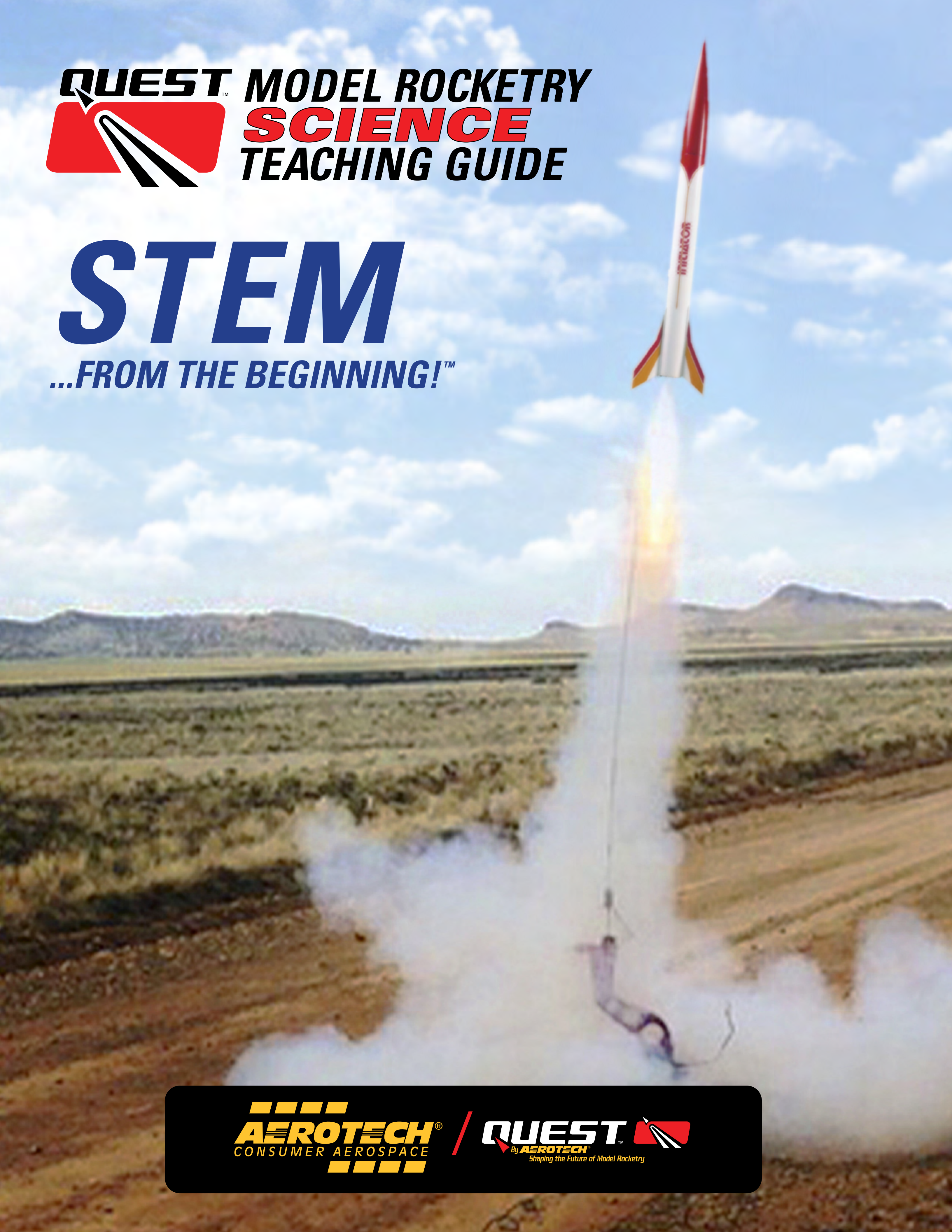
QUEST™ MODEL ROCKETRY SCIENCE TEACHING GUIDE

STEM

...FROM THE BEGINNING!™



AEROTECH® CONSUMER AEROSPACE / QUEST™ By AEROTECH® Shaping the Future of Model Rocketry

QUEST SCIENCE MODEL ROCKETRY TEACHING GUIDE

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AUTHOR
Jeff Flygare

PUBLISHER
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DESIGNER/EDITOR
Grant Boyd

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AeroTech/Quest Division,
RCS RMC, Inc.
2113 W. 850 N., Cedar City, UT 84721
www.aerotech-quest.com

Welcome to QUEST Educational Model Rocketry

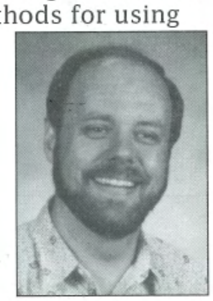
Model rocketry is a learning process in disguise! For over 30 years at thousands of schools it's been an activity that is motivating, affordable and safe. For many youngsters a model rocket project is their first opportunity to set goals, define solutions, and use their minds and skills to achieve those goals... all in a setting of positive socializing and self-esteem building.
Each QUEST Teaching Guide is similar and modular, with many sections unique to its particular discipline. Activities may be adapted for grades 5-12 and up, and fitted to the rocketry experience level of students and teachers.

QUEST model rocket kits, motors and other supplies are priced to fall within tight budget limitations and designed for successful use. They are available thru local hobby retailers and factory direct. Ask for a catalog if you don't yet have one... it's a learning tool also!

Introduction

For Science teachers, Quest model rocketry offers an exciting and fun way of involving students in their own learning. A model rocket that students have constructed themselves arcing gracefully into the sky is an inspiring way of demonstrating basic scientific principles. More importantly, it provides a hands-on approach; it shows students that Science plays an important part in their everyday lives.

With model rocketry, teachers find that students are eager to be involved. The action and excitement are a natural attraction, and the learning is easy because students are curious. This teacher's guide is designed to acquaint you with the hobby of model rocketry and to suggest ways it can be used as a teaching tool. If you're not familiar with model rockets, you'll want to read this book carefully. Teachers who have used model rocketry in the past may want to skip to the section specific to teaching to discover innovative, up-to-date methods for using model rocketry in the Science classroom.



Author Biography

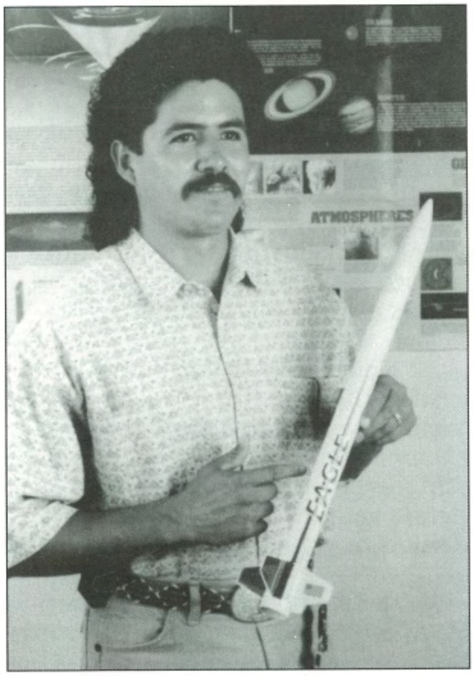
Jeff Flygare has been active in model rocketry since the early 1960's. A veteran of national model rocketry competitions, he has held a national record for Design Efficiency, worked for two major model rocket manufacturers, and as a sponsor in the 1980 World Spacemodelling Championships.

In later years, Jeff has changed careers, focusing on secondary education. He has taught English and Drama at Air Academy High School, at the Air Force Academy in Colorado. He obtained a Master's Degree in Gifted Education and administered the gifted and talented English program. He was also a speaker at regional educational conferences.

Quest Aerospace Education was a golden opportunity to "marry" two important interests for him — model rocketry and education.

RECOMMENDED TEACHING SEQUENCE

Recommended Teaching Sequence



1. **Gather information.**
Read this book, along with the current Quest catalog.

2. **Build and fly a rocket.**
Never tried anything like this before? Don't worry - rockets are fun and easy to build and fly, and our instruction sheets are designed to make you 100% successful! Be ready for some positive feedback - enjoy the success of accomplishing this task, and remember that your students will enjoy this feeling too.

3. **Let your imagination run.**
Keeping in mind the ideas in the teaching guides, imagine how you might use this versatile teaching tool in your class. No lesson plan we provide for you will be able to take the place of one you develop yourself, utilizing your knowledge of your students as well as your own abilities and enthusiasms.

4. **Write instructional objectives.**
Once you've decided what you want your students to learn from their model rocketry experience, how will you know when they have learned it? Some sample structional objectives are provided in this teaching guide. Or, write your own objectives, specific to the unit you'll be teaching.

5. **Order your materials.**
Be sure to plan ahead so that you have enough time to receive your teaching materials from Quest. If your district requires that you order through a central warehouse, be sure and plan for the additional time this will take.

6. **Plan the rest of your unit.**
If your students (and you) are up to it, why not let the students have some input into the activities? Provide a list of possible activities and let them choose, keeping the instructional objectives in mind all the time. This is a great critical thinking exercise, and it allows the students some say in what they'll be doing. (They'll start getting excited about the unit,too.)

7. **Introduce the unit.**
There are a number of ways to do this, and you'll find several suggestions in the lesson planning section of this teaching guide. Students are inherently interested in rockets, so you'll have no problem getting their attention.

8. **Follow your plan**
Now you're off and running, with your students actively engaged in learning. Don't forget to move them steadily along toward Launch Day, and when it comes, look for an exciting, fun response to all their work.

9. **Evaluation.**
Not only will you evaluate your student's learning, but you should evaluate the unit as well. Did your students become actively involved? Were they enthusiastic? Did using model rocketry inspire your students to become active learners? Will you use the unit again next year? What will you want to do differently?

Table A

Depending on what your instructional objectives are, you may choose to teach model rocketry in any one of a number of different ways. If you're just starting with rockets, and you intend for your students to build and fly their own rockets, we recommend you follow this sequence in preparing for and teaching a model rocketry unit.

Critical Thinking Activities

Addressing critical thinking in the classroom becomes easy with model rocketry. The students will start asking the questions of themselves - all you'll need to do is guide their investigation. What is a model rocket? What will happen if we use a more powerful motor? How accurate are predictions we've made about changes? The sequence of progessively more challenging critical thinking questions just described is the kind of discussion students get into all the time.

Model rocketry addresses all levels of critical thinking. Table C lists Bloom's Taxonomy, with appropriate model rocketry activities listed at each level. It is meant merely to inspire you to creatively generate your own activities, specific to the needs of your class.

In Table D you'll find a generic table of typical verbs and activities that reflect those levels. Use this table for brainstorming instructional objectives.

Cooperative Learning

Many students find they are more fully engaged in their learning if they are able to explain (teach) concepts to other students. Often students find that other students can do the best job explaining ideas to them. This is the concept behind cooperative learning.

Cooperative learning is ideal for reaching higher level critical thinking skills and for fostering leadership in students. However, the effectiveness of cooperative learning instruction is dependent upon how well the atmosphere in the cooperative learning groups is established. Here is where most cooperative learning programs succeed or fail. The following are some basic recommendations.

- Set the "mood" early and be consistent.
- Promote face-to-face interaction.
- Each student must understand that while the group "sinks or swims together," he or she retains individual accountability for his or her own learning.
- Teach and develop interpersonal and small group skills.
- Group processing. Give the students time to reflect and evaluate how they are doing in their groups.

Teachers who use cooperative learning all the time will doubtless be able to find ways to adapt nearly all the activities described in this guide for their own needs. But let's assume that you, like most teachers, use cooperative learning only occasionally.

Science:

- Construction of the model rocket
- Follow-up project on space science
- Lab experiment in the physics of rockets
- Planning of launch activities
- Evaluative report of launch activities
- Planning or evaluation of nearly any stage of the model rocketry unit.

Oral Discourse Activities

As an exciting activity, model rocketry lends itself well to a variety of activities that allow students to practice oral discourse. Some of these include:

- Oral presentations on model rocketry
- Lessons taught by students concerning model rocketry or space science
- Panel discussions on topics of importance to the unit, either relative to model rocketry or to associated topics such as the politics of the space race
- Debates on relevant social or thematic topics (this is not limited to Social

studies or English. Science and Math students can debate the effectiveness of particular mathematical or scientific processes related to model rocketry)
- Acting/oral interpretation, including the creation of videos and/or radio dramas featuring activities related to model rocketry, space science, history, or science fiction.

Leadership Training

Model rocketry can be an effective

method for teaching leadership training. Depending upon how you approach it, model rocketry offers many situations in which hierarchies of responsibility can be created. Construction of the rocket, planning of launch activities, execution of the launch all offer the opportunity for certain students to practice leadership skills. Leadership skills can be practiced by a large number of students in your class and by changing the responsibilities of students within those groups often.

Technology Education

Obviously, an activity so oriented toward science and mathematics as model rocketry lends itself well to the use of computers in the classroom. Students can design simple programs which utilize mathematical formulas to process data on rocket flights, determining altitude and design efficiency.

Special Needs Students

Learning Disabled/Challenged

Students who are extraordinarily challenged by classical teaching methods may find the "hands-on" approach offered by a unit in model rocketry a refreshing and engaging experience. The learning disabled or specially-challenged student may be able to discover the best method of learning and reporting that learning, and in that context, the departure from traditional learning methods may be valuable for the teacher as well. A student who has not achieved success in other learning situations may do very well in the rocketry unit, and may provide the teacher with just the information needed to create successful learning situations.

Gifted Students

Students in gifted and talented programs may respond particularly well to a program in model rocketry. Again, the departure from traditional student/teacher roles inherent in a model rocketry program is a highly recommended approach for teaching gifted students. Also, model rocketry impacts a wide variety of associated topics, and gifted students may pursue specialized areas of interest under the guidance of the teacher.

