Syllabus

3D Printing

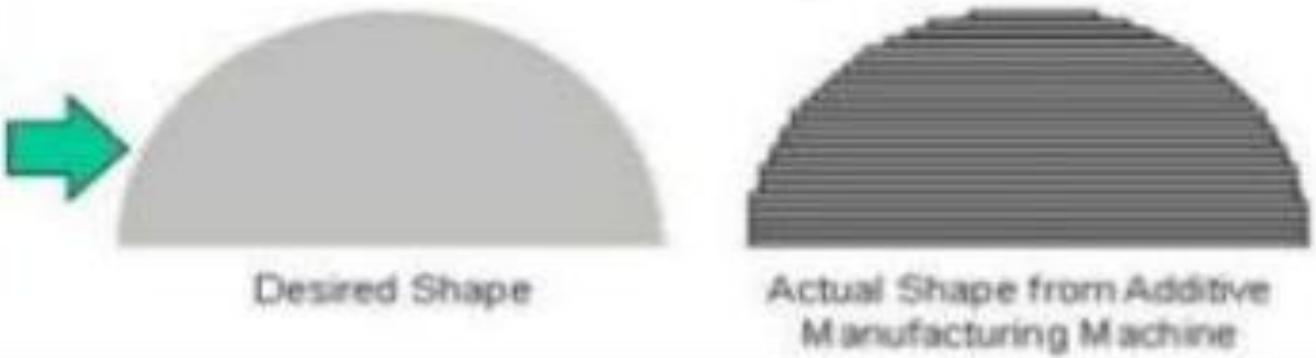
Liquid-based 3D Printing: Photo Polymerization - Principle and working of stereolithography apparatus (SLA) based 3D printing process; Applications; Post Processing, Solid ground curing (SGC).

Solid state 3D Printing: Basic Principle and working of Fused deposition modeling (FDM) process and laminated object manufacturing (LOM) process; Post Processing, Applications.

Powder-based 3D printing: Principle and working
of Selective Laser Sintering (SLS) process; Applications; Post
Processing.

What is Additive Manufacturing?

- *The process of joining materials to make objects from three-dimensional (3D) model data, usually **layer by layer***
- Commonly known as **"3D printing"**
- Manufacturing components with virtually no geometric limitations or tools.
- AM uses an ***additive process***
- *Design for manufacturing to manufacturing for design*
- Distinguished from traditional subtractive machining techniques

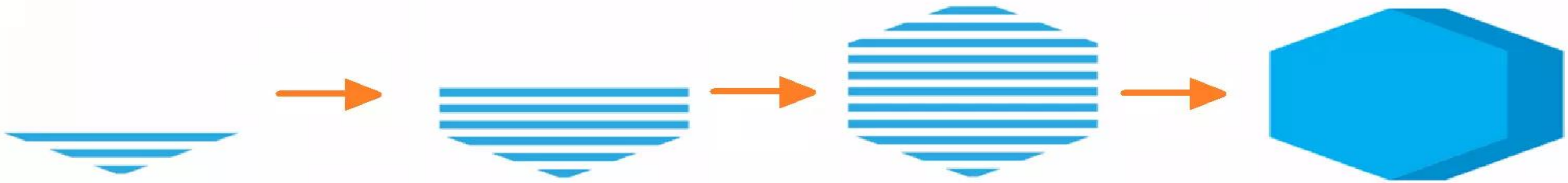


3D Printing

- **Additive manufacturing** is the opposite of **subtractive manufacturing** which was used widely in the past involving gradual removal of layers from a solid block of any material either be wood or metal to form a 3D object.
- Additive manufacturing as the name indicates is the layer by layer deposition of a specific material to form a 3D shape or structure.
- This technique can be employed in powders be it glass, ceramic, metal and resins in liquid form.
- Complex shapes and design elements can be easily cured on the materials using **additive manufacturing techniques**.
- There is almost zero wastage of the raw material in the **additive manufacturing process**.
- A narrow range of materials can be employed for the process which has relatively **low melting points**.

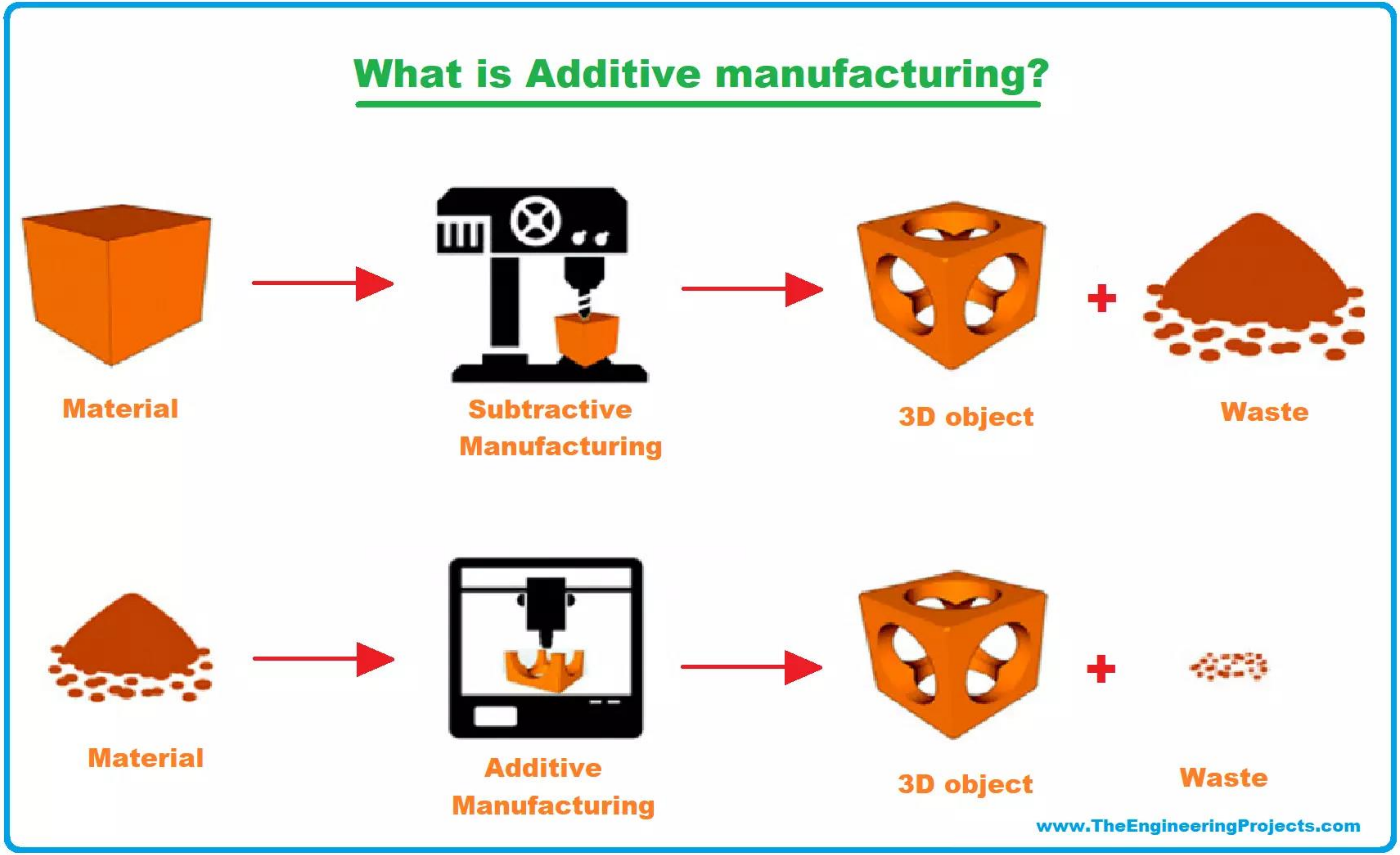
What is 3D Printing?

