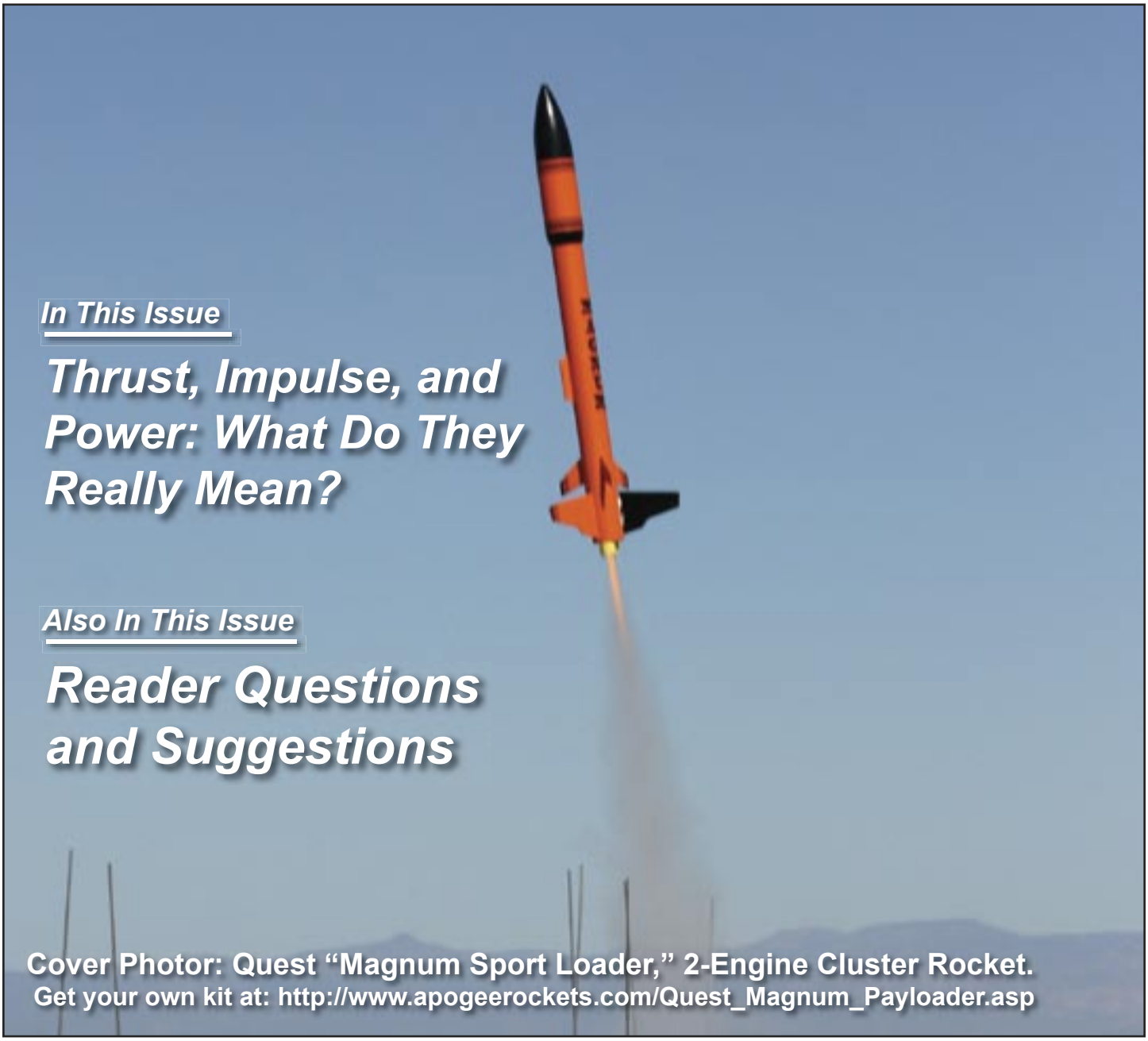
Apogee Components

PEAK OF FLIGHT

NEWSLETTER



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Cover Photor: Quest "Magnum Sport Loader," 2-Engine Cluster Rocket.
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ISSUE 285 APRIL 26, 2011

Thrust, Impulse, and Power: What Does it Mean?

