STUDENT HANDBOOK

MODEL ROCKETRY

STUDENT NAME

Table of Contents

Table of Illustrations

LD01: Introduction to Model Rocketry

The Team America Rocketry Challenge

The Team America Rocketry Challenge was conceived originally as a way to promote interest in science and aerospace careers among high school students, and to celebrate the 100th anniversary of the Wright brothers' 1903 flight. The response was so great that it became an annual event. Approximately 7,000 students from across the nation compete in TARC each year.

Team America Rocketry Challenge (TARC) is an aerospace design and engineering event for teams of US secondary school students (7th through 12th grades) run by the NAR and the Aerospace Industries Association (AIA). Teams can be sponsored by schools or by non-profit youth organizations such as Scouts, 4-H, or Civil Air Patrol (but not the NAR or other rocketry organizations). The goal of TARC is to motivate students to pursue aerospace as an exciting career field, and it is co-sponsored by the American Association of Physics Teachers, 4-H, the Department of Defense, and NASA. The event involves designing and building a model rocket (2.2 pounds or less, using NAR-certified model rocket motors totaling no more than 80.0 Newton-seconds of total impulse) that carries a payload of 1 Grade A Large egg for a flight duration of 40 - 45 seconds, and to an altitude of exactly 825 feet (measured by an onboard altimeter), and that then returns the egg to earth uncracked using only a streamer as a recovery device. Onboard timers are allowed; radio-control and pyrotechnic charges are not.

The first seven Team America Rocketry Challenges, held in 2003 through 2009, were the largest model rocket contests ever held. Co-sponsored by the NAR and the Aerospace Industries Association (AIA), the five events together attracted about 5,100 high-school teams made up of a total of over 50,000 students from all 50 states. These students had a serious interest in learning about aerospace design and engineering through model rocketry. The top 100 teams each year came to a final fly-off competition in late May near Washington, DC, to compete for $60,000 in prizes. These teams were selected based on the scores reported from qualification flights that they conducted locally throughout the US.

