

# **Brza izrada prototipova i alata**

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# 7 Families of Additive Manufacturing

According to ASTM F2792 Standards



**VAT  
PHOTOPOLYMERIZATION**

## Alternative Names:

SLA™ - Stereolithography Apparatus  
DLP™ - Digital Light Processing  
3SP™ - Scan, Spin, and Selectively Photocure  
CLIP™ - Continuous Liquid Interface Production

## Description:

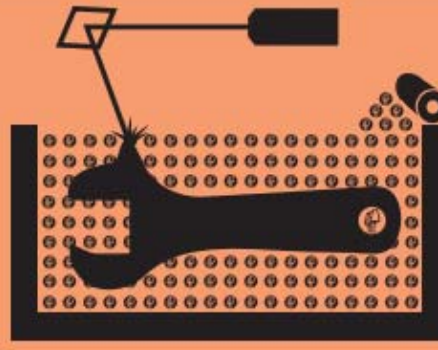
A vat of liquid photopolymer resin is cured through selective exposure to light (via a laser or projector) which then initiates polymerization and converts the exposed areas to a solid part.

## Strengths:

- High level of accuracy and complexity
- Smooth surface finish
- Accommodates large build areas

## Typical Materials

UV-curable Photopolymer Resins (with various fillers)



**POWDER BED  
FUSION (PBF)**

## Alternative Names:

SLS™ - Selective Laser Sintering; DMLS™ - Direct Metal Laser Sintering; SLM™ - Selective Laser Melting; EBM™ - Electron Beam Melting; SHS™ - Selective Heat Sintering; MJF™ - Multi-Jet Fusion

## Description:

Powdered materials is selectively consolidated by melting it together using a heat source such as a laser or electron beam. The unfused powder surrounding the consolidated part acts as a support material for overhanging features.

## Strengths:

- High level of complexity
- Powder acts as support material
- Wide range of materials

## Typical Materials

Plastics, Metal and Ceramic Powders, and Sand



**BINDER  
JETTING**

## Alternative Names:

3DP™ - 3D Printing  
ExOne  
Voxeljet

## Description:

Liquid bonding agents are selectively 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.

## Strengths:

- Allows for full color printing
- High productivity
- Uses a wide range of materials

## Typical Materials

Powdered Plastic, Metal, Ceramics, Glass, and Sand.



**MATERIAL  
JETTING**

## Alternative Names:

PolyJet™  
SCP™ - Smooth Curvatures Printing  
MJM - Multi-Jet Modeling  
ProJet™

## Description:

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.

## Strengths:

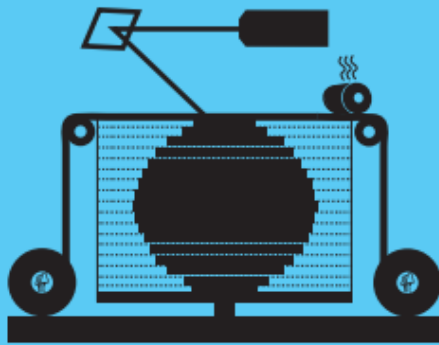
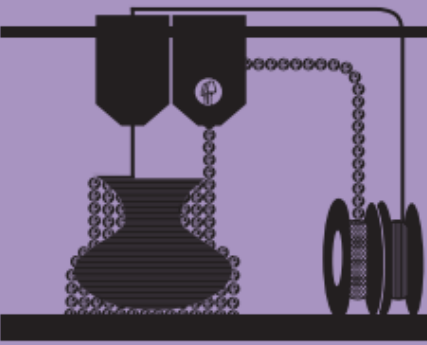


- High level of accuracy
- Allows for full color parts
- Enables multiple materials in a single part

