ROCKET ENGINES

Model rocket engines are produced under exacting quality and safety conditions on precise and expensive automated machinery. The engines are intended for one time use and cannot be reloaded by the individual. This is one of the important factors in the marvelous safety record enjoyed by this hobby. No propellant loading or mixing is ever done by the individual rocketeer. To follow through on safety, you the rocketeer must always use these engines as intended, in a stable model rocket, fired from an approved launching pad, and always ignited by remote electrical means.

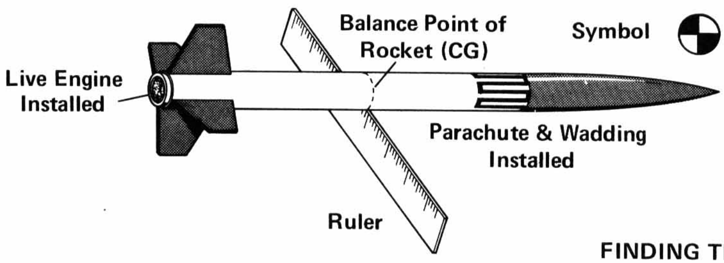
CENTURI'S "SERVO-LAUNCHER" and "ASTRO 1" Rocket Kit illustrated.

Chapter 3: Basic Design Requirements

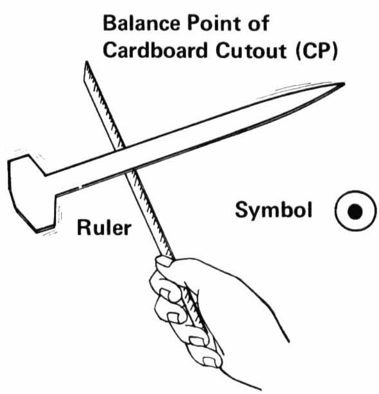
STABILITY: There are two primary factors which influence the flight stability of a model Rocket.

1. **Center of Gravity:** the point at which the rocket balances.
2. **Center of Pressure:** the theoretical point at which all forces directed against the rocket would center.

FINDING THE C.G.



FINDING THE C.P.

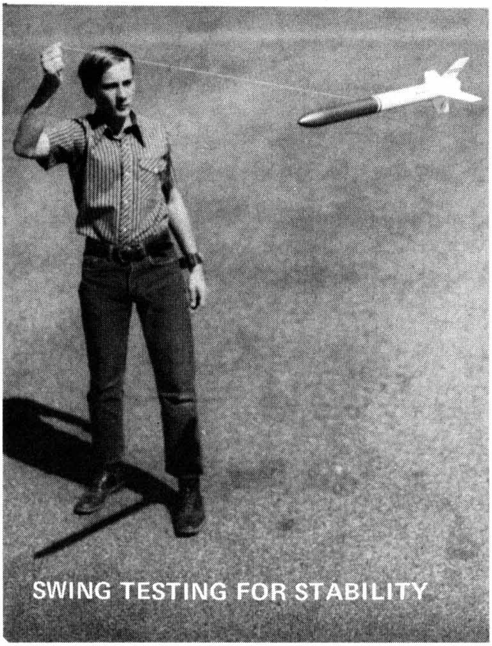


In order for a model rocket to fly stable, the center of gravity must be ahead of the center of pressure. Always remember this rule in designing your model rockets. The center of gravity is quite easy to determine. Simply balance the rocket (with live engine in place, chute wadding, etc. installed) on a ruler or thin piece of wood. The point at which the rocket balances is the center of gravity. (Abbreviated CG.) The approximate center of pressure may be found by making an exact size cutout of the rocket from cardboard. This cutout is balanced on the ruler to show the center of pressure (CP). Note: the formulas for determining the true CP of a rocket are discussed fully in Centuri's Technical Report TIR-33. In order for a rocket to have a reasonable stability margin, the CP should be at least one body diameter* behind the CG.

*This figure applies only to this method of calculation of CP-CG.

