

Rapid Prototyping

The Technologies & Applications of
Rapid Prototyping & Rapid Tooling

Definitions

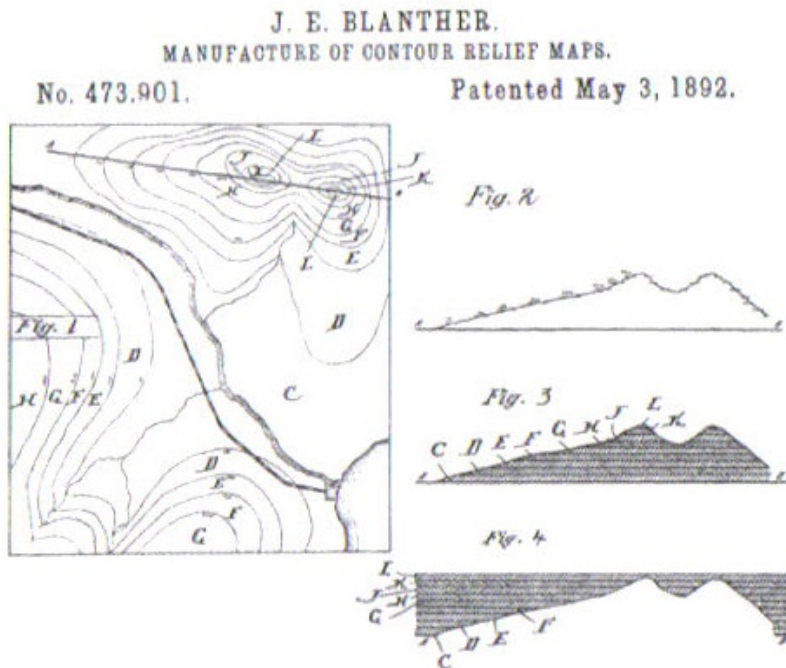
- Rapid Prototyping
 - Quickly creating physical models & functional prototypes directly from CAD models
- Rapid Tooling
 - The production of tooling using inserts
- Both RP & RT are means for **compressing the time-to-market** of products & as such, are **competitiveness enhancing** technologies.
- RP technologies can be virtual & physical

Virtual Prototyping (VP)

- Virtual Prototyping (VP) is a means of carrying out the:
 - analysis
 - simulationof products by employing digital mock-ups (3D product representations).
- Product performance can be investigated before any physical parts are built.
- VP is tightly integrated with CAD/CAM
- VP is often referred to as Computer Aided Engineering (CAE)

Historical Perspectives

The roots of RP can be traced to two areas



– Topography

- Topological relief maps using wax plates (, 1892)
- Layering process from metallic contoured (milled) sheets. (DiMatteo, 1976)

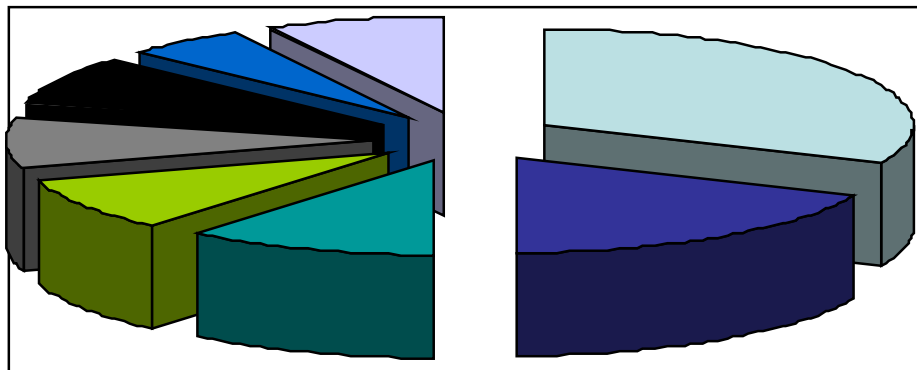
– Photosculpture

- Creating replicas of 3D objects.
- Photographing the object simultaneously with 24 cameras equally spaced around a circular room
- Use each photograph to carve 1/24th of a cylindrical portion of the object
- In 1956 Munz developed & patented a layer manufacturing system for fabricating the cross-sections

Active RP Patents *Beaman, 1997*

Name	Title	Filed	Country
Housholder	Moulding process	Dec 79	U.S.
Murutani	Optical mould method	May 84	Japan
Masters	Computer automated manufacturing process & system	Jul 84	U.S.
Andre et al.	Apparatus for making model of an industrial part	Jul 84	France
Hull	Apparatus for making three-dimensional objects by stereolithography	Aug 84	U.S.
Pomerantz et al.	Three-dimensional mapping and modelling apparatus	Jun 86	Israel
Feygin	Apparatus & method for forming an integral object from laminations	Jun 86	U.S.
Deckard	Method & apparatus for producing parts by selective sintering	Oct 86	U.S.
Fudim	Method & apparatus for producing three-dimensional objects by photosolidification; radiating an uncured photopolymer	Feb 87	U.S.
Arcella et al.	Casting shapes	Mar 87	U.S.
Crump	Apparatus and method for creating three dimensional objects	Oct 89	U.S.
Helinski	Method & means for constructing three-dimensional articles by particle deposition	Nov 89	U.S.
Marcus	Gas phase selective beam deposition: three-dimensional, computer-controlled	Dec 89	U.S.
Sachs et al.	Three-dimensional printing	Dec 89	U.S.
Levent et al.	Method and apparatus for fabricating three-dimensional articles by thermal stray deposition	Dec 90	U.S.
Penn	System, method and process for making three-dimensional objects	Jun 92	U.S.

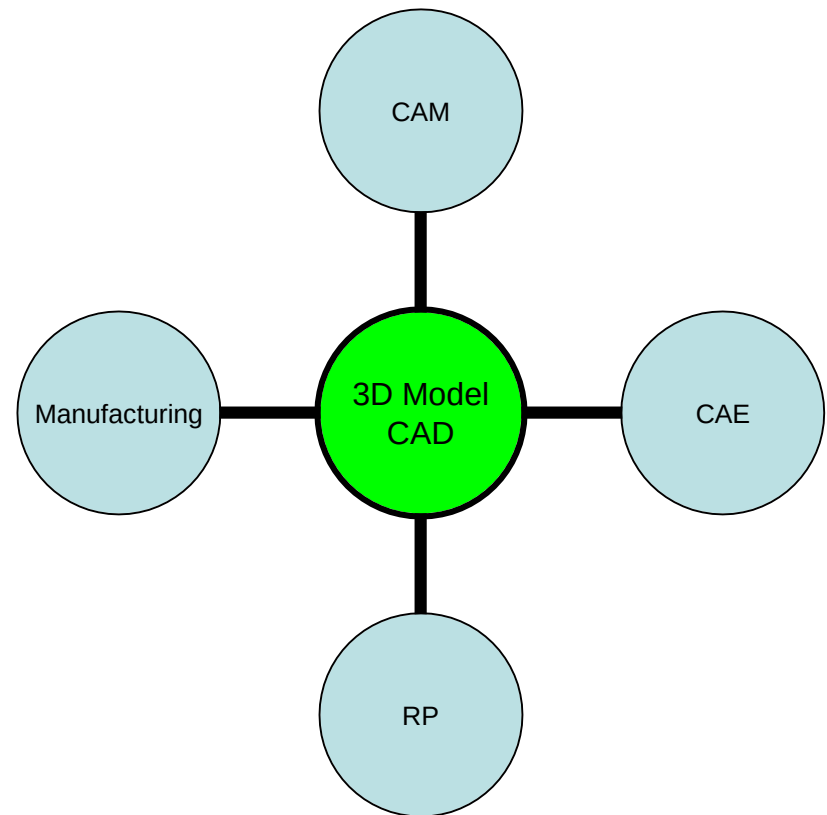
The use of RP Systems in Different Sectors



