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State
University

Extension

MC1303A
Member's Manual



18 USC 707



**4-H Intermediate
Model Rocketry**

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TO MEMBERS:

Unit 3 is written for the rocketeer who has completed unit 2 Basic Model Rocketry. Now you are ready for more detail in Intermediate Model Rocketry. This unit will cover new and exciting areas not covered in unit 2. Welcome back to the "hands on" hobby of today and tomorrow. You just may be a future astronaut. Discover what is ahead of you since you now have the basics.

SUMMARY OF UNIT 2 BASIC MODEL ROCKETRY:

Areas of discussion in unit 2:

- three types of rocketeers
- why model rocketry was started
- the history of rocketry
- the code of safety by which rocketeers abide
- the basic parts of a model rocket
- recovery parts of a model rocket
- launching equipment and what it is about
- tools
- rocket kits
- construction of rockets
- types of rockets
- recovery systems
- rocket fuels
- stability
- engines
- igniters
- launching
- altitude tracking
- glossary of terms
- model rocket companies
- completion of unit 2

REQUIREMENTS TO BE COMPLETED BEFORE YOU GO ON TO UNIT FOUR:

1. Completion of all questions after each adventure, signed by you and your leader.
2. Fill in record section completely, signed by you and your leader.
3. Assemble, fly and track your two skill level three rockets.
4. Exhibit your best rocket and your record book at county fair.

GENERAL INFORMATION

23. NATIONAL FIRE PROTECTION ASSOCIATION CODE

A. CODE FOR MODEL ROCKETRY, NFPA 41L.

1. The purposes of this code are: (a) to prohibit the making and launching of dangerous homemade "rocket bombs", and (b) to eliminate the deaths and tragic injuries to young people that have occurred because of experiments with explosive "rocket fuels", home manufacture of rocket engines, and attempted launchings of those homemade rocket devices.
2. The code contains permissive, instructional guidelines and standards for: design construction, limitation of charge and power, and reliability of all model rocket engines manufactured for sale; for the design and construction of model rockets propelled by these model rocket engines; and for the conduct of launchings, tests, and other operations involving model rockets so that hazards are minimized.

24. FEDERAL AVIATION REGULATION PART 101

A. APPLICABILITY - This part prescribes rules governing the operation of unmanned rockets in the United States except:

1. "MODEL ROCKETS - Using not more than 4 ounces of propellant; a slow-burning propellant made of paper, wood, or breakable plastic containing no substantial metal parts and weighing not more than 16 ounces, including the propellant; and operated in a manner that does not create a hazard to persons, property, or other aircraft."

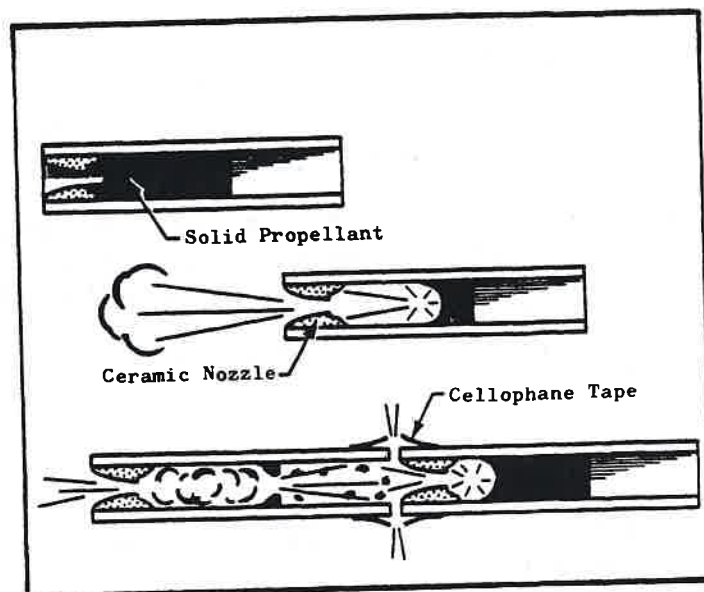
ADVENTURE VI - WHAT, HOW AND WHY MULTI-STAGE

25. WHAT IS MULTI-STAGING? - It is one of the prominent characteristics of rocketry. This method is used with solid and liquid propellant rockets, used in rockets less than 1 foot tall to well over 100 feet. The main advantage of multi-staging is doing away with unnecessary weight later in the rocket's flight. The principles of model rocketry and professional rocketry are the same, although the model rocketeer uses a different operating method than the professional. The young rocketeer who masters the principles of multi-staging is gaining knowledge that will be useful in the future.
26. MULTI-STAGING IGNITION - The first or lower stage is ignited by standard electrical means. Second stage ignition is automatically accomplished upon burnout of the first stage. The booster or first stage engine has no delay or ejection charge. This is necessary to assure instant ignition of the next stage upon burnout. As the propellant burns, it leaves a large combustion chamber. As it continues to burn, the walls become thinner until it is too thin to withstand the pressure in the

combustion chamber. (See Figure 1.) At this time, the propellant wall ruptures, letting the high pressure exhaust forward into or toward the nozzle of the next stage, carrying hot gases and pieces of propellant into the nozzle of the second stage engine. If the upper stage engine is placed ahead of the booster engine so the two can separate easily, ignition reliability will be as low as 40 percent, depending upon booster engine used (except when a Series II engine is used in the upper stage, which increases reliability to about 80 percent). The simplest and most reliable method of joining stages tightly is cellophane tape.

By wrapping one layer of tape around the joint between the two engines and recessing this joint 1/2 inch toward the rear of the booster body tube, reliability jumped to almost 100 percent. It was then discovered that coupling is the most important part in multi-stage ignition reliability.

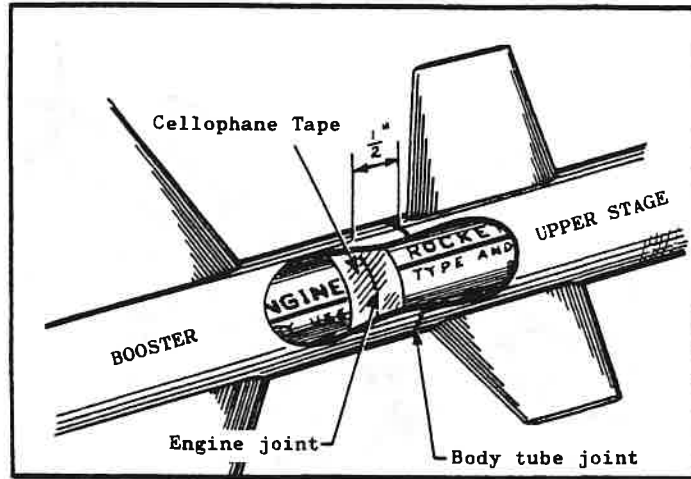
Figure 1



Courtesy of Estes Industries

27. MULTI-STAGE COUPLING - To help you understand how tight this joint must be, wrap a single layer of 1/2 inch tape (cellophane) tightly around the joint between the two engines. (See Figure 2.)

Figure 2

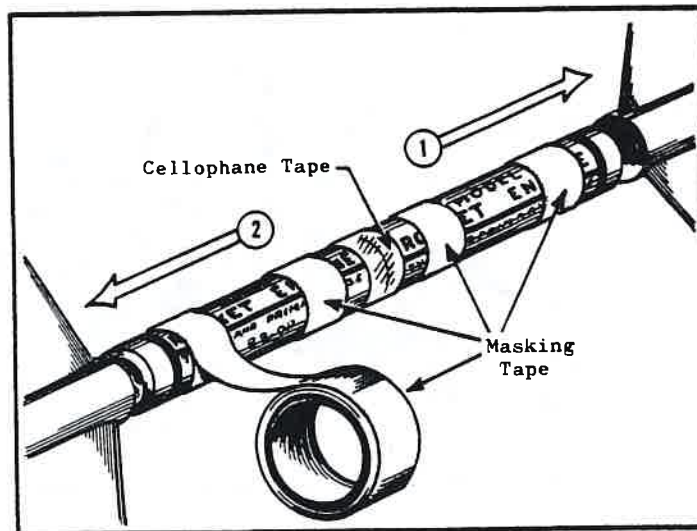


Courtesy of Estes Industries

Then, by grasping each engine firmly, pull them apart. Repeat this process a few more times until you develop a feel for stage coupling, which will prove valuable when you build and fly multi-stage rockets. The proper procedure for coupling will depend on the size of the body tube. With a body tube size of $\frac{3}{4}$ inch, the upper stage engine must project at least $\frac{1}{2}$ inch rearward into the booster body tube to ensure a straight line separation. Make sure the engines are taped together before insertion into the rocket.

