UK Aerospace Youth Rocketry Challenge 2008 Team Handbook

28th August 2007

HANDBOOK

Section 1. Introduction.

Section 2. Getting Started

Section 3. Rocket Design

Section 4. Rocket Construction

Section 5 Rocket Flying

Section 6 Qualifying and Practice Flights

Section 7. Resources

Appendix 1. Typical team Costs

Appendix 2. Perfectflite Maximum Altitude Altimeter

Appendix 3. Civil Aviation Authority NOTAM Procedures

Appendix 4. UKRA Model Rocketry Handout

Section 1. INTRODUCTION

The United Kingdom Aerospace Youth Rocketry Challenge (UKAYRoC) provides secondary school students a realistic experience in designing a flying aerospace vehicle that meets a specified set of mission and performance requirements. Students work together in teams the same way aerospace engineers do. It is not intended to be easy, but it is well within the capabilities of secondary school students with a good background in science and math and some craftsmanship skills.


The winning rocket from 2007

The purpose of the 2008 Challenge is to design and build a safe and stable model rocket flight vehicle and use it to lift a fragile payload (two raw hen's eggs) to an altitude of exactly 750 feet and also for a total flight duration score of exactly 45 seconds, then return this payload safely and undamaged. Why feet and not meters? By international convention all air users measure altitude in feet.

The detailed rules for the challenge can be downloaded from the website www.ukayroc.org.uk. It is worth taking some time to study these rules.

The winner will be the team whose rocket and egg payload comes closest to exactly 750 feet altitude and 45 seconds flight duration score in a safe and stable flight, and returns the egg undamaged. The 20 finalists will be selected by a process of independently witnessed qualification flights, and they will compete for the grand prize at a "fly-off" hosted in Charterhouse School on Friday 28th March 2008. Teams that reach the fly-off will also be required to present a static display showing how they designed and built their rocket. A prize will be awarded for the best static display.

This Team Handbook provides some guidelines on how to approach the process of rocket design and flight. It also provides additional sources of information on general model rocket design, construction, flying and safety. It is not a "cookbook"; no completed design is provided as an example. The challenges and the learning for each team come from developing and testing your own completely original design.

Good luck!

Section 2. GETTING STARTED

Teams should begin the Challenge by becoming familiar with the basics of model rocketry. Those who have no experience with how these models are built and flown should begin by reading G. Harry Stine's Handbook of Model Rocketry (available from Amazon) and by purchasing, building, and flying a basic model rocket kit, available from many model shops or the vendors listed in Section 7, "Resources".

UKRA has a produced short course for learning the basics of model rocketry. The course handbook is available as a free download from the UKRA website, together with tests, PowerPoint slides and other supporting material. www.ukra.org.uk/docs/youth/RocketryHandbookV1.2.pdf

If you live near one of the UKRA affiliated clubs, or near experienced members of the UKRA who have volunteered to be mentors, you are encouraged to consult with them. The clubs are listed at the UKRA web site, www.ukra.org.uk. These rocketeers can help teach you the basics of how to build and fly a payload-carrying rocket. Typically they can also help you in locating a test-flying launch sites and notify the Civil Aviation Authority (CAA) of the launch. Many will allow you to do your practice or "qualification" flight at one of their already-organised launches (launch dates and locations also listed at the UKRA web site). **Remember neither these "experts" nor any other adult can help you design, build or fly your actual entry**. All of this work must be done by the student members on your team.

If model rocketry interests you and you want to be connected to the rest of the people in the UK who are part of the hobby's "expert team," you should join the UK Rocketry Association. You can do this online at www.ukra.org.uk or by filling out the membership application forwarded to each team. Membership brings you insurance coverage and a whole range of other benefits and resources.

Section 3. ROCKET DESIGN

Designing a rocket that will reach an altitude of approximately 750 feet and stay up approximately 45 seconds is not particularly hard to do, although designing one that cushions and protects the eggs is a bit harder. The Challenge is finding the exact combination of airframe design, rocket engines, and duration-control technique that will achieve exactly 750 feet and 45 seconds.

Designing your rocket will require either lots of trial-and-error (not recommended), or smart use of a rocket-design and flight-simulation computer program to get the design "roughly right" first. Modern aerospace engineers do lots of "flight tests" on a computer before they start building and flying hardware; it's quicker and cheaper!

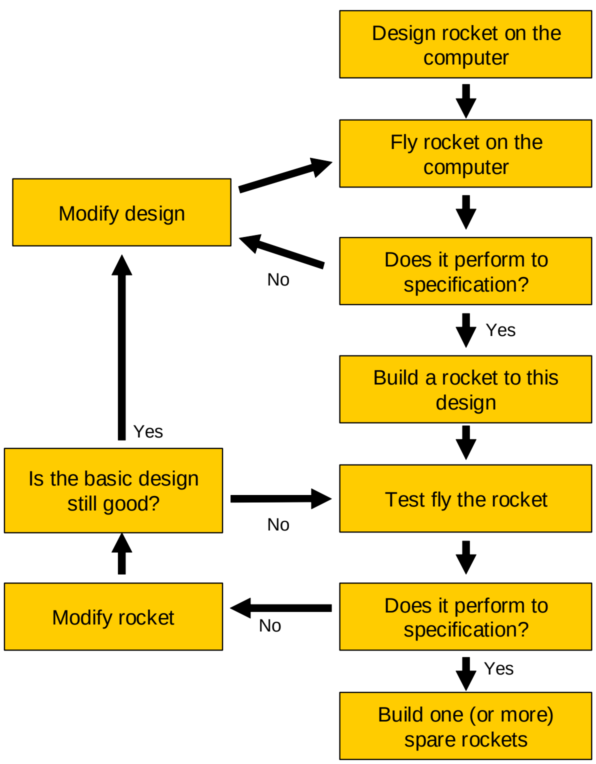
How do you approach the process of designing a flight vehicle? Engineers start with what is a fixed, given quantity, such as the size and shape of the egg payload and its cushioning and the altimeter, and with what the mission performance requirements are. In this case the requirement is to go to 750 feet and stay up for exactly 45 seconds, then make a safe return to earth at the end. No matter what your design, it must incorporate this payload and achieve the performance requirement.

