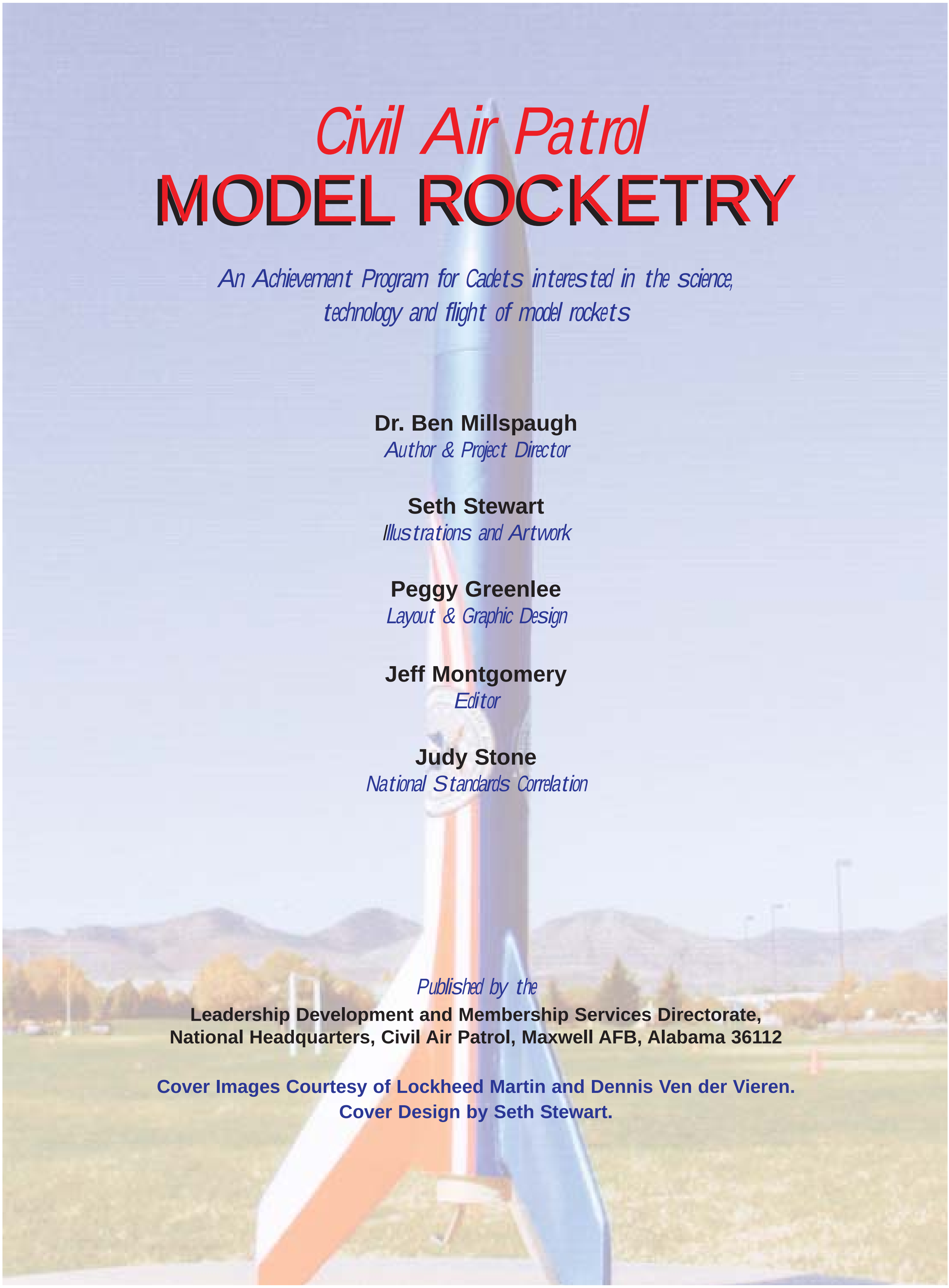
An Achievement Program For Cadets Interested In The Science, Technology, Construction and Flight of Model Rockets

CIVIL AIR PATROL MODEL ROCKETRY



Civil Air Patrol
MODEL ROCKETRY

An Achievement Program for Cadets interested in the science,
technology and flight of model rockets

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In any production, there is always a team that works directly with the author and "makes it all happen."The author expresses special appreciation to the dedication, support, encouragement and hard work given by Judy Rice, Deputy Director of Aerospace Education, Jeff Montgomery, Chief of Internal Aerospace Programs and Judy Stone, Instructional Systems Specialist. These are truly the "missionaries" of aerospace education and the author considers it an honor to work with them on any project.

This text became a reality because of the outstanding vision and leadership of James L. Mallett, Director of Leadership Development and Membership Services.

IN MEMORY

This text is dedicated to Mr. Bob Sharpe, (1945-2002) a true professional who gave much of his life sharing the excitement of model rocketry and aerospace education with others. He was one of the best and he will be missed.

Dr. Ben Millspaugh
Author & Project Director
National Headquarters Staff CAP

Table of Contents

Introduction

THE NEW CAP
MODEL ROCKETRY PROGRAM

THE BASICS

This pamphlet was designed to be a transition from Module 4, *ROCKETS*, of Aerospace Dimensions, into the hobby and science of model rocketry. The author starts out with simple alternative-power models and progressively challenges the cadet with more advanced models.

This publication is about the basics. The author wants the cadet to understand the basics of rocket history, rocket science, rocket building, and the safe launch and recovery of a model rocket.

Launching and recovery takes only a few seconds but a large amount of the fun of model rocketry is in the construction and finishing. For this reason, the author has used "how-to" sequential photography to elaborate on the many accepted methods of building a quality model.

The program has been developed so that even the youngest cadets can participate in and have fun building inexpensive rockets. It has been created in three stages; Redstone, Titan and Saturn. Each stage is more challenging and, upon completion of the Saturn Stage, a cadet is eligible for the official Civil Air Patrol Model Rocketry Badge.

This program was also designed to include those cadets who live in areas where solid fuel rockets are against the law. Cadets in these circumstances are given the option of launching air-powered rockets.

This program has been designed to get cadets, qualified senior members and the squadron commander all working together. Upon completing this program, the cadet will be recognized by both peers and senior staff members as having leadership skills in the field of model rocketry.

National Standards

SCIENCE STANDARDS: National Research Council (NRC)

Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Standard B: Physical Science
- Properties and changes of properties in matter
- Chemical reactions
- Motions and forces
- Transfer of energy

Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Standard F: Science in Personal and Social Perspectives
- Risks and benefits
- Natural and human-induced hazards
- Science and technology in society

Standard G: History and Nature of Science
- Science as a human endeavor
- Historical perspectives
- History of science

Unifying Concepts and Processes
- Constancy, change, and measurement
- Evidence, models, and explanation
- Form and function

MATHEMATICS STANDARDS: National Council of Teachers of Mathematics (NCTM)

4. Measurement Standard
- Understand measurable attributes of objects and the units, systems, and processes of measurment.
- Apply appropriate techniques, tools, and formulas to determine measurements.

5. Data Analysis and Probability Standard
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.

6. Problem Solving Standard
- Solve problems that arise in mathematics and other contexts.

8. Communication Standard
- Use the language of mathematics to express mathematical ideas precisely.

9. Connections Standard
- Recognize and apply mathematics in contexts outside of mathematics.

TECHNOLOGY STANDARDS: International Technology Education Association (ITEA)

Standard 8: Understanding of the attributes of design.
Standard 10: Understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
Standard 11: Ability to apply the design process.

SOCIAL STUDIES STANDARDS: National Council for the Social Studies (NCSS)

2. Time, Continuity, and Change
6. Power, Authority, and Governance
8. Science, Technology, and Society

Learning Outcomes

STAGE ONE - REDSTONE

After completing this stage, you should be able to:

- Identify historical facts about the development of rockets.
- Describe the major contributions of the four great rocket pioneers.
- Recall facts about the rocket pioneers' lives and accomplishments.
- Design, build and launch two non-solid fuel hands-on rocket options.

STAGE TWO - TITAN

After completing this stage, you should be able to:

- Explain Newton's three Laws of Motion.
- Describe the aerodynamics of a rocket.
- Design, build and launch two of the hands-on rocket options.
- Demonstrate knowledge of the NAR safety code.

STAGE THREE - SATURN

After completing this stage, you should be able to:

- Describe altitude tracking.
- Explain baseline distance.
- Describe the ingredients of a model rocket engine.
- Define Newton seconds.
- Define total impulse.
- Demonstrate knowledge of the NAR safety code.
- Design, build and launch one rocket in the Saturn stage.

The New Model Rocketry Program

Requirements

STAGE ONE - Redstone

1. The Written Phase

The cadet must successfully pass a written examination on the history of rockets and the lives of four great rocket pioneers.

2. The Official Witness Log (OWL) and Testing

The cadet must have the squadron testing officer (STO) administer the required test, and sign the cadet's Official Witness Log (OWL).

3. The Hands-On Phase

The cadet is required to build two non-solid fuel rockets, with alternate sources of power. There are four options:

(1) the rubber band powered Goddard rocket;
(2) the AlkaSeltzer® and water rocket;
(3) the rubber band junk rocket;
(4) and the compressed air and water pop-bottle rocket.

4. The Official Witness Log (OWL) and Model Rocket Flights

The cadet must have a Qualified Senior Member (QSM) witness the launch of the two models, with alternate sources of power, and sign off the Official Witness Log (OWL). A Qualified Senior Member (QSM) may be any unit command staff member, or a currently registered Aerospace Education Member (AEM).

5. The Role of the Squadron Commander

After completion of all the above requirements, the cadet is entitled to the Redstone certificate. The Squadron Commander must review the completed Official Witness Logs and sign this certificate so the cadet may advance to the Titan stage. It is recommended that the certificate be presented at a squadron awards ceremony.

STAGE TWO - Titan

1. The Written Phase

The cadet must pass an examination on Newton's Laws of Motion and Rocket Aerodynamics.

2. The Official Witness Log (OWL) and Testing

The Squadron Testing Officer (STO) must administer the written test and sign the cadet's Official Witness Log (OWL).

3. The Hands-on Phase

(1) The cadet is required to build two rockets in this stage: **One may be a commercial single-stage kit model powered by a commercial, solid fuel model rocket engine.** (The example used in the text is the Estes Alpha.)

(2) **OR** In some states, model rockets are considered a fire hazard, or for other reasons, are outlawed. If this is the case, the cadet has the option to launch and safely recover a **commercial air-powered rocket.** If the cadet chooses this option, he/she must give mathematical proof of the altitude achieved in the flight. This can be done using an astrolabe (as featured on page 29 in *Aerospace Dimensions, Rockets, Module 4)*, or one of the commercial altitude finders such as the Estes Altitrak®.

(3) If the cadet lives in an area where rockets are allowed, he/she is required to build a single-stage model rocket **that is a scale reproduction of an actual rocket from Aerospace history.** (The example given in the text is the Estes Redstone.)

(4) **If the cadet lives in an area where rockets are outlawed, a plastic scale model of an actual rocket, from aerospace history, may be built and presented to the QSM.** Rockets like the V-2, Redstone, Nike, Sidewinder, etc. are examples of scale models. Models from "sci-fi" movies, or TV series, do not count.

4. The Official Witness Log (OWL) for Construction and Flight of Rockets.

The cadet must prove, before flight, that the models are stable. The cadet may use the swing test described in the text for proof of stability. A Qualified Senior Member (QSM) must then witness the successful launch, flight and recovery of the model rockets required in this phase. **It is the responsibility of the Qualified Senior Member (QSM) to see that the NAR SAFETY CODE guidelines are followed in all model rocket launches. The cadet must demonstrate NAR Safety Code Proficiency, follow a set pre-flight checklist, and execute the launch and recovery with safety.** If the QSM feels that the cadet has been responsible in all areas of the NAR safety code, then he/she may sign the OWL for this phase.

5. The cadet must have a working knowledge of the NAR SAFETY CODE and give proof of this during all launches.

6. The Role of the Squadron Commander

After completion of all the above requirements, the cadet is entitled to the Titan certificate. The Squadron Commander must review the completed Official Witness Logs and sign this certificate so the cadet may advance to the Titan stage. It is recommended that the certificate be presented at a squadron awards ceremony.

STAGE THREE - Saturn

1. The Written Phase

a. The cadet is required to pass an examination on how to determine a model rocket's altitude at the apogee of its flight.
b. The cadet is required to pass a second component of the written examination that covers model rocket engines.
c. **The cadet is to have a working knowledge of the NAR safety code.**

2. The Official Witness Log and Testing

The squadron testing officer must administer the test and hear the recitation of the NAR Safety Code.

3. The Hands-On Phase

The cadet is required to build **ONE** rocket in the Saturn Stage.

a. The cadet MAY ELECT TO BUILD a two-stage rocket that requires two engines to reach altitude. The rocket must reach at least 500' and be safely recovered.
b. **OR** the cadet may elect to build a model rocket that is capable of carrying at least a 3-ounce pay load to an altitude of 300' or more.
c. **OR** the cadet may elect to build a model rocket that has a separate glider attachment. The glider and rocket must return to earth safely and within NAR safety codet guidelines.

d. **OR, if the cadet lives in an area where solid-fuel model rockets are outlawed, he/she may elect to build an air-powered rocket of his/her own design from scratch. It may be launched by a commercial launcher such as the Estes or Air Burst.** If this is the case, the cadet must give proof of the altitude attained, by the scratch-built model, using an astrolabe or a commercial model such as the Estes Astrotrak®. This must be verified by the QSM as part of the OWL sign-off.

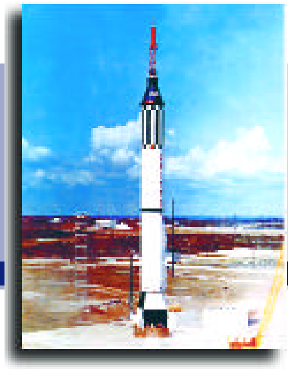
4. The Official Witness Log For Flight and Recovery of the Models

A qualified senior member (QSM) must witness the launch and safe recovery of the rocket. All of the NAR Safety Guidelines must be followed and the Official Witness Log (OWL) must be signed by the QSM after these flights.

5. The Role of the Squadron Commander.

The squadron commander is required to sign the OWLs for the Saturn stage. After completion of this stage, the cadet is entitled to receive the official CAP Model Rocketry Badge. It is recommended that this honor be given to the cadet at a squadron awards ceremony.


REDSTONE
Stage One
UNITED



REDSTONE Requirements

1. THE WRITTEN PHASE

The cadet must successfully pass a written examination on rocket history and the lives of rocket pioneers.

2. THE OFFICIAL WITNESS LOG (OWL) AND TESTING

The cadet must have the Squadron Testing Officer (STO) administer the written examination and sign the Official Witness Log (OWL) after a successful score is achieved by the cadet.

3. THE HANDS-ON PHASE

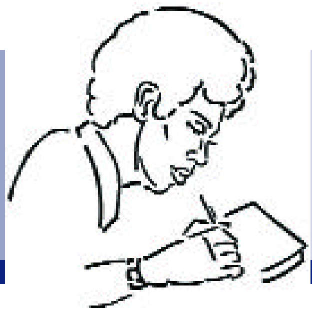
The cadet is required to build two non-solid fuel rockets, with alternate sources of power. There are four options in this text; the cadet must complete two.

4. THE OFFICIAL WITNESS LOG (OWL) AND MODEL ROCKET FLIGHTS

The cadet must have a Qualified Senior Member (QSM) witness the successful launch of the two models built with alternate sources of power.

5. THE SQUADRON COMMANDER

After completion of all the above requirements, the cadet is entitled to the Redstone certficate. The Squadron Commander must review the completed Official Witness Logs and sign this certificate so the cadet may advance to the Titan stage. It is recommended that the certificate be presented at a squadron awards ceremony.



REDSTONE Written Phase

A BRIEF HISTORY OF ROCKETRY AND ITS GREAT PIONEERS

Perhaps the first true rockets were "accidents!" In the first century AD the Chinese were reported to have experimented with a simple explosive powder made from saltpeter, sulfur and charcoal. Although these powders were used to create small explosions in religious festivals, they eventually ended up in a weapon. The Chinese would fill bamboo tubes with this mixture and attach them to arrows. These "fire arrows," as they were called, were used at the battle of Kai-Keng where the Chinese repelled the Mongol invaders with a "rocket barrage." This occurred in the year 1232.

Much later, in 1405, a German engineer by the name of Konrad Kyeser von Eichstadt devised a rocket that was propelled by gunpowder. Another European country, France, used rockets to defend Orleans against the British in 1429 and again at the siege of Pont-Andemer in 1449.

During the Thirty Year War (1618-1648) rockets weighing as much as 100 pounds were fired. These exploded and sent small pieces of shrapnel in all directions. Rockets were extensively used in India when they were fired at the British in the battles of Seringapatam (1792 and 1799).

During the latter part of the 17th century the scientific foundations for modern rocketry were laid by Sir Isaac Newton, a great British scientist. Newton organized his understanding of physical motion into three scientific laws (covered in the Titan Stage of this text). Newton's laws soon began to have a practical impact upon the design of rockets in those days. During the 18th century, rockets experienced a brief revival as a weapon of war. India used rockets with great success against the British in 1792 and this caused Colonel William Congreve, a British artillery expert, to start using more of a scientific approach to the development of sophisticated rockets. He standardized the composition for gunpowder explosives and then added flight-stabilizing guide sticks. Congreve was able to increase the rocket's range from approximately 300 to over 3000 yards. Approximately 25,000 Congreve rockets were used in 1807 at the battle of Copenhagen.

In the War of 1812 between Britain and the United States, the British used rockets against the U.S. troops. During a typical siege the rockets would light up the night sky and in the battle at Fort McHenry, in 1812, Francis Scott Key witnessed the display. This inspired him to write a poem which later became part of America's National Anthem, the "Star Spangled Banner."

Even with William Congreve's technological developments the accuracy of rockets still left much to be desired. William Hale, an Englishman, developed a technique called spin stabilization. In this technology, the escaping exhaust gases struck small vanes at the bottom of the rocket, causing it to spin like a bullet in flight. This gave the rocket much greater stability and accuracy.

Even with improvements in stabilization the rocket was never used as a major military weapon until the 20th century. Standard artillery was much more widely used because of the superior accuracy of a cannon projectile for hitting a specific target.

By the end of the 19th century, men were beginning to dream of traveling into space and reaching other planets. To accomplish such a feat required a machine that had great power and speed. At first, the scientific community scoffed at the idea of space flight, but a few brave scientists continued to dream and even develop experiments using rocket power.

FOUR OF THE GREAT ROCKET PIONEERS

Konstatin Eduardovich Tsiolkovsky (1857-1935)

Tsiolkovsky was a Russian teacher who made some of the first mathematical computations for rocket flights into space. He was born in Izhevskoe, Russia, and was the 5th of 18 children. His father was a forester by trade.

Konstatin Eduardovich Tsiolkovsky

He was a visionary and is still considered by his countrymen to be the first scientist to lay the foundation for space exploration. At the age of ten, he came down with scarlet fever and was handicapped with near total deafness for the rest of his life. This disability forced him to turn inward and he developed a lifelong passion for books. The hearing impairment forced him to leave public education, and it was then young Konstatin decided to educate himself at home. In the early 1870's, his family recognized the boy's brilliance and sent him to Moscow to study. Here he met Nikolai Fedorov, an eccentric philosopher who shared his radical theories on "cosmism." This relationship had a profound effect on the future thinking of the young Tsiolkovsky. Historians agree that Nikolai Fedorov's theories inspired Tsiolkovsky's interest in space flight. In his quest to read everything about the subject, he discovered the novels of Jules Vern and was especially fascinated with the novel *Earth To The Moon* (1865).

He decided to try his own luck at writing science fiction and his work reflected technical expertise that was based on real science, not fantasy. This included such previously unknown concepts such as microgravity, space suits and control of a rocket outside the atmosphere.

Years of study paid off when Tsiolkovsky passed the examination to become a certified teacher. He moved to the town of Borovsk where he was assigned to teach mathematics. During this period, he met and married Varvara Sokolova in 1880. Over the next few years, the teacher-scientist wrote a piece titled *Svobodnoe Prostranstvo* or "Free Space." It was never published during his lifetime, but was later put into print in the mid-twentieth century. In this historic text he spoke of vacuum, weightlessness and many of the other dangers facing future space voyagers. He also talked about using gyroscopes to control the orientation of a spacecraft.

In 1903, Tsiolkovsky published an article titled *"The Exploration of the World Space with Jet Propulsion Instruments"* in *Nauchnoe Obozrenie* (Scientific Review) magazine. Experts now recognize this as being the first true, scientifically-based proposal for space exploration. In the article, he formulated relationships between the changing mass of a rocket as it burned fuel, the velocity of exhaust gases and the rocket's final velocity. His work also included, and illustrated, a rocket engine that was fueled by liquid hydrogen and oxygen, a fuel combination that is used to this day in the Space Shuttle. In later works, he spoke of multi-stage rockets, rocket-powered airplanes, an orbiting space station and eventually colonization of the galaxy.

Although he never built an actual rocket, he did lay much of the groundwork in theoretical aerospace engineering. He was a humble teacher who is, today, held in the highest regard by the people of Russia. He is recognized as the **Father of Space Travel.**

Hermann Oberth (1894-1989)

Hermann Julius Oberth was born on June 25, 1894 in the town of Hermannstadt, Transylvania. In some circles he too is given the title of "Father of Space Travel." His interest in rocketry started in 1905 when he was 11 years old. Once again the book *From the Earth To The Moon,* by Jules Verne, excited his imagination about the possibilities of manned space exploration. After careful study, Oberth realized that many of the "fantasies" found in the book, had sound scientific principles behind them. By age 14, Oberth theorized that a "recoil rocket"

Hermann Oberth

that could travel through space by the expulsion of exhaust gases.

As a student in college, he found that it was not much of a challenge. However, when he reached graduate school, and was working on his doctoral degree, he found many challenges and immersed himself in science. It was during this time that he wrote a thesis on the development of a rocket. This work, published in 1923, was titled *The Rocket into Planetary Space.* At first, it was rejected by the scientific community, In this book, Oberth covered concepts such as a rocket's fuel consumption, fuel handling hazards, the dangers of working with solid propellants and the possible hazards to humans. He also reasoned that as a rocket flies higher and higher, the mass of the propellant becomes less while the mass of the rocket remains unchanged. In relative terms, this means that the rocket becomes heavier in relation to the engine's ability to provide thrust. It was this thinking that gave Oberth the idea of multi-staging. When the first stage fuel is burned off, that stage should be discarded. Needless to say, that idea is still in use today.

In the thirties, Oberth developed a close working relationship with Werner von Braun. They worked together on the development of the infamous V2, or Vengence Weapon, for the German Army. Later, after World War II, the two, von Braun and Oberth, worked at the United States' Army Ballistic Missile Agency in Huntsville, Alabama.

Hermann Oberth, a great pioneer in the field of astronautics, died in West Germany on December 29th, 1989, at the age of 95. He made an enormous contribution to mankind's space exploration.

Robert H. Goddard (1882-1945)

Robert H. Goddard

Dr. Robert Goddard is considered to be the father of practical modern rocketry. Robert's father was a great believer in education and encouraged his son to experiment with things. Robert and his father spent many hours hiking through the woods studying nature. He had a telescope and while still in primary school, developed an interest in space.

Goddard eventually entered Clark University and majored in the sciences. This allowed him an opportunity to put his scientific knowledge to work with rocket experimentation. As a graduate student, Robert worked closely with a nationally-known physicist, Dr. Gordon A. Webster. This association gave him an extensive background in the sciences. He eventually earned his PhD. and was hired by Clark University as a faculty member.

After a long period of experimentation, Goddard built a successful liquid-fuel rocket that was launched on March 16, 1926, from a field near the city of Worcester, Massachusetts. Although the rocket flew for just 2.5 seconds and rose to a height of only 41 feet, it proved that liquid-fuel rockets worked. One of the great advantages of liquid-fuel is that it can be controlled, whereas, solid-fuel burns to completion once ignited.

During World War I, Goddard received a grant from the U.S. Army to work on solid fuel rocket projects. One invention, developed during this time, was a three-inch rocket fired through a steel tube. This later evolved into the well-known anti-tank bazooka that was so widely used in World War II.

In the 20s, Goddard's rocket experiments caught the attention of the media. In one of his papers, published by the Smithsonian Institution, he speculated on the eventual travel to the moon using high-powered rockets. Unfortunately, he was ridiculed by the press and this caused him to continue most of this later experiments in secret.

Goddard and his wife, Ester, eventually moved to Roswell, New Mexico, where he conducted experiments without the humiliation of the news media. Much of his work was funded by the Guggenheim Foundation and was even witnessed by Charles A. Lindbergh, world famous aviator. Although not recognized as being a scientist of any significance in the United States, his work was seen as very important by scientists in Germany who were preparing for war in Europe.

His experiments included fuel feeding devices, propellant pumps, gyroscopic stabilizers, and instruments for monitoring the flight of rockets. Just before WWII, Dr. Goddard was hired to help develop rocket-powered, quick-takeoff propulsion units for U.S. Navy aircraft. In Germany, rocketry went forward with the development of higher-powered engines. These experiments eventually evolved into the infamous V-2 which was used as intercontinental ballistic missiles against Great Britain.

After World War II, both the U.S. and Russia acquired German rocket scientists. These men formed the nucleus of a program that developed into the powerful launch vehicles used today.

DR. WERNER von BRAUN (1912-1977)

Werner von Braun was one of the most important figures in the advancement of space exploration in aerospace history. As a youth, he was inspired, like many others, by the fictional works of Jules Verne and H.G. Wells. During his teen years, von Braun became involved in a German rocket society and used this connection to further his desire to build large rockets. He

Werner von Braun

was also a great follower of Hermann Oberth and worked with him in the thirties and during the development of German rocketry during World War II. He continued his college work and eventually received a PhD. in physics.

Werner von Braun was the team leader of a group that developed the V-2 ballistic missile for the Nazis during WWII. Today, there is still controversy over his role in the use of slave labor to build the highly successful rockets. The V-2 was incredible for its time and was eventually used in the rocket development program of the United States. The V-2 was 46 feet long, weighed 27,000 pounds and had a sophisticated, but reliable liquid fuel propellant system. The rocket could fly at speeds in excess of 3,000 miles per hour and would deliver a 2,200-pound warhead to a distance of 500 miles from its launch site. Before the end of WWII, von Braun managed to get many of his top rocket scientists to surrender to the Americans. This enabled the U.S. to get most of the science and test vehicles from the Germans before the Russians.

For 15 years after the war, von Braun worked with the U.S. Army in the development of ballistic missiles. As part of the military operation, known as "Project Paperclip," von Braun and his team were sent to Fort Bliss, Texas, and did the experimental launch work at White Sands Proving Ground in New Mexico. Eventually, the team moved to the Redstone Arsenal near Huntsville, Alabama.

In 1960, the rocket center transferred from the Army to a newly established organization called NASA, or National Aeronautics and Space Administration. It was during this time that von Braun was given the task of developing the giant Saturn rockets. He was to become the chief architect of the Saturn V launch vehicle that propelled American astronauts to the moon.

He became one of the most prominent spokesmen of space exploration for the United States during the latter part of his career. In 1970, NASA asked him to move to Washington, D.C., to head up the strategic planning efforts of the Administration. He left Huntsville, Alabama, but in less than two years, retired from NASA and went to work for Fairchild Industries. He died in Alexandria, Virginia, on June 16, 1977.

Rocket posters make great cadet bulletin board learning tools. This poster features many of the rockets that were the result of pioneering work of the scientists featured in this unit. It can be purchased from the Pitsco company for under $10 and is titled as "Space Rockets." Pitsco's toll-free number is 1-800-835-0686 and item number is AA52715. Cadets left to right are Nathan Cuellar, Kyle Drumm and Alec Atwood, of the Valkyrie Squadron, Denver, Colorado.

