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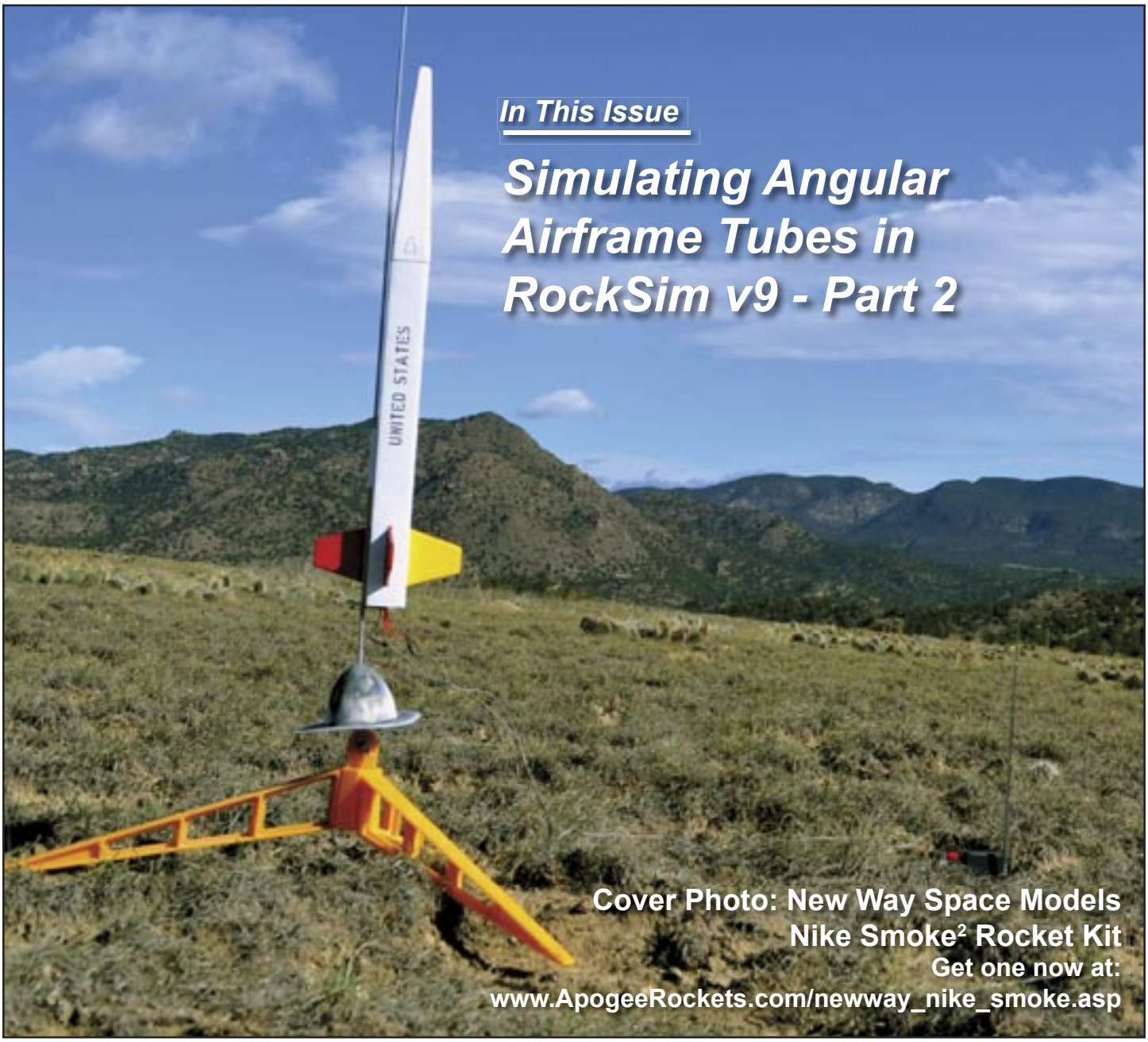

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ISSUE 297 OCTOBER 11, 2011

Simulating Angular Airframe Tubes in RockSim v9 - Part 2 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}

In our last article, you saw how to simulate square rockets in RockSim version 9. This article will build upon that information, so you'll want to review it by downloading Peak-of-Flight Newsletter #296 at: www.ApogeeRockets.com/Education/Downloads/Newsletter296.pdf.

Part 2: Triangular body tubes

Another way to check these simulation modeling techniques is to use them for other angular tube shapes. I put all these models to the test using the triangular shaped body tube of the Fliskits "Caution Rocket Launch in Progress" (CMRLIP) model rocket (see Figure 1), a paper origami fold up design available as a free download at: www.fliskits.com/products/free_dl/paper_rockets/caution_rocket.htm.

Again let's start out by ignoring the angular aspects of the body tube and run a simulation on a round cross-sectioned rocket with the equivalent frontal (transverse) surface area of the triangular tube design. This should represent the "best case" simulation of the angular design; keeping in mind that the angular body tube would be expected to provide less stability than one with round body tubes of a similar frontal surface area, weight, etc. The triangular tube having narrower angled sides (shaper corners) would also be expected to be even less stable than that for a square design. The mathematics I used to generate a round body tube whose diameter is set to exactly match the frontal surface area of the triangular body tubes is calculated as below.