## Typical Materials

Photopolymers, Polymers, Waxes

# 7 Families of Additive Manufacturing

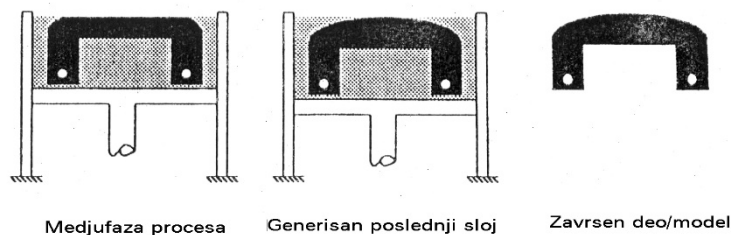
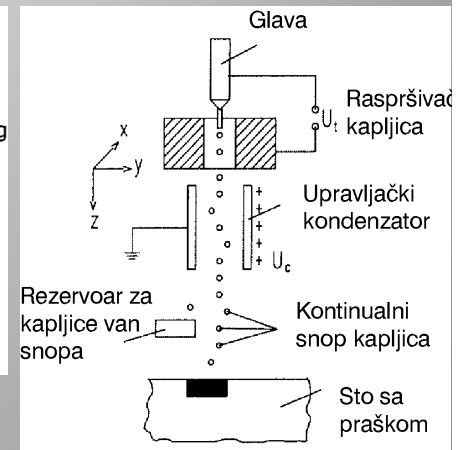
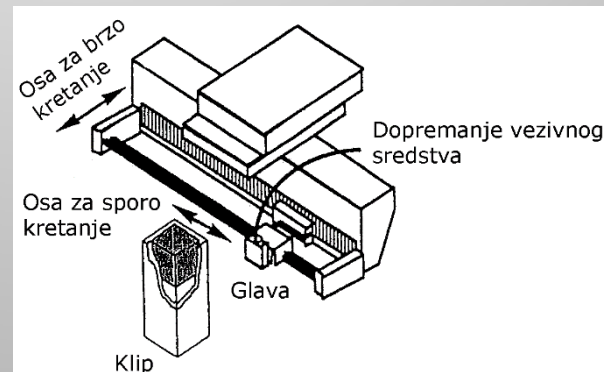
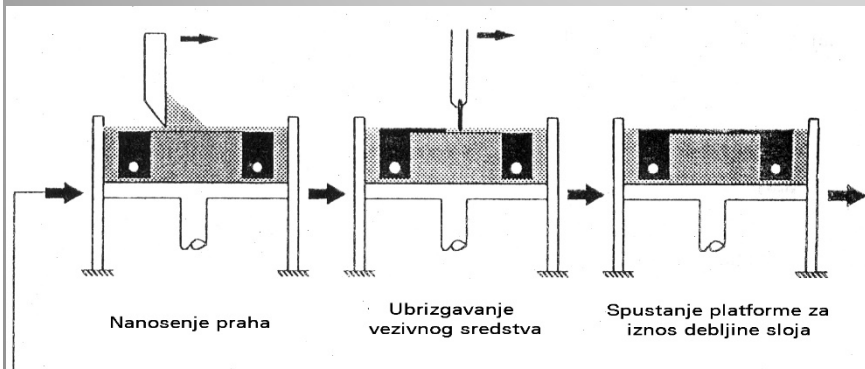
According to ASTM F2792 Standards

			
SHEET LAMINATION	MATERIAL EXTRUSION	DIRECTED ENERGY DEPOSITION (DED)	HYBRID
<p><b>Alternative Names:</b> LOM - Laminated Object Manufacture SDL - Selective Deposition Lamination UAM - Ultrasonic Additive Manufacturing</p>	<p><b>Alternative Names:</b> FFF - Fused Filament Fabrication FDM™ - Fused Deposition Modeling</p>	<p><b>Alternative Names:</b> LMD - Laser Metal Deposition LENS™ - Laser Engineered Net Shaping DMD™ - Direct Metal Deposition</p>	<p><b>Alternative Names:</b> AMBIT™ - Created by Hybrid Manufacturing Technologies</p>
<p><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.</p>	<p><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.</p>	<p><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.</p>	<p><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.</p>
<p><b>Strengths:</b></p> <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>	<p><b>Strengths:</b></p> <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>	<p><b>Strengths:</b></p> <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>	<p><b>Strengths:</b></p> <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>
<p><b>Typical Materials</b> Paper, Plastic Sheets, and Metal Foils/Tapes</p>	<p><b>Typical Materials</b> Thermoplastic Filaments and Pellets (FFF); Liquids, and Slurries (Syringe Types)</p>	<p><b>Typical Materials</b> Metal Wire and Powder, with Ceramics</p>	<p><b>Typical Materials</b> Metal Powder and Wire, with Ceramics</p>