REDSTONE
Official Witness Log

WRITTEN PHASE EXAMINATION

A cadet is required to have a basic knowledge of rocket history and the lives of aerospace pioneers Robert H. Goddard, Konstantin Tsiolkovsky, Werner von Braun and Hermann Oberth. Once the cadet has studied the text and feels ready, he/she must take an examination administered by the Squadron Testing Officer (STO). The minimum passing grade for this examination is 70%. Upon successful passage of this test, the cadet must have the STO sign this document.

CADET ____

of____
Squadron, has successfully passed the written examination required of the Redstone phase.

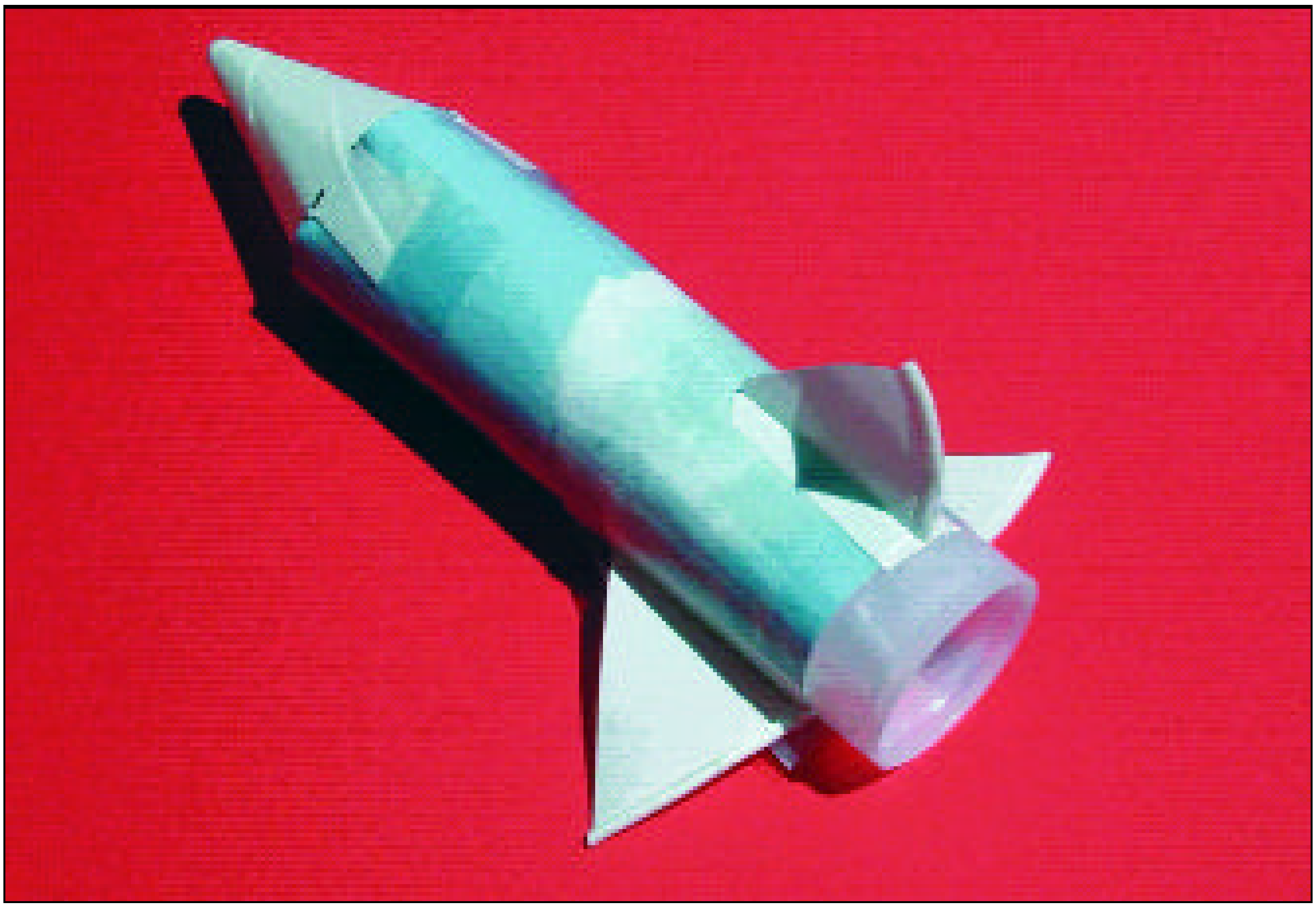
As the STO, I have administered the test and found that Cadet

____
passed with a score that meets or exceeds the minimum requirements of the Redstone phase of the Model Rocketry achievement program.

____
STO

REDSTONE
Hands-on Option One

THE FIZZY FLYER



The Completed Rocket

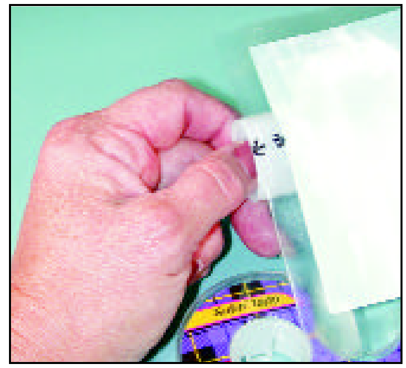
OBJECTIVE: This "Fizzy Flyer" is designed to be an entry-level rocket. It is a rocket that is incredibly easy to build, incredibly cheap to operate, and incredibly fun for cadets.

MATERIALS:

1. 4" X 4" Piece of paper
2. 1 cone shaped paper drinking cup
3. tape
4. scissors
5. Alka Seltzer™ or other effervescent antacid tablet
6. 35mm film cannister with lid that fits inside cannister (see page 9)

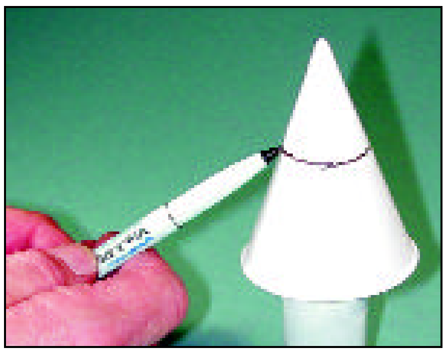
PROCEDURE:

Cut a sheet of paper to 4" x 4".
Apply tape to two sides of the paper as shown.



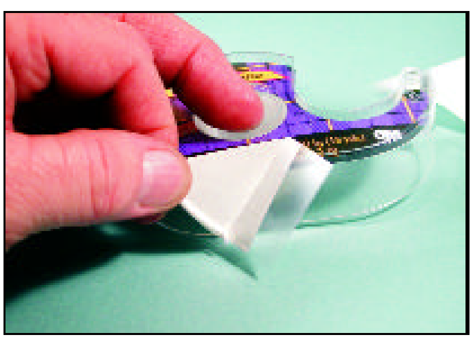
Remove lid from cannister and tape one edge to the open end about 1/2 inch up from opening.

Carefully wrap the paper around the cannister to form a tube. Press the remaining taped edge to seal the tube.

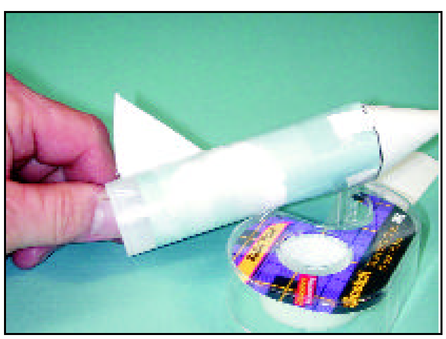


A common cone drinking cup is placed on top of the tube. By holding the cone and tube up to a light you will be able to see the top of the tube inside the cone and mark it as shown.

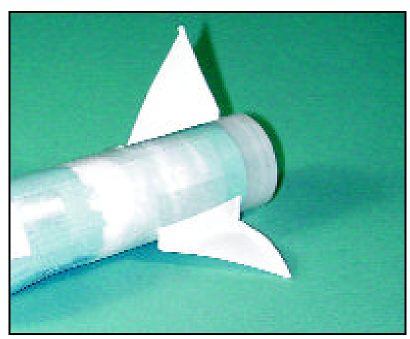
To attach the nose cone, leave little tabs so that you can tape it to the rocket's tubular body. The base of the drinking cup now becomes the rocket's nose cone.



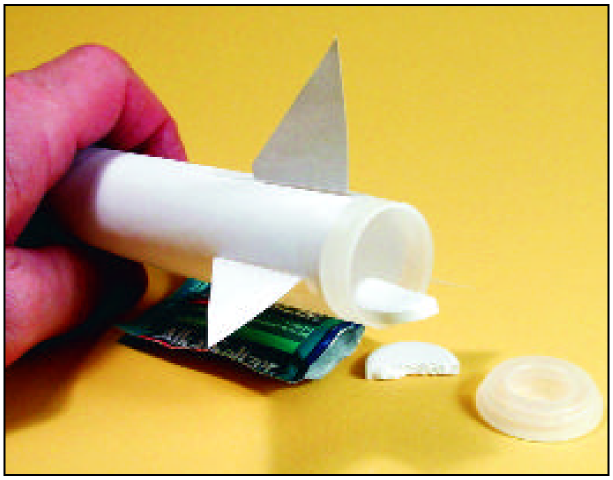
You can make tail fins from the remainder of the drinking cup, or from the remainder of the paper from which the tubular body was cut. Put tape on the fin as shown.



The fins are taped to the bottom of the rocket body next to the cannister opening as shown. This one was made from the remainder of the drinking cup.



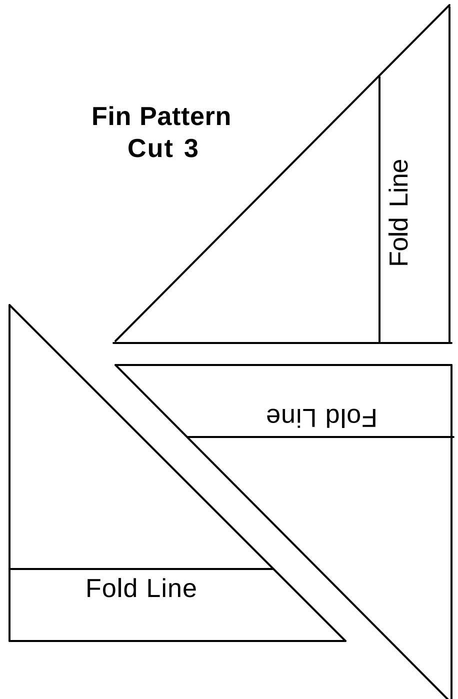
Tape 3 fins to the rocket base to make it more stable.

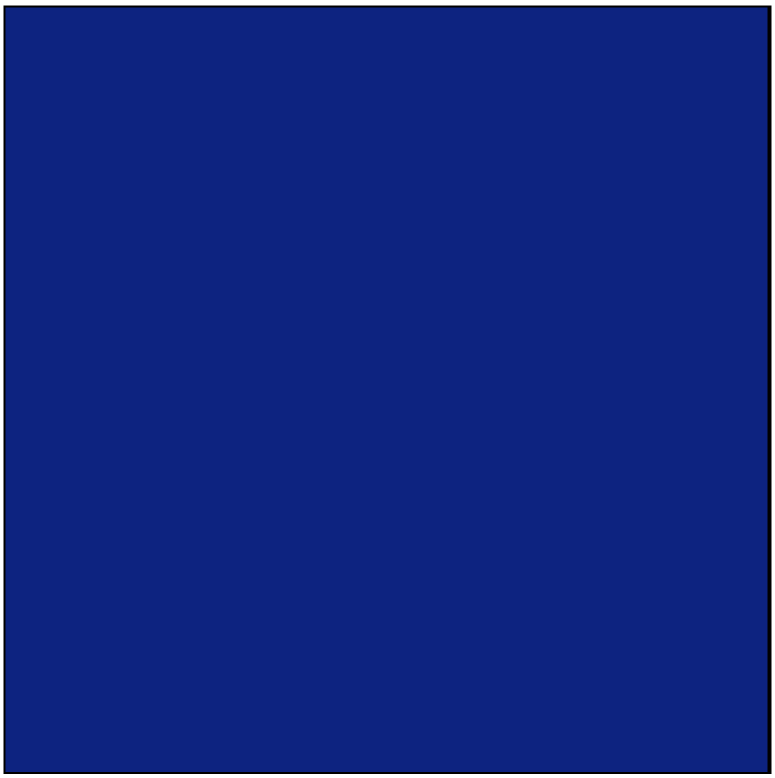


A trash bag on a table or the floor makes a good launch pad and easier clean-up.

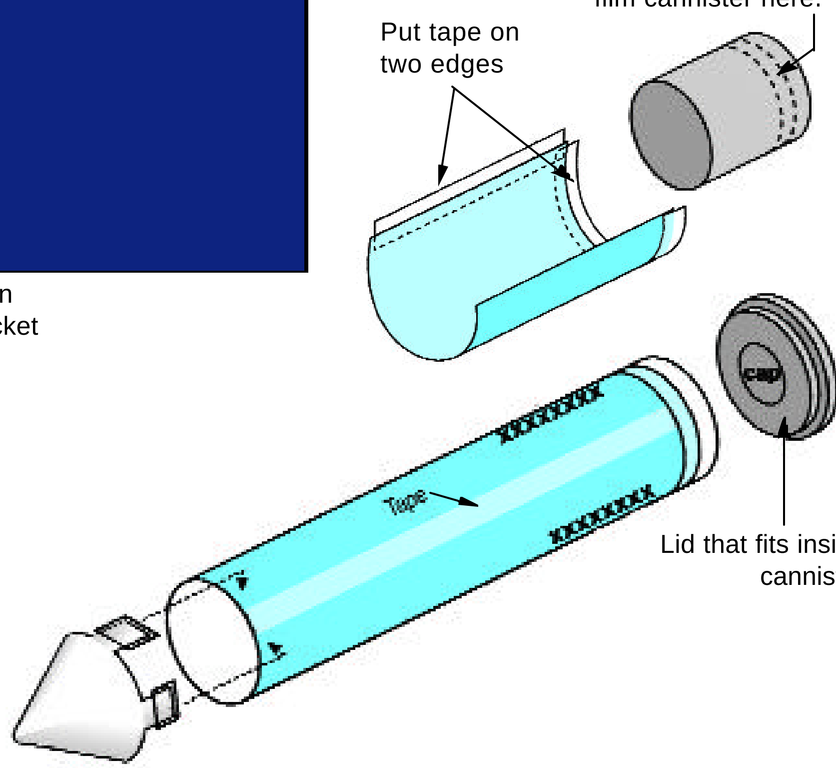
You are now ready to load the"fuel." Hold the rocket nose down, pour in 1 teaspoon of water and drop in 1/2 Alka Seltzer™. Press on the cap and position the rocket on the trash bag and wait. Countdowns are fun but it's a little difficult to tell when the Fizzy Flyer is going to take off. But that's part of the fun.

Fin Pattern
Cut 3





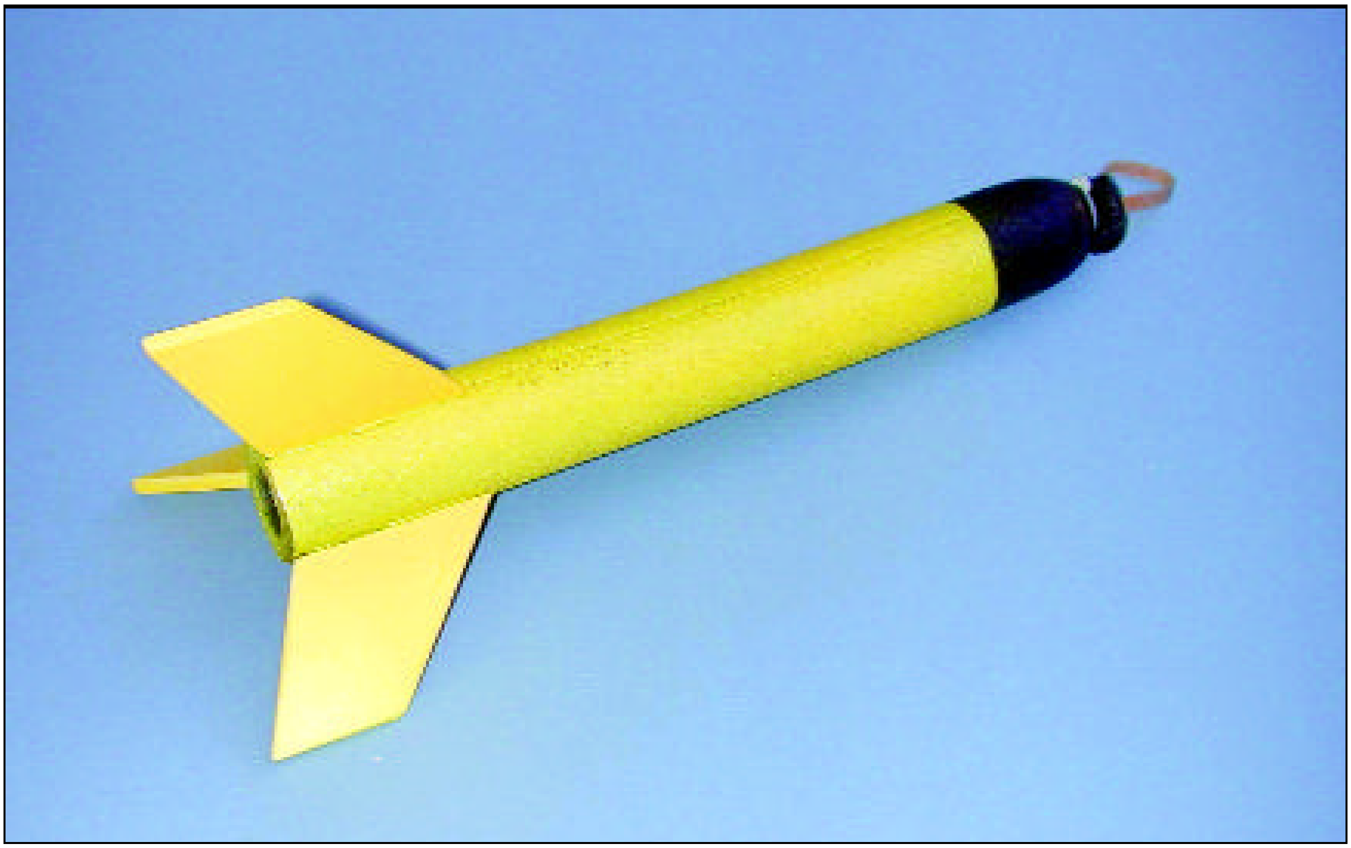
4" x 4" Pattern
for Body of Rocket



For better results, use heavy weight paper, approximately 60 lb. cover stock. It can be purchased at any office supply store.

REDSTONE
Hands-on Option Two

THE GODDARD ROCKET

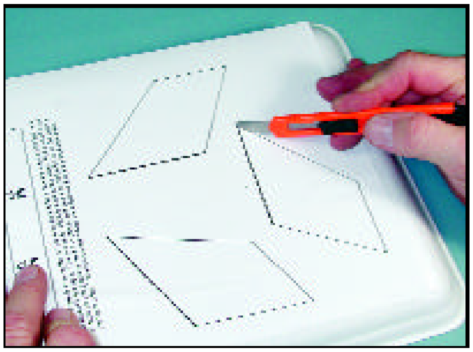


The completed Goddard Rocket - a foam rocket that can be built for a quarter!

OBJECTIVE: This activity allows cadets to build an inexpensive, safe, flying model of a rocket.

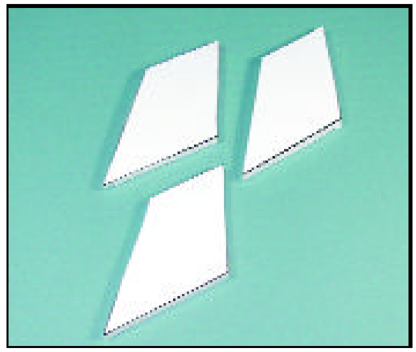
MATERIALS:

1. A template sheet for fins (make reproduction for class or squadron on a copy machine)
2. One foam meat tray
3. One pipe insulation tube cut to a length of 14” (Note foam pipe insulation tubes come in five foot lengths. You can get 4 rockets from one tube. For a class of 30, you will need 8 tubes. The cost varies, but the average is around $1.00 per tube.
4. One hot glue gun
5. One snap knife to cut foam
6. One or two cable ties
7. One #64 rubber band
8. One soda straw



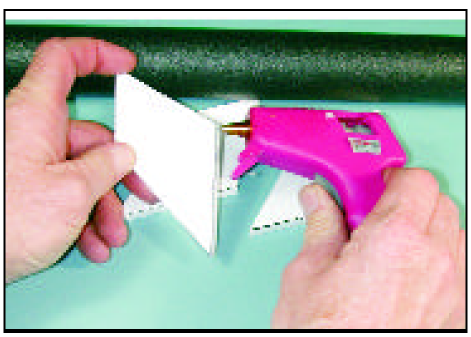
PROCEDURE:

Position the template on the foam meat tray and cut out the fins using a snap knife.

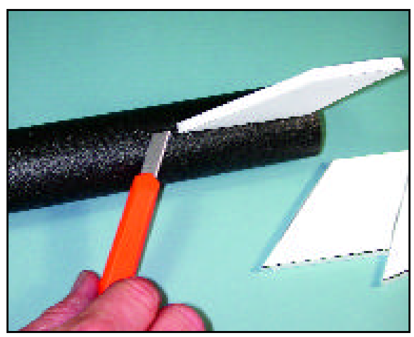


The fins may be left as is or sanded to round the edges for a more aerodynamic shape.

Cut a piece of pipe insulation to a length of 14”.

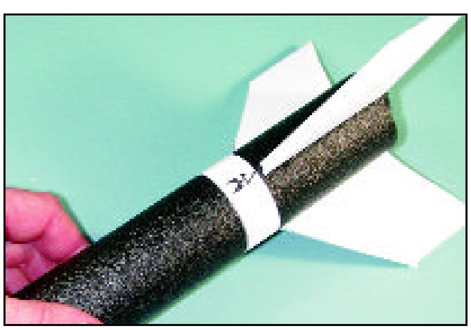


Apply hot glue to the edge of the fin, not to the pipe foam.

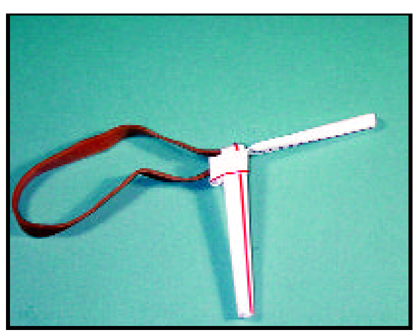


Place the fin on the pipe covering seam. This seam acts as a positioning guide.

Wrap the fin guide around the pipe foam as shown. Wrap it around the tube so that it ends at the seam. Secure with tape.

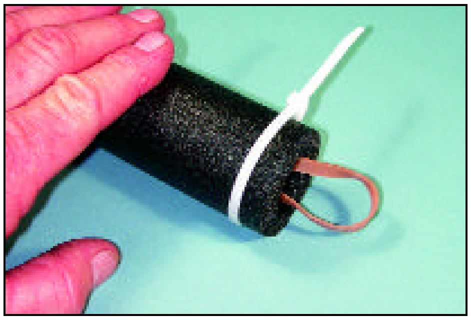


The small arrows show the builder where the other fins are to be mounted.

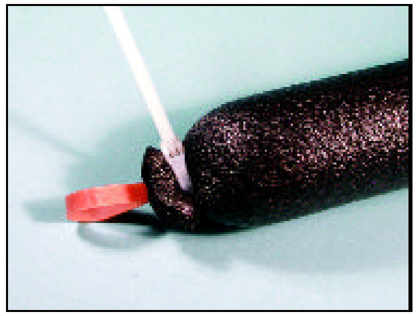


You are now ready to work on the power source. Tie a soda straw or a cable tie around a #64 rubber band.

Stuff the soda straw ends into the nose of the foam tube so that some of the rubber band sticks out.

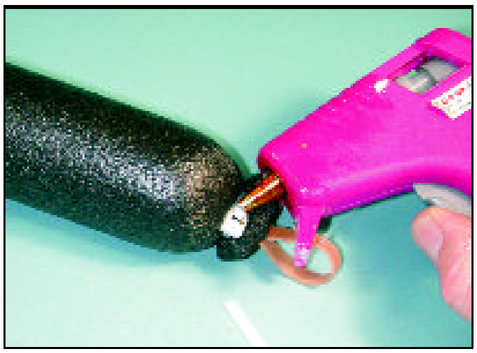


Wrap a cable tie around the opening about 3/8" from edge as shown. Notice how much of the rubber band is showing out the end of the tube.

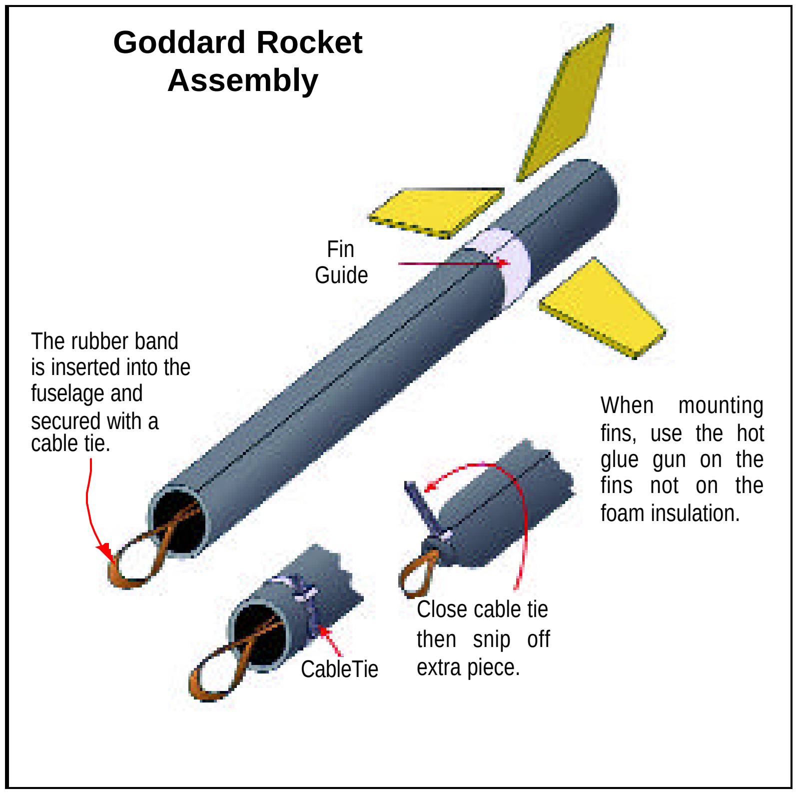


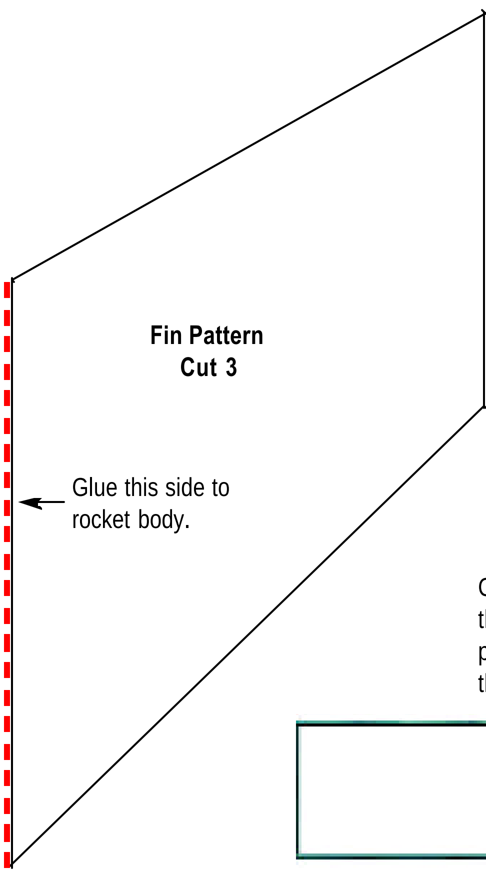
The cable is cinched down with force. Make it tight.