In a manner analogous to the square body tube from part one above, the radius of a circle with a surface area equivalent to the triangular body tube can be determined. The area of an equilateral triangle with a side width (T) is given by the formula;

Figure 1: Fliskits' "Caution Rocket Launch In Progress"

$A_{(triangle)} = (\sqrt{3})/4\ T^2$

Using the same mathematical treatment for a square tube from part 1 in Newsletter 296, setting the two areas equal $A_{(triangle)} = A_{(circle)}$ gives;

$A_{(triangle)} = A_{(circle)}$

$(\sqrt{3})/4\ T^2 = \pi\ r^2$

Since T the width of the side of the triangular 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:

$r = \sqrt{((\sqrt{3})\ T^2/4\pi)}$

For the "Caution Rocket Launch in Progress" triangular cross sectioned model, the side width T = 32.1 mm, r the radius of the circle with the equivalent surface area is:

$r = \sqrt{((1.732)\ (32.1)^2/4(3.14))} = 11.9$ mm

The diameter of a round body tube (d = 2r) with the equivalent transverse surface area or the triangular airframe would be:

d = 2(11.9) = 23.8 mm

This can be visualized from the 23.8 mm diameter circle inscribed through the 32.1 mm on a side (equilateral) triangle shown in Figure 2.

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Simulating Angular Tubes in RockSim 9

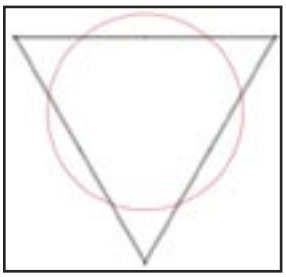

Figure 2: An equalateral triangle with the same perimeter as a circle.

I then created a Rocksim file for a rocket with round body tubes and nosecone 23.8 mm in diameter with the fins and all other measurements from the "Caution Rocket Launch in Progress" rocket. See Figure 3 below.

With a C6-5 motor installed notice the CP to CG safety margin is 1.31 calibers and the rocket reaches a simulated altitude of 1606 ft AGL. Again for comparison purposes a constant wind speed of 10 mph, with no thermals, no launch angle and all other variables the same were used in all flight simulations. I also kept the weight and it's distribution (CG) of the design in all the subsequent models as close to this "Round Tube Equivalent" as is possible in all the following simulations. This model represents what would be the absolute best case scenario for flight simulation of this design. Since the effects of the body tube are out of the equation, it gives the best CP to CG separation that can be expected for a rocket with the same motor, effective frontal diameter, nosecone shape (albeit round) and fin shape and orientation.

Now let's look at the worst case scenario Rocksim simulation for this design as seen in Figure 4.

This is the "Flat Panel" design file I came up with for CMRLIP that actually looks like it has a trianglar shaped body tube simulating each of the three sides of the tube separately as flat fins. Since the actual nosecone also

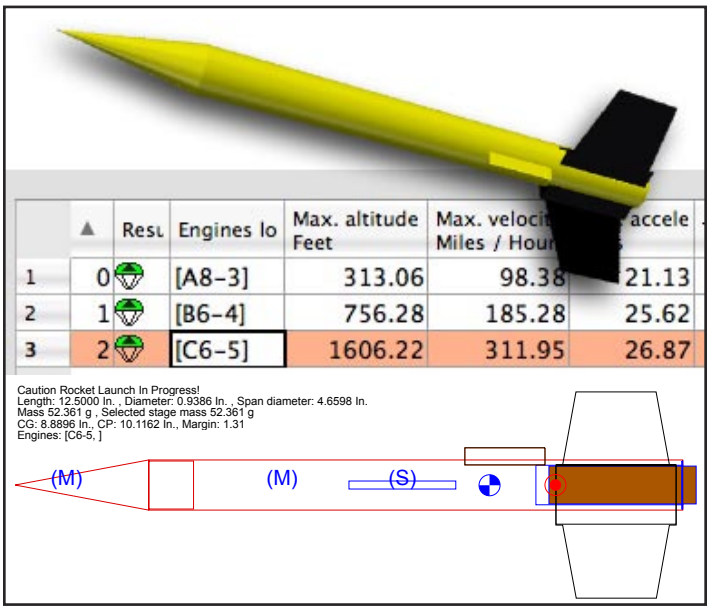

Figure 3: Round tube equivalent version of the rocket.

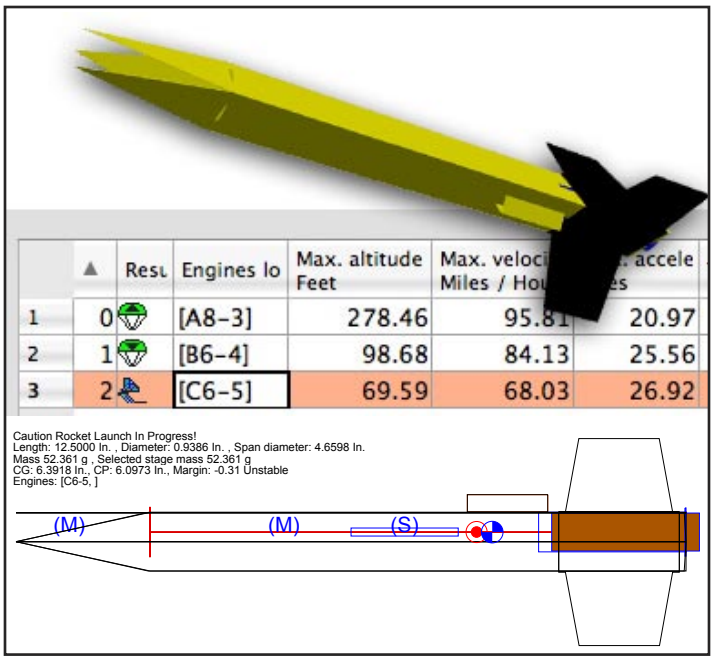

Figure 4: "Flat Panel" model of the CMRLIP.