➡ Structuring a three-dimensional object in its physical configuration from its digital form.



3D printing and additive manufacturing

Process of 3D Printing



What is Additive manufacturing?
Material
Subtractive Manufacturing
3D object
Waste
Material
Additive Manufacturing
3D object
Waste
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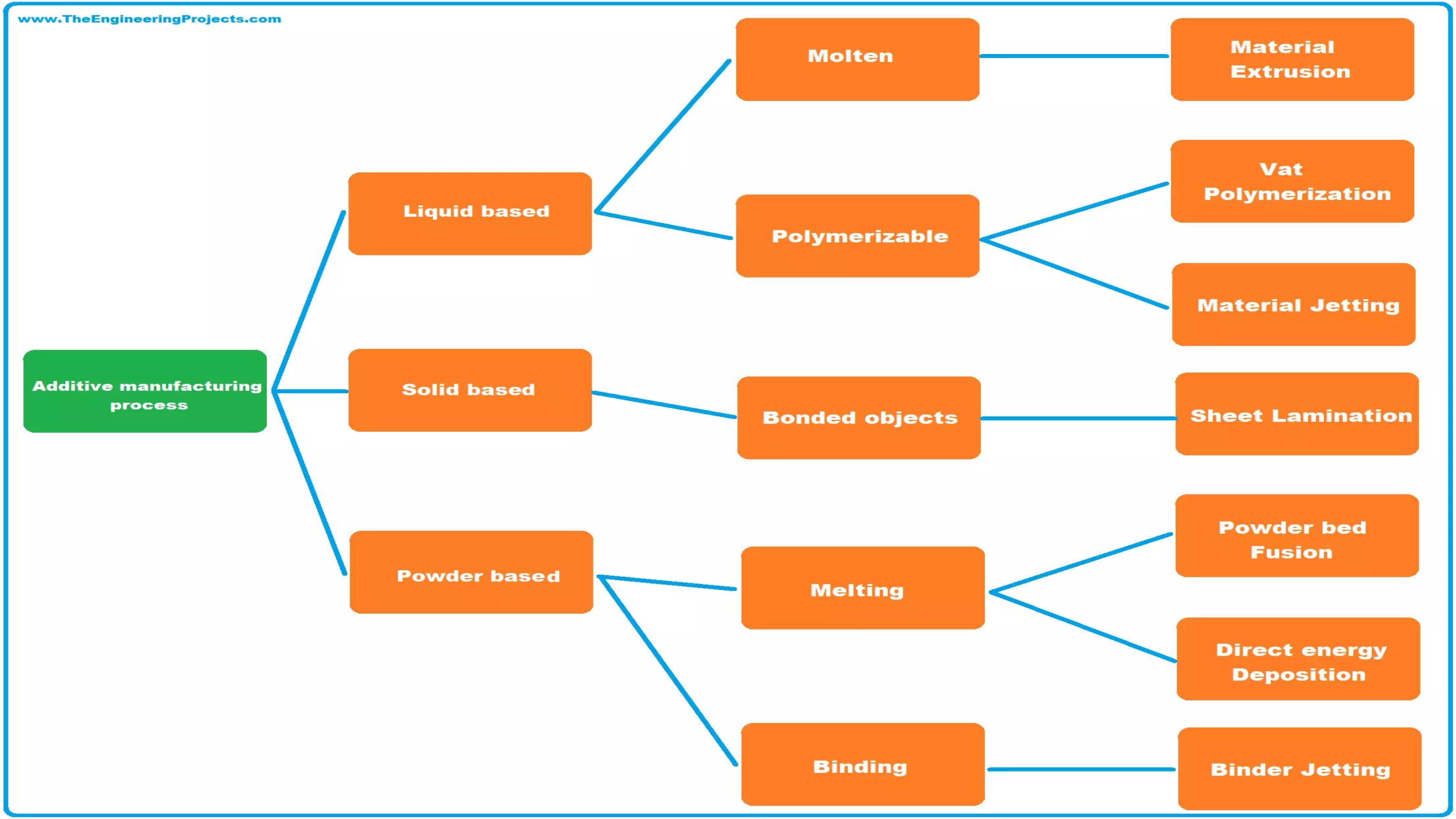
Pros and Cons

Pros	Cons
Freedom to design and innovate without penalties	Unexpected pre- and post-processing requirements
Rapid iteration through design permutations	High process cost
Excellent for mass customization	Lack of industry standards
Elimination of tooling	Low speed, not suitable for mass production
Green manufacturing	Inconsistent Materials
Minimal material waste	Limited number of materials
Energy efficient	High equipment cost for high-end manufacturing
Enables personalized manufacturing	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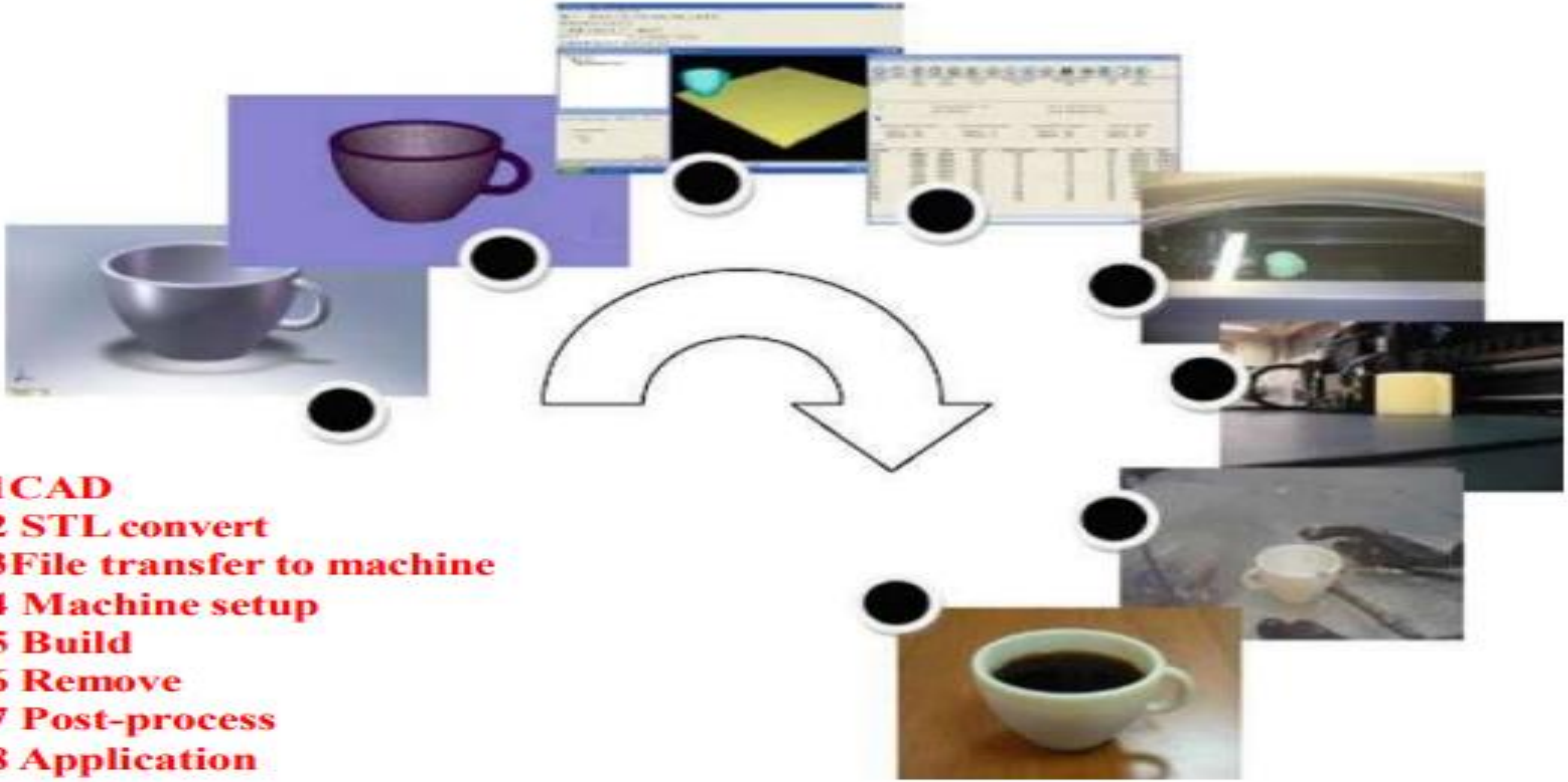
Additive manufacturing process
Liquid based
Solid based
Powder based
Molten
Polymerizable
Bonded objects
Melting
Binding
Material Extrusion
Vat Polymerization
Material Jetting
Sheet Lamination
Powder bed Fusion
Direct energy Deposition
Binder Jetting

