Introduction To 3D Printing For The Radio Amateur

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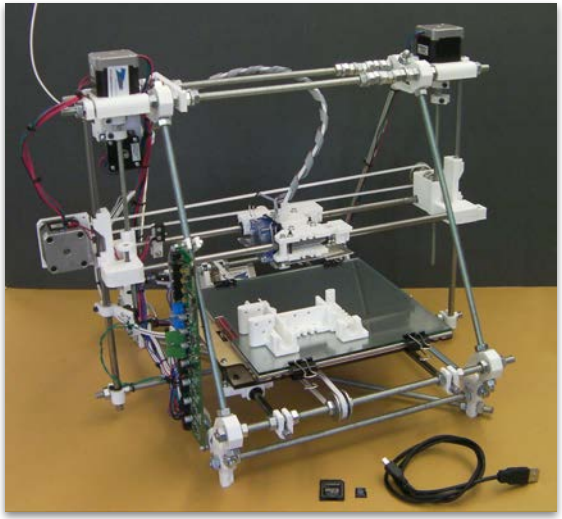
About Me:

- Interested in amateur radio since 1995 (first FD on Mt. Tom in 95)
- Licensed in 2001 as KB1GJQ, N1BMX and now NT1K
- Into contesting, chasing DX, digital modes and modulations
- Background in Computer Aided Drafting (CAD) and metal fabrication
- Got interested in 3D printing in 2010 with RepRap project
- Purchased 1st 3D printer in 2016 (Monoprice Select)
- Not an engineer but I did stay at a Holiday Inn express.

What Is 3D Printing?



- Material that is joined or solidified using computer control to create a 3 dimensional object.
  Typically done layer by layer
- Also known as Additive Machining (AM).
- History as far back since the 1970's. First SLA machine were produced in the mid 1980's. First FDM machine were developed in the early 1990's . Mostly for industrial use
- RepRap (**Rep**licating **Rap**id-prototyper) was started around 2005 as way to bring the hardware costs down to more affordable levels. Published under open source licenses caused massive popularity. Many variations in the market
- RepRap style printers can self replicate 70% or more of its parts.
- No, you can't buy a printer, print another one and return the original... Well...

3D Printers Making 3D Printers

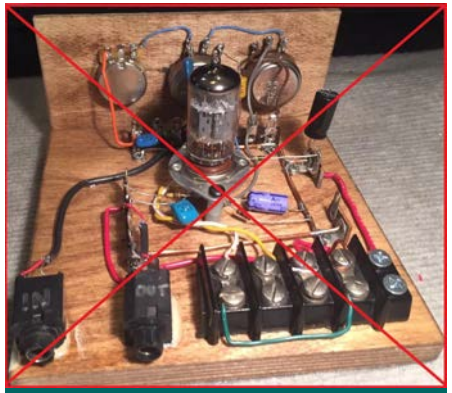
PRUSA Factory Printer Farm. 300 machines in this photo. Very popular, well known reprap style printer.

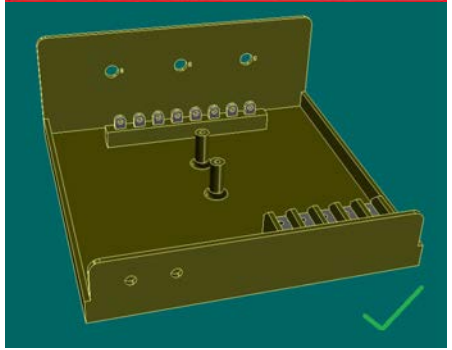
Safety First!

- **Potential Fire Hazards** - Nozzles can get up 554F (290C) and beds can get up to 248F (120C). There is a potential for fires.
- **Potential For Burns** - Since nozzles and beds are heated, skin contact is possible.
- **V**olatile **O**rganic **C**ompound**s** - filaments/resins can give off VOCs (fumes) that can affect your health.
- **Nano Size Plastic Particles** - The heating and extrusion process can release microscopic particles that could be inhaled if near the printer.