STABILITY TEST:

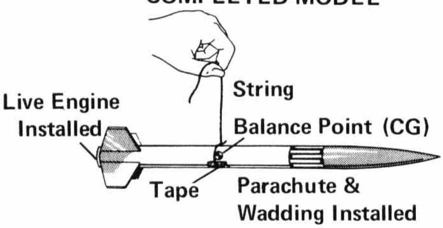
The easiest way to determine if the rocket will really fly stable involves the use of the swing test. Prepare the rocket as you would for launching. Use the heaviest engine you would ever fly in the rocket.



SWING TESTING FOR STABILITY

The rocket must be fully "flight prepped" with the exception of the igniter. Locate the balance point of the rocket (CG). Tie a loop in a 10 foot piece of cord and place around the rocket at the CG point. Tape the cord to the body so it will not slip forward or backward. Hold the rocket at

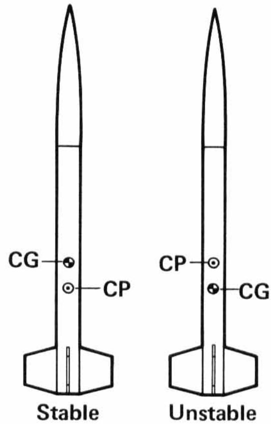
COMPLETED MODEL



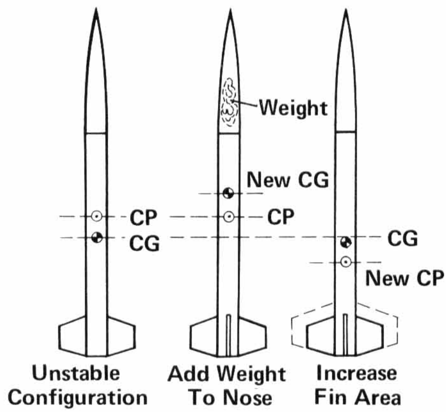
arms length, point the rocket's nose in the direction you will swing and begin to swing the rocket around your head. As the rocket picks up speed, let the cord out to about 8'. If the nose of the rocket points in the direction you are swinging and stays pointed that way, the rocket will fly stable. If it twists, turns flat against the wind or if the tail of the rocket turns forward, the rocket does not have sufficient stability. Note: on very large rockets, a longer cord is necessary. In order to get a reliable test, for instance, on a Centuri Saturn V, you would have to stand on a high platform and swing the rocket in a 20' arc.

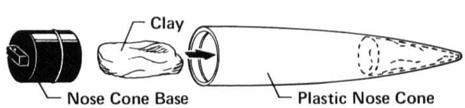
CORRECTING INSTABILITY:

One way to correct instability is to move the CP to the rear. Enlarging the fins or extending them rearward will accomplish this. An easier method (especially if the rocket is completed) is to move the CG forward. This is done by adding weight to the nose of the rocket. After any alterations are made, the rocket must be re-tested to verify stability. Remember that the CG will change when you modify the rocket, so locate the new CG before flying



CORRECTING INSTABILITY





To advance the center of gravity on a rocket a wad of modeling clay can be pushed into the extreme end of the plastic nose cone prior to snapping the base into place.

DRAG:

Drag is the resistance created by a body moving through the air. There are several types of drag that influence the performance of a model rocket. Rather than go into a prolonged discussion of aerodynamic drag at this point, we'll just mention a few things you can do to reduce drag on your model rocket.

FINISH:

A good finish on your rocket (see Chapter 7) is important in reducing the friction experienced in flight. The better the finish, the higher the flight.

NOSE CONE:

Although tests show this is not as critical as was once thought, a parabolic shaped cone is the most optimum shape for reducing drag on subsonic flight models. (See top of page 13.)

FINS:

The shape of the fins has some effect on drag. A swept back fin with rounded corners will generally produce a little less drag than a fin with sharp corners. Of greater importance in reducing drag (especially in the case of a light weight rocket) is the cross section shape of the fin. A gently rounded leading edge and a tapered trailing edge on a fin will produce less drag than a fin on which all edges are square or just rounded. Drag is also produced in the area where the fins join the body tube. Fillets along the fin-body joints (see Chapter 6) will reduce this "interference drag".