Remember that this event is about teamwork; engineers design in teams because complex projects that are due in short periods of time demand some kind of division of labour. There are many ways to divide the labour. Perhaps one person could become expert in computer flight-simulation programs, another in the craftsmanship techniques of model rocket building, a third in launch system design, and a fourth in charge of fundraising. All the members need to meet and communicate regularly, because what each one does affects how all the others approach their part of the job. You will need to elect or appoint a Program Manager to make sure everything fits together at the end so that your complex system will work in flight test. And you need to start early!

What, then, are the variables in yours aerospace system's design? Well, the size and shape of the rocket certainly has a wide range of possibilities, subject to the overall limitations that the rocket must be safe and stable, and must not exceed 1.5 kg in weight. And the selection of the vehicle's rocket motors is another major variable. Since certified commercially made model rocket motors (those with 0.0625 kg (62.5 grams) and less of propellant each) must be used, you must pick which ones you plan to use from the "Approved Motor List" posted (and updated) at the UKAYRoC website at www.ukayroc.org.uk and in Appendix 3. The list of certified motors is quite long, so there is a wide range of possibilities here as well. There are other design variables to be considered including: what recovery system to use; how to predict or control flight duration in various weather conditions; how to cushion and protect the fragile eggs; and what kind of electrical launching device to use.

Because of the size of the payload (the hen's eggs must weigh between 57 to 63 grams and requires the inside of the rocket body to be a diameter of at least 45 millimeters), rockets entered in this Challenge will be fairly large and heavy. The minimum liftoff weight is probably about 0.15 kg, but there is no need for the rocket to be the minimum weight; a larger rocket is also fine, but it will require larger rocket motors.

What all of this means is that, like all engineers, you must engage in an "iterative" design process, as shown in the diagram below. You start with a very rough design, evaluate its performance against the requirements, and change the design progressively until your analysis shows that you have a design that is likely to meet them. Then you build, test, evaluate the success or failure of the test, and adjust the design as required until your analysis and tests show that the performance requirement is approximately met. Initial tests are best done as "virtual" flights on a computer, with the time-consuming construction and relatively expensive flight testing of an actual rocket saved for the second step.



Here is a path that you may wish to follow to take you through the design process, along with some additional explanation of the design implications of rocketry terminology used in the event rules and in the UKRA Safety Code.

1. **<u>Accommodate the Payload</u>.** Determine what size compartment is required to contain the altimeter and (separately) medium eggs (maximum diameter 45 millimeters) and cushion them against the shocks of rocket launch, recovery system deployment in flight, and impact with the ground at the end of flight. If you have a flight-termination system that may lead to the egg landing at higher (but still safe) speeds, this requires more egg cushioning. <u>Hint</u>: Make sure you cushion the egg from impact with the walls of the payload compartment or metal hardware in every direction including the sides when the rocket's parachute snaps open.

2. **<u>Accommodate the Instrumentation</u>**. The electronic altimeter specified for the event (which you must buy separately from the manufacturer at a special UKAYROC discount price) must be used in your rocket, and will be the sole basis for measuring the rocket's achieved maximum altitude. You may install other additional altimeter-based systems if you wish, to control "drogue then main" parachute deployment, but only the official altimeter can be used for the official record of achieved altitude. It is very important that the compartment in which the altimeter is placed be properly positioned on the rocket and vented with holes as described in Appendix 4, so that the air pressure inside it is always at equilibrium with the outside air pressure. The instrument measures altitude on the basis of the air pressure changes it senses during flight.

<u>Hint</u>: Place the altimeter in a compartment that is totally sealed on the bottom against intrusion by high-pressure gases from the rocket motor's ejection charge. These gases will make the altitude reading inaccurate.

Hint: Place the altimeter compartment well away from the egg compartment. Turbulent flow over the rocket's nose cone-body tube joint at the top of the rocket (where the eggs are located) will introduce pressure fluctuations for a few inches down the body tube and this will make the altimeter readings unreliable if it is placed in these first few inches behind the egg compartment

Hint: Secure the altimeter in place mechanically in its compartment, don't let it "rattle" around or rely on foam padding to hold it in place (such padding might interfere with proper pressure equalization of the compartment, anyway). But make it easy to remove, because you will have to remove the altimeter both before and after flight for inspection by event officials.

3. **Decide on Duration-Control Approach.** There are two fundamental paths you can take to try to achieve precise flight duration: fly without an onboard autonomous control system or fly with such a system. Remember that the rules prohibit the use of external man-in-loop controls like radio-control signals that you send to the rocket once it is in flight. The basic tradeoff is between the altitude the rocket flies to and the sink rate (in feet per second) after the recovery system deployment at apogee (maximum altitude). This is based on the size and shape of the parachute or other recovery system you select. This tradeoff can be initially simulated on a computer.
    a. Free Flight. If you choose the free-flight route (no control system), then the flight vehicle can be fairly simple but you must develop a more complex strategy for adjusting the rocket's recovery system size, shape, etc. before flight in response to the weather conditions at that time. And you will have to do a larger number of practice flights to "calibrate" your adjustments.
    b. Control. If you choose the more complex control route, you need to decide what form of time or altitude-based control system you plan to use, and what you plan to have it do. If it is a device that triggers an igniter to burn through some number of parachute shroud lines, for example, then where do you plan to install the device in the rocket, how do you initiate it, and how do you plan to attach the parachute so it does not simply "cut away" completely and leave the egg capsule in an unsafe free-fall? These factors will significantly determine the shape and arrangement of your rocket.

4. **Learn to use a rocket-design computer program.** Such a program is the best way to work through the remaining steps of flight vehicle design on a basis other than trial-and-error. There are two good rocket-design programs currently available on the market: SpaceCAD and RockSim, both available to UKAYRoC fliers at a discount. There is no single "right" design for this Challenge; there are many different combinations of motor types, rocket length and diameter, rocket weight, and recovery system size and shape that could lead to a flight altitude of 750 feet and flight duration of 45 seconds. A computer program will let you work through the rough possibilities fairly quickly and discard approaches that simply will not work or designs that are not aerodynamically stable. No simulation, however, is exactly accurate. Its estimate of the aerodynamic drag forces on your rocket may be off due to your construction techniques; the rocket motors you use may perform slightly differently from the notional data for them in the program due to normal manufacturing variations, etc. Just because even the best simulation says your rocket will go a specific altitude and then descend at a specific speed under parachute does not mean that it will, exactly. It may go to a lower altitude (usually simulations over-estimate the achieved

altitude) and descend more quickly because a parachute shroud line got tangled during its deployment. Or it may crash because of a reliability problem such as how you attached the shock cord! That's why you still need to (and are required to) test-fly at the end of the design process.

