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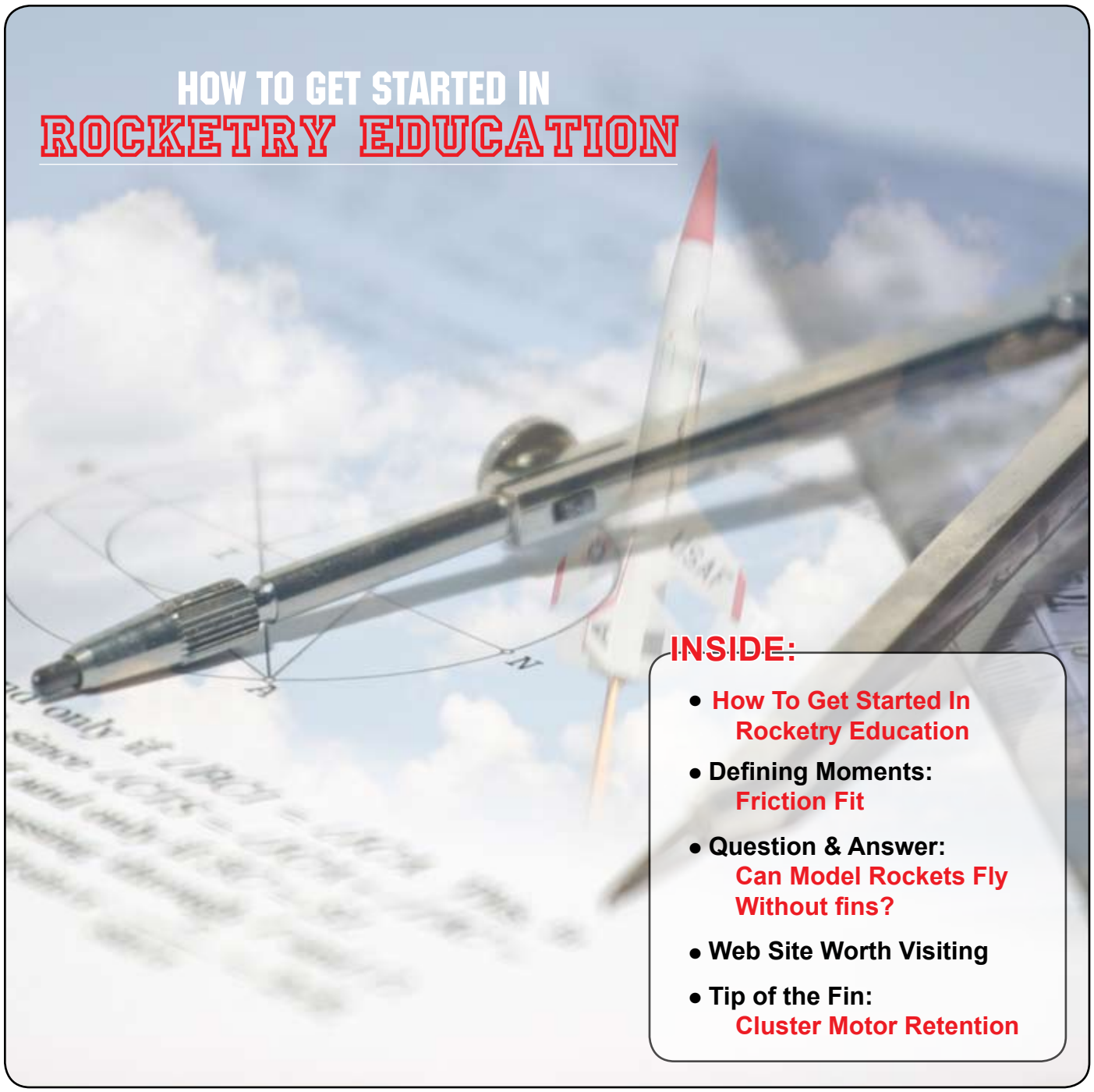
APOGEE PEAK OF FLIGHT NEWSLETTER



HOW TO GET STARTED IN ROCKETRY EDUCATION

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- Tip of the Fin: Cluster Motor Retention

