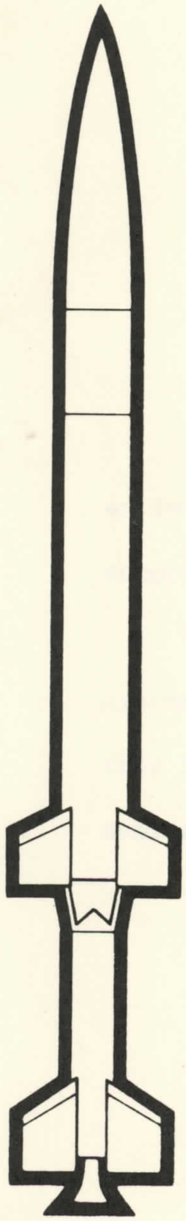

MODEL ROCKETRY

by

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PREFACE

This booklet contains information and suggested activities in Rocketry for teachers attending a NASA supported Aerospace Education Workshop.

It is not intended that it provide all the background information necessary to complete every activity. This is done by the instructor during the workshop-seminar.

TITAN - SATURN - NIKE ...these names, in the past familiar only to students of mythology or astronomy, are today terms used by most school age youngsters. To these students, the phrase "Titan rocket" occupies as comfortable a niche in their vocabulary as did "Ford motor car" for their parents and elders.

Modern television and newspaper coverage can provide only incidental exposure to space age concepts. They cannot provide an understanding of the basic principles needed to design, fly and control rocket vehicles. The study of rocket propulsion, rocket flight, and a knowledge of launch site facilities and procedures should be a part of the student's experience in the classroom. Even though a detailed mathematical description of rocketry is not possible on the elementary school level, the student can through techniques of observation, description, "model" design and experimentation involve himself in a worthwhile educational experience.

Ninety-five percent of all the scientists who ever lived are alive right now. New developments in technology will demand not only better trained scientists in the future, but also a curious citizenry competent to ask and answer questions stimulated by space exploration. You can help develop this capability by introducing your students to the exciting, experimental study of rocketry during the upcoming school year.

A MODEL ROCKET LAUNCH

Where do you begin? Why not start with an actual rocket launch? It is more meaningful to the student to ask and seek answers to questions about the rocket and the launch, than it is to attempt to develop the complete basis for understanding rocket flight exclusively inside the classroom.

The model rocket can become the tool that you need. Unlike the amateur rocket constructed of metal and loaded with home concocted fuels, the model rocket is designed to be flown safely by elementary school students. Like the model airplaine, the model rocket is constructed of materials such as paper, cardboard, and balsa wood. It has a parachute recovery system which returns it gently and safely to the earth to be flown again and again. To date, over four million commercially manufactured model rocket engines have been fired without accident.

A list of approved model rocket suppliers is available on request from the National Association of Rocketry, 1239 Vermont Avenue, Northwest, Washington, D. C., 20005. Complete instructions for assembly and suggestions for launching are included in the model rocket kits.

THE STUDENTS ASK QUESTIONS

At this point, model rocketry could seem to be nothing more than an interesting hobby. It is, if you stop reading, launch a rocket, and don't hesitate long enough to ask questions and develop the activities that can make it of educational value.

Here are just a few of the questions that have been asked, and will be asked by your students:

WHAT ARE THE PARTS OF A ROCKET CALLED?

WHY DOES IT HAVE A SPECIAL SHAPE?

HOW DOES THE ENGINE WORK? WHY DIDN'T IT BURN LONGER? WHY IS THE END OF THE ENGINE SHAPED LIKE AN ICE CREAM CONE?

WHAT PUSHES AGAINST THE ROCKET AS IT CLIMBS THROUGH THE AIR?

HOW HIGH DID IT GO? CAN IT GO HIGHER?

WHY DIDN'T IT FLY IN A STRAIGHT LINE?

HOW IS THE ROCKET USED?

HOW MUCH CAN IT CARRY?

WHY DIDN'T IT GO INTO ORBIT?

The following discussion and activities are designed to assist you in guiding your students to the solutions to these questions.

THE MODEL ROCKET RESEMBLES A SOUNDING ROCKET

Rockets can vary from the large and complex vehicles in the Saturn series to the more or less simplified sounding and meteorological rockets. It is best to approach the study of the principles of rocketry by contrasting the sounding rocket and the model rocket.

Both are slender, are stabilized by fins, and can carry small packages to a pre-calculated altitude. The sounding rocket carries scientific instruments to altitudes of from 50 to 4,000 miles above the earth's surface. Model rockets can be designed to go no higher than one hundred feet or, if desired, can be built to achieve altitudes of several miles.

THE ROCKET ENGINE

While the sounding rocket may use either liquid or solid fuels, the model rocket uses only commercially manufactured solid fuel motors. Both types of engines, though, operate in basically the same manner. The fuel in the engine is ignited, the propellants burn, pressure develops in the combustion chamber, the gases are forced through the throat, expand with high velocity and leave the engine nozzle. Figure 4 illustrates the shape of the nozzle and indicates that the gases move with velocities below the speed

The JAVELIN Sounding Rocket

Figure 1

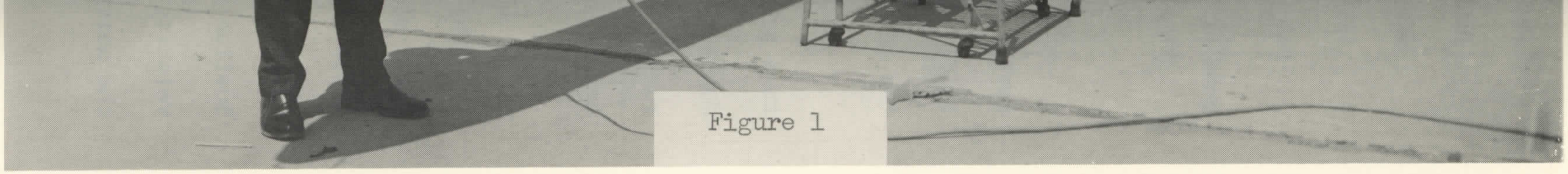


Figure 1

The NIKE APACHE Sounding Rocket

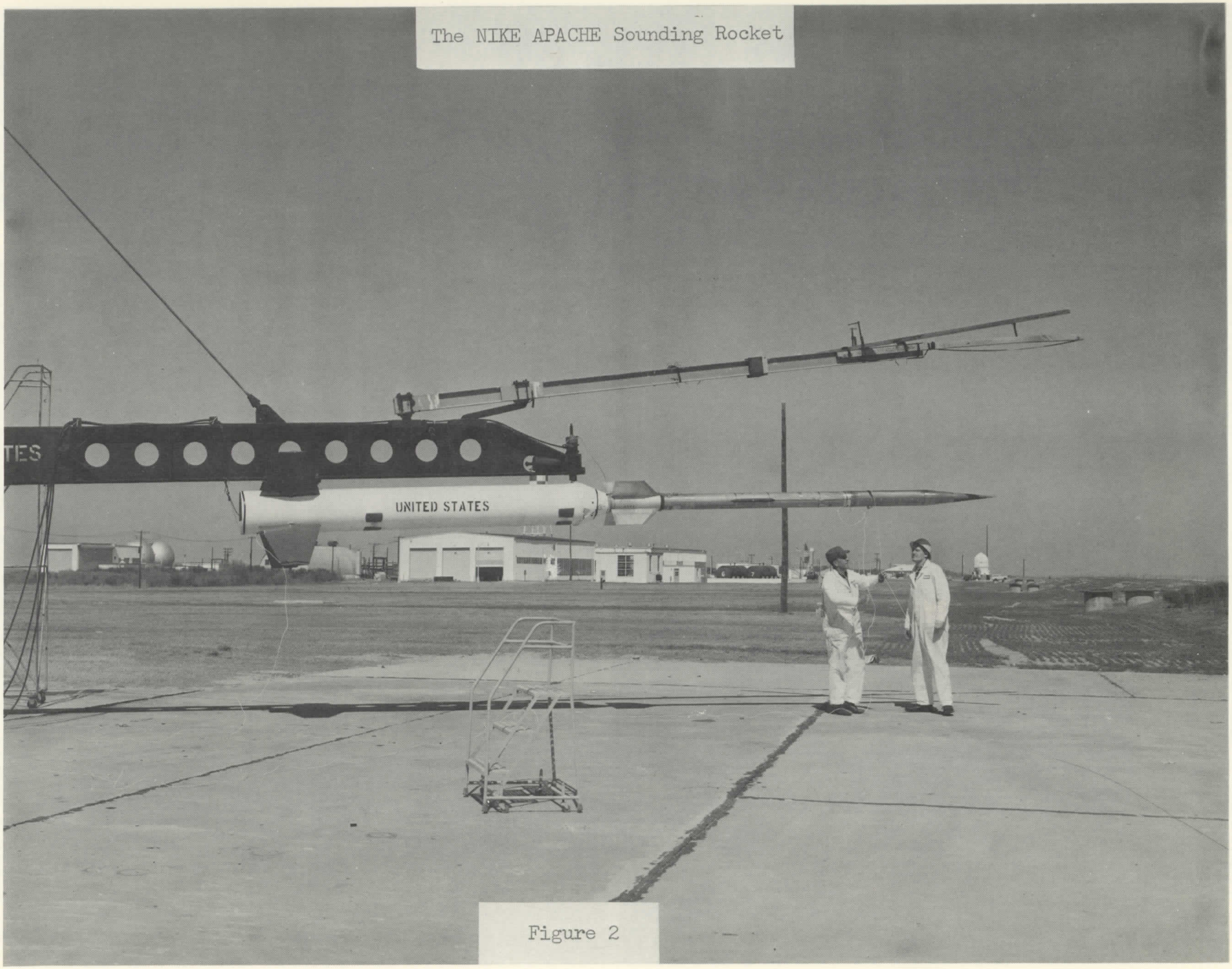
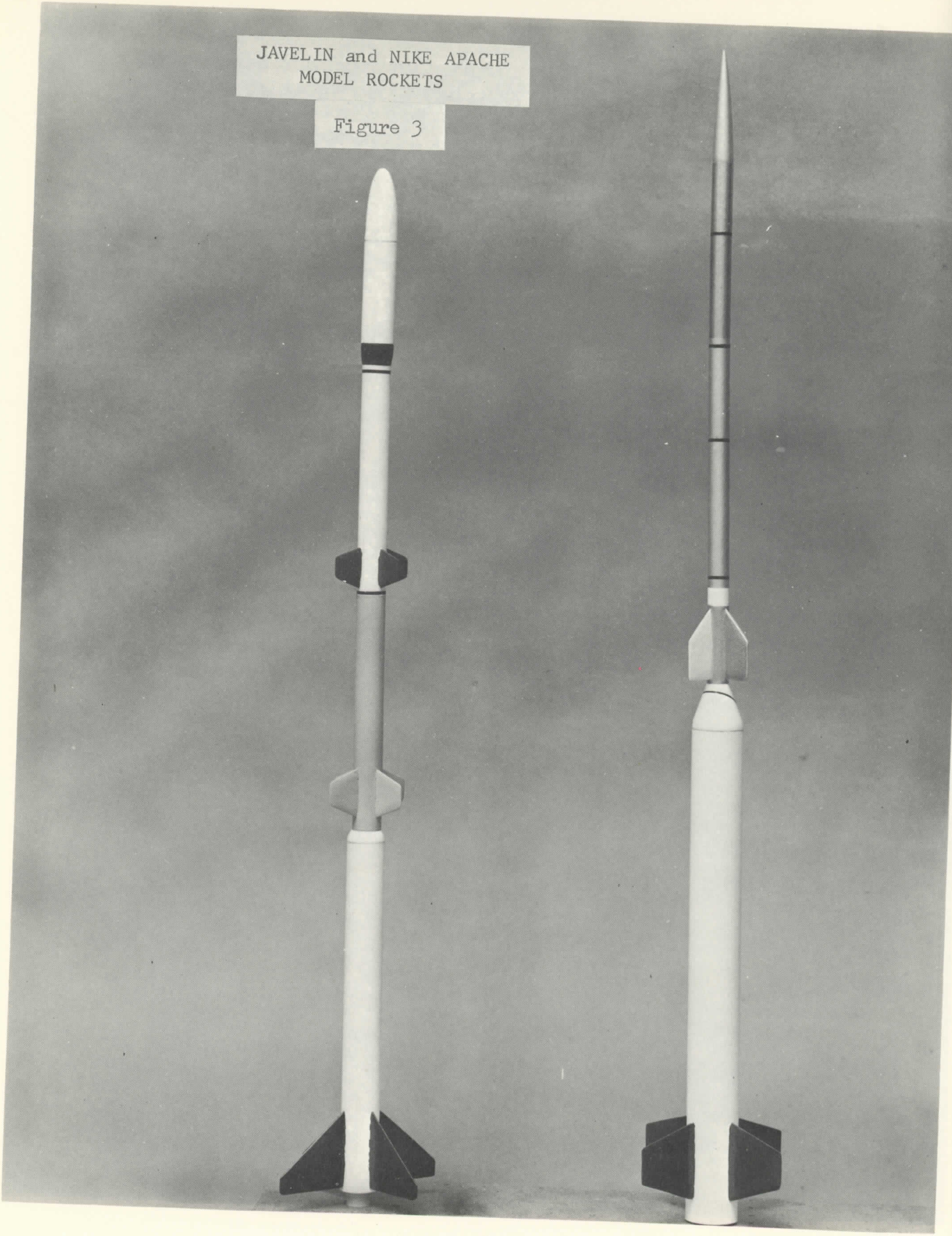
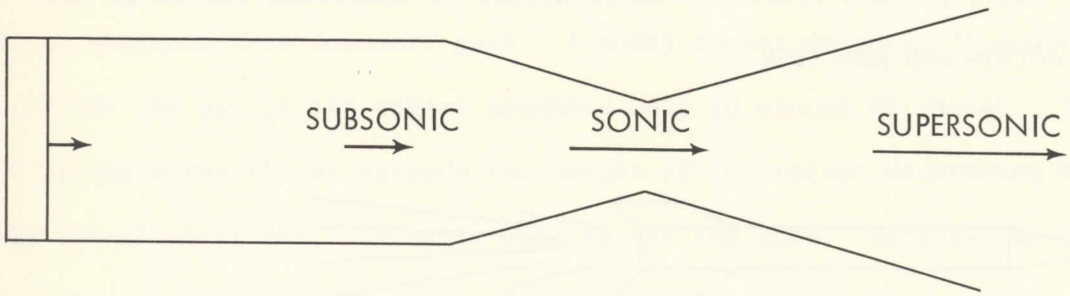


Figure 2


JAVELIN and NIKE APACHE
MODEL ROCKETS
Figure 3

of sound as they pass through the throat, and finally expanding leave the nozzle at supersonic speeds.



