TX-954 Model Rocketry Team Handbook

Wharton High School

AFJROTC

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I . PROGRAM DESCRIPTION:

The model rocketry program provides an opportunity for cadets to learn the basic principles of aerospace rocketry. During the program, the cadets get the opportunity to design and build and launch model rockets and perform designated staff positions. Models rockets built use safe engines.

Successful completion of program requirements make cadets eligible for the model rocket badge. We will conduct the model rocketry program according to the provisions of this instruction and the following guidelines:

National Association of Rocketry (NAR)
United States Model Rocket Sporting Code.
NAR Model Rocket Safety Code.
Contest rules and safety regulations of the
National Aeronautics Association (NAA) and
the Federation Aeronautique Internationale (FAI)
Federal Aviation Regulations, Part 101, Manned
Balloons, Kits, and Unmanned Rockets.
Federal Communications Commissions, Part 95,
Citizens Radio Service.
State and local governments.

II-PROGRAM OBJECTIVES:

1. To acquaint cadets with the importance of rocketry and its role in the future

2. Increase cadets' knowledge of aerospace sciences and motivate them to attain and even greater knowledge of aerospace

3. Employ the cadets' interest in model rocketry to enrich their development

4. Provide activities an opportunities for the development of aerospace leadership skills

5. Arouse interest in aerospace careers that require the knowledge of rocketry

6. Contribute to the development of an understanding of aerospace power

7. Lead to the discovery of the individual educational need of cadets aspiring to careers in aerospace

III-OPERATIONAL PERFORMANCE REQUIREMENTS (OPRS)

Cadets participating in the model rocketry program must satisfy the following requirements either as individuals or in groups:

OPR 1. Construct, launch, and evaluate at least one model suitable for the altitude competition described in the NAR United States Rocketry Sporting Code (NARUSRSC).

OPR 2. Construct, launch, and evaluate at least one model rocket suitable for the scale, plastic scale, or payload competition described in the NARUSRSC.

OPR 3. Construct, launch, and evaluate at least one model rocket suitable for the drag race, parachute duration, boost, or glide competition described in the NARUSRSC.

OPR 4. Construct, launch, and evaluate at least one model rocket suitable for the aerospace systems or research and development competition described in the NARUSRSC (Optional for advanced rocketry program only).

OPR 5. Prepare a diagram of a typical model rocket launch site. This diagram may be as elaborate as desired, but must include: launcher, model rocket, igniter, and land area requirements.

OPR 6. Submit for evaluation a journal of all activities completed in the model rocketry program. The journal must indicate completion of all OPRs.

IV- LEADERSHIP PERFORMANCE REQUIREMENTS (LPRS)

Cadets participating in the rocket program must achieve proficiency and become successful in model rocketry activities. The following LPRs must be satisfied:

LPR 1. Demonstrate a knowledge of the AFJROTC model rocketry program and its concepts and techniques by satisfactorily implementing, administering, supervising, and evaluating model rocketry activities.

LPR 2. Demonstrate a knowledge of the organization of AFJROTC model rocketry program activities, including personnel required, skills necessary, and the job responsibilities of cadets and adult supervisors for rocketry activities.

LPR 3. Demonstrate knowledge of the physical facilities required for all model rocketry operational activities, to include facilities for storage, handling, and building static models, flying and safety precautions, and spectator protection.

LPR 4. Demonstrate the leadership skills necessary to conduct an individual test, group test, and NAR-sanctioned model rocketry competitive meet.

LPR 5. Serve successfully as the safety officer in addition to a minimum of three of the remaining positions listed in para 2.4.2.6.

LPR 6. Pass an oral examination covering the topics of model rocketry techniques, procedures, operations, and safety precautions using material in this handbook.

V- Model Rocket Badge

This badge (fig 1) will be awarded to cadets that complete program requirements of building a rocket, successfully launching and recovering it 4 times, and completing OPR6/LPR6.

Figure 1 – Model Rocketry Badge

VI- Program Procedures

1. Cadets will keep a record of their rocket launchings to include those rockets launched on individual or group basis. Records will be maintained using AFROTC Form 26, AF JROTC Model Rocket Launching Data Sheet.

2. Model rocketry program activities involving launchings or flying will be conducted under the supervision of the range officer, safety officer, and first aid officer.

VII- Program Staff Positions

The following staff positions with corresponding responsibilities will be designated and filled to conduct program activities

Range Officer or Contest Officer. The range or contest officer takes complete charge of the range or flying field, directs all action, gives all orders, makes all decisions, supervises all operations, and is normally positioned at the control center. For AFJROTC launches or meets sponsored by AFJROTC, the range officer will be an AFJROTC instructor.

Safety Officer. The safety officer is responsible for checking all critical points of the operation in advance to ensure safety regulations are followed. The safety officer conducts safety briefings prior to launches and instructs all personnel in safety procedures. No launching or flying will take place until the safety officer issues clearance to the range officer.

First Aid Officer. The first aid officer administers first aid to participants and spectators as required. The first aid officer will be an individual who qualifies for the job by completing a Red Cross first aid course or similar training required by school officials.

Launch Supervisor, Flight Line Officer, or Contest Security Officer. Ensures established procedures are followed at the launch site/flying field, monitors launches and landings, and certifies a clear launch/flight area to the range officer before activity begins. This officer is responsible for ensuring the security of displayed static models.

Spectator Control Officer. The spectator control officer is responsible for clearing launch areas of all personnel not assigned to specific posts and ensuring spectators and personnel are at a safe distance before giving clearance for activity to the range officer.

Range Guards. Range guards are responsible for keeping passers-by out of the area, scanning the sky for aircraft, and certifying to the range officer that it is safe to launch rockets.

Observers and Trackers. Observers and trackers are responsible for tracking the path of the rocket and taking observations on the azimuth and angle of the elevation at the peak of the trajectory for plotting. They are also responsible for advising the range officer of in-flight emergencies and dead-stick landings, assisting in the safe recovery of downed aircraft, and reporting all pertinent data to the control center.

Public Affairs Officer. The public affairs officer arranges for advance publicity and provides for newspaper, radio, television, and magazine coverage of the activities, seeking favorable public relations. The public affairs officer is also responsible for maintaining lines of communication with supporting organizations, parent booster clubs, and school authorities as to the current activities of the program.

VIII- NAR SAFETY CODE

The following National Association of Rocketry (NAR) safety code, although it may seem as annoying and inconvenient, must be followed at all times. If followed correctly, it will prevent serious accidents.

1. Construction – My model rockets will be made of lightweight materials such as paper, wood, plastic, and rubber without any metal as structural parts.

2. Engines – I will use only pre-loaded, factory-made model rocket engines in the manner recommended by the manufacturer

3. Recovery – I will use a recovery system in my model rockets that will return them safely to the ground so that they may be flown again.

