Three-Dimensional (3D) Printing Applied to General Public Use & Public Work Use

Lecture 1
Three-Dimensional (3D) Printing Technologies

by

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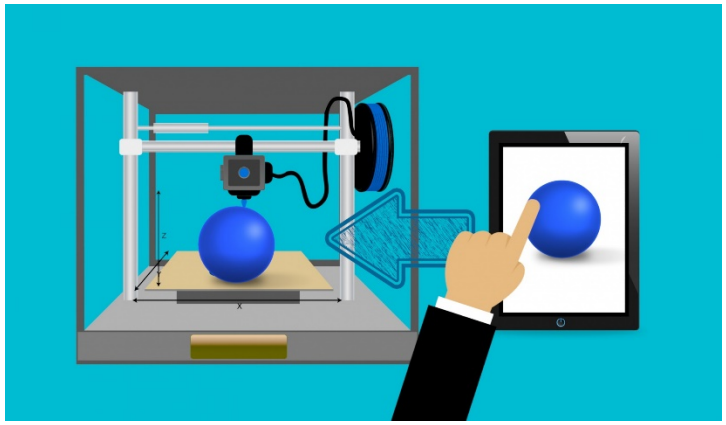
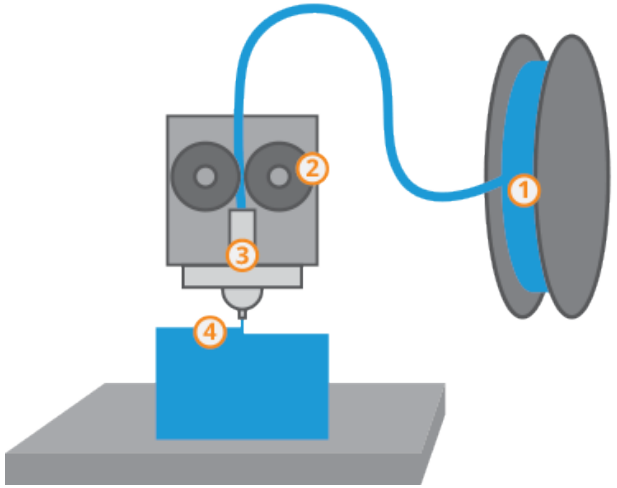
This OER material was produced as a result of the PIT-UN network Challenge Grant – New America

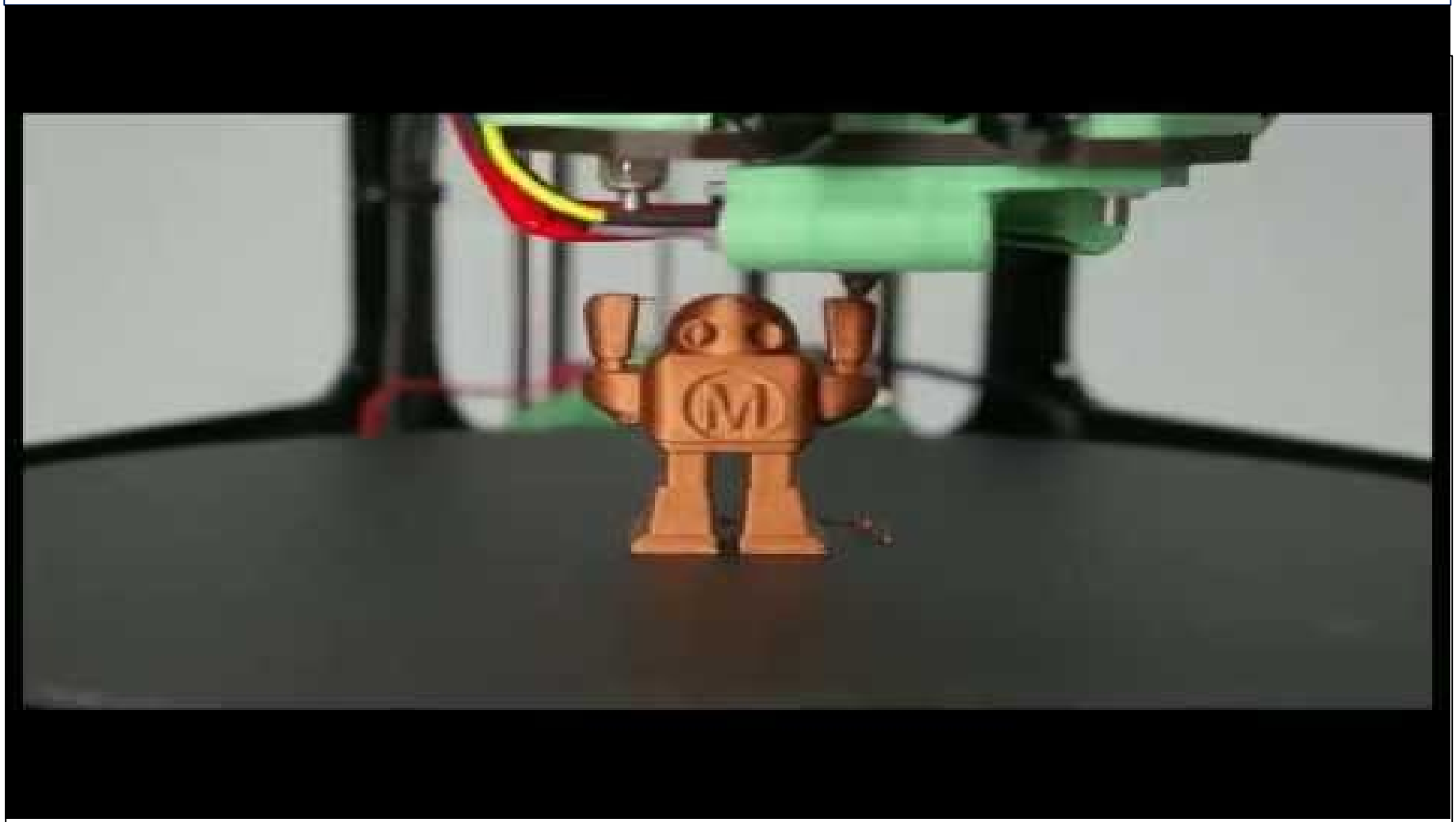
Three Dimensional (3D) Printing

- 3D Printing, or Additive Manufacturing, is the construction of a three-dimensional object from a Computer Aided Design (CAD) model or a digital 3D model.
- The term "3D Printing" can refer to a variety of processes in which material is joined or solidified under computer control to create a three-dimensional object, with material being added together (such as liquid molecules or powder grains being fused together), typically layer by layer.





