



Tech Report 10

Getting Started in 3D Printing

One of the new and exciting areas of model rocketry is the area of 3D printing. 3D printing has opened up a whole world of innovation. You can design and print your own nose cones, adapters, fin cans and more.

Are you new to 3D printing? Wondering what it involves, or the types of things you can do with a 3D printer. If so, we have a series of posts that you will probably find helpful. It discusses what is 3D printing, software you need, tools, materials, the filaments you use, and some ideas on what you can make with your printer.

The recent availability of consumer 3D printers has opened up an entire new world for the model rocket hobbyists. We can take advantage of this exciting new technology to create parts for our models to our exact specifications. We can create tools, equipment and support materials and more.

This is not going to be an in-depth discussion about 3D printing. You can write an entire book on the subject (and many have been written and are available). Instead we are going to review the basics of 3D printing (what it is, how it works, basics on materials, etc.) and then describe some of the ways you can use it with your model rockets.

A Quick Note About The Products Mentioned

Any product that you see mentioned in these articles is listed because I bought it, use it, and found it did the job I asked of it. No person or company sent me anything. I don't get compensated if you buy anything I mention here.

What is 3D Printing?

3D printing is a new style of manufacturing often referred to as “additive manufacturing.” The 3D printer builds products by building one thin layer upon another, until all the layers placed on top of each other result in a finished product.

This is different from “subtractive manufacturing” which is the most common method of production in use today. Subtractive manufacturing starts with a single solid piece of material which is then cut down into the part desired. We see this in rocketry and how we create our models. We start with a piece of balsa wood and cut out our fins and other parts. They are then sanded to shape. The large piece of wood was cut into small pieces and formed to shape.

Additive manufacturing offers some distinct advantages over subtractive manufacturing:

- **Design Freedom**
Because you create the part in the computer and build it layer by layer, you can create complex geometrical parts. You can create parts that are impossible to create using the subtractive process
- **Use Less Material and Have Less Waste**
When you create your fins from sheet balsa as describe above, there is always left over wood. Often that wood finds its way into the trash can. With additive manufacturing most printed parts will only use the amount of material needed to create the part (there may be some waste if the printed part has overhangs that need to have supports created during the printing process).

Additive manufacturing is not all rainbows and unicorns; it also has some disadvantages that include:

- **Slower Process**
Anyone who has watched a 3D printer knows it takes a while for the product to print. Depending on the size and complexity of the object it can take hours to get a finished product.
- **Lower Mechanical Strength**
Most additive manufacturing products are made from some type of plastic or resin. These materials do not have the strength of solid steel. However, there are new materials that are being developed that may soon provide the extra strength needed.

3D Printing Methods

There are a number of different methods used in 3D printing, but the most common method in the consumer realm (and the one we will focus on in this series) is called Fused Deposition Method (FDM) or Fused Filament Fabrication (FFF).

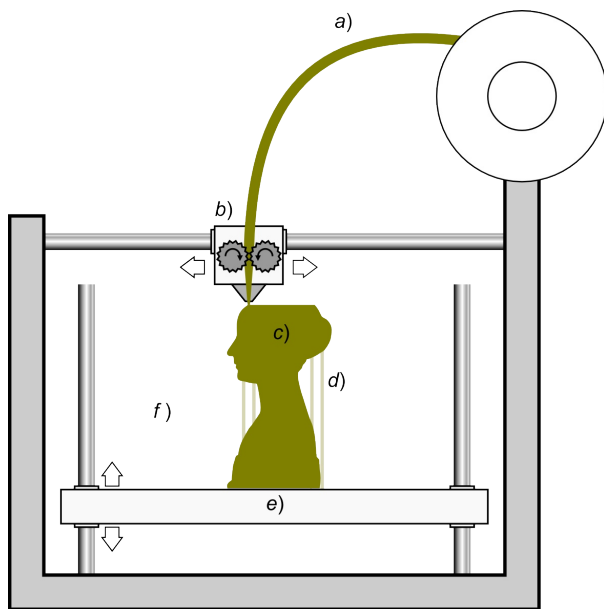
You have probably worked with a hot glue gun in the past. When you insert a solid rod of glue into the back of the gun a heating element melts the glue rod into semi-solid ooze that is squeezed out of the nozzle when you pull the trigger. You control how much glue comes out by how hard you pull the trigger and how fast you move the gun. Once the glue exits the gun, it begins to harden until it reverts back to its solid, more rigid form. A FDM/FFF printer works in much the same way.

Another common form of 3D printing is called stereolithography (STL). This method uses resin as a material and the object is typically printed from the top down. This form of printer is very good at printing highly detailed objects without leaving the lines one typically sees when using an FDM printer.