4. Weight Limits – My model rockets will weight no more than 453 grams (16 ounces) at liftoff, and the engines will contain no more than 113 grams (3 ounces) of propellant.

5. Stability – I will check the stability of my model rockets before their first flight, except when launching designs of already proven stability.

6. Launching System – The system that I use to launch the rockets must be remotely controlled and electrically operated. It will contain a switch that will return to “off” when released. I will remain at least 15 feet away from any rocket being launched.

7. Launch Safety – I will not let anyone approach a model rocket on a launcher until I made sure that either the safety interlock key has been removed or that the battery has been disconnected from the launcher.
8. Flying Conditions - I will not launch my rocket in high winds, near buildings, power lines, tall trees low flying, low flying aircraft, or under any conditions which might be dangerous to people or property.

9. Launch Area – My model rockets will always be launched from a cleared area, free of any easy to burn materials, and I will only use nonflammable recovery wadding in my rockets.

10. Jet Blast Deflector (JBD) – My launcher will have a JBD device to prevent engine exhaust from hitting the ground directly.

11. Launch Rod – To prevent accidental eye injury, always place the launcher, so that the end of the rod is above eye-level or cap the end of the rod with the launch.

12. Power lines – I will never attempt to recover my rocket from a powering or other dangerous place.

13. Launch Targets and Angle – I will never launch rockets so that their flight paths will carry them against targets on the ground, and will never use an explosive warhead or payload that is intended to be flammable. My launching device will always be pointed within 30 degrees of vertical.

14. Pre-Launch Test – When conducting research activities with unproven design and methods, I will, when possible, determine their reliability through pre-launch tests. I will conduct launching of unproven designs in complete isolation from persons not participating in the actual launching.

IX BASIC MODEL ROCKET COMPONENTS

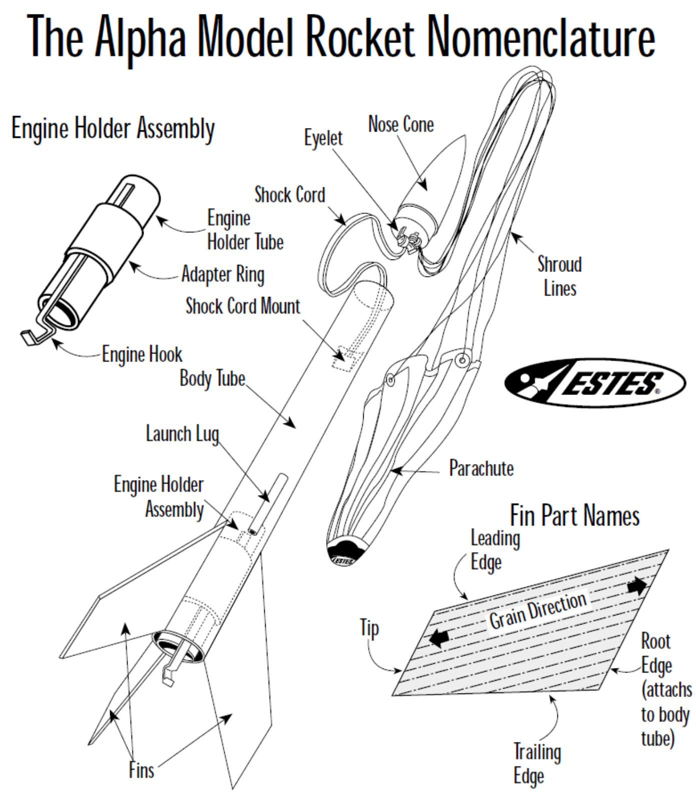


Figure 2 – Typical Model Rocket

These are the *main* components of a typical model rocket as shown in Figure 2:

1. Nose Cone – Usually made of Plastic or balsa, the nose cone guide the air around the rocket.

2. Recovery Device- Usually composed of the parachute and a streamer, is designed to slow the rocket's decent to a gentle landing. Usually made of thin plastic. Shroud lines attach the parachute to the nose cone

3. Shock Cord – Absorbs the shock of the parachutes opening and connects the nose cone to the body of the rocket.

4. Body Tube - Is the basic airframe of the rocket. I s made of rolled paper with special coating to add strength and make the tube easy to paint.

5. Launch Lug – Is a small tube located on the side of the rocket. It slips over the launch rod on the launch pad and guides the rocket during the first phase of the flight

6. Engine Mount – Holds the engine in place in the body tube

7. Fins – Usually made of balsa wood or plastic, the fins provide guidance to the rocket after it leaves the launch pad.

8. Wadding – The recovery wadding is put in the body tube between the parachute (or streamer) and the rocket motor. The wadding is designed to take the brunt of the hot gases in order to protect the parachute. Without wadding the parachute (or streamer) would most likely melt and the rocket will fall quickly to the ground after the ejection charge.

