Additive Manufacturing

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Additive Manufacturing
3D Printing
Rapid Prototyping

Introduction

- Also referred as Additive Manufacturing and Rapid Prototyping
- Rapid - How to make things faster?
- The goal is to speed up the design, evaluation and manufacturing cycles.
- Detailed planning is the bottleneck to speed. Therefore, eliminate or at least minimize it through automation.

Lithography

Old method:

- Mirrored letters assembled in a block.
- Limited choice of fonts, styles and sizes; restricted graphics (no color or photograph)

New method:

- Choose any 2D matter including color photographs and create it virtually in the computer.
- No assembly. Printing occurs in total automation.

ABCDEFGHIJKLM

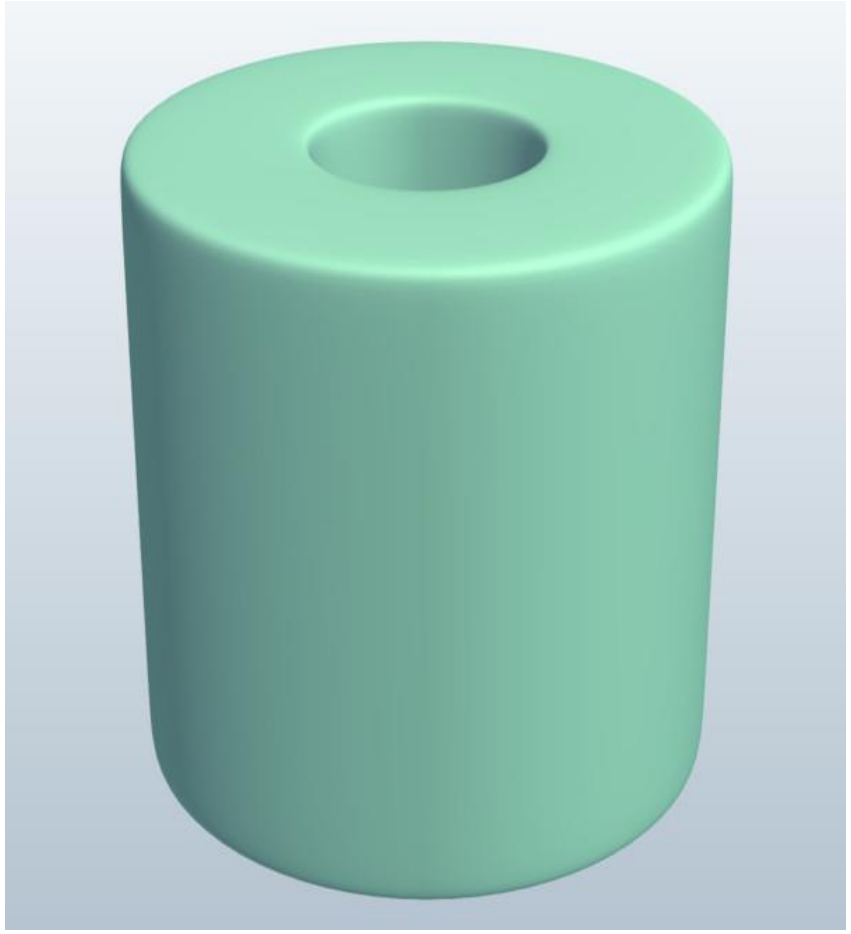
NOPQRSTUVWXYZ

Basic Principle of AM

Look at a shape as a not as an single object, but as a sum total of repetitive elements

How does it work?

Basic Principle of AM



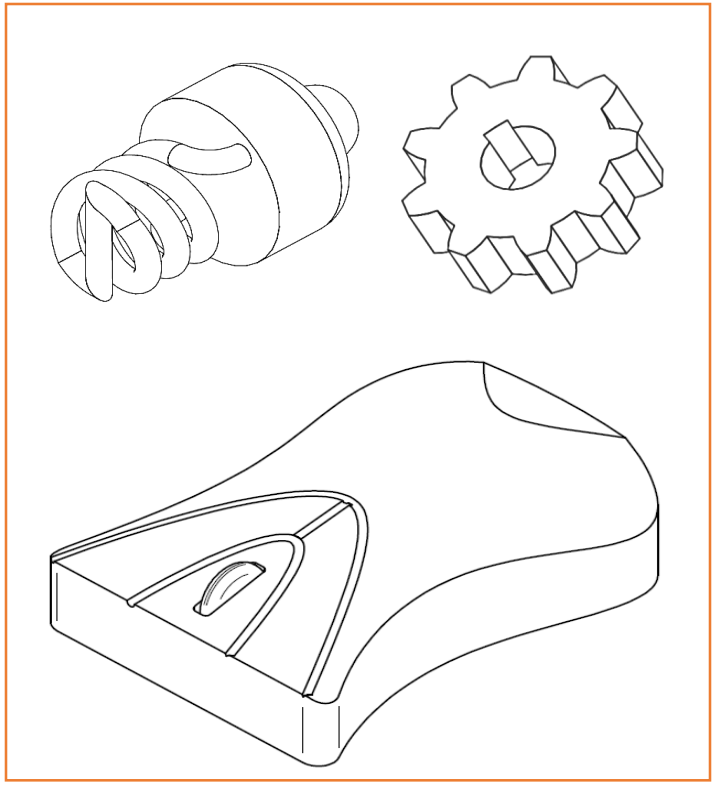
3D Printing (Additive Manufacturing)

"process of joining materials to make objects from three-dimensional (3D) model data, usually layer by layer, as opposed to subtractive manufacturing methodologies"

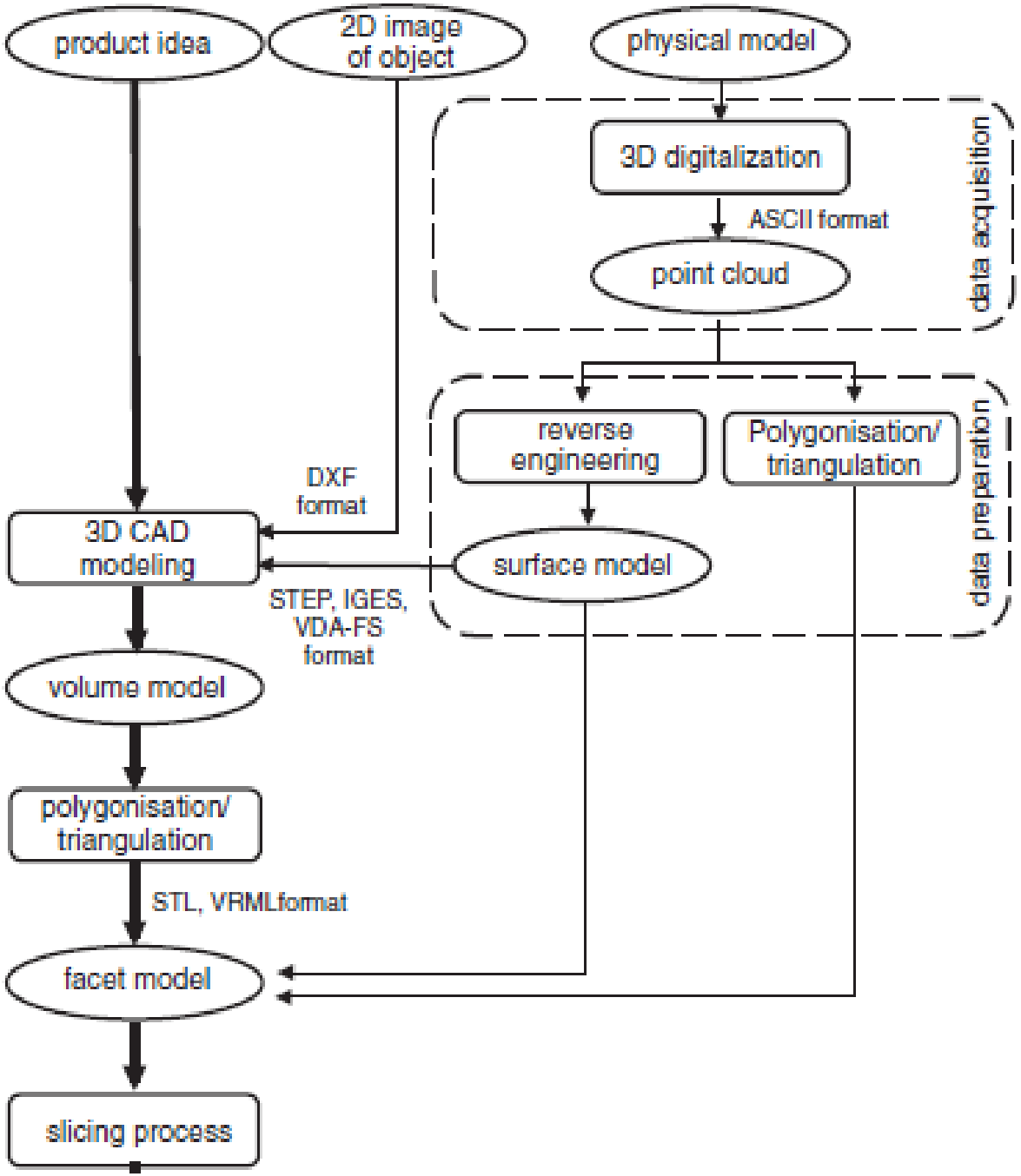
- ASTM International Committee F42 on additive manufacturing

Course Overview

How to Create 3D models → How to process 3D models for 3D Printing → How to print the Objects



Additive Manufacturing

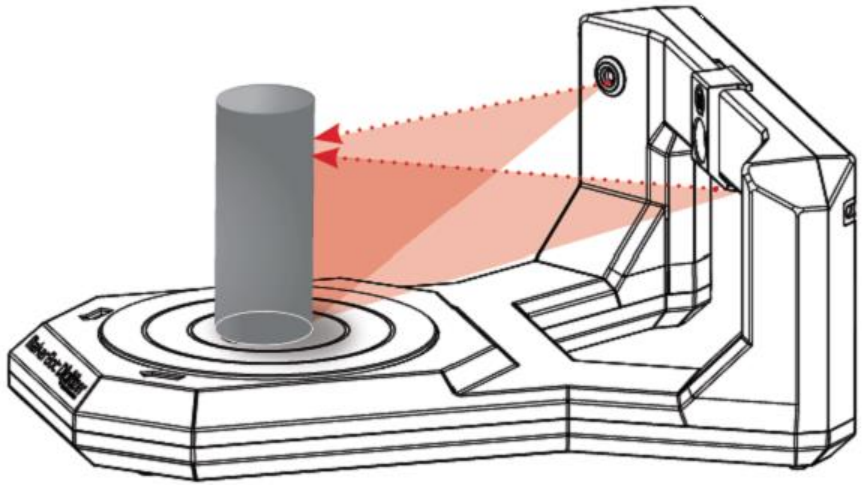


Reverse Engineering

- Parts / Components which cannot be modeled with 3D CAD software
- Legacy parts
- work of art
- Complex Geometries (Human Body parts)

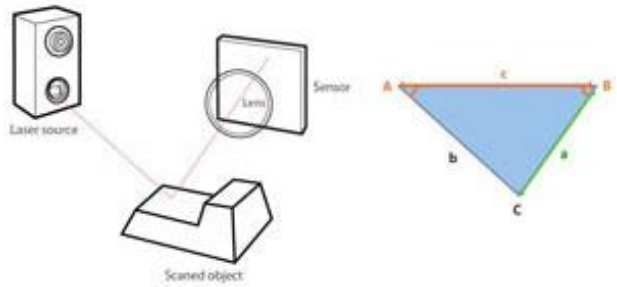
Co-ordinate Measuring Machine (CMM)

Desktop Digitizer - (Laser Scanner)



Principle: Triangulation

- An emitter and a receptor are integral with the measuring head at a constant distance. These two, together with the point of measurement – the point where the emitted pulse of ray falls – form a triangle.



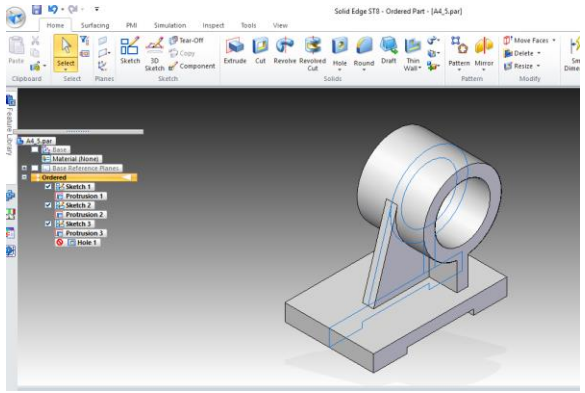
- When adequate level of signal is received, the point on the surface can be calculated from the current position of the measuring head and time taken for the flight of a pulse from the emitter to receptor.

Range Scanner

Body Scanner

Overview AM Process

- **CAD Modeling**



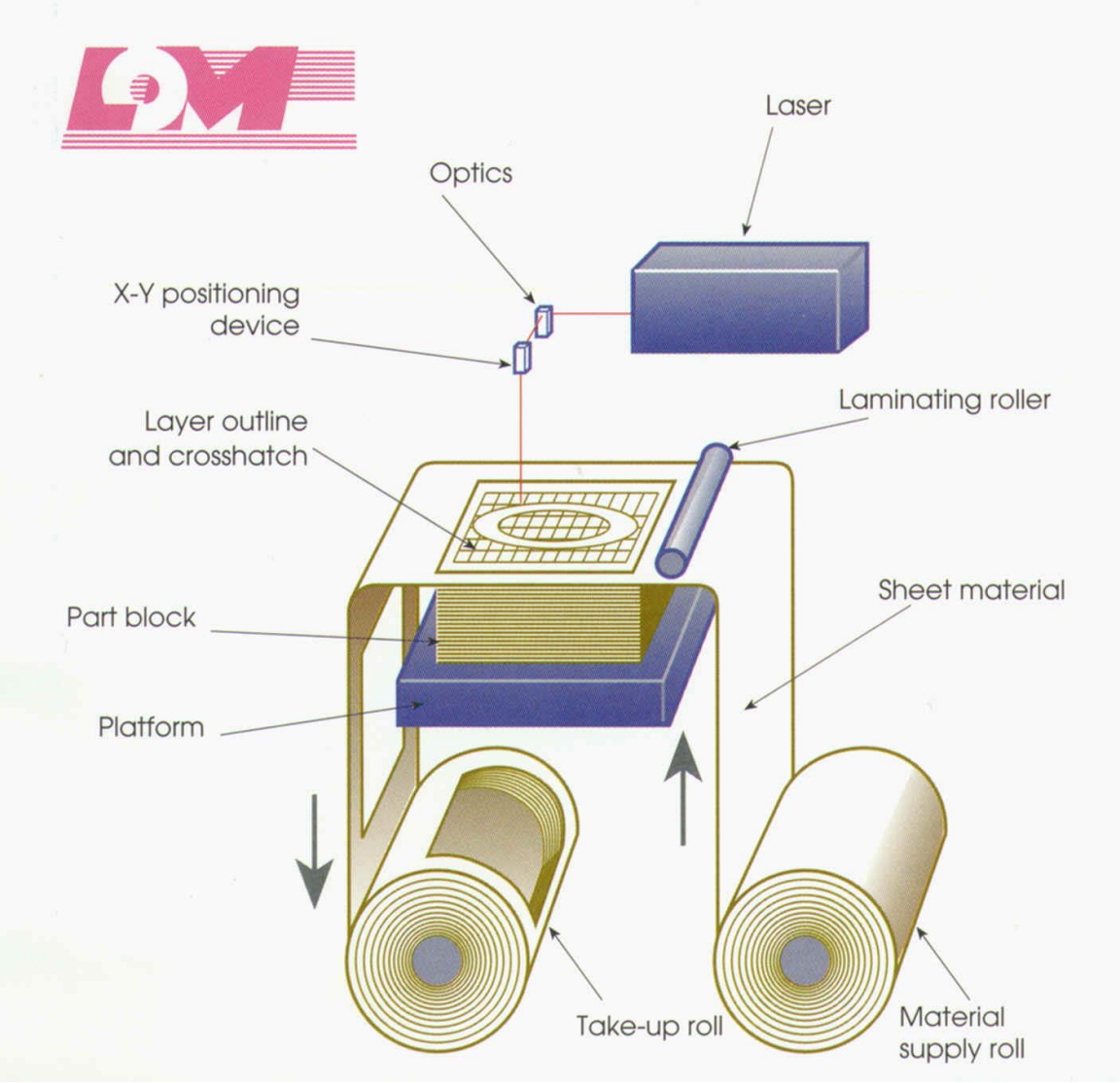
- **3D Printing (Preprocessing)**

3D Printed Part (Post Processing)

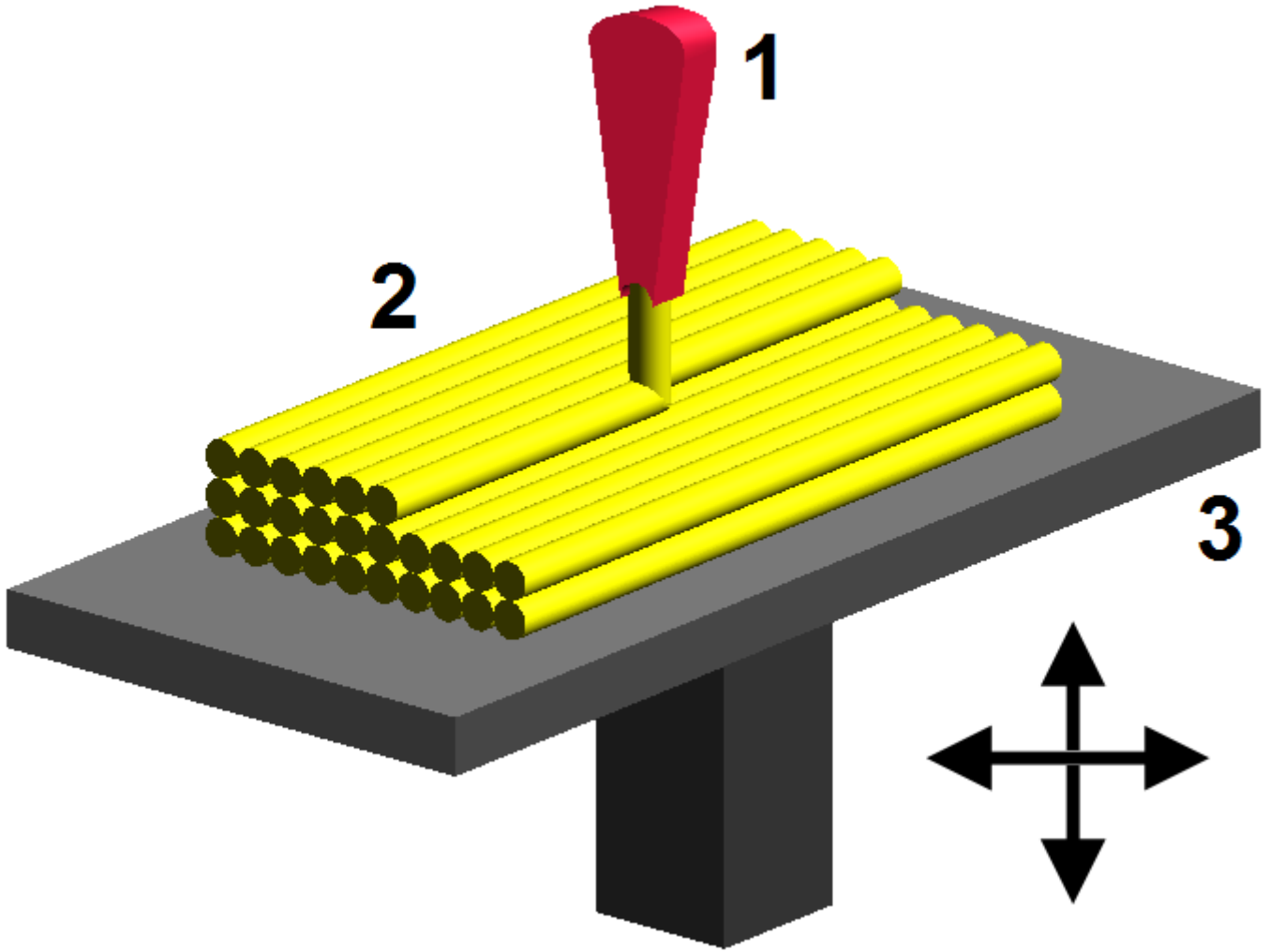
The AM Processes

- Sheet Lamination - LOM
- Material Extrusion - FDM
- Vat photo-polymerization – SLA
- Powder Bed Fusion - SLS
- Binder Jetting – 3DP
- Material Jetting – Objet
- Direct Energy Deposition - LENS

Laminated Object Manufacturing (LOM)



