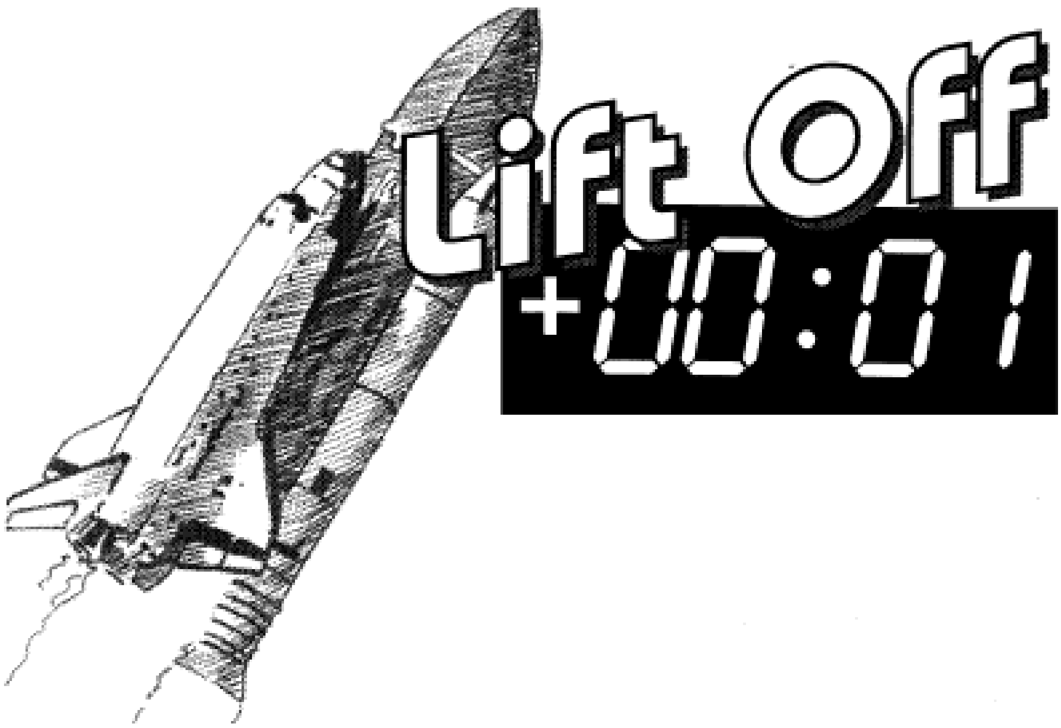


Liftoff!

The School Rocket Programme

Teachers' Guide

Produced by the

Department of Physics, University of Surrey

UniS
School of Physics and Chemistry
Department of Physics

Supported by the

Particle Physics and Astronomy Research Council

PPARC

Welcome

Welcome to *Liftoff!* the School Model Rocket Programme produced by the Department of Physics at the University of Surrey. The *Liftoff!* programme is designed particularly for students aged 13 – 15 years, or Key Stage 3 under the British school system. The programme gives a range of teacher-led activities which aim to stimulate student interest in the science and technology of rocketry and space flight.

Contents

Section 1: Teacher/Pupil Classroom Activities

Three classroom sessions that allow student groups to explore the basic science behind rocket flight using simple non-powered models. Teachers' notes and Student Sheets are provided for classroom use.

Section 2: How to Build and Fly a rocket kit

Advice on the construction and flight of simple powered rocket kits that can be bought from model shops. Information and safety rules about model rocket engines are discussed, along with guidance on suitable starter sets for beginners.

Useful contact information and web sites are also given for rocket suppliers and enthusiasts clubs.

Section 3: Extension Activities

Extension rocket activities for school groups, such as water and air powered rockets and other 'home-made' designs. Water powered rockets can be particularly suitable for school science clubs and can achieve impressive results.

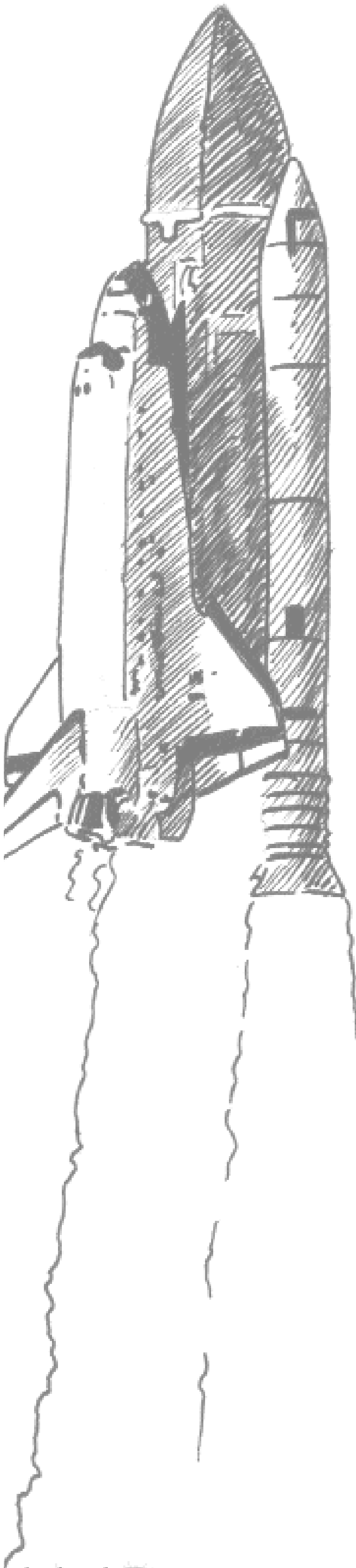
Credits

The *Liftoff!* Teachers' Guide was produced by Dr Paul Sellin and Ms Averil Macdonald from the Department of Physics at the University of Surrey. *Liftoff!* was partly funded by the Particle Physics and Astronomy Research Council (PPARC) under their Small Grants scheme for the Public Understanding of Science.

You can obtain more free copies of this Guide by contacting us at the following address:

Liftoff! Model Rocket Programme
Department of Physics
University of Surrey
Guildford GU2 7XH, UK

Or you can download copies from the *Liftoff!* website at: www.ph.surrey.ac.uk/liftoff



Lift Off +00:01

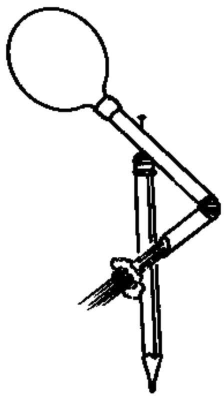
Why does a Rocket go up?

Introduction
It is the gravitational attraction between the Earth and a rocket that gives it its weight. If a rocket is going to take off it must be going fast enough to escape from the Earth's gravity. How can we make this happen? It would be no use fitting it with a car engine and wheels.

Activity
Build your own Rocket Pinwheel

Apparatus
- A wooden pencil with a rubber on the end.
- A small pin.
- A flexible drinking straw.
- Around party balloon.
- Sticky tape.

Diagram



What to do to build your pinwheel:
- Inflate the balloon so that it is slightly stretched and easy to work with.
- Insert the straw into the neck of the balloon and seal it to the balloon using sticky tape. You should be able to inflate the balloon by blowing into the straw.
- Bend the straw into a right-angle at the flexible section.
- Find the balance point of the straw and balloon by balancing the straw on your outstretched finger. Push the pin through the straw at the balance point.
- Push the pin into the rubber at the end of the pencil and spin it a few times to loosen up the hole.
- Blow into the straw to inflate the balloon and watch what happens when you let the balloon deflate.

Finding Out:
1. What happens to your pinwheel when you allow the balloon to deflate?
2. Does it make a difference whether the straw is bent or straight?
3. Does the air coming out of the straw have to push against something, such as a piece of card for the pinwheel to work?
4. Does it make a difference if the balloon is inflated more?

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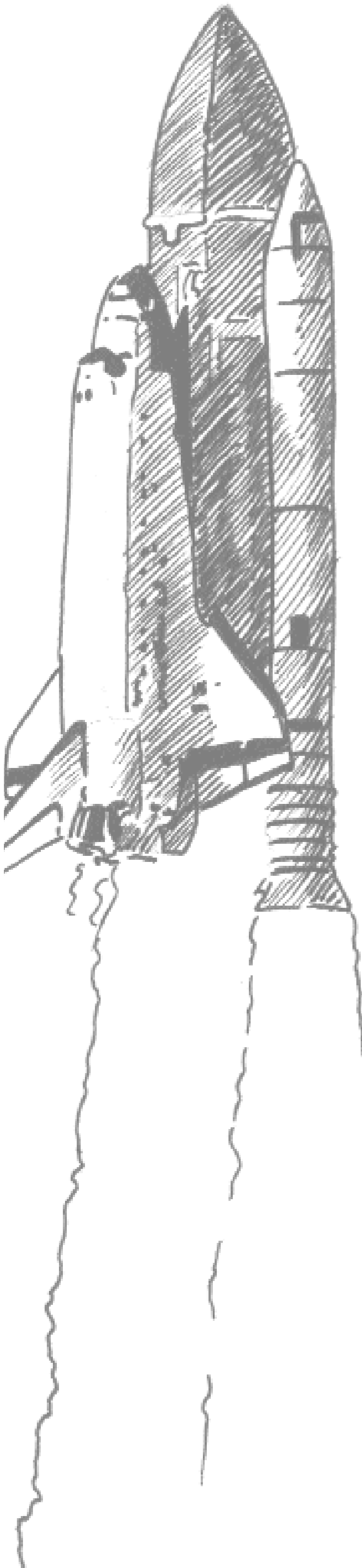


Lift Off +00:01

Why does a Rocket go straight up?

