# PEAK OF FLIGHT NEWSLETTER

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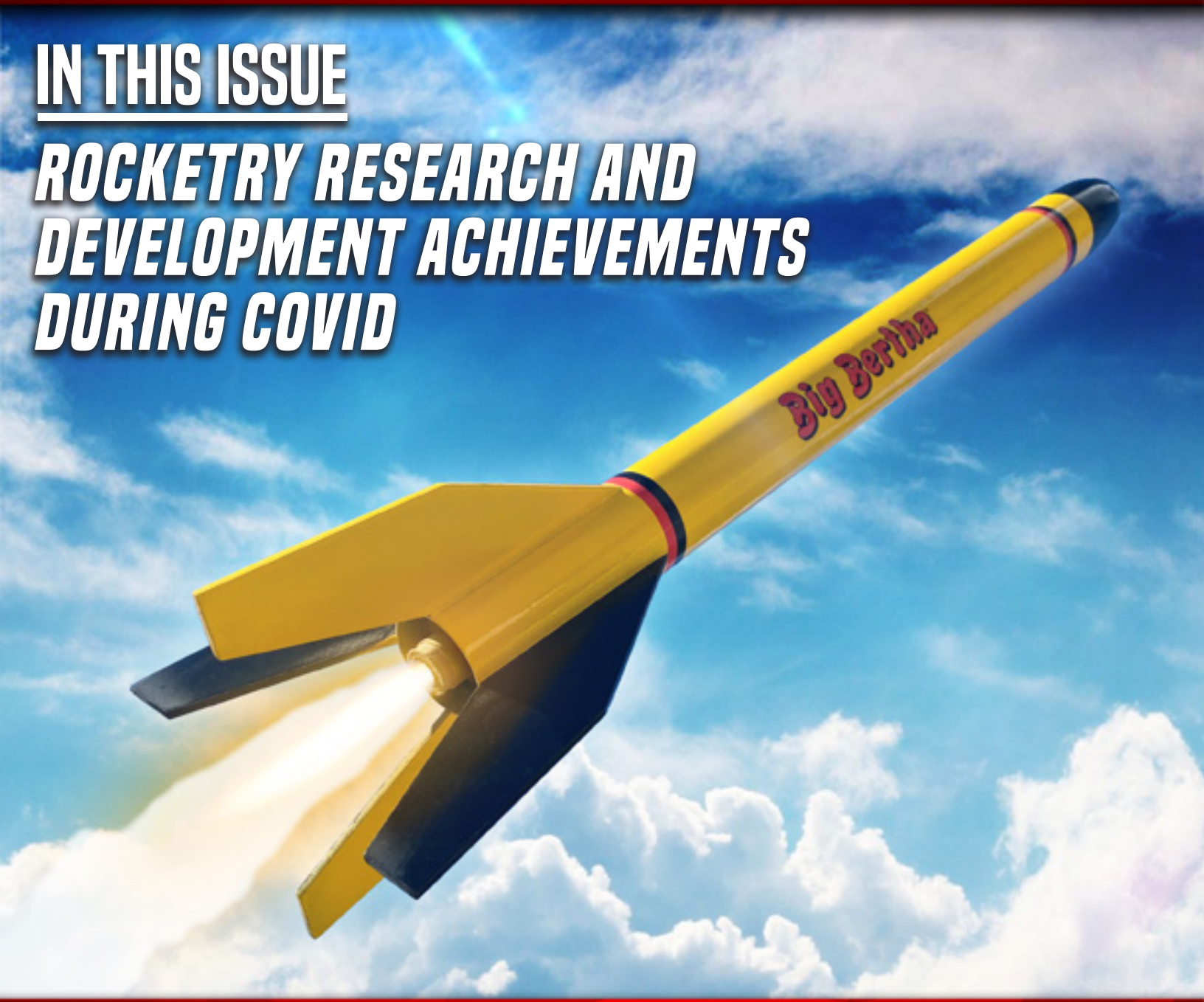
## ROCKETRY RESEARCH AND DEVELOPMENT ACHIEVEMENTS DURING COVID

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PEAK OF FLIGHT

# Rocketry Research & Development Achievements During Covid

## By Tim Van Milligan

This article is another one of my blog-type reminiscences of what I worked on over the last couple of years. I'd like for this to inspire and promote rocketry.

