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.

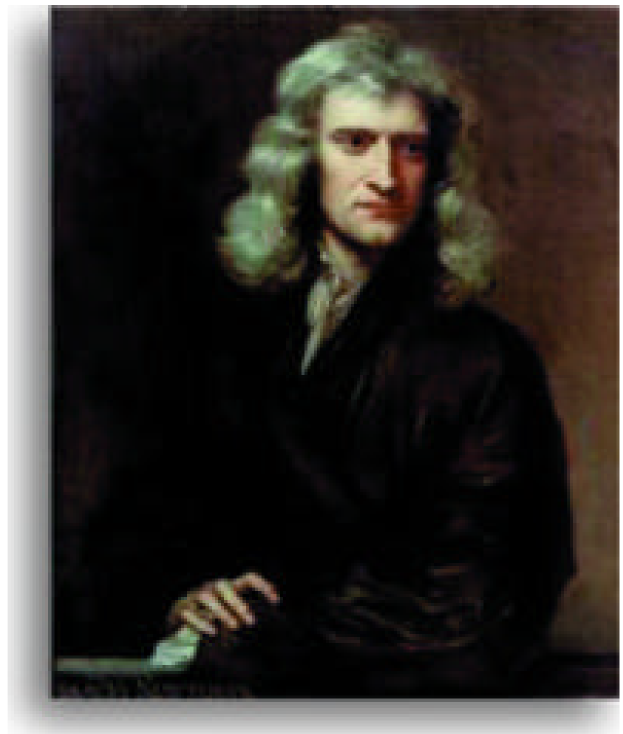
TITAN Written Phase

LAWS THAT GOVERN ROCKET SCIENCE

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.



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

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.

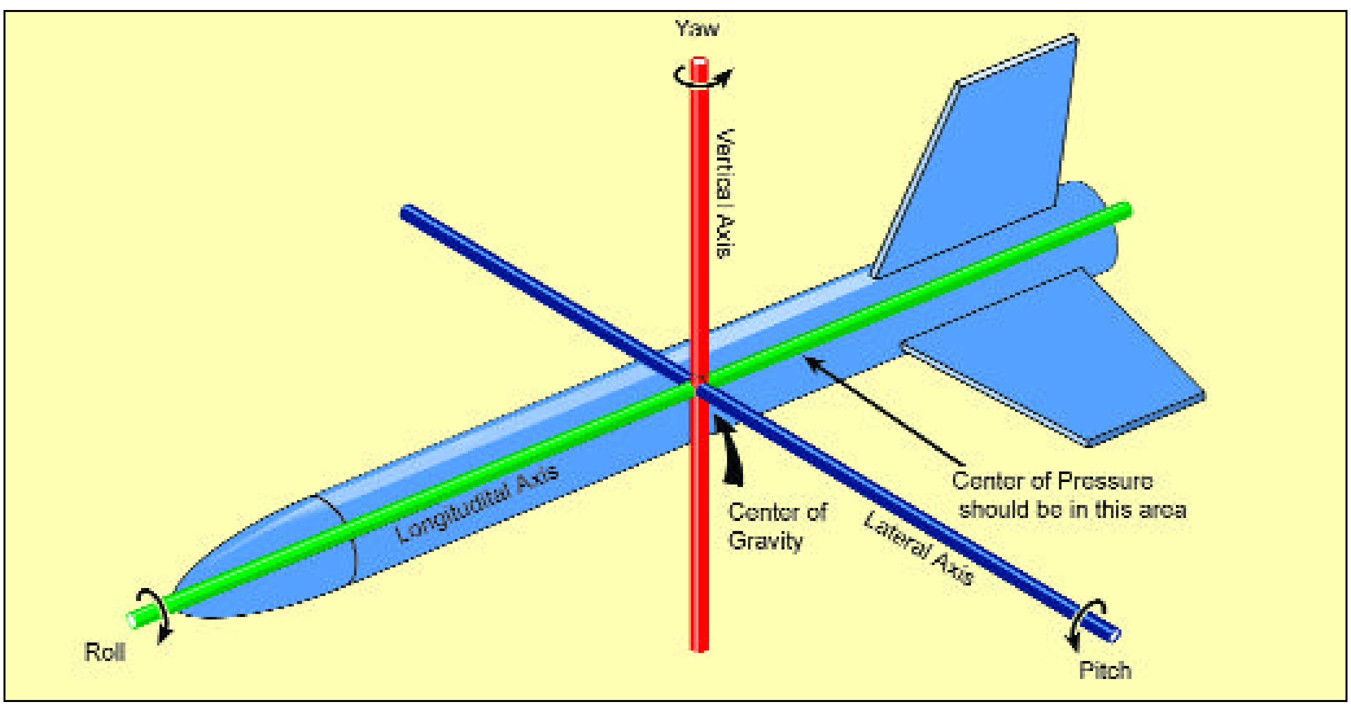
It is extremely important that the center of pressure of a model rocket be located toward the tail and the center of gravity be located more toward the nose. If they are very near each other, the rocket will be unstable in flight. With the center of pressure located in the right place, the rocket will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