However, there are several additional steps that need to be taken once the printing is complete. The resin also has a tendency to smell and needs to be in an enclosed printer. It also tends to be a bit more expensive than the plastic filament typically used in a FDM printer. While its popularity is growing, it is not as popular as FDM – at least not yet. How does the FFF printer work?

The FFF printer will heat a material filament until it is a semi-solid that flows out of a nozzle. The material seen most often in the

consumer market and the one you are probably familiar with is a plastic, or more correctly, thermoplastics. However not all plastics are created the same and there are different types of plastics that you can use. This is dictated by the requirements of the printed object (more on this later). The material is extruded in layers in a pattern, adding layer upon layer and slowly building up into the shape of the product. The material will bind together as it cools, creating a solid object.



Schematic representation of Fused Filament Fabrication¹

Any FFF printer will have a number of elements in common and tend to work in a similar fashion. To begin a plastic filament is fed into the printer (a) and makes its way down to the heater and nozzle (b). The heater helps melt the filament so that it can be extruded through the nozzle. The plastic comes out of the nozzle as a very thin line of plastic. A small computer in the printer controls the nozzle and/or the print bed (e) which moves to create design. This allows the

plastic to be laid one layer upon another, building up the object a layer at a time. When the object is finished being printed it is removed from the printer and is ready to be cleaned up and made ready for use.

Filaments

In the hobby arena the filament is usually sold by weight and comes on a spool. Spools of filament weighing 1 kilogram (2.2 pounds) are available in a wide variety of materials and colors. In addition to the material, the filament is also categorized by diameter, the most common being 1.75mm. You will also see the accuracy of the filament listed (such as +/- 0.03mm) along with the recommended extruding temperatures.



ABS, PETG, and PLA Filaments for FFF printer

There are a number of filament materials. The most common types for hobbyists are:

- PLA (Polylactic Acid)
PLA is a highly popular 3D filament. It is fairly easy to print, especially for the person new to 3D printing. It doesn't have a tendency to warp and rarely creates problems that cause a print to fail. It can ooze and string, but if this occurs it can be minimized by optimizing your 3D slicer

settings. You don't need a heated bed to print with PLA, but using one will improve the quality of your prints. PLA is made from renewable and biodegradable crops like corn starch. When printing there is no foul smell or toxic fumes.

- **ABS (Acrylonitrile Butadiene Styrene)**
ABS is another commonly used 3D printer. ABS is known for having good mechanical properties, being both tough and possessing good impact resistance, and generally being durable. ABS also has good heat resistance, with a glass transition temperature of around 105-degrees C. This is nearly twice that of PLA (60-65-degrees C). ABS filament does require a heated bed and during the printing process ABS is known for giving off an acrid odor.
- **PETG filament (Polyethylene Terephthalate with added Glycol)**
PETG filament has good impact resistance and fantastic thermal characteristics. It doesn't have the problems with warping associated with ABS or brittleness associated with PLA. PETG is considered a viable third option between PLA and ABS. PETG has a natural stickiness which improves layer adhesion, leading to strong and durable parts that do not warp. Printing long, thin parts that are a nightmare for ABS are significantly easier with PETG. PETG does have a softer surface than either PLA or ABS. This makes it prone to increased wear and tear.
- **Nylon filament (Polyamide)**
Nylon filament is known for being very tough as well as heat and impact resistant. It is difficult to scratch or wear down. Nylon is considered tougher than ABS and it does

not create bad odors during printing. It is mainly used for projects that require strength, impact resistance and flexibility. Good quality Nylon filament tends to be more expensive than filaments like PLA. It also requires a heated bed and an enclosed heated chamber. It can be considered difficult to work with.

Heat

One area of concern when looking at creating 3D prints in model rocketry is heat. Our model rocket engines burn hot. Our models are flown outside typically on hot sunny days. We need to make sure that the filament we use can withstand the heat generated by the environment and the burning propellant.

The temperature at which any substance loses its rigidity is call the "glass transition temperature." When creating things like motor mounts or fin cans, you need to use a filament with a high glass transition temperature. Even something like a nose cone could lose its rigidity and become deformed if left inside a hot vehicle.

The following chart should be considered a general guide for various types of filaments and their glass transition temperature (GTT). Check with the manufacturer of the filament you intend to use for specifics on how well it holds up to high temperatures.

Filament Type	Glass Transition Temp
Nylon 6, Nylon 6.6 (PA)	47-60 c
PLA	60-65c
PET	70c
PVA	85c
ABS	105c
Soda Glass	520-600c

The Software

3D printing would be next to impossible if not for three very important pieces of software. The first type is generally referred to as a CAD (Computer Aided Design) program. The second is called a Slicer, and the third is called GCode.