I mentioned previously in *Peak-of-Flight* Newsletter #559 (https://www.apogeerockets.com/education/downloads/Newsletter559.pdf) that I consider my own experiences over the last year to year-and-a-half to be like winning a gold medal. I learned so much in the process of getting ready for the 2021 World Space Modeling Championships that I didn't even care if it would have gotten canceled due to Covid (it almost was -- several times). I was having so much fun and developing new skills that I was happy as a puppy.

***FIGURE 1: RESEARCH IS ABOUT TESTING IDEAS. THIS IDEA OF A LIGHTWEIGHT CARBON FIBER ROCKET VAPORIZED INTO CONFETTI.***

While this article is about my own research and development projects, I have hesitated writing about it, because I don't want to sound like I'm blowing my own horn and bragging. My purpose by writing it here is to jog my own future memory of what I've worked on. My business coach recommends doing this, because there are seasons in life where you don't feel you're making progress. So documenting how far you've come can give you a perspective and calm those feelings of inadequacy.

Actually, this article is part of a series surrounding the 2021 World Space Modeling Championships. Others in the series are: *Peak-of-Flight* Newsletter #559 and #560 (https://www.apogeerockets.com/education/downloads/Newsletter560.pdf), which was basically a launch report of the actual event. In *Peak-of-Flight* Newsletter #562 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter562), I wrote down what I saw other modelers show off at the contest and what we can learn from their achievements. And in *Peak-of-Flight* Newsletter #554 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter554), I described one approach that I used for creating models for the contest — which was to 3D print the tools that were used to create new parts.

### *Doing Research And Development for Competition Rockets*

My approach to R&D is that I treat it as an investment. Whether the outcome is successful or not, I want to learn from it, and carry that new knowledge into the future. It is like Thomas Edison trying over 10,000 different filaments in the light bulb. Each test that didn't produce long-lasting light wasn't a "failure," it was a step to finding what did work.

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**Newsletter Staff**
Writer: Tim Van Milligan
Cover & Layout: Derek Villar
Proofreader: Michelle Mason

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FIGURE 2: BOXES AND BOXES OF REJECT TUBES WERE THE RESULT OF HUNDREDS OF EXPERIMENTS TO MAKE A LIGHTWEIGHT CARBON FIBER ROCKET.

In today's modern age, this philosophy of experimenting is pretty rare. I know this because I deal with newbie rocketeers every day. It seems that most people aren't even willing to make the investment of reading what is on our website. The answers are there, it is just a matter of reading. But they want answers spoon-fed to them.

Incidentally, I know that you are different. If you are actually reading this, I know you have genuine interest in making an investment in your own knowledge. You wouldn't be reading this otherwise. And because of that, I honor and praise you. I like to be around people like you.

This is a bit of a personal rant, or maybe I'm just turning into an old-fart, but I find that most newbies are not willing to make an investment in their own skills or knowledge. They desire to get a "showroom" model the first time they attempt a new project so that they can appear to others as being an expert. But they won't willingly build a "prototype" that would be cut-open or destroyed later. They won't experiment for the sole purpose of getting new knowledge and skills.

FIGURE 3: I OFTEN SLICED OPEN THE COMPLETED TUBE TO LOOK AT THE INSIDE SURFACE. DESTRUCTIVE TESTING IS PART OF THE R&D PROCESS.

Instead, they want to pinch pennies, and have someone else do the expensive and time-consuming R&D. But they get offended if that person doing the R&D doesn't hand over their results for free. I sense this, because every

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time I recommend that a newbie buy my book *Model Rocket Design and Construction* (https://www.apogeerockets.com/Rocket_Books_Videos/Books/Model_Rocket_Design_And_Construction), they look at me with eyes that seem to say: "Are you kidding me? You want me to buy a book to find out one piece of information? Why don't you just tell me the answer?" < end of rant >

When my daughters and I started working on building a carbon fiber/epoxy rocket in the fall of 2018, I knew I didn't have any skills or knowledge to make it. In the realm of competition rocketry, I only had the knowledge to make a fiberglass/epoxy tube. And I already knew those weren't going to be competitive in 2020. They weren't even very competitive in 2018 against the best modelers in the world.