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has a triangular cross section it was also simulated as the top part of the fins. To get the fins to lay flat in the proper orientation for each side of the tube I used a fin pod and attached two fins of the same shape together giving the silhouetted shape of one side of the rocket. The radial positions of the fin sets were placed at the proper angles (0, 120 and 240 degrees) to form the triangular tube around the rocket. This simulation looks like the real thing; again the obvious problem is that the tops of the fins don't 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 nosecone of the equivalent diameter (as calculated above) located at the point where the nosecone starts and the actual body tube ends. This nosecone sets the proper frontal (transverse) surface area. To set the nosecones distance from the base of the rocket, I used an extremely thin and light body tube the full length of the rocket's actual body tube (not including the length of nose cone).

When I attempted to use a short thin nosecone located at the very top of this rocket design the Rocksim program would not perform any of the flight simulations. As before the fins were attached to an extremely light and appropriate diameter band of body tube at the base of the rocket. This tube has the diameter of a circle inscribed within the triangular body tube. The short thin nosecone and long thin body tube as well as the narrow band of body tube used for the fin mount don't change the simulation by very much.

With a C6-5 motor installed notice the CP to CG safety margin is -0.34 calibers; unstable, and the rocket is predicted to crash. This stability margin is not correct since I know from my personal experience this design flies stable with a C6-5 motor. Even though the rocket might look like what is depicted on the simulation screen this simulation model does not work for the CMRLIP triangular tube design.

As before with the square rocket this is probably because the sides of the tube were simulated as fins which by definition have both of their sides "wetted" or exposed to the air stream. In reality, a body tube only has its outer surface, (one side) "wetted" by the air flow. Using the same trick as before, simply cutting the fin span of each body tube panel in half to halve its wetted surface should once again provide a workable solution. This is shown in Figure 5.

This "Picket Fence" concept model is expected to give a simulation of an angular body tube that should be close approximation to the real rocket. As before, each fin is

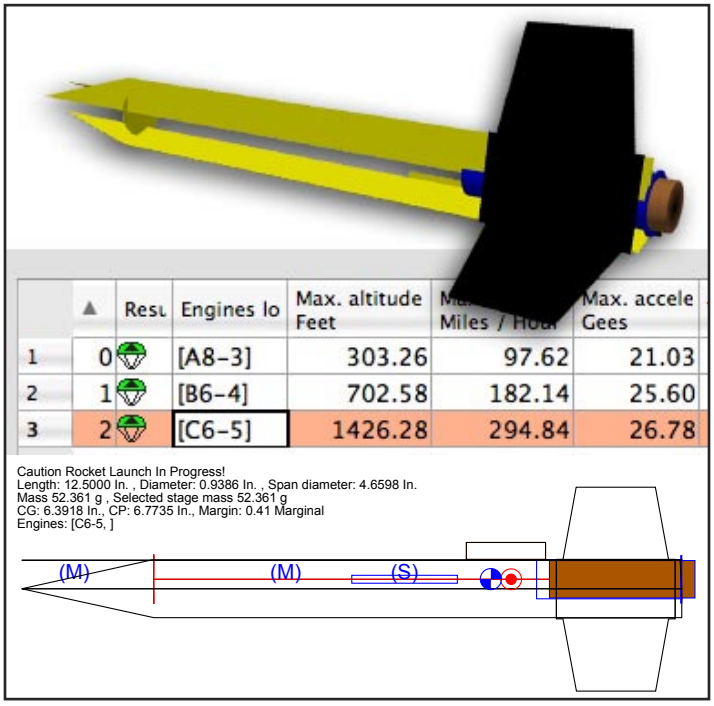

Figure 5: "Picket Fence" model of the CMRLIP.

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pushed to the vertex or corner of the tube and the next fin does not share the same vertex. For this triangular shaped body tube the projection of the area from the backs of the other two fins into the plane of the remaining fin will fill in for the half of the wetted surface that is missing. As above,

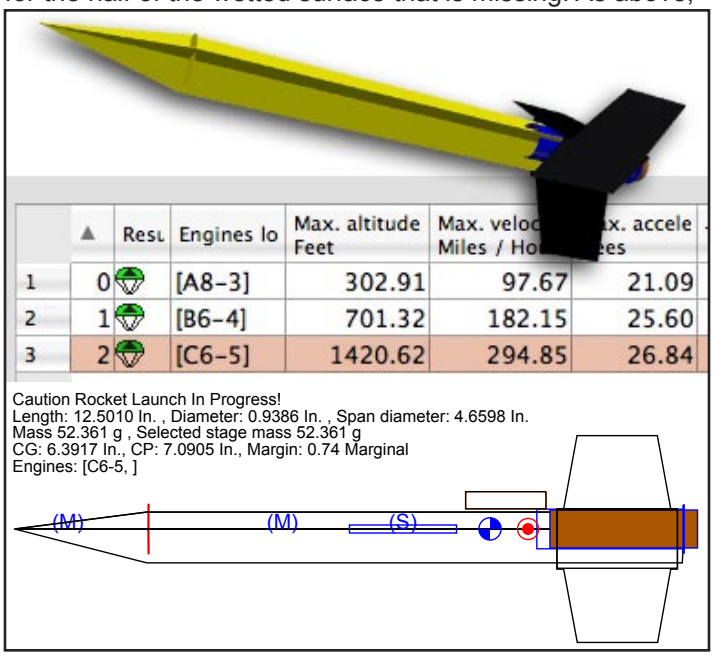

Figure 6: "Skeleton" model of the CMRLIP.

the difference between this "Picket Fence" simulation and the "Flat Panel" model is that I set the number of fins from two to one on each of the fin pods. With a C6-5 motor installed notice the CP to CG safety margin is 0.39 calibers and the rocket reaches a simulated altitude of 1421ft AGL. The flight is marginally stable and the maximum altitude is a respectable value.

