Computational Fabrication

CS 491 and 591
Professor: Leah Buechley
https://handandmachine.cs.unm.edu/classes/Computational_Fabrication_Spring2021/

Weekly Designers: Emerging Objects

Virginia San Fratello & Ronald Rael

https://www.rael-sanfratello.com/
http://emergingobjects.com/

Rael San Fratello

Rael San Fratello

https://www.instagram.com/rrael/

Last Class: Slicers

The magic of multiple Turtles

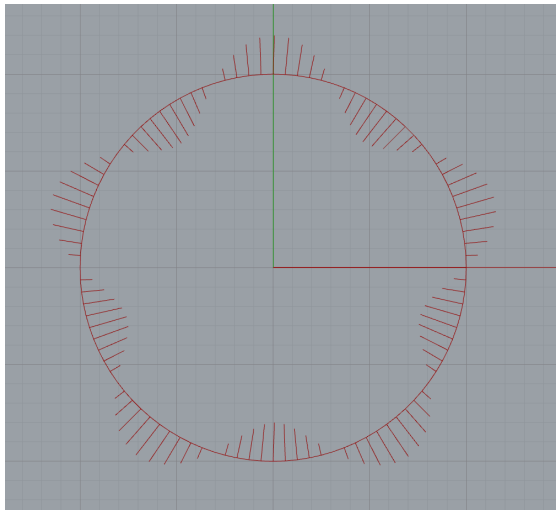
- Use one turtle to generate interesting points that are based on the slice curve for each layer. This turtle might generate a bunch of extraneous lines that you don't want to include in your print
- Use a second (primary) turtle to follow only the points that you want to include in your toolpath.

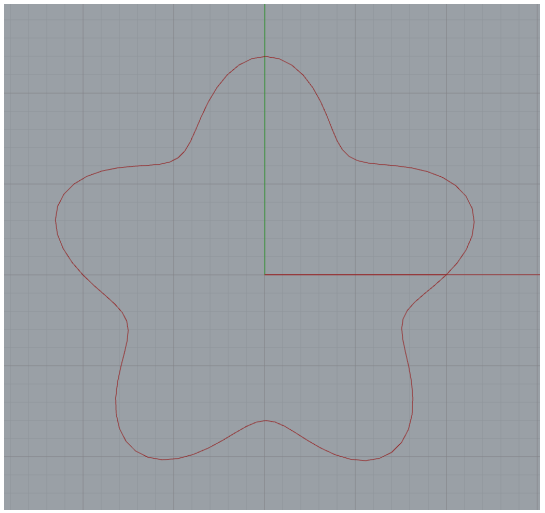
Two turtle example code

```
19 slices = rs.AddSrfContourCrvs(shape,(bottom,top),layer_height)
20
21 num_points = 100
22 amplitude = 2.0
23 num_oscillations = 5
24 for l in range (len(slices)):
25     points = rs.DivideCurve(slices[l],num_points)
26     for i in range (len(points)):
27         x0 = points[i].X
28         y0 = points[i].Y
29         z0 = points[i].Z
30         t2.set_position(x0,y0,z0)
31         theta = 360.0/num_points*i
32         delta = amplitude * math.sin(num_oscillations*math.radians(theta))
33         t2.right(90)
34         t2.forward(delta)
35         x = t2.getX()
36         y = t2.getY()
37         z = t2.getZ()
38         t2.back(delta)
39         t2.left(90)
40         t.set_position(x,y,z)
```

