

# ***Wind-Powered Vehicle Feasibility Demonstration***

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**Program: Student Engineering Contest**



85 Collamer Crossings  
East Syracuse, NY 13057

*Detect the Difference*

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## 2 OVERVIEW

Sensis is expanding into the eco-friendly ground vehicle market. In order to evaluate the feasibility of wind-powered vehicle concepts, Sensis is soliciting proposals for the design, construction and demonstration of an affordable, high-performance, wind-powered ground vehicle.

Sensis is sponsoring a competitive evaluation program prior to awarding the procurement contract. The objective of this evaluation program is to downselect to a small set of potential vendors. Each bidder will design, construct and demonstrate a scale model of a wind-powered ground vehicle that satisfies key performance objectives. All prospective bidders are required to participate in this evaluation program.

The vehicle will be tested for both downwind and upwind performance. Also, since the vehicle will ultimately be marketed to a wide range of customers, simplicity and minimization of configuration changes are critical performance attributes. Steering systems and cross-wind performance will not be examined in this program.

For safety and consistency, and to ensure cost-effectiveness of the final design, the materials used to build the device will be prescribed by Sensis.

## 3 PERFORMANCE OBJECTIVES

The scoring system is set up to evaluate the prototype vehicle based on its ability to satisfy the following performance objectives (listed in no particular order):

- **Downwind Capability** – The ability of the vehicle to travel downwind
- **Upwind Capability** – The ability of the vehicle to travel upwind
- **Speed** – The ability of the vehicle to maximize distance traveled in a particular amount of time
- **Ease of Use** – The ability to reconfigure the vehicle for upwind vs. downwind travel with minimal user interaction
- **Manufacturing Cost** – The time and materials required to construct the prototype

## 4 VEHICLE REQUIREMENTS

The wind-powered ground vehicle shall be constructed solely from materials on the Sensis approved materials list (See Appendix B: Approved Material List). The vehicle shall be capable of direct downwind travel and direct upwind travel on the Track described in Appendix A: Track. All parts needed for upwind and downwind travel shall remain attached to the vehicle while the vehicle is in motion. The vehicle in all configurations shall fit inside a 2 foot tall cylinder with a 2 foot diameter base.

The vehicle shall provide a means to temporarily attach to a guide-rail during the performance evaluation. (Since this phase of the program is looking solely at direct upwind and downwind performance, steering is not required.) It shall be possible to attach and remove the vehicle from the guide-rail without altering the guide-rail mounting.

## 5 DESIGN REVIEW

Shortly after the competition kickoff, each bidder will conduct a Design Review at Sensis. To complete a successful Design Review each bidder must satisfy the following criteria:

- 1) The design artifacts (slideshow and schematic) are well-written. The design artifacts will use proper English and simple language, and be thoroughly proofread.
- 2) The bidder will prepare and present a design review slideshow. The design review slideshow will:
  - a. Summarize the problem you are trying to solve.
  - b. Identify the key areas that affect the performance of your design.
  - c. Describe how each of the key areas that affect the performance will be addressed by your design.
  - d. Identify at least three tradeoffs in your design, and describe what your team did or plans to do to resolve the tradeoff.
  - e. Identify any risk areas in the design – For example, if you choose a very sophisticated subsystem for your design, how much will it weigh and what would be the impact of this weight on the overall performance?
  - f. Explain the management structure of your team.
- 3) The bidder will prepare and explain a design schematic (see Appendix A: Schematics).
  - a. The design schematic will be dimensioned in inches, and the contest prototype will follow the schematic as closely as possible. This means: extra materials that aren't specified on the schematic will not be permitted.
  - b. The design schematic will contain all of the pieces of the materials used to construct the vehicle (including spares).
  - c. The design schematic will include clear assembly instructions.
  - d. The design schematic will be used in the inspection at the Contest Demonstration. You may find that schematic changes are required between the Design Review and the Contest Demonstration. See section 7.1 for details on how to handle that situation.

## 6 CREDIT MANAGEMENT SYSTEM OVERVIEW

Sensis will use a credit management system to track how much it will cost to manufacture the vehicle. Each team will have a starting budget of 100 credits. See Table 1 for a summary of ways to earn credits. See Table 2 for a summary of how credits are spent.

