A LETTER TO THE TECHNICAL EDITOR

(Editor's note: This letter was originally written to NAR President Jim Barrowman, and then forwarded to Pat Stakem.)

Dear Jim,

I am seeking your help on a project I am about to undertake for school. For a semester project in Physics I plan to attempt to fire a rocket at or beyond Mach 1.

My major problem at this time is the design of the rocket. I understand that strange things happen to the CP and CG near the speed of sound. I need to know what this will do to the stability of the rocket. Must I make the rocket "super stable" by increasing nose weight, or will the rocket remain stable at this speed even though the CP may be ahead of the CG?

Also, I need an accurate and reliable method of determining the CP and CG. I understand that you have done some work on this subject. How can I find out about it? I also need to find the best design for this rocket. What fin shape would be the best: elliptical or clipped delta—or neither? What about the best ratio ogive for the nose cone at this speed? Will the Mach 1 design hinder the rocket at subsonic speeds?

Has there been any documented research in this area by anyone else?

If you could answer these questions directly or refer me to a source for the answers I would certainly appreciate it. My project is due in December, so please answer me promptly.

At the present time I am planning a two stage rocket using single F engines. I will probably use FSI Fs unless Enerjets prove to give me a better acceleration.

Thanks!

Sincerely,
David M. Scott
Apollo/NASA
Houston, Texas

Dear Dave,

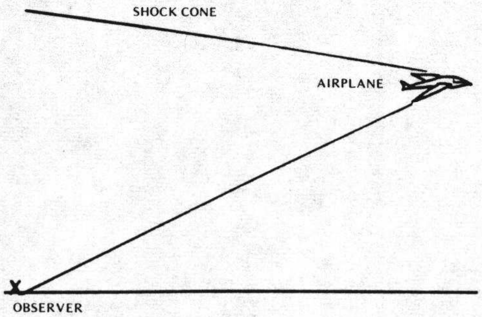
Your letter was referred to me by NAR HQ for answer.

I think the best you'll get from a Mach 1 modroc project is a design analysis. There have been reports of breaking the sound barrier, but they are not supported by hard evidence. I looked at the problem a few years ago and decided that it could be done by firing the vehicle down from a height so that gravity helps and doesn't hinder; obviously, this shouldn't be attempted from a safety standpoint.

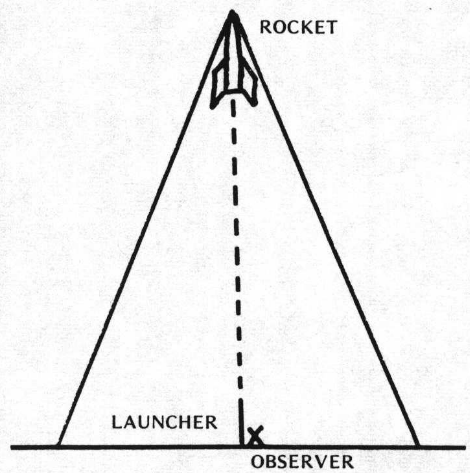
True, strange things happen to CP/CG during near-sonic flight. That's the least of your worries. The average model rocket will exceed the "speed of balsa" before it approaches Mach 1. Aerodynamic heating becomes a severe problem at these speeds because the heat generated in the vehicle by the impacting air molecules can't be dumped fast enough. Thus, epoxy coatings must be used on leading edges to prevent charring and burning.

As you mention, the aerodynamics of a vehicle designed for transonic flight differ from those of a subsonic vehicle. Thus, something designed for breaking Mach 1 may be unstable at lower speeds. Close to Mach 1, the drag force goes up as velocity raised to the third, or even higher, power, so normal modroc velocity/altitude calculating programs don't give accurate answers.

Lastly, the biggest problem. How do you know the vehicle has achieved Mach 1? The sonic boom? Well, you hear an airplane because the disturbance cone intersects the ground:



But for a rocket in vertical flight, you would't necessarily hear the shock:



As for your specific questions, the best nose cone shape would probably be conical, and the fins should be thin wedges instead of the standard symmetrical airfoil.

I didn't mean to discourage you, but I hope I pointed out some of the problems involved, and the areas you should look into. Data really doesn't exist. What is the CP shift for a model rocket from .9 Mach to 1.1 Mach? No one knows.

When you do get a transonic flight documented, send me the report for publication in the *Model Rocketeer*.

Yours truly,
Pat Stakem

P.S. I just talked to Jim Barrowman, and got this additional information. His CP report assumed, essentially, that Mach number approached zero.

The key lies in the $C_{N\alpha}$ term for the fins. Actually,

$$\overline{C_{N\alpha}} = 2\pi(AR) \times (A_{fin}/A_{ref}) \,/\, \left(2+\sqrt{4+\beta(AR)/\cos\gamma}\right).$$

$$AR = \text{aspect ratio} = \frac{2 \times \text{Span}^2}{\text{Area of fin}}$$

$$\beta = \sqrt{1-\text{Mach } \#^2}$$

γ = average sweep angle of fin

A_{ref} = reference area of vehicle = area of nose

Essentially the CP moves aft, making the vehicle more stable. If you can use this modified C_α fins in Barrowman's equations to get a two caliber or better static margin the bird should be stable at Mach 1. No guarantee beyond.