Output

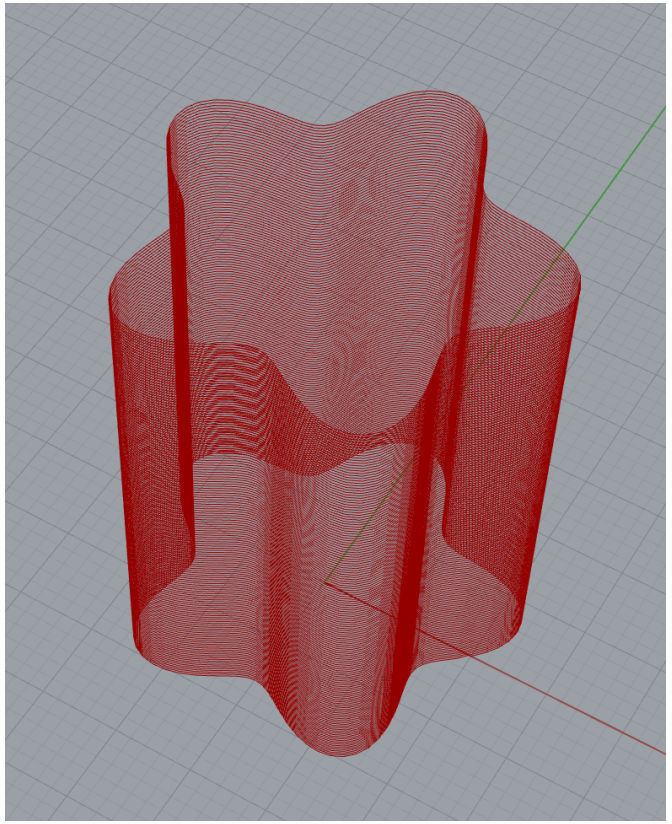
top view





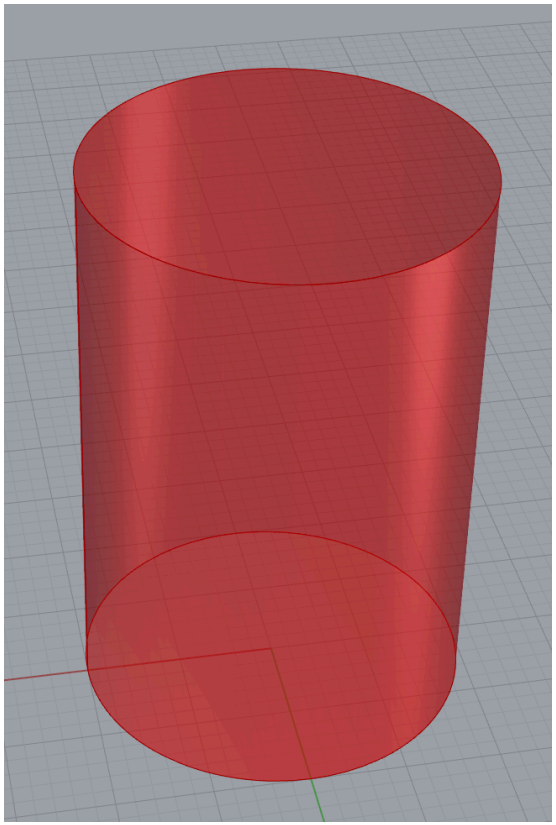
t2 path

t path

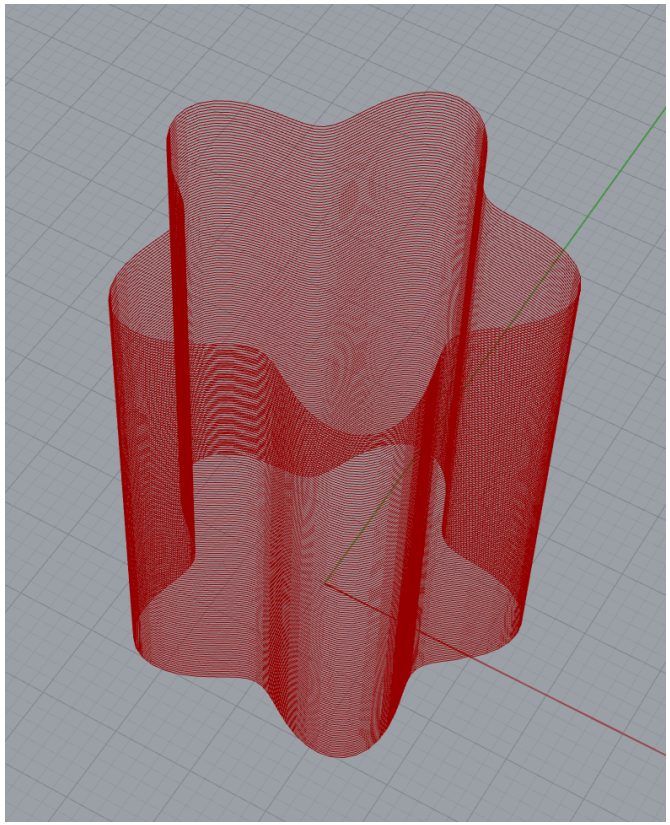


t path

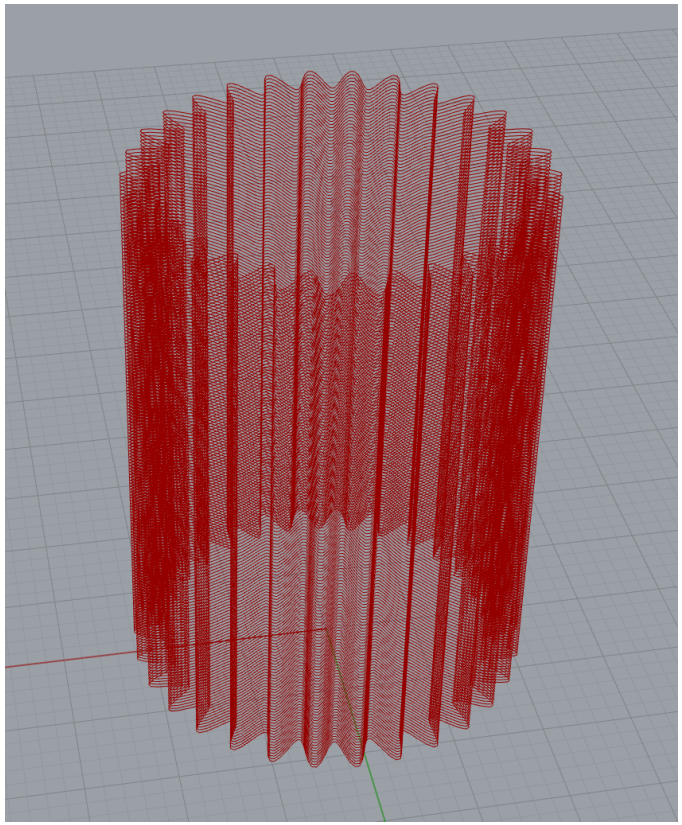
Play with Parameters



input

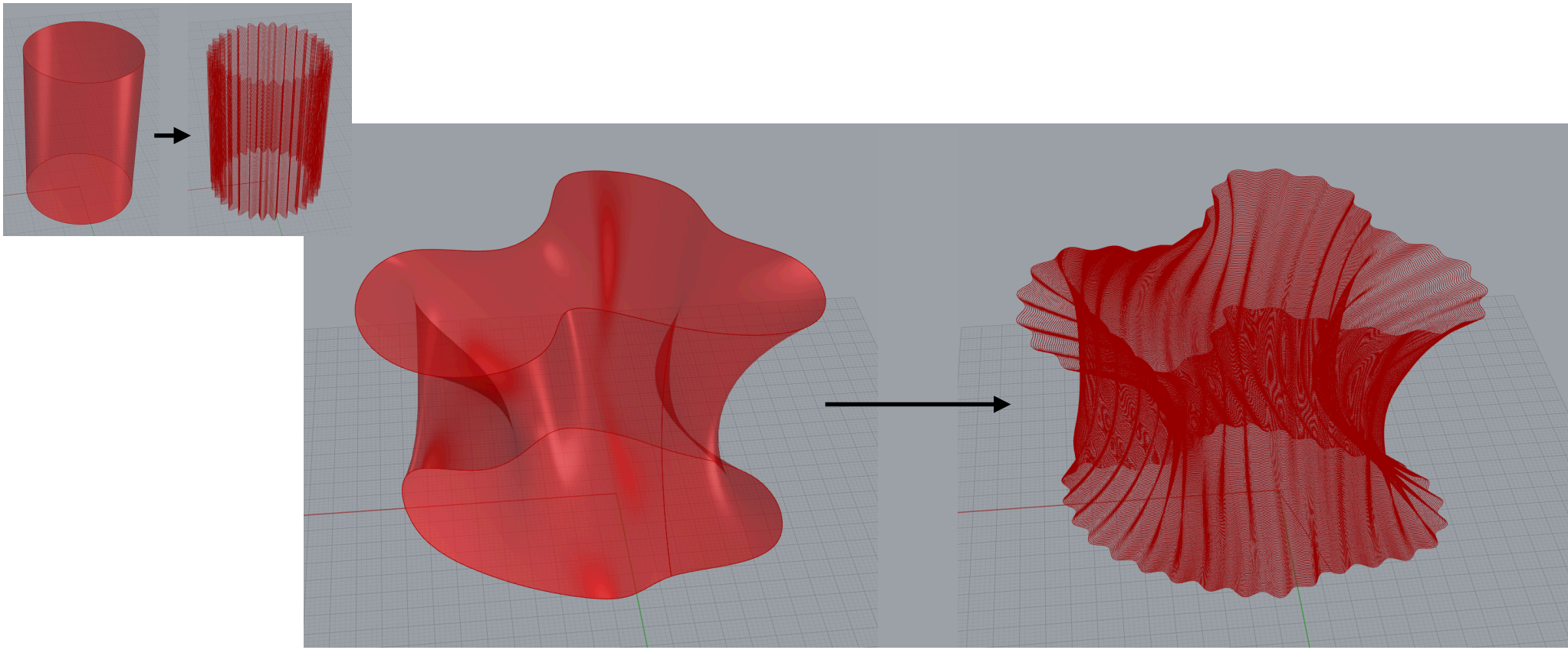


oscillations = 5



oscillations = 30

Slicing a more interesting shape



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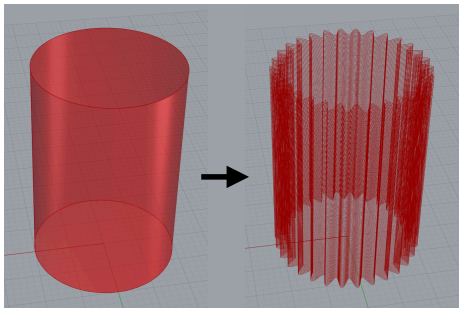

