

09 Michigan Aerospace Challenge

APRIL 24 & 25, 2009

GUIDEBOOK

**The Michigan Aerospace Challenge
is a student program of the
MAISD REGIONAL MAISD REGIONAL MATHEMATICS & SCIENCE CENTER
In cooperation with
The Michigan Aviation Hall of Fame**

See Page Two For “What’s New”

For more information contact the MRMSC at
1001 East Wesley Avenue Muskegon, MI 49456 Phone 231-767-7316 Fax 231-773-0505

What's New

The following items have changed for the 2009 Michigan Aerospace Program:

- ☞ Web site is optional, but points earned in this category will be added to the overall score. Websites submitted by April 10th.
- ☞ Several corrections have been made in the Altitude Estimation section, so review this new version carefully.
- ☞ Step Eight in the Red Arrow Hobby directions instruct you to drill two $\frac{5}{32}$ " holes opposite of each other 5" from the top of the payload tube and the booster tub. We are suggesting that this be changed to a single $\frac{5}{32}$ " hole in the **booster tube** and a single $\frac{1}{4}$ " hole in the **payload** section 5" from the top of each tube to equalize the air pressure during flight. If this is not done premature parachute deployment is possible.

Reminders

Here are some reminders and changes that have been made over the last two years to keep in mind:

- ☞ All teams (except first year teams) are required to build an altimeter, based on a common design, for their payload project. They will also be required to build a calibration chamber for calibrating their altimeter. See page 7. All teams participating will be required to keep a payload project log, documenting their payload project activities including construction, calibration trials, etc. and have it available during judging. See page 9.
- ☞ Payload score value has been increased from 40 points to 85 points to reflect the importance of this category. See pages 10 and 16.
- ☞ The attachment of the launch lugs on each rocket will be tested during the "Fit and Finish" judging. Please review the process on page 17 and make sure your rocket will pass this test.
- ☞ Teams are required to use the "grooved" cardboard body tubes frequently referred to as "flexible phenolic." The smooth plastic tubes, also known as "Quantum" body tubes will not be allowed. Should a team submit such a body tube it will not be judged in sections A-7 and A-8 of the "Fit and Finish" category.
- ☞ The rivets supplied with the kit to secure the nosecone to the payload tube be replaced with nylon machine screws. See page 12.
- ☞ The written altitude calculation test takes place at the same time as the oral presentation judging. Therefore, do not assign the same students to take the altitude test and deliver the oral presentation.
- ☞ Students are to perform all rocket prep and attend Pre-Launch Meeting on Friday– coaches are to pay an advisory role only.

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Michigan Aerospace Challenge
Muskegon, Michigan – April 24 & 25, 2009
Important Dates and Schedule

March 13, 2009 (Fri.)

Rocket Supplies Order Form & Registration Form Deadline

Teams must submit their registration form and motor casing/fuel order by March 13, 2009. Motor casings can be purchased or rented. See page 34 for the order form and page 35 for the registration form. Submit to the fax or address below.

March 27, 2009 (Fri.)

Certificate of Student Work Deadline

See page 36 for the Certificate of Student Work. These forms must be received by March 27, 2009. Submit to the fax or address below.

April 10, 2009 (Fri.)

Website Judging (Optional Category)

The website must be in it's final form and the address submitted for judging by the end of the day on Friday, April 10, 2009. Email the website address to: rwitham@muskegonisd.org

Submit the above forms to the following mailing address or fax number :

Mail: Michigan Aerospace Challenge
The MAISD Regional Mathematics & Science Center
1001 Wesley Ave.
Muskegon, MI 49442
Fax: 231-773-0505

April 24, 2009 (Fri.)

Team On-Site Registration & Set Up in Muskegon

High Power Team Registration	10:00 AM to 1:00 PM
Judges Briefing	1:00 PM to 1:30 PM
High Power Opening Ceremony	1:30 PM
High Power Project Judging	2:00 PM to 5:00 PM
Altitude Calculation Challenge	2:15 PM to 3:15 PM
Pre-Launch Meeting <i>Student Prep Team To Attend</i>	3:30 PM

April 25, 2009 (Sat.)

Michigan Aerospace Challenge Rocket Launch

High Power Launches	8:00 AM
High Power Awards Ceremony (or immediately following the last launch)	3:00 PM

Check our Website for Updates

<http://www.muskegonisd.org/departments/mathscience/studentpgms/aerospace-challenge/>

MAC Facts

What is the Michigan Aerospace Challenge? The Michigan Aerospace Challenge/Rockets for Schools program is an exciting educational opportunity for middle and high school students. Student rocket teams construct a high power rocket, build two theodolites and create a display board. The program is designed to allow students to integrate math and physical science concepts and apply technology and problem solving skills in a real world context.

What is High Power Rocketry (HPR)? HPR uses powerful motors to lift large rockets to high altitudes. HP rockets must be launched in coordination with regional and local FAA air traffic control. MAC officials handle all regulated procedures. HP rockets are large enough to carry a significant payload for educational purposes. Payloads may include: altimeters, accelerometers, barometers, and other information gathering devices.

What are the types of rockets? Teams may chose to construct a RFS Kit-1 rocket or an RFS Kit-2. First year teams must construct the RFS Kit-1. The RFS Kit-1 is about 6' tall and 4" in diameter and features an 18" payload section. The cost is approximately \$115. Experienced HP rocketeers may choose to build the RFS Kit-2. The Kit-2 is ~8' tall, has an 18" payload section and a cost of about \$240. The RFS Kit-2 requires a Close Proximity Recovery (CPR) module for parachute deployment. The Co-pilot module (purchase cost approx. \$125) has an altimeter and includes the ejection system. Call Public Missiles for current prices: 1-888-782-5426 and for additional ordering information. Please refer to the following page (page 6) under the **Fuel and Motor Casing** heading for details about obtaining these items.

Who may participate? Students must be in the middle through high school age range. A student team must have at least one adult supervisor. Teams must have at least six (6) members. Teams must be affiliated with a sponsoring organization. Sponsors include: local schools, math/science centers, 4-H Extensions, businesses and churches. Students must do ALL project work. All teams must register (see page 35), purchase a rocket kit, fuel and purchase or rent a motor casing (see page 34).

What are the team objectives? Each team must construct a Kit-1 or Kit-2 high power rocket, complete a display board and build two theodolites for determining rocket altitude. Only RFS Kit-1 and Kit-2 rocket projects will be judged. (See page 10 for judging categories and page 11 for judging criteria). Reminder: Students must do ALL project work. See the "Certificate of Student Work" on page 36.

Are awards given? Each team's project is judged in accordance with the criteria on page 11 (see page 10 for judging categories). Teams do not compete against each other, instead teams are challenged to achieve as many points as possible in each category. Ribbons are awarded in each judging category to teams achieving at least 70% of the available points in the category. If no team achieves this performance level, no ribbons will be awarded. Conversely, if more than one team earns enough points to earn a ribbon in a given category, multiple ribbons will be awarded. A white ribbon will be awarded if the team earns at least 70% of the available points, a red ribbon for achieving 80% to 89% of the available points and a blue ribbon for teams achieving 90% or more of the available points. The awards presentation will take place on Saturday at approximately 3:00 pm or following the last launch. Overall awards, based on points, are given in high school, middle/junior high school and first year teams categories. An overall award is given to the team accumulating the greatest number of points.

Who will judge? Judges are qualified volunteers from business, industry, and education. Each rocket category will be judged by at least two judges. The committee reserves the right to revoke prizes and special awards or to reject exhibits if a rule violation is discovered. **The decision of the judges in all situations will be final.**

Rules and Regulations

On-Site Registration: All rockets must be registered on Friday, April 24. Registration begins at 10:00 AM and will conclude 1:00 PM. Teams are encouraged not to wait until the last minute to register, as teams are assigned to judging sessions in the order they register (see the judging section below). The coach and three students will register and set up the display. Each student must submit the “**Student Participation Forms**” at registration. See pages 38 & 39. Teams bringing their own motor casing must deliver it to the registration table on Friday when they register.

Rocket: Each team must have an RFS Kit-1 or RFS Kit-2 rocket to be considered for an award. Please note that smooth plastic rocket body tubes may not be used; all body tubes must use the “grooved” style or “phlexible phenolic” body tubes. New teams may order an **RFS Fit-1** directly from a vendor or the MAISD Regional Math/Science Center. **RFS Kit-2** is for more experienced rocketeers only (See page 5: [What are the types of Rockets?](#)). Teams returning from last year may re-fly last year’s rocket. A “re-fly” rocket **must** be refinished and **must** contain a payload that collects meaningful data (rocket performance and/or ambient atmospheric conditions, for example). **Teams flying the RFS Kit-2 rocket** may modify the Computer Parachute Recovery (CPR) system to eliminate the gunpowder charge. This modification creates an interesting, yet achievable engineering challenge for students. If teams choose to modify the CPR, please send a full description of the modification to MAC officials no less than one month before the event (rwitham@muskegonisd.org.) If teams do not choose the mechanical conversion, the Kit-2 must be “prepped” and launched by certified personnel using the team’s computer. A damp Kit-2 computer may NOT be used. Students will not be allowed in the CPR loading process. Teams launching a Kit-1 rocket **MAY NOT MODIFY** the parachute deployment device in any way.

Fuel and Motor Casing: Each team is responsible for ordering a motor casing and fuel. The Math/Science Center will rent casings to teams. See page 34 for details. Certified launch officials will assemble the motor on Friday afternoon or evening. Each rocket motor will be installed just prior to launch according to a master launch schedule. Motors will be removed immediately upon return to the boat dock.

Judging: Judging will be broken down into two sessions on Friday, April 24 (2:00 PM to 3:30 PM and 3:30 PM to 4:00 PM). Teams will be assigned to a judging session in the order in which they register. Two team members must prepare a 3-minute oral presentation for judges following the criteria on pages 15. Presenters should also be prepared to answer questions from the judges on their project and payload, see page 17 for more details. Do not assign the same students to make the oral presentation and to take the altitude calculation test, as they are scheduled during the same time period.

Websites must be submitted on or before April 10 or they will not be JUDGED. Send address to rwitham@muskegonisd.org. Please consider using a site such as Weebly.com to create your website, as there aren’t issues with pop-ups and participants can focus on content instead of programming. Websites are optional, but the points earned will be added to the overall score.

Rocket Display: The team display is much like a science fair display. Two or three self-supporting panels surround the rocket and other display items. The display must include information on (1) how a rocket motor works or (2) how center of gravity and center of pressure determine rocket stability. In even-numbered years (use event date, 2008, 10, 12, etc.) - coaches with last names beginning with letters A-K will do (1). Other coaches will do (2). In odd-numbered years (2009, 11, 13, etc.) coaches A-K will do (2), others (1). The topics must be presented in detail and must address the fundamental *causes* of rocket stability and motor force. The team’s display panels must not exceed the height of the rocket as it sits on the RFS display stand. A table and stand will be provided. The entire display must fit inside a 4’ wide by 30” deep by rocket height volume on the tabletop. Items larger than this can be displayed in picture form. Large items not on the display table but essential to a judging category should be made available to judges, then stored elsewhere. Note access to AC power cannot be guaranteed and internet access will not be available.

Determining Team Category The team’s grade category (middle school or high school) is determined by the grade of the oldest student participant. If the oldest student is a junior in high school the team is deemed a high school team.

SAFETY RULES:

Display Area: No rocket fuel at display tables. If a team brings its own motor casing and fuel, both must be brought to the registration table on Friday. The adult team member responsible for the motor must be available to assemble it Friday afternoon or waive this responsibility to the MAC launch team.

Launch Area: All team members and coaches can accompany their rocket to the launch site, but must heed all directions issued by the launch site personnel.

2009 Michigan Aerospace Challenge Payload Category

In past years, teams participating in the payload category of the Michigan Aerospace Challenge Program were responsible for a payload of their choosing. Again this year, teams are required to construct a mechanical altimeter based on a common design provided by the MAC organizers. First year teams will still be exempt from the payload category.

There is a slight variation between the altimeter construction instructions for the middle school teams and the high school teams. Middle school teams must use a hard plastic pill bottle (66 mm tall by 48 mm in diameter) from which to build their altimeter, while high school teams will be allowed to select any non-metal/non-glass (NMG) container. Teams will also have to construct a chamber for calibrating their altimeter.

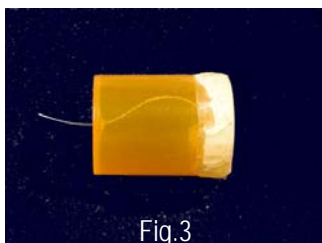
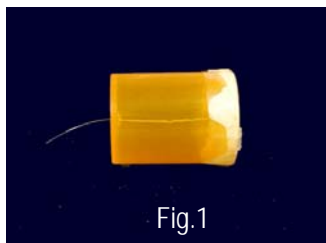
Teams will be judged on the accuracy of their altimeter, the construction of the altimeter and calibration chamber and thoroughness of their graph.

In addition to the pill bottle or NMG jar (for high school teams only), teams will need a piece of latex from a thin, disposable latex glove, a length of fishing line, and rubber band.