For the next simulation model I present the simpler "Skeleton" simulation technique that involves putting the same three fin panels in a "Y" pattern along the centerline of the rocket. This is shown as the Skeleton model seen in Figure 6.

With a C6-5 motor installed notice the CP to CG safety margin is 0.80 calibers and the rocket reaches a simulated altitude of 1416 ft AGL. Making the fin panels thicker, 32.1 mm, (the width of the triangular sides) for the "Space Filling" method and using mass override to keep the weight and its distribution the same gives the "Space Filling" model simulation shown in Figure 7.

With a C6-5 motor installed notice the CP to CG safety margin is 0.73 calibers and the rocket reaches a simulated altitude of 1296 ft AGL. Both the "Skeleton" and "Space Filling" models indicate marginally stable flights with similar maximum altitudes on a C6-5 motor. The rocket design in

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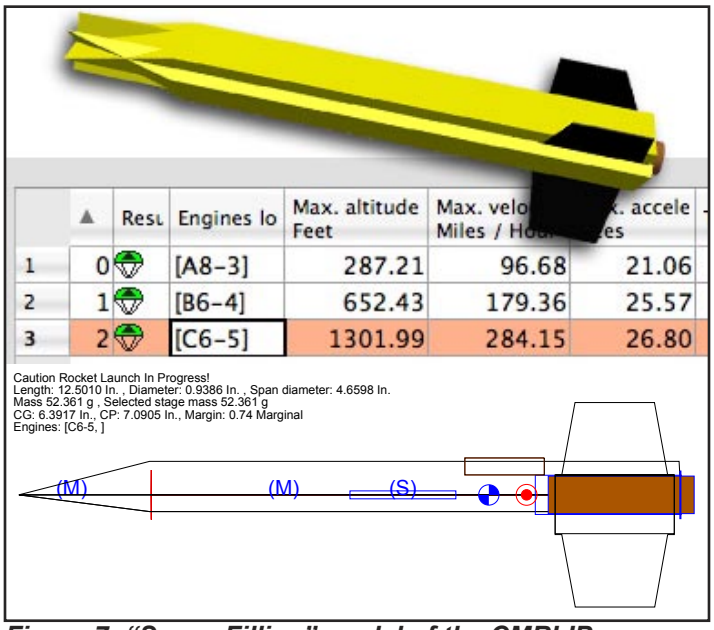

Figure 7: "Space Filling" model of the CMRLIP.

this "space filling" simulation technique looks more distorted than the shape of the real rocket. Will the "Non-Overlapping Space Filling" model look better and provide a better solution?

The triangular body tube simulation points out the shortcomings of the "Non-Overlapping Space Filling" model technique. When I set out to do this simulation it was not immediately obvious what thickness to use to represent the fin panels for this modeling technique. I wanted the total frontal surface area of the three fins to be equivalent to (or match) the frontal surface area of the rocket as was done above in the square tube case. Using half the fin panel thickness and the normal span gives a frontal area of 1/2 T^2 and the area should be $(\sqrt{3})/4\ T^2$. Since there are three fins and their span is already halved:

$A_{(triangle)} = 3\ (A_{(fin)})$

$(\sqrt{3})/4\ T^2 = 3\ (1/2\ TX)$ where X is the fin thickness

Solving for X gives: $X = \sqrt{3}/6\ T$

Therefore, to get the proper frontal area for the Non-Overlapping Space Filling model shown in Figure 8, I had to set the fin thickness to $\sqrt{3}/6$ T or 9.27 mm and use mass override to keep the weight and its distribution the same.

It is apparent that with other angular air frames (those with a shape other than a square) this extra calculation to determine the proper fin thickness for the "Non-Overlapping Space Filling" model must be performed to set the frontal fin area to match that of the rockets transverse frontal area. This extra step was not required for the "Picket Fence" model. The simplicity of the square model allowed me to

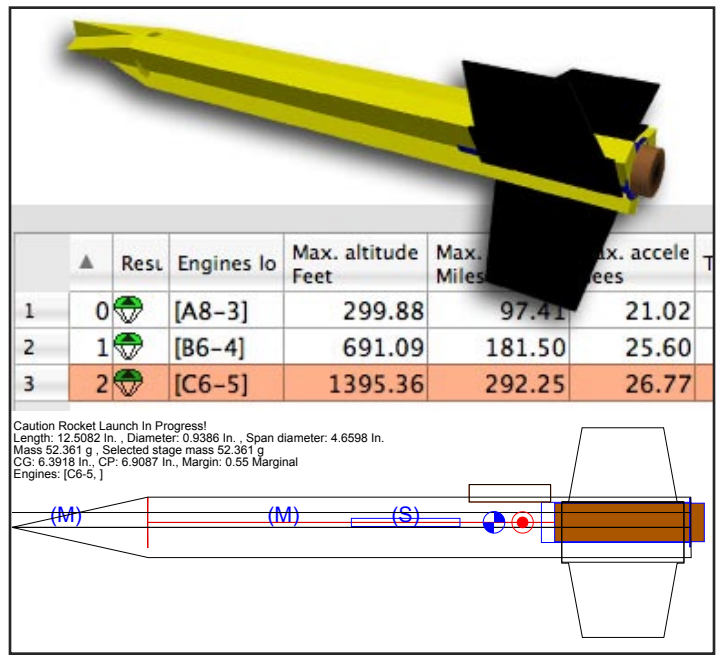

Figure 8: "Non-Overlap Space Filling" CMRLIP model.

