RE i RP u BMI

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Rapid Prototyping & Aditivna Proizvodnja. Razlika?

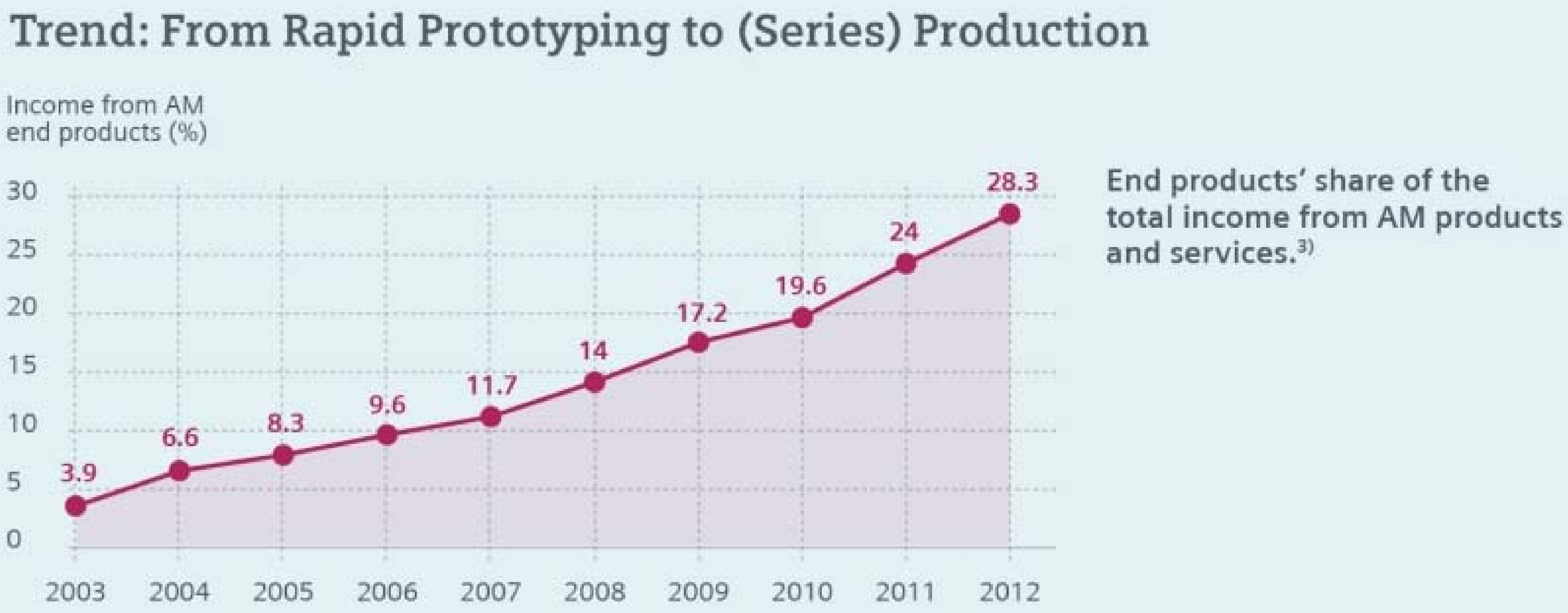
Razlika je nameni, ne u samoj tehnologiji:

Rapid Prototyping: koristi se za generisanje ne-strukturnih i ne-funkcionalnih demo delova ili pojedinačnih komada u svrhu potvrde koncepta.

Additive Manufacturing: koristi se u smislu pravog proizvodnog procesa, za generisanje potpuno funkcionalnih komponenti od visoko kvalitetnih materijala u malo-serijskoj proizvodnji.

Morongo Casino, Palm Springs

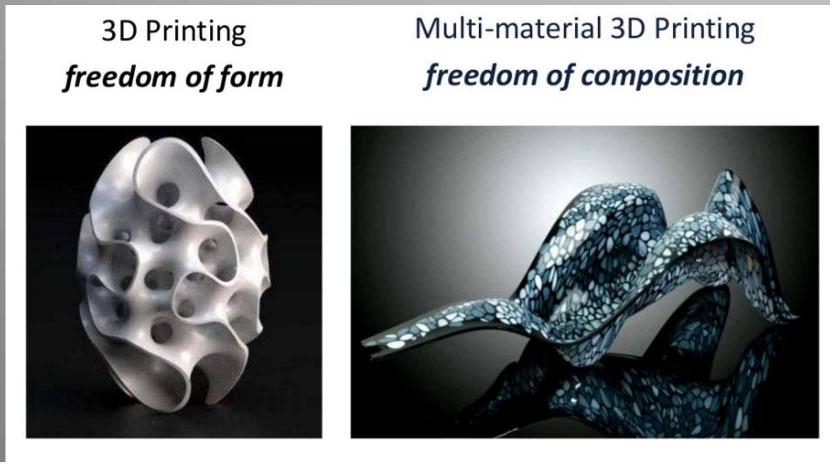
Rapid Prototyping & Aditivna Proizvodnja - Trend



Aditivna proizvodnja
prednosti i nedostatci

- 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

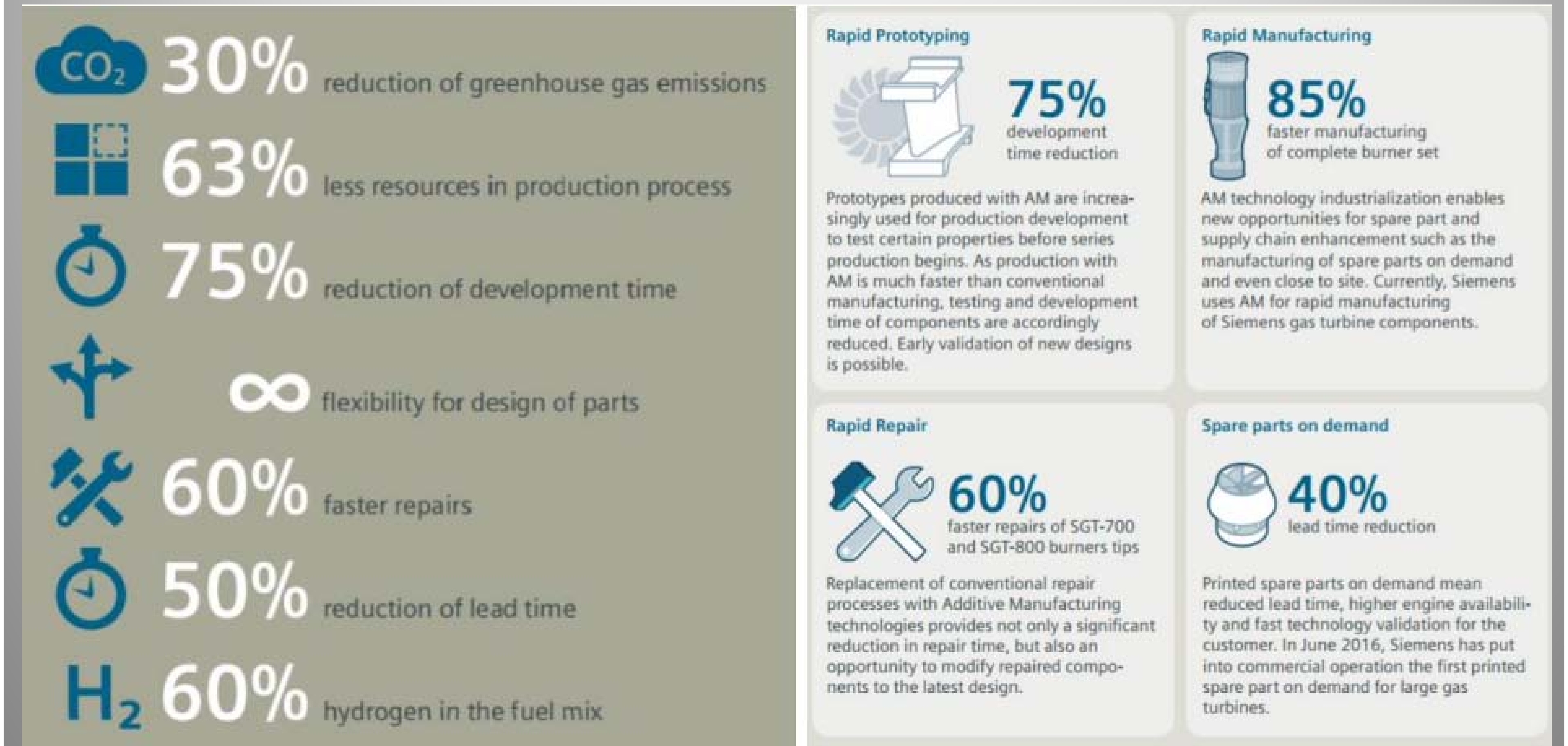
o Produktivnost (pojedinačna i maloserijska proizvodnja)
o Tačnost i kvalitet proizvoda
o Mehaničke karakteristike




GREAT BRITAIN
Standard Life


sample illustration,
not actual protoype

Kako SIEMENS vidi prednosti AP



Razvoj AM 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

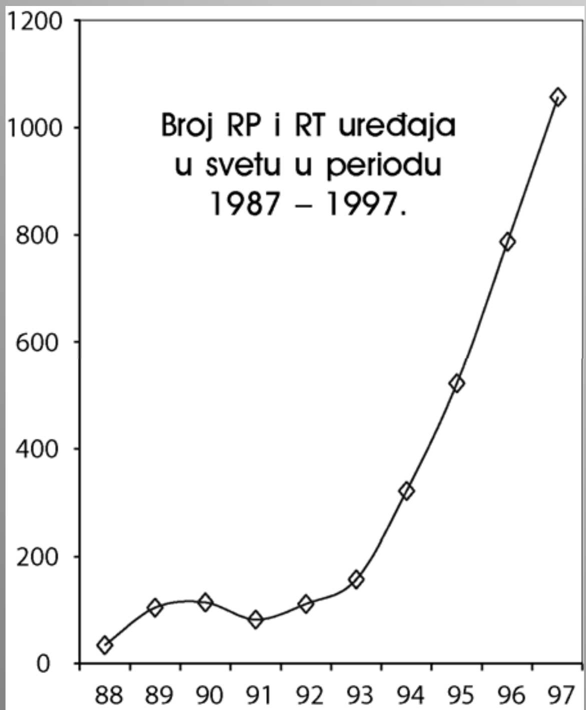
Geometric Modeling	Prototyping

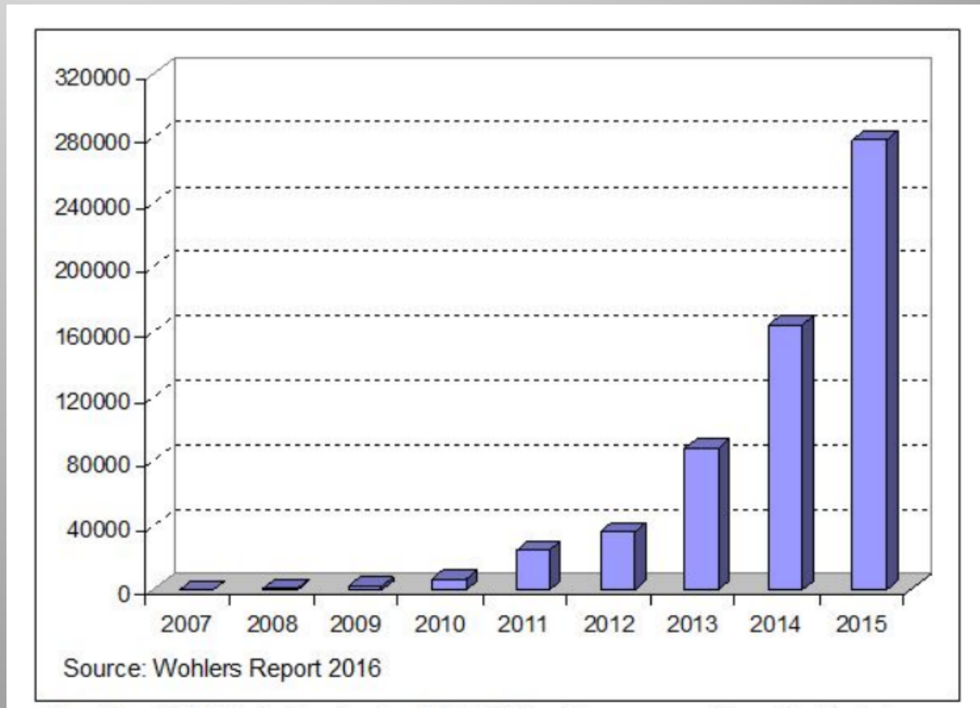
❶ **First Phase: 2D Wireframe**
• Started in mid-1960s
• Few straight lines on display may be:
  • circuit path on a PCB
  • plan view of a mechanical component
• "Natural" drafting technique
	❶ **First Phase: Manual Prototyping**
	• Traditional practice for many centuries
	• Prototyping as a skilled crafts is:
	  • traditional and manual
	  • based on material of prototype
	• "Natural" prototyping technique

❷ **Second Phase: 3D Curve and Surface Modeling** • Mid-1970s • Increasing complexity • Representing more information about precise shape, size and surface contour of parts	❷ **Second Phase: Soft or Virtual Prototyping** • Mid-1970s • Increasing complexity • Virtual prototype can be stressed, simulated and tested, with exact mechanical and other properties
❸ **Third Phase: Solid Modeling** • Early 1980s • Edges, surfaces and holes are knitted together to form a cohesive whole • 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 • No longer ambiguous but exact	❸ **Third Phase: Rapid Prototyping** • Mid-1980s • Benefit of a hard prototype made in a very short turnaround time is its main strong point (relies on CAD modeling) • Hard prototype can also be used for limited testing • Prototype can also assist in the manufacturing of the products

Razvoj AM tehnologija

- Prvi rezultati primene AM (RP) 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 AM).
- U početku proces je bio skup i komplikovan.
- Veliki broj različitih uređaja.
- Brzo rastuće tržište.

