

# RE i **RP** u BMI

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# Aditivne Tehnologije

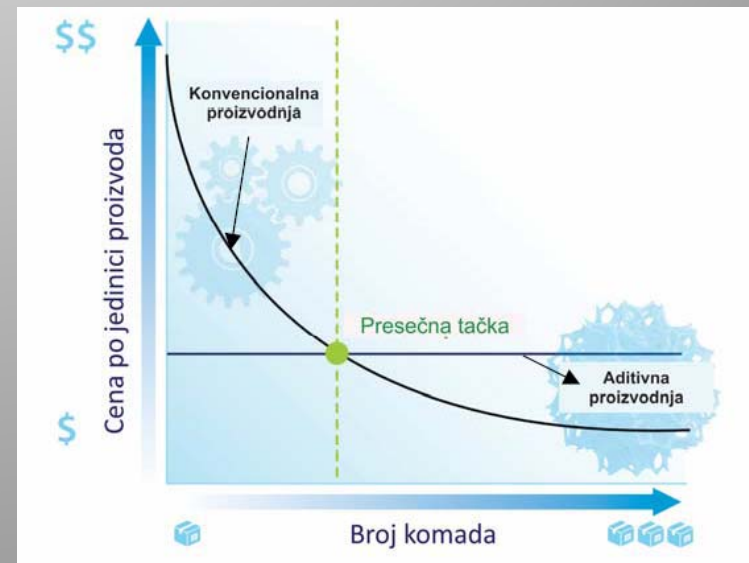
## prednosti i nedostaci

- Izrada proizvoda proizvoljnog geometrijskog oblika i složenosti
- Proizvoljna raznolikost proizvodnog programa
- Mogućnost izrade gotovih sklopova
- Minimalni gubici materijala
- Proizvodnja bez alata!!!!!!
- Kratko vreme obuke
- Individualizacija proizvoda
- Mogućnost kombinovanja različitih materijala
- Planiranje tehnološkog procesa je automatsko i bazira se na CAD modelu
- Nije potrebna posebna priprema mašine
- Proizvodnja sa minimalnim zahtevima u pogledu angažovanja radne snage
- Produktivnost (isključivo se koristi za pojedinačnu i maloserijsku proizvodnju)
- Tačnost i kvalitet proizvoda
- Mehaničke karakteristike
- Cena opreme (industrijske mašine)

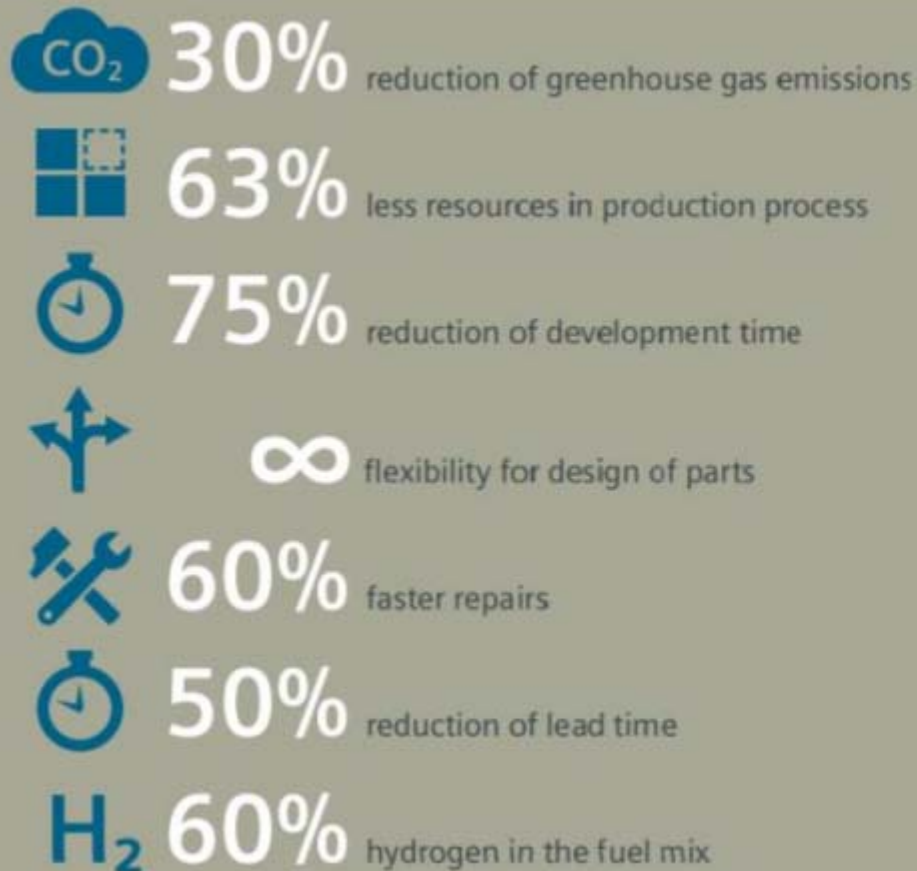
3D Printing  
*freedom of form*



Multi-material 3D Printing  
*freedom of composition*



# Kako SIEMENS vidi prednosti AP



## Rapid Prototyping



**75%**  
development  
time reduction

Prototypes produced with AM are increasingly used for production development to test certain properties before series production begins. As production with AM is much faster than conventional manufacturing, testing and development time of components are accordingly reduced. Early validation of new designs is possible.

## Rapid Manufacturing



**85%**  
faster manufacturing  
of complete burner set

AM technology industrialization enables new opportunities for spare part and supply chain enhancement such as the manufacturing of spare parts on demand and even close to site. Currently, Siemens uses AM for rapid manufacturing of Siemens gas turbine components.

## Rapid Repair



**60%**  
faster repairs of SGT-700  
and SGT-800 burners tips

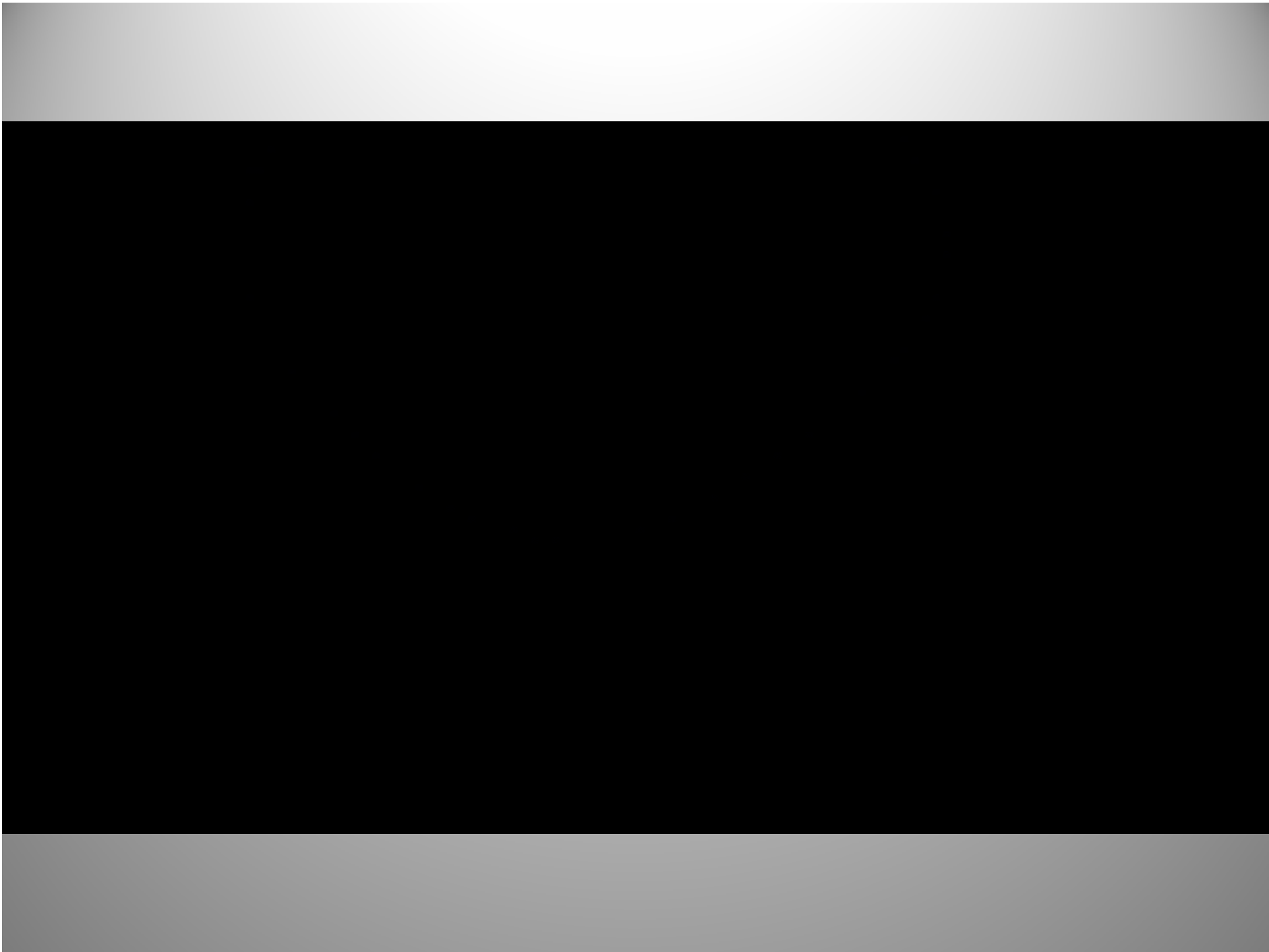
Replacement of conventional repair processes with Additive Manufacturing technologies provides not only a significant reduction in repair time, but also an opportunity to modify repaired components to the latest design.

## Spare parts on demand



**40%**  
lead time reduction

Printed spare parts on demand mean reduced lead time, higher engine availability and fast technology validation for the customer. In June 2016, Siemens has put into commercial operation the first printed spare part on demand for large gas turbines.



# Razvoj aditivnih tehnologija

Year of Inception	Technology
1770	Mechanization [4]
1946	First Computer
1952	First Numerical Control (NC) Machine Tool
1960	First commercial Laser [5]
1961	First commercial Robot
1963	First Interactive Graphics System (early version of Computer-Aided Design) [6]
1988	First commercial Rapid Prototyping System



Geometric Modeling	Prototyping
<b>❶ First Phase: 2D Wireframe</b> <ul style="list-style-type: none"> <li>Started in mid-1960s</li> <li>Few straight lines on display may be: <ul style="list-style-type: none"> <li>circuit path on a PCB</li> <li>plan view of a mechanical component</li> </ul> </li> <li>"Natural" drafting technique</li> </ul>	<b>❶ First Phase: Manual Prototyping</b> <ul style="list-style-type: none"> <li>Traditional practice for many centuries</li> <li>Prototyping as a skilled crafts is: <ul style="list-style-type: none"> <li>traditional and manual</li> <li>based on material of prototype</li> </ul> </li> <li>"Natural" prototyping technique</li> </ul>
<b>❷ Second Phase: 3D Curve and Surface Modeling</b> <ul style="list-style-type: none"> <li>Mid-1970s</li> <li>Increasing complexity</li> <li>Representing more information about precise shape, size and surface contour of parts</li> </ul>	<b>❷ Second Phase: Soft or Virtual Prototyping</b> <ul style="list-style-type: none"> <li>Mid-1970s</li> <li>Increasing complexity</li> <li>Virtual prototype can be stressed, simulated and tested, with exact mechanical and other properties</li> </ul>
<b>❸ Third Phase: Solid Modeling</b> <ul style="list-style-type: none"> <li>Early 1980s</li> <li>Edges, surfaces and holes are knitted together to form a cohesive whole</li> <li>Computer can determine the inside of an object from the outside. Perhaps, more importantly, it can trace across the object and readily find all intersecting surfaces and edges</li> <li>No longer ambiguous but exact</li> </ul>	<b>❸ Third Phase: Rapid Prototyping</b> <ul style="list-style-type: none"> <li>Mid-1980s</li> <li>Benefit of a hard prototype made in a very short turnaround time is its main strong point (relies on CAD modeling)</li> <li>Hard prototype can also be used for limited testing</li> <li>Prototype can also assist in the manufacturing of the products</li> </ul>



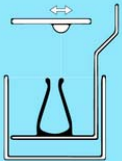
# Razvoj aditivnih tehnologija

- Prvi rezultati primene AT (RP) sistema objavljeni su 1982. godine, a prva industrijska primena počela je 1988. godine (firma 3-D Systems, SAD koja je i sad lider na tržištu sistema za AT).
- U početku proces je bio skup i komplikovan.
- Veliki broj različitih uređaja.
- Brzo rastuće tržište.

## From the 1970s to today, key 3-D printing moments

Wyn Kelly Swainson patents directing a laser onto a tray submerged in liquid plastic, fusing a layer of solid plastic on top.

**1977**



Sources: Madmuseum.org, The Guardian

Scientists at the Wake Forest Institute for Regenerative Medicine 3-D print a bladder — the first 3-D printed organ.

**1999**

A baby's life is saved by a 3-D printed splint created by the University of Michigan.

**2013**



**1986**

Chuck Hull patents stereolithography, focusing UV light at a liquid photopolymer surface, creating crosslinked layers.

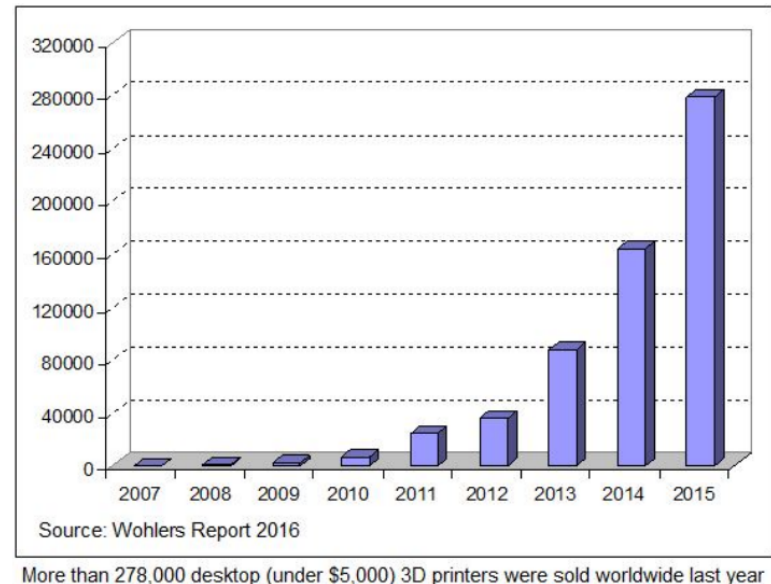
**2005**

The first functional furniture is 3-D printed by French artist Patrick Jouin.

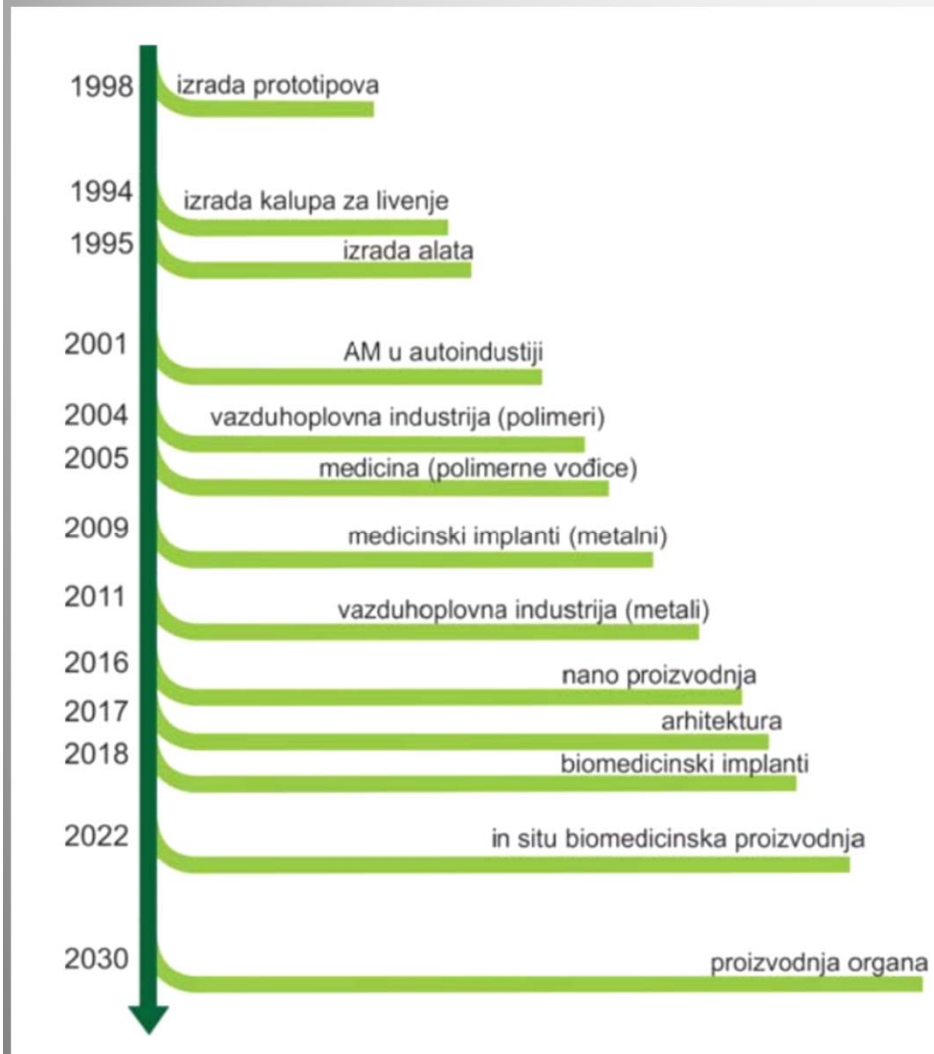


**2017**

Boeing debuts FAA-approved 3-D printed titanium parts for the 787 Dreamliner.



