Unit- 6

Rapid Prototyping

Content

- Classification of RPT systems,
- Process chain,
- 3D modelling,
- Data conversion,
- Checking-building- postprocessing,
- Stereolithography (STL)-process, principle,
- CAD for RPT,
- Creation of STL file from 3D solid models

Additive Manufacturing

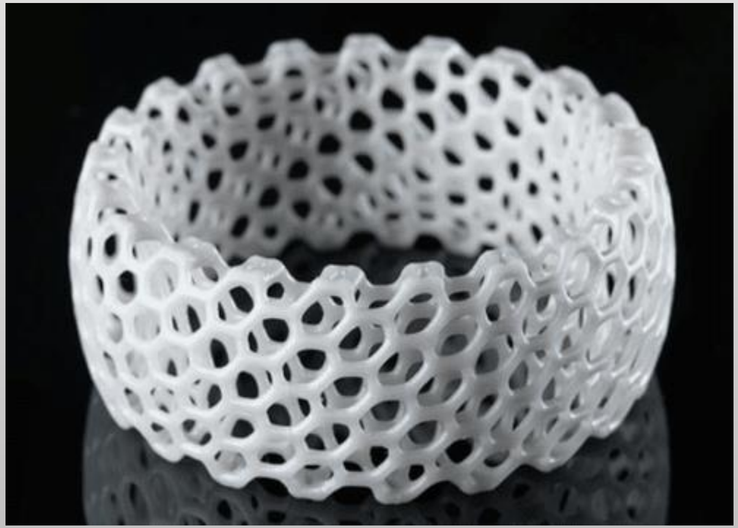
Additive manufacturing (AM), also known as **3D printing**, is a process in which a three-dimensional object is built from a computer-aided design (CAD) model, usually by successively adding materials in a layer-by-layer fashion.

Stereolithography (SLA)

Stereolithography (SLA)

- **Stereolithography** is a common rapid manufacturing/ rapid prototyping technology for producing parts with high accuracy and good surface finish,
- A device that performs stereolithography is called an SLA or **S**tereo**l**ithography **A**pparatus,
- Stereolithography is an **additive fabrication process** utilizing a vat of liquid UV-curable photopolymer "resin" and a UV laser to build parts a layer at a time,
- On each layer, the laser beam traces a part cross-section pattern on the surface of the liquid resin.

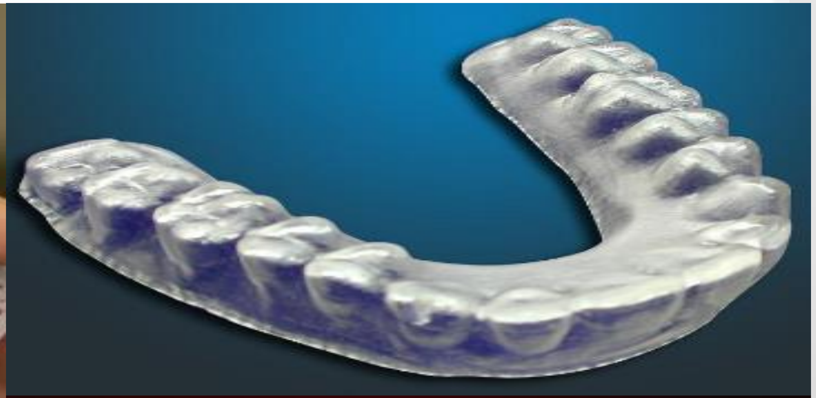
https://www.youtube.com/watch?v=yW4EbCWaJHE&t=39s

