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PEAK OF FLIGHT

NEWSLETTER

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Can You Hear The Sonic Boom of a Rocket?

Cover Photo:
Quest Big Dog rocket kit. Get yours at:
www.ApogeeRockets.com/Quest_Big_Dog.asp

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3355 Fillmore Ridge Heights
Colorado Springs, Colorado 80907-9024 USA
www.ApogeeRockets.com e-mail: orders@apogeerockets.com

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Can You Hear The Sonic Boom of A Rocket?

By Tim Van Milligan

Andrew Metanias asks: *"I ordered the Dr. Zooch Saturn V kit a little over a week ago and at the end of the instructions, it said that the rocket goes over 800 feet high and 1144 feet per second on a C6-5. Are they just telling me a bunch of junk to try to make the rocket look cool, or is this really true? 1144 fps is 780 mph. Thats about 20 mph more than the speed of sound (depending on the temperature). It's hard for me to believe that the detailed Saturn V can break the sound barrier. If anything does go the speed of sound, when it makes a sonic boom and it's that close by, don't you have to wear earmuffs or something like that because the sonic boom is extremely loud? Please let me know because I am unsure if I should get a set of C6-5's for this kit or not."*

I don't have a copy of the instructions for the Dr. Zooch Saturn V kit (www.ApogeeRockets.com/Dr_Zooch_Saturn_V.asp) with me. But I'm pretty sure that the maximum speed that you mention of 1144 feet per second is a typo. When I run a RockSim simulation (www.apogeerockets.com/rocksim.asp) for the kit, I come up with a maximum speed of about 184 miles per hour (Mach 0.24). But a max altitude of 800 feet is pretty close to what I see from RockSim.

With that out of the way, your next question about sonic booms is a good one. A lot of people ask the question about whether or not you can hear the sonic boom made by a model rocket. So I'll try to answer it with a bit more detail than with a simple "yes" or "no".

Before I begin, isn't it cool to be in the only hobby in the world that you can get something that you've built with your own two hands to go faster than the speed of sound? No one has done it in RC airplanes, trains, or even any other affordable hobby that I know of. In rocketry, supersonic speed is achievable by almost anyone with good construction skills. You can do it! See our report about how to build a supersonic rocket, like the Apogee Aspire rocket kit. You can download it from our web page: www.ApogeeRockets.com/aspire_rocket.asp

First, where does the sonic boom come from?

It comes from a unique property of air. Air can be both incompressible and compressible. What does that mean? Good question.

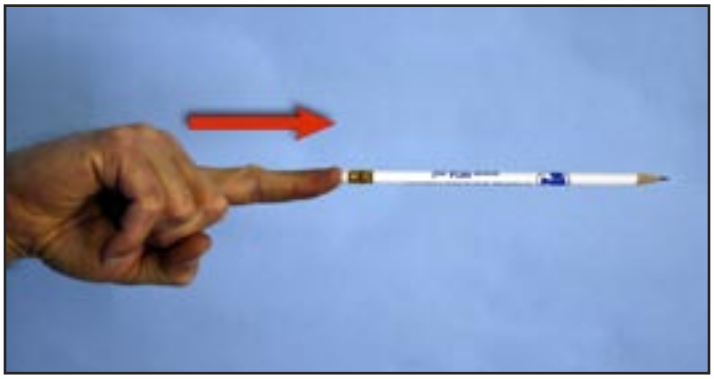

Figure 1: When you push on an incompressible object, the molecules at the point feel the same push and move at the same speed as the molecules on the back end.

At low air speeds, air acts like an incompressible material, sort of like a solid object. As shown in Figure 1, when you push on an incompressible object like a pencil, the molecules at the point feel the force and move at the same speed as the molecules at the base where you doing the pushing.

In rocketry, as the rocket is ascending into the air, the air molecules ahead of the rocket see and feel the rocket coming. They are pushed forward too. This happens at rocket speeds at which most small models fly.