Always check before and after taping to be sure the engines are in proper positions (nozzle of upper stage engine against top of booster engine). If you forget to check carefully, it can be very embarrassing as well as do damage to your rocket. Wrap masking tape around top and rear to give it a tight fit in the body and push it into place (upper stage). Repeat process for booster stage, then push booster into place. (See Figure 3.)

Figure 3



Courtesy of Estes Industries

The best method of mounting engines in rockets that have a large diameter tube involves correct positioning of the upper stage holder to extend 1/4 inch rearward from the end of the main body tube and, also, position of the engine block so engine extends 1/4 inch rearward from the end. Engine mounting in the booster must leave space for this engine mounting. If proper care is not taken, almost anything can happen.

28. MULTI-STAGE BOOSTER RECOVERY - Recovery system uses one of the simplest (discussed in unit 2) methods, which is the tumbling method. This is caused by its center of gravity (C/G) being so near the end of the booster stage. The booster stage should be painted a very bright color if you expect to keep track of it and use it again.
29. ENGINES TO USE IN MULTI-STAGE ROCKETS - Booster and intermediate stages use an engine that has no delay and tracking charge and no parachute ejection charge. Selection of your booster engine will depend upon several factors: rocket stability, weight, launch rod length and weather conditions. Wind has a definite effect on how your multi-stage rocket will perform. Rockets have a tendency to flop in the slightest breeze. In the upper stage, you should use an engine with a 4-second or more delay because the speed of the rocket might tear apart your parachute.

Please complete questions for Adventure VI found on page 32.

ADVENTURE VII - WHY COLD, HOW COLD?

Since this section was originally written, Cold Propellant Engines have generally been replaced by solid fuel rockets, and may not be obtainable in your area. We include this section, however, for the value of the information it presents.

30. COLD POWER MODEL ROCKET - It works in the same manner as a solid propellant rocket except it uses a liquid (Freon), which is under pressure when released in the engine. At this point it turns into gas, which provides the power or thrust needed to lift the rocket into flight. You will use the same launching pad as you did with your solid propellant rocket. Most cold power rockets use a parachute recovery system, as do a lot of solid propellant rockets. One of the advantages of the cold power is that you do not have to wait because of the weather. It can be tested indoors. A lot of tests or experiments can be conducted and are too numerous to name here. The gas has no color, taste or odor. It does not produce any heat. Three parts are used in filling a cold power rocket: the can the propellant comes in (RP-100 Estes), loading hose to carry it from the can into the engine, and the engine itself.

31. MODEL ROCKET SAFETY CODE FOR COLD PROPELLANT ROCKETS

All project members are expected to comply with the following model rocketry safety code approved by the National Association of Rocketry and the Hobby Industry Association of America.

A. MODEL ROCKET SAFETY CODE

1. ENGINES - I will use only factory-made model rocket engines in the manner recommended by manufacturer. I will reload cold propellant rocket engines only with the propellant recommended by the manufacturer.
2. RECOVERY - I will always use a recovery system in my model rockets that will safely return them so that they may be used again; I will conduct pre-flight tests to assure that recovery system functions properly before launching the rocket.
3. WEIGHT LIMITS - My model rocket will weigh no more than 16 ounces at lift-off.
4. STABILITY - I will check the stability of my model rockets before first flight, except when launching rockets of proven design.
5. FLYING CONDITIONS - I will not launch my model rocket in high winds, near buildings, power lines, tall trees, low-flying aircraft or under any conditions that might be dangerous to people or property. I will never attempt to recover a model rocket from a power line or other dangerous place.
6. LAUNCH ROD - To prevent accidental eye injury, I will always place the launcher so the end of the rod is above eye level or cap the end of the rod with my hand when approaching it. I will never place my head or body over the launching rod. When my

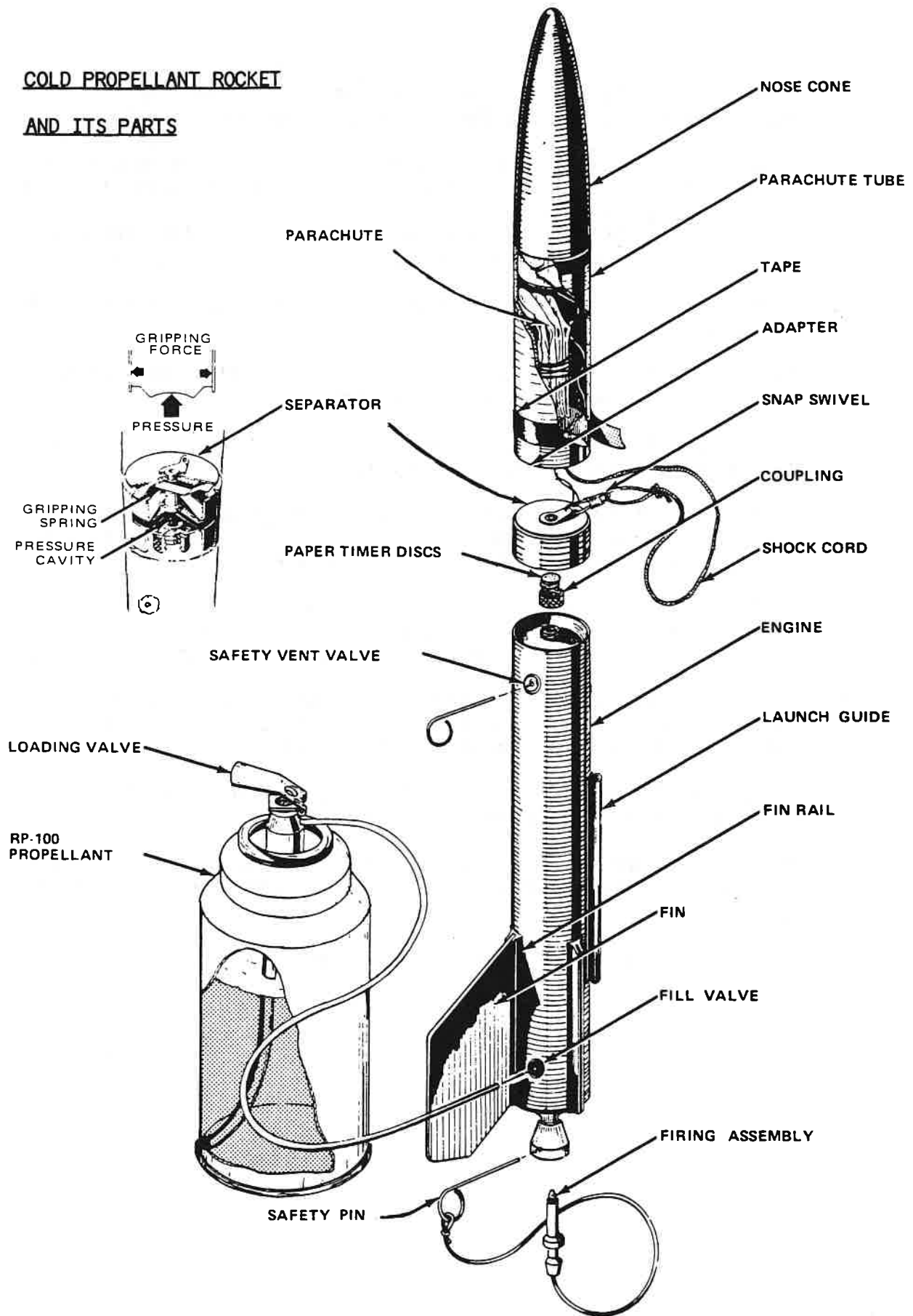
launcher is not in use, I will always store it so that the launch rod is not in an upright position.