TAKE ALL SAFETY PRECAUTIONS!!! SERIOUSLY!

Applications for the Radio Amateur





- Custom Project Enclosures
- Antenna Parts (Insulators, Clamps, Traps)
- Organization (Gridfinity)
- Replacement Parts (VFO Knobs, Mic buttons)
- Test fixtures
- Prototyping
- Custom brackets/mounts

We (hams) have a lot in common with the 3d printing community. Big push for open source and sharing of prints and ideas. Interest in electronics, Interest in making things better, stronger and quicker. Endless arguments about little particulars that may or may not make a difference.

3D Printing Myths

- Easily make parts with the push of a button*
- Can only make small parts
- Not structurally sound
- It will replace traditional manufacturing (CNC machining, Injection Molding)
- Need to have CAD (Computer Aided Drafting) experience.*
- Very expensive
- Can print anything

3D printing used to be a hobby itself. You had to be deeply involved. With progress within the community, 3D printing has improved to where it’s seen as tool to aid you with other hobbies/projects instead of it being a hobby of its own.

Equipment Needed

- **3D Printer** - So many different types of printers that it's hard to suggest one. I'll provide recommendations for the radio amateur at the end!
- **3D Printing Media** - Can't print without it - Too many varieties to list!
- **Computer and Software** - Need a decent PC that will deal with 3D software for design (CAD) and for the slicing software that will generate the G-Code that will be used by the printer
- **Measuring tools** - Digital vernier calipers, solid metal rulers/straight edge
- **Misc tools** - End/Flush cutters, Wrenches, Allen keys, scraper, cleaning agents (denatured alcohol), possible bed adhesion (glue stick, painters tape), extra parts

Common Types Of 3D Printing (For the Home User)

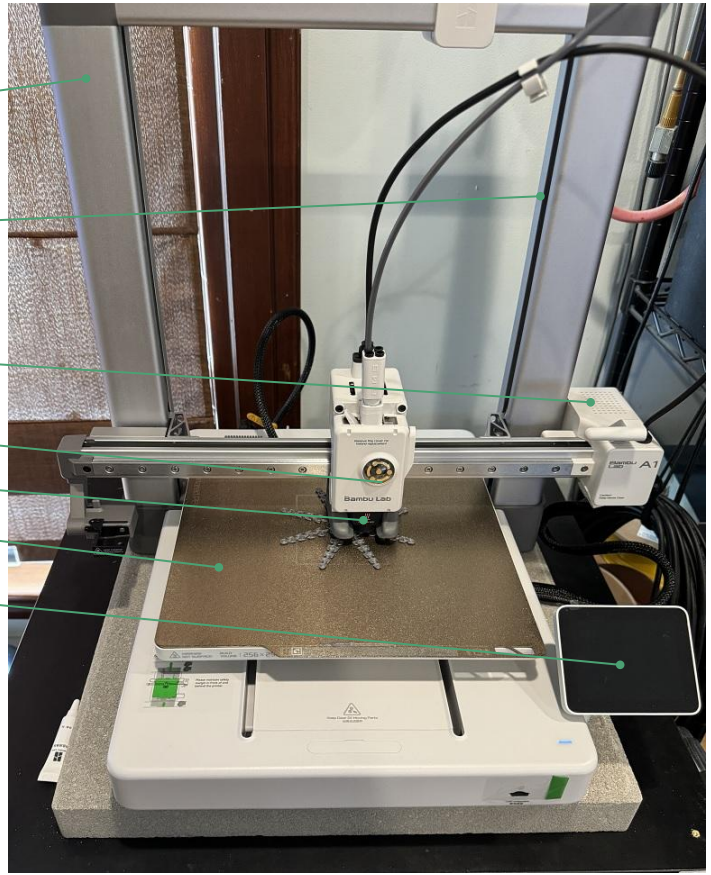
- **FDM/FFF** - **F**used **D**eposition **M**odeling - Uses filament similar to weed eater line. Filament is extruded through a nozzle (like a hot glue gun) controlled by a computer. **This will be the main focus of this presentation** as it's most commonly used. Best for entry level CNC/3D printing. Also cheapest!
- **SLA** - **S**tereo**l**ithogr**a**phy - Uses a vat of photopolymer resin that reacts to light. Uses a UV Laser to "Draw" each layer. Needs cleaning and a UV bath to fully cure. Excellent for small items with lots of detail (tabletop gaming)
- **SLS** - **S**elective **L**aser **S**intering - Similar to SLA but uses a powder instead of resin. Very expensive for the home user
- There are other types such as Digital Light Processing (DLP), Selective Laser Melting (SLM), Electronic Beam Melting (EBM), Laminated Object Mfg (LOM), Binder Jetting and Material Jetting. Mostly industrial applications