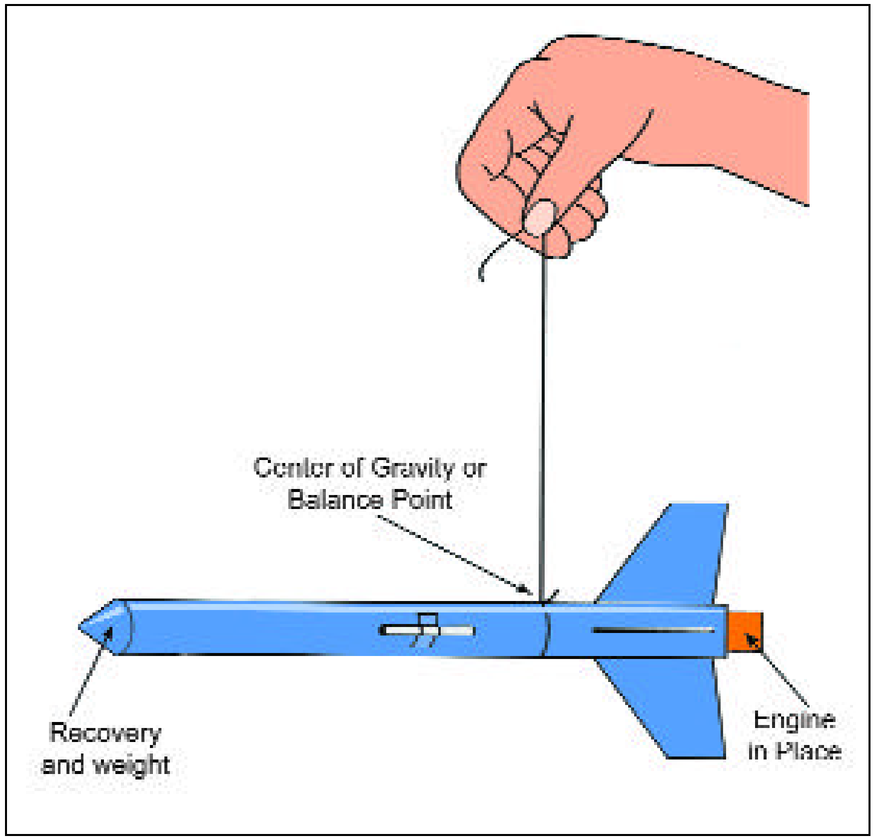


straight. This is done by holding the rocket in one hand with an arm extended and then pivoting the entire body as the rocket is started on its circular path. It may take several attempts before a good start is achieved.

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.

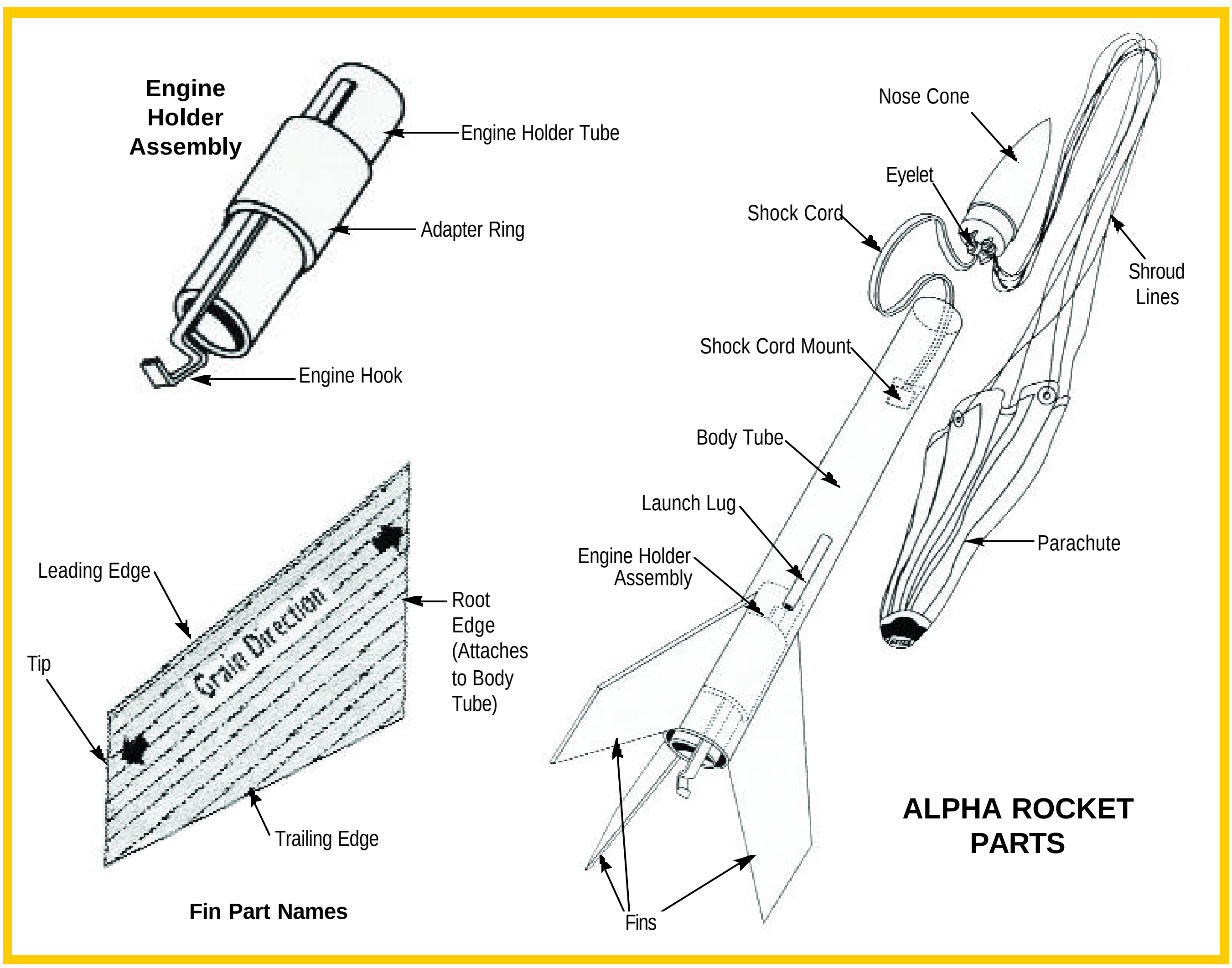
BUILDING THE ESTES ALPHA, A CLASSIC ENTRY-LEVEL MODEL ROCKET

