PEAK OF FLIGHT NEWSLETTER

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COMPARING ROCKET MOTORS & TIM'S MESSY DESK

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PEAK OF FLIGHT

Comparing Rocket Motors

By Tim Van Milligan

A customer asked me a while back on how rocket motors get their names, and in particular, they were interested in the Estes A10 motor.

The long and short of it is that sometimes rocket motors names can be misleading. They don't always follow the standard naming convention that we use in rocketry. So in this article, we'll mostly ignore the marketing names created by the manufacturers, and why you may want to examine the actual thrust curves of the motors if it is important to you when selecting a rocket engine.

Background

In *Peak-of-Flight* Newsletter #486 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter486), I described how to select the rocket motor based on the name. I think, for the most part, that most modelers who have been in rocketry for a while understand the general concepts of this.

But every once in a while, usually when someone actually looks at the official thrust curve data from the National Association of Rocketry (https://www.nar.org/standards-and-testing-committee/nar-certified-motors/), they have some questions regarding the names of the motors. Sometimes, they don't make sense.

A case in point is the 13mm diameter Estes A10 rocket motor. The average thrust of the motor should be 10 N-s, because the number after the letter is 10. But if you go to the official thrust curve supplied by the NAR, the average thrust is 2.35 Newtons. That's not even close to 10…

ESTES A10T

CERTIFIED VALUES

Total Impulse:	2.50 newton-seconds
Delays:	0, 3 seconds
Propellant Type:	Black Powder
Propellant Mass:	3.8 grams
Casing Dimensions:	13 mm × 45 mm
Certification Date:	Continuing
Contest Use Date:	Continuing
Certification Type:	Model Rocket

STATIC TEST DATA

Date Tested:	95-June-24	
Total Impulse:	2.00 newton-seconds	(σ 0.12)
Peak Thrust:	12.64 newtons	(σ 0.60)
Burn Time:	0.85 seconds	(σ 0.12)
Average Thrust:	2.35 newtons	
Mass After Firing:	3.4 grams	

Delay Time	Average Measured Delay	Initial Mass	Mfg Recommended Max Liftoff Weight
0	0.00	6.0 g	141.5 g
3	2.35	6.5 g	141.5 g

TYPICAL THRUST-TIME CURVE

FIGURE 1: THE OFFICIAL DATA SHEET OF THE A10T MOTOR SHOWS THE AVERAGE THRUST AT ONLY 2.35 NEWTONS.

To be honest, I don't know how the A10 got its name. I don't even know how long the motor has been in production. But from my own recollection, it has been around for decades. I can't even remember a time it wasn't available. This is purely speculation, so don't pass it around as being the truth, because I just don't know. But it may have been some previous naming system that people used in the past, and the name could have been grandfathered in.

What difference does the name of the motor make? Personally, I don't think the name matters much these days, because we have new and better ways of selecting a rocket motor than just what the name is that is printed on the label.

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Comparing Rocket Motors

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I always recommend that people use the RockSim software when picking motors. In RockSim version 10, we added a feature to make picking a rocket motor based on several parameters of the flight of the rocket, such as lift-off speed, weather cocking, and optimal delay time. It makes for a safer selection process, and it can compare hundreds of rocket motors in just a few minutes. We call this feature the "recommended motor" process.

But let's get back to the A10 motor. Let's compare it to some other motors. First, let's start with the Estes A3 motor. The way to do this is to compare more than just the physical dimensions of the motor. You also have to compare the thrust curves of the motors.

Physically, the A3 and the A10 are very similar. Figure 2 shows a chart comparing them.

	A3	A10
Propellant Mass	3.3 g	3.8 g
Cassing Dimensions	13mm X 45mm	13mm X 45mm
Total Impulse	2.22 N-s	2.00 N-s
Peak Thrust	5.83 N	12.64 N
Burn Time	1.01 s	0.85 s
Average Thrust	2.20 N	2.35 N
Mass after Firing	3.8 g	3.4 g

FIGURE 2: PHYSICAL SPECIFICATIONS OF THE A3 AND THE A10 MOTORS.

With the exception of the peak thrust, you could say that they are very close in all other regards. Even the Average thrust is pretty similar.

If you were a stickler for naming the motors based on Average thrust, the A3 could probably be called an A2. Similarly, the A10 could also be called an A2. Would that be confusing? Heck yea.

