



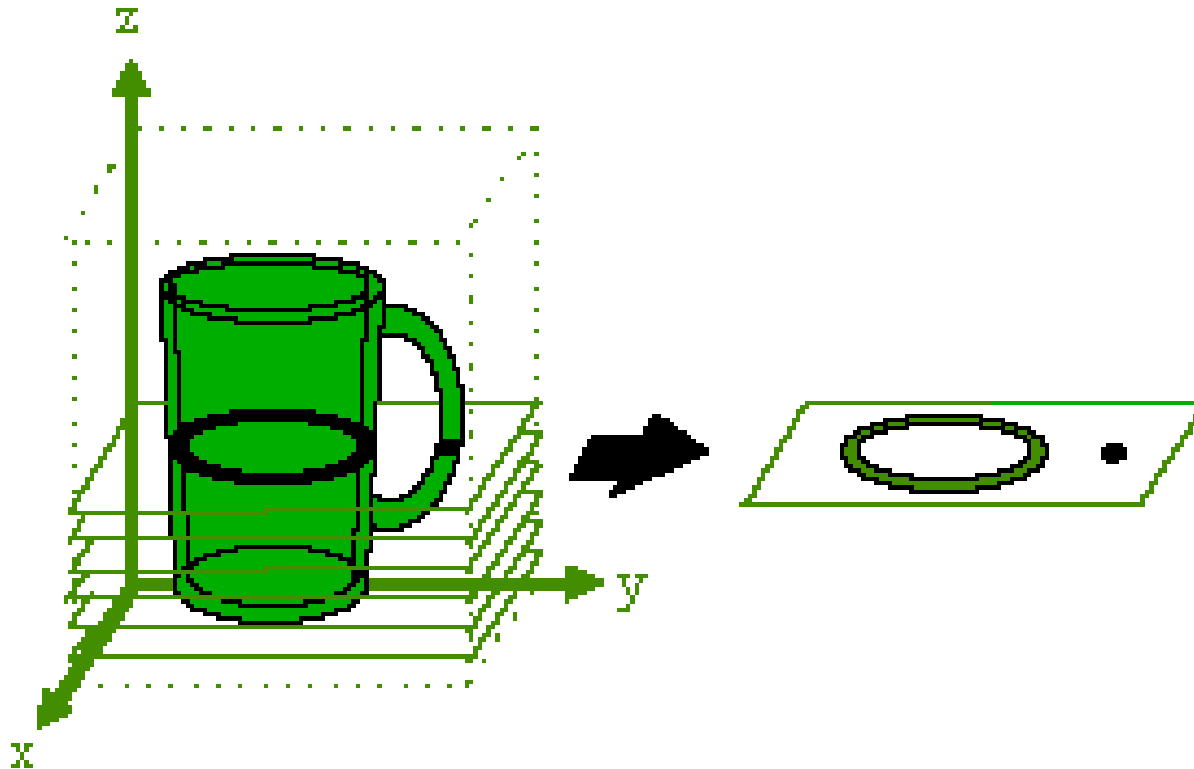
**An Overview of Methods for
Rapid Prototyping
and Near Net Shape Manufacture**

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- **Rapid Prototyping**
 - Basic Principle
 - Data Requirements
- **RP Processes**
 - Laminating
 - Stereolithography
 - Sintering
 - Fused Deposition Modelling
 - Printing
- **Applications**
- **Conclusions**

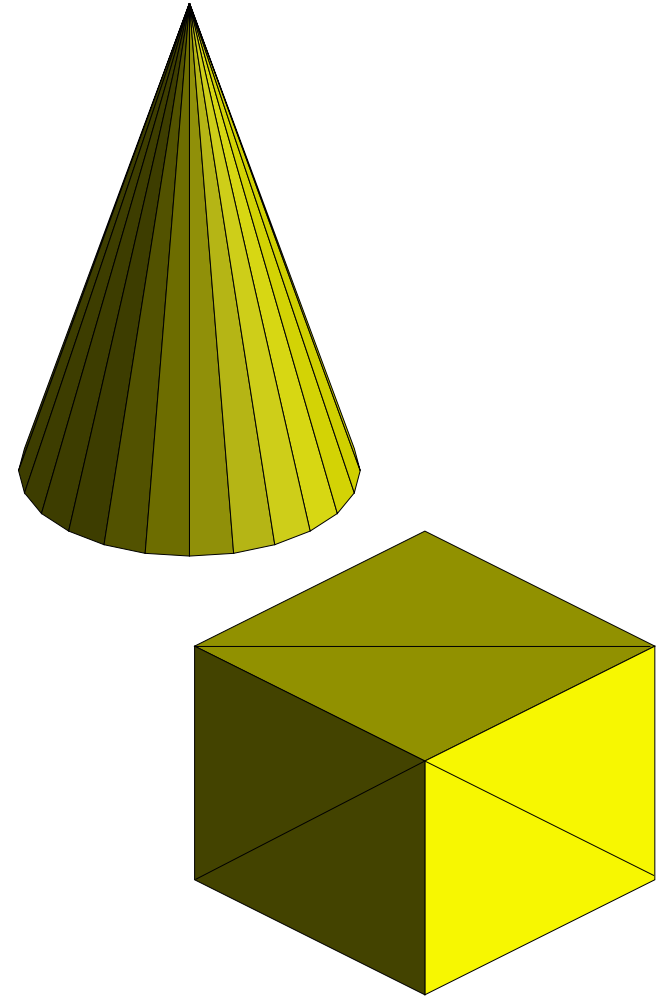
Rapid Prototyping - Principle



The Lamination of a Series of 2D Cross Sections Together to form a 3-Dimensional Object