TEACHING MODEL ROCKETRY SCIENCE

Introducing Model Rocketry

One of the great advantages of an activity like model rocketry is that it impacts so many areas of Science. A great critical thinking activity for your students is to allow them to discover those connections. Some teachers use the method described below simply to introduce the rocketry unit, then head in a direction specific to the particular Science content that will be covered. Other teachers use the activity to inspire students to discover a particular area of interest and, within the confines of the model rocketry unit, allow students to do some individual exploration in the particular area and then report back to the class. Whichever way you use this activity, expect your students to be surprised by the wide range of associated scientific areas of interest touched by a simple activity like model rocketry.

Webbing Model Rocketry

Discovering what students already know about model rocketry is an essential first step in a model rocketry unit. Using a webbing technique can be highly effective for this purpose. Distribute a copy of the blank webbing worksheet or make a transparency of the Webbing Work Sheet and place it on the overhead. Ask students to brainstorm areas of Science that are associated with model rocketry. They can do this individually, or in groups, but the important thing is to give them sufficient time and guidance to develop many associations. Webbing ideas shows a completed web - your students may not come up with all of these associations. In fact, you may want to make the webbing an on-going activity. Add to it during the unit, as you discover the wide range of associated activities. Be sure to make the point that a simple activity like model rocketry involves many very complex subjects. Ask them to make similar connections to other daily activities....like riding a bicycle, or a skateboard. Science plays an important part in their lives.

One variation on the web which will also allow you to measure their prior knowledge about model rocketry is to ask students to develop the kinds of associations described above, but do not place them in the web. Record all of their responses on the chalkboard or on a blank overhead transparency, and then ask students to suggest an effective means of categorizing the random information. Once a system of categories has been established, the class then tries to categorize all of the responses that are listed on the board or overhead. This not only accomplishes the objective of discovering connections between model rocketry and Science, it allows students to practice the critical thinking skills of classification and categorization.

You also might try doing this as an acrostic puzzle. Provide each student with a copy of the Acrostic Work Sheet. Each student fills in the blank spaces with all the associations he or she can make about model rocketry. The difficult part is that all the names, objects, and thoughts must fit the acrostic pattern. After students have filled out the sheet, have a class discussion in which student responses are shared.

SCIENCE TEACHING IDEAS

Note: The activities described in this section are not designed for any particular grade level. With only a few exceptions, they can be modified in either direction for use with elementary or secondary students.

Expert Groups

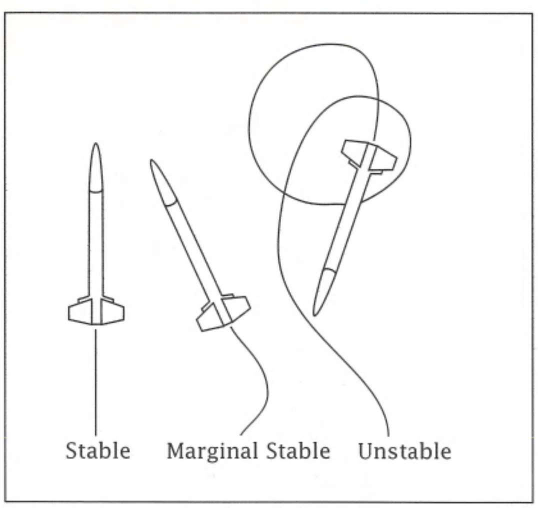
Consider doing many of the activities listed below and having a group of three or four students work on a project together. You could have certain groups become "expert" in a particular aspect of model rocketry. One could look closely at rocket design, another at construction, launching, recovery, planning, future studies or whatever. This is the same system NASA uses in launching the space shuttle, so operating the classroom in this way would take on some relevance to real life.

Flight

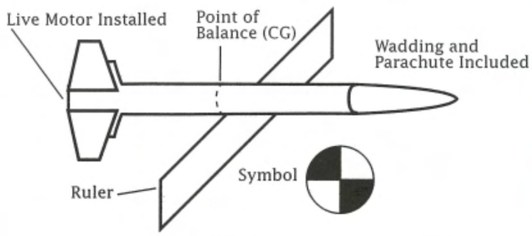
You can use model rocketry to explain the basics of flight. Whether you decide to discuss the importance of thrust versus gravity in rocket flight, or take it beyond this to a description of aeronautics (lift, drag and gravity), model rockets provide the motivating tool to get students involved with a basic understanding of the principles of flight.

Couple a model rocket unit with one using balsa gliders to back up this instruction. Advanced students might even be able to design their own model rocket boost-glider. It would have to ascend like a rocket and then convert to a glider.

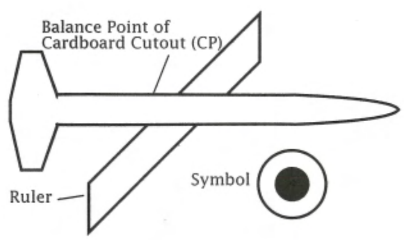
Stability Studies



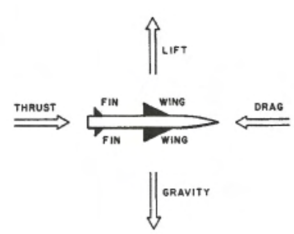
One important factor in the successful flight of a model rocket is stability. Instruction in this critical area involves an understanding of center of gravity and center of pressure of model rockets (and other flying vehicles). A brief description is provided here.



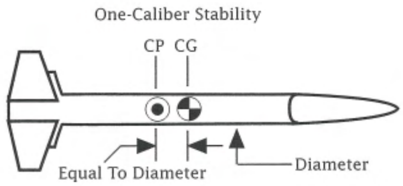
The center of gravity (CG) of a model rocket is that point where all the gravitational forces can be considered to be acting. The rocket will balance at this point, so it is relatively easy to determine. It is the relationship between this point on the rocket and the Center of Pressure (CP) which determines whether the rocket will fly straight while under power.



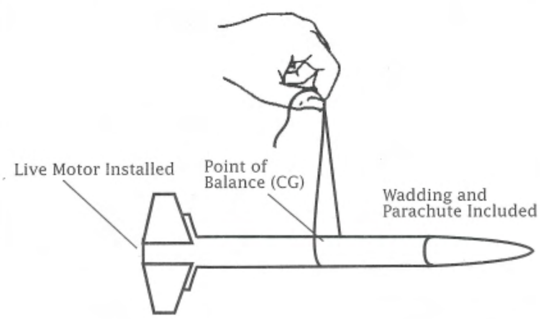
The center of pressure is significantly more difficult to locate. The CP of a model rocket is that point where all the aerodynamic forces (lift, drag) can be considered to be acting. Obviously, the rocket must be encountering these forces in order for the point to be determined. Students can go through an elaborate mathematical process to determine CP, but this isn't really necessary. The relationship between CG and CP can be determined for any given model fairly easily. CG/CP studies can be done with the aid of a simple wind tunnel, or by something called the "swing test."



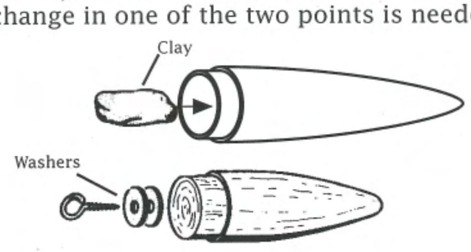
SCIENCE TEACHING IDEAS



In order for a model rocket to fly stably, the center of gravity must be in front of the center of pressure by at least one-and-one-half body diameters. Doing a "swing test" will not locate the center of pressure of the rocket, but it will determine whether the CP is located in such a position relative to the CG that the rocket will be stable.



To do a "swing test," first ready the rocket for flight by inserting a motor and packing the recovery device. Determine the point where the fully loaded rocket balances (Center of Gravity) and tie one end of a six foot string to the rocket at that point. Make sure the string is tight and will not slip. Now swing the rocket rapidly around your head, watching the rocket as it passes on each revolution. If the rocket is stable, the nose of the rocket will point in the direction of travel. The Center of Pressure is sufficiently behind the Center of Gravity for the model to be stable. If the nose does not point in the direction of travel, the rocket is not stable. Some change in one of the two points is needed.



The Center of Gravity can be easily moved forward with the addition of a small amount of nose weight (clay tamped into the nose cone is often used). Or, rarely, the Center of Pressure can be moved rearward by the addition of more or larger fins. Again, once the changes have been made, do another "swing test" to make sure the rocket is stable.

This activity lends itself well to hands-on experience of a basic principle of flight. The theory can be taught initially, but the students will grasp the idea when they have the opportunity to put it to work testing their own rockets.

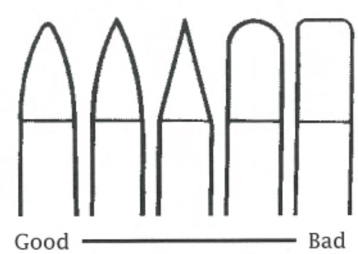
Drag

Students should be aware of the forces acting on a model rocket in flight. One of the few over which one has control is drag. Drag can be described by the following equation:

$$D = 0.5pV^2C_dA$$

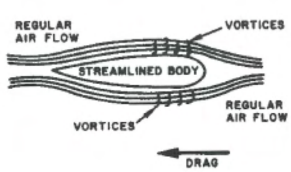
where D = drag force, p = air density, V = velocity of the rocket, C_d = a dimensionless number called the drag coefficient and A = the frontal area of the model. While this may seem a bit "deep" for some students, the equation is fairly straightforward.

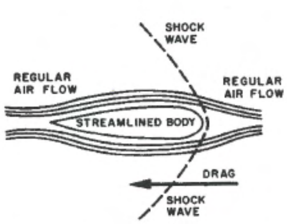
How can you reduce the drag on a rocket? Reducing the frontal area (A) is one method, but there is a point at which you cannot reduce this area, and that is dictated by the size of the rocket motor. Air density is another factor, but we rarely have much control over this, unless you can do your flying from the top of Pikes Peak. What most students are left with is the coefficient of drag, and this takes into account the degree of finish on the rocket,



and the shape of the design.

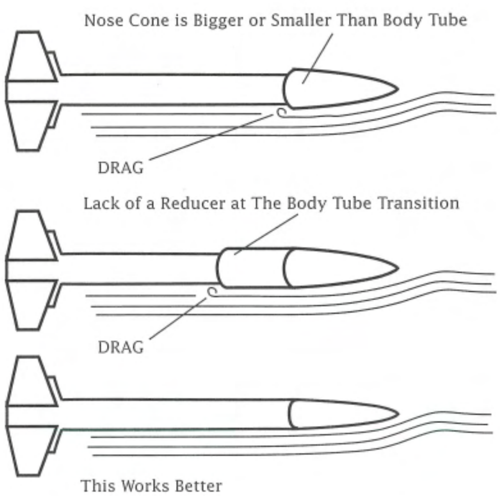
Another factor in trying to reduce frontal area is angle of attack. This refers to the degree a rocket deflects away from an absolute vertical ascent, relative to the center line of the body. Increases in angle of attack present more surface area and therefore increase drag. Your students





may also notice that increased angles of attack produce another force - lift. They'll want to investigate its effect on rocket performance.

An excellent research project would be to determine which rocket shapes perform better than others and why. Students have a variety of choices in tube size and nose cone shape. Which should they choose for better performance? Model rocketry not only offers them the opportunity to learn about



drag but to test their theories.

Another factor in drag research involves the flow of air particles around the surface of the rocket. Laminar (smooth) flow is encountered at low velocities and rockets travel easily through this type of flow. At a certain point, air flow becomes turbulent. This transition to turbulent flow causes a great deal of the drag around a model rocket. Interestingly though, once the transition to turbulent flow has occurred, drag reduces significantly. This is due to the fact that while turbulent air is "thicker" than laminar air, the layer of air molecules closest to the rocket "sticks" to the rocket better than in laminar flow. This "boundary layer," as it separates from the rocket body, causes a great deal of drag. At what velocity does transition to turbulent flow occur? A good research project might investigate this, and the use of a "turbulator," a device which actually causes the transition to turbulent flow, could be researched.

Weather

In what ways can weather affect performance? Air density is certainly a factor as described above, and humidity is a factor in air density.

Also, wind speed and direction can be measured and relationships between measured factors at launch (and in the air) and rocket performance can lead some students to an understanding of the affects of wind on rocket performance.

Wind velocity can be measured on the ground using a simple anemometer. Students might launch and time a simple weather balloon filled with helium and time the drift to determine wind velocities at higher altitudes. Rocket launches immediately after such measurements would likely encounter similar conditions, and the resultant altitude determinations could be used as data for research of this type.

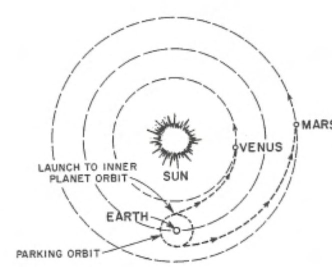
Biological experiments

Many Quest model rockets come with or can be fitted with a simple payload section. These rockets can carry scientific instrumentation and, in certain cases, small biological payloads. Students can research the effects of quick acceleration on insects or algae.

NOTE: While model rockets are perfectly safe for spectators, you may wish to consider that not every rocket flight may have a "perfect" recovery. In this sense, students may be troubled by the destruction of research insects. For these reasons we recommend that teachers consider this possibility before undertaking such a project. We also STRONGLY urge that research with model rockets NOT include any higher life forms.

Orbital mechanics

A unit in model rocketry might be a good opportunity to investigate the physics of planetary orbits. Everything from the basics of elliptical orbits to the problems of traveling from one planet in the solar system to another (using dawn and dusk orbits) might be encountered.



Future Studies

Model rocketry can be the inspiration for many activities in the field of future studies. Why study the future? Well, that's where your students will live! Also, future studies offers an enormous opportunity for coupling student's imagination with viable critical thinking activities. Here are just a few ideas.