Stages in



1CAD
2 STL convert
3File transfer to machine
4 Machine setup
5 Build
6 Remove
7 Post-process
8 Application

Step 1: CAD

- All AM parts must start from a software model that fully describes the external geometry. This can involve the use of almost any professional CAD solid modeling software, but the output must be a 3D solid or surface representation.

- Reverse engineering equipment (e.g., laser scanning) can also be used to create this representation.

Step 2: Conversion to STL

- Nearly every AM machine accepts the STL file format, which has become a de facto standard, and nearly every CAD system can output such a file format.
- This file describes the external closed surfaces of the original CAD model and forms the basis for calculation of the slices.

Step 3: Transfer to AM Machine and STL File Manipulation

- The STL file describing the part must be transferred to the AM machine.
- Here, there may be some general manipulation of the file so that it is the correct size, position, and orientation for building.

Step 4: Machine Setup

- The AM machine must be properly set up prior to the build process.
- Such settings would relate to the build parameters like the material constraints, energy source, layer thickness, timings, etc.

Step 5: Build

- Building the part is mainly an automated process and the machine can largely carry on without supervision.
- Only superficial monitoring of the machine needs to take place at this time to ensure no errors have taken place like running out of material, power or software glitches,

Step 6: Removal

- Once the AM machine has completed the build, the parts must be removed.
- This may require interaction with the machine, which may have safety interlocks to ensure for example that the operating temperatures are sufficiently low or that there are no actively moving parts.

Step 7: Post processing

- Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. Parts may be weak at this stage or they may have supporting features that must be removed. This therefore often requires time and careful, experienced manual manipulation.

Step 8: Application

- Parts may now be ready to be used. However, they may also require additional treatment before they are acceptable for use.
- For example, they may require priming and painting to give an acceptable surface texture and finish. Treatments may be laborious and lengthy if the finishing requirements are very demanding.

Advantages of AM

- Freedom of design
- Complexity for free
- Potential elimination of tooling
- Lightweight design
- Elimination of production steps

Applications of AM

AM has been used across a diverse array of

- industries, including;
- Automotive
- Aerospace
- Biomedical
- Consumer goods and many others

Classification of Additive Manufacturing Systems

The Better way is to classify AM systems broadly by the initial form of its material, categorised all AM Systems can be easily into

1) Liquid Based
2) Solid Based
3) Powder Based

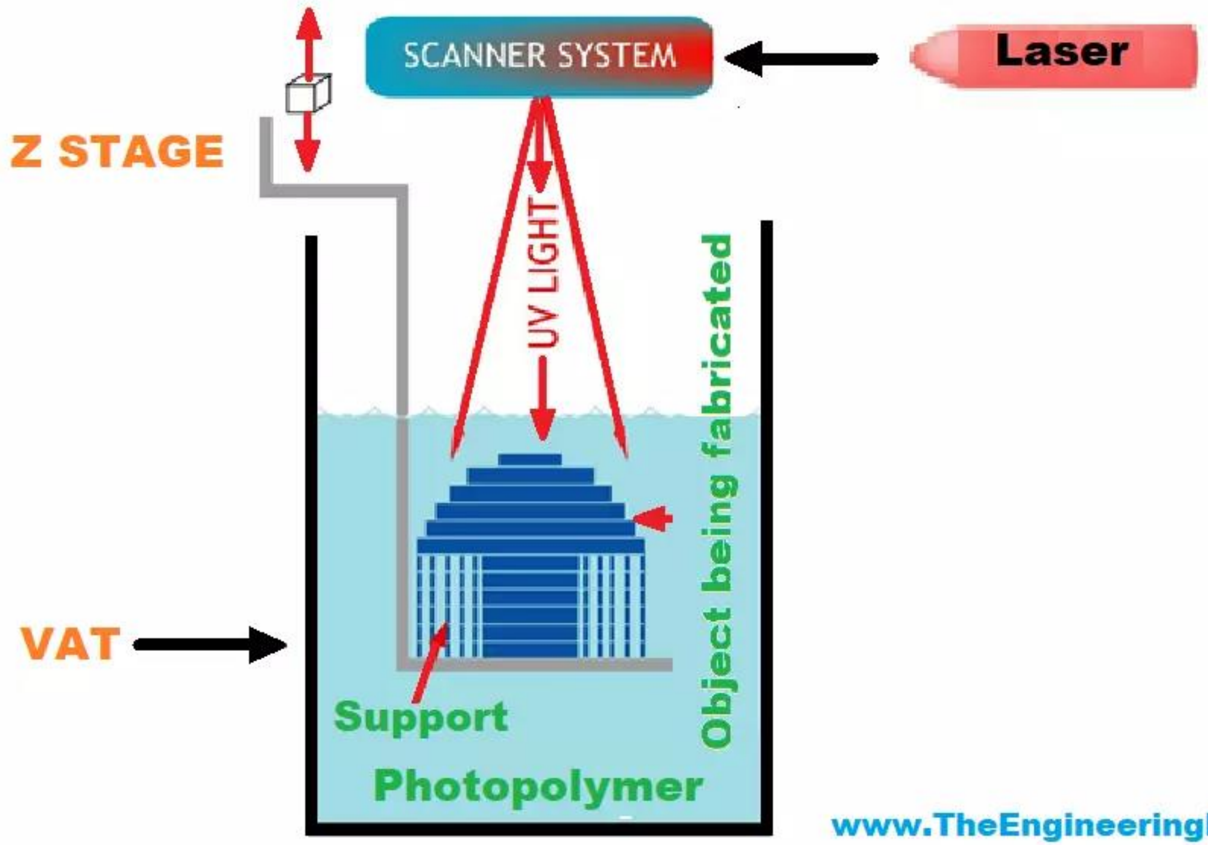

AM Processes
Liquid Based
Stereolithography
Jetting Systems
Direct Light Processing
Powder Based
Selective Laser Sintering
Three-Dimensional Printing
Fused Metal Deposite Systems
Electron Beam Melting
Selective Laser Melting
Selective Masking Sintering
Selective Inhibition Sintering
Electro photographic Layered Manufacturing
High Speed Sintering
Solid Based
Fused Deposition Modelling
Sheet Stacking Technologies

SLA- Stereolithography

- The term Stereolithography was coined by Chuck Hill in 1984.
- SLA is also called VAT Polymerization.
- SLA process involves the production of a 3D model by casting a light beam on the photopolymer resins.
- When the UV light beam strikes the polymer layer, it castes a design on the polymer bed, the design then solidifies and moves one inch downward, afterwards another sheet is polymerized in the same way, the process continues until the 3D object is formed completely.
- After the competition, the modeled object is washed with the solvent to remove excess resin from the layers making the design neat and sleek.
- This process is highly expensive yet fast, you can generate your model in a day.