**Table 1. Earning Credits**

Category	Description	Credits
Starting Budget	100 credits are allotted to each team at the beginning of the contest.	100
Design Review	Each team is scored on their Design Review performance. Teams can earn up to 25 credits for the Design Review.	25 <u>max</u>
Discretionary Fund	Sensis may award bonus credits to <i>any</i> team at <i>any</i> time for <i>any</i> reason.	15 max per team

**Table 2. Spending Credits**

Category	Description
Materials	See Section 7.1.
Schematic errors	The bidder will be charged when a part is not accurately captured in the vehicle design documents. Examples include missing parts, or parts that are improperly specified (such as the wrong length for a dowel). <del>The charge for schematic errors is to be determined at the discretion of the judges. The maximum charge for schematic errors is 20 credits.</del> See Section 7.1.
Initial build time	5 credits per minute when pre-purchased before building begins. 20 credits per minute for time over the original purchase. A fractional minute will be charged as a full minute. See Section 7.2.
Trial setup time	5 credits per minute when pre-purchased before the team begins setup for an individual trial period. 20 credits per minute for time over the original purchase. A fractional minute will be charged as a full minute. <b><i>The first minute is free.</i></b> During this time the bidder may make repairs or adjustments (using only approved and inspected materials), perform a test run, or do anything else allowed by the rules. See Section 7.3.
Penalty reduction	See Section 7.4.
Other	Other violations of requirements or contest rules will be penalized at the discretion of the judges.

## 7 DEMONSTRATION DETAILS

Each bidder shall participate in a contest where they will demonstrate the degree to which their vehicle satisfies the performance objectives in section 3 and vehicle requirements in section 4.

### 7.1 STAGE 1: INSPECTION

All material preparation (e.g., cutting, sanding, etc) will be made prior to the contest demonstration day. The bidder will arrive at the contest site with design schematics and pre-cut components. Updates to design schematics made after the Design Review must be clearly identified as redlines on the drawings.

The design will be inspected to ensure that the design documents match the pre-cut materials. Schematic penalties will be assessed at this time.

Penalties due to illegal materials and improperly identified redlines will be left up to the discretion of the judges at the inspection stage.

Material costs will be assessed at this time using the rates in Table 3.

**Table 3. Material Costs**

Material Category	Credits Charged	Example
Wheel diameter	The sum of the squares of all wheel diameters will be divided by 10. The result will be rounded up to the nearest whole number and the team will be charged that number of credits.	A vehicle uses two 3” wheels and one 2.1” wheel. $(3^2 + 3^2 + 2.1^2)/10 = 2.241$  <i>Credits charged: 3</i>
Springs & Rubber Bands	5 <del>points-credits</del> per spring 5 <del>points-credits</del> per rubber band	
Duct tape	0.5 credits per square inch of duct tape, rounded up to the nearest half square inch.	A vehicle uses 6.55 square inches of duct tape.  <i>Credits charged: 3.5</i>
Metal fasteners (see note)	Includes the following material list categories: <ul style="list-style-type: none"> <li>• simple fastening hardware</li> <li>• copper wire</li> <li>• pennies</li> </ul> Cost: 5 credits per ounce, rounded up to the nearest ounce.	A vehicle uses 1.1 ounces of metal fasteners.  <i>Credits charged: 10</i>
Everything else (see note)	Includes material not listed in the “metal fasteners,” <del>“free materials,”</del> or “duct tape” categories. Cost: 2 credits per ounce, rounded up to the nearest ounce.	A vehicle uses 3.2 ounces of non-metal-fastener materials.  <i>Credits charged: 8</i>

*Note: Bring all your materials (including spares) on contest day separated into clear plastic bags – one for “metal fasteners” and one for “everything else.” (Duct tape is excluded from these three bags.) The judges will weigh your parts in these groups, and then compare the parts to your schematics.*

## 7.2 STAGE 2: CONSTRUCTION

Vehicle construction commences after setup and inspection are complete. There will be a half hour time limit to construct the vehicle, but using less time leaves more credits for other uses.

Sensis will retain the materials after the weigh-in. After weigh-in, the bidder will organize the assigned construction area and inform the assigned judge how much initial build time is being purchased. After this, the bidder’s materials will be returned from the inspection area and the clock will start for the initial build. The clock will stop for the initial build when the completed vehicle is handed back to the judge for storing in the depot while awaiting the first trial. Unused pre-purchased credits will still be charged, and any overages will also be assessed at this time. While the bidder’s vehicle awaits its first trial it will be inspected for compliance with rules such as the vehicle dimension constraints. Any modifications required to bring the vehicle into compliance with rules will be performed by the bidder after the purchase of additional “initial build time” minutes.

### 7.3 STAGE 3: SETTING UP FOR A TRIAL PERIOD

Each bidder will test their vehicle four (4) times. Each trial period will last five (5) minutes. Each bidder will attempt to send the vehicle from the Start Line to the Finish Line and back in order to score as many points as possible.

