M.Tech
Digital Manufacturing

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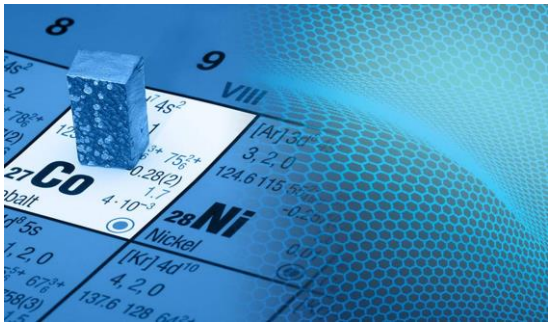
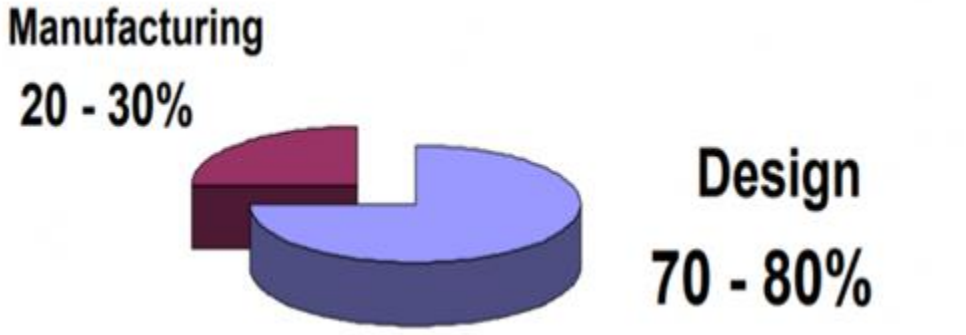
DMZG521- Design for Additive Manufacturing
Lecture 1-2

Design for Manufacturing

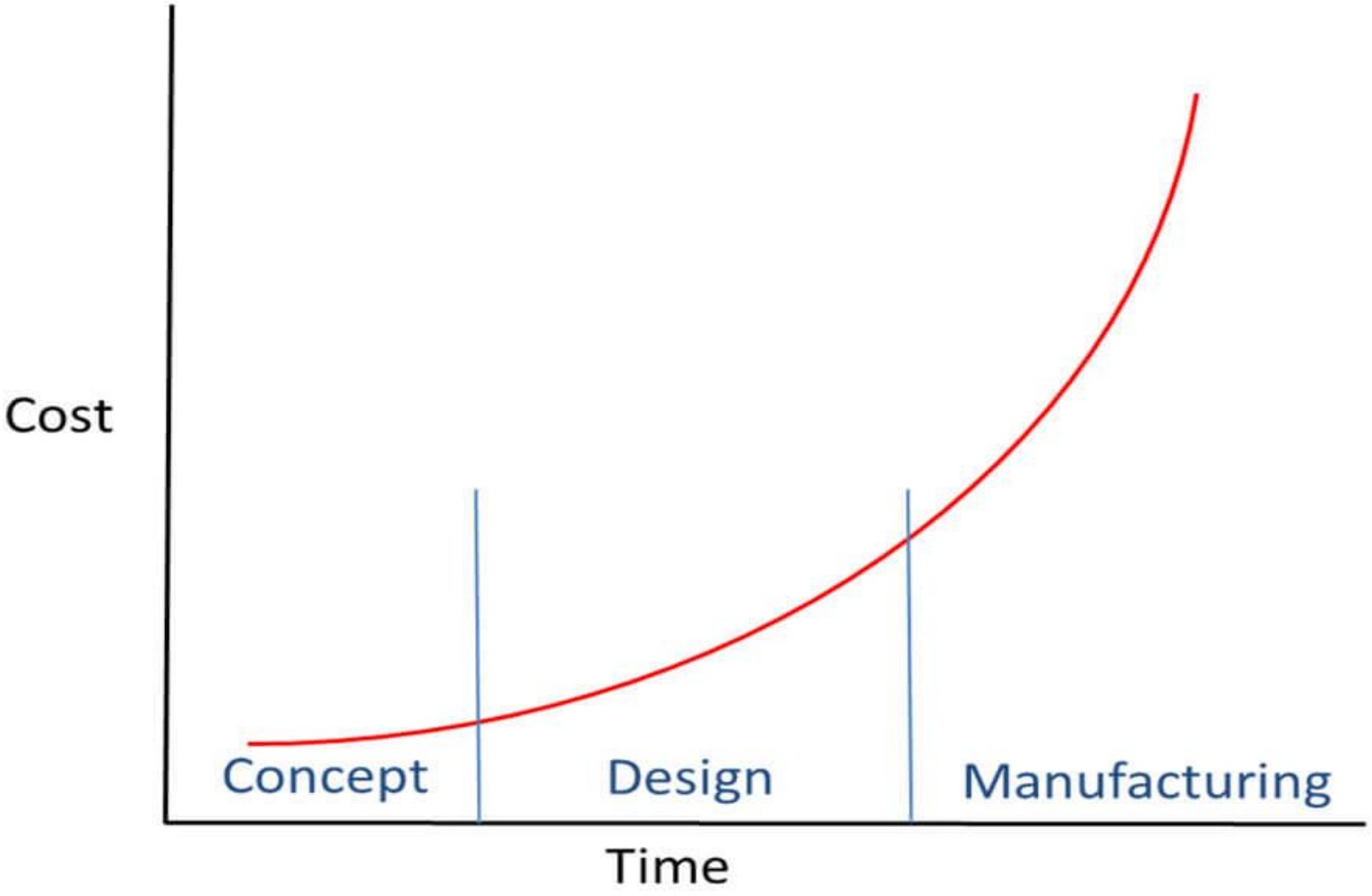
- Development of new materials
- Improved design methods
- Increased societal demand

DfM

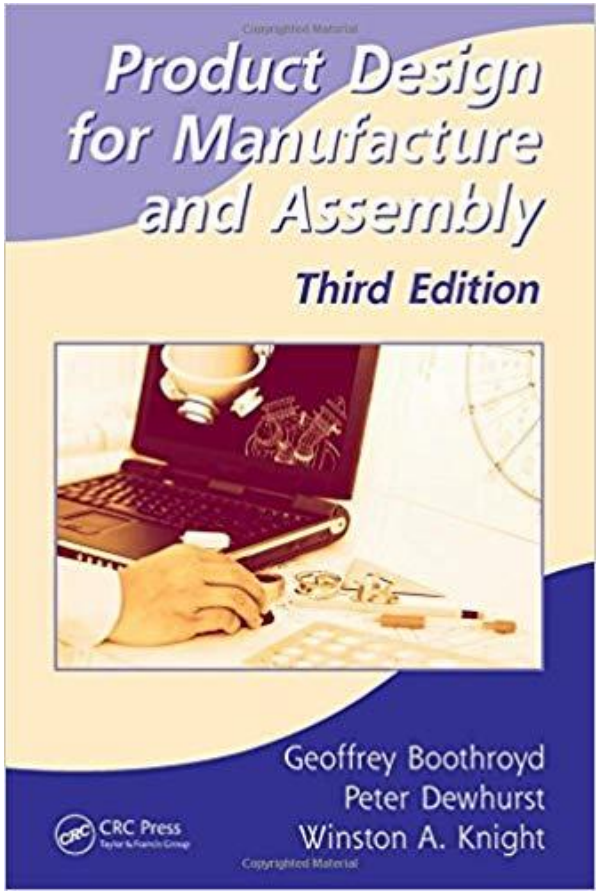


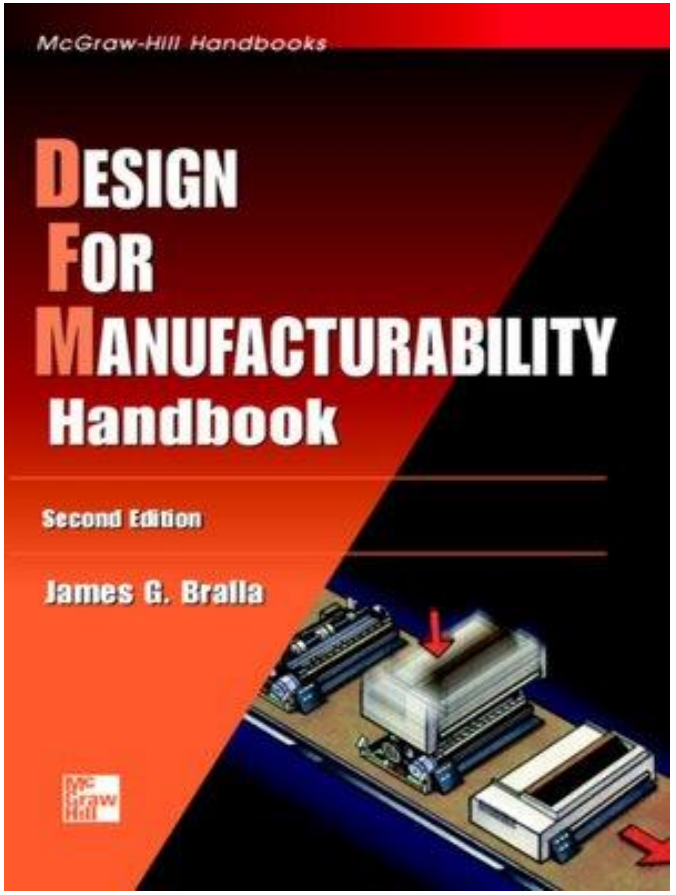


Cost of design changes



Ref Books for DFM



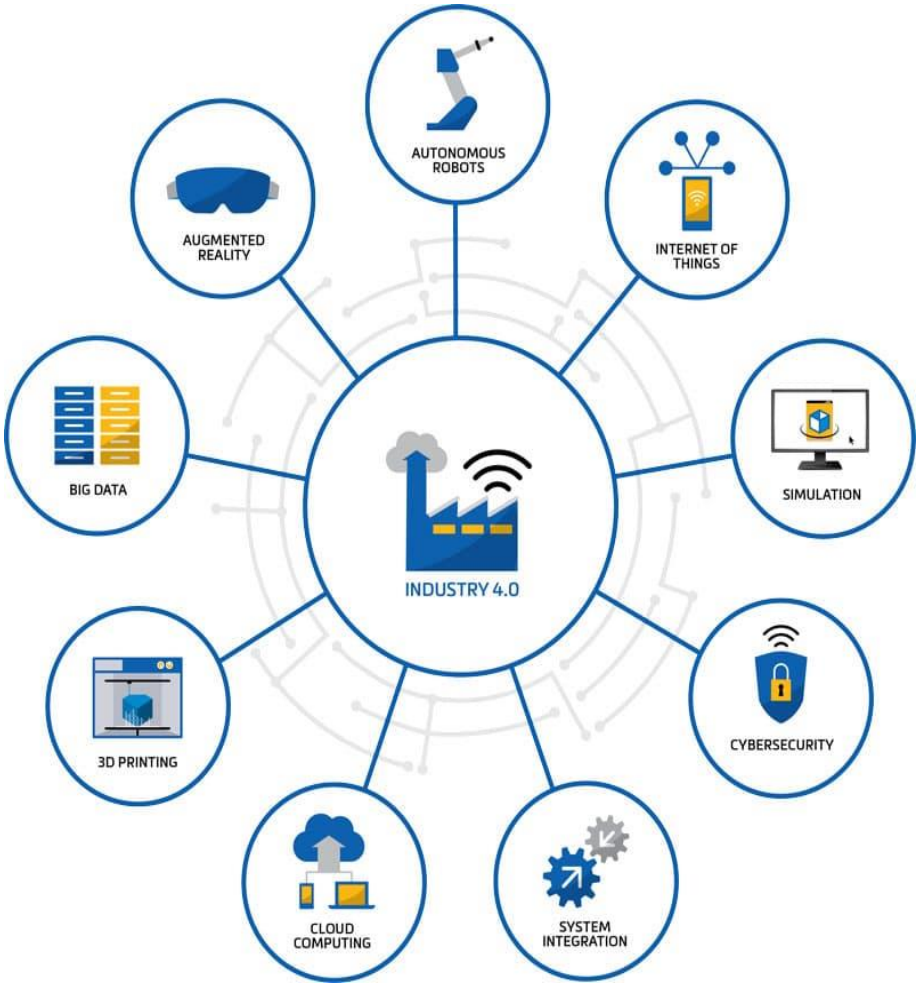


DfM Rules

- Minimize the part count
- Use of standard parts
- Create modular design
- Design the part with multifunctionality
- Design for ease of fabrication
- Minimize the assembly directions
- Minimize handling

