

PEAK OF FLIGHT

NEWSLETTER

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What Parts Can Be
Made by 3D Printing?

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What Parts Can be Made by 3D Printing?

By Tim Van Milligan

I think the technology of 3D printing is still in its infancy, and it has a long way to go. But it has been around a long time. I remember seeing my first 3D printed part when I was working for Estes in the 1992-93 time frame. Back then it was a technology of using an ink-jet printer head that squirted out a starch that was then later impregnated with some type of resin to help solidify it.

The one question that has always been plaguing my mind since then, and it always comes up when people come to me when they want to write an article for the Peak-of-Flight newsletter is this: "What are you going to print?" and "Why do you want to print it instead of using some other technique to create it?" The authors always seem want to describe the technology and how to fiddle around with different 3D printers and in particular the software that drives the printers, so that the parts are printed correctly. 3D printers are so cheap now, that selecting one is an arduous process of comparing features versus cost.



Figure 1: A 3D printed altitude rocket by Gary Crowell.

I'm really not interested in those things and articles that talk about them, because it is not evergreen content. In other words, it becomes dated almost as soon as it is written because technology is improving and software always is superseded by a new software. My point is this: "HOW you are printing parts is going to change in the future." So writing about that isn't something that would be good for my newsletter archives because it will be irrelevant tomorrow.

So I don't care how it is printed. What is more important to me is what you are going to have 3D printed, and why you would do it.

When I ask that question, the first answer that pops out of the typical person is: "I want to make a nose cone and some fins." Ho hum. Is that all you can come up with?

When I ask them why those items, the answer is usually something like, "because I have this cheap printer, and now I can make rocket parts." That didn't answer my question. So I'll ask it again, "why those parts?" This is the *why* question.



Figure 2: Gary Crowell's fin can, with the break-off support on the rear that allows the printer to build up the base of the fins.

When they try answering that question, it seems to come back to "it is cheaper than buying them." But is it really cheaper than making them using some other technique? Give me a hobby knife and some scrap balsa wood, and I can cut and carve both fins and nose cones really fast and really cheap. I have a video to prove it; see: https://www.apogeerockets.com/Rocket_Books_Videos/Videos/Making_Custom_Nose_Conos_With_Simple_Hand_Tools_CD_Video_Book.

If you just want to make simple nose cones and fins for your rocket, you're missing the real benefit of 3D printing. So enough of my ranting. I'm here to encourage you to do better and push the envelope of what can be done with 3D printing technology.

The real benefit of 3D printing is to make parts that you couldn't otherwise make using other construction techniques. And the second benefit is to make precise parts that would be really expensive to make using other techniques.

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Figure 3: Gary Crowell's 3D printed Egglofter model. Note the shape of the transition and how swoopy it is.

What I'm saying is that simple nose cone shapes and simple fins don't excite me because they can be made using other construction techniques. Additionally, they don't have to be all that precise for the rocket to work correctly.

The downside of 3D printing is the process of designing the part to be printed. You will have to invest a lot of time learning CAD software before you even think about sending it to the printer. It is a huge investment of time, and also money to buy the software. And remember, the software changes constantly, so what you learn now may not be usable later.

I want you to do really cool things that advance the hobby. So if you are going to put in the time and effort to learn the CAD software, I hope that you do other things than just being able to make some simple nose cone shapes.

What Cool Things Can You Do?

This past summer, as I was walking around the NARAM contest range, someone came up to me and said, "Tim, you have to see the models that Gary Crowell has made for the contest. They are all 3D printed." I'm really glad when people say this stuff to me, because that means they know me and know that I love things that are unique and different.



Figure 4: Gary Crowell - a true pioneer in 3D printed rockets

When I walked over to Gary's prep area, I was not disappointed. Spread out in many little boxes, Gary brought out one after another 3D printed models.

What I liked was that Gary had obviously thought about each contest event in great depth, and tried to solve the engineering challenges that arise with 3D printed models.

For example, when it comes to weight, plastic models are heavy. There is no way that they can compete on lightness because the density of plastic is higher than paper and wood. The only thing you can do is to minimize the wall thickness of the parts. That is what I do when I make competition fiberglass parts (<https://www.apogeerockets.com/education/downloads/Newsletter434.pdf>). I make the thickness as thin as possible because glass is dense and makes heavy parts. And the rockets

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that Gary showed me were as thin as he could get them on the 3D printer he was using. He even wrote a paper just on how to make them thin on an FDM printer by using a corkscrew printing method. (<https://www.thingiverse.com/thing:3056609>).

