

## Walking Robot Race

### Objective

A walking robot must autonomously walk from one end of a course to the opposite end and then return back to the starting point. The robot with the fastest total round trip time will be the winner. Since different robots use different walking gaits and have different leg geometries, Alexander's Formula will be used to handicap all robots so that every robot can compete equally with every other robot.

### Definition of a Walking Robot:

- All legs must operate in a cyclical fashion.
- No wheels or rotary wheel-like appendages will be permitted for locomotion.
- The ground contact point on the foot can not revolve around some origin that is located on the leg or hip.
- The entire weight of the robot must be completely supported by the robot's legs.
- All legs must be actively used to move the robot.
- All passive legs/appendages that are used to assist in balancing the robot, or locomotion, must separate (lift/hop/move) off the ground at some point during each walk cycle.
- If the robot falls over, external appendages/arms can be used to help the robot get back on its feet.

While the famous and capable robot called [RHEX](http://www.rhex.net) ([www.rhex.net](http://www.rhex.net)) is quite spectacular in operation, it would not qualify for this event because its legs operate in a rotary motion.

### Robot Specifications

Robots must be autonomous.

- Wireless data links to off-board computers are allowed.
- Tethered data links to off-board computers are not permitted.
- No human-operated remote controls will be permitted except to start and stop the robot.

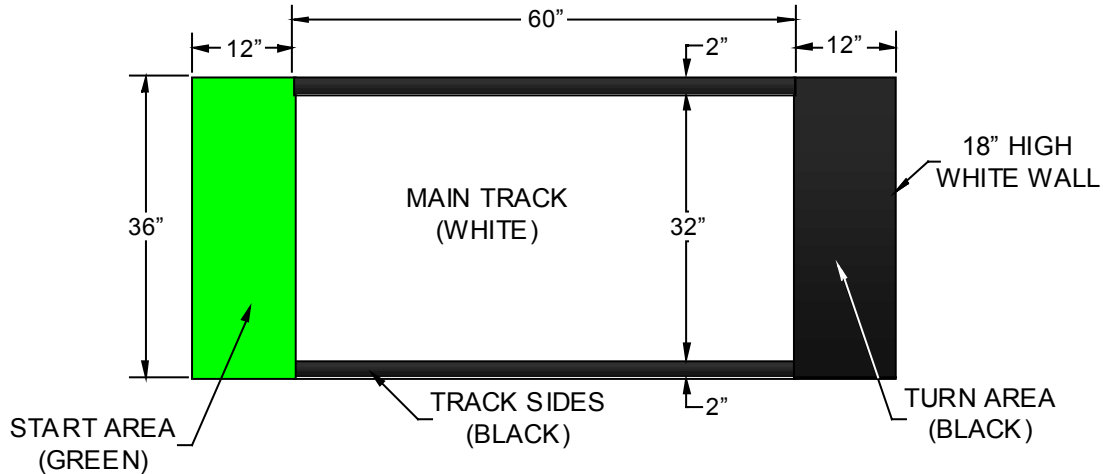
The maximum length, width, height, and weight of a robot are not specified in this contest. The only requirement is that the robot must remain completely on the course during the event. It is the designers' responsibility to design the robot to accomplish this task.

Propulsion must be electrical in nature. No pneumatic, combustion, or other exotic propulsion devices will be permitted. All power must be carried on board the robot.

The race officials shall make the sole decision as to the suitability of a robot for this contest. Robots deemed a hazard to the course or persons will not be permitted to compete.

All robots leg lengths will be measured before the contest. The length of a leg shall be measured at its fullest extension. If legs are of different lengths, the length of the longest leg will be used for handicapping. Officials may re-measure robots at any time. The goal is to measure the actual gait used in the contest by the robot.

## Course Specifications



The overall dimensions of the walking race course is 3 feet wide by 7 feet in length. The course can be made from any material as long as it is flat, smooth, and there are no seams, edges, cracks, etc., that are greater than 0.06 (1/16) inches in height.

The entire course is divided into three areas, the starting area, the main track, and the turn area.

### Starting Area

This area will consist of the first foot of the seven-foot long course. The entire robot must be placed within or behind this area at the start of the race. This area will be painted Krylon #2327 Fusion Spring Green. (All paint mentioned is currently available at Home Depot, Fred Meyer, and other stores in the Northwest.)