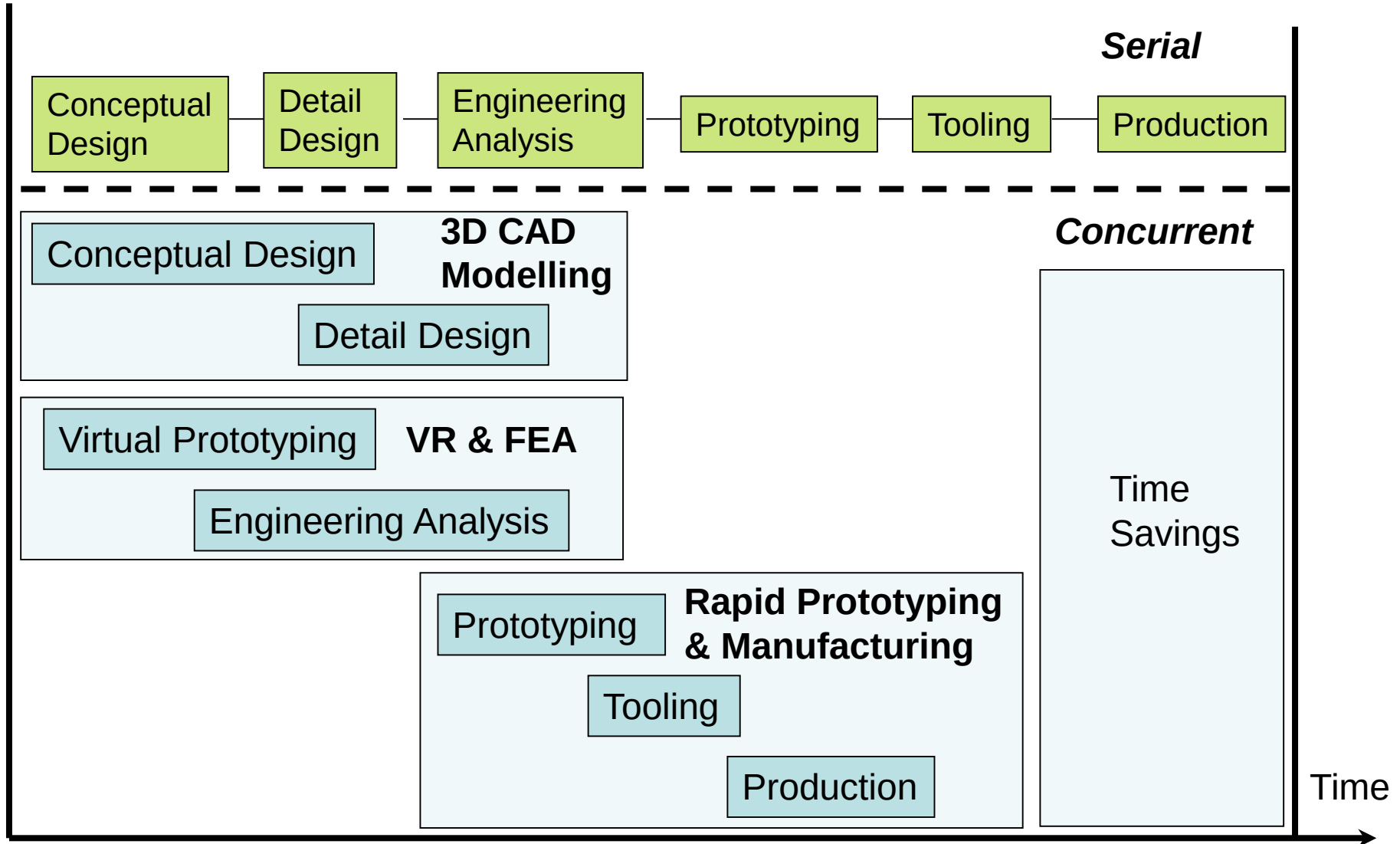
- Motor Vehicles
- Consumer Products
- Buisness Machines
- Medical
- Academic
- Aerospace
- Government / Military
- Others

RP & TCE

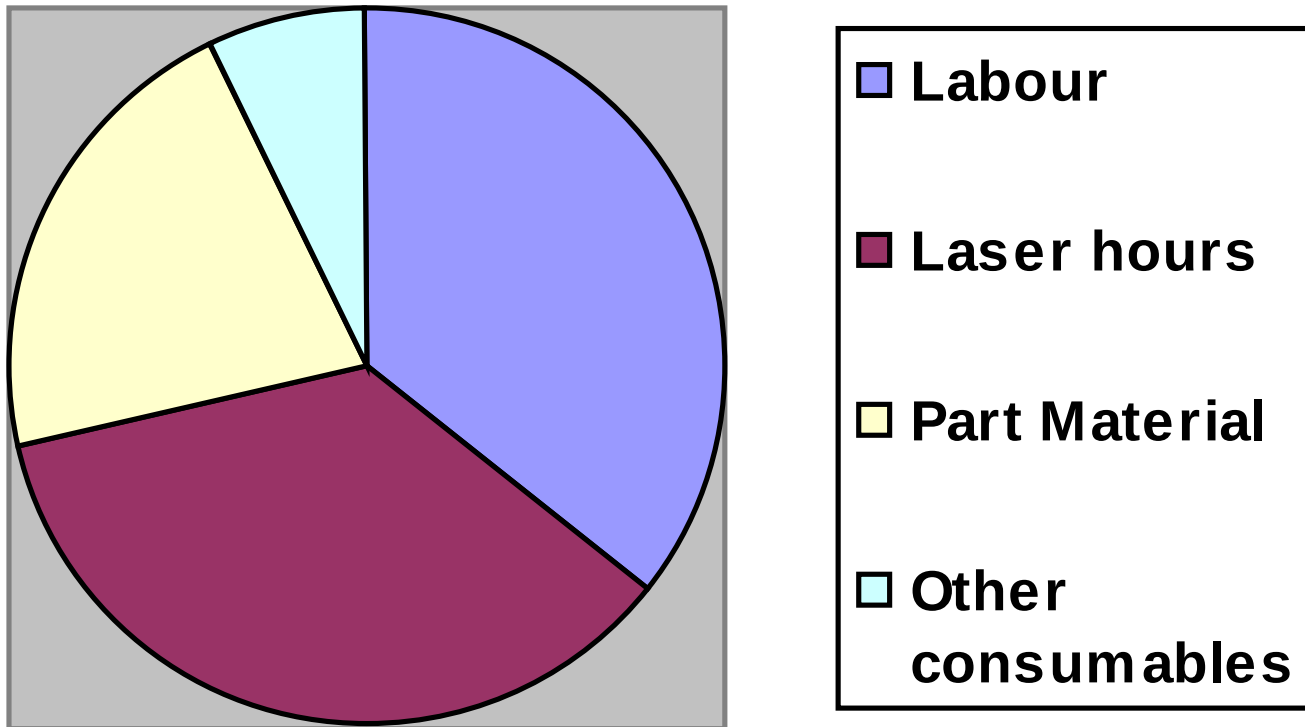
- Time-Compression-Engineering (TCE)
- Concurrent engineering
- 3D CAD modelling integrated with:
 - Computer Aided Manufacturing (CAM)
 - Computer Aided Engineering (CAE)
 - Rapid Prototyping (RP)
 - Manufacturing