## “3D PRINTING’S POTENTIAL TO REVOLUTIONIZE MANUFACTURING IS QUICKLY BECOMING A REALITY.”

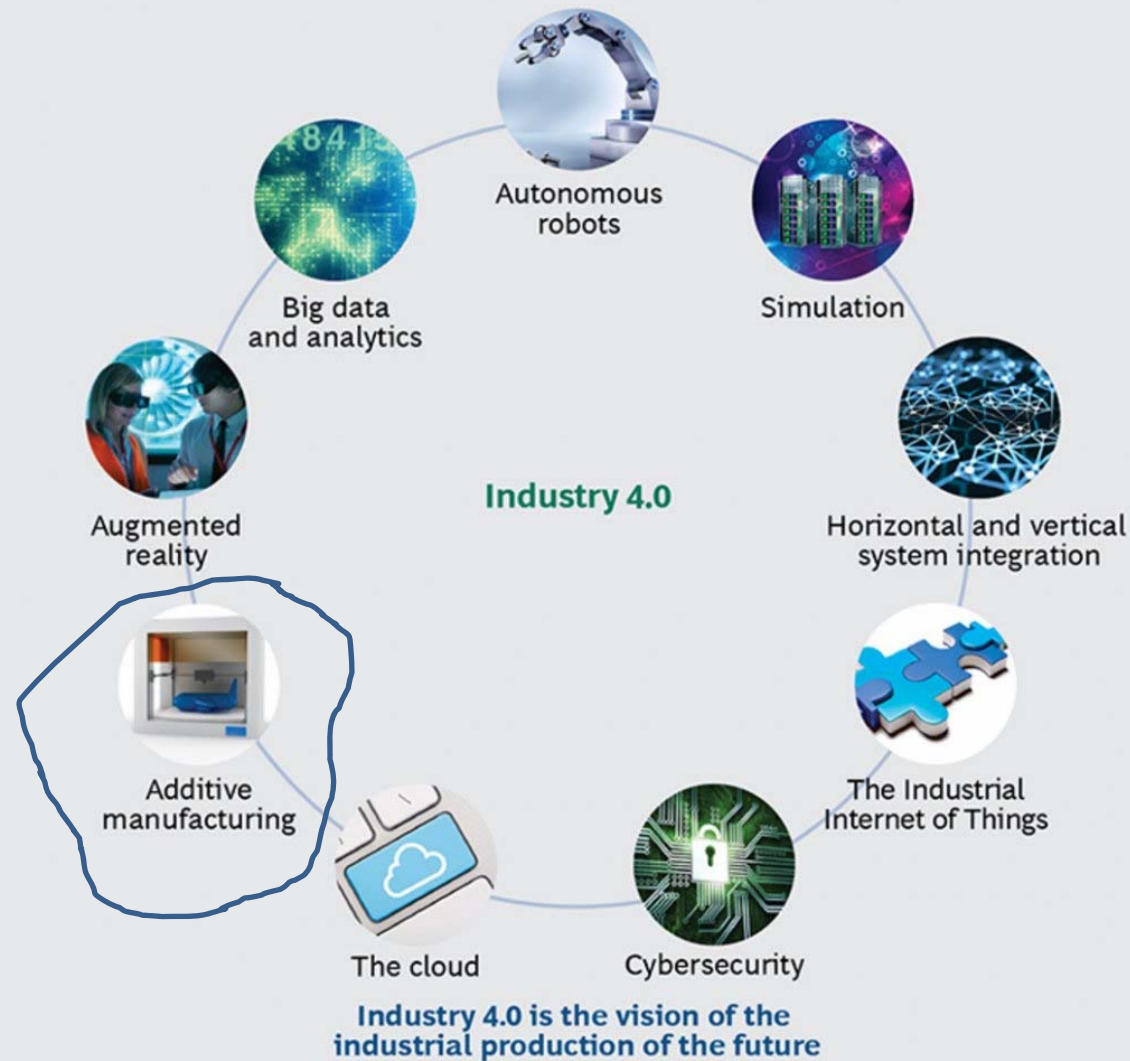


MANUFACTURER FILES FOR BANKRUPTCY  
**3D PRINTER COMPANY ASKS  
CLIENTS NOT TO PRINT 3D PRINTERS**



# Aditivne tehnologije i Industrija 4.0

## EXHIBIT 1 | Nine Technologies Are Transforming Industrial Production

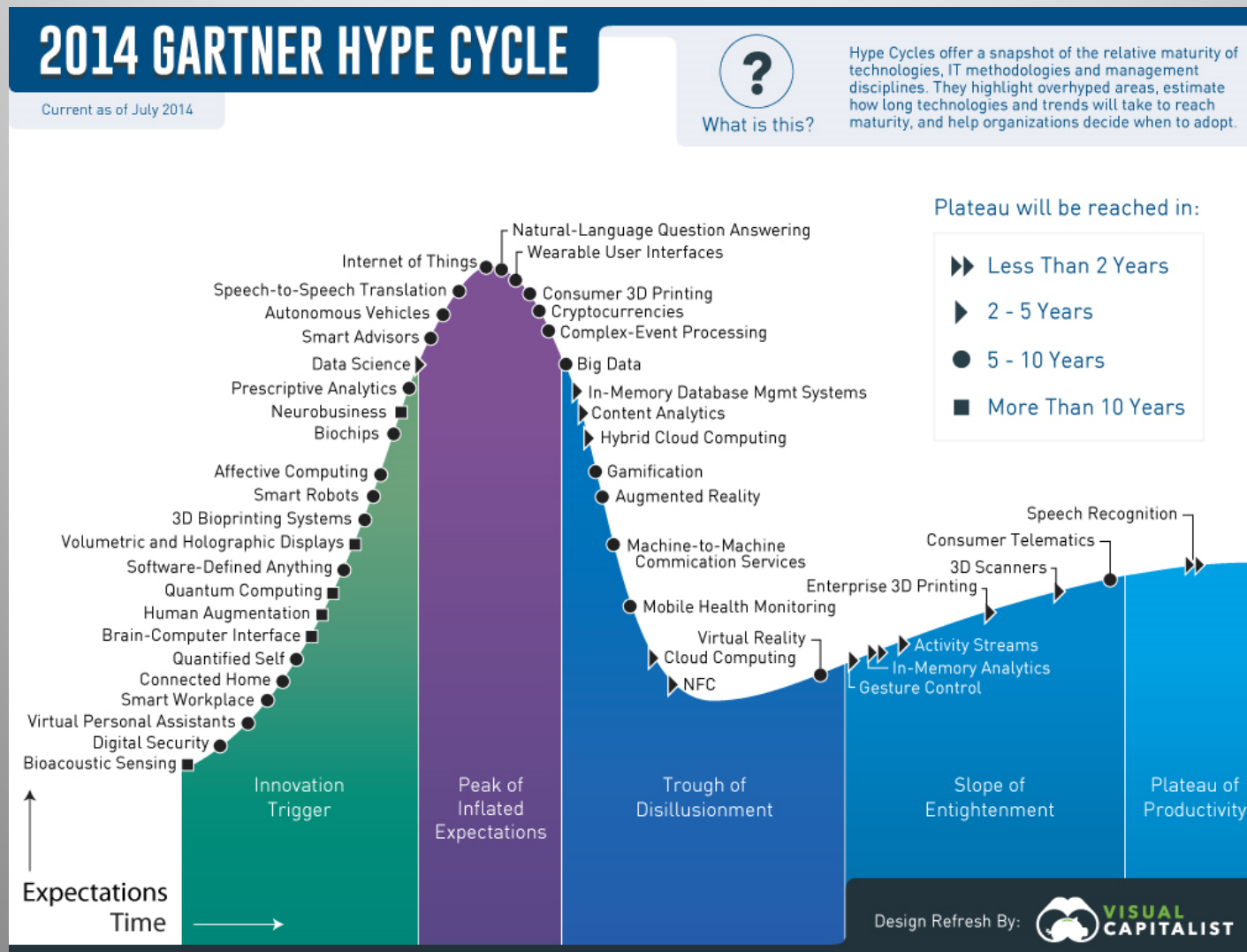


Source: BCG.



# Pozicija AT u Hype cycle-u

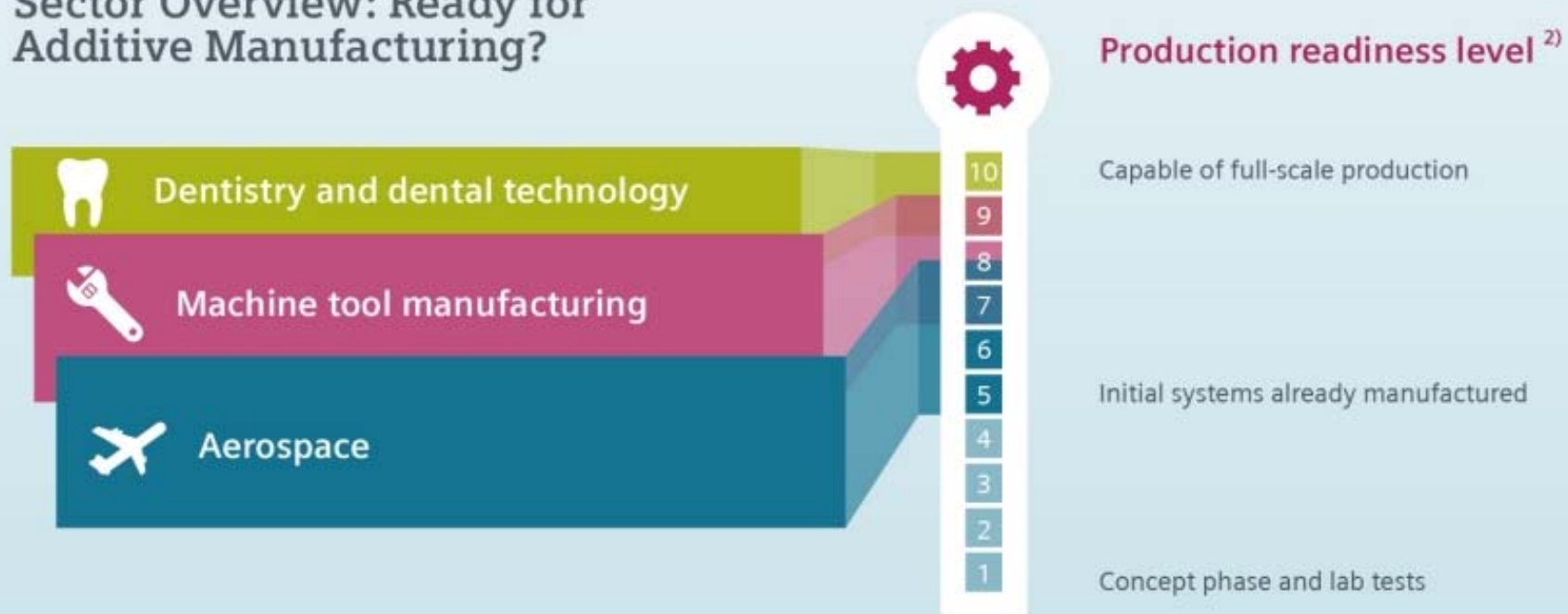
The hype cycle je grafička prezentacija koju je američka firma za istraživanje, savetovanje i informacione tehnologije Gartner da predstavi nivo razvoja/zrelosti, prihvaćenosti i društvenu primenu specifičnih tehnologija tj. kako će se određena tehnologija ili aplikacija razvijati tokom vremena



# Razvoj AM sektora

- ▶ Tri najbrže rastuće oblasti primene AM tehnologija su: **medicina, mašinska industrija i sector aeronautike**

## Sector Overview: Ready for Additive Manufacturing?



## CURRENT

### Fluid handling

**Applications:** Pumps, valves  
**AM technology:** Selective laser melting, electron beam melting  
**Materials:** Aluminum alloys

### Exterior/exterior trim

**Applications:** Bumpers, wind breakers  
**AM technology:** Selective laser sintering  
**Materials:** Polymers

### Manufacturing process

**Applications:** Prototyping, customized tooling, investment casting  
**AM technology:** Fused deposition modeling, inkjet, selective laser sintering, selective laser melting  
**Materials:** Polymers, wax, hot work steels

### Exhaust/emissions

**Applications:** Cooling vents  
**AM technology:** Selective laser melting  
**Materials:** Aluminum alloys

## FUTURE

### Interior & seating

**Applications:** Dashboards, seat frames  
**AM technology:** Selective laser sintering, stereo-lithography  
**Materials:** Polymers

### Wheels, tires, & suspension

**Applications:** Hubcaps, tires, suspension springs  
**AM technology:** Selective laser sintering, inkjet, selective laser melting  
**Materials:** Polymers, aluminum alloys

### Electronics

**Applications:** Embedded components such as sensors, single-part control panels  
**AM technology:** Selective laser sintering  
**Materials:** Polymers

### OEM components

**Applications:** Body-in-white  
**AM technology:** Selective laser melting, electron beam melting  
**Materials:** Aluminum, steel alloys

### Powertrain, drivetrain

**Applications:** Engine components  
**AM technology:** Selective laser melting, electron beam melting  
**Materials:** Aluminum, titanium alloys

### Frame, body, doors

**Applications:** Body panels  
**AM technology:** Selective laser melting  
**Materials:** Aluminum alloys

Source: Deloitte analysis.

Graphic: Deloitte University Press | DUPress.com

## Urbee, the first AM-produced car



- Built external frame comprised of 20 separate panels built through rapid prototyping using fused deposition modeling (FDM)
- Partnered with a major rapid prototyping service bureau in production of the frame
- Used design and simulation software

- CAD modeling begun in 2013
- 3D print interiors in addition to the external body
- More parts—40–50 major body and interior parts will be 3D printed
- Greater complexity of parts which cannot be produced through traditional manufacturing methods



# Istorija primene AM u medicini



1984 - 86

Charles Hull invents 3D printing and coins the term "Stereo Lithography"



1989

First 3D printer built by 3D Systems



1999

First application of 3D printing in the medical field  
- creating the human bladder





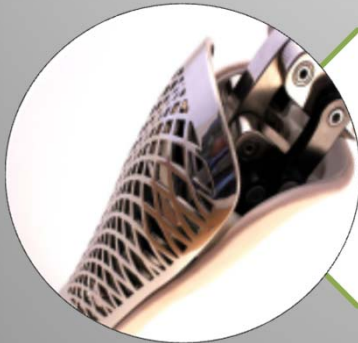
2000

Miniature human kidney created through 3D printing



2006

The Selective Laser Sintering machine – printing multiple materials & fields



2009

First usable prosthetic leg – this opens the door for customized products using 3D printing



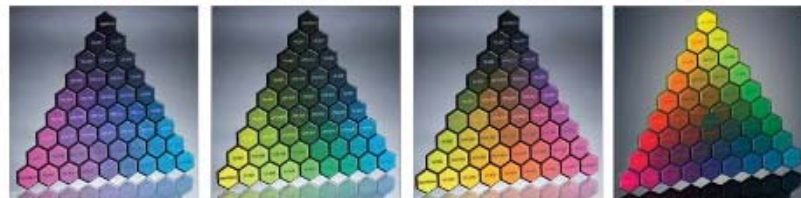
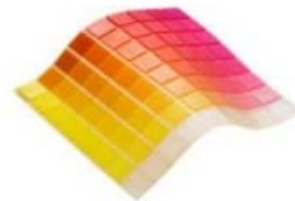
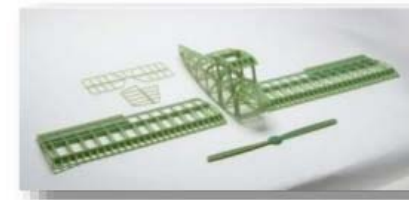
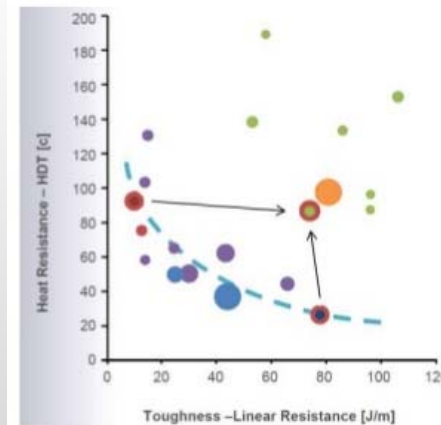
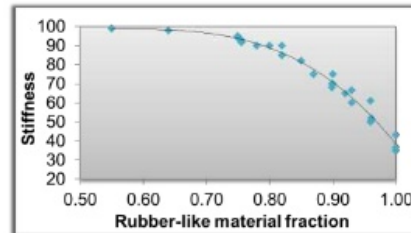
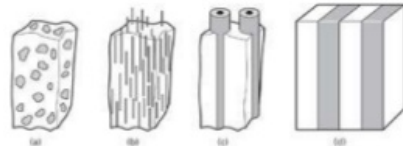
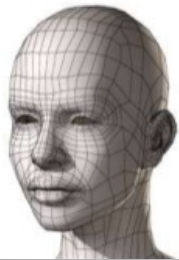
2011

3D printers start offering 14k gold as printable material

# Digitalni (kompozitni) materijali

Digital Materials are engineered materials manufactured from two or more different constituent materials, according to a digitally encoded three dimensional phase structure design (the DM code), and produced by an additive manufacturing process.