Digital Manufacturing

- **Digital manufacturing** can be defined as an integrated approach to **manufacturing** that is centered around a **computer system**.
- A machine is able to read a CAD (computer aided design) file in order to deliver it in a few hours



Courtesy: materialize/future-industry-4.0

Additive Manufacturing

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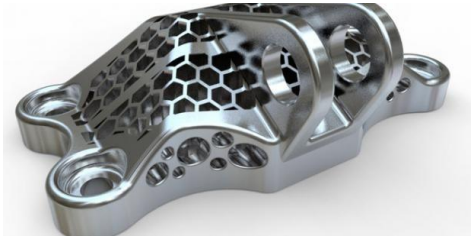
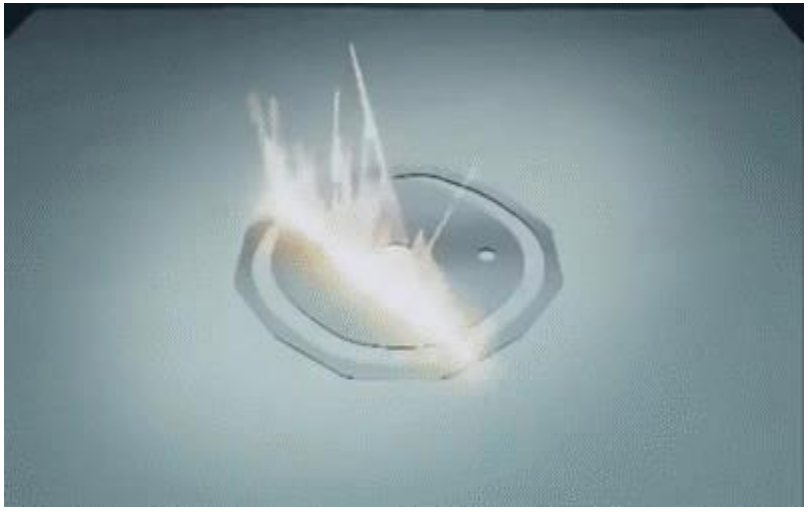
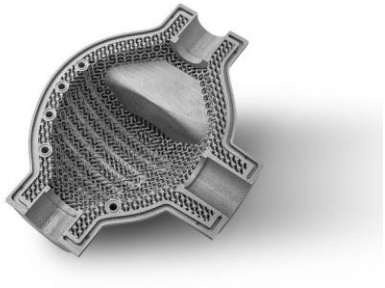
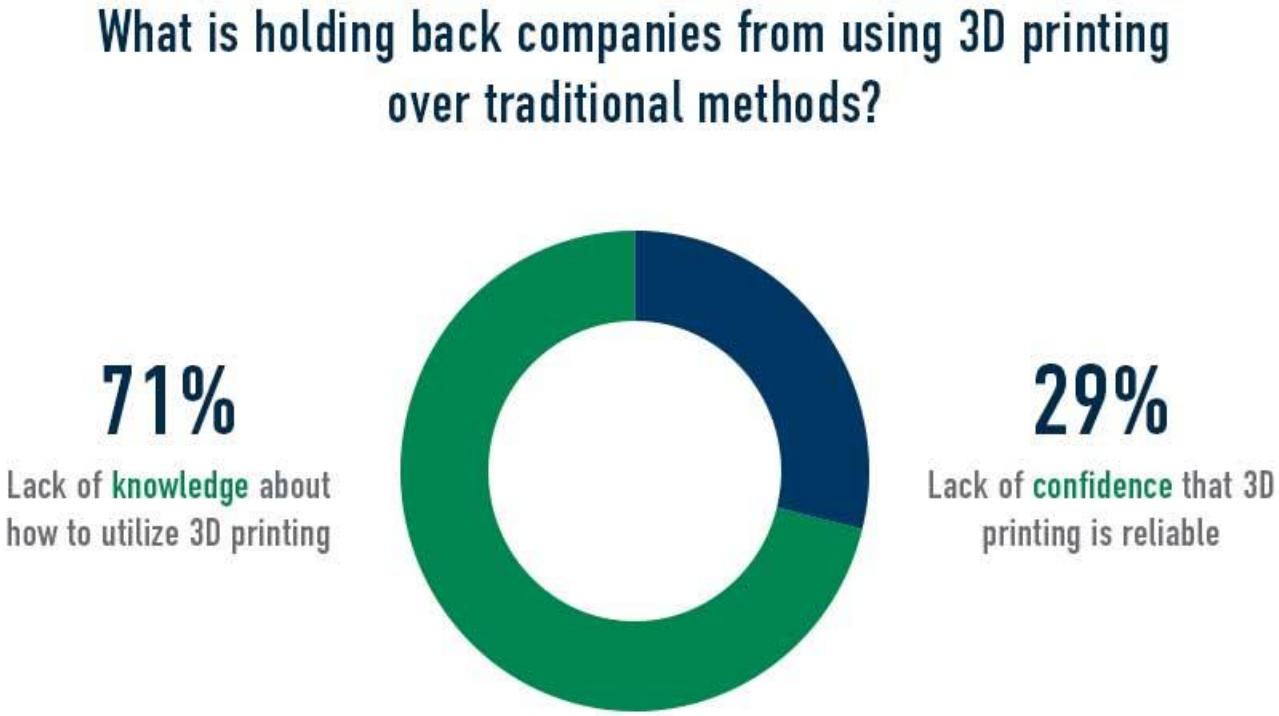
What You See Is What You Build (WYSIWYB)







Why DfAM?



Courtesy:™Jabil

Design for Additive Manufacturing

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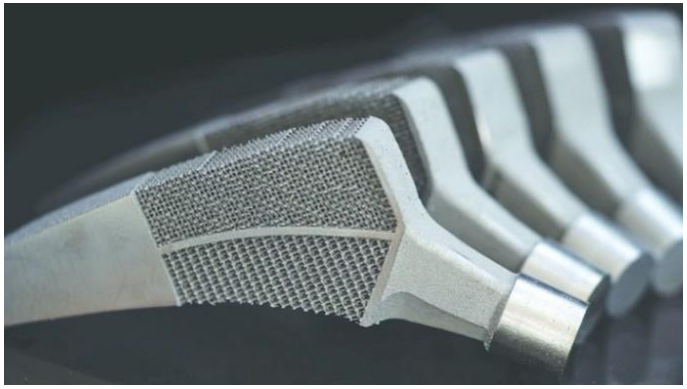
- Design for Manufacturing (DfM) to Design for Additive manufacturing (DfAM)
- Limitations in Traditional Manufacturing
- Capabilities of Additive Manufacturing

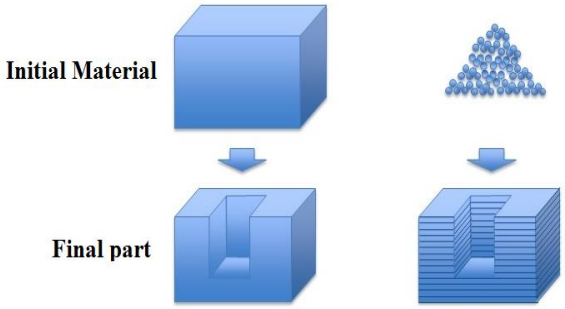
Aim of DfAM

"Synthesis of shapes, sizes, geometric mesostructures, and material compositions and microstructures to best utilize manufacturing process capabilities to achieve desired performance and other lifecycle objectives"

-Chen Chu, Greg Graf and David W. Rosen



Drivers of AM



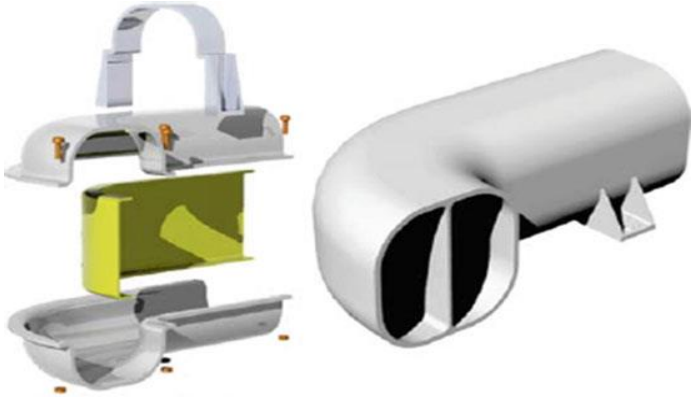
Material efficiency

Mass customization

Function integration

Flow optimization

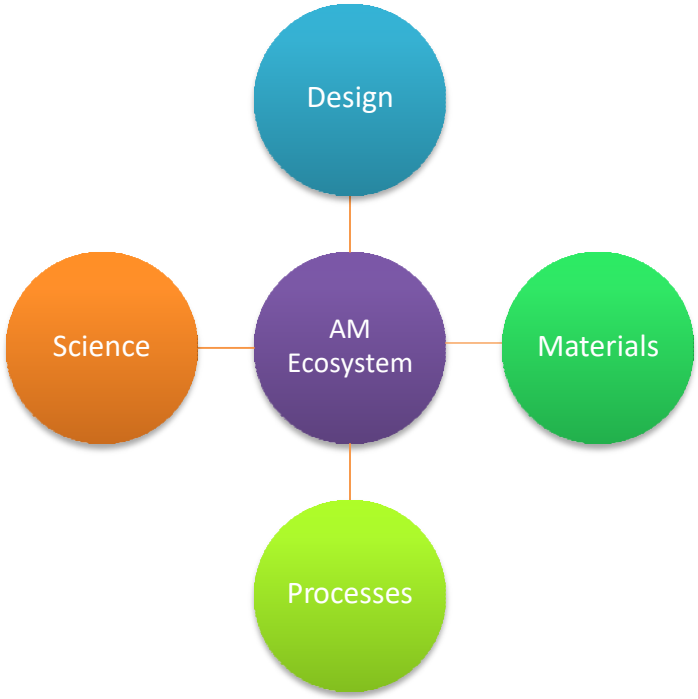
Tailoring porosities and properties



Part consolidation

Courtesy: google images

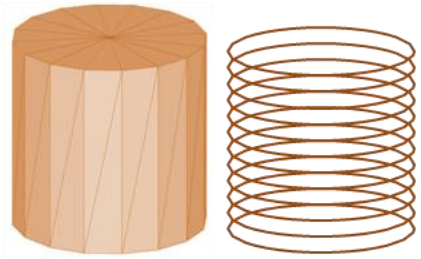
Additive Manufacturing Ecosystem



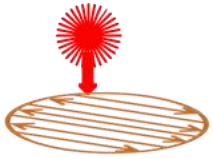
Additive Manufacturing

- Refers to the group of processes that build parts layer upon layer.
- ASTM F2792-12a

