STREAMER DURATION OPTIMIZATION

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The introduction of the Streamer Duration event into NAR competition has brought about extensive but unsystematic attempts by various modelers to determine exactly what combination of streamer and model is most likely to win this event. Each person has his own ideas about what is best, and no two entries seem alike in body, streamer, or attachment mechanism design. We have conducted tests to determine the optimum performance design.

The selection of a streamer design for a particular class of SD is basically a compromise between small size (for minimum rocket size) and high drag (for lowest fall rate). A common mistake is to design for minimum fall rate, without regard for the fact that this may cost so much in altitude capability that the rocket's total duration will be small.

The tests on which this project's results are based were of two types—indoor drop tests and outdoor flight tests. The drop tests were made down an air shaft with an 18-gram, 19 mm rocket body containing a burned-out standard engine. To this were attached at various times crepe paper, ¼-mil aluminized mylar, and 0.4-mil polyethylene streamers of 2, 4, and 6-inch widths, each in 54-inch, 108-inch, and 162-inch lengths. Each of these twenty-seven configurations was dropped at least three times, with the rocket body exactly 50 feet from the ground each time, and with the streamer fully unrolled. The results are presented in Figure 1. They indicate the following:

1. crepe paper streamers have higher drag than mylar or polyethylene ones of the same size;
2. increasing the width of any streamer increases its drag;
3. increasing the length beyond ten times the width (the NAR-set minimum ratio) increases the drag of mylar and polyethylene, but not of crepe paper;
4. 0.25-mil mylar and 0.4 mil polyethylene are almost equal in drag for every size.

It is not particularly instructive to compare the performances of equal areas of various materials; more important are the relative performances of streamers whose volumes when rolled and in a body tube are equal. We found that we could get more than 40 inches of crepe paper into a CMR-RB-50 body tube (diameter 13 mm), and 60 inches into a CMR RB-74 (19 mm). The mylar is thinner, but harder to roll; we got 110 inches into the smaller tube and 250 inches into the larger. By NAR rules, the 40-inch streamer could only be 4 inches wide; all of the others were 6 inches wide. Greater widths, while legal for the mylar streamers, seemed impractical because of their weight and the size of the rocket necessary to hold them.

The following weights per area were measured for the various materials tested:

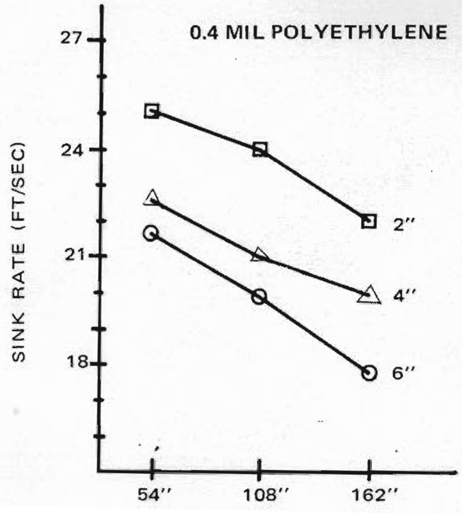
Crepe paper from a 26-inch wide sheet	2.5 g/100 sq. in.
Crepe paper from a 2-inch wide roll	1.8 g/100 sq. in.
0.25-mil aluminized mylar	0.59 g/100 sq. in.
0.4-mil polyethylene	1.05 g/100 sq. in.

