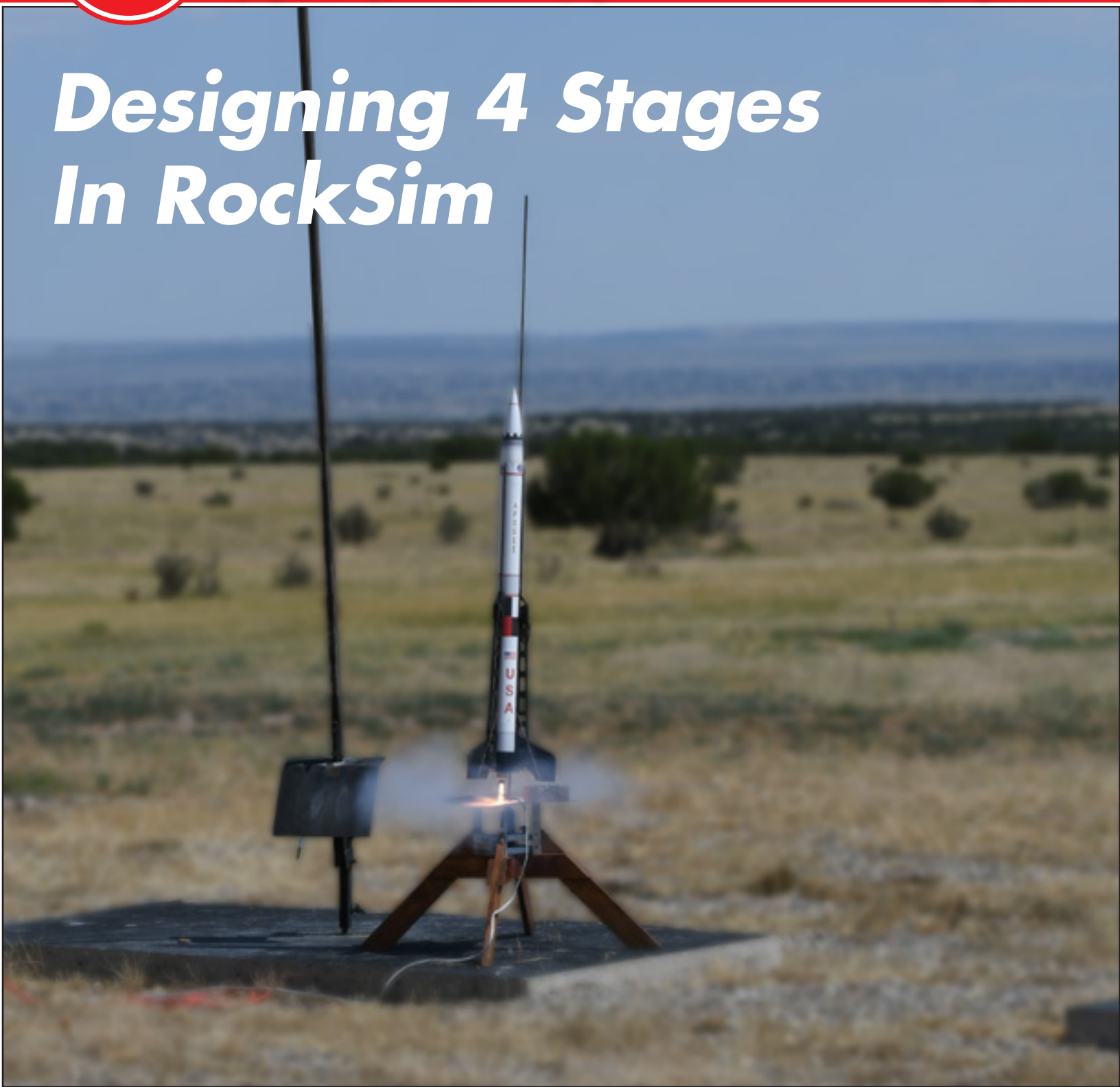
Issue 636 / October 8th, 2024

PEAK OF FLIGHT NEWSLETTER

Apogee Components, Inc. / ApogeeRockets.com / Colorado Springs, CO

Designing 4 Stages In RockSim



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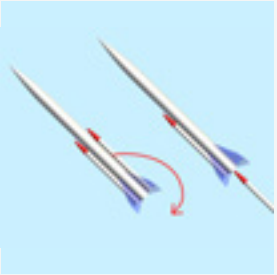
COVER PHOTO

Apogee Star Lift Mega Lander Rocket

The Star Lift Mega Lander features articulating legs that spring open and allow for an upright touchdown. This big rocket flies on composite propellant F and G size rocket motors.

FEATURED ARTICLE



Designing 4 Stages in RockSim

by Tim Van Milligan

In our feature article on multi-stage rockets in RockSim, we explore various methods of creating 4 stage rockets in this advanced rocketry software.

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Mini Condors Rockets built and ready for launch at Chili Blaster XIII in Pueblo, Colorado

Would you like to see your launch photo featured in the *Peak-of-Flight* newsletter? Submit your photo at apogeerockets.com.