This mechanical device works on the same principle of decreasing atmospheric pressure that causes a rising balloon to expand. Instead of using a balloon, team members will use a hard-walled chamber (pill bottle or NMG container) with a balloon-type membrane (latex rubber) gently stretched over the open end. When the chamber is launched in the payload section of a high power rocket, the decreased atmospheric pressure causes the trapped air in the chamber to expand and create a 'bulge' in the latex membrane. A method for measuring how much bulge is created will lead to an altitude determination.

Mechanical Altimeter

The mechanical altimeter consists of a pharmaceutical pill bottle with a small hole drilled in the bottom to allow monofilament fish line to pass inside and attach to a flexible latex diaphragm. Figure 1 shows the altimeter set for calibration or actual rocket launch. The fish line is straight and latex diaphragm is flat. Figure 2 shows the altimeter at apogee or in calibration chamber (vacuum) with the latex expanded and line pulled into the bottle. As the ambient pressure increases, the diaphragm returns to its original state leaving excess fish line in the bottle – Figure 3. See the attached instructions for details on translating the change in length of fish line outside the bottle into an altitude

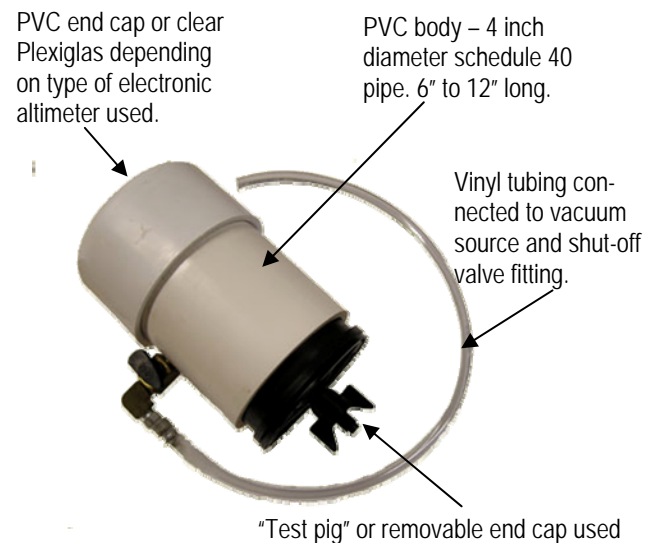


Altimeter Materials List

- Hard plastic pill bottle 66 mm tall by 48 mm in diameter (mandatory for middle school) or any NMG jar (optional for high school only)
- Thin, disposable latex glove
- Length of 15-pound test monofilament fishing line
- Rubber band to hold latex membrane in place (or other suitable system)
- Hot glue gun
- Soldering iron
- Super Glue
- A small amount of vegetable oil

Calibration Chamber

The diagram below depicts an example calibration chamber. This picture shows a chamber that does not need the clear window at one end, because it is used with an electronic altimeter that records a maximum altitude –thus no visual access inside the chamber is needed.



Calibration Chamber Materials List

- 12 to 16-inch long piece of 4-inch PVC schedule 40 pipe
- Expansion rubber plug for 4-inch PVC pipe (sometimes called a 'test plug')
- 5-inch by 5-inch piece of 1/4-inch clear Plexiglas or equivalent
- 6-foot long piece of 3/8 inch diameter polyethylene tubing
- A shut-off valve with 3/8-inch compression fittings on both ends
- Tube of silicone sealer or equivalent
- Casio watch with altimeter or equivalent.

(The test plug, along with the other materials, can be found at a good hardware store.)

2008 Payload Category cont'd

Altimeter Construction

Begin by drilling a 3/16" diameter hole in the center of the bottom of the pill bottle or NMG jar. Cut approximately a 12" long piece of 15-pound monofilament fishing line and coat it with a layer of vegetable shortening. Heat up the glue gun. While positioning the middle of the line in the center of the 3/16" hole, apply hot glue all around the fishing line and into the hole as in figure 2. Make certain hot glue completely seals the 3/16" hole and surrounds the fishing line. When the glue cools – gently pull on the fish line and make sure it slides freely. DO NOT pull the string out of its 'glue' hole. It will be nearly impossible to get it back in position.

Next, take the end of the line that extends into the pill bottle or plastic NMG jar and hold it to the soldering iron. This will melt the end and form a flat "button". This button will provide sufficient surface area for gluing the fishing line to the latex material. Cut a piece of latex from the glove large enough to more than cover the open end of the pill bottle or NMG jar. Lay the latex circle on a flat surface. Place a very small drop of super glue on the bottom of the fishing line button and press it onto the middle of latex material. Hold the fish line perpendicular to the latex for a few seconds until the glue dries.

Stretch the latex piece over the open end of the pill bottle positioning the glued fishing line to the middle of the open end. Stretch the latex just slightly more than enough to remove any wrinkles and secure it in place with a rubber band or other means to form an airtight seal.

Now, pull the excess fish line in the bottle out through its glue hole until the latex membrane just begins to deflect inward. Cut the fish line at exactly 1.5" in length.

That completes the construction of the altimeter.

Calibration Chamber Construction

A chamber must be made to simulate an atmospheric pressure drop; the same pressure drop a rocket experiences as it rises to apogee. This chamber will allow the payload team to make a graph used to relate the amount of latex bulge to a corresponding altitude (pressure drop).

Cut a 12-inch long piece of 4-inch PVC pipe (schedule 40) and square up (by sanding) the ends. Cut a 5" x 5" piece of 1/4" thick Plexiglas or equivalent and glue it with silicone sealer centered to one end of the PVC pipe. Allow it to dry overnight. An expansion plug (test plug) is used to close the end of the pipe opposite the Plexiglas window.

Drill a hole in the center of the sidewall of the pipe large enough to accommodate the shut off valve. Connect a shut-off valve to the pipe at the hole and attach the 6-foot section of 3/8" polyethylene tubing to the cut-off valve.

A tank vacuum cleaner (shop vacuum) is then attached to the hose to evacuate some of the air from inside the PVC pipe.

Altimeter Calibration

Next, calibration data must be collected on the mechanical altimeter and made into a graph. This graph is used to transpose the amount of bulge in the altimeter membrane into a rocket altitude.

To operate the calibration chamber:

- Clean all surfaces of the chamber and attached tubing.
- Open the shut-off valve.
- Place the watch (with integrated altimeter) or electronic altimeter into the chamber.
- Place the mechanical altimeter into the altimeter chamber so nothing will interfere with the bulging membrane.
- Insert and tighten the expansion plug.
- Read the watch's altimeter through the Plexiglas window and record.
- Connect the vacuum source (shop vacuum - off) to the vinyl tubing and close the valve on the chamber.
- Turn on the vacuum source and let it run for a couple seconds – then open the valve and close quickly after a couple seconds.
- Notice the bulging latex on the mechanical altimeter. Record the reading on the altimeter.

Note: A vacuum equal to 300 to 1500 meters is desired. Student's rockets will achieve apogees within this range.

A good altitude calibration chamber will hold a steady vacuum after the valve is closed but, do not wait to read the altimeter; read it immediately after the valve is closed.

Remove the mechanical altimeter from the chamber and carefully measure the length of the fishing line protruding from the base of the pill bottle. An ACCURATE measuring system must be used.

Record the fishing line length along with the corresponding watch altitude reading.

Repeat the above steps as many times as necessary to obtain sufficient data to have confidence in the graph that will be made next.

Plot a graph of altitude in meters vs. length of line beyond pill bottle base. This graph will be used to determine how high the rocket carrying the altimeter went. It is important to note that modifying the mechanical altimeter in any way after the calibration process will require recalibration.

Other important Things

Each team will have to devise a way to house the mechanical altimeter in the rocket payload section so that high g-forces and limited space does not interfere with its' operation. MAC officials will place an electronic altimeter on TOP of the team altimeter project in the payload bay. The electronic altimeter will be housed in a cylinder three centimeters tall and 9.5 centimeters in diameter. The electronic altimeter housing will allow air movement through it so the student altimeter will experience an accurate pressure drop. Scores will be determined by comparing the MAC electronic altimeter to the results reported by students from their mechanical altimeter.

Payload Project Log

The payload project log (PPL) is a dated diary of all student team work. Handwritten entries should be accurate and detailed. All data, drawings, graphs, thoughts, conclusions, etc. must be included. All team members may submit entries to the log, signing and dating the log following their entry. The log should not be recopied.

Recommendations for keeping the Payload Project Log.

- The PPL should be kept in a spiral or other bound notebook (A three-ring binder is not acceptable).
- Number the pages of the logbook.
- Write the team name and payload type on the first page.
- Reserve the second page of the log for the table of contents (the reverse side of this page may be used if required). This can be completed as work is recorded and the project progresses.
- The PPL should include records of any of these activities:
 - Name, date, time and location of anyone interviewed.
 - Names of any videos, television shows, magazines, books, or websites viewed while researching the payload project.
 - If special tool(s) or device is made for the project, include any designs and drawings.
 - Records of data collected.
- When collecting data, write down the date and time, as well as the data collected.
- Show all the work for any calculations done. Include proper units. Do not erase errors. Cross them out and start again. Project logs are not always pretty!
- NEVER tear a page out of the PPL. Do not submit a copied PPL for judging. The judges want to see the original document. Neatness is not scored here, but legibility is important.

Judging Information

Judging will begin at 2:00 p.m. on Friday, April 24, 2009 – immediately after a program welcome. Rockets must be displayed with payload removed from rocket. Judging will be broken down into two, one and a half-hour judging sessions (2:00 PM to 3:30 PM and 3:30 PM to 5:00 PM). Teams will be assigned to a judging session in the order in which they register. Judging categories are listed below. **Web sites must be finished and submitted for judging on or before April 10, 2009 (see page 6).** Awards will be given on Saturday, April 25, 2009 at approximately 3:00 p.m. or immediately following the last launch. Awards will be presented in all categories. Total points accumulated from all judging categories will determine the awards.

Judging Categories

A. Fit and Finish (90 Points)

- A-1.) Fin Alignment (10 points)
- A-2.) Fin Taper (10 points)
- A-3-a.) Fin Fillet Size (5 points)
- A-3-b.) Fin Fillet Finish (5 points)
- A-4-a.) Tail – Centering Ring Recess (5 points)
- A-4-b.) Tail – Centering Ring Fillet (5 points)
- A-5-a.) Payload Section Fit (5 points)
- A-5-b.) Payload Section Base – Fillet (5 points)
- A-6-a.) Nose Cone Surface (5 points)
- A-6-b.) Nose cone fastening (5 points)
- A-7) Body – Payload & Booster (10 points)
- A-8.) Paint Surface (5 points)
- A-9.) Center Pressure/Center Gravity (5 points)
- A-10.) Launch Lugs (10 points)

B. Artistic Design (20 Points)

- B-1.) Design Complexity (10 points)
- B-2.) Execution of Design (10 points)

C. Table Top Display (30 Points)

- C-1.) Required Topic (10 points)
- C-1.) Team Activity (10 points)
- C-3.) Display Organization (10 points)

D. Oral Presentation (30 Points)

- D-1.) Presentation Organization (10 points)
- D-3.) Assigned Topic Knowledge (10 points)
- D-4.) Judge’s Questions (10 Points)

E. Web Site (40 Points) (Optional, but will be included in the overall score)

- E-1.) Navigation & Organization (10 points)
- E-2.) Communicates Team Activities (10 pnts)
- E-3.) Visual Appeal/Aesthetic Design (10 pnts)
- E-4.) Usefulness to Rocketeers (10 Points.)

F. Payload (85 Points)

- F-1.) Documentation (20 points)
- F-2.) Payload Calibration (20 points)
- F-3.) Execution of Design (20 points)
- F-4.) Accuracy (20 points)
- F-4a) Accurate & Efficient Method (5 points)

G. Altitude Determination Written Test (40 Points)

H. Altitude Determination—Theodolite Method (40 Points)

I. Rocket Flight Performance (30 Points)

- I-1.) Rocket Recovered in Flyable Condition
- I-2.) Damage to Straps, Etc.
- I-3.) Flight Stability

Judging Category Criteria

A. Fit and Finish

As in any construction project – careful attention to detail will result in a product that is pleasing to look at and performs well and in a safe manner.

A-1 Fin Alignment (Ten Points) The fin slot along the rocket booster tube determines the fin alignment (parallel to the length of the tube). This alignment will not be judged. The alignment of the fin's plane surface as it passes through the motor mount will be judged. The fin's plane surface should pass through the center of the motor mount tube. During construction, it will be helpful to employ a jig that assures this alignment. (Caution: the three fins may appear to be 120 degrees apart and their plane surfaces still not pass through the center of the motor mount.)

A gauge will be used to measure the rocket's fin alignment. If all three fins are in alignment, all ten points will be awarded. Points will be deducted if the fins are out of alignment. The number of points deducted will be determined by the average of fin misalignment. For example, if one fin is out of alignment by three degrees, another by two degrees and a third by one degree, two points will be deducted ($3+2+1=6$ and $6 \div 3 = 2$).

A-2 Fin Taper (Ten Points) All three exposed edges of the fin should be tapered like the shape of the nose cone, but not pointed or sharp. The tapers should start about 1/2" from the edge of the fin. This includes the trailing edges as well as leading and outside edges. This taper will reduce drag, even on trailing and surfaces.