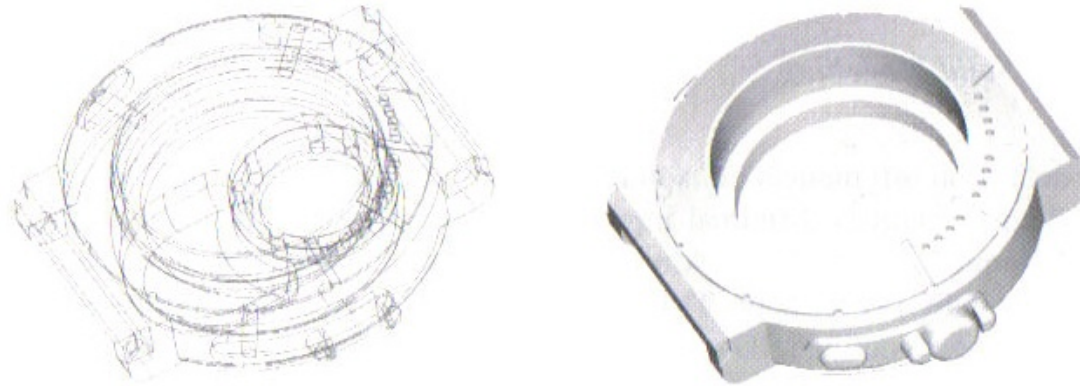
Time Compression Engineering (TCE)



RP Costing (*SICA*, 2016)



Geometric Modelling Techniques



Wireframe Modelling

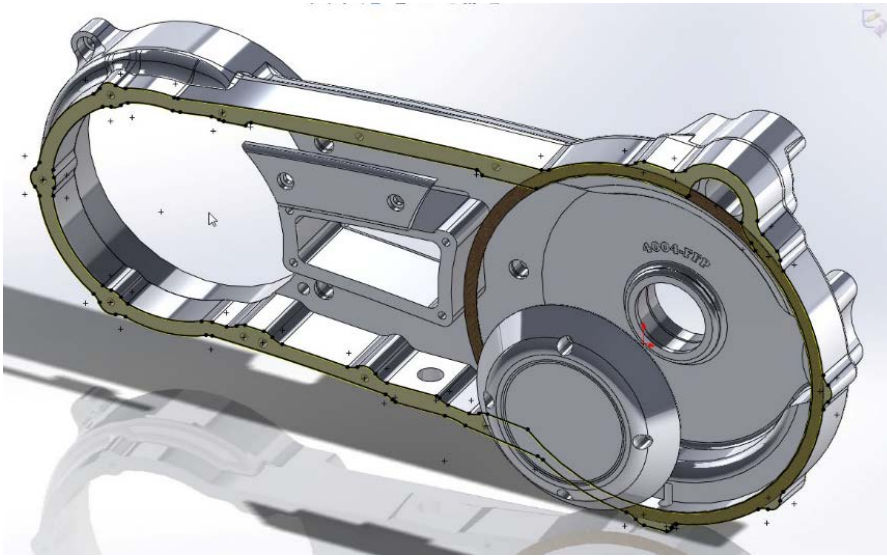
- Graphical primitives
- Lengthy & difficult process
- 3D Designs can not be interpreted uniquely
- Complex designs impossible to interpret
- Edges & lines can be hidden to help interpretation
- Most 3D wireframe packages are only used in 2D within industry
- No surface volume data so unusable for RP

Geometric Modelling Techniques

Surface Modelling

- Based on wireframe models
- Vertices & edges of wireframe define the boundaries of surfaces
- Data is sufficient for use in basic CAM packages
- Can only be regarded as a set of surfaces belonging to one object
- If one edge is common to two surfaces this data is not stored in the model
- Gaps between surfaces mean that surface models can not define closed volumes
- To use a surface model for RP the gaps need to be removed

Geometric Modelling Techniques



Solid Modelling

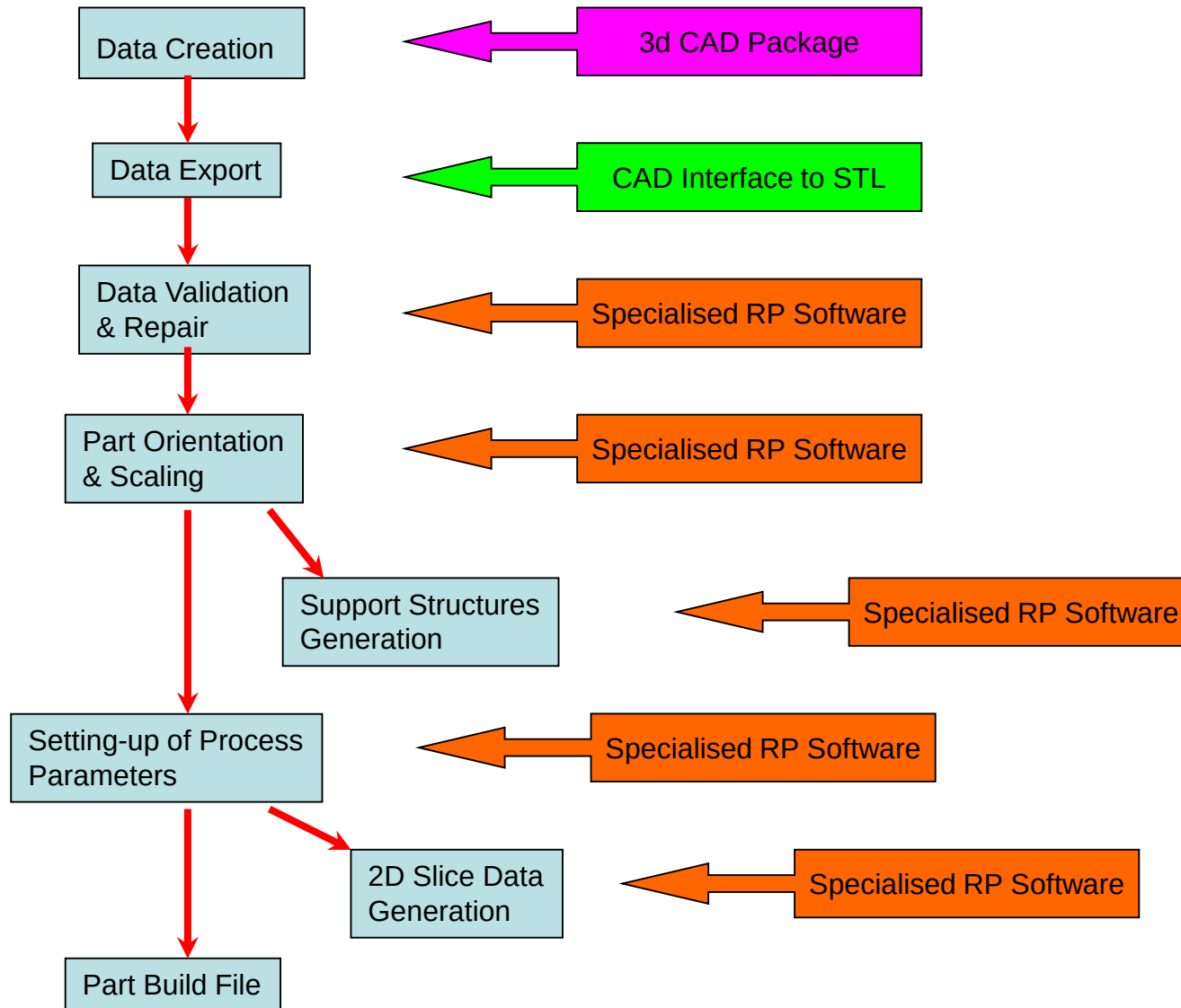
- The definition of solid models is relatively easy
- The user interface allows complex geometries to be built from a set of predefined 3D primitives & boolean operations
- Solid modelling is acknowledged as the key element in the integration of design & manufacturing (Zeid, 1991)
- Solid modelling is now considered the most reliable way of creating 3D models for RP purposes

