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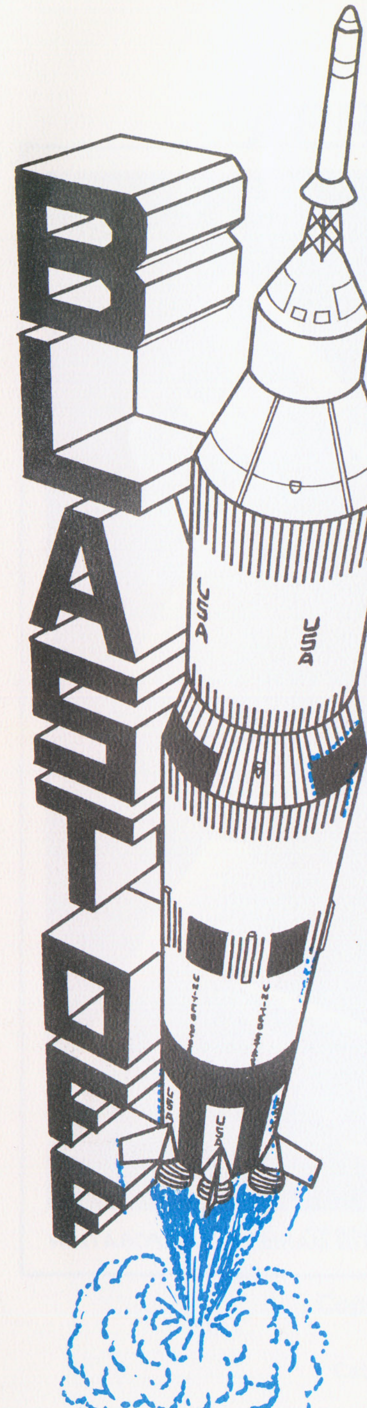


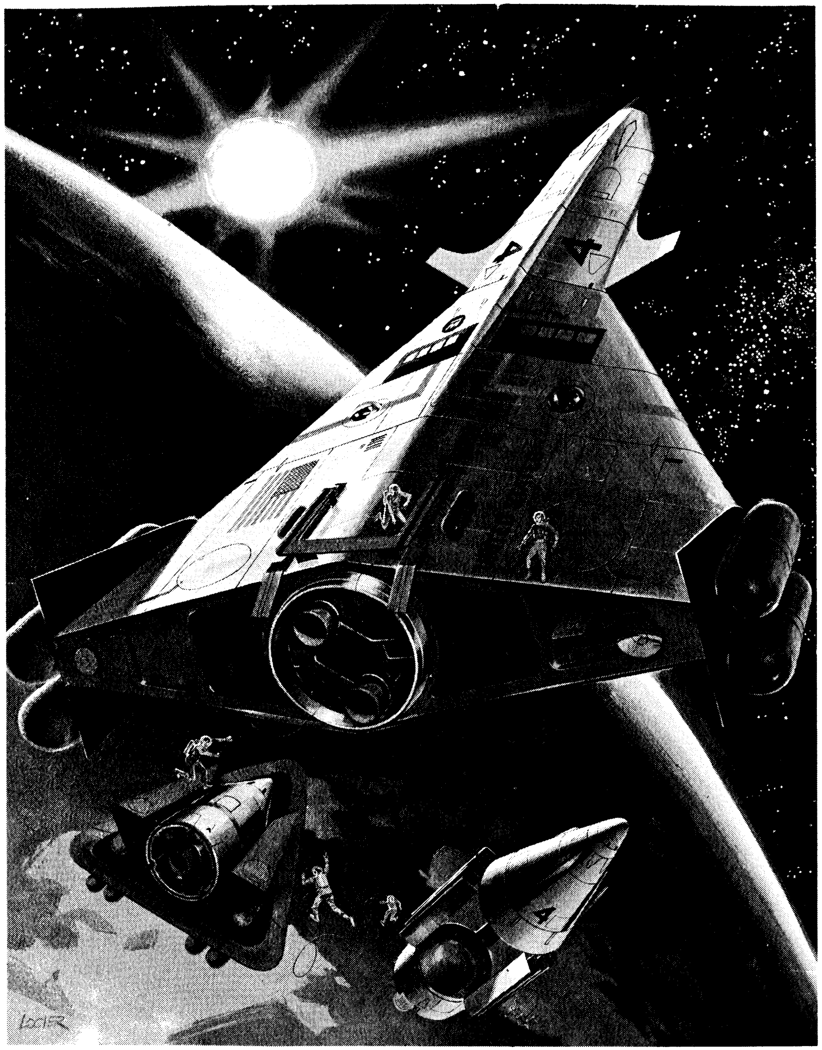
AEROSPACE EDUCATION AND MODEL ROCKETRY

SECOND EDITION

An Educator's Guide for Grades Four through Ten

by

Daniel F. Saltrick,
Alfred M. Kubota,
and Robert L. Cannon



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Model rocketry was created to provide a safe, inexpensive way for science-minded individuals to build and launch their own rockets. The appeal of model rocketry is so strong that about one million people each year now participate in the hobby. More than sixty million model rockets have been safely launched.

What way could be better to introduce your students to the study of aerospace that to involve them in meaningful, "hands-on" learning experiences? Model rocketry has proven itself in thousands of classrooms as an exciting teaching aid which captures the students' interest and provides both motivation to learn and valid learning experiences.

Successful learning activities involving model rocketry occur in thousands of classrooms. Experience has proven that meaningful and exciting learning takes place from fourth grade classes on up through university level. The type of activity and level of content varies to match the objectives of the teacher and the capabilities of the class, but one element which unites all of the classes is ---------

LEARNING IS FUN!

Robert L. Cannon
Education Director

THE IDEAS PRESENTED IN THIS BOOK ARE USEFUL FOR ANY LEADER WORKING WITH A GROUP NEW TO MODEL ROCKETRY.

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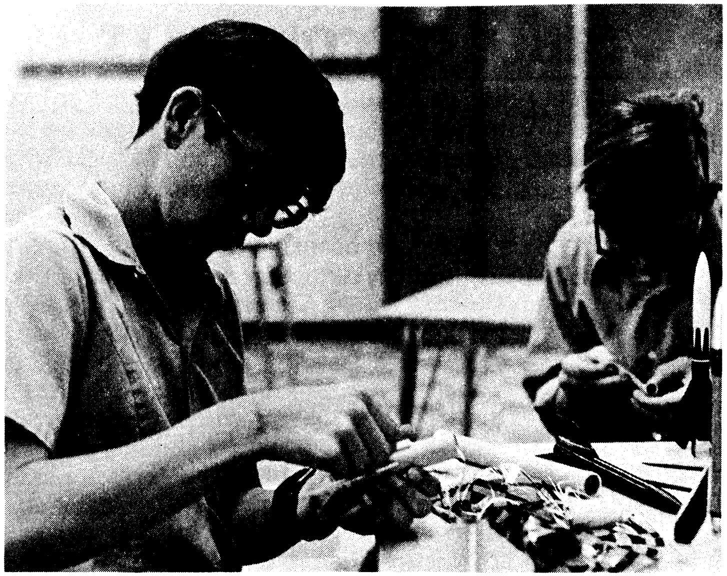
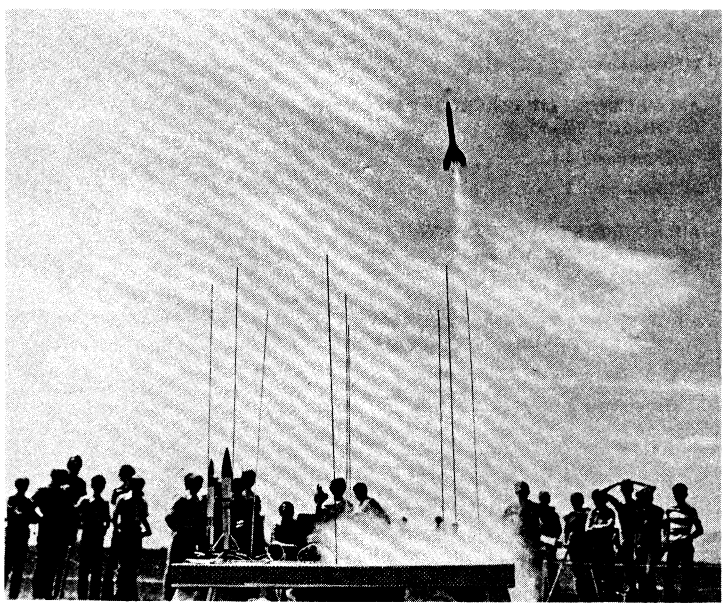


ESTES PHOTO

Model rockets make learning fun!



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AEROSPACE EDUCATION

Aerospace as defined in the dictionary is the atmosphere and the space beyond. Aerospace also pertains to the design, manufacture, and flight of vehicles which operate in aerospace.

Everyone on Earth is influenced by man's remarkable achievements in the air and in space. Remarkable as these achievements are, we must ask if understanding always accompanies the awareness.

One out of fifteen adults employed in manufacturing today earns his livelihood either directly or indirectly from aerospace. We owe our survival and security to aerospace. Tomorrow, the pupil of today will learn, earn, and participate even more in aerospace.

A question which we as educators must ask ourselves is—— "Are we educating our students for the world of tomorrow in which they will be making contributions as adults?" Many dreams of yesterday which were considered impossible by most people are realities today. Who knows what new developments the future will bring? Aerospace is here to stay. It has become a part of our society.

The study of aerospace is not intended to be an end in itself. In the elementary classroom, it can help students to understand better the world in which they live. In secondary education programs, aerospace education can increase this understanding and offer rich experiences for those students who wish to pursue careers requiring specific training. In both cases, we will be preparing youth for their adult world.