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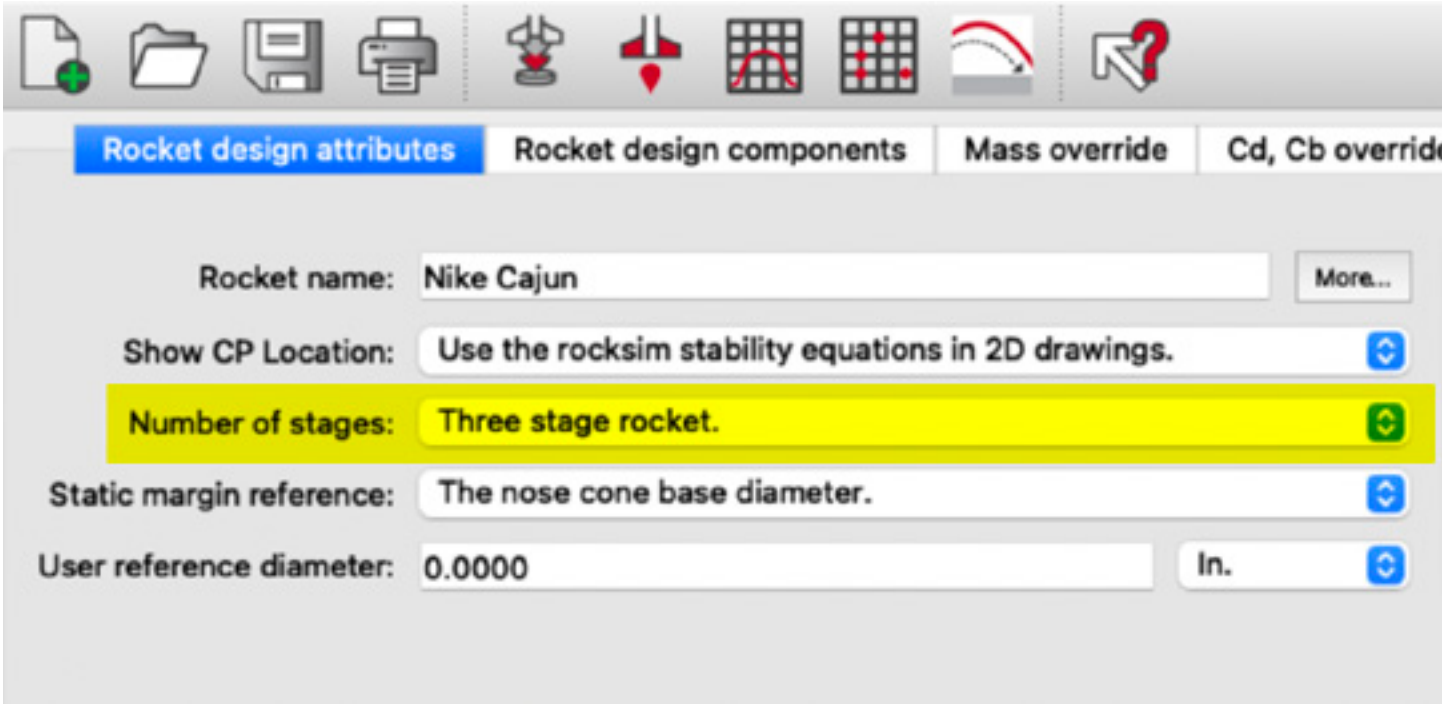

Figure 1 (above): The default maximum number of stages in RockSim is three. But can we trick it to do more?

A question recently came up in our RockSim Live Training session about whether or not RockSim can be used to design a four-stage rocket. Up until that point, this is something that I hadn't given much thought to, because the older version of the Model Rocketry Safety Code limited rockets to just three stages.

That being said, when you're doing rocket simulations inside a computer, there isn't any reason why you shouldn't give it a try. By simulating the flight, you can gain insight in designing and flying rockets safety within the limitations of your flying site.

RockSim Limitations

When we designed RockSim, we specifically limited it to three stages because it was a safe and practical limit.. We just didn't build the infrastructure in the software to allow for four or more stages on the rocket. So if you're looking for a button, or a drop-down menu that will allow for additional stages on a rocket, you won't find anything. The most you'll find is a drop-down to build a three stage rocket, like shown in **Figure 1.**

Previously, I did write an article about how to make a 4-stage rocket in Rocksim, which you can refer to in **Peak-of-Flight Newsletter #384 (https://www.apogeerockets.com/education/downloads/Newsletter384.pdf)**. That was a specific type of design called a "rack-rocket." In that design, all the motors are held in one stage of the rocket, and are ejected out the back end as the motors burn