Trim the tail off the cable tie. Make sure that no sharp edges remain.



A big blob of hot glue is squeezed on to the cable tie head to add a measure of safety to the construction.





To Launch the Rocket

1. Put one thumb into the "tailpipe" and hold the tail firmly.
2. Put the other thumb into the rubber band.
3. Stretch the rubber band to about 4".
4. When you launch the rocket, pitch it forward in a slight arc. This adds just a small amount of thrust and makes the rocket fly straighter.

Copy the guide in the diagram below, then wrap it around the pipe foam tube a little more than 3" from the rocket's tail pipe. The two ends should meet at the seam. Put a small piece of tape on this guide to hold it in place. Hot glue one rocket fin on to the seam of the foam tube. The arrows show where the other two fins should then be mounted.

REDSTONE
Hands-on Option Three

JUNK ROCKETS

Your "junk" includes filing folders, meat trays, drinking cups, rubber bands, pipe foam insulation, Styrofoam™ Easter eggs, film cans, toilet paper cylinders, paper towel cylinders, white glue and index cards. Can you build a great rocket from these materials?

OBJECTIVE: Using only common household items, cadets can create a rocket that has a propulsion system.

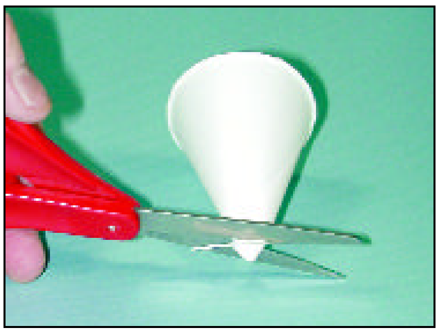
MATERIALS: The Challenge: the builder can only use common household paper, foam and plastic items. There can be no fire or explosions. The image above shows a few allowable items.

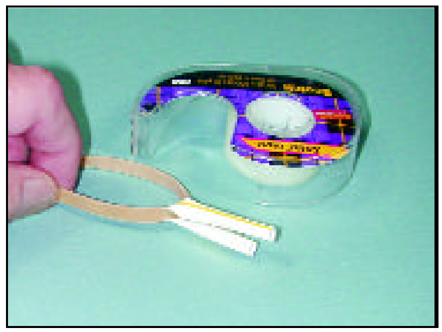
AN EXAMPLE: THE T.P. TORPEDO

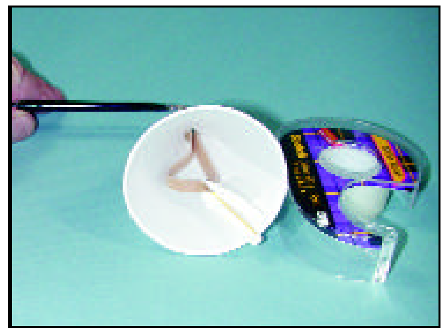
The "T.P. Torpedo!" is made from a toilet paper cylinder, a drinking cup, one rubber band, a drinking straw and the fins are made from index cards. In test flights, this "junk rocket" went more than 60 feet! Not a bad performance for a freebie!

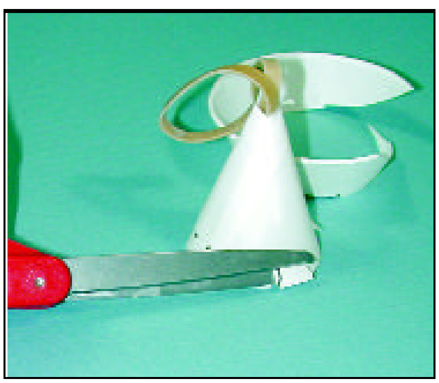
MATERIALS:

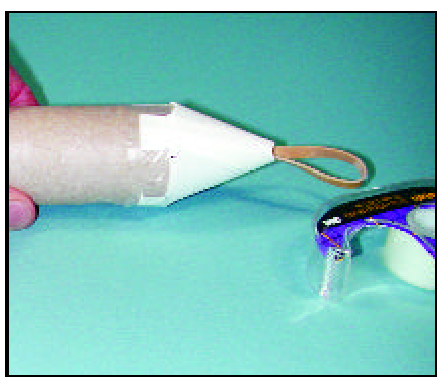
1. The "T.P." part of this activity is a cylinder from a roll of toilet paper.
2. The "propulsion" mechanism will be a rubber band that is secured inside a cone-shaped drinking cup.
3. The drinking cup will be attached to the top of the toilet paper cylinder.
4. Fins are made of index cards and attached to the toilet paper cylinder.

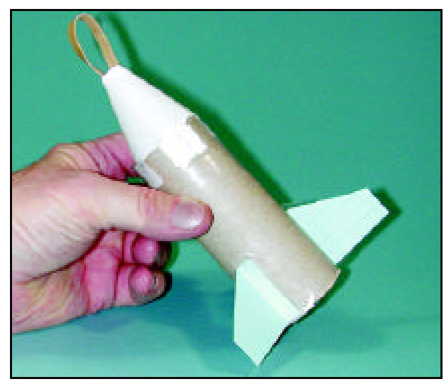

The very tip is cut off of a cone-shaped drinking cup as shown.


A piece of soda straw is bent over and taped to a #64 rubber band.

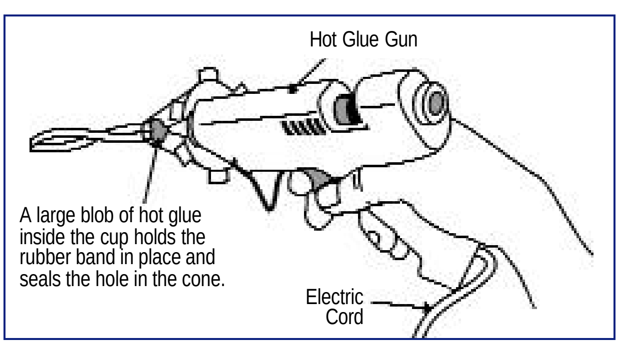

The rubber band is drawn through the hole in the cup.

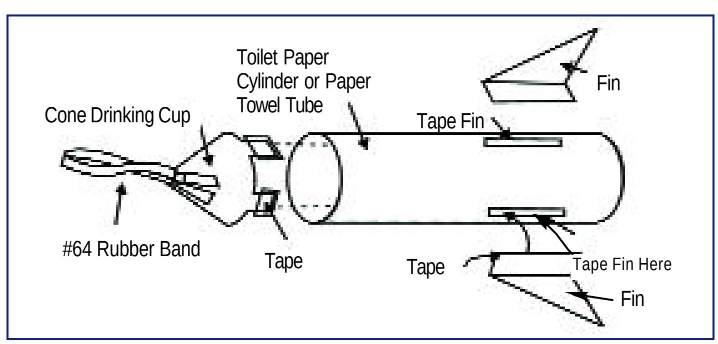

The cone is now cut so that it fits the top of the toilet paper cylinder.


Cut small tabs into the cup so that it may be taped to the t.p. cylinder.


Fins like these can be cut from index cards and taped to the cylinder. Voila! “T.P. Torpedo,” a Junk Rocket!

To launch, put one thumb in the tail pipe of the cylinder, stretch the rubber band with the other and let go.





REDSTONE
Hands-on Option Four

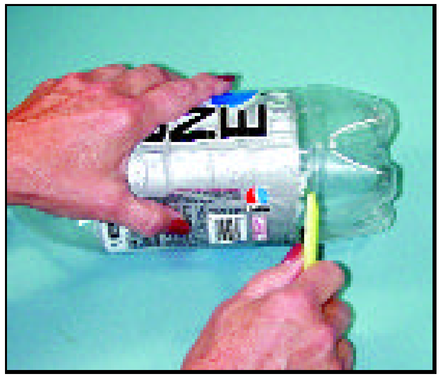
POP BOTTLE ROCKETS

Pop Bottle Rocket Mounted On Versey Launcher

The launcher shown in the photograph can be purchased by contacting Wayne Versey, Versey Enterprises, 1258 N. 1100 East, Shelly, Idaho 83274. The phone, as of this publication, was 1.208.357.3428.

OBJECTIVE: To introduce cadets to an inexpensive, high powered rocket that can be launched again and again at virtually no cost!

After countless teacher workshops and CAP activities, it has been found that the standard Pepsi™ and Coke™ two-liter bottles seem to work the best.



PROCEDURE:

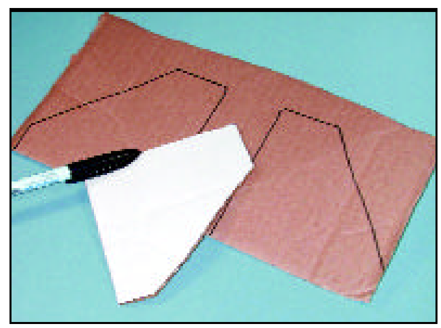
You will be adding weight to the rocket to make it come straight back down.

Cut off the bottom of one of the two-liter bottles. The bottoms of the bottles must be identical.

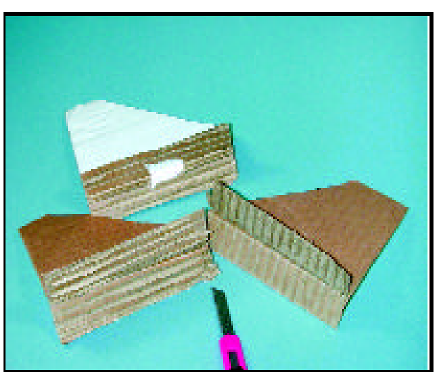
The idea is to mount several washers to the top of the bottom of a pop bottle. The bottom of the bottle will become the top or nose of the rocket. To do this, washers are going to be duct-taped to a rocket bottle and secured with a cap from another pop bottle.

The washers are positioned as shown on top of the rocket bottle.

The bottom cap that you removed from the other pop bottle is now placed over the washers and duct-taped to the rocket bottle.

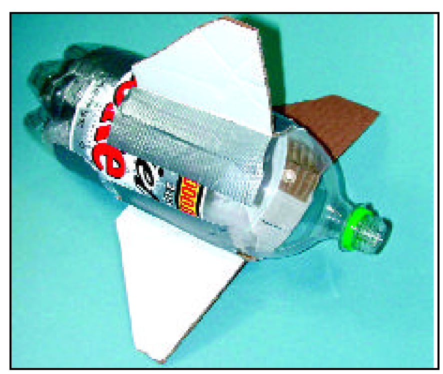


Fins can be made from just about anything; however, cardboard works very well and takes the abuse of repeated flights.

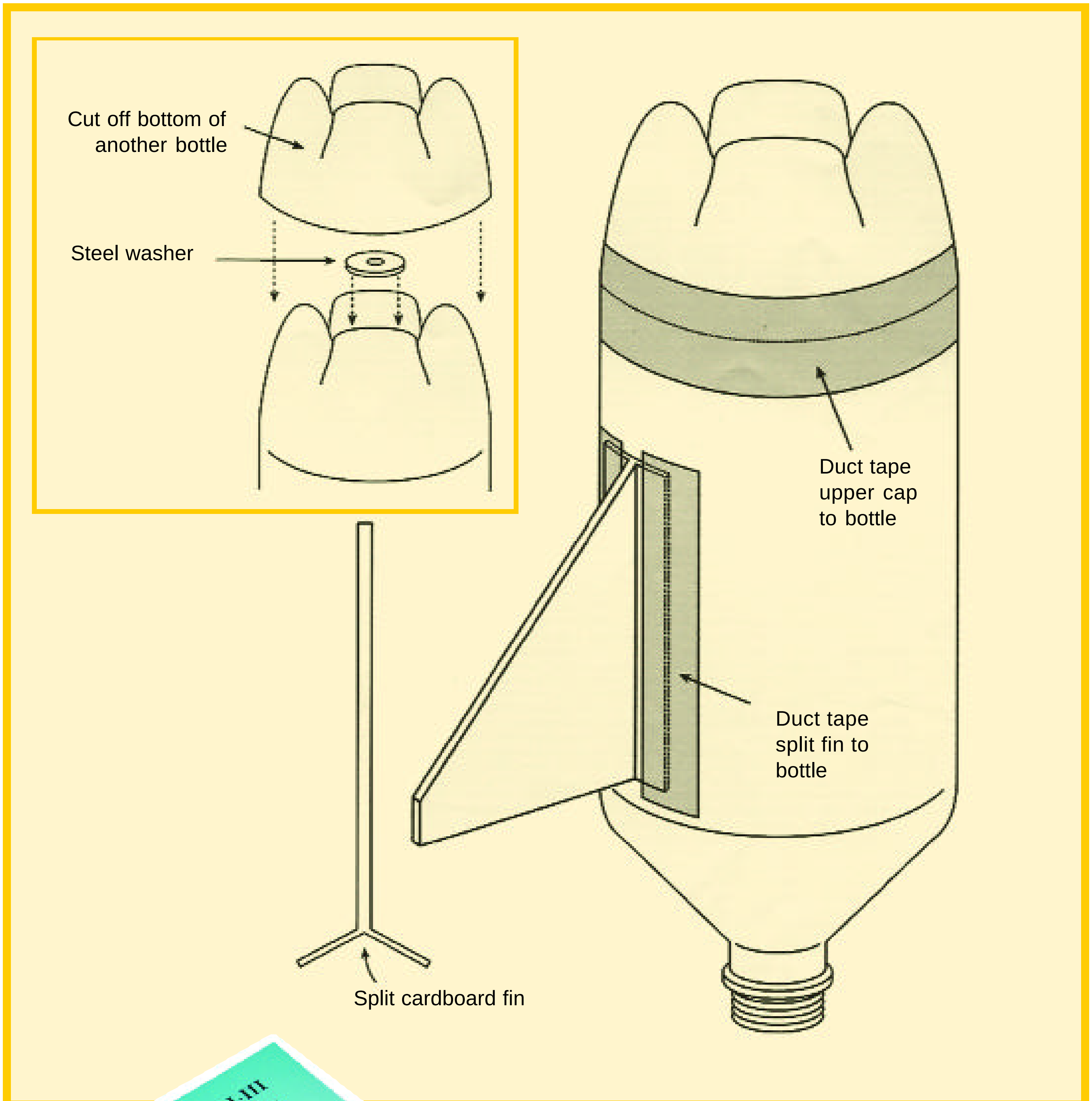


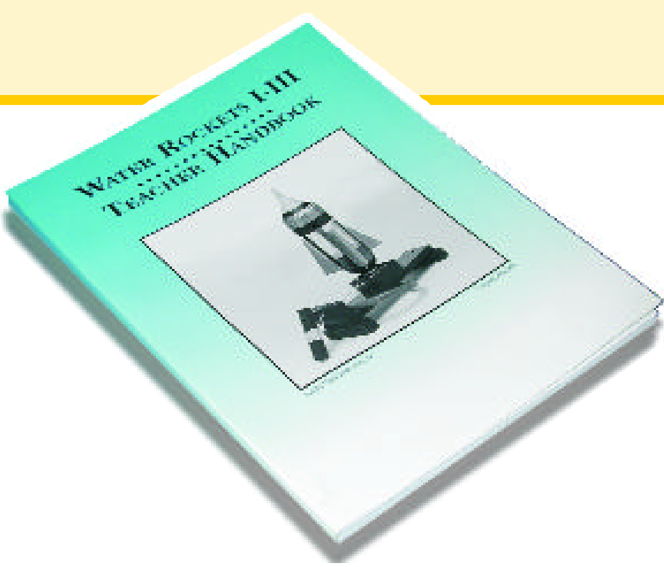
The fin pieces are split about 1" up from the bottom as shown. A snap knife works well for this task.

The reason for the splitting of the fin can be seen here. Each "flap" is used to secure the fin in place on the rocket bottle. Duct tape works very well for this mounting.



Here's your completed pop bottle rocket. To make it fly, add a little water, mount it on a launching platform, secure it with a pin, add a little pressure (start out small and work upward in pressure) then pull the pin.





Water Rockets I-III Teacher Handbook,
a highly recommended guide is available from Pitsco. **See page 78 for address and toll free number.**

REDSTONE Optional Project

NOTE: **This is an option for the Pop Bottle Rocket builder. This does not count as one of the Redstone Hands-On Options. It is only a suggested project that can be used in the launching of pop bottle rockets.**

SCRATCH-BUILDING A POP BOTTLE ROCKET LAUNCHER

The author highly recommends *Water Rockets I-III Teacher Handbook.* This outstanding guide book was written by two highly-qualified science teachers from the Lincoln, Nebraska area. The authors, Jake Winemiller, of Lincoln Southeast High School, and Ronald J. Bonnstetter, University of Nebraska, Lincoln, have produced a very detailed publication that will guide the cadet through the science and technology of bottle-rocket flight. Their manual contains information on how to build and fly bottle rockets from a beginner version up through computer-engineered, multi-stage launches! The text is available through PITSCO, an educational supply company based in Pittsburg, Kansas. Their toll-free number is 1-800-835-0686.

The author has tried numerous pop bottle rockets and launchers and found one of the best for everyday use is the one in the Winemiller-Bonstetter book. Permission has been granted from Insights Visual Productions, Inc., to feature this launcher in the Civil Air Patrol Model Rocketry program. Instructions for the creation and assembly of the launcher may be found on Pages 94-97 of the *Water Rockets I-III Teacher Handbook.*

MATERIALS:

WOOD:

1. (1) 1" x 4" x 16" Plywood, or other hardwood, that will become the base launching platform.
2. (2) 2" x 2" x 6" wooden blocks. These become the wood supports (legs).
3. (1) 2" x 3" x 4" wooden block. This is the stop block that keeps the U-shaped retainer pin from flying off the pad.
4. (1) 1" x 1" x 6" piece of wood, or a large dowel rod 1 inch in diameter, is needed for a handle.

HARDWARE:

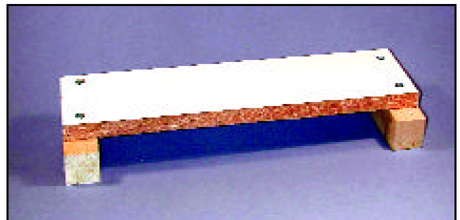
5. (1) Electrical box that is approx. 4" x 4" x 1 1/2" high. It is recommended that you use one that has two holes on each side. If you study the illustration of the basic launch pad, you will see how the steel rod (launch pin) is inserted into these holes.
6. (1) 1 foot of 3/16" steel rod. This is formed into a "pin" that secures the rocket to the electrical box.
7. (4) 1" Flat head wood screws to fasten legs to bottom of launcher.
8. (2) #10 wood screws for fastening the electrical box to the launch platform.
9. (2) 2" (#10) flat head wood screws for mounting the stop block.
10. (2) 1/2" (#8) wood screws to hold the conduit strap (1/2" EMT) to the launch pad.
11. (1) 10" x 1/2" nail to anchor the launcher to the ground.
12. (1) Large metal washer with a 5/8" hole in the center.
13. (1) 5 foot length of 5/8" inside diameter garden hose.
14. (2) Hose clamps to hold the garden hose to the PVC elbow and the valve stem.
15. (1) PVC elbow. This should be the 90° ribbed kind that has a ½" inside diameter.
16. (1) Conduit strap (½" EMT strap) to hold the elbow and hose to the launch pad.
17. (1) 10 foot length of 1/8" nylon cord to pull the launch pin.
18. (1) 9/16" cone washer. This washer provides the seal between the rocket and the PVC elbow. If you can't find one this large in a regular hardware store, they can be ordered.
19. (1) Large valve stem. These can be found at tire stores. It is shown in the illustration of the "Pressure hose assembly" on page 24.

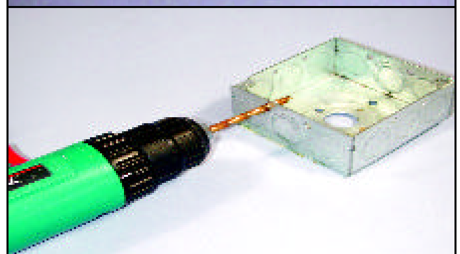
TOOLS:

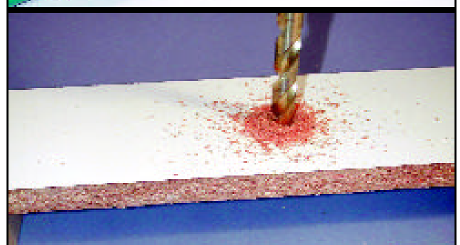
20. Hand or electric saw.
21. Electric drill.

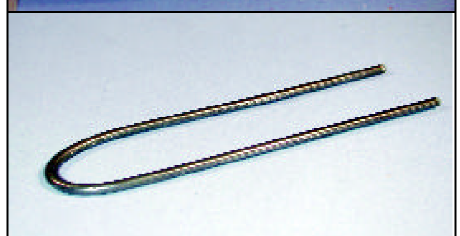
22. Drill bits, 5/8" and 7/32".
23. Dremmel tool.
24. Hack saw.
25 Hammer.
26. Broom handle.

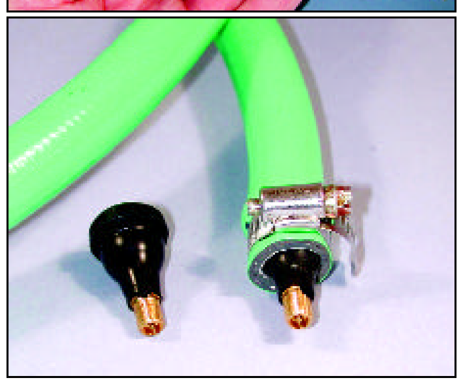
LET'S BUILD IT!







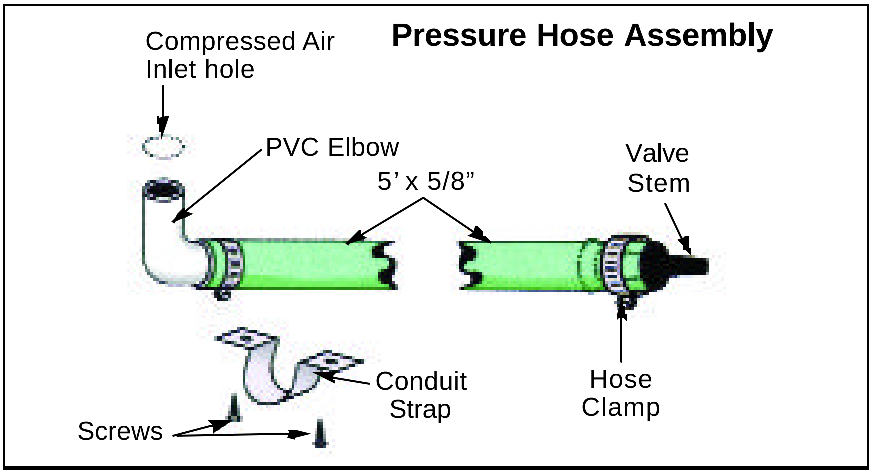


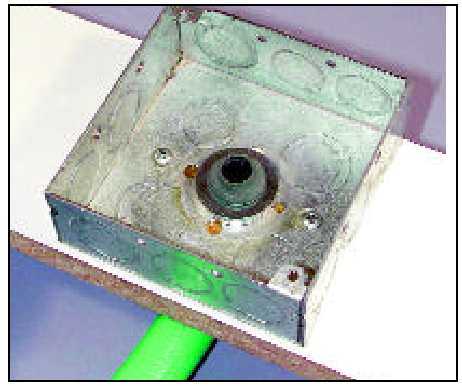


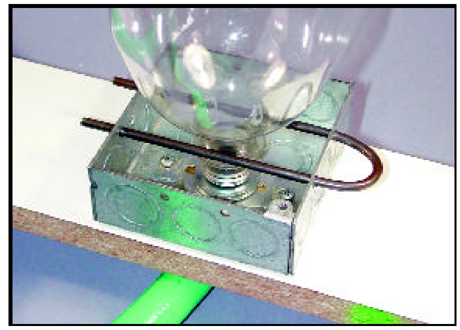
PROCEDURE:

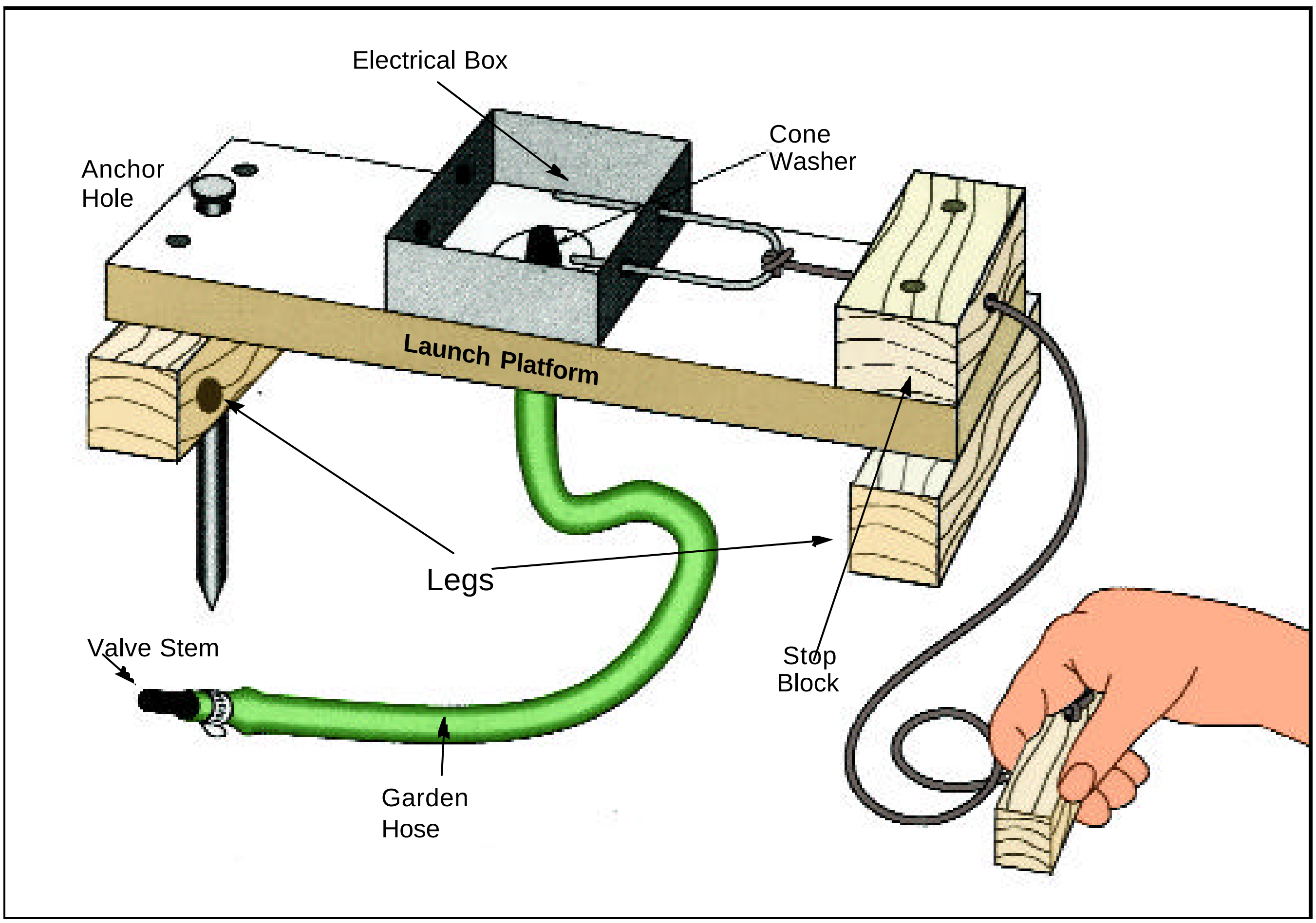
1. Using a saw, cut a piece of ¾" to 1" plywood to a 1" x 4" x 16". If you look around, places like Home Depot will often have scraps that are free. In some instances, they will even cut the piece if you tell them you are doing a CAP project in rockets!
2. Your electrical box will have two holes pre-drilled on each side. Ream out four of these holes (two each on opposite sides with a 7/32" bit.) These holes will be used to secure the U-shaped retaining pin made from the 3/16" rod.
3. Drill a 5/8" hole in the middle of the base. The hole should be approximately 7" from one end. Enlarging this opening slightly with a Dremmel tool will allow for easier assembly.
4. Using a hack saw, cut a 12" length of the 3/16" diameter rod. Bend the rod around a broom handle. That makes a nice "U" shape. Now test it in the electrical box so that slides easily in all four holes as shown in the illustration.
5. Attach the legs to the bottom of the launch pad using 1" wood screws.
6. A large nail will be used to hold the launcher to the ground. A ½" to 5/8" hole should be drilled in one of the elevation blocks to hold the nail when not in use.
7. Attach a stop block into position as shown in the illustration. It will take two 2" screws to keep it secured to the launch pad. A 7/32" inch hole should be drilled into this stop block so that the nylon pull cord can be attached to the U-shaped retaining pin and a handle on the other end.
8. Punch out the center hole of the electrical box. Attach it to the base platform so that the hole in the bottom of the box is over the 5/8" opening. Also make sure that the holes for the retaining pin are aligned as shown in the illustration. Use two ¾" #10 wood screws to secure the electrical box to the launch platform.
9. Drill an additional 5/8" hole in the opposite end of the pad from the stop block. This will be an anchor hole and will go all the way through the pad. A large nail goes through this hole and secures the pad to the ground during launch.
10. Using something like a liquid detergent, lubricate the inside of the ends of your garden hose piece.
11. Slip the PVC elbow into one end of the garden hose and secure it with a hose clamp as shown in the illustration.
12. Place the large end of the valve stem into the other end of the hose. Place the hose clamp slight ahead of the valve stem bulge and then tighten. This is essential to stop the valve stem from being blown out of the hose as pressure is added.
13. Place the PVC elbow through the 5/8" air inlet hole in the base platform. You may have to tap it in with your hammer. Secure the elbow with the ½ " Conduit strap and wood screws (#8 wood screws).
14. Add one or two 5/8" metal washers, then slip the cone gasket over the end of the PVC pipe.