Aerospace education is necessary for students who will be living in the 21st Century. Today, aerospace activities can provide the teacher with a "vehicle" to capitalize on the students' interests. Model rocketry activities are excellent "involvement" learning experiences. Many important concepts may be taught through model rocketry experiences which really "relate" to the students' interests. Any curriculum which hopes to be releveant must deal with the distinct possibilities for exploring space in this aerospace age.

In one area of aerospace, our pupils study the development of early types of aircraft and their uses. They learn that the conventional aircraft flew only in the atmosphere. Man's curiosity drove him to explore above the earth, but he was restricted in the distance he could go. His limitations were due to the engines' dependence on oxygen from the air and the dependence of the lifting surfaces on air pressure.

Man's curiosity and the desire to learn more about space soon led to the design of newer vehicles. These new vehicles had no wings and were propelled by a rocket engine which carried its own oxygen supply. Just as the study of aviation is necessary to understand our progress in atmospheric flight, the study of rockets is necessary to help students understand the progress we are making in outer space exploration.

Aerospace education is not limited to vehicles and their flight. It also includes geography, weather study, communications, biology, chemistry, medicine, physics, flight training, environmental control, and even mythology, in addition to the basic skills of reading, writing, and arithmetic.

No one teacher can be expected to provide opportunities for experiences in every area mentioned. The teacher, however, should be aware of those experiences and activities which can be handled safely by students to develop further their understanding of the aerospace age.

In the classroom the teacher has been aware that simplified model airplanes can be used to demonstrate the principles of flight. Now safe, reliable model rockets are available to demonstrate the principles of rocket flight for the students.

COURTESY SMITHSONIAN

Robert L. Cannon, Education Director for Estes Industries, presents an Estes Saturn 1B scale model for the Smithsonian Institution to S. Paul Johnson, Director of National Air Museum, and Fred C. Durant III, Assistant Director of Astronautics of the National Air and Space Museum.

MODEL ROCKETRY

Children and adults witness the rocket launches of manned space flights and often do not understand what makes the rocket perform. Too many think that rockets and the principles of rocket flight are too complicated—something only a scientist can understand. Nothing could be further from the truth!

All children want to know more about their world and what's going on in it. Talking about something or seeing it on TV captures their interest, but rarely satisfies their curiosity. Most children have seen rocket launches on TV. Viewing the launches on TV cannot be considered "real" experiences. We know that the student becomes more interested, remains interested, and retains a larger part of what he learns when he can relate his learning experiences with the events that take place in his daily life.

Model rocketry can be a real "hands on" experience for your students. How many of your students have had an opportunity to build and fly a model rocket, not a wind-up or a toy that is already put together, not a toy that flies on a string, but a real, safe, miniature rocket? Model rocketry is a safe, reliable means to allow your students to explore the field of rocketry and space flight.

Model rocketry is a tremendous motivator. Its effectiveness as a "turn on" for students must be seen to be believed. Model rocketry utilizes **real** science in a "do-it-yourself" environment in which a student is not afraid to ask questions or to dig a little deeper into the subject. The math which is involved is a natural part of it, and the student probably doesn't even think of it as math while he is using it.

"Following directions" takes on real meaning, perhaps for the first time, as instructions suddenly become important.

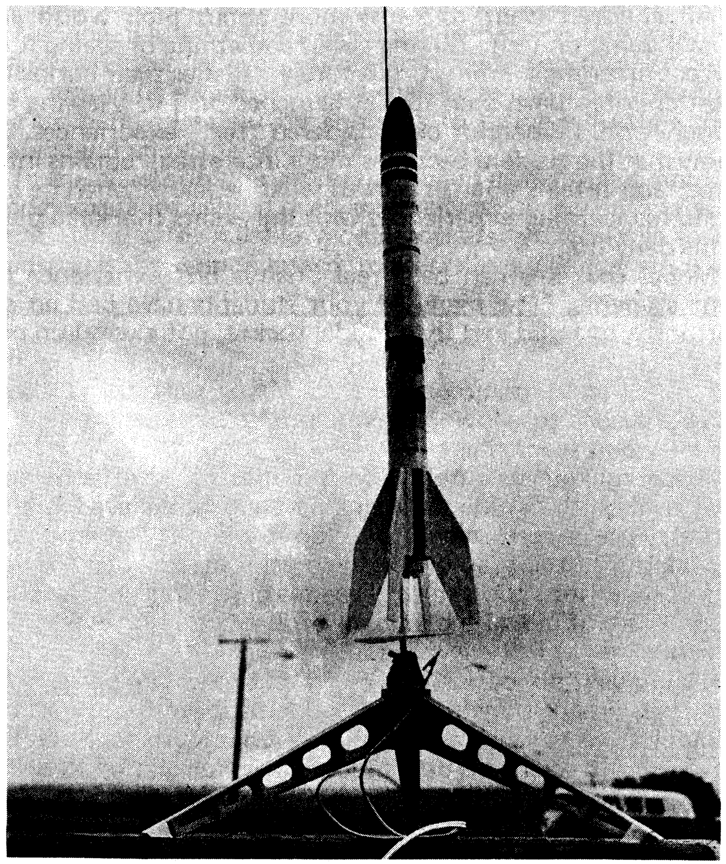
Model rocketry can help you give your students a creative experience in science. Your students may not master all of the principles of rocketry, but they will become more interested in learning.

Best of all, your students will be learning—by doing.

SOME OBJECTIVES ACHIEVABLE THROUGH MODEL ROCKETRY

1. **To learn the principles of rocket propulsion.**
2. **To demonstrate the operation of a reaction engine.**
3. **To develop a better vocabulary of aerospace terms.**

4. To gain experience in following directions.
5. To experience satisfaction in achievement.
6. To increase sense of responsibility for own efforts.
7. To enhance self-image through successful accomplishments.
8. To improve skills in group activities.
9. To understand functions of the primary systems of a model rocket.
10. To learn and understand safety rules for model rocketry.
11. To become competent in skills necessary for a successful model rocketeer.



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BIG BERTHA - - Single-engine model rocket designed for sports and demonstration flights. This is an actual photo of the craft as it prepares to leave the launch pad. This is but one of many kits available from Estes Industries.

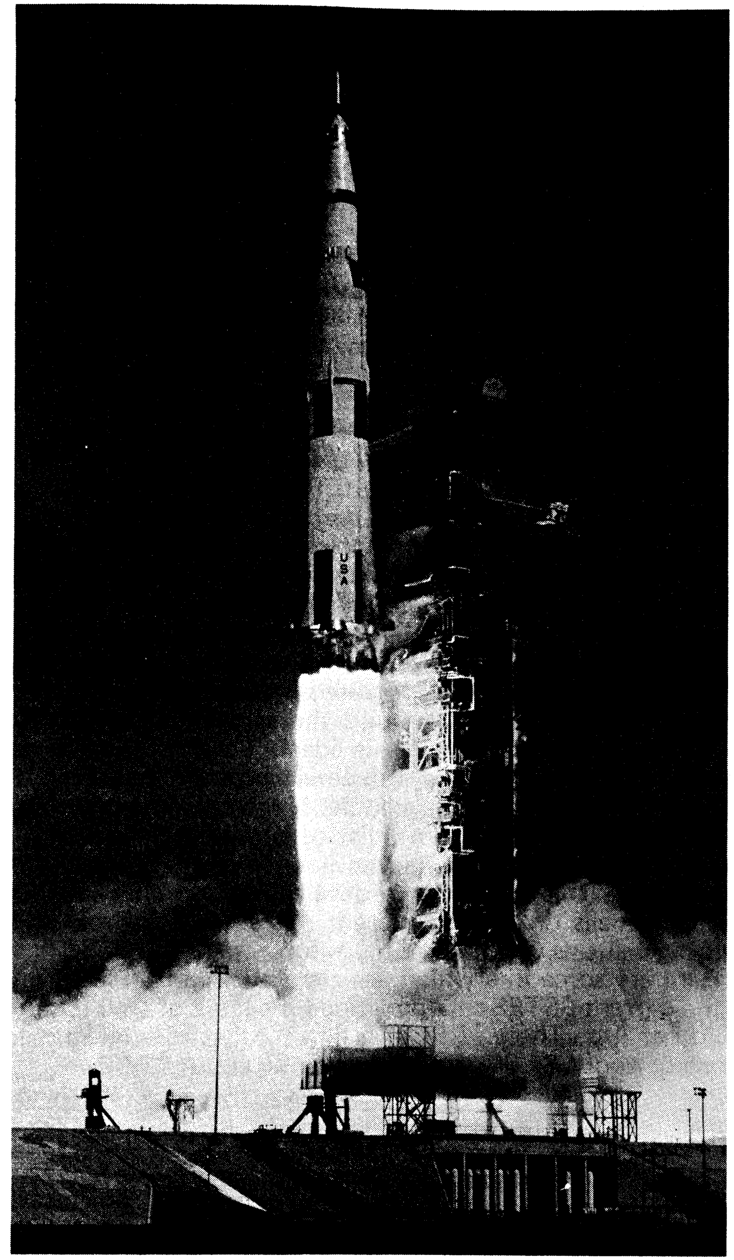

PHOTO COURTESY NASA

APOLLO 15 - - - The Saturn V lifts off on it's historic flight.

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I. TEACHER PREPARATION

A. While the study of rocketry rarely needs motivation, some setting of the scene could be advantageous. The teacher (you) should become thoroughly familiar with the available materials so that they may be applied to the students in your class. Some sources are:

1. Regional NASA Offices
2. United Air Lines Educational Office
3. U. S. Government Printing Office
4. FAA Regional Offices
5. Estes Industries*

The materials, charts, display, models etc., available from these sources can be set up in the classroom prior to the study of rocketry. Students, also, are good sources for models which can be displayed in your classroom.