Stereolithography

- SLA process involves the production of a 3D model by casting light beam on the photopolymer resins.



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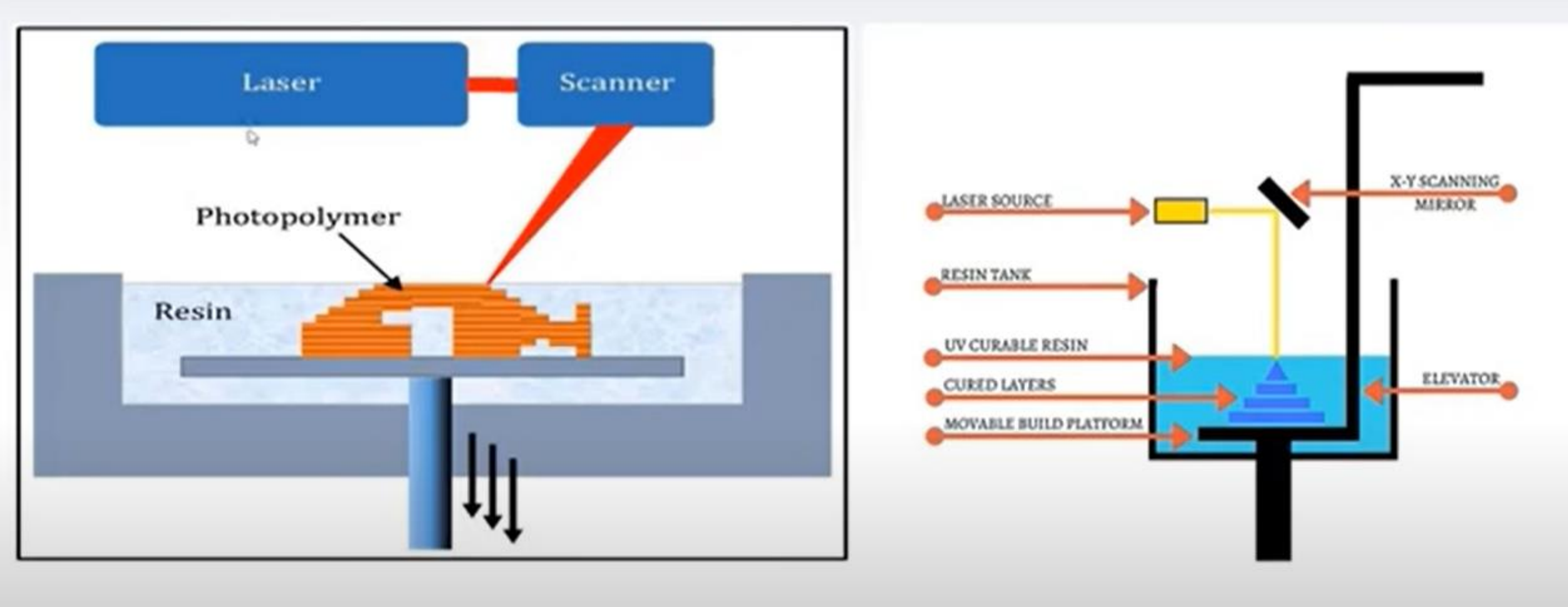
SLA- Stereolithography



https://www.youtube.com/watch?v=oNpAnBhgIIs&list=RDQM59OrwtIc-fE&start_radio=1

Molten Material Systems

- Molten material systems are characterized by a pre-heating chamber that raises the material temperatureto melting point so that it can flow through a delivery system.

The most well -known method for doing this is the Fused Deposition Modeling (FDM) material extrusion technology developed by the US company Stratasys.

Fused Deposition Modeling

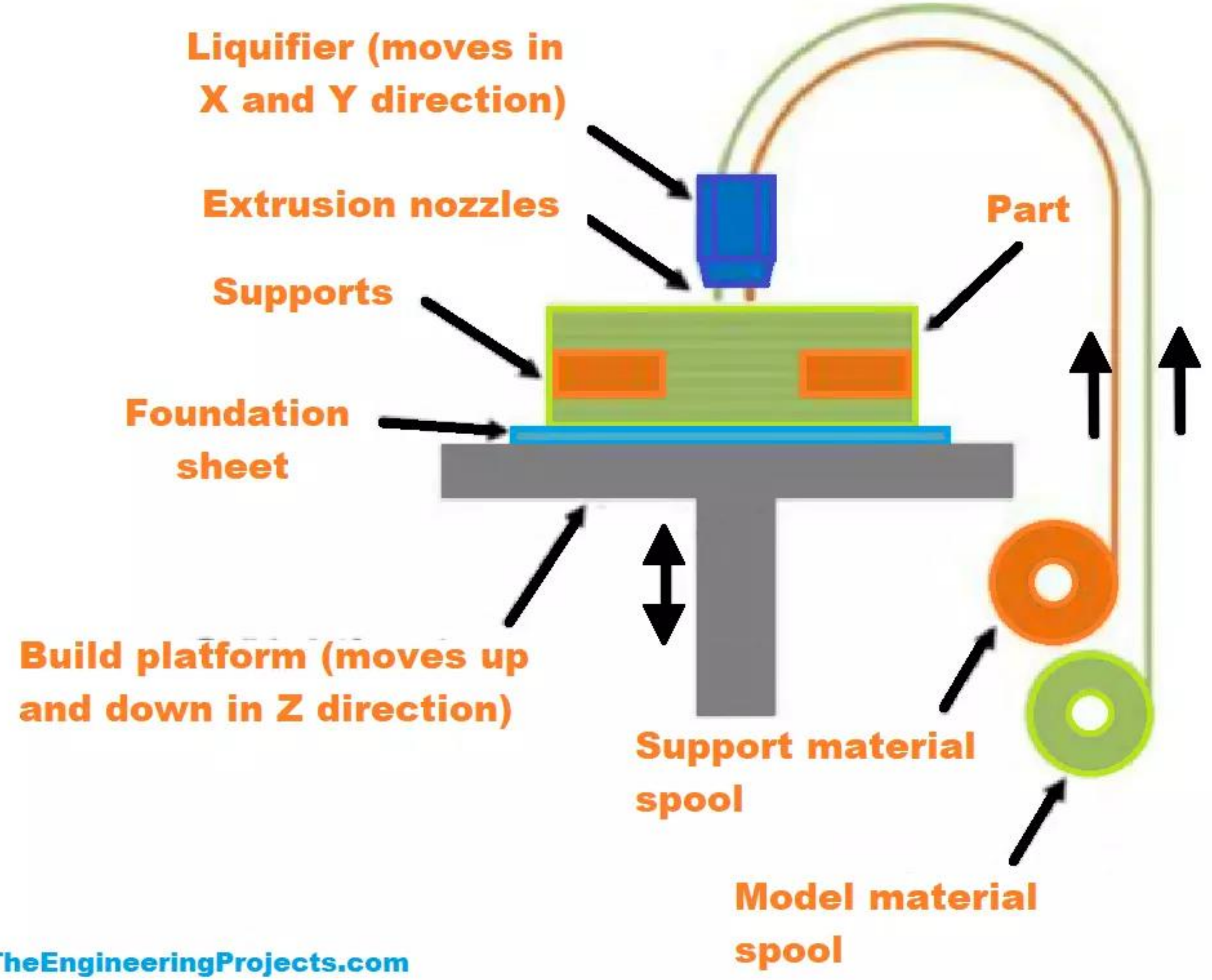
- FDM is a filament-based technology where a temperature-controlled head extrudes a thermoplastic material layer by layer onto a build platform.
- A support structure is created where needed and built in a water-soluble material.