PROPELLENT SPEEDS IN A ROCKET MOTOR

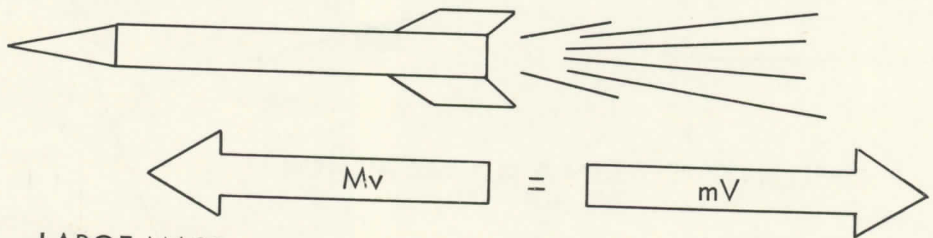
Figure 4

The many very small particles moving at high velocities possess a property called MOMENTUM. Momentum is calculated by multiplying the mass of a particle by its velocity (M x V). For example, a brick of mass 2, with a velocity of 10, has a momentum of 20. A brick of mass 4, with a velocity of 5, also has a momentum of 20.

4 units of mass x 5 units of velocity =
2 units of mass x 10 units of velocity =
20 units of momentum

In the rocket engine, even though the exhaust particles are extremely small in mass, the velocities are so great (4,000 mi/hr or 6,000 ft/sec for some fuels) that the particles leaving the rocket nozzle possess a great deal of momentum. Scientists have discovered by experimenting that throughout nature MOMENTUM IS ALWAYS CONSERVED. Therefore, if the exhaust gases possess momentum in one direction, the rocket should move in the opposite direction so as to maintain this balance.

Because the rocket has much more mass than the particles of fuel, it will as a result of this balance move much slower than the particles leaving the exhaust nozzle. This conservation principle is sometimes stated as the LAW OF ACTION AND REACTION.



LARGE MASS OF ROCKET X LOW VELOCITY = SMALL MASS OF PARTICLES X HIGH VELOCITIES

ACTION = REACTION

Figure 5

To increase the reaction, the action must be increased. This can be done in two ways. Large rockets eject a greater mass of propellant to propel the bigger vehicle. Also, more efficient fuels with greater energy can be developed to increase the exhaust velocities. Either one, or both, of these changes will cause the product of M and V, or the reaction, to be greater.

The action-reaction principle can be best demonstrated away from the earth. In a spacecraft far from all celestial objects, the action in one direction is always accompanied by a reaction in the opposite direction. The situation is not so simple, though, as the rocket stands on the launch pad.

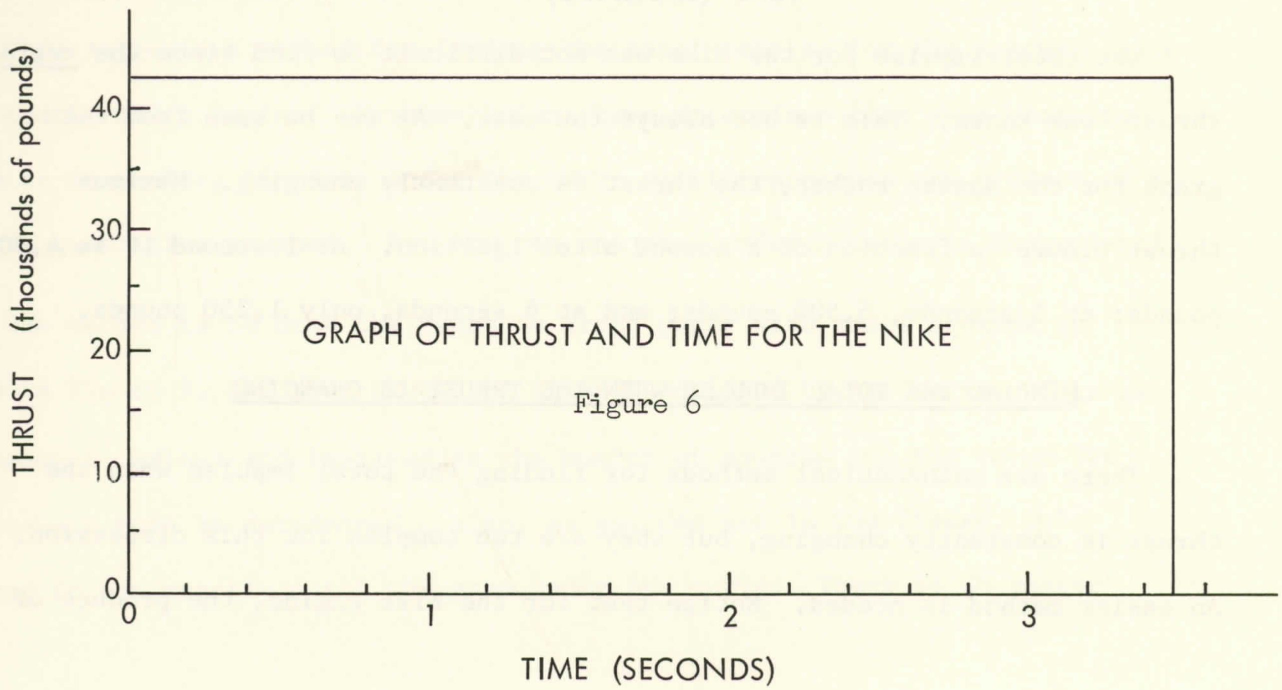
Here, an action may produce no apparent reaction of the rocket. Another fact must be considered.

On the launch pad the rocket is held down by its own weight -- the force of gravity. The rocket engine must be able to produce enough upward push or THRUST to overcome this downward pull. A model rocket weighing 30 ounces will not lift off the pad if its engine produces only 20 ounces of thrust. The amount by which the thrust exceeds the weight of the rocket determines how rapidly it will lift off. In orbit this is not the case. Because the craft is weightless, any amount of thrust for any time will produce a reaction.

In addition to the thrust and the weight of the vehicle, the time that the thrust lasts, called BURNING TIME, also determines the rocket's reaction. The product of the thrust and the burning time is called TOTAL IMPULSE.

THRUST X BURNING TIME = TOTAL IMPULSE

The Nike sounding rocket has an average thrust of 42,500 pounds which lasts for 3½ seconds. The steady horizontal line in the graph in Figure 6 represents the average thrust for the time that the propellants burn.



GRAPH OF THRUST AND TIME FOR THE NIKE

Figure 6

Therefore, the impulse that causes the reaction equals:

42,500 pounds x 3.5 seconds = 148,000 pound-seconds

For sounding rockets and model rocket engines, the thrust does <u>not</u> actually remain the same for the entire burning time. A graph of thrust and burning time for the Apache rocket will resemble that shown in Figure 7.

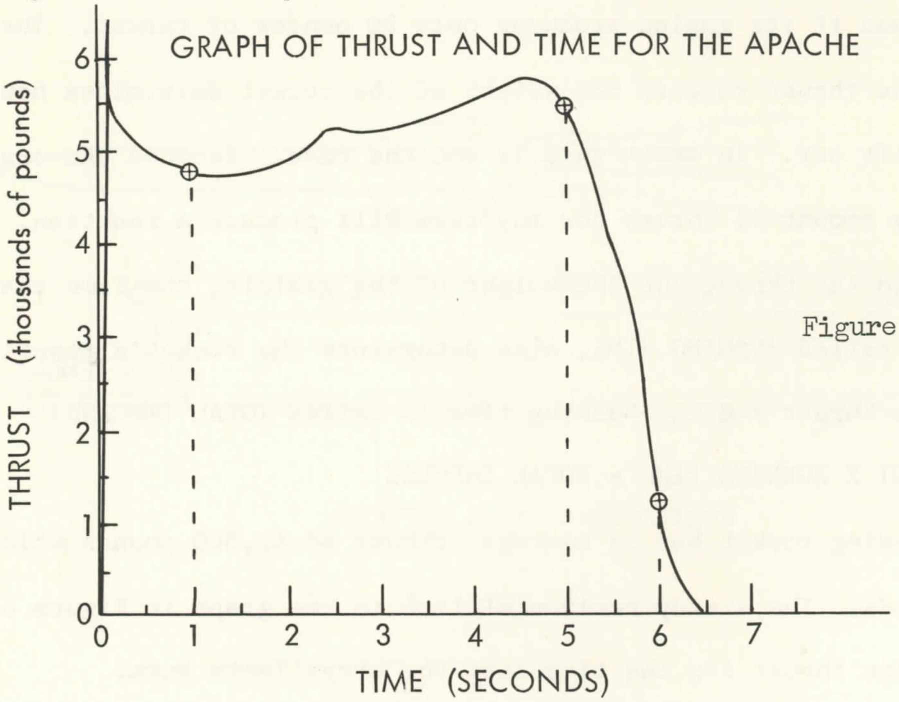


Figure 7

The total impulse for the Nike was not difficult to find since the <u>average</u> thrust was known. This is not always the case. As can be seen from the graph for the Apache rocket, the thrust is constantly changing. Maximum thrust occurs a fraction of a second after ignition. At 1 second it is 4,800 pounds; at 5 seconds, 5,500 pounds; and at 6 seconds, only 1,250 pounds.

<u>FINDING THE TOTAL IMPULSE WHEN THE THRUST IS CHANGING</u>

There are mathematical methods for finding the total impulse when the thrust is constantly changing, but they are too complex for this discussion. An easier method is needed. Notice that for the Nike engine, the product of thrust and time is the same product as the height times the width of the rectangular graph.

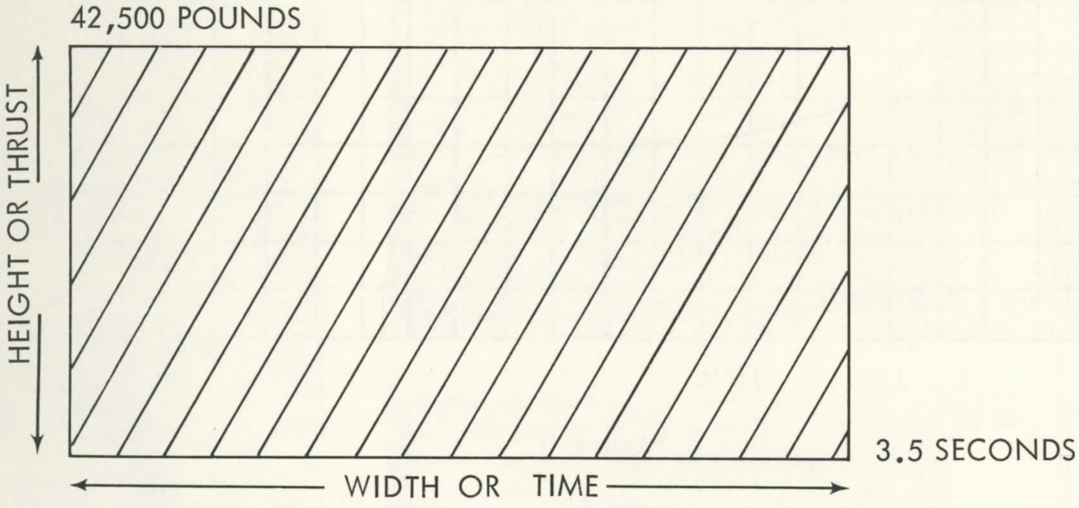


Figure 8

In other words, the <u>area</u> of the rectangle is:

	HEIGHT	x	WIDTH	= AREA
or	THRUST	x	TIME	= TOTAL IMPULSE
and	42,500 pounds	x	3.5 seconds	= 148,000 pound-seconds

This suggests a method for finding the total impulse for the Apache engine or a model rocket engine. Mathematicians have determined that even when the graph is irregular, the area under the curve still represents the product of the two quantities graphed. But how can the area under a curve be determined?

