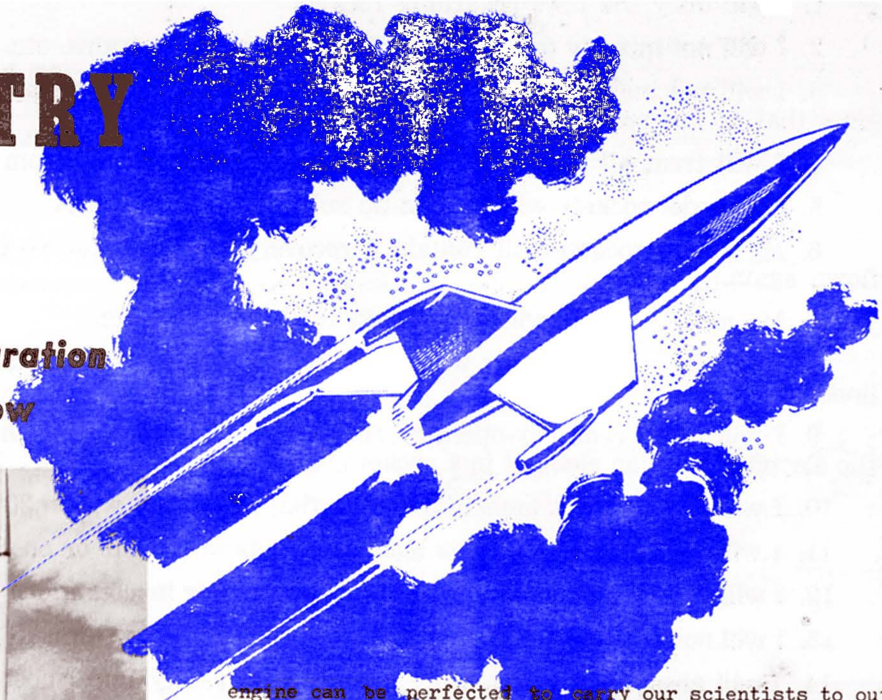
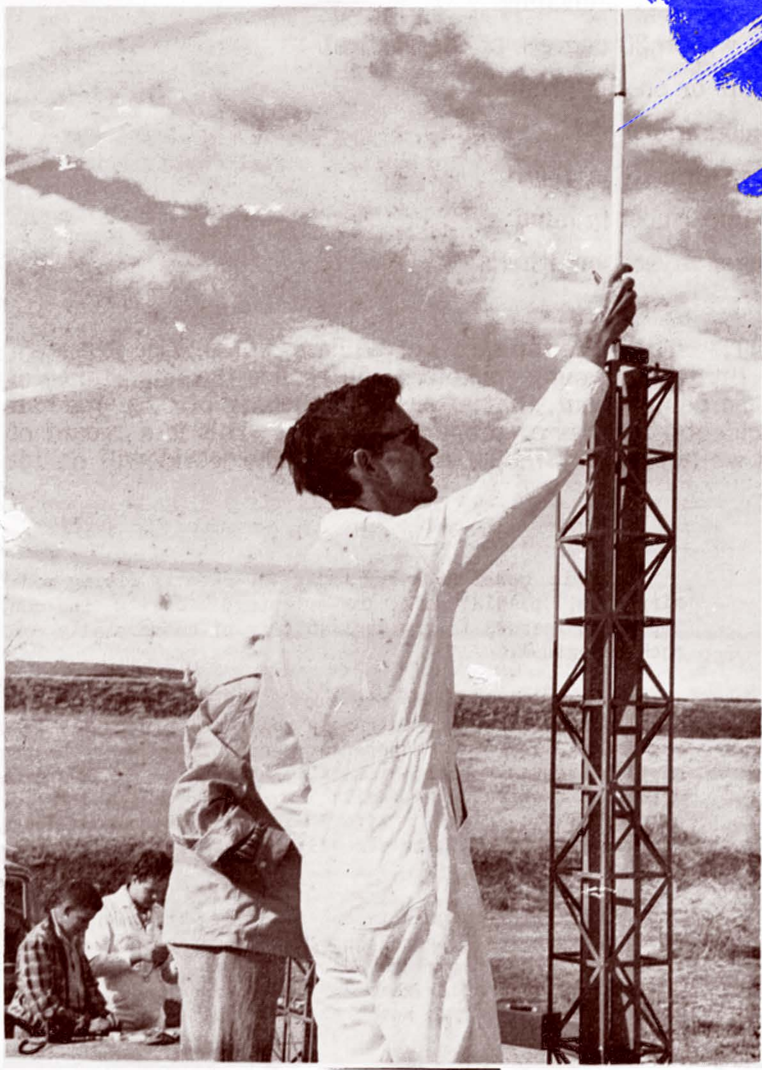
MODEL ROCKETRY

- ***Scientific***
- ***Educational***
- ***Youth Preparation For Tomorrow***





NAR Photo

daily our newspapers, radio and TV stations feature stories telling of new developments in the field of rocketry; a new shot is made into outer space, a new fuel is developed, or a new guidance system is perfected or a new record is set.

Many youths of today's world look forward with great anticipation to the new developments tomorrow will bring. Will we inhabit the moon? To what extent is radiation a hazard? Is there life on various planets? What new engine can be perfected to carry our scientists to outer space and new worlds?

The destiny of almost every great engineer, scientist, physicist, mathematician, and chemist was started early in life. In his youth he was encouraged in his special field by a free pursuit of his own interests. When those interests fall in the field of rocketry and its associated scientific fields, model rocketry satisfies a special need for the young rocketeer's development and enjoyment. The principles of rocket design, acceleration, thrust, aerodynamics, stability, trajectory, tracking, and many other fields are identical for model rocketry and professional rocketry. Through model rocketry much scientific knowledge is gained by the young rocketeer to coincide with his normal academic studies.

For many youngsters and adults who do not plan to become engineers or scientists, but are looking for an inexpensive hobby which offers pleasure, relaxation, excitement, and competition, the sport of model rocketry is their choice. The fascination of this sport can well be appreciated when it is realized that a small home built rocket weighing from a fraction of an ounce to only a few ounces can travel at speeds of several hundred miles per hour and attain altitudes of over 2,000 feet. Not only is it possible to achieve this fantastic performance but the same rocket can be built to return safely for many additional flights.

Increased interest is being shown in the development of clubs, organizations and teams for group participation in the field of model rocketry. Various rocket classifications have been established and competitive events are conducted. Trophies are awarded for performance and designs. Safety rules and procedures have been established. Indeed, the field of model rocketry is well underway to becoming a major national hobby. The outstanding organization today in this field is the National Association of Rocketry, Suite 1962, 11 W. 42nd Street, N.Y. 36, N.Y. This organization has established firing procedures and safety rules, and has gone a long way toward promoting acceptance by officials and guidance organizations. Safety in model rocketry is of prime importance. Since not every model rocket enthusiast will desire to join the National Association of Rocketry, a copy of its safety code is reprinted here in its entirety.

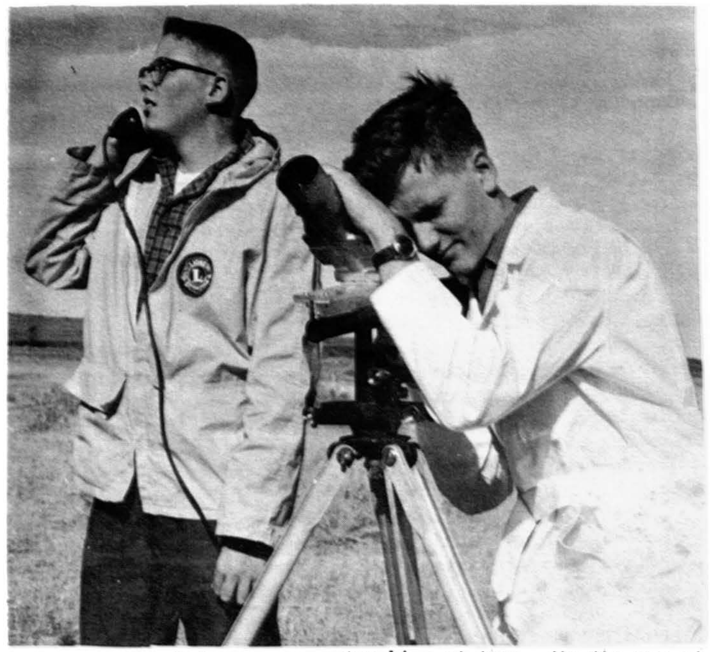
NAR SAFETY CODE

As a member of THE NATIONAL ASSOCIATION OF ROCKETRY, I will do my best to maintain the safety record of the hobby of model rocketry, and I will obey this NAR Model Rocket Safety Code.

1. **I will obey the laws regarding rockets.**
2. **I will not mix my own rocket propellants or delay trains, etc.**
3. **I will not make my own rocket engines. I will use pre-loaded, factory-made commercial model rocket engines that do not require mixing the propellant.**
4. **I will treat all rocket engines with care, keeping them from heat and not dropping them.**
5. **My model rockets will contain no substantial metal parts.**
6. **My model rockets will contain a recovery device to return them safely to the ground so that they may be flown again.**
7. **My model rockets will not contain explosive warheads.**
8. **I will fly model rockets with adult supervision in open areas away from houses, buildings, trees and power lines.**
9. **I will use a remotely-operated electrical firing system to ignite model rocket engines, and I will not install the electrical ignition element in a rocket engine until shortly before launching.**
10. **I will always use a launching device that is pointed within 30 degrees of the vertical.**
11. **I will not fly model rockets against targets in the air or on the ground.**
12. **I will not fly model rockets in windy weather or in conditions of low visibility.**
13. **I will not fly model rockets where they may endanger aircraft in flight.**
14. **I will always act in a mature manner with safety uppermost in mind.**
15. **I will not engage in any operation that may endanger myself or others.**

MODEL ROCKET SAFETY

"A PERFECT SAFETY RECORD IS NO ACCIDENT." These are the words of William S. Roe, Vice President of The National Association of Rocketry. It is our hope that every young rocketeer will realize the importance of these words. In making the above statement, Mr. Roe was pointing out, that after the launching of over one-half million model rockets, there still has been no record of accidental injuries or property damage. This is a record of which those associated with model rocketry are proud, and we hope every model rocketeer in the world will do his part to maintain this record.



Two young rocketeers man a tracking station. By the use of trigonometry they will be able to make an exact calculation of the heights attained by their rockets. NAR Photo

Why is model rocketry today as safe as flying model airplanes, playing golf, or swimming? One of the most important reasons is the availability of commercially made rocket engines.

Commercial engines are built completely free of all metal parts. They are extremely reliable, are by far less expensive, and will out-perform anything the rocketeer could attempt to build himself. Each engine is a cylindrical unit which fits easily into the rocket and is replaced in its entirety after each flight. The model rockets illustrated here are all designed to use only commercial engines.

Each engine is simply constructed. It consists of a paper body, nozzle, propellant charge, delay charge, ejection charge and paper end cap. Estes Industries, Inc. manufactures and sells these propellant devices. They are also available through hobby stores in some localities.

TYPES OF ROCKETS

Several types of rockets are easily constructed at home. Three of the best known general designs are similar to the Arrow-C (Plan No. 1), Sky Bird (Plan No. 2), and Orange Bullet (Plan No. 3). Early in 1960, the Orange Bullet set a NAR class 1 B altitude record of 1280 feet at the NAR Hog Back Rocket Range. The model rocketeer will do well to follow instructions exactly at first, leaving variations of basic designs for later experimentation as his knowledge increases.

Before starting construction of your model rocket, study carefully these general instructions as well as the instructions for the particular type of rocket you wish to make.

Metal should not be used in any part of the construction of model rockets. It is more dangerous and heavier than paper or balsa wood as well as more expensive.

BODY TUBES: Although several sizes of body tubes are commercially available, it may sometimes be necessary for the rocketeer to roll his own to fit a certain design. Almost any kind of paper will be suitable, although a bond paper is generally the easiest to work with. Apply an even layer of hard drying paper glue or paste (flour and water make a suitable paste) and wrap tightly around the proper size mandril. A wood dowel, metal rod, tubing, etc. will make a suitable mandril. Always remove the tube immediately after wrapping.

NOSE CONES: Certain rocket designs demand that the rocketeer make his own nose cones. These nose cones can be built from almost any type of wood or soft plastic, but not metal. A rounded nose cone is safer than a pointed one, and performs better at the speeds the model rocket will travel.

Nose cones can be turned on a lathe, but generally a more satisfactory result may be obtained by drilling a ¼ x 1 inch long hole in the base end of 1" x 1" balsa nose cone stock. Glue into the hole a two inch length of ¼" hard wood dowel. After the glue has dried, chuck the dowel into a high speed electric drill. Then sand the balsa block to the desired shape using a fine grit sand paper. When the nose cone has been shaped, cut off the protruding dowel. Balsa stock as well as finished plastic and balsa cones are available from Estes Industries.

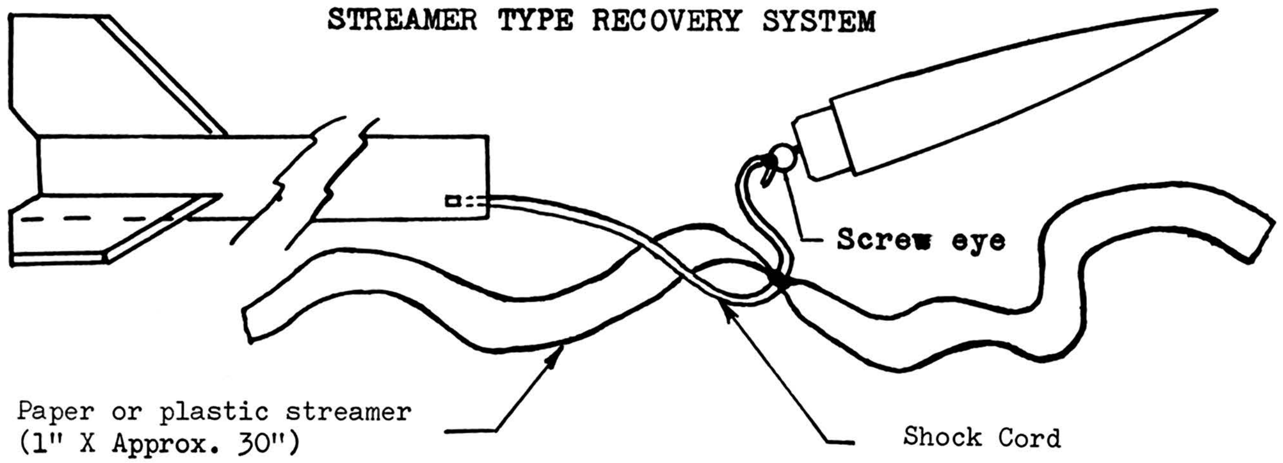
FINS AND STABILITY: Sheet balsa either 1/16" or 3/32" thick makes ideal material for stabilizing fins. Cut the fins from the balsa sheet using a sharp knife. For the best design in finishing the fins the leading edges should be rounded, and the trailing and outermost edges should be sanded to a long tapered knife edge. In most rocket designs the fins should be as large as possible and as light in weight as possible. Fins must be carefully aligned and securely glued to the rocket body. Stabilizing fins should always be placed as far to the rear of the rocket as possible. Never place any fins on a model at any point in front of the center of gravity. (The center of gravity of a rocket is the point along the body at which the rocket will balance on a knife edge with an engine in place.) For a rocket to fly, the center of gravity with the engine installed must be ahead of the center of pressure by at least one-half the diameter of the rocket body. (The center of pressure is determined approximately as the point about which a cardboard cut-out of the minimum view area of the rocket will balance on a knife edge.) The farther the center of gravity is ahead of the center of pressure the greater will be the stability and the better the rocket will fly.

RECOVERY SYSTEMS: A recovery system constitutes any means of causing the rocket to return to earth in a non-streamlined and safe manner. There are several suitable systems employed today, three of which are described below. They are the streamer ejection system, the blowing off of a removable set of fins, and the breaking up of the aero-dynamic stability by shifting of the center of gravity behind the center of pressure. Although the principle of this last system is more difficult to understand, it is cheaper and simpler to build and easier to operate. Its zero weight permits the construction of a rocket of extremely light weight and high performance.

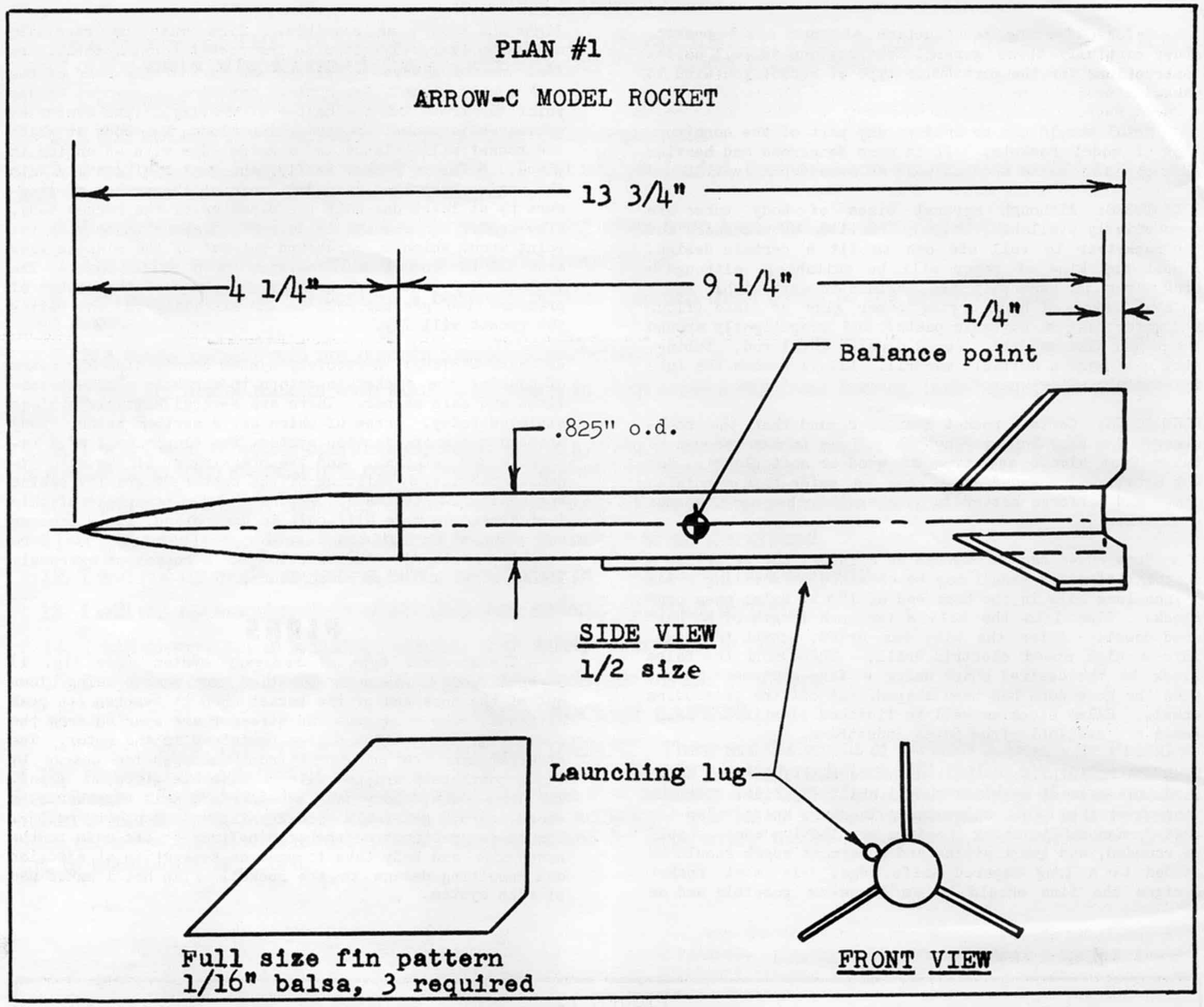
PLANS

The streamer type of recovery system (see fig. 1) depends upon a paper or plastic drag member being blown out of the nose end of the rocket when it reaches its peak altitude. The nose cone and streamer are ejected from the rocket by an ejection charge contained in the motor. The streamer must be protected from the ejection charge by being completely wrapped with a suitable piece of paper. The nose cone, body and streamer are held together by a shock cord, generally model airplane contest rubber. The shock cord must be anchored solidly at its ends to the nose cone and body tube to prevent separation at ejection and resulting damage to the rocket. Plan No. 1 makes use of this system.