Future Space Vehicles

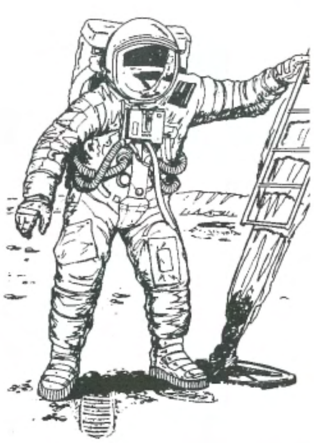
How will man explore the planets? What will the spacecraft be like? Allow your students to use their imagination, and let them consider how environment will be maintained. Will gravity be necessary? How will it be achieved if it is? What new kinds of propulsion might be used? How will fuel be carried?

Once they've done some brainstorming, let them do some designing on paper. With model rocketry, you also have the possibility of letting your students construct models of what they design. These can be either flying or non-flying models.

By the way, once you take the project this far, your students (and their English teachers) would love it if you let them write stories depicting life aboard their space vehicle. Even if you can't do this in Science class, keep it in mind if you do interdisciplinary units, or pass the suggestion along to the English teachers.

Construction

Once they've designed their space vehicle, let them consider how it might be built. What materials will be required? Where will they be obtained? This might bring up the whole question of orbital construction stations, coupled with lunar colonies that produce raw materials. This isn't blue sky - the plans for such colonies are on the drawing boards today. This would allow the discussion of the geology and physics of the Moon, in the context of information students want to have to solve problems in the design and construction of their space vehicle.

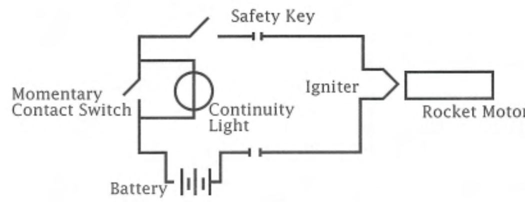


Space Exploration

Where would they go in their space vehicle? Many teachers have coupled the future studies unit with a mini-unit on astronomy and celestial mechanics. Sound inspiring? Picture this happening in a room where the students' models, the vehicles that will take them on their imaginary voyage to the stars, are hanging from the ceiling!

Electricity

Model rockets are launched only by electrical means. This means students can gain a knowledge of the fundamentals of electrical circuits.



A model rocket launch system must accomplish two basic tasks. It must deliver a current to the electrical igniter, sufficient to cause the igniter to ignite the solid propellant motor. Also, the launch system must at certain times send a reduced (and safe) current though the entire circuit to make sure the circuit is functioning properly, without causing the igniter to ignite the motor. This is a fairly sophisticated electrical problem.

To solve it requires a thorough understanding of current and resistance. Model rocket igniters work on the principle of electrical resistance. Igniters include an area of high resistance at the point where the igniter touches the solid propellant grain. Students can be taught why the igniter heats at this point, and how the simple electrical circuit delivers the correct amperage to the igniter.

What kind of power source is sufficient? Why do alkaline cells work when regular cells won't? Why does a wet cell battery (like a car battery) work better than a dry cell? All of these questions will lead students to a thorough understanding of simple electrical principles.

Research Methods

Methodology for research projects can be taught around an activity which students have an inherent interest in. The motivation students enjoy because of an activity like model rocketry will encourage them to "go the extra mile" when conducting research projects.

The Laws of Motion

Because rockets are based on Newton's Third Law, they provide an excellent vehicle for investigating this basic principle of physics. See the lesson-planning section for a sample lesson plan on Newton's Third Law.

Addressing the Affective Domain

While the gains of students in the affective domain are often harder to measure and therefore don't lend themselves to a world focusing strongly on immediately measurable results, they can be some of the most significant gains students will make in their development as self-confident, thinking people.

But even if you don't formally write affective objectives, take a few moments to consider the impact of model rocketry on a student's self-image. The student will not only have gained knowledge and understanding of the content, but the knowledge that they can create something of their own and make it work. They'll know how to organize others, and how to follow-through on responsibilities. Best of all, they'll realize that hard work, and hands-on experience can combine to create success and fun. And that might just be the most important lesson they'll ever learn in school!

Levels of Affective Behavior

Receiving

- Attending
- Becoming aware of an idea, process or thing
- Is willing to notice a particular phenomena

  Sample objective: Shows sensitivity to social problems

  Verbs: asks, chooses, describes, follows, gives, holds, uses, identifies, locates, names, points to, selects, replies

Responding

- Makes response at first with compliance later willingly, and with satisfaction

  Sample objective: Participates in class discussion

  Verbs: answers, assists, complies, conforms, discusses, greets, helps, labels, performs, practices, presents, reads, recites, reports, selects, tells, writes

Valuing

- Accepts worth of a thing, idea or a behavior
- prefers it

  Sample Objective: Appreciates the role of science in everyday life

  Verbs: completes, describes, differentiates, explains, follows, forms, initiates, invites, joins, justifies, proposes, reads, reports, selects, shares, studies, works

Organization

- organizes values
- determines interrelationships
- adapts behavior to a value system

  Sample Objective: Recognizes the role of systematic planning in problem solving

  Verbs: adheres, alters, arranges, combines, compares, completes, defends, explains, generalizes, identifies, integrates, modifies, orders, organizes, prepares, relates, synthesizes

Characterizing

- generalizes certain values into controlling tendencies
- emphasis on internal consistency
- later integrates these into a total philosophy or world view

  Sample Objective: Demonstrates self-reliance in working independently

  Verbs: acts, discriminates, displays, influences, listens, modifies, performs, practices, proposes, qualifies, questions, revises, serves, solves, uses, verifies

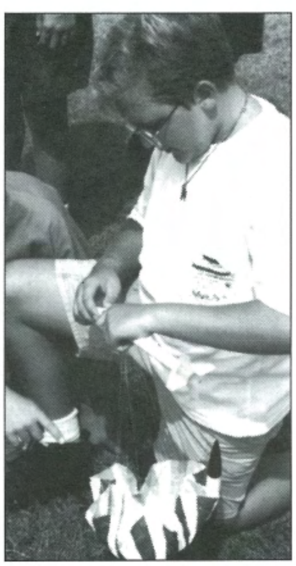
Table B

Table B lists a Taxonomy of Educational Objectives relating to the Affective Domain. (Krathwohl, D.R., Bloom, B.S., and Masia, B.B. (1964). *Taxonomy of Educational objectives. Handbook II: Affective Domain.* New York; David McKay.) As with Bloom, this taxonomy is hierarchical; one must achieve each level and build upon it before achieving the next.

Table C

Behavioral Objectives

The first step in planning any lesson is to write instructional objectives. Behavioral objectives, which define an achievable and measurable behavior, provide teachers with a way to assess the amount of learning which has taken place. At the same time, teachers are careful to address higher level thinking skills in their instructional objectives. The table below gives examples of instructional objectives at each level of Bloom's Taxonomy for model rocketry in the Science classroom.



Bloom's Taxonomy Related to Model Rocketry

Category	Activity
Knowledge	• Defining model rocketry terminology on a quiz • Identifying the parts of a model rocket on a worksheet • Recite the NAR/NFPA Safety Code for model rocketry • Describe orally the relationship between increased rocket weight and lower achieved altitude • Explain orally that drag and gravity prevent the rocket from achieving altitude, and that thrust works against these forces
Comprehension	• Describe orally why a rocket achieves less altitude in a given set of launch circumstances • Demonstrate the correct method of packing a model rocket parachute • Illustrate how to use simple mathematics formulas to determine the altitude of a model rocket • Rephrase the definitions of the parts of a model rocket
Application	• Use a learned mathematical formula to determine the altitude of a model rocket given the particular set of circumstances defined by the student • Organize the correct procedures for running a safe model rocket launch • Choose the correct methods for construction of a model rocket, given a particular design the student has created
Analysis	• Compare the actual altitude results measured for a rocket flight and the predicted results • Analyze the measured data of a rocket flight to determine how the flight demonstrates the effects of Newton's Third Law of Motion
Synthesis	• Design, build and fly your own model rocket • Propose a solution to a design problem - Ex. reducing the drag of an existing model rocket design • Given three or four different mathematical methods of altitude determination, organize the methods according to accuracy, practicality, and/or reliability
Evaluation	• Evaluate the quality and performance of your own rocket design • Recommend the most effective mathematical method of altitude determination • Discuss the importance of a model rocketry unit to your learning

VERBS & PRODUCTS FOR BUILDING

CRITICAL THINKING

VERBS YOUR CAN USE	PRODUCTS YOUR CAN USE
ASSESS, VERIFY	VERDICT, CONCLUSION, QUESTIONNAIRE
EVALUATE, RATE	PANEL, OPINION, SURVEY
DETERMINE, DISCUSS, JUDGE	JUDGEMENT, EVALUATION
CHOOSE, DECIDE	SCALE, VALUE, EDITORIAL
SELECT, GRADE, DISPUTE	REPORT, INVESTIGATION
IMAGINE, COMPOSE, INFER	PREDICTION, INVENTION, POEM
COMBINE, PRODUCE	STORY, ART PRODUCT, DISPLAY
HYPOTHESIZE, ESTIMATE	FORMULA, FILM, MACHINE
FORECAST, CREATE	NEW GAME, SOLUTION, MUSIC
INVENT, DESIGN	PROJECT, MEDIA, ADVERTISEMENT
COMPARE, DISSECT, SUMMARIZE	QUESTIONNAIRE, CONCLUSION
ABSTRACT, ORDER	CHART, DIAGRAM, SUMMARY
CONTRAST, INVESTIGATE, CLASSIFY	OUTLINE, SURVEY
DEDUCE, CATEGORIZE	GRAPH, LIST, CATEGORY
DIFFERENTIATE, SEPARATE	REPORT, PLAN
SOLVE, TEACH, MAKE	DIARY, COLLECTION, MAP
DEMONSTRATE, RECORD, SHOW	ILLUSTRATION, MODEL
APPLY, TRANSLATE	REPORT, PICTURE, DIAGRAM
MODIFY, ILLUSTRATE, CONSTRUCT	DIORAMA, PARAGRAPH
OPERATE, DISCOVER	LESSON, PUZZLE
SUMMARIZE, ESTIMATE, EXPLAIN	TEST
GENERALIZE, CONVERT	RECITATION
PARAPHRASE, INFER	CONCLUSION
DISTINGUISH, PREDICT	AWARENESS
REWRITE, DEFEND	QUIZ
DEFINE, LIST, SELECT	NAMES
DESCRIBE, IDENTIFY, LOCATE	REPRODUCTION
NAME, MATCH, MEMORIZE	LABELS, LIST
LABEL, REPRODUCE, READ	DEFINITION
OUTLINE, STATE, REVIEW	FACTS

Table D

These actions can lead to results which are building blocks for higher thinking levels.

- EVALUATION
- SYNTHESIS
- ANALYSIS
- APPLICATION
- COMPREHENSION
- KNOWLEDGE

SCIENCE TEACHING LESSON PLANNING

Note: The lesson plans contained in this section of the teacher's guide are based on the Hunter method and the Elements of Instruction. While this method is by no means considered a national standard, the Hunter method has been shown to be an effective methodology for presenting a lesson. Teachers will, of course, wish to modify the lesson to reflect methods that are successful for them.

When you write behavioral objectives for your model rocketry unit, try to reach all six levels of Bloom's Taxonomy during the unit. Remember, you're writing objectives for the unit now; you won't achieve all six levels every day in every lesson.

Let's suppose that your unit will use model rocketry to allow students to investigate Newton's Laws of Motion. Your behavioral objectives for all six levels with regard to Newton's Third Law might be as follows:

1. Knowledge
2. Comprehension
3. Application
4. Analysis
5. Synthesis
6. Evaluation

Knowledge Level:

The learner will define Newton's Third Law of Motion.

Comprehension Level:

The learner will explain Newton's Third Law of Motion in his own words.

Application Level:

The learner will diagram how Newton's Third Law of Motion operates in a model rocket.

Analysis Level:

The learner will investigate how changes in the amount of thrust in a model rocket will affect the rocket's performance.

Synthesis Level:

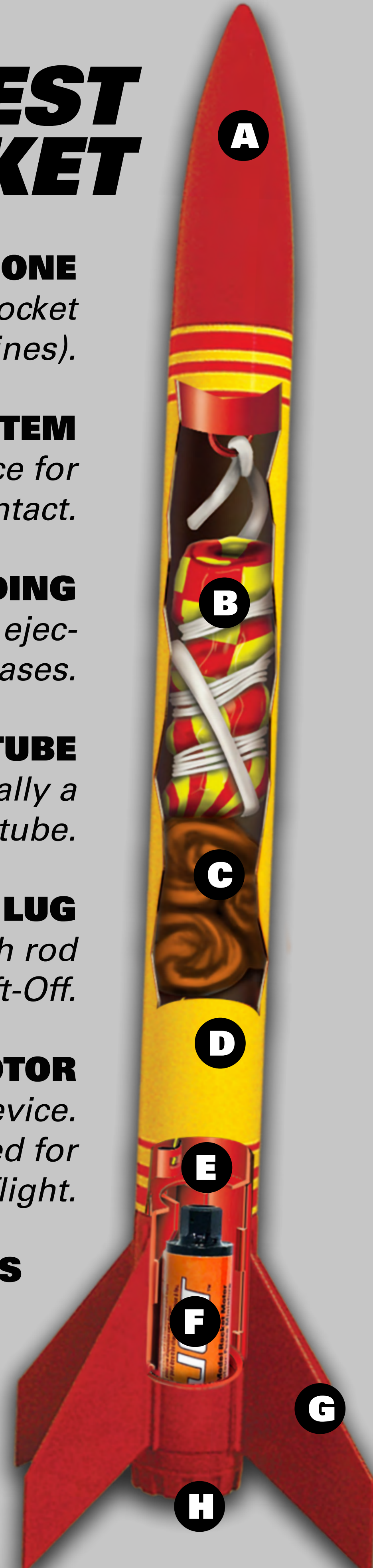
The learner will predict how changes in the amount of thrust in a model rocket will affect the rocket's performance.

Evaluation Level:

The learner will assess how changes in the amount of thrust in a model rocket will affect the rocket's performance by running a series of experimental flights and reporting the results in writing.