FDM- Fused Deposition Modelling

•It is the most commonly used method of 3D printing these days.
•FDM is used for the production of 3D prototypes and small-scale end products as well.
•Thermoplastic material like Polyacetic acid is used in the process as the core material.
•A 3D object is printed in layers by heating the thermoplastic material and extruding it on the layers by extrusion nozzles.
•The liquefier head along with the extrusion nozzles moves in X and Y coordinates according to the instructions already fed into the printer depending on the design of the 3D object.
•Each layer when formed is consolidated with the layer beneath it which hardens by time.
•The Fused Deposition Model is quick and produces sturdy 3D products with sleek finishing.

https://www.youtube.com/watch?v=BFvmmrsgJxU

Fused Deposition Model FDM



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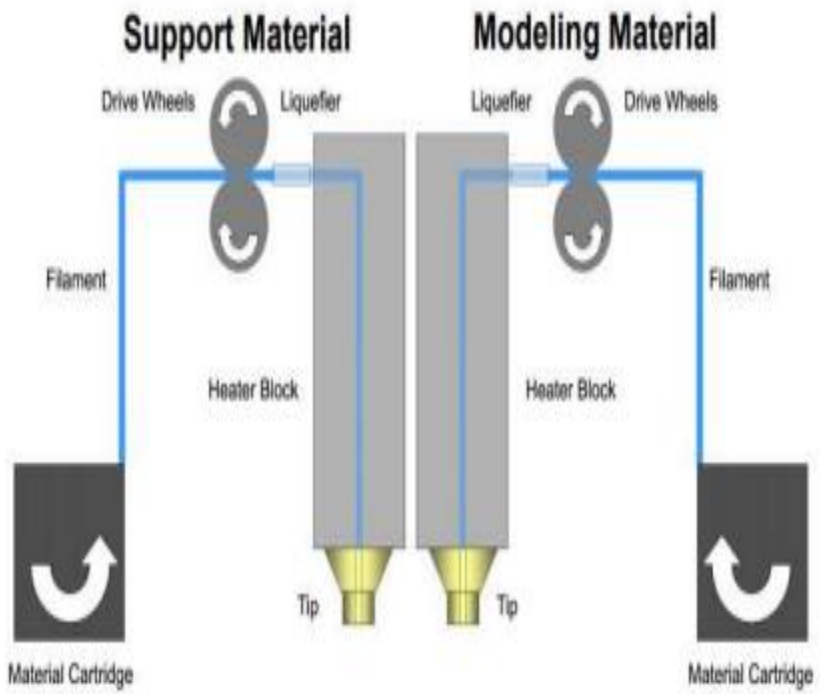
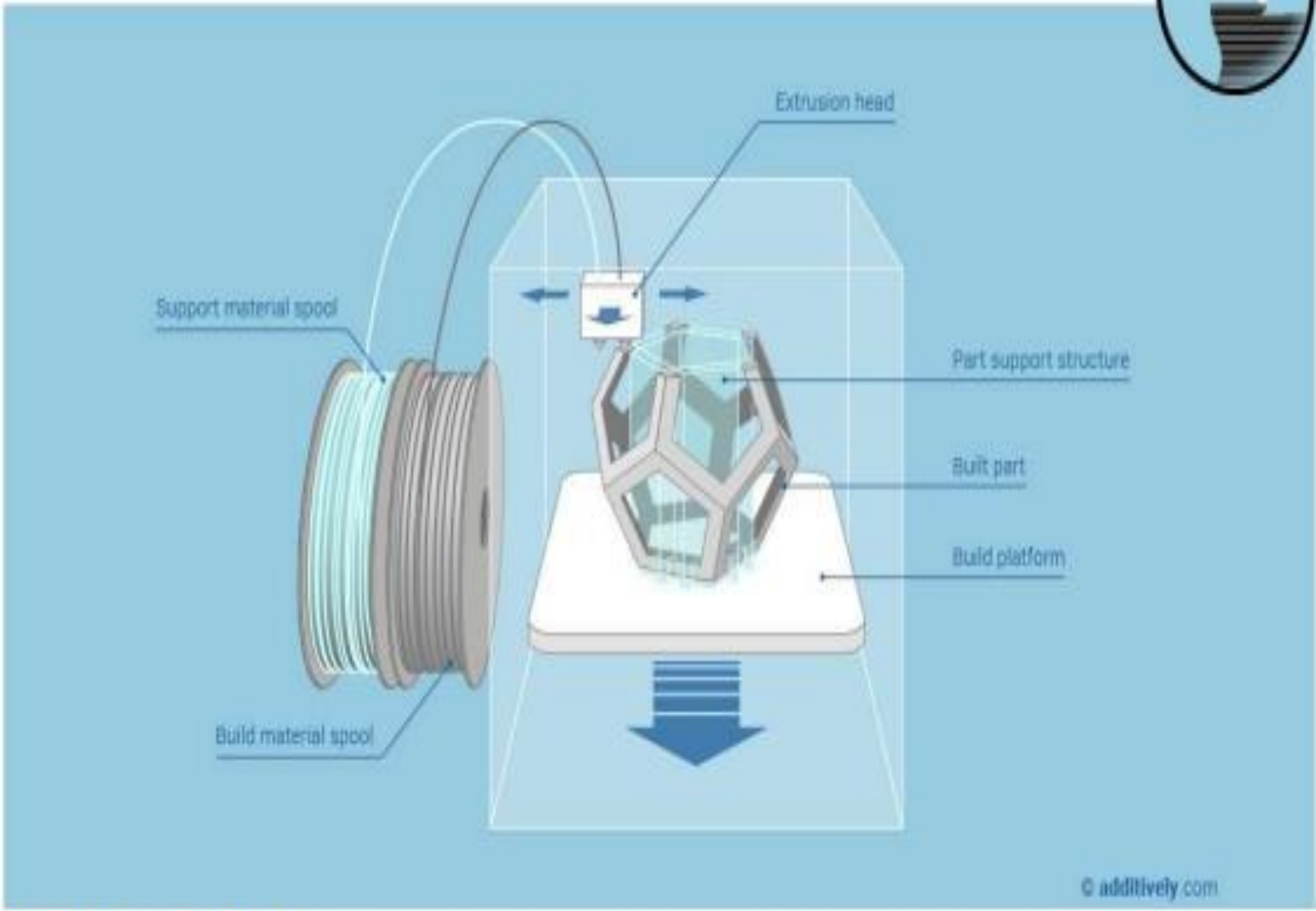
- Dual extruder machines exist
  - Temporary support structures can be made from water-soluble material
  - Two colors





Application areas

Prototypes are produced for form / fit and functional testing in standard materials by FDM

Support parts (jigs, fixtures, helps) can be produced directly

Small series parts down to one of a kind are built in standard materials by fused deposition modeling

Solid Sheet Systems

- One of the earliest AM technologies was the Laminated Object Manufacturing (LOM) system from Helisys, USA.
- This technology used a laser to cut out profiles from sheet paper, supplied from a continuous roll, which formed the layers of the final part.
- Layers were bonded together using a heat-activated resin that was coated on one surface of the paper. Once all the layers were bonded together the result was very much like a wooden block.