Robot 3D Print Timelapse on RepRapPro Fisher 3D Printer



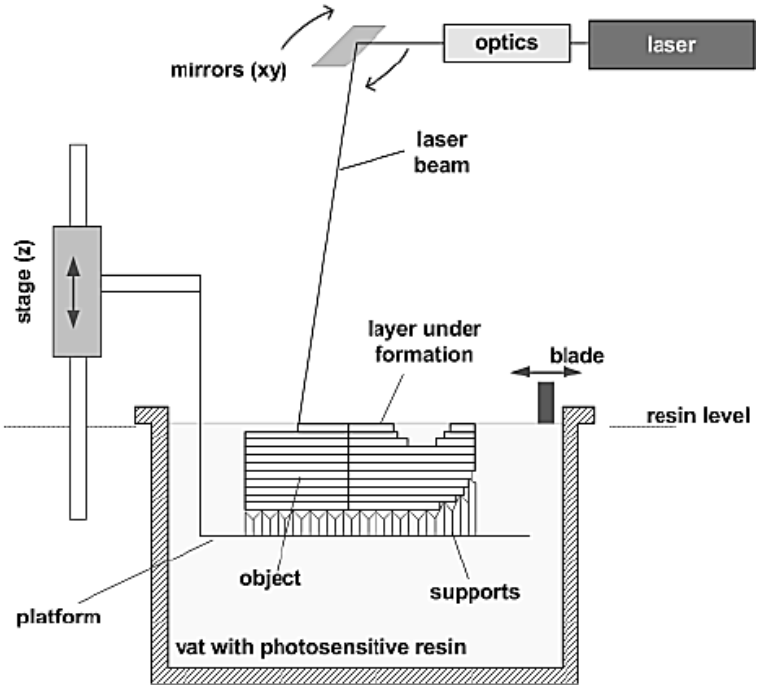
https://www.youtube.com/watch?v=r5nDrae3gJg

Types of 3D Printing Technology

1. Stereolithography
2. Fused Deposition Modeling (FDM)
3. PolyJet
4. MutiJet Fusion
5. Direct Metal Laser Sintering
6. Selective Laser Sintering
7. Laminated Object Manufacturing

Stereolithography, 1

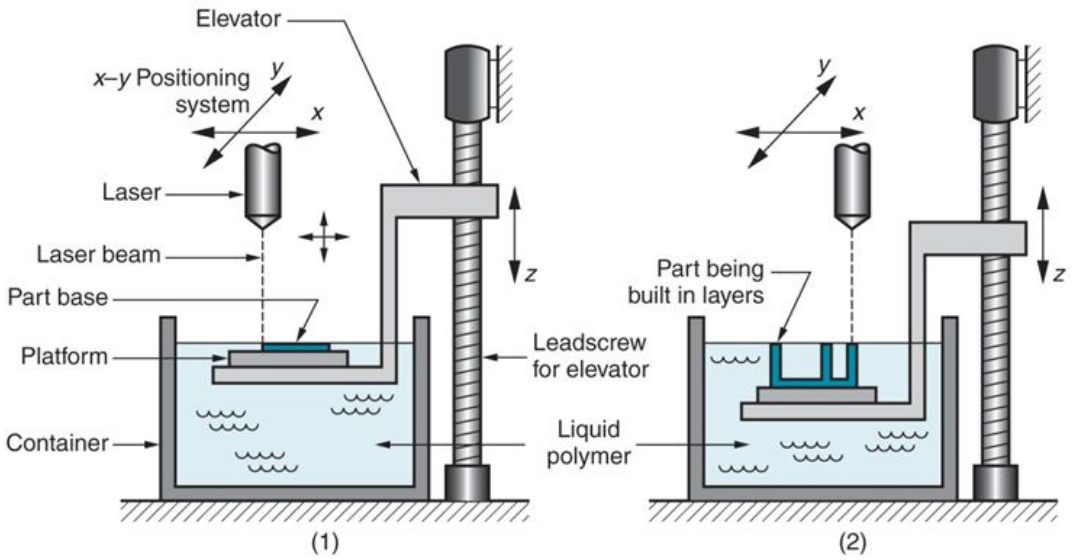
- Part under construction is supported by the platform
- Platform moves downward by a layer thickness (0.1 mm / 0.004 inch) for each layer
- Laser beam traces out the shape of each layer and hardens the resin



Stereolithography, 2

Stereolithography

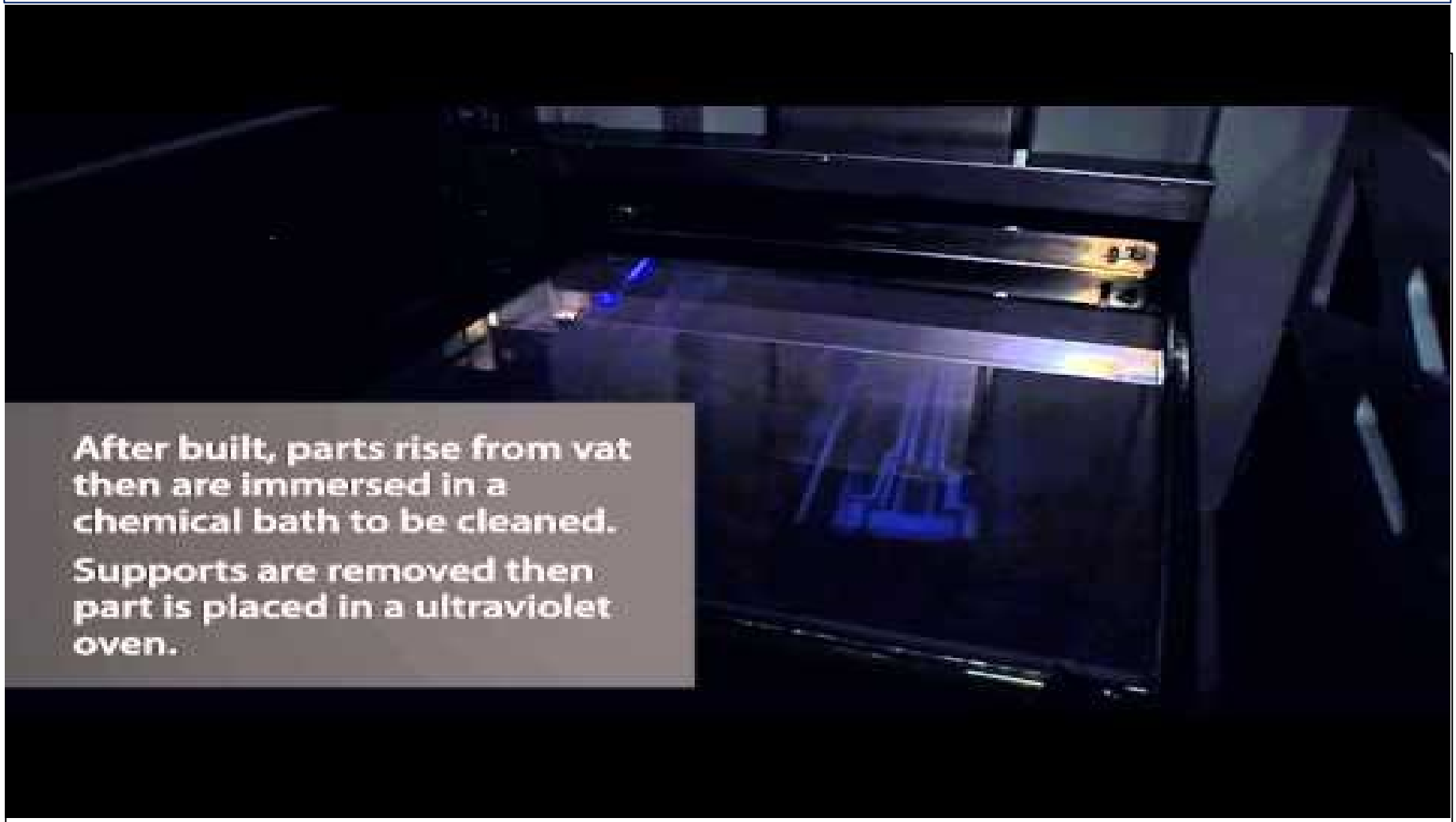
1. At start of the process, in which the initial layer is added to the platform; and
2. After several layers have been added so that the part geometry gradually takes form