But the challenge of paper and wood is that you can't easily make complex curvatures. This plays to the advantage of 3D printed parts. They can easily be streamlined to make them have those swoopy organic shapes that are more aerodynamic (see **Figure 3**). So while you lose a little bit of performance due to the extra weight of plastic, you can pick up extra altitude by making them more streamlined. To know how much altitude you'd gain/lose by using a 3D printed rocket, you'll have to do some testing.

Gary's egglofter rocket is really a thing of beauty. It just looks cool even as a static model. But there is a lot of technology in the rocket besides the swoopy shape. And this is the stuff that gets me really excited, because you're doing two or more tasks at once. That saves time and effort after the rocket is printed. It is really harnessing the potential of additive manufacturing (the term that is used for 3D printing).



Figure 5: Internal stiffeners inside the tube.

First are the fins. They have an elliptical shape (see **Figure 2**), which is has the lowest induced drag of any shape (<https://www.apogeerockets.com/education/downloads/Newsletter442.pdf>). But they are molded into

the fin can, along with the necessary fin fillets that help reduce interference drag on the model.

Next, there are internal stiffeners inside the tube. The part, according to Gary, is very fragile, so the stiffeners help give it some extra strength. And remember, this is an egglofting model, so there is a heavy egg sitting on top. The ribs helps transfer the load of the egg down and prevent it from splitting. These molded ribs would be difficult to add to the rocket after it was printed because of the curved shape of the transition. So putting them in during the printing process is really taking advantage of the technology.



Figure 6: The altimeter bay bonded to the rear of the egg capsule.

The other neat feature that I liked in this model was the little altimeter box that he put on the base of the egg capsule (see **Figure 6**). It was designed around the MicroPeak altimeter (<https://www.apogeerockets.com/Electronics-Payloads/Altimeters/MicroPeak-Altimeter>). The altimeter is securely held in the rocket because it was designed into the rocket from the get-go. But he did mold in some little tabs that are used as anchor points to tie a little lanyard onto the altimeter so that it couldn't fall away free, just in case the rocket did come apart during launch or landing.

Now the capsule on the top didn't really excite me. It is after all, a simple nose cone shape. And you could get an Apogee egg capsule that is smoother and lighter weight (<https://www.apogeerockets.com/Building-Supplies/Nose-Cones/For-up-to-24mm-Body-Tubes/Vac-Form-Egg-Capsule-CLEAR-1-pk>).

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But the way he solved the issue of attaching the nose to the shock cord was neat. It doesn't have much to do with 3D printing, other than thin-wall parts don't make good anchor points. Because of that, you have to have some sort of way to keep everything attached. What Gary did was to run a thin music wire leader over the egg, and attach the shock cord to that instead of trying to attach to plastic.



Figure 7: Music wire bonded into the nose acts as a shock cord anchor.

The one drawback that Gary has yet to solve is the heat issue. Because of the hot ejection charge gases from the motor, the plastic gets soft and deforms after the flight reaches apogee. It isn't so bad if you're using the rocket just once. But on each subsequent flight, the rippled plastic reduces the aerodynamic efficiency of the rocket. My suggestion is to make a tube made out of Quest wadding (https://www.apogeerockets.com/Building_Supplies/Parachutes_Recovery_Equipment/Disposable_Wadding/Quest_Recovery_Wadding), and use that as a liner inside the transition. In effect, the ejection charge blows through this wadding tube, which takes the brunt of the heat. You have to put wadding in the rocket anyway, so why not have it protect the delicate plastic? Incidentally, this is the technique used in FAI competition rockets to protect the fiberglass tubes.



Figure 8: Warping of the plastic caused by the heat of the ejection charge.

Streamer Duration Rocket Technology

Another rocket Gary showed me was his break-apart streamer duration rocket. I've had this similar idea for a long time, but Gary beat me to it when it came to actually building it. It is a break-apart rocket! Why make a break-apart rocket?

The problem with streamer duration models is that the rocket really doesn't add much drag during descent. But if you could break it into several parts (keeping them attached with string), then you could greatly increase the drag of the descending rocket. You don't have to just depend on the streamer to provide all the drag. The individual parts increase the surface area and the parts tumble and flutter to the ground creating a lot of drag.

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Figure 9: Break apart rocket to eject the streamer and make extra drag

The problem with paper tubes is that once you split them into sections, they lose all their strength. They won't function well as a tube during the upward portion of the flight.

By 3D printing the sections of tube, you get the stiffness of plastic, so the rocket has the strength it needs to stay together during launch. And you can build in stiffeners in the parts in case you need them, like Gary did with this egg-lifting rocket.



