Introduction

Chapter 1

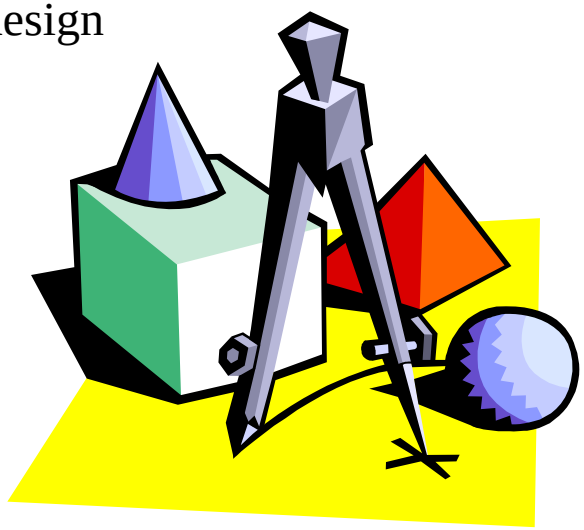
Dr M B Vaghela
Assistant Professor
Mechanical Engineering Department
L. E. College Morbi
Email: mbvaghela@lecollege.ac.in

Introduction

- **Prototype:**
- It is the first or preliminary version of a product from which other forms are developed.
- It is a model from which further models and eventually the final product will be derived.
- It is the representation of a solution to a design problem in such a way that a user can experience it.
- It is not meant to function but rather to let users interact with them so as to provide feedback.

Introduction

- Prototyping is critically important during product/process design
  - Reduce time to market
  - Early detection of errors
  - Assist concurrent manufacturing engineering



- Prototypes are used to convey a products':
  - *Form*
  - *Fit*
  - *Function*

Need for model accuracy increases

- Prototype building can be a time-consuming process requiring a highly skilled craftsperson
  - Time spent testing prototypes is valuable
  - Time spent constructing them is not…

- "Rapid Prototyping" (RP) methods have emerged
  - (*Solid Freeform Fabrication, Additive Manufacturing, Layered Manufacturing)*

Introduction

- Rapid Prototyping?
  - Technology for producing ~~accurate parts~~ directly from CAD models ~~in a few hours~~ with little need for human intervention.
    - Pham, et al, 1997

physical models

- Prototype?
  - A first full-scale and usually functional form of a new type or design of a construction (as an airplane)
    - Webster's, 1998
- Model?
  - A representation in relief or 3 dimensions in plaster, papier-mache, wood, plastic, or other material of a surface or solid
    - Webster's, 1986

History Of RP Systems

- **In 60's**, the first rapid prototyping technique became accessible in the later eighties and used for production of prototype and model parts.
- **In 70's, Herbert Voelcker**, engineering professor developed the basic tools of mathematics that clearly describe the three dimensional aspects and resulted in the earliest theories of algorithmic and mathematical theories for solid modeling.
- **In 80's**, **Carl Deckard**, researcher from the University of Texas. He pioneered the layer based manufacturing, he thought of building up the model layer by layer.

History Of RP Systems

- He printed **3D models** by utilizing **laser light** for **fusing metal powder in solid prototypes**, single layer at a time. Technique called '**Selective Laser Sintering**
- Nowadays, the computer engineer has to simply sketch the ideas on the computer screen with the help of a design program that is computer aided.

Discuss the STL File Repair Methods

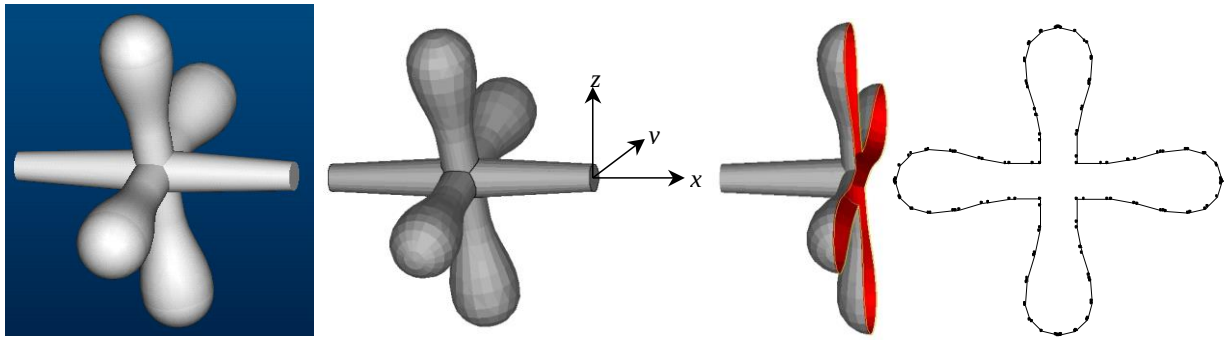
- Computer aided designing allows to make modification as required and can create a physical prototype that is a precise and proper 3D object.