Commonly Used Filaments (For FDM/FFF)

- **PLA** - **P**oly **L**actic **A**cid - Derived from corn. Easy to print. Can get brittle over time/UV exposure. Low heat resistance. Most used for toys/inside applications
- **PETG** - **P**olyethylen**e** **T**erephthalate (**G**lycol) - Strong, decent heat resistance and smooth finish. Very stringy, Poor bridging (over gaps). But it's controllable!
- **ABS** - **A**crylonitrile **B**utadiene **S**tyrene - Strong, Decent heat resistance and smoother finish. Very fumey, Dimensional tolerance questionable
- **ASA** - **A**crylonitrile **S**tyrene **A**crylate - Similar to ABS with more UV resistance, better tolerancing. Still fumey
- **TPU/TPE** - Similar characteristics to rubber, flexible and soft. Difficult to print
- **Others** such as wood (30% mix), metal (powder/plastic mix), carbon fiber, HIPS (Dissolvable), and various other plastics/materials

Common Parts of a FDM Printer

- Frame
- Z Axis
- X Axis
- Extruder
- Hot End
- Heated Bed/Build Plate
- Control Panel



3D Printing is a balancing act!

You have to balance

- Nozzle/Hot end temp
- Bed temp
- X,Y Speed
- Extruder Speed
- Motion settings (Acceleration, Jerk, Retraction)

Most 3D printing slicing software will have profiles depending on the material and quality that takes a lot of guesswork out

There are so many variables involved that it can lead to more difficulty the more you get involved with 3D printing. However, 3D printing technology has been ever improving to make it easier for the home user.

Typical Process

- Think of a product or problem that can be solved with 3D printing
- Did someone else think of it as well? Search repositories
- If not, design or modify using CAD software
- Generate a .STL (3D model) file within the CAD software or download It
- Import model into slicing software
- Choose settings and/or profiles depending on model and/or material
- Check placement and possible support structure (if needed)
- Slicing software creates G-Code used by the printer
- Printer setup (Power, homing, pre-heating, material loading, bed leveling)
- Printer operation (first layer, quality spot checking)
- Finishing (sanding, smoothing, priming) if needed.

CAD Software (For Amateur Radio Applications)

Various 3D modeling/CAD software out there that allows exportation of .stl files that your slicing software will need. Each will have its own learning curve.

- **Fusion360** (Free Personal Use) - Most commonly used within the community
- **TinkerCAD** (Free W/ Account) - Browser based design that is simple
- **OnShape** (Free W/ Account) - More complex browser based design. Designs are online (anyone can view)
- **FreeCAD** (Free) - Alternative to Fusion360
- **OpenSCAD** (Free) - Code based 3D design
- **Solidworks “3DExperience”** (48yr/15month) - SW is commonly used in the mfg industry. This is their software for 3D printing
- **Inventor** ($$$$$$) - Big brother of Fusion360

Or just download it.