7. LAUNCH TARGETS AND ANGLE - I will not launch rockets so their flight path will carry them against targets on the ground, and I will never use an explosive warhead or a payload that is intended to be flammable. My launching device will always be pointed within 30 degrees of vertical.
8. LOADED ROCKETS - I will never store or leave a loaded, cold propellant rocket untended. I will always keep a loaded rocket on a launcher or firmly restrained. I will never point a loaded rocket or its rocket nozzle at anyone or allow anyone to be in the flight path of a rocket during launch preparations.
9. CONSTRUCTION - I will never use metal nose cones or metal fins.

32. PARTS OF COLD PROPELLANT ROCKET AND HOW THEY WORK

- A. NOSE CONE - Pre-formed styrofoam cone adds sleek appearance, safety to rocket.
- B. PARACHUTE TUBE - Replaceable fiber tube contains parachute during flight.
- C. PARACHUTE - Ultra-light mylar canopy packs small, opens easily; shroud lines and tape discs for attachment are included.
- D. TAPE - Tape connects adapter to parachute tube.
- E. ADAPTER - Aluminum adapter tube permits proper grip and release of parachute tube by separator.
- F. SEPARATOR - Pressure from propellant in loaded engine causes separator to grip inside of adapter tube, hold it in place during upward flight.
- G. SNAP SWIVEL - Snap provides easy connection of parachute and nose to main rocket body.
- H. COUPLING - Threaded collar connects separator to engine. Timer discs fit inside.
- I. PAPER TIMER DISCS - Two or three discs delay escape of pressure from separator and permit rocket to reach top of flight before separator releases parachute tube.
- J. SHOCK CORD - Elastic cord absorbs shock of sudden deceleration when parachute opens.
- K. SAFETY VENT VALVE - Spring-loaded valve permits escape of excessive pressure, may be manually opened with pin to vent air from engine during loading.

COLD PROPELLANT ROCKET
AND ITS PARTS



Courtesy of Estes Industries

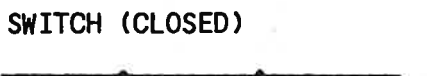
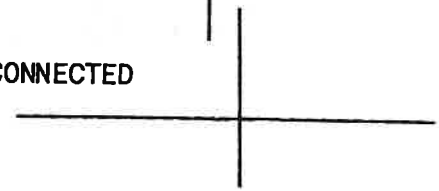
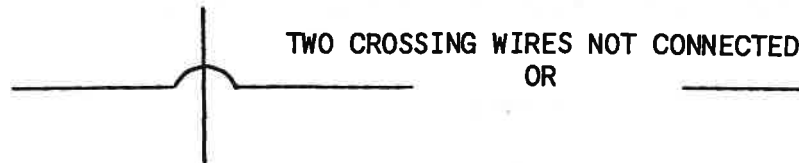
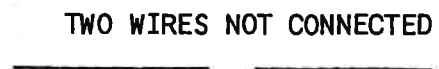
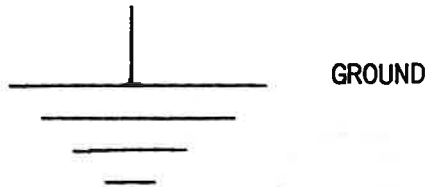
- L. ENGINE - Engine is loaded with liquid fuel under pressure, which exhausts from nozzle, providing thrust to accelerate rocket.
- M. LAUNCH GUIDE - Plastic tube is bonded to rocket, slides on 1/8 inch diameter launch rod to guide rocket during initial portion of flight.
- N. FIN RAIL - Plastic slot is bonded to engine. Fins slide into slot in rail, may be removed or replaced.
- O. FIN - Fins provide straight, stable flight when rocket is moving fast through air.
- P. FILL VALVE - Self-sealing rubber valve accepts fueling hose while loading engine, seals when hose is withdrawn.
- Q. SAFETY PIN - Pin holds nozzle plug in place when engine is loaded. Withdraw pin to launch rocket manually.
- R. FIRING ASSEMBLY - Plug seals nozzle while engine is loaded and is allowed to blow out when rocket is launched. Tether wire prevents loss. Optional remote unit is interchangeable.
- S. REMOTE ELECTRIC FIRING UNIT - When installed, a short piece of igniter wire holds the nozzle plug in place. Battery voltage applied to the cable melts the wire, allowing the plug to blow out.
- T. LAUNCHER - Vertical, 36-inch long rod guides rocket until it is moving fast enough for fins to provide straight, stable flight. Launch from the middle of a large, clear field.
- U. LOADING VALVE - Valve allows propellant to flow from container to engine when hose is withdrawn from the container.
- V. RP-100 PROPELLANT - Non-flammable, aerosol liquid under vapor pressure (about 70 pounds) vaporizes almost instantly while flowing from nozzle, provides thrust.

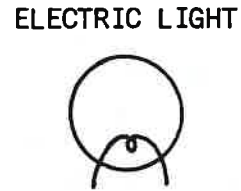
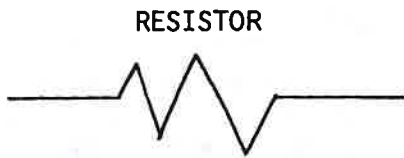
Please complete questions for Adventure VII found on page 32.

ADVENTURE VIII - OUT TO LAUNCH AND FIRING TO RETURN

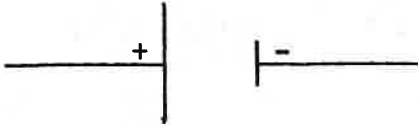
33. MODEL ROCKET LAUNCH SYSTEMS - There are three main types of launch systems. The first launch system was discussed in unit 2, which is the launch rod (such as a Porta Pad); second is a launch rail, which its name implies. It uses a device similar to a square metal tube with the center of one side cut out so that a T-shape or T-bar is attached to the rocket instead of a launch lug. The third method is the launch tower, which is very much like that used with real rockets at Cape Canaveral. One system not mentioned yet is a self-contained launch system, which is called Electro-Launch. The base contains eight 1.5-volt batteries (in plastic case), a blast shield and launch rod. The launch rod on the Electro-Launch serves the same purpose as other launch rods: it guides it during the first few feet. The electric current is adequate to heat the igniter (use "D" size photocell dry cells), which causes the propellant to ignite. The blast deflector helps protect the plastic base of the Electro-Launch from the heat of the rocket's exhaust.

34. SYMBOLS USED IN ELECTRICAL CIRCUITS - The following symbols will be used in Adventure VII:





SINGLE DR CELL (PRODUCES 1.5 VOLTS)

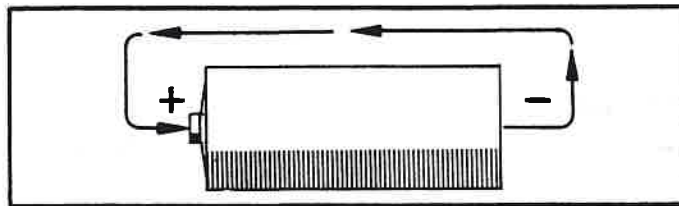


BATTERY (A BATTERY IS TWO OR MORE CELLS CONNECTED IN SERIES)



35. PRINCIPLES OF ELECTRICAL CIRCUITS - An electrical current is the flow of electrons. A circuit is the path the electric current takes or follows. Electrons will only flow when a circuit is complete.