STEP #1
CAD model creation



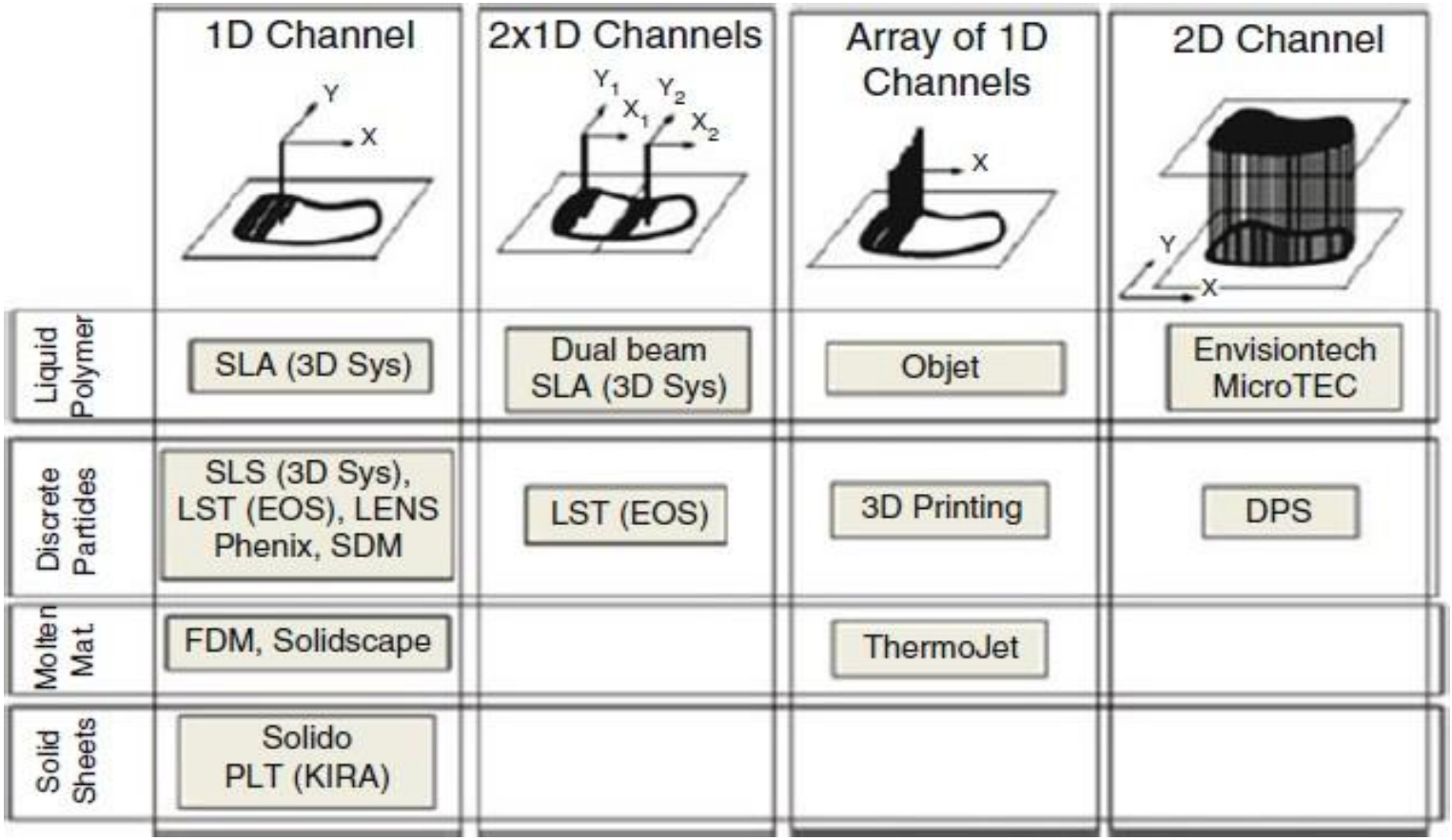
STEP #2
Tessellation & Slicing



STEP #3
Part fabrication

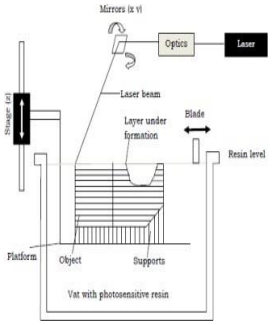
STEP #4
Part finishing

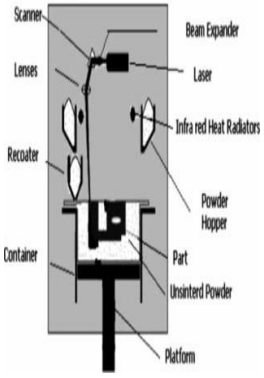
Additive manufacturing (LM) processes as classified by Pham

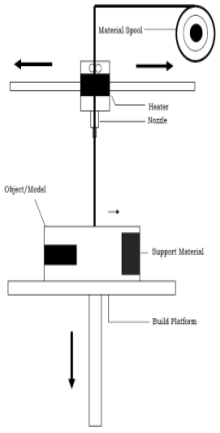


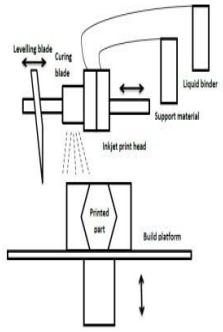
ASTM Classification

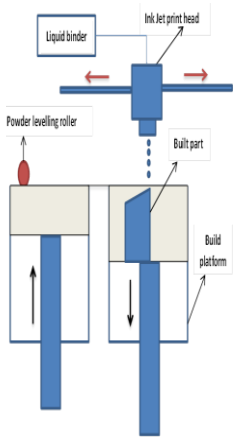
- Additive Manufacturing
  - Vat Polymerization
  - Powder Bed Fusion
  - Material Extrusion
  - Material Jetting
  - Binder Jetting
  - Sheet Lamination
  - Directed Energy Deposition

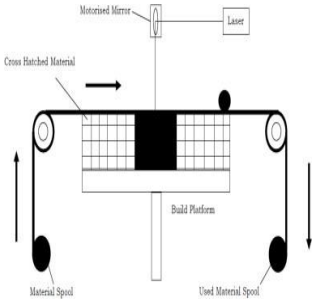


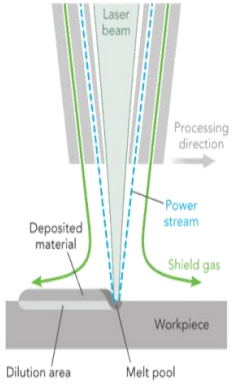






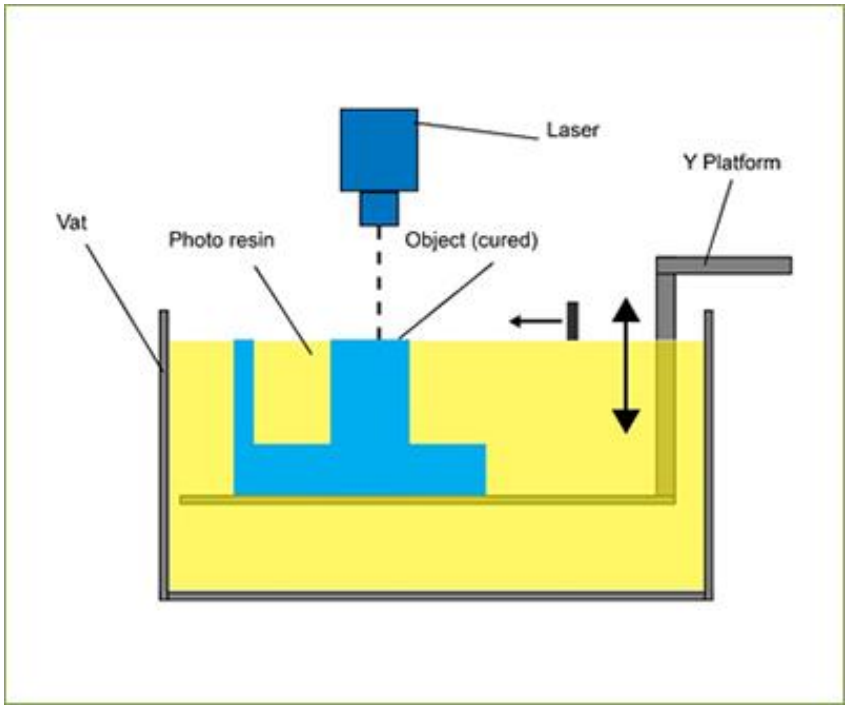




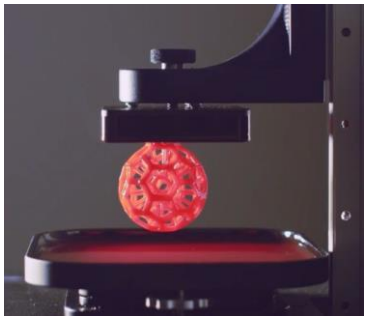


Vat Polymerization

- Uses UV-curable photopolymer resins
- Stereolithography (SLA)
- Digital Light Processing (DLP)
- Continuous Liquid Interface production (CLIP)
- Daylight Polymer Printing (DPP)