You will tell your assigned judge the amount of trial setup time your team would like to pre-purchase BEFORE retrieving your vehicle from the depot. This purchase of time should consider your estimate of how long it will take you to repair, modify, and otherwise prepare your vehicle prior to the launch. Bonuses are also requested at this time. The clock will start when you retrieve your vehicle from the depot. Your team performs all repairs and setup at this time. The clock will stop when you have your vehicle at the line and ready to launch.

Any energy storage devices on the vehicle shall be discharged at the start of the trial period in order to ensure all vehicle motion is the result of wind-derived power. Examples of energy storage devices (which may or may not be on the approved materials list) include preloaded structural members, suspended masses, springs, and elastic materials. Determination of the state of charge of these devices will be made by the Sensis judge based on the vehicle design.

The vehicle's Reference Marker shall be in a stationary position behind the Start Line no later than 15 seconds prior to the start of the trial period. Physical contact with the vehicle by the bidder will be prohibited in the 15 seconds before the start of the trial period.

### 7.4 STAGE 4: EXECUTING A TRIAL PERIOD

The trial period will start with the fan blades in a stationary position. The start of the trial period will coincide with the application of power to the fan motor.

The vehicle shall be reconfigured for the upwind leg at the time and position of the bidder's choosing. At all times during the evaluation, the bidder shall receive verbal approval from the Sensis judge before touching the vehicle to ensure that proper credit is given for the distance traveled. The bidder shall be awarded a contact penalty each time contact is made with the vehicle, including but not limited to vehicle reconfiguration.

The contact penalty is 10 points per contact. It is possible to reduce the contact penalty by spending 5 credits per penalty point, with a minimum penalty of 5 points. That is, the bidder may use 25 points to reduce the contact penalty to 5 points per contact, but may not go lower. The request for the contact penalty reduction shall be made during the setup for a trial period, and shall only apply to the current trial period. Contact penalty reductions for future trials must be made with different credits during the setup time for that trial period.

The vehicle shall maintain the same basic orientation for the upwind and downwind legs (i.e., the vehicle is not "turned around"). If manual reconfiguration is desired, the vehicle shall be reconfigured for the next downwind leg after receiving verbal approval from the judge. The Reference Marker shall remain stationary during any reconfiguration. The bidder shall avoid adding energy to the system during any reconfiguration (i.e. lifting weights, charging elastic members, etc).

The Reference Marker crossing the Start Line in the upwind direction shall be considered the completion of the previous lap and the beginning of the next. If the vehicle does not progress all the way back to the Start Line during the upwind leg, the bidder shall move the Reference Marker back to the Start Line prior to the start of the next downwind leg. If repositioned to the Start Line, the vehicle shall be moved to the Start Line in such a way that energy is not added to the system.

## 7.5 STAGE 5: COMPLETING A TRIAL PERIOD

After the run is complete and the distance is measured, the pre-purchased credits for trial setup time will be deducted from your account (even if unused). If your team took more time than was pre-purchased, any overages will also be assessed at this time.

Next, the charge for your bonuses is deducted from your account. If setup took more time than pre-purchased, and the cost for the additional setup time causes your team to be unable to cover your contact penalty reduction bonus, you will not receive the bonus.

After the vehicle has finished its run, it will be returned directly to the depot without any modification, including repairs or charging. Any repairs, modifications, or re-charging will be done prior to the next trial using new, pre-purchased minutes for that next trial.

## 7.6 STAGE 6: COMPUTING SCORE FOR A TRIAL PERIOD

For each downwind leg the Downwind Final Marker (DFM) shall be defined as the highest valued distance marker that is completely passed by the Reference Marker. For each upwind leg the Upwind Final Marker (UFM) shall be defined as the lowest valued Distance Marker that is completely passed by the Reference Marker. Any Distance Markers passed while the bidder is in contact with the vehicle shall not count in scoring.

The score for each complete lap of the course (Downwind leg followed by Upwind leg) shall be computed as follows and rounded to the nearest integer:

$$DFM > UFM: \text{ Lap\_Score} = (DFM - UFM)^{2.58} + 2 * DFM$$

$$DFM \leq UFM: \text{ Lap\_Score} = 2 * DFM$$

The score for each Trial Period shall be the sum of all *Lap\_Score* values completed before the time expires minus the total penalty points (negative scores are possible). Any partial laps shall not be counted in the scoring.

## 7.7 FINAL SCORE

The final score is the sum of the four Trial Period scores.

# 8 APPENDIX A: TRACK

Each vehicle will be evaluated on a course that approximates a one-lane, straight roadway. The evaluation course is shown in Figure 1: Vehicle Test Course. The layout consists of a straight and level Course that is 2 feet wide and 10 feet long. One of the 2 foot edges will serve as the Start Line and the other will serve as the Finish Line. The course surface will be comparable in smoothness and levelness to a typical high school gym floor.