15. Drill a 7/32" hole through the center of the handle and thread the cord through this hole. Knot it. Slip the cord through the hole in the stop block and tie the other end to the "U-shaped" retaining pin.
16. The cone washer is mounted over the elbow and when in position, will seal the pop bottle. The retaining pin will keep it from moving while pressure is applied.









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REDSTONE
Official Witness Log

HANDS-ON PHASE

When a cadet completes the written examination, he/she is required to have a Qualified Senior Member (QSM), witness the successful launch of TWO non-solid fuel rockets with alternate sources of power. After witnessing the successful flight of these rockets, the QSM must sign this Official Witness Log (OWL).

CADET ____

of____

Squadron, has selected the following two rockets to build of the four listed below.

1. The Fizzy Flyer
2. The Goddard Rocket (a foam tube and rubber band rocket)
3. The Junk Rocket (a paper tube, rubber band, paper cup and fins model)
4. The Pop Bottle Rocket (a compressed air model using a one or two liter pop bottle for the main body of the rocket)

As the QSM, I have witnessed the successful flight of each of the chosen rockets.

____

STO/QSM

REDSTONE STAGE
Squadron Commander's Approval

I have reviewed the Official Witness Logs, both written and hands-on, of Cadet

____

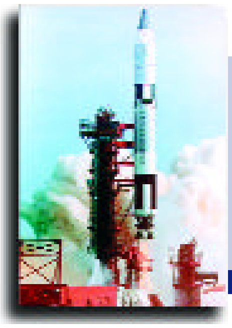
and have found that this individual has successfully passed the Redstone Stage requirements and is now qualified to advance to the Titan Stage of the Model Rocketry Program of the Civil Air Patrol.

The cadet will be now be awarded a certificate of Completion of the Redstone Stage.

____

Squadron Commander


TITAN
StageTwo



TITAN Requirements

1. THE WRITTEN PHASE

The cadet must successfully pass a written examination on Newton's Laws of Motion and the Rocket Aerodynamics.

2. THE OFFICIAL WITNESS LOG (OWL) AND TESTING

The cadet must have the Squadron Testing Officer (STO) administer the written examina tion and sign the Official Witness Log (OWL) after a successful score is achieved by the cadet.

3. THE HANDS-ON PHASE

The cadet is required to build a commercial, single-stage, solid-fuel model rocket, or if living in an area where model rockets are banned, launch an air-powered rocket. (See the section on TITAN AIR-POWER OPTION at the end) The cadet is also required to build a single stage model rocket that is a replica of one that was part of aerospace history.

4. THE OFFICIAL WITNESS LOG (OWL)FOR CONSTRUCTION AND FLIGHT OF THE REQUIRED MODEL ROCKETS

A QSM must first examine and then witness the successful launch, flight and recovery of the model rockets required in this stage. It is the responsibility of the QSM to see that all NAR Safety Code guidelines are followed in the rocket launches.

5. THE ROLE OF THE SQUADRON COMMANDER

The squadron commander must sign the Titan Certificate.

Model Rocket
SAFETY CODE

This official Model Rocketry Safety Code has been developed and promulgated by the National Association of Rocketry. (Basic Version, Effective February 10, 2001)

1. MATERIALS. I will use only lightweight, non-metal parts for the nose, body and fins of my rocket.

2. MOTORS. I will use only certified, commercially-made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer.

3. IGNITION SYSTEM. I will launch my rockets with an electrical launch system and electrical motor igniters. My launch system will have a safety interlock in series with the launch switch, and will use a launch switch that returns to the "off" position when released.

4. MISFIRES. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

5. LAUNCH SAFETY. I will use a countdown before launch, and will ensure that everyone is paying attention and is a safe distance of at least 15 feet away when I launch rockets with D motors or smaller, and 30 feet when I launch larger rockets. If I am uncertain about the safety or stability of an untested rocket, I will check the stability before flight and will fly it only after warning spectators and clearing them away to a safe distance.

6. LAUNCHER. I will launch my rocket from a launch rod, tower, or rail that is pointed to within 30 degrees of the vertical to ensure that the rocket flies nearly straight up, and I will use a blast deflector to prevent the motor's exhaust from hitting the ground. To prevent accidental eye injury, I will place launchers so that the end of the launch rod is above eye level or will cap the end of my launch rod when it is not in use.

7. SIZE. My model rocket will not weigh more than 1500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320N-sec (71.9 pound-seconds) of total impulse. If my model rocket weighs more than one pound (453 grams) at liftoff or has more than 4 ounces (113grams) of propellant, I will check and comply with Federal Aviation Administration regulations before flying.

8. FLIGHT SAFETY. I will not launch my rocket at targets, into clouds or near airplanes, and will not put any flammable or explosive payload in my rocket.

9. LAUNCH SITE. I will launch my rocket outdoors, in an open area at least as large as shown in the accompanying table, and in safe weather conditions with wind speeds no greater than 20 miles per hour. I will ensure that there is no dry grass close to the launch pad, and that the launch site does not present risk of grass fires.

Installed Total Impulse (N-sec)	Equivalent Motor Types	Minimum Site Dimensions (ft)
0.00 - 1.25	1/4A,1/2A	50
2.26 - 2.50	A	100
2.51 - 5.00	B	200
5.01 -10.00	C	400
10.01 - 20.00	D	500
20.01 - 40.00	E	1,000
40.01 - 80.00	F	1,000
80.01 - 160.00	G	1,000
160.01 - 320.00	Two G's	1,500

10. RECOVERY SYSTEM. I will use a recovery system such as a streamer or parachute in my rocket so that it returns safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

11. RECOVERY SAFETY. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places.

TITAN Written Phase

LAWS THAT GOVERN ROCKET SCIENCE

Sir Isaac Newton (Born Jan. 4, 1643, died Mar. 31, 1727)

To best understand how rockets fly, you must have a basic knowledge of the scientific rules that govern objects on the Earth and in the sky above. A rocket is a machine and it operates according to a set of scientific rules. A rocket sits on a pad (static) until it is launched into motion (dynamic). What it does on the pad, and in flight, can be studied, and to some degree, predicted by scientific laws. If you understand the laws, you will have a greater understanding of the rocket.

Although he lived hundreds of years ago, Sir Isaac Newton is one of the most highly regarded scientists of all time. His Laws of Motion are still considered to be as valid today as they were in the Seventeenth Century. During that period in history (his lifetime), much of mankind's understanding of scientific knowledge was based on superstition. His foresight and thinking was like a beacon of brilliant light overlooking a dark ocean of ignorance.

In school, you have probably heard over and over again, "for every action, there is an equal and opposite reaction." This is one of Newton's laws of motion and you might say that a law is a statement of a predictable event; a classic example is gravity. On Earth, gravity is predictable and constant; it is a force that always pulls matter toward the center of our planet. Newton made some observations of gravity and then set about to prove it with mathematics. If the math could predict an event, then a law could be written about it and that is exactly what Sir Isaac did with his theories of motion. Newton never saw a rocket in flight; however, he could have explained a great deal about it by observing its launch, flight and landing.

FIRST LAW OF MOTION

This law of motion is just an obvious statement of fact, but to know what it means, it is necessary to understand the terms *rest*, *motion* and *unbalanced force*.

Rest and motion can be thought of as being opposite to each other. Rest is the state of an object when its not changing position in relation to its surroundings. If rest were defined as a total absence of motion, it would not exist in nature! Even if you were sitting in a chair at home, you would still be moving because your chair is actually sitting on the surface of a spinning planet that is orbiting a star. The star is moving through a rotating galaxy that is also moving through the universe. While sitting "still," you, in fact are still traveling at thousands of miles per second!

Motion is also a "relative" term. All matter in the universe is moving all the time, but in the first of Newton's laws, motion means changing position in relation to the surroundings. A ball is at rest if it is sitting on the ground. The ball is in motion if it is rolling. A rolling ball changes its position in relation to its surroundings. A rocket blasting off the launch pad changes from a state of rest to a state of motion!

In rocket flight, forces become balanced and unbalanced all the time. A rocket on the launch pad is balanced. The surface of the pad pushes the rocket up while gravity pulls it down. As the engines ignite, the thrust from the rocket unbalances the forces, and the rocket travels upward. Later, when the rocket runs out of fuel, it slows down, stops at the highest point of its flight, then falls back to Earth.

Objects in space also react to forces. A spacecraft moving through the solar system is in constant motion. The spacecraft will travel in a straight line if the forces on it are in balance. This happens only when the spacecraft is very far from any large source of gravity sources such as the Earth or other planets. If the spacecraft comes near a large body in space, the gravity of that body will unbalance the forces and curve the path of the spacecraft. This happens, in particular, when a satellite is sent by a rocket on a path that is parallel to the Earth's surface. If the rocket shoots the spacecraft fast enough, it will orbit the Earth. As long as another unbalanced force, such as friction with gas molecules in orbit or the firing of a rocket engine in the opposite direction from its movement, does not slow the spacecraft, it will orbit the Earth forever.

A formal statement of Newton's First Law of Motion is: *a body in a state of rest and a body in motion tend to remain at rest or in uniform motion unless acted upon by some outside force.*

NEWTON'S SECOND LAW OF MOTION

The second law states: *The rate of change in the momentum of a body is proportional to the force acting upon the body and is in the directon of that force.* This law is essentially a statement of a mathematical equation. The three parts of the equation are "mass" (**m**), "acceleration" (**a**) and "force." (**f**). The basic formula is **f = m x a**. The amount of force required to accelerate a body depends on the mass of the body. The more mass, the more force required to accelerate it.

The term "acceleration" is defined as the rate of change in velocity with respect to time. Use a cannon as an example to help understand the application of the law. When the cannon is fired, an explosion propels a cannon ball out the open end of the barrel. The projectile flies to its target. At the same time, the cannon recoils, or is pushed backward. The force acting on the cannon and the projectile is the same. Since f = m x a, if the mass increases, the acceleration decreases; on the other hand, if the mass decreases, the acceleration increases.

Applying this example to a rocket, replace the mass of the cannon projectile with the mass of the gases being ejected out the rocket engine. Replace the mass of the cannon with the mass of the rocket moving in the other direction. Force is the pressure created by the controlled explosion taking place inside the rocket's engine. That pressure accelerates the gas one way and the rocket the other.

NEWTON'S THIRD LAW OF MOTION

Beyond any doubt, this is Newton's most often quoted scientific law! Imagine Sir Isaac, in his eloquent English voice, stating, *"For every action there is an equal and opposite reaction."* The law is so profound, so important, it is the foundation of "rocket science". The engine creates the action and the forward motion of the rocket is the "opposite reaction".

A rocket can lift off from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas and the gas in turn pushes on the rocket. The action is the expulsion of gases out of the engine; the reaction is the movement of the rocket in the opposite direction.

NEWTON'S LAWS COMING TOGETHER

An unbalanced force must be exerted for a rocket to lift off from a launch pad or for a craft in space to change speed or direction (Newton's First Law). The amount of thrust (force) produced by a rocket engine will be determined by the mass of rocket fuel that is burned and how fast the gas escapes the rocket (Newton's Second Law). The reaction, or forward motion, is equal to and in the opposite direction of the action, or thrust, from the engine (Newton's Third Law).

ROCKET AERODYNAMICS

BASICS OF STABILITY AND FORCES IN FLIGHT

A rocket is very much like an arrow. It has a long cylindrical body with fins at the back for stability. If a rocket is stable, it will fly well; on the other hand, if it is unstable its flight will be erratic, at best.

All matter, regardless of size, mass, or shape has a center of gravity. The center of gravity is the exact spot where all of the mass of the object is perfectly balanced. You can easily find the center of gravity of an object, such as a ruler, by balancing it on your finger. If the material used to make the ruler is of uniform thickness and density, the center of gravity should be at the halfway point between one end of the stick and the other. If the ruler were made of wood, and a glob of clay were stuck on one end, the center of gravity would shift toward the weight and away from the middle. You would then have to move your finger toward the weighted end to find the balance point.

It is easy to see this concept when applied to a rocket. When the engine is installed, the center of gravity will move toward the rear. If a payload is added to the front of the rocket, the center of gravity will again shift and most likely end up at a different balance point than when the rocket was empty. A change in the center of gravity will also occur when fuel is burned off in the rocket engine.

One of the first things a rocket builder learns is that a model will not fly right unless it is aerodynamically stable. Stability means that it will tend to keep its nose pointed in the same direction through its upward flight. Good aerodynamic stability keeps the rocket on a true flight path even though outside forces try to make it become erratic and unpredictable. The end result of the flight may be tumbling and a possible crash.

In the illustration below you see a line going from nose to tail. This is the longitudinal axis and a movement around this axis is called roll. A line going through the center of gravity, from side to side, is known as the lateral axis and movement around this axis is called pitch, or nose-up, nose-down. When the nose of a rocket swings from side to side, the tail moves in the opposite direction because the rotation occurs around its vertical axis. When the nose moves right, the tail moves left, and vice versa. Movement around this axis is called yaw.

Notice in the illustration there is another "center," and it is known as the center of pressure. The center of pressure exists only when air is flowing past the moving rocket. This flowing air, rubbing and pushing against the outer surface of the rocket, can cause it to begin moving around one of its three axes. For an example of this concept, think of a weather vane shaped like an arrow. This arrow is mounted on a rooftop and is used for telling wind direction. The arrow is attached to a vertical rod that acts as its pivot point. The arrow is balanced so that the center of gravity is right at the pivot point. Now, when the wind blows, the arrow turns, and the head of the arrow points into the on-coming wind. The reason that the weather vane arrow points into the wind is that the tail of the arrow has a much larger surface area than the arrowhead. The flowing air imparts a greater force to the tail.

If the center of pressure were in the same place as the center of gravity, neither end of the arrow would be favored by the wind and the arrow would not point. The center of pressure is between the center of gravity and the tail end of the arrow. This means that the tail end has more surface area than the nose end.

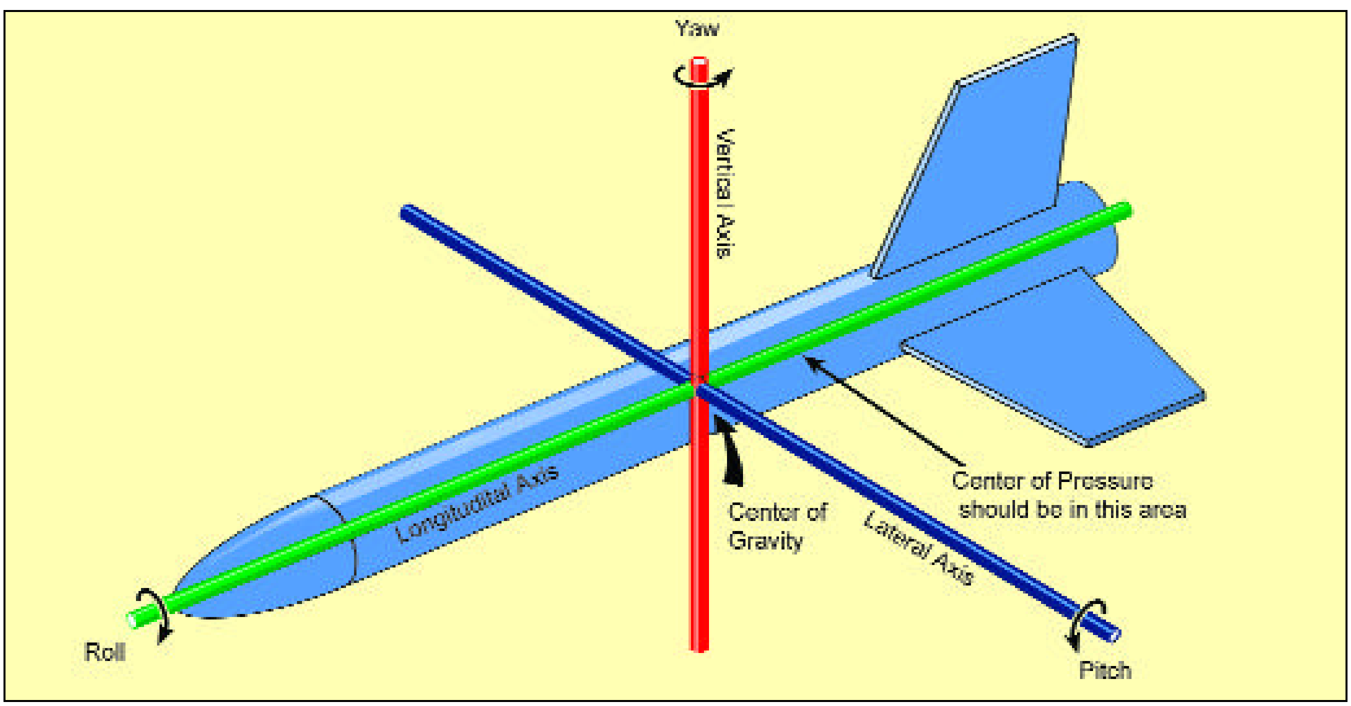
It is extremely important that the center of pressure of a model rocket be located toward the tail and the center of gravity be located more toward the nose. If they are very near each other, the rocket will be unstable in flight. With the center of pressure located in the right place, the rocket will remain stable.

FLIGHT TEST

The model is tested by first loading it with the engine, wading and all other attachments. A loop in the end of a six to ten foot long string is attached to the model at the center of gravity. When suspended, the string should be at 90° to the rocket's body. Slide the loop to the proper position around the rocket and secure it with a small piece of tape.

With the rocket suspended at its center of gravity, swing it around in a circular path. **If the rocket is very stable, it will point forward into the wind created by its forward motion**. This wind, by the way, is known as the relative wind.

Some rockets, although stable, will not point forward on their own accord unless they are started

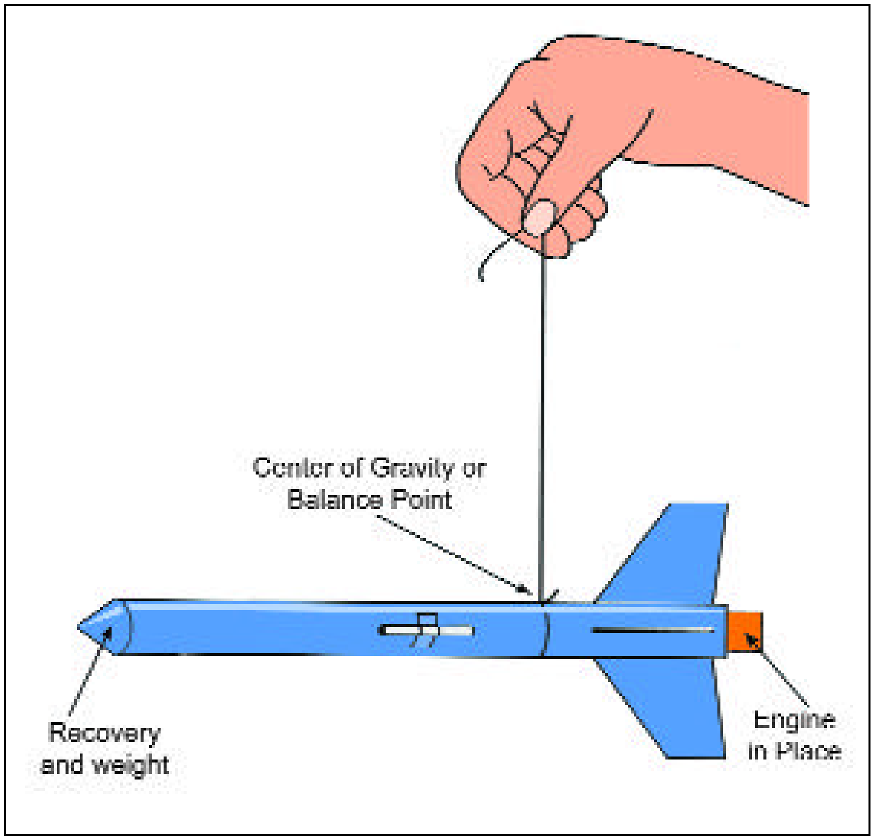


straight. This is done by holding the rocket in one hand with an arm extended and then pivoting the entire body as the rocket is started on its circular path. It may take several attempts before a good start is achieved.

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

It is recommended that a rocket not be launched until it has passed the stability test. If the rocket does not pass the stability test, it can usually be made stable. Two methods can be used: the balance point can be moved forward, or the fin area can be enlarged. To move the balance point forward, add weight to the nose cone. For models with hollow plastic nose cones, simply pack some modeling clay into the tip of the nose. To add weight to balsa nose cones, attach washers to the base of the cones where the parachute is attached. The center of gravity can also be moved forward by adding a payload section to the model. Fins can either be replaced with larger ones or additional fins can be added to the model. Once modifications are made, swing test the model until it flies in a STRAIGHT ARC.

A MODEL THAT IS BUILT AND TESTED PROPERLY WILL BE A JOY TO FLY.



The model is tested by first loading it with the engine, wading and all other attachments. A loop in the 6-10' string is attached to the model at the center of gravity. When suspended, the string should be at 90° to the rocket's body. Secure it with a small piece of tape. With the rocket suspended at its center of gravity, swing it around in a circular path. If the rocket is very stable, it will point forward into the wind created by its forward motion. This is known as the relative wind.

TITAN
Official Witness Log

WRITTEN PHASE EXAMINATION

The cadet is required to take an examination on Newton's Laws and Rocket Aerodynamics. Once the cadet has studied the text and feels ready, he/she must take an examination administered by either the Squadron Testing Officer (STO) or other qualified Senior Member (QSM). The minimum passing grade for this examination is 70%. Upon successful passage of this test, the cadet must have the STO or QSM sign this document.

CADET____

of____
Squadron, has successfully passed the written examination on Newton's Laws and Rocket Aerodynamics of the Titan Stage of the Model Rocketry Program.

As the STO, or QSM, I have administered the test and found that Cadet ____________________________________ passed with a score that meets or exceeds the minimum requirements of the Titan phase of the Model Rocketry achievement program.

____

STO/QSM

TITAN
Hands-on Option One

COMMERCIAL SINGLE-STAGE MODEL ROCKET

The Completed Estes Alpha Rocket

OBJECTIVE: This is the cadet's first opportunity to build an entry level, solid fuel powered, single-stage commercial rocket.

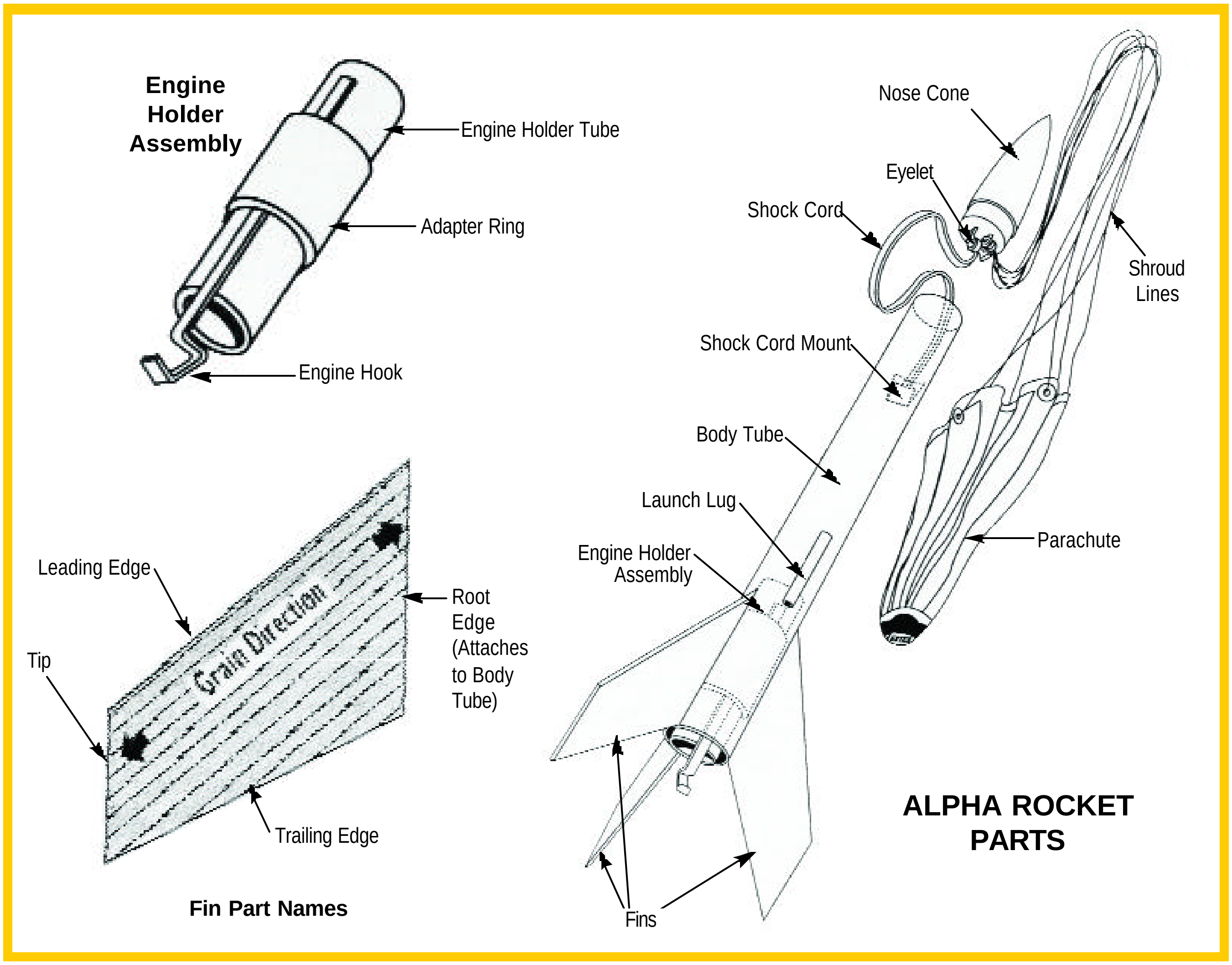
BUILDING THE ESTES ALPHA, A CLASSIC ENTRY-LEVEL MODEL ROCKET

To meet the hands-on requirements of this phase, it is necessary for the cadet to build a single-stage, solid-fuel model rocket. The author has elected to use, for illustration purposes, the Estes Alpha; it has been around for years and is still one of the best to learn the basics. The author realizes that the majority of cadets have already built model rockets, many to a very advanced level. However, after observing thousands of Civil Air Patrol and secondary school model projects, one thing stands out above all others, very few builders really know how to properly finish a model. So many rockets end up looking like cardboard toys that have been hastily built and quickly launched.