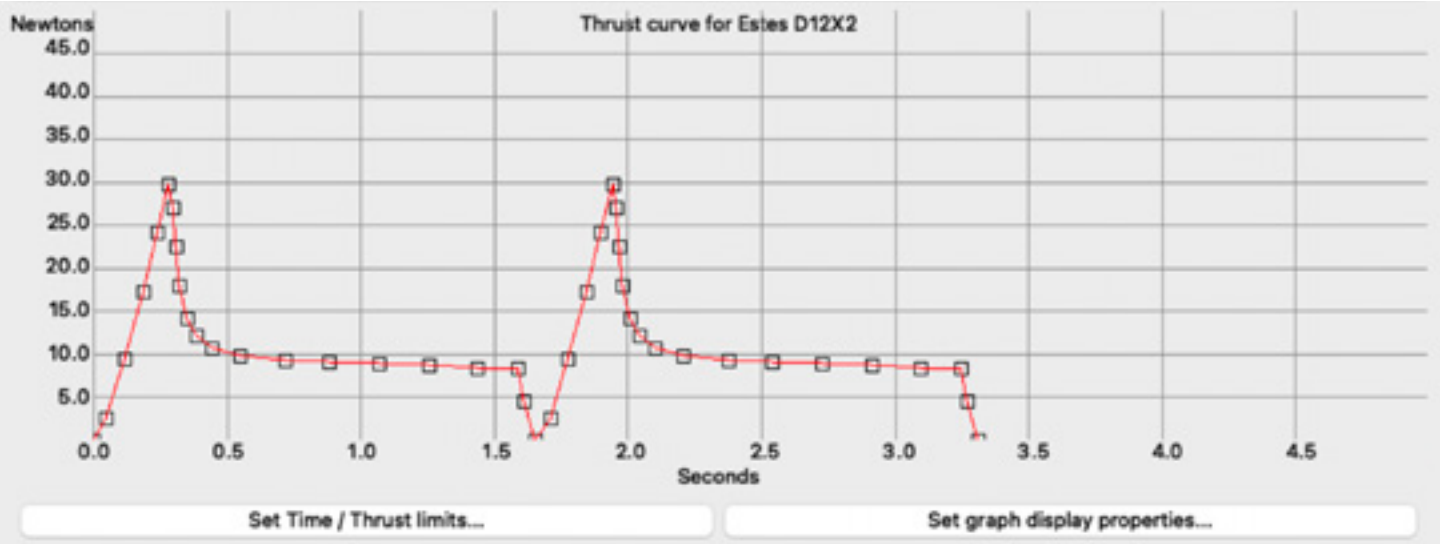

Figure 2 (above): A modified thrust curve to simulate two motors burning back-to-back.

out. So it only has one set of fins. It was because it had a special configuration and only one set of fins that I was able to force into it a fourth rocket engine. It wasn't really an additional stage.

To make that rack-rocket design, the trick I used was to create a "fake" rocket engine file. The fake engine had a modified thrust curve so that it operated like it was two motors that burned back-to-back. The thrust curve can be seen in **Figure 2.**

This special engine was put in the lowest stage of the rocket, allowing us to simulate two motors in one operation. It did work, but it took a lot of effort to set up the special engine file. Since writing this article, I don't recall seeing anyone that ever did something similar in RockSim. Admittedly, it was a really advanced trick.

What I will show you in this article is also advanced, but doesn't require you to make special motor files. What you do have to do, though, is to think about how rockets are staged.

In RockSim, staging is going to be very similar to how Estes rockets motors are staged. We decided to do it this way because most modelers are familiar with how to use a special booster motor that has no delay, and the ejection charge fires immediately after the propellant is consumed. These motors end with a -0, such as a D12-0, or a C6-0.

As an aside, whenever I say that Estes booster motors have an ejection charge, there are a few people that disagree and insist that they don't. But I contend they do, because there is hot gas that blows forward. This hot gas can either eject a parachute, or it can ignite the rocket motor above it in the multi-stage rocket.

Anyways, in RockSim, the motors in the upper stages are triggered by the "time" of the delay in the stage below it. So if you have a A10-0T in the booster, and an A3-6T in the upper stage, then the upper stage will be ignited at zero seconds after the propellant in the A10-0. The -0 on the end tells us that at zero seconds after propellant burn-out, the ejection charge is fired.

If you had accidentally flipped the position of the motors in the rocket, and put the A3-6T motor in the booster stage, then the

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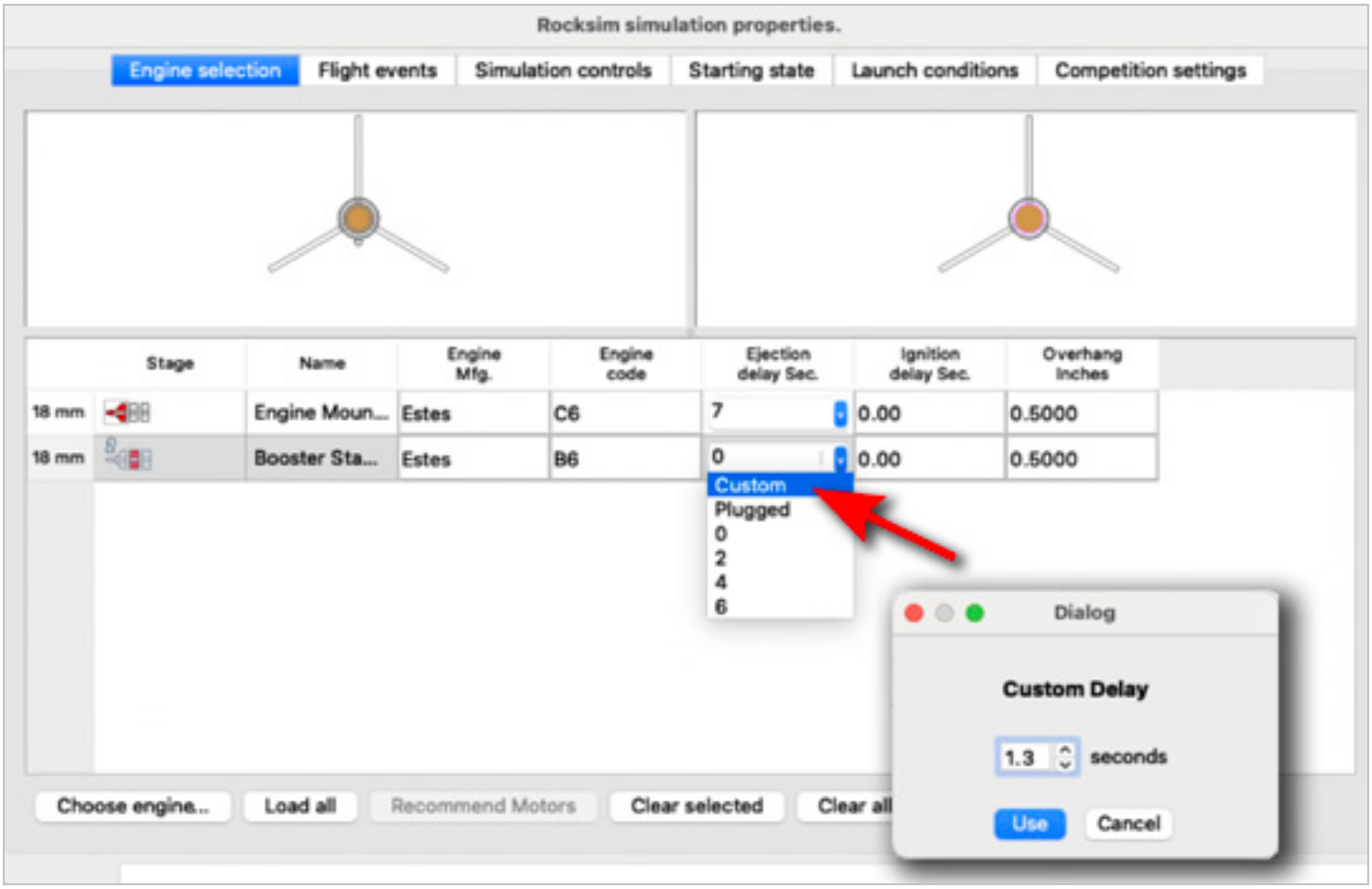