# 3D Printing

- Institut za tehnologiju, Masačusets (MIT), SAD
- ZCorporation
- Prvi komercijalni 3D štampač se pojavio 1997. godine - Z402 sistem.
- Vezivanje čestica praha adhezivima
- Materijali: prah na bazi skroba, prah na bazi gipsa, prah za izradu kalupa



Prečnik mlaznice  $46 \mu\text{m}$   
Prečnik kapljice  $80 \mu\text{m}$

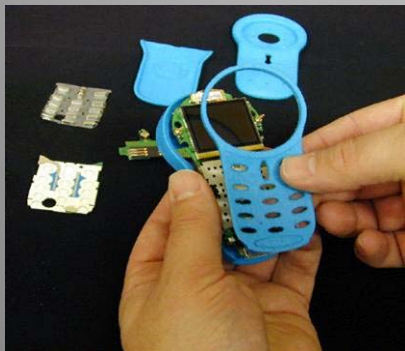
# Prednosti i nedostaci 3DP

- Velika brzina
- Svestranost
- Jednostavnost upotrebe
- Nema otpadnog materijala
- Pun kolor

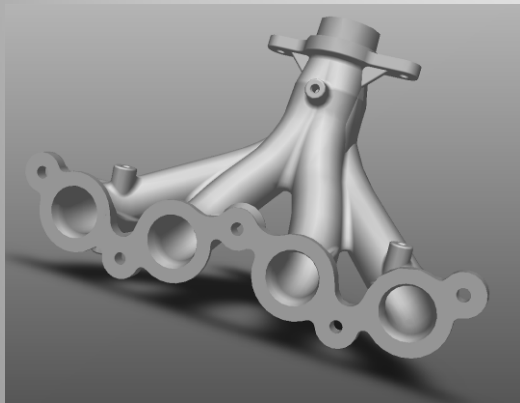
- Ograničena funkcionalnost delova
- Ograničen izbor materijala
- Slab kvalitet površine
- Postprocesiranje

# Primena 3DP

- Konceptijski modeli
- Funkcionalni modeli i prototipovi
- Šabloni za livenje
- Direktno livenje obojenih metala
- Izrada kalupa za RTV formiranje



# Primena 3DP



# Karakteristike 3D šampača kompanije ZCorporation

Model	ZPrinter 310 System	Spectrum Z510	Z810 System
Maksimalne dimenzije dela	203x254x203 mm	254x356x203 mm	500x600x400 mm
Brzina izrade sloja	2 sloja/min	Kolor: 2 sloja/min Jednobojni: 6 slojeva/min	Kolor: 2 sloja/min Jednobojni: 6 slojeva/min
Debljina sloja	0,089 – 0,203 mm	0,089 – 0,203 mm	0,089 – 0,203 mm
Rezolucija u horizontalnoj ravni	300x300 dpi	600x540 dpi	300x300 dpi
Boja	Ne	Da	Da
Broj glava za štampanje	1	4	4

