



# 2023 ASABE Student Robotics Challenge

Release 0.1RC1, December 2022. Please see the [competition website](#) for updates.

The ASABE Student Robotics Challenge provides a challenging and fun hands-on learning experience for undergraduate and graduate students. This year's challenge, which will be held during the ASABE International Meeting in Omaha, NE, July 9–15, 2023, will simulate the harvesting of cotton. Although the theme is similar to last year's competition, please read the new rules carefully as there are many changes.

**At a glance:** Autonomous robots will harvest cotton on a brown 8' x 8' playing field with a brown, 4" tall border. The playing field has 6 rows, and each row contains 9 cotton plants. Each plant has one, two, or three bolls of cotton at heights between 7" and 11", and each ripe boll contains between three and five distinct cotton balls. Robots score points by collecting cotton, mapping the location of "unripe" bolls of cotton, and "delivering" the cotton to a corner of the playing field. As described below, there are two divisions with different rules and levels of difficulty.

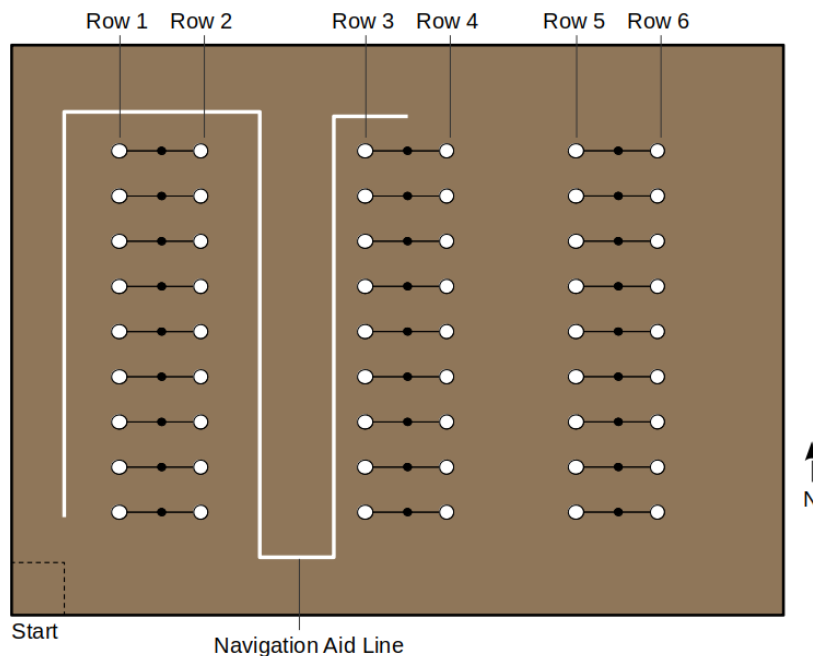


Figure 1: Top view layout of playing field. There are six rows, each with nine cotton plants (the figure will be corrected in future version). A navigation aid line is available along the first three rows. Note the designation of the direction "North", which is simply for reference elsewhere (not magnetic north). More detailed drawings of the arena are provided in subsequent sections.

## Glossary of Terms

- boll: a capsule in which cotton seeds grow. Each ripe (opened) boll contains three to five distinct “balls” of cotton. Each unripe (closed) boll is represented by a single green ping pong ball.
- cotton plant: a structure that holds cotton bolls on the playing field.
- simulated plant: a cotton plant made using dowel rods that protrude horizontally from a row wall. Cotton bolls are attached to the ends of the dowel rods. The husk of the cotton bolls is natural, but the original cotton has been replaced with cotton balls that are hot-glued into place. Simulated plants are used in all rows except advanced division rows 5 and 6. See Figure 2.
- realistic plant: a cotton plant made using flexible wire stems that protrude vertically from the floor. All-natural cotton bolls are attached to the wire stems. Realistic plants are used only in the advanced division rows 5 and 6. See Figure 3.
- row: a set of cotton plants arranged in a line. There are six rows, as shown in Figure 1.
- row wall: a wall that separates adjacent rows.
- border: a wall at the edge of the playing field.
- time trial: a ten-minute period during which a single team’s robot(s) collects cotton on the playing field.
- round: a set of time trials during which each team competes once.
- activation: (at the beginning of a time trial) preparing a robot for the time trial until it autonomously moves out of the starting area.
- deactivation: (at the end of a time trial) turning a robot off and removing it from the playing field.
- physical intervention: permitted manual interaction with the robot during a time trial.