- Heterogeneous/Homogeneous
- Anisotropic/Isotropic
- Geometry Dependent



Sandwich X



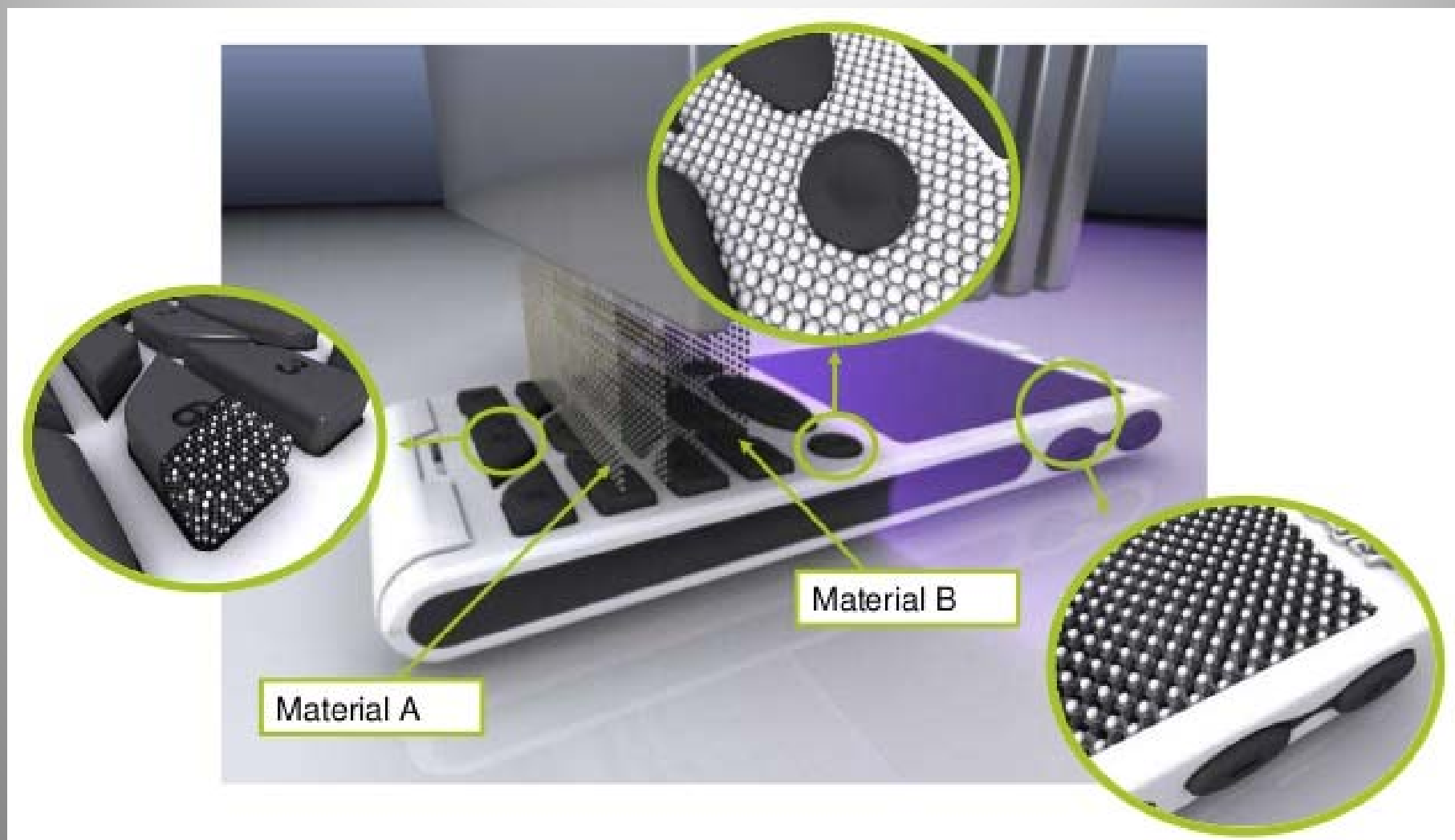
Sandwich Y



Sandwich Z



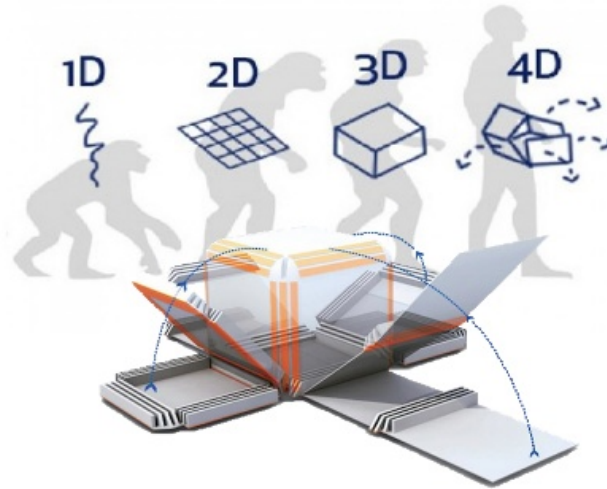
# Digitalni (kompozitni) materijali



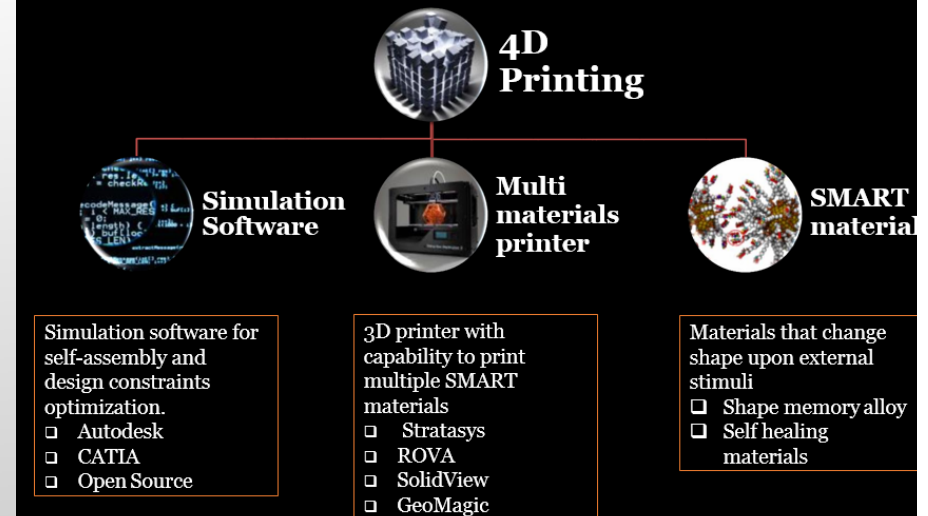
# 4D Printing

## 4D PRINTING

Skyler Tibbitts is shaping the next development, which he calls 4D printing, where the fourth dimension is time. This emerging technology will allow us to print **objects that then reshape themselves or self-assemble over time.**



## Important Aspects of 4D Printing



## Year of Impact (4D printing)

Sectors	Expected Year of Impact									
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Healthcare										
Military										
Infrastructure										
Automobile										
Packaging										
Aerospace										
Manufacturing										

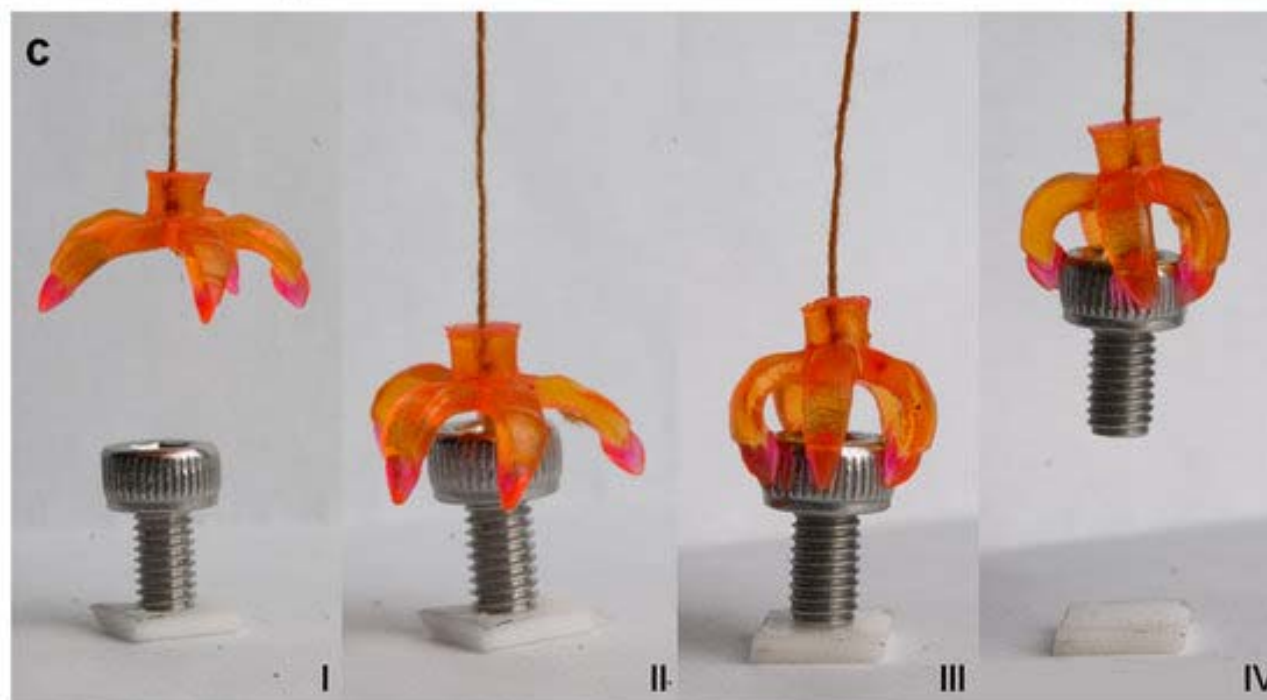
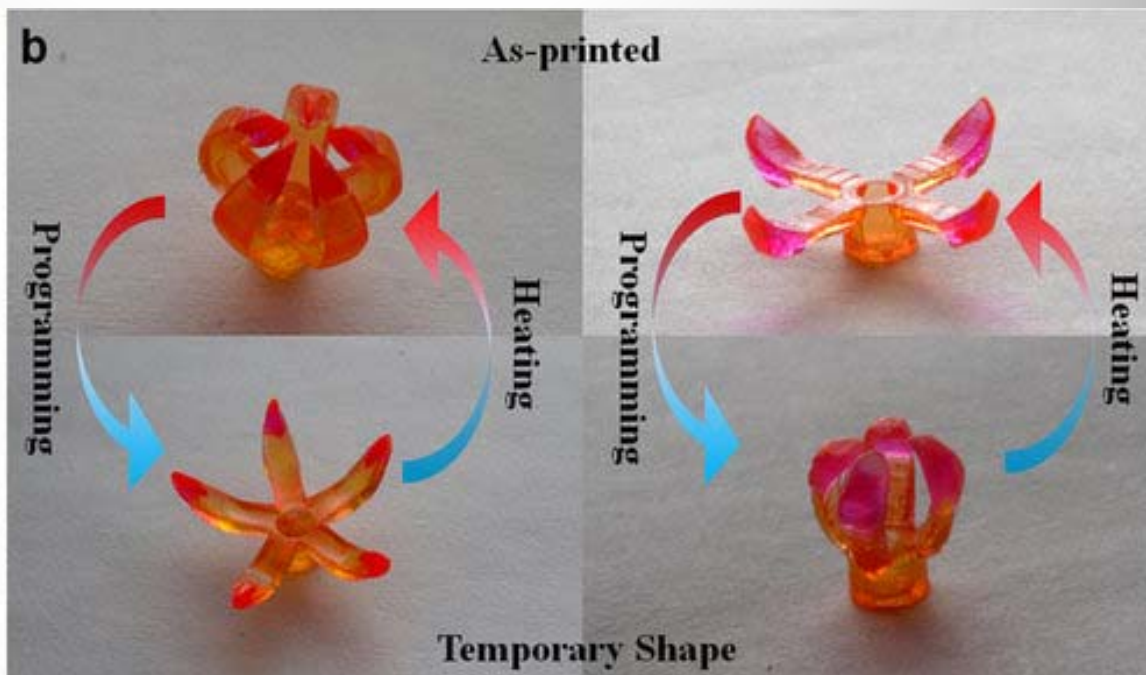
Source: Frost & Sullivan, June 2014

The expected year of widespread/ large-scale adoption of 4D Printing technology has been computed through assessments of technology advances, industry initiatives, challenges, advances in related industries, and market potential

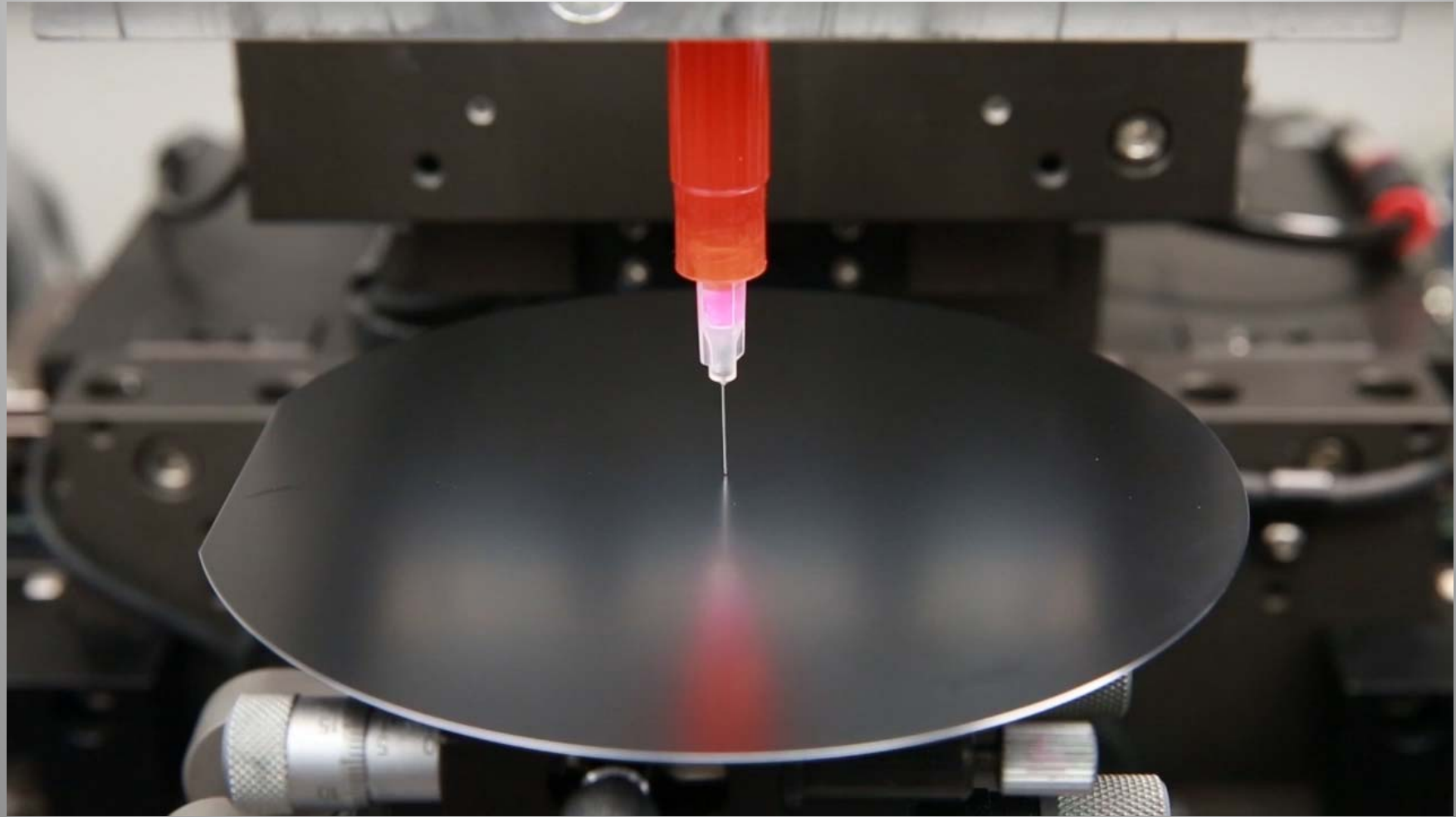
## Further Applications of Smart Materials

