MODEL ROCKETRY IN SCIENCE FAIRS

By Trip Barber, NAR #4322

Model rocketry is an ideal tool for use with school science projects. It permits the student to conduct many repetitions of a flight experiment at a reasonable cost, and in the process of doing the experiment the student not only learns but also gets to do something that is a lot of fun—fly rockets! If the student understands the experimental method and uses rockets the right way for the right topics, a rocketry-based project can be an impressive entry in the Engineering or Physics category of a science fair at any grade level. This guide provides some specific guidelines and advice for using model rocketry in science fairs.

SAFETY

Model rockets involve the use of small, high-energy commercially made rocket motors in flight vehicles that can reach speeds of several hundred miles per hour. The National Association of Rocketry (NAR) has developed a simple, commonsense 14-rule Safety Code for those who participate in this hobby. If this code is followed, model rocketry is totally safe—far safer than almost any other outdoor activity. The first step in any science fair project involving rocketry should be to read and follow this code. It can be downloaded from the NAR website at www.nar.org. It is also included in virtually all kits and motors sold in the U.S..

RESOURCES

The best single resource on applying rocketry in science fair projects is the book 69 Simple Science Fair Projects with Model Rockets, by Tim Van Milligan. This book is available for about $11.95 from his company, Apogee Components, at www.ApogeeRockets.com. This book has both procedural information and, as the title suggests, ideas for projects. Estes Industries at their educator website (see address below) also offers the more basic and shorter publication Estes Projects in Model Rocketry. Although there are a number of good books on how to do science fair projects in general, there are no other publications that includes specific rocketry procedures and project ideas.

There are many excellent websites with general procedural guidelines on how to do a science fair project, and on proper application of the scientific method and experimental technique in science projects. This basic information is not specific to rocketry and will not be repeated in this guide. Three of the best of these science fair sites are:

Kennedy Space Center @ http://atlas.ksc.nasa.gov/education/general/scifair.html
Discovery Channel School @ http://school.discovery.com.sciencefaircentral
Mankato State University Cyber Fair @ http://www.isd77.k12.mn.us/resources/cf

There is a huge variety of sources for technical material on model rocketry, to help you understand and explain how and why your rocket works. The best sources for reports on specific topics are the NAR (through its Technical Services, www.nar.org/NARTS, and the two model rocket manufacturers that currently offer significant educator resources, Estes and Apogee. The Handbook of Model Rocketry, by G. Harry Stine (published by John Wiley & Sons and available through NAR Technical Services or many booksellers) is the best single-volume reference book on all aspects of rocketry. Another good general book is Van Milligan's Model Rocket Design and Construction (from Apogee Components). There are also numerous on-line resources for rocketry information, such as Rocketry Online or the rocketry "Frequently-Asked Questions (FAQ)" website.

National Association of Rocketry: www.nar.org
Estes Industries: www.esteseducator.com
Apogee Components: www.ApogeeRockets.com
Rocketry Online: www.rocketryonline.com
FAQ: http://sunsite.unc.edu/pub/archives/rec.models.rockets/RMRFAQ

GENERAL GUIDELINES FOR ROCKETRY PROJECTS

What kinds of things can you do in a science fair with rockets? First, it depends on whether you are using rocketry for a lower-grade-level "demonstration" type project to explain how something works, or for an upper-grade-level "experimentation" type project with a hypothesis that you are testing.

- Demonstration project. Rocketry is a great tool for demonstrating the laws of physics, particularly Newton's First Law of action-reaction. That's what the flight of a rocket is all about. You can also do simple demonstrations of how a rocket works, why it needs fins to be stable in flight, how a parachute or glider works, or how a rocket motor works. The manufacturers and other technical references listed above have a number of good, well-illustrated publications that explain all these things.

- Experimentation project. There are two characteristics of a rocket's flight that you can measure with some precision and use for data to test a very wide range of hypotheses: maximum altitude and total flight duration. Almost any hypothesis you can develop concerning the design of a rocket or its recovery system can be evaluated in considerable detail using one or both of these two characteristics. You can also use a pass-fail test on certain hypotheses: the rocket was or was not stable; or the rocket or its scientific payload did or did not work as intended.

Before you embark on an experimentation-type project using sport rockets, you need to understand how a rocket works, how to prep and fly a rocket, and the basic physics of rocket flight in the atmosphere. The technical references will explain all this to you. If you do not understand this material, you will have a hard time designing good, valid experiments that test only one variable and that produce repeatable results.

There are also a few lessons-learned and rules of thumb about how to do experimentation with rockets that you need to know.

- Plan to do at least three flights of identical rockets with identical engines for each variable that you want to test. There is a lot of "scatter" in the data from rocket-based experiments, and you will get much better results if you use the average of three or more flights for a data point rather than a single flight. This scatter is the result of a combination of experimental error (such as in measuring altitude), weather-based variations (such as in measuring parachute flight duration), and/or slight differences in the construction of the rocket or the motor. If you understand statistics, having multiple data averaged into a single point gives you the opportunity to impress the judges with an analysis of standard deviations and confidence intervals in your data.

- Measuring a rocket's maximum altitude accurately is not easy, but is generally the best way to show conclusively how differences in rocket characteristics affect performance. Altitude measurement should be done using data from at least two trackers who look at the flight from different directions but about the same distance, and who communicate by radio to make their measurements at the same moment in the rocket's trajectory. This is generally either at the exact highest point or "apogee" or (this is easier) at the moment of parachute ejection. Using the more complex tripod-mounted trackers that measure both horizontal "azimuth" angle as well as vertical "elevation" angle gives far more accurate results than simple hand-held elevation-only trackers.