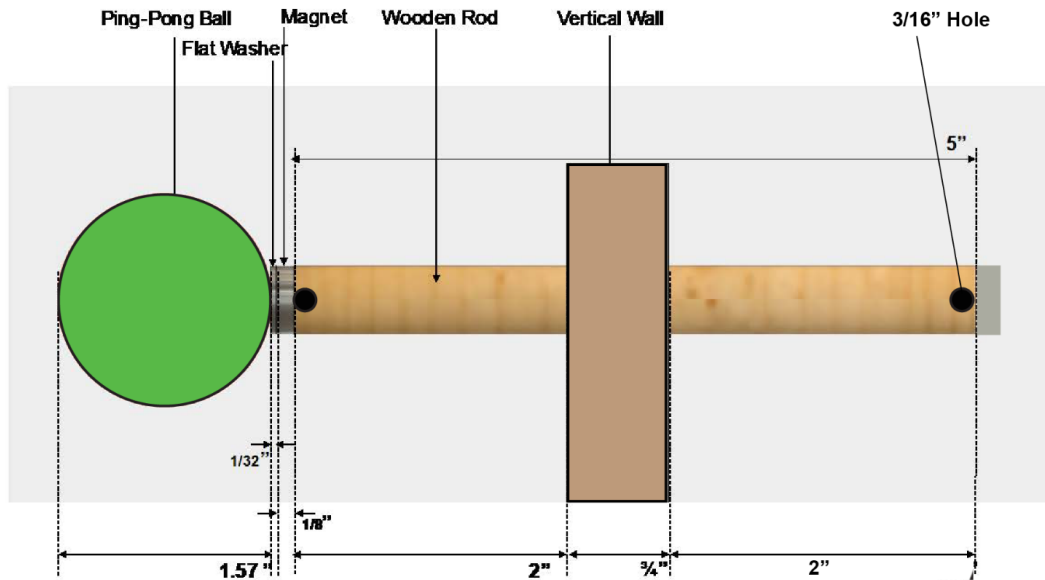
## Competition Rules

### Beginner Division

1. Designed for undergraduate students with limited coursework in robotics and undergraduates who are new to the competition.
2. Undergraduate students only.
3. Maximum of two teams per institution.
4. Limit of one robot per team.
5. Robot must begin each time trial at the specified Start location. (See Figure 1.)
6. Maximum robot size of 12”x12”x12” at the start of each time trial.
7. Robots earn points by harvesting cotton from simulated cotton plants, which are located at each of the positions specified in Figure 1. See Figure 2

for a diagram of a simulated cotton plant.

8. Points may also be earned by creating a map of unopened bolls and saving the resulting map to a USB drive in CSV format. See Figure 4 for details.
9. Upon completion of the harvesting operation, robots may earn points by “delivering” cotton to any corner of the playing field other than the starting location.



*Figure 2: Side view (e.g. from south looking north) of a simulated cotton plant used in the beginner division and rows 1-4 of the advanced division. The vertical wall separates adjacent rows. A future version of this document will include an example with opened bolls and with bolls at both 7" and 11" heights.*

### **Progressive Difficulty**

The course begins with a very regular placement of ripe cotton bolls in row 1, close to the starting corner. As the robot moves toward the opposite end of the playing field, cotton placement becomes increasingly irregular to provide a greater challenge. Locations that would regularly be occupied by a ripe boll will be chosen at random (with uniform probability) and replaced with an unripe boll or removed altogether. Specifically:

Row 1: One ripe cotton boll will be attached to each plant at a height of 7" from the ground, approximately 2" from the row wall, and facing perpendicular to the row wall.

Row 2: Same as Row 1, but 2-3 bolls will be unripe.

Row 3: Same as Row 1, but a second set of bolls is added at a height of 11".

Row 4: Same as Row 3, but 4-6 bolls will be unripe.

Row 5: Same as Row 3, but 2-4 bolls will be missing.