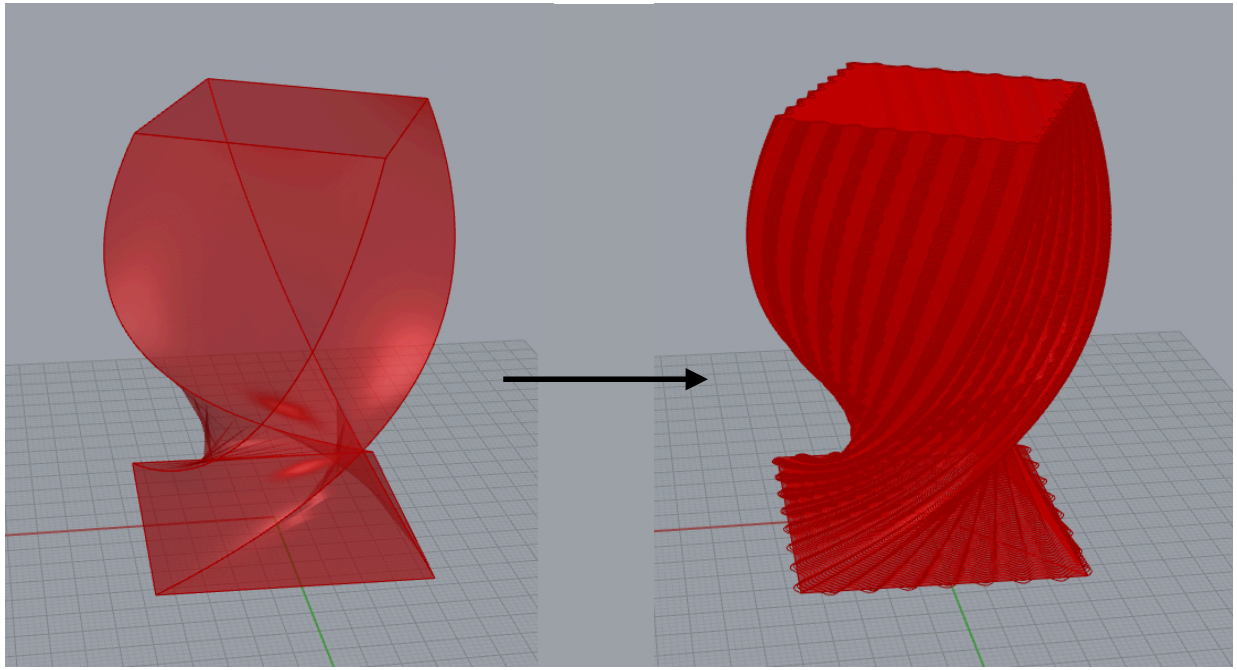

vase from Vessel assignment

questions?

Today: 3D Printing

3D Printing is Additive

Additive: add material to construct something

Subtractive: remove material to construct something

Types of 3D Printing

Extrude a material
- Fused Deposition Modeling (FDM)/Fused Filament Fabrication (FFF)
- Clay, Cement, and Adobe Printers

Harden a liquid
- Stereolithography (SLA)
- Digital Light Processing (DLP)

Bind or fuse a powder
- Selective Laser Sintering (SLS)
- Selective Laser Melting (SLM)
- Direct Metal Laser Sintering (DMLS)
- Binder Jetting (BJ)

Spray/Jet a material
- PolyJet
- Material Jet (MJ)

Cut and glue layers
- Laminated Object Manufacturing (LOM)

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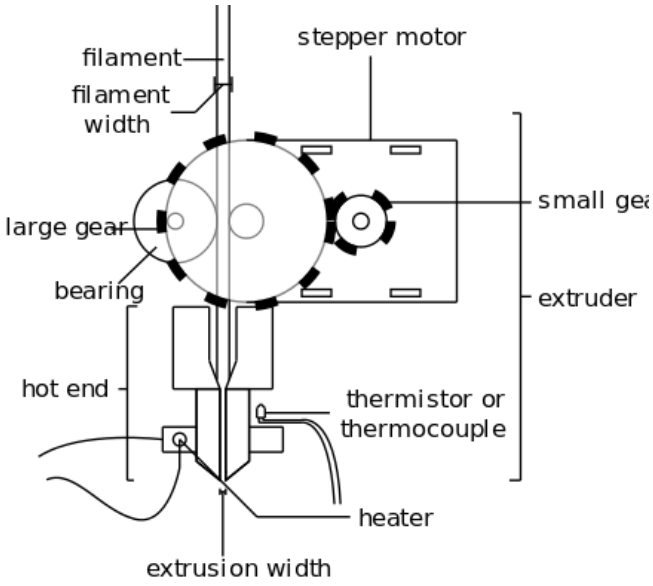
Fused Deposition Modeling (FDM)
Fused Filament Fabrication (FFF)

- Essentially a glue gun attached to an XYZ table.
- Invented in 1988 by Scott Crump, co-founder of Stratasys
- “FDM” is trademarked by Stratasys, hence “FFF”
- Patent expired in 2009, which is part of what led to development of cheap desktop printers
- Our Ender 3D printers are FDM/FFF machines
- Cheap and accessible

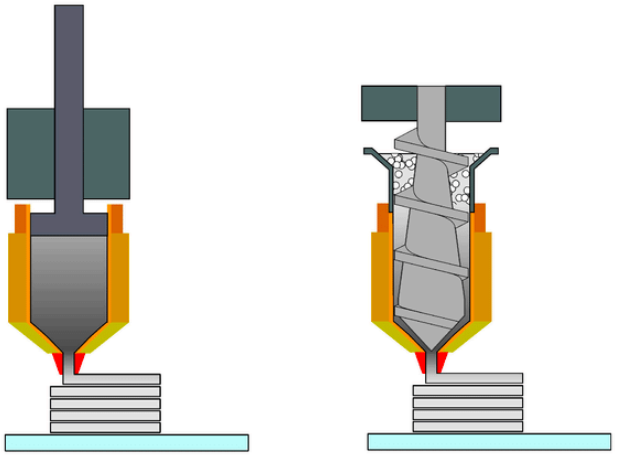


Materials

- Thermoplastic polymers (plastics that melt when heated): PLA (what we're using), ABS, PC, HDPE, PETG, etc.
- Thermoplastic Polyurethane (TPU): A fairly new flexible material that can be used in FDM printers (see Alan's post)
- Thermoplastic composites, thermoplastics with additives: wood, coffee, carbon fiber, sandstone, metal powders, glass, hemp…
- Other materials: wax, conductive PLA, polycarbonate…

Other Extrusion Based Printing
Extrusion-Based Additive Manufacturing (EAM)

- Essentially any extruder attached to an XYZ table, or other 3d machine (ie: a robot arm).
- Plunger-based extrusion: squeeze a material through a tube.
- Screw-based extrusion: use a screw to move material to the print head (ie: for hose-fed applications)



Materials (!)