- Sharing is encouraged. Many people share their projects on repositories.
- Yes... You can download a car!
- Popular projects are forked, and improved upon
- Most popular repository for 3D printable files is Thingiverse.com
- Other repositories available such as
  - https://www.yeggi.com/ - Search engine just for 3D models. Searches other repositories.
  - https://www.printables.com/ - Prusa's sponsored repository
  - https://thangs.com/
  - https://grabcad.com/ - more for technical applications.
  - https://makerworld.com/en - Bambu lab's sponsored repository
  - Many others that are for niche aspects/hobbies (gaming, biomedical, RC)

Printing Services Available - No printer needed

There are many services out there that will print objects for you. Just need to provide them with a model, type of filament/resin/plastic/metal needed and they'll do the work for you. Of course it will cost you but beneficial for small batches.

Services include

- https://www.makelab.com/ - US Based
- https://www.makexyz.com/ - Crowdsource based - Make $$$ with your printer!
- https://www.shapeways.com/ - Well known company in the industry
- https://jlc3dp.com/ - Same people that own JLC PCB
- So many more out there! Google it

Slicing Software

- Breaks the 3d model file down into layers
- Assigns X, Y, Z axis and Extrusion servos. Adds Temp Control
- Adds supports and other features to make printing easier
- Adjustability - So many options to control the fine details.
- Some have pre-loaded configurations for your exact printer
- Some have pre-loaded slicing and material profiles that you can use to start
- Popular software packages include Cura (free), Slic3r (free),
- Some printers have proprietary software (bambu)
- Will give an estimate filament useage/costs (Price of spool/est amount used)

Software will generate the code (G-Code) that is used by the printer’s firmware

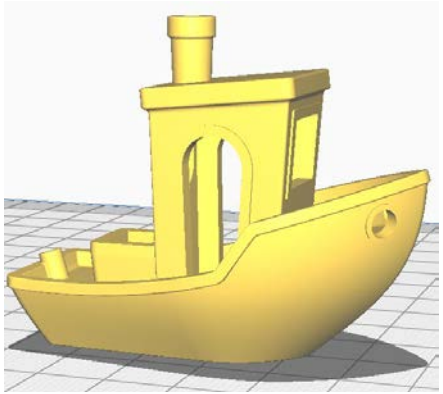
Dry Filament Is Happy Filament

- Filaments can absorb moisture which could cause issues with the quality and strength of your prints. Varies depending on the type of material (nylon, PETG), mfg, your location and the printer/storage location (damp basement/garage).
- “Wet” Filament turns into steam at the extruder causing blisters, uneven layers, spotty adhesion. People often confuse it with printer issues.
- Filament storage and dryness is **often debated** within the community.
- Suggested to store filament in sealed bags with desiccant packets when not in use. Some filament mfgs will send spools in resealable bags with packets included. Modified containers or vacuum sealing is also considered.
- Some will use purposely built filament dryers or modified food dehydrators to maintain 20% or less Relative Humidity (RH).

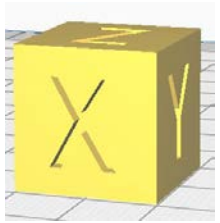
Causes of most issues

- **Bed level** - Printing surface needs to be straight and level with nozzle tip. Most beds have adjustments. Newer printers come with additional hardware (sensors) to help with leveling the bed (BL Touch, Prox sensor)
- **Bed adhesion** - The 1st layer is your foundation. If it's poorly constructed, the rest of your print will suffer or even fail. Caused by oils and/or dirt/material
- **Speed** - It's possible to go too fast and it's also possible to go too slow.
- **Cooling** - Most filaments need to be cooled for it to bond with previous layers.
- **Temperature** - Each filament is unique. Test new rolls and make note of optimal hot end/bed temps. Keep filament dry (low humidity).
- **Poor extrusion** - Speed and flow rate matters. You can suffer from over or under extrusion.
- **Environment** - Consider enclosing your printer if not already.

Meet Benchy - Calibration Prints



- Model file(s) used in the hobby as a standard/benchmark.
- Has various features to test how well your 3D printer is printing/programmed.
- Used to compare with other 3D printers, extruders and hot ends.
- Visual indicators to diagnose issues with your 3D printer and/or slicing software.
- If you ask a question about your print, you may be asked to make a benchy
- Other “test” files available. XYZ cube, 1st layer pads, towers and more depending on the issue you are trying to solve.
- Online communities and guidebooks are there to help you



Maintenance

Periodic maintenance is key to a long, happy relationship with your printer.