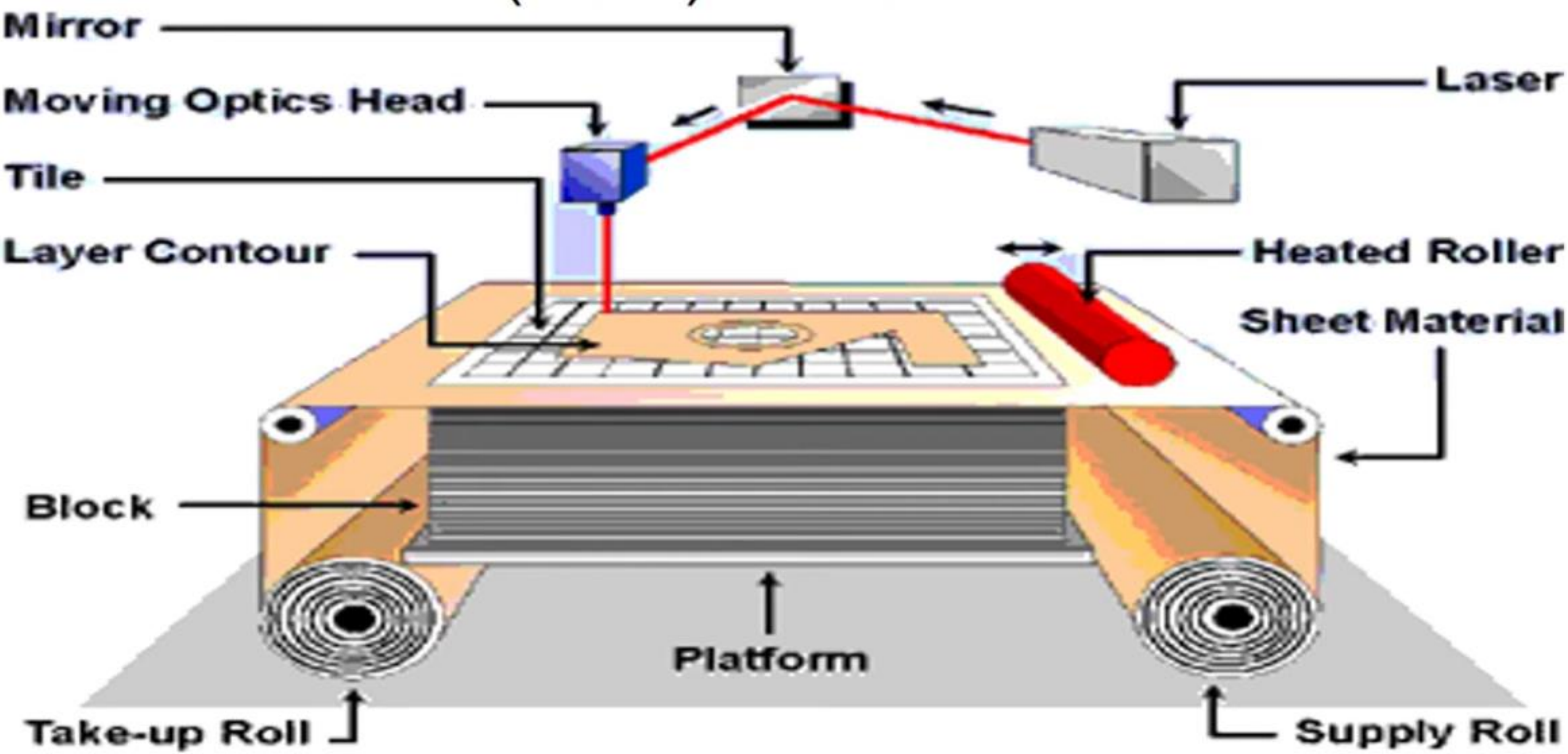
Laminated Object Manufacturing

- Laminated Object Manufacturing (LOM) is a process that combines additive and subtractive techniques to build a part layer by layer.
- In this process the materials come in sheet form. The layers are bonded together by pressure and heat application and using a thermal adhesive coating.
- A carbon dioxide laser cuts the material to the shape of each layer given the information of the 3D model from the CAD and STL file.
- The advantages of this process are the low cost , no post processing and supporting structures required, no deformation or phase change during the process, and the possibility of building large parts.
- The disadvantages are that the fabrication material is subtracted thus wasting it, low surface definition, the material is directional dependent for machinability and mechanical properties, and complex internal cavities are very difficult to be built.
- This process can be used for models with papers, composites, and metals