BOAT TAIL:

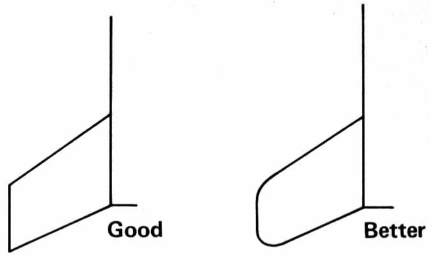
Curving the rear portion of the rocket inward will reduce base drag at this point. This is of course, only possible on rockets that have an inside body diameter larger than that of a model rocket engine.

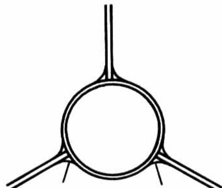
ROCKET COMPONENTS:

FINS:

Many different fin shapes may be used for a model rocket. Centuri's fin pattern sheet is an excellent source for fin designs. If you desire, you may purchase sheets of balsa from Centuri with fin designs printed right on the balsa. A rule of thumb in determing fin area is that each fin should be at least 1½ times (in both directions) the diameter of the body. Fins can be cut from a single piece of balsa, or may be made up of two or more balsa sections. Remember that the grain line should always run parallel with the leading edge of the fin. The fins should be positioned to the extreme rear of the rocket.

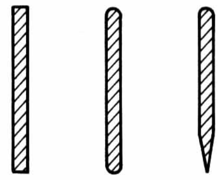
Fins should not be placed near the front of the rocket since this tends to move the center of pressure forward and reduces the stability margin. Small, decorative fins may be placed forward, only if the main fins are quite large.

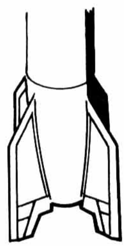




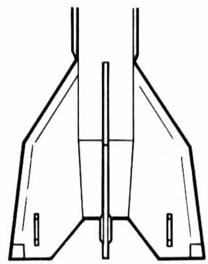
Fillets Reduce Drag Here

Fin Cross Section Shape

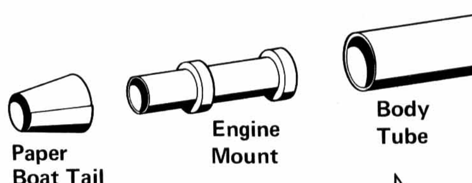


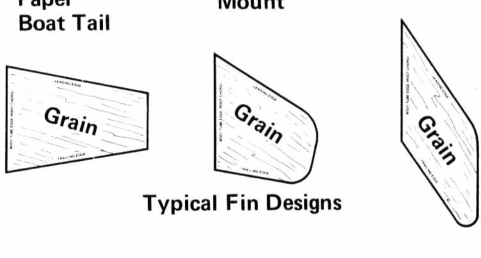


Balsa Boat Tail (Centuri V-2)

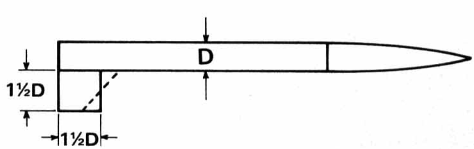


Paper Boat Tail (Centuri MX-774)



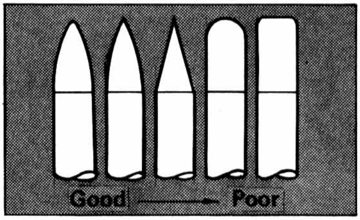


Typical Fin Designs



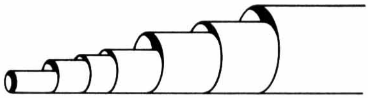
NOSE CONES:

Nose cones are available in a wide variety of sizes and shapes. The choice is up to you. In terms of performance, the relative efficiency of the shapes are shown here. Centuri produces both balsa and plastic nose cones. The Centuri plastic nose cones have a snap in base which allows the cone to be used as a payload compartment.