Figure 3 (above): The upper stage ignition is controlled by the motor in the booster stage. The Ejection delay controls when the upper stage starts burning. This delay can be customized to your needs.

upper stage would ignite 6-seconds after the motor burned out.

It is with this technique that you can use it to intentionally do "delayed staging" of rockets in RockSim. Just put some delay time in the booster motor, and it will force the upper stage to ignite later in the flight. And with RockSim, you can use any amount of time you wish, since it allows for "Custom" delays. Just select the drop-down for the motor delay, and choose custom. Then just type in a delay value on the screen. It even allows you to do decimal numbers to really get precise, as shown in Figure 3.

The key thing to remember is the "trigger" for the upper stage motor to start burning is the ejection charge of the stage below it.

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The Hack Using a Part Called a "Pod"

When I was asked the question in the live-stream about creating a 4 stage rocket **(see: https://youtube.com/live/Gh8LH-rBBJk)**, I thought about it for a few seconds. I was specifically wondering whether my hack of using a "pod" could be used in this situation.

A "pod" in RockSim is defined as a collection of parts - and the parts are attached to the outside of the central core portion of the rocket. Being able to attach things to the outside of the rocket has been useful for many things, such as attaching fins onto other fins to make "T-shape" fin arrangements. I've made all sorts of rockets by starting out with a pod and manipulating it to do something else.

Normally, when you think of a pod, you think it's like a strap-on booster, similar to the SLS rocket ship. But I began wondering, what if the pod we strap on to the side of the rocket could be shifted downward and moved to the centerline of the rocket? This is illustrated below in **Figure 4.**

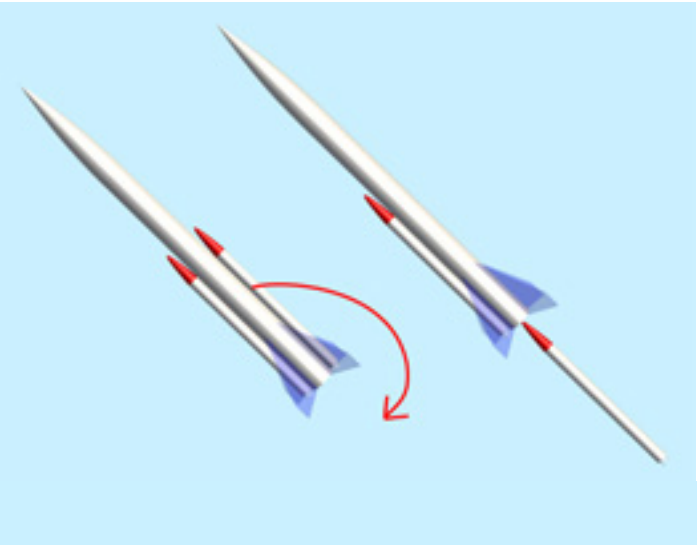

Figure 4 (above): Can we move a pod from the side of a rocket and place it below the rocket to become an extra stage?

I was pretty sure that moving the pod could be done easily. The controls for moving the location of the pod are shown in **Figure 5,** but the other problem that took a little bit more thought was how to ignite the motor in the pod.

As mentioned previously, in a staged rocket inside RockSim, the upper stage is ignited by the ejection charge of the motor below it. But now we're moving things around. The question is how are booster pods triggered to ignite in RockSim?

The new pods are on the same level as the core engine, which means they are in the same stage **(see Figure 6).** This means the pod motor(s) will ignite at the same time as the core motor.

We need a way to delay the ignition of the core motor in the rocket, so that the motor in the pod fires first. Fortunately for us, there is a way to do just that.