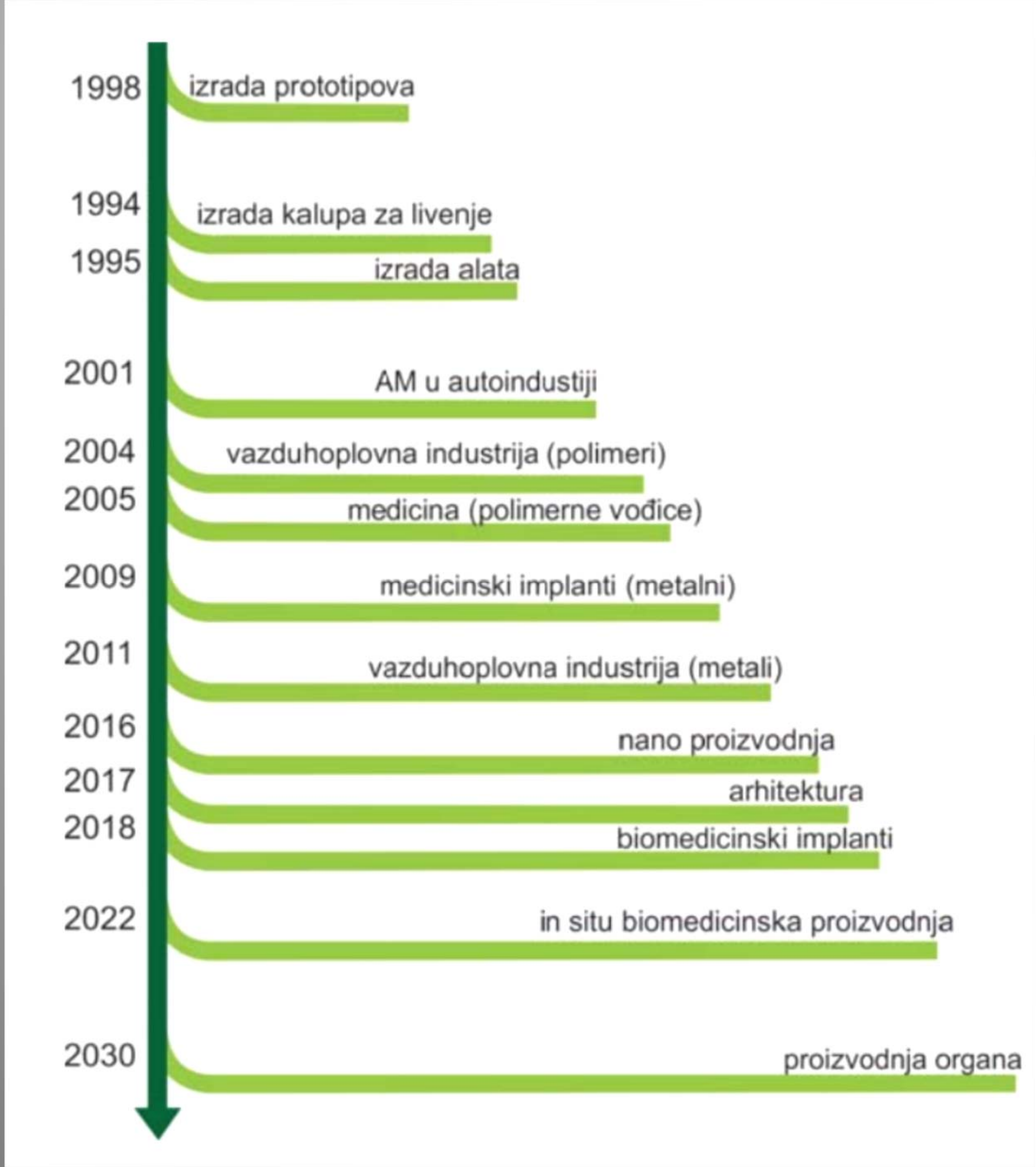




More than 278,000 desktop (under $5,000) 3D printers were sold worldwide last year


MakerBot
Leading the Next Industrial Revolutio
MakerBot

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



Obama said (Feb. 2013):
"A once-shuttered warehouse is now a state-of-the art lab where new workers are mastering the 3-D printing that has the potential to revolutionize the way we make almost everything“

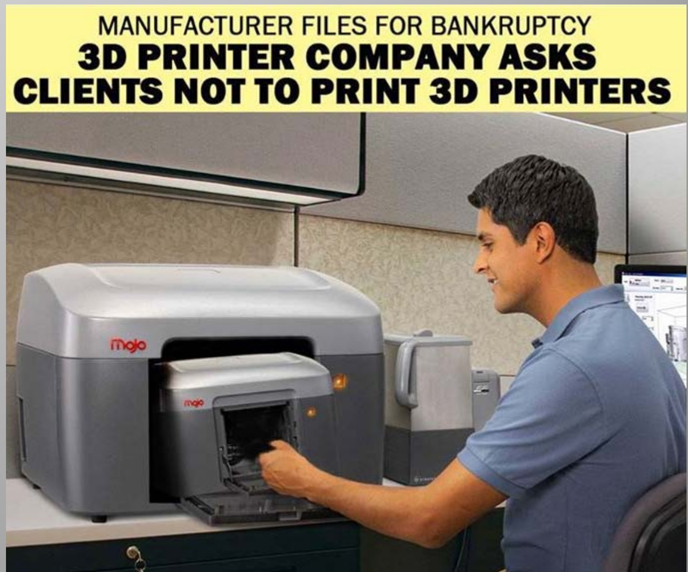
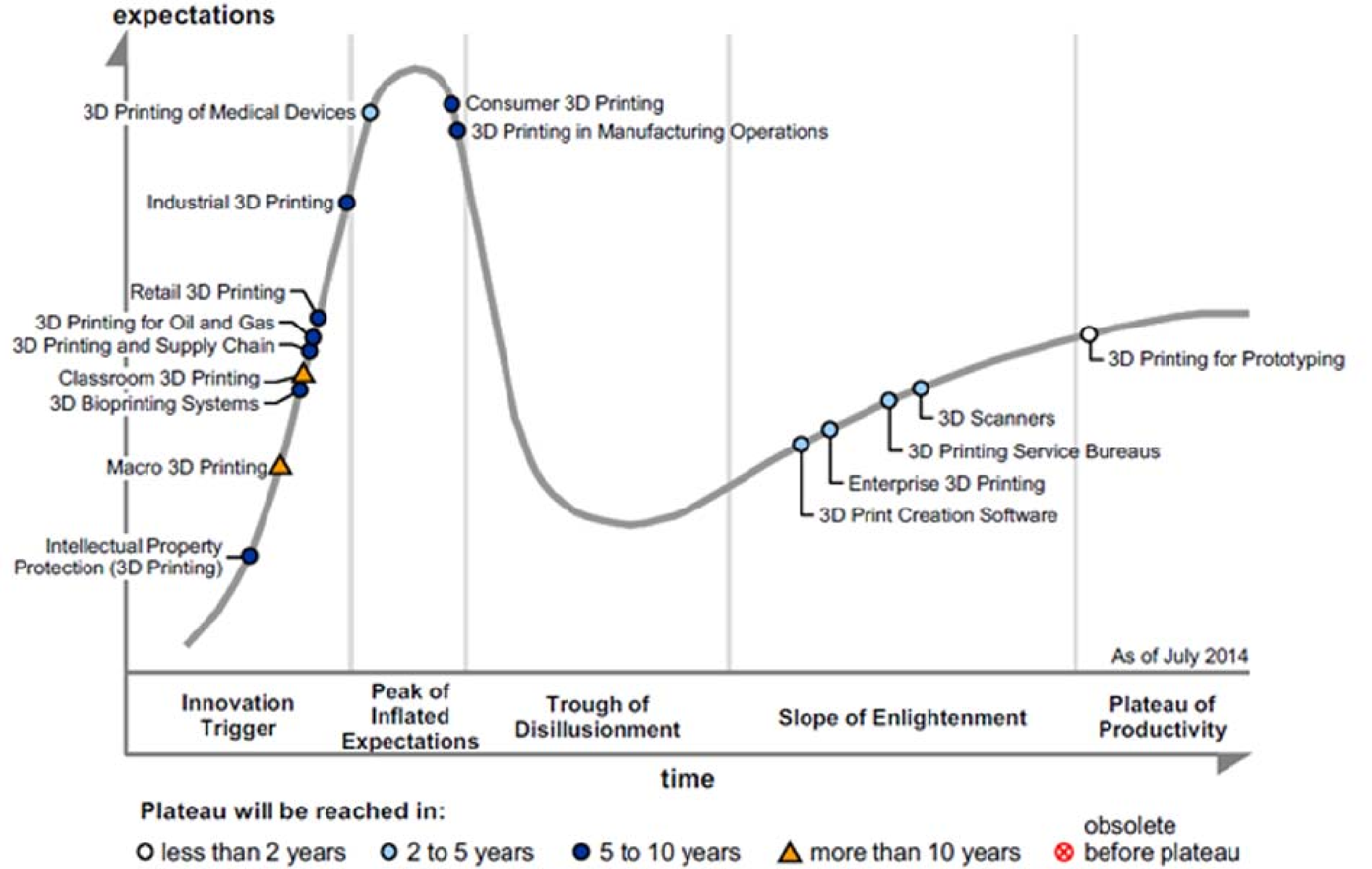
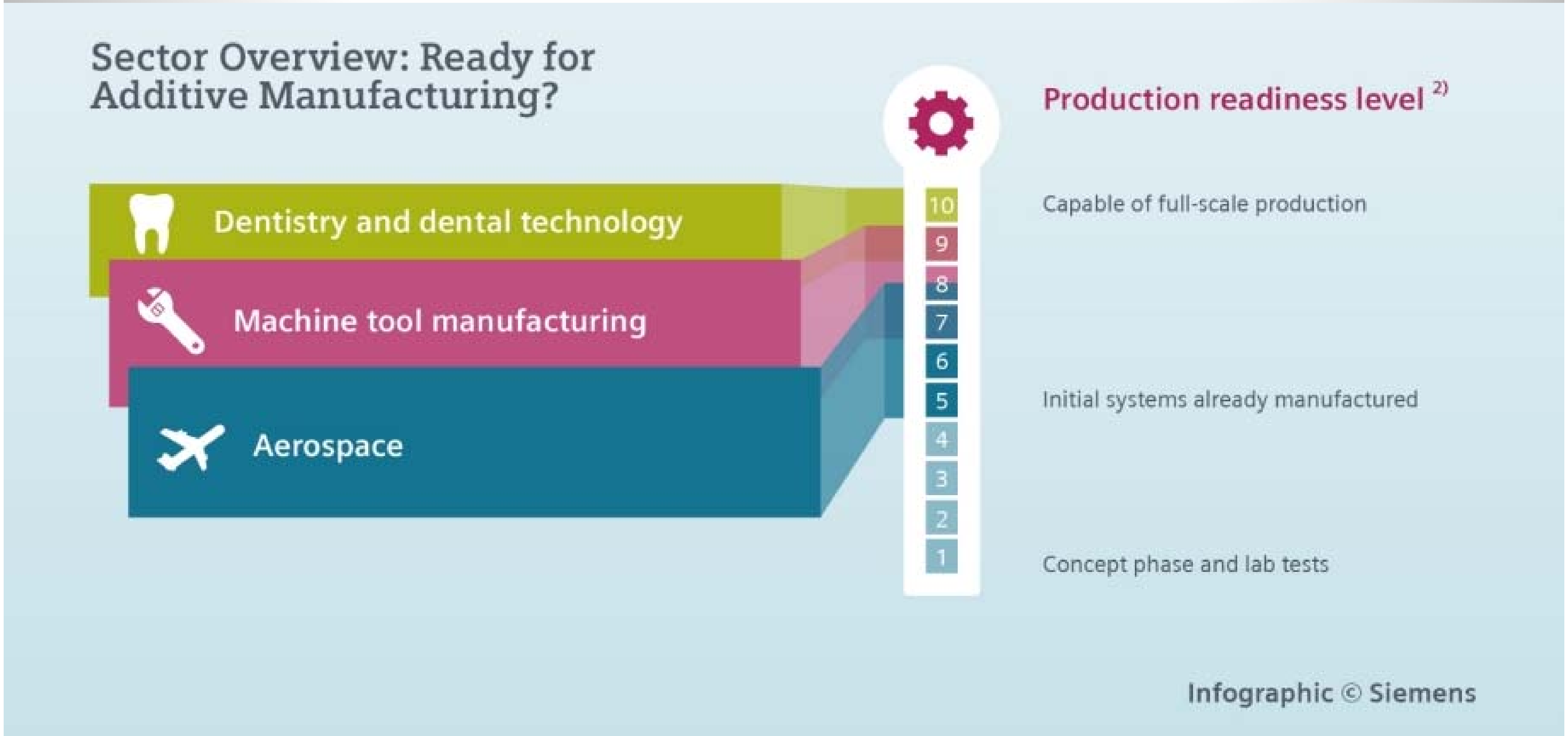