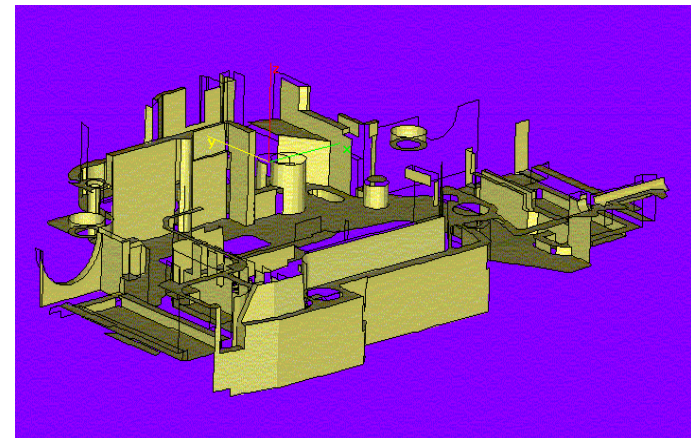
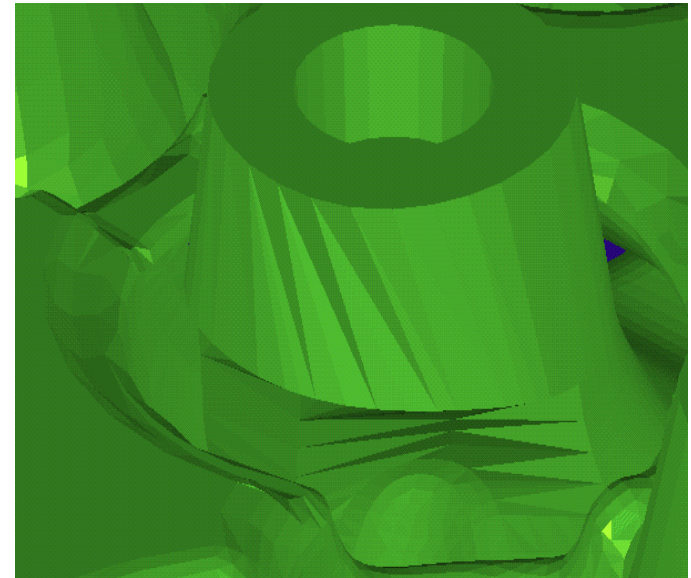
Data Requirements - STL File

- **STL File exported From a 3D**
- **Modelling System**
 - κ Pro Engineer
 - κ SDR3 IDEAS
 - κ Delcam Powershape
 - κ Catia etc
- **Triangulated representation of CAD intent**
 - κ **More Triangles = Better Definition**