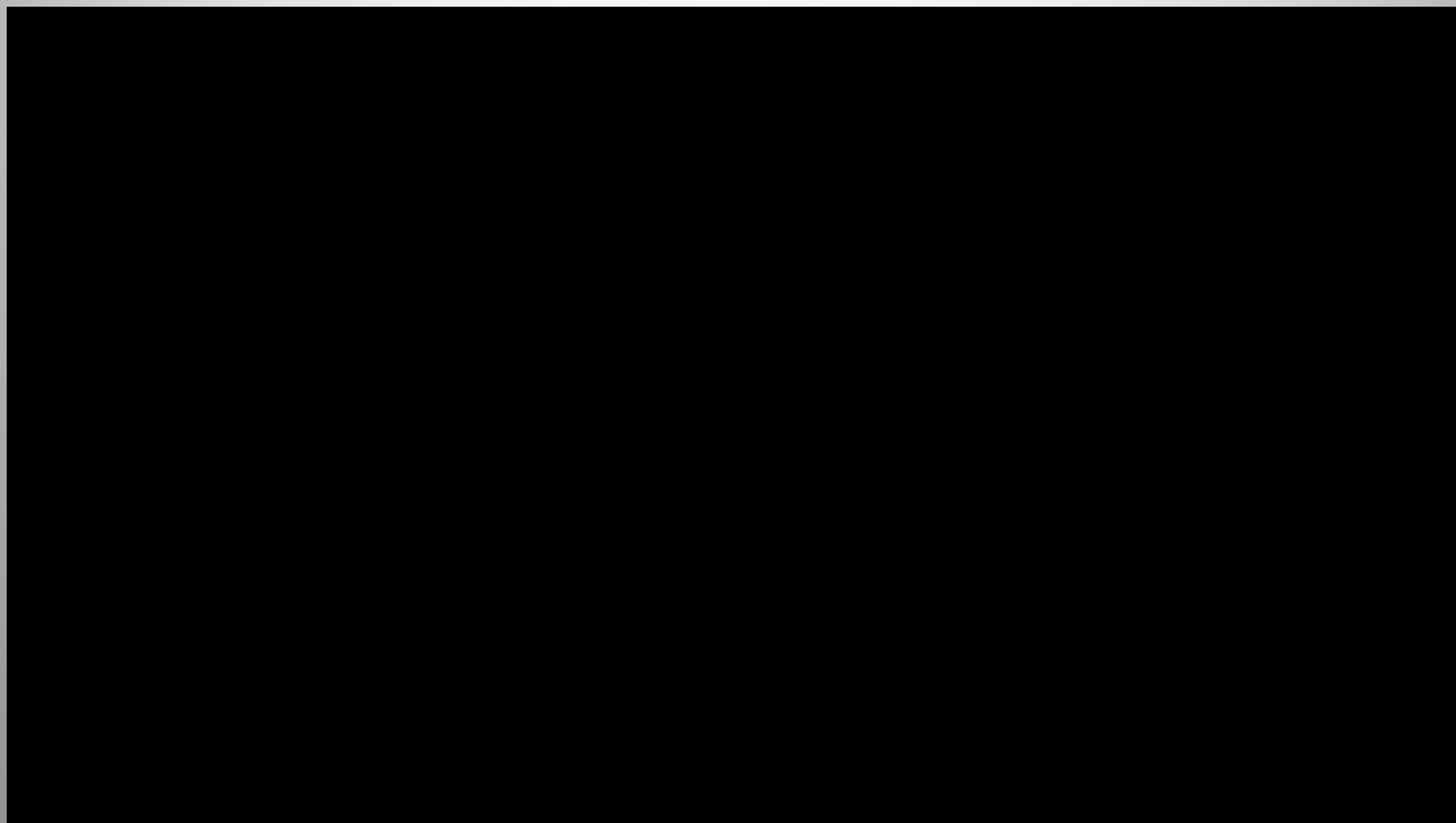








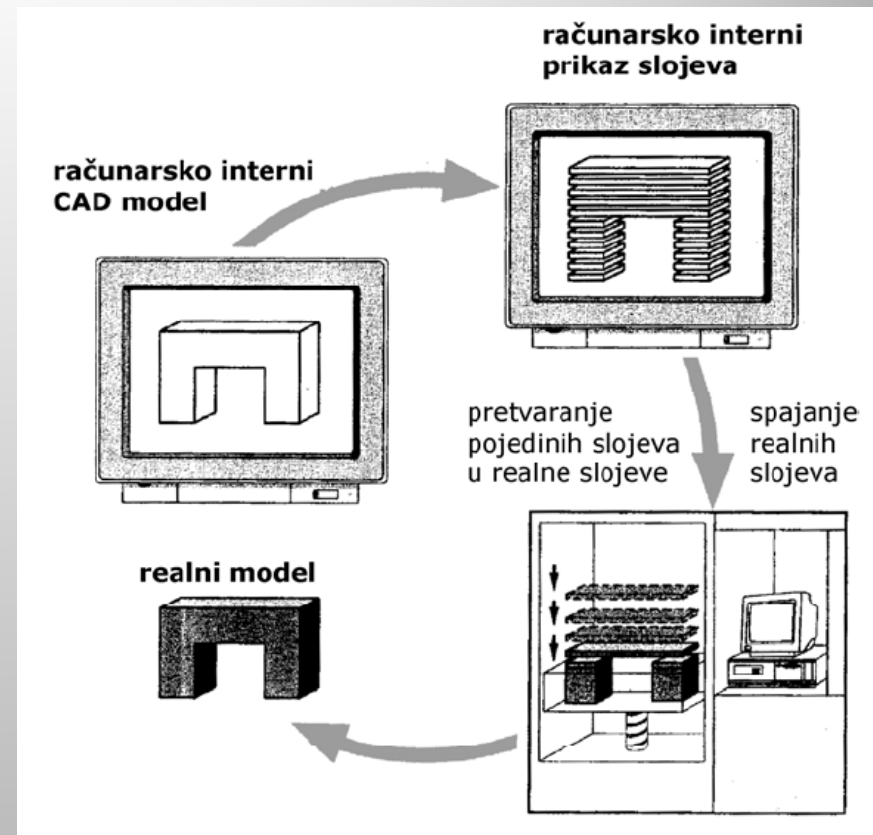





# Opšti tehnološki tok/faze RP/AM/RT postupaka

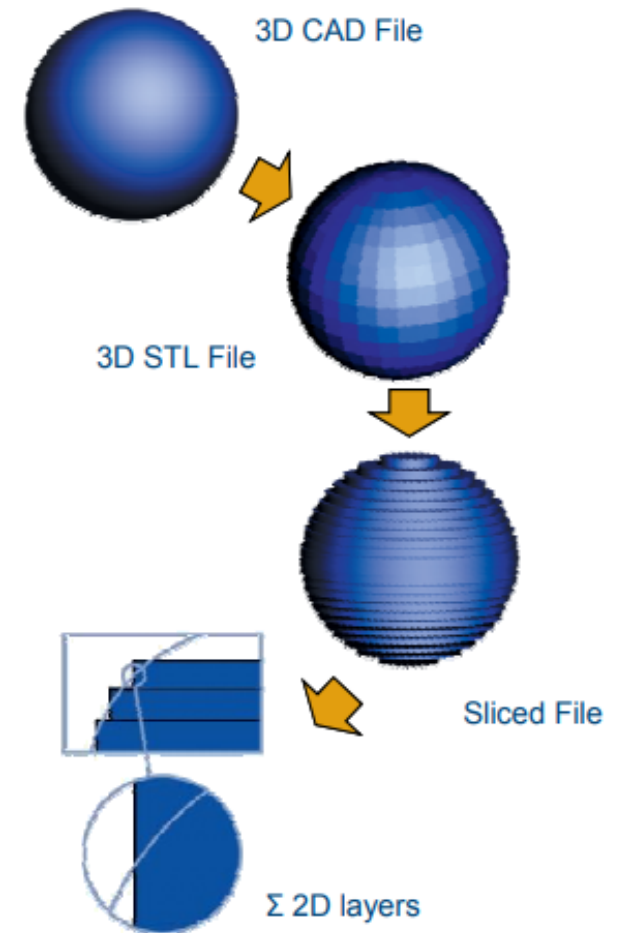
Opšti pristup zajednički za sve RT/AM/RT tehnologije je sledeći:

- I. Generisanje digitalnog 3D modela. Model mora biti predstavljen zatvorenim površinama.
- II. Dobijeni model se zatim konvertuje u neki od standardnih formata za razmenu podataka. Obično se koristi STL (*STereoLitography*) fajl format. To je fajl ASCII ili binarnog tipa i predstavlja listu trougaonih površina koje opisuju kompjuterski generisani prostorni model. Pored STL- formata koriste se i CLI, VRML, STEP ili IGES formati.
- III. Poseban softver analizira poligonalni model i pretvara ga u niz poprečnih preseka. Podaci se procesiraju na taj način što se virtuelni model deli u slojeve debljine od 0.05 mm do 0.3 mm.
- IV. Mašina dalje ovakav model koristi za formiranje modela sloj po sloj, pri čemu se svaki sloj vezuje sa onim pre i onim posle njega - Procesiranje.
- V. Dorada radnog predmeta - Postprocesiranje

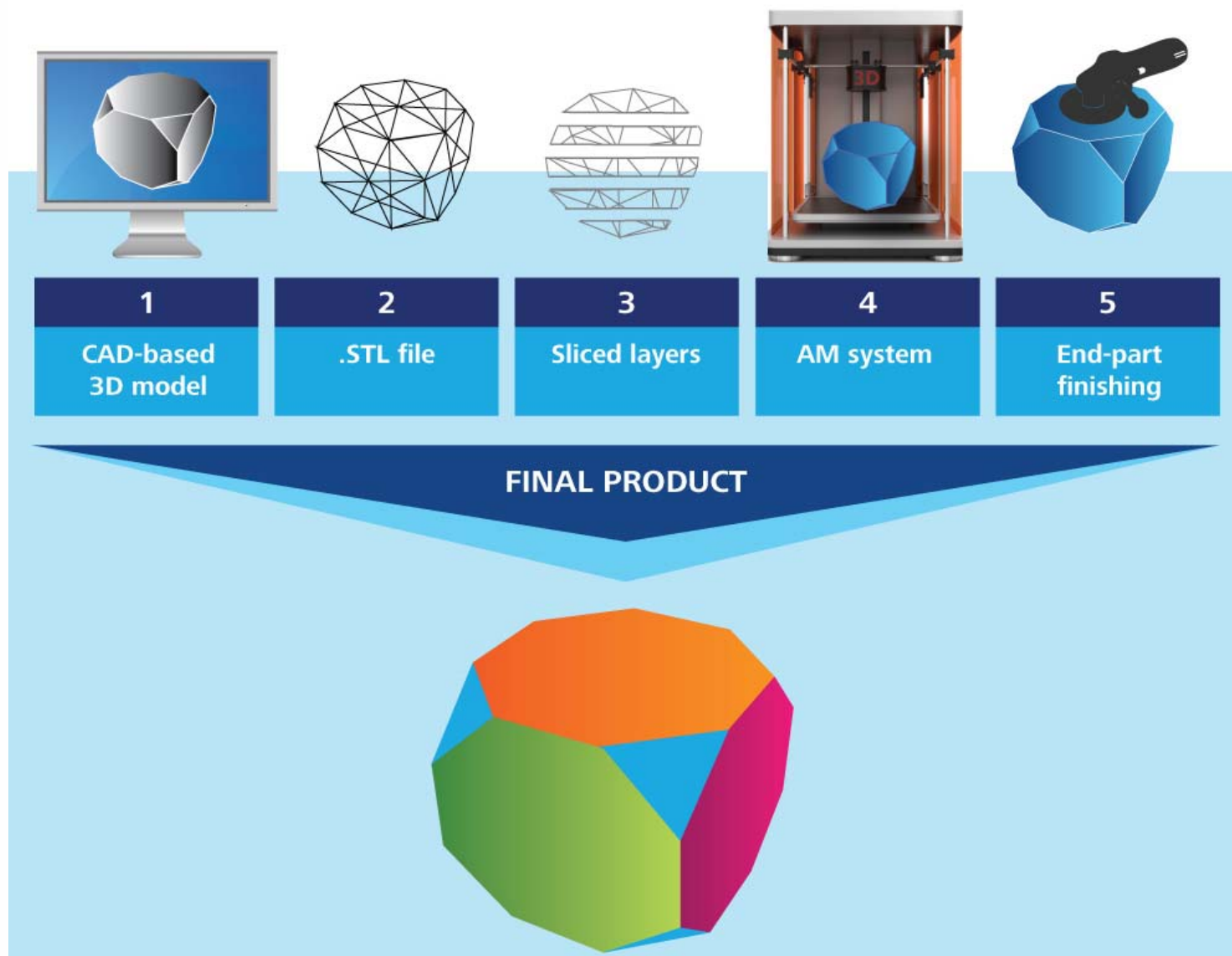


# Opšti tok/faze RP/AM/RT postupaka

- 
- **Basic data** : Ulazni podaci – generisanje modela  
Scan / 3D CAD files – STL
  - **Pre-treatment** : Pre-procesiranje  
STL corrections, orientation, supports, 2D slicing
  - **Manufacturing** : Procesiranje  
Full automatic
  - **Post-treatment** : Post-procesiranje  
Cleaning, sand blasting, coating, finishing



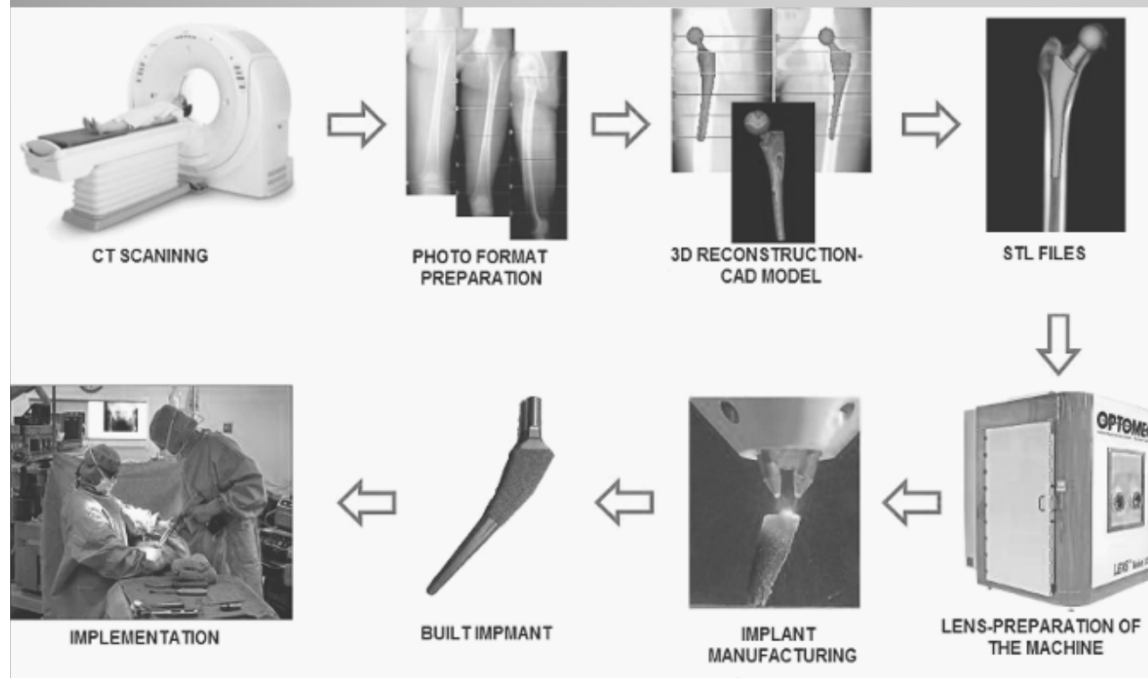
# Opšti tok/faze RP/AM/RT postupaka

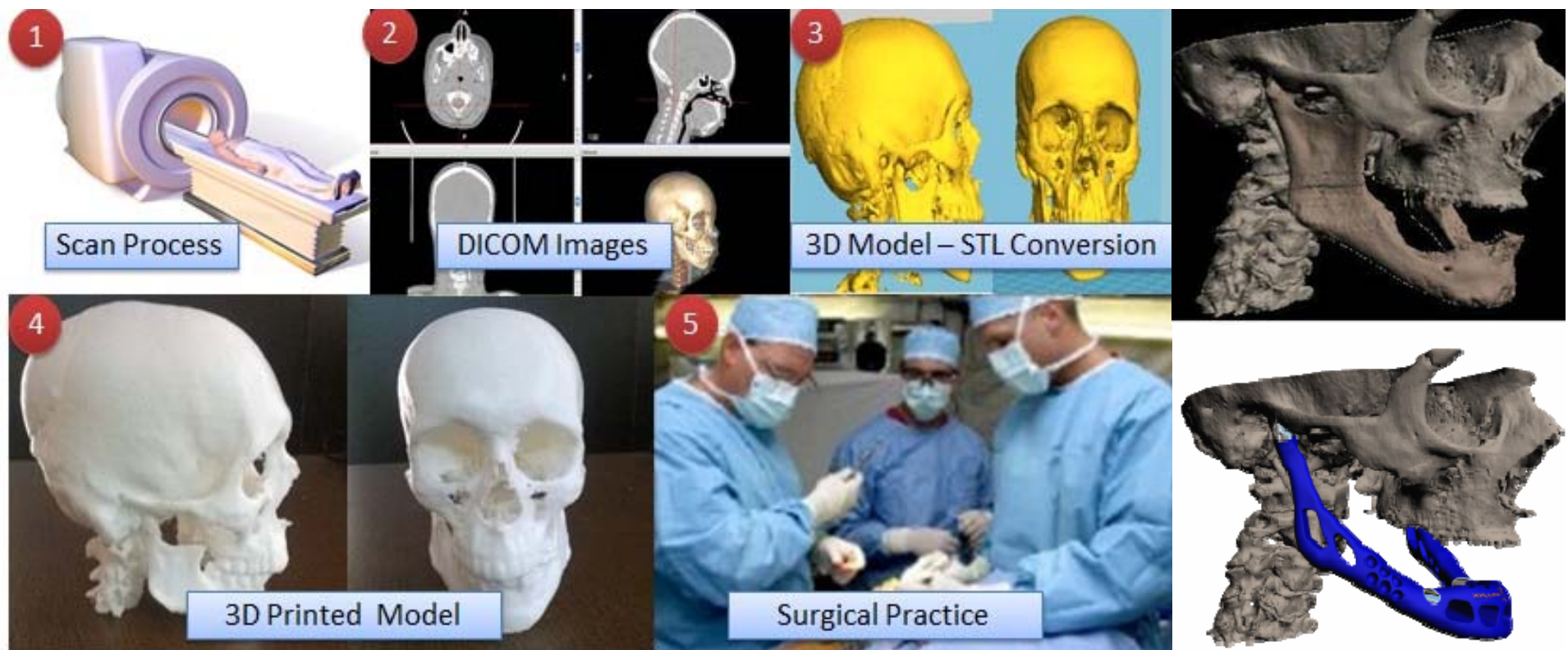




# Generisanje 3D digitalnog modela

- a) 3D CAD softverski sistemi
- b) Reverzibilni inženjering (RE)
- c) Podaci o poprečnim presecima (geofizika, topografija)
- d) Medicinski podaci (CT, MRI)
- e) Matematički podaci (eksperimenti, algoritmi..)