**FIGURE 4: THIS WAS THE CULMINATION OF OUR R&D EXERCISE: A COMPLETED ULTRA-LIGHTWEIGHT CARBON FIBER ROCKET.**

To be competitive in the Senior Division, it was going to take a new type of manufacturing process, and a new material: Carbon Fiber cloth.

See *Peak-of-Flight* Newsletters #430, #431, #432, and #434 for the process of making lightweight fiberglass tubes. At the end of Newsletter #434, I specifically said that my next goal would be to try a 2-piece mold. So that was my aim for this R&D project. I wanted to learn or develop the process to make a rocket out of a two-piece mold.

Now I have made high-power parts out of a 2-part mold before. But there is a difference. In those parts, you can load up the mold with epoxy to fill any voids in the mold to make them look nice. My goal was to minimize the amount of epoxy to almost nothing. Our objective was a tube that weighed about 3.5 grams, and was 40mm diameter X 250mm long - about the size of an Estes Big Bertha. The entire rocket with fins and nose had to weigh under 6 grams. So you can get a perspective of the challenge, for reference, the Big Bertha weighs almost 71 grams.

A significant difference from our ultra-light rockets to a molded part for a high power rocket is that you can't be rough on the mold to pop the part out. On a high-power part, the walls are thick, the parts are rigid and aren't easily damaged. In these competition tubes, the parts are thinner than a sheet of paper, and are therefore very flexible and tear easily. Everything requires gentleness and extreme precision.

Another difference between a high-power fiberglass part (like a nose cone), is that they are not internally pressurized with a bladder to squeeze out the excess epoxy. The fiberglass fabric is just laid in both halves of the mold, and they are brought together along with a liberal amount of epoxy to give a nice surface finish. Typically, there is nothing that pushes the cloth up against the surface of the mold. It is only held to the surface by the layer of epoxy on

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the inside of the mold. The fiberglass cloth often puckers away from the surface, and you have a void or air-pocket on the outside surface when you pull the part from the mold. But that is OK, since the bubble can be popped, and more epoxy can be used to fill the defect or depression on the surface. Making a high-power nose cone is easy by comparison, since excess epoxy usually isn't a detriment to the part.

In competition, weight is critical. We can't have any excess epoxy because it adds weight.

From my original research, which was finding out how other competitors made them, I learned that they used either a rubber balloon or a plastic bladder to press the material against the walls of the mold. So those were some of the first experiments that I planned for when I started this project.

However, the first monetary investment I had to make was designing and buying a 2-piece mold. This is the critical piece.

Designing the mold was easy. Having it made for a reasonable amount of money was the challenge. I finally found a machinist that would cut it from a plastic block for about $600. You might be thinking, "that is a lot of money." I was shocked too. But I was willing to invest, even though the price was high. I don't think I'll ever recoup the money from anything I could sell, but the knowledge-value was worth the money.

Incidentally, I had a second mold machined from aluminum that cost even more than that. But it was worth it too.

*FIGURE 5: A TWO-PART ALUMINUM MOLD, WHERE THE COMPLETED FIBERGLASS TUBE IS PARTIALLY REMOVED.*

With a two-piece mold in the house, I could now begin playing around. I started with fiberglass cloth, since I didn't have any carbon fiber cloth yet. The first bladder I used was a rubber balloon. What I discovered was that epoxy sticks really well to latex rubber balloons. So I couldn't get the balloon out of the tube. In fact, when I depressurized the balloon after the epoxy cured, the tube collapsed. Additionally, the mold release I used on the surface of the mold was almost useless. The epoxy stuck to the inside surface of the mold too.

This was the worse of the two problems. Epoxy sticking to the surface meant that the surface of the plastic mold was going to be ruined. I had to carefully pick the epoxy off the surface to get it smooth again. So I first had to solve the issue of finding a good mold release.