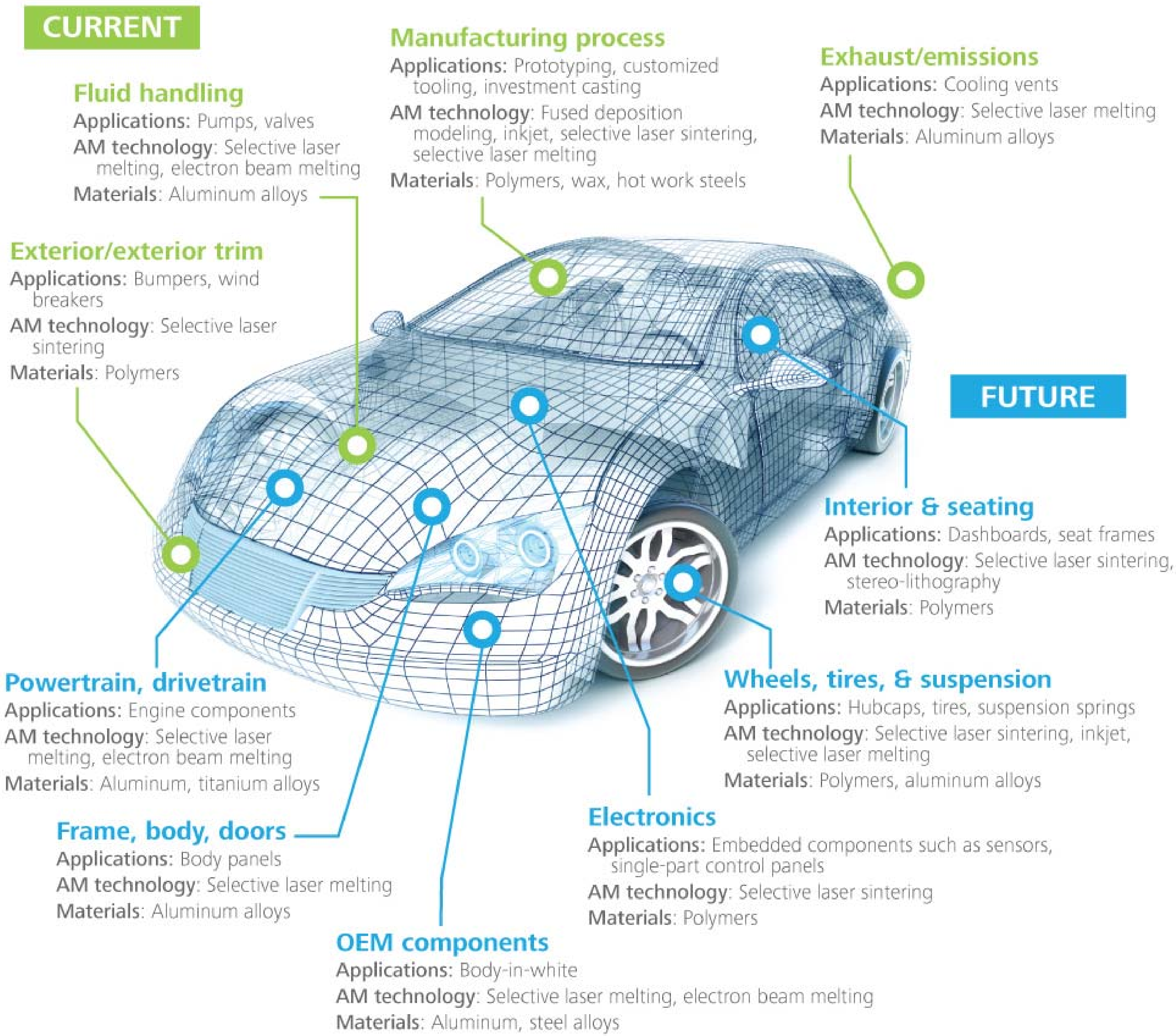
Figure 1. Hype Cycle for 3D Printing, 2014



Razvoj AM sektora

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





Source: Deloitte analysis.

Graphic: Deloitte University Press | DUPress.com

Urbee, the first AM-produced car

2011

URBEE

- 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

2015

Proposed

URBEE2

- 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

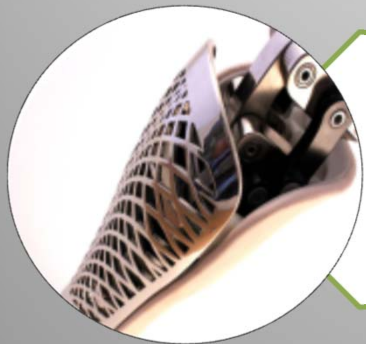
First application of 3D printing in the medical field - creating the human bladder

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

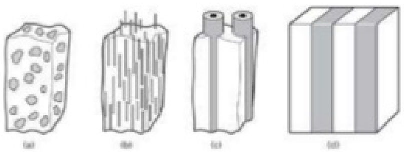
2011

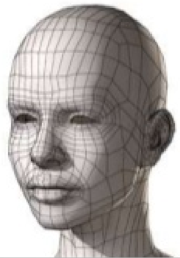
3D printers start offering 14k gold as printable material

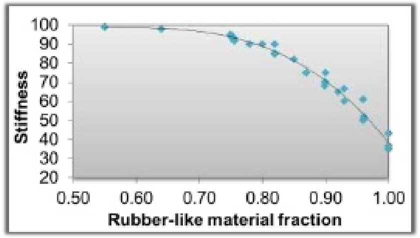
Digitalni (kompozitni) materijali

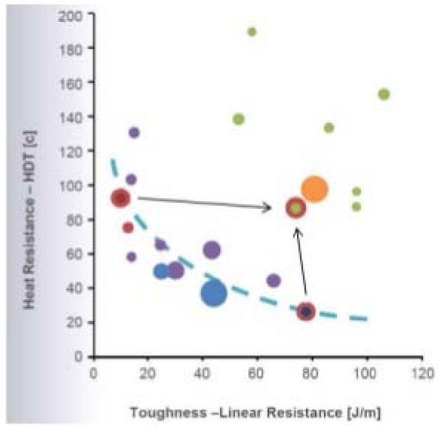
Digital Materials are engineered materials manufactured from two or more different constituent materials, according to a digitally encoded three dimensional phase structure design (the DM code), and produced by an additive manufacturing process.

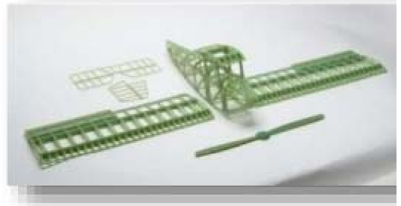
- Heterogeneous/Homogeneous
- Anisotropic/Isotropic
- Geometry Dependent