9. Electric Igniter- Starts the solid-propellant motor (engine) when charged electrically

10. Rocket Engine – the expendable solid-propellant motor of the rocket. Ignites when ignited electrically.

X- ROCKET FLIGHT

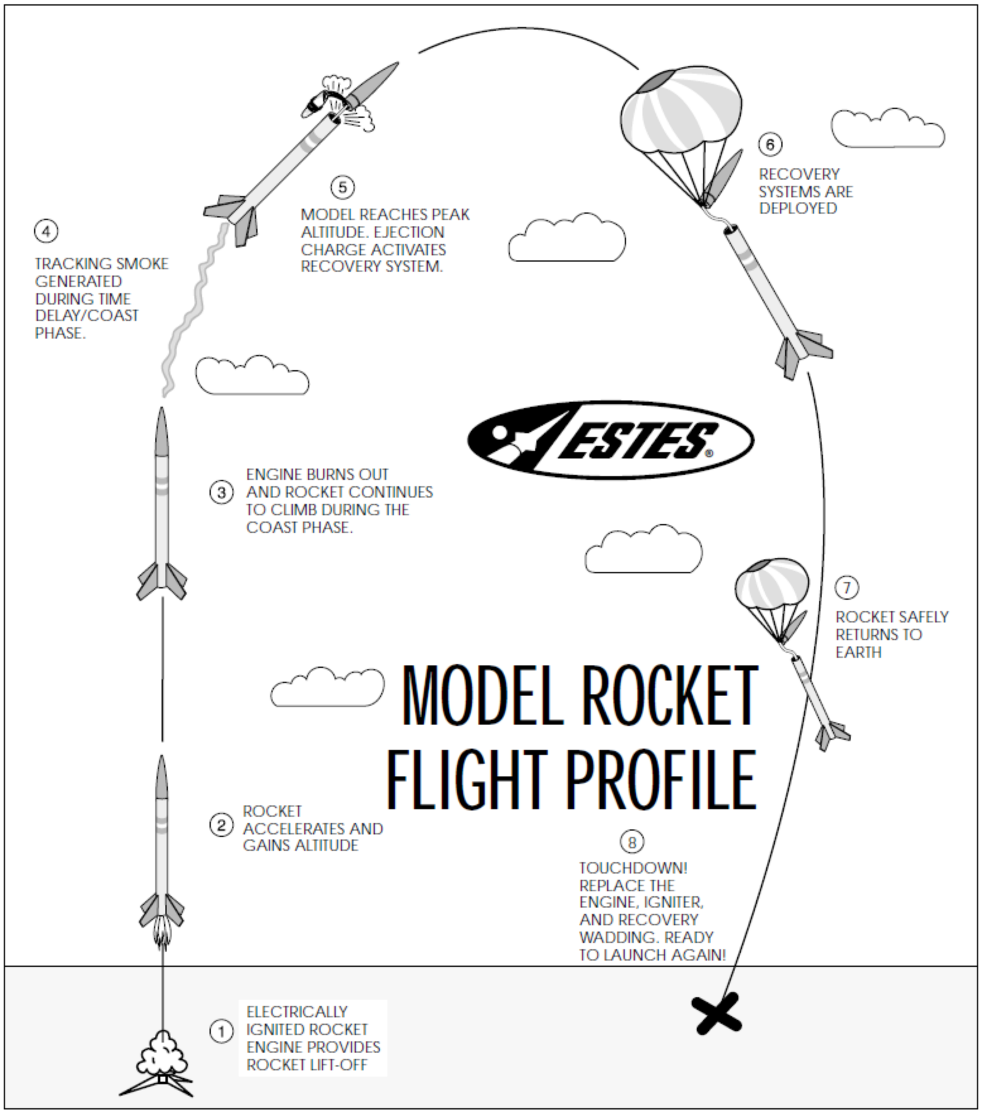


Figure 3: Rocket Flight

Figure 3 shows the different phases of a model rocket flight. It begins with the electrical ignition of the rocket engine, flight, burnout, coasting flight, peaking altitude, recovery device ejects, descent and landing.

XI ROCKET ENGINES

The model rocket engine provides the propulsive force to thrust the rocket hundreds of feet in the air and the means to eject the recovery device. Pre-manufactured and ready-to-use, it slips into the engine mount of the rocket.

Construction – Most model rocket engines consist of a large, single grain propellant inside a thick walled paper tube. It has a ceramic nozzle plug in the back end. The explosive powder has a time delay grain and is capped with a thinner, solid plug in the front end to provide compression for the explosive and to prevent the propellant from being forced out of the engine casing and into the rocket (Figure 4).

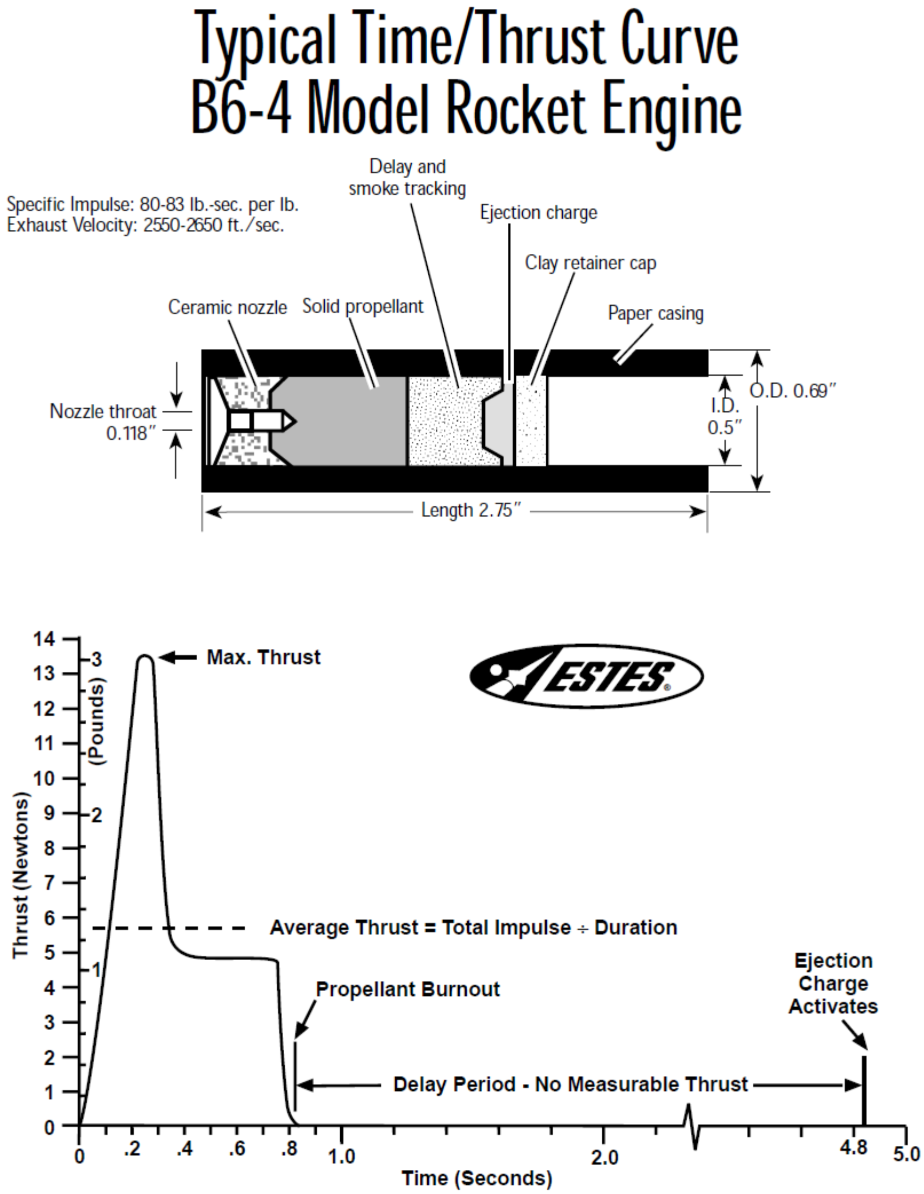


Figure 4: Typical Rocket Motor

Principles of Operation (Figure 5) – An electrical ignitor is needed and thus inserted into the engine's nozzle. It is usually held in place with a plastic ignitor plug. The alligator clips from the launch controller attached to the ends of the ignitor. The ignitor is really a piece of high resistance wire which thins in the middle where it is coated with a flammable, gunpowder-like substance.