BODY TUBES:

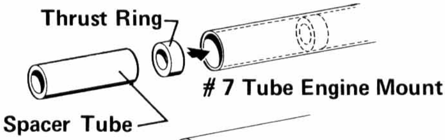
Centuri body tubes are made of a specially rolled, hi-strength kraft paper. The wall thickness of most of these tubes is .022". This is ideal for maximum strength with the lightest weight. Centuri body tubes are finished with a poly-glassine coating which produces a very smooth finish and provides a good bond with glue or paint. Body tubes are available in a variety of sizes (see Chapter 5). A #7 tube (.76" diameter) is the smallest tube in which a model rocket engine will fit. Body tubes are available in several lengths and also may be easily cut to any desired length. In designing your first rockets, make the length of the body at least 10 times the diameter of the tube. Short rockets offer more design problems and the balance is more critical.

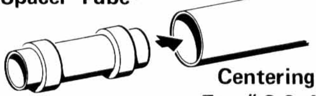


Body tubes available in lengths up to 18".

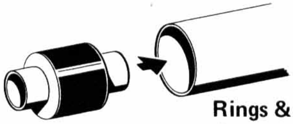
ENGINE MOUNTS:

The simplest engine mount is a thrust ring glued into a # 7 body tube. In larger body tubes, a 3" long # 7 tube with thrust ring is used to hold the engine. This tube is centered in the larger tube with centering rings or a ring and sleeve combination. In some cases where a # 13, # 16, or # 20 body tube is used, the engine mount can be recessed an inch or so into the body to help increase the stability margin. (Moving the engine and its mount forward moves the CG forward.)

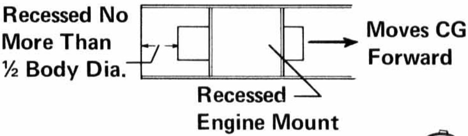




Centering Ring Mount For # 8 & 10 Body Tubes



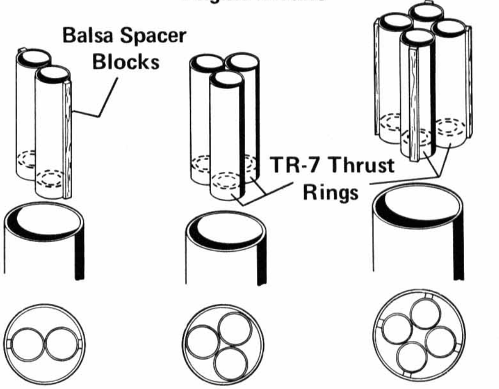
Rings & Sleeve Mount For # 13, 16 & 20 Body Tubes



CLUSTERING:

Clustering involves the use of two or more engines, fired simultaneously, to boost a rocket which would be too large and heavy for a single engine. Centuri's Saturn 1B (2 engines) and Saturn V (3 engines) are good examples of cluster "birds". In order to have simultaneous ignition, it is absolutely necessary to use Sure Shot Igniters and a heavy duty power supply. A cluster mount is relatively simple to build. ST-73 engine tubes are fitted with thrust rings and the tubes are glued together to form the cluster. Two or three engine cluster mounts will fit nicely into a #16 body tube and a four engine mount will fit easily into a #20 tube. Be sure to read Centuri's Technical Report TIR-52 "Reliable Cluster Ignition" before attempting launch of a cluster rocket.

NOTE: Gaps between cluster tubes must be filled with balsa or cardboard to prevent ejection gas from escaping to the rear.



2 Engine Mount In # 16 Tube **3 Engine Mount In # 16 Tube** **4 Engine Mount In # 20 Tube**

RECOVERY SYSTEMS:

The most common recovery system used on model rockets is the plastic parachute. Several other types of recovery systems are used on certain rockets. They are listed here:

A. FEATHERWEIGHT RECOVERY:

A very lightweight, small rocket which upon ejection of the spent engine casing, falls gently back to earth. The Lil Hercules is an example of this type of rocket.