With great appreciation and thanks, Ann Grimm, Director of Education for Estes-Cox Incorporated, has provided the author with permission to use all of the instructions and illustrations from those published with their model rocket line. We begin with the instructions for the Estes Alpha.

The author has included the "Model Rocket Nomenclature" first. This will allow the cadet to learn the "language" of a model rocket. Following this is the "Model Rocket Flight Profile", and it will acquaint the builder with a picture of the launch-to-touchdown action.

At this time, the cadet is asked to review the nomenclature, list of parts ("Exploded View"), needed supplies, and building steps. Then it is recommended that the cadet buy a model rocket similar to the Alpha in basic construction. The author will take the cadet beyond the instructions into the exciting realm of model paint and finishing. Once completed, it should be a rocket that will be a source of great pride for the builder. The model featured in this unit has graphics that are similar to the Civil Air Patrol's search and rescue airplanes. It is a striking red, white and blue finish with an official CAP seal. Let the fun begin!



MATERIALS:

In the Estes Alpha instruction sheet, it states, "you will need these construction supplies. Each step shows which supplies will be required." You will need a ruler, pencil, hobby knife, glue (white or yellow), scissors, sandpaper, masking tape, sanding sealer and paint.

Cadet Nathan Cuellar, of the Valkyrie Squadron, in Denver, Colorado, reads over the Estes Alpha instruction sheet before beginning the project.

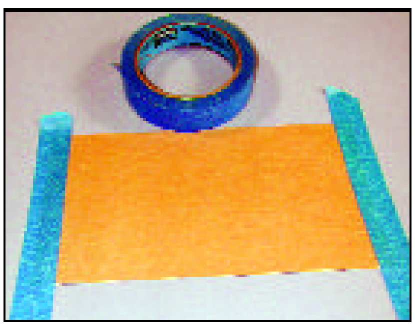
PROCEDURE

All too often, cadets get in a hurry and construct a model rocket with very little reference to the instructions. It is highly recommended that the builder go over each step carefully and arrange the parts in the order that they will be used in construction.

Grit Guide

60	Coarse
100	Medium
150	Fine
240	Very Fine
400	Super Fine
600	Ultra Fine
1500	Ultra Micro Fine

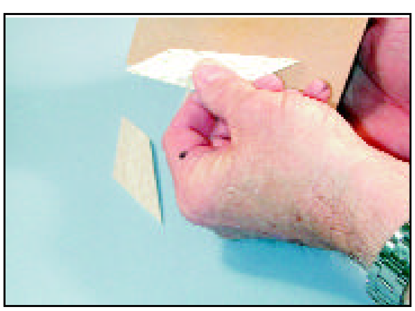
Not everybody knows the difference in sandpaper. To be sure, follow this grit guide and purchase a sheet that won't damage the balsa used on model rockets. Something in the range of 150-240 works well for sanding fins.



Masking tape can be used to hold sandpaper to a flat surface. This makes a solid base for sanding edges and flat surfaces.

The builder can also use a sanding block. The paper is wrapped around a block for sanding the balsa pieces. This creates a flat surface when sanded.

The fins can be held together and the surfaces sanded. This makes all of the fins uniform.



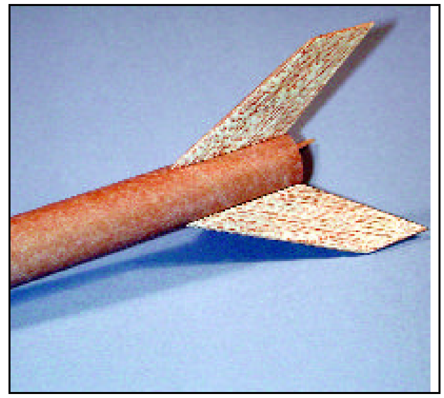
The leading edges can be rounded using the same technique.

It is highly recommended that the builder use a sanding sealer on the balsa. This seals the surface and makes a more professional looking paint finish.

The body can also be sealed. Sandable automotive primer surfacer also works well.

For sanding rounded surfaces, you can purchase a foam sanding pad at most hobby shops and some home supply stores.

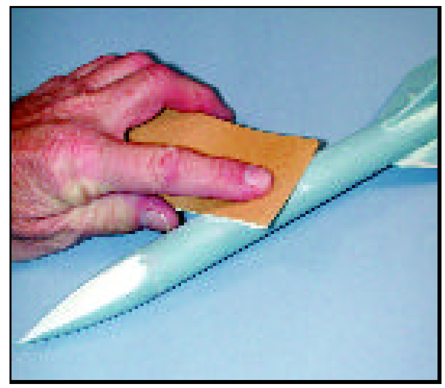
Cadet Alec Atwood applies one of two of the recommended adhesives for this type of model rocket. Both white and yellow glues work well.



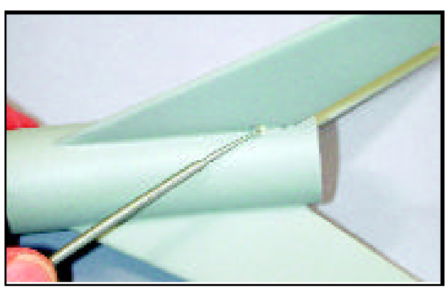
When the fins are properly aligned and glued, there should be no glue showing. It is important to have the Alpha fins 120° apart.

To make a really outstanding finish, the author recommends that the builder start out with a sandable automobile primer, or primer surfacer. The rocket body can be held by a rolled piece of paper stuffed in the open end and the first primer coat should be a "mist," or very light application. Follow with two wet coats after the mist coat dries. Let the two wet coats set for several hours, or over night, so the primer can "gas out." This means that all of the solvents in the primer have a chance to evaporate. Make sure that the primer is applied in a well-ventilated area.

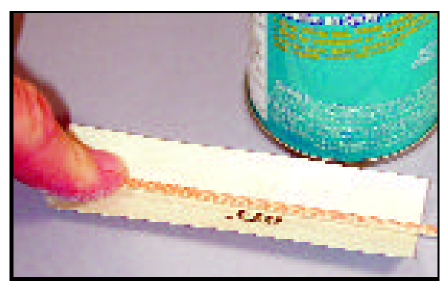
White putty, purchased at a hobby shop, can be used to fill in the imperfections in the primer finish. It can also be used to make a nice, rounded fillet between the fins and body.



When using sandpaper, be careful of this technique. The finger pressure can actually dig into the surface and make it uneven.



When sanding the area where the fin has been bonded to the body, be very careful.

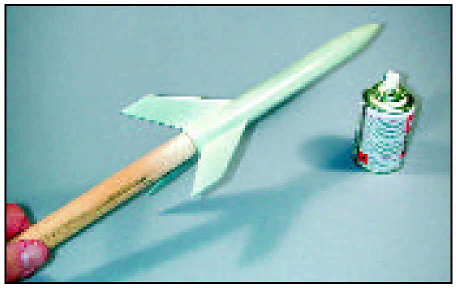


To make a round sanding "tube," roll a piece of sandpaper around a dowel rod or pencil.

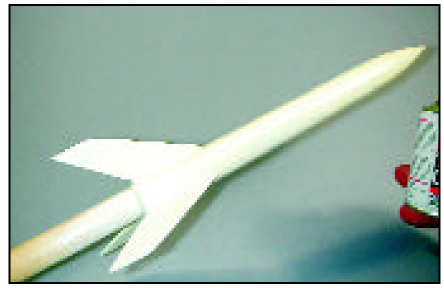
←

It is recommended that very fine sandpaper be used for the final step. After spraying one or two final coats of automotive primer, carefully sand the surface with a finer grade of paper. It is recommended that the builder let the rocket set for at least two days so the primer has a chance to cure.

Once the finish is flawless, it's time to paint. The author recommends a high quality hobby grade of paint for the rocket's base, or first, coat.

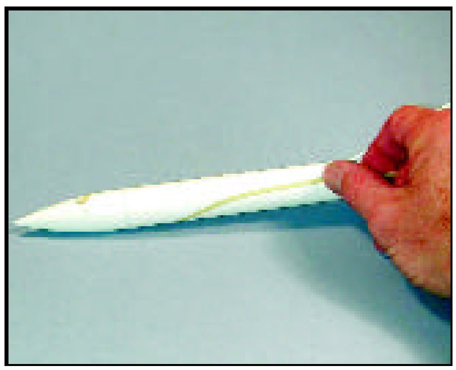


For the rocket used in this publication, the author used Tamiya TS 16 Pure White as the base coat. The rocket was held with a dowel rod while being sprayed. The first two coats are light mist followed by two wet coats. Let the model dry for about 15 minutes between coats.

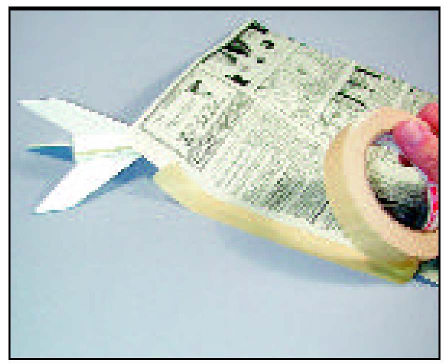


Once the builder is satisfied with the finish, it is highly recommended that the rocket be allowed to set overnight. As a matter of safety, ALWAYS PAINT YOUR MODELS IN WELL VENTILATED AREAS. NEVER PAINT NEAR A STOVE OR ANY OPEN FLAME. SOME PAINTS WILL IGNITE. And of course, wear eye protection.

If the builder wants to have a custom finish, with several colors, thin masking tape will be needed. These small roles can be purchased at hobby and automotive paint supply stores.

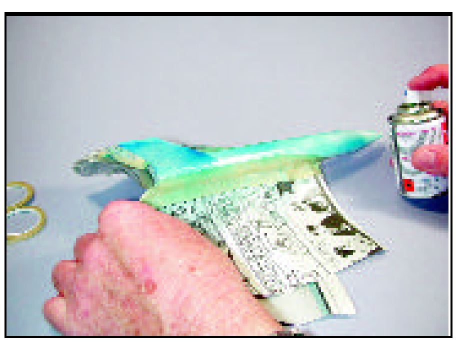


The thin (1/8 or 1/16) tape is applied to make a graphic such as this curved line. (See the photograph of the finished rocket).

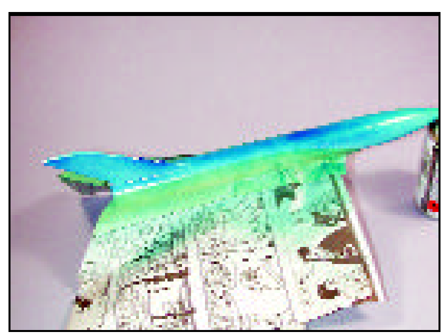


To make a larger masking paper, apply masking tape so that ½ of the tape is on the paper and the other ½ is open.

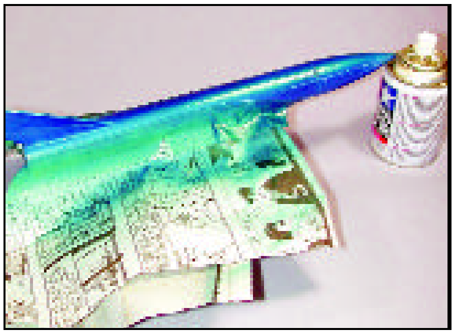
The masking tape open edge is laid down on the thin tape line. Make sure that it is properly aligned and sealed so that spray paint won't "bleed" through.



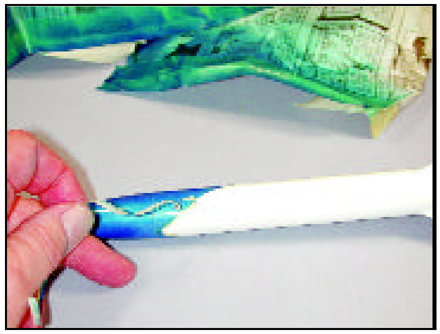
Tamiya's TS 19 Metallic Blue was used for a second color. First apply a mist coat allowing some drying time between coats. If the builder gets in a hurry, runs and sags may occur.



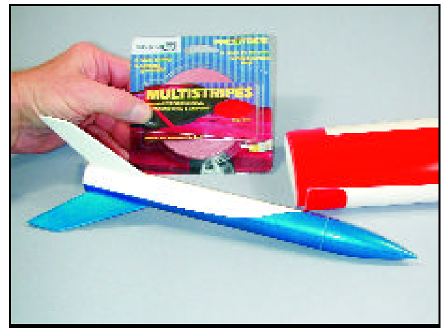
After the mist coat dries, apply a full color coat. Let dry for at least 20 minutes.



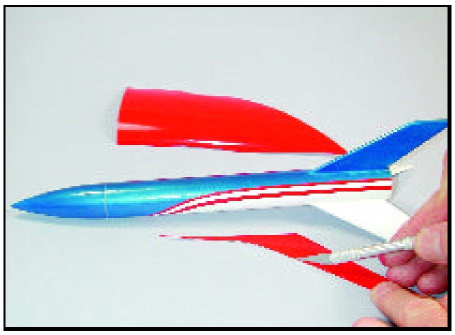
Two wet coats are applied and it is recommended that the builder let it dry overnight.



The masking paper and thin line tape can be removed after the paint is cured.



Here is a tip for making some spectacular graphics. Go to a shop that makes vinyl signs and see if they have some scraps in the colors you want. Most of the vinyl used on computer signs is as thin as a coat of paint! It is recommended that the builder experiment with these scrap sheets of vinyl on something like a two-liter pop bottle, before putting it on the body of the rocket model. Automotive striping tape shown above also works on models. The striping tape comes in various widths and colors.



The author used automotive striping tape for second line shown here. Next, a piece was cut from the vinyl sheet to make the graphic for one of the fins.

To finish off the "look," the author used the CAP seal that was purchased from the Bookstore catalog. They are inexpensive and give the rocket an "official" look!

The finished product can be seen on the TITAN Hands-On Option One page.

LAUNCH SUPPLIES

To launch your rocket you will need the following items:

1. Estes Electrical Launch Controller and Launch Pad
2. Estes Recovery Wadding No 2274
3. Recommended Estes Engines: A8-3 (First Flight), A8-5. B4-4, B4-6, B6-4, B6-6, B8-5,C6-5 or C6-7

To become familiar with your rocket's flight pattern, use an A8-3 engine for your first flight. Use only Estes products to launch this rocket.

FLYING YOUR ROCKET

A. Choose a large field away from power lines, tall trees, and low flying aircraft.Try to find a field at least 76 meters (250 feet) square. The larger the launch area, the better your chance of recovering your rocket. Football fields and playgrounds are great.

B. Launch area must be free of dry weeds and brown grass. Launch only during calm weather with little or no wind and good visibility.

C. Don't leave parachute packed more than a minute or so before launch during cold weather [colder than 4^{o} Celsius (40^{o}) Fahrenheit]. Parachute may be dusted with talcum powder to avoid sticking.

MISFIRES

If the igniter functions properly but the propellant does not ignite, keep in mind the following: An estes igniter will function properly even if the coated tip is chipped. However, if the coated tip is not in direct contact with the engine propellant, it will only heat and not ignite the engine.

When an ignition failure occurs, remove the safety key from the launch control system and wait one minute before approaching the rocket. Remove the expended igniter from the engine and install a new one. Be certain the coated tip is in direct contact wih the engine propellant, then reinstall the igniter plug as ilustrated above. Repeat the countdown and launch procedure.

FOR YOUR SAFETY AND ENJOYMENT

Always follow the NAR (National Association of Rocketry) MODEL ROCKETRY SAFELY CODE while participating in any model rocketry activities.

COUNTDOWN AND LAUNCH

10.....BE CERTAIN SAFETY KEY IS <u>NOT</u> IN LAUNCH CONTROLLER

9...... Remove safety cap and slide launch lug over launch rod to place rocket on launch pad. Make sure the rocket slides freely on the launch rod.

8...... Attach micro-clips to the igniter wires. Arrange the clips so they do not touch each other or the metal blast deflector. Attach clips as close to protective tape on igniter as possible.

7...... Move back from your rocket as far as launch wire will permit (at least 5 meters - 15 feet).

6......INSERT SAFETY KEY to arm the launch controller. Give audible countdown **5...4...3...2...1**

LAUNCH!!

PUSH AND HOLD LAUNCH BUTTON UNTIL ENGINE IGNITES.

REMOVE SAFETY KEY FROM LAUNCH CONTROLLER. KEEP SAFETY KEY WITH YOU OR REPLACE SAFETY KEY AND SAFETY CAP ON LAUNCH ROD.

If you use the ultrasafe E2™ or Command™ Launch Controllers to fly your models, use the following launch steps:

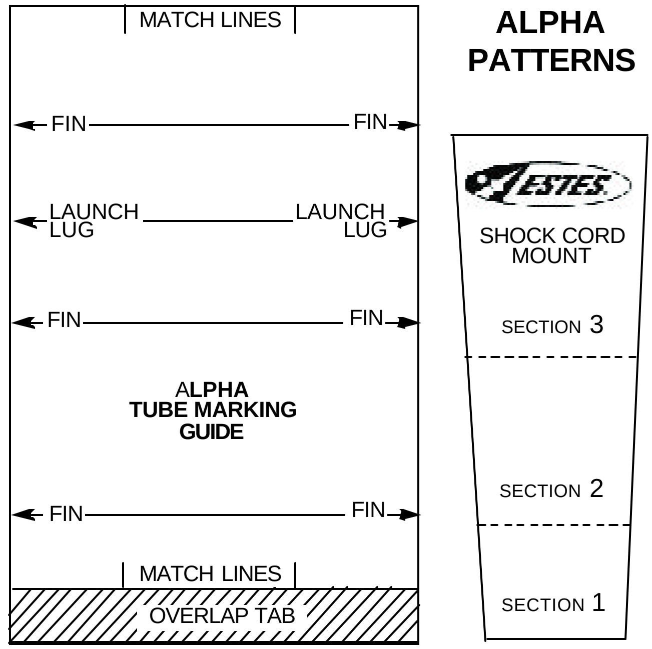
A. After attaching micro-clips, etc., insert the safety key into the controller recepticle. If the igniter clips have been attached properly to the igniter, the red L.E. D. will now begin to flash on and off and the audio continuity indicator will beep on and off.

B. Hold the yellow (left) arm button down. The L. E. D. will stop flashing and the audio indicator will produce a steady tone.

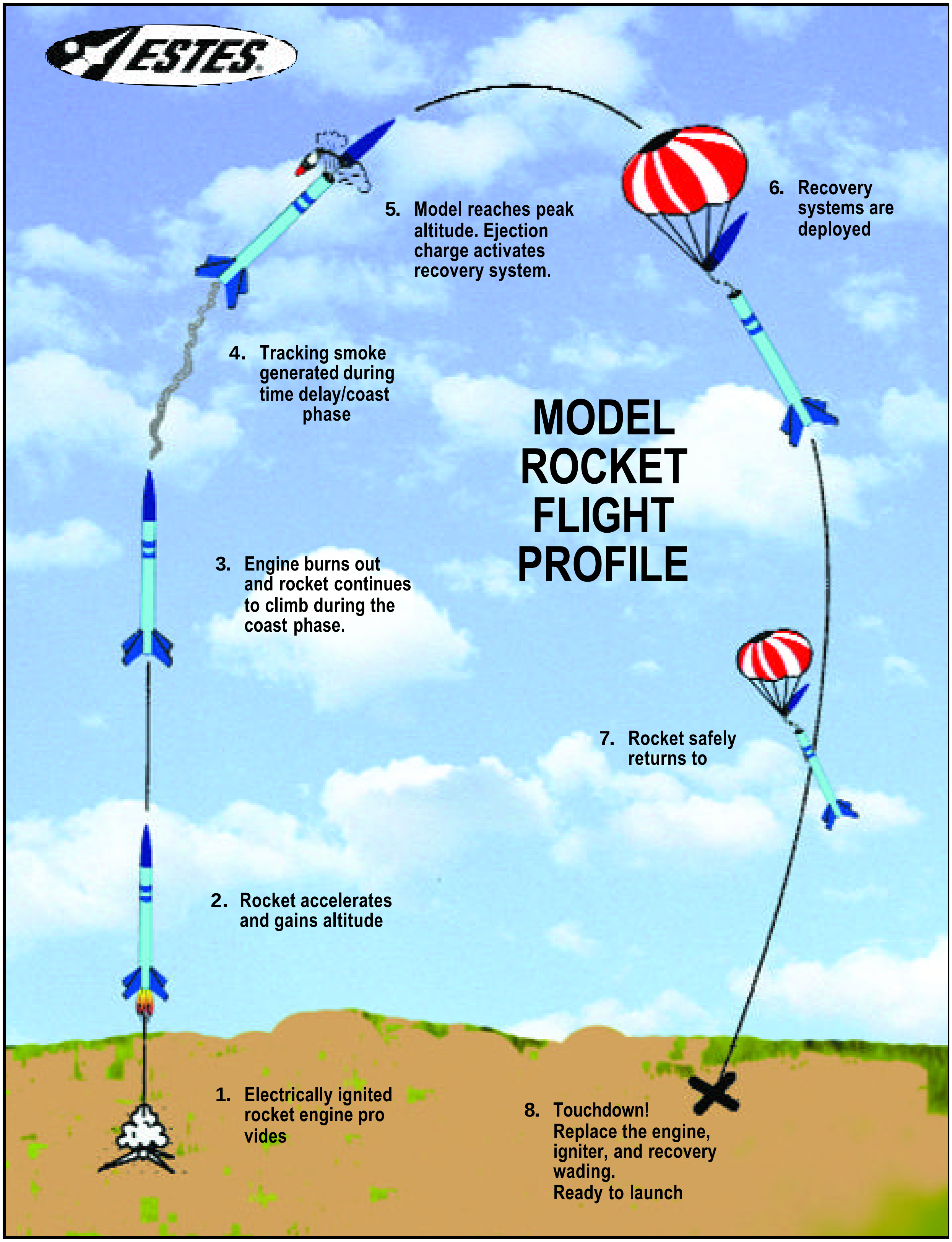
C. Verbally count down from five to zero loud enough for the bystanders to hear. Still holding the yellow arm buttondown, push and hold the orange (right) button down until the rocket ignites and lifts off.

Cadet Stark watches as Cadet Kevin Rutherford prepares his rocket for lift off.

ALPHA PATTERNS

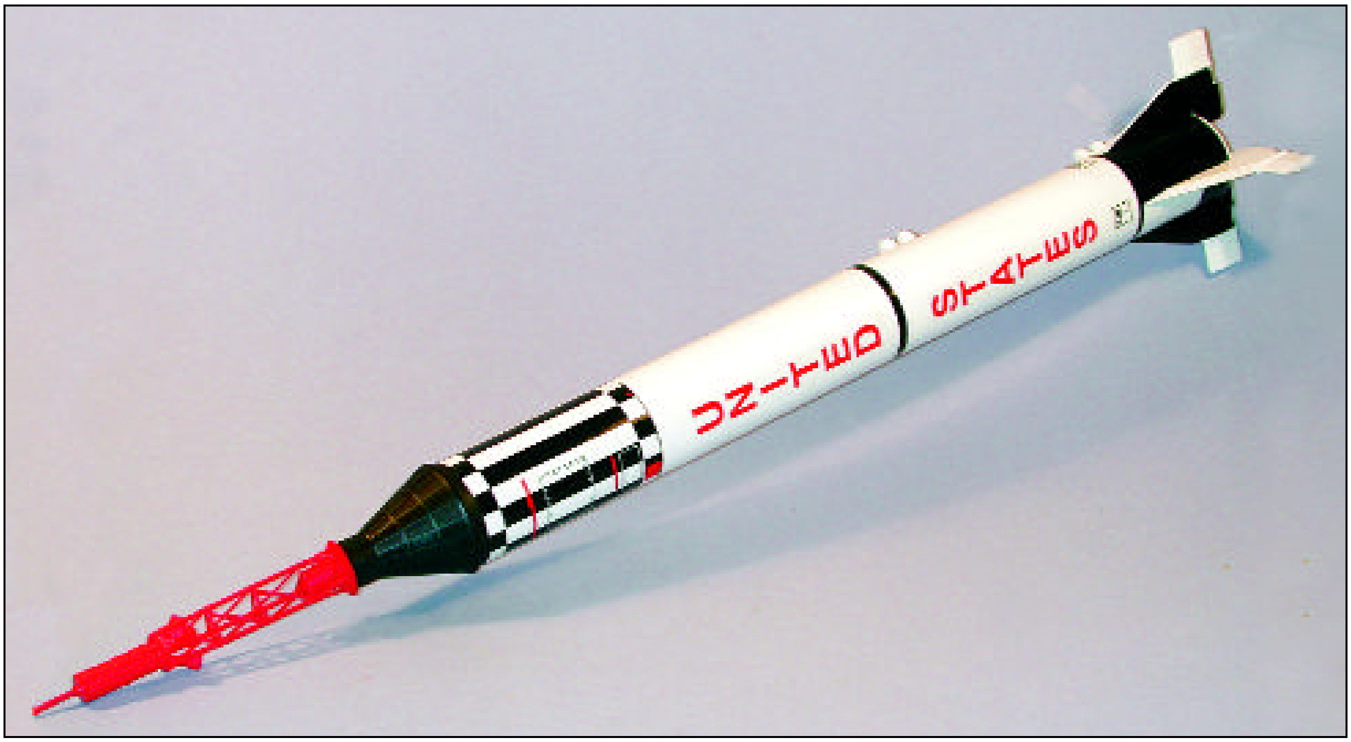


Launching the rocket is Cadet Kristopher Turner. Standing by is Cadet David Van der Vieren. Both are members of the Dakota Ridge Composite Squadron, Littleton, Colorado.


ESTES
MODEL ROCKET FLIGHT PROFILE
1. Electrically ignited rocket engine pro vides
2. Rocket accelerates and gains altitude
3. Engine burns out and rocket continues to climb during the coast phase.
4. Tracking smoke generated during time delay/coast phase
5. Model reaches peak altitude. Ejection charge activates recovery system.
6. Recovery systems are deployed
7. Rocket safely returns to
8. Touchdown! Replace the engine, igniter, and recovery wading. Ready to launch

TITAN
Hands-on Option Two

COMMERCIAL SINGLE-STAGE MODEL ROCKET



The Estes Mercury-Redstone with Liberty Bell 7

OBJECTIVE: The cadet can opt to build a scale model of an actual rocket that was a significant part of aerospace history. At this writing, there were numerous offerings such as the Phoenix, the V-2, the AGM-57X Heatseeker, and Saturn, all by Estes-Cox Corporation, and from Quest there is DCY Space Clipper, and the Tomahawk SLCM Cruise Missile, just to name a few. The requirements are that the model be a single-stage rocket and the cadet must show proof that the model is a replica of one that actually existed.

The model selected for an example is the currently offered Redstone-Mercury with the Liberty Bell 7 capsule. Recently, this capsule was recovered from the ocean and is being shown around the United States at various locations. The author recommends this one because of the incredible amount of documentation available on both the rocket and the

The author recommends the book *LOST SPACECRAFT, The Search For Liberty Bell 7.* This gives not only a fascinating account of how a team actually recovered the sunken capsule, it also covers the life history of astronaut Gus Grissom and the United States space program of that time (1961). The Liberty Bell 7 was lost at sea on July 21, 1961, during America's second manned space mission. An accident happened shortly after the capsule returned from its flight and the controversy still rages to this day concerning its sinking.

Because of its importance in aerospace history and the mystery surrounding the sinking of the capsule, the author has selected the Estes Redstone-Mercury model rocket with a replica of Grissom's Libery Bell 7 for the example "option" in this stage.