Team America Rocketry Challenge 2010's target flight duration of 40-45 seconds is measured from the moment of rocket liftoff until the egg payload lands. The target flight altitude of 825 feet is measured by an onboard altimeter. The top 100 teams from among all those who have entered will meet in a final fly-off competition on May 15, 2010 at Great Meadow, The Plains, VA. These top 100 teams will be selected based on the duration and altitude scores reported from local qualification flights that they conduct in front of an NAR Senior (adult) member observer at their choice of time up until the flight deadline of April 5, 2010

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.

4H

4-H has grown into a community of 6 million young people across America learning leadership, citizenship and life skills. 4-H can be found in every county in every state, as well as the District of Columbia, Puerto Rico and over 80 countries around the world. The 4-H community also includes 3,500 staff, 518,000 volunteers and 60 million alumni. 4-H'ers participate in fun, hands-on learning activities, supported by the latest research of land-grant universities, that are focused on three areas called Mission Mandates:

Science, Engineering and Technology

Healthy Living

Citizenship

The NAR 4H partnership

In May 2007 the NAR and 4-H initiated a national partnership. The purpose of this alignment is to get more kids to fly rockets and form rocket clubs which will lead to more TARC teams, more people joining NAR and more kids becoming scientists and engineers

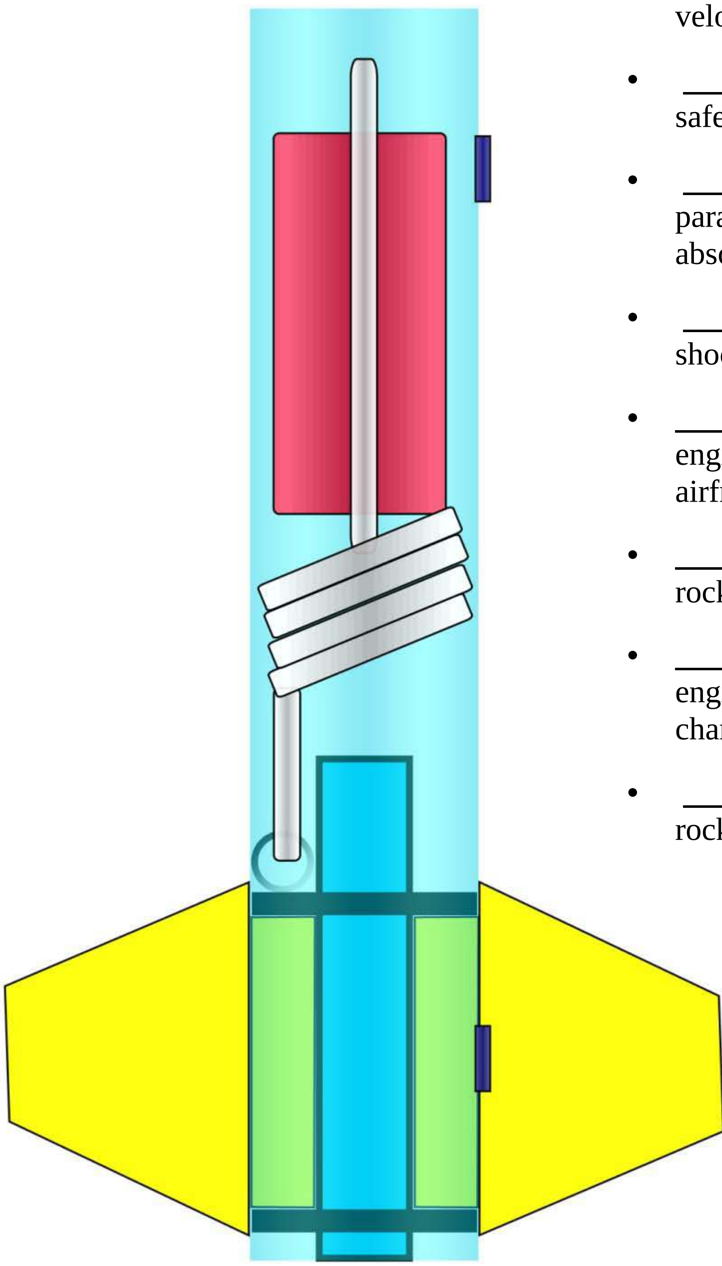
Together 4H clubs and NAR sections can hold sport, contest or TARC launches. They can have training and building sessions, or work on science fair and engineering challenges using rocketry. 4H has many 'state fair' events that need innovative ideas for student projects. In serving young people 4H and NAR can both elevate the visibility of one another in their mutual community.