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pick out this equivalent area without doing the extra calculation. This model with a C6-5 motor installed yields CP to CG safety margin of 0.55 calibers and the rocket reaches a simulated altitude of 1395 ft AGL. Again these results are closer to those from the "Picket Fence" model as on the square tube case presented earlier. The rocket design in this "Non-Overlapping Space Filling" simulation technique looks more distorted than the shape of the real rocket yet a bit less distorted than the "Space Filling" model.

Again the question arises as to which simulation method is best or closest to being correct? The same answer still applies; since these simulations are all approximations and not based on any real world or wind tunnel data, I would again suggest the real answer lies somewhere between the "Picket Fence" and the "Non-Overlap Space Filling" simulation technique. Since the "Non-Overlapping Space Filling" model requires an extra calculation to determine the fin thickness, and to err on the side of safety, I suggest using the "Picket Fence" model. The "Picket Fence" model yields a more conservative (or forward) estimate for the model's CP value. In lieu of wind tunnel data, the only supporting evidence that suggests that the safety margin for the CMRLIP rocket is actually 0.41 are several reports (on Rocket Reviews www.rocketreviews.com/fliskits-caution-rocket-by-kyle-hancock.html) of unstable flights with this model using C6-5 motors.

Technique	Margin	C6-5 Altitude	Simulation	CG Unloaded	Mass
Round Tube Equivalent	1.31	1606'	Figure 3	6.9298	29.261
Flat Fins	-0.31	Unstable	Figure 4	6.9297	29.261
Picket Fence	0.41	1426'	Figure 5	6.9298	29.261
Skeleton	0.74	1421'	Figure 6	6.9298	29.261
Space Fill Overlap-ping	0.74	1302'	Figure 7	6.9298	29.261
Space Fill Non-Over-lap	0.55	1395'	Figure 8	6.9299	29.261

Table 1: Results of Different Simulation Strategies for Triangular Airframes

The "Picket Fence" model simulation techniques can easily be adapted for air frames with more sides. As more sides are added to the airframe the approximations from these techniques would be expected to more closely approach that of a round tube model with an equivalent frontal surface area.

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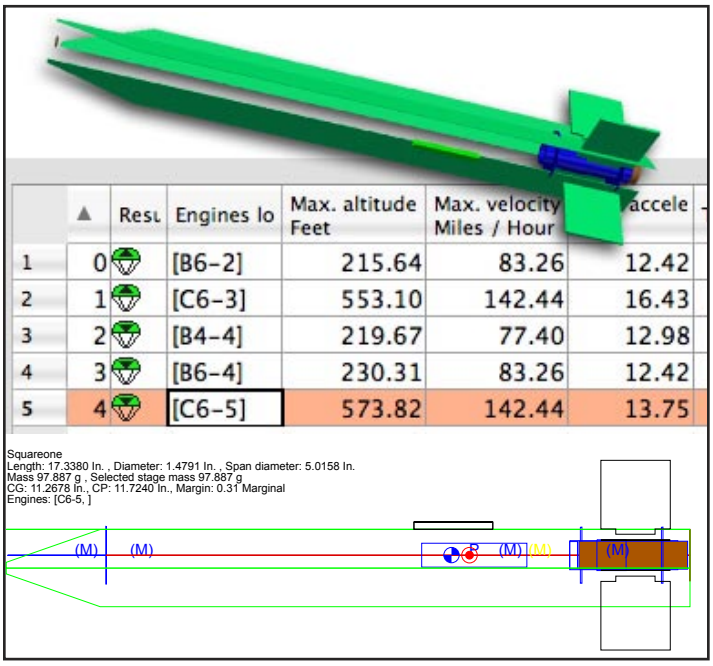
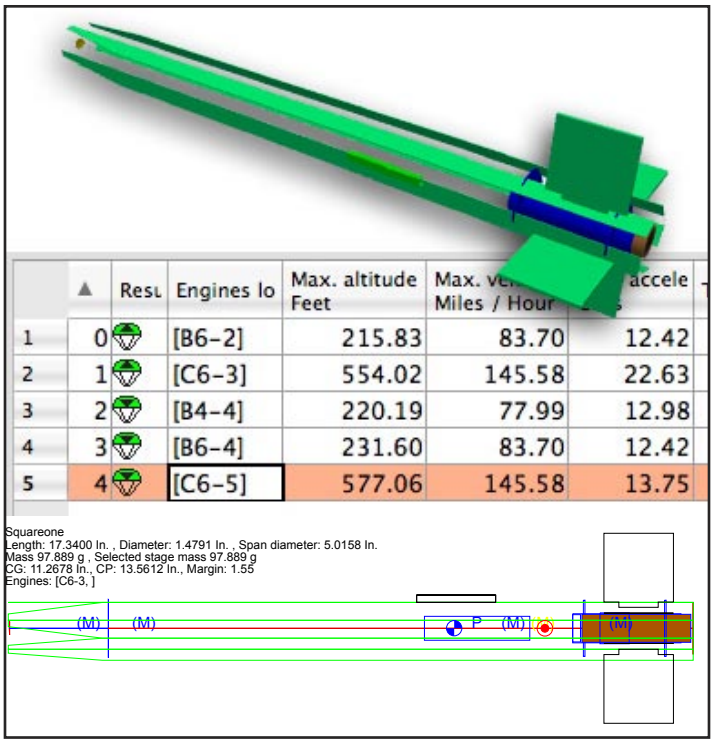
Technique Picket Fence	Margin	C6-5 Altitude	Simulation
Round Tube Equivalent	1.83	679'	Figure 4 (Newsletter #296)
Triangle	0.31	574'	Figure 9
Square	1.47	571'	Figure 6 (Newsletter #296)
Pentagon	1.55	577'	Figure 10
Hexagon	1.70	578'	Figure 11
Octagon	1.99	580'	Figure 12
Decagon	2.07	578'	Figure 13
Dodecagon	2.18	579'	Figure 14