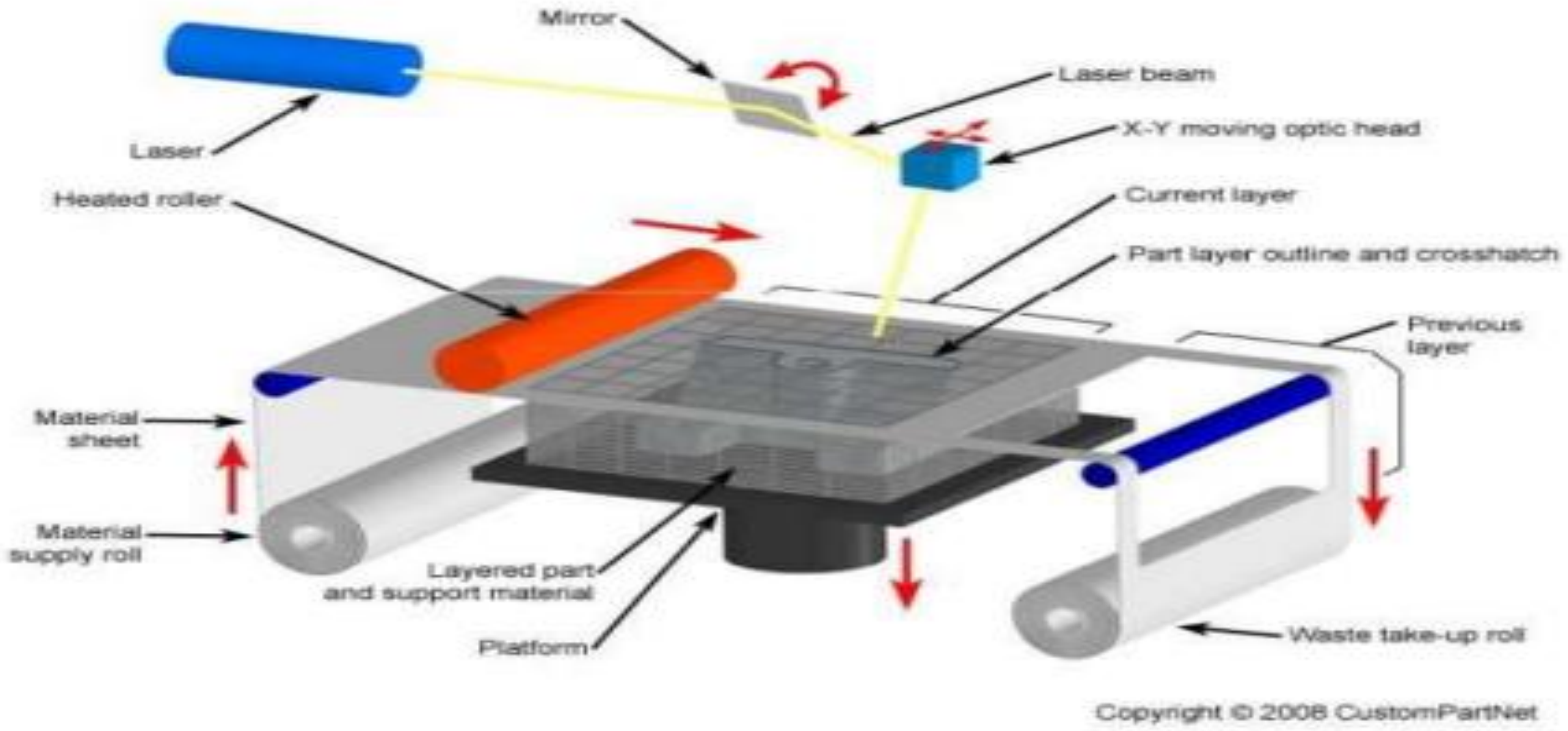
LOM- Laminated Object Manufacturing

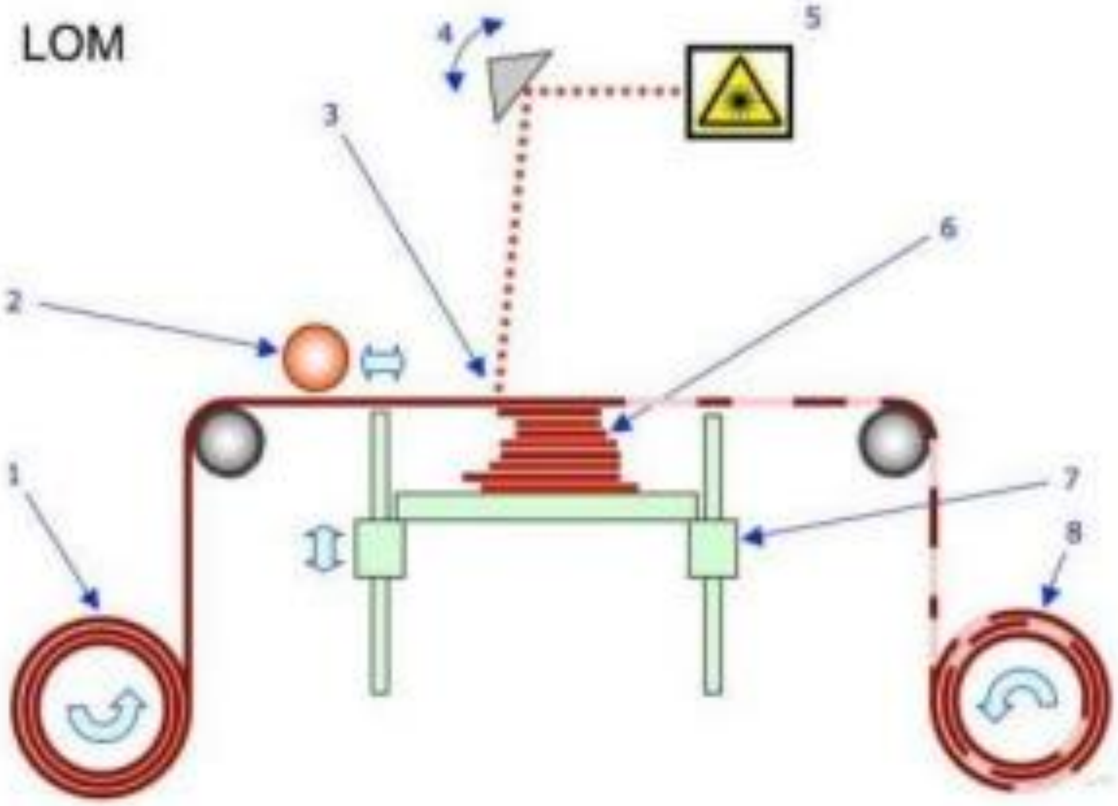
- As the name suggests, laminated object Manufacturing makes use of laminated sheets coated with adhesive material.
- The sheets can be made of plastic or paper according to the requirement of the 3D model.
- All the laminated sheets are glued together under specific temperatures and pressure.
- The laminated sheets are then cut into the desired 3D shape with the help of a laser or anything other cutting-edge technology.
- This is one of the outdated methods of 3D printing which aren't used today.
- https://www.youtube.com/watch?v=GUvnz0borAI

LAMINATED OBJECT MANUFACTURING (LOM) Process



Laminated Object Manufacturing





1 Foil supply. 2 Heated roller. 3 Laser beam. 4. Scanning prism. 5 Laser unit. 6 Layers. 7 Moving platform. 8 Waste.

- Sheet is adhered to a substrate with a heated roller
- Laser traces desired dimensions of prototype
- Laser cross hatches non-part area to facilitate waste removal
- Platform with completed layer moves down out of the way
- Fresh sheet of material is rolled into position
- Platform moves up into position to receive next layer

Advantages

- Ability to produce larger-scaled models.
- Uses very inexpensive paper
- Fast and accurate
- Good handling strength
- Environmentally friendly
- Not health threatening.

Disadvantages

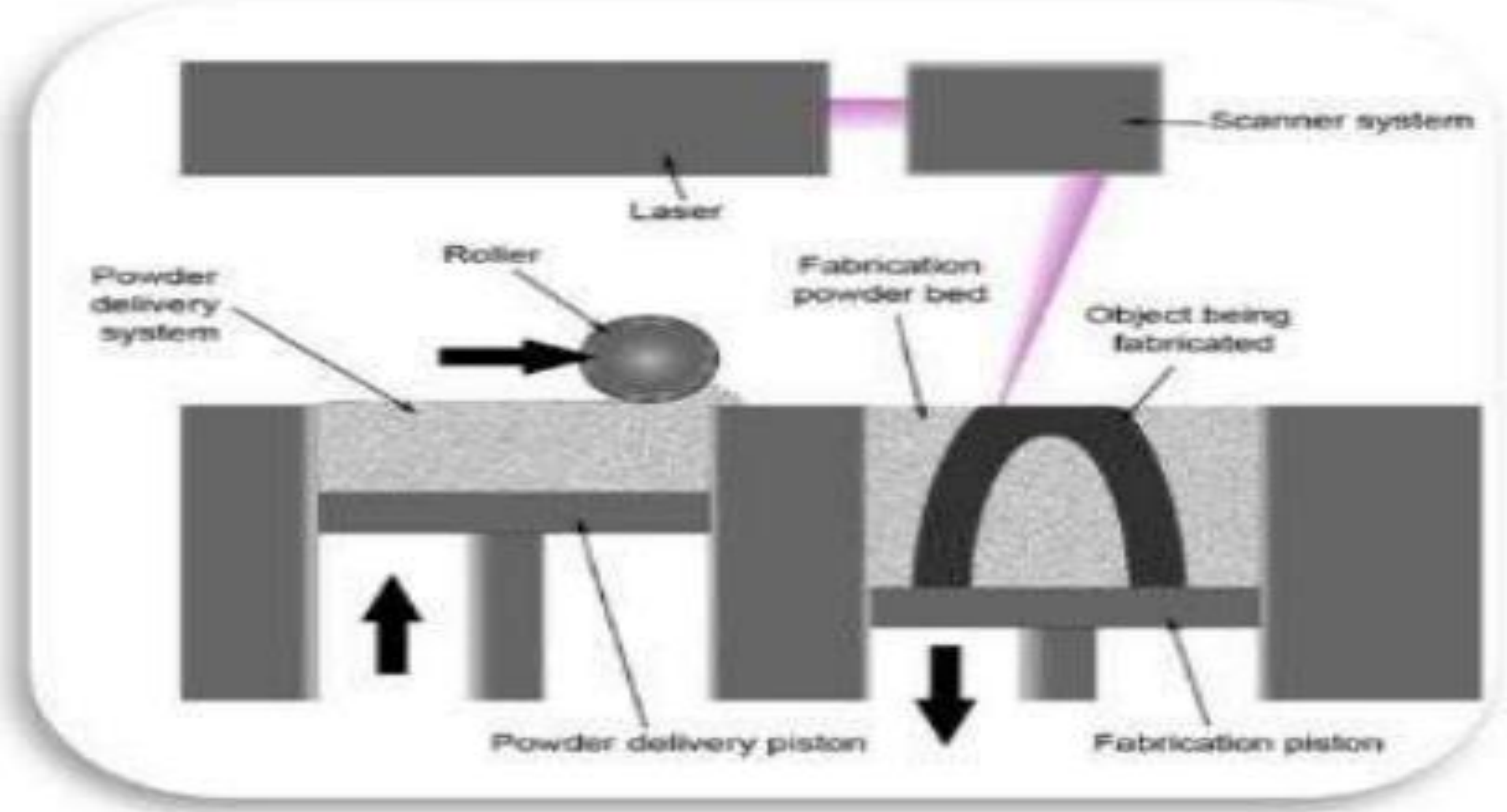
- Need for decubing, which requires a lot of labor
- Can be a fire hazard
- Finish, accuracy and stability of paper objects not as good as materials used with other RP methods