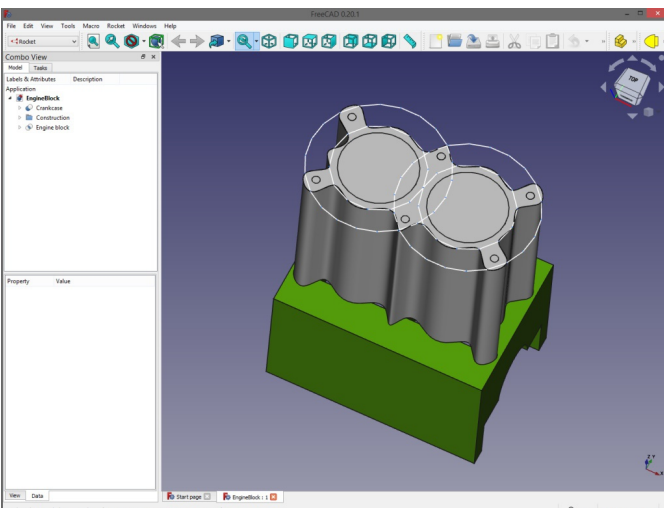
Computer Aided Design Software

Computer Aided Design (CAD) software is the start of the printing process. This software is used to design the item that will eventually be printed. While you may choose to download objects ready to be printed, someone had to create the design and they used some type of CAD program to do it.

There are several free CAD programs available on the web that you can download and try. These three programs are all free and open source, and are available for Windows, Linux and Mac. They include:

FreeCAD

It can provide highly detailed drawings that can be exported to use for 3D printing. FreeCAD uses the idea of 'workbenches' that provide objects and tools for a specific type of drawing.

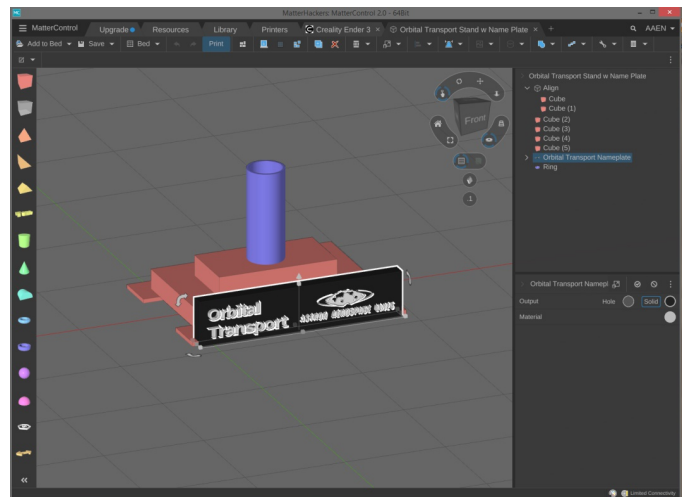


Recently they have added a Rocketry Workbench that is focused on creating model rocket parts. Available at <https://www.freecadweb.org/>

MatterControl

MatterControl goes beyond just a CAD design program and also incorporates slicer and printer control features. MatterControl uses predefined objects that are dropped into the design area and then stretched and cut to shape. The software is very good for new users, allowing an easy way to start creating designs.

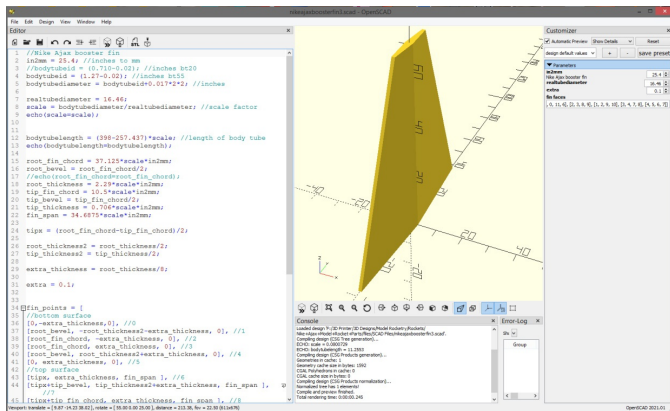
While not as detailed or intricate as FreeCAD it can provide for a way to get started in creating your own designs. Available at <https://www.matterhackers.com/store//mattercontrol/sk/MKZGTDW6>



OpenSCAD

Unlike the other two CAD programs described above, OpenSCAD is not an interactive modeler. Instead, it is more like a program scripting language that when compiled generates a 3D object.

This is completely different from the CAD programs above. One of the advantages of this type of software is that it allows you to create designs where you can change certain parameters “on the fly.” From a model rocketry perspective, it would allow you to create a particular style of nose cone and then be able to adjust the diameter and length based on the body tube and style of rocket you are creating. Available at <https://www.openscad.org>.