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HOW TO GET STARTED IN ROCKETRY EDUCATION

By Dave Virga

I am a member of the local rocket club here in Colorado Springs. Every Spring, we are deluged with requests for help from school teachers, Cub Scouts, Boy Scouts, Girl Scouts, 4-H leaders and after-school program coordinators, all wanting to include rocketry in their activities. It's a big effort to support all of them, but I actually find it to be invigorating. There is a great sense of accomplishment in seeing a group of youngsters talking excitedly after launching their rockets or watching a multimedia presentation on rocketry and space exploration, knowing that they are envisioning space shuttles, space stations, satellites, lunar bases and interplanetary scouts. If just one of those hundreds of kids each year is inspired by the experience to become a scientist, an engineer, or even an astronaut, then my efforts have been redeemed. This is the basis of the tenet that we in the rocketry community call "*paying forward*."

It's no secret that Tim Van Milligan is a very strong proponent of rocketry education; he has been paying forward through Apogee Components for well over a decade. Not only does he offer an excellent collection of educational publications for sale, but the Apogee website has a huge collection of free information (technical publications, Peak Of Flight newsletter articles, etc.) as well as links to other rocketry and science education web sites. The starting point for all of this great information is http://www.ApogeeRockets.Com/Education/index.asp.

It is very important that we, as dedicated and experienced rocketeers, make ourselves available to the educational community. School budgets are tight; they are only able to allocate resources to core education requirements. Future budgets are driven by student scores on standardized tests, so the curriculum is geared directly to published learning objectives. As a result, lower-priority activities such as rocketry are often eliminated simply because the school staff cannot allocate the time to prepare and conduct the activities. This is where we can help. We can work to ensure that rocketry continues to be a part of our schools' activities by offering a prepared package that they can simply drop into an available time slot. It's a win for everyone involved – students, teachers, and rocketeers.

So what does it take to become a rocketry educator? All of the resources that you will need are readily available, and none of the steps are particularly difficult. The main thing that you will need is time to prepare yourself and your lesson plans. My goal for this article is to lay out a process that you can follow to get there, and to get you started in exploring the vast expanse of online resources for information that you can use along the way.

KNOW YOUR SUBJECT

The first step to becoming a successful rocket science educator is to educate yourself. And at the risk of sounding biased, I strongly feel that the best place to start your education journey is the Apogee web site. If you don't find what you're looking for directly, then you will find a link to a site that has it.

There is no better comprehensive introduction to rocket science and model rockets than the Apogee Components book *Model Rocket Design & Construction*. It contains easy-to-understand discussions of the principles behind rocket stability and aerodynamic efficiency. The book goes on to cover every type of model rocket design and recovery method, with information and tips to help you design and build all of them yourself. This book is a must-have for every model rocketeer – period. http://www.ApogeeRockets.com/design_book.asp

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About this Newsletter
You can subscribe to receive this e-zine FREE at the Apogee Components web site (www.ApogeeRockets.com), or by sending an e-mail to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.

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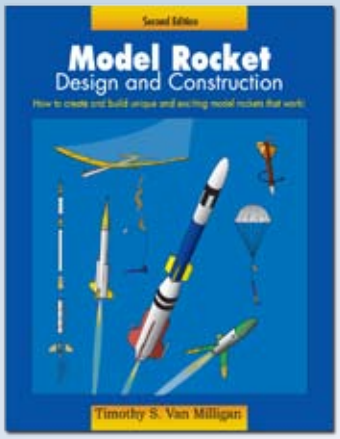

This book is the centerpiece of the Apogee Components Educator's Ensemble. In addition, you get *Model Rocket Propulsion*; this publication tells you everything you need to know about how model rocket motors work and how they are classified. The Ensemble includes *Teaching With Model Rocketry* as well, which describes rocketry in education and how to incorporate rocketry into topics other than just rocket science. You also get *Electronic Model Rocket Launcher Construction Plans* and *Conducting A Safe and Scientific Launch in Large Group Settings*, which will prepare you for your launch activities. http://www.ApogeeRockets.com/educators_ensemble.asp

If, after assimilating all of the information in this set, you are left craving more, then you need *Topics in Advanced Model Rocketry*, by Mandell, Caporaso and Bengan (http://www.apogeerockets.com/topics_advanced_model_rocketry.asp). This book was first published in 1973, but absolutely nothing in it has become outdated in over thirty years! It contains over 600 pages of detailed descriptions and the full mathematical equations for all of the principles of rocket flight. You will find all of your rocket science answers in this book. If you intend to give technical rocket science presentations at the high school level or above, then this book is a must-have.