It was about this time that I got a little smarter. I found a friend (Kevin Kuczek) that had made lightweight tubes

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previously, and he was much further along the process than I was. Kevin let me pick his brain for knowledge, and he put me onto a good mold release and showed me several techniques that were time savors, like using a plastic bladder and how to make a bed-of-nails. The nail bed makes it much easier to wrap fishing line around the mold, which is used to fold the overlap material on the seams into the mold so it can be closed up. Kevin's knowledge transfer really accelerated my progress.

***FIGURE 6: THE NAIL BED IS POSITIONED UNDER THE MOLD SO IT CAN BE WRAPPED WITH STRING. THE STRING ASSISTS IN CLOSING UP THE MOLD WHILE THE EPOXY CURES.***

And while I was still a long way away from making a usable tube, I could see the tubes beginning to resemble a competition tube in places. For example, on some tubes, parts of the surface were glass smooth. But a lot of challenges were still there, like the tubes were heavy, the bladders were still giving me problems, the tubes leaked air, and the surface finish was inconsistent from one tube to the next. But they weren't sticking in the mold anymore. So I was feeling good as 2019 ended.

As everyone knows, in March 2020, the Covid-19 virus hit humanity. How did this affect my progress? It basically shut it down. With the economy in shambles due to the government lock-downs, I had to pull away from the work on carbon fiber tubes, and concentrate most of my efforts on Apogee Components. It was a strange time in 2020.

I did work on-and-off on the carbon fiber tubes throughout the first part of the year, but then I realized that progress seemed to be going nowhere. It felt like I was encountering the same problems over and over again. And literally, I was. I was forgetting what experiments I had tried in the past, and I was repeating them over and over again expecting a different result. Isn't that Einstein's definition of "crazy?"

The breakthrough came in September 2020. And it was a simple process of keeping a notebook where I wrote down every experiment that I tried and what was the outcome. That sounds so stupid-silly, doesn't it? Of course you should keep notes. But up until that time, I wasn't. I was just trying to remember what I had done in the past, and it didn't work.

As an engineer, I should know better and keep notes, right? But I wasn't.

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FIGURE 7: JOURNALING TURNED OUT TO BE THE GAME-CHANGER IN THE PROCESS. KEEPING TRACK OF THE VARIOUS EXPERIMENTS AND THEIR OUTCOME ACCELERATED TUBE DEVELOPMENT.

Once I started though, I found that the very process of writing things into the notebook forced my mind to work differently. As I was writing down the problem I was having on any particular day, the potential solution (or two) would pop into my mind.

I was actually looking forward to the time when I got to write down my observations in my journal. Because it felt that I was making new discoveries just through the "thinking process." Since it took time to write things down, it was slowing down my thought process so I could devote time to think through things. It was like I was observing things through a microscope, and I would see the problem differently by exaggerating it. It may just be that defining the problem adequately holds the key to solving it.

I have since filled almost two spiral bound notebooks that document my work on the process of making carbon fiber tubes. Most of it was about stupid and clumsy mistakes I made, so reading it now is just embarrassing. The eventual solutions were profound, but most times they were simple. That's kind of when you know you have a real solution - in hindsight it seems simple and elegant.

FIGURE 8: A FINISHED TUBE THAT WEIGHS ONLY 2.75 GRAMS.

Recently, I made a video course on how to build carbon fiber/epoxy tubes. The process looks simple now, but developing it was a long process of eliminating dozens of problems—one at a time. I've literally built hundreds of tubes just to make the process simple and consistent enough that I could have my daughters build their own rockets for the contest that was held in September 2021.

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FIGURE 9: ASHLEY VAN MILLIGAN DURING THE PROCESS OF CUTTING THE CARBON FIBER CLOTH USING SOME SIMPLE CARDBOARD PATTERNS.

If you'd like to join the course and discover how to make your own ultra-lightweight tubes that have a glass-smooth surface, that are airtight, and are strong and resilient, you can check it out at: https://www.udemy.com/course/make-ultra-lightweight-carbon-fiber-tubes-for-model-rockets

## Other Projects

Making carbon fiber airframes in a two-piece mold wasn't my only R&D project that I was working on. The goal was to build rockets for: Streamer Duration, Parachute Duration, Helicopter Duration, Glider Duration, and an A/B engine Altitude event. There were a lot of models that I wanted to optimize.