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.

PROCEDURE

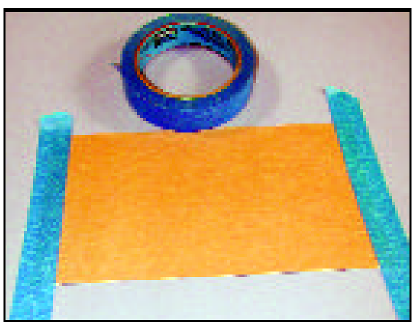
All too often, cadets get in a hurry and construct a model rocket with very little reference to the instructions. It is highly recommended that the builder go over each step carefully and arrange the parts in the order that they will be used in construction.

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

Grit Guide

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

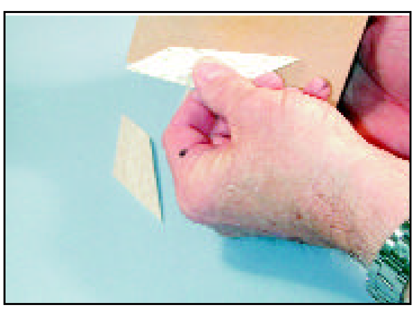
Not everybody knows the difference in sandpaper. To be sure, follow this grit guide and purchase a sheet that won't damage the balsa used on model rockets. Something in the range of 150-240 works well for sanding fins.



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

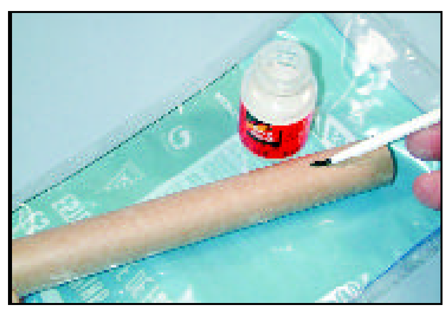
The builder can also use a sanding block. The paper is wrapped around a block for sanding the balsa pieces. This creates a flat surface when sanded.

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.

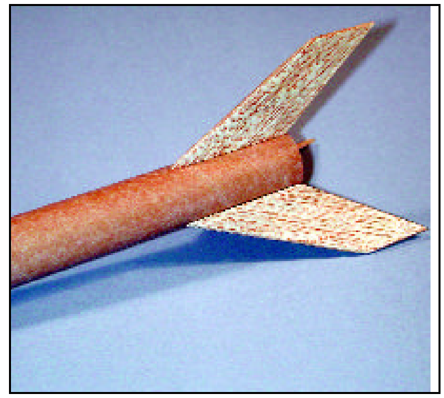
It is highly recommended that the builder use a sanding sealer on the balsa. This seals the surface and makes a more professional looking paint finish.



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.

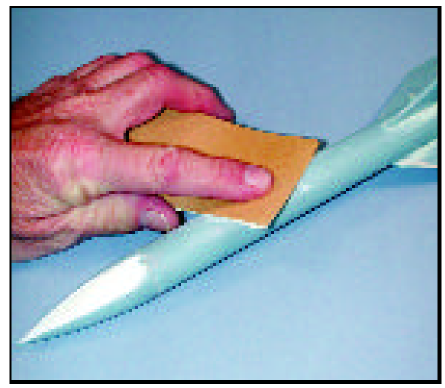
Cadet Alec Atwood applies one of two of the recommended adhesives for this type of model rocket. Both white and yellow glues work well.



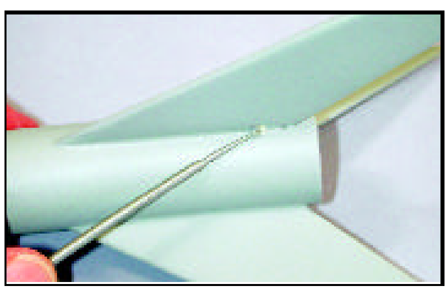
When the fins are properly aligned and glued, there should be no glue showing. It is important to have the Alpha fins 120° apart.

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.