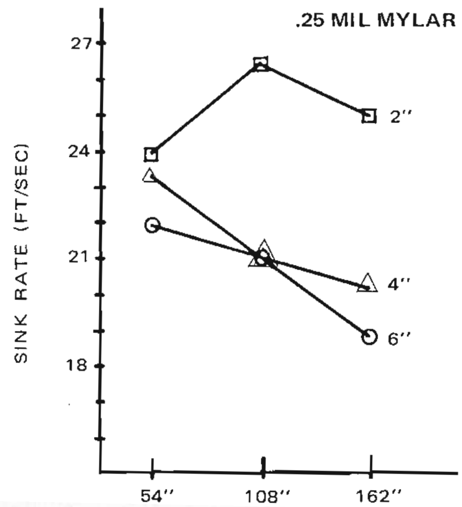
These weights were then added to an assumed basic airframe weight of 6 grams for a 13 mm diameter contest model and 11 grams for one of 19 mm and to the average flight weights of ½A, A, and B regular and mini engines, and C regular engines. The peak altitude to be expected from each engine-streamer configuration was computed from Malewicki-type graphs, with both the largest possible streamers and very small (2 x 20 inches) ones being considered, the latter to determine if their higher fall rate would be offset by the increased altitude made possible by their reduced weight. The expected flight durations were computed from these altitudes and from the fall rates observed in the drop tests. The fall rates were assumed to vary linearly with the ratio of the drop-test rocket's no-streamer weight (18 grams) to that of the test rocket; i.e., a rocket weighing 9 grams (with expended engine) would fall half as fast as the drop-test graphs indicate.

From these calculations, we obtained the following general recommendations for SD models of the various classes:

Class 0 (½A): mini-engine, 13 mm body tube, 4 x 40 inch crepe paper streamer
Class 1 (A): mini-engine, 13 mm body tube, 4 x 40 inch crepe paper streamer
Class 2 (B): mini-engine, 13 mm body tube, 4 x 40 inch crepe paper streamer
Class 3 (C): regular engine, 19 mm body tube, 6 x 60 inch crepe paper streamer

Eight flight tests made with ½A engines in a 13 mm rocket established that a 4 x 40 inch crepe paper streamer is by far the best design for a Class 0 rocket; calculations before hand had indicated that the lighter 2 x 20 inch crepe streamer might equal it. The larger streamer turned in times 30 percent greater. Ten tests with A engines indicated that a 4 x 40 inch crepe paper streamer outperforms a 6 x 110 inch mylar one for that class by 15 percent, resolving another situation where the calculations gave no clear choice. The calculations indicated no uncertainty in the streamer choice for Classes 2 and 3; the large crepe paper streamers were clearly superior. Repeated flight tests were not possible here because of launch site limitations, but one of the authors (Barber) has flown Class 2 SD three times over the past several months using the above recommendations, and has turned in times of 90, 125, and 168 seconds. The last two were not recovered. These times are greatly superior to the average times of every other streamer-body design in current use.





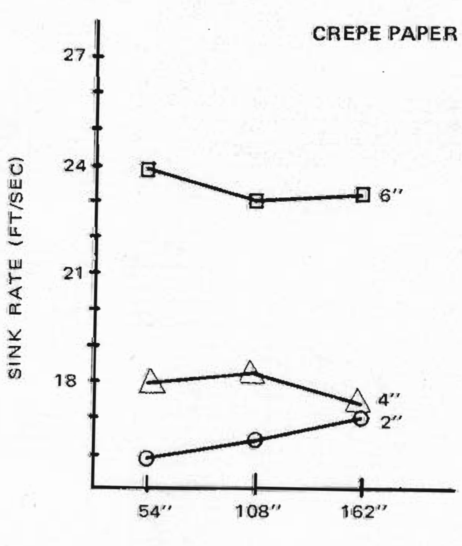


Figure 1 — SINK RATES OF 18MM DIA MODEL WITH VARIOUS STREAMERS

There are several ways in which the performance of Streamer Duration models may be further improved while keeping within Pink Book regulations. The most effective of these is to use an external recovery system anchor. This should be attached at the burnout CG of the model with streamer removed. The only good place to make this attachment is at the root of the fin, but this is probably very close to the burnout CG of a lightweight duration model, anyway. The attachment point should be well reinforced with epoxy. A piece of shroud line or similar sturdy material (not thread or nylon monofilament) runs from here, parallel to the length of the rocket, through a groove in the shoulder of the nose cone, to the inside of the model, where it is attached to a piece of shock cord, the nose cone, and the streamer shroud line, in that order. With this system, the rocket will come down sideways, and the drag on it tends to lift the bottom edge of the streamer and create a bow in it. This increases drag and duration greatly. It also leaves the inside of the body tube free of impediments to the easy exit of streamer, so a larger streamer can be used.