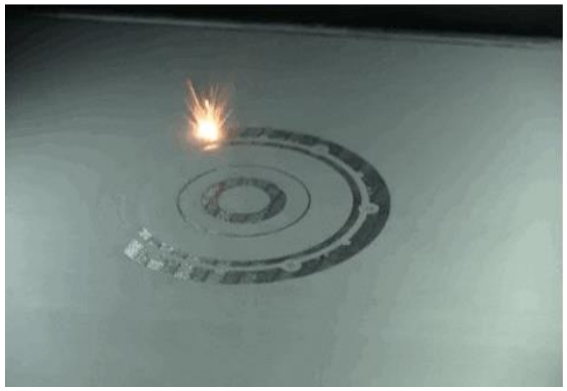
Carbon

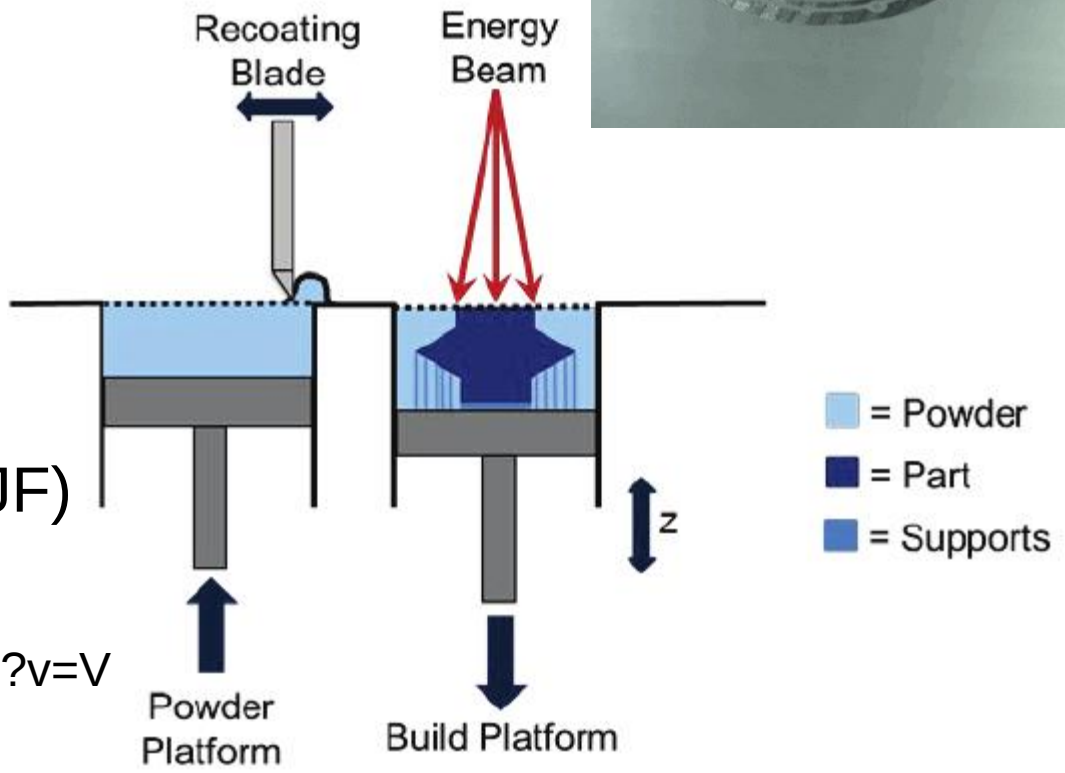


Powder Bed Fusion

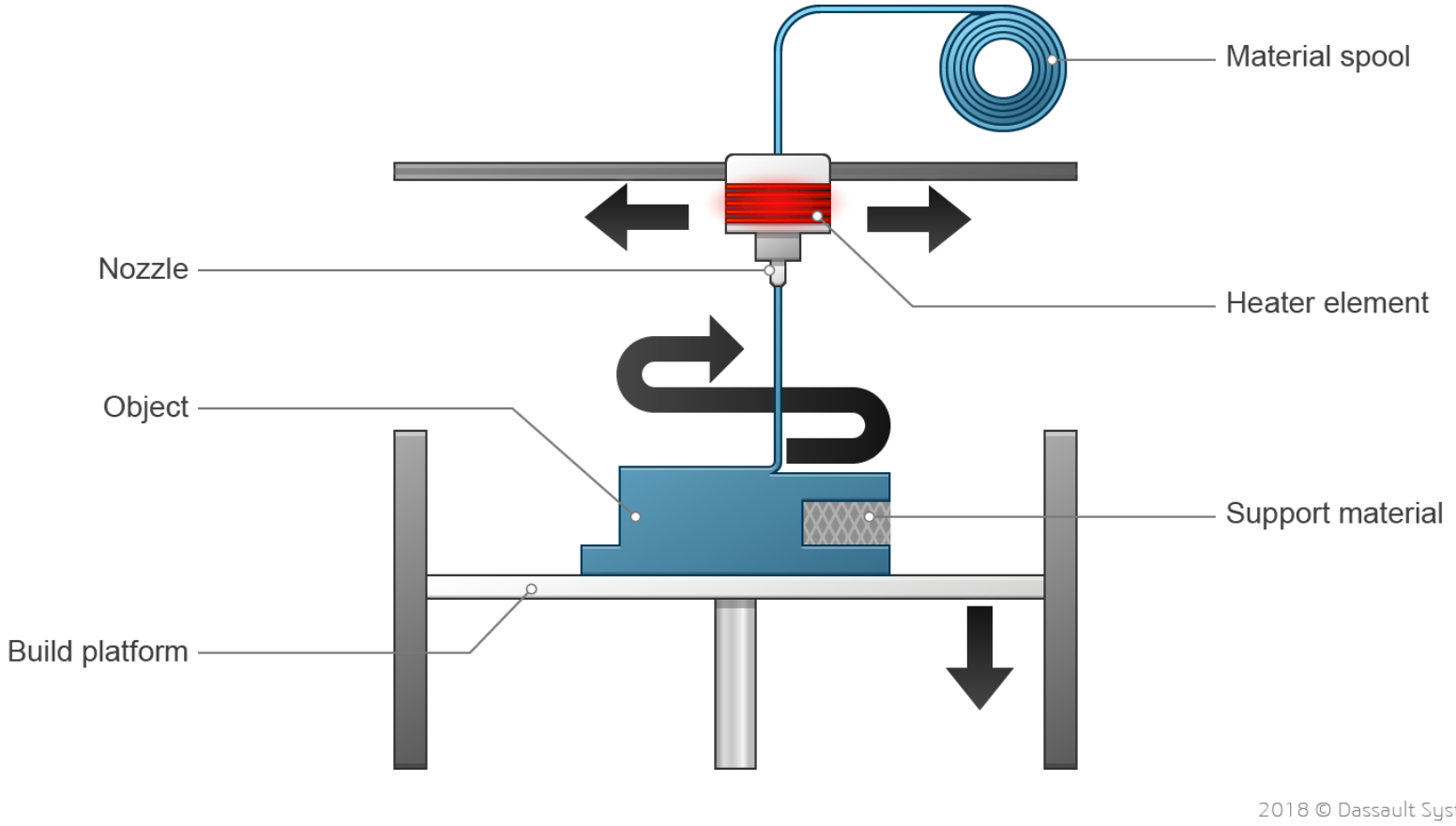
- For both Metals and Polymers
- Selective Laser Sintering (SLS)
- Selective Laser Melting (SLM)
- Electron Beam Melting (EBM)
- Multi Jet Fusion (MJF) by HP