By Greg McArthur

When I was a kid, I got a lot of fun and satisfaction from building and flying model rockets. I even learned a little too. I remember when I was about the age of ten reading a technical bulletin about how to calculate the maximum altitude of a rocket using trigonometry. I remember how excited I was when the "lightbulb" finally came on and I understood about sine, cosine, and tangent. This interest eventually led me to degrees in Physics and Engineering.

I've recently decided to get back into rocketry as a diversion from restoring classic mustangs during the winter when it's too cold to work in the garage. As a result of my renewed interest, I've read several articles on rocket motors and have been very disappointed in the quality of those articles. Almost all of them misuse and interchangeably abuse the terms "thrust", "impulse", and "power". I thought I would try to clear up the rampant misunderstanding and misuse of these terms.

Rocket motor manufacturers use letters and numbers to designate the characteristics of a particular motor. For example, the typical motor designation have a letter followed by a number, a dash, and another number. The Letter represents the total impulse of the motor, the first number is the average thrust of the motor (in Newtons), and the number following the dash is the time from the end of the thrust phase until the ejection charge fires (in seconds). So for example, a C6-5 motor is a motor that will provide 10 Newton-seconds of impulse (the "C" indicates between 5.01 and 10.00 Newton Seconds), has an average thrust of 6 Newtons, and a delay of 5 seconds {see Peak-of-Flight Newsletter 131 (www.ApogeeRockets.com/Education/Downloads/Newsletter131.pdf) for more details on the motor designation system}.

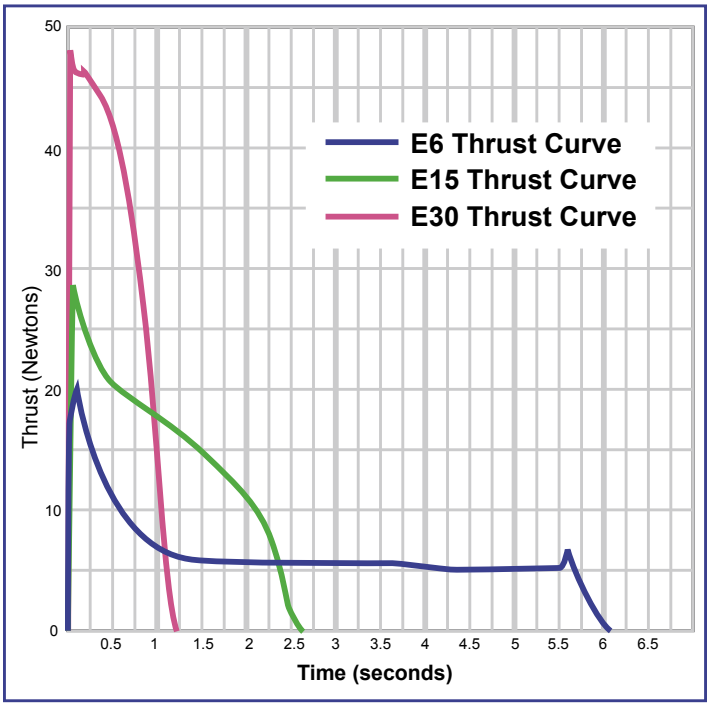

Figure 1: Thrust curves of three different E-size motors.

Thrust is the force that propels a rocket. Newton's second law is the relationship between force, mass and acceleration. Stated mathematically, F=ma, where F is force, m is mass, and a is acceleration. The MKS unit of mass is the Kg, and the unit of acceleration is m/sec^2. The MKS unit of Force is the Newton and is 1 Kg*m/sec^2. The thrust of a given motor is not usually constant but varies over time. The thrust that manufacturers report for their motors is the average thrust. Motor manufacturers also provide a graph of thrust as a function of time as shown in Figure 1. If you know both the total impulse and the average thrust of the motor, you can calculate the burn time (in seconds) by dividing the total impulse (in Newton-seconds) by the average thrust (in Newtons).