When enough current is put through it, the thin part of the wire glows red-hot, setting off the gunpowder coating. The resulting flames ignite the propellant grain of the engine. Once the propellant is lit, it burns very rapidly and produces a lot of exhaust gasses. These gasses are produced more rapidly than they can readily escape thru the nozzle, and pressure builds up within the casing. The gases being forced out through the nozzle under great pressure is what generates the thrust that propels the rocket. At the end the propellant grain is a smaller grain of powder that produces thick white smoke. This tracking smoke does not provide any thrust but helps you see the rocket as it coasts upward toward the apogee, the top of its flight, After the smoke powder had burned, it lights the ejection charge, an explosive composition that blows off the engines forward plug, suddenly pressurizing the inside of the boy tube with hot gasses and fire. This blows the nose cone off the rocket, deploying the recovery device. The rest is up to the recovery device.

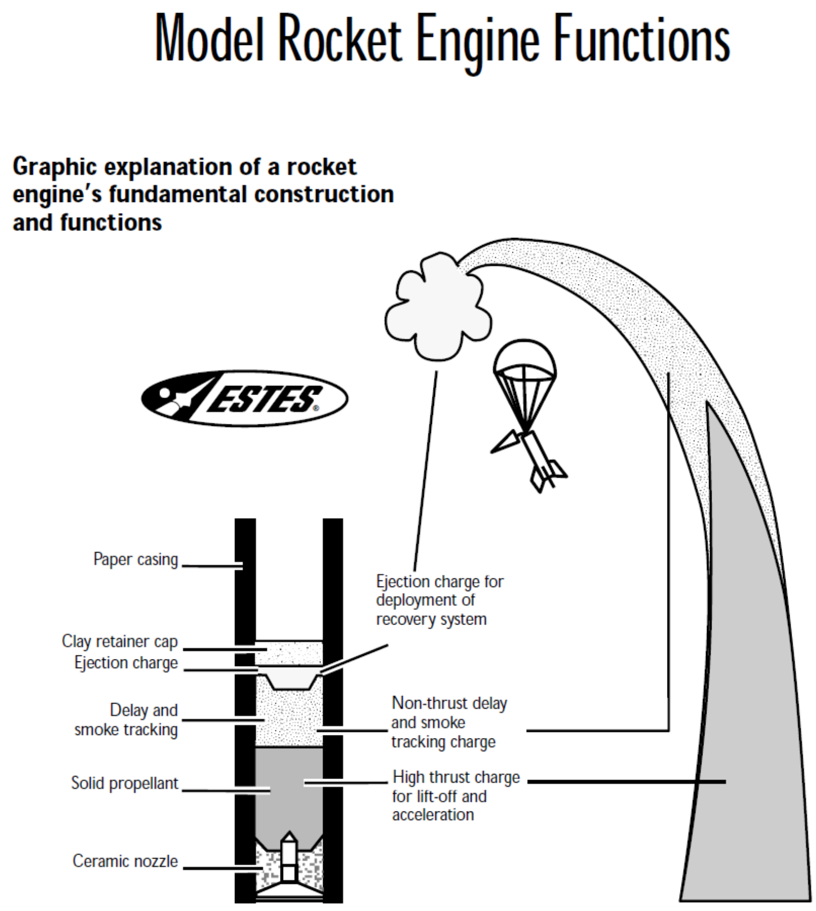


Figure 5: Typical Rocket Motor

XII- Rocket Aerodynamics

Identifying and Controlling sources of drag – As the rocket moves through the air, it has to fight against the pressure from all the molecules of air it pushes out of its way, and against the partial vacuum behind it where the molecules have not yet been able to fall back into place. These aerodynamic pressures are drag. There are three primary kinds of drag that affect model rockets. In order of impact on rocket performance, they are pressure drag, back drag, and parasite drag.

a. **Pressure Drag** – Relates to the general frontal area of the rocket body tube (how wide it is), and the shape of the nose cone. For example, a narrow diameter body tube with a real "pointy" nose cone will have less drag than a narrow body tube with a real "blunty" nose cone.

b. **Back Drag** – Is caused by a low-pressure area immediately behind the back of the rocket, where the displaced air has not yet been able to flow back yet. This partial vacuum is trying to suck the rocket back. If your rocket's diameter is larger than the diameter of your engines, make a "boat tail" to reduce the blunt rearward area. A surprisingly high performance of a rocket's total drag comes from back drag.

c. **Parasite Drag -** Is caused by things that are attached to the airframe and protrude and disrupt the airstream, such as fins and lunch lugs. How to reduce parasite drag

1) Fins should be well sanded on both leading and trailing edges.
2) Fins shouldn't be made any larger or more complicated than absolutely necessary, and remember more sweep = less drag.
3) Fillets at fin/body tube junctions will both increase the strength of the joint and reduce parasite drag.

Stability – Always test your model rocket for stability before flying it. Testing stability is easy to do. Just use the swing test done as follows: Find the rocket's center of gravity (CG) by balancing the rocket on straight edge. The rocket should be fully loaded, just as if you were to launch it. Tie one end of a 6 to 8 foot string around the rocket at the CG. Now string the rocket around your head and watch as it passes your eyes. If the nose of the rocket points straight into the oncoming air it is stable. You can now launch your rocket. However, if your rocket doesn't point into the wind, correct the stability by adding a small nose weight and try the test again.

XIII - Types of Engines and Recommended Launch Site Dimensions

Depending on the type of engine and given the lift-off weight, a rocket will reach a certain altitude and will a minimum field size to launch rocket safely as estimated by the chart below. See Figure 6 for specific engine details.

Motor	**Lift-off Weigh (ounces)**	**Altitude Range (ft)**	**Field (ft)**
Type A	1	235 to 560	150 X 300
	2	170 to 260	150 X 300
	3	100 to 120	150 X 300
Type B	1	400 to 1,040	300 X 300
	2	370 to 760	200 X 300
	3	280 to 425	150 X 300
Type C	2	650 to 1,620	400 X 400
	3	600 to 1,270	350 X 350
	4	520 to 800	200 X 300
	5	460 to 580	150 X 300

6	330 to 420	150 X 300

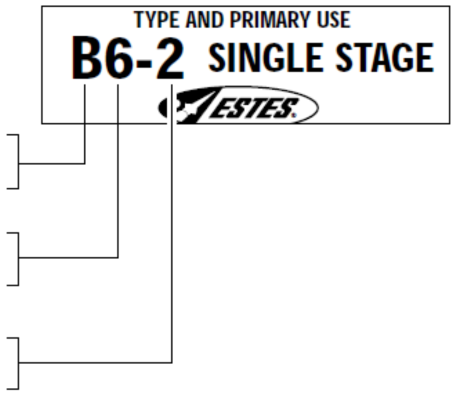
Model Rocket Engines

ENGINE CODING FOR QUICK-N-EASY IDENTIFICATION

1. Label color indicates recommended use of the engine.

a. Green . . . . Single Stage rockets
b. Purple. . . . . Upper Stage or Single Stage, if used in very light rockets
c. Red . . . . *Booster and intermediate stages of multi-stage rockets
d. Black . . . . *Special plugged engines for R/C gliders
*These contain no delay or ejection charge.