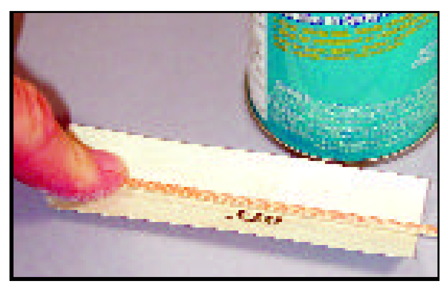
White putty, purchased at a hobby shop, can be used to fill in the imperfections in the primer finish. It can also be used to make a nice, rounded fillet between the fins and body.



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.

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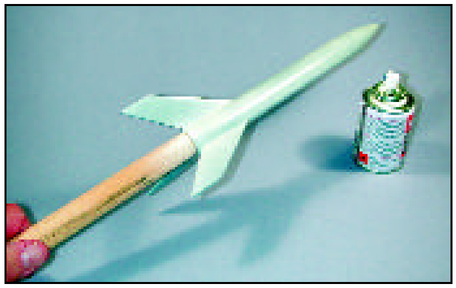
It is recommended that very fine sandpaper be used for the final step. After spraying one or two final coats of automotive primer, carefully sand the surface with a finer grade of paper. It is recommended that the builder let the rocket set for at least two days so the primer has a chance to cure.

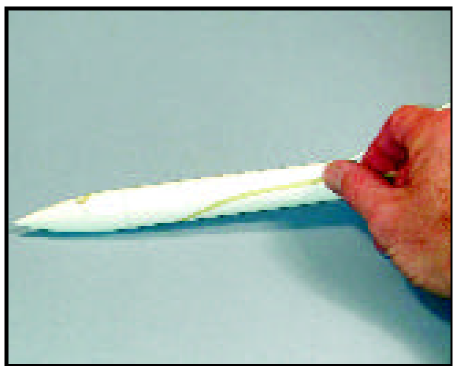
Once the finish is flawless, it's time to paint. The author recommends a high quality hobby grade of paint for the rocket's base, or first, coat.



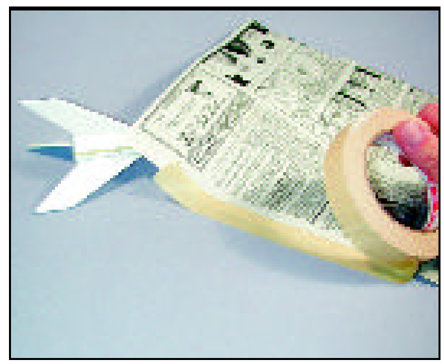
For the rocket used in this publication, the author used Tamiya TS 16 Pure White as the base coat. The rocket was held with a dowel rod while being sprayed. The first two coats are light mist followed by two wet coats. Let the model dry for about 15 minutes between coats.

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.

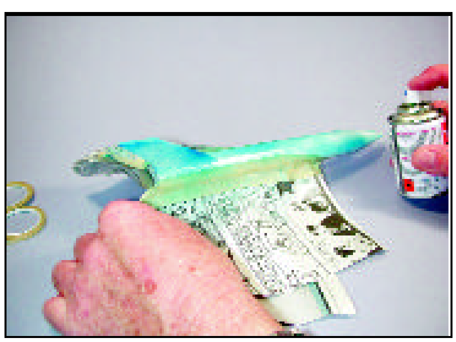


The thin (1/8 or 1/16) tape is applied to make a graphic such as this curved line. (See the photograph of the finished rocket).

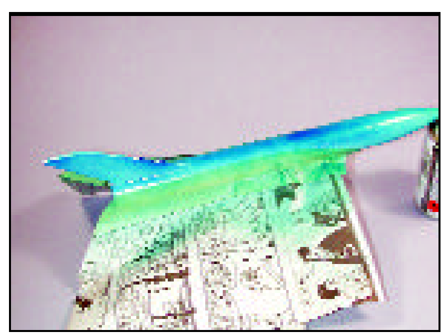


To make a larger masking paper, apply masking tape so that ½ of the tape is on the paper and the other ½ is open.

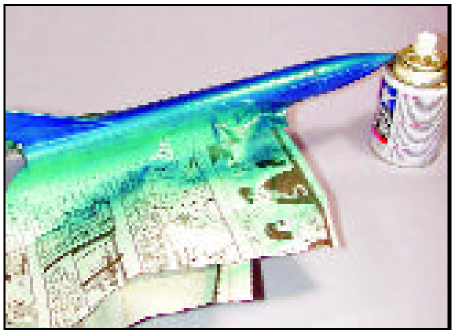
The masking tape open edge is laid down on the thin tape line. Make sure that it is properly aligned and sealed so that spray paint won't "bleed" through.



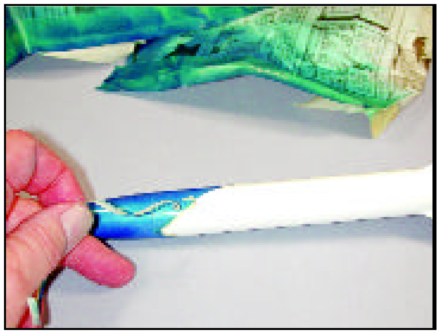
Tamiya's TS 19 Metallic Blue was used for a second color. First apply a mist coat allowing some drying time between coats. If the builder gets in a hurry, runs and sags may occur.