5. **Simplicity**. The more complex you make your rocket design, the more things it has that can go wrong and the more it will cost both to develop and test. In the real world of engineering, low cost, rapid delivery, and high reliability is what the customer wants. In this Challenge, since you only get one flight attempt at the fly-off, whatever you fly has to work the first time.

   Add complexity (such as clustered rocket motors, staging, etc.) only where you need to in order to meet performance requirements. It may turn out that you need to use one or more of these, but don't assume so from the start.

6. **Basic design safety**. First and foremost, your rocket must be "stable". Read the Handbook of Model Rocketry chapter on stability if you do not know what this means, and use a computer program to calculate stability if in doubt. Because your rocket will be nose-heavy as a result of the egg and altimeter, you should not need extremely large fins. Aim to be conservative and design for a stability margin of at least two "calibers" (Center of Gravity ahead of Center of Pressure by at least two body tube diameters). Second, make sure that the motor(s) you pick provide enough thrust to give your size/weight rocket a speed of 15 m/s or so by the time it reaches the end of its launcher, so that it does not "stagger" slowly into the air and tip over and fly non-vertically if there is any wind. Generally, you need a motor or combination of motors whose combined average thrust is at least five times the rocket liftoff weight. As a rule of thumb, make sure that the model's motors' combined average thrust (in units of Newtons, which is how these are marked on the engine casing) is at least 10 times the rocket's liftoff weight in kg.

   And finally, plan on using a launch rod of at least 2m in length and 6mm in diameter or a rail for flying these heavy rockets -- they will need the length to achieve safe speed and the rigidity to avoid "rod whip" when the heavy rocket is at the end of the launch rod on its way up.

   Electronic parachute deployment systems, if you choose to use them, must be SAFE. If they are designed to sense acceleration or deceleration of the rocket as the basis for starting an ignition or ejection sequence, then there is a great risk that they can trigger on the ground or in your hands if you drop or jog the rocket while carrying it. Such systems must have a power switch, plug, or other electrical disconnect mechanism that permits you to maintain them in a completely "safe" configuration until placed on the launching pad, and will not be allowed to fly if they do not.

7. **Commercial vs Custom Parts.** The flight vehicle must be made by the student team members. You may use commercially-available "off the shelf" component parts (body tubes, nose cones, egg capsules, etc.) and may adapt some kinds of rocket kits for the event, or you can scratch-build components if you prefer. You may not adapt kits that were specifically designed to carry egg payloads, however. If a company should release a kit or design specifically for the UKAYROC event (none has, so far) you would not be allowed to use such a kit or design. Having a custom flight vehicle part fabricated by a composite or plastics company or custom wood machining company (even if it is to your design) does not constitute sale of a "standard off the-shelf product"

and is not allowed. However, having a mandrel fabricated to your specifications that is used to wrap fiberglass on to make your rocket body would be OK. In this case, the company is making a tool; you are making the part that flies.

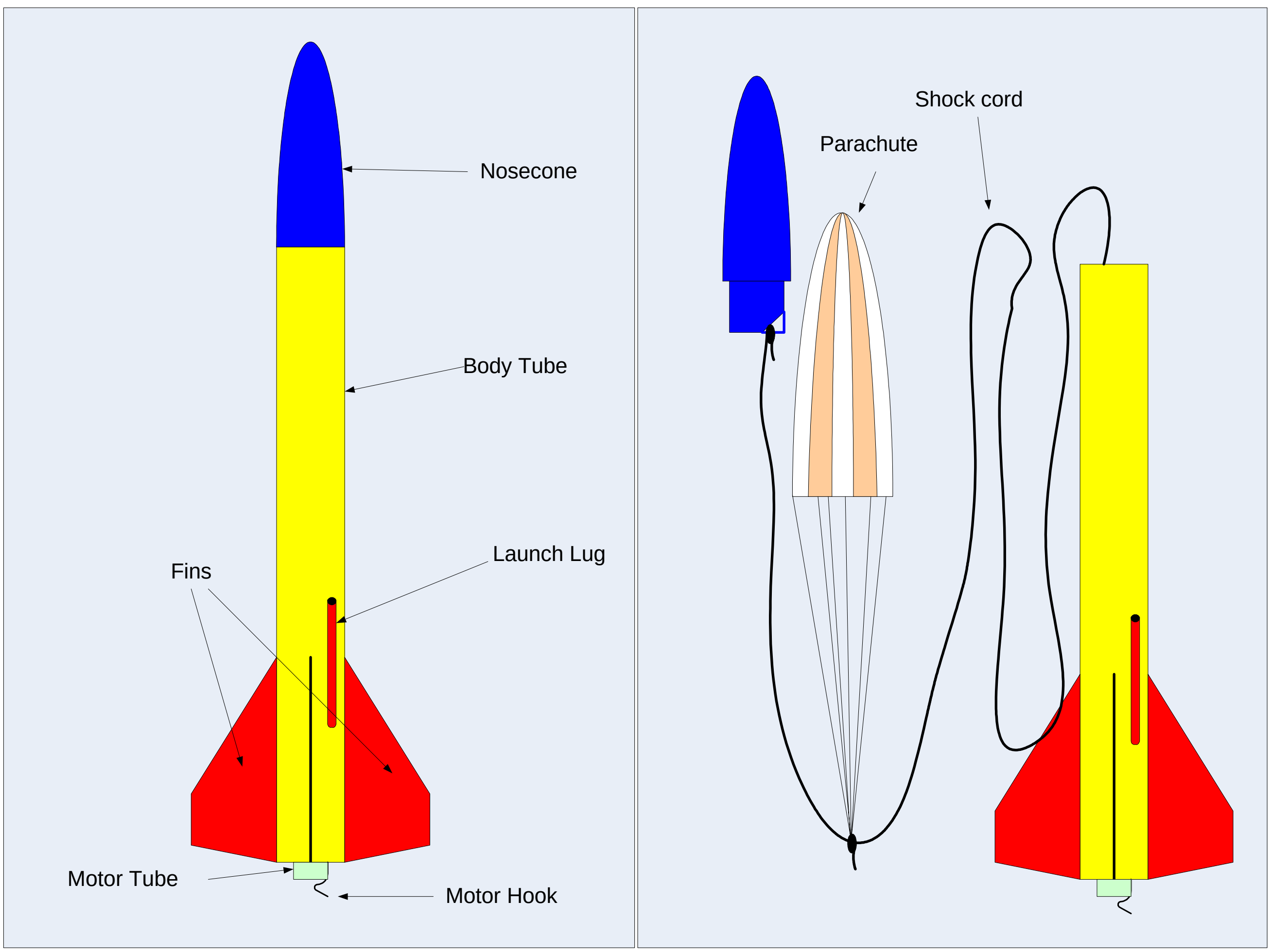
8. **Metal Parts.** You may only use non-metal parts for the nose, body, and fins of your rocket, those parts that are the main structure of the vehicle. Fiberglass is OK. You may use miscellaneous metal hardware items such as screws, snap links, engine hooks, electronic circuit boards, and (if you wish) commercial re-loadable metal rocket engine casings.