B. Order a good beginner's outfit such as the Estes Teachers Special or the Deluxe Starter Outfit and ask for the Estes Educator's Packet for yourself so that you may become familiar with model rocketry. You might also order a BIG BERTHA rocket and additional engines since it has been proven that this model is very effective as a demonstration rocket. The Estes Teachers Special #1456 is the best starter set with a Big Bertha kit, a launch pad, a launch system, engines, and the other things necessary to start a program immediately.

The students should all build the same kit for their first rocket. The Astron ALPHA is ideal. Later the types and number of rockets built will depend upon the finances available and the launch area available. If the students order their own, let them choose from a list of simple designs. It is suggested that you order kits for your students at this time. Section E of this chapter provides background knowledge for you and ideas on how to present this subject for maximum learning value as well as maximum fun.

Here are some kits which are simple to build. Please refer to the current ESTES catalog rating for degree of skill required for other kits. These kits range in price from under one dollar up to about $4.00 with most costing about $2.00.

Rocket	Recovery System	Kit Number
Alpha	Parachute	1225
Sky Hook	Parachute	1208
Big Bertha	Parachute	1223
X-Ray	Parachute	1218
WAC Corporal	Parachute	1211
Mark II	Streamer	1202
Scout	Tumble	1201
Streak	Featherweight	1204

*See page 33, item J.

The supplies which will be needed for the entire class as the students build their model rockets and prepare for the launch include the kits, fine sandpaper, white glue, single-edge razor blades or modeling knives, and paint (use either spray enamel or butyrate dope). A suggested checklist of supplies for the class is given below. Survey your class about these materials. Model builders may be able to help with some supplies.

- ☐ **Rocket kits (one per student or per group, if students work as team): Astron Alpha is best for first model.**
- ☐ **Launchers (one for each 10-15 students): Estes Solar Launch Control System (for portable operation) or Launch Control System (for car battery power supply) plus Porta-Pad launcher is an excellent system.**
- ☐ **Sandpaper sheets (one per student): Fine or extra fine sandpaper is best.**
- ☐ **Engines (at least one per student): Follow catalog recommendations. Use lower total impulse engines for first flights.**
- ☐ **Paint (one spray can for each three students): Spray enamel is easiest to use. If butyrate dopes are chosen, order paint brushes and thinner. Enamel paint should not be used under butyrate dope.**
- ☐ **Igniters: Extra igniters are suggested because beginners often waste one or more of the igniters which come with the engines.**
- ☐ **Altiscopes (two for the class): These are recommended if rockets are to be tracked to determine the altitudes reached.**
- ☐ **Knives (one for each two students): Single-edge razor blades or modeling knives may be used.**
- ☐ **Recovery wadding (one pack for each ten engines): This material protects the parachutes or streamers from the hot ejection gases.**
- ☐ **Booklets (a classroom set to be shared): The Alpha Book of Model Rocketry provides much valuable information for your beginning students. The Model Rocketry Technical Manual provides help on technical matters for both beginners and advanced students.**

As your class progresses you will probably want your students to study more of the scientific aspects of rocketry. Such technical yet simple publications as these available from Estes are excellent. Additional publications are listed on pages 34-36.

Technical Report TR-1:	"Rocket Stability"
Technical Report TR-2:	"Multi-Staging"
Technical Report TR-3:	"Altitude Tracking"
Technical Report TR-4:	"Rear Engine Boost-Gliders"
Technical Report TR-5:	"Building A Wind Tunnel"
Technical Report TR-6:	"Cluster Techniques"
Technical Report TR-7:	"Front Engine Boost-Gliders"
Technical Report TR-8:	"Model Rocketry Study Guide"
Technical Report TR-9:	"Designing Stable Rockets"
Technical Report TR-10:	"Altitude Prediction Charts"
Technical Report TR-11:	"Aerodynamic Drag of Model Rockets"

C. Build a model rocket. This will give you the needed experience to determine how difficult this task will be for your class. You will also find this easy and fun, and you will also get an idea of how long each building phase takes to help you schedule the class time. Don't be surprised if you discover that your students build models faster and better than you.

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D. Test fly your rocket before the unit begins. Observe all recommended safety precautions. The Model rocketry Safety Code is found on page 14.

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E. Prepare your presentation. Many helpful suggestions on teaching about rocketry in general, on organizing your own presentation, on demonstrations to use both indoors and outdoors, and on possible class discussions, homework assignments, concepts to cover, and specific learning objectives to reach are contained in the following sections. Additional facts and ideas for presenting them are available in the Estes publication titled "The Laws of Motion and Model Rocketry".

INTRODUCING ROCKETS

Rockets are fascinating to youngsters. They wonder why the rockets can go so fast. They want to know how the rockets "work".

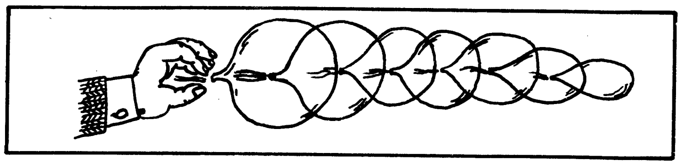
Perhaps the most effective way to start the study of rockets is to ask your class "What is a rocket?". You will probably get a variety of answers ranging from "things that go 'whoosh' up in the air" to "machines that take our astronauts to the moon". What do you accept as a definition for the whole class? That is up to you, but I suggest that you accept a definition which includes the idea that a rocket moves because the gases rushing out of its nozzle push it forward.

A rocket moves because it is pushed by the **reaction** to the gases which escape from the nozzle of the rocket engine. The thrust developed by the rocket is determined by the mass (roughly similar to weight, but not identical) of the gases issuing from the nozzle and their velocity. The greater the mass of gases escaping in a given period of time, the greater is the thrust developed. The faster the gases are moving, the greater is the thrust produced.

One way to look at the operation of a rocket is to make a balloon into a rocket. Pick up a balloon. Show it to the class. Stretch it with your fingers to show them that it is elastic. Now blow up the balloon. As you force more and more air into the balloon, it gets bigger and bigger.

You are storing energy in the balloon as you inflate it. The air inside the balloon is under pressure. The molecules of the air are pushing against one another, and those molecules near the "skin" are pushing against the balloon. The force exerted by the trapped air is balanced by the force of the balloon's wall pressing inward and the force of the air around the balloon pressing on the balloon.

The air pushing outward on the inside surface of the balloon is a force which is the same at all points on the inside surface of the balloon. When air is permitted to rush out of the mouth of the balloon, the force pushing on the point on the balloon's inside surface opposite the mouth is no longer balanced. This force pushed the balloon away from the direction in which the air rushing from the balloon is traveling.



Blow up the balloon until it is reasonably inflated, then release it. If you use common penny or nickel balloons, the balloon will move rapidly in the direction opposite the direction of the escaping air. Blow up, release, and recover the balloon several times so that each student can clearly observe the balloon's behavior.

You have just demonstrated Newton's Third Law of Motion — **"For every action there is an equal but opposite reaction."** The balloon moved as a rocket because of the operation of this action-reaction principle. Some people call all jet or rocket engines "reaction engines".

DEVELOPING THE SUBJECT

Ask your students to name some of the things about the simple balloon rocket which need to be changed if you are to make a good vehicle for transporting things. An improved **guidance system** will probably be one of the first things mentioned. After all, if a vehicle is to carry something, there won't be much demand for that type of vehicle unless it can be depended upon to deliver its cargo to the right place.

Other problems such as change in the amount of thrust during a flight, difficulty in controlling variations in amount of energy stored for each flight, impracticability of this source of power for lifting larger rockets or for going further, or cost of frequent replacement of the vehicle (the balloon) may be mentioned.

Fins are the simplest method for providing guidance. The fins must be near the rear of the rocket and must be of a certain minimum size. The mathematics of why this is so and the method of determining minimum fin size is best left until later, possibly **much** later. ("Ask your teacher next year to explain this after you have learned some more mathematics.")

You might point out that an arrow has feathers near its end. If the arrow starts to go off course, the air which moves past the feathers (which no longer are parallel to the wind) creates forces which cause the arrow to rotate until it is again traveling straight. If you have enough time, you can get into angles of attack and their effects on lift and drag forces.

If no one notices this point, ask the class how the rocket can be kept going straight during its first few feet of travel before the rocket moves through the air fast enough for the fins to become effective in providing guidance. The usual method for providing this initial guidance for model rockets is to mount a small tube on the rocket and let this tube slide over a metal rod as the rocket takes off. By the time the rocket leaves the rod (A three foot launch rod is adequate.) it will be going fast enough for the fins to provide guidance.

Someone will probably point out that the thrust produced was very weak so the rocket couldn't carry very much.

Since you are talking about carrying things in rockets, your rocket will need a cargo space.

Someone may point out that a balloon is not a very durable device, especially if you accidentally broke one during the earlier flights.

The landing which the rocket's cargo or **"payload"** will experience from your balloon-rocket's flight may occur at maximum velocity. Few payloads are able to take this type of "impact recovery" without damage to themselves and/or the landing site. A safe recovery system for gently landing of the rocket's cargo is sometimes needed.

A compartment to stow the recovery parachute is necessary. The tube between the engine and the nose cone is satisfactory for this.

Putting a **shock cord** between the rocket and the parachute can be a good idea, especially should the rocket still be moving fairly fast when the parachute comes out of the parachute compartment. If only a string were used to attach the parachute to the rocket, the snap when the parachute pops open could tear it free. This would not do much to slow down the descent, and the rocket may not be quite as attractive when recovered as when launched.