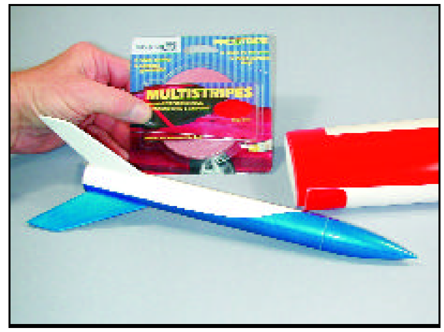
After the mist coat dries, apply a full color coat. Let dry for at least 20 minutes.



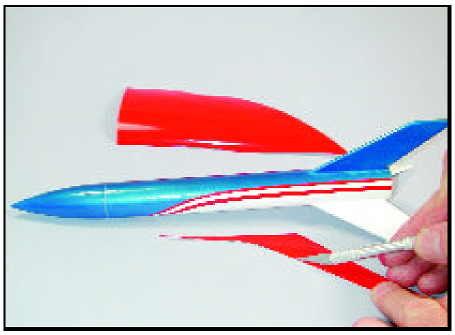
Two wet coats are applied and it is recommended that the builder let it dry overnight.



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 4^0 Celsius (40^0) 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 NOT 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:

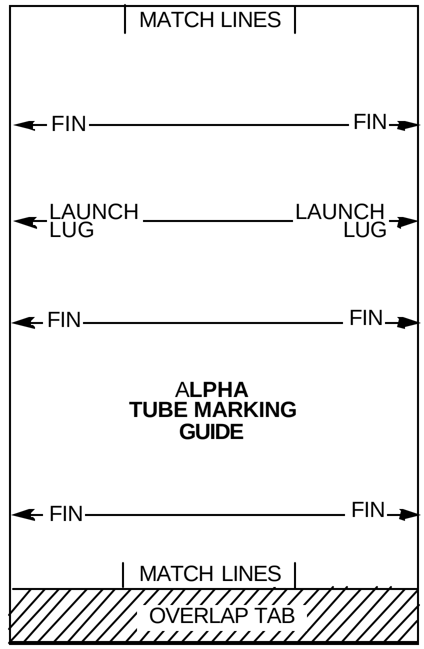
A. After attaching micro-clips, etc., insert the safety key into the controller recepticle. If the igniter clips have been attached properly to the igniter, the red L.E. D. will now begin to flash on and off and the audio continuity indicator will beep on and off.

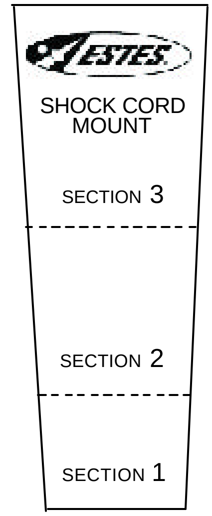
B. Hold the yellow (left) arm button down. The L. E. D. will stop flashing and the audio indicator will produce a steady tone.

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.

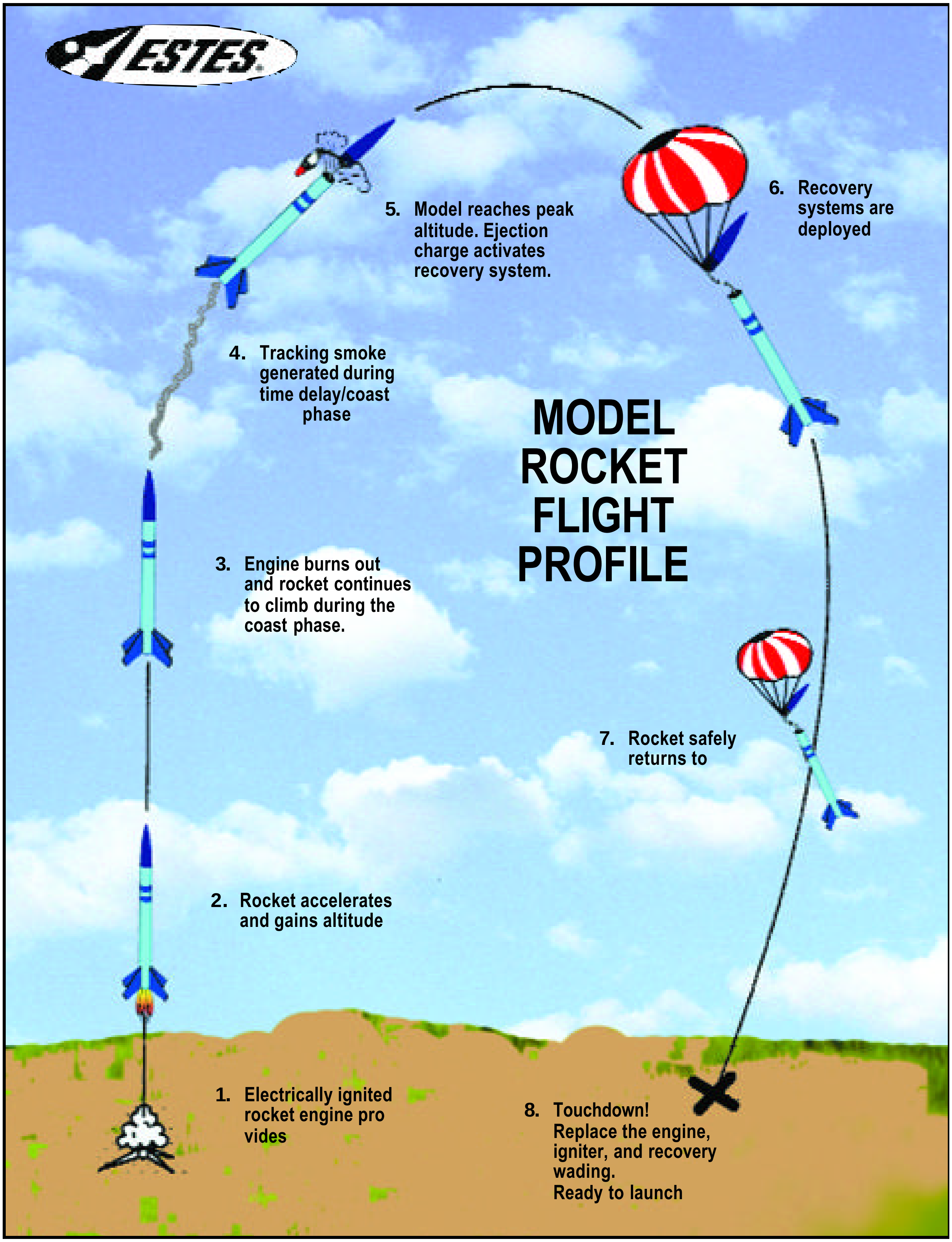
Cadet Stark watches as Cadet Kevin Rutherford prepares his rocket for lift off.