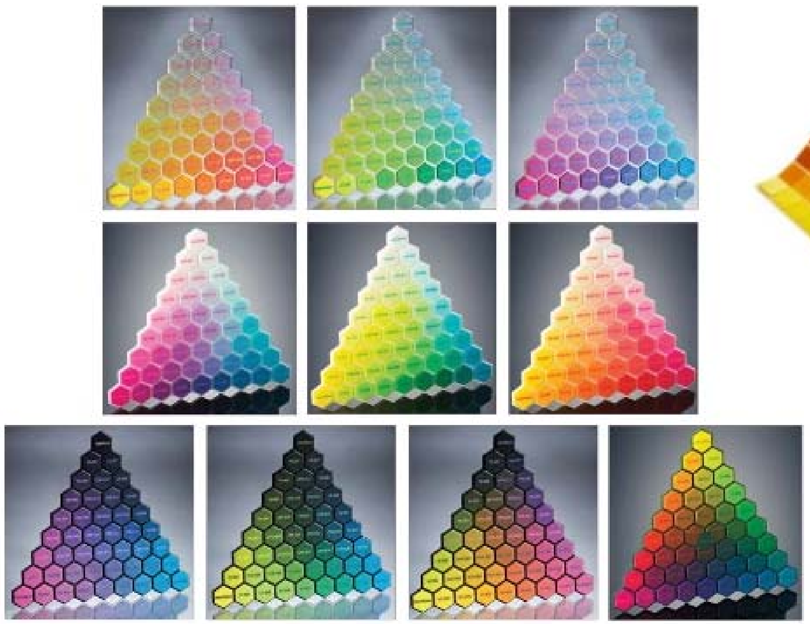


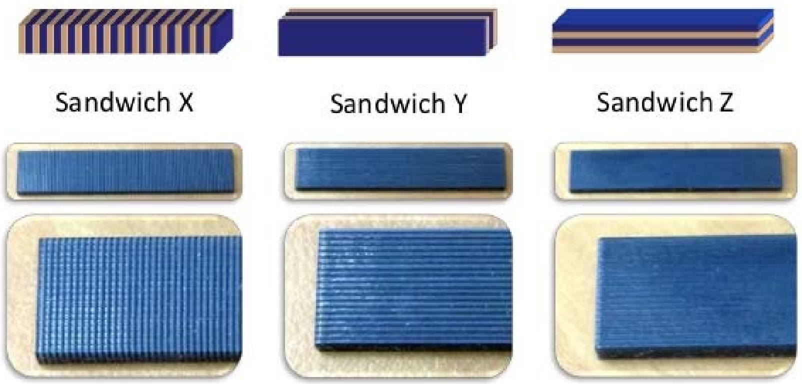


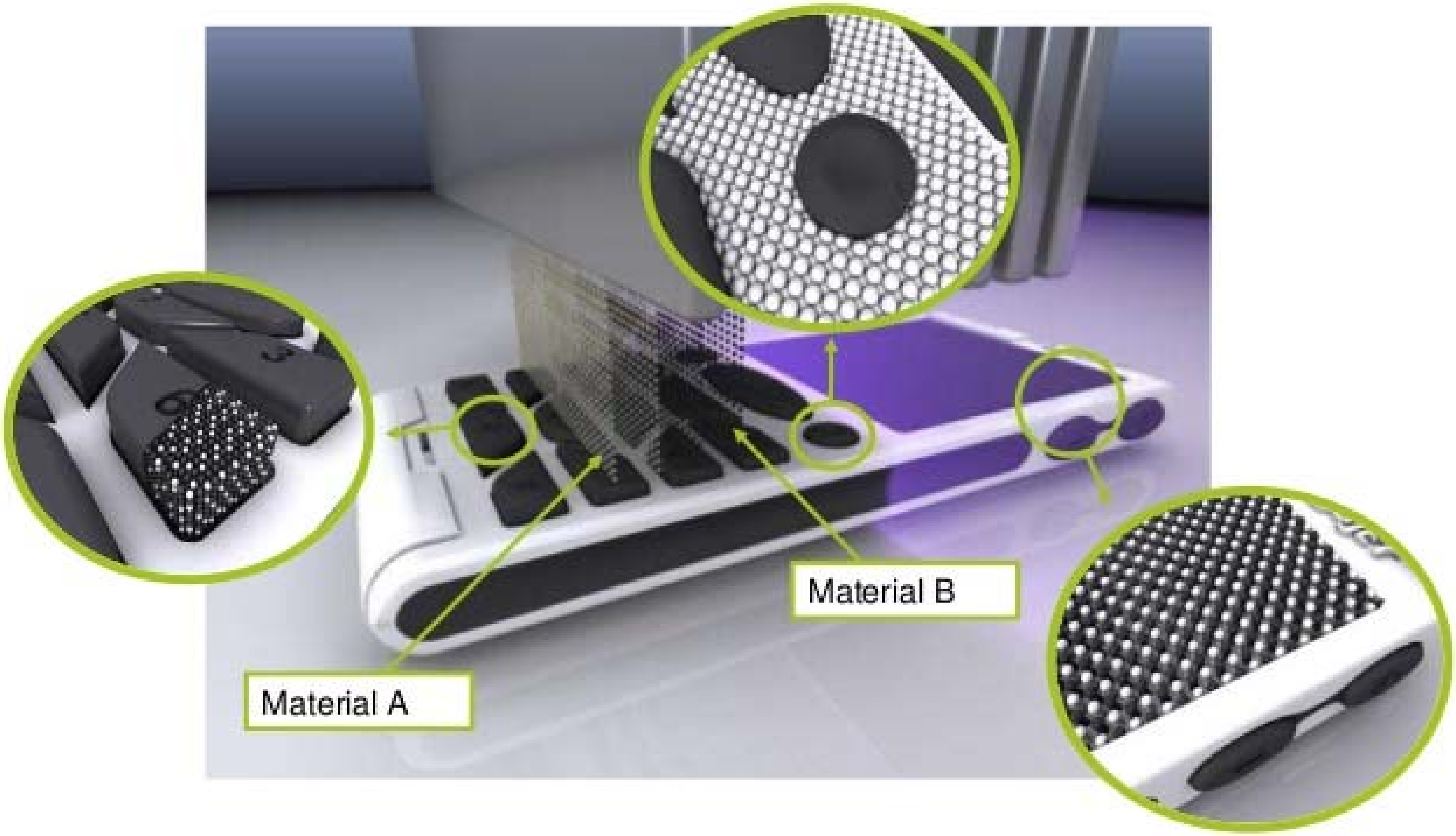




High Toughness Material + High Temperature Material ⇨ Composite Digital Material

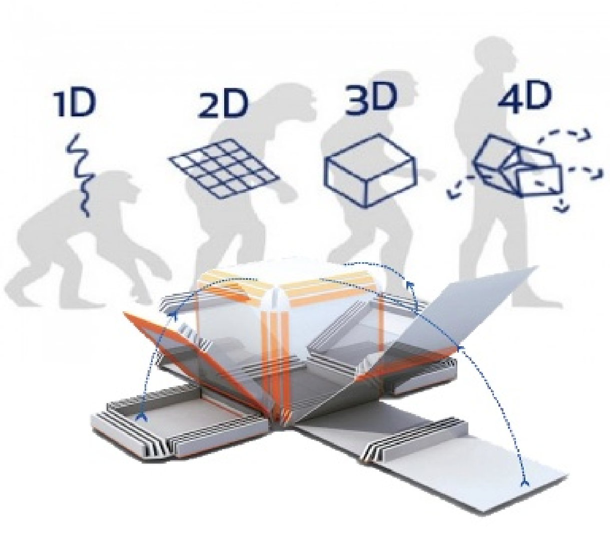


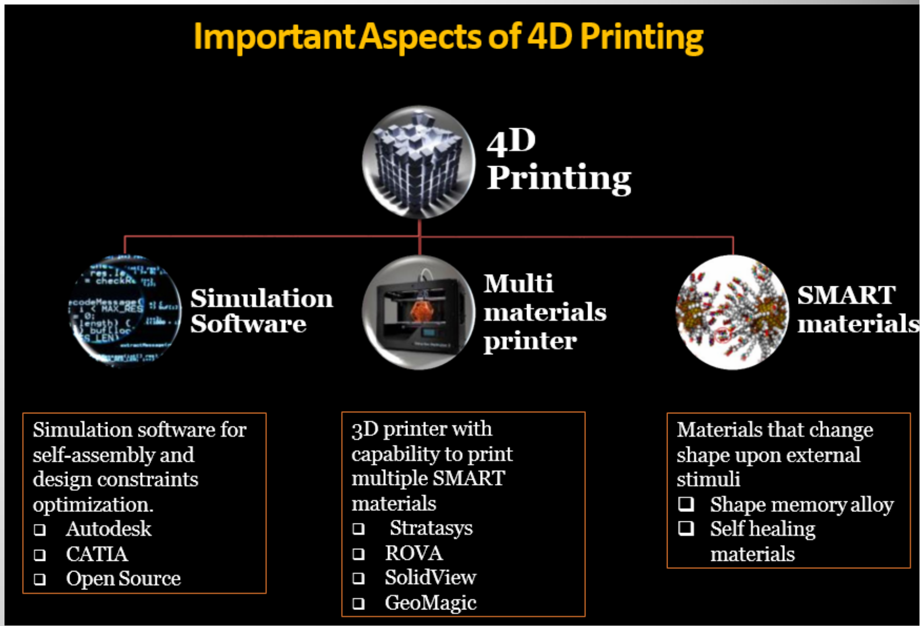



Material B
Material A

4D PRINTING

Skylar Tibbits 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.**





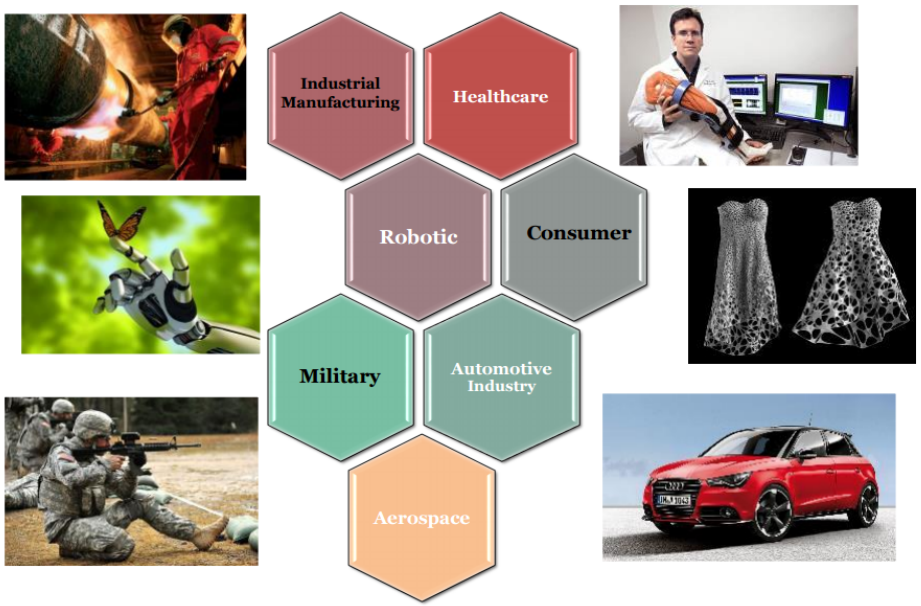
Year of Impact (4D printing)

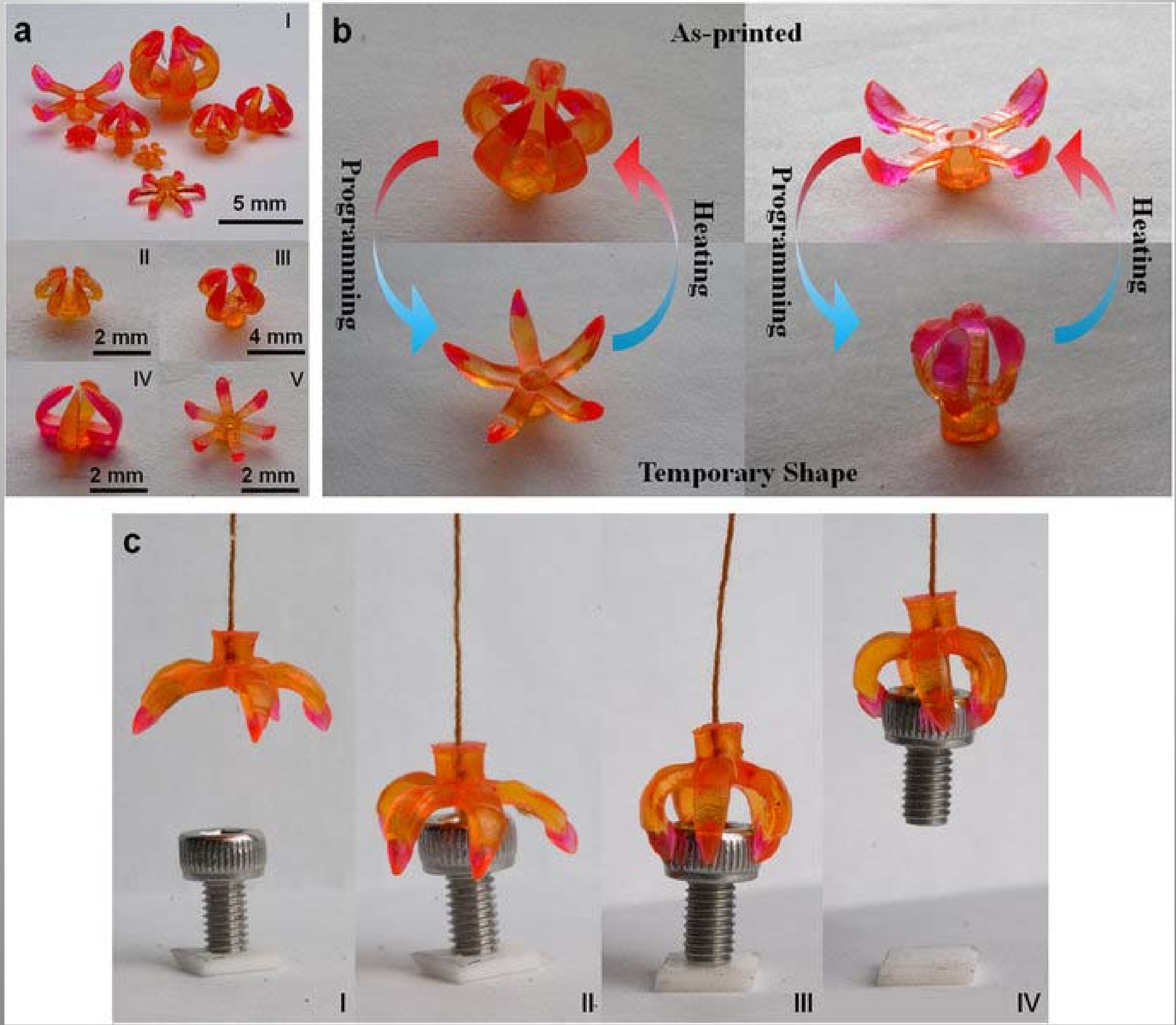
Sectors	Expected Year of Impact									
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Healthcare										
Military										
Infrastructure										
Automobile										
Packaging										
Aerospace										
Manufacturing										

Source: Frost & Sullivan, June 2014

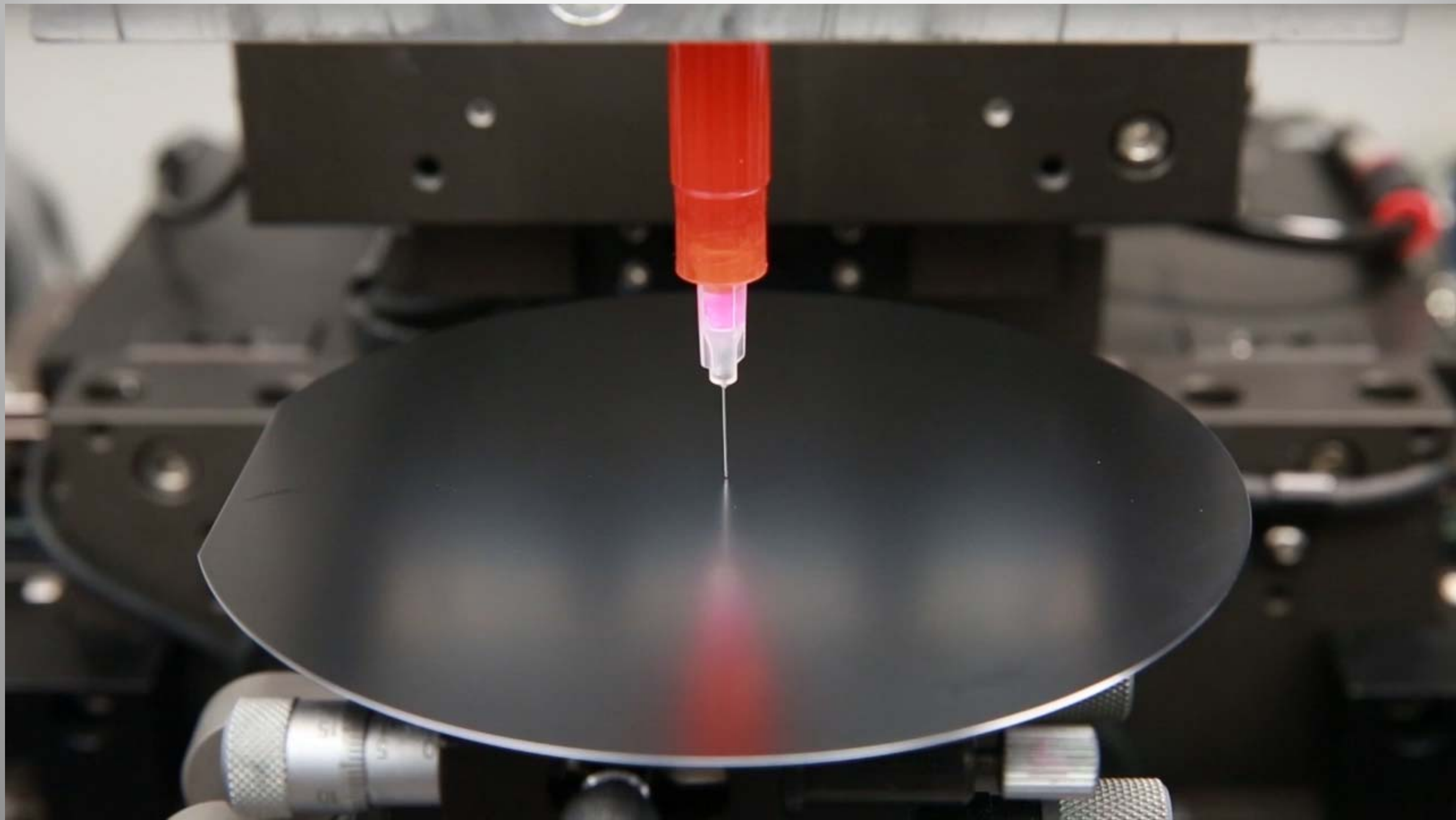
The expected year of widespread/ large-scale adoption of 4D Printing technology has been computed through assessments of technology advances, industry initiatives, challenges, advances in related industries, and market potential

