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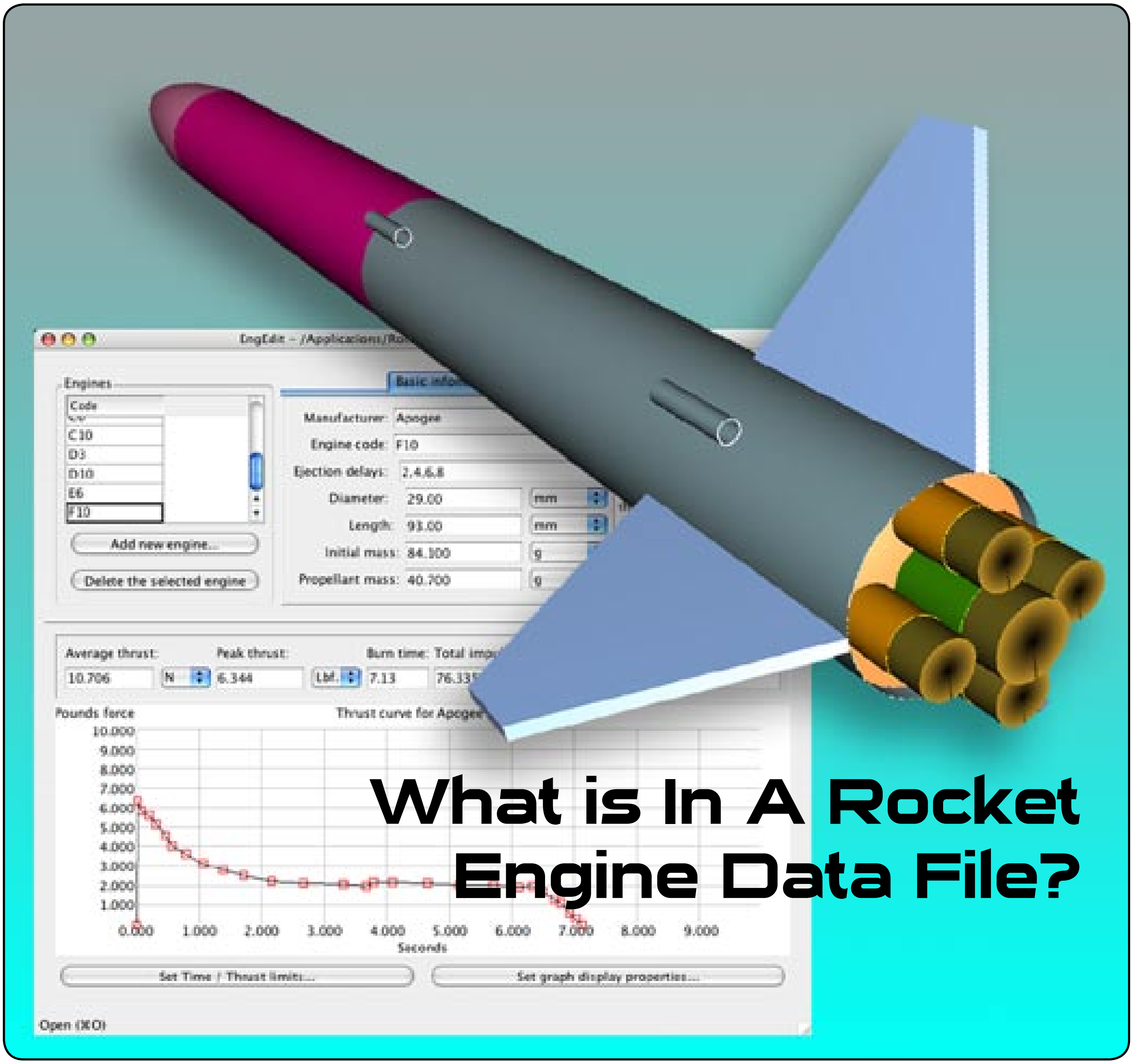

What is In A Rocket Engine Data File?

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Under The Hood: What Is In A Rocket Motor Data File?