Rapid Prototyping

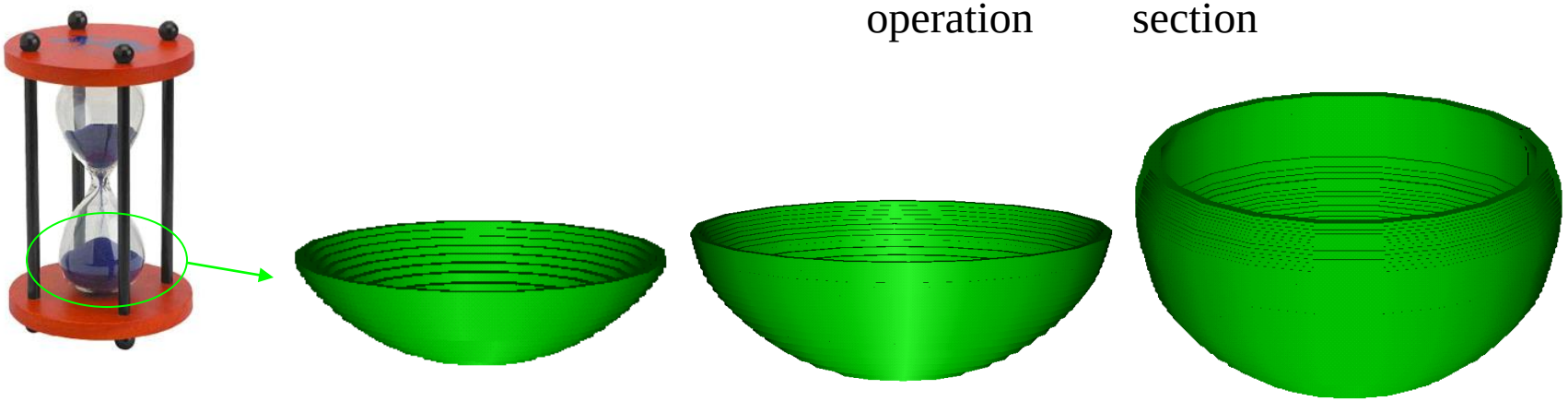
- The term **Rapid Prototyping (RP)** refers to a class of technologies that can automatically construct physical models from Computer-Aided Design (CAD) data.
- It is a process for rapidly creating a system or part representation before final release or commercialization.
- It is a process for fabricating of a physical, three – dimensional part of arbitrary shape directly from a numerical description (typically a CAD model) by a quick, totally automated and highly flexible process.
- **Alternative names for RP:** Additive Manufacturing, Layer Manufacturing, Direct CAD Manufacturing, Solid Freeform Fabrication.

Rapid Prototyping

- **Basics:**
  - Solid model (CAD) is converted to STL format
    - Facetted representation where surface is approximated by triangles
    - Intersect the STL model with parallel planes to create cross sections
  - Create each cross section, adding on top of preceding one