Material Extrusion



FDM

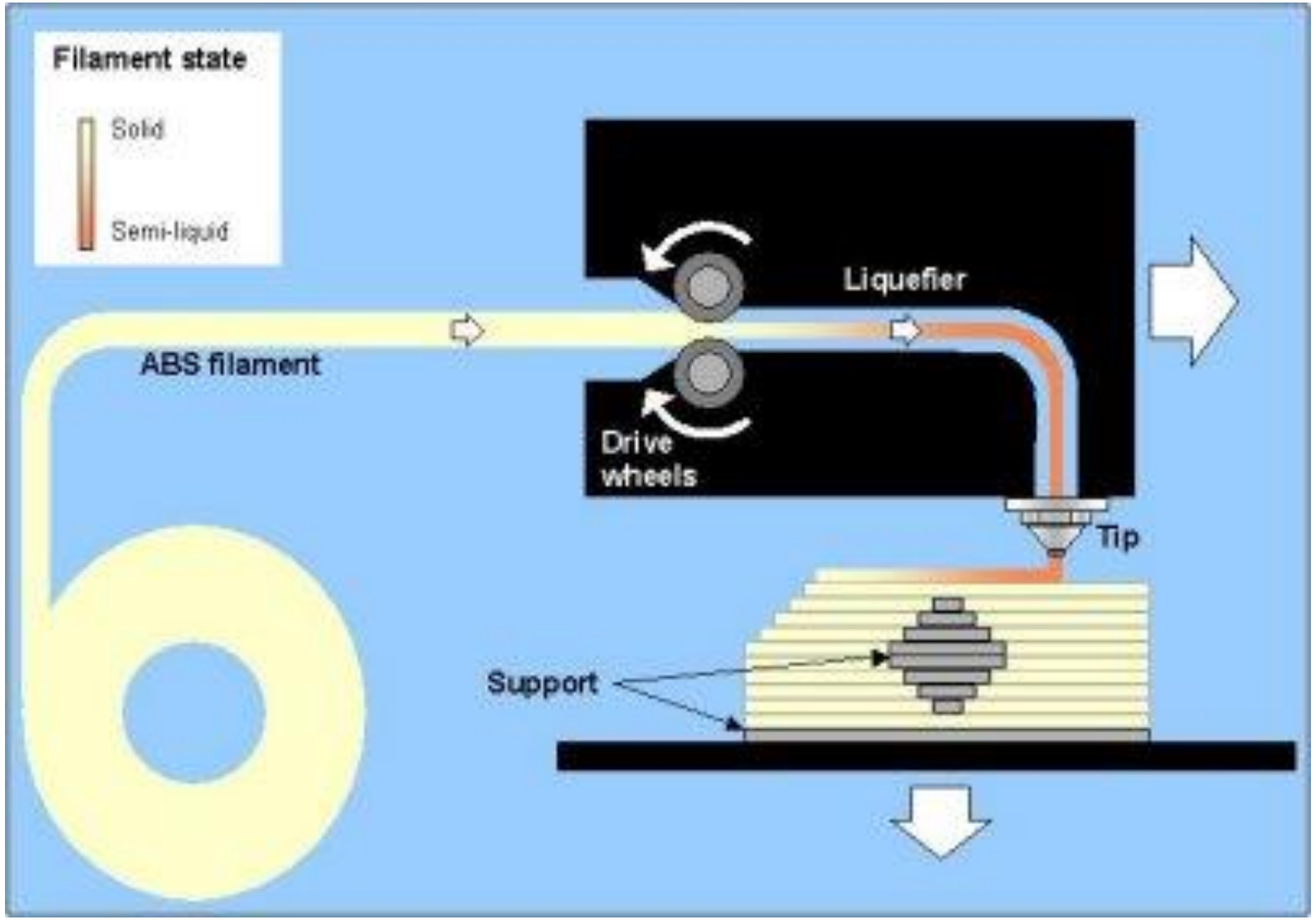
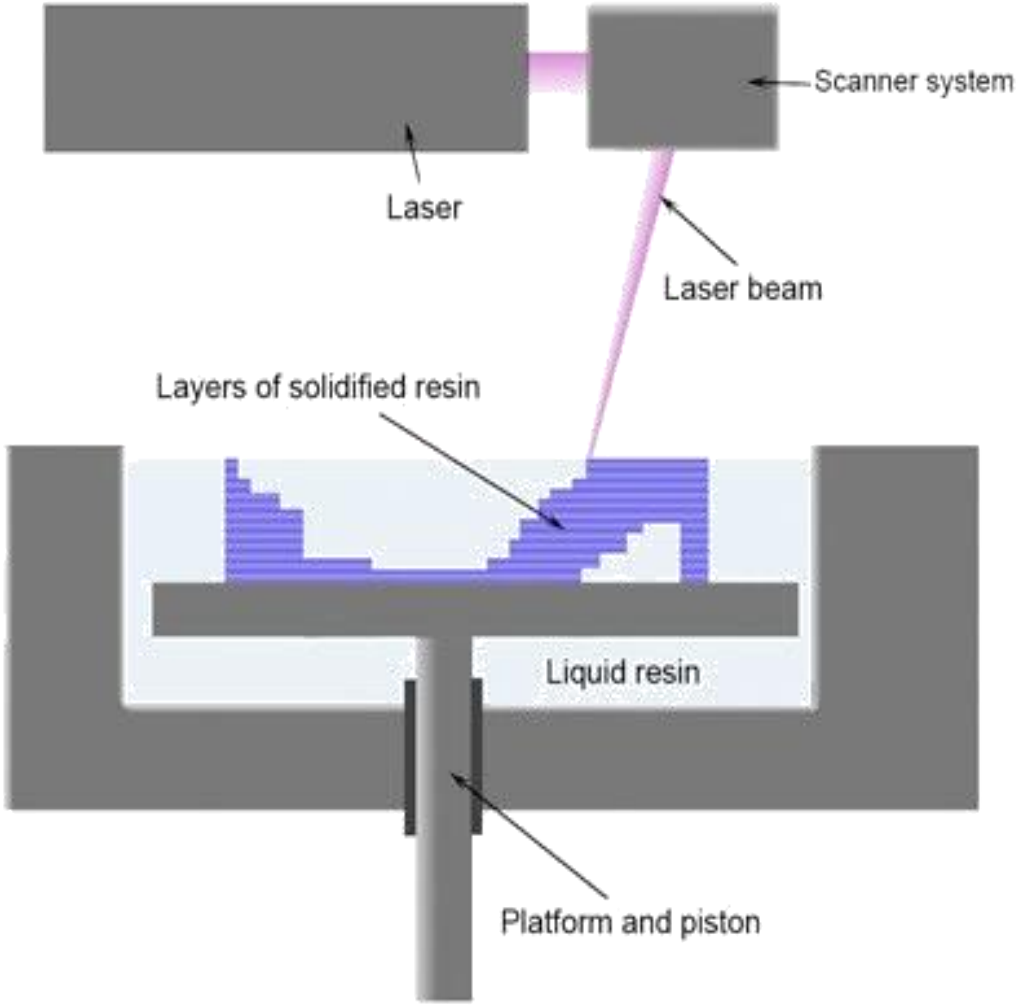
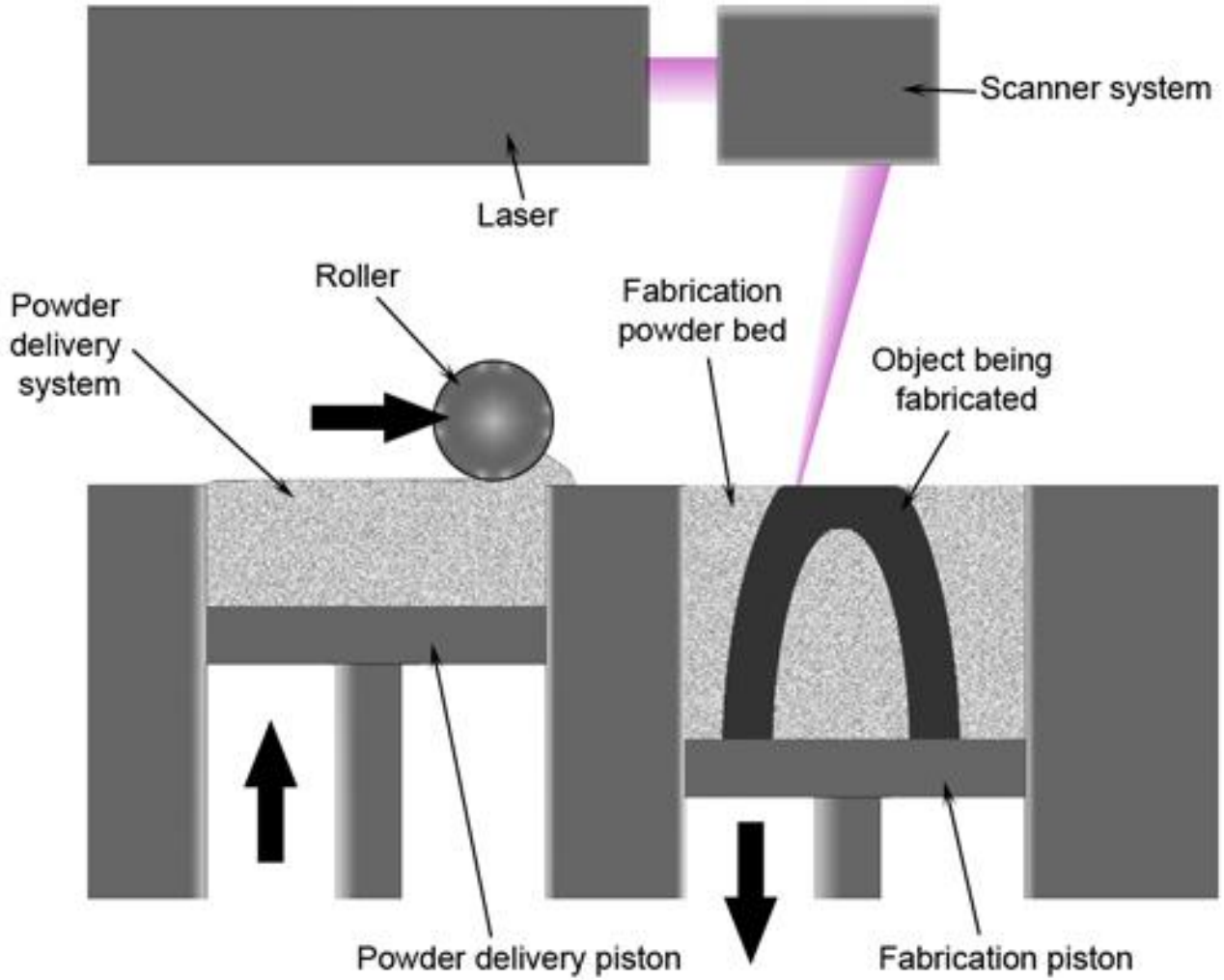

Filament state
Solid
Semi-liquid
Liquefier
ABS filament
Drive wheels
Tip
Support

Photo-polymerization

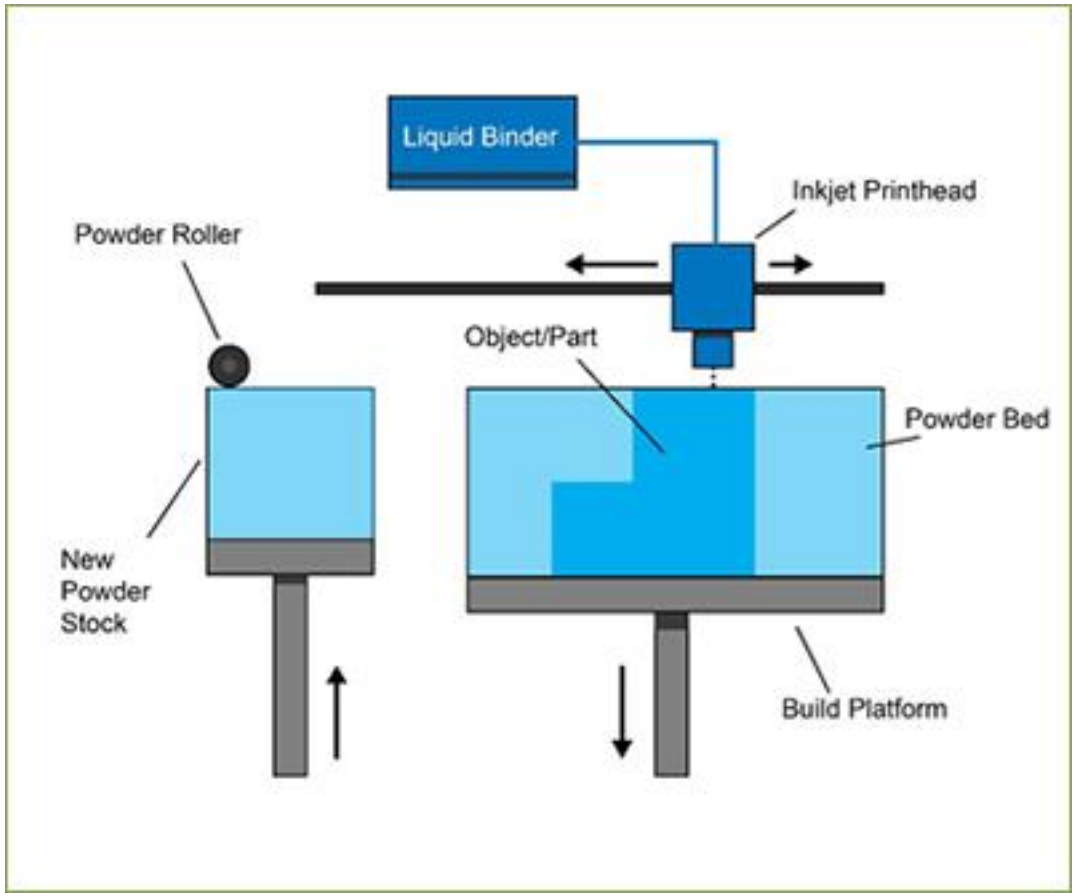
Stereolithography Apparatus (SLA)

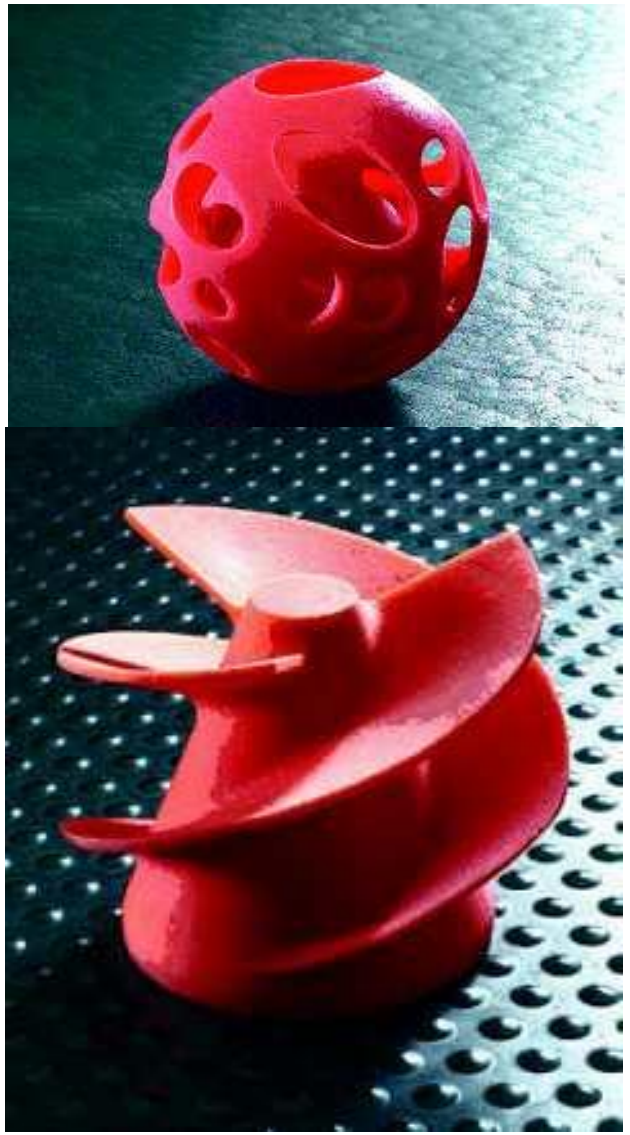


Powder Bed Fusion – SLS



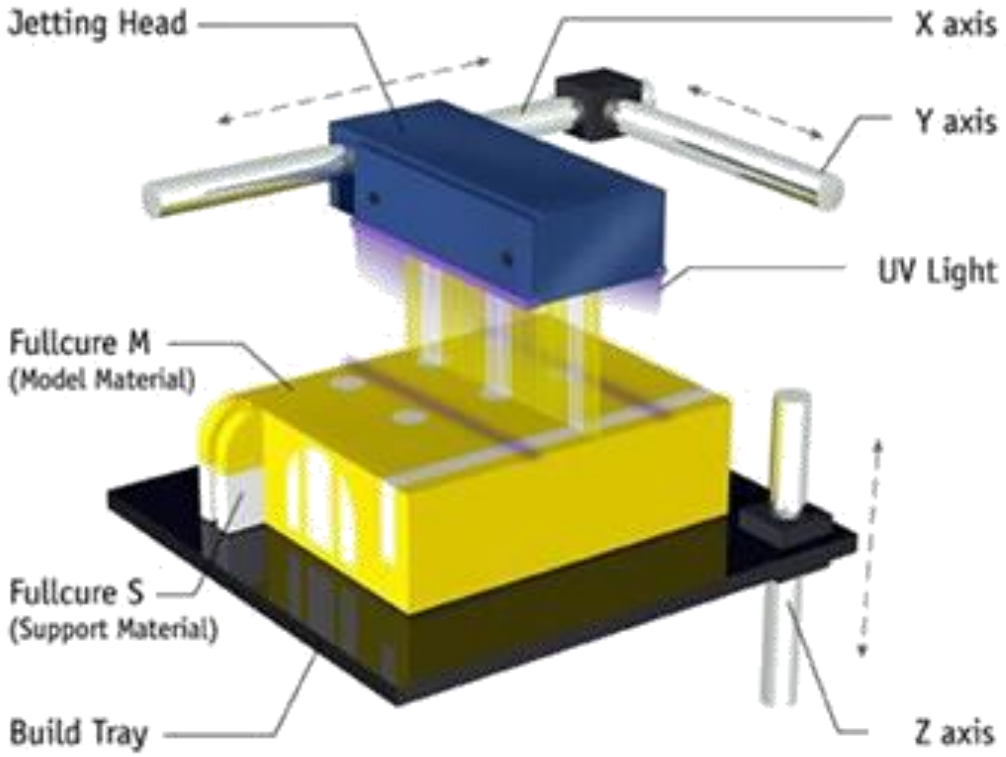
Binder Jetting – ZCorp's 3D Printing





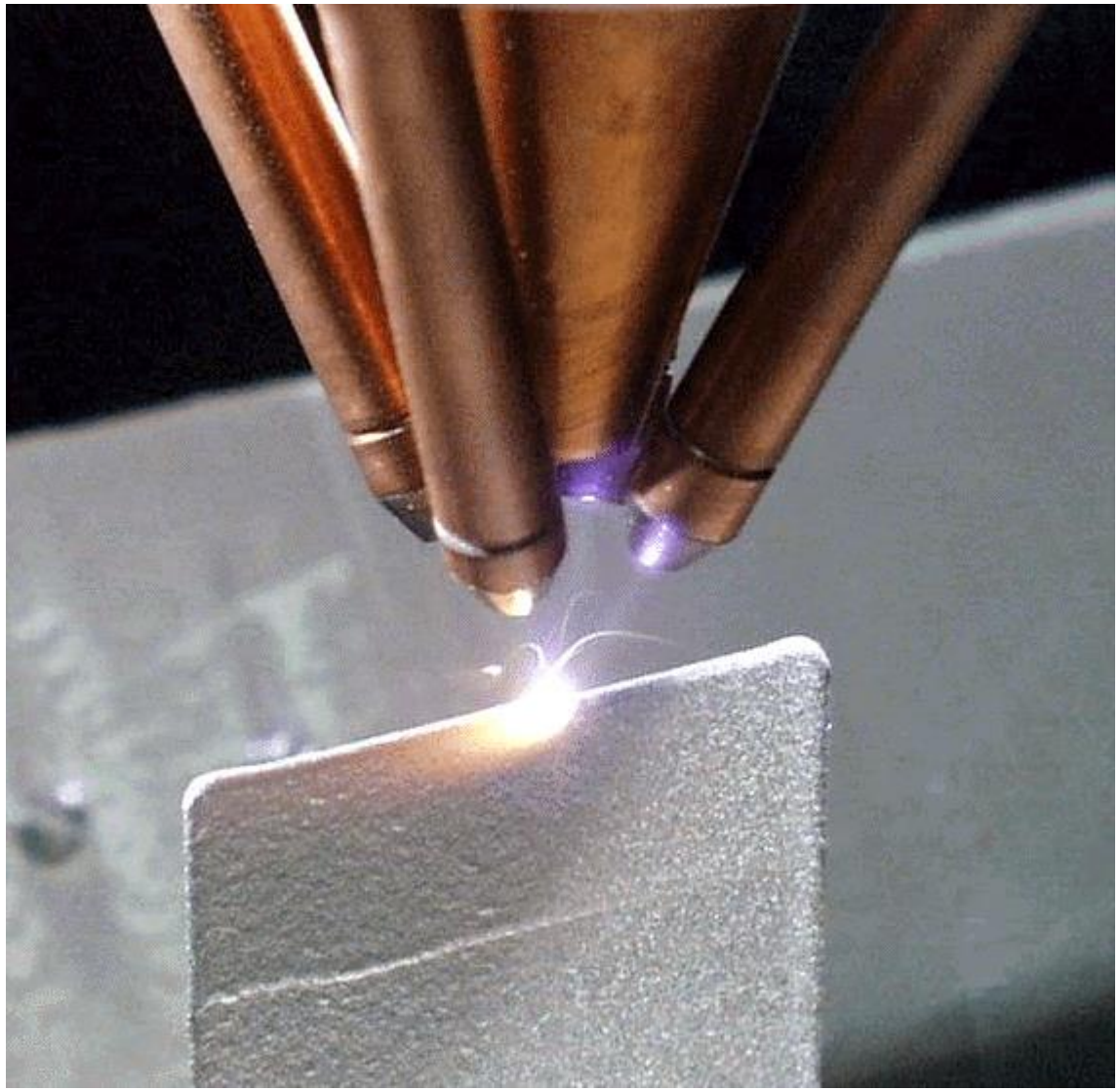
Material Jetting – Objet

- Direct deposition of material



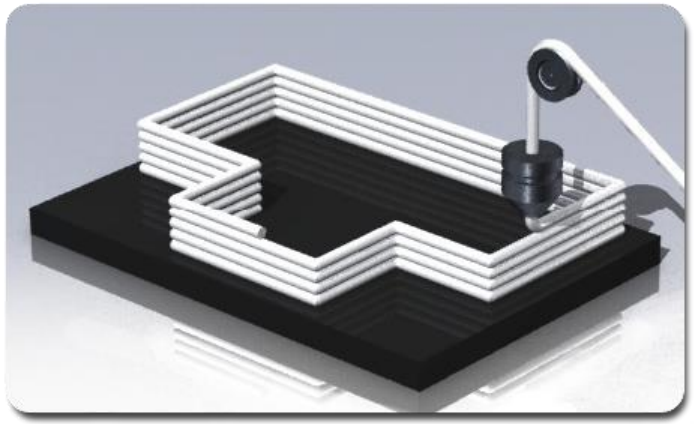
The Objet PolyJet Process

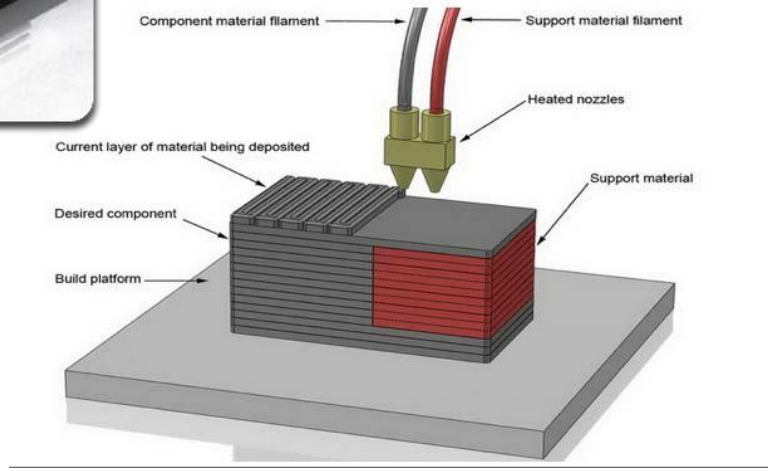
Laser Engineered Net Shaping (LENS)



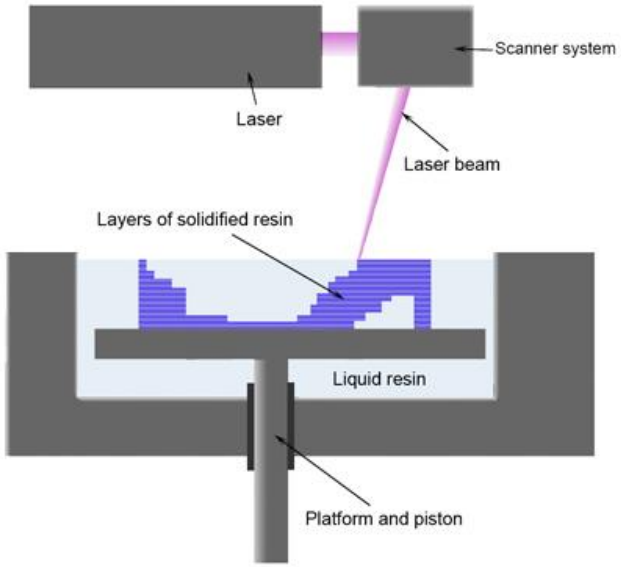
Basic Principle of AM

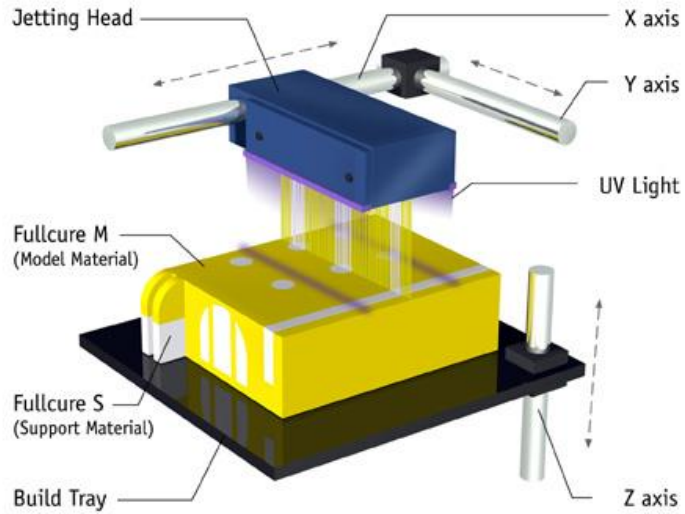
- Then realise each layer at a time



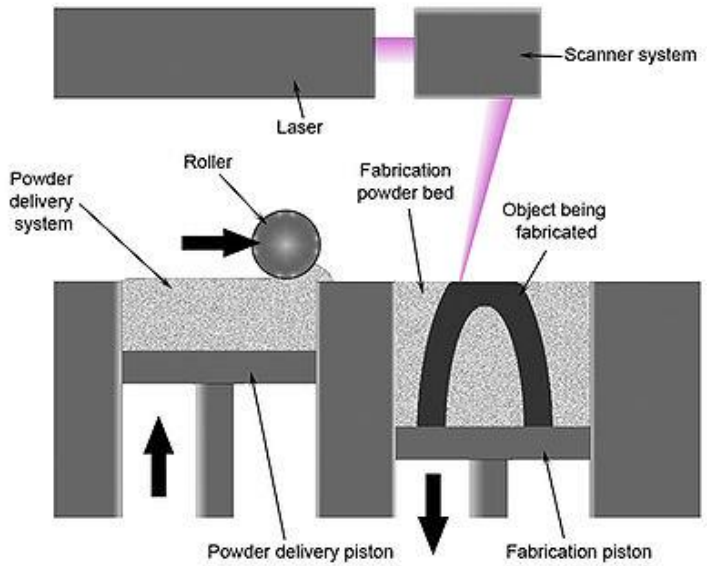


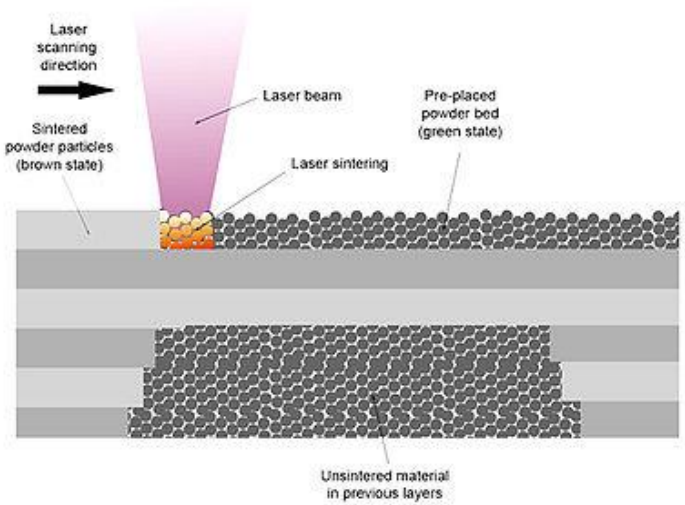
Many other variants





The Objet PolyJet Process





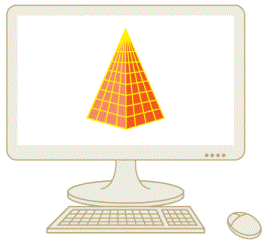
FDM

But this discussion is more focused on

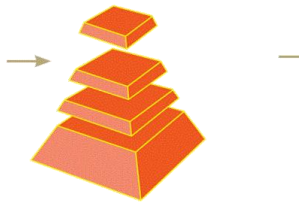
FDM (Fused Deposition Modelling)