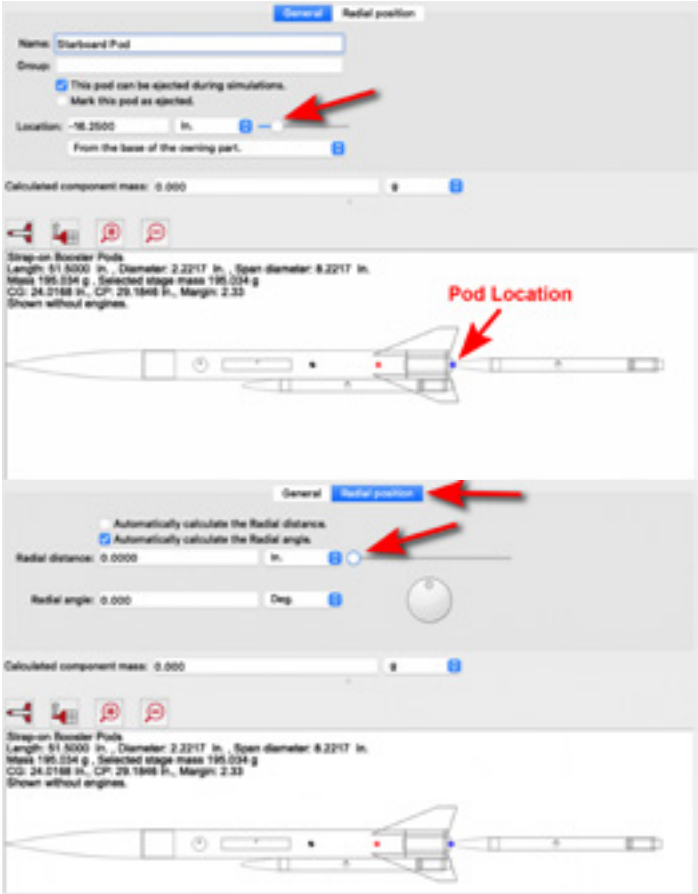

Figure 5 (above): The placement of the pod can be changed by editing the "Location" and "Radial Distance."

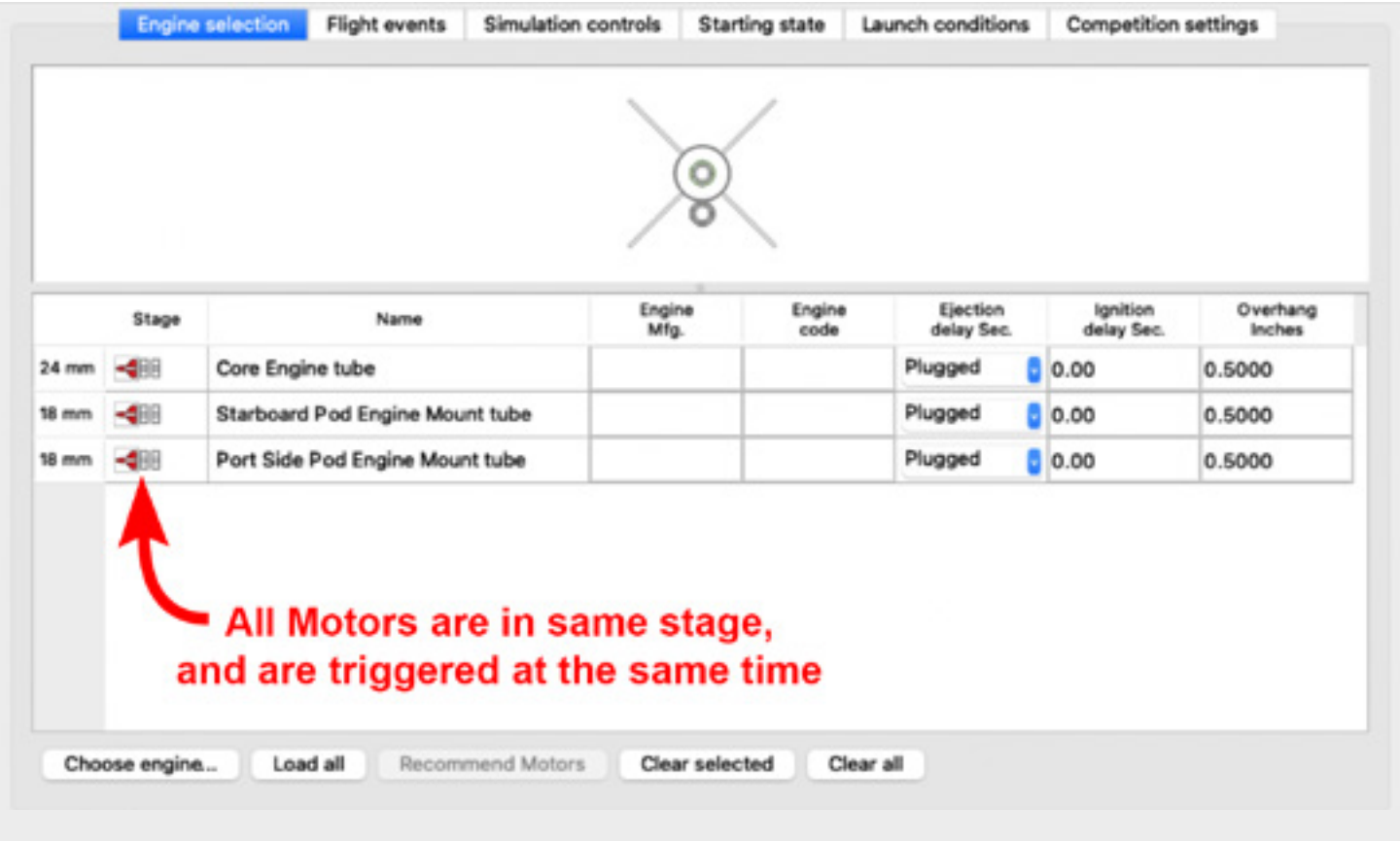

Figure 6: The pod and the core motor are going to ignite at the same time because they are in the same stage.