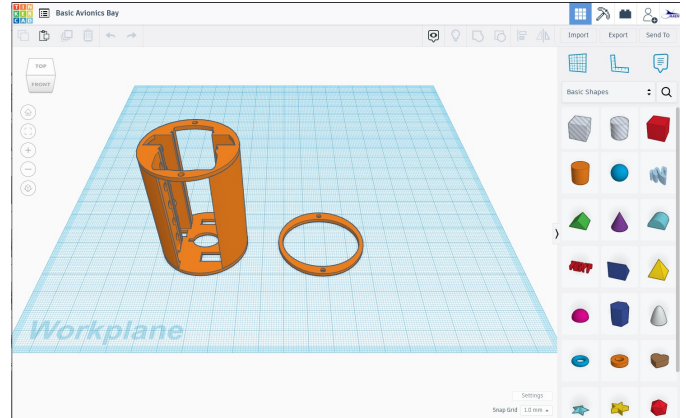


There are several CAD programs that work through your web browser. Two of the most popular are SketchUp (<https://www.sketchup.com>) and TinkerCAD (<https://www.tinkercad.com>). Both of these products allow you to draw your object using your web browser. This provides flexibility as you are not restricted to a laptop or desktop computer. You can also connect to your designs anytime as long as you have an internet connection.

Most of the web-based CAD programs offer an entry level tier for free. To gain access to more features, tools, and storage space, there is usually a monthly fee involved. Check to make sure that you can download all of your designs to your local computer if you decide to leave the service at a later time.

Tinkercad

We have been using Tinkercad for a while now and really like the flexibility as well as the detail that can be achieved.



We have several Tinkercad projects that are available including:

- Base Arduino Avionics Bay
- Project: Icarus Payload Adapter and Accessories
- AstroCam Housing
- Estes Space Shuttle Display Pad
- Mounting Hook for Magnifying Visor

These can be found at <https://www.tinkercad.com/users/kGt9Dmmc88b>

Tinkercad also has a circuit design section. It comes with a number of modules and sensors as well as an area to write your code. This allows you to design and test simulated circuits. We have posted the circuitry for the Base Arduino Avionics Bay and for Project: Icarus.

Whichever method is used to design the object doesn't matter. What is important is that an object is created that can then be printed on your printer.

Exporting the Object

Regardless of the type of software you use to create the object, it needs to be exported in a format that can be read by a Slicer program. This will usually be an STL or OBJ file. These are not design files. Make sure you save your design in the native format of the CAD program you used or you may not be able to come back later and make changes.

STL Format

The STL file is an open format and one of the original formats for 3D printing. It describes the surface geometry of an object by converting it into a series of triangles. It is widely used throughout the 3D printing community. Almost every 3D printer made today can support the STL format. However, because it uses triangles to describe the object, it will never be able to develop ultra-fine resolution images (this is typically not an issue when printing model rocket components). The STL file can be exported in either a binary format or as plain ASCII text. The binary format tends to be smaller, while the plain text format allows you to open the file in any text viewer and see how the software is designing the object. This can be helpful when trying to troubleshoot an image file.

OBJ Format

The OBJ file is newer, open source and it has several advantages. It can provide for a more accurate print than the STL format, provided you need that level precision. It will also allow for multiple colors and textures to be included. Because of this the OBJ format will likely increase in popularity in the future.

Which to Use?

You will find that most of the files available for download will be in the STL format. If most of your printing is on a small scale and only involves a single color, STL will work just fine. If you need multiple colors or high fidelity prints, OBJ will likely work better. Also, if you are creating huge prints, you may find the STL file is too big and will need to use OBJ instead. Regardless of which one you use, make sure it will work with your printer/slicer software.

Slicers

Earlier we described how a 3D printer creates an object by building it up layer by layer. A slicer program is the software that decides how those layers are created and creates the instructions that the printer will use. It will take either the STL or OBJ file of the object and “cut it” into the thin layers that the printer will lay down on the print bed – hence the term “slicer”.

The slicer does more than just determine the layers, however. It will also determine the path the nozzle will take as it creates the object. It will also create the interior between the inner and outer walls. Most prints are not solid and they really don't need to be. The slicer will create an interior area based on triangles (or other shapes) that will allow the object to retain the strength it needs without wasting filament. This (and more) is based on the parameters that are entered into the slicer software.