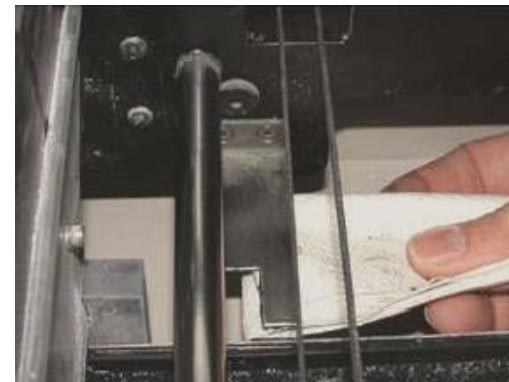


**ZPrinter 310 System**



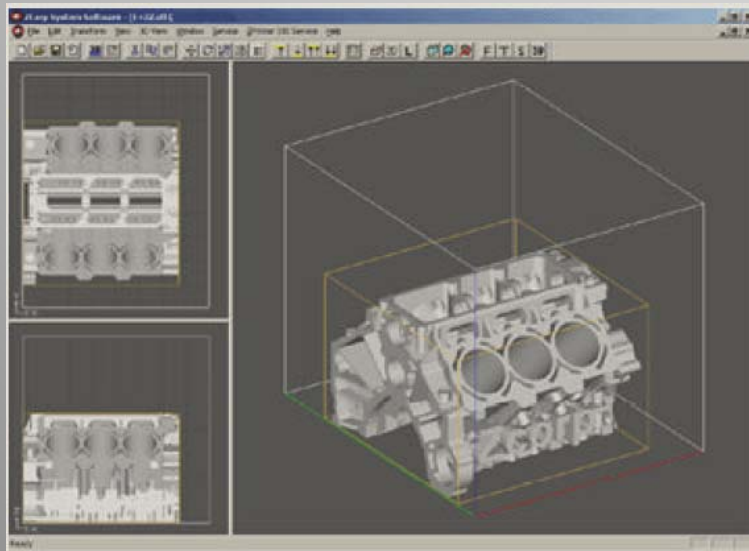
# Primer 3D štampe na ZPrinter 310 System

## ➤ Priprema štampača za rad



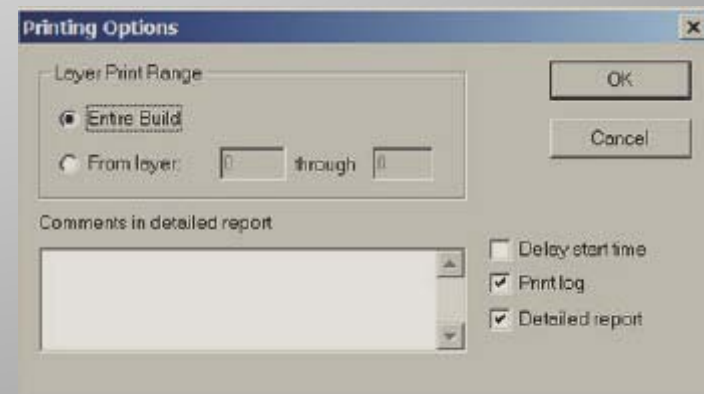
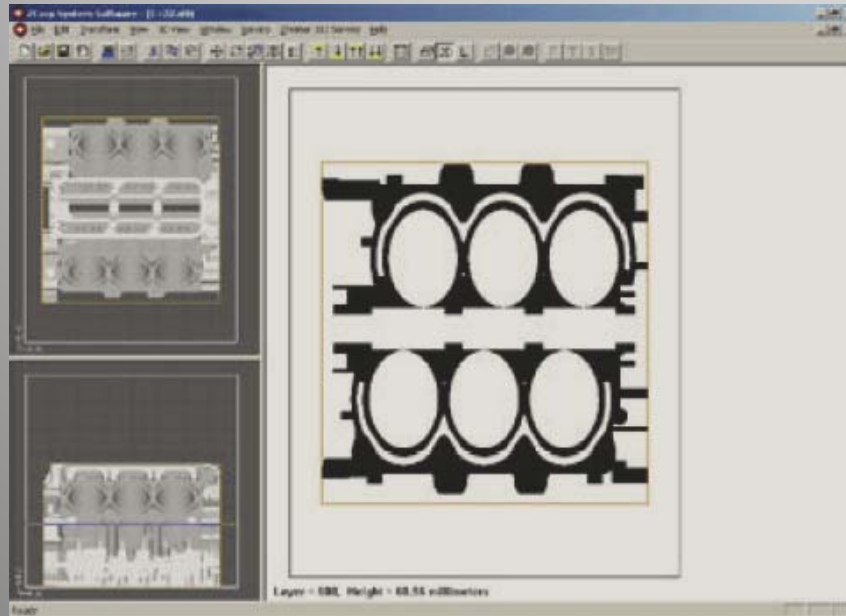
# Primer 3D štampe na ZPrinter 310 System