Impulse is the area under the thrust/time curve for a given motor and can be expressed as the product of average thrust and burn time for the motor. The impulse applied to the rocket is directly related to the momentum of the rocket at the end of the burn. Refer again to Newton's second law, $F = ma$. Since a is the time rate of change of velocity, $\Delta v/\Delta t$, this equation can be expressed as $F = m\,\Delta v/\Delta t$ or $F\,\Delta t = m\Delta v$. $F\Delta t$ is impulse and $m\Delta v$ is momentum. This is the impulse momentum principle, but this is a very simplified expression. For a rocket, both the thrust (F) and mass (m) vary with time and not all of the impulse is converted to momentum since the drag on the rocket is an additional force that must be accounted for. Another complication of the equation is that the drag

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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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Thrust, Impulse, and Power

force is proportional to the velocity of the rocket squared. Solving these equations is extremely complex and requires methods of differential calculus or numerical methods as used in "RockSim". If friction (drag) is ignored, and the propellant weight is much less than the weight of the rocket, the velocity of the rocket at the end of the thrust phase can be approximated: $v = F * t/m$, where F is the average thrust, t is the thrust duration, and m is the weight of the rocket and empty motor casing.

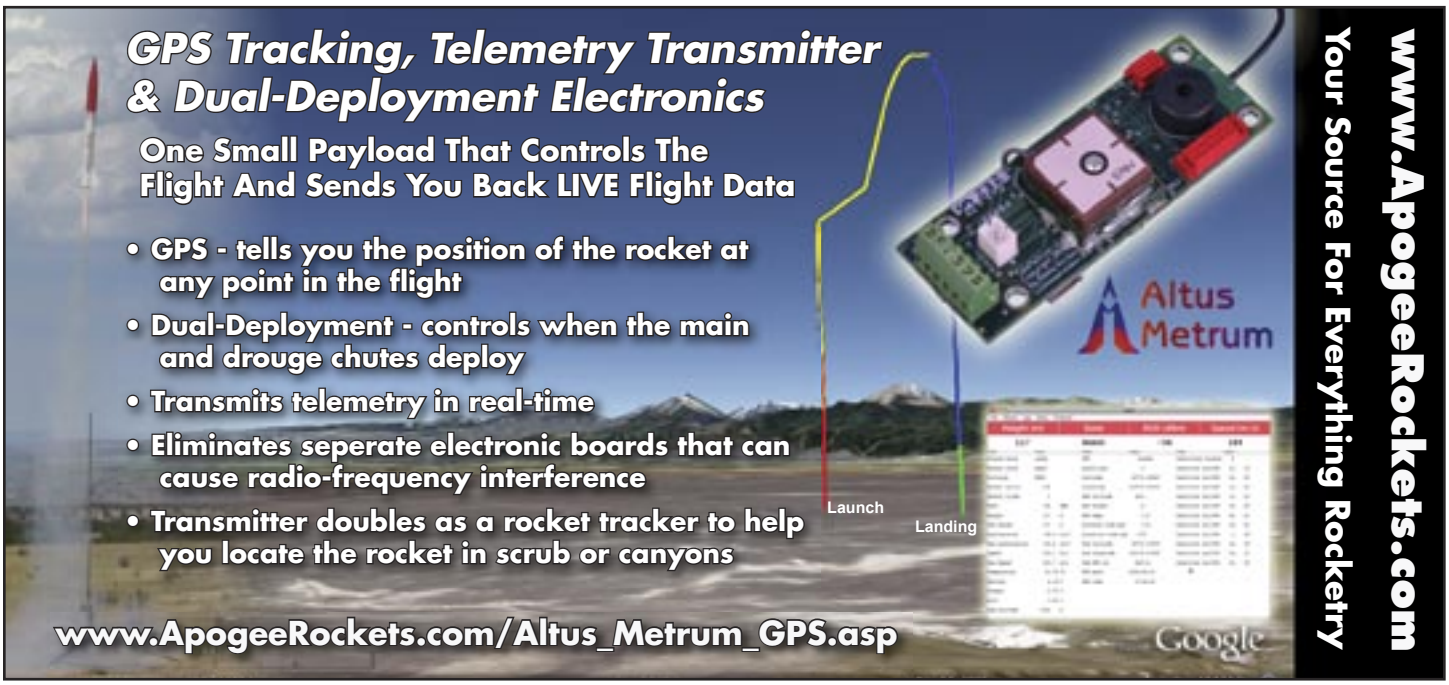
Power is the rate at which work is done. A high impulse motor is not necessarily a high power motor. Work is defined as the product of force and distance. The MKS unit of work is the Joule and is 1 N*m. The MKS unit of power is the Watt. One Watt is one J/sec.