The performance of a crepe paper streamer may be considerably improved by rolling kinks and wrinkles into it when packing it, and by always using fresh paper; old paper stretches and loses its drag-producing wrinkles, particularly in moist weather. To pack a crepe paper streamer tightly, roll it up on a hard surface, exerting considerable pressure on the roll with your fingertips as you do so.

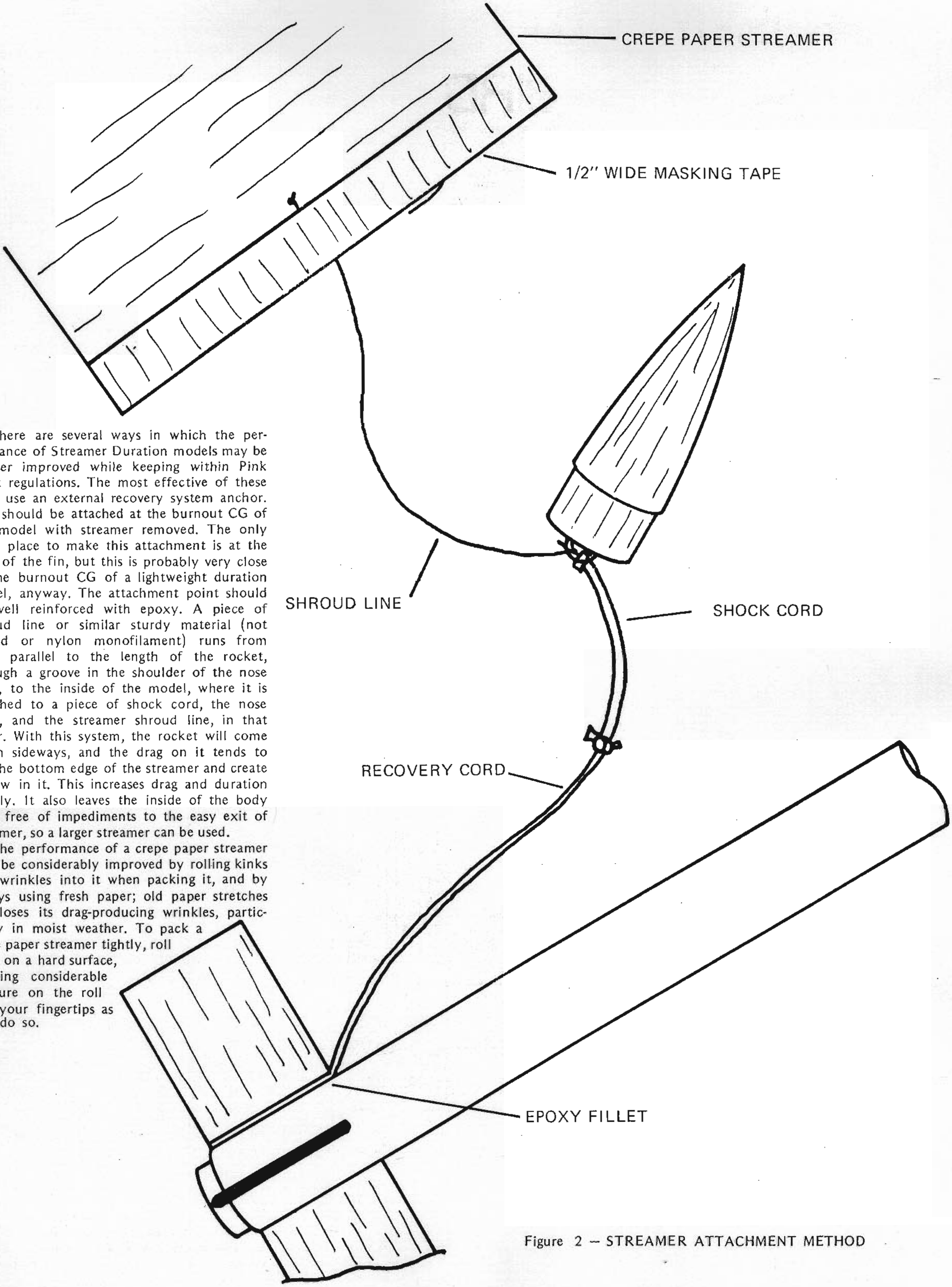


Figure 2 – STREAMER ATTACHMENT METHOD

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Winning Streamer Duration

Streamer Duration was introduced as an NAR contest event as an easy-to-run substitute for altitude events. Its inventors felt that most streamers were roughly equal in performance, so that the rocket with the best duration should also be the one that went the highest. Unlike FAI SD, however, the NAR version does not specify that all contestants must fly the same size streamer, so the door was left open for US model rocketeers to develop it into a duration event of considerable sophistication, and they have done so. This article summarizes my observations of what has won consistently at contests in the past seven years, and incorporates the results of research on streamer performance conducted by Chris Flanigan, Tom Milkie, and myself. Because SD is a duration event, the elements of chance and weather will sometimes determine who takes first place in competition, but just as in all duration events skill will still greatly improve a rocketeer's chance of winning.

The most important rule of all for SD is the one its inventors intended: design for maximum altitude. Use the smallest-diameter engine availabe for the power class (mini-engines for Class 0 to Class 2, 18mm engines for Class 3) and use the smallest-diameter body tube that will hold the engine. Never increase bodv diameter to hold a long streamer; beyond a certain point streamer drag does not increase with length. This will be discussed in more detail later. Every unnecessary gram of mass added to an SD model extracts a double penalty: it reduces altitude on the way up and increases rate of fall coming down. Engines and bodies larger in diameter than the smallest available not only increase frontal area and drag but also add unneccessary mass. As an example of this, in Class 2 SD a good mini-engine contest design would mass about 24 grams at liftoff and go about 460 meters