An approximately 20 inch box fan will be placed behind the Start Line to serve as the wind source. The fan’s protective grate will be 3 feet behind the start line. The axle of the fan blades will be approximately parallel with a line drawn down the center of the Course. The horizontal projection of the fan blade axle onto the Course will be no further than 2 inches from the centerline of the Course. The guide rail will consist of a single member at least 14 feet in length with the cross section shown in Figure 2. Distance Markers will be placed at one foot intervals from the Start Line to the Finish Line.

The bidder shall not make any alterations to the Course.

Figure 1: Vehicle Test Course

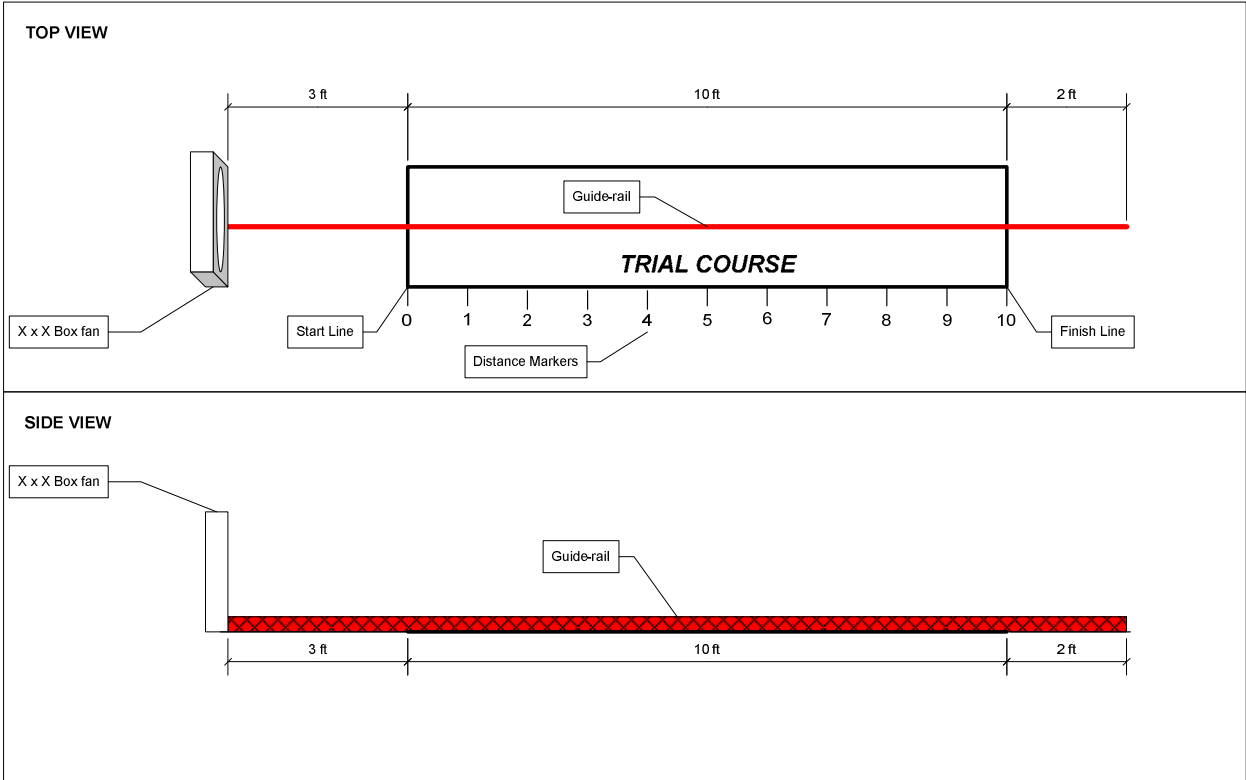
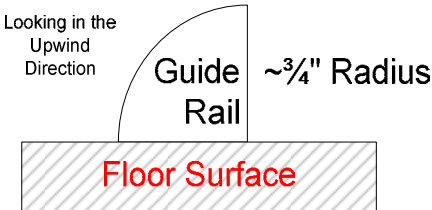


Figure 2: Gide Rail Cross-Section



## 9 APPENDIX B: APPROVED MATERIAL LIST

- 1) Wood Dowel, up to 3/8" diameter
- 2) Styrofoam blocks / sheets
- 3) Plywood, up to 1/8" thickness
- 4) Rubber blocks / sheets
- 5) Balsa wood blocks
- 6) SIMPLE fastening hardware (when in doubt, ask your mentor)
  - a) OK: screws, bolts, nuts, wing-nuts, washers, nails
  - b) NO: hinges, brackets, etc.
- 7) Duct Tape
- 8) Rubber Bands
- 9) Springs
- 10) Pennies
- 11) Copper wire (no thicker than 18 AWG)
- 12) Gears
- 13) Fabric
- 14) String

## 10 APPENDIX C: SCHEMATICS

It is important for all engineers to properly convey their design concepts to the customer. This is typically done via schematics built into design review packages.