These objectives represent only a portion of the total objectives for the entire unit, but they are probably much more than you might cover in a single lesson. You might also have unit objectives concerning the construction of the rocket, understanding the vocabulary and functioning of a model rocket, understanding and applying the safety code and launch procedures, and many other objectives relating to Science content. The choice is yours, and it depends upon the particular learning your students are capable of and need.

PARTS OF A QUEST MODEL ROCKET



A. NOSE CONE
Guides airflow around the rocket (streamlines).

B. RECOVERY SYSTEM
Parachute, streamer or other device for retrieving the rocket safely and intact.

C. WADDING
Protects recovery system from hot ejection charge gases.

D. BODY TUBE
Main structural part, (airframe), usually a strong paper tube.

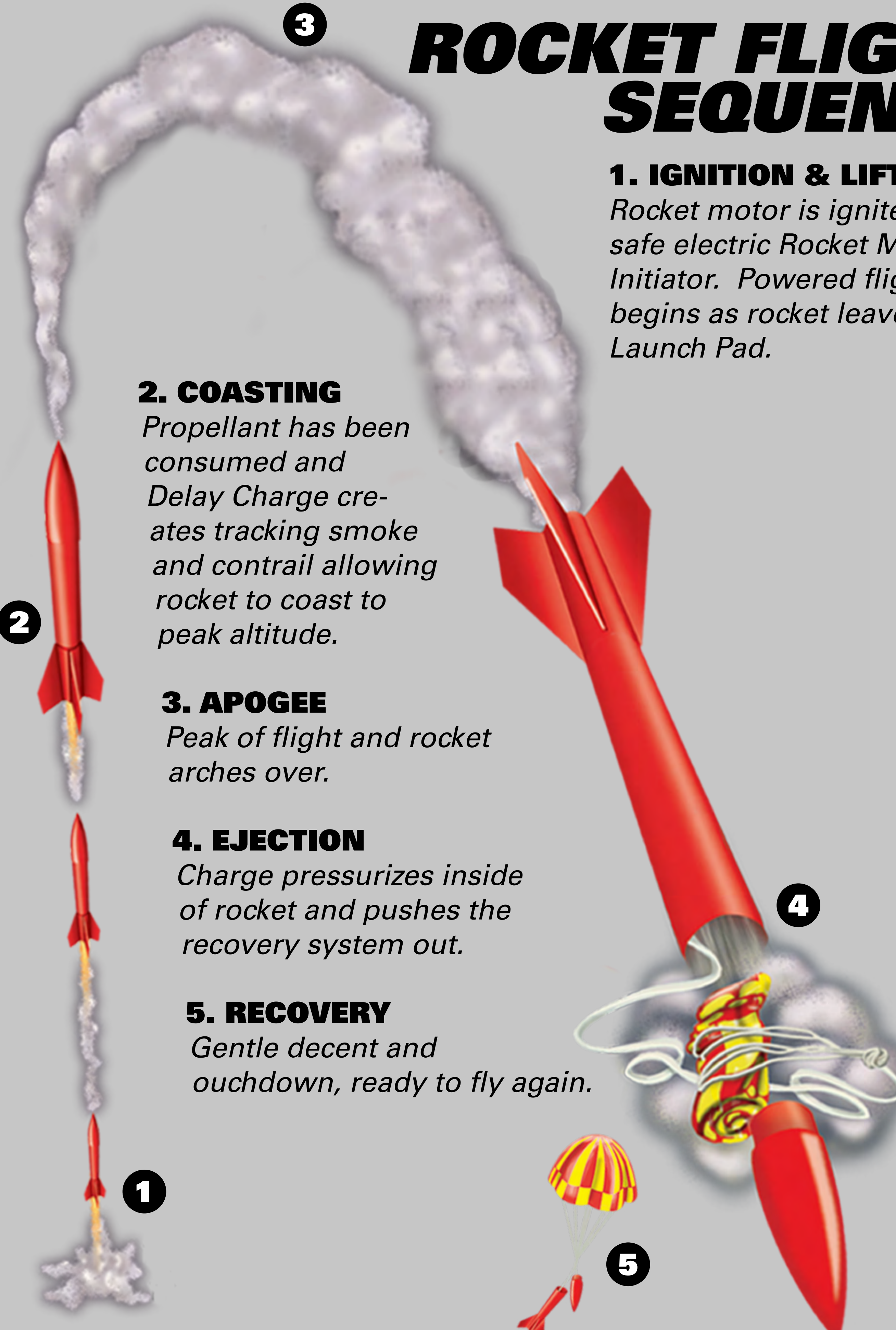
E. LAUNCH LUG
Attaches rocket to Launch Pad launch rod for initial guidance at Lift-Off.

F. Q-JET ROCKET MOTOR
Safe non-reusable device. A new Q-Jet rocket motor is needed for each rocket flight.

G. FINS
Keep rocket traveling straight.

H. MOTOR MOUNT
Holds rocket motor in place.

ROCKET FLIGHT SEQUENCE



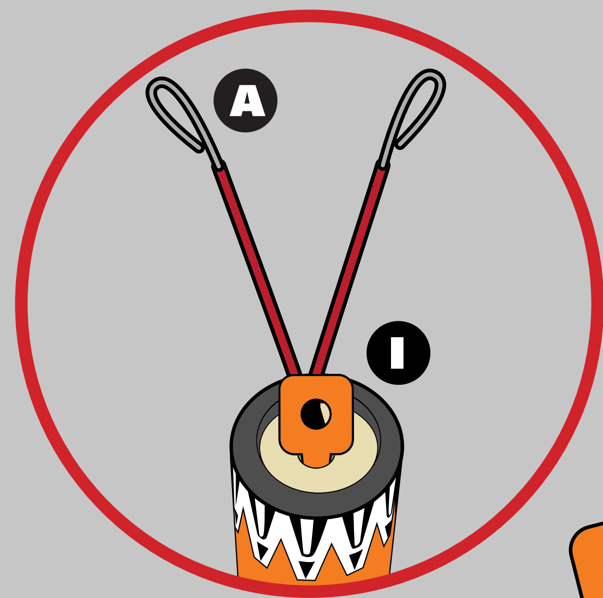
1. IGNITION & LIFT-OFF
Rocket motor is ignited by safe electric Rocket Motor Initiator. Powered flight begins as rocket leaves Launch Pad.

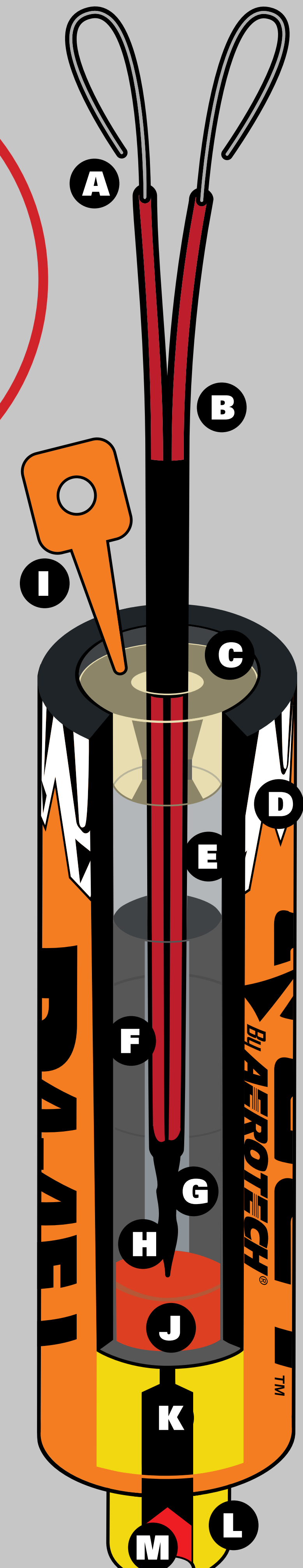
2. COASTING
Propellant has been consumed and Delay Charge creates tracking smoke and contrail allowing rocket to coast to peak altitude.

3. APOGEE
Peak of flight and rocket arches over.

4. EJECTION
Charge pressurizes inside of rocket and pushes the recovery system out.

5. RECOVERY
Gentle decent and ouchdown, ready to fly again.





Q-JET MOTOR CUT-AWAY

- ***A.*** *"Bunny Eared" Initiator Leads*
- ***B.*** *FirstFire™ Micro Initiator*
- ***C.*** *Clay Nozzle*
- ***D.*** *Motor Casing*
- ***E.*** *Casing Void*
- ***F.*** *Composite Propellant Grain*
- ***G.*** *Propellant Slot/Core*
- ***H.*** *Initiator Tip*
- ***I.*** *Q-Pic™*
- ***J.*** *Delay Element*
- ***K.*** *Ejection Charge*
- ***L.*** *Bulkhead*
- ***M.*** *Ejection Cap*

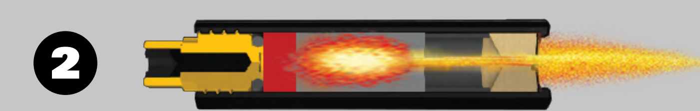
Q-JET MOTOR OPERATION

1. COUNTDOWN

Rocket Motor Initiator is positioned at the forward end of the composite propellant grain, beyond the rocket motor nozzle, and is held in with a Q-Pic initiator holder.

2. IGNITION

Launch Controller fires FirstFire™ Micro Rocket Motor Initiator and rocket motor starts to produce thrust.

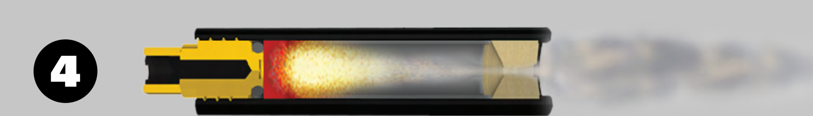


3. LIFT-OFF

Rocket Motor develops enough thrust for powered flight.

4. COASTING

Propellant has been consumed. Tracking Smoke charge continues to burn while rocket coasts to peak altitude.



5. APOGEE

Rocket reaches peak altitude, slowing down as it arcs over and begins to fall back to Earth as Delay Charge is consumed.

6. EJECTION

Ejection Charge is activated, creating expanding gases to pressurize the body tube to deploy a parachute or other recovery device.

Lesson Plan Example

Objectives: The learner will define Newton's Third Law of Motion.The learner will explain Newton's Third Law of Motion in his own words.The learner will diagram how Newton's Third Law of Motion operates in a model rocket.

Materials: For this lesson you'll need the following materials:
- Balloon
- Completed model rocket
- Overhead projector
- Blank overhead transparencies and pens
- Overhead transparency showing parts of a model rocket

Anticipatory Set: Here, students are involved in a critical thinking process which gets them mentally ready to learn about Newton's Third Law. At the start of class, blow up a balloon. Stand in front of the class, release the balloon and let it fly around the room. Then ask students to take a moment and write down a scientific explanation why the balloon traveled around the room. Be sure they understand that you're looking for as complete an explanation as they can provide.

Lesson: Share student responses to the anticipatory set. Try to develop the idea that there is a reactive force to the escape of air out of the rear of the balloon. Students might also point out that the balloon travels erratically because it has no inherent aerodynamic stability. State Newton's Third Law: For every action, there is an equal and opposite reaction. Check for understanding, then ask each student to write Newton's Third Law in his or her own words. Share responses and check for accuracy.

Now place a completed model rocket in front of the class. Ask them to develop a diagram of how Newton's Third Law relates to the flight of the model rocket. Provide time for them to work in cooperative learning groups to develop, check, revise, and write out this diagram. (If available, let them draw this diagram on a blank overhead slide. When reporting, each group can place their slide on the overhead and discuss how they reached a consensus about model rockets and Newton's Third Law.)

When all groups are done, have each group describe its diagram, with the other members of the class checking for accuracy. How many explanations are basically similar? What significant differences were reported? Why? Let the class discuss this until everyone is satisfied that they understand the Third Law of Motion in relationship to model rockets.

Guided Practice: Place a diagram of the parts of a model rocket on the overhead projector. Ask students to predict which parts of the rocket will be involved in the reaction to a force of thrust applied to the rocket.

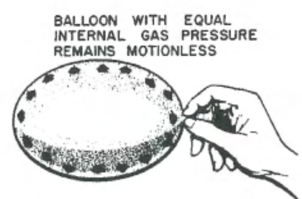
Independent practice: Students might be asked to predict ways in which a rocket flight would be impacted by a change in engine power. If the motor used was changed from an A 6-4 to a B 6-4, what changes in performance might occur? Would altitude be doubled? Why or why not? How about the rocket itself? Would anything structural be needed for the change in power?

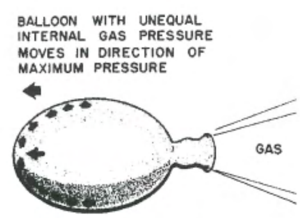
Closure: Ask student to respond to the following questions:
1. What is Newton's Third Law of Motion?
2. How can you state the law in your own words?
3. Name some other activities or events in real life that involve Newton's Third Law of Motion.

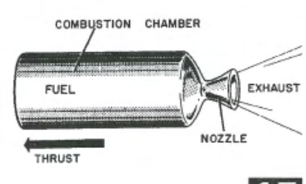
(Auto Transportation, bicycle, walking, nearly any form of reactive motion)

Table E

Let's walk through a sample lesson plan for Newton's Third Law. Let's assume that the students have only just started their unit on model rocketry. Perhaps you've done some form of the webbing exercise described earlier, and they may have started building their rockets. We'll use some of the objectives above for this lesson:







Unit Planning

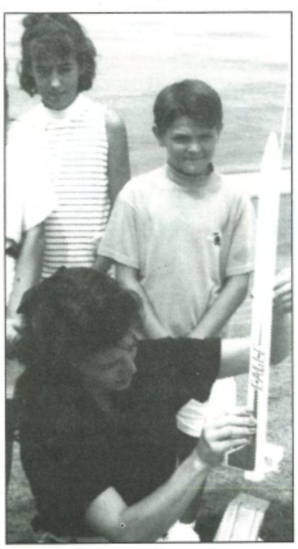
You can use the lesson plan just described as a model for nearly any model rocketry activity in your unit. Planning a unit takes more attention to overall learning outcome and less to the specifics of what will happen in the class each day.