There is a column in the "RockSim simulation Properties" screen called "Ignition delay Sec." This is what we'll use to tell RockSim that we want to pause the ignition of the core engine for a certain amount of time.

Ignition delay is exactly what it sounds like. Imagine you push the button on your launch controller to fire off your rocket, but after pressing the button, the rocket doesn't immediately ignite. The ignition is paused for a bit before it finally lights, sending your rocket off into the sky.

In RockSim, we can simulate the pause by using a value in the Ignition delay column. The amount of time will be determined by the value we type into the column. As you can see in figure 6, the default value is zero. That is why the core and the pod motors ignite at the same time.

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Building the Design

I hope that you understand the concept of how to make the four-stage rocket. We'll start by making a traditional 3-stage rocket design, and then on the lowest booster stage, we'll add a strap-on booster to the outside. This strap-on booster will then be shifted downward and onto the centerline of the rocket.

This is exactly what I did for my design in the RockSim Live Training session. You can see the final design shown in **Figure 7.**

The cool thing is you can install fins and put recovery devices in each of the stages of the rocket, including the pod that is the fourth stage. All the lower stages would use rear-ejection of the stuffer tube in order to do "direct-staging" where the bottom motor ignites the stage above it. **See Peak-of-Flight Newsletter #416 (https://www.apogeerockets.com/education/downloads/Newsletter416.pdf),** which shows how to convert a rocket into a multi-stage vehicle utilizing rear ejection. The only difference in our rocket design here compared to the one in issue #416 is the addition of two more stages. Theoretically, it could work.

Figure 8 (above): The motors are loaded in the three stages, and the pod which is the lowest stage of the rocket.

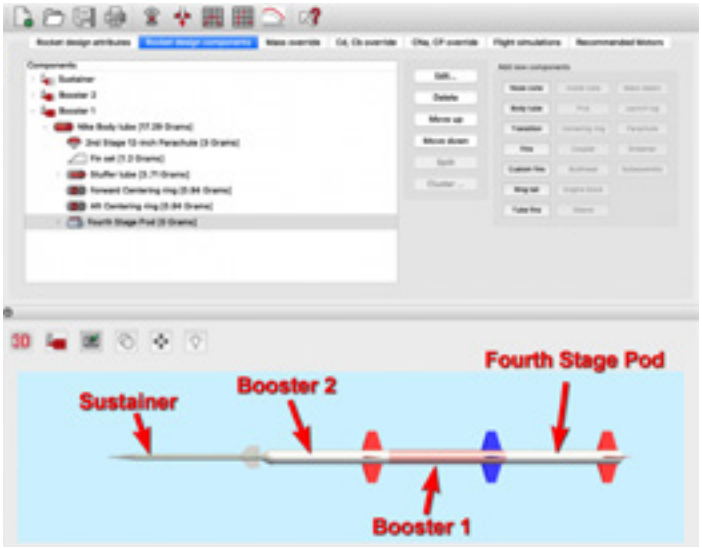

Figure 7 (above): The parts tree shows that the fourth stage is a "pod" that is attached to the "Booster 1" stage.

Loading the Motors

Once the design is complete, you can load up the motors into the various stages, and run some simulations.

In this design, I'm putting an Estes A10-0 motor in the three lower stages, and an A3-6 in the sustainer. This is what would be flown in real life to do direct-staging, so that is what I used in the RockSim design. This is shown in **Figure 8.**

The ignition delay was chosen at 0.85 seconds for a reason. That is the burn time of the A10-0 motor. We want the pod motor to burn first, and then at .85 seconds just as it burns out, the upper stage ignites. This will mimic the real flight.

Now we have to set up when the parachutes for each of the stages are deployed. This is where it takes a little more thinking because recovery device set-up for "booster" stages are treated differently than either sustainer stages or pods. As **Figure 9** shows, the options for parachute deployment for

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Figure 9 (below): The options for when the parachute can be deployed are different for pods than for booster stages.

booster stages are different from what is available in pods. If we had the same options for when parachutes were deployed in both types of stages, then things would be simpler and more uniform.

In the pods and the sustainers, we have the option to deploy the parachute at the Max Ejection Delay. This is not available for booster stages. But you can deploy at stage separation, which is basically the same thing in our case because the ejection is at zero seconds, which is when the stage will separate. So our final set-up for the recovery system is shown in **Figure 10.** Note that the ordering of the recovery devices is not the same as our list of rocket engines. But we can figure out which device goes into each stage if we give everything unique names in our design.

At this point, we can run the simulation and see what it looks like.

Now the 2D flight profile in RockSim can only display 3 stages, and completely ignores pods in the animation. But the trajectory is still correct.