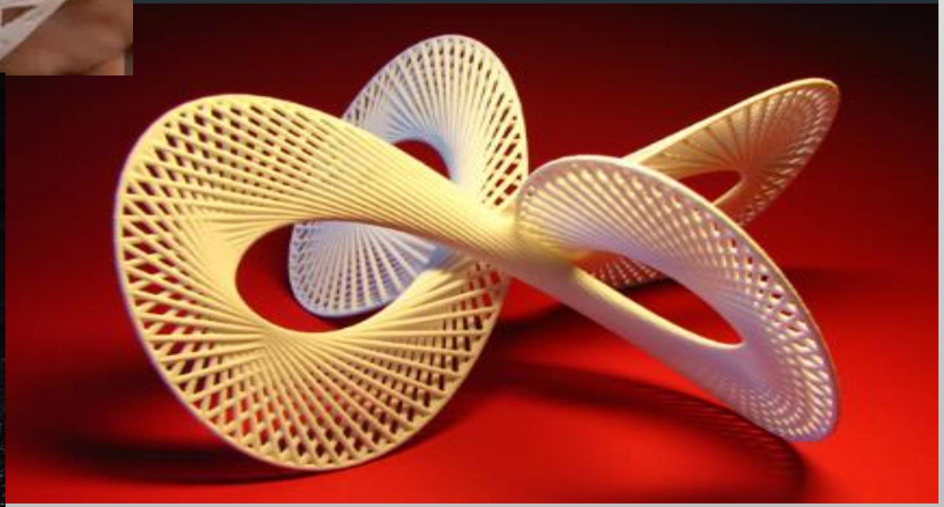


Few example products

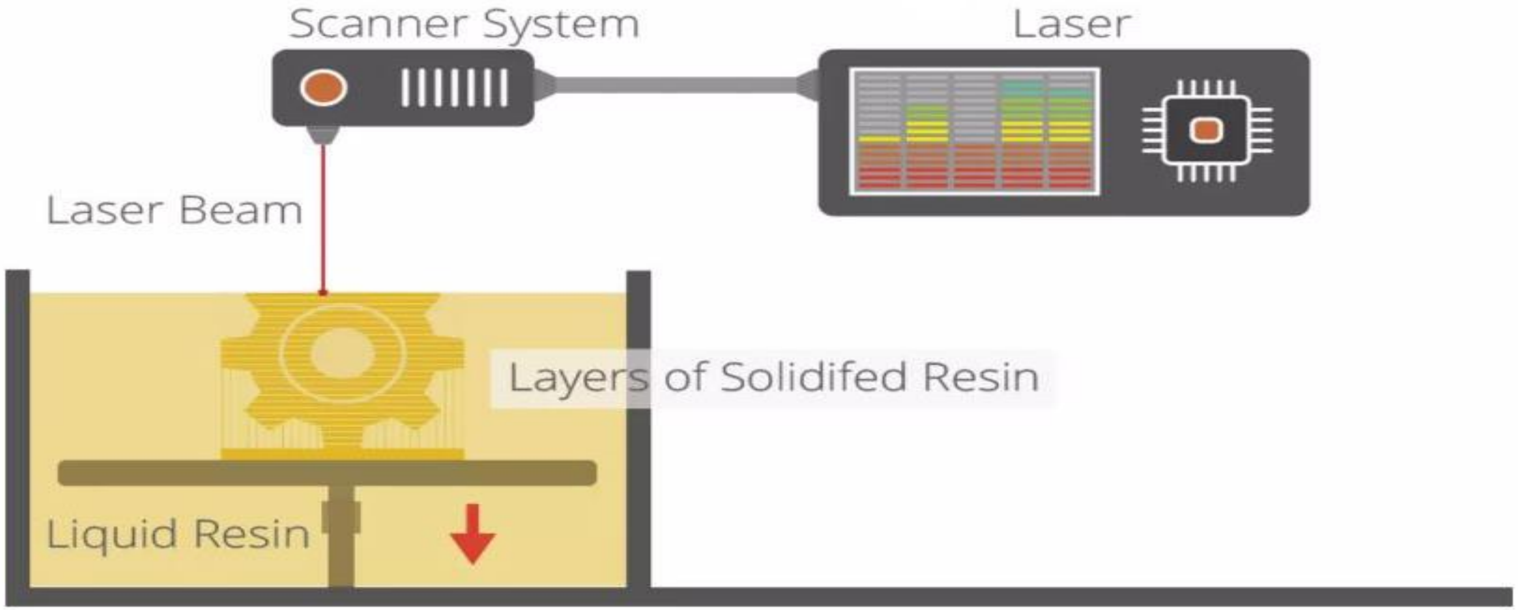






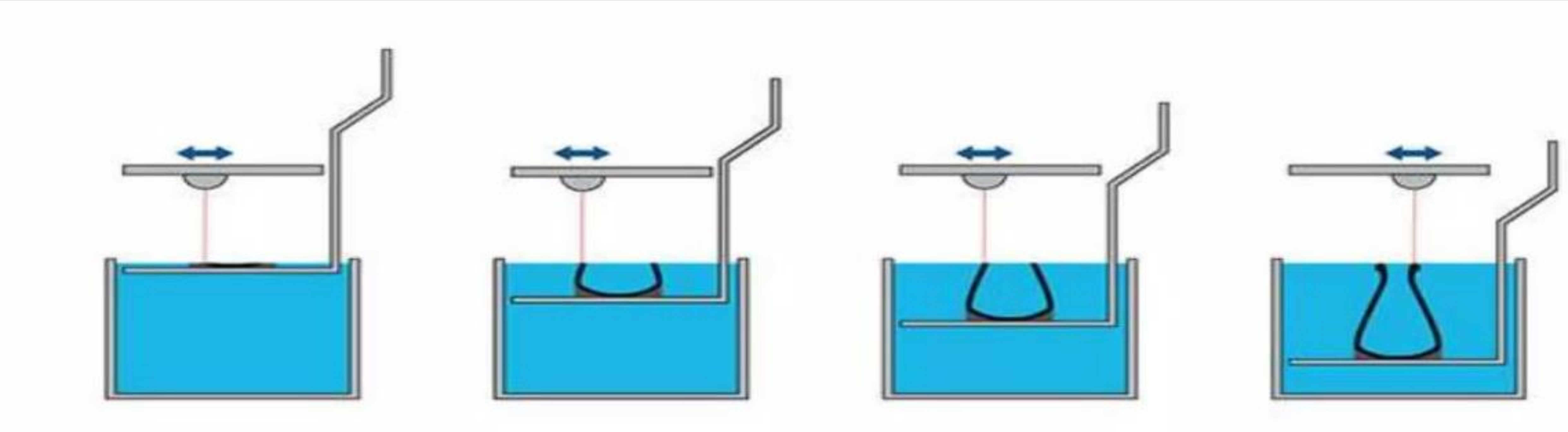
Stereo lithography Process Diagram



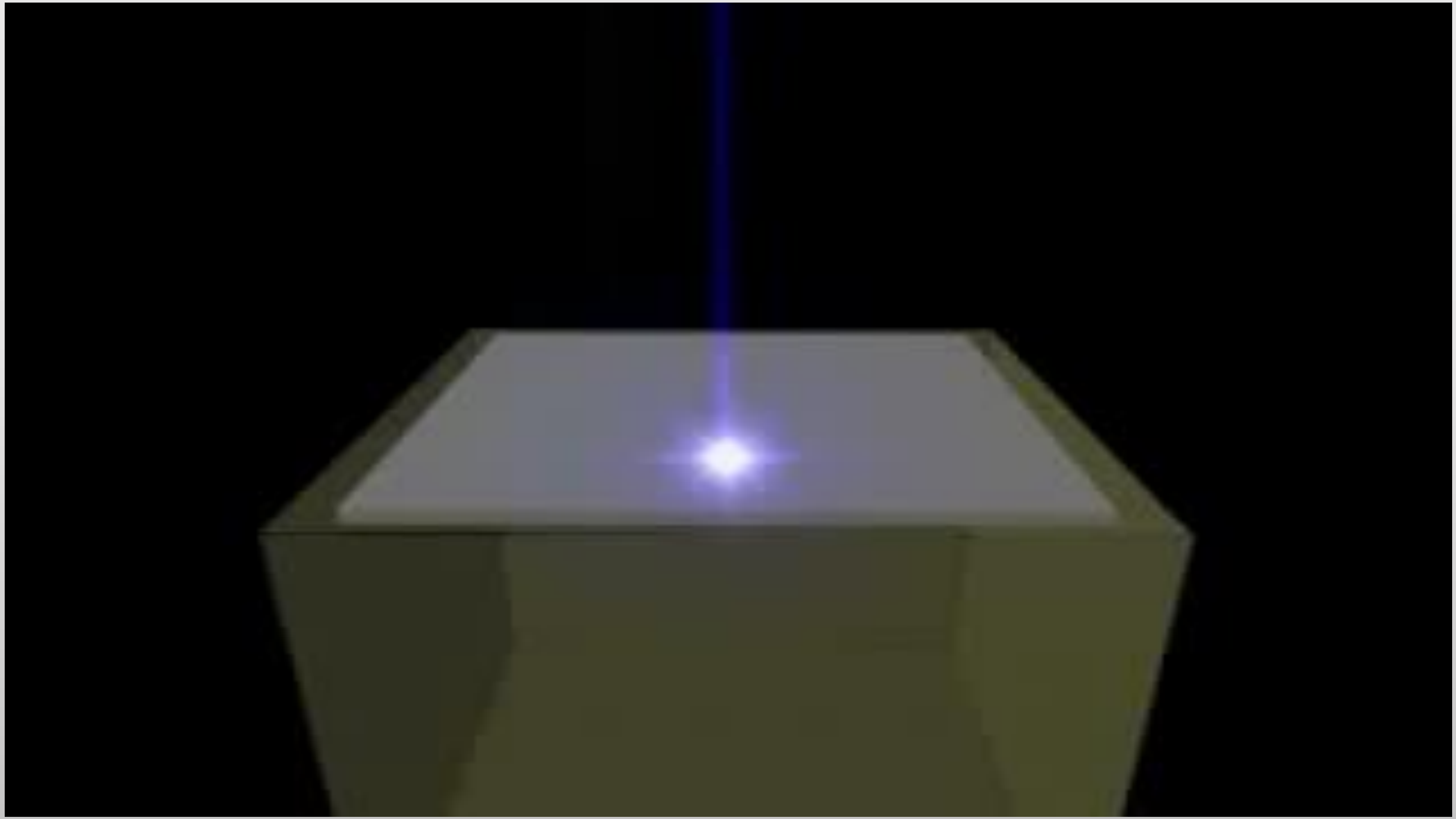
The scanner system here can move in the XY plane.

While the platform moves in Z direction i.e Up and Down building the structure layer by layer.

Stereo lithography Process Diagram

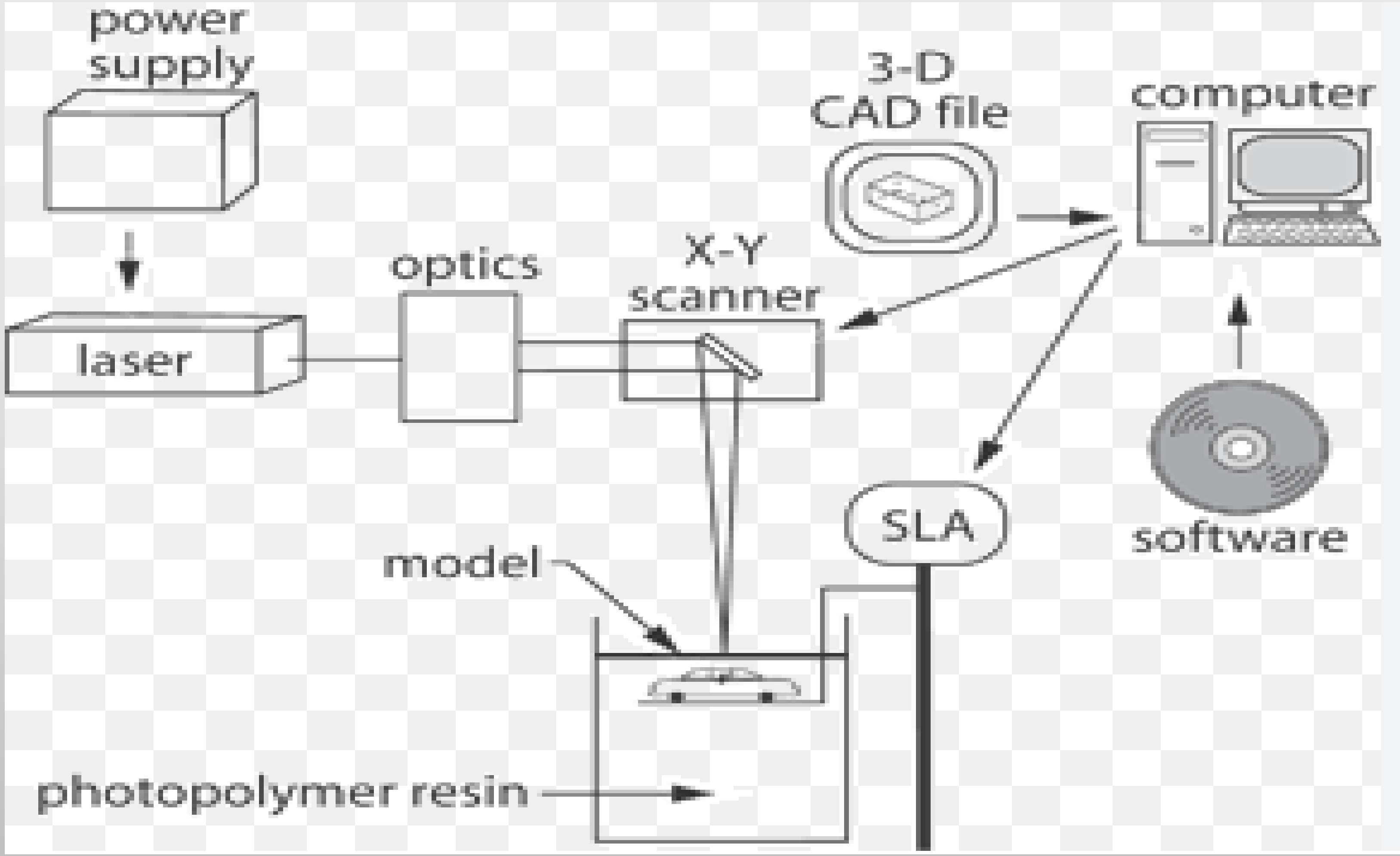


Process animation



Process Video

Stereo Lithography Schematic Diagram



Stereo lithography Highlight

1. The **first RP technique** and is still **most widely** used.
2. **Inexpensive** compared to other techniques.
3. Uses **light-sensitive liquid polymer**.
4. **Requires post-curing** since laser is not of high enough power to complete.
5. **Long-term curing**.
6. Parts are quite **brittle** and have a tacky surface.
7. **Support structures** are typically required.
8. Process is **simple**: There are no milling or masking steps required.
9. Uncured material can be **toxic**.