9. **Recovery.** Your rocket may be recovered in several separate sections if you wish. Each section or piece of the rocket must come down safely. A heavy piece (booster stage, nose cone, body section, rocket engine casing, etc.) that falls to earth in a stable, non-tumbling/non-gliding mode at high speed without a recovery system of some kind (parachute, streamer, etc.) is not safe, and flights that have this happen will be disqualified for being unsafe. You cannot have a flight-control system that completely cuts away the recovery system from your egg capsule at a predetermined time and causes it to free-fall to the ground with no recovery device from that point; this is not safe. Normally the only part that must be returned to the event officials after the flight is the part with the egg and altimeter.

Section 4. ROCKET CONSTRUCTION

Designing a rocket on a computer is important, but in the end you have to actually build it right for it to fly the way the computer says it will. There are two key resources available to you for learning the craftsmanship techniques for building a model rocket for UKAYROC: One is the instructional DVD on rocket building provided to each new 2008 UKAYROC team , the other resource is the Handbook of Model Rocketry by G. Harry and Bill Stine, which can be purchased separately from Amazon or some UK rocketry vendors.

Watch the DVD and read the applicable chapters of the book before you start trying to put together your rocket. Then build and fly a simple rocket kit before you build your UKAYROC entry. You can learn the names of the main parts of your model rocket from the diagrams below.



There are many aspects to constructing a rocket, and this section will not review everything that the DVD tells you. Years of experience have taught rocketeers to avoid many common mistakes:

1. Don't over-spend on parts. The basic components of a rocket, such as paper body tubes, balsa fins, and balsa or plastic nose cones are not going to cost you a lot if you design your rocket to use the inexpensive parts that are available from the specialist vendors in the Resources section.

2. Use the right tools. You will need a couple of X-Acto hobby knives with sharp new blades, a steel ruler or straight edge, and various grits of fine sandpaper to build most rocket designs. And you will need a well-lighted work area with a cutting surface. You should not need power tools.

3. Use the right materials in the right places. Body tubes and launch lugs should be commercially-made, smooth, and strong. Don't try using paper towel rolls or other "economy" parts for the main structural member of your rocket, or soda straws for launch lugs. Use balsa wood (or aircraft plywood or basswood) from a hobby store for your fins, probably at least 3mm thickness (for balsa), and make sure that the wood grain lines start on the fin-body glue joint. Put at least 0.5m of 3mm or 6mm wide sewing elastic in your recovery system as a "shock cord" between the egg section and the main body of the rocket, to absorb the opening shock of the recovery system.

4. Use the right glues. Body parts should be held together with yellow carpenter's wood glue, not white glue. You can use cyanoacrylate "super" glues for repairs, but do not use them for structural construction. You can reinforce fin-body joints with a "fillet" of hobby epoxy if you're worried about fins breaking off.

5. Use the right recovery system. A standard plastic model rocket parachute with 6-8 shroud lines held on using tape discs at the edges of the canopy will not usually work with a heavy model carrying an egg; the plastic will split, or the shroud lines will come off due to the forces of the heavy egg. Use thin nylon parachutes, or thicker plastics, to make the parachute. For plastic chutes, run the shroud lines over the top of the chute canopy – do not just attach them at the edges. Make sure that you fold the chute carefully (see the Handbook of Model Rocketry on this) and use plenty of non-flammable recovery wadding to protect it from melting together due to the hot gases of the rocket motor ejection charge.

Section 5. ROCKET FLYING

Once your flight vehicle (rocket) is designed and built, it's time for flight test. This section provides some suggestions for organizing and conducting these tests, and for preparing for your single flight attempt at the fly-off. First and foremost, of course, is safety: **read and follow the UKRA Safety Code.**

Launching system. Consider the launching system to be an integral part of the flight vehicle system design, not an afterthought. Of course, the system has to be electrical and incorporate the standoff distance, safety interlock switch, and other requirements of the Safety Code, and it must be on the ground. But it also has to be able to provide the right amount of electrical current and voltage to fire your rocket motor(s) igniter(s), and it must provide rigid guidance to the rocket until it has accelerated to a speed where its fins can properly stabilize it (generally about 15m/s). At the fly-off, an electrical launch system will be provided that can fire a single igniter of any type, and the launching devices provided will be 1.5m long, 6mm diameter launch rods. If your design requires something different (such as a rail or tower-type launcher), you must bring your own equipment and power source. In any case, you will need to have (or borrow) a system for pre-fly-off test-flying. You may want to have one team member assigned the job of designing and building the launcher, particularly if you do not use a commercially-made "off the shelf" system.

Of course, you must follow the UKRA Safety Code and not fly when aircraft are nearby or might be endangered or frightened by your flight! Within the UK it is required to advise the CAA of all rocket launches. The CAA will issue a “Notice to Airmen”, commonly called a NOTAM, to advice other air users about the launch. UKRA affiliated rocketry clubs can advise you about NOTAMs or, better still, fly with the clubs as they will already have a NOTAM in place. The issue of a NOTAM does not remove the responsibility to avoid other air users.

Launch Site. The launch site for the Challenge fly-offs is about 300m by 400m of closely-mowed grassland with a few trees. If the winds on the date of the fly-off are fairly light, recovery will be easy; in windy conditions (above 10 miles per hour), rockets that achieve a 45-second duration could drift out of the field. The site you use for pre-fly-off flight testing may or may not be large, but note the minimum site dimensions in the UKRA Safety Code, which depend on the size of the motor(s) in your rocket.