One method is to draw the graph on graph paper with small squares as shown in Figure 9, and then count the squares enclosed by the curve. This can be somewhat tedious and involved as the number of squares and the value for each square must be determined. Also, as you can see in the figure, the squares do not exactly match the area under the curve. There is an easier

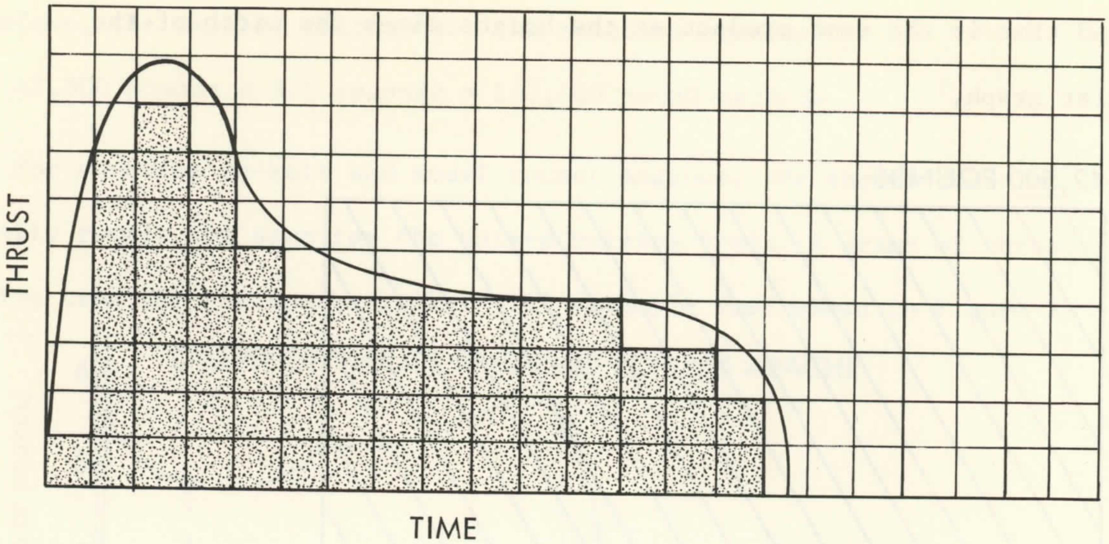
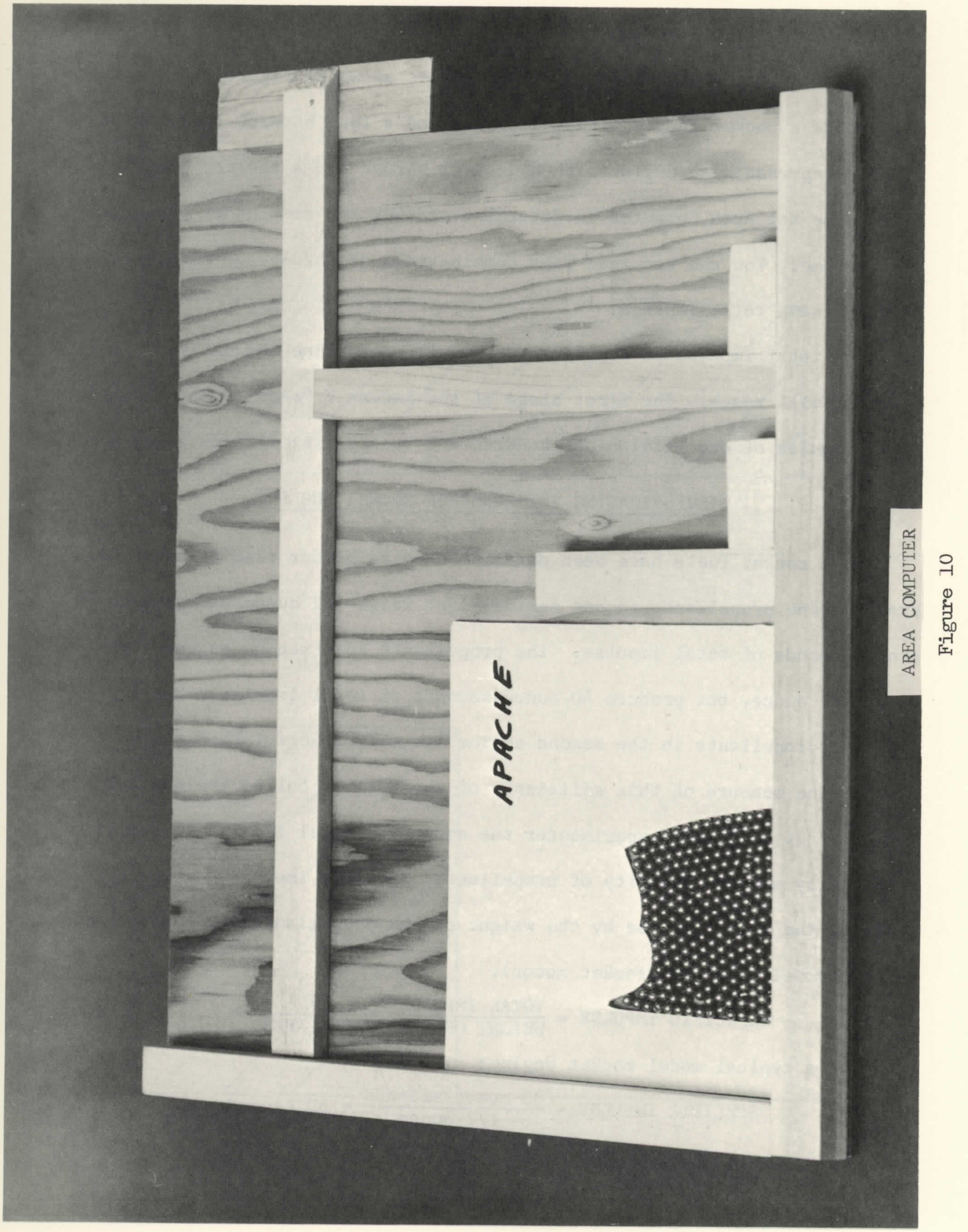


Figure 9

method. Let's find a rectangle with the same area as that contained under the curve.

Figure 10 shows a simple device, an Area Computer, that can be used. Trace the irregular thrust curve for the Apache on heavy cardboard. Cut along the curve, saving the section outside the curve. Place the cut-out in the lower left hand corner of the Area Computer. Fill the cut-out with "BB" shot. Place a vertical and a horizontal guide board on the base. Take out the cardboard cut-out, and using the guide boards carefully rearrange the "BB" shot into a rectangle. With this shape, you can now find the total impulse by multiplying the thrust times the time.

Model rocket engines, as well as others, are designed to produce different thrusts. Larger thrusts are necessary to lift larger packages or payloads. Sometimes lower thrusts but longer burning times are desired for better performance and long gentle acceleration. The Area Computer can be used to answer another question. Can two rockets have different thrusts and



AREA COMPUTER

Figure 10

still have the total impulse?

Cut out two cardboard forms in the shapes shown in Figure 11. Graph A represents a rocket engine with low thrust and a long burning time, while graph B represents an engine with a greater thrust and a shorter burning time. Use the Area Computer to determine whether the area under each graph is the same. You can see that many combinations of thrust and time will produce the same total impulse.

The total impulse is one factor that will determine the maximum altitude a rocket will reach. The first stage of the Saturn V "moon rocket" has a total impulse of one billion-one hundred and twenty-five million pound-seconds!

INVESTIGATING THE POWER OF ROCKET FUELS

Some rocket fuels have been determined to be better than others. For example, the propellants in one engine might weigh 1/2 ounce and produce 30 ounce-seconds of total impulse. The propellants in a second engine might also weigh 1/2 ounce, but produce 40 ounce-seconds of total impulse. You can see that the propellants in the second engine are more powerful than those in the first. The measure of this efficiency of the fuel is called the SPECIFIC IMPULSE. It tells the experimenter the amount of total impulse that will be produced by a given quantity of propellant. Specific impulse can be found by dividing the total impulse by the weight of the propellants (the fueled minus the empty weight of the rocket motor).

$$\text{SPECIFIC IMPULSE} = \frac{\text{TOTAL IMPULSE}}{\text{WEIGHT OF THE PROPELLANTS}}$$

For a typical model rocket engine:

$$\text{SPECIFIC IMPULSE} = \frac{\text{30 ounce-seconds}}{\text{1/2 ounce}} = \text{60 seconds}$$

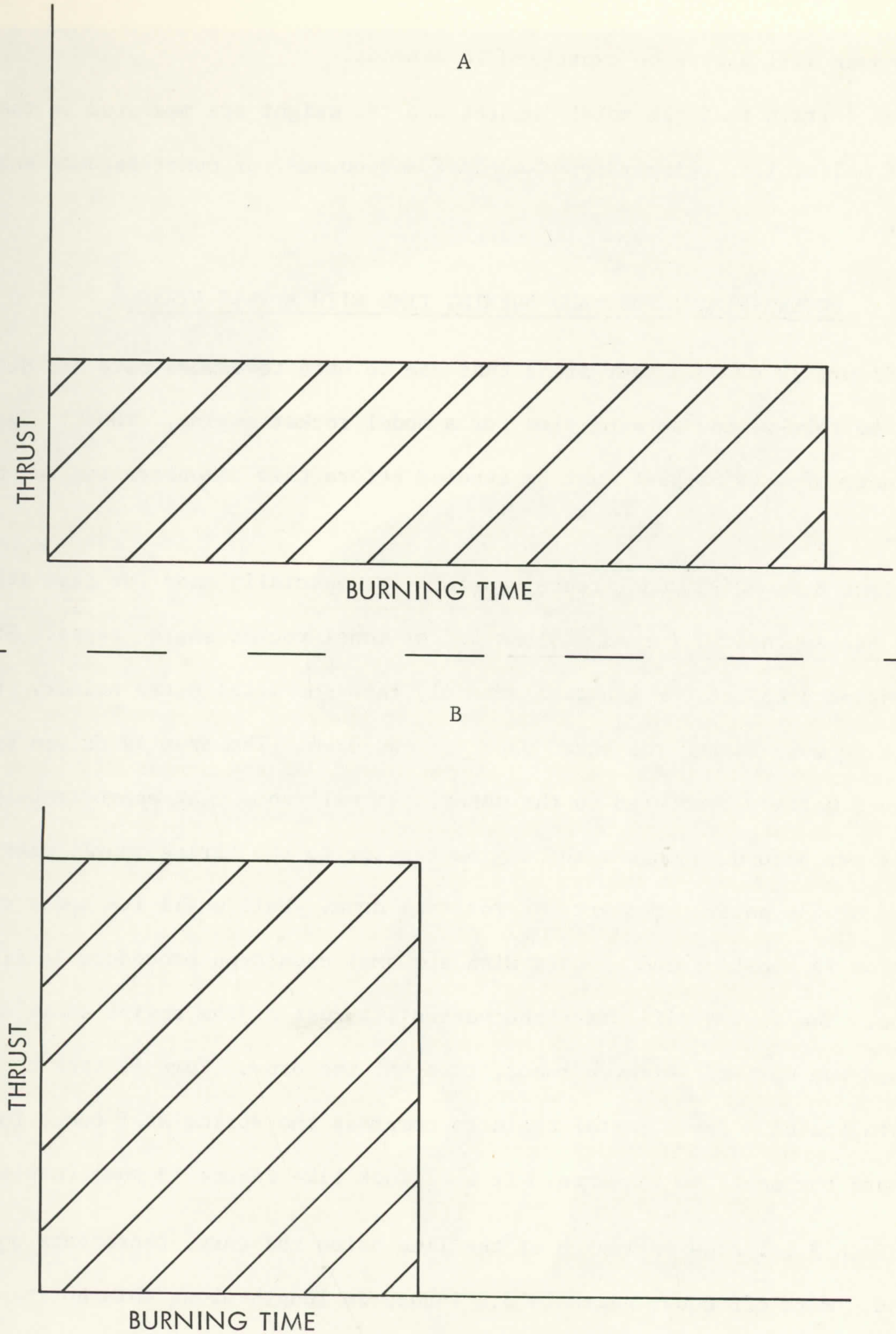


Figure 11

The answer will always be expressed in seconds.

Be certain that the total impulse and the weight are measured in the same set of units, i.e., either pound-seconds and pounds, or ounce-seconds and ounces.

DETERMINING THRUST AND BURNING TIME WITH A TEST STAND

Figure 12 shows a test stand that can be used to demonstrate and determine the thrust and burning time for a model rocket engine. (NOTE: The remainder of this booklet must be studied before this demonstration can be done).

Type B.8 - 0(P) model rocket engines are specially made for test stand use. See Appendix I for an explanation of model rocket engine types. Strap the engine prepared for ignition securely into the metal strap holder. Use Scotch tape to fasten the waxed paper to the drum. The drum is driven by a six-volt battery connected to the motor. It will rotate at approximately 3.6 inches per second. Connect the engine ignitor to the firing panel. Set the stylus on the paper and start the rotating drum. Wait until its speed of rotation is constant and proceed with a normal countdown procedure to fire the engine. The stylus will trace the variable thrust of the engine as it compresses the spring. After burnout, turn off the drum. Turn it back to the starting point. Use a postal scale to compress the spring at 5 ounce intervals and mark the paper in sequence. It will look like Figure 13 when completed.