The next step can be to ask the students if they would like the opportunity to help you make a bigger, better rocket and maybe even build one of their own. The answer should be a resounding "Yes", with maybe a "Yippee" or two thrown in.

At this point a review of rocket performance may be in order. Ask your class if someone can state the Third Law of Motion. After this is successfully done, ask someone to explain why a guidance system is needed. (A guidance system is needed to keep the rocket going in the direction you want it to go.)

Ask your students if anyone thinks that a rocket moves by the exhaust gases pushing against the air through which the rocket is moving. If anyone answers "Yes", you have a problem. Review how a rocket actually pushes itself through action and reaction. It is a good idea at this point to ask your students if they know the two chief forces which slow down a rocket and keep it from going as fast or as high as it could go.

The two forces which slow down a rocket are **gravity** and **drag** (resistance which a body encounters as it moves through a fluid such as water or air). If anyone has trouble grasping the concept that gravity pulls on a rocket, let him or her toss an object into the air and watch what happens to the object. It slows down and eventually starts to fall. The physics of this experiment is fascinating. For example, does the object (such as a rubber ball) you toss straight up stop before it starts to fall? Anyway, that is a different story which we will not go into here.

The concept of fluids offering resistance to objects passing through them is an easy one. Anyone who has felt the wind on his face as he ran or who has felt the wind against her hand held out the window as she rode in a car has ample evidence for forming this concept.

To minimize drag which slows down a rocket and reduces the distance it can travel, a streamlined shape is necessary. A **nose cone** mounted on the front of a rocket does much to reduce drag by guiding the air flow around the rocket.

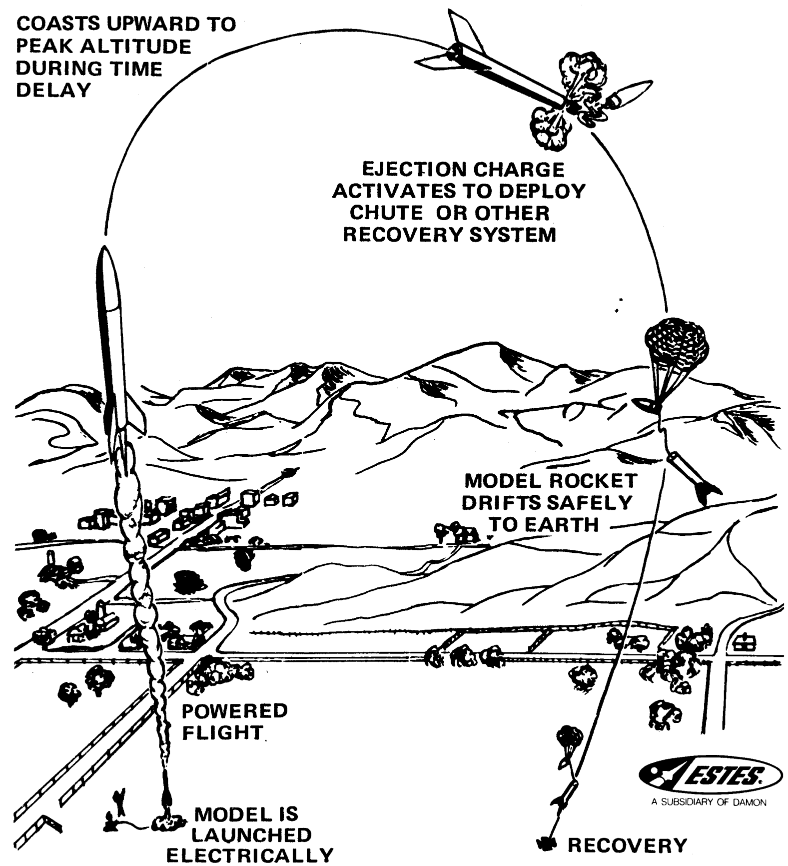
F. Utilize a "standard" model rocket course. Space Age Technology, a booklet published by Estes Industries, was written for use as a mini-text. If the schedule provided in the Teacher's Manual available for this book is followed, a four-week class involving both study of the theories involved in rocket and airplane flight and actual model rocket construction and launch activities will be successfully accomplished.

II. DEMONSTRATION LAUNCH

This section suggests one proven method of giving a demonstration launch. Some teachers prefer to give the demonstration first and save most of the explanations until after the demonstration launch.

A. Before going outside for the launch, briefly discuss the following with the students. (The Estes catalog and the "Model Rocketry Technical Manual" will supply much technical information concerning model rocket flight performance.)

1. The similarity of the model rocket to be flown to a full-sized rocket. Using this drawing, explain the steps in the flight they are about to see.



2. The safety code that you will follow in executing the launch.

SOLID PROPELLANT

Model Rocketry Safety Code

1. **Construction** — My model rockets will be made of lightweight materials such as paper, wood, plastic and rubber, without any metal as structural parts.
2. **Engines** — I will use only pre-loaded factory made model rocket engines in the manner recommended by the manufacturer. I will not change in any way nor attempt to reload these engines.
3. **Recovery** — I will always use a recovery system in my model rockets that will return them safely to the ground so that they may be flown again.
4. **Weight Limits** — My model rocket will weigh no more than 453 grams (16 ozs.) at liftoff, and the engines will contain no more than 113 grams (4 ozs.) of propellant.
5. **Stability** — I will check the stability of my model rockets before their first flight, except when launching models of already proven stability.
6. **Launching System** — The system I use to launch my model rockets must be remotely controlled and electrically operated, and will contain a switch that will return to "off" when released. I will remain at least 10 feet away from any rocket that is being launched.
7. **Launch Safety** — I will not let anyone approach a model rocket on a launcher until I have made sure that either the safety interlock key has been removed or the battery has been disconnected from my launcher.
8. **Flying Conditions** — I will not launch my model rocket in high winds, near buildings, power lines, tall trees, low flying aircraft, or under any conditions which might be dangerous to people or property.
9. **Launch Area** — My model rockets will always be launched from a cleared area, free of any easy to burn materials, and I will only use non-flammable recovery wadding in my rockets.
10. **Jet Deflector** — My launcher will have a jet deflector device to prevent the engine exhaust from hitting the ground directly.
11. **Launch Rod** — To prevent accidental eye injury I will always place the launcher so the end of the rod is above eye level or cap the end of the rod with my hand when approaching it. I will never place my head or body over the launching rod. When my launcher is not in use I will always store it so that the launch rod is **not** in an upright position.
12. **Power Lines** — I will never attempt to recover my rocket from a power line or other dangerous places.
13. **Launch Targets & Angle** — I will not launch rockets so their flight path will carry them against targets on the ground, and will never use an explosive warhead nor a payload that is intended to be flammable. My launching device will always be pointed within 30 degrees of vertical.
14. **Pre-Launch Test** — When conducting research activities with unproven designs or methods, I will, when possible, determine their reliability through pre-launch tests. I will conduct launchings of unproven designs in complete isolation from persons not participating in the actual launching.

Revised 2/4/70

B. Select the Launch Operations Team to assist you during the launch in the following capacities:

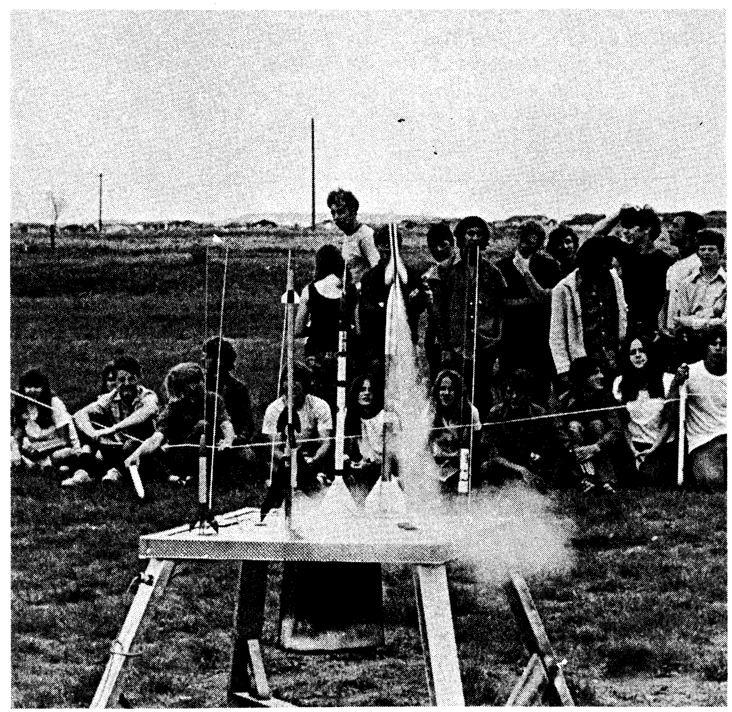
1. Range Safety Office — to make certain that the launch area meets all safety requirements and to keep all students away from the launch pad area.
2. Inspector (teacher or student appointee) — to make certain that the model rocket is well-built, properly balanced to be stable, has the proper type of engine, and has a safe recovery system.
3. Weather Officer — to check the wind direction and wind speed.
4. Tracking team — to determine altitude reached by each rocket (may be omitted during demonstration launch).
5. Recovery Team — to retrieve rockets.
6. Recorders or Secretaries — to note questions or comments from the students and to keep records on all launches.

The students should follow these same procedures during subsequent launches.

C. Outside for the demonstration launch: Prepare for the launch. (Use a small engine for first flight.) Have students join you in the countdown. Then ask for questions or comments. The questions and comments are usually along the following lines:

1. "What made the rocket go?"
2. "How high did it go?"
3. "How fast?"
4. "What made the parachute pop?"
5. "How did you start the engine?"
6. "What controlled it?"