In all fairness, G. Harry Stine's *Handbook of Model Rocketry* is also an excellent all-around book. It is available from numerous sources, including the National Association of Rocketry's website (http://www.nar.org).

KNOW HOW TO BUILD AND FLY ROCKETS

Since you are reading this newsletter, it is safe to presume that you have some actual model rocket experience. Still, it is worth noting that there is no better way to learn about model rocketry than by building and flying rockets. So have at it! Build and fly as many different types of rockets as you can. Go to public rocket launches and pay attention to everyone else's rockets and flights. Learn what works; equally as important is to learn what doesn't work, and why. Use RockSim to practice designing your own rockets, paying particular attention to the software's assessment of your design's stability. Run multiple flight simulations using different motors, and also adjusting the rocket's mass, to see the effects of both on the rocket's altitude. You can never do too much designing, building or flying; and the best part is that it's all fun! http://www.ApogeeRockets.com/Rocksim.asp

KNOW YOUR AUDIENCE

Once you have established a firm understanding of your subject matter, you need to identify your target audience. You need to tailor the degree of technical complexity to the age and education level of the students. For example, don't expect elementary school students to be engaged by a Doctorate level dissertation on the effects of varying exhaust molecular weight on specific impulse. You should also try to find out the degree of rocketry experience of your audience so that you don't bore even an elementary school aged group with basic introductory information.

K-6: Elementary school aged children have very limited technical understanding – basic arithmetic using simple numbers. They are very good at visualizing though. You can describe Newton's Laws, but they won't be able to grasp any meaning of the equations behind them. They understand simple physics concepts such as friction, gravity and speed. The key to this group is to keep the discussion and presentation lively and exciting to hold their attention and appeal to

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their imagination. If you build rockets with this group, keep them very simple – those with one-piece plastic fin units such as the Estes® Generic E2X, Alpha III as well as the Quest® Starhawk or Viper (all available in bulk).

6-8: Middle school students are developing more mathematical understanding, into the realm of algebra; you can present Newton's equations, describe the factors of the equations, and show how they work through examples using proportions (If you apply twice the force to a rocket, what happens to the acceleration?). They can apply simple analytical concepts, and can understand rates (Speed is miles per hour – like on a car's speedometer) and also rates of change (Acceleration/deceleration is miles per hour increasing/decreasing on the speedometer). They are starting to think of themselves as more mature, and may be turned off by some of your more elementary-level approaches, but they still like to have fun, and enjoy an animated presentation. If you are given sufficient time, you can introduce them to computer-based tools (RockSim!). Middle school students have the patience and attention span to build simple balsa-finned rockets, but if time is short the plastic fin options above will still work.

9-12: High school students have a much more functional understanding of math and physics concepts. You can use algebra and geometry concepts freely, and delve into more detailed physical aspects of rocket science (motor design concepts; thrust; aerodynamics; Center of Pressure calculation). A complete RockSim demonstration of model rocket design and flight simulation would be very well received. They are certainly not above a few rousing rocket launch videos, so be sure to entertain them as well. If you build rockets with these students, you should incorporate an experiment; you could have them compare actual flight performance to computer simulations with various parameter changes, for example.

COLLEGE: If you have the opportunity to address a college-level group, you first need to determine if they are a technical group or not. If they aren't, then you can use the high school approach. If they are well versed technically, then you can really let the science fly; the only limit here is your level of knowledge and expertise.