2. Code designation stamped on the engine gives useful and important information on its performance capabilities.



a. This portion indicates total impulse or total power produced by the engine.

b. This portion shows the engine's average thrust in Newtons and helps you choose the proper engine for your rocket's flight.

c. This number gives you the delay in seconds between burnout and ejection charge. It lets you choose the engine with the delay time you want for any flight.

TOTAL IMPULSE CLASSIFICATION

Code	Pound-Seconds	Newton-Seconds
1/2A	0.14 - 0.28	0.625 - 1.25
A	0.28 - 0.56	1.26 - 2.50
B	0.56 - 1.12	2.51 - 5.00
C	1.12 - 2.24	5.01 - 10.00
D	2.24 - 5.00	10.01 - 20.00

HOW HIGH WILL YOUR ROCKET GO?

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

Engine Size	Altitude Range depending on rocket size and weight)	Approximate Altitude in a typical 1 oz. model
1/2A6-2	100' to 400'	190'
A8-3	200' to 650'	450'
B6-4	300' to 1000'	750'
C6-5	350' to 1500'	1000'

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

Figure 6: model Rocket Engine Quick Reference

XIV - INSTRUCTION PROGRAM/SYLLABUS GUIDE FOR MODEL ROCKETRY CLUB

Week #	Activities	Labs
1	a. Introduce basic model rocketry glossary b. Discuss construction of body tubes, nose cones, and fins c. Explain construction of commercial model rocket engines and their principles of operation d. Present the Model Rocketry Safety Code	a. Demonstrate the tools and materials needed to construct a simple single-stage rocket b. Demonstrate types of engines available c. Provide lists of tools and materials needed to construct a single-stage rocket; provide plans for a rocket
2	a. explain techniques for constructing recovery devices b. Explain rocket aerodynamics	Begin construction of a single-stage rocket (all cadets use the same basic plan)
3.	a. Explain rocket ignition techniques b. Explain paints and finishes suitable for rockets being constructed c. Explain launching devices suitable for launching rockets d. Decide which launching device to construct	a. Continue construction of rockets b. Begin construction of a launching device from materials available; procure remainder of needed materials before next meeting
4.	a. Explain basic techniques of altitude determination and the type of tracking device used at unit rocket launching events b. Get volunteers to construct or obtain a suitable tracking device	a. Complete construction of rockets b. Continue construction of launching device
5.	a. Plan rocket launching activity b. Make assignments (range officers, special details, etc.…) c. Review safety code	a. Complete launching and tracking devices b. Inspect completed model rockets
6.	Unit model rocket launching	

NOTE - Interested cadets apply for membership in local NAR sections. AFJROTC units or cadets may then enter into competitive meets with other NAR units on section, area, regional, and national levels. Applications for membership or establishment of an NAR Model Rocketry Section may be obtained from the National Association of Rocketry. This is ***NOT*** a requirement to compete with other AFJROTC units in model rocket competitions.

XV- Model Rocketry Glossary

Cadets need to learn the following terms used in this program:

1. Apogee – The highest point of a rockets flight path, this is where the ejection charge is supposed to go off.

2. Burnout – The point on a rocket's flight path, this is where the ejection charge is supposed to go off.

3. Fillet – A smoothed bead of glue run in the gap between the body tube and an external attachment such as a fin. Fillets greatly strengthen the joint and reduce drag.

4. Boat Tail - A rocket design feature where the rocket becomes narrower at the back, reducing pressure back drag.

5. Terminal Velocity – The maximum speed at which an object cannot accelerate past without reaching one of the following:

a) An equilibrium between acceleration and drag, resulting in a constant, maximum speed.

b) It goes fast enough that there is enough drag, lift and other pressure differences and anomalies that the object's structure fails

6. Max-Q – This is a rocket-scientist term describing the maximum aerodynamic pressure that an airframe can withstand before structural failure occurs. Example: If you put a "D" engine in a rocket not designed to take an engine bigger than "C" and the fins come off in flight, the rocket hit Max-Q.

7. Minor Structural Failure – In this case, the airframe is weakened, but it remains intact and airworthy. Example: A cracked fin or creased body tube.

8. Catastrophic Structural Failure (CSF) – This involves the complete destruction or separation of a component or components. Example: At a lunch one day, a rocket suffered a CSF when the top of the engine failed, causing the burning propellant to blow out the top of the rocket roman-candle style. The engine-core fireball melted the parachute, severed the shock chord, and blew off the nose cone. The sudden reverse in thrust stopped the rocket abruptly in mid-air. The shock from this blew off the fins and blew out the internal engine mount.

9. Safety Interlock Key – This is the primary safety feature on most commercial launch controllers. When inserted into the launcher, the interlock key completes a sub-circuit so that the primary launch circuit will be complete when the launch button is pressed. During preflight times, the safety key must be kept in your pocket or your hand to insure safety. When clear to launch (about 15 feet away), after you insert the safety key, the ignition continuity light in the launch controller should come indicating that you have a hot circuit ready to launch.. To launch give the countdown: "five…four…three…two…one…start"

10. Center of Gravity – The balance point of a rocket.

11. NAR - The National Association of Rocketry (NAR) is the organized body of rocket hobbyists. Chartered NAR sections conduct launches, connect modelers and support all forms of sport rocketry. NAR was founded in 1957 to help young people learn about science and math through building and safely launching their own models.