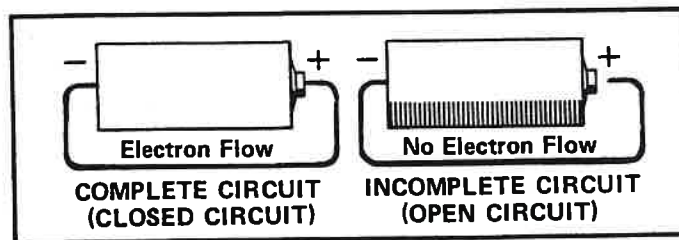
Figure 4



Courtesy of Estes Industries

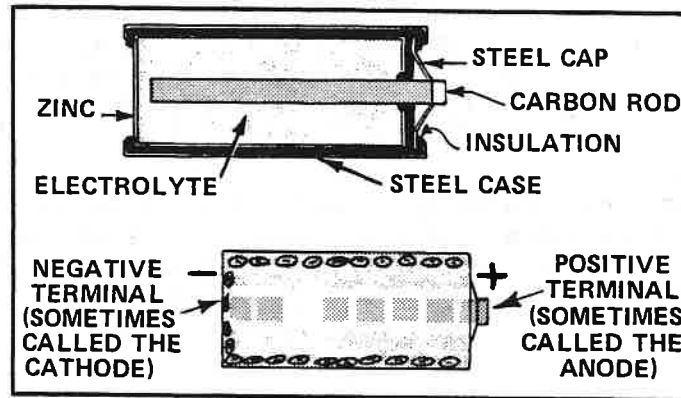
In a sense, electricity must come from a source and have somewhere to go. Whenever there is an interruption in the circuit, the electrons will not flow from the negative terminal of a power source, through the circuit and to the source through its positive terminal.

Figure 5



Courtesy of Estes Industries

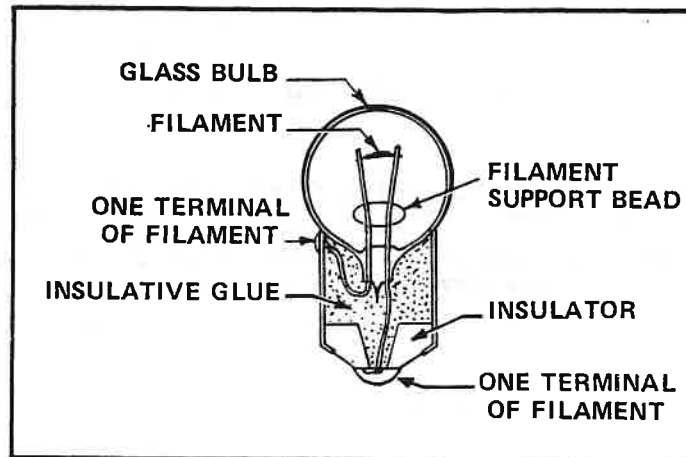
Figure 6



Courtesy of Estes Industries

As in any other circuit, an electric bulb will not light unless the electricity flows through it. The electron may enter through either terminal and exit through the other terminal. The most common failure occurs when the filament melts or breaks in an electrical bulb. A sealed bulb contains nitrogen or an inert gas that does not react with the hot filament.

Figure 7

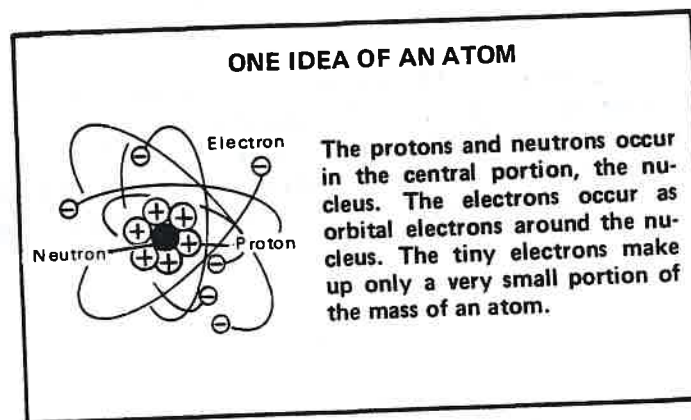


Courtesy of Estes Industries

36. **ELECTRICAL MATHEMATICS** - The amount of electrical current that flows is determined by the number of electrons going through the conductor. The unit used to measure this flow of current is a coulomb. (A coulomb is equal to about 6,250,000,000,000,000 electrons.) When one coulomb goes through a wire in one second, the current is flowing at a rate of one ampere. An ampere is a unit used to measure the rate at which electricity is flowing, hence, the ampere is equal to one coulomb per second.

The pressure pushing the electrons may also be measured. Electrons try to move from where they are crowded to places they are not. This tendency of electrons produces electrical pressure. This pressure or force is called electromotive force. A volt is the unit used to measure this force. It is also called electrical potential. The greater the pressure, the greater the voltage in the circuit.

Figure 8



Courtesy of Estes Industries

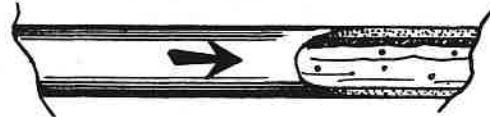
The power of the electricity flowing in circuit is determined by how many amperes of electricity are flowing and by the voltage pushing them. This total amount of electricity with which to do work is measured in watts. (See Figure 9.)

Figure 9

An electric current is a flow of electrons. This flow may be compared to a flowing liquid.



WIRE WITH FLOW OF ELECTRONS



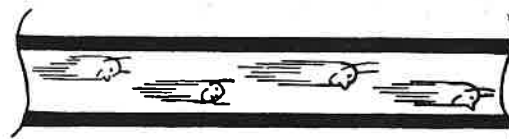
PIPE WITH FLOW OF WATER

Courtesy of Estes Industries

When electricity flows in only one direction, we call this flow direct current. When electricity flows rapidly back and forth, this motion or flow is called alternating current. When a substance presents very little resistance to the flow of electricity, this process is called conducting or conductors of electricity.

Figure 10

Any substance that easily conducts or carries a flow of electricity is called a conductor. Most metals are good conductors of electricity. Some other materials are also good conductors of electricity.



ELECTRONS MOVING THROUGH CONDUCTOR

Courtesy of Estes Industries

When an object presents a high resistance to the passage of electricity, it is called an insulator. (See Figure 11.)

Figure 11

Some substances are not good conductors of electricity. These substances which do not readily conduct electricity are called insulators. Many non-metals, such as glass, wood, and porcelain, are good insulators.



ELECTRONS MOVING THROUGH INSULATOR

Courtesy of Estes Industries

Units used to measure the amount of electrical resistance are called ohms. We need to know several things to determine the amount of current that will flow from a given power supply through a specific object. The amount of current that will flow may be determined by dividing the voltage by the resistance in ohms. This formula is called Ohm's Law.

$$I = \frac{E}{R} \text{ Current} = \frac{\text{Electromotive force}}{\text{Resistance}}$$

I = Amperes of current flowing in the circuit

E = Electromotive force in volts

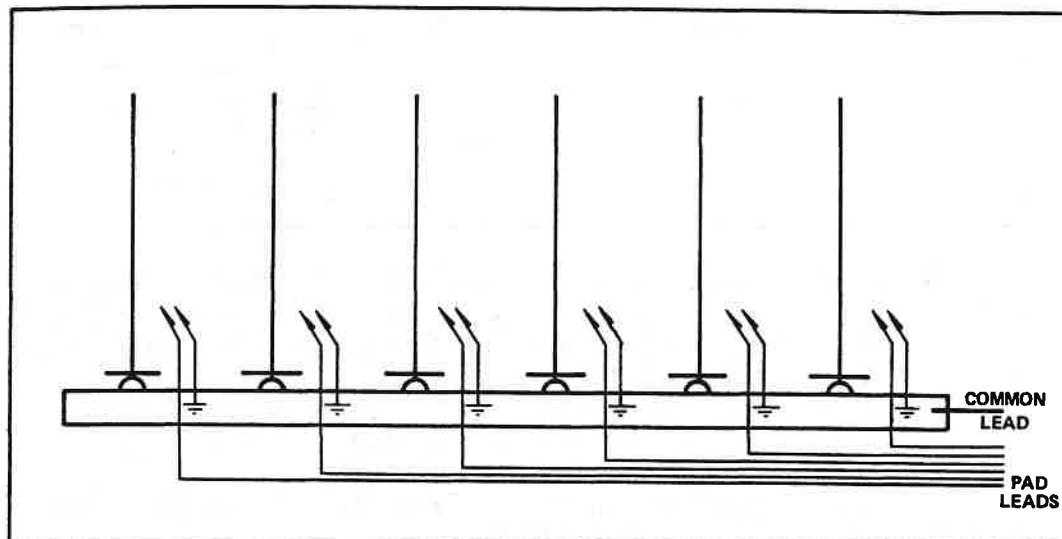
R = Resistance in ohms

The number of amperes that will flow in a circuit may be determined by dividing the voltage of the power supply by the resistance (in ohms) of the circuit.