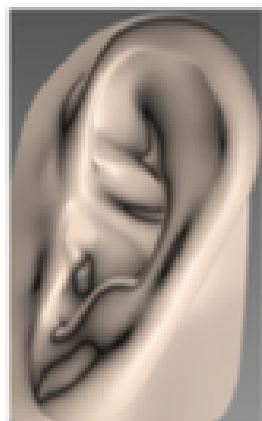
Medical imaging  
(CT, MRI)

3D CAD model

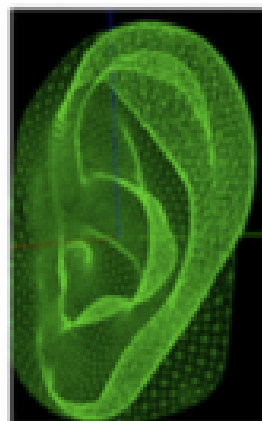
Visualized motion  
program

3D printing process

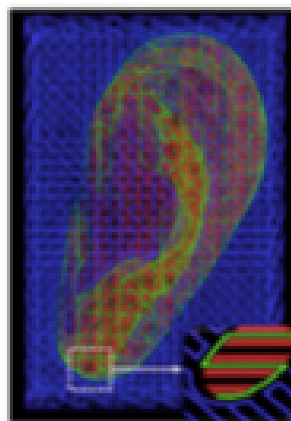
3D bioprinted  
tissue product



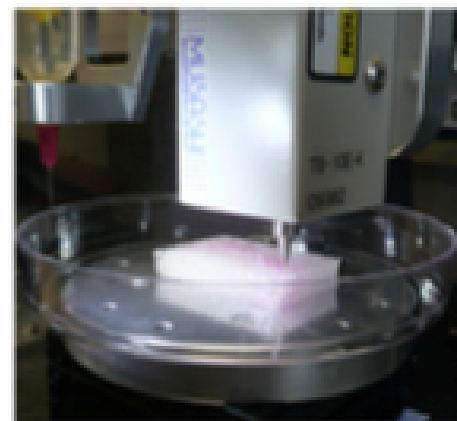
DICOM format



STL format

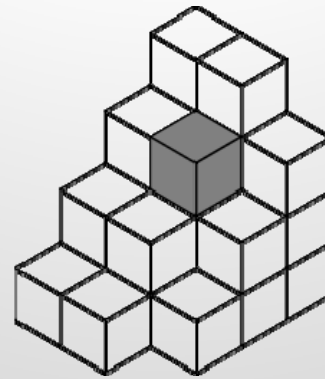


Text-based  
command list

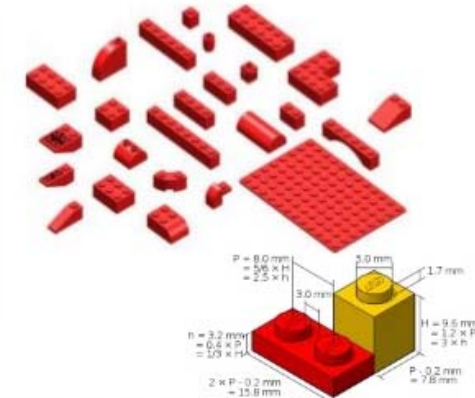
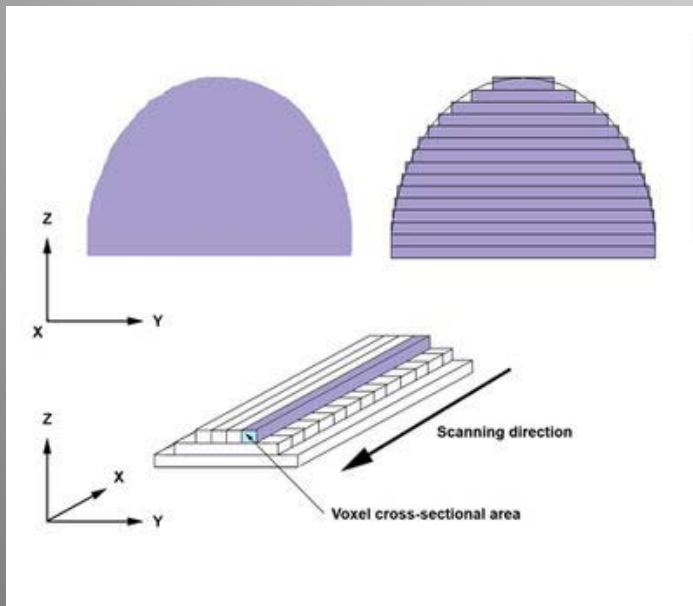
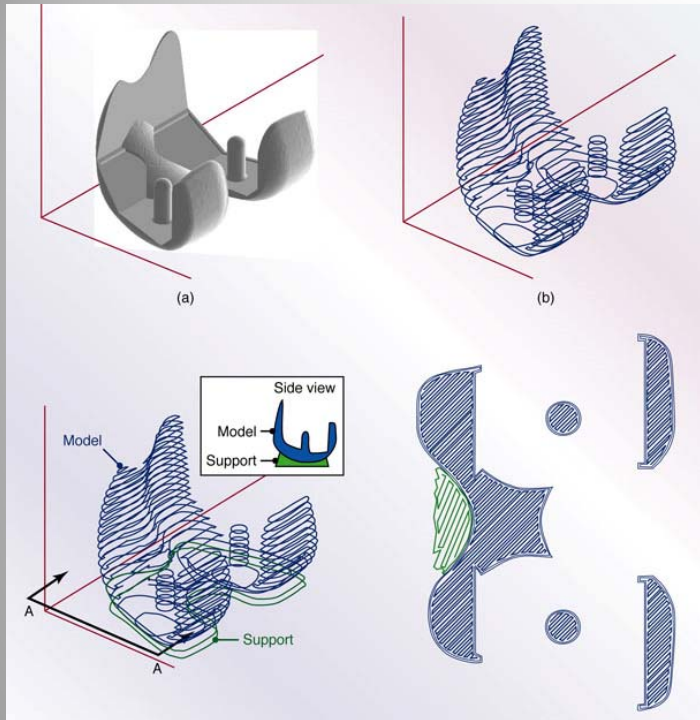


10 mm

# VOXEL



**VOXEL** (volumetric pixel ili tačnije Volumetric Picture Element) je zapreminski element koji predstavlja osnovni parametar mreže u trodimenzionalnom prostoru. On je analogan pixel-u, koji se koristi kao parametar 2D slika (bitmap).



- 1 cubic millimeter – ~20,000 Objet voxels
- The smallest Lego brick – ~4,000,000 Objet voxels
- Full tray –  $10^{12}$  Objet voxels

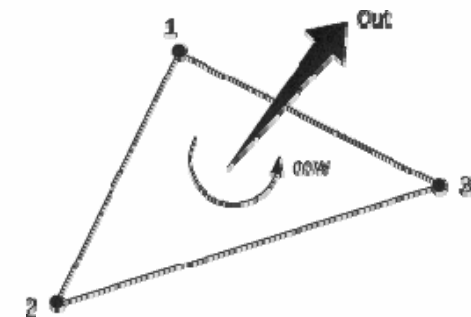
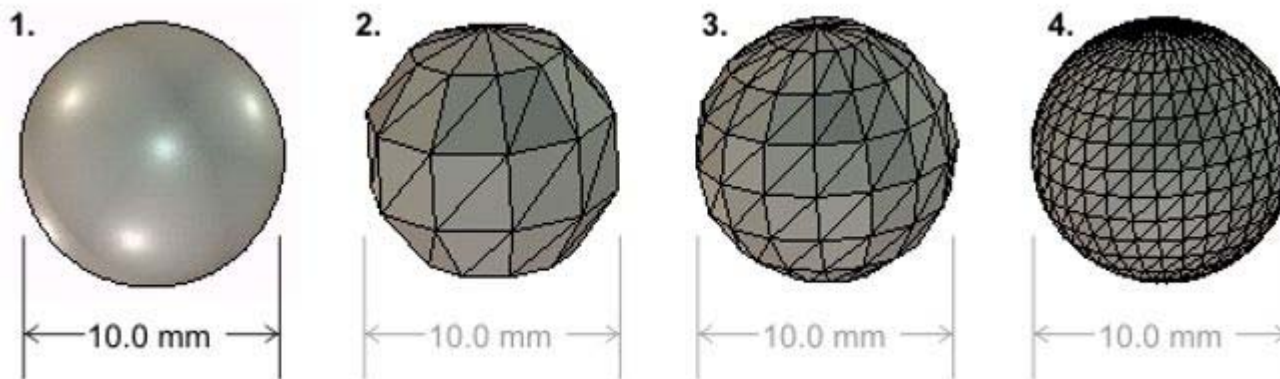
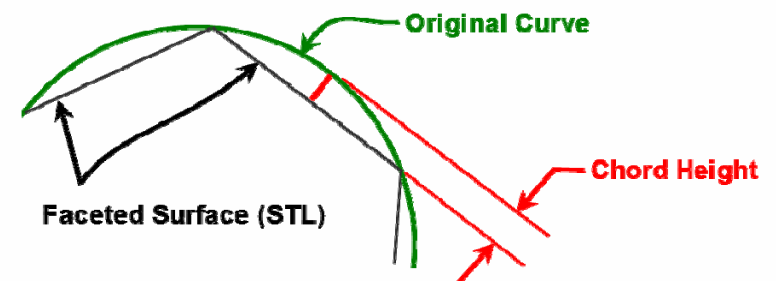
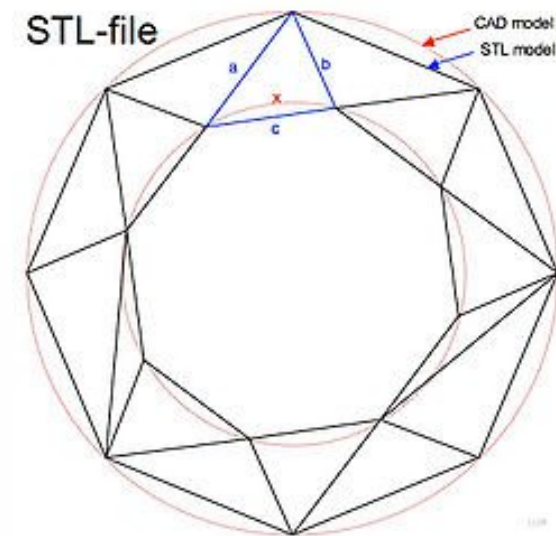


# STL file format

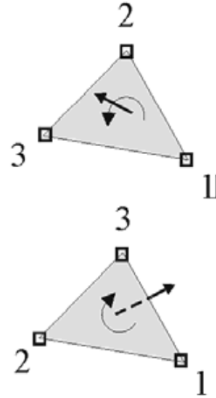
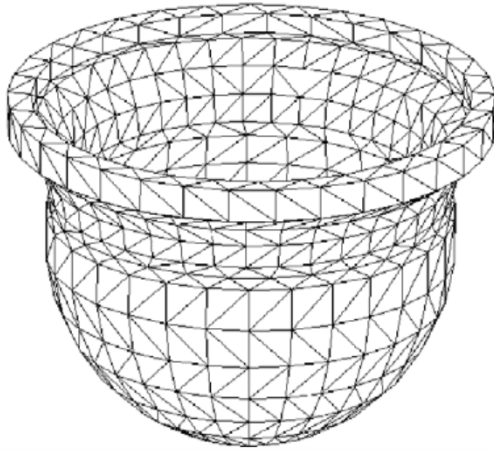
**STL** (stereo lithography) file format podržava većina CAD softvera, a bazično je razvijen za potrebe tehnologija brze izrade prototipova/aditivne proizvodnje

**STL** file opisuje samo geometriju površine trodimenzionalnog objekta, bez prikaza drugih atributa (boje, teksture) karakterističnih za CAD sisteme.

**STL** file prikazuje diskretizovanu površinu u vidu jediničnih trougaonih elemenata i kreiranu na bazi odgovarajućih pravila.



# STL file format



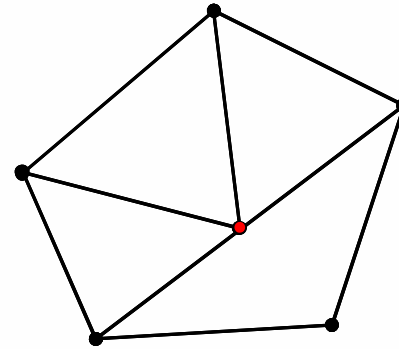
## STL Pravila:

1. Površina proizvoljnog (konačnog) oblika → objekat može imati otvore
2. Višestruke površi su dozvoljene (sklopovi)
3. Površina mora biti zatvorena
4. Vertex-to-vertex rule

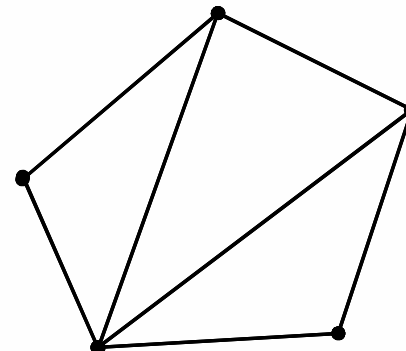
Svaki trougao mora da deli dva temena sa svakim od susednih trouglova. Drugim rečima, temena jednog trougla ne mogu ležati na strani drugog.