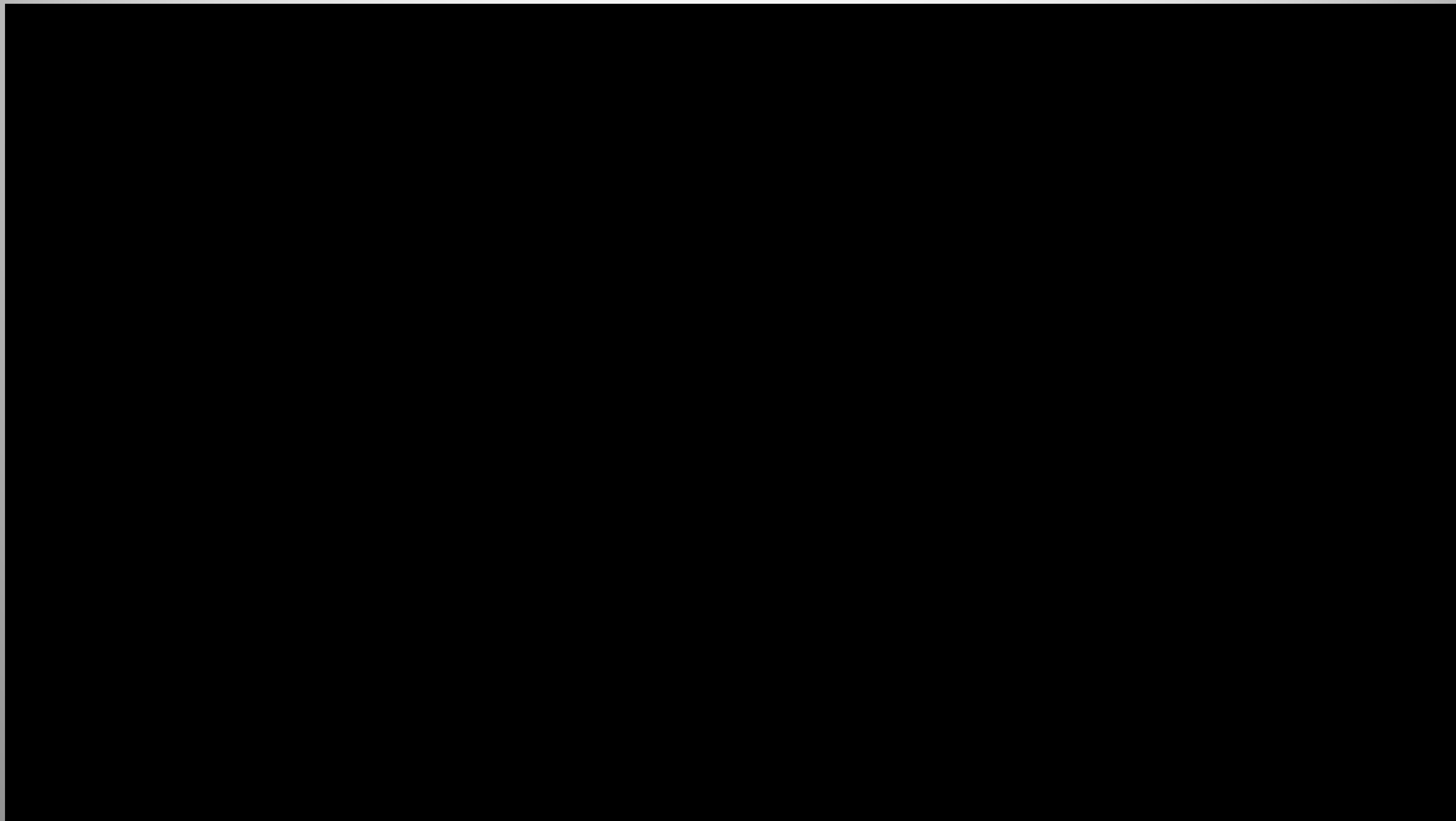
Further Applications of Smart Materials





a
I
5 mm
II
2 mm
III
4 mm
IV
2 mm
V
2 mm
b
As-printed
Programming
Heating
Programming
Heating
Temporary Shape
c
I
II
III
IV





Opšti tehnološki tok aditivne proizvodnje

Opšti pristup zajednički za sve AM tehnologije je sledeći:

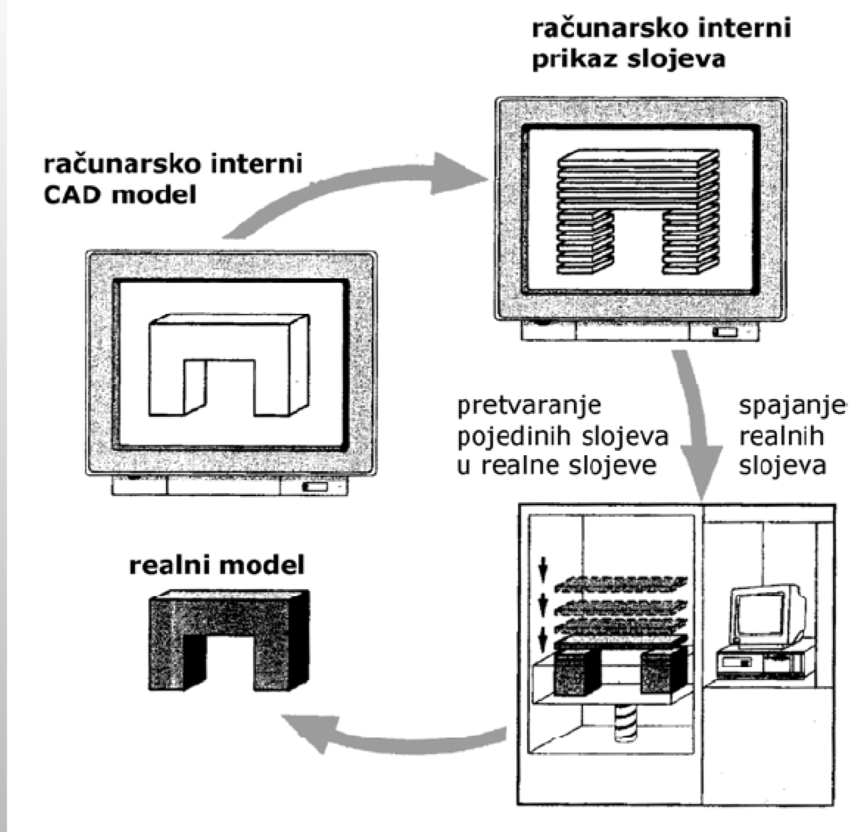
I. Generisanje digitalnog 3D CAD modela. Model mora biti predstavljen zatvorenim površinama.

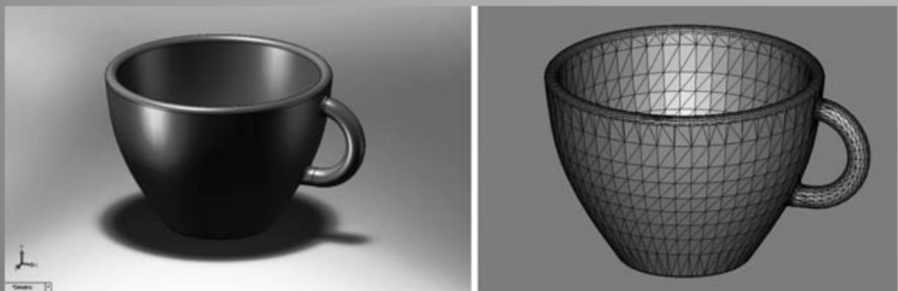
II. Dobijeni model se zatim konvertuje u neki od standardnih formata za razmenu podataka. Obično se koristi STL (*STereoLitography*) fajl format. To je fajl ASCII ili binarnog tipa i predstavlja listu trougaonih površina koje opisuju kompjuterski generisani prostorni model. Pored STL- formata koriste 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.

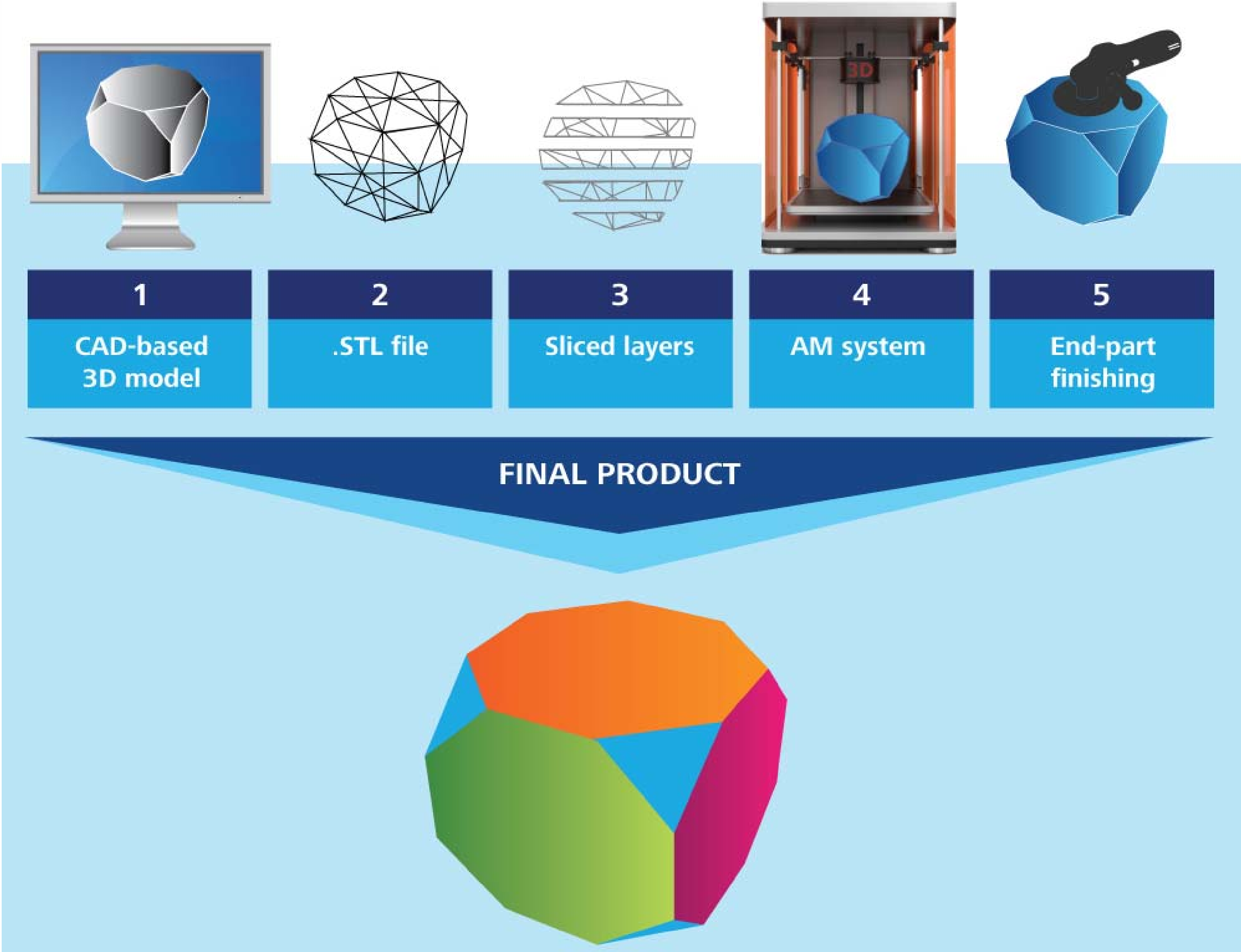
IV. Mašina dalje ovakav model koristi za formiranje modela sloj po sloj, pri čemu se svaki sloj vezuje sa onim pre i onim posle njega - Procesiranje.