We can confirm that all four stages ignited in succession if we plot out the graph of thrust versus time. We should see four distinct thrust curves, which is shown in **Figure 11.**

Figure 10 (below): The final set-up for the recovery devices in all the stages of the rocket.

Engine selection | Flight events | Simulation controls | Starting state | Launch conditions | Competition settings

Stage	Location	Device	Event description	Time (s)	Altitude (Ft.)
Sustainer		S: Streamer	Deploy at Max.ejection delay.	0.00	0.00
Booster 1		P: 12 inch Parachute	Deploy at Max.ejection delay.	0.00	0.00
Booster 1		P: 2nd Stage 12-inch Parachute	Deploy at stage separation	0.00	0.00
Booster 2		P: 3rd Stage 12-inch Parachute	Deploy at stage separation	0.00	0.00

While the 2D flight profile in RockSim doesn't show that bottom stage, we can open up the simulation in RockSim-Pro or upload it to the Launch Visualizer at www.RockSim.com and take a look at the flight in the 3D earth view. It looks like **Figure 12.**

I've displayed the weathercocking cone in the visualizer so you can get some perspective on how far the rocket is arcing over during the launch. This particular trajectory has the apogee point (the highest point in the flight) that is outside of the weathercocking cone. This indicates that the rocket isn't going straight enough up over the launch pad to be considered safe. We want the apogee point of the flight to stay inside of that weathercocking cone.

It is because the rocket arcs over so much on four stage rockets that it requires extreme care to fly more than three stages. This is really typical of multi-stage flights and why it is important for you to test things out by running simulations before you head to launch your rocket in real life.

Figure 11 (below): Graph of the thrust of the rocket during the flight. You can see the four separate burn times to verify everything worked correctly.

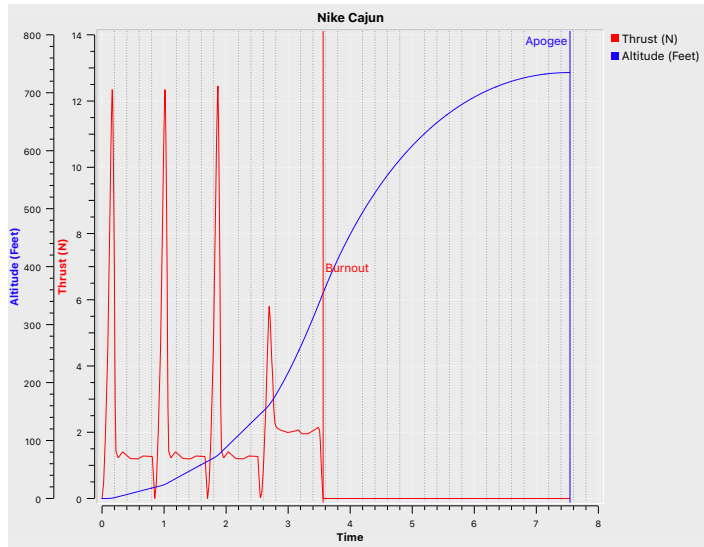
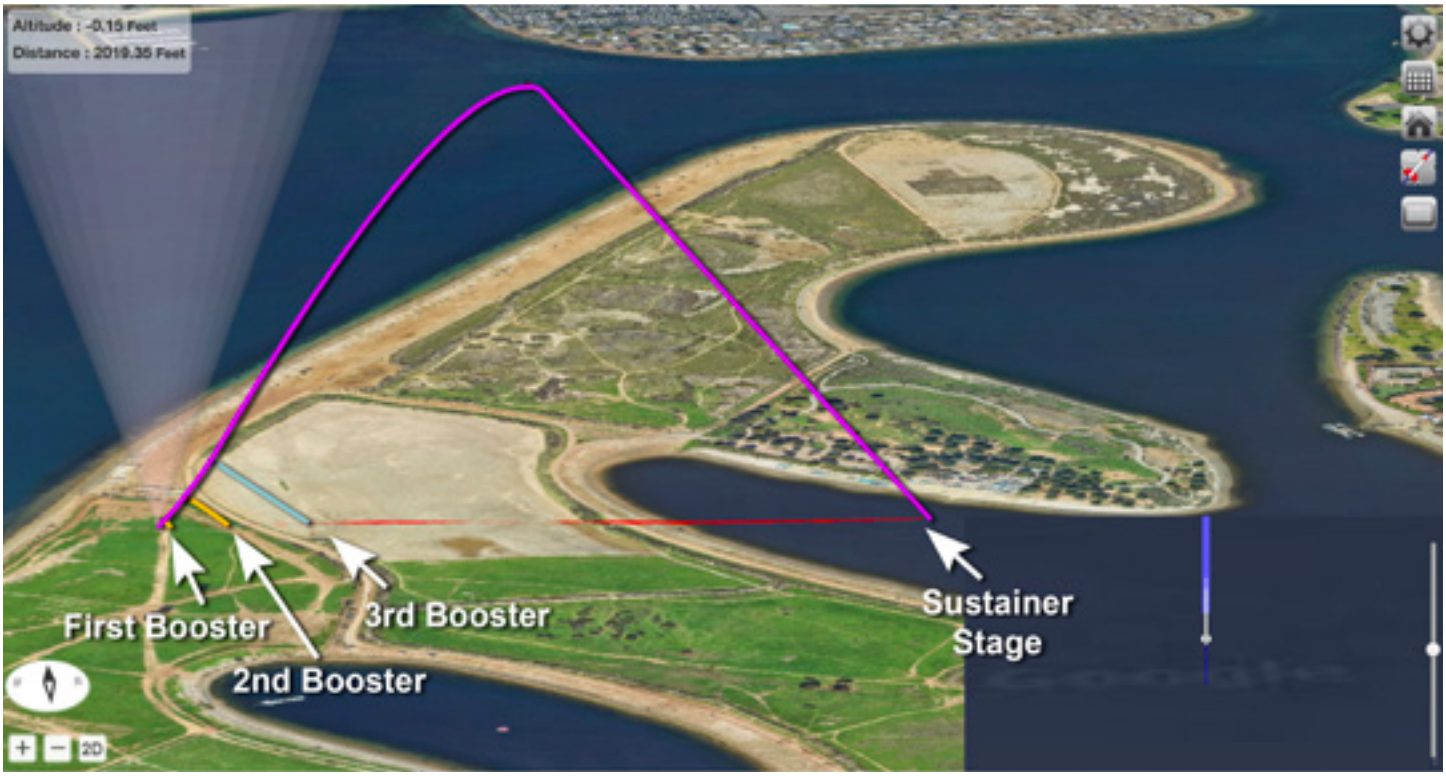