Basic Principle of AM

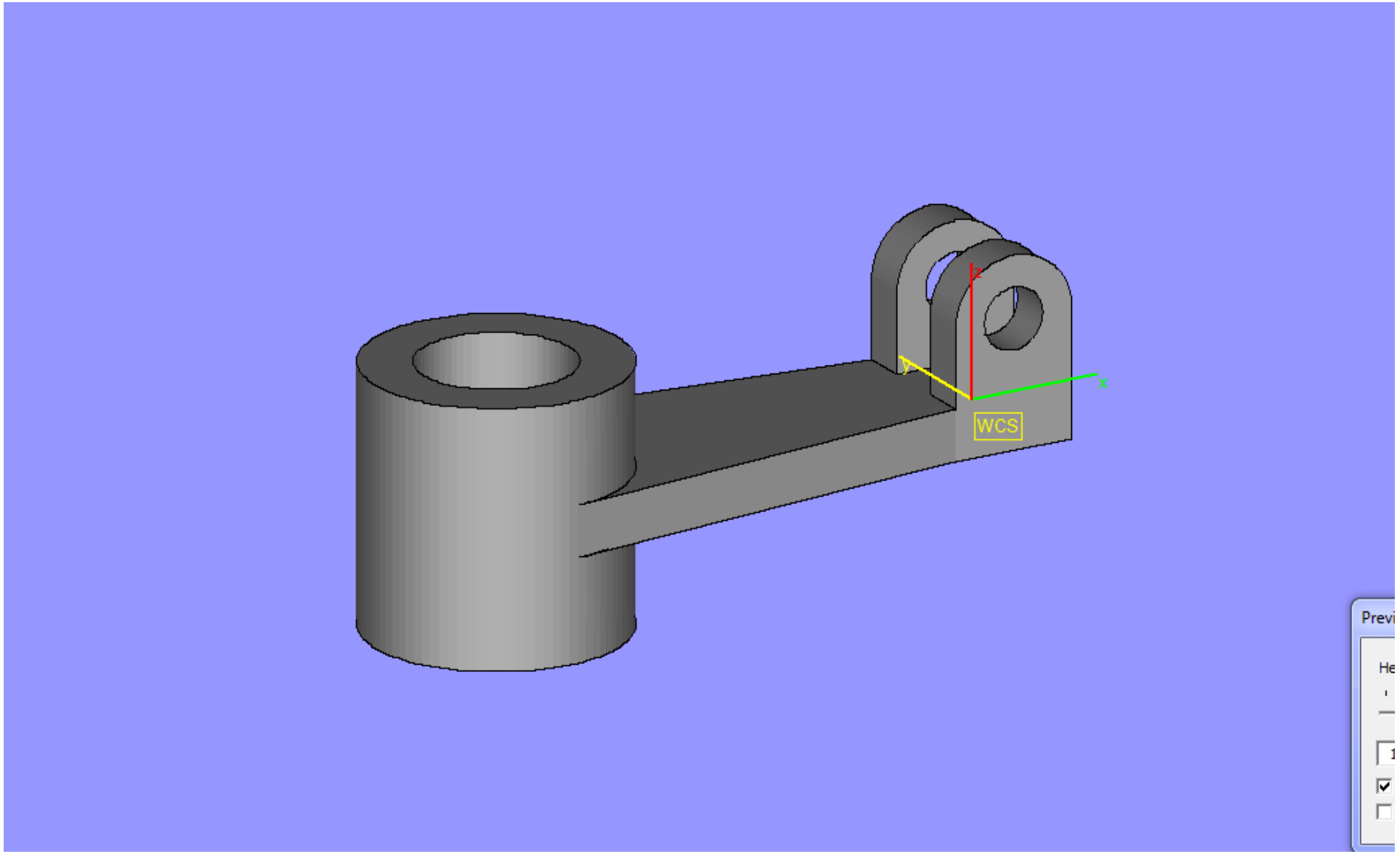
- What's that elemental way to simplify a 3D object?



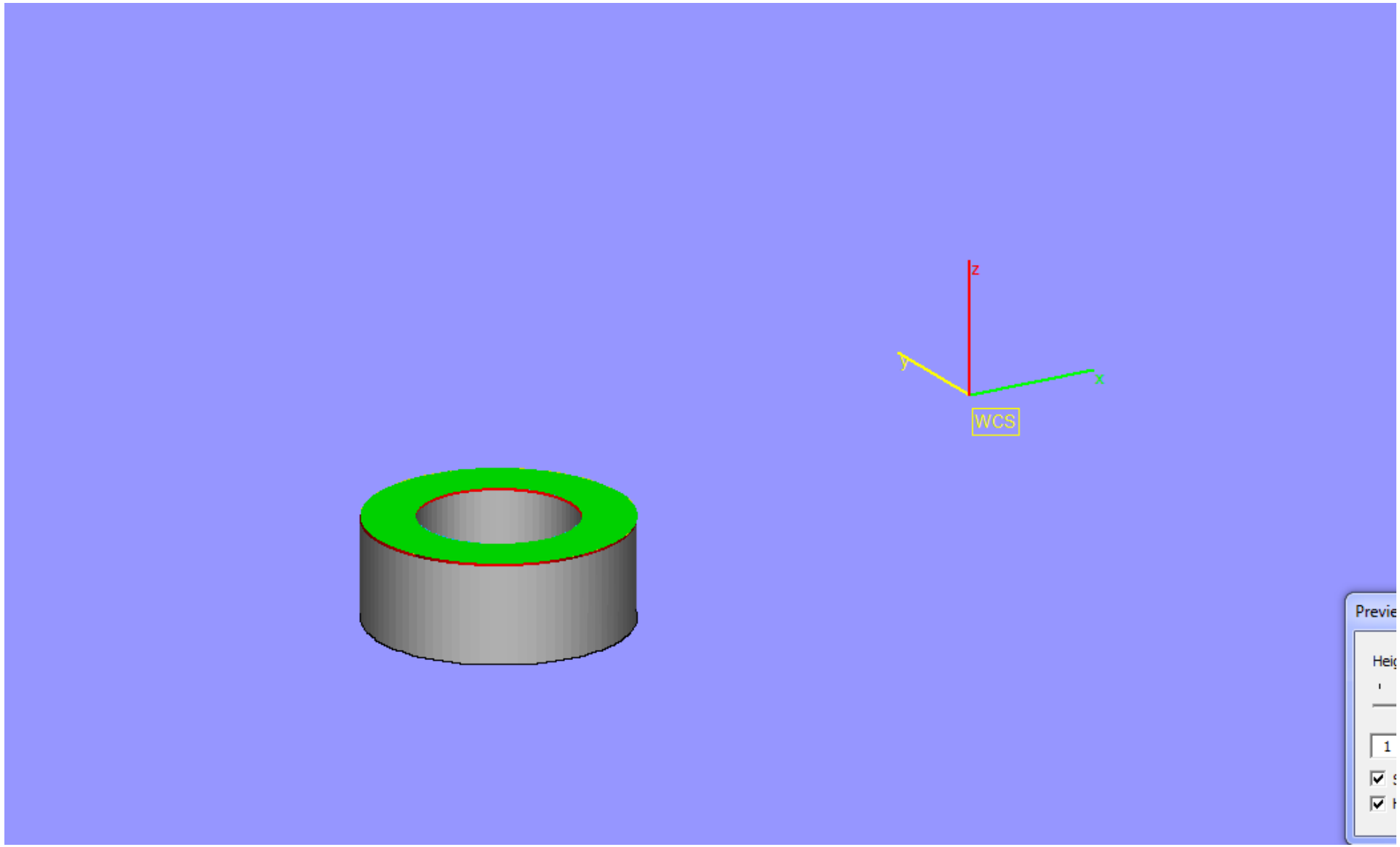
- Reduce it into 2D layers.



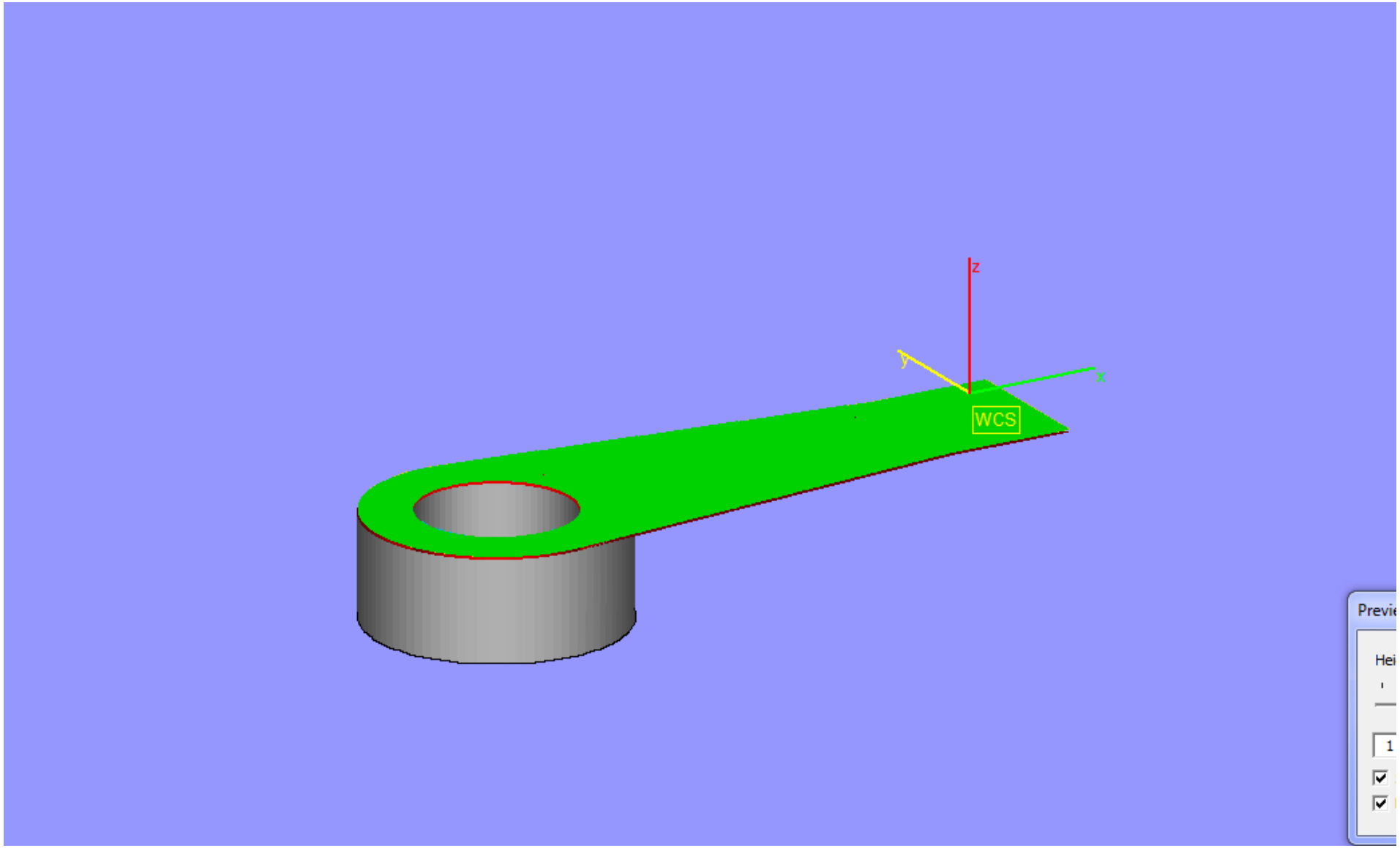
The problem of Support Mechanism



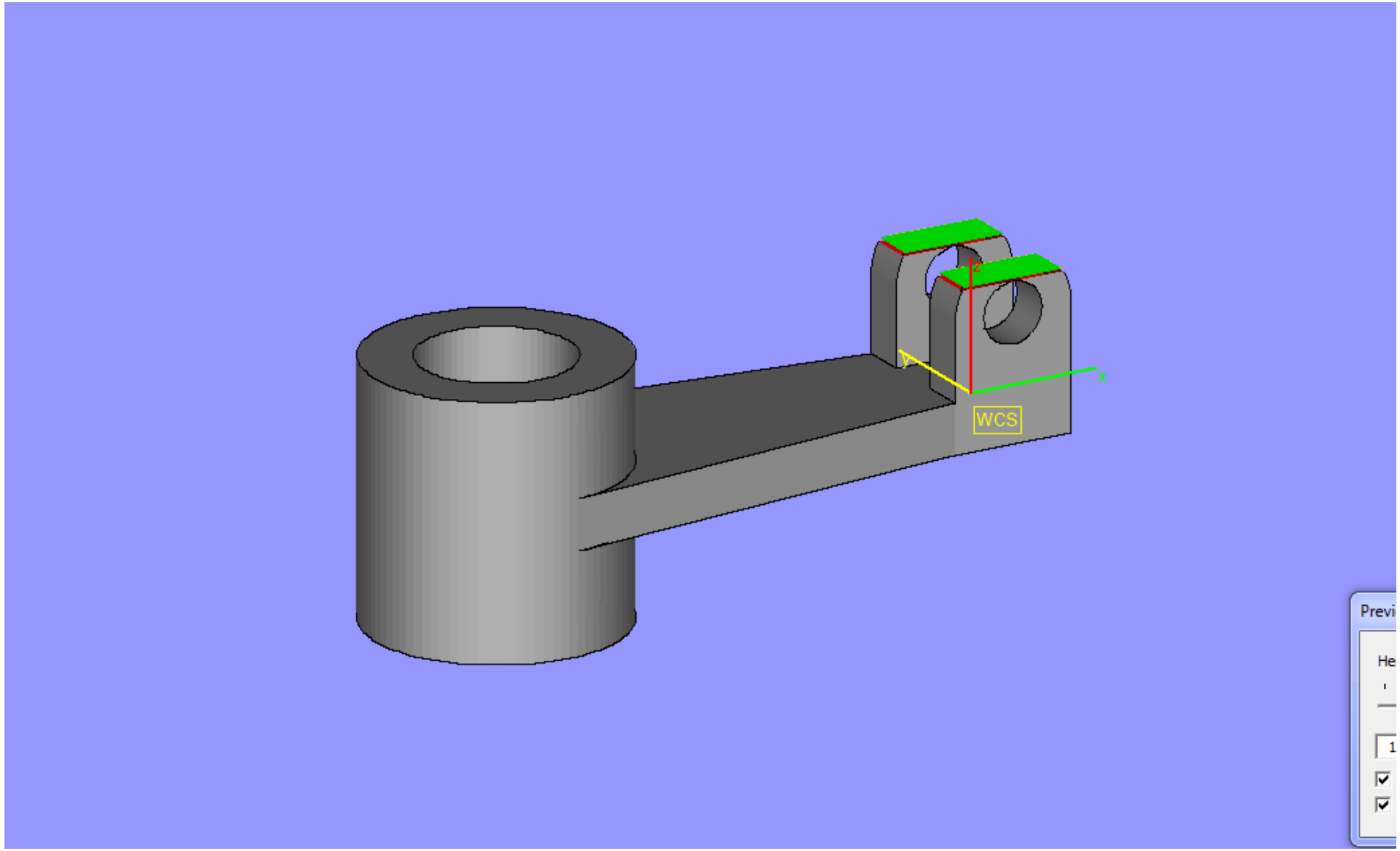
The problem of Support Mechanism



The problem of Support Mechanism

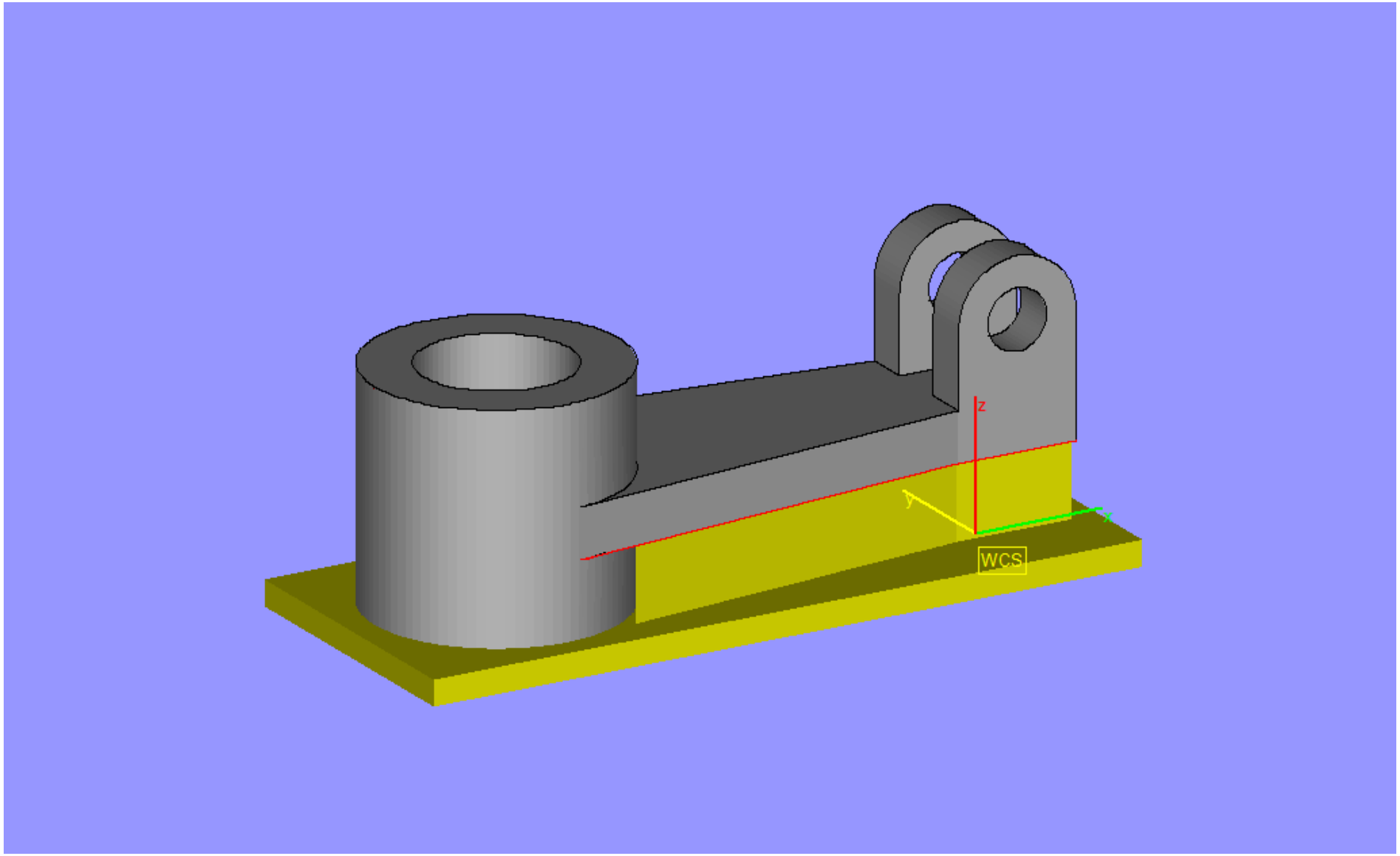


The problem of Support Mechanism



Solution – temporary support

Solution – temporary support



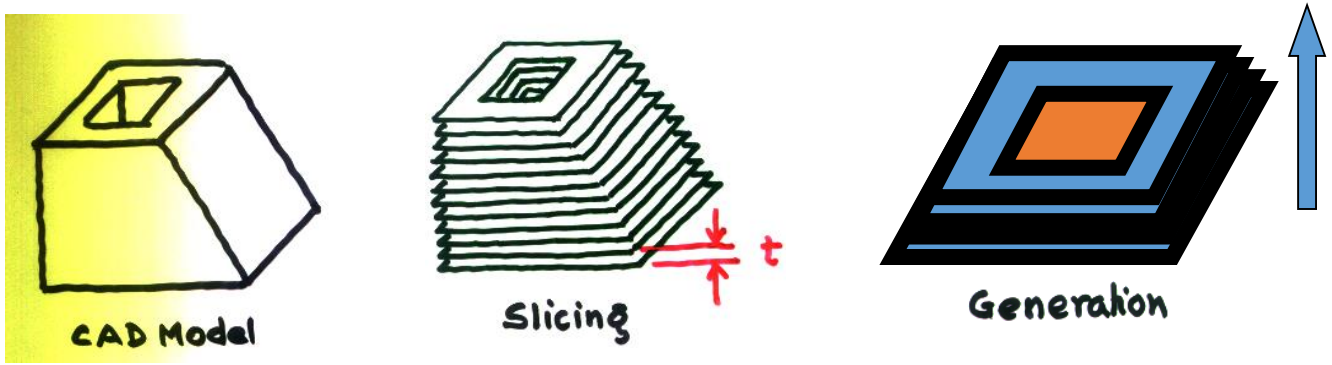
Support Material

And its water soluble!!!

Software Demo

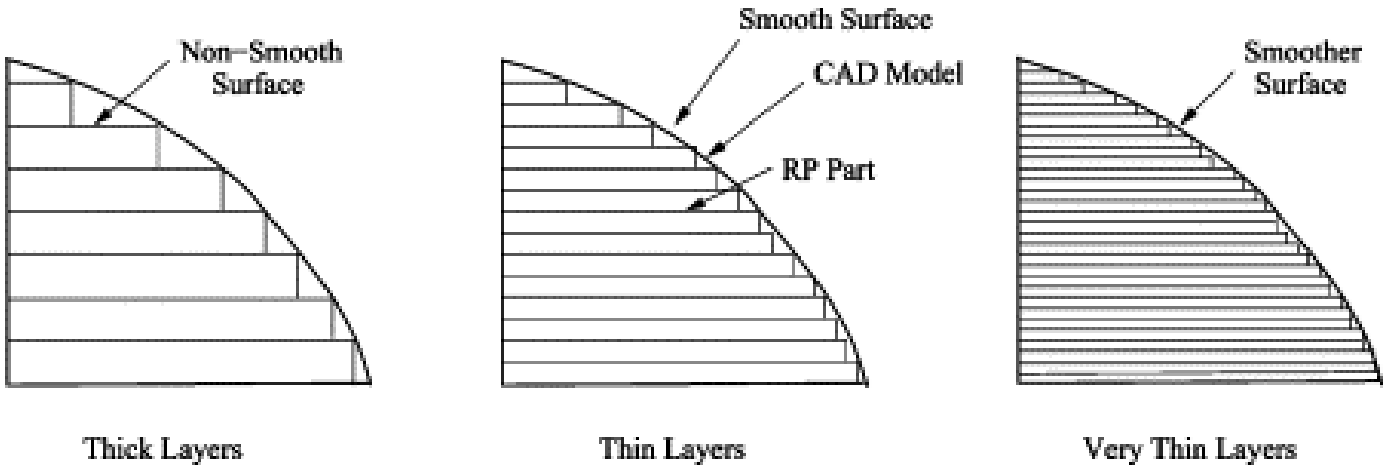
Design Considerations…

Layer-by-Layer



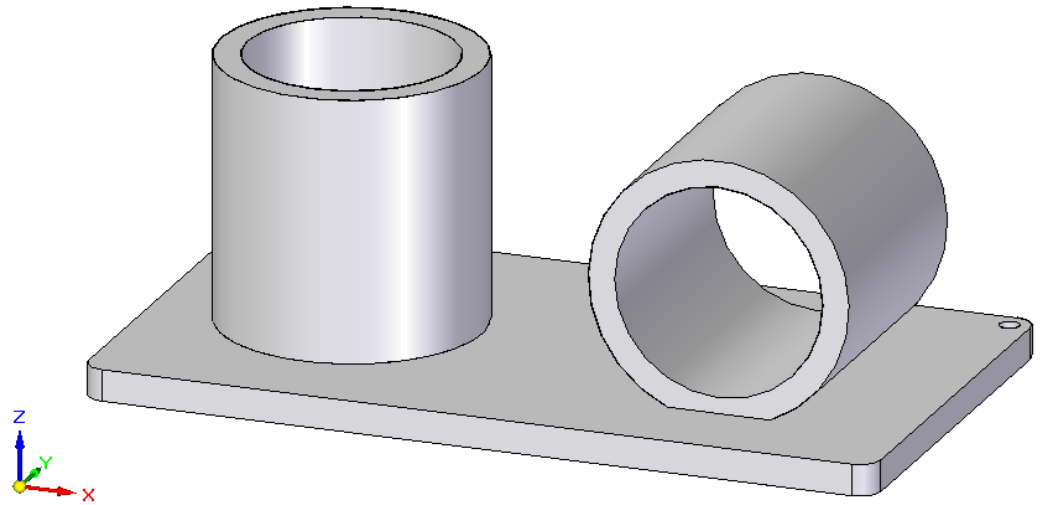
Staircase effect!