But if you push hard enough on the rocket and get it going faster, eventually the air molecules don't push the ones way out in front. It is sort of like pushing on the end of a string; somewhat spongy and the molecules start going sideways instead of straight forward. Now you're in what is called the transonic region of flight. The rocket is going over 500 miles per hour. In this region, the molecules are beginning to stack up because they can't get out of the way fast enough.

Push even harder, and now the air molecules can't move fast enough and really compress hard against each other, forming a wall.

It gets harder and harder to push against this wall. The rocket really feels this too, in the form of extreme drag.

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Newsletter Staff

Writer: Tim Van Milligan
Layout / Cover Artist: Tim Van Milligan
Proofreader: Michelle Mason

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You might equate it with trying to poke your finger into a balloon. It is very hard to penetrate it, and the point of your finger creates a conical depression into the rubber.

It is very hard to push a rocket past this point, but it can be done with enough thrust. That's why to achieve supersonic speeds, you need a really high thrust motor.

The sonic boom is a pressure wave made up of this wall of stacked-up air molecules. When the wave goes past your ear, there is a very sharp but very brief sensation of sound as it rattles the bones in your inner ear. That's why you would hear the pop or the boom.

But the question is, "is it possible to hear the boom?"

Theroretically, yes. It is possible for you to hear it, but it is not likely. The conditions must be optimized.

Figures 2 through 4 show the situation and why it is not likely that you'll hear the boom. As the rocket takes off it gathers speed. But it doesn't go supersonic immediately. At some altitude, the rocket exceeds Mach 1, and the shock wave immediately forms and starts propagating away from the rocket. The shock wave moves like a ripple in a pond

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Figure 2: The rocket lifts off and gathers speed as it burns propellant. Figure 3: The rocket surpasses the speed of sound. A shock wave forms and propagates outward away from the rocket. Figure 4: Motor burnout. The speed rapidly decreases. The rocket drops down below the speed of sound. The shock wave ceases at that point, but still propagates outward.

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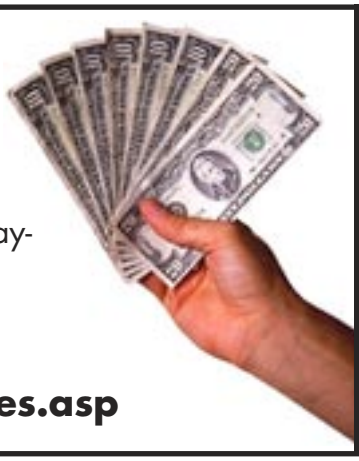

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from a single drop of water. The only difference is that as the rocket moves forward, a new wave forms. Like running your finger along the surface of the water at high speed, the wave forms a "V" shape. But in this case, since we're in a 3D space, it is actually a cone, as shown in Figure 3.

In Figure 4, the rocket motor burns out. But the rocket will still have a lot of speed, and may still be coasting above Mach 1. But it will quickly drop below Mach 1 because the drag force is intense at supersonic speeds.

As soon as it drops below Mach 1, the shock wave is no longer produced by the rocket. But the ripples of the shock wave that was created earlier are still moving out perpendicular from the rocket's path.

The reason you don't typically hear the sonic boom is that the shock wave is above your head, and moving parallel to the ground. It never goes past your ear, so you probably won't hear it.

It is like the old philosophy riddle: "If a tree falls in the forest and no one is around, does it make any sound?" Sound is only sound if your ear hears it and registers the noise.

It is the same with the sonic boom. It is there, but your ear is not in the right place to hear it.

How High Up Does The Boom Begin?

We can get a pretty good estimate of how high your rocket might be when it goes supersonic by running a simulation in RockSim.

