



LOYOLA MARYMOUNT
UNIVERSITY

3D Printing. Technology, Applications, and Selection

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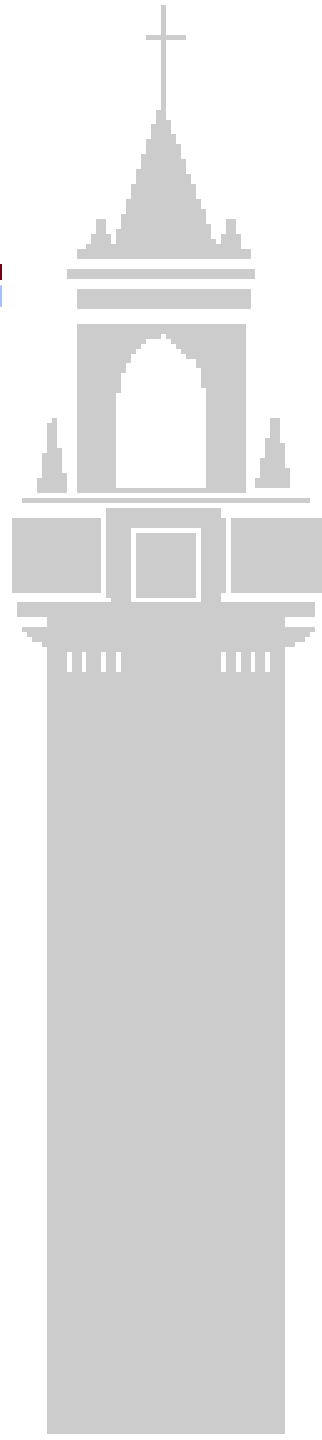
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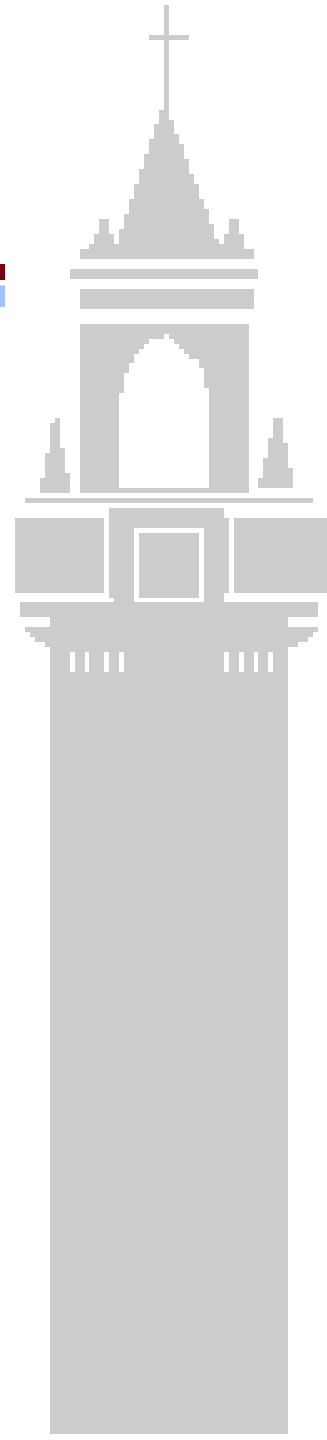
Sept 20th , 2017





Topics of Presentation

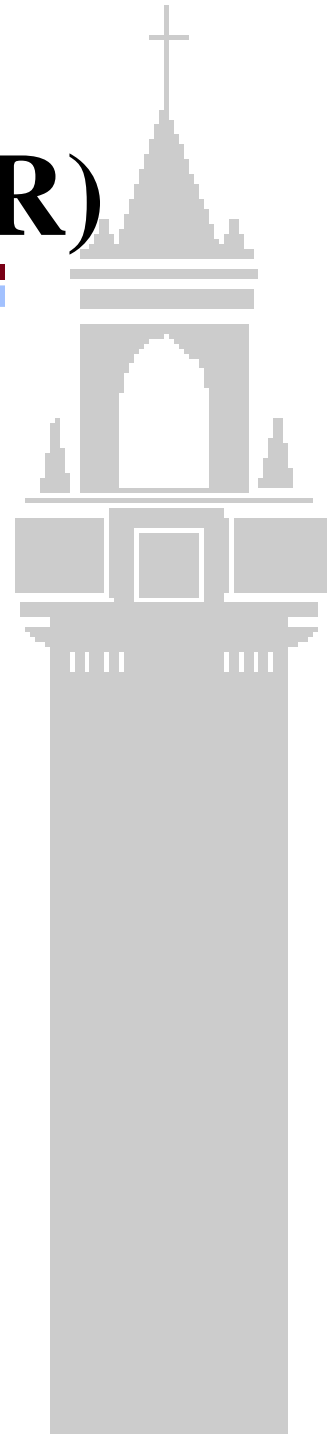
- Industrial Revolution
- Introduction to 3D Printing
- Introduction to RP + 3DP
- Challenges of 3D Printing
- Methodology
- Applications of 3DP
- Discuss the Selection of RP/3DP Systems
- Discuss the Development of an Expert System
- Demonstration of the Program
- Discussions and Conclusions





4 Industrial Revolutions (IR)

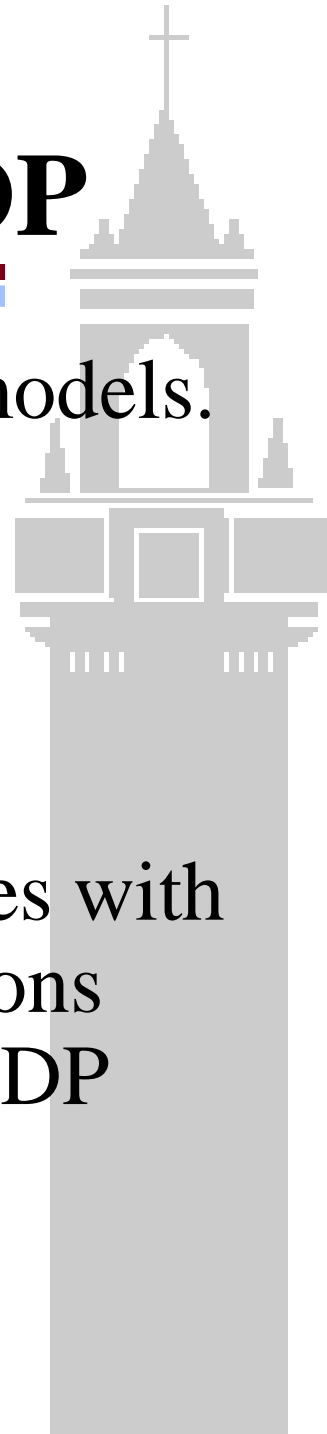
- First IR used water and steam power to mechanize production.
- Second IR used electric power to create mass production.
- Third IR used electronics and information technology to automate production.
- Fourth IR is the digital revolution that has been taking place since the middle of last century, which is being built on the third IR. It includes 3D printing, Artificial Intelligence, Expert System, Robotics, Nanotechnology, Biotechnology, Material Science, Energy Storage and Quantum Computing.





Introduction to RP and 3DP

- Rapid Prototyping (RP) prototypes 3D models. It is also known as 3D Printing (3DP)
- The ever-increasing demand for quality products at lower costs is fueling this technology
- The availability of over twenty companies with wide ranging capabilities and specifications creates a problem for selection of a RP/3DP





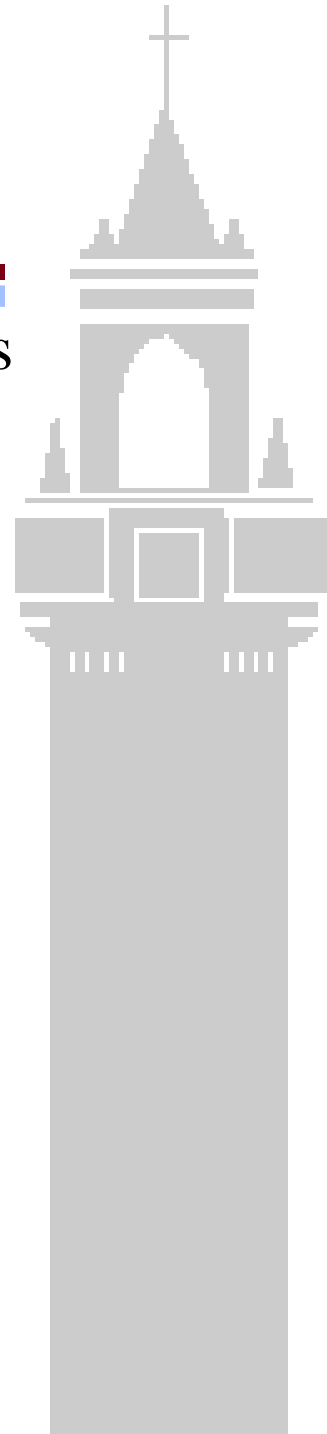
Definition of RP and 3DP

- Rapid Prototyping (RP) is a special class of machine technology that quickly produces models and prototype parts from 3D data using additive approach to form the physical models.
- 3D printing (3DP), as described in this text, refers to the fabrication 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 without any tooling.
- 3DP is similar to RP except its cost is less than \$5,000