https://www.youtube.com/watch?v=VXntl3ff5tc





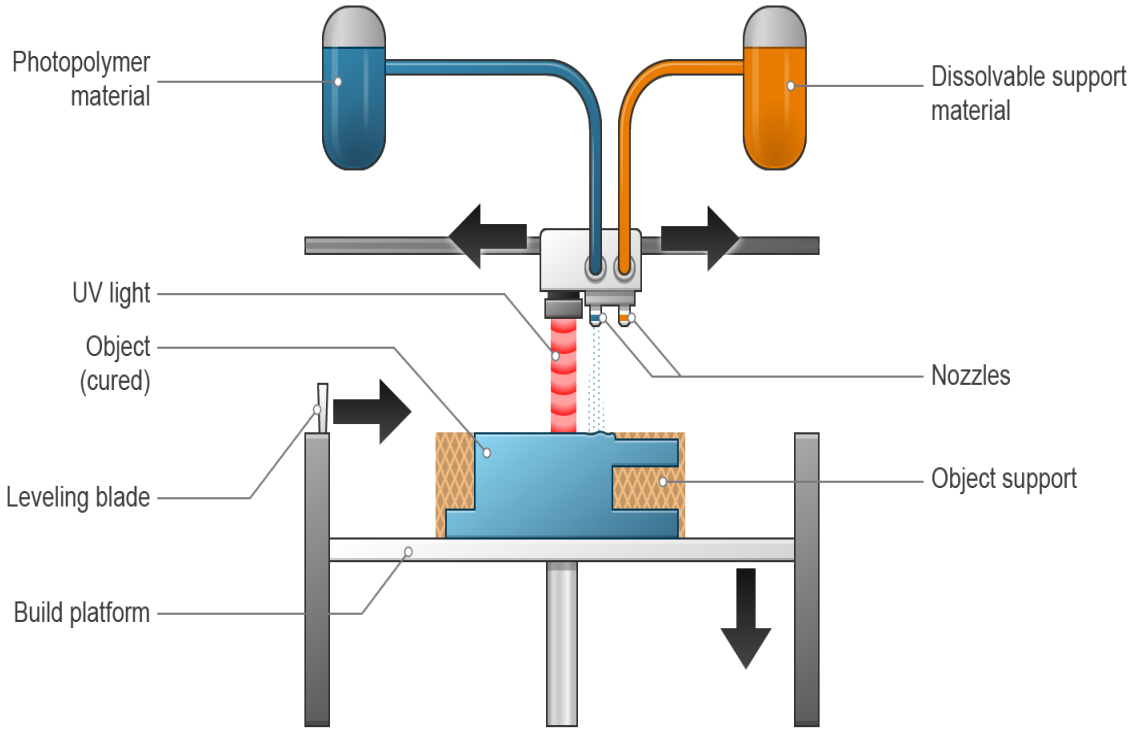
Material Extrusion



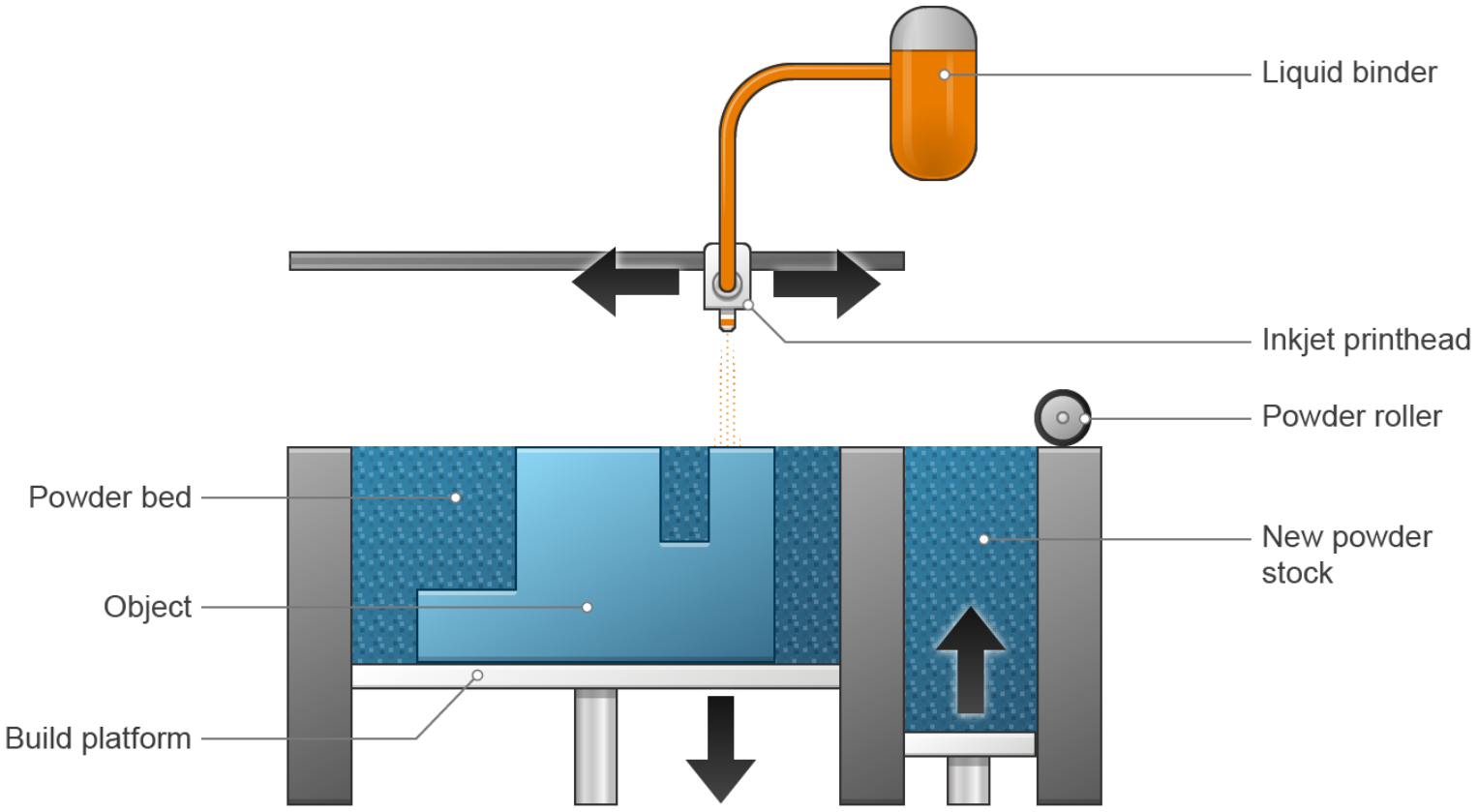
Courtesy: Dassault systems

Material Jetting

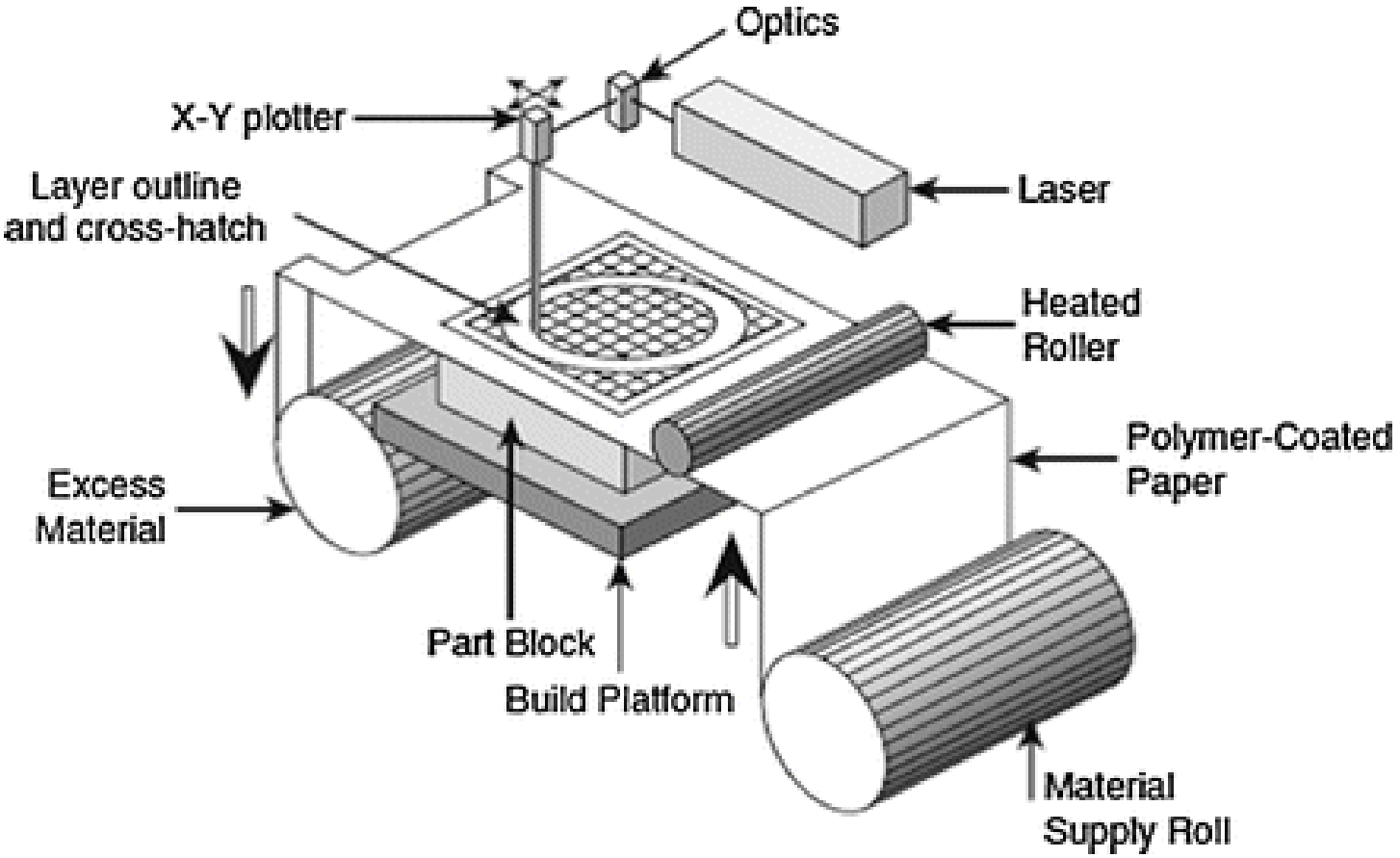
- Drop On Demand
- PolyJet by Object
- NanoParticle Jetting (NPJ) by XJet



Binder Jetting



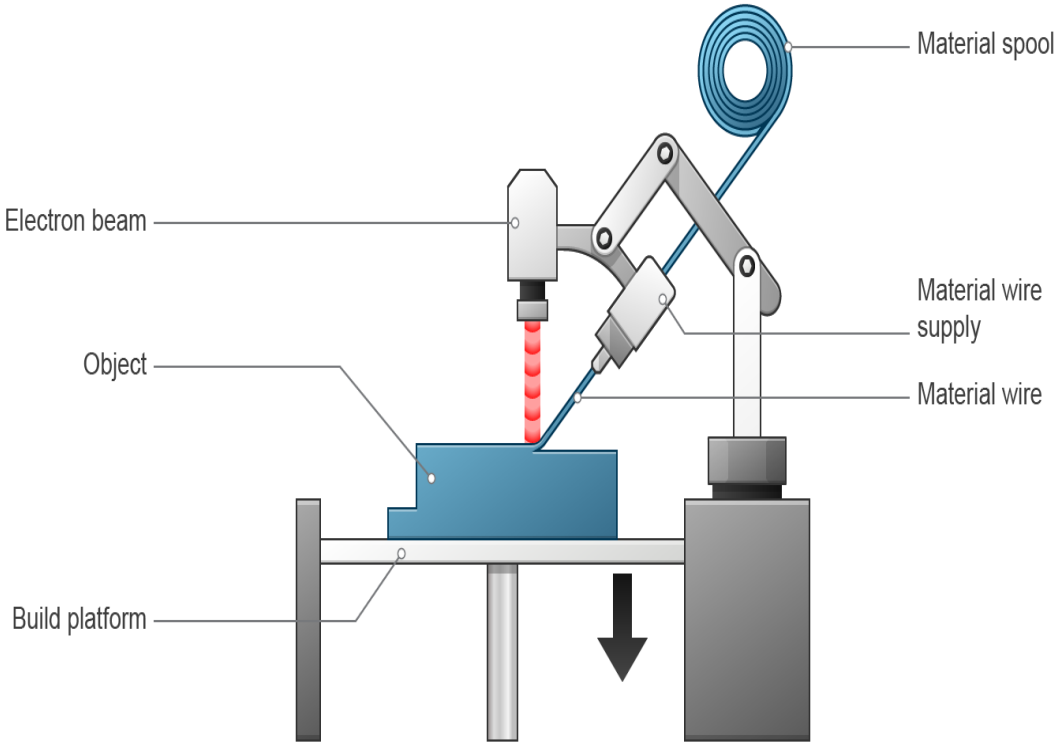
Sheet Lamination or Laminated Object Manufacturing (LOM)



Courtesy: IanGibson

Directed Energy Deposition (DED)

- Laser Engineered Net Shaping (LENS) by Optomec
- Aerosol Jet Technology by Optomec
- Electron Beam Additive Manufacturing (EBAM)
- Laser Deposition Welding and Hybrid Manufacturing by DMG MORI



AM Workflow

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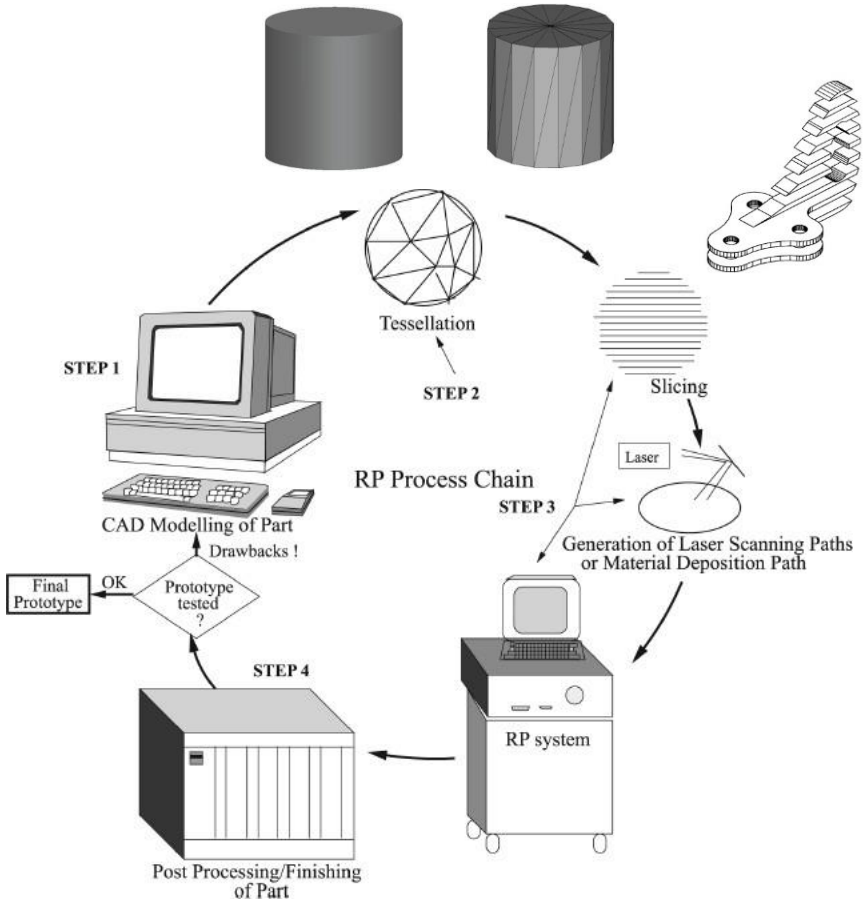
Plan		Prepare			Print		Perfect	
3D scanning & Medical Imaging	**CAD model creation**	**Part quoting and order management in service bureau**	**Repositories for ready to download designs for customers**	**Part build preparation**	**Part building and control**	**Material Handling**	**Part Post Processing**	**Inspection and Testing**
• Point cloud Gathering • Point cloud Processing • Surface reconstruction • Interface to File formats • Repair volume generation	• Parametric, feature based and free form surface modelling software • Haptic modeling tools • Interface to standard file formats	• Part cost estimation using part attributes and process attributes • Quote management and support services	• Web based platforms for ordering end use products by selecting designs • Web based platforms for ordering just the designs	• Tessellation and slicing • Error fixing • Platform specific part placement • Support generation • Collision detection • Part packaging • Cost Estimation • Build Time estimation	• Scan path generation and control • Axes and beam Parameter control • Gas generation • Environment control • Process monitoring	• Material loading • Part unloading • Assist gas handling • Used Powder, liquid and sheet handling etc.,	• Part cleaning and finishing • Material recycling	• Inspection tools and software • Test methods and Protocols

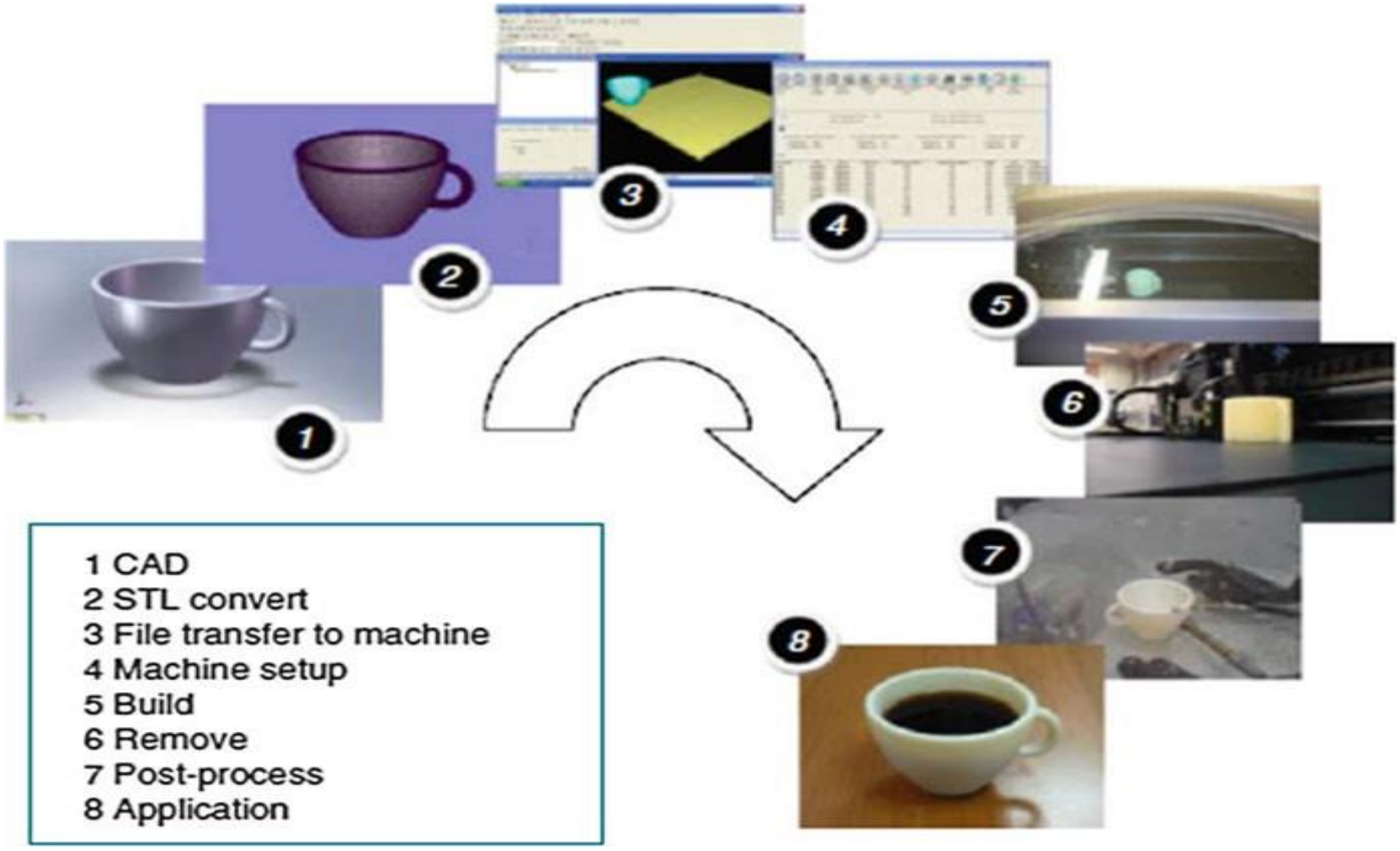
CAD image of a tea cup with further images showing the effects of building using different layer thicknesses