Regardless of the audience's education level, don't ever try to teach beyond your level of understanding. Sooner or later you will have a run-in with a fifth-grade brainiac who will eat your lunch; don't risk your personal credibility for future presentations, or that of any organization or club that you're representing. For general presentations, I recommend talking a bit below your level of expertise, so that you have some room to speak technically to any advanced questions that you may be asked.

Will your audience be building and flying rockets? If so, then you need to be prepared for this as well. All of your experience building and flying rockets yourself will be invaluable here. Be sure to thoroughly familiarize yourself with the kit being built. Review the instructions, and formulate your plan for leading the group through the construction steps. Try to envision the errors that could be made during construction, and ways to both avoid and correct the mistakes. Plan for the worst case by having tools, glues and extra parts on hand so that you can deal effectively with the problems when they arise.

KNOW YOUR TIME LIMITS

It's a cold, hard fact – you will never have as much time for your presentation as you would like. The key to success in all circumstances and time constraints is flexibility. Design your presentation so that you can quickly add or remove pieces both before and during the session. As you gain experience, you will learn exactly what you can do in a given amount of time.

I have found that one hour is the absolute minimum amount of time to give a well-rounded introduction to rocketry. If your hosts suggest this much or less, try to convince them that the quality of the lesson will improve immensely with every additional quarter-hour of time. Turn on the salesmanship here; explain all of the great things that you include in your presentation, and the enthusiastic response that will surely result. If even polite groveling doesn't gain you more time, by no means ever

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refuse an opportunity; the audience's reaction to even a short introductory presentation will convince your hosts to allot more time next time.

MAKE IT A BLAST!

Rocketry, by its very nature, is exciting. You will have more difficulty containing your audience's excitement than boring them. Share your personal enthusiasm for rocketry with them. Throw in a few personal examples, preferably of real rockets if you can. Have you ever witnessed a commercial rocket launch, a Saturn or a space shuttle? Have you worked in the aerospace industry? Tell them about it.

Take full advantage of today's multimedia resources. Build your presentations and lessons using a slide show program such as Microsoft PowerPoint. Include lots of pictures and videos throughout. There are literally terabytes of source material on the internet of hobby, professional and commercial rocketry endeavors; use it!

Here's your homework assignment for this issue. Starting at the Apogee Education link at the beginning of this article, find a website that has over thirty rocketry related PowerPoint presentations, all free!

SUGGESTED TOPICS

Here is a list of topics that would make for a thorough discussion of rocketry. You can use this list either as an outline for a single introductory presentation, as a list of modules for a highly thorough course on rocketry, or anything in between.

- History of rockets
- Important cultures, people, scientists
- Basic definition of a rocket motor
- How rocket motors work (Newton's laws)
- How a nozzle maximizes thrust
- Motor design principles – fuels and oxidizers; specific impulse
- Solid motors – pros and cons
- Liquid motors – Pros and cons
- Uses for rockets – Atmospheric research; orbit; interplanetary missions; manned, unmanned flight

Be sure to explore the Apogee web page specifically geared to teaching rocketry: http://www.apogeerockets.com/education/teaching_tips.asp.

CONCLUSION

In this article, I have laid out the path to help you get started as a rocket science educator. The main focus is to prepare you to give introductory lessons on rocketry. This is obviously just the tip of the iceberg for rocketry education though. You can build upon this foundation, and work up towards giving full, in-depth multi-session courses in rocketry. The best teachers are those who are passionate about the subject material. So if you love rocketry, share that love with those who will become tomorrow's scientists, engineers and astronauts. Pay forward!

ABOUT THE AUTHOR

Dave Virga holds a Bachelor's degree in Computer Science, and is an Information Technology Specialist for the Department of Defense. A typical Born Again Rocketeer, he enjoyed building and flying rockets through high school, then set the hobby aside for college, career and family. He re-discovered rocketry in the late '90s, and has become a voracious student, teacher and practitioner of rocket science. In past lives, he has been a naval submarine officer, computer systems engineer, ski instructor and Scout leader. A trombonist since elementary school, he will also on occasion sit in with his wife's early music ensemble when a bit of sackbut is needed. He lives in Black Forest, Colorado with his wife, son, dogs and parakeets.