Vektor normale  
Početak petlje  
Vektori čvorova  
Završetak petlje  
Kraj bloka podataka

```
...
facet normal 0.000000e+000 0.000000e+000 -1.000000e+000
  outer loop
    vertex 1.000000e+001 2.000000e+000 0.000000e+000
    vertex 1.000000e+001 0.000000e+000 0.000000e+000
    vertex 8.610815e+000 2.121538e+000 0.000000e+000
  endloop
endfacet
facet normal 0.000000e+000 0.000000e+000 -1.000000e+000
  outer loop
    vertex 8.610815e+000 2.121538e+000 0.000000e+000
    vertex 1.000000e+001 0.000000e+000 0.000000e+000
    vertex 8.263518e+000 1.519225e-001 0.000000e+000
  endloop
endfacet
facet normal 0.000000e+000 0.000000e+000 -1.000000e+000
  outer loop
    vertex 8.610815e+000 2.121538e+000 0.000000e+000
    vertex 8.263518e+000 1.519225e-001 0.000000e+000
  endloop
endfacet
...
```



WRONG



CORRECT





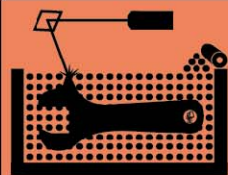


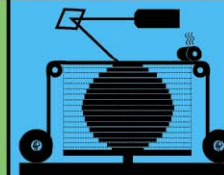
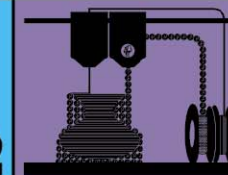


# STL file format

	Opis	Komentar
Prednosti	Jednostavna konverzija 3D u STL	Konverzija 3D modela u STL format odvija se primenom standardnih, jednostavnih algoritama, uz mogućnost kontrolisanja tačnosti aproksimacije
	Univerzalnost	Svi tipovi 3D geometrije mogu se aproksimirati mrežom ravanskih trouglova
	Jednostavno generisanje ravanskih preseka	Algoritmi za generisanje ravanskih preseka na STL modelu najčešće su jednostavni
	Mogućnost segmentiranja STL datoteke	Za potrebe prilagođavanja radnom prostoru RP mašine, veći modeli mogu se podeliti na nekoliko STL datoteka
Nedostaci	Problemi svojstveni STL formatu	Opširnost i ponavljanje podataka Veličina datoteke Pojava greške zaokruživanja
	Greške u procesu konverzije	
	Nedostaci u pogledu projektovanja tehnološkog postupka	Skupo i vremenski zahtevno korigovanje STL datoteke Nedostatak topoloških informacija Nedostatak tehnoloških parametara

# Osnovna klasifikacija AM postupka

ASTM (The American Society for Testing and Materials Standard) F2792 – 12a

- 1) Fotopolimerizacija u kadi (*Vat photopolymerization*)
- 2) Fuzija praškastog supstrata (*Powder bed fusion*)
- 3) Brizganje vezivnog sredstva (*Binder jetting*)
- 4) Brizganje materijala/Direktna 3D štampa (*Material jetting*)
- 5) Ekstrudiranje materijala (*Material extrusion*)
- 6) Laminacija folija (*Sheet lamination*)
- 7) Direktno energetsko taloženje/Deponovanje materijala primenom usmerene energije (*Directed energy deposition*)
- 8) Hibridna proizvodnja (*Hybrid manufacturing*)

7 Families of Additive Manufacturing							
According to ISO/ASTM52900-15 (formerly ASTM F2792)							
							
VAT PHOTOPOLYMERIZATION	POWDER BED FUSION (PBF)	BINDER JETTING	MATERIAL JETTING	SHEET LAMINATION	MATERIAL EXTRUSION	DIRECTED ENERGY DEPOSITION (DED)	
<b>Alternative Names:</b> SLA™ - Stereolithography Apparatus DLP™ - Digital Light Processing SSP™ - Scan, Spin, and Selectively Photocure CLIP™ - Continuous Liquid Interface Production	<b>Alternative Names:</b> SLS™ - Selective Laser Sintering; DMLS™ - Direct Metal Laser Sintering; SLM™ - Selective Laser Melting; LBM™ - Electron Beam Melting; SHS™ - Selective Heat Sintering; MJF™ - Multi-Jet Fusion	<b>Alternative Names:</b> 3DP™ - 3D Printing ExOne Voxeljet	<b>Alternative Names:</b> Polyjet™ SCP™ - Smooth Curvatures Printing MJM - Multi-Jet Modeling Project™	<b>Alternative Names:</b> LOM - Laminated Object Manufacture SDL - Selective Deposition Lamination UAM - Ultrasonic Additive Manufacturing	<b>Alternative Names:</b> FFF - Fused Filament Fabrication FDM™ - Fused Deposition Modeling	<b>Alternative Names:</b> LMD - Laser Metal Deposition LENS™ - Laser Engineered Net Shaping	<b>Alternative Names:</b> AMBIT™ - Created by Hybrid Manufacturing Technologies
<b>Description:</b> A vat of liquid photopolymer resin is cured through selective exposure to light (via a laser or projector) which then initiates polymerization and converts the exposed areas to a solid part.	<b>Description:</b> Powdered materials are collectively consolidated by melting it together using a heat source such as a laser or electron beam. The powder surrounding the consolidated part acts as support material for overhanging features.	<b>Description:</b> Liquid bonding agents are collectively applied onto thin layers of powdered material to build up parts layer by layer. The binders include organic and inorganic materials. Metal or ceramic powdered parts are typically fired in a furnace after they are printed.	<b>Description:</b> Droplets of material are deposited layer by layer to make parts. Common varieties include jetting a photocurable resin and curing it with UV light, as well as jetting thermally molten materials that then solidify in ambient temperatures.	<b>Description:</b> Sheets of material are stacked and laminated together to form an object. The lamination method can be adhesives or chemical (paper/plastics), ultrasonic welding, or brazing (metals). Unneeded regions are cut out layer by layer and removed after the object is built.	<b>Description:</b> Material is extruded through a nozzle or orifice in tracks or beads, which are then combined into multi-layer models. Common varieties include heated thermoplastic extrusion (similar to a hot glue gun) and syringe dispensing.	<b>Description:</b> Powder or wire is fed into a melt pool which has been generated on the surface of the part where it adheres to the underlying part or layers by using an energy source such as a laser or electron beam. This is essentially a form of automated build-up welding.	<b>Description:</b> Laser metal deposition (a form of DED) is combined with CNC machining, which allows additive manufacturing and 'subtractive' machining to be performed in a single machine so that parts can utilize the strengths of both processes.
<b>Strengths:</b> <ul style="list-style-type: none"><li>• High level of accuracy and complexity</li><li>• Smooth surface finish</li><li>• Accommodates large build areas</li></ul>	<b>Strengths:</b> <ul style="list-style-type: none"><li>• High level of complexity</li><li>• Powder acts as support material</li><li>• Wide range of materials</li></ul>	<b>Strengths:</b> <ul style="list-style-type: none"><li>• Allows for full color printing</li><li>• High productivity</li><li>• Uses a wide range of materials</li></ul>	<b>Strengths:</b> <ul style="list-style-type: none"><li>• High level of accuracy</li><li>• Allows for full color parts</li><li>• Enables multiple materials in a single part</li></ul>	<b>Strengths:</b> <ul style="list-style-type: none"><li>• High volumetric build rates</li><li>• Relatively low cost (non-metals)</li><li>• Allows for combinations of metal foils, including embedding components.</li></ul>	<b>Strengths:</b> <ul style="list-style-type: none"><li>• Inexpensive and economical</li><li>• Allows for multiple colors</li><li>• Can be used in an office environment</li><li>• Parts have good structural properties</li></ul>	<b>Strengths:</b> <ul style="list-style-type: none"><li>• Not limited by direction or axis</li><li>• Effective for repairs and adding features</li><li>• Multiple materials in a single part</li><li>• Highest single-point deposition rates</li></ul>	<b>Strengths:</b> <ul style="list-style-type: none"><li>• Smooth surface finish AND High Productivity</li><li>• Geometrical and material freedoms of DED</li><li>• Automated in-process support removal, finishing, and inspection</li></ul>
<b>Typical Materials</b> UV-Curable Photopolymer Resins	<b>Typical Materials</b> Plastics, Metal and Ceramic Powders, and Sand	<b>Typical Materials</b> Powdered Plastic, Metal, Ceramics, Glass, and Sand.	<b>Typical Materials</b> Photopolymers, Polymers, Waxes	<b>Typical Materials</b> Paper, Plastic Sheets, and Metal Foils/Tapes	<b>Typical Materials</b> Thermoplastic Filaments and Pellets (FFF); Liquids, and Slurries (Syringe Types)	<b>Typical Materials</b> Metal Wire and Powder, with Ceramics	<b>Typical Materials</b> Metal Powder and Wire, with Ceramics

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## Osnovna klasifikacija AM postupka

Grupa	Način generisanja konture	Komercijalni naziv tehnologije	Skr.
Fotopolimerizacija u kadi	Laser, projektor, printerska glava	Stereolitografija	(SLA)
Fuzija praškastog supstrata	Laser, mlaz elektrona	Selektivno lasersko sinterovanje	(SLS)
		Selektivno lasersko topljenje	(SLM)
		Topljenje mlazom elektrona	(EBM)
		Direktno lasersko sinterovanje metala	(DMLS)
Laminacija folija	Laser, nož	Proizvodnja laminiranih obj.	(LOM)
		Laminacija plastičnih folija	(PSL)
Vezivna 3D štampa	Printerska glava	Vezivna 3D štampa	(3DP)
Ekstrudiranje materijala	Glava ekstrudera	Deponovanje istopljenog filamenta	(FDM)
Direktna 3D štampa	Printerska glava i UV lampa	PolyJet, PolyJet Matrix	(PJ)
Nanošenje materijala primenom usmerene energije	Mlaz elektrona	3D lasersko oblaganje	(DED)
		Direktno taloženje metala	

## 1 MATERIAL EXTRUSION

Also known as FDM, a term trademarked by Stratasys. This machine uses a glue gun-like nozzle that builds models by layering molten material in small flattened strings.



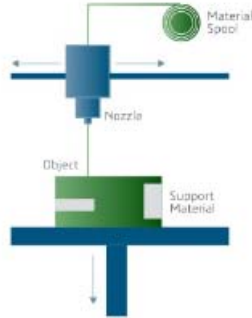
Cost-effective



Uses easy-to-find polymers and plastics



Ideal for high-strength models



## 2 BINDER JETTING

Where the term 3D printing came from, this technology uses an inkjet printer head that selectively binds powdered material together one layer at a time. Leftover powder is shaken, blown or brushed off.



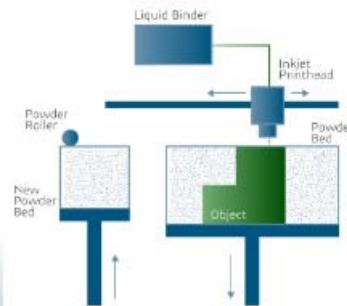
Fast process



Can use almost any material that is in powder form



Flexible to meet various mechanical properties



## 3 MATERIAL JETTING

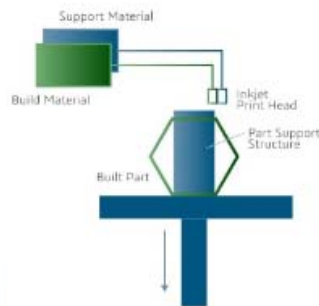
Uses an inkjet to jet drops of wax and other material, including metal, onto a build tray. As the material cools and solidifies, new layers are added to form the complete model.



Higher rate of part accuracy



Superior surface finishes



## 4 POWDER BED FUSION

Powder Bed Fusion (PBF) includes several techniques like direct metal laser sintering and selective laser sintering. It utilizes a laser or electronic beam to fuse material powder together.



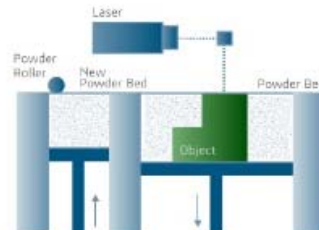
Cost-effective



Large range of material options



Fine laser beam produces high-resolution features



## 5 DIRECTED ENERGY DEPOSITION

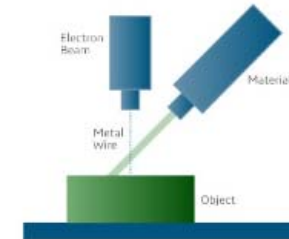
A nozzle mounted on a multi-axis arm using a metal wire or powder fired into place. The powder or wire is melted and welded onto the previous layer or surface by an electron beam or laser.



Excellent for high-quality repair work



Able to achieve a high level of accuracy



## 6 VAT PHOTOPOLYMERIZATION

Starts with a vat or tank of photopolymer, a liquid resin that hardens when exposed to a light source. One layer is cured via a light source or laser and is moved up out of the liquid, or down into the liquid for the next layer to be processed.



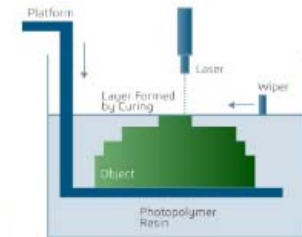
High level of accuracy



Excellent finish



Ideal for large models



## 7 SHEET LAMINATION

Technically subtractive, but since it builds layer by layer it is considered additive. This technique applies a laser or scalpel to cut to shape sheets of material and then layer them on top of one another.



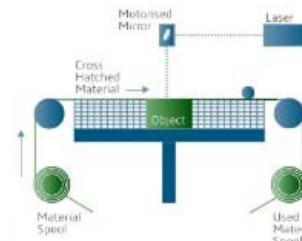
Cost-effective



Fast cutting process



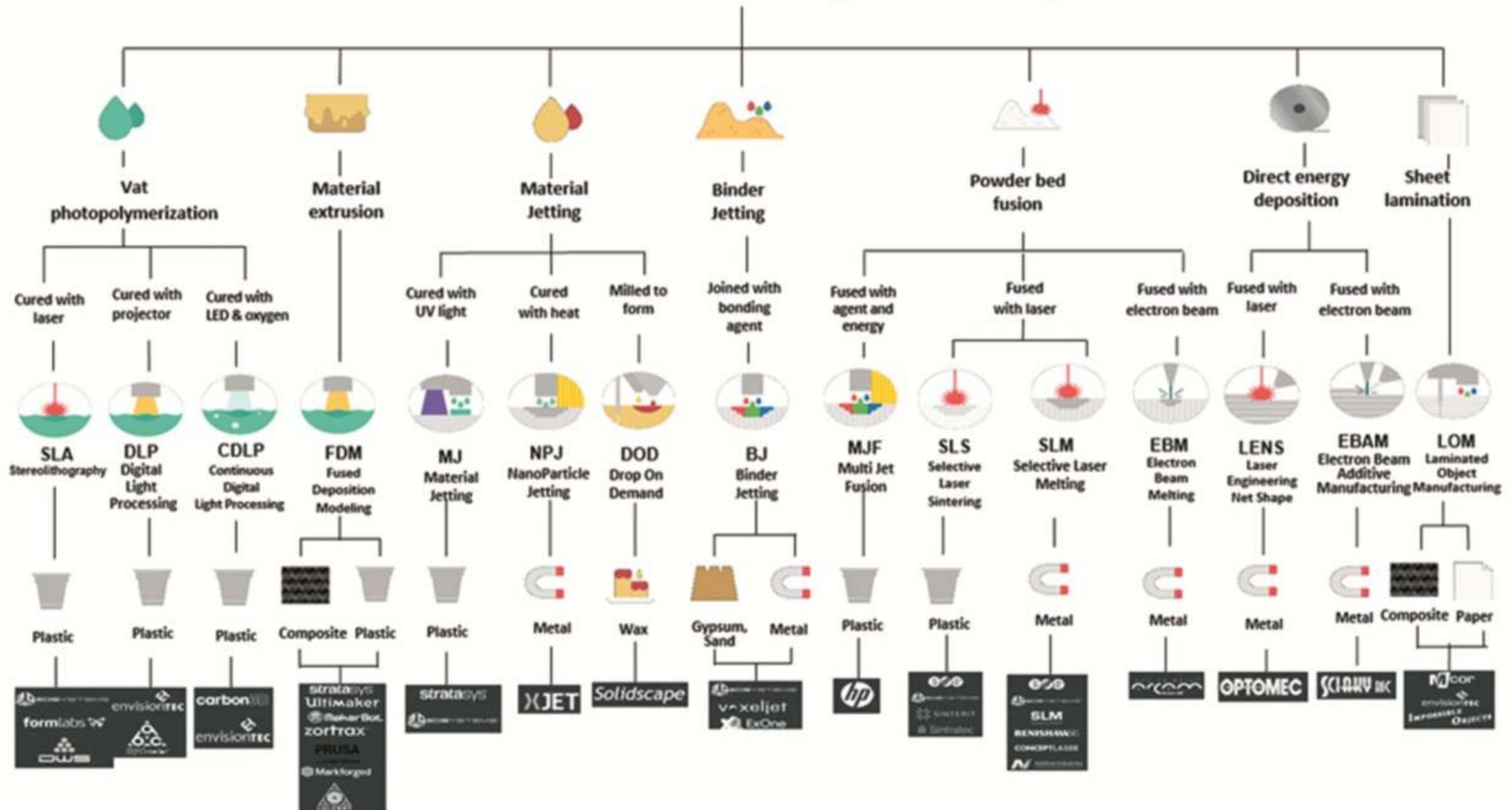
Easy material handling





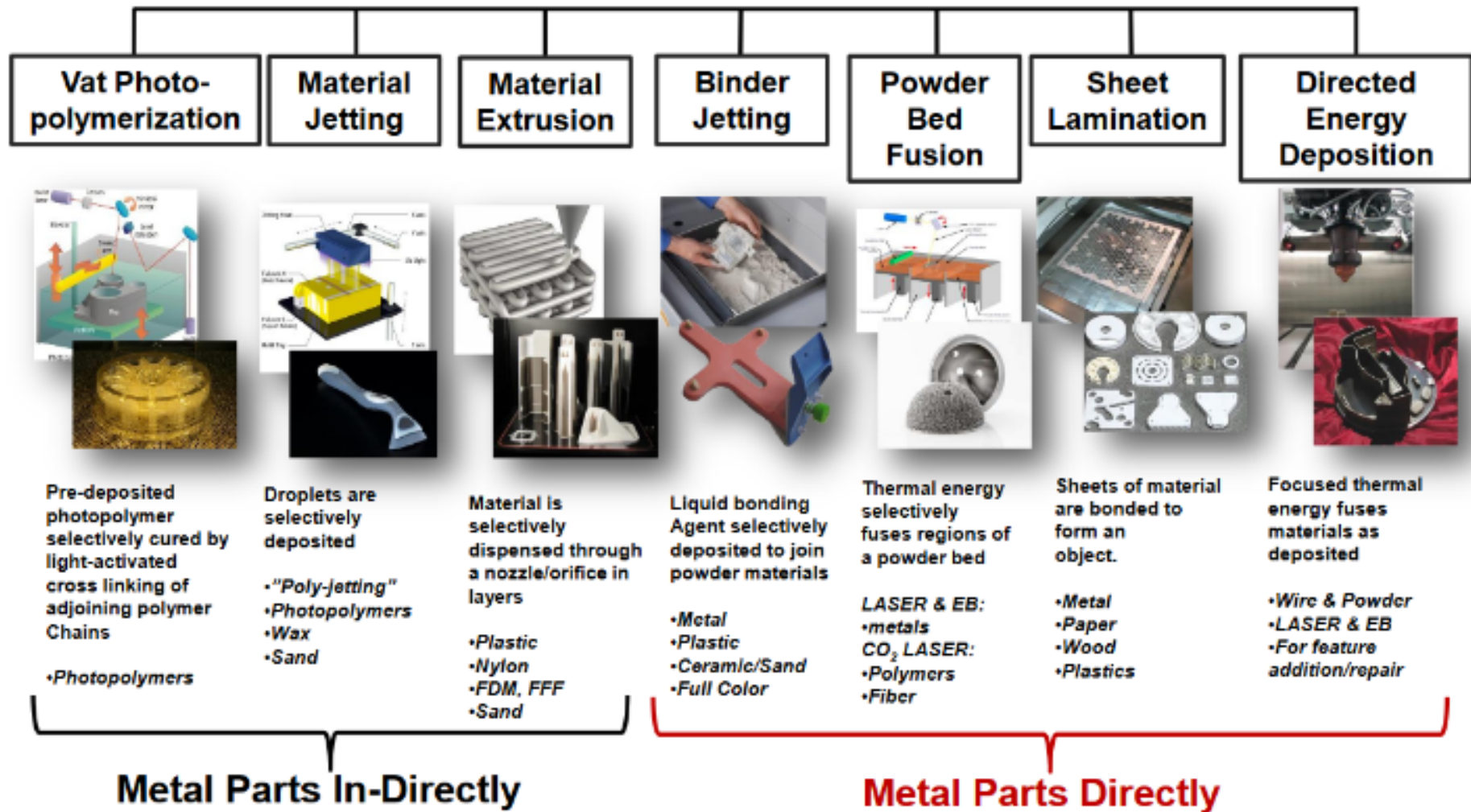
# Podela AM postupaka prema početnom stanju materijala