Each 3.6 inches of length of the line below the curve represents <u>one</u> second. Mark off equal segments 3.6 inches in length along this horizontal

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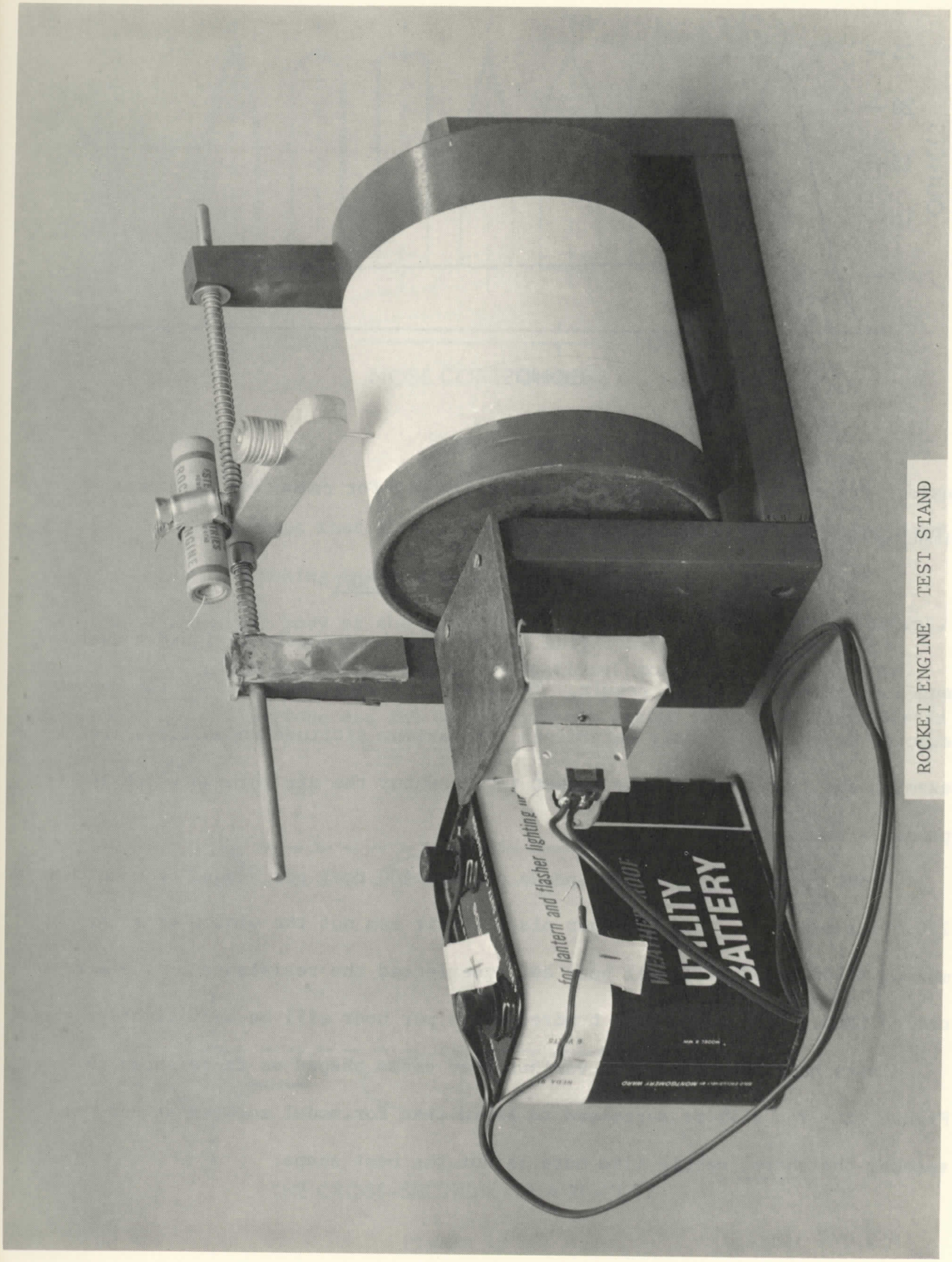


ROCKET ENGINE TEST STAND

Figure 12

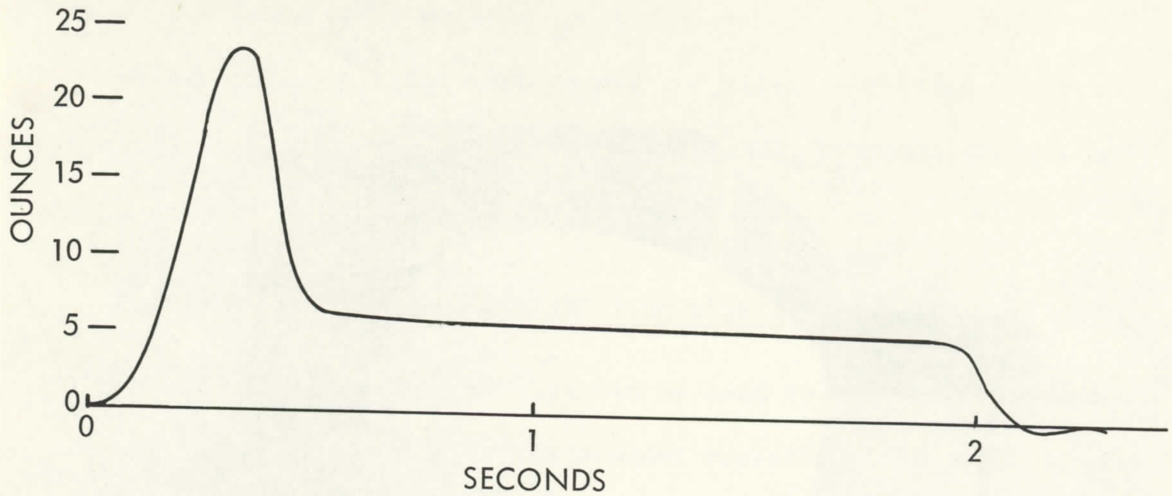


Figure 13

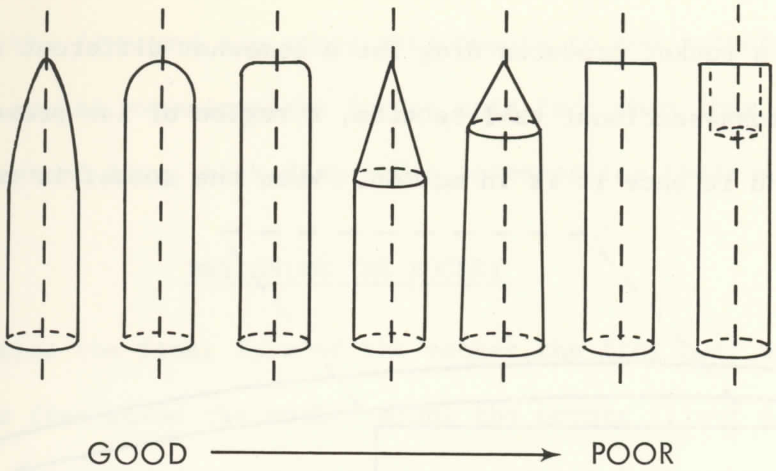
axis. Proceed in the manner outlined previously for computing the total impulse and the specific impulse.

EXAMINING THE PARTS OF A ROCKET

A very efficient rocket engine can be used in a poorly designed rocket and poor performance will result. The design of those portions of the rocket exposed to the air greatly determines its maximum altitude capability. Let's examine the first part of the rocket to encounter the air through which it passes - the nose cone.

Model rockets can achieve speeds of over 400 feet per second or more than 270 miles per hour. Everyone has placed their arm out the window of a car moving at 50 or 60 miles per hour and experienced the resistance of the air called DRAG. Drag at several hundred miles per hour will be many times greater.

Tests have been made with various nose cones shaped as those shown in Figure 14. You will be surprised to learn that for model rockets at subsonic speeds, the sharp, needle-like nose is not the best shape.

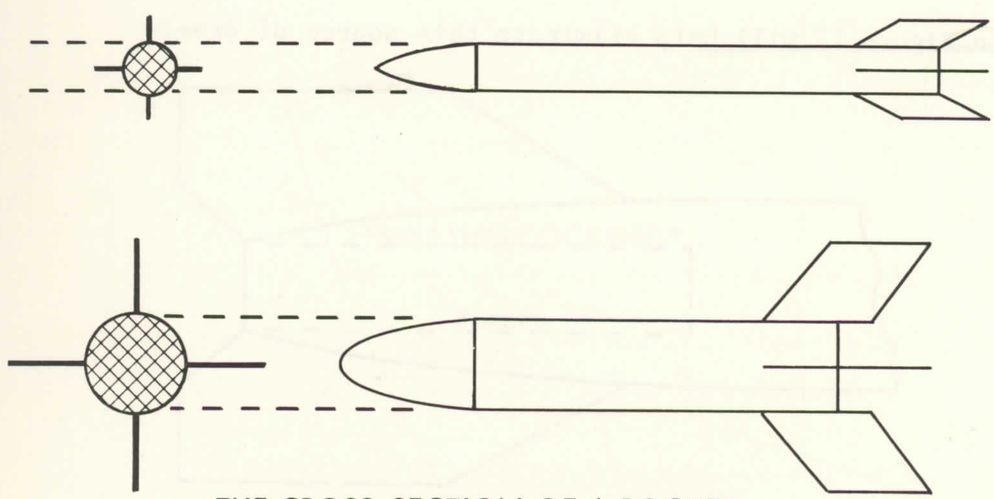


NOSE CONE SHAPES

Figure 14

This is due to the fact that a slightly rounded and tapered nose cone has less surface actually "running into" the air particles.

The cylindrical body of the rocket cannot be altered to any great extent. The diameter, which determines the cross-sectional area, the base, and the smoothness of the surface are the most important design factors to consider in reducing drag.



THE CROSS-SECTION OF A ROCKET

Figure 15

The base of a rocket produces drag for a somewhat different reason. If it has a flat, cross-sectional tail section, a region of low pressure air will be produced behind it once it is in motion. When the rocket is coasting and

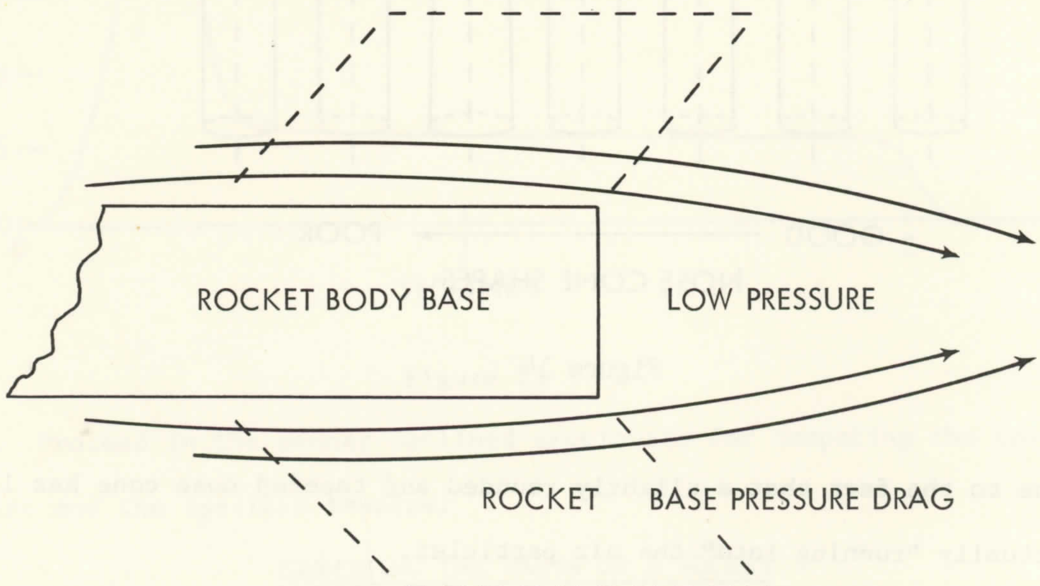
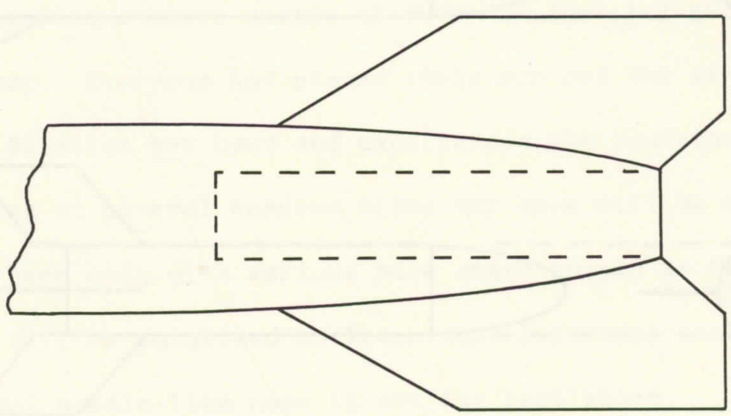


Figure 16

there are no exhaust gases to fill this region, there is a pressure difference acting on the rocket. The rocket tends to be "pushed back" into the low pressure region and performance and speed are reduced. Using a "boat tail" shape as shown in Figure 17 will help eliminate this source of drag.