Table 3: Results of the Picket Fence Model Simulation Technique of Angular Airframes



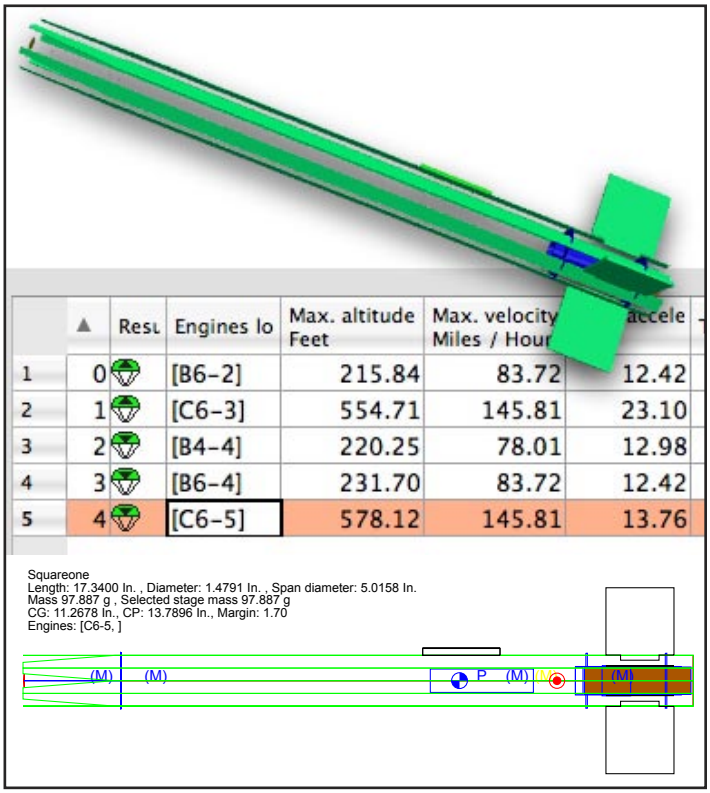
	▲	Resu	Engines lo	Max. altitude Feet	Max. velocity Miles / Hour	accele
1	0		[B6-2]	215.64	83.26	12.42
2	1		[C6-3]	553.10	142.44	16.43
3	2		[B4-4]	219.67	77.40	12.98
4	3		[B6-4]	230.31	83.26	12.42
5	4		[C6-5]	573.82	142.44	13.75

Figure 9: Triangular Rocket Simulation



	▲	Resu	Engines lo	Max. altitude Feet	Max. ve Miles / Hour	accele
1	0		[B6-2]	215.83	83.70	12.42
2	1		[C6-3]	554.02	145.58	22.63
3	2		[B4-4]	220.19	77.99	12.98
4	3		[B6-4]	231.60	83.70	12.42
5	4		[C6-5]	577.06	145.58	13.75

Figure 10: Pentagon Rocket Simulation



	▲	Resu	Engines lo	Max. altitude Feet	Max. velocity Miles / Hour	accele
1	0		[B6-2]	215.84	83.72	12.42
2	1		[C6-3]	554.71	145.81	23.10
3	2		[B4-4]	220.25	78.01	12.98
4	3		[B6-4]	231.70	83.72	12.42
5	4		[C6-5]	578.12	145.81	13.76