while an 18mm-engine design having the same drag coefficient and streamer would mass about 35 grams and go 320 meters. The larger diameter rocket could hold a much longer streamer, but this would add even more mass and cost more altitude without reducing the rate of fall enough to compensate for the lost altitude. For the same reason, 18mm C engines are better than the 21mm FSI C engines for Class 3 SD. (Actually, the best engine for Class 3 is tandemed B mini-engines, but this is probably illegal since NAR competition rules for SD require a "single" engine.)

Those of you who are familiar with altitude-prediction charts such as the Centuri TIR-100 are aware that there is an "optimum" mass for a given combination of engine and rocket drag form factor, and that rockets massing less than this as well as more will not go as high. In Classes 0 through 2 SD, the minimum practical rocket takeoff masses are greater than these optimums. Before streamer size and mass is increased in these classes it is necessary to decide if the decrease in rate of fall from using a larger streamer will be offset by the substantial reduction in peak altitude from its additional mass. For Class 3, most reasonable competition models using C6-engines will be near the optimum mass (40 grams), so adding streamer mass does not reduce altitude much as long as the total takeoff mass stays below 50 grams.

Naturally, designing for maximum altitude requires careful attention to minimizing drag. A smooth but lightweight finish is important, and the fins should be made of a thin and light material such as 1/16" balsa or 1/64" plywood. Dynamic stability is a major but often forgotten factor in altitude performances. SD models, particularly in Class 3, tend to be tail-heavy and if very small fins are used to minimize drag the rocket may "cone" or wobble on the way up and lose a great deal of altitude even though calculations would show it to be statically stable. Naturally, you should avoid using a launch lug if possible; launch towers are the most reliable substitute. Pop lugs are less desirable because they often lead to tip-off and a non-vertical flight, which reduces altitude. Zero-volume piston launchers are an excellent way to boost performance by 10 percent or more, but only if short guide rails are added to the top to ensure that the rocket does not fly off at an angle because of uneven separation from the piston.