V. Dorada radnog predmeta - Postprocesiranje



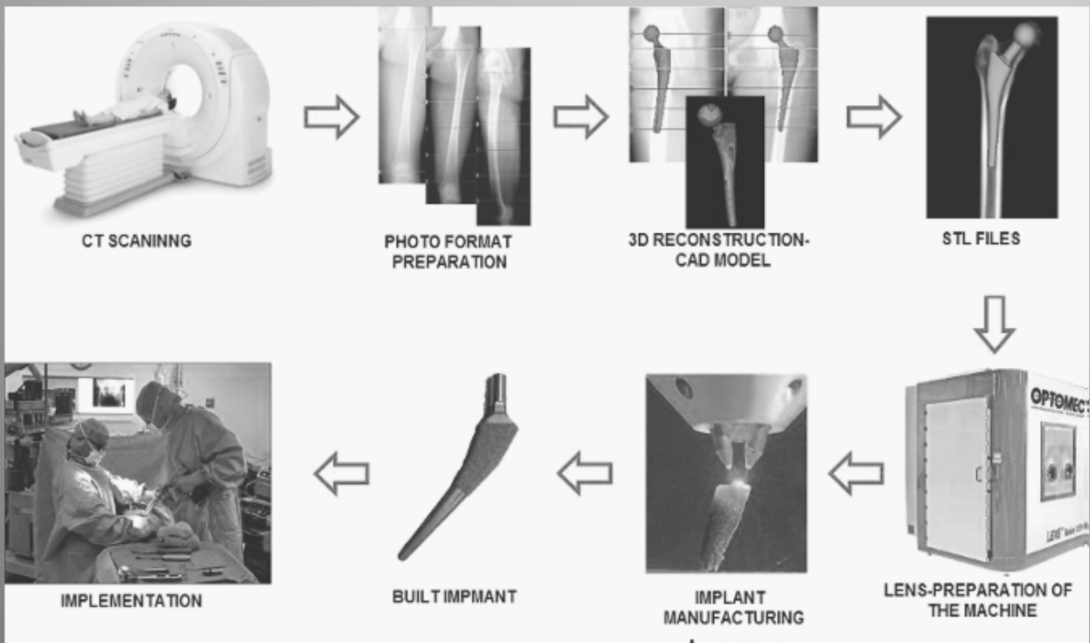


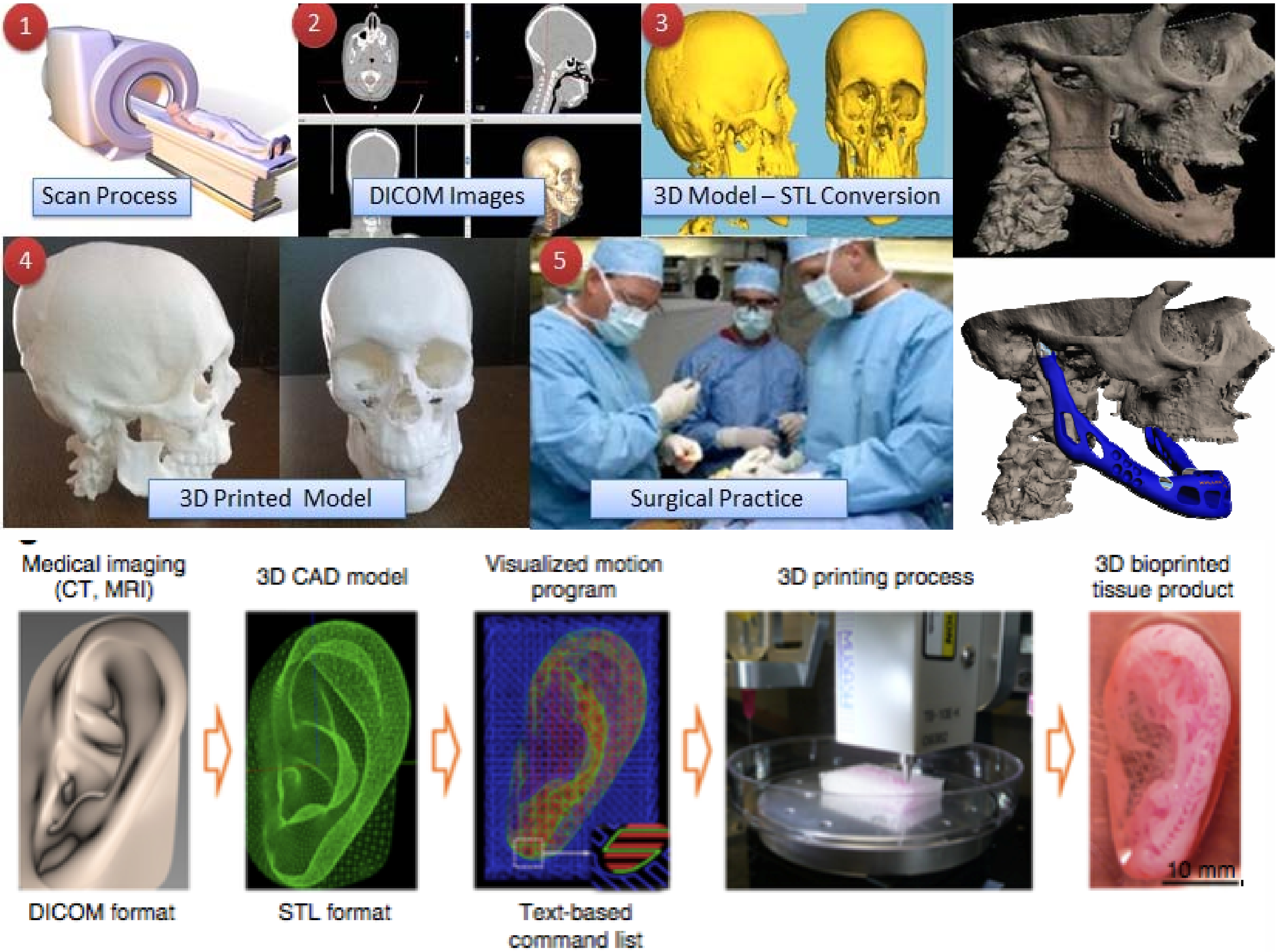
Opšti tehnološki tok aditivne proizvodnje

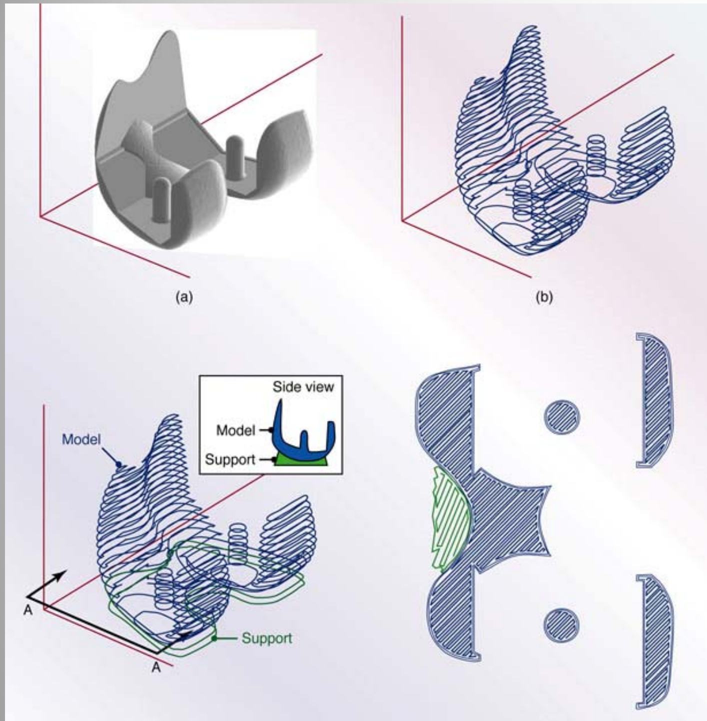


Generisanje 3D digitalnog modela

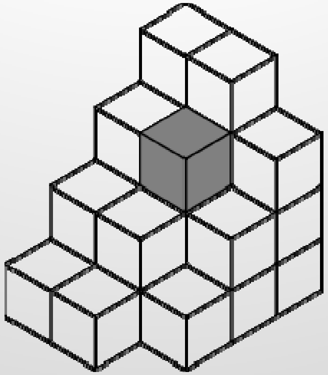
a) CAD softverski sistemi
b) Matematički podaci
c) Reverzibilni inženjering
d) Podaci o poprečnim presecima
e) Medicinski podaci (CT, MRI)



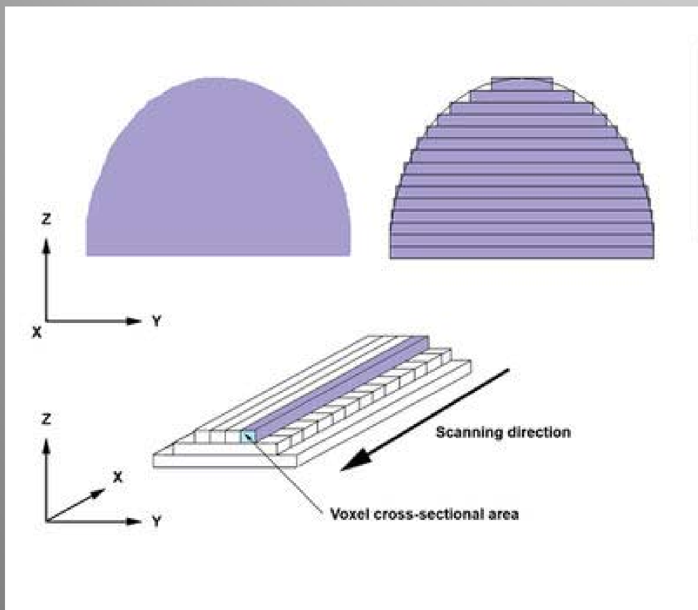

1
Scan Process
2
DICOM Images
3
3D Model – STL Conversion
4
3D Printed Model
5
Surgical Practice
Medical imaging (CT, MRI)
3D CAD model
Visualized motion program
3D printing process
3D bioprinted tissue product
DICOM format
STL format
Text-based command list
10 mm

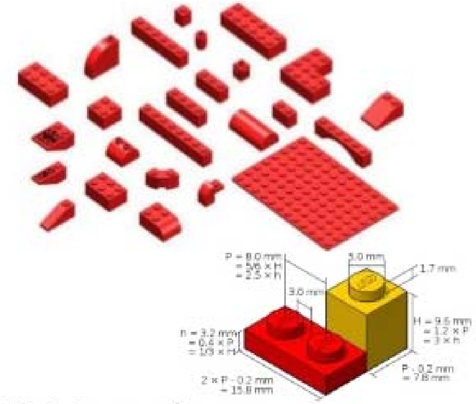


VOXEL



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).

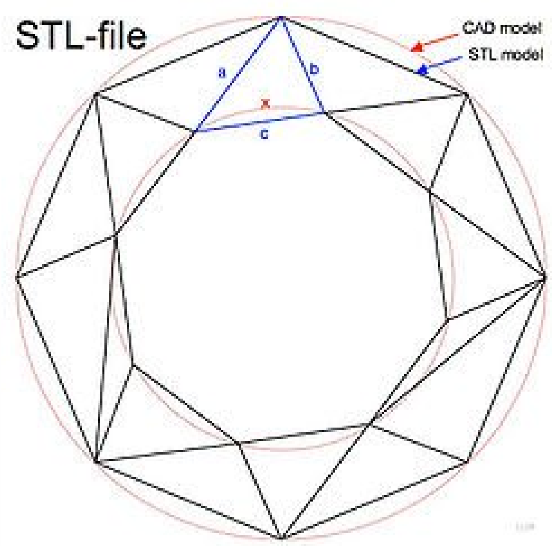


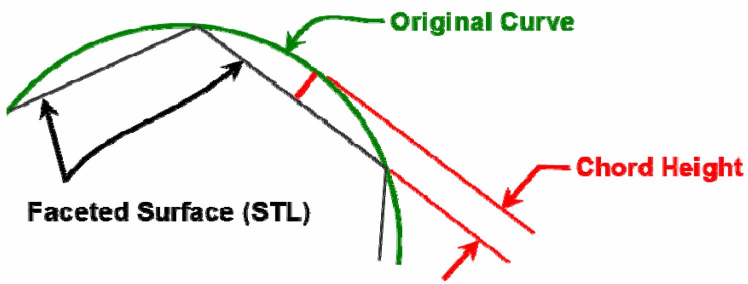


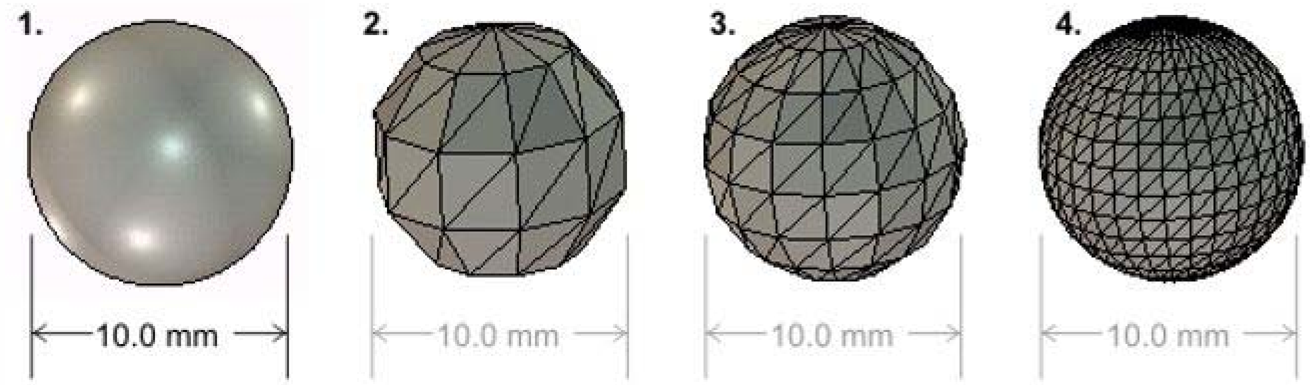
- 1 cubic millimeter – ~20,000 Objet voxels
- The smallest Lego brick – ~4,000,000 Objet voxels
- Full tray – 10^{12} Objet voxels

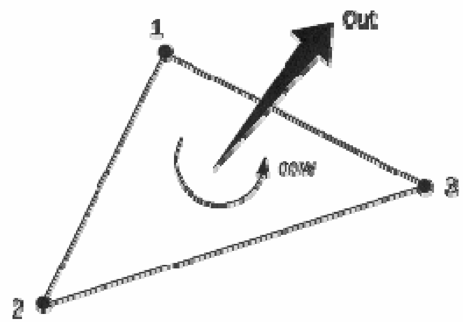
STL

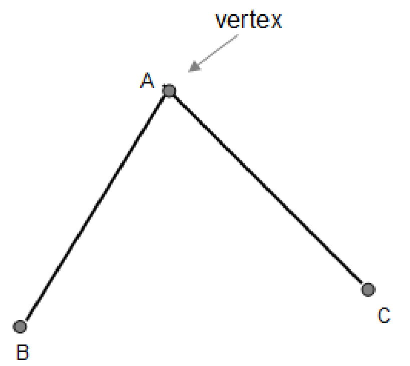
STL (stereo lithography) file format podržava većina CAD softvera, a bazično je razvijen za potrebe tehnologija brze izrade prototipova/aditivne proizvodnje
STL file opisuje samo geometriju površine trodimenzionalnog objekta, bez prikaza drugih atributa (boje, teksture) karakterističnih za CAD sisteme.
STL file prikazuje diskretizovanu površinu u vidu jediničnih trougaonih elemenata i kreiranu na bazi odgovarajućih pravila.

