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PEAK OF FLIGHT

N E W S L E T T E R

The Tail of the Boosted Dart

INSIDE:

- The Tail of the Boosted Dart
- Rocket Tip: Cleaning Your Clips
- Web Site of the Week
- Coloring Contest Winner!
- Defining Moments: Canted Nozzles

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The Tail of the Boosted Dart

by Bruce S. Levison

The Simulation of a Sustainer or Boosted Dart That Has a Tail Cone Seated Inside the Booster Stage Using RockSim Version 8:

Bruce S. Levison has asked us to share this article with other RockSim users. It describes a method that he feels will help to simulate a boosted dart with its tail cone intercalated into the booster. This procedure maintains the Center of Pressure (CP) of the complete assembly and adds in the effects of the boat tail on the boosted dart when the dart is released from the booster stage. Please note: The user assumes all risk for the information obtained with this method.

Background

How can you simulate a sustainer or boosted dart that has a tail cone which is seated inside the booster stage? RockSim software normally won't let you put part of the sustainer inside the booster stage. All the program will allow is adjustment of the rockets CG to compensate for the tail cone by adding a mass object (the weight of dart's tail cone) which can be moved anywhere to get any desired CG. But the lack of the tail cone on the dart gives a boosted dart with the wrong CP for the boosted stage of the flight. With the method outlined in this article, RockSim is actually forced to include the tail cone's effects in the dart stage only, the CP of the full configuration (sustainer plus booster) can be adjusted back to where the software has calculated it should be in a file without the tail cone being included in the aerodynamics of the rocket.

Tweaking the Design File

I figured out a way to force RockSim software to perform this kind of simulation where the sustainer tail cone is buried inside the booster. I started with a simu-

lation file where the tip of the dart's tail cone is touching the top of the transition on the booster tube (see figure 1, stage 2 selected). The upper stage of this simulation

Length: 27.4031 in., Diameter: 0.9760 in., Span diameter: 4.879 in., Mass: 1.9150 Oz., Selected stage mass: 1.9150 Oz., CG: 9.0851 in., CP: 23.6907 in., Margin: 26.84 Overstable Shown without engines.



Figure 1

in figure 2 (stage 2 selected) is just the boosted dart and gives the expected CG and CP of the dart. The next file, (figure 3), contains the full stack as it would appear with the tail cone of the dart buried into the upper transition of the booster. Note that there is no corresponding part

Length: 696.04 mm, Diameter: 24.79 mm, Span diameter: 124.48 mm, Mass: 1.9150 Oz., Selected stage mass: 1.1963 Oz., CG: 68.62 mm, CP: 195.84 mm, Margin: 9.21 Overstable Shown without engines.

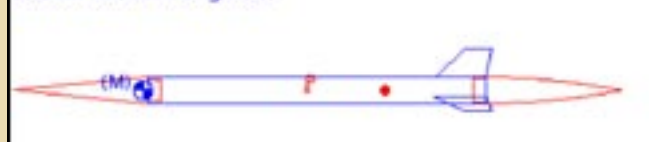


Figure 2

for the dart's tail cone, only a mass object accounting for its mass. This gives the expected CG and CP of the full stack.

A realistic simulation of this boosted dart configuration, which has the dart's tail cone buried into the upper transition on the booster, should give the same CG and CP relationships from the simulation in figure 1 and fig-



Figure 3

ure 2 during the coast and boost phases of the flight.

The next example (see figure 4), shows how you can put a tail cone (transition) inside the booster stage. It was created from the RockSim file from figure 1 where the dart and booster do not insert within or mate together.

continued on page 4

About this Newsletter

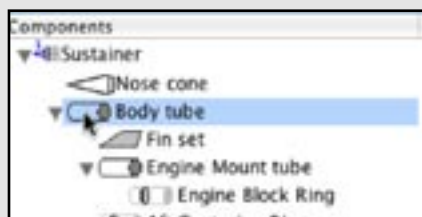
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Questions and Answers

A question that pops-up every now and then is, "Is there a way to copy components from one design to another? For example, I want to use fin can of a 4" rocket as the booster for an already complete 3" rocket."

The answer is yes. Select the component you want to transfer. Highlight it in the parts tree. From the edit menu, choose "COPY." Open the new design. Select the location in the rocket you want it to go to. Again from the Edit menu, select "PASTE."

You may need to go back and edit some components. For example, you'll have to change the 4 inch tube to be 3 inches, but all the internal components and the fin shape will stay the same.