By Tim Van Milligan

In preparation for the release of RockSim version 8, I've been scouring the world for rocket engine files. Why? Because the number one question I get from RockSim users is: "Does RockSim have in its motor database the *XYZ* (take your pick) engine?" This leads me to the conclusion that users of RockSim would love to have a more complete motor database with every engine on the "combined CAR/NAR/TRA Certified Motor List." (http://nar.org/SandT/pdf/CombinedList.pdf)

So that has been my task the last few weeks — to track down the engine files and get them ready for inclusion into RockSim. It has been a huge job, which is why I have to say that I have a lot more respect for John Coker who runs the web site: http://www.ThrustCurve.org. To just compile the list is one thing, but to keep it updated as new motors come out is a never ending task. "Thanks John!"

It was because of this search for engine data files that was the inspiration for me to write this article. I was able to track down a lot of missing motors, even though it was in a lot of different forms. Some of it was directly usable, and some of it took a bit of massaging to get it into a usable form. What do I mean by that?

To explain, first let me tell you a little bit about the file format that RockSim uses. It is called the R.A.S.P. format.

R.A.S.P. stands for "Rocket Altitude Simulation Program," and the first place I ever saw it was in G. Harry Stine's classic book: *Handbook of Model Rocketry*.

The RASP file format was chosen for RockSim and it's engine editor program named "EngEdit" due to the fact that RASP engine files are readily available on the internet and other on line services. Each RASP style engine file can contain definitions for one or more engines.

It is a very simple format, and in fact, the first "data files" were created using a text editor program like MS Word. I still open up engine files in a text editor and modify them. And you should take a look at one too.

A description of the file layout follows.

General file features:

1. The files are standard ASCII text files consisting of printable ASCII data lines followed by DOS or UNIX style line terminators. (<CR><LF> or <LF>).
2. Any data line preceded by a semi-colon is treated as a comment line and ignored.
3. Text strings cannot contain embedded spaces.

The file layout:

```
Engine 0
Engine 1
.
.
Engine n
```

The Engine description layout:

Code - NAR style engine code. (Example: D12)
Diameter - The casing diameter in mm.
Length The casing length in mm.
Ejection delays - This is a list of available ejection delays. Each delay time is delimited by a dash ('-') character. (Example: 0-3-5-7)
Propellant weight - The mass of the propellant in Kg.
Initial weight - The total weight of the engine including the propellant. This is the prelaunch weight.
Manufacturer name - This is a text string indicating the manufacturer of the engine. This can be any contiguous string of text w/o spaces.

Thrust data - The thrust data points for the engine. This consists of Time Thrust pairs, where time is in seconds and thrust is in newtons. A time of n seconds and a thrust of 0.0 mark the end of the list. The original RASP format supported a maximum of 30 data points.

A sample engine definition is shown here:

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```
; This is a comment
D12   24   70   0-3-5-7   0.0211   0.0438   Estes
0.04   1.00
0.08   3.00
0.12   5.00
0.16   10.00
0.20   15.00
0.24   22.70
0.28   22.70
0.30   15.00
0.35   13.00
0.50   10.50
1.50   9.44
1.55   0.00
;
;
; Next engine file would start after two
; blank comment lines
```

It doesn't look so imposing, does it? So then why are engine files so hard to come by?

First off, in order to create a RASP data file, you have to have all the information about the motor, including it's thrust curve. For the average rocketeer, you only have two sources to get this data. One is the manufacturer of the motor, and the other is the organization that certified the motor.

Most modelers would prefer to get the "official" certified engine files from the testing organizations, such as the NAR, Tripoli, or Canadian Association of Rocketry. And fortunately, these organizations are seeing the benefits of having modelers run rocket simulations, and are slowly starting to put out RASP data files.

The NAR was the first. When they started, they looked around to see what file format was the most popular, which turned out the be the RASP format. So if you go to their web site, and download the PDF data files for the motors, you'll see that they are in the same format listed above.

The individual files are PDF format, so what you'll need to do is open them in Acrobat Reader and hi-light the text and copy it. Then you'll open up a text editor, like Word or Notepad, and simply paste it into the page. When you save it to your hard drive, make certain you choose "TEXT ONLY" and add the file extension ".eng". At that point, it is a RASP motor file which can be used by RockSim or opened up in EngEdit.

There is one problem though. RockSim v7 used an older RASP format, and requires the time and thrust data to be two-point precision. In other words, there can only be two places after the decimal point. The NAR data files use three places after the decimal point. If you tried to open them up directly in EngEdit after saving them in the text editor, it would come up as a blank screen because it can't handle the extra data.

In order to use the NAR data files, you had to open them up in a text editor and manually delete the third digit after the decimal point. As you guessed, it is very time consuming, which is why no one felt any great urge to create RockSim data files directly from the NAR data.

But there is some good news! The first change we made when updating the Engine Editor that comes with RockSim v8 is to allow the extra precision in the data files. So now it will be much easier to import the data into a usable RockSim format.

The other problem is that the NAR data files are not totally complete. For example, the Quest motors (A6, B6, and C6) and a few of the Animal Motor Works engines are missing the RASP portion of the data files. However, it is a work-in-progress effort performed by under-appreciated volunteers; so I understand why they are not perfect. To their credit, they have made a great start and are getting it out as fast as new motors come in. And the data files they do have in place are really excellent, including comments where necessary.

Tripoli has been a little slower in getting RASP data files available. But there is good news on that front too. I've been corresponding with Paul Holmes, who is running the Tripoli motor testing, and he wants to get data out to users too. So I'm sure that in the near future, new motor data files will appear faster, and it will be easier to get them into RockSim.