Stereolithography, 3

https://www.youtube.com/watch?v=yW4EbCWaJHE

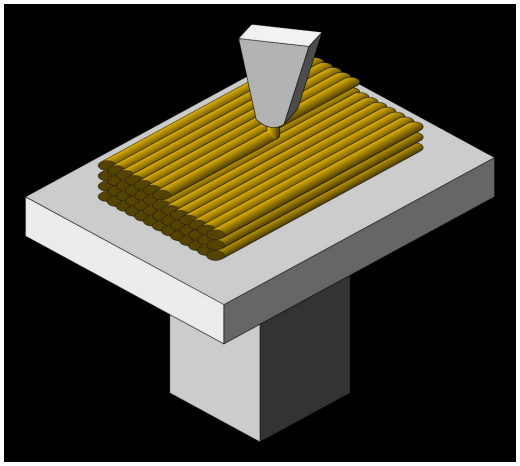
Stereolithography, 4

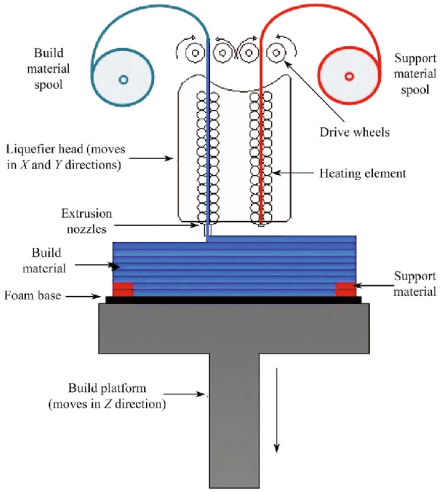


https://www.youtube.com/watch?v=FtmgKYyeXnA

Fused Deposition Modeling (FDM), 1

- Fused deposition modeling (FDM), or Fused Filament Fabrication (FFF), is a 3D printing process that uses a continuous filament of a thermoplastic material.
- Filament is fed from a large spool through a moving, heated printed extruder head, and is deposited on the growing work.
- The print head is moved under computer control to define the printed shape.
- The head moves in two dimensions to deposit one horizontal plane, or layer, at a time; the work or the print head is then moved vertically by a small amount to begin a new layer.