- Measuring a rocket's flight duration is fairly easy, but the data is generally only useful for demonstrating differences in the performance of recovery systems (such as parachutes of various sizes) rather than the rocket. Because wind and thermal lift can have a significant and unpredictable effect on duration, you need to either do several flight tests and use averaged values for each duration data point, or you need to do all your tests in absolutely identical weather conditions. It is best to use two people with stopwatches to collect each duration data point, in case one loses sight of the model or has a stopwatch malfunction. If your hypothesis has to do with measuring the performance of recovery systems, you will get less scatter in the data if you can do "drop tests" of the rocket and recovery system from a roof or tower 30 feet or more in the air, rather than flight tests.

- Make sure that you vary only one variable between flights. The height a rocket reaches depends on the engine type and delay time; the smoothness of the surface finish on the rocket; the weight of the rocket; and the shape/size/alignment of the rocket and all its parts (fins, launch lug, nose, etc.). How long it stays up depends on how high it goes, plus on the type and size of the recovery system, the weather conditions, and whether the recovery device deploys fully and properly. If your hypothesis is that rockets with one shape of nose go higher than with another shape, for example, make sure the rockets you test are identical in design, liftoff weight, and surface finish and fly them in the same weather conditions off the same launcher. Make sure that the nose cone difference is the only difference. And use identical motors (preferably from the same pack or with the same date-of-manufacture code on the casing) in all your tests of the two different rockets.

THINGS NOT TO DO WITH ROCKETRY PROJECTS

- Do not try to make your own rocket motors. This is a Safety Code violation, but more importantly it is dangerous to the point where you have a better than 50-50 chance of seriously injuring or killing yourself or others by even trying to do it. And the resulting motors will be unreliable and highly variable in performance even if they do not blow up. Leave this to professionals who have the training and safety equipment to do it right. Buy and use commercially pre-made motors, they are rigorously tested by the NAR for safety and repeatability.

- Do not fly live warm-blooded animals in your rocket. This is a Safety Code violation, and experiments on animals are prohibited by the rules of most science fairs.

- Do not launch your rockets with fuses. Fuses are unpredictable, and electrical ignition from a safe distance (15 feet or more) is required by the Safety Code. Electrical ignition keeps you in complete control of when the motor ignites—just unplug the battery and you are guaranteed that the rocket will not launch when you do not want it to or when someone is near it.

- Do not assume that you will be able to collect all your data with one rocket on one day of flying, and do not wait until the last minute to do the flying. Rockets sometimes break when they land and need repair back in a workshop, or land in trees and cannot be recovered. Launchers sometimes malfunction. Bad weather (especially high winds) can unexpectedly "scrub" a day of flying or can lead to lots of variation in results so that you end up needing more flights than you planned.

- Do not fail to get permission to use the site (field) where you fly. Model rocketry is legal in every state in the U.S., although a few local jurisdictions may have ordinances restricting it. But you still need the landowner's permission to be on and use his property, even for a legal activity. Membership in the NAR, with its associated insurance, is a valuable tool in persuading landowners (including schools) that you are participating in a safe, recognized activity.

- Do not include live rocket motors in your science fair display. These motors are generally classified as a "hazardous material" and most science fairs prohibit such materials from use in exhibits. Burned-out casings are normally OK for display.

POTENTIAL PROJECT TOPICS

Here is a short list of suggested science fair project topics that can probably be done with some success at the high school level using model rocketry. See Van Milligan's book for a longer list, including more complex projects.

- Predicted rocket altitude vs actual altitude achieved. How good are your theoretical predictions vs tracked altitude, what are the factors that go into making an accurate prediction?

- Rocket fin size and location vs stability. How big must fins be to make a rocket stable, and why? What difference does it make where the fins are located, and why?

- Effects of spin on rocket performance. What change occurs in the tracked height that a rocket reaches or the straightness of its boost if the fins are placed at a slight angle so that the rocket spins in flight, compared to an identical rocket whose fins are not angled?

- Parachute shape and size vs performance. Which performs better, a round parachute with many shroud lines or a polygon shape of the same area with only a few shroud lines? How about a round chute with a spill hole in the middle vs a slightly smaller round chute with no spill hole and thus the same total chute area?

- Streamer shape and size vs performance. Fly the same rocket design with a series of streamers of different lengths and widths but the same total area. Or use a series of streamers of identical size and shape but different materials. Which stays up longest and why?

- Rocket weight vs altitude. How much difference does the weight of a rocket (with variable weights in its payload compartment) make in how high it goes with a given engine?

- Rocket engine average thrust vs altitude. What difference does it make in tracked altitude performance if the same rocket is flown with two engines of very different average thrust levels (like the Estes A3 or A8) but the same total impulse and liftoff weight?

- Rocket surface finish or shape vs altitude performance. What difference does a smooth surface finish vs a coarse one make to the drag of the rocket, and thus to its altitude performance? Or compare the effect of nose cones of different shapes, or of identical fins with and without airfoil streamlining.

- Multi-staging vs single staging. Which goes higher, a two-stage design with a B motor in each stage, or a single-stage model with a C motor having the same total impulse as the combined total of the two B motors?

- Aerial mapping by photo interpretation of images from a rocket-borne camera.

- Building and flying a radio transmitter that sends roll rate (or altitude, or air temperature) back from a rocket in flight.

- Design and build an electrical launching system for rockets, perhaps with special features such as igniter continuity check, automatic countdown, or capacitive discharge for igniting clusters.