The first and most important thing you must have at a launch site is permission from the owner! If your school or organization has a suitable site and supports this event, your problem is easily solved. Otherwise, you must work with local park authorities, private landowners, etc. for permission to use a suitable site. There are generally two concerns expressed by landowners concerning rocket flying:

- **"It's dangerous"**. Not true -- the UKRA handout at Appendix 7 summarizes why this is so, and should be used (along with the UKRA Safety Code) to persuade site owners of this. The accident rate for model rocket flying is nearly zero (exactly zero fatalities), and it is hundreds of times safer than any of the organised athletic events that use similar open fields!

- **"I'm afraid of the liability (lawsuit) consequences if anything happens"**. If you are a member of UKRA, you have personal coverage of up to £5 million against the consequences of an accident that occurs while you are flying, as long as you are following the UKRA Safety Code. Your organization, school, or other landowner of your rocket launch site will require liability insurance. Your team can obtain cover for this potential liability by having your supervising teacher/adult and all student members of the team join UKRA.

Launch Safety. Your rocket (and your launch system, if any) will be inspected for flight safety by an event official before they may be used in the fly-off. Any discrepancies noted there must be corrected before flight is allowed. **AT THE FINALS, YOUR ROCKET MUST HAVE PREVIOUSLY BEEN SUCCESSFULLY TEST-FLOWN.** You must also be prepared to show and explain any complex rocket features affecting flight such as electronic timer systems, etc. The pre-flight safety check will also look for the following types of things:

- Do the motors (or motor) have sufficient thrust (average thrust to liftoff weight ratio 5 or greater) to give the rocket a safe liftoff velocity from its launcher?
- Is the rocket stable (CG at least one caliber ahead of CP) with motor(s) and egg installed?
- Are the motor(s) used listed on the UKAYROC Approved Engine List, and are they clearly not modified in any manner by the user?
- Are the fins and launch lugs attached securely and straight?
- Is the recovery system (shock cords and anchors, parachute, etc.) sturdy enough to withstand the shock of opening with that rocket, and is it large enough to produce a safe landing speed?
- Does every separable part of the rocket have a recovery system or a design (e.g. gliding, tumbling) that will ensure it lands at safe, slow speed?
- Does the design prevent any expended motor casings or other massive objects from being separated in flight without a recovery system?
- If there is an electronic in-flight recovery control system, does it have a safety/arming technique (switch or safety plug) that positively ensures it is not capable of causing a pyrotechnic event until the rocket has been installed on the launch pad? Hint: If your rocket is complicated, develop a pre-flight checklist and use it before every launch of you rocket. That's what real engineers do!
- Does the launch system (if the team provides its own) comply with Safety Code requirements for interlocks and standoff distance; can it deliver enough current to ignite multiple motors at once (if cluster ignition is planned); and does the launcher have sufficient length (1.5 meters is expected) and stiffness (if a launch rod is used, it must be 6mm) to guide the rocket securely until it reaches safe speed?

Section 6. QUALIFYING AND PRACTICE FLIGHTS.

Practice-fly early and often. A successful team would have around 20 practice flights with several crashes and/or lost rockets before doing their qualification flights for the fly-offs. A team that leaves it until the last week before the deadline to do their first test flight is unlikely to succeed. Only by test-flying can you master the skills of recovery system deployment, egg cushioning, and overall flight reliability and repeatability needed for success.

Each team that enters this competition must conduct an UKRA-observed "qualification" flight and FAX the results of that flight to the UKAYRoC Helpdesk using a copy of the form provided on the website no later than noon on 22nd February 2008. Space Connections' fax number is 0845 600 3612. Plan ahead for weather (rain or wind that "scrubs" a launch day, problems with the rocket's flight, etc.) and do not wait until the last minute to try and fly this flight. Teams must provide their own eggs and timing stopwatches for all qualifying and practice flights; pre-measured eggs and timers with watches will be provided by the UKRA at the fly-offs.

The top ten qualifying teams, based on their reported scores, will be invited to attend the competitive "fly-off" event that will be held on Friday 28th March 2008 at Charterhouse School. All teams who submit a qualification flight form will be notified of Wednesday 12th March 2008, by UKAYRoc Helpdesk, and the list of those accepted will be posted at www.UKAYRoC.org.uk. Notification will be sent to you using the email addresses provided on your application.

Selection of the top 20 teams will be made on the basis of the lowest (best) scores reported on the qualification flight forms. Score is calculated in accordance with the rules. Note that cracking of the eggs carried by the rocket will result in disqualification..

The official qualifying flight must be observed by a senior (adult) member of UKRA, who must be "impartial", i.e. not related to any member of the team and not a paid employee of the school or member of the non-profit organization sponsoring the team. This UKRA observer is one of your two required flight timers. In addition, a second "impartial" person not on the team (who does not have to be a member of the UKRA, or an adult) must be the second flight timer. There are three ways to obtain an UKRA observer, if you do not already know of a qualified local UKRA Senior member who is ready to do this for you:

- Attend an organised launch run by an UKRA section, and fly your rocket at that launch. You can also use these launches as a place to practice-fly before you do your official qualification flight. These launches are listed in the "Launch Windows" Calendar on the UKRA web site, www.UKRA.org. Always call a launch's point of contact before attending to confirm the time and place of the launch.
- Contact the nearest UKRA affiliated club to see if they have launches not listed on the web site. Check the UKRA site for a list of these clubs and contact information.
- Contact someone on the list of volunteer "mentors" posted on the UKRA web site (some of these folks live in places remote from a UKRA affiliated club).

Obtaining an observer and providing stopwatches **is the responsibility of each team.** **PLAN AHEAD**, to find an observer for your qualification flight(s). **DO NOT WAIT** until late March to try to find someone on a day's notice to observe your flight, and do not expect them to drive a long distance to do so. Upon request, we will help you to find a UKRA member to observe your flights. Not every UKRA member is aware of the UKAYROC event, so you may have to explain it a bit first when you call one who is not already signed up as a mentor!

If there is no UKRA member available within reasonable distance (and this will be true in a number of areas of the UK), it is OK to have an impartial adult, i.e. someone who is not related to any member of the team and not a paid employee of the team's sponsoring school or member of the team's sponsoring non-profit organization, become a UKRA member in order to be an observer. Experienced rocketeers are certainly preferred to do the observer duties because they can usually understand the rules better and offer advice and tips at the same time, but experience is not absolutely required. We do not pre-approve observers, but we will check the form they sign to verify that the observer who signs is a current UKRA senior (adult) member.