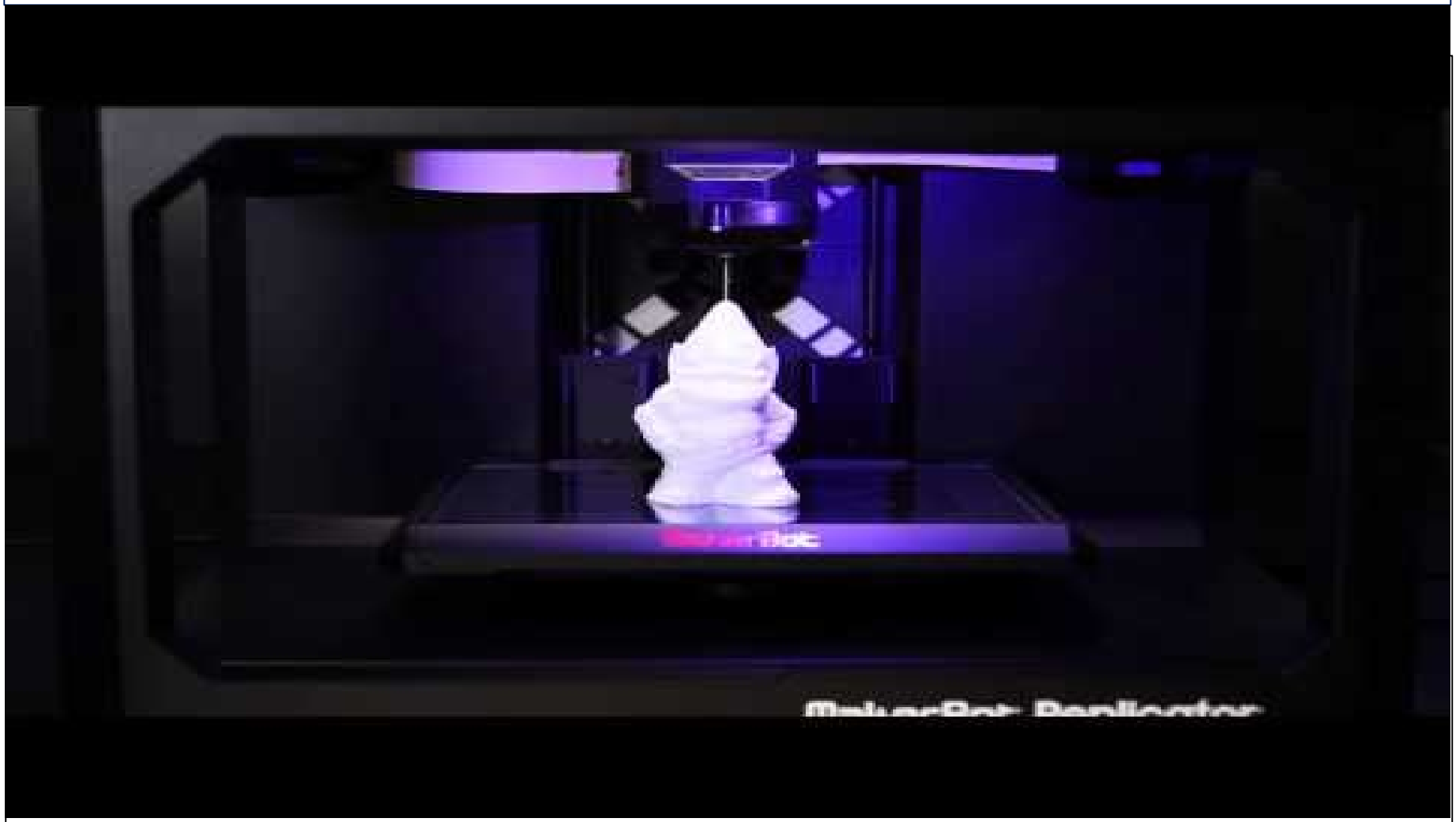




Fused Deposition Modeling (FDM), 2

https://www.youtube.com/watch?v=WHO6G67GJbM

MakeBot Relicator 5th Generation 3D Printer – FDM

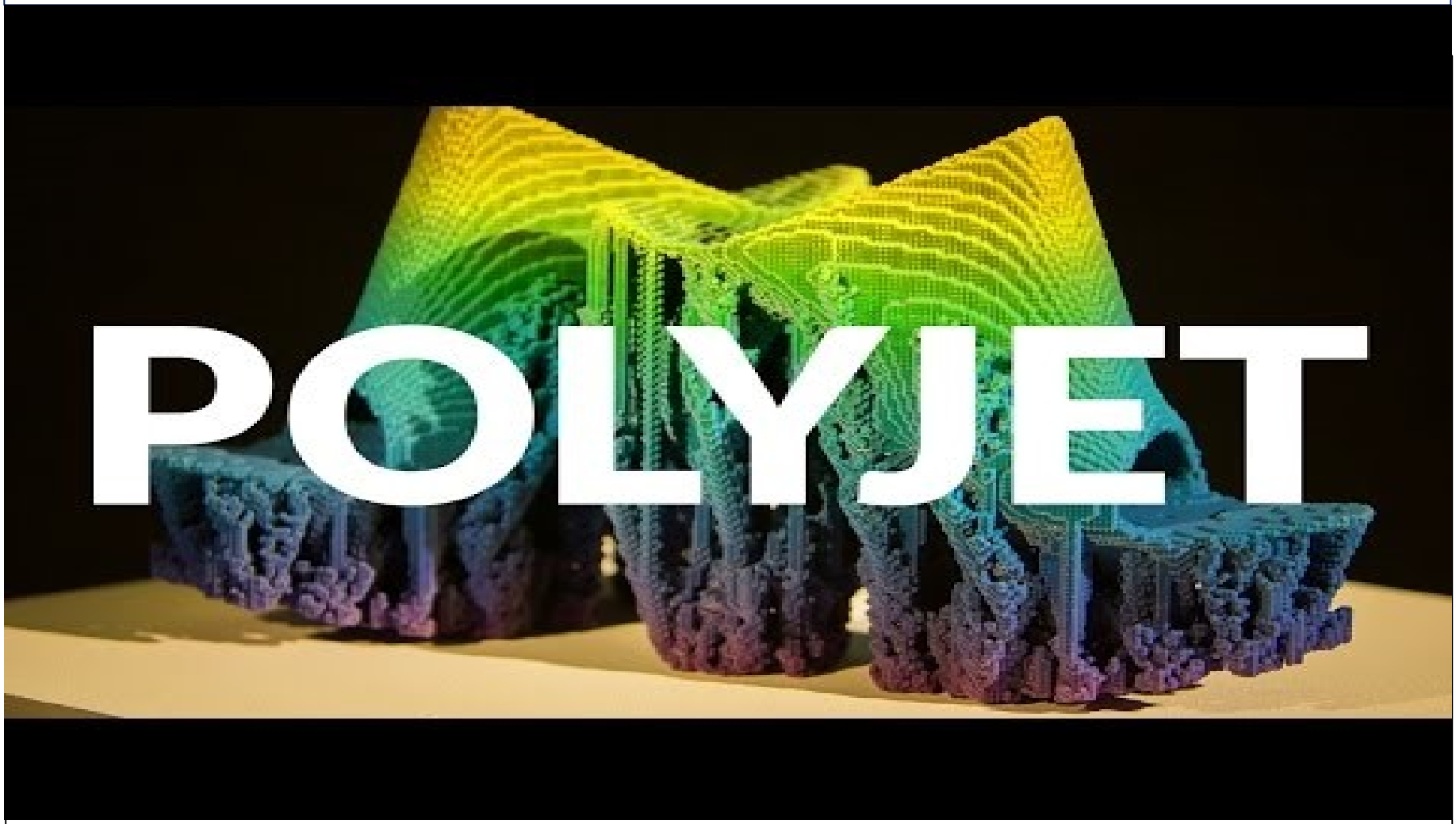


https://www.youtube.com/watch?v=ITK3j2QWpHw

PolyJet, 1

- PolyJet Technology, or Liquid Additive Manufacturing (LAM), is an additive manufacturing technique which deposits a liquid or highly viscous material (e.g. Liquid Silicone Rubber) onto a build surface to create an object, which is then vulcanized using heat to harden it.

PolyJet, 2



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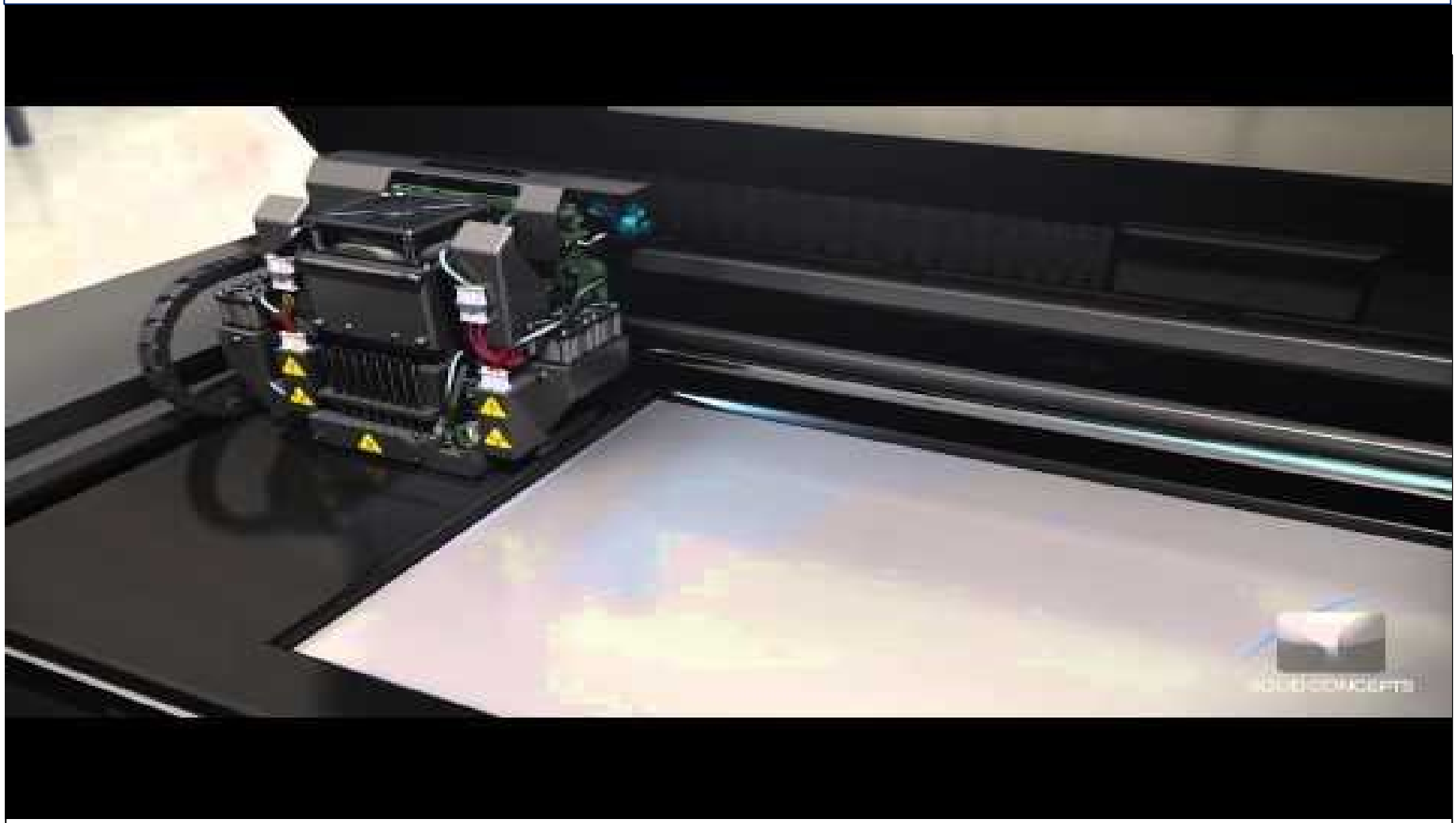
PolyJet, 3