B. STREAMER RECOVERY:

A streamer is a long ribbon made from crepe paper or plastic. Upon ejection from the rocket, the tails of the streamer flutter in the breeze and slow the descent of the rocket. Normally used on lightweight models such as the Micron, streamers may be used interchangeably with parachutes on larger models for flying in a stiff wind. Since a streamer allows the rocket to fall straight, there is less chance of drift on windy days than with a parachute.

C. PARACHUTE RECOVERY:

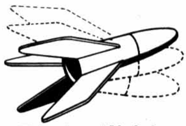
The parachute ejects, fills with air and lowers the rocket gently to the ground. The size of the parachute varies depending on the weight of the rocket. Large rockets may use two or even three parachutes for recovery.

D. GLIDE RECOVERY:

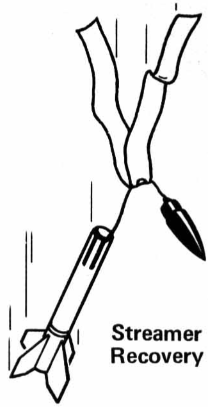
The model glides to earth like a conventional airplane. The Swift boost glider is an example of this. In the case of the Swift, the engine is located in a separate pod which recovers with a parachute. Ejection of the pod leaves the conventional appearing, lightweight glider high in the sky to wheel and turn gently toward the earth. Boost gliders can stay aloft for considerable amounts of time. In a rocket plane such as the Mach-10, the engine remains in the plane and the glide is similar to but faster than that of the Swift.

E. RETRO SPIN RECOVERY:

The rocket is designed in such a manner that drag surfaces are deployed by the engine ejection charge. These deployed surfaces cause the rocket to spin and thus slow its descent.

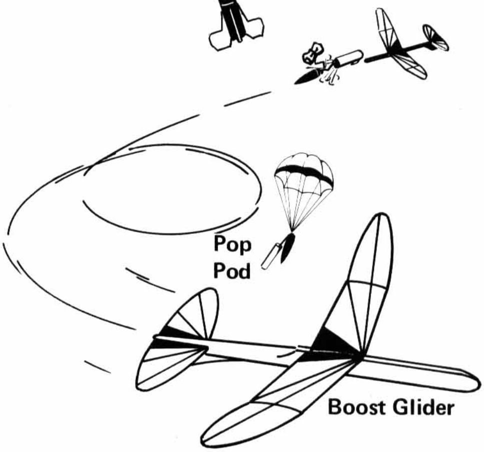


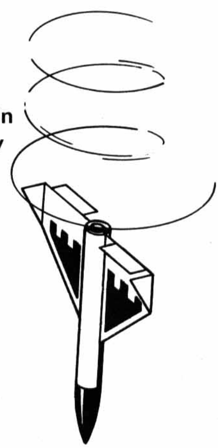
Feather Weight Recovery



Streamer Recovery

Parachute Recovery





Retro Spin Recovery

Rocket Plane Glide Recovery

PARACHUTE DESIGN AND ASSEMBLY

Centuri offers a number of different sizes of colorful printed parachutes. Should you wish, however, to make your own chute, the construction methods are shown here. These methods can be used with a variety of materials. Recently introduced, chrome mylar is becoming quite popular. The mylar is stronger and more heat resistant than plastic and is much thinner (.0005″) which allows it to be folded into a smaller chute compartment. Another advantage is the mylar's reflective surface which makes it highly visible during descent. Parachutes are occasionally made from silk, but due to its greater bulk and cost, this material is generally restricted to the Mini-Max/Enerjet field.

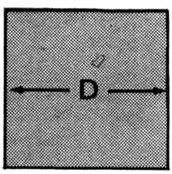
PARACHUTE SELECTION GUIDE

APPROX. ROCKET DESCENT WT.	PARACHUTE SIZE		
	SQUARE	HEXAGON	OCTAGON
1 oz.	D=14″	D=13″	D=12″
2 oz.	D=18″	D=17″	D=16″
3 oz.	D=24″	D=22″	D=20″
4 oz.	D=28″	D=26″	D=24″

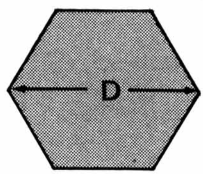
"D" is the width dimension of the parachute canopy as shown below.