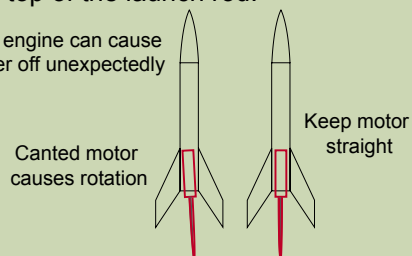


DEFINING MOMENTS

A **Canted Rocket Engine** has a rocket nozzle whose center line does not lie on, or parallel with, the center line of the of the main body tube, but is tilted (canted) at some angle. As you can see in the illustration, if your motor is canted or off the centerline of the model, the fins will have to be much larger to provide the restoring force needed to overcome the unbalanced force of the engine.

This is why you should always keep the thrust forces concentric with the centerline of the model. Otherwise, the model may become unstable as soon as it clears the top of the launch rod.

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continued from page 3



Figure 4

Rocksim File Modification

I used a word processor to add four blank spaces in front of every line in the RockSim xml file that specifies the aft transition (and its associated motor mount) on the dart. I also added these lines ahead of the last two lines for the forward transition on top of the dart's airframe tube. This makes the transition an inside assembly. Here are the details of what the file looked like before and after modification with the word processor.

Before modification:

```
.....</FinSet>
.....</AttachedParts>
.....</BodyTube>
.....<Transition>
.....<KnownMass>0.</KnownMass>
.....<Density>128.148</Density>
.....<Material>Balsa</Material>
.....<Name>Transition</Name>
.....<KnownCG>0.</KnownCG>
.....<UseKnownCG>0</UseKnownCG>
.....<Xb>0.</Xb>
.....
.....
.....
.....<AttachedParts>
.....<BodyTube>
.....<PartMfg>Estes</PartMfg>
.....<KnownMass>0.</KnownMass>
.....<Density>1121.29</Density>
.....<Material>Paper</Material>
.....<Name>Dart Motor Mount</Name>
.....
.....
.....<IsInsideTube>1</IsInsideTube>
.....<AttachedParts>
.....</AttachedParts>
.....</BodyTube>
.....</AttachedParts>
.....</Transition>
.....</Stage3Parts>
.....<Stage2Parts>
```

After modification:

```
.....</FinSet>
.....<Transition>
.....<PartMfg>Custom</PartMfg>
.....<KnownMass>0.</KnownMass>
.....<Density>128.148</Density>
.....<Material>Balsa</Material>
.....<KnownCG>0.</KnownCG>
.....<UseKnownCG>0</UseKnownCG>
.....<Xb>177.8</Xb>
.....
.....
.....
.....<AttachedParts>
.....<BodyTube>
.....<PartMfg>Estes</PartMfg>
.....<KnownMass>0.</KnownMass>
.....<Density>1121.29</Density>
.....<Material>Paper</Material>
.....<Name>Dart Motor Mount</Name>
.....
.....
.....<IsInsideTube>1</IsInsideTube>
.....<AttachedParts>
.....</AttachedParts>
.....</BodyTube>
.....</AttachedParts>
.....</Transition>
.....</AttachedParts>
.....</BodyTube>
.....</Stage3Parts>
.....<Stage2Parts>
```

End Results

This produces a file where the transition is at the inside top of the body tube for the boosted dart. The value for Xb (the distance of the transition from the top of the body tube) is adjusted from 0 mm [<Xb>0.</Xb>] to the same value as that of the length of the tube, 177.8 mm [<Xb>177.8</Xb>]. This places the transition back to the aft end of the rocket where it should be, figure 3. You can always manually go back and adjust this value to place the transition where it is needed.

Once the transition is placed inside the tube you will not be able to use the RockSim program to change things like the tail cone's dimensions. You should be able to change everything else in the simulation file

continued on page 5

continued from page 4

except the tail cone transition that was created outside of RockSim using a word processor. This trick will be used in part four of my short wide rockets simulation series. This is the method I came up with to simulate the base drag caused by the upper disk on a spool rocket design.

Simulation Problems?