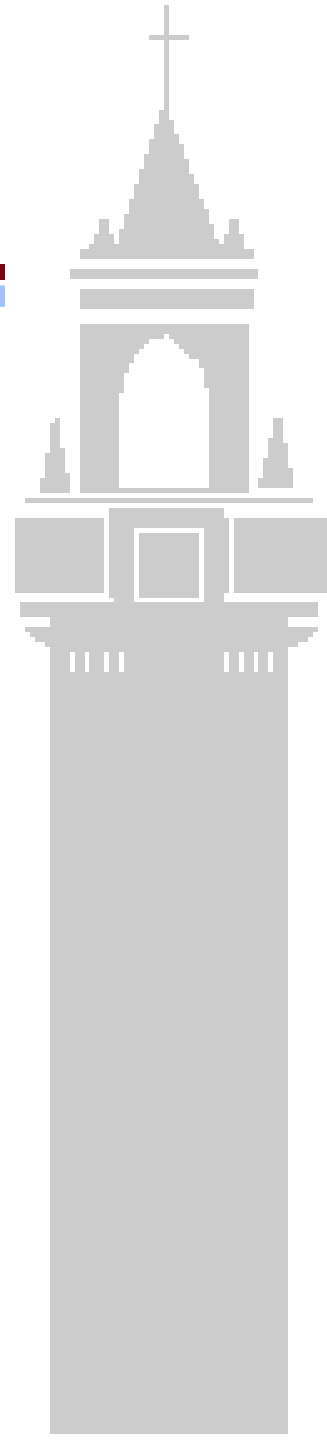
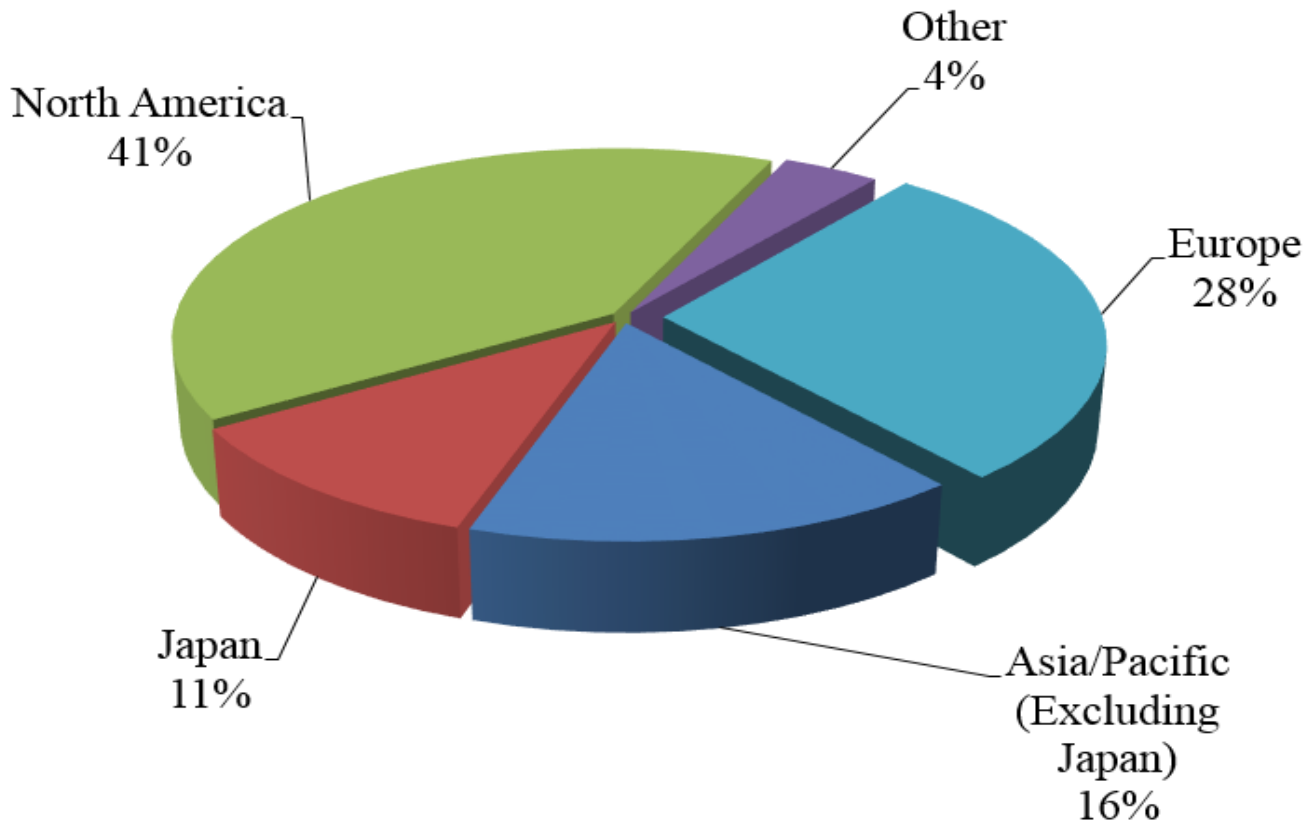
Advantages of RP & 3DP

- Reduced lead times to produce prototyped components
- Improved ability to visualize part geometry
- Earlier detection and reduction of design errors
- Increased capability to compute mass properties and assemblies.
- Communication of product characteristics
- Facilitate meeting schedule and making milestones
- Tooling for injection molding
- Form, fit and function testing
- Engineering change clarification
- Client presentations and consumer evaluations



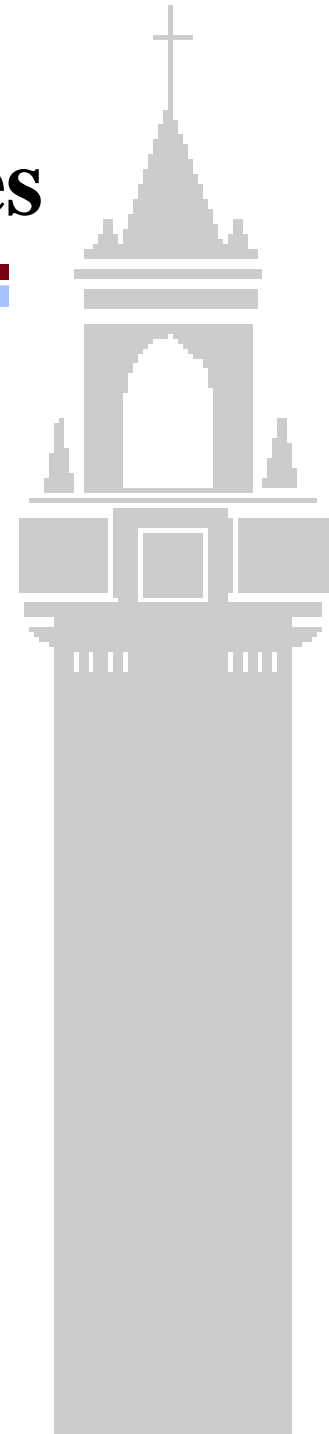
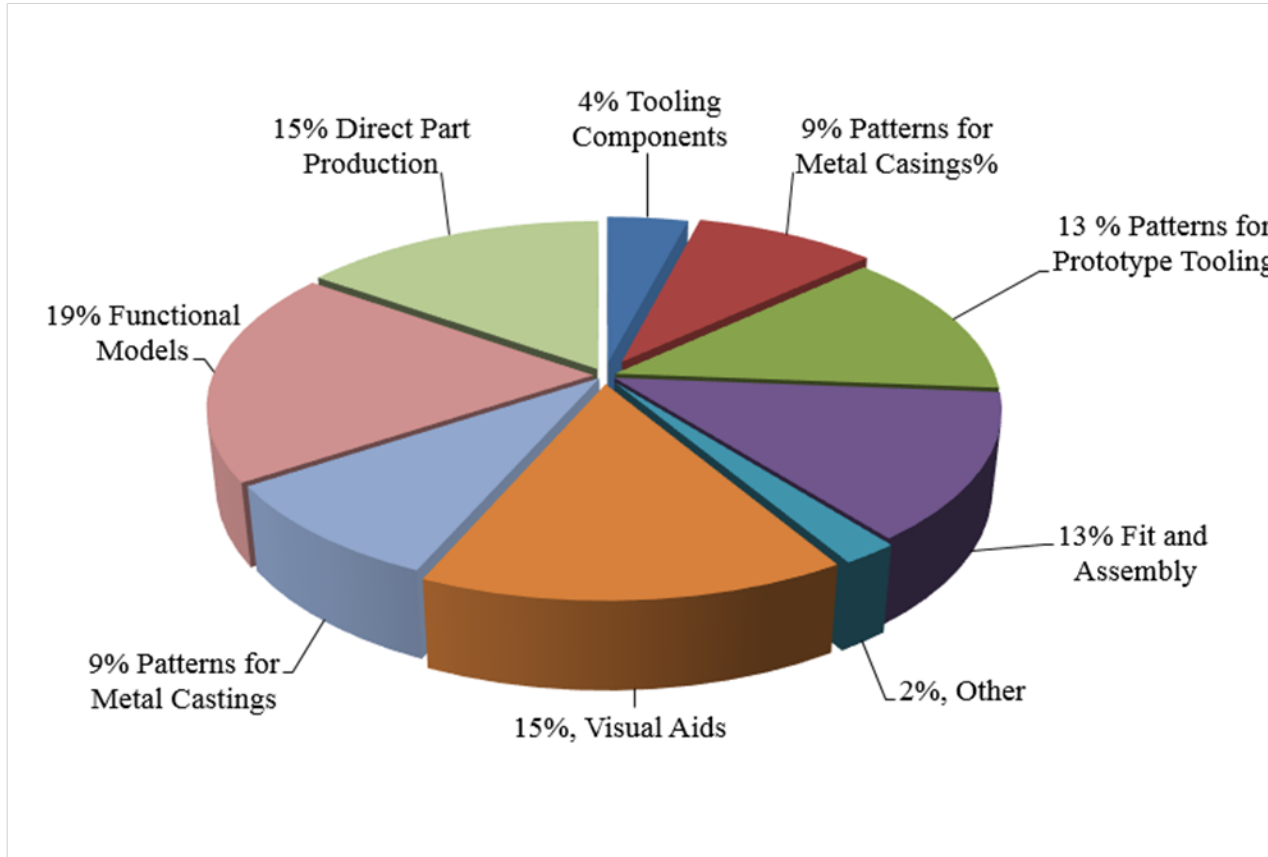


Installations by Country



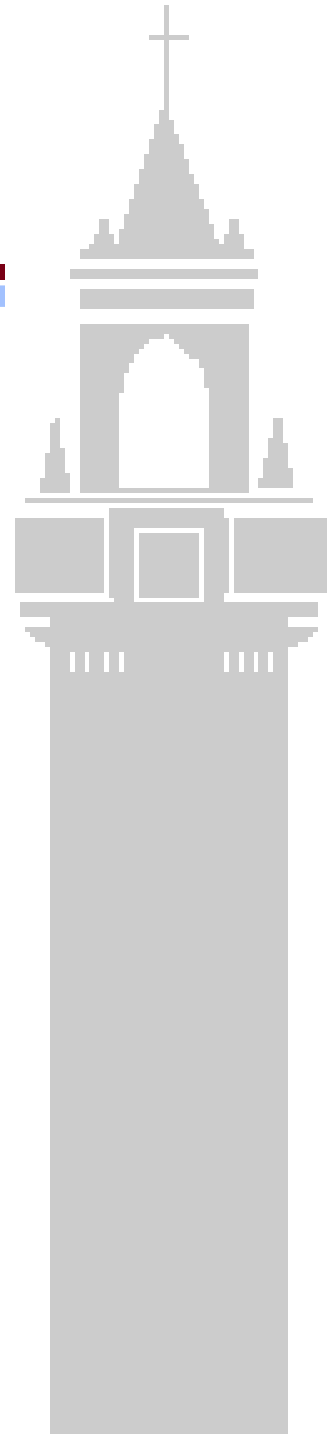
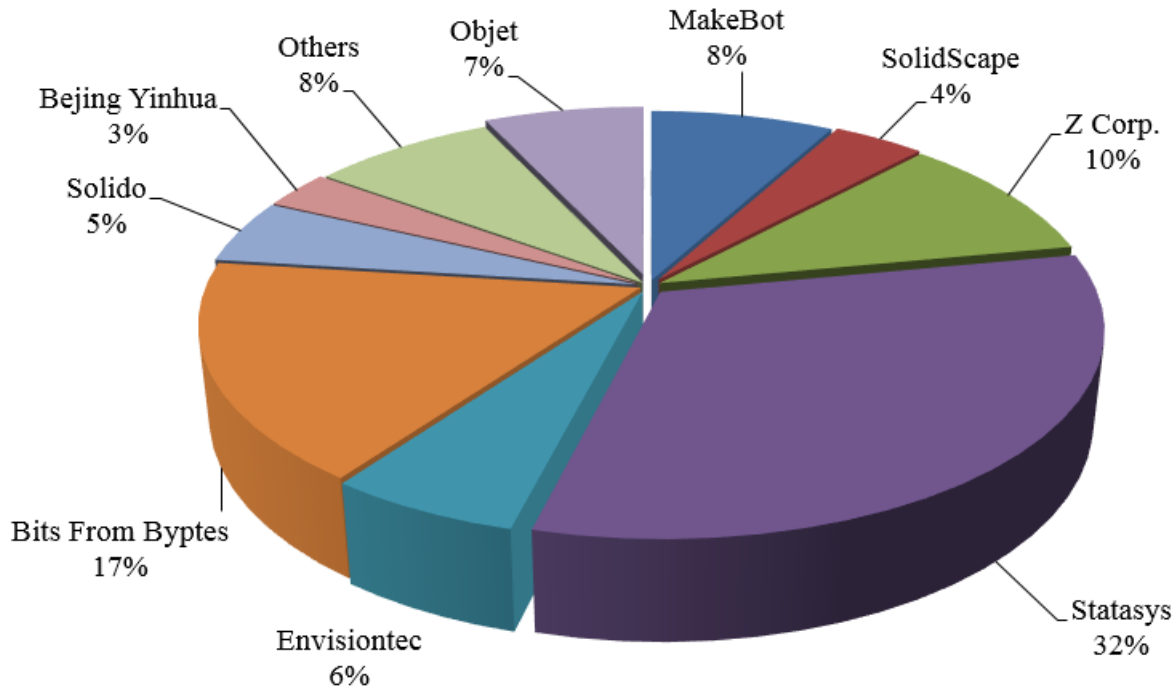