The NAR has a wide range of online resources that are immediately useful to 4-H youth group leaders in organizing and running rocketry programs.

NAR board members have had several planning meetings with the 4H National Council and Headquarters Directors. The first steps to implementing these plans are to establish connections between the organizations, such as this web link. Members from both groups need to get familiar with each other. As a few joint rocketry activities get started and promoted in some regions, other areas will get the idea and follow. 4H teams will eventually become big players in TARC. The goal is that in five years the partnership will have engaged over 100,000 students in a rocketry event.

THE BOOSTER SECTION

- ______________________ – 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.



2009 Tom Sarradet

Figure 1: Booster Section

Rocket Fin Parts and Shapes

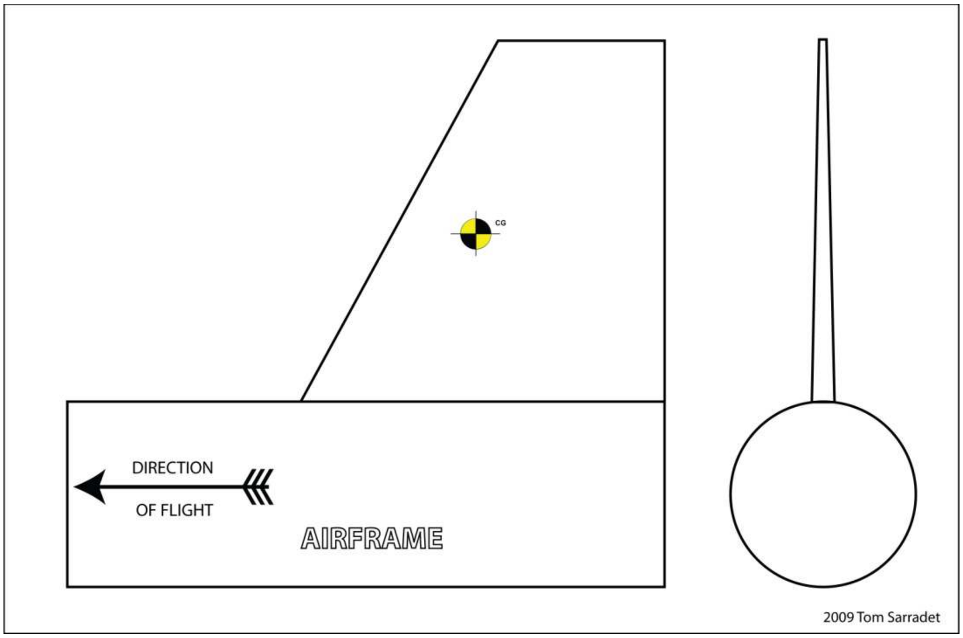


Figure 2: Fin Parts

