6.8 km). For ease of printing, the model is printed in two halves and then the two halves are glued together.

Cost to print: 83¢

The design is available for free at: nasa3d.arc.nasa.gov/detail/eros

Hurricane Katrina Model

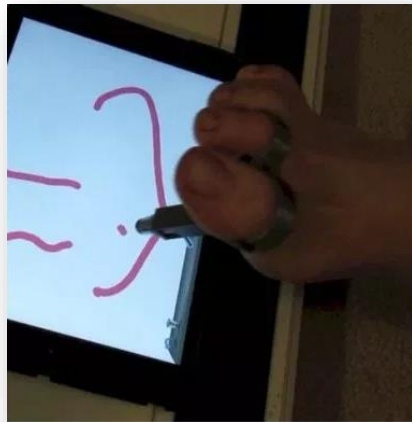


This model shows the storm at maximum intensity in the Gulf of Mexico on Aug. 28, 2005. At this moment, Katrina was a Category 5 storm with maximum sustained winds of 175 mph. The model is 2,350 miles on a side. The printed model may be helpful for individuals with visual impairments to imagine the size and shape of a hurricane.

Cost to print: \$1.66

The design is available for free at: nasa3d.arc.nasa.gov/detail/hurricane-katrina

6th Finger / 6th Toe Stylus



3D printable capacitive stylus that can be used by individuals with limited hand control to interact with a smartphone or tablet either with their hand or with their foot.

Cost to print: \$1.00 - \$1.50

The design is available for free at: volksswitch.org/index.php/sixth-finger-sixth-toe-capacitive-stylus

Personalized Cuff Utensil Holder

3D printable cuff and utensil holder that can be used by people with limited hand strength to use knives, forks and spoons to prepare and eat meals.



Cost to print: 25¢ - 50¢

The design is available for free at: volksswitch.org/index.php/volks-devices/personalized-cuff-utensil-holder

Magnetic Shoelaces



Individuals with limited dexterity due either to muscle control or to joint pain can have difficulty lacing and tying their shoes. These magnetic shoelaces make it possible to easily put on and tighten and, later, take off lace-up shoes.

Cost to print: \$1.45

- 3D printed parts (25¢)
- Magnets (\$1.20)

The design is available for free at: volksswitch.org/index.php/volks-devices/magnetic-shoelaces

Pop-top Can and Bottle Opener



Individuals with limited dexterity due either to problems with muscle control or to joint pain can have difficulty opening pop-top cans and opening small bottles. This assistive device makes it easier to accomplish both tasks.

Cost to print: 75¢

The design is available for free at: volksswitch.org/index.php/volks-devices/pop-top-can-and-bottle-opener

Kobayashi Fidget Cube



This may be the ideal “fidget device” for students with emotional or behavioral disabilities. It provides tactile manipulation and feedback without distracting the student visually like a fidget spinner or a squishy toy. **Printed all in one piece, no assembly required!** The cube is also an excellent example of a geometry (particularly the joints) that could not have been produced through any process other than 3D printing.

Cost to print: 38¢ - 79¢ (depending on size)

The design is available for free at: www.thingiverse.com/thing:1269699

Beverage Holder



It is designed to be adjustable in height and inclination. You can put a glass, cup or can in it. If you put a little ribbon around it, it keeps neatly in place, even if someone hits the table it is standing on. With its wide legs it is almost tip-over-proof.

Cost to print: \$3.35

The design is available for free at: www.myminifactory.com/object/3d-print-the-next-beverage-holder-57768

The design of the straw holder is available for free at: <http://volksswitch.org/index.php/volks-devices/customizable-straw-holder/>

Ring Pull Can Opener



This is a support for people with less ability to open ring pull cans. Suitable for users with either arthritis or a weak grip. Extremely easy to use, just hook the end under the ring, fold forwards and then roll back.

Cost to print: 48¢

The design is available for free at: www.myminifactory.com/object/3d-print-ring-pull-can-opener-5732

Ergonomic & Friendly Asthma Inhaler Stabilizer



This cool and simple 3D printed health-related object is an effective ergonomic solution to improve the usage of the inhaler devices by people suffering from asthma. The particular shape of this object lids to firmly push the canister without struggling.

Cost to print: 31¢

The design is available for free at: www.instructables.com/id/3D-Printed-Ergonomic-Friendly-Asthma-Inhaler

Dyslexia Reading Bar – Flat or Curved



A reading tool that helps readers with dyslexia to focus on a few lines of text. Available in flat or curved forms and with one or multiple lines of text exposed.

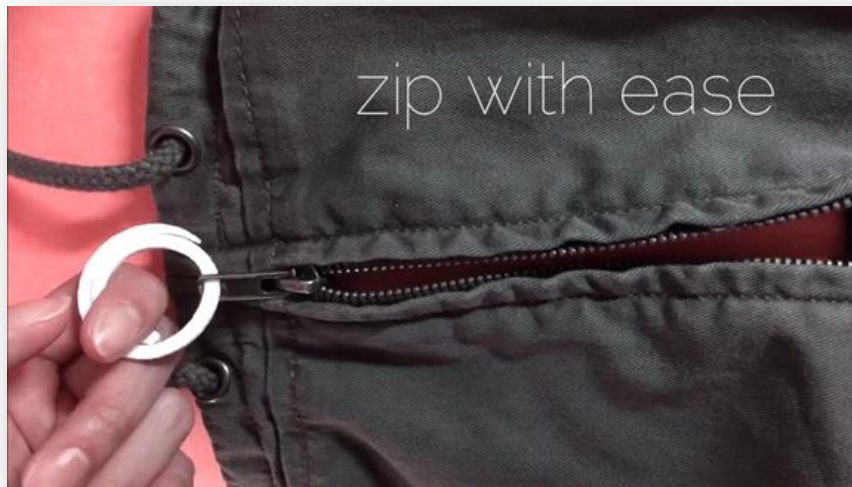
Cost to print: 25¢ (flat) - 50¢ (curved)

The design is available for free at:

www.thingiverse.com/thing:2802065 (flat)

www.thingiverse.com/thing:2802057 (curved)

“Quick-Zip“ Zipper Aid and Easy Keychain Ring



The Quick-Zip is a simple, fun and attachable clip for zippers and keychains. The clip is designed for anyone who wants a easier way to zip up. It allows people to easily grasp onto a zipper. There is no more fumbling with zippers with the Quick-Zip. As a keychain ring, it is easy to attach unlike metal counter parts. Also, the zip can be used for winter months for when it is hard to zip up or unzip in gloves/mittens.

Cost to print: 3¢ each

The design is available for free at: pinshape.com/items/25738-3d-printed-zipper-aid-and-easy-keychain-ring

Customizable, 3D Printable Keyguard for Grid-based, Free-form, and Hybrid AAC Apps on Tablets



Keyguards help individuals with limited muscle control the ability to point reliably at regions of an app running on a tablet. In this case, the apps are associated with Augmentative and Alternative Communication. Many AAC apps organize their content in grids – sets of rows and columns. Others are much more creative and unpredictable in their layouts. Hybrid apps are largely grid-based but their keyguards can be enhanced by selectively exposing specific regions

of the app. This keyguard designer allows the user to provide specific characteristics for the keyguard that they need and then generate and 3D print that exact keyguard.

Cost to print: 75¢ - \$2.00

The design is available for free at: volksswitch.org/index.php/volks-devices/fully-customizable-3d-printable-aac-keyguard-for-tablets