Plugged Engines

There is one other little problem I discovered as I was sorting through all the data files. That has to do with "plugged" rocket engines.

As you know, a plugged engine has no delay grain and no ejection charge. Most all of the newer and bigger reloadable engines are classified as plugged. Also included in this category are all of the hybrid rocket engines. What I found was that there is no standardized way to designate a "plugged" engine in RASP engine format.

Many people have used a zero "-0" to designate a plugged motor, because it does not have a delay. However, this is completely wrong! A *zero* after the dash in the engine code signifies a "booster" motor, such as the popular Estes D12-0. This motor does have an ejection charge, and it fires immediately after the thrust phase of the burn ends.

It would be logically that a plugged motor should be designated by a "-P", such as the Aerotech K250W-P. That

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is the standard way to designate a plugged engine using the standard NAR/TRA/CAR engine code system.

However, the data files out there on the internet are a mess.

Not only are some of the files I looked at designated with a “0”, but some of them have “NONE” or “P”. To compound the problem, the RASP format only allows for numbers in the delay area; letters are not permissible. So a “NONE” or a “P” in the raw engine file will crash a program. I suppose that is why a lot of data files I came across use a zero for a plugged motor.

Right now, I don’t have a good solution to the RASP format problem. We didn’t create it. We inherited it.

So what I’ve been doing when I come across a plugged motor is to enter a value of 100 seconds into the delay field. While this isn’t technically accurate, the effect is the same when it comes time to run a simulation. The rocket will have impacted into the ground long before 100 seconds of flight time is reached. Even on big motors, such as L’s, M’s and N’s, the rocket will crash with a 100 second delay. It acts just like a plugged motor. Gravity really has a pull on rockets.

I actually recognized this problem several years ago. People were sending me rocket designs that were ejecting only a few hundred feet into the air, when they should have ejected at several thousand feet. The reason they were ejecting early is that they were using a zero second delay, like a K250W-0. The problem was the engine file. (http://www.apogeerockets.com/education/newsletter70.asp)

The solution we came up with was a fix to RockSim (this was way back in RockSim v5). We forced a “NONE” to appear as one of the delay choices in the simulator — while leaving the RASP engine file alone. Then the user had to tell RockSim when they wanted the parachute to deploy; this was the beginning of the “FLIGHT EVENTS” feature within RockSim. We continue to use this feature because it seems to work. The people that fly plugged motors are able to figure out what exactly a “NONE” delay is.

The UNITS problem.

Yet another problem with the RASP engine file format is the units required. Everything has to be in the metric units of Newtons and Kilograms. But if you look at the certification papers that Tripoli generates, you’ll notice that they give the thrust in pounds-of-force, not Newtons. This is another reason RockSim users have been reluctant to create the data files based on Tripoli or manufacturer data. One first has to convert everything to metric before you can even start to create the data file.