RP Information Workflow

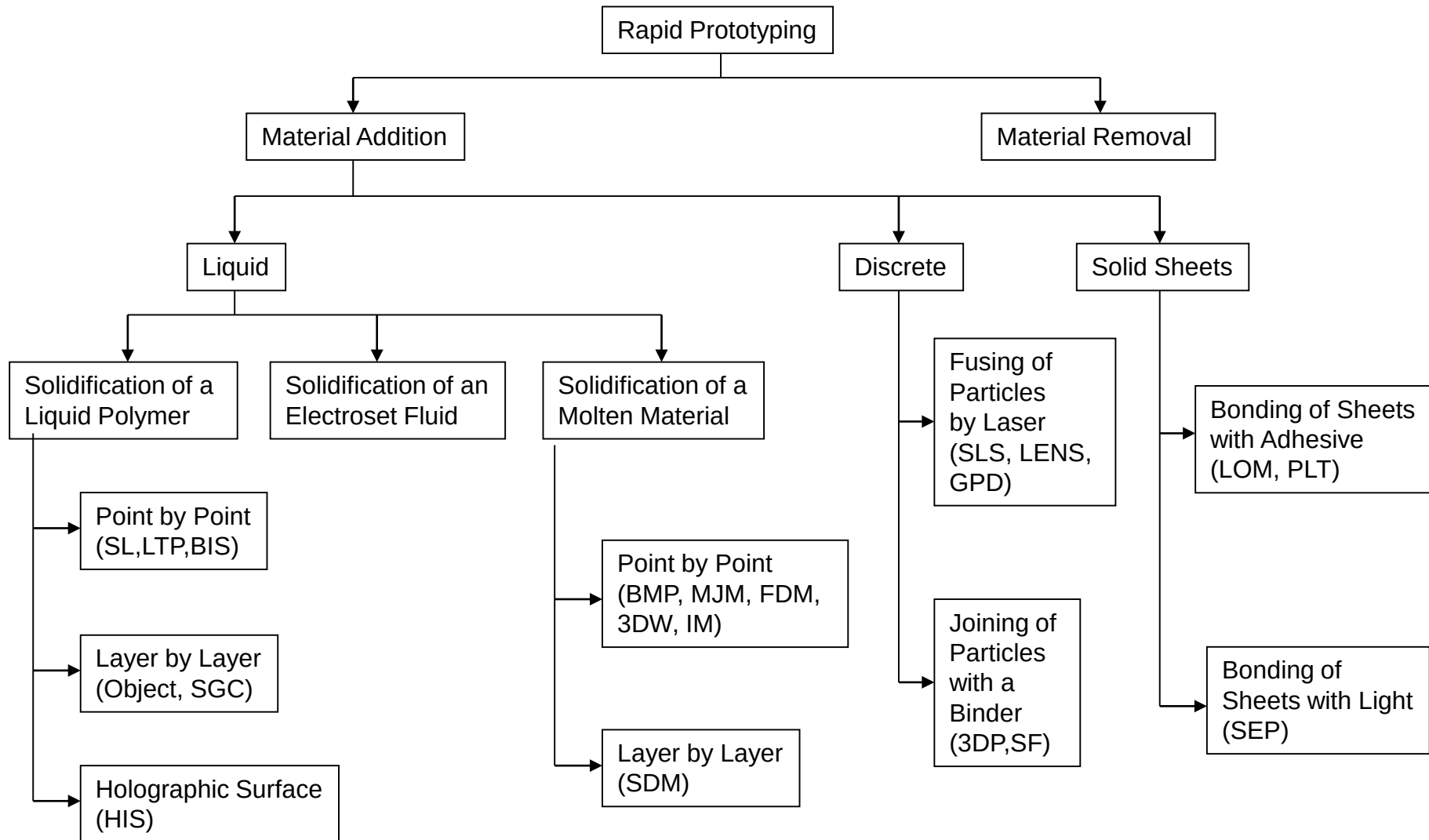
All RP systems have a common information workflow

- 1) Data Creation
- 2) Data Export
- 3) Data Validation & Repair
- 4) Part Orientation & Scaling
- 5) Support Structures Generation
- 6) Setting-up of Process Parameters
- 7) 2D Slice Data Generation