Figure 11: Hexagon Rocket Simulation

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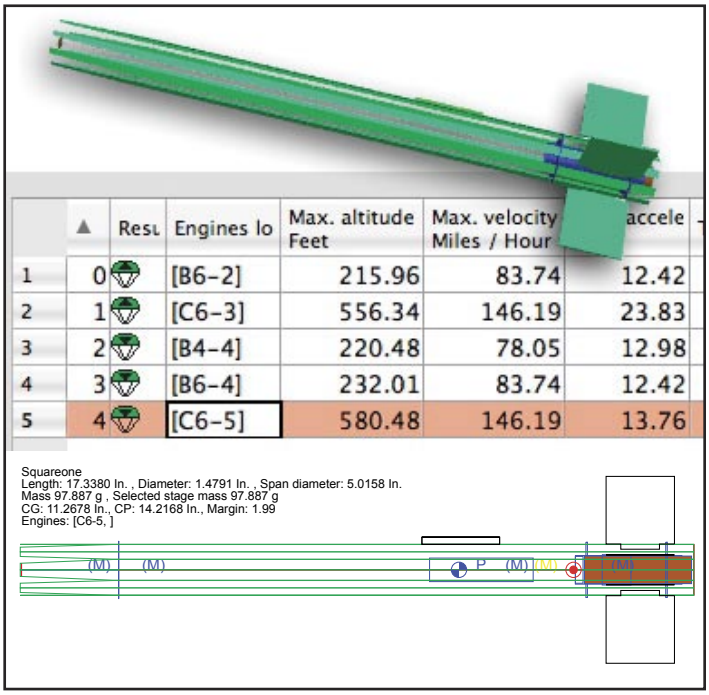
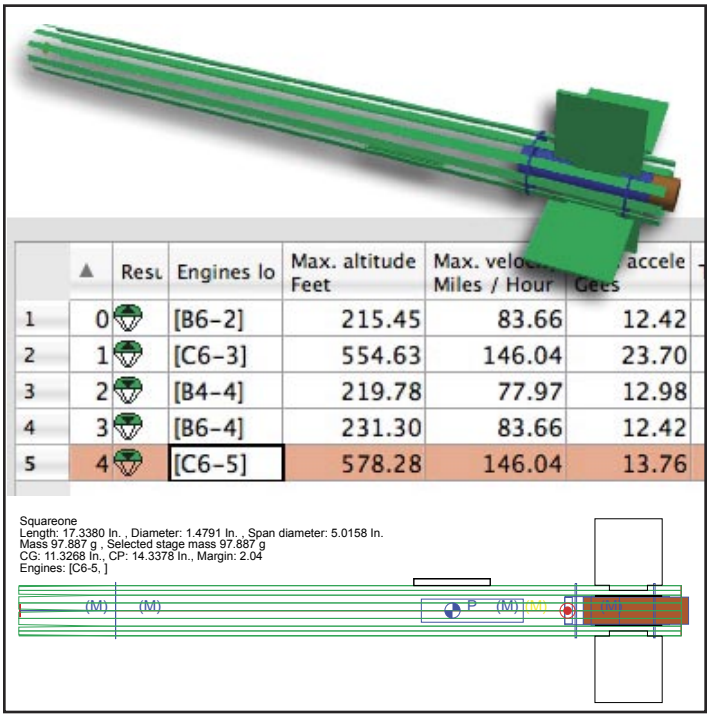


	▲	Resu	Engines lo	Max. altitude Feet	Max. velocity Miles / Hour	accele
1	0		[B6-2]	215.96	83.74	12.42
2	1		[C6-3]	556.34	146.19	23.83
3	2		[B4-4]	220.48	78.05	12.98
4	3		[B6-4]	232.01	83.74	12.42
5	4		[C6-5]	580.48	146.19	13.76

Figure 12: Octagon Rocket Simulation



	▲	Resu	Engines lo	Max. altitude Feet	Max. velo Miles / Hour	accele Gees
1	0		[B6-2]	215.45	83.66	12.42
2	1		[C6-3]	554.63	146.04	23.70
3	2		[B4-4]	219.78	77.97	12.98
4	3		[B6-4]	231.30	83.66	12.42
5	4		[C6-5]	578.28	146.04	13.76

Figure 13: Decagon Rocket Simulation

For the values in Table 2, I used the Squareone model from the prior discussion with a different number of sides on its body tube, but everything else was kept the same. As can be seen from the table, the rocket's stability margin gets better as more sides are added to the body tube. Also noteworthy is that the maximum attained altitude keeps on increasing as well. Both of these phenomena are as one would expect, more sides means more stability since there is less of a corner effect because the corner angle is wider. Beyond the hexagonal body tube case, the CP to CG margin matches or exceeds the "Round Tube Equivalent" case. In these instances it would be best to use the "Round Tube Equivalent" model approximation along with a larger drag factor in the simulation of these model rocket flights.

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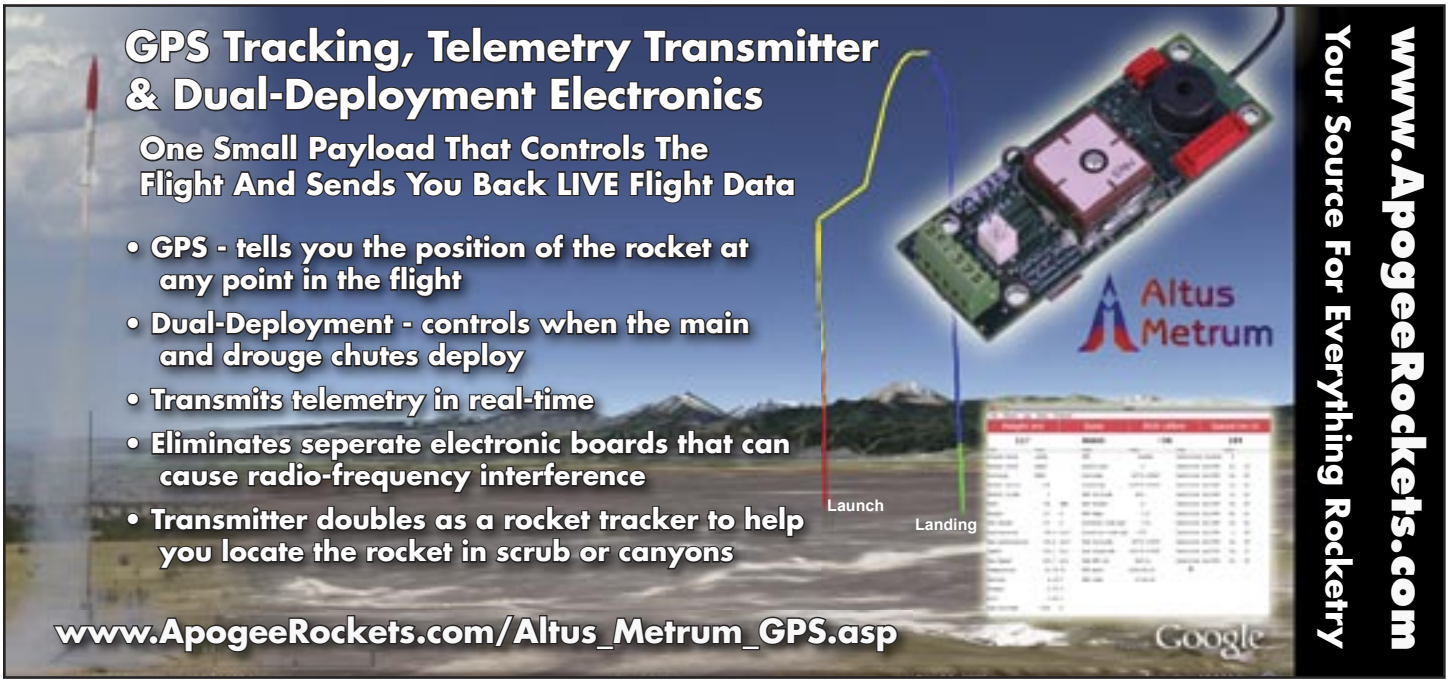