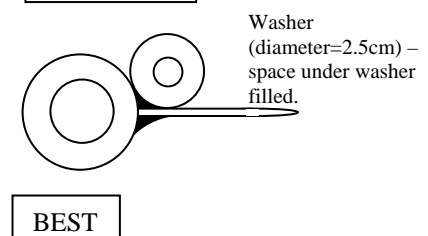
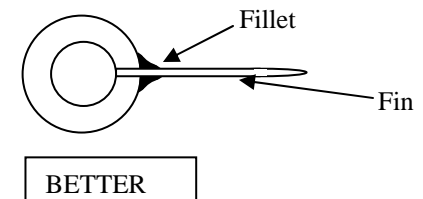
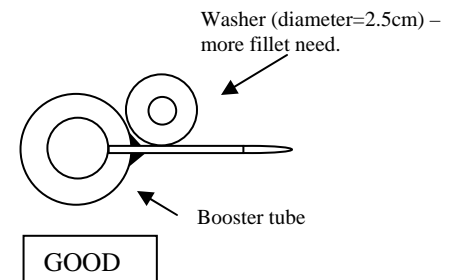
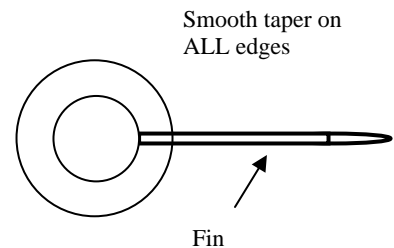
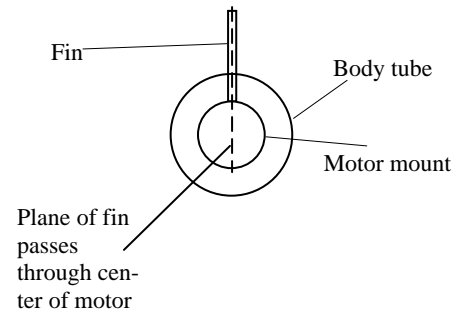
Ten points will be awarded if all of the exposed edges are tapered. If only the two edges are tapered, eight points will be awarded and if only one edge is tapered, five points will be awarded. No points will be awarded if none of the edges are tapered.

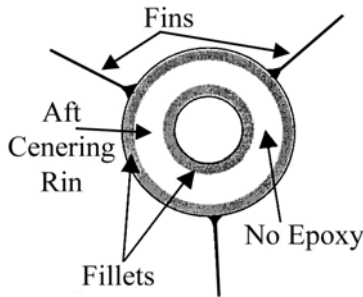
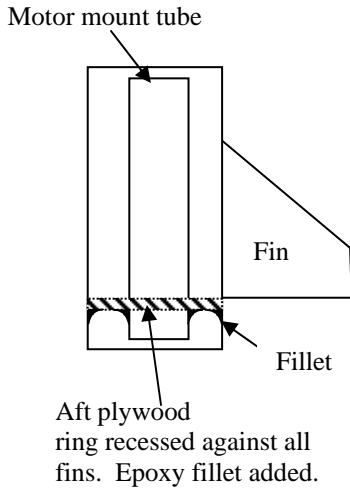
A-3 Fin Fillet (Five Points for Fillet Size and Five Points for Fillet Surface) Where the fins meet the booster tube, a fillet of epoxy, overlaid with sandable filler will provide strength and a pleasing aerodynamic appearance. The fin should look like it "grew" out of the booster tube – much like a dolphin's dorsal fin emerges from the dolphin's body. Points will be awarded on the size of the fillet and how smooth it is.

To determine how much fillet is needed place a 2.5cm O.D. (1") washer with edges touching both fin and booster tube. The area between the washer edge, fin, and booster tube should be filled with epoxy and sandable filler. See the "GOOD, BETTER, BEST" diagrams.

Five points will be awarded if there is no gap between the 2.5 cm washers and the fillet, as in the best example. Four points will be awarded if there is no gap between the fillet and a 7/8th of an inch washer, three points with a 3/4" washer, two points with a 1/2" washer and 1 point if there is no gap between the fillets and a 7/16" washer.

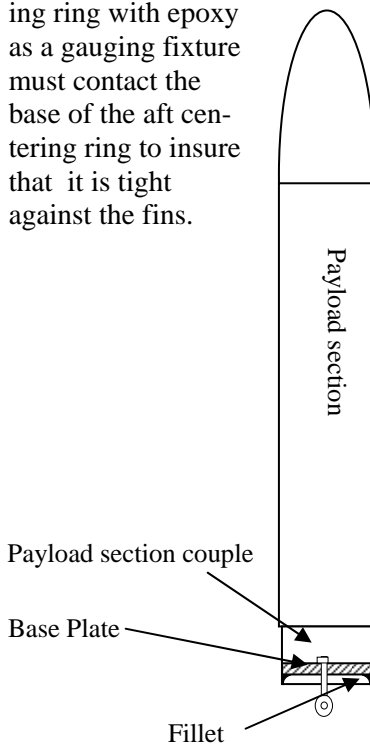
If the fillet is smooth to the touch and there are no gaps or pinholes in the fillet surface, five points will be awarded. If the fillet is smooth to the touch,





Bottom View of Rocket

NOTE: Care should be taken not to cover the entire aft centering ring with epoxy as a gauging fixture must contact the base of the aft centering ring to insure that it is tight against the fins.



but pinholes are visible, three points will be awarded. If there are noticeable gaps in the fillet (depressions or voids) or if the fillet is rough to the touch only one point will be awarded.

A-4 Tail (Five Points for Centering Ring Recess and Five Points for Fillet)

The aft motor mount centering ring must recess against the base of all fins. To allow for this, keep the epoxy off the bottom 3 cm of the motor mount tube during fin attachment. The aft motor mount centering ring will be recessed about 1.0 cm. Fin position will be measured with a gauge. Five point will be awarded if the centering ring is tight against all three fins as indicated by the gauge. The number of points deducted will be determined by adding the total gap, in millimeters, of all three fins and dividing that total by five. The result will be deducted from five.

Fillets need to be added where the booster tube and the motor mount tube meet the plywood aft motor mount centering ring. Five points will be awarded if the fillet goes all the way around the tubes, three points if it only goes half way around and no points if there is no fillet at all. Care should be taken not to cover the entire aft centering ring with epoxy as a gauging fixture must contact the base of the aft centering ring to insure that it is tight against the fins.

A-5 Payload Section (Five Points for Fit and Five Points for Fillet)

The friction fit between the payload coupler tube and the booster is important for a successful deployment of the recovery system. The fit should not be too tight or too loose. Error on the side of too loose. A good fit is determined by holding the entire rocket vertically by the payload section only. With a gentle upward tug on the payload section, the booster section should separate slowly from the payload section (without further tugging). Five points will be awarded if the payload section and the booster tube come apart in this manner. Three points will be awarded if they come apart without the tug and zero points if they don't come apart at all.

The base plate of the payload section should have a wide epoxy fillet to secure the plate. Five points will be awarded if this fillet goes all the way around the perimeter of base plate and is as wide as possible. Three points will be awarded if it goes around half of the perimeter and zero points if there is no fillet at all.

A-6.1 Nose Cone Surface (Five Points) Sand the nose cone smooth to get rid of "mold" marks. Mold marks can be the "parting lines" left by the two halves of the metal mold or other "divots" or depressions in the nose cone left over from the molding process. If there is no evidence of these "parting lines" or other marks and the nose cone is smooth to the touch, five points will be awarded. If there is minor evidence of the "parting lines" or other marks three points will be awarded. If the "parting line" or other marks are visible, no points will be awarded.

A-6.2 Nose Cone Fastening (Five Points) The nose cone is to be secured to the payload section by nylon machine screws purchased at a hardware store. The plastic rivets included with the kit should not be used. This is the case whether or not the rocket will be carrying a payload.

Recess the screws into payload tube and sand the screw heads as flush as possible with payload tube. The screws should not stick out from the payload section

any more than the rivets they replace. When installed properly the rivets stick out from the payload section by a little less than 1/8th of an inch so if the set screws don't stick out any further than that five points will be awarded

A-7 Body – Payload Section and Booster Body Tube (*Ten Points*) The body of the rocket should be as smooth as possible. The spiral groove should be filled and sanded so it cannot be detected by eye. Prime, and then paint the surface with high gloss enamel. A “clear coat” may be added to protect the finish and add high-luster. **Note:** *Smooth plastic body tubes will not be judged. Any teams submitting this style tube will receive no points.*

A total of ten points are available in this category and will be awarded if the body is completely smooth. Deductions will be determined by randomly placing a one foot ruler in three different places on the body tube, counting the number of grooves visible, dividing the total number of grooves visible by two and deducting that number from 10.

A-8 Paint Surface (*Five Points*) Edges between colors should be smooth and undetectable by touch. **WARNING:** The use of vinyl tape or decals will result in a low score unless the “ridge” created can be eliminated.

Five points will be awarded if the transition between paint colors or other decoration (vinyl tape or decals) cannot be detected by eye or touch, i.e. there is not a ridge can seen or felt. Three points will be awarded if these transitions are detectable or if the rocket is only one color.

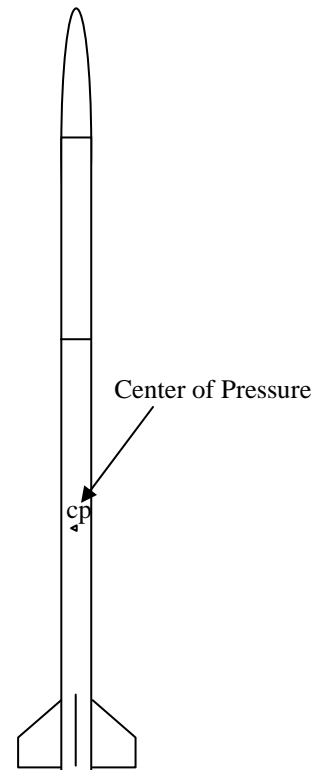
A-9 Center of Pressure & Center of Gravity (*Five Points*) The Center of Pressure (CP) must be marked on the body tube. The RFS Kit-1 (manufactured by Red Arrow Hobbies) has the CP placed 55.5” from the nose cone tip. **CHECK YOUR KIT INSTRUCTIONS FOR THE CP OF YOUR MODEL.** If a rocket is suspended from the CP in a wind perpendicular to the rocket body, the rocket will not rotate.

Five points will be awarded if the Center of Pressure is marked clearly and no points awarded if it is not marked.

The center of gravity of the rocket (CG) does NOT have to be marked. The CG will vary as payloads and different motor sizes are used. The CG will be checked before launch to make certain it is in front of the center of pressure (CP) by at least 1 body diameter.

A-10 Launch Lugs (10 Points) Make certain that the two launch lugs are aligned with one another. The rocket cannot be launched if there is friction between the launch lug and launch pad rod because of misalignment. To assure alignment, epoxy launch lugs to the rocket body with a straight rod through both lugs. Remove the rod after the epoxy on both lugs has set. Fillet should be added around lugs for added strength and to enhance aerodynamics (see section A-3 Fin Fillet).

The alignment of the launch lugs will be tested with a $\frac{7}{16}$ ” steel rod (the lugs have an interior diameter of $\frac{1}{2}$ ”). If the rod slides smoothly in the launch lugs, 10 points will be awarded. If there is minor friction 5 points will be awarded and if there is too much friction, rod has to be forced into the lugs, or it will not pass through both rods at all, no points will be awarded.



The following categories are more subjective than the construction categories and, therefore, are more difficult to judge. In these categories, we have given the judges and teams guidelines for scoring. Generally speaking, one point will be awarded if the work just meets the criteria or only meets some of the criteria, 50% of the points will be awarded if the work meets all of the criteria and 100% of the points will only be awarded if the work exceeds the criteria.

B. Rocket's Artistic Design

Judging for this category tends to be subjective, but we have tried to select criteria that are less subjective; complexity of the design and the execution of the design.

B-1 Design Complexity The more complex the design, the more points that will be awarded. If the design is simple and bold and uses only one or two colors, it will receive one point. If the design is more interesting, but not intricate and uses three to five colors five points will be awarded. Ten points will be awarded if the design exhibits intricate designs or patterns and uses multiple colors and shades.

B-2 Design Execution The execution of the design will also be judged. One point will be awarded if the design elements are applied carelessly, if there are paint drips, runs and the straight lines are not straight, or curved lines do not curve smoothly. Five points will be awarded if the design elements are applied with care; most lines and design elements are applied smoothly and carefully. Ten points will be awarded if the design elements are applied with the utmost of care – all lines and design elements are applied smoothly and carefully.

C. Table Top Display

The team's tabletop display is much like a science fair display. The display must clearly communicate details about the team's activities and the required topic. It should be neat and organized. Two or three self-supporting panels surround the rocket and other display items, such as the payload, calibration chamber, and payload project log./

The display must include information on one of two required topics. The topics are – (1) *How a rocket motor works* and (2) *How center of gravity and center of pressure determine rocket stability*. In even-numbered years (use event date, 2008, 10, 12, etc.) -coaches with last names beginning with letters A-K will do (1). Other coaches will do (2). In odd-numbered years (2009, 11, 12, etc.) coaches A-K will do (2), others (1). The topics must be presented in detail and must address the fundamental causes of rocket stability and motor force.

Each display must fit in a table space of 48" wide by 30" deep. The height of the display may not exceed the height of the rocket.

Three areas of the tabletop display will be judged; the coverage of the required topic, the coverage of the team's activities and the execution of the table top display.

