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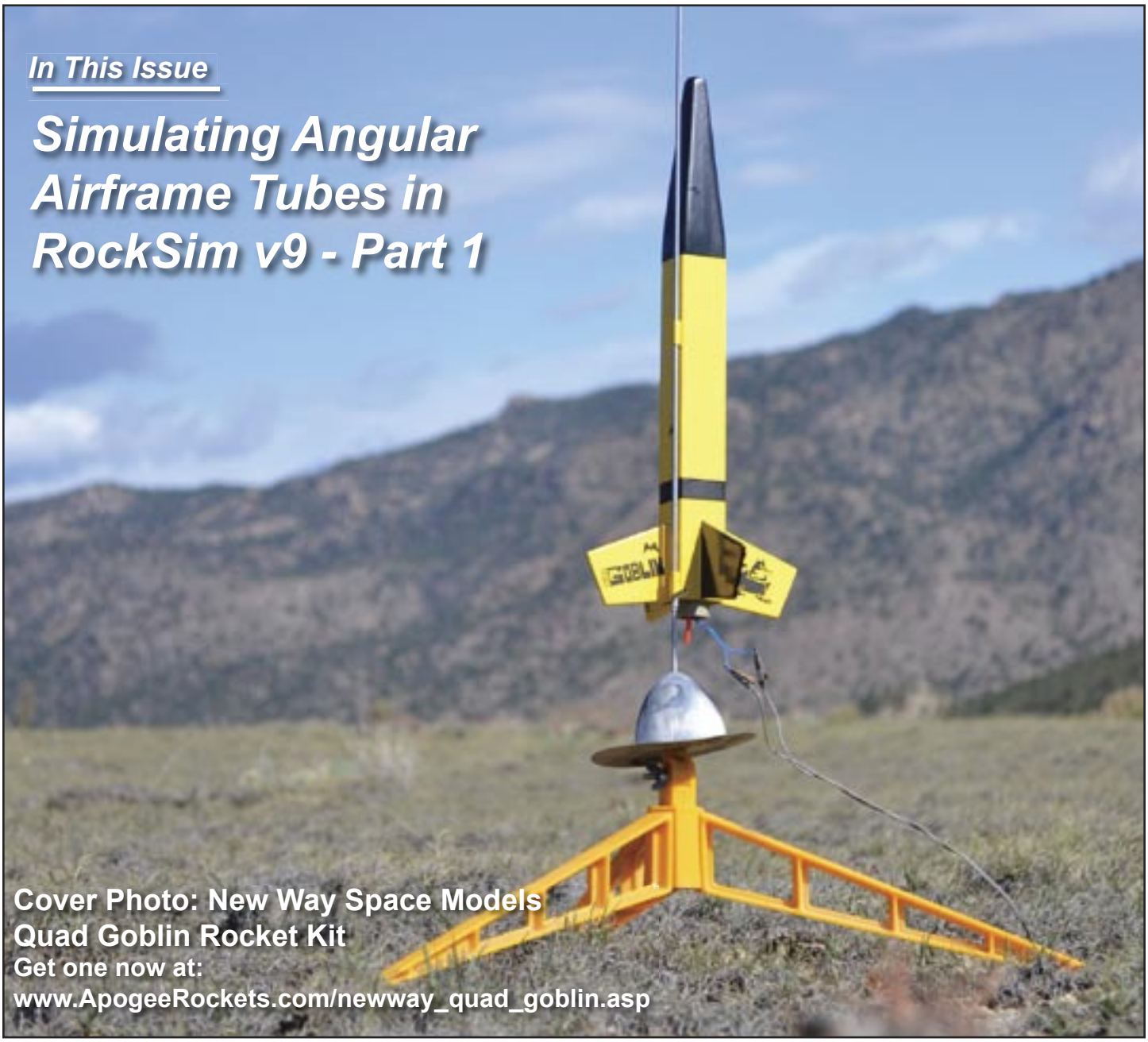

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Simulating Angular Airframe Tubes in RockSim v9 - Part 1 of 2

By Bruce Levison

{Editor's Note: The RockSim design files for this article are available for download from the Apogee Components web site at: www.ApogeeRockets.com/Education/Downloads/RSimsForArticle.zip}

Rocksim Version 9 is the most flexible and advanced model rocket flight simulation software available to the general model rocketry community, however it does not directly lend itself to the simulation of angular airframes, namely rockets with triangular and square body tubes. This article suggests ways to perform the flight simulation of these designs using Rocksim software that should give a close approximation for the actual flight characteristics of rockets with angular body tubes.