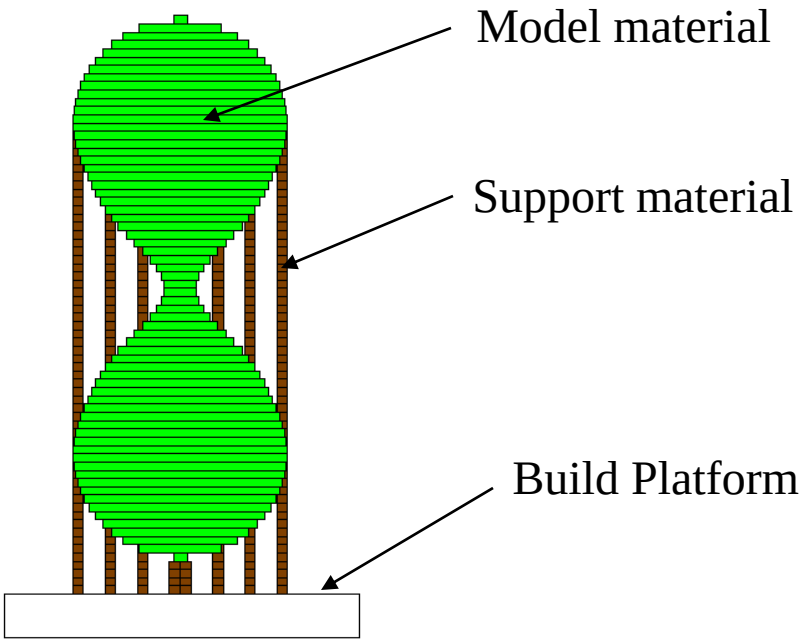


CAD (ProE) ➡ STL ➡ "slicing" operation ➡ 2-D cross section



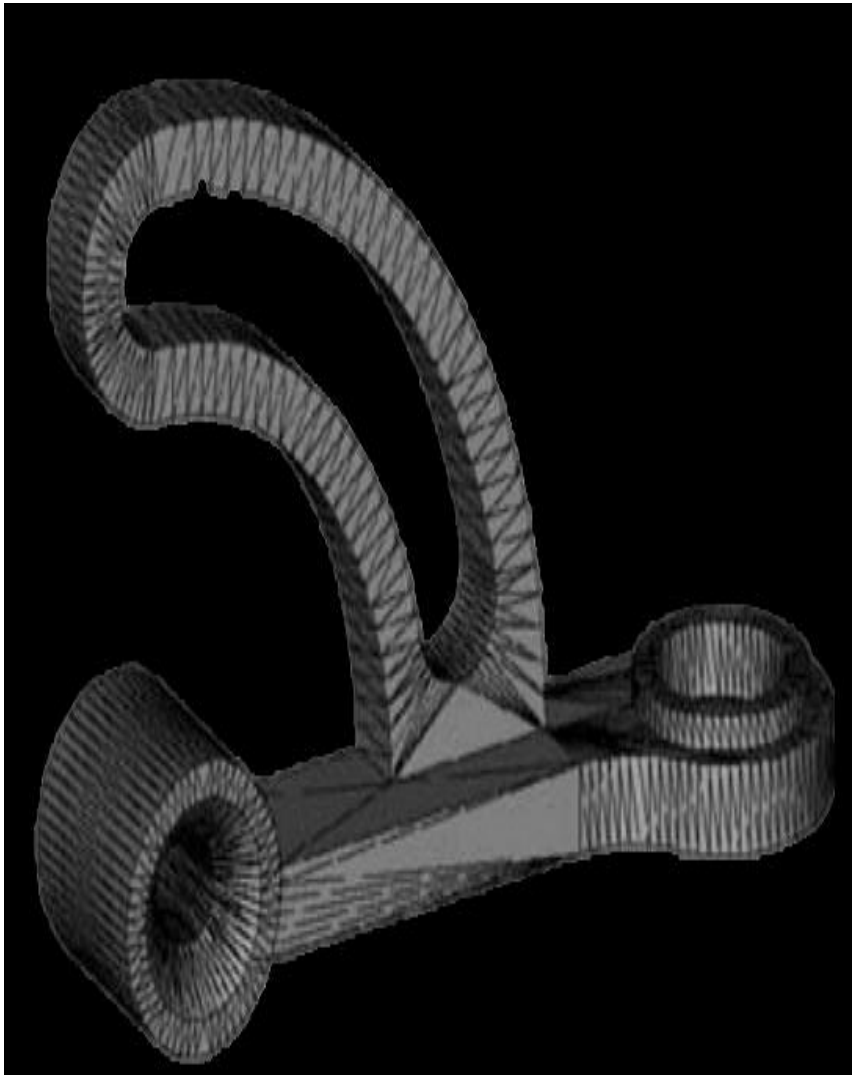
Rapid Prototyping

- Fixtures are created in-process (Sacrificial Supports)
  - Secure model to the build platform
  - Support overhanging features
- Remove fixture materials in post-process step