Recent Application of AM Processes



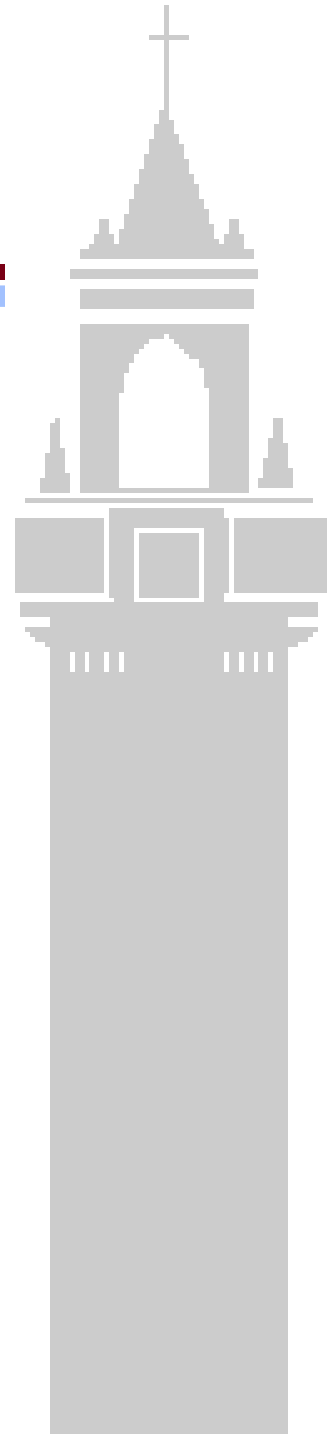
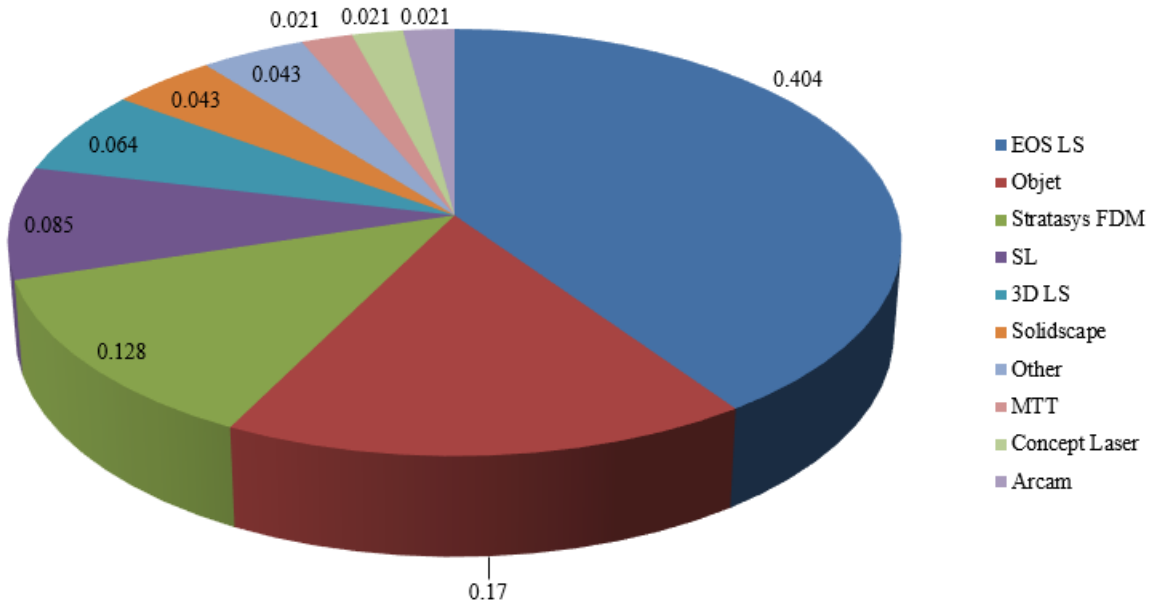


Market Share



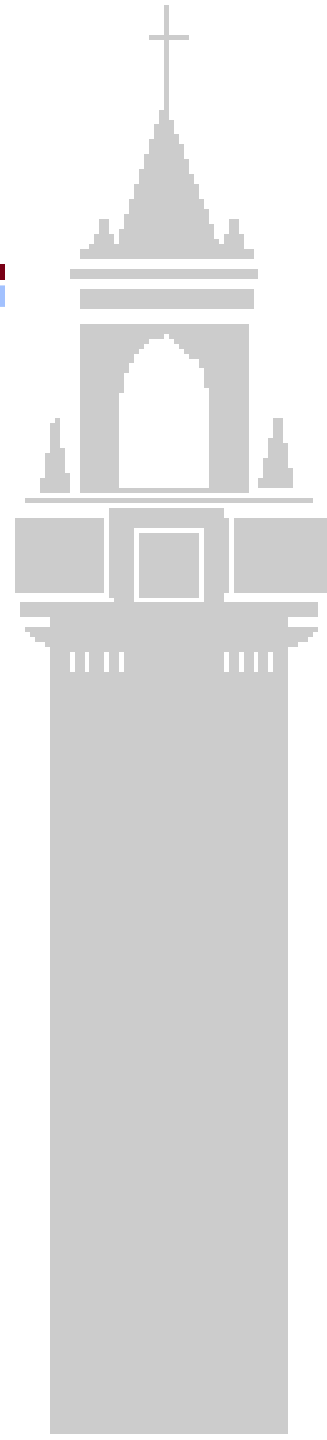
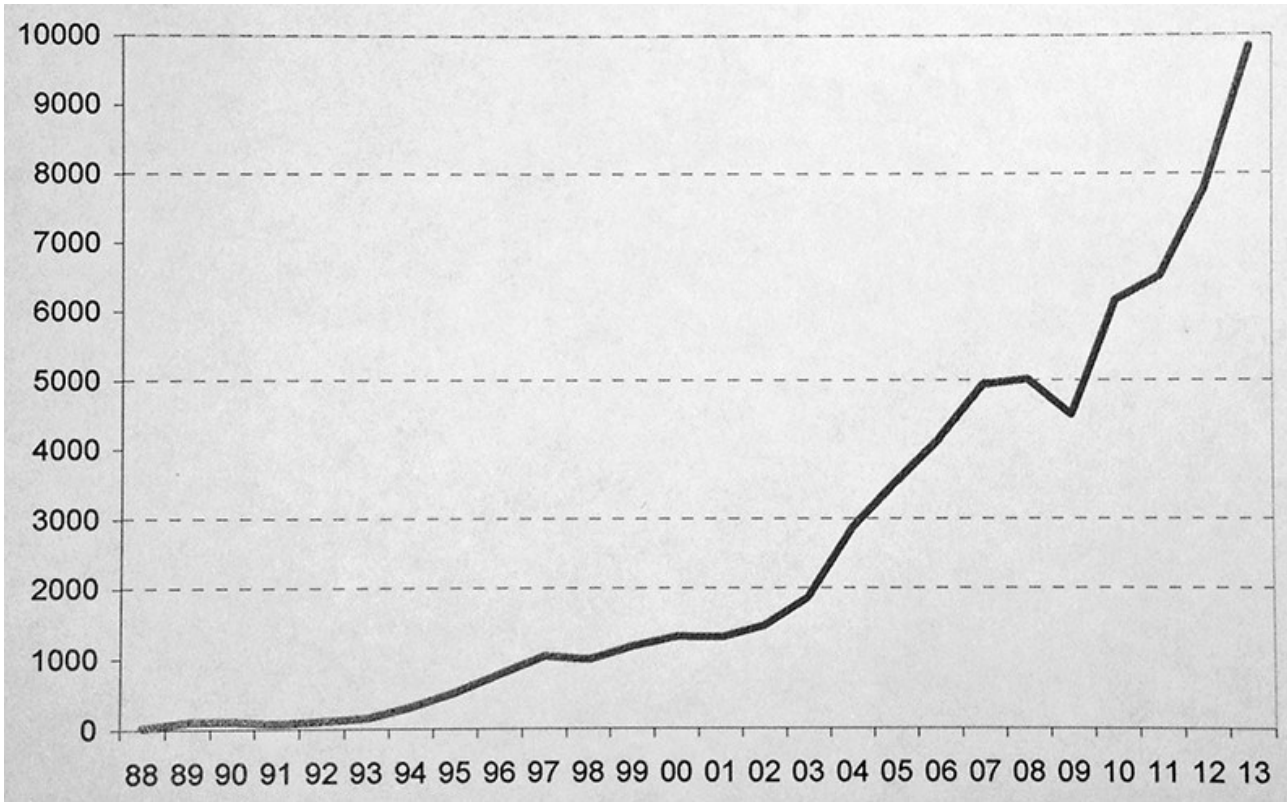


Preferred Technology





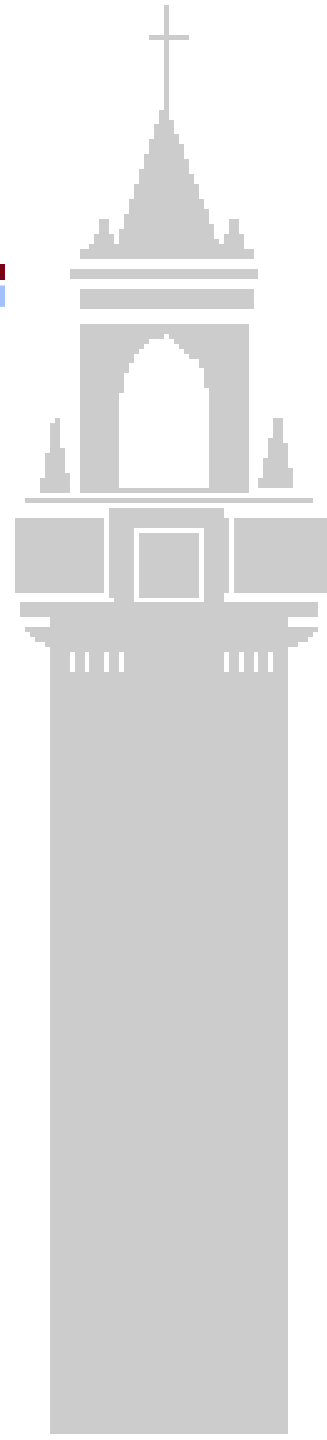
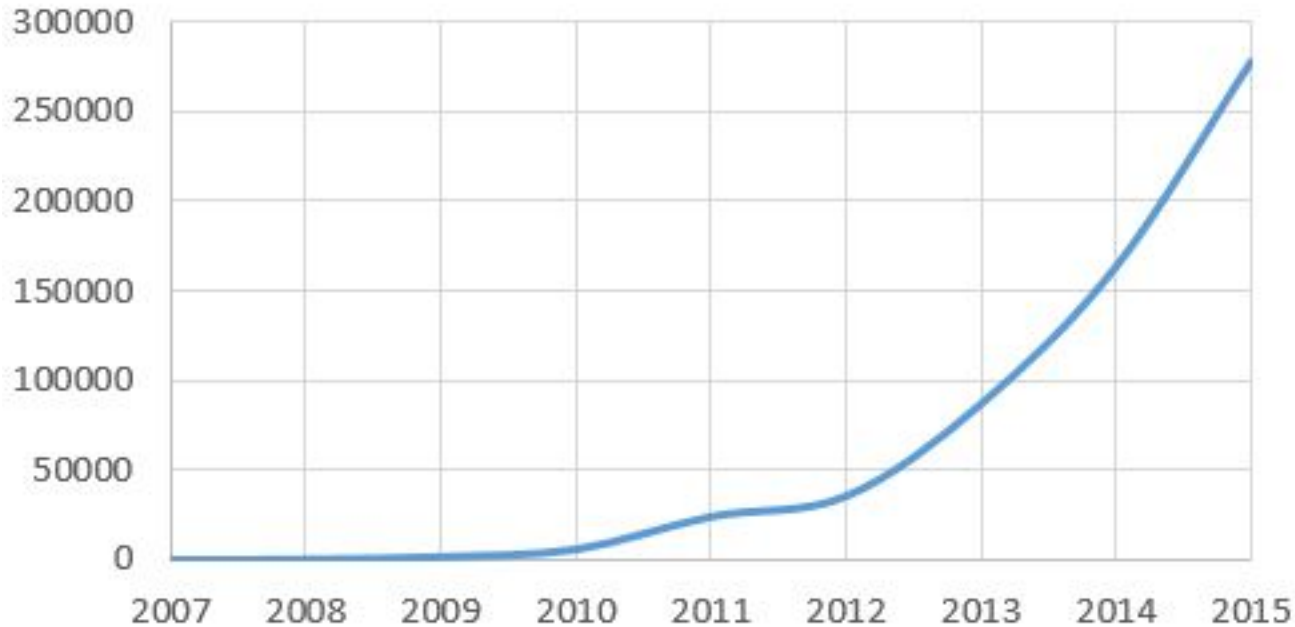
Growth of RP