Be sure to record these questions since they can be of great assistance in planning the scope and sequence of your rocket study. If students do not ask such questions, you might question them and record their answers. This reveals their knowledge of rockets and again tells you what instruction will be needed and at what level it should begin.



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. . . . 2 . . . . 1 . . . . LAUNCH!

Launch again using a more powerful engine, and then ask for a comparison of the two flights, or ask:

1. "Did it go higher?"
2. "Did it go faster? Why?"
3. "Did it perform the same as the first time?"
4. "How were the two flights different?"
5. "How were they the same?"

Be sure to tell the students that they will soon be building their own models and will be able to answer many of these questions themselves.

D. Return to the classroom and prepare the questions and comments made by the students for display in a prominent place.

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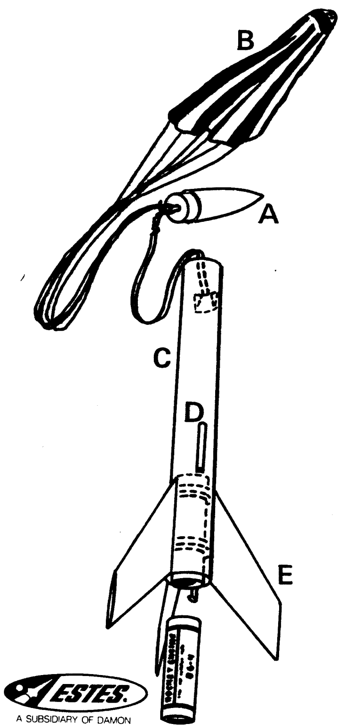
III. STUDENTS BUILD MODEL ROCKETS

A. Assign work areas. It is advantageous to have students work together in small groups so that they can assist each other.

B. Distribute the kits and materials (no engines at this time). It is desirable for each student to bring a shoe box for storage of materials.

C. Have students open the kits and, using the parts list, check to be sure all parts for each kit are present. At this point, the students should familiarize themselves with each rocket part and its function. Use this drawing to construct a transparency or a master to make copies for the students. The drawings contained in the Teacher's Manual for Space Age Technology, the mini-text published by Estes Industries, are designed for making overhead projection transparencies.



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BASIC MODEL ROCKET COMPONENTS

Model rockets vary greatly in appearance and purpose, but whether for sport and recreation or scientific experiment, most models use certain basic components. The arrangement of these components is shown in the diagram of a typical working rocket. The functions of these components is explained below.

A NOSE CONE
The front end of a rocket. Usually shaped to minimize air resistance.

B RECOVERY SYSTEM
Slows rocket descent, bringing it back to earth in an undamaged, reflyable condition. In this model a parachute deployed by an ejection charge in the engine is used.

C BODY TUBE
The basic airframe of the rocket, around which all other parts are built or attached.

D LAUNCH LUG
A tube which slips over the launch rod to guide the model until it reaches the speed necessary for the fins to control the flight.

E FINS
Act like the feathers on an arrow, guiding the rocket in a precise flight pattern.

ENGINE
A pre-packaged solid propellant device which provides the power to make the rocket fly. Single and upper stage engines contain a smoke tracking-delay charge to let the model coast up to peak altitude before the ejection charge pops out the parachute.

D. Have students read the assembly instructions. The teacher, using the transparency or student copies, can guide their reading. This gives them a general overview of what is involved in the actual construction. Be sure to emphasize the importance of following instructions precisely.

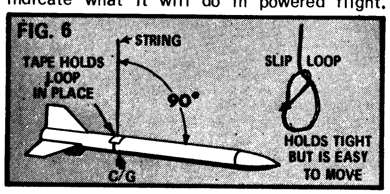
E. Relying on your own experience, estimate the time needed for each building step. It is suggested that you plan each step carefully so that sufficient glue-drying time is provided. You may wish to show filmstrips, films, listen to tapes or records, or have students read about rockets between building stages. The Estes Technical Reports, "Model Rocketry Technical Manual", and the books listed in the Estes catalog are excellent reading material. You may wish to time these steps so that gluing comes at the end of the session and drying occurs overnight. Be sure to provide adequate storage (or shoe boxes) for the models to avoid damage or loss of parts. As the students build the models, be sure to circulate among them to check their progress. You may wish to provide "Stop Steps" where students check with you or other students before going on with construction.

F. Depending on time and money limitations, the model rockets can be painted and decorated. Refer to the instruction sheet for suggestions on the type of paint to be used.

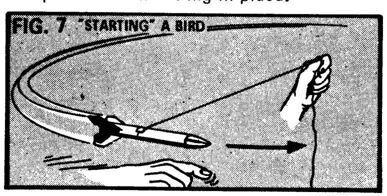
G. When the students' model rockets are completed, they should be tested for stability. Point out to the students that a model rocket is capable of speeds exceeding 400 MPH. Before they can be flown at these speeds, however, they must be proven airworthy (stable).

The following information is an excerpt from the "Model Rocketry Technical Manual" published by Estes Industries.

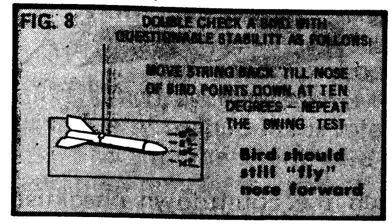
The easiest way of testing the stability of a model is to fly it--without launching it. This is done by attaching a string to the model and swinging it through the air. If the string is attached at the rocket's CG, its behavior as it is swung through the air will indicate what it will do in powered flight.



Make the test on your model by forming a loop in the end of a six to ten foot string. Install an engine in the rocket. (The center of gravity is always determined with an engine in place.) Slide the loop to the proper position around the rocket so the model balances horizontally. Apply a small piece of tape to hold the string in place.



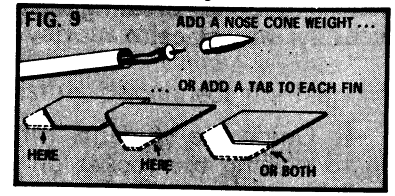
With the rocket suspended at its center of gravity, swing it overhead in a circular path. If the rocket is very stable, it will point forward into the wind created by its own motion. Some rockets which are stable will not point forward of their own accord unless they are started straight. This is done 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. It may take several attempts before a good start is achieved.



If it is necessary to hold the rocket to start it, an additional test should be made to determine whether the model is stable enough to fly. Move the loop *back* on the body until the tube points down at a 10° angle *below* the horizontal. Repeat the swing test. If the model will keep its nose pointed ahead once started, it should be stable enough to launch.

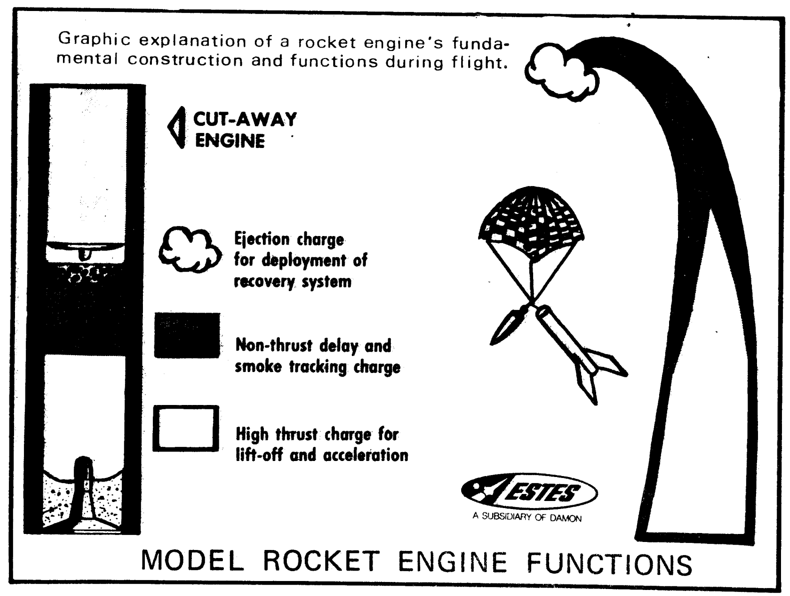
Be careful when swinging a rocket overhead: A collision with a nearby object or person could be serious. Always do your testing in an open, uncluttered area.

Don't try to fly a rocket that has not passed the test. Most unstable rockets loop around in the air harmlessly. However, a few marginally unstable models will make a couple of loops and then become stable due to the lessening of the propellant load. When this happens, the model can crash into the ground at high speed. A person standing in the wrong place could get hurt.

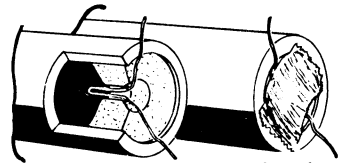


If your rocket does not pass the stability test, it can usually be made stable. Two methods can be used: The balance point can be moved forward or the fins can be enlarged. To move the balance point forward, attach nose cone weights to the base of the nose cone. Fins can either be replaced with larger ones or extra tabs can be glued to the rear or tip edges of the fins. (Some scale models use supplementary plastic fins.) After making your changes, test the model again to be sure it is now stable.

H. Distribute the engines and igniters. Using the Phantom model or a chart, discuss the engine parts with the class. Discuss igniter installation. This discussion should help students understand what is happening when a model rocket engine is operating and why the engine is constructed as it is.



To operate properly the igniter must touch the propellant grain. Insert the igniter and spread the leads. Apply a strip of masking tape to the nozzle and leads as shown. The eraser on the end of a pencil is good for pressing the tape securely into place.



Insert igniter . . . **and apply tape**

I. Guide the students through the countdown checklist up to placing the rocket on the launcher. This checklist is available on each plan and on the Estes Flight Data Sheet.