Introduction
When people started building rockets they had a lot of failures. Often the rocket blew up on the launch pad. Other times it went up, then came straight back down. Sometimes it went off in a strange direction. For the rocket to escape the Earth's gravity it must go straight up and not veer to the left or right.

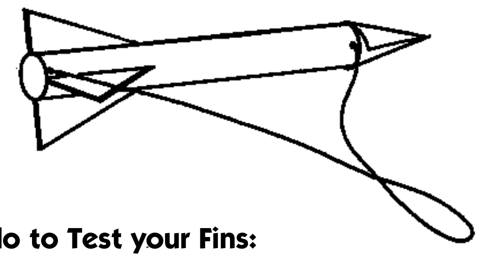
Activity
Testing the fins on a rocket

Apparatus

Either
- A centre tube from a kitchen roll
- A piece of card from which to make the nose cone
- A sheet of balsa wood from which to cut the fins (alternatively sheets of card from which to cut the fins)
- Glue
- Cutting Knife
- 1m length of thin string

Or
- A complete Rocket Kit
- 1m length of thin string
- Glue
- Cutting Knife

Diagram



What to do to Test your Fins:
- Construct the basic rocket shape with tube-shaped main body and nose cone.
- Cut out four identical fins for the rocket.
- Mark equally spaced positions for the four fins. This is easily done by gently wedging the vertical tube between a door and door jam (hinge edge).
- Stick three of the fins in position around the rocket body, but leave off the fourth.
- Tie the string through the holes made at each end of the body and tie the ends of the string into a loop.
- Carefully swing the rocket around you, horizontally, to see how it feels.
- Add the fourth fin and swing the rocket around you again.

Finding Out:
1. Does the rocket feel different when it has three fins compared with four? Which feels better balanced?
2. Does it make a difference when the rocket is travelling faster?
3. Is it possible to make a well-balanced rocket using only three fins ?

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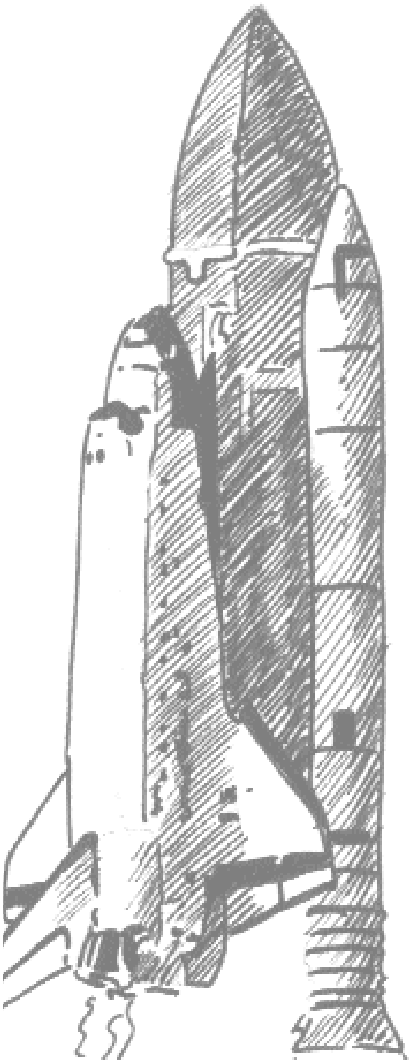


Lift Off +00:01

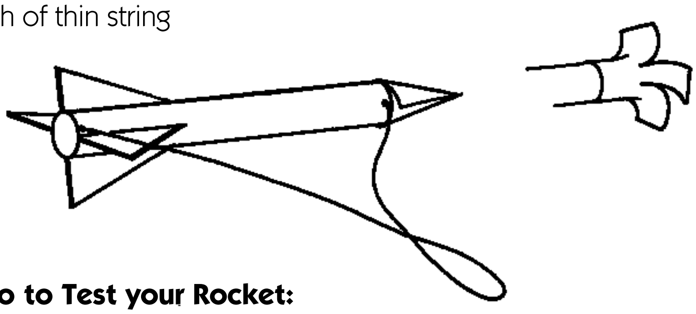
Why does one Rocket go higher than another?

Introduction
In normal air travel the biggest expense is the fuel. The fuel is needed mainly to overcome drag from the air (air resistance) during flight. Rockets also suffer from drag which will slow them down and limit how high they can get.

Activity
Reducing the drag on a rocket

Apparatus
Either
- A centre tube from a kitchen roll
- A piece of card from which to make the nose cone
- A sheet of balsa wood from which to cut the fins (alternatively sheets of card from which to cut the fins)
- Glue
- Cutting Knife
- 1m length of thin string

Or
- A complete Rocket Kit
- 1m length of thin string
- Glue
- Cutting Knife

Diagram


What to do to Test your Rocket:
- Construct the basic rocket shape with tube-shaped main body and nose cone.
- Cut out four identical fins for the rocket.
- Mark equally spaced positions for the four fins. This is easily done by gently wedging the vertical tube between a door and door jam (hinge edge).
- Stick all four fins in position around the rocket body.
- Tie the string through the holes made at each end of the body and tie the ends of the string into a loop.
- Carefully swing the rocket around you, horizontally, to see how it feels.
- Add a flat nose piece to change the drag (air resistance) on the rocket and swing it round you again.

Finding Out:
1. Does the rocket feel different as it flies when it has a flat nose compared with a cone shaped nose? Which feels better?
2. Does it make a difference when the rocket is travelling faster?

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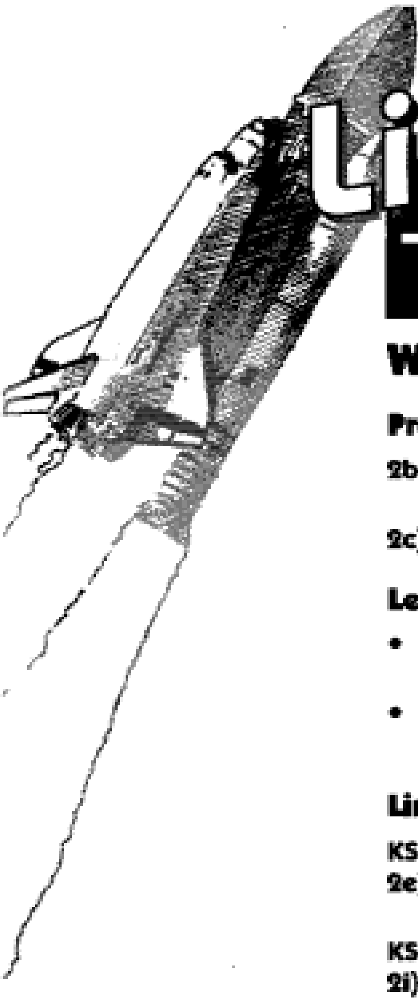

Lift Off +00:01 Teachers' Guide

Why does a Rocket go up?

Prerequisite knowledge from Key Stage 3

2b) that the weight of an object is the result of gravitational attraction between its mass and the earth.

2c) that unbalanced forces change the speed of moving objects.

Learning Objectives

- Pupils learn that there is an action and reaction pair of forces acting on a rocket which causes it to lift off.
- Pupils learn that a greater force results in a greater effect OR a lighter object experiences a greater effect from the same force.

Links to Key Stage 4

KS4 Physics Processes

2e) Pupils learn that there is a relation between force, mass and acceleration.

KS4 Scientific Enquiry

2i) Pupils learn to make sufficient relevant observation and comparisons to obtain reliable evidence.

Activity

- Pupils build a rocket pin wheel and see how varying the rate of flow of air increases the rate of rotation of the straw.

Learning Outcomes

- Pupils work in teams to identify how to vary and control key variables.
- Pupils combine results to conclude that a greater force results in a greater change of speed.
- More advanced pupils may see the effect of the reaction force on the straw pushing it round as the air is expelled. Mention may be made of change of momentum if appropriate to the pupils concerned.

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Why does a Rocket go straight up?

Prerequisite knowledge from Key Stage 3

2c) that balanced forces produce no change in the movement of objects.