As an example, work is done when one climbs stairs. That work is the person's weight times the height of the stairs. I weigh 200 lb (889 N) and one flight of stairs in my home is 9 feet high (2.7 m). In climbing those stairs I do 1800 lb*ft of work (2440 J). It doesn't matter if I take one minute or one hour to climb the stairs, the work is the same. If I sprint up the stairs in 3 seconds the power of the excursion is 813 Watts ($2440J/3sec$). If I walk up the stairs in 10 seconds, the power of the excursion is 244 Watts ($2440J/10sec$). The same amount of *work* is done (or the same amount of energy is expended) in both cases but the *power* is not the same. Similarly, the *power* of a rocket motor is a function of the total energy in the motor and the burn time. Since *power* is directly proportional to *thrust* and inversely proportional to burn time, you can see that a motor that has total energy of 100 J and a burn time of 1 second (100 Watts) is twice as *powerful* as a motor that has total energy of 100 J and has a burn time of 2 seconds (50 Watts).

Since we are promoting rocketry as a hobby that provides a learning experience, we should be careful about how the terms "thrust", "impulse", and "power" are used. Readers of articles describing the physics of the hobby deserve correct information.

About the Author

Greg McArthur earned his B.S. degree in Applied Physics at the University of Utah. He also has M.S. & Ph.M. degrees in Biomedical Engineering from the University of Utah. He has worked in the Medical Device industry in various engineering capacities for the past 30 years.



Reader Questions and Suggestions

By Tim Van Milligan

Autism and Model Rocketry

A. Riggs writes: *Thank you for your shipment, everything was in order and was in working order. When I was a kid I used to fly rockets all of the time. Now I am a bit older (I won't say how much, but enough, let's just leave it at that). My mother was cleaning out her attic and found all of my old rockets, in bad repair of course. I am also the father of an 8 year old autistic boy. I don't know how much you know about autism, but it is a serious disorder and not something I would wish on any child. Nonetheless it is a fact of life at our house. Children with autism have trouble connecting with the world in general, and often live in their own "bubble". Parents are always trying to find a way to reach into their worlds and make a connection. Often, when that connection is made the child will learn to make other connections, and this improves the quality of their lives greatly.*

You can probably see where I am going with this - I introduced rockets to my son about a year ago, and now he loves them. We have been building and flying them together, he helps count down the launch and then chases them down. We have been inviting other kids too, who don't have autism, and together with the rockets my son and the "typical" children have been bonding. His "bubble" is getting a little smaller and he is doing ever better. Rockets can be wonderful in so many ways. We keep fixing up the old, broken rockets from my mother's attic and making them fly again, but we are needing more and more parts to do the repairs. Thus the reason for my purchase. Thank you so much for the products - the rockets I repaired were over 25 years old, can't be purchased anymore, and you were the only one selling the parts we needed. My son and I will keep flying rockets and beating his autism. I am sure we will need some more of your stuff in the future. I am hopeful that, as my son gets older, he will begin to build his own rockets without my help (a big wish, but one I hope comes true).