There are a couple of Cesaroni motors that have the same name, and they are always confusing me. One example is the F36. There are two different F36 motors with the same name. The F36 with the Blue Streak propellant formulation (https://www.apogeerockets.com/Rocket_Motors/Cesaroni_Propellant_Kits/29mm_Motors/1_Grain_Motors/Cesaroni_P29-1G_Blue_Streak_F36) and the F36 with the Smoky Sam propellant (https://www.apogeerockets.com/Rocket_Motors/Cesaroni_Propellant_Kits/29mm_Motors/1_Grain_Motors/Cesaroni_P29-1GSmoky_Sam_F36).

I do believe there is some latitude that is given to manufacturers by the NAR and Tripoli when it comes to certifying motors - just to keep things separate. They probably could have named one of them an F35 to keep them straight in the minds of rocketeers.

But the naming of the A10 has always baffled me.

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Comparing Rocket Motors

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When things are confusing, it helps to dig a bit deeper, and look at the thrust curves and do a direct comparison of the two. In Figure 3, I overlaid the two motors onto the same graph.

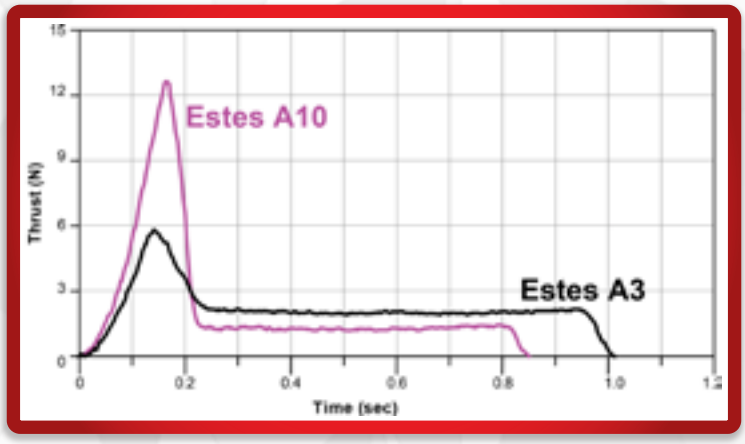

FIGURE 3: THE THRUST CURVES OF THE ESTES A3 AND THE A10 MOTORS.

For those people that are new to rocketry, let me explain what a thrust curve is. Simply, it is a measurement of the thrust of the motor, over the entire burn duration of the motor.

If that doesn't make sense, think of a bathroom scale that you have in your house. The scale measures the "force" of the person standing on it. When we stand on a scale, the units are in pounds or kilograms. As soon as you stand on the scale, you see the needle move back and forth until it finally settles in on a final number corresponding to your weight.

If you jumped on and off the scale very quickly, the scale probably couldn't settle on a final weight. We'd need to record the values quickly and over a long period of time to finally determine the force pushing on the scale.

That is very similar to what a rocket engine scale does. Not only is it similar to our bathroom scale, but it records the force over a long period of time because the thrust of the rocket motor is not constant. The thrust of the rocket motor varies from the first instant it ignites to when the propellant is fully burned out. It is like the person jumping up and down on the scale. So you have to record the force at each mili-second during the burn.

The other difference is that our rocket engine scale uses the units of Newtons instead of lbs or kilograms.

So the chart you see in Figure 3 is simply the force applied to the scale at any given time during the burn of the motor. If the point on the graph is near the top of the graph, you can say the thrust is high. If it is near the bottom, then it is low.

From Figure 3, the most obvious difference is the A10 motor has a peak thrust that is about double the peak thrust of the A3.

What this means is that it has a higher kick-in-the-pants as soon as the motor starts burning. That higher thrust force is useful to overcome the inertia of a heavier rocket, and get it moving up the launch rod.

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Comparing Rocket Motors

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Or, if the models are about the same size, then the A10 will accelerate about twice as fast as the A3 for a brief instant of time.

The point in time where the highest thrust occurs is very similar for both the A10 and the A3. The peak thrust occurs between .01 and .02 seconds for both.

After the peak thrust, you see that both motors drop thrust quickly, and transition to a flat thrust level for the remainder of their burn. While this particular graph makes them look radically different, if you compared them to other rocket motors, you might say that with the exception of the peak thrust, these two motors are very hard to tell apart.

The final difference that is obvious from the thrust curve is the burn time of the two motors. The A10 burns out about 0.14 seconds sooner than the A3. That number sounds like a lot, but take a stopwatch app on your phone and start/stop the timer and try to get it to land exactly at .14 seconds. It is about as fast as you can lift your finger up and put it back down on your screen. It is a blip in time. Try it. Then remember that this is the difference in burn time between the A10 and the A3.