37. **MULTIPLE LAUNCHER CIRCUITS** - A launcher with several launch pads provides a convenient device for flying many model rockets in rapid sequence. Multi-pad unit or system provides a number of launcher set-ups attached to one power supply and control unit. Electrical power is usually supplied by a separate wire to each launch pad with a common return or ground wire. The control panel usually incorporates a key-operated power supply switch, a power supply pilot bulb, a rotary selector switch, a continuity light and a launch switch.

Figure 12

A TYPICAL MULTIPLE LAUNCHER

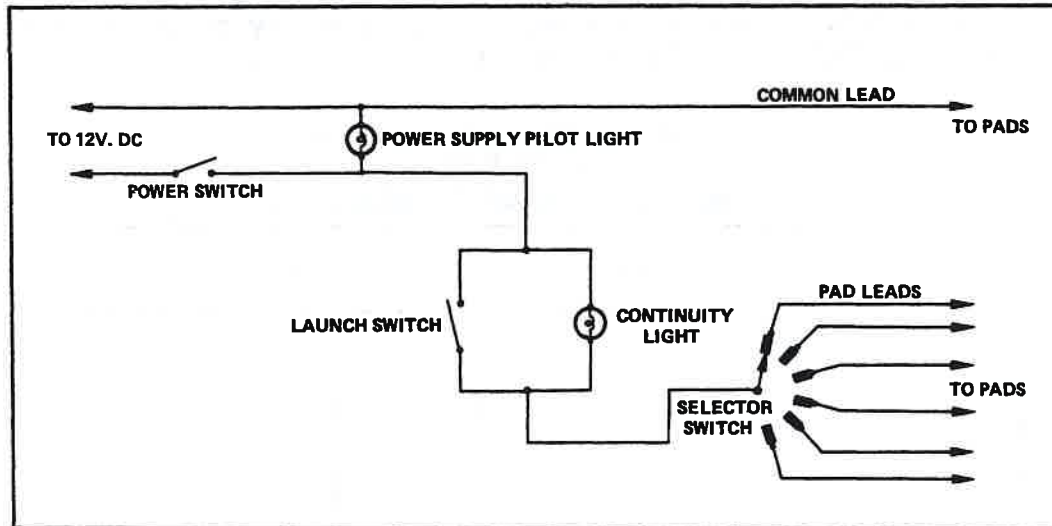


The electrical power supply to the micro-clips is usually a separate wire to each launch pad to carry the electrical current to that pad and a common (shared) return or ground wire.

Courtesy of Estes Industries

Figure 13

PARTIAL SCHEMATIC DIAGRAM FOR A TYPICAL MULTIPLE LAUNCHER



The control panel for a multiple launcher usually incorporates a key-operated power supply switch (to turn power supply off and on), a power supply pilot bulb (to indicate when the power supply is on), a rotary selector switch (to direct current to the pad in use only), a continuity light to indicate if the electrical circuit through the igniter is complete, and a launch switch.

A multiple launcher can be easily built. It is very handy for contests and demonstration launches.

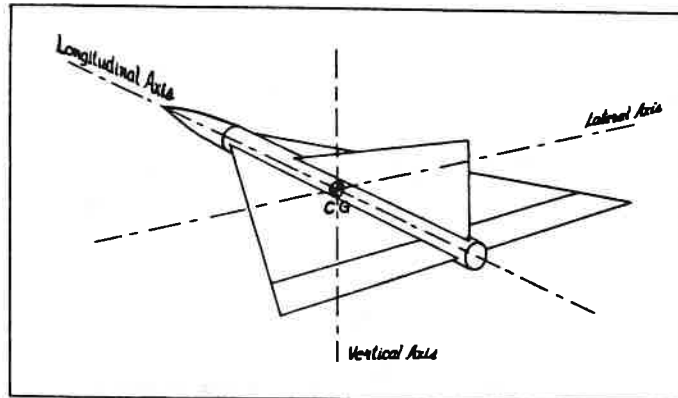
Courtesy of Estes Industries

Please complete questions for Adventure VIII found on page 33.

ADVENTURE IX - A BOOST FROM BEHIND THE GLIDER

38. REAR ENGINE BOOST-GLIDERS - More than 50 boost-glide vehicles have been constructed. One way to describe the rear-engine glider is a rocket with wings or an airplane with a rocket engine (both with vertical take-off or V.T.O. capability). The boost-gliders use the glide pattern type of recovery instead of the conventional parachute recovery method.
39. THE BOOST PHASE - The glider is stabilized the same way as a normal rocket with its center of pressure (C/P) behind the center of gravity (C/G). Its wings must be located so it brings C/P well behind C/G. (See Figure 14.)

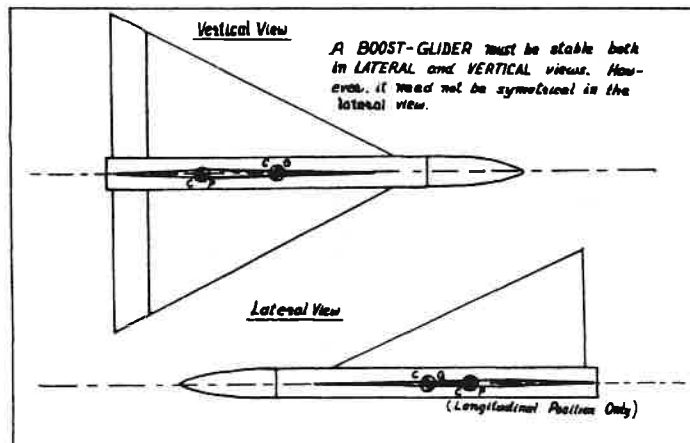
Figure 14



Courtesy of Estes Industries

The distance between the C/G and the C/P in physics is called a moment-arm. The stabilizing force exerted by wing and rudder, multiplied by the length of the moment-arm, results in a corrective moment. This moment is proportional to the force of air hitting the surfaces, which is dependent on two factors: the speed of the rocket and the angle that its body makes with the relative wind. The ideal example of glider stability is where very little corrective moment is applied because it flies with little or no oscillation into the relative wind. When the air hitting the surfaces at an angle also produces a component of force acting perpendicular to the body to push the glider back into parallel with the relative wind, it produces a component of force pointing directly rearward from the glider and parallel to the wind. This latter force is called drag. The more the rocket oscillates, the greater will be the corrective moment and drag. Generally, the center of pressure will be at least three-fourths the body diameter behind the center of gravity. (See Figure 15.)

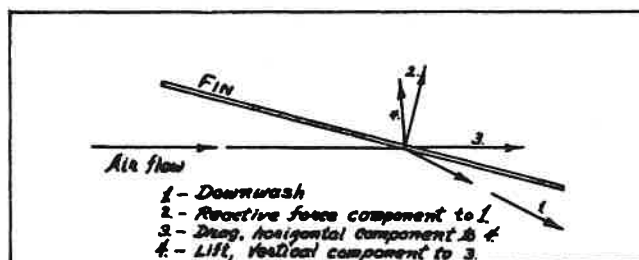
Figure 15



Courtesy of Estes Industries

40. THE GLIDE PHASE - In the glide phase, the rear engine boost-gliders use what is known as the flat-plate effect. The flat-plate effect makes use of the relative wind bouncing off the wing and produces a component of force that is perpendicular to the wing. If the wing is tilted at an angle to the relative wind, the force will also be tilted at this angle. When resolved into components parallel with and perpendicular to the wind, drag and lift are determined for the wing surface.