C-1 Required Topic Up to 10 points can be awarded for the required topic. One point will be awarded if the topic is not covered adequately or is inaccurate. Five points will be awarded if the topic is covered adequately and accurately, as in the guidebook. Ten points will be awarded if the topic is covered in greater detail than in the guidebook and /or if a unique approach or examples are used to explain the topic.

C-2 Team Activities A maximum of ten points will be awarded for the team activity section of the tabletop display. Areas that can be covered include rocket construction, design and finishing, oral presentation preparation, payload design and construction, tabletop display creation and theodolite construction. Any problems that the team encountered and the solutions developed should also be considered for inclusion.

Ten points will be awarded if all phases of the team's activities are covered thoroughly and if photos and/or complete descriptions of each phase included. Five points will be awarded if most phases of the team's activities are included and only one point will be awarded if there is only minimal coverage of the teams activities.

C-3 Execution The execution of the team's display will also be judged with a maximum of ten points awarded. Ten

points will be granted if the display is very well organized, easy to find/differentiate team activities from the required topic, very neat and visually appealing. Five points will be awarded if the display is reasonably well organized, neat and the proper size and only one point will be awarded if the display is not well organized, neat or correctly sized.

D. Oral Presentation

Students must present a brief (approx. 3 minutes) overview of the team's project. Presenters will be judged in three areas; organization of the presentation, knowledge of the assigned topic, and answers to the judges questions. Total time for the oral presentation and the judges' questions will be less than 10 minutes.

D-1 Organization A maximum of ten points will be awarded for the oral presentation's organization. One point will be awarded if the presentation lacks clear direction and organization, five points will be awarded if the presentation flows logically from point to point and presenter(s) are comfortable with material and ten points will be awarded if the presentation flows freely and logically, presenter(s) is confident and very comfortable with the material.

D-2 Presenter's Knowledge – Assigned Topic Up to ten points will be awarded based on the presenter's knowledge of the assigned topic. If the presenter does not have a strong understanding of the assigned topic one point will be awarded. Five points will be awarded if the presenter has a good understanding of the assigned topic and if the presenter(s)' understanding of the assigned topic exceeds the written material provided in the guidebook

D-4 Judges Questions

The judge's questions will be pulled from the oral presentation, the tabletop display and the potential judges questions in the guidebook (see page 17). A maximum of ten points will be awarded if the presenter(s) give answers to the judge's questions in detail that exceeds that of the material in the H.P. Guidebook. Five points will be awarded if the presenter(s) is able to answer the judge's questions in line with the printed material and one point will be awarded if the presenter(s) is unable to answer the judge's questions satisfactorily.

E. Web site

Four categories will be judged regarding the team's website; navigation/organization, communication of the team's activities, visual appeal/aesthetic design and usefulness to other rocketeers. All good web sites are organized, efficient about communicating information, and visually interesting. Keep in mind they are focused on their message. For example, a rocket team web site would not host a school activity calendar.

E-1 Navigation/Organization Up to ten points will be awarded for web site navigation and organization. One point will be awarded if navigation to other pages is difficult, the navigation buttons are difficult to use or find, or if it takes more than three clicks to get anywhere on the site. Five points will be awarded if the navigation buttons are easy to find and use, layout is logical, no more than three clicks to get to any place in the site. Ten points will be awarded if the site incorporates all of above features plus navigation is intuitive and/or animation is used to guide you through the site.

E-2 Team Activities The activities covered in the "communicates the team's activities" section include rocket construction/finishing, theodolite construction, web site development, table display creation, payload design/construction & oral presentation preparation. Ten points will be awarded if all of the team's activities are described and well documented with diagrams, drawings and/or photographs. Five points will be granted if most of the team's activities are described and some are documented with drawings or photos. Only one point will be awarded if there is minimal description or documentation of the team's activities and no drawings or photos are used.

E-3 Visual Appeal/Aesthetic Design The next category is the website's visual appeal and aesthetic design. If the site lacks coherent design, exhibits an inconsistent look between pages and the graphics/animations are distracting or inappropriately used only one point will be awarded. If the site is visually appealing, exhibits a consistent look between pages, and the use of color, graphics and animation is appropriate five points will be awarded. If the site is exceptionally appealing, very creative and exhibits an appropriate/meaningful use of graphics and animation ten points will be awarded.

E-4 Usefulness to Other Rocketeers The last category in the website section is the site's usefulness to other rocket-

eers. If there is minimal assistance to other rocketeers one point will be awarded. Five points will be given if helpful tips and hints for other rocketeers are incorporated and ten points will be awarded if extensive helpful tips and hints are incorporated into the site with descriptive diagrams, graphs or photos.

F. Payloads **(Optional for new rocket teams)**

For the 2008 MAC all teams participating in the Payload Category will be required to construct a mechanical altimeter based on a common design provide by MAC organizers. Teams will also be required to construct a chamber for calibrating their altimeter.

F-1 Documentation: Payload Project Log Judges will be looking for four items when judging this category: (a) hand-written, legible entries, (b) entries that appear accurate and complete, (c) inclusion of procedures, observations, data collected, drawings, tables and photographs and (d) the original bound notebook with the pages numbered and a table of contents. If all four of these items are evident judges will award 20 points, if three are evident 15 points will be awarded, and so forth.

F-2 Payload Calibration Process In this category judges will also be looking for four items: (a) the necessary tools for measurement (i.e. tool for measuring altitude in chamber and length of finishing line), (b) a detailed and accurate graph, (c) quality and neatness of calibration chamber construction, and (d) sufficient trials. If items a, b and c are present 15 points will be awarded, if only two are present 10 points will be awarded and so forth.

A maximum of 5 points will be awarded in the “sufficient trials” category, with 5 points for 20 or more trials, 4 points for 15 to 19 trials, 3 points for 10 to 14 trials, 2 points for 5 to 9 trials and 1 point for fewer than 5 trials.

F-3 Execution of Design In the “execution of the design” category the judges will be looking at three items: (a) the quality and neatness of the payload’s construction, (b) whether the payload housing accommodates the MAC supplied altimeter. (c) how the payload is mounted in the payload housing, how easily it can be removed and confirmation that the mounting method doesn’t interfere with the operation of the payload. If three items are present 20 points will be awarded, if two are present 12 points will be awarded and if only one is present six points will be awarded.

F-4 Accuracy To score this category judges will compare payload derived altitude with the altitude registered by the onboard electronic altimeter. Scores will be awarded based on per cent of error; 0-9% error 20 points, 10-15% error 15 points, 16-20% error 10 points, 21-25% error 5 points. No points will be awarded for an error of 26% or greater.

F-4a Accurate and Efficient Method Five points can be awarded by the judges for an accurate and efficient method of altitude determination after rocket recovery. Graph interpolation and other methods will be considered.

G. Altitude Determination - Written Test

This category requires a two-member (maximum) team to calculate the maximum altitude of a rocket (including payload), based on the physical characteristics of the rocket and rocket motor. The test is administered on Friday afternoon during the MAC event and will take about 1 hour. A procedure for calculating maximum altitude is included in the guidebook and can be downloaded at the Michigan Aerospace Challenge website. Students may use calculators (non-programmable) and one side of a 3”x 5” card to record equations. The card may only contain equations, no words or instructions. Cards will be checked before the test is administered.

H. Altitude Determination –Theodolite Method

There are two observation stations at the launch site area that are used by students to collect angle data at the rocket’s apogee. The angle data is then used to calculate the rocket altitude. A procedure for calculating measured altitude is included in this guidebook. The first two rockets launched at the competition will carry an electronic altimeter. MAC officials will take team measurements and calculate “measured” altitude then compare the “actual” altitude from the onboard altimeter to the calculated altitude. Points are awarded based on percentage error.

I. Rocket Flight Performance

Points are awarded to each team based on the actual performance of the rocket. There are three categories in the flight performance section; recovered in flyable condition, straps, lines and connectors intact at recovery and flight stability.

I-1 Flyable Condition Ten points will be awarded if the rocket is recovered in flyable condition and no points if it is not refluable.

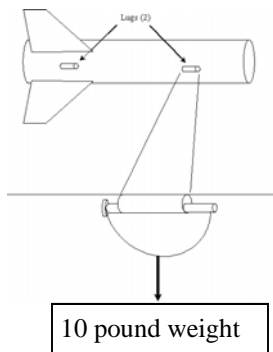
I-2 Damage of Straps, Etc. If the straps, shroud lines and connectors sustain serious damage during flight only one point will be awarded. Five points will be awarded if only one of these items (straps, shroud lines and connectors) sustains damage and ten points will be awarded if there is no damage at all.

I-3 Flight Stability In the area of flight stability no points will be awarded if the rocket loses a fin, becomes unstable or tumbles. Five points will be awarded if the rocket fishtails slightly through the entire flight. Ten points will be awarded if the rocket travels straight and true.

J. CPR Mechanical Conversion (Optional)

Experienced rocket teams may choose to build a Kit-2 Rocket (a more complicated and larger rocket with a close proximity recovery system --CPR) that uses a computer interfaced with a barometer to deploy the recovery system. This recovery system uses gunpowder along with the electronics to deploy the parachute. As an engineering challenge, students may convert this system to another (less violent) energy source. Examples may include, springs, compressed gas, electrical motors or combinations of these. The design should be simple, low cost and well executed. If teams choose to modify the CPR, please send a full description of the modification to MAC officials no less than one month before the event (rwitham@muskegonisd.org.)

Launch Lug Test



Each MAC rocket kit has two launch lugs that will be tested for adhesion to the rocket booster tube. The launch lugs are critical components that guide the rocket along the launch rail before sufficient rocket speed allows the rocket fins to provide stability of flight. The metal launch lugs are attached with epoxy to the booster tube according to assembly instructions.

The rocket booster will be placed in a horizontal position and rotated so the launch lugs are in the down position. A 3/8" diameter x 3.5" long bolt with a rigid wire harness will be placed into the launch lug. A 10-pound weight will be attached to the rigid wire harness in such a way that the force is equally shared with both ends of the launch lug. A successful test result will be no separation between lug and booster tube when a 10-pound force is applied.

Sample Oral Presentation Questions

Questions related to rocket construction.

- What was most difficult about constructing the rocket?
- What unique solutions to construction problems were developed?
- How were the fins aligned during construction?
- How were the launch lugs aligned?
- How was the surface design and painting accomplished?
- What materials and techniques were used to fill the body tube spiral?

Questions related to rocket operation.

- How does the parachute deploy?
- How is the rocket designed to be stable?
- How does a rocket motor produce an upward force on the rocket?
- Why do the assembly instructions place the parachute closer to the payload section?
- Why is the rocket launched on an 8 foot long metal rod?

Note: Teams should also be prepared to answer questions the judges might ask about their mechanical altimeter payload project and their payload project log..

Rocket Altitude Estimation High School

There are a number of ways to estimate the altitude of a model rocket -some more accurate than others. The method used depends on the information available. The process outlined here will be straightforward involving two distinct calculations, distance traveled through the *thrust phase* and distance traveled through the *coast phase* (after the motor burns out, the rocket coasts to apogee). In both phases, the initial velocity and acceleration of the rocket and phase duration must be determined to calculate distance traveled. If you perform the calculations that are included here your answers may differ slightly due to differences in rounding

Thrust Phase:

First, it is helpful to know how rocket motors are rated. Rocket motors are rated with a concept called TOTAL IMPULSE. The total impulse value represents the average force produced multiplied by the total burn time of the motor, i.e. Total Impulse = average force x burn time ($I_T = F_{avg.} \times t_{burn}$). For example, 300 Newton's of force generated for 2 seconds yields a total impulse of 600 Newton-seconds (Ns); $600Ns = 300N \times 2 \text{ sec}$. An identically rated motor of 600 Ns may average 200N of force over a longer three second burn time yielding the same total impulse, $600Ns = 200N \times 3s$. The second motor generates less force but exerts this force over a longer period of time. Theoretically, both motors will lift identical rockets to the same altitude, but in the real world aerodynamic drag will affect the rockets differently.

**Total Impulse =
average force x burn time**

$$I_T = F_{avg.} \times t_{burn}$$

1

In rocket flight calculations it is important that all forces, velocities and accelerations directed in the upward direction be given a "sign" component different than quantities directed downward. In this article, "+" and "-" will be used for quantities directed upward and downward respectively. (Quantities, which have both direction and size, are called "vector" quantities.)

Vector Quantities

"+" - upward direction

"-" - downward direction

2

The first step in calculating an estimated altitude is to determine the net force on the rocket. The net force is the result of adding together all upward and downward forces acting on the rocket. Upward forces = average motor force. Downward forces = rocket weight due to gravity *and* drag due to air resistance.

Net upward force

$$F_{net} = F_{up} + F_{down}$$

$$F_{net} = F_{motor} + (F_{weight} + F_{drag})$$

3

The upward force of the motor is determined by dividing the motor total impulse by total burn time. $F_{motor} = I_T / t_{burn}$. A motor having a total impulse of 600 Ns and burning for 2 seconds will generate an average force of 300N over the 2-second burn time.

Motor Average Force

$$F_{motor} = I_T / t$$

$$F_{motor} = 600Ns / 2sec.$$

$$F_{motor} = 300N$$

4

Next, determine the weight of the entire rocket in Newtons. Since the rocket's weight decreases as fuel burns we will use an average weight. One-kilogram mass has a weight of approximately 10 N (9.8 Newtons to be more precise). For the example calculations, a 3kg or 30N rocket including payload and fuel (0.5kg) will be used (about 6.5 lb).