https://www.youtube.com/watch?v=Som3CddHfZE

Stratasys J750 3D Printer – PolyJet

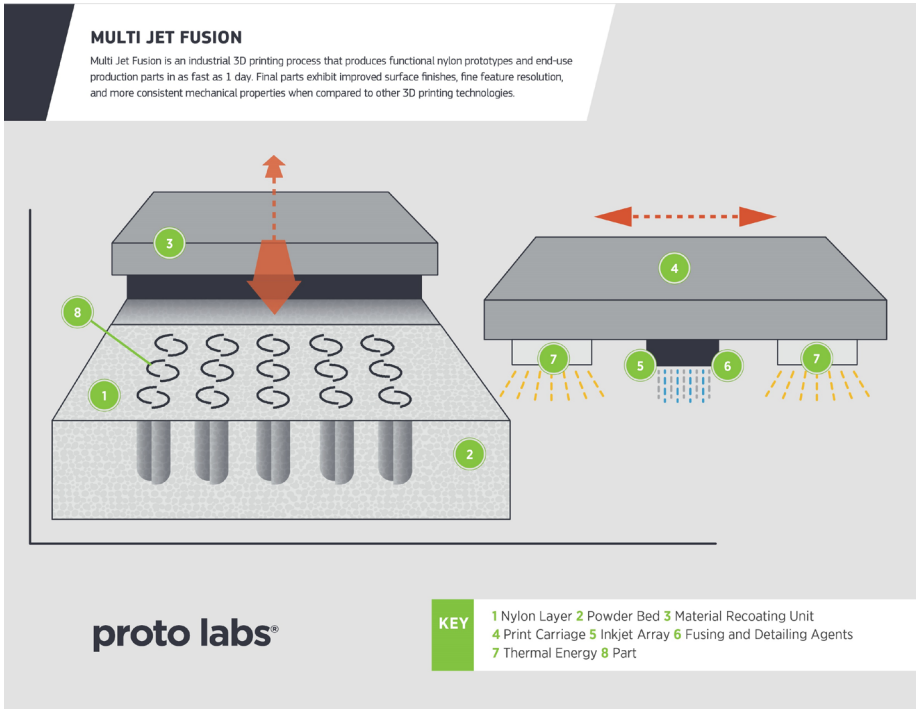
https://www.youtube.com/watch?v=fpUspPBUe9Y

Objet 1000 Printer – PolyJet

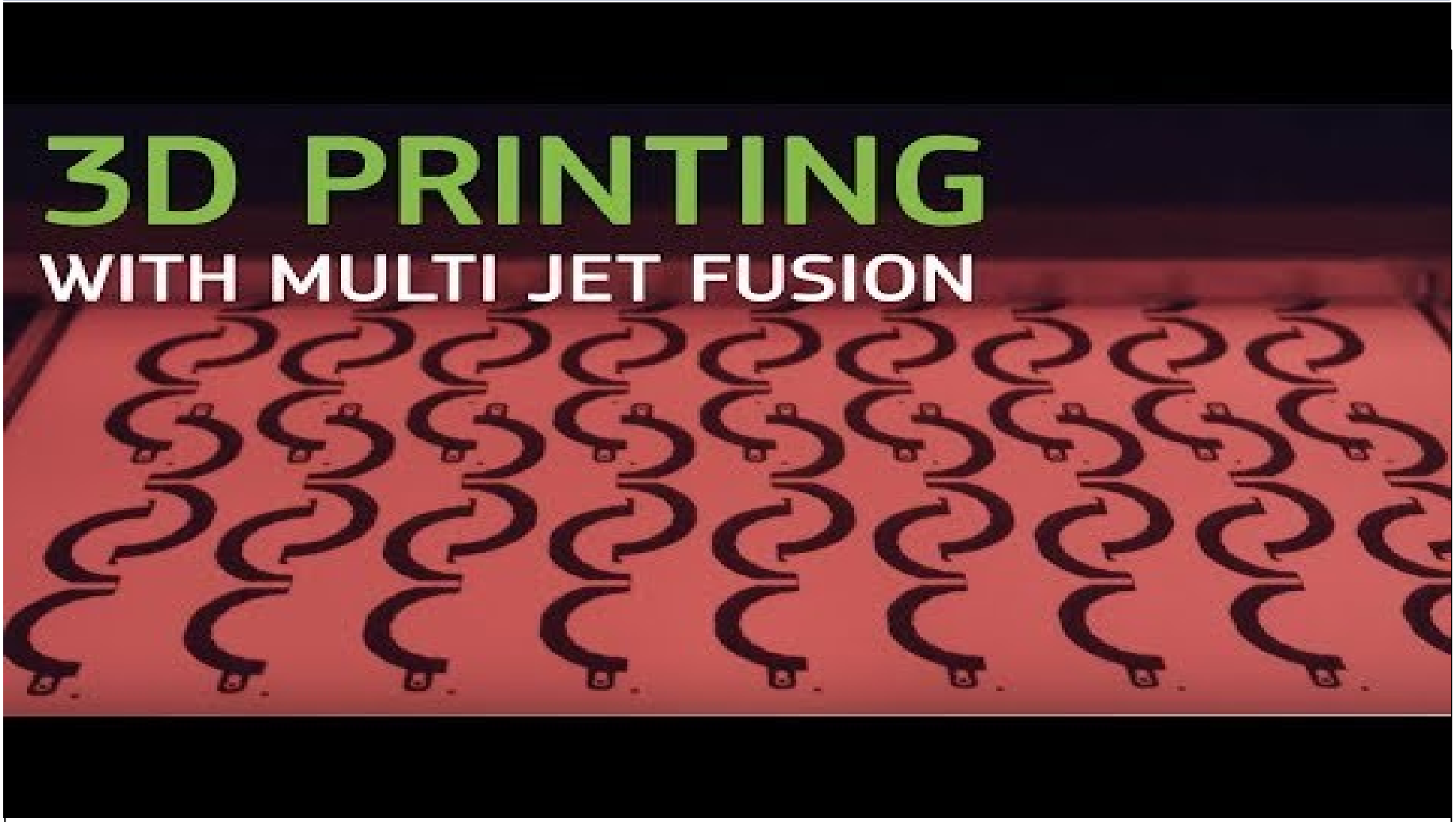
https://www.youtube.com/watch?v=jpTzjCfGSnM

MultiJet Fusion, 1

- MutiJet Fusion uses an inkjet array to selectively apply fusing and detailing agents across a bed of nylon powder, which are then fused by heating elements into a solid layer.
- After each layer, powder is distributed on top of the bed and the process repeats until the part is complete.