As you plan any unit of learning, consider the overall experience the students will receive. Teachers should consider:

- What you will teach (Content)
- How you will teach (Activities -better known as Process)
- How you will evaluate learning (Product)

None of these steps is more important than any other, and learning can't happen unless all three are carefully planned. Model rocketry provides a unique way to approach how you will teach. The teaching ideas in this guide will inspire you to plan a great unit, but your task will be to find ways to tie the process in with the content you wish to teach, and to determine how the learning will be evaluated.

As you plan your unit, be sure to address all levels of critical thinking. One effective way to increase your students' depth of understanding of what they're learning is to use an "into, through and beyond" instructional model for unit planning. "Into" activities address where the student begins the learning (background knowledge), and then lead them into the new material. Examples of such activities include preparatory activities which start students thinking about the topic, background information in books, videos, or handouts, vocabulary words, quick-writes in journals, and concept-formation techniques such as classifying and predicting."Through" activities are designed to involve students deeply in the new material. Here teachers might ask students to discuss new ideas with a partner or in cooperative learning groups, pause in instruction to predict outcomes of situations posed by the teacher, debate issues surrounding the material learned, write journal entries focusing on their reactions to what they've learned, or complete a project or a report on a topic concerning the material learned. "Beyond" activities concern the highest levels of critical thinking, and are designed to allow students to connect the material they've learned with other information they already know - to place new information in their existing "schemata" to expand and revise them. "Beyond" activities might include allowing students to design their own projects related to model rocketry, create a video presentation or game relating model rocketry to other material, or letting students create learning materials for future students that make these same kind of connections.



Duration

How long should you spend on model rocketry? This depends upon what you want to accomplish. Simply building and flying the rockets can be accomplished in as little as five class sessions. Some teachers expand the unit to include many ancillary topics and spend as long as a month on it. The choice is up to you.

Activities

You can select from the teaching ideas provided in this guide and/or come up with your own ideas. Any generic teaching guide such as this one cannot take the place of your professional planning for your students. Only you know their capabilities and desires. Use your insight to custom-design a program that will excite and inspire your students to greater learning.

A fundamental choice you need to make at the start of unit planning is the scope of the unit. Should you focus on one or two key concepts, or would you like to allow students the opportunity to head in many directions at once? The second choice takes much more time, but it might make the unit more meaningful to your students. Again, gauge what will be best for your students.

Unit Plan Example

Week 1:

MONDAY:	Web the unit **(I)** Introduce model rocketry **(I)** Basic vocabulary **(I)**
TUESDAY:	Begin construction of student rockets **(T)**
WEDNESDAY:	Continue construction of student rockets **(T)** Go over the model rocketry safety code **(T)**
THURSDAY:	Introduce Newton's Third Law **(T)**
FRIDAY:	Continue rocket construction **(T)** Relate Newton's Third Law to construction of rockets **(T)**

Week 2:

MONDAY:	Follow-up on Newton's Third Law (Short instructional video and discussion) **(T)**
TUESDAY:	Complete rocket construction **(T)**
WEDNESDAY:	Instruction on flying model rockets **(T)** Introduction to electrical circuits **(T)**
THURSDAY:	Testing of launch system as part of follow-up instruction on launching rockets. **(T)** Static test firing of a rocket motor **(T)**
FRIDAY:	Students develop launch operations procedures **(T)** • safety checks • readying rockets for flight • recovery • Countdown and launch procedure • Altitude tracking

Week 3:

MONDAY:	Methods of altitude tracking **(T)** Go over the basic geometry and algebra involved in data reduction **(T)**
TUESDAY:	Practice altitude tracking - measure the height of a building in several ways, including using model rocket altitude trackers **(B)**
WEDNESDAY:	Review of safety procedures launch operations altitude tracking **(T)**
THURSDAY:	LAUNCH DAY! **(T)**
FRIDAY:	Evaluation of launch day **(T)** Evaluation of student learning (test or other evaluation procedure) **(T)** Introduce follow-up project **(B)** • create a video • relate Newton's Third Law to your life! • create a game • create learning materials for other students

Table F

A rough, overall plan will help you to get an overview of what will happen in your unit. Start with instructional objectives, then develop a rough plan such as the one which follows. Remember, the following is only a suggestion, and certainly would need to be modified to your instructional objectives.

Activities

(I) = "Into"
(T) = "Through"
(B) = "Beyond"

INTERDISCIPLINARY TEACHING WITH MODEL ROCKETRY

IDEAS

Each teaching guide contains ideas on these topics:

SCIENCE Teaching Guide #9500

Expert Groups
Flight
Stability
Drag
Weather
Biological
Orbital Mechanics
Future Studies
Electricity
Research Methods
Laws of Motion

MATH Teaching Guide #9505

Measurement
Graph & Set Theory
Geometry
Trigonometry
Algebra
Problem Solving
Computer
Games
Video Production
Music
Future Studies

SOCIAL STUDIES Teaching Guide #9510

Political Science
Economics
History
Cultural Diversity
Geography
Research Methods
Inventions
Future Studies
Video Production
Field Trips
Quest Speakers

ENGLISH Teaching Guide #9515

Narrative
Exposition
Research Projects
Poetry
Literature
Films
Video Production
Future Studies
Humanities
Vocabulary

Even if your school does not have interdisciplinary programs, model rocketry may provide just the impetus to try a program of this kind. The benefits for teachers can be great - flexible teaching schedules, easy planning and the fun of working with several other teachers on the same material. The benefits for students may be even greater - increased opportunity for understanding basic concepts and, more importantly, the possibility of "cross-over" understanding between several disciplines.

Model rocketry can be used in a variety of ways for an interdisciplinary educational program. A partial program might include only the Science and Math teachers, or Social Studies and Science. Or, it might inspire a program involving all four major content areas: Science, Math, Social Studies and English.

Planning an Interdisciplinary Program

The potential for a program of this kind has a great deal to do with the flexibility of the scheduling at your school. If you are an elementary or middle school teacher the possibilities for interdisciplinary teaching probably already exist. If you teacher junior high or high school things may be a bit more difficult, but don't be discouraged. The benefits of the program outweigh the frustrations you may face trying to schedule it.

If you are in a traditional schedule, where there are six to nine periods a day and you see your students for forty to fifty-five minutes per day, you may ask your administrator for some help. Or, start in a more modest way. Two teachers may be able to line up schedules of classes back to back. Even if you can't schedule consecutive sessions, you can work together on the planning and execution of the program. The important thing is to do what you can and let the students benefit.

Start by doing some brainstorming of your own. Each teacher should sit down and consider how model rocketry can be used in the particular content area they teach. Refer to the Quest Teacher Guide for each content area. Get excited about a potential program, and then get some ideas down on paper.

Next all teachers should meet to share their ideas. Try to establish a common theme which can pervade the rocketry studies in all four content areas. "Transportation," "The Space Age," or "Future Worlds" might be possibilities, but don't use the theme you find here. It's important that all teachers reach a consensus about what the unit should do thematically.

Now start sharing your ideas and resources. One of the great values of the interdisciplinary approach is that instructionally, the unit is greater than the sum of the parts. Look for ways the unit can reach students across all content areas in ways that no single content area could achieve. The most obvious answer is often applicability to student lives. As kids start studying the same theme in their Science, English, Social Studies and Math classes, they will make connections outside these content areas. Suddenly, the theme of the unit takes on whole new learning potential.

In what ways can you help each other as teachers? Are there resources (money as well as teaching materials and expertise) that can be shared. In a model rocketry unit, if one teacher has had experience with model rockets before, this can save the other teachers much time in preparation. Perhaps a brief "in-service" on rocketry would be a valuable use of planning time before the unit begins.

Another way to assist each other is to divide up the teaching responsibilities in new ways. Team teaching in a flexible schedule means that not every class needs to meet every day. Each teacher might take a two-hour block twice a week, where students discovered model rocketry in their Science class for two hours Monday, another discipline for two hours each of the next three days, and a traditional schedule on Friday. Use whatever works for you, but think "laterally" - what innovative things can be done that will help the students learn?

Table G

Often times, teaching teams can visualize the effectiveness of the interdisciplinary unit by creating a "Thematic Plan," which includes the subjects and teaching responsibilities in all content areas. A sample one follows:

Thematic Plan Example: "Future Worlds"

Science

- Construction of the model rocket
- Exploration of nearby planets - astronomy of the solar system
- Biology - Life support in alien environments
- Exobiology - non-terrestrial possibilities for life
- Propulsion systems - alternative fuels

Mathematics

- Construction of the model rocket
- Design of space colonies - scale drawings and possibly scale models built
- Orbital mechanics - Traveling to other planets and the associated mathematics of planetary orbits
- Life support needs - estimating food production, oxygen usage.

Social Studies

- Construction of the model rocket
- Brief history of planetary exploration and NASA
- Brainstorm possible problems in future societies
  - How would space colonies be governed?
  - Who would pay for the exploration? How?
  - What new laws would have to be created?
- Mock congressional hearing on funding of the new colonies
- Ecological impact of colonization?

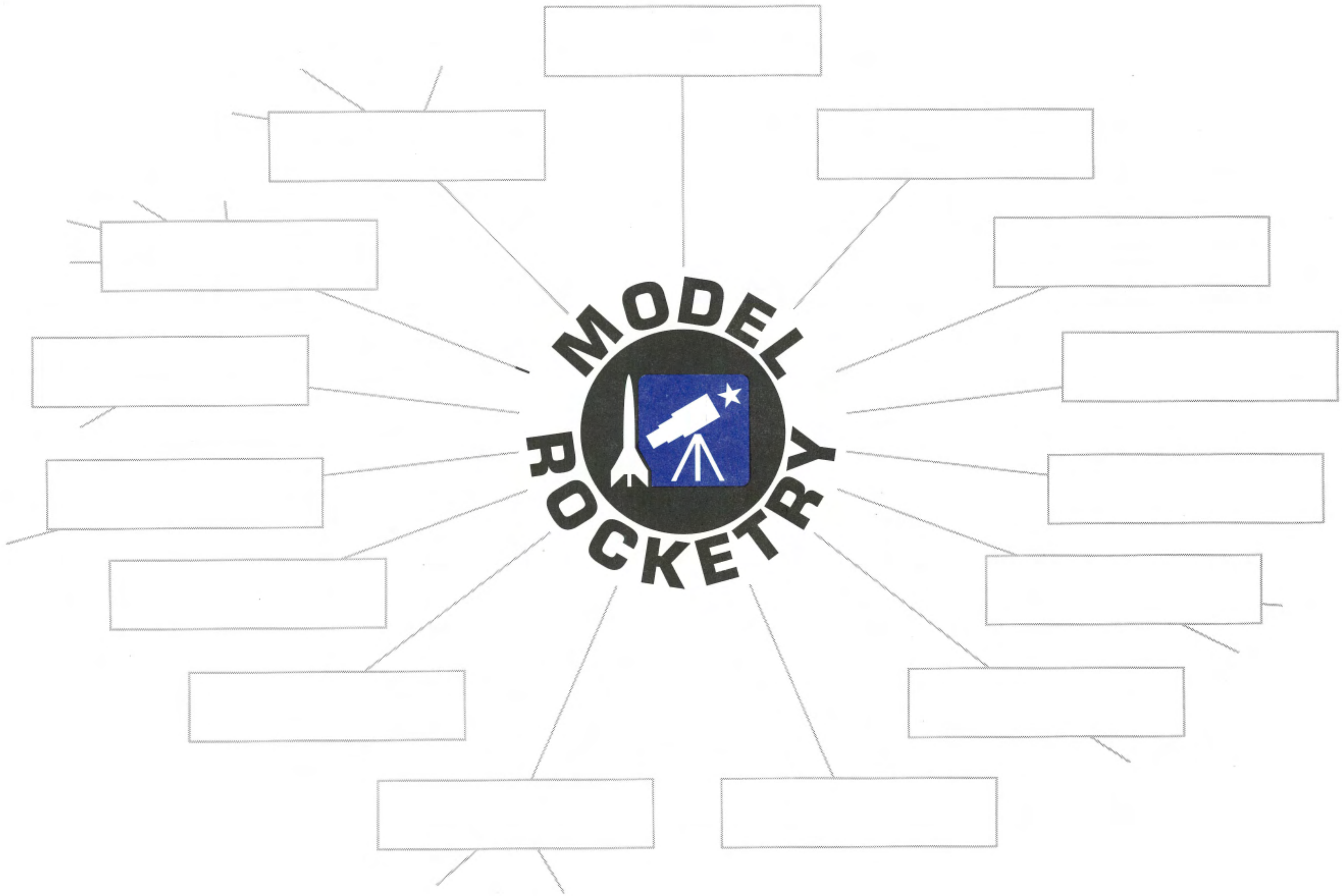
English

- Construction of the model rocket
- Description of life in future worlds - basis for the creation of the scale drawings/models
- Write poems reacting to life lived on another world
- Journal entries
- Write the laws suggested in social studies