FDM Model with/without supports

CAD Model & STL Triangulation Model

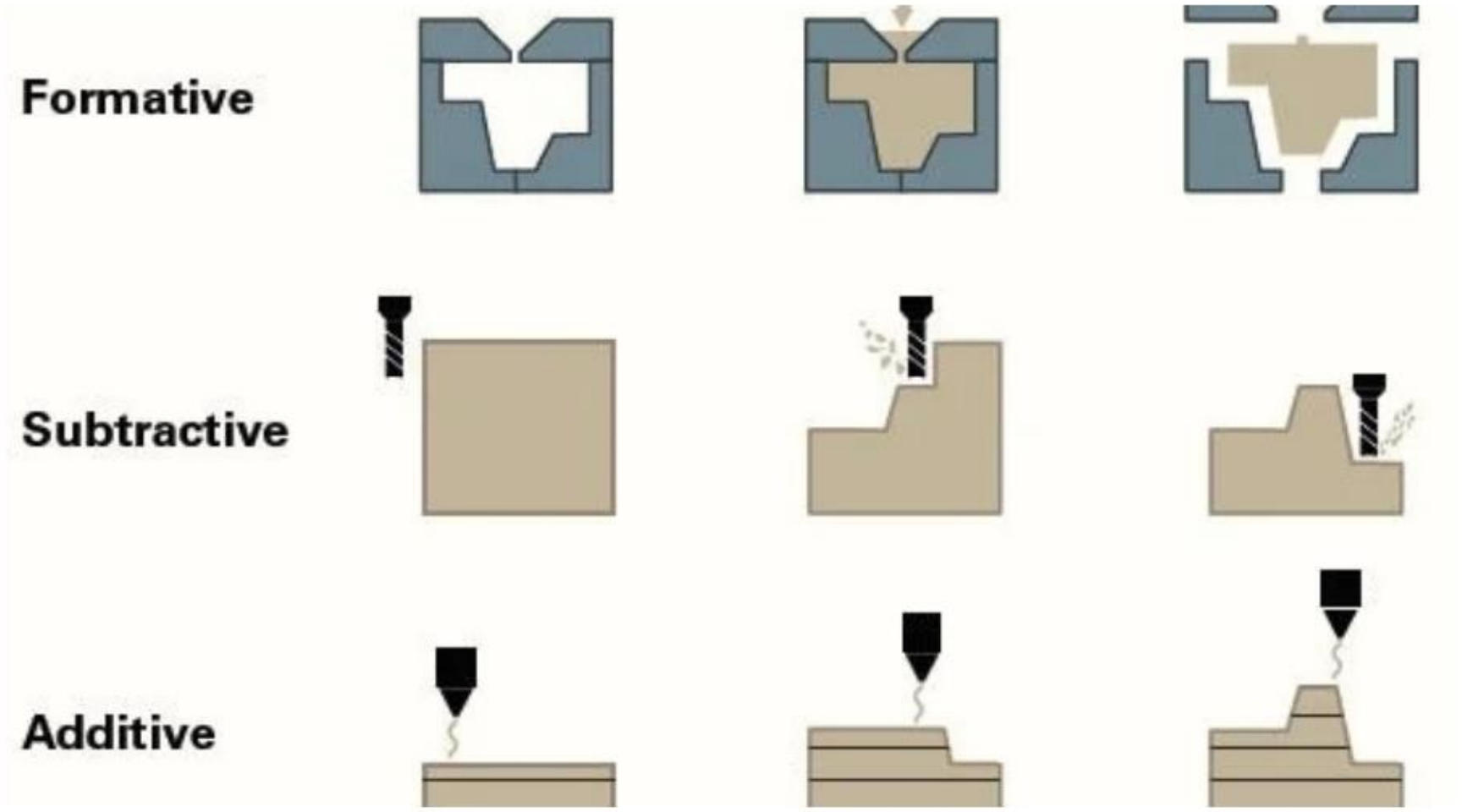


Traditional Prototyping	Rapid Prototyping
It could include building a model from CLAY, carving from wood, bending wire meshing etc.	**It could include building a model from thermoplastic, photopolymer, metals, paper, titanium alloys etc.**
These methods are time consuming.	**These methods consume less time.**
Lack the quality to serve its purpose.	**Gives better quality.**
It can't effectively evaluate the alternative design concepts in the product definition stage.	**It can effectively evaluate the alternative design concepts in the product definition stage.**
Generally these methods are performed manually.	**Generally these methods are performed automatically.**
Increases product launch time.	**Reduces product launch time.**

Classification of Rapid Manufacturing Processes