MutiJet Fusion, 2

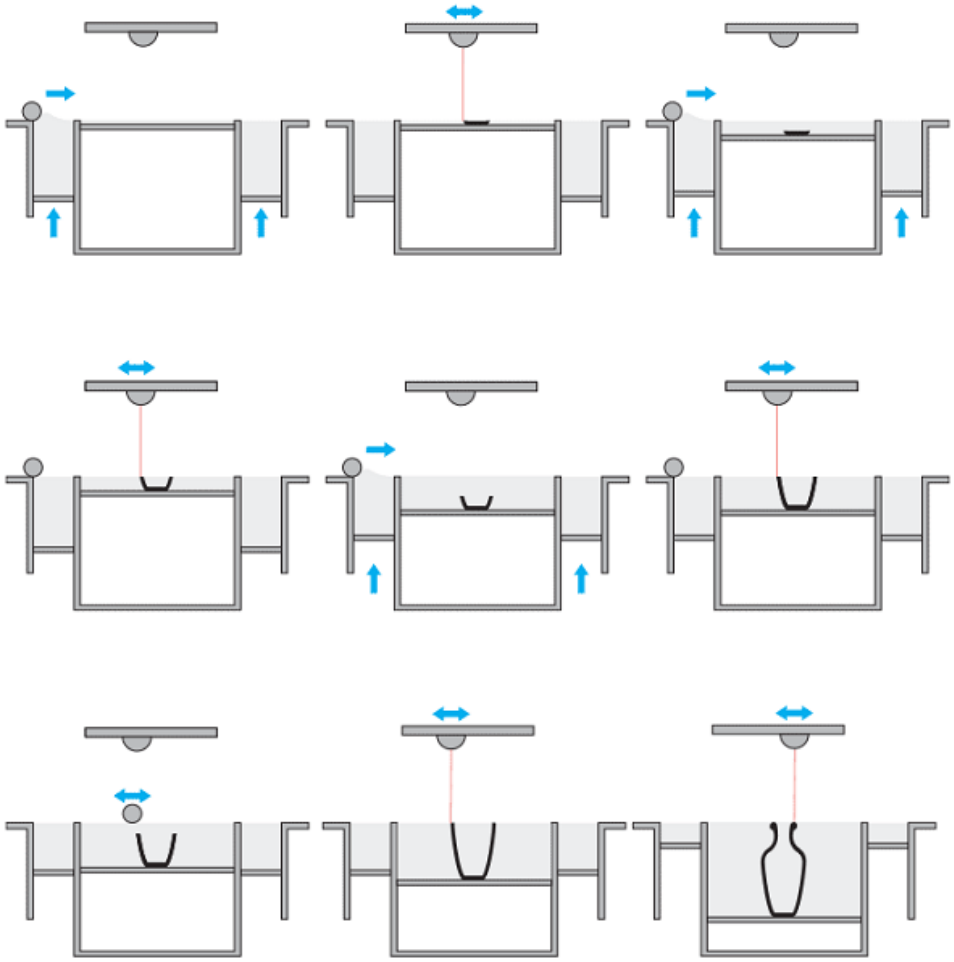


https://www.youtube.com/watch?v=dDIAtU65M6Y

Direct Metal Laser Sintering, 1

- Direct metal laser sintering is one of the most fascinating 3D printing techniques that allow printing 3D designs in metals such as aluminum or titanium.
- To create your 3D print, a laser in the printer melts the powder together.
  1. A super-thin layer of aluminum or titanium powder is spread out by a roller.
  2. The print chamber of the 3D printer is then heated up. However, the powder does not melt yet since it has not reached its melting point.
  3. A laser touches those areas of the layer that are part of the design, raising the temperature of those areas just above the melting point. The part is sintered.
  4. The 3D printer continues to spread out one layer of powder after another, and the laser will systematically touch the correct spots of each layer and sinter the object together.

Direct Metal Laser Sintering, 2



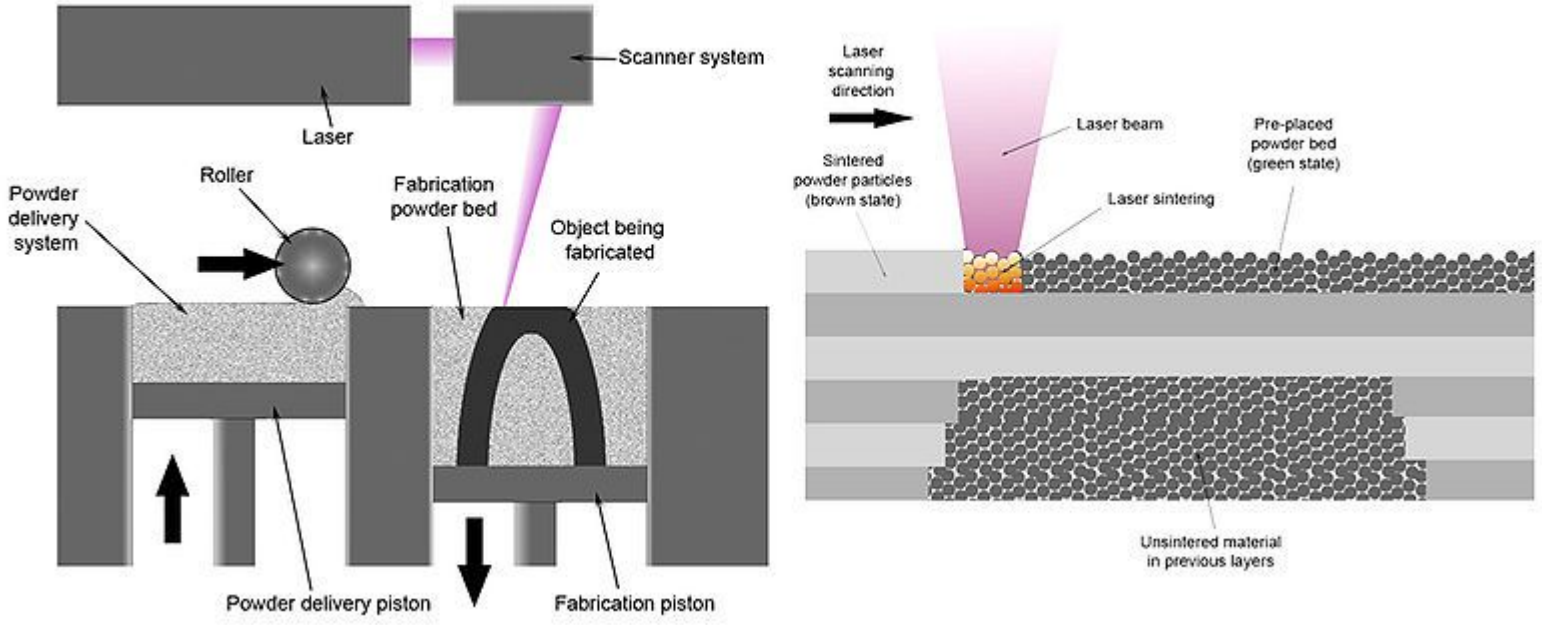
Section view of the DMLS 3D printing process.