FIGURE 1.
STREAMER TYPE RECOVERY SYSTEM



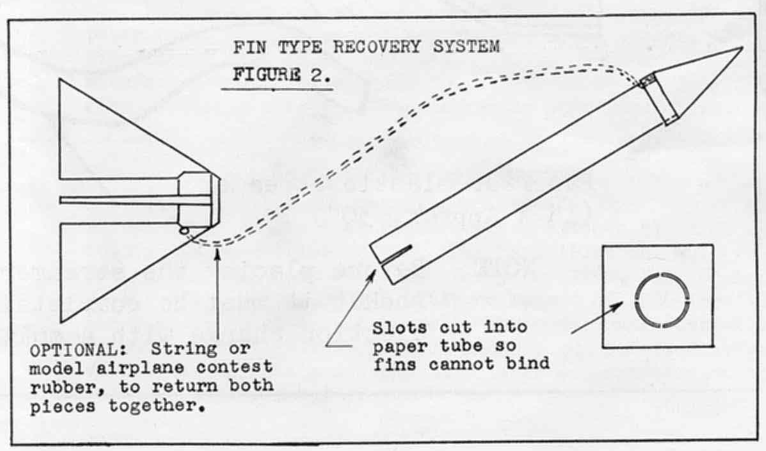
NOTE: Before placing the streamer into the body of the rocket it must be completely protected from the ejection charge with a suitable paper wrapper.

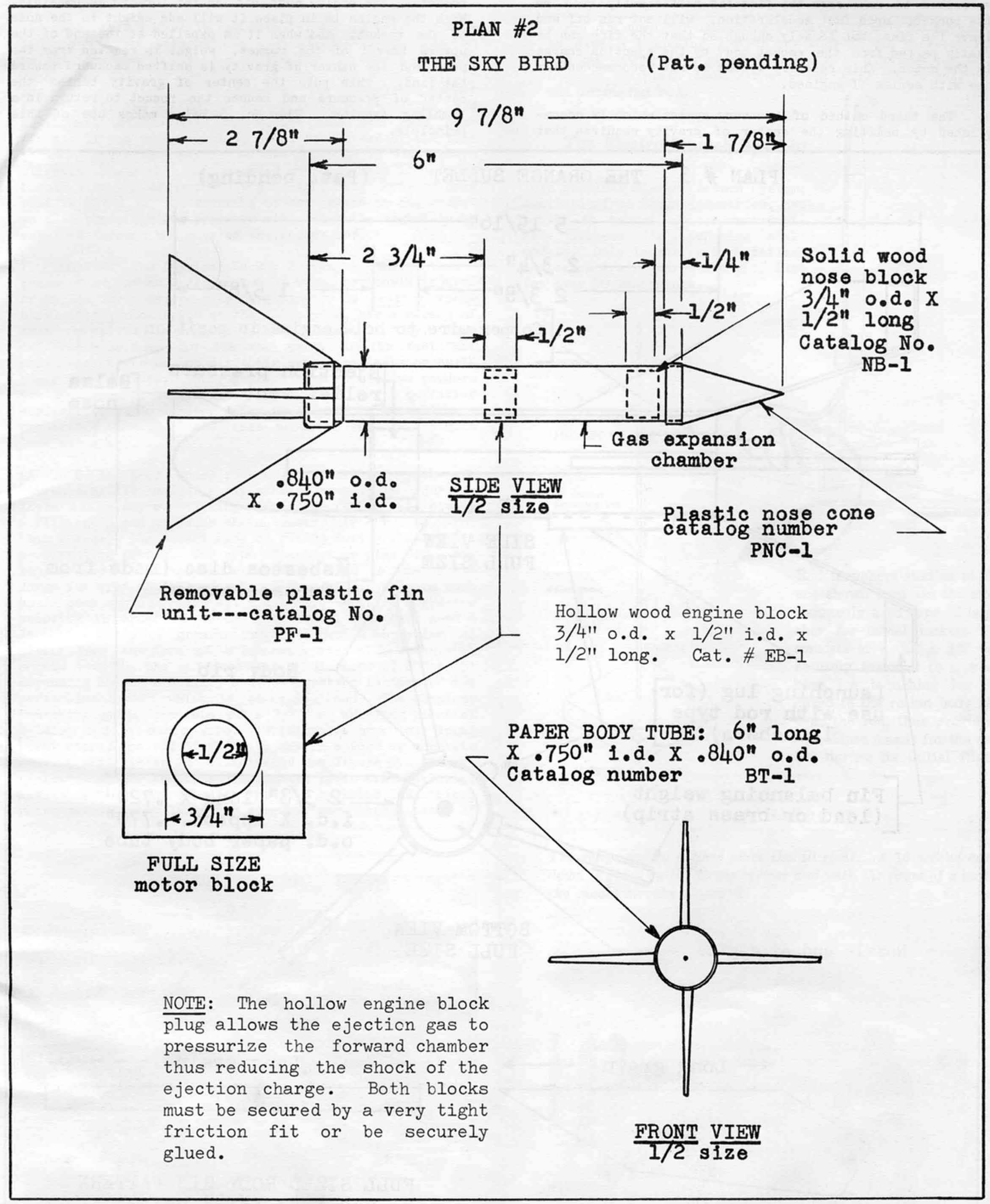


Plan No. 1

Care should be taken in building the Arrow-C model rocket to be sure the balance point is at least as far forward as indicated in the plans. Additional weight may be added to the nose to shift the balance point forward if necessary. The plan shown here is of the original Arrow-C. If a wood nose cone is used, it may be rounded to increase safety and performance. As the rocketeer progresses in the art of model rocketry he will be able to deviate considerably from the plans presented here in building rockets of his own design. Remember in constructing the Arrow-C or similar rockets that the nose cone must fit loosely enough to permit the ejection charge in the engine to easily blow off the nose cone and streamer.

The second type of recovery system shown in Fig. 2 employs a removable tail section. The fins can either separate completely from the rocket body or the two pieces may be held together by a nylon string or shock cord. This general type of design is quite popular for spot landing contests.

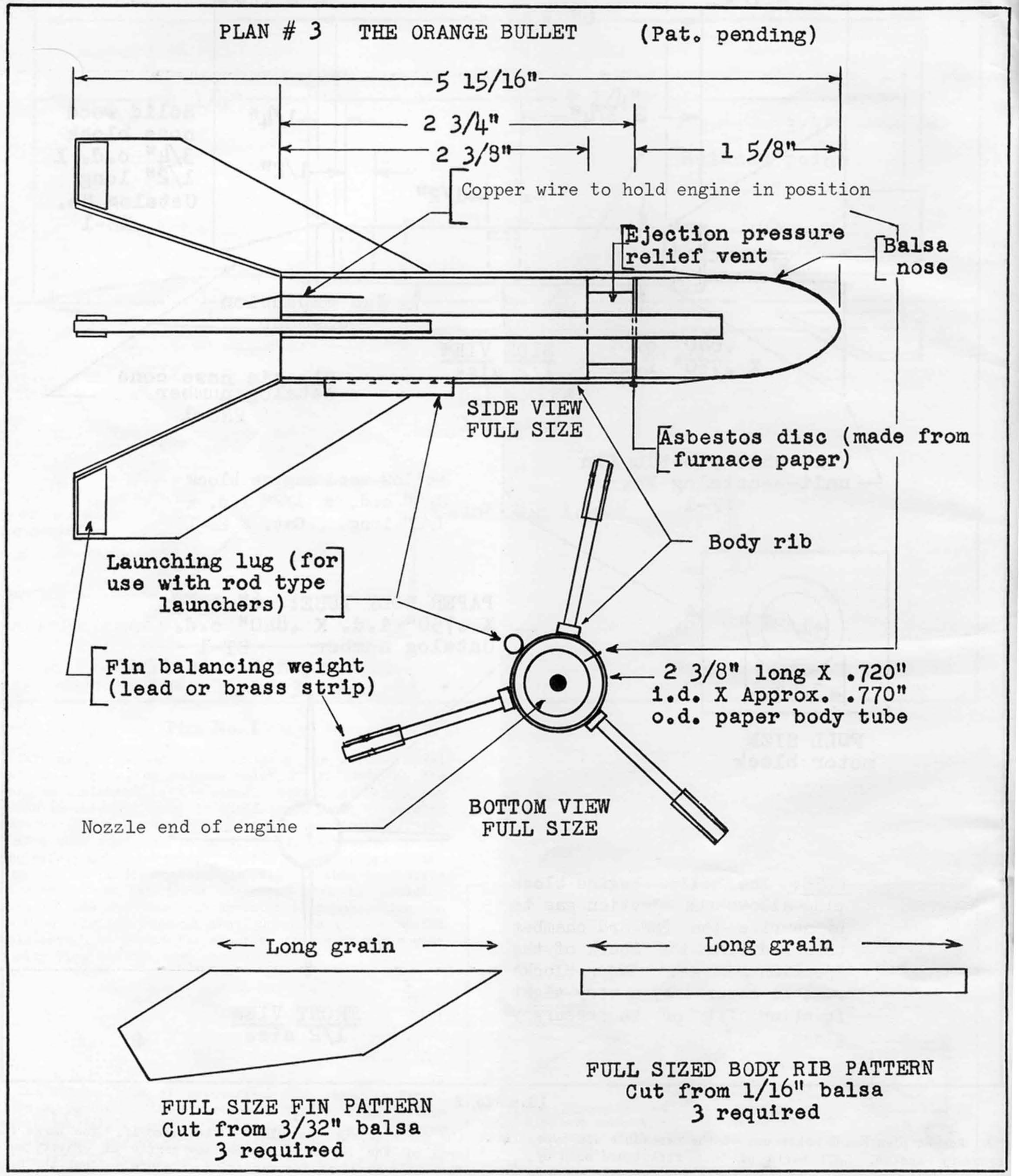




Plan No. 2

Rocket plan No. 2 makes use of the removable fin type recovery system. All parts on this rocket are sold by Estes Industries, Inc., or the rocketeer can make all of the parts except the plastic fins himself. The large fin area of the Sky Bird places the center of gravity sufficiently ahead of the center of pressure so that the balance point of this bird is not critical. Care should be exercised to make sure the fins fit sufficiently well so the rocket, upon fast acceleration, will not run off and leave the fins, but loosely enough so that the fins can be easily parted from the rocket body by the ejection charge in the motor. This recovery system is not recommended for use with series II engines.

The third method of recovery system which is accomplished by shifting the center of gravity requires that very careful consideration be given to the balance of the rocket. The engine must sit as far forward as possible. When the engine is in place it will add weight to the nose of the rocket, and when it is expelled at the end of the upward travel of the rocket, weight is removed from the nose and the center of gravity is shifted backward toward the fins. This puts the center of gravity behind the center of pressure and causes the rocket to return in a tumbling fashion. Plan No. 3 below makes use of this principle.



When this rocket is completed it should weigh approximately ¼ ounce without the engine installed. Enough weight is added to the tips of the fins to barely make the rocket unstable for its return flight. The proper weighting can be determined by throwing the motorless rocket into the air and noting the manner in which it falls. Add additional weight until the rocket does not fall nose first. If too much weight is added to the end of the fins it will cause the rocket to be unstable in its upward flight. The rocket is weighted properly when it is just barely unstable without the engine in place. Extreme care must be given to the mounting of the engine in the rocket so that the slightest pressure will allow the engine to be expelled through the rear of the rocket body.

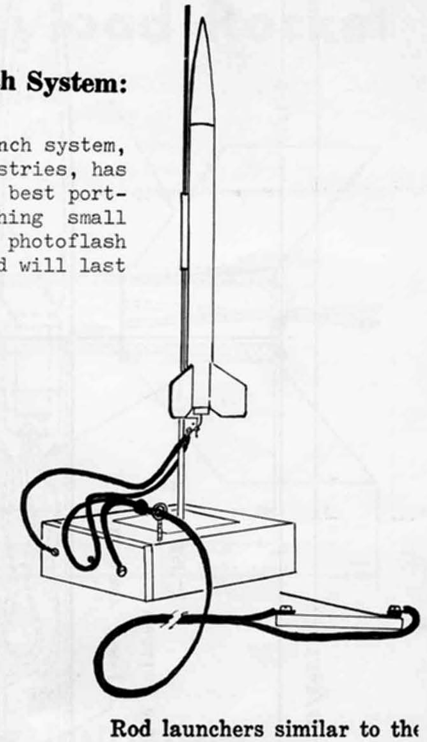
PROPELLANTS: The American Rocket Society estimates that a person has a one in seven chance of being seriously injured or killed for every year he participates in amateur rocketry. Model rocketry, on the other hand, has a record of over one million launchings without a single injury. This difference is due, for the most part, to the fact that model rocketeers do not mix their own propellants or build their own engines. They realize that explosive powders are dangerous to handle and that it would take a qualified engineer to build a motor which would perform as well as a production model. Also, mass produced engines are much less expensive.

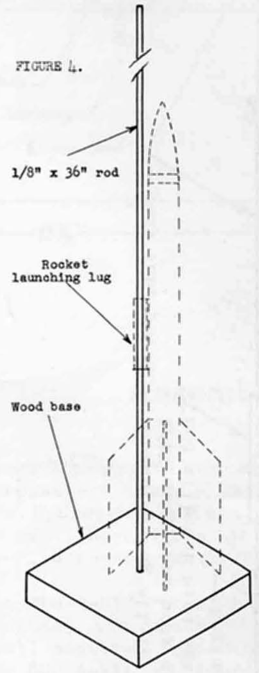
LAUNCHING SYSTEMS: Model rockets are stabilized by the air currents acting against their surface areas. In order for there to be any stabilizing effect the rocket must attain sufficient speed to cause the necessary air currents. For this reason, the rocket must be guided during its initial accelerating period. The type of rocket in plan No. 2 may be launched with a very short guide. This is due to its large fin area and high degree of stability. Rockets such as the ones shown in plans No. 1 and No. 3 require a greater velocity in order to become stabilized, thus they need a launching guide of greater length. Such a mechanism can either take the form of a launching rail or a tower. It should provide the guidance for a distance of 20" to 5' depending on the stability and acceleration factors of the particular rocket which is to be launched. The simplest launching guide consists of a 1/8" x 36" long piece of welding rod or music wire, (obtainable from your local hobby store) one end of which is set in a wood or concrete base. This system is illustrated in Figure 3. Commercially produced towers and launching rails are available, including the Electro-Launch produced by Estes Industries, which makes rocket launching somewhat more convenient. If a rod is used for launching rockets, it will be necessary to glue a launching lug to the body of the rocket. This lug can either be a piece of 5/32" x 2" aluminum tubing or a piece of plain soda straw which will fit loosely over the launching rod.

The shapes and designs obtainable in model rockets are limited only by the scope of the imagination of the young rocketeer.

The Electro Launch System:

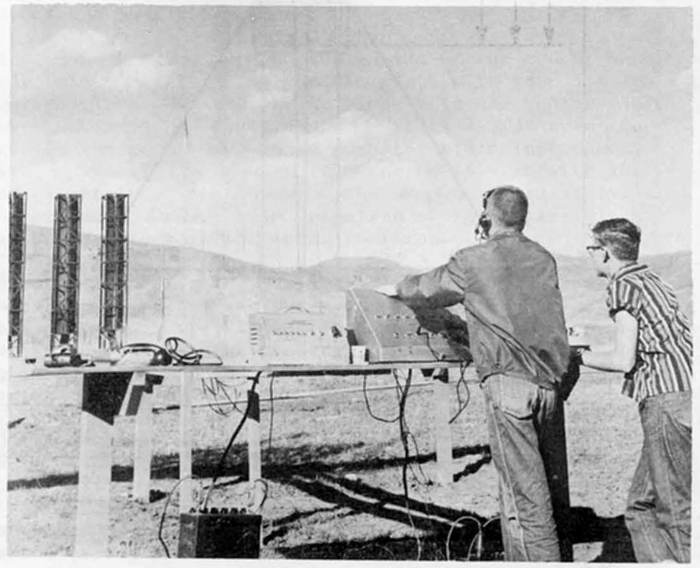
This complete Electro Launch system, available from Estes Industries, has proven to be one of the best portable systems for launching small models. Only four size D photoflash batteries are required and will last for over 50 launchings.





