STREAMER RECOVERY BASICS FOR TARC

All rocket recovery devices are designed to produce aerodynamic drag to slow the descent of the rocket once they are deployed. The drag that a falling object experiences increases as the square of its velocity. When a descending rocket stabilizes at "terminal velocity", the drag forces on all the connected parts of the descending rocket at that velocity exactly offset its weight and its acceleration becomes zero. No matter how far it falls after this, the rocket's descent velocity will not further increase. The heavier a rocket, the higher this terminal velocity will be. The larger and more "draggy" a rocket is in its recovery configuration, the lower this terminal velocity will be.

For TARC 2010, if your rocket goes up 825 feet and takes 7 seconds after liftoff to reach this altitude and deploy its streamer, and you want the total flight duration to be 42.5 seconds, then the descent terminal velocity that you want is 825 / (42.5 – 7) = 23 feet/second. The heavier the rocket, the more drag it will need on recovery to achieve a velocity this small. Higher recovery drag is easy to achieve with a parachute, just make it bigger in diameter; with a streamer, it is not that simple.

"Streamers" as used in rocketry are rectangular strips of a very flexible material that are rolled up inside the rocket body for boost and unroll when deployed for recovery. Rockets may use one or more of these as a recovery device. For TARC 2010 the pertinent rules requirements are as follows: "*The portion of the rocket containing the egg and altimeter must return to the ground using only one or more streamers as its deployed recovery system. The rest of the rocket may be attached to this portion, or may return separately as long as it does so safely. Each streamer that is used must be a separate single rectangular strip of thin flexible material such as paper or plastic that is at least five times as long as wide, and each must be attached to the rocket only by a single line that connects to one or more places on a single one of that streamer's narrow sides.*"

Although the largest contributor to the total drag of a descending rocket is its recovery device (parachute, streamer, etc.), at the higher descent rates typical for streamer recovery the rocket body and fins contribute useful drag as well, particularly if the body falls in a sideways orientation. A lightweight body with fins that falls sideways while attached to its streamer can reduce the rocket's terminal velocity significantly compared to performance if the rocket just hangs straight down below the streamer. Simple calculations of streamer performance usually assume that the rocket attached to the streamer is a dragless point mass, but may not actually be correct unless you are using the streamer only for a small, heavy egg capsule.

Steamers create drag by a combination of the drag from airflow across their surface area, and the drag from any aerodynamic activity that they can be made to perform by their shape, such as flapping, whipping, etc. The larger the surface area (size) of a streamer, the more drag it will have. But <u>size</u> alone is not the whole story in getting the streamer to have lots of drag. A streamer that descends straight behind a rocket with no aerodynamic activity has only modest drag so the terminal (recovery) velocity it provides a heavy rocket is fairly fast. An otherwise-identical streamer that performs vigorous aerodynamic activity will make a rocket fall much slower. This aerodynamic activity can be induced by the way that the streamer is <u>attached</u> or <u>folded</u>, but the ability to do this depends on the type of <u>material</u> used to make the streamer. So there are four important factors in streamer design: size; material; folding technique; and how it is attached.

SIZE

Larger streamers produce more drag than smaller streamers, if all else is equal, because they have a larger surface area. Beyond this, however, a single large streamer has been found to produce more than twice as much drag as two smaller streamers that have the same combined surface area. And wide shorter streamers have been found to produce more drag than thin longer ones that have the same surface area. In fact, extensive testing by rocket hobby researchers over the years has shown that streamer lengths much beyond about 10 times the streamer width normally add little to performance. The extra length adds weight of streamer material (increasing terminal velocity) without a significant compensating increase in drag.

MATERIAL

Since a streamer creates drag by skin friction with the passing air, you would expect that materials with a rough surface finish, such as crepe paper, would be good for use as streamers. And since terminal velocity on descent is reduced by reducing weight you'd expect that the lightest-weight streamer material would be the best. All else being equal, and if the streamer simply descended as a flat, motionless sheet, these would be true. However, the majority of a streamer's effective drag actually comes from aerodynamic flapping. Achieving this flapping requires the use of streamer materials that are stiff enough to hold curls and creases and to maintain some shape despite the flapping. Crepe paper and very thin, light, or soft and flexible plastic films cannot do this.

The optimum streamer material is lightweight but stiff, capable of holding curls and creases but not susceptible to ripping in the face of aerodynamic forces. Rocket fliers who compete in streamer duration contests are always on the hunt for such a "perfect" streamer material; they call it "unobtanium." They have not found it yet, but along the way they have found a number of things that work pretty well. These include the following, but there is plenty of room still for discovery and innovation to add to this list by finding the plastic film that no one has found yet. Note that any streamer used in TARC (like in NAR competition) must all be made of a single type of material.