Direct Metal Laser Sintering, 3

https://www.youtube.com/watch?v=yiUUZxp7bLQ

Selective Laser Sintering, 1

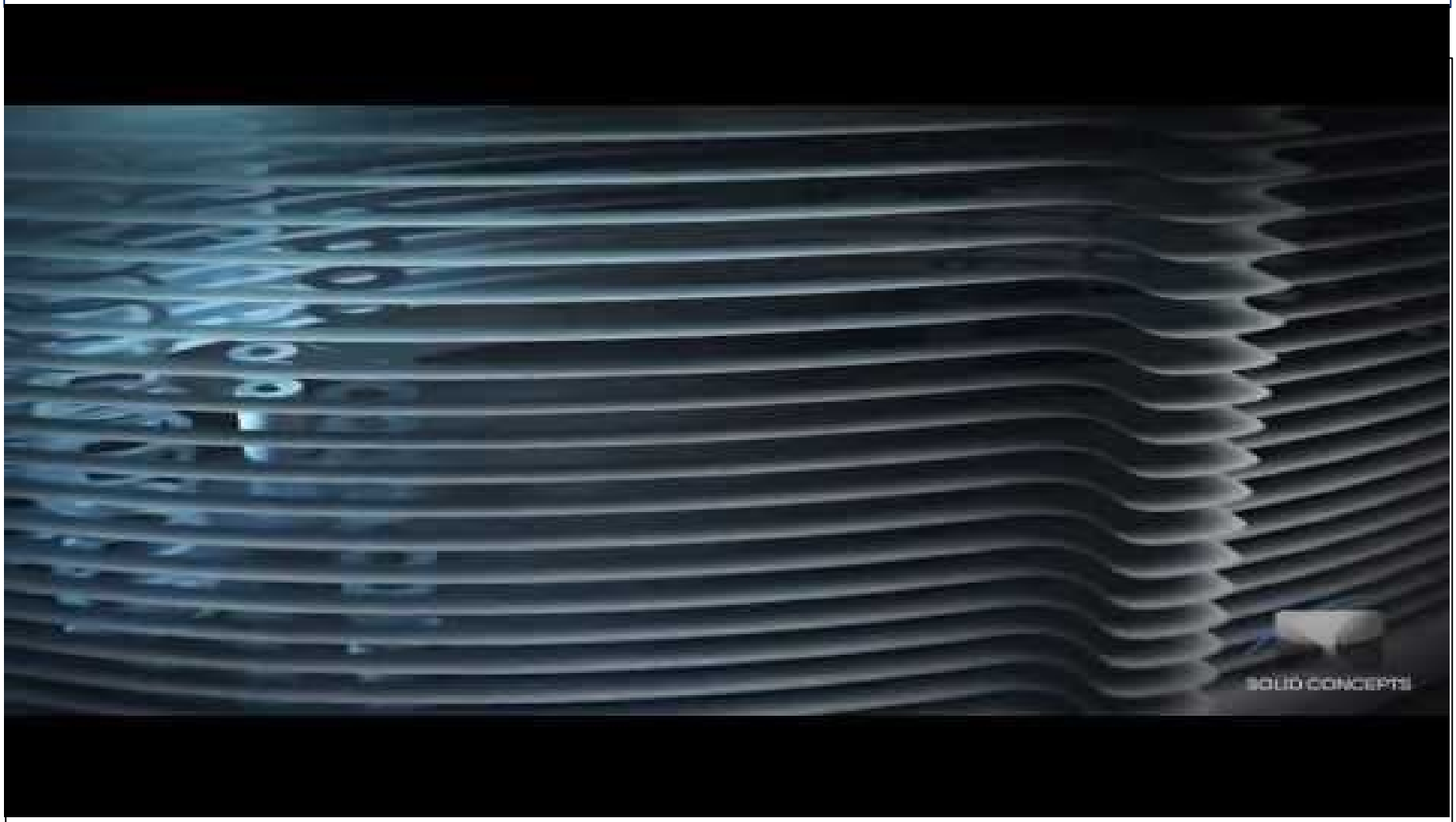
- Selective laser sintering (SLS) is an additive manufacturing (AM) technique that uses a laser as the power source to sinter powder material ((typically nylon or polyamide), aiming the laser automatically at points in space defined by a 3D model, binding the material together to create a solid structure.



Selective Laser Sintering, 2

https://www.youtube.com/watch?v=xorCFh-9EWA

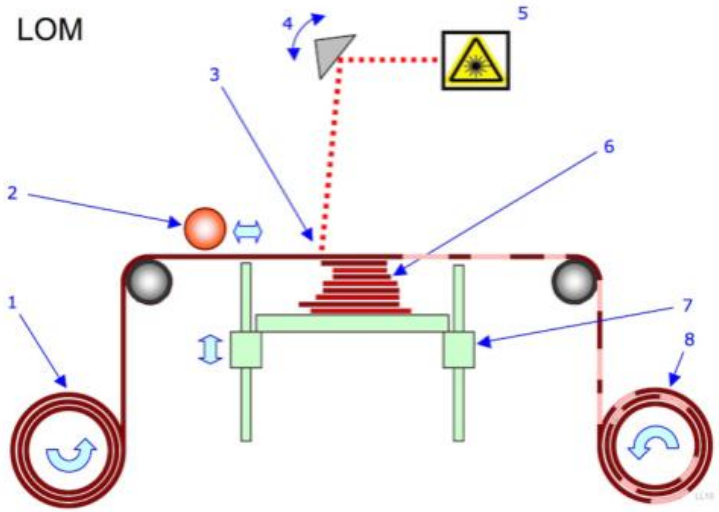
Selective Laser Sintering, 3



https://www.youtube.com/watch?v=9E5MfBAV_tA

Laminated Object Manufacturing, 1

- Laminated object manufacturing (LOM) is a rapid prototyping system.
- In it, layers of adhesive-coated paper, plastic, or metal laminates are successively glued together and cut to shape with a knife or laser cutter.



1. Sheet is adhered to a substrate with a heated roller.
2. Laser traces desired dimensions of prototype.
3. Laser cross hatches non-part area to facilitate waste removal.
4. Platform with completed layer moves down out of the way.
5. Fresh sheet of material is rolled into position.
6. Platform downs into new position to receive next layer.
7. The process is repeated.

Laminated Object Manufacturing (LOM) Technology

Laminated Object Manufacturing, 2

https://www.youtube.com/watch?v=GjJKuteh4xM

Major Types of 3D Printing Materials

1. Plastics
2. Metals
3. Ceramics
4. Paper
5. Bio Materials
6. Food
7. Other proprietary materials

Plastics

Metal Powder

Paper Pulp 3D Printing

Ceramic Powder

Bio Material 3D Printing

Pasta 3D Printing

Common 3D Printing Materials

Thermoplastic (plastics) Materials

1. Acrylonitrile Butadiene Styrene (ABS)
2. Polylactic Acid (PLA)
3. Acrylonitrile Styrene Acrylate (ASA)
4. Polyethylene Terephthalate (PET)
5. Polycarbonate (PC)

ABS

PET

PLA

Composite Materials

1. Carbon Fiber Composite

Carbon Fiber Composite

Powder Materials

1. Metal powders
2. Ceramic powders
3. Composite powders

PC

ASA

Basic Steps of 3D Printing

1. Design and create a 3D model using Computer Aided Design (CAD) software including SolidWorks.
2. Convert design file to STL file format.
3. Transfer file to 3D printing machine.
4. Setup 3D printing machine.
5. Build part by the machine.
6. Remove part from the machine.
7. Clean part in post-processing.
8. Apply treatments/applications