Technical details of the Process

1. The starting materials are **<u>liquid monomers</u>**
2. Each layer is **<u>0.076 mm to 0.50 mm</u>** (0.003 in to 0.020 in.) thick
3. Thinner layers provide **<u>better resolution</u>** and **<u>more intricate shapes</u>**; but processing time is **<u>longer</u>**
4. Laser scan speeds typically **<u>500 to 2500 mm/s</u>**

Process Overview

1. Stereolithography is one of the more commonly used rapid manufacturing and rapid prototyping technologies.

2. It is considered to provide high accuracy and good surface finish.

3. It involves building plastic parts a layer at a time by tracing a laser beam on the surface of a vat of liquid photopolymer.

4. The photopolymer is solidified by the laser light.

Process Overview

5. Once one layer is completely traced, it is lowered a small distance into the liquid and a subsequent layer is traced, adhering to the previous layer.

6. After many such layers are traced, a complete 3D model is formed.

7. Some specific technologies require further curing of the polymer in an oven."

Process Details – Step by step

1. A **moveable table, or elevator**, initially is placed at a position just below the surface of a **vat** filled with liquid photopolymer resin.

2. This material has the property that when light of the correct color strikes it, it turns from a **liquid to a solid**.

3. The most common photopolymer materials used require an **ultraviolet light**.

4. The system is **sealed** to prevent the escape of fumes from the resin.

Process Details – Step by step

5. A **laser beam** is moved over the **surface of the liquid photopolymer** to trace the geometry of the cross-section of the object.

6. This causes the **liquid to harden** in areas where the laser strikes.

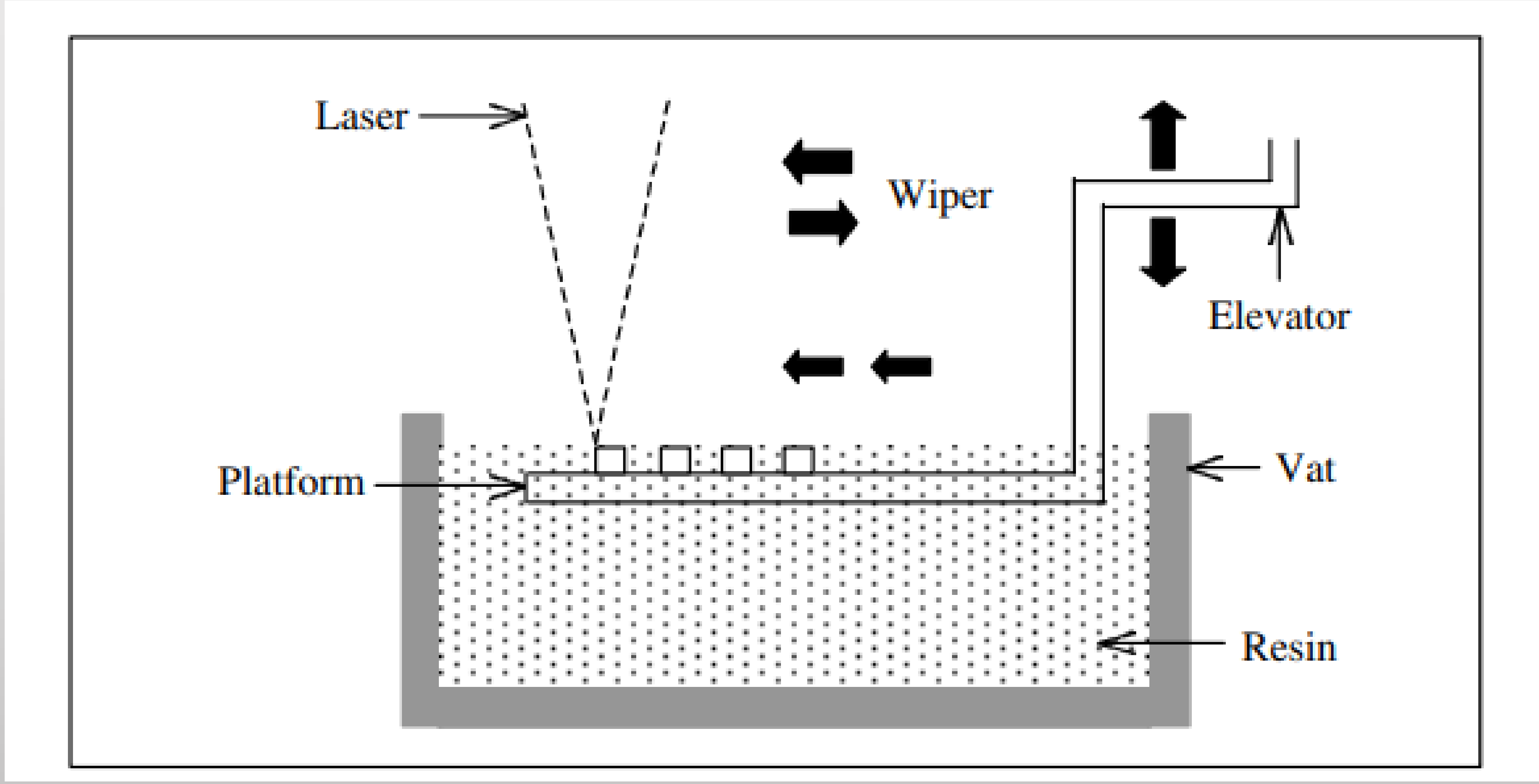
7. The laser beam is moved in the **X-Y directions by a scanner system**.