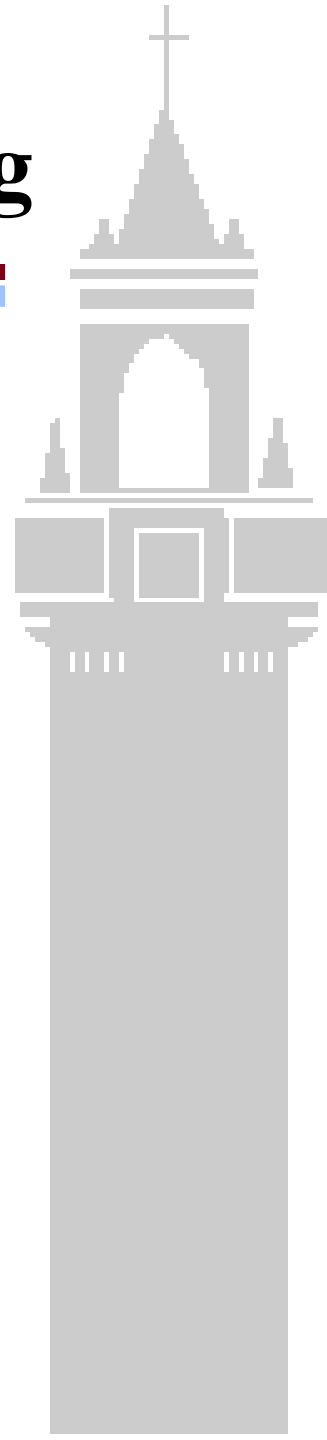
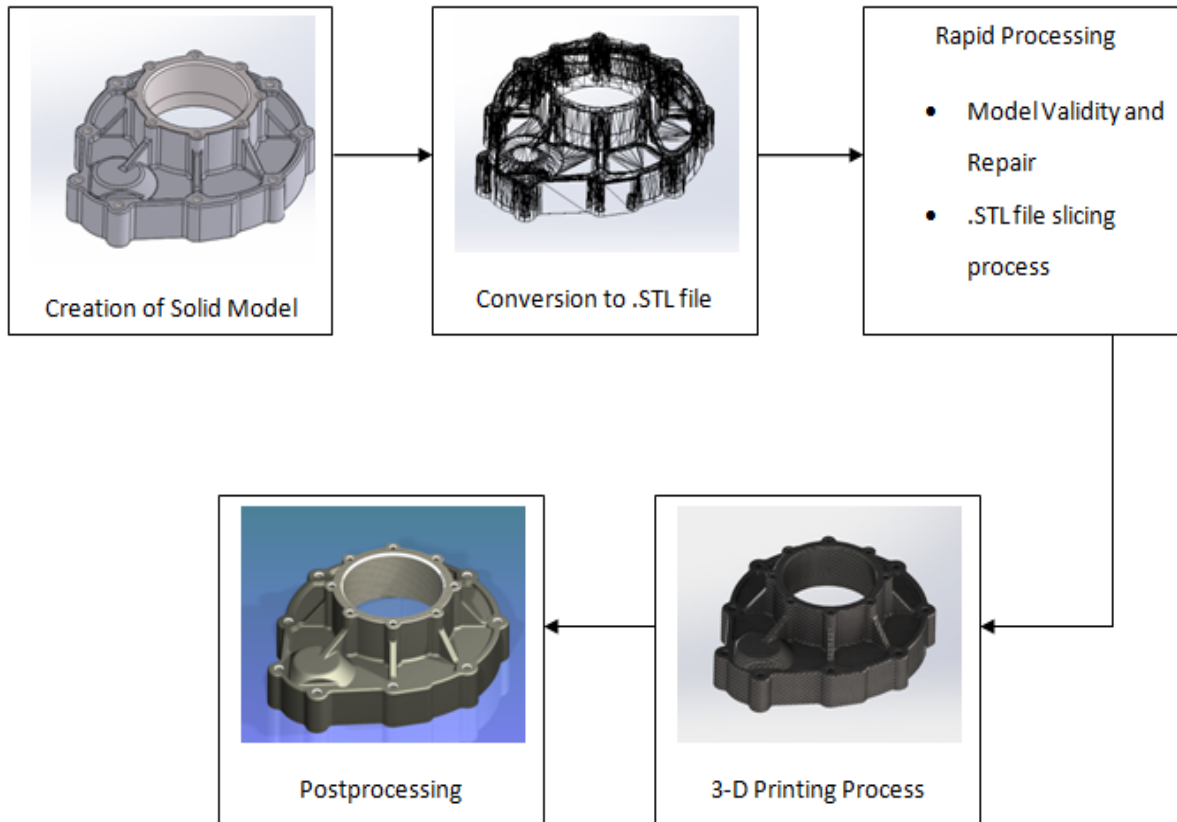
Growth of 3DP

Growth of 3D printing





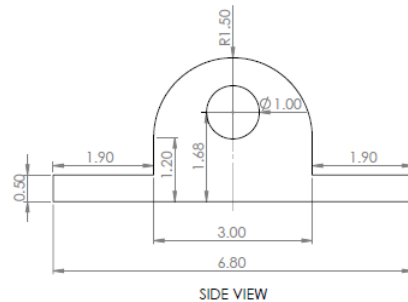
Five-step process of 3D printing



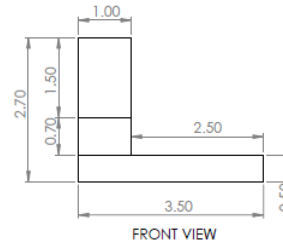


Case Study: Design & Printing of Eye Bracket

- The eye bracket is a very common engineering part that is used to mate parts in a convenient way using standard fasteners
- All the dimensions and features that are contained in engineering drawing, a 3D CAD model of the eye bracket was created in SolidWorks CAD software