"BOAT TAIL" ON A MODEL ROCKET

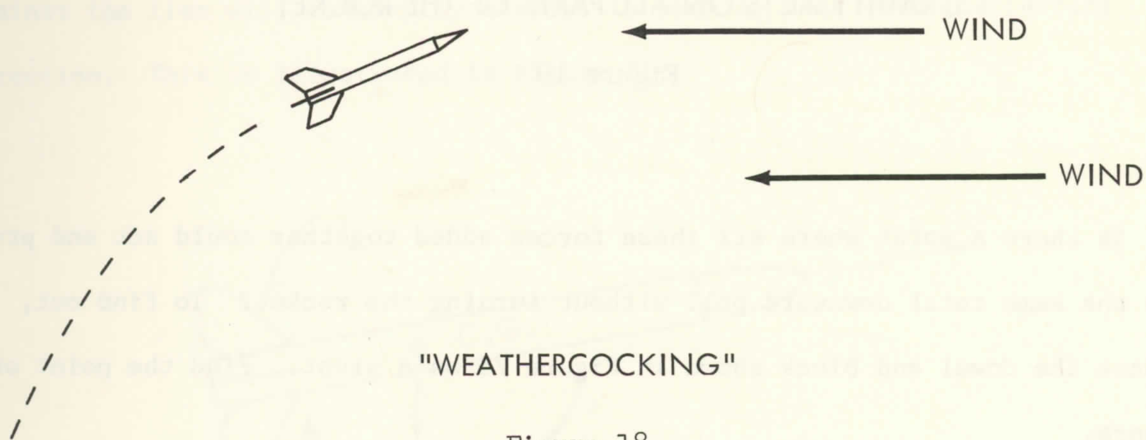
Figure 17

Finally, the fins and any other attachments to the rocket increase drag. Many sounding rocket experimenters forget this fact when they ask the rocket designers to extend long, high-drag radio antennas for their experiments.

DESIGNING THE ROCKET

To determine the final form of the rocket, the fins must be designed properly. The fins guide the rocket along the proper flight path just as the feathers on an arrow guide it to the target. A quick thought about the fins might lead one to the conclusion that better guidance would be obtained by using large fins. Such is not the case. Several factors must be considered.

First, large fins produce greater drag. Secondly, they also increase the weight of the rocket. Large fins will also cause the rocket to point into the wind, away from the vertical as shown in Figure 18, just as a weather vane swings into the wind stream. This is called "weathercocking".

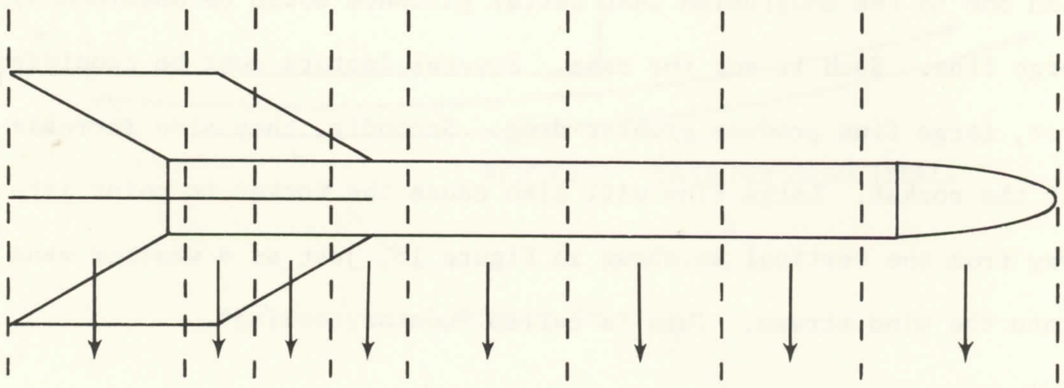


"WEATHERCOCKING"

Figure 18

The area and the shape of the fins are not the only factors that determine the stability of the rocket in flight. Gravity also acts upon it at all times. This poses a problem. Since gravity acts on all parts of the rocket, many different pulls would seem to result. This is indeed the case, but the dilemma can be simplified.

Consider that the rocket is divided into small sections with equal gravitational pull on each. See Figure 19.



GRAVITY ACTS ON ALL PARTS OF THE ROCKET

Figure 19

Is there a point where all these forces added together could act and produce the same total downward pull without turning the rocket? To find out, balance the dowel and block shown in Figure 20 on a pivot. Find the point of balance.

Gravity is still acting on all portions of the device, but you have found a point where the upward push of the pivot equals the total downward pull of gravity and also a point where the forces attempting to turn the device are balanced. This point is called the CENTER OF GRAVITY (C.G.). Outdoors, throw

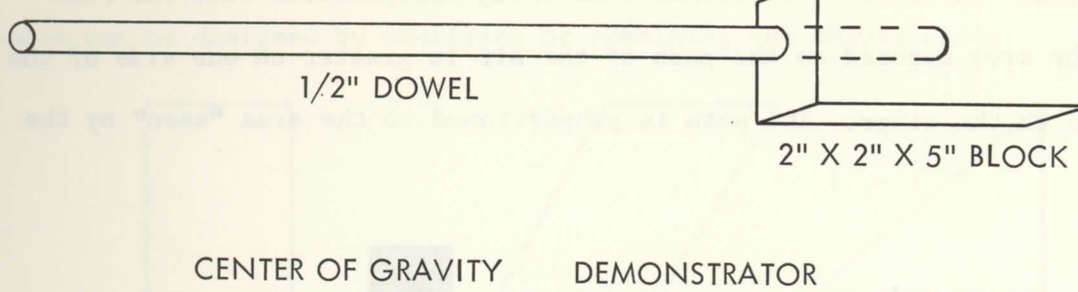


Figure 20

the dowel and block through the air so that it turns end over end. Does it appear to turn about the C.G.? Repeated trials will show that it does.

A rocket may try to rotate in exactly the same manner, but the air against the fins will constantly attempt to push it back into its initial direction. This is illustrated in Figure 21.

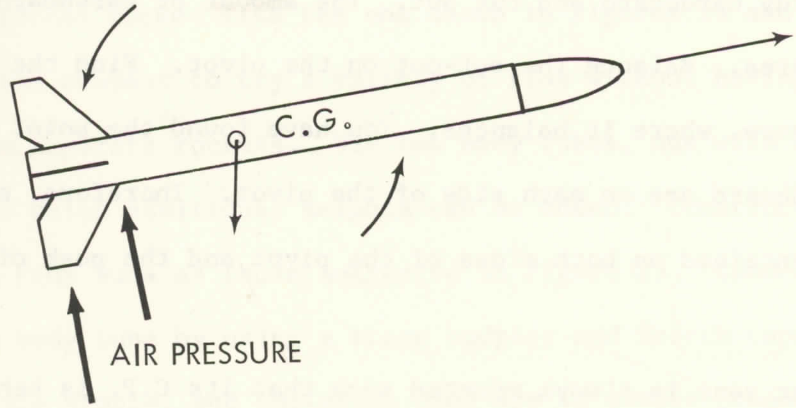
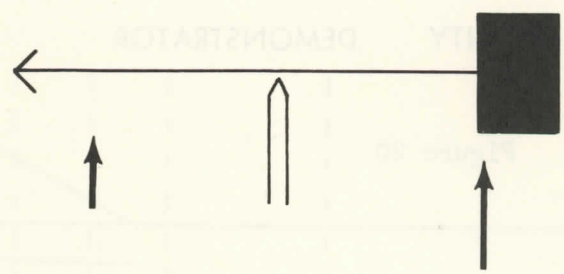


Figure 21

Just as all the gravitational forces can be considered as acting at the center of gravity, the push of the air on the rocket can be considered as acting at a point called the CENTER OF PRESSURE (C.P.).

A rocket behaves like a weather vane which always turns into the wind because the area exposed to the push of the air is greater on one side of the pivot than on the other. The push is proportioned to the area "seen" by the



UNEQUAL PUSH OF THE AIR TURNS THE WEATHERVANE

Figure 22

air. To find the center of pressure of a model rocket, carefully trace its outline on sturdy cardboard and cut out. The amount of cardboard cut will depend upon the area. Balance the cut-out on the pivot. Find the point, the center of pressure, where it balances. You have found the point where equal amounts of cardboard are on each side of the pivot. Therefore, equal areas must also be contained on both sides of the pivot and the push of the air will be balanced.

The weather vane is always mounted such that its C.P. is behind the pivot point. If this were not the case, the vane would turn aimlessly or not at all.

In like manner, the rocket is designed so that the CENTER OF PRESSURE IS BEHIND THE CENTER OF GRAVITY. A good "rule of thumb" is a distance equal to one body diameter.

Figure 23 shows examples of fin shapes that can be used on a model rocket. Others can be designed by modifying or combining the shapes shown.

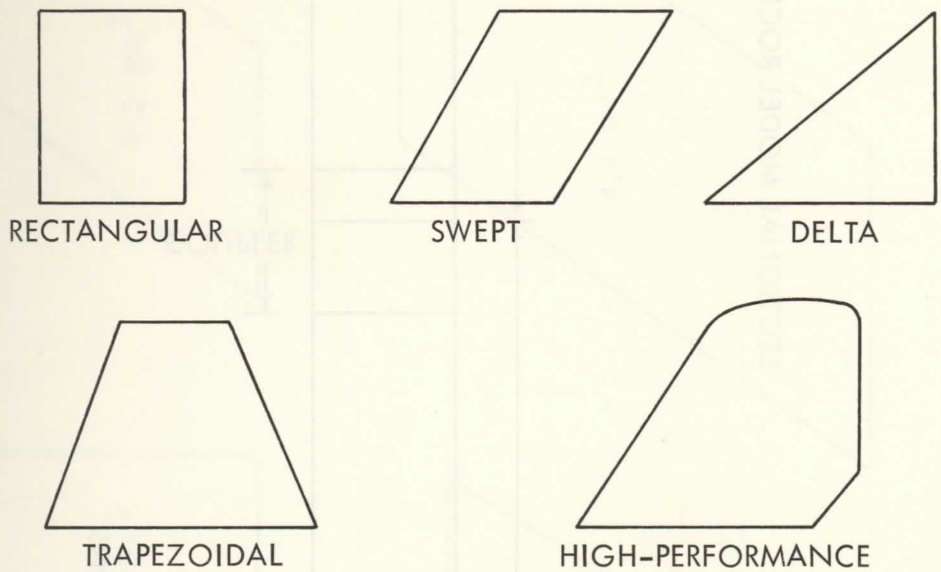
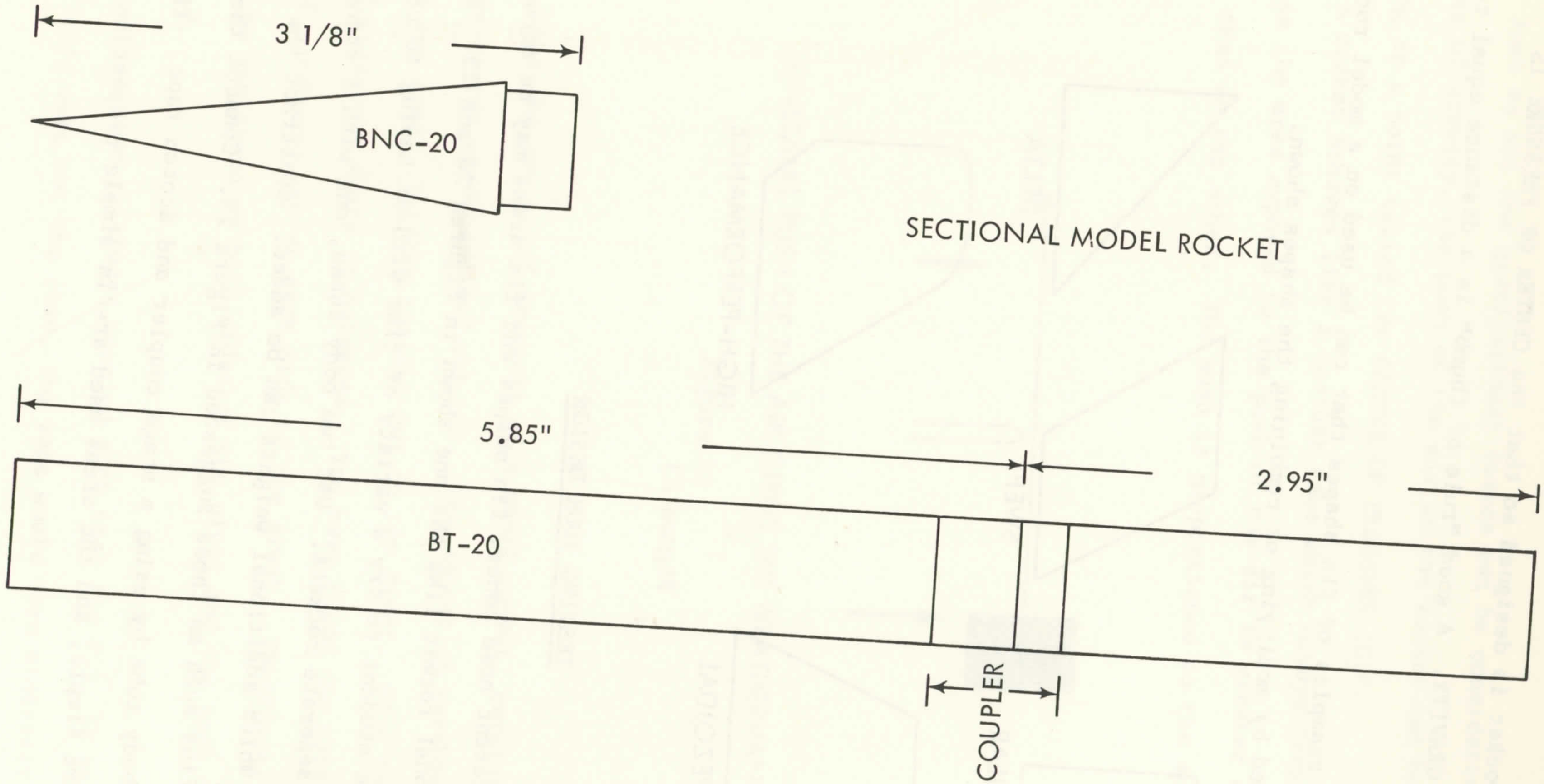