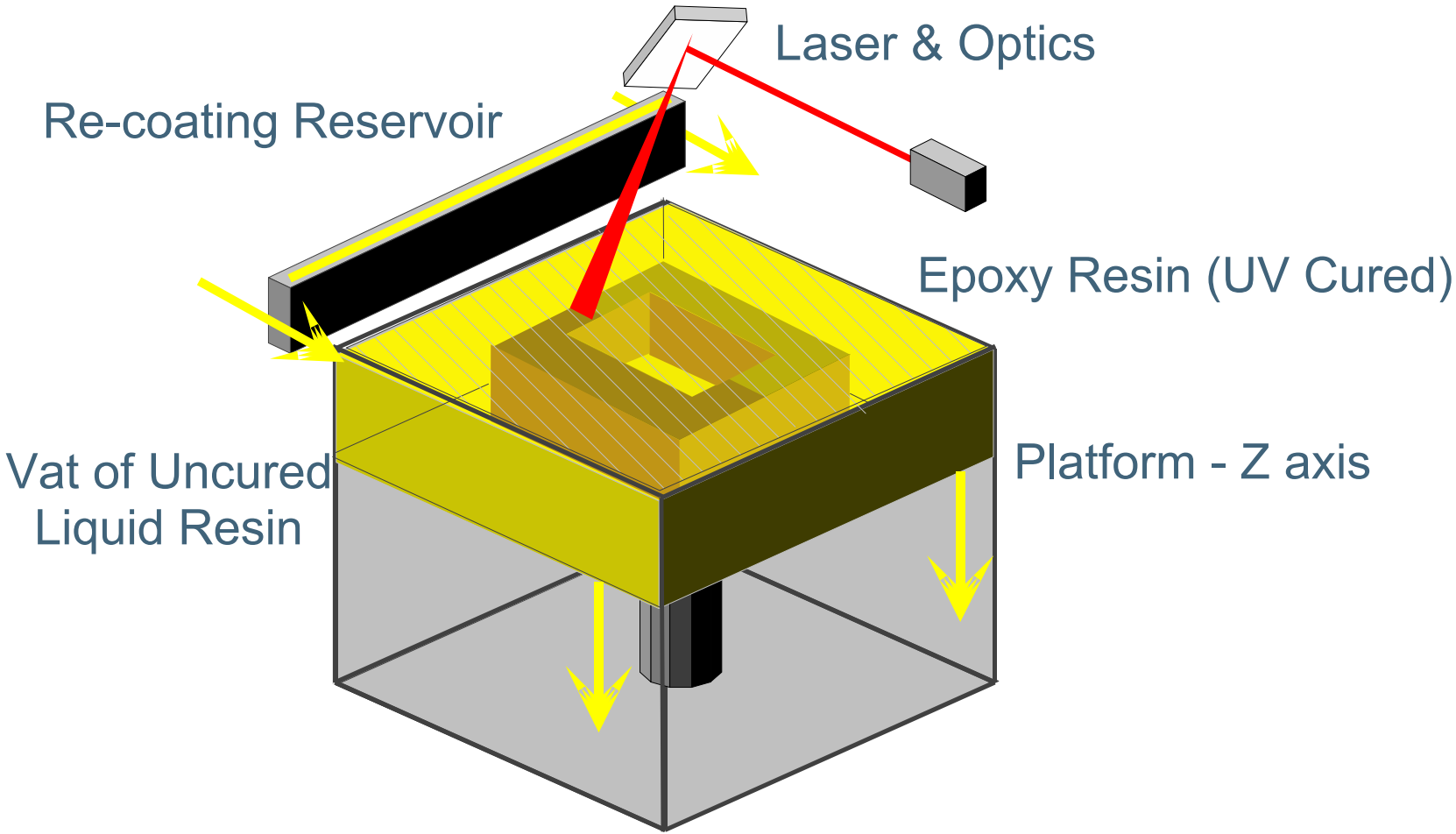


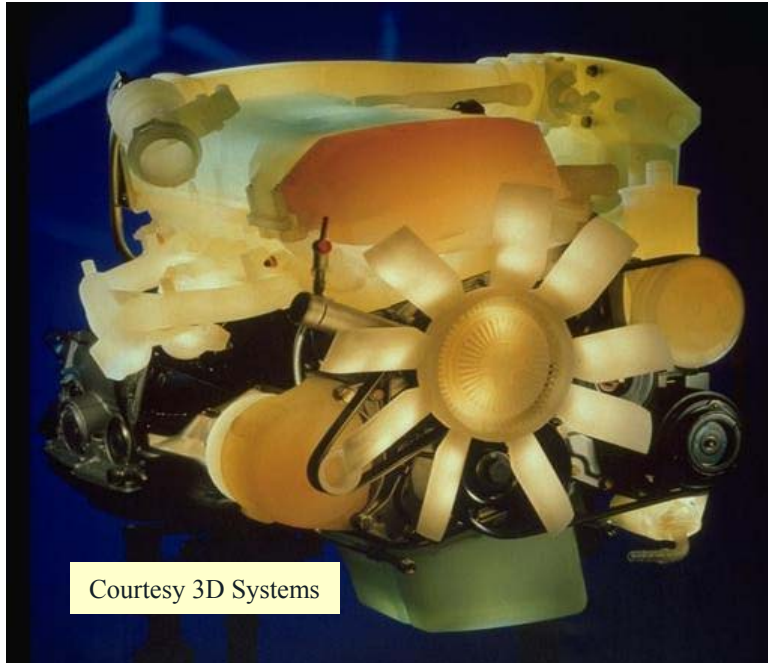
Data Requirements - STL File

- No. of triangles are user defined
- Files are not always acceptable
 - Poorly constructed data
 - Poor translation
- Files have to be perfect for use
 - No holes in the mesh
- Files in most instances can be repaired
 - Materialise
 - Deskartes
 - Delcam etc



RP Processes - Stereolithography





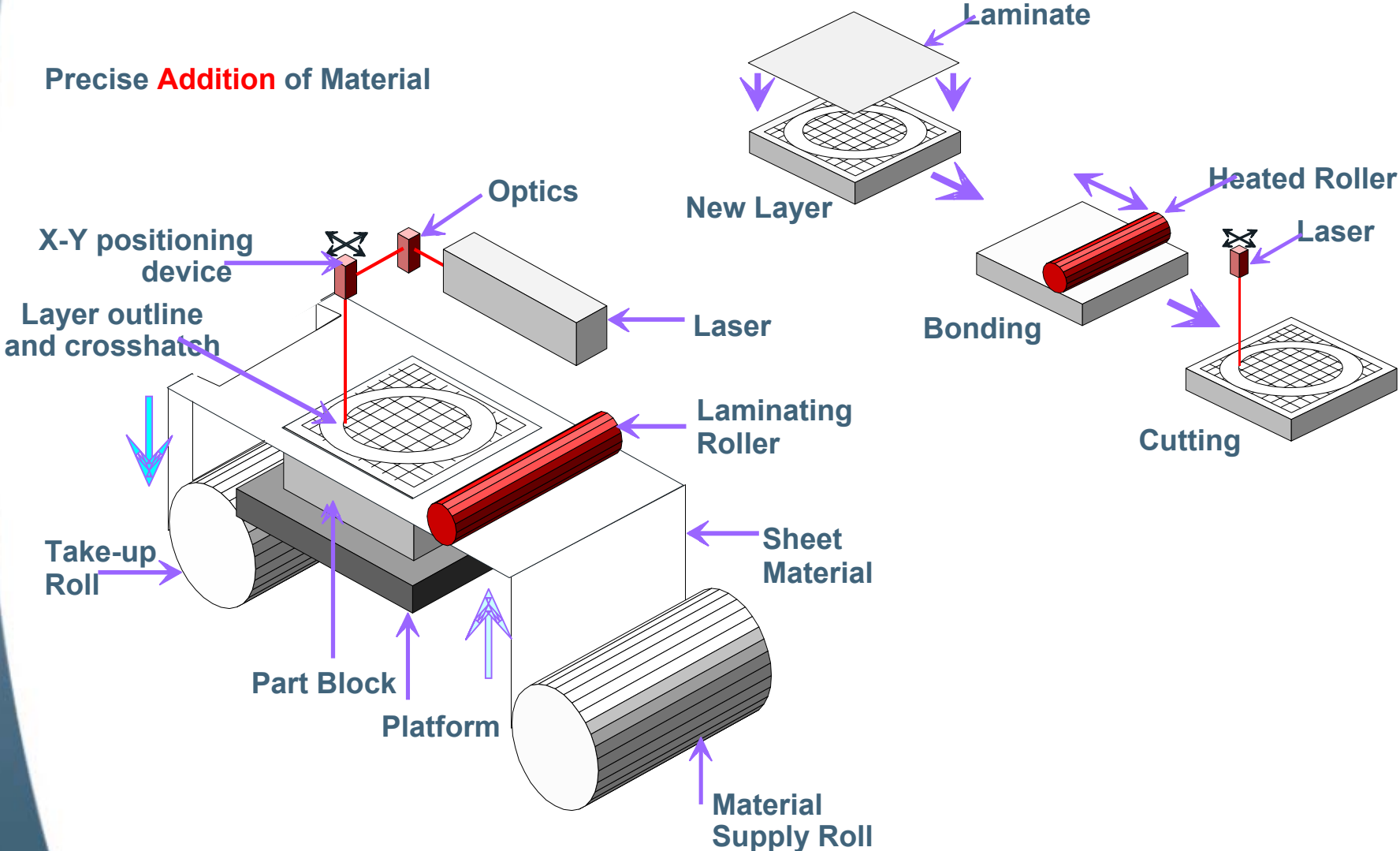
Courtesy 3D Systems

Stereolithography (SLA)