Rod launchers similar to the one shown here are the most commonly used type of launcher for model rockets. It consists of a ⅛" x 36" rod securely fastened to a wood base. A launching lug secured to the rocket body fits over the rod, thus providing a guidance means for the rocket during its initial flight.

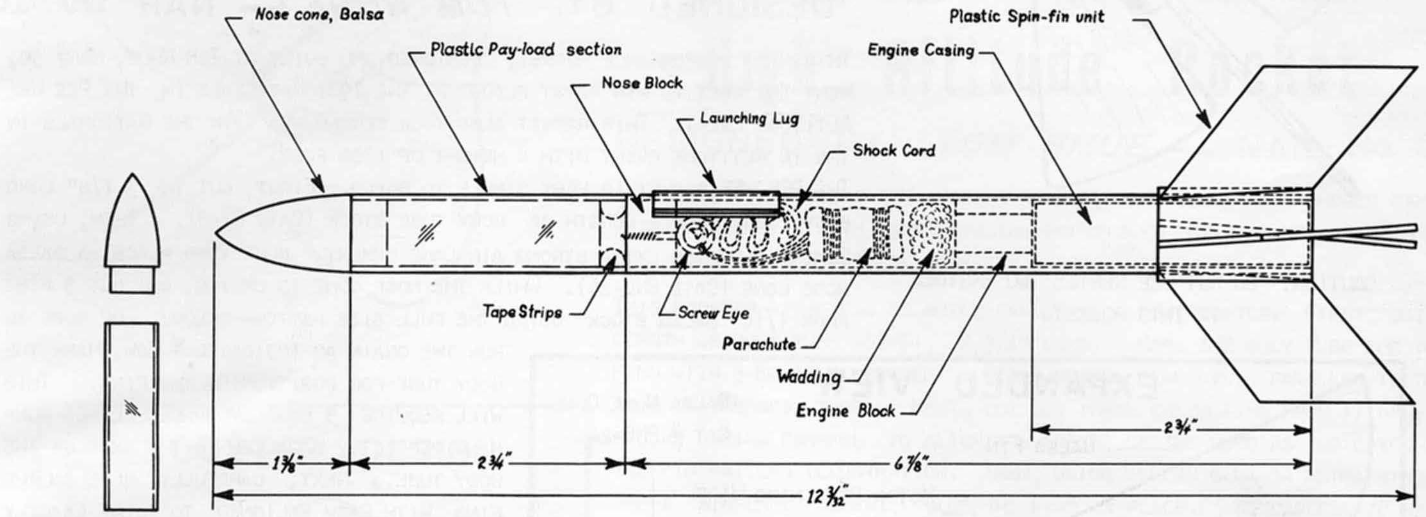
The range safety officer gives the all clear. A 10 second count down is given by the firing officer and with the press of a button the model streaks skyward. NAR Photo

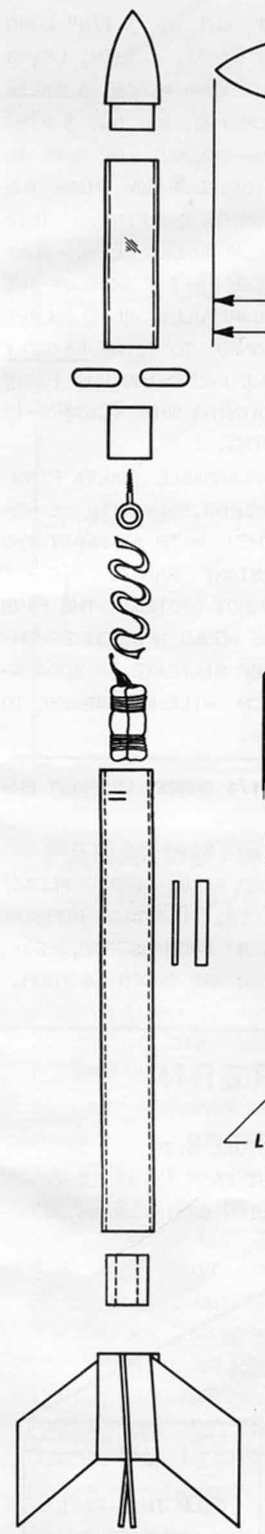


Estes Industustries Rocket Plan No. 4

BUG-A-BYE

Payload Rocket

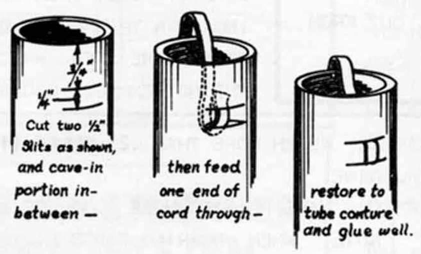


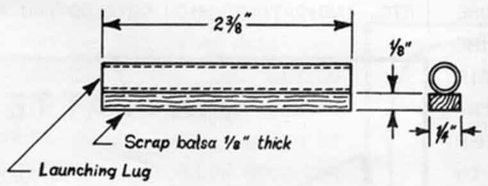


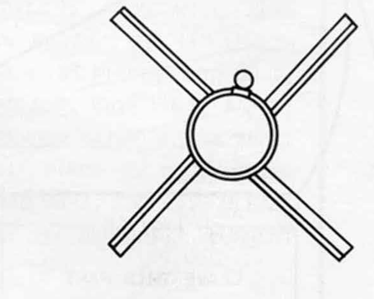
PARTS LIST

1-Payload section kit	#PS-40A
1-Launching lug	#LL-1B
1-Shock cord	#SC-1
1-Parachute material	#PM-1
1-Body tube (Cut to length.)	#BT-40
1-Engine block	#EB-40
1-Fin set	#PF-40B

Shock Cord Installation







Assembly Instructions

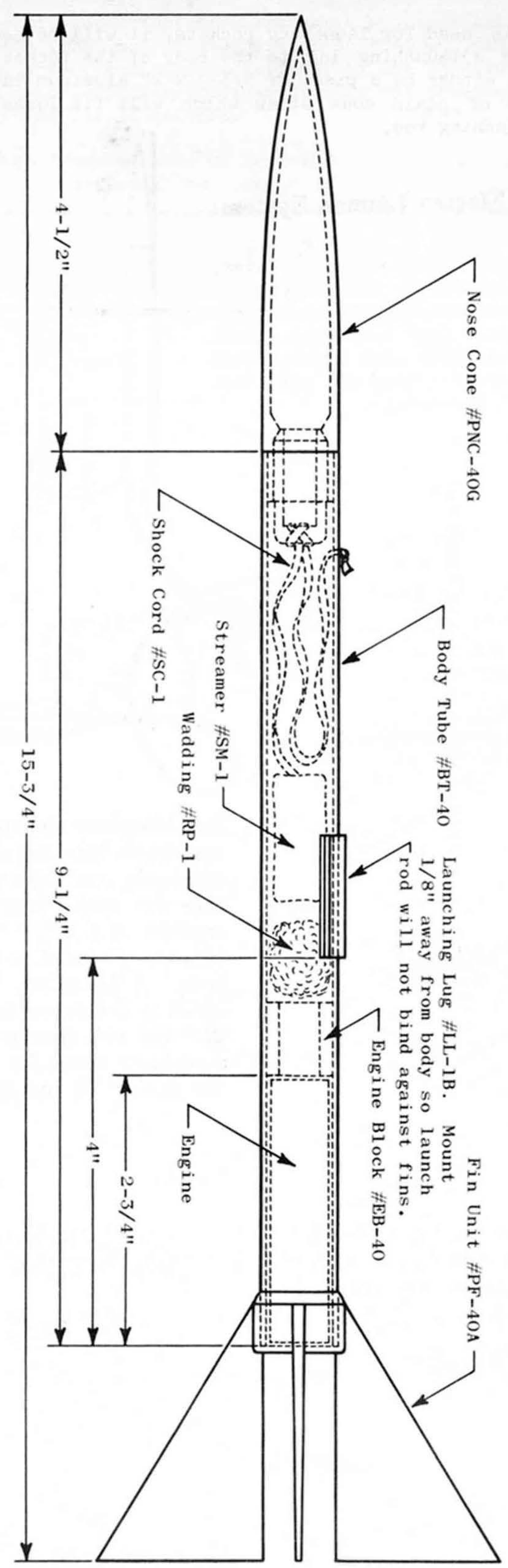
Every commercial or military rocket is designed for a purpose--to carry a payload. The payload may be a camera, hydrogen bomb, mail sack, radio transmitter, animal or man. Regardless of the payload requirements, however, a rocket can be designed to do the job.

The BUG-A-BYE rocket has been designed for its special purpose, the study of the effects of acceleration on small objects, including biological specimens. When the BUG-A-BYE is launched with a Series II engine the acceleration can exceed 100 G's. If the average man were to be subjected to G forces of this nature he would weigh about 17,000 pounds. What effect would this have on other objects? You can do your own experimenting and find out.

The BUG-A-BYE rocket is easy to build. The complete rocket can be built from standard parts listed in our current catalog. For constructing the rocket it has been found that white glue is best.

First spread glue around the inside of one end of the body tube as far in as you can reach with your little finger. Then push the engine block into the end of the tube and push it forward until it is 2-3/4" from the end.(An engine may be used to push the block into place. Push in until the end of the engine is even with the end of the tube, then remove the engine immediately.) Do not pause during this operation or the engine block may become stuck in the wrong position.

Glue the launching lug in place as shown in the drawing. Assemble the payload section according to the directions that accompanied it. Attach the shock cord and recovery system as shown in the drawing. The fin unit should be attached as shown in our catalog. If you are using a Series II engine be sure the fins are secured very tightly. Under acceleration of 100 G's they will have 100 times their normal weight. If they should come off your rocket could be damaged, and someone could be hurt if it hit him. The nose cone should fit tightly. If it is too loose wrap its shoulder with tape to increase the diameter. The maximum payload weight for this rocket is one ounce.



Dirty Bird III

THE DIRTY BIRD III, DESIGNED BY G. HARRY STINE, PRESIDENT OF THE NAR, IS ONE OF HIS FAVORITES, AS IT IS SO VERY EASY TO FLY AND ASSEMBLE. HERE IS HOW IT IS DONE. . .

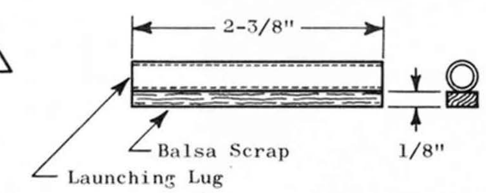
FIRST CUT A BODY TUBE 9 1/4" IN LENGTH. THEN GLUE THE ENGINE BLOCK IN PLACE AT A DISTANCE OF 2 3/4" FROM THE REAR OF THE BODY TUBE (SEE ILLUSTRATION). TO DO THIS, PLACE A LARGE DAB OF GLUE ON THE END OF YOUR LITTLE FINGER. REACH THROUGH THE END OF THE BODY TUBE AND SPREAD THE GLUE AROUND THE INSIDE OF THE TUBE AS FAR FORWARD AS POSSIBLE. BE VERY CAREFUL NOT TO GET ANY GLUE NEAR THE END OF THE TUBE. INSERT THE ENGINE BLOCK IN THE END OF THE TUBE AND USING AN ENGINE CASING PUSH IT FORWARD UNTIL IT IS 2 3/4" FROM THE REAR. WHEN INSERTING THE ENGINE BLOCK DO NOT STOP UNTIL IT IS IN ITS PROPER POSITION. SOME GLUES SET VERY QUICKLY, AND STOPPING FOR A MOMENT MAY CAUSE THE BLOCK TO SET IN THE WRONG PLACE. BE SURE TO IMMEDIATELY REMOVE THE ENGINE CASING.

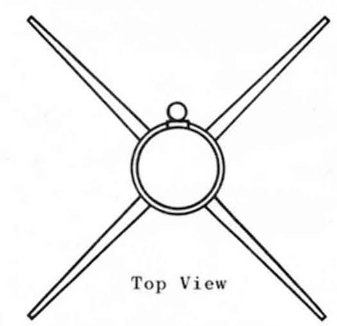
PUNCH A SMALL HOLE IN SIDE OF THE BODY TUBE ABOUT 1" FROM THE FRONT END. THEN TIE A KNOT IN ONE END OF THE SHOCK CORD, AND PUT THE OTHER END DOWN THROUGH THE HOLE IN THE BODY TUBE. REACH IN AND PULL THE SHOCK CORD THROUGH UNTIL THE KNOT COMES UP SNUG AGAINST THE BODY TUBE. PLACE THE STYRENE INSERT INTO THE NOSE CONE AND TIE THE MIDDLE OF THE SHOCK CORD TO THE EYELET. USE A TAPE DISC TO ATTACH THE OTHER END OF THE SHOCK CORD TO A 12" LENGTH OF STREAMER MATERIAL. CAREFULLY ALIGN AND GLUE THE LAUNCHING LUG TO THE SIDE OF THE BODY TUBE ABOUT HALF WAY ALONG THE TUBE. AFTER PLACING AN ENGINE IN THE END OF THE BODY TUBE, PUT ON THE TAIL FIN UNIT. TO ASSURE A TIGHT FRICTION FIT, IT MAY BE NECESSARY TO WRAP THE END OF THE BODY TUBE WITH SCOTCH OR MASKING TAPE.

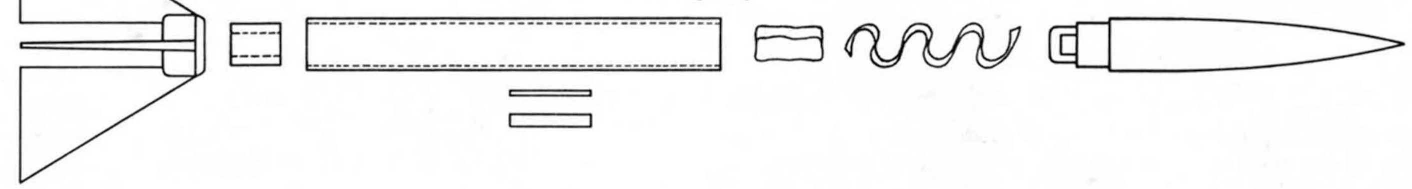
THE DIRTY BIRD FLYS BEST WITH "B" TYPE ENGINES (B.8-4 AND B 3-5). THE A.8-3 IS FINE IF YOU HAVE A LIMITED FLYING AREA OR DON'T WANT TOO MUCH PERFORMANCE. MAKE SURE THE FINS FIT VERY TIGHTLY WHEN YOU USE THE B 3-5 ENGINE.

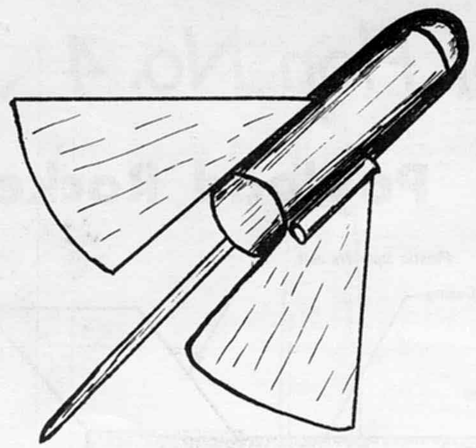
PARTS LIST

Plastic Nose Cone	# PNC-40G
Body Tube	# BT-40
Shock Cord	# SC-1
Streamer Material	# SM-1
Plastic Fins	# PF-40A
Engine Block	# EB-40
Launching Lug	# LL-1B









PEE WEE

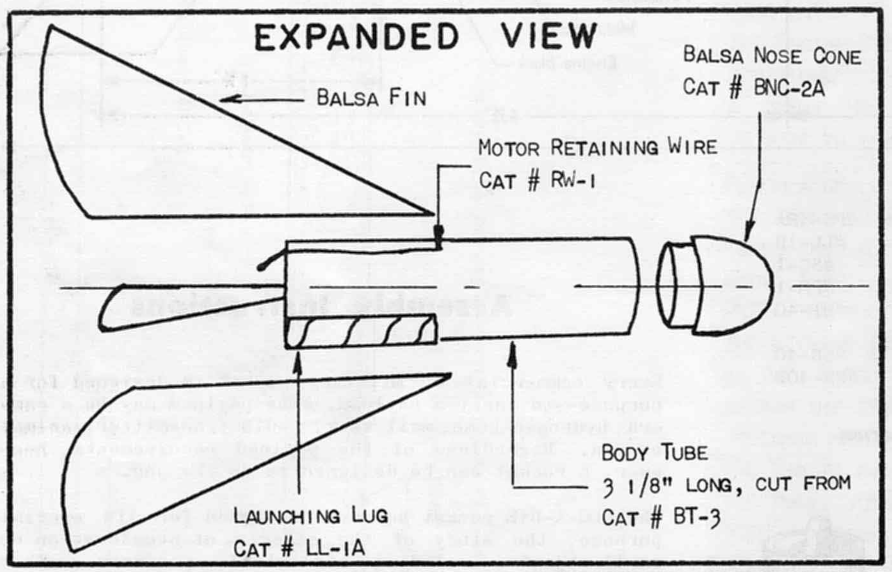
High Altitude Rocket

DESIGNED BY: *TOM RHUE* -- NAR No. 50

THIS HIGH PERFORMANCE ROCKET, DESIGNED AND BUILT BY TOM RHUE, NAR# 50, WENT 580 FEET TO WIN FIRST PLACE AT THE 1961 NATIONALS IN THE PEE WEE ALTITUDE EVENT. THIS ROCKET ALSO TOOK SECOND PLACE IN THE NATIONALS IN THE 1B ALTITUDE EVENT WITH A HEIGHT OF 1380 FEET.

THE PEE WEE ROCKET IS VERY SIMPLE TO BUILD. FIRST, CUT THE 3 1/8" LONG BODY TUBE FROM A LENGTH OF BODY TUBE STOCK (CAT# BT-3). THEN, USING ELMERS GLUE OR EXTRA STRONG AIRPLANE CEMENT, GLUE INTO PLACE A BALSA NOSE CONE (CAT# BNC-2A). WHILE THE NOSE CONE IS DRYING, CUT OUT 3 FINS FROM 1/16" BALSA STOCK USING THE FULL SIZE PATTERN BELOW. BE SURE TO RUN THE GRAIN AS INDICATED. NOW, MARK THE BODY TUBE FOR POSITIONING THE FINS. THIS WILL REQUIRE 3 EQUALLY SPACED LINES RUNNING PERFECTLY PARALLEL TO THE AXIS OF THE BODY TUBE. NEXT, CAREFULLY GLUE ON THE FINS WITH EACH ALIGNED TO POINT EXACTLY FORWARD. GLUE ON THE LAUNCHING LUG (CAT# LL-1A) AND MOTOR RETAINING WIRE (CAT#RW-1) AS SHOWN IN THE DRAWING.