Drop tests and flight tests have shown that the method of anchoring the shock cord to the rocket can greatly affect duration. The standard technique of attaching the shock cord to the inside of the body tube is unsatisfactory for two reasons: it makes the rocket body hang vertically below the streamer, where its area can add very little to the total drag during recovery; and it clutters the body tube, reducing the size of the streamer it can hold and interfering with the smooth ejection of the streamer.

Virtually all winning SD designs today use an "external" anchor, an thin piece of line epoxied into one fin-body joint then led straight up the side of the rocket and through the nose cone-body joint. A loop is made in the end inside the body and a shock cord is tied on. The nose cone and the streamer shroud line are attached to the other end of the shock cord in the normal manner. During descent, the rocket body falls sideways because it is suspended from a point near its burnout balance point. This causes the body's lateral area to add to the total drag during recovery and reduces the rate of fall by 15 percent to 50 percent. The external anchor line must be thin to reduce its drag during boost but also strong and not easily burned by ejection gases. Shroud line and nylon monofilament will not work; I use braided nylon line of the sort used to repair fishing poles. For Class 3 SD, use two pieces of anchor line twisted together for added strength.

Optimizing the choice of material and dimensions of the streamer is the most complex aspect of SD design. NAR rules require that the streamer be rectangular and at least 10 times as long as it is wide, and that it have a single shroud line attached at one narrow end. It must not be glued either, which eliminates pasted-together strips of mylar or tissue. This still leaves a lot of room for innovation.

There are about as many choices of streamer material as there are model rocketeers. Controlled drop tests and flight tests have been done on six that are commonly used: crepe paper from 26" wide sheets, crepe from 2" wide rolls, ¼-mil and ½-mil aluminized mylar, tissue paper, and 0.4-mil polyethylene (cleaner bags). According to these tests, the stiffness of a streamer matieral is much more important than surface roughness in determining how much drag it will have for a given size. Apparently some sort of dynamic "flapping" effect rather than skin friction is the dominant effect in streamer drag. This would explain the importance of stiffness. Measured streamer drag coefficients are at least 10 times greater than the theoretical skin-friction-only values. Typical streamer material densities, which are roughly equivalent to stiffness, are listed in Table 1.

¼-mil mylar and polyethylene are very light materials and they perform very poorly as streamers, even in large sizes. A 6 x 100" streamer of either material falls much faster than a 4 x 40" streamer of crepe, tissue, or ½-mil mylar, and masses more besides! Clearly, these are two materials to avoid. In 4" or greater widths, there is no consistent difference in the rate of fall of crepe paper, tissue, and ½-mil mylar streamers of the same size with the same attached mass, despite their differences in mass per unit area and surface roughness. (Crepe from rolls is the best performer in 2" widths, but this width is seldom used in SD competition).

Comparing streamers of equal size is not very useful for competition. What matters is this: how does the biggest crepe streamer that can fit into a certain size body tube compare to the biggest tissue (or ½-mil mylar) streamer that can go into the same tube? Tissue and mylar are thinner than crepe, and much greater lengths of these two can be rolled into a given body tube. A 13mm body will hold 40" of crepe and at least 80" of tissue/mylar, and an 18mm body will hold 65" and over 130", respectively. Because mass is so critical in SD models, what we have is a tradeoff; increasing streamr size will reduce rate of fall (up to a point), but it will also reduce the altitude from which the rocket will start its descent. It is the combination of these two that determines total duration.

Most rocketeers feel that in streamers, bigger is better. Controlled tests show that this is not true. A streamer should be **as wide as possible**, but making it more than 15 times as long as it is wide will actually reduce performance. The extra material just adds mass and waves uselessly in the wake of the rest of the streamer. A quick rule for choosing crepe, tissue, or ½-mil mylar streamer dimensions is this: use the widest possible 10:1 streamer, then if there is any space left in the body tube, increase streamer length up to a maximum length-to-width ratio of 15:1. This ignores the important effects of the streamer's mass on altitude performance.

MATERIAL	MASS/100 SQ IN
crepe - 26" sheets	2.43 gm
crepe - 2" rolls	1.80 gm
½-mil aluminized mylar	1.16 gm
¼-mil aluminized mylar	0.59 gm
o.4-mil polyethylene	1.05 gm
tissue	1.29 gm

TABLE 1. Streamer material area densities.