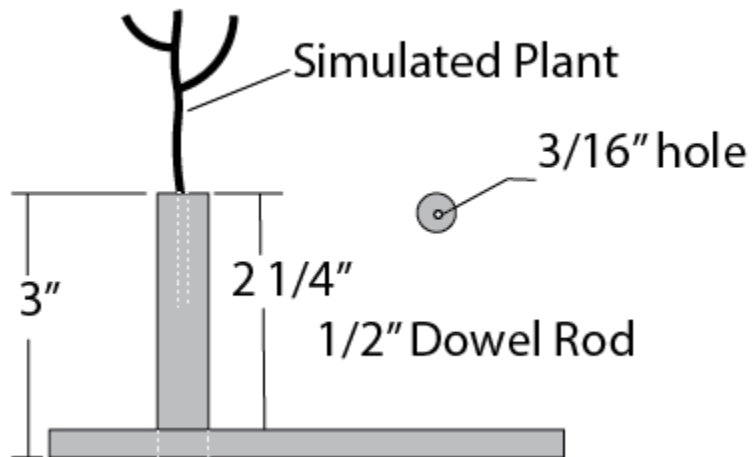
Row 6: Same as Row 5, but 4-6 bolls will be unripe.

**Table 1:** Summary Table for Beginner Division

	Heights	Navigation Line	Possible Bolls/Plant	Actual Number of Bolls/Row	Number of Unripe Bolls	Simulated or Realistic Plants
Row 1	7"	Y	1	9	0	Simulated
Row 2	7"	Y	1	9	2-3	Simulated
Row 3	7" & 11"	Y	2	18	0	Simulated
Row 4	7" & 11"	N	2	18	4-6	Simulated
Row 5	7" & 11"	N	2	14-18	0	Simulated
Row 6	7" & 11"	N	2	14-18	4-6	Simulated

## Advanced Division

1. Designed for upper-level undergraduate and graduate students.
2. Both graduate and undergraduate students.
3. Maximum of one team per institution.
4. Maximum of two robots per team. If two robots are used, they are used simultaneously in a single time trial.
5. Robot(s) must start and end each time trial at specified locations. Robot(s) can start from any corner of the playing field. If a team has two robots, they must start from two different corners of the playing field.
6. Maximum robot size of 12"x12"x12" at the start of each time trial.
7. Robots earn points by harvesting cotton from cotton plants, which are located at each of the positions specified in Figure 1.
  - a. See Figure 2 for a diagram of a simulated cotton plant in Rows 1-4.
  - b. See Figure 3 for a diagram of a "real" cotton plant in Rows 5-6.
8. Points may also be earned by creating a map of unopened bolls and saving the resulting map to a USB drive in CSV format. See Figure 4 for details.
9. Upon completion of the harvesting operation, robots may earn points by "delivering" cotton to any corner of the playing field other than the starting location.



*Figure 3: Side view (e.g. from south looking north) of a realistic (not “simulated”) cotton plant used in rows 5-6 of the advanced division. There is no vertical wall separating adjacent rows. A future version of this document will include a more detailed illustration.*

### **Progressive Difficulty**

The advanced division has a progressive difficulty scheme like that of the beginner division, but with additional challenges. Rows 1 and 2 of the advanced division are similar to rows 5 and 6 of the beginner division.

Row 1: Cotton bolls may be attached to each plant at heights of both 7” and 11”, but some of these locations will be empty; 2-4 bolls will be missing. All cotton bolls will be located approximately X” from the stem of the plant and will face perpendicular to the row.

Row 2: Same as Row 1, but 4-6 bolls will be unripe.

Row 3: Same as Row 1, but the locations of bolls vary between 7” and 11”, and there may be up to three bolls per plant.

Row 4: Same as Row 3, but 4-6 bolls will be unripe.

Row 5: Same as Row 3, but the simulated cotton plants are replaced with realistic cotton plants (see Figure 4), which will not be evenly-spaced.

Row 6: Same as Row 5, but 4-6 bolls will be unripe.

**Table 2:** Summary Table for Advanced Division

			Actual	Simulated or		
	Navigation	Possible	Number of	Realistic		
	Line	Bolls/Plant	Bolls/Row	Plants		
	Heights		Number of	Unripe Bolls		
Row 1	7" & 11"	Y	2	14-18	0	Simulated
Row 2	7" & 11"	Y	2	14-18	4-6	Simulated
Row 3	7" & 11"	Y	2-3	14-18	0	Simulated
Row 4	7" & 11"	N	2-3	14-18	4-6	Simulated
Row 5	any, 7"- 11"	N	2-3	14-18	0	Realistic
Row 6	any, 7"- 11"	N	2-3	14-18	4-6	Realistic