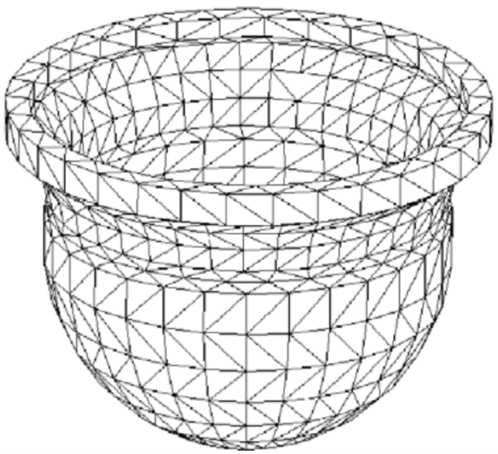


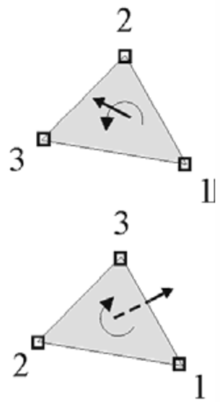


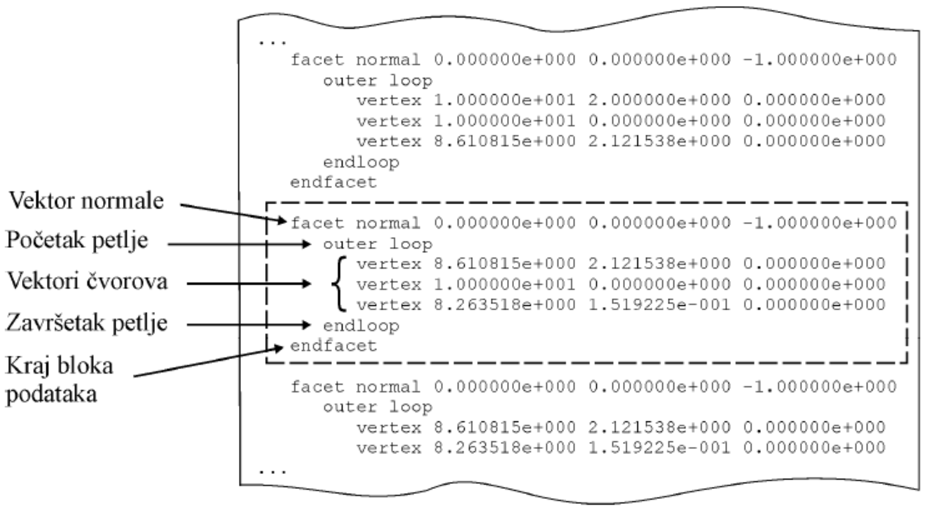








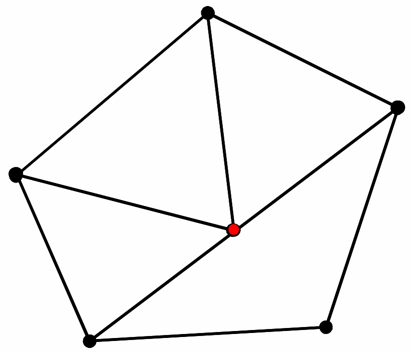




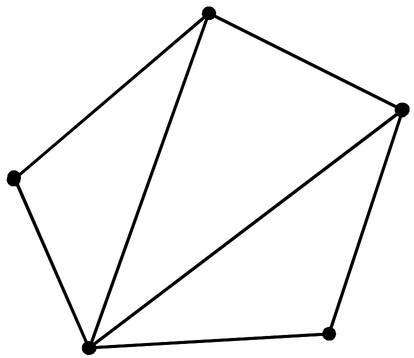
STL Pravila:

1. Površina proizvoljnog (konačnoh) 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.



WRONG

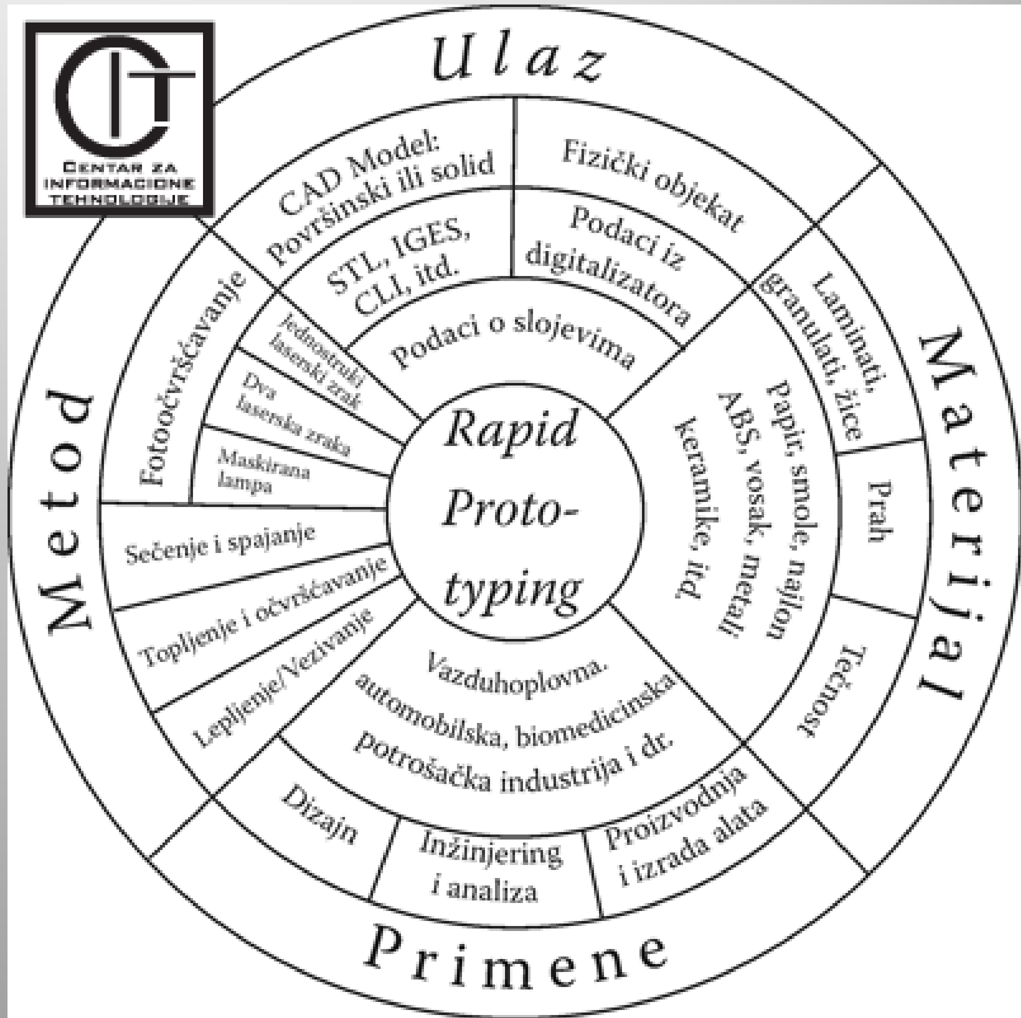


CORRECT

	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
Prednosti	Univerzalnost	Svi tipovi 3D geometrije mogu se aproksimirati mrežom ravanskih trouglova
Prednosti	Jednostavno generisanje ravanskih preseka	Algoritmi za generisanje ravanskih preseka na STL modelu najčešće su jednostavni
Prednosti	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
Nedostaci	Greške u procesu konverzije	
Nedostaci	Nedostaci u pogledu projektovanja tehnološkog postupka	Skupo i vremenski zahtevno korigovanje STL datoteke Nedostatak topoloških informacija Nedostatak tehnoloških parametara

Četiri glavna aspekta AM tehnologija

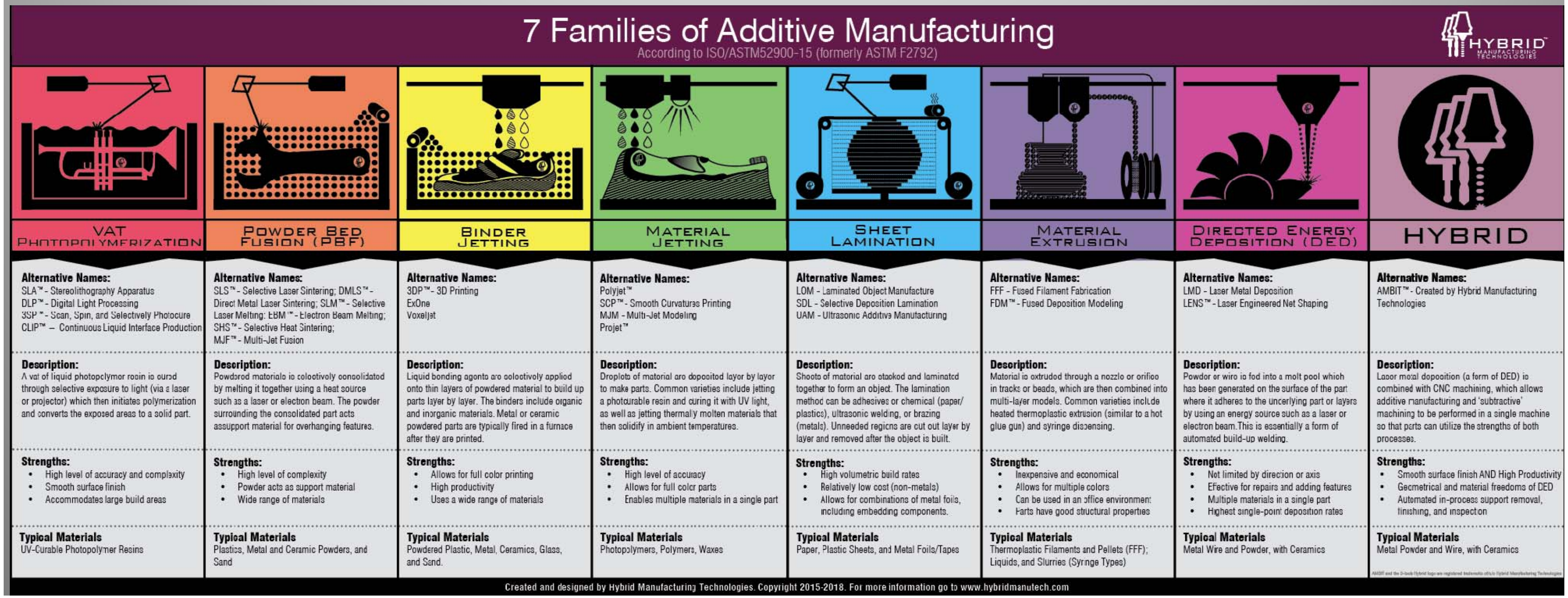
- Ulazni podaci
- Metod izrade
- Materijal izrade
- Primena



Osnovna klasifikacija AM postupka

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

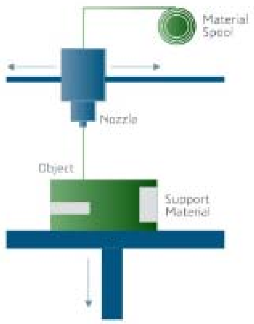
1) Fotopolimerizacija u kadi (*Vat photopolymerization*)
2) Fuzija praškastog supstrata (*Powder bed fusion*)
3) Brizganje vezivnog sredstva (*Binder jetting*)
4) Brizganje materijala/Direktna 3D štampa (*Material jetting*)
5) Ekstrudiranje materijala (*Material extrusion*)
6) Laminacija folija (*Sheet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



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.

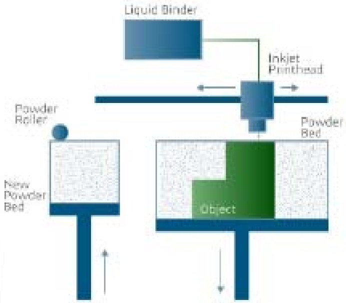
- Cost-effective
- Uses easy-to-find polyers and plastics
- Ideal for high-strength models



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.

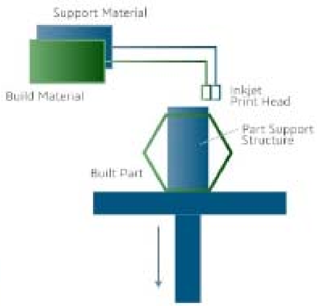
- Fast process
- Can use almost any material that is in powder form
- Flexible to meet various mechanical properties



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.

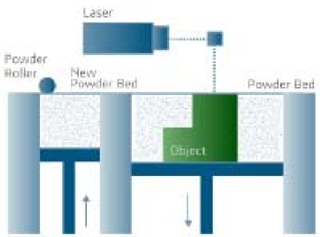
- Higher rate of part accuracy
- Superior surface finishes



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.

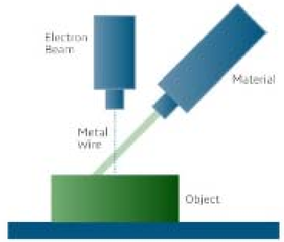
- Cost-effective
- Large range of material options
- Fine laser beam produces high-resolution features



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.

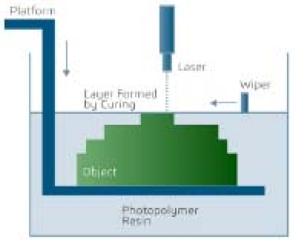
- Excellent for high-quality repair work
- Able to achieve a high level of accuracy



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.