It is recommended that the cadet research the model that was significant in aerospace history. The author has selected for this option, the Mercury-Redstone that carried Gus Grissom aloft in Liberty Bell 7.

A fascinating book, *LOST SPACECRAFT,* and a Discovery Channel VHS video, In Search of Liberty Bell 7 are outstanding sources of information about the controversial sinking, and recovery, of one of NASA's spacecraft. The mission patch shown is a replica of the one issued for America's second manned space flight.

MATERIALS:

A model kit of a rocket that was significant in aerospace history.

PROCEDURE:

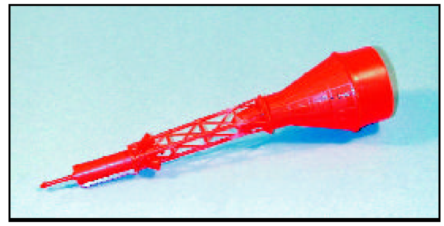
As always, it is good idea to lay the parts out and spend some time reading the instructions. One of the most important benefits is to learn the sequence of building a rocket the right way.

The author has chose the Estes Mercury-Redstone with Liberty Bell 7 as the sample model.

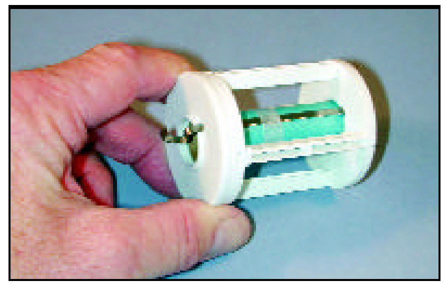
The author found that the escape tower mechanism proved to be difficult. It is suggested that just a small amount of plastic be clipped from the edges of this triangular piece. It allows the tower structure to be glued without distortion.

In some kits, the tower structure is white, in others it's red. The white one was used for clarity.

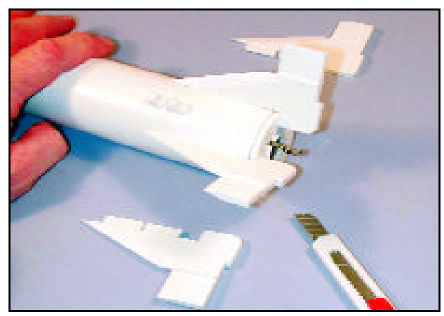
While the escape tower structure is drying, the builder can start on the Liberty Bell 7 capsule. This goes together reasonably well, but care should be used when fitting the sides of the three parts together. Every effort should be made not to get the plastic cement on the fingers; smearing this on the surface of the model will damage it.



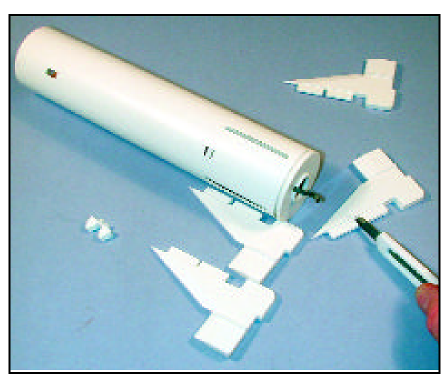
Once the structure is cemented, according to the instructions, the capsule can be painted flat black and the tower structure a flat red.

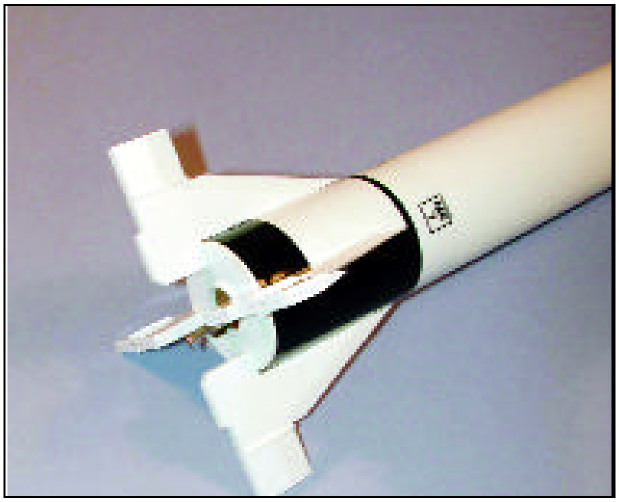


This is what the engine assembly looks like when completed. The horizontal structures will hold the fins when properly mounted in the body of the rocket.

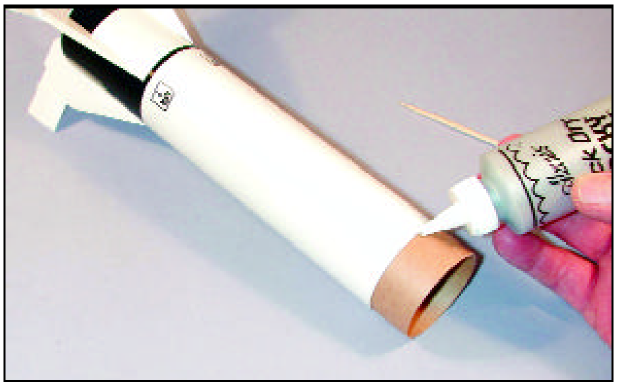


Once the engine housing is inserted into the body, it is a good idea for the builder to "pre-fit" the fins. To make the fins fit the slot, a hobby knife can be used to trim the tabs.

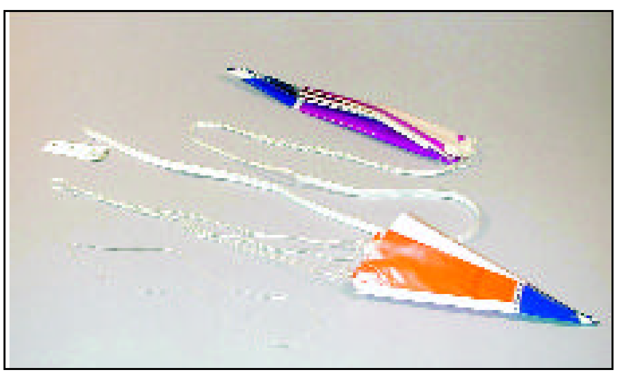




Before the fins are glued to the engine mounting, the lower body graphics must be applied.

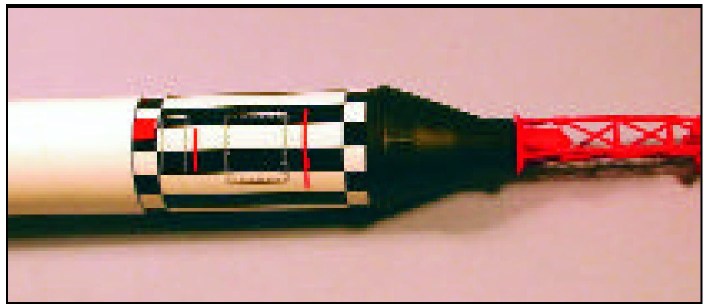


There is a coupling ring that has to be glued in position to bring the upper and lower body halves together. Be careful when gluing this and make sure the body tube is perfectly aligned.



The parachutes are glued into the body as shown in the Kit instruction sheet. Before launching, these chutes should be removed and dusted with talcum powder.

Cadet Kevin Rutherford presses the firing button on the Quest launcher and Redstone heads skyward!



Now the upper graphics and "United States" decals are to be applied. Note that the capsule has been painted flat black and the escape tower has been painted red.

. It's time to launch "Gus" so check to make sure the proper amount of wading is placed in the body along with the two required parachutes.

Cadets Jesse Macku and Kevin Rutherford, of the Dakota Ridge Composite Squadron, Littleton, Colorado, prepare the Redstone for launch.

The completed Mercury-Redstone is an awesome-looking model. To make the Liberty Bell 7 capsule look even more realistic, Estes has included the proper graphics showing the "crack" painted on the surface.

TITAN
The Air Power Option

THIS OPTION IS NOT FOR EVERYONE!

Cadet Ryan Lacy brings the pressure to nearly 80 pounds for a launch of the Air Burst rocket. First Lieutenant Chuck Sellers witnesses the launch

This option is only available to cadets who live in a city, county, or state, where commercial, solid-fuel model rockets are against the law and only after a cadet presents written proof that solid-fuel rockets are against the law in the city, county, or state surrounding the squadron to which the cadet belongs.

OBJECTIVE: The cadet is required to launch an air-powered model rocket, determine its altitude and recover it safely.

TITAN
AIR POWER OPTION
Requirements

1. THE WRITTEN PHASE

The cadet must successfully pass a written examination on Newton's Laws of Motion and the Rocket Aerodynamics.

2. THE OFFICIAL WITNESS LOG (OWL) AND TESTING

The cadet must have the Squadron Testing Officer (STO) administer the written examina tion and sign the Official Witness Log (OWL) after a successful score is achieved by the cadet.

3. THE HANDS-ON PHASE

The cadet is required to purchase, borrow, or share a commercial air-powered rocket and launcher. The apparatus must then be constructed according to the manufacturer's instructions. Once built, the cadet must safely launch and recover the air-powered rocket. The cadet must then determine the altitude of the air launched rocket by using an altitude tracker (as featured in *Aerospace Dimensions, Module 4, Rockets*), or a commercial altitude tracker, such as Estes Altitrack™. The cadet may also use the equations and tables, illustrated in the text of the "It's Rocket Science" article found in the test, to show how to determine the rocket's altitude using mathematics.

4. THE OFFICIAL WITNESS LOG (OWL)

A QSM (Qualified Senior Member) must witness the cadet's launch, altitude determination, and safe recovery of the air-powered rocket. The cadet is also required to have a working knowledge of the NAR Safety Code and must apply those guidelines which would be relevant to air powered flight. Once the QSM feels the cadet has met the basic requirements of this Option, he/she may sign off on the Titan Hands-on phase of the Official Witness Log.

AIR POWERED ROCKETS ARE GAINING IN POPULARITY

Model rocketry is a very exciting hobby and literally millions have been launched since they were introduced in the sixties. Aside from the traditional hobbyist, classroom teachers have built entire units around model rockets as a supplement to regular curriculum. Several units of advanced Civil Air Patrol cadets have gone several steps beyond the basics to build re-loadable composite fuel rockets. The possibilities are endless and the technology seems to be getting better and better.

But there is one drawback to solid fuel rockets that eventually has to be considered by model builders at all levels - the cost. Engines are not all that expensive, but for someone trying to live on a limited allowance, or money from a part-time job, it can add up to be quite a sum. This is where the air-powered model has the advantage. Since compressed air is used to propel the rocket model, it can be fired repeatedly without any cost involved other than the original purchase price of the system and a bicycle pump. The Estes model HL-X150 even comes with its own pump!

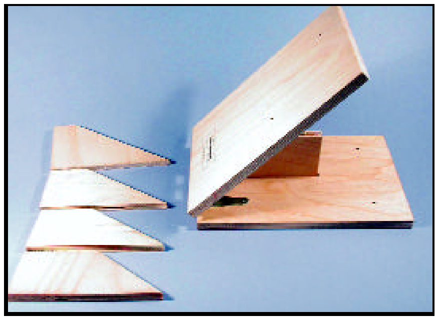
There is another side to model rocketry that limits some hobbyists; model rockets are not always allowed, by law, to be launched. If this is the case, the air powered rocket can be launched and recovered legally just about anywhere.

If the cadet qualifies for the Air Power Option, there are currently three systems available that meet the requirements of this alternative.

ARBOR SCIENTIFIC AIR POWERED ROCKET

Arbor Scientific produces a unique air powered model rocket and launcher that can be used in both a classroom or squadron setting. Everything is ready to go as a kit and it only takes a few minutes to assemble.

The Arbor Scientific launch pad has a hinged platform designed to be used with an air-powered rocket. The Launch Pad makes it easy to launch the rocket consistently at various angles. Note the angled wooden wedges. This allows a launch angle from 30° to 50°.



The Arbor Scientific Hinged Platform

The Arbor Scientific system has four "thrust washers" that are attached to the top of the launcher. These are snapped into position and then the nosecone is mounted on to the top of the rocket. Once everything is snapped into position, the launcher is attached to the hinged platform using two wing nuts.

The Arbor Scientific System Parts

"It's Simple and Safe"

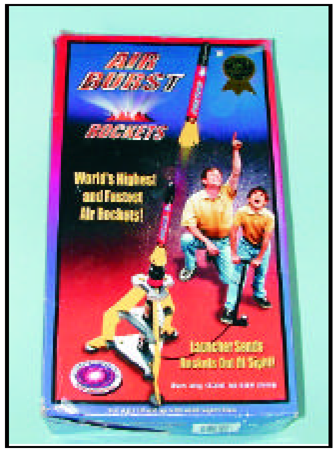
The Arbor Scientific's instruction sheet gives the following for a launch sequence:

(1) Select a launching site clear of obstructions and preferably about 50 meters in diameter. Attach the Arbor Scientific air pump and adjust the launch pad to the desired angle. Set the rocket in launching position.
(2) Select the super, high, medium or low thrust washer according to desired altitudes. Snap the thrust washer onto the launcher.
(3) Push the rocket completely onto the launcher and attach the nose cone. Push the cone on only about 2".
(4) Stand sideways to pump and pump until the rocket automatically launches.
(5) Have a student retrieve the rocket and nose cone.
(6) Push the thrust washer out of the end of the rocket with your thumb or finger and repeat the above steps for the next launch... again and again, all at no additional cost.

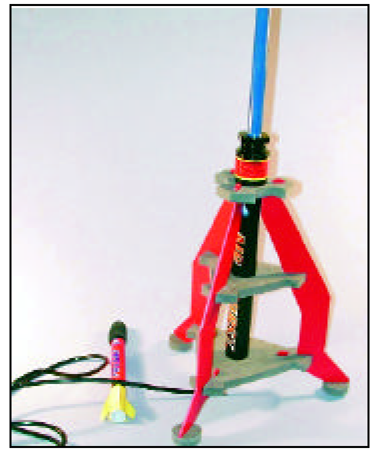
At the time of this writing, the entire cost of the Arbor Scientific air rocket system was $58.11. This included the Rocket Launch Pad, Rocket, Angle Wedges and shipping. Their address is Arbor Scientific, P.O. Box 2750, Ann Arbor Michigan 48106. Email is mail@arborsci.com. Their toll-free number is 1-800-367-6695. The web address is *www.arborsci.com.*

THE AIR BURST ROCKET

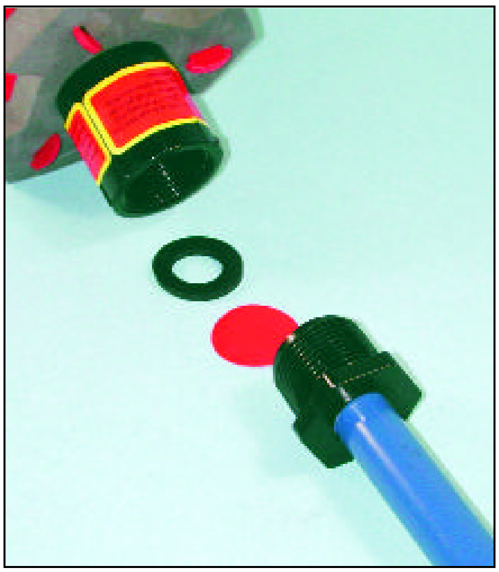
A company by the name of Mondo-Tronics, Inc., produces an excellent air rocket called the "Air Burst" and specifically, their projectile is known as the Pulsar. The rocket is launched using a bicycle pump, much like the others; however, a small wafer is required for each launch. When the pressure from the bicycle pump is applied, the wafer will eventually rupture and this sends a surge of air into the tube that holds the rocket. The rocket launches and when the whole process is ready for another launch, another wafer has to be installed. The small wafers are the only expense associated with the launch and they are far less expensive than a solid-fuel engine.



The Air Burst box says, "World's Highest and Fastest AirRockets!"



The Air Burst Launcher System is not as hefty as the Arbor Scientific apparatus, but it is very portable and easily carried to an open area.



The red "wafer" is required to seal the system. A bicycle pump is used to raise the pressure and once it reaches the point where the wafer ruptures, a blast of air shoots the rocket skyward.

A group of Dakota Ridge (Colorado) Cadets prepare for the countdown. Sometimes the rocket will launch when everyone least expects it and this adds to the excitement.

"It's Rocket Science"

ANSWERING THE QUESTION: *HOW HIGH DID MY AIR POWERED ROCKET GO?*

Roger G. Gilbertson
roger@AirBurstRockets.com

I. A LITTLE HISTORY

"*In 1666, as tradition has it, [Sir Isaac] Newton observed the fall of an apple in his garden at Woosthorpe, later recalling, 'In the same year I began to think of gravity extending to the orb of the Moon.' Newton's memory was not accurate. In fact, all evidence suggests that the concept of universal gravitation did not spring full-bloom from Newton's head in 1666 but was nearly 20 years in gestation. Ironically, Robert Hooke helped give it life. In November 1679, Hooke ini-*

tiated an exchange of letters that bore on the question of planetary motion. Although Newton hastily broke off the correspondence, Hooke's letters provided a conceptual link between central attraction and a force falling off with the square of distance."

From "Sir Isac Newton"
by Dr. Robert A. Hatch
University of Florida
<http://web.clas.ufl.edu/users/rhatch/pages/01-Courses/current-courses/08sr-newton.htm>

Newton and Hook's key observation about gravity, that the force of gravity decreases in proportion to the second power of the distance, also explains the "up and down" flight of a ballistic object like air powered rockets.

II. SOME NOT-SO-SCARY EQUATIONS

The following equation gives the time *t* for a falling object to cover a given distance *x*, in a gravitational field that provides an acceleration force of *g*.

$$t = \sqrt{\frac{2x}{g}} \qquad (1.1)$$

At the surface of Earth, the acceleration of gravity, *g*, is equal to 9.8 meters per second squared.

(Notice how no factor in equation 1.1 involves the *mass* of the object falling...this means that all objects fall the same regardless of their mass! In the vacuum on the Moon, a feather and a hammer fall at the same rate. Of course, on Earth air resistance plays a big factor in rocket performance. More about that later.)

Now, if you only know *t*, the time it took an object to fall, you can calculate the distance it fell by rewriting the equation:

$$x = (t^2 g)/2 \qquad (1.2)$$

With air powered rockets, the maximum speed occurs at the moment the rocket leaves the launcher, since no further force can be applied to it once it departs.

If we consider the rocket to be on a ballistic flight under ideal conditions (i.e. no friction due to the air), the rocket will travel upwards to its peak and return to the ground in equal amounts of time (time up = time down). If you know the total time of flight, t_{total}, then divide it by two to get the time to maximum altitude, and use the equation below to get the maximum altitude.

$$\text{Maximum Altitude} = ((t_{total}/2)^2 g)/2 \qquad (1.3)$$

III. SOME USEFUL TABLES

If you have the total flight time of your rocket (from launch to hitting the ground), table 1 below gives a rough estimate of the maximum altitude it must have reached, using equation 1.3.

However, in actual flights, the climb and fall times are not equal. In general, the time to climb to maximum altitude is less than half of the flight time, due to the high initual speed of the rocket, and the time to fall back down to Earth is more than half of the flight time, due to the air resistance that limits the maximum speed of the falling rocket (known as the "terminal velocity").

In our tests, performed with actual rockets at sea level at a variety of power levels, we've found an average ratio for climb time versus fall time of around 4:5. The factor *f* is the percentage of the total flight time used in the climb portion of flight (in this example 4/9 or about 0.44). Adjusting equation 1.3 to include this ratio thus gives:

$$\text{Maximum Altitude} = ((f\, t_{total})^2 g)/2 \qquad (1.4)$$

And substituting equation 1.4 into Table 1 give the following adjusted calculated altitudes in Table 2 below.

So go fly some rockets, measure the times (use a video camera with a frame counter for real accuracy), then plug in the times to the above equations and see how high they went.

Happy flying!
Roger G.
With thanks to Zach Radding and Mark Forti.

Acc. of gravity (meters/sec^2)	9.8															
Total flight time (in seconds)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Max Altitude (in meters)	1.2	4.9	11	20	31	44	60	78	99	122	148	176	207	240	276	314
Max Altitude (in feet)	4	16	37	65	102	147	200	261	331	408	494	588	690	800	919	1045

Table 1. Rough estimate of altitude from total. flight time.

Ratio Climb Time to Fall Time	4	:	5														
Acc. of gravity (meters/sec^2)	9.8																
Total flight time (in seconds)	1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Max Altitude (in meters)	1.0		3.9	9	15	24	35	47	62	78	97	117	139	164	190	218	248
Max Altitude (in feet)	3		13	29	52	81	116	158	206	261	323	390	465	545	632	726	826

Table 2. Better estimate of altitude by including ratio of rise time to fall time.

TITAN Official Witness Log

HANDS-ON PHASE

When a cadet completes the written examination, he/she is required to have a Qualified Senior Member (QSM), witness the successful launch of two solid fuel rockets. After witnessing the successful flight of these rockets, the QSM must sign this Official Witness Log (OWL).

CADET____

of____
squadron has completed the following requirements:

1. Commercial single stage basic model rocket.
2. A commercial single stage model rocket from aerospace history.

As a Qualified Senior Member (QSM), I have witnessed the successful flight of each of the required rockets.

____
(QSM)

TITAN STAGE
Squadron Commander's Approval

I have reviewed the Official Witness Logs, both written and hands-on, of Cadet

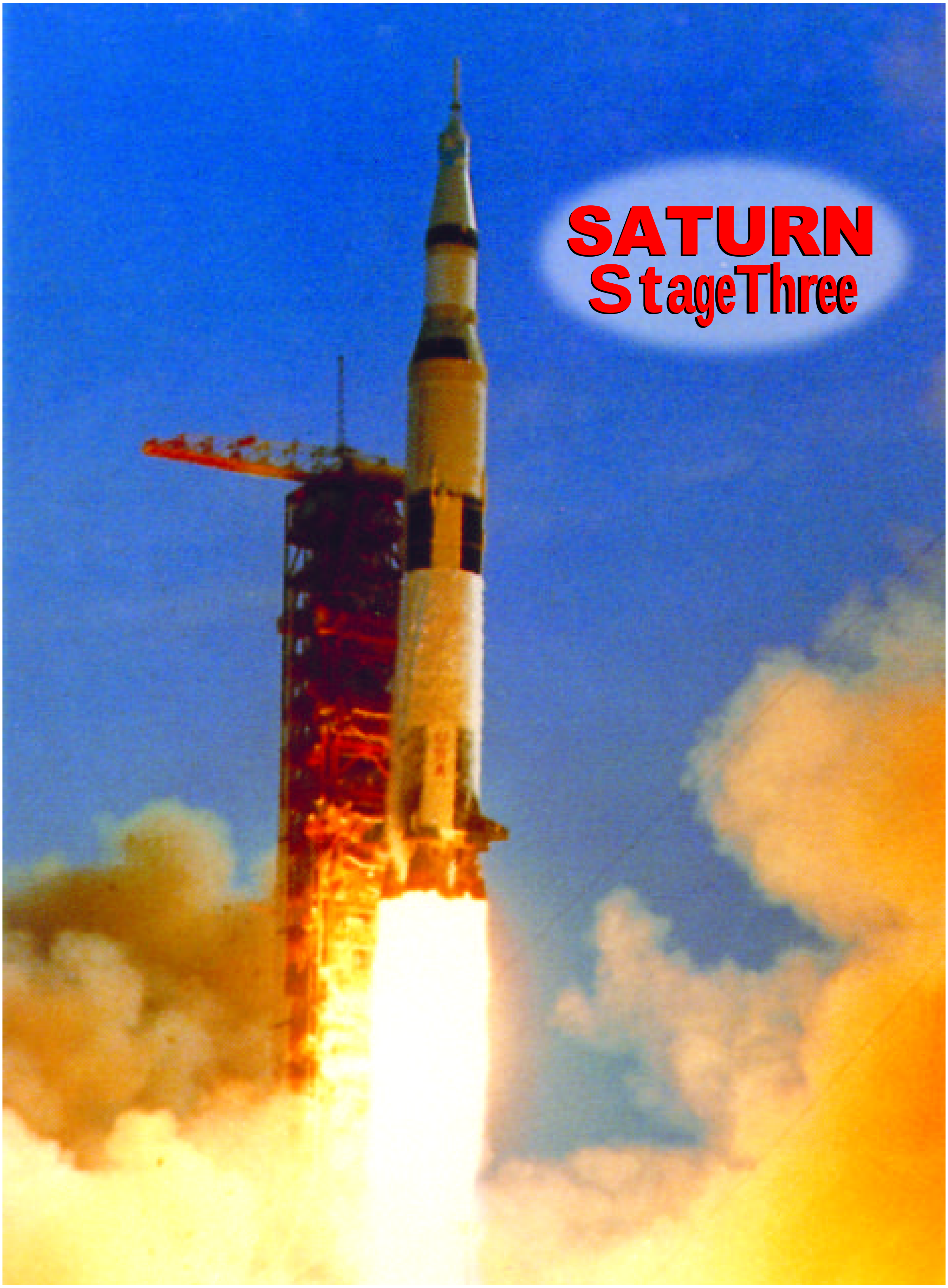
____

and have found that this individual has successfully passed the Titan Stage requirements and is now qualified to advance to the Saturn Stage of the Model Rocketry Program of the Civil Air Patrol.

The cadet will receive a certificate as a testimony of the completion of the second stage of this program.

____

Squadron Commander


SATURN
StageThree

SATURN Requirements

1. THE WRITTEN PHASE

The cadet is required to pass an examination on how to determine a model rocket's altitude at the apogee of its flight. The cadet is required to pass a second component of the examination that deals with model rocket engines.

2. THE OFFICIAL WITNESS LOG (OWL) AND TESTING

The Squadron Testing Officer (STO) must administer the written examination and once passed, sign the OWL for the cadet.

3. THE HANDS-ON PHASE

The cadet is required to build one of the following options:

a. The cadet may elect to build a two-stage rocket that requires two engines to reach altitude.
b. **OR** The cadet may elect to build a model rocket that is capable of carrying a payload of at least 3 ounces to an altitude of 300' or more.
c. **OR**..If the cadet lives in an area where solid-fuel rockets are banned, he/she may elect to take the Air Power Option. If this is the case, the cadet is required to scratch-build a model rocket that works on a commercial launcher (like one of those featured in the Titan section). This rocket must achieve an altitude of at least 100 feet and proof must be given by either mathematical calculations or an altitude tracking device.
d. OR..If the cadet is taking the Air Power Option, he/she must also build a static plastic model of a rocket that was significant in aerospace history. This rocket and a short presentation must be made to the squadron.
e. All cadets in this program must have a working knowledge of the NARs Safety Code.

4. THE OFFICIAL WITNESS LOG FOR FLIGHT AND RECOVERY OF MODELS

A Qualified Senior Member must witness the launch of all flights. Once it is determined, by the QSM, that the cadet has met the requirements, he/she will sign the OWL for the Hands-On Phase.

5. THE ROLE OF THE SQUADRON COMMANDER

The Squadron Commander will sign the OWL and in an awards ceremony, present the cadet with the Model Rocketry Badge.

Model Rocket
SAFETY CODE

This official Model Rocketry Safety Code has been developed and promulgated by the National Association of Rocketry.
(Basic Version, Effective February 10, 2001)

1. MATERIALS. I will use only lightweight, non-metal parts for the nose, body and fins of my rocket.

2. MOTORS. I will use only certified, commercially-made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer.

3. IGNITION SYSTEM. I will launch my rockets with an electrical launch system and electrical motor igniters. My launch system will have a safety interlock in series with the launch switch, and will use a launch switch that returns to the "off" position when released.

4. MISFIRES. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

5. LAUNCH SAFETY. I will use a countdown before launch, and will ensure that everyone is paying attention and is a safe distance of at least 15 feet away when I launch rockets with D motors or smaller, and 30 feet when I launch larger rockets. If I am uncertain about the safety or stability of an untested rocket, I will check the stability before flight and will fly it only after warning spectators and clearing them away to a safe distance.