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DEFINING MOMENTS

Friction Fit

Friction fitting is a method used in rocketry to create a temporary union between two close-fitting components where one slides inside of the other. The concept is simple – the diameter of one part, typically the inner part, is adjusted to achieve the desired fit. Tape is the most common material used to increase the inner part's diameter; cellophane, packing or masking tapes may be used. A too-tight fit is loosened by sanding the inside part's surface, thereby reducing its diameter.

The most common friction fit is the nose cone into the body tube. The fit should be snug, so that the nose cone doesn't fall off if the rocket is held nose-down and shaken. Do not make this fit excessively tight, or the ejection charge will not be able to blow the nose cone off and deploy the recovery device.

Friction fitting is also used as a method of motor retention. You should never have to loosen the fit of a motor in a motor tube. Motor friction fits must be very snug, so that the ejection charge does not blow the motor out of the back of the rocket, but not so tight that you risk damaging the rocket during installation or post-flight removal. Be aware that the motor's heat will soften the tape, which will loosen the fit during flight. If you have never friction fitted a motor before, it is strongly recommended that you seek the help of someone with experience for your first couple of attempts.

You may also use this technique to allow a very long rocket to be easily disassembled for transport. Instead of permanently gluing all of the tube couplers, pick one joint in the middle of the rocket and use a tight friction fit instead. Be sure to inspect the coupling closely before each flight to make sure that it will not separate from the ejection charge.

Friction fitting is as much art as technique. It takes a light touch and the right choice and application of tape or other materials to achieve the perfect temporary fit.

Question & Answer

David W. writes:

Q: Is it possible to make a model rocket fly in a stable manner without fins? I've considered scratch building historical and up and coming spacecraft but many of the real rockets have very small or no fins. How is it that they can fly without them but models of the same cannot?

That's a great question, David!

A: The reason is that real rockets use "**active guidance**" - on-board electronic systems that track the rocket's flight path and steer it using either vanes or motor gimbaling to make it follow the desired path. Vane control can be either fin-based (utilizing the outside air stream) or motor exhaust based (utilizing the motor's exhaust flow). Gimbal control is a system where the motor's nozzle is swiveled to control the direction of its thrust. An outboard motorboat is a good example of a gimbaled motor; if you turn the motor so that its thrust is directed to the left, then the boat will turn to the left.

Each method of directional control has its pros and cons. Fin-based vane control only works when the rocket has sufficient velocity for the outside air to generate lift forces. Also, fins have no effect in space, where there is no air; gimbaling is the method of choice for space maneuvering. Exhaust-based vanes and gimbaling only work when the motor is firing, and need long-burning motors to be effective; so, these methods are best for low-speed maneuvering.

Active guidance systems are far too complex and expensive to incorporate into model rockets. This is actually good, since it helps to keep our sport and educational rocketry endeavors separated and distinct from "missiles". Model rockets rely on "**passive guidance**" – fixed control surfaces that utilize the laws of aerodynamics to maintain stability and keep the rocket traveling in the direction established by the launch rod.

One method used by many scale modelers is to add detachable clear plastic fins to the rocket for flight; they detract very minimally from the rocket's appearance and add a lot of stability.

When you're ready for it, the grand-daddy of all scale model rockets is here: http://www.apogeerockets.com/Saturn5.asp.

Web Site Worth Visiting

Stardate Online

I enjoy listening to the local National Public Radio station here in Colorado Springs, not just for the fine classical and jazz music, but for the other programs that they broadcast as well. One such program is called StarDate. It's a daily audio publication from the University of Texas McDonald Observatory that presents an always interesting lesson on astronomy or space science.

I recently discovered that StarDate has a very good web site as well as a magazine. You can find it at http://StarDate.Org. The online offerings include stargazing tips, radio broadcast and magazine archives, image galleries and teacher resources.

Remember, rockets are our only means of getting into space (thus far). Keep practicing, keep learning, and shoot for the stars!