It is only when you really, really need a particular motor file that you’ll sit down and do the conversion. That is why you’ll see so many data files that contain just one specific rocket engine.

In the new EngEdit program that comes with RockSim v8, this problem will go away! Like RockSim, it will allow you to mix and match units. So you can have a data file that lists the thrust in pounds and the case dimensions in inches. When the EngEdit program saves the data file, it will automatically convert it to metric so that it is in the RASP format.

Creating a Curve From Thrust Stand Data

There are a lot of people and schools out there with thrust stands. The use of these units has a lot of educational benefit, such as learning how to gather data in a methodical and scientific way. Using rockets just makes the whole process fun

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and exciting!

So we begin to wonder, why hasn't this abundant thrust stand data made its way to the RASP format? If it had, there would be a lot more motor files that would be available.

My guess is that it is the time that it takes to "normalize" the thrust curve, and choose the points on the curve to enter into the RASP format (as well as converting to metric units). It can be a confusing and time consuming process.

First of all, what do I mean by normalize the thrust curve. In essence, it means to smooth out the curve and get rid of the random spikes and dips. In this case, random means those spikes and dips in the curve that would not be present if things were perfect. The peak-thrust point on the curve is not "random." So it would be left alone. But all the "noise" of the apparatus should be smoothed out.

Determining what is random noise and what is an actual and repeatable spike on the thrust curve takes a bit of human decision. I think most people are cautious, and don't want to put out data files that others might criticize. If that is your concern, let me put your mind at ease.

I did a little experiment and compared simplistic thrust curves against those highly accurate data files made by the NAR.

Comparing Simple Versus Complex Curves

Using the new Engine Editor program that comes with RockSim version 8 made this an easy to perform experiment. First I had to select a representative thrust curve from all the choices of engines available. I narrowed it down to Estes motors, since everyone seems to be familiar with them, and I had a RASP engine file in the RockSim database already.

The current engine files in RockSim v7 are well accepted by most folks, even though they are fairly simplistic. If you look at the number of Time/Thrust points in a typical engine in the Estes.eng file, you'll see that they range from 5 to 12 Time/Thrust data points. The average is closer to 5. The D12 engine file shown on page 3 has 12 data points.

My next step was to create a new Estes.eng data file based on the NAR's certified data. This involved going to the NAR web site and downloading all the pdf files for the Estes motors. Then I did some cutting and pasting of the RASP text into a word processor program (as described above). The NAR's data files have closer to 30 points of Time/Thrust data for each motor. So most people consider this data to be more accurate. The general philosophy is that "more points" equates to "more accuracy." This is what we want to put to the test. We'll only assume the NAR file is more accurate, because it is based on the NAR's tests, not because it just has more data points on the thrust curve.