## Additive manufacturing technologies



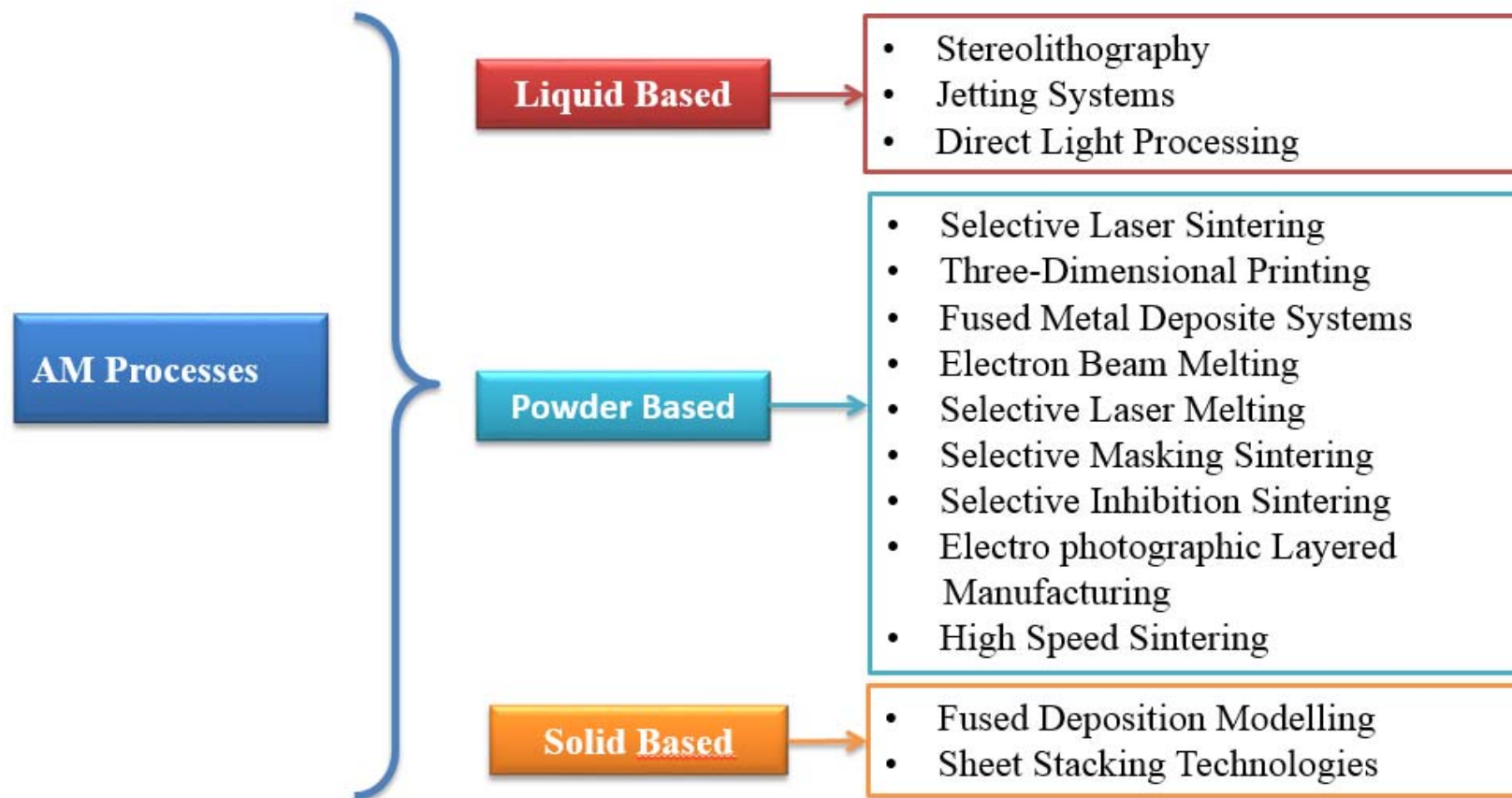


# Osnovna klasifikacija AM postupka

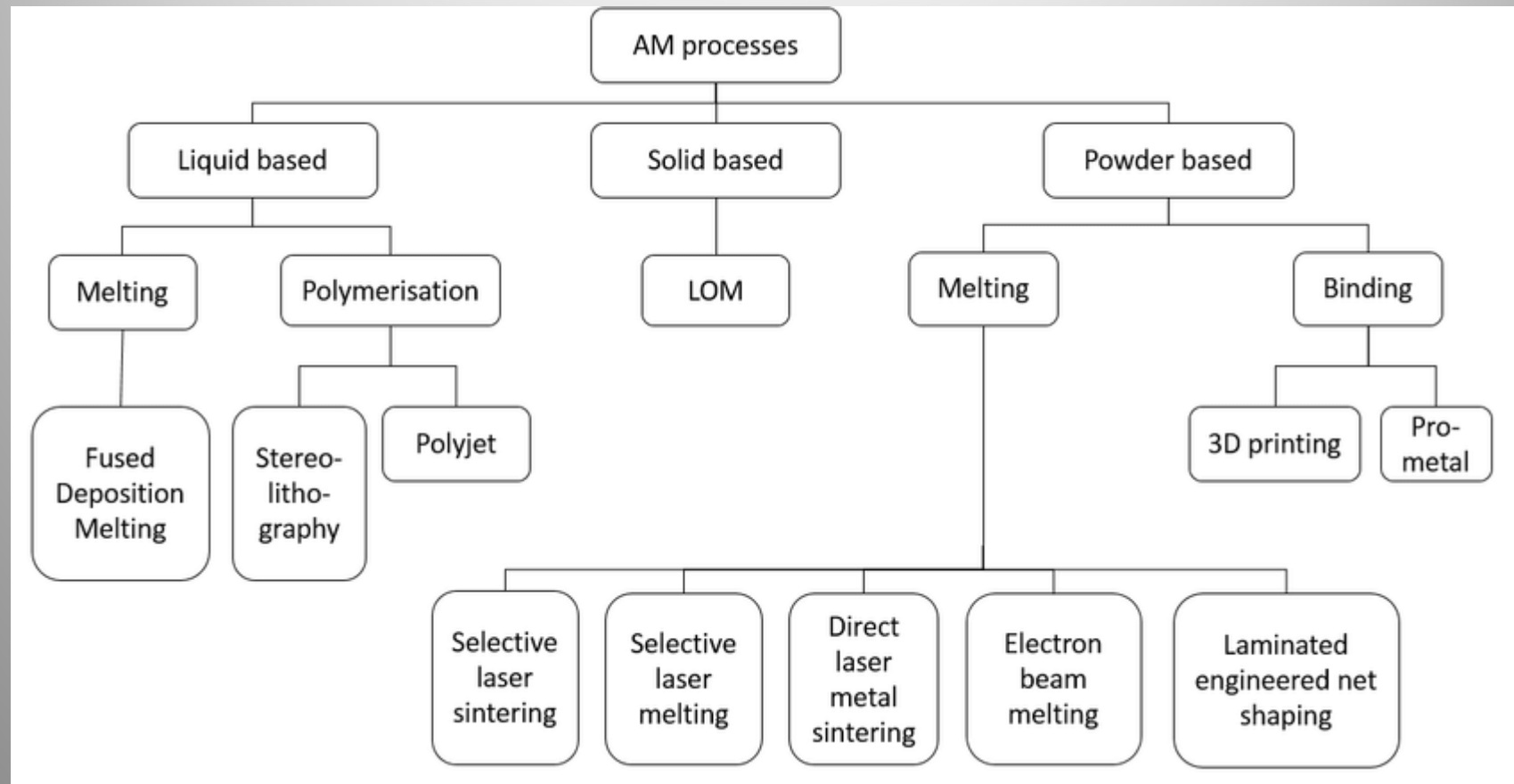


# Podela AM postupaka prema početnom stanju materijala

- A. Materijali u tečnom stanju
- B. Materijali u praškastom stanju
- C. Materijali u čvrstom stanju



# Podela AM postupaka prema početnom stanju materijala

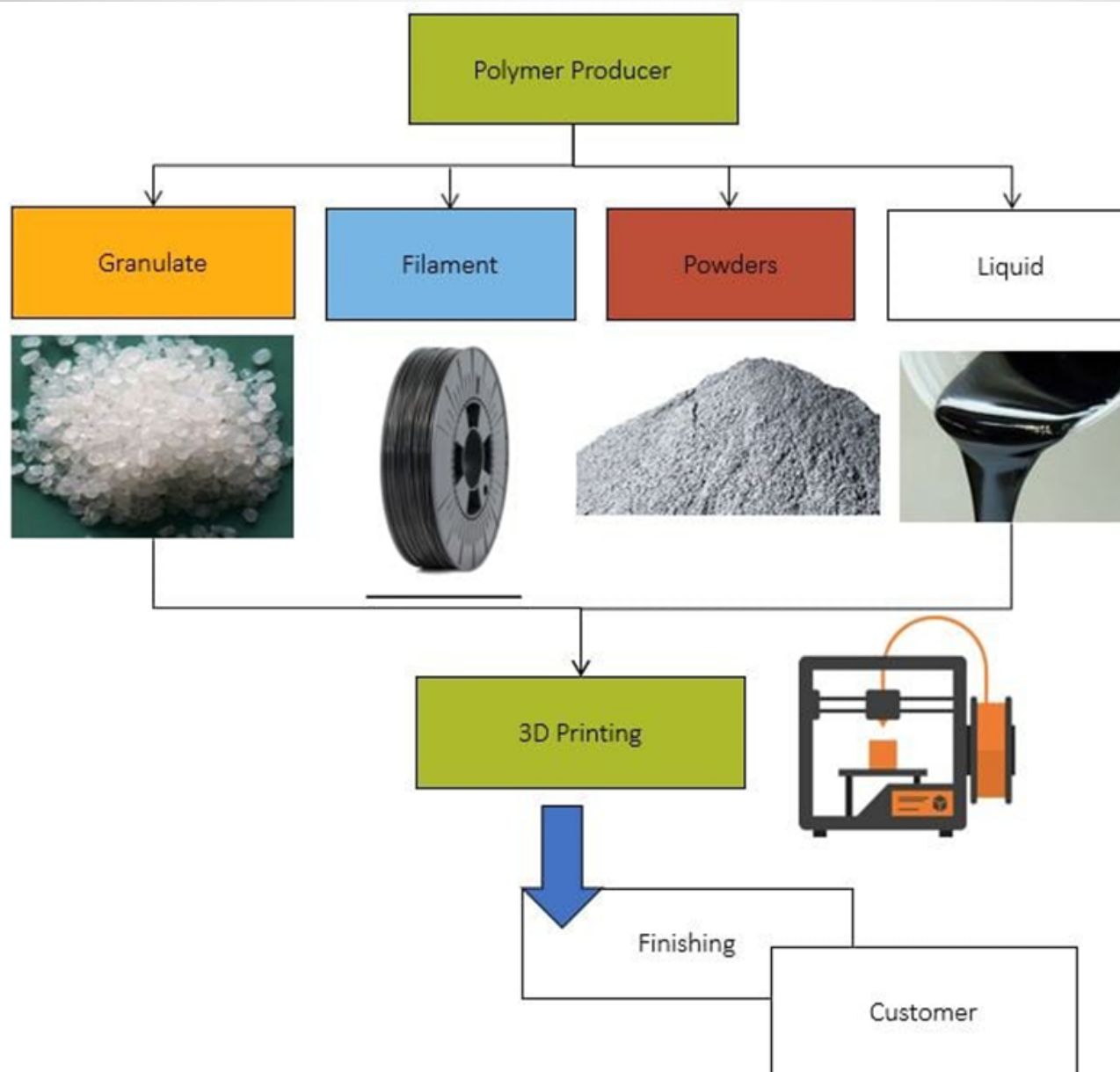


# Podela AM postupaka prema početnom obliku materijala

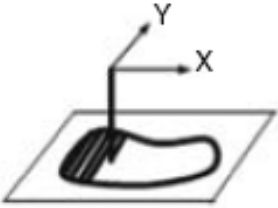
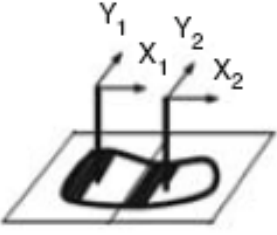
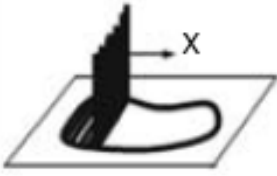
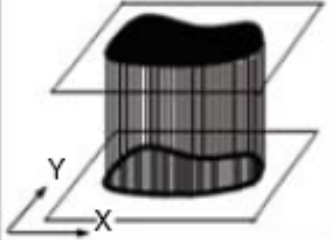




# Podela AM postupaka prema početnom obliku materijala



## Podela AM postupaka prema načinu generisanja sloja

	1D Channel 	2x1D Channels 	Array of 1D Channels 	2D Channel 
Liquid Polymer	SLA (3D Sys)	Dual beam SLA (3D Sys)	Objet	Envisiontech MicroTEC
Discrete Particles	SLS (3D Sys), LST (EOS), LENS Phenix, SDM	LST (EOS)	3D Printing	DPS
Molten Mat.	FDM, Solidscape		ThermoJet	
Solid Sheets	Solido PLT (KIRA)			

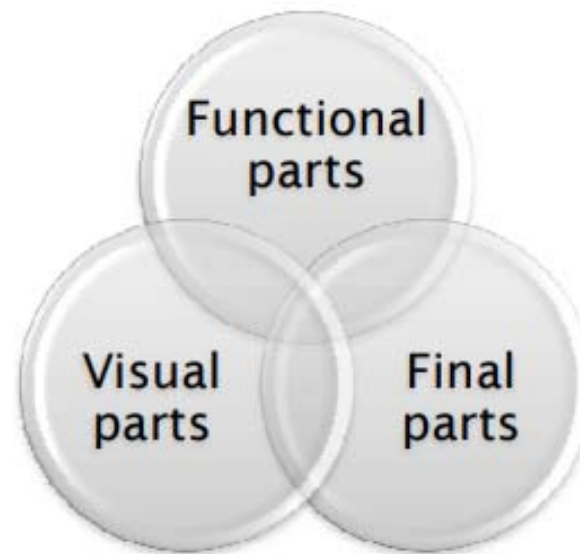
# Rapid Prototyping vs Additive Manufacturing