Learning Objectives

- Pupils learn that the fins on the rocket need to be regularly spaced to ensure balanced forces keep the rocket form being turned from a straight trajectory.
- Pupils work in teams to devise a test of the effect of moving the fins.

Links to Key Stage 4

KS4 Scientific Enquiry

- Pupils carry out preliminary work and make predictions where appropriate.
- Pupils consider how to vary and control key variables.

Activity

- Pupils build a rocket and determine whether fitting the fins regularly or irregularly spaced affect the flight. The flight test is undertaken by attaching a string loop to the rocket and spinning it around the head.

Learning Outcomes

- Pupils work in teams to build a rocket.
- Pupils combine their findings to conclude that if the fins are not regularly spaced the rocket is poorly balanced and tends to veer off course.
- Pupils conclude that balancing the forces on an object will result in it continuing on a straight trajectory.

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Lift Off +00:03 Teachers' Guide

Why does a Rocket go higher than another?

Prerequisite knowledge from Key Stage 3

2b) that the weight of an object is the result of gravitational attraction between its mass and the mass of the earth.

2d) the ways in which frictional forces, including air resistance, affect motion.

Learning Objectives

- Pupils learn that the shape of the rocket nose cone affects drag and therefore the maximum height attained.
- Pupils learn that the time taken for a parachute to fall depends upon the air resistance.

Links to Key Stage 4

2h) the forces on a falling object.

2j) why falling objects reach a terminal velocity.

Activity

- Pupils build a rocket and determine whether a pointed or open nose cone affects the flight. The flight test is undertaken by attaching a string loop to the rocket and spinning it around the head.
- Alternative activity if not done previously : pupils may test parachutes to determine how to achieve the maximum fall time.

Learning Outcomes

- Pupils work in teams to build a rocket.
- Pupils combine their findings to conclude that streamlining will allow the rocket to move faster while drag will impede the flight.
- Pupils conclude that reducing the drag will result in the rocket attaining a greater maximum height.

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Section 2: How to Build and Fly a rocket kit

Teachers may want to build a powered model rocket kit with their students, in parallel with the 3 classroom activities. There's no more exciting way to finish off the classroom activities than with a real model rocket launch with your students. The simplest way for a beginner to build a powered model rocket is to use one of the many commercial kits that are now available from good model shops. In this section we describe the principles behind these kits for beginners and provide you with details on where to obtain them.

If you are already familiar with these simple powered rocket kits, then you can skip straight to the Extension Activities described in Section 3. The Extension Activities include plans for making your own powered model rockets from scratch. Remember though, you will still need a launch set (tripod, launch pole and battery box) to launch your home-made powered rockets. For safety reasons we do not recommend that you make these items yourself, and they can be bought as a 'starter set' from a model shop for under £20 (see details later).

Estes Model Rocket kits

The principal source of easy-to-build model rocket kits is an American company called Estes Industries. Estes make a large number of kits in the US suitable for different levels of skill on the part of the constructor. A subset of their range is available in Britain through all good model shops.

If you have trouble finding a good local stockist of Estes Rockets you can find the name of a local supplier by contacting the sole UK agent, Ripmax. All model shops in this country obtain their Estes products through Ripmax, who can be contacted at the following address:

Ripmax
Head Office
Green Street
Enfield EN3 7SJ
Tel: (020) 8804 8272

You may also have to contact Ripmax to buy your engines, since local model shops sometimes only small stocks and supply can be a problem. Ripmax also have their own website; the web address is given at the end of this section.

Remember that if you have never flown an Estes Rocket before, you will need an Estes Starter Pack (cost about £20) that contains the launch pad and electronic ignitor, as well as a pre-assembled plastic starter rocket. We have used the 'Code Red' Estes starter pack, that contains a read-to-fly rocket suitable for a B engine. All you need to buy to get flying, in addition to the starter set, is a pack of rocket engines.

Model Rocket Safety

Here we review the Safety Guidelines for powered model rockets. Every Estes rocket kit comes with a copy of the US National Association of Rocketry (NAR) Safety Code that is reprinted below. In addition there are some British guidelines that apply to model rocket use in this country:

Safety Disclaimer: *Whilst we have made every effort to provide accurate and comprehensive safety information as part of this model rocket programme, the University of Surrey cannot be held responsible for your rocket launching activities. In particular, it is your responsibility to carry out any necessary risk assessments and to implement appropriate safety measures.*

British Safety Guidelines for Model Rocketry

These guidelines are *in addition* to the NAR Safety Code that is reprinted below.

Model rockets and engines are not toys. Rocket engines may not be purchased by those under 16 years of age. Adult supervision is required during use with those under 16 years of age.

Model rocketry in Britain using engines up to D size is not restricted by aviation law unless you are close to an airport. Never launch a rocket near an aircraft in flight, nor within 8 kilometres of a major airport.

However there are some local bylaws in parts of the UK that either restrict or ban the launching of model rockets. These are similar to restrictions also placed on the flight of radio-controlled model aircraft.

Rocket motors up to size D do not require by law any special storage arrangements for personal use. However it is recommended that you store your engines in a locked cabinet or box, in a similar way that you would store fireworks.

It is prohibited under a number of UK laws to manufacture your own solid fuel rocket motors.

National Association of Rocketry (NAR) Safety Code

1. Materials. My model rocket will be made of lightweight materials, such as paper, wood, rubber, and plastic suitable for the power used and the performance of my model rocket. I will not use any metal for the nose cone, body, or fins of a model rocket.

2. Motors / Engines. I will use only commercially made NAR certified model rocket engines in the manner recommended by the manufacturer. I will not alter the model rocket engine, its parts, or its ingredients in any way.

3. Recovery. I will always use a recovery system in my model rocket that will return it safely to the ground so it may be flown again. I will use only flame resistant recovery wadding if required.

4. Weight and Power Limits. My model rocket will weigh no more that 1,500 grams (53 oz) at lift-off, and its rocket engines will produce no more than 320

Newton-seconds (4.45 Newtons equals 1.0 pound) of total impulse. My model rocket will weight no more than the engine manufacturer's recommended maximum lift-off weight for the engine used, or I will use an engine recommended by the manufacture for my model rocket.

5. Stability. I will check the stability of my model rocket before its first flight, except when launching a model rocket of already proven stability.

6. Payloads. Except for insects, my model rocket will never carry live animals or a payload that's intended to be flammable, explosive, or harmful.

7. Launch site. I will launch my model rocket outdoors in a cleared area, free of tall trees, power lines, buildings, and dry brush and grass. My launch site will be at least as large as that recommend in the following table:

Total impulse (Newton-seconds)	Engine Type	Minimum Site Dimension (Feet / Meters)
0.00 - 1.25	1/4A & 1/2A	50 / 15
1.26 - 2.50	A	100 / 30
2.51 - 5.00	B	200 / 60
5.01 - 10.0	C	400 / 120
10.01 - 20.00	D	500 / 150

8. Launcher. I will launch my model rocket from a stable launching device that provides rigid guidance until the model rocket has reached a speed adequate to ensure a safe flight. To prevent accidental eye injury, I will always place the launcher so that the end of the rod is above eye level or I will cap the end of the launch rod when approaching it. I will cap or disassemble my launch rod when not in use and I will never store it in an upright position. My launcher will have a jet deflector device to prevent the engine exhaust from hitting the ground directly. I will always clear the area around my launch device of brown grass, dry weeds and other easy-to-burn materials.

9. Ignition System. The system I use to launch my model rocket will be remote controlled and electronically operated. It will contain a launching switch that will return to "off" when released. The system will contain a removable safety interlock in series with the launch switch. All persons will remain at least 15 feet (5 meters) from the model rocket when I am igniting model rocket engines totalling 30 Newton-seconds or less of total impulse. I will use only electrical igniters recommended by the engine manufacturer that will ignite model rocket engines within one second of actuation of the launching switch.

10. Launch Safety. I will ensure that people in the launch area are aware of the pending model rocket launch and can see the model rocket's liftoff before I begin my audible five second countdown. I will not launch a model rocket using it as a weapon. If my model rocket suffers a misfire, I will not allow anyone to approach it or the launcher until I have made certain that the safety interlock has been removed or that the battery has been disconnected from the ignition system. I will wait one minute after a misfire before allowing anyone to approach the launcher.

11. Flying conditions. I will launch my model rocket only when the wind is less than 20 miles (30 kilometres) an hour. I will not launch my model rocket so it flies into clouds, near aircraft in flight, or in a manner that is hazardous to people or property.

12. Pre-Launch Test. When conducting research activities with unproved model rocket designs or methods, I will, when possible, determine the reliability of my model rocket by pre launch tests. I will conduct the launching of an unproved design in complete isolation from persons not participating in the actual launching.

13. Launch Angle. My launch device will be pointed within 30 degrees of vertical. I will never use model rocket engines to propel any device horizontally.