CAUTION: DO NOT USE SERIES TWO ENGINES IN THIS ROCKET.



TO KEEP THE HIGHLY FLAMMABLE BALSA FINS FROM CHARRING OR BURNING, IT WILL BE NECESSARY TO PAINT THEM WITH AT LEAST TWO COATS OF FLAME RESISTANT PAINT. IF THE PAINT YOU USE DOES NOT PROTECT THE FINS SUFFICIENTLY, THEN WE WOULD SUGGEST BRUSHING ON A THIN COAT OF SILICATE OF SODA AROUND THE AREA WHICH WILL BE EXPOSED TO THE HOT EXHAUST GASES.

AS YOU WILL NOTICE, THE FINS ARE DESIGNED IN SUCH A WAY AS TO PROVIDE A HOLDER FOR A BOOSTER STAGE. FOR BOOSTER DESIGN, SEE OPPOSITE PAGE.

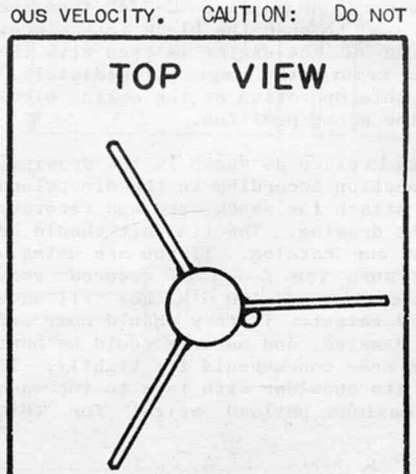
RECOVERY SYSTEM: THIS ROCKET MAKES USE OF ITS LIGHT WEIGHT (WITHOUT ENGINE) TO BRING IT BACK SAFELY. THIS IS KNOWN AS THE "FEATHER WEIGHT" RECOVERY SYSTEM. THE EXPENDED ENGINE CASING BLOWS OUT AT PEAK ALTITUDE THEN RETURNS SLOWLY BECAUSE IT IS LIGHT WEIGHT AND IS NOT AERODYNAMICALLY STABLE. THE ROCKET IS STABLE ON ITS RETURN FLIGHT, BUT BECAUSE OF THE AIR DRAG AGAINST SUCH A LIGHT WEIGHT, IT WILL NOT REACH A DANGEROUS VELOCITY. CAUTION: DO NOT TRY TO USE THE "FEATHER WEIGHT" RECOVERY SYSTEM ON ROCKETS OF YOUR OWN DESIGN WHICH:

A. HAVE HARD NOSE CONES (USE ONLY BALSA WOOD).

B. WEIGH MORE THAN .25 OUNCE (1/4 OUNCE) WITHOUT ENGINE.

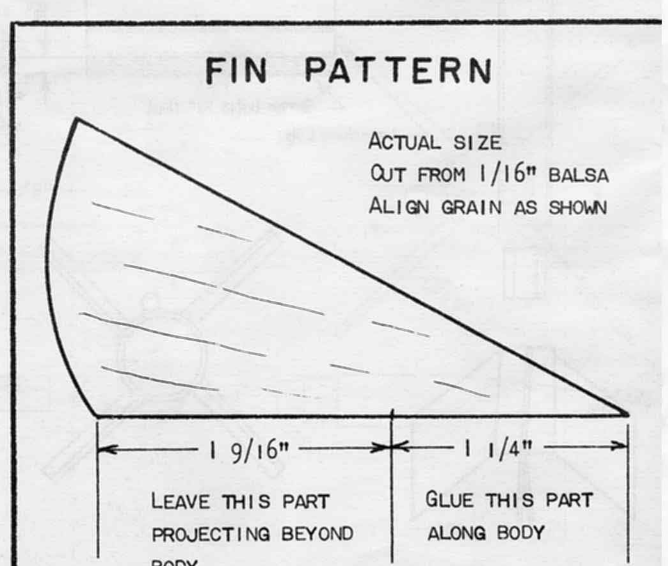
C. HAVE POINTED NOSE CONES OF ANY MATERIAL.

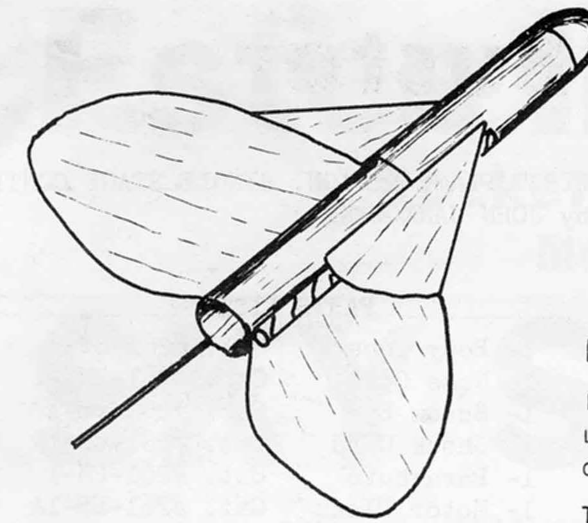
NOTE: WHEN ORDERING PARTS LISTED BELOW LEFT, PLEASE CONSULT CATALOG FOR CURRENT PRICES. (CATALOG NUMBERS ARE PRECEDED BY A 3 DIGIT NUMBER SUCH AS 162, 261, ETC. INDICATING WHICH CATALOG YOU ARE ORDERING FROM.



PARTS LIST

1-BT-3 BODY TUBE
1-BNC-2A NOSE CONE
1-LL-1A LAUNCHING LUG
1-RW-1 RETAINING WIRE
1-BFS-2 FIN STOCK





TWO STAGE PEE WEE

High Altitude Rocket

DESIGNED BY: *TOM RHUE* -- NAR No. 50

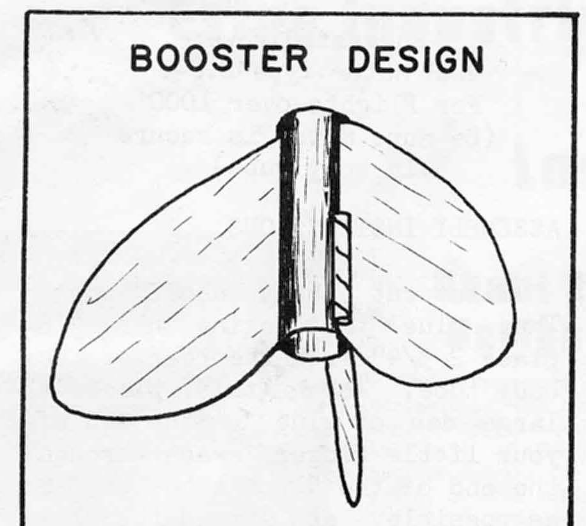
IF YOU HAVE NOT BUILT A TWO-STAGE ROCKET, PREVIOUSLY, YOU SHOULD FAMILIARIZE YOURSELF WITH MULTI-STAGING PRINCIPLES BY READING OUR TECHNICAL REPORT ON MULTI-STAGE ROCKETS.

THIS BOOSTER STAGE CAN BE BUILT EASILY IN A FEW MINUTES. FIRST, CUT A LENGTH OF BODY TUBE (BT-3), 2 3/4" LONG. MARK THE BODY TUBE FOR THE FINS WITH 3 EQUALLY SPACED LINES RUNNING PERFECTLY PARALLEL TO THE AXIS OF THE BODY TUBE. NEXT, CUT OUT THREE BALSA FINS FROM 1/16" FIN STOCK, BEING CAREFUL TO ALIGN THE GRAIN OF THE WOOD AS INDICATED IN THE FIN PATTERN ILLUSTRATION. THEN, USING ELMERS GLUE OR EXTRA STRONG MODEL AIRPLANE CEMENT, GLUE THE FINS IN PLACE. BE CAREFUL TO HAVE THEM ALL POINTING EXACTLY FORWARD. GLUE THE LAUNCHING LUG, CAT# LL-1A NEXT TO A FIN, BUT ON THE OPPOSITE SIDE OF THE FIN FROM THE LUG ON THE UPPER STAGE.

THIS ROCKET IS DESIGNED SO THE TWO STAGES ARE COUPLED TOGETHER BY FITTING THE LOWER STAGE BODY INTO THE PROJECTING FINS OF THE UPPER STAGE. WHEN THE SECOND STAGE IGNITES (AT BURN-OUT OF THE LOWER STAGE) THE LOWER STAGE WILL DROP OFF. THE ROCKET ENGINE IS SECURED IN THE LOWER STAGE WITH A RUBBER BAND OR BY TAPING AS SHOWN IN THE ROCKET ENGINE INSTRUCTION SHEET. THE UPPER STAGE ENGINE IS HELD IN PLACE <u>ONLY</u> BY THE MOTOR RETAINING WIRE, SINCE IT MUST BE FREE TO BLOW OUT AT THE APEX OF THE FLIGHT.

THE BOOSTER STAGE, WHEN SEPARATED FROM THE FIRST STAGE, IS NOT STABLE IN FLIGHT. AFTER SEPARATION, IT WILL FLUTTER BACK SAFELY TO THE GROUND. THE PARTS LISTED FOR THE UPPER STAGE WILL GIVE YOU SUFFICIENT MATERIALS FOR BUILDING THIS BOOSTER STAGE, TOO.

TWO STAGE ROCKETS TEND TO WEATHER COCK VERY BADLY-----DO NOT FLY YOUR TWO STAGE ROCKET IN WINDY WEATHER.

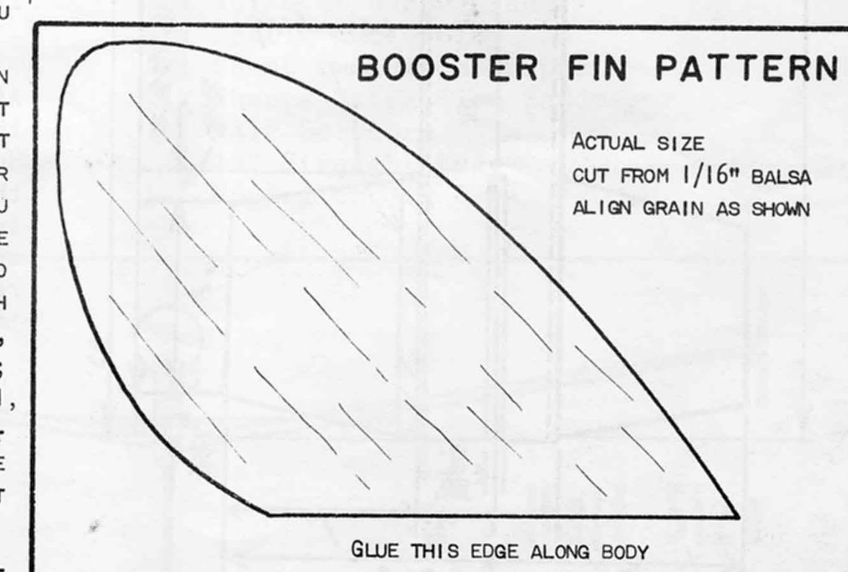


PARACHUTE OR STREAMER RECOVERY SYSTEM

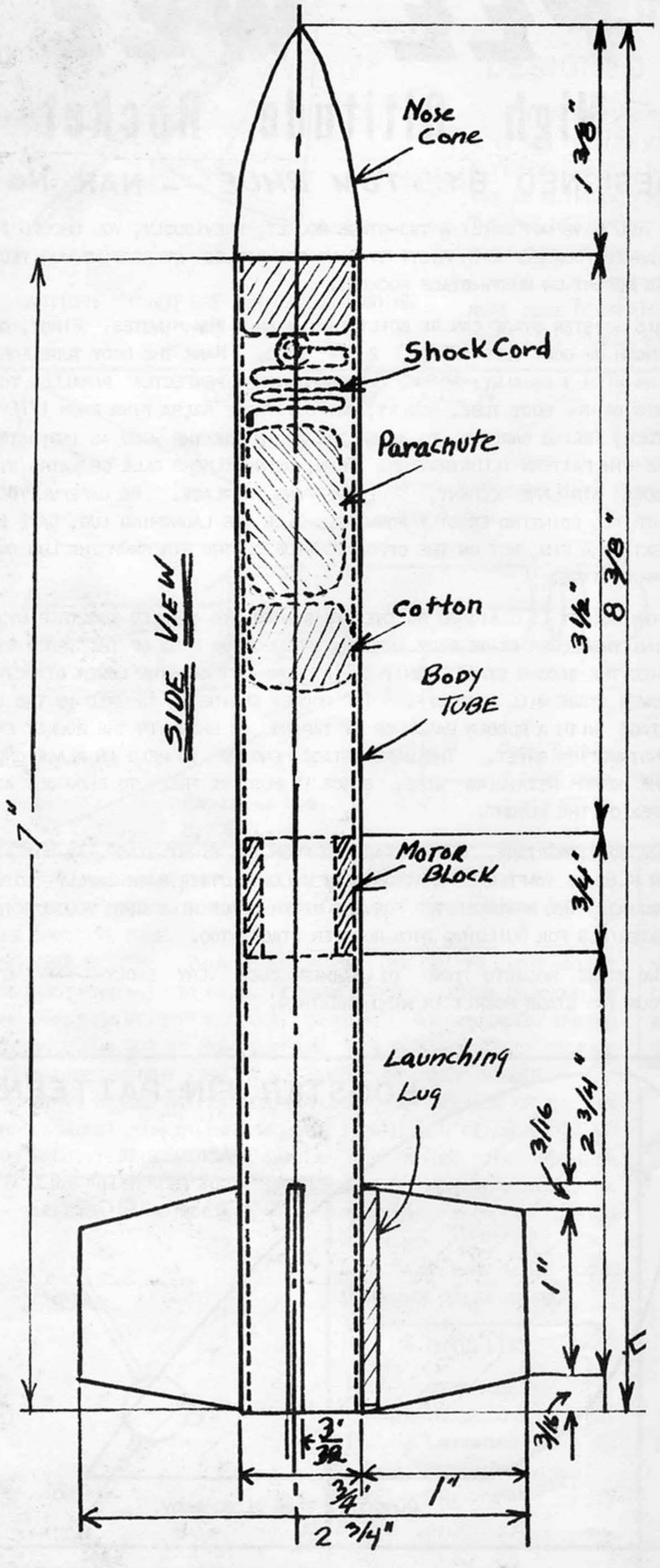
THE UPPER STAGE IS VERY HARD TO SEE WHEN IT IS 2000 FEET UP IN THE AIR. IN FACT, YOU WILL BE LUCKY IF YOU CAN SEE IT AT ALL.

TO IMPROVE THE VISIBILITY FOR THE RETURN FLIGHT, YOU MAY WISH TO REDESIGN YOUR ROCKET SO THAT A PARACHUTE OR STREAMER EJECTS AT THE APEX OF THE FLIGHT. TO ALLOW ROOM FOR THE STREAMER AND THE PROTECTIVE STUFFING YOU SHOULD ADD TWO INCHES TO THE LENGTH OF THE BODY TUBE (5 1/8" TOTAL). YOU WILL ALSO NEED THESE ADDITIONAL PARTS. USE 11" LENGTH OF <u>SHOCK CORD</u> CUT FROM 18" PIECE, CAT# SC-1, 20¢ EA; ONE <u>ENGINE HOLDER</u>, CAT# EH-1, 15¢EA; ONE 22" PIECE OF <u>STREAMER MATERIAL</u>, CAT#SM-1, 15¢ EA; AND ONE SMALL PIECE OF <u>GAUZE REINFORCING MATERIAL</u>, CAT# GR-2, 20¢ EA. PLEASE CONSULT OUR CURRENT CATALOG FOR CURRENT PRICES ON THE ABOVE ITEMS.

ASSEMBLE YOUR PARACHUTE OR STREAMER ACCORDING TO STANDARD PROCEDURE.



the Cloud Buster



FIRST PLACE DESIGN, SINGLE STAGE CONTEST
by JOHN JANKOWSKI

PARTS LIST

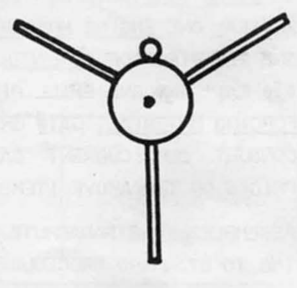
1- Body Tube	Cat. #261-BT-3
1- Nose Cone	Cat. #261-BNC-1
1- Screw Eye	Cat. #261-SE-1
1- Shock Cord	Cat. #261-CR-1
1- Parachute	Cat. #261-PM-1
1- Motor Block	Cat. #261-EB-1A
1- Fin Stock	Cat. #261-BFS-1
1- Launching Lug	Cat. #261-LL-1B

Suggested Power
NAR Motor Type B.8-6
For Flights over 1000'
(Be sure motor is secure
in body tube)

ASSEMBLY INSTRUCTIONS

First cut a body tube 7" long. Then glue the engine block in place 2 3/4" from the rear of the body tube. To do this, place a large dab of glue on the end of your little finger, reach through the end of the body tube as far as possible, and spread the glue around the inside of the tube. Insert the engine block into the end of the tube, and using an engine casing push it forward until it is the right distance from the rear. Do not stop until it is in its proper position.

Glue the fins solidly in place. Attach the launching lug. Attach the screw eye to the nose cone. Hook one end of the shock cord to the body tube near the top, glue in position, and fasten the other end to the screw eye. Put the rocket together and paint to taste.



TOP VIEW

Estes Industries

Rocket Plan No. 12

March, 1963

SKY SLASH II

Winning Design

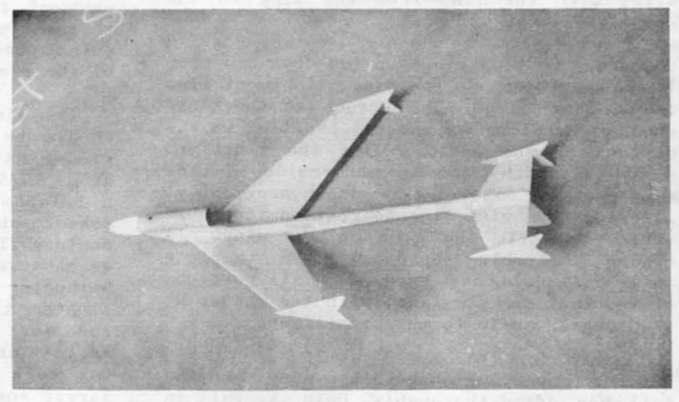
Estes Industries Boost-Glide Contest

by

Larry Renger

About the Designer

Larry Renger is a Senior in Aeronautical and Astronautical Engineering at Massachusetts Institute of Technology. A serious modeler for over seven years, he also holds three AMA indoor records, and combined his skills in model aeronautics and model rocketry to produce this design.