Surface Finish in AM



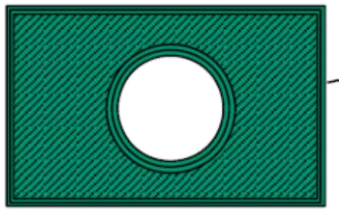
- Staircase effect is a Geometrical Constraint in AM and cannot be avoided
- Layer thickness controls the Surface finish of the part

Part Orientation



Part Orientation

In-plane



Better Surface finish & strength

Out-of-plane

Lower Surface finish & strength

Materials	Example materials	Process categories						
		Vat photo-polymer-ization	Material jetting	Binder jetting	Powder bed fusion	Material extrusion	Directed energy deposition	Sheet lamination
Thermoset Polymers	Epoxies and acrylates	X	X					
Thermo-plastic polymers	Polyamide, ABS, PPSF		X	X	X	X		X
Wood	paper							X
Metals	Steel, Titanium alloys, Cobalt chromium			X	X		X	X
Industrial ceramic materials	Alumina, Zirconia, Silicone nitride	X		X	X			X
Structural ceramic materials	Cement, Foundry sand			X	X	X		
Note: Combinations of the above material classes, e.g. a composite, are possible								

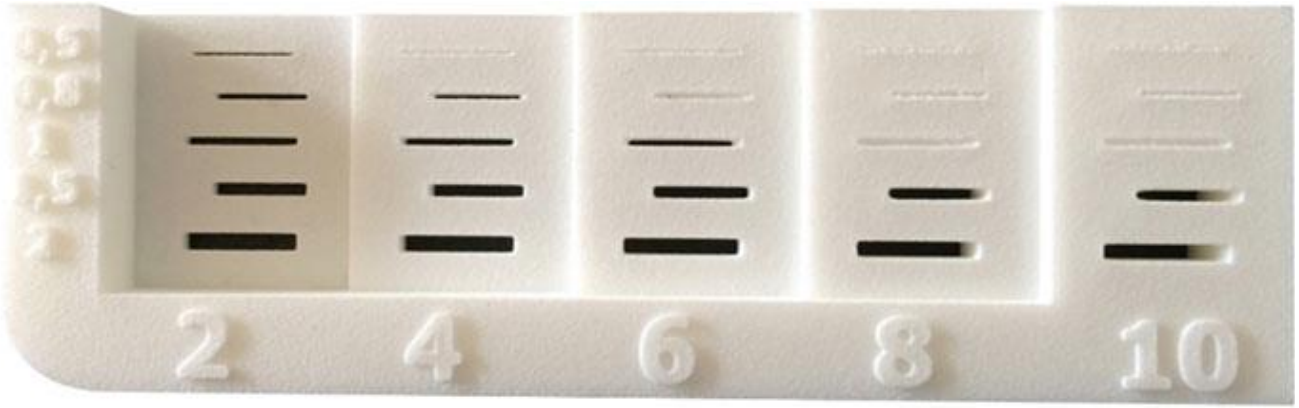
Other variables…

- Strength
- Surface properties
- Type of applications
- Durability
- Dynamic properties
- Part complexities
- Aesthetic considerations
- Etc….

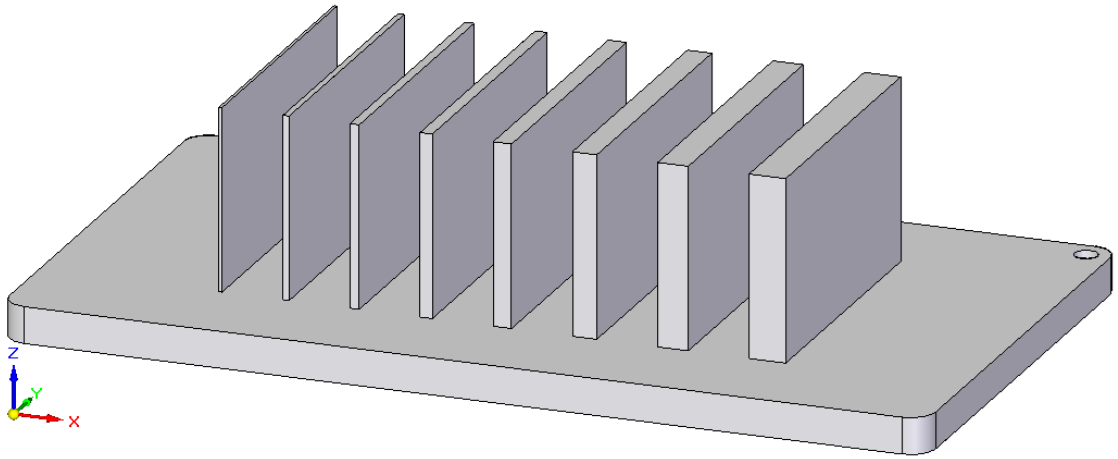
Few Guidelines

- minimum hole or slot size is directly related to the thickness of the part, the layer thickness, print orientation, as well as to the machine it is made on

#1: Know the limits…!

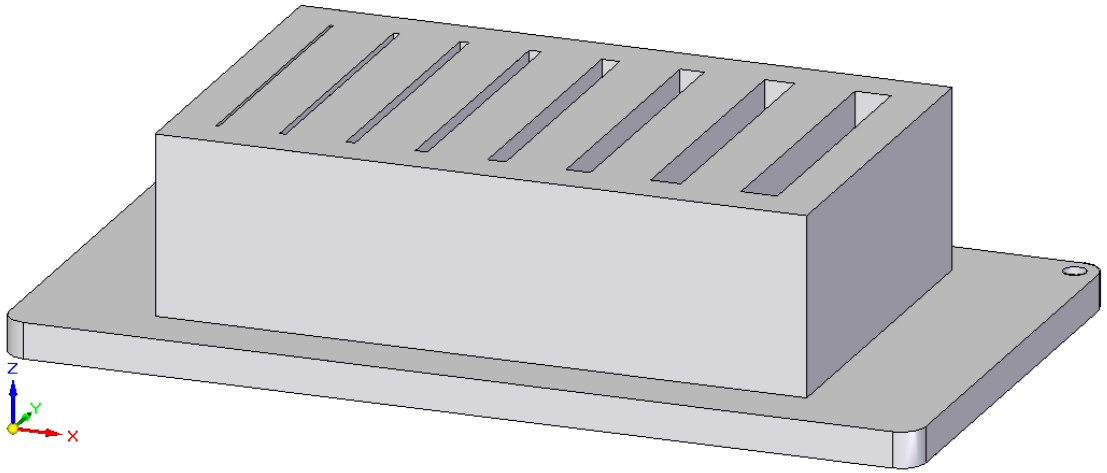


Minimum feature sizes: Wall Thickness



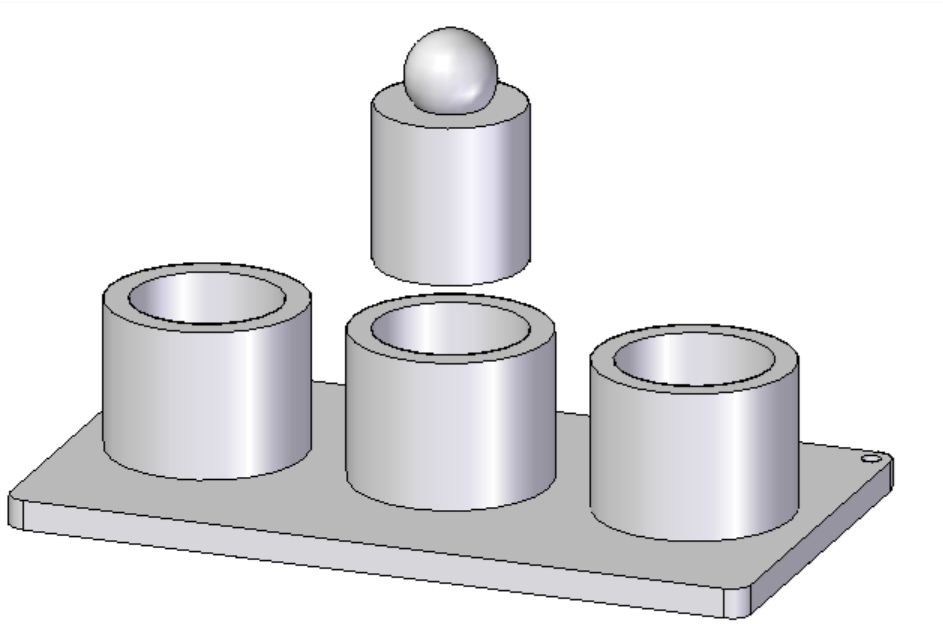
0.25 | 0.5 | 0.75 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0

Minimum feature sizes: Gap



0.25 | 0.5 | 0.75 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0

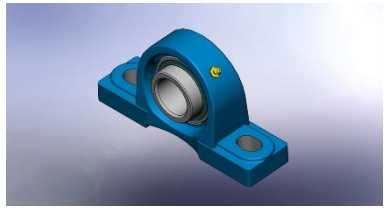
Moving Parts



0.1 0.2 0.3

Design for Assembly guidelines

Material Differentiation



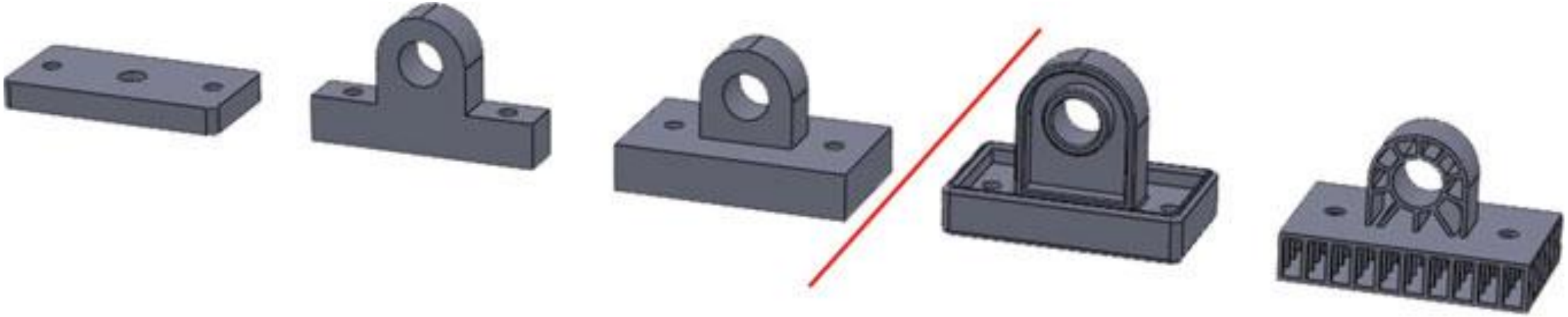
Relative Motion

Repair / Maintenance

Compliant Parts

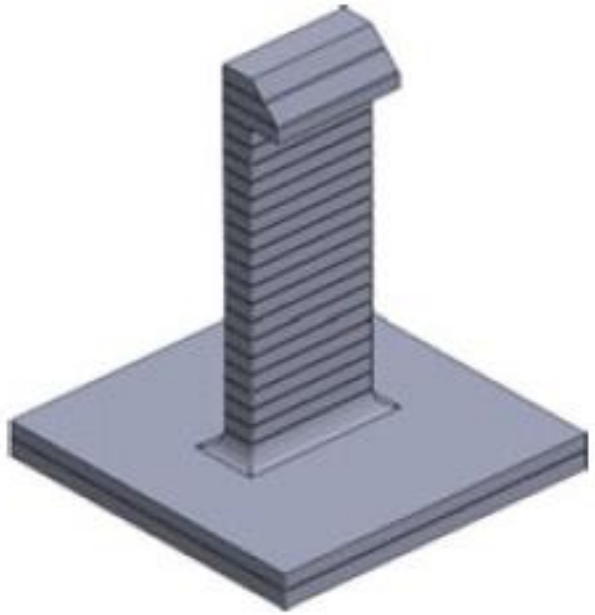
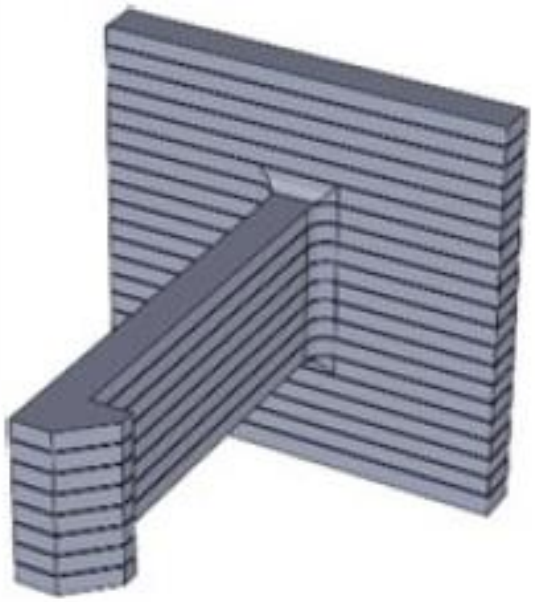
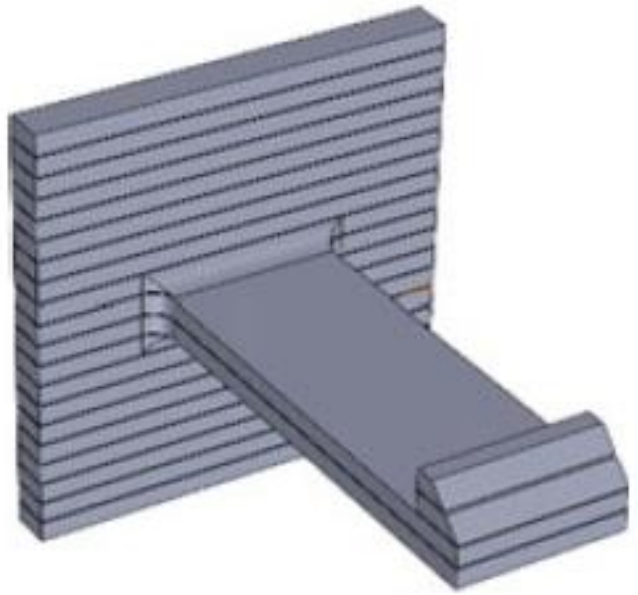
#2: Reduce number of parts…!

When to use AM processes

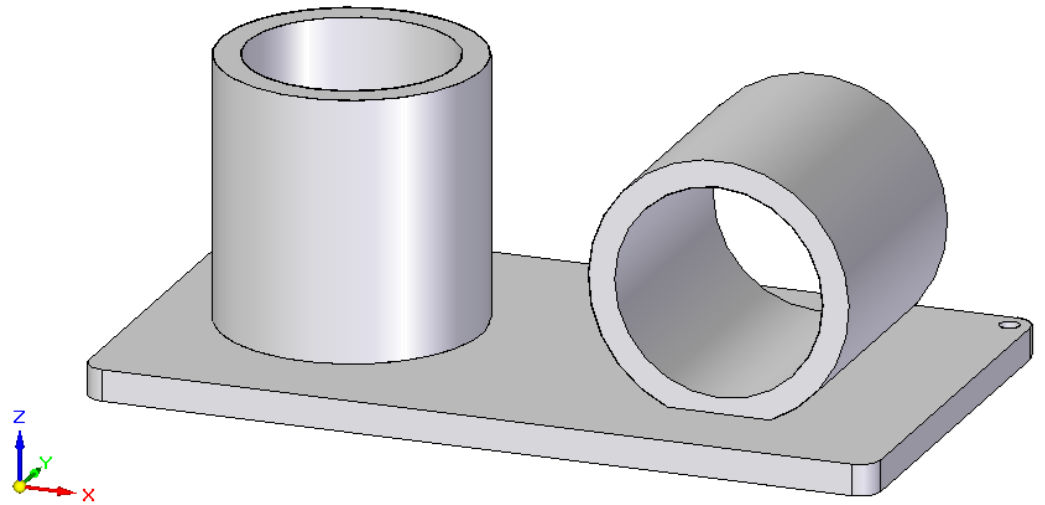


#3: Am process are better for complex parts…!

Printing Direction and required qualities

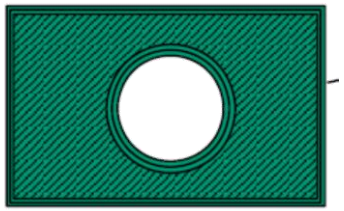
		
Clip will be weak and, almost certainly, break	Good compromise clip, with decent spring and strong hook	Clip has the best spring strength and flexibility but a weak hook