It sounds like I may be saying that the A10 is probably redundant. I'm not.

While they are very similar, that Peak Thrust point is very significant. As mentioned, it allows you to get a heavier rocket up and moving (overcome the property of inertia of the mass). In particular, if you have a two stage rocket, it becomes very important. That extra kick in the butt coming off the launch pad is needed.

Now let's throw the Estes A8 and the Quest A3 motors into the comparison mix.

FIGURE 4: PHOTOS OF THE A-SIZE ROCKET MOTORS

	Estes A8	Quest A3
Propellant Mass	3.3 g	2.0 g
Cassing Dimensions	18mm X 70mm	18mm X 80mm
Total Impulse	2.32 N-s	2.5 N-s
Peak Thrust	9.73 N	7.0 N
Burn Time	.73 s	0.8 s
Average Thrust	3.18 N	3.4 N
Mass after Firing	10.2 g	?

FIGURE 5: PHYSICAL SPECIFICATIONS OF THE ESTES A8 AND THE QUEST A3 MOTORS.

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Comparing Rocket Motors

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Figure 5 shows a chart of the physical characteristics of the motors. The first thing we notice is the Average thrust of the Estes A8. Like the A10 motor, the average thrust of the A8 is nowhere near the 8 Newtons that the name of the motor would suggest. It is only 3.18 Newtons of average thrust, not 8.

By comparison, the Quest A3 has an average thrust of 3.4 Newtons, so its official name is very appropriate.

The other thing that stands out to me is the propellant mass. The Quest A3 motor uses only 49% of the propellant mass of the Estes A8. The reason, of course, is that it uses composite propellant, which is much more efficient than the black powder propellant in the Estes A8. However, I couldn't find a mass after firing for the Quest A3, because it is a Tripoli certified rocket engine. Tripoli doesn't display the official certification data on their website like the NAR does.

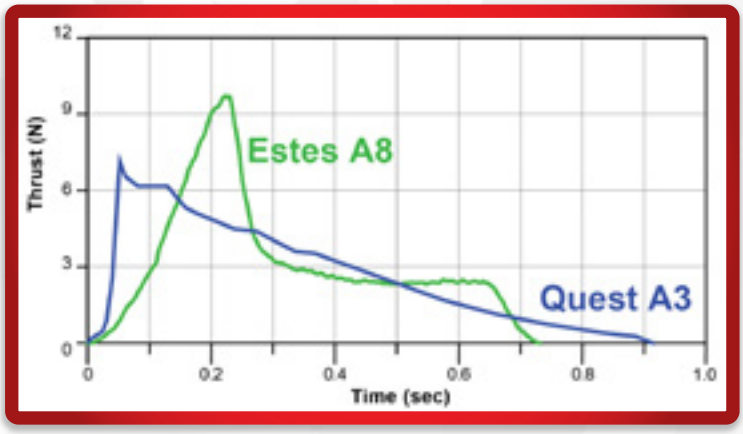

FIGURE 6: THE THRUST CURVES OF THE ESTES A8 AND QUEST A3 MOTORS.

Personally, I find this lack of transparency to be annoying, and I hope Tripoli gets someone to work on their website to make this official SAFETY DATA available to everyone, even non-Tripoli rocketeers.

The final thing I noted from data shown in Figure 5 is that the Quest A3 has a total impulse at 2.5 N-s, which is right at the upper limit of the "gas in the tank." If it had 2.51 N-s, it would no longer be called an A-motor, but would instead be called a B-motor. So if you want as much gas as possible for an A-size motor, the Quest A3 motor is maximized.

Looking at the thrust curve chart shown in Figure 6, you can quickly see that the Estes A8 has a higher peak thrust. But it takes a longer time for the motor to burn before it hits that peak thrust level.

On the other hand, the Quest A3 motor very quickly gets to maximum thrust. Even compared to the Estes A10 and the Estes A3, it is the fastest motor to reach peak thrust.

Is this a good or bad thing? I like to think of it as a good thing. Why?

That initial thrust is important in overcoming the inertia of the rocket as it sits on the launch pad.