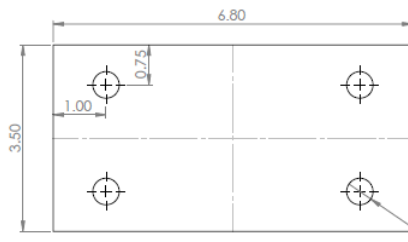


SIDE VIEW



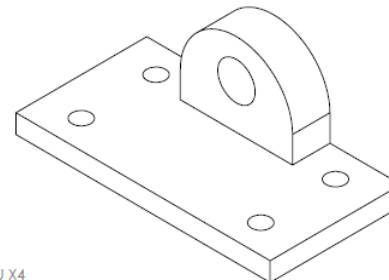
FRONT VIEW

ALL DIMENSIONS
ARE IN INCHES

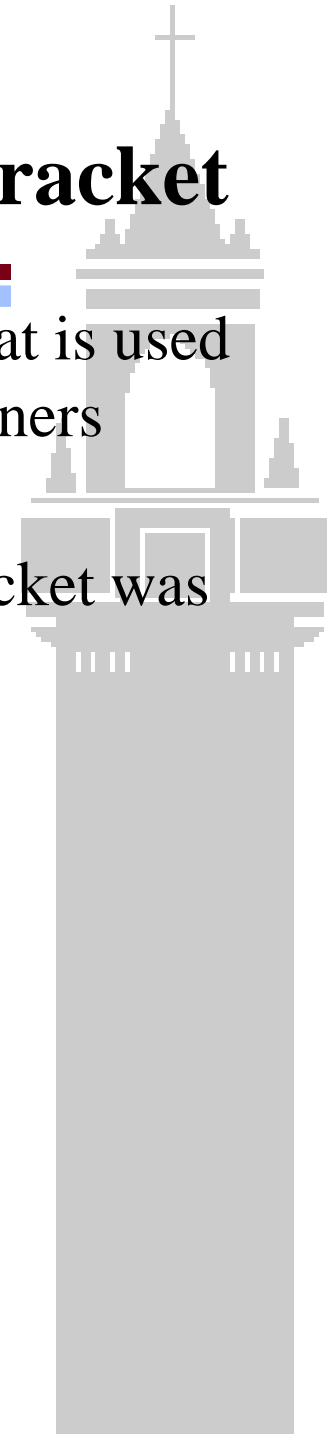


BOTTOM VIEW

Ø0.50 THRU X4



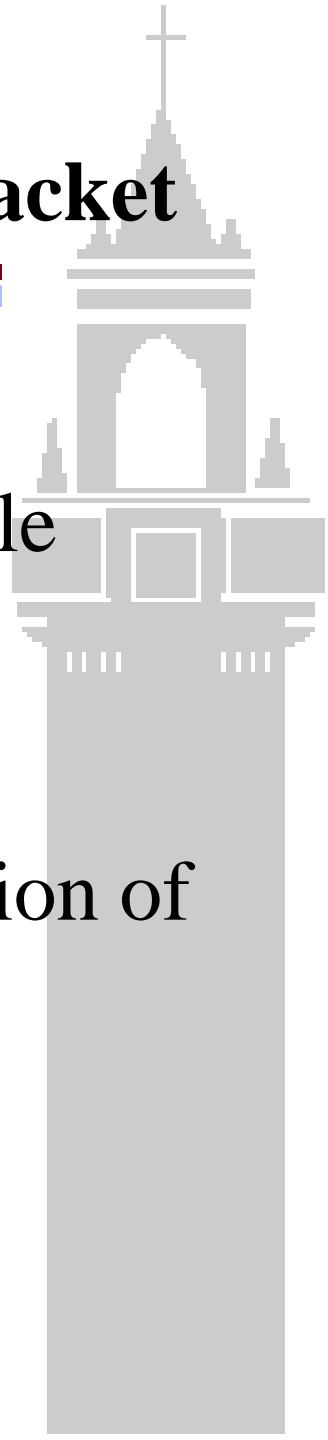
ISOMETRIC VIEW





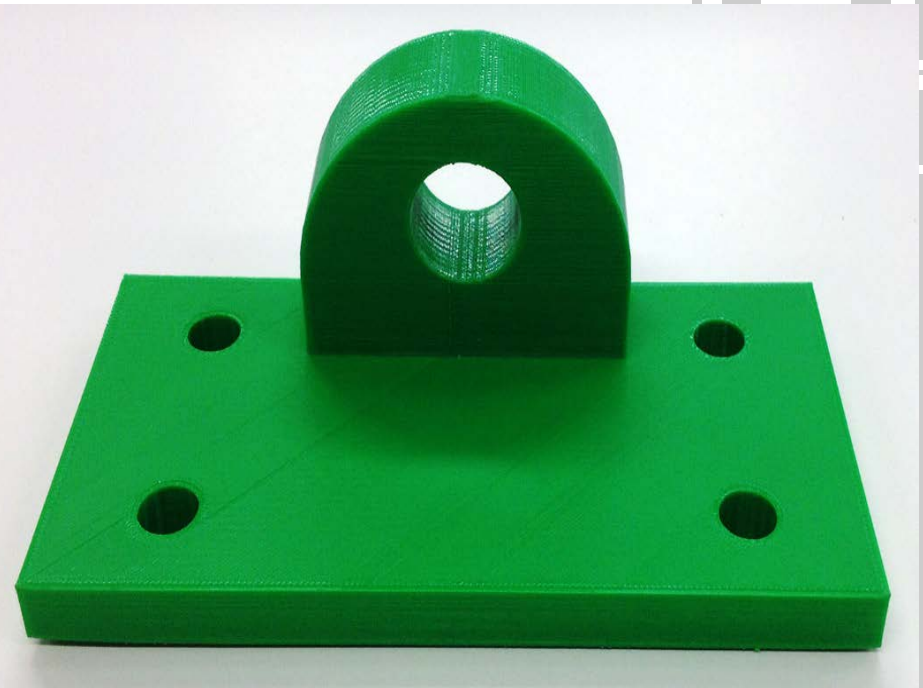
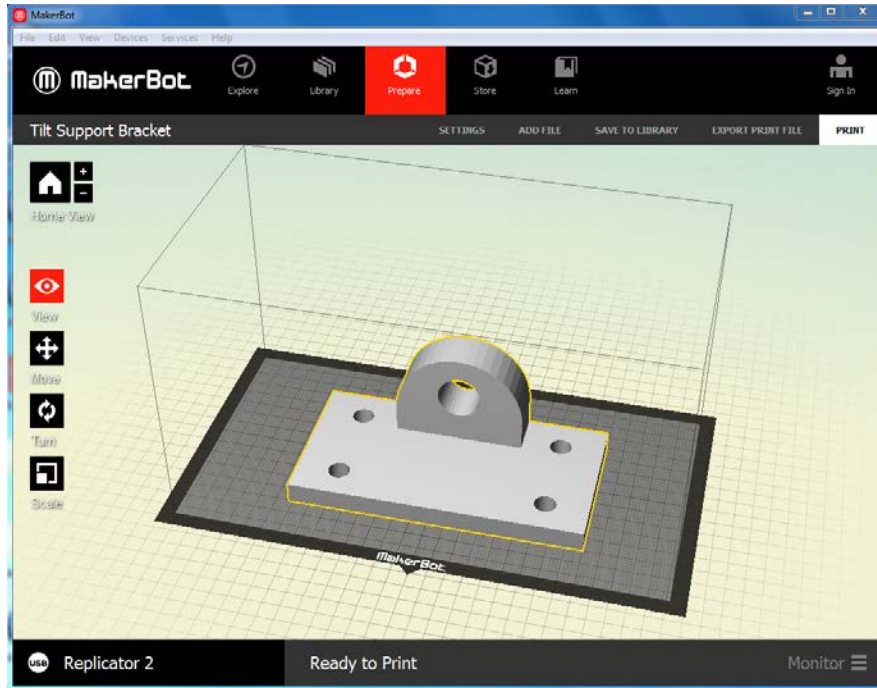
Steps of Design and Printing of Eye Bracket

- CAD modeling process
- Conversion of CAD model file to STL file
- Slicing the STL file; 3D printer setup
- Actual 3D building process
- Post processing; evaluation and verification of the produced prototype

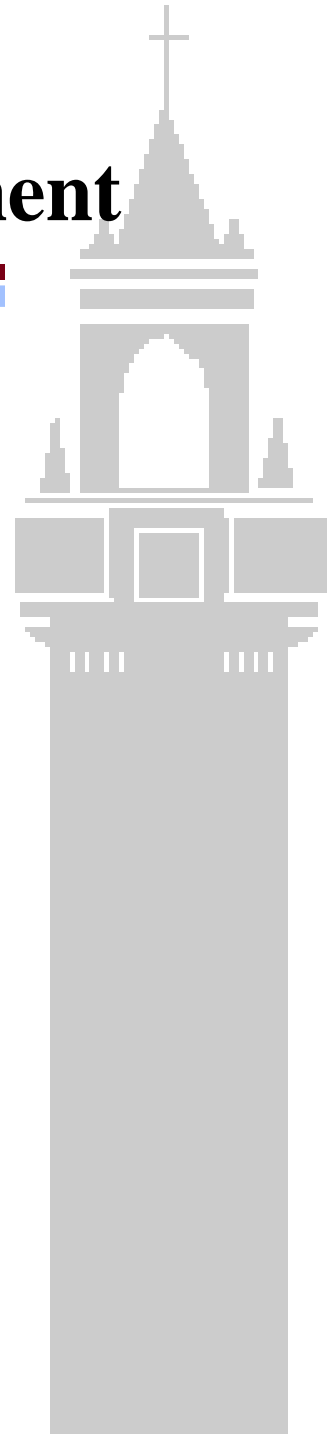
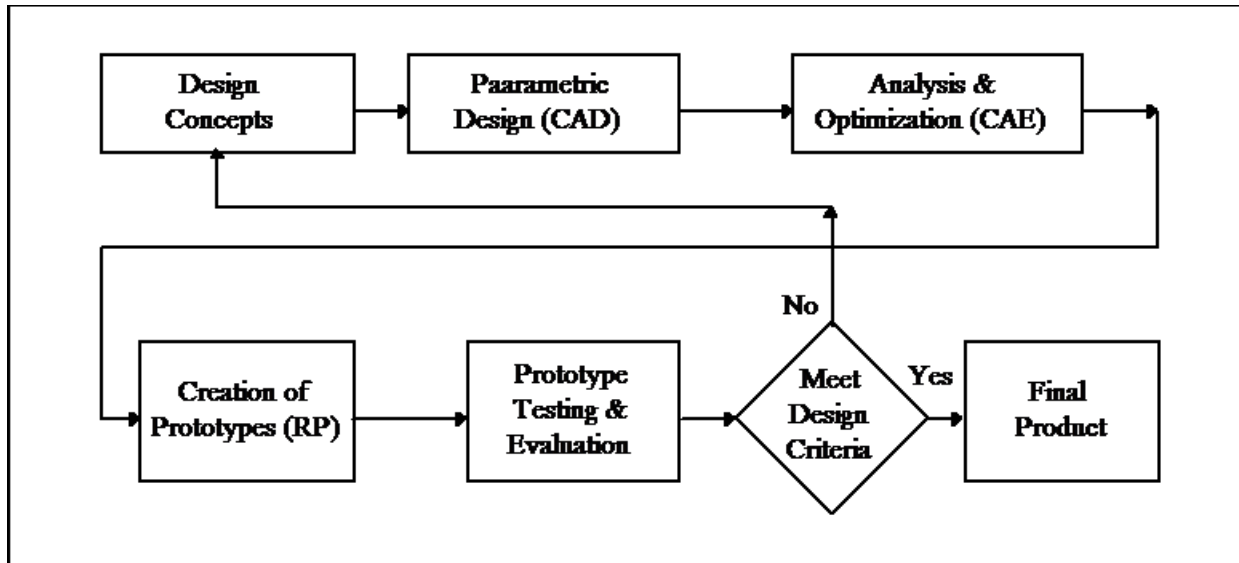




STL CAD File vs. Prototype



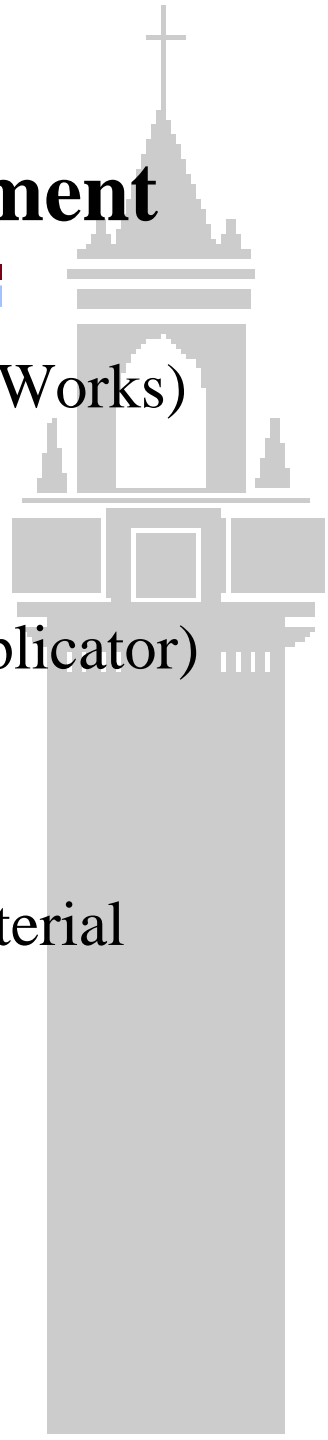
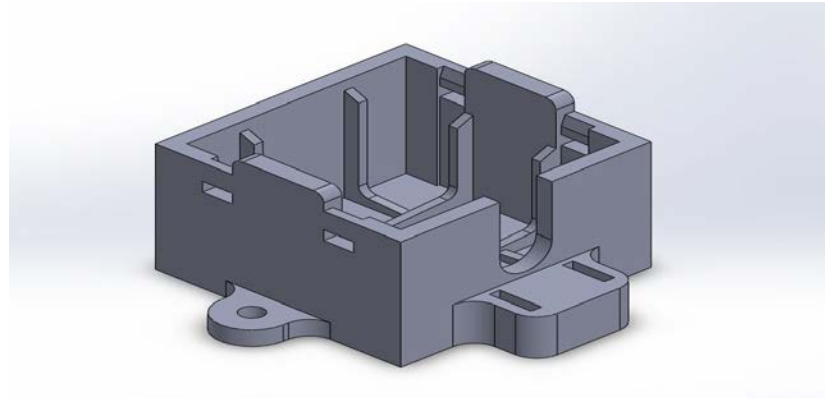
Role of Prototyping on Product Development





Application of RP in Product Development

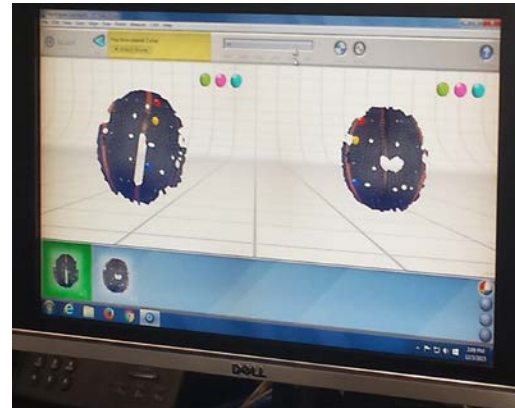
- Create a CAD model using a CAD software (i.e, SolidWorks) as shown below.
- Save the CAD file as an STL file.
- Open the STL file in a RP machine (i.e, MakerBot Replicator)
- Adjust build configurations (dimensions, axes)
- Grow the prototype
- Postprocess the prototype by getting rid of support material