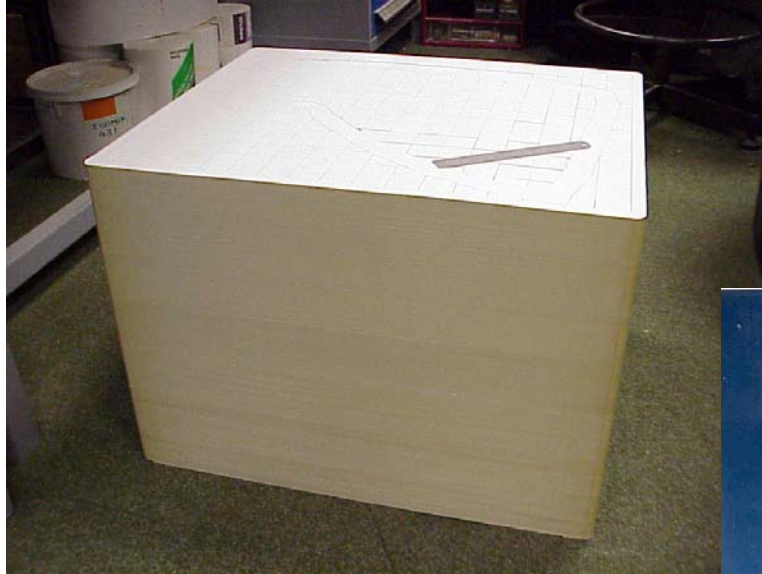
- Fine detail
- Transparent or opaque
- Wide range resins give different properties

RP Processes - Laminated Object Manufacture

Precise **Addition** of Material



RP Processes - Laminated Object Manufacture

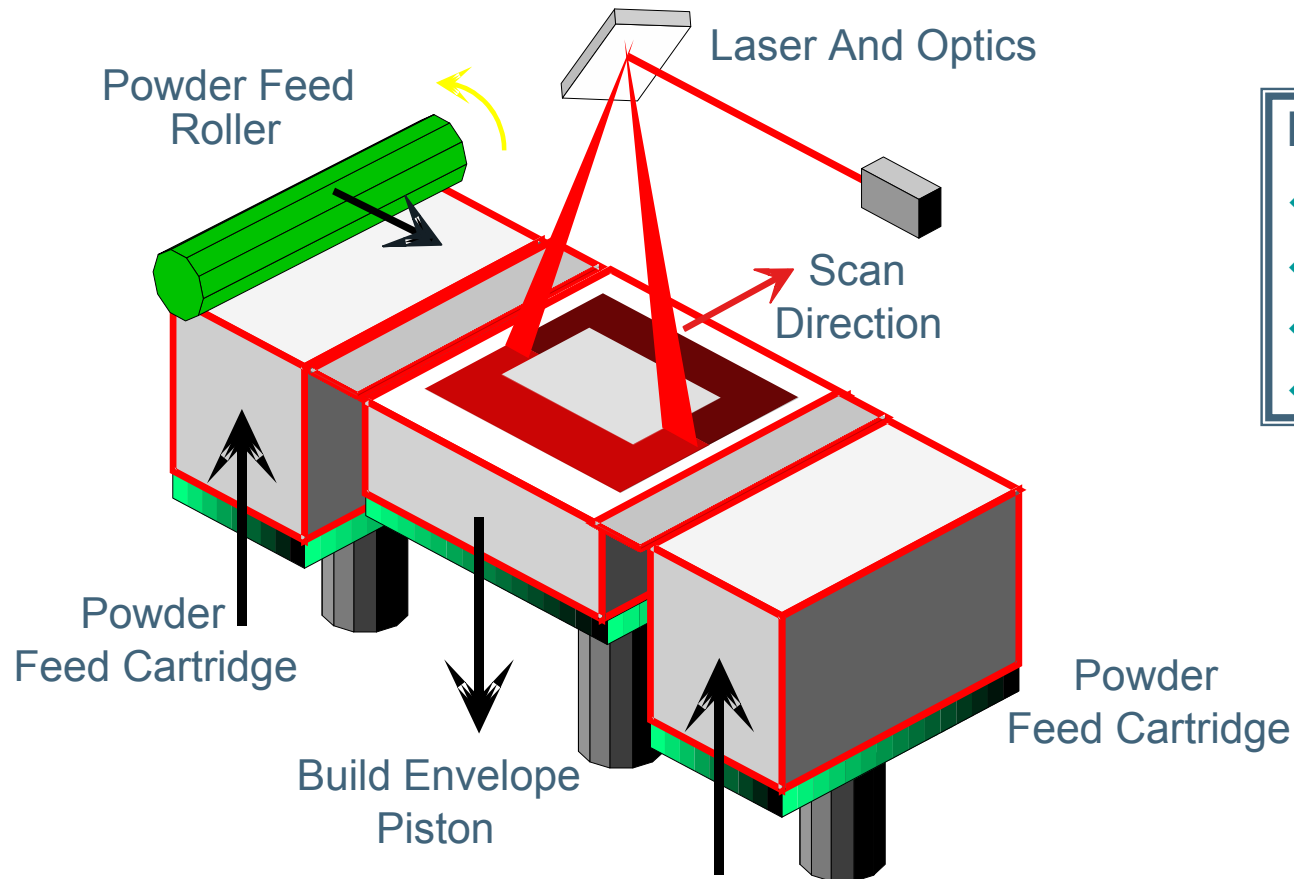


Laminated Object Manufacture (LOM)