### Main Track

The Main Track will be 5 feet in length and 36 inches in width. The Main Track includes the two 2" wide black Track Sides. The main track area will be Polar White in color. The width of the Polar White area will be 32".

### Turn Area

This area will consist of the last foot of the track. It will be painted with a Krylon Fusion #2321 Gloss Black. This color is a strong contrast to the white with both IR and visible sensors.

### Track Sides

The main track will be bounded on each side with a 2-inch wide strip. This strip can be either painted with the same paint used in the turn area, or it could be composed of black PRO-Pak plumber's tape, available at Home Depot and any plumbing supply. The white printing normally present on this tape will be removed by wiping it with acetone.

### Wall

In addition, a 3 feet wide by 18 inches high wall (that is painted the same white color that is used on the main track) will be provided at the turn end of the course as an aid in navigation. A robot may use this wall as an aid in detecting the proper turn location.

The contestant may position the wall at any distance beyond the turn area.

Additionally a contestant may place any target he or she desires as an aid to navigation on the wall. The entire wall and any targets must be placed entirely behind the turn area.

### **External Environment and Course Variations**

The robot must deal with the lighting conditions as they appear at the event. That is, room lighting and window drapes will be set as desired by the judges and will not be modified for individual contestants. Also, flash photography and IR focusing cameras will be allowed, unless the judges deem such activities as intentionally interfering with the ability to hold the event in general.

It is impossible to ensure that all practice arenas built at home will be exactly identical to the contest arena (in geometry, color, texture, and lighting conditions). All contestants must be aware that their robot may perform differently on the official arena than other arenas. It is the contestant's responsibility to ensure that their robot will operate on the official contest arena. Keep in mind that all robots will run on the same official arena, so all the robots will be running in the same environment. Robots that can adapt to their environment may perform better than robots that can not adapt to their environment.

### **Practice Runs**

Each robot will be allowed at least one opportunity for a "test drive" on the track (or similar official test track construction) for testing and calibration. All test opportunities are on a first-come, first-served basis.

### **Race Procedure**

A robot must begin completely in the start area, proceed to the turn area and then return back to the start area. At least one of the robot's feet must touch the surface in the turn area or the run will not count. The run ends when the robot has completely reentered the start area.

### **Setup**

- Five minutes prior to the start of the competition, and "On Deck" call will be made. At the end of the five minute "On Deck" call, all robots must be ready to compete when they are called.
- The entire robot must be behind the front edge of the Start Area at the start of the contest. The front edge of the Start Area is defined as the edge between the Start Area and the Main Track. This is also known as the Start Line.
- The robot (or portions of the entire robot) may extend behind the 12 inch depth of the Start Area.
- No part of the robot is allowed to extend past (outside) the 36 inch width of the Start Area.

### **Race Procedures**

The following are the race procedures

- Contestants start their own robot.
- The time clock will begin when the forward most part/edge of the first leg or foot, that crosses the Starting Line. Any other part of the robot (such as: arms, body, head, etc) that crosses Start Line before the first leg will not start the time clock.
- Once the time clock has started; no contestant or official may touch the track, the robot, or assist, or interfere with the robot in any way.
- At least one foot of the robot must touch the surface inside the turn area before returning to the start area.
- The time clock will stop when the rear most part/edge of the last leg or foot, that crosses the Starting Line. Any other part of the robot (such as: arms, body, head, etc) that crosses Start Line after the last leg will not be used to stop the time clock.
- The robot must remain on the course at all times.
- If any part of the robot touches the ground on either side of the course, the race is ended, and the time clock is stopped. The total distance robot traveled will be recorded. If the robot went towards the turn area and then went out of bounds, then the distance from the start area, to the turn area, then to the point where the robot went out of bounds will be recorded. This robot will be classified as NOT completing the course.
- If the robot failed to touch the turn area, and successfully returned to the starting area, then the robot will be classified as NOT completing the course. The distance will be measured (and recorded) from the starting line to the closest point the robot touched near the turn area and measured back to the starting line.

### **Termination**

The robot's operator can terminate the race at any time.

- If the operator terminates the robot's run prior to the starting of the time clock, then the robot will be allowed to restart the race.
- If the robot's operator terminates the robot's run after the start of the time clock, while the robot is still on the course, then the robot is disqualified from the race.
- The robot's operator is allowed to turn off the robot after it has returned back to the Start Area, or after it has gone out of bounds.