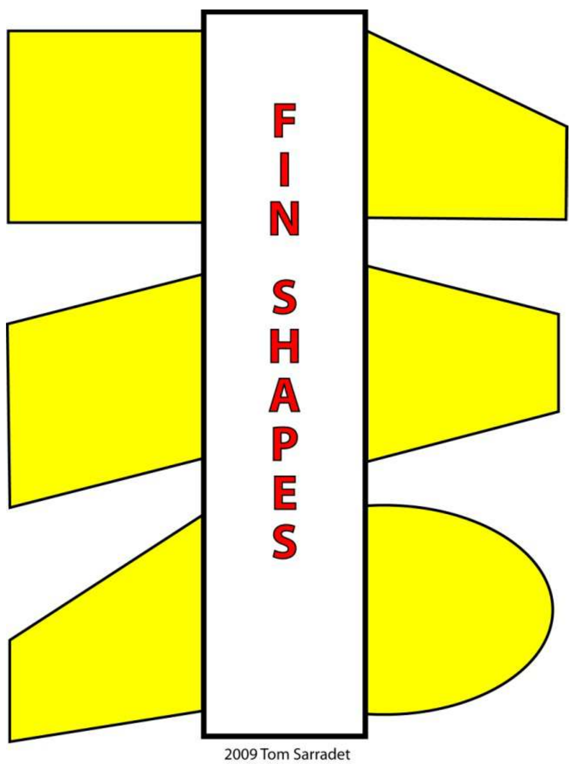


Figure 3: Fin Shapes

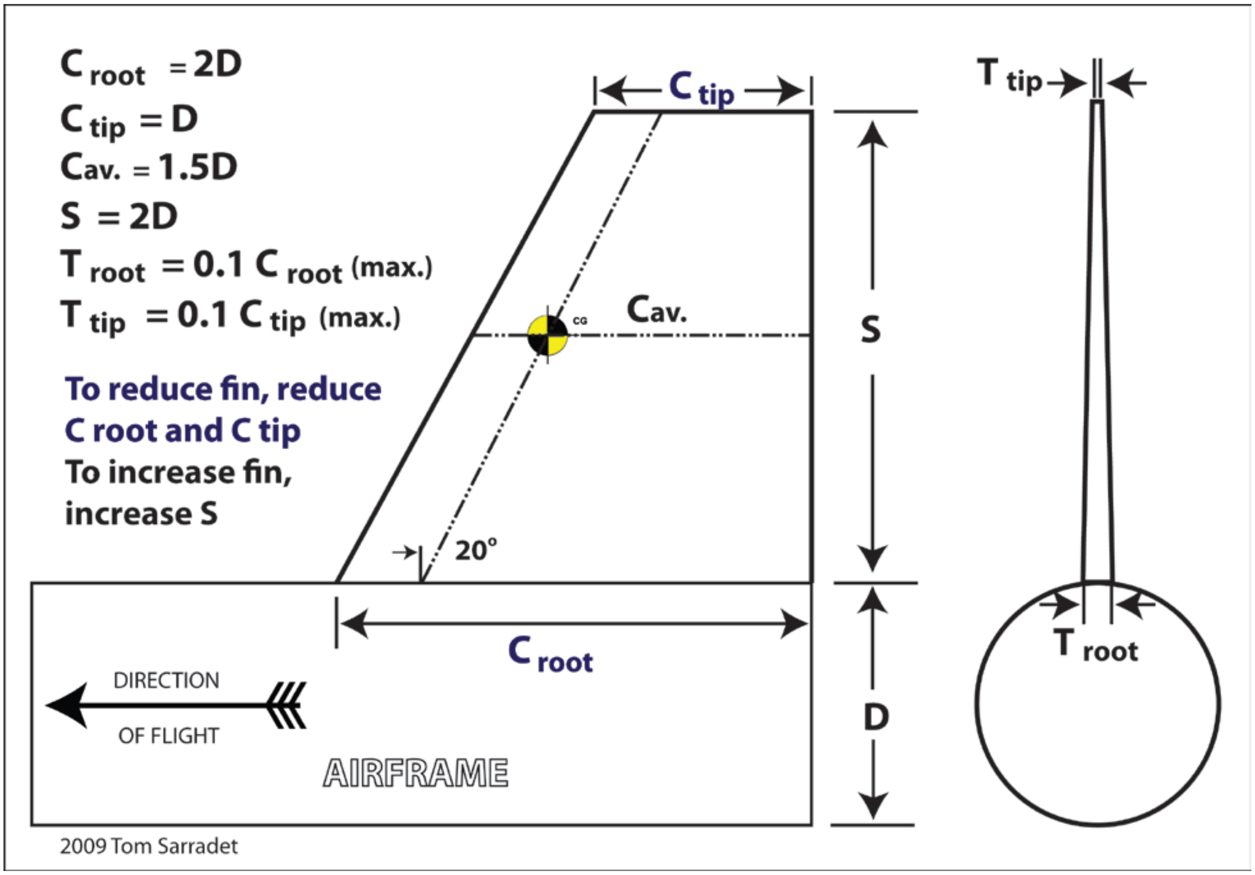


Figure 4: Low Drag Fin

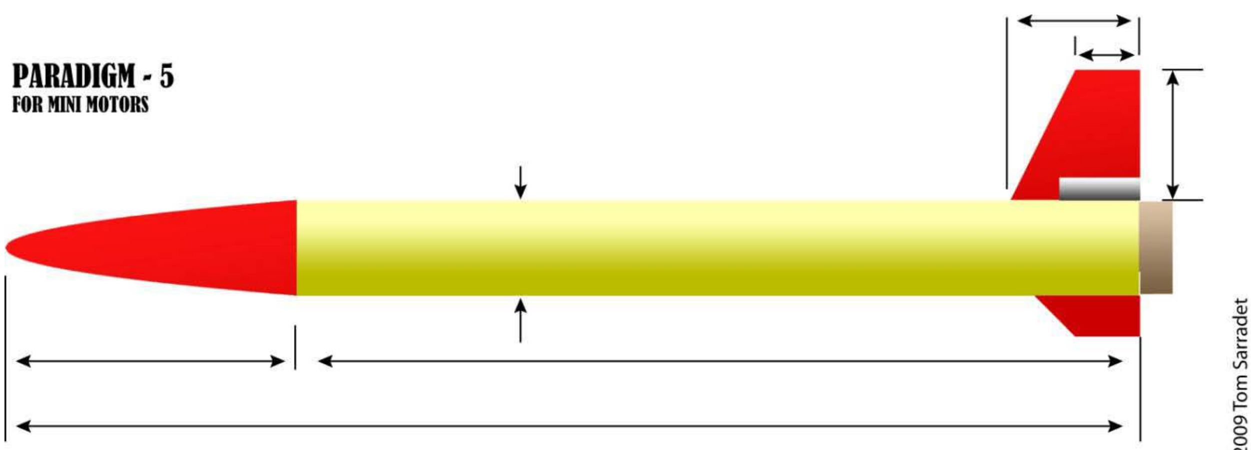
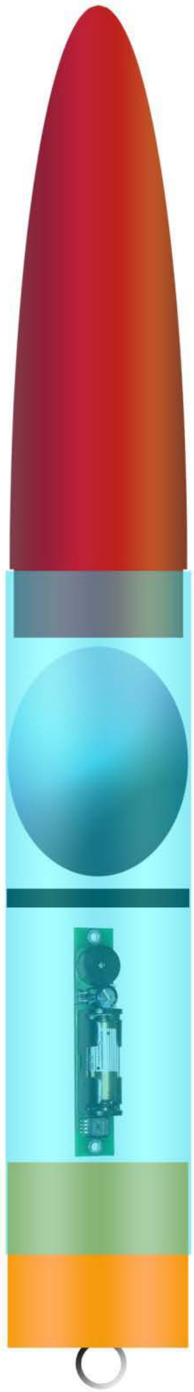


Figure 5: Low Drag/High Performance Rocket



2009 Tom Sarradet

Figure 6: Payload Section

THE PAYLOAD SECTION

- _______________ – creates an aerodynamic shape. May also hold a payload.
- _______________ – holds the payloads in place.
- _______________ – separates the egg section from the electronics section, preventing vortex effect and causing a false altimeter reading.
- _______________ – measures the changing air pressure to calculate apogee. Must have vent holes in airframe in order to operate properly.
- _______________ – connects the payload section to the booster section by means of the shock cord. Also protects the payload from the ejection gases.
- _____________________________________– a metal eye for the secure attachment of the shock cord.