For rockets with 13mm body tubes, the largest possible and legal streamers are 4 x 40" crepe and 8 x 80" mylar or tissue. Although the larger mylar and tissue streamers mass more and require a longer and heavier rocket, they fall much slower. For Class 2 SD, the best choice is a 8 x 80" ½-mil mylar or tissue paper streamer. For Classes 0 and 1, a 6 x 60" mylar or tissue is better - the extra mass of the 8 x 80" streamer costs a greater percentage of altitude as engine impulse decreases and its drag is not enough greater than the 6 x 60" to offset this.

Class 3 SD rockets, having an 18mm body, can hold 6.5 x 65" crepe or 13 x 130" tissue or mylar streamers. Continuous single strips of mylar or tissue 130" long are hard to find, and a 13" wide streamer has never, to my knowledge, been tried. It would require an extremely large rocket to hold a streamer this wide, and it is not known if the streamer's drag would compensate for its huge mass. Space Rescue Blankets (the best source of ½-mil mylar) are 84" long, making 8.4 x 84" mylar a logical compromise size for a streamer. I have seen both mylar and tissue streamers of this size win Class 3 SD on many occasions, so this is probably the best choice.

Long tissue and mylar streamers are most efficiently packed by rolling them up on a very thin metal tube or a dowel (launch rods are good also), which is then removed. Using this technique, it is sometimes possible to fold wide tissue or mylar streamers in half and still fit long ones into small bodies, saving several inches of body tube in the rocket. Crepe is best packed by rolling it up with the fingertips on a hard surface, with nothing in the center. Crepe loses its stiffness and falls off in performance when damp or after several uses.

The method of connecting the shroud line to a streamer can have a noticeable effect on performance. The best legal method I have seen and tested is to run a strip of stiff ½" tape across the width of the streamer at one end, then to attach the shroud line with a second, shorter piece of tape on top of this about ½" from one edge of the streamer. This off-center attachment usually causes the streamer to "corkscrew" on the way down. Any lucky combination of weather conditions, folded-in creases, and attachment techniques which makes the streamer go into this sort of motion will greatly increase its duration. So far, no one has figured out how to get a streamer to do this consistently.

The accompanying drawing illustrates the various design techniques discussed in this article and is typical of current winning competition designs.

From Ellis Lee Knox, Houston, TX:

I'm sure that everyone has found a use for old motor casings. Here's one more. Cut a coat hanger into a length of about 8 to 10 inches as shown in figure 1. Clean out the used motor casing and push the hanger through the nozzle. Sometimes a little epoxy will be needed to make the hook stay in place. The casing and hook can then be pushed into a model, and the model will then hang nicely upside-down in a closet or in a workshop. If the model's nose is a loose fit, a bit of tape around the shoulder will keep it from falling out. This gadget works great with those models having an engine clip.

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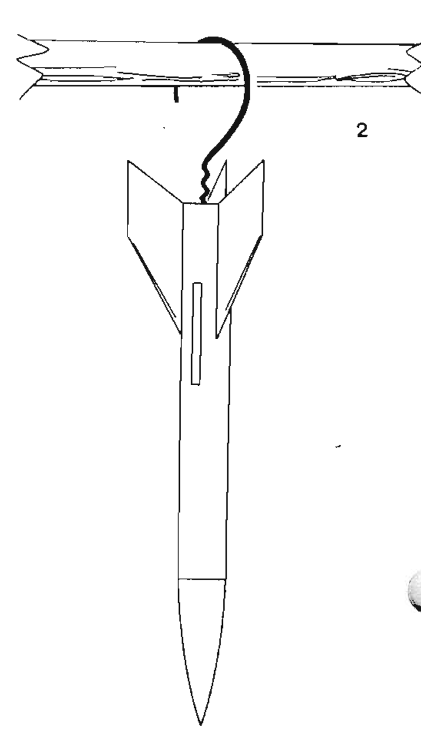