Typical Uses

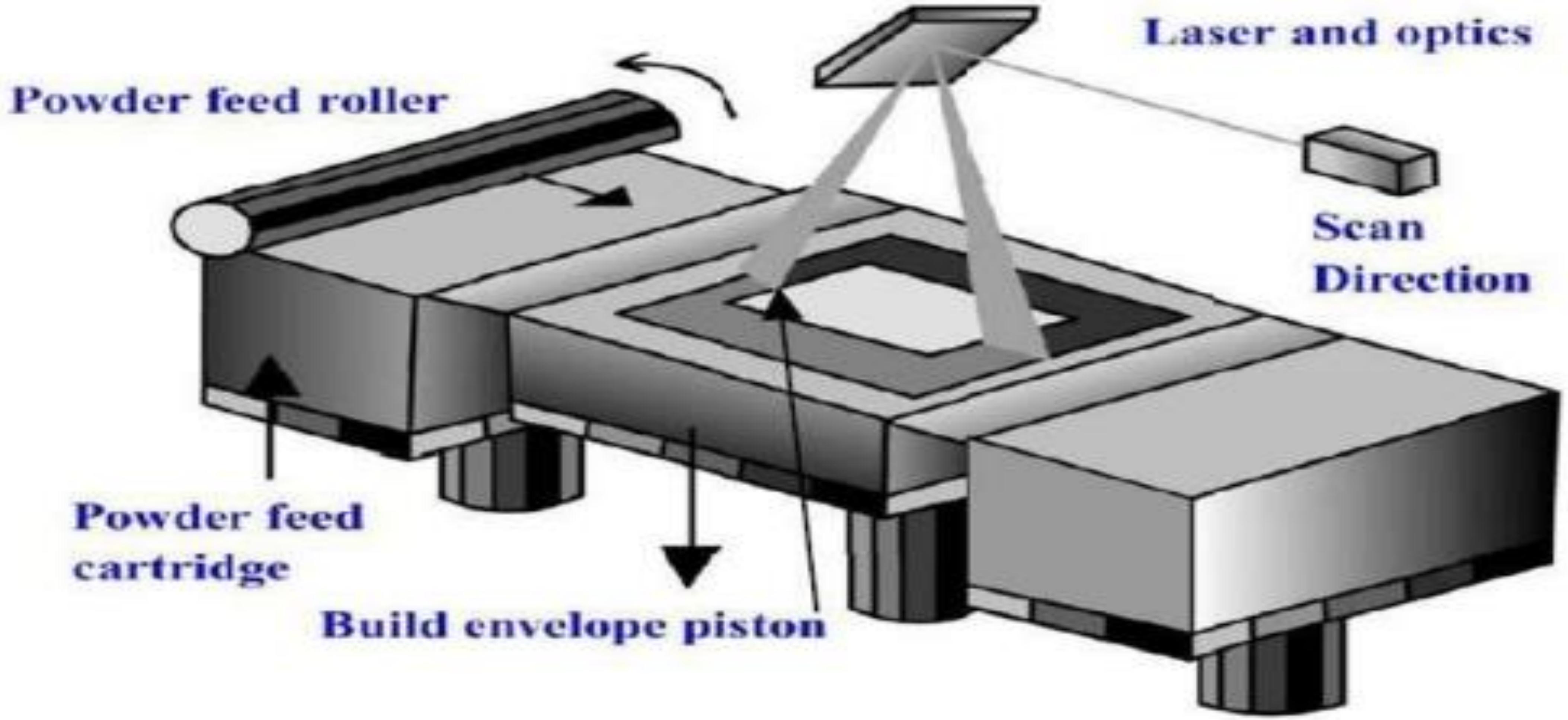
- Investment casting patterns
- Concept verification
- Masters for silicone-rubber injection tools
- Fit-check
- Direct use

Powder Bed Fusion Processes

Selective Laser Sintering(SLS)



Powder Bed Fusion Processes



Powder Bed Fusion Processes

- Selective Laser Sintering (SLS), the most prominent of the powder bed fusion processes, was originally developed at the University of Texas at Austin.
- In SLS a layer of powdered material is spread out and levelled over the top surface of the growing structure.
- A laser then selectively scans the layer to fuse those areas defined by the geometry of the cross-section; the laser energy also fuses layers together.
- The unfused material remains in place as the support structure. After each layer is deposited, an elevator platform lowers the part by the thickness of the layer, and the next layer of powder is deposited.
- When the shape is completely built up, the part is separated from the loose supporting powder.

Post processing of AM parts

- Post-processing is an essential stage of additive manufacturing. It's the last step in the manufacturing process, where parts receive finishing touches such as smoothing and painting.
- Why is post-processing important?
- Post-processing improves the quality of parts and ensures that they meet their design specifications.
- The finishing process can enhance a part's surface characteristics, geometric accuracy, aesthetics, mechanical properties, and more. For samples and prototypes, this can mean the difference between a sale or a loss.
- For production parts, finishing creates a part that is ready to use.

AM Applications

1. **Rapid Prototyping**

- Models and parts for research purposes can be easily manufacture whenever required. Easy to make changes in the models as per the research proceedings.

2. **Food**

- Cornell Creative Machines Lab is making food items such as chocolates, candy, pasta, pizza using 3D printing technique since 2012.

3. **Apparel**

- Products such as customize shoes, clothes and eye wears are being manufactured. •Nike is using 3D printing to manufacture the "Vapor Laser Talon" football shoe for players of American football

4. Vehicle

- In 2010 Urbee became the first car whose whole body was 3D printed (by US engineering group Kor Ecologic and the company Stratasys).
- In early 2014, Swedish supercar manufacturer, Koenigsegg ,manufactured a supercar having many 3D printed mechanical parts in it.

5. Firearms

Defense arms such as guns, rifles and safety equipment has also been manufacture by AM.

In 2012 US based group "Defense Distributed", designed a working plastic gun that could be downloaded and reproduced by anybody with a 3D printer.

In 2013, ,,Solid Concepts", based in Austin, Texas, US Asucceeded in manufacturing first working metal gun.

6. Medical

- •Nowadays medical devices, specific implants, hearing aids, dental products and pills are being manufacture by AM. •During October 2014, a five year old girl born without fully formed fingers on her left hand
- became the first child in the UK to have a prosthetic hand made with 3D printing . Till now more than 400 hands have been transplanted by E-NABLE.
- •In august 2015, US FDA (Food and Drug administration) approved 3D printed pills which allows very porous pills to be produced, which enables high drug doses in a single pill which dissolves quickly and can be ingested easily.
- Currently, active research is pursued by different groups to use cells and biomaterials by different print-heads to produce organs on demand. This might answer the organ shortage scenario in regenerative medicine application."