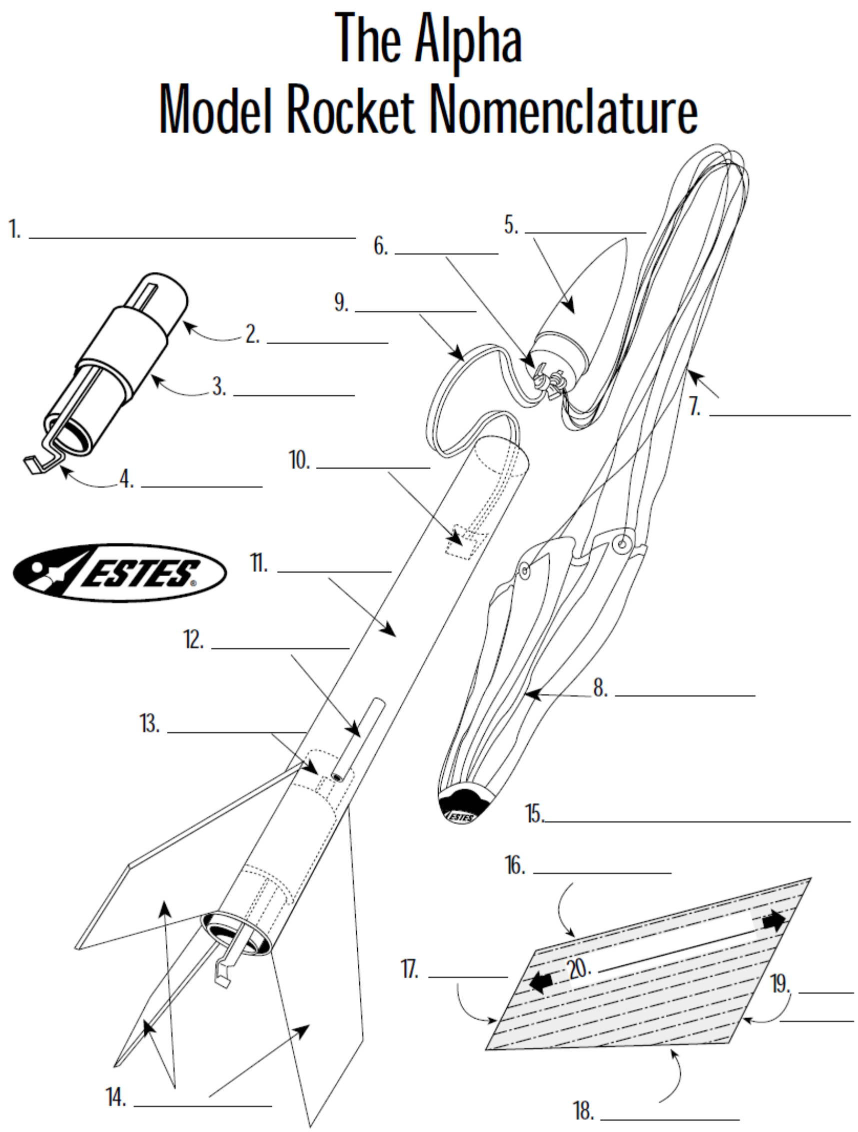
RECOMMENDED READING

Books available for purchase:
The Handbook of Model Rocketry by G. Harry Stine
Model Rocket Design and Construction by Timothy S. Van Milligan.

Available for free from Estes at http://www.esteseducator.com/
*Science and Model Rockets*by Sylvia Nolte, Ed. D.
Physics and Model Rockets Curriculum by Sylvia Nolte, Ed. D.
Mathematics and Model Rockets by Sylvia Nolte, Ed.D.
*Industrial Technology & Model Rockets Curriculum*by Richard Kalk, Ed. D and Steve Walsh.

Available free from NASA:
Rockets Educator Guide by Deborah A. Shearer & Gregory L. Vogt, Ed.D.
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html
Adventures in Rocket Science by Deborah Shearer, Greg Vogt, Carla Rosenberg, Vince Huegele, Kristy Hill,& Benda Terry
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Adventures_in_Rocket_Science.html
*Meteorology: an Educator's Resource for Inquiry-Based Learning for Grades 5-9*byDr. Joseph D. Exline, Dr. Arlene S. Levine & Dr. Joel S. Levine
http://www.nasa.gov/centers/langley/science/met-guide.html

SUPPLEMENTAL MATERIAL:



- ______________________ – helps to guide the rocket upward until it reaches enough velocity for the fins to engage.
- ______________________ – assists in the safe recovery of the rocket.
- ______________________ – connects the parachute and nosecone to the booster. It absorbs the shock of ejection charge.
- ______________________ – attaches the shock cord to the booster section.
- ______________________ – attach the engine mount (and sometimes the fins) to the airframe.
- ______________________ – holds the rocket engine inside the rocket.
- ______________________ – prevents the engine from being ejected by the ejection charge.
- ______________________ – guides the rocket in a straight path.

Newton's Laws of Motion

The laws of motion were discovered by ______________________________ after he witnessed an ______________ fall in his mother's garden. He wrote the ________ laws of motion.

The law of inertia is the ___________ law. It states that Objects at rest will stay at______ (________) and objects in _________ will stay in ___________ in a straight line unless acted upon be an ____________ force. This means that there is a _____________ tendency of objects to keep on doing what they're doing.

The second law states that acceleration is _____________ when a force acts on a ________. This law uses the mathematical formula F=MA, whereas F is _____________, and equals M(____________) times (__________________).

EXAMPLE: A car that weighs 1,000 kg runs out of gas. The driver pushes the car to a gas station at a speed of 0.05 meters per second. How much force is the driver applying to the car to go that speed?

F = MA F = _____________ X ___________________

_____N =______________ X ________________

N stands for _________________, which is equal to the amount of force required to accelerate a mass of one __________________ at a rate of one ___________per second per second.

Everyone knows that heavier objects require ________ force to move the same distance as _________ objects.

For every _______ there is an equal and opposite __________ is the definition of the ________ law of motion, also known as the law of _____________________________.This means that for every force there is a _______________ force that is _____________ in size, but ____________________ in direction.

This means that for every _________ there is a _______________ ____________ that is equal in size, but
______________ in direction. Whenever an object pushes another object it gets pushed back in the opposite direction with _______________________________.

Aerodynamics

Aerodynamics is a branch of dynamics concerned with studying the _______________________, particularly when it interacts with a moving object.

In physics the term __________________ customarily refers to the time evolution of physical processes.

Factors that affect aerodynamics are the _______________, the ___________________ and the ___________.

The lift and drag act through the __________________which is the average location of the aerodynamic forces on an object.

__________________is a force used to stabilize and control the direction of flight.

__________________is the component of aerodynamic force parallel to the relative wind.

__________________ is the force generated by gravity.

__________________ is the force which moves the rocket forward.

Aerodynamic forces are generated and act on a rocket as it ______________________________.

Lift and drag art through the ______________________________ which is the average location of the aerodynamic forces on an object.

Aerodynamic forces are __________________. They are generated by the interaction and contact of a solid body with a fluid, a liquid, or a gas.

For __________________to be generated, the rocket must be in contact with the air, liquid or a gas.

__________ occurs when a flow of gas is turned by a solid object. The flow is turned in one direction, and the lift is generated in the opposite direction, according to Newton's third law of action and reaction. For a model rocket, the nose cone, body tube, and fins can turn the flow and become a source of __________________ if the rocket is inclined to the flight direction.

When a solid body is moved through a fluid (gas or liquid), the fluid resists the motion. The object is subjected to an __________________in a direction opposed to the motion which we call __________________.

__________ is _____________________________, and one of the sources of drag is the ______________________ between the molecules of the air and the solid surface of the moving rocket.