Figure 10: Close-up of how the tube section engages into the nose cone.

However, the weight of the plastic is the issue. Excess weight kills your altitude. And you have to answer

the question of can you keep the weight down enough to make sure that it still is high enough in the air to get a long descent time?



Figure 11: Close-up of how the tube section engages into the fin can.



Figure 12: Fin can with helicopter blade hold-down hooks already built into the part.

Another model that Gary showed me was a fin can for a helicopter model. The fin can was ordinary enough, but it has built in hooks that engaged the tips of the rotor blades to hold them flat against the rocket body. Again, when you can build-in a feature like that into another part, it saves a lot of assembly time. It also has the effect of a stronger part, and ensures that everything is aligned correctly for the flight. Precision is a wonderful

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thing in rocketry, because it promotes proper function of the parts, which increases the reliability of the rocket.



Figure 13: Gary's payload altitude showing music wire anchor and tube coupler with altimeter bay.

Gary's Payload Altitude Rocket is somewhat similar to his egglofter, with the obvious difference being that it is a different shape and smaller. But again, it is designed to minimize the drag.

And like the egglofter, he uses a music wire loop to wrap over the top of the payload to act as an anchor for the shock cord (see **Figure 13**).

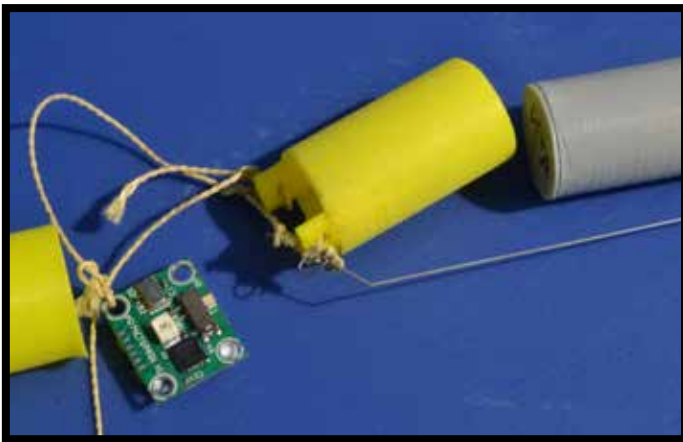


Figure 14: The 3D printed tube coupler function as an altimeter bay.

What intrigues me though, is the little 3D printed coupler in the middle of the rocket (**Figure 14**). As before, Gary had the part do three tasks at once. The obvious thing it is a coupler to join the sections of the rocket together. Then it houses the MicroPeak altimeter. Again, it was sized so that the altimeter fits perfectly inside of it so you don't need much padding around it. And finally, it has anchor attachment points built into it so that shock cord can be attached to keep the rocket together. By 3D printing this part, you don't have to build those extra features by hand, which

saves you a lot of time. And the more models you assemble of the same design, the more time and effort you save.

Precision Parts - Where Fit is Important

This was mentioned before, but one of the advantages of 3D printing is the precision of the parts that are created. This is especially important when two parts mate together. You want things straight and even, so that they function correctly.

As I was doing research for this article, I came across Newsletter #435 (<https://www.apogeerockets.com/education/downloads/Newsletter435.pdf>) that talks about creating a transition for boosted darts. This is a complex part, because the inside shape is just as important as the outside surface shape. If the tailcone of the dart doesn't nest properly into the transition, it will either wobble during ascent, or it won't separate properly at motor burn out. I think that this would be a great project to do in 3D printing, because you could match the tail cone perfectly to the inside of the transition. And as a preview of what kit I'm working on, I'm building a transition for a Nike Hercules rocket, where I have this exact problem. The way I'm solving it is to build the 3D printed parts and test fly them to make sure they work properly. Yes, I'm planning on this being a 2-stage rocket!

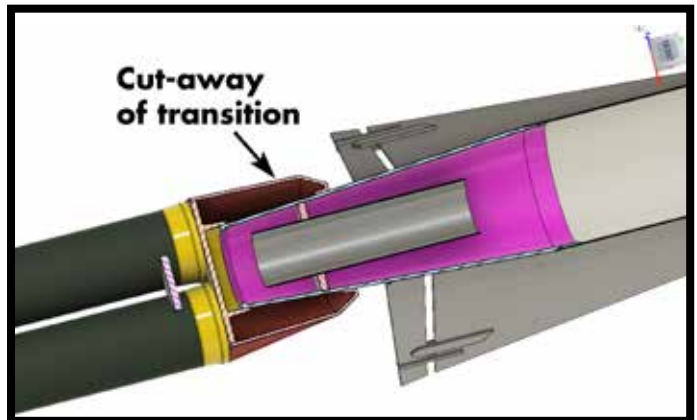


Figure 15 - The transition on a Nike-Hercules rocket will initially be 3D printed to make sure the fit is correct to allow drag separation of the upper stage.