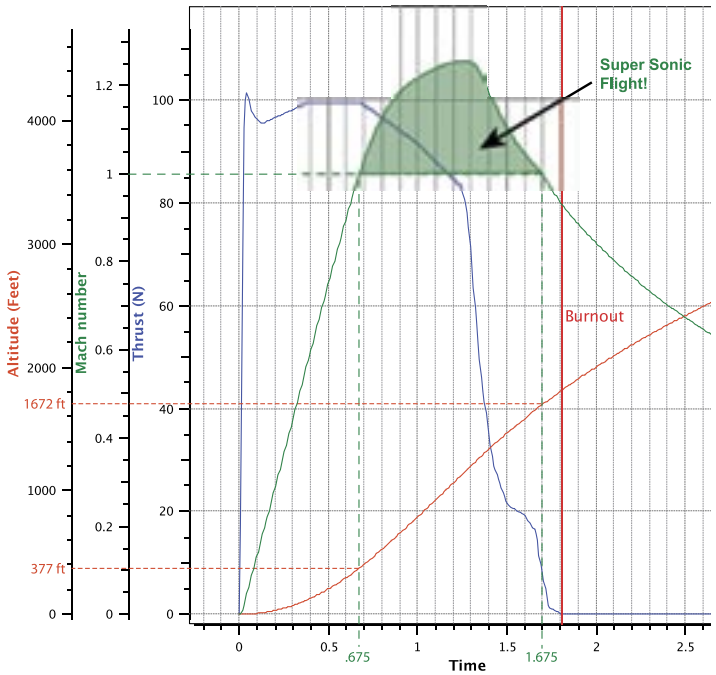

Figure 5: Plot from RockSim of the Apogee Aspire rocket kit on a G80 motor. The rocket is supersonic any time the speed is greater than Mach 1.0

Figure 5 shows a graph that was generated after running a launch simulation for a rocket that went supersonic. I plotted out Thrust, Mach Number, and Altitude on this particular graph.

The rocket simulated was the Apogee Aspire (www.

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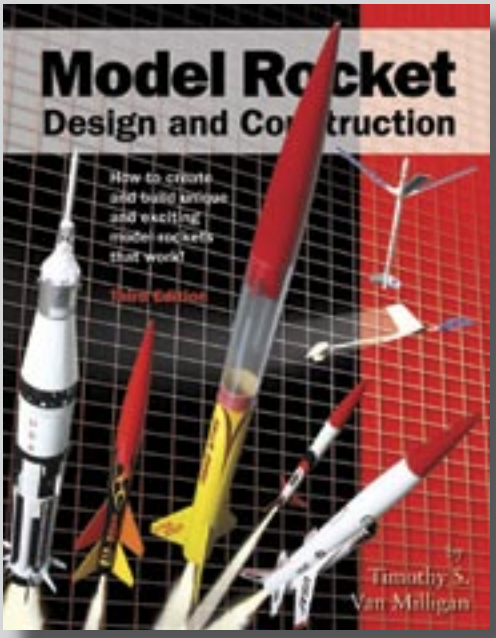

Model Rocket Design and Construction

By Timothy S. Van Milligan

New 3rd Edition Now Shipping!

This new 328 page guidebook for serious rocket designers contains the most up-to-date information on creating unique and exciting models that really work. With 566 illustrations and 175 photos, it is the ultimate resource if you want to make rockets that will push the edge of the performance envelope. Because of the number of pictures, it is also a great gift to give to beginners to start them on their rocketry future.

For more information, and to order this hefty book, visit the Apogee web site at: www.ApogeeRockets.com/design_book.asp

Apogee Components
3355 Fillmore Ridge Heights
Colorado Springs, Colorado 80907 USA

telephone: 719-535-9335
website: www.ApogeeRockets.com

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ApogeeRockets.com/aspire_rocket.asp) launched on a G80-10 rocket motor. From the chart, start by drawing a line horizontally from Mach 1.0 on the velocity scale. Anything greater than this is in supersonic flight regime. By doing this, you can see when on the timeline the rocket is flying above Mach 1. In Figure 5, this particular rocket is supersonic for exactly 1.0 seconds, from .675 seconds until 1.675 seconds.

At .675 seconds, you can then find out from the graph the approximate altitude the rocket was when it broke Mach. In this case, the rocket was 377 feet up. That is pretty far from your ear at ground level, wouldn't you say?

The rocket fell back below Mach 1 when it was 1672 feet up in the sky. In one second, it travelled 1292 feet!