But there still is a problem with the simulation, as the stability effects of the dart's tail cone are apparently



Figure 5

incorporated into the boosted phase of the flight (see figure 5) with the booster section in place and a D12-0 motor installed (CG 376.50 mm and CP 538.34 mm, static $C_d = 0.856$). Compare this to figure 6 with the booster section in place and a D12-0 motor installed (CG 376.46 mm and CP 534.10 mm, static $C_d = 0.856$). Since the dart's tail cone isn't exposed until the sustainer phase of the flight, a way needs to be found to eliminate the CP effects of the dart's tail cone from the boosted phase of the flight. You can see the effects of the dart's tail cone by looking at the simulation files of just the boosted dart and the dart without the tail cone.

Figure 7 gives a simulation of just the boosted dart and yields a stability margin of 9.21 with respect to the



Figure 6

diameter of the base of its nose cone. This is real (or true) center of pressure of the dart including its tail cone. Note that the simulation with the inserted tail cone in figure 8 at least gives the correct stability margin for the dart.

However, the simulation in figure 9 of the full configuration (booster plus boosted dart without the tail cone, D12-0 motor installed) gives a stability margin of 11.41 with respect to the diam-

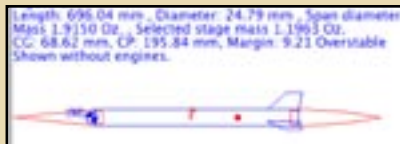


Figure 7

eter of the booster's body tube or air frame. This should be the CP of the full configuration even after adding the buried tail cone to the dart.

The simulation with the intercalated tail cone in figure 5 (with stage 2 selected, booster plus boosted dart with the tail cone, D12-0 motor installed) gives a different stability margin, 11.71, for the full configuration indicating that the tail cone from the dart is playing some role in this calculation. Thus an additional correction to the full configuration (booster plus dart) needs to be made.



Figure 8

Figure 9 shows a simulation of the full configuration (booster plus dart) with the tail cone, D12-0 motor installed, giving a stability margin of 11.41. This indicates that the tail cone from the dart is playing some role in this calculation. Thus an additional correction to the full configuration (booster plus dart) needs to be made.

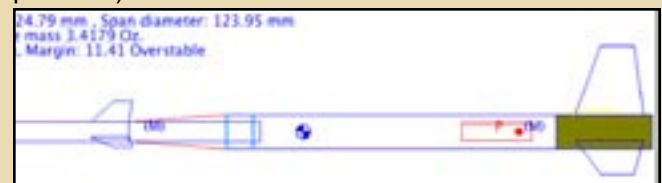


Figure 9

Cancelling CP Effects

This next file (figure 10) is one where I compensated for the effects of the buried dart tail cone in the booster section by adding yet another inside transition, this time to the booster stage, to cancel out the CP effects of the dart's tail cone. The inside transition was added in the same manner as the tail cone for the boosted dart above. To start with, I created a mass-less transition of the same length but with the forward and aft diameters reversed from those of the dart's tail cone. X_b was adjusted so this new internal transition completely overlays the dart's tail cone. I then adjusted the aft diameter of the tail cone in the booster until the CP of the full configuration (with tail cones included) matched that of the simulation from figure 3 (with stage 2 selected). This gives a full configuration with a CP of 534.1 mm (as it should be) and a dart with a CP at 195.83 mm as in the dart only simulation file figure 2.

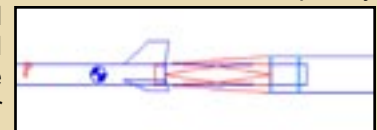


Figure 10

A Special Dart Motor

For these simulations I also created a dart motor according to the instructions outlined in Apogee Technical Publication #14: Software Simulation Tricks at: http://www.apogeerockets.com/technical_publication

continued on page 6

continued from page 5

[14.asp](#). I also included a 13mm motor mount in the dart for this motor so the simulation would run correctly. In addition, I used the RockSim equations for the static CP estimation and flight equations. For more information about the RockSim equations visit the Apogee web site at: http://www.apogeerockets.com/rocksim.asp#design_process

The dart's tail cone in figure 11 does not have any effect on the CP of the configuration with the booster in place. To compensate for the dart's tail cone CP on the full configuration I added another transition in the opposite orientation to the booster stage. This effectively subtracts back out the change in the CP due to the dart's tail cone. This gives the full configuration (dart plus booster) the correct CP and when the dart separates, the CP for the tail cone automatically gets added back in to the dart's CP!