Part Orientation



Part Orientation

In-plane

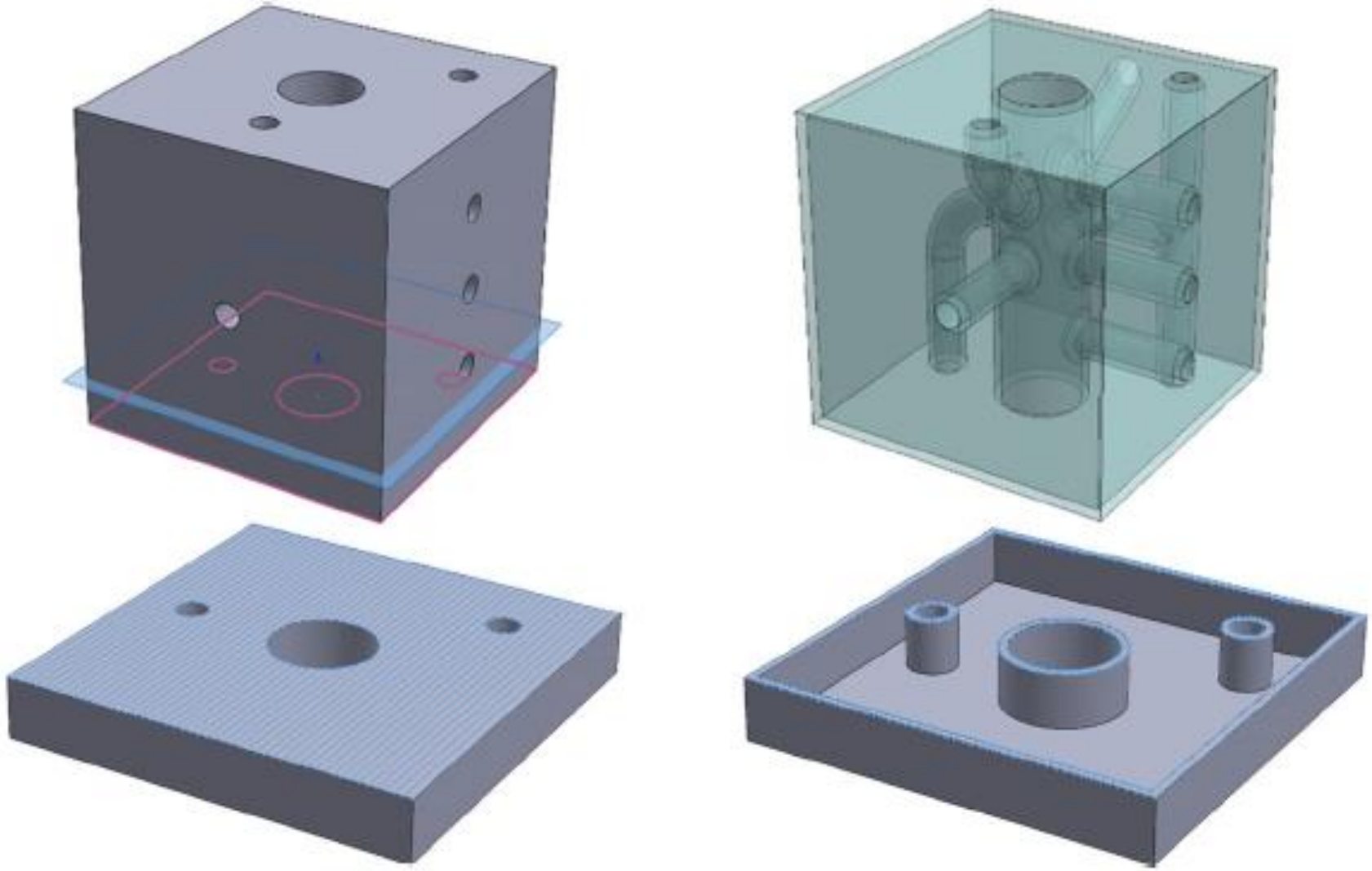


Better Surface finish & strength

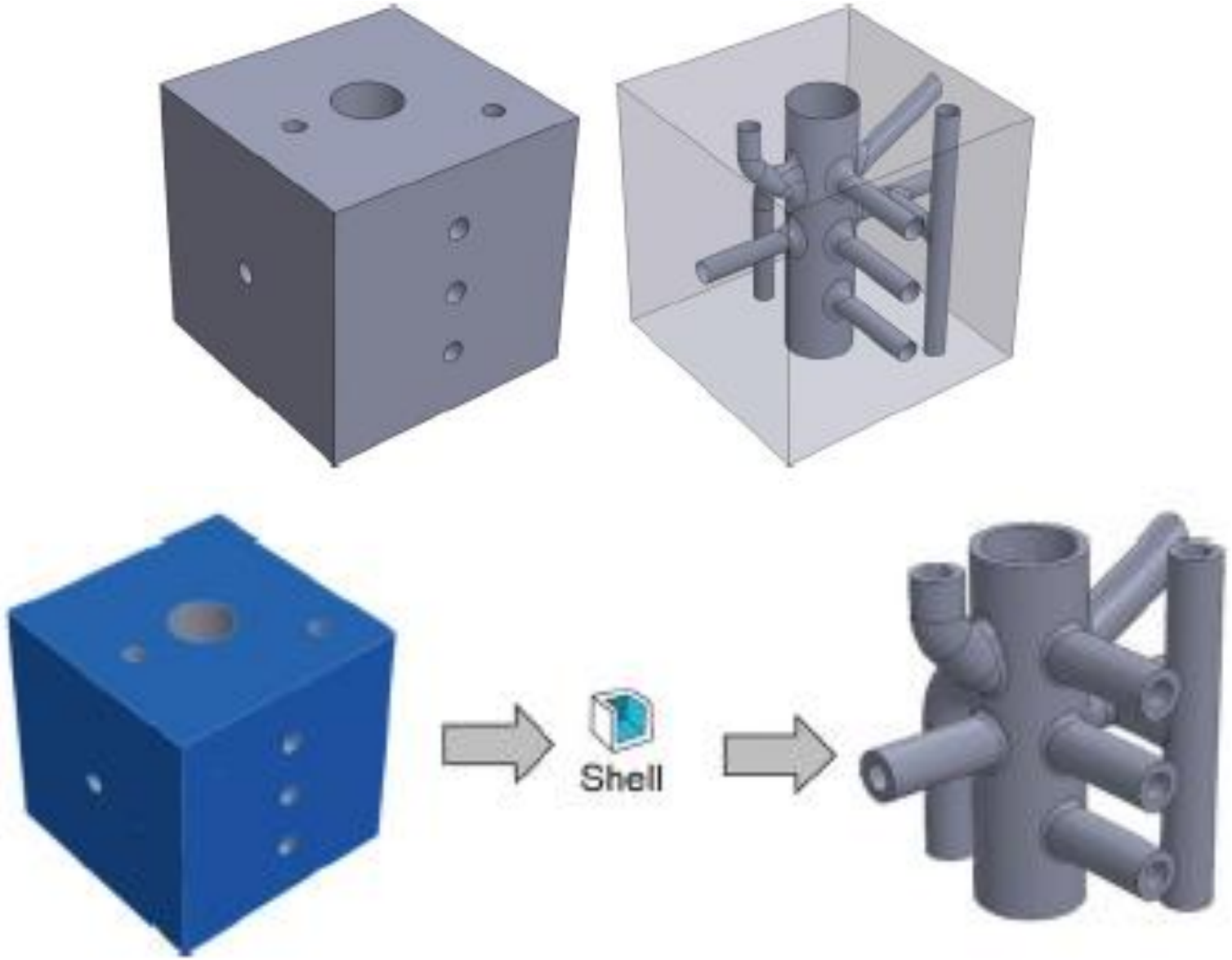
Out-of-plane

Lower Surface finish & strength

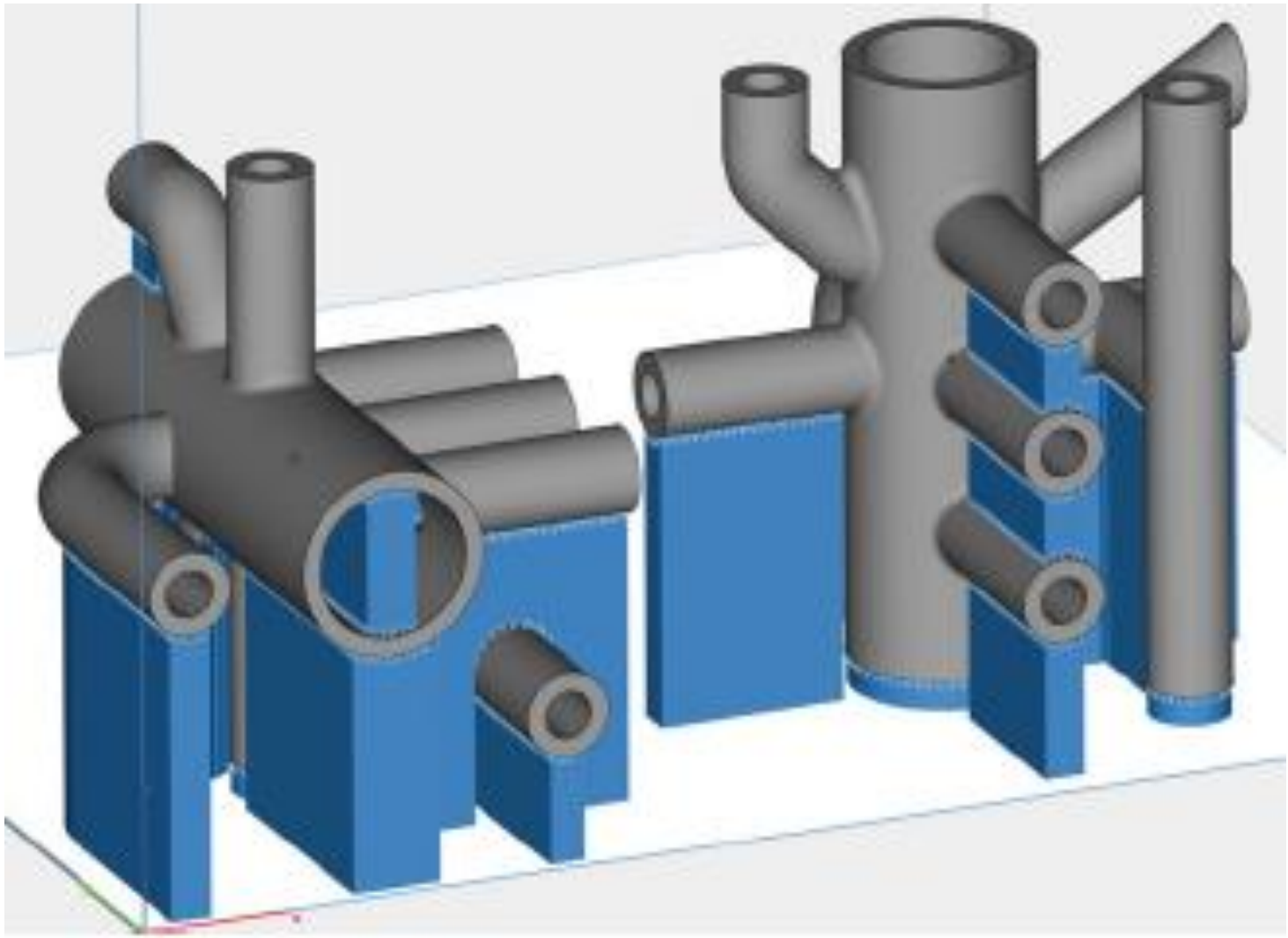
Shelling to reduce the print time



Reduce Post-Processing

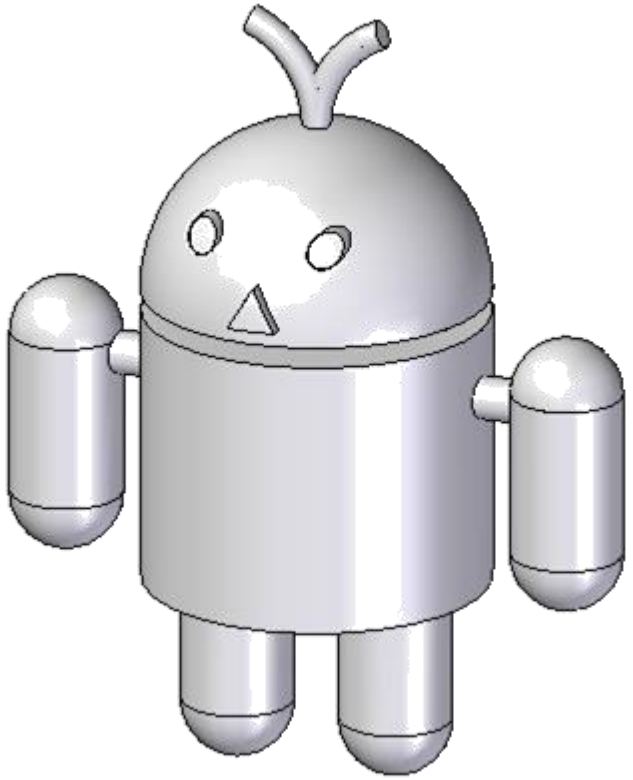


Part orientation

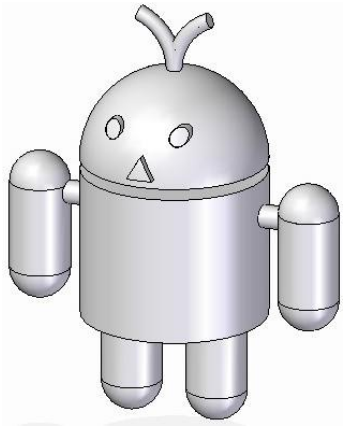
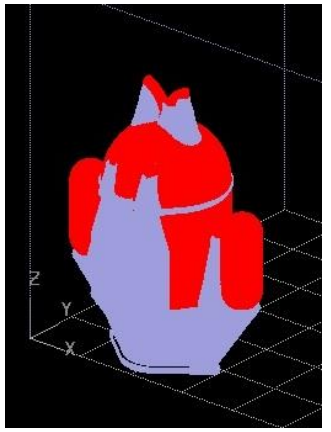


Case Study: Android Bot

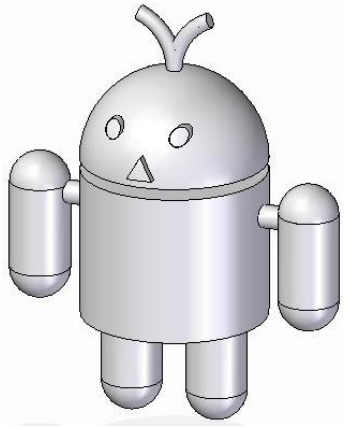
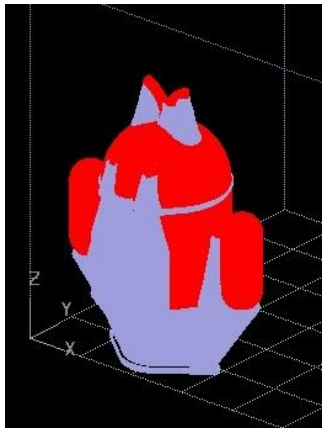
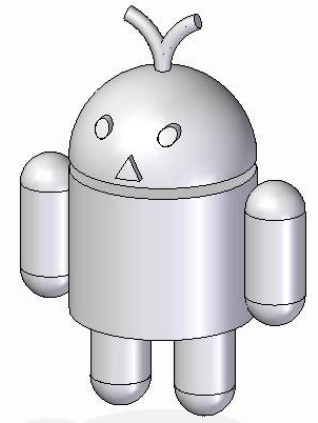
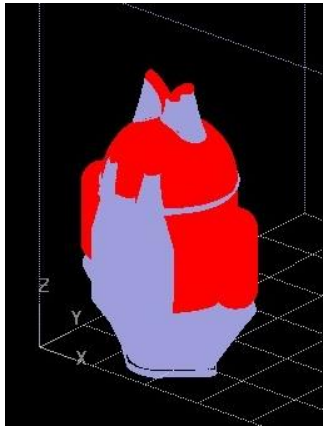
Build Orientation
and
Support material
considerations



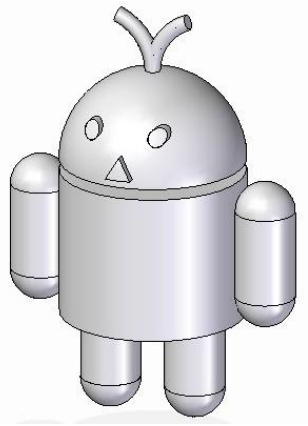
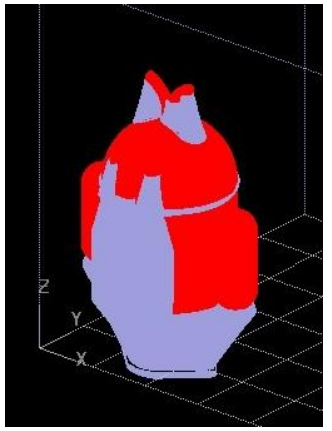
Step-1: Avoid Loosely Connected Parts

445mins	109.62cc	17.8cc		

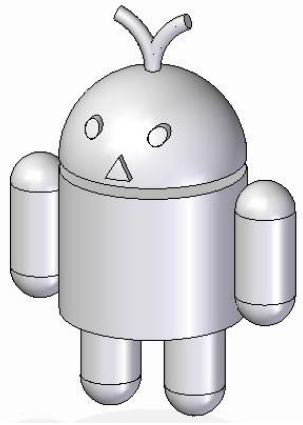
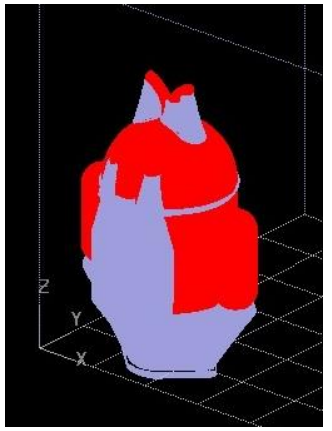
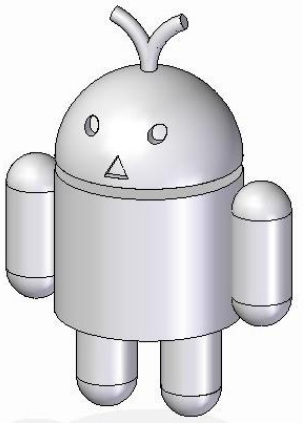
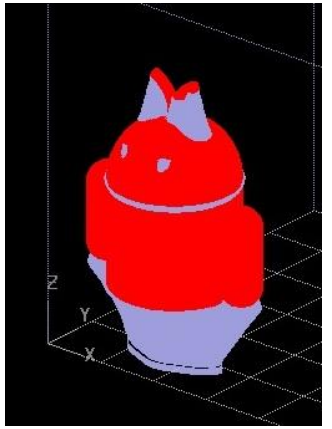
Step-1: Avoid Loosely Connected Parts

445mins	109.62cc	17.8cc		
431mins	109.01cc	14.98cc		
3.1%	0.6%	15.8%		

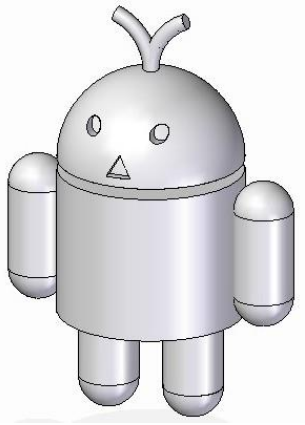
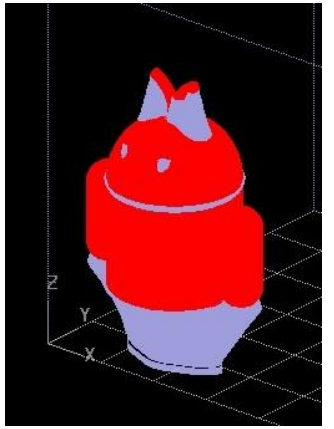
Step-2: Avoid Protruding Parts

431mins	109.01cc	14.98cc		

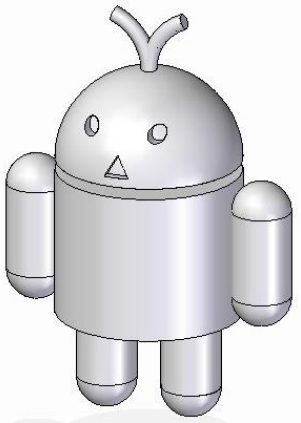
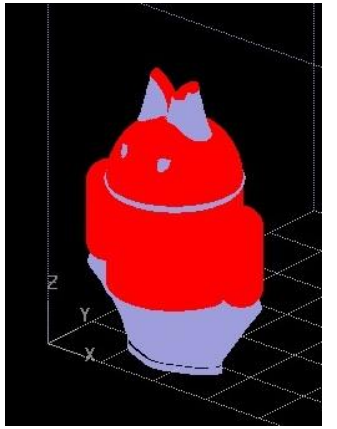
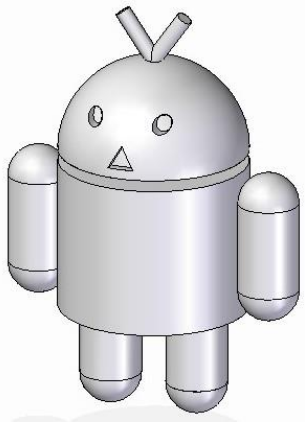
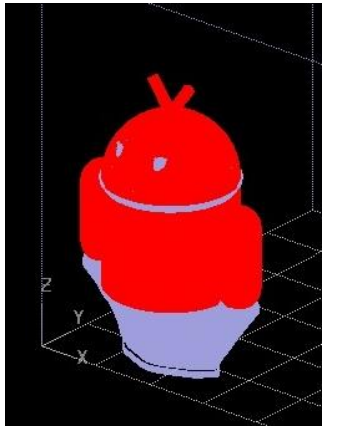
Step-2: Avoid Protruding Parts

431mins	109.01cc	14.98cc		
354mins	108.83cc	10.91cc		
17.9%	0.2%	27.2%		

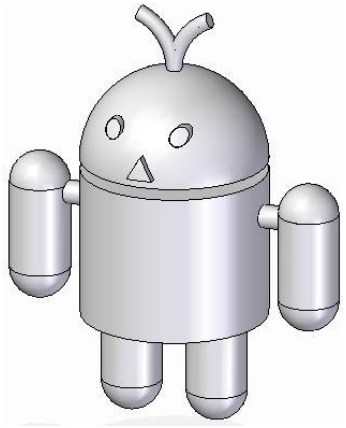
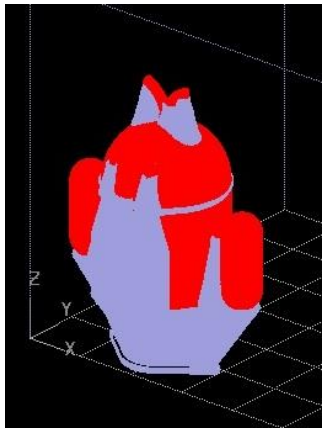
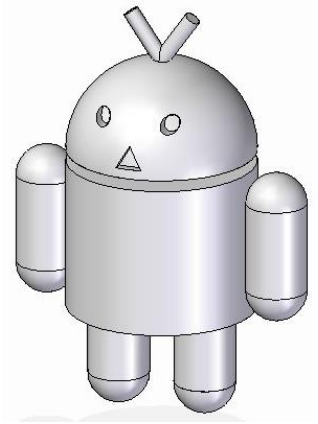
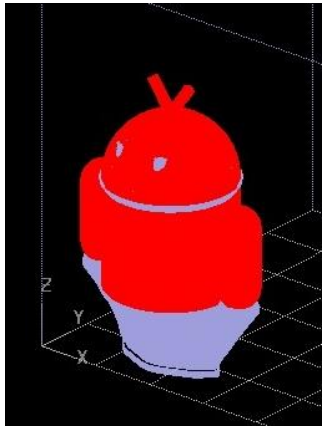
Step-3: Simply Small & Insignificant Parts

354mins	108.83cc	10.91cc		

Step-3: Simply Small & Insignificant Parts

354mins	108.83cc	10.91cc		
325mins	108.57cc	5.25cc		
8.2%	0.2%	51.9%		

Total Saving

445mins	109.62cc	17.8cc		
325mins	108.57cc	5.25cc		
27.0%	1.0%	70.5%		

Observations…

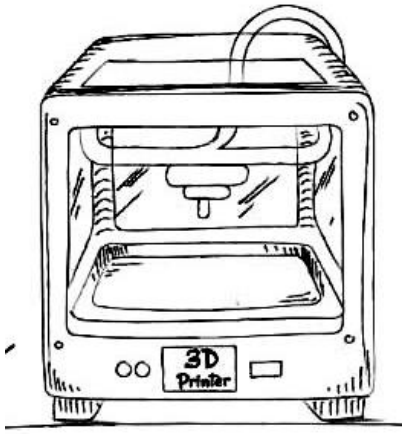
- Avoid Loosely connected parts
- Minimize / eliminate very small features
- Depressions are better that protrusions
- Make use of overhangs

The story: An ordinary day in future…

Mr. Ajay

Mr. Ramesh

Ms. Seema



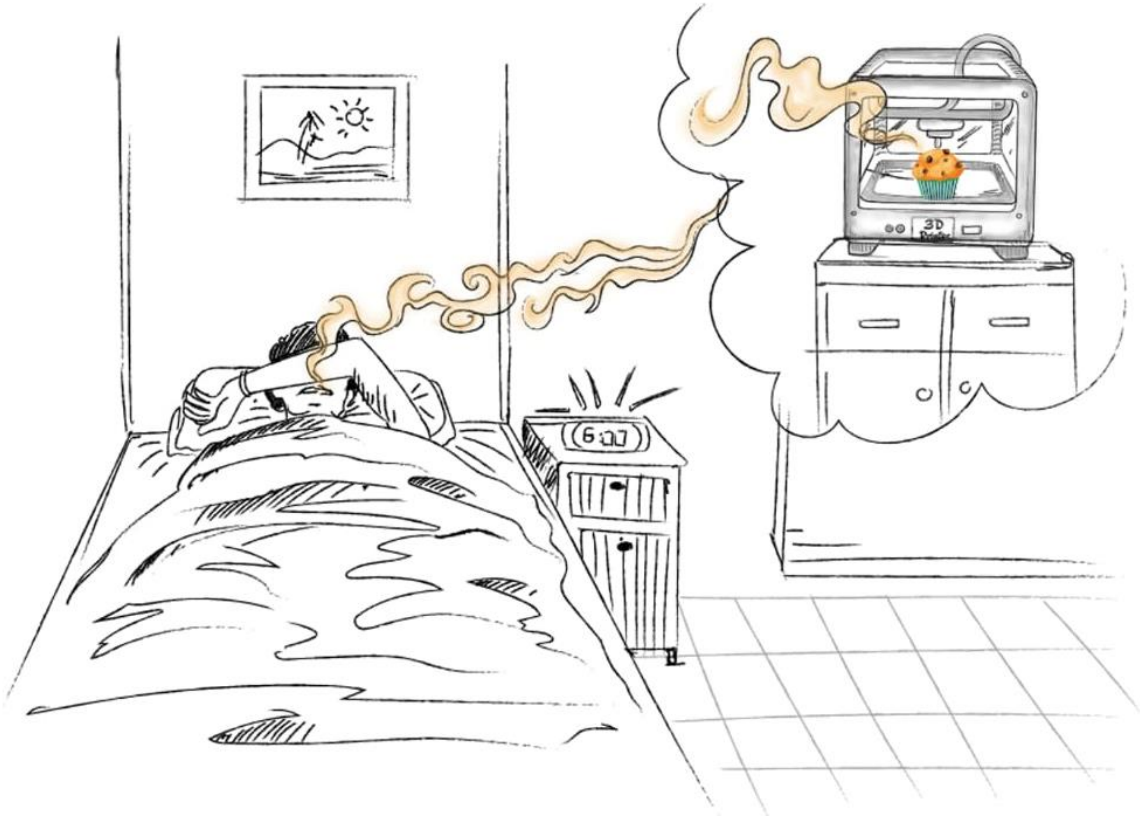
3D Printer

The Day Starts…

When: Few decades later….(or even earlier)

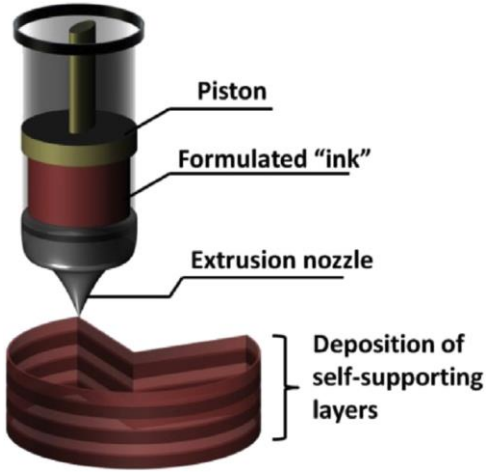
Where: In the life of Mr. Ajay (or it may be you…)!