This work was inspired by my visit with a new model rocketry company at NARAM 53, New Way Space Models, which markets an entire catalog of model rockets with square body tubes (see Figure 1). Even their motto is "Dare to be Square"! Apogee Components is now selling a few of them, and they can be found at: www.apogeerockets.com/rocket_vendors.asp

Figure 1: New Way Space Models has built a fleet of models around square airframe tubes.

As part of my job, I work with a large group of scientists that simulate bio-molecules, namely proteins and lipid complexes (such as those that make up High Density Lipoprotein or HDL particles). Part of their work involves computer modeling of these complicated structures which do not readily lend themselves to direct measurement or observation. The techniques they use for creating a picture of these complex structures involves generating computer models for the possible structure and then evaluating and fine tuning these models based on the data we have (or new data we generate), and then selecting a "best fit" model as representing the actual structure of the molecule. This article on simulating angular body tubes for model rockets parallels this iterative approach.

Figure 2: The kits even have square launch lugs.

The question is can Rocksim simulate the flight characteristics of angular tube designs? The software currently lacks any direct way to input a body tube with a square or triangular shaped cross section. So let's start by ignoring the angular aspects of the body tube and run a simulation based on a round cross-sectioned rocket with the

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Simulating Angular Tubes in RockSim 9

equivalent frontal (transverse or circular) surface area of a square tube design. This should represent the "best case" simulation for this angular tube design. Actually taking into account the effects of the angular body tube is expected to provide a simulation that shows less stability and less altitude than a simulation of a rocket with round body tubes with the same length, fins, frontal surface area and weight. Indeed one of the main assumptions of the Rocksim (and the Borrowman) equations used for calculating flight stability are that at low angles of attack, the round airframe of the rocket does not have any effect on the rocket's center of pressure. Both sets of equations ignore any effects from the shape of the body tube.

One of the primary parameters that will affect the rocket's flight characteristics is contributed by the airframes frontal or transverse surface area. Using some basic algebraic relations, you can determine the diameter of a round body tube whose frontal surface area will match the frontal surface area of an angular body tube. In part 1 of this article, I will look at square airframes since they are the easiest to handle mathematically. I will be using the New Way "SquareOne" model rocket as a typical square tube example.

The area of a square is the square of its side measurement (S);

A (square) = S^2.

The area of a circle (representing the frontal cross sectional area of a round body tube) is the radius (where the radius is half the diameter, r = 1/2d) of the circle squared times the constant pi;

A (circle) = πr^2.

Setting these two areas equal A (square) = A (circle) gives;

$S^2 = \pi r^2$

Since S the width of the side of the square body tube is known (or can actually be measured) solving this equation for r the radius of the circle with an equivalent surface area gives:

$r = \sqrt{(S^2/\pi)}$

Plugging in 33.3 mm the measurement of the width of the Squareone rockets body tube gives:

$r = \sqrt{((33.3)2/3.14)} = 18.8$ mm

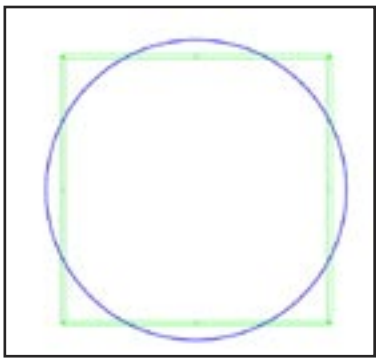

Figure 3: A square with the same frontal area as a circle.