RP Process chain

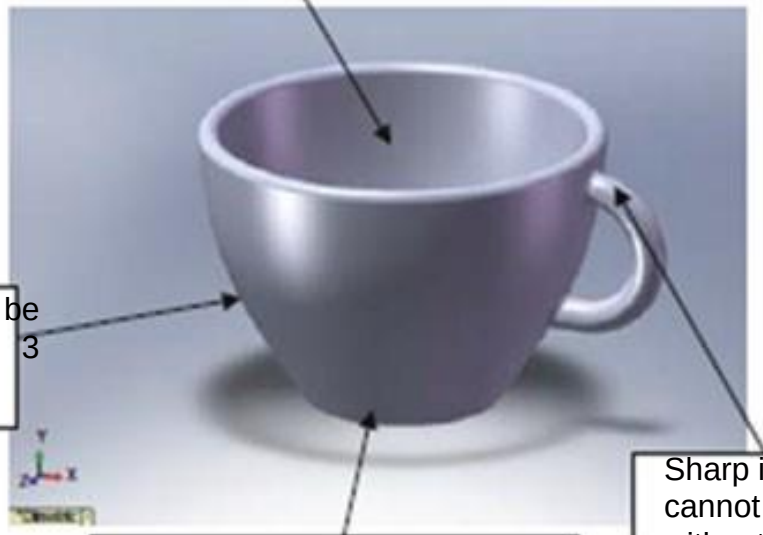
- Creation of Geometric Model
- Tessellation
- Slicing
- Generation of Laser Scanning Path
- Part Fabrication
- Post Processing



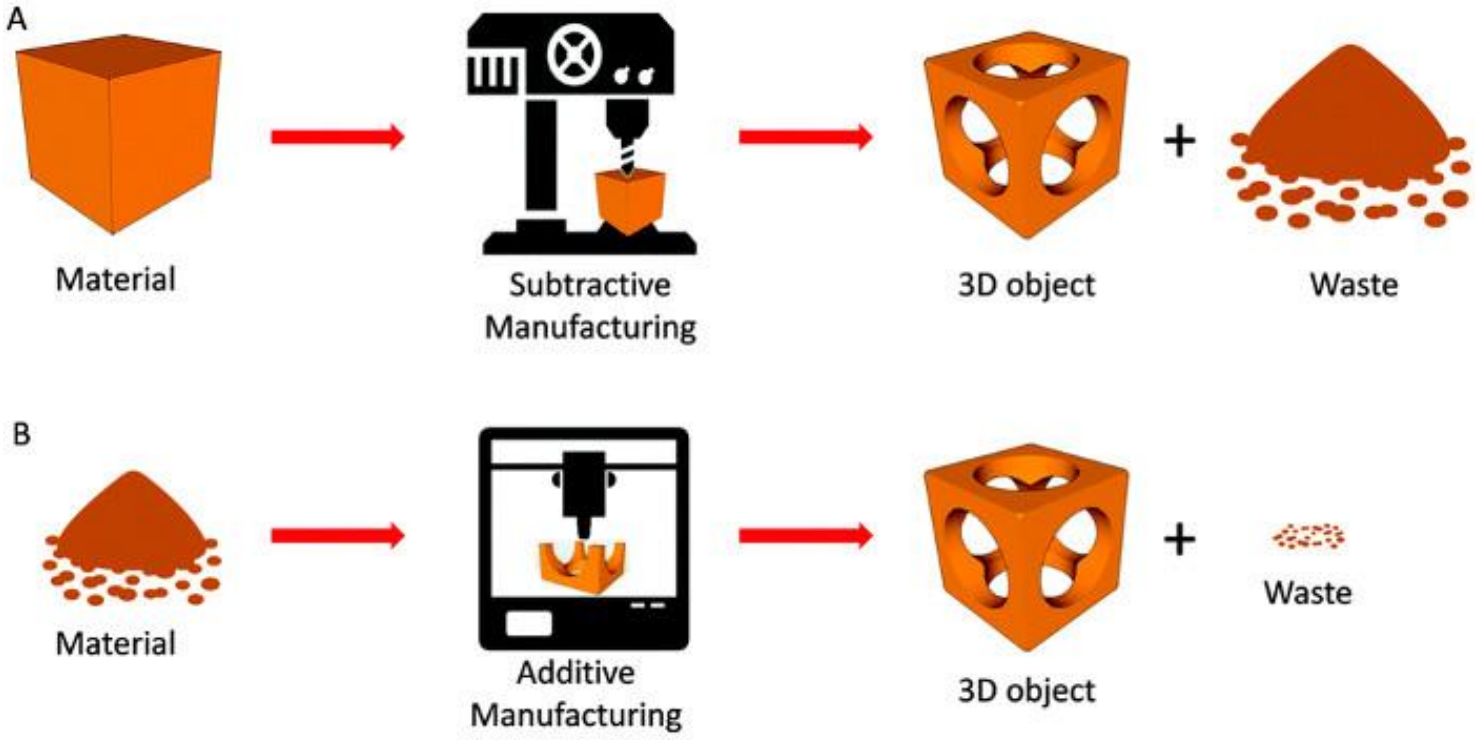
Generic process of CAD to part, showing all eight stages



Features that represent problems using CNC machining



3D Printing Vs CNC Machining



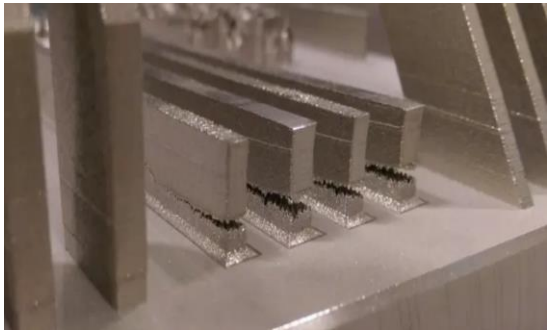
3D Printing Vs CNC Machining

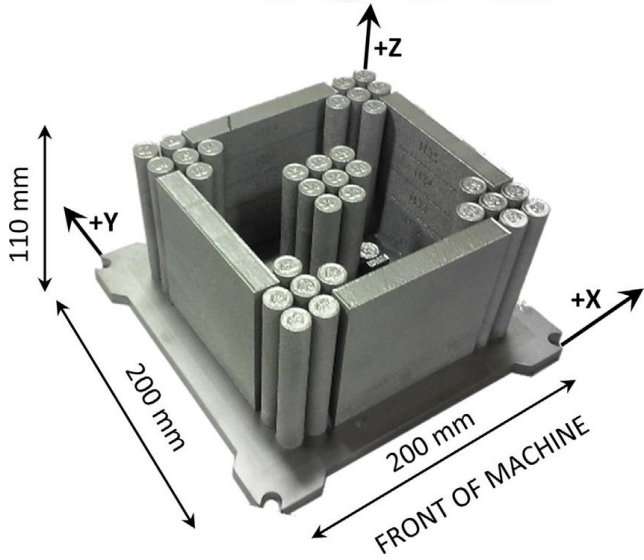
	Tolerance (mm)	Min. Layer Thickness (mm)	Max. build volume (mm)
CNC Milling	± 0.025 – 0.125 mm	cutting depth 0.01 mm	2000 x 800 x 1000 mm
SLS	± 0.3 mm	0.7 – 1.0 mm	300 x 300 x 300 mm
Industrial FDM	± 0.5 mm	0.8 – 1.0 mm	900 x 600 x 900 mm
DMLS	± 0.1 mm	0.4 mm	230 x 150 x 150 mm

AM Limitations

Factors

- Speed
- Accuracy
- Cost
- Volume- Quantity
- Size (Build Volume)
- Complexity
- Material Capability





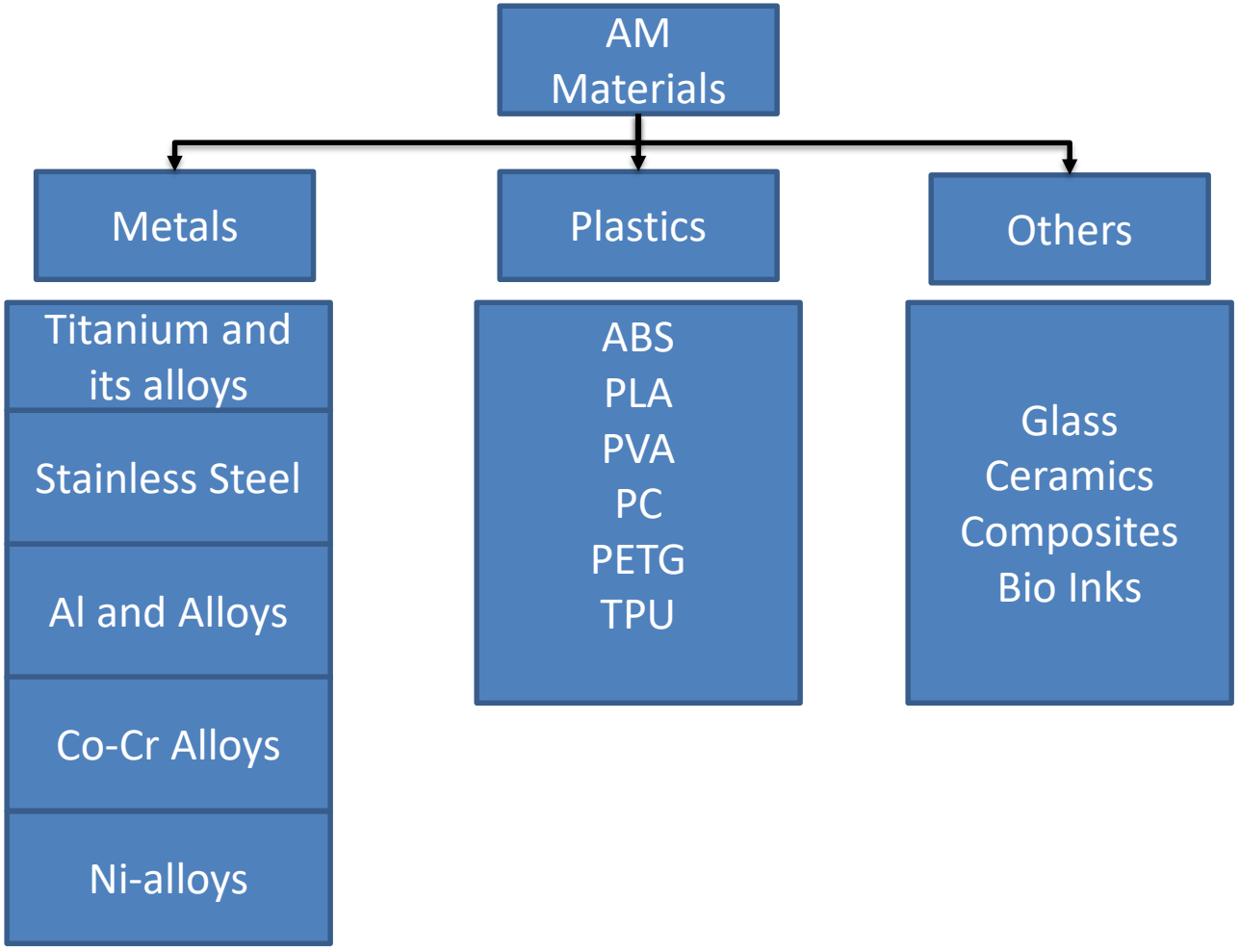
Speed

Below is a head-to-head comparison* of producing a 51mm diameter complex object like the one on the left. It can't be fabricated by traditional manufacturing techniques.