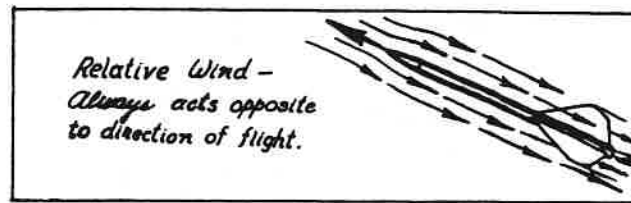
Figure 16



Courtesy of Estes Industries

The wing must be inclined upward in the wind to produce a lift. This is accomplished by means of flaps at the rear of the wing commonly called the elevons (in a delta or flying wing design). In the glide phase, the engine has been ejected and the only forces acting on the glider are air and gravity. When the glider reaches its flight apex or highest point, it produces a relative wind that is directly opposite to the direction of travel. (See Figure 17.)

Figure 17

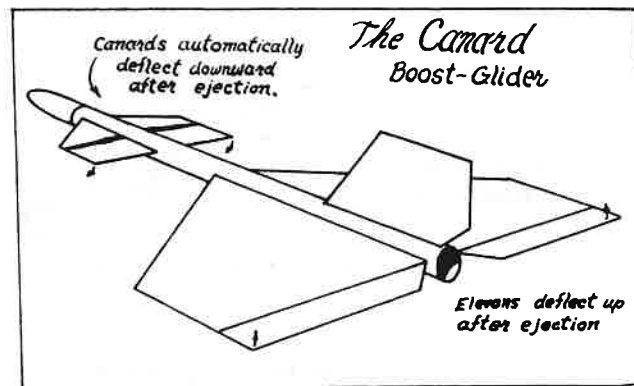


Courtesy of Estes Industries

As the engine is ejected, it activates the elevons to force the tail down and nose up; this puts it in the correct glide pattern better known as the flat-plate effect. This effect is very important because, when the C/P shifts forward, it will cause the glider to nose toward the ground and crash in a nose dive. We now know that elevons, to be effective, must produce a depressive force greater than the glider's corrective force at the terminal velocity of glide. The size of the elevons required depends on: the distance between the C/P and the C/G of the top view in glide, and the velocity of the vehicle in glide. Elevons of approximately 20 to 30 percent of the total wing area are needed for an easily adjustable glide. A glider that has elevons more than 35 percent of wing area or has the engine too far to the rear, or excessive stability, is not designed correctly.

Another type of glider is called a canard. A canard is any lateral stabilizing surface (that is, one that prevents pitching) located forward of the main lifting surface. On the canard models, the rear elevons must flip up and the canard flaps must flip down at the ejection of the engine. (See Figure 18.)

Figure 18



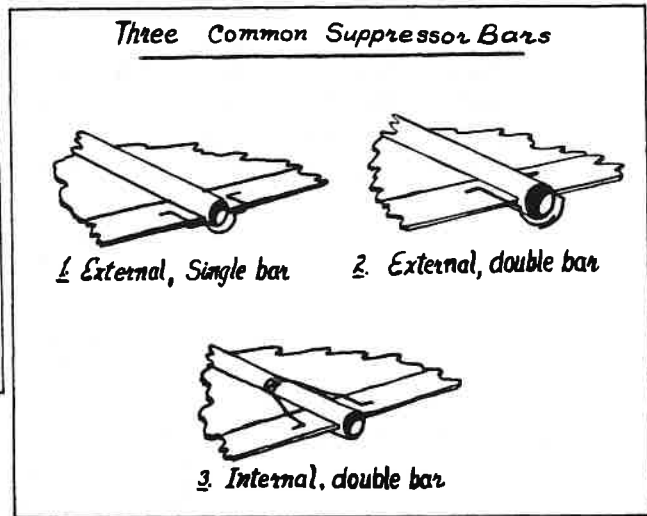
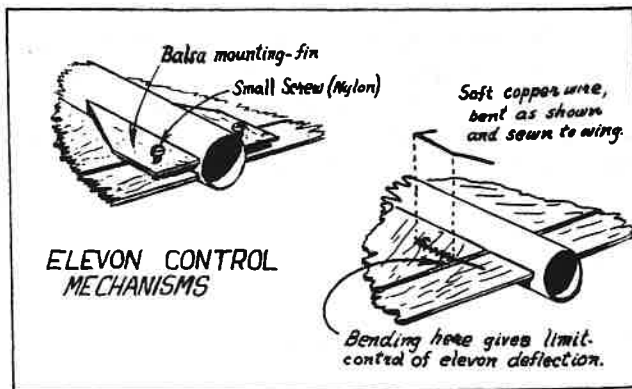
Courtesy of Estes Industries

Boost gliders will have better resistance to rolling in glide when the center of directional guidance lies above the C/G, when the rudder or tail is located on the top of the body tube. As yet, there are no definite rules for wing-tip rudders and for dihedral angle of lifting surfaces. The dihedral angle in moderate amounts improves glide by giving a pendulum effect while not detracting from the rocket's performance. Another factor in building a boost-glider is wing loading, which is arrived at by dividing the area of the lifting surfaces by the weight of the vehicle in glide condition (without engine).

41. STRUCTURAL AND FLYING PRACTICE - The size and thickness of the wing area needed depend on size and number of engines or stages. Normally a 1/16-inch thickness is enough with Series 1 engines to withstand all air forces created by this engine. Above this series it begins to warp or twist the wing area. Acceleration effect during boost is very important since a 1-ounce model's wings may weigh as much as 23 times their normal weight for a short time during boost. Wings should be kept as light as possible and consistent with aerodynamic strength. Strongest wing-to-body joints are possible when the wings are joined with each other and with the body at the underside and where the connection is reinforced by 1/2-inch wide strips running parallel to the body at the joint. The grain of these strips should be at right angle to the grain of the wings.

The simplest method for using internally operated elevon actuators is one in which a piece of wire is held depressed by the engine casing. When one end of the actuator is held in place by the engine, the other end of the wire or balsa is attached to the elevon, so the elevon is in the neutral position with casing in place. Elastic thread is fastened to the elevons, which will pull them up (or canard's flaps down) when the engine leaves the body tube, allowing the wire depressor bar to travel to the actuating position. A single bar has been tried for both elevons, but the two-bar method allows individual settings of each elevon; this is done either by a small balsa brace or set screw, or by a single-strand soft copper wire. (See Figures 19 and 20.)

Figures 19 and 20



Courtesy of Estes Industries

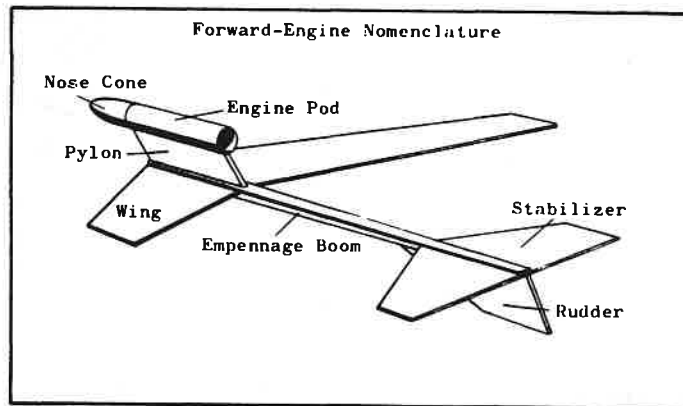
Earlier types of gliders set their engines forward of the rear end of the body tube. This proved to be costly because, after a few firings, it burned away the end of the body tube. The body tube or the whole glider itself had to be replaced. Aluminum foil glued to the surface solved this problem and the engine was moved to the rear of the body tube. A better method was devised using an expended engine casing to shift weight forward.

Please complete questions for Adventure IX found on page 34.

ADVENTURE X - THE POWER BOOST IS FORWARD IN GLIDE

42. FRONT ENGINE BOOST GLIDERS - This glider was, perhaps, the most revolutionary and radically different from its conventional predecessor (rear-engine boost-glider). Many ideas which have been formerly accepted about design must be changed to fit the special cases encountered in forward engine design if the best configuration is to be achieved. Now we will go through each step of the boost and glide phase and airfoil shape to see the difference between the front and rear engine boost-glidors.