- **Additive:** an appropriate name to describe the technologies that build 3D objects by ***adding*** **layer-upon-layer** of material, whether the material is plastic, metal, concrete or one day….human tissue.
  - The most visible machine in this category is the **3d printer**
- **Subtractive:** **involves material removal with turning, milling, drilling, grinding, cutting, and boring**. The material is typically metals or plastics, and the end product has a smooth finish with tight dimensional tolerances. A wide variety of materials are available.
  - The most visible machine in this category is the **mill**, but there are many others, including the **lathe**.
- **Formative:** the machine **injects or pours liquid material into a mold and allows it to cool**.
  - The most visible machine in this category is the **injection molder**, but even jello molds are a formative manufacturing process.

Classification of Rapid Manufacturing Processes



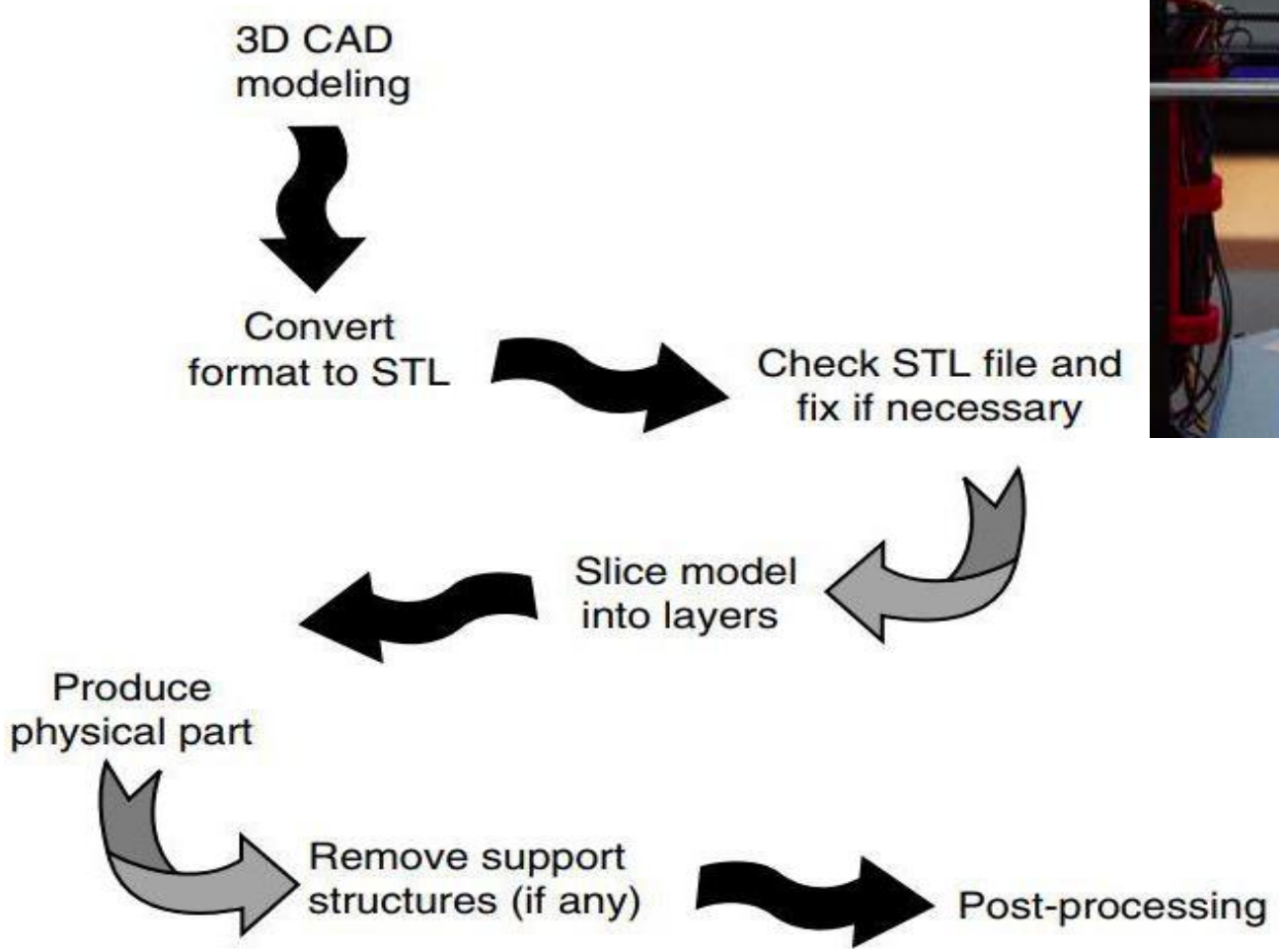
Illustrations of manufacturing principles