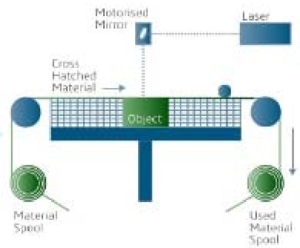
- High level of accuracy
- Excellent finish
- Ideal for large models



7 SHEET LAMINATION

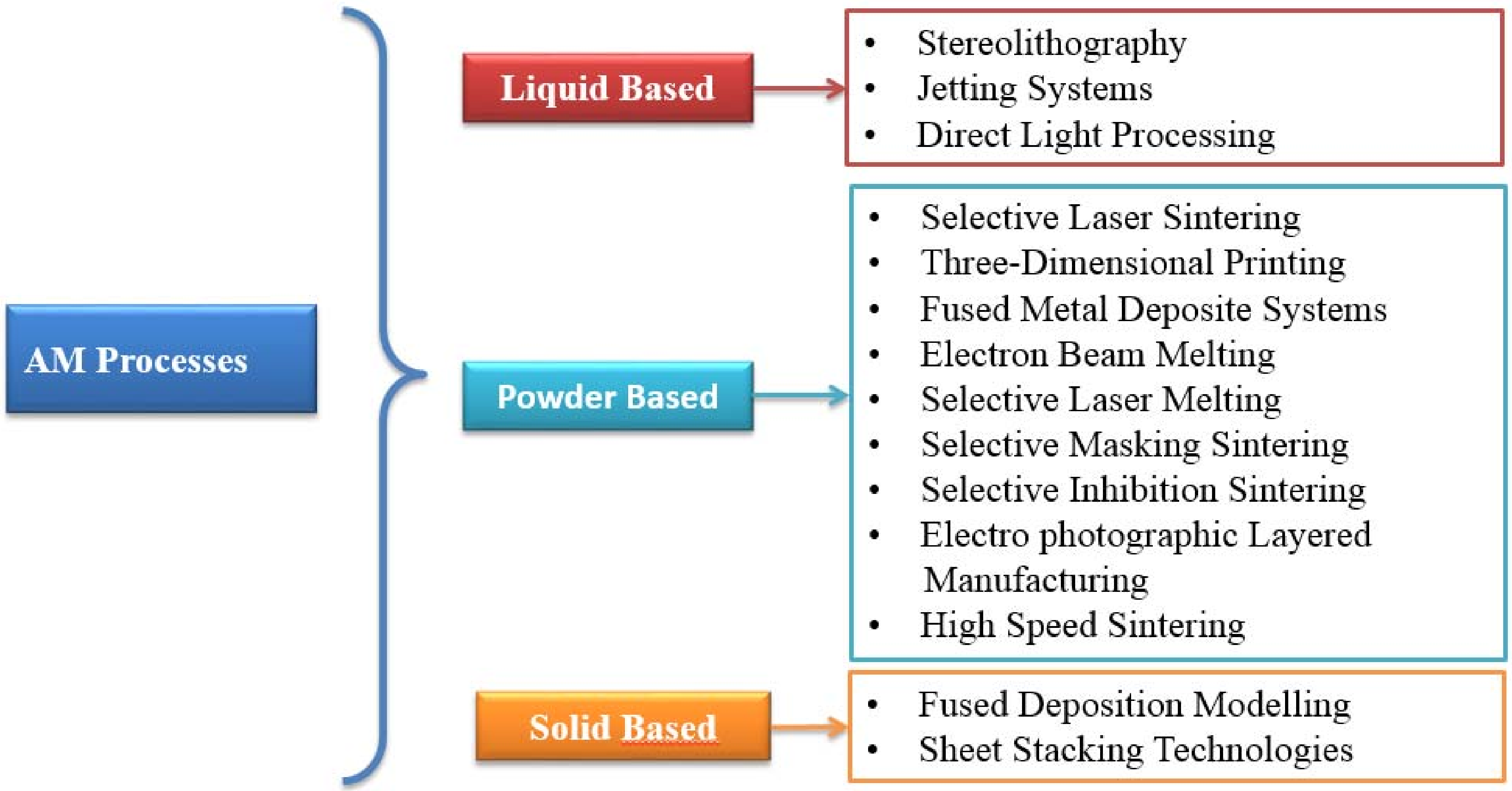
Technically subtractive, but since it builds layer by layer it is considered additive. This technique applies a laser or scalpel to cut to shape sheets of material and then layer them on top of one another.

- Cost-effective
- Fast cutting process
- Easy material handling

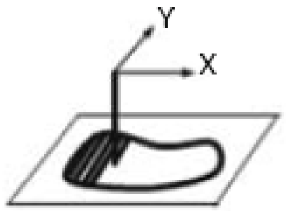
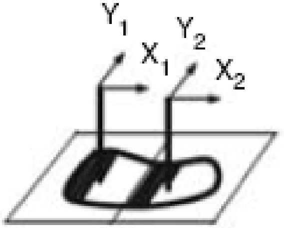
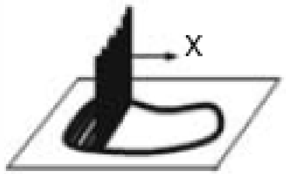
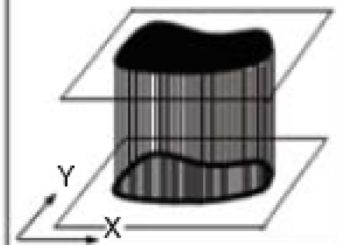


Podela AM postupaka prema početnom stanju materijala

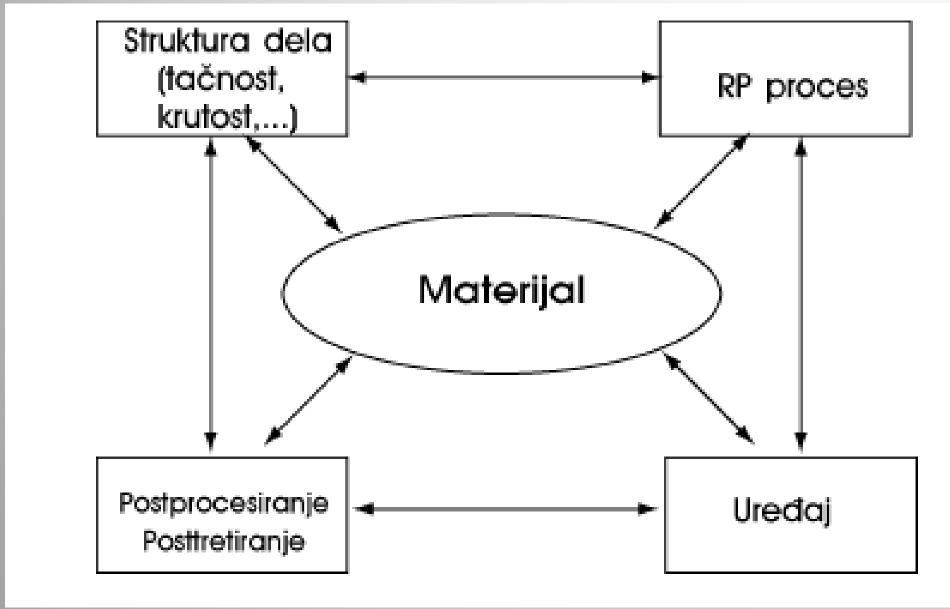
A. Materijali u tečnom stanju
B. Materijali u praškastom stanju
C. Materijali u čvrstom stanju



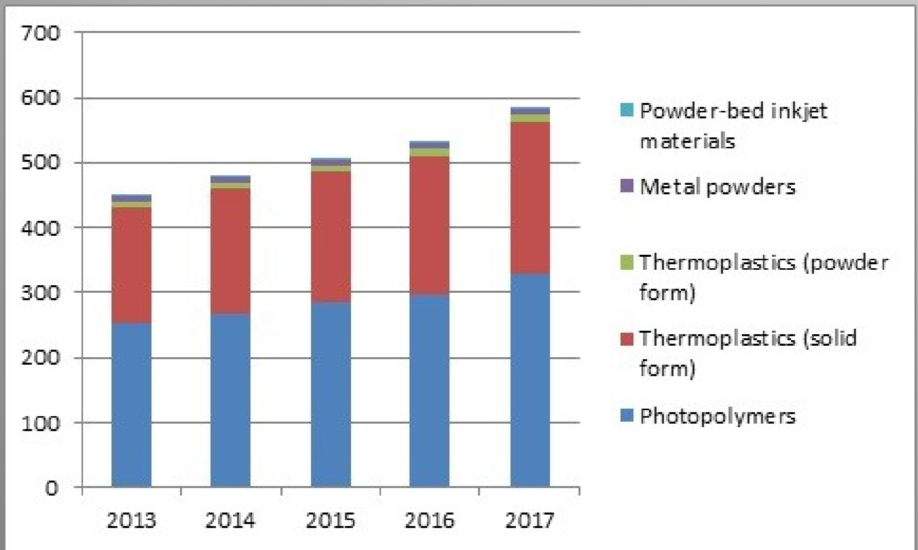
Podela AM postupaka prema načinu generisanja sloja

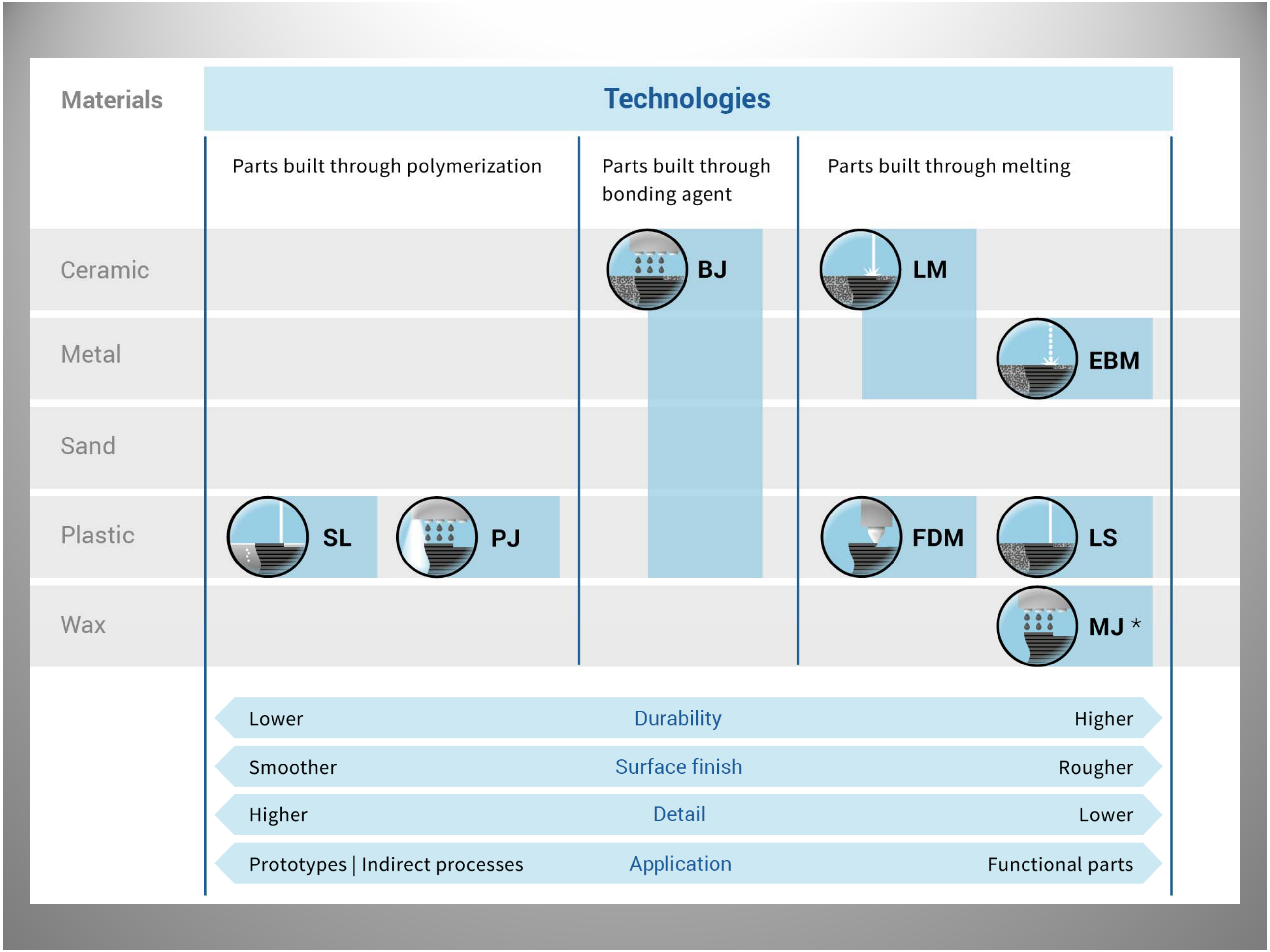
	1D Channel 	2x1D Channels 	Array of 1D Channels 	2D Channel 
Liquid Polymer	SLA (3D Sys)	Dual beam SLA (3D Sys)	Objet	Envisiontech MicroTEC
Discrete Particles	SLS (3D Sys), LST (EOS), LENS Phenix, SDM	LST (EOS)	3D Printing	DPS
Molten Mat.	FDM, Solidscape		ThermoJet	
Solid Sheets	Solido PLT (KIRA)			

Materijali



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




Materials
Technologies
Parts built through polymerization
Parts built through bonding agent
Parts built through melting
Ceramic
Metal
Sand
Plastic
Wax
BJ
LM
EBM
SL
PJ
FDM
LS
MJ *
Lower
Durability
Higher
Smoother
Surface finish
Rougher
Higher
Detail
Lower
Prototypes | Indirect processes
Application
Functional parts


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

Mechanical Properties of Selected Materials for Rapid Prototyping

Process	Material	Tensile strength (MPa)	Elastic modulus (GPa)
Stereolithography	SL5180[a]	55-65	2.4-2.6
	SL5195[a]	46.5	2.1
	SL5510[b]	73	2.8
	SL7940[b]	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[c]	305	137
Three-dimensional printing	S3 stainless steel	406	148
	S4 stainless steel	682	147

[a] After a 90-min UV cure; [b] after a 90-min UV cure at 80°C; [c] sintered and bronze-infiltrated steel powder