3D Printing

Where is it today
• What is 3D “printing”

• A bit of HISTORY

• Types of 3D printing technology

• Really Interesting 3D printing Applications!

• Bringing it Home
What is 3D Printing

• “A process for making a **physical object** from a three-dimensional **digital model**, typically by laying down successive thin **layers** of a material”.

• 3D Printing is also referred to as-

  “**ADDITIVE MANUFACTURING**”
A “Three-Dimensional Digital Model”

(Paper ‘n Pencil holder designed by students in recent FPL class)

Prepared by-Robert Persing April 2017
Finished product printed with the library’s 3D printer
• Invented in 1983, 3D printing is not all that new

• Chuck Hull, recognized as the “inventor” of 3D printing, filed for a patent August 8, 1986

• Hull coined the phrase “Stereo Lithography” for the technology used in his 3D printer when applying for the patent (granted March 11, 1986)

• Let’s watch a brief CNN interview with Chuck Hull
The year 2005 is a notable point in the history of 3D printing. This marks the start of the RepRap Project by Dr. Adrian Bowyer at Bath University in England.

RepRap is short for replicating rapid prototyper. RepRaps are 3D printers with the additional ability to produce most of the parts necessary to assemble another identical printer.
“Darwin”

The First RepRap Printer
How Do You “Print” 3D

• With the history lesson covered, let’s look at 3D Printing in the 21st century

• What Technology is used to print 3D?

• How do you actually make a 3D printed object?
## Types of Printing Technology

<table>
<thead>
<tr>
<th>Type</th>
<th>Technologies</th>
<th>Materials</th>
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<tbody>
<tr>
<td><strong>Extrusion</strong></td>
<td>Fused deposition modeling (FDM)</td>
<td>Thermoplastics (e.g. PLA, ABS), HDPE, eutectic metals, edible materials, Rubber (Sugru), Modeling clay, Plasticine, RTV silicone, Porcelain, Metal clay (including Precious Metal Clay)</td>
</tr>
<tr>
<td><strong>Wire</strong></td>
<td>Electron Beam Freeform Fabrication (EBF&lt;sup&gt;3&lt;/sup&gt;)</td>
<td>Almost any metal alloy</td>
</tr>
<tr>
<td><strong>Granular/Powder</strong></td>
<td>Direct metal laser sintering (DMLS)</td>
<td>Almost any metal alloy</td>
</tr>
<tr>
<td></td>
<td>Electron-beam melting (EBM)</td>
<td>Almost any metal alloy including Titanium alloys</td>
</tr>
<tr>
<td></td>
<td>Selective laser melting (SLM)</td>
<td>Titanium alloys, Cobalt Chrome alloys, Stainless Steel, Aluminum</td>
</tr>
<tr>
<td></td>
<td>Selective heat sintering (SHS)</td>
<td>Thermoplastic powder</td>
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<tr>
<td></td>
<td>Selective laser sintering (SLS)</td>
<td>Thermoplastics, metal powders, ceramic powders</td>
</tr>
<tr>
<td><strong>Powder bed and inkjet head 3D printing</strong></td>
<td>Plaster-based 3D printing (PP)</td>
<td>Plaster</td>
</tr>
<tr>
<td><strong>Laminated</strong></td>
<td>Laminated object manufacturing (LOM)</td>
<td>Paper, metal foil, plastic film</td>
</tr>
<tr>
<td><strong>Light/Polymerized</strong></td>
<td>Stereolithography (SLA)</td>
<td>Photopolymer</td>
</tr>
<tr>
<td></td>
<td>Digital Light Processing (DLP)</td>
<td>Photopolymer</td>
</tr>
</tbody>
</table>

*Concrete*
3D Printing Technologies

• Simplest form:
  – Fused Filament Fabrication – FFF
  – Fused Deposition Modeling – FDM

(FDM and FFF are pretty much the same)

These are names for the printing technology used in many 3D printers, particularly popular with the RepRap and other desktop printers.
How Does it Work?

The technology used by many 3D printers,—especially hobbyist and consumer-oriented models—is “**Fused Filament Fabrication**”, a special application of plastic extrusion.