## Scoring

1. Harvesting cotton (Maximum ~200 Points)
  - a. Material collected by a robot will be separated manually into "cotton" and "foreign material" (e.g. cotton husks, stems). Any cotton that is not easily separated from foreign material will be included with the foreign material. For example, cotton balls still attached to the husk will be considered foreign material.
  - b. The cotton in the realistic cotton plants in the 5th and 6th rows of the advanced division contain seeds. The seeds are not considered to be foreign material; they do not need to be separated from the cotton itself.
  - c. One point will be awarded per gram of cotton.
  - d. One point will be subtracted per gram of foreign material.
2. Mapping of unripe bolls. (Maximum ~65 points)
  - a. Robots may earn points by providing a map of the playing field that indicates the location of unripe bolls.
  - b. Each unripe boll is worth six points in the beginner division and five in the advanced division; every other boll (unripe or missing) is worth one point. For each boll that is labeled correctly, the team earns the indicated number of points; for each incorrectly labeled boll, the team loses the indicated number of points.
  - c. The map must be written in plain text CSV format to a blank USB drive provided by the competition organizers, which will be plugged into the robot just before the time trial begins. The map should be written with a "1" indicating an unripe boll and with the row and column headings shown Table 4. All locations with bolls that are either ripe or not present should be indicated with a "0".
  - d. Tables that are incorrectly formatted or missing will receive a score of 0 points.

3. Delivery Score (Maximum 20 Points)

- a. Each robot may earn points by “delivering” cotton. All that is required for a robot to complete delivery is to end the time trial in a “delivery corner” (whether the robot collected cotton or not).
- b. All corners of the playing field other than the one in which the robot started the time trial is a “delivery corner”.
- c. If only one robot is present in a time trial, ten points will be awarded for ending the time trial in a delivery corner (within a square with 14” sides).
- d. If two robots are present in a time trial (advanced division only), five points will be awarded per robot that ends the time trial in a delivery corner.

4. Autonomy Score (Maximum 20 points)

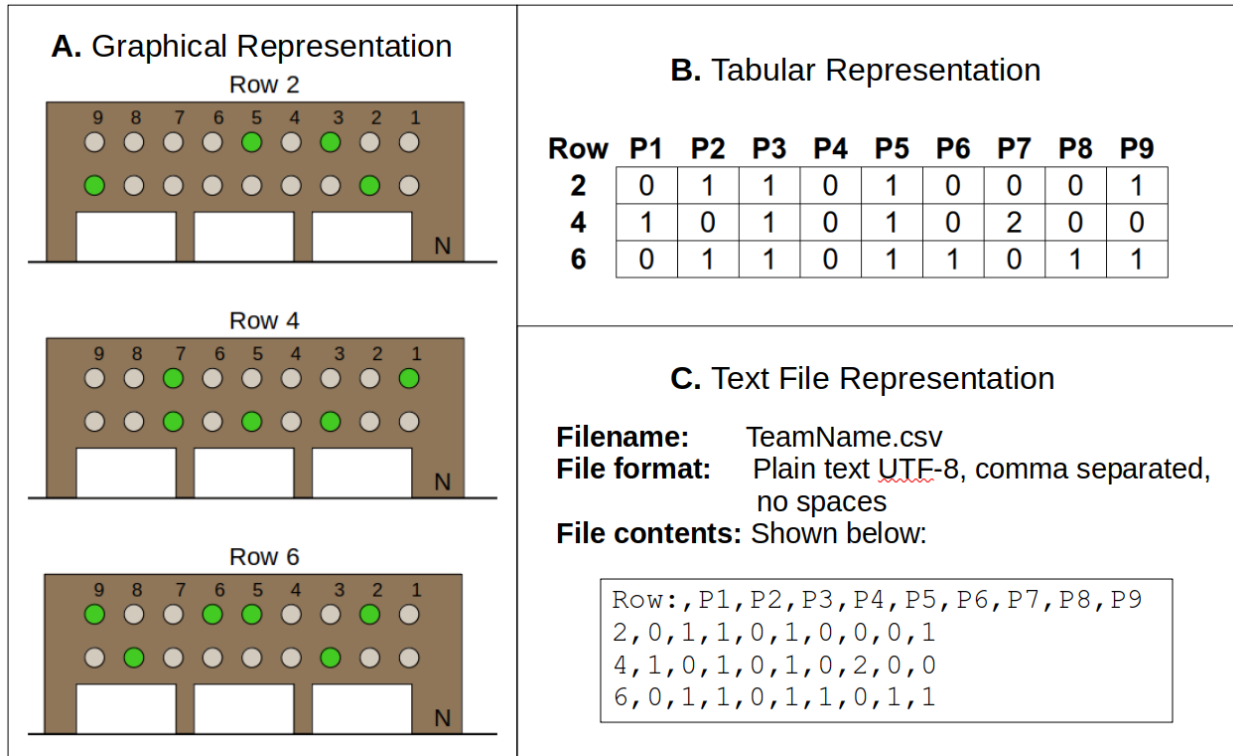
- a. Robot controllers must be fully autonomous once activated at the beginning of a time trial. Robots that are controlled by humans (e.g. via wireless control) during a time trial will be disqualified.
- b. Robots will be scored based on their degree of autonomy from physical human intervention. Each team will begin a time trial with a 20-point autonomy score. Four (4) points per intervention will be deducted from the autonomy score.
- c. Physical intervention is any situation other than initial activation and final deactivation in which a human manually aids a robot. This includes but is not limited to:
  - i. Moving a robot back to its starting position
  - ii. Pushing a robot to correct its direction of travel
  - iii. Manually articulating a device on the robot
  - iv. Resetting the robot’s electronics
  - v. Removing debris that obstructs robot functions