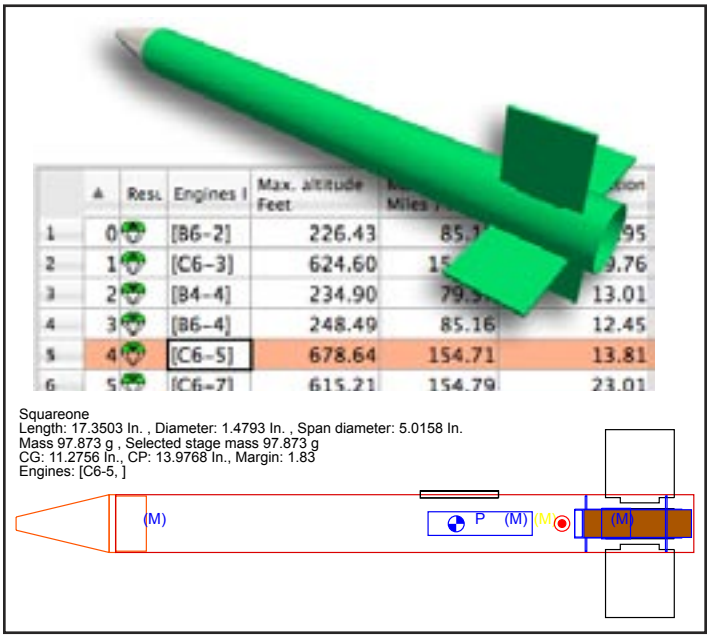

Figure 4: Round tube equivalent version of the rocket.

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By definition the diameter (d) of the body tube is twice its radius (d = 2r) so the diameter of the equivalent area body tube for the Squareone rocket should be;

d = 2(18.8mm) = 37.6 mm

This can be seen from the 37.6 mm diameter circle inscribed through the 33.3 mm on a side square in Figure 3.

I then created a Rocksim file for a rocket with round body tubes and nosecone 37.6mm in diameter with the fins and all other measurements from the SquareOne rocket model being the same.

Note since the top of the nosecone for the Squareone rocket is flat, I used a similar circular diameter equivalence calculation to create its round frontal cross section. With C6-5 motor installed, notice the CP to CG safety margin is 1.83 calibers and the rocket reaches a simulated altitude of 679 ft AGL. For comparison purposes a constant wind speed of 10 mph, with no thermals, a launch angle of zero, with all the other variables set the same were used in all flight simulations. This “Round Tube Equivalent” model represents the best case scenario for a flight simulation of the SquareOne design. Since the effects of the body tube are out of the equation, this simulation represents the optimal CP to CG separation that would be expected for a rocket with the same motor, effective frontal diameter, nosecone shape (albeit round) and fin shape and orientation. Note that in all the following models and simulations of the “SquareOne” rocket I set the weight and CG of the designs as close to this “Round Tube Equivalent” model as is possible for comparative purposes. A C6-5 motor, the heaviest motor, represents the worst case for the CP to CG safety margin in all the simulations.

Next let’s look at what could be the worst case scenario Rocksim simulation for this design. This is the first design file I came up with that actually looks like it has a square shaped body tube. I simulated each of the four sides of the tube separately as flat fins. Since the rocket nosecone also has a square cross section, I also included it as the top part of these fins. To get the fins to lay flat in the proper orientation, I used a fin pod and attached two fins of the same shape together along their root edges; the fin pod lies along the lateral center midline of each side of the square tube. I set the radial positions of the two fins at the proper square angles (0, 90, 180 and 270 degrees) to form the square tube around the rocket. This file gives the correct silhouetted shape of one side of the rocket looking fairly close to the real thing (see Figure 5).