- Pokretanje aplikacija *ZPrint Software*
- Provera *3D Print Setup*
- Izmena parametara štampe



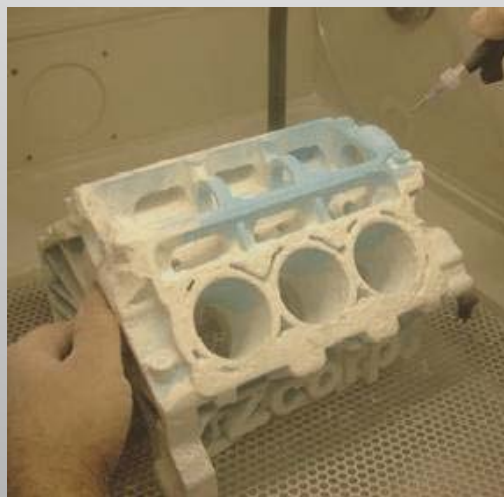
# Primer 3D štampe na ZPrinter 310 System

- Provera poprečnih preseka objekta korišćenjem opcije *2D View*
- Pritiskom dugmeta *3D Print* započinje štampanje



# Primer 3D štampe na ZPrinter 310 System

## ➤ Postprocesiranje

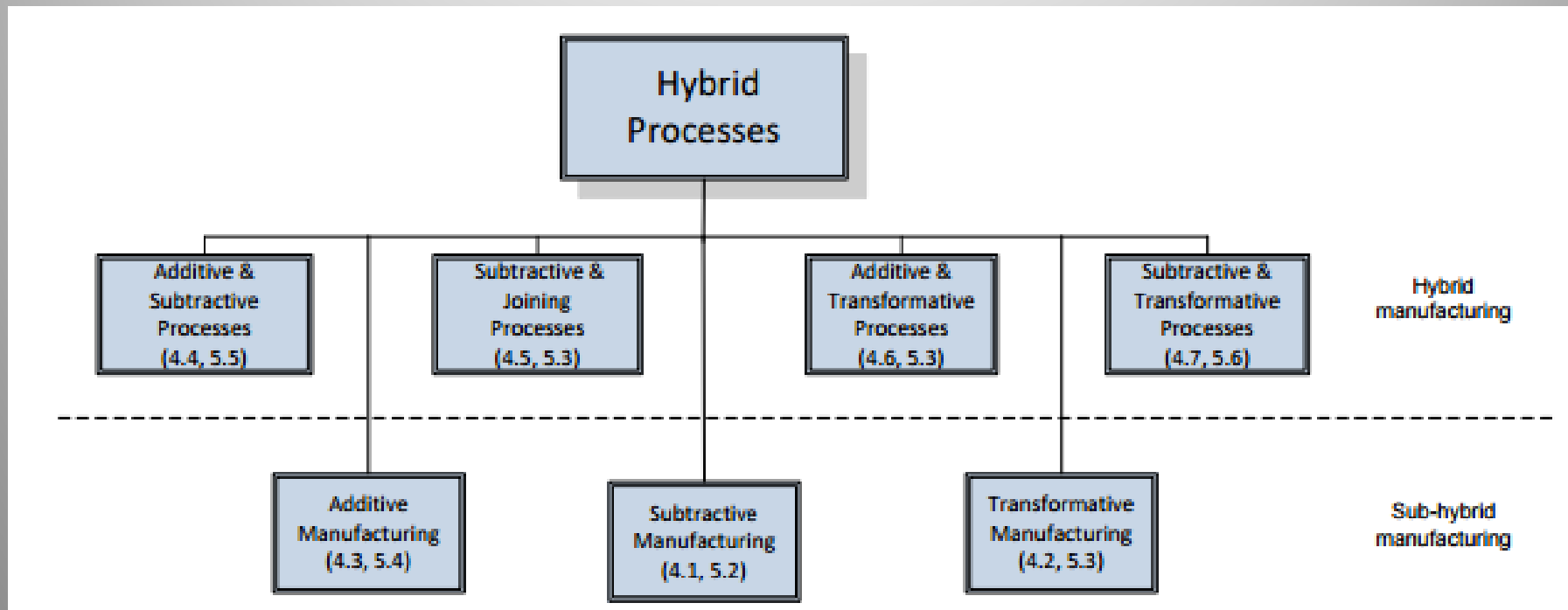




**The ZPrinter creates  
an iPhone 4**

# Hybrid manufacturing

A manufacturing process that seeks to combine the characteristics and advantages of more than one classical process.