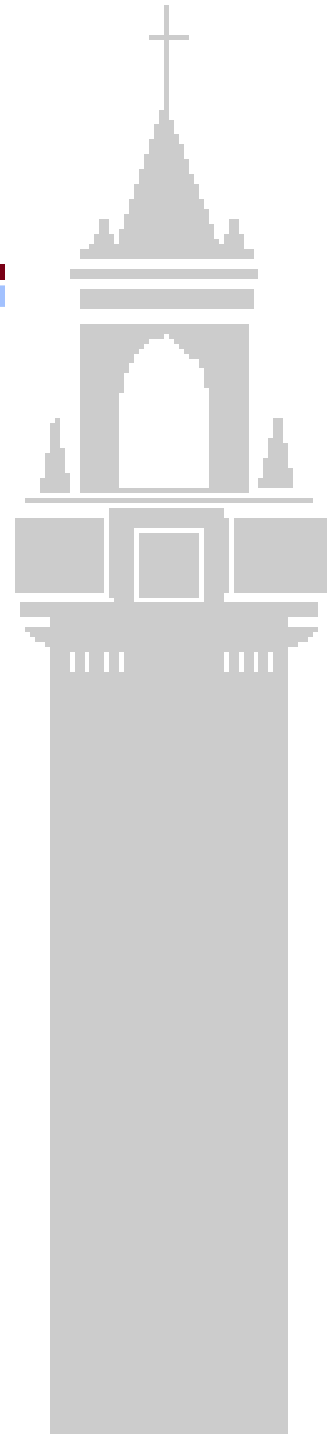
Reverse Engineering

- Reverse Engineering (RE) is the technique of reproducing the surface geometry of an existing physical part or model directly into a three-dimensional (3D) data file format by using contact or non-contact 3D scanner
- RE technique starts by 3D scanning the part and capturing its all geometry, then the 3D scan is uploaded to the software where it can detect its flaws and reproduce a new CAD file for the sake product development.





Results of RE Technique





Rapid Tooling

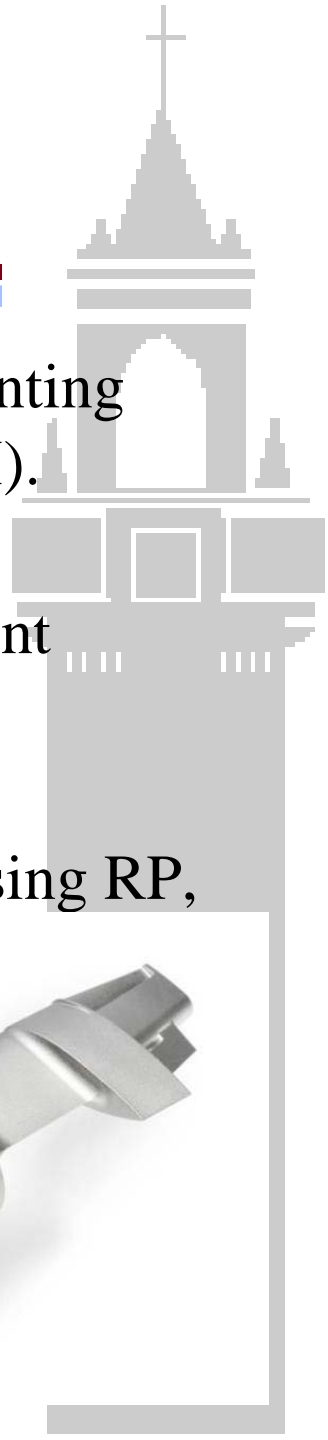
- Rapid tooling is a manufacturing process that combines 3D printing technology with conventional tooling practices to produce molds quickly. RT typically uses 3D printed model as a pattern or uses the 3D printing process directly to fabricate a tool for a limited volume of prototypes.
- Advantages of Rapid Tooling (also Called Rapid Forming) that it can lower the time of production for sheet metal forming from 96 hours down to 2-4 hours, as shown below.





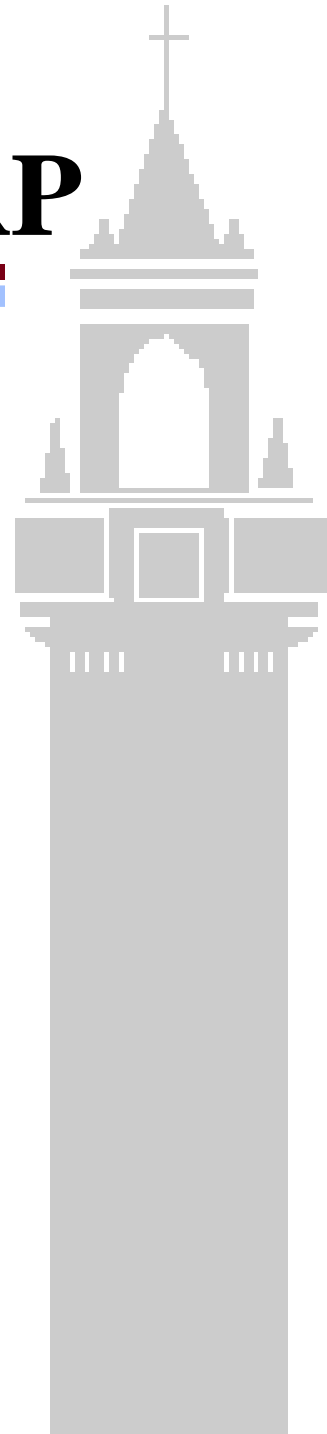
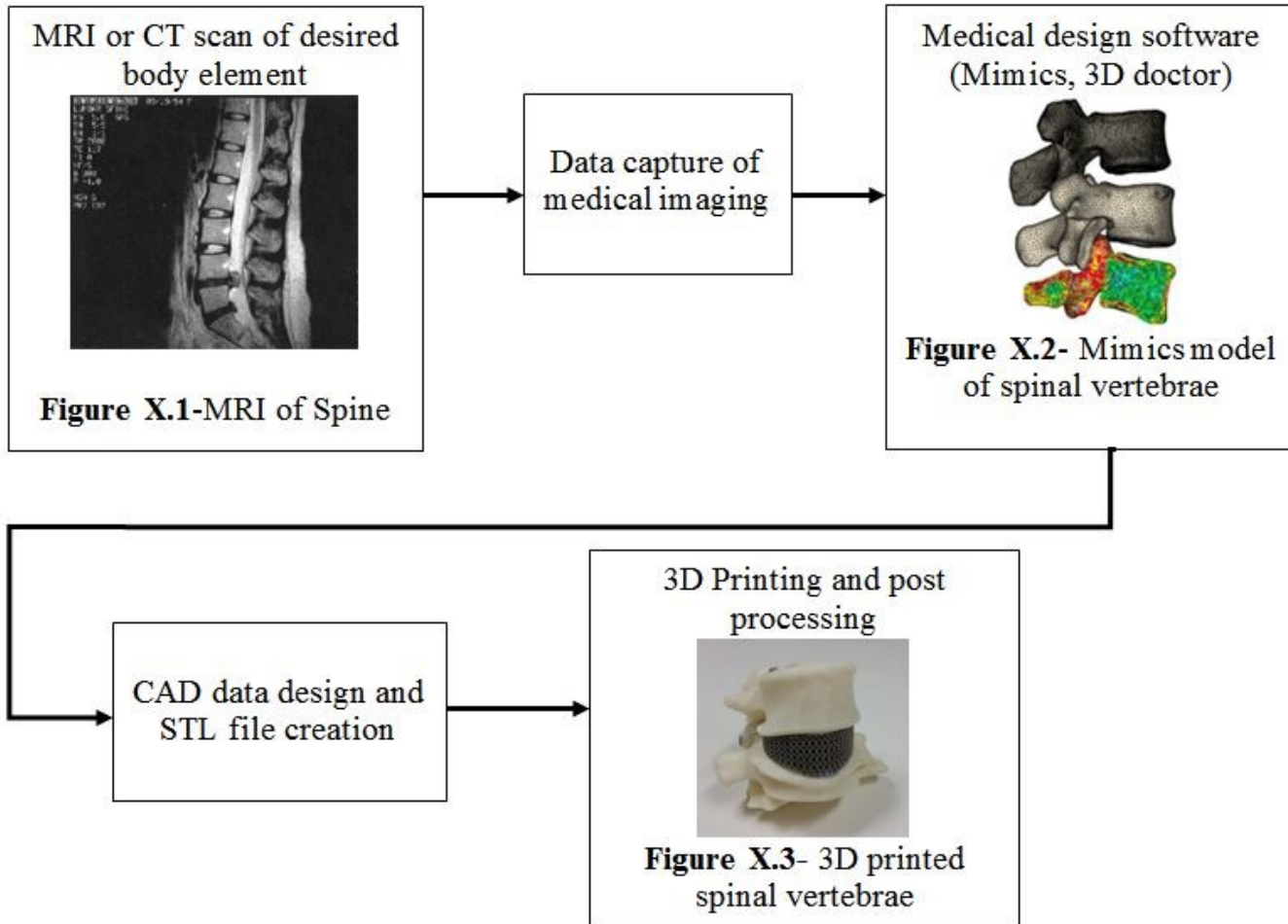
Rapid Manufacturing

- Some companies are extending the envelope of 3D printing and RT into a process called rapid manufacturing (RM).
- The aerospace industry is one of the biggest users of the technology. However, the industry imposes stringent quality controls on all the prototypes used for various applications.
- 3D Printed Fuel Nozzle from GE Aviation is shown using RP, 3DP, and RM techniques