FORMULA FOR CUTTING PARACHUTE SHROUD LINES

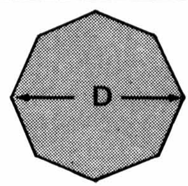
SHROUD LINE LOOP LENGTH	
SQUARE	2½ TO 3 TIMES "D"
HEXAGON or OCTAGON	2 TO 2½ TIMES "D"



SQUARE



HEXAGON

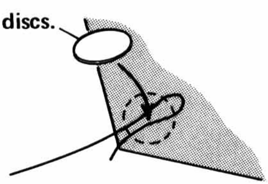


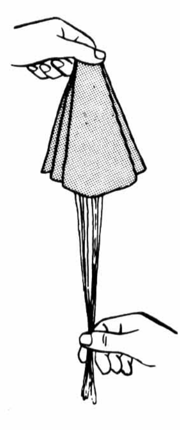
OCTAGON

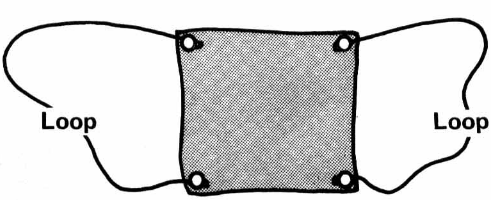
Three basic parachute shapes will be discussed here. They are square, hexagon, and octagon. The table above shows the approximate size of the chute required for rockets of different weights and the recommended length of shroud lines.

SQUARE:

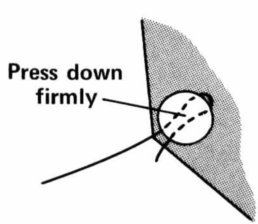
A square piece of material is cut to the desired size. Shroud lines are attached to the corners with tape discs. The shroud lines are pulled tight and tied to complete the chute.





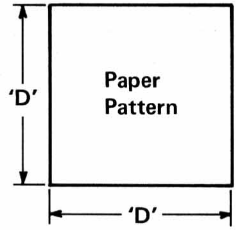


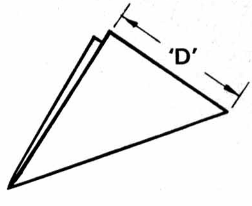
Square Chute

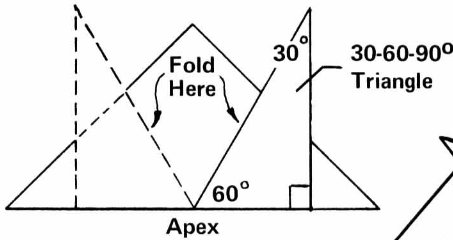


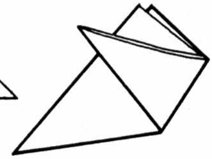
HEXAGON:

Cut a square piece of paper to size so that each side equals the desired dimension (D) of the chute. Fold the paper into a right triangle. Mark the paper with a 30-60-90° triangle and fold the legs over as shown. Cut across the folded paper to complete the pattern. Lay the pattern on the chute material and cut out. Attach shroud lines and tie ends to complete the chute.



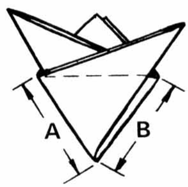


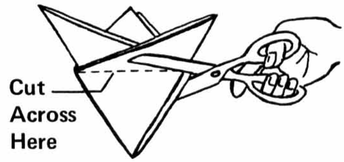




OCTAGON:

Cut the piece of paper as above, with each side equaling the desired "D" dimension. Fold the paper in half and fold again to form a square one-fourth the original size. (See below.) Fold this on a 45 degree angle. Mark length "B" equal to length "A". Draw a line across and cut to complete pattern. The chute is cut out, shroud lines are cut, attached and tied to finish the chute.





The method of attaching the chute to the rocket is described in Chapter 6. Note: If the rocket tends to drift during descent, a small spill hole can be cut in the center of the parachute While this makes the rocket come down faster, it also reduces the drift.