6. LAUNCHER. I will launch my rocket from a launch rod, tower, or rail that is pointed to within 30 degrees of the vertical to ensure that the rocket flies nearly straight up, and I will use a blast deflector to prevent the motor's exhaust from hitting the ground. To prevent accidental eye injury, I will place launchers so that the end of the launch rod is above eye level or will cap the end of my launch rod when it is not in use.

7. SIZE. My model rocket will not weigh more than 1500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320N-sec (71.9 pound-seconds) of total impulse. If my model rocket weighs more than one pound (453 grams) at liftoff or has more than 4 ounces (113grams) of propellant, I will check and comply with Federal Aviation Administration regulations before flying.

8. FLIGHT SAFETY. I will not launch my rocket at targets, into clouds or near airplanes, and will not put any flammable or explosive payload in my rocket.

9. LAUNCH SITE. I will launch my rocket outdoors, in an open area at least as large as shown in the accompanying table, and in safe weather conditions with wind speeds no greater than 20 miles per hour. I will ensure that there is no dry grass close to the launch pad, and that the launch site does not present risk of grass fires.

Installed Total Impulse (N-sec)	Equivalent Motor Types	Minimum Site Dimensions (ft)
0.00 - 1.25	1/4A,1/2A	50
2.26 - 2.50	A	100
2.51 - 5.00	B	200
5.01 -10.00	C	400
10.01 - 20.00	D	500
20.01 - 40.00	E	1,000
40.01 - 80.00	F	1,000
80.01 - 160.00	G	1,000
160.01 - 320.00	Two G's	1,500

10. RECOVERY SYSTEM. I will use a recovery system such as a streamer or parachute in my rocket so that it returns safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

11. RECOVERY SAFETY. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places.

SATURN Written Phase

ALTITUDE TRACKING

It's great fun to launch and recover model rockets, but let's face it, after so many it "loses some of its excitement" and the average builder wants more. So what is the "next step?" Most model rocket builders advance to longer bodies, larger engines, multiple stages and various experiments with payloads. If you are short on cash and still have the excitement, there is another way to enjoy your current "inventory," yet still keep the interest alive.

It is recommended that you take the time to learn more about the science of model rocketry. In other words, the cadet is urged to study performance variables. Two very important parameters are altitude determination and engine performance. Both are covered as part of the Written Phase of the Saturn Stage.

ALTITUDE DETERMINATION

By definition, apogee is the highest point in the flight of a model rocket. It is the point at which a rocket reaches its highest altitude and begins a return to Earth. There are several ways to determine the altitude at which a rocket reaches its apogee. The method described in *Aerospace Dimensions, Module 4, ROCKETS*, uses a sighting device called an "Altitude Tracker." It is part of Activity Three-Altitude Tracking. The cadet is urged to read the text, on pages 29, 30, 31, and to build the "Altitude Tracker" and use it as described. The cadet may also elect to purchase a commercially-built one like the Estes Altitrak ™ (retails for around $24.00).

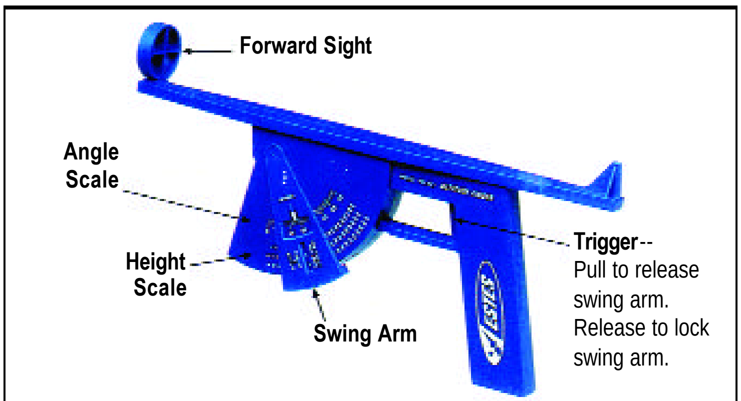
With permission from Estes, the author will explain how to determine the altitude of a model rocket using simple trigonometry. In the illustration "Using the degree scale to calculate altitude," first notice the term "baseline distance." This is essentially the base of a right triangle and the length is the distance from an observer to the launch pad of a model rocket. Refer now to number "1", in their diagram that shows how to use the Altitrak. The observer is asked to pace off a distance of 500', or in other words, make a baseline distance of 500' (150 meters). Once the observer is ready, he/she signals the launcher. The Altitrak ™, or astrolabe as it is know in scientific terms, is aimed at the rocket. This is shown in illustration "2." As the rocket is launched it will climb to its apogee and then start a return to earth. The trigger is released and this will record the desired angle.

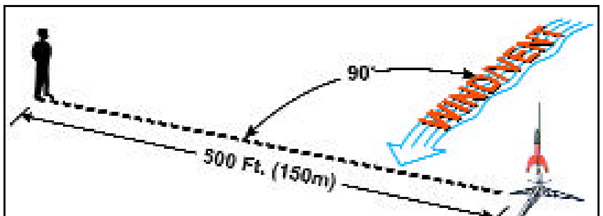
Refer now back to "Using the degree scaled to calculate altitude." Once this angle is known, the observer, or team, looks up the corresponding tangent on the Angle Tangent Chart. The altitude at which the rocket reached its apogee is found by:

Baseline Distance X Angle Tangent = Altitude.

Example: Baseline Distance is 500'; Angle observed is 50°; Tangent number from chart 1.19.

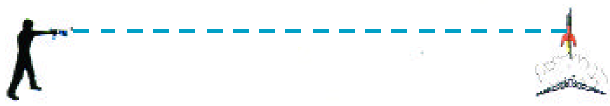
500' x 1.19 = 595' altitude at apogee



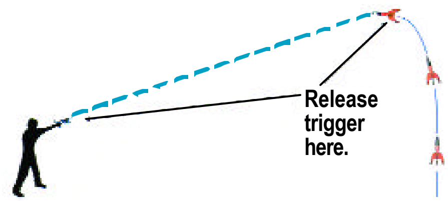


1. Pace off 500 ft. from launch pad at a right angle to the wind. (A pace equals the average walking stride of a 10-12 year old - approximately 2½ ft.)

NOTE: For low altitude rockets, pace off 250 ft. and divide height by 2. For high altitude rockets, pace off 1,000 ft. and multiply height by 2.



2. Hold the Altitrak™ at arm's length, pointed at rocket. Pull & hold trigger then signal for launch.



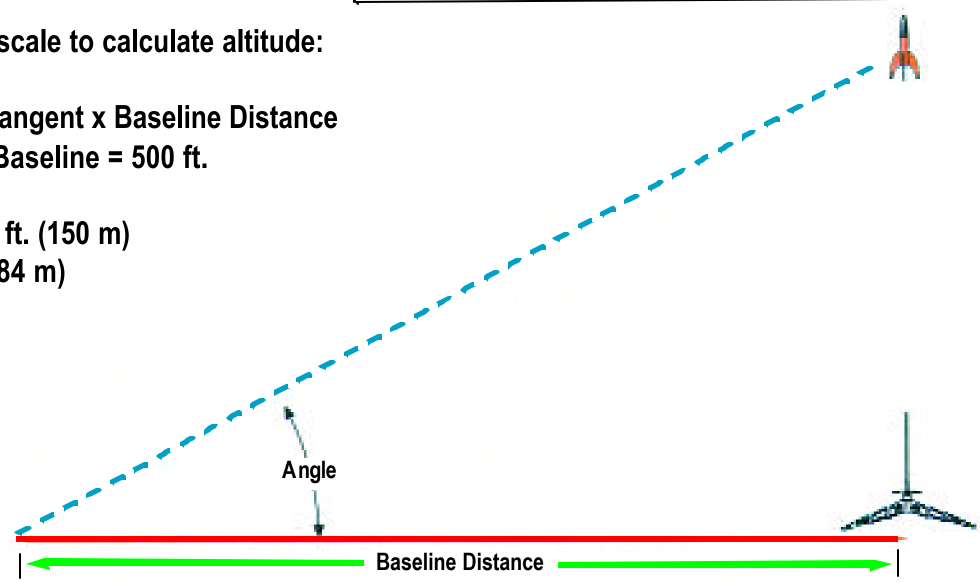
3. Track rocket through forward sight. When rocket reaches apogee (maximum altitude) release the trigger. Read the height indicated on swing arm.

To convert feet to meters: 1 foot x 3.28 = 1 meter

Using the degree scale to calculate altitude:

Altitude = Angle Tangent x Baseline Distance
30 Angle = .58, Baseline = 500 ft.

Altitude = .58x500 ft. (150 m)
= 290 ft. (84 m)



ANGLE TANGENT CHART

Angle	Tan.	Angle	Tan.	Angle	Tan.	Angle	Tan.
1	0.02	21	0.38	41	0.87	61	1.80
2	0.03	22	0.40	42	0.90	62	1.88
3	0.05	23	0.42	43	0.93	63	1.96
4	0.07	24	0.45	44	0.97	64	2.05
5	0.09	25	0.47	45	1.00	65	2.14
6	0.11	26	0.49	46	1.04	66	2.25
7	0.12	27	0.51	47	1.07	67	2.36
8	0.14	28	0.53	48	1.11	68	2.48
9	0.16	29	0.55	49	1.15	69	2.61
10	0.18	30	0.58	50	1.19	70	2.75
11	0.19	31	0.60	51	1.23	71	2.90
12	0.21	32	0.62	52	1.28	72	3.08
13	0.23	33	0.65	53	1.33	73	3.27
14	0.25	34	0.67	54	1.38	74	3.49
15	0.27	35	0.70	55	1.43	75	3.73
16	0.29	36	0.73	56	1.48	76	4.01
17	0.31	37	0.75	57	1.54	77	4.33
18	0.32	38	0.78	58	1.60	78	4.70
19	0.34	39	0.81	59	1.66	79	5.14
20	0.36	40	0.84	60	1.73	80	5.67

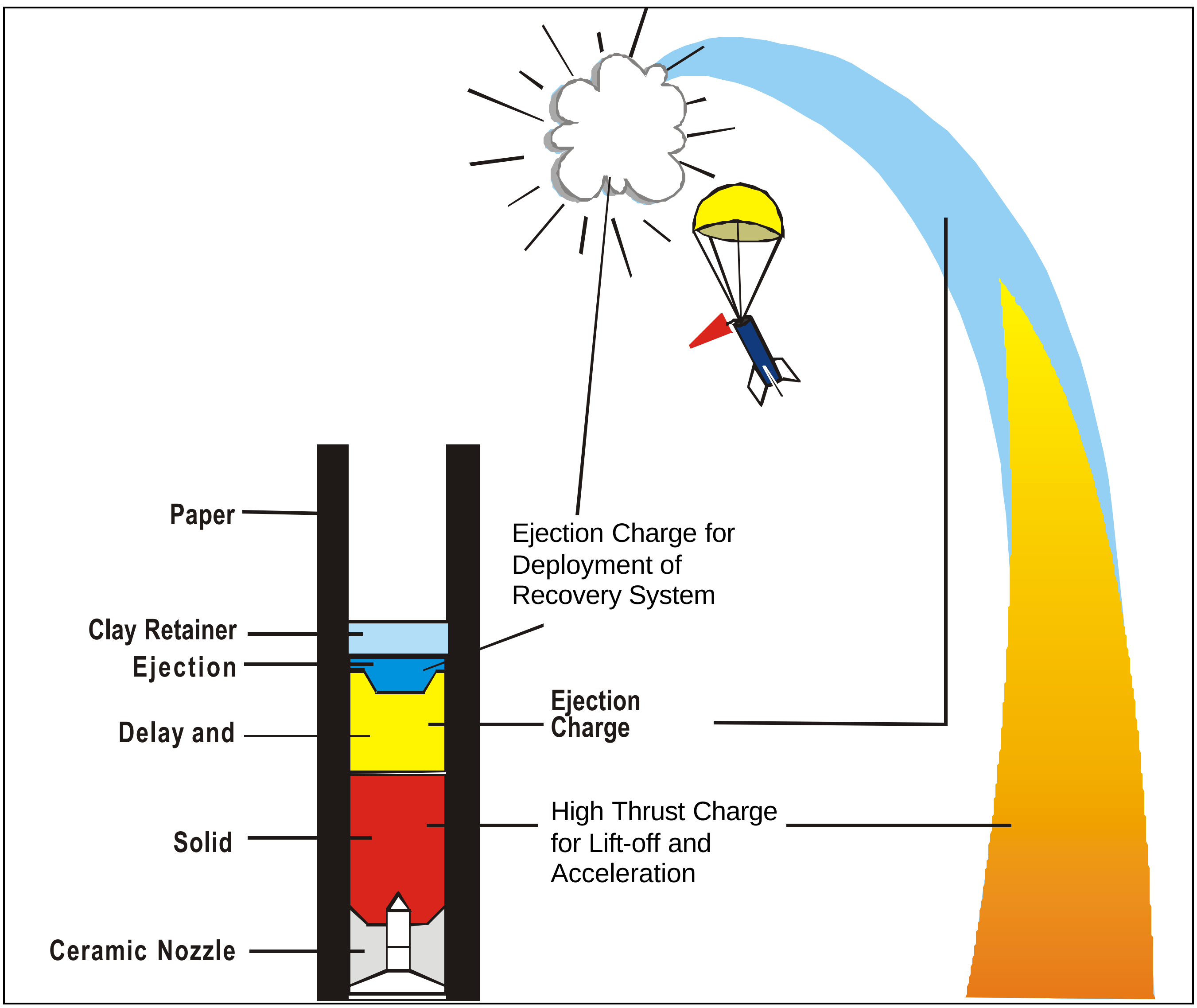
Cadets Brandon Ybarra and Bronson Montield demonstrate the use of the Estes Altitrak™

SATURN Written Phase

MODEL ROCKET ENGINES

The model rocket engine is a very powerful, yet reliable source of thrust. Several companies market these engines including Quest, Estes and Pitsco. All engines comply with the National Fire Protection Association and are certified by the National Association of Rocketry (NAR).

The model rocket engine is made up of a ceramic nozzle, a solid propellant for lift-off and acceleration, a delay and smoke tracking chemical, an ejection charge, a clay retainer cap and all of this is enclosed in a heavy paper casing.



Thrust—Push Power!

The model rocket engine is designed to provide thrust and to provide forward motion. When the solid fuel is ignited, usually by electrical means, a chemical reaction occurs and the gases created in this reaction are forced out the nozzle. According to Newton's Third Law of Motion, this is an action and propels the rocket skyward as a reaction. The altitude, speed and weight-lifting capability is determined by amount of solid fuel and the duration of the chemical reaction.

The thrust that an engine creates is measured in terms of "Newtons" over a period of time in "seconds." When the two terms are spoken in terms of performance, it is said "maximum thrust was achieved in 'so many' Newton Seconds." Another term is total impulse and this is the total power produced by the engine. The engines are classified according to letters of the alphabet. The further into the alphabet, the more powerful. Here's how it works:

ENGINE	IMPULSE	ENGINE TYPES
1/4 A	0.313-0.625 (Newton-seconds)	Mini
1/2 A	0.626-1.25 (Newton-seconds)	Standard (also Mini)
A	1.26-2.50 (Newton-seconds)	Standard (also Mini)
B	2.51-5.00 (Newton-seconds)	Standard
C6	5.01-10.00 (Newton-seconds)	Standard
C11	5.01-10.00 (Newton-seconds)	In "D" size
D	10.01-20.00 (Newton-seconds)	D size
E	20.01-30.00 (Newton-seconds)	E size

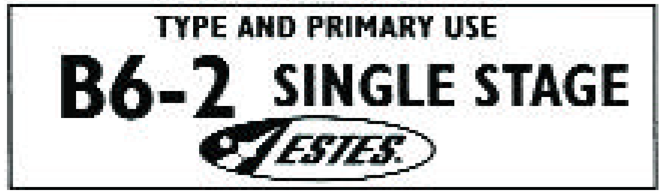
Using a common engine, the B6-4, let's investigate what the lettering on the rocket engine means:

The "**B" is the total impulse, or power,** (in Newton-seconds) produced by the engine. Each succeeding letter has up to twice the total power as the previous letter. An example of this is the letter "B." It has up to twice the power of an "A" engine and this, in turn, means that it should reach approximately twice the altitude, given the same rocket. In higher powered engines, for example, a "G" has 160 Newton Seconds of total impulse!

The **"6" shows the engine's average thrust, or how fast the engine powers the rocket.** This parameter is measured in just Newtons. It might be noted that the 4.45 Newtons = 1 pound of thrust, or 0.225 pounds equal one Newton.

The next letter, in this case the "**4" means the "Time Delay."** This number gives you the time delay in seconds between the end of the thrust burn-out and ignition of the ejection charge. It should be noted that **engine types that end in "O" have no time delay,** or ejection, and are used for booster stages only.

Engine Coding for Quick and Easy Identification



Material Courtesy Estes-Cox Corporation. Used with permission.

Label color indicates recommended use of the engine.

- **a. Green**...........Single stage rockets
- **b. Purple**...........Upper stage or Single stage, if used in very light rockets
- **c. Red**.............*Booster and intermediate stages of multi-stage rockets
- **d. Black**...........*Special plugged engines for R/C gliders

*These contain no delay or ejection charge.

TOTAL IMPULSE CLASSIFICATION

CODE	POUND-SECONDS	NEWTON-SECONDS
1/2 A	O.14 - 0.28	O.625 -1.25
A	1.26 - 2.50	1.26 - 2.50
B	2.51 - 5.00	2.51 - 5.00
C	1.12 - 2.24	5.01 - 10.00
D	2.24 - 5.00	10.01 - 20.00

HOW HIGH WILL YOUR ROCKET GO?

The chart below shows the approximate altitudes that can be achieved with single stage rockets.

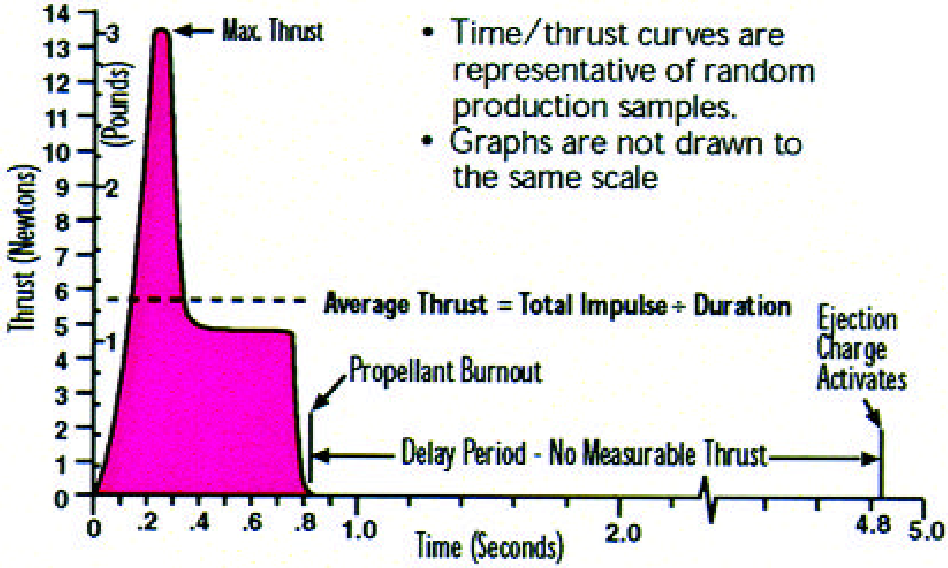
ENGINE SIZE	ALTITUDE RANGE DEPENDING ON ROCKET SIZE AND WEIGHT	APPROXIMATE ALTITUDE IN A TYPICAL
1/2A6-2	100' to 400'	190'
A8-3	200' to 650'	450'
B6-4	300' to 1000'	750'
C6-5	400' to 1500'	1000'

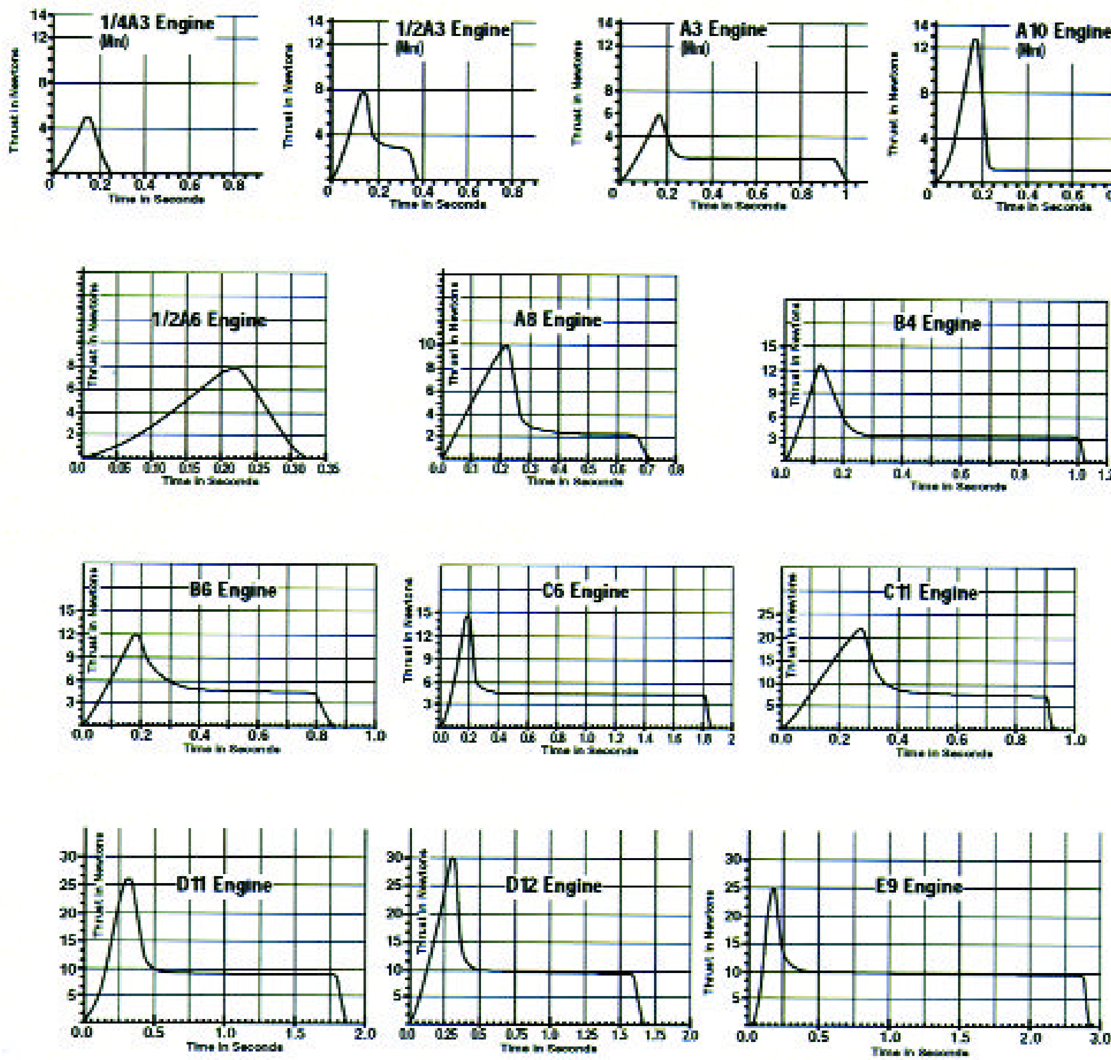
(Some high performance rockets will reach higher altitudes than shown above.

Material Courtesy Estes-Cox Corporation. Used with permission.

TIME/THRUST CURVES

- Time/thrust curves are representative of random production samples.
- Graphs are not drawn to the same scale





This illustration was provided courtesy of Pitsco, Inc.

Safety First and Foremost

The model rocket engine of today is a very safe, reliable powerplant. Cadets, students, seniors and teachers must, however, take every precaution to maintain a high level of safety. The National Association fo Rocketry has eleven guidelines that will help promote safety in the building of model rockets. It is highly recommended that these rules be followed during every launch. The Model Rocketry Safety code is found on page 54.

ESTES® ENGINE CHART

- Delays have a tolerance of plus or minus 10% or 1 second, whichever is greater.
- All Estes® engines come complete with igniters and patented igniter plugs (Pat. No. 5,410,966 and 5,509,354). The Estes® Igniter Plug makes engine ignition extremely reliable.
- Do not fly a rocket/engine combination whose maximum lift-off weight exceeds the recommended maximum lift-off weight.

Prod. No.	Engine Type	Total Impulse	Time Delay	Max. Lift Wt.		Max. Thrust		Thrust Duration	Initial Weight		Propellant Weight	
		N-sec	Sec.	Oz.	g	Newtons	Lbs.	Sec.	Oz.	g	Oz.	g
SINGLE-STAGE ENGINES (GREEN LABEL)												
1502	1/4A3-3T	0.625	3	1.0	28	4.9	1.1	0.25	0.20	5.6	0.03	0.85
1503	1/2A3-2T	1.25	2	2.0	57	8.5	1.9	0.3	0.20	5.6	0.06	1.75
1507	A3-4T	2.50	4	2.0	57	8.5	1.9	0.6	0.27	7.6	0.12	3.50
1511	A10-3T	2.50	3	3.0	85	13.0	2.9	0.8	0.28	7.9	0.13	3.78
1593	1/2A6-2	1.25	2	2.0	57	11.8	2.7	0.3	0.53	15.0	0.06	1.56
1598	A8-3	2.50	3	3.0	85	11.8	2.7	0.5	0.57	16.2	0.11	3.12
1601	B4-2	5.00	2	4.0	113	13.2	3.0	1.1	0.70	19.8	0.29	8.33
1602	B4-4	5.00	4	3.5	99	13.2	3.0	1.1	0.74	21.0	0.29	8.33
1605	B6-2	5.00	2	4.5	127	12.1	2.7	0.8	0.68	19.3	0.22	6.24
1606	B6-4	5.00	4	4.0	113	12.1	2.7	0.8	0.71	20.1	0.22	6.24
1613	C6-3	10.00	3	4.0	113	15.3	3.4	1.6	0.88	24.9	0.44	12.48
1614	C6-5	10.00	5	4.0	113	15.3	3.4	1.6	0.91	25.8	0.44	12.48
1622	C11-3	10.00	3	6.0	170	22.1	4.9	0.8	1.14	32.2	0.39	11.00
1623	C11-5	10.00	5	5.0	142	22.1	4.9	0.8	1.18	33.3	0.39	11.00
1666	D12-3	20.00	3	14.0	396	32.9	7.4	1.6	1.49	42.2	0.88	24.93
1667	D12-5	20.00	5	10.0	283	32.9	7.4	1.6	1.52	43.1	0.88	24.93
1673	E9-4	30.00	4	15.0	425	25.0	5.6	2.8	2.00	56.7	1.27	35.80
1674	E9-6	30.00	6	15.0	425	25.0	5.6	2.8	2.00	56.7	1.27	35.80
UPPER STAGE ENGINES (PURPLE LABEL)												
1504	1/2A3-4T	1.25	4	1.0	28	8.3	1.9	0.3	0.21	6.0	0.06	1.75
1599	A8-5	2.50	5	2.0	57	13.3	3.0	0.5	0.62	17.6	0.11	3.12
1607	B6-6	5.00	6	2.5	71	12.1	2.7	0.8	0.78	22.1	0.22	6.24
1615	C6-7	10.00	7	2.5	71	15.3	3.4	1.6	0.95	26.9	0.44	12.48
1624	C11-7	10.00	7	4.0	113	22.1	4.9	0.8	1.22	34.5	0.39	11.00
1668	D12-7	20.00	7	8.0	226	32.9	7.4	1.6	1.55	44.0	0.88	24.93
1675	E9-8	30.00	8	15.0	425	25.0	5.6	2.8	2.00	56.7	1.2	35.80
BOOSTER STAGE ENGINE (RED LABEL)												
1608	B6-0	5.00	None	4.0	113	12.1	2.7	0.8	0.58	16.4	0.22	6.24
1616	C6-0	10.00	None	4.0	113	15.3	3.4	1.6	0.80	22.7	0.44	12.48
1621	C11-0	10.00	None	6.0	170	22.1	4.9	0.8	0.98	27.8	0.39	11.00
1665	D12-0	20.00	None	14.0	396	32.9	7.4	1.6	1.44	40.9	0.88	24.93
PLUGGED ENGINES - FOR USE WITH R/C ROCKET GLIDERS (BLUE LABEL)												
1669	D11-P	20.00	None	16.0	453	27.6	6.2	1.8	1.55	44.0	0.88	24.93
1676	E9-P	30.00	None	15.0	425	25.0	5.6	2.8	2.0	56.	1.27	35.80

The data listed above is from randomly chosen production samples.
NOTE: The "T" designates a mini-engine.