Finding a launch site is the responsibility of each team, but you do not have to fly at an UKRA launch site. You simply need to locate an open field of suitable size (at least 300m on a side), get permission from the landowner, and comply with any local laws regarding model rocketry. You must arrange for issue of a NOTAM from the CAA. The procedures for doing so are explained here in the Appendix 6. There is a safety handout in Appendix 7 of this Handbook that you should read and can share with concerned landowners and public safety officials.

Teams may practice as much as they wish, but may only make TWO (2) official qualification flight attempts. Both these attempts must be made on the same day. The form provided in this Handbook, or a copy, must be used to report the results of these flights. Be sure to get the signatures of the supervising teacher/adult of the team and the Senior UKRA member who is the official observer. It is the responsibility of the team to fax your completed form for successful qualification flights to UKAYRoC Helpdesk on 0845 600 3612 noon on 22nd February 2008. UKRA observers who observe a qualification flight attempt that is not successful (i.e. crash or broken egg) are asked to fax the form on that flight to the UKAYRoC Helpdesk.

Section 7. RESOURCES

This Team Handbook is the most important resource you need to participate in this Challenge. In addition, many answers to questions on contest specifics may be found in the Frequently Asked Questions section at www.ukayroc.org.uk. There are many resources that may be useful in learning the basic model rocketry skills needed to succeed in this Challenge or in getting the supplies necessary to participate.

UKAYRoC Reources

There is a lot of important information on the UKAYRoC Website www.ukayroc.org.uk , including:

- The competition rules
- Registration and contact information
- The 2008 Approved Motor List
- The 2008 Qualification Flight Form

UKRA Resources

The UK Rocketry Association, the largest non-profit model rocket consumer and safety organization. From their website you can link to UKRA's affiliated clubs, for advice and general assistance. www.ukra.org.uk.

Design & Simulation Software

Rocksim. RockSIM is approved simulation software for UKAYROC, and information regarding its successful use and other useful rocket design information can be found here.
www.apogeerockets.com

SpaceCAD. SpaceCAD is approved simulation software for UKAYROC, and information regarding its successful use and other useful rocket design information can be found here.
www.SpaceCAD.com

Model Rocketry Books

There are many good books on model rocketry. Particularly noteworthy are:

"**The Handbook of Model Rocketry**" by G Harry Stine. This is the classic book about model rocketry.
"**Model Rocket Design and Construction**" by Tim Van Milligan. This book is only available from Apogee Rockets, but is full of constructional advice and tips.
"**The Model Rocket Handbook**" by Stuart Lodge. A very useful introduction to model rocketry by one of the UK's leading experts.

Materials - UK Specialist Rocketry Vendors

TriPolus™ UKRA United Kingdom Rocketry Association Space Connections

The UK is fortunate to have four excellent suppliers of model rocketry equipment and materials:

Rockets and Things: www.rocketsandthings.com
Apollo 11 Model Rocketry: www.apo11o.co.uk
The Rocket Store: www.rocketstore.co.uk
Congreve Rockets: www.rocketmotors.co.uk

Altimeters

Perfectflite: www.perfectflite.com (USA vendor)

Information

There are many resources on the web to help you to get started. You'll find a lot of useful information and "how to" tips on the following sites:

The Rocketry Forum: www.rocketryforum.com
Essence Model Rocketry Reviews: www.rocketreviews.com
Rocketry Online: www.rocketryonline.com

The UKRA has developed a nationwide list of experienced rocketeer "mentors" who are willing to be a resource to teams. A "mentor" is an adult rocketry expert advisor who helps a team learn basic rocketry skills and shows them where to get rocket supplies and launch sites. They can do this in person, by phone or e-mail. Teams are not required to have mentors, and mentors are not required to be UKRA-approved (i.e. you can get local help from non-UKRA rocket experts.)

APPENDIX 1.

Typical Team Costs

The purpose of this Appendix is to give teams an idea of the typical costs of participation in UKAYRoC, and some ideas for fundraising.

Sponsorship of teams is encouraged, and the organizers are happy for sponsor logos to appear on rockets. UKAYRoC has attained regional and national TV coverage, radio coverage, and also articles in the local and national press. Potential sponsors might be attracted by the public relations opportunities that sponsorship could bring.

Registration and Rocket Design

The costs below include the costs to get from team registration through to the qualification flights. This includes the software for designing the rocket, materials to build and flight-test prototypes, and the construction and test flights for the rockets to be used in the qualification flights.

Item	Amount	Notes
Registration	£ 100	Includes altimeter, UKRA membership
Design and simulation software	£ 50	Rocksim,or SpaceCad
Components for prototype rockets	£ 90	
Motors for test flights	£ 120	
Components for final rockets	£ 50	Two rockets for qualification flights
Motors for qualification flights	£ 25	
Tools, glues, paints	£ 40	
TOTAL	£ 475	

Fly Off

Teams that are successful and get to the fly-off will need to pay for food and accommodation at Charterhouse School. The accommodation is full board, and is very competitively priced compared to local motels. Teams will also need to consider the cost of transport to Charterhouse School, which is located near Guildford in Surrey.

Item	Amount	Notes
Accommodation at Charterhouse school	£ 300	Full board is £50 per person per night. Cost is for teacher plus 5 for one night
Propellant for competition flight	£ 25	Have enough motors for two flights.
TOTAL	£ 325	

The Winners

The winners will need to pay for their travel to and from Heathrow Airport. Travel to and around the USA, hotels, meals and entry fees will be paid for by the organisers.

APPENDIX 2.

PERFECTFLITE MAXIMUM ALTITUDE ALTIMETER

Perfectflite Electronics
www.perfectflite.com
PO Box 328, Mirror Lake, NH 03853
(603) 569-1344

DESCRIPTION

The altimeter approved for use in UKAYROC 2008 (the Perfectflite ALT15K/WD Model) is a "maximum altitude altimeter" that precisely measures the air pressure at the altitude where your rocket is located every 0.1 second and convert this to an above-ground altitude value. It is energized by inserting the battery. It senses the liftoff of the rocket from the sudden air pressure drop that results from its altitude change, then senses the maximum altitude that the rocket subsequently reaches, and "freezes" and beeps out this maximum altitude thereafter using a piezoelectric buzzer, until the battery is removed to turn it off. It will not work on flights that achieve less than 160 feet altitude or greater than 15,000 feet altitude (far beyond the 750-foot UKAYROC 2008 target) above ground level. It is accurate to about 1 percent of the measured altitude, which is far better accuracy than any other altitude-measurement technique readily available to hobby rocketeers.