14. Recovery Hazards. If a model rocket becomes entangled in a power line or other dangerous place, I will not attempt to retrieve it.

How Model Rockets Work - An Introduction to Model Rockets

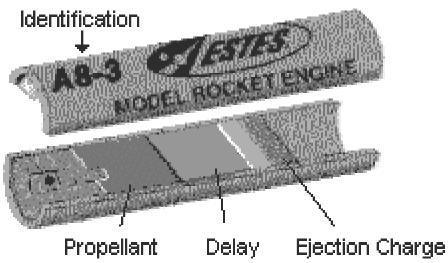
With acknowledgement to Estes Industries

We include here an overview of the standard type of simple model rocket supplied by Estes, and others.

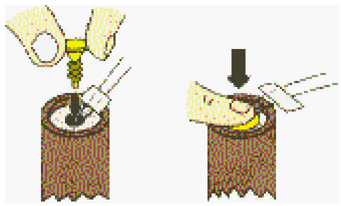
The Rocket

All model rockets have the following parts: (1) One or more body tubes, the long round tube that holds the engine and payload, (2) a nose cone to reduce air resistance, (3) fins to provide stability in flight, (4) an engine to power it, (5) a launch lug, and a (6) a recovery system. The more complex rockets may have several body tubes connected by tube couplers.

Rocket Engine



Igniters



The heart of the rocket is its engine. It contains a propellant for lift-off, tracking smoke for the coasting phase, and an ejection charge to activate the recovery system. The engine is activated through the use of an electrically controlled ignitor. This is an important safety device as it lets the operator be a significant distance away from the rocket when the engine begins to burn.

The Launch Pad

The launch pad provides stability for lift off. It consists of a long launch rod to provide direction. (Shown left is the Estes Porta-Pad; its launch rod is 32 inches long.) and a deflector plate. Both are mounted on a tripod support.

The rocket is placed on the launch pad by sliding the rocket's launch lugs down the launch rod.

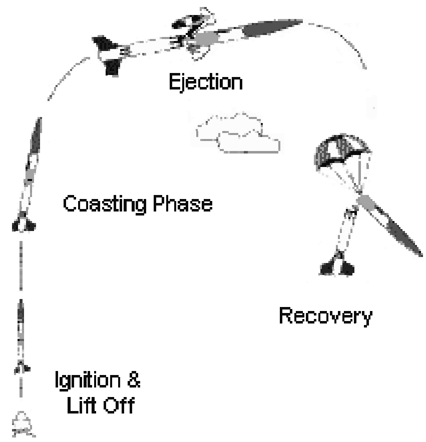
The Launch Controller

The Controller is a simple battery powered switch. A wire runs from the controller to the ignitor placed in the engine. Controllers have a continuity light that comes on to indicate that the circuit is complete and a safety key to prevent the switch from being accidentally pushed.

Launching the Rocket

The completed rocket is taken to the launch site, the ignitor is placed in the engine, and the rocket is placed on the launch pad. The operator moves a safe distance away from the rocket. He alerts spectators and participants that a launch is about to take place. He double checks the controller's continuity light to insure the circuit is OK, then removes the safety interlock key, and counts down to launch.

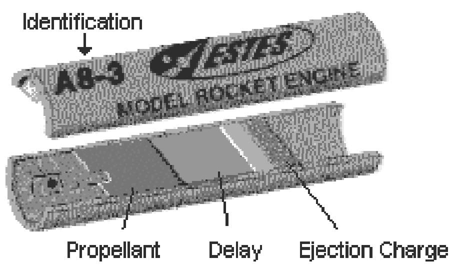
There are several phases to the rocket's flight. The first is the thrust phase during which the impulse section of the engine burns. Once this is exhausted, the coasting phase begins. The engine is still active, but it is burning smoke, permitting you to follow the flight. The rocket is still climbing at this point. Then the ejection charge ignites, which actives the recovery system. This is usually a parachute to permit the slow descent of the rocket, or it can be a streamer so that you can follow its path. The rocket can then be recovered, a new engine installed, and it is ready to be launched again.



Model Rocket Engine Information

A model rocket engine, such as those manufactured by Estes and several other companies, consists of a cardboard casing with a clay nozzle at one end a clay retaining cap at the other. The engine contains three type of charges:

- The **Propellant** provides the power for the model to lift off and climb. When the propellant is exhausted the rocket is travelling with its maximum velocity, and it continues to climb in height.
- During this 'coasting' phase a **Delay charge** is burned which emits smoke to help visually follow the model.
- Finally the **Ejection charge** is ignited. This charge fires in the forward direction up inside the rocket body to eject the parachute, or other recovery system. At this point the forward motion of the rocket is brought to a sudden halt.



The specification of a model rocket engine is denoted in the form of a three-digit identification code. On the above engine the code is: A8-3.

The three digits represent the following:

- **Total Impulse Power.** The letter indicates the range of total impulse of the engine. The total impulse is a measure of the power the engine produces, determined by the mass of propellant it contains.

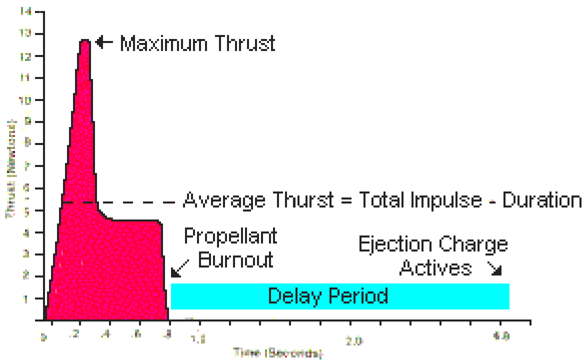
  Total impulse is measure in Newton seconds. One Newton second is the amount of impulse by one Newton of thrust for a duration of one second. For example a "B" type engine has a maximum total impulse rating of five

Newton seconds. All Estes engines have the maximum total impulse permitted for a given size.

Engine Type	Total Impulse (N s)
½A	0.626-1.25
A	1.25-2.5
B	2.5-5.00
C	5.0-10.0
D	10.0-20.0
E*	20.0-40.0

**Note: only engine sizes up to D are available over the counter in the Britain. In the US sizes up to double-G are possible!*

- **Average Thrust.** The first number states the average thrust in Newtons that the engine delivers during the thrust phase. The actual thrust varies, and is shown on the time thrust curve. For a particular engine size (for example a "B" engine), the propellant may be burned quickly, giving high thrust for a short time, or slowly, giving lower thrust for a longer time. A higher average thrust engine is best for heavier models while lower average thrust and longer burn engine is more efficient for lighter models.



Time Thrust Profile for a B6-4 Engine

- **Time Delay.** The second number shows the time delay. This is the number of seconds between the end of the thrust phase (propellant burned) and activation of the ejection charge. The time delay allows the model to coast to its peak altitude before the recovery system is deployed.

Thus the "A8-3" pictured above delivers 2.5 Newton seconds of power at an average thrust of 8N for a duration of approximately 0.3s. There is then a 3s delay before the ejection charge is activated.

Similarly a "B6-4" has 5.0 total Newton seconds of power, but delivers an average thrust of 6N for a duration of approximately 0.8s.There is a four second delay before the ejection charge is activated.

In addition to the engine's 'letter rating', rocket engines are grouped into different physical sizes (of which only 3 sizes are relevant in Britain): mini, standard and large. The table below shows the dimensions of each type of Estes rocket engines:

Engine Type	Length	Diameter	Number per pack
Mini Engines (½A, A)	44 mm	12.7 mm	4
Standard Engines (½A, A, B, C)	70 mm	17.5 mm	3
Large Engines (D)	70 mm	24 mm	3

Estes rocket engine dimensions

Note that a D engine has a larger diameter than a C engine – if you want to swap between these two engine sizes for a particular model you will need to use a cardboard tube insert to accommodate the smaller diameter C engine.

- **Engine Performance & Weight.** Estes Model Rocket Engines have colour coded labels:

  Green labels - single stage rockets.

  Purple labels - for upper stage rockets, but these may also be used to light single stage rockets.

  Red labels - "0" delay engines, for use in booster stage or special projects only. Contain no delay or ejection charge.

If you have a choice of engines for a particular rocket, then you can experiment with the different performance of each. The various trade-offs can be quite subtle, but here are a few general tips:

1. Choose a lower power engine for a first flight, eg. a B engine instead of a C engine. When you have got familiar with the power/weight ratio of your rocket, the wind speed, and the size of your landing area you can use a more powerful engine.
2. To stop a rocket going up too high, choose an engine with a shorter delay time. This is particularly useful if you want to restrict the possible drift distance as the rocket comes back down to the ground.
3. You need a larger power engine if your rocket is either heavy, or large diameter, or both. Don't be tempted to fix a very large engine onto a very light rocket as it will go up like a firework and probably never be seen again!
4. For a given engine letter (eg. a B engine) a smaller average thrust will give a longer burn time. This will tend to make the launch speed slower and arguably more impressive. However if your rocket is too heavy or too wide it may barely get off the ground.