THE EGG

____

____

____

____

____

____

____

____

The Nose

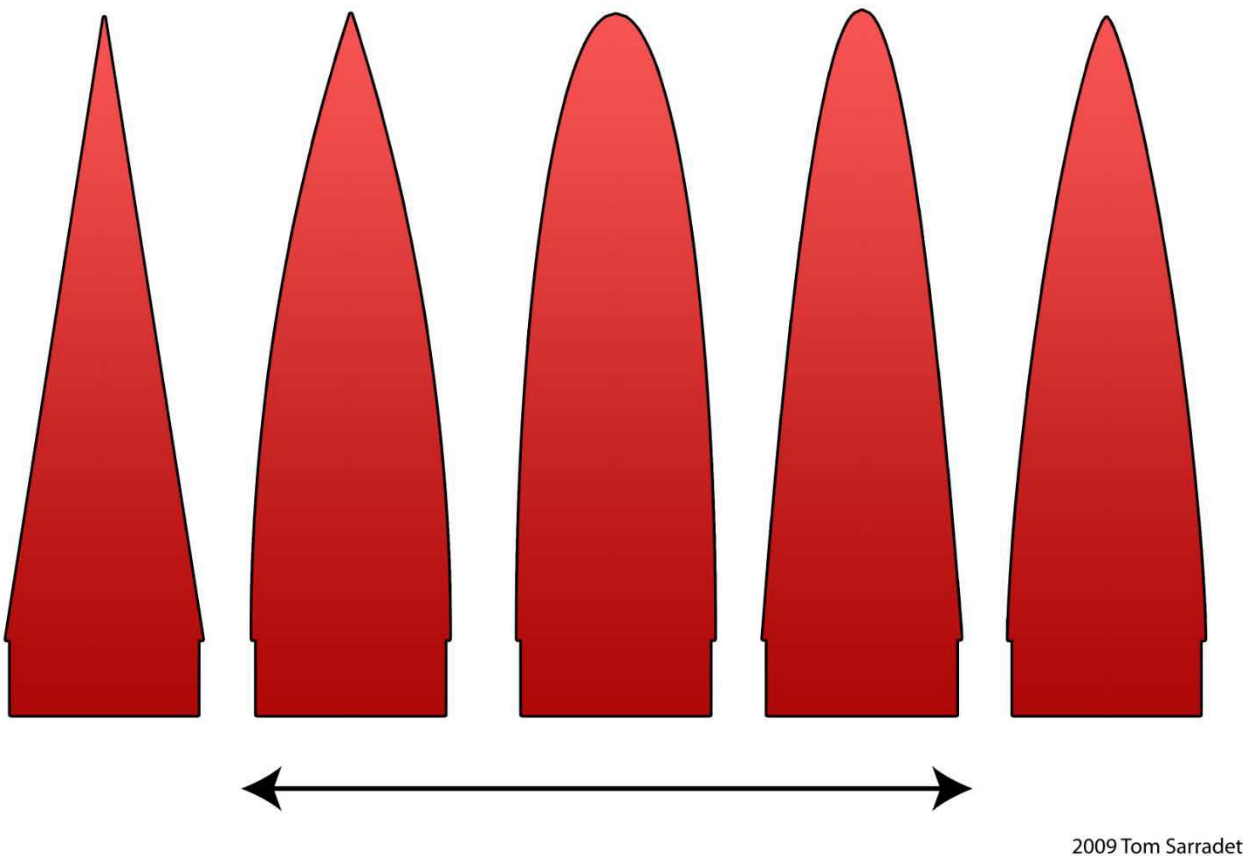


Figure 7: Nose Shapes

NOTES:

Rocket Motors

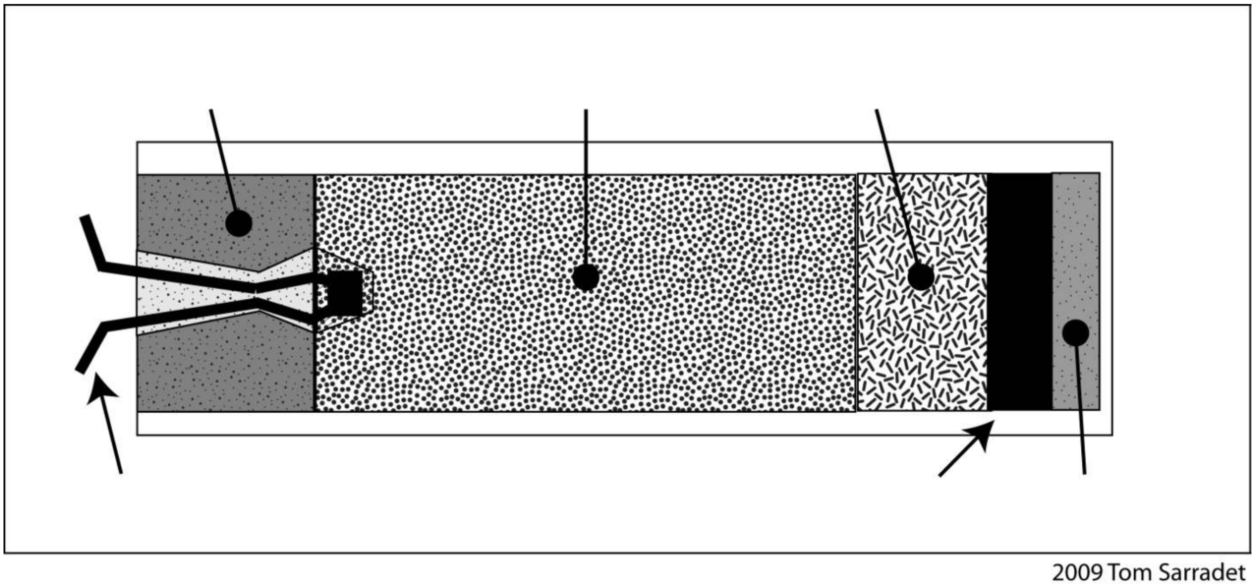


Figure 8: Black Powder Motor

NOTES:

____

____

____

____

____

____

____

____

____

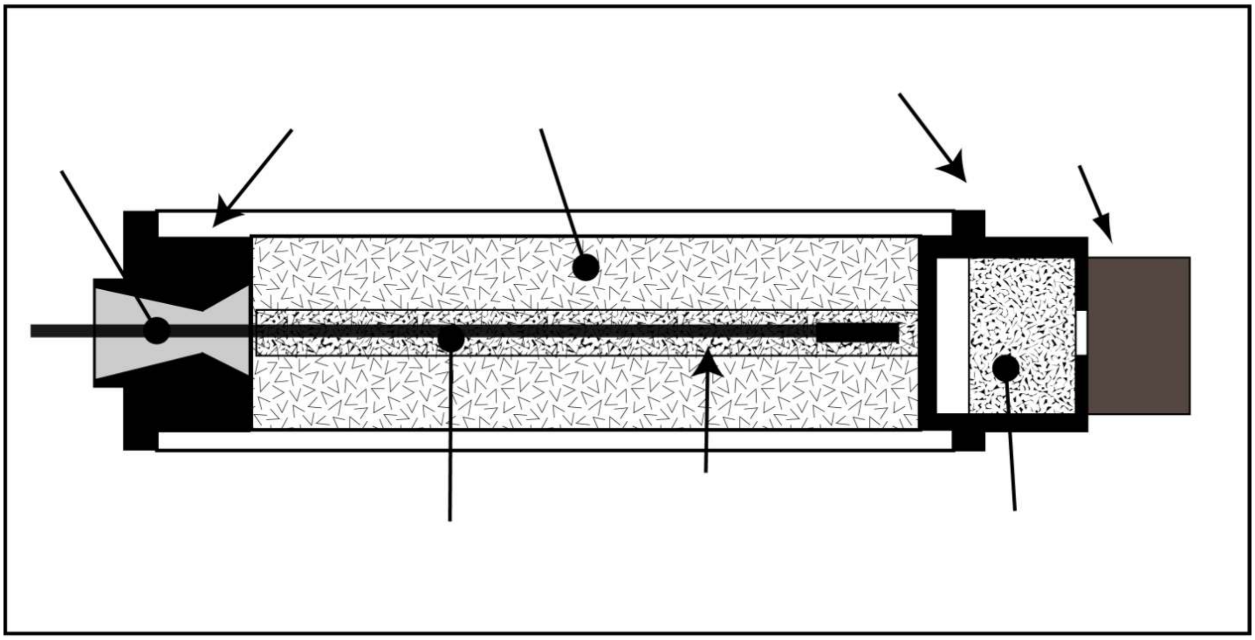
____

____

____

____

____



2009 Tom Sarradet

Figure 9: Composite Reloadable (RMS) Motor

NOTES:

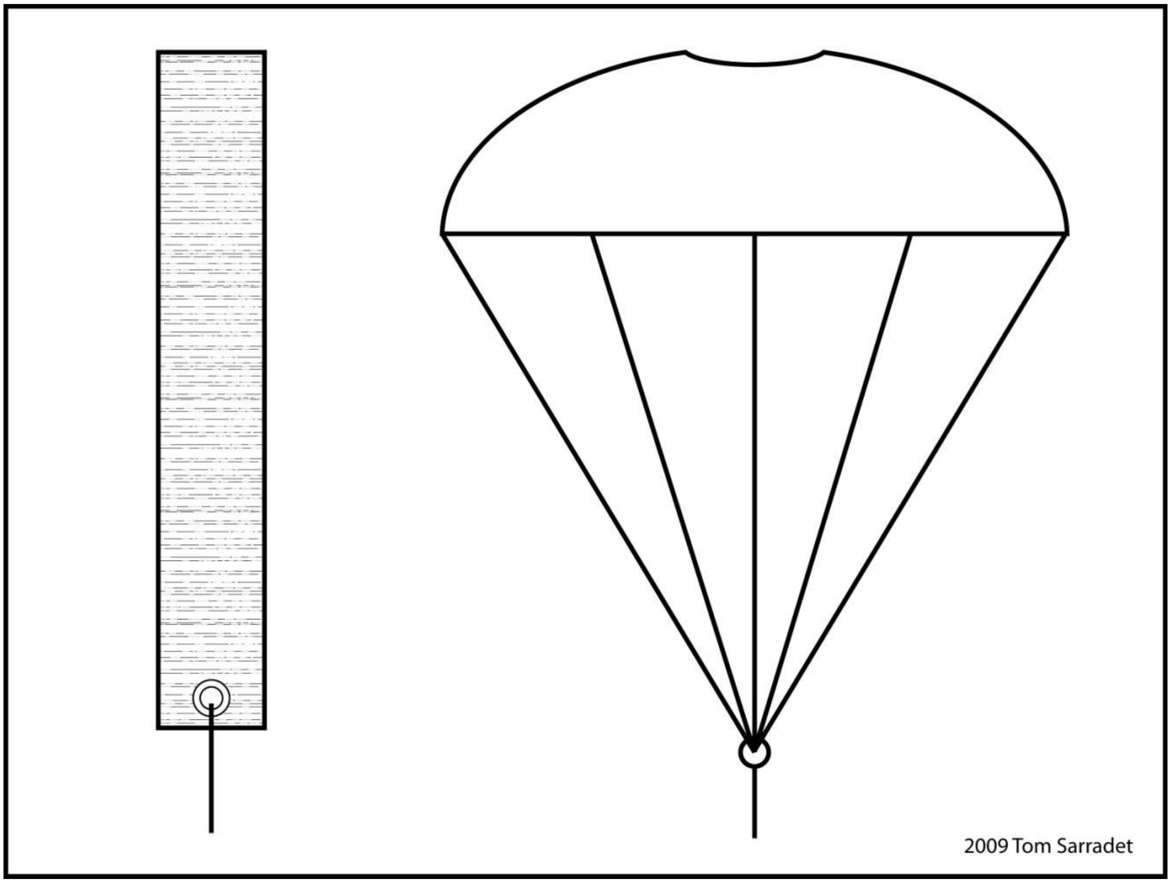


Figure 10: Streamer and Parachute

STREAMERS	PARACHUTES

LD03: 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 ______________________________.