There is one other thing I want you to notice from this particular plot. If you look where burnout is, you'll see that the rocket was back down below supersonic speeds even before the motor had consumed all its propellant.

The reason for this is that the motor's thrust tails off slowly, even though it looks like it drops off in thrust rather quickly. That tail-off means the rocket isn't pushing hard against that wall of air molecules, and the air wins rather quickly.

How can you hear the boom?

To put conditions in your favor where you can hear a boom, you really need the rocket to be travelling horizontally, as shown in Figure 6. When a rocket is launched this way, that shock wave cone will actually intersect with the ground. And if you're standing under it when it goes over your head, there is a better chance of hearing the boom.

BUT...

You knew there was going to be a "but" didn't you?

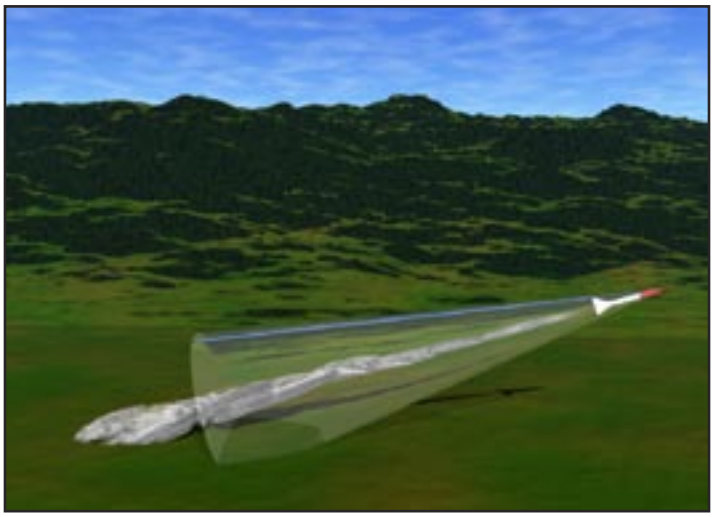

Figure 6: To get the shock wave cone to intersect the ground, you'd have to launch the rocket nearly horizontal, and you'd have to be standing below the rocket when it exceeds Mach 1.

Obviously, this is a major-major safety hazard and would violate the model rocketry safety code of launching the rocket past 30° from vertical. Don't ever do it in real life! Just use RockSim to simulate it.

In Figure 7, I ran the simulation identical to that done in Figure 5, with the exception that the launch angle was changed to 15° from horizontal instead of going straight up.

A lot of things are similar. The rocket reaches Mach 1 at .675 seconds into the flight. At that point in time, we read from the graph that the rocket is at an altitude of 89 feet, and is downrange 361 feet.

Therefore, if you wanted to hear the boom, a good place to stand would be about 375 feet downrange, and fire the rocket over your head.

Oh... By the way, you won't hear the rocket coming, so

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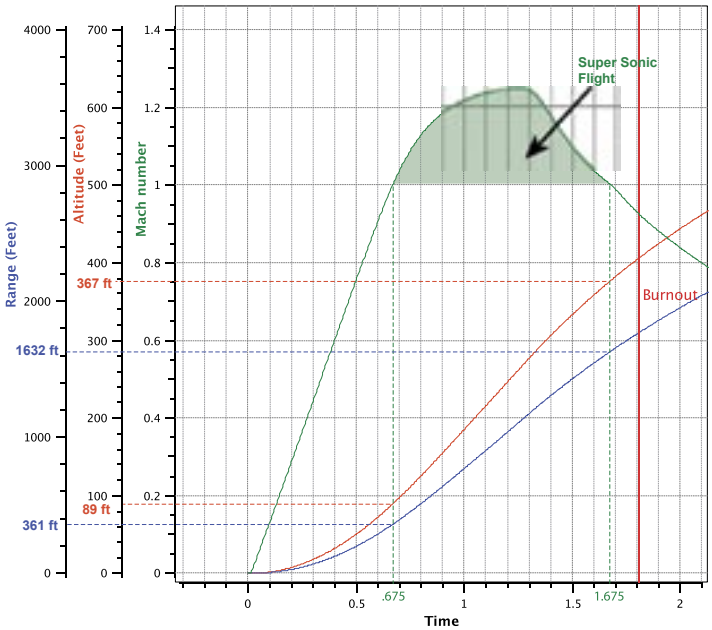

Figure 7: Apogee Aspire rocket launched 15° from horizontal to find out where to stand to hear the boom.

be sure to have a walkie-talkie radio so you can hear the countdown (so you know when to duck and cover). As we mentioned, it is going to be over your head in 0.675 seconds. Incidentally, how fast can you run if the rocket should veer off course and head towards your head?