With the two data files ready, I now switched to RockSim itself to run some side-by-side tests. I wanted to compare how different the flight results would be — old and simplistic engine files ver-

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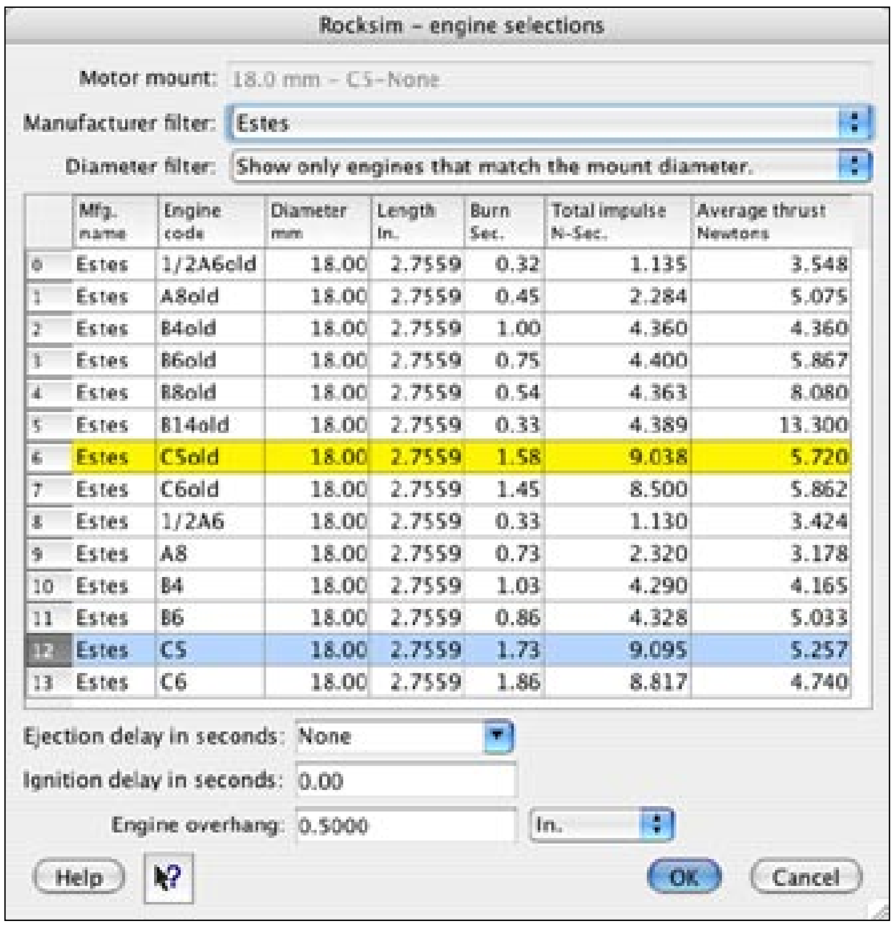

	Mfg. name	Engine code	Diameter mm	Length In.	Burn Sec.	Total impulse N-Sec.	Average thrust Newtons
0	Estes	1/2A6old	18.00	2.7559	0.32	1.135	3.548
1	Estes	A8old	18.00	2.7559	0.45	2.284	5.075
2	Estes	B4old	18.00	2.7559	1.00	4.360	4.360
3	Estes	B6old	18.00	2.7559	0.75	4.400	5.867
4	Estes	B8old	18.00	2.7559	0.54	4.363	8.080
5	Estes	B14old	18.00	2.7559	0.33	4.389	13.300
6	Estes	C5old	18.00	2.7559	1.58	9.038	5.720
7	Estes	C6old	18.00	2.7559	1.45	8.500	5.862
8	Estes	1/2A6	18.00	2.7559	0.33	1.130	3.424
9	Estes	A8	18.00	2.7559	0.73	2.320	3.178
10	Estes	B4	18.00	2.7559	1.03	4.290	4.165
11	Estes	B6	18.00	2.7559	0.86	4.328	5.033
12	Estes	C5	18.00	2.7559	1.73	9.095	5.257
13	Estes	C6	18.00	2.7559	1.86	8.817	4.740

Figure 1: The top engines are the original RockSim v7 files. The ones on the bottom were new ones based on NAR data.

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sus the new and more-data-points NAR files.

To run this simulation test, I chose the Estes Alpha design. The reason for this is that most people are familiar with the rocket. I could have chosen any rocket, because the rocket design will be factored out of the process.

Next, I went into the engine-prep screen and listed all the Estes motors (sorting by Manufacturer is a new feature in RockSim version 8), and filtered only the 18mm diameter motors that would fit into the rocket. The result is shown in Figure 1.

You can see, I have the old engines listed on the top, and the new ones at the bottom. My number of engine choices was narrowed down to 13. Next, I had to narrow it down to just two.

I scanned over the list, and looked for two motors of the same type that were close in "Total Impulse." It appeared to me that the C5 engine files were good enough for my experiment — 9.038 N-sec (old) verus 9.095 N-sec (new files based on the NAR data).

To make sure I was running an apples-to-apples comparison, I set the launch conditions to zero wind, and a zero degree launch angle. As a check, I launched the same rocket twice in succession to see if the peak altitude was exactly the same. That is simulation #1 and #2 shown in Figure 2 below. You'll notice that I loaded the old (simple) engine file for these tests, and I had RockSim stop the simulation at peak altitude. The peak altitude in both simulations was 1417.16 feet.

Now I loaded the newer C5 engine (which was made from the NAR data). The simulation result is shown in line three, where the peak altitude is 1409.76 feet. The difference between the simplistic engine data file and the more-data-points engine file was just 7.4 feet, or 0.52 percent difference. That is pretty insignificant. Wouldn't you agree? After all, we're looking at a 1400+ foot flight, and we had just under 8 foot difference in predicted altitude.

The conclusion of this experiment is that while we think that having more data points in the thrust curve makes it more accurate — that is not necessarily the most important thing when creating a thrust curve. As it turned out from this little experiment, having more (or less) points didn't have a significant affect on the predicted altitude of the rocket.

The data files you have been using in RockSim v7 and older were proven to be reliable. But you probably already knew that, since you've been using them with good results since 1996.