LD04: 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 ______________ ______________ .

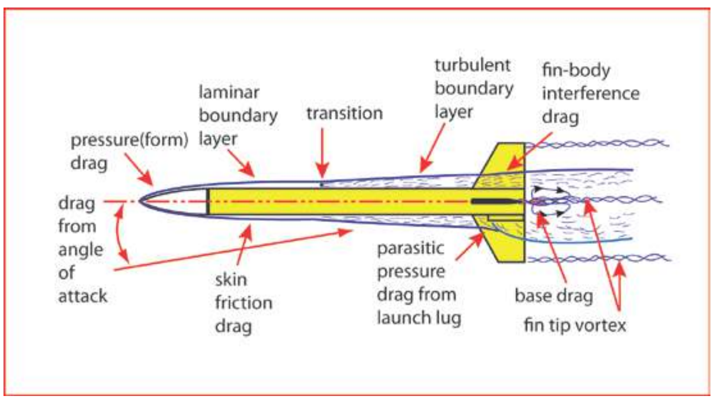


Figure 11: Model Rocket Drag

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 ___________________.

LD05: 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.

This lesson is about what makes a rocket unstable in flight and what can be done to improve its stability.

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.

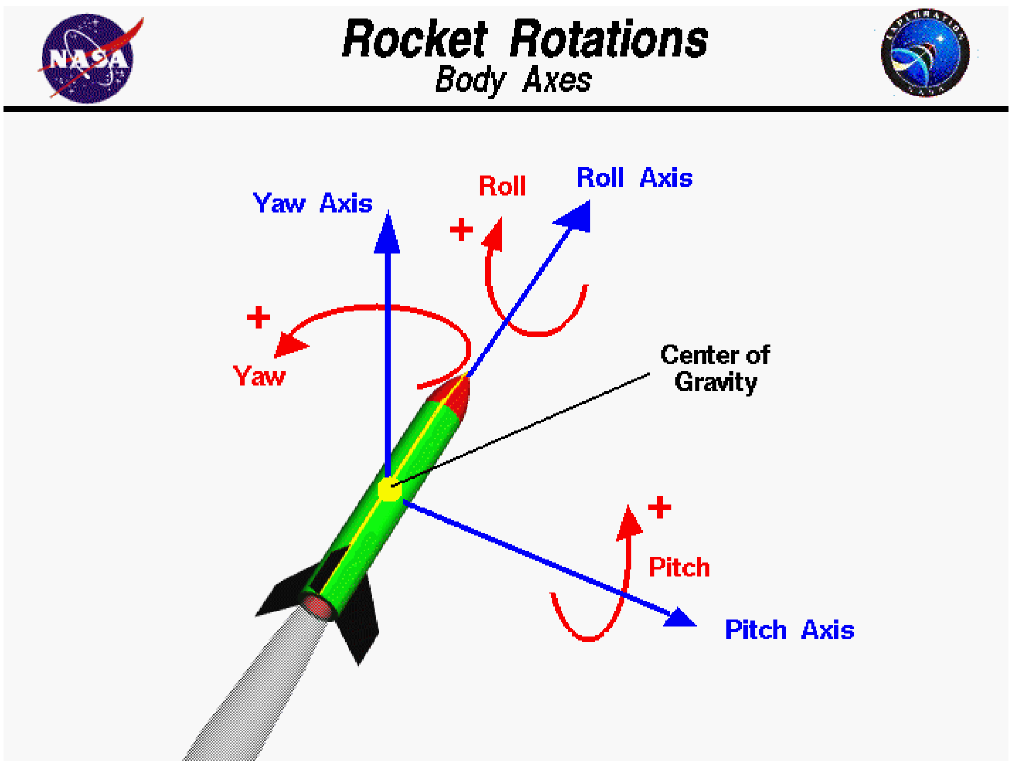


Figure 12: Rocket Rotations

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.

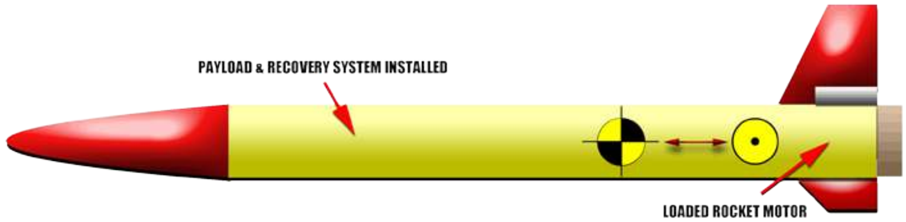


Figure 13 Model Rocket Stability

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 ________________________.