The judges present at the competition will decide the number of distinct physical interventions that occur during each interaction with the robot. For instance, if a team both moves the robot back to its starting position and separately removes debris that obstructs the robot’s functions, this may count as two physical interventions for a total of eight (8) points deducted from the autonomy score. On the other hand, if a team moves the robot back to its starting position and consequently needs to reset the controller, this may count as only one physical intervention.

- d. Robots that do not score any other points (positive or negative) will not earn an autonomy score of 20 points. For example, a robot that does not move during a time trial will earn an autonomy score of 0.
- e. The intent of physical intervention is to help the robot recover from a fault that might otherwise prevent it from scoring additional points. Robots may not score points directly as a result of physical intervention. For instance, a team may not manually actuate an end effector on the robot to collect cotton.

## Mapping Specifications

Mapping files should contain information as outlined below. Tables 1 and 2 specify that unripe bolls will only be present in Rows 2, 4, and 6. Thus, maps need not report any information for Rows 1, 3, or 5. An example scenario is shown in Figure 4 below, including graphical, tabular, and data file information. CSV files should be written to a USB drive (to be provided by competition staff), in UTF-8 plain text format with commas as the column delimiter and no spaces.



**Figure 4:** Panel A - A graphical depiction of Rows 2, 4, and 6, as viewed from the East of the playing field. Note that this diagram is for illustrative purposes and does not correspond directly to either the beginner nor the advanced division. Circles represent possible boll locations. Filled green circles indicate unripe bolls. The letter N represents the North end of each row identified in Figure 1, and position numbers increase from North to South

Panel B - Tabular representation of the number of unripe bolls at each row and position. Note that the mapping convention does not differentiate between the vertical location of bolls, only the number of unripe bolls at each location is to be reported.

Panel C - Text file representation of the information shown in Panels A and B.



## Competition Format

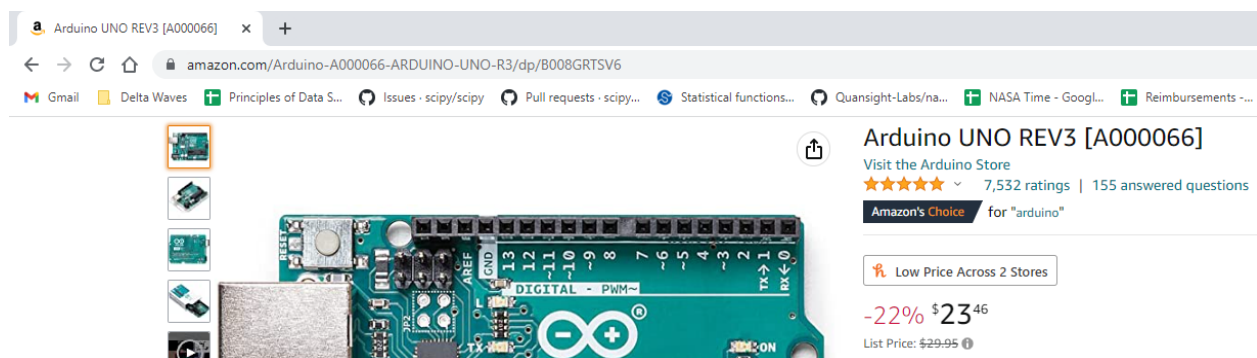
1. The competition will consist of two or three rounds (to be decided based on the number of entries). Each team will complete one time trial per round.
2. The order in which teams will complete their time trial will be announced at least 15 minutes before the start of each round.
3. Teams are responsible for monitoring the progress of the competition and reporting to the playing field with their robot before their time trial begins.
4. To keep the competition on schedule, each time trial will begin no more than five minutes after the previous time trial ends - whether the team designated to participate in the time trial is present or not.
5. Teams will have a total of 10 minutes to prepare their robot on the playing field, complete each time trial, and score as many points as possible. Touching the robot after it starts navigating the course is considered to be a physical intervention (see autonomy score).
6. No bonus points will be awarded for time remaining, but teams may choose to end their time trial early. In case of ties, however, this time will be used as a tie-breaker.