**SAUER**







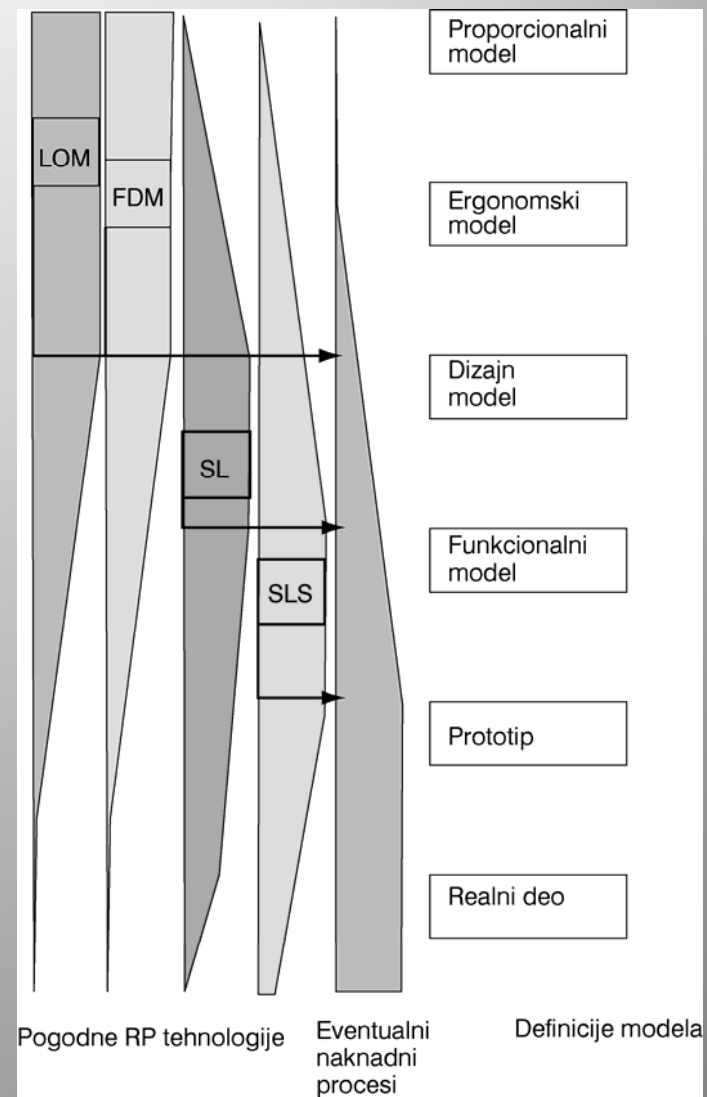
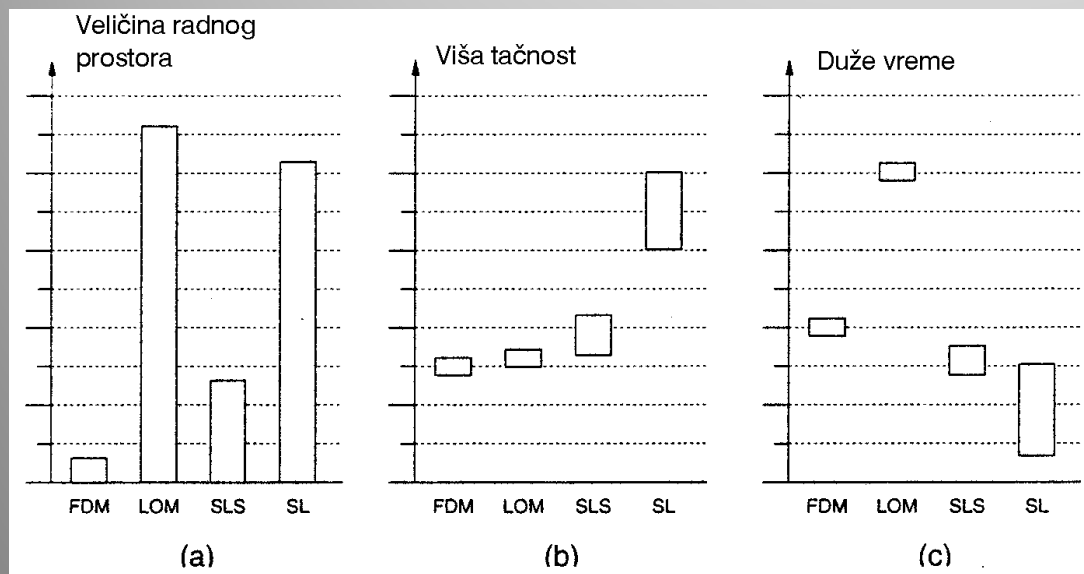
Automatic and semiautomatic  
**decomposition** of parts into  
features for additive/subtractive  
operations definition