LD07: Model Rocket Safety Code

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 model 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 the rod when it is not in use.
7. **Size.** My model rocket will not weigh more than 1,500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320 N-sec (71.9 pound-seconds) of total impulse.
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.
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.

Launch Log

Rocket Name: ______________________________________

Serial # ______________________

Builder:____

LAUNCH INFORMATION	FLIGHT DATA	
Date:	**Liftoff**	**Recovery**
Launch Time:	Successful:	Recovery System Deployment
Location:	***Misfire***	***Stage 1***
Launch Pad Elevation:	Stage 1:	Before Apogee:
	Stage 2:	At Apogee:
ROCKET DATA	**Pitch & Roll**	During Descent:
Fin Design:	***Thrust Phase***	Partial Deployment:
Fin #	No Pitch/Roll:	Failed to Deploy:
Engine	Pitched:	***Stage 2***
Stage 1:	Rolled:	Before Apogee:
Stage 2:	Tumbled:	At Apogee:
	Weathercock:	During Descent:
Recovery System	***Coast Phase***	Partial Deployment:
Stage 1:	Straight Trajectory:	Failed to Deploy:
Parachute -	Weathercock:	
Diameter:	Tumbled:	Recovery System Performance
Spill Hole Diameter:		***Stage 1***
Streamer -	**ALTITUDE**	Stable Descent:
Size:	***Tracking Station***	Oscillation:
Material:	Track. 1 Distance from pad:	Spinning:
Stage 2:	Track.2 Distance from pad:	***Stage 2***
Parachute -	Track.3 Distance from pad:	Stable Descent:
Diameter:	Tracker 1 Degrees:	Oscillation:
Spill Hole Diameter:	Tracker 2 Degrees:	Spinning:
Streamer -	Tracker 3 Degrees:	
Size:		**Landing**
Material:	***Marker Streamer***	Soft:
	Timer 1:	Hard:
Mass	Timer 2:	Crash:
Empty:		Distance from Pad:
Loaded:	***Electronic Altimeter***	Direction from Pad:
Post:	Reading:	
	FLIGHT TIMES	**Post Flight Inspection**
METEOROLOGY	***To Apogee***	***Damage***
Temperature:	Timer 1:	Nose:
Humidity:	Timer 2:	Airframe:
Barometer:	***Apogee to Landing***	Fins:
Wind Speed:	Timer 1:	Shock Cord:
Wind Direction:	Timer 2:	Recovery System:
Conditions:	***Total Time of Flight***	Can be reflown?
Cloud Type:	Timer 1:	
	Timer 2:	

Date: ________________ Time of Collection: _________________

Air Temperature (°F):	°	Wind Speed Range	KPH
Dry Bulb Temperature:	°	Wind Direction:	
Wet Bulb Temperature:	°	Barometric Pressure:	In Hg
Dry Bulb Temp. – Wet Bulb Temp. =	°	Visibility:	°
Relative Humidity:	°	Cloud Type:	
Dew Point:			

Sling Psychrometer Worksheet

Difference between Dry and Wet Bulbs in degrees

Dry Bulb °	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°
32	90	79	70	60	50	40	31	22	13	4					
34	91	81	72	62	53	44	35	26	18	9	1				
36	91	52	74	65	56	48	39	31	22	14	6				
38	92	83	75	67	59	51	42	35	27	19	11	4			
40	92	84	76	68	61	53	46	38	31	23	16	9	2		
42	92	85	77	70	62	55	48	41	34	28	21	14	7		
44	93	85	78	71	64	57	50	44	37	31	24	18	12	5	
46	93	86	79	72	65	59	52	46	40	34	28	22	16	10	4
48	93	86	80	73	67	61	54	48	42	36	31	25	19	14	11
50	94	87	81	74	68	62	56	50	45	39	33	28	22	17	12
52	94	87	81	75	69	63	58	52	47	41	36	31	25	20	15
54	94	88	82	76	70	65	59	54	49	43	38	33	28	23	20
56	94	88	83	77	71	66	61	56	51	45	40	36	31	26	22
58	94	89	83	78	71	67	62	57	52	47	42	38	33	29	24
60	94	89	84	78	73	68	63	58	54	49	44	40	35	34	27
62	95	89	84	79	74	69	64	60	55	51	46	42	38	34	29
64	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30
66	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32
68	95	90	85	80	75	71	67	62	58	54	50	46	42	38	34
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38
74	95	91	86	82	78	74	69	65	61	58	54	50	47	43	39
76	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41
78	96	91	87	83	79	75	71	67	63	60	56	53	49	46	43
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44
82	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45
84	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46
86	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47
88	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49
92	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50
94	96	92	89	85	82	79	75	72	69	66	63	60	57	54	51

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 Resourcefor 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