What you are doing at Apogee Components is not mundane. You have no idea how much all kids love rockets - not just autistic kids! We launched the repaired rockets this past Saturday and had another great session. Like most kids, my son is still having to learn to share a little bit. Mostly with who got to carry the rocket back to the launch pad. When he talks you can tell he has autism, but because of events like rocket launches, he is one of the most social autistic kids you could know.

As for other kids, yes, I think rockets would be great for a lot of autistic children. They are often sensitive to sound, and the noise of the engine can be a bit startling at first. There are a few things you can do to get over this though. Work the kids in slowly - let them stay back at first, away from the launch and the other kids. If the kid is pressured to be right up there then he or she will not like the experience and will not likely want to do it again, but if they are allowed to watch from a distance then eventually they will join in

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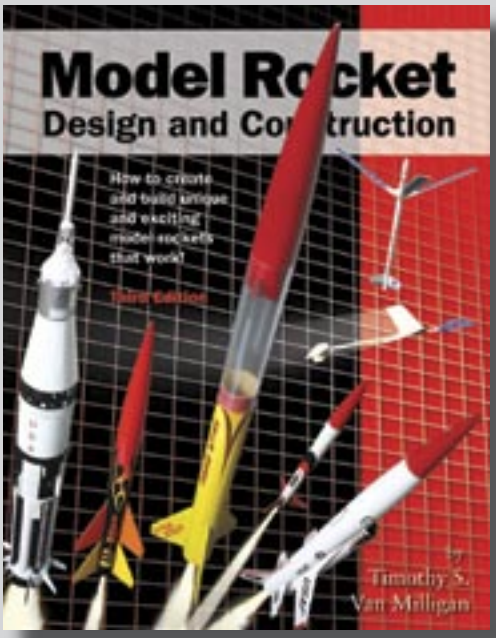

Model Rocket Design and Construction

By Timothy S. Van Milligan

New 3rd Edition Now Shipping!

This new 328 page guidebook for serious rocket designers contains the most up-to-date information on creating unique and exciting models that really work. With 566 illustrations and 175 photos, it is the ultimate resource if you want to make rockets that will push the edge of the performance envelope. Because of the number of pictures, it is also a great gift to give to beginners to start them on their rocketry future.

For more information, and to order this hefty book, visit the Apogee web site at: www.ApogeeRockets.com/design_book.asp

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Reader Questions and Suggestions

the fun on their own. For my son it took almost a year, but now he is in there just like the other kids having a blast. If you are thinking of trying a launch with autistic children let me know - I would be happy to offer additional suggestions. Thanks again!"

Model Rocket Fin Shape

David Foster asks: *"I read your piece on optimal fin shape for small competition rockets (www.ApogeeRockets.com/technical_publication_16.asp). However, now I have a question. You showed how the most useful part of the fins are the parts farthest from the tube because of airflow, so tapering reduces effectiveness. Why then do virtually all professionally designed rockets have fins that are shaped like triangles or some quadrilateral shape where the root is larger than the tip? There must be another advantage to that type of shape over a rectangle or an elipse. Do you have any articles on this? I would be really interested in the trade-offs."*

I do not have any other articles. But if you look for books on aerodynamics and wing design, you'll find lots of information. One shape does not fit all configurations.

Basically, you start by designing for the expected speed of the vehicle. It is going to fly fast or slow. Supersonic wings are usually the ones that have triangular shapes, like the Concord or interceptor missiles and high-speed fighter aircraft. However, these wings have very poor low speed characteristics. Landing the F102 was a challenge.

On top of that, you also have to consider the structural aspects of the wing. A tapered wing means that you can reduce the thickness of the internal structure; which means you can make it lighter weight. In addition, the tapered wing (thinner at the tip) also means lower drag. That weight and drag reduction means you can fly longer or faster. In a way, that is more efficient.