Some guidelines for your choice of engines for your home-made rockets are given in Section 3, the Extension Activities.

Finally, always remember to follow the sensible safety guidelines, such as the Rocket Safety Code produced by the US National Association of Rocketry (NAR) reprinted above.

Rocket Web Links

***Liftoff!* the Official Web Site -** we can be found at www.ph.surrey.ac.uk/liftoff

Here you can download electronic copies of this Teachers' Guide, and find out about the latest developments in the *Liftoff!* programme.

British Model Flying Association (BMFA) - www.bmfa.org

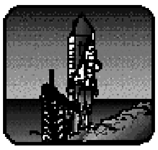
The BMFA is the body delegated by the Royal Aero Club to be responsible for all aspects of model flying in Great Britain. The Association numbers over 27,000 members, with more than 600 affiliated clubs.

US National Association of Rocketry - www.nar.org

The US National Association of Rocketry is the oldest and largest sport rocketry organisation in the world. Since 1957, over 80,000 serious modellers have joined the NAR to take advantage of the fun and excitement of organised rocketry.

NASA TEACHER'S RESOURCE CENTER

ROCKET ACTIVITY



NASA Rocket Classroom Activities –

www.lerc.nasa.gov/WWW/K-12/TRC/Rockets/RocketActivitiesHome.html

Despite the horrible web address, this is an interesting resource from NASA describing a range of simple school experiments related to rocket flight. We have included a couple of the best ones in Section 3.

Model Suppliers

If you want access to a wider range of Estes rocket kits then it is easy to buy direct from the US. Many web sites exist for online model shops selling rockets, and you can normally either place your order by fax or directly over the internet with a credit card if you wish.

Note that due to safety restrictions you cannot buy model rocket *engines* direct from the US. You will always need to get your engines from a supplier in this country.

Here are just a couple of sites from a large selection:

Rockets-2-Go - www.rockets-2-go.com

We have very successfully bought Estes 'Big Daddy' rockets from this company. You will pay directly in US dollars with a credit card, and save significantly on the price of each model compared to UK prices. The cheaper shipping option takes about 6 weeks, but if you need airfreight to get them in a hurry you will pay more.

Rocket Vision – www.rocketvision.com

Another US-based supplier and manufacturer of model rockets, as an alternative to Estes. Their site looks very comprehensive and allows on-line ordering. However we have never used them and you would have to check whether you can obtain suitable engines in this country.

Ripmax – www.ripmax.com

Ripmax are the sole importer of Estes model rockets into Britain. They have a large website covering all aspects of model flight.

Enthusiasts Web Sites

There are a large number of web sites set up by amateur model rocket clubs, particularly in the US. Many are catering for the more sophisticated market with much higher-powered rockets than are obtainable in this country. Keep in mind that only engines up to D size are available over the counter in Britain.

The enthusiasts' sites are too numerous to list here – try using a web search engine to hunt for a few. However an interesting starting point is the Rocketry WebRing:

Rocket WebRing - www.rickyrocket.com/webring.html

This is a system of linked web sites of amateur rocket enthusiasts – joined together via links into a virtual web 'ring'. Enter the ring via one site and then gain access to them all.

Southern England Rocket Fliers - www.serfs.co.uk/

SERFs are one of several groups of rocket enthusiasts in Britain that are on the web, and they are reasonably local to us in Guildford. These guys are serious rocket flyers – their web site contains many interesting details about launching large rockets in this country.

Section 3: Extension Activities

As extensions to the *Liftoff!* programme, students can be encouraged to make their own simple rockets to their own design. To get you started we enclose here a selection of designs and ideas, graded in level of difficulty. We also show you how to make an Altitude Tracker to estimate the height of your rocket.

The suggestions for home-made rockets are grouped into two sections – the first group consist of simple ideas for model rockets that do not use combustible engines. Instead they are powered by either water, baking powder or air, and so are ideal for use within a school environment.

The second group of rockets consists of plans for cardboard and balsa rockets that are designed to be powered by a normal model rocket engine. These would be suitable for teachers to build with their more able students, possible as part of a Science Club or similar activity.

Commercial Water and Air Rockets
Where to buy some simple water powered rocket kits

Build your own Altitude Tracker
Estimate the height of your rocket with this easy to build tracker

Build your own Water and Air Rockets
Water and Vinegar powered rockets
Balloon Staging

Model rockets with real engines
The Paper Tiger
The Bog-Roll Rocket
The Speed Queen

Disclaimer: We offer these suggestions for model rocket plans for teachers and group leaders to try out in their own groups. It is the responsibility of the individuals concerned to assess the potential risks involved in these activities and the University of Surrey cannot be held responsible in the event of any injury.

We do not claim to have tested all of these designs ourselves!

Commercial Water and Air Rockets

The following two rockets are commercially available from good model and kite shops, and form an excellent introduction to simple model rockets:

1. The STOMP air-powered rocket.

STOMP is a fantastic air-powered rocket made in the US but available now in this country. Simply stamp on the air pad and the small plastic rocket flies for up to 400 feet. Very impressive, for indoor or outdoor use!

UK distributors: TKC Sales and Marketing
20 Wansdyke Business Centre
Oldfield Lane, Bath BA2 3LY
Tel: 01225 466661
Guide price: £15

2. The 'Rokit' water powered rocket

Use this simple kit with a bicycle pump (not included) to send your old coke and lemonade bottles into orbit. Excellent for the beach or a large outdoor space, the impressive water jet really makes the bottle rocket fly.

This one's made in Britain, and sales information can be obtained from:

Hinterland Ltd
Stanstead Road
Hertford SG13 7HY
Guide Price: £10

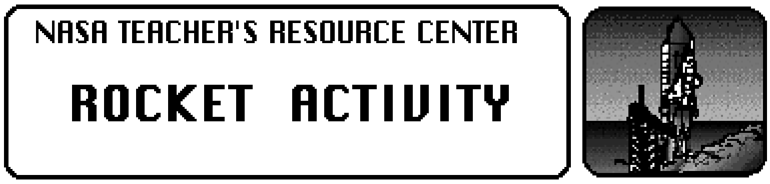
Many home-made variations are possible based on this idea of water powered rockets – large plastic soft-drinks bottles can be made to fly a long way using a bike pump or car tyre pump connected via a rubber bung. You will need to add stabilising fins along the sides of the bottle and possible some ballast to achieve a more level flight. Filling the bottle about half-full with water is usually about right.

Water and Vinegar powered rockets

Here is a very simple design, using a 35mm film canister as the 'rocket'. Make sure the rocket is used outdoors, since some mess is produced by the 'engine'!

1. Take a toilet tube and mark a spot 25mm from the end. Cut 5 slits up to that point and fold the slits out – these form the base of the rocket launcher. Take a paper or plastic plate and tape down the toilet tube with the legs bent out 'flat'. Decorate your rocket launcher as required.
2. Take your 35mm film canister – this will be the rocket. The clear ones work best in which the lid press fits *inside* the canister.
3. **For a water engine:** fill the canister about 1/3 full of water, then drop in about ¼ of an Alka-Seltzer (or equivalent) tablet. Put the lid on tightly and quickly place *lid down* inside the launcher tube.
4. **For a Vinegar engine:** place a tea spoon of vinegar inside the canister. Twist some tissue around a small amount of baking powder, then fit the lid onto the canister such that the edge of the tissue is caught under the lid. This will prevent the tissue paper containing the baking powder from falling into the vinegar. When the lid is on, quickly drop the canister *lid down* into the launcher tube – keeping your face away from the tube. The tissue paper slows down the production of gas by preventing the vinegar immediately reaching the baking powder.
5. Depending on which type of 'engine' is used the canister will launch quickly or slowly. Stand well back from launcher tube whilst waiting for the launch. With the vinegar engine launch may be very quick, and care will be needed. Experiment with the amount of the various ingredients to achieve the best propulsion effect.

'Balloon Staging' is a resource from the NASA Teacher's Resource Center - www.lerc.nasa.gov/WWW/K-12/



Balloon Staging

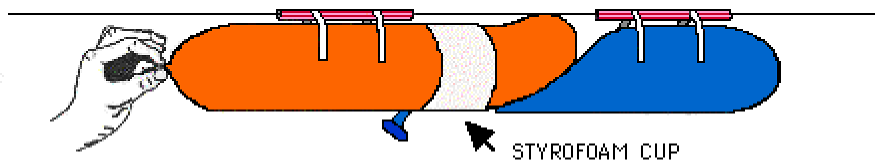
TOPIC: Rocket staging

OBJECTIVE: To demonstrate how several stages of of a rocket can operate in steps to propel a rocket.