Figure 23

TESTING YOUR DESIGN

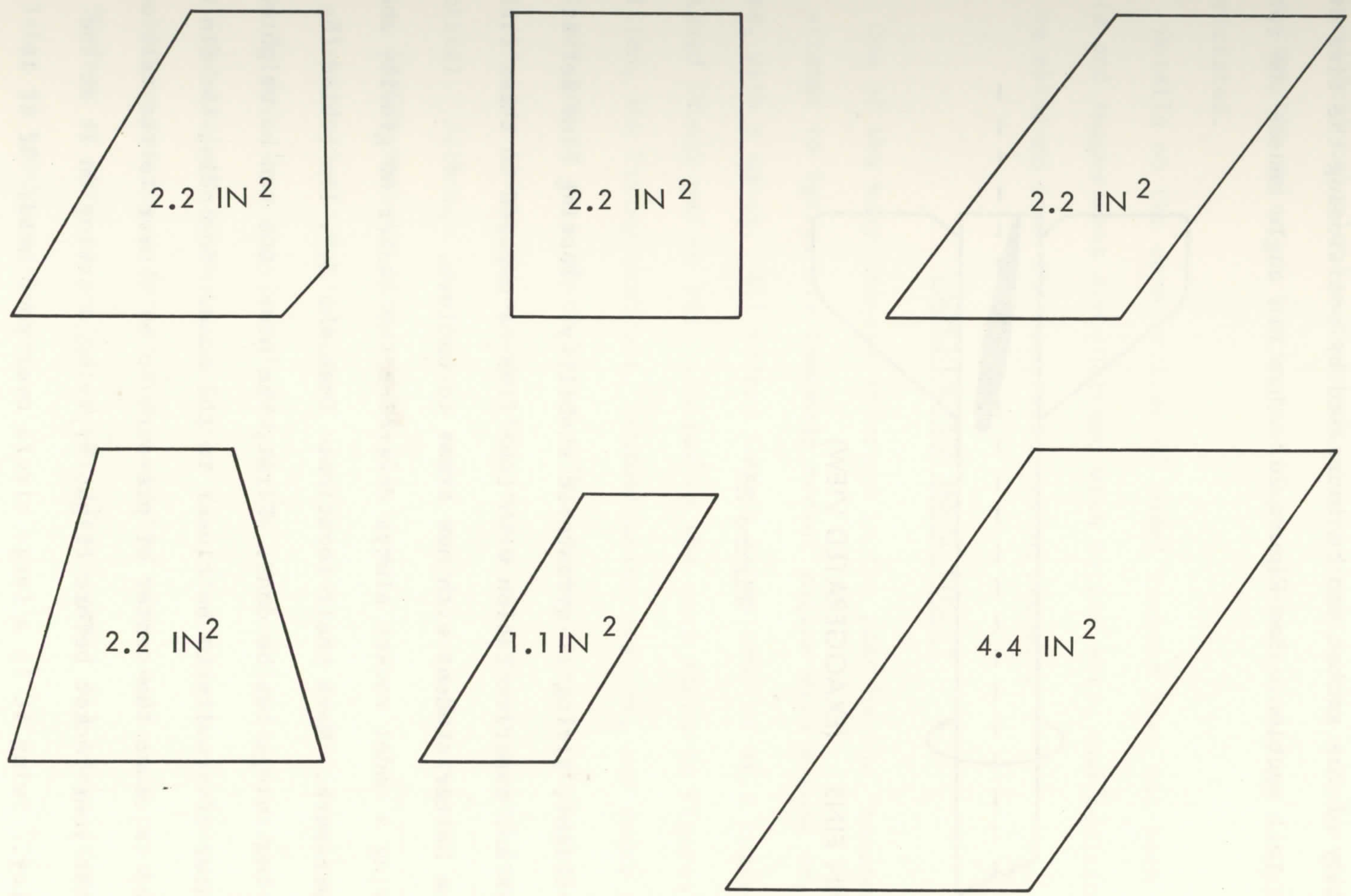
Testing different nose cones, fin shapes and fin areas may be accomplished by using a sectional rocket like the one shown in Figures 24 and 25. This rocket allows the student to try a variety of fins without having to complete construction on separate rockets. Use two body tubes, one with a standard nose cone and one to which additional weights can be added. Construct the tail sections using fins such as those suggested in Figure 25. Connect the tail section to the body tube by using a stage coupler and Scotch tape. If the shapes chosen are simple, and the areas used are in simple proportion such as

SECTIONAL MODEL ROCKET



SEE NEXT PAGE FOR SUGGESTED FINS

Figure 24



SUGGESTED FIN AREAS FOR SECTIONAL MODEL ROCKET

Figure 25

one-half or twice the area, flight observation will indicate the best choice for maximum performance.

The stability of the rocket can be increased by positioning the fins at an angle on the tail section. See Figure 26. This fin angle causes the rocket

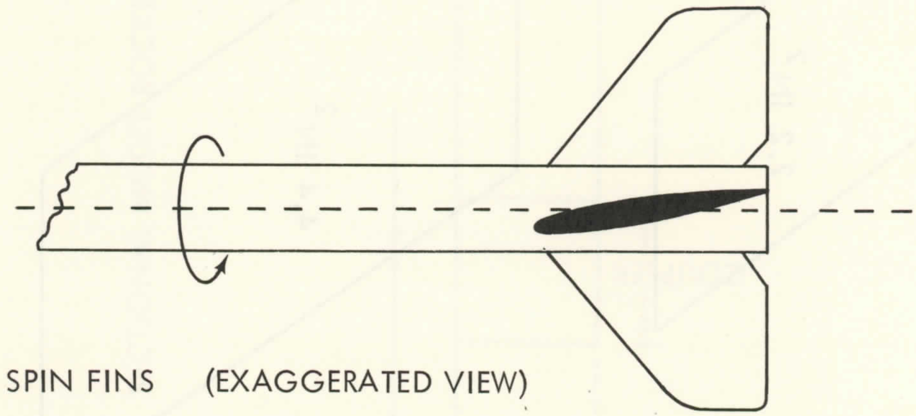


Figure 26

to spin during flight, giving it gyroscopic stability. Testing fins set at different angles and experimentation with four fins as opposed to three fins will provide the better student with new areas to explore.

Before flying a model rocket always determine the center of gravity and the center of pressure. Mark their location. Does the C.P. lie behind the C.G.? If not, two things can be done. First, the nose cone can be weighted causing the center of gravity to be closer to the nose. Secondly, the fin area can be increased to cause the center of pressure to be closer to the tail of the rocket. Test your rocket before flight by tying a string on it at the center of gravity. Swing it in a large circle over your head. If it is correctly balanced, it will "fly" without vibration or tumbling.

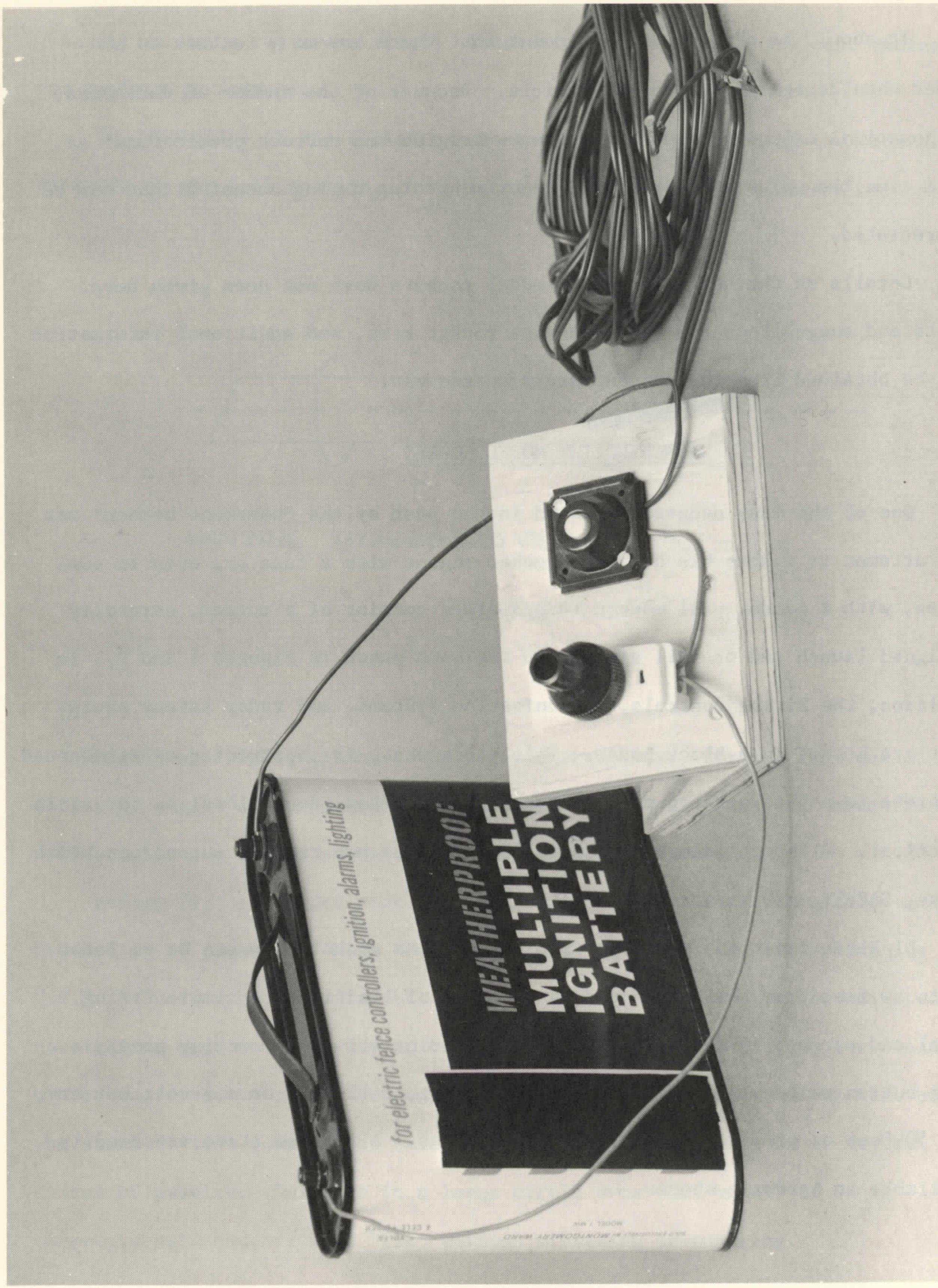
It should be obvious at this point that there are many factors to consider when designing the rocket vehicle. Because of the number of variables, methematical calculation does not always provide the correct prediction. At this time the value of testing and experimentation during actual flight can be appreciated.

Details on the construction of model rockets have not been given here. Hints and suggestions are included with rocket kits, and additional information can be obtained from the manufacturers on request.

LAUNCHING THE MODEL ROCKET

One of the many dangers incurred in the past by the "basement bomber" was his attempt to ignite his homemade rocket engine with a fuse or, even in some cases, with a match. All modern launch sites consist of a rugged, carefully designed launch pad or rail similar to the ones shown in Figures 1 and 2. In addition, the firing controls, communication systems, and radar safety equipment are housed in a block house. This block house is constructed of reinforced concrete to a thickness of many feet and placed below ground level as far as is practical. Although launching a model rocket does not require a concrete block house, SAFETY must be stressed at all times.

Electric ignition is always used so that the rocket crew can be at least 25 to 50 feet from the launch pad at the time of ignition. A simple firing panel and circuit is shown in Figure 27. It consists of a mounting panel, a push button switch, a socket and a shorted plug, a 12-volt or a 6-volt battery, and 50 feet of wire to extend to the launch pad. All these items are readily available in hardware stores.



FIRING PANEL and CIRCUIT

The panel shown includes the basic essentials for a firing circuit. The plug should be carried to the pad by the rocketeer while the clips are attached to the igniter. This serves as an important safety check. On his return to the firing panel, the plug is inserted, a countdown is followed, and the rocket lifts off.

Many sophisticated panels have been built by student rocketeers and include such added features as a key switch, warning and firing lights, a circuit check, and provisions for connecting several rockets at the same time for sequential launch.