**Simply put-**

1. **Plastic filament is melted and forced through a very tiny nozzle (extruder) onto the printer’s build platform.**

2. **The extruder nozzle is moved in such a way as to “draw” a single layer of our 3D object.**

3. **The build platform is then moved down a small amount and the second layer of our object is drawn on top of the first layer.**

4. **This process continues, layer upon layer, until the object is fully formed.**
3D Printing Technology
Fused Filament Fabrication

Extruder
Object build layers
Layer-3
Layer-2
Layer-1
Build Platform

Prepared by-Robert Persing April 2017
A time-lapse video will demonstrate the FFF printing process - FFF DEMO-1 and FFF DEMO-2
3D Printing Technology

Stereo Lithography

- Liquid Resin Holding Tank
- X-Y Scanning System
- Highly Focused Laser Beam
- Ultraviolet Laser
- Layers of Solidified Resin
- Build Platform Positioning Piston
- Build Platform
3D Printing Technology

Stereo Lithography

Stereolithography Apparatus (SLA)

Stereo Lithography Video
3D Printing Technology

Direct Metal Laser Sintering

DMLS Video
3D Printing Technology

Direct Metal Laser Melting

DMLM Video
What is 3D Printing

Additive vs Subtractive Manufacturing

In comparison with traditional “subtractive” manufacturing methods in which a block of finished material is machined down to make a product, additive manufacturing methods are fast, use less energy, and generate less waste material.
What is 3D Printing

SUBTRACTIVE MANUFACTURING

ADDITIVE MANUFACTURING

Note the amount of waste material

Prepared by: Robert Persing April 2017
Demonstration Time

- Draw the 3D model using CAD software *(SketchUp)*
- Export/Save an “STL” data file of 3D model
- Process the *STL* file to create “*Slices*” and useable “*G-code*” *(Slic3r)*
- Feed the G-code to the printer *(Repetier Host)*
- Print 3D object
Start SketchUp CAD program
Sketchup Drawing screen
Select the Rectangle tool
Draw a 20mm X 20mm rectangle
Select the Push/Pull tool
Pull surface UP to form a box 10mm high.
Select the Tape Measure Tool to create some guide lines
Use the Tape Measure tool to create a vertical guide line 10 mm from the left edge.
Now, create a guide line 5mm down from the top edge. This marks the center of this side.
Select the Circle tool
Center the circle at the intersection of the guide lines.
Draw a circle with a 2.5mm radius
Select the "Push/Pull" tool
"Push" the circle 20mm to make a hole through the block.
We have created a 5mm diameter hole in our block...no waste material created.
Rotate object to view adjacent side. Again, select the "Tape Measure" tool to draw guide lines.
Draw horizontal and vertical guide lines at the middle of each side.
Again, select the "Circle" tool.
Position the center of the circle at the intersection of the guide lines and draw a 3.3mm radius circle.
Again, select the "Push/Pull" tool.
Use the "Push/Pull" tool to "push" the circle 20mm creating another hole through the block.
Looking through the hole we just created.
Let's clean up our drawing by deleting the guide lines.
Our 3D digital model is now complete. Time to save our work as a digital data file.
To be able to print our 3D object we need an "STL" data file. Select "Export STL..."
Type a file-name and "Save" the STL data file. This file contains the data for our digital model.
Now that we have the required **STL** file for our 3D object, it must be processed to create the many **layers** that will be used to print the 3D object.

This process will generate "**G-code**", the specific instructions used to control the printer.

This process is called "**Slicing**".

We will use an application called "**Slic3r**" to complete this process.  
(This is a free application)
This rectangular grid represents the build platform of our 3D printer.

This is the opening screen of the "Slic3r" application.
The "STL" data file for our 3D object is loaded into "Slic3r".
Our 3D model is positioned on the build platform, ready for "slicing"
After slicing, "slic3r" displays our 3D model showing the individual layers that will build the object.
“Slic3r” allows us to examine each of the individual layers that will be used to build our 3D object.

This is the first layer...
Layer #3
Layer #7
Layer #9
Layer #13
"Slic3r" generated the G-code instructions needed to drive the printer. Let's save this data file.
**G-code** is a set of instructions that direct our 3D printer where to extrude the molten filament and how much filament to extrude.

This coding is an industry standard used to control many CNC machines.

This is a sample of what the G-code instructions look like-

```
M109 S205; wait for temperature to be reached
G21; set units to millimeters
G90; use absolute coordinates
M82; use absolute distances for extrusion
G92 E0
G1 E-3.00000 F1800.00000
G92 E0
G1 Z0.350 F6600.000
G1 X34.073 Y34.921 F6600.000
G1 E3.00000 F1800.00000
G1 X35.466 Y33.562 E3.17693 F900.000
G1 X37.714 Y32.464 E3.40443
G1 X40.000 Y32.125 E3.61455
G1 X50.000 Y32.125 E5.43314
G1 X62.470 Y32.523 E5.66064
G1 X64.691 Y33.675 E5.88814 F900.000
```
Prepared by Robert Persing April 2017
REVIEW THE BASICS

1. Get an idea*
2. Use CAD software to draw your design idea
3. Feed CAD data into a “slicer” program to generate G-code
4. Feed the G-code data to the printer
5. Warm the extruder
6. Load the plastic filament
7. Print
3D Printing Applications

- Architecture
- Construction
- Industrial design
- Automotive
- Aerospace
- Military
- Engineering
- Dental and medical industries
- Biotech (human tissue replacement)
- Fashion
- Footwear
- Jewelry
- Eyewear
- Education
- Food
- and many other fields.