Think of it this way. Say your car was stuck, and you had to push it out of the road to somewhere safe. You get behind the car, and start to push on it. But it doesn't want to move. So you lock your feet harder into the ground and strain even harder to move it. Finally, the wheels start to roll

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Comparing Rocket Motors

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and the car moves. Once it is moving, the amount of effort you have to put into moving it is a lot less. But it took a lot of energy to get it started. That is "overcoming inertia."

Now think of this… remember how you put a lot of energy into pushing at first, and the car didn't move? That energy, because you weren't pushing hard enough to get it started, was actually wasted. You'll never get it back, and it can't be used to make the car roll any faster. It is gone.

That is the downside to having the peak thrust further into the burn of the motor. You may end up wasting energy because you aren't pushing hard enough to overcome the inertia of the rocket.

So the Quest A3 motor, even though it doesn't have as high of a peak thrust, may actually be a more efficient use of the energy that it produces. I actually like the look of the Quest A3 thrust curve; it is generally OK..

But there is a downside of the Quest A3 motor. That is the delay time. The shortest delay for the motor is 4 seconds (A3-4), where the A8 does have a 3 second delay (A8-3). I really wish the Quest A3 motor had an option for a 2 or 3 second delay. That would make it a really useful motor for all sorts of rockets.

You can compare the versatility of the Estes A8-3 versus the Quest A3-4 by using the special tool on our website that displays all the kits we recommend each motor for. That tool is at: https://www.apogeerockets.com/index.php?main_page=motor_rocket_kits. The Quest A3-4 motor is only recommended in 9 lightweight kits, where there are dozens and dozens of kits the A8-3 can be used in. The only difference is the available delay time before the chute comes out. I really hope that Quest will eventually figure out how to get a shorter delay in the A3 motor, as it would really make it more versatile for a lot of kits.

Finally, Figure 7 shows the thrust curves of all the A-size motors that were discussed here in this article.

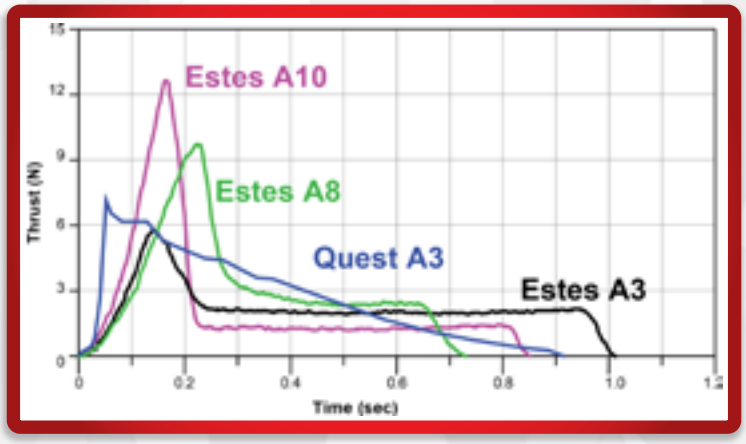

FIGURE 7: THRUST CURVES OF ALL THE A-SIZE MOTORS IN THIS ARTICLE.

The problem with displaying so many motors in the same graph, is that the lines criss-cross each other, and that makes it harder to read.

But you can make some general observations from the chart:

- The Estes A3 has the longest burn time
- The Estes A10 has the highest peak thrust
- The Quest A3 reaches peak thrust the quickest
- The Estes A8 has the shortest burn time

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Comparing Rocket Motors

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Conclusion

I don't know how the Estes A10 or Estes A8 got their names, but they obviously don't match the current conventional naming system used in model rocketry. They are not even close to what they should be called. But it is probably too late to do anything about that now, as they've become standardized.

For the most part, you really don't need to worry about most of this information if you are flying kits that you purchased from the Apogee website. We display the recommended motors for each kit, so if you pick from our list, you'll typically have a safe and successful flight.

If you're designing your own rockets, then use the "recommend motor" tool in the RockSim software. It will quickly run a comparison of all the motors that will fit into your design, and find the ones that will give a safe flight, along with the correct delay times for the motors that will have the parachute deploying at the optimal time.

Only the true rocket geeks (like me) will dig into the motor thrust curves to try to contort our logic in an attempt to explain why the names are what is printed on the labels. It will only lead to frustration and a headache.

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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.

www.ApogeeRockets.com/RockSim/RockSim_Information

Tim's Messy Desk

A mentor of mine suggested that I write occasional articles about what is going on in my corner of the world. I'm calling this particular article: "Tim's Messy Desk." If you saw my desk, you'd know that this is an appropriate title. My desk has all sorts of stuff on it.