RP Information Workflow



Rapid Prototyping Processes

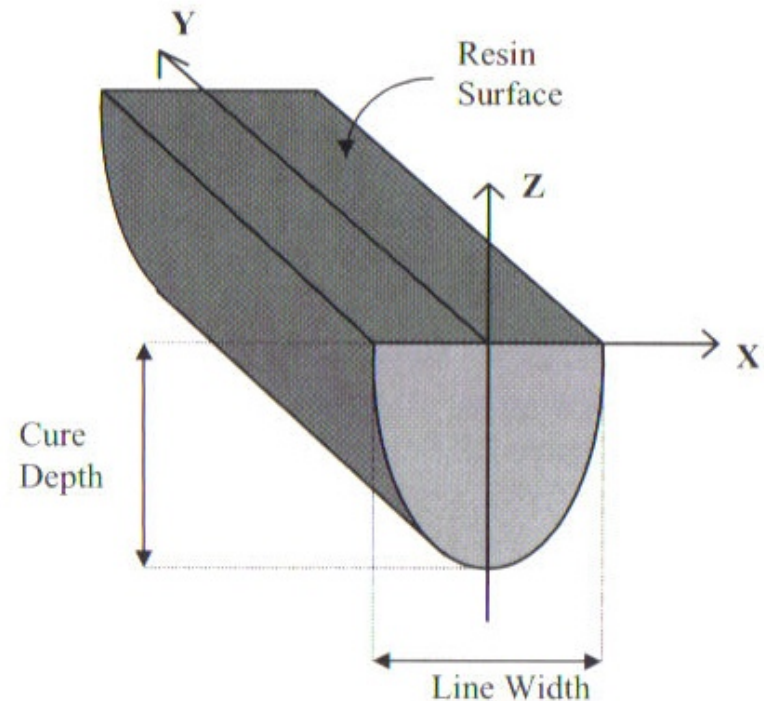


<https://clickv.ie/w/tZGI>

<https://www.youtube.com/watch?v=NYDzsPvywPc>

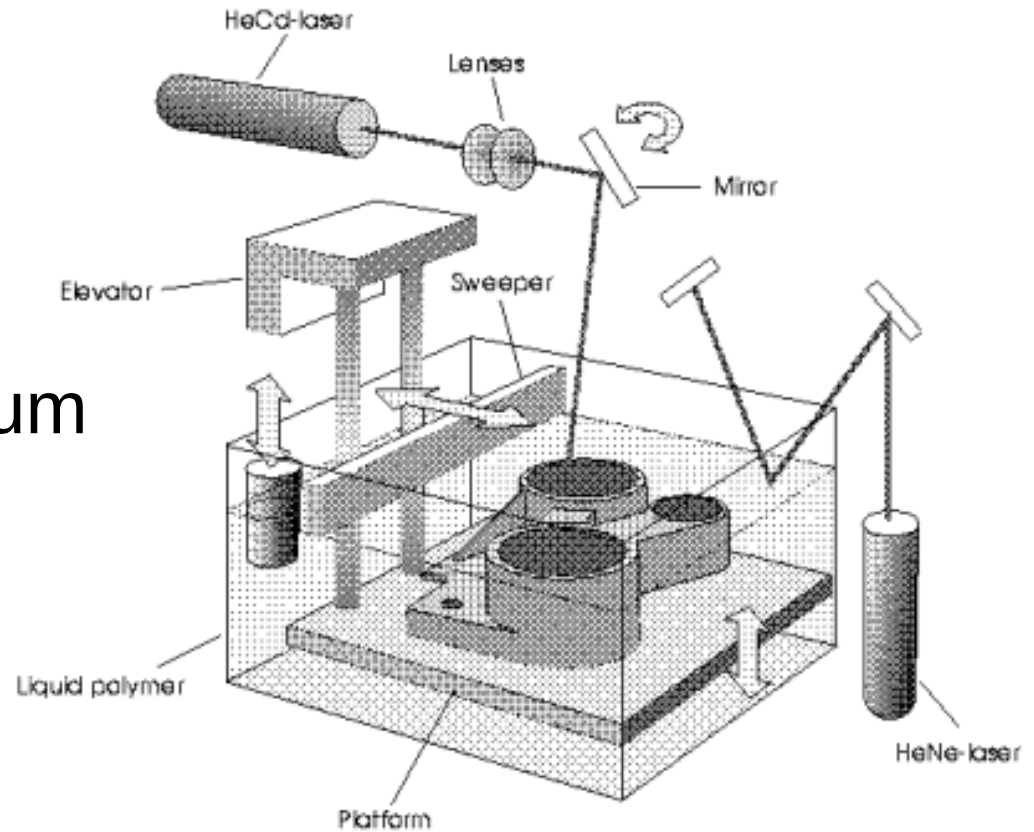
Stereolithography (SL)

- Most widespread RP technology
- Photosensitive liquid resin
- Forms a solid polymer when exposed to UV light
- Absorption & scattering of beam minimises curing depth
- Voxels (3D pixels) characterised by:
 - Line width (horizontal)
 - Cure depth (vertical)



Stereolithography (SL) Apparatus Components

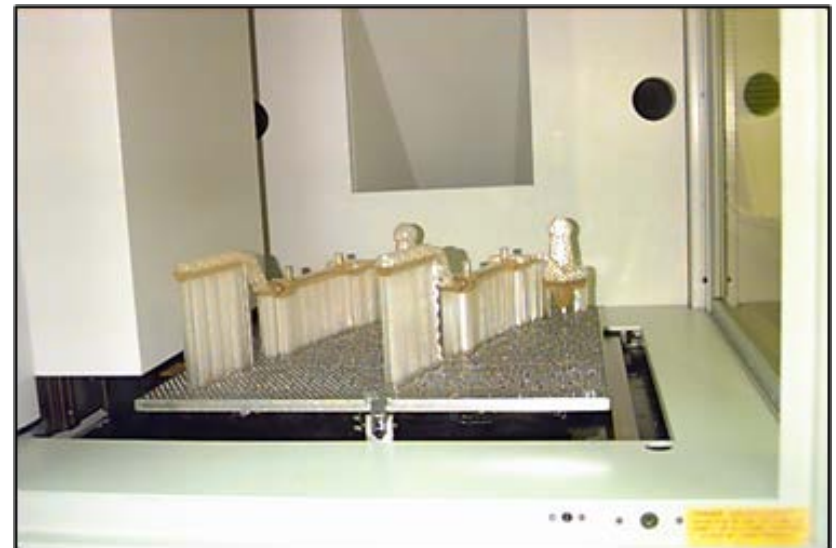
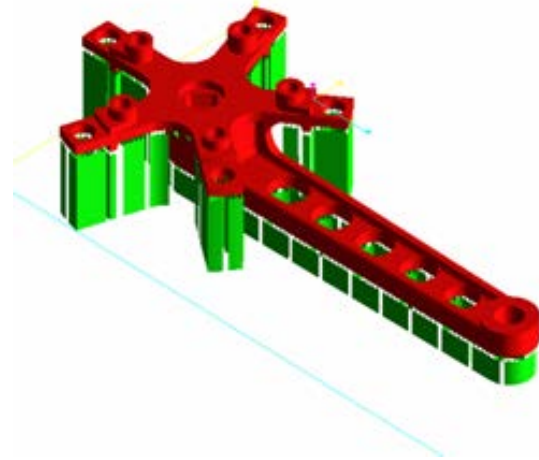
- Build platform (substrate)
- Vat (resin)
- UV Helium-Cadmium or Argon ion laser
- Mirror
- Sweep Blade



Stereolithography (SL)

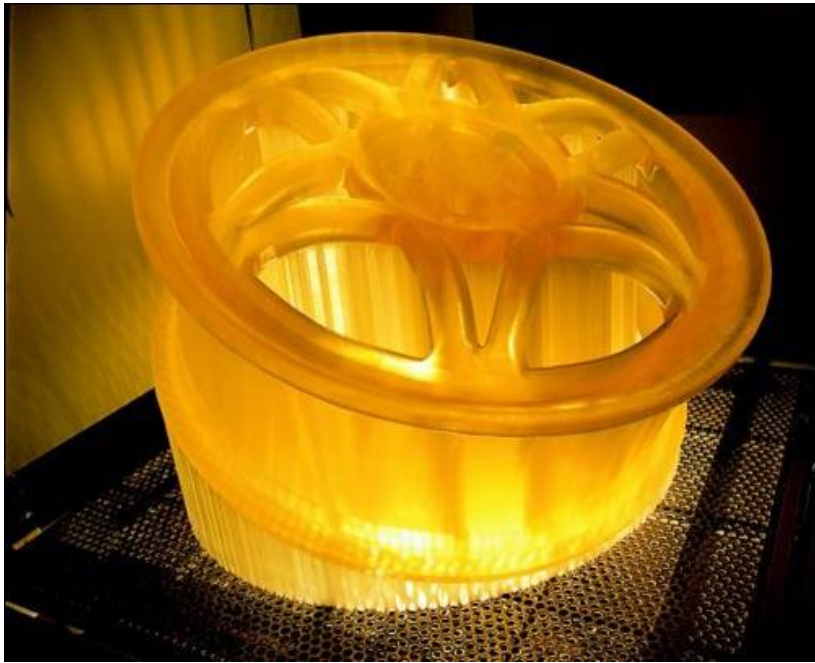
General RP Sequence

- Final Build File
 - Part sliced
 - Supports sliced
 - RP technology parameters set layer thickness, scan speed etc.
 - Send file to RP machine
- Fabrication of part/s
 - Models built on SLA
 - Parts & supports shown attached to platform
- Post processing
 - Removal of part from platform
 - Removal of supports from part
 - Cleaning of part (wiping, rinsing)
 - Curing (UV Oven)
 - Finished part (sanding, polishing)