- Any paste that cures, dries, or can be cooked
- Any meltable substance that hardens
- Food: Chocolate, Pasta, Marzipan, Candy, etc.
- Clay
- Adobe
- Cement

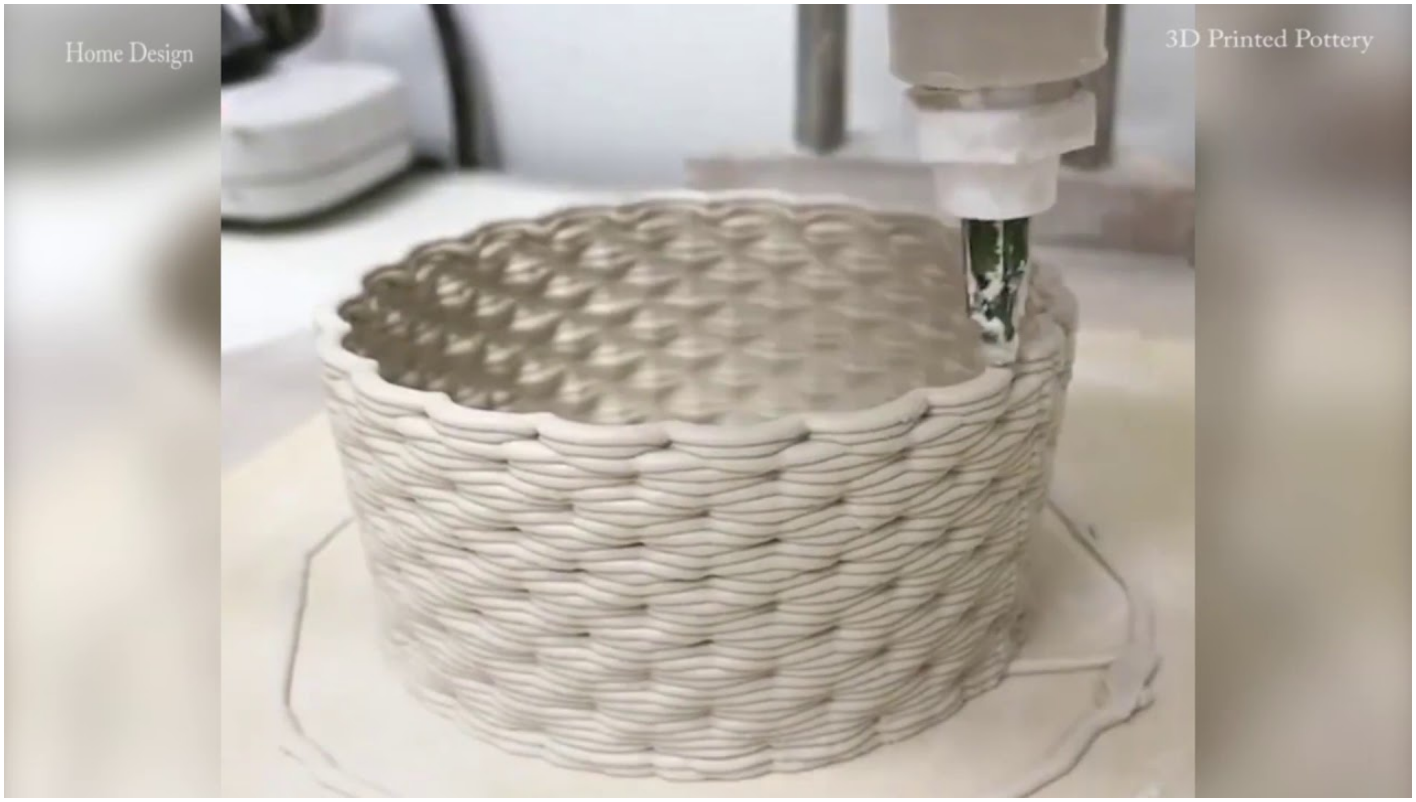
3D Printing Chocolate

https://www.youtube.com/watch?v=LaQ8AeO8Mu0 start at ~3 minutes

3D Printing Meat Alternatives

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

3D Printing Clay



3D Printing Concrete

Printing lab at UNM puts school ahead of the curve

BY KEVIN ROBINSON-AVILA / JOURNAL STAFF WRITER
Monday, June 3rd, 2019 at 12:02am

Civil engineer and doctoral candidate Daniel Marcia, left, and civil engineer Dr. Moneeb Genedy operate UNM's new 3D concrete printer. (Courtesy of UNM)

3D Printing Adobe

3D Printing Glass

https://www.mapleglassprinting.com/

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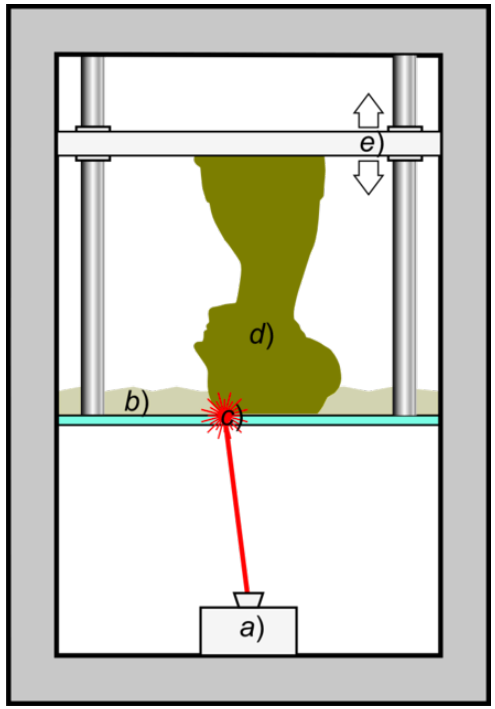
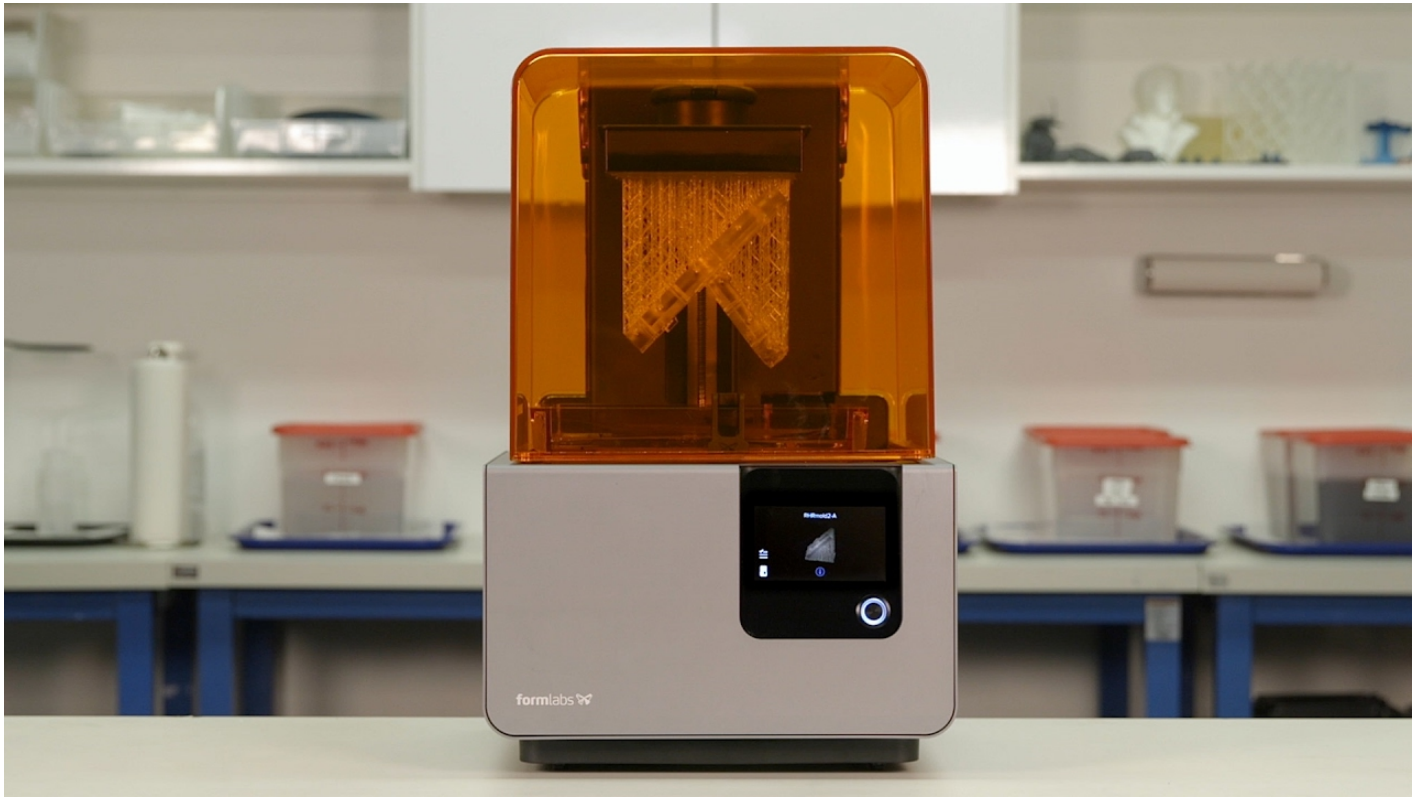
Stereolithography (SLA)