As part of the design review all teams are required to submit schematics on their designs. A schematic is a diagram that represents the elements of a system using abstract, graphic symbols rather than realistic pictures (ref: Wikipedia).

For this competition, all teams shall include schematics of the following items:

- 1) Total vehicle assembly (identifying components and overall assembly size)
- 2) Details of the assembly process (written or graphically)
- 3) Individual drawings for each of the components/parts that will make up the vehicle

### 10.1 SCHEMATIC GUIDELINES

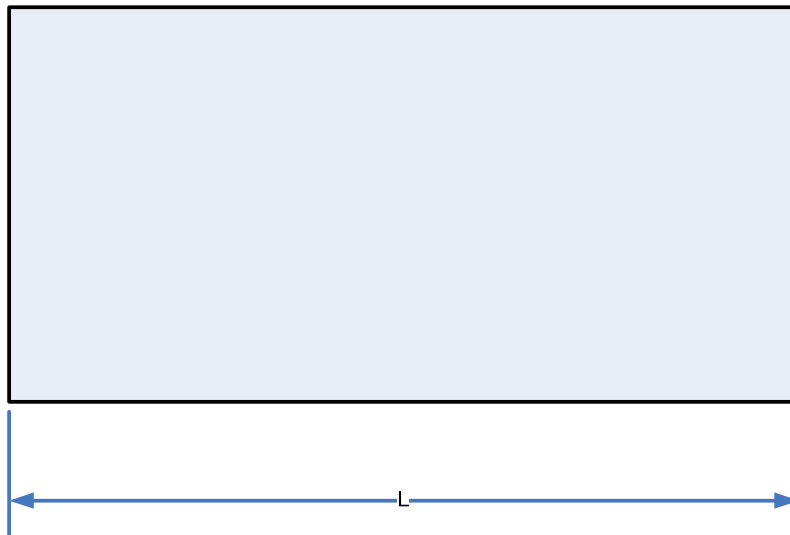
- 1) All assemblies and component drawings are basic. There is no need for excessive artistic detail.
- 2) All assemblies and components are clearly labeled with name and material.
- 3) All drawing packages start with the overall assembly drawing followed by the individual components.
- 4) All materials that make up the component are listed. For example, if the component is a modified wooden dowel the material “wood” is identified.
- 5) All assemblies and components are properly dimensioned.
- 6) When identifying dimensions, choose a view that most clearly conveys the information.
- 7) All dimensions are unambiguous.

8) All dimension lines end with arrows and all dimension values are centered.