* Based on 3rd party tests commissioned by Carbon3D to compare CLIP against a leading commercial printer in each technology category.

Courtesy: Carbon 3D

Materials in AM



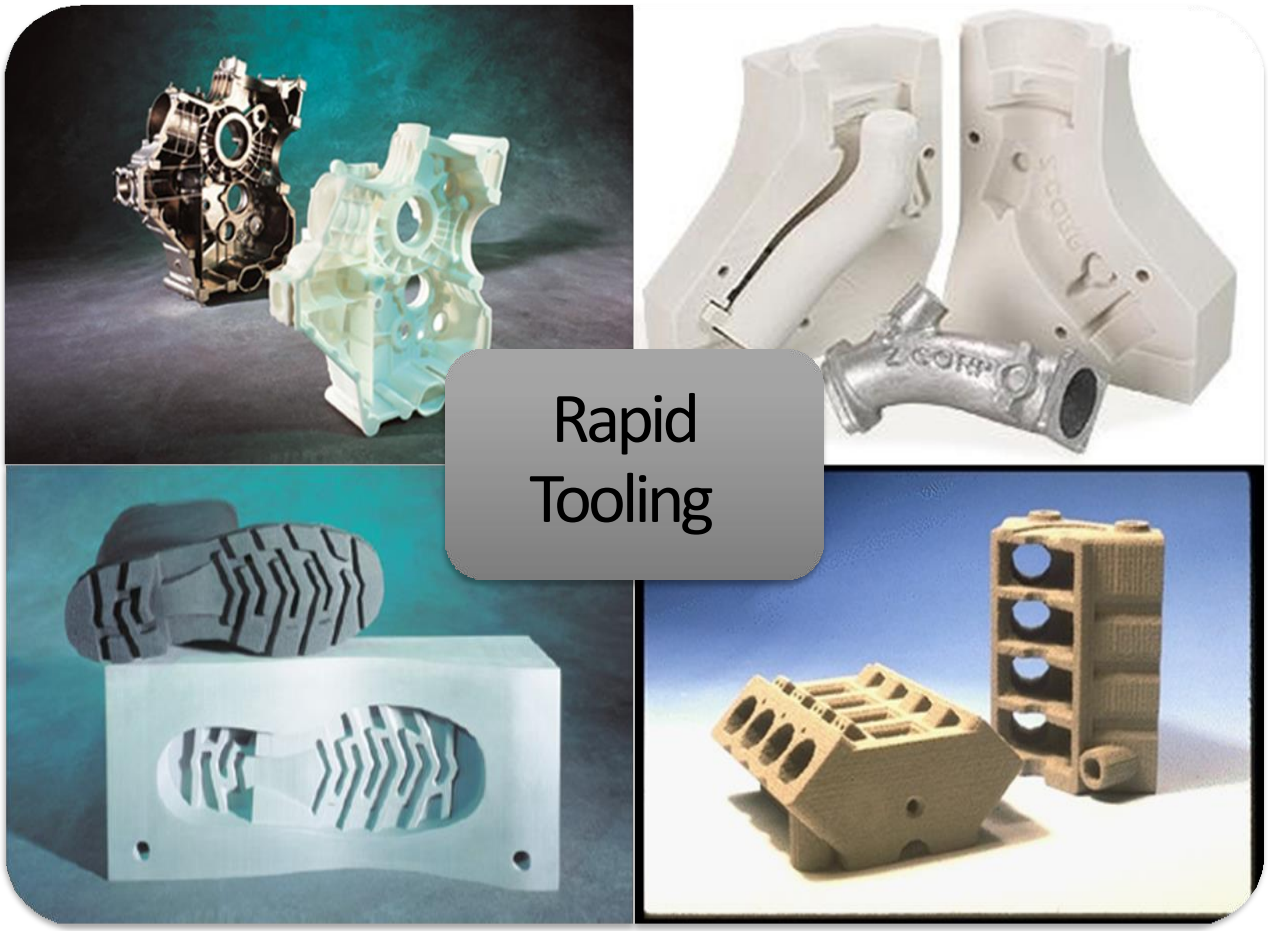
UMaine showcases world's largest 3D printed boat and polymer 3D printer

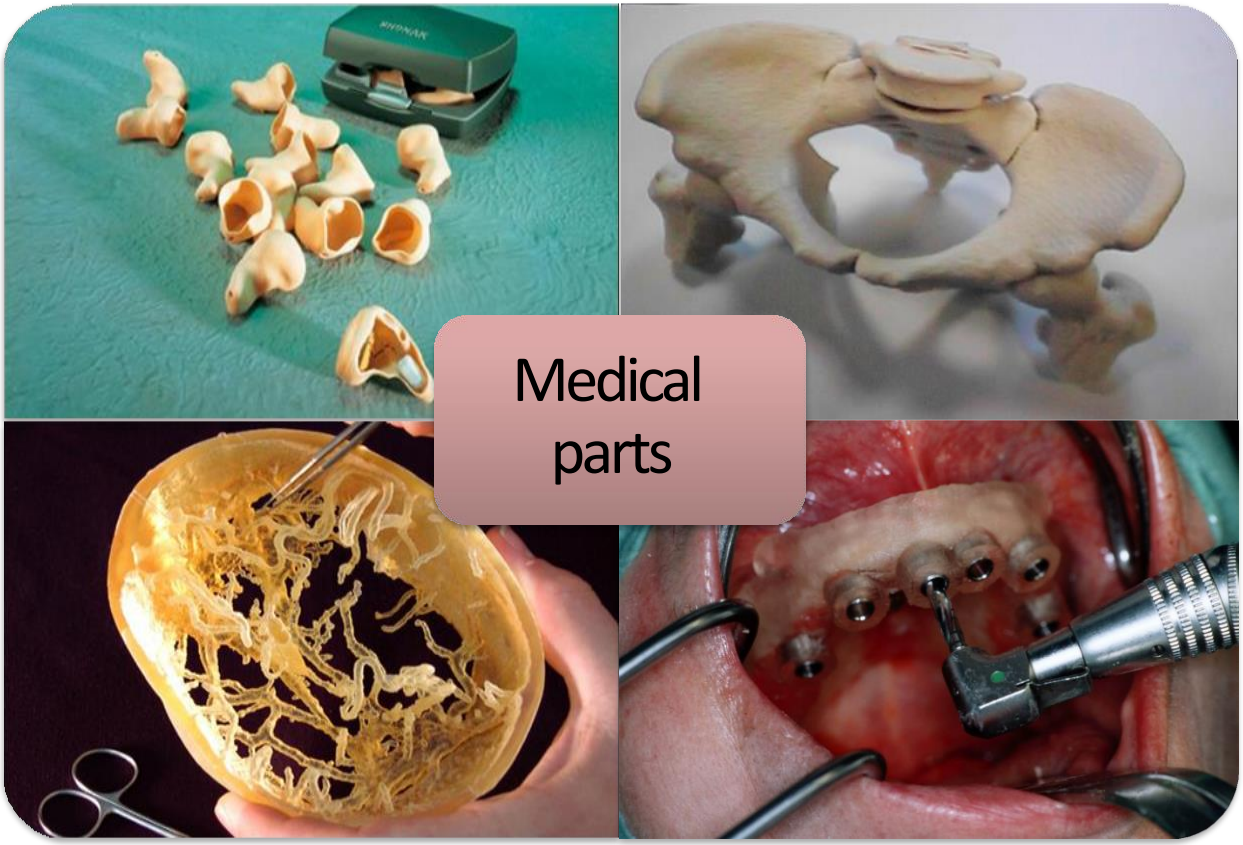
Metal AM Machines

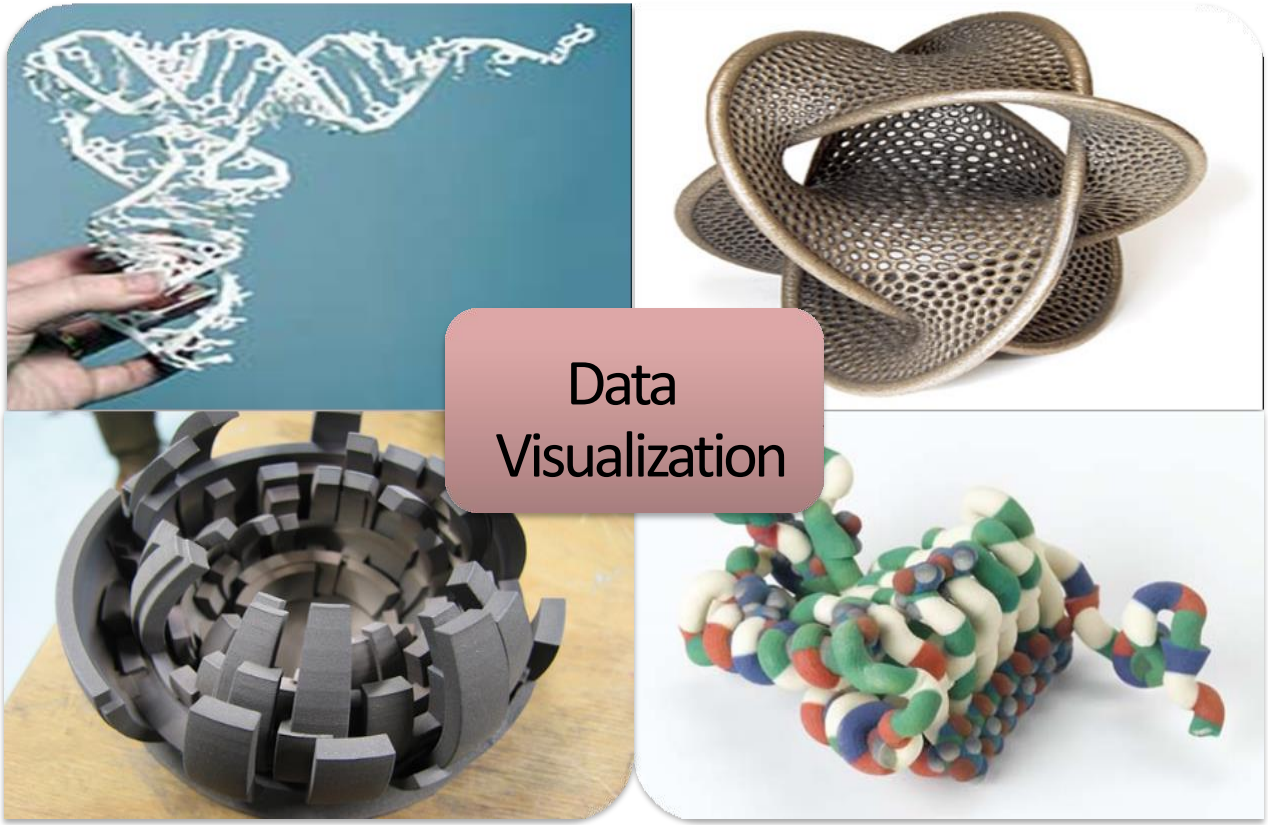
- 3D Systems
- DMG Mori
- EOS
- Renishaw
- SLM Solutions