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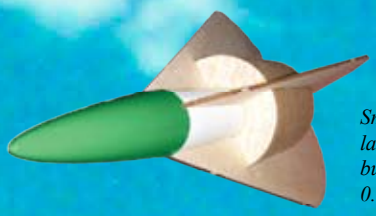
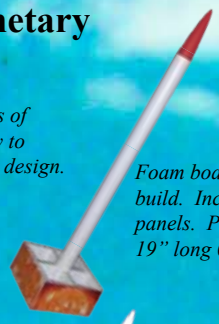


Interplanetary Shuttle

Small rocket with lots of laser cut balsa. Easy to build with distinctive design. 0.976" dia 11"long



Box Racer

Foam board fins for a different build. Includes pre-printed side panels. Plastic nose cone. 19" long 0.976 dia.

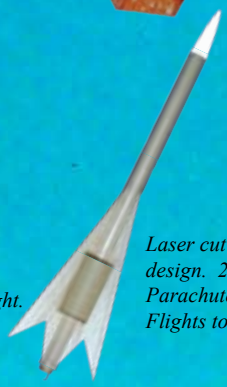
Space Speedster

Printed body with foam board fins. Preprinted fins. Laser cut foam mounting rings.

Flechette

3 fins 6 piece laser cut balsa. Flights to 1000'/ 300m. Parachute recovery.

Flechette: *The word flechette is French for "dart." In military use, it is a projectile having the form of a small metal dart: a sharp-pointed tip and a tail with several vanes to stabilize it during flight.*



Explorer

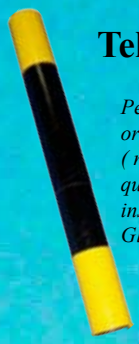
Laser cut 4 fin with distinctive design. 21" long 0.976" dia Parachute recovery. Flights to 750'/ 250m

Bug Me Not!

Great beginner's rocket. Laser cut fins. Streamer recovery. 0.976" dia 11" long.

Lightning Fury

Simple to build. Laser cut fins. Streamer recovery. 0.796" dia, 21" long



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TIP OF THE FIN

By Dave Virga

The Nuts and Bolts of Cluster Motor Retention

The standard method of securing rocket motors is to use a motor hook. When you have clusters of motors though, the multiple motor hooks can become ungainly. Friction fitting multiple motors can be excessively time consuming as well as risky. There is a simple and lightweight solution – use threaded rod and standard nuts and washers. A single length of threaded rod, placed at the center of the cluster, will allow you to secure up to four motors.

First, determine which size threaded rod will fit in the center of your cluster. Common sizes available include 2-56, 4-40, 6-32, 8-32 and 10-24; the first number represents the rod's diameter, and the second number is the thread count per inch. The smaller two sizes are typically only found in hobby shops, but the larger sizes are readily available in most hardware stores. Photo 1 shows a 3x13mm cluster, with one motor removed for clarity; 2-56 threaded rod is needed for the small space between the motors in this example. Photo 2 shows a 4x18mm cluster, which can accommodate 8-32 threaded rod with room to spare; glue-soaked paper wrapped around the rod works well to fill the extra space and hold the rod securely.