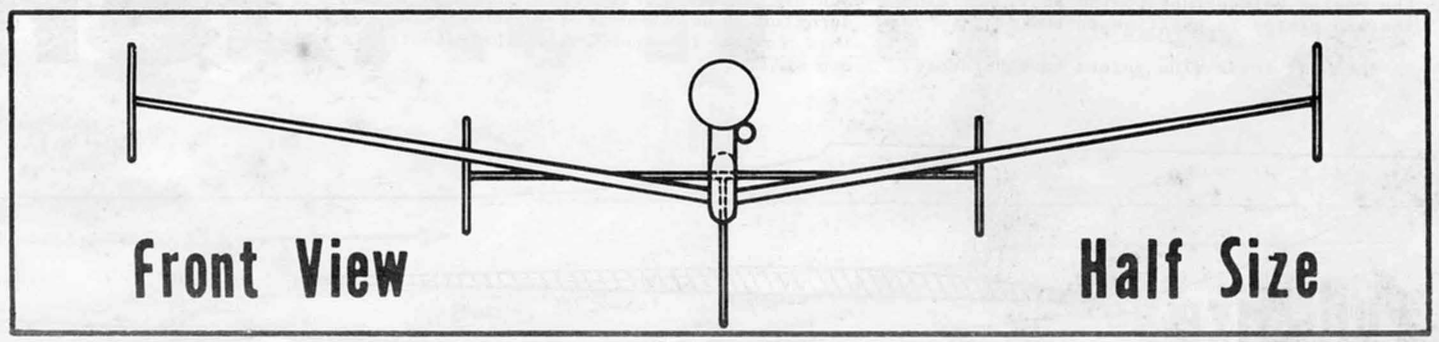


Parts List

1 Nose Cone BNC-20B
1 Sheet Balsa BFS-80
2 Sheets Balsa BFS-40
2 Sheets Balsa BFS-20
1 Body Tube BT-20
1 Launching Lug LL-1B
1 Nose Cone Weight NCW-1

Eqipment Needed

1 Knife or Razor Blade
1 Bottle White Glue
1 Sheet Medium Sandpaper
2 Sheets Extra Fine Sandpaper
1 Pair Scissors
1 18" Straight Edge
1 Coping or Jig Saw



Assembly Instructions

This model is recommended only for the experienced modeler, as care and precision in the building are necessary for satisfactory results. The rocketeer who has previous experience with both boost-gliders and model airplanes is in the best position to build this glider.

Begin construction by tracing the patterns for the balsa parts onto the proper sized balsa sheets. Be sure that the balsa thickness is the same as that indicated on the plan sheet. Cut out the parts, being careful to run the wood grain in the direction required.

Sand the wings to the airfoil shown on the plans, and sand all other parts to achieve a smooth surface. Using a straight edge at least 18 inches long, mark the body for wing, stabilizer, and engine alignment. For this alignment, hold one end of the straight edge so that its edge is at the point on the rear of the body where the top of the stabilizer will come, run the other end of the straight edge to fall on the position for the bottom of the wing, and draw a line here for aligning the wing. Sand the 2 1/4" notch in the bottom of the rear of the body so that the notch's surface will run exactly on the line from the bottom of the wing to the rear of the body. Sand the upper forward part of the body so that the edge to which the engine holder tube is attached will be exactly parallel with the line from the wing to the stabilizer.

Turn the body piece upside-down and prop it in position so the wing attachment line is one inch from the surface of the table and so the line is exactly parallel to the surface of the table. Glue the wings in position, with the flat underside of the wing exactly on the line drawn previously, allowing the wing tips to rest on the table surface. While the glue on the wings is drying, assemble separately the complete tail section. Make sure that all portions of the tail are straight, with the rudder at a 90 degree angle to the stabilizer.

After the glue on both the wings and the tail has dried thoroughly, hold the tail in place against the body, and using the straight edge, check to be sure the wings and tail will fall exactly in line, and be sure that the forward upper surface where the engine holder tube will be attached is exactly parallel to the wing-tail line. Glue the assembled tail in place, checking to be sure that the alignment is still correct. If a wide, circular glide is desired, glue the tail assembly in place so that one tip is 1/8" higher than the other tip. After the glue holding the tail to the body has hardened, check the alignment again, then check to be sure the forward upper surface is still parallel to the wing-tail line. Glue the nose cone in the engine holder tube, glue the engine holder tube to the body, and glue the tip plates in position on the wings.

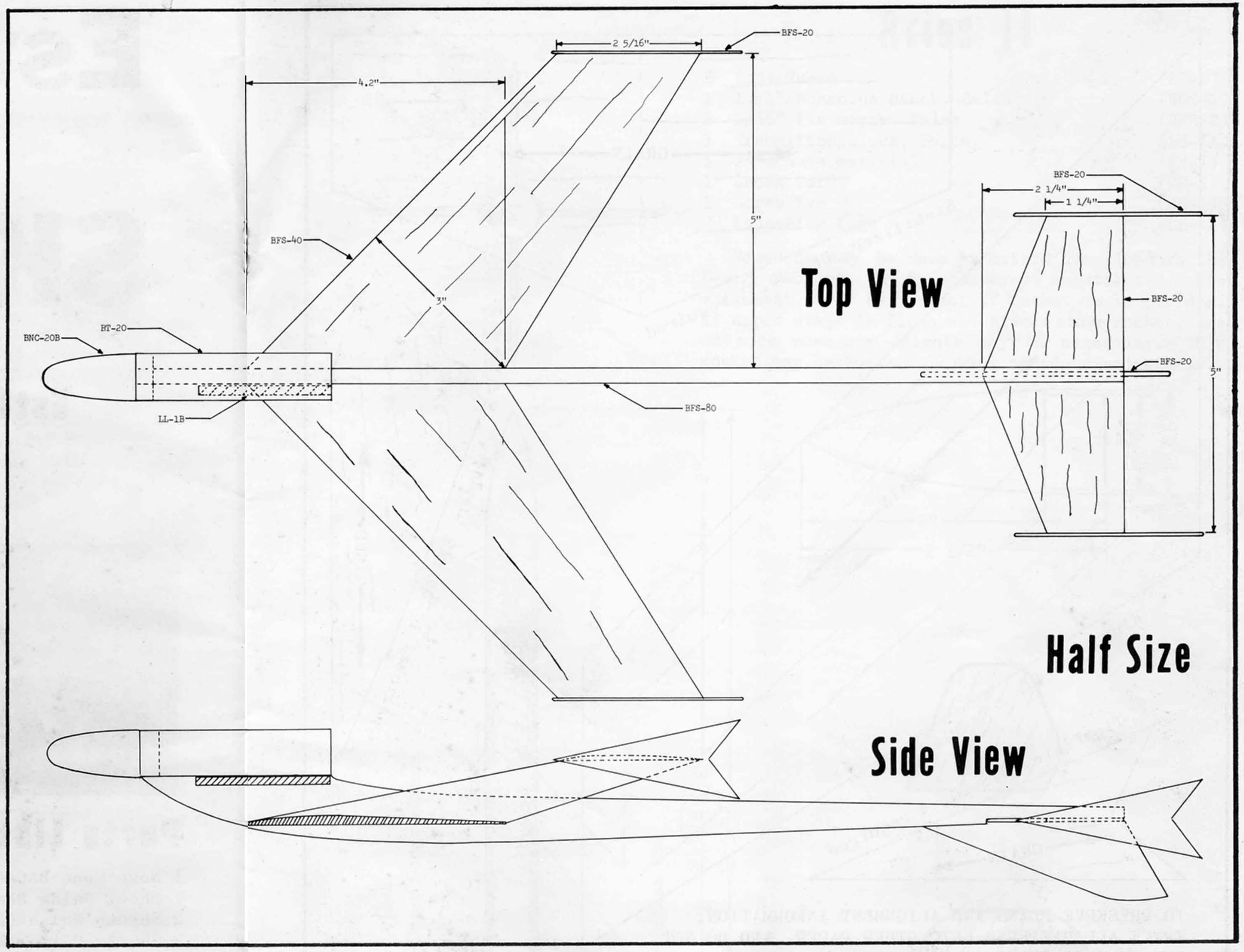
When all these glue joints have hardened, apply a glue fillet to all joints with the exception of the nose cone joint. Apply a light coating of white glue to the upper surface of the body for its entire length to protect the body from the exhaust gases. Glue the launching lug in place. A second fillet layer may be applied to the wing-body joint to give it additional strength.

Punch or cut one 3/16" diameter or several 1/16" diameter ejection pressure relief vent holes in the engine holder tube 1/8" back from the base of the nose cone. To check the positioning of the holes, place an engine casing in the holder tube, mark the casing where the rear of the holder comes, take the casing out, lay the casing against the tube with the mark next to the rear of the tube, mark the tube where the forward end of the casing touches it, and cut the hole 1/8" back of this point.

Before flying the Sky Slash II, balance it for glide by hand launching it and adding small amounts of weight (slivers of nose cone weight NCW-1) to the nose if the rocket stalls, or to the tail if the rocket comes in too fast. When the Sky Slash II is properly balanced, it should travel at least 20 feet forward for every foot of drop when hand launched lightly. Hand launched duration should average over four seconds for a well balanced model, although the maximum for a particular model will vary. The best way to get the best glide is to work on the balancing until the model feels right and appears to glide right, both of which are part of the modeler's skill gained only through practice. Generally the balance point for the glider will be in the region of the rear of the wing-body root joint.

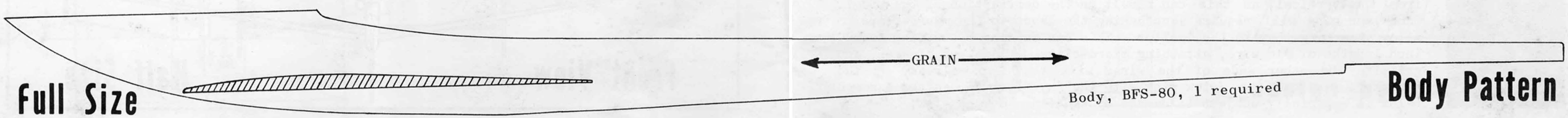
The first flights on the Sky Slash II should be made with 1/4A.8-2 engines if the glider without engine weighs less than 20 grams (3/4 ounce, determined by weighing on a balance; the science department at your school should have one) or with 1/2A.8-2 engines if the rocket is heavier. Individual weights will vary with the amount of sanding, balancing weight, and paint. Generally, the lighter the glider, the longer the flight. For most sport flying, the 1/4A and 1/2A engines are recommended, as the Sky Slash II may well go out of sight on the glide with larger engines. For contest use, the B.8-2 engine is recommended.

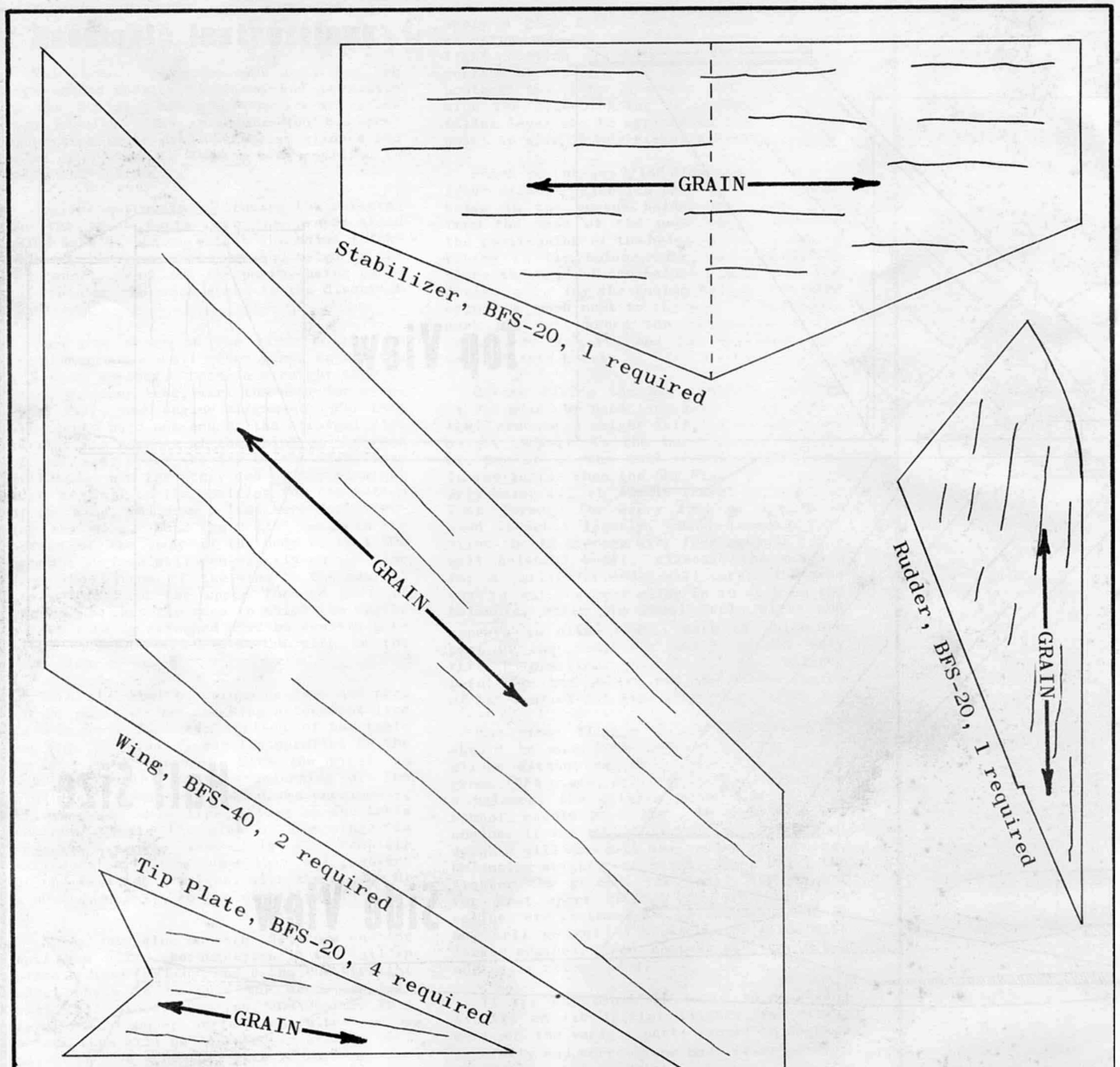
If the Sky Slash II fails to rise vertically on its initial flights, the alignment of the various parts should be checked carefully and corrections made if necessary. In addition, if one wing is heavier than the other, the glider may tend to turn in the direction of the heavier wing under power and in glide. If this is the case, the proper amount of weight added near the tip of the light wing will correct this. If there is much difference between the airfoils of the two wings, this may also cause a poor flight. As experience is gained in the use of this design, it will be possible to achieve better vertical flights and longer durations, as much of the performance of this rocket is dependent on the rocketeer's own skill.



SKY SLASH II

Design by Larry Renger





TO PRESERVE PLANS AND ALIGNMENT INFORMATION, TRACE ALL PATTERNS ONTO OTHER PAPER, AND DO NOT CUT UP THIS SHEET.

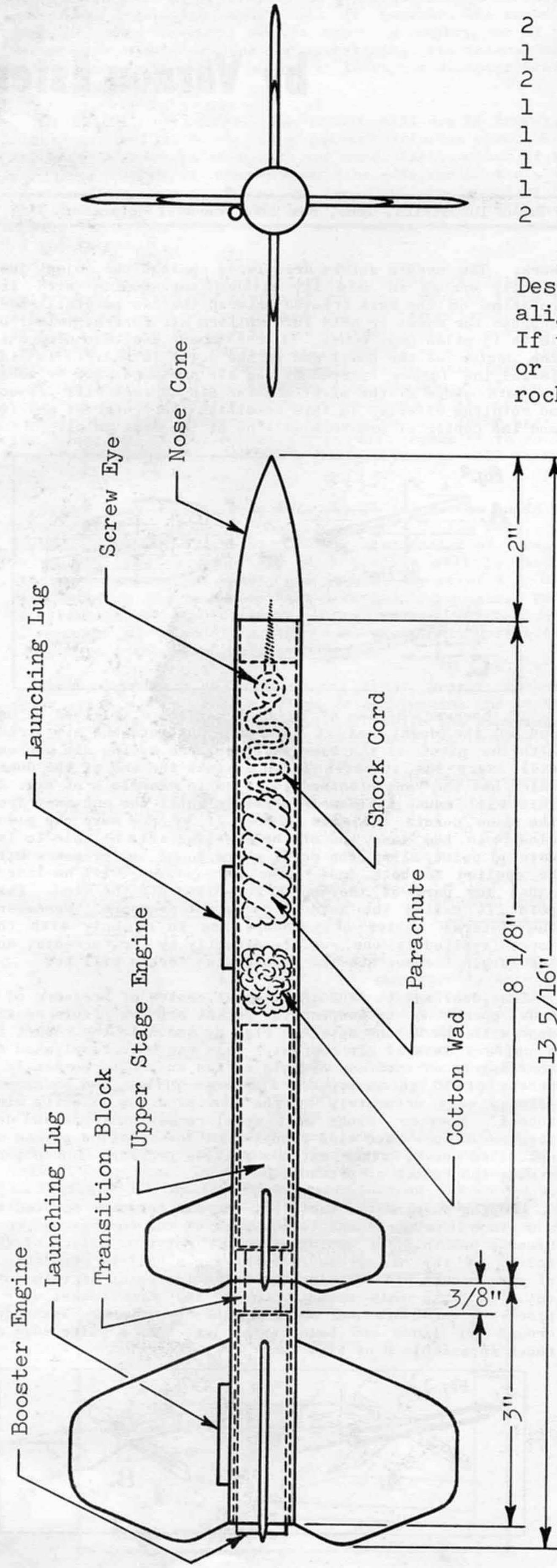
Launching Information

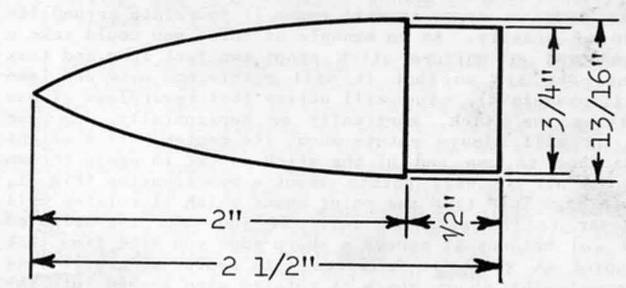
The Sky Slash II is launched vertically using an electric firing system. DO NOT launch the Sky Slash II at any angle greater than 30 degrees from the vertical, as this can result in the destruction of the model. Some launchers will require lengthening the leads to the micro-clips to allow attaching them to the ignitor. This can be done by cutting two 20 inch lengths of #18 wire, attaching micro-clips to one end of each, and gripping the other ends of the wires with the clips already on the launcher. Do not use Jetex wick with the Sky Slash II, as the exposed balsa is especially subject to damage by the flame of the wick.