## Rapid Prototyping

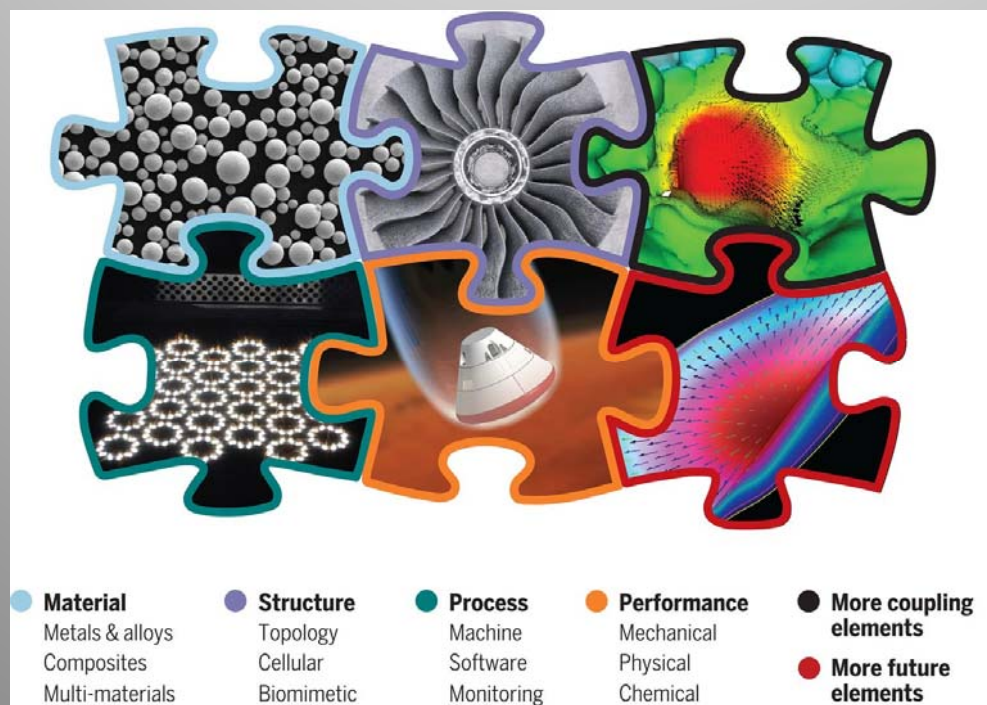
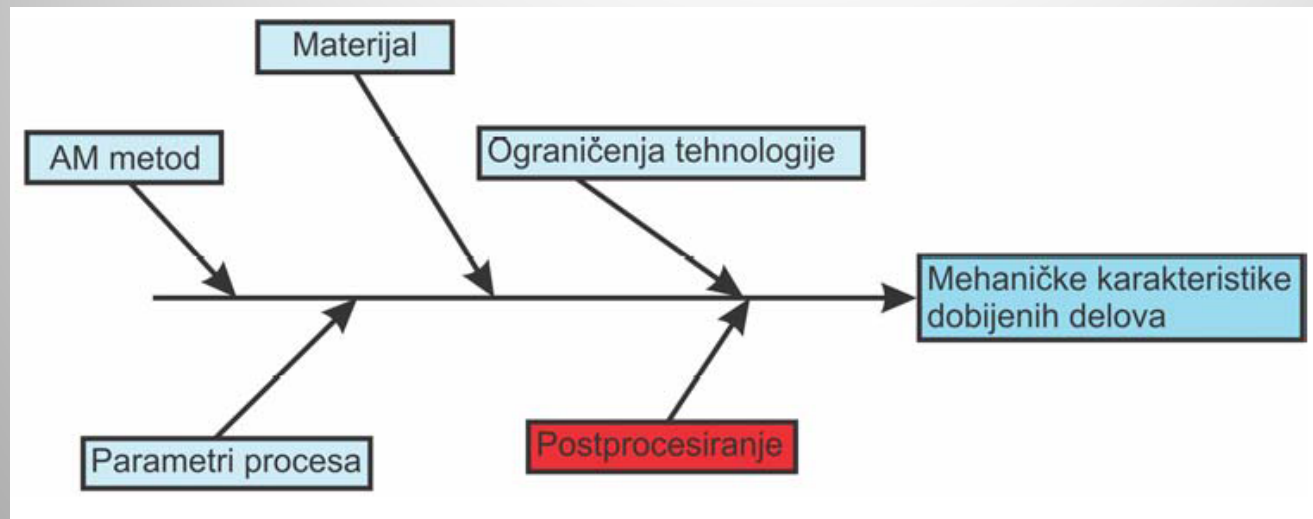
- Stereolithography
- Bi-material 3D Printing
- 3D Printing of wax
- Selective Laser Sintering
- 3D Printing of polymers / plaster

## Additive Manufacturing

- Electron Beam Melting
- Selective Laser Melting
- Laser Cladding
- Hybrids of Stereolithography

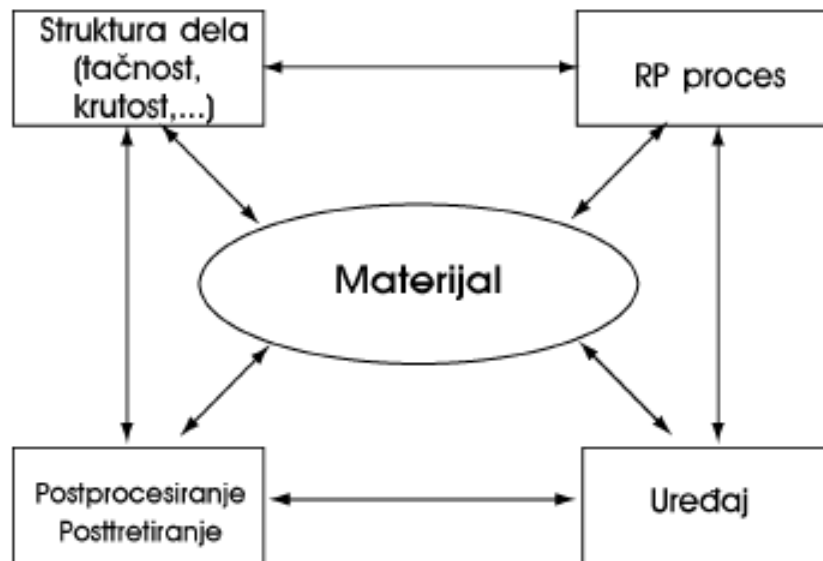


# Uticajni faktori na mehaničke karakteristike delova dobijenih aditivnim tehnologijama



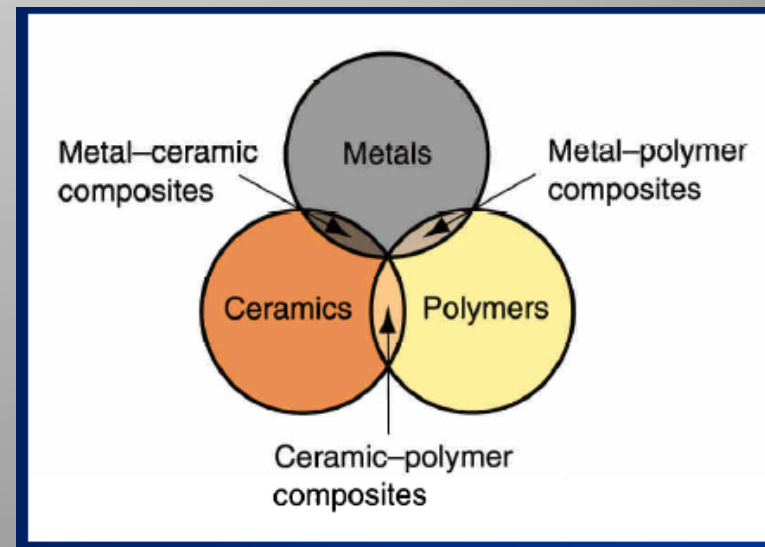
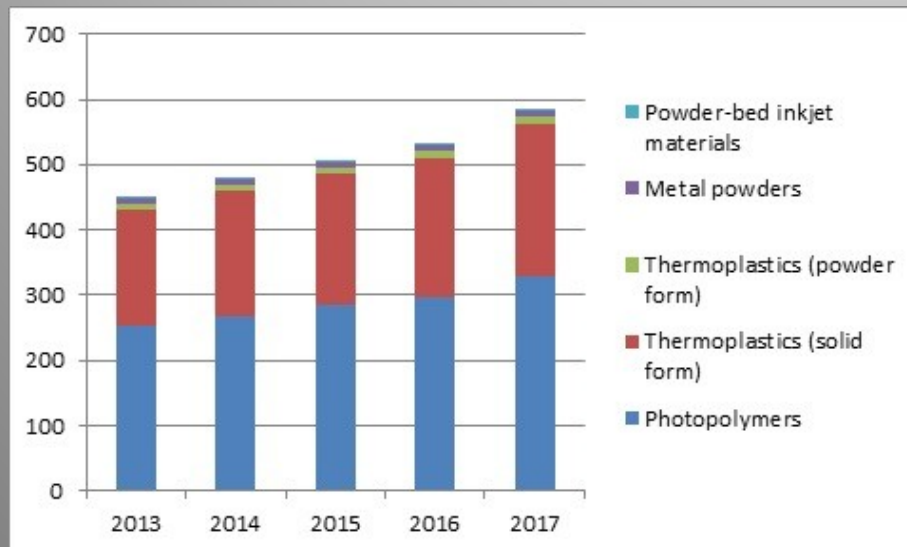


# AM materijali



## Karakteristike:

- mehaničke osobine
- aspekt zaštite čovekove sredine
- reološke osobine (fluid)
- regulisanje parametara za vreme procesa
- postprocesiranje



# AM materijali

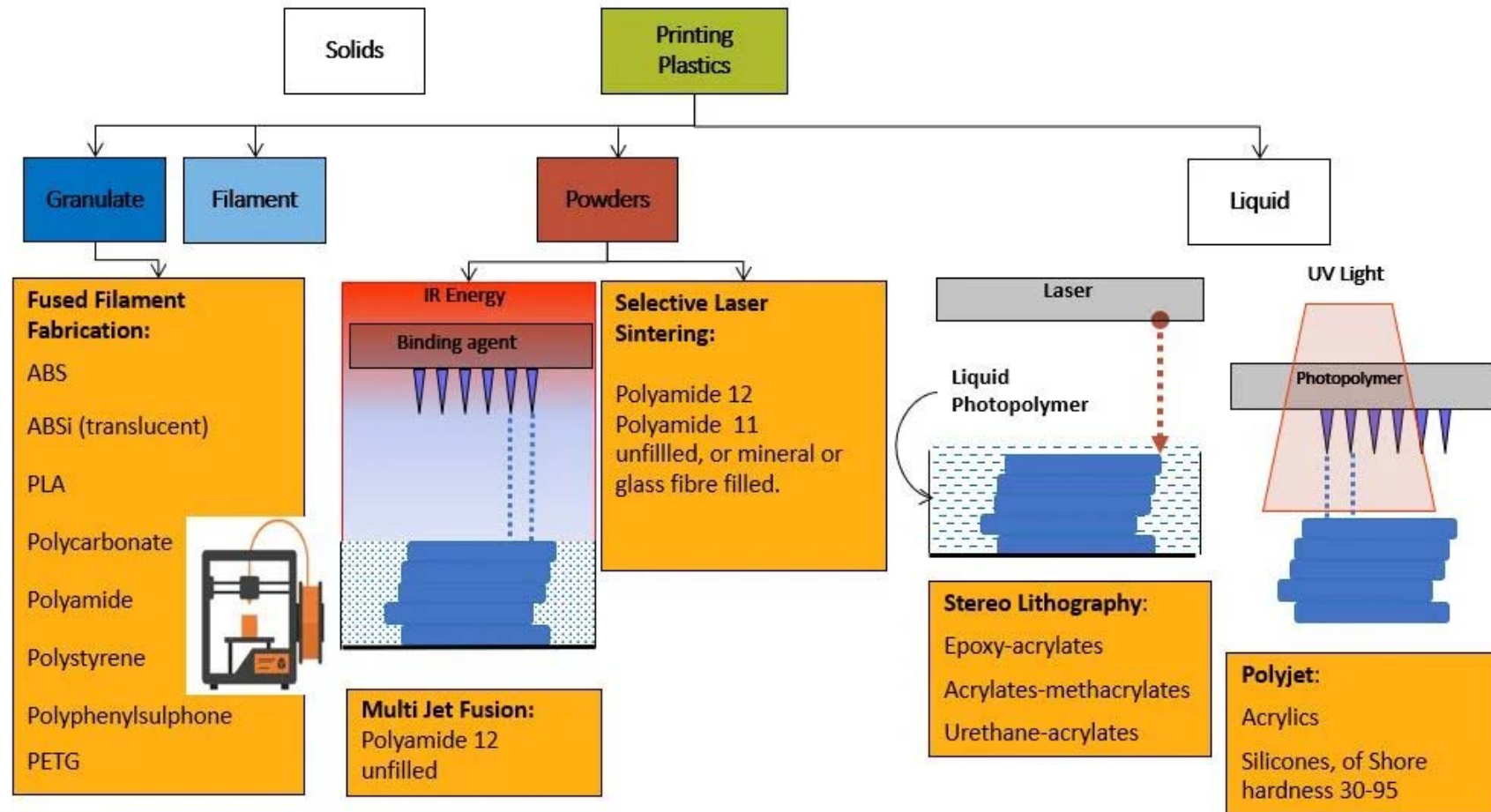
## Mechanical Properties of Selected Materials for Rapid Prototyping

Process	Material	Tensile strength (MPa)	Elastic modulus (GPa)
Stereolithography	SL5180 <sup>a</sup>	55-65	2.4-2.6
	SL5195 <sup>a</sup>	46.5	2.1
	SL5510 <sup>b</sup>	73	2.8
	SL7940 <sup>b</sup>	37-39	1.3
Fused-deposition modeling	Polycarbonate	62	-
	ABS	35	2.5
Selective laser sintering	Nylon	36	1.4
	Polycarbonate	23.4	1.2
	Polyamide	44	1.6
	SOMOS 201	17.3	14
	ST-100 <sup>c</sup>	305	137
Three-dimensional printing	S3 stainless steel	406	148
	S4 stainless steel	682	147

<sup>a</sup> After a 90-min UV cure; <sup>b</sup> after a 90-min UV cure at 80°C; <sup>c</sup> sintered and bronze-infiltrated steel powder

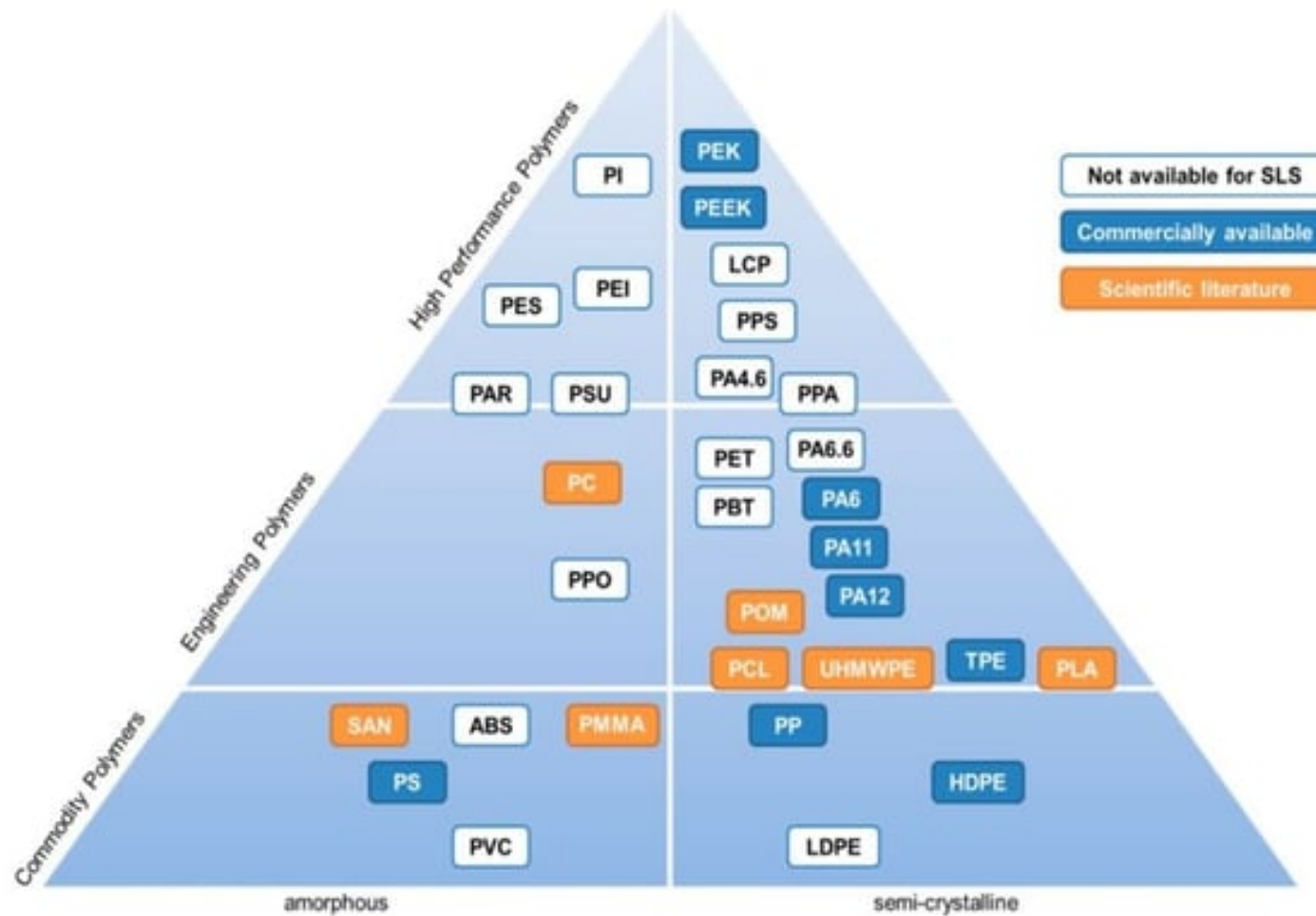
# AM materijali

## Polymer use in Additive Manufacturing



# AM materijali

## Materials for Selective Laser Sintering additive manufacturing





# AM materijali



Platinum



Gold



Sterling Silver



Precious Plated Metal



Strong & Flexible Plastic



Frosted Detail Plastic



Acrylic Plastic



Metallic Plastic



Brass



Bronze



Steel



Full Color Sandstone



Porcelain



Castable Wax



Elasto Plastic



Aluminum