Note: The weight of the rocket is given a negative sign because weight acts in the downward direction.

Next, the drag force (F_{drag}) will be considered. Estimating the drag force for any rocket is tricky business. Major factors affecting aerodynamic drag are rocket cross-sectional area, nose cone shape, rocket body finish, fin shape and finish, atmospheric density and rocket speed. The best method is data from wind tunnel tests or actual flight data. It will be left to the reader to select methods for drag determination.

For the example, accelerometer data from an actual RFS kit-1 flight will be used. An RFS kit-1 at engine burnout (I284W motor) measured a drag force of approximately 25N (-1" g") as measured by the accelerometer. If the drag force can be assumed to increase uniformly from zero N at ignition to 25N at motor burnout (two seconds later) then an average drag force of $25\text{N} / 2 = 13\text{N}$ may be assumed over the entire two seconds.

As mentioned earlier, the Net Upward Force can be calculated by adding the average motor force, average rocket weight and drag force. (Note that the weight and drag force are given negative signs because each is a vector quantity directed downward.) In our example, the net upward force is calculated to be 259N.

Next, the average acceleration of the rocket through the thrust phase will be determined using Newton's second law of motion. $F_{\text{net}} = ma$. In fancy language the law states that the acceleration of an object is directly proportional to the force applied (and in the same direction) and indirectly proportional to the mass. Since the acceleration is desired, the " $a_{\text{avg.}} = F_{\text{net}} / m$ " form of the above equation is used. Get F_{net} from box 7, the average mass from box 5.

An average acceleration of 93 m/s^2 means, the rocket will increase its speed an average of 93 m/s every second. Knowing the average acceleration, the upward distance traveled through the thrust phase can finally be determined by using the equation $d = v_i t + 1/2 a t^2$. Since the initial velocity (v_i) is zero the $v_i t$ component equals zero and is ignored. Now the acceleration and burn time of the

Rocket Weight

Mass w/ fuel = 3.0 kg
 Mass w/o fuel = 2.5 kg
 Average Mass = 2.8 kg

$$F_{\text{weight}} = -2.8\text{ kg} \times 10\text{m/s/s}$$

$$F_{\text{weight}} = -28\text{N}$$

5

Drag Force

$$F_{\text{drag}} = -13\text{N}$$

6

Net Upward Force Calculation

$$F_{\text{net}} = F_{\text{motor}} + (F_{\text{weight}} + F_{\text{drag}})$$

$$F_{\text{net}} = 300\text{N} + (-28\text{N} + (-13\text{N}))$$

$$F_{\text{net}} = 259\text{N}$$

7

Average Rocket Acceleration - Thrust Phase

$$a = F_{\text{net}} / m$$

$$a = 259\text{N} / 2.8\text{ kg}$$

$$a = 93\text{ m/s}^2$$

8

Distance Traveled - Thrust Phase

$$d = v_i t + 1/2 a_{\text{avg.}} t_{\text{burn}}^2$$

$$d = 0 + 1/2 (93\text{ m/s}^2) (2.0\text{sec})^2$$

$$d = 186\text{ m}$$

9

motor can be substituted. For our example rocket, the altitude achieved during the thrust phase is calculated to be 186 meters (~500 ft.)

Coast Phase:

During the “coast” phase the rocket has no thrust - gravity and drag are pulling back on it resulting in reduced speed (negative acceleration). To determine the distance traveled through the “coast” phase the equation $d = v_i t + 1/2 a t^2$ is again applied. The initial velocity (v_i) of the **coast** phase is the final velocity of the **thrust** phase. “t” is the time of “coasting” and “a” is the acceleration of the rocket during the coast phase. Determine V_i using $v = a t$. “a” is the average acceleration through the thrust phase and “t” is the total time the rocket experienced this average acceleration (motor burn time).

The acceleration component (a_{coast}) in the equation $d_{\text{coast}} = v_{i\text{-coast}} t + 1/2 a_{\text{coast}} t^2_{\text{coast}}$ is that due to the gravitational pull on the rocket (-10m/s^2 for any “free falling object) *and* the drag force caused by friction between the rocket and the atmosphere. Calculate acceleration using the equation: $a_{\text{coast}} = (F_{\text{drag}} + F_{\text{weight}}) / m_{\text{rocket}}$. The drag force is the same as calculated above : -13N . F_{weight} is the weight and mass of the rocket without fuel. $a_{\text{drag}} = (-13\text{N} + (-25\text{N}) / 2.5\text{kg} = -15 \text{ m/ s}^2$.

The duration of the coast phase (t_{coast}) is the total motor delay (t_{delay}) minus the burn time (t_{burn}). The delay fuse starts burning at the same time the motor ignites. For our example, a ten second delay fuse and 2 second motor burn results in an 8 second coast phase (10 second delay - 2 second burn = 8 second “coast”).

Substituting the above values into the equation:
 $d_{\text{coast}} = v_{i\text{-coast}} t + 1/2 a_{\text{coast}} t^2_{\text{coast}}$ results in the coast phase displacement.

Thrust Phase

distance traveled = 186m

10

Coast Phase

Initial Velocity of Coast Phase = Final Velocity of Thrust Phase

11

Final Velocity of Thrust Phase

$V_{f\text{-thrust}} = a t$ $V_{f\text{-thrust}} = 93 \text{ m/s}^2 (2.0 \text{ sec})$ $V_{f\text{-thrust}} = V_{i\text{-coast}} = 186 \text{ m/s}$

12

Acceleration - Coast Phase

$a_{\text{coast}} = (f_{\text{drag}} + f_{\text{weight}}) / m_{\text{rocket}}$ $a_{\text{coast}} = (-13\text{N} + (-25\text{N})) / 2.5\text{kg}$ $a_{\text{coast}} = -15 \text{ N}$

13

Coast Phase Duration

$t_{\text{coast}} = (t_{\text{delay}}) - (t_{\text{burn}})$ $t_{\text{coast}} = (10 \text{ sec.}) - (2 \text{ sec.})$ $t_{\text{coast}} = 8 \text{ sec.}$

14

Coast Phase Displacement

$d_{\text{coast}} = v_{i\text{-coast}} t + 1/2 a_{\text{coast}} t^2_{\text{coast}}$ $d_{\text{coast}} = (186 \text{ m/s})(8\text{sec.}) +$ $1/2 (-15 \text{ m/ s}^2)(8\text{sec.})^2$ $d_{\text{coast}} = 1008 \text{ m}$
--

15

The final step is to add the thrust and coast phase displacements together. For our example: $186\text{m} + 1008\text{m} = 1194\text{m}$. This translates into approx. 3800ft.

Total Displacement

$$d_{\text{total}} = d_{\text{thrust}} + d_{\text{coast}}$$

$$d_{\text{total}} = 186\text{m} + 1008\text{m}$$

$$d_{\text{total}} = 1194 \text{ m}$$

16

The calculations above assume a perfectly vertical launch. If the launch angle (measured from vertical) can be determined, a rough correction involves using the cosine function. Multiply the cosine value of the launch angle (A_{launch}), by the calculated altitude as described above. For our example, a launch angle of 15° will be assumed.

Correction for Launch Angle:

$$d_{\text{corrected}} = d_{\text{total}} \text{Cos} (A_{\text{launch}})$$

$$d_{\text{corrected}} = (1194\text{m}) \text{Cos} (15^{\circ})$$

$$d_{\text{corrected}} = (1194\text{m}) (.97)$$

$$d_{\text{corrected}} = 1158\text{m}$$

17

Rocket Altitude Estimation Middle School

There are a number of ways to estimate the altitude of a model rocket -some more accurate than others. The method used depends on the information available. The process outlined here will be straightforward involving two distinct calculations, distance traveled through the *thrust phase* and distance traveled through the *coast phase* (after the motor burns out, the rocket coasts to apogee). In both phases, the initial velocity and acceleration of the rocket and phase duration must be determined to calculate distance traveled.

Thrust Phase:

First, it is helpful to know how rocket motors are rated. Rocket motors are rated with a concept called TOTAL IMPULSE. The total impulse value represents the average force produced multiplied by the total burn time of the motor, i.e. Total Impulse = average force x burn time ($I_T = F_{avg.} \times t_{burn}$). For example, 300 Newton's (N) of force generated for 2 seconds yields a total impulse of 600 Newton-seconds (Ns); $600\text{Ns} = 300\text{N} \times 2 \text{ sec}$. An identically rated motor of 600 Ns may average 200N of force over a longer three second burn time yielding the same total impulse, $600\text{Ns} = 200\text{N} \times 3\text{s}$. The second motor generates less force but exerts this force over a longer period of time. Theoretically, both motors will lift identical rockets to the same altitude, but in the real world aerodynamic drag will affect the rockets differently.

In rocket flight calculations it is important that all forces, velocities and accelerations directed in the upward direction be given a "sign" component different than quantities directed downward. In this article, "+" and "-" will be used for quantities directed upward and downward respectively. Quantities, which have both direction and size, are called "vector" quantities. Examples include: velocity, acceleration and force.

The first step in calculating an estimated altitude is to determine the net force on the rocket. The net force is the result of adding together all upward and downward forces acting on the rocket. Upward forces = average motor force. Downward forces = rocket weight due to gravity. (Drag due to air resistance will not be considered.)

The upward force of the motor is determined by dividing the motor total impulse by total burn time. $F_{motor} = I_T / t_{burn}$. A motor having a total impulse of 600 Ns and burning for 2 seconds will generate an average force of 300N over the 2-second burn time.

Total Impulse
=average force x burn time

$$I_T = F_{avg.} \times t_{burn} \quad 1$$

Vector Quantities

$$\begin{array}{l} \text{"+" - upward direction} \\ \text{"-" - downward direction} \end{array} \quad 2$$

Net upward force

$$\begin{array}{l} F_{net} = F_{up} + F_{down} \\ F_{net} = F_{motor} + F_{weight} \end{array} \quad 3$$

Motor Average Force

$$\begin{array}{l} F_{motor} = I_T / t \\ F_{motor} = 600\text{Ns} / 2\text{sec.} \\ F_{motor} = 300\text{N} \end{array} \quad 4$$

Next, determine the weight of the entire rocket in Newtons. Since the rocket's weight decreases as fuel burns we will use an average weight. One-kilogram mass has a weight of approximately 10 N (9.8 Newtons to be more precise. For the example calculations, a 3kg or 30N rocket including payload and fuel (0.5kg) will be used (about 6.5 lb). **Note:** The weight of the rocket is given a negative sign because weight acts in the downward direction.

Rocket Weight

Mass w/ fuel = 3.0 kg Mass w/o fuel = 2.5 kg Average Mass = 2.8 kg $F_{\text{weight}} = -2.8 \text{ kg} \times 10\text{m/s/s}$ $F_{\text{weight}} = -28\text{N}$	5
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As mentioned earlier, the Net Upward Force can be calculated by adding the average motor force and average rocket weight. (Note that the weight is given a negative sign because it is a vector quantity directed downward.) In our example, the net upward force is calculated to be 272N.

$F_{\text{net}} = F_{\text{motor}} + F_{\text{weight}}$ $F_{\text{net}} = 300\text{N} + (-28\text{N})$ $F_{\text{net}} = 272\text{N}$	6
---	---

Next, the average acceleration of the rocket through the thrust phase will be determined using Newton's second law of motion. $F_{\text{net}} = ma$. In fancy language the law states that the acceleration of an object is directly proportional to the force applied (and in the same direction) and indirectly proportional to the mass. Since the acceleration is desired, the " $a_{\text{avg.}} = F_{\text{net}} / m$ " form of the above equation is used. Get F_{net} from box 6; the average mass from box 5.

Average Rocket Acceleration Thrust Phase

$a = F_{\text{net}} / m$ $a = 272\text{N} / 2.8 \text{ kg}$ $a = 97.1 \text{ m/s}^2$	7
--	---

An average acceleration of 97.1 m/s^2 means, the rocket will increase its speed an average of 97.1 m/s every second. Knowing the average acceleration, the upward distance traveled through the thrust phase can finally be determined by using the equation $d = v_i t + 1/2 a t^2$. Since the initial velocity (v_i) is zero the $v_i t$ component equals zero and is ignored. Now the acceleration and burn time of the motor can be substituted. For our example rocket, the altitude achieved during the thrust phase is calculated to be 194.2 meters (~500 ft.)

Distance Traveled - Thrust Phase

$d = v_i t + 1/2 a_{\text{avg.}} t_{\text{burn}}^2$ $d = 0 + 1/2 (97.1 \text{ m/s}^2) (2.0\text{sec})^2$ $d = 194.2 \text{ m}$	8
--	---

Coast Phase:

During the "coast" phase the rocket has no thrust - gravity is pulling back on it resulting in reduced speed (negative acceleration). To determine the distance traveled through the "coast" phase the equation $d = v_i t + 1/2 a t^2$ is again applied. The initial velocity (v_i) of the coast phase is the final velocity of the thrust phase. "t" is the time of "coasting" and "a" is the acceleration of the rocket during

Thrust Phase

distance traveled = 194.2m	9
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Coast Phase

Initial Velocity of Cost Phase = Final Velocity of Thrust Phase	10
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the coast phase. First, determine V_i using $v = a t$. “a” is the average acceleration through the thrust phase and “t” is the total time the rocket experienced this average acceleration (motor burn time).