In the Altitude event, I was attempting to find a process to make an ultralight weight internal tube. It needed to be a simple carbon fiber tube that would be an engine mount tube inside of the larger outer tube. Simple in this case means a straight tube without any transitions. Since it was on the inside of the rocket, I didn't care what the surface finish of the tube was like.

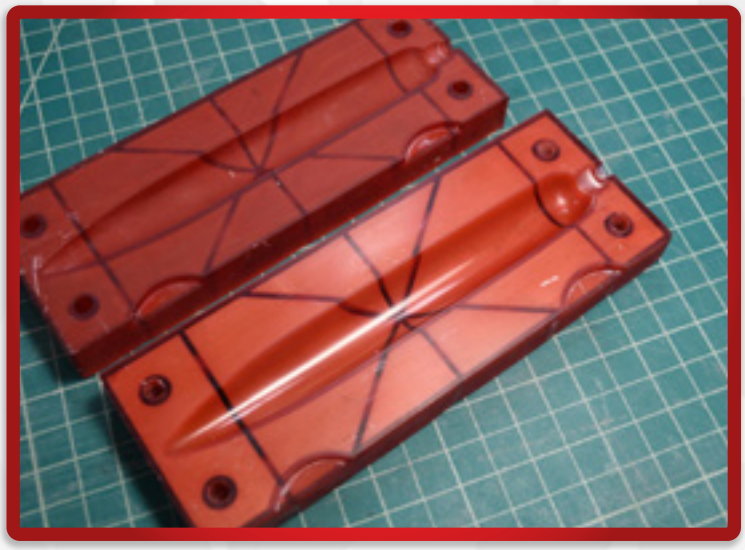

FIGURE 10: THIS IS MY 2-PART MOLD FOR MAKING SUSTAINER BODY TUBES FOR THE 2-STAGE ROCKET ALTITUDE EVENT. THE TOP PART IS JUST OUT OF THE 3D PRINTER, WHILE THE BOTTOM ONE HAS BEEN POLISHED SMOOTH.

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This process started similarly to what I described in *Peak-of-Flight* Newsletter #479 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter479) where the tubes are made over the top of a steel mandrel. But these tubes are larger in diameter, and the process described in the newsletter wasn't working when I tried it on these mandrels. The tubes were sticking to the mandrel, and worse, they all leaked air really badly. If they aren't airtight, then the ejection charge of the rocket motor won't push out the recovery device from inside the rocket. The hot air just blows out the sides of the tube and the rocket doesn't deploy at all.

I initially attempted to use tissue paper as the initial layer of the tube against the mandrel so that it would seal the tube and make it airtight. But that didn't solve the issue of the epoxy sticking to the steel rod (mandrel). It was still impossible to get the tube to slide off the mandrel after the epoxy cured. No matter what mold release I used, I couldn't get a consistent tube that I liked. And the tissue paper soaked up epoxy like a sponge, which made it heavier than I desired.

The solution, which wasn't perfect but seemed to work at the time, was to use Kapton as the inside layer of the tube. Kapton is a high-temperature plastic film that is relatively expensive. It is used in the space industry a lot because it doesn't burn easily.

By putting the Kapton inside the tube, it instantly solved the problem of the tube being airtight. There are no holes in the film, and therefore no way for air to come out the sides.

***FIGURE 11: A LIGHTWEIGHT TUBE WAS MADE BY WRAPPING HEAT-RESISTANT KAPTON FILM WITH CARBON FIBER/EPOXY.***

The heat resilience of the Kapton also solved a different problem with thin-wall tubes. Because the walls are so thin, the hot ejection charge of the motor fries them instantly. The typical solution in the past was to make them thicker so they could absorb some of the heat. But that adds weight, which I didn't want.