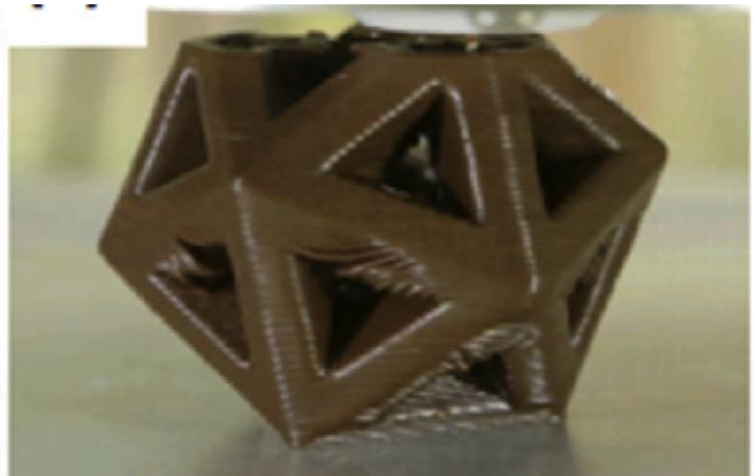
3D Printing in Food Fabrication



3D Printing in Food Design

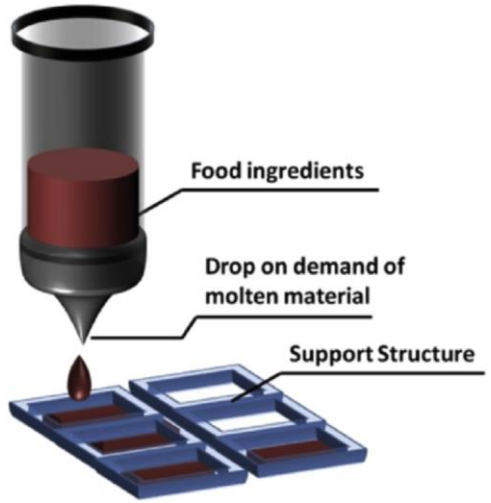
- Material:
  - Liquid
- Principle:
  - Extrusion and deposition
- Binding Mechanism:
  - No phase change (Frosting, processed cheese, dough, etc.)
  - Solidification upon cooling (Chocolate, confection)
  - Ionic or enzymic cross-linking (gum and gelatin)

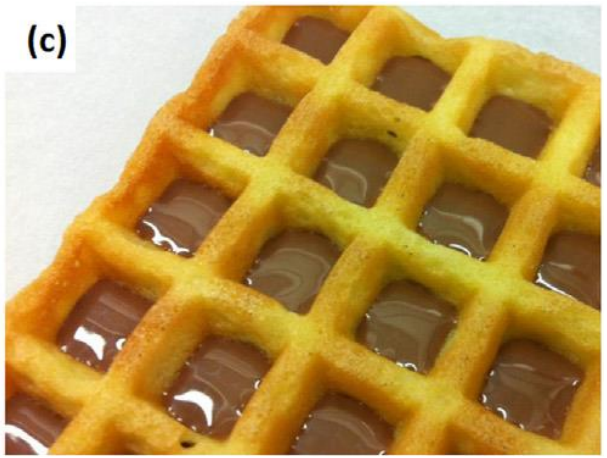




3D Printing in Food Design

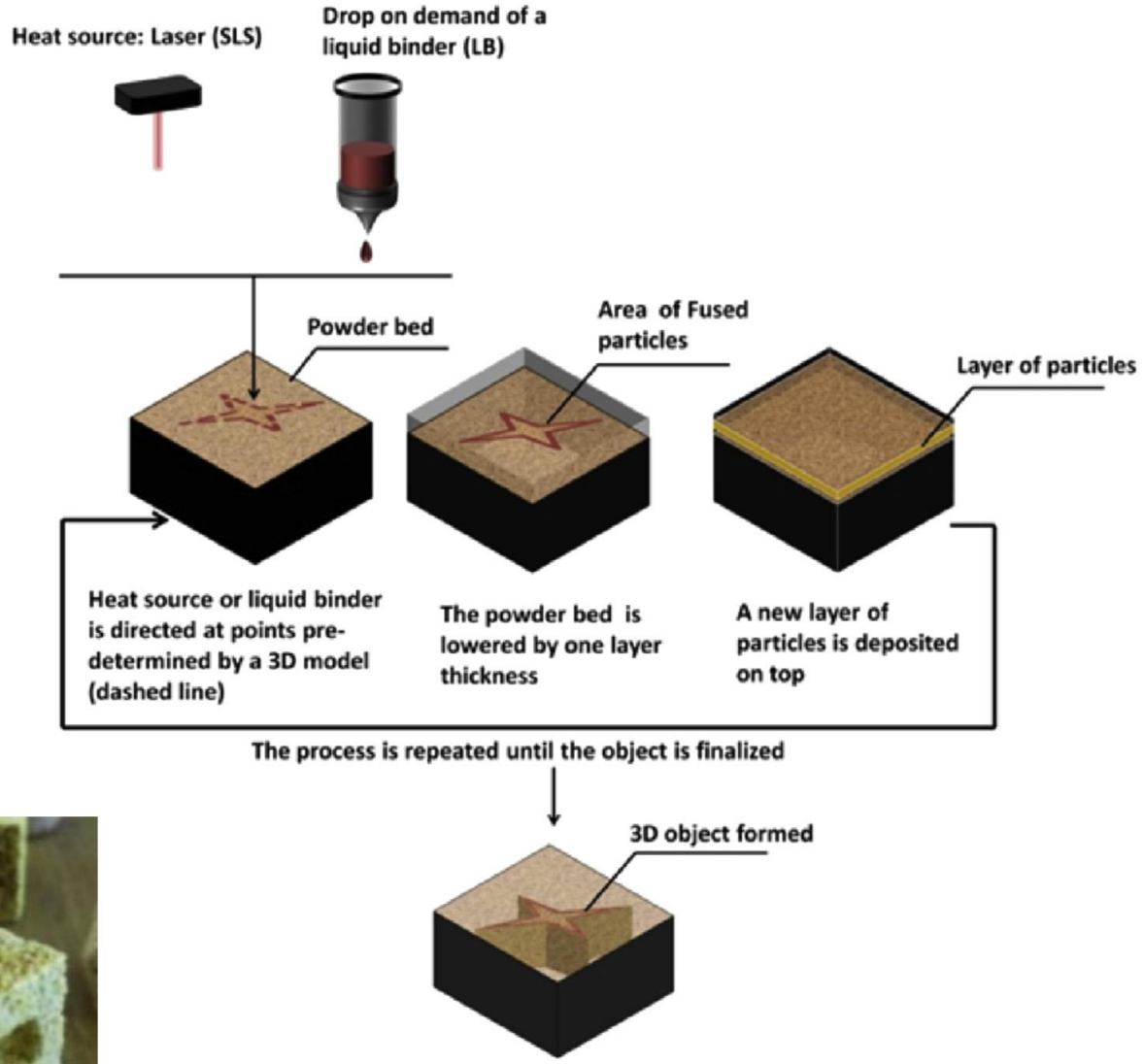
- Material:
  - Liquid
- Principle:
  - Drop-on-demand (Ink jet)
- Binding Mechanism:
  - No phase change (Chocolate, liquid dough, sugar icing,)





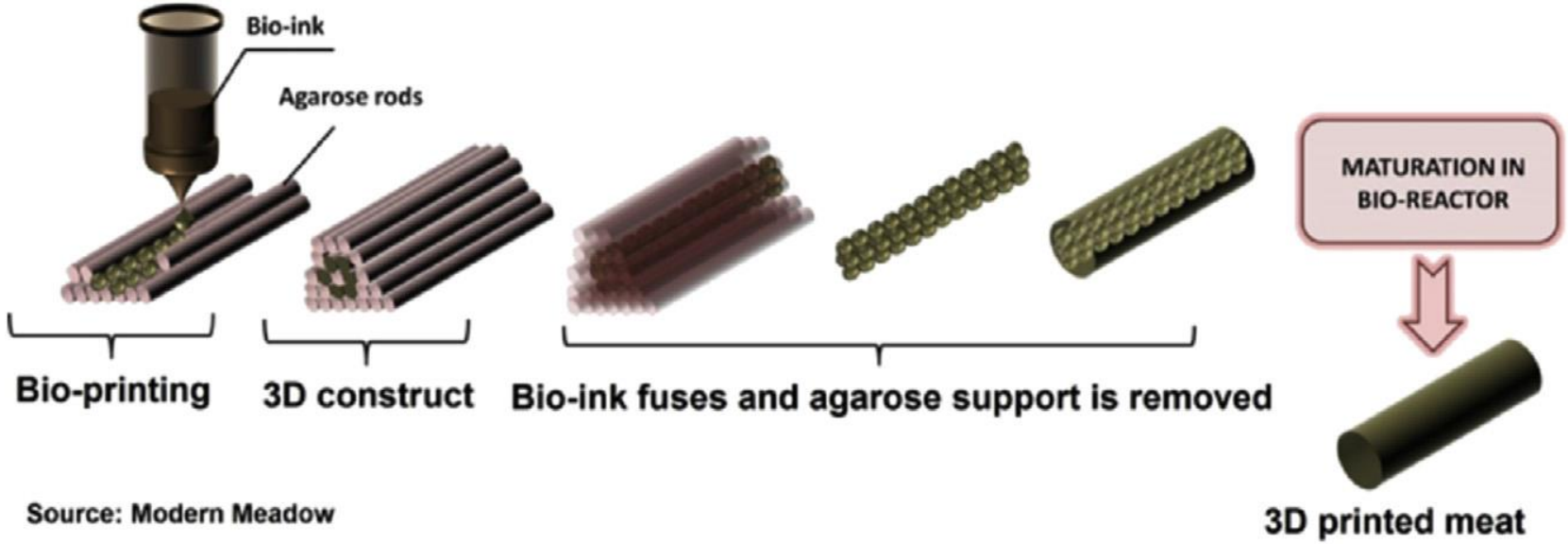
3D Printing in Food Design

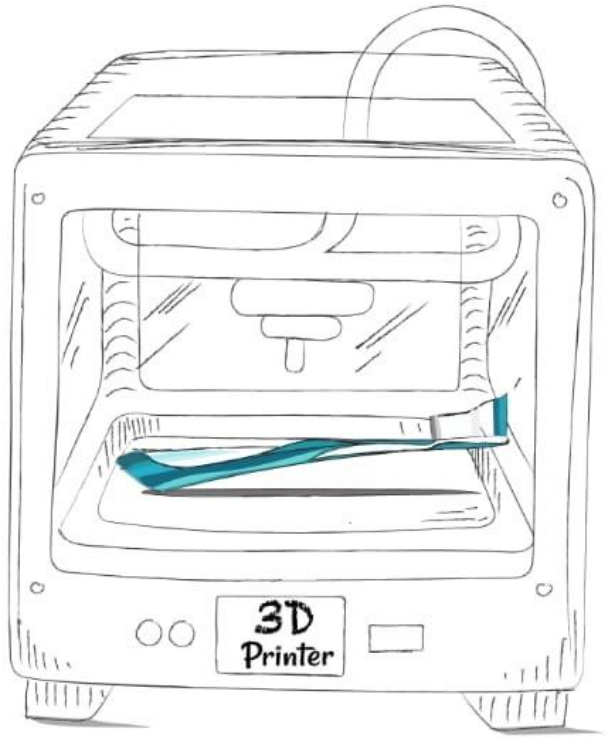
- Material:
  - Powder
- Principle:
  - Powder binding and binder drop-on-demand deposition
- Binding Mechanism:
  - Adhesive forces or chemical reactions between powder and binder (Chocolate)



3D Printing in Food Design

- Material:
  - cell
- Principle:
  - Drop-on-demand deposition (Bio-Printing)
- Binding Mechanism:
  - Self-assembly of the cells (Meat)





On Demand Product Design

NERI OXMANN - *an American–Israeli architect, designer, and professor at the MIT Media Lab*

Gemini - combination of a solid wood milled shell housing and an intricate cellular skin made of sound absorbing material

Gemini by Neri Oxman 2014, *Stratasys Connex Technology, CNC milling. Paris, France*

NERI OXMANN

Qamar *Luna's Wonderer* - wearable pneumatic surface for generating and storing oxygen

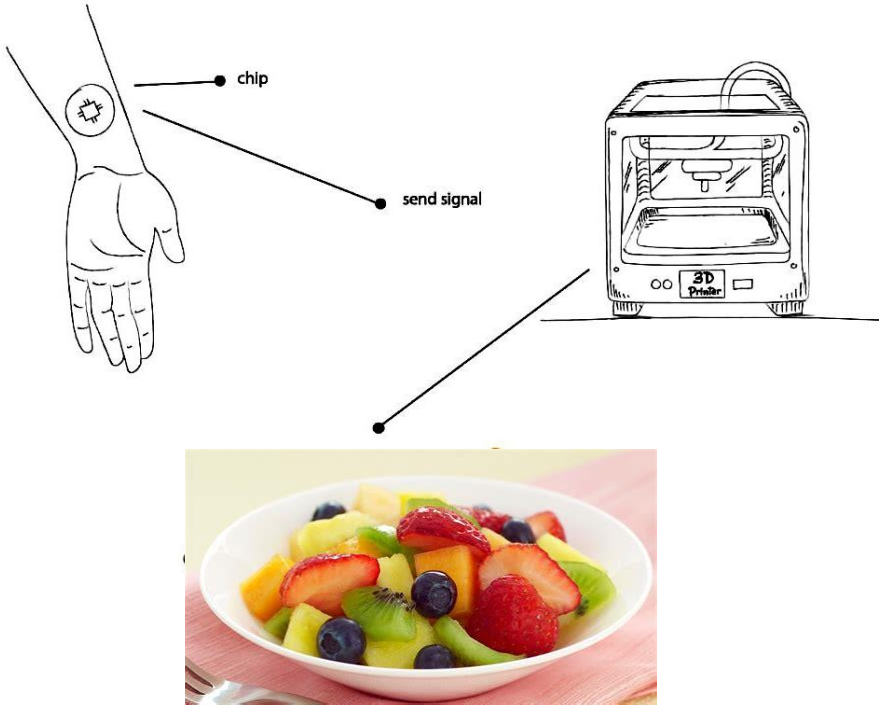
Qamar, Luna's Wander by Nari Oxman 2014 *3D print Euromold, Frankfurt, Germany*

NERI OXMANN

Vespers - a collection of death masks from Neri Oxman and her team at MIT's Mediated Matter Group.

Death Masks from MIT Capture Your Dying Breath by Nari Oxman, *Courtesy of MIT Media Lab*

My father thinks that this is an automated bread making machine…



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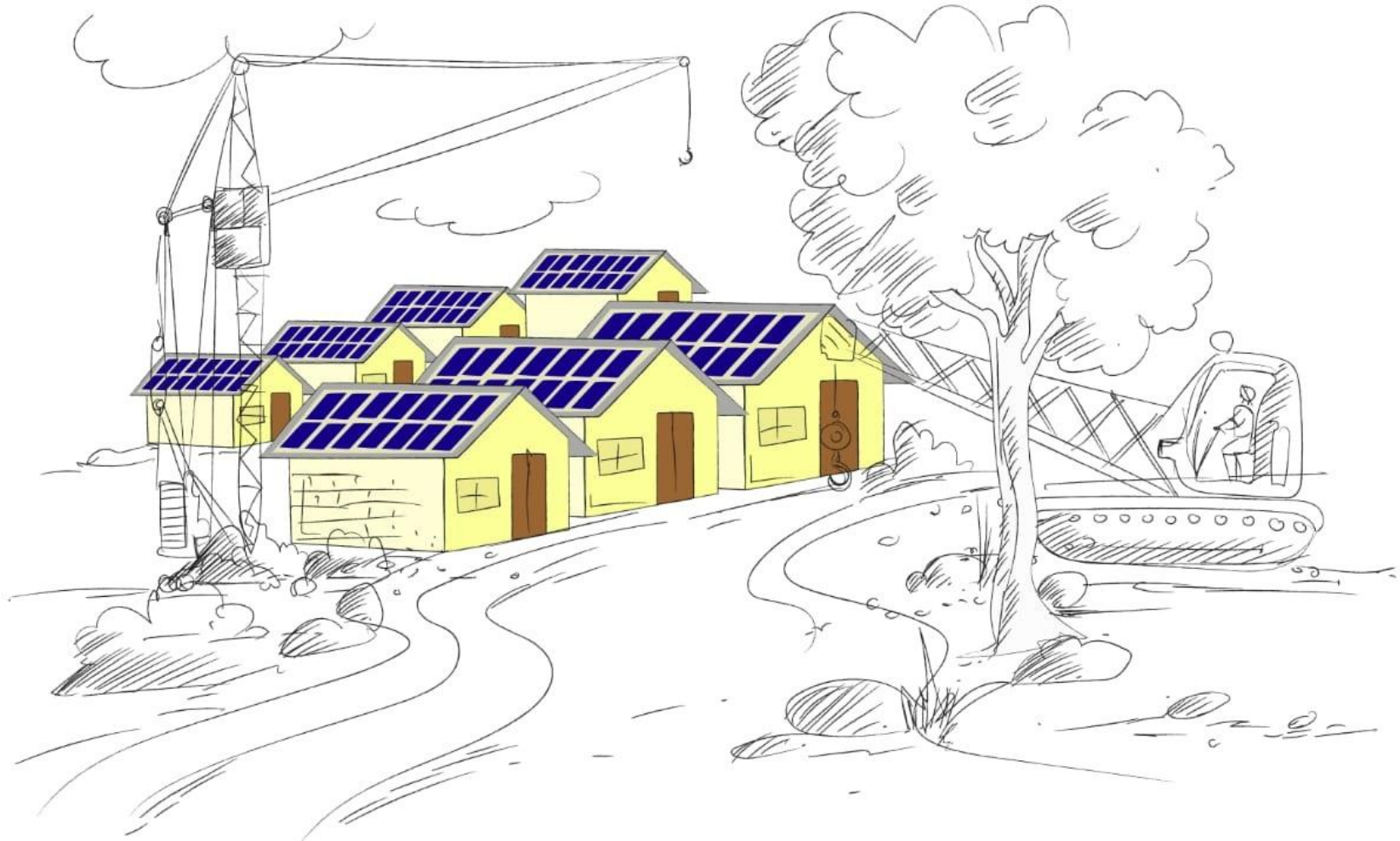
Looking to the future: Creating novel foods using 3D printing

By Nathan Gray
23-Dec-2010 - Last updated on 04-Jul-2012 at 15:43 GMT

RELATED TAGS: Food

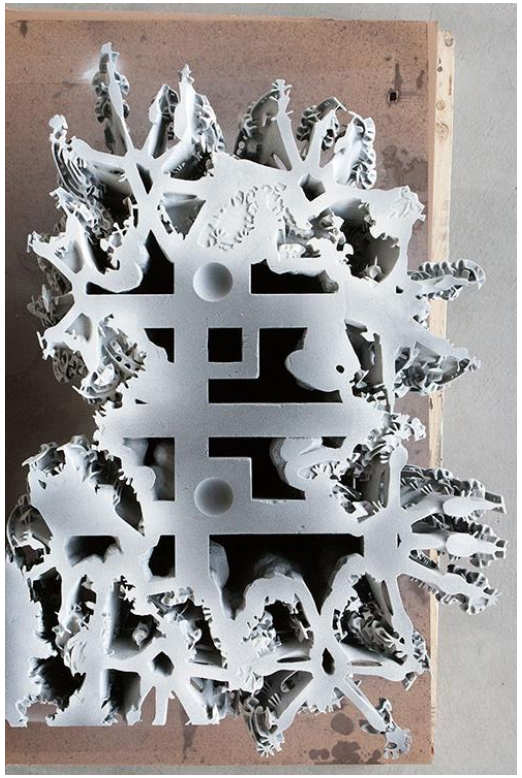
Techniques such as 3D printing, elctrospinning, and laser sintering could work together as one process, to produce whole products from raw components like algae protein, fat and starch, TNO predicts.



3D Printing in Construction Technology


亚创3D打印全球最高建筑

MICHAEL HANSMEYER - *post-modern architect who utilizes algorithmic architecture techniques`*



Digital Grotesque II - a full-scale 3D printed grotto premiered at Centre Pompidou's 'Imprimer

le monde' exhibition

This Mysterious 3D Printed Grotto Challenges Boundaries of Computational Geometry and Human Perception, © Fabrice Dall'Anese

MICHAEL HANSMEYER

Subdivided Columns - *A New Order (2010)*

new column order based on subdivision processes

Subdivided Columns - A New Order (2010) by Michael Hansmeyer

MICHAEL HANSMEYER

Arabesque Wall - massive 3D printed wall with ornamental details

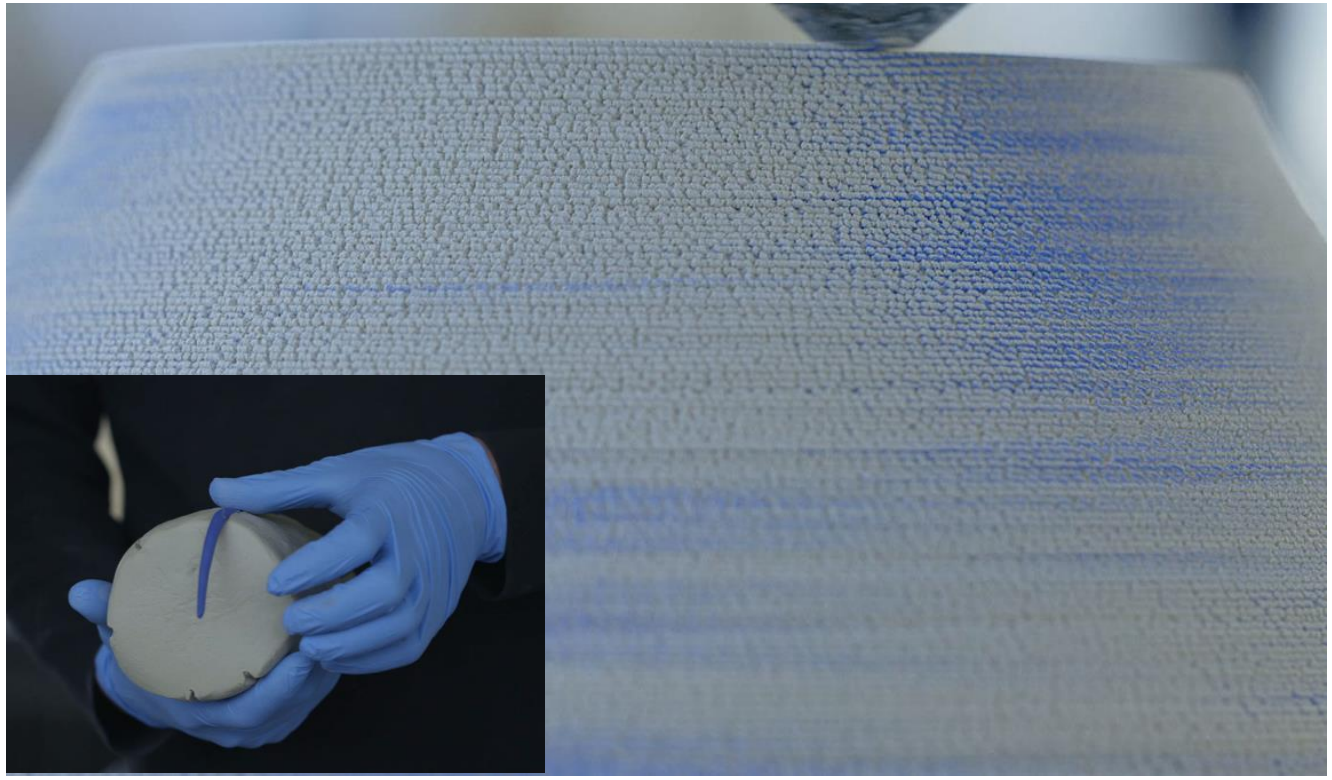
Arabesque Wall - by Michael Hansmeyer with Benjamin Dillenburger

OLIVIER VAN HERPT- *Research and product development in Eindhoven, Netherlands*

3D Printed Ceramics - Explorations in functional 3D Printing in Ceramics *(2012 – ongoing)*

3D Printing in Ceramics by Olivier van Herpt on the 3D printer designed by him

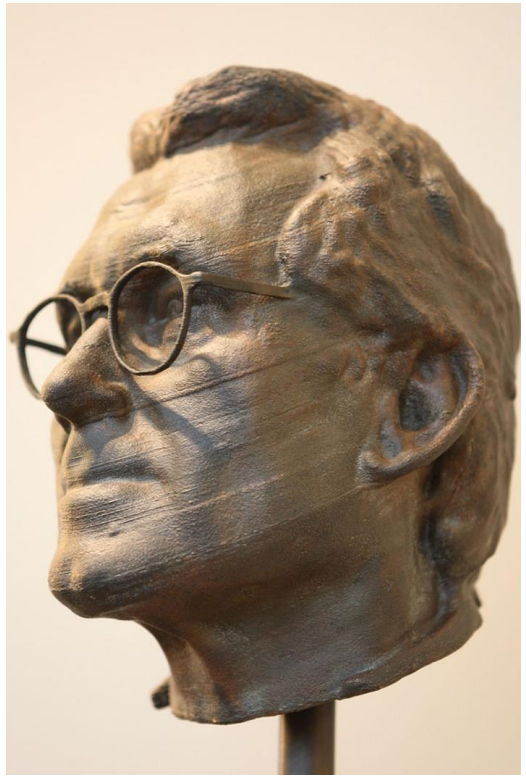
OLIVIER VAN HERPT



Arcanum - 3D Printed Porcelain Flower Pyramid *(2016 – 2017)*

Arcanum, 3D Printed Porcelain Flower Pyramid by Olivier van Herpt

OLIVIER VAN HERPT



Nobel Prize Portrait - Bronze head of Ben Feringa *(2017)*

Nobel Prize Portrait Bronze head of Ben Feringa and 3D printer designed by Olivier van Herpt

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3D Printing in Fashion Technology

DANIT PELEG - *fashion Designer known for her 3D Printed Fashion work*

3D Printed jacket and shoe - first ready-to-wear 3D printed jacket available to purchase online

Meet Danit Peleg: the designer making 3D printed fashion collections, by WGSN Insider Dec 04, 2015