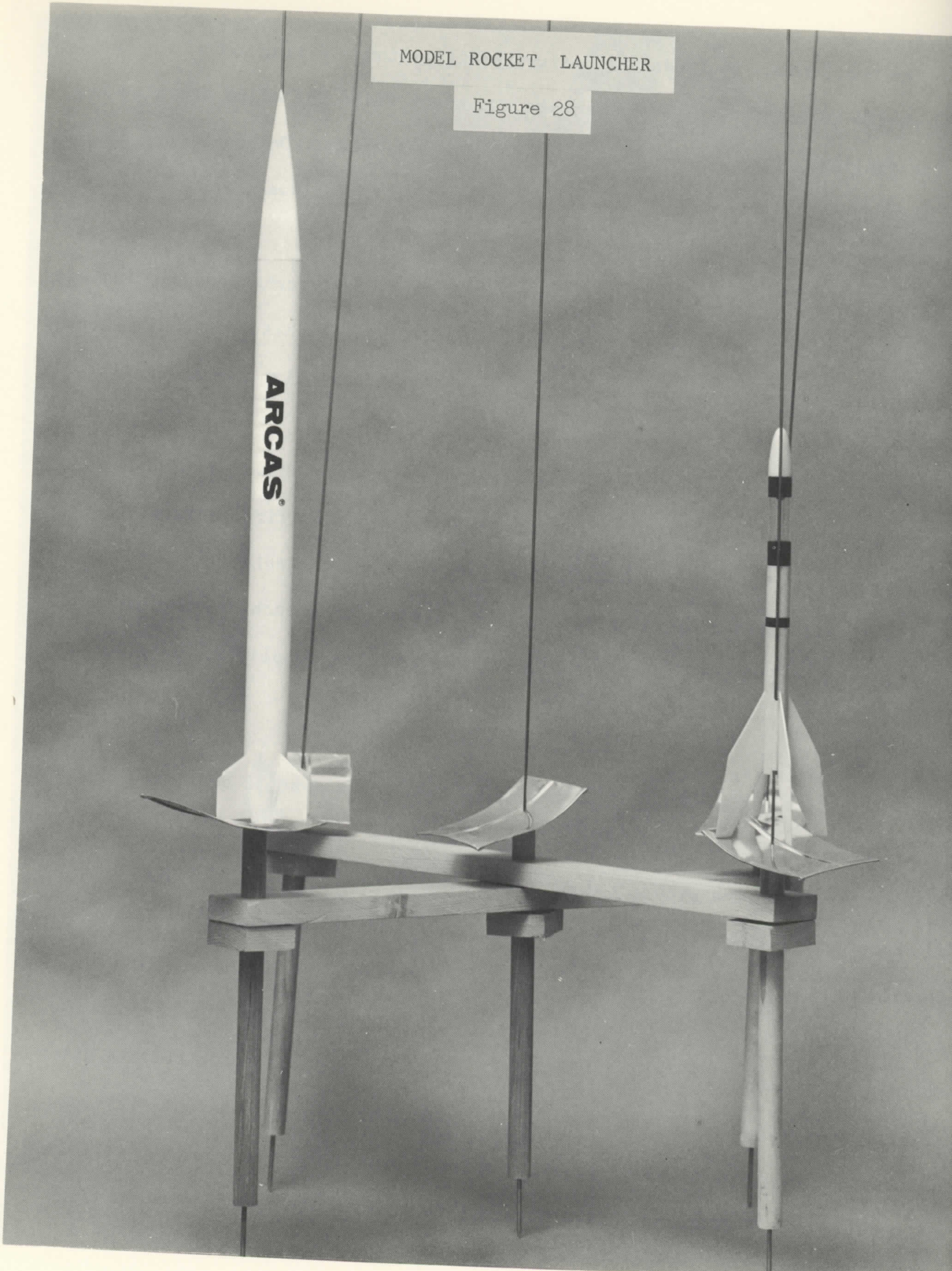
The rocket is launched from a pad similar to the one shown in Figure 28. The launch rod provides guidance for the rocket during the first several feet or until it has sufficient speed for the fins to keep it stable.

Further details concerning optional techniques for launching, and hints on readying the rocket for launch can be obtained from the suppliers.

THE LAUNCH SITE

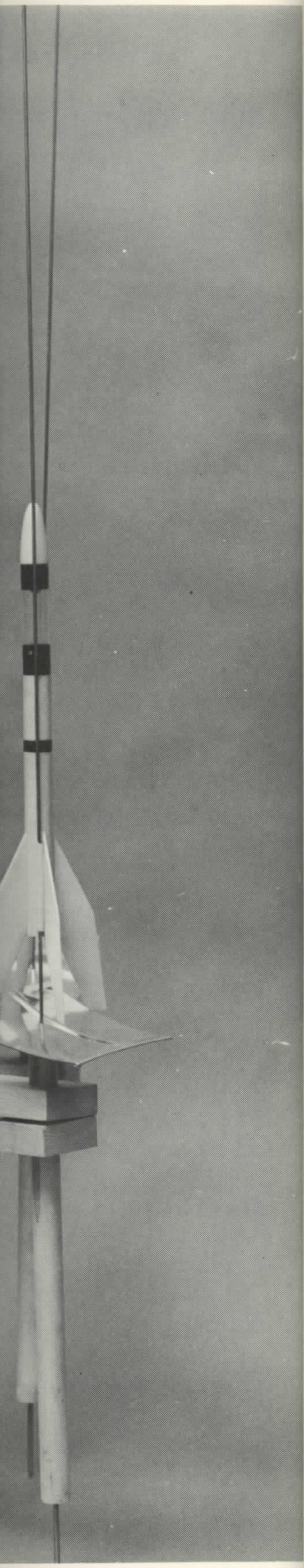
The altitude the rocket will reach determines the size of the field that is necessary for a SAFE launch.

As small rockets with a 1/2 A engine will not exceed several hundred feet, an open field with a length and width equal to this distance will be adequate for flying. Most school yard areas are large enough <u>if</u> only the smallest engines are used. There actually is no reason for the students or teacher to concern themselves with reaching higher altitudes. The challenge lies in using the lightest weight rocket with the smallest engine to reach maximum altitude. To assure that no problems of legality arise - usually no problem with schools - enlist the aid of your local fire marshall in training the youngsters in fire



MODEL ROCKET LAUNCHER

Figure 28



safety. He will probably become a steady member of the class!

To the author, the most valuable portion of model rocketry is extending the basic activity by finding further applications of mathematics, electronics weather, and team work. Some of these activities follow.

DETERMINING ROCKET ALTITUDE

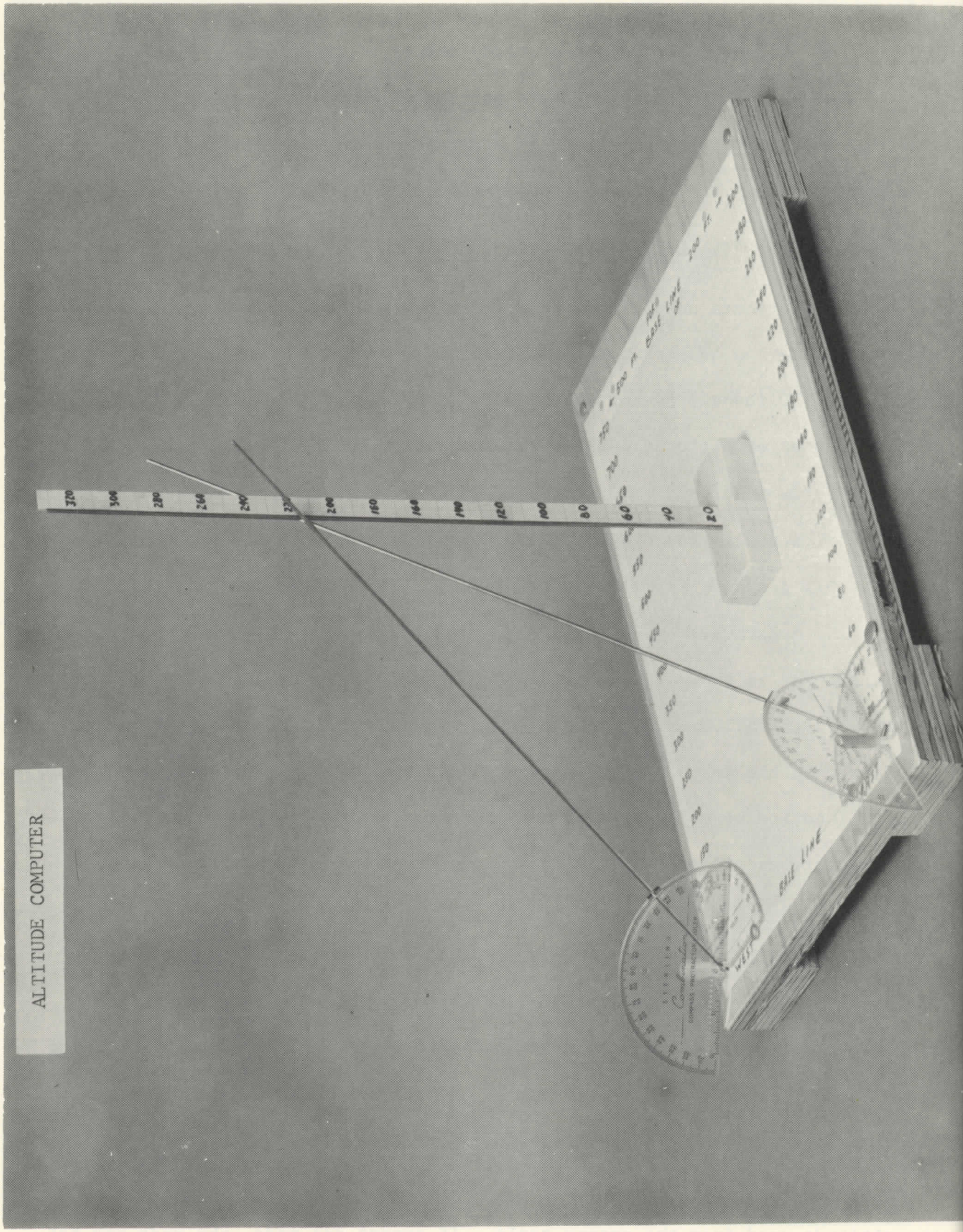
Most references on altitude determination immediately include a discussio of mathematics too complex for the elementary student.

Figure 29 shows a device which helps to eliminate this difficulty. The Altitude Computer pictured enables the student to build a "model" of rocket altitude determination.

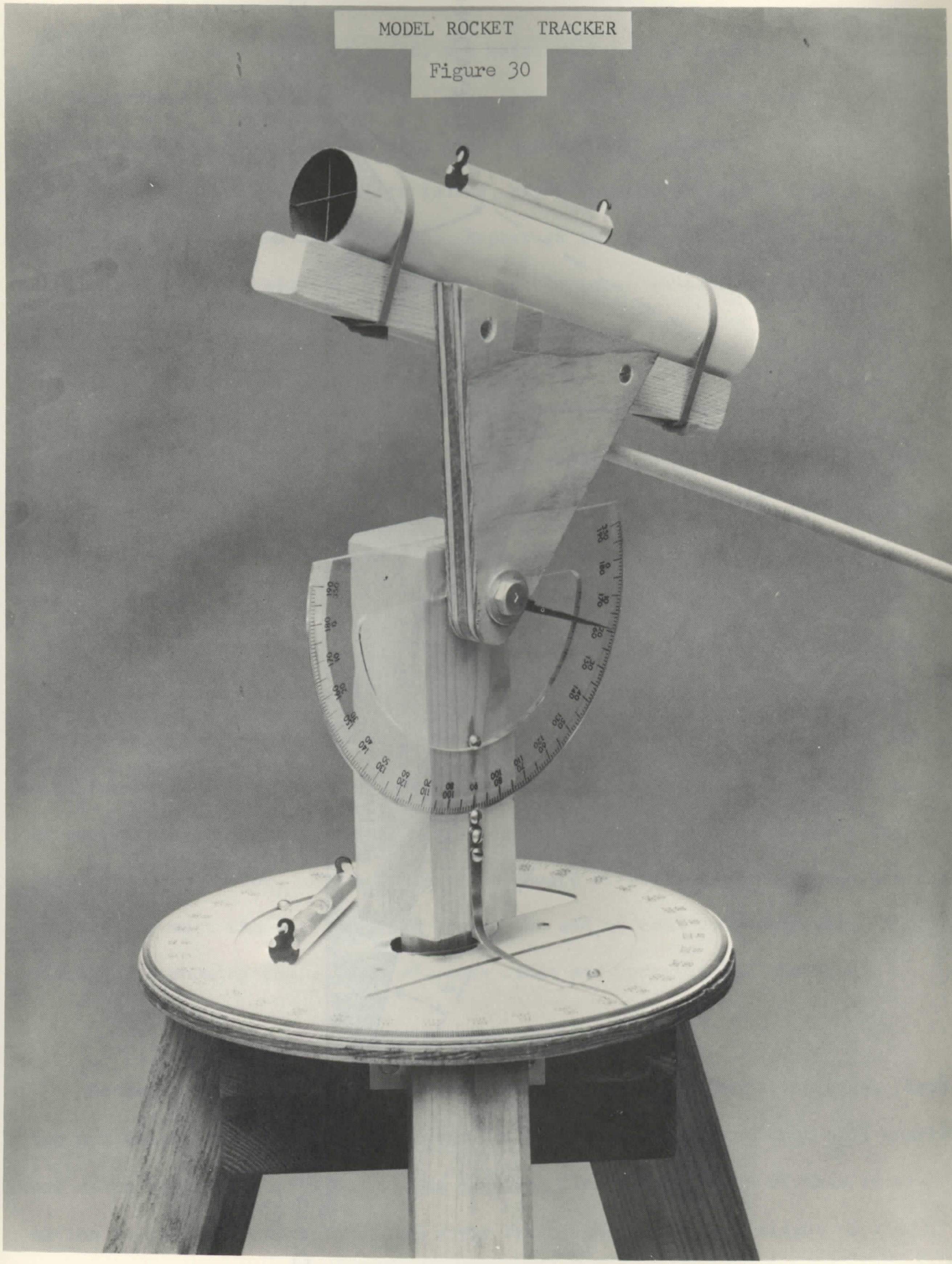
The altitude is found by using two trackers stationed 100 to 500 feet apart. This distance is called the BASE LINE. The longer the base line, the greater the accuracy.