COUNTDOWN CHECKLIST

Flight #1 Flight #2 Flight #3 Flight #4 — **Parachute or Streamer**	Flight #1 Flight #2 Flight #3 Flight #4 — **Feather-weight or Tumble**	Flight #1 Flight #2 Flight #3 Flight #4 — **Boost-Glide**
☐☐☐☐ 12) Pack flameproof recovery wadding into the body tube. Insert the parachute or streamer.	☐☐☐☐ 10) Fit the engine in the body tube carefully so that the recovery system will function properly.	☐☐☐☐ 12) Check payload section (if used) and slide it into position.
☐☐☐☐ 11) Install the nose cone or payload section. Check condition of the payload (if any).	☐☐☐☐ 9) Install an igniter in the engine.	☐☐☐☐ 11) Set trim adjustments for desired flight path and for existing weather conditions.
☐☐☐☐ 10) Apply masking tape to the engine(s) to achieve a tight friction fit in the body tube(s). When launching a multi-stage rocket be sure that the engines are in their proper relative positions and that a layer of cellophane tape is wrapped tightly around each engine joint.	☐☐☐☐ 8) Place the rocket on the launcher. Clean and attach the micro-clips.	☐☐☐☐ 10) Check engine for proper fit in body tube.
☐☐☐☐ 9) Install an igniter in the engine.	☐☐☐☐ 7) Clear the area, check for low flying aircraft, alert recovery crew and trackers.	☐☐☐☐ 9) Install an igniter in the engine.
☐☐☐☐ 8) Place the rocket on the launcher. Clean and attach the micro-clips.	☐☐☐☐ 6) Arm the launch panel.	☐☐☐☐ 8) Place the rocket on the launcher. Clean and attach the micro-clips.
☐☐☐☐ 7) Clear the area, check for low flying aircraft, alert recovery crew and trackers.	☐☐☐☐ 5)	☐☐☐☐ 7) Clear the area, check for low flying aircraft, alert recovery crew and trackers.
☐☐☐☐ 6) Arm the launch panel.	☐☐☐☐ 4)	☐☐☐☐ 6) Arm the launch panel.
☐☐☐☐ 5)	☐☐☐☐ 3)	☐☐☐☐ 5)
☐☐☐☐ 4)	☐☐☐☐ 2)	☐☐☐☐ 4)
☐☐☐☐ 3)	☐☐☐☐ 1)	☐☐☐☐ 3)
☐☐☐☐ 2)	☐☐☐☐ LAUNCH!	☐☐☐☐ 2)
☐☐☐☐ 1)		☐☐☐☐ 1)
☐☐☐☐ LAUNCH!		☐☐☐☐ LAUNCH!

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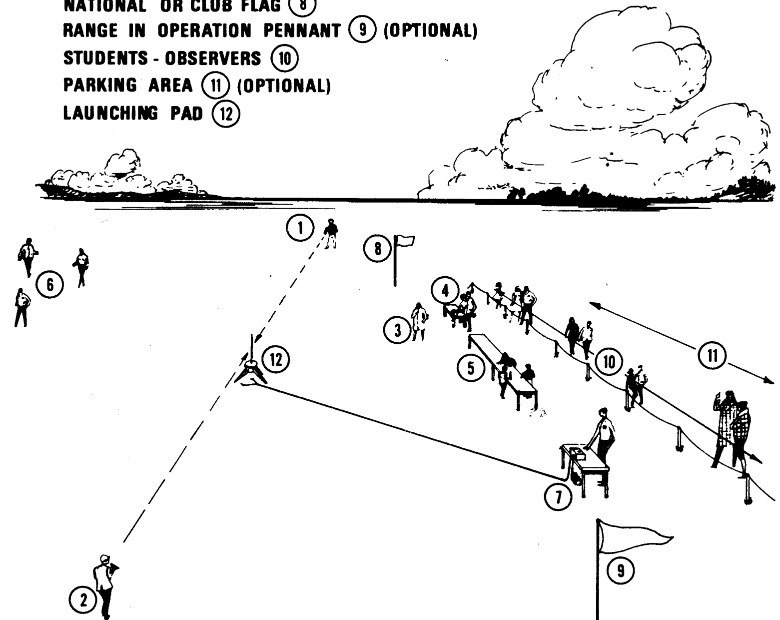
IV. CLASS LAUNCH STANDARDS

A. Ground Rules:

1. Review Safety Code.
2. Use launch procedures as established in demonstration launch, assign students the various roles, and be sure each is properly trained in his role.
3. In the event of a misfire, disconnect the launcher and then remove the rocket.
4. Permit only launch crew members, tracking party, and person launching his rocket on the launch site.
5. Permit recovery of rocket only by recovery team or builder.

TRACKER 1 (1)
TRACKER 2 (2)
RANGE SAFETY OFFICER (3)
DATA RECORDING TABLE (4)
PREPARATION TABLE (5)
RECOVERY TEAM (6)
LAUNCH DIRECTOR (7)
NATIONAL OR CLUB FLAG (8)
RANGE IN OPERATION PENNANT (9) **(OPTIONAL)**
STUDENTS - OBSERVERS (10)
PARKING AREA (11) **(OPTIONAL)**
LAUNCHING PAD (12)



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B. Launch data record. Design a chart or use the Estes Model Rocket Flight Data Sheet (Shown on page 23) to record all pertinent data.

MODEL ROCKET - LAUNCH DATA SHEET

Student	Rocket name or number	Engine	Launch	Recovery gear deployment	Height	Recovery
DAN BROWN	BIG BERTHA #610	B4-2	✓	✓	300 FT.	✓

Recovery gear deployment
✓ = Successful
Ơ = Unsuccessful

C. Altitude tracking. Procedure with Altiscopes or student-made altitude measuring devices: Refer to the "tracking" section of the "Model Rocketry Technical Manual" for background to be used in instructing your students. Practice using Altiscope or student-made altitude measuring device in the classroom or on the school grounds before attempting altitude tracking on an actual launch. Technical Report TR-3, "Altitude Tracking", treats the subject of tracking in more detail.

Tracking can be fun, but it takes some skill. Using the two-station tracking system produces more accurate tracking results than are achieved by a one-station tracking system. Practice in altitude tracking can be secured by calculating the heights of flagpoles and similar tall objects. Tracking a baseball tossed vertically into the air provides experience in tracking a moving object.

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Model Rocket
FLIGHT DATA SHEET

USE ONE FLIGHT DATA SHEET FOR EACH MODEL
FOUR FLIGHTS MAY BE RECORDED ON EACH SHEET

PREFLIGHT INFORMATION

Rocket Name	Nose Cone Type
Rocket Number	Fin Type
Date Completed	No. of Fins
Type of Rocket	Color Scheme
No. of Stages	Weight Empty

LAUNCH

Flight Number		Flight #1	Flight #2	Flight #3	Flight #4
Date of Launch					
Launch Location					
Payload	Description				
	Weight				
Recovery System	Type				
	Color				
Engines	1st Stage				
No. of / Type	2nd Stage				
	3rd Stage				
Total Weight					
Method of Launch					
Launch Angle					
Predicted Altitude					

WEATHER

Wind Direction				
Wind Velocity				
Humidity				
Temperature				
Visibility				
Remarks				

FLIGHT DATA

Altitude	Estimated				
	Tracking Information				
	Computed Alt.				
Flight Duration					
Stability Information					
Flight Performance					

COUNTDOWN CHECKLIST

Flight #1 Flight #2 Flight #3 Flight #4 — Parachute or Streamer

☐☐☐☐ 12) Pack flameproof recovery wadding into the body tube. Insert the parachute or streamer.

☐☐☐☐ 11) Install the nose cone or payload section. Check condition of the payload (if any).

☐☐☐☐ 10) Apply masking tape to the engine(s) to achieve a tight friction fit in the body tube(s). When launching a multi-stage rocket be sure that the engines are in their proper relative positions and that a layer of cellophane tape is wrapped tightly around each engine joint.

☐☐☐☐ 9) Install an igniter in the engine.

☐☐☐☐ 8) Place the rocket on the launcher. Clean and attach the micro-clips.

☐☐☐☐ 7) Clear the area, check for low flying aircraft, alert recovery crew and trackers.

☐☐☐☐ 6) Arm the launch panel.

☐☐☐☐ 5)

☐☐☐☐ 4)

☐☐☐☐ 3)

☐☐☐☐ 2)

☐☐☐☐ 1)

☐☐☐☐ LAUNCH!

Flight #1 Flight #2 Flight #3 Flight #4 — Featherweight or Tumble

☐☐☐☐ 10) Fit the engine in the body tube carefully so that the recovery system will function properly.

☐☐☐☐ 9) Install an igniter in the engine.

☐☐☐☐ 8) Place the rocket on the launcher. Clean and attach the micro-clips.

☐☐☐☐ 7) Clear the area, check for low flying aircraft, alert recovery crew and trackers.

☐☐☐☐ 6) Arm the launch panel.

☐☐☐☐ 5)

☐☐☐☐ 4)

☐☐☐☐ 3)

☐☐☐☐ 2)

☐☐☐☐ 1)

☐☐☐☐ LAUNCH!

Flight #1 Flight #2 Flight #3 Flight #4 — Boost-Glide

☐☐☐☐ 12) Check payload section (if used) and slide it into position.

☐☐☐☐ 11) Set trim adjustments for desired flight path and for existing weather conditions.

☐☐☐☐ 10) Check engine for proper fit in body tube.

☐☐☐☐ 9) Install an igniter in the engine.

☐☐☐☐ 8) Place the rocket on the launcher. Clean and attach the micro-clips.

☐☐☐☐ 7) Clear the area, check for low flying aircraft, alert recovery crew and trackers.

☐☐☐☐ 6) Arm the launch panel.