8. **Stepper motors** are **fast and highly controllable motors** which drive mirrors and are guided by information from the CAD data.

Process Details – Step by step

9. Some geometries of objects have **overhangs or undercuts**. These must be supported during the fabrication process.
10. The support structures are either **manually or automatically designed**.
11. Upon completion of the fabrication process, the object is **elevated from the vat and allowed to drain**.
12. **Excess resin** is swabbed manually from the surfaces. The object is often given a **final cure** by bathing it in intense light in a box resembling an oven called a Post-Curing Apparatus (PCA).

Process



Advantages

1. **Round the clock operation**. The SLA can be used continuously and work round the clock.

2. **Good user support**. The computerized process serves as a good user support.

3. **Build volumes**. The different SLA machines have build volumes ranging from small to large to suit the needs of different users.

4. **Good accuracy**. The SLA has good accuracy and can be used or many application areas.

5. **Surface finish**. The SLA can obtain one of the best surface finishes amongst RP technologies.

Disadvantages

1. **Requires support structures**. Structures that have overhangs and undercuts must have supports that are designed and fabricated together with the main structure.
2. **Requires post-processing**. Post-processing includes removal of supports and other unwanted materials, which is tedious, time consuming and can damage the model.
3. **Requires post-curing**. Post-curing may be needed to cure the object completely and ensure the integrity of the structure

Types of RP Systems

Prototyping Technologies	Base Materials
Selective laser sintering (SLS)	Thermoplastics, metals powders
Fused Deposition Modeling (FDM)	Thermoplastics
Stereolithography (SLA)	photopolymer
Laminated Object Manufacturing (LOM)	Paper
Electron Beam Melting (EBM)	Titanium alloys
3D Printing (3DP)	Various materials

Classification of RPT systems

- RPT systems
  - Liquid Based
  - Solid Based
  - Powder Based

Liquid-Based Rapid Prototyping

- Liquid-based RP systems have **initial form** of its material in **liquid state**. Through a process commonly known as **curing**, the liquid is converted to the **solid state**. The following RP systems fall into this category:

1. **3D Systems' Stereolithography Apparatus (SLA)**
2. **Cubital's Solid Ground Curing (SGC)**
3. **Sony's Solid Creation System (SCS)**
4. **CMET's Solid Object Ultraviolet-laser Printer (SOUP)**
5. **Autostrade's E-Darts**
6. **Teijin Seiki's Soliform System**
7. **Meiko's Rapid Prototyping System for the Jewelry Industry**
8. **Denken's SLP**
9. **Mitsui's COLAMM**
10. **Fockele & Schwarze's LMS**
11. **Light Sculpting**
12. **Rapid Freeze**
13. **Two Laser Beams**
14. **Microfabrication**
15. **Aaroflex**

Solid Based

- Solid-based RP systems are meant to encompass **all forms of material in the solid state**,
- The solid form can include the shape in the form of a **wire, a roll, laminates and pellets**.

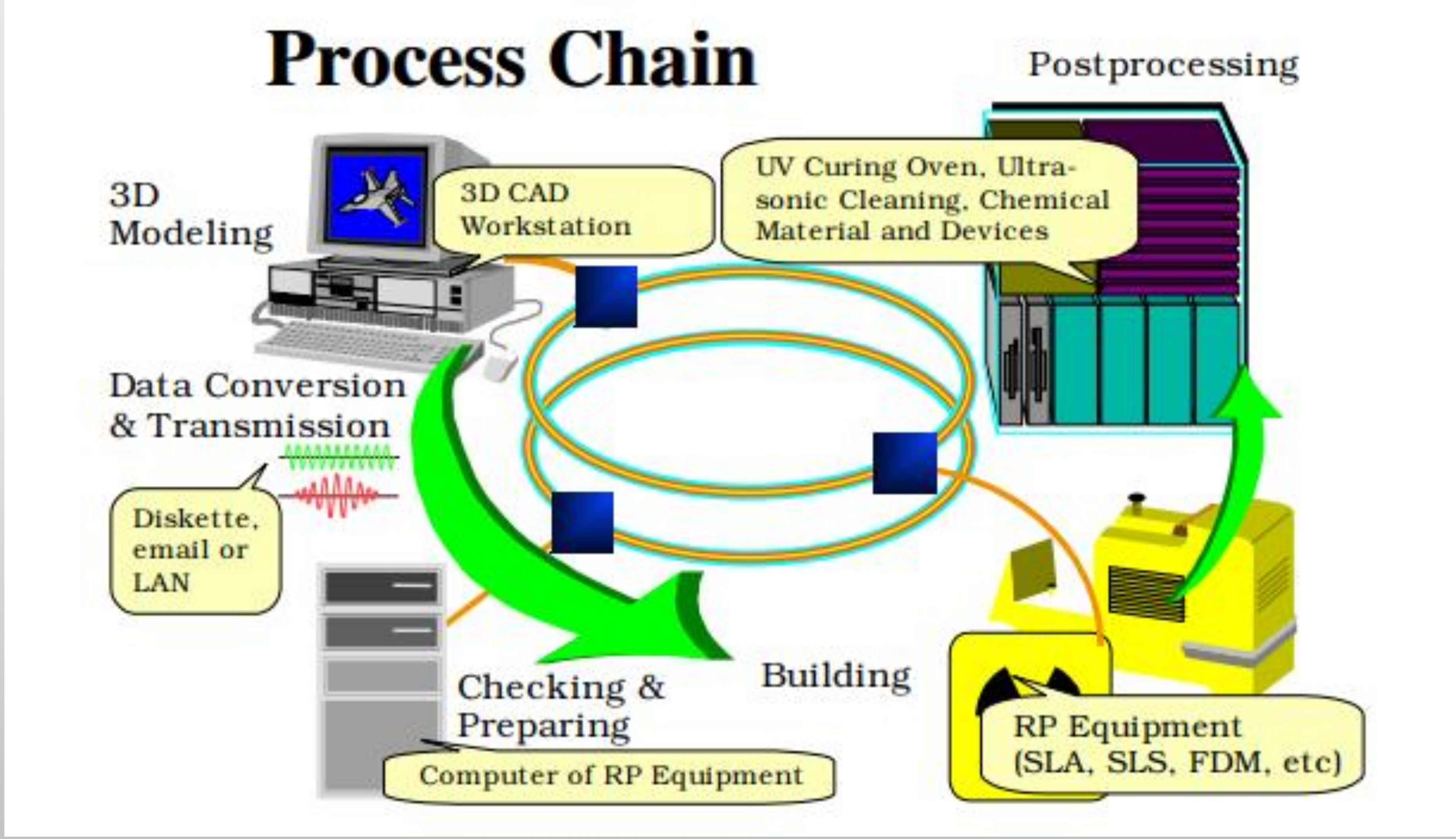
1. Cubic Technologies' Laminated Object Manufacturing (LOM),
2. Stratasys' Fused Deposition Modeling (FDM),
3. Kira Corporation's Paper Lamination Technology (PLT),
4. 3D Systems' Multi-Jet Modeling System (MJM),
5. Solidscape's ModelMaker and PatternMaster,
6. Beijing Yinhua's Slicing Solid Manufacturing (SSM), Melted Extrusion Modeling (MEM) and Multi-Functional RPM Systems (M-RPM),
7. CAM-LEM's CL 100,
8. Ennex Corporation's Offset Fabbers