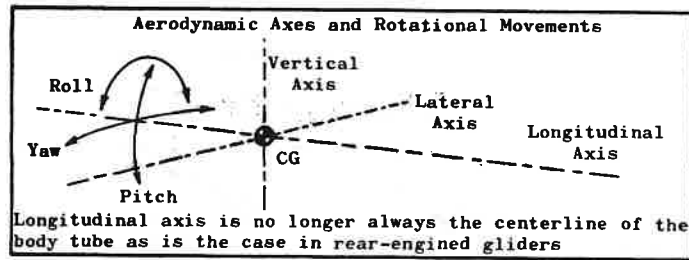
Figure 21



Courtesy of Estes Industries

43. THE BOOST PHASE - The front engine boost-glider, despite its airplane-like appearance, must, to meet the definition of its type, be capable of a vertical lift-off without relying on lifting surfaces. Here, as well as elsewhere, conflicting demands of aircraft and rocket design must be met to obtain a workable vehicle. As in the rear engine glider, its center of pressure must be far enough behind the center of gravity to produce enough corrective force to prevent oscillation. (See Figure 22.)

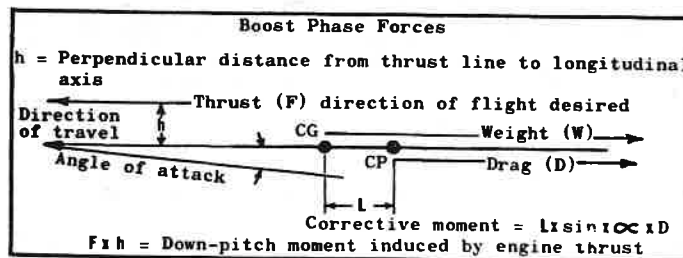
Figure 22



Courtesy of Estes Industries

The front engine model makes this fairly easy since weight is concentrated in the nose when the engine is in place. However, this aid to design is countered by several undesirable features, including asymmetry of the front engine gliders. The most serious result of asymmetry is the offsetting of the thrust line from the C/G along the vertical axis. It produces a downward-pitching effect whose moment-arm is equal to offset distance and whose magnitude is equal to this distance times the engine's thrust.

Figure 23



Courtesy of Estes Industries

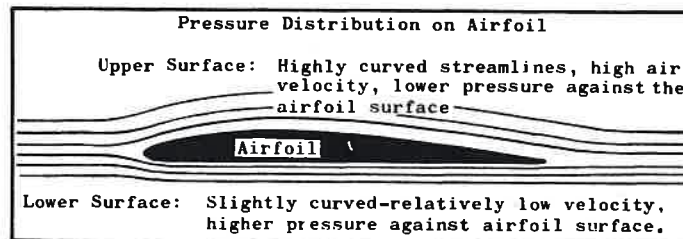
Using low pylons and large dihedral (the angle of the "V" formed by two-panel wings), the engine-induced, down-pitch moment can be greatly reduced and sometimes entirely eliminated. But to carry this to extreme would also be disastrous.

Within limits, the tendency to pitch or loop is readily countered by normal, positive stability and an additional type of stability, which we shall call stick, or trailing member, stability. The center of gravity trails below the suspending and accelerating force of the rocket engine, thus adding to the model's stability. We find that minimum stability for front engine boost gliders is about three-fourths of the body diameter.

44. THE GLIDE PHASE - Main advantage lies in its method of attaining and maintaining a gliding attitude following engine ejection. Front engine gliders rely solely on the shift of the C/G and loss of weight that accompanies ejection to initiate the recovery phase. Consequently it can be more reliable than many conventional designs.

There are two methods of designing the glider to initiate glide. One is placing a small shim of balsa wood under the stabilizer trailing edge so the stabilizer forms a slight negative angle (never to exceed 1 degree) with the empennage boom, making possible use of very thin wings and wings with no airfoil at all. It has one disadvantage: It produces poor boost characteristics, which results in nose-up pitching, reduces altitude and results in loops and crashes. This method is usually unacceptable for general use. Second is the use of airfoil wings. The airfoil wing operates on a principle discovered by Swiss physicist Daniel Bernoulli, producing a lifting force even when held at zero angle of attack to the relative airstream. He also found that when air moves rapidly, its pressure decreases. The upper side of the wing, being more highly curved than the often flat and undercambered lower side, forces the air to move more rapidly over it.

Figure 24

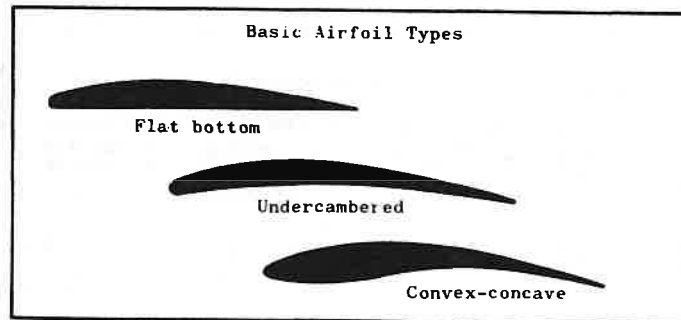


Courtesy of Estes Industries

This pressure produces a low pressure above and high pressure below. Such a wing may be mounted at zero angle of attack and, since it stalls at a high angle, it produces little pitch-up moment in boost phase, thereby allowing a smoother vertical flight along with producing a superior glide.

45. AIRFOIL SHAPE - There are many airfoil shapes, and some are more efficient than others. (See Figure 25.)

Figure 25

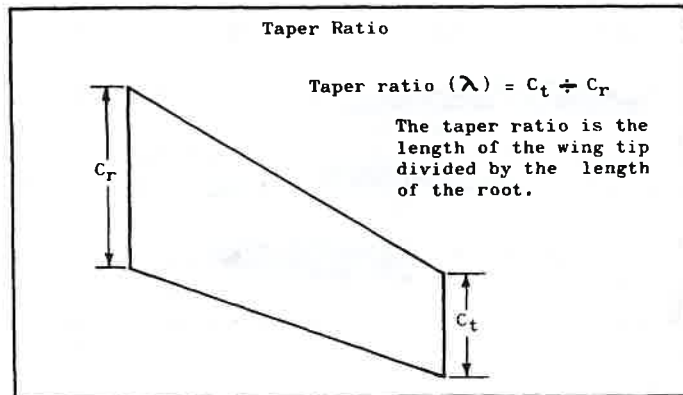


Courtesy of Estes Industries

The important effect is that airfoils suited for larger and faster vehicles are relatively poor on the boost-glider. Thin, flat-bottomed sections with a maximum thickness of 7 to 10 percent of the wing chord (the distance from the leading to the trailing edge) and with the maximum thickness between 25 percent and 35 percent back on the wing are satisfactory. Proportions and areas of the various parts of a forward engine boost-glider and their relations to each other have a great effect on its performance.

Front engine boost-glider designs operate best with a wing area between 20 and 40 square inches. Less area would result in high wing loadings and rapid descent, while more area results in excessive drag and susceptibility to warping. The best length for a balsa empennage boom is between 0.9 and 1.1 times the wing span because, if the empennage boom is too short, it will result in loss of stability. If it is too long, it adds too much weight. The area of the horizontal stabilizer will not fall below 30 percent of the wing area when zero-incidence airfoiled wings are used. But when areas are more than 40 percent, excessive weight and drag will result. The rudder area should be between 8 percent and 15 percent of the wing area; a lower percent would result in loss of control and unnecessary drag. The rudder is normally below the empennage boom to avoid exhaust gases. For best results in dihedral angles for wings, you should use angles of 4 degrees to 16 degrees. This range of angle increases roll stability. The taper ratio should be between 0.3 and 0.6. Lower ratios reduce roll stability and higher ones are subject to structural limitations. (See Figure 26.)

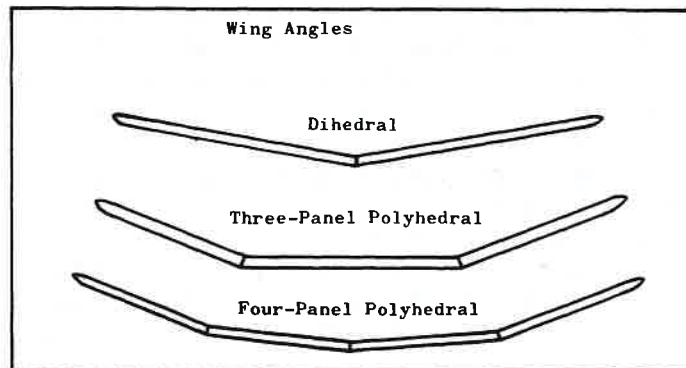
Figure 26



Courtesy of Estes Industries

The successful models with the best compromise between structural and aerodynamic requirements lie between 40 degrees and 45 degrees (see dihedral diagrams), and the sweep of the wing (within certain limits) increases the effectiveness of dihedral.