- Consider purchasing consumable items (nozzles, build plates) prior
- Check belt tension
- Check bed level (if manual)
- Check extruder gear (Worn? Galling?)
- Check nozzle for deformation, clogs
- Clean bed surface
- Check guide rails for straightness, ease of motion
- Check wiring for cracks/worn

What to look for when purchasing.

- **Safety** -It's still possible for printers to catch on fire due to cheap/quick design. Consider enclosed printer if possible (google before purchasing) to combat VoCs/temp variations
- **Bed Size / Build Area** - Prints are limited by the build plate and height*
- **Open source** - Able to update printer over time by printing and purchasing minimal parts. Able to dive into firmware setting or able to replace it.
- **Extrusion system** - Bowden Vs. Direct
- **Bed slinger** (Bed moves Y,Z Axis) **Vs. CoreXY** (Head moves X/Y, Bed Moves Z)
- **Multiple nozzles/extruders** - Allows for multiple colors or material types (print supports using dissolvable filament). Could also swap material/color mid print
- **Computer controlled Vs. independant** (no computer needed to operate)
- **Features Vs. Price** - Worth having auto bed leveling?

Upgrades!

- Depending on the printer you purchase, there will be upgrades to make 3d printing easier.
- Some upgrades you can print on your own 3D printer!
- Allows you to purchase an “entry level” printer and upgrade it over time
- Allows you to “test the waters”. Doesn’t hurt the wallet as much.
- Upgrades include
  - 12v to 24v
  - 8 bit main board to 32 bit
  - Hot end swap
  - Extruder replacement (Bowden Vs. Direct)
  - Bed (Glass, Spring steel)
  - Add ons (bins/supports)

This all depends on the printer. Technology is constantly changing/evolving!!!

Are you organized? - Gridfinity!

- 3D Printed Shop/Tool Storage System
- Modular - Snaps into grids of 42mm X 42mm
- Open Source - Many contributors
- Free* - As in you can download projects for free
- Almost 100% 3D Printable (might have to purchase screws, nuts and magnets).
- Excellent for ham radio operators that have a lot of components (resistors, caps, inductors, etc.)
- Perfect way to keep your printer busy!
- Search your favorite repository for it.

Current Recommendations (Sep/Oct 2024)

- **Anycubic Kobra 2 Neo** - $109 (10” X 9” X 9”), Currently “on sale”
- **Creality Ender 3 V3 SE** * - $169 (9” X 9” X 9”) / $239 for KE verison
- **Bambu A1 Mini** - $199 standalone | w/ AMS (4 Color) $349 (7” X 7” X 7”)
- **Elegoo Neptune 4** - Starting @ $217 (9” X 9” X 10”)
- **Elegoo Centauri Carbon** * - $299 (10” X 10” X 10”) Fully enclosed / CoreXY
- **Bambu A1** * - $339 standalone | W/ AMS (4 Color) $489 (10” X 10” X 10”)
- **Prusa Core One** - $949 (Kit) / $1199 (Assembled)

Consider costs for consumable items such as nozzles/hot end and build plates.

Also consider the costs of filament. **DO YOUR RESEARCH!!! RESEARCH IS FREE!!!**

Things I wish I knew prior

- Patience. You'll need lots of it!
- Dry filament is happy filament. Store filament in sealed containers.
- Bed leveling sensors basically removes an entire step during setup
- You will have failures and issues (ex. Clogged Nozzles, bed adhesion).
- Keep a log/journal of your prints (material, temps). More so with failures
- During troubleshooting, change one variable at a time. Take notes!
- During design using CAD software, factor in tolerancing. +/- 0.5mm (0.020") typically. Could dial it in close to +/- 0.13mm (.005") with good printer, nozzle and filament. Not sure about repeatability with tighter tolerancing.

HamXPo 2025 Door Prize - Bambu 3D printer