Final Velocity of Thrust Phase

$$\begin{aligned} V_{f\text{-thrust}} &= a t \\ V_{f\text{-thrust}} &= 97.1 \text{ m/s}^2 (2.0 \text{ sec}) \\ V_{f\text{-thrust}} &= V_{i\text{-coast}} = 194.2 \text{ m/s} \end{aligned}$$

11

The acceleration component (a_{coast}) in the equation $d_{\text{coast}} = v_{i\text{-coast}} t + 1/2 a_{\text{coast}} t^2_{\text{coast}}$ is that due to the gravitational pull on the rocket (-10m/s^2 for any “free falling object”).

Acceleration - Coast Phase

$$\begin{aligned} a_{\text{coast}} &= a_{\text{gravity}} \\ a_{\text{coast}} &= -10 \text{ m/s}^2 \end{aligned}$$

12

The duration of the coast phase (t_{coast}) is the total motor delay (t_{delay}) minus the burn time (t_{burn}). The delay fuse starts burning at the same time the motor ignites.) For our example, a ten second delay fuse and 2 second motor burn results in an 8 second coast phase (10 second delay - 2 second burn = 8 second “coast”).

Coast Phase Duration

$$\begin{aligned} t_{\text{coast}} &= (t_{\text{delay}}) - (t_{\text{burn}}) \\ t_{\text{coast}} &= (10 \text{ sec.}) - (2 \text{ sec.}) \\ t_{\text{coast}} &= 8 \text{ sec.} \end{aligned}$$

13

Substituting the above values into the equation:

$d_{\text{coast}} = v_{i\text{-coast}} t + 1/2 a_{\text{coast}} t^2_{\text{coast}}$ results in the coast phase displacement.

Coast Phase Displacement

$$\begin{aligned} d_{\text{coast}} &= v_{i\text{-coast}} t + 1/2 a_{\text{coast}} t^2_{\text{coast}} \\ d_{\text{coast}} &= (194.2 \text{ m/s})(8\text{sec.}) + \\ &\quad 1/2 (-10 \text{ m/s}^2)(8\text{sec.})^2 \\ d_{\text{coast}} &= 1233.6 \text{ m} \end{aligned}$$

14

The final step is to add the thrust and coast phase displacements together. For our example: $194.2 \text{ m} + 1233.6\text{m} = 1427.8\text{m}$. This translates into approximately 4500ft.

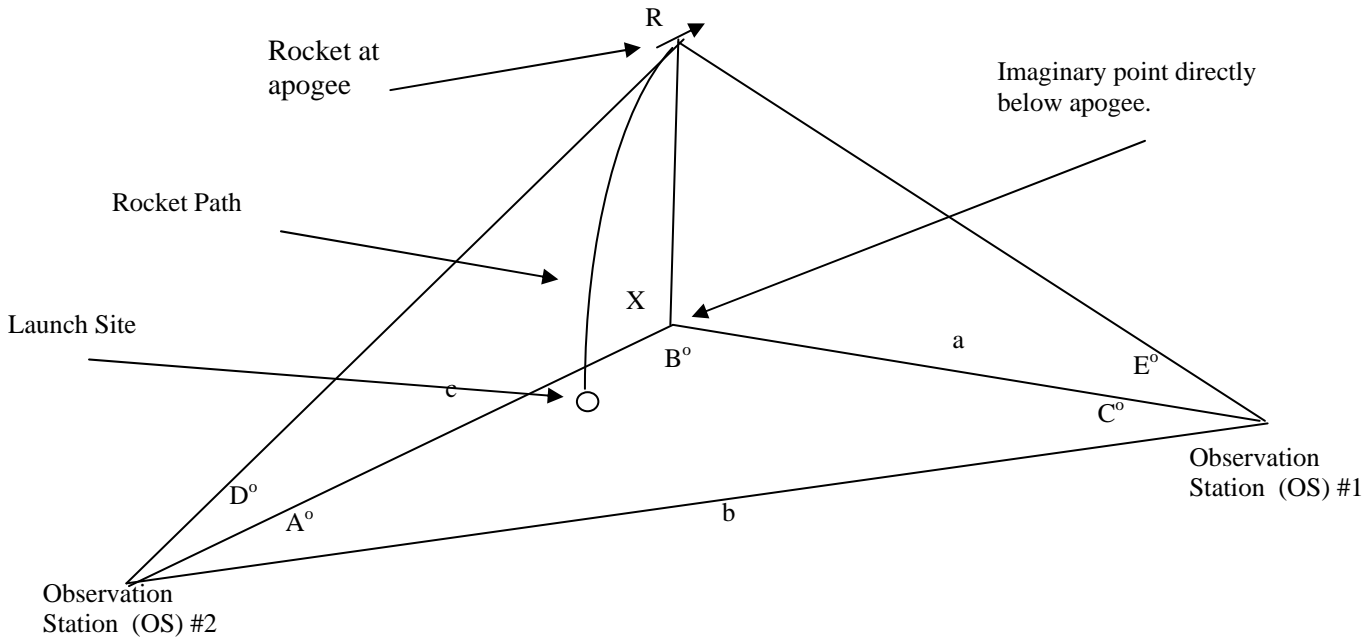
Total Displacement

$$\begin{aligned} d_{\text{total}} &= d_{\text{thrust}} + d_{\text{coast}} \\ d_{\text{total}} &= 194.2\text{m} + 1233.6\text{m} \\ d_{\text{total}} &= 1427.8\text{m} \end{aligned}$$

15

DETERMINING ROCKET ALTITUDE THEODOLITE METHOD

Each rocket team is required to build two theodolites for determining rocket altitude. The theodolite is used to obtain the vertical and horizontal angles of position of the rocket at apogee. This data is then used to determine altitude. This measured/calculated altitude may be compared to the actual altitude (as determined by an onboard altimeter supplied by launch officials) and used for comparison (competition).



$$\text{Altitude 1 (RX)} = (\sin C^\circ)(\tan D^\circ)[b/\sin(180^\circ - (A^\circ + C^\circ))]$$

$$\text{Altitude 2 (RX)} = (\sin A^\circ)(\tan E^\circ)[b/\sin(180^\circ - (A^\circ + C^\circ))]$$

(Find the average of the two results. The average is considered a very good estimate of the actual altitude if each result is within 10% of the average.)

A° = angle between bearings - OS #2 -> X & OS #2-> OS #1 D° = altimeter reading at OS #2
 C° = angle between bearings - OS #1 -> 2 & OS #1-> X E° = altimeter reading OS#1
 baseline b = **will be given prior to first theodolite rocket launch**

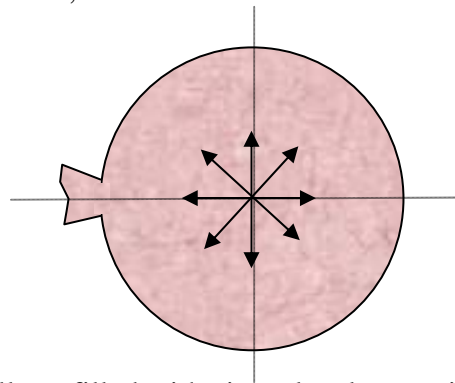
If angles A and/or C are obtuse, substitute the supplementary angle (180-obtuse angle) into the equation.

How a Rocket Motor Works

Understanding how a rocket motor works requires an understanding of the behavior of gas molecules. All rocket and jet motors (sometimes called engines or ‘reaction engines’) use hot gases to produce force. The gas molecules are created from a chemical reaction between molecules of liquid or solid fuel and oxidizer. The chemical reaction produces much heat (exothermic). The heat causes the resulting product (gas molecules) to attain very high speeds. The speedy molecules move in random directions resulting in violent collisions among particles and on engine surfaces. Collisions between these high-speed particles and the inside surface of the reaction engine cause the desired force to produce forward motion.

A balloon is often used as a familiar example to explain how reaction engines produce motion. Unfortunately, most of these explanations are not helpful. The most common (and incorrect) explanation suggests that the air molecules rushing out of the balloon is an ACTION and the balloon moving in the opposite direction is the REACTION. Students hearing the above believe that the gases rushing out of the engine produce the forward motion. This is counter intuitive and wrong. This explanation relies on a misinterpretation of Newton’s third law – *for every action there is an equal and opposite reaction* – and does not explain the forward motion. More on this later. To discover the cause of a balloon’s motion (as air escapes) one must study what occurs inside the balloon, not outside.

Fig. 1

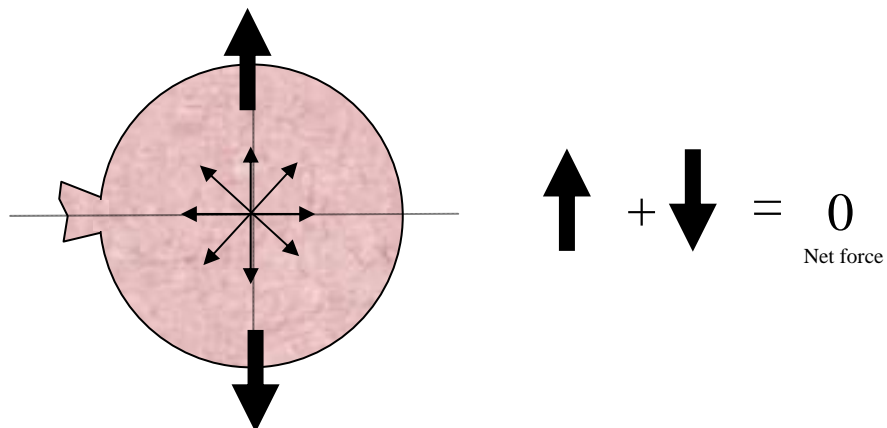


The diagram above shows a balloon filled with air molecules moving in random directions at high speed. At room temperature, air molecules move at over 1000 miles per hour! (Much hotter rocket engine gases travel at thousands of miles per hour.) In the following discussion, the balloon will be divided into hemispheres – top, bottom, front and rear (where the gas escapes).

Looking at the molecules in the top and bottom hemispheres, the moving molecules produce a net upward and downward force due to violent collisions with the inside surface. Because the top and bottom hemisphere have the same geometry and the speeding molecules, on average, strike both surfaces with the same speed and mass, equal forces are created. Adding these opposite and equal forces together results in a zero net force.

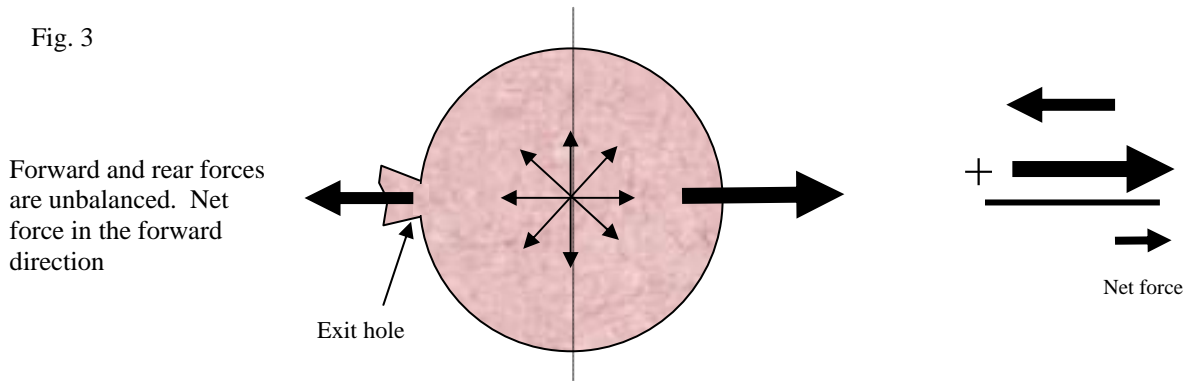
Fig. 2

Upward and downward forces due to gas molecules colliding with surface inside balloon.
Net force equals zero.



The front and rear hemispheres have different geometry. The rear hemisphere has a surface area equal to the front hemisphere LESS the area of the exit hole. Thus, the rear hemisphere surface area is less than the front hemisphere. Speeding air molecules colliding with less surface area will produce less force. The rear hole then, allows for a smaller rearward force compared to the forward force.

Fig. 3

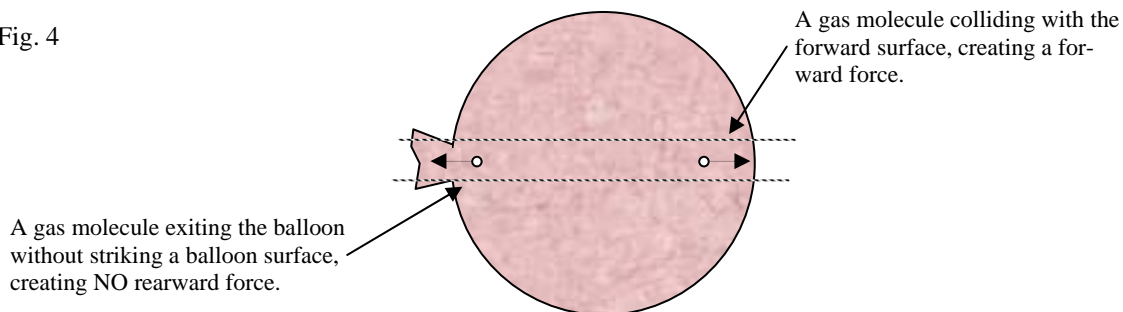


The forward force of a reaction engine is due to an unbalanced force generated because of a greater surface area at the front of the engine. The key points here are – 1) Molecules striking the rear hemisphere create a force that tends to move the balloon rearward. 2) The balloon does not move rearward because of a greater forward force in the front hemisphere.