- Invented by Hideo Kodama in the early 1980s
- First 3D printing method developed
- Patented by Chuck Hull in 1986, founder of 3D Systems, the first 3D printing company
- Laser light hardens a liquid resin
- A laserbeam traces out path for each layer in a vat of liquid layer, hardening the resin
- Part is lifted out of the resin as it is built
- FormLabs developed first desktop SLA printer in 2012

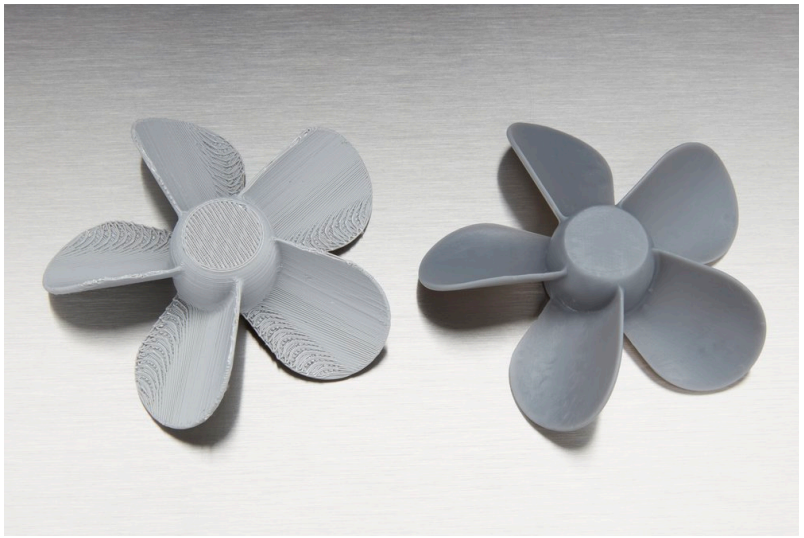


Stereolithography (SLA)



SLA vs. FDM/FFF

- SLA: High precision parts, 85 vs. 250 microns
- Different range of materials
- Available in desktop versions later (later patent + more complex tech)
- Messy awkward process
- Slightly more expensive



Example cheap desktop SLA printer

‹ Back to results

VIDEO

Roll over image to zoom in

ELEGOO Mars 2 Pro Mono MSLA 3D Printer UV Photocuring LCD Resin 3D Printer with 6.08 inch 2K Monochrome LCD, Printing Size 129x80x160mm/5.1x3.1x6.3inch

Visit the ELEGOO Store

4.5 out of 5 stars 511 ratings | 22 answered questions

Amazon's Choice for "sla 3d printer"

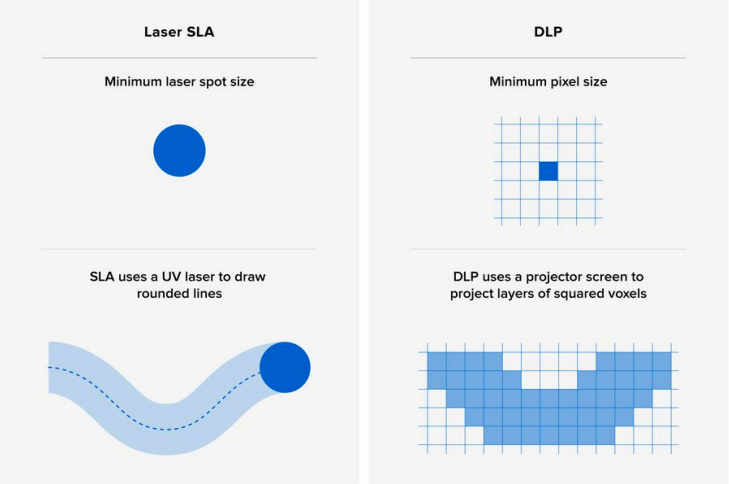
Price: $329.99 prime & FREE Returns

Extra Savings Promotion Available. 1 Applicable Promotion

- 【Fast Printing and less maintenance】 Mars 2 Pro comes with a 6.08 inch monochrome LCD of 2K HD resolution and only takes 2 seconds per layer exposure to cure resin, which could significantly enhance your printing efficiency. Mono LCD has a much longer lifespan and stable performance during long term printing, thus saves your cost.
- 【Outstanding prints and ultra accuracy】 Brand new light source structure provides more even UV light emission and working together with 2K mono LCD, the printing details and precision are greatly improved and the 3D printed models are fascinating.
- 【Sturdy build quality】 CNC machined aluminum body makes Mars 2 Pro a very

Digital Light Processing (DLP)

- Very similar to SLA, but each layer is exposed all at once via projection instead of via laser drawing
- Faster than SLA for large or densely packed parts
- https://formlabs.com/blog/resin-3d-printer-comparison-sla-vs-dlp/