A Tracker is shown in Figure 30. With this device or a simpler one, the AZIMUTH and ELEVATION ANGLES can be found. Study Figure 31 until you are familiar with the terms for the distances and the angles. The method of deter-mining location by using azimuth and elevation angles is used in radar plottir and tracking and is one application of the branch of mathematics called Trigonometry.

Each tracking station follows the rocket to peak altitude or to parachute ejection, at which time the Tracking Officer says "mark". The azimuth and elevation angles are quickly read at each station. The Computer Section using the Altitude Computer sets in the angles at both stations, being careful to read the angles in the proper direction and to align the rods correctly. The altitude rod is then moved to the intersection of the two tracking rods, and the altitude read from the proper scale. If errors are made, the rods may not



ALTITUDE COMPUTER



MODEL ROCKET TRACKER

Figure 30

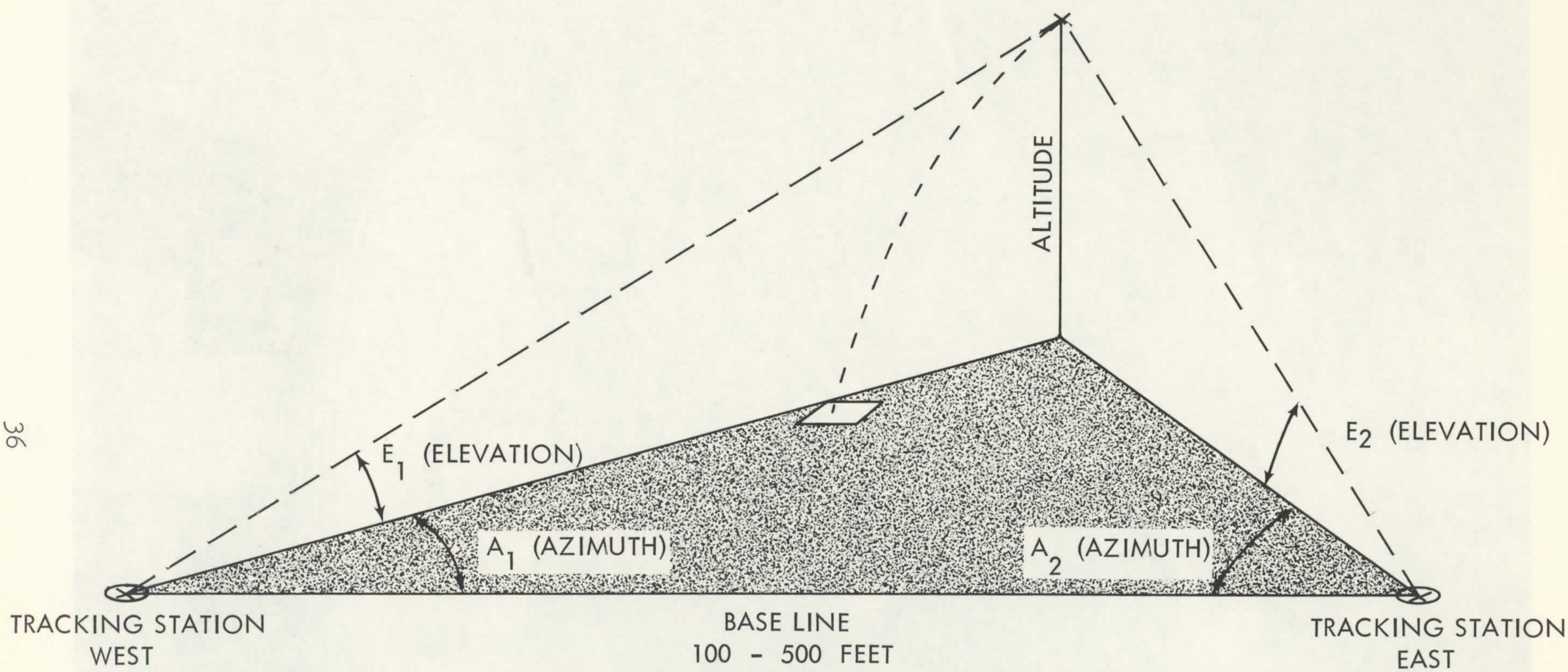

ALTITUDE
E2 (ELEVATION)
E1 (ELEVATION)
A1 (AZIMUTH)
A2 (AZIMUTH)
TRACKING STATION
WEST
BASE LINE
100 - 500 FEET
TRACKING STATION
EAST

Figure 31

intersect. If this error is great, the measurements will have to be repeated or discarded. A small error will always exist when using crude instruments, but the Altitude Computer will give good approximate results.

To align the trackers before launch, sight towards Station 2 from Station 1. Set the pointer on zero azimuth. Repeat in the same manner for the other station. Check the sighting tube with a bubble level to zero the elevation protractor.

TRACKING THE WINDS

Tracking is fun, but it also takes some skill. To develop this skill and gather information on wind direction and speed before the launch, fill brightly painted balloons with helium gas. Release the balloons and track until they are lost from sight. As the balloons are approximately the same size as the model rocket parachute, they will enable the student trackers to determine the maximum altitude to which they can visually follow the rocket.

Wind information helps predict the path or TRAJECTORY of the rocket. Release a helium balloon and "mark" azimuth and elevation from both stations at 30 second or one minute intervals. The time will depend upon the speed with which the readings can be taken. Use additional cardboard altitude markers on the Altitude Computer to mark the balloon positions at the end of each time interval. A visual path showing the effects of cross winds and updrafts will be seen.

YOU'RE ON YOUR OWN

Rocketry, even to the professional, is still an experimental science. Each day new discoveries are being made and new techniques are found that will enable our space program to grow to new and exciting dimensions. Much of this information is gained through trial and error during the launch and flight of the rocket. Will your students keep pace with these developments by investigating the exciting activity of model rocketry?

APPENDIX I

Model rocket engines are grouped according to total impulse range. The first letter of the code on the engine tells you the classification:

Type Half-A	=	0.00	to	0.35	lb-sec
Type A	=	0.35	to	0.70	lb-sec
Type B	=	0.70	to	1.20	lb-sec
Type C	=	1.21	to	2.0	lb-sec
Type D	=	2.01	to	4.0	lb-sec
Type E	=	4.01	to	8.0	lb-sec
Type F	=	8.01	to	16.0	lb-sec

The first number gives the engine's average thrust. The last number indicates the delay time in seconds that is built into the engine. For example, an A.8-3 engine has an average thrust of 0.8 pounds and a delay time of 3 seconds.

APPENDIX II

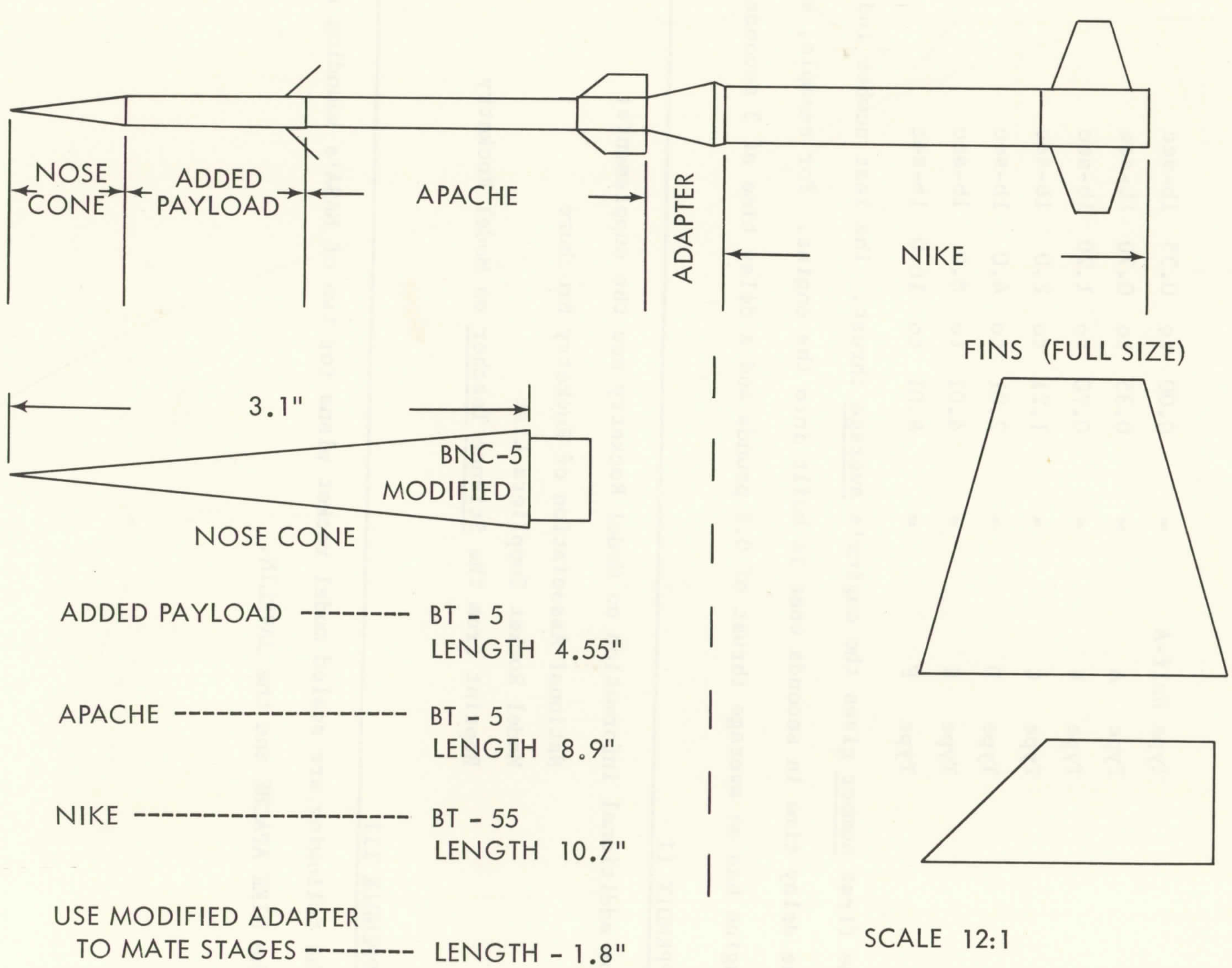
For additional information on Model Rocketry see the supplements:

National Association of Rocketry Brochure
Model Rocket Suppliers List
Reprint from the Science Teacher on Model Rocketry

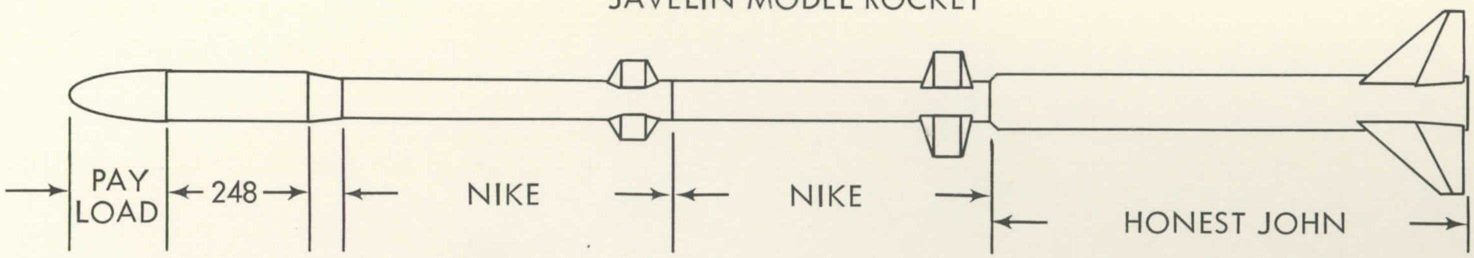
APPENDIX III

The following are scaled model rocket plans for two of NASA's sounding rockets, the NIKE APACHE and the JAVELIN.

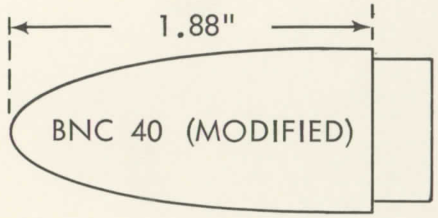
NIKE APACHE MODEL ROCKET



JAVELIN MODEL ROCKET



PAYLOAD



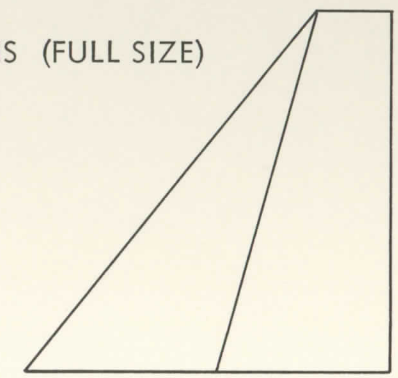
248 STAGE --------------- BT - 40
LENGTH - 2.65"

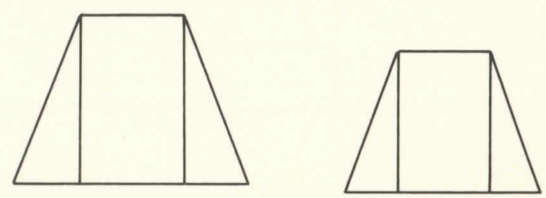
NIKE STAGES ------------ BT - 20
LENGTH - 6.0"

HONEST JOHN ----------- BT - 50
LENGTH 8.95"

USE MODIFIED ADAPTERS TO MATE STAGES

FINS (FULL SIZE)





SCALE 22.5:1