Figure 27



Courtesy of Estes Industries

The average wing loading for a forward engine model is between 0.17 and 0.3 pounds per square foot compared with 0.25 to 0.7 for most rear engine designs. Higher loadings will result in rapid descent and short duration, while lower ones raise doubts as to structural strength.

NOTES:

1. STRUCTURE OF WINGS - There are two basic types of wings: solid and built-up. Built-up wings are fine in larger types of vehicles, but the weight difference is negligible in the front engine boost-glider.
2. SELECTING EMPENNAGE BOOM - Boom cross-section from 1/4 inch square to 1/4 inch by 1/2 inch are adequate, but a T section made of 1/8 inch or 1/16 inch sheet balsa often gives more strength with less weight than a solid boom.
3. STANDARD TAIL CONFIGURATION - Horizontal stabilizer with a subrudder is best, compared to the V-shaped, which is more apt to break and catch the firing clips.
4. PYLON - Best height for the engine pod pylon is 1/2 inch. Higher pylons are weaker, lower pylons result in exhaust damage.

Please complete questions for Adventure X found on page 35.

46. GLOSSARY OF TERMS:

- A. AIRFRAME - The structure of an aeronautical device, including everything except engine.
- B. AIRFLOW - The movement of air across a surface.
- C. ANGLE OF ATTACK - The angle at which a wing strikes the air stream.
- D. ASPECT RATIO - The relationship of the wing span length to the wing chord expressed numerically by the number of times the span can be divided by the chord (straight line drawn connecting leading and trailing edges of an airfoil).
- E. BERNOULLI'S LAW - When the air flow is increased over the airfoil shape, the pressure is decreased on the upper, or curved, side and increased on the lower, or bottom, side.
- F. BOOST-GLIDER - A combination airplane and rocket with glider capabilities.
- G. BOOST PHASE - Period of powered flight for a glider when the rocket engine is providing thrust.
- H. BOUNDARY LAYER - The region next to the surface of a solid body moving through the air
- I. CAMBER - The rise of the curve of an airfoil section.
- J. CANARD - An airframe configuration with the wings at the rear end and the pitch controlling surface at or near the nose.
- K. COAST PHASE - The period following the boost phase when the model climbs unpowered prior to transition to gliding flight
- L. CONSTANT TAPER - A wing in which the chord or the thickness progressively decreases from root to tip.
- M. CONVEX-CONCAVE AIRFOIL - A combination convex-concave curve on the underside of an airfoil.
- N. DEPRESSOR BAR - A small metal bar that holds the elevators in place during boost phase and changes position upon ignition of ejection charge for glide phase.
- O. DIHEDRAL - The upward or downward inclination of a wing or other supporting surface with respect to the horizontal.
- P. DOWNWASH - The vertical downward motion of the airflow induced by, and behind, an airfoil of a wing.
- Q. ELEVATORS - Control surface on a boost glider that is designed to change, upon activation, the altitude of the craft from a stable rocket to a gliding object.

- R. ELEVON - An aerodynamic control surface used to control both pitch and roll simultaneously or separately.
- S. EMPENNAGE BOOM - Glider frame projecting back from the wings and to which the stabilizer and rudder are attached.
- T. ENGINE POD - Assembly housing model rocket engine, which detaches from rest of glider when ejection charge operates.
- U. FLAT BOTTOM AIRFOIL - Airfoil with flat underside.
- V. GLIDE PHASE - The non-powered descent of a glider.
- W. INCIDENCE - The angle between the chord line of the airfoil and the longitudinal axis of the glider.
- X. IRREGULAR TAPER - A wing in which the chord or thickness does not progressively decrease from root to tip.
- Y. LAMINAR FLOW - Non-turbulent airflow near the surface of a body, usually found at the front of a smooth body.
- Z. LATERAL AXIS - The axis from wing tip to wing tip of an aircraft; the aircraft can pitch up or down about this axis.
- AA. LIFT - The component of the total aerodynamic force perpendicular to the relative wind and exerted normally (in an upward direction opposing the force of gravity) to the wings.
- BB. LONGITUDINAL AXIS - The axis from the nose to tail of a aircraft; movement about this axis is called roll.
- CC. OSCILLATION - A periodic motion such as the rolling, pitching or yawing of an aircraft or a combination of these.
- DD. POLYHEDRAL - A modification of dihedral, wherein the different panels of a wing are tilted upward at varying angles.
- EE. POP-POD - Engine pod that is jettisoned from glider as the glide phase begins.
- FF. PRESSURE DISTRIBUTION - The variation of air pressure over a surface, such as the pressure around an airfoil.
- GG. PYLON - A fin-like mount for the pop-pod.
- HH. RELATIVE WIND - The direction of the air with reference to a body in it.
- II. RUDDER - A movable aerodynamic control surface used to cause yaw rotations.
- JJ. STABILIZER - A fixed stabilizing surface, generally the tail section on a normal rocket.
- KK. TAPER RATIO - The ratio of the tip chord to the root chord of a wing.

- LL. TIP VORTEX - Twisting air disturbance at the tip resulting from the wing acting on the air to generate lift.
- MM. UNDERCAMBERED AIRFOIL - An airfoil possessing a concave curve on its underside.
- NN. VERTICAL AXIS - The axis extending in a vertical direction from the glider's center of gravity. Movement about this axis is called yaw.
- OO. VERTICAL STABILIZER - The vertical fixed stabilizing surface of a glider.
- PP. WARP - A twist in the chord line of a surface across its span.
- QQ. WING - The main lifting surface of an aircraft.
- RR. WING CHORD - The length of a straight line through the centers of curvature of the leading and trailing edges of an airfoil.
- SS. WING LOADING - The gross weight of the glider divided by the gross wing area.
- TT. WING SPAN - The overall distance between the wing tips of an aircraft.

QUESTIONS TO ADVENTURE VI

1. In what type of rockets is multi-staging used?

2. How is the lower stage ignited?

3. Why is it important to check the engines before and after taping?

4. What is the simplest and most reliable method of joining stages?

5. What type of recovery is used in the booster stage?

6. What engines are used in the lower stage?

4-H member signature

4-H leader signature

Date of completion

QUESTIONS TO ADVENTURE VII

1. What type of fuel does a cold power rocket use?

2. Can the cold power rocket be flown safely and properly indoors?

3. Should you leave a loaded, cold power rocket untended?

4. How does the separator work?

5. Is RP-100 propellant under pressure when released and how much, if any?

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QUESTIONS TO ADVENTURE VIII

1. What are the three main types of launch systems?

2. List four symbols used in electrical circuits.

3. What is an electrical current?

4. What is a coulomb?

5. What is an ampere?

6. Describe direct current and alternating current.

7. What is the difference between a conductor and an insulator?

8. What is an ohm?

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QUESTIONS TO ADVENTURE IX

1. Would you stabilize a boost-glider differently than you would a normal rocket?

2. What are the three axes of a boost-glider?

3. Does relative wind act the same as direction of flight?

4. Explain "flat-plate effect." What happens?

5. Size of elevons depends on what two things?

6. Describe canard.

7. What determines size and thickness of wing area?

8. A 1-ounce model may weigh as much as ____ times its normal weight during acceleration.

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QUESTIONS TO ADVENTURE X

1. What two conflicting demands must be met for the front boost-glider?

2. Name the seven basic parts of front boost-glider.

3. There are three axes. Name them.

4. Airfoiling a wing produces what kind of pressure above and below the wing?

5. How many square inches is best for wing area of a front boost-glider?

6. Name the three basic airfoil types.

7. Describe taper ratio.

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Date of completion