Besides that, look at where the rocket is from the pad at engine burnout. It is over 1771 feet downrange, and still moving "like way too fast." I can't over emphisize how dangerous this situation is, and why the model rocket safety code makes so much sense.

One Last Problem...

There is one last problem that probably will prevent you from hearing a definite pop or crack of the sonic boom. That is the roar of the rocket motor.

When that rocket zooms past your head, it is making the shock wave. But notice that the motor is still burning with an awesome amount of thrust. The sound wave from the motor is only inches behind the sonic boom, and travelling at the same speed (Mach 1 of course).

Did you ever notice how loud a high-thrust motor really is? A lot of people cover their ears, and for good reason.

So if the roar of the motor is so loud, and arrives at your ear at nearly the exact same time as the pressure wave from the rocket, you have to ask yourself: "Is it really possible to distinguish the pop from the sound of the motor?"

Ideally, you'd want to find a motor that burned out before the rocket drops out of super sonic flight. But then you'd be further down range, and the rocket would be higher in the sky when it went overhead.

As you can see, there are a lot of variables to play with. That is what makes this exercise so fun, and RockSim so valuable. I hope you'll give it some additional thought and

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try out a number of different size motors and launch angles. Be sure to look at the 2D flight profile, since you try to fire the rocket horizontally, gravity is still pulling it down and it could be buried in the ground before it reaches you to hear the shock wave. A rocket launched perfectly horizontal doesn't go very far because gravity is still pulling down at 32 feet per second per second. In 0.675 seconds, the rocket will have fallen 21 feet. In other words, it will have buried itself in the dirt even before it reaches supersonic speed.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes 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. 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. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and the curator of the rocketry education web site: http://www.apogeerockets.com/education/. He is also the author of the books: *"Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics"* and publisher of a FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site or by sending an e-mail to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.

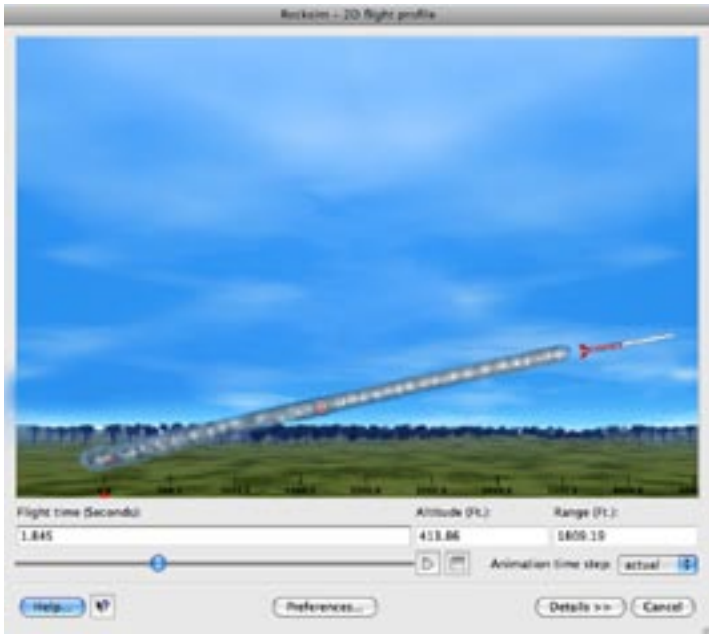

Figure 8: When running simulations, be sure to check the 2D flight profile to make sure the rocket isn't on the ground before burnout.