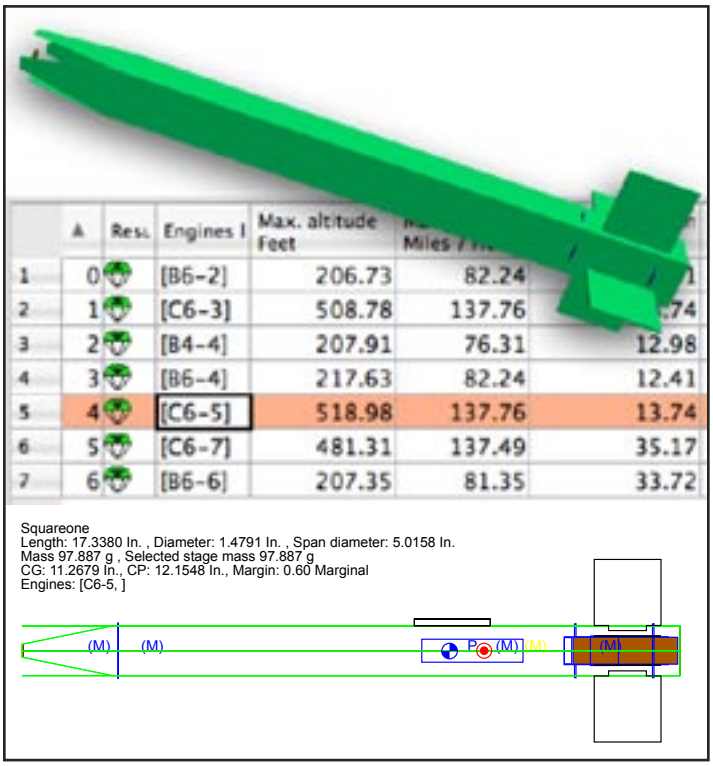

Figure 5: “Flat Panel” model for the SquareOne.

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An obvious problem is that I didn't get the tops of the fins to angle in over the top of the rocket to fully envelop a nose cone. To make this simulation work (or allow the software to use this design to do the math) I used an extremely short and light transition of the equivalent diameter calculated as above located at separation of the point between the nosecone and body tube. This disk sets the proper frontal (transverse) surface area. To set the nosecone's distance from the base of the rocket, I used an extremely thin and light body tube that is the full length of the rocket's actual body tube. The fins were attached to a short length of body tube (almost mass-less) at the base of the rocket. This tube has the diameter of 33.3 mm, the width of the square tube allowing the fin panels to lie at the proper distance from the rockets lateral centerline. The short thin nosecone and long thin body tube as well as the narrow band of body tube used to set the spacing for the fin pod mounts shouldn't change the simulation by very much.

Notice in Figure 5 that the CP to CG safety margin is 0.60 calibers; and the rocket reached a simulated altitude of 519 ft AGL, about 75% of the altitude a rocket with round body tube. Both of these values are contradictory to the known flight characteristics for the rocket. Even though the design's picture might look close on the Rocksim display screen, this simulation approach must be considered *inaccurate*. The critical aspect being that all four sides of the tube were simulated as fins which by definition have both their sides "wetted" or exposed to the air stream. In reality, a body tube has only its outer surface, (corresponding to one side) "wetted" by the air flow. After many attempts at using other software packages to modify files as I had done in previous articles, I found the .rkt files themselves can not be opened and changed to only use the outer half of the wetted surface of a fin. I had to come up with another way to modify the .rkt file to properly use angular body tube shapes I created for these flight simulations.

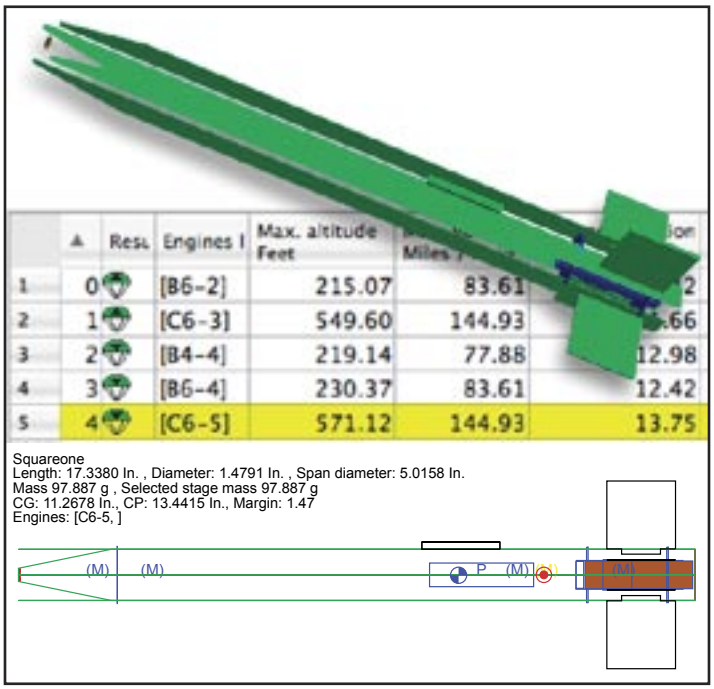

Figure 6: "Picket Fence" model for the SquareOne.