**Bad**

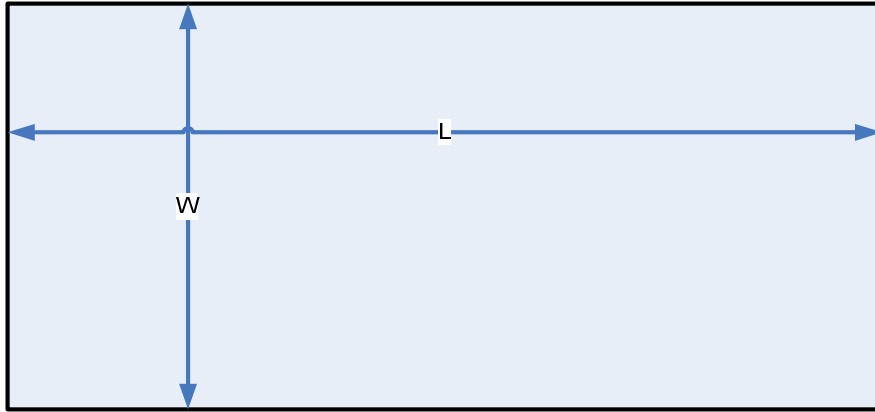


**Good**

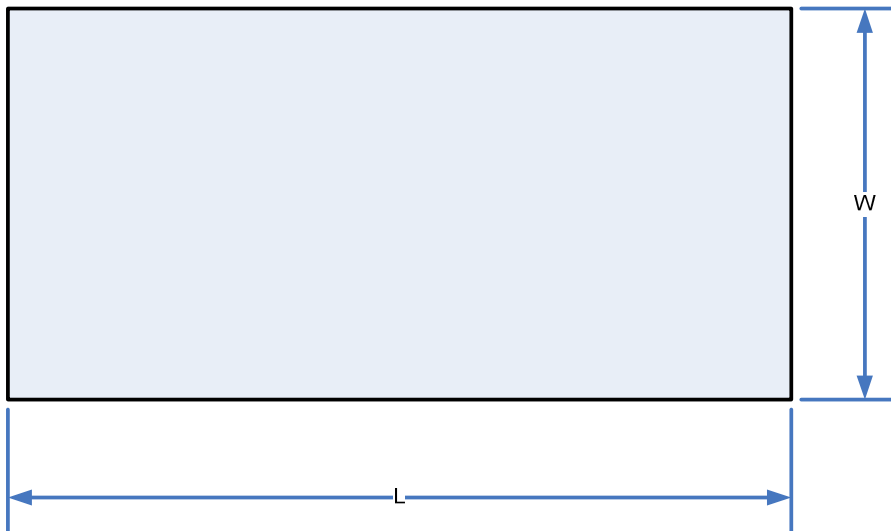


- 9) Do not clutter a view with dimensions. All part lines are clearly visible and dimension lines are clear. No dimensions are drawn within the lines of the drawn component.

**Bad**

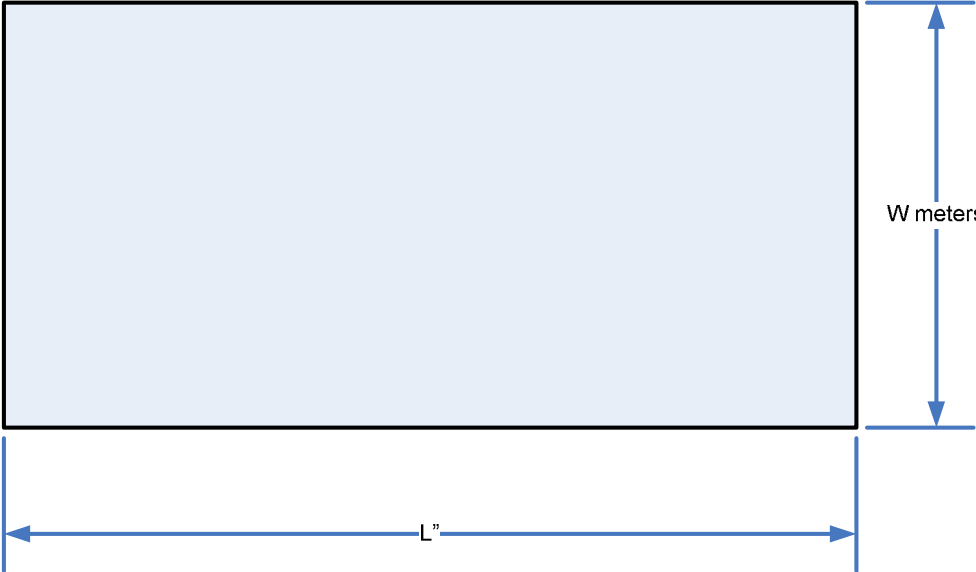


**Good**

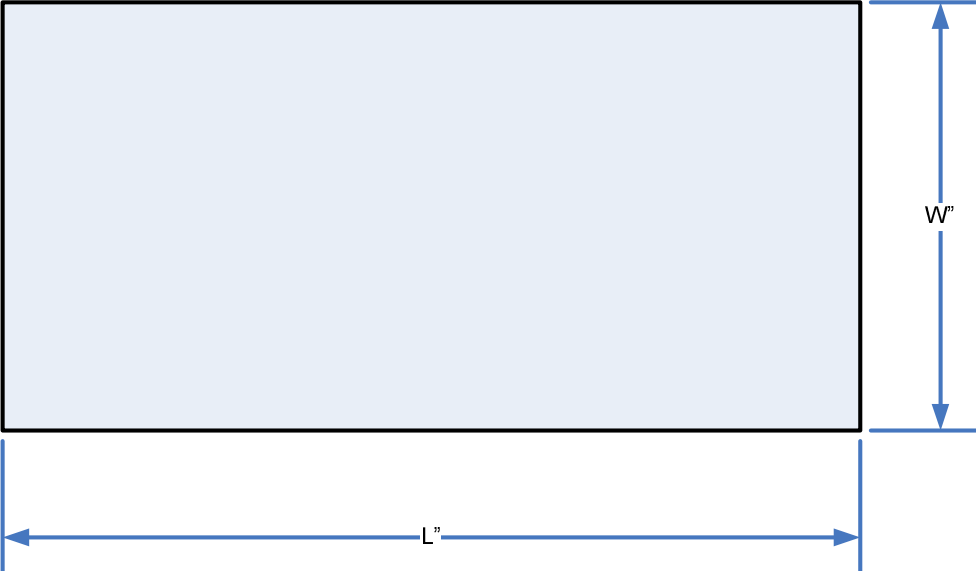


10) All dimensional units are consistent (i.e. metric should not be mixed with inches)