And I discovered a unique problem with carbon fiber tubes that I didn't notice in the past when I made them out of fiberglass cloth. Since the carbon fiber uses less material, they are even more susceptible to heat damage than fiberglass tubes. But it is a different type of damage. When you overheat a fiberglass tube, the epoxy chars away, and the glass turns brown. Maybe you've seen that with some of your fiberglass rockets. You can easily tell when they are damaged by heat. On a carbon fiber tube, it is a lot harder to tell if they are damaged just by looking at them.

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The reasoning for this is because the carbon fiber tubes are thinner and the amount of epoxy is reduced. Therefore, the epoxy doesn't simply char away -- it vaporizes! However, the carbon fibers don't burn or char. The individual filaments are left intact. So the damage is harder to notice, because the tube still looks ok. But there is no epoxy in the damaged area, it is just a bundle of fibers. If you aren't careful, you might refly the rocket, thinking it is OK. But without the epoxy, the tube isn't strong nor airtight; and the ejection charge will go out the side instead of up through the tube. That would easily lead to a crashed rocket.

The Kapton on the inside of the tube will always make sure that the tube is air tight. That is what is nice about it. But it can soften and deform with high heat. So you do have to protect it in the area immediately in front of the rocket motor (for about 2 inches distance). You have to stiffen the tube in this area to make sure the heat doesn't cause the Kapton to shrink and restrict the flow of air through the tube. This can happen on long stuffer tubes inside a rocket (see *Peak-of-Flight* Newsletter #418 at: https://www.apogeerockets.com/education/downloads/Newsletter418.pdf). Once I discovered the problem, I just stiffened the area in front of the tube with an extra layer of paper over the Kapton. That seems to do the trick on keeping the tube from collapsing due to heat damage.

The one issue that I haven't quite licked yet (to this day), is that epoxy doesn't seem to make a permanent bond with the Kapton. It "sorta" sticks. But that is better than with other plastics.

By comparison, epoxy doesn't stick at all to mylar or polyethylene plastic. But epoxy sticks somewhat to Kapton. So you can bond the carbon fiber cloth to Kapton, and you can make a tube.

The downside though, is that I found that if you abuse it with rough handling, the edges of the Kapton will start to peel away from the inside surface of the carbon fiber tube. So you do have to be careful to not roughly handle the rocket. An example would be when you are sliding the rocket motor in or out of the tube. You have to put the motor in slowly so that the front of the motor tube doesn't catch the edge of the Kapton liner. Otherwise it will start peeling away.

When I started making engine mount tubes with this method of putting Kapton down first, I used 1-mil thick Kapton. But I eventually found a ¼-mil Kapton sheet, and that was a game changer. It is really lightweight, like those competition mylar chutes. So I was able to significantly reduce the weight of the tubes I was making.

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The downside is that ¼-Mil thick Kapton sheeting is really difficult to cut. If you use a dull knife, it will tear instead of cutting nice and straight. So every single time I cut a piece of Kapton to use as a liner inside of a tube, I had to start with a fresh hobby knife, and cut really slowly.

The other issue that I still would like to work out is wrapping the ¼-mil Kapton around a mandrel. It is so thin that it doesn't want to roll easily. It needs to stay in place long enough for me to wrap it with carbon fiber cloth, which can then be wetted out with epoxy.

I've used the same Kapton film in another application as well. That was to make ultra-lightweight centering rings. The lightest way to make centering rings is to make them in a hub-and-spoke pattern, like a bicycle wheel. But those would allow air to pass through. So to make them airtight, I've made rings that have the ¼-Mil Kapton on the surface that cover over the spokes.

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*FIGURE 12: A CENTERING RING WITH YELLOW-ISH KAPTON FILM OVER IT TO MAKE SURE AIR DOESN'T PASS THROUGH IT.*

The centering rings were molded inside a tool that I 3D printed, which is described in *Peak-of-Flight* Newsletter #554 (see **Figure 6** at: https://www.apogeerockets.com/Peak-of-Flight/Newsletter554). The only modification I had to do was slip the Kapton sheet into the mold before I clamped it down while the epoxy cured. It added less than a tenth of a gram in mass, and worked nicely to make them airtight.

## *3D Printing of Tools*

Like the example shown in **Figure 10**, I did extensive 3D printing of speciality assembly tools in preparation for the 2021 World Space Modeling Championships. I do feel that it was one of the keys to making high quality models.