- Large models
- Wood like properties
- Easily hand finished



RP Processes - Laser Sintering



Powder Process

- ◆ Nylon (2 grades)
- ◆ Polystyrene
- ◆ Sand
- ◆ Metal

Selective Laser Sintering

RP Processes - Laser Sintering



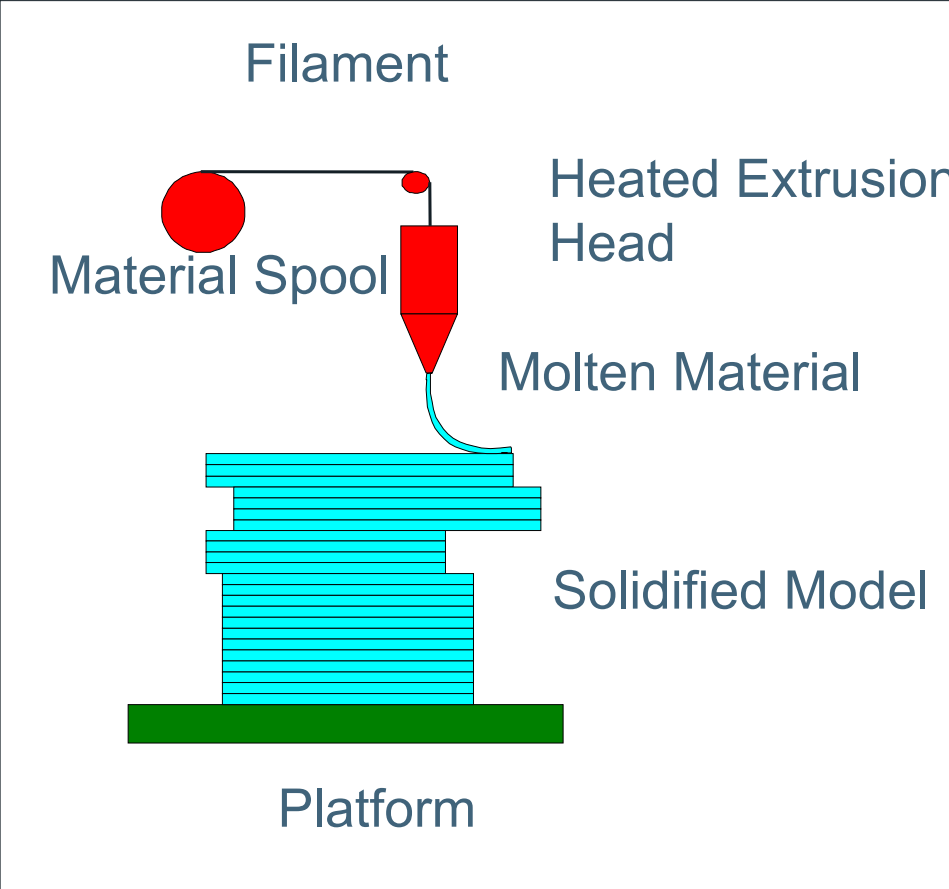
Courtesy 3D Systems

- High strength
- Powdered textured finish
- Flexible material available

Laser Sintering (LS)