☐☐☐☐ 5)

☐☐☐☐ 4)

☐☐☐☐ 3)

☐☐☐☐ 2)

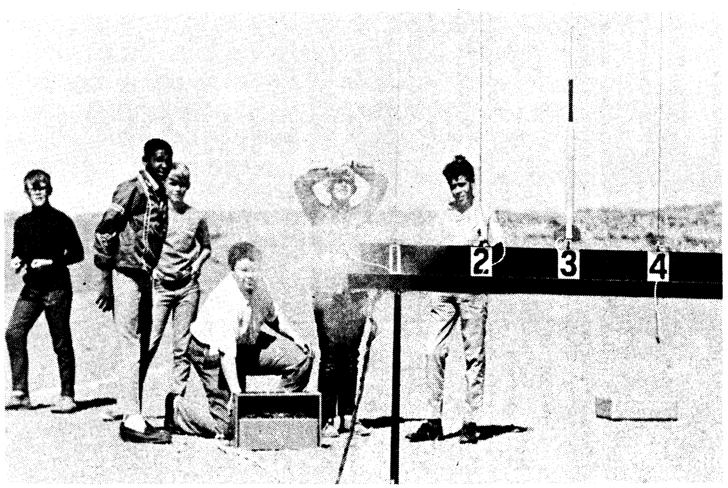
☐☐☐☐ 1)

☐☐☐☐ LAUNCH!

V. STUDENTS LAUNCH

The altitudes to which the model rockets are launched should be approximately equal to the width of the field which is available for launching. Since small rockets with low-power engines will not rise over several hundred feet, an open field with length and width equal to this distance is adequate. At this point in your study, it is not necessary to concern yourself with high altitudes. The greatest challenge is to have the rocket achieve a perfect flight. If time permits, attempt two launches for each rocket. Refer to the "Launching" section of the "Model Rocketry Technical Manual" published by Estes Industries. Remind students to be very observant and to record pertinent information about the performance of their rockets.

Rocketry, even to the professional, is still somewhat of an experimental science. Each day new discoveries are being made, and new techniques are being found that will enable our space program to grow to new and exciting dimensions. Much of this information gathered by our scientists is gained through trial and error during the launch and flight of the full-sized rockets. The same will happen to your students if you continue to provide them with the opportunities to continue their investigations.



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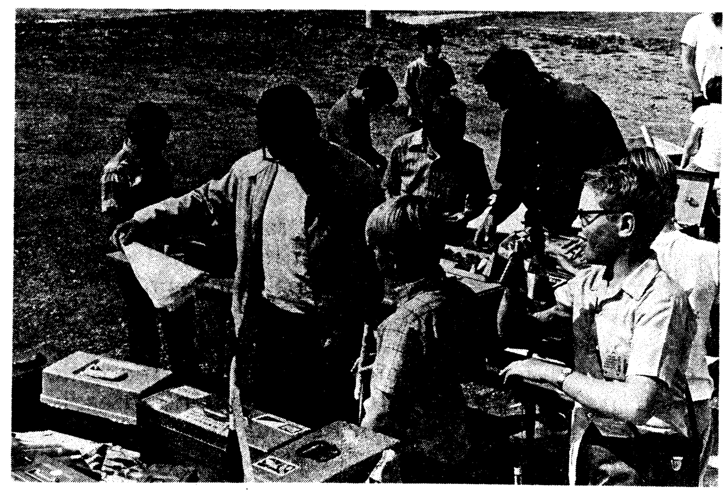

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SUGGESTED FURTHER ACTIVITIES TO EXPLORE OUR AEROSPACE ENVIRONMENT

You have just given your students a "hands on" experience. If there are concepts which you wish to stress, you can refer to the actual experiences shared by all students. The following activities are suggested to help each student to perceive the effects of gravity, lift, drag, and air pressure, and to demonstrate the principle of action-reaction, as these forces affect rockets and other aerospace vehicles. Through the use of model rockets and these activities, the students should be able to answer most of their initial questions. Select experiments from each area for use in your class to demonstrate those concepts which you wish to emphasize.

One very effecitve means of letting the students summarize the knowledge they have gained from the materials studied, from the launch activities, and from those experiments from this section which you let them perform or demonstrate for them, is to let them design an efficient vehicle to operate both in the air environment and in the space environment. This project can be undertaken individually, in teams, or as a class project. The vehicle should be controlled by the men in it. Encourage the students to use their imagination, but make them prove the scientific validity of each idea incorporated into their design.

ACTION-REACTION

Experiment 1

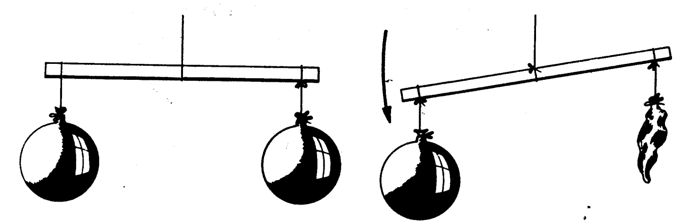
Materials needed: Balloon, soda straw, tape, string. Have a student inflate the balloon and then release it. Upon release, the air molecules rush out of the balloon, and the balloon flies in the opposite direction to the direction in which the escaping air molecules move. Air moving out of the balloon is the action, and the forward movement of the balloon is the reaction. Taping a straw to the balloon and threading the string through the straw will provide a guidance system. Attach one end of the string to the wall and have a student hold the other end. Blow up the balloon and release it. Observe the guided flight of the balloon "rocket".

AIR HAS MASS AND WEIGHT

Experiment 1

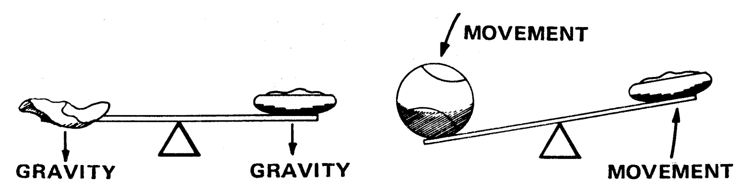
Materials needed: A wooden dowel rod or ruler or any straight stick approximately 12" long, 3 lengths of string, 2 balloons exactly the same size. Blow up the balloons to the same size and tie each of them with a piece of string. Then tie one balloon to each end of the rod as shown. Tie another piece of string around the center of the rod and move it until the balloons are balanced. Then hang the rod so that a student can reach the balloons. Ask the students what will happen if the air is let out of one of the balloons. Have a student let the air out of one balloon. The air-filled balloon drops down. This allows the students to see for themselves that the air trapped in the balloon has weight.

The mass of air in each balloon has weight because the gravity of Earth is pulling on it. The air pressure in an inflated balloon is greater then the air pressure outside of the balloon, so the air inside an inflated balloon is denser (more mass per unit of volume) than the air around the balloon.



Experiment 2

Materials needed: Playground ball, hand pump, a flat piece of wood, approximately 12" long, 1/2" thick, and 1" wide, a triangular piece of wood to act as a fulcrum, a bowl, and aquarium sand. Deflate a playground ball and place on the balance scale. Set the bowl on the opposite side and fill it with sand until the two objects are balanced. Carefully remove deflated ball and inflate it. Now place the ball back on the balance. The inflated ball now weighs more and causes the scale to be unbalanced—illustrating that air has weight.

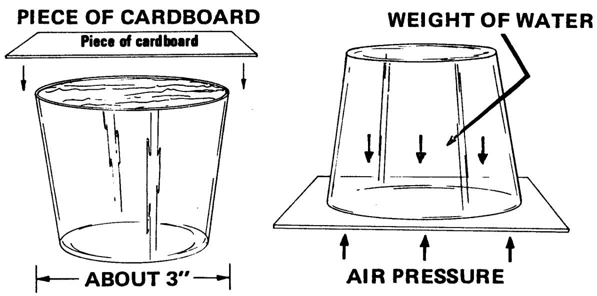


AIR EXERTS PRESSURE

Experiment 1

Since air has weight, it presses down on anything it touches, and it presses with force in all directions. To illustrate to the students that air pushes upward, have several students perform the following activities.

Materials needed: Water glass or small jar (opening no larger than 3" – 4" for easy handling), flat and thin piece of cardboard. Fill the glass with water making certain that the water comes exactly to the top. Carefully place the cardboard on top of the glass. Hold the cardboard tightly, and turn the glass upside down. Remove the hand holding the cardboard. The cardboard will stay in place against the glass. Ask the students what keeps the cardboard in place. Why isn't the water coming out? The pressure of the air against the cardboard is greater than the pressure caused by the weight of the water in the glass. The adhesion between the cardboard, the water, and the glass also helps to hold the cardboard in place.



Experiment 2

Materials needed: Gallon can, lid for can, heat source, small amount of water, insulated gloves. Pour the water into the can, and place the can over a heat source without the lid. Allow boiling to start and continue until a cloud appears around the can opening. Remove the can from the heat source, and then immediately replace the lid tightly. Observe the can as it cools. Boiling water has driven most of the air from the can. Cooling the can causes the remaining water vapor to condense causing a partial vacuum (lowering the air pressure). The outside air pressure is greater than the pressure inside and crushes the can.

AIR PRESSURE DIFFERENCES CAN CAUSE AN OBJECT TO MOVE

Experiment 1

Materials needed: A strip of paper 1" wide and 12" long. Have your students hold the strip of paper between their thumb and index finger. Then ask them to hold that thumb near to their chin and blow over the top of the strip. The strip of paper will lift upwards. Ask students to explain the movement of the paper.

The paper is lifted because the rapidly moving air above the paper strip has less pressure pushing on the paper than the slower moving air beneath the paper strip. This illustration of Bernoulli's principle (When the velocity of a fluid increases, the pressure decreases.) is quite useful when studying why an airplane wing produces lift as the wing moves through the air.