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And it particularly helped simplify the assembly process of the models - especially for my daughters. If you don't have skills, then you really need tools to help guide the process.

One particular problem that my daughters had was drilling holes in carbon fiber tubes. The tubes are so thin that you can't put any pressure on the drill, or the tube just deflects.

If it was a fiberglass tube, the solution was pretty easy. We'd cheat and mount the tube in the laser-cutter machine and burn a hole through the tube. The fiberglass doesn't really burn though. When the laser beam hits the glass fibers, it shatters them, which effectively cuts them.

When you try to laser-cut a carbon fiber tube, it doesn't work. The individual filaments of carbon don't burn (I mentioned this previously, remember?). The laser only burns away the epoxy and leaves the strands of carbon intact. So you don't get a hole at all.

Making a hole in a thin-wall carbon fiber tube requires physical cutting of the fibers with a knife edge. So I made a 3D printed cutting tool that had a shaft that slipped inside the tube to support the wall—so it couldn't flex when the knife was pressed into the outside surface. In fact, I probably made four or five of these tools for holes for various parts. That is what I mean by making tools that help you build rockets. The first time my daughters used the tools, they got perfect holes located in the right spots.

You can see other specialty tools that I 3D printed in *Peak-of-Flight* Newsletter #554. The whole point of that article is to drive home the point that you'll get a better rocket

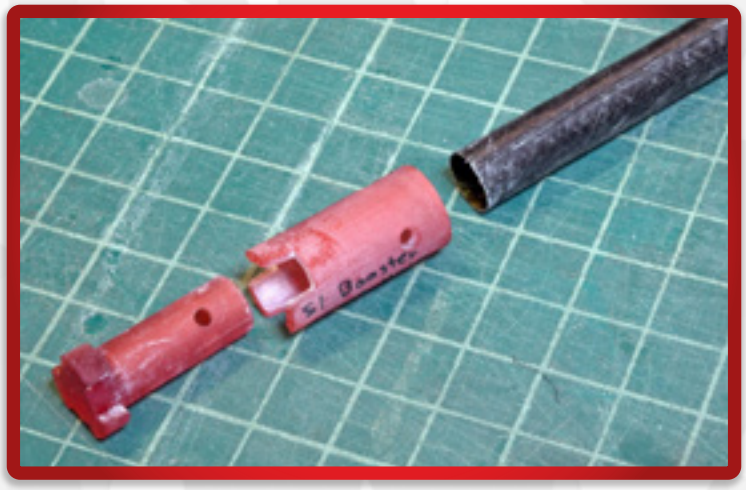

***FIGURE 13: A SPECIAL 3D PRINTED TOOL THAT ALLOWS YOU TO CUT A HOLE IN THE LIGHTWEIGHT CARBON FIBER TUBES. IT WAS THE EASIEST WAY TO CUT THROUGH THIS HIGH-TECH MATERIAL.***

(lighter weight, stronger, faster flying) if you use your 3D printer to make the assembly tools and jigs, rather than just trying to print the actual parts for the rocket. This is certainly the case for competition rockets where weight and performance need to be optimized. However, when you get into sport models that are just for fun, then 3D printing the parts is probably the way to go.

### *Making Ultra Lightweight Fins*

One of the other research projects that I worked on for this contest was to make better fins. By 'better,' I wanted something smoother, and lighter weight than I used in the past. So what did I use in the past? I used balsa wood fins - like any normal modeler would.

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So how do you make something better than that?

At first, I tried super-thin carbon fiber fins. These were nice, but in order to get a nice surface finish on the fins, you needed a lot of epoxy on them. Even the thinnest sheets of carbon fiber at 0.010 inches thick were heavier than a similar sized 1/32 inch (0.0321 inch) balsa wood fin.