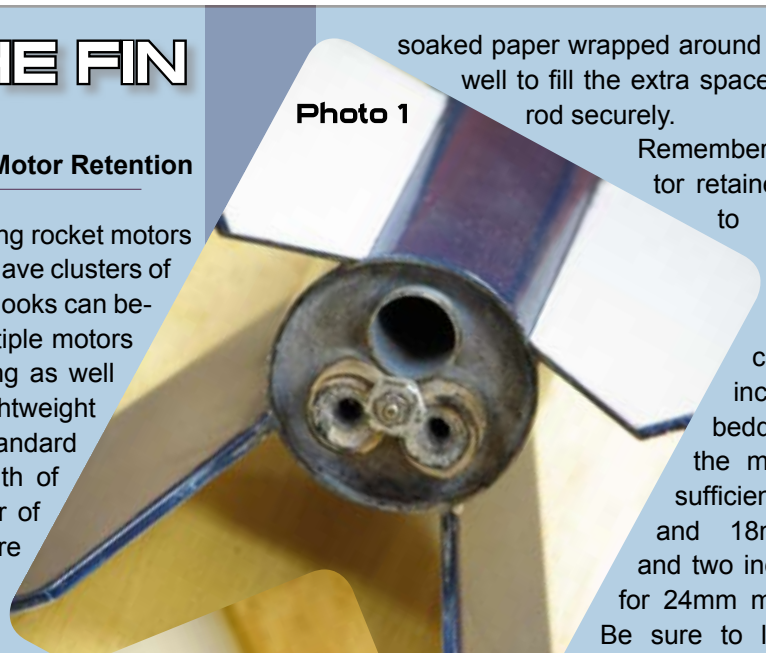


Photo 1

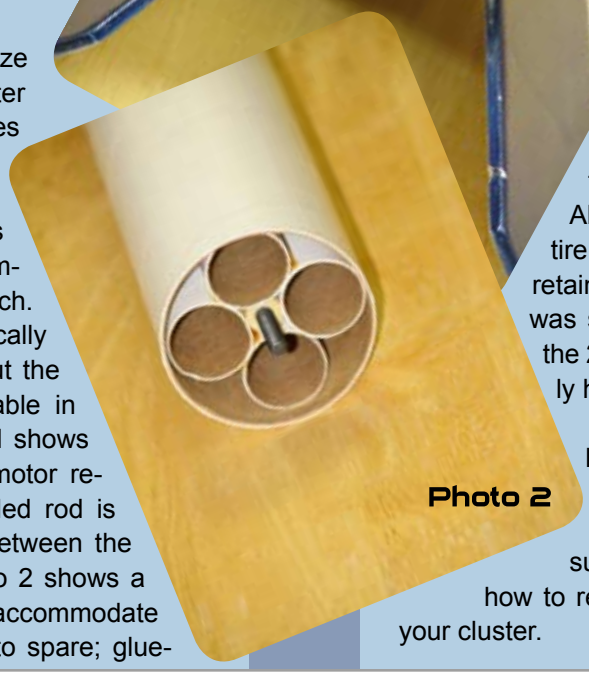


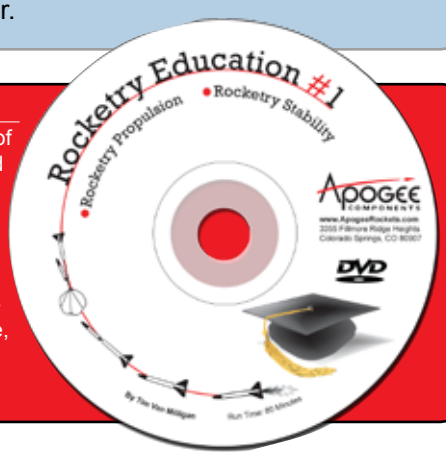
Photo 2

Remember that the motor retainer only needs to hold against the rearward force of the ejection charges. One inch of rod embedded between the motor tubes is sufficient for 13mm and 18mm clusters, and two inches is plenty for 24mm motor clusters. Be sure to leave enough rod extending beyond the motor casings to allow the use of the necessary washers and nuts. Also be sure that you cover the entire motor casing thickness with your retainer; in Photo 1, a larger #8 nut was slipped over the 2-56 rod, since the 2-56 nut is too small to adequately hold the motors.

Dig back in the Apogee Newsletter Archives (http://www.apogeerockets.com/education/newsletter_archive.asp) to Issues 154 and 155 for more info on how to reliably ignite all of the motors in your cluster.

New Rocketry Education DVD

This DVD was videotaped at a graduate course I presented for the Space Foundation as part of their summer institute course "Rocketry and the Biology of Living in Space, Space History, and Space Law."

The purpose of my particular presentation was to give teachers a strong foundation in rocketry, so that they could be ready to take it back to their classrooms. There was particular emphasis on rocket propulsion and rocketry stability. In the rocket propulsion discussion, we talked about the physics - how rockets produce thrust, the types of propellants used in model rocketry, characteristics of high and low thrust motors, the nomenclature for rocket motors, the thrust curve, and how to select the best motor for a model rocket.

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