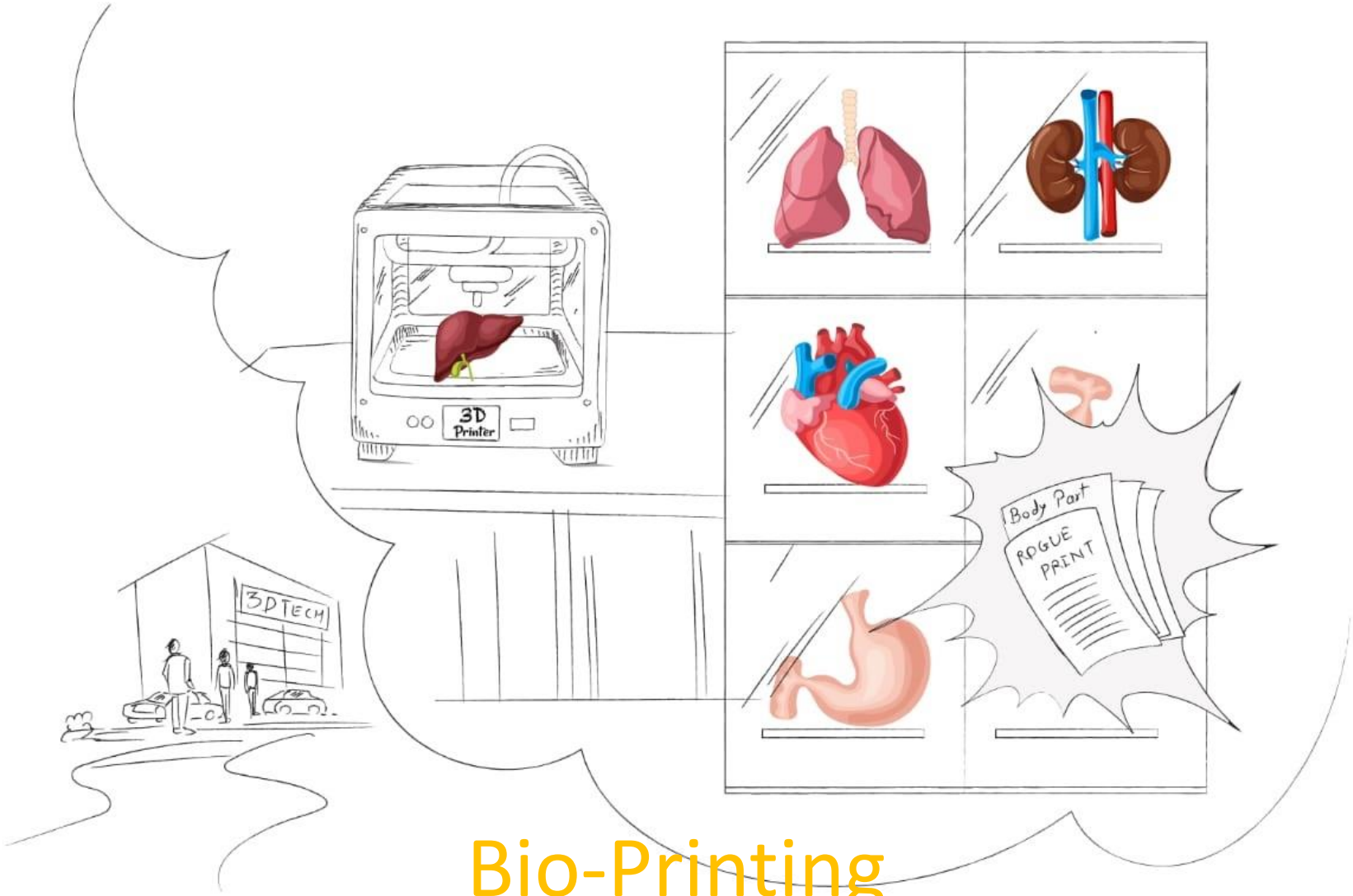
DANIT PELEG

‘Liberty leading the people’ - first 3D Printed Fashion Collection Printed Entirely at Home

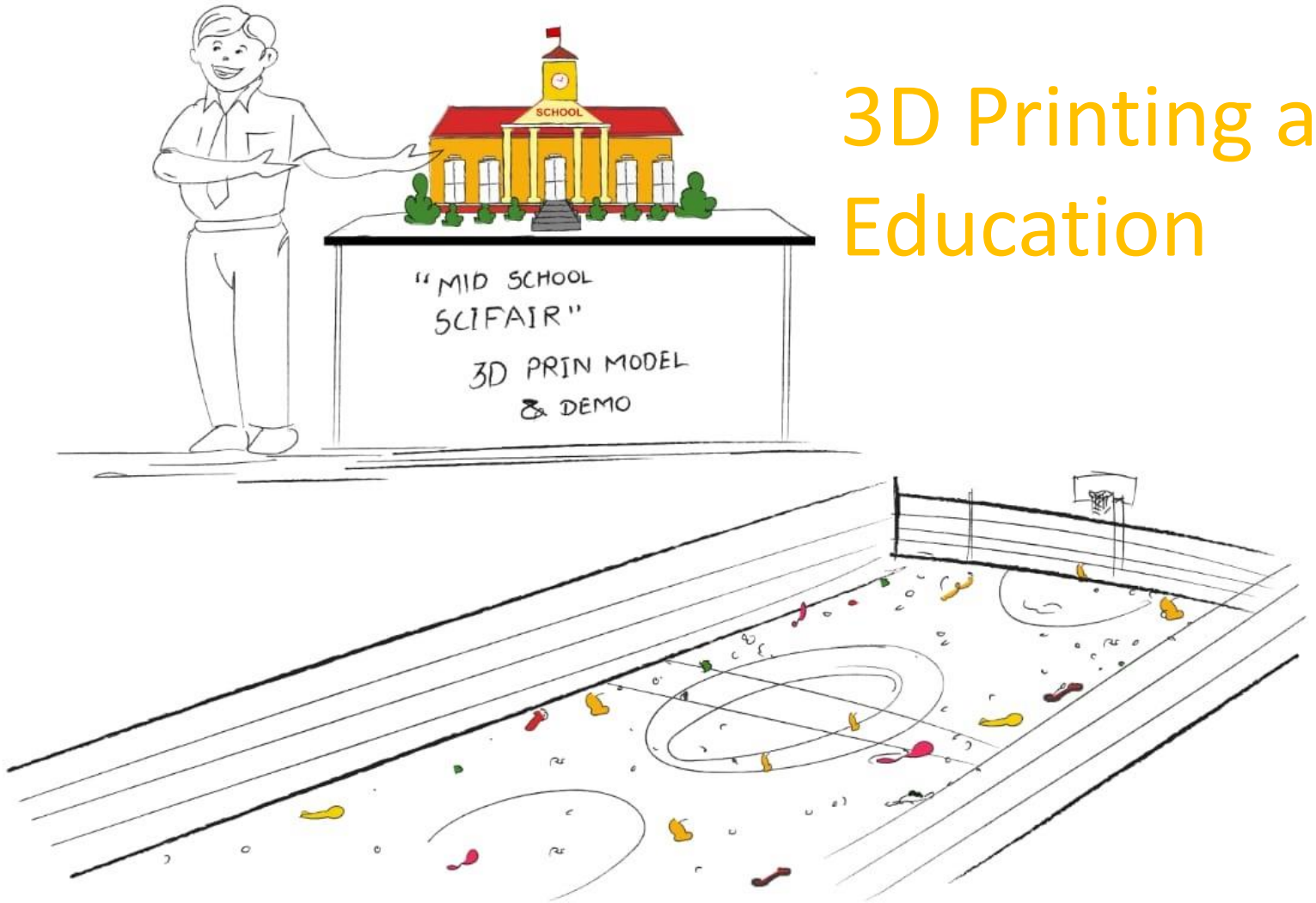
Meet Danit Peleg: the designer making 3D printed fashion collections, by WGSN Insider Dec 04, 2015

DANIT PELEG

Paralympics dress - Amy Purdy’s dress at the Paralympics opening ceremony



Bio-Printing



3D Printing and Education

Overview of The course @IIT Hyderabad

- Course Name: Digital Fabrication
- Credits: 2 (1.5 hrs Theory+1.5 hrs lab per week)
- Same course offered in IIT Bhilai and IIIT Raichur (mentored by IITH)
- Common course for all 1st year B. Tech. Students
- No. of students taken the course in 2017 batch: 419

  (291 in IIT Hyderabad + 118 in IIT Bhilai)

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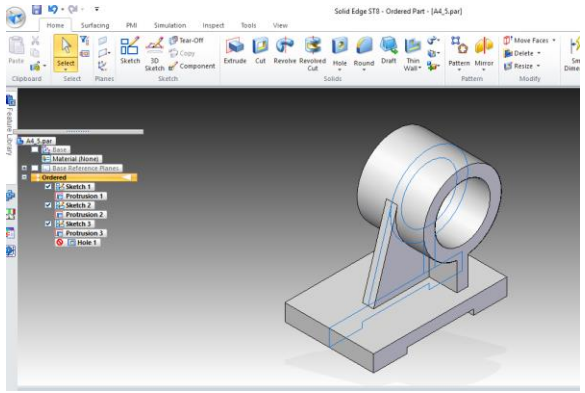
Course Outline

- **CAD Modeling**

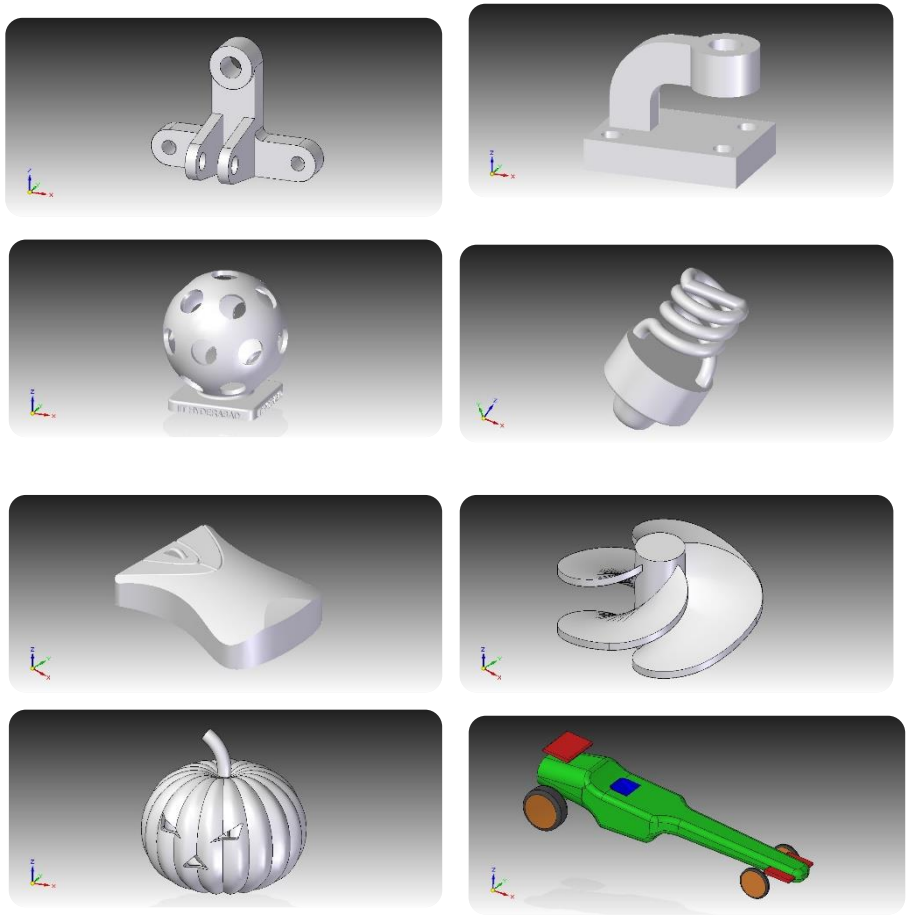


- **3D Printing (FDM)**

3D Printing Project

Module1: CAD Modeling

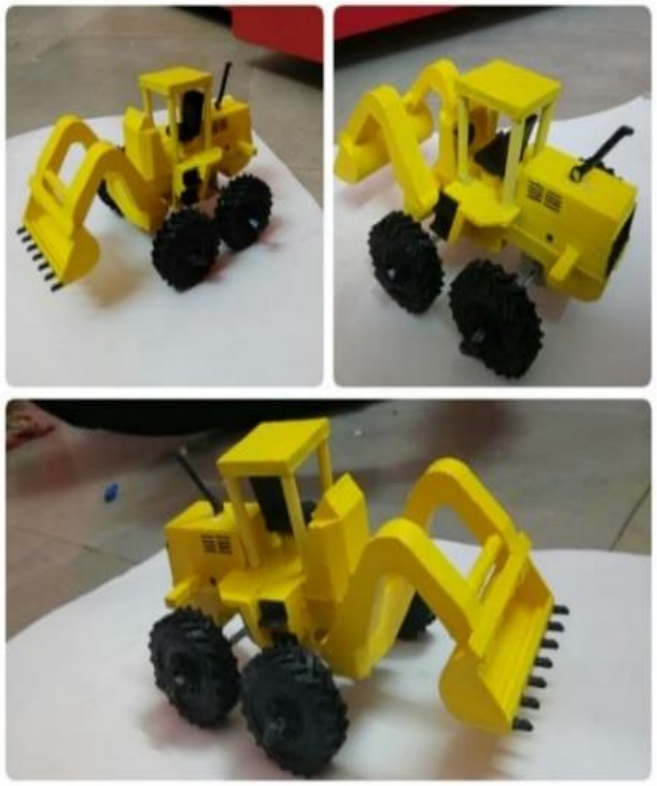
- 2D Sketching
- Basic 3D Modeling
- Multiple planes and offsets
- Orthographic projections
- Patterning
- Feature based modeling
- Free style sketching
- Rendering



Module 2: 3D Printing

- Introduction to Mojo Software
- CAD data Exchange
- STL file processing
- Toolpath visualization
- Design Considerations
- 3D printing Project

IIT HYDERABAD – 3D FABRICATION COURSE



Project work – by first semester of students of IIT Hyderabad

First Semester work of students in The Digital Fabrication course, Indian Institute of Technology Hyderabad, 2017

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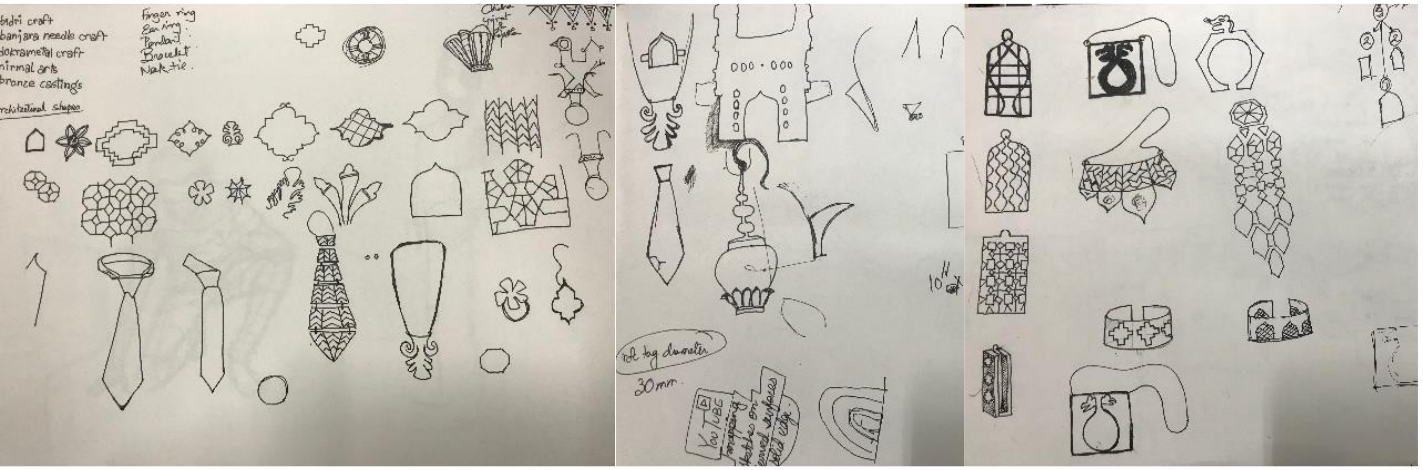
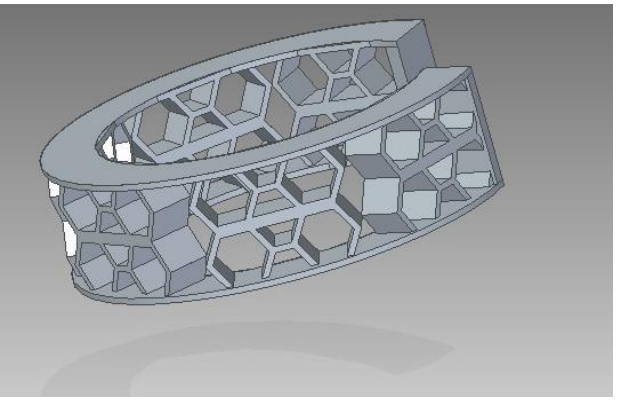
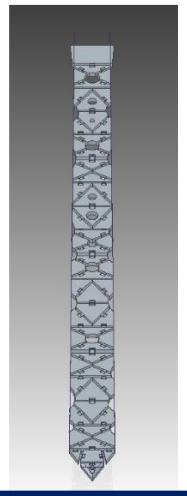
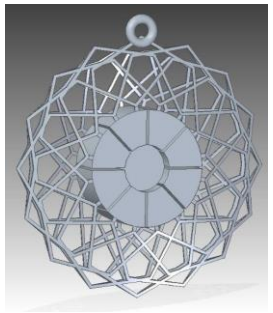
Jaalidar









NFC Enabled Interaction

The smart accessories designed and developed under *Jaalidar* Collection, are 3D printed and they can interact with smartphone devices to perform specific tasks instantly like making a phone call, sending out email, play a song, controlling Wi-Fi/Bluetooth connections etc.

JAALIDAR

SMART FASHION ACCESSORY

Inspired from Architecture of Charminar, Hyderabad

Fashion accessories were inspired from the various *Jaali* (Net) structures of The Charminar, constructed in 1591, a monument and mosque located in Hyderabad, Telangana, India.

DIGITAL FABRICATION
FACULTY: DR PRASAD ONKAR
BALARAM K
INDRANIL SAHA

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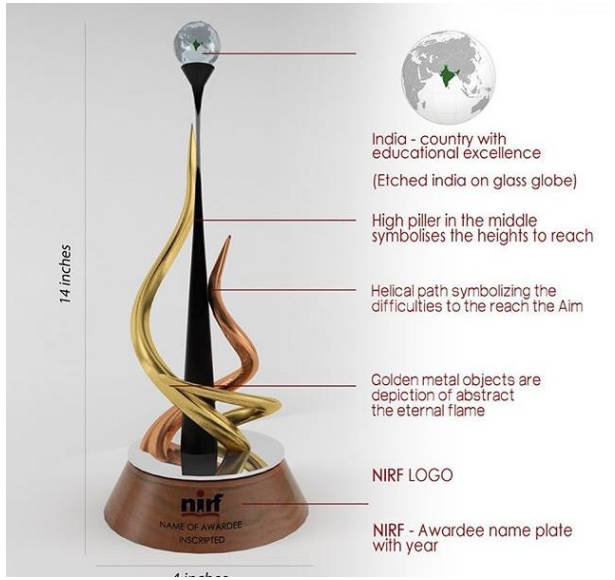
Indian Institute of Technology Hyderabad

NIRF trophy



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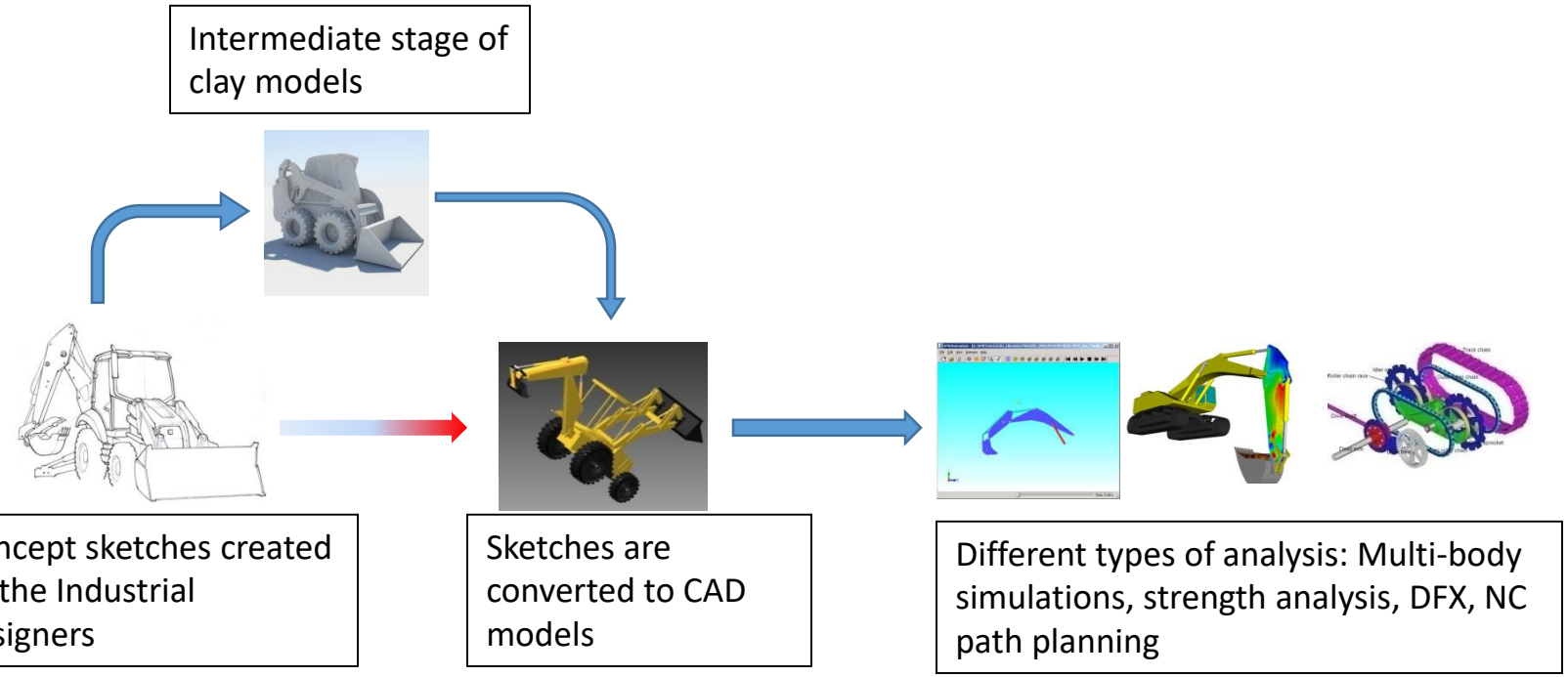
Product Development – Industrial perspective

People having different skills carry-out different activities.

Lot of information exchange is required across different designers.