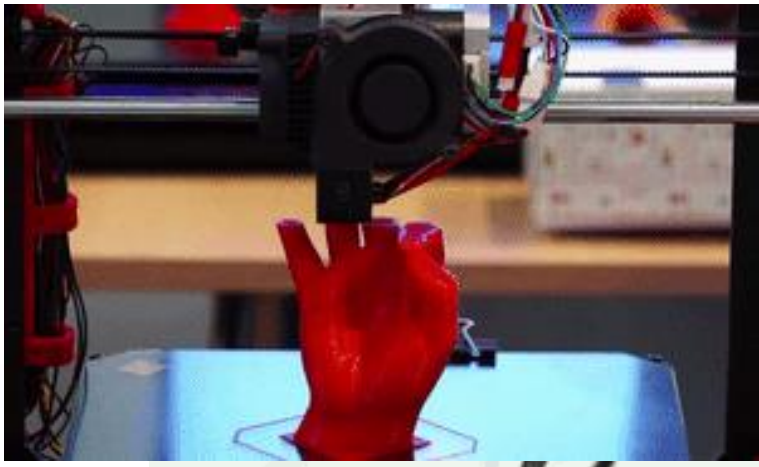
Classification of Rapid Manufacturing Processes

Manufacturing machine and materials examples:

Process	Sub-category	Machine	Typical material
Subtractive	Rotating stock, movable tool	lathe	metal, wood
	Fixed stock, Rotating tool	mill	metal, wood
Additive	fused filament fabrication (FFF)	3d printer	ABS, PLA, PET
	selective laser sintering (SLS)	3d printer	thermoplastic powder
	stereolithography (SLA)	3d printer	photopolymer
Formative	forging	forge + hammer	metal
	casting	injection molder	thermoplastic pellets

Generic RP process:
A Typical Rapid Prototyping Process





RP versus CNC Machining

- RP processes are very flexible and very capable
- However:
  - RP processes rely on specialized materials
  - Limited accuracy in some cases

} *Functional* prototypes?

- CNC Machining is:
  - *Subtractive* process
  - Accurate
  - Capable of using many common manufacturing materials

- CNC Machining is NOT:
  - Automated
  - Easily usable except by highly skilled technicians

- CNC machining cannot create all parts
    - No hollow parts
    - No severely undercut features
- The time consuming tasks of process and fixture planning are major factors which prohibit CNC machining from being used as a Rapid Prototyping Process
  - Wang *et al*, 1999

Manufacturing cost

- One time costs
  - Process planning and design
  - Fixture engineering and fabrication
- Set up cost (C_{set})
  - Cost to set up a process
- Processing cost (C_{psc})
  - Cost of processing a part
- Production cost (C_{pdc})
  - Cost of tooling and perishables

So how can engineering costs be reduced for CNC machining?

Machine cost

Fixture cost

Process planning cost

Thanks