**Bad**

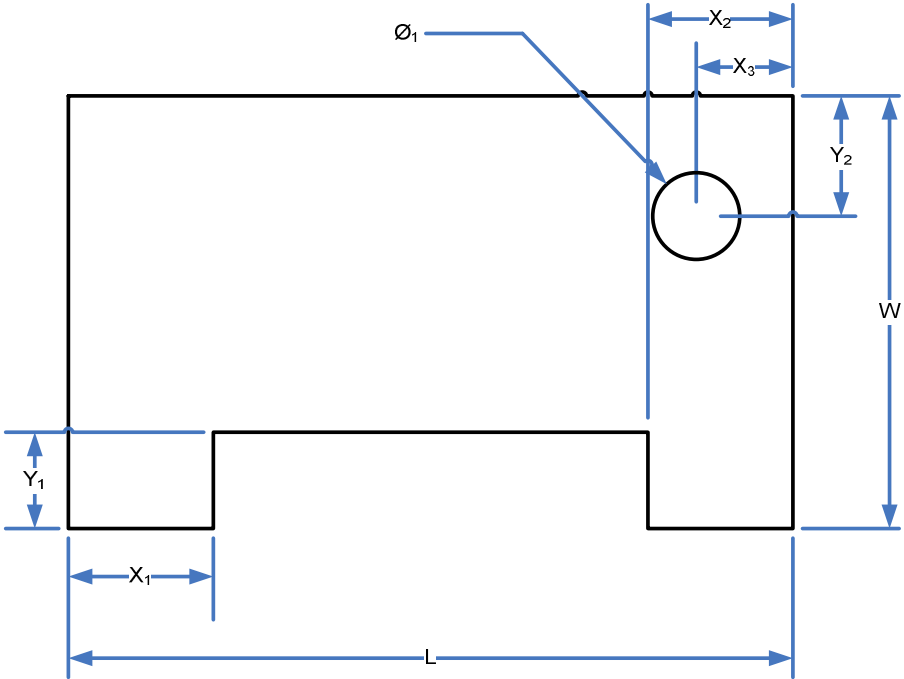


**Good**

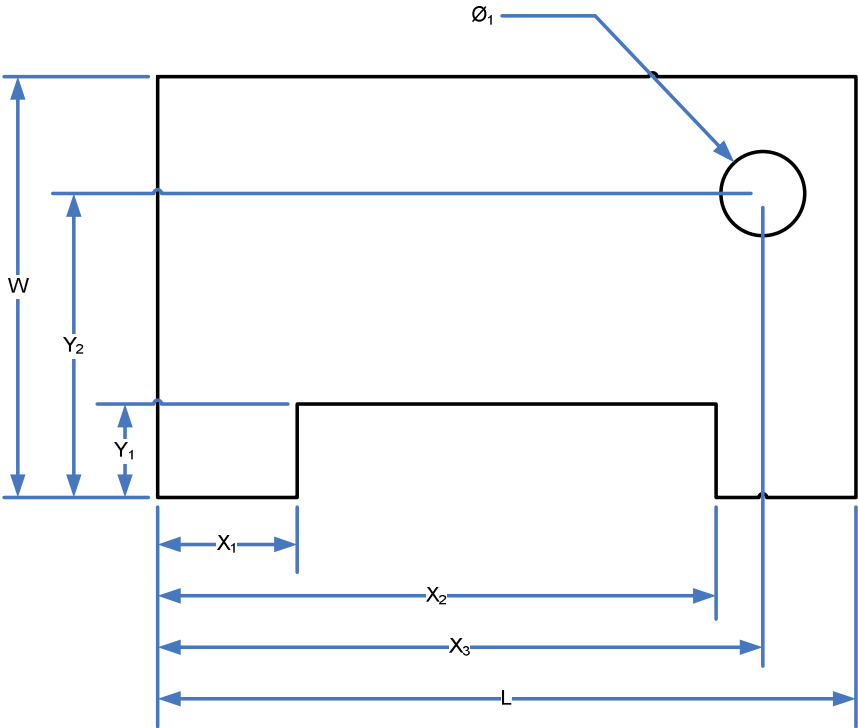


11) All dimensions are taken from one reference point.