- Mylar – a thin polyester plastic film (usually with a silver metallization layer) used as a sun shield for windows or as "sun film" in hydroponics greenhouses, as electrostatic discharge packaging film, etc. It comes in a variety of thicknesses, but only the types that are "1 mil" (0.001 inches) to 2 mils in thickness are stiff enough to be useful for high-performance streamers. Sometimes you can buy Mylar with this kind of thickness as party streamers.
- Micafilm – a model airplane wing-covering material made by Coverite and sold through model aircraft hobby vendors. Streamer creases have to be folded in, not ironed or baked in, as this is an iron-on wing covering with adhesives that are activated by heat. This is a tough material that is very resistant to tearing.
- Tracing paper – vellum paper sold in rolls by graphics and art suppliers for use in drafting/tracing. The heaviest grades have good stiffness to take and hold creases, but can be a bit vulnerable to tearing when used as a streamer.

FOLDING

A flat streamer attached to a rocket by a single line at the midpoint of one narrow end will normally demonstrate minimal aerodynamic flapping activity during recovery; it will fall smoothly and fast. In order for the streamer to whip around and create the aerodynamic flapping that increase its effective drag, it needs some kind of creasing or folding that makes it behave as something other than a flat surface. In order to hold these creases and folds at the drop rates of 20 – 25 feet/second that TARC rockets will experience, the streamer material needs to have a certain amount of stiffness.

There are many different theories among rocket streamer duration competition fliers as to what the best way is to crease or fold a streamer, and there has been a certain amount of research done. This research has shown conclusively that one form of creasing, called the "accordion fold", does work. This technique involves putting sharp folds across the width of the narrow axis of the streamer in back-and-forth "Z" shaped pleats similar to those seen in an accordion. The width of these pleats should be anywhere from 0.5 to 1.0 inches, and they should extend for at least the last 75 percent of the streamer length, up to as much as 100 percent. The pleats can either be folded in using a metal ruler to provide a sharp mechanical creasing, or (for Mylar or other plastic films only) they can be ironed in using a very low-temperature iron that does not melt the streamer material. When this kind of streamer flies, properly made pleats will retain their shape and break of the flat surface of the streamer to improve its drag. Various forms of additional diagonal folds can be added to a pleated streamer to improve its tendency to whip around. There is lots of room here for experimentation and optimization.

A second popular technique, useful only with mylar/plastic streamers that can be heated, is called the "scorpion roll". This technique requires that the steamer be rolled around a ¼ to ½-inch diameter rod, and then slipped off the rod. The rolled streamer is then clamped completely flat between two pieces of wood and heated in an oven to a very low temperature (generally no more than 140 degrees F) for an hour or so. When it is flown, the streamer wants to curl back up on itself against the airflow like the tail of a scorpion, once again breaking up the flat surface and improving drag.

ATTACHING

There are two key elements to attaching a streamer to a rocket: how and where you attach the single line to one of the narrow edges of the streamer; and how and where you attach the other end of this line to the rocket. This line needs to be fairly long (at least three feet) and should be wrapped loosely around the rolled streamer so the streamer takes a second or two to unroll after deployment. This slows the velocity seen by the streamer when it first unrolls, reducing its tendency to tear.

The leading edge of a streamer (the edge to which the line is attached) must maintain its straight shape in order for the streamer to function well. If you are using a wide streamer, this generally requires stiffening the leading edge somehow. You can do this by putting a piece of wide stiff packing tape across this edge, or by putting an extremely thin (1/64 inch or less) piece of steel wire ("music wire" or "piano wire") across this edge under a tape strip.

The attachment method and location for the single line is also important. It must be very securely attached, since it will absorb significant stress when the streamer deploys. If you are using a thin steel wire on the leading edge, tie the line to it before you secure it to the streamer. If you are using a tape strip for stiffness, then put a hole through it for the line and use a reinforcing eye around this hole. A line that is simply taped to the flat surface of the streamer will usually not hold. Most fliers find that if the single line is attached away from the midpoint of the narrow end of the streamer, anywhere from ¼ of the way from one edge to all the way at one edge, the streamer has a significantly greater tendency to whip around. An additional option is to secure the line to the narrow end of the streamer using more than one attachment point, such as a “yoke” that attaches to both ends of the streamer then is attached to the single line at a point offset from its center.

Finally, how and where the streamer line is attached to the rocket determines the orientation that the rocket body will fall in during recovery. If you attach the streamer to an anchor inside the body tube or on one end of the egg capsule, these heavy objects will fall end-on beneath the streamer and present minimal surface area to the airflow past them. If the streamer is attached to a point at (center of gravity or balance point) of the capsule or rocket, then these objects will fall sideways and present maximum surface to the airflow, increasing recovery drag and reducing terminal velocity. If you want to place your anchor point at the recovery CG, remember to determine this point with the rocket in post-burnout configuration, i.e. with an empty expended rocket motor casing. Experiment with this; it may turn out that the rocket hangs purely horizontal when this anchor point is slightly closer to the fins than the CG.

One technique often used by rocket competition fliers is to attach a strong line to the root of one fin (or to the screw eye on the end of the payload compartment) and run this line along the body and into the body tube where the shock cord and recovery device are stored during boost. You can tape or glue the line at the point along the body where the burnout CG is located. When the recovery system deploys the rocket then hangs sideways from this line at its CG balance point.