DESCRIPTION: Two inflated balloons are joined in a way simulate a multistage rocket launch as they slide along a fishing line on the thrust produced by escaping air.

CONTRIBUTED BY: Gregory Vogt, OSU

EDITED BY: Roger Storm, NASA Glenn Research Center



MATERIALS and TOOLS:

- 2 long party balloons (round balloon will not work)
- Nylon monofilament fishing line (any weight)
- 2 Plastic straws (milkshake size, non-bendable)
- Styrofoam cup
- Masking tape
- Scissors

PROCEDURE:

1. Thread the fishing line through the two straws. Stretch the fishing line snugly across a room and secure its ends. Make sure the line is just high enough for people to pass safely underneath.
2. Cut the cup in half so that the lip of the cup forms a continuous ring.
3. Loosen the balloons by preinflating them. Inflate the first balloon about 3/4 full of air and squeeze its nozzle tight. Pull the nozzle through the ring. While someone assists you, inflate the second balloon. The front end of the second balloon should extend through the ring a short distance. As the

second balloon inflates it will press against the nozzle of the first balloon and take over the job of holding it shut. it may take a bit of practice to achieve this.

4. Take the balloons to one end of the fishing line and tape each balloon to a straw. The balloons should be pointed along the length of the fishing line.
5. If you wish, do a rocket countdown and release the second balloon you inflated. The escaping gas will propel both balloons along the fishing line. When the first balloon released runs out of air, it will release the other balloon to continue the trip.

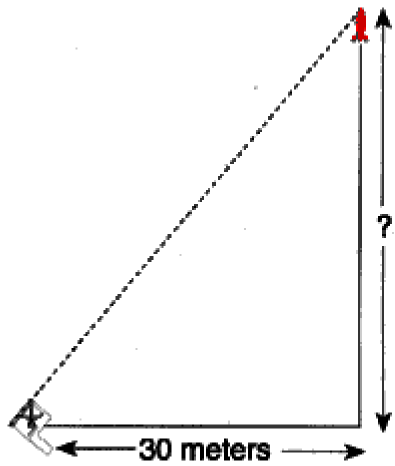
Conclusion

Travel into outer space takes enormous amounts of energy. Much of that energy is used to lift rocket propellants that will be used for later phases of the rocket's flight. To eliminate the technological problems and cost of building giant one-piece rockets to reach outer space, NASA, as well as all other space fairing nations of the world have chosen to use a rocket technique that was invented by 16th-century fireworks maker Johann Schmidlap. To reach higher altitudes with his aerial displays, Schmidlap attached smaller rockets to the top of larger ones. When the larger rockets were exhausted, the smaller rocket climbed to even higher altitudes. Schmidlap called his invention a "step rocket."

NASA utilizes Schmidlap's invention through "multi staging." A large first stage rocket carries the smaller upper stages for the first minute or two of flight. When the first stage is exhausted, it is released to return to the Earth. In doing so, the upper stages are much more efficient and are able to reach much higher attitudes than they would have been able to do simply because they do not have to carry the expired engines and empty propellant tanks that make up the first stage. Space rockets are often designed with three or four stages that each fire in turn to send a payload into orbit.

'Altitude Tracking' is a resource from the NASA Teacher's Resource Center - www.lerc.nasa.gov/WWW/K-12/

Altitude Tracking



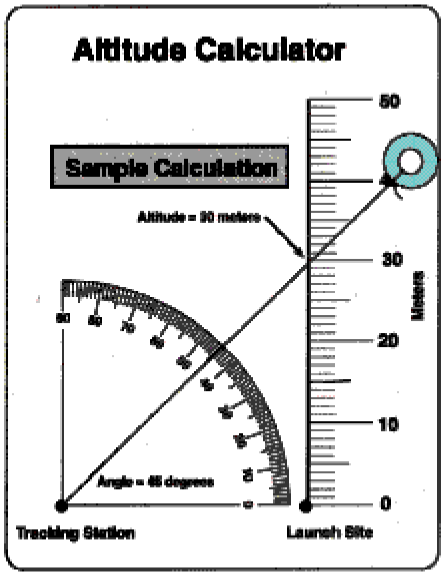
TOPIC: Altitude tracking

OBJECTIVE: To use geometry to find the altitude of model rockets

DESCRIPTION: In this activity, students construct simple altitude tracking devices that are used to measure the angle a rocket reaches above ground, as seen from a remote tracking site. The angle is drawn on a graph and the altitude is read from a scale.

EDITED BY: Roger Storm, NASA Glenn Research Center

Materials and Tools:



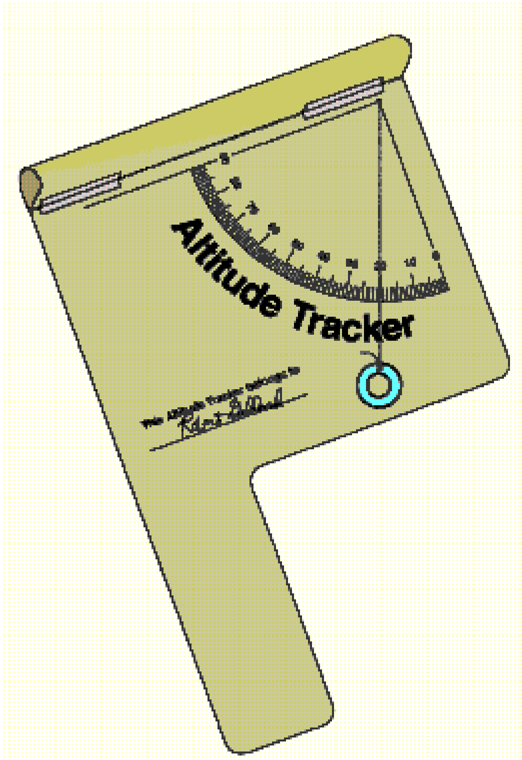
- Altitude Tracker patterns
- Thread or lightweight string
- Scrap file folders or poster board
- Glue
- Cellophane tape
- Small washer
- Scissors
- Meter stick or steel tape measure (metric)

Procedure: Constructing the Altitude Tracker

1. Copy the Altitude Tracker pattern on white or coloured paper. Cut out the outline and glue the pattern to a piece of scrap file folder or poster board. Do not glue the hatched area to the folder or poster board.

   A full size template of the tracker is provided at the end of this exercise.

2. Cut off the excess file folder or poster board.



3. Roll the hatched area at the top of the pattern into a tube and tape the upper edge along the dashed line at the lower edge. Shape the paper into a sighting tube.
4. Punch a tiny hole in the apex of the protractor quadrant.
5. Cut out the Altitude Calculator and punch a hole at the apex of its protractor quadrant. Glue the Altitude Calculator to the back of the tracker so that the two holes line up.
6. Slip a thread or lightweight string through the holes. Knot the thread or string on the calculator side.
7. Hang a small washer from the other end of the thread as shown in the diagram of the completed tracker.

Procedure: Using the Altitude Tracker

1. Select a clear spot for launching water or bottle rockets.
2. Measure a tracking station location exactly 30 meters away from the launch site.
3. As a rocket is launched, the person doing the tracking will follow the flight with the sighting tube on the tracker. The tracker should be held like a pistol. Continue to aim the tracker at the highest point the rocket reached in the sky. Have a second student read the angle the thread or string makes with the quadrant protractor.

Procedure: Determining the Altitude

1. Use the Altitude Calculator to determine the height the rocket reached. To do so, pull the thread or string through the hole in the tracker to the Altitude Calculator side until the washer stops it. Lay the string across the protractor quadrant and stretch it so that it crosses the vertical scale. (See sample calculation.)
2. Read the altitude of the rocket. The altitude is the intersection point of the string and the vertical scale to that number. Add the height of the person holding the tracker to determine the altitude the rocket reached.