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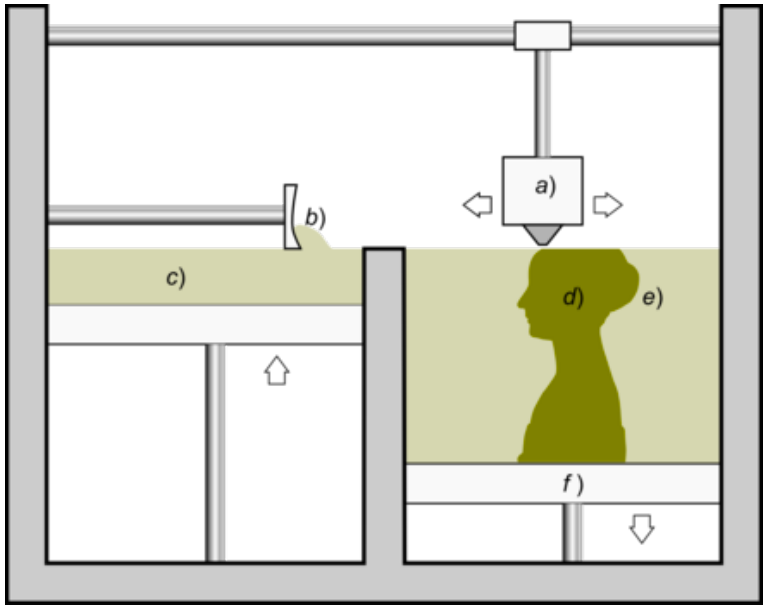
Binder Jetting

- Developed at MIT by a team led by Ely Sachs
- Patented in 1993
- ZCorporation (ZCorp) founded in 1994, acquired by 3D Systems in 2012
- Based on inkjet technology
- An inkjet head moves across a bed of powder, solidifying the material wherever it deposits ink
- First use of the term “3D printing” to describe the process



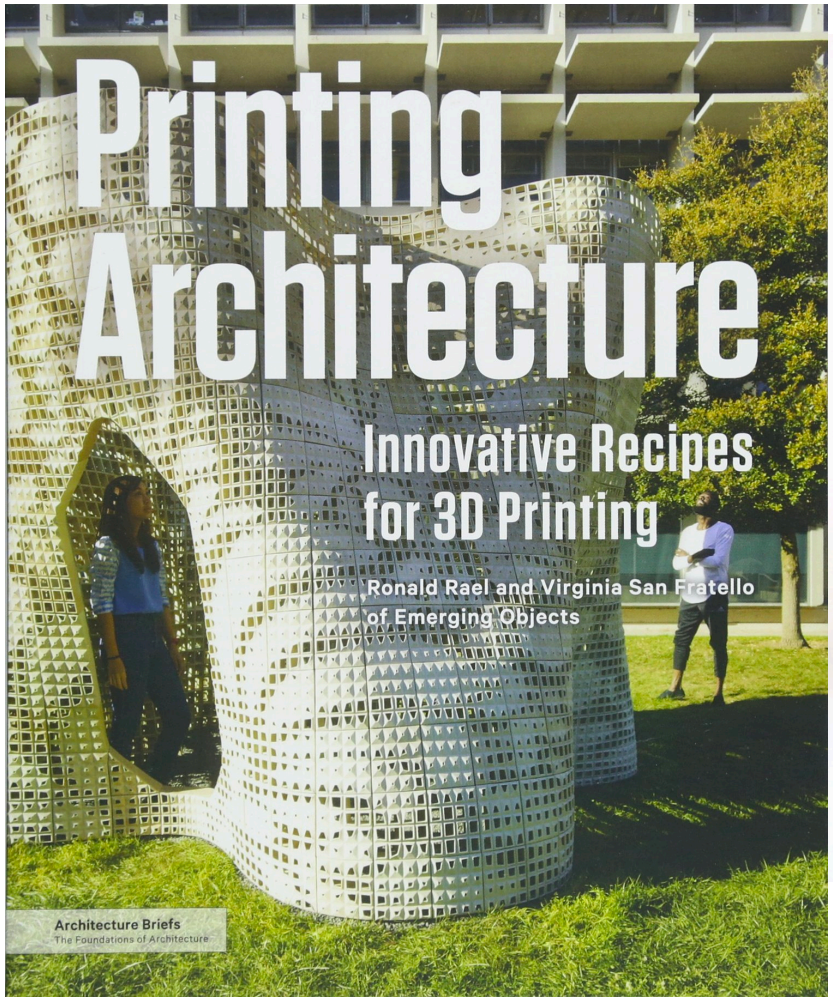
Materials

- Originally a starch powder bound with traditional printer inks
- Using printer inks, full color capable
- Very hackable!
- Any powder material that hardens when exposed to a companion liquid
- Unfortunately ZCorp machines are no longer manufactured. Rebranded Color Jet.

Binder Jetting (BJ)