What's on my desk right now? I'm looking at a new e-bay kit that I've been working on for a while. The kit is for a BT-80 size model. It's sitting here because the instruction sheet needs to be re-written. It isn't an urgent project, so it will probably sit for a few weeks. The amount of work on the instructions is massive, so I'm procrastinating a bit on it.

FIGURE 8: TIM'S MESSY DESK

Also on my desk, I see a new marketing flier for our Launch Visualizer. I have to proofread it and send it back to the graphic artist (Derek) so that he can finalize it for release. We recently have created the ability to accept electronic coupons on the Launch Visualizer (www.rocksim.com), so these new fliers will announce this promotion.

On the other side of the desk is a stack of loose sheets and post-it notes that I've made over the last year. I haven't gone through that stack in a long while, so I suppose I should toss it out.

The book: *Fans First* by Jesse Cole is on my desk too. I just finished reading it, and it is going to go into the bookcase of business books that I keep. What I liked about the book was how he suggests we treat customers. In order for them to keep coming back, they need to be treated like fans, not clients. A fan is a higher level of customer than a client, and I think there is a higher level of responsibility to keep the experience fresh each time they do business with a company. Fans want the experience, not just a transaction. So I'm asking myself, what type of experience could we offer here at Apogee that would make us stand out? I'm open to suggestions.

There is a time-card on my desk too. It isn't mine. I don't clock in -- since I never clock out. It is from my oldest daughter Allison who is working here this summer. But Monday was her last day. She is getting married on Saturday, and is leaving the state - hopefully permanently ;-). I've been trying to prepare her for entering the "real world" for a long time, and I'm proud of her leaving the nest and going out on her own.

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Tim's Messy Desk

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FIGURE 9: ALLISON ON HER LAST DAY (LEFT), AND ALLISON IN 2004 HELPING ME TO SHOW OFF ROCKETS

She has decided that as a career, she wants to be in medicine. She graduated a few weeks back with a B.S. in Biomedical Sciences from Liberty University in Virginia. You may have seen her video from 4-years ago when she was entering college (https://www.youtube.com/watch?v=YP-kmAOKaes). It just seemed like last week when we made that together.

After the wedding, she's going to work her way into graduate school, and wants to eventually end up as a Physician's Assistant.

My youngest daughter, Ashley, is still flying rockets and is trying to earn a spot on the U.S. National Team to compete as an adult in the World Space Modeling Championships in Texas next summer. So she and I are getting ready for that. That is why I'm seeing competition flight cards on my desk too. We did a launch together last weekend down in Pueblo, Colorado at the S.C.O.R.E. club's launch site. That is the default site that you see when you run a sample simulation on the Launch Visualizer. It was a beautiful day for launching. Not only was it a great Father's Day weekend, but I also got to share it with so many of my club friends as they were launching with their kids too.

If you've ever been around me when I'm launching rockets, you'd swear that I was a newbie. We crash and lose rockets all the time. At the launch earlier this month, we crashed three glider rockets, and had a separation on an egg lofter. This time around, we were much more successful. With the exception of a missing nose cone on a small rocket, all the rockets were successful. And I count

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the two gliders that flew away on thermals to be successful too - we wanted them to stay in the air as long as possible, and they did.

FIGURE 10: VERN ESTES PREPPING ROCKETS WITH SOME GRAND-KIDS

Speaking of the launch a few weeks ago, the other noteworthy launch event was that Vern and Gleda Estes came out to launch with their grandchildren too. And they parked right next to our car, so we got to just hang out with them and enjoy the beautiful Colorado day. I gotta say, Mr. Estes hasn't lost a beat when it comes to rockets. He was prepping and flying the rockets, while explaining everything important to his grandkids. I hope when I'm over 90 years old, I'll be as sharp as he is.

At the same time, he took time out to pose for photos with any rocketeer that wished one. That impressed me too. He is an idol to a lot of rocketeers, and he graciously accepts the duty that comes with it. Without a doubt, he is the greatest ambassador for the hobby that we could ever wish for. I look up to him too.

That is what is on my desk, and I'm thankful for those of you that are interested in this little corner of the rocketry world. It's a small corner.

– Tim Van Milligan

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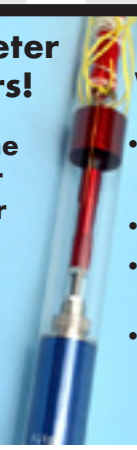

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