These group of parameters are often referred to as ‘profiles’ and it is not uncommon to have a number of profiles that you might use. Profiles can be set up for different filaments (even from manufacturers of the same type of

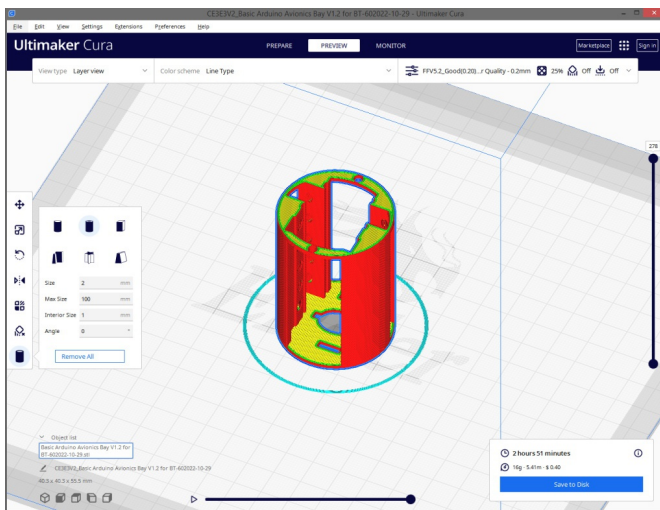
filament) that use different extruder and bed temperatures. You may have profiles for coarse printing (say for a proof of concept print) and an ultra-fine profile (for a high quality print).

Chances are the 3D printer you purchase will come with a slicer program that includes at least one general profile to allow you to get started printing. The more you use and learn about your printer you will likely start to create the additional profiles to meet your specific needs.

Generally you are not restricted to the slicer software supplied by the printer company (unless they are using a proprietary system). The following slicer programs are all open source and available to download and use for free. They are available for Windows, Linux and Mac systems. They include:

Ultimaker Cura

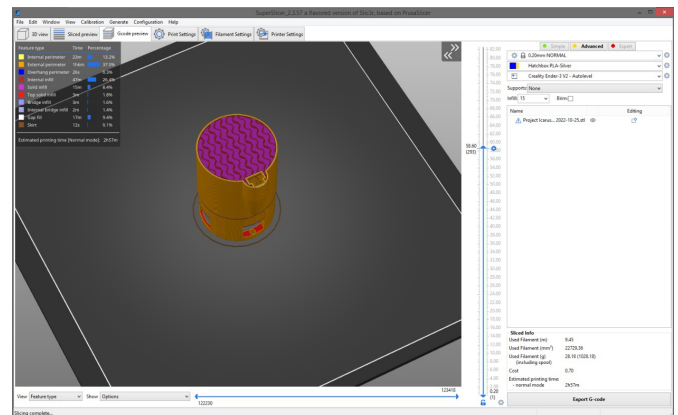
This slicer comes in two versions; a free version that can be used by most hobbyists and a paid enterprise version.



The paid version has a number of additional options that most hobbyists won't need. It is available at <https://ultimaker.com>

SuperSlicer

SuperSlicer is a fork of the PrussiaSlicer (https://www.prusa3d.com/page/prusaslicer_424/) which is itself a remix of the original open source slicing program, Silc3r (<https://silc3r.org/>). It combines the best of all of these and then adds additional adjustments and settings.



No matter which slicer program you use, check to make sure it's compatible with your system. The purpose of the slicer is to convert all of these instructions into code that is used by your printer to create the object. The file created by the Slicer called "GCode."

GCode

The GCode is the actual instructions for the printer. The bulk of the code tells the printer about each layer. This includes the layout of the object, how thick to make each layer, how much fill to use, how to move the print head and where to extrude filament.

There is also some additional information contained in the code that is critical to the operation of your printer. For example, it tells

the printer when to turn the heaters on, how hot they should be, when to turn fans on, etc.

GCode comes in various types. Most of these are based on the type of printer they will be used on. Marlin is a popular open source version and is used on a number of printers. 3GDrem is a version used primarily on Dremel printers.

Sample of GCode

GCode is written as a standard text file allowing you can open it with a text reader (like Notepad) and see the instructions. The sample below shows information on the filament and layer thickness as well as setting temperatures. This sample ends with the print head being sent to the 'home' position to get ready to start printing.

```
; filamentDiameter = 1.73
; extrusionWidth = 0.4
; firstLayerExtrusionWidth = 0.4
; layerThickness = 0.1
; firstLayerThickness = 0.25
; automatic settings before
start_gcode
G21 ; set units to millimeters
M107 ; fan off
M140 S55 ; start heating the bed
M104 T0 S205 ; start heating T0
T0 ; set the active extruder to 0
; settings from start_gcode
G28 ; home all axes
```

The good news is that you don't need to know what any of this means in order to use your printer. However, if you are interested in seeing what is going on "under the hood" these files can provide a wealth of information.

Reviewing the code can also be helpful in figuring out what is wrong when you have a project that simply doesn't print out correctly.