Medical Methodology of RP





Medical Applications of RP

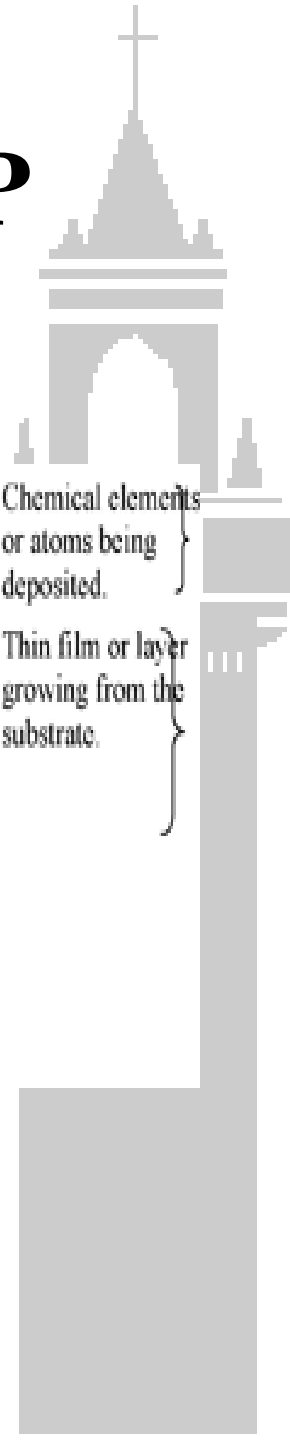
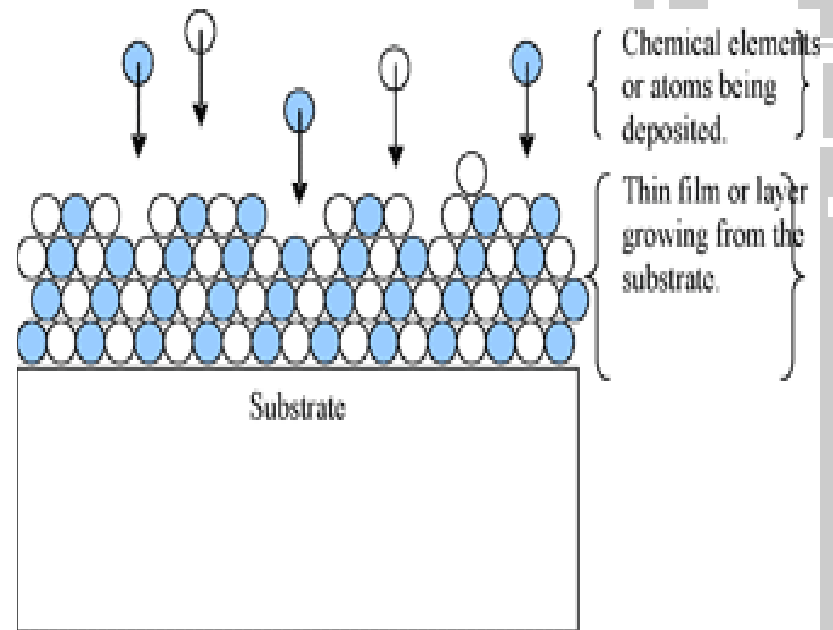
- 3D printing applications in medical field can be categorized in the following categories: tissue and organ fabrication, prosthetics, implants, anatomical models, drug delivery and dosage forms.
- 3D printing is used to produce a customized hearing aid shells and responsible for 99% of the hearing aid manufacturing nowadays.





Nanomanufacturing using RP

- Consists of both nanotechnology and AM because it builds additively, layers by layers.
- MBE is essentially atomic spray painting on surfaces, one atomic layer at a time





Toys

- RP provides engineering and toy design assistance and is able to provide toy prototypes with fine detail and high resolution.

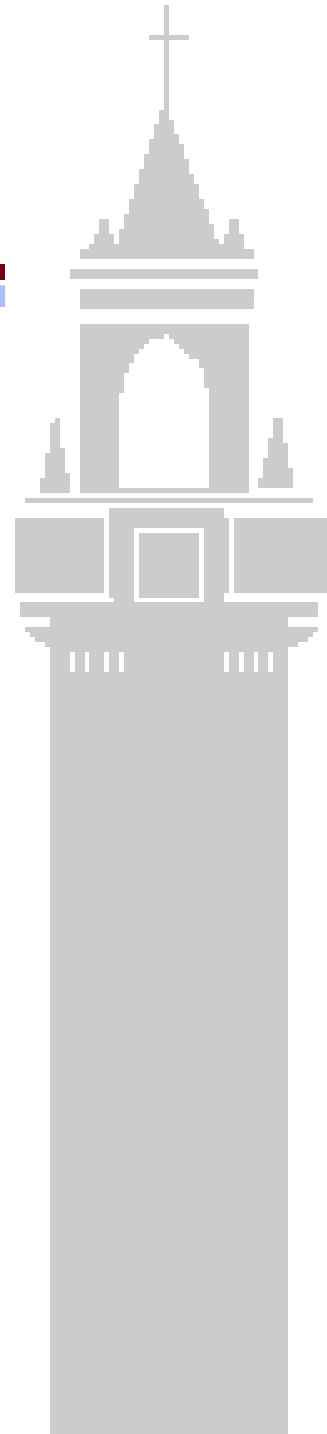




Challenges of RP Selection

RP System Specification

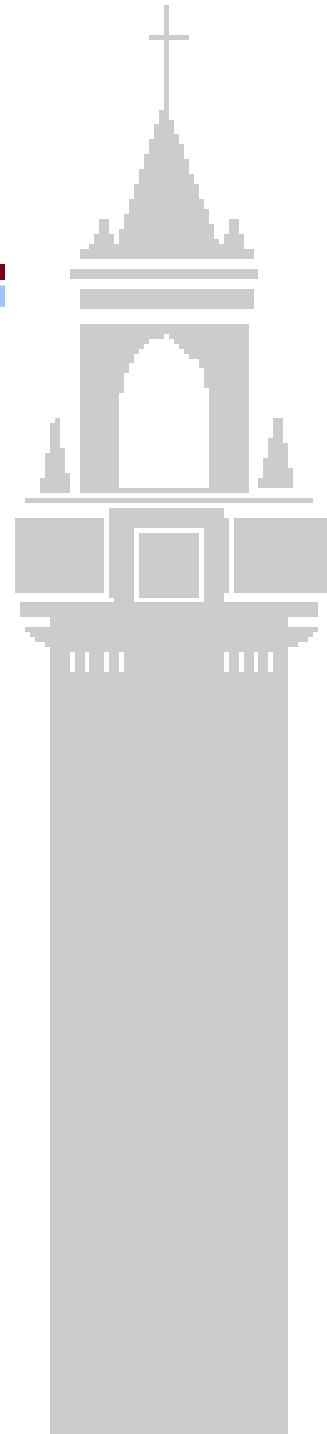
	EOS Formiga P 110	Stratasys Fortus 400mc	Stratasys Connex 350	CMET Inc Rapid Meister ATOMm- 4000	3DS Projet 6000 SD	3DS Projet 5000	Optomec LENS 450
Plat Length (cm)	20	35.6	35	61	25	55	10
Plat Width (cm)	25	25.4	35	61	25	39.3	10
Plat Height (cm)	33	25.4	20	50	25	300	10
Price (USD)	140150	105000	200000	378500	200000	159900	299000
Roughness (um)	60	200	16	25	100	32	25
Sys Length (cm)	132	128.1	142	190	78.7	153	100
Sys Width (cm)	106.7	89.535	112	119	73.7	90.8	100
Sys Height (cm)	220.4	196.2	113	217	182.9	145	150
Weight (kg)	600	593	500	550	181	538	200
Speed (mm/h)	20	50	60	40	30	30	80





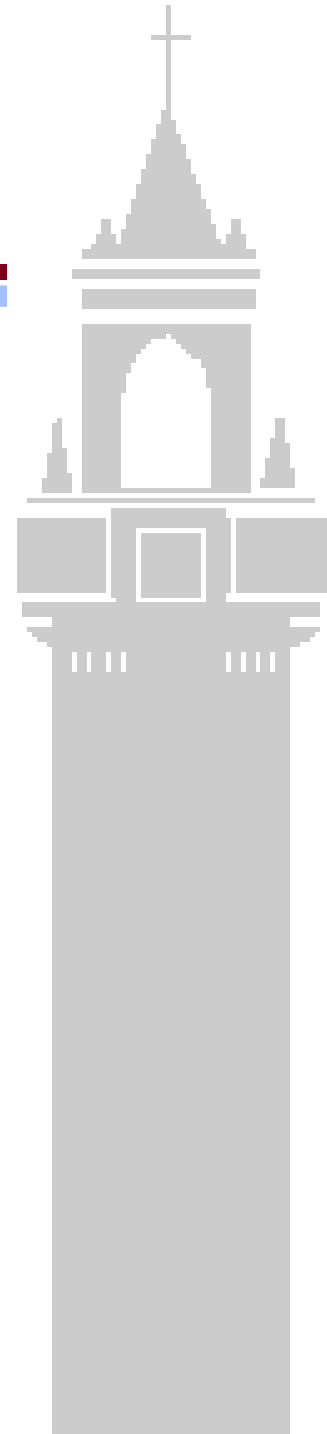
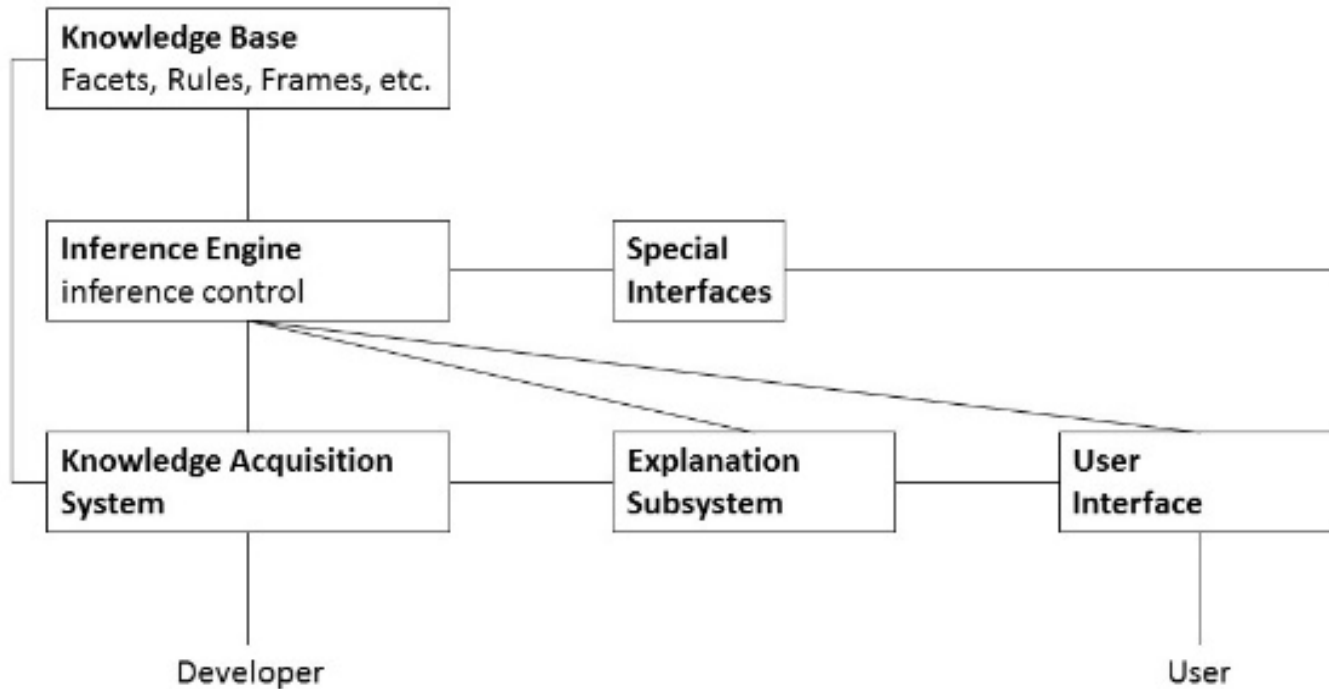
Expert System

- Expert System is one of the elements of Artificial Intelligence which is concerned with the use of computers in tasks that require knowledge perception, reasoning, learning understanding and similar cognitive ability.
- An Expert System is an intelligent computer that uses knowledge and inference procedures to solve difficult problems.
- Features of an Expert System are: (1) A knowledge base of domain facts and heuristics associated with the problem, (2) An inference procedure for the utilization of the problem and (3) A working memory or global database for keeping track of the problem status