A ________________________________ is the layer of air in the immediate vicinity of the rocket's surface.

Boundary layers can be ____________ (smooth flow) or ________________ (swirling). The point in which a laminar boundary layer becomes turbulent is called the_________________________. ___________________ is also ____ to the motion of the object through the fluid. This source of drag depends on the _________________ of the rocket and is called ___________________ or ____________________ drag.

___________________ ___________________ occurs whenever two surfaces meet at sharp angles, such as at the fin roots. Interference drag creates a ___________________ which creates drag.

___________________ ___________________ reduce the effects of this drag.

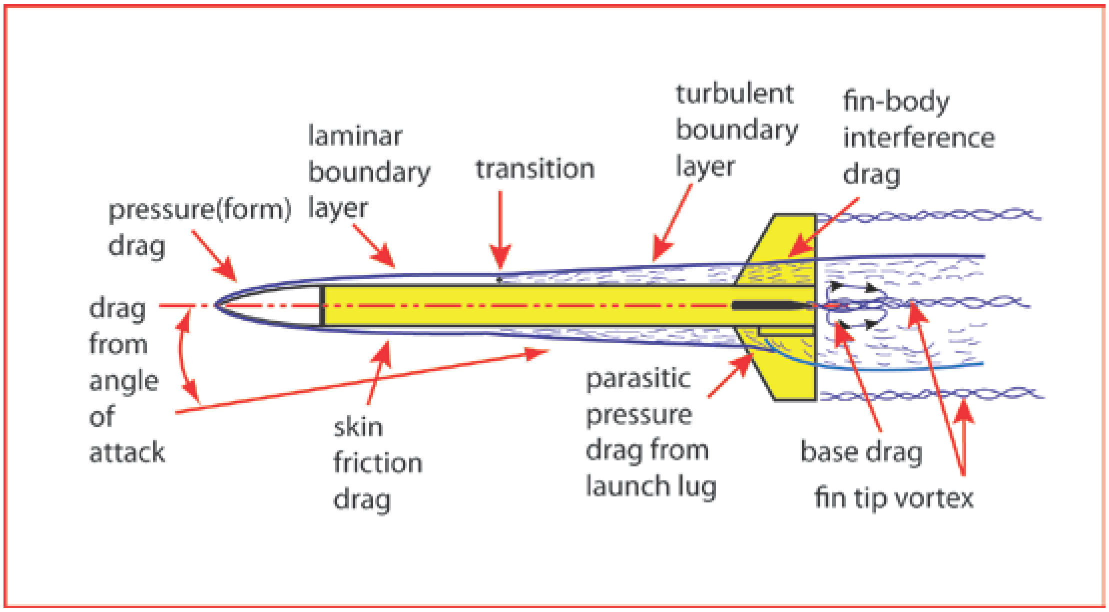
Air passing by the tips of the fins form a ______________________________________. Accelerating the air into this vortex causes ___________________ on the fins, and a ___________________ pressure area behind them. ___________________ fin tips reduce this drag.

___________________ ___________________ is produced by objects like the launch lug. The launch lug can account for_________ **%** of all drag. Cutting the lug's leading edge to ______ degrees reduces this type of drag.

A model rocket's fin that is _____________ on the edges creates a lot of _____________ and ______________ . If the fin's leading and trailing edges are sanded in a _____________ _____________ , called an _____________ , it reduces the drag.

_____________ _____________ _____________ creates high pressure behind the fin and pushes it

_____________, cancelling out most of the pressure drag caused by the fins. This is called _____________ _____________ .



Model Rocket Drag

Weight is the force generated by the ___________________ attraction on the rocket.

The gravitational force is a ___________________; the source of the force does not have to be in physical contact with the object.

___________________ is the force which moves the rocket through the air, and through space.

Thrust is generated by the _________________________ of the rocket through the application of Newton's third law of motion.

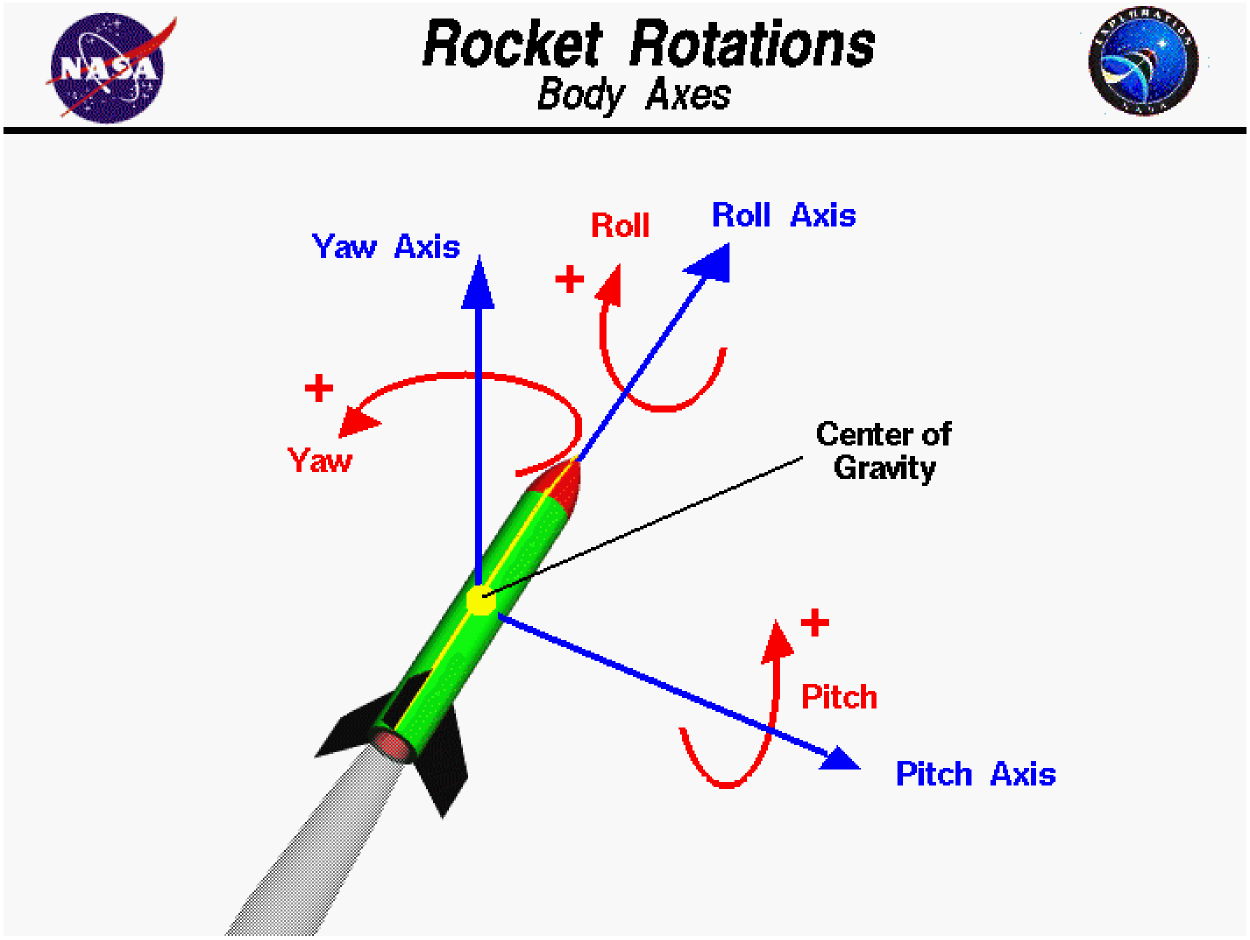
The direction of the thrust is normally along the longitudinal axis of the rocket through the rocket's ___________________.