Getting the Code to the Printer

Once you have the GCode file created by the slicer software, you need to get it into the 3D printer so you can create your object. There are generally four ways this can be done:

- Transfer the GCode file to SD/MicroSD Card then insert the card into the printer.
- Transfer the GCode file to a flash drive then insert the drive into the printer.
- Connect the computer to the printer using a USB cable.
- Connect the computer to the printer using WiFi.

The use of a USB cable and/or WiFi makes transferring the GCode simple and easy. However, there is a risk that any interruption in communication between the computer and the printer will ruin the print. The interruption could be something as simple as a screen saver or a background process starting up. Once the print has been interrupted, it may be difficult, if not impossible, to get the print to complete. When this happens you will need to start the print again.

The Flash Drive and the SD/MicroSD card are a bit more of a hassle. You have to physically transfer the drive/card from the computer to the printer. However, the risk of interruption is nearly zero.

Not all of these methods may be available for your particular printer. Try the various methods that are available for your printer and then decide which method makes the most sense for you and your work flow.

Printing the Object

At this stage you are ready to create the print of your object. It can be fun and mesmerizing to sit there and watch the object come into existence.

Tools

Like any new tool or process, you will need some additional tools and supplies that allow the printing process go a lot smoother. Since you are already building rockets, chances are you probably have a number of these items already on hand.



- Putty knife and needle nose pliers
Helps removing the completed object from the print bed
- Screw driver and Hex key wrench set
For making adjustments to the printer
- Alcohol/alcohol wipes
Used for cleaning the print bed prior to starting a new print
- Tape and/or glue
Used to help with bed adhesion. Glue sticks,

painters tape, and hairspray are common methods

- Sandpaper/Files
To smooth any rough edges on the print
- Zip lock bags and silica gel packs
Once you open a spool of filament, it will begin to absorb moisture. This degrades the filament and makes it harder to get good prints. Keep the filament in a zip lock bag with a silica gel pack to absorb any moisture. Remember to replace the gel packs occasionally.

Be Safe!

3D printers, by the very nature, generate a lot of heat. The extruder has to get hot enough to melt the plastic filament to allow it to flow out the nozzle. The print bed has to be hot enough to allow the extruded filament to stick and keep the print steady as the printer begins to build layer after layer. Many of these filaments are extruded at or above 200-degrees C (nearly 400-degrees Fahrenheit). Because of this, consider purchasing two things for the room where you will set up your printer:

- Fire Alarm
Consider purchasing and installing a fire/smoke alarm. You won't be able to watch your printer every single minute that it is printing. A working fire alarm can alert you to issues.
- Fire Extinguisher
If that alarm does go off, having a fire extinguisher nearby can stop a fire in its tracks. It doesn't happen often, but there are news reports where a printer fire caused significant damage to a house. Don't make

the mistake of mounting the fire extinguisher by the printer. If the printer or the items around it catch fire, you may not be able to reach it. Instead mount it by the door to your work area, near the light switch. That can typically be reached by anyone, including someone coming to help you out!



Take time to consider where you set up your printer. In addition to the fire hazard, some filaments can give off a foul smelling odor. You should never set up your printer in a room where people sleep. Depending on the filament you are using you may need to consider a printer enclosure, including venting the printer to the outside.

Lastly, you want to keep an eye on your printer when it is creating a print. This can be a challenge as some of the large, complex and detailed prints can take 12-hours or more to complete. You don't want to waste a day just watching the printer create another layer of plastic. One of the solutions to this issue is the use of a web cam. Set it up on your local home network and you can keep an eye on the printer from your computer, tablet or phone. There are even instructions on the web about setting up a camera that you can access from your phone over the internet.

Putting the Pieces Together

Not all of your prints will come out as a single piece. There are times you will need to join two or more printed parts together. There are several ways you can join the pieces together for a strong joint.

Cyanoacrylate (CA) Adhesives

If you have built a rocket or two, the chances are good you already have a bottle or two of this stuff. CA is good for bonding most 3D printed materials, including PLA. The CA tends to adhere better if both surfaces are slightly scuffed and not perfectly smooth.

Other issues you may experience with CA glue and 3D printed filaments include a whitening effect appearing around the joint. It may also degrade the dyes in some color filaments.

On a positive note, heating the joint to between 150-200 degrees c will usually allow for disassembly of the joint. You need to be careful when doing this, as the excess heat can also cause warping and degrading of the part.

Acetone

This can be used on ABS filaments, and joint adhesion can be improved by using "ABS Juice". ABS juice is created by adding 10-20 ml of 1.75mm diameter filament scraps into 1 ml of acetone. This is left to dissolve overnight. When ready to use, brush on the joint and then clamp it until it is dry.

Polystyrene Adhesives

Any glue intended for use with polystyrene should work with ABS as well. You should twist both joint faces together to improve the strength of the joint. However, when used on PLA it will likely not create as strong a joint as you would want, especially if the part is on a section of the rocket that may experience a number of stresses.