### **Restarts**

The robot will be allowed to restart the race under the following conditions:

- Interference by another competitor.
- Interference by a spectator.
- Interference by an official.
- Flaws in the arena where the officials believe that it will have a negative effect on multiple robots.
- External forces that cause the robot to change its course. i.e. earthquakes, tornadoes, floods, acts or war, etc.

Robots will NOT be allowed to restart a run if they have any electrical, optical, acoustic, mechanical, or software failures after the start of the time clock.

### **Bonus Scoring**

All robots are encouraged to turn around when they reach the Turn Area. To encourage this, the final time will be reduced by 30% for all robots that turn around when it reaches the Turn Area.

Turning around is defined as the robot's entire body (including torso, legs, arms, head, etc) turning 180 degrees. In addition, the same side of the robot that enters the Turn Area is the same side of the robot that returns into the Start Area.

The 180 degree turn is not required to be completed in the Turn Area. But the turn must be completed where the centroid of the robot is within 12 inches from the edge between the Turn Area and the Main Track.

### **Penalty Scoring**

If any part of the robot physically touches the white wall, either intentionally or by accident, a 10% score penalty will be imposed. This penalty will be applied to the final score, after any bonus scores have been applied.

### **Final Scoring**

Final scoring shall be as follows:

1. Record the robot's time,  $t$ , according to the time clock.
2. Apply the Turn Around Time Bonus. The 30% time bonus will be computed by multiplying the time recorded from step 1 by 0.7. If the robot did not receive the Turn Around Time Bonus, then skip this step.
3. Apply the 10% Wall Touching Time Penalty if the robot touched the white wall. The 10% time penalty will be calculated by multiplying the adjusted time that was computed in step 2 by 1.10. If the robot did not receive the Wall Touching Penalty, then skip this step. If the robot did not receive a Turn Around Time Bonus, then the penalty will be applied to the original time recorded in step 1.
4. Calculate the robot's velocity using the following formula:

$$V = \frac{D}{t}$$

Where:  $V$  = Velocity, in/sec  
 $D$  = Total travel distance, in  
 $t$  = Clock time, sec

Note: The distance,  $D$ , will be either twice the Main Track distance (2 x 60 inches = 120 inches) or the total distance the robot traveled if it when out of bounds.

5. Calculate the Adjusted Score according to ALEXANDER'S FORMULA:

$$F = \frac{V^2}{gL}$$

Where:  $F$  = Froude Number (Adjusted Score)

$V$  = Robot's Velocity, in./sec  
 $g$  = Acceleration due to gravity, 386.2 in/sec<sup>2</sup>  
 $L$  = Leg length distance, in.

Note: This formula describes the maximum speed of an animal (or robot) by knowing its leg length. It tends to negate size advantages and can be shown to reward efficient walking and advanced gaits, such as hopping, trotting, skipping, cantering, pacing, prancing, galloping, or running. It employs the concept of dimensionless speed. The idea is to handicap robots so that the size of a robot becomes less important and to encourage varied and original designs.

### **Final Placing**

Robots will be ranked according to the highest score to the lowest score. The robot with the highest score wins the race.

All robots that did not complete the course (i.e. ran off the side of the course), but received a score, will be ranked below ALL robots that completed the course. It is possible that a robot that did not finish the course can receive a higher score than a robot that did complete the course, but that robot will still be ranked below the robot that finished the course.

### **Additional Races**

Additional races may be conducted at the discretion of the race officials. Additional races will not be conducted if there is not sufficient time for all of the robots to complete the additional races. If additional races are conducted, the robot's best overall score will be used in the final ranking.

### **Violations and Penalties**

Any contestant violating any of the rules in this race will be disqualified.

### **Rules Committee**

The event committee, rules committee, and race officials reserve the right to clarify, augment, or modify these rules in the interests of fair play. Changes should be published prior to the event. But in some rare circumstances a change in the rules may be implemented during event if it is found that someone is trying to violate the spirit of the rules by using a technicality in the rules that was unforeseen by the rules committee. Any changes will be made in the interest of fair play for all of the contestants.

All decisions by the race officials are final.

The rules committee should be consulted prior to the event if a robot has some unique feature that might be questionable according to the published rules. All inquiries will be kept confidential. The rules committee will provide an answer if the unique feature is permitted to be used, guidance in the design of the unique feature to remain in compliance of the rules, or in some cases, changes in the written rules to specifically address the unique feature.