Figure 12 (below): The Launch visualizer shows the trajectory of our 4 stage rocket on a map. Here we're launching from the site of the San Diego club in California. You can see where each stage will land.



Can You Do A 5-Stage Rocket?

Using this technique of adding pods below the Booster 1 stage, and adjusting when each motor starts with an ignition delay, it is actually possible to make as many stages in the design as you want. The only limit is your imagination!

I think it is fun to run these types of simulations, but I hope you keep a critical mind and look at some of the lift-off parameters to make sure that you keep things in perspective. In my simulations here, I didn't look at the lift-off speed of the rocket, or the thrust-to-weight ratio of the rocket. I was so interested in seeing if it was possible, that only now am I looking at some of the other safety aspects of the launch. In this case, I'm only getting off the pad at 19mph, and a thrust-to-weight ratio of 1.19. Both of these values are dangerously low, and the rocket shouldn't be flown in real life.

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 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.

SUBMITTING ARTICLES TO APOGEE

We are always looking for quality articles to publish in the *Peak-of-Flight* newsletter. Please submit the "idea" first before you write your article. It will need to be approved first.

When you have an idea for an article you'd like to submit, please use our contact form at **https://www.apogeerockets.com/Contact**. After review, we will be able to tell you if your article idea will be appropriate for our publication.

Always include your name, address, and contact information with all submissions. Including best contact information allows us to conduct correspondence faster. If you have questions about the current disposition of a submission, contact the editor via email or phone.

CONTENT WE ARE LOOKING FOR

We prefer articles that have at least one photo or diagram for every 500 words of text. Total article length should be between 2000-4000 words and no shorter than 1750 words. Articles of a "how-to" nature are preferred (though other types of articles will be considered) and can be on any rocketry topic: design, construction, manufacture, decoration, contest organization, etc. Both model rocket and high-power rocket articles are accepted.

CONTENT WE ARE NOT LOOKING FOR

We don't publish articles like "launch reports." They are nice to read, but if you don't learn anything new from them, then they can get boring pretty quick... Example: "Bob flew a blue rocket on a H120 motor for his certification flight." As mentioned above, we're looking for articles that have an educational component to them, which is why we like "how-to" articles.

You can see what articles and topics we've published before at: **https://www.apogeerockets.com/Peak-of-Flight?pof_list=archives&m=education**. You might use this list to give you an idea or two for your topic.

Here are some of the common articles that we reject all the time, because we've published on these topics before:

- How to get a L1, L2, or L3 Cert
- Building cheap rockets and equipment (pads & controllers)
- How to 3D print parts, or a Rocket Kit
- How to Build a cheap Rocket Kit
- Getting Back Into Rocketry After a Long Hiatus

ARTICLE & IMAGES SUBMISSION

Articles may be submitted by emailing them to the editor. Article text can be provided in any standard word processor format (MS Word, Libre Office, etc.) or as plain-text. Graphics, meanwhile, should be provided in either a vector format (Adobe Illustrator, SVG, etc.) or a raster format (such as jpg or png) with a width of at least 600 pixels for single column images or a width of 1200 pixels for two-column images. If possible, it is generally preferable for images to be simple enough to be readable in a two-column layout, but special layouts can use the whole page width if required.

Send the images separately via email as well as show where they go by placing them in the word processor document.

ACCEPTANCE

Submitted articles will be evaluated against a rubric (available here on our website). All articles will be evaluated and the results will be sent to the author. In the evaluation process, our goal is to ensure the quality of the content in *Peak-of-Flight*, but we want to publish your article! Resubmission of articles that do not meet the required standard are heavily encouraged.

ORIGINALITY

All articles submitted to Peak-of-Flight must not run in another publication before inclusion in the *POF* newsletter, but it may be based on another work such as a prior article, R&D report, etc. After we have published and paid for an article, you are free to submit them to other publications.

RATES

Apogee Components offers **$300** for a quality-written article over 2,000 words in length. Payment is pro-rated for shorter articles.

WHERE WILL IT APPEAR?

These articles will mainly be published in our free newsletter, *Peak-of-Flight*. Occasionally some of the higher-quality articles could potentially appear in one of Tim Van Milligan's books that he publishes from time to time.

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