Note that the Coefficient of Drag (C_d) for the full rocket configuration (stage 2 selected) in figure 3 is identical to that of figure 11 at every speed. The differ-

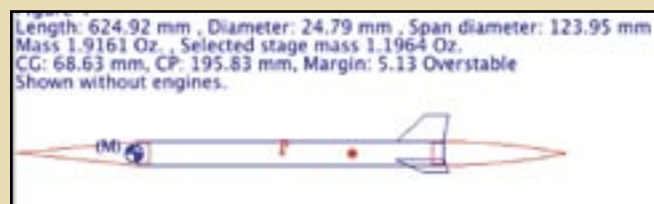


Figure 11

ence between these two files is that figure 3 is the full configuration without the added internal transitions and figure 11 is the same full configuration with the added internal transitions (one is the dart's tail cone and the other compensates for the dart's tail cone C_d in the booster stage). So, there is no effect from the dart's tail cone on the full configurations C_d .

The C_d for the dart in figure 12 (same length tube in place of tail cone) is 0.817 static and for the dart in file figure 1 (with tail cone) 0.734 static. So the tail cone does reduce the C_d on the dart by a significant amount! Make sure you click on the 1st stage configuration button on the right side of the drag analysis menu to view only the C_d of the dart.

You can simulate a recovery device in the booster! John Manfredo wrote this up in a recent Apogee *Peak of Flight* Newsletter at: <http://www.apogeerockets.com/education/downloads/Newsletter153.pdf>.

To simulate the booster falling away at motor burn-out, a zero delay motor must be specified in the booster, along with the Flight Events set to deploy the booster

recovery device at staging. The Flight event for the dart's recovery device is then set to deploy at apogee.

This completes another simulation article that



Figure 12

bends the RockSim program into doing something it was not designed for. There is no qualification statement in this article since the corrections made yield results that are the same or agree with simulation files for either the boosted dart alone or the booster and dart coupled together without an intercalated tail cone. This article shows how to create a buried transition and account for its effects during staging. This technique will be used in a fourth coming article on the simulation of spool rockets.

You can download the RockSim files for the images used in this article. They can be found at: http://www.ApogeeRockets.com/education/downloads/nested_boattail.zip

About the Author

Bruce S. Levison (NAR #69055, MTMA #606) is a rocketeer from Ohio and a member of the National Association of Rocketry (NAR). 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.



TIP OF THE FIN

Do you need the clean your launch system's igniter clips?

Visit your local hardware store's plumbing section and pick up some plumber's sanding cloth (emery cloth). This rough stuff will take the crud off the clips faster than you can say '5, 4, 3, 2, 1.....Launch!'

Coloring Contest Winner

Clint Underwood



Apogee put on a coloring contest at the I Hobby Expo. We handed out coloring books with scenes like this one, and let the kids go wild. The prize for the contest was a complete rocketry starter set.

We sifted through many outstanding entries and finally chose one we thought showed the greatest creativity. Congratulations Clint Underwood, we really enjoyed your picture. The graphics on the rocket really put this one over the top. We will be sending you your starter set very soon!

Web Sites Worth Visiting



Our website for this issue is that of Creston Aeronautics and Space Association at

www.crestonaerospace.org.

Their mission is to promote and encourage education in science, technology, engineering and math (STEM) through hands-on design, construction and testing of real-world aerospace technologies.

President Dave Springer says, "My experience is that there is an enthusiastic reception to rockets in the schools - especially at middle school and freshman/sophomore high school - and getting RockSim into the classroom and even integrating it into a curriculum is usually not the hard part. The difficulty comes in keeping the kids interested once they build and fly a rocket. This works about two times



and then it's hard to keep the kids motivated to do more experiments.

For the upper-level high school project, they built a larger rocket that flew on 3 K-550 motors. They used RockSim for the original design of the airframe, in conjunction with other CAD programs for the internal parts.

Dave states, "I think we would have the most impact at the middle school level, grades 7 and 8. This seems to be where we lose the kids from a STEM track, the girls lose interest in math and science and the boys get distracted by video games. I think the social aspects of school overwhelm the kids at these ages, and STEM takes a far back seat. If we can hold their interest through these years, then I am convinced the kids will go on to follow a STEM track in high school and beyond. Flying rockets that you design and build yourself can play a big part in this."



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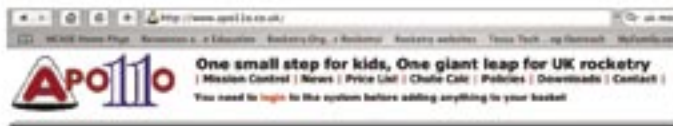
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