Time: 1:04

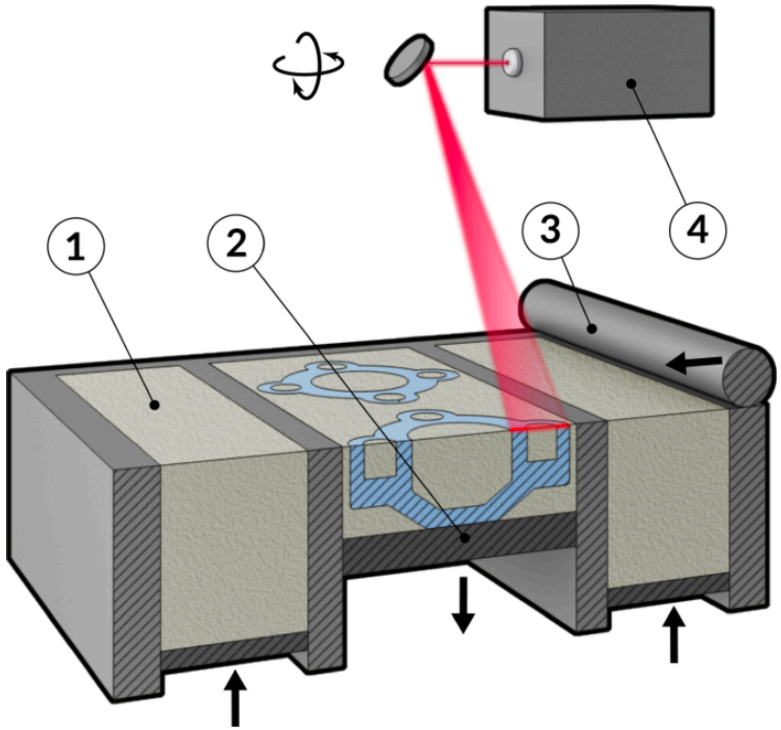
Hacked Binder Jet (ZCorp) Printers



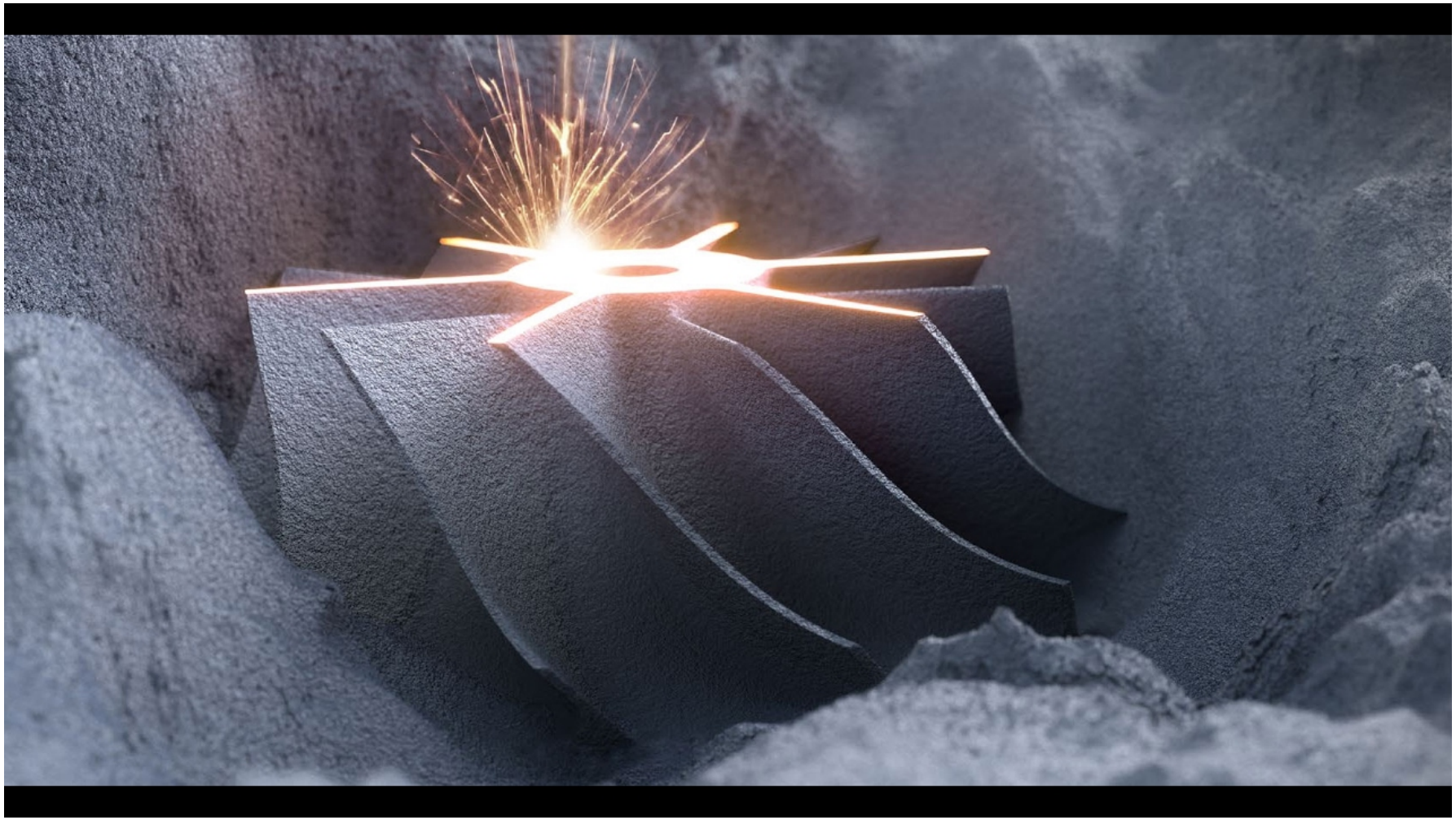
Rael San Fratello

Selective Laser Sintering (SLS)
Selective Laser Melting (SLM)

- Invented by Carl Deckard and Joe Beaman at UT Austin in 1980s
- Patented in 1987, DTM company, acquired by 3D Systems in 2001
- A laser beam traces out a path for each layer in a bed of powder, melting/ sintering the powder together
- DMLS = SLS with metal powder
- Newly available desktop machines



Selective Laser Melting



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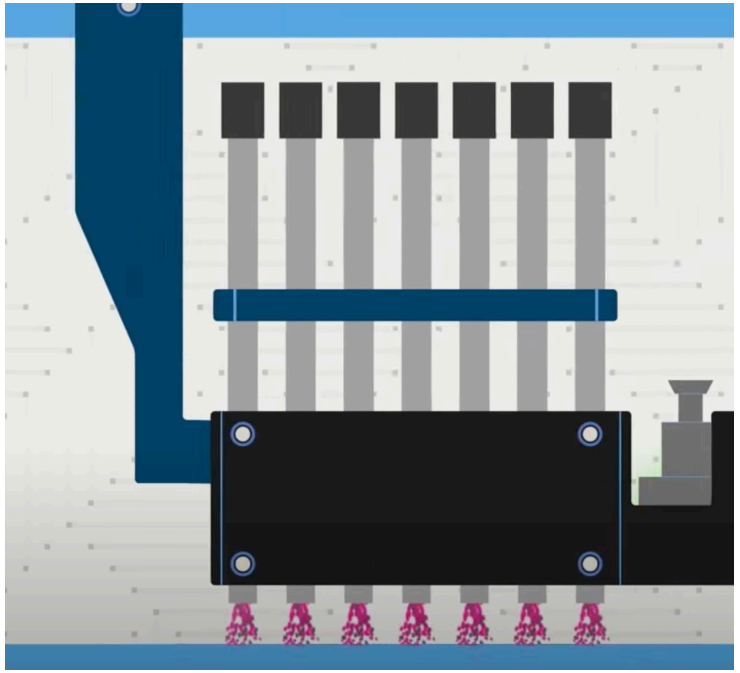
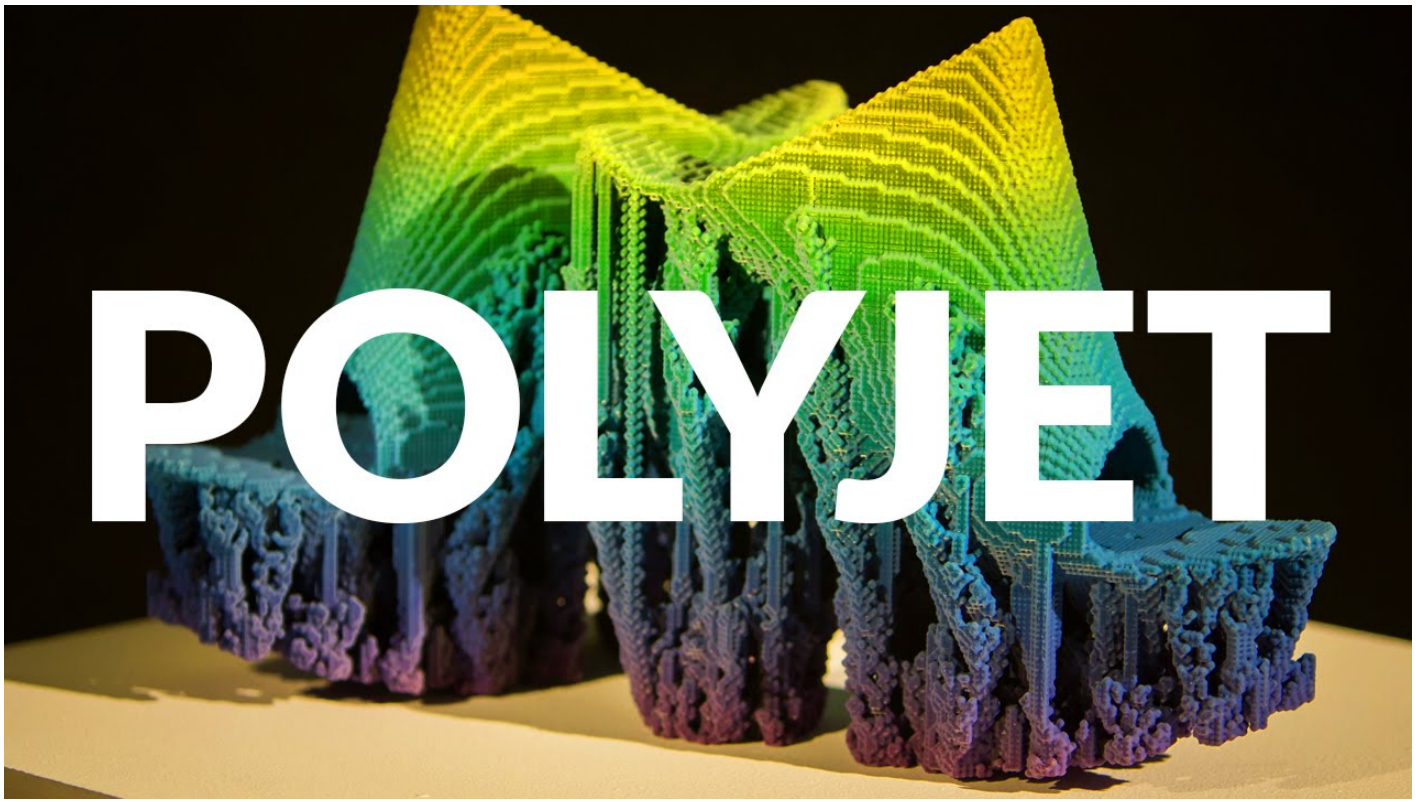
PolyJet Printing or MultiJet Modeling