## Controller Restrictions

Robots must be fully autonomous. With the exception of activation, deactivation, and physical intervention, robots controlled by humans during a time trial will be disqualified.

To make the competition more accessible to teams with limited budgets, the total cost of control components (e.g. CPUs, GPUs) used on a robot is limited. Specifically, the sum of the manufacturer's suggested retail price (MSRP, also known as list price) of control components must not exceed \$400. This restriction does not include the cost of sensors with basic integrated processing.

Please document the MSRP at the time you purchase your hardware (e.g. by saving webpages or taking screenshots). For instance, here is documentation of the \$29.95 list price of an Arduino UNO Rev 3 on 11/22/2022.



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If you have questions about these restrictions, please consult with the competition committee.

## **Additional Regulations**

1. Teams must declare their division (beginner or advanced) at the time of registration (March 1). Teams may elect to change their division until July 1, 2023, after which no division changes will be allowed.
2. A robot may NOT be used in both the “beginner” and “advanced” divisions.
3. An undergraduate student may be a member of both a “beginner” and an “advanced” team.
4. Due to space and resource limitations at the competition, each team must designate up to three (3) team members who are allowed in the competition area for each time trial. Additional team members will be permitted in the setup/work area as space permits.

## **Poster and Poster Presentation**

To be eligible to compete, all teams must participate in a two-hour poster session prior to the competition. Posters must be 24-inches wide and 36-inches tall and include the following information (at a minimum):

- Team Name
- University
- Team member names
- Team advisor's name
- Pictures of the completed robot
- A description of what tasks the robot is capable of performing and how it accomplishes them
- A high-level description of the mechanical, electrical, and software design of the robot

At least two team members must present their poster during the poster session. Teams must also submit a digital version of their poster in PDF format, which will be publicly available after the competition.

## **Written Report**

A written report will be submitted to provide documentation of the robot design and functionality. Reports will be judged according to the information below. An award will be presented for the best report. Reports will be submitted in PDF format. Reports and scores will be publicly available after the competition.

<b>I. Technical Merit</b>	<b>Points Possible</b>
A. Establishment of Need and Benefit to Agriculture	<b>5</b>
B. Approach and Originality	<b>5</b>
C. Definition of Design Objectives and Criteria	<b>10</b>
D. Parts List and Table:	<b>5</b>
1. Actuators, sensors, microprocessors, screen(s), etc.	
E. Hardware Description	<b>20</b>
1. Engineering drawings, CAD models, pictures, etc.	
2. A clearly written description of how hardware works	
F. Software Overview or Logic Flowchart:	<b>20</b>
1. Driving, sensing logic, etc.	
G. Appropriateness of Tests and/or Performance Data	<b>5</b>
H. Achievement of Objectives	<b>5</b>
<b>II. Written Report Quality &amp; Composition</b>	
A. Professional-looking page design and layout	<b>5</b>
B. Appropriate organization and logical flow of information	<b>5</b>
C. Completeness of the report	<b>5</b>
D. Clarity and style	<b>5</b>
E. Quality of the documentation - including figures & drawings	<b>5</b>
 <b>Total: 100</b>	

## Rankings and Prize structure

1. Rankings for each team will be determined by adding scores from the two highest-scoring rounds together. The team with the highest combined two-round score will be the winner for that division.
  - a. In the event that there is a tie, the time used by the teams in their best time trials will be used as a tiebreaker.
  - b. In the event that there is still a tie after the time is considered, teams will split the prize for that ranking, and the competition committee will revise the prize structure to fairly compensate all teams.
2. Trophies and prize money will be awarded to the top three teams in each division.
3. Prize ribbons will be awarded to the best poster/video presentation, as determined by the judges.
4. Prize ribbons will also be awarded to the best report, as determined by the judges.

## Playing Field Construction Details

To be released in a future version of this document.

## Contact

If you have any questions regarding the competition rules, please contact [asabe.p127@gmail.com](mailto:asabe.p127@gmail.com).