David continues: *"I do know of an exception to this. The Soviet (or Russian) R-27. The front fins are smaller at the root and get larger away from the rocket. Why does this rocket use this shape fin?"*

It is for maneuverability. This is a missile that is designed to make very fast course corrections. That makes sense, doesn't it? You want the missile to be able to turn

Photo 1: AIM-7 Sparrow Missile with it's triangle shaped fins launched from an F-15. Source: Wikipedia.

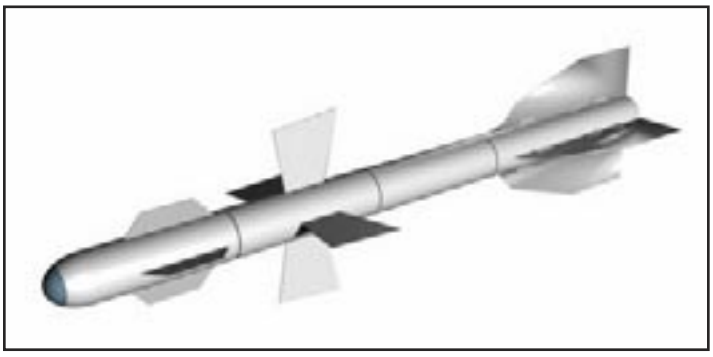

Photo 2: Russian R-27 missile uses fins with a greater tip length than the root-chord length.

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We're Paying Cash

For Great Articles for This Newsletter

Are you a writer looking for some serious pocket change? We're paying up to $350 for good how-to articles for this newsletter. If you're interested, see our submission guidelines on the Apogee web site.

www.ApogeeRockets.com/Newsletter_Guidelines.asp

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Reader Questions and Suggestions

quickly so that it can zero in on the target. Because of limited fuel supply, a missile like this only gets a single pass at the airplane it is trying to shoot down. Therefore extra maneuverability increases the likelihood that it will be successful and kill the aircraft. Excellent question!

Quick Change Fin Cans

Glenn Roth writes: "*Hi Tim, Don't know if anyone thought of this before, but I've come up with a "quick change" fin assembly, using "quicklinks" and tubular nylon. The idea started when I built a "goony" version of Bluebird zero and lost the fin assembly. This rocket separates in the middle and pulls the parachute out. I found this idea in "Sport Rocketry" and it is called the "Anti-zipper" design. Well, when my fin assembly separated and was lost, I thought, "what if I wanted to use a 3 engine cluster and vice-versa?" So now I have two fin assemblies for my rocket. A 3 engine cluster and a single 24 mm engine. Only takes a minute to change from one to the other.*

The one thing I can't over emphasize enough is the proper "connection." The eye bolt should be reachable with ease. I cut mine but I guess you could leave it long enough to pull forward to "undo" the quicklink (www.apogeerockets.com/quicklinks.asp) easier. An eye bolt through plywood, with a washer, then a quicklink, then about 12" of Kevlar™ (www.apogeerockets.com/shock_cord.asp) or "tubular nylon", another quicklink, and 15" of tubular nylon. Lengths of tubular nylon have to be long enough to pull out the chute and clear the rocket, typically about 2 to 3 times length of rocket. I recommend that the chute gets hooked up to the middle quicklink. At the Main rocket end a solid plywood ring is installed with an eye bolt too. Then the coupler to "mate" fine assembly.

This also uses a "baffle system," but I still plan on using a piece of wadding around chute for extra protection."

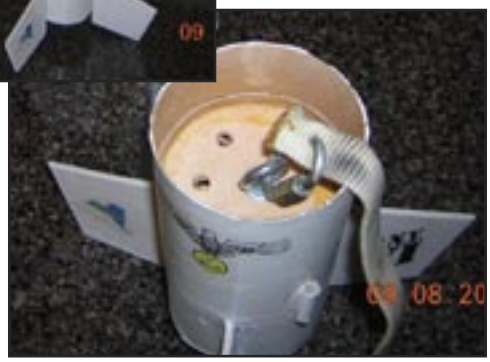

Photo 3 (left): Interchangeable fin units allow different size motor mounts and cluster configurations.

Photo 4 (below): Make sure you can get to the quicklink easily to detach the parts.