Epoxies

Epoxies are suitable for all types of 3D printed materials. You should exercise caution when mixing your epoxy. Adding too much accelerant can cause an excessive amount of heat to be created, which can deform and degrade the part it is used on.

Anaerobic Adhesives

These should not be used on 3D printed plastic materials. The joints are not strong and the adhesive can cause cracking in the part.

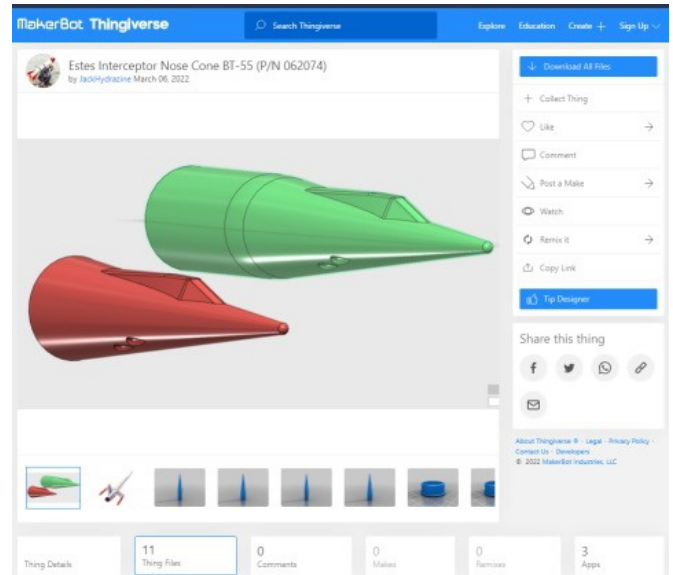
3D Printing and Rocketry

3D printing brings a number of advantages to the hobby of model rocketry. It allows you to build rockets that would have been very difficult if not impossible to do before. It provides a way to bring old, out of production rockets back to life. It provides a method to try new designs and to change those designs rather easily based on lessons learned. It does all of this and more.

Retro-Rocketry

For me personally, one of the neat things about 3D printing is that it allows us to recreate some of the models from years past that are no longer in production. Some of these models may have had unique nose cones, fin cans, or other details that were created from molded plastic.

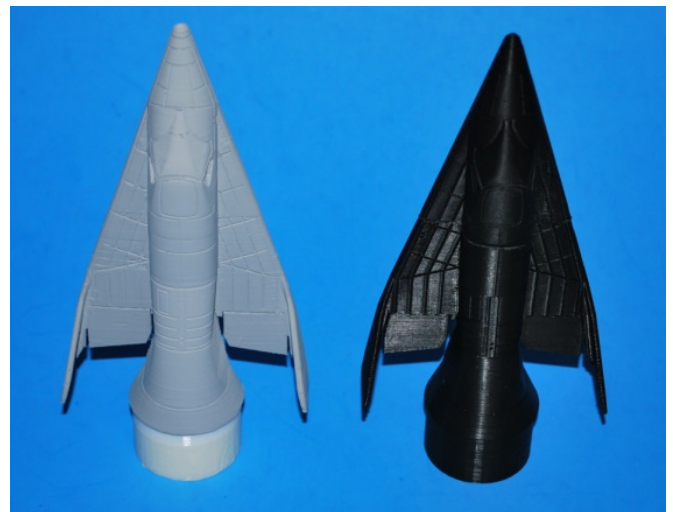
There are a number of rocketry designs that are freely available on the Internet. Web sites like Thingiverse have a number of design files that you can download and use. With a little bit of searching you may find that someone has already created a 3D file of that part. There are number of old kit parts that have been recreated on Thingiverse (such as the



Estes GeoSAT and LTV Scout). With these files and the original instructions it isn't hard to recreate that retro rocket that is no longer available.

New Rocket Designs

You can also use designs found on the web as a starting point to create your own designs. You can modify these files to meet your specific needs. You can mix and match files to create all new designs.



If you are designing something unique you can always design your own 3D printed parts.

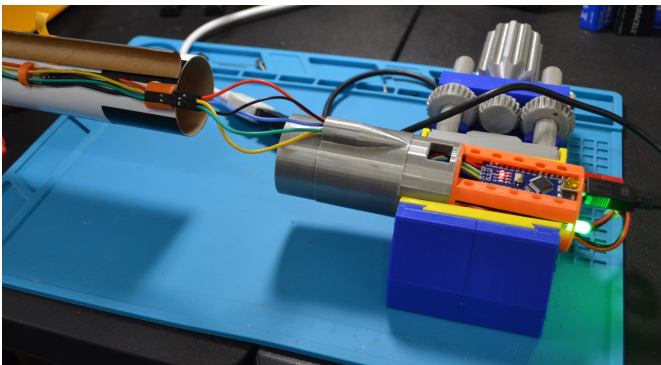
This may take a little bit longer and involves a bit more work. You will need to learn how to use a CAD (Computer Aided Design) program to draw out the parts you want to print. This may take some time and effort depending on the CAD software and the level of detail you are striving for.