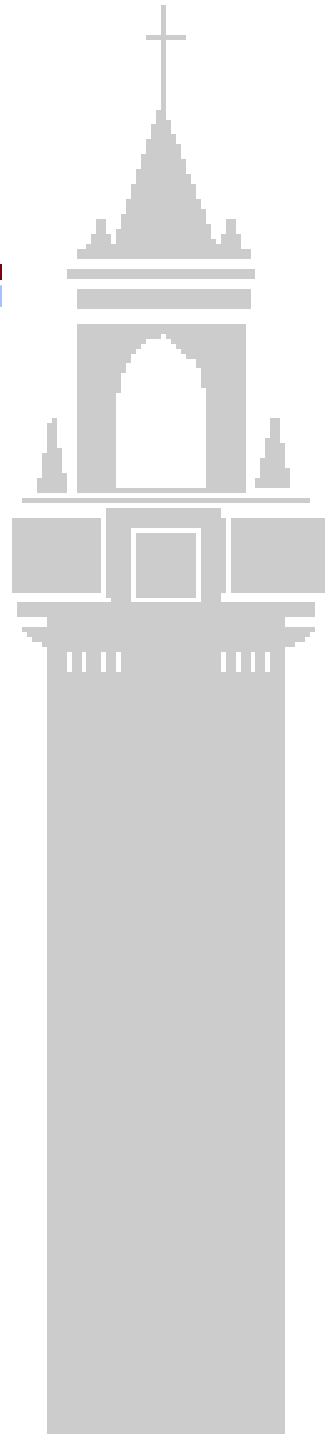
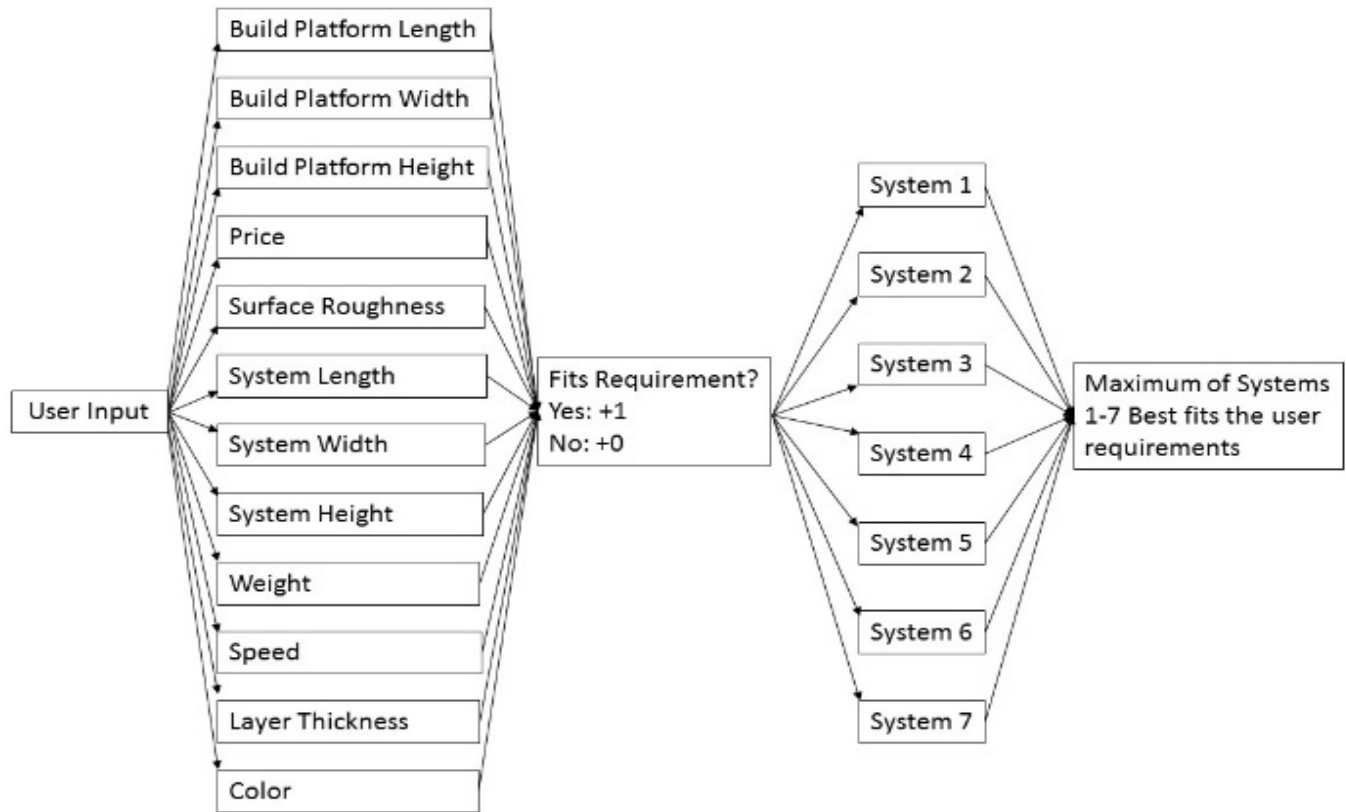


Expert System Concept





Expert System Flow Diagram





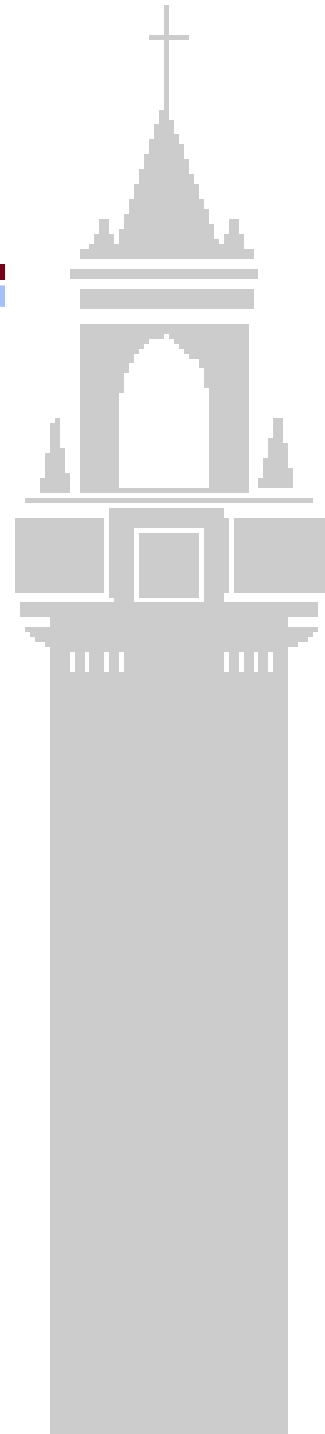
Input and Output Parameters

Input Parameters:

- $l = \text{input}(\text{'minimum build platform length desired (mm):'})$
- $w = \text{input}(\text{'minimum build platform width desired (mm):'})$
- $h = \text{input}(\text{'minimum build platform height desired (mm):'})$
- $p = \text{input}(\text{'maximum price (USD):'})$
- $r = \text{input}(\text{'maximum desired surface roughness (in microns):'})$
- $L = \text{input}(\text{'maximum desired system length (mm):'})$
- $W = \text{input}(\text{'maximum desired system width (mm):'})$
- $H = \text{input}(\text{'maximum desired system height (mm):'})$
- $z = \text{input}(\text{'maximum desired system weight (kg):'})$
- $s = \text{input}(\text{'minimum desired speed of system (in mm/hour):'})$
- $t = \text{input}(\text{'maximum desired layer thickness (in mm):'})$

Output Parameters:

- $a_l = 10.16;$
- $a_w = 10.16;$
- $a_h = 10.16;$
- $a_p = 349.00;$
- $a_r = 100;$
- $a_L = 38.1;$
- $a_W = 29.21;$
- $a_H = 25.4;$
- $a_z = 4.99;$
- $a_s = 6;$





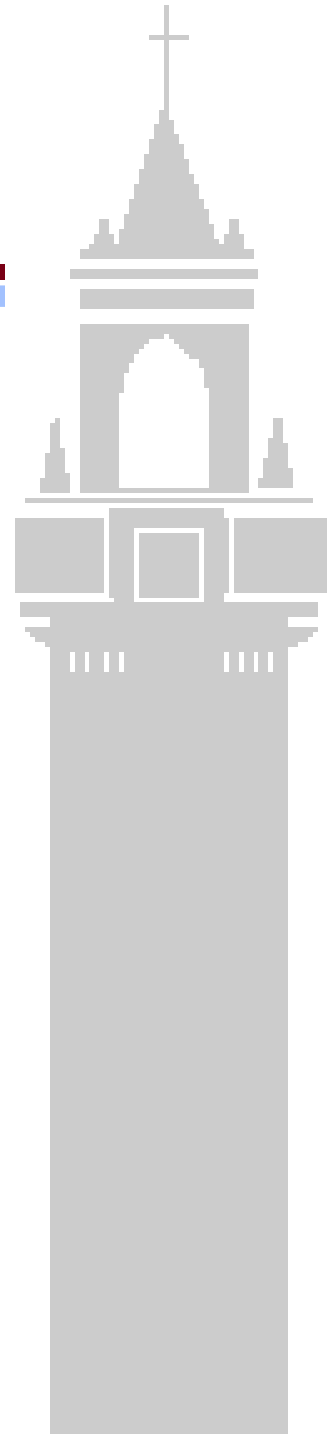
Software Code

$X = [a \ b \ c \ d \ e \ f \ g];$

$F = \max(X)$

```
minimum build platform length desired (cm): 15
minimum build platform width desired (cm): 15
minimum build platform height desired (cm): 15
maximum price (USD): 3000
maximum desired surface roughness (in microns): 60
maximum desired system length (cm): 100
maximum desired system width (cm): 10
maximum desired system height (cm): 100
maximum desired system weight (kg): 15
minimum desired speed of system (in mm/sec): 5
desired number of colors: 1
The Lulzbot Taz 5 best fits your needs.
```

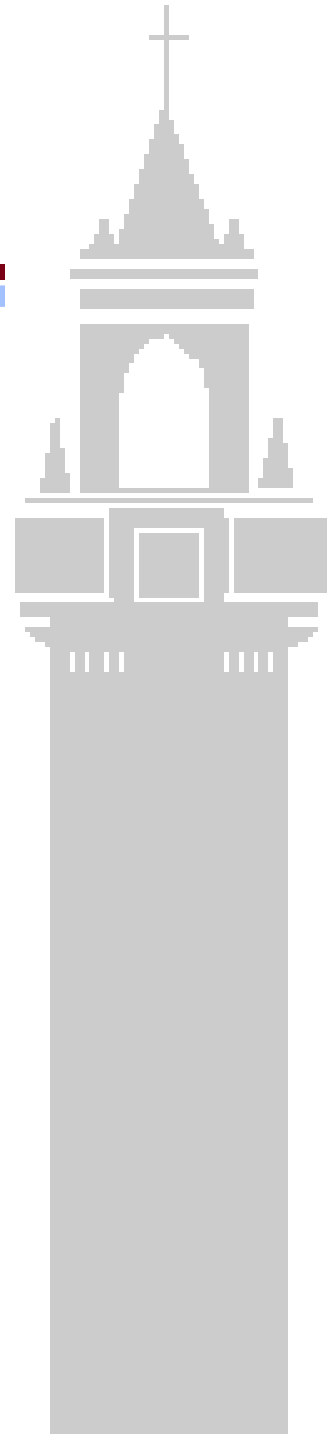
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Conclusions

- RP & 3DP are new technologies that are fueling product development
- 3DP applications include RE, RT, medical applications, etc.
- The Expert System developed here is interactive program that helps a potential buyer select a conventional RP or 3D Printer. The program has been developed using MATLAB.
- The buyer could be from academia or industry
- The Expert System is open-ended so that the program could be easily modified to take into consideration the availability of new products in the future
- The program is user friendly, easy to use and has the potential to be used on a wide scale





Acknowledgement of Grants

- The authors are pleased to acknowledge the financial support provided by the Undergraduate Research Opportunities (UROP) of Loyola Marymount University for the completion of the project.