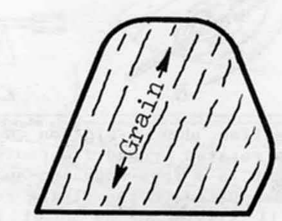
Aries II

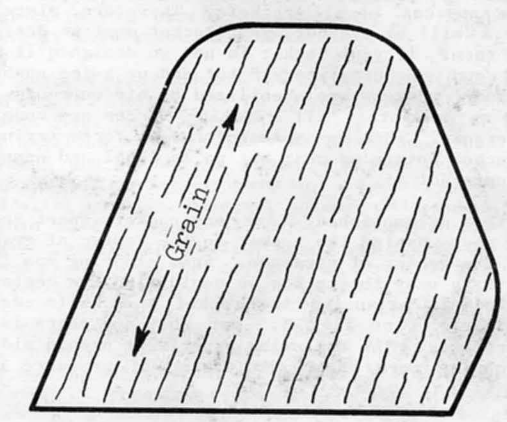
2	Body Tubes	(BT-3)
1	1 x 1" Nosecone stock, Balsa	(NCS-1)
2	1/16" Fin stock, Balsa	(BFS-2)
1	Transition block, Balsa	(EB-1A)
1	Parachute material	(PM-1)
1	Shock Cord	(CR-1)
1	Screw Eye	(SE-1)
2	Launching Lugs	(LL-1A)

Nosecone may be made by method described in the Design Booklet, or BNC-3A may be substituted. Fin alignment must be perfect if rocket is to perform. If upper stage is flown as a single stage rocket, one or more nosecone weights may be necessary. This rocket may be built following standard procedures.









design by Ric Wilson

Estes Industries Technical Report TR-1

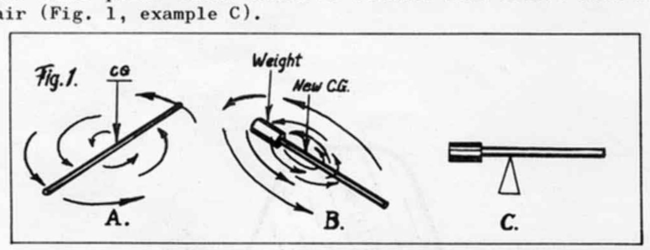
ROCKET STABILITY

by Vernon Estes

These reports are published as a service to its customers by Estes Industries, Inc., Box 227, Penrose, Colorado.

One of the first principles any rocket designer must learn is that unless a rocket has a complex electro/mechanical guidance system, it will fly only if its center of gravity (also known as center of mass) is far enough ahead of the center of pressure to allow air currents to act against the rocket causing a stabilizing effect.

From your science class or other scientific studies you have probably learned that if a rotating force is applied to a free body in space it will cause it to rotate around its center of gravity. As an example of this, you could take a wooden dowel or uniform stick about two feet long and toss it into the air so that it will rotate end over end (see Fig. 1, example A). You will notice that regardless of how you throw the stick, vertically or horizontally, hard or easy, it will always rotate about its center. If a weight is attached to one end of the stick and it is again thrown into the air it will rotate about a new location (Fig. 1, example B). This time the point about which it rotates will be closer to the weighted end. If you take the weighted stick and balance it across a sharp edge you will find that the point at which it balances (its center of gravity) is the same point about which it rotated when tossed into the air (Fig. 1, example C).

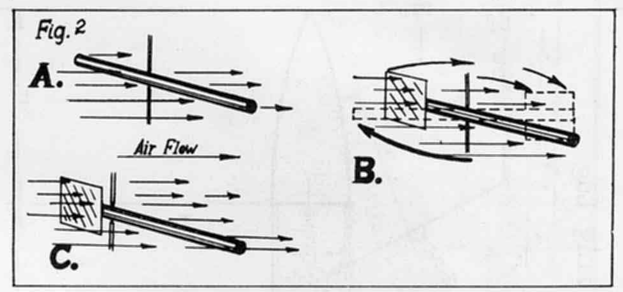


This simple explanation should aid you in understanding how a free body in space rotates around its center of gravity. A model rocket in flight is a free body in "space." If, for any reason, a force is applied to the flying rocket to cause it to rotate, it will always do so about its center of gravity.

Rotating forces applied to rockets in flight can result from lateral winds, air drag on nose cones, weights off-center, air drag on launch lugs, crooked fins, engine mounted off-center or at an angle, unbalanced drag on fins, unequal streamlining, etc. Obviously, some of these factors are going to be present in all rockets. Therefore, since rotating forces will be present, your rocket must be designed to overcome them. If your rocket is not so designed it will loop around and go "everywhere," but end up going nowhere. Nearly all model rockets are stabilized by air currents. By stabilized, we mean that all rotating forces are counteracted or overcome. This means that for each force trying to make the rocket rotate we must set up an equal and opposite force to counteract it.

How is this accomplished? Ask any rocket expert and he will simply say to design the rocket so the center of gravity is ahead of the center of pressure. From studying our first experiment it is easy to see how we could find the center of gravity by simply balancing the rocket on a knife edge as shown in example A of Fig. 3. But what and where is the center of pressure? The following experiment should aid you in understanding more about the center of pressure of a rocket.

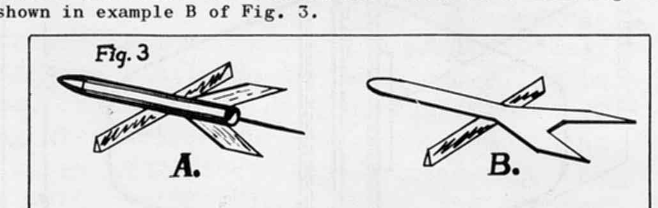
Suppose we take the same 2 foot long piece of dowel used in our first experiment and place it on a low friction pivot as shown in example A of Fig. 2. (The low friction pivot consists of two needle points held rigidly in place on opposite sides of the object by a heavy wire or board framework. The needle points are placed against the object just tightly enough to hold it, without interfering with its rotating on the axis created between the two points.) Then suppose the dowel is held in a uniform air current (wind) of 10 to 15 miles per hour. If the pivot has been placed in the center of the dowel and if the dowel is uniform in size (area) the forces exerted by the air pressure will be equal on both sides of the pivot and the air current will produce no rotating effect. In this condition the center of gravity and the center of pressure will be at the same point.



If, however, a vane of 3" x 3" cardboard is glued to one end of the dowel and it is again put into the air stream with the pivot in the same position, the moving air current will exert the greatest force against the end of the dowel which has the vane attached to it as in example B of Fig. 2. This will cause the dowel to rotate until the end away from the vane points into the wind. If we now move the pivot closer to the vane end of the dowel we will be able to locate a point along the dowel where equal air pressure will be applied to both ends. The air current will no longer cause any part of the dowel to point into the wind. This point is called the lateral center of pressure. Remember, the lateral center of pressure has to do only with the forces applied to the surface directly by air currents, and the larger the surface the greater the forces will be.

The ideal way to find the lateral center of pressure of a model rocket is to suspend the rocket between pivots as was done with the 2 foot dowel in Fig. 2, and hold the rocket in a uniform lateral air current. This can be accomplished to some degree of accuracy by holding the suspended rocket in a breeze of 10 to 15 m.p.h. The same effect can be accomplished very accurately by the use of a low velocity wind tunnel. However, since most model rocket builders and designers do not have wind tunnels and low friction pivots as described above, other methods must be provided for determining the center of pressure.

Keeping in mind the fact that the air pressure applied to a surface is proportional to the area of the surface, it then becomes possible to approximate the rotating effect of the action of the air pressure by making a uniform area cutout of your rocket and locating the balancing point of this cutout. To make this cutout, simply lay your rocket over a piece of cardboard and mark around the edges. Next, cut around the lines and balance the cutout on a knife edge as shown in example B of Fig. 3.



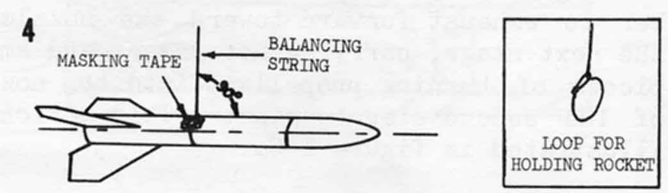
This method will determine the lateral center of pressure (the center of pressure with the air currents hitting the rocket broadside). If the rocket is designed so the lateral center of pressure is 1/2 the body diameter (1/2 caliber) behind the center of gravity it will have ample stability under all reasonable conditions. If, however, the rocket's fins are very crooked, set at opposing angles, or if the rocket uses a disc or cone for stabilizing, the lateral center of pressure should be set at least one diameter behind the center of gravity.

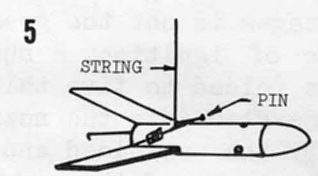
In flight, of course, the rocket will not be traveling sidewards, but with its nose pointed into the wind. With the model's nose pointed into the wind, the location of the effective center of pressure will be affected by the shape of the fins, the thickness of the fins, the shape of the nose cone, location of the launching lug, etc. With most designs this shift is to the rear, adding to the stability of the rocket.

Suppose a model rocket starts to rotate in flight. It will rotate around its center of gravity. When it turns the air rushing past it will then hit the rocket at an angle. If the center of pressure is behind the center of gravity on the model, the air pressure will exert the greatest force against the fins. This will counteract the rotating forces and the model will continue to fly straight. If, on the other hand, the center of pressure is ahead of the center of gravity the air currents will exert a greater force against the nose end of the rocket. This will cause it to rotate even farther, and once it has begun rotating it will go head over heels in the air.

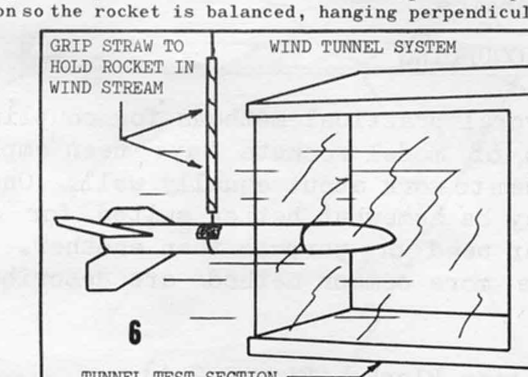
It is easy to see from this why it is best to build the rocket with its fins as far as possible to the rear. The farther behind the center of gravity the center of pressure is placed, the stronger and more precise will be the restoring forces on the model, and it will fly straighter with less wobbling and power-robbing side-to-side motion. Under no circumstances should fins be placed forward of the center of gravity on a model, as they will add to its unstability tendencies rather than help stabilize it.

When building high performance, light weight rockets, quite often a more precise method of determining the stability margin of the rocket is desired. While the experienced rocketeer will develop an ability to tell, by looking, approximately how stable a rocket will be, any rocket, once constructed, should be checked to determine whether or not it has sufficient stability to be safe in flight. The simplest, least expensive method of doing this requires only a string and some tape.





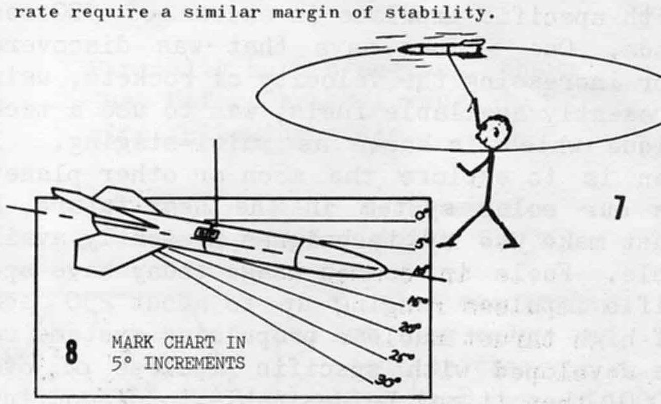
The rocket to be tested (with an engine in flight position: The center of gravity is always determined with an engine in place.) is suspended from a string as illustrated in Fig. 4. The string is attached around the rocket body using a loop as shown. Slide the loop to the proper position so the rocket is balanced, hanging perpendicular to the string. Apply a small piece of tape to hold the string in place. If the rocket's center of gravity (balance point) falls in the fin area, it may be balanced by hooking the string diagonally around the fins and body tube as shown in Fig. 5. A common straight pin may be necessary at the forward edge of one of the fins to hold the string in place. This string mounting system provides a very effective low friction pivot about which the rocket can rotate freely.



For the first system slide a soda straw along the string to a position just above the rocket. Then suspend the rocket in a low velocity air stream (wind tunnel or gentle breeze), with the nose of the rocket pointing into the wind, and then turn the rocket approximately 10° out of the wind to see if it recovers. If so, the rocket is stable enough for flight.

The second method involves swinging the suspended rocket overhead in a circular path around the individual, as shown in Fig. 7. If the rocket is stable, it will point forward into the wind created by its own motion. If the center of pressure is extremely close to the center of gravity, the rocket will not point itself into the wind unless it is pointing directly forward at the time the circular motion is started. This is accomplished by holding the rocket in one hand, with the arm extended, and then pivoting the entire body as the rocket is started in the circular path. Sometimes several attempts are required in order to achieve a perfect start. If it is necessary to hold the rocket to start it, additional checks should be made to determine if the rocket is flight-worthy.

Small wind gusts or engine misalignment can cause a rocket that checks out stable when started by hand as described above to be unstable in flight. To be sure that the rocket's stability is sufficient to overcome these problems, the rocket is swung overhead in a state of slight imbalance. Experiments indicate that a single engined rocket will have adequate stability for a safe flight if it remains stable when the above test is made with the rocket rebalanced so the nose drops below the tail with the rocket body at an angle of 10° from the horizontal (see Fig. 8). With cluster powered rockets a greater degree of stability is needed since the engines are mounted off center. The cluster powered rocket should be stable when imbalanced to hang at 15° from the horizontal. Heavier rockets which accelerate at a lower rate require a similar margin of stability.



Caution should be exercised when swinging rockets overhead to avoid collision with objects or persons nearby. Velocities in excess of 100 miles per hour are possible. This is sufficient to cause injury.

Suppose you construct a rocket and find that it will not be stable. Do not try to fly it. Corrections must be made. Tests have been made where the stability of the rocket was in question. If it was completely unstable it would loop around and around in the air, seldom reaching over 30 feet in height and never reaching a velocity in excess of 20 or 30 miles per hour. However, occasionally one of these rockets would make a couple of loops, suddenly become stable due to the lessening of the fuel load, and make a bee line straight into the ground. Had anyone been standing in the wrong place a serious injury could have resulted.

If a rocket does not show the degree of stability required for safety it can be easily altered to conform either by moving the center of gravity forward or by moving the center of pressure rearward. To move the center of gravity forward, a heavier nose cone is used or a weight is added to the nose of the rocket. To move the center of pressure rearward, the fins may be made larger or moved farther back on the body tube. With the Astron Scout rocket and many other designs, greater stability is obtained by constructing it so that a large portion of the fins project beyond the rear of the rocket body.

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ESTES TR-2

Multi-stage Report

by Vernon Estes, NAR #380

Multi-staging is probably the most prominent characteristic of modern rocketry. This technique is used with solid propellant rockets and liquid propellant rockets, in rockets less than a foot tall and in rockets over one hundred feet tall. Multi-stage rockets send up ants and humans, for 500 feet or into orbit. Multi-staging is no longer the exclusive practice of the professionals, for today more multi-stage rockets are launched by modelers than amateurs and professionals together.

In professional rocketry it has been found that orbital velocities of about 17,000 miles an hour cannot be attained using single stage rockets unless practical fuels are developed with specific impulses in excess of 300 seconds. One of the ways that was discovered for increasing the velocity of rockets, using presently available fuels, was to use a technique which is known as multi-staging. If man is to explore the moon or other planets in our solar system in the near future, he must make use of techniques presently available. Fuels in common usage today have specific impulses ranging up to about 250 secs. If high thrust nuclear propulsion systems can be developed with specific impulses of over 1000, then it may be desirable to discontinue the use of multi-stage rockets. However, in the foreseeable future, even with high efficiency chemical fuels with specific impulses of 300 to 400, the use of multi-stage rockets will still be advantageous.

Generally speaking the principles of model rocketry and professional rocketry are about the same, although somewhat different systems are employed with models in respect to separation, coupling, ignition, etc. We believe that the young rocketeer who learns these principles is gaining knowledge which he will find useful in his future career.

IGNITION

The lower or first stage of a multi-stage rocket is always ignited by standard electrical means. For further details, refer to the instruction sheet which is included with all rocket engines. The second stage ignition is accomplished automatically upon burnout of the first stage. As you will notice in figure 1-A, the first stage engine has no delay or ejection charge. This is to assure instant ignition of the following stage upon burnout.

In figure 1-B the propellant has been partially burned leaving a relatively large combustion chamber. As the propellant continues to burn, the remaining wall of propellant becomes thinner and thinner until it is too thin to withstand the high pressure inside the combustion chamber. At this point the remaining propellant wall ruptures, allowing the high pressure inside the combustion chamber to exhaust forward toward the nozzle of the next stage, carrying hot gasses and small pieces of burning propellant into the nozzle of the second stage engine. This action is illustrated in figure 1-C.