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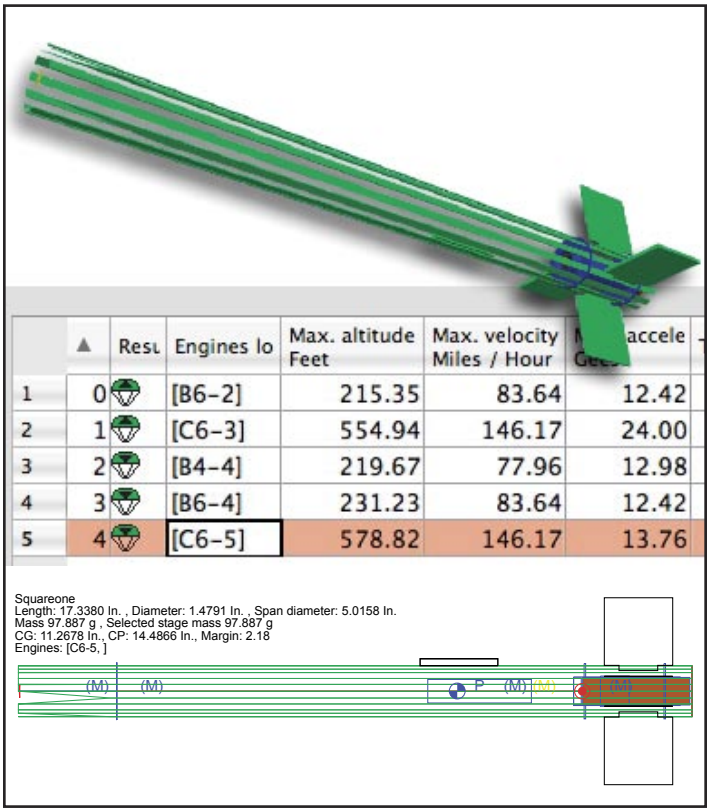
Again I must stress these techniques are my best guess at what the simulation of a rocket with an angular body might look like. Use them at your own risk as they have not been validated with wind tunnel or actual flight data.

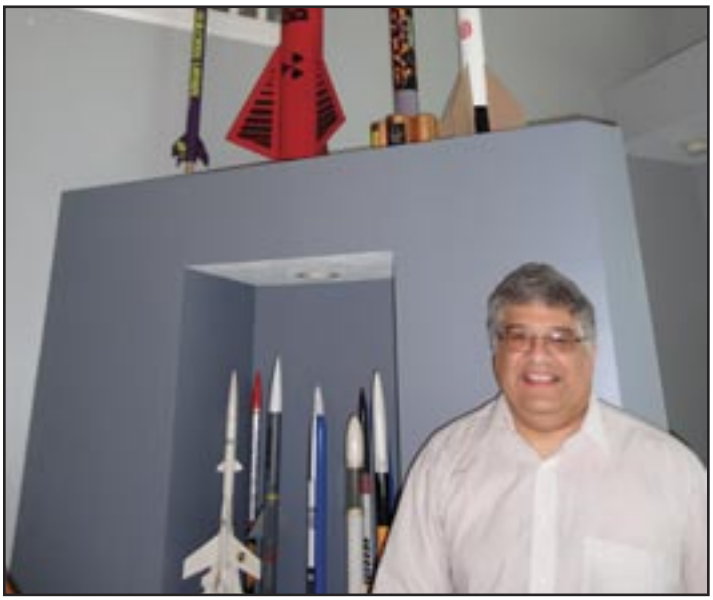


	▲	Resu	Engines lo	Max. altitude Feet	Max. velocity Miles / Hour	accele
1	0		[B6-2]	215.35	83.64	12.42
2	1		[C6-3]	554.94	146.17	24.00
3	2		[B4-4]	219.67	77.96	12.98
4	3		[B6-4]	231.23	83.64	12.42
5	4		[C6-5]	578.82	146.17	13.76

Figure 14: Dodecagon Rocket Simulation

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.



Bruce Levison standing with some of his models.