The above discussion is a good approximation of what really happens in reaction engines. Rarely are the opposite hemispheres of equal geometry. As geometries differ though the action of gas molecules striking them always result in a net forward force.

Where is this ACTION and REACTION business taking place that textbooks often refer to? The air molecules at the front hemisphere strike it causing a forward force - ACTION. The REACTION is the balloon pushing back on the colliding molecules - causing them to rebound. If we simplify what actually happens in the balloon we may consider that the molecules rebounding from the front hemisphere and opposite the rear opening are directed to the opening at the rear and exit without striking anything,

Fig. 4



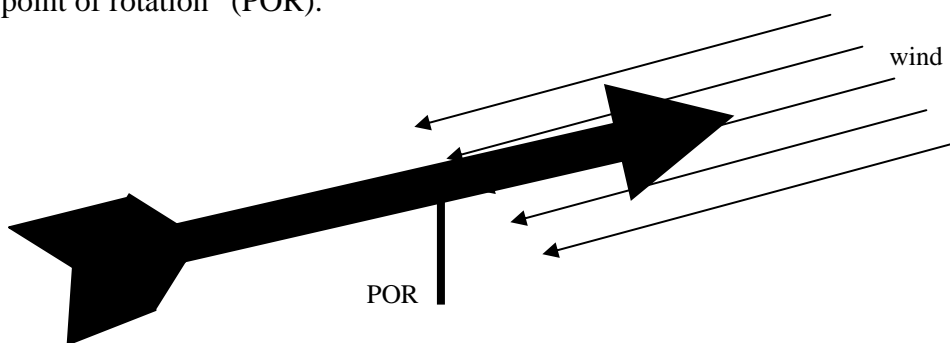
The cause of the balloons motion is the gas molecules striking at the front – creating a forward force - ACTION. After a gas molecule strikes the balloon we can imagine it rebounding moving toward the rear of the balloon. This rebound is caused by the balloon creating an equal and opposite REACTION force on the gas molecule to send it rearward. The escaping gas molecules (moving rearward due to a REACTION force) have done their work at the front of the balloon and we "see" them leaving after they have produced a forward force on the balloon. The rush of gas molecules exiting the rear of the balloon is evidence of the balloons REACTION force on the gas molecules. The ACTION and REACTION forces correspond to the force of collision (ACTION) then the corresponding opposite and equal force (REACTION) from the balloon on the colliding molecule. Newton intended his law to read - "forces are created in (equal and opposite) pairs".

So, escaping gas is not the cause of the balloon (rocket, jet airplane) motion as many textbooks usually suggest. The sight of escaping gas is a "symptom" of the cause - frontal collisions and corresponding rebound of energetic gas particles. Much like a runny nose is a symptom of a cold; we would not say the runny nose is the cause of the cold, but a symptom with other causes (virus). Likewise, the motion of the balloon is caused by an imbalance of collisions inside the balloon. The expelled air is only a symptom of these collisions and not the cause of motion. Ironically, all students who have a good mental model of gas molecule behavior can easily understand the real mechanism that causes reaction engines to work. There is no reason to "simplify" and risk developing misconceptions.

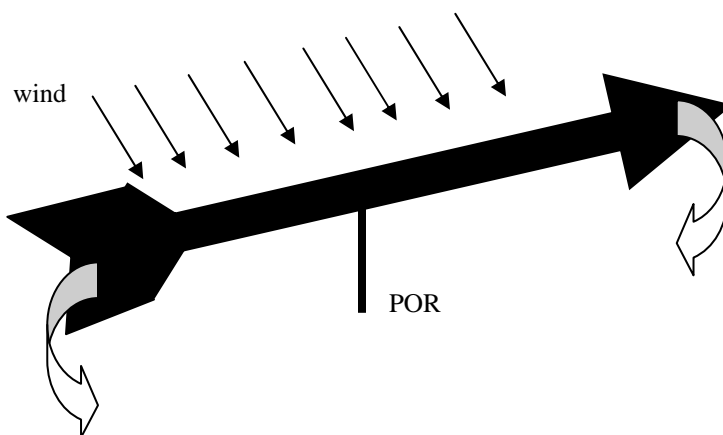
Rocket Stability

A weather vane is designed to always point into the wind. A stable rocket is designed for the same purpose. The wind for a rocket is the air movement relative to the motion of the rocket. As the rocket moves off the launch pad the rocket feels a wind due to its own motion relative to the atmosphere. A stable rocket design keeps the nose pointing into this relative wind, just like a good weather vane.

To understand better how rocket stability is achieved, it is helpful to look closely at how a weather vane works. A weather vane has a fixed pivot point about which the opposite ends rotate. We shall call this pivot point the “point of rotation” (POR).

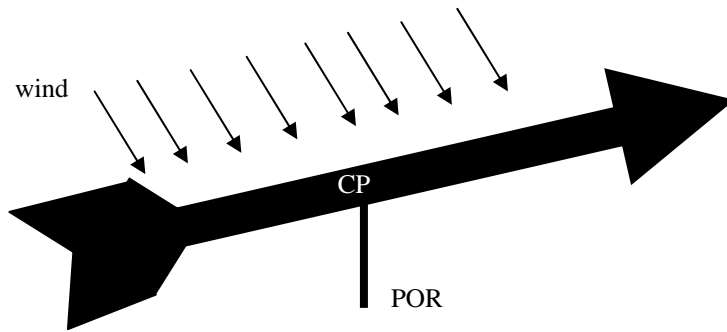


Imagine that the POR on a simple weather vane is moveable and is moved to a position where the wind has no effect in rotating the vane.

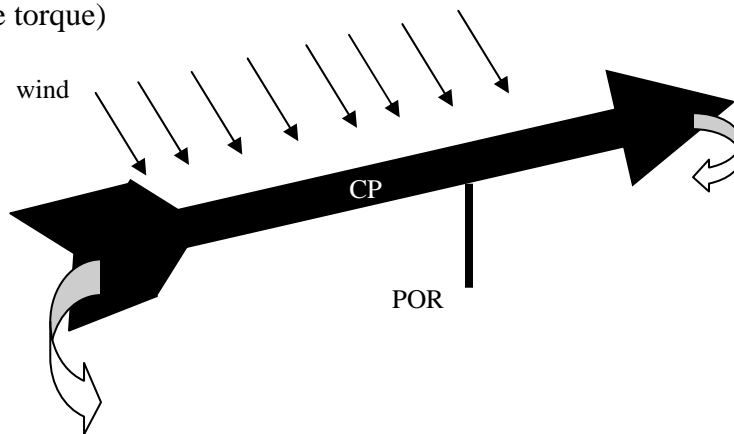


In the diagram above the POR has been moved closer to the tail of the vane. In this position the wind has an equal but opposite turning effect on each end of the vane. Ahead of the POR, the wind wants to turn the vane clockwise (CW). Behind the POR, the wind wants to rotate the vane counter-clockwise (CCW). Placing the POR here produces an equal CW and CCW turning effect or ‘torque’.

There is only one POR like this on the weather vane. Any other POR will allow the weather vane to rotate either CW or CCW. The POR that produces no rotation in a side wind is called the center of pressure (CP).



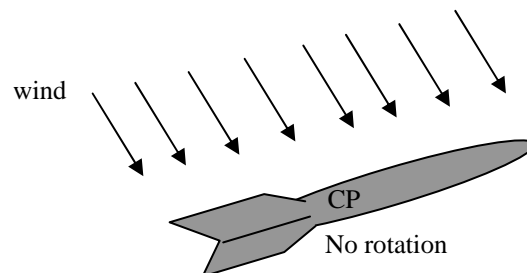
Having the POR of the weather vane at the CP does not make for a very good weather vane. If the weather vane does not reliably point into the wind we refer to it as “unstable”. How is it made stable? Moving the POR from the CP point toward the head of the vane will produce more torque on the tail section (The surface area behind the POR increases along with the distance between POR and the average surface area. Both factors increase torque)



In summary, a weather vane is stable (will reliably point into the wind) when the POR is ahead of the CP. In other words, the POR is between the CP and the end of the vane desired to be pointing into the wind.

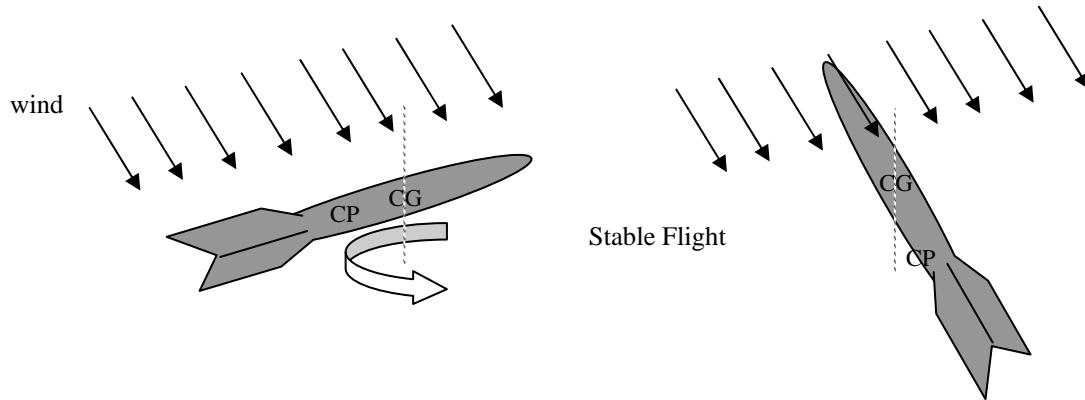
Rocket stability works the same way. Rocket designers want the POR of the rocket to be between the CP and the nose cone. The POR of a rocket is more abstract than the POR of the weather vane. How is the POR of a rocket found? And for that matter, the CP?

The CP of a rocket can be found mathematically, indirectly or directly. Only the direct method will be explained now. When the rocket is completed, tape a string to the body. Suspend the rocket on the string in a breeze from a box fan. The rocket will probably rotate. Move the string on the body until no rotation occurs (Clay weights may have to be placed inside the rocket to get it to balance.). Where the string is attached, and no rotation occurs, is called the CP.



Now find the POR of the rocket. Like a weather vane all rockets have a POR but unlike the weather vane, the rockets' POR is not as obvious. All objects that are in 'free-flight' have a natural POR. You can prove this by taking any object (a stick will do) and throwing it into the air so it rotates. The center of rotation is the POR. Add some clay to one end of the stick and toss it aloft again and the POR will change. There is another name for this POR for any object in free flight. – center of gravity (CG). The CG can more easily be found by simply balancing the object on a finger. When the balance point is found the natural POR (CG) for the object is also found.

When finding the POR for a rocket it is important to balance the rocket in a launch configuration; meaning the motor, parachute and other materials that will be launched with the rocket are in place. **A stable rocket will have the POR or CG in front of the CP** –just like a weather vane.



A simple test of rocket stability begins by finding the CG. Balance the rocket (in launch configuration) on the edge of a ruler. Tie a string to this point and swing the rocket in a circle. If the rocket tumbles or flies tail first – it is unstable. Do not attempt to launch it! If the rocket is unstable the CP must be too close to the CG or ahead of it. To reverse this situation, one of two simple changes can be made to the rocket. Add weight to the nose cone (this moves the CG forward) or increase the fin size or area (this moves the CP backward toward the rear of the rocket.) In some cases both the CG and CP can be moved so the CG ends up ahead of the CP. Question to ponder. Weight is lost from the rear of the rocket as the motor burns in flight. How does this affect the stability of the rocket? How do rocket designers take this weight loss into account?

Tips For Completing A Rocket Project That Scores Well and Launches Safely.

The challenge of building a high power rocket kit lies in careful assembly of the many components beneath the simple looking exterior. Many of the terms used in the following paragraphs are defined in the rocket kit assembly instructions. Please read them carefully.

Aft Booster Assembly

The most important rocket quality for a safe launch is having three solidly attached fins. Fin integrity will be tested before launch. If the rocket fails this test, it is unlikely that corrections can be made in a short time period to safely launch the rocket. Each fin passes through the body (booster) tube and butts up against the motor mount tube. This geometry creates three surfaces that contact both sides of each fin (inside and outside surface of the booster tube and the motor mount tube outside surface). Where a fin surface meets a tube surface a good amount of epoxy must connect the two (called a fillet). Both surfaces (fin and tube surface) must be roughed up with course sand paper to enhance adhesion. The three fins, along with the surfaces described create the need for eighteen (18) fillets.

Another critical construction area is at the base of the fins. A doughnut shaped plywood piece called the aft motor mount-centering ring (AMMCR) is epoxied up against the base of all three fins. The most common error for beginning rocket builders is to have the AMMCR in place but not recessed enough to rest against the base of the three fins. Plan for this placement during the fin fillet process described above. The AMMCR must be removed during construction then reinserted as described above. The instructions may suggest using scotch tape tabs to help remove the AMMCR. A better method is to screw two screw eyes or dry wall screws partway into it to use as handles. The 'handles' can be removed after the AMMCR is epoxied in place.