ALPHA PATTERNS



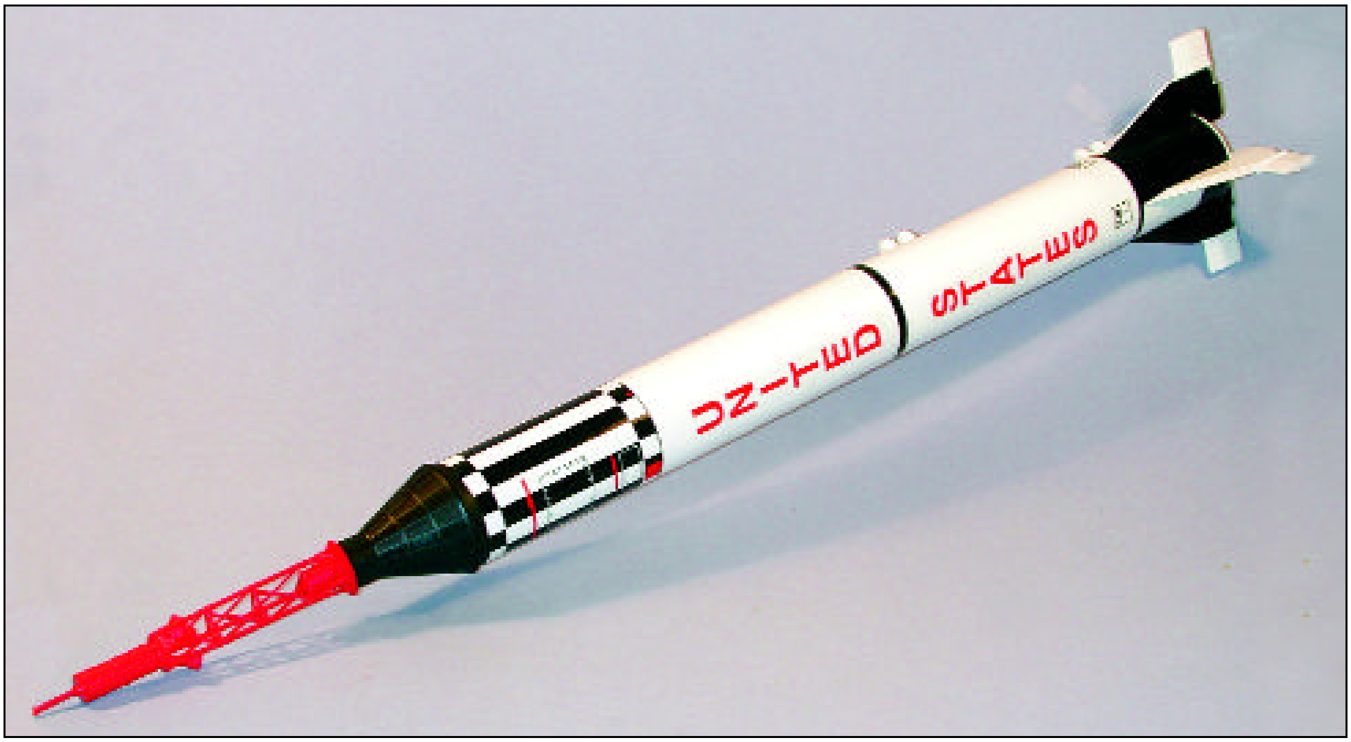


Launching the rocket is Cadet Kristopher Turner. Standing by is Cadet David Van der Vieren. Both are members of the Dakota Ridge Composite Squadron, Littleton, Colorado.