APPROVED ALTIMETERS

Only one altimeter is approved for use in UKAYROC 2008: the Perfectflite ALT15K/WD. It is about 70mm long, fits in an 18mm-diameter body tube like Estes BT-20, weighs 13-14 grams with battery, and uses a 12 volt "N" size lighter battery. Only this UKAYROC-approved altimeter may be used as the basis for official event scores in either local qualification flights or in the final fly-offs.

USING THE ALTIMETER

Read and follow the detailed manufacturer usage instructions provided with the altimeter. Always handle them by the edges when testing or installing to avoid touching any of the circuitry. Never store the device bare in a clear plastic bag; use a small cardboard box, or wrap the altimeter in a paper towel inside a plastic bag. Do not use tape on the altimeter, and use care to keep it clean and dry. Protect it from the fumes and residue created by rocket motors and their ejection charges by installing it in a compartment of your rocket that is totally sealed from motors and charges. Make sure that it cannot "rattle around" in this compartment and get damaged in flight. Always mount the altimeter with the spring end of the battery holder facing upward toward the nose end of the rocket. This will avoid compression of the spring and battery disconnection during a very high acceleration liftoff.

The altitude achieved by the rocket (and the altitude read by the altimeter) depends on launch site altitude and air temperature. If you live at an altitude much different from the UKAYRoC launch site (300 feet above sea level), or fly when the temperature much different from the temperature on "fly-off" day, your rocket will go to a different altitude (and the altimeter will read a different altitude) than it will at the fly-off. You need to compensate for this in your planning.

An altimeter must be mounted in a "sealed" chamber which must have a vent hole or holes to the outside. A sealed bulkhead below the altimeter chamber is necessary to avoid the vacuum caused by the aft end of a rocket during flight. A sealed bulkhead above the altimeter chamber is necessary to avoid any pressure fluctuations that may be created at the nose end of the rocket. If the front of the payload section slip fits to another section such as a nosecone, then the fit must be as free as possible from turbulence. A breathing hole or vent (also known as a static port) to the outside of the rocket must be in an area where there are no obstacles above it that can cause turbulent air flow over the vent hole. Do not allow screws, ornamental objects, or anything that protrudes out from the rocket body to be in line with and forward of a vent hole. Vents must be neat and burr free and on an outside surface that is smooth and vertical where airflow is smooth without turbulence.

Some rocketeers use multiple static ports (vent holes) instead of just one. Very strong wind blowing directly on a single static port could affect the altimeter. Multiple ports evenly spaced around the rocket tube may help cancel the effects of strong wind on the ground, the effects of transitioning through wind shears during flight, the pressure effects of a non-stable liftoff, or the pressure effects that occur due to flipping and spinning after deployment. If you wish to use multiple ports, then use three or four. Never use two. Ports must be the same size and evenly spaced in line around the tube.

Direct exposure to sunlight will trigger the altimeter pressure sensor and cause it to incorrectly "sense" maximum altitude and beep out a false value before liftoff. Be sure to shade the altimeter from the time you zero it before flight until it is safely inside the altimeter compartment in your rocket.

If the altimeter is reporting an altitude of some very small value (a number less than 160, the launch detect trigger altitude for UKAYROC 2008 altimeters vs 80 feet in previous years) post-flight, this is a result of it getting a brief (approximately 0.1 second) vacuum spike due to a wind gust over the vent hole or other causes. The altimeter would see the altitude going from 0 to over 80 to 160 in 0.1 second (more than 800 feet per second, obviously not a valid reading around apogee) so the spike itself would be excluded from the beeped out apogee reading. Any small number that the altimeter does beep out (4, 8, 12...) would just be the result of background or wind-induced noise.

If direct sunlight shines in the sensor hole, you will get such a spike, though you can exclude this possibility if the altimeter is already shielded inside the rocket and emitting the periodic "ready" chirp.

It is possible (though extremely unlikely) that RF energy from a nearby mobile phone, FRS/GMRS radio, etc could cause such a spike. The altimeter does have RF bypassing to reduce such effects, but a full power GMRS radio held about an inch away from the altimeter could trigger it.

Another much more likely possibility is that of wind gusts triggering the altimeter as it sits on the pad. If a wind gust creates a brief vacuum in the compartment that exceeds the equivalent vacuum of the launch detect altitude, then the altimeter will be triggered and will report a small number as the vacuum bleeds out. There are ways to minimize this effect. The size of the sampling hole depends on the altimeter compartment dimensions, but generally should be quite SMALL. There is a table in the manual, and for most UKAYROC sized rockets a 1.5mm or smaller hole is proper. Many people seem to be drilling a nice large 6mm hole in the side of their rocket, which not only isn't necessary, but will increase wind noise on the data. It will also increase the likelihood and magnitude of spikes in the data when the rocket separates, which can affect the apogee reading. Since the goal of the contest is consistency, clean data is essential. In order to get the cleanest data, the sampling holes should NOT be oversized, and ejection should be slightly after apogee so any turbulence-induced noise on the data will not spike up over the true apogee height.

The altimeter manual should be followed regarding size and placement of sampling holes. In addition to the proper size (about 1.5mm) and placement (3X body tube diameter back from the nosecone) it is also
recommended in the manual that multiple holes be used around the circumference to minimize the effects of gusts blowing across the rocket. The best configuration would be four 0.75mm holes (1/4 the area of the single 1.5mm hole) spaced at 90 degree intervals around the circumference of the body tube. This will reduce the likelihood of false triggering and insure the cleanest, most consistent data.