Discussion:

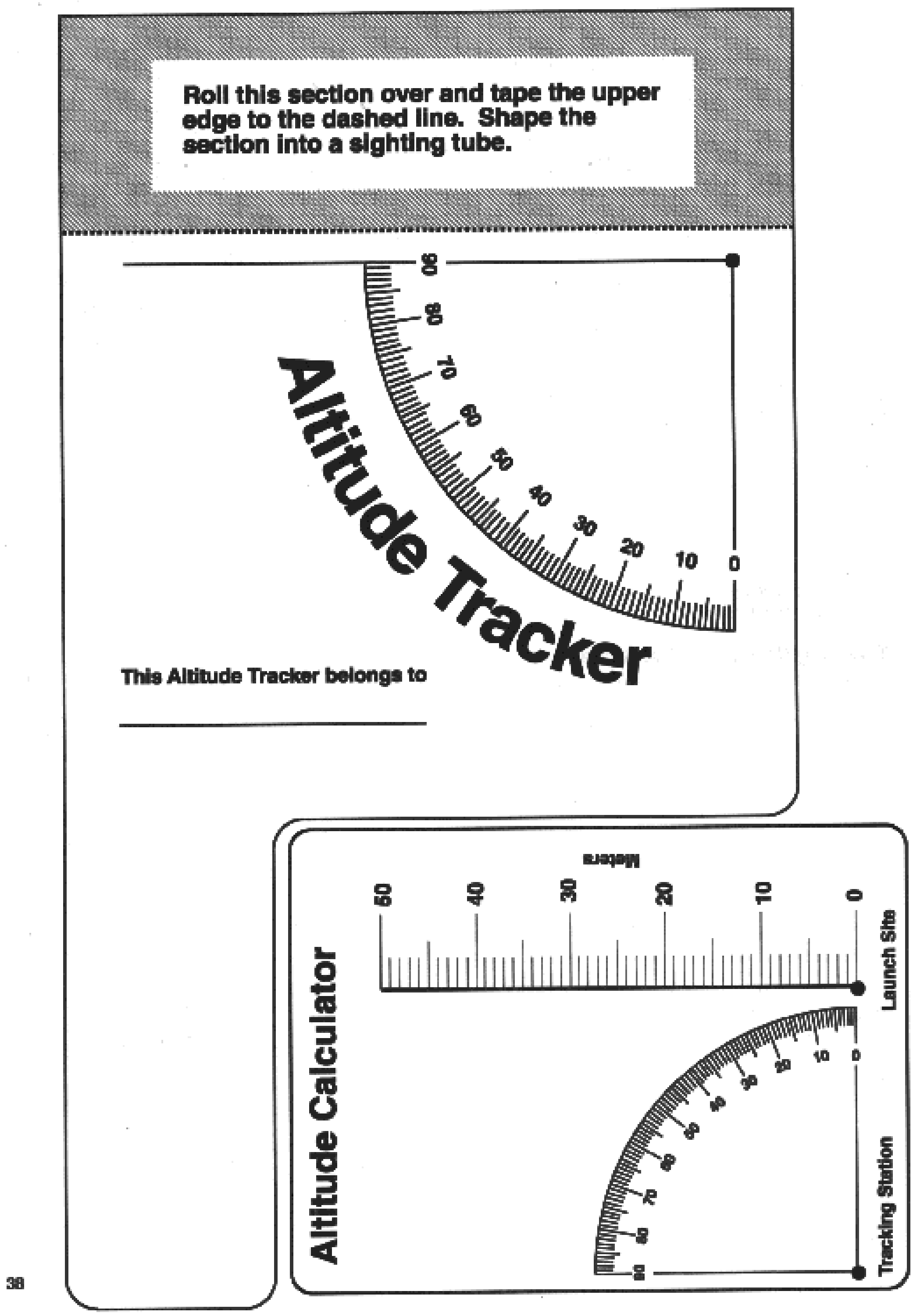
This activity makes use of simple trigonometry to determine the altitude a rocket reaches in flight. The basic assumption of the activity is that the rocket travels straight up from the launch site. If the rocket flies away at an angle other than 90 degrees, the accuracy of the procedure is diminished. For example, if the rocket flies toward a tracking station as it climbs upward, the altitude calculation will yield an answer higher than the actual altitude reached. On the other hand, if the rocket flies away from the station, the altitude measurement will be lower than the actual value. Tracking accuracy can be increased, however, by using more than one tracking station to measure the rocket's altitude. Position a second or third station in different directions from the first station. Average the altitude measurements.

Additional Notes for Teachers

This activity is simple enough so each student can construct his or her own Altitude Tracker. Permit each student to try taking measurements while other students launch the rockets. To assure accuracy in taking measurements, practice measuring the height of known objects such as a building or a flagpole. It may also be necessary for a few practice launches to familiarise each student with using the tracker in actual flight conditions.

Why should the height of the person holding the tracker be added to the measurement of the rocket's altitude?

For more advanced students there are many possibilities for more sophisticated rocket tracking measurements. These activities include two station tracking with altitude and compass direction measurement and trigonometric functions.



Full-size template for the Altitude Tracker

Home-made model rockets with real engines

It's surprisingly easy to make your own model rockets with real engines. Some of the designs listed in the next few pages use genuine scrap parts such as cardboard tubes and paper. Others need some level of pre-fabricated model rocket parts. You can buy a full range of Estes model rocket components from any good model shop stocking Estes products, or from Ripmax (see contact details in Section 1).

You may also have to contact Ripmax to buy your engines, since local model shops tend to keep small and variable stocks.

Remember that if you have never flown an Estes Rocket before, you will need an Estes Starter Pack (cost about £15) that contains the launch pad and electronic ignitor, as well as a pre-assembled plastic starter rocket.

If you want to buy one of the many Estes Rockets that is not imported into the UK, then try buying direct from the US over the Internet. Again, contact details for several websites are given in section 1. You will pay directly in US dollars with a credit card, and save significantly on the price of each model compared to UK prices. The cheaper shipping option takes about 6 weeks, but if you need airfreight to get them in a hurry you will can pay more. Note that you cannot buy engines direct from the US due to explosives legislation.

You should take care to select the appropriate size of engine for your home-made rocket, based on its mass and diameter. The following table gives some guidelines:

Engine Type suggested for first flight	Rocket Mass
1/2A	<30g
A	30-50g
B	50 - 120g
C	100 – 150g
D	120 – 180g

It is recommended to perform a simple non-powered stability test on your home-made rocket before fitting an engine. This can be achieved by fixing string or cord to either end of the rocket and whirling around carefully around your head. Any misalignment of the fins etc. will be felt as vibration during the rocket's motion.

You should always carry out the first launch of a new rocket using a low powered engine – just in case it doesn't fly as you hope.

The Paper Tiger

Paper Tiger

by Peter Galindez

A Low-Cost Tumble Recovery Rocket for Introducing Class Groups to Model Rocketry

Mom and Dad may have had their paper airplanes, but the space age generation has its own thing: the "Paper Tiger" model rocket.

It's an easy-to-build, low-cost (or no cost) bird that can be a swell hobby or science class project. She's matchless in the durability and versatility department. After a 200-foot swan dive into the pavement, she will fly again and again, even though her appearance would make the "R&D" boys in Penrose, Colorado shudder in disbelief. And she grabs altitude with any engine from 1/2A6-2 on up.

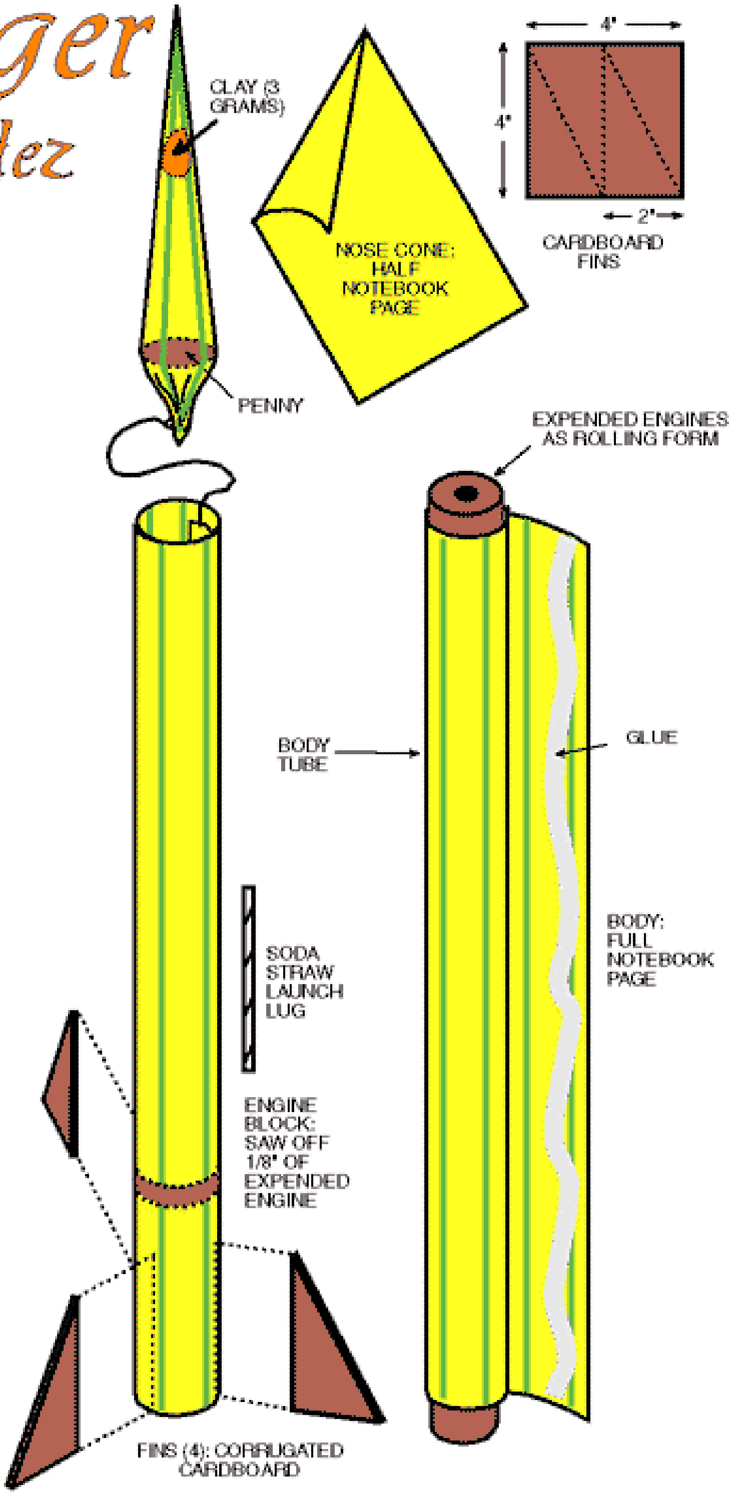
Aerodynamically (though not aesthetically) she is designed to fly. Her center of gravity is well ahead of her center of pressure, with her streamlining left to the "Model T" school of design.