ESTES
5. Model reaches peak altitude. Ejection charge activates recovery system.
6. Recovery systems are deployed
4. Tracking smoke generated during time delay/coast phase
MODEL ROCKET FLIGHT PROFILE
3. Engine burns out and rocket continues to climb during the coast phase.
7. Rocket safely returns to
2. Rocket accelerates and gains altitude
1. Electrically ignited rocket engine pro vides
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, <u>In Search of Liberty Bell 7</u> 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:

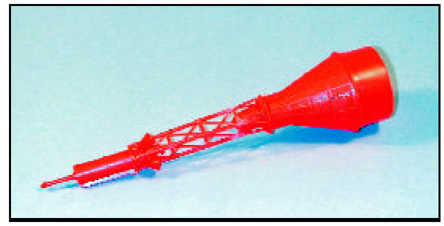
As always, it is good idea to lay the parts out and spend some time reading the instructions. One of the most important benefits is to learn the sequence of building a rocket the right way.

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

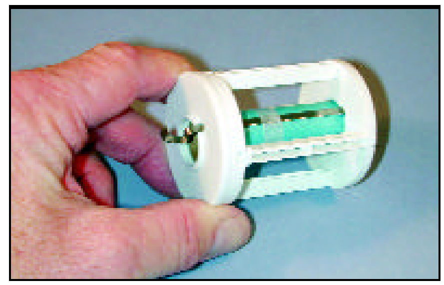
The author found that the escape tower mechanism proved to be difficult. It is suggested that just a small amount of plastic be clipped from the edges of this triangular piece. It allows the tower structure to be glued without distortion.

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

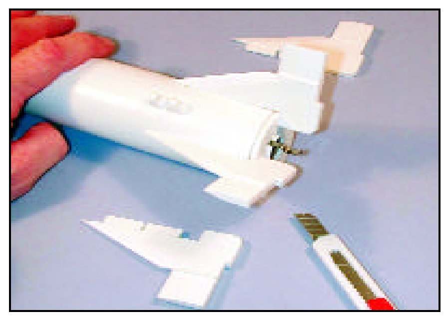
While the escape tower structure is drying, the builder can start on the Liberty Bell 7 capsule. This goes together reasonably well, but care should be used when fitting the sides of the three parts together. Every effort should be made not to get the plastic cement on the fingers; smearing this on the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



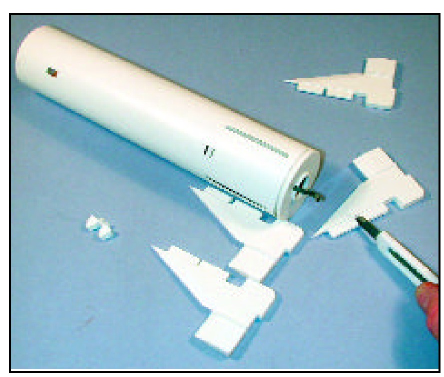
Once the structure is cemented, according to the instructions, the capsule can be painted flat black and the tower structure a flat red.

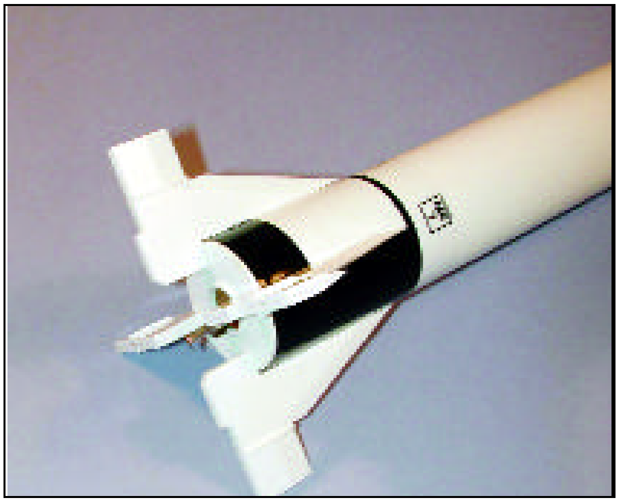


This is what the engine assembly looks like when completed. The horizontal structures will hold the fins when properly mounted in the body of the rocket.

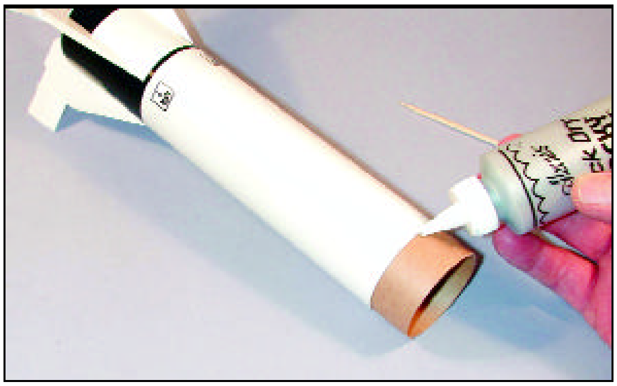


Once the engine housing is inserted into the body, it is a good idea for the builder to "pre-fit" the fins. To make the fins fit the slot, a hobby knife can be used to trim the tabs.