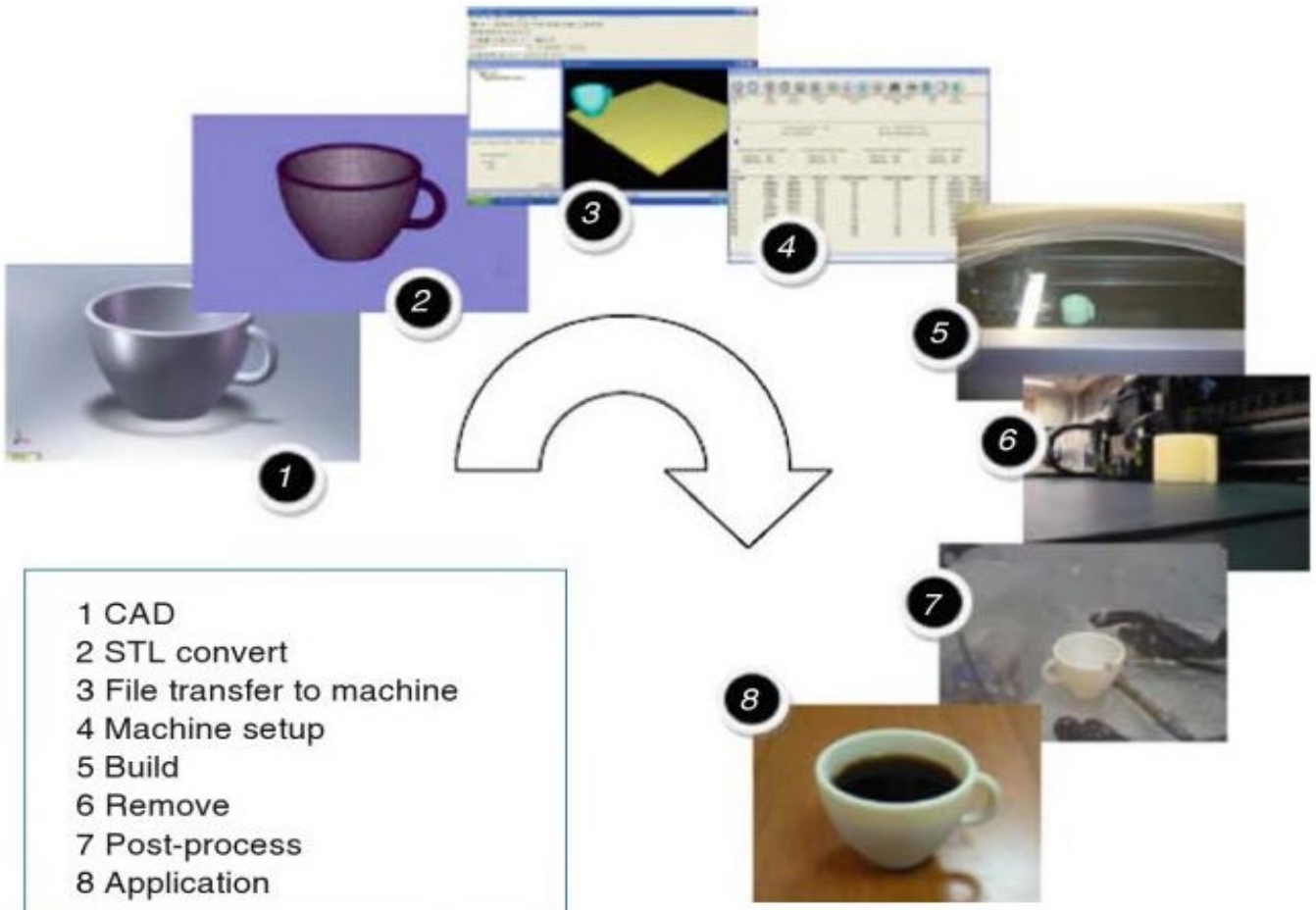
General 3D Printing Steps, 1

1. Computer-Aided Drawing (CAD)
   - Create a CAD solid model, a computerized 3-dimensional virtual object, from design concept
   - Any CAD solid modeling software can be used to make a solid model.
   - Reverse engineering equipment (i.e. Laser scanning) can also be used to create this representation.
2. Conversion to STL file (**ST**ereo**L**ithography file)
   - Save CAD solid model as an STL file.
   - Almost every AM machine accepts STL file format – a standard.
   - Describe external closed surfaces of the original CAD model
   - Form the basis for calculation of the slices or layers.
3. Transfer to AM machine and STL file manipulation
   - STL file is converted into thin horizontal sections stacked on top of each other
   - The machine is now ready to read the modified file and build a 3D model
   - General manipulation of the file can be done to correct the size, position and orientation for building.

General 3D Printing Steps, 2

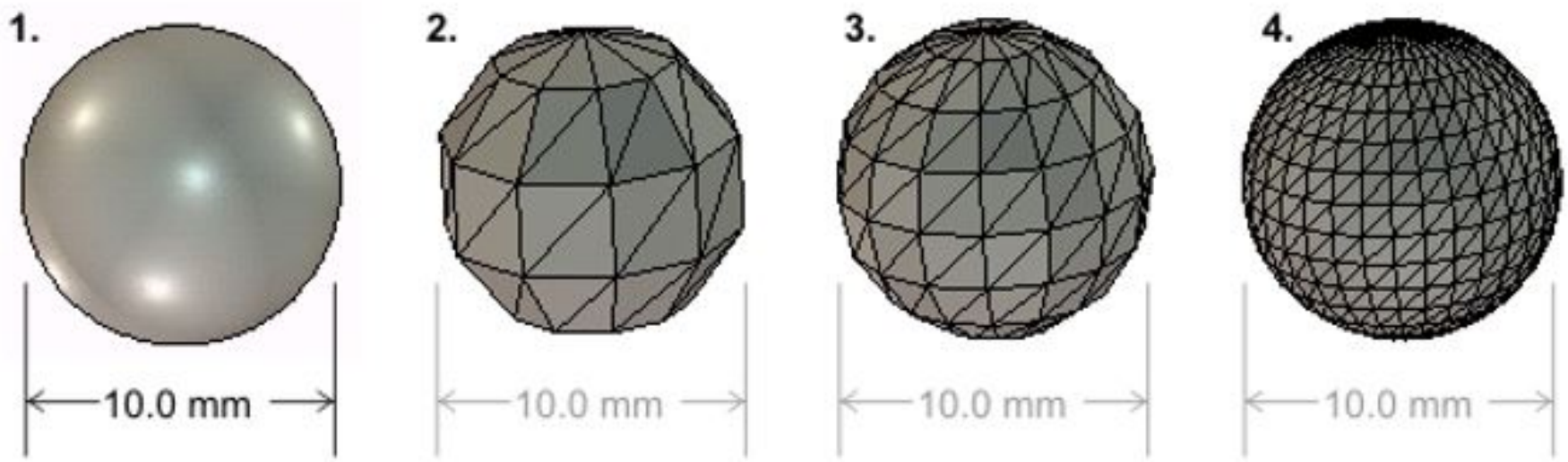
4. Machine setup
   - Set up additive manufacturing (AM) machine properly prior to the build process
   - Settings related to the build parameters like material constraints, energy source, layer thickness, timing, etc. can be adjusted.
5. Build
   - Building part is an automated process and machine can carry on without supervision.
   - Superficial monitoring is needed to ensure no errors of running out of material, power, or software glitches, etc.
6. Removal
   - Remove the part once the part is completed.
7. Post processing
   - Parts may require additional cleaning up before using.
   - Remove supporting features.
8. Application
   - The parts may require additional treatments, such as priming and painting, and assembly to give an acceptable surface texture and finish before application.

Basic Steps of 3D Printing



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

Printing Resolution



Intended Design

Lower Resolution With Facets, Small File

Best Possible Resolution

Very Fine Resolution With Large File

Effect of Layer Thickness

CAD Model

Thick Layers (coarse resolution)

Thin Layers (fine resolution)

Equipment in Advanced Manufacturing Lab of Queensborough Community College

1. MakerBot Replicator 5th Generation-Desktop 3D printer.
2. MakerBot Replicator Z18 3D printer
3. Stratasys uPrint SE Plus 3D printer
4. Stratasys Mojo 3D printer
5. Stratasys Fortus 450 mc 3D printer
6. Stratasys J750 3D printer
7. Stratasys Objet 30 Pro 3D printer
8. FARO Edge Scan Arm.
9. Zeiss Contura Coordinate Measuring Machine (CMM)

Summary of 3D Printers at Queensborough Community College

Printer	Makerbot Replicator 5th Generation	Makerbot Replicator Z18	Stratasys uPrint	Stratasys Fortus 450mc	Stratasys Mojo	Stratasys J750	Stratasys Objet 30
Print Technology	FDM	FDM	FDM	FDM	FDM	PolyJet	PolyJet
Build Size L W H, inch	11.6 7.6 6.5	11.8 12 18	8 8 6	16 14 16	5 5 5	19.3 15.35 7.9	11.57 7.5 5.85
Layer Resolution, inch	0.0039	0.0039	0.010 to 0.013	0.005	0.007	0.00055	0.0011

End of Lecture 1