Construction is simplicity in itself, and may be accomplished within two hours.

So grab your cardboard, notebook paper, string, tape, scissors, Elmer's glue, clay, and penny (don't forget the clay and the penny—they put your CG where it needs to be for stability) and get going!

With reasonable care in construction, you may be surprised by the startling performance of that sky streak known as the "Paper Tiger!"

Peter Galindez was a science teacher at Suffern High School, NY, who used this design to teach hundreds of novices to fly.

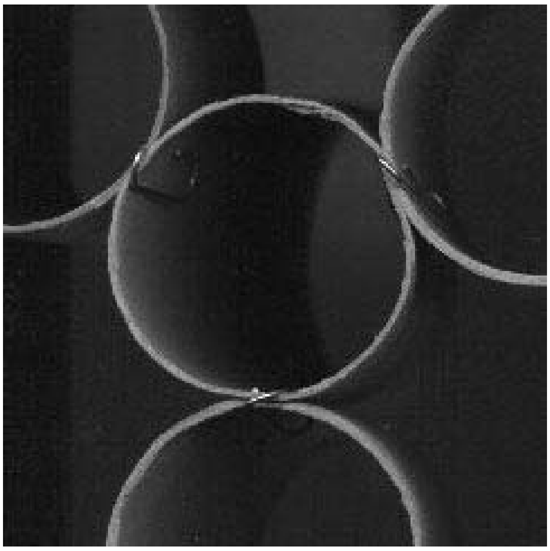


The Bog-Roll Rocket

With acknowledgement to SERFS, the South of England Rocket Flyers Club.

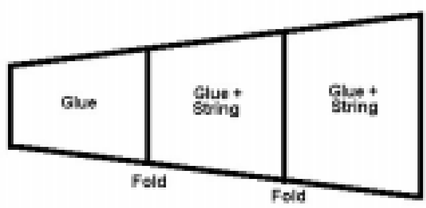
This is an ingenious rocket, using toilet tubes as novel stabilising fins.

1. **Body Tube**. Take one kitchen paper towel inner tube.
2. **Fin Tubes**. Take two toilet roll inner tubes. Cut the toilet tubes in half around the centre of the tube.



3. Place the 3 fin tubes around the bottom of the body tube so that they look equal and pin them with paper clips.

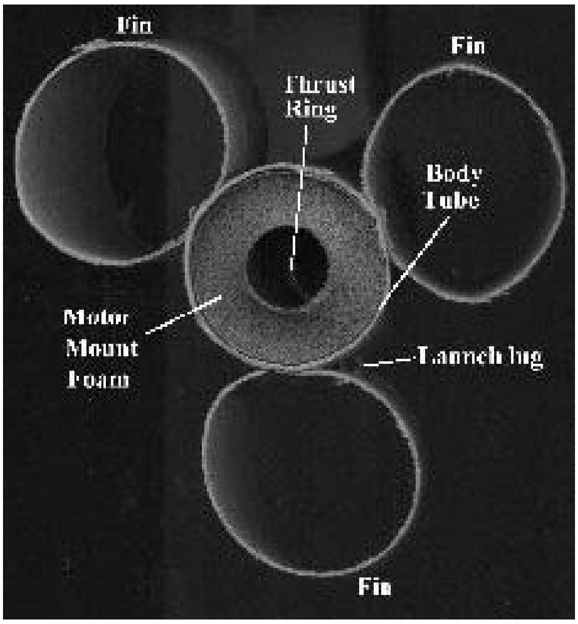
4. Run some glue between each side of the fins and body tube. Flatten the fin slightly so that it squashes the glue a little. This helps it run deep into the gap.
5. **Nose Cones**. Cut a length of string or elastic 250mm long. Take a plastic Easter egg and separate the two halves. Place the string through the drilled hole in the bottom. Tie a couple of knots. Then pull the string to make sure it does not pull through the hole. Put the egg back together.



6. **Shock cord mounting**. Cut out the cord mount from the template above. Fold the paper into 3 along the lines. Apply a blob of glue in each of the sections. Lay one end of a piece of the string, in the middle and larger section glue blobs. Fold the small bottom section over on top

of the string in the middle section and fold this over the larger section. Put a paper clip on it. Leave it to dry. When dry put glue on **one** side of the paper and place it inside the body tube about finger length from the top.

7. **The Motor mount.** Cut a length of pipe lagging foam **60mm** in length. Place a little ring of glue in one end of the motor foam. Take the Thrust Ring (10mm of old motor casing) and push it into the end of the motor foam with the glue.

8. 

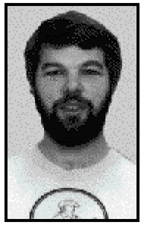
9. Apply a ring of glue inside the body tube, about **30mm** in from the bottom. Now insert the motor mount. It should compress slightly as it fits. Push it in so that the bottom of the motor mount is level with the bottom of the body tube.

10. **Launch Lug**. Cut it to about **40mm** in length. Place a blob of glue in the gap between a fin tube. Lay the straw into the glue. Apply more glue over the straw so that it holds it all around. Ensure the straw is aligned straight with the body tube.

The Speed Queen. A serious model rocket for the enthusiast. The parts, or similar, are obtainable from an Estes stockist.

SPORT PLAN, JUNE 1990

BUILD THE SPEED QUEEN



by Tony Vincent

Those of you who lived through the Kennedy Years may recognize the name *Speed Queen* as a brand of a washing machine. In fact, this model is named the *Speed Queen* precisely because Diana Ryan says it reminds her of a washing machine agitator.

Glue the two BT-20 body tubes together using the JT-20C coupler. Make sure they are straight.

Glue the EB-20A engine block 2⅝" into the 4" body tube end. This will leave ¾" of the engine exposed.

Cut out three of each fin section, and sand the edges square. Glue sections 1 and 2 together as shown (but not section 3, which goes outside the tail ring). Finish the fins with sanding sealer before assembling further.

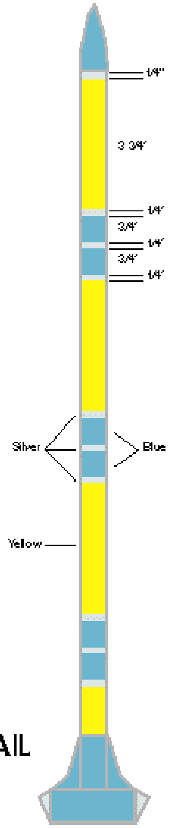
Mark the tube for the fins and launch lugs. Glue the fin assemblies flush with the end of the tube. Test-fit the BT-80 tail ring over the fins, sanding as necessary for a good fit. Glue it in place, aligning the top of the ring flush with the top of the fins.

Glue section 3 of the fins to the outside of the ring in line with the main fins. Glue the launch lugs 1" and 8" from the aft end of the tube. Fillet all fin, lug, and tube joints.

Install a standard Estes shock-cord mount. Glue the screw eye into the nose cone and tie the shock cord to it. A small or medium size streamer is sufficient to recover this model.

The original *Speed Queen* is painted yellow, sky blue, and silver, according to the paint pattern shown at right.

Fly with A through C engines with medium to long delays. And no fair pouring Downy in the nozzles.



PAINT PATTERN DETAIL

SPEED QUEEN

by Tony Vincent

PARTS LIST		
1	18"	BT-20
1	4"	BT-20
1	1"	BT-80
1		EB-20A
1		JT-20C
1		BNC-20B
1		Screw Eye
1	12"	⅛" Shock Cord
2	¾"	⅛" Launch Lugs
1	12"	Streamer
	3/32"	Balsa Fin Stock