Stereolithography (SL)

Applications / Examples

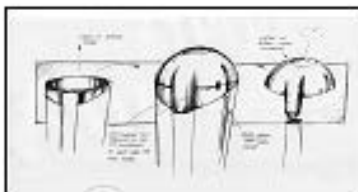


Stereolithography (SL)

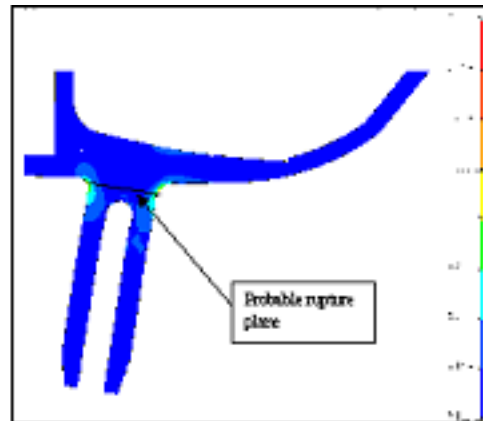
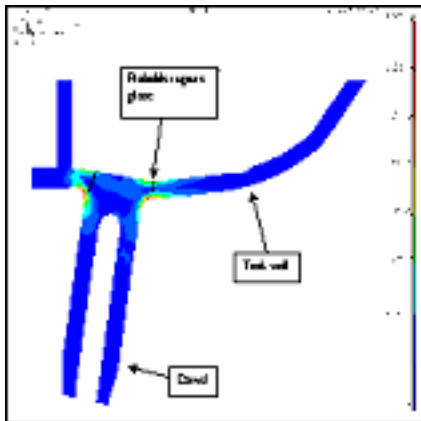
Applications / Examples



Case Studies



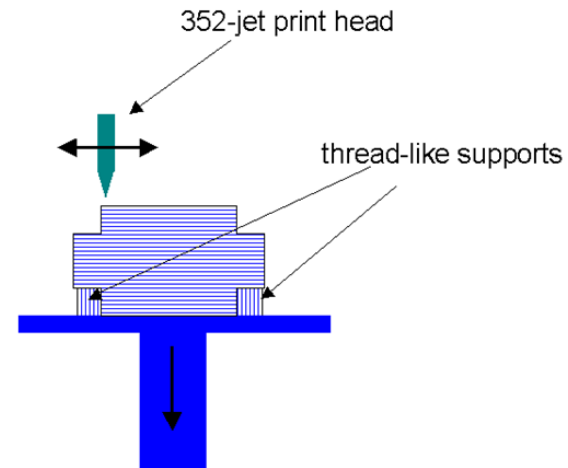
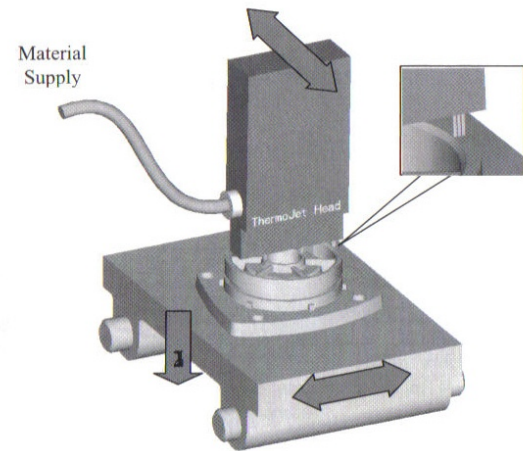
Case Studies



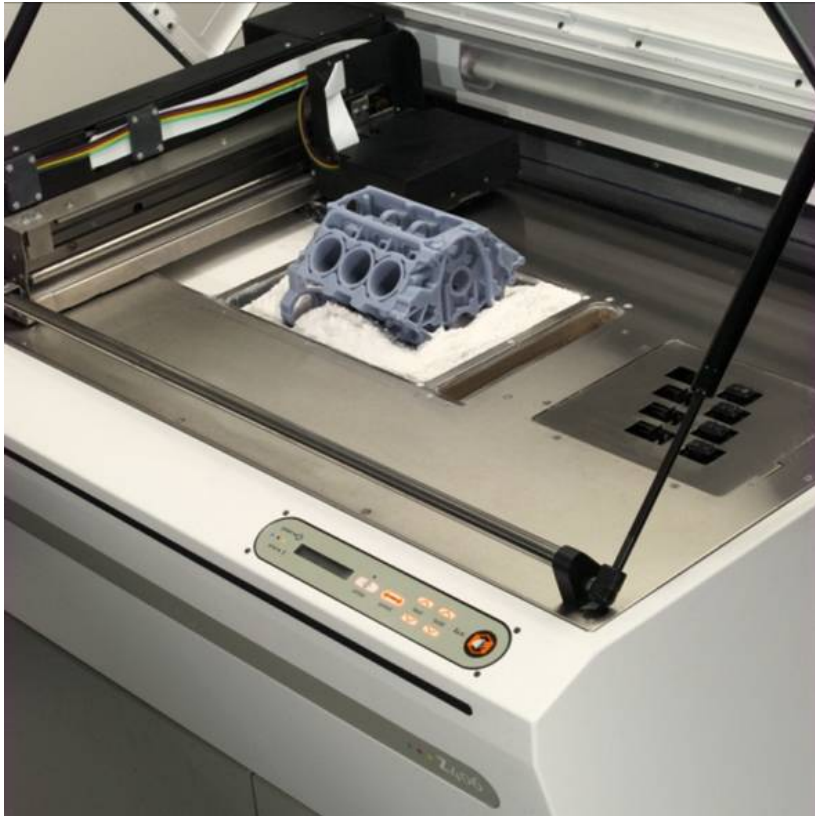
Commercially Utilised RP Technologies

Multi Jet Modelling / 3D Printing (MJM)

- MJM uses inkjet printing technology
- Uses a print head with 352 jets (linear)
- Jets deposit a special thermo-polymer material in successive layers
- Layer thickness is $40\mu\text{m}$
- The head shuttles across the x axis like a printer
- As each layer is finished the platform is moved away from the head (Z axis)

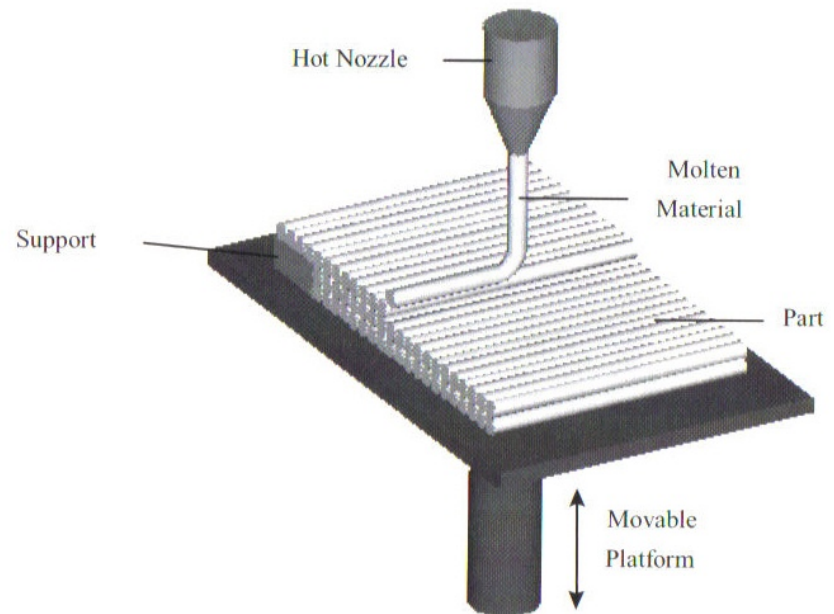


Multi Jet Modelling / 3D Printing (MJM)