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Here is my way around this; I cut the fin span of each body tube panel in half to effectively halve its wetted surface! The problem with this approach is the simulated structure becomes something that doesn't really a look like a closed angular surface anymore.

However, this "Picket Fence" model in Figure 6 should give a simulation of an angular body tube that is a closer approximation to the SqaureOne rocket. Notice that each fin is pushed to the vertex or corner of the tube and the next fin does not share the same vertex. For a square shaped body tube one can envision that the back of an opposing fin will substitute (or fill in) for the wetted surface of its opposing partner. This is just one way to get Rocksim software to use only half the wetted surface of the fin for the angular airframes side panel. The difference between this simulation and the last is that I simply set the number of fins from two to one on each of the fins on the fin pod mount for the side panel. With C6-5 motor installed notice the CP to CG safety margin is 1.47 calibers and the rocket reaches a simulated altitude of 571 ft AGL. The flight using a C6-5 motor is stable, as expected; the maximum altitude is also a respectable value.

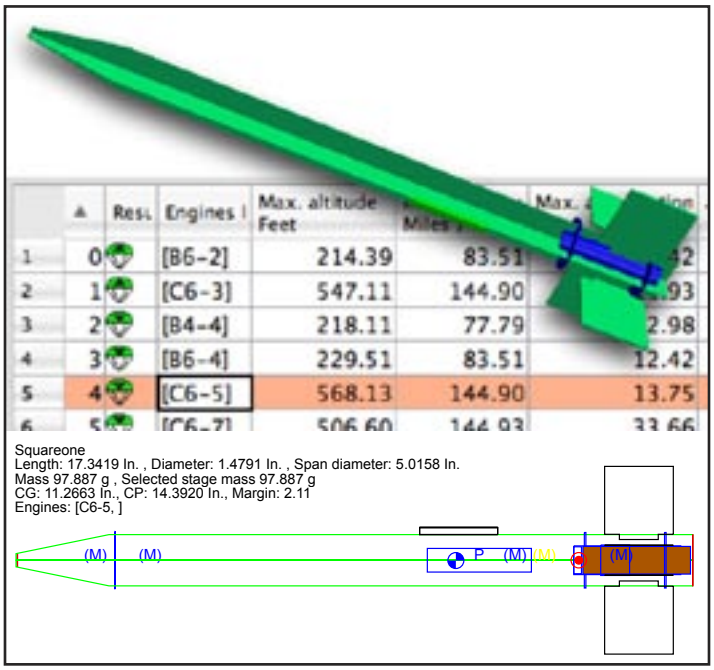

Figure 7: Skeleton version of the SquareOne.

A cleaner or simpler simulation using this same half panel concept involves putting the same four fin panels in a cross pattern along the lateral centerline of the rocket, giving the "skeleton" model shown in Figure 7. It is simpler since it avoids using the fin pod concept I used to mount the fins around the outside of the airframe.

With the C6-5 motor installed, notice the CP to CG safety margin is 2.11 calibers and the rocket reaches a simulated altitude of 568 ft AGL. This treatment gives as stable a flight as in the "Picket Fence" model above, with a similar maximum altitude and velocity.

But what about making the fins thicker in the "skeleton" model to simulate the width of the actual square body tube? Using mass override to keep the weight and its distribution the same and setting the fin thickness equal to 33.3 mm (the width of the square tube on the SquareOne rocket) gives the "Space Filling" simulation model in Figure 8.

With C6-5 motor installed notice the CP to CG safety margin is 2.11 calibers and the rocket reaches a simulated altitude of 549 ft AGL. The results are nearly as above with the skeleton model, the same safety margin but the maximum altitude on the C6-5 motor is slightly lower. But this model is actually taking twice the frontal area of the rocket into account since the fins simulating the side panels now overlap with each other.