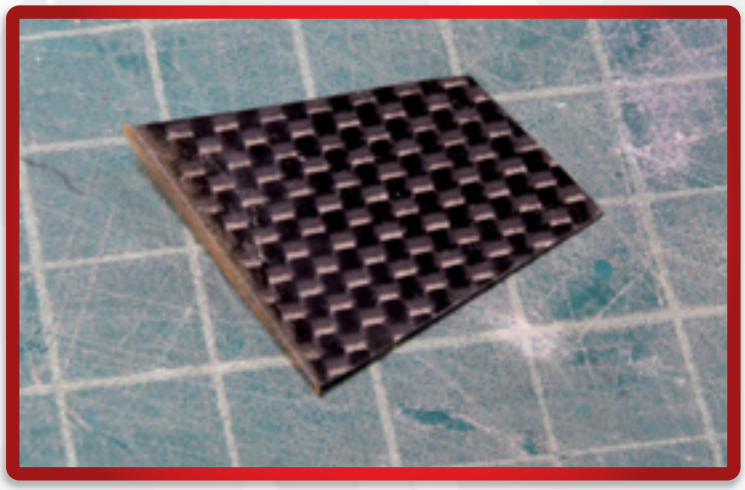

**FIGURE 14: AN EXAMPLE OF A FIN CUT FROM A WOVEN CARBON FIBER SHEET. IT IS THIN, SO IT IS LIGHTWEIGHT. BUT IT'S NOT AS LIGHTWEIGHT AS A BALSA WOOD FIN WOULD BE.**

I also tried coating the balsa fins with carbon fiber cloth, attached with epoxy. Again, it was adding weight that I didn't need. The strength wasn't the issue with balsa fins. It was weight and surface finish. It is not sexy, but the truth is, balsa wood is a miracle material. Its strength-to-weight ratio is better than that of carbon fiber (see *Peak-of-Flight* Newsletter #30 at https://www.apogeerockets.com/education/downloads/Newsletter30.pdf). It is a great material for a fin.

The only question is how to get a nice surface finish on the balsa wood fin without adding much weight?

What I ended up doing was starting with the thinnest sheet of balsa wood that I could get (1/32 inch thick) and sanded that down to 1/64 inch thick. That got the weight down. But being so thin, it was also very flimsy.

Next was to apply a coating to it to smooth out the finish to make it low drag. For that, I filled the surface with wood filler (see https://www.apogeerockets.com/Advanced_Construction_Videos/Rocketry_Video_228).

The wood filler is lightweight, but not very durable. So I put a skin of epoxy over the surface to give it a hard outer coating. The epoxy added just enough strength to the fins to stiffen them up so they wouldn't flutter. They ended up being just stiff enough.

It is possible for the epoxy to add a lot of weight, so to make sure it was as thin as possible, I vacuum bagged it to the fin. I've never done vacuum bagging before, so this was my first time for that process. That was a new skill that I learned, and I'm so happy I acquired that technique. And since I already had a spare air pump, the additional supplies needed were less than $50. That was less than the cost of buying sheets of carbon fiber, and I can use it to make hundreds and hundreds of fins in the future. So it was a bargain.

I went one step further and put an aluminum coating on the surface of the fin, which added a bit of mirror shine to the skin. The purpose of that was that I wanted the model to sparkle in the sky to make it easier to see as the rocket was drifting away. Of course, my streamer and parachute were also aluminized mylar, so the fins really didn't need

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the mirror finish. But I learned the process anyway, and I'm glad I did. It just made the model look "finished" instead of having just balsa-colored fins.

***FIGURE 15: I COATED THE BALSA WOOD FINS WITH AN ALUMINUM COATING TO MAKE THE SPARKLE IN THE SUNLIGHT. IT WASN'T REALLY NEEDED, BUT LOOKED REALLY COOL.***

I am planning on doing a newsletter article on this technique, so be on the lookout for that in the near future.

## *Conclusion*

From a perspective of learning and acquiring new rocketry skills, the past two years were very productive for me personally. And that is in spite of the whole Covid-19 pandemic. I tried my best not to let that whole situation define what I was going to accomplish. It slowed things down, but it didn't stop me..

It is my hope that you were also productive in your own progress with your projects. You can send me a note and let me know what new skills you've acquired recently. I'm interested because I'm always looking for authors for this space here in the newsletter. What do you consider to be something that you've learned that is worthy of passing on to other rocketeers?

## *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 (http://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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