Powder Based

- **Powder** is by-and-large in the **solid state** in the form of grains.

1. 3D Systems's Selective Laser Sintering (SLS),
2. EOS's EOSINT Systems,
3. Z Corporation's Three-Dimensional Printing (3DP),
4. Optomec's Laser Engineered Net Shaping (LENS),
5. Soligen's Direct Shell Production Casting (DSPC),
6. Fraunhofer's Multiphase Jet Solidification (MJS),
7. Acram's Electron Beam Melting (EBM),
8. Aeromet Corporation's Lasform Technology,
9. Precision Optical Manufacturing's Direct Metal Deposition (DMDTM),
10. Generis' RP Systems (GS),
11. Therics Inc.'s Theriform Technology,
12. Extrude Hone's Prometal TM 3D Printing Process

Process Chain



PROCESS CHAIN

- There are a total of five steps in the chain and these are

  1. 3D modeling,
  2. data conversion and transmission,
  3. checking and preparing,
  4. building
  5. and post-processing.

- Depending on the quality of the model and part in Steps 3 and 5 respectively, the **process may be iterated** until a satisfactory model or part is achieved.

3D MODELLING

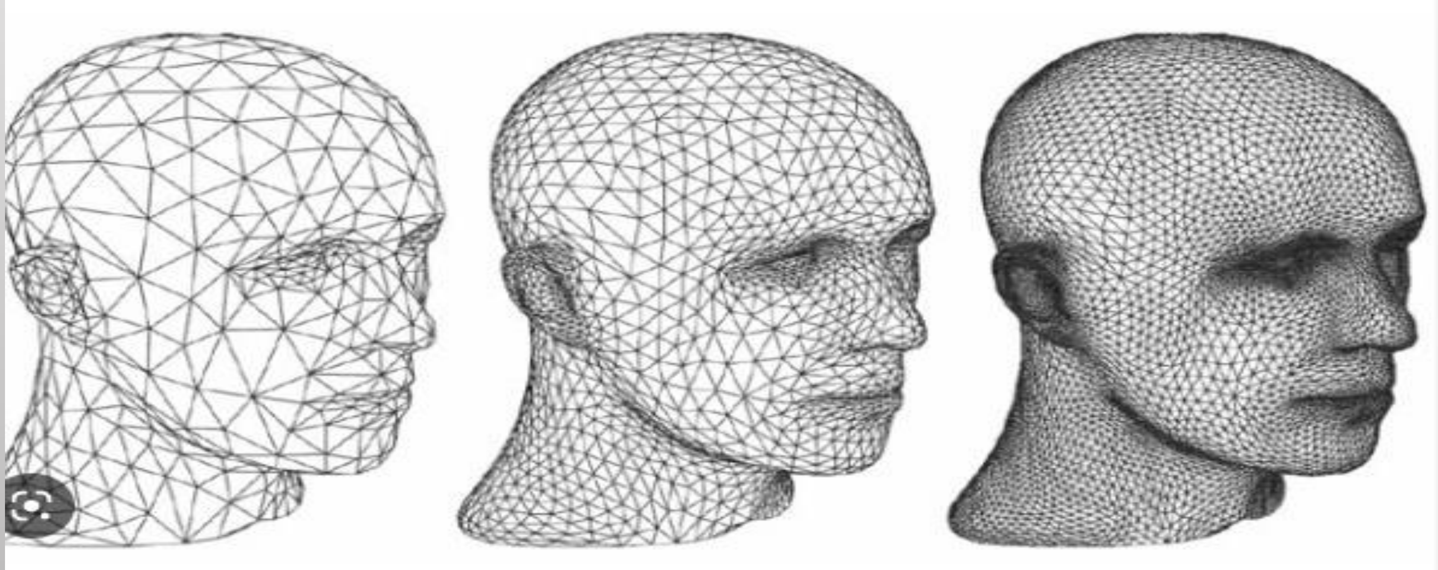
- **Advanced 3D CAD** modeling is a general prerequisite in RP processes
- It also involved **FEM analysis, detail design and drafting, planning for manufacturing**,
- **Special care** to be taken for **orientation of part, need for supports, difficult-to-build part structure** such as thin walls, small slots or holes and overhanging elements.
- Under-specifying parameters to the RP systems, resulting in poor performance and non-optimal utilization of the system.