Setting the fin thickness for the body panels to 16.7

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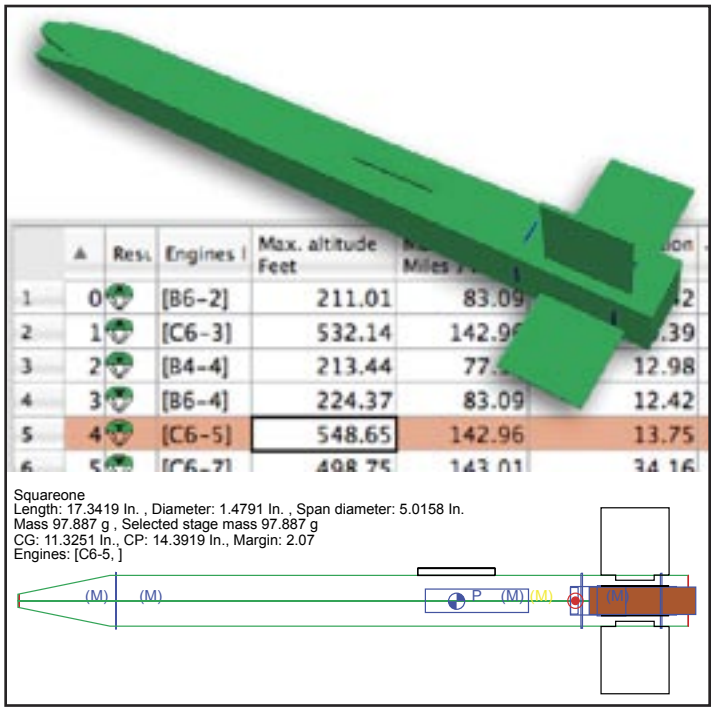

Figure 8: Space Filling RockSim Model of the Square-One.

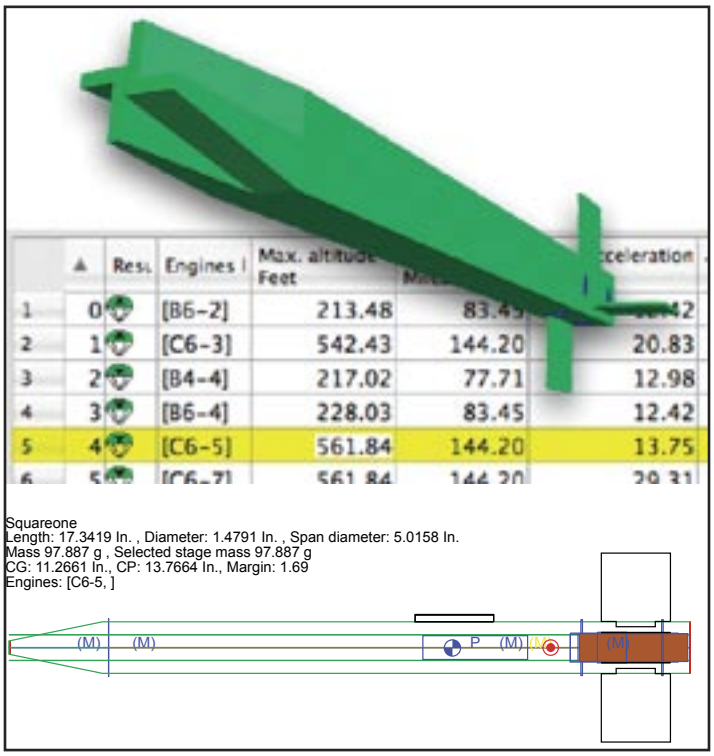

Figure 9: Non-Overlapping Space Filling RockSim Model of the SquareOne.

mm (half the side measurement since twice the area was represented) and rearranging them around the center will remove the overlap, giving the "Non-Overlapping Space Filling" model in Figure 9.

This model with C6-5 motor installed yields CP to CG safety margin of 1.69 calibers and the rocket reaches a simulated altitude of 562 ft AGL. Again these results are similar to those from the "skeleton" model on which this model was based. The stability margin is less but the altitude is closer; at least this modeling technique looks closer

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to the real rocket than any of the other simulation models.