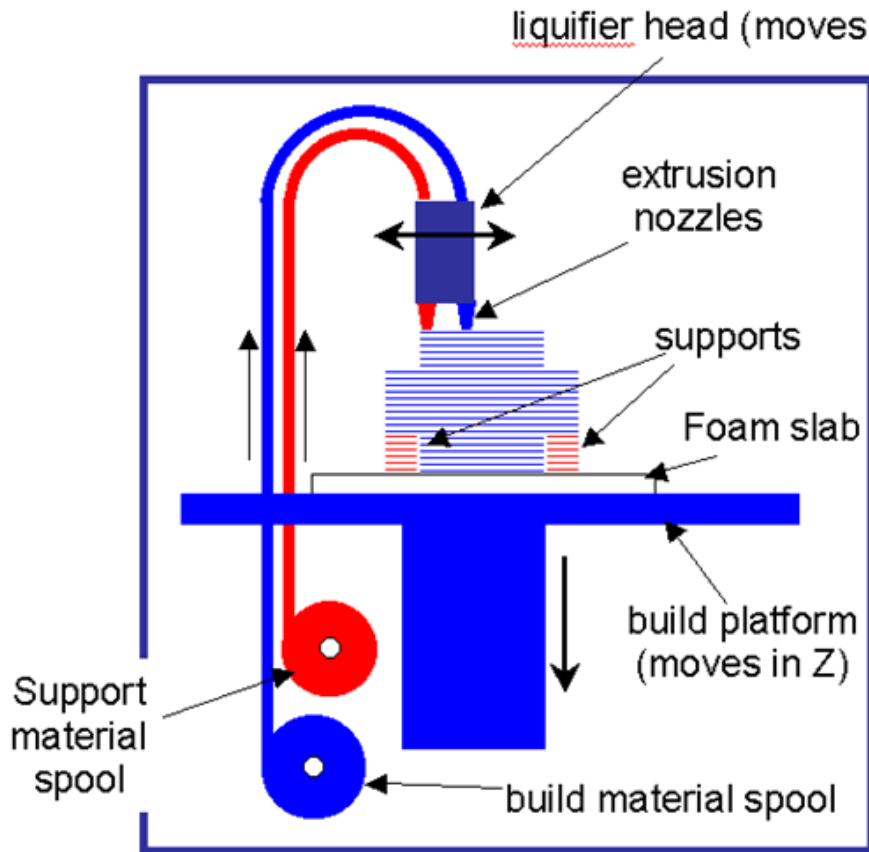


Fused Deposition Modelling (FDM)

- Movable head deposits a thread of molten material onto a substrate
- Build material is heated to 0.5° above its MP
- The material solidifies approx 0.1s after extrusion cold welding onto previous layer
- Steady nozzle speed & support structures necessary
- Newer systems use two nozzles
 - 1) Model material
 - 2) Support material
- Accuracy 375 microns

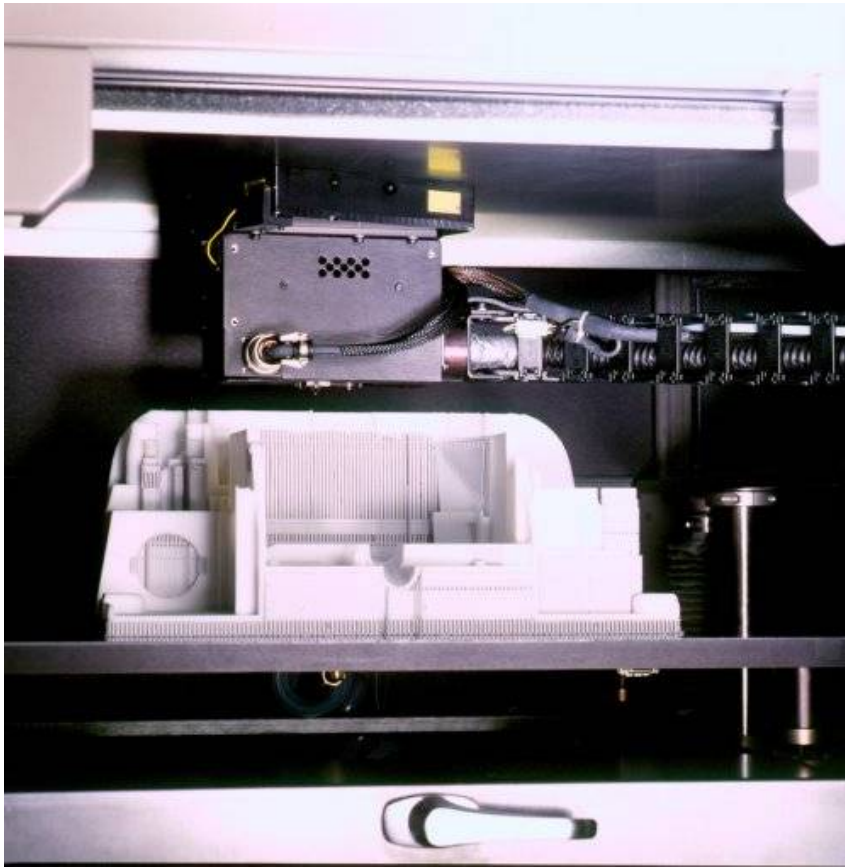


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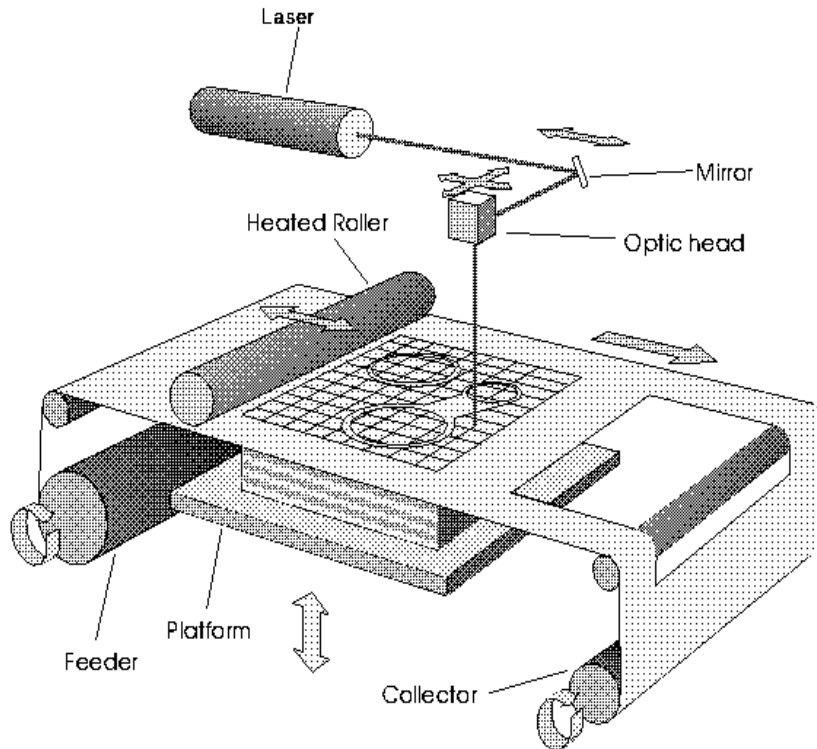