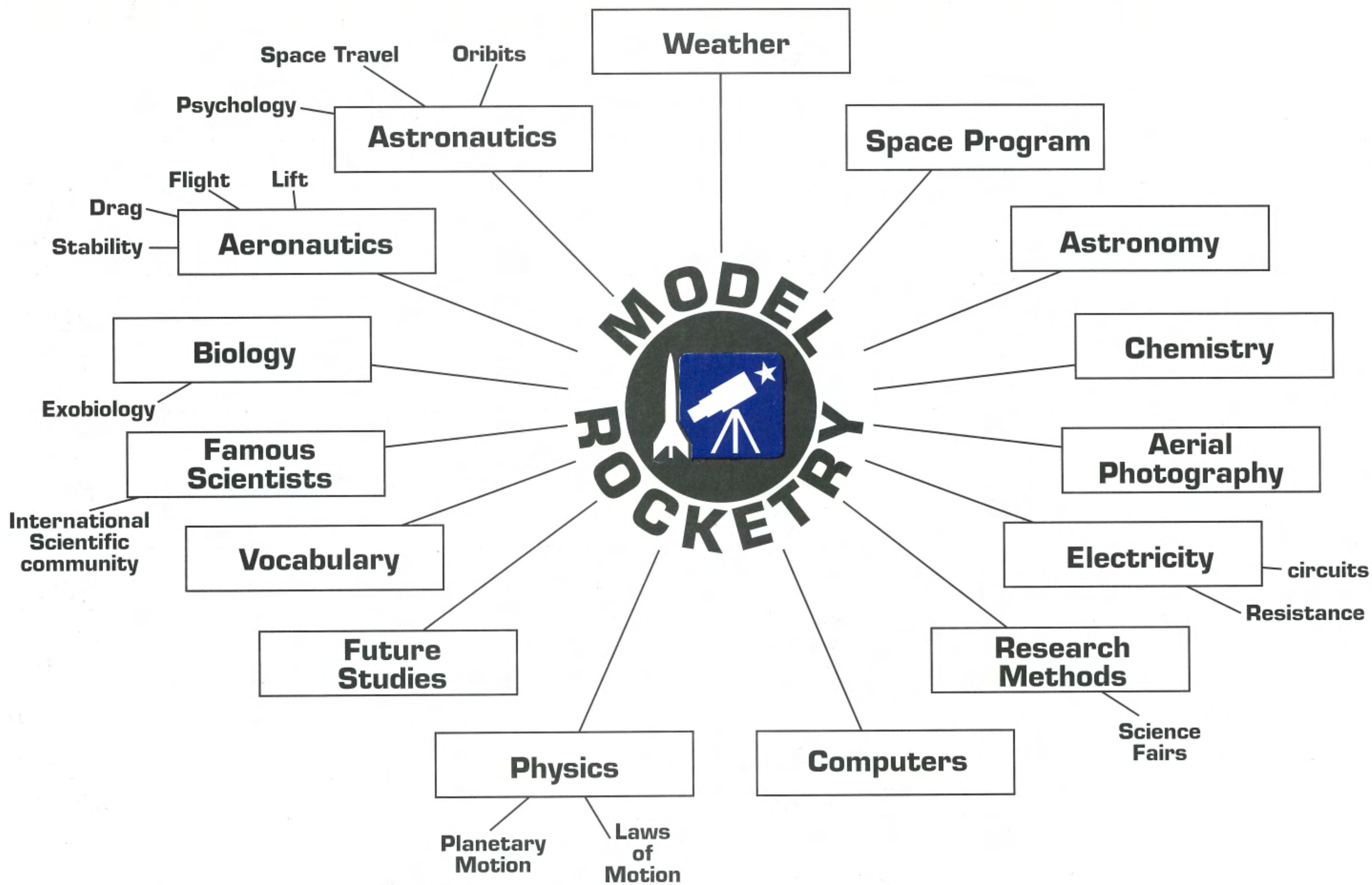
As you can see, much of the work can be interrelated. Some teachers start with a plan such as this one and let students be inspired by what is happening in the classroom, then allow them the opportunity to define where the unit will go.

Exploration can be fun and meaningful for everyone that way. And students will always remember the unit on model rocketry!

Science "Model Rocketry" Webbing Work Sheet



Science "Model Rocketry" Webbing Ideas



Science "Model Rocketry" Acrostic Work Sheet

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QUEST AEROSPACE EDUCATION

Science "Model Rocketry" Acrostic Ideas

M	MEDICINE	METEOROLOGY
	MECHANICS	MASS
	MATTER	MANUFACTURING
	MACH	MILKY WAY
O	ORBITS	OZONE
	OPTICS	OXYGEN
	OBSERVATORY	ORGANIZATIONS
	OCILLOSCOPE	ORBITER (SPACE SHUTTLE)
D	DRAG	DENSITY
	DENSITY	DOPPLER SHIFT
	DATA REDUCTION	DYNE
	ELECTRICITY	DISCOVERY
E	LAWS OF MOTION	EARTH SCIENCES
	LIFT	ECOLOGY
	LAMINAR FLOW	EINSTEIN, ALBERT
	LUNAR	ENERGY
L	EQUATIONS	LABORATORY
	ENGINEERING	LIFE SUPPORT
	EXPLORATION OF SPACE	LEONARDO DA VINCI
	DEEP SPACE	

R	ROBERT GODDARD.	RADAR
	REACTION	RADIOACTIVITY
	RADIO TELESCOPE	R & D
	ROBOTICS	REMOTE CONTROL
O	OUTER PLANETS	OCCAM'S RAZOR
	OSCILLATION	OPEN LOOP
	OHM'S LAW	OPERATING SYSTEM
	OBSERVATION	ORGANIZING FACTS
C	CIRCUITS	COLONIZING SPACE
	CHEMISTRY	CELESTIAL
	CENTER OF GRAVITY	CLIMATE
	CENTER OF PRESSURE	COMPUTERS
K	KEPLER, JOHANN	KILOWATT
	KELVIN, LOARD	KNOWLEDGE
	KINETIC ENERGEY	
	KENNEDY SPACE CENTER	
E	EXOBIOLOGY	ESCAPE VELOCITY
	EXPERIMENT	EXTRA TERRESTRIAL
	EARTH SATELLITE	EHRICKE, DR. KRAFTE
	ELECTRONICS	ELEMENTS
T	THRUST	THEORY
	TEST RESULTS	TELE COMMUNICATIONS
	TELEMETRY	THERMAL
	TOOLS & MACHINERY	TELESCOPE
S	SPACE PROGRAM	SCIENTISTS
	SCIENCE FAIR	SPECTRUM
	STUDY FUTURE	SEARCH FOR LIFE
	STABILITY	SCIENTIFIC METHOD

MODEL ROCKETRY DEFINITIONS
GLOSSARY

A

Acceleration The rate of change in an object's speed usually measured in "g's".
Accelerometer A device that measures acceleration, usually in "g's".
Aerodynamics The branch of physics that deals with forces exerted by air in motion.
Airfoil A surface (wing or fin) designed to provide lift, control, or a stabilizing effect.
Airflow The movement of air across a surface.
Airframe (see fuselage).
Amateur Rocketry Involves the mixing of solid or liquid-fuel, and fabrication of rockets from metal. Amateur rocketry is largely carried out by those who have been trained in such specialized fields. (also see Basement Bomber, Professional Rocketry).
Angle of Attack The angle at which a wing or fin moves in relation to the relative air stream.
Apogee The highest point in a rocket's flight.
Armed The condition of the electrical ignition system after the safety key is inserted; ready-to-launch condition.
Aspect ratio The relationship of wing span to wing chord, expressed as the number of times the span can be divided by the chord.
Average Thrust The total impulse of a rocket motor divided by the thrust duration.
Azimuth Angle The horizontal angle between rocket track and the other tracking station.

B

Ballistic The science that deals with the motion, behavior, appearance or modification of missiles acted upon by propellants, rifling, wind, gravity, temperature or other forces.
Balsa Wood An extremely light wood, with a high strength-to-weight ratio. Ideal for building flying models.
Base Line Distance between the tracker and the launch pad in single station tracking or between tracker #1 and tracker #2 in two station tracking.
Basement Bomber Person with inadequate knowledge who attempts to mix own propellant and usually builds rockets out of metal. (Also see Amateur Rocketry, Professional Rocketry)
Blast Deflector Metal plate protecting launcher base and ground from hot rocket exhaust.
Blow-Through A motor failure where the propellant blows out of the front end of the motor. Multi stage motors use this method to ignite propellant in the next stage.
Boat-Tail Cone-shaped fitting extending from the rear end of the body tube to the engine mount. Used to decrease drag.
Body tube A cardboard or plastic cylinder that comprises the fuselage of a model rocket.
Boilerplate A metal replica of the proposed professional rocket, but usually heavier and cruder for test purposes.
Boost The extra power given to a rocket during lift-off, climb or flight.
Booster A detachable portion of the rocket which contains an engine to give the main rocket an initial velocity. The booster separates from the main body after burnout and tumbles to the ground.
Boost-glider A model rocket which, through a change in its weight distribution or form, becomes a glider at apogee. A B/G ejects its motor after burnout, unlike a rocket glider.
Boost phase The part of a model rocket flight during which the motor is providing thrust.
Boundary layer The region next to the surface of a rocket moving through air where there is loss of fluid motion relative to the body.
Bulkhead A fitting used to block off a payload section or body tube.
Burn The total amount of time the propellant is burning in the engine. Burnout The point at which a motor ceases to produce significant thrust, even if the ejection charge is still burning.
Burnout velocity The speed of a rocket at the instant the propellant has been used up.
Burnout weight The weight of a rocket after all propellant has been used up.

C

Caliber Ratio of rocket body diameter to length.
Camber In aeronautics, the rise of the curve of an airfoil section.
Canard A configuration with the wings at the rear and the pitch controlling surface near the nose.
Centerbore Round cavity in propellant for burn control and easier ignition.
Center of gravity The point in a rocket's length where it's weight is evenly balanced. Abbreviation: CG.
Center of pressure The "balancing point" for aerodynamic forces acting on a rocket. Abbreviation: CP.
Chamber pressure The pressure exerted on the walls of the combustion chamber of a rocket motor by the burning propellant gases.
Check light Launch controller's indication of electric continuity (ready to ignite).
Chord The length of a straight line crossing the leading and trailing edges of a wing.
Clip whip Micro-clip assembly used to ignite a cluster of motors simultaneously.
Cluster A group of model rocket motors working as a single unit, ignited simultaneously. The total thrust of a cluster is equal to the thrust of the motors added together.
Coast The flight of a model rocket immediately following propellant burnout and before the ignition of the ejection charge.
Coefficient of drag A measure of how easily a shape moves through air.
Combustion The action of burning. Configuration The external shape or form of a rocket.
Connector Solid structure for joining two body tubes of same diameter. Constant taper A wing in which the chord or the thickness progressively decreases from root to tip.
Continuity The condition of a launch system having a complete electrical circuit to allow ignition.
Control surface A rudder or flap built into a wing or fin that can be moved to alter the surface and thus interact with the air flow to alter the direction of the aircraft or rocket. Core-burning Model rocket motor with deep centerbore provides a large propellant burning area. This produces a high thrust level.
Countdown A count in reverse order in seconds, of the time remaining before the launch.
Coupler Hollow structure for joining two tubes of same diameter.

D

Data reduction Calculating the performance of a model rocket, based on observations and measuring.
Deceleration The rate of decrease in an object's speed, usually measured in "g's".
Deflector (See Blast Defector).
Delay charge A slow burning chemical added to the rocket motor to provide a time delay between burnout and activation of recovery system.
Dethermalizer A small fuse or timing device to activate a mechanism for destroying a glider's lift so that the glider will return to the ground.
Dihedral The upward or downward tilt of a wing with respect to the horizontal. (Also see: Polyhedrol)
Dope A strong lightweight lacquer paint sometimes used on balsa and paper but not on most plastics.
Downwash The vertical downward motion of the airflow caused by an airfoil or a wing.
Drag Aerodynamic forces acting to slow an object in flight.
Ducted Ejection Method of passing ejection gases through tubes to a particular area; system of ducting hot ejection gases until they are cool before the deployment of the recovery device.
Duration The length of time a model rocket motor produces thrust. The length of time a model rocket is airborne.

E

Ejection charge A chemical added to the rocket motor to produce gas pressure at a very fast rate to activate the recovery system.
Elevation angle The vertical angle recorded by trackers, used to figure altitude.
Elevators The control surface on a boost glider; designed to change the craft from a stable rocket to a gliding object.
Elevon An aerodynamic control surface controls pitch and roll.
Empennage boom Glider frame projecting back from the wings. The stabilizer and rudder are attached to it.
End-burning Solid propellant rocket motor which is ignited at the nozzle end and burns through to the forward end; Versus a core-burning which burns from the center to the sides.
Engine (See Motor).
Exhaust velocity The velocity of the exhaust leaving the nozzle.

F

FAA (Federal Aviation Administration) regulates air traffic, including flying models.
FAI (Federation Aeronautique Internationale) organization that is responsible for documenting all records in aviation and astronautics, real and model.
Fillet A layer of glue placed at the joining of a fin (or other model rocket component) and the body tube (or other component). The fillet adds strength to the joint and cuts drag.
Fin In rocketry, an airfoil attached to the fuselage, which helps guide the flight.
Finishing The art of producing a quality surface on the model rocket. A well-finished rocket will allow a model to perform better than a model not so well done.
Flight duration The length of time during a model rocket is in flight.
Flight substantiation Official data stating the proven flight characteristics of a professional rocket.
Frangible The quality of a model rocket being made of fragile materials to minimize damaging whatever it may hit by accident.
Fuel The substance burned with an oxidizer to produce thrust in a rocket motor.
Fuselage The body, or main structure of a rocket. Also called the air frame.

G

"g" A unit of measurement of acceleration, equal to the rate at which objects fall toward Earth (32 feet per second per second).
Gantry A crane-like structure used to erect, assemble, and service large rockets. It is next to the rocket during launch preparations, but rolled away before launching.
Glide phase The non-powered descent of a boost glider or rocket glider.
Grain The direction of the fibers in balsa wood. Also describes the fineness of solid propellant.
Ground support Equipment consisting of launch controller, launch pad, and any related devices.

H

High-power rocketry The use of any motor (or combination of motors) higher than a D, or having total impulse of more than 20 newton- seconds.
Horizontal Level or parallel with the horizon.

I

Igniter An electrical device which starts combustion of the propellant in a model rocket motor.
Ignition The moment when a rocket motor's propellant starts to burn.
Ignition system The complete electrical system including batteries; micro-chips, and associated circuits and components.
Impulse A force which produces motion.
Incidence The angle between the airfoil chord line and the longitudinal axis of the glider.
Irregular taper A finor wing in which the chord does not decrease progressively from root to tip.