Revising the concept takes time

Analysis and behavior verification can be done only after CAD modeling



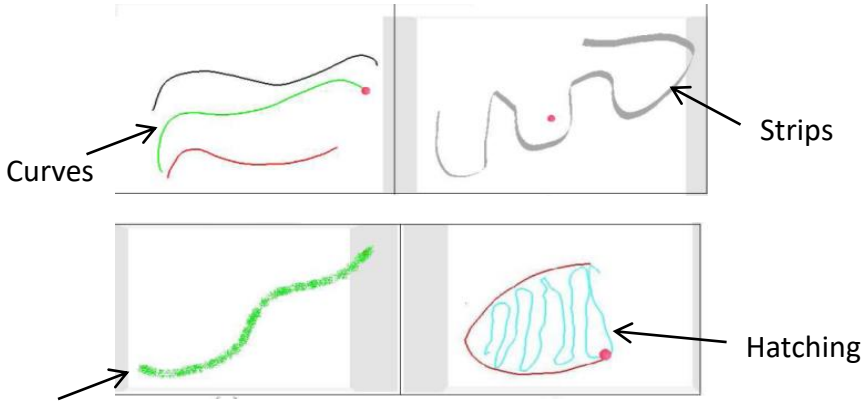
3D Sketching Application

- Sketch strokes are created by the movement of hand in 3D space
- The motion tracked by a device is visualized in the computer
- Collection of such strokes is called 3D sketch

Difficulties

- Lack of visual perception of 3D space
- Lack of control over the stroke creation process

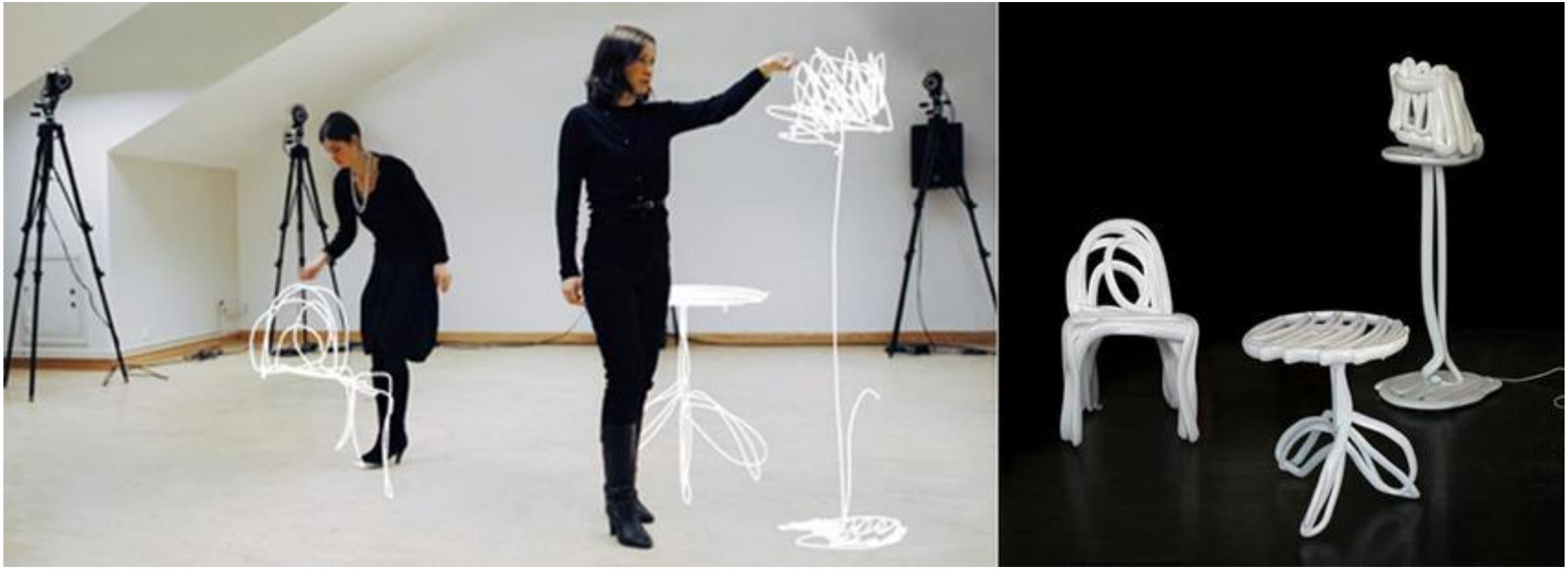
Strokes drawn in 3D sketching

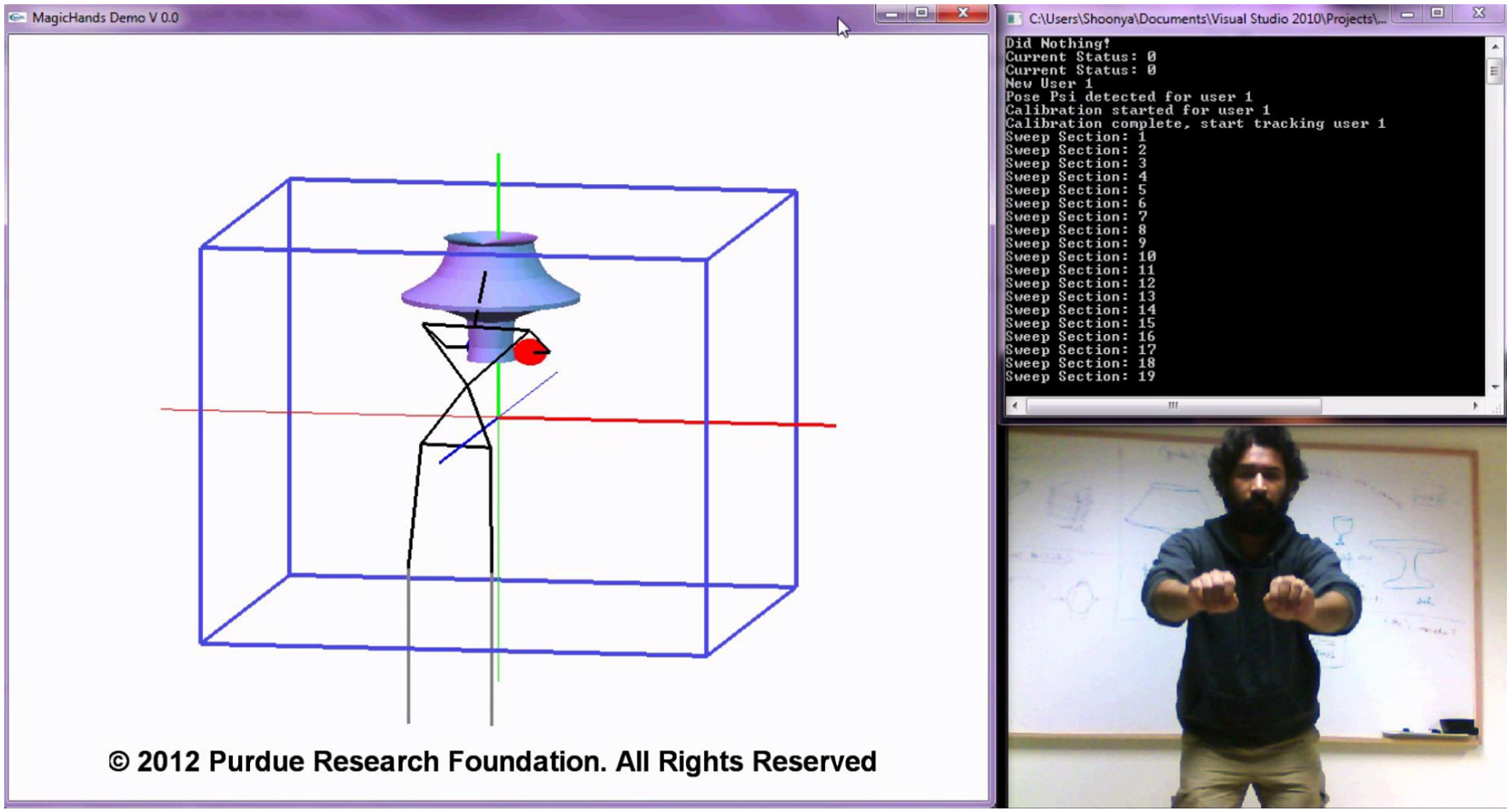


3D sketching setup

Desktop based system with Phantom™ Omni For Haptic feedback and E-Magin Z800 for stereo feedback

Interactive Modeling




MagicHands Demo V 0.0
C:\Users\Shoonya\Documents\Visual Studio 2010\Projects\...
Did Nothing!
Current Status: 0
Current Status: 0
New User 1
Pose Psi detected for user 1
Calibration started for user 1
Calibration complete, start tracking user 1
Sweep Section: 1
Sweep Section: 2
Sweep Section: 3
Sweep Section: 4
Sweep Section: 5
Sweep Section: 6
Sweep Section: 7
Sweep Section: 8
Sweep Section: 9
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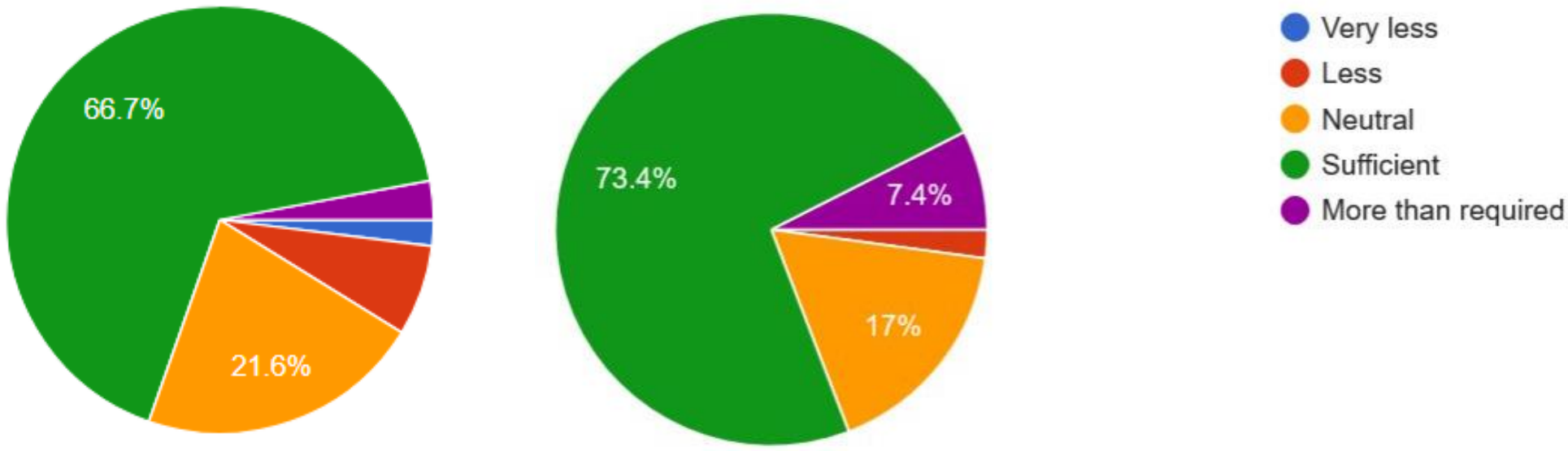
Course Feedback

The initial introduction given for the course was adequate.

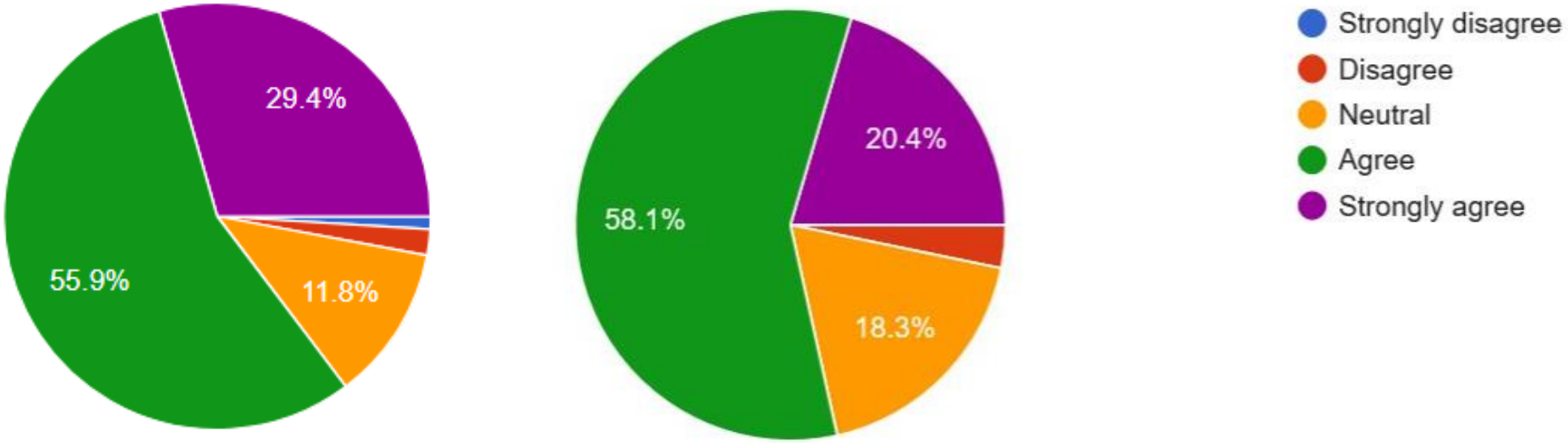
102 responses



2017 2018

The assignments given in the course was appropriate and in sync with the course.

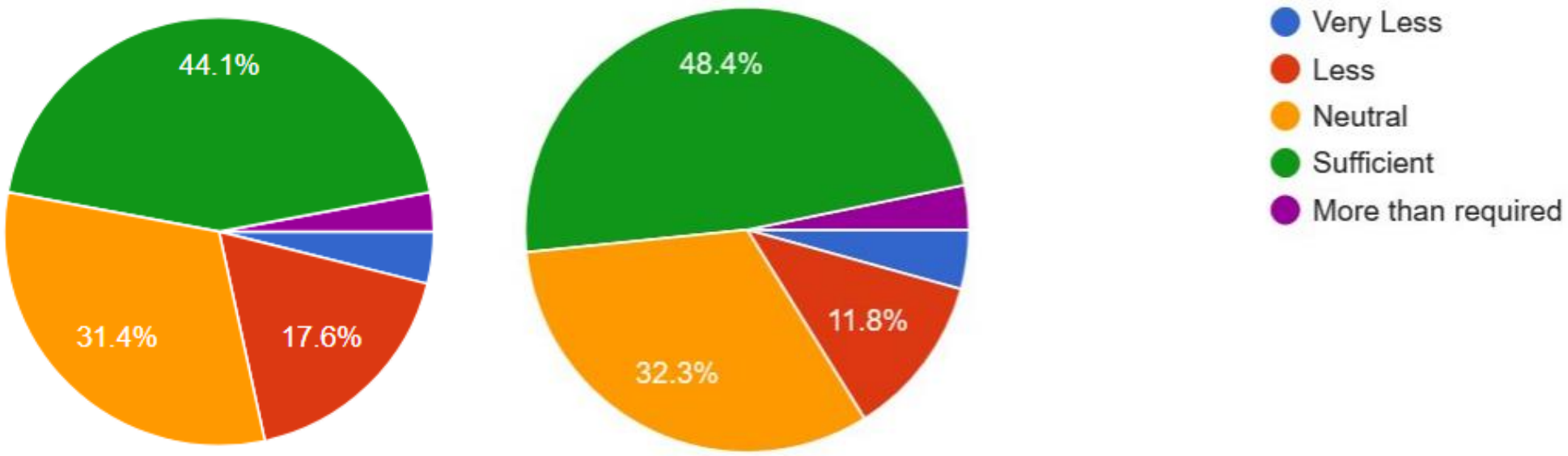
102 responses



2017 2018

Information given regarding the design aspects of 3D printing.

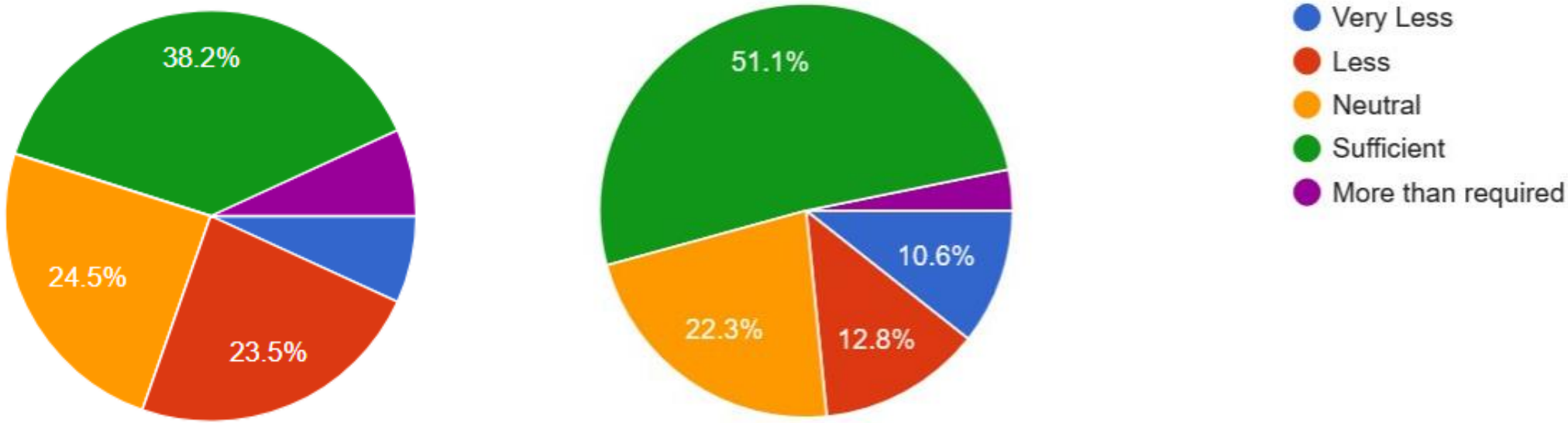
102 responses



2017 2018

Time given for the 3D printing of the project work.

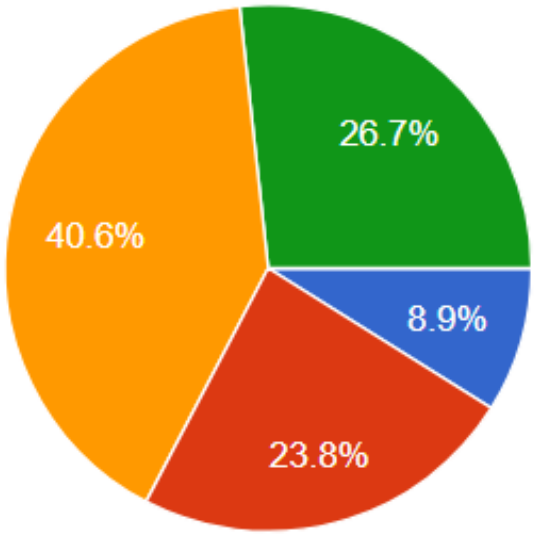
102 responses



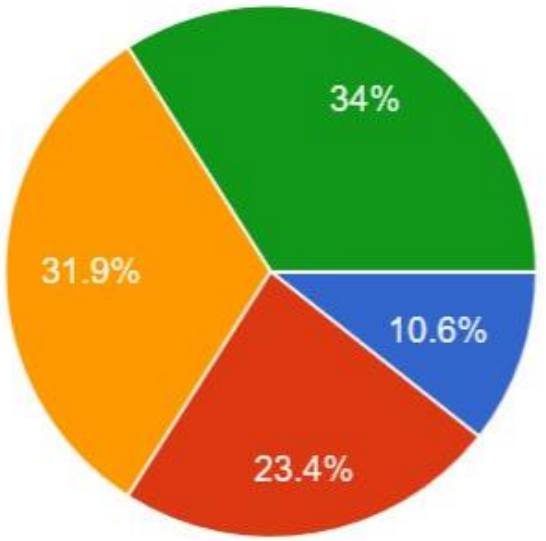
2017 2018

Built volume o printer.

101 responses



2017



2018

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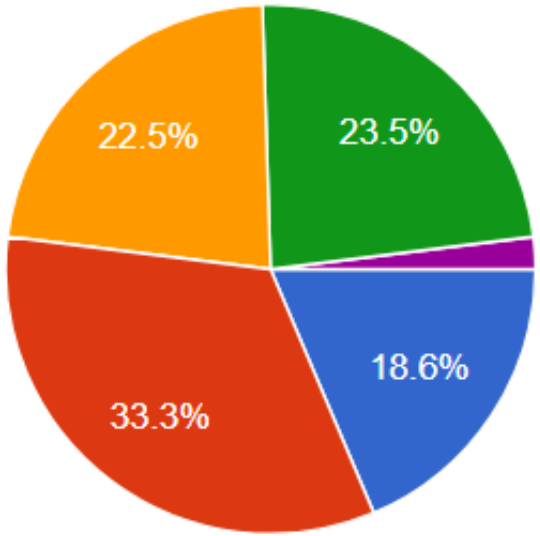
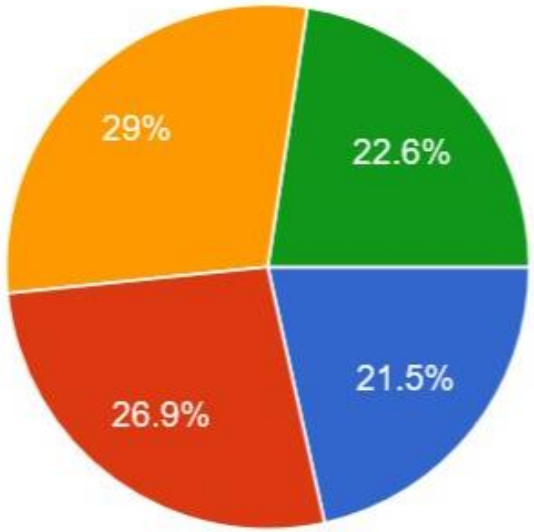
Available color options in printer.

102 responses



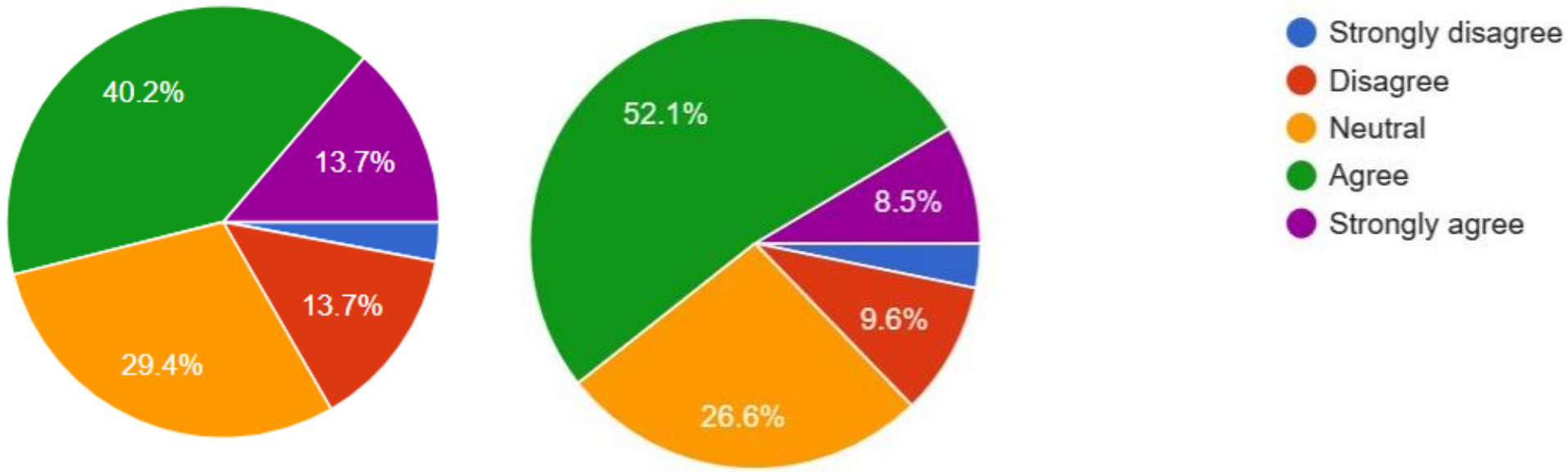
2017



2018

The 3D printed object was useful in real life.

102 responses



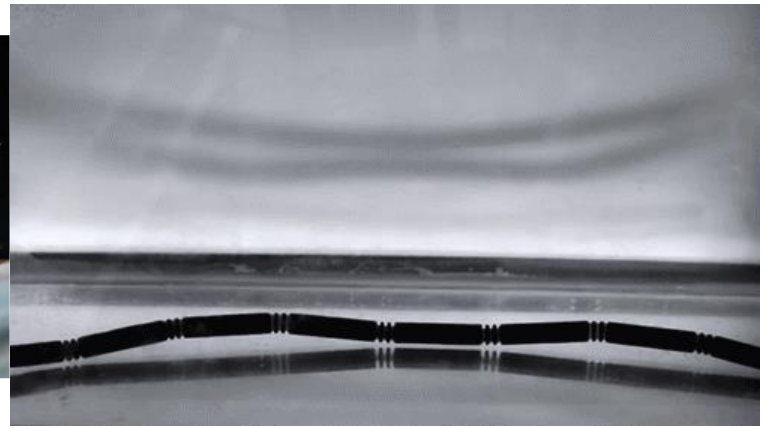
2017 2018

Students' Remarks

- Since object had to be printed in single colour, there is no point of available colour options.
- Time given for printing(10-12 hours) was very very less.
- Even after making good models the project had to be highly modified to meet the time criteria due to which the essence of original model was lost.
- We could design some useful products in relation to our department, If we are allowed to pursue 3D printing after the course then it will be a great help.

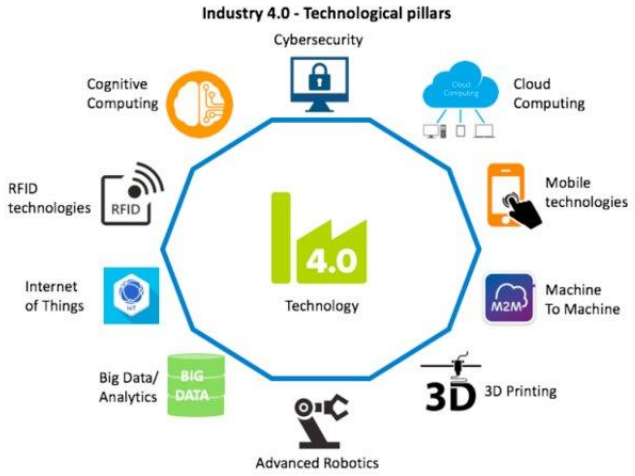
Possible Future directions…

- Develop new 3D printers capable of printing with
  - Reusable materials
  - Multi materials
  - Bigger print volume
  - Lesser time
  - More accurate features



- Introduce other 3D Printing Techniques
  (SLA, SLS, Binder Jetting, etc…)

- Introduce other Digital Fabrication Techniques
- 4D Printing
- Industry 4.0



Thank You…