- Advantages
 - ABS Material
 - Function testing
- Disadvantages
 - Surface finish not as good as SLS process
 - Long build times

Fused Deposition Modelling (FDM)

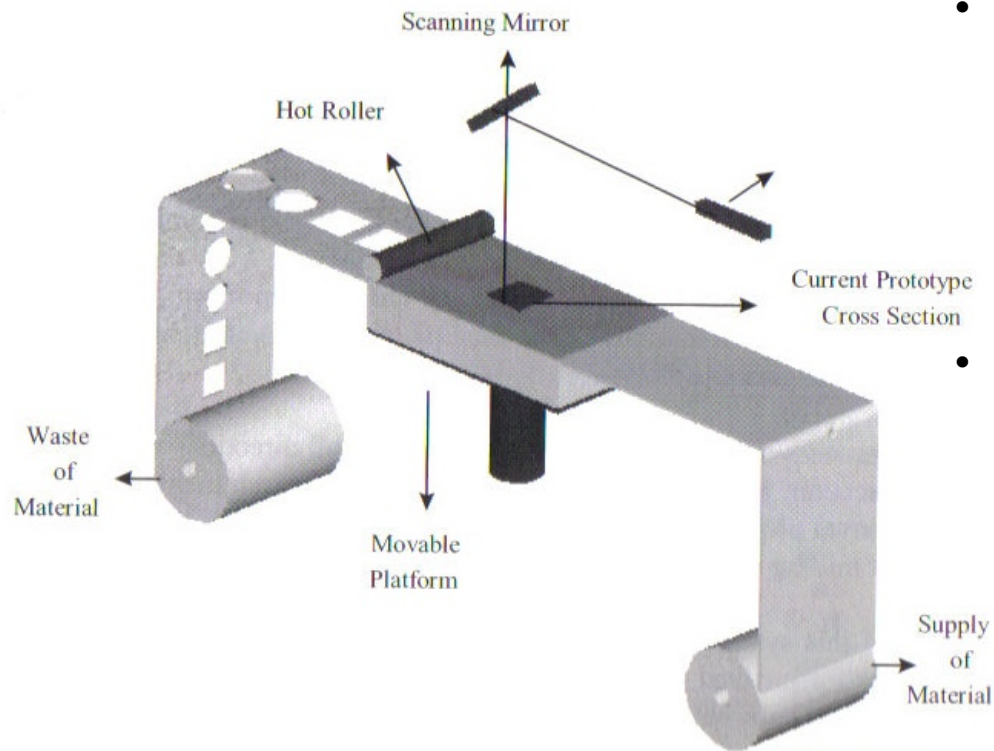


Laminate Object Manufacturing (LOM)



- Build material is applied to the part from a roll
- A hot roller bonds the material to the part by activating a heat sensitive adhesive
- Each layers contour is profiled by a laser
- The laser beam (25 or 50 Watt CO₂) is modulated to penetrate only one layer at a time
- Unwanted material is trimmed into rectangles but remains in place during the build
- Build may be stopped to excavate material

Laminate Object Manufacturing (LOM)



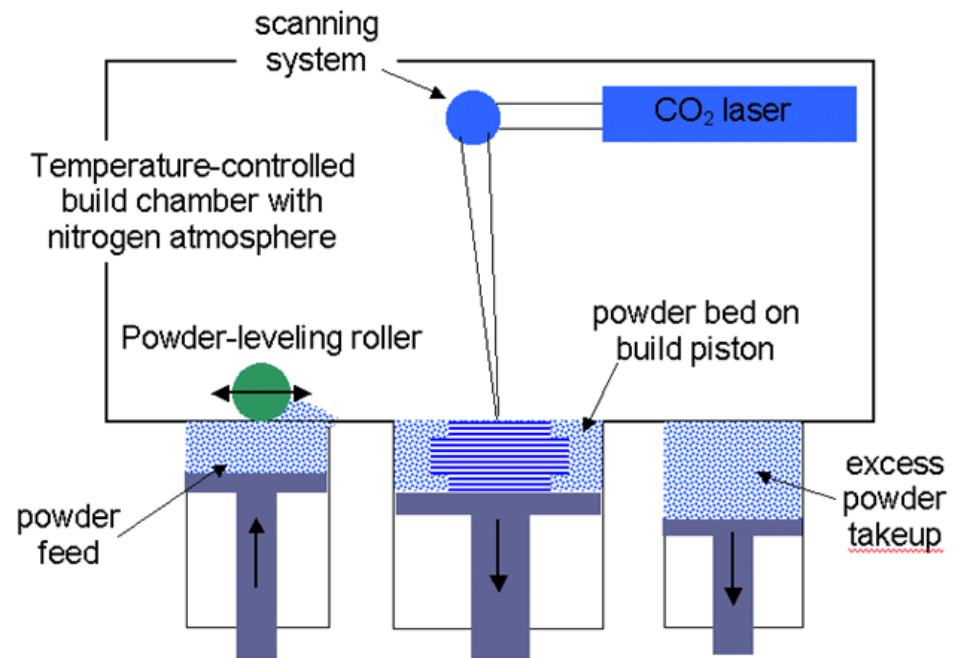
- Advantages
 - Range of lamination materials
 - Large parts can be produced
 - Wooden appearance
 - Speed of manufacture (cutting profile only) 5 to 10 times faster than SLA
- Disadvantages
 - Poor surface finish
 - Difficult to produce hollow parts
 - Hi scrap rates
 - Machines need to be constantly manned
 - Parts must be hand finished
 - Laser cutting presents a fire hazard
 - Finished part must be epoxy coated

Laminate Object Manufacturing (LOM)

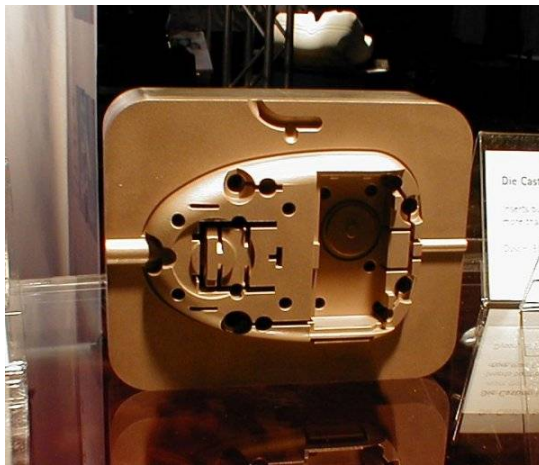


Selective Laser Sintering (SLS)

- Fine powder is heated by a CO₂ laser
- Surface tension of particles is overcome and they fuse together
- Before sintering the entire bed is heated to just below melting point
 - Minimize thermal distortion
 - Facilitates fusing to the previous layer
- Once the layer has been sintered
 - Bed is lowered
 - Powder feed is raised
 - Roller spreads powder evenly



Selective Laser Sintering (SLS)



- Advantages
 - No supports – powder support
 - No post processing
 - Can be used for physical testing
- Disadvantages
 - Rough surface finish
 - Long build times