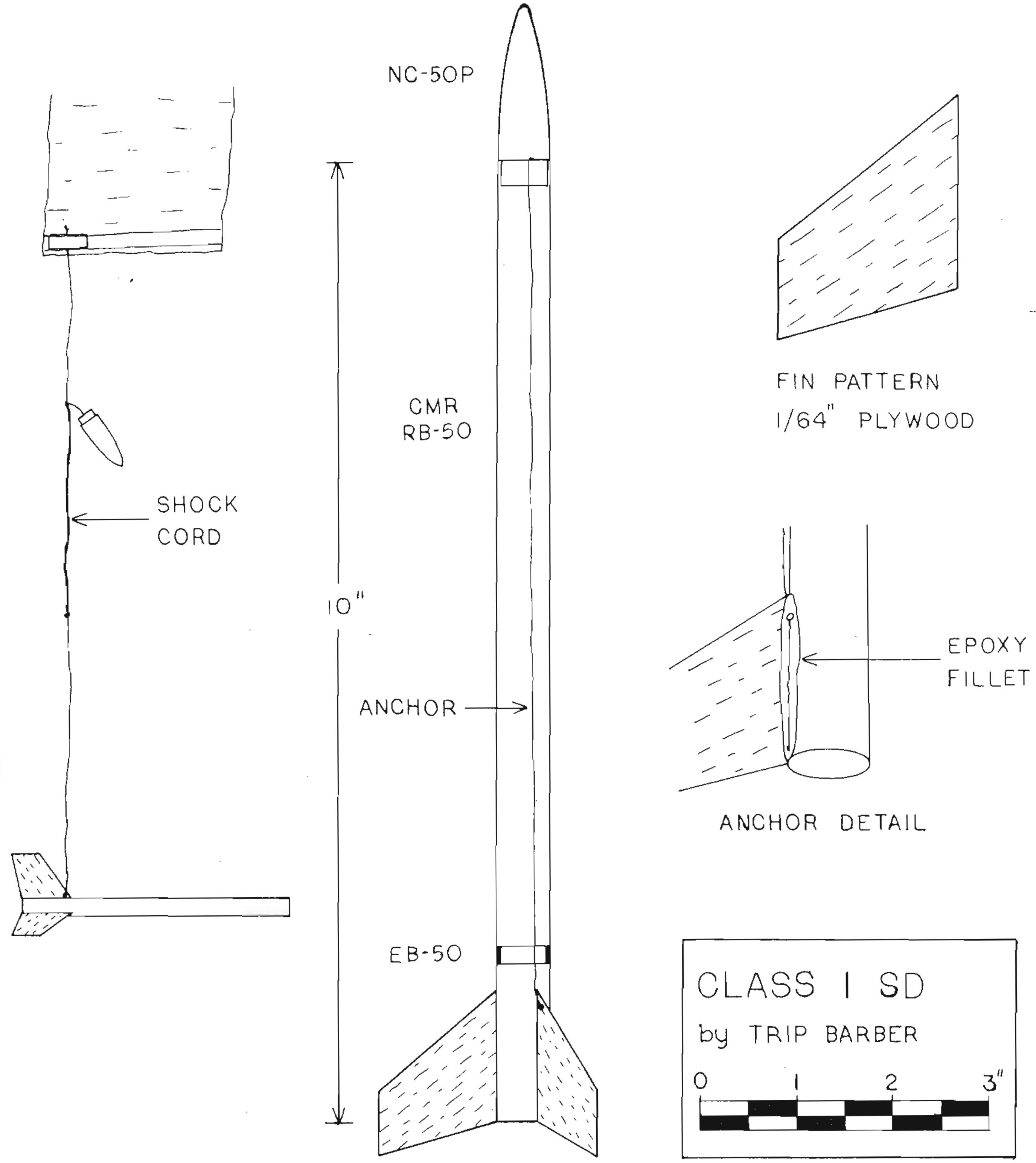
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CMR
RB-50
10"
ANCHOR
EB-50
SHOCK
CORD
FIN PATTERN
1/64" PLYWOOD
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