- Developed by Objet Geometries company, founded in 1998
- 2000, raise significant funding, begin to develop multi-material 3D printers
- Acquired by Stratasys in 2012
- Very thin layers of liquid plastic are sprayed/ jetted onto a surface. Hardened by UV light.
- Multiple nozzles allow for multiple materials, including material blends



PolyJet Printing



Neri Oxman

Materials

- A range of materials with different visual and mechanical properties: color, transparency, hardness, strength, etc.
- Full color
- The ability to print many materials at the same time
- **Blend-able** materials for the first time
- https://www.stratasys.com/materials/

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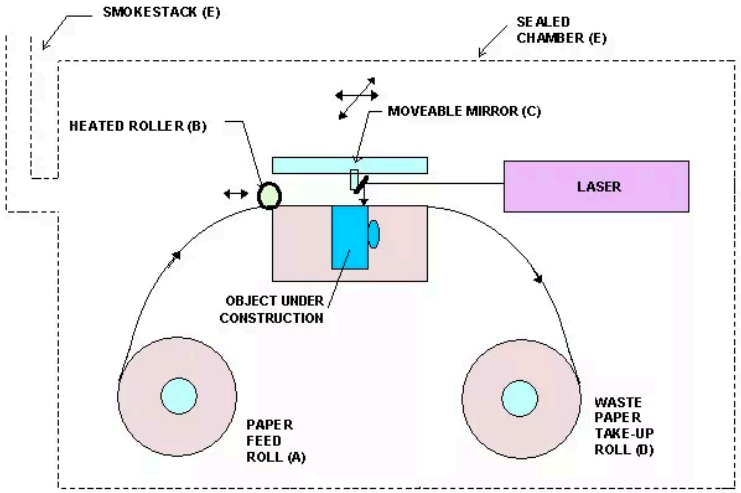
Laminated Object Manufacturing (LOM)

- Developed by Helysis (now Cubic Technologies)
- Layers are cut with a knife or laser and glued together in layers to form a part
- Layers can be printed before they are cut to produce full color models
- Can cut thin layers of plastic or (most commonly) paper
- Mcor technologies now manufactures and sells

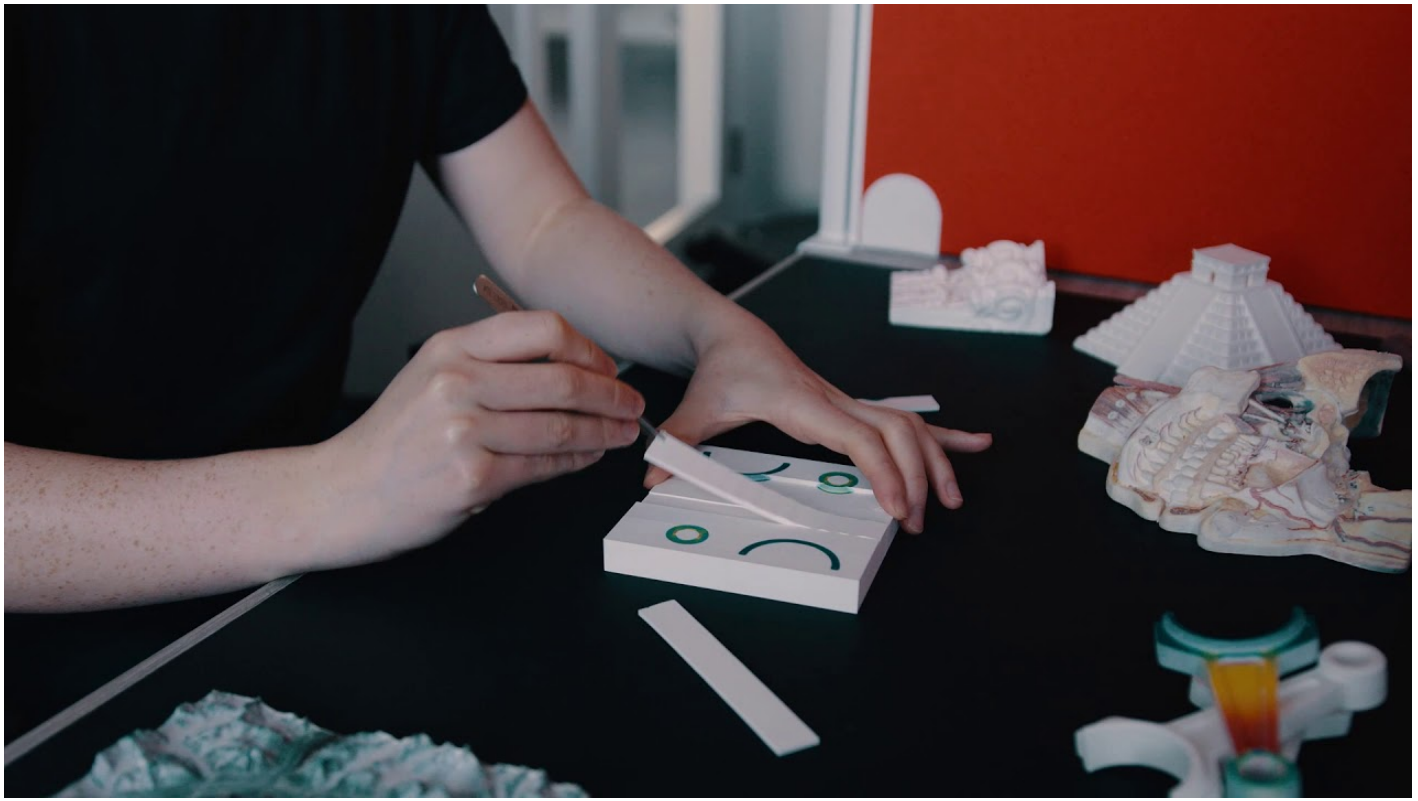


Laminated Object Manufacturing

Laminated Object Manufacturing

Time: 0:30

Laminated Object Manufacturing



Time: 0:30

questions?

Thank you!

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