J

Jet propulsion The forward propulsion of a rocket by the rearward discharge of a high-speed stream of gases.

K

Krushnik Effect When the motor is recessed forward in the body tube more than one diameter of the body, thrust is very ineffective.

L

Laminar flow Airflow near the surface of a body which is not turbulent. Usually found at the front of a smooth body.
Lateral axis The axis from wing tip to wing tip; the aircraft can pitch up or down about this axis.
Launch The liftoff of a rocket after ignition.
Launch controller An electrical device used to send current to a igniter. Launch controllers normally have several safety features, such as a spring-loaded switch, a continuity check light and a safety key.
Launcher (see Launch pad)
Launch lug Small pieces of balsa tubing or plastic that allows the rocket to be guided in early flight from the launch pad.
Launch pad Structure used to support a launch rod, rail or tower which guides a model in a vertical path. Includes blast deflector.
Launch rail Rail with a special cross section which guides a model during its first few feet of flight.
Launch rod Round rod used to support and guide a model in a vertical path during the first few of flight.
Launch stand (see Launch pad)
Launch system Combination of launch pad and ignition system.
Launch tower Generally a structure in which the rocket fins travel in slots to guide the rocket during liftoff.
Leading edge The front edge of a fin, facing the direction of rocket travel.
Lead wire The wire going from the launch controller to the micro-clips (and igniter).
Lift The total aerodynamic force perpendicular to the relative wind and exerted upward to the wings. This allows aircraft to remain airborne.
Lift-off The start of a rocket's flight from it's launch pad ("blast-off").
Loaded weight The weight of a model

EDUCATOR TIP: This glossary may be photocopied and adapted for use as a learning aid or exercise tool.

- sketching a visual depiction of selected terms
- grouping terms by family
- rewording definitions
- finding opposites.

rocket with motor, igniter, wadding, recovery device and any payload.

Longitudinal axis The axis from the front to tail of an aircraft; movement about this axis is called roll.

M

Mach number The ratio of the speed of an object to that of sound. A body moving at a Mach number of one (Mach 1.0) has a velocity of approximately 1100 feet per second (sea level, normal atmospheric pressure).

Mass ratio The ratio of the mass of a rocket at liftoff to it's mass after fuel has burned. The rocket's fuel comprises half of it's total weight if the mass ratio is Zil.

Maximum thrust The greatest amount of thrust created at some point during a rocket motor firing.

Metric system A system of weights and measures based on decimals. Conversion from one unit to the next is a simple matter of moving decimal points.

Micro-clips Small clips with flat jaws that are used launch controller wires to igniter leads.

Mini motor The smaller size model rocket engine; 1.75 inches long by 0.500 inches in diameter; used in high-performance rockets or for small launch sites.

Mock-up A full-size replica or dummy of a vehicle often made of some substitute material such as wood to assess design features.

Model rocket A model made of such materials as paper, wood and plastic, without substantial metal parts. Powered by a commercial solid propellant model rocket motor. A model rocket launches without lift-producing aerodynamic surfaces and includes a recovery device to bring it safely back to the ground.

Momentum The product of a moving object is velocity times it's mass.

Monopropellant A propellant mixture which contains both the oxidizer and the fuel in a single compound.

Motor Non-metallic motors produced commercially under controlled conditions specifically for use in model rockets. Sometimes called an engine by mistake (engines are generally machines with moving parts).

Motor classification A system of coding used to designate a model rocket motor's performance parameters.

Motor hook A clip which secures the nozzle end of motor to prevent it from being ejected when ejection charge ignites.

Motor mount A structure positioned in a model rocket body to prevent the engine from moving forward during acceleration while allowing a free forward travel of the ejection gases.

Motor pod Assembly housing model rocket motor which detaches from rest of glider when ejection charge operates.

Multi-stage rocket A rocket having two or more stages which operate one after the other.

Mylar A lightweight and strong plastic sometimes used for streamers and parachutes. Some Mylar has a silvery coating to make it highly visible from the ground.

N

NAR (The National Association of Rocketry) Official organization which certifies motors, validates competition records, sets safety standards and promotes model rocketry.

Newton The amount of force needed to move a mass of one kilogram with an acceleration of one meter per second each second; one Newton is equal to 0.225 pounds of force.

Newton-second The metric unit of impulse. A newton-second is one newton of force applied for one second.

Newton's Third Law "For every action there is an equal but opposite reaction."

Nichrome A type of high-resistance electrical wire that heats up when electrical current is passed through it, sometimes used in model rocket engine igniters.

Nose cone The front end of a model rocket, generally tapered in for streamlining.

Nozzle The narrow open end of a model rocket motor (usually ceramic) that directs the flow of exhaust gases.

Nozzle blow A model rocket motor failure in which the nozzle is forcibly expelled.

O

Ogive Curved shape of most nose cones, versus straight side found in true conical shape.

Oxidizer A part of a rocket's propellant must be oxidizer. This substance produces oxygen to support combustion.

Oscillation A periodic motion, such as the rolling, pitching, or yawing of a rocket, or a combination of these.

P

Parachute An umberella-shaped device, made of fabric or lightweight plastic and attached to an object by shroud lines. Used to slow the fall of a body through the atmosphere.

Parallel Ignition Method of simultaneously igniting two or more motors in a cluster.

Parasite glider Small boost glider attached to base of larger rocket for boost.

Payload Any objects to be lifted that are not a functional part of the rocket itself.

Payload section A compartment in the rocket designed to carry and protect a payload (also called payload capsule).

Peak thrust (See Maximum thrust)

Pitch Rotational movement around the lateral axis of the rocket.

Polyhedral A modification of dihedral, wherein the different wing panels are tilted upward ar varying angles.

Pound-second The English unit of total impulse, now replaced by the newton-second.

Pop-pod A motor pod that is jettisoned from a boost glider after the activation of the motor's ejection charge.

Powered flight The "boost phase" of a model rocket flight.

Pressure Distribution The variation of air pressure over a surface, such as the pressures around wing's airfoil.

Professional rocket NASA vehicle or rocket built by government agency, aerospace industry, or professional scientists. (Also see Amateur rocketry, Basement bomber)

Propellant The source of energy in a rocket motor; a combination of a fuel and oxidizer.

Propulsion Act of driving forward or propelling.

Prototype An original model on which other rockets are patterned.

Pylon The mount for the motor holder in a boost glider or rocket glider.

R

R & D (See Research & Development)

Range Complete outdoor launch facility with all features and equipment needed.

Recovery system A devise incorporated into the design of a model rocket for the purpose of returning it safely to earth. All model rockets must use some form of recovery system.

Recovery wadding Flame-resistant material packed between the model rocket motor and the streamer or parachute to protect it from the hot ejection charge.

Reducer Round tapered balsa fitting used to connect body tubes of different diameters.

Relative wind The apparent motion of the air in relation to a body in it; motion may by caused by a body moving in relation to still air.

Research & Development (R&D) Process of planned experimentation leading toward a predetermined goal or a competitive event.

Rocket glider A model rocket that, through a change in weight distribution or configuration, becomes a glider after engine burnout. Similar to a boost glider, but it retains it's engine after burnout. Also known as R/G.

Roll Rotational movement of a rocket about a longitudinal axis.

Root edge The edge of a wing or fin attached to the fuselage.

Rudder A moveable or fixed aerodynamic control surface used to cause yaw movement, or to prevent such movement, to keep an aircraft or rocket on a fixed horizontal path.

S

Safety key A special key used to arm a launch system. No power can get to an igniter without use of a safety key.

Scale data Official documentation of the configuration, details and colors of a professional rocket.

Scale model A detailed model that duplicates the appearance of a prototype.

Screw eye Metal eye screwed into nose cone (or payload compartment base) to attach parachute and shock cord.

Shock cord An elastic cord used to attach the nose cone and parachutes to the body of the rocket. This absorbs the shock force of the ejection charge.

Shroud line The string used in making parachutes.

Single station tracking Tracking system using one tracker. It is the least accurate of the tracking methods. (Also see Two station tracking)

Smoke trail Most model rocket motors put out a stream of smoke during the coasting phase to allow visual tracking.

Snap swivel Used to attach parachute or shock cord. Parachute may be changed easily from one rocket to another.

Solid propellant A rocket in solid form; usually consisting of a mixture of fuel and oxidizer.

Sounding rocket Term for research rockets used to obtain data on the upper atmosphere.

Span The overall distance between the fin tips of a rocket.

Specific impulse The measure of energy content per pound of propellant, used for determining relative performance.

Stability The tendency of a rocket having the proper center of gravity/center of pressure relationship to maintain a straight course.

Stabilizer A fixed surface; generally the tail surfaces on conventional models.

Stage Coupler Tubing used to properly position one stage to another.

Staging (See Multi-stage rocket)

Standard motor A model rocket motor of the usual size; 2.75 inches by 0.690 inches in diameter.

Static test stand Device used to measure an engine's performance and reliability, and produce a thrust-time curve.

Streamer A strip of flexible material that serves in place of a parachute when a fast recovery is desired.

Stuffer tube A smaller tube placed inside a larger body tube to direct ejection gases to a particular area.

Supersonic speed The speed at which a model rocket breaks the sound barrier.

Sustainer engine Single or upper stage motor equipped with a delay charge and and ejection charge.

Swing test Pre-flight test to check the stability of a model rocket.

T

Taper ratio The ratio of the tip chord to the root chord of a wing.

Telemetry The science of transmitting data from a rocket back to receiving equipment on the ground.

Theodolite An optical instrument for precision measurement of azimuth and elevation angles when tracking.

Throat The smallest opening of the nozzle of a rocket motor.

Thrust The propulsive force developed by the rearward ejection of gases during the combustion of the fuel.

Thrust duration The length of time a model rocket produces thrust.

Thrust phase The period of time during which the propellant burns and the rocket motor produces thrust.

Thrust ring Ring positioned in a model rocket body tube or engine mount to prevent the motor from moving forward during acceleration.

Thrust-time curve A graphic expression of the relation between thrust produced by a rocket motor and time.

Time delay The time between the burnout of the motor and the activation of the ejection charge.

Tip The end of a fin outermost from the fuselage.

Total impulse The average thrust of a model rocket motor multiplied by the duration.

Touchdown The moment when rocket makes contact with the earth.

Tracker Person staffing a theodolite or other device used for measuring rocket altitude.

Trade-offs Compromises made in model rocket design involving weight, diameter, and drag to achieve best overall effect.

Trailing edge The rear edge of a fin or wing surface.

Trajectory The flight path of a projectile, missile, rocket or satellite.

Turbulent flow Uneven air movement over the surface of a body in which the air movement is not smooth.

Two station tracking Tracking system employing two trackers. It is more accurate than single station tracking. (Also see Single station tracking)

V

Velocity A rate of motion in a given direction, measured by distance moved per unit time.

Vertical At right angles to the horizon.

Vertical axis The axis going in a vertical direction from the glider's center of gravity; movement about this axis is called yaw.

Vortex Corkscrew turbulence of air at a specific place on flying rocket.

W

Wadding(See Recovery wadding)

Warp A twist in a surface.

Weathercock Tendency of a rocket to turn into the wind, away from a vertical path.

Wind tunnel An enclosed chamber through which air is forced at different velocities. Used to test the stability and flight characteristics of rockets in model or full-size form.

Wing The main lifting surface of an aircraft.

Y

Yaw Rotation of a craft about its vertical axis.

MODEL ROCKETRY EDUCATION RESOURCES

ACME Rocket CO.
Box 28283
Tempe, AZ 85285

AD ASTRA
P.O. Box 96651
Wash DC 20077

Advanced Space Design Journal
Project Center
Worcester Poly. Inst.
Worcester, MA 01609

Aerospace America
P.O. Box 1439
Tulsa, OK 74101

AEDP
6991 Madison Way
Littleton, CO 80122

CAP-Civil Air Patrol
HQ CAP-USAF
Maxwell AFB, AL 36112

CAR-Canadian Assoc. of Rocketry
4269 Torino Crescent
Mississauga, Ontario
CANADA L4W 3TH

Challenger Center for Space Science Education
1101 King St., #700
Alexandria, VA 22314

CORE
15181 Route 58
Oberlin, OH 44074

Countdown
Main Stage Publications, Inc
P.O. Box 216
Athens, OH 45701

FAA-Fed. Aviation Adm
Office of Pub. Affairs
800 Independence Ave, SW
Wash DC 20591

Final Frontier
1422 W. Lake St., #312
Minn, MN 55420

Fine Scale Modeler
P.O. Box 1612
Waukesha, WI 53187

4-H Nat'l 4-H Council
7100 Conn Ave.
Chevy Ch., MD 20815

KCC
John W. Burns
3213 Hardy Dr.
Edmond, OK 73013

LHS/GEMS
Lawrence Hall of Sci
University of Calif
Berkeley, CA 94720

Miniature Astronautics
4269 Torino Crescent
Mississauga, Ontario
CANADA L4W 3TH

MN-4H-Minn Extension Service
Rm3, Coffey Hall
1420 Eckles Ave
Univ of Minnesota
St. Paul, MN 55108

NAR-Nat'l Assoc of Rocketry
1311 Edgewood Dr.
Altoona, WI 54720

(Alas, Ariz, Calif, Hawaii, Idaho, Mont, Nev, Oregon, Utah, Wash, Wyom)

NASA Ames Res. Ctr.
Teacher Resource Ctr.
Mail Stop TO-25
Moffett Field, CA 94035

(Conn, Dela, Dist of Columbia, Maine, Maryland, Mass, New Hamp, New Jersey, Penn, Rhode Is, Vermont)

NASA Goddard Space Flight Ctr
Teacher Resource Lab.
Mail Code 130.0
Greenbelt, MD 20771

(Colo, Kansas, Neb, New Mex, N Dak, Okla, S. Dak, Texas)