SATURN
Official Witness Log

WRITTEN PHASE

The cadet is required to have a basic knowledge of ALTITUDE TRACKING and MODEL ROCKET ENGINES.The cadet is also required to have a working knowledge of the NAR Safety Code. Once the cadet has studied the text and feelsready, he/she must take an examiniation The cadet is required to take an examination administered by the Squadron Testing Officer (STO) The minimum passing score is 70%. Upon successful passage of this test, the cadet must have the STO sign this document.

CADET____

of____
squadron has successfully passed the written examination required of the Saturn Stage on altitude tracking and model rocket engines.

As the STO I have administered the test and found that Cadet passed with a score that meets or exceeds the minimum requirements of the Saturn Stage of the Model Rocketry Achievement Program

____
STO

SATURN
Hands-on Option One

A MODEL ROCKET DESIGNED TO CARRY A PAYLOAD

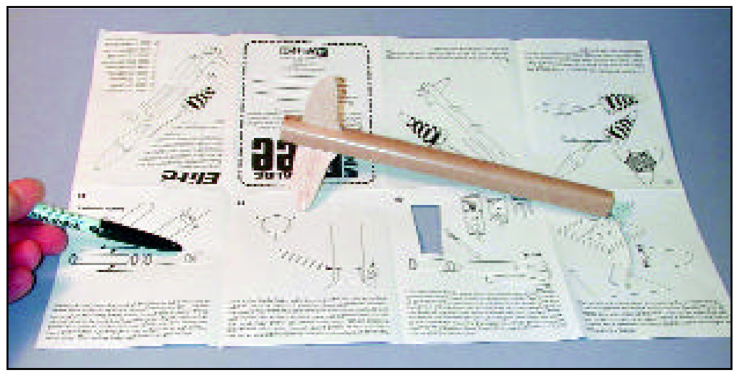
This Elite rocket has a fresh egg sealed in its nose section. The object is to launch it to an altitude of at least 300' and return the egg safely to the ground.

OBJECTIVE: The purpose of this project is to acquaint the cadet with advanced rockets. The cadet is required to build a model rocket capable of carrying load to an altitude of at least 300 feet and returning it safely to the ground. In the example featured in this unit, the author used an egg-carrying model offered by Custom Rocket Company. If you're interested in this model, you may write them at P.O. Box 1865, Lake Havasu City, AZ 86405.

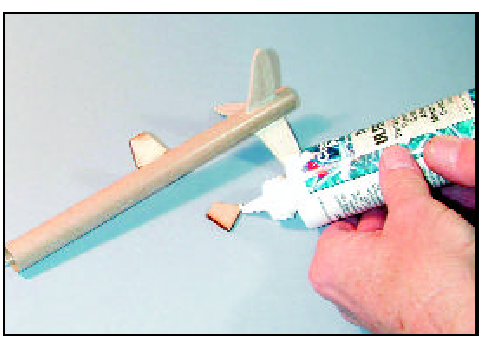
It's always a good idea to lay out the parts and make sure nothing is missing.

After carefully reading the instructions, it's time to get started. Matching, sanding and preparing the fins for mounting is the first step.

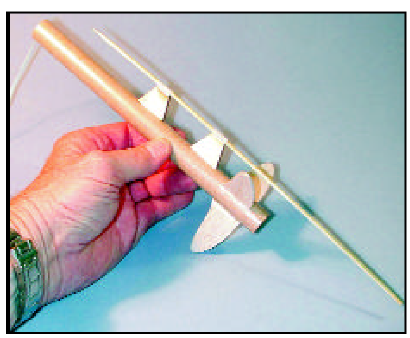
A good quality white or yellow glue is used to properly mount the fins.



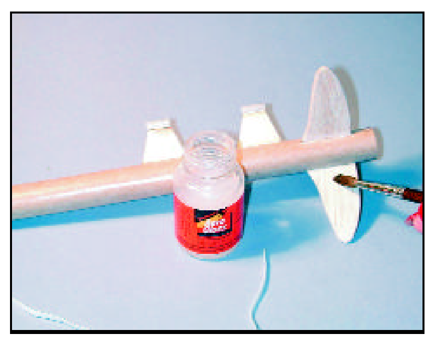
The rocket engine structure is constructed as shown in the Elite plans. Always make sure that your measurements are exact. A model rocket is engineered by experts and it is the cadet's responsibility to build it according to their specifications.



Because of the size of the egg-carrying nose compartment, two small pieces have to be installed so that the nose cone stands away from the launch rod.

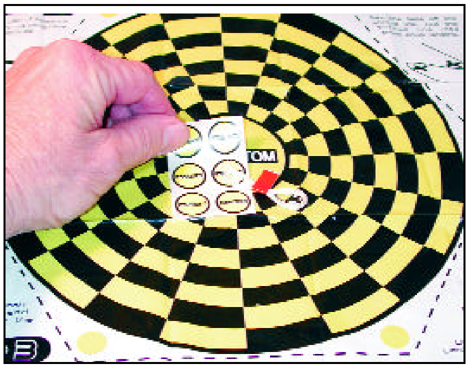


A simple skewer stick was used to align the launch lugs.

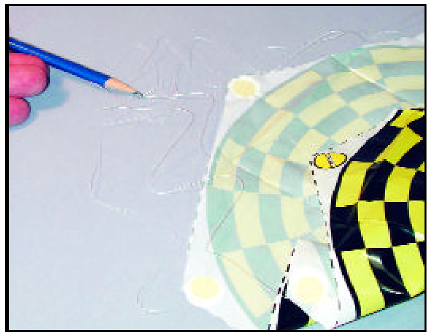


It is highly recommended that the builder use sanding sealer on all wood parts. This keeps the final paint coat from soaking in.

Once the glue sets, it is time to prepare the model for painting. If the cadet wants the model to be "show quality," it is recommended that the procedures featured on the Alpha rocket (in the Redstone Stage) be followed. However, the object with this model is to lift weight and paint adds weight. If color is to be added, the minimum preparation would be brushing in sanding sealer on the wooden parts and then spraying one mist and two color coats of satin or flat black.



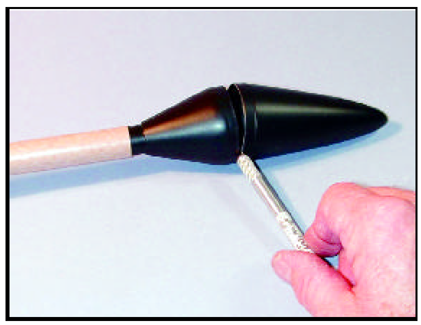
One of the most important parts of this model is the parachute. Since the parachute is going to have to bring both a rocket and an egg safely back to earth, it's important that it is constructed properly and fully operational when ejected during flight.



Make sure that the shroud lines are all exactly the same length. This is important when maximum drag is required.

To prepare for a flight, the proper amount of wading is first stuffed into the body. Read the instructions and follow their recommendations.

The egg is first put in a plastic bag "...just in case it breaks!"



A folded tube or dowel rod can hold the rocket while paint is applied. The recommended color for the elite was flat or satin black.

A folded tube or dowel rod can hold the rocket while paint is applied. The recommended color for the elite was flat or satin black.

When the egg is loaded, the front cone is held in the plastic with black electrical tape.

The egg fits and is ready to be sealed in the payload compartment.

The payload compartment is sealed.

The black Elite has some interesting silver graphics. Your rocket is ready for its engine. It's time to head out to the launch site!

The finished rocket on the launch pad.

SATURN
Hands-on Option Two

BUILDING A TWO-STAGE MODEL ROCKET

The finished sample of the Quest Zenith II Payloader

OBJECTIVE: The second option is to have the cadet build a rocket that requires two engines to achieve its maximum altitude. Each stage must be safely recovered. The QSM and cadet must discuss, before launching, the performance and altitude expectations of the model as recommended in the commercial kit application. Using knowledge gained in the written phase, the cadet and QSM must work together to determine the proper engines to use and to calculate the altitude each rocket achieved.

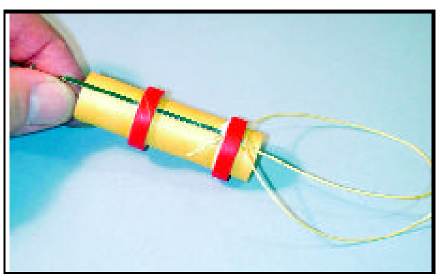
For our example model, the author selected the Quest Zenith II Payloader On the package that contained the rocket parts, it states, "Skill level 3 for Advanced Modelers." It also stated, "High-performance, two-stage rocket (that) flies up to 1500 ft. (457m)." It has a 14" parachute for recovery and features die-cut balsa fins. It is 22.75 inches long, weighs 1.4 ounces. The engine recommendations are A6-4,B6-4, C6-3 or C6-5 for the upper stage and B6-0 or C6-0 for the booster stage. For a Quest catalog of other fine rockets, it is recommended that the cadet write Quest Aerospace, P.O. Box 42390, Phoenix, AZ 85080-2390.

MATERIALS:

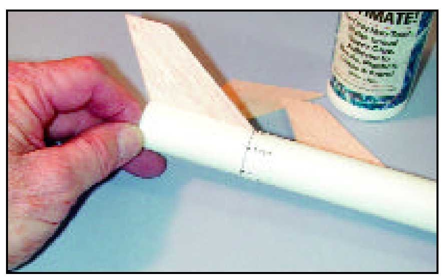
1. White glue
2. plastic cement
3. a hobby knife
4. sandpaper
5. masking or office tape
6. scissors
7. sandpaper
8. sanding sealer

The paint preparation is featured in this "how-to" and it is recommended, by the author, that the finish prodecure be followed for a professionally built model.

It's always a good idea to lay out the parts and check everything against the "parts list" as in the picture to the right.

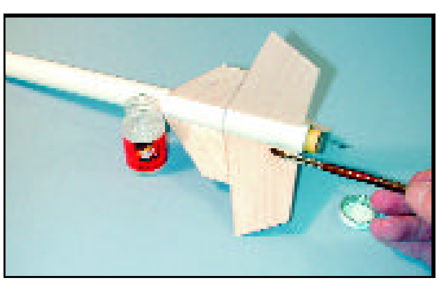


The first 8 steps involves building the Motor Mount Assembly. Follow the instructions carefully. The Kevlar cord keeps the first and second stages together.



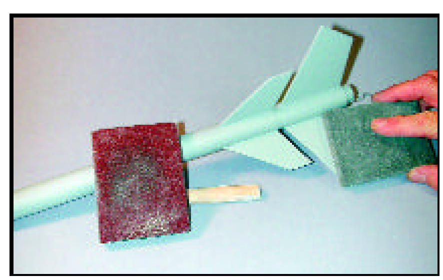
The tube marking guide gives the exact placement of fins and launch lug.

The black tube coupler joins the main body and payload section. Using plastic cement, these components are glued together. Follow your instructions for insertion depth.



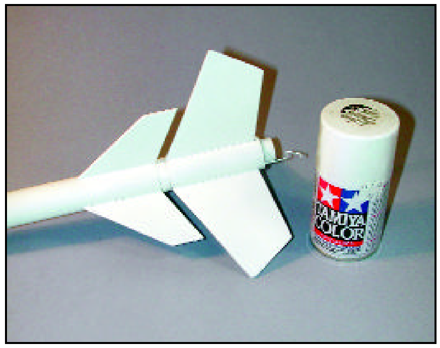
The booster section is now assembled. When gluing, make sure the booster fins align with the main body fins. After the glue has cured, paint the fins with several coats of sanding sealer.

Automotive sandable primer was used by the author. This can be purchased at most automotive aftermarket supply stores. It is also called "automotive primer surfacer."



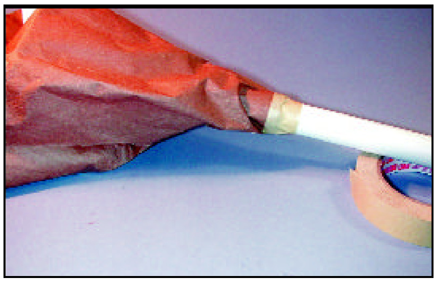
Regular sandpaper in the grit range of 240-320 can be used to carefully smooth out the cured primer. Another technique is to use sanding pads, such as 3M's Scotchbrite. These work very well on rounded surfaces.

After two or three primer coats, even finer sandpaper can be used to perfect the finish.

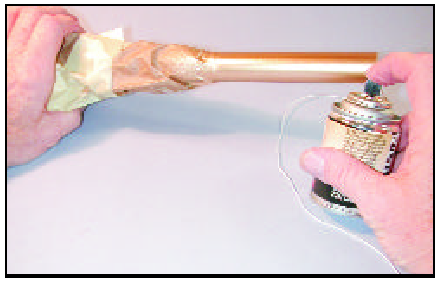


A white undercoat will make all other colors, applied over it, much more vivid. Since the author elected to use a candy final coat, Tamiya Pure White was sprayed first.

Testor's Gold and Candy Red are applied in separate stages. The gold is applied first and then the red. The final finish is spectacular.



The upper section is taped off using masking tape and paper. Supermarket bags, plastic trash bags and newspaper work well.



The gold is applied first to the body section…

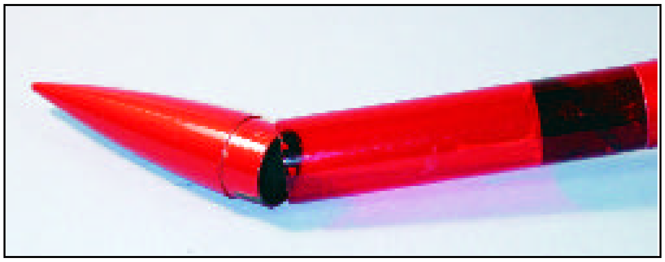
…then the nose cone.

The Translucent Candy Apple Red is applied over the gold. Apply two mist coats and then, after at least 30 minutes, two wet color coats. Let dry overnight.

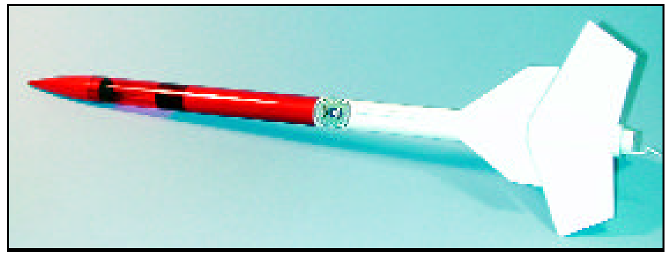
Don't get in a hurry. Let the candy finish dry thoroughly.

The parachute is very important to proper recovery. Remember that this chute will be supporting more weight than usual so build it correctly.

Once assembled properly, the parachute is attached to the shock cord, which is attached to the engine assembly which is attached to the body tube—a very well-engineered recovery system!



The payload compartment can carry, "...insects, electronics or other experiments" according to the Quest package. The nose cone is held in place with electrical tape so that the payload remains in place during flight.



The rocket is finished with the CAP seal. The candy finish and payload compartment all blend together to make a very professional-looking model.

Cadet Ryan Lacy and Dylan Stark prepare the two-stage Quest Rocket for Launch.

The moment of truth....Zenith II blasts off!

SATURN
Official Witness Log

HANDS-ON PHASE

The cadet is required to build two model rockets to complete this requirement. One of the rockets must be have two engines that fire in two stages and the other must be capable of carrying a payload. The launch must be witnessed by a designated Qualified Senior Member (QSM). Finally, the cadet must have a working knowledge of the NAR Safety Code.

CADET____

of ____

squadron, has successfully built, launched and recovered one of the following options:

1. A model rocket capable of carrying a payload to an altitude of 300'.
2. A two-stage model rocket.
3. A rocket equipped with a glider both of which return safely to earth.
4. **OR**, in the event a cadet is required to take the air-power option due to local restrictions, a scratch-built, air-powered rocket is required as stated in the text. The cadet is required to track and record the altitude of the air-powered rocket.

The cadet must have a working knowledge of the 11 parts of the NAR Safety Code.

As a Qualified Senior Member (QSM), I have found that the cadet has successfully met the requirements of this phase of the Saturn Stage.

____
(QSM)

SATURN STAGE
Squadron Commander's Approval

I have reviewed the Official Witness Logs, both written and hands-on, of Cadet

____

and have found that this individual has successfully passed the Saturn Stage requirements.and is now qualified to receive the official Model Rocketry Badge of the Civil Air Patrol Cadet Program.

____

Squadron Commander

ONE STEP BEYOND

The Project of the Valkyrie Cadet Squadron, Denver, Colorado.

This 122 cadet squadron has won several Wing, Regional and National honors. Their commander is Captain Courtney Walsh, of Englewood, Colorado.

Rocket enthusiast, Preston Prunty, and cadets of the Valkyrie Cadet Squadron, built an awesome rocket that was launched on the second day of June, 2001. Prior to that, over a five-month period, Prunty and the cadets scratch-built an advanced model rocket that had the following dimensions:

- Height 12' 8 inches
- Weight 31.3 pounds (launch ready)
- Power - 24 Class C and Class G motors. This included 4 sustainer motors, 4 secondary motors, 7 main motors, and 9 outboard motors.

Initial planning began in November of 2000, and it was finally launched on the second of June, 2001. Every Tuesday evening, and most Saturday mornings, cadets worked on the basic construction at their meeting site in the Wings Over the Rockies Aerospace Museum located in Denver, Colorado. The rocket began life as two large cardboard tubes reinforced with fiberglass. The overall configuration was scaled to look like a Delta II/III rocket. All of the engine design and much of the detail work was completed by Preston while the cadets worked on the main airframe.

The Valkyrie Vision is being prepared for Launch. In the background, Preston Prunty (NASA t-shirt) works with CAP Brig. General James Bobik (foreground) to get the igniter assembly ready. The awesome 12 foot tall rocket was an impressive site to nearly 100 honored guests who showed up for the launch.

The Moment of Truth

It was a chilly June morning when the scheduled launch sequence began. It started with 7 main and 9 outboard motors all igniting at once. The 9 outboards burned for 7.5 seconds and the mains burned for 1.5 seconds. The sustainer motors burned for 2 seconds after liftoff. All of the 9 outboard motors separated from the rocket and were scheduled to be recovered by parachutes. Secondary sustainer motors ignited 7.5 seconds into the sequence and burned for 1.5 seconds. Four seconds after burn-out of the final thrust stage, payload separation was scheduled to occur and deployment of two parachutes were to bring the Vision safely back to the surface. On the day of the launch, not everything went as planned, but it did roar into the sky over Buckley Air Force Base and the cadets of Valkyrie Squadron all said, "…it will fly again!"

The power of aerospace education takes to the skies over Denver, Colorado.

GLOSSARY of MODEL ROCKETRY TERMS

Aerodynamics - The science and study of air in motion.

Acceleration - A rate of change in the speed of an object over a unit of time.

Accelerometer - An instrument that measures acceleration.

Aerospace - A compound term used to describe the atmosphere and space as one medium. The science of aeronautics and space spoken as one.

Altimeter - A device, usually an aneroid barometer, that reads in feet of altitude based on atmospheric pressure in inches of mercury.

Apogee - The highest point reached in the flight of a rocket.

Airfoil - A component of an airplane or a rocket that causes a dynamic reaction from the air through which it moves. A fin is an airfoil.

Armed - A ready-to-launch condition in which a safety key is inserted.

Ballistic - A projectile that receives an initial thrust from a power source then continues in motion due to momentum. A bullet is an example of a ballistic missile.

Ballast - Added weight, such as clay in a nose cone.

Blast - A burst of hot rocket motor exhaust.

Blast Deflector - A device that is designed to deflect the exhaust in a direction away from the source.

Boost - An additional source of power or thrust.

Boost Phase - The period in a model rocket's flight where a motor is providing thrust.

Burn - The time in which a model rocket motor is providing thrust.

Burn-out - The point where all of the fuel is expended and thrust is no longer provided.

Center of Gravity - The balancing point of all of the mass. This is also known as the Center of Mass.

Center of Pressure - The point were all of the aerodynamic forces will balance while the rocket is in motion. This is usually behind the center of gravity near the tail of the model.

Cluster - A group of rocket motors working together.

Coasting - A time in the flight of a model rocket right after the fuel is expended and the ejection charge is not yet fired.

Combustion - A chemical reaction that occurs inside the combustion chamber and provides a controlled explosion resulting in thrust.

Deceleration - Slowing down or decreasing speed.

Drag - Forces acting upon an object to slow it down.

Duration - The length of time in flight.

Ejection - To be forcefully moved.

Ejection Charge - A component of fuel in a model rocket's motor that provides enough thrust to blow the recovery system out of the body.

Elevation - An angle measured above the horizon.

FAA - Federal Aviation Administration. This is the governing body that controls all of the airspace above the USA.

Fillet - A filler added at the juncture of two components. In the case of a model rocket, a fillet is a layer of glue or putty that smooths out a right angle joint. This can add strength and improve aerodynamic flow.

Fin - An airfoil attached to the body. In the example of a model rocket, a fin is attached to aft section and adds stability in flight.

Finish - The final surface of a model rocket.

Fuel - The chemical, which reacts with oxygen to create thrust.

G - A unit of gravity.

Glide - The non-powered descent of a model with airfoils controlling part of the descent.

High-Power Rocketry - An advanced segment of the model rocketry hobby where motors larger than a "D" are used for thrust.

Igniter - An electrical device, usually nichrome wire, that provides enough heat to cause the chemical reaction between the fuel and the oxidizer.

Impulse - A motion-producing force.

Ignition - A point where fuel and oxidizer combine.

Lateral axis - The axis running through the center of gravity from side to side as viewed from the front. Movement about this axis is called "Pitch."

Launch - The takeoff.

Launch controller - An electrical system that provides a current to the igniter.

Launch lug - A tube that is attached to the body of the rocket for the purpose of guiding the model up the launch rod during liftoff.

Launch rod - A rod used to guide a model rocket in the first moments of ascent. This rod provides a path in the first seconds of launch.

Launch tower - A structure that provides a path for the rocket, during launch, by exerting slight pressures upon the fins.

Leading Edge - The front edge of an airfoil. This is the edge that encounters the oncoming wind first.

Longitudinal axis - The axis going from the nose to the tail through the body of the rocket. Movement about this axis is called "Roll."

Mass Ratio - A ratio between the mass (weight) of a rocket at liftoff to its mass after the fuel has burned off.

Maximum Thrust - The greatest amount of thrust created during the combustion process.

Momentum - Mass times velocity equals momentum.

Motor - A device that converts chemical energy into thrust. The word is used interchangeably with "engine."

Multi-Stage - A rocket having two or more sections that operate one after the other.

NAR - The National Association of Rocketry. This is the official governing body of the model rocket hobby.

Newton - In scientific terms, it is method of measuring **impulse**. It is the amount of force necessary to move one kilogram of mass through a distance of one meter per second per second.

Nichrome - An alloy wire used to ignite model rocket motors when an electrical current is passed through it.

Nozzle - A small area of a rocket motor where exhaust gases pass through and are directed outward.

Oxidizer - A chemical in a rocket motor that reacts with the fuel to provide combustion.

Payload - An object (s) that is carried on board of a rocket during its flight. The payload is not normally a permanent fixture of the rocket.

Propellant - The combined mass of the fuel and the oxidizer.

Propulsion - The act of moving the rocket forward.

Range - An outdoor launch area.

Recovery System - A system built into a model rocket to bring it safely back to Earth after a flight.

Relative Wind - As a rocket moves through the air, it creates a "wind" that travels in the opposite direction. This is the relative wind.

Shock cord - An elastic cord that attaches the parts that separate when the ejection charge is ignited.

Shroud Line - The lines that make up the parachute.

Solid Propellant - When the fuel and oxidizer are dry chemicals, they make up the solid propellant.

Specific Impulse - The number of pounds of thrust delivered by consuming one pound of propellant in one second.

Stability - A measure of performance based on the ability of a rocket to maintain a desired course.

Streamer - A strip, or ribbon, of material used to slow the descent of a model rocket-other than a parachute.

Swing Test - A method of testing the basic stability of a model rocket.

Thrust - A force produced when the propellant burns.

Trajectory - The flight path of a model rocket.

Velocity - The speed per unit of time in a given direction.

Vertical Axis - The axis going through the center of gravity and 90° to the lateral and horizontal axes. Movement around this axis is known as "yaw."

Wadding - A flame resistant material (usually paper) that is packed between the motor (ejection charge) and the recovery system. This keeps the heat from damaging the parachute, payload and/or streamer.

MODEL ROCKET MANUFACTURERS, SUPPLY HOUSES and ORGANIZATIONS

Associations and Publications

National Association of Rocketry (Safety Rules featured in Text)
P.O. Box 177
Altoona, WI 54720
www.nar.org

Tripoli Rocketry Association, Inc. (High Power Rocketry)
P.O. Box 339
Kenner, LA 70063
www.tripoli.org

Sport Rocketry Magazine (The official magazine of the NAR)
P.O. Box 177
Altoona, WI 54720
www.nar.org

Academy of Model Aeronautics (An organization that welcomes free flight, radio control, control line, rockets, boats and kites)
5151 E. Memorial Dr.
Muncie, IN 47302
www.modelaircraft.org

The following businesses offer a line of products related to model rocketry. It is recommended that the cadet search the internet to see what is available.

Estes Industries (Featured in Text)
1295 H Street
Penrose, CO 81240
www.estesrockets.com

Quest Aerospace (Featured in Text)
350 E. 18th St.
Yuma, AZ 85364
www.questrockets.com

Custom Rocket Co. (Elite model featured in text)
P.O. Box 1865
Lake Havasu, AZ 86405
www.greathobbies.com

Arbor Scientific (Air Powered kits / featured in text)
P.O. Box 2750
Ann Arbor, MI 48106
www.arborsci.com

Apogee
1130 Elkton Dr., Ste A
Colorado Springs, CO 80907
www.apogeerockets.com

Air Burst Rockets (Air Powered Model Rockets/ featured in text)
MMI Mondo-tronics, Inc.
PMBN 4286 Redwood Hwy.
San Rafael, CA 94903

True Modeler's Rocket Kits
P.O. Box 186
Harbeson, DE 19951
www.truemodeler.com

Pitsco, Inc.
915 E. Jefferson
P.O. Box 1708
Pittsburg, KS 66762
This company is primarily a school supply, however, they have a huge inventory of model rockets and related components.
1-800 835-0686

Fliskits, Inc.
6 Jennifer Drive
Merrimack, N.H. 03054
www.fliskits.com

Civil Air Patrol Bookstore
30 S. Arnold St
Maxwell AFB, AL 36112
1-800-633-8768

The Leadership Development and Membership Services Directorate of the CIVIL AIR PATROL invites CADETS, AEROSPACE EDUCATION OFFICERS and PROFESSIONAL EDUCATORS to Participate in the Science, Technology, Construction and Flight of Model Rockets.

FEATURING:

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- **The Science Of Newton's Laws Of Motion**
- **Pre-Flight Testing**
- **Model Rocket Engine Technology**
- **Altitude Tracking**
- **Rockets With Alternative Sources Of Power**
- **A Two-Stage Model Rocket**
- **An Egg-Carrying Model**
- **Construction Tips**
- **Painting And Finishing Techniques**
- **Advanced Models**
- **National Standards For Science And Technology Correlation**

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