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Model Rocket Design Software for Mac & Windows



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Other parts where the fit is important are canopies that make the rocket look like an airplane. You can build them by hand, following the techniques described in Newsletter #443 (<https://www.apogeerockets.com/education/downloads/Newsletter443.pdf>), or you can print them as shown in Newsletter #408 (<https://www.apogeerockets.com/education/downloads/Newsletter408.pdf>). Both are great, but the advantage of 3D printing is you can easily make multiple copies at the press of a button.

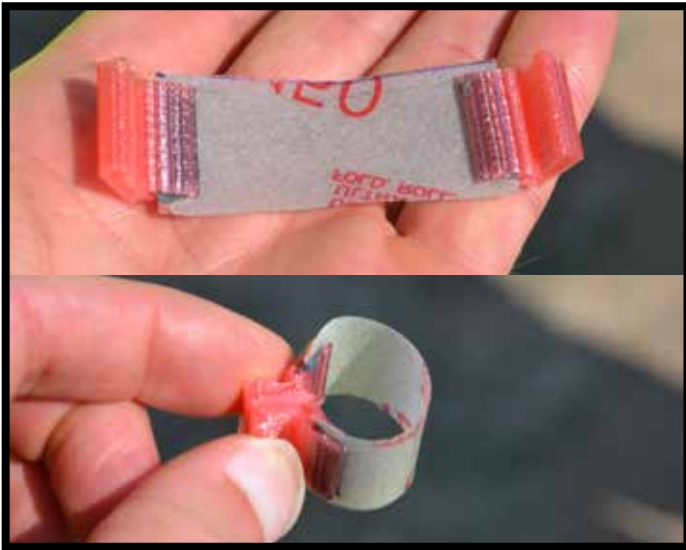


Figure 16: A new style of Fly-Away Rail Guide made from 3D printed parts and some plastic-backed sandpaper to grip the rocket.

Bob Zurek, had some really cool Fly-Away Rail Guides (<https://www.apogeerockets.com/Launch-Accessories/Fly-Away-Rail-Guides>) at NARAM that were different from any other 3D printed designs that I have ever seen. They were a combination of a flexible plastic (actually some plastic-backed sandpaper) and the 3D printed part that engaged the runners on a launch rail. This is some serious “outside-the-box” thinking when it comes to problem solving that is enhanced with the ability to 3D print parts.

But what I hope this inspires is that you should think about what tools and fixtures you might use to build a rocket or to launch them that could be made using the process of 3D printing them. I think this area could be a huge opportunity for modelers to explore.

Transforming Rockets

The other area where 3D printing will advance rocketry is in the area of what I call transformer rockets (https://www.apogeerockets.com/Advanced_Construction_Videos/Rocketry_Video_56). These are rockets like helicopters that change shape during the flight. This is where I think you can get really innovative.

An example of this would Gary's streamer duration model which we discussed above, that breaks apart in flight to increase the surface area.

Another example is his helicopter model with the 3D printed fin can that has the built in hooks to hold down the blades during launch.

Chris Flannigan as well as I have printed some different hubs for helicopters. These are the mounting posts that the blades attach into. The advantage of a 3D printed hub is again the precision of the parts. All the blades are attached at the exact same angle.

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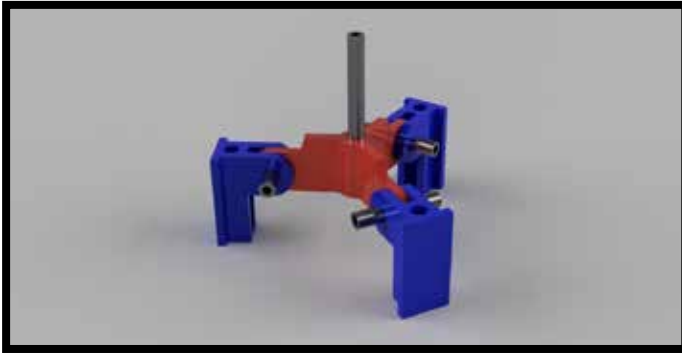


Figure 17: A rendering of Chris Flannigan's helicopter hub that is made with 3D printed parts.