DATA CONVERSION AND TRANSMISSION

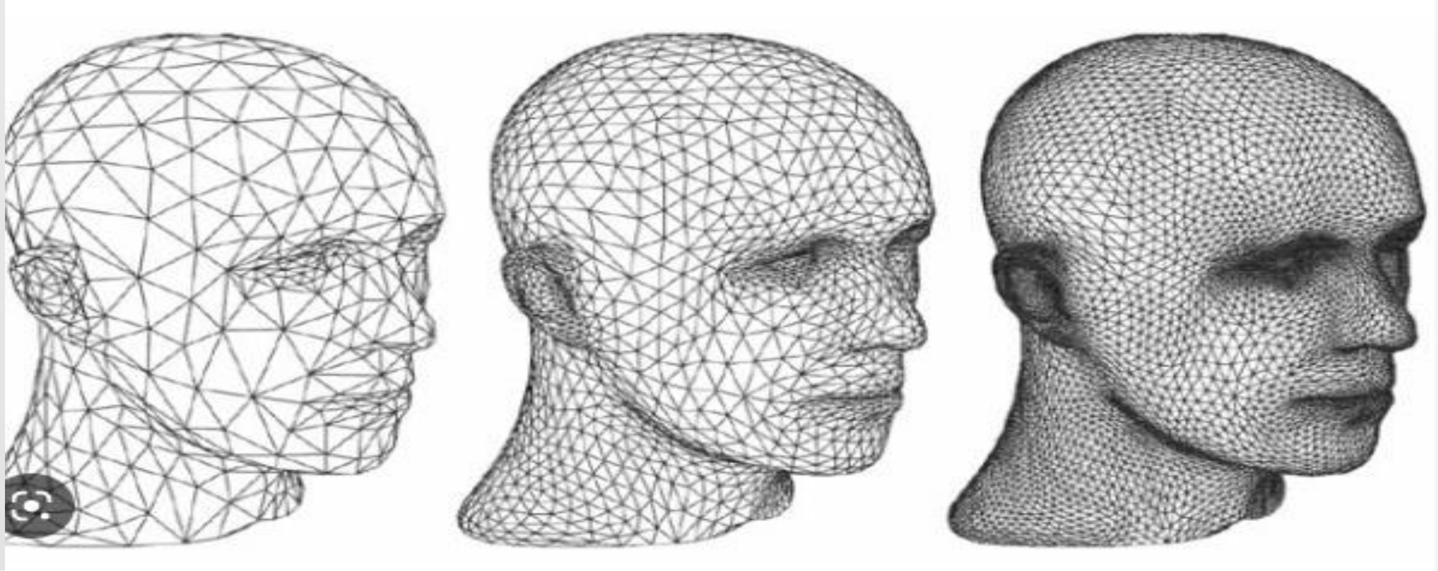
- The solid or surface model to be built is next **converted** into a **format dubbed the STL file** format.

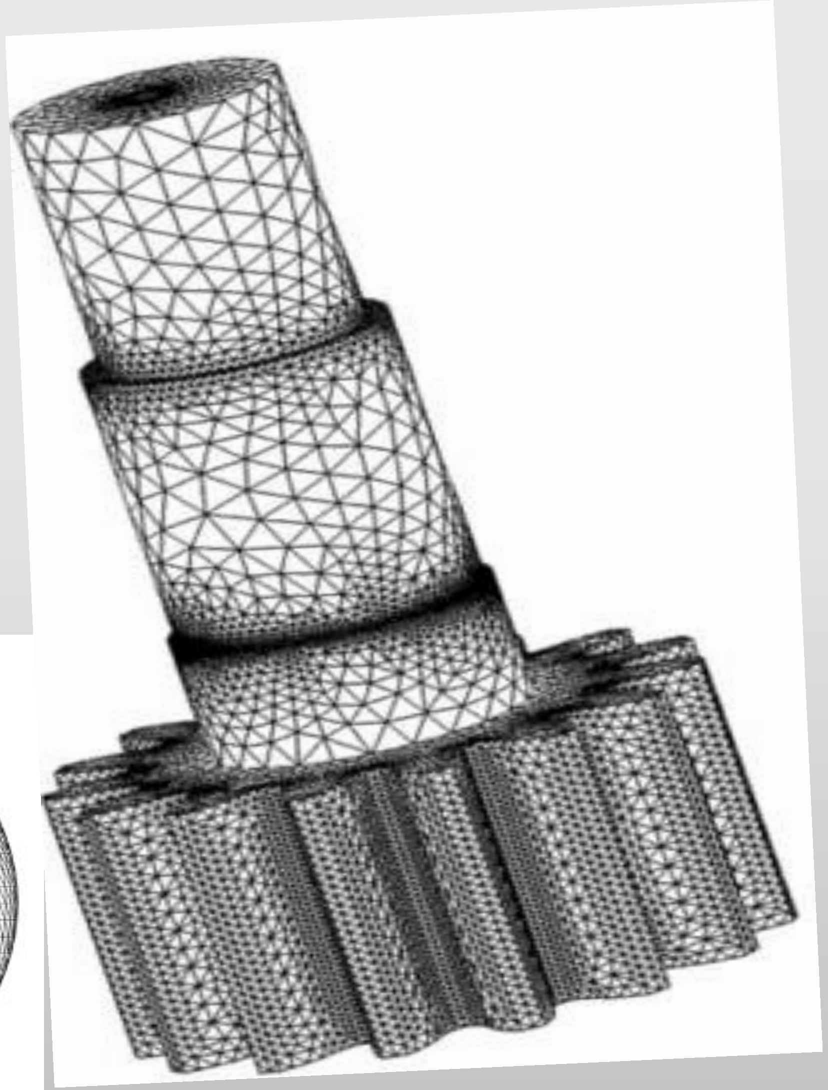
- The STL file format **approximates the surfaces** of the model using **tiny triangles**.