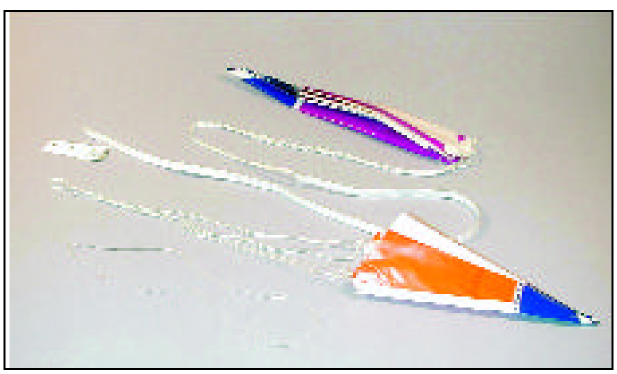




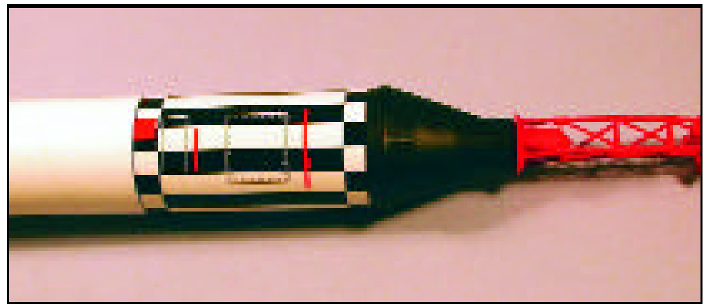
Before the fins are glued to the engine mounting, the lower body graphics must be applied.



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.



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.

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

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!

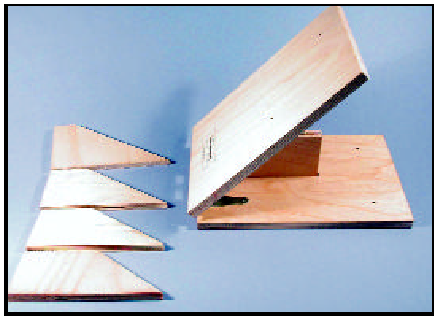
There is another side to model rocketry that limits some hobbyists; model rockets are not always allowed, by law, to be launched. If this is the case, the air powered rocket can be launched and recovered legally just about anywhere.

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"

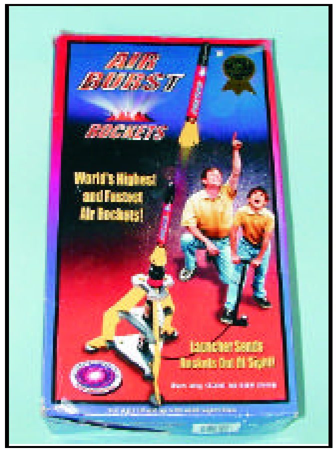
The Arbor Scientific's instruction sheet gives the following for a launch sequence:

(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.

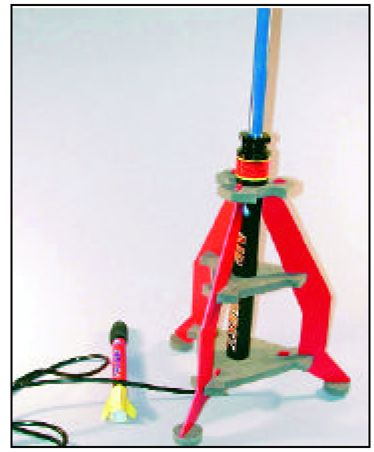
At the time of this writing, the entire cost of the Arbor Scientific air rocket system was $58.11. This included the Rocket Launch Pad, Rocket, Angle Wedges and shipping. Their address is Arbor Scientific, P.O. Box 2750, Ann Arbor Michigan 48106. Email is mail@arborsci.com. Their toll-free number is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

THE AIR BURST ROCKET

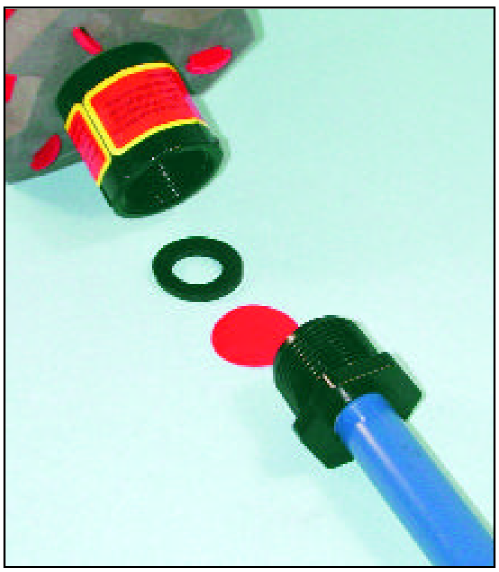
A company by the name of Mondo-Tronics, Inc., produces an excellent air rocket called the "Air Burst" and specifically, their projectile is known as the Pulsar. The rocket is launched using a bicycle pump, much like the others; however, a small wafer is required for each launch. When the pressure from 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:

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

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