Forward Booster Tube and Payload Sections

Inside the booster tube is a piston that pushes the parachute out of the booster tube at apogee. The piston is driven by an explosion of hot gases produced in the top chamber of the rocket motor. This piston must move freely and smoothly through the entire length of the booster tube. A common error is to check the piston movement near the forward end of the booster tube and not check the aft end. At launch, the piston with parachute sitting above it may be forced toward the aft end of the booster tube. If the piston becomes wedged in place it may have difficulty deploying the parachute or excessive pressures created between the motor and stuck piston can cause the booster tube to rupture. Either problem results in disaster. Keeping stray epoxy from the booster tube area above the forward motor mount-centering ring will aid in obtaining proper piston function.

The payload section connects to the booster tube with a coupler tube. One-half of the coupler tube is epoxied into the base of the payload section and the other half must slide smoothly into the forward booster tube. A proper fit is estimated by holding the completed rocket vertically by the payload section. The payload should not separate from the booster section unless the payload section is jerked upward a couple times, allowing the weight of the booster section to pull the two sections apart.

Information/Suggestions for Teams

1. **Tool Kits** – Bring a tool kit including tape, sandpaper, epoxy, x-acto knife, etc. If modifications of the rocket are required for launch, you want to be ready.
2. **Volunteers** – Coaches are asked to volunteer for a couple hours on Saturday. Some assignments require previous experience, but most require only a few minutes of instruction. We appreciate your help. Sign-up at on-site registration – April 30. You will be scheduled for a time that does not conflict with your launch time.

Motor Loading
Payload/Parachute Packing Station
Traffic Control at the launch site

Launch Pad Monitor
Motor Removal — post launch
Boat Launch Monitor

3. **Pre-Launch Meeting** - A mandatory meeting to announce last minute details and to review rocket preparation procedures will be held Friday afternoon at 3:30 pm. The location of the meeting will be announced. Each team's student launch prep team is expected to attend.

Pre– Launch Checklist

This is a duplication of a card that will be given to team members
(Motor Build will be completed by MAC Officials)

Student Pre-Launch Checklist

- Motor mount (inside) is clear (no epoxy) to allow motor insertion
- Piston moves smoothly — full range of motion
- Piston strap is secure
- Shock cord is attached to piston
- Parachute is attached at 1/3 position on the shock cord
- Shock cord is attached to payload section
- Payload — coupler bulk plate (plywood) and eyebolt are secure
- Payload section fits smoothly into booster section

On-site Preparation— Completed by MAC Officials

- Launch lugs secure
- Motor nozzle plus installed
- Motor installed — retainer attached
- Standard parachute deployment device is utilized

Payload Section — Students to Perform

- Payload is inserted
- Nose cone is secure — rivets are inserted
- Ready to Launch (All above boxed checked)**

Michigan Aerospace Challenge
Rocket Kit, Motor Casing and Fuel Order Form
Order Information
(Due March 13, 2009)

Name of Organization _____

Shipping Address _____

City _____ State _____ Zip _____ Contact Person _____

Phone: (____) _____ FAX (____) _____ E-mail _____

Rocket Kit - (ordered from Math/Science center only)

Rockets For Schools **Kit 1** - Required for new teams -- \$115. each. Shipping included.

Purchase – RFS **Kit 1** \$115.00 each. # of Kits _____ Subtotal for RFS Kits _____

Motor Casing

A motor casing is an aluminum tube for holding solid fuel and has a forward closure and aft nozzle retainer. All RFS-1 rockets will use a 38/600 motor casing. Teams may choose to rent a 38/600 casing for a \$25 fee.

Purchase – 38/600; \$120.00 each. # of Casings _____ Subtotal for Casings _____

Rental – 38/600; \$25.00 each. # of Casings _____ Subtotal for Casings _____

Purchased Motor casing and fuel will be safely stored in Muskegon by program officials.

Only qualified personnel will handle fuel at the April launch weekend.

Purchased motor casing will be surrendered to owner after launch.

Fuel (Reload).

Purchase – I284 Reload for 38/600 casing - @ \$ 50.00 each. (For all RFS-1 & 2 rockets)
reloads 1/rocket _____ Subtotal for Reloads _____

Total for rocket kits / motor casings / reloads \$ _____

(No shipping charges required)

Payment Method: Bill Us Check Enclosed

Purchase Order Number (if Applicable) _____

You may include a check, Purchase Order or request that we bill you. Please contact the Math/Science Center at (231-767-7318 or 213-767- 7316) with billing instructions. If you are paying by check please have it made out to: Muskegon Area Intermediate School District. Send Kit/Motor Casing/Fuel Reload Order Form to Michigan Aerospace Challenge, MAISD Regional Math/Science Center, 1001 Wesley Avenue, Muskegon, Michigan 49442. Or you may fax to 231-773-0505.

Rocket Kits can be ordered from a commercial vendor.

RFS Kit-1 rocket kits can also be ordered from a commercial vendor. Contact either Red Arrow Hobbies at 5095 Red Arrow Highway, Stevensville, MI 49127, (269-429-8233) or Public Missiles, Ltd. At 349 Cass Avenue, #C, Mt. Clemens, MI 48043 (888-782-546). Experienced teams may choose to build a launch a RFS Kit-2 rocket (purchase price approx. \$240. Kit-2 rockets utilize a close proximity recovery module for delayed parachute deployment to facilitate recovery closer to the launch point. The Co-pilot module controls the deployment (purchase cost approx. \$125) with an altimeter and includes the ejection system. Call Public Missiles for current pricing and ordering information.

Michigan Aerospace Challenge

Team Registration Form

Muskegon, Michigan – April 24 & 25, 2009

Due March 13, 2009

NO Registration Fee required / One registration form per team

Team Name _____ Circle One: JR MS HS

Sponsoring Organization _____

(School, M/S Center, Scout troop, Church, etc.)

Org. Address _____ City _____ State ____ Zip _____

Team Advisor _____

Home Address _____ City _____ State ____ Zip _____

Send additional information to Organization Address Advisor's Home Address

Phone (W): (____) _____ FAX: (____) _____

Phone (H): (____) _____

E-mail Address: _____ Web Site Address: _____

(Please complete one form for each team that is participating)

First Year of Participation - for Advisor? YES NO -for all Students? YES NO

Type of Rocket: (check one)

- RFS Kit-1** - (New teams – choose this one)
 Re-fly RFS Kit-1 - (Must refinish & have payload)
 RFS Kit-2 - (For experienced teams only)

Motor Casing (check one)

- We will **purchase** motor casing(s) from MRMSC.
 We will **rent** a motor casing(s) from MRMSC.
 We will **bring our own** motor casing(s) MRMSC
(Please contact R. Witham at rwitham@muskegonisd.org prior to the event)

Rocket Fuel (check one)

- We will **purchase** fuel (reload) through MRMSC.
 We will **supply our own** fuel

Judging Categories (Specific information about each category can be found on pages 8 –14)

- | | |
|---|---|
| A. Fit & Finish – Rocket Construction | F. Payload (optional for first year teams) |
| B. Artistic Design | G. Altitude Determination – Written Test (actual vs. calculated) |
| C. Tabletop Display | H. Altitude Determination – Theodolite Method (actual vs. measured) |
| D. Oral Presentation | I. Rocket Flight Performance |
| E. Web Site (optional, but included in score) | K. CPR Conversion |

The MAISD Regional Mathematics and Science Center is not acting as a dealer in any purchase transactions for those teams purchasing motor casings and fuel. Purchased motor casings and fuel will be safely stored in Muskegon by program officials. Only qualified personnel will handle fuel on the April launch date. Purchased motor casings will be returned to owner after the launch.

Michigan Aerospace Challenge Rocket Team – On-Site Registration Form

Turn in at Registration on April 24th – Fill out one form for each team

Team Name _____ Circle One: MS JR HS
(If one school or organization has more than one rocket/team each must have a name)

Sponsoring Organization _____
(M/S Center, Scout troop, School or other, if any)

Team Advisor(s) _____

First year of participation for school/organization? YES NO

If not how many years has school/organization been participating? _____

The MAC no longer classifies elements of the program as mandatory or optional, with the exception of the website category. We encourage teams to participate in as many elements as possible. However, each team must build a rocket, create a tabletop display, prepare and give an oral presentation and construct two theodolites. Please indicate below the activities your team will participate in.

- Rocket Construction Fit & Finish
- Rocket's Artistic Design
- Team tabletop display:
- Oral presentation
- Website (optional)
- Payload
- Rocket Flight Performance—you will automatically be judged in this category when your rocket is recovered
- CPRRFS Kit 2 – Mechanical Conversion (optional)
- Altitude Determination – Written test
- Altitude Determination – Theodolite method

Name of Students Participating the in Oral Presentation _____

Name of Students Participating in the Written Test _____

Are you bringing your own motor casing (circle one) YES NO

**If you are bringing your own motor casing, please contact Rick Witham
at (231)767-7316 or rwitham@muskegonisd.org.**

Do you know of parents/grandparents who are attending the program? (Please ask team members).
of persons _____

Do you know of parents/brothers/sisters/relatives who are using local motels?
of persons _____

Michigan Aerospace Challenge
Student Participation Form — Part One
(Submit this form on Friday April 24 at Registration)

Special Note: All forms must be completed and signed by parent/guardian before youth can participate in "Michigan Aerospace Challenge" activities.

COVENANT NOT TO SUE INDEMINITY AGREEMENT

The term "sponsors" as used herein includes the MAISD, MAISD Regional Math & Science Center, MI Aviation Hall of Fame, City of Muskegon Michigan, County of Muskegon Michigan, U.S. Coast Guard, their officers, agents, contractors, employees or any persons using facilities in conjunction with the Michigan Aerospace Challenge Program in Muskegon, Michigan on April 24 & 25, 2009.

I. Agreement

I _____(participant's name) will voluntarily participate in the Michigan Aerospace Challenge Program held April 24 & 25, 2009 in Muskegon, Michigan. I understand that program participation includes the launching of sport rockets and that during the launch I will be in the open at least 200 feet beyond the launch danger area. I also acknowledge that I may be exposed to other unknown hazards associated with this and other operations at the launch site in Muskegon.

In consideration for the above named sponsors permitting me to participate in the rocket launch and other activities held at the West Michigan Dock and Market Corporation (known as the "Mart Dock Property" and the launch site), the Frauenthal Center for the Performing Arts and the Walker Arena in Muskegon, I, for myself, my heirs, administrator, executors, and assignees, hereby covenant and agree that I will never institute, prosecute, or in any way aid in the institution of prosecution of, any demand, claim or suit against the above named sponsors and or their officers, agents, employees, or facility users, acting officially or otherwise, for any loss, damage, or injury (including death) to my person or my property which may occur from any cause whatsoever as a result of my participation in this activity.

I understand and agree that I am assuming the risk or any personal injury, death, or property damage that may result while participating in this activity.

Date: _____ Participant's Signature _____

II. Agreement for Minor Participant:

For "minor" (minor's name): _____

I/we, parent(s) and/or legal guardian(s) of the above named minor hereby consent to him/her participating in the activities of the Michigan-Rockets for Schools Program, agree to the provisions of the above agreement, and adopt it as my own.

Date: _____ Signature: _____

Address: _____ City: _____ State: _____

I understand that participants are sometimes photographed and/or videotaped during Rockets for Schools activities. I am giving my permission to MAC to use images of my son/daughter in promotional and/or educational ways. CIRCLE ONE: YES NO

Parent/Guardian Signature or Student if 18 years or older

Date

I give my permission the MAISD to add a link on our Math/Science Center Web page to your son/daughter's rocket's web page.

Parent/Guardian Signature or Student if 18 years or older

Date

One form for each team member must be submitted

Michigan Aerospace Challenge

Student Participation Form — Part Two

Special Note: All forms must be completed and signed by parent/guardian before youth can participate in “Michigan Aerospace Challenge” activities.

(Submit this form on Friday April 24 at Registration)

Student Name: _____

Address: _____

City: _____

State: _____ **Zip:** _____

Phone Number: _____ **Age:** _____

School: _____ **Grade:** _____

Team Advisor: _____

EMERGENCY INFORMATION

EMERGENCY PHONE NUMBERS:

NAME: _____	PHONE NUMBER: _____
NAME: _____	PHONE NUMBER: _____

Information Needed Regarding Participants

YES **NO**

If yes, indicate below.

Is there any chronic problem or illness?

Is there any acute illness now present?

Has the person been treated recently for some medical problem?

List any medications now being taken for treatment of any medical problem.

Are there any allergies to medication?

Date of last tetanus shot

Medication: Students will be responsible for their own medication(s). There will not be a nurse on duty but emergency services will be supplied by the Muskegon Fire and Police Department.

One form for each team member must be submitted

Student Pre-Launch Checklist

- Inside of Motor mount () is clear (no epoxy)
- Piston Moves smoothly — full range of motion
- Piston strap is secure
- Shock cord is attached to piston
- Parachute is attached at 1/3 position on the shock cord
- Shock cord is attached to payload section
- Payload — coupler bulk plate (plywood) and eyebolt are secure
- Payload section fits smoothly into booster section

MAC Officials On-site Preparation/Checklist

- Launch lugs secure
- Motor nozzle plug installed
- Motor installed — retainer attached
- Standard parachute deployment device is utilized

Payload Section — Students to Perform

- Payload is inserted
- Nose cone is secure — NYLON screws are inserted
- Ready to Launch (All above boxed checked)