NASA Johnson Space Center
Teacher Resource Rm.
2101 NASA Road One
Code AP-4
Houston, TX 77058

(Florida, Georgia, Pto Rico, Virgin Is)

NASA Kennedy Space Center
Educators Resource Laboratory
Mail Code ERL
Kennedy Space Ctr FL 32899

(Kent, N Carol, S Carol, Virg, W Virg)

NASA Langley Research Center
Teacher Resource Ctr.
Mail Stop 146
Hampton, VA 23665

(Illinois, Ind, Mich, Minn, Ohio, Wisc)

NASA Lewis Research Center
Teacher Resource Ctr.
Mail Stop 8-1
Cleveland, OH 44135

(Alab, Ark, Iowa, Louis, Mississippi, Missouri, Tenn)

NASA Marshall Space Flight Ctr
Teacher Resource Ctr.
Alabama Sp & Rct Ctr
One Tranquility Dr.
Huntsville, AL 35807

(Mississippi)

NASA Stennis Space Center
Teacher Resource Ctr.
Building 1200
Stennis Space Ctr MS 39529

NASA-ED
Educational Pub Svcs, LFC-9
400 Maryland Ave, SW
Wash, DC 20546

NASA-HQ
400 Maryland Ave, SW
Wash, DC 20546

NASA-JPL Jet Prop
Teacher Resource Ctr.
Attn: JPL Education
Mail Stop CS-530
Pasadena, CA 91109

NASA REPORT to Educators
NASA
Code XEP
Wash, DC 20546

NASM Educ Resource Center
Office of Education P-700
Nat'l Air & Space Mus.
Smithsonian Inst.
Wash, DC 20560

NSS National Space Society
922 Penn Ave, SE
Wash, DC 20003

OSU-4H-Cooperative Extension Service
Ohio State University
Columbus, OH 43210

Rockwell International
Rocketdyne Division
2330 E. Imperial Hwy
El Segundo, CA 90245

Space News
Springfield, VA 22159

Superintendent of Documents
Government Printing Office
Washington, DC 20402

Teaching Space
P.O. Box 19270
Cincinnati, OH 45219

TIES
c/o Hartley Data
1807 Glenview Rd
Glenview, IL 60025

Tripoli Rocketry Assoc
P.O. Box 40475
St. Petersburg, FL 33743

USSF-U.S. Space Foundation
P.O. Box 1838
Colo Springs, CO 80910

U.S. Space Camp
Alabama Sp & Rkt Ctr
One Tranquility Base
Huntsville, AL 35807

Young Astronaut Council
1211 Conn Ave, NW
Suite 800
Washington, DC 20036

Listed below are some generalized organizations under the headings of Local and State levels. The National level organizations and publications have addresses on this page (use keyword at end of each description to locate).

ORGANIZATIONS

LOCAL LEVEL

Community resources for assistance in planning.
MODEL ROCKET CLUBS: Volunteer hobbyist groups are often willing to help or perform flight demos. Check with local hobby shops.
SCHOOLS: 5-12 College and university, space camps and alternative schools.
YOUTH GROUPS: Scouting, 4-H, summer camps, YMCA/YWCA, Boys & Girls clubs, Civil Air Patrol and Young Astronauts.
SERVICE ORGANIZATIONS: Parks & Recreation, museums, military recreation.
EXPERIENCED CITIZENS: People in the community with background in some phase of rocketry or space activity.

STATE LEVEL:

Most often the assistance will be information referral. Speakers are also occasionally available.
STATE DEPARTMENT OF PUBLIC INSTRUCTION: May be able to assist in aerospace course development.
STATE DEPARTMENT OF AERONAUTICS: Most are keyed to the needs of schools in this field.
AVIATION/AEROSPACE RESOURCE CENTERS: These are at colleges and have information on course organization and materials.

NATIONAL LEVEL

NATIONAL ASSOCIATION OF ROCKETRY: Promotes MR safety, contests, activities. It is the enthusiastic rocketeer's best resource (NAR).
CANADIAN ASSOCIATION OF ROCKETRY: Similar to the U.S. NAR (CAR).
TRIPOLI ROCKETRY ASSOCIATION: Promotes high-power MR. For adults (Tripoli).
NASA TEACHER RESOURCE CENTERS: Maybe visited to reference or duplicate materials (lesson plans, guides, slides, audio & video tapes). Contact center serving your state (NASA...).
NASA EDUCATIONAL MAILING LIST: Headquarters office handles general announcements (NASA-ED).
NASA JET PROPULSION LABORATORY: Space exploration inquiries (NASA-JPL).
CORE-CENTRAL OPERATION OF RESOURCES FOR EDUCATORS: Mail order retailer of most commonly requested items at NASA Teacher Resource Centers (CORE).
NATIONAL AIR & SPACE MUSEUM: Educator Resource Center: all levels and disciplines for space and aviation (NASM).
CHALLENGER CENTER FOR SPACE SCIENCE EDUCATION: Memorial to crew (CHALLENGER).
UNITED STATES SPACE FOUNDATION: Space activist group (USSF).
NATIONAL SPACE SOCIETY: Space activist group; includes L-5 Society (NSS).
CIVIL AIR PATROL: Civilian auxiliary of USAF, with aerospace education & MR activities. Ask for list of free educator materials (CAP).
U.S. SPACE CAMP & U.S. SPACE ACADEMY: Space education "camps" (U.S. SPACE).
YOUNG ASTRONAUTS: Private sector program with local chapters (YOUNG).

PUBLICATIONS

Directories

HANDBOOK FOR AEROSPACE EDUCATION, 2ND EDITION: Many resource contacts (AEDP).
DIR. OF AEROSPACE EDUCATION RESOURCES: Many museum contacts. Free (Rockwell).
EDUCATORS GUIDE: DOD AEROSPACE RESOURCES: Military contacts. Free (CAP).
TEACHER'S GUIDE TO AVIATION EDUCATION RESOURCES: Aeronautics. Free, #APA-5-149 (FAA).
INSIDE INFORMATION: Ready-to-use address labels of 50 model rocketry suppliers. $4.00 cost includes free catalog (ACME).

INSTRUCTIONAL MATERIALS

QUEST is the major source of state-of-the-art publications and products specifically designed to fit educator's needs. See current catalog.
BLUE SKY BELOW MY FEET: 4-H program teaching space technology of forces, fibers, foods. Includes videos and many other materials (4-H).
4-H MODEL ROCKETRY: Manual developed at Ohio State University 4-H (OSU 4-H).
MODEL ROCKETRY LEADER'S GUIDE-BEGINNER LEVEL: Teaching guide from University of Minnesota (MN-4-H).
CAP MODEL ROCKETRY PROGRAM: Civil Air Patrol Manual, includes NAR contest code (CAP).
EXPERIMENTING WITH MODEL ROCKETS: Teaching guide and materials for doing controlled experiments, chiefly altitude. Lawrence Hall of Science, UC Berkley (LHS/GEMS).
NASA EDUCATIONAL PUBLICATIONS: Catalog of available titles. Free, # PAM-107 (SUPER).
NASA SOURCE LIST: Supplier addresses for models, souvenirs, photos, charts, special sources, etc. Free, Information Summaries # PMS-DO6-B (Hgs) May 1991 (NASA-HQ).
ACME ROCKET COMPANY: Supplier of hard-to-find and out-of-production MR products, publications, plans and instruction sheets. Free catalog (ACME).

BOOKS

HANDBOOK OF MODEL ROCKETRY: Stine, G. Harry, New York, Arco Publishing, 1983. NAR Official handbook.
BASICS OF MODEL ROCKETRY: Pratt, Douglas R., Milwaukee, Kalmbach Books, 1981. Brief and thorough introduction.
ADVANCED MODEL ROCKETRY: Banks, Michael A., editor, Milwaukee, Kalmbach Books, 1985. Challenging projects.
THE ETV MODEL BOOK: Schleicher, Robert, Radnor PA, Chilton Book Co., 1979. Creating spacecraft of all types, including MR.
THE ROCKET BOOK: Cannon, Robert L. and Banks, Michael A., Englewood Cliffs NJ, Prentice-Hall, 1985. Very thorough.
COUNTDOWN: THE COMPLETE GUIDE TO MODEL ROCKETRY: Banks, Michael A., BlueRidge Summit PA, Tab Books, 1985. Thorough.

MAGAZINES

AMERICAN SPACEMODELING: NAR news, MR plans and articles (NAR).
MINIATURE ASTRONAUTICS: Canadian, for educators & rocketeers (MINI).
HIGH POWER ROCKETRY: Journal of the Tripoli Rocketry Association (TRIPOLI).
KIT COLLECTOR'S CLEARING HOUSE: For collectors & builders of plastic display model kits; including spacecraft (KCC).
FINE SCALE MODELER: In-depth how-to info for scale modelers of all types (FINE).
TEACHING SPACE: For educators, mostly K-12 (TEACHING).
NASA REPORT TO EDUCATORS: Announcements, all levels. Free, (NASA-REPORT).
SKYLINES: Newsletter of NASM Educator Resource Center (NASM).
AIR & SPACE: Deluxe NASM aerospace magazine (NASM).
ADVANCED SPACE DESIGN JOURNAL: Student produced at Worcester Polytech. Free (ADVANCED).
TIES TECHNOLOGY/INNOVATION/ENTREPRENEURSHIP FOR STUDENTS: Drexel University. Free (TIES).
AD ASTRA: NSS; news, space articles (NSS).
FINAL FRONTIER: Newsstand magazine; news, history (FINAL).
COUNTDOWN: Reports recent launches and space activities (COUNTDOWN).
SPACE NEWS: Newspaper reports on space business & politics (SPACE NEWS)
AEROSPACE AMERICA: America Institute of Aeronautics & Astronautics' magazine of broad coverage. Free if qualified (AEROSPACE).
MODEL ROCKET CLUB NEWSLETTER: Hard to locate, but many affiliated with national association (NAR).

FLYING MODEL ROCKETRY SAFETY

N.A.R. MODEL ROCKET SAFETY CODE

1 MATERIALS. My model rocket will be made of lightweight materials such as paper, wood, rubber, and plastic suitable for the power used and the performance of my model rocket. I will not use any metal for the nose cone, body, or fins of a model rocket.

2 MOTORS. I will use only commercially-made NAR certified model rocket motors in the manner recommended by the manufacturer. I will not alter the model rocket motor, its parts, or its ingredients in any way.

3 RECOVERY. I will always use a recovery system in my model rocket that will return it safely to the ground so it may be flown again. I will use only flame resistant bio-degradable recovery wadding if required by the design of my model rocket.

4 WEIGHT AND POWER LIMITS. My model rocket will weigh no more than 1,500 grams (53 ounces) at lift-off and its rocket motors will produce less than 320 Newton-Seconds (4.45 Newtons equals 1.0 pound) of total impulse. My model rocket will weigh less than the motor manufacturers recommended maximum lift-off weight for the motors used, or I will use motors recommended by the manufacturer for my model rocket.

5 STABILITY. I will check the stability of my model rocket before its first flight, except when launching a model rocket of already proven stability.

6 PAYLOADS. My model rocket will never carry live animals except insects, or a payload that is intended to be flammable, explosive, or harmful.

7 LAUNCH AREA. I will launch my model rocket outdoors in a cleared area, free of tall trees, power lines, buildings, and dry brush and grass. My launch area will be at least as large as that recommended in the following table.

Motor Type	Minimum Site Dimensions (feet)
A	100
B	200
C	400

8 LAUNCHER. I will launch my model rocket form a stable launch device that provides rigid guidance until the model rocket has reached a speed adequate to ensure a safe flight path. To prevent accidental eye injury, I will always place the launcher so the end of the rod is above eye level or I will cap the end of the rod when approaching it. I will cap or disassemble my launch rod when not in use and I will never store it in an upright position. My launcher will have a jet deflector device to prevent the motor exhaust from hitting the ground directly. I will always clear the area around my launch device of brown grass, dry weeds, or other easy-to-burn materials.

9 IGNITION SYSTEM. The system I use to launch my model rocket will be remotely controlled and electrically operated. It will contain a launching switch that will return to "Off" when released. The system will contain a removable safety interlock in series with the launch switch. All persons will remain at least 15 feet from the model rocket when I am igniting model rocket motors totalling 30 Newton-Seconds or less of total impulse and at least 30 feet from the model rocket when I am igniting model rocket motors totalling more than 30 Newton-Seconds of total impulse. I will use only electric igniters recommended by the motor manufacturer that will ignite the model rocket motor(s) within one second of actuation of the launching switch.

10 LAUNCH SAFETY. I will ensure that people in the launch area are aware of the pending model rocket launch and can see the model rocket's lift-off before I begin my audible five-second count down. I will not launch a model rocket so its flight path will carry it against a target. If my model rocket suffers a misfire, I will not allow anyone to approach it or the launcher until I have made certain the safety interlock has been removed or that the battery has been disconnected from the ignition system. I will wait one minute after a misfire before allowing anyone to approach the launcher.

11 FLYING CONDITIONS. I will launch my model rocket only when the wind is less than 20 miles per hour. I will not launch my model rocket so it flies into clouds, near aircraft in flight, or in a manner that is hazardous to people or property.

12 PRE-LAUNCH TEST. When conducting research activities with unproven model rocket designs or methods I will, when possible, determine the reliability of my model rocket by pre-launch tests. I will conduct the launching of an unproven design in complete isolation from persons not participating in the actual launching.

13 LAUNCH ANGLE. My launch device will be pointed within 30 degrees of vertical. I will never use model rocket motors to propel any device horizontally.

14 RECOVERY HAZARDS. If a model rocket becomes entangled in a power line or other dangerous place, I will not attempt to recover it.

In a spirit of cooperation and safety promotion, Model Rocketry has set an enviable safety record while fulfilling the creative needs of thousands of people. All participants are urged to read and voluntarily follow the Model Rocket Safety Code.

NATIONAL ASSOCIATION OF ROCKETRY


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