# Komparacija RP tehnologija

Kriterijumi:

- veličina radne komore (modela)
- tačnost modela
- vreme izrade

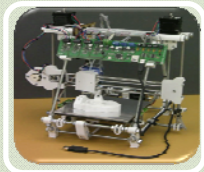


# Komparacija RP tehnologija

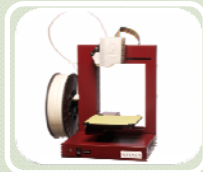
Karakteristika	POSTUPAK				
	SL	FDM	SLS	3DP	LOM
Postprocesiranje potrebno	da	ne	da	da	ne
Potpore potrebne	da	da	ne	ne	ne
Materijal	Epoksi smola, akril	ABS, MABS, vosak, elastomer, polietilen, poliamid	Najlon, metal, vosak, polikarbonat, polistirol	Keramika, metalni prah	Papir, plastika, keramika, drvo, tanak lim
Laser potreban	da	ne	da	ne	da
Debljina sloja ( $\mu\text{m}$ )	50	125 – 250	76	177	76 – 203
Tačnost ( $\mu\text{m}$ )	$\pm 100$	$\pm 127$	51	127	127
Maksimalne dimenzije dela ( $\text{mm}^3$ )	500x500x 584	254x254x 254	330x380x 425	355x457x 355	813x559x 508
Cena mašine (x 1000€)	225 – 600	150	375 – 550	–	180 – 350

	<a href="#">Stereo-lithography</a>	<a href="#">Wide Area Inkjet</a>	<a href="#">Selective Laser Sintering</a>	<a href="#">Fused Deposition Modeling</a>	<a href="#">Single Jet Inkjet</a>	<a href="#">Three Dimensional Printing</a>	<a href="#">Laminated Object Manufacturing</a>
Technology >>							
Representative Vendor >>	3D Systems			Stratasys	Solidscape	Z Corp.	Cubic Technologies
General Qualitative Features							
Maximum Part Size (inches)	20 x 20 x 24	10 x 8 x 8	15 x 9 x 9	24 x 20 x 24	12 x 8 x 8	20 x 24 x 18	32 x 22 x 20
Speed	average	good	average to fair	poor	poor	excellent	good
Accuracy	very good	good	good	fair	excellent	fair	fair
Surface Finish	very good	fair	fair	fair	excellent	fair	fair to poor
							(depending on application)
Strengths	market leader, large part size, accuracy, wide product line	market leader, office okay,	market leader, accuracy, materials,	office okay, price, materials,	accuracy, finish, office okay,	speed, office okay, price, color, price	large part size, good for large castings, material cost
Weaknesses	post processing, messy liquids	size and weight, fragile parts, limited materials, part size	size and weight, system price, surface finish	speed	speed, limited materials, part size	limited materials, fragile parts, finish	part stability, smoke, finish and accuracy
System Price	\$75-800K	\$50K	\$300K	\$30-300K	\$70K-80K	\$30K-70K	\$120-240K
Material Costs \$/pound							
plastics	\$75-110	\$100	\$30-80	\$115-185	\$100		\$8
metal			\$25-30				
other			\$5			starch:	\$5.8 (paper)
			(foundry sand)			\$0.35 / cu in	
						plaster:	
					\$0.80 / cu in		
					+infiltrant		