ROCKET STABILITY

During the flight of a model rocket, gusts of ________ or thrust ________________, can cause the rocket to "________ ", or change its attitude in flight.

Poorly built or designed rockets can also become _______________ in flight.

A rocket in flight can move two ways; it can _____________, or change its location from one point to another, and it can ___________, meaning that it can roll around on its axis.



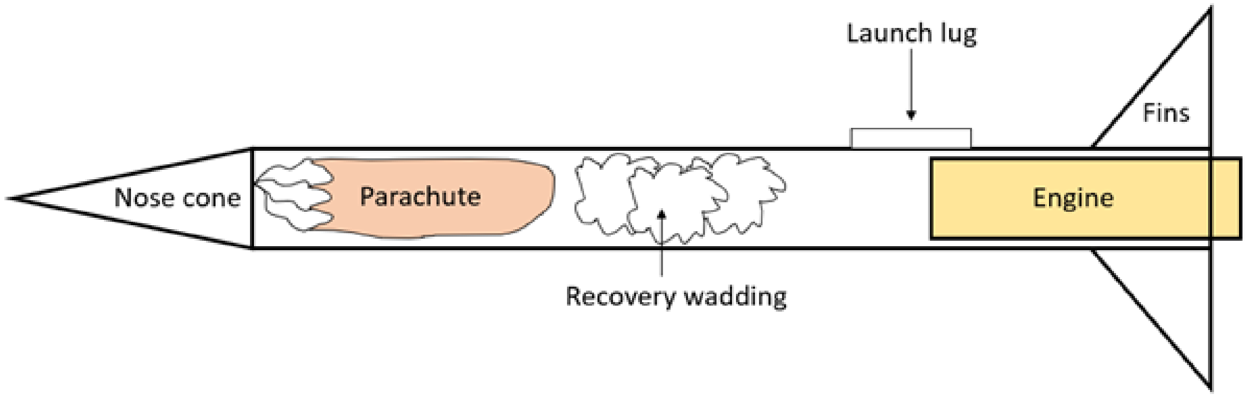
Rocket Rotations

Most rockets are symmetric about a line from the tip of the nose to the center of the nozzle exit. We will call this line the ________________ and motion about this axis is called a ___________________________.

The ____ lies along the roll axis.

When a rocket wobbles from side to side, this movement is called a ______________ motion.

A __________________ motion is an ____ or ______________ movement of the nose of the rocket.



Model Rocket Stability

As a rocket ______________ and _______________, the rotation occurs about a point called the center of _______________________, which is the average location of the weight of the rocket.

The average location of the __________________ on the rocket is called the _______________.

The parts of the rocket that influences the location of the center of pressure the most are the _____________.

If the ________________________ is in front of the _______________________ , the rocket will return to its initial flight conditions if it is disturbed. This is called a ___________________ because the forces "restore" the rocket to its initial condition and the rocket is said to be __________________.

If the center of ______________ and the center of ______________ are in the same location, it is called _______________________. A rocket with ______________ ______________ may make a stable or unstable flight depending on the forces acting on it.

If the center of ______________ is behind the center of ______________, the lift and drag forces maintain their directions but the direction of the torque generated by the forces is ______________ . This is called a ______________ ______________ ______________ . Any small displacement of the nose generates forces that cause the displacement to increase. Such a flight condition is______________ .

Correcting Unstable Flight

To move the Center of Gravity:

____

____

To move the Center of Pressure: ____

____

____

The best separation between the center of __________ is for the __________ to be at least

______________________ in front of the ___________. This is called ____________________.

Following the liftoff of a model rocket, it often _________________________. This maneuver is called _________________________ _________________________ and it is caused by forces, such as a strong wind, pushing on the side of the rocket's fins.

Causes of Weather Cocking:

____

____

____

Using ___________ fins reduce weather cocking because of the aerodynamic side profile.

________________________ should be used carefully because these types of rockets tend to be ________________________.

NOTES

AFJROTC MODEL ROCKET LAUNCHING DATA SHEET

NAME OF CADET *(Last, First, Middle Initial)*		GRADE
UNIT: TX-954	CHARTER NUMBER	FLIGHT: TX-954 Rocketry Team
PERSONNEL PARTICIPATING		
RANGE OFFICER	SAFETY OFFICER	
FIRST AID OFFICER	OTHERS	

WEATHER DATA

TEMPERATURE	WIND DIRECTION	WIND VELOCITY	VISIBILITY	CEILING

MODEL ROCKET DATA

NAME AND/OR MODEL NUMBER	DIMENSIONS	
NUMBER AND TYPE OF FINS	MOTOR	TOTAL WEIGHT

EXPECTED PERFORMANCE

TOTAL FLIGHT TIME	MAXIMUM ALTITUDE	AVERAGE VELOCITY

LAUNCHING DATA

LOCATION OF LAUNCH SITE	TYPE LAUNCHER
LAUNCHING ANGLE	DATE AND TIME OF LAUNCHING

MISFIRE	☐ YES	☐ NO	(IF YES, GIVE REASON AND CORRECTIVE ACTION TAKEN IN REMARKS.)
SUCCESSFUL FIRING	☐ YES	☐ NO	(IF NO, EXPLAIN IN REMARKS.)
TAKEOFF NORMAL	☐ YES	☐ NO	(IF NO, EXPLAIN IN REMARKS.)
PART FAILURE	☐ YES	☐ NO	(IF YES, EXPLAIN IN REMARKS.)

TOTAL FLIGHT TIME	ESTIMATED MAXIMUM ALTITUDE	ESTIMATED AVERAGE VELOCITY
IMPACT DISTANCE	FLIGHT BEHAVIOR	OTHER

REMARKS *(If additional space is needed, use reverse side.)*

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Model Rocket Launch Data Sheet