To prove my point, I went back to my old engine file, and tweaked the C5 thrust curve. I only moved data points around on the time/thrust graph, I didn't add any new ones. By moving points around, I was able to change the Total Impulse of the engine. I tried to match the NAR's total impulse for the C5, which was 9.095 Newton-Seconds. In the process, I also had to change the burn time of my data file. To make sure that only the number and position of the data points were the deciding factor, I also changed the weights of the propellant and casing in my data file. See Figures 3 and 4 on the next page.

Now when I ran the simulation again in RockSim with my modified engine file (which remember has just a few data points), the altitude was 1408.61 feet. Now the altitude difference was just a mere 1.15 feet, or 0.081 percent.

What I found out from this is that the number of data points in the thrust curve isn't nearly as important as the Total Impulse created by the motor.

So if you are creating a thrust curve from raw thrust stand data, you can really purge a lot of spikes and dips. Just as so long as the Total Impulse of the motor remains the same, the simulations run from the RASP files will be highly reliable and accurate.

That isn't to say that the shape of the thrust curve isn't important. Where the peak thrust occurs is very important to determining the maximum lift-off weight of the rocket engine. But as far as peak altitude prediction goes, the Total Impulse is more significant than the number of data points.

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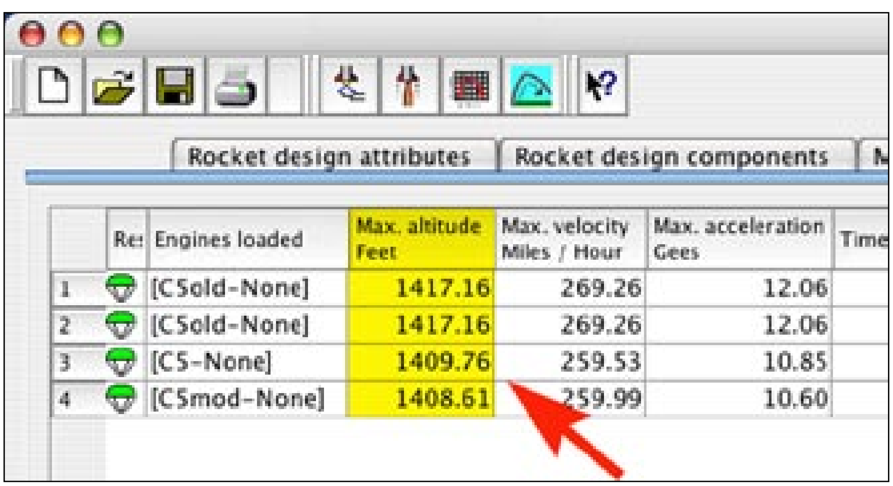

Figure 2: From the simulation results, you can see that a engine file doesn't need to have a lot of data points to be accurate.

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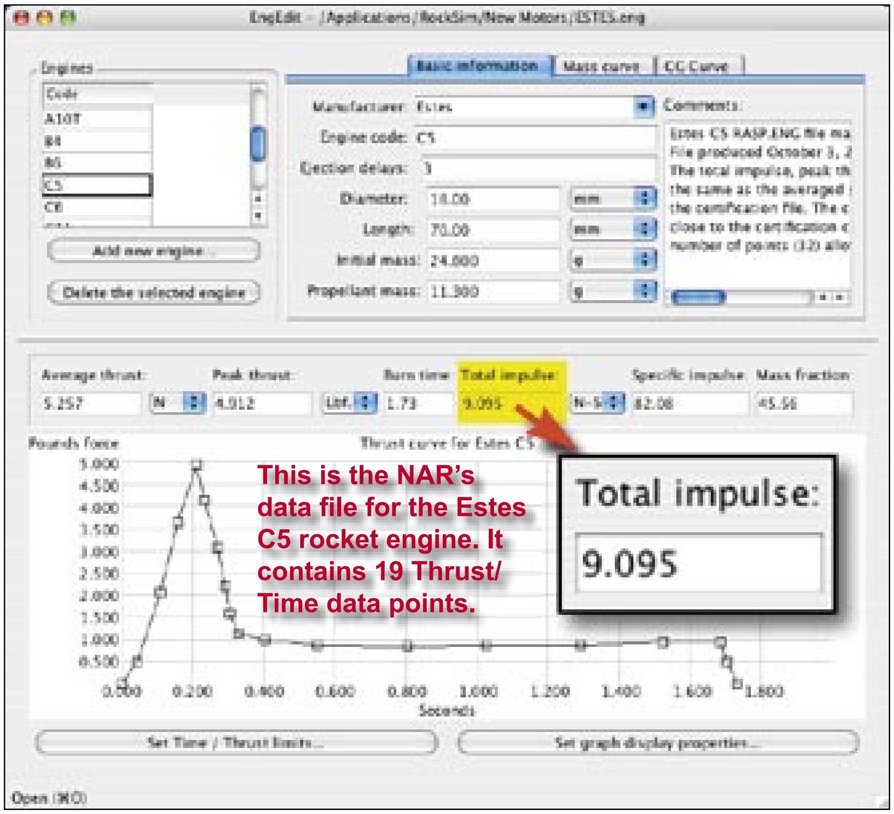

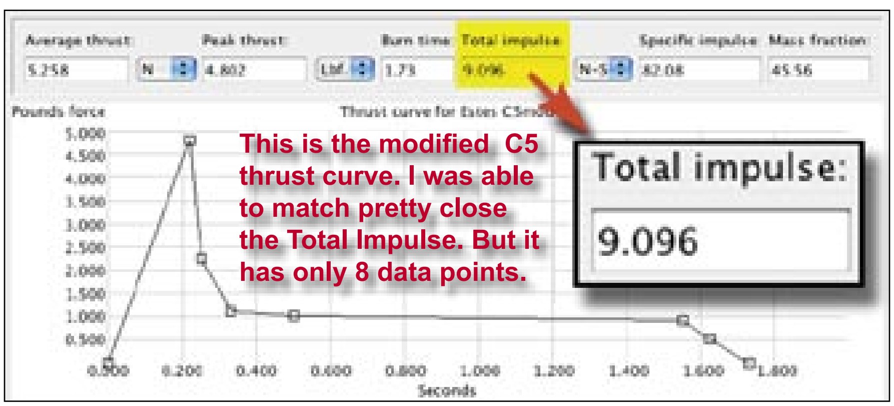

Figure 3 (Top) & 4: The NAR's engine data file shown in EngEdit. The simple curve (bottom) gives very similar simulation results.

Other RASP File Implications

While the RASP engine format has been around a long time and will continue into the future, I think that it is reaching the limits of its potential.

An example of this is hybrid motors. These burn different from black powder or composite propellant motors. When these burn, the CG moves aft instead of forward. So the rocket becomes less stable as the motor burns. See: http://www.apogeerockets.com/education/newsletter55.asp for a work-around that hybrid users had to use when running a RockSim simulation.

Unfortunately there is nothing in the RASP engine format that would indicate this.

Because of this unique problem, we are creating a new engine format, and are calling it the RockSim Engine Format (.rse). It will allow you to save the CG curve of the motor along with the thrust curve. This will make Rocksim simulations even more accurate, especially for hybrid powered rockets.

But don't worry. RockSim will still be able to open standard RASP engine files. You aren't being forced to the new format. But it is available if you want to the most accurate simlulations.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who looks forward to helping out other rocketeers. Before he started writing articles and books about rocketry, he worked on the Delta II rocket, that launched satellites into orbit around the earth. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida.

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