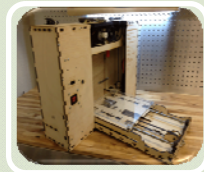




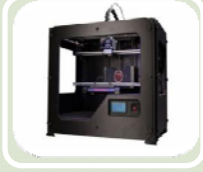
Rep Rap  
**Model:**  
RepRapPr  
o Huxley  
**Price:**  
\$599



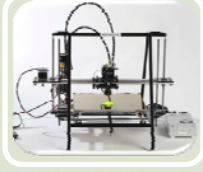
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Delta Micro  
Up Afinia  
H-Series  
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\$1,500



Printrbot  
**Model:**  
Printrbot  
GO  
**Price:**  
\$1,500



Makerbot  
**Model:**  
Replicator  
2x  
**Price:**  
\$2,800



The Future  
is 3D  
**Model:**  
Glacier  
Steel  
**Price:**  
3000



3D  
Systems  
**Model:**  
CubeX  
**Price:**  
\$3000



Formlabs  
**Model:**  
Form 1  
**Price:**  
\$3,300



Stratasys  
**Model:** U  
print SE  
Plus  
**Price:**  
\$15,000

# Komparacija RP tehnologija

Process	Advantages	Disadvantages
SLA (3D Systems)	<ul style="list-style-type: none"> <li>– High dimensional accuracy</li> <li>– Excellent reproduction of thin structures</li> <li>– Allows the visualization of inner structures (translucent material)</li> <li>– Excellent screws fixation</li> <li>– Possibility of constructing color prototypes (two colors)</li> </ul>	<ul style="list-style-type: none"> <li>– Difficult surfaces visualization in prototypes constructed of translucent material (Figure 5)</li> <li>– High cost</li> </ul>
SLS (3D Systems)	<ul style="list-style-type: none"> <li>– Good dimensional accuracy</li> <li>– Excellent reproduction of thin structures</li> <li>– Excellent screws fixation</li> <li>– Autoclave sterilizable</li> <li>– Bone verisimilitude</li> </ul>	<ul style="list-style-type: none"> <li>– Extremely hard material</li> <li>– High cost</li> </ul>
FDM (Stratasys)	<ul style="list-style-type: none"> <li>– Good dimensional accuracy</li> <li>– Good reproduction of thin structures</li> <li>– Excellent screws fixation</li> </ul>	<ul style="list-style-type: none"> <li>– Extremely hard material</li> <li>– Baixa velocidade de construção</li> <li>– Slow construction</li> </ul>
3DP (Z Corporation)	<ul style="list-style-type: none"> <li>– Low cost</li> <li>– Rapid construction</li> <li>– Cutting facility</li> <li>– Possibility of constructing color prototypes (many simultaneous colors)</li> <li>– Bone verisimilitude</li> </ul>	<ul style="list-style-type: none"> <li>– Reasonable dimensional accuracy</li> <li>– Reasonable reproduction of thin structures</li> <li>– Surface porosity</li> <li>– Cutting dust release</li> </ul>
Polyjet (Objet)	<ul style="list-style-type: none"> <li>– High dimensional accuracy</li> <li>– Excellent reproduction of thin structures</li> <li>– Allows the visualization of inner structures (translucent material)</li> <li>– Excellent screws fixation</li> </ul>	<ul style="list-style-type: none"> <li>– Difficult surfaces visualization in prototypes constructed of translucent material</li> <li>– High cost</li> </ul>

# Komparacija RP tehnologija sa konvencionalnim tehnologijama za generisanje modela

## Materijal

# Alati

## Konstrukcija prototipa

## Kompatibilität

## Tačnost