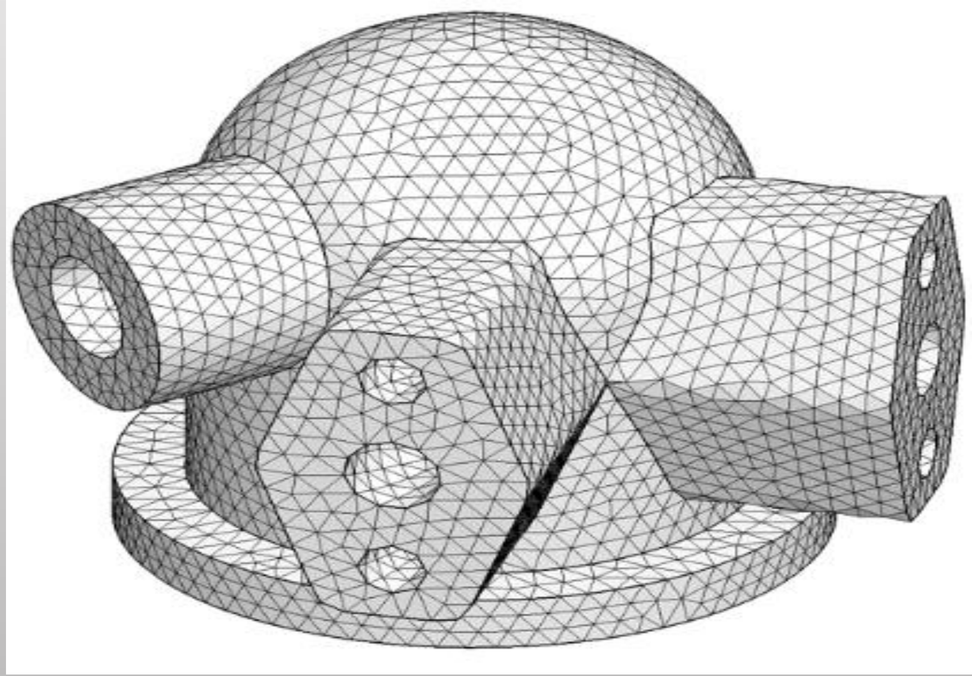
- Highly curved surfaces must employ many **more triangles**, which mean that STL files for curved parts can be **very large**,

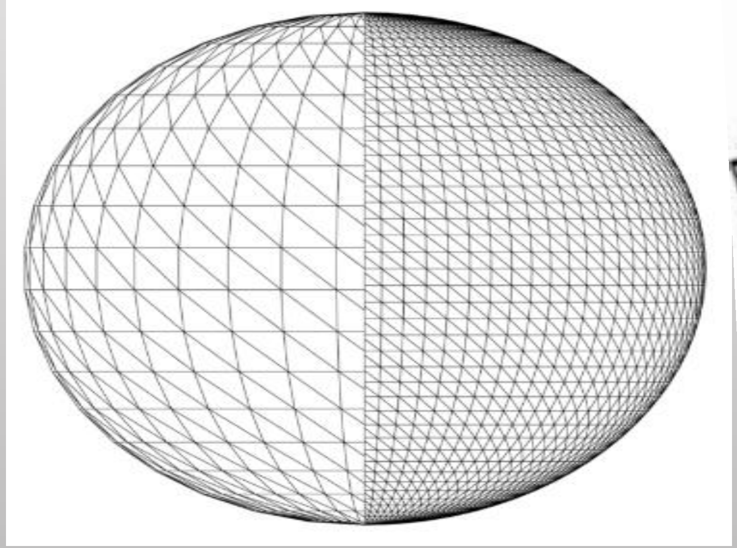


STL FILE









DATA CONVERSION AND TRANSMISSION

- Almost, if not all, major CAD/CAM vendors supply the CAD-STL interface.
- This conversion step is probably the simplest and shortest of the entire process chain.
- For a highly complex model coupled with an extremely low performance workstation or PC, the conversion can take several hours.
- Otherwise, the conversion to STL file should take only several minutes.
- Where necessary, supports are also converted to a separate STL file.

CHECKING AND PREPARING

- This process of manual repair is very tedious and time consuming,
- The CAD model errors are corrected by human operators assisted by specialized software such as MAGICS,
- Once the STL files are verified to be error-free, the system slices the model into cross-sections,
- Each output file is sliced into cross-sections, between 0.12 mm (minimum) to 0.50 mm (maximum) in thickness,
- The model is sliced into the thinnest layer as they have to be very accurate,
- The supports can be created using coarser settings

BUILDING

- For most RP systems, this step is fully automated,
- Thus, it is usual for operators to leave the machine on to build a part overnight,
- The building process may take up to several hours to build depending on the size and number of parts required.

POSTPROCESSING

- The final task in the process chain is the postprocessing task.
- At this stage, generally some manual operations are necessary.
- As a result, the danger of damaging a part is particularly high.
- Operator for this last process step has a high responsibility for the successful process realization.

	Rapid Prototyping Technologies			
Postprocessing Tasks	SLS[1]	SLA[2]	FDM[3]	LOM[4]
1. Cleaning	✓	✓	✗	✓
2. Postcuring	✗	✓	✗	✗
3. Finishing	✓	✓	✓	✓

[1]SLS — Selective Laser Sintering
[2]SLA — Stereolithography Apparatus
[3]FDM — Fused Deposition Modeling
[4]LOM — Layered Object Manufacturing

Few Basic Terms

- **Photopolymerization**: Polymerization is the process of **linking small molecules** (known as monomers) into **chain-like larger molecules** (known as polymers),
- When the **chain-like polymers** are linked further to **one another**, a **cross-linked** polymer is said to be formed,
- **Photopolymerization** is polymerization initiated by a **photochemical process,** whereby the starting point is usually the induction of energy from the radiation source.

- **Photopolymers**: The term photopolymer refers to a class of **light-sensitive resins** that **solidify** when exposed to **ultraviolet (UV) light**,
- When the **liquid photopolymer resin** comes into contact with a **UV light source** - typically a **lamp, laser, or projector** - **photoinitiators transform that light energy into chemical energy**,
- Then, **oligomers or "binders"** and **monomers combine, harden, and form bonds** that create the polymer structure,
- Photopolymers are either **thermoplastics**, which **melt at high temperature**, **thermosets**, meaning they can't be melted or reshaped once cured by heat.

Thanks