This system is practical only if the distance between the two stages is not too great. To give added assurance of ignition, a short length of jetex wick is folded to five thicknesses at one end and inserted into the nozzle in such a manner that the unfolded end is bent out to follow the curve of the nozzle, leaving a clear path down the nozzle to the folded portion. Thus the jetex wick is more accessable to the ignition flame of the lower stage engine.

STAGE COUPLING

Several practical methods for coupling the stages of model rockets have been employed. All seem to work about equally well. One system may be somewhat better suited for a particular need or purpose than another. Some of the more common methods are described below.

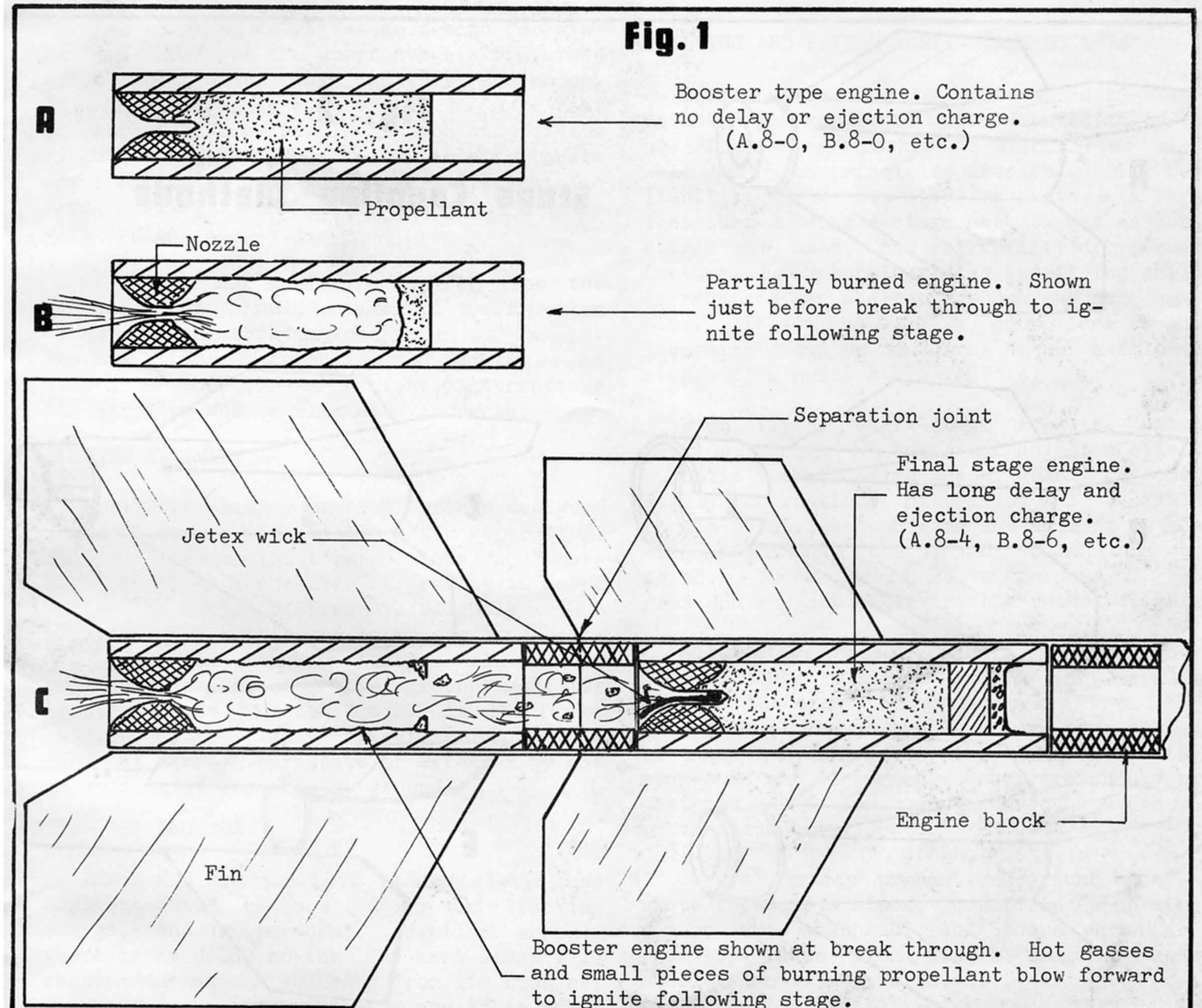
Transition Block: (Figure 2-A)
Using a standard hollow engine block or bulkhead it is possible to make a transition or coupling block. This method requires that the engine of the upper stage be set approximately 3/8 inch forward from the rear of the body tube. The block is to be thoroughly glued to the lower or booster stage and should make a fairly snug fit into the lower end of the succeeding stage. Upon ignition of the second stage the hollow portion between the engines will quickly pressurize, forcing off the booster portion. The greatest advantage of this method is that it allows considerable design flexibility

Slip Ring or Collar: (Figure 2-B,C)
This method is easy to use and gives very light weight. A paper ring or collar is secured to either the inside or the outside of the body tube of the booster.

The outside ring is illustrated in figure 2-B. The collar is made of the same size body tube as is used on the booster stage. The ring is slit down one side and glued over the forward end of the booster. Generally the ring should be about 1 inch long, with 1/2 inch glued to the booster and 1/2 inch projecting forward. The fins on the upper stage will then have to be recessed forward 1/2 inch.

Figure 2-C shows the inside ring method. The ring is still a section of body tube 1 inch long, but in this case about 1/4 inch is cut from the side of it to decrease its diameter. The bottom 1/2 inch of the ring is glued to the inside of the forward end of the booster, with 1/2 inch projecting forward. If the inside ring is used with BT-3, the

Fig. 1



upper stage engine will have to be recessed forward 1/2 inch and the lower stage engine back 1/2 inch.

Engine Projection: (Figure 2-D)
This is one of the first coupling systems used in model rocketry, and affords simplicity and economy of design. The booster tube is cut about 3/8 inch shorter than the length of the engine. The engine projects forward from the booster as illustrated. Build up the forward portion of the engine with tape so it makes a snug fit into the lower end of the following stage. This same system can also be used by leaving the second stage engine projecting rearward into the top of the booster stage. The first method is somewhat superior to the second since the weight of the engines is farther forward, thus producing greater stability.

Projecting Fin Method: (Figure 2-E)
This system is almost always foolproof. When constructing the upper stage allow the fins to project rearward from the body a minimum of about 1 inch. The forward portion of the booster body fits into the projecting area as illustrated. Care must be exercised to be sure the fit is free, so as to allow the lower stage to readily drop off by simply holding the rocket by the upper stage and letting the bottom stage drop off by the force of gravity. The fit must be designed so the upper stage does not wobble or vibrate or prevent the aerodynamic structure from acting as a single unit.

Because the projecting fins are exposed to the hot exhaust gasses, it is desirable to protect them with two or more coats of flame resistant paint or flameproofing material,

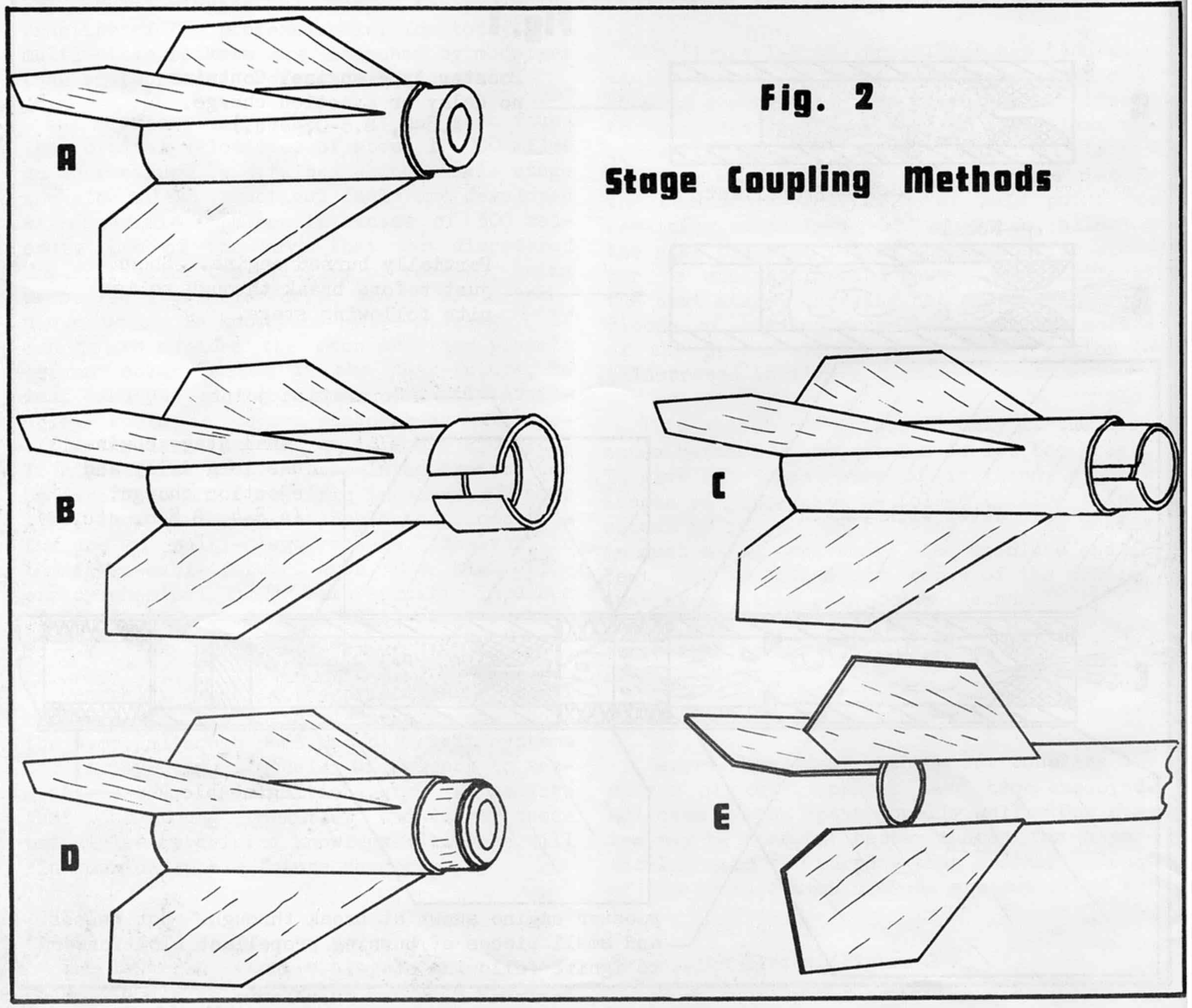


Fig. 2
Stage Coupling Methods

such as silicate of soda. In the event that flameproofing material is not available, it has been found that most paints provide a limited amount of protection.

STABILITY

Multi-stage rockets, like single-stage rockets, are stabilized by air currents acting against the fins (See Technical Report TR-1, NAR #13). Since two or more engines are mounted near the rear of the rocket, it has a tendency to become tail-heavy. To compensate for this rearward movement of the center of gravity, extra large fins must be used on the booster or lower stages. As a general rule the lower set of fins on a two stage rocket should have two to three times the area of the upper set. Each additional stage then requires even greater fin area.

When checking a multi-stage design for stability, test first the upper stage alone, then add the next lower stage and test, and so on. In this manner the builder can be sure that his rocket will be stable in each step of its flight, and he will also be able to locate any stage which does not have sufficient fin area. Always check for center of gravity with engines in place.

To obtain the maximum stability from the fin area, care should be taken in construction to create an aerodynamically "clean" shape. The transitions between stages should be as smooth as possible to prevent interrupting the air flow and causing eddy currents.

BOOSTER RECOVERY

Most lower stages or boosters are designed so that they are unstable after separation. This is because the booster alone is "nose-light," since the center of gravity is moved behind the center of pressure slightly. Thus boosters will require no parachute or streamer, but will normally tumble, flutter, or gently glide back to the ground. If the booster is to be used again, it should be painted an especially bright color, as it does not have a parachute or streamer to aid in spoting it once on the ground.

TYPES OF ENGINES

Lower and intermediate stages always use engines which have no delay and tracking charge, and no parachute ejection charge. there is no delay so that the next stage will receive the maximum velocity from its booster. The engines which are suitable are those which have designations ending in zero, such as the A.8-0, B.8-0, and B3-0 (previously called B16-0). A series II engine should be used in the lower stage of extra heavy rockets to give them sufficient acceleration at liftoff.

In the upper stage an engine with a delay and tracking charge and parachute ejection charge is used. As a general rule, the longest possible delay should be used, as multi-staging imparts considerably more velocity to the final stage, and the rocket must have an opportunity to lose some of this velocity before the parachute is ejected. Greater height will be attained and damage to the recovery system avoided in this manner. Engines suitable for upper stage use are those with NAR designations ending in a positive number, such as the B.8-6, A.8-4, B3-5 (previously called B16-5), etc.

BUILDING AND FLYING MULTI-STAGE ROCKETS

Before attempting to build a multi-stage rocket, the rocketeer should build at least one single-stage rocket to familiarize himself with the principles involved. The reliability of a two stage rocket is always less than a single-stage rocket, and as more stages are used, the reliability drops even further. Hence more building and flying skill is required as the rockets become more complex. It is usually a good idea to put launching lugs on both the upper and lower stages of a multi-stage vehicle.

When flying multi-stage rockets, extra caution should be taken to select a field which is free of dried weeds, grass, or other highly combustible materials. The field should be at least as wide and as long as the maximum altitude the rocket is expected to reach. There should be no persons in the area who are not observing the rocket flight.

Multi-stage rockets should be flown only in reasonably calm weather, as they have an extreme tendency to weathercock. When the rocket is placed on the launcher, care should be taken to assure that the alignment of the stages is not disturbed. Observers should be assigned to follow each individual stage to prevent its being lost.

General safety precautions, such as adequate recovery systems, not firing when airplanes are overhead, and others which are normally taken with single-stage rockets should also be taken with multi-stage rockets. Always follow the NAR Safety Code.

Estes Industries Technical Report

Altitude Tracking

Report No. TR-3

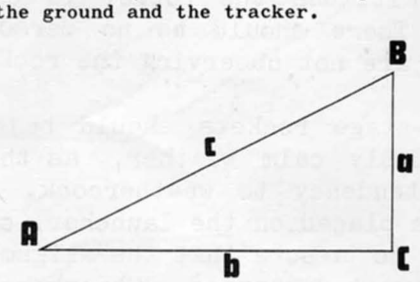
Single Station Tracking

Every Rocketeer asks the question: "How high did it go?" However, previously few model rocketeers had the facilities to determine altitudes with any reasonable degree of accuracy. Some have attempted to find the altitude achieved by their rockets by the use of a stop watch, but this method is so highly inaccurate that the computed altitude may fall anywhere within 200% of the actual altitude. Several years of experience among model rocketeers have proven that optical systems are the only practical means for finding altitudes with any reasonable degree of accuracy.

The use of an optical tracking system requires the use of mathematics. The particular field of mathematics which is used the most in altitude computation is trigonometry. While this field is normally considered an advanced high school subject, any rocketeer can master its basics and apply them to his rocketry activities. If the rocketeer masters a few simple processes, he is ready to solve almost any problem in altitude computation.

One of the first principles of trigonometry is that all of the angles and sides of any triangle can be found if any three of its parts, <u>including</u> one side are known. Now every triangle has six parts: three angles and three sides. So if we know two angles and one side, we can find the other angle and the other two sides.

In determining the height of a rocket we collect two types of data: Distances and angles. This data is used to create a triangle which is a model of the lines which would join the tracker and the rocket, the rocket and a point directly below it on the ground, and the point on the ground and the tracker.

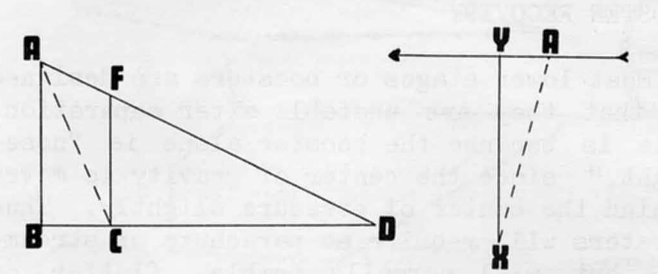


In the diagram above, point A represents the tracking station, B the rocket at its maximum altitude, and C a point on the ground directly below the rocket. The angle formed by the lines at C is then a right angle or 90°. Since there are 180° in the angles of a triangle, if we know angle A, we can find angle B, since B = 180° - (A + C), or B = 90° - A. (In trigonometry, a capital letter represents an angle, a small letter represents a side. The small letter "a" will always be used to represent the side opposite angle A, "b" the side opposite B, etc. Two capital letters together represent a distance. Thus BC represents the distance from angle B to angle C, or side "a."

At the firing range, A is found by the tracker when he locks his scope at the rocket's peak altitude. If we now know the distance from A to C, or side b of the triangle, we can find side c and side a. Side a is the one in which we are interested: It is the height of the rocket. This of course assumes that angle C is a right angle.

Now if we only use one tracker, we have the problem of knowing only one angle and one side. This is not enough information to solve the other sides of the triangle. However, we can guess at one of the unknown angles, and obtain a good approximation of the height achieved by the rocket.

If only one elevation tracker is used, it is a good idea to station it at a right angle to the wind flow. For example, if the wind is blowing to the west, the tracker should be either north or south of the launcher. In this way we will keep the angle at C as close to a right angle as possible. By experimenting with a protractor and a straight edge, the rocketeer can demonstrate why the error would be less if the tracker is on a line at a right angle to the flow of the wind.

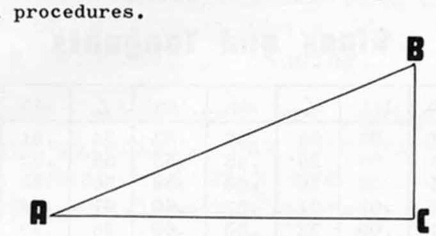


In the diagram above, the wind is blowing from B to D. The rocket is launched at point C, weathercocks into the wind, follows approximately line CA, and at its maximum altitude is at point A. If the tracker is downwind from the launcher, he will see the rocket at point F, and compute the altitude as the distance from C to F. So his computed altitudes will be considerably lower than the true altitudes. On the other hand, if the rocket drifts toward him, his computed altitude will be considerably higher than the true altitude.