If the altimeter remains silent post-flight, there are a number of possibilities. First is a weak battery. Battery voltage must be at least 11 volts. Second are dirty battery contacts or battery holder contacts. If the altimeter starts beeping again when the battery is rotated a turn or two in the battery holder it would indicate that the contacts were dirty. Clean with an eraser and blow out debris. Third is that the battery lost contact briefly during flight (shock at motor ignition or ejection are the most likely times, especially if the altimeter is free-floating in a compartment and can slam around). The altimeter should be padded to protect it from shock, the battery holder should be inspected for cracks from previous crashes which could loosen the battery retention force, and the altimeter should be installed with the spring end of the battery holder facing "up" so the spring is not compressed during acceleration. While it shouldn't be necessary, a wrap of tape around the battery holder can prevent deformation, especially if the holder is cracked.

If the altimeter is still beeping the launch ready chirp on landing, this is almost without question a case of the altimeter losing power during flight. It detected launch, started recording the flight, then lost power momentarily during flight (again, shock from boost, ejection, etc breaking battery contact). It would then start over from scratch, waiting thirty seconds and beep awaiting launch. But since the rocket would be on its way down by then, another launch detect would never get triggered, so it would still be beeping readiness on the ground.

APPENDIX 5.

CIVIL AVIATION AUTHORITY NOTAM PROCEDURES

It is a Civil Aviation Authority (CAA) requirement that all air users should be advised of unusual air activities that might be hazardous. This includes model rocket launches. The process for notifying air users is called the "Notice to Airmen" or NOTAM. This appendix tells you how to request a NOTAM.

NOTAMs are requested 28 days before the event by sending an email to ausops@dap.caa.co.uk. The email follows a specific format which is summarized below:

A. School 250605
B. Anytown. Grid Ref SX5678. 1 mile radius.
C. 0606251000 local
D. 0606251700 local
E. Model rocket flying. Surface to 1500 ft. POC Fred Smith 07711 123123.

Decode of their automatic input format:

Line A: Reference number, user defined
Line B: Location in text and 4-figure grid reference or lat-long
Line C: YY MM DD time for start. Add "local" otherwise they assume GMT.
Line D: YY MM DD time for finish
Line E: Activity and requested airspace, Ask for what you really need and don't overstate it. Contact number should be someone onsite that pilots can talk to.

The email should be sent to ausops@dap.caa.co.uk and titled "NOTAM Request". If you want to talk to the cell for advice telephone 0207 453 6589.

APPENDIX 4.

United Kingdom Rocketry Association.

MODEL ROCKETRY: THE WORLDS SAFE, EDUCATIONAL AEROSPACE HOBBY

WHAT IS MODEL ROCKETRY?

Model rocketry is aerospace engineering in miniature. This popular hobby and educational tool was founded in 1957 to provide a safe and inexpensive way for young people to learn the principles of rocket flight. It has grown since then to a worldwide hobby with over 5 million flights per year, used in some30, 000 schools worldwide. Its safety record is extraordinarily good, especially compared to most other outdoor activities, and its safe and inexpensive products are available in some model shops and dedicated vendors in the US, Europe and more importantly the UK. Model rocketry has inspired at least two generations of young people to pursue careers in technology.

WHAT IS A MODEL ROCKET?

A model rocket is a reusable, lightweight, non-metallic flight vehicle that is propelled vertically by an electrically-ignited, commercially-made, certified, and non-explosive solid fuel rocket motor. Beside very important safety reasons, it is illegal for any rocket hobbyist to mix, load chemicals or manufacture raw propellant; all model rocket motors are bought pre-made, including reusable casing type systems. Model rockets are always designed and built to be returned safely and gently to the ground with a recovery system such as a parachute. They are always designed to be recovered and flown many times, with the motor being replaced between flights. Model rockets come in two size classes: LOW POWER rockets, which are less than 500 gram in weight (1500 gram under some conditions), have less than 62.5 gram (125 gram under some conditions) of propellant, and generally available to consumers of all ages; and HIGH-POWER rockets, which are larger, use motors larger than "G" power, and are available only to adults.

ARE THESE ROCKETS LEGAL?

Model rockets may be legally flown provided that the entire flight starts and finishes land for which the landowner has given permission. Flights may be made in uncontrolled airspace, which is away from airfields. The guiding principle is that model rockets must not cause a hazard to other air users. This is amplified in the Air Navigation Order and CAA publication CAP 658.

Flights should not be made in mountainous areas or on estuaries, as the rockets could be confused with emergency flares causing an inadvertent call-out of the rescue services.

IS THIS HOBBY SAFE?

In well over 250 million flights since the founding of the hobby, there has never been a death caused by the flight of a model rocket. Injuries are rare and generally minor. They are almost always the result of failure to follow the basic safety precautions and instructions provided by the manufacturers. Model rocketry's record shows that it is safer than almost any model or other outdoor physical activity. The hobby operates under the simple and easy-to-follow Model Rocket and High-Power Rocket Safety Codes of the United Kingdom Rocketry Association, which have been fine-tuned by professional engineers and public safety officials to maximize user and spectator safety. The foundations of these Safety Codes are that model rockets must be electrically ignited from a safe distance with advance warning to all those nearby, must have recovery systems, must be flown vertically in a suitably-sized field with no aircraft in the vicinity, and must never be aimed at a target or used to carry a pyrotechnic payload. All model rocket motors are subjected to extensive safety and reliability certification testing to strict HSE guidelines and European standards.

AREN'T THESE ROCKETS FIREWORKS?

All HSE and European guidelines recognize model rockets as different from fireworks. Fireworks are single-use recreational products designed solely to produce noise, smoke, or visual effect. They have few of the designed-in safety features or pre-consumer HSE safety testing of a reusable model rocket, and none of the model rocket's educational value. Fireworks are fuse-lit, an inherently dangerous ignition method that is specifically forbidden in the hobby of model rocketry. Model rockets are prohibited from carrying any form of pyrotechnic payload; their purpose is to demonstrate flight principles or carry educational payloads, not blow up, make noise, or emit a shower of sparks.

WHO ARE THE EXPERTS?

The oldest and largest organisation of model rocketeers in the UK is the United Kingdom Rocketry Association (UKRA). This non-profit organization represents the hobby to public safety officials and legislative agencies, playing a key role in maintaining the safety of the hobby and safety code development. The UKRA also has its own web site, runs national model rocketry events, competitions, and offers liability insurance coverage through BMFA for model rocketeers. You may reach the UKRA at:

UKRA
Post Office Box 1561
Shefield S11 7XA
www.UKRA.org.uk

You may download copies of the UKRA handbook here: http://www.ukra.org.uk/node/18

And the UKRA safety code here: http://www.ukra.org.uk/node/33