Scale Rockets

One area where 3D printing can be advantageous is building scale models. If you have a scale drawing of the rocket you can transfer that information into a CAD program to recreate a specific section. The result can be a highly detailed model that might otherwise have been impossible to create.

Payload Capsules

Prior to 3D printing if you wanted to make a nose cone for a specific payload you had to carve it out of wood, mold it out of fiberglass or plastic, or try to modify an existing nose cone. With 3D printing you can design your own capsule and simply print it out. You can try different designs until you find the one that works best for you.



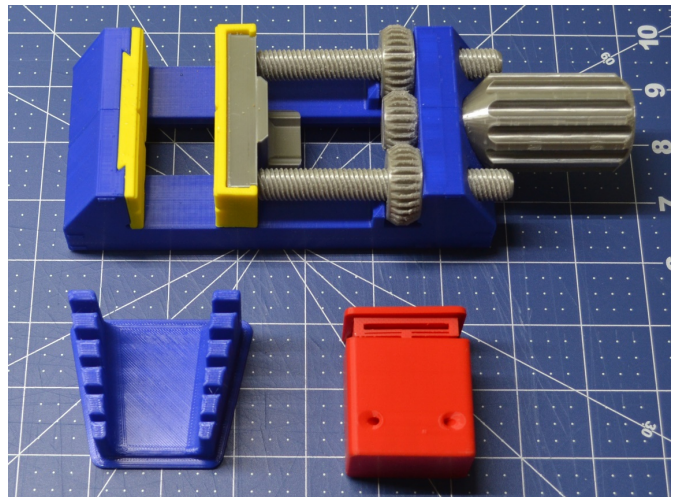
You can also print out parts to assist with various types of payloads. Maybe you have found a small video camera that you want to mount to your rocket. Using a 3D printer you could even design a payload section that will provide a way to change the viewing angle.

Support Equipment

Another aspect of 3D printing is the ability to create the tools that make it easier to build, fly and track your rockets. This can be everything from adapters, tools, and jigs to help with construction to tracking scopes to help determine altitude to model stands.

Building Tools

A search of the Thingiverse web site will reveal a multitude of tools that can make building your rockets easier. You can download and print tube marking and cutting guides. This can help you make straight cuts on your body tubes as well as marking fin lines evenly around the body tube. There are several styles of fin alignment jigs to choose from. You can even print out jigs that will help you cut and construct engine mounting tubes accurately.



Launch Systems

Did you know you can print a launch pad as well as the electrical launch controller? There are several styles available of both pads and controllers. There are also plans for the rod end cap. You can print these straight from the downloaded file or pull it into your local CAD program & modify them to meet your needs.

Flying

If you have ever lost the plastic motor retainer, you know this can bring a day of flying to quick end. Now you can print out a new one. Print out several extras and never worry about cutting short your launch day due to a missing retainer. You can even find printer plans for the motor igniter retaining plugs. If you want to keep your motors stored in an organized fashion, there are plans for that too!

3D printing opens up a new method for creating model rocket parts and tools. As time goes on, I have little doubt that a 3D printer will be a common sight in most every model rocketeer's workshop.

Image Credits

1. Scopigno R., Cignoni P., Pietroni N., Callieri M., Dellepiane M. (2017). "Digital Fabrication Techniques for Cultural Heritage: A Survey". *Computer Graphics Forum* 36 (1): 6–21. DOI:10.1111/cgf.12781. https://en.wikipedia.org/wiki/3D_printing#/media/File:Schematic_representation_of_Fused_Filament_Fabrication_01.png

If You Enjoy Rocketry, Consider Joining the NAR

If you enjoy model rocketry and projects such as the Arduino Launch Control System, then consider joining the National Association of Rocketry (NAR). The NAR is all about having fun and learning more with and about model rockets. It is the oldest and largest sport rocketry organization in the world. Since 1957, over 80,000 serious sport rocket modelers have joined the NAR to take advantage of the fun and excitement of organized rocketry.

The NAR is your gateway to rocket launches, clubs, contests, and more. Members receive the bi-monthly magazine "Sport Rocketry" and the digital NAR Member Guidebook—a 290 page how-to book on all aspects of rocketry. Members are granted access to the "Member Resources" website which includes NAR technical reports, high-power certification, and more. Finally each member of the NAR is cover by \$5 million rocket flight liability insurance.

For more information, visit their web site at <https://www.nar.org/>