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Who wants to live in a castle?

Your realtor can’t find one locally?

Well… just 3D print it!

Here’s how to do it…. watch.
3D Printing Applications

Medical-

Apparel plus-

Architecture-

Culinary Arts-

Video

Video-1

Video-2

Video-3

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3D Printing

Where is it today?
In your home!
DIY Printers

Let’s look at the evolution of some RepRap printers so prominent in schools, homes, Maker Spaces and industry.
The Family Album

Our family album has some interesting 3D printers from the past and their modern day siblings. All are of RepRap heritage.

The “Prusa” RepRap, “Printrbot” and the “Makerbot” line of 3D printers all started out as DIY kits.
“Darwin”
The first RepRap 3D printer
Prusa designs have been widely copied throughout the world.

“Mendel”
An early design by Josef Prusa of the Czech Republic.

“Mendel 90”
A later design

Prusa i3
A current design
Chinese “COPY” of a popular “Prusa” design

(Licensing permits other companies to legally use Prusa’s designs. Check out “GPL” on Wiki.)
First Printrbot

2nd Generation Printrbot

Simple Maker 2013

Simple Metal 2015

Prepared by-Robert Persing April 2017
“Printrbot Simple Metal 2016-2017”

(Lot$ of fancy Feature$)

- Wireless connection
- Touch-screen control
- Simplified commands
MakerBot's very first printer kit.

The Replicator
MakerBot's flagship printer

MakerBot Replicator
Current version sold today
"Robo Mini"

Current model of a new breed of desktop 3D printers

Prepared by Robert Persing April 2017
“Makerbot Replicator Mini”
“Kossel”

A RepRap with a very different architecture. “X” – “Y” motion is achieved by moving three “arms” up/down the three support columns. This design is claimed to provide a faster printing speed when compared to other RepRaps.
“Kossel”

A RepRap printer with a very different architecture.

“X” – “Y” motion is achieved by moving three “arms” up/down the three support columns.

This design is claimed to provide a faster printing speed when compared to other RepRaps.
“Snappy”
A current RepRap design.
Almost all parts are printed.
Almost no fasteners are used.
Parts just “snap” together.

This supports the quest of the RepRap movement...a printer creating another printer
Some of these very same desktop 3D printers have found their way into-

• Business
• Industry
• Education
• Homes

D.I.Y. “Makers” continue to push the envelope of what can be done to improve designs and reduce the cost of owning a 3D printer.
Bringing 3D Home

Check this out→
The printer just viewed is a “home-brew” 3D printer using “CoreXY” kinematics for movement of the printing head (extruder).

The design, called “HyperCube”, is attributed to “Tech2C” from Australia.

Full details to build one of your own can be found here-

www.thingiverse.com/thing:1752766
D.I.Y. 3D Printing

Some practical application of a home-based 3D printer

(or use the printer in the library)
Some useful designs?

See next page for descriptions of objects

Prepared by-Robert Persing April 2017
Description of printed objects

All of the objects shown on the previous page were designed by the author and printed using his “Printrbot Simple Metal” 3D printer, a printer similar to the one available at the Florida Public Library.

1. Protective guard for a round “punch” used to punch holes in leather.
   (This was printed using a flexible, rubber-like filament called “NinjaFlex”)
2. Sink strainer
3. Curtain rod holder with magnetic mount
4. Retaining device for “fake” divided light window grid
5. Glide device for a casement window
6. Internal part of a sliding door locking mechanism
7. Protective cover for a Stanley block plane (Printed with NinjaFlex)
8. Positioning template for mounting knobs on new kitchen cabinets
9. Tool storage holder with cover for a set of “nut drivers”
10. Replacement watch band for a Casio watch (printed with NinjaFlex)
11. 17mm wrench used for making adjustment on 3D printer
12. Protective guard for wood chisel (printed with NinjaFlex)
13. Woodworking template used to route recess for a door latch
14. Woodworking templates used to route recess for “D” style door hinges
3D Printer Recap...
“Mendel 90”
An early RepRap printer
“Prusa i3”

This is the current design being offered by Josef Prusa. (3rd iteration)
“Printrbot jr.”
(Second offering from Printrbot)

This printer kit was the follow-up to their “Kickstarter Program”.

Prepared by: Robert Persing April 2017
“Printrbot Simple Maker”

This printer is available at the Florida Library

Prepared by-Robert Persing April 2017
“Printrbot Simple Metal”
“Makerbot Replicator”

(The original “Replicator” design)

Prepared by-Robert Persing April 2017
“Makerbot Replicator”

(Makerbot’s current “Replicator” design)