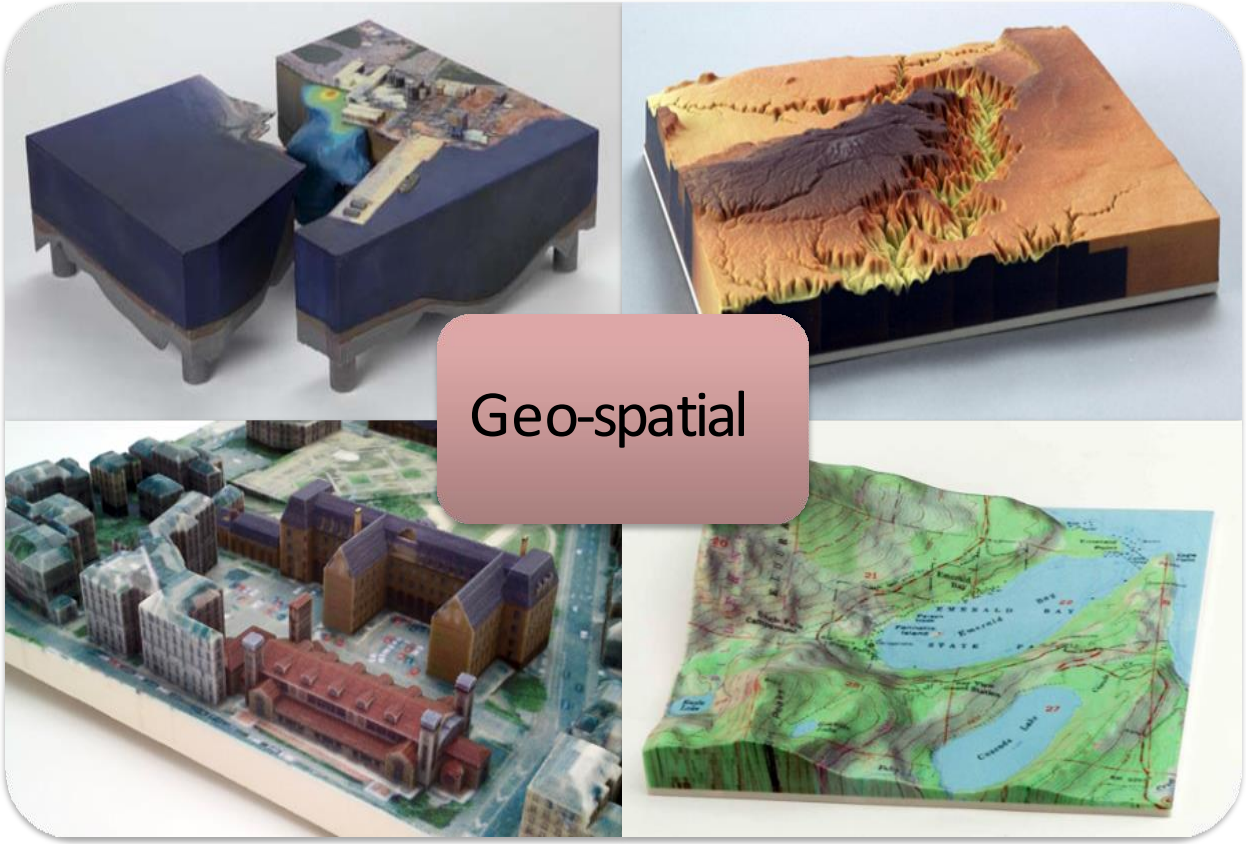
AM Applications

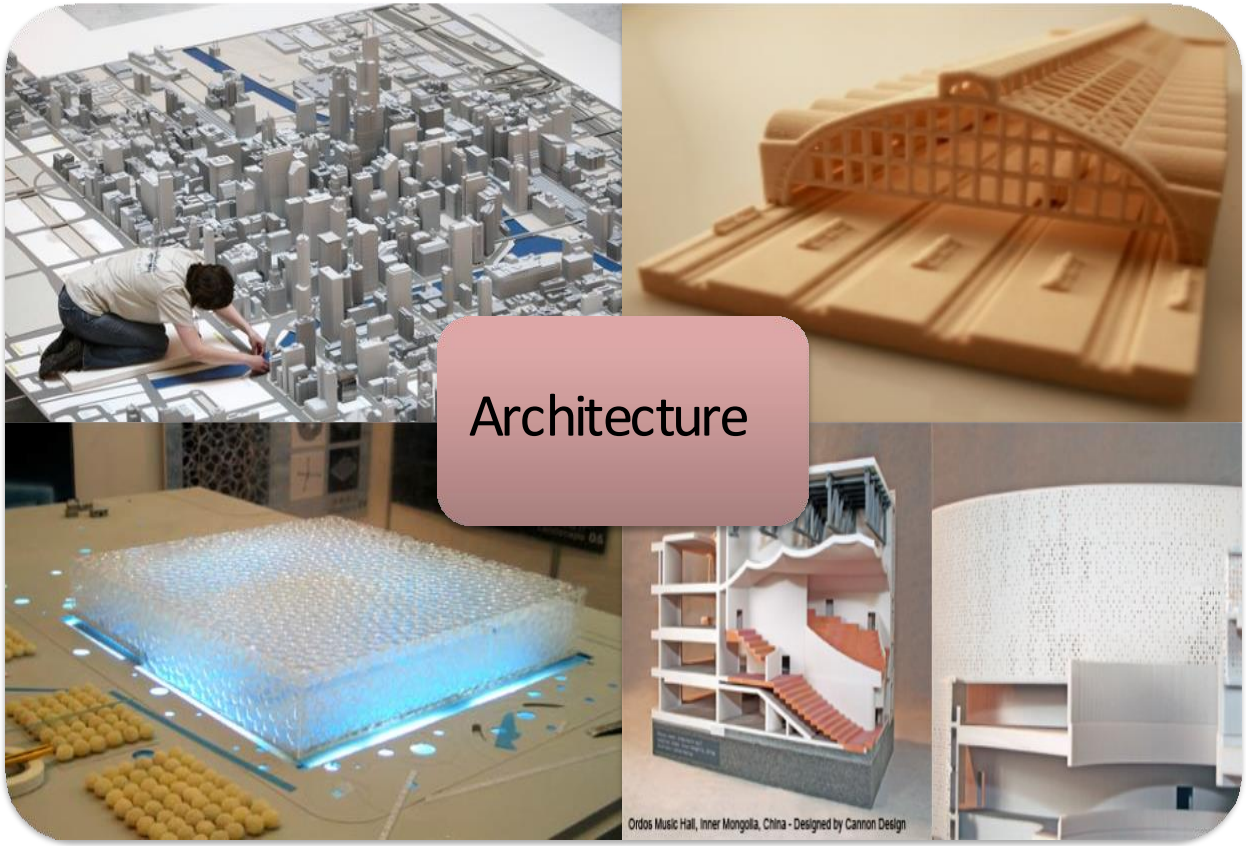

Form fit
testing


Rapid
Tooling


Medical
parts


Data
Visualization


Geo-spatial

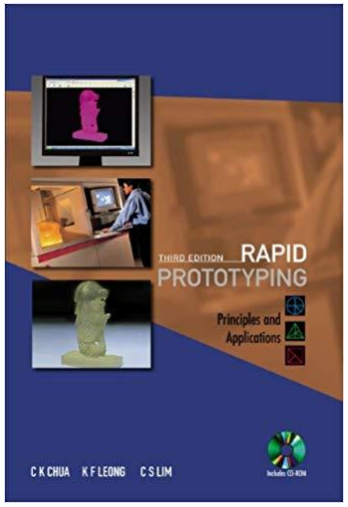

Architecture
Ordos Music Hall, Inner Mongolia, China - Designed by Cannon Design

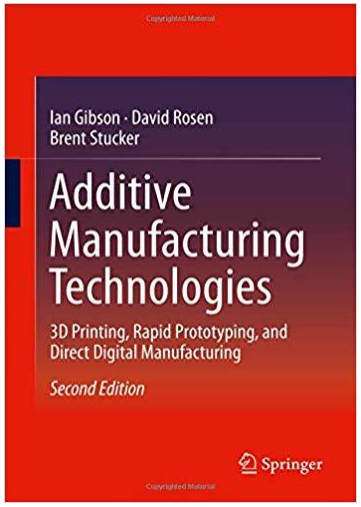

Trend
Objects


Entertainment
© NOMILI.co.za

Reference Books

- Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing by Brent Stucker, David W. Rosen, and IAN GIBSON
- Additive Manufacturing by Bandyopadhyay,Amit Bose, Susmita
- RAPID PROTOTYPING-Laser based and other technologies-Patri K. Venuvinod and Wei yin Ma(2004)
- Rapid Prototyping-Principles and applications Chua.C.K





Evaluation Scheme

Evaluation Component	Name (Quiz, Lab, Project, Mid-term exam, End semester exam, etc.)	Type (Open book, Closed book, Online, etc.)	Weight
EC - 1	Assignment	Online	10%
	Virtual Lab	Online	20%
EC - 2	Mid-Semester Test	Closed Book	30%
EC - 3	Comprehensive Exam	Open Book	40%

Softwares in Lab

- Fusion 360
- ANSYS Additive Suite
- Materialize Mimics
- Ultimaker Cura

Contact Details

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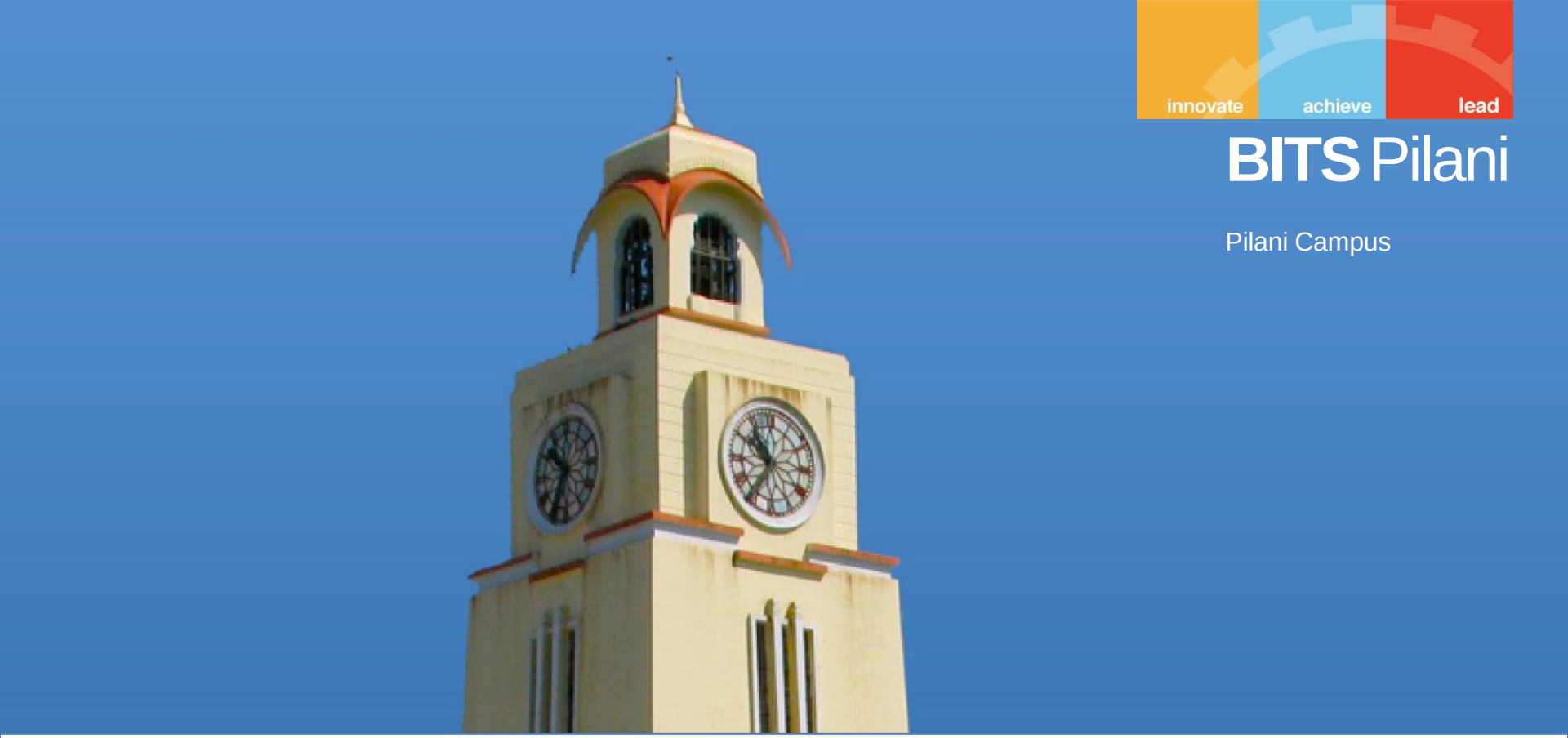

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End of Lecture 1-2