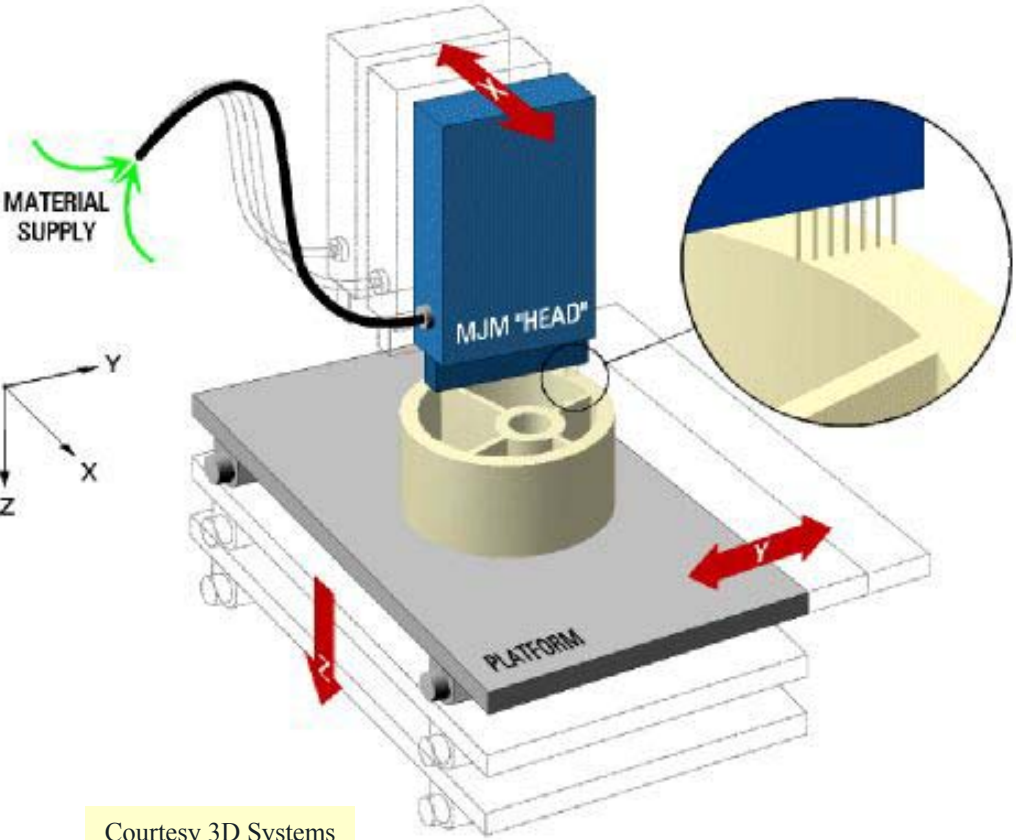


RP Processes - Fused Deposition Modelling



- Extrusion Process**
- ◆ ABS
 - ◆ Polycarbonate
 - ◆ Wax

RP Processes - 3D Printing



Courtesy 3D Systems

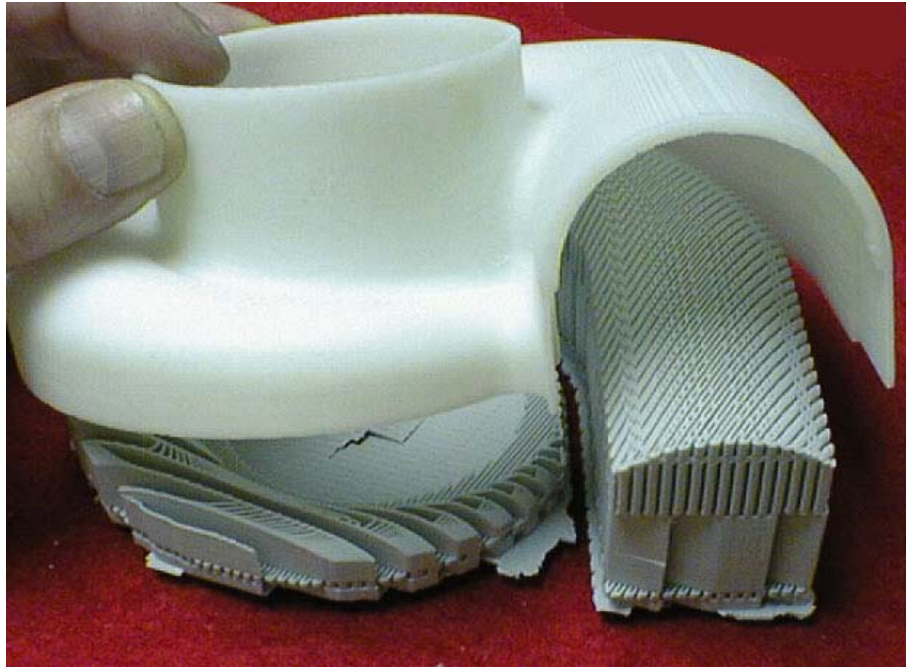
RP Processes - 3D Printing

**3D Systems -
Thermojet
Therics
Prometal - Metal
Printing
ZCorp - Z406 etc
Solidscape - MMII**

- Various Systems
 - Print Build Material
 - Print Binders etc
- Generally very quick
- Different Material Options Available



RP Processes - Deposition



Fused Deposition Modelling (FDM)

- High strength
- Water resistant
- Flexible material available

- ◆ **Concept models**
- ◆ **Functional models**
- ◆ **Experimental analysis**
 - **Thermal stress analysis**
 - **Photoelastic analysis**
- ◆ **Flow visualisation**
- ◆ **Sculpture / Art work**
- ◆ **Tooling - Master patterns**
 - **Silicone tooling**
 - **Resin tooling**
- ◆ **Metal spray tooling**
- ◆ **Direct tooling cavities**
- ◆ **Casting**
 - **Investment casting**
 - **Sand casting**

◆ Traditional routes

- Rendered images
- Machined models
 - Modelling board
 - Metal
- Model making

◆ Virtual reality

◆ Rapid prototyping*



Functional Models

◆ RP capable of manufacturing

- Live hinges/clips
- Metal components
- Assemblies

◆ Limited capability

- Wrong materials
- Inconsistencies in manufacture

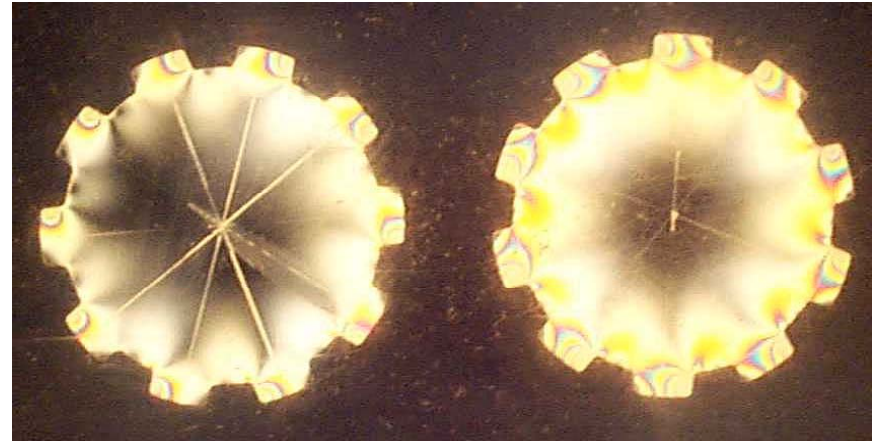


Thermal Stress Analysis

- ◆ RP models cyclically stressed
- ◆ Areas of high stress change temperature
- ◆ Thermal imaging camera monitors change in temp
($^{\circ}\text{C} \times 10^{-3}$)
- ◆ Surface stresses only

Photoelastic Analysis

- ◆ Load model
- ◆ View through polarised filters
- ◆ Stress patterns appear
- ◆ Useful for looking at internal stress



- ◆ **Check flow in cylinder heads**
 - Used to confirm non-turbulent flow
 - Effective cooling required to prevent engine failure
- ◆ **Gas flow in manifolds**
 - Poor flow affects engine performance and emissions