However, if the tracker is at point X in figure 2 and the launcher at Y, then the rocket will appear to be at point A as in figure 1, although the distance from the tracker to point A will be slightly greater than the baseline used in computing the altitude, the error will not be nearly as great. Also, the small additional distance will serve to make altitude readings more conservative, as the baseline will be increased.

So by observing the proper relation between wind direction and the position of the tracker, we can generally determine with 90% or better accuracy the altitude the rocket reaches from data given by only one elevation tracker. Of course, the closer the rocket flight is to the vertical, the more accurate will be the figures obtained. Thus on a calm day with a good model, we can approach almost perfect accuracy.

The method used to determine altitude with one tracker is outlined below. Bear in mind that this system assumes that the flight will be almost vertical, if not completely vertical. The rocketeer would do well to master this system before going on to more complex systems, as this method is used as a part of the more involved procedures.



Assuming a vertical angle of flight, we can proceed to call angle C a right angle or 90°. In that case, B would equal 90° - A, since the sum of the angles in a triangle is 180°. Hence to determine distance BC, or the height achieved by the rocket, we take the tangent, (abbreviated tan) of angle A times the distance AC (distance from tracker to launcher). For example, if the distance from the tracker to the launcher (baseline) is 250 feet, and the angle observed at the rocket's maximum height is 62°, (read from the scope after it has been locked), we look in the table of trigonometric functions and find the tangent of 62°, or 1.88, multiply this times 250, which gives us 470'. Standard practice dictates that all altitude figures be rounded off to the nearest ten. So if the angle observed is 53°, and the baseline is 250', we have 1.33 times 250, which equals 332.5 feet, and is rounded off to 330 feet.

Why do we use the tangent to determine altitude? The tangent of an angle is the ratio of the opposite side to the adjacent side, or in other words, the opposite side divided by the adjacent side. In this case, the adjacent side is the distance from the tracker to the launcher, and the opposite side is the distance from the launcher to the rocket's maximum altitude.

Kind souls of many years ago were nice enough to determine the tangents for all angles of right triangles, so we have a table which lists them. Since the tangent of the angle equals the opposite side divided by the adjacent side, or in the case of our first example, 470 divided by 250, by multiplying the quotient times the divisor we find the dividend. In our case, the quotient or tangent is 1.88, the divisor 250, and the dividend 470.

SUMMARY

(1) In single station elevation tracking, we make sure that the line from the tracking station to the launcher is 90° from the direction of wind flow.

(2) The angle of flight is assumed to be vertical.

(3) The tracking scope is locked at the rocket's maximum altitude, the angle read, and the tangent of the angle found.

(4) The tangent is multiplied times the distance from the tracker to the launcher, giving the rocket's altitude.

Two Station Tracking

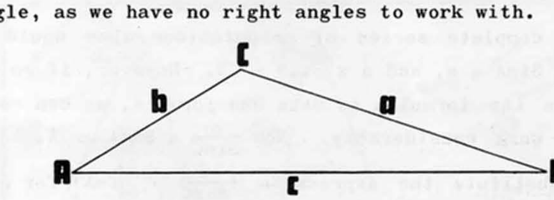
A higher degree of accuracy is possible when two elevation tracking stations are employed. In such a case, we will have triangles with 2 angles and one side given, enabling us to determine the other parts of the triangle without guesswork.

When using two trackers without azimuth readings the tracking stations are set up on opposite sides of the launcher. Preferably, to obtain the greatest accuracy, the stations should be <u>in line with the wind</u>, unlike the system used in single station tracking. Thus, if the wind is blowing to the south, one station will be north and the other south of the launch area.

The distance between the two trackers is not critical. One might be 100 feet from the launcher and the other 500 feet away. However, for the greatest ease in data reduction, the distances should be equal. For the greatest accuracy, they should be as far apart as possible. A general rule is that the distance from the stations to the launcher should be equal to or greater than the maximum altitude the rocket is expected to achieve.

Some provision should be made to insure that the trackers lock their instruments at the same time. This is one of the greatest problems with any system using more than one station: The one tracker may lock his scope when the rocket appears to him to have ceased rising while the other tracker is still following the rocket. If a phone system is used, one of the trackers or a third party should call "mark," and the trackers should lock their scopes immediately. In the system described here this is especially important, as the elevation readings from the two trackers must be taken at the same point or the altitude computed will be somewhat incorrect.

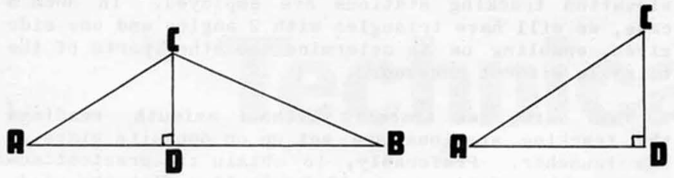
In this more accurate system we will work with sines instead of tangents. To determine altitude, then, we will first have to find the unknown sides of the triangle, as we have no right angles to work with.



For example, stations A and B are located on a 1000' baseline with the launcher between them. Station A calls in an elevation of 34°, and station B calls in an elevation of 22°. The total of these two angles is 56°, so angle C, located at the peak of the rocket's flight, is equal to 180° - 56°, or 124 degrees. We now have 3 angles and one side to work with. Our first step will be to list the angles and their sines. Since the sine of any angle greater than 90° is equal to the sine of the supplement of the angle, the sine of 124° is equal to the sine of 180° - 124°, or 56°.

Angle A = 34° Sine A = .5592
Angle B = 22° Sine B = .3746
Angle C = 124° Sine C = .8290

The law of sines states that $\frac{c}{\text{SinC}} = \frac{b}{\text{SinB}} = \frac{a}{\text{SinA}}$ c = 1000', sinC = .8290 Therefore, $\frac{1000}{.8290} = \frac{b}{.3746} = \frac{a}{.5592}$ Pulling out the slide rule, we determine that $\frac{1000}{.8290} = 1205$. So we have a dividend, divisor, and quotient. In solving for side b, our dividend is b, our divisor .3746, and our quotient 1205. To find the dividend we multiply the divisor times the quotient. Now .3746 times 1205 = b, and pulling out the slide rule again, we find that b = 451. The same process is repeated to find side a: $1205 = \frac{a}{.5592}$, a = 1205 x .5592, a = 674'. So we now have the three sides of the triangle.



The altitude of the rocket is then the distance from C to D in the diagram above. The angle formed by the meeting of lines AB and CD is a right angle. Since the sine of an angle in a right triangle is the relation of the opposite side to the hypotenuse, and since we wish to determine the value of the opposite side, we find that the sine of A (34°) is .5592. Hence $.5592 = \frac{a}{451}$ since $\text{SinA} = \frac{\text{opposite side}}{\text{hypotenuse}}$. .5592 x 451 = 252, hence CD = 252', and we now know the altitude reached by the rocket was 252'.

Fortunately, our computations to determine the altitude of the rocket can be simplified. To find the altitude we need only determine one of the unknown sides of the original triangle. So if we find the distance BC (side a) on the triangle, we can multiply it times the sine of B to find the height CD.

So $\frac{c}{\text{SinC}} = \frac{a}{\text{SinA}}$. Since we have found $\frac{c}{\text{SinC}}$ equal to 1205 when C = 124°, $\frac{a}{\text{SinA}} = 1205$. Then 1205 x SinA= side a = 674'. Now we have the one needed side of the triangle, so we can solve for distance CD in the right triangle BCD. The sine on an angle is equal to its opposite side divided by the hypotenuse, so we take the sine of B, which is .3746, times the hypotenuse, or 674' to find the opposite side CD. Thus .3746 x 674 = 252'.

The complete series of computations then would be $\frac{c}{\text{SinC}}$ x SinA = a, and a x SinB = CD. However, if we can combine the formulas to make one formula, we can speed up our work considerably. Now $\frac{c}{\text{SinC}}$ x SinA = A, so we can substitute the expression ($\frac{c}{\text{SinC}}$ x SinA) for a in the formula a x SinB = CD. Our formula then becomes $\frac{c}{\text{SinC}}$ x SinA x SinB = CD. One of the basic rules of algebra tells us that if the dividend is multiplied by a number and the result divided by the divisor, the result is the same as if the division were carried out first and the quotient multiplied by the number. For example, $\frac{10 \times 4}{5} = 8$, and $\frac{10}{5} \times 4 = 8$.

So we can change the expression $\frac{c}{\text{SinC}}$ x SinA x SinB = CD to read $\frac{c \times \text{SinA} \times \text{SinB}}{\text{SinC}}$ = CD. So by performing two multiplications and one division, we can find the altitude of the rocket. The division of SinC into the expression (c x SinA x SinB) can occur at any point, as $\frac{c \times \text{SinA}}{\text{SinC}}$ x SinB = CD, and c x $\frac{\text{SinA} \times \text{SinB}}{\text{SinC}}$ = CD also. This last form of the equation will give the same result as the first, and actually involves the same steps, but is generally easier to use.

SUMMARY

(1) In two station tracking without the use of azimuth readings we station the trackers on a base line approximately equal to twice the altitude the rocket is expected to reach.

(2) The trackers are located in line with the wind.

(3) The scopes are locked at the rocket's maximum altitude, the angles read, and the sines of the angles found.

(4) The altitude is computed by the formula height = $\frac{c \times \text{SinA} \times \text{SinB}}{\text{SinC}}$, when A and B are the angles read by the trackers, c is the baseline distance, and C is the third angle formed by the meeting of the lines of sight of the two trackers.

Sines and Tangents

∠	sin	tan	∠	sin	tan	∠	sin	tan
1	.02	.02	28	.47	.53	54	.81	1.38
2	.03	.03	29	.48	.55	55	.82	1.43
3	.05	.05	30	.50	.58	56	.83	1.48
4	.07	.07	31	.52	.60	57	.84	1.54
5	.09	.09	32	.53	.62	58	.85	1.60
6	.10	.11	33	.54	.65	59	.86	1.66
7	.12	.12	34	.56	.67	60	.87	1.73
8	.14	.14	35	.57	.70	61	.87	1.80
9	.16	.16	36	.59	.73	62	.88	1.88
10	.17	.18	37	.60	.75	63	,89	1.96
11	.19	.19	38	.62	.78	64	.90	2.05
12	.21	.21	39	.63	.81	65	.91	2.14
13	.22	.23	40	.64	.84	66	.91	2.25
14	.24	.25	41	.66	.87	67	.92	2.36
15	.26	.27	42	.67	.90	68	.93	2.48
16	.28	.29	43	.68	.93	69	.93	2.61
17	.29	.31	44	.69	.97	70	.94	2.75
18	.31	.32	45	.71	1.00	71	.95	2.90
19	.33	.34	46	.72	1.04	72	.95	3.08
20	.34	.36	47	.73	1.07	73	.96	3.27
21	.36	.38	48	.74	1.11	74	.96	3.49
22	.37	.40	49	.75	1.15	75	.97	3.73
23	.39	.42	50	.77	1.19	76	.97	4.01
24	.41	.45	51	.78	1.23	77	.97	4.33
25	.42	.47	52	.79	1.28	78	.98	4.70
26	.44	.49	53	.80	1.33	79	.98	5.14
27	.45	.51				80	.98	5.67

For angles of 81° through 89° the sine is .99, the sine of 90° is 1.00. Tangents over 80° are not given, as no sensible data reduction is possible for angles that great.

Parachute Recovery

Parachute recovery is by far the most spectacular method of returning a model rocket to the ground. While it is not always the most efficient system, the sight of a rocket drifting gently to earth suspended from a bright canopy is always impressive.

Unfortunately, not all model rocketeers have mastered the simple art of parachute recovery, and far too many parachutes fail to function properly. Often the result is that the model wobbles in with a glob of plastic on a string above it, and then cracks a balsa fin on landing.

Several substances are suitable for parachute material, but thin polyethylene plastic sheet and silk are generally the best. Polyethylene has certain advantages over silk, including ease of packing and attaching shroud lines and a lower cost.

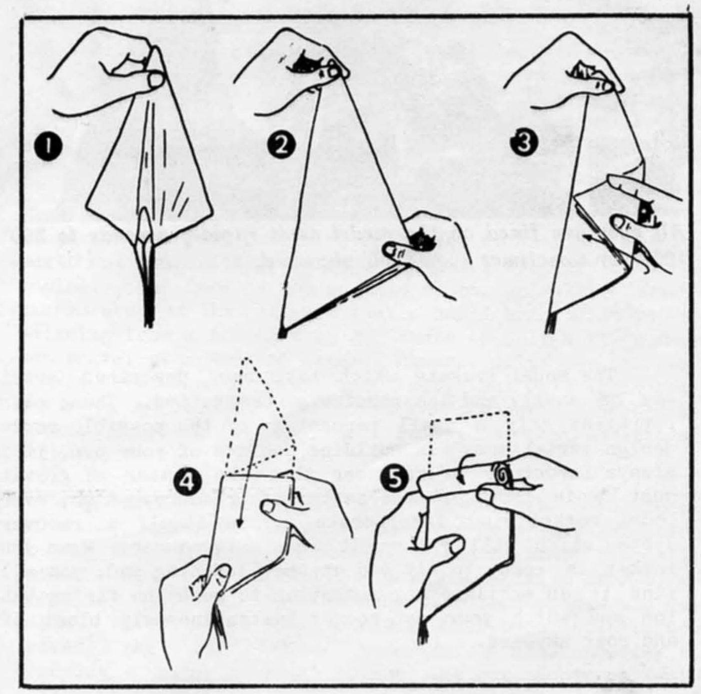
The selection of shroud line material is just as important as securing parachute material. Since a parachute will deploy only if the shrouds let it, these lines should be of the highest quality possible. A good quality string with a smooth surface will work, while heavy waxed thread of the type used in shoes is better, and four-pound-test nylon monofilament fishing line appears to be about the best. Care must be taken to find a material which will not readily knot, foul, or tangle.

After the parachute has been carefully constructed from quality materials, its proper operation is still dependent on the care of the rocketeer. Before even considering packing the parachute into the rocket body he should have on hand some paper parachute protectors, talcum powder, and cotton wadding or facial tissue.

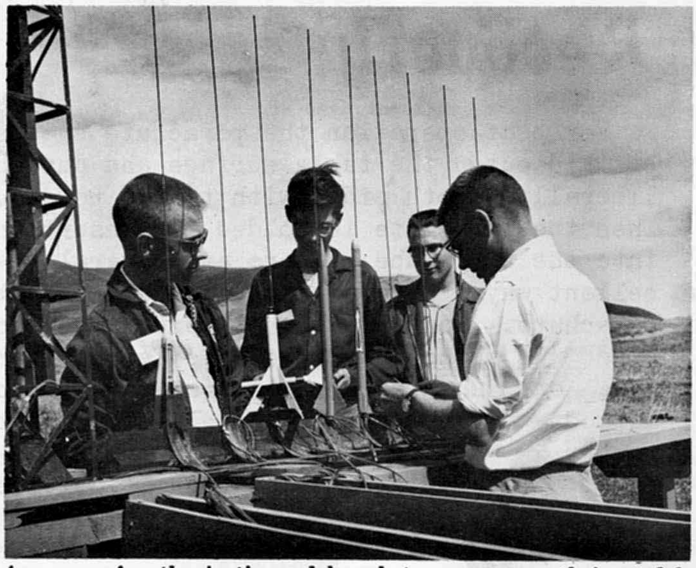
The first big step in the preparation of a parachute recovery system is to place a wad of cotton or facial tissue into the body tube. This material will act as a gas seal and piston, assuring efficient control and utilization of the ejection charge gasses. Care should be taken to secure an even, free-slipping fit between the wad and the inner wall of the body tube. A very tight fit may hinder the activation of the recovery system, while too loose a fit will neutralize the value of the wad.

For best operation the parachute should be laid out on the table surface and dusted liberally on both sides with talcum powder. Then the parachute is folded for insertion into the body tube. There are several excellent ways of folding a model rocket parachute. You may wish to experiment to find the method that proves effective for you, or the diagram illustrates a proven method of parachute folding that a great number of model rocketeers currently employ. When folding the parachute, it is highly desirable to keep an equal amount of tension on all shroud lines until the folding is completed. Parachutes should be folded tightly enough so that they will slip easily into the body tube of the rocket. If it is necessary to use any force at all to insert the parachute it should be repacked so that a loose fit is obtained.

When the parachute has been satisfactorily folded, it should be placed in a paper parachute protector before insertion into the rocket body tube, as shown in the illustration. The parachute protector will insure against the possible searing of the



parachute and shroud lines by the hot ejection gasses. Both parachute and parachute protector should slip easily into the rocket body tube.



A group of enthusiastic model rocketeers prepare their models for flight at the N. A. R. Hogback Rocket Range near Denver, Colorado. NAR Photo

All eyes are fixed on the model as it rapidly ascends to 500' 1000', or sometimes even 2000' skyward. NAR Photo

The model rockets which have been described herein may be easily and inexpensively constructed. These plans represent only a small percentage of the possible rocket design variations. In building designs of your own, it is always important to remember that the center of gravity must be in front of the center of pressure. Also, every model rocket must incorporate within itself a recovery system which will return it in a safe manner. When your rocket is ready to fly and on the launching pad, you will find it an exhilarating sensation to push the firing button and watch your own rocket instantaneously blast off and roar skyward.

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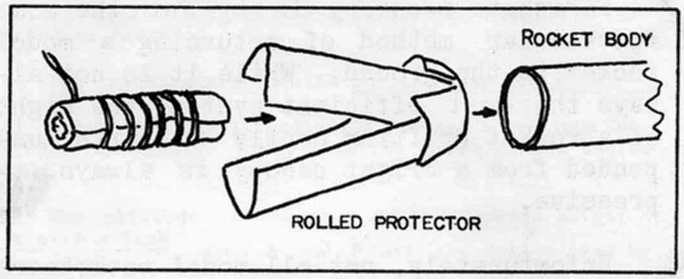
The parachute may now be inserted and the nose cone fitted. The nose cone should



never be so tight that considerable force is required to displace it, as such a condition will seriously impair the efficiency of the recovery system.

Two final words of caution: When employing a parachute recovery system, always make certain that your rocket engine is fixed solidly in the rocket body tube. A loose engine will usually be blown free by its own ejection charge, and the recovery system will fail to actuate. Also, never leave your parachute packed for over half an hour before launching your rocket. Parachutes have a tendency to compact and take a "set." The longer a parachute is left packed before launching, the less chance there will be that it will open.