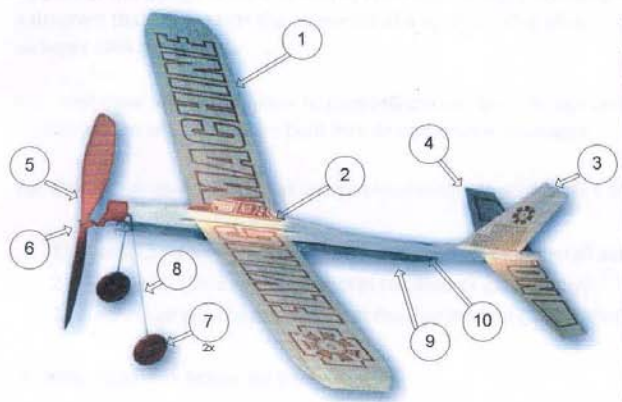
**Bad**



**Good**

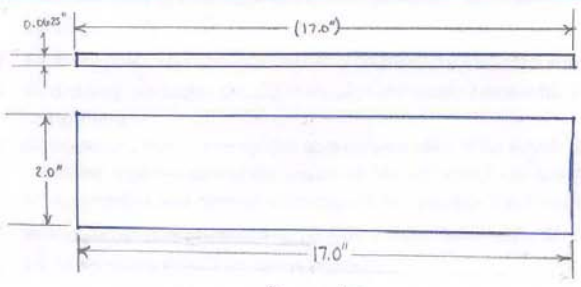


10.2 SCHEMATIC EXAMPLE



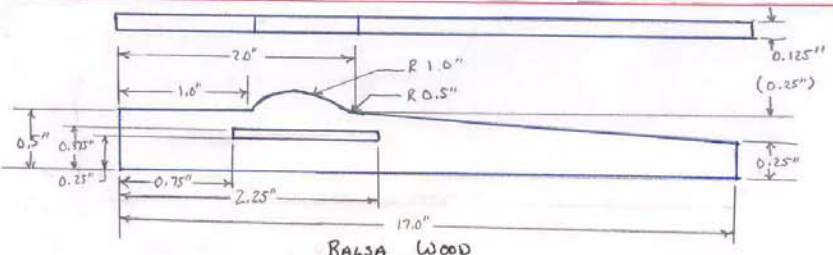
Balsa Glider Bill of Materials		
Item #	Component Name	Quantity
1	Wing	1
2	Fuselage	1
3	Vertical Stabilizer	1
4	Horizontal Stabilizer	1
5	Propeller	1
6	Propeller Axle	1
7	Wheel	2
8	Wheel axle	1
9	Rubber Band	1
10	Tail hook	1

Balsa Wood Glider Assembly

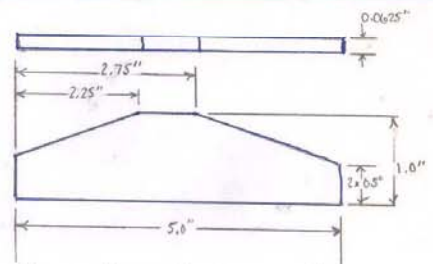


Note: All repetitive dimensions used for reference should be enclosed by "( )."

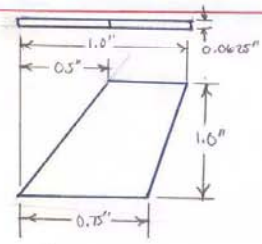
BALSA WOOD WING



BALSA WOOD FUSELAGE



BALSA WOOD HORIZONTAL STABILIZER



BALSA WOOD VERTICAL STABILIZER

## 11 APPENDIX D: HELPFUL HINTS

- 1) The test environment (hallway vs. gym) will have a big influence. It is always best to design for robustness to less “input power.”
- 2) History has shown that bidders who are well-prepared for the Design Review possess two qualities:
  - a) Being able to quickly and effortlessly build a prototype of the system. It may be helpful to have a mockup of your system at the Design Review, but this isn’t required. *Hint: A well-prepared team will bring a prototype to the Design Review.*
  - b) System design documentation is written very clearly.
- 3) If design documents are easy to follow, and you have practiced building your car, you should have no trouble building your demonstration car on the contest day.
- 4) Remember to plan for construction mishaps. Also, keep in mind that spare parts need to appear on your schematic and must be purchased with credits.
- 5) Manage your credits carefully. There are many ways to spend (and lose!) credits, and only a few ways to gain them. Having someone on your team maintain the credit budget is one way to accomplish this.