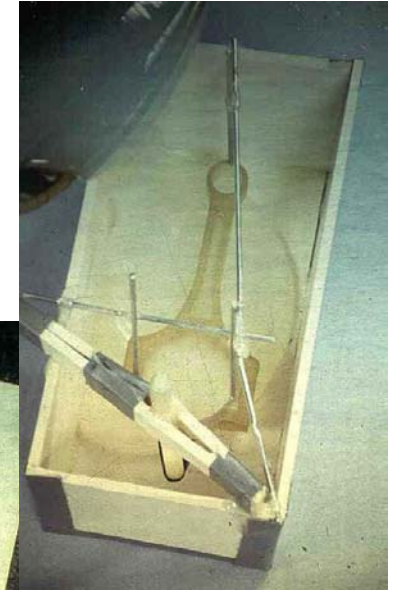
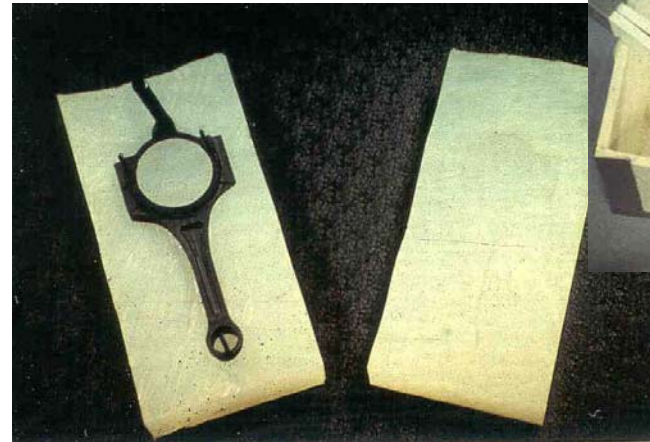
- ◆ Artists using CAD
- ◆ RP ignores traditional material constraints
- ◆ Calm Project



- ◆ **Silicone replication**
- ◆ **Resin tooling**
- ◆ **Metal faced tooling**
 - Metal spray
 - Plated metal
- ◆ **Direct RP**
 - SLA//SLS tools
- ◆ **Metal tooling**
 - Cast
 - Sintered
 - Direct
 - Indirect
 - Machined
- ◆ **Ceramic**

Silicone Tooling - Method

- ◆ Create master pattern
- ◆ Cast RTV silicone resin
- ◆ Create split line
- ◆ Remove master pattern
- ◆ Inject or vacuum cast
 - PU resin
 - Wax



Advantages: Silicone Replication

- ◆ **Comparatively quick and simple**
- ◆ **Wide range of resins available for injection**
 - flexible
 - rigid
- ◆ **Faster production rates than RP equipment**
- ◆ **Higher temperature materials**
- ◆ **Colour matching**
- ◆ **Do not need to worry about draft angles**

Disadvantages: Silicone Replication

◆ Limited tool life

- 10 - 50 mouldings depending on complexity

◆ Material properties rarely match actual production material

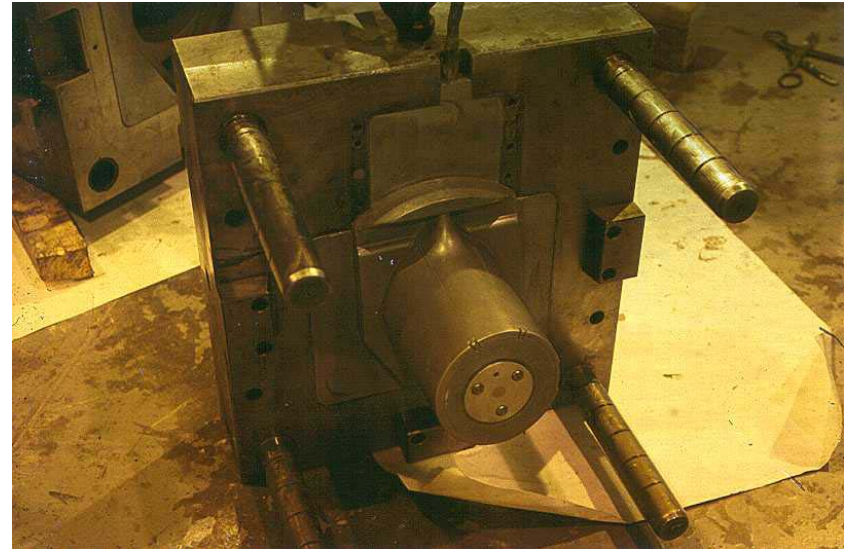
◆ Accuracy variable

Design Considerations For Rigid Tooling Techniques

- ◆ Draft angles
- ◆ Material temperatures
- ◆ Thermal conductivity
- ◆
- ◆ Material shrinkage
 - Tooling material
 - Component shrinkage (Prototype part)
- ◆ Material properties
 - Glass filled?
- ◆ Injection pressures
- ◆ Ejection method
- ◆ Undercuts and cavities
 - No of Cores
- ◆ Accurate tool alignment

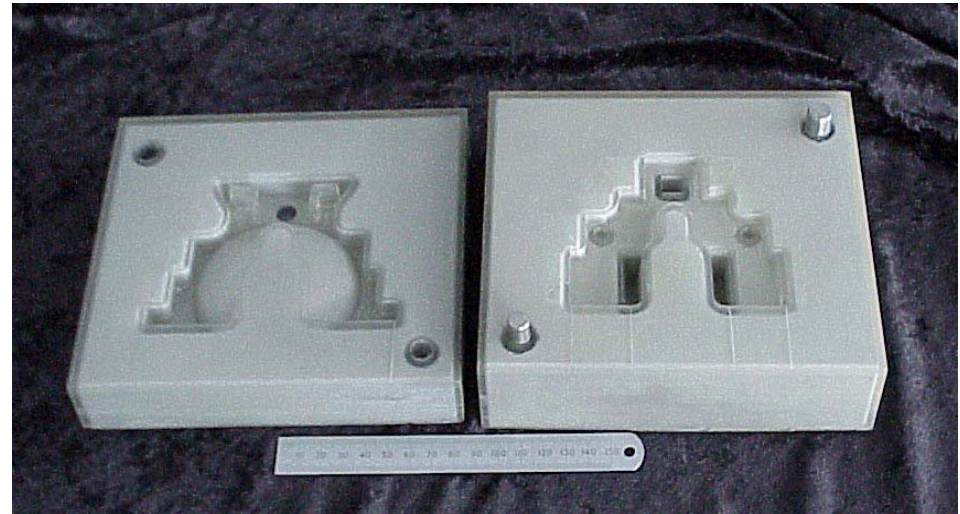
Rigid Resin Tooling - Method

- ◆ Create master pattern
- ◆ Determine split lines, ejection method and coring.
- ◆ Apply release agent to master pattern
- ◆ Cast resin - aluminium filled
- ◆ Fit to bolster
- ◆ Inject thermoset /plastic material