But which of these simulation models is the best or closest to being correct?

Model	Margin C6-5 Motor	C6-5 Altitude	Simulation
Round Tube Equivalent	1.83	679'	Figure 4
Flat Panel	0.6	519'	Figure 5
Picket Fence	1.47	571'	Figure 6
Skeleton	2.11	568'	Figure 7
Space Filling	2.11	549'	Figure 8
Non-Overlap Space Filling	1.69	562'	Figure 9

Table 1: Results of Different Simulation Strategies for Square Airframes

The "Round Tube Equivalent" model, while providing a simple basis for comparison, completely ignores the effect of the angular airframe tube. If anything, it is overestimating the altitude and safety margin of this design. While the "Flat Panel" model looks good, it indicates marginal safety and a much lower than expected altitude. This is because the "Fat Panel" model wrongly assumes both the inside and outside of the airframe is wetted by the airflow.

The "Picket Fence" model is looking like a possible candidate to use to simulate angular airframes, providing a safety margin and altitude between those from the "Round Tube Equivalent" model and "Flat Panel" model as desired.

The skeleton model is by far the easiest model angular airframe model to construct for the evaluation by Rocksim software. The "Skeleton" model and "Space Filling" models seem to be better at handling the pyramidal shape of the angular nose cone. As far as flight stability is concerned, the safety margin of the "Skeleton" and "Space Filling" models is even higher than the safety margin from the "Round Tube Equivalent" model; this is not what you would expect since the safety margin (or stability) of the angular tube rocket should be less than an equivalent design with round tubes.

That leaves the "Non-Overlap Space Filling" model. Again this model is looking like a possible candidate that can be used to simulate angular airframes, providing a safety margin and altitude between those from the "Round Tube Equivalent" model and "Flat Panel" model. Also notice the close agreement of the safety margins and altitudes from "Picket Fence" and "Non-Overlap Space Filling" models. Since these simulations are all approximations and not based on any real world or wind tunnel data, I would suggest the real answer probably lies somewhere between the "Picket Fence" and the "Non-Overlap Space Filling" model simulation techniques. Wind tunnel and/or altimeter data for the SquareOne model would be required to confirm or refine either of these models.

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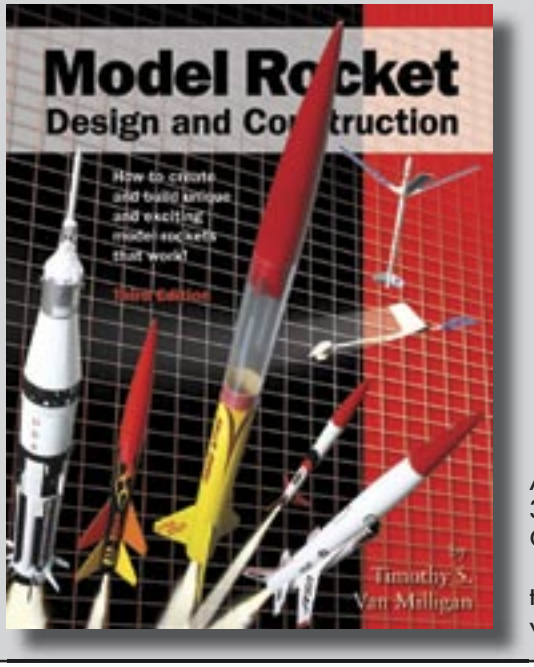

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Bruce Levison standing with some of his models.

Coming Next Time

In our next issue, we'll look at rockets using three-sided tubes, instead of four.

About the Autor:

Bruce Levison (NAR #69055, L2) is a hobbyist from Ohio, a member of the National Association of Rocketry (NAR) and the Mantua Township Missile Agency (MTMA, NAR section #606). He has published numerous articles on model rocketry related to many practical aspects of the hobby. Bruce enjoys tricking RockSim software into performing simulations of non-standard rocket designs. Bruce earned an advanced degree in chemistry and works as a research scientist at the Cleveland Clinic Foundation.