The sky's the limit when it comes to designing and printing models that transform. You can do swing wing gliders, and all types of landers. You might even try designing some of the other recovery categories that are only found in the book *Model Rocket Design and Construction* (https://www.apogeerockets.com/Rocket_Books_Videos/Books/Model_Rocket_Design_And_Construction). I'd love to see some magnus rotors and drag brake recovery rockets.

Scale Models

Making transforming rockets, I'll have to admit, requires a lot of engineering. It may not be for everyone. But where 3D printing will really shine is in the area of scale rockets.

With scale rockets, there are always some parts attached to the rocket that are hard to hand carve or build up in paper or wood. Think of all the extra details on a Saturn V model, if you want some examples. With 3D printing, you can design these parts, and then you can scale them up or down to make rockets of any size.

There were numerous examples of rockets at NARAM with 3D printed parts. Tim Doll displayed a gorgeous Saturn 1B (it was actually the Apogee 1/70th scale version - <https://www.apogeerockets.com/Rocket-Kits/Skill-Level-5-Model-Rocket-Kits/Saturn-1B-1-70th-Scale>) that he had enhanced with extra parts that didn't come with the kit, like the hold-down supports that hang down from the bottom of the eight fins (see **Figure 19**).

For the first timer to the world of 3D printed parts, you may want to start with some easier projects. Some examples are simulated nozzles on the aft end of the rocket, or a nose cone like a Gemini capsule that has a special shape.

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Figure 18: John Boren shows off his scale model of the Russian SA-5 Gammon missile that used 3D parts for the nose cones and the nozzles on the rear.



Figure 19: The hold down supports on the bottom of the fins are great details that are easily made with 3D printed pieces.

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Figure 20: This nicely built Gemini Titan model has a 3D printed nose cone and nozzles.

The one thing that I do worry about though, is that we may end up with entire scale models that are 3D printed. Would that take away some of the joy of actually building the model? But then again, if you remove the tedious part of assembly, you can devote more time to performing some visually stunning flight events. Staging, clustering, and airstarts would make for a better spectator sport.

The Disadvantages of 3D Printing

Before you think that 3D printing will solve all your problems, there are some issues that you have to be concerned with.

1. **Weight** - Plastic is always going to be heavier than a paper and balsa wood rocket. So your designs may not fly as high.
2. **Heat Tolerance** - Because it is plastic, you do have to worry about high temperatures melting or deforming the plastic. Maybe in the future we'll have new resins, but for now this is a legitimate concern.
3. **Strength** - You do have to watch out what resin you're using when you 3D print a model. Some common resins are low strength or brittle.
4. **Cost** - While the plastic can be cheap, a lot of times you can build models much more cheaply using other construction techniques. Especially simple rockets with just a nose cone and three fins.
5. **Time Investment** - Designing parts on a computer involves a time investment. It is really high at the beginning when you don't know your way around the computer software. It gets better as you gain experience, but you need to recognize that you will need a lot of time to get educated in the process.
6. **Post processing** - Current 3D printers make parts that have many layers that create ridges on the surface of the parts. These will have to be sanded off or filled to make the surface smooth if you want optimum performance from your rocket. There are also build supports that have to be removed. Hopefully as 3D printer technology progresses, that these post processing issues can be removed. Sometimes it can take hours to get a 3D printed part into flight worthy condition.

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Conclusion

The purpose of this article was to inspire you about what you can do with 3D printer technology. Making simple shapes like nose cones and fins is probably where you'll start your first project. But getting other people excited about joining in on the 3D printer revolution will be hard if all you are doing are projects that any good modeler could replicate with some decent carving and cutting skills. I want you to step up and really utilize the benefits you can get by leveraging the benefits of what 3D printed parts real give you:

1. Organic (swoopy or streamlined) shapes. These shapes are very difficult to produce by hand, but are easy to make by printing them.
2. Precision - parts fit together better, leading to better flight characteristics.
3. Repeatability - You get the same results time and again.
4. Scale Models - You can make some intricate parts that would be difficult and expensive to make by hand. Once designed, you can also increase or decrease their size to make different scales of the same rocket.
5. Functionality - The parts you make can incorporate multiple tasks in a single part. You can also make transforming rockets that change shape during the flight.

Now I'd like to see what you're doing with your 3D printer. Please post pictures of your cool 3D printed rocket parts on our Facebook page so we can all get inspired by what things you've done.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward an M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (<https://www.apogeerockets.com>) and also the author of the books: *Model Rocket Design and Construction*, *69 Simple Science Fair Projects with Model Rockets: Aeronautics* and publisher of the "Peak-of-Flight" newsletter, a FREE ezine newsletter about model rockets. You can email him by using the contact form at <https://www.apogeerockets.com/Contact>.



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