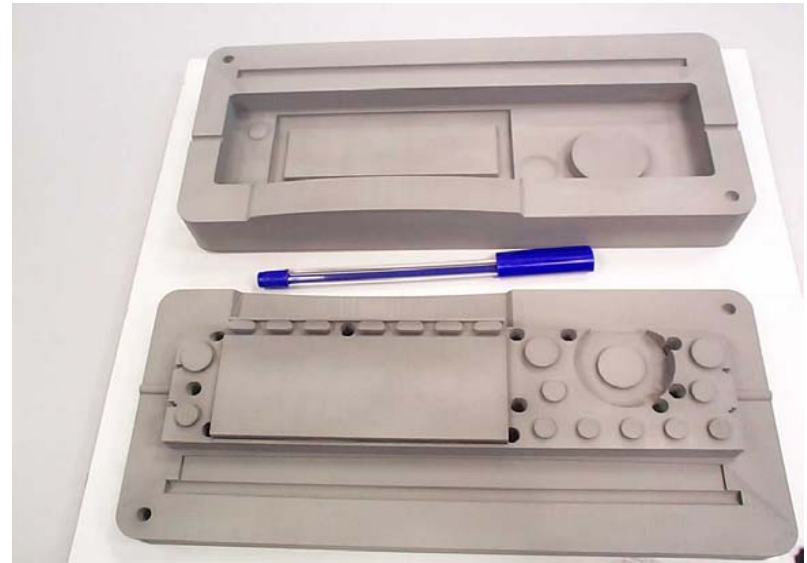
Direct RP Tools

- ◆ Directly build RP tool
- ◆ Various routes possible
 - SLA
 - Epoxy
 - SLS
 - Copper Polyamide
 - Better thermal conductivity



Direct Tooling: Sintered Metal

- ◆ Sintered metal tools
- ◆ DTM or EOS
- ◆ Route
 - Design part
 - Modify CAD (or STL file)
 - Create STL file of tool
 - Metal sinter on RP machine
- ◆ Fit tool out for manufacturing Process



◆ DTM - Indirect metal sintering

◆ Material

- Stainless steel/bronze alloy

◆ Route

- Epoxy coated metal powder
- Laser bonds epoxy coated metal powder together
- Green parts post sintered
 - 1st stage - Debind
 - 2nd stage - Bronze infiltration

◆ EOS - Direct metal sintering

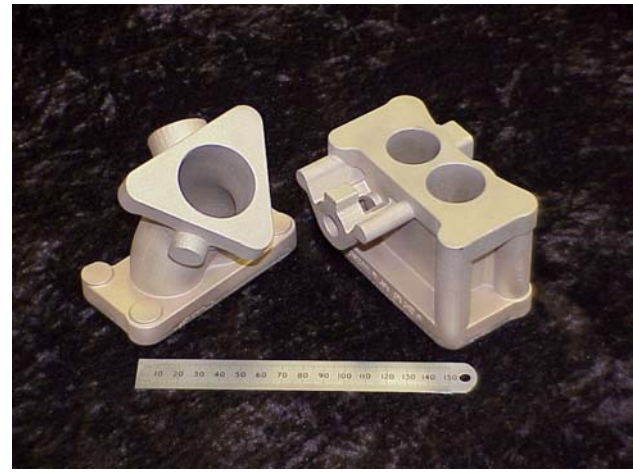
◆ Materials

- Bronze based powder
- Steel

◆ Route

- Metal powder directly sintered by 200W CO₂
- Optional Infiltration
 - Tin
 - Resin

Metal Parts - Sintering



- ◆ **Sand casting**
- ◆ **Ceramic casting**
 - **Investment casting**
 - Shell/block moulding
 - Shaw type processes
- ◆ **Die casting**

- ◆ **Create pattern on RP machine**
 - SLA/SLS/LOM/FDM/etc

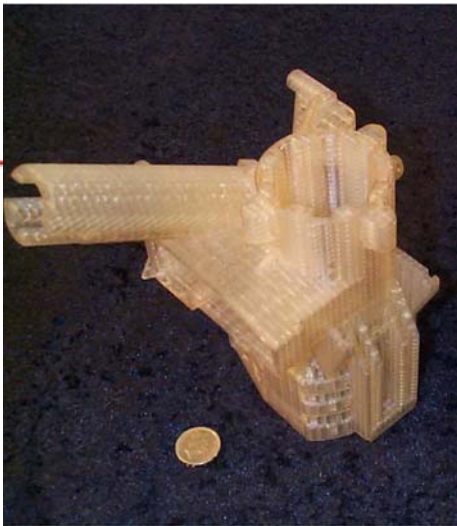
- ◆ **Add feeding/gating system**

- ◆ **Create block mould/shell**

- ◆ **Dry**

- ◆ **Burn/autoclave model from shell**

- ◆ **Cast**



Model Distortion & Instability

- ◆ Most systems suffer from some form of model instability
- ◆ Use quickly
- ◆ Create a stable master pattern
- ◆ New materials are being developed all the time

Accuracy

- ◆ **Currently approximately +/- 0.12mm**
- ◆ **Best achievable +/- 0.025mm**

Conclusions / Considerations

- ◆ **RP is a quick means of generating models directly from CAD data**
- ◆ **Complex model geometries can be achieved easily**
- ◆ **RP can be used for a wide range of applications**
- ◆ **Wide variety of materials are available**
- ◆ **Processes are still evolving**
 - **New materials**
 - **New processes**
 - **New applications**