Experiment 2

Materials needed: Two sheets of paper approximately 8" x 10" or regular notebook paper. Instruct students to hold the sheets of paper approximately 4 inches apart and blow between them. The two sheets will come together. Ask students to try to explain the movement of the sheets. (This is another example of Bernoulli's principle.)

AIR MOVEMENT AFFECTS MOVING OBJECTS IN THE AIR

Experiment 1

Materials needed: An Astron Alpha model rocket, a launch facility (launch stand, launch control system, and power supply), C6-5 engine and igniter, and Altiscope.

Launch the Alpha using the C6-5 engine. Track the rocket and calculate the altitude at the moment the ejection charge deploys the parachute. Have several students mark the point on the ground under the rocket at parachute deployment as closely as they can. Fifteen seconds later again track the rocket and calculate its altitude at this time. Have several students mark this point on the ground at the 15 second "mark" as closely as possible. Having a student with a watch having a sweep second hand call out "mark" exactly 15 seconds after parachute deployment may help the altitude and "ground position" trackers.

Calculate as closely as possible the vertical and horizontal movement of the rocket in 15 seconds. The wind speed can be calculated from the horizontal movement. The temperature of the air affects the vertical movement or "sink rate" of the rocket. However, this topic may be a bit difficult to study except by comparison. Launching the rocket again with a different-sized parachute can allow the students to see the effects of different conditions on the descent or sink rate.

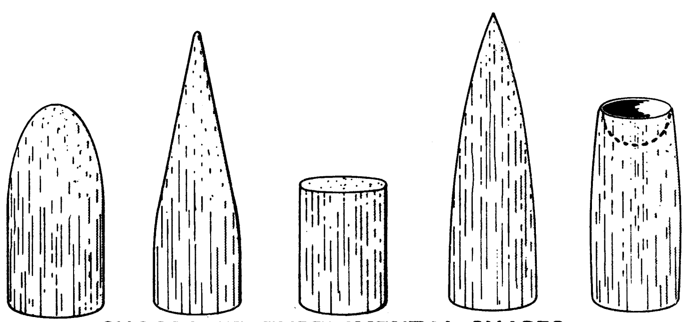
AIR PRESENTS RESISTANCE (DRAG) TO OBJECTS MOVING THROUGH AIR

Experiment 1

Materials needed: Balsa wood, tray of water, sandpaper, light, string. Buy or construct nose cones of various shapes.

Attach string to tip of each nose cone and pull the cones through the tray of water to observe which makes the least amount of disturbance. Shining a light through the water helps students observe the shadows of the disturbance. You can feel the drag on each nose cone as you pull it through the water. Notice which shapes have the least drag. Differences in the drag developed on these varied shapes is easily detected. If a wind tunnel is available, these experiments may be conducted using moving air (a fluid) rather than by moving the shapes through still water. Performing this experiment in a glass tray on the stage of an overhead projector produces good "ripple tank" effects visible to the whole class on a screen. Be certain to waterproof the nose cones, as with sanding sealer, before placing them in water.

Technical Report TR-11, "Aerodynamic Drag of Model Rockets", available from Estes Industries, is an excellent source of information on drag on aerodynamic vehicles.



SUGGESTED EXPERIMENTAL SHAPES

Experiment 2

Materials needed: Well-built Astron Alpha model rocket, well-built Astron Big Bertha model rocket, Altiscope, recovery wadding, small lead weights (such as Estes NCW-1 and PL-1), launch facility for model rockets, 6 B6-4 model rocket engines, and 6 igniters. The two rockets should be smoothly finished. A properly-built Big Bertha should weigh about 2.25 ounces. A properly-built Alpha should weigh about 0.8 ounce. The two rockets must weigh the same for the experiment to work properly, so about 1.45 ounces must be added to the Alpha in such a way that its stability is not adversely affected. This is best done by hollowing out the nose cone of the Alpha to hold a 1 ounce payload weight. Attach about 3 nose cone weights NCW-1 to the nose cone of the Alpha by securing them with the screw eye and glue. Some weight reduction for the Big Bertha may be achieved by hollowing out its nose cone. Be careful not to remove enough to make the Big Bertha unstable.

Once the two rockets weigh the same, launch each 3 times, and track each flight. Record altitude reached on each flight and determine average height reached by each rocket. The large difference in altitude is caused chiefly by the effects of air drag on the two rockets in flight.

Rocket flight is affected by gravity as well as by drag.

GRAVITY

Experiment 1

Materials needed: Well-built Astron Alpha model rocket, A8-3 model rocket engines, B4-4 (or B6-4) engines, C6-5 engines, igniters, launch facility for model rockets, recovery wadding, and Altiscope. Launch the Alpha with each engine, and determine the altitude reached on each flight. Performing three launches with each type of engine and using the average result produces much more relible data than simply making only one flight with each engine. The effect on altitudes reached caused by increased thrust of the more powerful engines will be very evident. Since the same rocket was used in each flight and the rocket's total weight varied only slightly between flights (about 1/3 ounce maximum variation) the increased altitude was probably caused by the increased energy delivered by the more powerful engines. The small weight variation between flights can be removed by carefully adding weights to the nose of the Alpha to cause the rocket to have the same total weight before each flight.

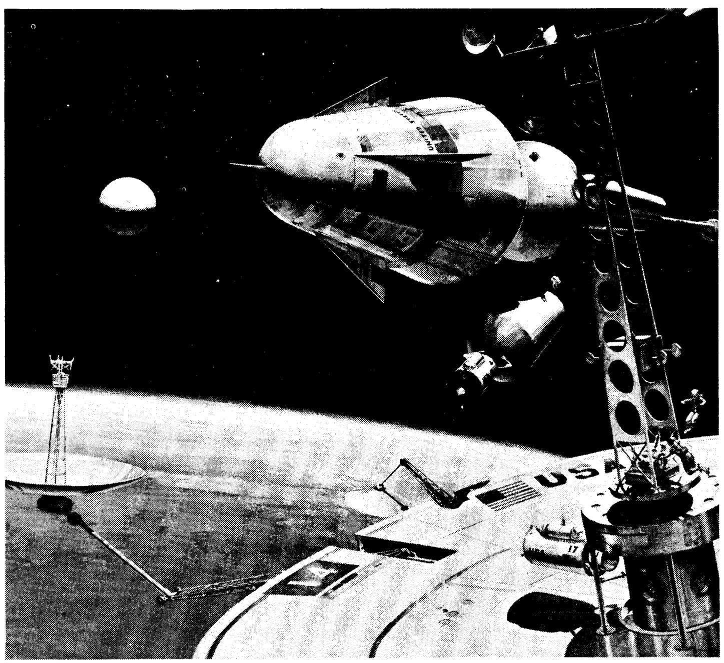
The importance of using very powerful rocket engines to carry payloads into space can be more readily appreciated by your students after they have seen a model rocket launched several times with engines of different total impulse.

A simple payload-carrying model rocket such as the X-Ray may be used for these tests. The use of a rocket with a payload compartment makes it very easy to adjust the total weight of the rocket before each flight so the rocket weighs the same before each flight.

SPACE

Experiment 1

Materials needed: Vacuum pump, bell jar, vacuum hose, pressure can of shaving lather. Connect the materials properly to produce a partial vacuum inside the bell jar once the vacuum pump is started. Place a small amount (about a golf ball size) of the shaving lather on the vacuum plate just before positioning the bell jar in place and starting the vacuum pump. Observe the size of the lather as the air pressure inside the bell jar is reduced. Compare what happens to the lather to what would happen to an unprotected human body in space. A similar experiment can be performed using a partially inflated balloon. Let the students explain why the balloon gets larger as the air is pumped from the area inside the bell jar.



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CONTINUING ACTIVITIES

Model rocketry is most valuable when used to extend the basic activities to apply to more sophisticated experiments in the fields of mathematics, electronics, weather, and team work,

A. Use the basic data from the launches to construct graphs which illustrate altitude reached, reliability of ignition, etc.

B. Display various models with comparisons on size, weight, drag, etc.

C. List new vocabulary words for spelling—thrust, velocity, etc. (Technical Report TR-8 and "Space Age Technology" provide suggested lists.)

D. Construct more refined instruments for determining the altitudes reached by the rockets.

E. Assign reports by students on early pioneers in rocketry such as Tsiolkovsky, Goddard, and Oberth.

F. Build model rockets from original designs. (Technical Report TR-9, "Designing Stable Rockets", provides information on how to design your own rocket. Technical Report TR-1, "Rocket Stability", provides an explanation of rocket stability and a way to test your rocket for stability before launching it.)

G. Launch a well-finished model rocket with one type of engine. Launch a similar but poorly built model rocket of same weight with same type of engine. Record altitude performance of each for several flights. Compare performances and explain differences.

H. Improve standard designs for models built from kits by weight-saving techniques and by improving the finish you give models to reduce their drag.

I. Design more refined launch systems: A multiple launch system with safety devices may be built as a class project. ("Model Rocket Launch Systems" is available from Estes Industries and is an excellent guide.)

J. Encourage your students to do research projects in model rocketry. Estes Industries supplies a great amount of information to get you started. Consult your Estes catalog for a listing of these publications. Write to Education Department, Estes Industries, Dept. 161, Box 227, Penrose, Colorado 81240, when you have specific questions about educational applications of model rocketry.

K. Start a model rocket club. A club provides an excellent way for interested students to pursue model rocketry as an exciting and educational hobby. Write to the Rocketeer Communications Department, Estes Industries, Dept. 161, Box 227, Penrose, Colorado 81240 for information on starting a model rocket club.

L. Here's a partial bibliography of technical information available from Estes Industries.

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